HYDROGEOLOGY, CHEMICAL QUALITY, AND AVAILABILITY

OF GROUND WATER IN THE UPPER FLORIDAN AQUIFER,

ALBANY AREA, GEORGIA

By D.W. Hicks, H.E. Gill, and S.A. Longsworth

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# CONVERSION FACTORS

For those readers who may prefer to use metric (International System) units rather than inch-pound units, conversion factors for the terms used in this report are listed below:

| Multiply inch-pound unit | By | To obtain metric unit |
|---|---|---|
| | Length | |
| inch (in.) | 25.4 | millimeter (mm) |
| foot (ft) | 0.3048 | meter (m) |
| mile (mi) | 1.609 | kilometer (km) |
| | Area | |
| acre | 0.4047 | hectare (ha) |
| square mile ($mi^2$) | 2.59 | square kilometer ($km^2$) |
| | Volume | |
| gallon (gal) | 3.785 | liter (L) |
| million gallons (Mgal) | 3,785 | cubic meter ($m^3$) |
| | Flow | |
| cubic foot per second ($ft^3/s$) | 0.02832 | cubic meter per second ($m^3/s$) |
| gallon per minute (gal/min) | 0.06309 | liter per second (L/s) |
| million gallons per day (Mgal/d) | 0.04381 | cubic meter per second ($m^3/s$) |
| million gallons per day per square mile [(Mgal/d)/$mi^2$)] | 1,460 | cubic meter per day per square kilometer [($m^3/d$)/$km^2$)] |
| inch per year (in/yr) | 25.4 | millimeter per year (mm/yr) |

CONVERSION FACTORS--Continued

Transmissivity

foot squared per day                    0.0929     meter squared per day
   (ft$^2$/d)                                          (m$^2$/d)


Hydraulic conductivity

foot per day                            0.3048     meter per day
   (ft/d)                                              (m/d)


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 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

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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. West of the river, yields of 800 to 1,200 gallons per minute 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 probably percolates 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 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 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-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.
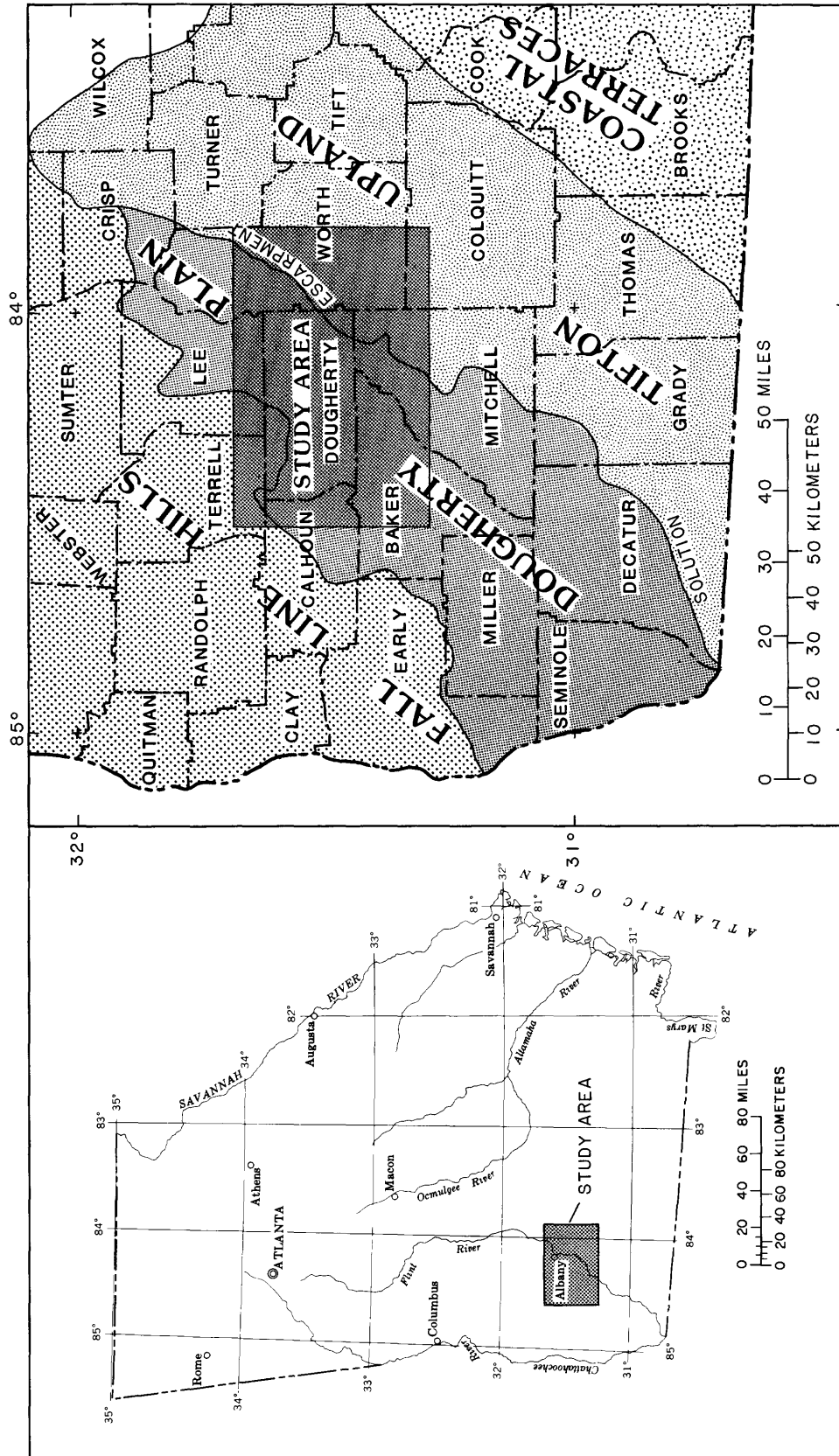
Figure 1.—Location of the study area and physiographic districts of the western Georgia Coastal Plain.

## 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 U.S. Geological Survey, Doraville, GA 30360.

The 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. The 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 over-burden. 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).

## 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 geohydrologic 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 overburden, 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 geohydrology 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 geohydrology 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 geohydrology 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, stream-flow, 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 U.S. Geological Survey topographic maps (pl. 1). Each 7 1/2-minute topographic quadrangle map in Georgia has been given a number and letter designation beginning at the southwest 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 "OO" 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 U.S. Geological Survey 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

# 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. The 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 it 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 With-lacoochee 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, the 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 inter-layered 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 (pl. 1) in southeastern Lee County, the upper part of the Lisbon Formation consists of sandy, fossiliferous limestone.

### 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.

| ERA-THEM | 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 | | Undifferentiated sediments |
| | | | Ducklakian | | |
| | | | Napoleonvillian (restricted) | | |
| | | | Anahuacian | | |
| | | Oligocene | Chickasawhayan (restricted) | | Suwannee Limestone |
| | | | Vicksburgian | | |
| | | Eocene — Late Eocene | Jacksonian | Ocala Limestone | Ocala Limestone |
| | | | | Clinchfield Sand | |
| | | Eocene — 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.

## 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 (pl. 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 (pl. 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 west side of the Flint River and from 40 to 80 ft on the east side of the river (pl. 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.)

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## Hydraulic Characteristics

The principal geohydrologic 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.

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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.)

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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.
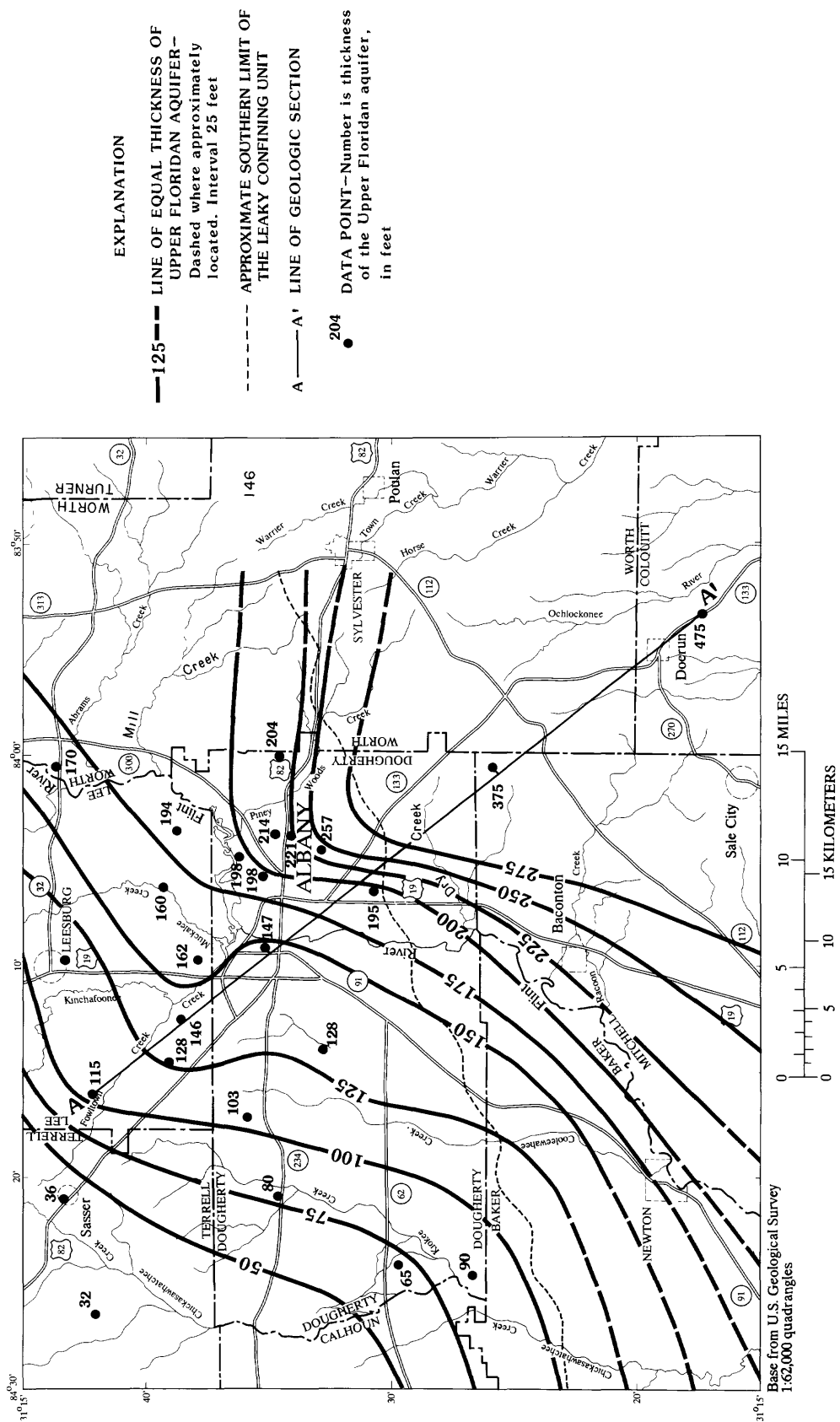
The distribution of transmissivity in the Upper Floridan aquifer is highly variable (fig. 5) because of areal differences in primary permeability of the Clinchfield Sand in Lee County and secondary permeability of the Ocala Limestone, the upper part of the Lisbon Formation, and the Suwannee Limestone. 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 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.

Figure 5.—Transmissivity of the Upper Floridan aquifer.

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## 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 (pl. 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.
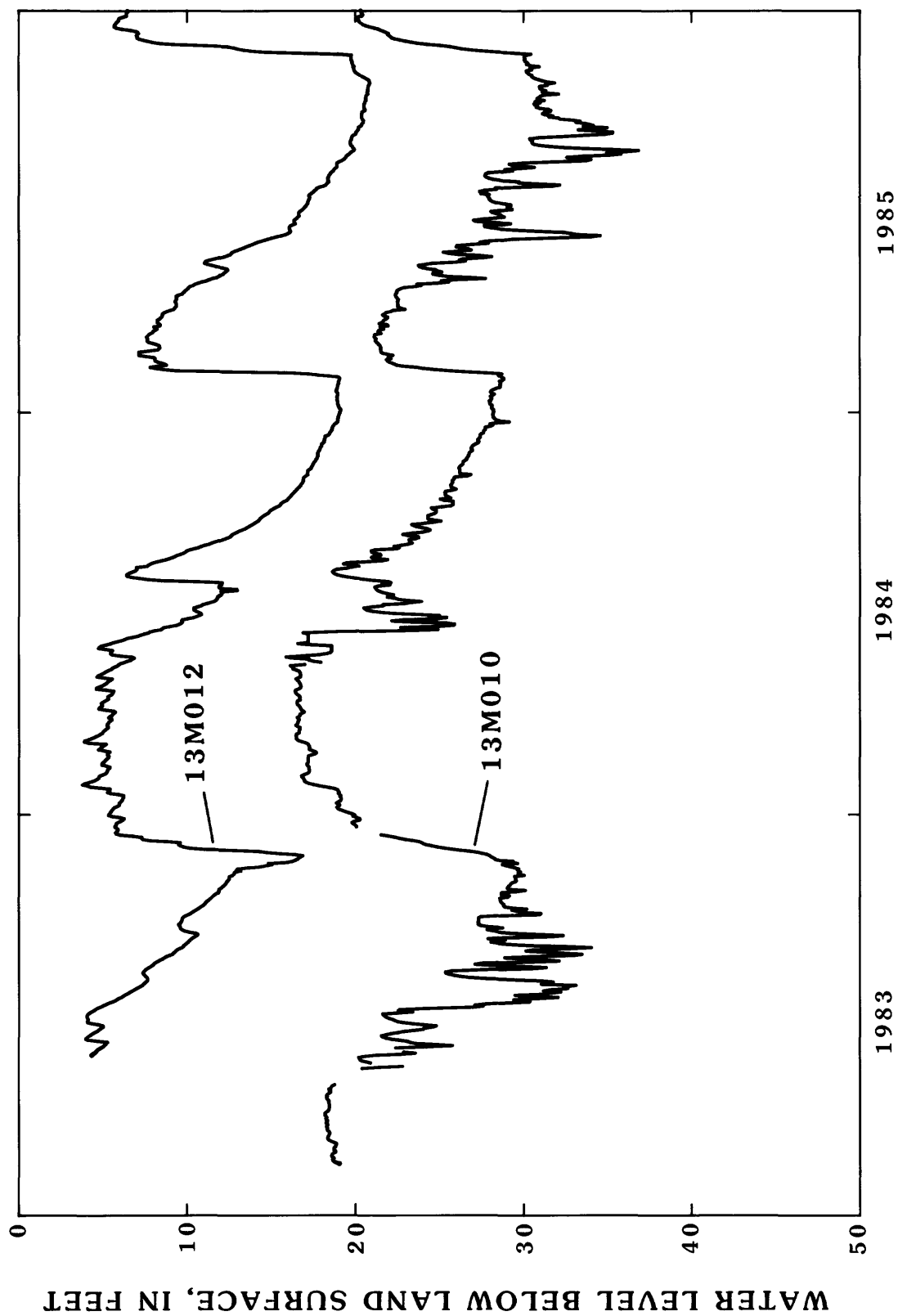
Figure 6.—Hydrographs for wells 13M010 and 13M012, 1983-85.

WATER LEVEL BELOW LAND SURFACE, IN FEET

13M012

13M010

1983    1984    1985

19

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; pl. 1). The 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 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 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.
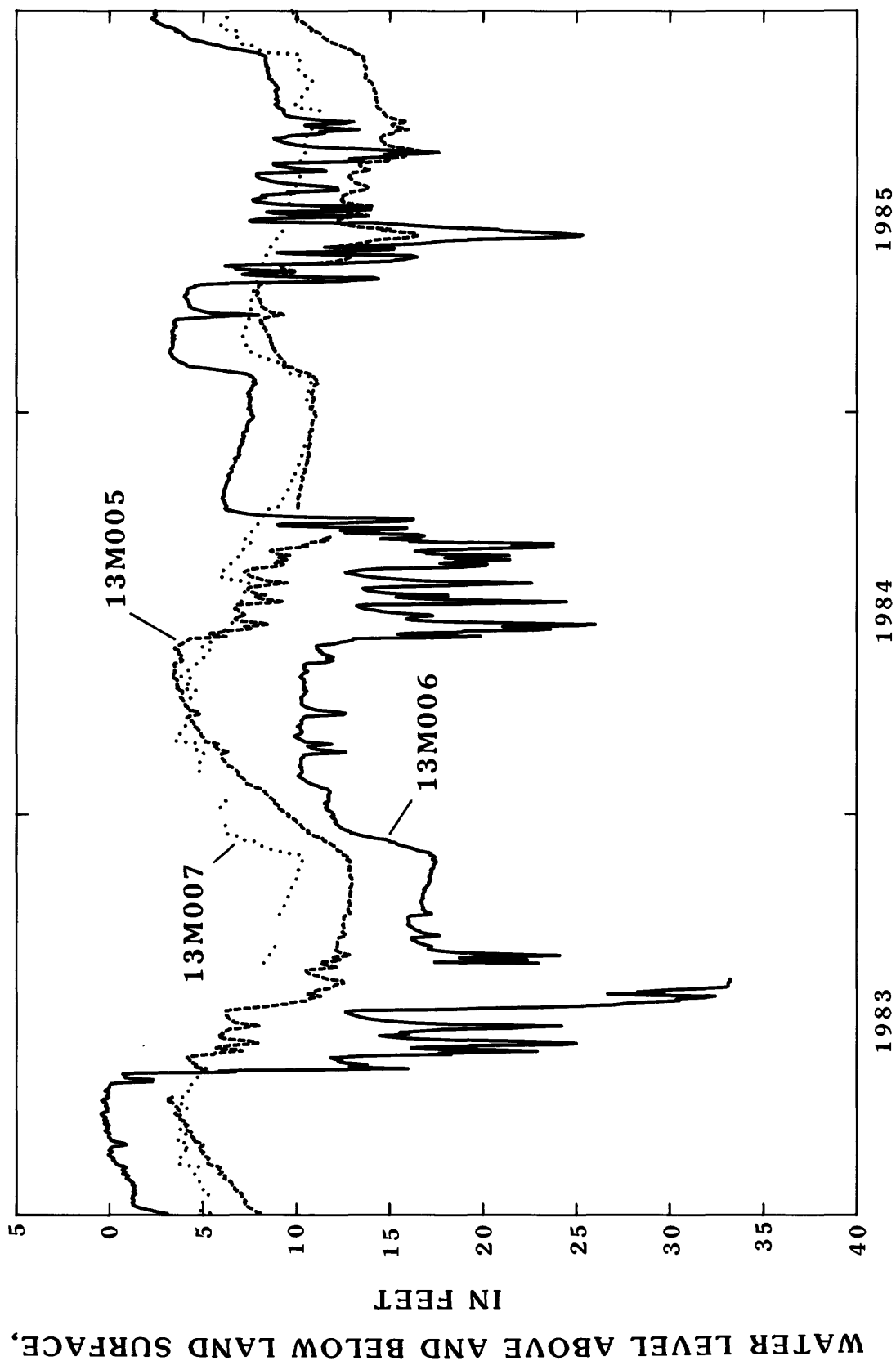
Figure 7.—Hydrographs for wells 13M005, 13M006, and 13M007, 1983-85.

WATER LEVEL ABOVE AND BELOW LAND SURFACE, IN FEET

21

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 (pl. 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 (pl. 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 (pl. 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.
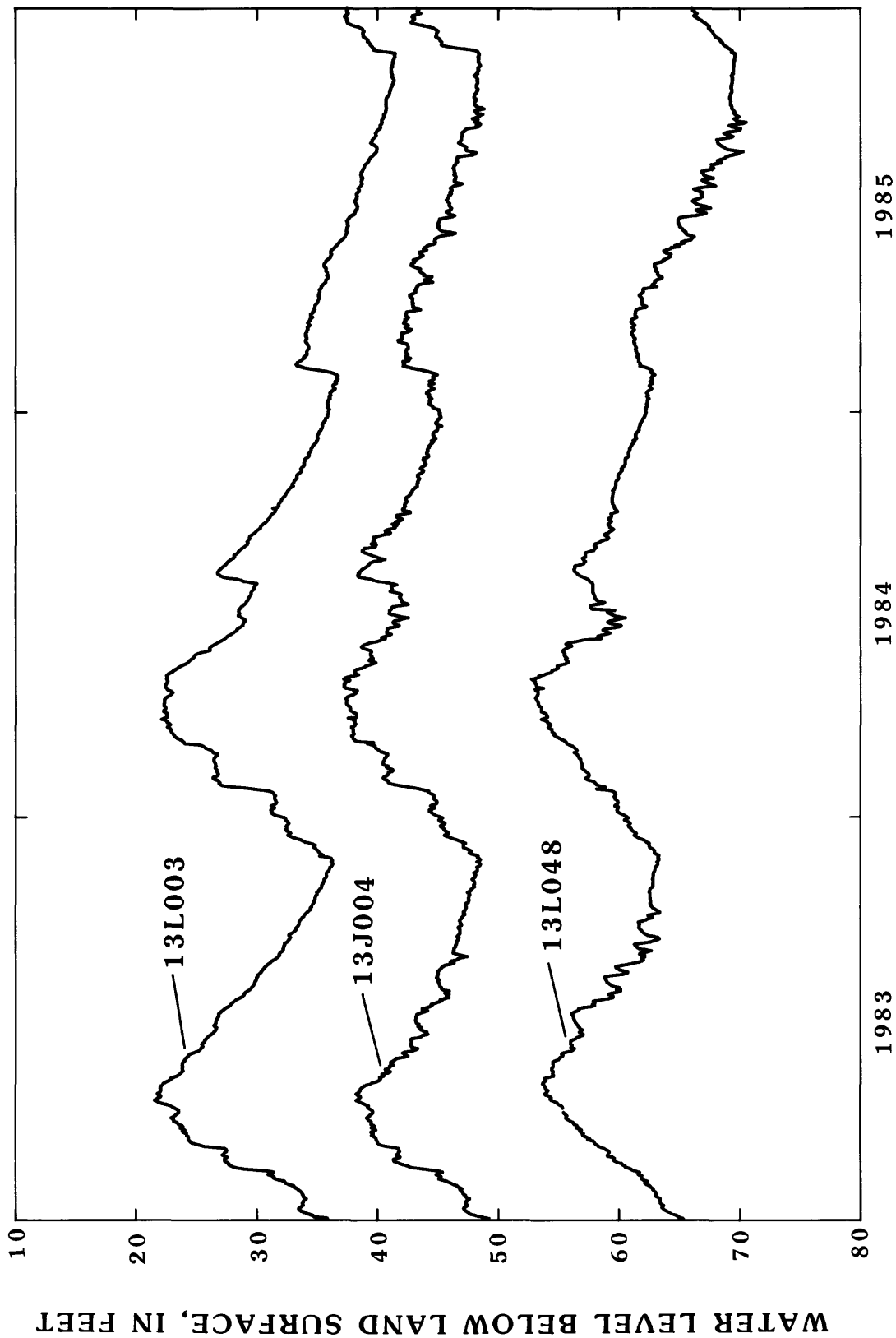
Figure 8.—Hydrographs for wells 13L003, 13L048, and 13J004, 1983-85.

WATER LEVEL BELOW LAND SURFACE, IN FEET
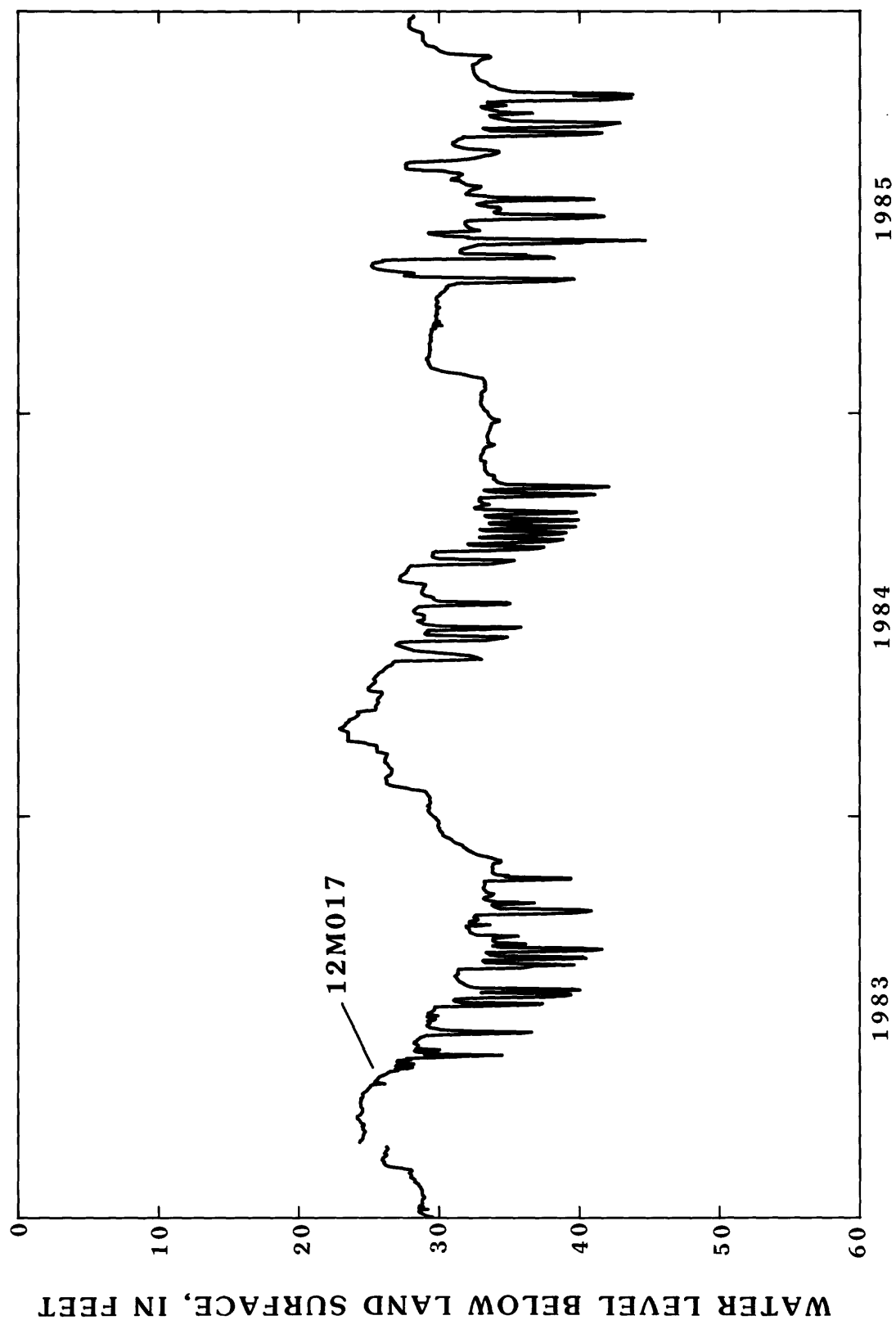
Figure 9.—Hydrograph for well 12M017, 1983-85.

WATER LEVEL BELOW LAND SURFACE, IN FEET

12M017

1983       1984       1985

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.

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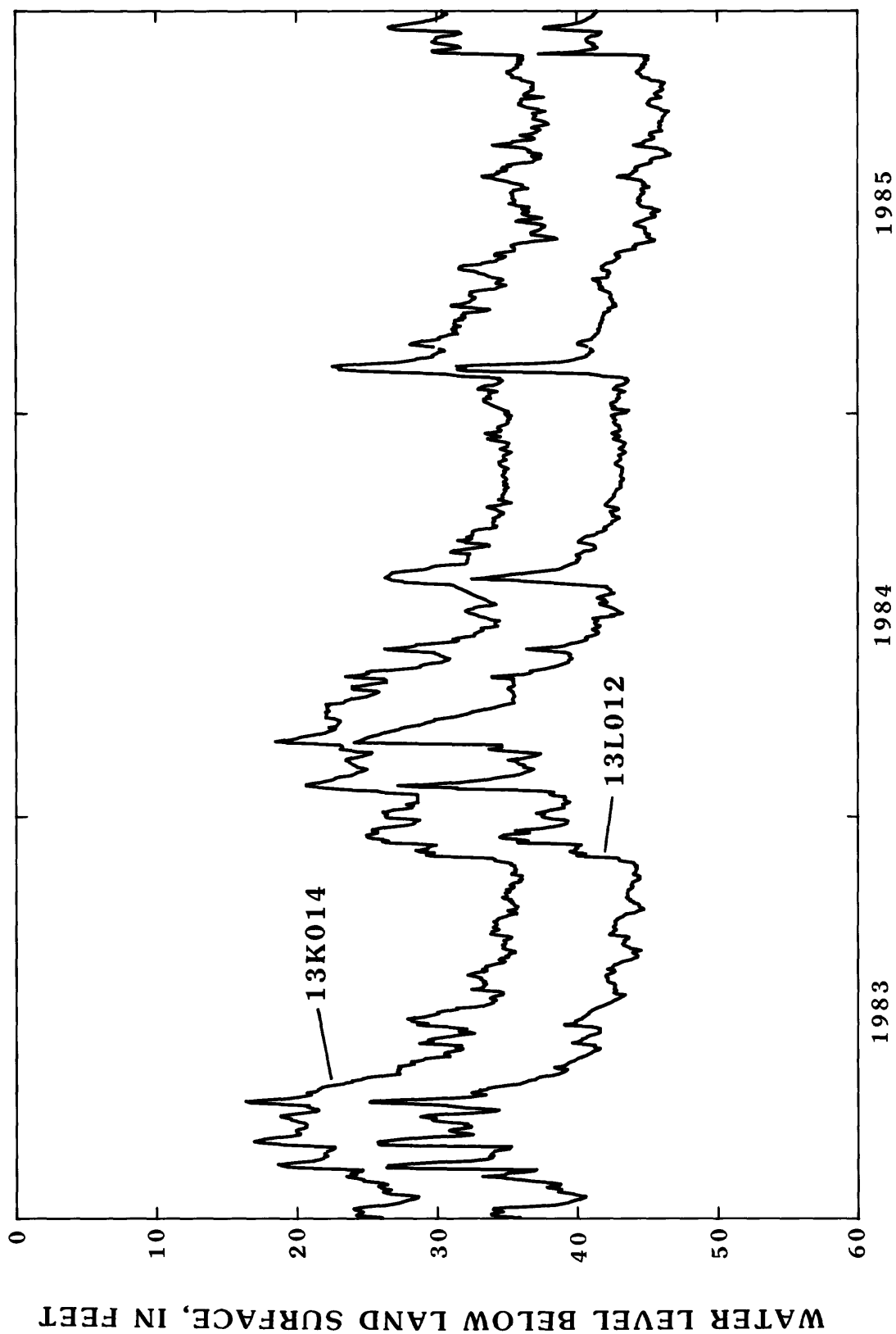
Figure 10.—Hydrographs for wells 13K014 and 13L012, 1983-85.

WATER LEVEL BELOW LAND SURFACE, IN FEET

13K014

13L012

0
10
20
30
40
50
60

1983

1984
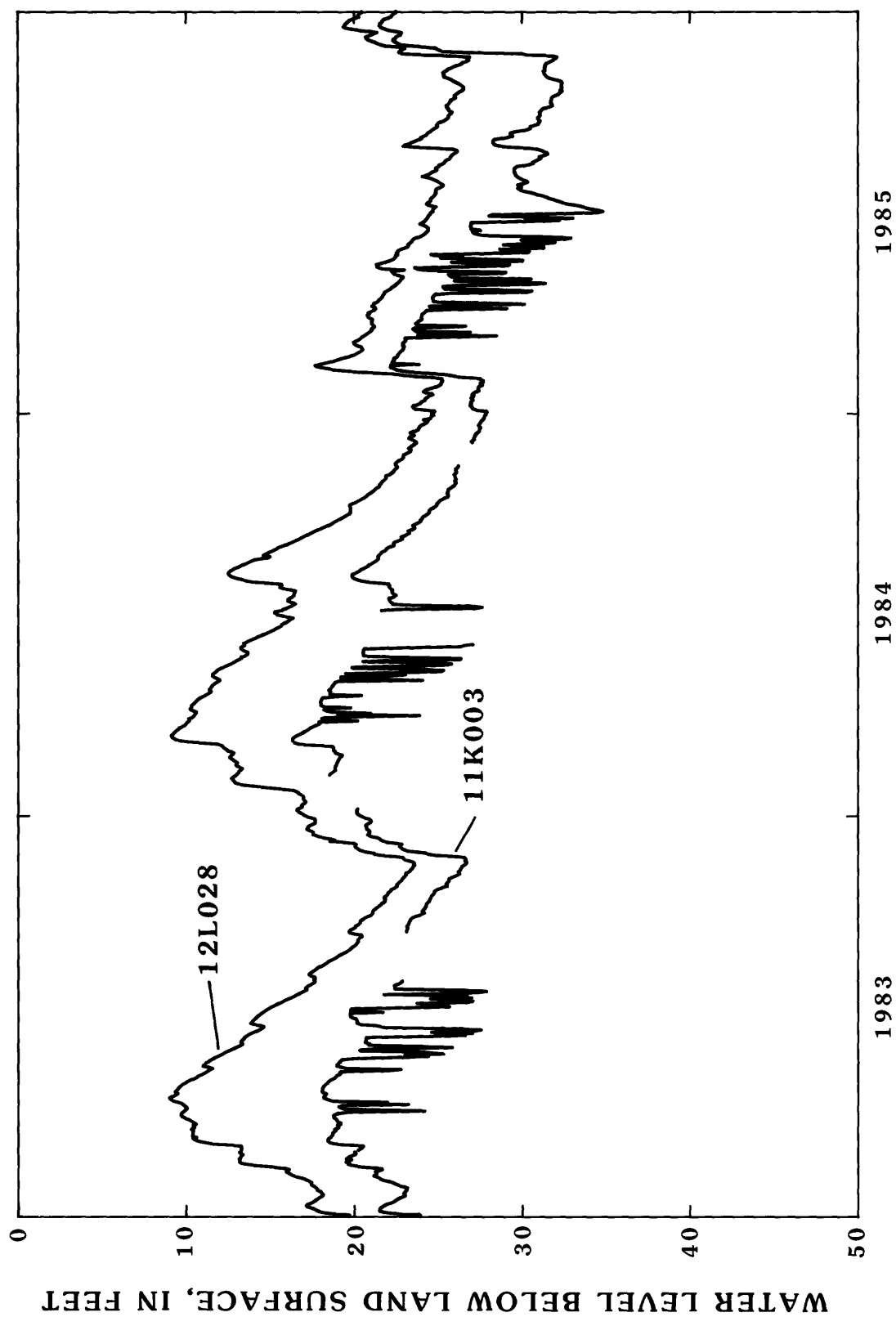
1985

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

27
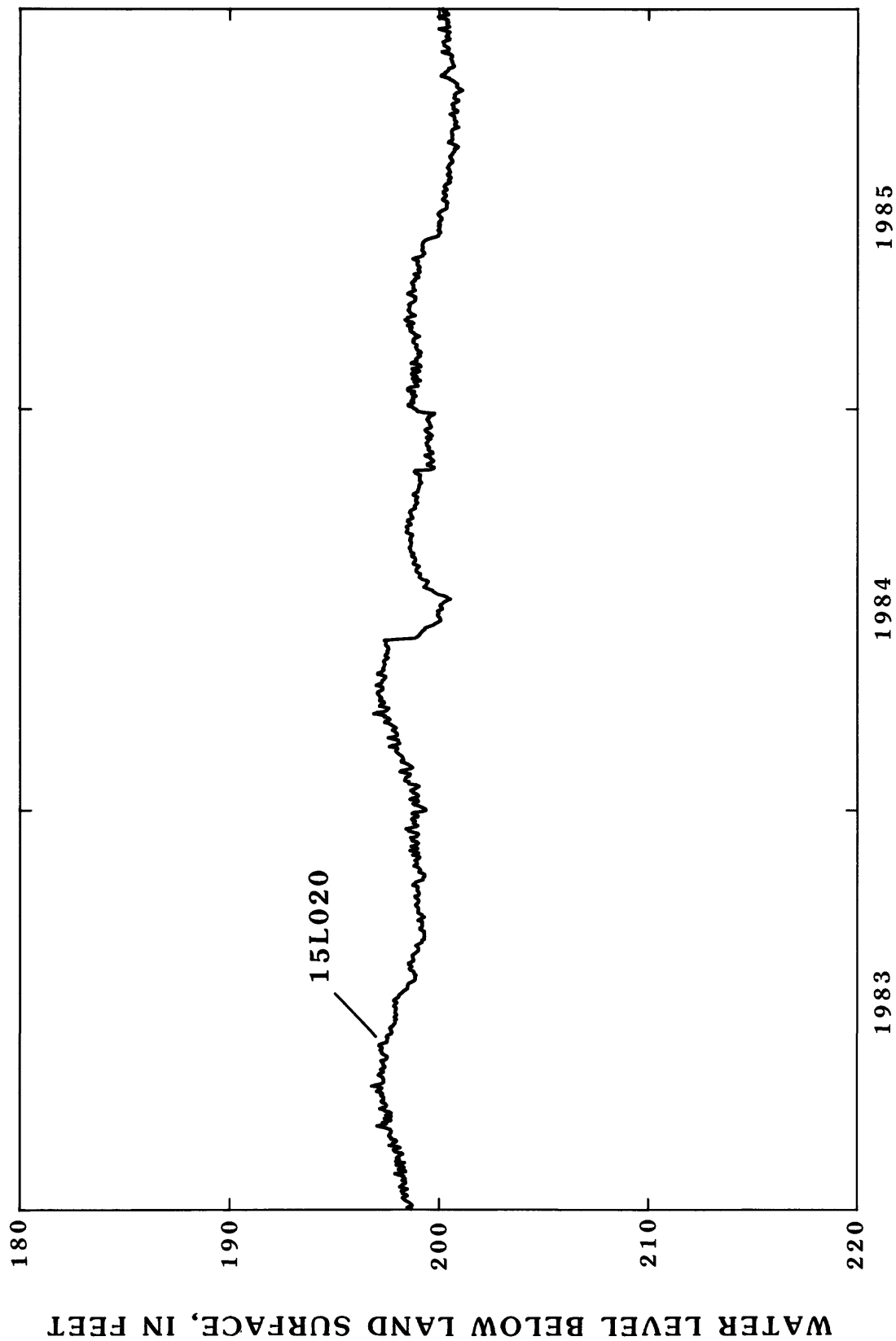
Figure 12.—Hydrograph for well 15L020, 1983-85.

WATER LEVEL BELOW LAND SURFACE, IN FEET

15L020

1983        1984        1985

180   190   200   210   220

28
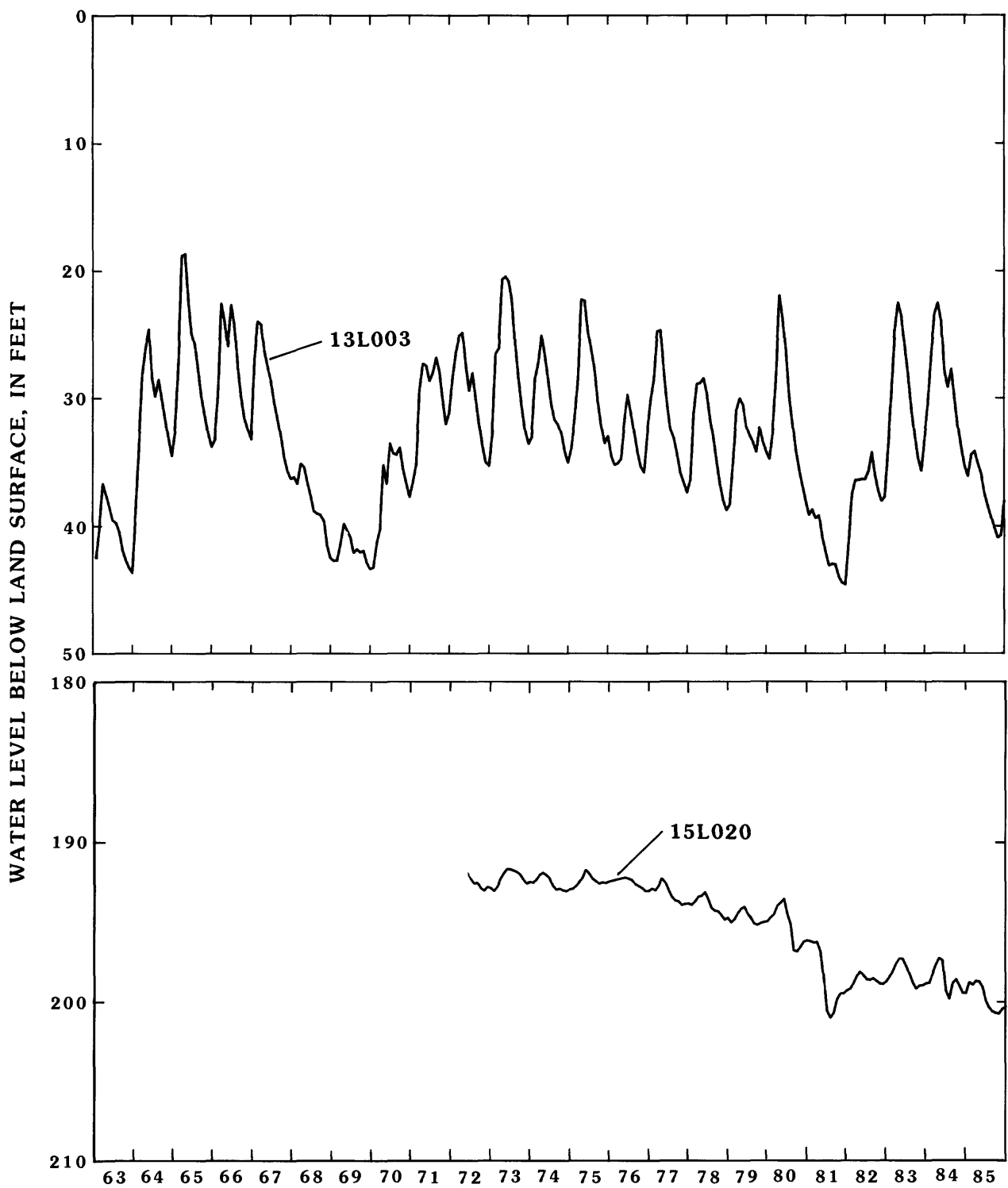
Figure 13.—Hydrographs for well 13L003, 1963-1985 and well 15L020, 1972-85.

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## 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 (pl. 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 (pl. 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 (pl. 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 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.

Base from U.S. Geological Survey
1:62,000 quadrangles
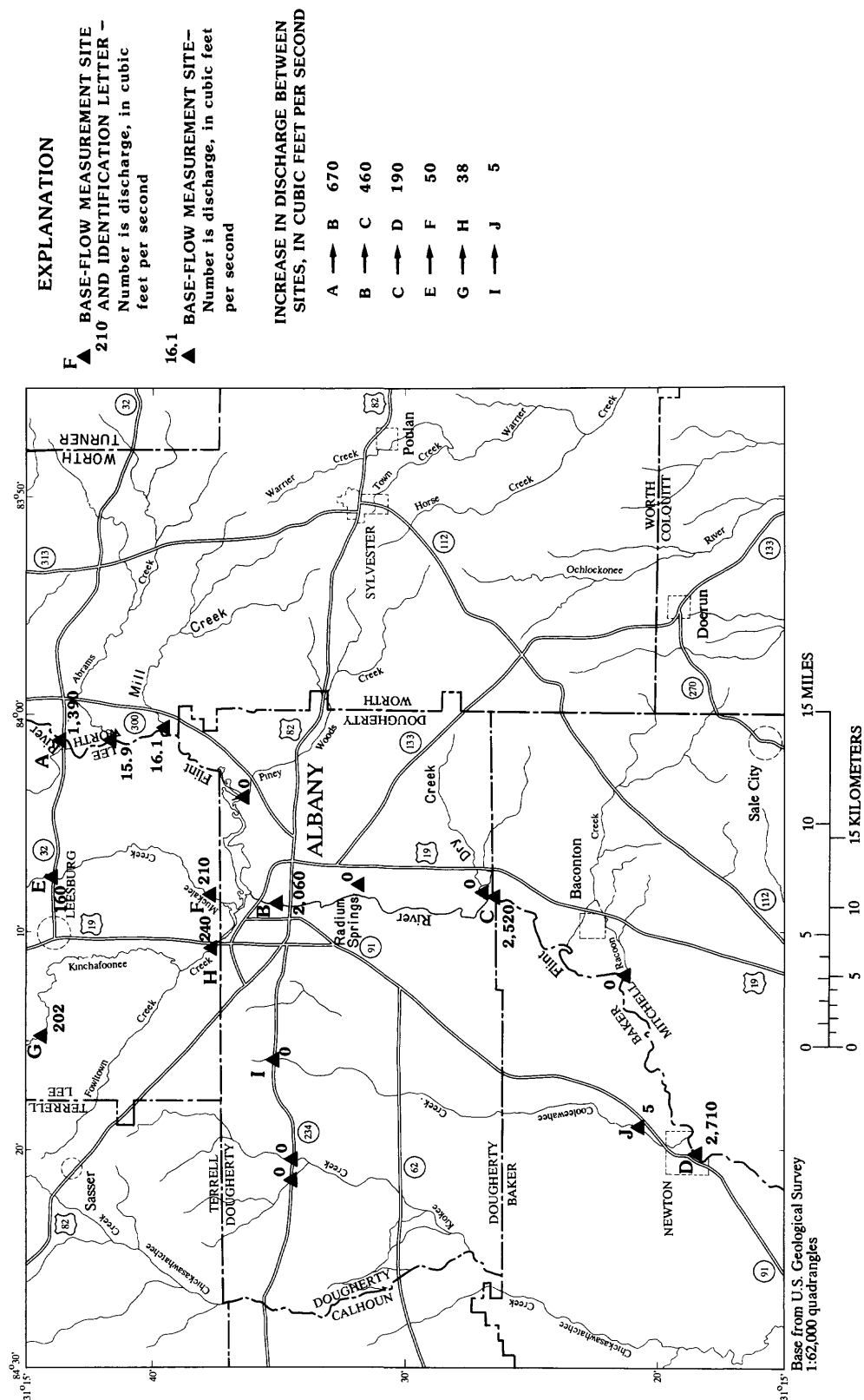
Figure 14.–Base-flow measurements, November 27-28, 1984.

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## 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 (pl. 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 constitutent 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.

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 Transdicl-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 | .02 | 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 |

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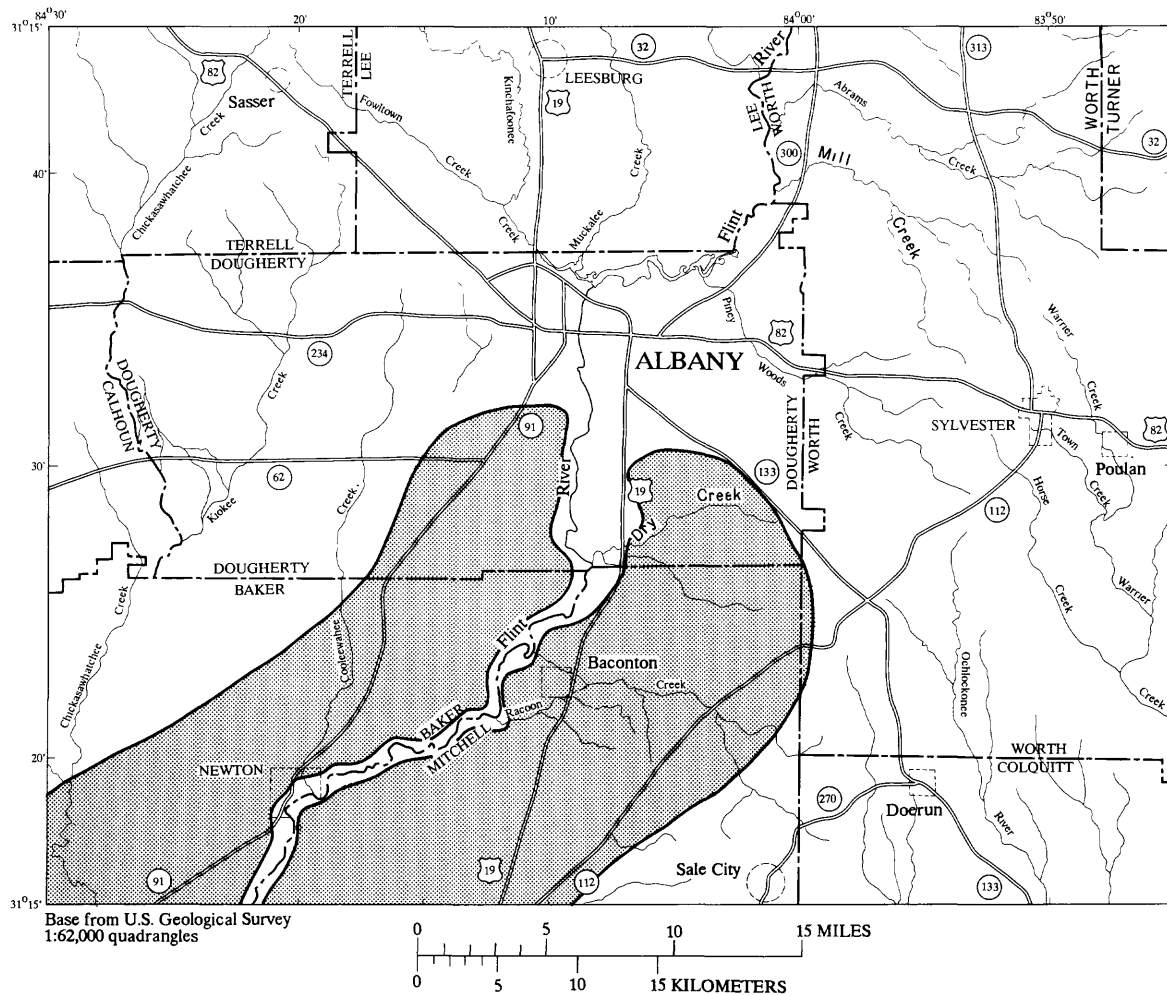
Figure 15.—Generalized areas of greatest development potential
for public water supply in the Upper Floridan aquifer.

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. 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 (pl. 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; pl. 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 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 (pl. 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 and is thought to be most prevalent in the area. Most of the depressions lack natural outlets and after heavy rains they are covered by water for weeks or months. Many 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 (pl. 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 in the land surface (pl. 3).

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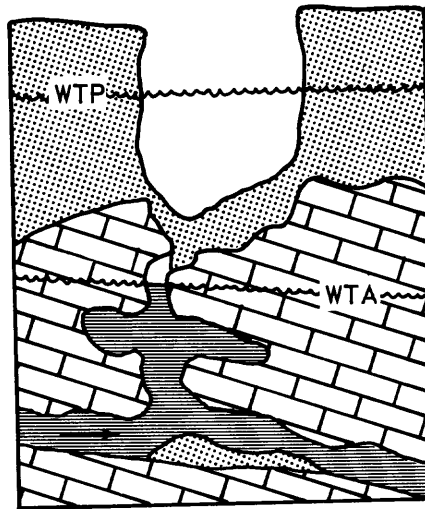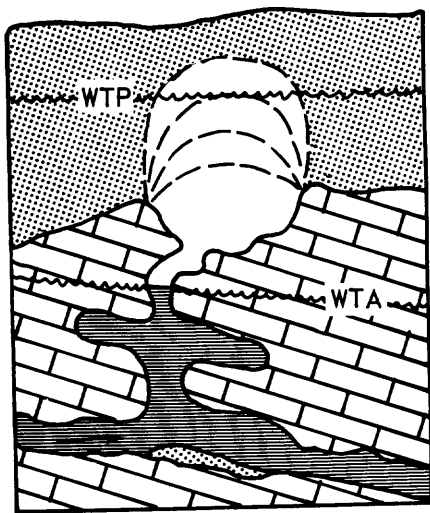
A. Vertical enlargement and resulting collapse.
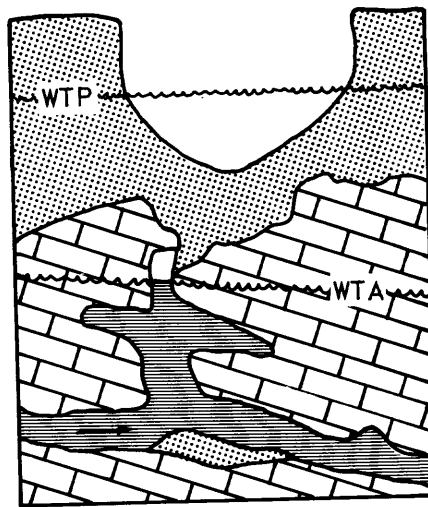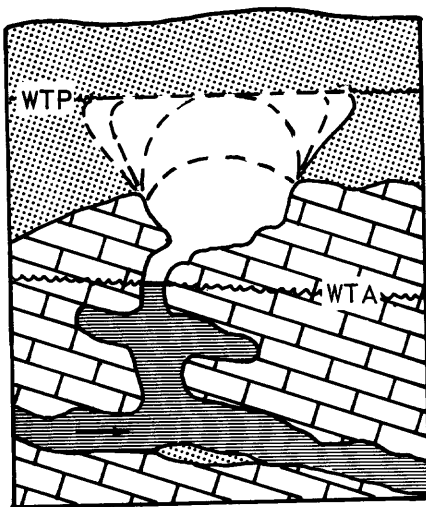


B. Vertical and lateral enlargement and resulting collapse.

EXPLANATION

Boundary designating cavity growth

WTP-Water table prior to decline

WTA-Water table after decline

▦ - Unconsolidated deposits

▬ - Water-filled opening in limestone

➤ - Direction of water movement
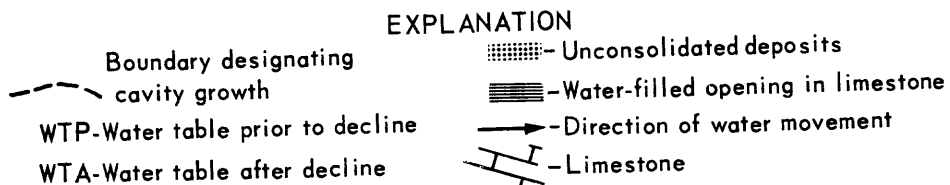
- Limestone

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

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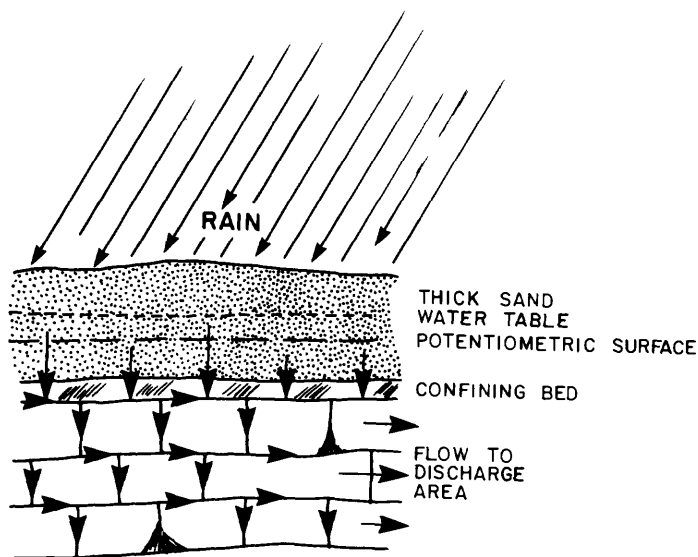
a. Rainwater percolates through incohesive deposits to underlying limestone. Highly transmissive joints dissolve faster than others.
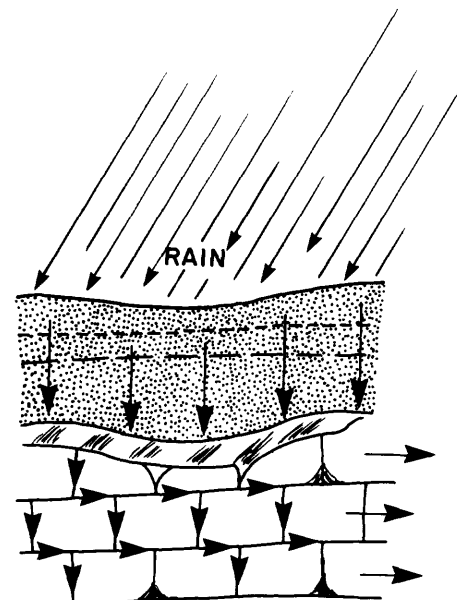
b. Differential solution of bedrock is expressed by a depression at land surface that funnels water to the enlarged joints.
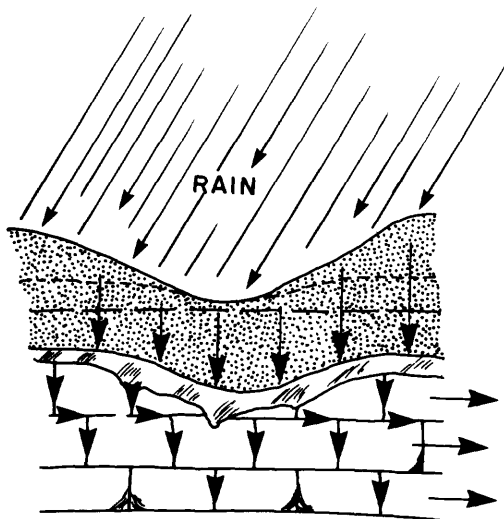
c. Sinkhole intersects the water table and cypress trees begin to grow. Rate of dissolution is reduced because there is less head difference between the water table and potentiometric surface and, thus, less percolation.
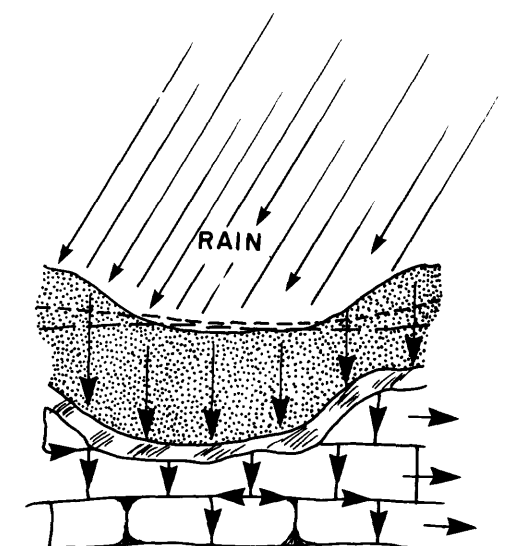
d. Sinkhole spreads laterally faster than it subsides. A cypress dome forms with old trees in the center and young trees on the perimeter.

Figure 17.—Stages in development of a cover-subsidence sinkhole. Arrows indicate direction of water movement. From Sinclair and others (1985).
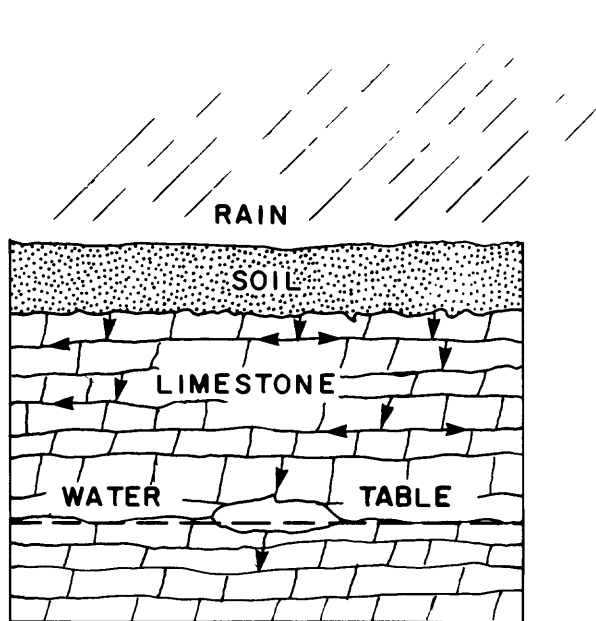
a. Solution cavity develops along joint or other plane of weakness at the water table.
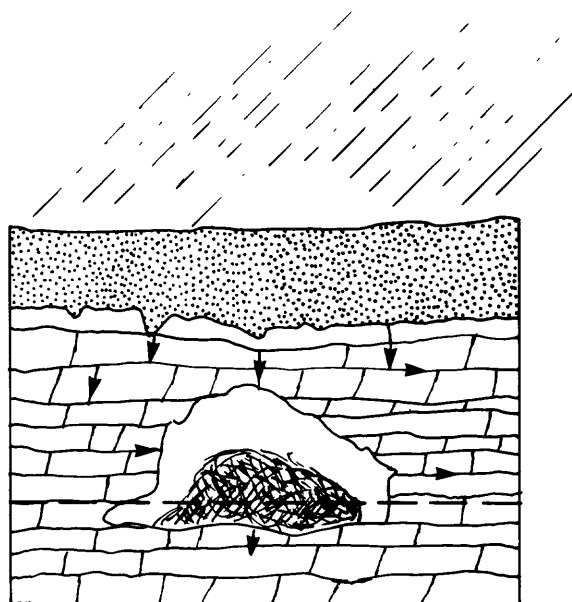
b. Roof collapses, most likely at joint intersection. Undercutting of cave walls by diverted ground water.
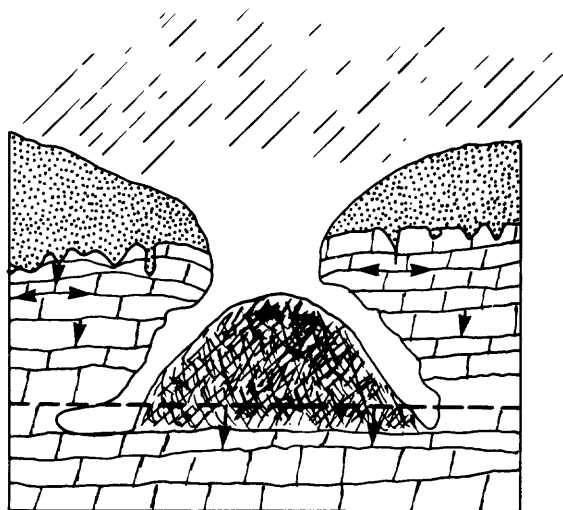
c. Roof collapse reaches land surface. Undercutting continues.
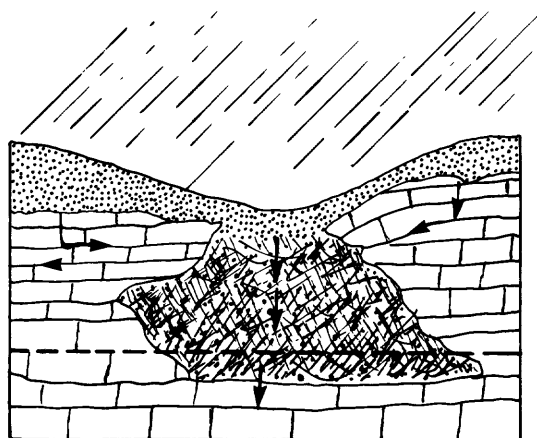
d. Soil washes into depression and obscures its origin. Breakdown and cave roof cemented by recrystallized limestone.

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).

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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.

## 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 quantitites 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) the depressions may overlie limestone cavities filled with sand or clay that could interfere with well yield, development, and production.

SELECTED REFERENCES

Bedinger, M.S., and Reed, J.E., 1964, Computing stream-induced ground-water
fluctuation, in Geological Survey Research, 1964: U.S. Geological Pro-
fessional Paper 501-B, p. B177-B180.
Carter, R.F., 1983, Effects of the drought of 1980-81 on streamflow and on
ground-water levels in Georgia: U.S. Geological Survey Water-Resources
Investigations Report 83-4158, 38 p.
Clark, W.Z., Jr., and Zisa, A.C., 1976, Physiographic map of Georgia: Georgia
Department of Natural Resources, Georgia Geological Survey, 1:2,000,000.
Cooke, C.W., 1943, Geology of the Coastal Plain of Georgia: U.S. Geological
Survey Bulletin 941, 121 p.
Fenneman, N.M., 1978, Physiography of the Eastern United States: New York,
McGraw Hill, 714 p.
Georgia Geological Survey, 1976, Geologic map of Georgia, 1:500,000.
Hayes, L.R., Maslia, M.L., and Meeks, W.C., 1983, Hydrology and model eval-
uation of the principal artesian aquifer, Dougherty Plain, southwest
Georgia: Georgia Geologic Survey Bulletin 97, 93 p.
Herrick, S.M., 1961, Well logs of the Coastal Plain of Georgia: Georgia
Geological Survey Bulletin 70, 462 p.
----- 1972, Age and correlation of the Clinchfield Sand in Georgia: U.S.
Geological Survey Bulletin 1354-E, 17 p.
Herrick, S.M., and Vorhis, R.C., 1963, Subsurface geology of the Georgia
Coastal Plain: Georgia Geological Survey Information Circular 25, 78 p.
Hicks, D.W., Krause, R.E., and Clarke, J.S., 1981, Geohydrology of the Albany
area, Georgia: Georgia Geologic Survey Information Circular 57, 31.p.
Kernodle, J.M., 1978, Linear ground-water flow, flood-wave response program
for programmable calculators: U.S. Geological Survey Open-File Report
78-356, 48 p.
LaForge, Laurence, Cook, Wythe, Keith, Arthur, and Campbell, M.R., 1925,
Physical geography of Georgia: Georgia Geological Survey Bulletin 42,
189 p.
Lohman, S.W., 1972, Ground-water hydraulics: U.S. Geological Survey Pro-
fessional Paper 708, 70 p.
MacNeil, F.S., 1947, Geologic map of the Tertiary and Quaternary Formations
of Georgia: U.S. Geological Survey Oil and Gas Inventory (Preliminary)
Map 72.
McCallie, S.W., 1898, A preliminary report on the artesian well system of
Georgia: Georgia Geological Survey Bulletin 7, p. 63-64, 177-183.
McFadden, S.S., Hetrick, J.H., Kellam, M.F., Rodenbeck, S.A., and Huddlestun,
P.F., 1986, Geologic data of the Gulf Trough area, Georgia: Georgia
Geologic Survey Information Circular 56, 345 p.
Middleton, R.G., 1968, Soil survey of Dougherty County, Georgia: U.S. Depart-
ment of Agriculture, Soil Conservation Service, 64 p.
Mitchell, G.D., 1981, Hydrogeologic data of the Dougherty Plain and adjacent
areas, southwest Georgia: Georgia Geologic Survey Information Circular
58, 124 p.
Newton, J.G., 1976, Early detection and correction of sinkhole problems in
Alabama, with a preliminary evaluation of remote sensing application:
Montgomery, Alabama, State of Alabama Highway Department, HPR Report No.
76, 83 p.

Owen, Vaux, Jr., 1958, Summary of ground-water resources of Lee County, Georgia: Georgia Geological Survey Mineral Newsletter, v. 11, no. 4, p. 118-121.

----- 1963a, Geology and ground-water resources of Lee and Sumter Counties, southwest Georgia: U.S. Geological Survey Water-Supply Paper 1666, 70 p.

----- 1963b, Geology and ground-water resources of Mitchell County, Georgia: Georgia Geological Survey Information Circular 24, 40 p.

Pinder, G.F., Bredehoeft, J.D., and Cooper, H.H., Jr., 1969, Determination of aquifer diffusivity from aquifer response to fluctuations in river stage: Water Resources Research, v. 5, no. 4, p. 850-855.

Sinclair, W.C., Stewart, J.W., Knutilla, R.L., Gilboy, A.E., and Miller, R.L., 1985, Types, features, and occurrence of sinkholes in the karst of west-central Florida: U.S. Geological Survey Water-Resources Investigations Report 85-4126, 81 p.

Stephenson, L.W., and Veatch, V.O., 1915, Underground waters of the Coastal Plain of Georgia, and a discussion of The quality of the waters, by R.B. Dole: U.S. Geological Survey Water-Supply Paper 341, 539 p.

Stringfield, V.T., 1966, Artesian water in Tertiary limestone in the Southeastern United States: U.S. Geological Survey Professional Paper 517, 134 p.

Theis, C.V., 1938, The significance and nature of the cone of depression in ground-water bodies: Economic Geology, v. 33, no. 8, p. 889-902.

Vorhis, R.C., 1972, Geohydrology of Sumter, Dooly, Pulaski, Lee, Crisp, and Wilcox Counties, Georgia: U.S. Geological Survey Hydrologic Atlas HA-435, 2 sheets.

Wait, R.L., 1960, Source and quality of ground water in southwestern Georgia: Georgia Geological Survey Information Circular 18, 78 p.

----- 1962, Geology of the Albany West quadrangle, Georgia: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-348, 1 sheet.

----- 1963, Geology and ground-water resources of Dougherty County, Georgia: U.S. Geological Survey Water-Supply Paper 1539-P, 102 p.

Watson, T.W., 1976, The geohydrology of Ben Hill, Irwin, Tift, Turner, and Worth Counties, Georgia: Georgia Geological Survey Hydrologic Atlas 2.

----- 1981, Geohydrology of the Dougherty Plain and adjacent areas, southwest Georgia: Georgia Geologic Survey Hydrologic Atlas 5.

White, W.B., 1969, Conceptual models for carbonate aquifers: Ground Water, v. 7, no. 3.

Zimmerman, E.A., 1977, Ground-water resources and geology of Colquitt County, Georgia: U.S. Geological Survey Open-File Report 77-56, 70 p.

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

[UFA, Upper Floridan aquifer; CLBR, Claiborne aquifer; M/A, 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 [(gal/min)/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 | 3135500B41538 | 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. Mitchell | -- | -- | -- | 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 | 180 | -- | -- |
| 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.

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

[UFA, Upper Floridan aquifer; CLBR, Claiborne aquifer; M/A, Multi-aquifer;
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 [(gal/min)/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 | -- |
| 13K018 | 3126400840112 | St. Marys Church | -- | -- | -- | UFA | 330 | -- | -- |
| 13K019 | 3128460840719 | Nichols Road Church | -- | -- | -- | UFA | 195 | 20 | -- |
| 13K020 | 3127070840700 | Frank Wetherbee (abandoned 3-in. well) | -- | 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 | 1,100 | 14 |
| 13L043 | 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 | Firestone, 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--Continued

[UFA, Upper Floridan aquifer; CLBR, Claiborne aquifer; M/A, Multi-aquifer;
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 [(gal/min)/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 | -- | -- |

See footnotes at end of table.

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

[UFA, Upper Floridan aquifer; CLBR, Claiborne aquifer; M/A, 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 [(gal/min)/ft] |
|---|---|---|---|---|---|---|---|---|---|
| Worth County--Continued | | | | | | | | | |
| 14J019 | 3121570835303 | Union Church | -- | -- | -- | UFA | 390 | -- | -- |
| 14J020 | 3120560835446 | L. E. Baxley | -- | -- | -- | UFA | 390 | -- | -- |
| 14J021 | 3122300835603 | Carver (trailer) | -- | -- | -- | UFA | 376 | -- | -- |
| 14J022 | 3122300835603 | Liberty Church | -- | -- | -- | UFA | 418 | -- | -- |
| 14K006 | 3129300835801 | Hines Place Farm, 1 | 1982 | -- | -- | UFA | 320 | -- | -- |
| 14K007 | 3122540835739 | Bridgeboro Plantation | 1982 | -- | -- | UFA | 400 | -- | -- |
| 14K008 | 3123580835832 | Brown Milling 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. O. 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 | 1978 | -- | -- | UFA | 260 | -- | -- |
| 14L012 | 3133020835517 | Terry Young | -- | -- | -- | UFA | 355 | -- | -- |
| 14L013 | 3130270835709 | Lawrence Bridges | -- | -- | -- | UFA | 280 | -- | -- |
| 14L014 | 3137290835503 | Salem Church | -- | -- | -- | UFA | 284 | -- | -- |
| 14L044 | 3137290835911 | Worthy Manor Subdivision | 1972 | 185 | -- | 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 Cemetary | -- | -- | -- | 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 | Doyle Medders | 1978 | -- | -- | UFA | 325 | 15 | -- |

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

Prepared in cooperation with
CITY OF ALBANY
WATER, GAS, AND LIGHT COMMISSION

Table 2.--Chemical analysis of well and river water for inorganic constituents

[Analyses by U.S. Geological Survey; UFA, Upper Floridan aquifer; <, less than; --, no data]

**Milligrams per liter / Dissolved solids / Hardness / other**

| Site number | Owner or name | Sample source | Date sampled | Alkalinity as CaCO3 | Calcium (Ca) | Carbon dioxide (CO2) | Chloride (Cl) | Fluoride (F) | Magnesium (Mg) | Nitrate (NO3) | Nitrite (NO2) | Potassium (K) | Silica (SiO2) | Sodium (Na) | Sulfate (SO4) | Residue at 180°C | Sum of constituents | Hardness Calcium, magnesium | Noncarbonate | Specific conductance, in micromhos at 25°C | pH | Water temperature, in degrees Celsius | Color in platinum-cobalt units | Sodium, absorption ratio | Sodium percent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Drinking water standards[1] | | | | | | 250 | 1,400 | | 10 | | | | | 250 | 500 | 500 | | | | | | | |
| 13L012 | U.S. Geological Survey, TW3 | UFA | 06-17-77 | 120 | 45 | -- | 2.6 | 0.0 | 0.90 | -- | -- | 0.2 | 8.3 | 1.8 | 0.5 | 131 | 132 | 120 | 0 | 190 | 7.4 | 21.5 | 5 | -- | 3 |
| 11K015 | do. TW14 | UFA | 06-02-83 | 125 | 51 | 12 | 3.0 | <.1 | .53 | 0.43 | 0.01 | .3 | 7.6 | 2.0 | <5.0 | 133 | -- | 130 | 5 | 247 | 7.3 | 20.2 | 17 | 0.0 | 3 |
| 12L029 | do. TW13 | UFA | 06-02-83 | 256 | 110 | 63 | 20 | <.1 | 3.1 | 2.5 | .01 | 2.6 | 9.4 | 22.0 | 33 | 366 | 365 | 290 | 32 | 590 | 6.9 | 22.5 | 15 | .6 | 14 |
| 12L030 | do. TW16 | UFA | 06-02-83 | 129 | 53 | 16 | 3.7 | <.1 | .46 | .81 | .01 | .5 | 7.4 | 3.3 | <5.0 | 150 | -- | 130 | 5 | 260 | 7.2 | 20.5 | 15 | .1 | 5 |
| 13L048 | do. TW17 | UFA | 06-02-83 | 144 | 57 | 22 | 3.3 | .1 | 2.4 | .30 | .01 | .4 | 13.0 | 2.3 | <5.0 | 168 | -- | 150 | 8 | 282 | 7.1 | 20.3 | 17 | .0 | 3 |
| 13K014 | do. TW15 | UFA | 06-06-83 | 129 | 53 | 20 | 2.7 | <.1 | .98 | .54 | .01 | .2 | 9.1 | 2.0 | <5.0 | 149 | -- | 140 | 7 | 252 | 7.1 | 20.2 | 13 | .0 | 4 |
| 13M008 | do. TW18 | UFA | 06-01-83 | 91 | 38 | 8.9 | <.2 | <.1 | .65 | .47 | .01 | .3 | 24.0 | 1.9 | <5.0 | 125 | -- | 98 | 7 | 178 | 7.3 | -- | 17 | .0 | 4 |
| 12M017 | do. TW19 | UFA | 06-02-83 | 124 | 51 | 12 | 2.0 | <.1 | 1.2 | .76 | .01 | .5 | 11.0 | 1.9 | <5.0 | 131 | -- | 130 | 8 | 243 | 7.3 | 21.0 | 19 | .0 | 3 |
| 023530 | Flint River at Newton | Flint River | [2]05-17-84 | 50 | 19 | -- | 5.5 | .1 | 1.1 | .48 | <.01 | 1.1 | 8.0 | 7.0 | 5.0 | 89 | -- | -- | -- | 133 | 7.8 | 22.5 | -- | -- | -- |
| 023530 | do. | do. | [3]08-22-84 | 48 | 18 | -- | 5.3 | .1 | 1.1 | .77 | .16 | 1.3 | 9.5 | 5.0 | 7.1 | 87 | -- | -- | -- | 122 | 7.7 | 27.0 | -- | -- | -- |

**Micrograms per liter**

| Site number | Aluminum (Al) | Arsenic (As) | Barium (Ba) | Beryllium (Be) | Cadmium (Cd) | Chromium (Cr) | Cobalt (Co) | Copper (Cu) | Iron (Fe) | Lead (Pb) | Lithium (Li) | Manganese (Mn) | Mercury (Hg) | Molybdenum (Mo) | Nickel (Ni) | Selenium (Se) | Strontium (Sr) | Vanadium (V) | Zinc (Zn) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Drinking water standards[1] | | 50 | 1,000 | | 10 | 50 | | 1,000 | 300 | 50 | | 50 | 2.0 | | | 10 | | | 5,000 |
| 13L012 | 10 | 1 | 0.0 | -- | 0.0 | 0.0 | 0.0 | 0.0 | <10 | 3 | -- | 10 | 0.0 | -- | 0.0 | 0.0 | 50 | -- | 10 |
| 11K015 | 120 | <1 | 28 | <0.5 | <1.0 | <1.0 | <3.0 | <10 | 7 | <10 | <4 | 2 | <.1 | <10 | 3.0 | <1 | 25 | <6 | 10 |
| 12L029 | 90 | 1 | 80 | <.5 | <1.0 | <1.0 | <3.0 | <10 | 10 | 20 | <4 | 2 | <.1 | <10 | 2.0 | 1 | 82 | <6 | 14 |
| 12L030 | 20 | <1 | 42 | <.5 | <1.0 | <1.0 | <3.0 | <10 | 37 | <10 | <4 | 3 | <.1 | <10 | 2.0 | <1 | 27 | <6 | 12 |
| 13L048 | <10 | 1 | 77 | <.5 | <1.0 | 4.0 | <3.0 | <10 | <3 | <10 | 5 | 3 | <.1 | <10 | 2.0 | <1 | 160 | <6 | 5 |
| 13K014 | 10 | 1 | 37 | <.5 | <1.0 | <1.0 | <3.0 | <10 | 16 | <10 | <4 | 8 | <.1 | <10 | 3.0 | <1 | 39 | <6 | <3 |
| 13M008 | 10 | 1 | 44 | <.5 | <1.0 | <1.0 | <3.0 | <10 | <3 | <10 | <4 | 8 | <.1 | <10 | 1.0 | <1 | 47 | <6 | 9 |
| 12M017 | 20 | <1 | 42 | <.5 | <1.0 | <1.0 | <3.0 | <10 | <3 | <10 | <4 | 16 | <.1 | <10 | 3.0 | <1 | 81 | <6 | 4 |
| 023530 | 30 | -- | 26 | <.5 | <1.0 | 1.0 | <3.0 | 2.0 | 520 | 5 | 6 | 16 | <.1 | <10 | 2.0 | <1 | 30 | <6 | 41 |
| 023530 | 20 | -- | 27 | <.5 | <1.0 | 1.0 | <3.0 | 2.0 | 440 | 2 | 6 | 10 | <.1 | <10 | 1.0 | <1 | 31 | <6 | 7 |

[1] Georgia Department of Natural Resources, Environmental Protection Division's standards for safe drinking water, 1977.
[2] Instantaneous streamflow at time of sample collection was 5,990 ft³/s.
[3] Instantaneous streamflow at time of sample collection was 4,270 ft³/s.