GEOHYDROLOGY OF THE JACKSONIAN AQUIFER IN CENTRAL AND EAST-CENTRAL GEORGIA

Harold R. Vincent

ABSTRACT

The Jacksonian (late Eocene age) sediments of the central and east-central Coastal Plain Physiographic Province of Georgia are the primary source of domestic water for that region. These sediments consist of an exposed updip clastic facies referred to as the Barnwell Group, and a subsurface downdip carbonate facies referred to as the Ocala Group. The downdip carbonate facies is hydraulically equivalent to overlying and underlying carbonate units of upper Oligocene and middle Eocene age, respectively, and forms part of a continuous Tertiary aquifer system referred to as the Principal Artesian Aquifer. Within the area of transition between the clastic and carbonate facies, the Jacksonian sediments consist predominantly of clay and (or) marl and exhibit poor aquifer characteristics.

A comparison of the historical potentiometric surface of the Jacksonian aquifer with the 1981 potentiometric surface indicates that water levels have declined an average of less than 10 feet in the updip region and an average of 25 feet in the downdip region. Well hydrographs plotted against cumulative precipitation curves indicate that certain areas in the downdip carbonate facies began to be less responsive to precipitation in the mid-1960's, a phenomenon that presently cannot be explained from the data available.

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HYDROLOGIC ATLAS 8 PLATE 1

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INTRODUCTION

Jacksonian (late Eocene age) sediments of the central and east-central Coastal Plain Physiographic Province of Georgia comprise a sequence of exposed updip clastic and subsurface downdip carbonate constituents. Previous workers have referred to the updip clastic facies as the Barnwell Formation, originally named by Sloan (1908). Recent work by Huddlestun and Hetrick (1979) has raised the Barnwell Formation to group status with the clastic constituents consisting of the Tobacco Road Sand (Huddlestun and Hetrick, 1978) and Dry Branch Formation. The downdip carbonate facies is referred to as the Ocala Group by Huddlestun (1981) and forms part of a Tertiary limestone aquifer system that includes units of middle Eocene to upper Oligocene. The units of this Tertiary limestone aquifer system are hydraulically interconnected in varying degrees, acting predominantly as a single aquifer in the downdip region. In the clastic facies, however, the water-bearing Jacksonian sediments are hydraulically separated from underlying water-bearing sediments of Cretaceous age by clays and sandy clays of Claibornian (middle Eocene) age and locally occurring basal clays of late Eocene age. The downdip carbonate facies of this Tertiary aquifer system is the principal source of agricultural, municipal, and industrial water for a substantial portion of south Georgia and is collectively referred to as the Principal Artesian Aquifer.

Extensive previous work has been done in the Principal Artesian Aquifer system of south Georgia (Krause and Gregg, 1972; Johnson and others, 1981; Watson, 1981). Until now, however, no concentrated work had been done on assessing the aquifer characteristics of the upper Eocene sediments in both the updip clastic facies and downdip carbonate facies. This atlas attempts to subdivide the Principal Artesian Aquifer into its proper lithologic units to determine the hydrologic relations between them. The location of the study area is shown in Figure 1.

WELL-NUMBERING SYSTEM

Wells are numbered according to a Georgia Geologic Survey code system in which 7.5-minute quadrangles in the State of Georgia are assigned a number-letter coordinate. For example, for well 25R001, 25R is the coordinate assigned to the Mount Vernon 7.5-minute quadrangle in Montgomery County. Each well in that quadrangle is then assigned a numerical designation beginning with 001.

FIGURE 1. Location of study area.

GENERAL GEOLOGY

The Atlantic Coastal Plain Physiographic Province of south Georgia is composed predominantly of unconsolidated sediments that range in age from Early Cretaceous to Holocene. Sediments of Cretaceous age unconformably overlie the igneous and metamorphic crystalline complex of the southern Appalachian Piedmont Province, as well as Triassic redbeds and intrusives, ill-defined Paleozoic sedimentary rocks, and variably aged felsic to mafic volcanic material. Within the study area, the Cretaceous-age sediments are unconformably overlain by sediments of Midwayan (Paleocene) age.

Sediments of Tertiary age within the study area dip southeastward approximately 15 ft/mi (LeGrand, 1956) and thicken gradually in this direction, reaching a total maximum thickness in excess of 1,500 ft. These sediments include units of sand, clay, marl, and limestone. A generalized lithologic correlation chart describing the major Tertiary-age units within the study area is presented in Figure 2.

The updip clastic facies (Barnwell Group) of the Jacksonian strata represents a marginal to nearshore marine environment of deposition and is characterized by sand and gravel (i.e., the Coarse Clastic Facies). Downdip, these relatively coarse clastics are gradually replaced by increasing clay, fine sand, and calcareous material as the environment of deposition changes to deeper water, offshore marine. Throughout the central portion of the study area, the Jacksonian strata consist predominantly of carbonaceous clays (Twiggs Clay Member/Dry Branch Formation) and calcareous arenites, hereinafter referred to as the Transition Facies (Fig. 3). The Ocala Group occurs to the south of the Transition Facies and consists predominantly of carbonate material (i.e., the Carbonate Facies).

The inferred areal extensions of the three sedimentary facies as illustrated in Figure 3 were attained by examining cuttings and descriptions of cuttings from wells throughout the study area. Although Figure 3 depicts the approximate updip and downdip limits of the Coarse Clastic and Transition Facies within the study area, the actual regional distribution of these facies is undoubtably more complex than illustrated here.

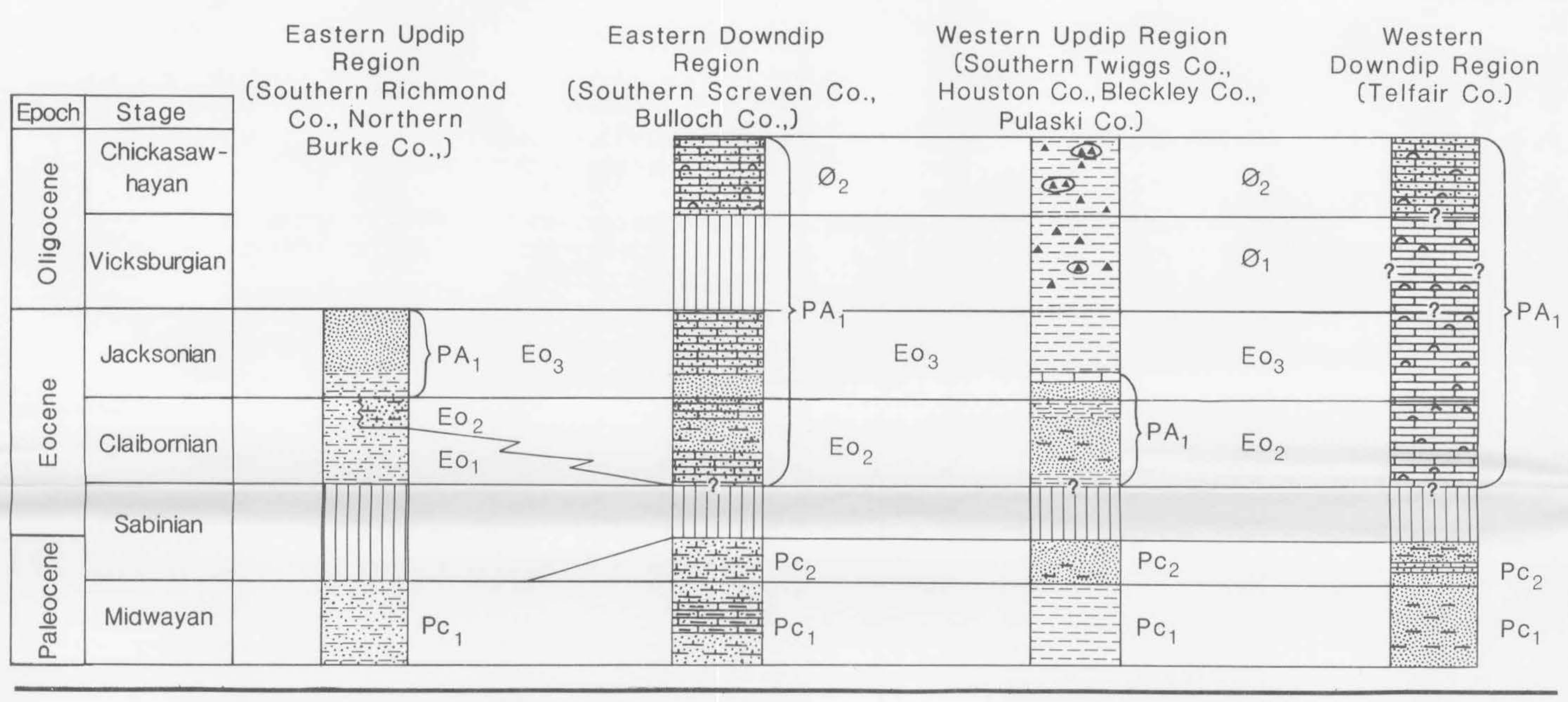


FIGURE 2. Generalized lithologic correlation chart of the major Tertiary formations in the study area.

EXPLANATION

▦	Argillaceous Limestone	▦	Chert Boulders
▦	Fossiliferous Limestone	▤	Clay
▦	Limestone	▒	Sand
▥	Unconformity	▒	Calcareous Sand

PA_1: Units designated by this notation form a continuous Tertiary aquifer system of which the Jacksonian aquifer is a part. In the eastern updip region, this aquifer system consists entirely of Jacksonian sediments.

$Ø_2$: Sediments of Oligocene age that occur in the study area are mostly restricted to the Chickasawhayan stage. The updip limit of the Oligocene sediments extends roughly from the Burke/Screven County line to northern Bleckley County (Huddlestun, personal commun., 1982). In these updip areas, the upper Oligocene sediments appear to be a weathered sequence (residuum) consisting of alternating clays, cherty clays, sands, and clayey sands. In the downdip region $Ø_2$ is a light-gray, fossiliferous limestone that is lithologically similar to the underlying Jacksonian strata. This carbonate unit is referred to as the Suwannee Limestone (Cooke and Mansfield, 1936).

$Ø_1$: Vicksburgian age residuum within the study area is very similar to that of late Oligocene age and is apparently restricted to the western updip region.

Eo_3: The upper Eocene unit in the eastern updip region consists of a sequence of sands and clays that, based on observations in the outcrop areas, can be subdivided into three subunits. The lowermost subunit is a silty to sandy, light-green to dark-gray clay that is locally fossiliferous and lignitic. This subunit is referred to as the Twiggs Clay Member (Shearer, 1917) of the Barnwell Formation. Recent work by Huddlestun and Hetrick (1979) refers to this subunit as the Twiggs Clay Member of the Dry Branch Formation of the Barnwell Group.

The second subunit is an alternating sequence composed of thinly interlayered fine to medium quartz sands and yellow to orange clayey sands. This subunit is referred to as the Irwinton Sand Member (LaMoreaux, 1946) of the Barnwell Formation (Dry Branch Formation of Huddlestun and Hetrick, 1979).

The third (uppermost) subunit is a clayey sand composed predominantly of fine to coarse quartz sand. Mica, heavy minerals, and fragments of white kaolin occur. Most of the constituents in this subunit have been stained a dark red-orange due to oxidation of the iron-bearing minerals. This subunit has been named the Tobacco Road Sand by Huddlestun and Hetrick (1978).

In the central and west-central parts of the study area, all of the fine to coarse clastic constituents of late Eocene age grade into the Twiggs Clay Member. This lithology represents part of a transitional facies between the updip coarse clastic and downdip carbonate units. In the southernmost part of the study area, the upper Eocene strata consist of the Ocala Limestone of Cooke (1918), a light grey to cream, locally dolomitic, fossiliferous limestone.

Eo_2: The upper unit of middle Eocene age in the eastern updip region is a bluish-gray to green-gray, silty to sandy clay or marl that is locally phosphatic. This unit contains minor amounts of glauconite and thin limestone interlayers. Exposures occur along the Savannah River at Blue Bluff in Burke County and represent the type locality of the Blue Bluff Member (formerly McBean Formation) of the Lisbon Formation (Huddlestun, 1981).

Eo_1: In the eastern updip region of the study area, this unit consists essentially of clays and fine to coarse quartz sand in a white kaolinitic matrix and has been named the Huber Formation by Buie (1978).

In the downdip regions, the kaolinitic clay content of the Huber Formation is replaced by montmorillonite and calcareous material. Within the study area, the middle Eocene (Claibornian) equivalent of the Huber Formation ultimately becomes a light-gray, soft, chalky, fossiliferous limestone.

In the eastern updip region, the Huber Formation may include kaolinitic sands of Midwayan age. These Midwayan sediments apparently grade downdip into the Porters Creek Clay/Clayton Formation (Pc_1).

Pc_2: In the eastern downdip region, the upper Paleocene unit consists of calcareous sand composed predominantly of fine to medium quartz sand in an off-white carbonate clay matrix. This sand is highly glauconitic and contains minor interlayers of calcarenite.

In the western updip region, this unit is generally a well-sorted, fine to medium, friable, quartz sand containing minor lignite and kaolin. Downdip, this sand is medium to coarse, phosphatic, and interlayered with dark-gray to black clay and gray, glauconitic, sparry, fossiliferous limestone. The stratigraphic position of this unit indicates that it is age equivalent to the Tuscahoma and Nanafalia Formations (Smith and others, 1894) of western Georgia, and probably to the Black Mingo Formation (Sloan, 1908) of South Carolina.

Pc_1: In the east-central part of the study area, this unit is a friable, clayey sand composed of fine to medium quartz sand in a calcareous clay matrix. Clay content increases downdip and the unit becomes a very clayey marl.

A stratigraphic equivalent to this unit occurs in the interval from 388 to 421 ft below land surface in the Arrowhead #1 test core in northern Pulaski County as a gray to grayish-green, hackly, waxy, slickensided clay containing minor pyrite. This unit is referred to as the Porters Creek Clay, originally named by Safford (1864).

Little is known of this unit in the western downdip region of the study area due to few samples and a lack of reliable data. It generally occurs as a fine to coarse, clayey, glauconitic sand. This lower Paleocene unit is equivalent in age and stratigraphic position to the Clayton Formation, originally named for exposures near Clayton, Alabama (Langdon, 1891), and first mapped in Georgia by MacNeil (1947).

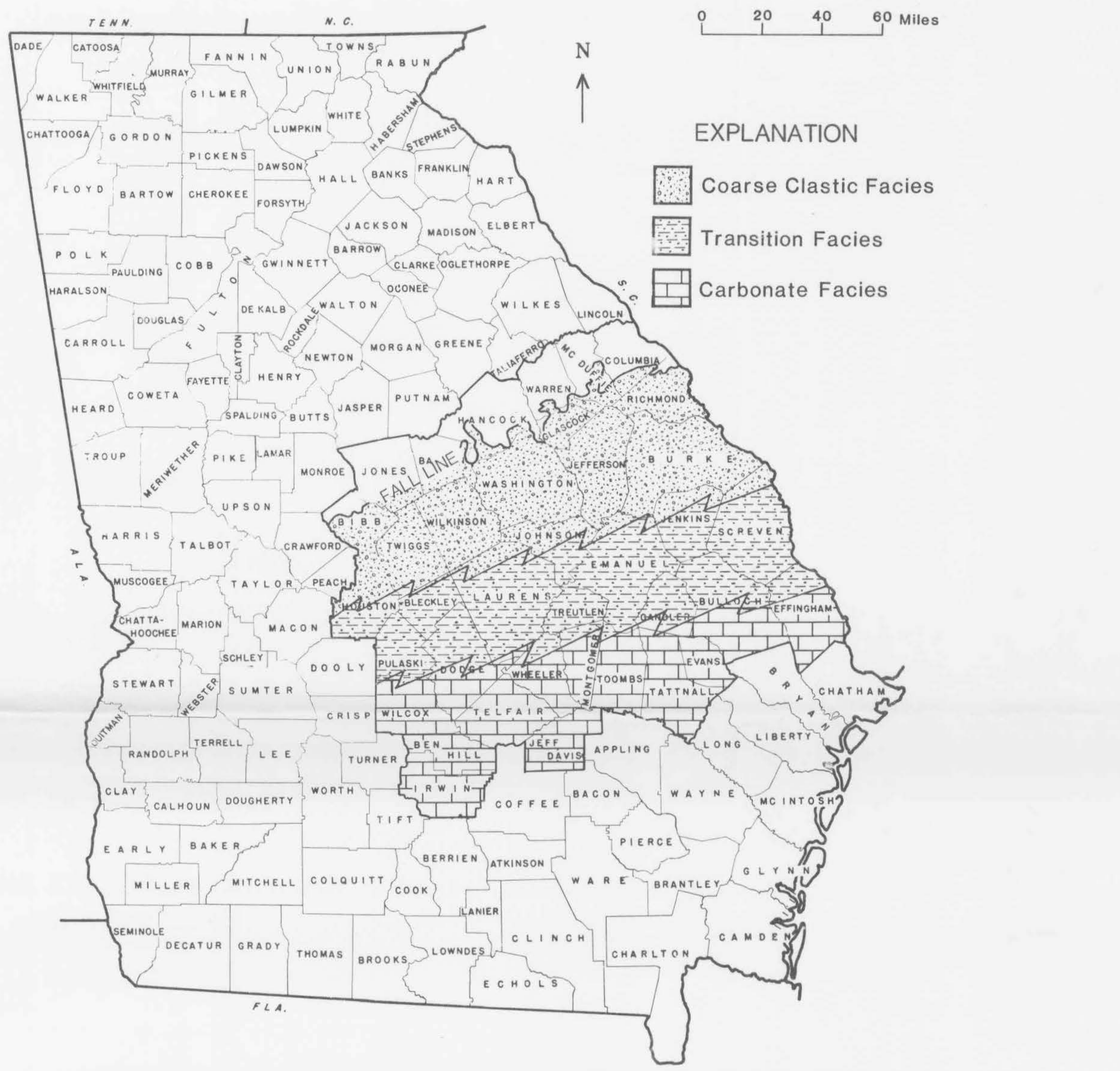


FIGURE 3. Generalized facies map of the Jacksonian sediments.

AQUIFER FRAMEWORK

As stated in the introduction, the Carbonate Facies of the Jacksonian strata is hydraulically interconnected to overlying and underlying carbonate units of late Oligocene and middle Eocene age, respectively. It should be kept in mind that what is referred to in this atlas as the Jacksonian aquifer is water-bearing sediments of late Eocene (Jacksonian) age that occur within the study area. The downdip Carbonate Facies of the Jacksonian strata therefore represents only a part of what is referred to as the Principal Artesian Aquifer.

In the eastern and central updip areas, the Jacksonian aquifer is hydraulically separated from underlying water-bearing units by regionally extensive, impermeable units that include the Lisbon Formation and upper clay beds of the Huber Formation, both of Claibornian (middle Eocene) age. This area of regional hydraulic separation apparently involves Wilkinson, Washington, Glascock, Jefferson, Richmond, and northern Burke counties. In the western updip areas, including Twiggs, Bleckley, and Houston Counties, the upper cllay beds of the Huber Formation are not as continuous as to the east (Hetrick, personal commun., 1982) and consequently, do not regionally separate the Jacksonian aquifer from underlying water-bearing sediments. Consequently, in these western updip areas, the coarser clastic constituents of the Huber formation are more in apparent hydrologic continuity with the overlying Jacksonian sediments. The Claibornian sediments display a facies relationship similar to that of the Jacksonian sediments in the sense that clastics grade progressively to the south and southeast into carbonates. Therefore, throughout the downdip region of the study area, the Claibornian sediments are a water-bearing carbonate sequence that is hydraulically connected to the overlying Carbonate Facies (Fig. 3) of the Jacksonian sediments.

The Twiggs Clay Member of the Dry Branch Formation, a basal clay unit of Jacksonian age, is a locally occurring, generally impermeable unit in the updip region, resulting in perched water tables in some areas. The Twiggs Clay Member, or a lithofacies equivalent, acts only as a local underlying "confining" unit in the updip region because it occurs as discontinuous lenses and layers as a result of deposition in small, intertidal lagoons (D.C. Prowell, personal commun., 1981) and tidal channels (P.F. Huddlestun, personal commun., 1982).

Local overlying confinement of the Jacksonian aquifer occurs in widely scattered areas throughout the downdip region by discontinuous units of clay and (or) marl that occur in a regionally continuous carbonate unit of late Oligocene age. This Oligocene carbonate unit is referred to as the Suwannee Limestone (Cooke and Mansfield, 1936). In areas where the discontinuous clay units are not present, the Suwannee Limestone is hydraulically equivalent to the Jacksonian aquifer. Consequently, with the exception of the eastern and central updip areas, no regionally extensive lithologies occur that hydraulically separate the Jacksonian aquifer from overlying or underlying water-bearing units.

Throughout the central and west-central part of the study area, the argillaceous Transition Facies occurs between the updip Coarse Clastic Facies and downdip Carbonate Facies (Fig. 3). Here, the Jacksonian sediments consist predominantly of the Twiggs Clay Member which does not store and transmit water as efficiently as its updip and downdip equivalents. The relative scarcity of wells that utilize the Transition Facies in this area attest to its poor aquifer characteristics. Most of the wells terminating in Jacksonian sediments apparently obtain the bulk of water from sand layers near the base of the argillaceous sequence. These sand layers probably are equivalent to the Clinchfield Sand of Pickering (1970), a thin (generally less than 20 ft.) basal sand unit of probable Jacksonian age.

Herrick (1972) was unsure of the regional extent of the Clinchfield Sand in the eastern part of the study area, and suggested it may only occur locally. The Clinchfield Sand pinches out downdip, but its exact downdip limit within the study area remains speculative. Throughout the study area, the Clinchfield Sand remains distinctively separate from other units of Jacksonian age (Huddlestun, personal commun., 1982). The Clinchfield Sand varies in thickness from approximately 16 to 35 ft. (Herrick, 1961, 1972). Consequently, its use as an aquifer is restricted primarily to a few domestic wells within the central and west-central parts of the study area that utilize Jacksonian sediments.

In the eastern part of the Transition Facies, including southern Screven and northern Bullock Counties, a major lithologic change occurs. In these areas, the Transition Facies consists of coarse clastic sediments that grade directly into carbonates containing little to no clay material (Huddlestun, personal commun., 1982). This suggests that the clay source of the Twiggs Clay Member was to the west and would account for extensive use of the eastern part of the Transition Facies as a source of ground water.

The general water availability in the Transition Facies is suggested by well construction data that indicate that the greater majority of wells that terminate in this facies are cased through the Oligocene. Consequently, the cased-off intervals preclude any possibility that significant amounts of water can be obtained from overlying sediments such as the Suwannee Limestone.

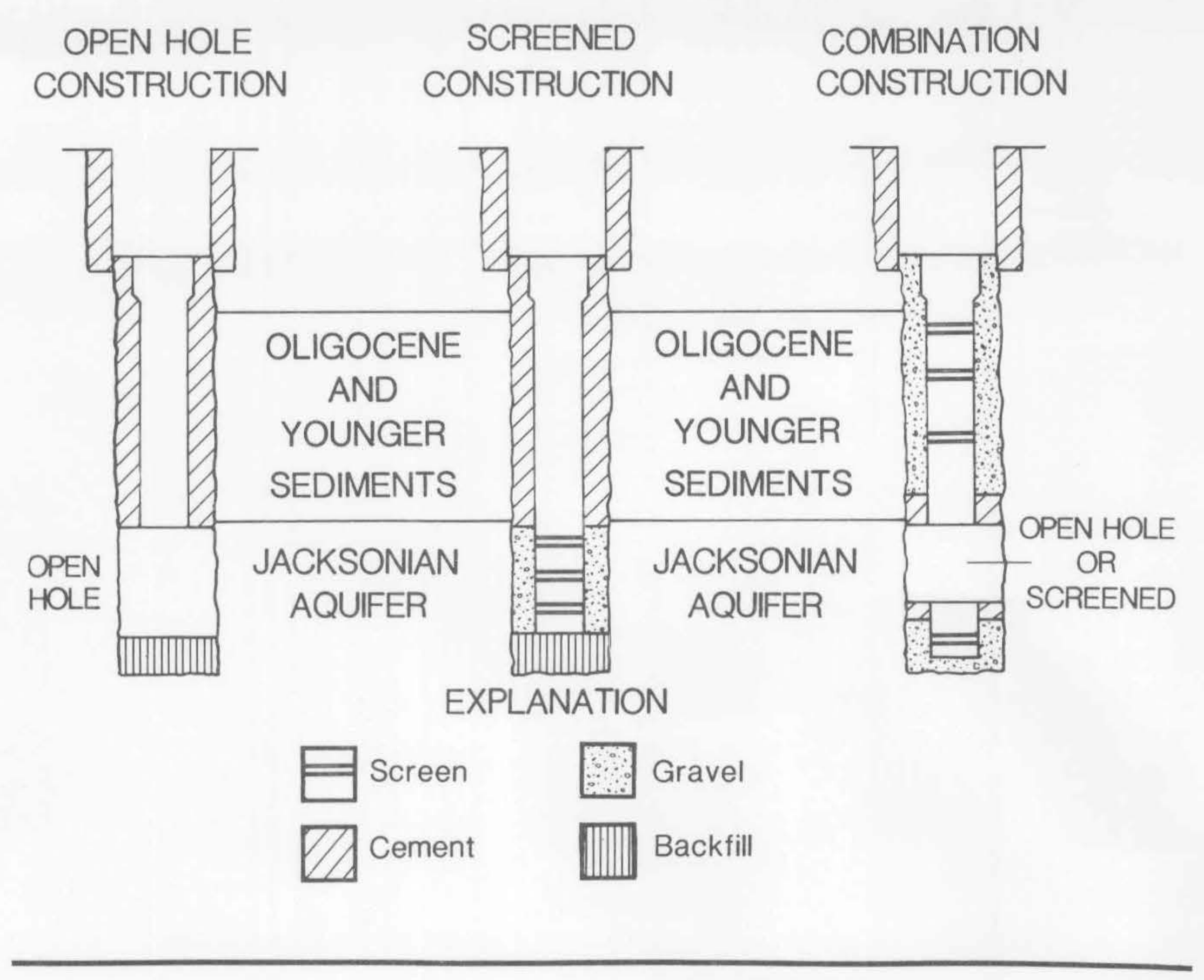


FIGURE 4. Typical well constructions.

EXPLANATION

—100— INTERPRETED POTENTIOMETRIC CONTOUR: Shows the altitude at which the water level would rise in a tightly cased well. Contour interval 50 feet.

● Data point (wells)

0 10 20 Miles

N

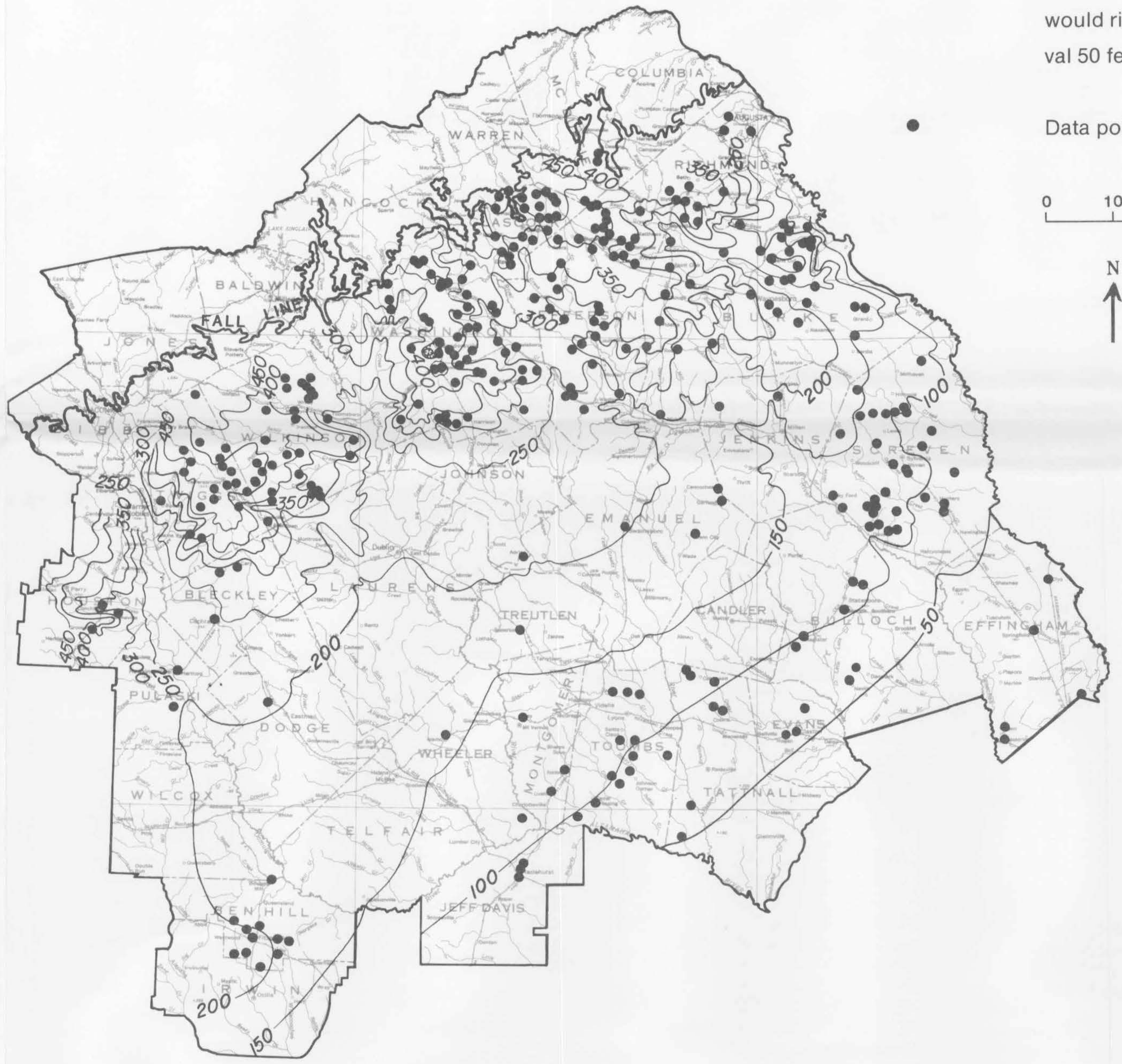


FIGURE 5. Historical potentiometric surface of the Jacksonian aquifer.

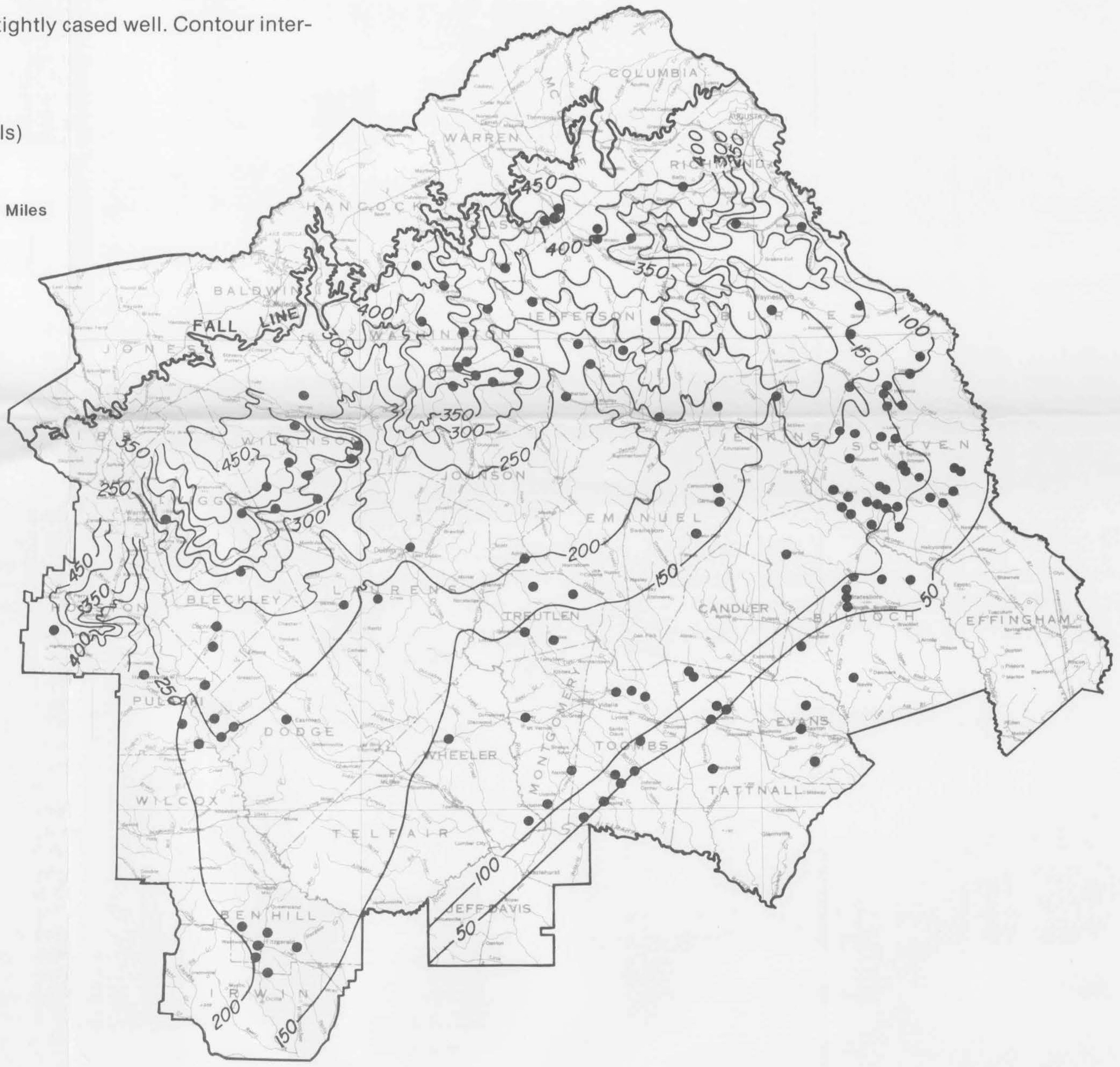


FIGURE 6. Current (1981) potentiometric surface of the Jacksonian aquifer.

WELL CONSTRUCTION

The majority of wells tapping the Jacksonian aquifer typically use open-hole construction (Fig. 4). With this type of construction, sediments younger than Jacksonian are "sealed off" by means of pipe casing lowered into the well to the depth of the Jacksonian sediments. This pipe is in turn encased in cement. As a result, water only comes from that part of the well below the casing that is open to the aquifer.

Screened construction (Fig. 4) typically is used where the water-bearing zones contain a high percentage of coarse sand. To prevent caving of these zones, screened intervals in the casing are constructed opposite to any sand layers.

In some areas, the Jacksonian sediments provide insufficient quantities of water and are used in combination with overlying and underlying units. In these instances, a combination well construction method is used (Fig. 4), which utilizes both open-hole and screened construction.

HYDROLOGY

Historical Potentiometric Surface

The historical potentiometric map (Fig. 5.) represents the potentiometric surface of the Jacksonian aquifer prior to 1969. Data for this map were derived from published and unpublished records of water-level data collected from 1939 to 1968. Water-level data for the updip counties were taken directly from LaMoreaux (1946) and LeGrand (1956). The mid to late 1960's marked the beginnings of agricultural pumpage of the Jacksonian aquifer. Consequently, any measurement made prior to this time is probably an indication of "predevelopment" conditions. An exception to this is in the vicinity of Sandersville (Washington County), where water-level data from the late 1940's suggest the existence of a cone of depression on the historical potentiometric surface.This cone was probably due to utilization of the aquifer by the Sandersville municipal wells in an area of low transmissivity.

The altitude of the potentiometric surface is illustrated by contour lines which are intended to depict the "average" hydraulic head for water within the Jacksonian sediments. The overall configuration of the potentiometric surface is largely controlled by discharge from the aquifer to streams, particularly in the updip areas where the Jacksonian sediments are thin (generally less than 200 ft) and either exposed or near land surface. This discharge is illustrated by contour lines deflecting upgradient where they cross a major stream.

Current Potentiometric Surface

The current potentiometric map (Fig. 6) was constructed from water-level data gathered from late October to mid-November 1981. In the updip region, the current potentiometric surface is predominantly unchanged (generally less than 10 ft in most areas) from the historical surface in spite of increased withdrawals for domestic and agricultural use. This is due largely to the Jacksonian sediments being thin, exposed, and hydraulically connected to streams. Also, when considering the fact that few municipalities or industries utilize the Jacksonian aquifer in the updip region, the aquifer apparently receives sufficient recharge from precipitation to maintain a more or less constant water level. Since access could not be attained to the Sandersville municipal wells that utilized the Jacksonian aquifer in the 1940's, no current potentiometric data exist that would indicate if the cone of depression illustrated on the historical potentiometric map still exists. The Jacksonian aquifer is no longer utilized for municipal purposes in the Sandersville area. Considering that the Jacksonian aquifer is hydraulically separated in this area from underlying water-bearing units that have since been developed for municipal purposes, the cone of depression illustrated on the historical potentiometric map is interpreted as being absent on the current potentiometric surface. The possibility exists that leakage occurs through the less permeable units separating the Jacksonian from underlying aquifers currently being utilized. If so, then a cone of depression may be present on the potentiometric surface of the Jacksonian aquifer in the vicinity of Sandersville. However, no data presently exist that would support such a conclusion.

In the downdip region, current data suggest that the potentiometric surface has declined regionally an average of about 25 ft since the late 1960's. This decline is illustrated on the current potentiometric map where contour lines have, in effect, "shifted" north relative to their positions on the historical map. Declines in this area are regional in the sense that no localized cones of depression have formed, leaving the potentiometric gradient relatively flat. The flat gradient, in spite of substantial declines, can be explained by the fact that the downdip region is an area of high transmissivity, and municipal and agricultural pumpage is limited and widely scattered throughout the region. High transmissivity in the downdip region would normally reduce the possibility of regional water-level declines. However, two consecutive years of below normal rainfall (1980 and 1981) combined with scattered agricultural and municipal pumpage are attributed to the occurrence of regional declines.

HYDROLOGY – continued on Plate 3.

HYDROLOGY

— continued from Plate 2

Seasonal and Long-Term Water-Level Changes

Long-term water-level fluctuations in wells from Laurens, Screven, and Montgomery Counties that tap the Jacksonian aquifer are illustrated graphically in Figures 7, 8, and 9, respectively. Long-term water-level changes in each particular well are plotted alongside cumulative precipitation departure curves from a rainfall gauge in the same vicinity as the well. Figures 8 and 9 illustrate that, prior to the mid-1960's, the altitude of the potentiometric surface of the Jacksonian aquifer was strongly controlled by seasonal precipitation. Although each water-level curve in these diagrams shows large-scale fluctuations, due largely to this seasonal variation in precipitation, the overall water-level trend is declining in elevation. The water level in well 21T001 in Laurens County (Fig. 7), for example, has declined approximately 9 ft from 1966 to 1981. This well, however, shows a great amount of seasonal fluctuation (approximately 11 ft) from 1972-1973 and is probably not a reliable indicator of long-term declines. The water column in well 32U016, a flowing well in Screven County (Fig. 8), has declined approximately 7 ft from 1949 to 1976. This downward trend is very apparent in well 25R001 in Montgomery County (Fig. 9), in which the water-level has declined approximately 13 ft from 1953 to 1976. Figures 8 and 9 indicate that the water-levels in wells 32U016 and 25R001 became less controlled by precipitation beginning around 1964. Although this phenomenon is roughly time equivalent to the beginning of agricultural/irrigation usage, further study is needed before a definite inference can be drawn.

WATER QUALITY

Water chemistry data of Sprinkle (1982a, b, c, and d) indicate the concentrations of chloride, sulfate, and dissolved solids within the Jacksonian aquifer system range from near zero in the outcrop/recharge areas of the Coarse Clastic Facies to a maximum of 250 Mg/l in the Carbonate Facies. Therefore, water from the aquifer system in any part of the study area is well within the Georgia Department of Natural Resources minimum standards for safe drinking.

WATER USE

The Jacksonian aquifer supplied an estimated 32.5 Mgal/d to municipalities, industries, and agriculture in the study area during 1980 (Table 1). Major users of the aquifer include the municipalities of Statesboro, Swainsboro, Vidalia, and Lyons with major agricultural users in Dodge, Laurens, and Bulloch Counties. Due to incomplete records, actual withdrawals by industry are probably higher than the estimated use listed in Table 1.

In recent years, the amount of ground water withdrawn for irrigation in east-central Georgia has increased substantially. During 1980, an estimated 20.3 Mgal/d were withdrawn from the Jacksonian aquifer for agricultural use. Values were estimated based on a 34 day/year irrigation period. Records indicate the total percentage of irrigated land in Bulloch, Burke, Candler, and Dodge Counties increased from less than 1 percent in 1973 to 4 to 10 percent in 1980 (Fig. 10). The percentage of irrigated land in Bleckley and Pulaski Counties increased from less than 1 percent in 1973 to greater than 10 percent in 1980.

Domestic use of the Jacksonian aquifer within the updip region is considered to exceed municipal, industrial, and agricultural use. For example, the total of three users in Washington County as indicated in Table 1 is .36 Mgal/d. However, Pierce and others (1982b) indicate that rural domestic use in Washington County for 1980 was 1.1 Mgal/d. When considering that the majority of all shallow wells in Washington County probably are completed in Jacksonian sediments, it is reasonable to assume that the bulk of this 1.1. Mgal/d comes from the Jacksonian aquifer. If similar relationships apply to other counties in the updip region, it is likely that domestic production from the Jacksonian aquifer in this part of the study area is the major water use.

As irrigational development has increased in recent years, the total amount of ground water withdrawn in the downdip region for agricultural purposes (including the Jacksonian and other aquifers) has greatly surpassed the total amount withdrawn for domestic purposes. Since the study area is relatively rural, with few large towns or industries, the amount of water withdrawn from the Jacksonian aquifer for agricultural purposes should eventually surpass the amount withdrawn for all other users (domestic, municipal, and industrial) of the Jacksonian aquifer combined.

TABLE 1. — Estimated ground-water use from the Jacksonian aquifer, 1980.

	Million gallons per day			
County	**Municipal**	**Industrial**	**Agricultural**	**Total***
Bleckley	.45	—	.92	1.37
Bulloch	2.61	.34	2.44	5.39
Burke	.02	—	.37	.39
Candler	.59	—	.52	1.11
Dodge	.97	—	4.34	5.31
Emanuel	1.45	—	1.24	2.69
Evans	.30	—	.26	.56
Glascock	.02	—	—	.02
Houston	—	—	.20	.20
Jefferson	.13	—	.29	.42
Jenkins	.12	.03	.99	1.14
Johnson	.14	—	.56	.70
Laurens	—	.01	2.53	2.54
Montgomery	.23	—	.20	.43
Pulaski	.43	—	1.84	2.27
Richmond	.03	—	—	.03
Screven	.64	—	1.54	2.18
Tattnall	1.16	—	.35	1.51
Toombs	1.73	—	.94	2.67
Treutlen	.23	—	.13	.36
Washington	.13	.02	.21	.36
Wheeler	.41	—	.41	.82
Total	11.79	.40	20.28	32.47

*excludes domestic use.

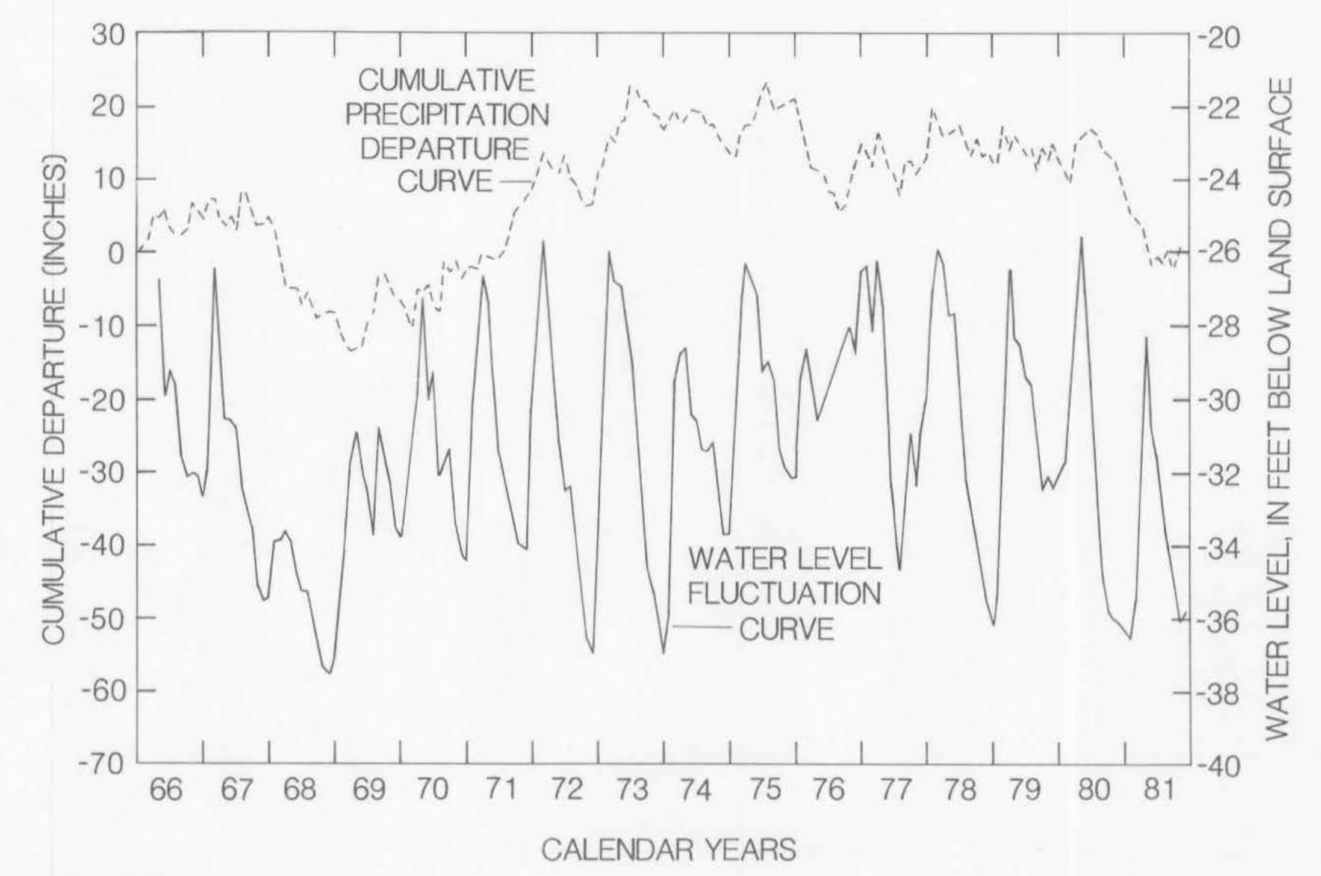


FIGURE 7. **Water-level fluctuation and cumulative precipitation departure curves for observation well 21T001, Dublin city well no. 3, Laurens County.**

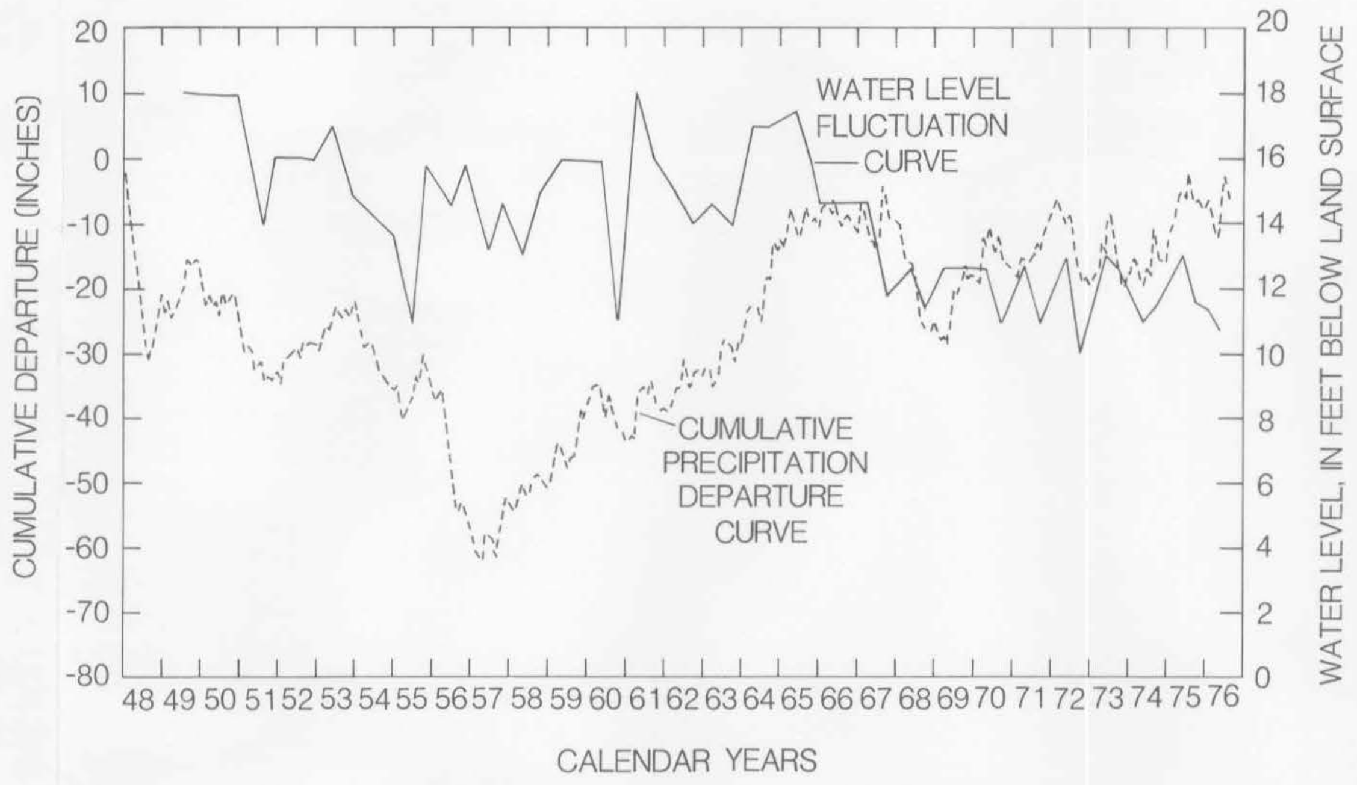


FIGURE 8. **Water-level fluctuation and cumulative precipitation departure curves for observation well 32U016 near Dover, Screven County.**

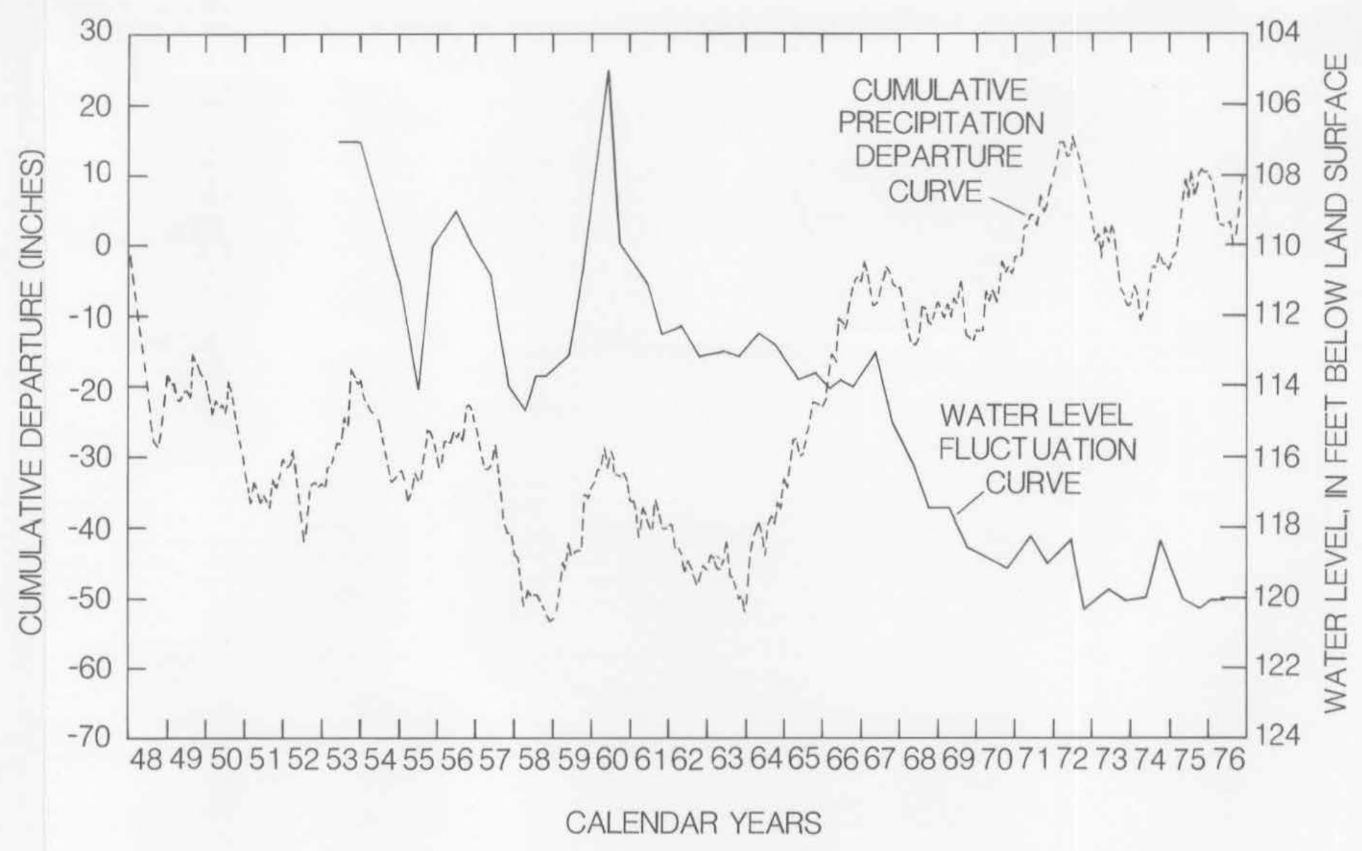
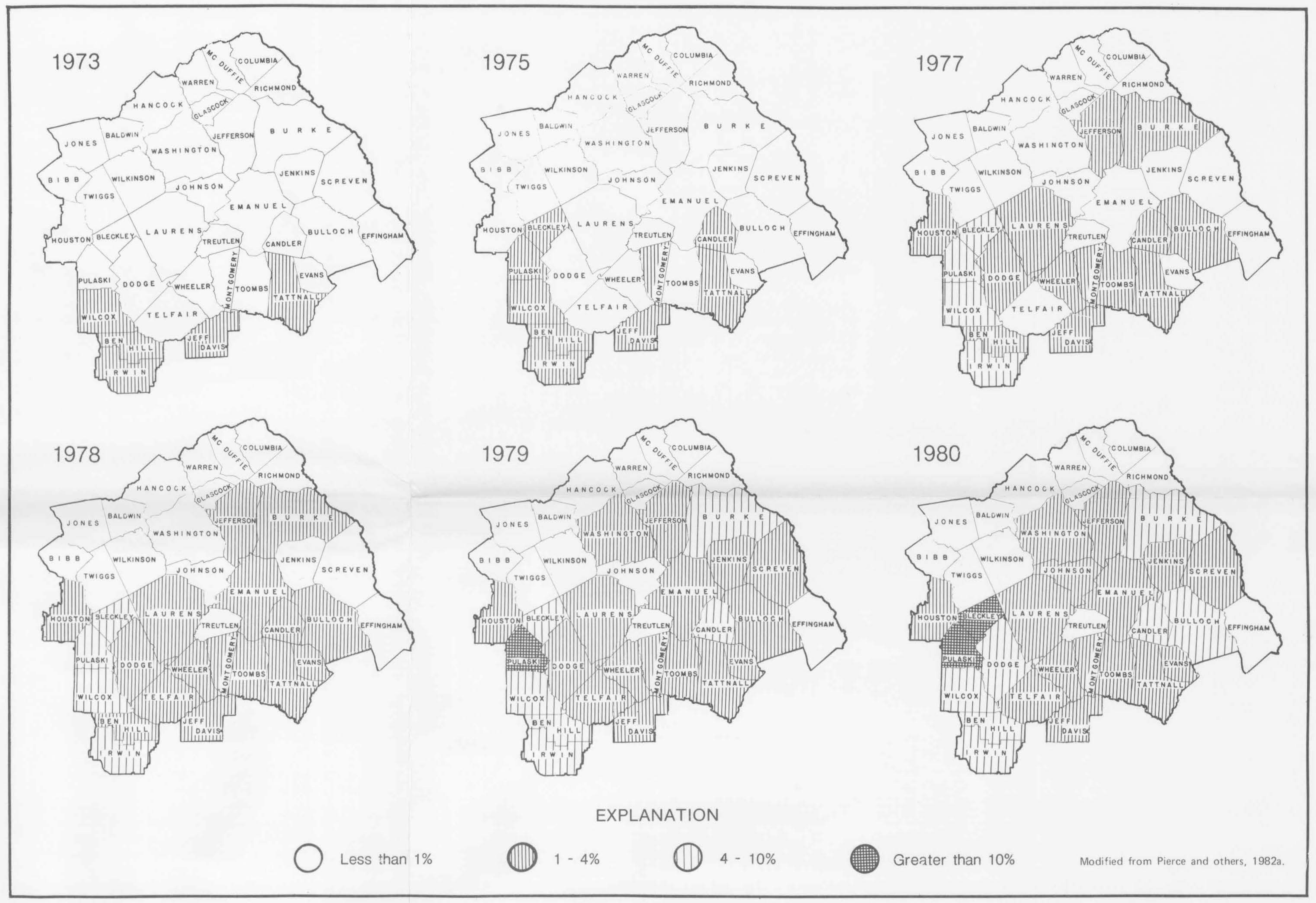


FIGURE 9. **Water-level fluctuation and cumulative precipitation departure curves for observation well 25R001 near Ailey, Montgomery County.**



Modified from Pierce and others, 1982a.

FIGURE 10. Percentage of irrigated land in the study area.

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