HYDROGEOLOGY, CHEMICAL QUALITY, AND AVAILABILITY OF GROUND WATER IN THE UPPER FLORIDAN AQUIFER, ALBANY AREA, GEORGIA

U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the

CITY OF ALBANY
WATER, GAS, AND LIGHT COMMISSION

WATER-RESOURCES INVESTIGATIONS REPORT 87-4145

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Atlanta, Georgia

1987

U.S. DEPARTMENT OF THE INTERIOR

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ILLUSTRATIONS
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CONVERSION FACTORS

Multiply	by	to obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	0.4047	hectare
square mile (mi^2)	2.590	square kilometer
	Volume	
gallon (gal)	3.785	liter
million gallons (Mgal)	3,785	cubic meter
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
gallon per minute (gal/min)	0.06309	liter per second
million gallons per day (Mgal/d)	0.04381	cubic meter per second
million gallons per day per square mile [$(Mgal/d)/mi^2$]	1,460	cubic meter per day per square kilometer
inch per year (in/yr)	25.4	millimeter per year
	Transmissivity	
foot squared per day (ft^2/d)	0.0929	meter squared per day
	Hydraulic conductivity	
foot per day	0.3048	meter per day

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.”

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ABSTRACT

Large withdrawals of ground water in the 1,500-square-mile Albany area of southwestern Georgia have lowered water levels in deep aquifers as much as 140 feet and raised concern about the aquifers' ability to meet increasing demands. This study was conducted to evaluate the development potential of the shallow Upper Floridan aquifer as an alternate source of ground water, especially for public supply.

The study area lies mainly within the Dougherty Plain district of the Coastal Plain physiographic province. The Upper Floridan aquifer is the shallowest major ground-water reservoir, generally covered by only 20 to 80 feet (ft) of overburden. The aquifer includes units of sand, clay, limestone, and dolomite of middle Eocene age and younger, that form, in ascending order, the Lisbon Formation, the Clinchfield Sand, the Ocala Limestone, and the Suwannee Limestone. The aquifer is overlain by undifferentiated sediments of Miocene age and undifferentiated overburden of Quaternary age. The Upper Floridan ranges in thickness from about 50 ft in the northwestern part of the area to more than 370 feet in the southeastern part. The Upper Floridan stores and transmits large quantities of water, mainly in a zone of high permeability in the lower part of the aquifer. The transmissivity of the aquifer ranges from less than 10,000 feet squared per day northwest of Albany, to as much as 150,000 feet squared per day south and southeast of Albany. Twenty-eight years of agricultural and industrial pumping has not produced a long-term decline of the water level in the Upper Floridan; the aquifer system remains at equilibrium. The Upper Floridan yields hard, calcium bicarbonate-type water that contains no constituents in concentrations that exceed State drinking water standards.

The Upper Floridan aquifer is the primary source of irrigation, industrial, and rural domestic water supplies in the study area. The aquifer has not been developed as a public-supply source, however, largely because of concern over possible ground-water contamination by agricultural and industrial chemicals and landfill leachate. The development potential of the aquifer as a public-supply source depends on the quantity and the chemical quality of water available to wells. Near Albany, active and abandoned landfills, industrial and commercial sites, railroad yards, and gasoline and chemical storage tanks are potential sources of contaminants and, thus, make the area unsuitable for well sites. The areas of high transmissivity southeast of Albany, east of the Flint River, and southwest of Albany, west of the river, have the greatest development potential for public water supply. East of the river, yields of 12- to 16-inch-diameter wells reportedly exceed 2,000 gallons per minute (gal/min). West of the river, yields of 800 to 1,200 gal/min can be sustained by wells that tap the lower part of the aquifer, and some wells are reported to produce more than 2,500 gallons per minute. In these areas, it may be possible to develop several fields of properly spaced wells capable of supplying tens of millions of gallons of potable water per day without overstressing the aquifer.

In most of the study area, contaminants applied to or spilled on the land surface eventually can be expected to percolate through the overburden and reach the aquifer. Thus, it is important that wells be sited away from areas that have been used for the storage and disposal of potential contaminants and, probably to a lesser extent, the application of agricultural chemicals. In the northern part of the study area, the upper part of the Upper Floridan aquifer acts as a leaky confining unit, and wells that derive water exclusively from the lower part of the aquifer probably would have added protection against contaminants that penetrate the overburden. To the south, the confining unit is missing and the entire aquifer is permeable; contaminants on the land surface that percolate through the overburden and reach the aquifer in this area are more likely to be drawn into a pumped well.

In the area of greatest development potential east of the Flint River, wells may penetrate major ground-water conduits. Where this occurs, contamination from distant sources that recharge the aquifer, such as losing streams, is possible, because conduit flow in the aquifer is comparatively rapid and contaminants can be transported long distances without natural filtration or purification. Water in some conduits could become turbid, especially during wet periods, and cause quality problems. Also, wells located near the river could draw river water into the aquifer.

In karst terrane, such as the Dougherty Plain, drawing the water level in the aquifer down below the top of limestone by pumping could initiate sinkhole development. By limiting drawdown during well development and during production, the likelihood of causing sinkholes to form can be minimized.

Closed depressions, or sinks, throughout the Dougherty Plain probably are unsuitable as well sites, because (1) they are subject to flooding, (2) they collect water from upgradient areas and could concentrate potential contaminants, (3) water may percolate through their bottoms and could transport contaminants into the aquifer, and (4) the depressions may overlie limestone cavities filled with sand or clay that could interfere with well yield, development, and production.

INTRODUCTION

The Upper Floridan aquifer underlies parts of Georgia, Alabama, South Carolina, and all of Florida. It is one of the most productive aquifers in the United States. In the Dougherty Plain area of southwestern Georgia (fig. 1), large withdrawals of water from this aquifer for supplemental irrigation began around 1975, with the introduction of center-pivot and cable-tow irrigation systems. North and west of Albany, irrigation pumping soon spread to the deeper aquifers that already were being used for municipal supplies.

Heavy pumping from the deep aquifers in the Eocene Claiborne Group, Paleocene Clayton Formation, and Upper Cretaceous rocks, which underlie the Upper Floridan, has caused water-level declines in the Albany area (Hicks and others, 1981). Long-term pumping from the Clayton aquifer by the city of Albany, coupled with recent increases in agricultural pumping, has resulted in water-level declines of as much as 140 feet (ft) in the Albany area since 1940. Thus, the water-level declines have raised questions about the ability of the deep aquifers to meet increasing demands. The Albany Water, Gas, and Light Commission is considering the use of the shallow Upper Floridan aquifer as an alternative municipal ground-water source. This study was conducted by the U.S. Geological Survey (USGS) in cooperation with the Albany Water, Gas, and Light Commission.

Purpose and Scope

The objectives of this report are to (1) describe the hydrogeology of study area, (2) assess the chemical quality of ground water in the Upper Floridan aquifer, and (3) define the development potential of the aquifer as a public-supply source in the Albany area and evaluate geologic hazards associated with increased development.

The report describes the lithologic character, thickness, and areal extent of the geologic units that form the Upper Floridan aquifer in the 1,500-mi^2 Albany area. It discusses the hydraulic characteristics, recharge-discharge relations, water-level fluctuations and trends, the ground-water and surface-water relation, ground-water quality, and potential sources of contaminates that could affect the quality of water in the Upper Floridan aquifer. The report also describes the development potential of the aquifer, delineates areas that have large development potential, and discusses the availability of ground water and the geologic hazards that could affect development of the aquifer.

Methods of Investigation

Data from more than 2,000 privately owned wells were used in this study. The data were obtained mainly from the files of the Dougherty County Health Department. Driller's logs for 806 of these wells were used to determine the character of the undifferentiated overburden in the study area. These wells are not tabulated in this report, but the well data are on file at the USGS, Atlanta, GA 30360.

Other well data used in this report are listed in table 1 (at back of report). Nine test wells were drilled in the Upper Floridan aquifer. Drill cuttings were taken from all the wells and continuous cores were collected to a depth of about 150 ft in two wells. Cores and cuttings were correlated with electrical resistivity, spontaneous potential, natural gamma, and caliper logs. These data and geophysical logs from 51 other wells were used to delineate and correlate stratigraphic and hydrologic units. Eight of the nine wells were cased, developed, and equipped with continuous water-level recorders.

Six test-monitor wells were constructed in the undifferentiated overburden. The water level was measured monthly in each well to monitor fluctuations in the overburden in response to water-level changes in the Upper Floridan aquifer.

A network of 94 wells was established to provide water-level data for constructing a potentiometric map of the Upper Floridan aquifer. Continuous recorders were installed on 14 wells to monitor ground-water-level fluctuations and trends in the Upper Floridan.

Precipitation data were collected at two sites maintained by the National Weather Service. These data were used to estimate recharge and correlate resultant changes in streamflow and ground-water levels in the Upper Floridan aquifer and the undifferentiated overburden.

Continuous streamflow and stage data were collected for the Flint River and Muckalee Creek to correlate with precipitation and ground-water-level data to evaluate the ground-water and surface-water relation. Base-flow measurements were made on selected streams during the period of November 27-28, 1984, to estimate the volume of ground water being discharged by the Upper Floridan aquifer into area streams.

Aquifer tests were conducted at five sites during this study. Water-level drawdown and recovery data from pumped and observation wells were used to compute transmissivity and storage coefficients for the Upper Floridan. Specific-capacity data were obtained from files of the Layne-Atlantic Company, Albany, and used to estimate transmissivity in parts of the study area where aquifer-test data were lacking. Aquifer diffusivity was determined at one site by the flood-wave-response method described by Pinder and others (1969).

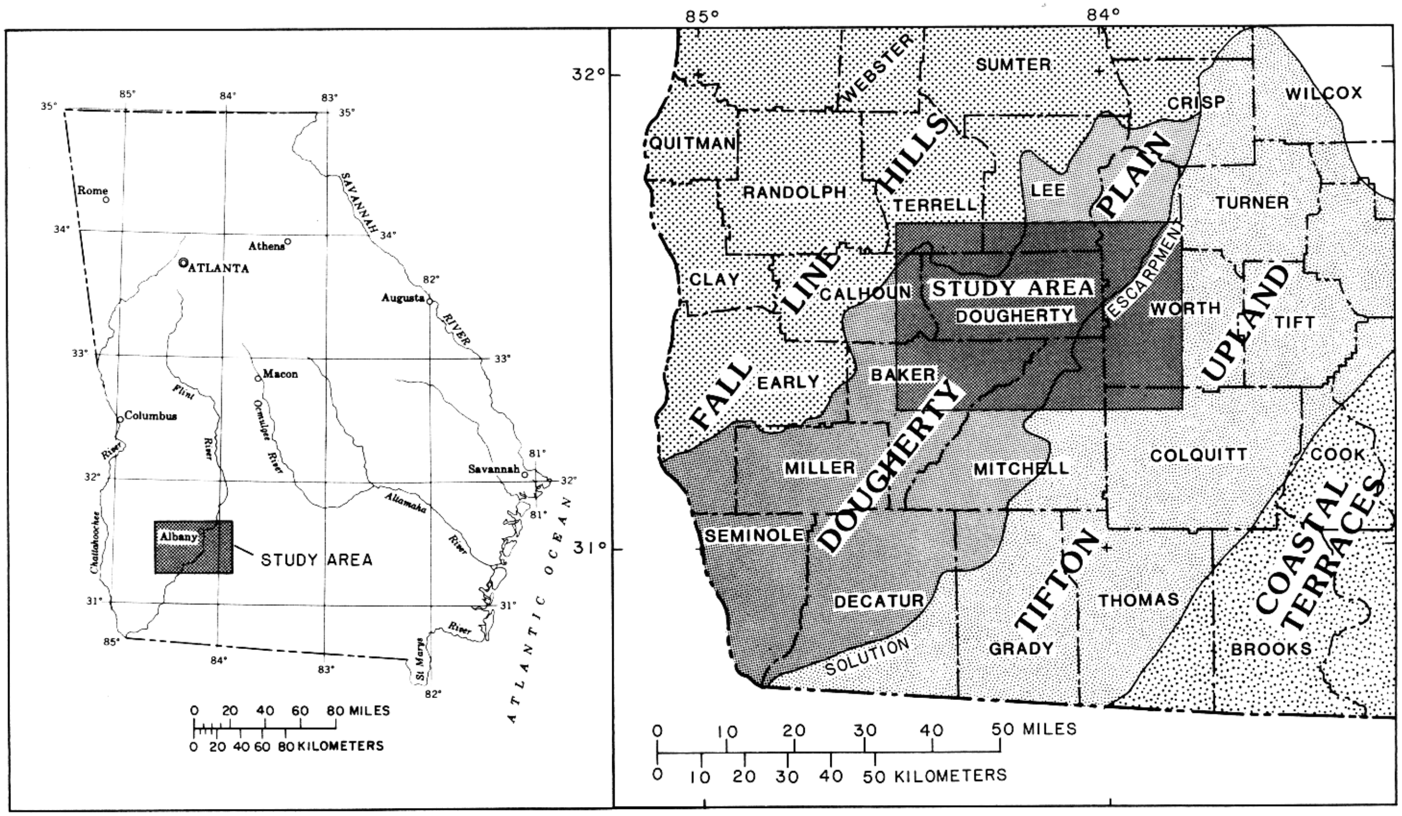


Figure 1.—Location of the study area and physiographic districts of the western Georgia Coastal Plain.

Previous Investigations

The geology and hydrology of the Albany area have been discussed in a number of reports. However, prior to the present study, the scale of the hydrogeologic data base was insufficient to evaluate the development potential of the Upper Floridan aquifer in the Albany area. McCallie (1898) reported on the artesian water supply of the Albany area and briefly discussed the geology, hydrology, water use, and water quality. Stephenson and Veatch (1915) presented detailed physiographic, geologic, and water-use information pertaining to the Albany area. Herrick (1961) presented paleontologic and lithologic descriptions for eight wells in the study area, and his descriptions were used as a guide in planning the test-drilling program for this study, and in the correlation of geologic strata.

Owen (1963a) presented a generalized geologic and hydrologic evaluation of Lee and Sumter Counties, and included a description of the Ocala Limestone in southern Lee County. Owen (1963b) gave a comprehensive discussion of the geology and hydrology of Mitchell County.

Wait (1963) presented a general description of the ground-water resources of Dougherty County, and included maps and sections showing the approximate thickness of the Upper Floridan aquifer and of the over-burden, the general configuration of the potentiometric surface of the aquifer during the fall of 1957, and water-use information for Dougherty County for 1957.

Hicks and others (1981) evaluated the hydrogeology of the Albany area; however, emphasis was placed on the aquifers underlying the Upper Floridan aquifer. Their report includes previously unpublished aquifer-characteristic and potentiometric-surface data for the Upper Floridan aquifer. Mitchell (1981) included the Dougherty Plain and presented climatologic, geologic, and hydrologic data for the Albany area.

A report by Watson (1981) presents a generalized, regional evaluation of the hydrogeology of the Upper Floridan aquifer in the Dougherty Plain, including the Albany area. Generalized maps showing the thickness of the residuum and the Upper Floridan aquifer are included in that report.

Hayes and others (1983) reported on the hydrology of the Dougherty Plain, including the Albany area. The study (1) defined the hydrogeology and hydraulic characteristics of the Upper Floridan aquifer, largely through a test-well drilling program, (2) developed a hydrologic budget in which total streamflow, base streamflow, and ground-water recharge and discharge were defined and quantified, and (3) developed a digital ground-water-flow model that was used to simulate regional water-level changes in the Upper Floridan aquifer that resulted from real or hypothetical pumping increases. Information on the hydraulic properties of the overburden, the Upper Floridan aquifer, and the confining unit underlying the aquifer, as well as ground-water-level, streamflow, and rainfall data, were used to construct a ground-water-flow model. Although the area of investigation covered the entire Dougherty Plain, the results are particularly pertinent to the Albany area and formed the basis for the present study.

Well and Surface-Water Station Numbering Systems

In this report, wells are numbered by a system based on the USGS topographic maps (plate 1). Each 7 1/2-minute topographic quadrangle map in Georgia has been given a number and letter designation beginning at the southwestern corner of the State. Numbers increase eastward through 39 and letters increase alphabetically northward through “Z,” then become double-letter designations “AA” through "PP." The letters “I,” “O,” “II,” and “00” are not used. Wells inventoried in each quadrangle are numbered sequentially beginning with “1.” Thus, the fourth well scheduled in the Leesburg quadrangle in Lee County is designated 12M004.

Surface-water stations are identified by a numbering system used for all USGS reports and publications since October 1, 1950. The order of listing stations is in a downstream direction along the main stream. All stations on a tributary entering upstream from a mainstream station are listed before that station. Each surface-water station is assigned a unique 8-digit number. The station number, such as 02351890, includes the 2-digit number “02,” which refers to it being a surface-water station, plus the 6-digit downstream order number “351890.”

Acknowledgments

Assistance in the compilation of data for this report was provided by many individuals throughout the Albany area. The writers wish to extend special thanks to U. Walter Rodemann, General Manager of the Albany Water, Gas, and Light Commission, for his support and assistance. Special appreciation also is extended to the many cordial people of the Albany area who provided historic information, allowed the installation of test wells on their property, and permitted the use of their wells for the collection of water-resources data. The Layne-Atlantic Company staff, Albany, in particular John W. Flatt and Hazel F. Andrews, were very helpful in providing historical records and well logs.

Special thanks to to the Eubanks Well Drilling Company of Leesburg for data provided on well construction and lithology for the study area and, in particular, input by J.C. Eubanks on unpublished historic data. Asa Edwards of the Dougherty County Tax Mapping Department suppplied maps and assisted in locating wells in the county. Glen Thomas of the Dougherty County Health Department provided construction data and driller’s logs for wells throughout Dougherty County. Special thanks also go to Gayle N. Manley and Charles E. Finley for allowing the USGS to collect data at Radium Springs, and to J. Roger Burner, Irrigation Plus of Dawson, for providing historic information and the loan of equipment.

Appreciation is extended to Douglas L. Pope, U.S. Department of Agriculture, Soil Conservation Service, Albany, for his help and support throughout this investigation. Special appreciation is extended to Frank G. Boucher for assistance in scheduling wells and for cartographic work, and to Robert P. Graves for assistance in locating and installing test-monitor wells and conducting an extensive file search.

DESCRIPTION OF THE STUDY AREA

The study area lies almost entirely in the Dougherty Plain district (Clark and Zisa, 1976) of the Coastal Plain physiographic province (fig. 1). The Dougherty Plain is an inner lowland (cuesta) that was formed mainly by the stripping away of sediments (Fenneman, 1938). It is bounded on the west by the Chattahoochee River and on the east by the crest of the Solution Escarpment, which separates it from the Tifton Upland. Although the Dougherty Plain is nearly level, it is not a single plain but includes a series of nearly level units. It slopes from an altitude of about 300 ft along the northern border of the study area to about 150 ft at the southern border. The slope of the Dougherty Plain averages about 5 ft/mi, and relief within the main part of the study area rarely exceeds 20 ft.

The Dougherty Plain is characterized by karst topography, marked by numerous shallow flat-bottomed or rounded sinkholes. The sinkholes range in depth from only a few feet to more than 25 ft; they are of all sizes up to several hundred acres. Many of the depressions are filled with material of low permeability and some hold water year round (Middleton, 1968).

Active solution in the Dougherty Plain has transferred most of the drainage from the surface to underground channels. Only the larger streams flow in terraced valleys. Major surface streams in the Dougherty Plain are the Flint River and its tributaries. The main tributaries are Muckalee, Kinchafoonee, Fowltown, Chickasawhatchee, Kiokee, and Cooleewahee Creeks.

At the east edge of the Dougherty Plain is a steeply sloping karst area that MacNeil (1947) named the Solution Escarpment. The escarpment itself, which has local relief as great as 125 ft, faces generally west to northwest and separates the Dougherty Plain and the Tifton Upland (fig. 1). In the study area, the Solution Escarpment has an average width of about 3 mi, and at its broadest point southeast of Baconton, is about 9.5 mi wide. The karst topography of the escarpment is somewhat different from that of the Dougherty Plain, in that sinkholes are less prevalent and generally are smaller in diameter and deeper. A sinkhole about 6 mi east of Baconton within the escarpment is 3 ft in diameter, 45 ft deep, and resembles a vertical mine shaft.

East of the Solution Escarpment is the Tifton Upland, an area characterized by gently rolling hills, smoothness of topography, and no marked parallelism of ridges. The Tifton Upland contrasts with the Dougherty Plain by having a high density of surface streams and minor karstification. Near the large streams, slopes are steep, but the steep slopes do not extend far from the streams (LaForge and others, 1925).

The crest of the Solution Escarpment forms the topographic and surface-water divide between the Flint River basin and the Ochlockonee and Withlacoochee River basins to the east. Several streams carry surface runoff westward down the slopes of the Solution Escarpment and go underground in swampy areas after traveling a short distance across the Dougherty Plain. In the Tifton Upland, streams generally emerge from swamps near the crest of the Solution Escarpment and flow southeastward to the Ochlockonee or Withlacoochee Rivers.

The northeastern and eastern parts of the Dougherty Plain are drained by Abrams, Mill, Piney Woods, Dry, and Raccoon Creeks. These tributary streams flow generally westward to the Flint River. According to LaForge and others (1925), remnants of the Okefenokee, Claxton, and Hazlehurst terraces that formed during the Pleistocene Epoch appear as slight ridges along the flood plain of the Flint River as far north as Leesburg. The terrace deposits are areally discontinuous, and consist of thin strips of surficial sand or gravel that extend away from the river channel.

HYDROGEOLOGY

Geology

The study area is underlain by Coastal Plain sediments of pre-Cretaceous to Quaternary age that consist of alternating units of sand, clay, sandstone, dolomite, and limestone that dip gently to the southeast and generally thicken in that direction. These sediments extend to a depth of at least 5,000 ft. Only sediments of late middle Eocene age and younger were investigated in this study. They include, in ascending order, the Lisbon Formation, the Clinchfield Sand, the Ocala Limestone, the Suwannee Limestone, undifferentiated sediments of Miocene age, and the undifferentiated overburden of Quaternary age (fig. 2).

Lisbon Formation

The lithology of the middle Eocene Lisbon Formation varies throughout the study area. In Lee, Terrell, and northern Dougherty Counties, the Lisbon is an easily defined unit that consists of brownish-gray to yellow, argillaceous, fossiliferous, sandy, glauconitic, dense limestone containing thinly interlayered calcareous sandstone and clay lenses. Downdip in the southeastern part of the area, the Lisbon consists of light-brown, slightly argillaceous, sandy, dolomitic limestone containing thinly bedded calcareous sandstone and trace amounts of glauconite. The Lisbon ranges in thickness from about 10 ft in central Lee County to about 100 ft at Albany, and averages about 100 ft thick in the southeastern part of the area. At well 13M028 (plate 1) in southeastern Lee County, the upper part of the Lisbon Formation consists of sandy, fossiliferous limestone.

ERATHEM	SYSTEM	SERIES		GULF COAST STAGE	GROUP AND FORMATION		
					Northwest Area		Southeast Area
Cenozoic	Quaternary	Holocene		Wisconsin to Nebraskan	Undifferentiated overburden		Undifferentiated overburden
		Pleistocene					
	Tertiary	Pliocene		Foleyan			
		Miocene		Clovellian Ducklakian Napoleonvillian (restricted)			Undifferentiated sediments
				Anahuacian			
		Oligocene		Chickasawhayan (restricted)			Suwannee Limestone
				Vicksburgian			
		Eocene	Late Eocene	Jacksonian	Ocala Limestone		Ocala Limestone
					Clinchfield Sand		
			Middle Eocene	Claibornian			
					Claiborne Group	Lisbon Formation	Lisbon Formation
						Tallahatta Formation	Tallahatta Formation

EXPLANATION

SEDIMENTS COMPRISING THE UPPER FLORIDAN AQUIFER

Figure 2.—Correlation of geohydrologic units.

Clinchfield Sand

In southern Lee County and northern Dougherty County, the Lisbon Formation is overlain by the Clinchfield Sand of late Eocene age (Herrick, 1972). The Clinchfield generally consists of medium to coarse, fossiliferous, calcareous quartz sand. The upper part of the formation at well 13M028 in southeastern Lee County consists of firmly cemented sandstone underlain by poorly cemented sand. Downdip at Albany, no cemented sandstone was penetrated in test well 12L029.

In the study area, the Clinchfield Sand attains a maximum thickness of 35 ft at well 13M028, thins toward Albany, and is absent at well 12L023 just south of Albany. The Clinchfield Sand is an ancient beach deposit.

Ocala Limestone

The Ocala Limestone of late Eocene age overlies the Lisbon Formation and the Clinchfield Sand, where present. Throughout much of the northern part of the study area, the Ocala Limestone can be divided into lower, middle, and upper lithologic units. In southern Lee and Terrell Counties and northern Dougherty County, the lower unit, which generally is highly fractured, consists of alternating layers of sandy limestone and medium-brown, recrystallized dolomitic limestone. The unit has well-developed secondary permeability along solution-enlarged joints, bedding planes, and other fractures. The thickness of the lower unit varies areally, ranging from about 46 ft at well 12L029 in Albany, to about 85 ft at well 13M010 in southeastern Lee County. West of Albany at well 11L017 the lower unit has a thickness of 58 ft.

The lower unit grades upward into a middle unit that consists of relatively impermeable white to brown, clayey, dense chalky limestone interlayered with noncalcareous clay and silt that has local permeability. The lithology of this unit varies areally.

The upper unit typically consists of fossiliferous, very fine-grained, recrystallized, chalky limestone that contains an abundance of chert and rhombohedral calcite. The upper unit and the middle unit have a combined thickness of 73 ft at well 13M010 in southeastern Lee County. The thickness of the combined middle and upper units does not vary significantly in the part of the study area southwest of Albany.

In the southern and southeastern parts of the study area, the lower unit of the Ocala consists of interlayered gray to dark-brown, recrystallized, glauconitic, dolomitic limestone. In those areas, the middle unit is missing and the lower unit is directly overlain by the upper unit. The upper unit consists mainly of white to pinkish-white, finely crystallized to oolitic, locally dolomitic limestone. Some layers are abundantly fossiliferous and contain a variety of shells, corals, and echinoid remains. The limestone is irregularly interbedded with thin layers of calcareous sand and firmly cemented calcareous sandstone.

The Ocala Limestone is exposed along the Flint River and its major tributaries, and at scattered locations in the northwestern part of the area. The limestone forms bluffs 30 to 40 ft high along the Flint River north of Albany, and in Lee and Worth Counties. South of Albany near the Flint River, the Ocala is covered by terrace deposits, or has been eroded, so that the limestone is visible only in the bed of the river during periods of low flow. However, several limestone bluffs overlook the Flint River near Baconton.

The thickness of the Ocala varies throughout the study area. In the northwestern part of the area the Ocala is about 25 ft thick, and it progressively thickens toward the southeast, attaining a maximum measured thickness of 270 ft in southeastern Dougherty County.

Suwannee Limestone

The Ocala Limestone is overlain by the Suwannee Limestone of Oligocene age. The Suwannee is present in the Dougherty Plain east of the Flint River and in the Solution Escarpment and the Tifton Upland (Owen, 1963b). Weathering and erosion have thinned the Suwannee and left discontinuous outliers in Dougherty and Mitchell Counties. The Suwannee is exposed in scattered sinkholes and road cuts near the base of the Solution Escarpment.

Owen (1963b) described a 70-ft section of the Suwannee Limestone at the Bridgeboro Quarry (plate 1), about 5.5 mi east of Baconton in the southeastern part of the study area, as light-gray to white, coarse to extremely fine-grained limestone. The limestone contains nodules of clastic limestone, large chert boulders, and abundant pelecypods, gastropods, and large foraminifera. Dissolution of the limestone has produced numerous interconnected solution openings in the upper 4 to 6 ft of the Suwannee exposure.

The Suwannee Limestone is reported to be about 100 ft thick in the Tifton Upland and in parts of the Solution Escarpment (James A. Miller, U.S. Geological Survey, oral commun., 1984). Limited subsurface data and the lithologic similarities of the Suwannee and the Ocala make thickness determinations difficult.

Undifferentiated Sediments of Miocene Age

Sands and clays of Miocene age overlie the Suwannee Limestone and crop out in the Solution Escarpment and in the Tifton Upland in Worth County. McFadden (1986) described a 65-ft section of sand and sandy clay from a well (14L007) in the Solution Escarpment. At well 14L002 on the western edge of the Tifton Upland, the Miocene section consists of 190 ft of fine to coarse sand, clayey sand, and bioclastic sandy limestone.

Undifferentiated Overburden of Quaternary Age

In the Dougherty Plain and the Solution Escarpment, the Ocala and Suwannee Limestones and the sediments of Miocene age are overlain by undifferentiated overburden composed of fine to coarse quartz sand and noncalcareous clay (plate 2). Overburden consisting mainly of sand may be alluvium deposited by area streams. Overburden consisting of sand and clay or mainly clay probably is residuum derived from weathering of the Ocala and Suwannee Limestones. Individual layers in the overburden generally are discontinuous and can be traced only for short distances. In the northern and northeastern parts of the study area, weathered rounded limestone pieces, ironstone nodules, chert boulders, and chalk are common near the base of the undifferentiated overburden.

In the Dougherty Plain, the undifferentiated overburden generally ranges in thickness from 20 to 40 ft on the western side of the Flint River and from 40 to 80 ft on the eastern side of the river (plate 2). In isolated areas the overburden is 100 ft to more than 400 ft thick, probably where colluvial material has filled ancient sinkholes. (See the section "Geologic Hazards"; fig. 18.)

Hydraulic Characteristics

The principal hydrogeologic units of interest in the study area are, in descending order, the undifferentiated overburden and the Upper Floridan aquifer. The geologic section in figure 3 shows the stratigraphic relations and thicknesses of these units, and selected geophysical logs. The line of the geologic section is shown on figure 4.

Undifferentiated Overburden

The dominant lithologic factor determining the transmissivity and hydraulic conductivity of the undifferentiated overburden is the relative amount of sand and clay (Hayes and others, 1983). According to Hayes and others (1983), estimated vertical hydraulic conductivity of the overburden varies from 0.001 ft/d to 9 ft/d, with a median of 0.003 ft/d. Estimated horizontal hydraulic conductivity varies from 0.004 ft/d to 30 ft/d, with a median of 0.02 ft/d. By using an average saturated thickness for the overburden, Hayes and others (1983) found that transmissivity values for the saturated part of the overburden range from 0.002 ft^2/d to 1,000 ft^2/d, with a median of 0.3 ft^2/d.

Upper Floridan Aquifer

The Upper Floridan aquifer in the study area consists primarily of the Ocala Limestone. In Lee County and extreme northern Dougherty County, the Clinchfield Sand interfingers with and underlies the Ocala Limestone and forms a major part of the aquifer (figs. 2, 3). In that area the upper part of the Lisbon Formation also has significant secondary permeability and forms part of the Upper Floridan. To the east and southeast in the Solution Escarpment and the Tifton Upland, the Upper Floridan includes the Suwannee Limestone, which is hydraulically connected with the Ocala Limestone (figs. 2, 3).

The Upper Floridan aquifer ranges in thickness from about 50 ft in the northwestern part of the study area to about 475 ft in the southeastern part (fig. 4). The aquifer is confined below by a layer of low permeability in the Lisbon Formation, and generally is confined above by the undifferentiated overburden and in the northern part of the area by low-permeability zones within the Upper Floridan (fig. 4).

The Upper Floridan aquifer stores and transmits large quantities of water, mainly in a zone of high permeability in the lower part of the Ocala Limestone. This deep permeable zone may have resulted from dissolution of the limestone by circulating ground water during a period of greatly reduced sea level. In much of the area, permeability is imparted by relatively small interconnected solution openings. Close to the Flint River, however, and between the river and the Solution Escarpment, the permeable zone includes a system of major ground-water conduits. In Dougherty and Mitchell Counties, the conduit system transports water from the Solution Escarpment to springs, such as Radium Springs, that discharge into the Flint River.

The distribution of transmissivity in the Upper Floridan aquifer is highly variable (fig. 5) because of areal differences in primary permeability of the Clinchfield Sand in Lee County and secondary permeability of the Ocala Limestone, the upper part of the Lisbon Formation, and the Suwannee Limestone. The transmissivity was calculated from aquifer tests or it was estimated from specific-capacity data (Hayes and others, 1983, tables 10, 11).

Major solution conduits in the limestone may account for only a small part of the cross-sectional flow area in the aquifer, but they conduct a major part of the ground-water flow (Hayes and others, 1983). Thus, point values of transmissivity commonly are higher or lower than regionalized transmissivity values, depending on whether wells intersect large conduits. Transmissivity near the Flint River in the central and southwestern parts of the study area is high (as much as 150,000 ft^2/d) because of the effects of solution conduits that tend to have the greatest development in major discharge areas.

From the northern boundary of the study area to approximately central Dougherty County (fig. 4), the upper part of the Upper Floridan aquifer has low transmissivity and acts as a leaky confining unit that separates the undifferentiated overburden and the permeable zone in the lower part of the aquifer. The upper part of the aquifer is, therefore, hydraulically connected to the water-table aquifer in the overburden.

Constructing a digital ground-water-flow model requires regionalized transmissivity values. In a limestone aquifer whose permeability results from interconnected solution conduits, regional transmissivity values can differ greatly from point transmissivity values calculated from aquifer tests or estimated from specific-capacity data. The interconnection of solution conduits in the Upper Floridan aquifer with the Flint River affords an opportunity to calculate the regional transmissivity of the aquifer. The aquifer's

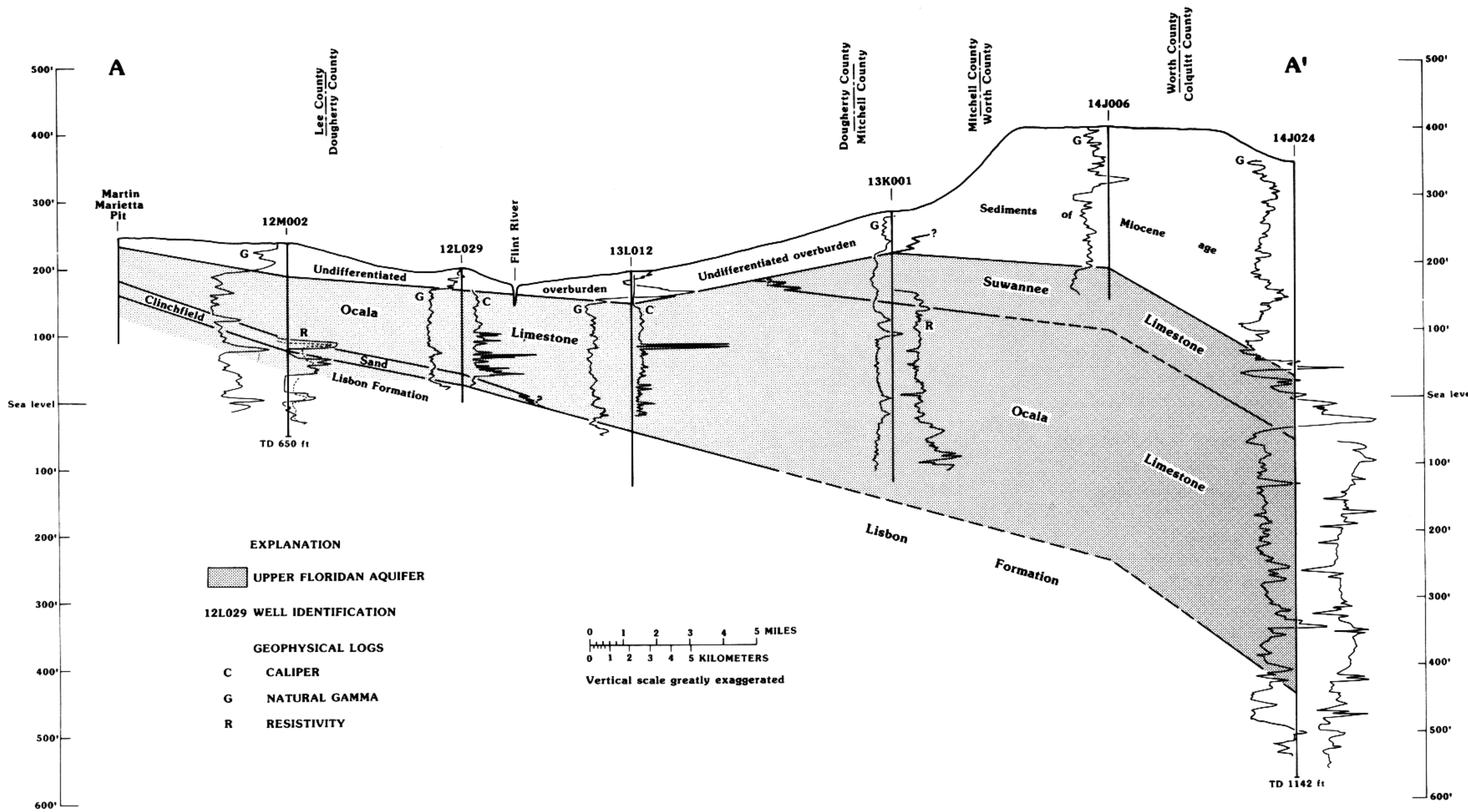


Figure 3.—Geologic section A-A'. Line of section is shown on figure 4. (Stratigraphy of Martin Marietta pit by Paul F. Huddlestun, Georgia Geologic Survey, oral commun., 1987).

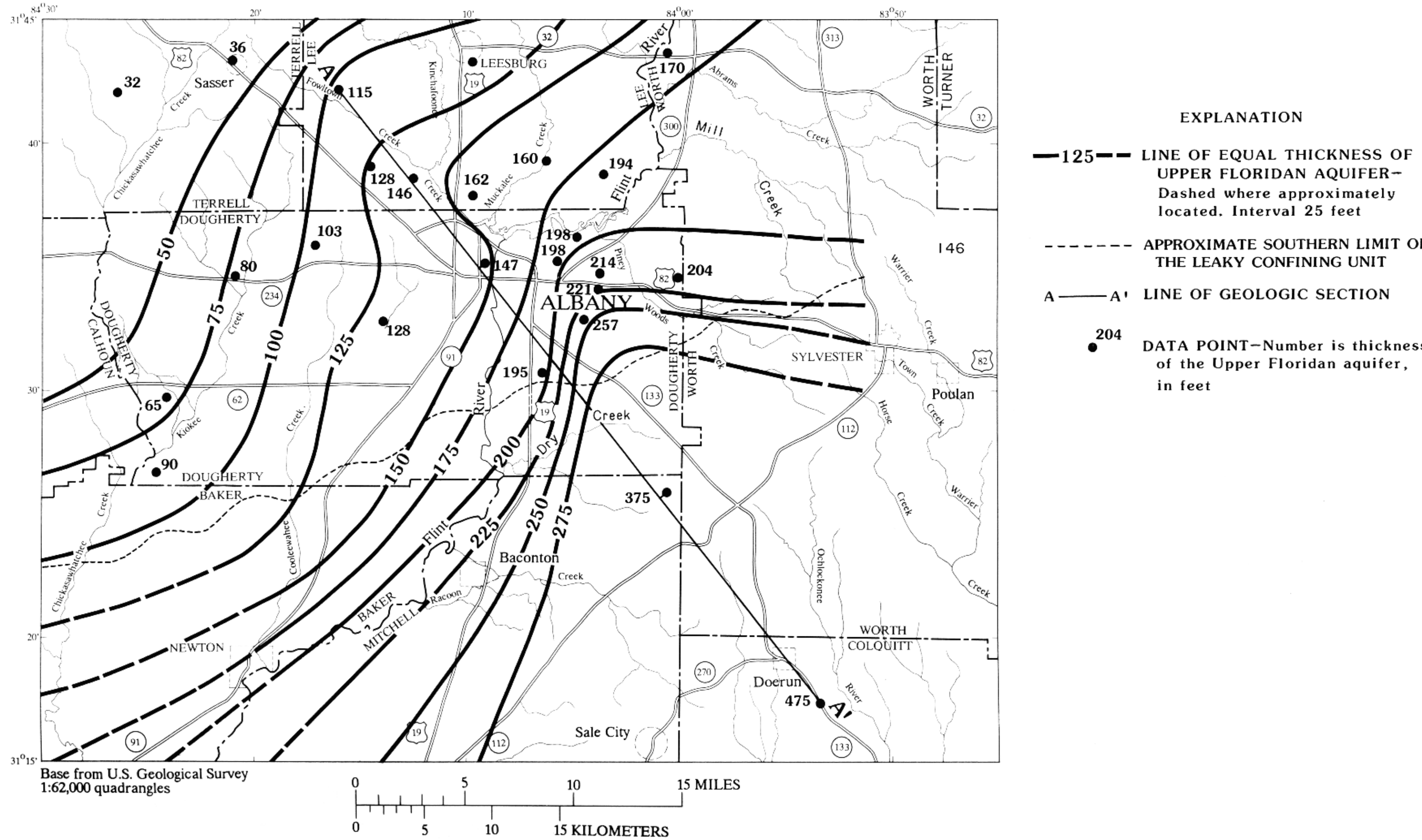


Figure 4.—Thickness of the Upper Floridan aquifer, line of geologic section A-A', and area where the upper part of the aquifer forms a leaky confining unit.

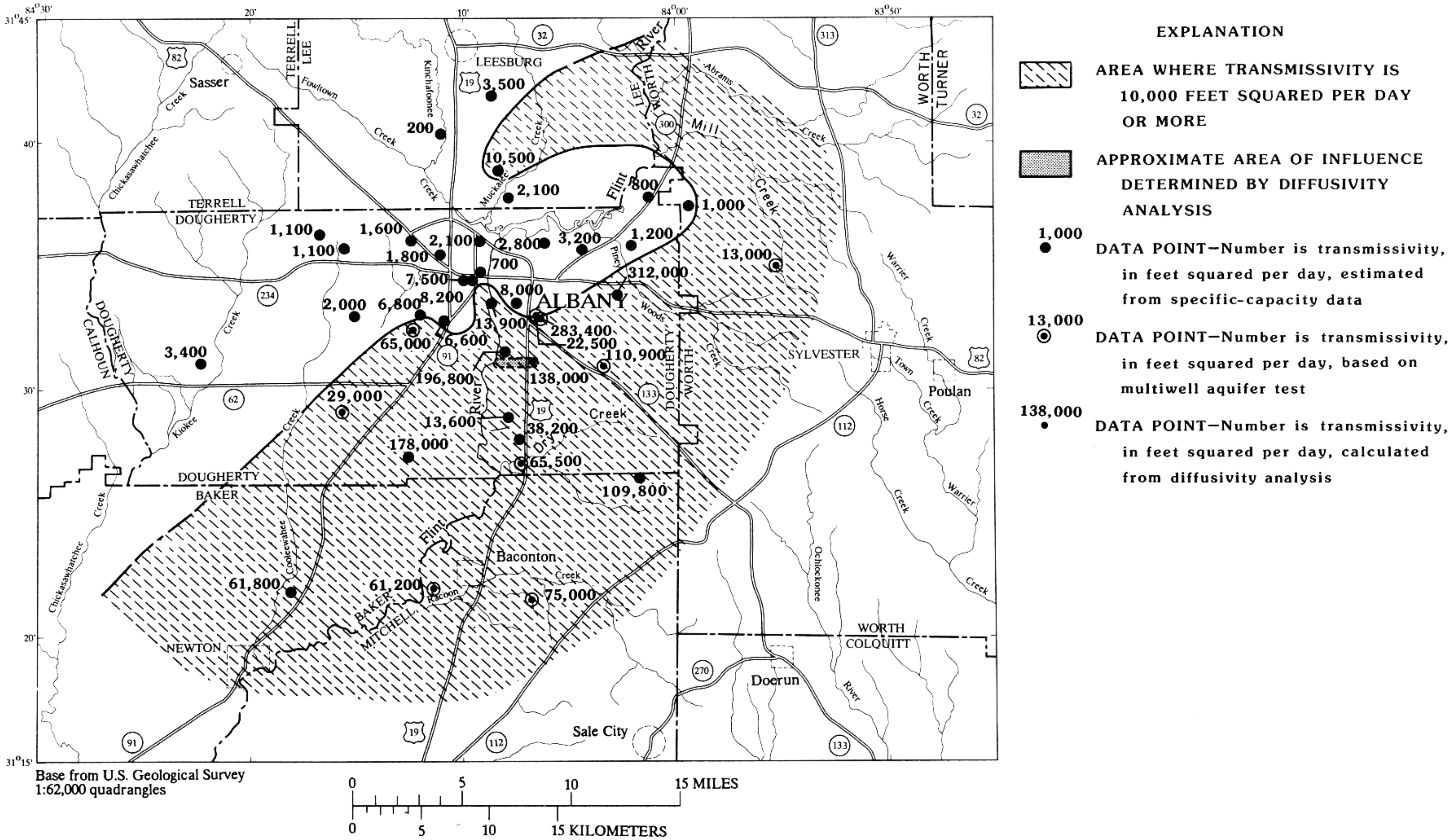


Figure 5.—Transmissivity of the Upper Florida aquifer.

response to a flood wave that passed down the Flint River during the period February 11-18, 1981, made it possible to calculate the regional diffusivity of the aquifer (ratio of transmissivity, T, to the storage coefficient, S).

The diffusivity of the aquifer in a small area can be calculated by the flood-wave-response method described by Pinder and others (1969). This method consists of generating a series of type curves from a river-stage hydrograph that predicts the response of the aquifer and matches the best fit to the observed aquifer hydrograph to obtain diffusivity. The advantage of this method is that aquifer diffusivity values are regionalized as required by areal ground-water models. Well 13L012, which taps the Upper Floridan aquifer about 1.5 mi east of the Flint River (fig. 5), was used in the calculation. At that site the aquifer is overlain by 50 ft of overburden. The limestone has greatly enhanced permeability below about 100 ft.

The analysis resulted in a diffusivity value (T/S) of 4,000 ft^2/s, which compares favorably with a value of 3,700 ft^2/s calculated from an aquifer test on well 11L023 (Hayes and others, 1983, p. 46). An estimated storage coefficient of 0.0004 produces a transmissivity of about 138,000 ft^2/d for this site.

Recharge, Discharge, and Flow Characteristics of the Upper Floridan Aquifer

The Upper Floridan aquifer is recharged primarily by precipitation in the Dougherty Plain and the Solution Escarpment. Most recharge water enters the aquifer by percolating through the undifferentiated overburden. The rate of recharge is controlled largely by the vertical hydraulic conductivity of the overburden, which in the study area has a median value of about 0.003 ft/d (Hayes and others, 1983). Variations in the lithology of the overburden cause the hydraulic conductivity to differ areally. Where clay layers are widespread, they form a semiconfining unit and the vertical hydraulic conductivity of the overburden is low. An increase in the percentage of sand in the overburden generally results in an increase in the vertical hydraulic conductivity. In some areas, the water table in the overburden rises rapidly after rainfall, indicating that the vertical hydraulic conductivity of some zones in the overburden may be greater than Hayes' median value of 0.003 ft/ d.

Recharge by precipitation occurs mainly during the period December through March when rainfall is heavy and evapotranspiration is low (Mitchell, 1981). Although rainfall is heavy during July and August, summer storms generally are of short duration and a large part of the water is lost to runoff, evapotranspiration, and soil-moisture replenishment. The rate of mean annual recharge to the Upper Floridan is about 6 to 14 in/yr (Morris L. Maslia, U.S. Geological Survey, oral commun., 1984). However, recharge rates are highly variable throughout the area (Hayes and others, 1983).

In areas where the water in the overburden has a higher head than water in the permeable zone of the Upper Floridan aquifer, leakage occurs from the overburden through the leaky confining unit into the Upper Floridan. The leakage rate depends on the vertical hydraulic gradient between the water table in the overburden and the head in the Upper Floridan aquifer, and the thickness and vertical hydraulic conductivity of the leaky confining unit. In southeastern Lee County (plate 1) paired wells were constructed to tap the permeable zone of the Upper Floridan aquifer (13M010), and a local permeable zone at the contact between the overburden and the Upper Floridan (13M012) that reflects the water level in the overburden. Hydrographs for the period 1983-85 indicate that although the water table generally was higher than the head in the Upper Floridan, the seasonal water-level change in both aquifers was similar (fig. 6). During late spring and early summer, when the Upper Floridan was pumped at a maximum rate, the water-level decline in well 13M012 was accelerated. The head decline in the Upper Floridan induced leakage from the overburden through the leaky confining unit within the Upper Floridan aquifer. The water level in the overburden continued to decline after pumping from the Upper Floridan ceased in late summer and early fall and it did not level off until the onset of recharge by precipitation in late fall.

In northwestern Worth County, wells 13M005, 13M006, and 13M007 were constructed to tap the overburden, the Upper Floridan aquifer, and the Claiborne aquifer, respectively (fig. 2; plate 1). Hydrographs for wells 13M005 and 13M006 indicate that for the first part of 1983 this was a discharge area for the Upper Floridan (fig. 7), because the head in the Upper Floridan was higher than the water level in the overburden. Under these conditions, leakage from the overburden into the Upper Floridan can only be induced by pumping that lowers the head in the Upper Floridan below the head in the overburden. From May 1983 until September 1984, the head in the Upper Floridan was lower than the head in the overburden and the Upper Floridan was recharged by water from the overburden. Moreover, a comparison of the hydrographs for wells 13M006 and 13M007 indicates that during periods of pumping, the head in the Claiborne aquifer is higher than the head in the Upper Floridan and the Upper Floridan is recharged by water from the Claiborne.

Ground-water flow in the study area can be classified generally as (1) diffuse, where flow is analogous to conditions in a homogeneous aquifer and can be described by using basic Darcian equations; and (2) conduit flow, where flow occurs in distinct conduits and the surrounding rock has comparatively low porosity and permeability. Ground-water flow in the conduits may be rapid and turbulent.

The Upper Floridan aquifer functions mainly as a conduit flow system in part of the study area, especially near the Flint River and in the area of high

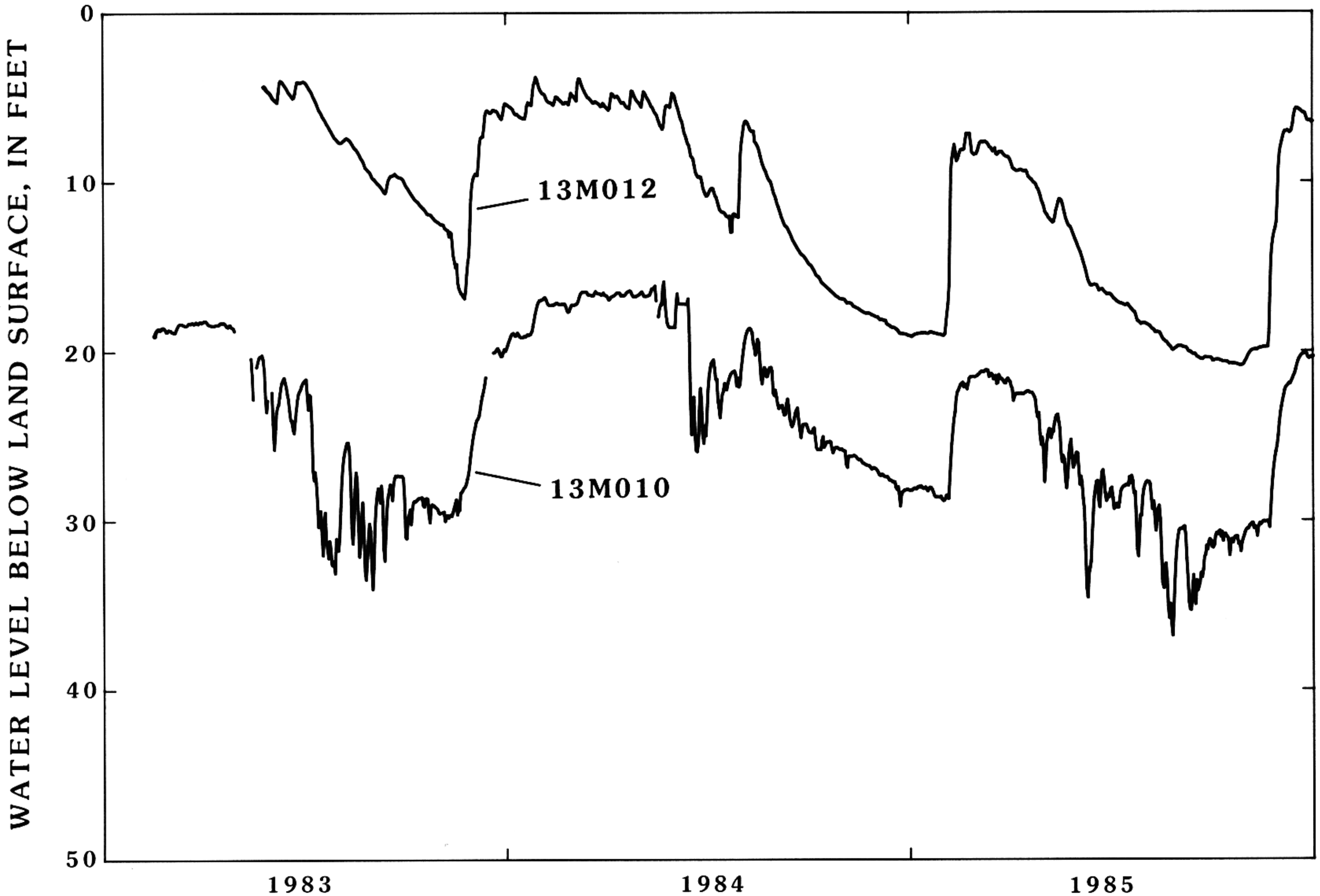


Figure 6.—Hydrographs for wells 13M010 and 13M012, 1983–85.

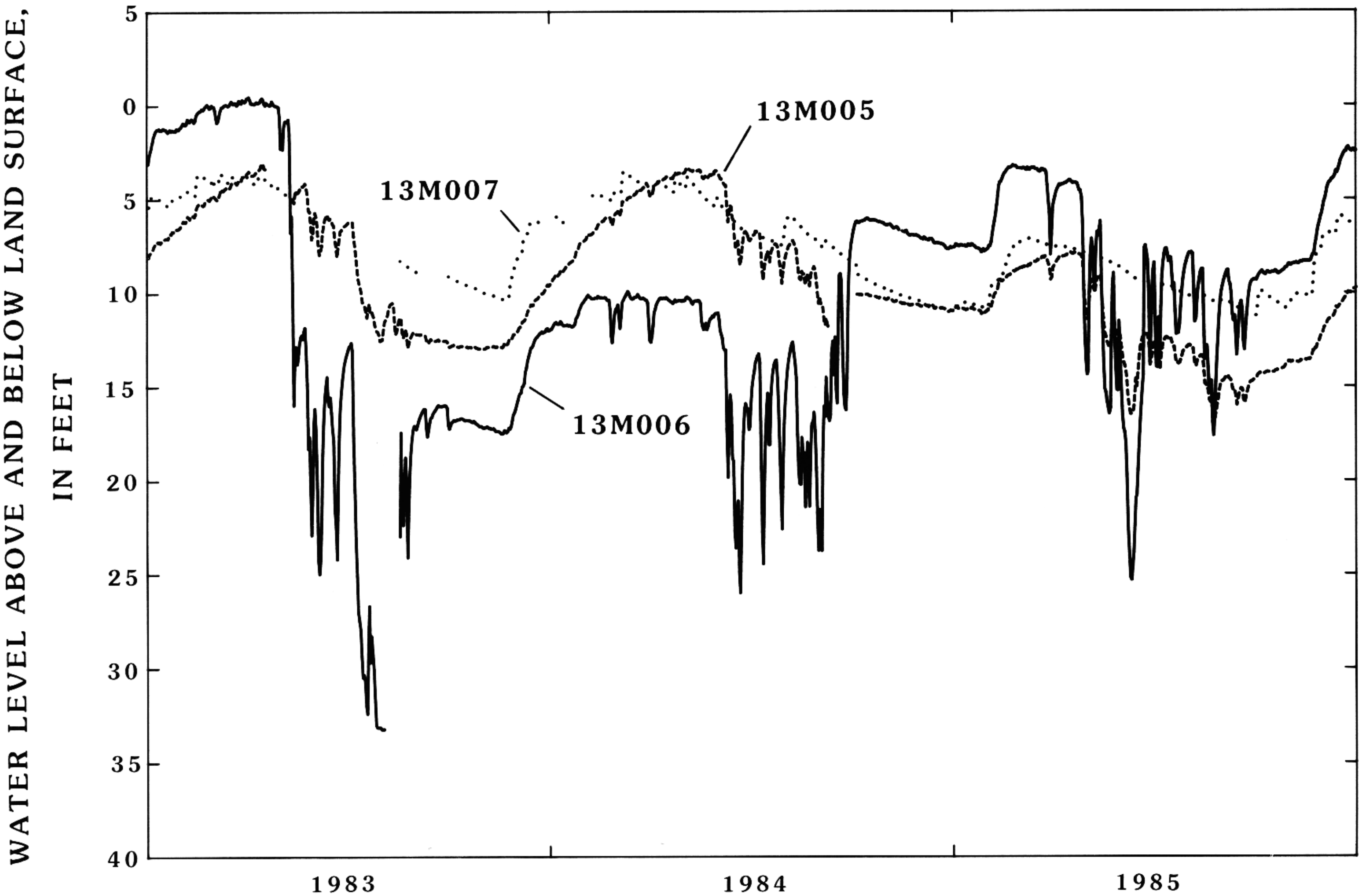


Figure 7.—Hydrographs for wells 13M006 and 13M007, 1983–85.

transmissivity east of the river (fig. 5). Caution needs to be exercised in the rigorous application of flow equations that assume a homogeneous and isotropic aquifer framework and laminar ground-water flow in these areas.

The rate of ground-water movement can vary greatly in the Upper Floridan depending on the type of flow. Hayes and others (1983, p. 55-56) found that effective hydraulic conductivity in areas of conduit flow exceeded 1,000 ft/d, whereas average ground-water flow was calculated to be about 3 ft/d. In areas of diffuse flow away from the river and streams, the hydraulic conductivity was about 100 ft/d and ground-water flow averaged 0.2 ft/d.

Ground-Water Levels

Water levels in the undifferentiated overburden and the Upper Floridan aquifer respond positively to recharge and negatively to discharge. Data from 53 monitoring wells indicate that the amount of water-level rise and the rate of rise in response to rainfall is not predictable, varies areally, and can be very slow or nearly instantaneous. Generally, the water level in the overburden is highest during February through April, declines during the summer and fall, and is at a minimum during November through January (fig. 6).

Water levels in 22 wells that tap the overburden and that were measured monthly, ranged from about 1 to 22 ft below land surface during the period April 1982 through December 1984 (Sandra C. Cooper, U.S. Geological Survey, oral commun., 1984). The maximum annual water-level fluctuations in individual wells ranged from about 10 to 16 ft.

The level at which water will stand in a tightly cased well that taps an artesian aquifer is referred to as the hydraulic head. An imaginary surface connecting points to which water would rise in tightly cased wells tapping the same aquifer is referred to as a potentiometric surface. The map showing the potentiometric surface of the Upper Floridan aquifer is useful for determining recharge areas, discharge areas, and the general direction of ground-water flow through the aquifer (plate 1).

Ground water flows downgradient, in directions approximately perpendicular to the potentiometric contours. In the Dougherty Plain ground water flows toward the Flint River and its tributaries (plate 1). Recharge that enters the Upper Floridan aquifer in interstream areas moves downgradient toward points of natural discharge along these streams.

During years of normal rainfall, seasonal fluctuations in the altitude of the potentiometric surface range from about 2 ft in the Tifton Upland to 30 ft in the Dougherty Plain east and southeast of Leesburg. Near major agricultural and industrial pumping centers, seasonal fluctuations of the potentiometric surface probably exceed 30 ft. Unlike the deeper aquifers, no pumping-induced cones of depression have developed in the potentiometric surface of the Upper Floridan aquifer.

A predevelopment potentiometric map of the study area was constructed from data collected prior to 1957 (Wait, 1963). The predevelopment potentiometric surface is similar to the potentiometric surface for November 1985 (plate 1). The similarity of the two surfaces shows that 28 years of ground-water withdrawal, averaging about 66 Mgal/d in 1983, has not produced a long-term decline of the water level in the Upper Floridan aquifer. Thus, the system remains in equilibrium; recharge received from normal annual rainfall approximately equals the combined natural and man-induced discharge.

Seasonal Water-Level Fluctuations

In the eastern and southeastern parts of the Dougherty Plain near the base of the Solution Escarpment, the Upper Floridan aquifer is relatively thick and has high transmissivity. The water levels in wells 13L003, 13L048, and 13J004 respond rapidly to increases in recharge and the maximum annual fluctuations range from about 13 to 24 ft (fig. 8). Moveover, the water levels remain elevated after each recharge event because water is held in aquifer storage rather than being rapidly dissipated to streams. Although wells 13L003 and 13L048 are near centers of agricultural pumping, the water levels in these wells do not show significant seasonal fluctuations. This can be attributed to the high transmissivity and storage of the Upper Floridan aquifer in that area.

In southeastern Lee County, the basal part of the Upper Floridan aquifer has moderate transmissivity, but the upper part is clayey and has relatively low transmissivity. At well 12M017, which was constructed to seal out the upper part of the aquifer, the water level is not sensitive to local rainfall (fig. 9), although the response to irrigation pumping (sharp down- spikes) is pronounced.

Wells 13K014 and 13L012 are in the Dougherty Plain east of the Flint River where the aquifer has high transmissivity and is confined by 50 to 100 ft of overburden. Each of these wells was constructed to monitor water-level fluctuations in the upper part of the aquifer. Water levels in these wells respond rapidly to precipitation, but have no apparent response to irrigation pumping (fig. 10). The water level in the aquifer responds more to river stage than to local rainfall.

West of the Flint River at wells 12L028 and 11K003 (fig. 11), the water level in the Upper Floridan aquifer is not affected by stage changes of the Flint River. There, the aquifer responds to recharge by precipitation, and in well 11K003, to local pumping. Annual water-level fluctuations in this area range from 10 to 15 ft.

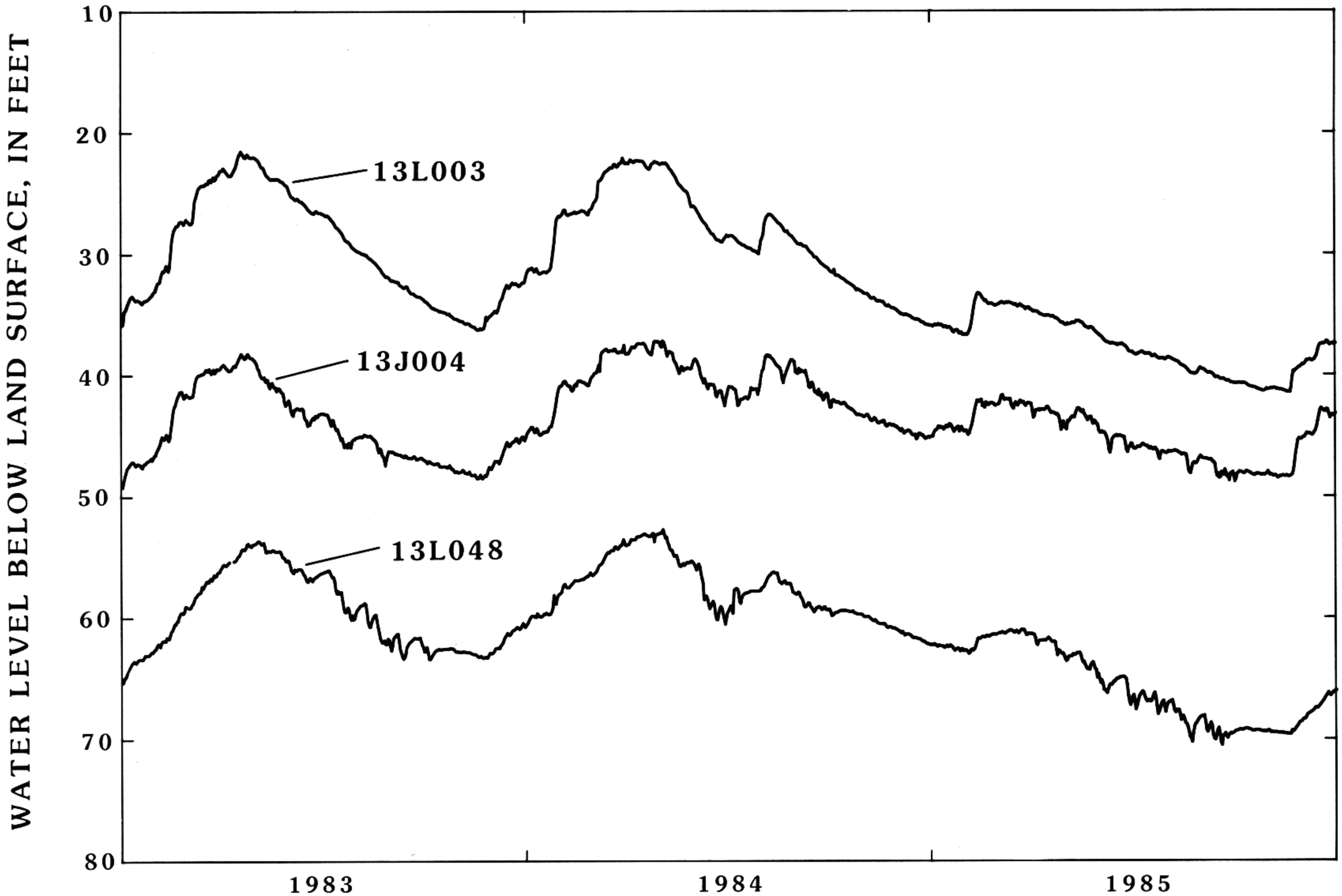


Figure 8.—Hydrographs for wells 13L003, 13L048, and 13J004, 1983–85.

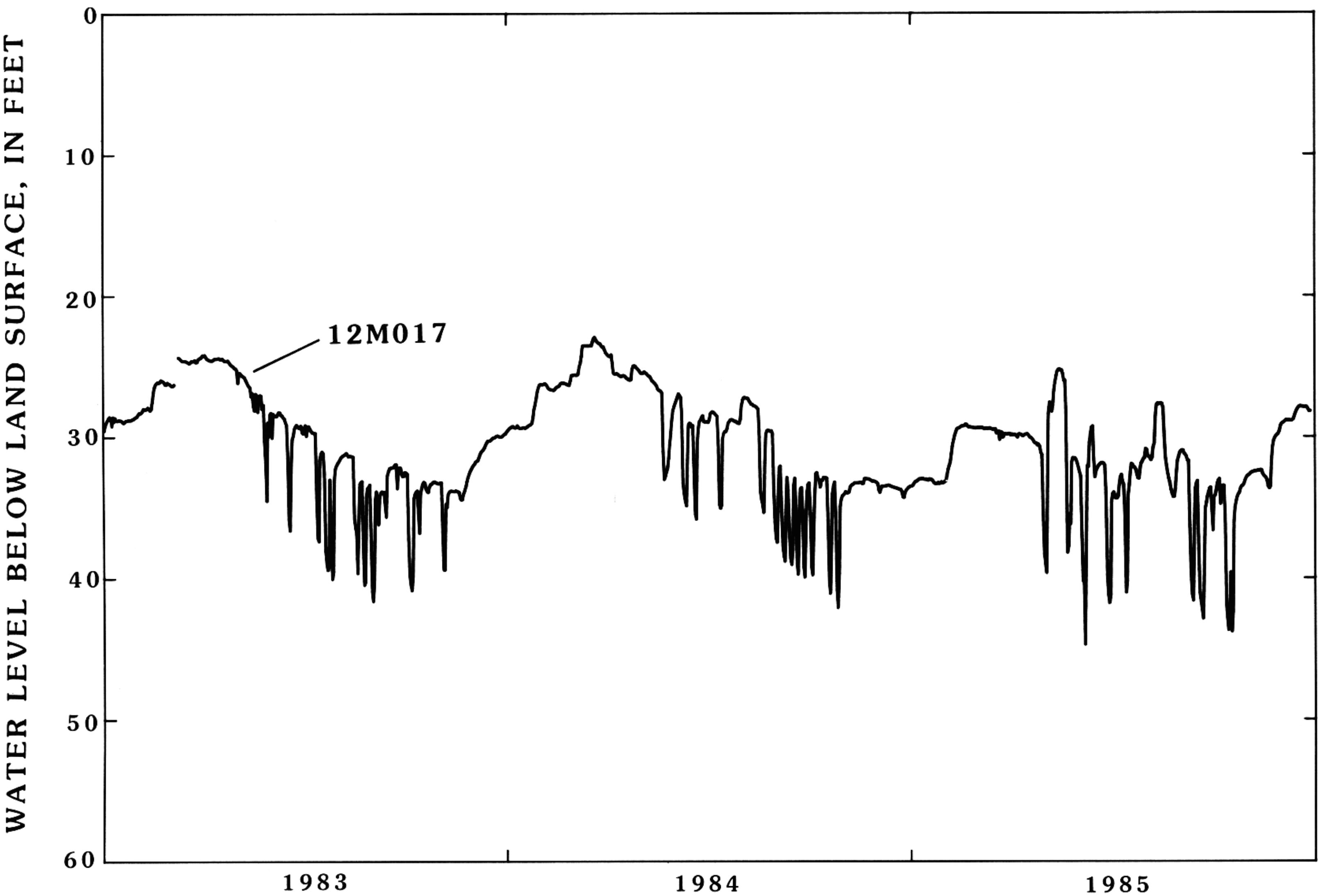


Figure 9.—Hydrograph for well 12M017, 1983–85.

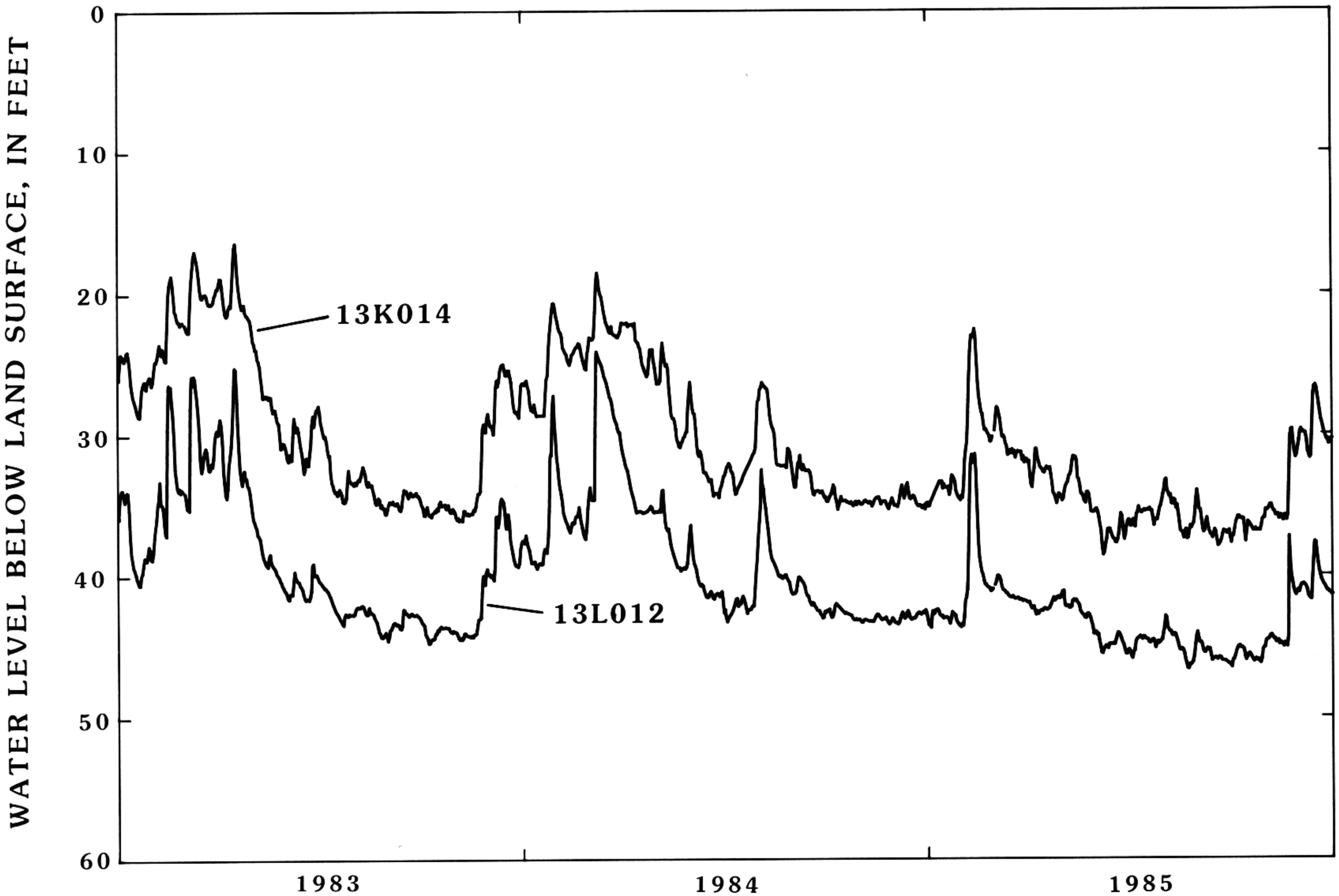


Figure 10.—Hydrographs for wells 13K014 and 13L012, 1983–85.

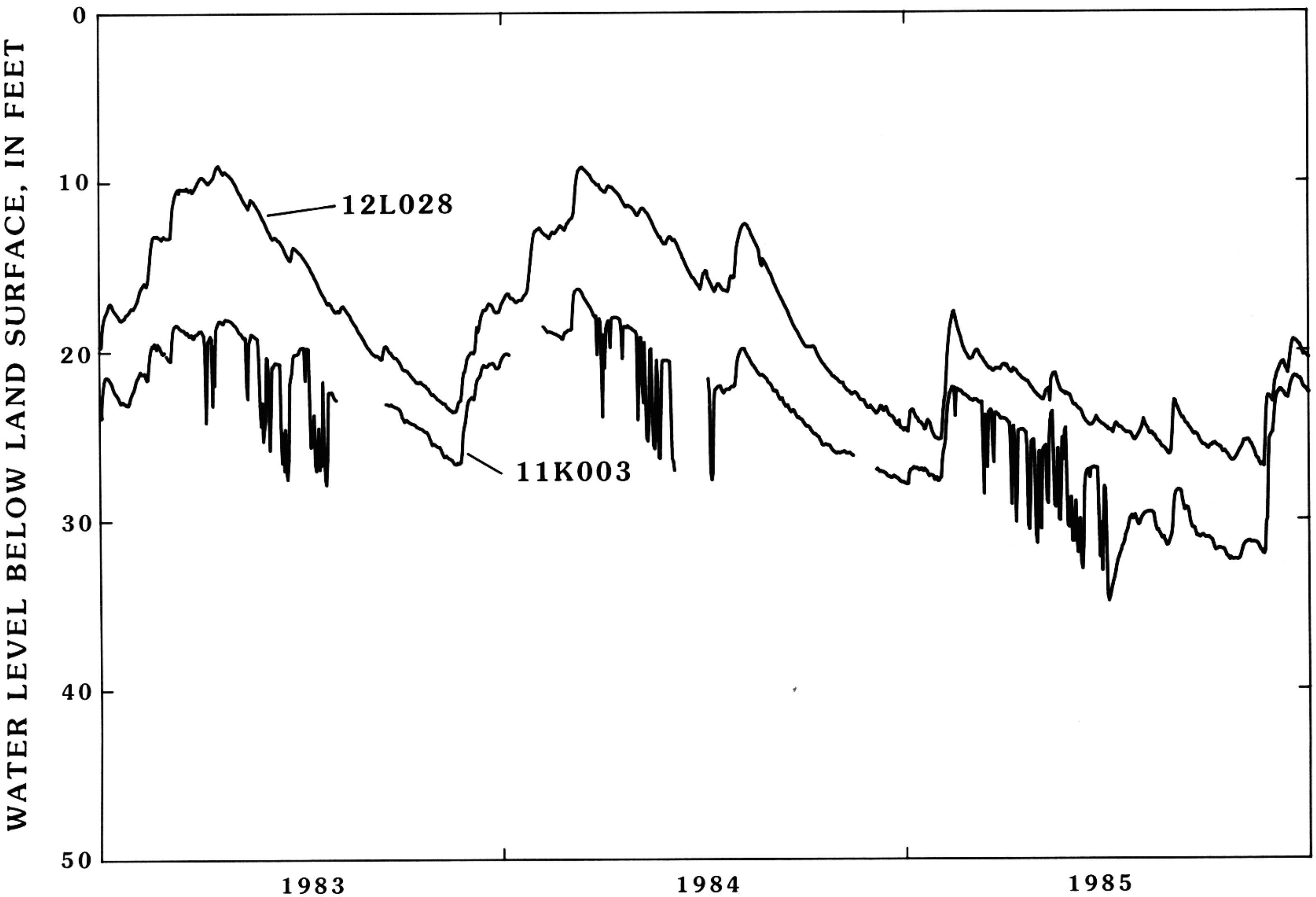


Figure 11.—Hydrographs for wells 12L028 and 11K003, 1983–85.

Near Sylvester on the Tifton Upland, the Upper Floridan is overlain by a thick sequence of undifferentiated sediments and overburden and the water level in the aquifer responds slowly to seasonal variations in rainfall. The greater thickness of the aquifer in that area coupled with limited ground-water discharge results in a water-level fluctuation of about 2 ft/yr in well 15L020 (fig. 12).

Long-Term Water-Level Changes and the Effects of Drought

In the Dougherty Plain, the water level in the Upper Floridan aquifer has not shown a significant long-term decline. Long-term fluctuations in well 13L003 in eastern Dougherty County are typical of the Dougherty Plain and are influenced by changes in rainfall, evapotranspiration, and irrigation pumping (fig. 13). The water level in the well generally is highest in the winter and early spring when rainfall is abundant, evapotranspiration is low, and there is little, if any, irrigation pumping. During the droughts of the early and late 1960's and the drought of 1980-81, the water level in well 13L003 declined to record or near-record lows, but with the return of normal precipitation it recovered to predrought levels.

Water-level fluctuations in the Tifton Upland are mainly due to changes in pumping rates and are typified by well 15L020 in Sylvester, Worth County (fig. 13). During 1974-85, the water level in well 15L020 declined about 9 ft in response to increased irrigation pumping. From the spring of 1980 to the summer of 1981, the water level in the well declined about 9 ft and a record low was measured in July 1981. Although the water level recovered slightly in 1982 following the cessation of the drought, it resumed its decline during 1983-85.

Ground-Water and Surface-Water Relation

Where major streams in the study area are incised into the Upper Floridan aquifer, a close relation exists between the ground-water and surface-water systems. Because of this relation, climatic and man-induced changes that affect one system also affect the other.

During early spring, the altitude of the potentiometric surface of the Upper Floridan aquifer is high and the aquifer discharges maximum quantities of water into the Flint River and its tributaries throughout their reaches. During late spring and early summer, heavy pumping, high evapotranspiration, and reduced recharge result in a gradual lowering of the potentiometric surface and decreased aquifer discharge.

The Upper Floridan aquifer discharges into streams where the altitude of the potentiometric surface exceeds the altitude of the streams. The rate of discharge is a function of the hydraulic conductivity of the aquifer, the hydraulic gradient between the aquifer and the stream stage, and streambed conductance in areas of diffuse discharge. Throughout the Cooleewahee Creek drainage basin in the western part of the study area, numerous springs discharge water from the aquifer. A streamflow measurement at site A, at Georgia Highway 234 (plate 1), showed that on March 15, 1984, Cooleewahee Creek had a flow of 53.9 ft^3/s (24,190 gal/min) that consisted primarily of spring discharge. The flow on the same day at site B, downstream from site A at Georgia Highway 91, was 410 ft^3/s (184,008 gal/min) and consisted mainly of spring discharge. Springs also are common throughout the Kiokee and Chickasawhatchee basins.

The base flow of these streams is maintained by discharge from the Upper Floridan aquifer. During the winter months, when artesian pressure normally is high, the streams flow vigorously, but as the ground-water level declines in late spring and early summer, streamflows progressively decline. During the drought of 1980-81, Cooleewahee and Kiokee Creeks ceased flowing in late July 1981, and remained nonflowing until December when winter rains recharged the ground-water system and produced surface runoff.

East of the Cooleewahee basin, ground water from the Upper Floridan flows through solution conduits and discharges into the Flint River. Although most springs emerge in the riverbed and are visible only during low-flow periods, several large springs, including Radium Springs (plate 1), emerge near the Flint River south of Albany.

In the northern part of the study area, the Upper Floridan discharges through springs into the Kinchafoonee, Muckalee, and Fowltown Creeks. Where the streams are deeply incised into the aquifer, ground water seeps from limestone cliffs and cascades into the streams.

Near the Flint River in the northeastern part of the study area, Abrams, Mill, and Piney Woods Creeks receive part of their flow from the Upper Floridan aquifer. Where the streams have eroded through the overburden, the aquifer is unconfined and ground water discharges into the streambeds. Ground-water discharge to these streams progressively diminishes eastward away from the Flint where the overburden is thicker and the aquifer is confined.

Periods of drought can lower the potentiometric surface and result in greatly reduced aquifer discharge to the river. This was demonstrated by Radium Springs, which emerges from a solution conduit in the limestone at the base of a small bluff about 1,000 ft east of the Flint River south of Albany (plate 1). Discharge measurements of Radium Springs have been made intermittently since 1937. During the drought of 1954, the lowest measured discharge was 4.09 ft^3/s (1,835 gal/min). During the drought of 1980-81, however, reduced aquifer recharge coupled with intense regional pumping, mainly for irrigation, resulted in record water-level declines in the Upper Floridan aquifer and, thus, decreased spring discharge (Carter, 1983, p. 39). On May 22, 1981, the flow of Radium Springs declined to 0.275 ft^3/s (123 gal/ min) and on July 1, 1981, the spring

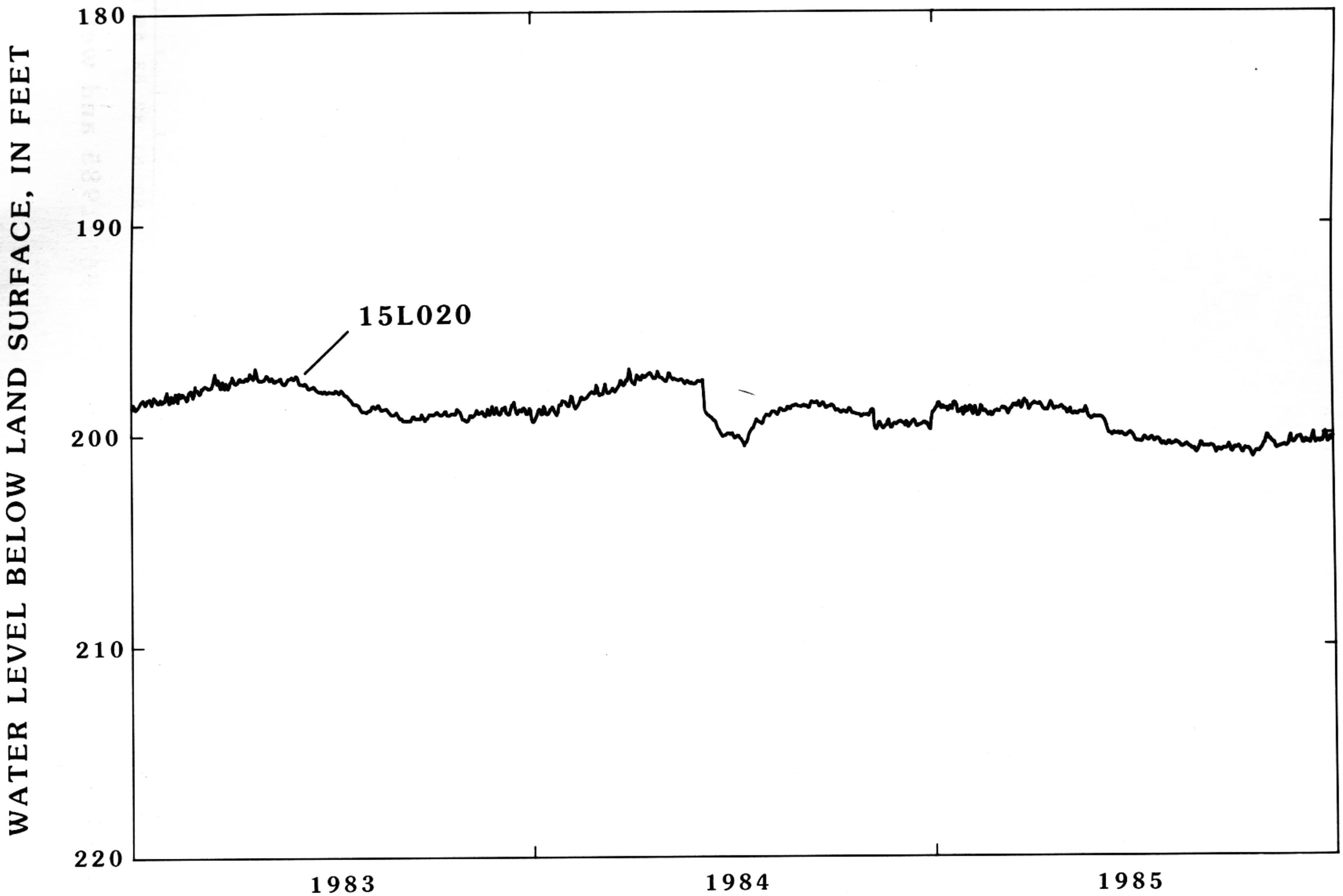


Figure 12.—Hydrograph for well 15L020, 1983–85.

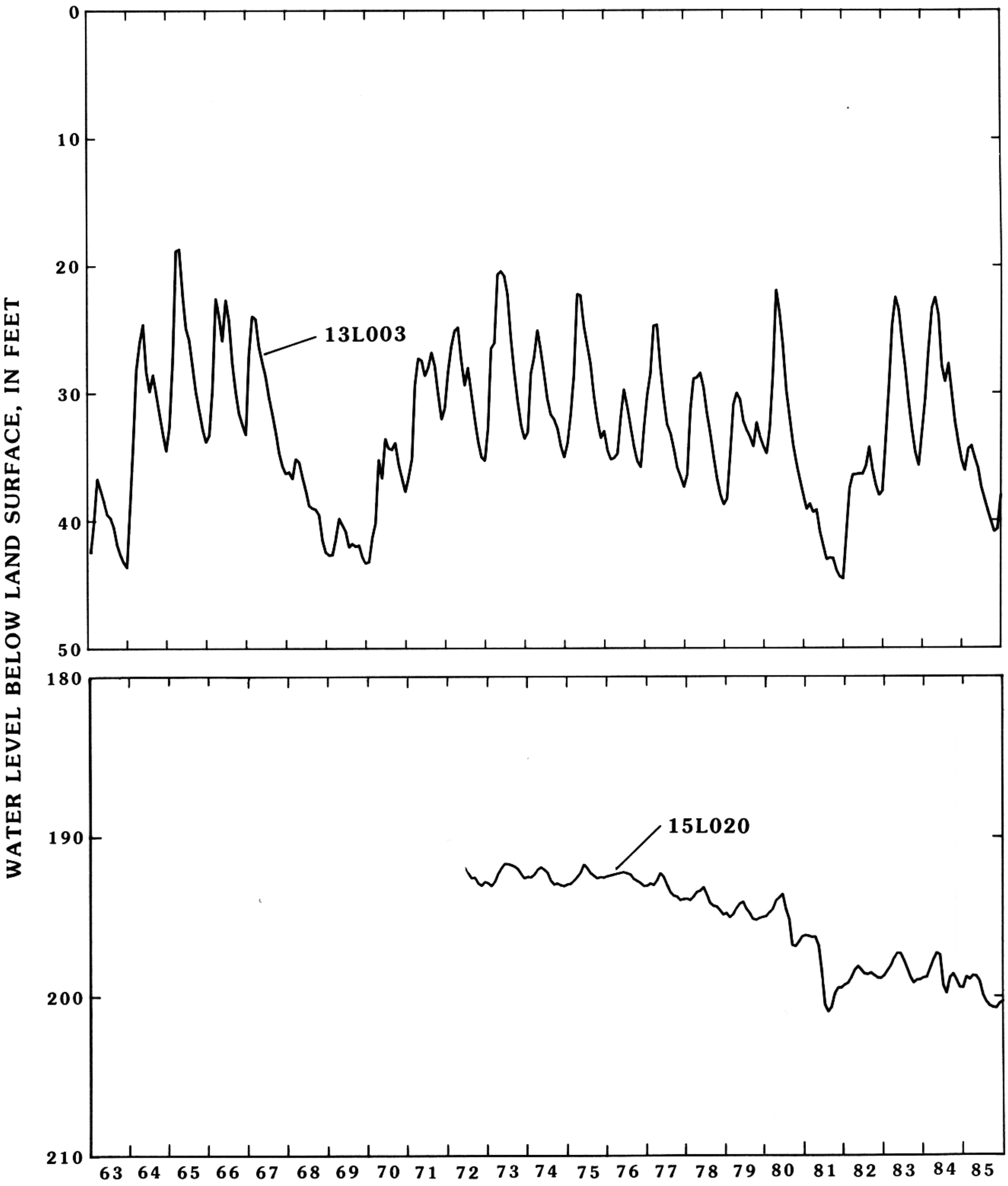


Figure 13.—Hydrographs for well 13L003, 1963–1985 and well 15L020, 1972–85.

ceased to flow for the first time on record. The spring flowed intermittently until the winter-recharge season began and on April 23, 1982, the discharge increased to 109 ft^3/s (48,900 gal/min), the largest ever recorded.

Base-flow measurements were made of the Flint River and its tributaries during the low-flow period of November 27 and 28, 1984 (fig. 14). The measurements show that between Leesburg and Newton the river received 925 ft^3/s of ground-water discharge, mainly from the Upper Floridan aquifer. The Flint River received almost 50 percent of this total, or 460 ft^3/s, between the gaging stations at Albany and Putney. This large volume of water discharged to the river through major solution conduits in the Upper Floridan, such as the one ending at Radium Springs.

Northeast of Albany the Flint River is regulated by a power-generation dam that maintains a pool elevation of about 182 ft. Although the head in the lower part of the Upper Floridan always is 10 to 15 ft less than the water level in the overburden, the leaky confining unit deters the infiltration of surface water into the lower part of the aquifer.

In most of the Dougherty Plain east of the Flint River and in the Solution Escarpment, the altitude of the potentiometric surface generally is lower than the streams, and the streams may lose water to the aquifer. The intermittent streams that flow down the face of the Solution Escarpment go underground in swamps at the edge of the Dougherty Plain. Water that enters the aquifer from losing streams probably travels through solution conduits and discharges into the Flint River. This is evidenced by a rapid increase in ground-water discharge and turbidity at Radium Springs following periods of heavy rainfall.

GROUND-WATER QUALITY

The Upper Floridan aquifer generally yields a hard, calcium bicarbonate-type water containing no constituent concentrations that exceed the State drinking water standards (table 2). Because water in the Upper Floridan aquifer has been in the ground a relatively short time, it generally is less mineralized than water in deeper aquifers (Hicks and others, 1981).

Water sampled from well 12L029 (plate 1) had generally higher constituent concentrations than water from the other wells (table 2). Well 12L029 is near downtown Albany, where the landscape is largely asphalt and concrete. According to Roger W. Lee (U.S. Geological Survey, oral commun., 1985), recharge water in an urban area probably would contain higher concentrations of trace metals and may be more acidic than recharge water in a rural area. Increased acidity of the recharge water could cause greater dissolution of aquifer materials, thereby increasing constituent concentrations in the ground water.

Water from the Upper Floridan was analyzed for more than 50 commonly used agricultural and industrial organic compounds. In addition to these analyses, a gas-chromatograph flame ionization detector scan (GC/FID) was performed on each sample. The GC/FID scan is a general screening method that will indicate the presence of most of the priority pollutant organic compounds, many of the toxic organic substances (table 3), and thousands of other organic compounds.

Organic compounds were detected in ground water from seven of the 14 wells sampled (table 4). Aldicarb, detected in three of the wells, is a nematicide widely used on peanut and soybean crops and more recently in pecan orchards. It is highly soluble in water, very mobile, and readily degrades into the compounds sulfoxide and sulfone. Although aldicarb degradation products were detected in samples collected in June 1984 from wells 13L012, 13L048, and 13M008, none were detected in samples collected from the same wells in November and December 1984 (table 4).

Ground water sampled from well 12L029 during December 1984 contained a trace amount (0.1 μg/L) of the pesticide chlordane. This well was not sampled during the June 1984 sampling period. The U.S. Environmental Protection Agency has cancelled registrations of pesticides containing chlordane, and its use is restricted to subsurface injection for termite control. Recent U.S. Environmental Protection Agency restrictions have significantly reduced the use of chlordane.

The insecticide dieldrin, an environmentally stable agricultural insecticide, was reported in trace concentrations in water from wells 12K014 (0.02 μg/L), 11K003 (0.01 μg/L), 12L029 (0.01 μg/L), and 13K014 (0.02 μg/L) collected in November and December 1984. Water samples collected in June 1984 from wells 11K003 and 13K014 did not contain detectable concentrations. The manufacture and use of dieldrin has been discontinued in the United States.

Water from well 12L029 contained two volatile organic compounds: tetrachloroethylene (5.9 μg/L) and 1,2-transdicl-ethylene (16 μg/L). These compounds are used as industrial degreasers and are listed by the U.S. Environmental Protection Agency as hazardous materials.

Water from the Upper Floridan aquifer generally is suitable for domestic, public-supply, industrial, and agricultural purposes. Although trace concentrations of organic compounds were detected in seven of the 14 wells sampled, these findings represent one-time samples collected at specific sites. Organic compounds were not detected in five of the seven wells during a later sampling, which indicates that the compounds were flushed out of the immediate area of the wells or were diluted below the level of detection.

Some organic compounds detected in water from the Upper Floridan aquifer are of the type applied to soils and apparently were transported into the aquifer by recharge water. Aldicarb and dieldrin probably were land-applied as agricultural pesticides. The presence of chlordane in ground water probably resulted from the application of this compound for termite control.

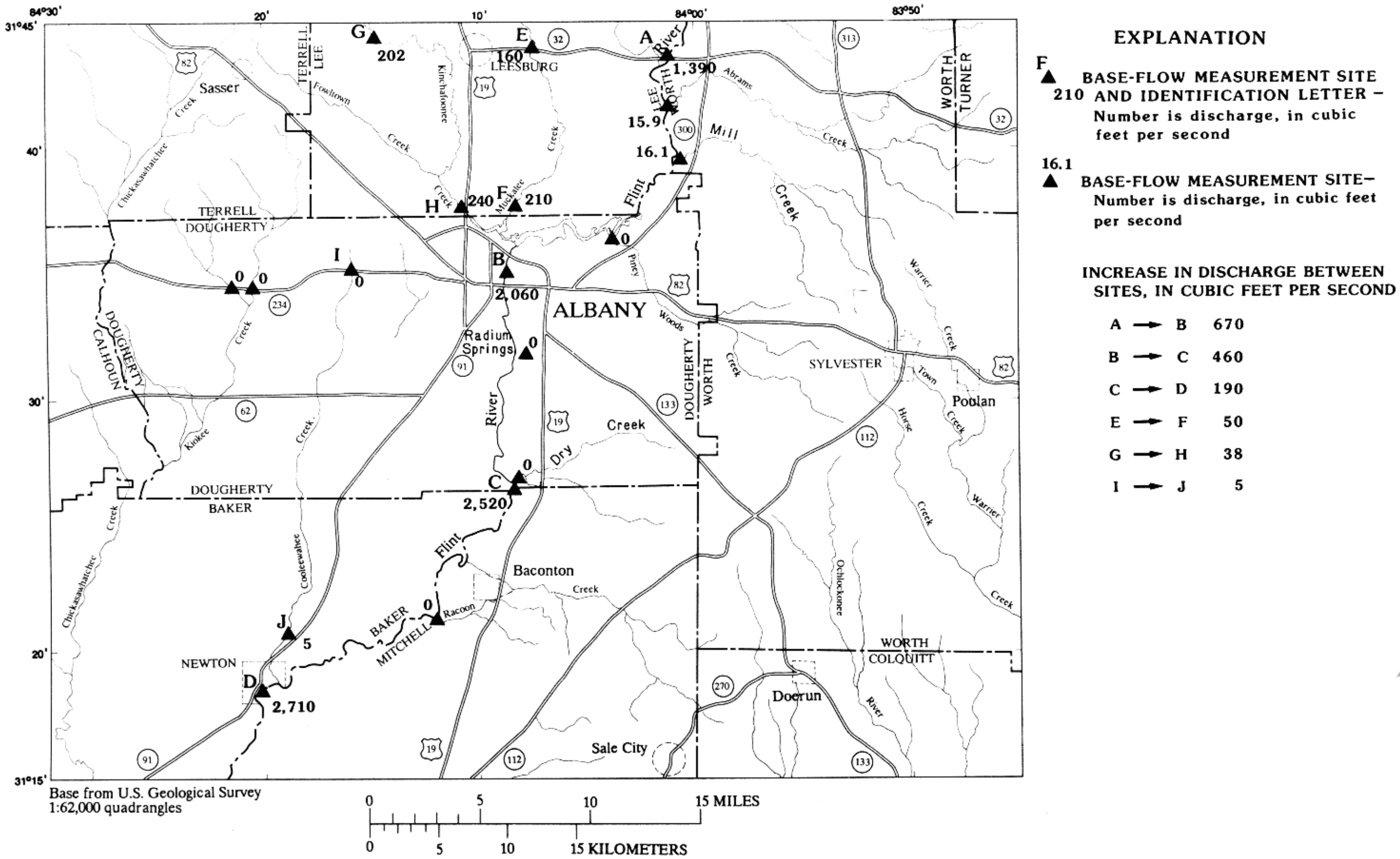


Figure 14.—Base-flow measurements, November 27–28, 1984.

Table 3. Organic compounds undetected in water from the Upper Floridan aquifer
[µg/L, micrograms per liter]

Compound analyzed	Detection limit (µg/L)	Compound analyzed	Detection limit (µg/L)
Aldrin	0.01	Methoxychloride	0.01
Benzene	3.0	Methylbromide	3.0
Bromoform	3.0	Methylene chloride	3.0
Carbofuran	1.0	Mirex	.01
Carbon tetrachloride	3.0	Perthane	.1
Chlorobenzene	3.0	Propham	.5
Chlorodibromoethane	3.0	Sevin	.5
Chloroethane	3.0	Toluene	3.0
Chloroform	3.0	Toxaphene	1.0
DDD	.01	Trichloroethylene	3.0
DDE	.01	Trichlorofluoromethane	3.0
DDT	.01	Vinyl chloride	3.0
Dichlorobromomethane	3.0	1,1- Dichloroethylene	3.0
Dichlorodifluoromethane	3.0	1,1-Dichloroethane	3.0
Endosulfan I	.01	1,1,1-Trichloroethane	3.0
Endrin	.01	1,1,2-Trichloroethylene	3.0
Ethylene dibromide	1.0	1,1,2,2-Tetrachloroethylene	3.0
Gross PCBS	.1	1,2-Dichloroethane	3.0
Gross PCNS	.1	1,2-Dichloropropene	3.0
Heptachlor epoxide	.01	1,3-Dichloropropene	3.0
Heptachloride	.01	2-CL-Ethylvinylether	3.0
Lindane	.01	GC/FID scan	Limits variable
Methomyl	.5		

Wells sampled and date					
Site number	Date sampled	Site number	Date sampled	Site number	Date sampled
10K005	06-27-84	12L030	06-28-84	12M026	06-27-84
10K005	12-12-84	12L030	12-18-84	12M026	11-07-84
12K016	06-28-84	13L048	11-08-84	11M016	06-28-84
13L012	12-19-84	13K014	06-26-84	11M018	06-28-84
11K003	06-27-84	12M021	06-28-84		
12L029	12-18-84	13M008	11-07-84		

Table 4. Organic compounds in water from the Upper Floridan aquifer
[ND, compounds not detected]

Site number	Date sampled	Concentration (micrograms per liter)						
		Aldicarb, total	Sulfoxide	Sulfone	Chlordane	Dieldrin	Tetrachloroethylene	1,2 Transidicl-Ethylene
12K014	12-19-84	ND	ND	ND	ND	0.02	ND	ND
13L012	06-26-84	15.9	7.5	8.4	ND	ND	ND	ND
13L012	12-19-84	ND	ND	ND	ND	ND	ND	ND
11K003	06-27-84	ND	ND	ND	ND	ND	ND	ND
11K003	12-19-84	ND	ND	ND	ND	.01	ND	ND
12L029	12-18-84	ND	ND	ND	0.1	.01	5.9	16
13L048	06-26-84	31.2	21.4	9.8	ND	ND	ND	ND
13L048	11-08-84	ND	ND	ND	ND	ND	ND	ND
13K014	06-26-84	ND	ND	ND	ND	ND	ND	ND
13K014	11-08-84	ND	ND	ND	ND	ND	ND	ND
13M008	06-26-84	41.3	18.4	22.9	ND	ND	ND	ND
13M008	11-07-84	ND	ND	ND	ND	ND	ND	ND
Detection limits		5	5	5	0.1	0.01	3.0	3.0

Contamination of the aquifer by tetrachloroethylene and 1,2-transdicl-ethylene could have resulted from improper disposal practices. The contamination of the Upper Floridan aquifer by chlordane, dieldrin, tetrachloroethylene, and 1,2-transdicl-ethylene at well 12L029 apparently is associated with the degree of urbanization in the area of the well. Ground water sampled from wells in rural areas did not contain these contaminants.

DEVELOPMENT POTENTIAL OF THE UPPER FLORIDAN AQUIFER

The quantity of water available to a well from the Upper Floridan varies throughout the study area and is determined primarily by the yield and transmissivity of the aquifer. Areas of the aquifer that have high transmissivity and large yield potential are mainly in the southern part of the study area, as shown on figure 5. The development potential of the Upper Floridan aquffer is, of course, dependent on the quantity of water available to wells.

The development potential of the aquifer also depends on the intended use of the water. As an example, for irrigation use, quantity and well efficiency are the chief concerns. For public water supply, however, maintaining a high standard of water quality is of primary importance, given the quantity of water available. Areas of the Upper Floridan aquifer that have the greatest development potential for public water supply are shown in figure 15.

Quantity of Available Ground Water

Large quantities of water from the Upper Floridan aquifer can be obtained from the areas of greatest development potential. In the area south and southeast of Albany, east of the Flint River (fig. 15), yields of 12- to 16-in. diameter wells are reported to exceed 2,000 gal/min without significant drawdown, and many wells probably can supply 1,000 to 1,500 gal/ min on a sustained basis. In the area southwest of Albany, west of the river, yields of 800 to 1,200 gal/min can be sustained by large-diameter wells tapping the lower part of the aquifer, and some wells are reported to produce more than 2,500 gal/min.

In these areas it may be possible to develop several fields of properly spaced wells in the Upper Floridan capable of supplying tens of millions of gallons of water per day without overstressing the aquifer. For example, in the area of high transmissivity southeast of Albany, a 2,500-acre farm is irrigated by 17 wells tapping the Upper Floridan. The wells, which are distributed uniformly over the area at about 0.5-mile intervals, have a reported combined pumping capacity of about 24 Mgal/d (P.E. LaMoreaux and Associates, Inc., written commun., 1979), and during periods of extended drought they could be pumped continuously for prolonged periods during the irrigation season. This well field has been in operation since about 1979 and has not produced a long-term decline in the water level.

Potential for Ground-Water Contamination

Within the city limits of Albany and near the Marine Corps Supply Center, active and abandoned landfills, industrial and commercial sites, railroad yards, and gasoline and chemical storage tanks (plate 3) are potential sources of contaminants. Thus, these areas are unsuitable as well sites. Areas near railroads and highways also may be unsuitable for locations of wells because of the possibility of chemical spills. Past and present land-use practices near proposed well sites may indicate whether potential contaminants are present in the ground. A water-quality evaluation of proposed sites could be made by analyzing samples collected from test wells.

In most of the study area, contaminants applied to, or spilled on, the land surface eventually can be expected to percolate through the overburden and reach the aquifer. In relative terms, this can be expected to occur slowly where the overburden is largely clay and more rapidly where the overburden is mainly sand, and slowly where the overburden is thick and more rapidly where the overburden is thin (plate 2). The time required for contaminants to percolate through the overburden and reach the aquifer depends on several factors and could be difficult to estimate. Thus, it is important that wells be placed away from areas that have been used for the storage or disposal of potential contaminants, and, probably to a lesser extent, the application of agricultural chemicals (fig. 15, plate 3).

In the northern parts of the areas of greatest development potential (fig. 15), the leaky confining unit in the Upper Floridan (fig. 4) probably would delay contaminants that percolate through the overburden from reaching the permeable zone in the lower part of the aquifer. To the south where the leaky confining unit is missing, the entire aquifer is permeable and contaminants that reach the aquifer are more likely to be drawn into a pumped well. The reader should be aware that the southern limit of the leaky confining unit is approximate and may be highly irregular.

The rate of downward movement of contaminants through the overburden may increase near pumping centers that lower the head in the upper part of the Upper Floridan aquifer. Therefore, if contaminants are discovered near a well, limiting withdrawals to minimize water-level drawdown in the upper part of the aquifer could reduce the rate at which they would infiltrate downward and toward the well.

In the area of greatest development potential between the Flint River and the Solution Escarpment, wells may penetrate major ground-water conduits. Where this occurs, contamination from distant sources that recharge the aquifer, such as losing streams, is possible, because conduit flow in the aquifer is comparatively rapid and contaminants can be transported long distances without natural filtration and purification. Moreover, water in some conduits can become turbid, especially during wet periods, and create quality problems. Wells that derive water from conduits

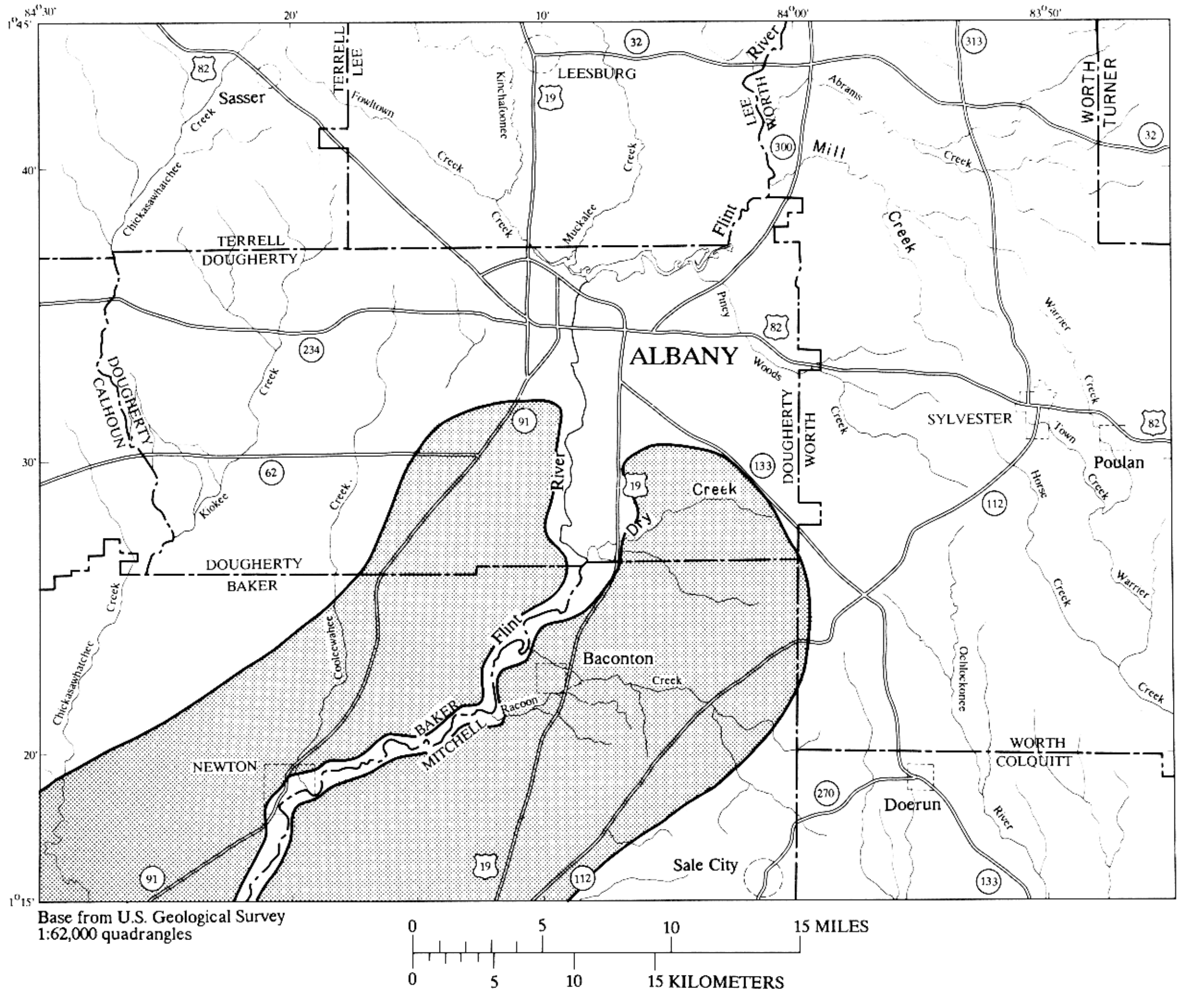


Figure 15.—Generalized areas of greatest development potential for public water supply in the Upper Floridan aquifer.

could require continuous monitoring to detect quality changes before they become a serious problem. Temporary shutdown of a well could be required until the quality problem abates, or the water could need treatment to remove contaminants or undesirable turbidity. Wells drilled close to the Flint River could draw river water into the aquifer.

In the area of greatest development potential west of the Flint River, flow seems to be mainly diffuse, which probably reduces the likelihood of well contamination from sources distant to a well. Moreover, turbid well water is not reported to be a problem in this area.

Geologic Hazards

The only significant geologic hazard in the study area that relates to the development of the Upper Floridan aquifer seems to be sinkholes. Although sinkholes are a common feature in the area, nearly all are ancient. However, in karst terrane there is a chance of initiating sinkhole development where pumped wells or well fields draw the water level down below the top of the limestone. The loss of buoyant support provided by the ground water can cause the downward erosion of overburden into limestone openings where it is carried away by circulating ground water. In overburden that contains clay layers, a large cavity may develop above the limestone, and failure of the cavity's roof can lead to the sudden collapse of the ground surface (fig. 16). Thus, it is possible that sinkholes may develop as a result of man's activities. However, because of the high transmissivity of the Upper Floridan aquifer in most of the study area, drawdown of the water level below the top of the limestone may be a problem only in the vicinity of heavily pumped well fields, or where a well is being overpumped.

Altering the distribution and quantity of natural recharge also can initiate sinkhole development. Included are such things as retention ponds, the diversion of drainage, and the discharge of well water onto the land surface during development and testing.

Topographic maps show a large number of closed depressions scattered over most of the study area (plate 3). Many of the depressions are very shallow and are difficult to recognize without the aid of a topographic map. These depressions are ancient sinkholes, or sinks, that formed by natural processes, one of which is shown in figure 17. Most of the depressions lack natural outlets and after heavy rains they are covered by water for weeks or months. Some of the larger sinks are fed by intermittent drainages that bring in surface water from upgradient areas. Although the depressions generally are lined with soils that have low permeability, according to Middleton (1968) they drain through the bottom. The depressions probably would not be suitable as well sites because (1) they collect water from upgradient areas and therefore could concentrate contaminants; (2) they are subject to flooding; (3) although they are lined with soil of low permeability, water probably percolates through the bottoms and could transport contaminants into the aquifer; and (4) there is no way to predict what conditions may exist in the aquifer beneath the depressions: cavities in the limestone could be filled with low-permeability sand or clay that would interfere with well yield, development, and production.

Several sites in the study area have much greater-than-average thicknesses of undifferentiated overburden (plate 2). These sites probably represent limestone-collapse sinkholes (fig. 18) or other openings in the limestone that have been filled with material of low permeability. Many of these sites show up as closed depressions on the land surface (plate 3). An attempt to construct an irrigation well tapping the Upper Floridan aquifer about 2 mi south of the Marine Corps Supply Center failed, because at that site most of the Ocala Limestone has been replaced by material of low permeability. The well penetrated 250 ft of undifferentiated overburden, in an area where the overburden generally is less than 80 ft thick, and the site is in a slight topographic depression (P.E. LaMoreaux and Associates, Inc., written commun., 1979). The well may have penetrated a filled limestone-collapse sinkhole (fig. 18). The failed well is only a short distance from two successful wells that derive water from limestone.

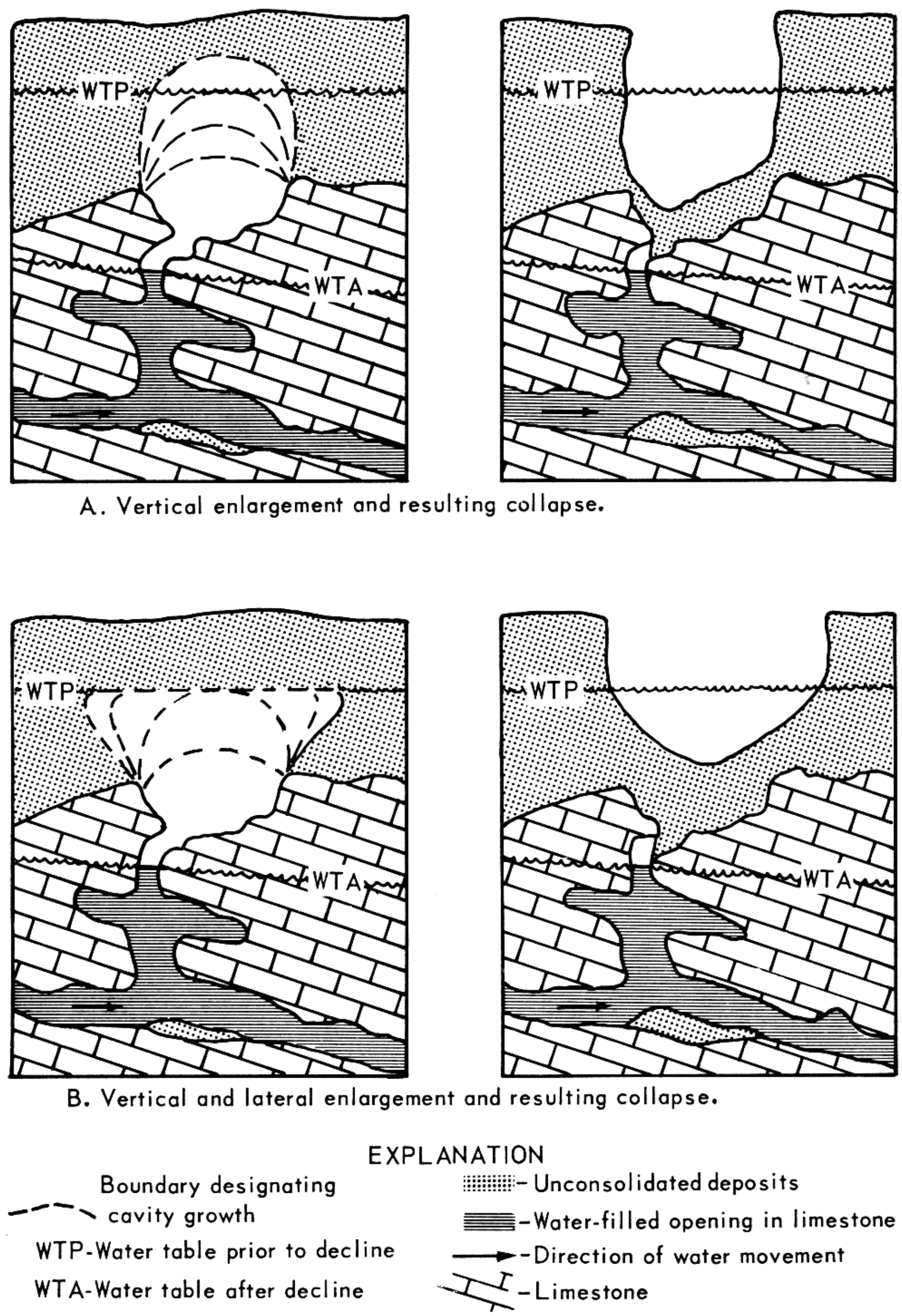
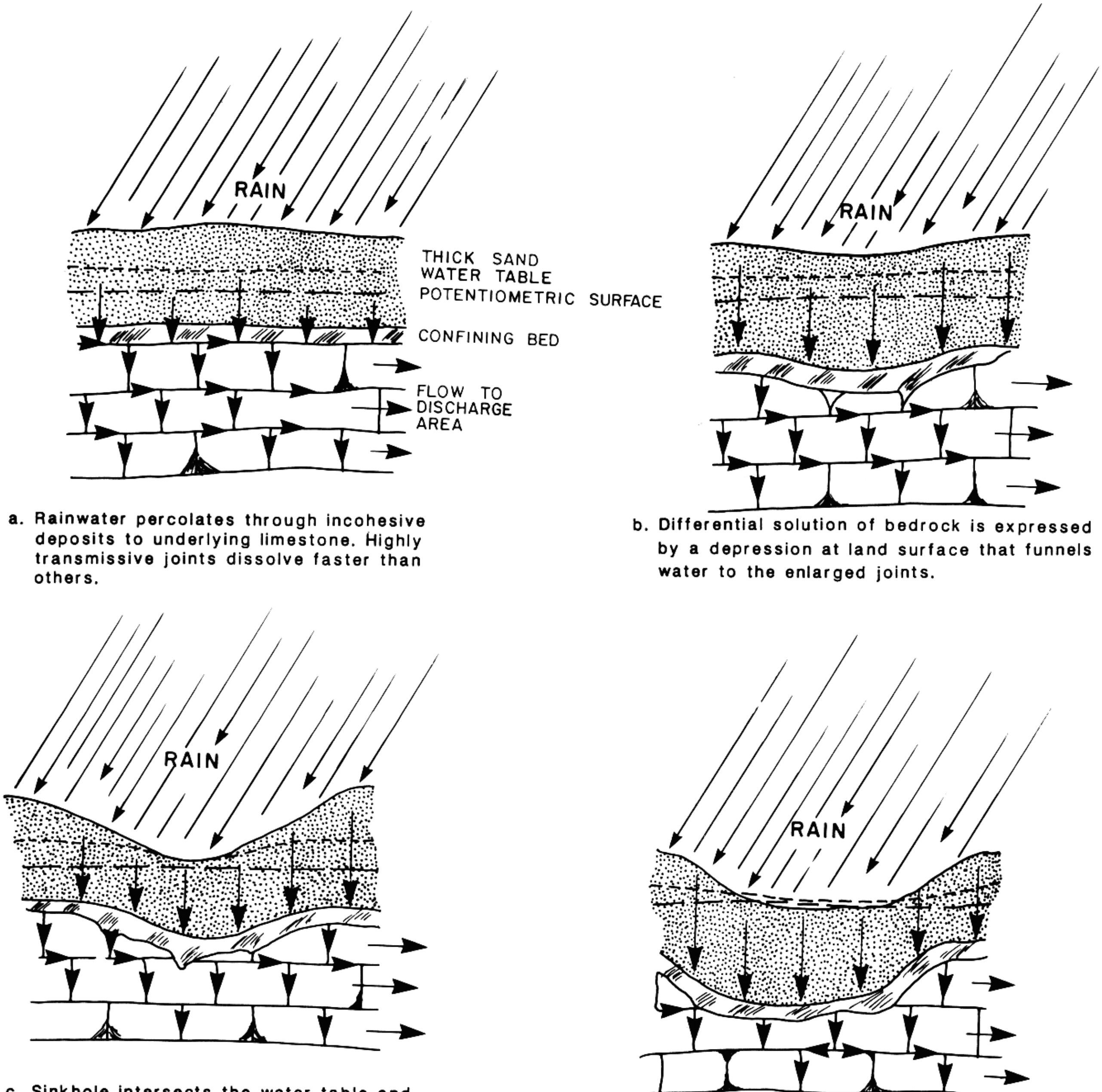


Figure 16.—Development of sinkholes in clay overburden. Modified from Newton (1976).



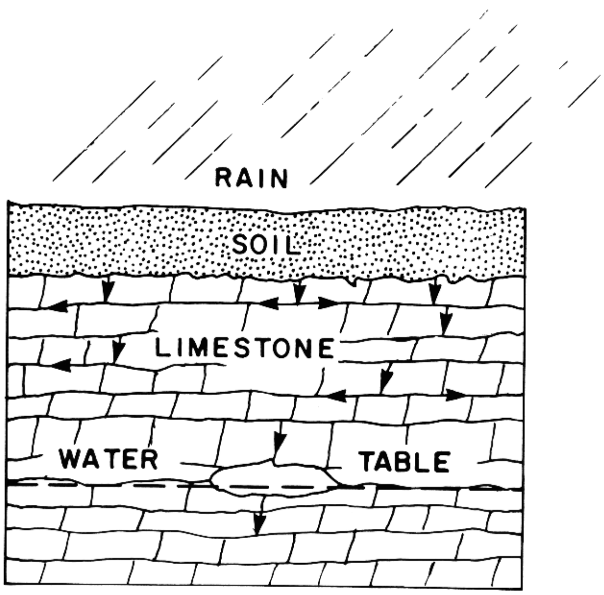
a. Rainwater percolates through incohesive deposits to underlying limestone. Highly transmissive joints dissolve faster than others.

b. Differential solution of bedrock is expressed by a depression at land surface that funnels water to the enlarged joints.

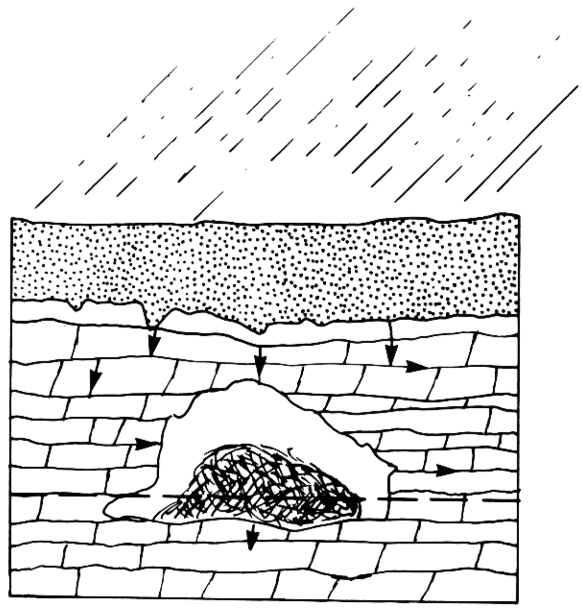
c. Sinkhole intersects the water table and cypress trees begin to grow. Rate of dissolution is reduced because there is less head difference between the water table and potentiometric surface and, thus, less percolation.

d. Sinkhole spreads laterally faster than it subsides. A cypress dome forms with old trees in the center and young trees on the perimeter.

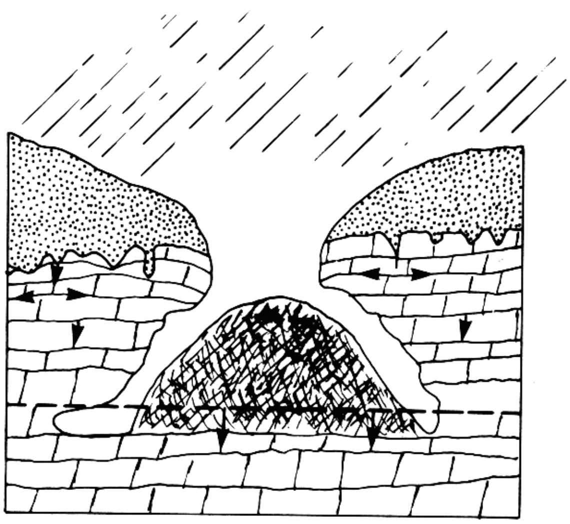
Figure 17.—Stages in development of a cover-subsidence sinkhole. Arrows indicate direction of water movement. From Sinclair and others (1985).



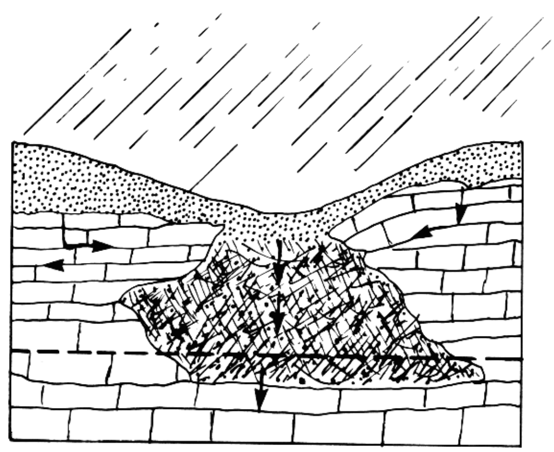
a. Solution cavity develops along joint or other plane of weakness at the water table.



b. Roof collapses, most likely at joint intersection. Undercutting of cave walls by diverted ground water.



c. Roof collapse reaches land surface. Undercutting continues.



d. Soil washes into depression and obscures its origin. Breakdown and cave roof cemented by recrystallized limestone.

Figure 18.—Stages in development of a limestone-collapse sinkhole such as could occur in the study area. Arrows indicate direction of water movement. From Sinclair and others (1985).

CONCLUSIONS

1. Most of the study area lies in the Dougherty Plain district of the Coastal Plain physiographic province. The 1,500-mi^2 study area is underlain by sediments of pre-Cretaceous to Quaternary age that consist of alternating units of sand, clay, sandstone, dolomite, and limestone that dip gently and thicken to the southeast. Only sediments of middle Eocene age and younger were studied. They include, in ascending order, the Lisbon Formation, the Clinchfield Sand, the Ocala Limestone, the Suwannee Limestone, undifferentiated sediments of Miocene age, and the undifferentiated overburden of Quaternary age. The Upper Floridan aquifer consists primarily of the Ocala Limestone. In the northern part of the area it also includes the Clinchfield Sand and the upper part of the Lisbon Formation. To the southeast the Upper Floridan includes the Ocala and Suwannee Limestones. The Upper Floridan ranges in thickness from about 50 ft in the northwestern part of the study area to more than 370 ft in the southeastern part. It stores and transmits large quantities of water, mainly in a zone of high permeability in the lower part of the aquifer. The aquifer is confined above by the undifferentiated overburden and below by low-permeability zones within the Lisbon Formation.

2. The Upper Floridan aquifer is the primary source of water for irrigation, industrial, and rural domestic use in the study area. The Upper Floridan has not been developed as a public-supply source, because it is near land surface and there is concern over possible ground-water contamination by agricultural and industrial chemicals and landfill leachate.

3. The Upper Floridan aquifer is recharged mainly by precipitation that percolates through the overburden. The rate of recharge is controlled by the vertical hydraulic conductivity of the overburden and the hydraulic gradient across it. The median vertical hydraulic conductivity of the overburden is about 0.003 ft/d (Hayes and others, 1983).

4. In much of the study area, permeability of the Upper Floridan aquifer is imparted by relatively small interconnected solution openings in the lower part of the aquifer and flow generally is considered to be diffuse. Close to the Flint River, however, and between the river and the Solution Escarpment, the lower part of the aquifer includes a system of major ground-water conduits and conduit flow predominates. The conduit system transports water from the Solution Escarpment to springs that discharge into the Flint River.

5. Transmissivity of the Upper Floridan was determined from aquifer-test analyses and was estimated from specific-capacity data. Transmissivity in the northwestern part of the area generally is less than 10,000 ft^2/d. In the eastern and some of the central parts of the area, the transmissivity ranges from 10,000 to 60,000 ft^2/d. In most of the central and southwestern parts of the area, the transmissivity exceeds 60,000 ft^2/d.

6. The similarity of the predevelopment potentiometric surface and the potentiometric surface for November 1985 shows that 28 years of pumping has not produced a long-term decline of the water level in the Upper Floridan aquifer in the study area; thus, the system remains in equilibrium.

7. The Upper Floridan aquifer yields hard, calcium bicarbonate-type water that does not contain constituents in concentrations that exceed State drinking water standards.

8. In the city limits of Albany and near the Marine Corps Supply Center, active and abandoned landfills, industrial and commercial sites, railroad yards, and gasoline and chemical storage tanks are potential sources of contaminants. Thus, these areas are unsuitable drilling sites for new wells. In most of the area, contaminants applied to or spilled on the land surface eventually can be expected to percolate through the overburden and reach the aquifer. For this reason, it is important that wells be sited away from areas that have been used for the storage and disposal of potential contaminants, and, probably to a lesser extent, the application of agricultural chemicals.

9. The development potential of the Upper Floridan is dependent on the quantity and chemical quality of water available to wells. The quantity of water available varies throughout the study area and is determined primarily by the yield and the transmissivity of the aquifer. Areas of the aquifer that have the greatest development potential are in the southern part of the study area. Large quantities of potable water probably can be obtained from the area south and southeast of Albany, east of the Flint River, where yields of 12- to 16-in. diameter wells reportedly exceed 2,000 gal/min without significant drawdown. Wells in this area can be expected to sustain yields of 1,000 to 1,500 gal/min. In the area of greatest development potential southwest of Albany, west of the river, yields of 800 to 1,200 gal/min can be sustained by large-diameter wells that tap the lower part of the aquifer, and well yields as large as 2,500 gal/min have been reported. In these areas it may be possible to develop several fields of properly spaced wells in the Upper Floridan capable of supplying tens of millions of gallons of potable water per day without overstressing the aquifer.

10. In the northern part of the area where the upper part of the Upper Floridan aquifer forms a leaky confining unit, wells that derive water exclusively from the lower part of the aquifer probably would have additional protection against contaminants from the land surface that percolate through the overburden. To the south where the confining unit is missing, the entire aquifer is permeable and contaminants from the land surface that reach the aquifer are more likely to be drawn into a pumped well.

11. In the southeastern part of the area between the Flint River and the Solution Escarpment, wells may penetrate major ground-water conduits. Where this occurs, contamination from distant sources that recharge the aquifer, such as losing streams, is possible, because conduit flow in the aquifer is comparatively rapid and contaminants can be transported long distances without natural filtration and purification. Moreover, water in some conduits could become turbid, especially during wet periods, and create quality problems. Wells located near the river could draw river water into the aquifer.

12. In karst terrane, such as the Dougherty Plain, drawing the water level in the aquifer down below the top of the limestone by pumping could initiate sinkhole development. By limiting drawdown during well development and during production, the likelihood of sinkholes forming can be minimized.

13. Anything that alters the distribution and quantity of natural recharge can initiate sinkhole development. Such things include retention ponds, the diversion of drainage, and the discharge of well water onto the ground during development and testing.

14. Topographic maps show a large number of closed depressions, or sinks, scattered over most of the study area. Many of the depressions are shallow and are difficult to recognize without the aid of a topographic map. The closed depressions probably are undesirable as well sites because (1) they are subject to flooding, (2) they collect water from upgradient areas and could concentrate potential contaminants, (3) water probably percolates through their bottoms and could transport contaminants into the aquifer, and (4) depressions may overlie limestone cavities filled with sand or clay that could interfere with well yield, development, and production.

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Table 1.--Record of wells in the Albany area

[UFA, Upper Floridan aquifer; CLBR, Claiborne aquifer; MIA, Multiaquifer; WTA, water table aquifer in undifferentiated overburden; obs. well, observation well; " gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot; RW, residuum well; TW, test well; and --, no data]

No.	Latitude-longitude	Name	Date drilled	Depth of well (feet)	Depth of casing (feet)	Aquifer	Land surface altitude (feet)	Yield (gal/min)	Specific capacity [(galmin)/ft]
Baker County									
11J020	3121570841755	Pineland pivot 1	1978	196	42	UFA	150	2,300	--
11K016	3124180842130	Pinebloom at swamp house	--	--	--	UFA	170	--	--
11K017	3124140841945	Pinebloom at big house	--	--	--	UFA	180	--	--
12K009	3125380841102	Blue Springs pivot 4	1977	160	120	UFA	180	1,200	--
12K014	3126170841107	Blue Springs obs. well	--	137	69	UFA	173	100	--
12K056	3126170841107	Blue Springs RW	1983	31.4	[1]31.4	WTA	173	--	--
Calhoun County									
10K005	3128530842751	Bill Jordan obs. well	1980	138	55	UFA	190	--	--
Colquitt County									
14J024	3117540835356	Colquitt, 11	1986	1,142	--	UFA	350	--	--
Dougherty County									
11K003	3129120841531	Nilo TW north	1978	150	63	UFA	195	--	--
11K014	3127450841742	Nilo Lake well	1956	250	79	UFA	180	1,270	--
11K015	3127090841616	U.S. Geological Survey, TW 14	1982	177	74	UFA	175	--	--
11K018	3127090841616	Nilo Plantation RW	1983	31.1	[1]31.1	WTA	175	--	--
11K033	3126540842101	St. Joe Ocala at Sealy	1980	77	43	UFA	183	20	--
11L003	3135330842031	Ocala Game and Fish	1977	84	30	UFA	220	--	--
11L014	3131210842219	H. Goodyear, Jr.	1976	145	40	UFA	210	--	--
11L017	3136040841628	U.S. Geological Survey, TW 20	1983	144	41	UFA	230	5	--
11L018	3135500841538	Doublegate Utility Co., 1	1976	125	70	UFA	215	370	16
11L019	3130090841846	St. Joe (3-in. home well)	--	--	--	UFA	180	--	--
11L020	3133000841849	Douglas Pope	1973	150	63	UFA	210	18	--
11L021	3135570841643	Byron Plantation	--	82	65	UFA	230	--	--
11L022	3135070841743	State Plantation	--	110	49	UFA	220	--	--
11L023	3133050841812	Graham Angus (Ocala well)	1982	109	40	UFA	200	75	--
12K015	3129530841215	Haley-United	1954	114	94	UFA	195	--	--
12K016	3127190841231	Cecil Avant	1980	131	84	UFA	195	20	--
12K017	3128530840753	S. O. Mritchell	--	--	--	UFA	190	--	--
12L023	3132430841056	Herty Nursery, 4	1954	165	69	UFA	190	90	--
12L028	3133020841200	V. W. Musgrove	1941	100	43	UFA	190	125	--
12L029	3134500840918	U.S. Geological Survey, TW 13	1982	178	35	UFA	200	--	--
12L030	3131300841010	U.S. Geological Survey, TW 16	1982	180	84	UFA	18D	--	--
12L031	3136020840905	Watkins Lumber	--	113	72	UFA	185	--	--
12L041	3136540840930	Bob Fowler	--	--	--	UFA	185	--	--
12L042	3135560840919	Estech, Inc., 2	--	--	--	UFA	195	--	--
12L043	3137210840854	Barfield (formerly Lathem)	--	--	--	UFA	190	--	--
12L044	3135560840919	Estech, Inc., 1	--	91	26	UFA	195	--	--
12L045	3136580840905	Scottish Rite Temple	--	--	--	UFA	190	--	--
12L047	3133020841242	Albany, 35	1985	170	100	UFA	202	1,000	60
12L048	3133000841243	U.S. Geological Survey, TW 21	1984	186	40	UFA	200	60	30
12L049	3131300841010	Haywire TW 16 (RW East)	1983	10.5	[1]10.5	WTA	180	--	--
12L050	3131300841010	Haywire TW 16 (RW West)	1983	22.65	[1]22.65	WTA	180	--	--
12L058	3131390840751	Radium Springs	1985	185	--	UFA	190	656	656
12L262	3134320840956	Colonial Dairies	--	--	--	UFA	190	400	30.8
12L263	3136230841229	Covenant Presbyterian Church	--	--	--	UFA	233	282	5.6
12L264	3133310840809	Dawes Silica, 3	--	--	--	UFA	153	697	46.5

See footnotes at end of table.

Table 1.--Record of wells in the Albany area

[UFA, Upper Floridan aquifer; CLBR, Claiborne aquifer; MIA, Multiaquifer; WTA, water table aquifer in undifferentiated overburden; obs. well, observation well; “ gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot; RW, residuum well; TW, test well; and --, no data]

No.	Latitude-longitude	Name	Date drilled	Depth of well (feet)	Depth of casing (feet)	Aquifer	Land surface altitude (feet)	Yield (gal/min)	Specific capacity [(galmin)/ft]
Dougherty County—Continued									
12L265	3135270841125	Central Baptist Church	--	--	--	UFA	200	329	2.2
12L266	3133040841041	McGregor Corp.	--	--	--	UFA	212	510	22.2
13K010	3126580840719	Frank Wetherbee, block well	1960	200	--	UFA	185	1,000	60
13K011	3127310840341	Frank Wetherbee, 2	1977	430	120	UFA	230	--	--
13K014	3127040840715	U.S. Geological Survey, TW 15	1982	131	99	UFA	185	--	--
13K015	3127030840715	Frank Wetherbee, 1	1977	235	212	UFA	180	--	--
13K016	3128440840721	Albany, 34	1984	440	440	M/A	194	1,623	11.2
13k017	3126360840346	Rocky Hill Church	--	--	--	UFA	240	15	h
13K018	3126400840112	St. Marys Church	--	n	--	UFA	330	n	--
13K019	3128460840719	Nichols Road Church	--	n	n	UFA	195	20	--
13K020	3127070840700	Frank Wetherbee (abandoned 3-in. well)	n	112	56	UFA	180	--	--
13L003	3133130840021	Albany-Dougherty County at Marine Corps Supply Center	1949	243	206	UFA	225	--	--
13L012	3131050840643	U.S. Geological Survey, TW 3	1977	218	54	UFA	195	--	--
13L014	3135490840440	Miller Ocala 2	1979	99	84	UFA	205	5	--
13L015	3136150840409	SAC Apron Fire Well	[2]1979	351	240	UFA and CLBR	200	--	--
13L019	3132520840222	U.S. Marine Corps, Albany, 2	1952	997	[1]997	M/A	258	1,530	13.9
13L028	3130410840208	Fleming Farms, 14 (Lobarton)	1978	300	110	UFA	230	1,500	--
13L032	3132090840252	Fleming Farms, 9 (Lobarton)	1978	285	93	UFA	220	1,500	--
13L033	3130500840313	Fleming Farms, 8 (Lobarton)	1978	310	70	UFA	245	1,500	--
13L040	3132210840406	Fleming Farms, FCR-11 (Lobarton)	1978	940	[1]940	M/A	220	1,.00	14
13 L043	3133110840629	Proctor and Gamble, 1	1971	215	106	UFA	180	1,390	925
13L044	3133110840630	Proctor and Gamble, 2	1972	210	99	UFA	180	1,730	23.3
13L045	3134030840312	Firestone, P1	1968	265	195	UFA	220	1,040	1,000
13L046	3133430840312	Fi restone, P2	1968	284	150	UFA	200	1,020	78
13L047	3136410840021	George Kirksey	1956	256	100	UFA	255	--	--
13L048	3130320840059	U.S. Geological Survey, TW 17	1982	345	71	UFA	245	--	--
13L049	3135210840510	Miller Ammunition Supply	1955	170	103	UFA	205	15	--
13L052	3136090840435	Miller Ocala 3	1979	105	60	UFA	210	--	--
13L054	3136430840217	William H. Perkins	--	--	--	UFA	205	--	--
13L055	3137080840142	James O. Barron	--	--	--	UFA	225	--	--
13L056	3133280835948	J. Champion (abandoned well)	--	199	45	UFA	235	--	--
13L057	3133470840211	Frank Boucher	1970	150	--	UFA	225	15	--
13L058	3135560840216	W. M. Chandler	--	173	62	UFA	225	--	--
13L059	3137190840608	Malphurs Fish Camp	--	--		UFA	188	--	--
13L175	3135490840438	Miller Brewery (Ocala 2) RW north	1983	32.5	[1]32.5	WTA	206	--	--
13L176	3135490840438	Miller Brewery (Ocala 2) RW south	1983	45	[1]45	WTA	206	--	--
13L177	3135540840611	Turner Field Concrete Plant	--	--	--	UFA	208	305	9.5
13L178	3137300840131	Norman Haas	1970	150	--	UFA	225	105	2.9
14K009	3128590835957	Hatcher	--	--	--	UFA	310	--	--
14L010	3135080840113	J. Champion, 1	1977	--	--	UFA	235	125	--

See footnotes at end of table.

Table 1.--Record of wells in the Albany area

[UFA, Upper Floridan aquifer; CLBR, Claiborne aquifer; MIA, Multiaquifer; WTA, water table aquifer in undifferentiated overburden; obs. well, observation well; " gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot; RW, residuum well; TW, test well; and --, no data]

No.	Latitude-longitude	Name	Date drilled	Depth of well (feet)	Depth of casing (feet)	Aquifer	Land surface altitude (feet)	Yield (gal/min)	Specific capacity [(galmin)/ft]
Lee County									
11M010	3138130841718	Holly Plantation	1952	120	[3]40	UFA	265	60	--
11M016	3139140841701	Jon Daniels	1980	150	40	UFA	270	900	24
11M017	3142100841519	Jan Clay (6-in. Ocala well)	--	--	--	UFA	265	60	--
11M018	3137320841742	Holly Plantation (irrigation well)	1980	160	40	UFA	250	850	25
12M003	3138130841250	Georgia Power (obs. well)	1977	140	40	UFA	235	--	--
12M004	3142360840914	Mike Moorman, TW 1	1979	190	64	UFA	240	--	--
12M012	3141580840812	Muckalee Plantation	1974	135	85	UFA	240	--	--
12M015	3138140841142	C. B. Mosley	1976	105	84	UFA	210	--	--
12M017	3138080840936	U.S. Geological Survey, TW 19	1982	181	41	UFA	225	--	--
12M021	3137330841046	Canuga Subdivision	1979	180	60	UFA	210	250	22
12M022	3137460840807	Chehaw Park	1956	164	88	UFA	190	15	--
12M023	3138490841029	Haley-Flint-West well	--	--	--	UFA	235	--	--
12M024	3140290841100	Kinchafoonee Church	--	--	--	UFA	230	--	--
12M025	3139450841021	Albany Nursery	--	--	--	UFA	225	--	--
12M026	3138080840936	Haley-Flint Farm	1983	220	42	UFA	235	1,100	23
12M027	3141530841311	Haley-Byne	--	--	--	UFA	245	--	--
12M028	3140400841014	Tolee Plantation (6-in. Ocala well)	1982	190	60	UFA	240	--	--
13M003	3137540840528	Steve Stocks (obs. well)	1978	163	73	UFA	240	--	--
13M004	3141320840438	B. F. Hodges	--	140	--	UFA	260	--	--
13M008	3139180840531	U.S. Geological Survey, TW 18	1982	180	40	UFA	240	--	--
13M009	3144220840252	Senah Plantation (4 in.)	1954	160	63	UFA	270	--	--
13M010	3140030840320	Jack Garrett, OW-1	1982	215	41	UFA	260	--	--
13M011	3140080840318	Jack Garrett, OW-2	1982	160	106	UFA	260	--	--
13M012	3140130840325	Jack Garrett, OW-3	1983	46	41	UFA	260	--	--
13M027	3142520840601	Piedmont Plant Farm	--	--	--	UFA	247	--	--
13M028	3140060840327	Jack Garrett, DH-3	1983	281	--	UFA	256	--	--
Mitchell County									
11J012	3118020841923	U.S. Geological Survey, DP-11	1980	225	62	UFA	165	--	--
12J003	3122010841134	Flint River Pecans	1980	82	62	UFA	160	--	--
13J004	3121290840657	Henry Wright, 1	1971	208	77	UFA	195	1,200	--
13J005	3119520840132	J. Reynolds	1981	--	--	UFA	250	1,000	--
13K021	3126260840206	Wetherbee (6 in.-well)	--	310	120	UFA	314	70	--
13K022	3125310840022	Henry Wright pecan well	--	--	--	UFA	310	--	--
13K023	3124560840019	Wright pond well	1963	386	116	UFA	333	732	366
Terrell County									
11M007	3139340842036	Alvin Vann	1976	95	63	UFA	260	--	--
11M019	3143160841943	Jon Daniels (3-in. well)	--	--	--	UFA	305	--	--
Worth County									
13M005	3143300840051	U.S. Geological Survey, DP-7	1980	345	[1]345	CLBR	230	--	--
13M006	3143300840051	U.S. Geological Survey, DP-8	1980	123	63	UFA	230	--	--
13M007	3143300840051	U.S. Geological Survey, DP-9	1980	25	[1]25	WTA	230	--	--
14J018	3121000835734	James K. Hembree	1982	--	--	UFA	390	--	--

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No.	Latitude-longitude	Name	Date drilled	Depth of well (feet)	Depth of casing (feet)	Aquifer	Land surface altitude (feet)	Yield (gal/min)	Specific capacity [(galmin)/ft]
Worth County—Continued									
14JD19	3121570835303	Union Church	--	--	--	UFA	390	--	--
14JD2D	3120560835446	L. E. Baxley	--	--	--	UFA	390	--	--
14JD21	3122300835603	Carver (trailer)	--	--	--	UFA	376	--	--
14JD22	3122300835603	Liberty Church	--	--	--	UFA	418	--	--
14K006	3129300835801	Hines Place Farm, 1	1982	--	--	UFA	320	--	--
14K007	3122540835739	Bridgeboro Plantation	1982	--	--	UFA	400	--	--
14K008	3123580835832	Brown r.1i1ing Company	1982	--	--	UFA	410	--	--
14K011	3128020835743	Wiregrass (pond well)	--	--	--	UFA	290	--	--
14K012	3128460835452	Hopewell Church	--	--	--	UFA	400	--	--
14K013	3125500835529	Chapel Hill Church	--	--	--	UFA	433	--	--
14K014	3124010835454	J. D. Stephens	--	--	--	UFA	370	--	--
14K015	3125230835241	Evergreen Church	--	--	--	UFA	418	--	--
14L002	3132590835240	W. J. Pate	1965	460	260	UFA	430	--	--
14L007	3133060835500	C. E. Buck, 1	--	180	--	UFA	350	--	--
14L009	3134590835506	E. J. McCrary (back-up well)	1981	238	74	UFA	290	--	--
14L011	3135030835852	J. Champion, 2	1 978	--	--	UFA	260	--	--
14L012	3133020835517	Terry Young	--	--	--	UFA	355	--	--
14L013	3130270835709	Lawrence Bridges	--	--	--	UFA	280	--	--
14L014	3137290835503	Salem Church	--	--	u	UFA	284	--	--
14L044	3137290835911	Worthy Manor Subdivision	1972	185	u	UFA	250	510	6.9
14M006	3143360835728	H. R. Tyson	1977	190	84	UFA	260	--	--
14M008	3143060835320	W. W. Tyson	--	102	60	UFA	290	--	--
14M009	3139290835750	St. James Church	--	-	--	UFA	250	--	--
15J015	3121540835119	E. Wimberly	1969	320	282	UFA	400	--	--
15K006	3122490835035	R. Evans	1969	305	266	UFA	410	--	--
15K009	3129200835126	House near Bethel Cemetery	--	--	--	UFA	390	--	--
15K010	3126450835228	Larry Byron	--	--	--	UFA	410	--	--
15L020	3131440834916	Sylvester, Ga. (obs. well)	1971	450	212	UFA	420	--	--
15L022	3135170834949	House near lookout tower	--	--	--	UFA	436	--	--
15L023	3127230835258	Antioch Church	--	--	--	UFA	324	--	--
15M004	3141230834958	Zack Aultman	--	--	--	UFA	340	--	--
15M005	3139090834912	Doyl e Medders	1978	u	--	UFA	325	15	--

[1]Screened construction.
[2]Modified from a well drilled in the 1800's.
[3]Estimated.