HYDROGEOLOGIC DATA FROM SELECTED SITES IN THE PIEDMONT AND BLUE RIDGE PROVINCES, GEORGIA

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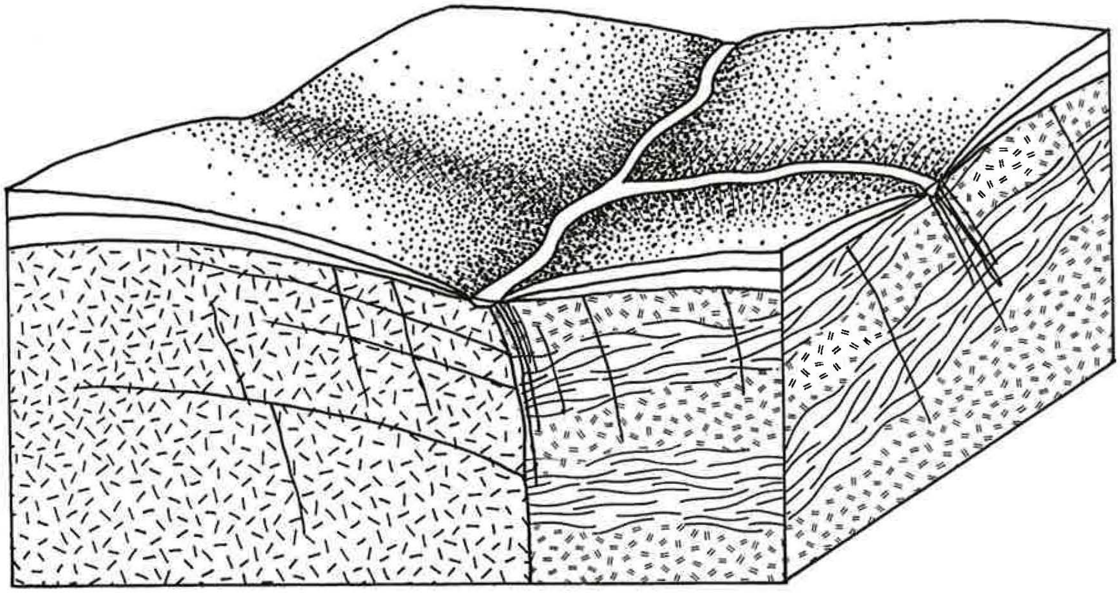

DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION
GEORGIA GEOLOGIC SURVEY

INFORMATION CIRCULAR 86

Cover: Line art showing some of the complexities that one can encounter in crystalline rock aquifers.

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David A. Brackett, William M. Steele, Thomas J. Schmitt, Robert L. Atkins, Madeleine F. Kellam, & Jerry A. Lineback

INTRODUCTION

PURPOSE AND SCOPE OF STUDY

The purpose of this study is to provide data (with some interpretations) on the principal hydrogeologic controls on the occurrence and movement of ground water at ten hydrologic test sites in the Piedmont and Blue Ridge Physiographic Provinces of Georgia (Fig. 1). These sites are the Ashland Subdivision (Oconee County), the Shoal Creek Subdivision (Coweta County), a private well at Lost Mountain (Cobb County), and the cities of Colbert, Locust Grove, Lexington, Newnan, and Watkinsville, all located in the Piedmont Province. Two sites are located in the Blue Ridge Province, the city of Dawsonville and Unicoi State Park. The knowledge gained from the test sites may assist in more effective development of the ground-water resources elsewhere in these provinces. Studies at the ten sites indicate that the key to obtaining additional ground water in the Piedmont and Blue Ridge is the proper siting of new wells with respect to those geological and hydrological criteria that most strongly influence ground-water availability.

This report presents geologic, geophysical, and hydrologic test data gathered from the ten test sites. All sites were investigated because one or more of the wells at these sites had a potential yield in excess of 50 gpm. Wells at four of these sites were drilled at locations selected by the Georgia Geologic Survey as potentially having high-yield possibilities. The Survey sited these wells in response to requests from cities or municipal water systems seeking to develop additional ground water. Wells drilled at random locations in the Piedmont and Blue Ridge have an average yield of less than 20 gpm, a yield sufficient for domestic use but not for reliable public water supplies.

The types of information collected at the ten test sites include:

1. Geologic mapping within a one-mile radius of the well and field measurements of geologic structures such as foliation, joints, faults, linear stream segments, discontinuities, and compositional layering.
2. Descriptions of the major lithologies in the map area.
3. Surface geophysical studies at three sites.
4. Borehole geophysical logging at six sites.
5. Test pumping of at least one well per site.
6. Water quality data.

In addition to presenting this information, this report includes some general observations on siting wells in the Piedmont and Blue Ridge and suggests avenues for further research.

JUSTIFICATION FOR STUDY

Rapid growth of both population and industry in north Georgia in recent years has increased the demand for potable water in this region. Regional water needs currently are being met primarily through the use of surface-water resources. The effects of severe rainfall shortages in 1980, 1981, 1986, and 1988 suggest that existing surface-water supplies may be unable to meet all of the future water demands of the area during periods of drought.

Ground water can provide a viable alternative or supplement to surface-water supplies in the future. In some cases, but not all, development of ground water is less environmentally disruptive than constructing surface-water reservoirs and may have economic advantages over surface-water systems in many cases. For example, extensive land areas need not be purchased, roads need not be rerouted nor wetlands

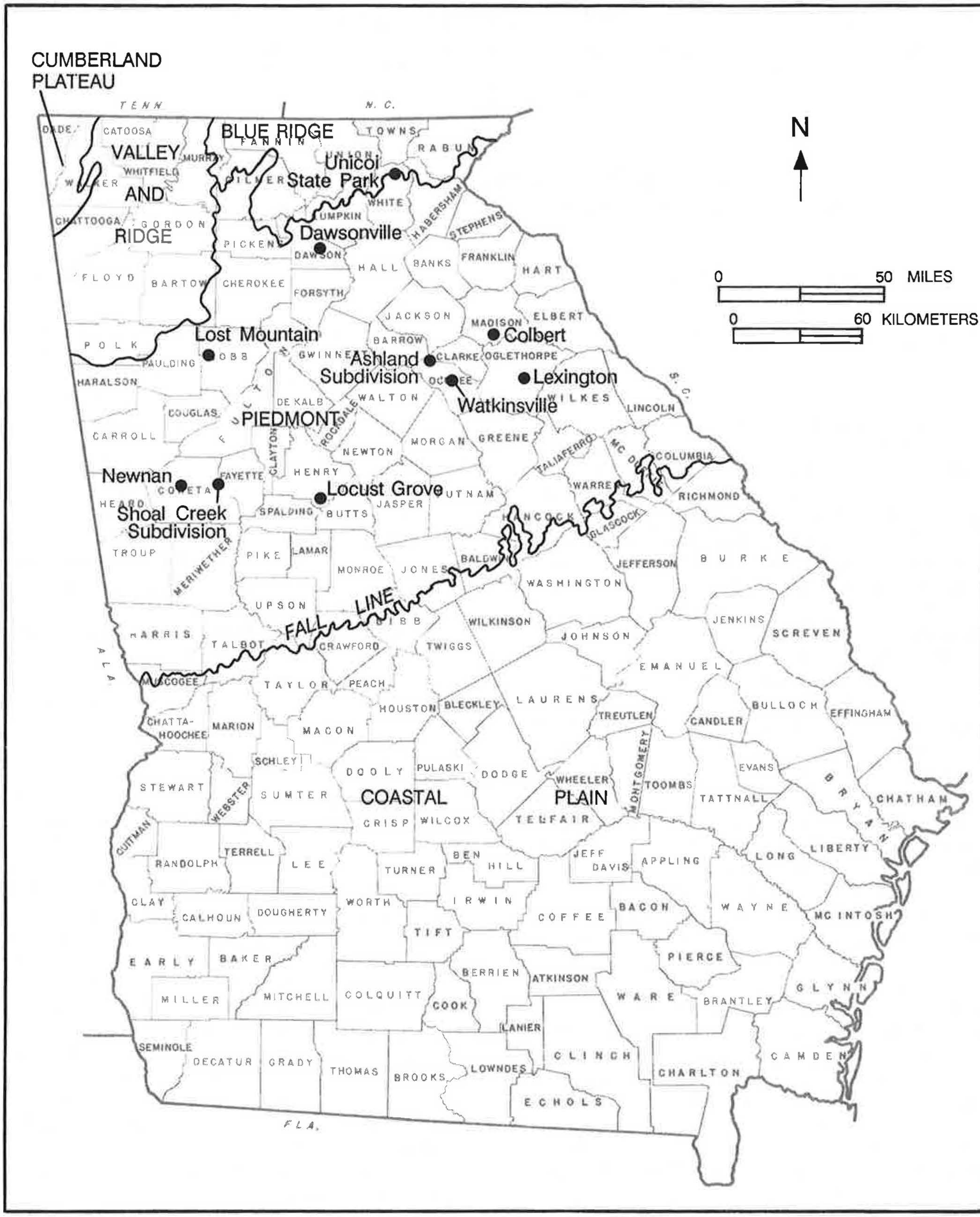

Figure 1. Locations of hydrogeologic test sites.

flooded.

Ground-water resources in the Piedmont and Blue Ridge Provinces currently are under utilized, due primarily to the difficulty of reliably and predictably locating wells having adequate yields. The North Georgia Hydrology Program was established in December, 1986, by the Georgia Geologic Survey to aid in developing the resource potential of ground water in north Georgia. One of the most important goals of this study was to identify what hydrogeologic criteria are most significant and necessary to reliably locate sites for high yield wells in the two provinces.

DESCRIPTION OF STUDY AREA

The Piedmont Province is a broad upland developed on complexly deformed Late Precambrian and Paleozoic metamorphic and igneous rocks. The topography of the province is rolling to rugged with elevations ranging from approximately 2000 ft in the Dahlonega area to 500 ft or less along the Fall Line, the southern margin of the province. Crystalline bedrock in the province has little intergranular porosity. Ground water in the bedrock is in open spaces formed through jointing or fracturing, along discontinuities formed by compositional layering or faulting, and in zones of weathering extending from the surface to more than 100 ft into the bedrock in places. The bedrock is overlain by a variable thickness (averaging 50 ft) of residual weathered rock called saprolite.

The Blue Ridge Province is a highland of conical peaks and broad summits. The highest elevation in the Blue Ridge in Georgia is Brasstown Bald (elevation, 4,784 ft). Intermountain plateaus average 1,600 to 1,700 ft in elevation. The topography is controlled largely by lithology. Valleys are developed on easily weathered lithologies, or on highly fractured rocks, and peaks are produced by more resistant rocks. Saprolite thickness is generally less than in the Piedmont because of the steeper slopes.

The climate of the Piedmont and Blue Ridge provinces is warm and moist. Average rainfall is 53 in. per year and is much higher in some mountainous areas. Significant rainfall deficits in the spring and summer months were recorded in 1980, 1981, 1986, and 1988.

The population of the Piedmont and Blue Ridge Provinces of Georgia was approximately 3,420,400 in 1985 (Bachtel, 1987). The largest population center is the Atlanta metropolitan area. Projections of population for the study area in the 1990's show that continued growth is expected.

METHODS OF INVESTIGATION

Geologic Mapping

A geologic map was constructed at each site, extending at least one mile from each well studied. Field maps, constructed at the scale of 1:24,000, showed major rock types and the orientation of joint sets, compositional layering, fold axes, and mineral lineations. Geologic descriptions included the nature of the saprolite and the length, spacing, aperture opening and mineralization of joints and other discontinuities. Analysis of structural trends included plotting data, such as the orientations of joints, compositional layering, and mineral lineations on equal area stereonets. The orientations of linear stream segments in the vicinity of each test site were measured on 7.5 minute topographic quadrangle maps. Summaries and interpretations of the geologic and structural data appear in each site report.

Surface Geophysical Methods

Surface geophysical investigations carried out at three sites included magnetic surveys and electrical resistivity soundings. Magnetic surveys at the Colbert, Shoal Creek Subdivision, and Unicoi State Park sites attempted to locate geologic contacts suspected from geologic mapping. Tape and compass methods were used to establish the survey lines and a station spacing of 16.5 ft (5 m) minimized background noise. An EG&G Geometrics GSD-856 proton precession magnetometer recorded magnetic measurements in its internal memory. Base station readings taken at regular time intervals during the survey corrected for the diurnal fluctuations in the earth's magnetic field.

The electrical resistivity survey conducted at Unicoi State Park utilized a Bison Signal Enhancement Earth Resistivity System, Model 2390, and the Bison Offset Sounding System (BOSS). Soundings were oriented parallel and perpendicular to structurally controlled valley segments.

Borehole Geophysical Logging

A suite of geophysical logs were run on test wells where possible. The logging was done by the Water Resources Division, U. S. Geological Survey (USGS), Doraville, Georgia, as part of Georgia Geologic Survey's cooperative agreement. Logs obtained included: Sonic televiewer, caliper, temperature, spontaneous potential, acoustic velocity, single-point resistance, and natural gamma.

Borehole logs show the depth of discontinuities which may yield water to the well. The logs were compared to the drillers log on which the driller noted water-bearing zones. Many water-bearing zones appeared as discontinuities on one or more of the borehole logs. Discontinuities observed by borehole logging have various origins. Many of these discontinuities are joints or fractures in the crystalline rocks which represent openings along which ground water can easily move. Other discontinuities have been interpreted as weathered zones that extend some distance into the bedrock along joints, fractures, or compositional layering. Compositional layering in the metamorphic and igneous rocks of the Piedmont and Blue Ridge may provide permeable pathways for ground-water flow. Differential weathering along susceptible compositional layers may result in water-bearing discontinuities. The drilling process itself produced apparent discontinuities because the borehole diameter increases in softer lithologies.

Sonic televiewer logs provide a 360° image of the borehole and allow measurement of the structural orientation of discontinuities. Discontinuities interpreted as joints or fractures usually appear as very dark gray to black areas with sharp boundaries on televiewer logs. Weathered zones or discontinuities caused by compositional layering often appear as gray mottled or gray and black mottled areas with uneven and indistinct boundaries on televiewer logs. The orientation of discontinuities in the boreholes as measured on the sonic televiewer logs was compared to the orientation of compositional layering and jointing measured during geologic mapping.

Hydrologic Methods

Hydrologic testing methods varied somewhat from site to site reflecting such factors as the availability of equipment and the incompleteness of knowledge of the yield characteristics of the wells. The hydrologic tests employed included constant-head tests (stress tests), constant-rate pumping tests, and step-tests.

Lack of previous quantitative hydrologic testing of the test wells required stress tests to be conducted in order to accurately define the yield characteristics of the wells. Accurate yield information proved to be a necessary precursor to a successful constant-rate pumping test. Nine of the site investigations included at least one constant-rate pumping test. In this type of test, a well is pumped at a constant rate of discharge for the duration of the test and the drawdown is measured periodically in the pumped well and in any observation wells. The water levels are again measured after pumping while they recover to pre-pumping levels. Most constant-rate pumping tests continued for a 24 hour period plus recovery time. Two 72- hour tests and one 41 - day test were also carried out.

Throttling the pump engines or adjustment of in-line valves regulated flow from the wells during the tests. Measurements of the flow rate were made using either a standard 4 in. by 2.5 in. orifice weir or an orifice bucket. Air lines were installed in some wells to measure water levels, otherwise a conductive probe indicator was used. Stilling wells allowed accurate water level measurements in wells exhibiting cascading water. The rate of drawdown dictated the time interval between water level measurements. Measurements were often taken more frequently than the logarithmic measurement schedule employed for most tests. Nearby wells at some test sites, used as observation wells, allowed additional water level data to be collected.

PREVIOUS INVESTIGATIONS

One of the earliest descriptions of ground water in the Piedmont and Blue Ridge provinces of Georgia was provided by McCallie (1908). The ground-water resources of the Atlanta area were described by Herrick and LeGrand (1949) and Carter and Herrick (1951). Stewart and Herrick (1963) described emergency water supplies for the Atlanta area. Sever (1964) reported on the ground-water resources of Dawson County. McCollum (1966) studied ground water in Rockdale County.

A general overview of ground-water occurrence and availability, along with a method of selecting favorable drilling sites in crystalline rocks of the southeastern United States, was presented by LeGrand (1967). Cressler and others (1979) reported on the geohydrology of Bartow, Cherokee and Forsyth Counties. Ground water in the greater Atlanta region was described by Cressler and others (1983) and included the results of several pumping tests conducted for the study. Watson (1984) studied the hydrology of Greene, Morgan and Putnam Counties. A regional study of the hydrogeology of northern Georgia was conducted by the Georgia Geologic Survey as part of the Survey's application for primacy over the Underground Injection Control Program (Arora, ed., 1984). Radtke and others (1986) investigated the occurrence and availability of ground water in an 11 county region surrounding Athens, Georgia; three pumping tests were conducted for this study. The hydrogeology of Lamar County was studied by Gorday (1989).

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ASHLAND SUBDIVISION, OCONEE COUNTY

INTRODUCTION

A constant-rate pumping test was conducted on a high-yield community-supply well for the Ashland Subdivision, Oconee County, located approximately 12 mi southwest of the city of Athens (Fig. 1). The subdivision water supply well was sited by Oconee Well Drillers at the head of an intermittent northeast trending stream. The driller reported that the well could produce more than 100 gpm. The Georgia Geologic Survey obtained access to the well to conduct a pumping test.

GEOLOGY

Ashland Subdivision lies in the Winder Slope District of the Piedmont Physiographic Province (Clark and Zisa, 1976). Stream valleys in the vicinity of the well are gently concave, and hill tops are gently convex to flat (Fig. 2). Local relief is approximately 240 ft. The largest streams in the Ashland Subdivision area are the Apalachee River and Barber Creek, which have floodplains up to one half mile wide. Large streams, such as the Apalachee River, exhibit dendritic drainage patterns; whereas smaller streams, such as Barber Creek, and intermittent streams have rectangular or trellis-style drainage. Straight stream valley segments in the area are oriented N27°E, N62°E, N23°W, and N59°W. The Ashland Subdivision well is in a northeast-trending valley of an intermittent stream.

Rocks within a mile radius of the test well include a red to light tan saprolite developed from biotite gneiss, a red to purple saprolite developed from a mica or sillimanite mica schist, an ocher to yellow-brown saprolite weathered from a hornblende plagioclase amphibolite, and a black saprolite developed from a garnet-rich quartzite. The mica schist, amphibolite and garnet quartzite are interlayered on a scale of a few feet. Dikes and sills of light-colored, coarse-grained, equigranular biotite granite intruded the abovementioned rocks in the Ashland area. These tabular intrusions range from less than one foot thick to several hundred feet thick. Pods and blebs of granite also occur along compositional layering.

The rocks in the Ashland Subdivision area have been polydeformed, and they exhibit north-south and east-west trending open upright warping folds. The geologic map (Fig. 2) illustrates the complexity of the structures in the study area. Compositional layering strikes to the northeast and northwest and dips generally greater than 45°.

Several steeply inclined joint sets can be

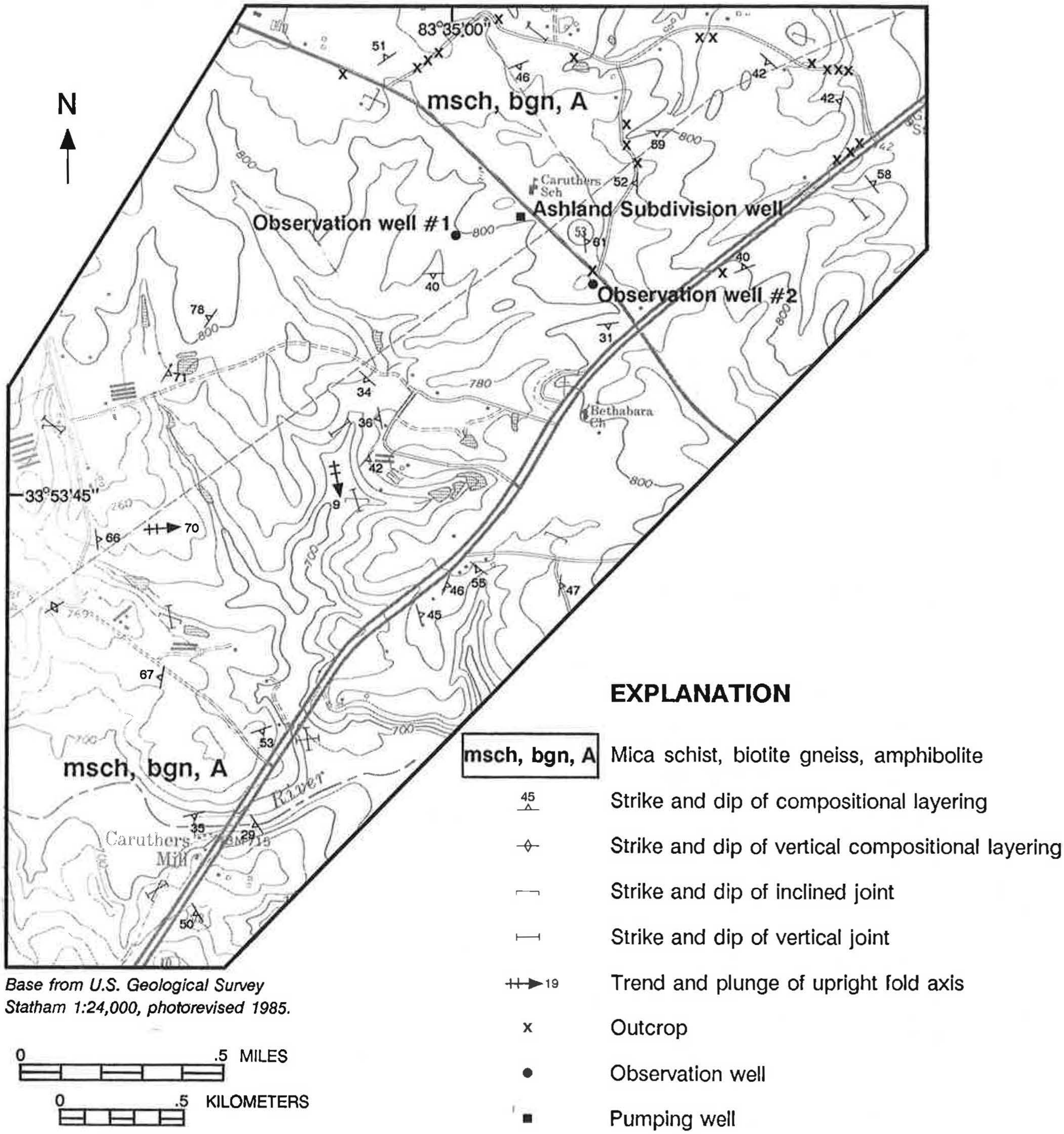


Figure 2. Geologic map of part of the Statham Quadrangle and locations of wells in the Ashland Subdivision, Oconee County.

observed in the vicinity of Ashland Subdivision (Fig. 2, Table 1). Some straight valley segments of at least a mile in length parallel these joint trends.

WATER QUALITY

Water quality analysis indicates that water from the Ashland Subdivision well meets Safe Drinking Water Standards (Table 2). Tests were performed by the Agricultural Service Laboratory of the Extension Poultry Science Department in Athens, Georgia.

HYDROLOGIC TESTING

The pumping rate of the Ashland Subdivision well averaged 138 gpm during a 24-hour constant-rate pumping test. A drilled well owned by the subdivision (observation well 1) is located 820 ft southwest of the pumping well and a shallow bored well (observation well 2) is located on adjacent property approximately 1200 ft southeast of the test well (Fig. 2). Water pumped from the well during the test was directed onto the ground. Because of the short duration of the test and the clayey nature of the soil at the site, recirculation of water discharged from the test well did not appear to significantly influence the test results.

The Ashland Subdivision well could not sustain the initial pumping rate of 150 gpm rate after the first few hours of the test (Fig. 3). The production rate was dropped gradually to 132 gpm at the end of the test giving an average rate of 138 gpm for the test.

Drawdown in the test well totalled 171 ft at the end of the 24-hour test. A graph of drawdown versus time for this well plots as a smooth curve (Fig. 4). The recovery curve also is smooth and is symmetrical to the drawdown curve.

Drawdown was first observed in observation well 1 after three hours of pumping. Observation well 1 showed a total of 1.4 ft of drawdown during the test (Fig. 5). A bottle found floating in this well during the recovery portion of the test apparently interfered with the conductive probe used to measure the water level, causing the data to be somewhat erratic. Observation well 2 recorded no drawdown for the duration of the test.

SUMMARY

The hydrologic test results show that the Ashland Subdivision well had a yield of 138 gpm for 24 hours. A total of 171 ft of drawdown was observed in the pumped well. Observation well 1 had a drawdown of 1.4 ft and observation well 2 showed no effects of the pumping. Water-quality analysis indicates that ground water from the Ashland Subdivision well meets drinking water standards.

COLBERT, MADISON COUNTY

INTRODUCTION

The city of Colbert is located in southern Madison County (Fig. 1). Madison County officials requested that the Geologic Survey assist in locating new municipal well sites for Colbert. Three wells were drilled at sites designated by the Geologic Survey and two additional wells were drilled at sites selected by the water well contractor hired by the city.

WELL SITING

The Geologic Survey sited three wells for the city of Colbert. The first step in identifying potential high-yielding well sites was to examine the locations and yields of existing wells in the vicinity of Colbert. The yields of these wells ranged from 0 to 35 gpm with the highest yielding well located at the head of a northwest-trending valley. This northwest topographic trend is prominent in the Colbert area and could indicate the orientation of discontinuities which may channel ground water to wells.

The criteria used in the selection of the site for Colbert well 1 included the intersection of topographic features trending parallel to discontinuities (Fig. 6). Well site 2 is located in a northwest-trending topographic feature near an intersecting north-south discontinuity. The drill rig could not reach the site due to wet conditions, and so well 2 was drilled about 150 ft north of the chosen site. The site for well 3 was selected because of intersecting topographic features and its location downdip from a perennial stream.

Two additional wells drilled at Colbert are

Table 1. Ashland Subdivision, joint orientations and descriptions.

Joint	Dip	Spacing	Surface	Coating
N27°E	60-80°	2 in-1 ft	smooth to irregular	manganese
N59°W	50-90°	2 in-4 ft	irregular	none
N62°E	60-90°	0.5 in-1 ft	smooth to irregular	none
E-W	60-90°	0.5 in-4 in	smooth to irregular	none

Table 2. Ashland Subdivision well, water-quality analysis.

Parameter	Results	Parameter	Results
Ag	<0.05 mg/l	Na	6.9 mg/l
As	<0.05 mg/l	Nitrate	0.843 mg/l
Ba	<0.05 mg/l	Pb	<0.02 mg/l
Cd	<0.005 mg/l	Se	<0.001 mg/l
$C0_2$	2.6 mg/l	$S0_4$	2.4 mg/l
Cr	<0.01 mg/l	Zn	0.34 mg/l
Cu	0.01 mg/l	Turbidity (NTU)	<1.00
F	0.1 mg/l		
Fe	0.059 mg/l	Alkalinity (as CaCO)	52 mg/l
Hg	<0.001 mg/l		
Mg	1.23 mg/l	Hardness (as $CaC0_3$)	15.1 mg/l
		Chloride	3.00 mg/l

< = below laboratory detection limits

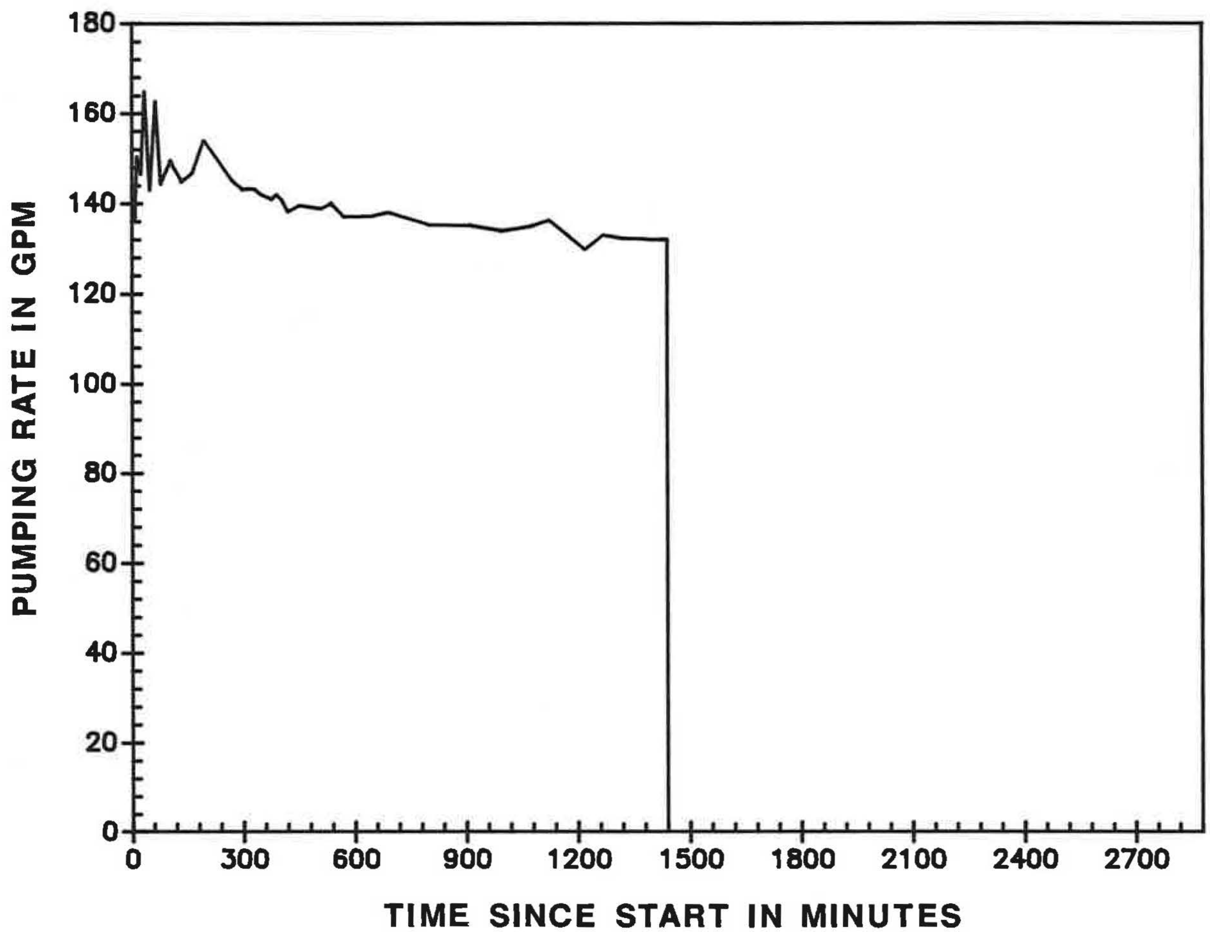


Figure 3. Pumping rate of Ashland Subdivision well during the 24-hour pumping test.

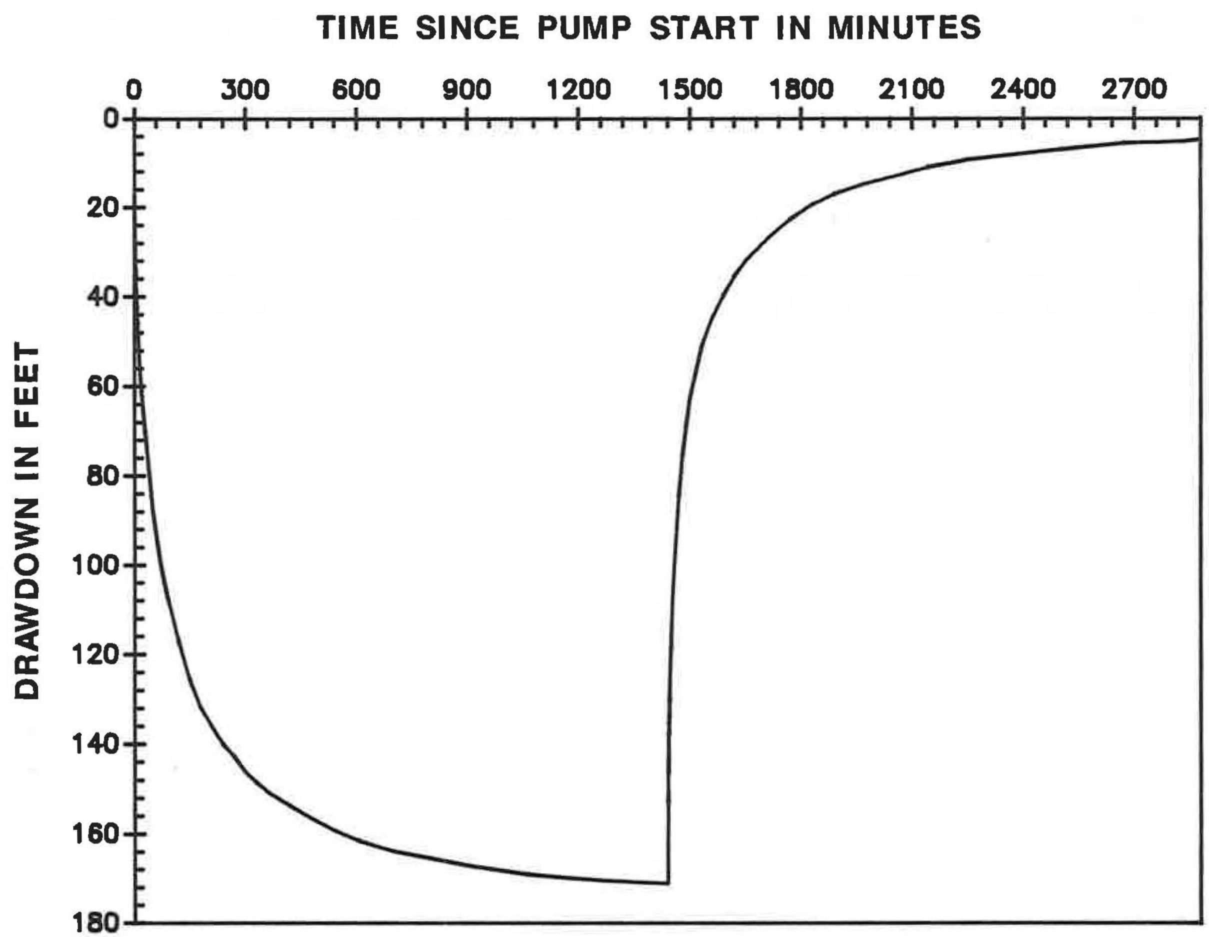


Figure 4. Drawdown and recovery curve for the Ashland Subdivision well.

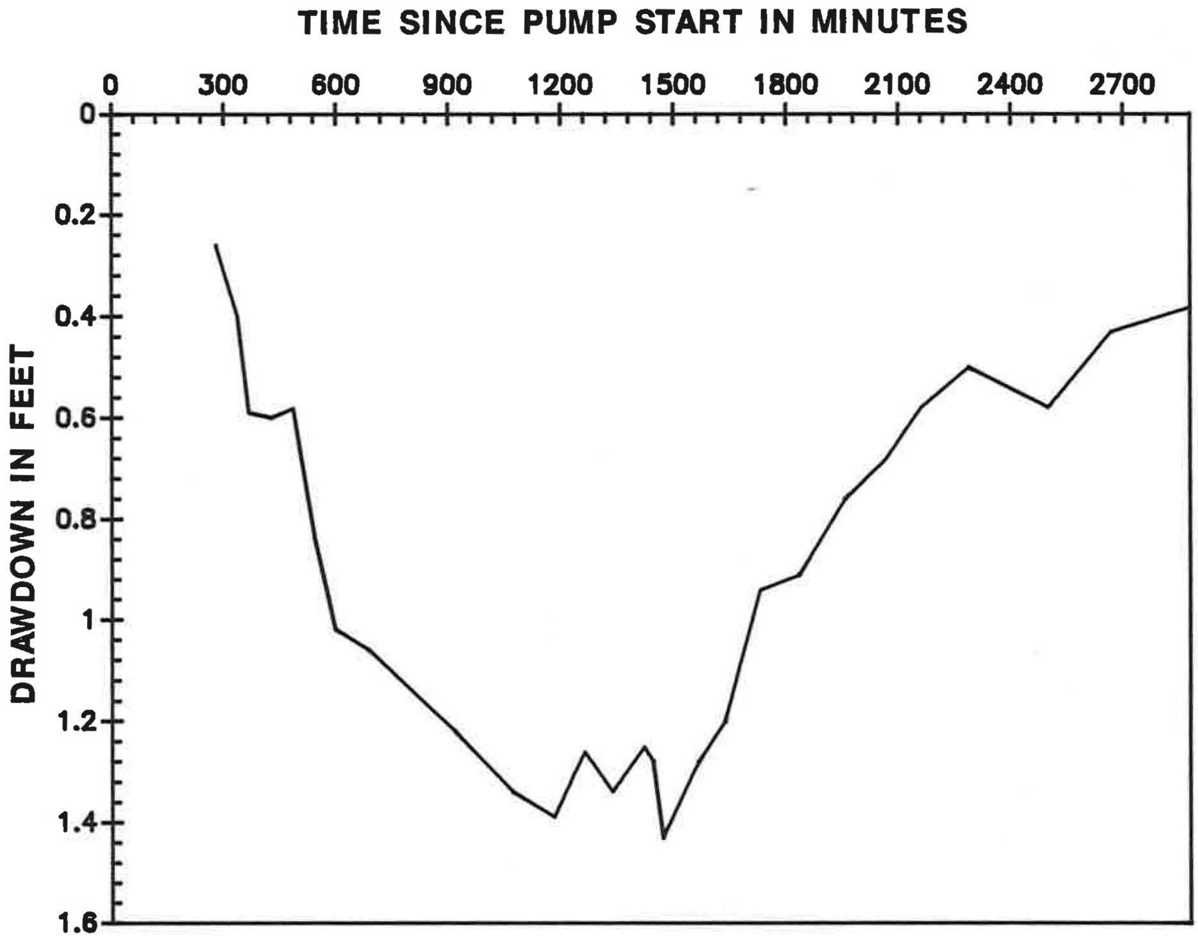
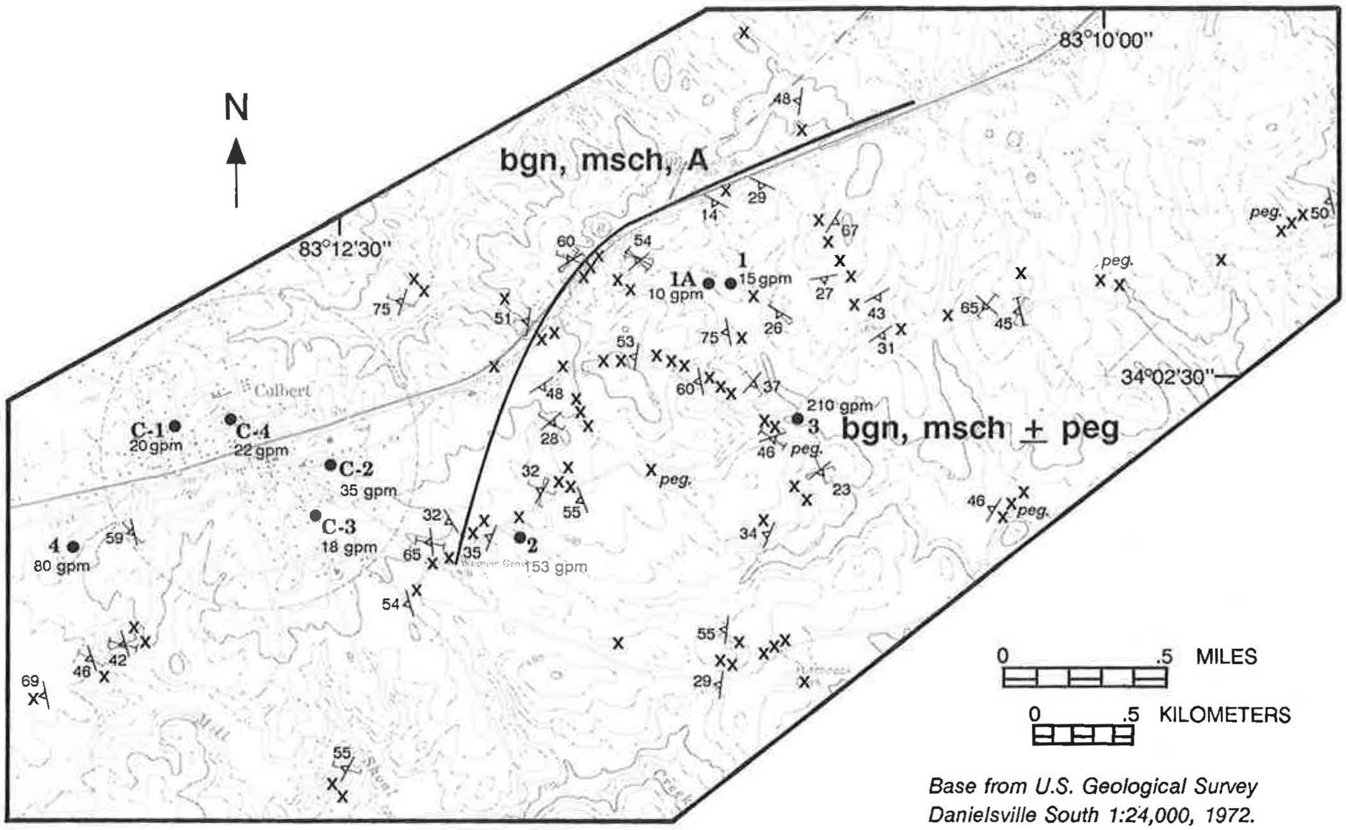


Figure 5. Drawdown and recovery curve for Ashland Subdivision observation well 1.



EXPLANATION

bgn, msch, A	Coarse-grained biotite plagioclase gneiss; coarse-grained graphite-bearing mica schist; and coarse-grained hornblende plagioclase amphibolite
bgn, msch ± peg	Coarse-grained biotite plagioclase gneiss; coarse-grained graphite-bearing mica schist with pods and lenses of pegmatite
15	Strike and dip of compositional layering
	Strike and dip of vertical joint
	Strike and dip of inclined joint
x	Outcrop
●	Well location
4	Well number
C-1	Existing city well
———	Contact

Figure 6. Geologic map of part of the Danielsville South Quadrangle and locations of wells in the Colbert area.

located at sites selected by the driller. Well 1A was picked at a T-intersection of two drainageways across the valley from well 1. The criteria for selection of the site of well 4 included convenience factors; the city owned the well site and possessed easy access. Well 4 is located between topographic features that curve away from each other in the upslope direction indicating a convergent dip configuration for the discontinuities responsible for these topographic features.

GEOLOGY

The city of Colbert lies in the Winder Slope District, a subdivision of the Piedmont Physiographic Province (Clark and Zisa, 1976). Stream valleys are gently concave with floodplains as wide as several hundred feet (Fig. 6). Hill tops are gently convex with interstream divides approximately 200 ft wide. Most land surface slopes gently, with a total relief of about 100 ft. Straight valley segments apparent on the 7.5 minute topographic map in the vicinity of Colbert are oriented N40°W, N66°W, N25°, N40°E, N6°E, and N85°E. The wells located by the Geologic Survey are at intersections of tributaries to Beaverdam Creek in an area of rolling topography.

The site is mostly underlain by red to tan saprolite weathered from a coarse-grained biotite gneiss. This saprolite is interlayered with red to tan saprolite weathered from graphite-bearing mica schist and ocher-colored saprolite weathered from an amphibolite. Coarse-grained, equigranular biotite granite and quartz feldspar pegmatite intruded the mica schist.

Compositional layering generally strikes northeast and dips to the southeast and northwest near Colbert (Fig. 6). The compositional layering at well site 1 trends northwest with a southwest dip. Near well site 2, compositional layering strikes north-south and dips to the west. Compositional layering strikes northeast with a southeast dip in the vicinity of well site 3. A fold trending northeast, and plunging to the southwest, may be present in the Colbert area (Fig. 6).

Joints strike N72°W with dips from 54°NE to vertical; N65°W and N-S with vertical dip; and N23°W dipping 55 to 75°SW (Fig. 6). At well 2, joint sets strike N22°E dipping 78°SE and N80°W with vertical dip. A joint set strikes N56°W with vertical dip near well 3.

GEOPHYSICAL TESTING

Surface Geophysical Testing

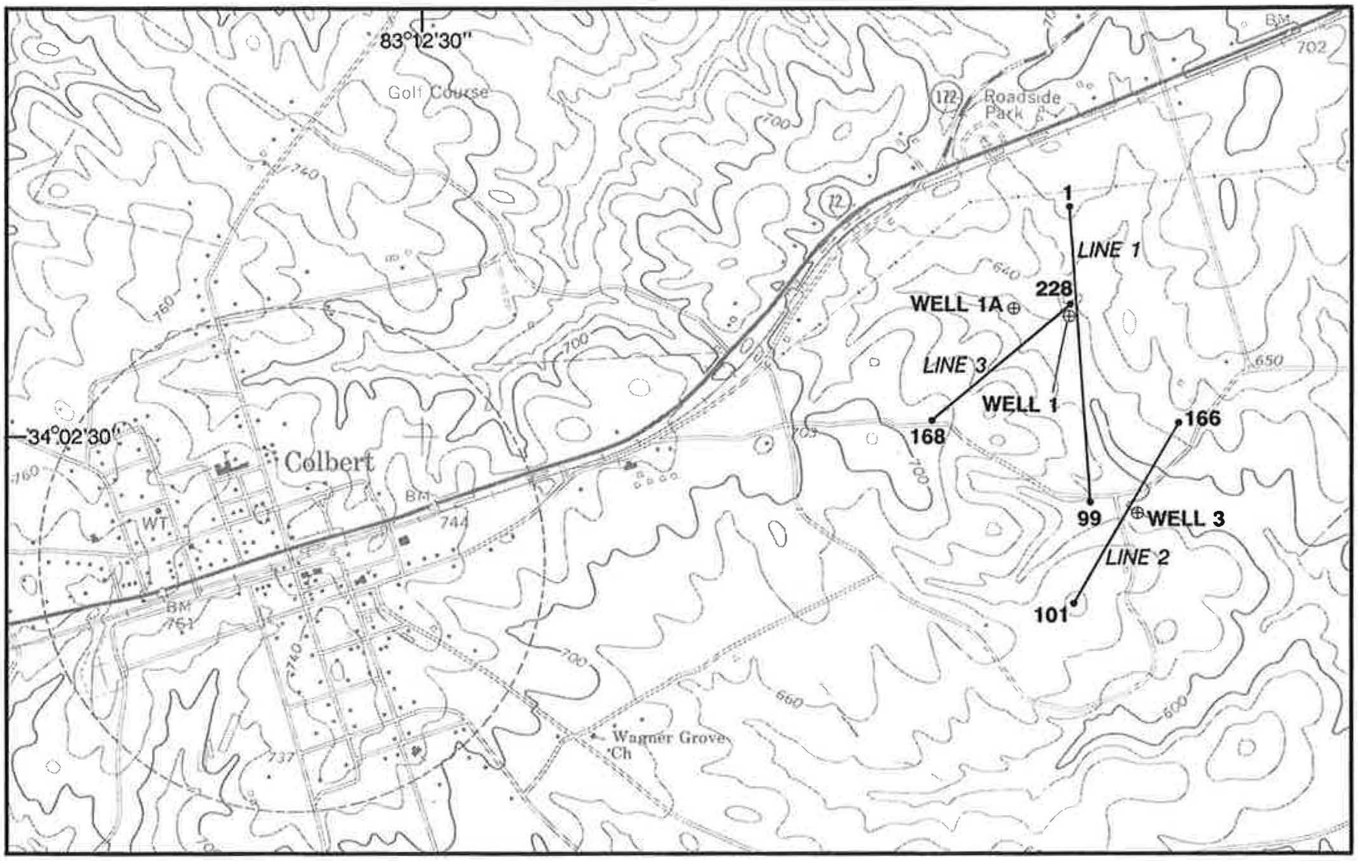
A magnetic survey conducted at Colbert near the well sites consisted of four profile lines (Fig. 7). Individual magnetic readings were subtracted from an average of readings at the site in order to identify magnetic anomalies. Profile line 1 showed a smooth increase in field values to the south, with no large magnetic anomalies near the sites of wells 1 and 1A. Neither were any large anomalies detected in profile line 4. Profile line 2 showed an anomaly of about 120 gamma near well 2 (Fig. 8). This anomaly is spike-shaped and is superimposed on a smooth decrease in the field values to the west. Profile line 3 shows a 50 gamma drop to the north near well 3 (Fig. 9). The 50 gamma anomaly on line 3 is much greater than the average 10-15 gamma variation in the magnetic field common over most of the site.

The magnetic anomaly in profile 2 is most likely due to a magnetic unit interlayered in the metamorphic sequence. The anomaly in profile 3 is a much more significant feature and may represent a geologic contact near well 3. Well 3 produced 210 gpm during a 72-hour pumping test and penetrated numerous discontinuities. The steepness of the change suggests that the contact is dipping at a high angle and is possibly vertical. The geographic locations of the anomalies suggest that lithologic boundaries may coincide with linear stream segments.

Borehole Geophysical Logging

A suite of borehole geophysical logs, including sonic televiewer, caliper, temperature, spontaneous potential, acoustic velocity logs, single-point resistivity and natural gamma were run on Colbert Wells 1, 1A, 2, 3, and 4. These logs aided in identification of discontinuities in the wells that may represent water-bearing zones.

Discontinuities are visible on the sonic televiewer log of Colbert well 1 at 68 ft, 140-145 ft and 383-385 ft (Figs. 10-12). Anomalies on the caliper, temperature, spontaneous potential, and acoustic velocity logs correlate with the discontinuity visible on the sonic televiewer log at 68 ft (Figs. 13-16). The caliper log shows an increase in borehole diameter at 140-145 ft, correlating with the discontinuity zone visible on the sonic



Base from U.S. Geological Survey
Danielsville South 1:24,000, 1972.

EXPLANATION

Magnetometry survey line

⊕ Well

1 Station number

N

0 .5 MILES

0 .5 KILOMETERS

Figure 7. Locations of wells and magnetic survey lines at Colbert.

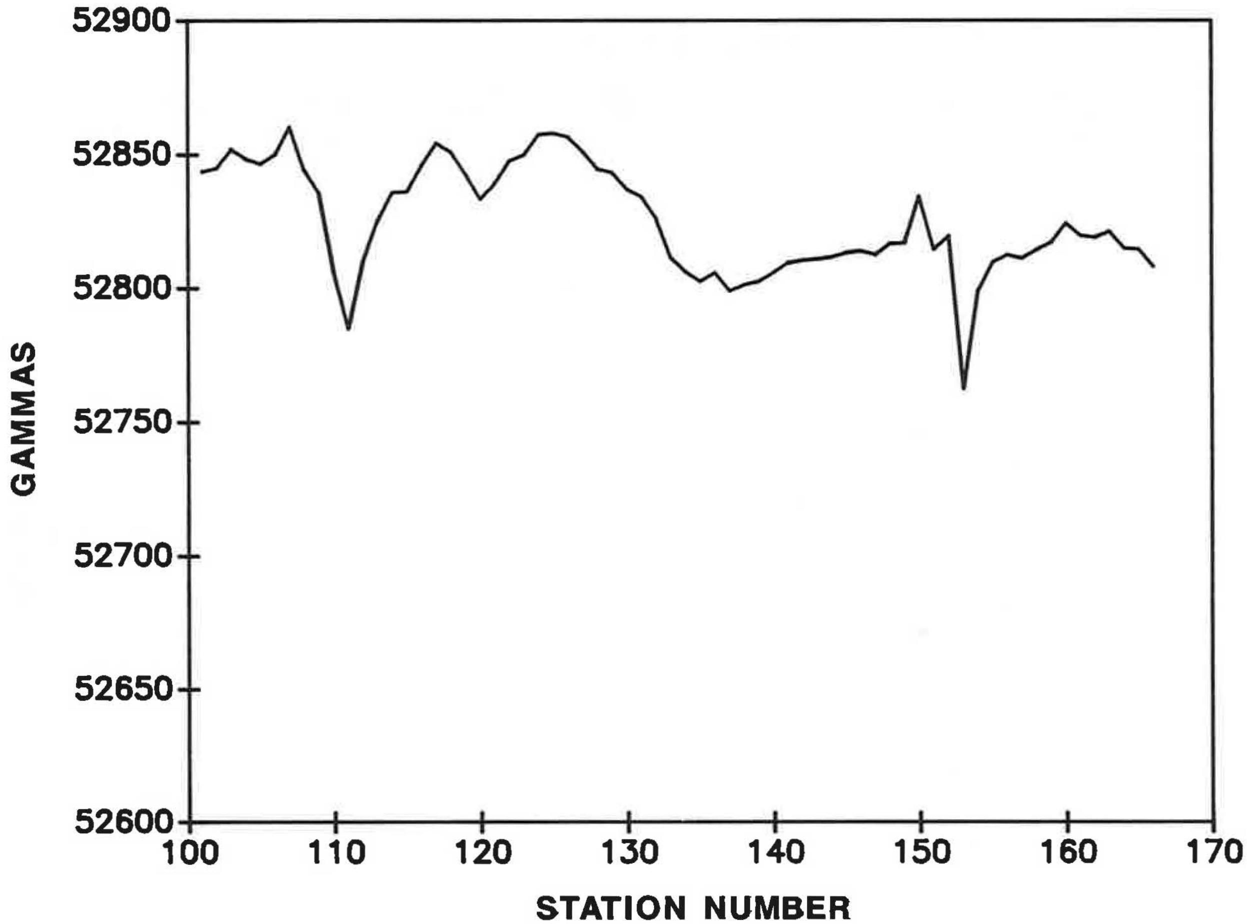


Figure 8. Drift corrected magnetic profile line 2 at Colbert.

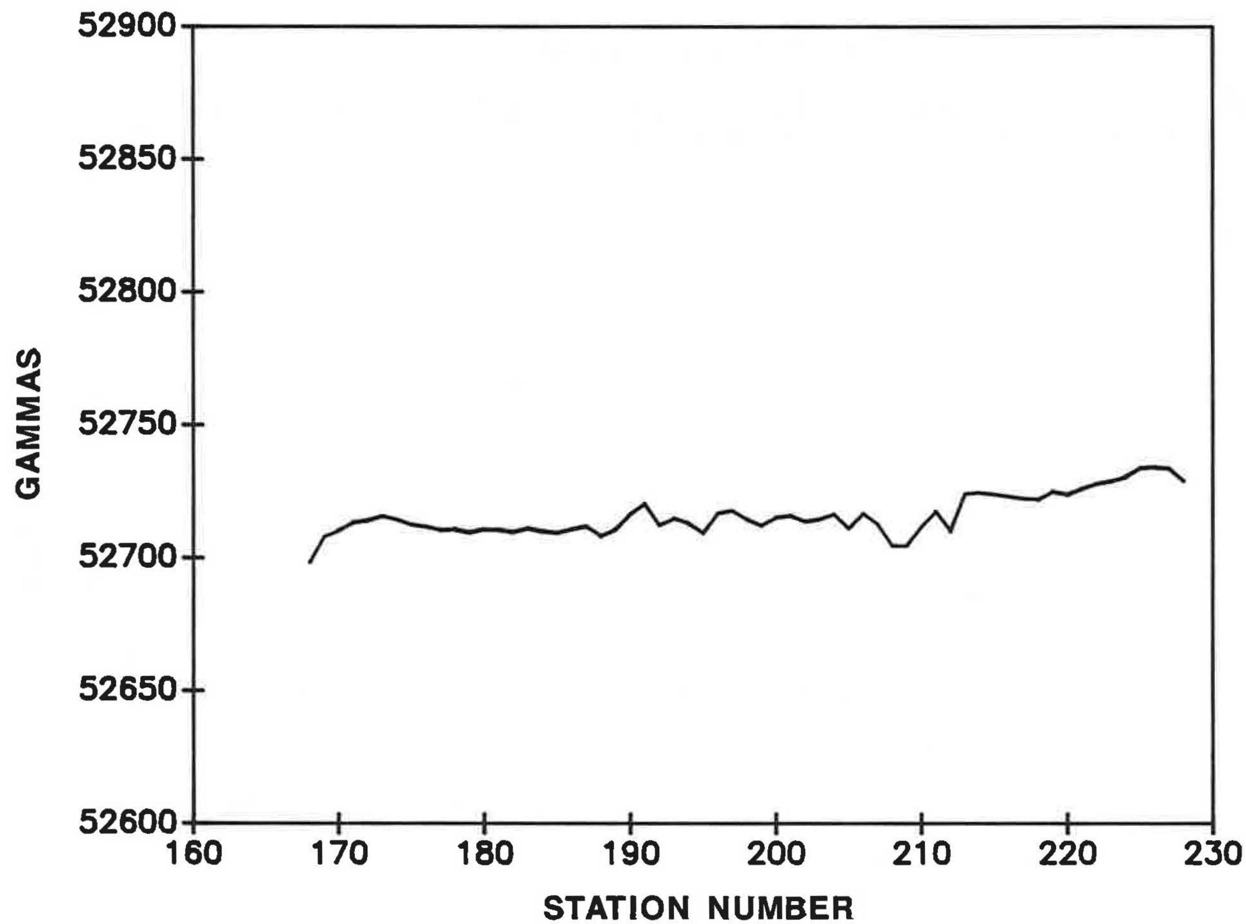


Figure 9. Drift corrected magnetic profile line 3 at Colbert.

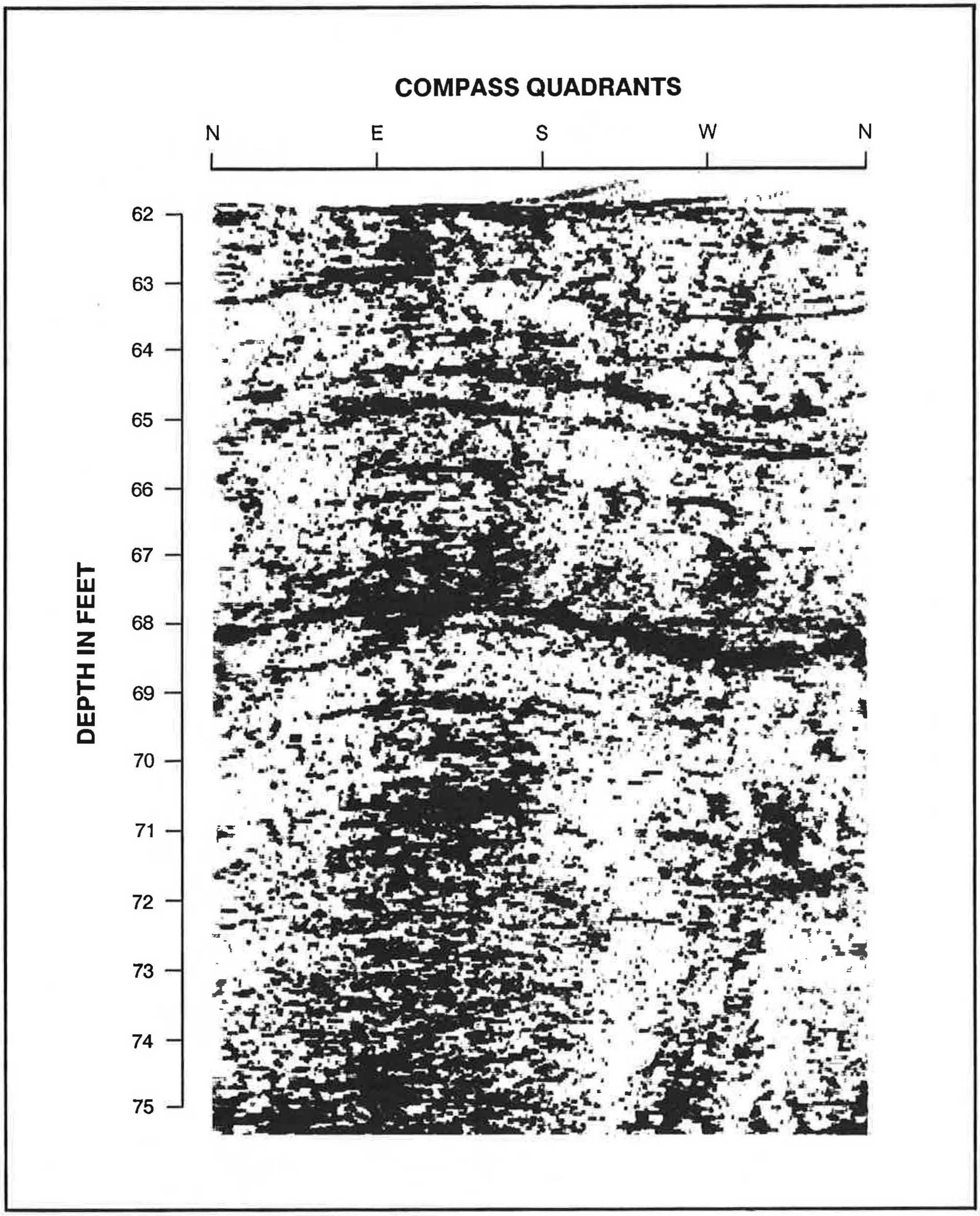


Figure 10. Sonic televiewer log of Colbert well 2, 62-75 ft.

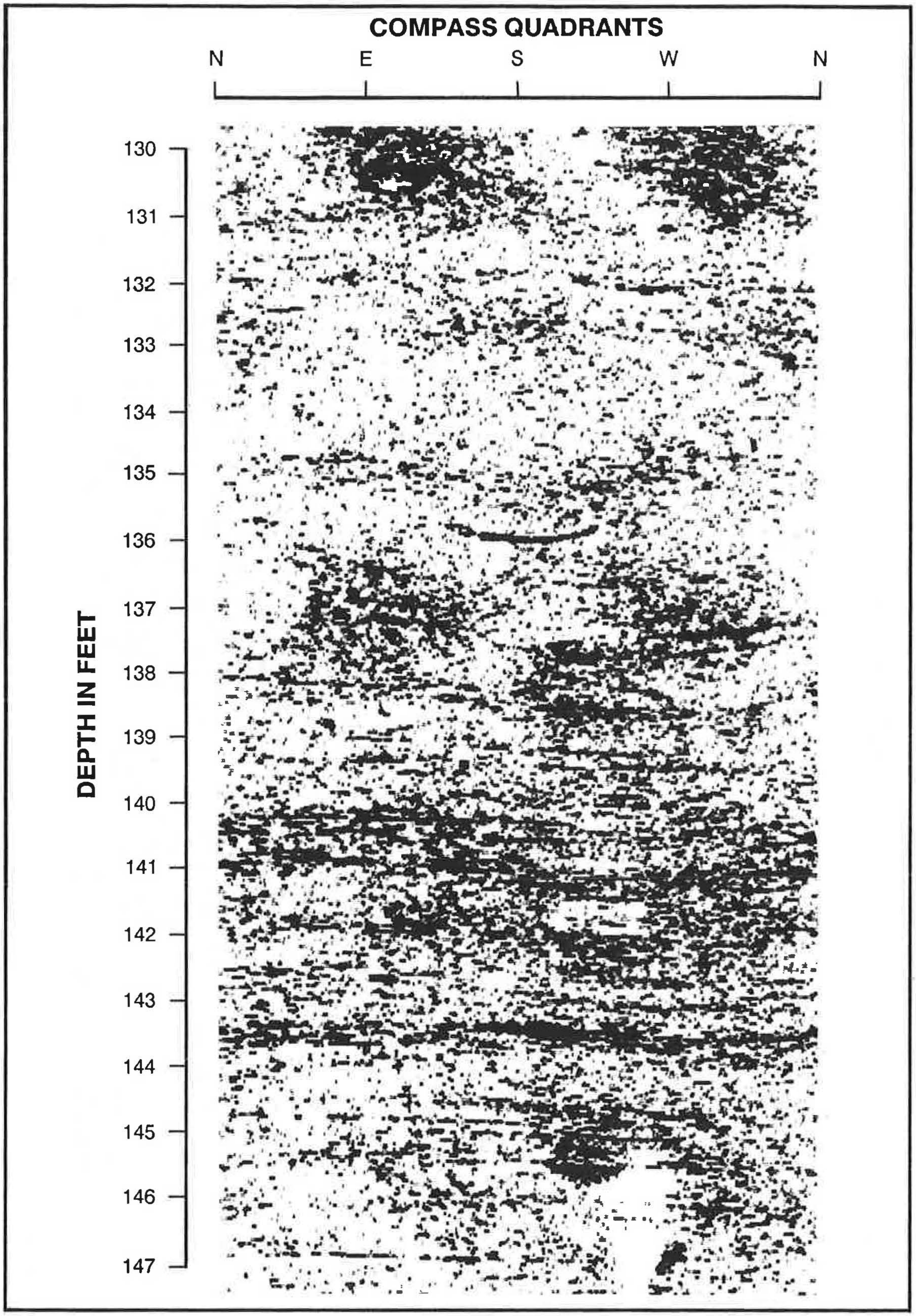


Figure 11. Sonic televiewer log of Colbert well 1, 130-147 ft.

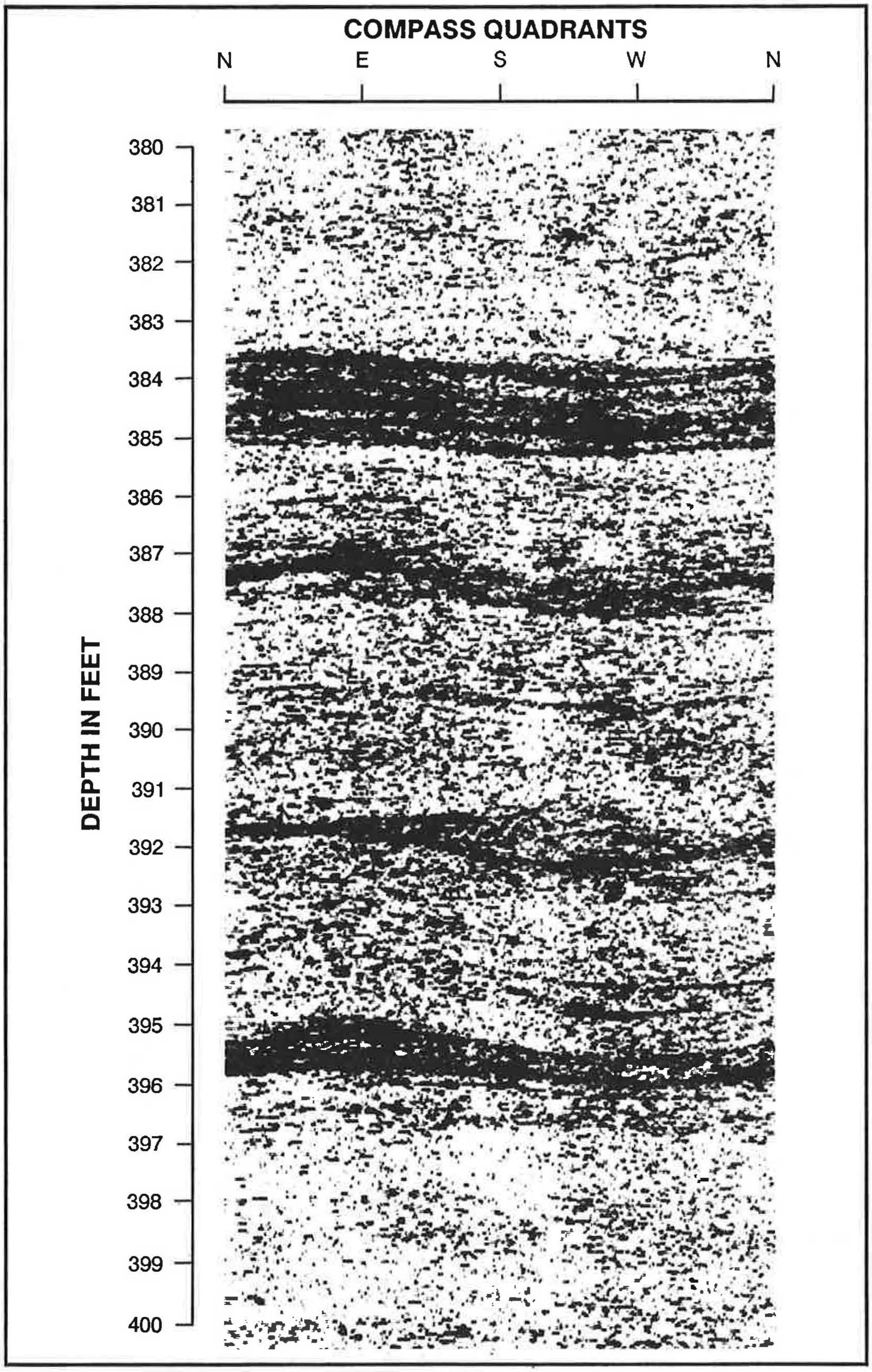


Figure 12. Sonic televiewer log of Colbert well 1, 380-400 ft.

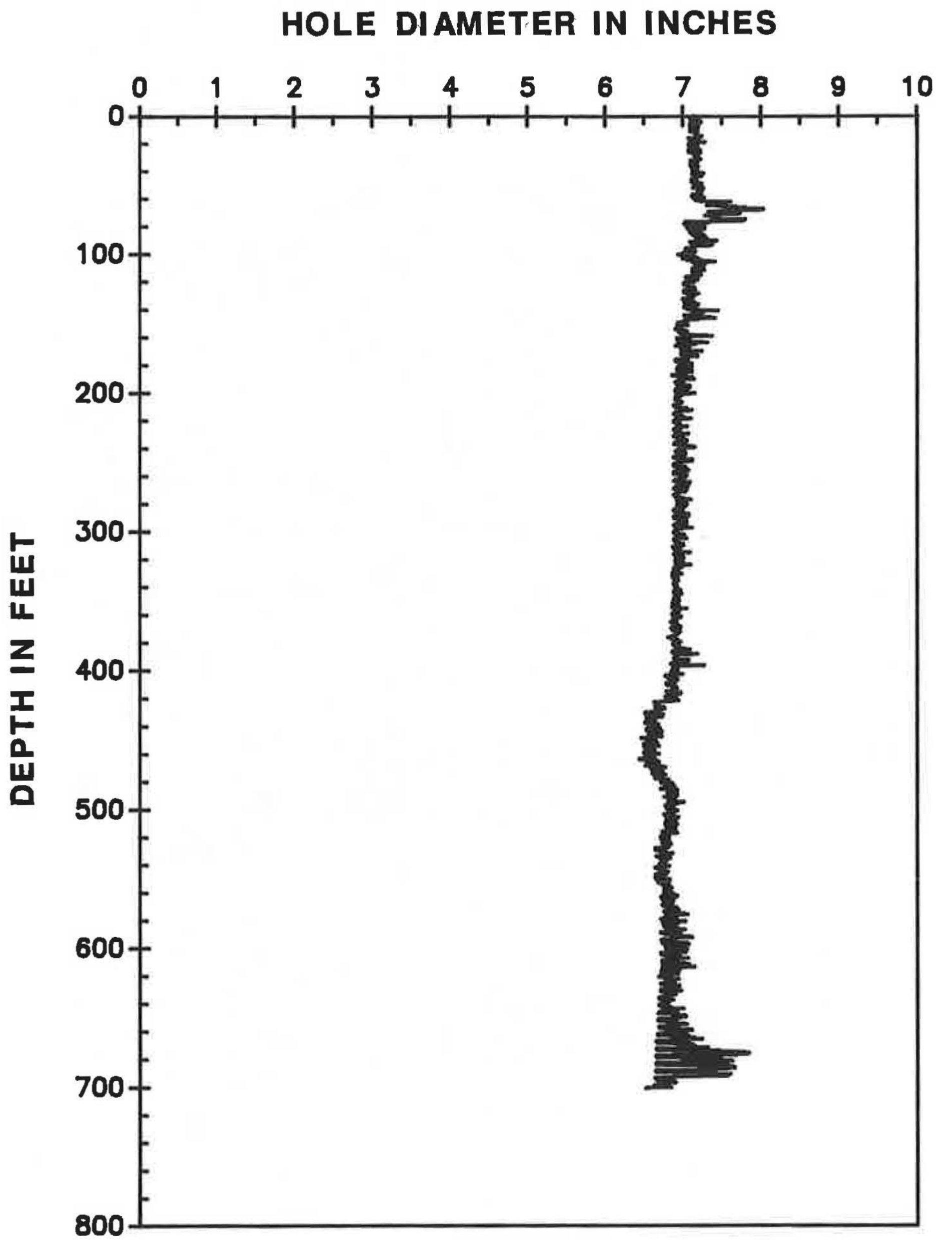


Figure 13. Caliper log of Colbert well 1.

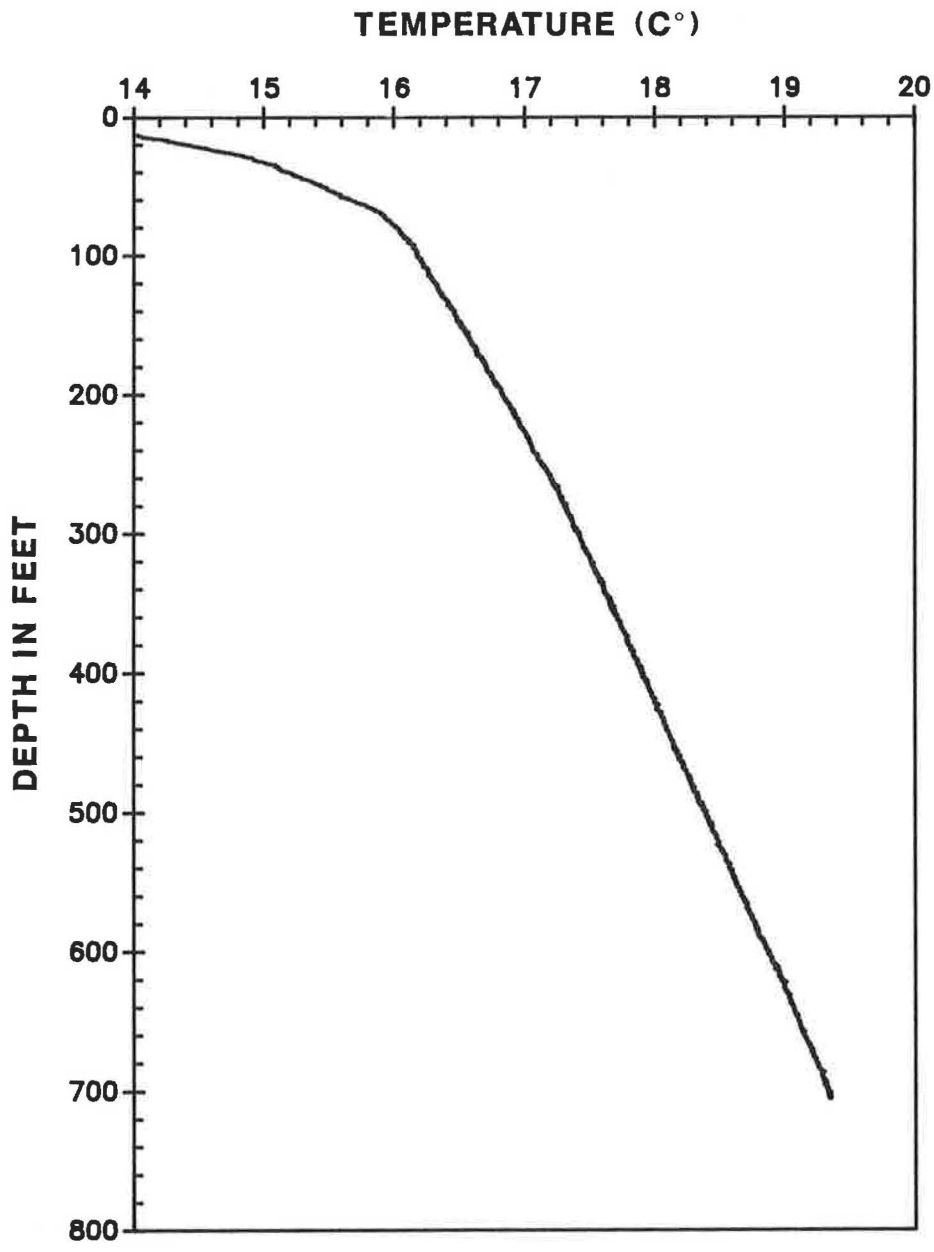


Figure 14. Temperature log of Colbert well 1.

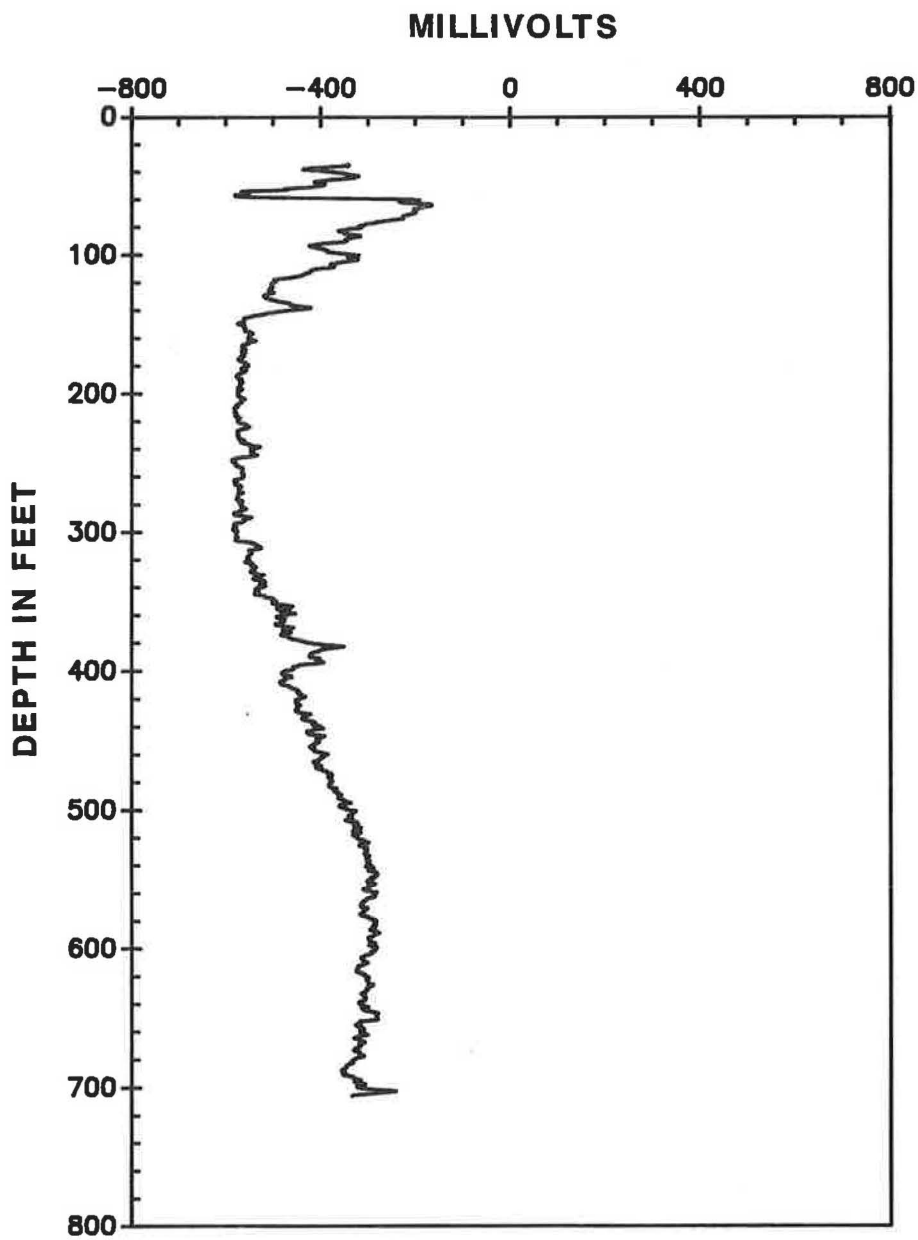


Figure 15. Spontaneous potential log of Colbert well 1.

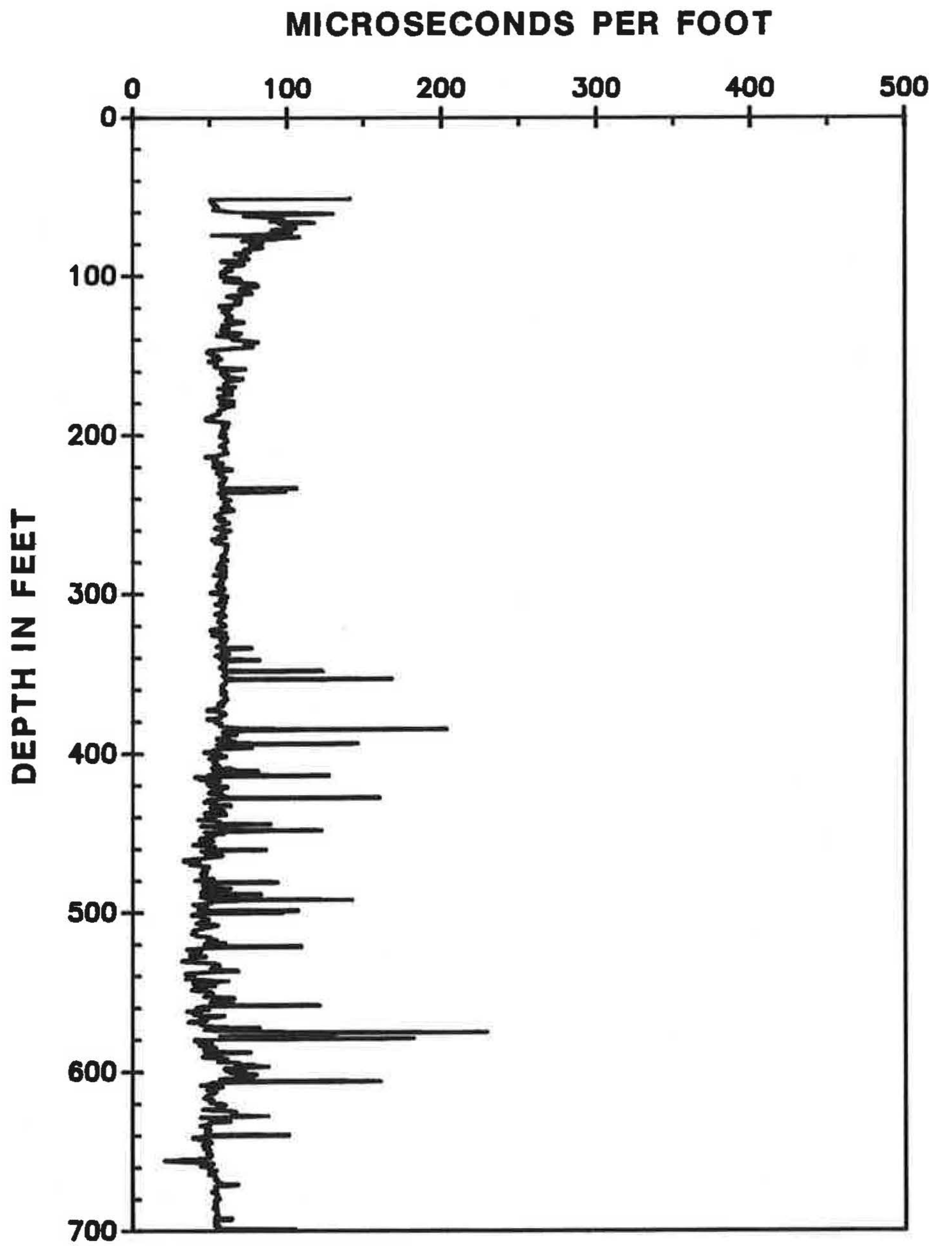


Figure 16. Acoustic velocity log of Colbert well 1.

televiewer log. This depth interval also correlates with anomalies on the spontaneous potential, single-point resistance (Fig. 17), and acoustic velocity logs.

The fractured zone visible on the sonic televiewer log at 383-385 ft in well 1 correlates with anomalies on the caliper, spontaneous potential, single-point resistance and acoustic velocity logs. Not all anomalies seen on borehole geophysical logs of well 1 could be ascribed to discontinuities, however. The caliper and resistance logs both contained anomalies which could not be correlated with discontinuities visible on sonic televiewer logs, and the gamma-ray anomalies on the natural gamma log showed no apparent correlation with any discontinuity seen on the sonic televiewer logs (Fig. 18).

The sonic televiewer logs from Colbert well 1A show discontinuities at 369-370 and 500-501 ft (Figs. 19 - 20). These zones are marked by anomalies on the caliper, single- point resistivity and spontaneous potential logs (Figs. 21, 23, and 24). Caliper and single-point resistance logs from Colbert well 1A indicate a possible water-bearing zone at 266-277 ft (Figs. 21 and 24). Temperature and natural gamma logs were not useful in identifying discontinuities in this well (Figs. 22 and 25).

Colbert well 2 was geophysically logged, but the well driller reported that the major water-bearing zone was penetrated at 450 ft, which was below the reach of the logging equipment (Figs. 26-30). The driller reported a minor weathered zone between 323 and 332 ft. The spontaneous potential log shows an increase at 310-330 ft and the single -point resistance values decrease slightly between 320 and 360 ft. These anomalies could suggest a minor water-bearing zone near 320 ft.

Anomalies on the sonic televiewer, caliper, spontaneous potential, single-point resistance, and acoustic velocity logs of Colbert well 3 indicate the presence of a discontinuity at 123-125 ft (Figs. 31-34, 36-38). Another discontinuity is indicated at 161-163 ft by anomalies on the sonic televiewer, caliper, resistance, and acoustic velocity logs. At 185-190 ft, the sonic televiewer shows a discontinuity that appears to be a weathered zone. The caliper, spontaneous potential, resistance, and acoustic velocity logs also show anomalies at or near this depth. A possible fractured or weathered zone may be indicated between 201 and 237 ft by anomalies on the spontaneous potential, resistance, and acoustic velocity logs. Natural gamma anomalies also occur near this interval (Fig. 39). Spontaneous potential and acoustic velocity logs show discontinuities at 248-254 ft. No temperature anomalies were logged in this well (Fig. 35).

The sonic televiewer log, and other logs, indicate a major discontinuity at 123-125 ft in Colbert well 4 (Figs. 40-45). A significant increase in borehole diameter occurs at this depth (Fig. 41) and the single-point resistance log shows an anomaly near this depth (Fig. 44). An increase in borehole diameter at 169 ft, along with an increase in ground-water temperature at 170 ft (Fig. 42), indicates a probable water-bearing zone. The single-point resistance log also shows a significant negative shift at 169 ft. A spontaneous potential log and a natural gamma log were also run on Colbert well 4 (Figs. 43 and 45).

The orientations of subsurface discontinuities were measured from sonic televiewer logs of Colbert wells 1, 1A, 2, 3 and 4. These orientations were plotted on equal area diagrams and compared with the orientations of foliation, joints, and straight valley segments.

Wells 1, 3 and 4 penetrated northwest-dipping discontinuities which are parallel or subparallel to the major structural features in the Colbert area. The strike and dip of foliation measured at the land surface are within 28° and 12°, respectively, of the strike and dip of subsurface discontinuities measured from televiewer logs. Well 3, the highest yielding of the five Colbert wells, intercepted numerous discontinuities of varying orientations.

HYDROLOGIC TESTING

Air lift tests on Colbert wells 1 and 1A indicated well yields of 15 and 10 gpm, respectively. No further hydrologic tests were performed on these wells. Stress tests, using a submersible pump powered by a generator, were performed on Colbert wells 2, 3, and 4 in order to estimate production capacity for these wells.

The stress test conducted on Colbert well 2 lasted for 72-hours. Outflow was directed to the floodplain of the creek 15 feet from the well. The pumping rate is shown in Figure 46. The drawdown and recovery curves generated from the data gathered during the test are irregular and asymmetrical (Fig. 47).

A 72-hour well stress test was also carried out on Colbert well 3. Variations in the power

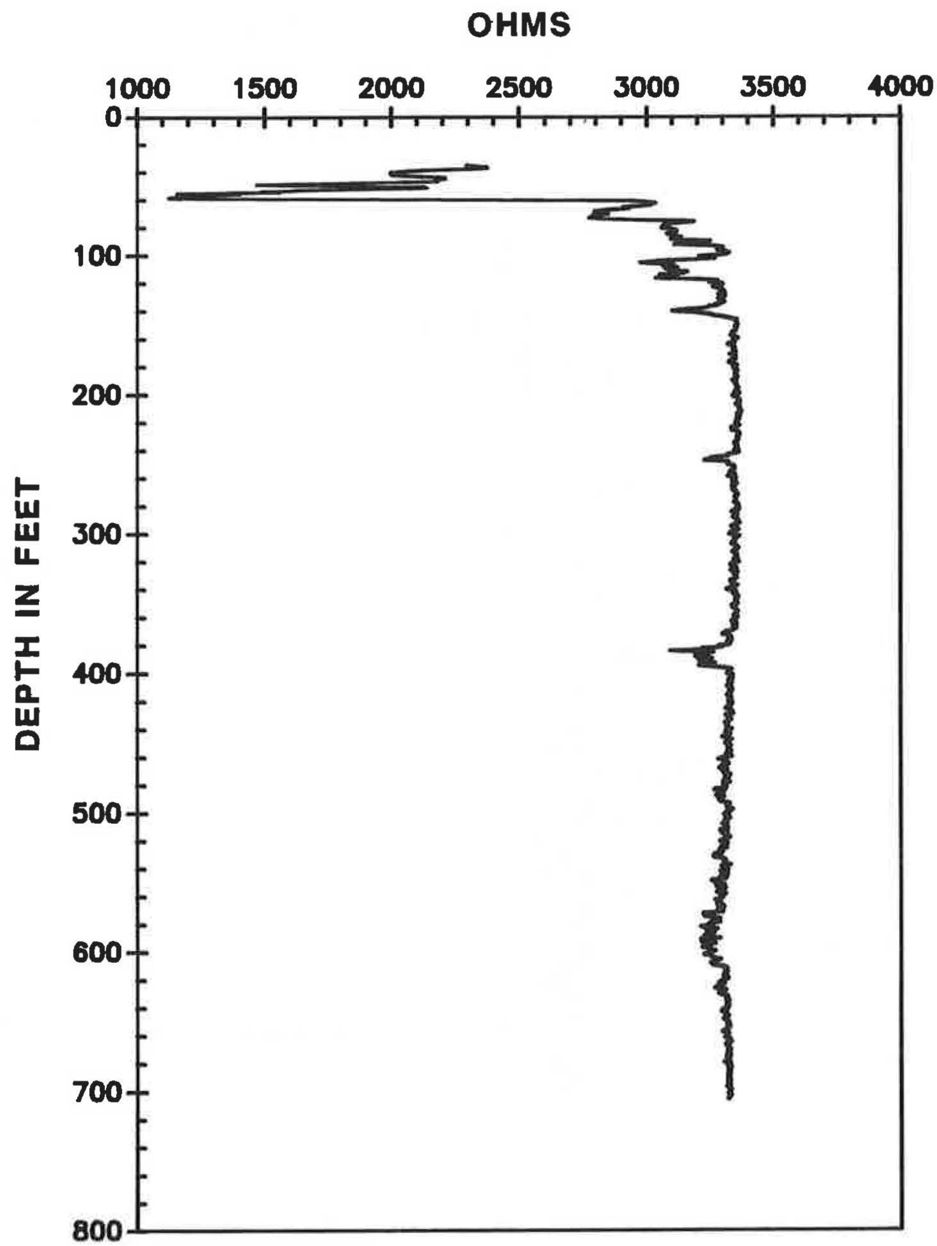


Figure 17. Single- point resistivity log of Colbert well 1.

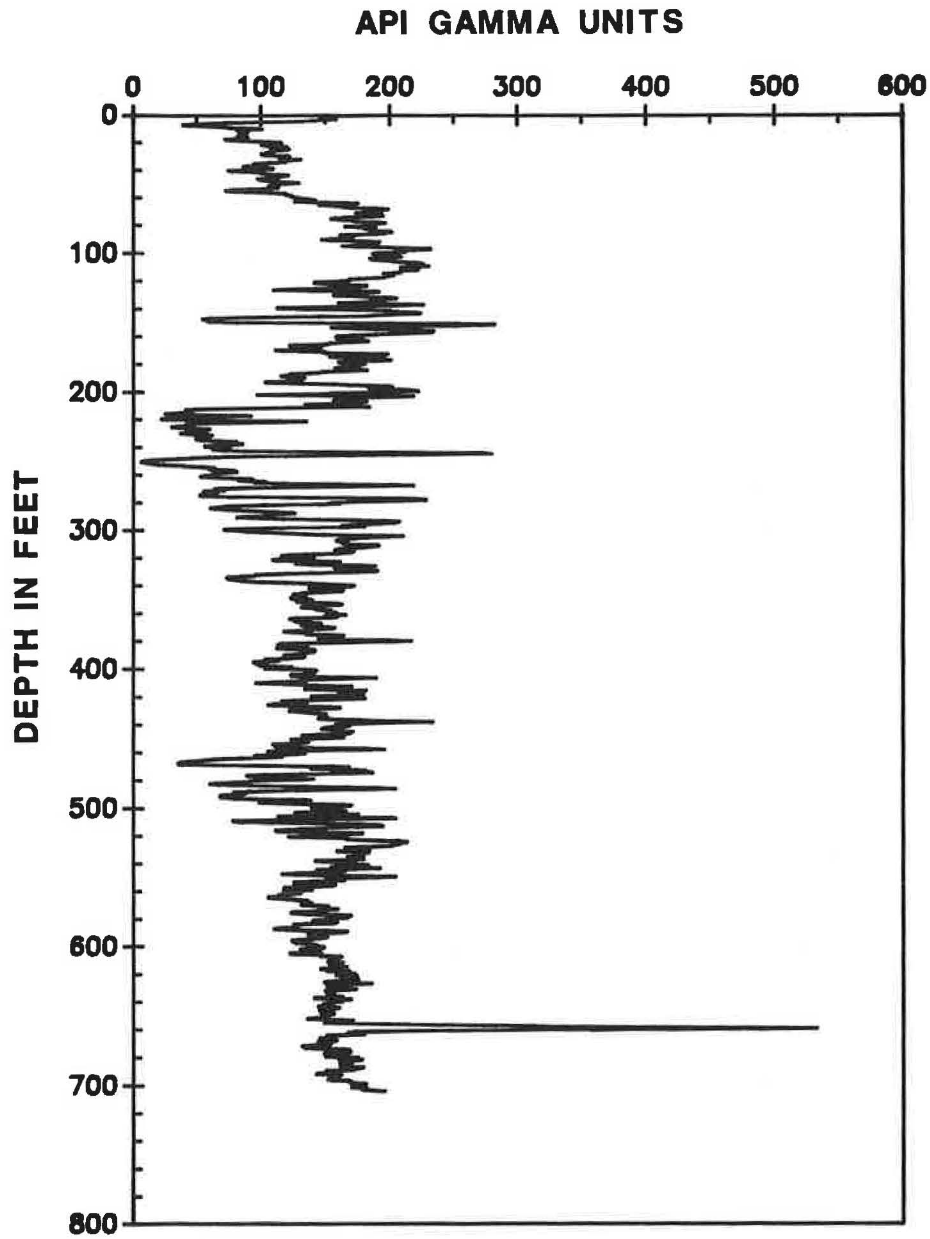


Figure 18. Natural gamma log of Colbert well 1.

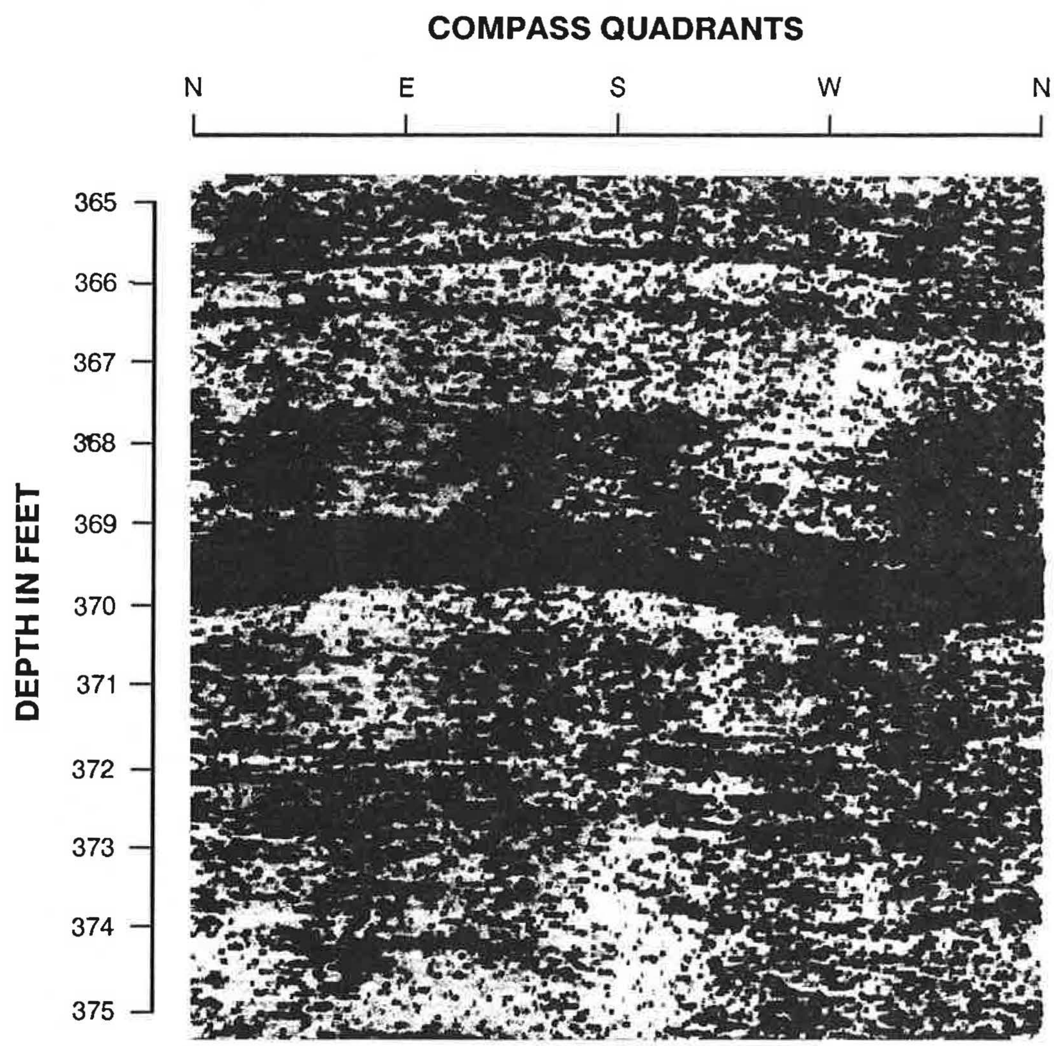


Figure 19. Sonic televiewer log of Colbert well 1A, 365-375 feet.

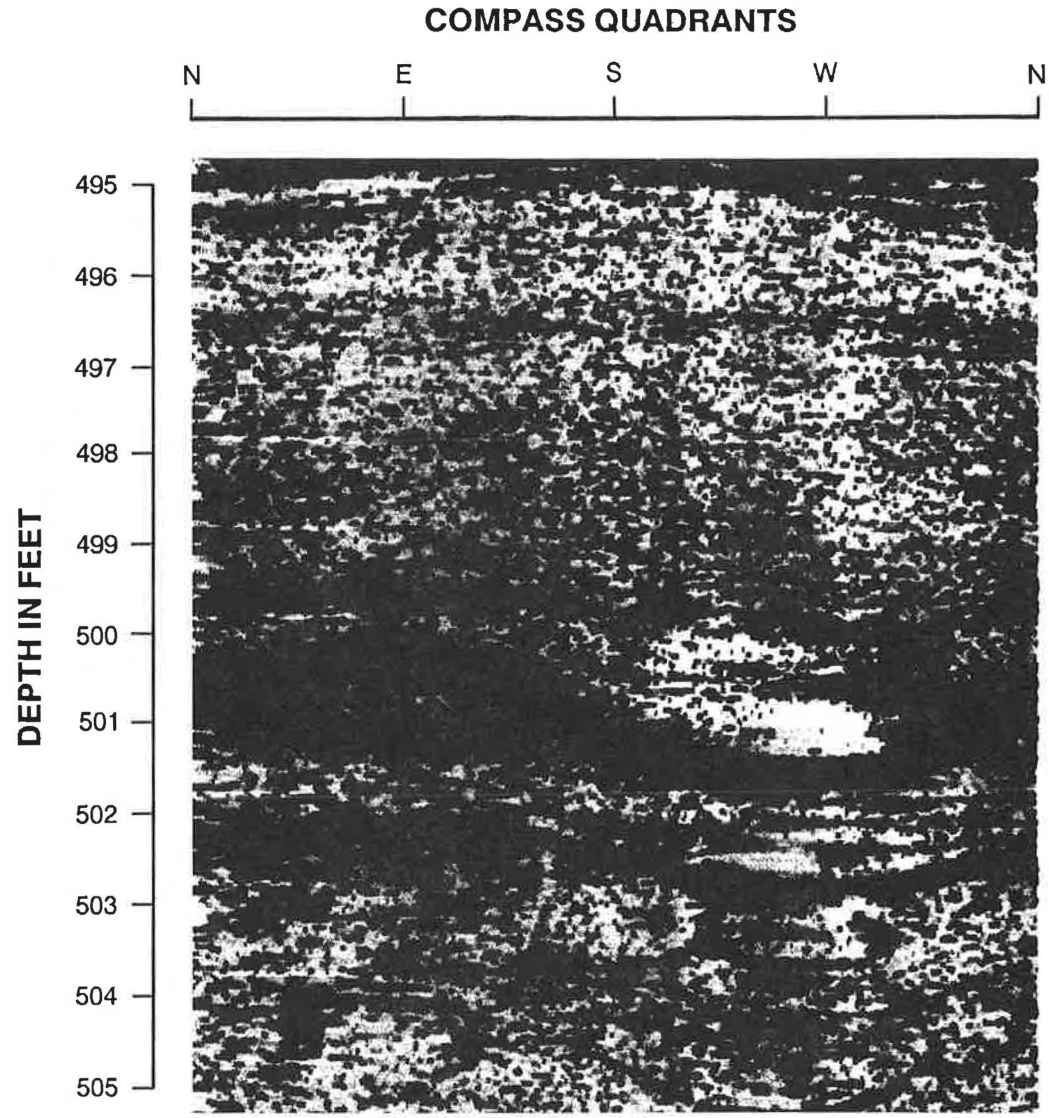


Figure 20. Sonic televiewer log of Colbert well 1A, 495-505 feet.

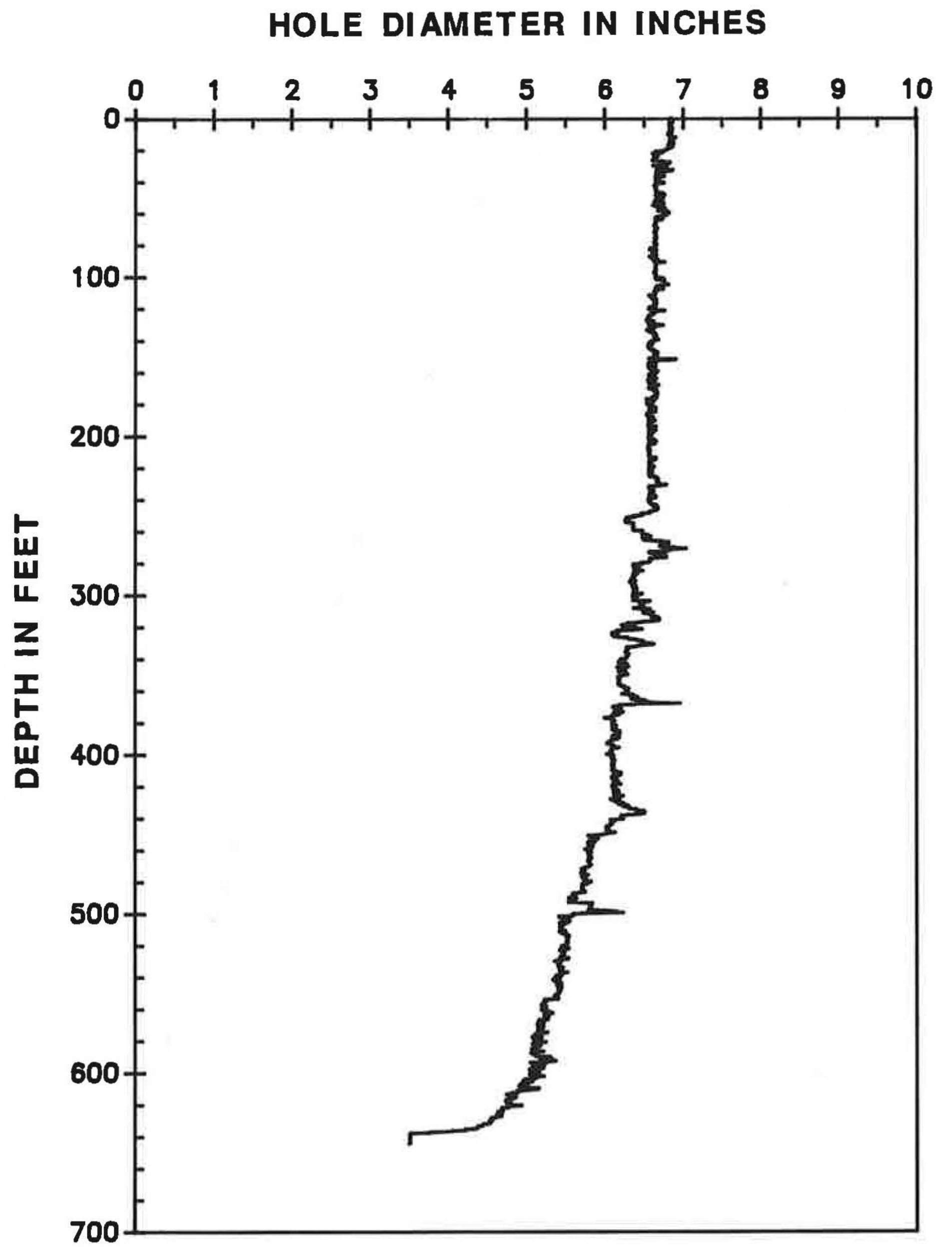


Figure 21. Caliper log of Colbert well 1A.

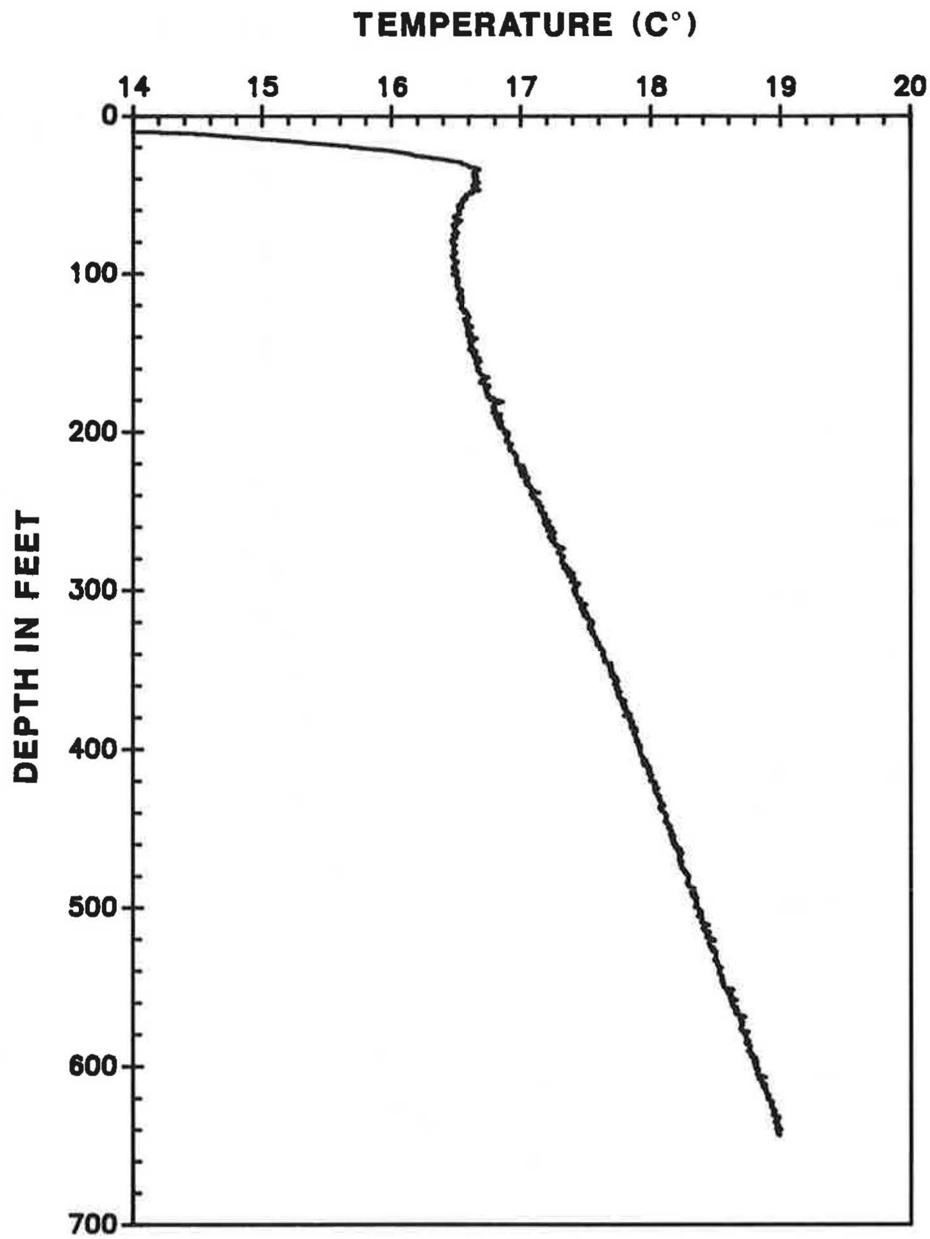


Figure 22. Temperature log of Colbert well 1A.

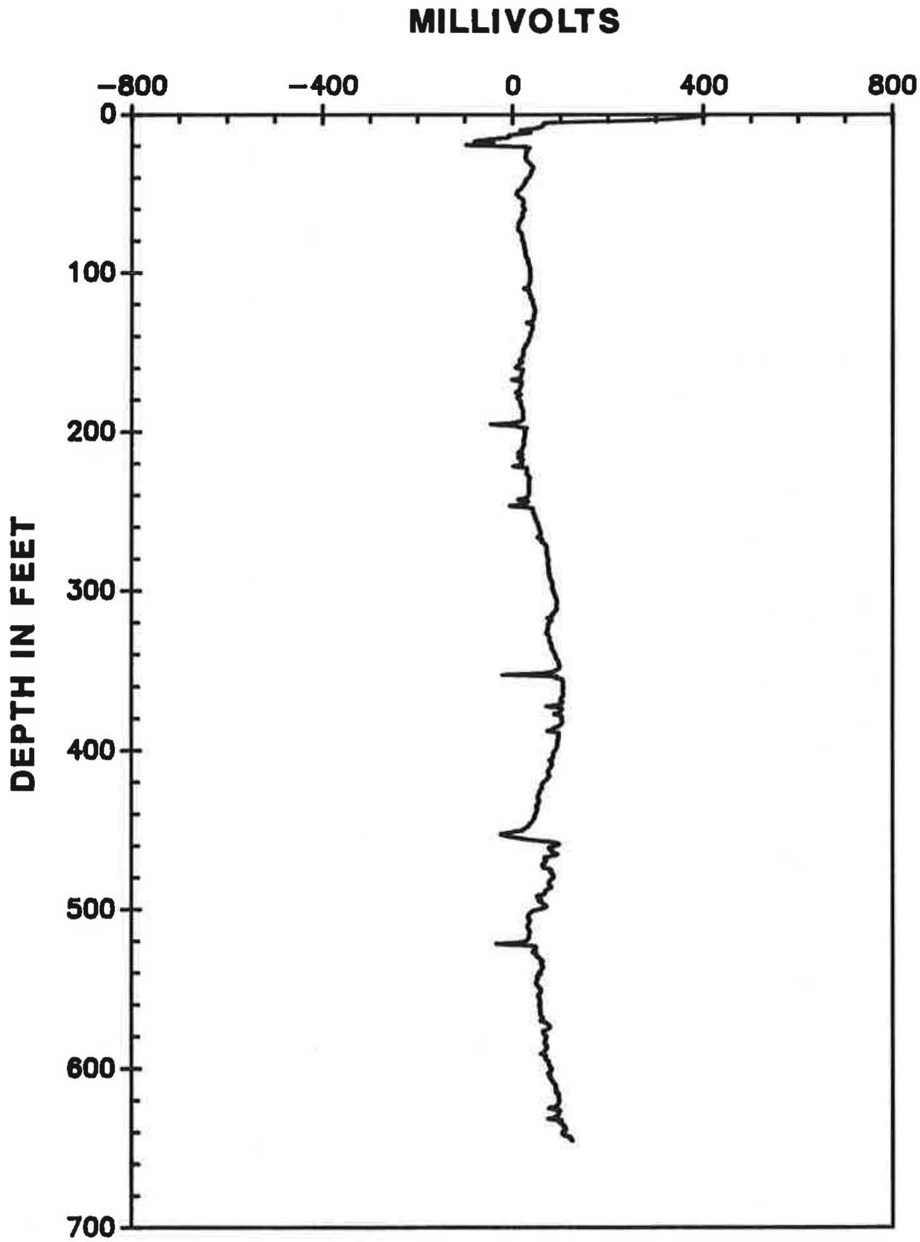


Figure 23. Spontaneous potential log of Colbert well 1A.

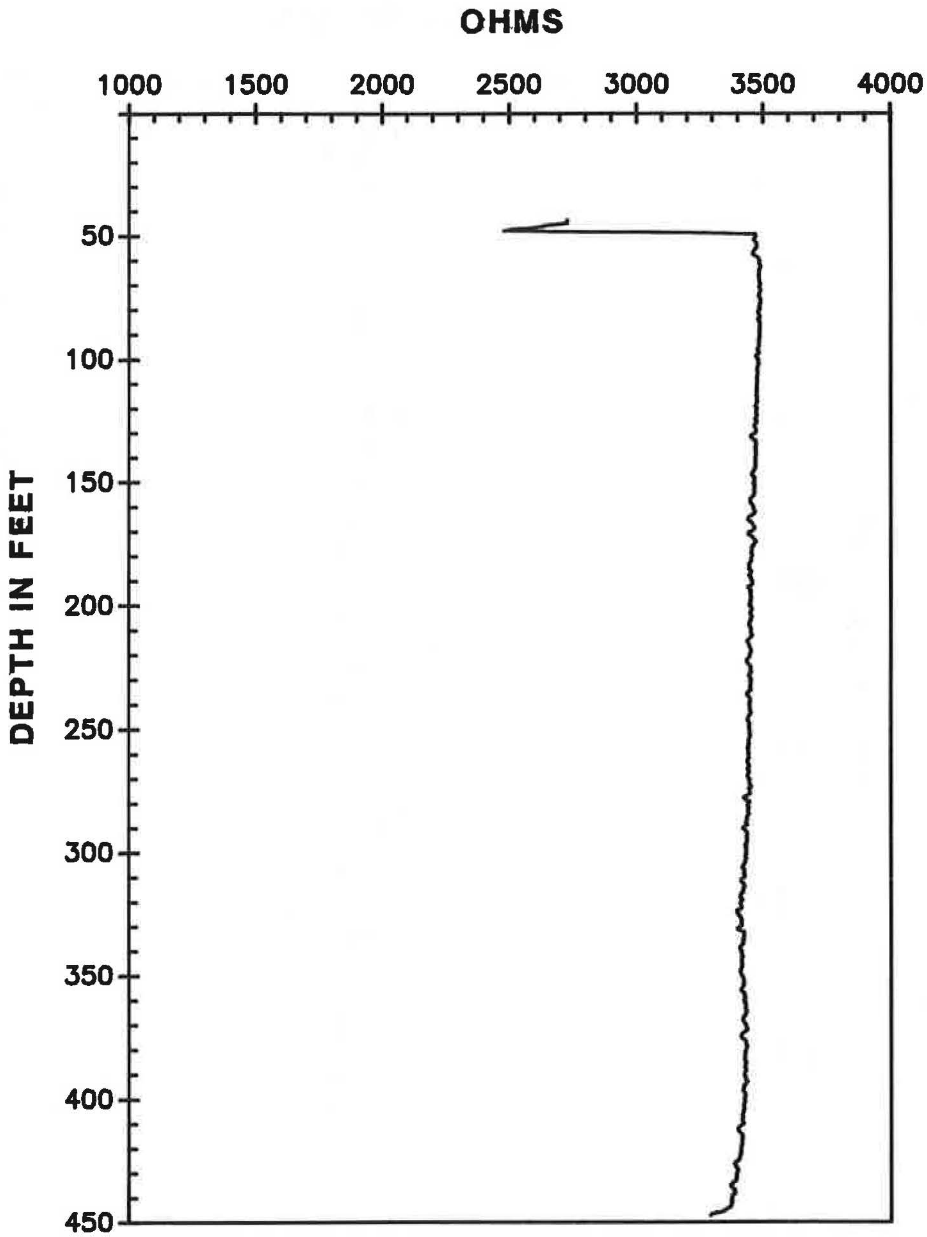


Figure 24. Single- point resistivity log of Colbert well 1A.

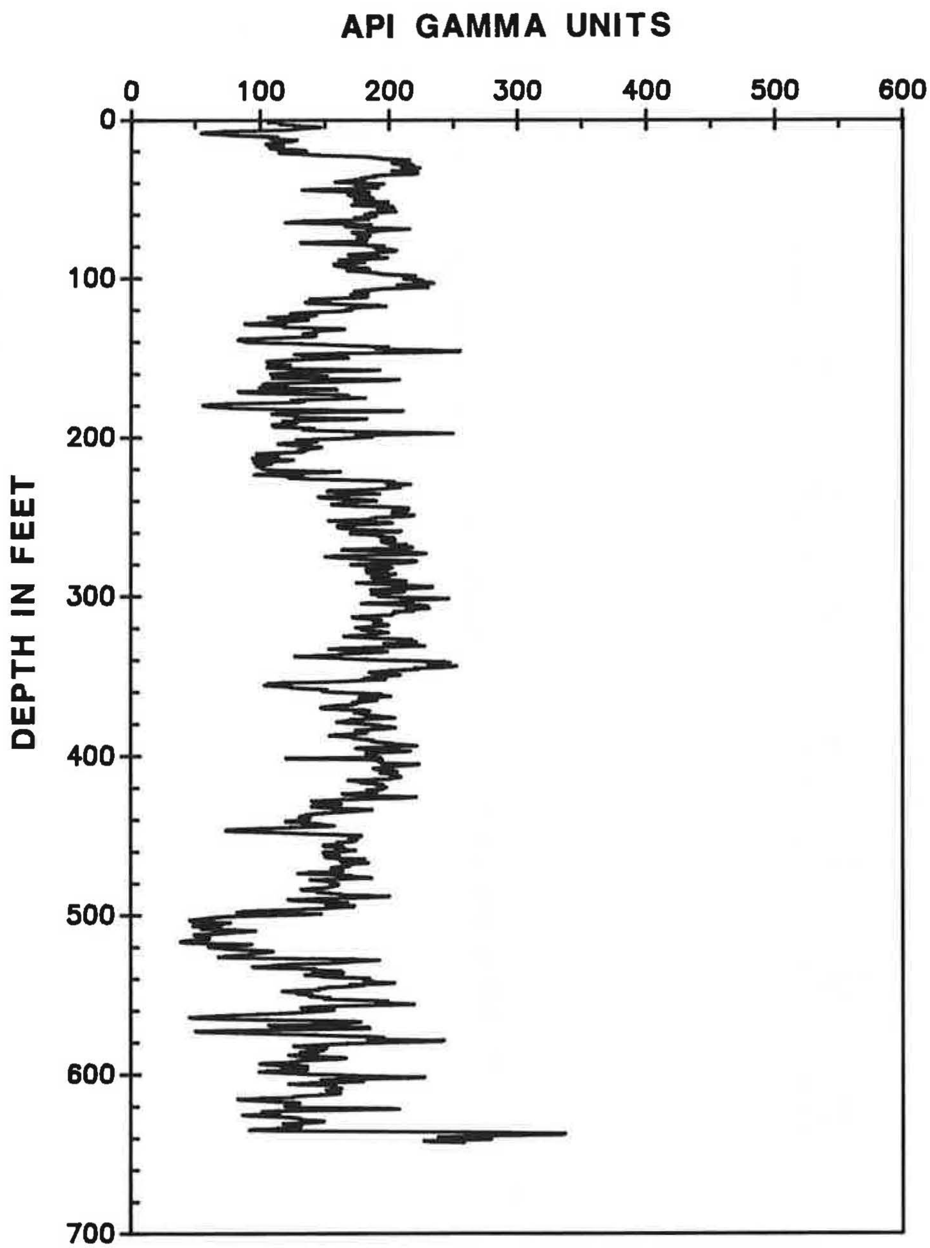


Figure 25. Natural gamma log of Colbert well 1A.

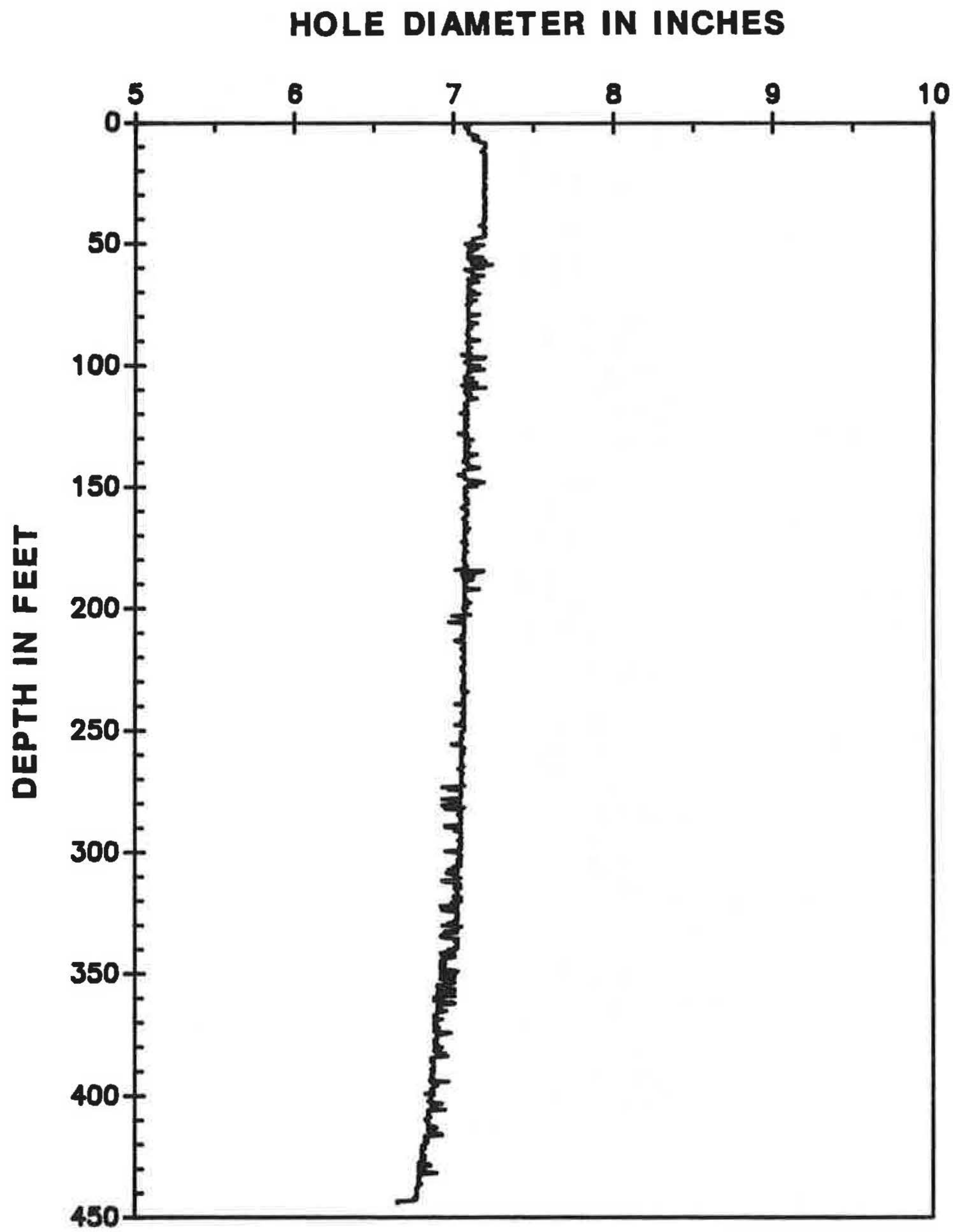


Figure 26. Caliper log of Colbert well 2.

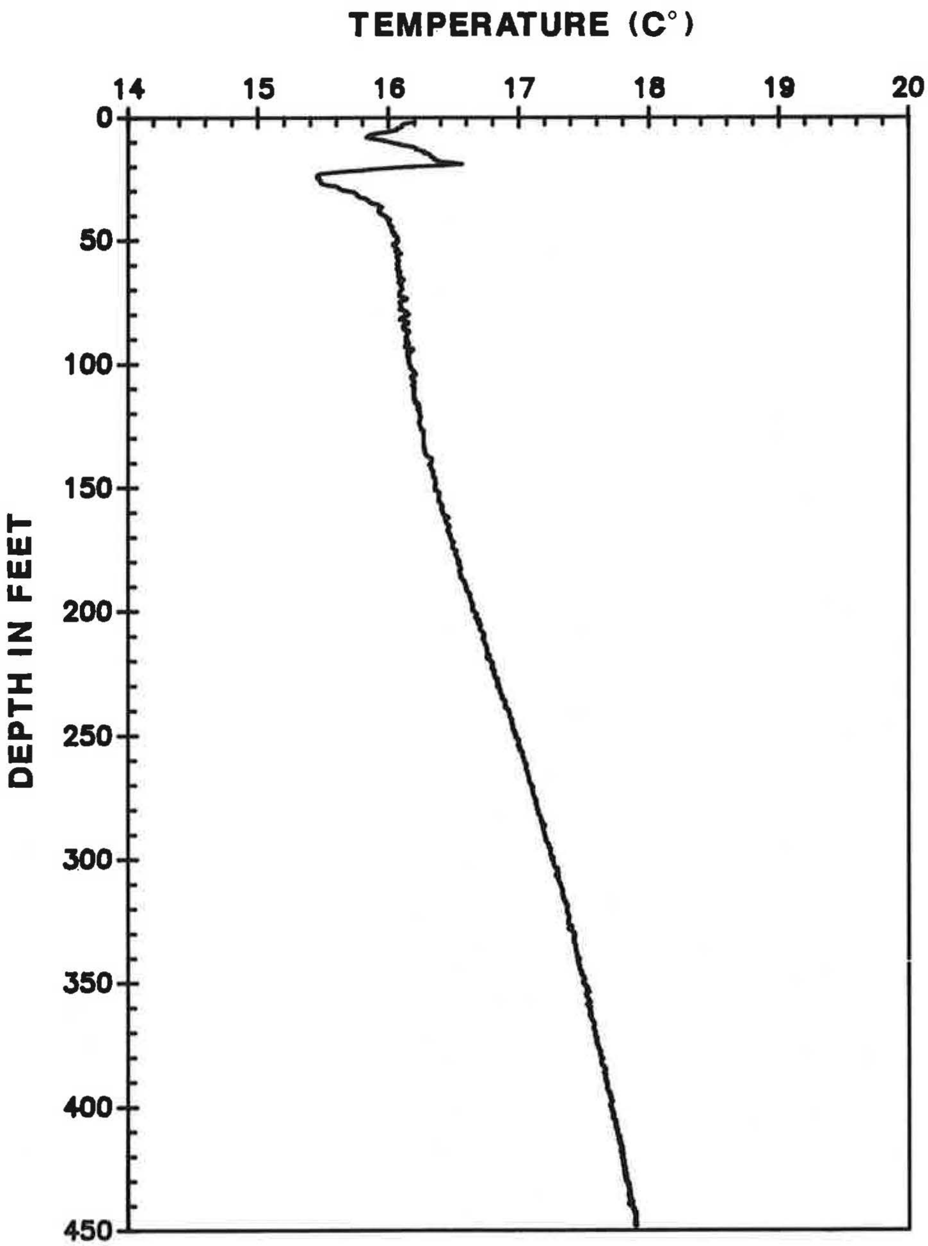


Figure 27. Temperature log of Colbert well 2.

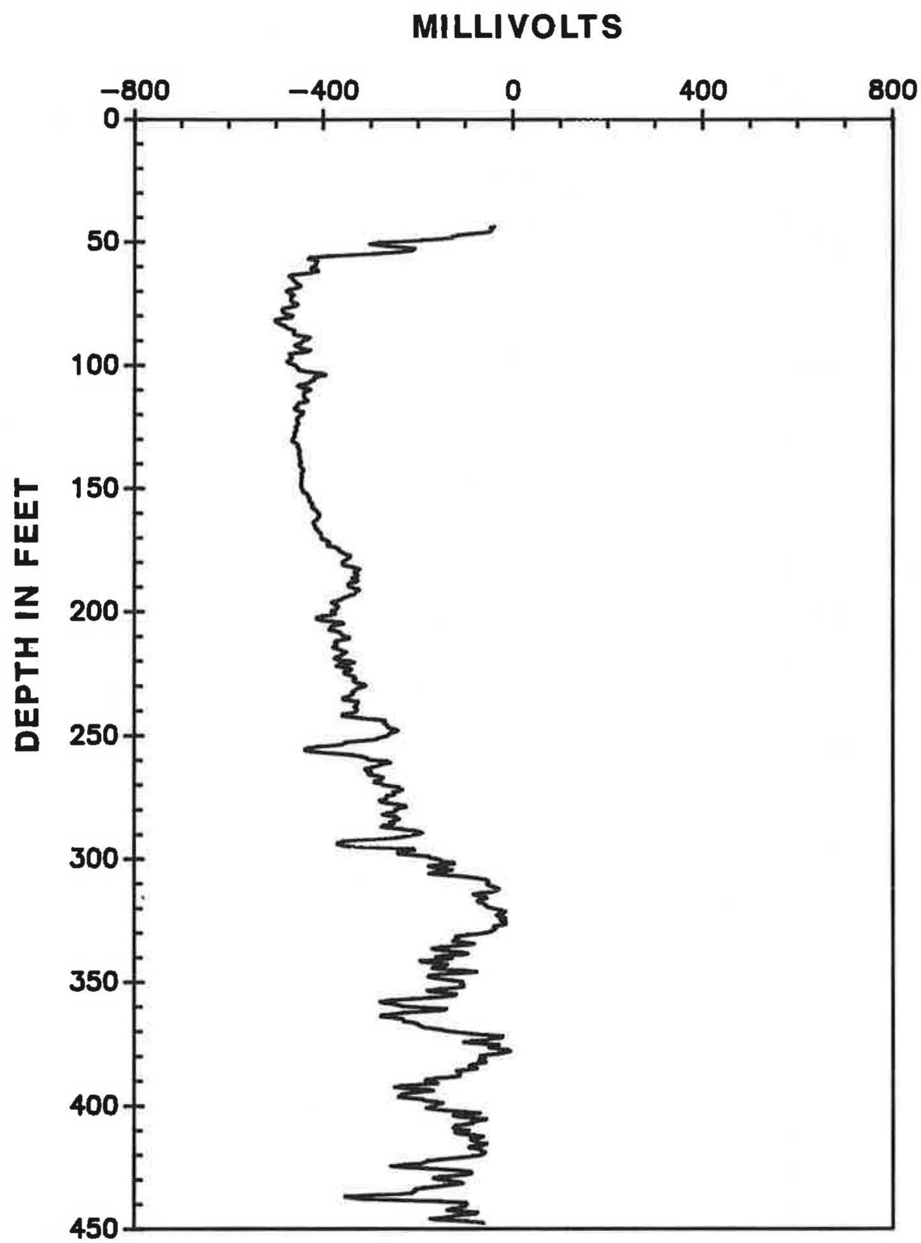


Figure 28. Spontaneous potential log of Colbert well 2.

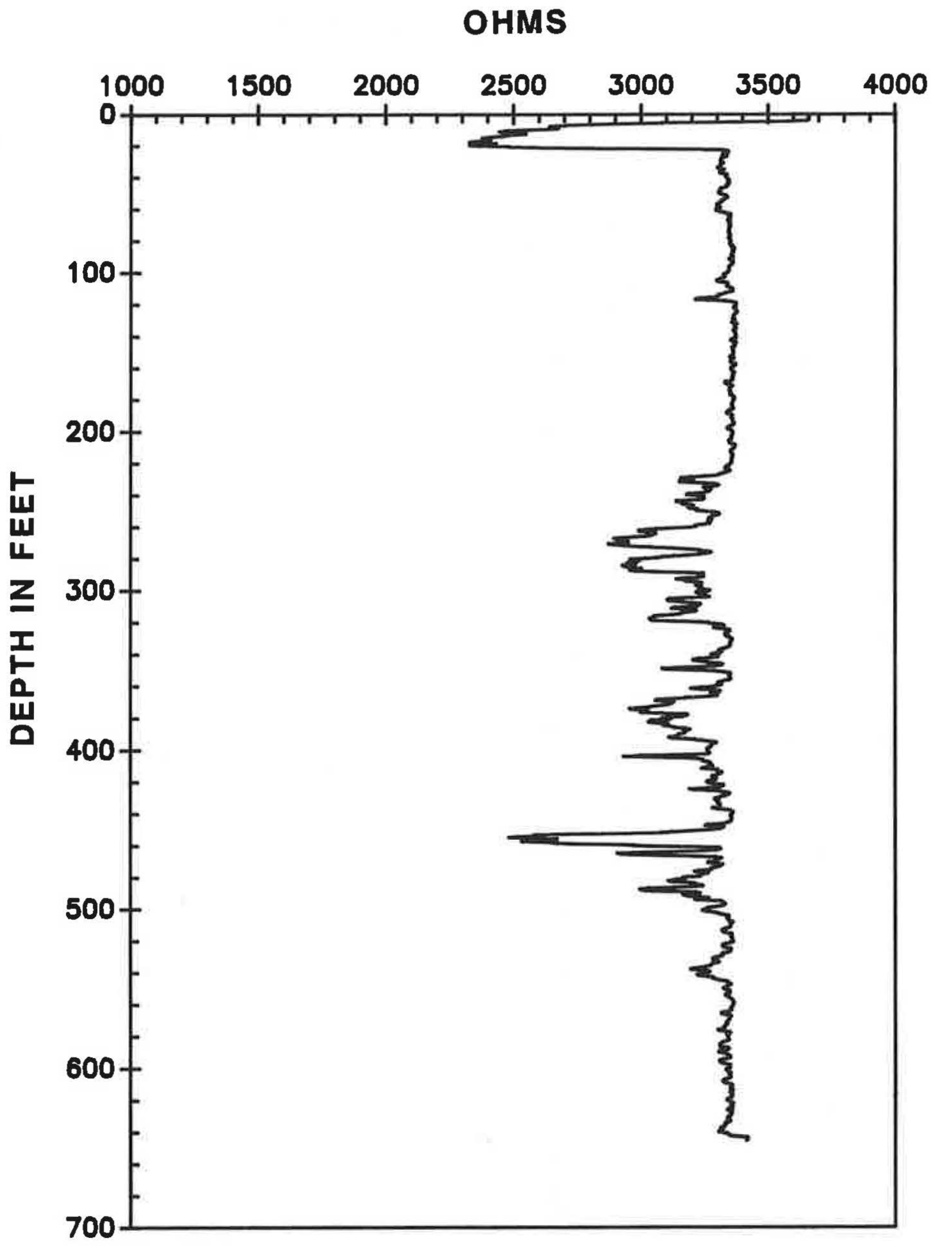


Figure 29. Single- point resistivity log of Colbert well 2.

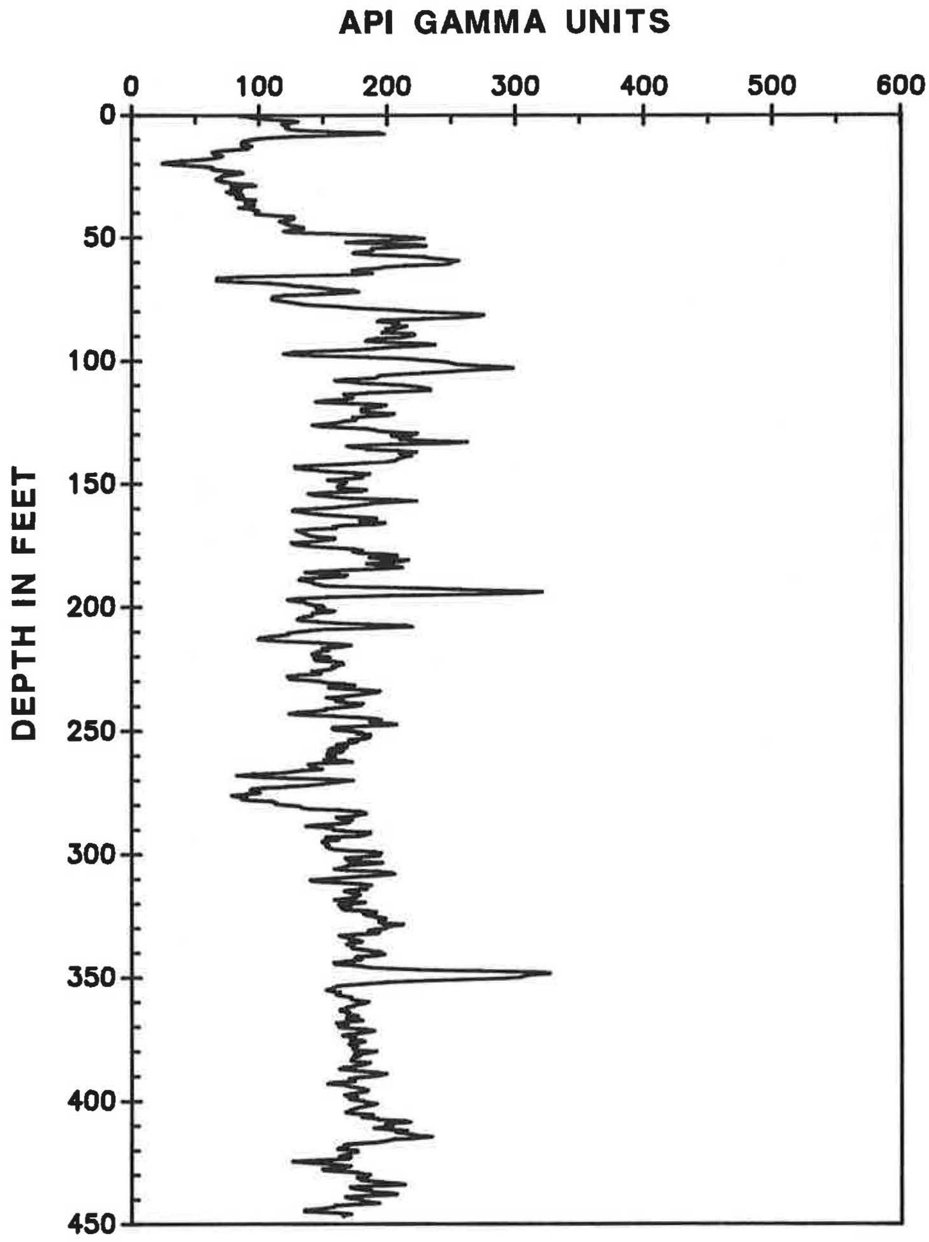


Figure 30. Natural gamma log of Colbert well 2.

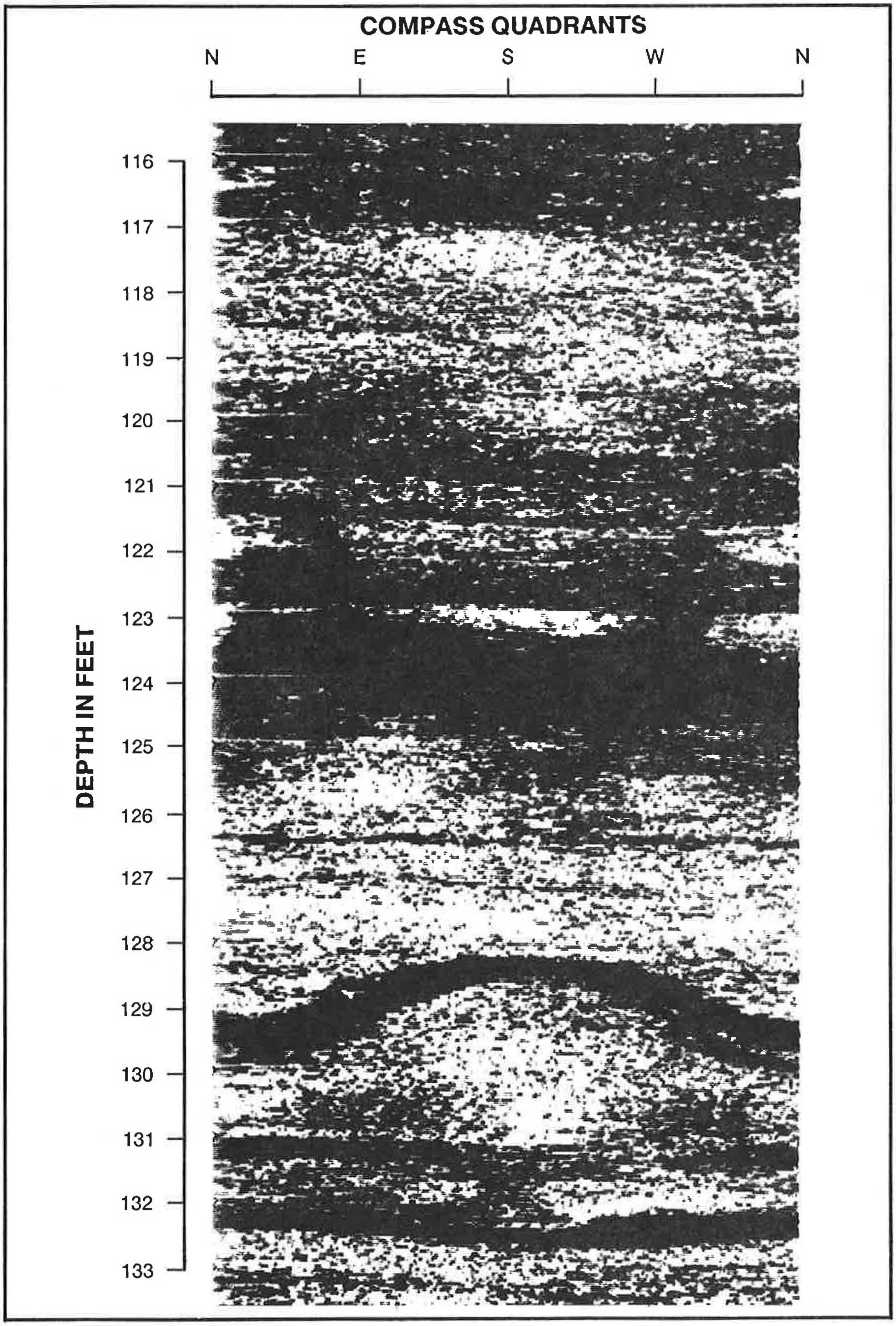


Figure 31. Sonic televiewer log of Colbert well 3, 116-133 ft.

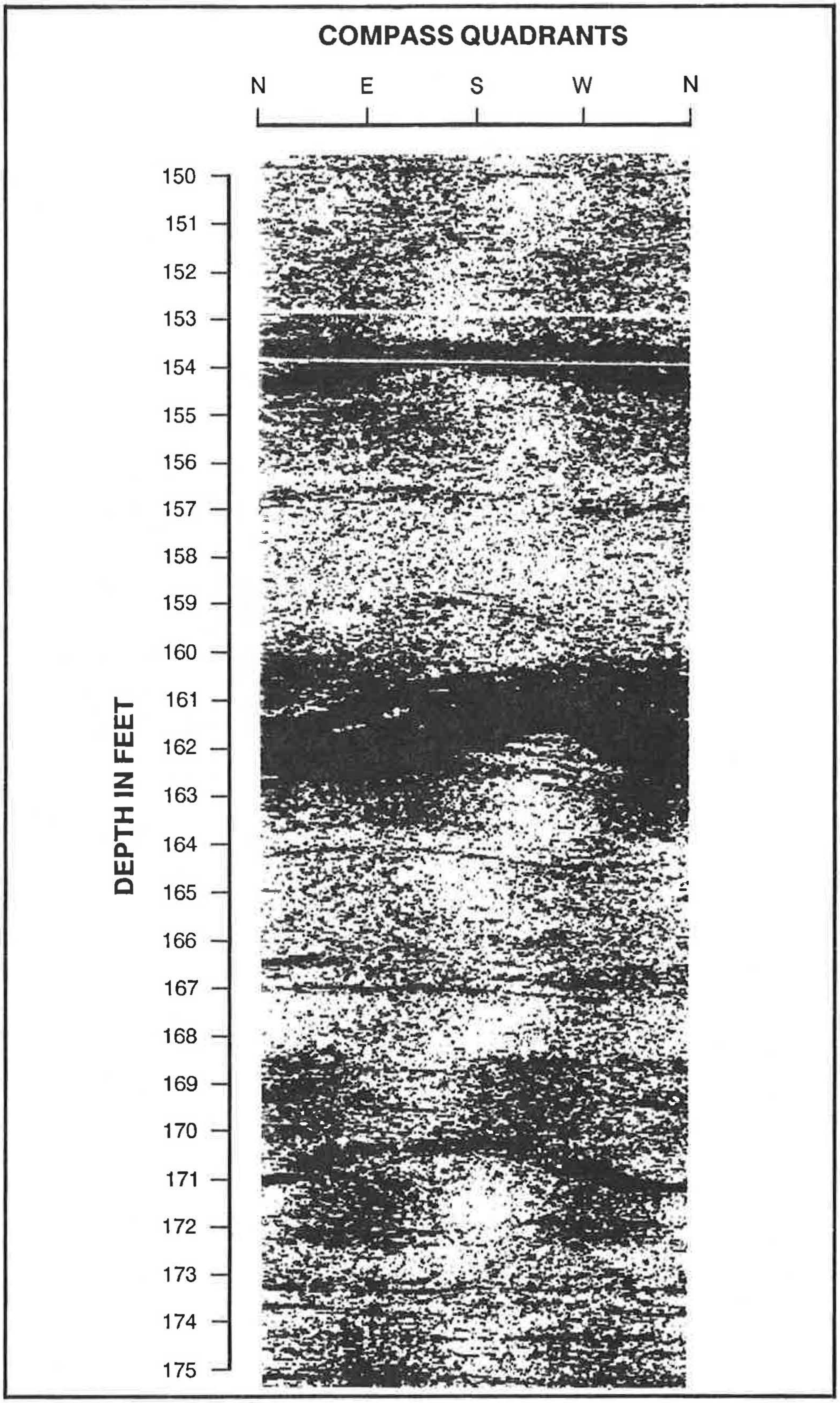


Figure 32. Sonic televiewer log of Colbert well 3, 150-175 ft.

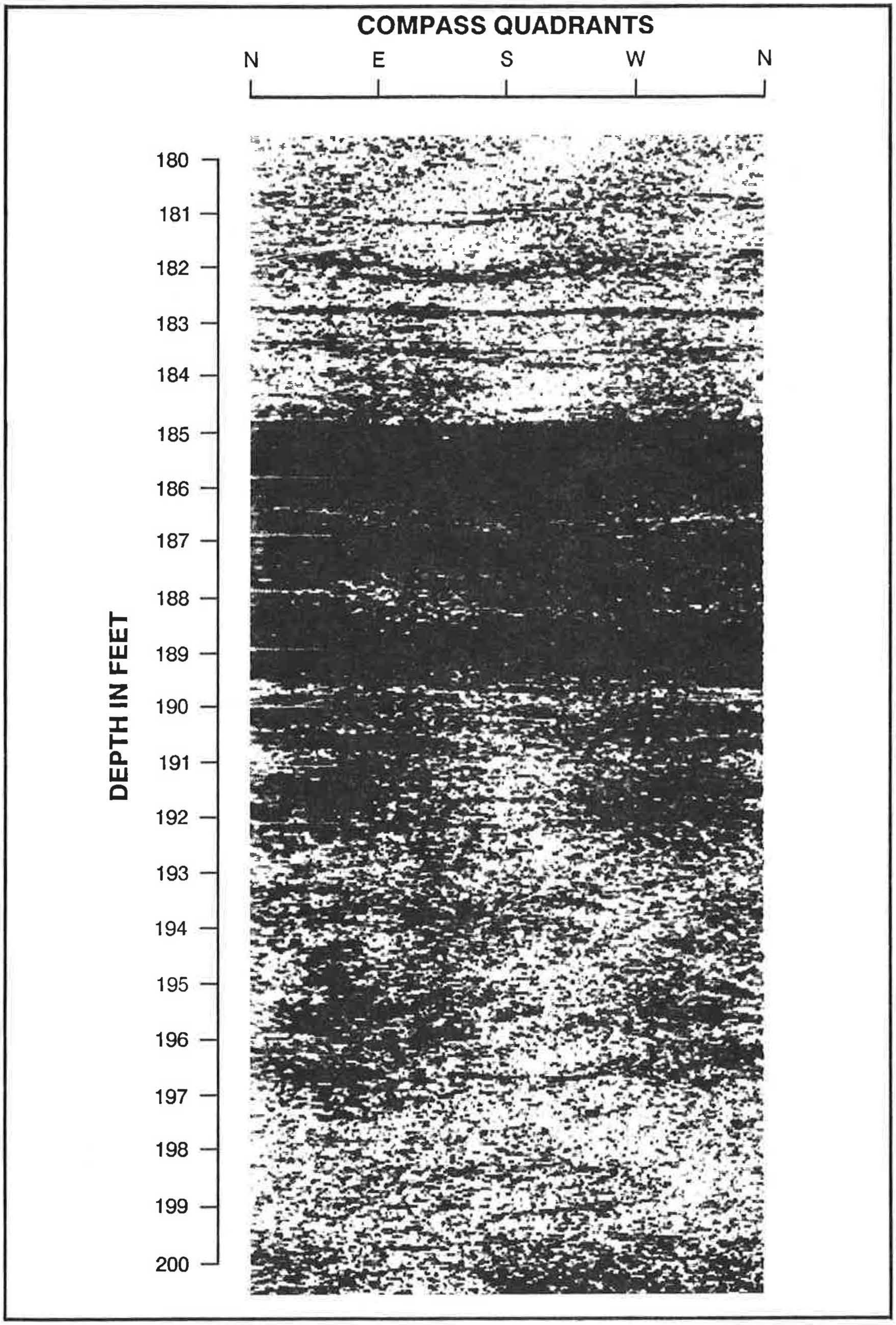


Figure 33. Sonic televiewer log of Colbert well 3, 180-200 ft.

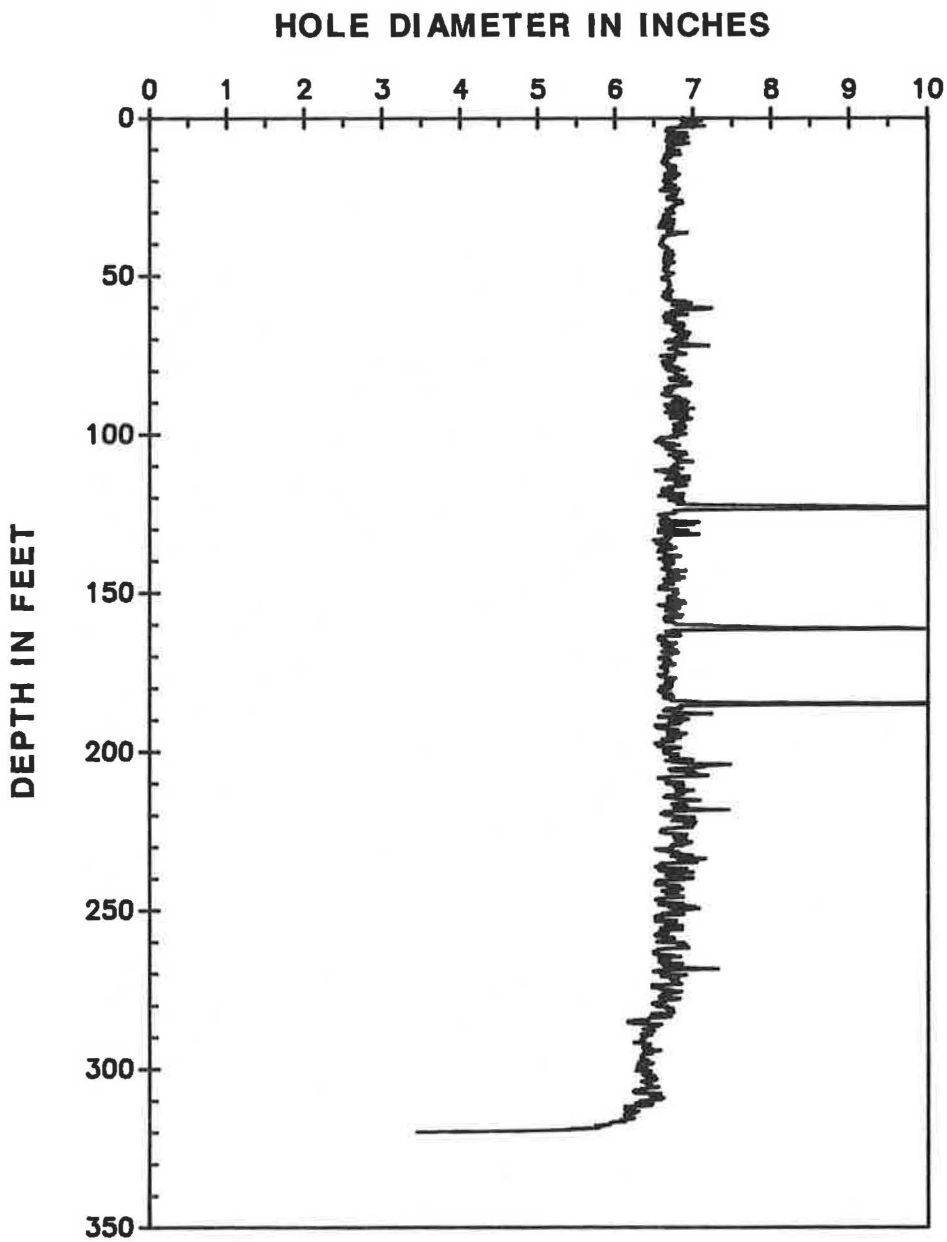


Figure 34. Caliper log of Colbert well 3.

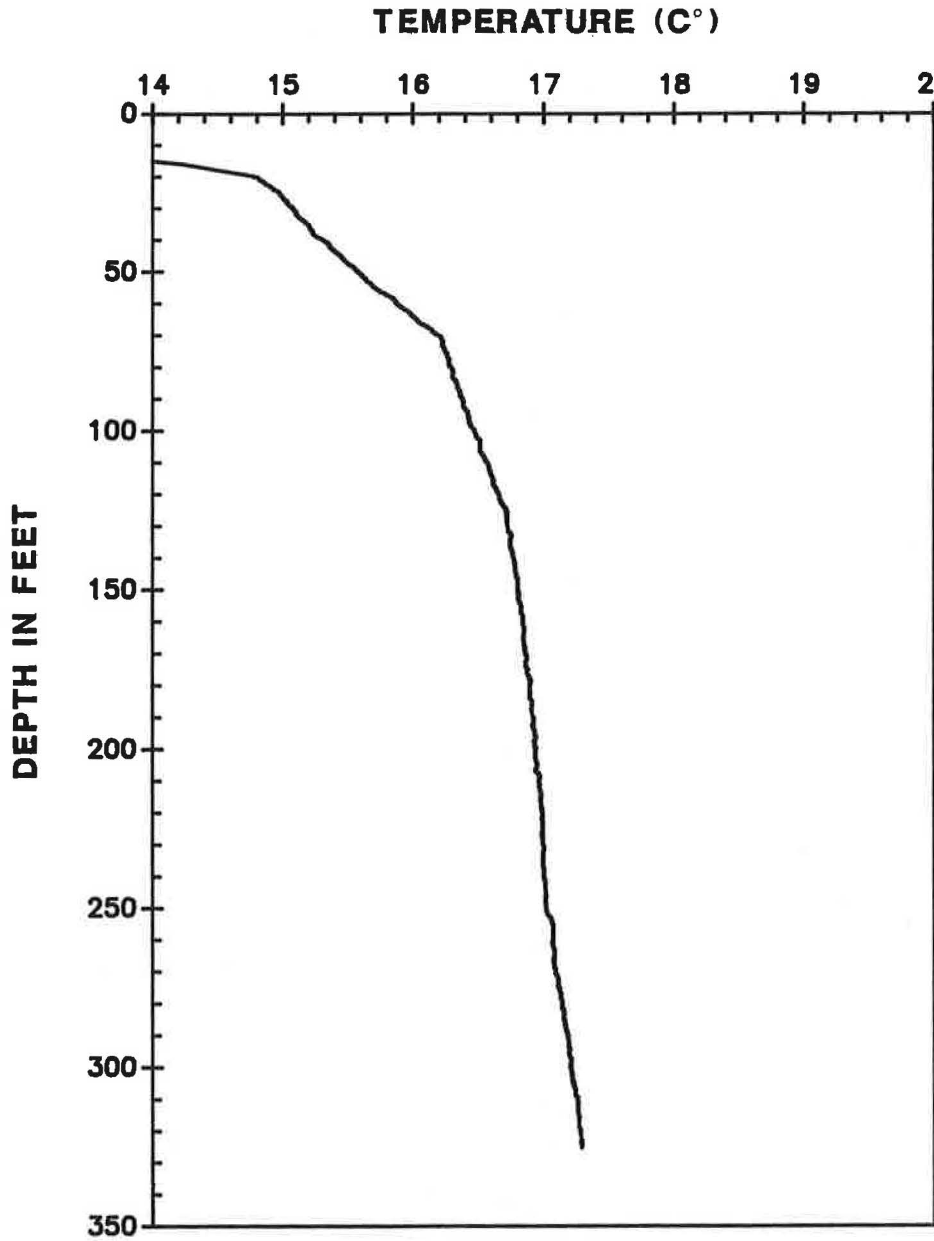


Figure 35. Temperature log of Colbert well 3.

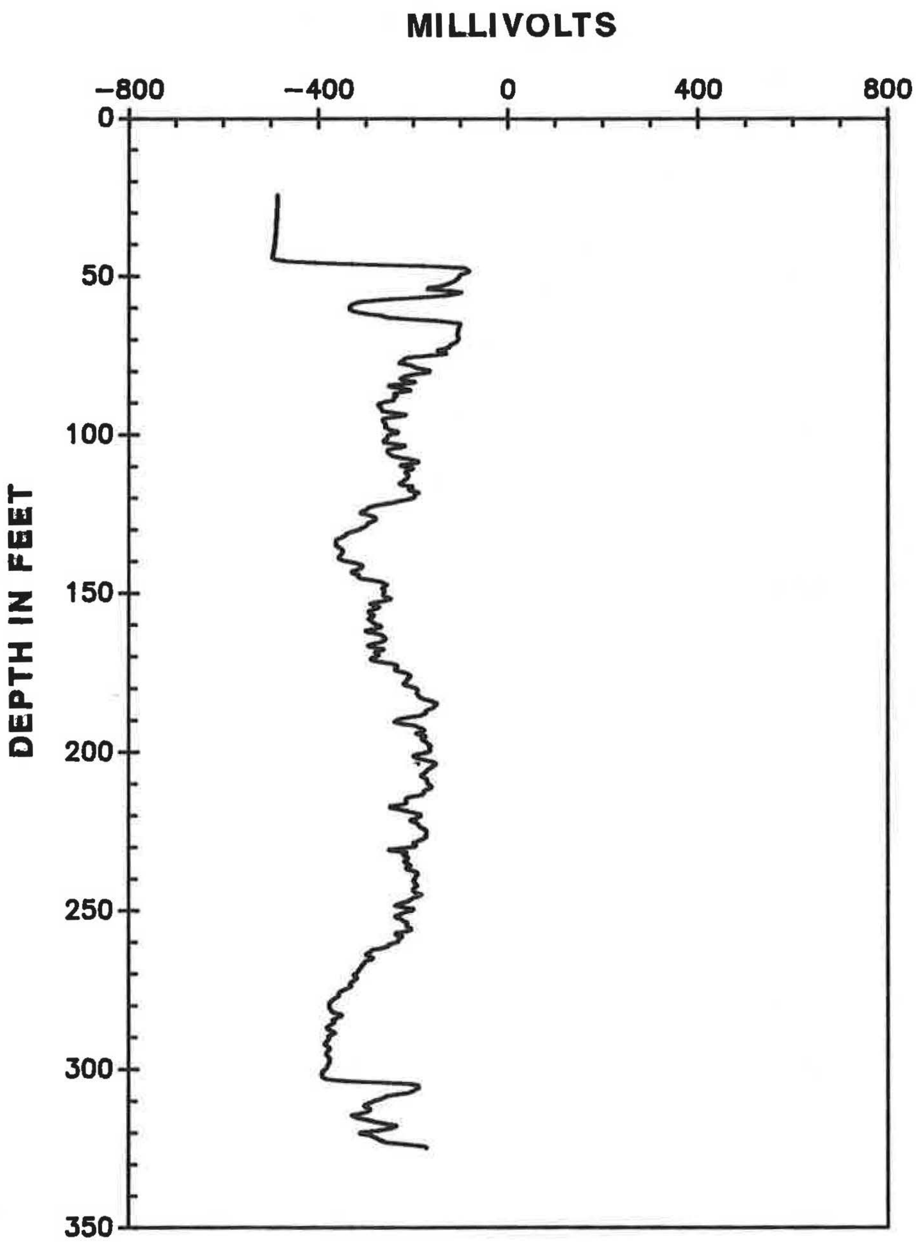


Figure 36. Spontaneous potential log of Colbert well 3.

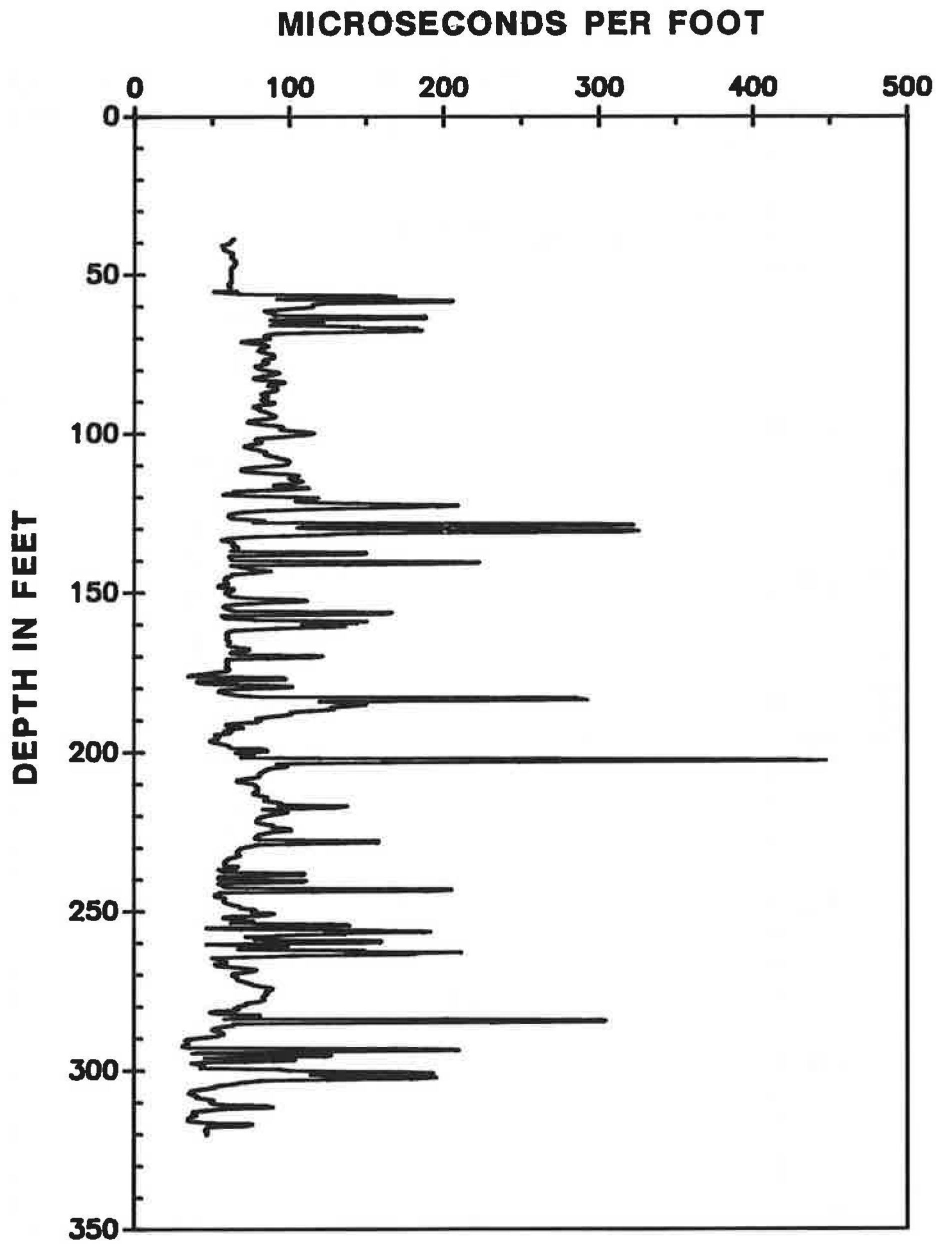


Figure 37. Acoustic velocity log of Colbert well 3.

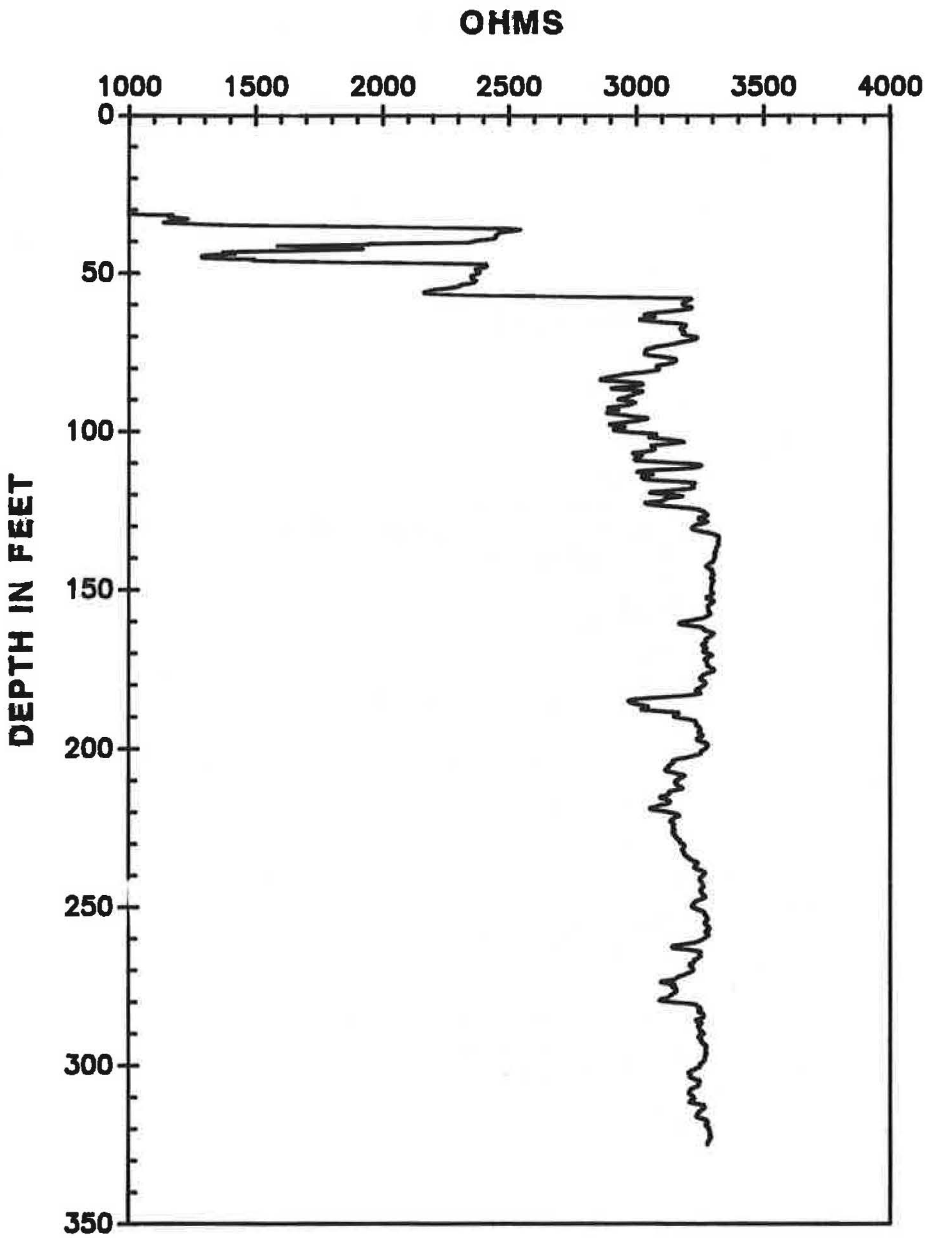


Figure 38. Single- point resistivity log of Colbert well 3.

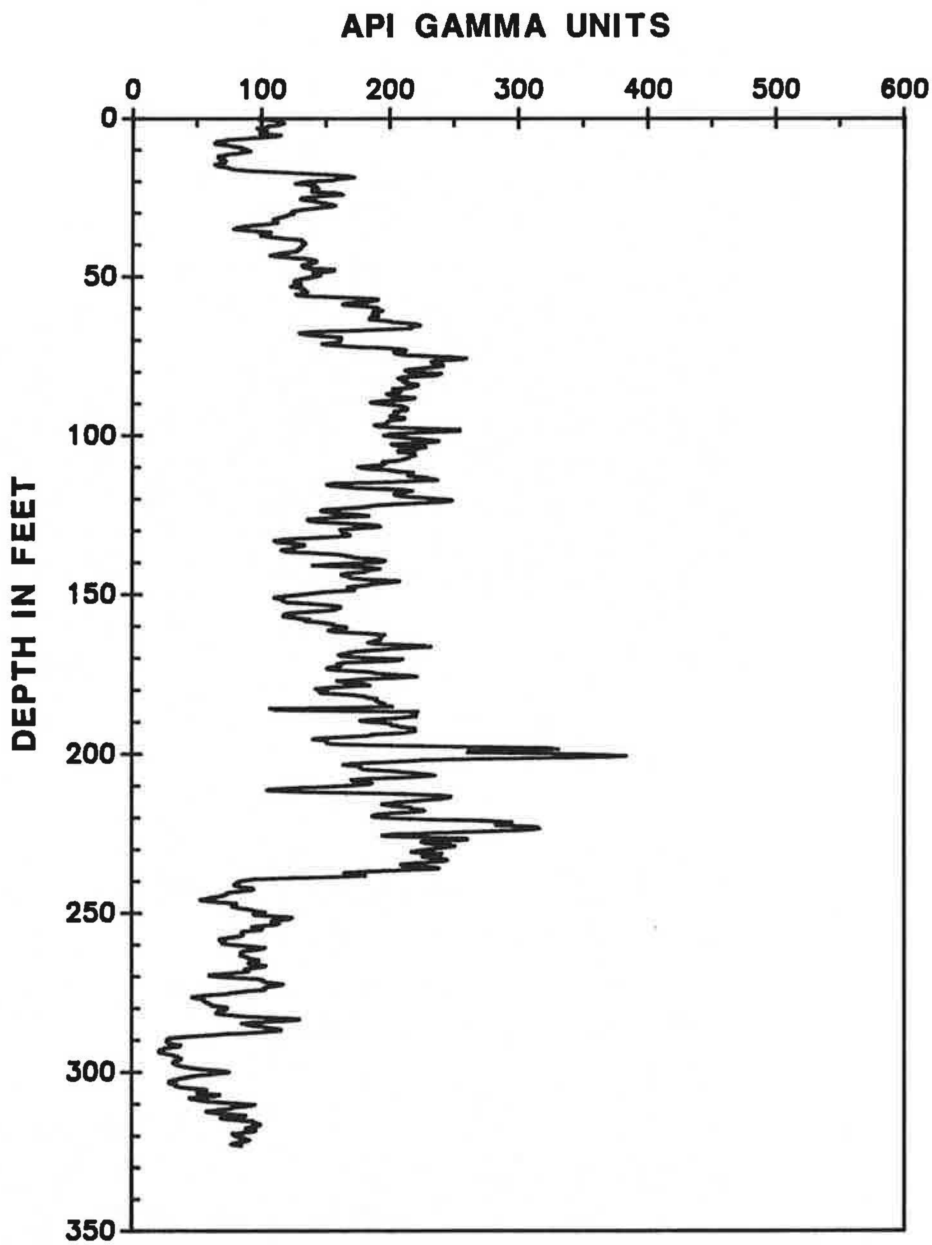


Figure 39. Natural gamma log of Colbert well 3.

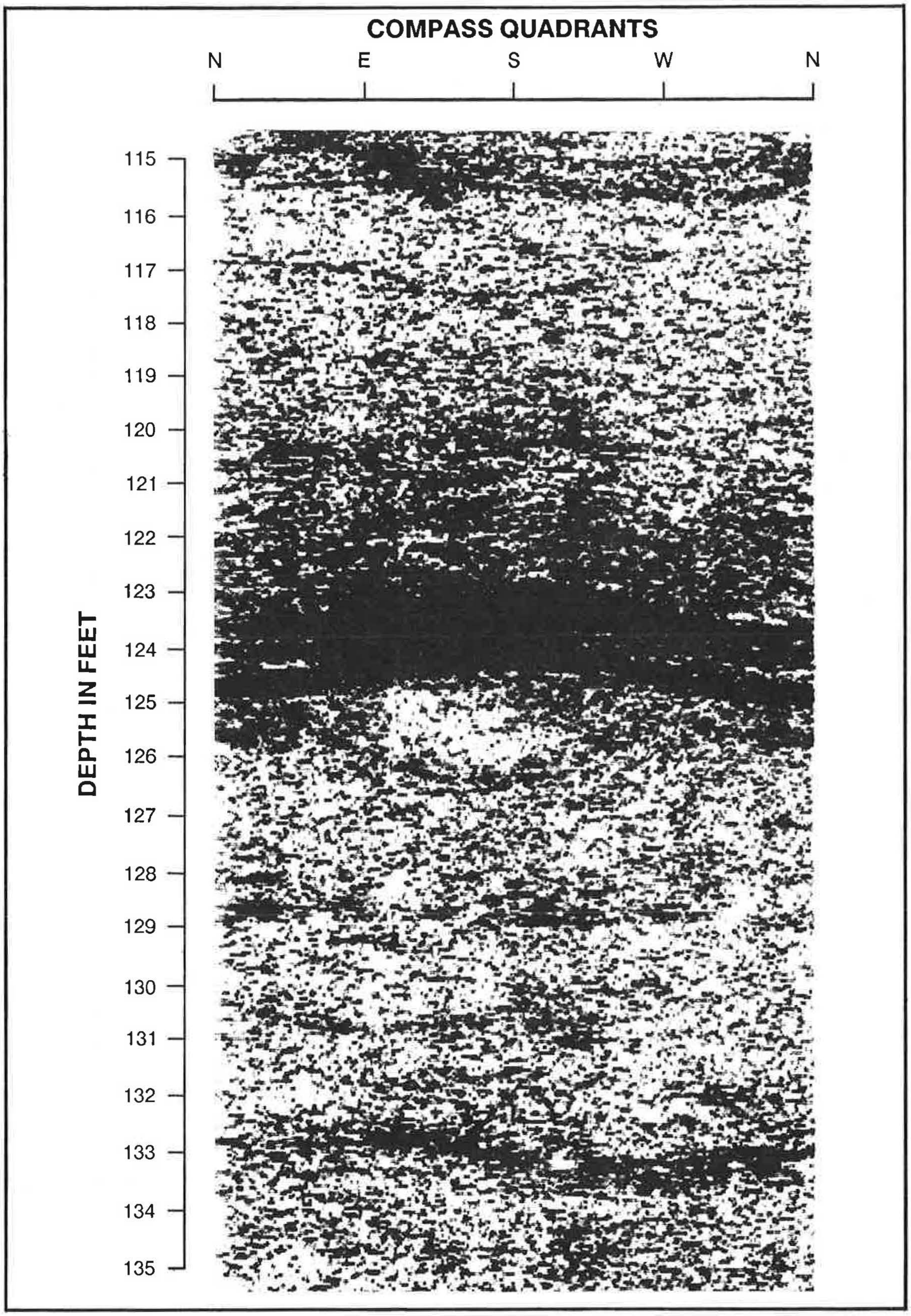


Figure 40. Sonic televiewer log of Colbert well 4, 115-135 ft.

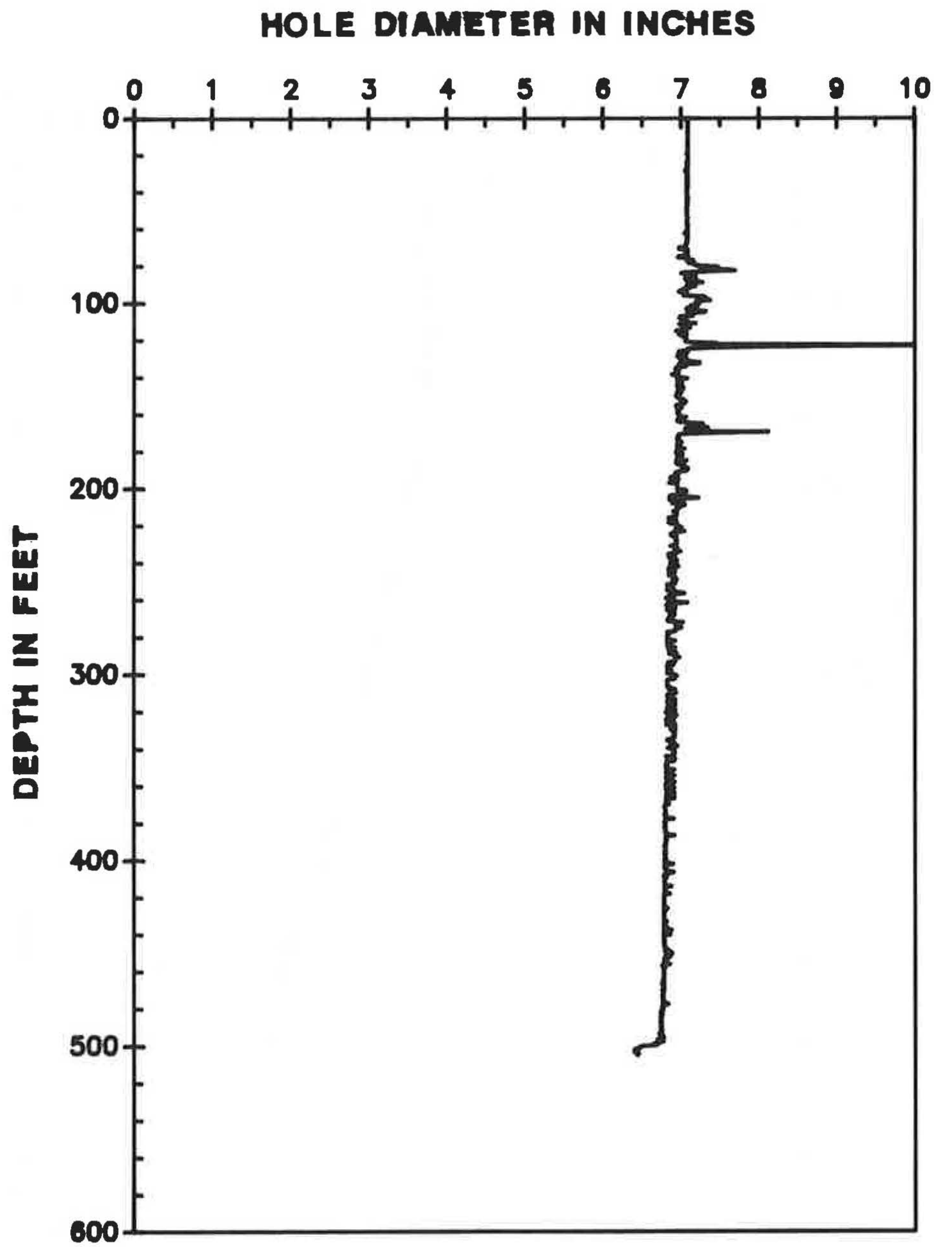


Figure 41. Caliper log of Colbert well 4.

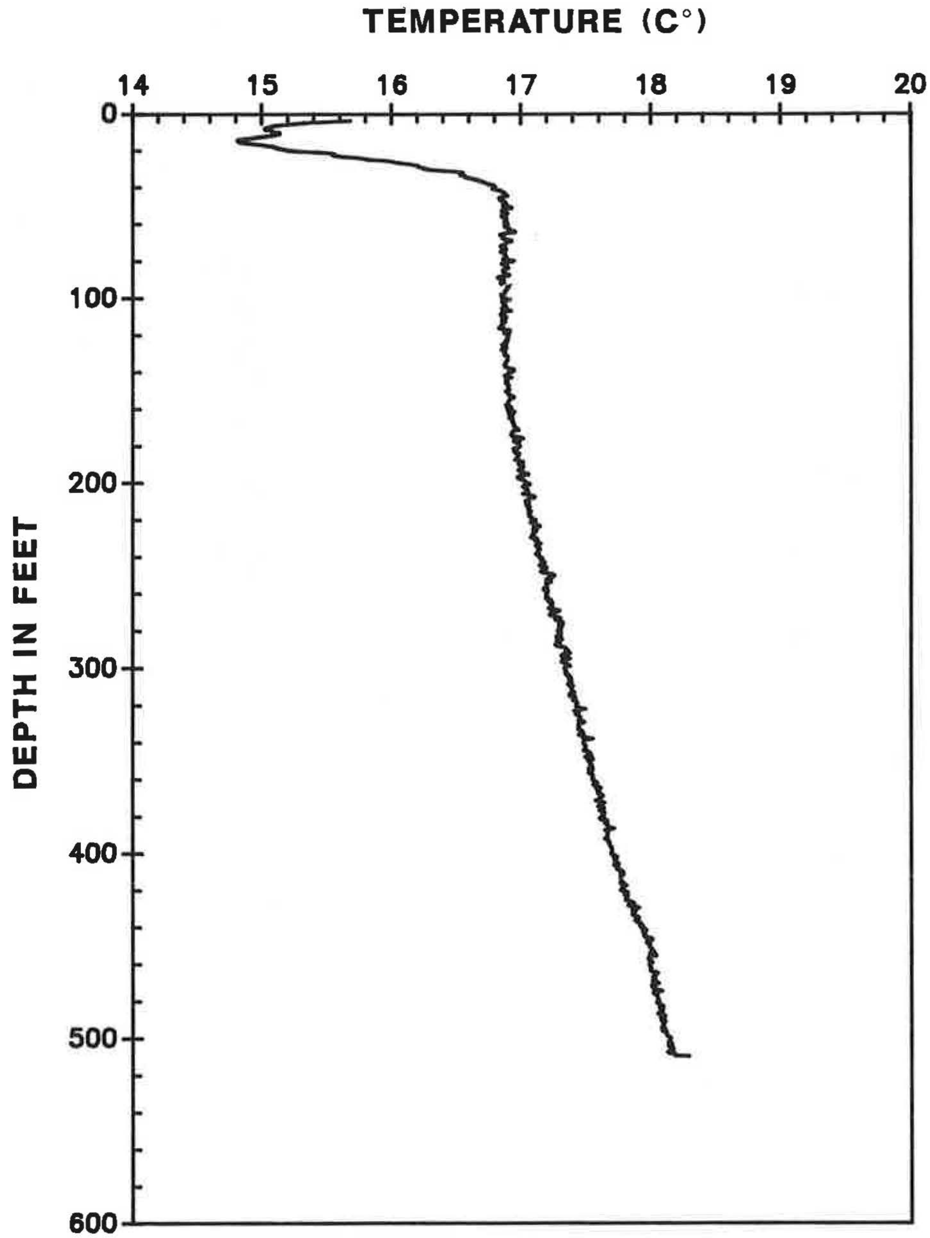


Figure 42. Temperature log of Colbert well 4.

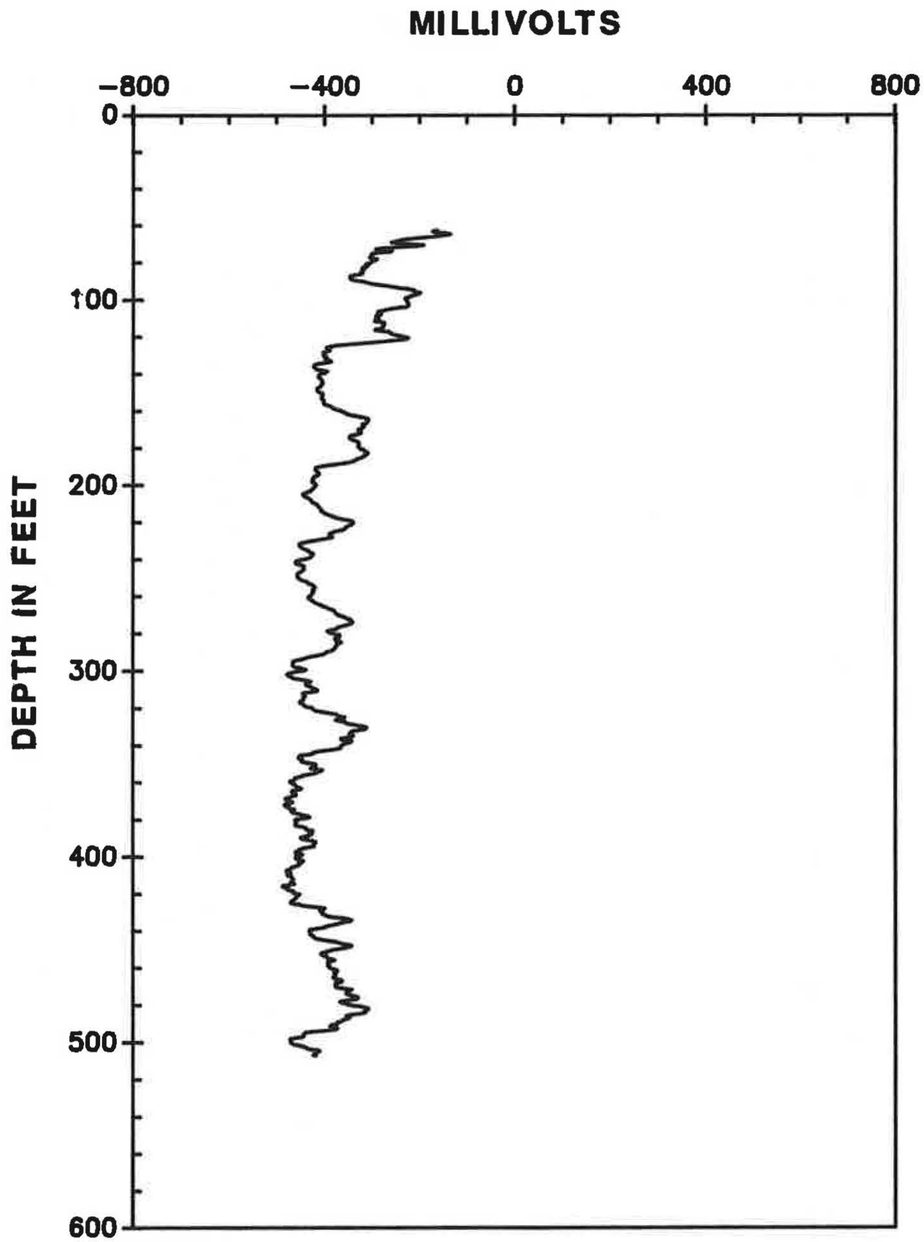


Figure 43. Spontaneous potential log of Colbert well 4.

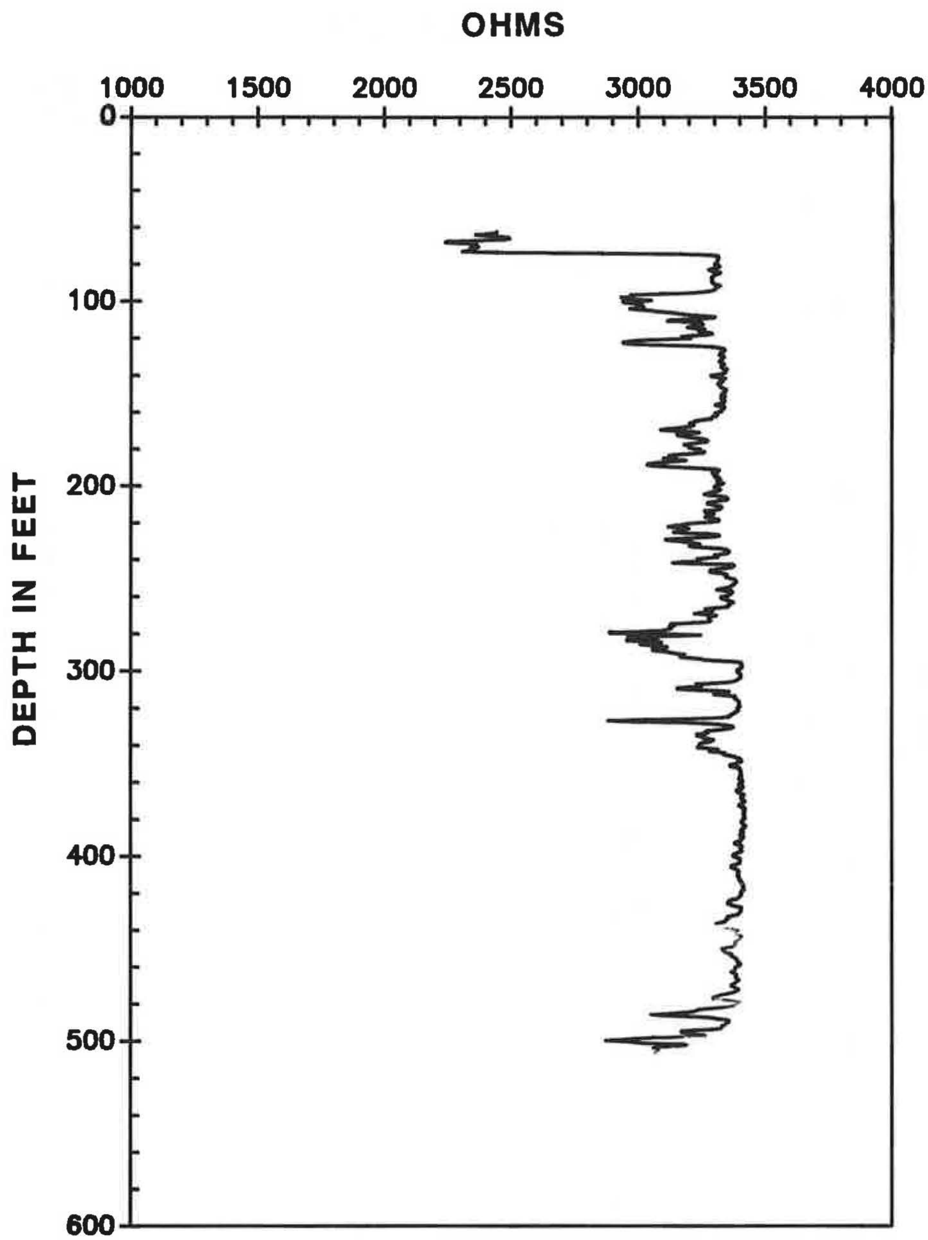


Figure 44. Single- point resistivity log of Colbert well 4.

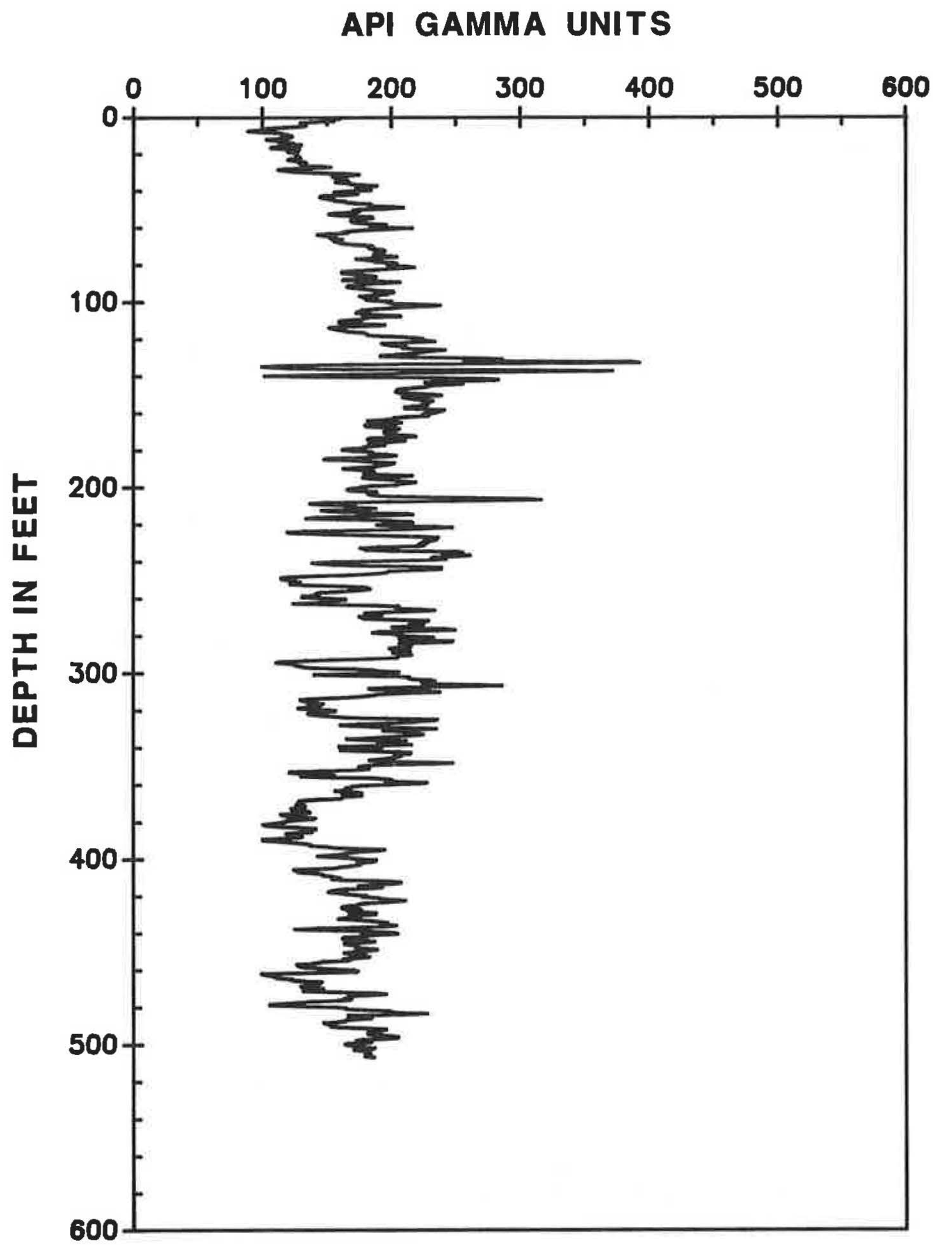


Figure 45. Natural gamma log of Colbert well 4.

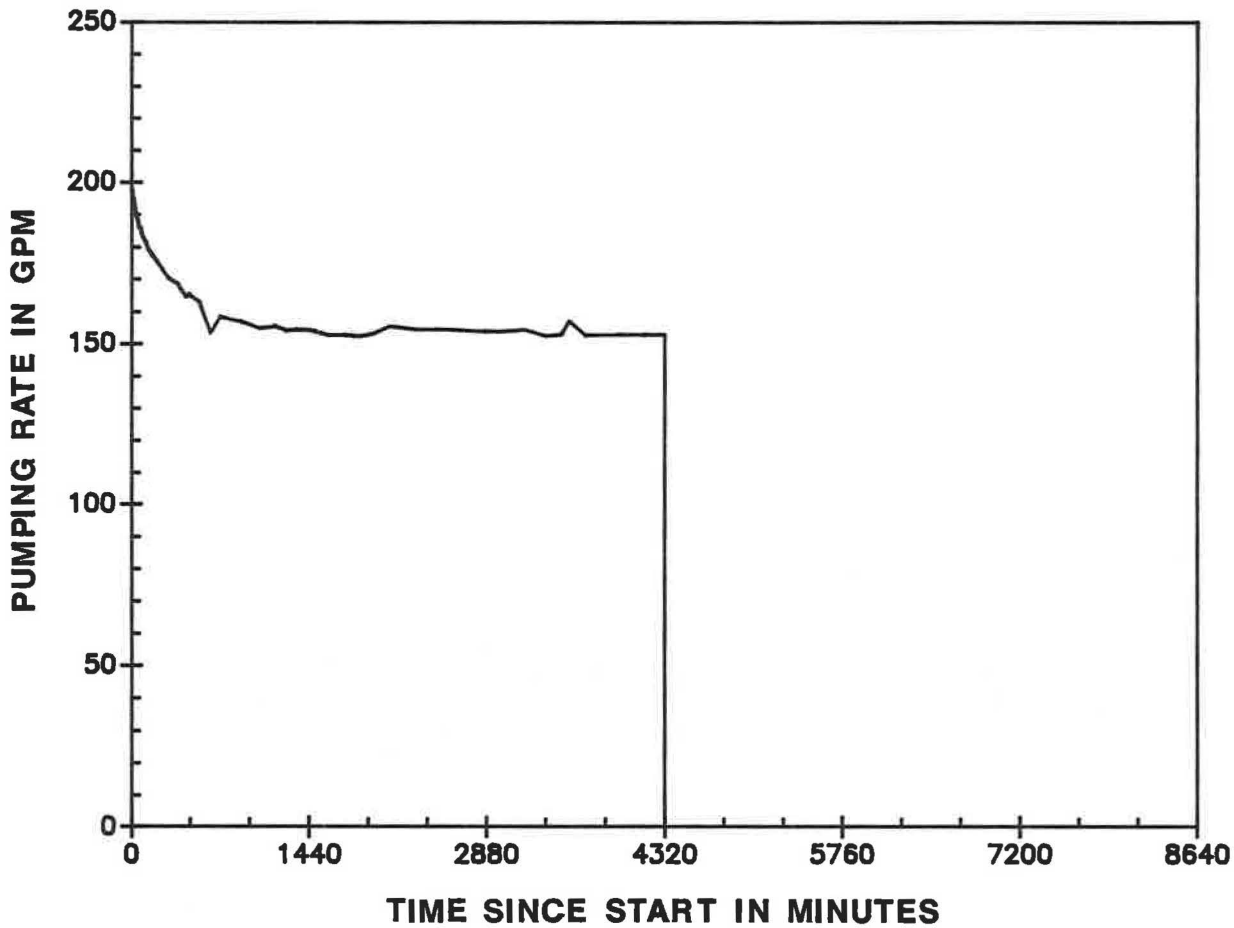


Figure 46. Pumping rate during test of Colbert well 2.

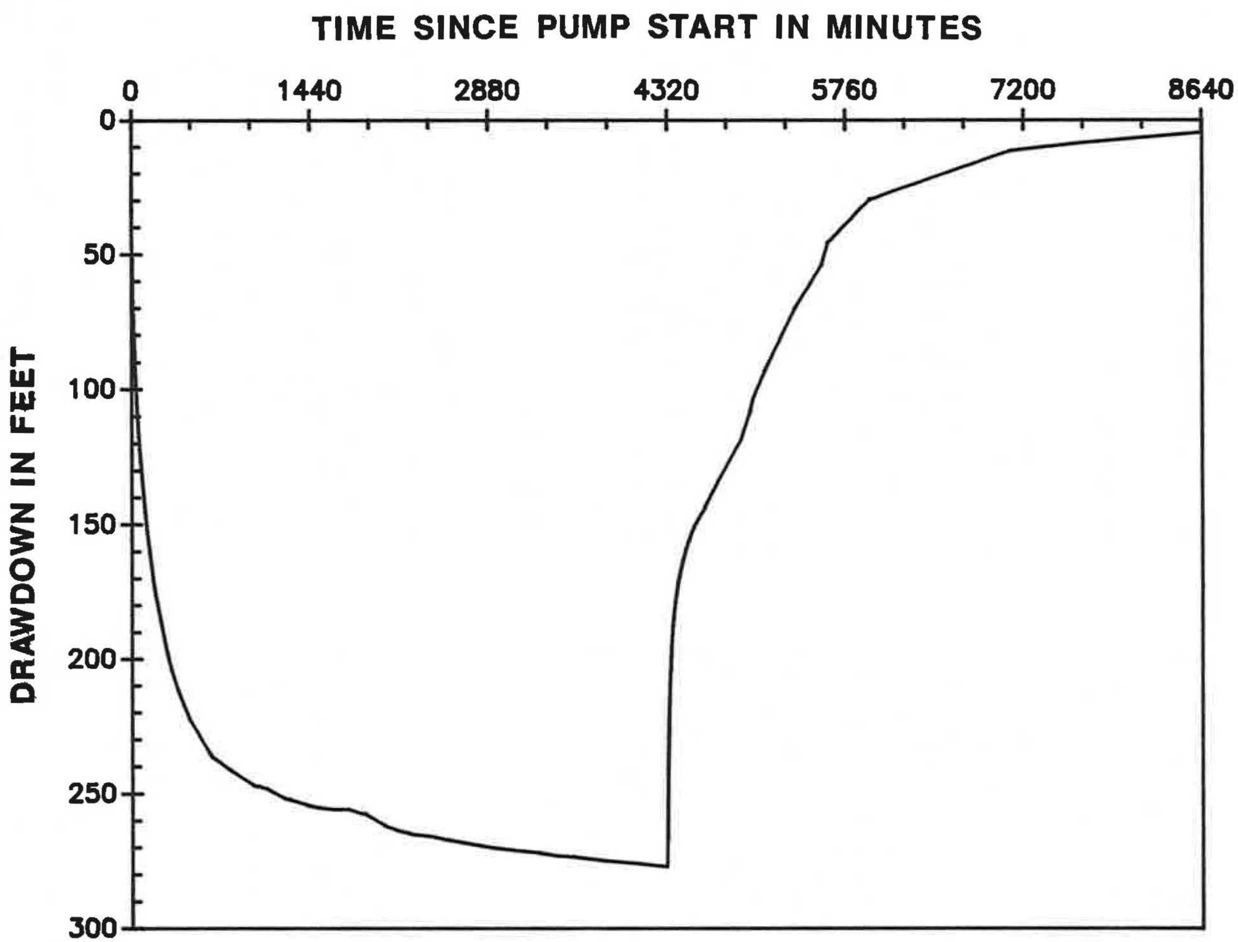


Figure 47. Drawdown and recovery curves for Colbert well 2.

output by the generator caused minor fluctuations in the pumping rate (Fig. 48). Discharge directed into the flood plain of the creek, 15 feet from the well, flowed away from the well. Rapid drawdown in well 3, noted during the first hours of testing, quickly transitioned into relative stability (Fig. 49). The total drawdown was 117 ft for a pumping rate of 210 gpm. The fluctuations in drawdown match fluctuations in the pumping rate. The water level in test well 3 rose rapidly during the first hours of the recovery period, followed by a short transition into a slow final recovery.

Discharge was directed onto the floodplain of a nearby perennial stream during a 24-hour stress test conducted on Colbert well 4. The pump maintained a rate of 83 gpm for most of the test period with a total drawdown of 66 ft recorded. Two major fluctuations in the pumping rate did occur during the test, however (Fig. 50). A truck severed the power line to the pump 230 minutes into the test. At the end of the test period, the driller requested that the well capacity be tested under a simulated water-system load. With the well at maximum drawdown, the pumping rate was varied in order to emulate well capacity at varying head values. Drawdown and recovery observed in the pumped well plot as asymmetrical and irregular curves (Fig. 51).

SUMMARY

Three wells sited for the city of Colbert by the Geologic Survey were selected on structural and topographic criteria. The three wells (wells 1, 2, and 3) produced yields of 15, 153, and 210 gpm, respectively. Two additional wells, sited and drilled, by the contractor produced yields of 10 and 83 gpm.

Well 3 penetrated numerous discontinuities which are parallel or subparallel to foliations and joints mapped in the Colbert area. This well produced the highest yield of the Colbert wells (210 gpm) suggesting that enhanced recharge may be available through the numerous discontinuities noted in the well bore.

DAWSONVILLE, DAWSON COUNTY

INTRODUCTION

Dawsonville is located in central Dawson County (Fig. 1) which lies in the Dahlonega Upland District of the Blue Ridge Physiographic Province (Clark and Zisa, 1976). The Geologic Survey selected a site for a new Dawsonville municipal water well at the request of the city. The Geologic Survey conducted a 24-hour constant rate pumping test on a well drilled on this site. No geophysical studies were carried out at the Dawsonville well site.

WELL SITING

The most productive of Dawsonville's previously drilled wells was located in a topographic low, at the intersection of two streams. A similar topographic situation was sought as the location for the new well. An examination of the Dawsonville area indicated that a northwest structural trend with a vertical dip was the most frequent in the area (Fig. 52). The Geologic Survey selected the new well site (well 4) at the intersection of a northwest-trending valley and a northeasterly trending valley oriented parallel to compositional layering. The well site is topographically low and is located in a large drainage basin.

GEOLOGY

Valleys near the Dawsonville well site are narrow and v-shaped and appear to be structurally controlled (Fig. 52). Ridge tops are narrow and irregular in shape. Most streams have rectangular or trellis drainage patterns, but the larger streams have dendritic drainage patterns. Relief in the study area is approximately 300 ft. Stream valley segments near Dawsonville are oriented N50°W, N44°W, N22°W, and N32°E.

Three mappable rock units occur in the study area. All three strike northeast and dip southeast. These are:

1) A unit containing mica schist, biotite gneiss, and amphibolite. These rocks consist of a coarse-grained tan- to purple-colored mica schist saprolite and coarse-grained tan to yellow-brown biotite gneiss and quartz-rich gneiss saprolite. The mica schist is interlayered with the biotite gneiss on a 1-2 ft scale. The mica schist locally contains thin layers of ocher-colored amphibolite saprolite.

2) A unit characterized by button mica schist and biotite gneiss. This unit consists of a coarse-grained tan to purple garnet bearing

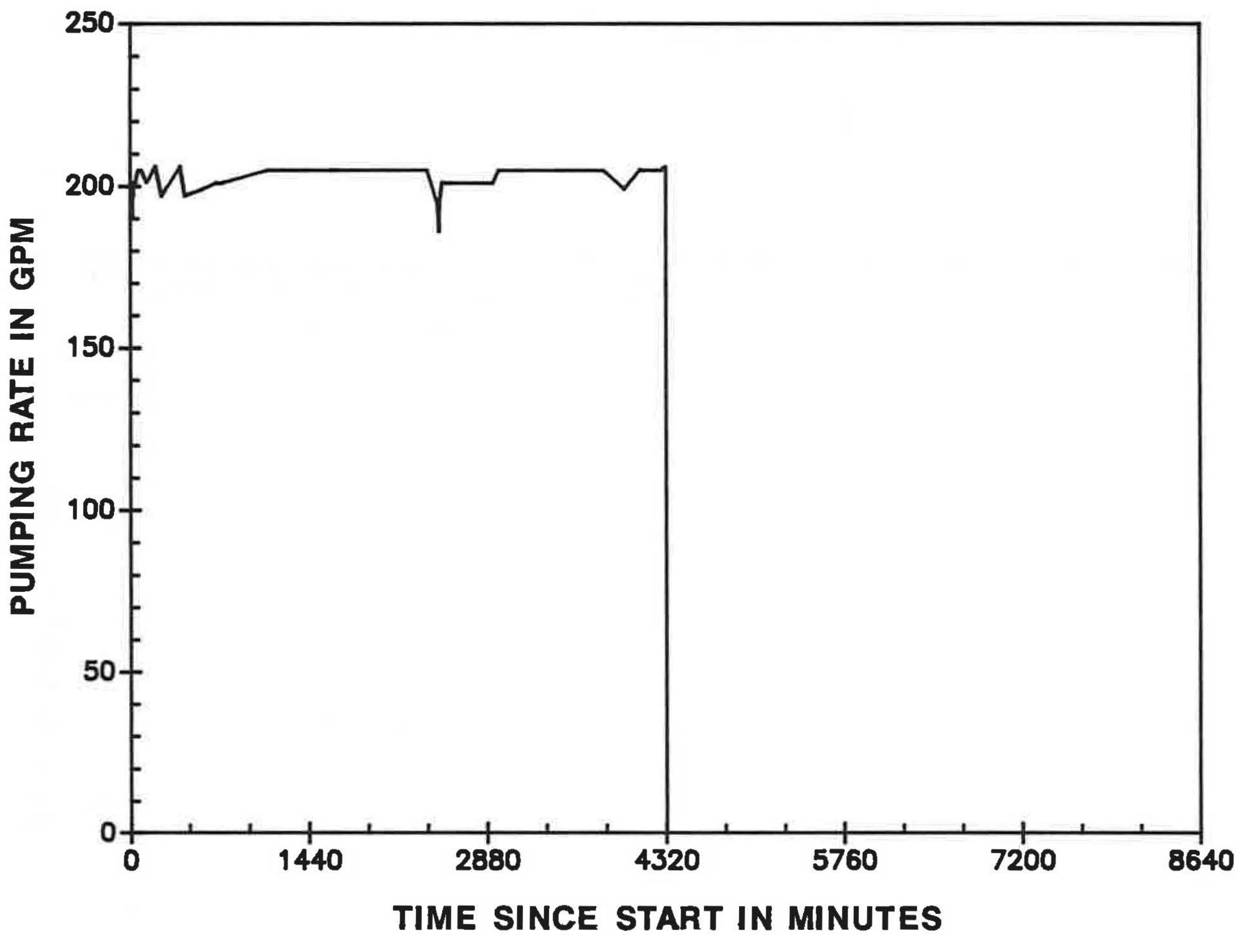


Figure 48. Pumping rate during test of Colbert well 3.

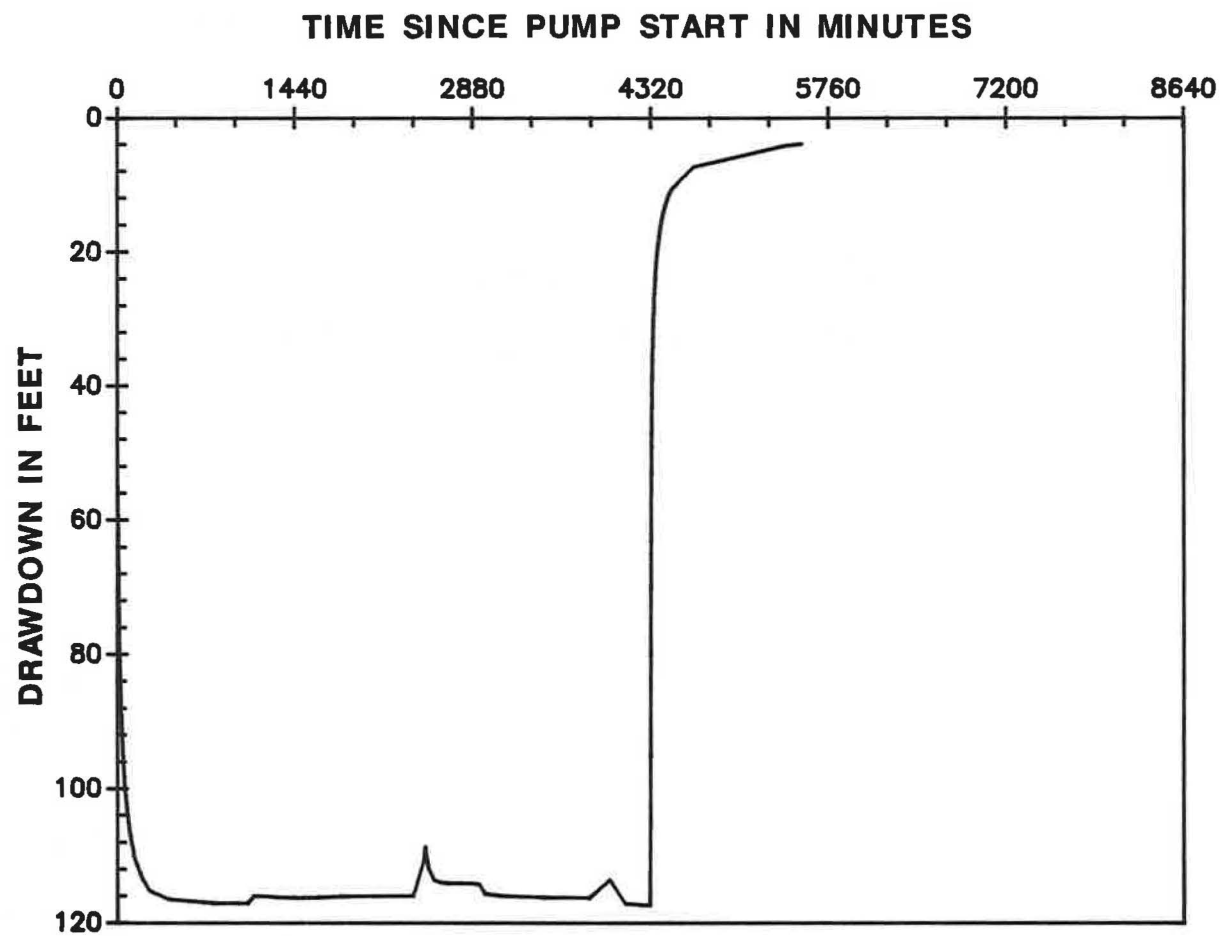


Figure 49. Drawdown and recovery curves for Colbert well 3

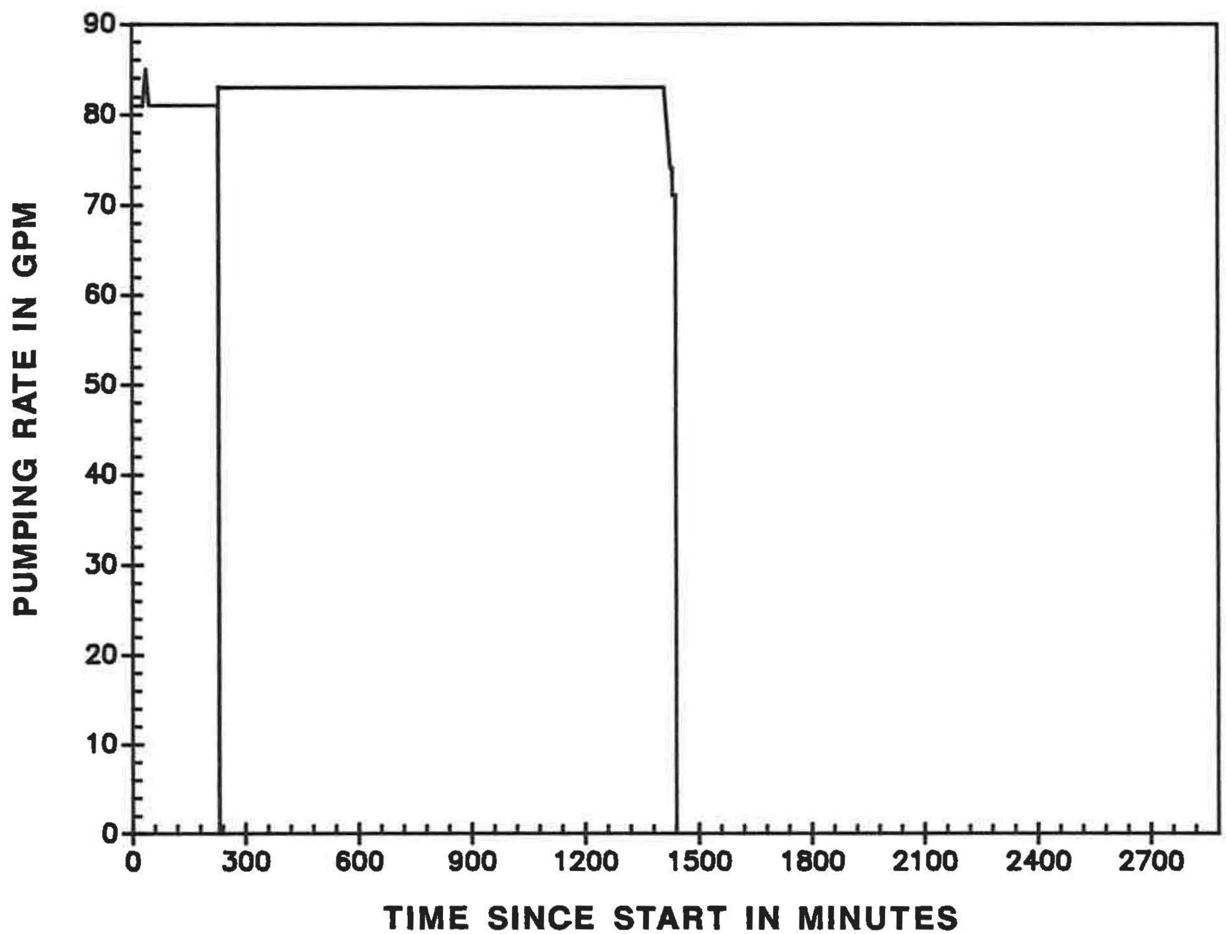


Figure 50. Pumping rate during test of Colbert well 4.

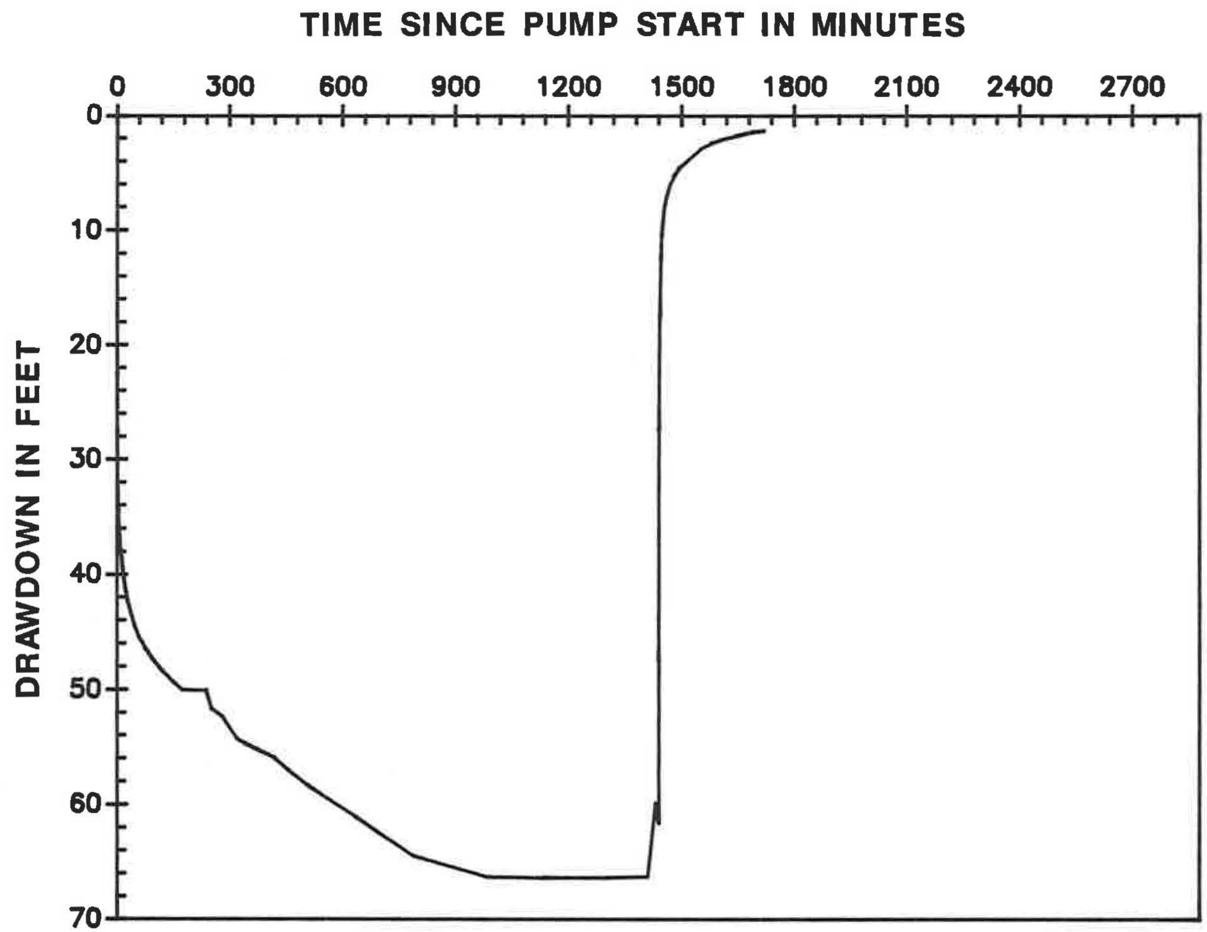
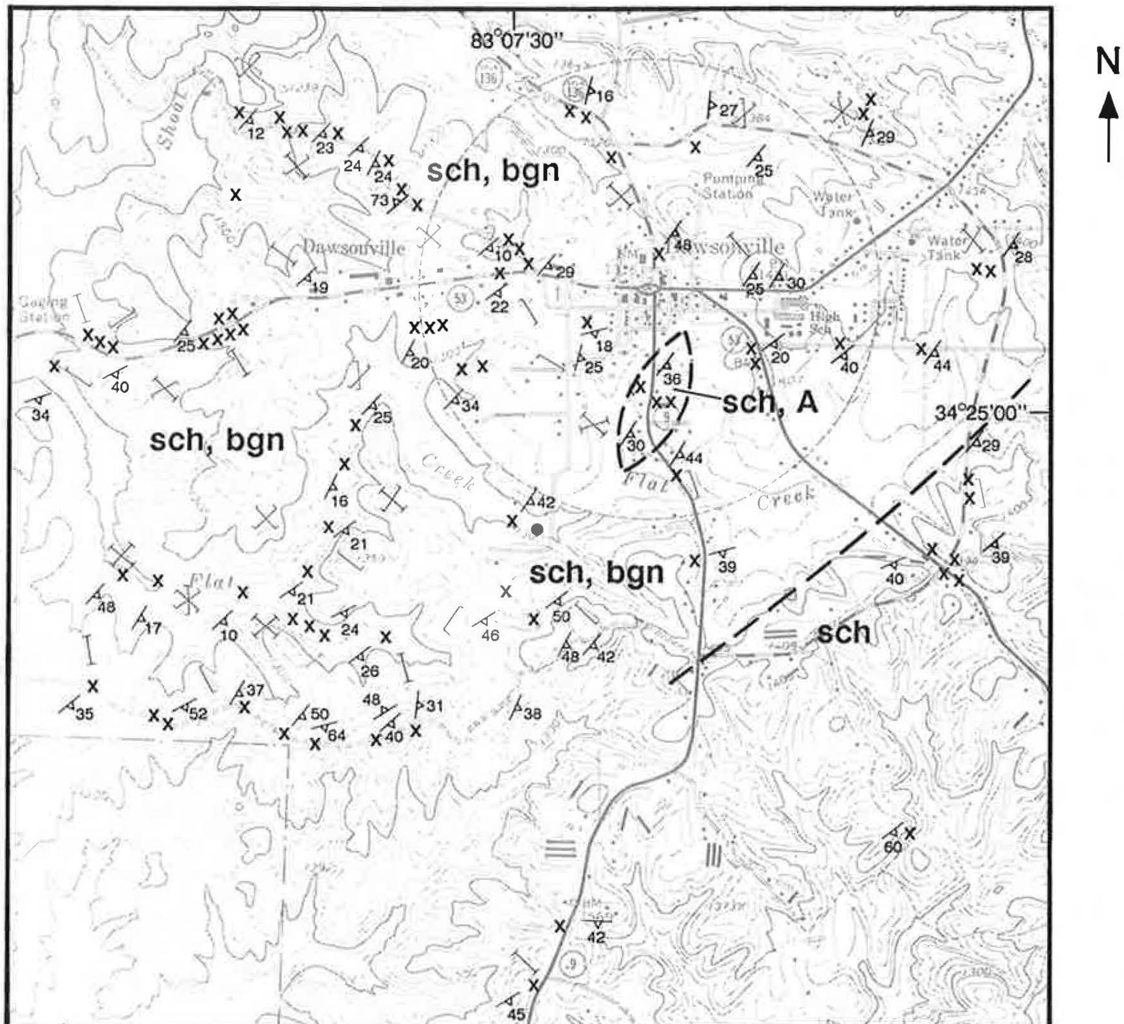


Figure 51. Drawdown and recovery curves for Colbert well 4.



Base from U.S. Geological Survey Dawsonville 1:24,000, photorevised 1985 and Juno 1:24,000, 1964.

EXPLANATION

- **sch, A** — Schist, amphibolite
- **sch** — Schist
- **sch, bgn** — Schist, biotite gneiss
- Strike and dip of compositional layering (21)
- Strike and dip of inclined joint
- Strike and dip of vertical joint
- x — Outcrop
- • — Well location
- — — — Inferred contact

0 .5 MILE

0 .5 KILOMETER

Figure 52. Geologic map of parts of the Dawsonville and Juno Quadrangles and location of Dawsonville municipal well.

button mica schist saprolite that is thinly interlayered with a tan to yellow-brown biotite gneiss saprolite. Garnets are less than 0.1 in. in diameter. The size of "buttons" in the schist varies. The gneiss is a coarse-grained massive to foliated biotite-quartz plagioclase gneiss. The gneiss forms shoals in Flat Creek and along tributaries to Flat Creek west of the well site.

3) A unit of mica schist. This sequence consists of a fine- to coarse-grained red to tan garnet mica schist saprolite with purple- to tan-weathered quartz-rich gneiss saprolite. Garnets in this schist have a diameter of up to 0.25 in.

The geologic map (Fig. 52) illustrates the northeast strike and southeast dip of compositional layering. Joints near the well site are spaced from one inch to several feet apart and their strike length varies from an inch to several feet (Table 3). Joint sets are oriented N45°W, N50°E, N62°W, and N18°W, and all dip vertically (Fig. 52). Aperture (joint opening) is less than 0.1 in. in saprolite and manganese commonly coats joint surfaces.

WATER QUALITY

A water-quality analysis conducted by the Water Supply Laboratory of the Environmental Protection Division indicates water from this well meets Safe Drinking Water Standards (Table 4).

HYDROLOGIC TESTING

Dawsonville's municipal well 4 was drilled to a depth of 200 ft and had an air lift yield of 100 gpm. The Geologic Survey conducted a 24-hour constant-rate test on the well using a submersible production pump and utility power. No observation wells were available for the test. A nearby stream received the discharge from the pumped well. The pumping rate remained constant at approximately 75 gpm for the duration of the test with only 9.43 ft of drawdown observed. Drawdown and recovery curves constructed from the test data are smooth (Fig. 53). The shape of the drawdown curve for the test well can be matched to an exponential integral (Theis Well Function) but the meaning of transmissivity and storativity values which could be derived from this methodology are unknown because the assumptions which govern the Theis method are not met in this crystalline rock aquifer.

SUMMARY

The Geologic Survey located a well site for the City of Dawsonville (municipal well 4). The site selected lies in a topographically low area at the intersection of two discontinuities. Hydrologic tests indicate that the well can easily sustain a pumping rate of 75 gpm for a period of 24 hours.

LEXINGTON, OGLETHORPE COUNTY

INTRODUCTION

The city of Lexington is located in central Oglethorpe County, about 20 miles east of Athens (Fig. 1). The Georgia Geologic Survey was asked by the city of Lexington to test municipal well 3 to evaluate the well's production capacity. Although the well site was not selected by the Geologic Survey, it is a moderately high-yield well located next to, but not on, a prominent linear stream segment.

GEOLOGY

The city of Lexington lies in the Washington Slope District, a subdivision of the Piedmont Physiographic Province (Clark and Zisa, 1976). Stream valleys in the Lexington area are gently concave and hill tops are gently convex to flat. Relief is roughly 120 ft, and most land slopes gently. Drainage patterns of the larger streams, such as Town Creek, are dendritic but have long straight valley segments (Fig. 54). Intermittent streams have dendritic or trellis drainage patterns. Straight valley segments near Lexington are orientated N11°E, N25°E, N84°E, and N68°W. Municipal well 3 is located on the west side of a northeast-trending straight valley segment.

Rocks within a mile radius of municipal well 3 are mainly light gray, medium-grained, massive, equigranular, biotite granite gneiss with intrusions of light-colored, medium-grained, equigranular granite. The granite is porphyritic in places, with feldspar phenocrysts up to 0.5 in in diameter. Medium- to coarse-grained chloritic

Table 3. Dawsonville, joint orientations and descriptions.

Joint	Dip	Spacing	Surface	Coating
N50°W	90°	2 in-1 ft	straight smooth	manganese clay
N50° E	90°	1-3 ft	smooth to irregular	manganese
N62° W	90°	1 ft	straight smooth	manganese clay
N18° W	90°	1 ft	smooth to curvilinear	manganese clay

Table 4. Dawsonville municipal well 4, water quality analysis.

Parameter	Results	Parameter	Results
pH	6.4	Pb	<25 µg/l
Ag	<25 µg/l	Mn	<25 µg/l
As	<25 µg/l	Na	2.3 mg/l
Ba	<50 µg/l	Se	<5 µg/l
Cd	<5 µg/l	Zn	640 µg/l
Cr	<25 µg/l	Spec.Cond.	34 µmho/cm
Cu	<50 µg/l	Alkalinity	14 µg/l
F	<0.1 mg/l	Hardness	10 µg/l
Fe	<50 µg/l	Total	
Hg	<0.5 µg/l	Dissolved	24 mg/l
Nitrate	0.80 mg/l	Solids	

< = below laboratory detection limits

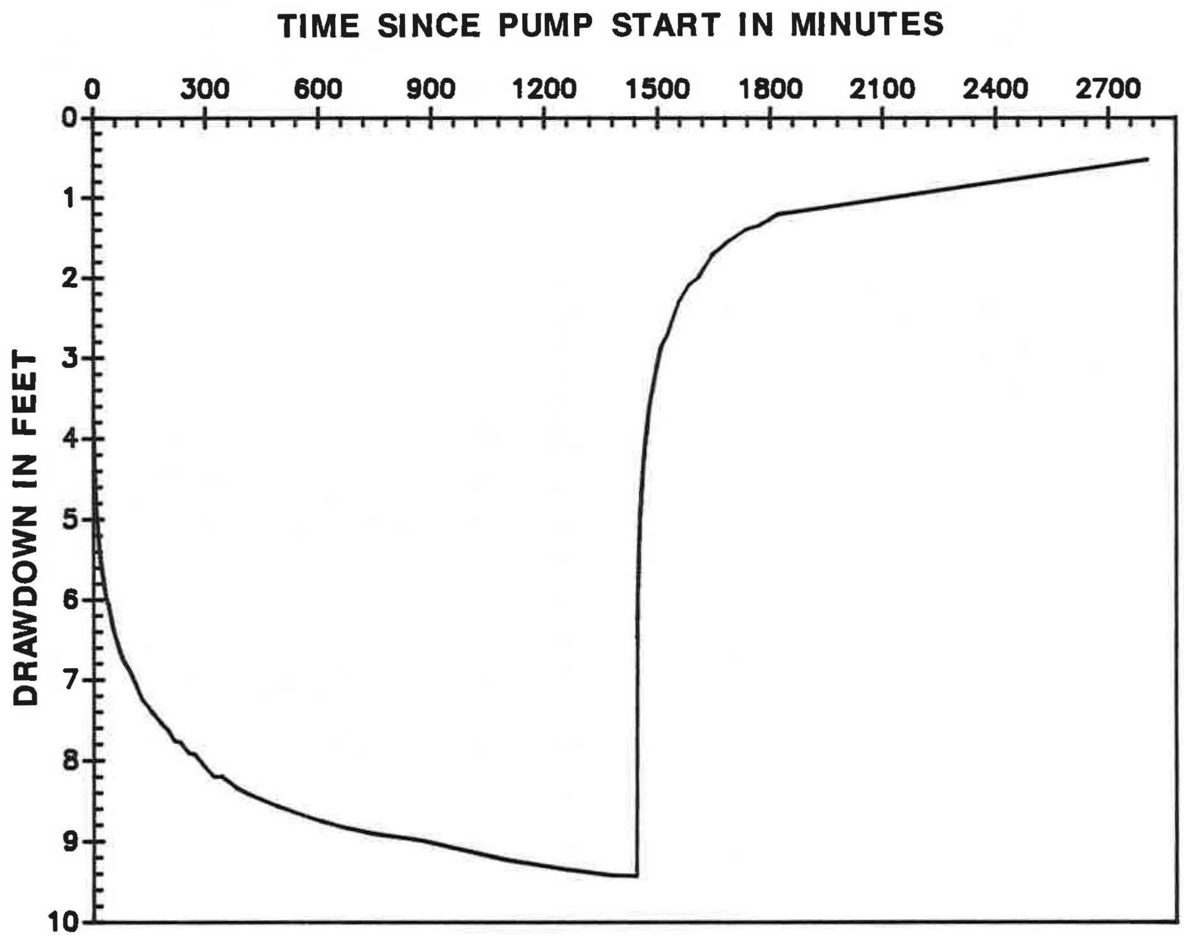
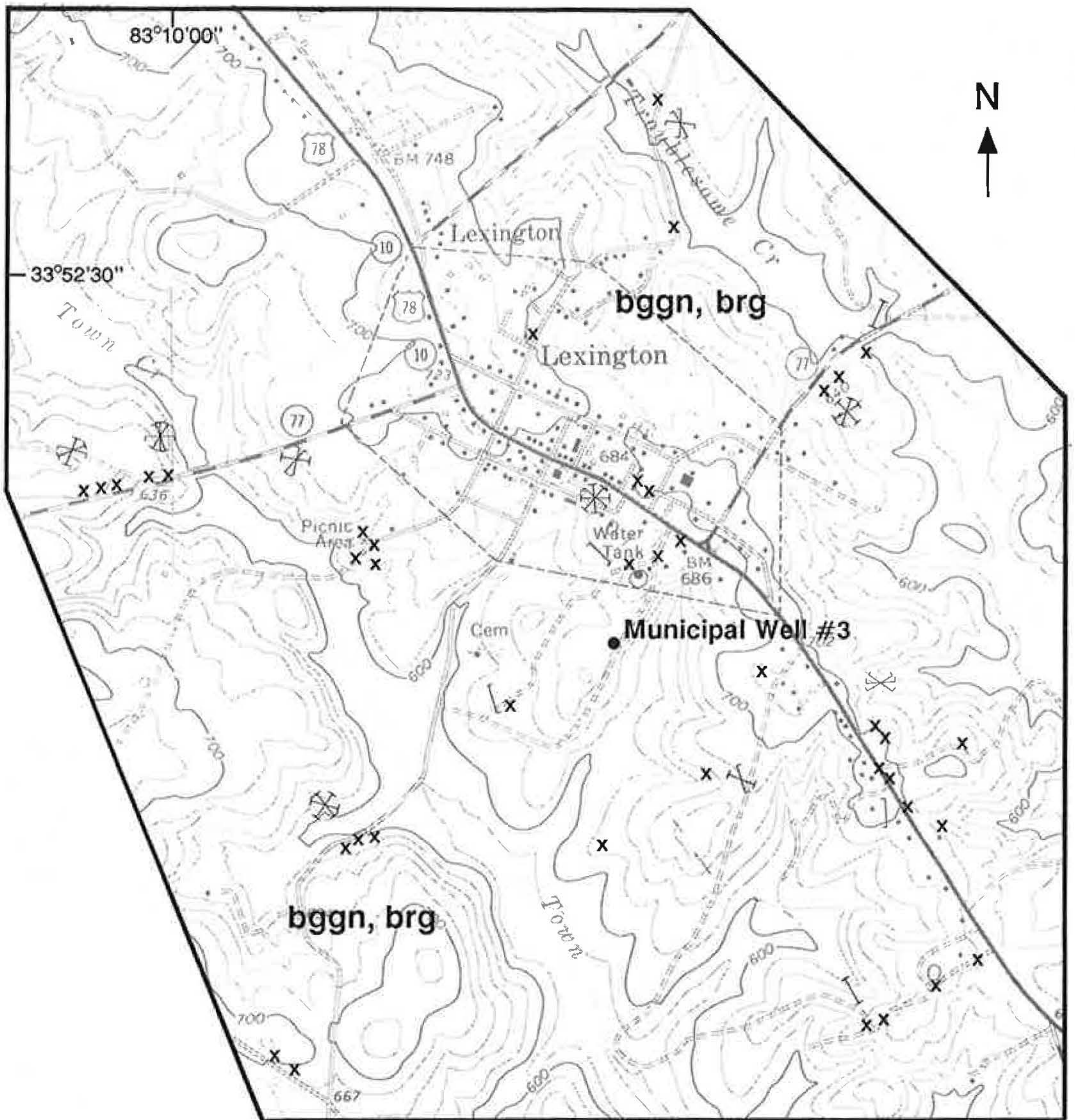


Figure 53. Drawdown and recovery curves for Dawsonville city well 4.



EXPLANATION

bggn, brg	Light-colored medium-grained equagranular biotite granite gneiss; light-colored medium- to coarse-grained biotite granite
⊢⊣	Strike and dip of vertical joint
⌞⌟	Strike and dip of inclined joint
x	Outcrop
●	Well location

0 .5 MILES

0 .5 KILOMETERS

Figure 54. Geologic map of part of the Lexington Quadrangle and locations of wells in the Lexington area.

epidote amphibolite and light-colored granite gneiss underlie the biotite granite gneiss. Borehole logs suggest that the contact between these two units is at 190-200 ft in municipal well 3.

Foliation was not apparent in the massive granite gneiss unit. The granite contains biotite schlieren; however, orientation data are insufficient to determine a trend. Joint surfaces are smooth, spacing is from 6 in. to 10 ft, and joints commonly are 1 to 5 ft in length. Joint sets are oriented N36°W, N50°E, N29°E, N80°W, and N2°E, all with vertical dips (Fig. 54).

WATER QUALITY

A water quality analysis performed by Law and Company indicates that water from this well has sulfate and TDS levels that exceed Secondary Maximum Contaminant Levels (Table 5).

BOREHOLE GEOPHYSICS

Sonic televiewer, caliper, temperature, acoustic velocity, single-point resistance and natural gamma logs were run on municipal well 3 (Figs. 55-62). The logs show discontinuities at 91-94, 211-225, and 486-498 ft.

The sonic televiewer log (Fig. 55) shows a discontinuity at 91-94 ft. Anomalies on the caliper, temperature, natural gamma, and to a lesser extent, the single-point resistance log, also indicate a discontinuity at this depth. A weathered zone at 211-225 ft is apparent on the sonic televiewer log (Fig. 56) and is also represented by anomalies in borehole diameter, water temperature, natural gamma and acoustic velocity. Observations made by the well driller, as well as the sonic televiewer log (Fig. 57), indicate that a water-bearing weathered zone lies between 486 and 498 ft. An increase in borehole diameter at this depth, in addition to a slight decrease in ground-water temperature, support this interpretation. The single-point resistance log also shows an anomaly at this depth (Fig. 61).

Increases in borehole diameter at 250-265 and 358-380 ft (Fig. 58) could not be correlated with water-bearing zones. Significant increasing anomalies on the natural gamma log (Fig. 62) occur at 113, 157, 215, and 309 ft, only one of which could be correlated with a water-bearing zone.

The orientations of subsurface discontinuities were measured from the sonic televiewer log of the Lexington well. These orientations were plotted on an equal area diagram and compared with the orientations of joints and straight stream valley segments measured at the surface near the well site. Discontinuities measured on the televiewer log strike within 11° of a surface joint set that strikes N50°E with vertical dip. Northwest-striking discontinuities measured on the televiewer log strike within 5° of a straight stream valley segment.

HYDROLOGIC TESTING

A 24-hour constant-rate pumping test was conducted on Lexington municipal well 3 using a submersible production pump and utility power. No observation wells could be located to monitor the test. The outflow from the test well was directed onto the ground and flowed to a nearby stream.

A drawdown of 186 ft took place during the test, carried out at a constant pumping rate of 60 gpm (Fig. 63). The drawdown curve formed by the data gathered during the test is irregular (Fig. 64). The recovery curve, while smoother than the drawdown curve, was not a smooth exponential integral curve.

SUMMARY

Lexington municipal well 3 is located on the side of a northeast-trending linear valley segment. Sonic televiewer logs indicate that the well penetrated several northeast-striking discontinuities. The well sustained a pumping rate of 60 gpm during a 24-hour test with an observed drawdown of 186 ft.

LOCUST GROVE, HENRY COUNTY

INTRODUCTION

The City of Locust Grove, in Henry County, obtains its municipal-supply water from a spring (Fig. 1). During the drought of 1986, the yield of the spring dropped and the city had to purchase water from Henry County. The mayor requested that the Geologic Survey locate a well to

Table 5. Lexington municipal well 3, water-quality analysis.

Parameters	Results	Parameters	Results
pH	7.0	Na	32 mg/l
Ag	<0.04 mg/l	Pb	<0.02 mg/l
As	< 0.02 mg/l	Se	<0.01 mg/l
Ba	<0.05 mg/l	SO_3	200 mg/l
Cd	<0.005 mg/l	Zn	0.20 mg/l
Cl	11 mg/l	Total	
CO_2	7.0 mg/l	Dissolved	503 mg/l
Cr	<0.04 mg/l	Solids	
Cu	<0.04 mg/l	Nitrate	0.55 mg/l
F	1.2 mg/l	Nitrogen (N)	2.7
Fe	<0.04 mg/l	Turbidity	
Hg	<0.001 mg/l	(NTU)	38 mg/l
Mn	<0.04 mg/l	Alkalinity (as	
		$CaCO_3$)	240 mg/l
		Total Hardness	
		(as $CaCO_3$)	

< = below laboratory detection limit

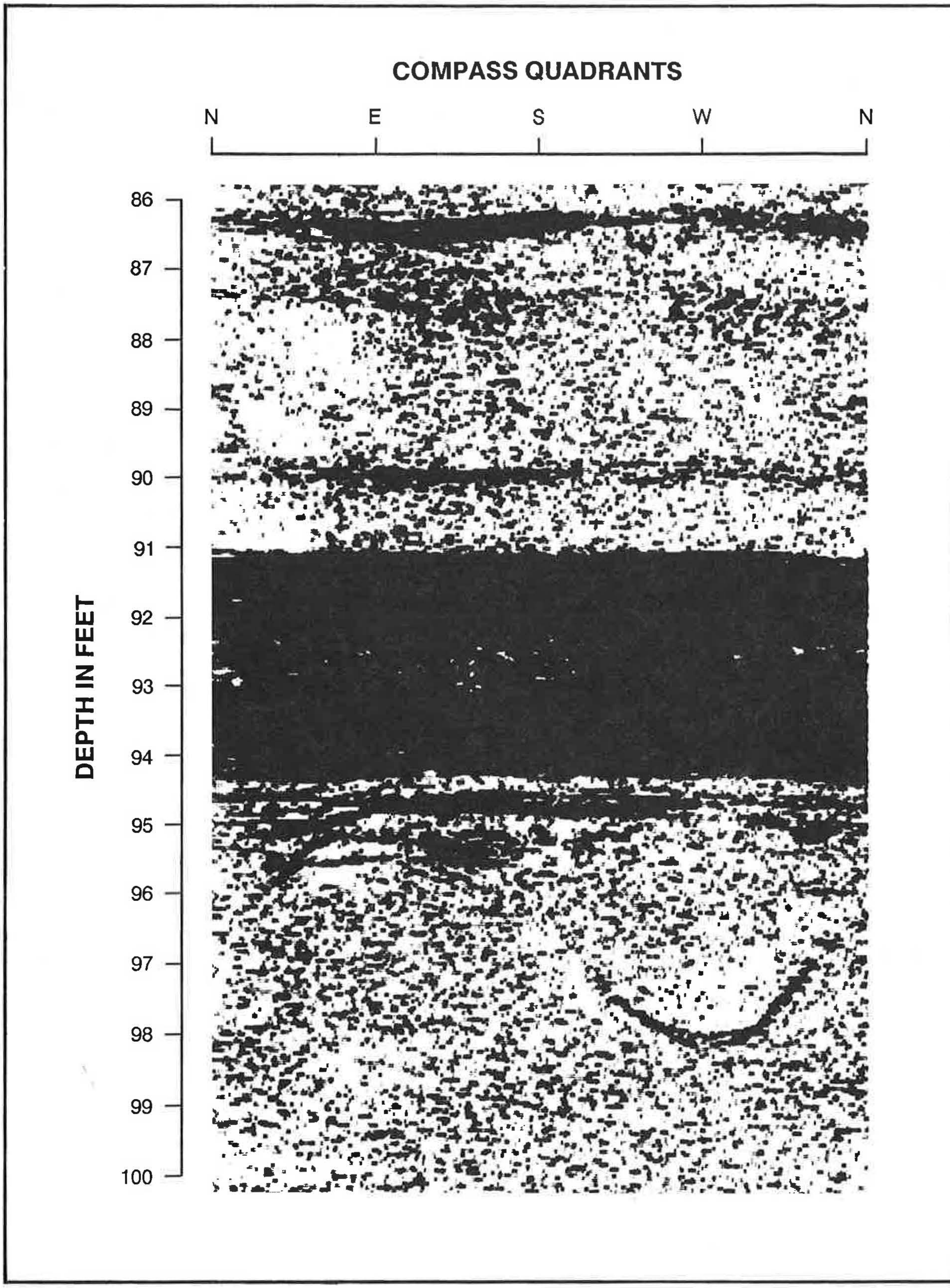


Figure 55. Sonic televiewer log of Lexington municipal well 3, 86-100 ft.

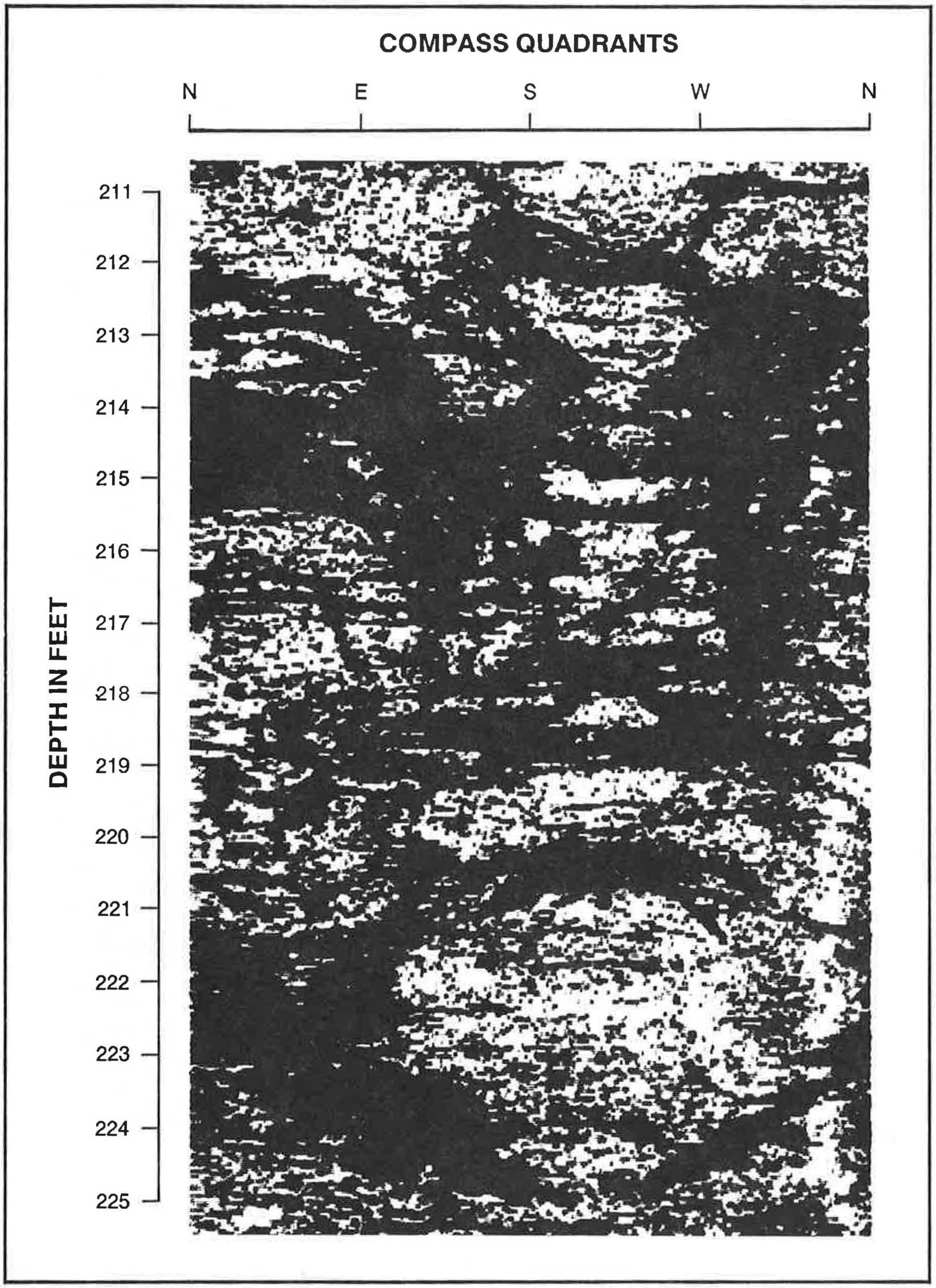


Figure 56. Sonic televiewer log of Lexington municipal well 3, 211-225 ft.

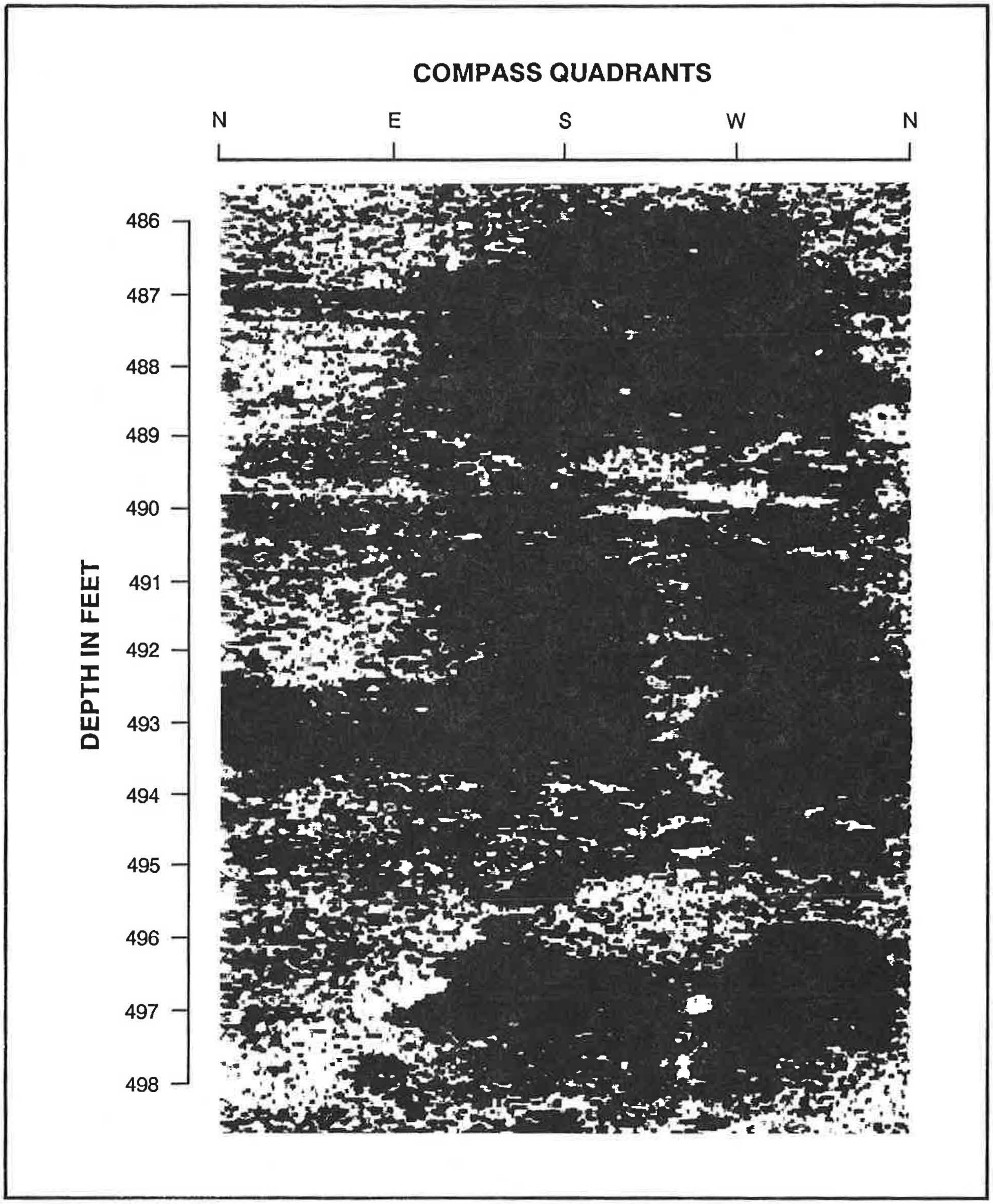


Figure 57. Sonic televiewer log of Lexington municipal well 3, 486-498 ft.

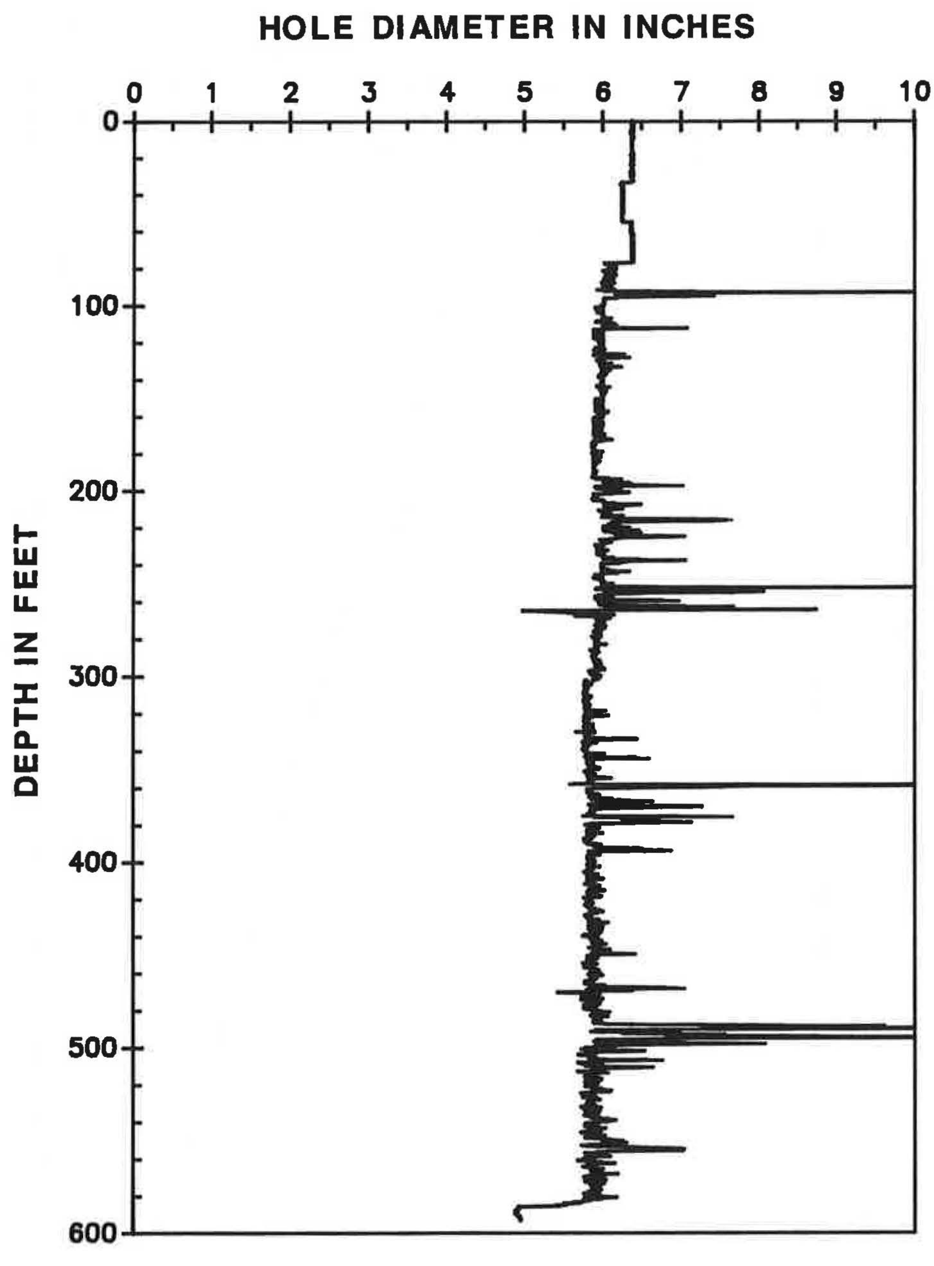


Figure 58. Caliper log of Lexington municipal well 3.

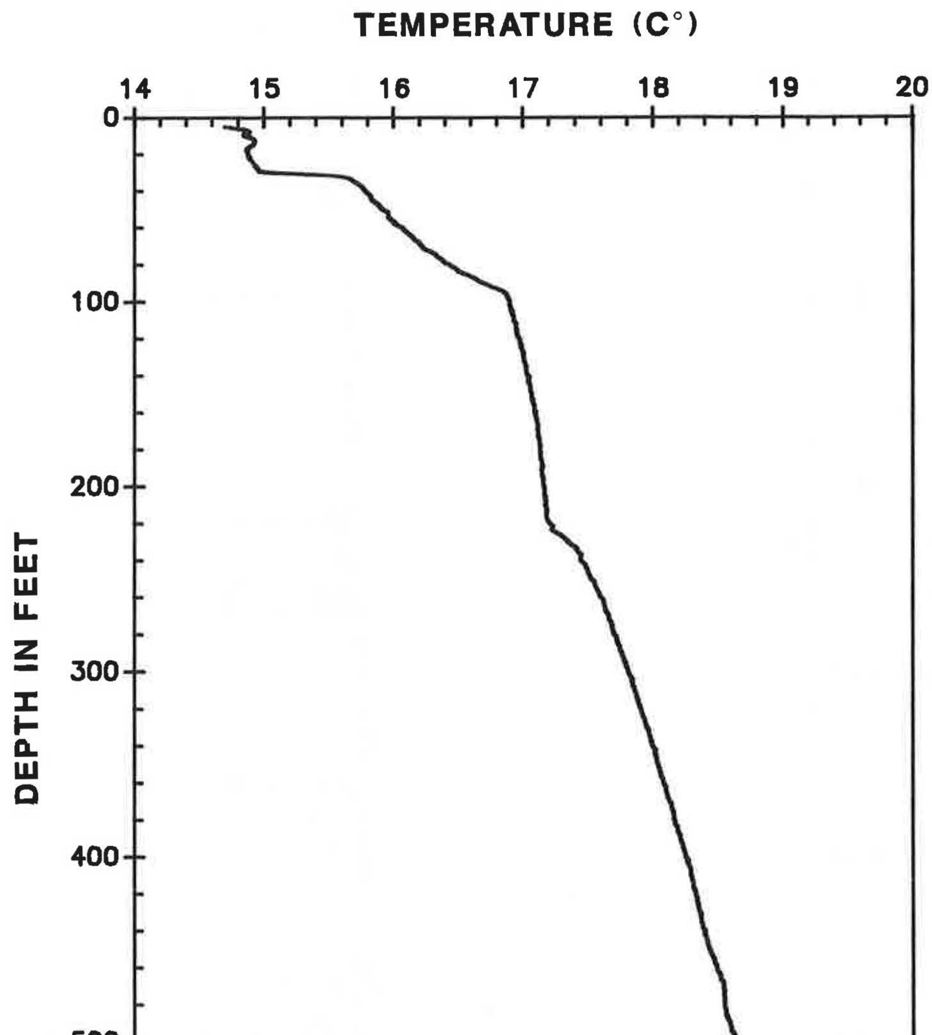


Figure 59. Temperature log of Lexington municipal well 3.

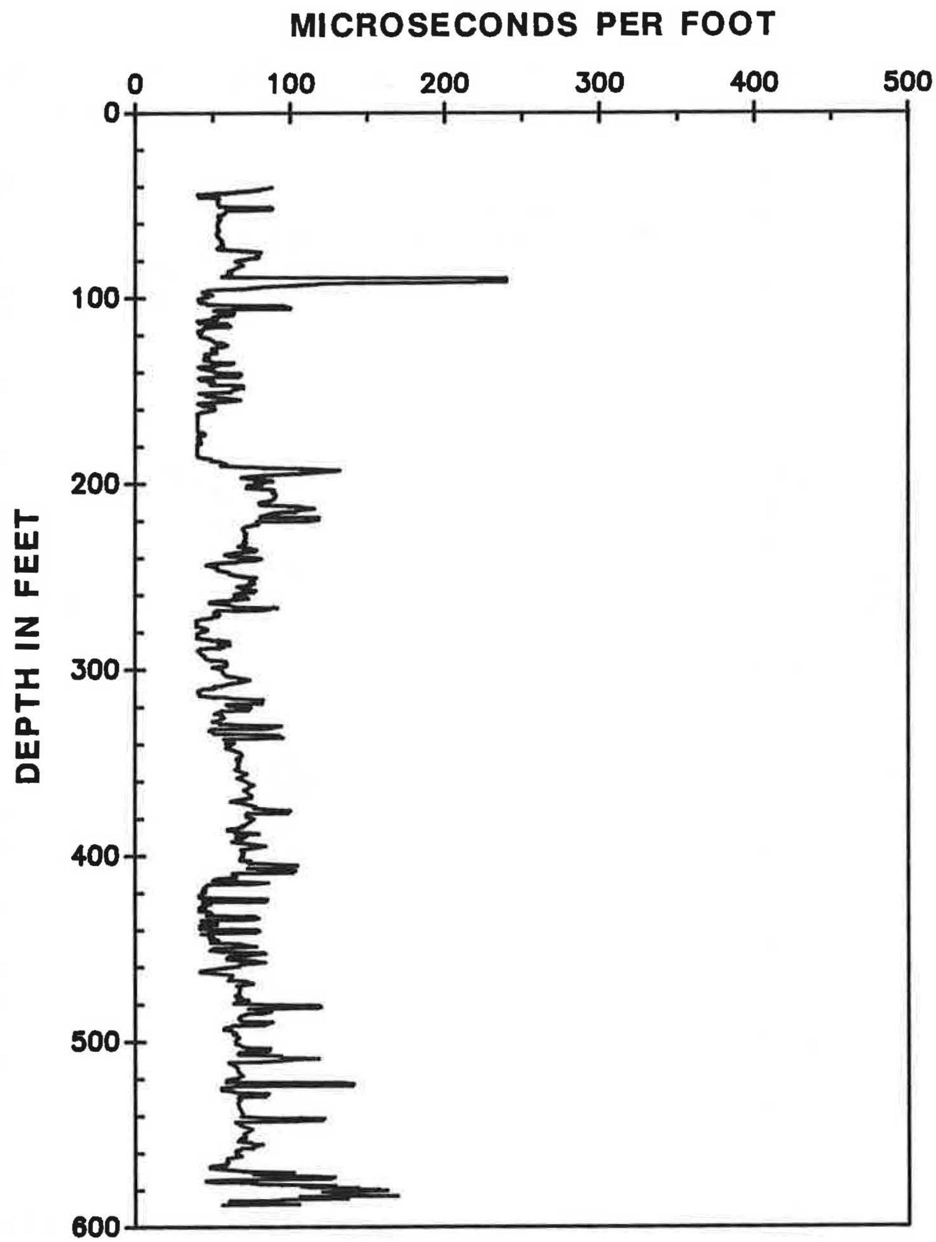


Figure 60. Acoustic velocity log of Lexington municipal well 3.

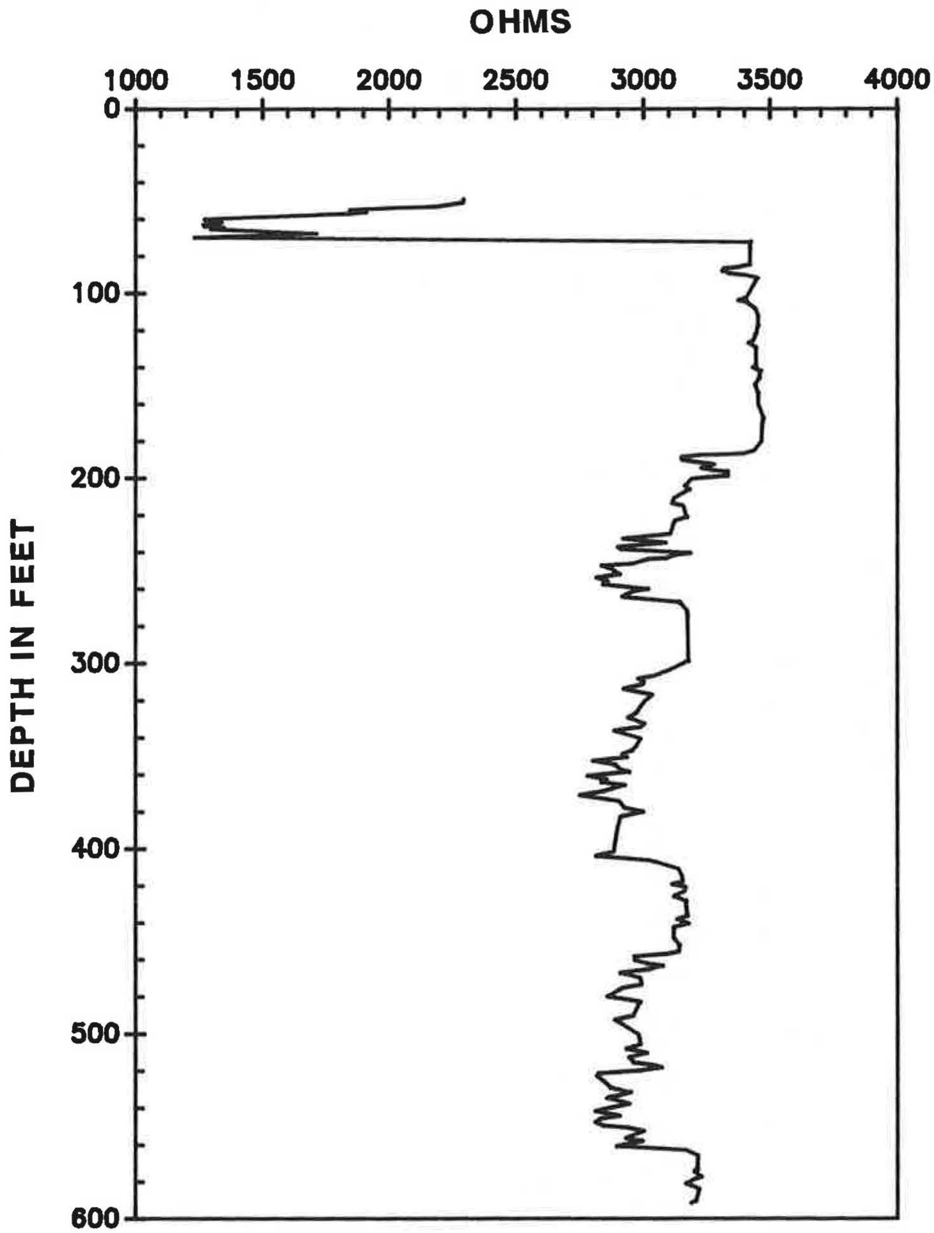


Figure 61. Single- point resistance log of Lexington municipal well 3.

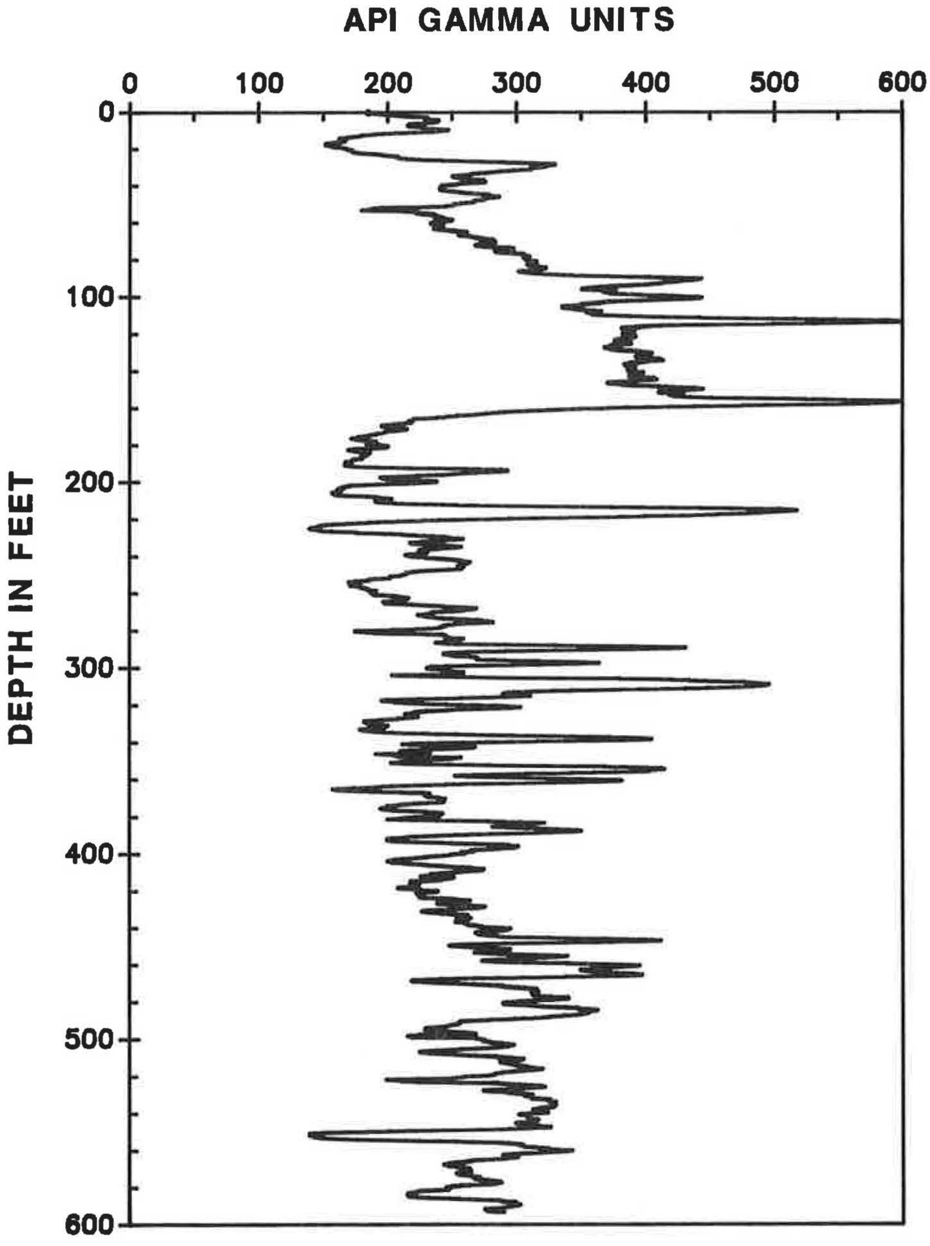


Figure 62. Natural gamma log of Lexington municipal well 3.

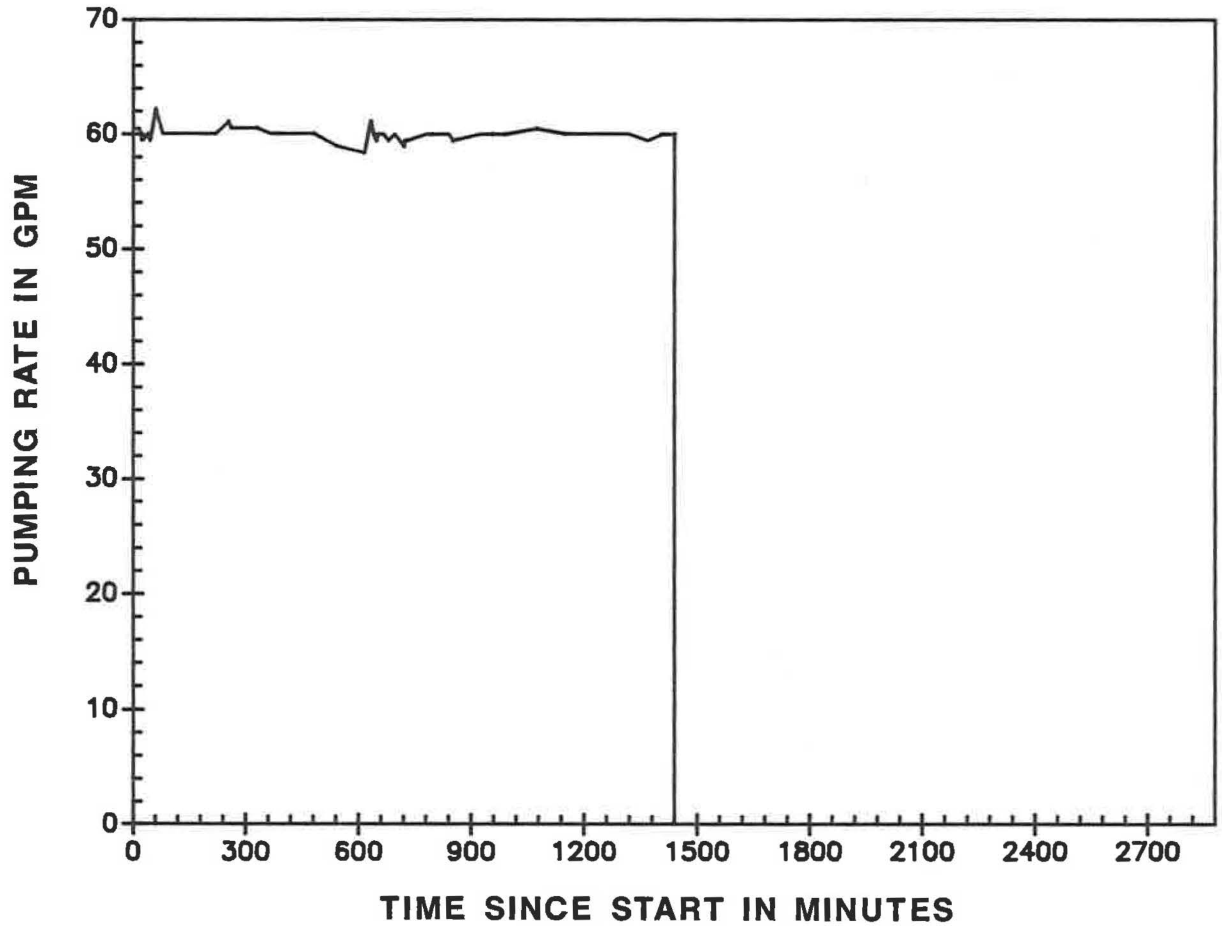


Figure 63. Pumping rate during test of Lexington municipal well 3.

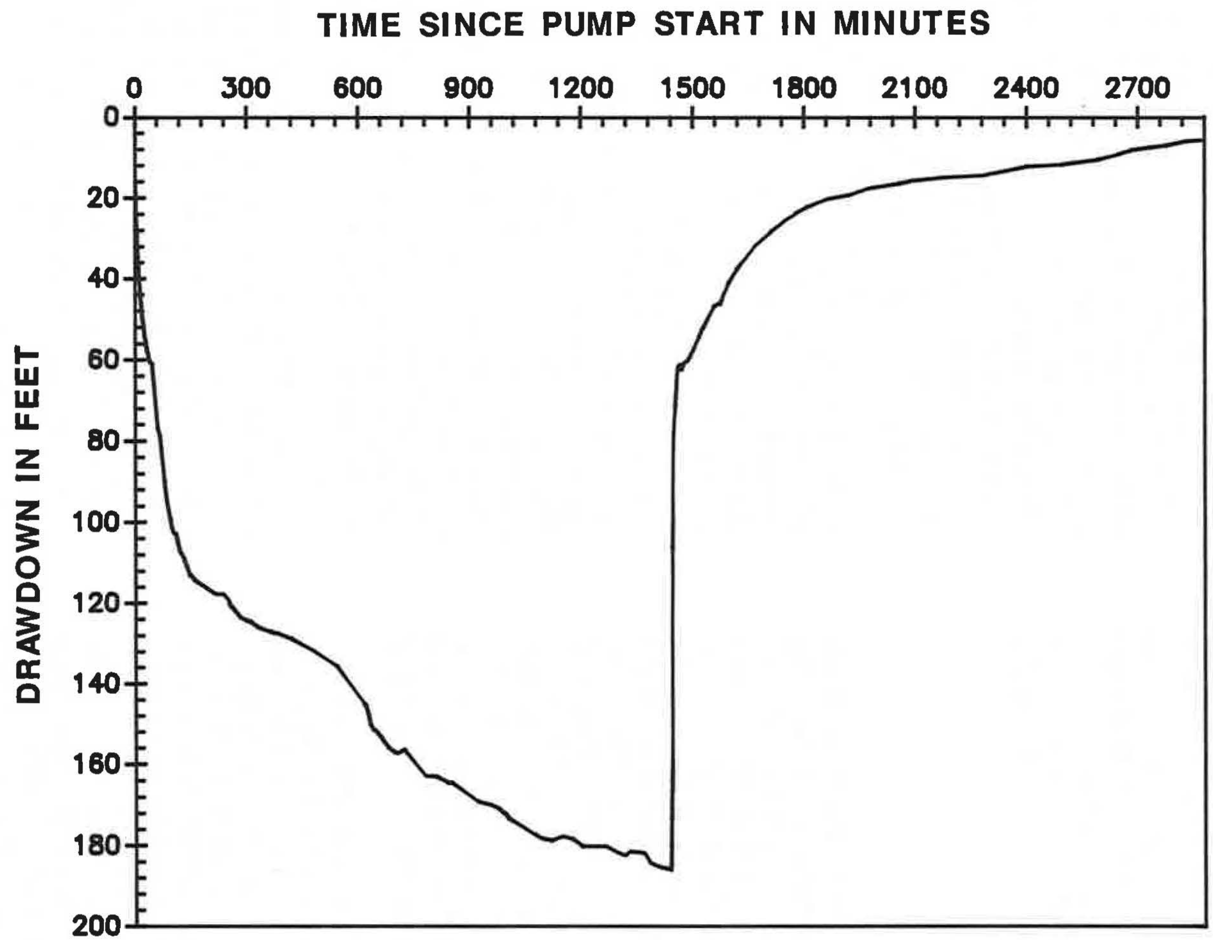


Figure 64. Drawdown and recovery curves for Lexington municipal well 3.

supplement their spring.

WELL SITING

Four well sites were chosen for the city of Locust Grove. Three of these sites were rejected by the city for drilling because they were too far from existing water lines or were located on property not owned by the city. A fourth site was accepted for drilling. This well site (municipal well 1) was located in a topographic low at the intersection of a structurally controlled, northeast-trending stream and a northwest-trending discontinuity.

GEOLOGY

The city of Locust Grove lies in the Washington Slope District, a subdivision of the Piedmont Physiographic Province (Clark and Zisa, 1976). Valleys in the vicinity of Locust Grove are concave (Fig. 65). Floodplains range between 100 and 200 ft wide, with gently convex interstream divides. Relief is approximately 190 ft. Intermittent streams in the Locust Grove area have trellis-style drainage patterns, and perennial streams have dendritic to rectangular drainage patterns. Straight stream valley segments in the Locust Grove area, measured on 7.5 minute topographic maps, are oriented N06°W, N54°W, N28°W, and N50-70°E. The well site is in a northeast-trending segment of the valley of Brown Branch.

Rocks within a mile radius of the Locust Grove well include coarse-grained biotite schist, coarse-grained sillimanite mica schist, and coarse-grained biotite gneiss. These rocks are interlayered on a scale of one inch to a few feet. The saprolite shows layering on a similar scale.

Compositional layering in the rocks strikes northeast and dips southeast (Fig. 65). Joint sets strike N78°W, E-W, N59°W, and N21°E. All joints have vertical to nearly vertical dips. Joint spacing ranges up to several feet and persistence along strike varies up to several feet. Joint planes are smooth to rough curvoplanar and joint aperture in weathered rock is less than 0.1 in.

WATER QUALITY

A water quality analysis indicates that water from this well is acceptable as a drinking water source (Table 6). The tests were performed by Law and Company, Clarkston, Georgia.

BOREHOLE GEOPHYSICS

A suite of borehole geophysical logs, including sonic televiewer, caliper, temperature, spontaneous potential, acoustic velocity, single-point resistance and natural gamma logs were run at Locust Grove municipal well 1 (Figs. 66-72). Geophysical logs and the well driller's observations indicate that probable water-bearing zones lie at 109-110 and 153-154 ft.

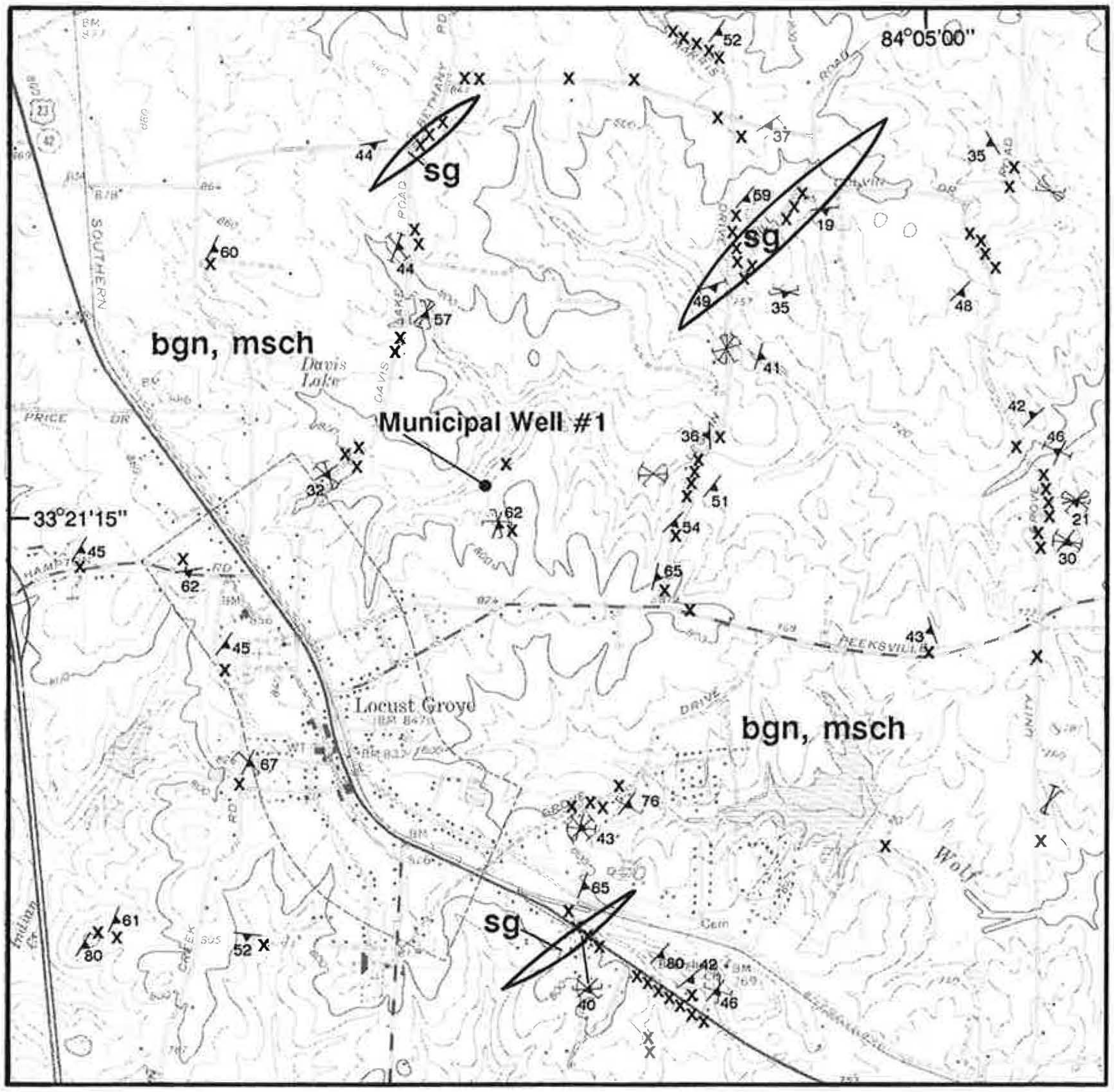
The sonic televiewer log shows a discontinuity at 109-110 ft (Fig. 66a). The temperature log indicates an increase in ground-water temperature at this depth probably resulting from water flowing into the borehole (Fig. 68). The spontaneous potential log changes character abruptly at approximately 100-110 ft, possibly due to the presence of a water-filled discontinuity at this depth.

The driller's report indicates that the discontinuity at 153-154 ft yields the largest quantity of water (Fig. 66b). This corresponds with an increase in borehole diameter on the caliper log (Fig. 67). The temperature log also shows an increase in temperature at this depth, suggesting that water enters the borehole from a water-bearing discontinuity at or near this depth. Although other geophysical logs (natural gamma, resistance, and acoustic velocity) were run, their results could not be correlated to water-bearing zones.

The orientations of ten discontinuities measured from the sonic televiewer log of the Locust Grove well are "scattered" when plotted on an equal-area diagram and no average orientation could be measured. The water-bearing discontinuity at 109-110 ft is oriented N03°W and dips 27°SW, subparallel to the N06°W orientation of straight valley segments near the well. The major water-bearing discontinuity at 153-154 ft strikes N90°E and dips 11°N. This strike is parallel to the E-W striking joint set, but the joints have vertical dips at the surface.

HYDROLOGIC TESTING

A 24-hour constant-rate pumping test was conducted on Locust Grove municipal well 1



Base from U.S. Geological Survey
Locust Grove 1:24,000, 1964.

EXPLANATION

sg	White to yellow-brown weathering graphite sillimanite mica schist
bgn, msch	Red weathering biotite plagioclase gneiss, sillimanite gneiss and sillimanite mica schist
45	Strike and dip of foliation
	Strike and dip of vertical joint
	Strike and dip of inclined joint
x	Outcrop
•	Well location
———	Contact

N

0 .5 MILE

0 .5 KILOMETER

Figure 65. Geologic map of part of the Locust Grove Quadrangle and the location of the new Locust Grove city well.

Table 6. Locust Grove municipal well 1, water-quality analysis.

Parameter	Results	Parameter	Results
pH	7.5	Na	6.9 mg/l
Ag	<0.04 mg/l	Pb	<0.02 mg/l
As	<0.02 mg/l	Se	<0.001 mg/l
Ba	<0.1 mg/l	SO_3	7.6 mg/l
Cd	<0.005 mg/l	Zn	<0.02 mg/l
CO_2	5.6 mg/l	Color (Pt-Co Units)	5
Cl	3.3 mg/l	Turbidity (NTU)	0.56
Cr	<0.04 mg/l	Alkalinity (as $CaCO_3$)	76 mg/l
Cu	<0.04 mg/l	Nitrate Nitrogen	<0.3 mg/l
F	<0.4 mg/l	Total hardness (as $CaCO_3$)	68 mg/l
Fe	0.18 mg/l	Total disolved solids	150 mg/l
Hg	<0.001 mg/l		
Mn	0.09 mg/l		

< = below laboratory detection limit

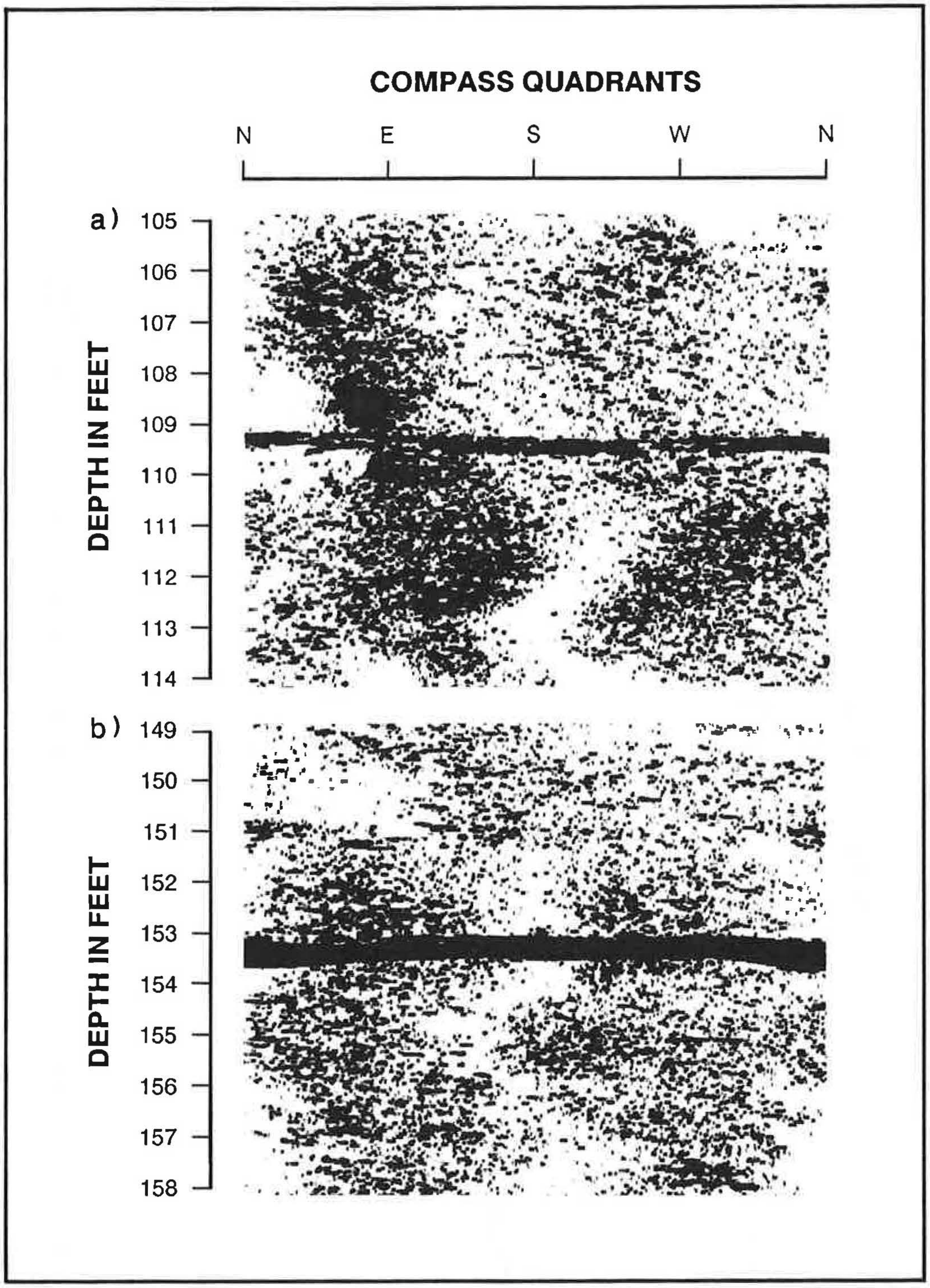


Figure 66. Sonic televiewer log of Locust Grove municipal well, (a) 105-114 ft., (b) 149-158 ft.

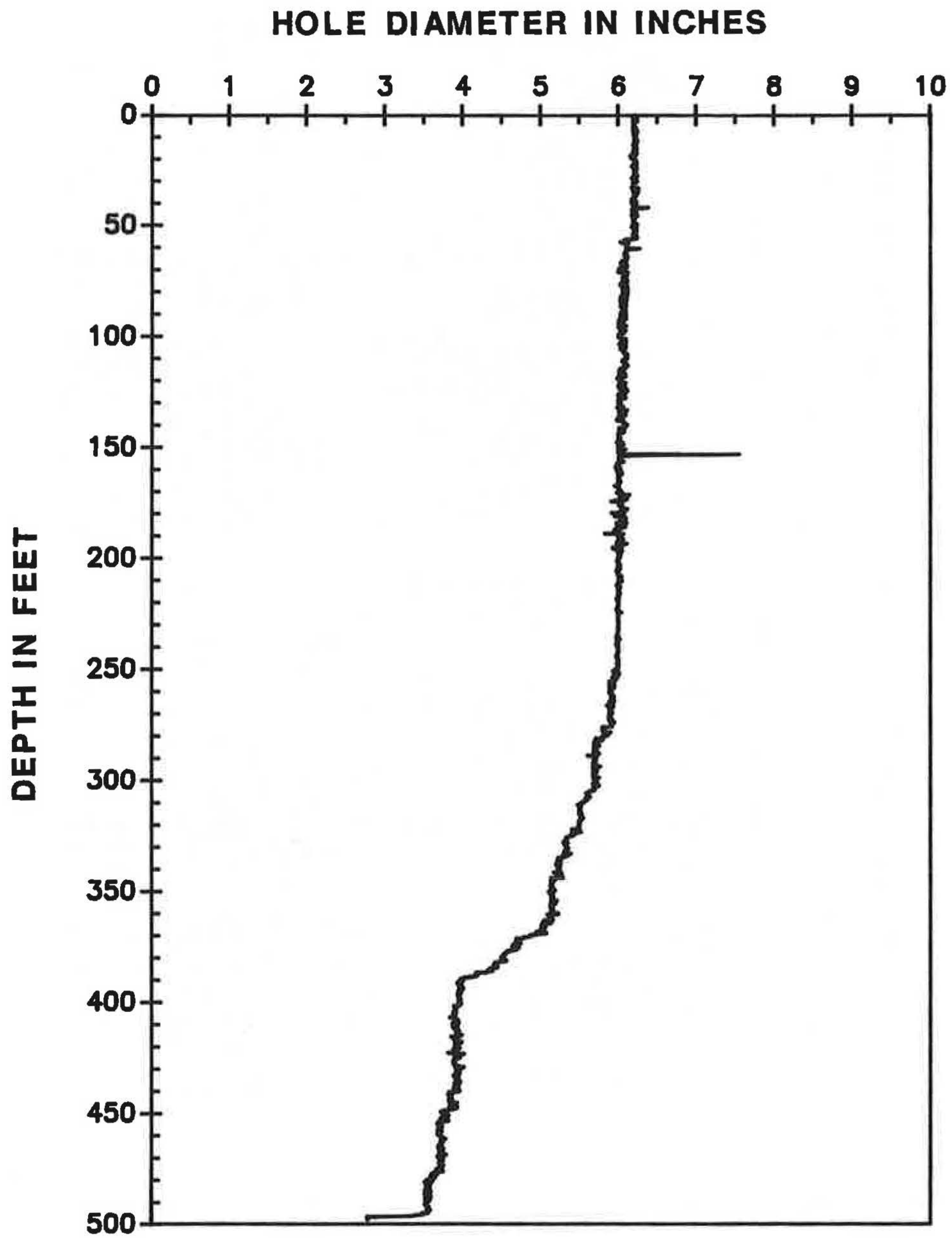


Figure 67. Caliper log of Locust Grove municipal well.

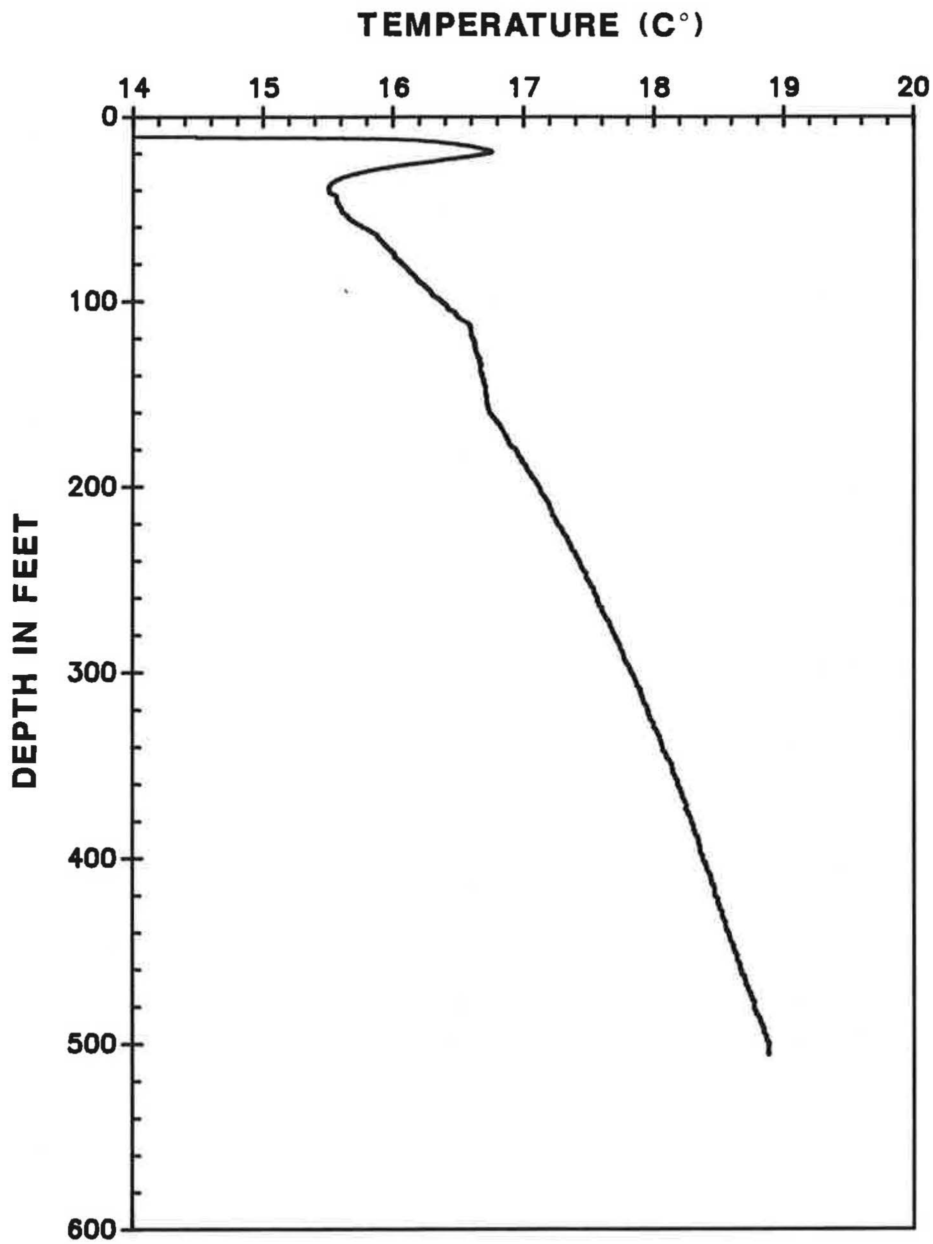


Figure 68. Temperature log of Locust Grove municipal well.

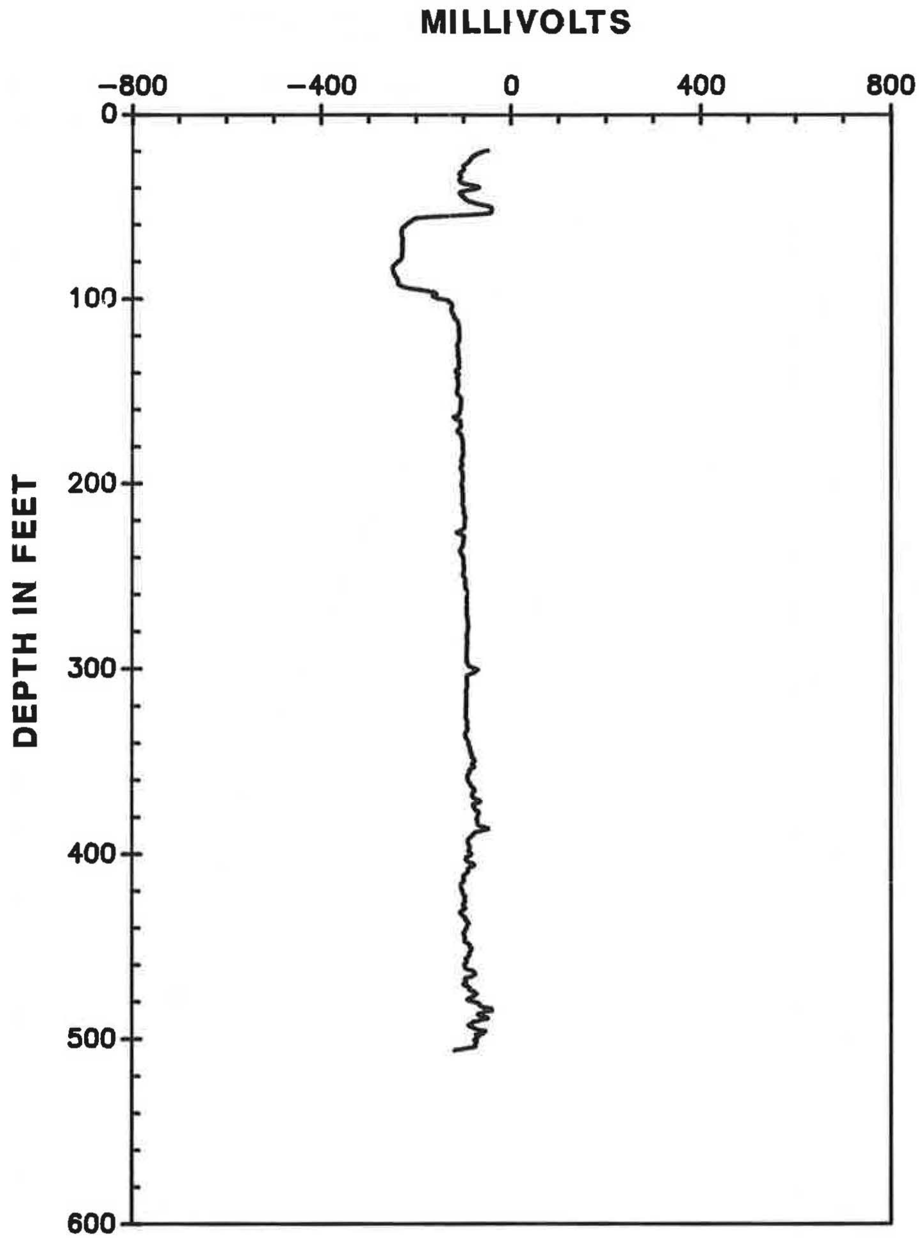


Figure 69. Spontaneous potential log of Locust Grove municipal well.

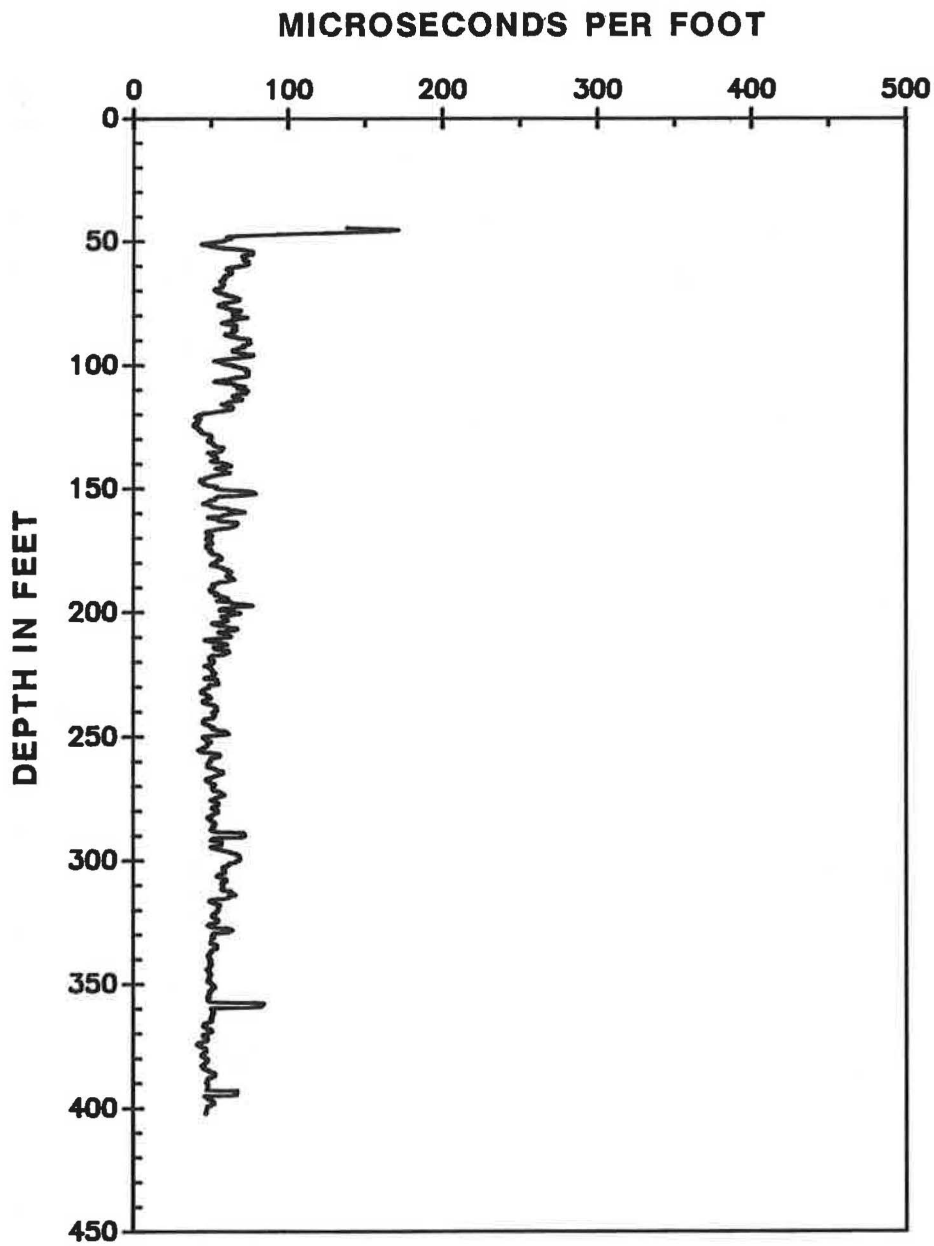


Figure 70. Acoustic velocity log of Locust Grove municipal well.

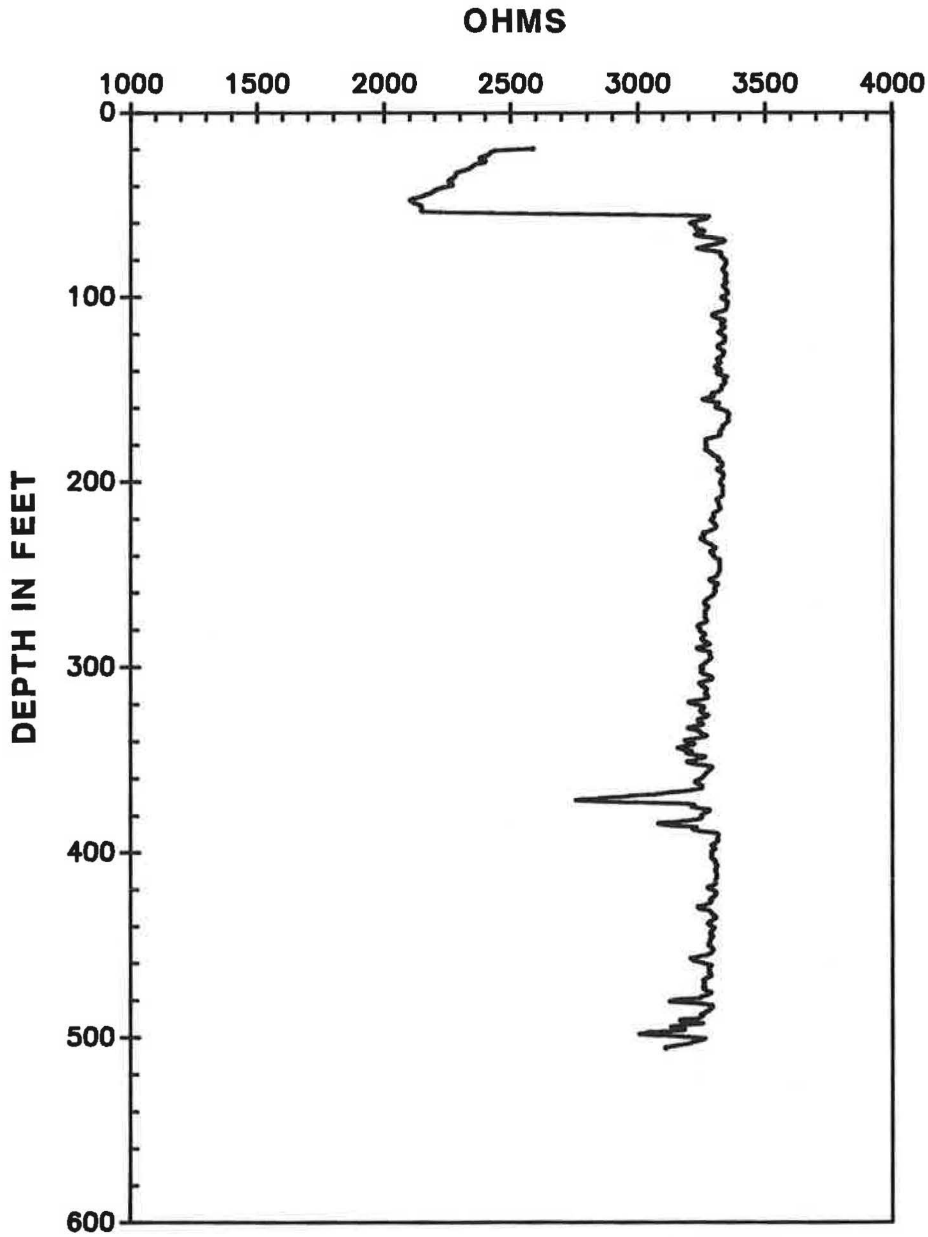


Figure 71. Single-point resistivity log of Locust Grove municipal well.

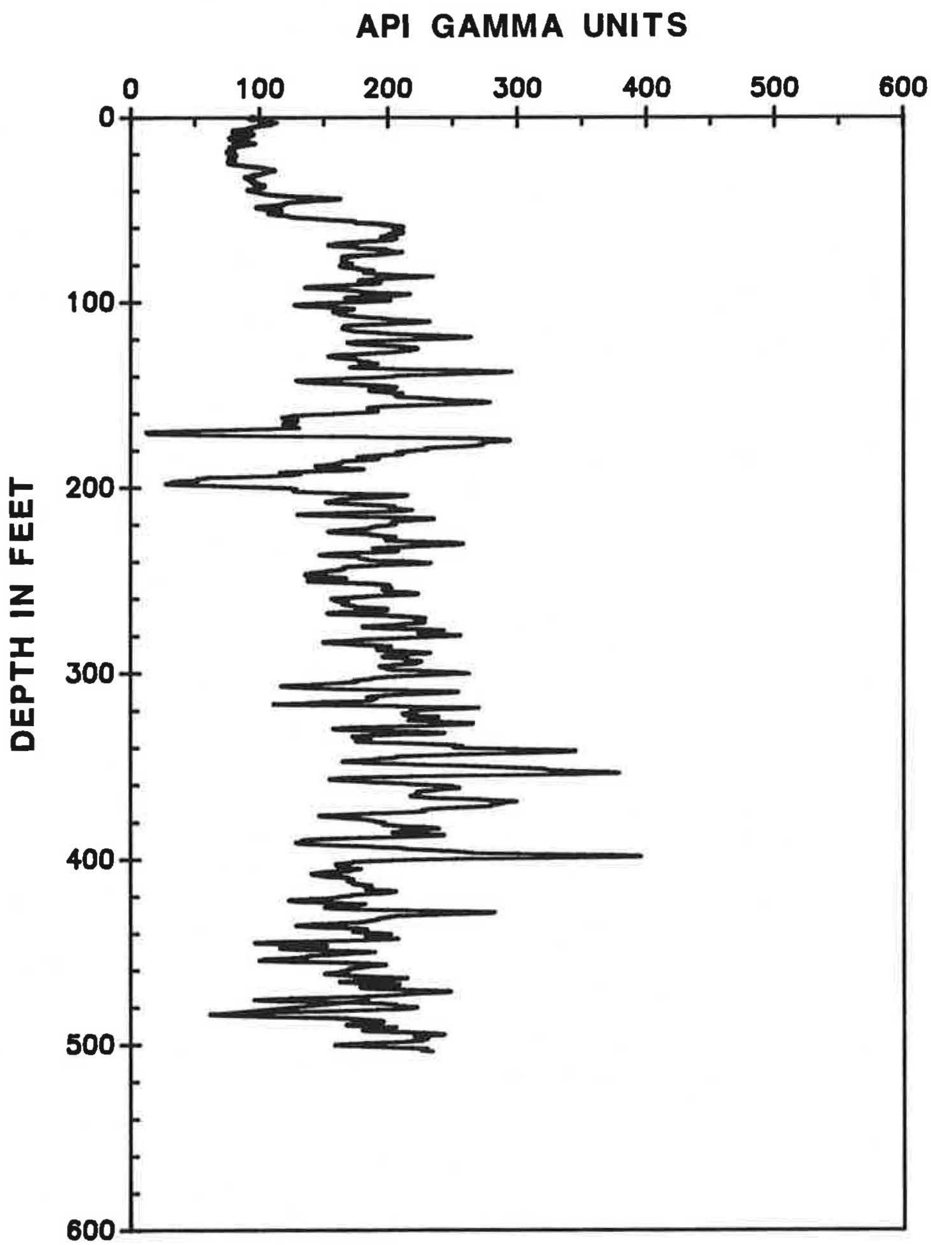


Figure 72. Natural gamma log of Locust Grove municipal well.

using a four-inch, shaft-driven turbine pump powered by a diesel engine. No observation wells could be located. An intermittent stream located about 300 ft northwest of the test well received the outflow from the test pumping. The well was pumped at a constant rate of 180 gpm (Fig. 73) which produced a total of 139 ft of drawdown. Drawdown and recovery curves formed by the test data are smooth but asymmetrical (Fig. 74).

SUMMARY

The Geologic Survey located municipal well 1 for the city of Locust Grove at the intersection of a structurally controlled straight stream valley segment and a discontinuity trend. The well had a yield of 180 gpm after a 24-hour pumping test (Fig. 74). The total drawdown recorded was 139 ft.

LOST MOUNTAIN, COBB COUNTY

INTRODUCTION

The community of Lost Mountain is located in western Cobb County (Fig. 1). A domestic well in Lost Mountain was tested for its hydrologic properties by the Geologic Survey because a report by the well driller indicated that the well produced a large volume of water from what may be a bottom-hole fracture at a depth of 616 feet. Bottom-hole fractures are a class of inferred, near- horizontal discontinuities that may have developed at depths of hundreds of feet due to stress relief as overburden is naturally removed from the crystalline rocks of the Piedmont by erosion (Cressler, Thurmond, and Hester, 1983). The Geologic Survey obtained access to this well in order to test the hydrologic properties of one of these presumed bottom-hole discontinuities. Geophysical logs were not run on this well.

GEOLOGY

The community of Lost Mountain lies in the Central Uplands District, a subdivision of the Piedmont Physiographic Province (Clark and Zisa, 1976). Total relief in the area is approximately 520 ft (Fig. 75). With the exception of Lost Mountain, the hill tops are gently convex and stream valleys are gently concave. Intermittent streams in the Lost Mountain area have trellis-style drainage patterns; whereas, larger streams commonly show dendritic drainage. Straight valley segments near Lost Mountain are oriented N50°E, N70°E, N20°E, N20°W, N45°W, and N85°E. The well site is located on an interstream divide on the southeastern flank of Lost Mountain and is several hundred feet higher than the surrounding area (Fig. 75).

Two mappable lithologic units are present in the vicinity of the Lost Mountain well. One is a unit containing amphibolite, biotite gneiss and garnet quartzite. Roughly 85-90 percent of this unit is a dark-green coarse-grained epidote-chlorite-plagioclase-hornblende amphibolite. Amphibolite weathers to a yellow-brown to ocher-colored saprolite with a boxwork texture. Gray coarse-grained biotite plagioclase granite gneiss makes up 5-10 percent of this unit. Scattered quartz and feldspar porphyroblasts are present and range in diameter up to 0.1 in. The gneiss contains a few garnets that are 0.1 in. in diameter. These two lithologies are interlayered on a scale one inch to a few feet. The remaining 5 percent of this unit consists of a reddish-brown weathered, garnet quartzite. Garnets range in diameter up to 0.4 in. The quartzite exhibits a "spotted" texture in places and is 10 to 30 ft in thickness.

The other unit in the vicinity of Lost Mountain is predominantly a coarse-grained, silver-grey to green, garnet-chlorite schist. The garnets range in diameter up to 1 in. Locally this unit has a "button schist" texture with buttons ranging from 1 to 3 in. The chlorite schist weathers to a red-brown or tan saprolite. The schist is a massive unit with a crude foliation characterized by chlorite wrapped around garnet porphyroblasts. Quartzite comprises a very small percent of this unit. The quartzite contains pyrite and possibly chalcopyrite. Outcrops of quartzite commonly are less than 5 ft wide in this map unit.

The geologic map (Fig. 75) illustrates the northeast strike and the southeast and northwest dip of the rocks. Joint spacing is from 2 in. to 1 ft and persistence along strike varies from 1 in. to 20 ft. Joints occur as en echelon fractures and as straight, curving, or irregular planes that are manganese coated in places. Most joints, however, are straight with smooth surfaces. Joint aperture in weathered rock is 0.1 in. or less. Joint sets oriented N50°W, N70°W, and N54°E are

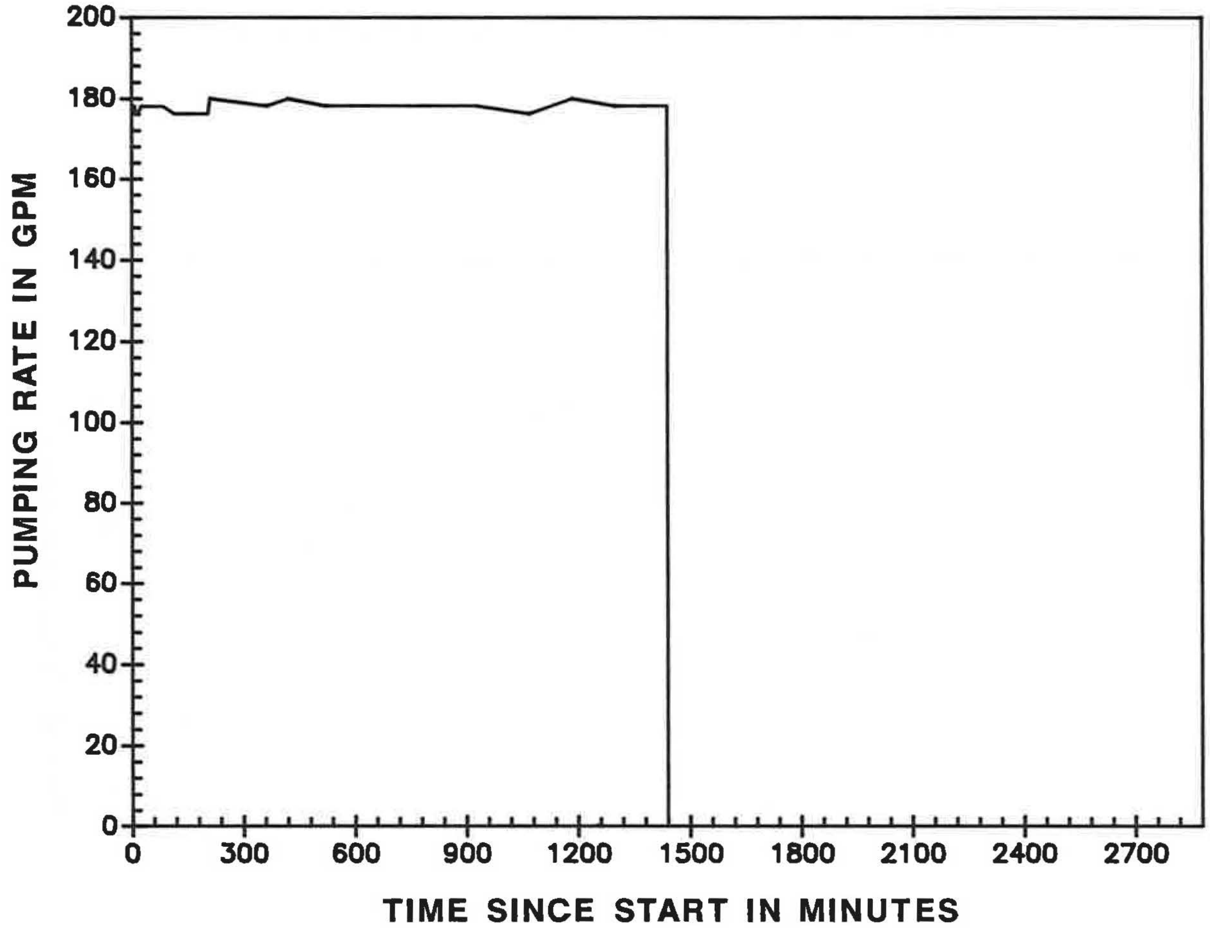


Figure 73. Pumping rate during test of Locust Grove city well.

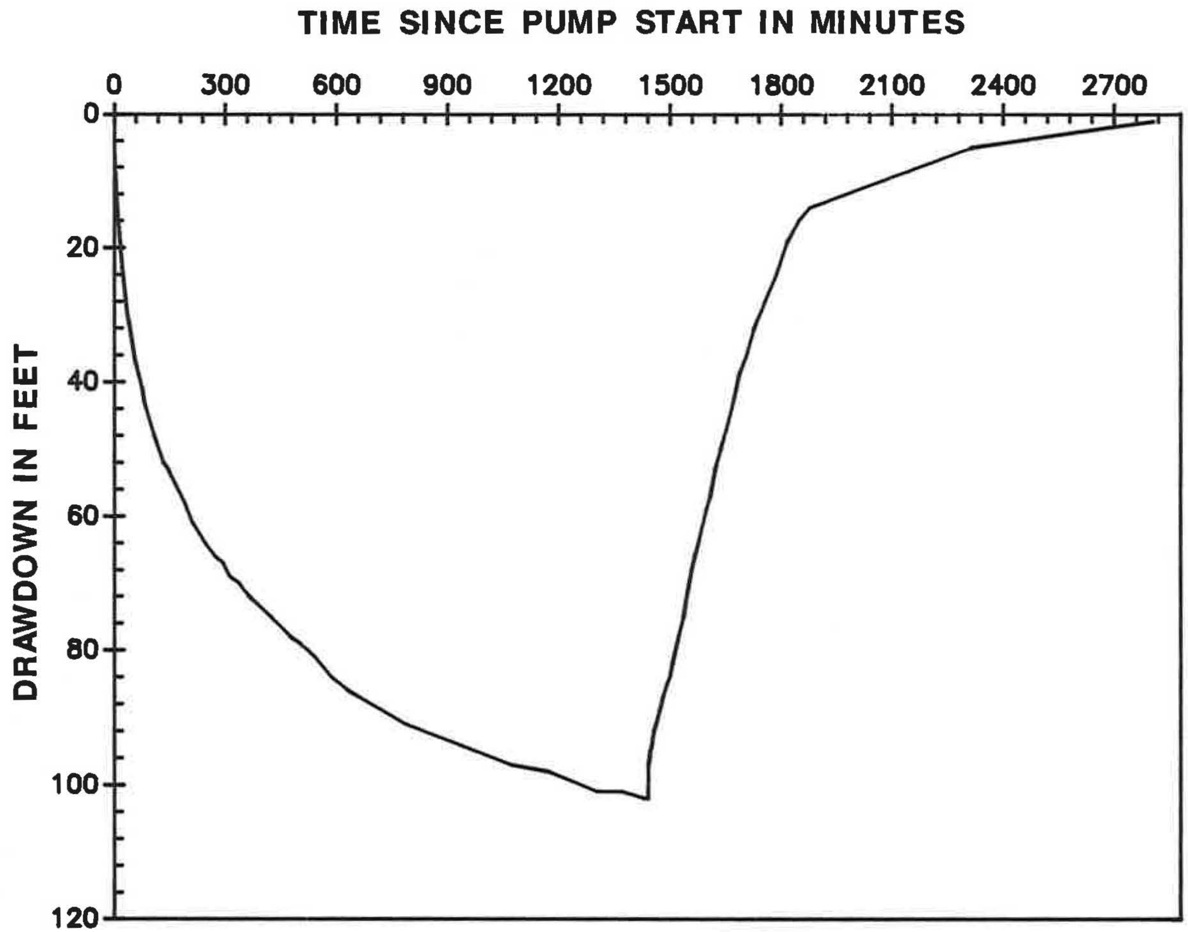
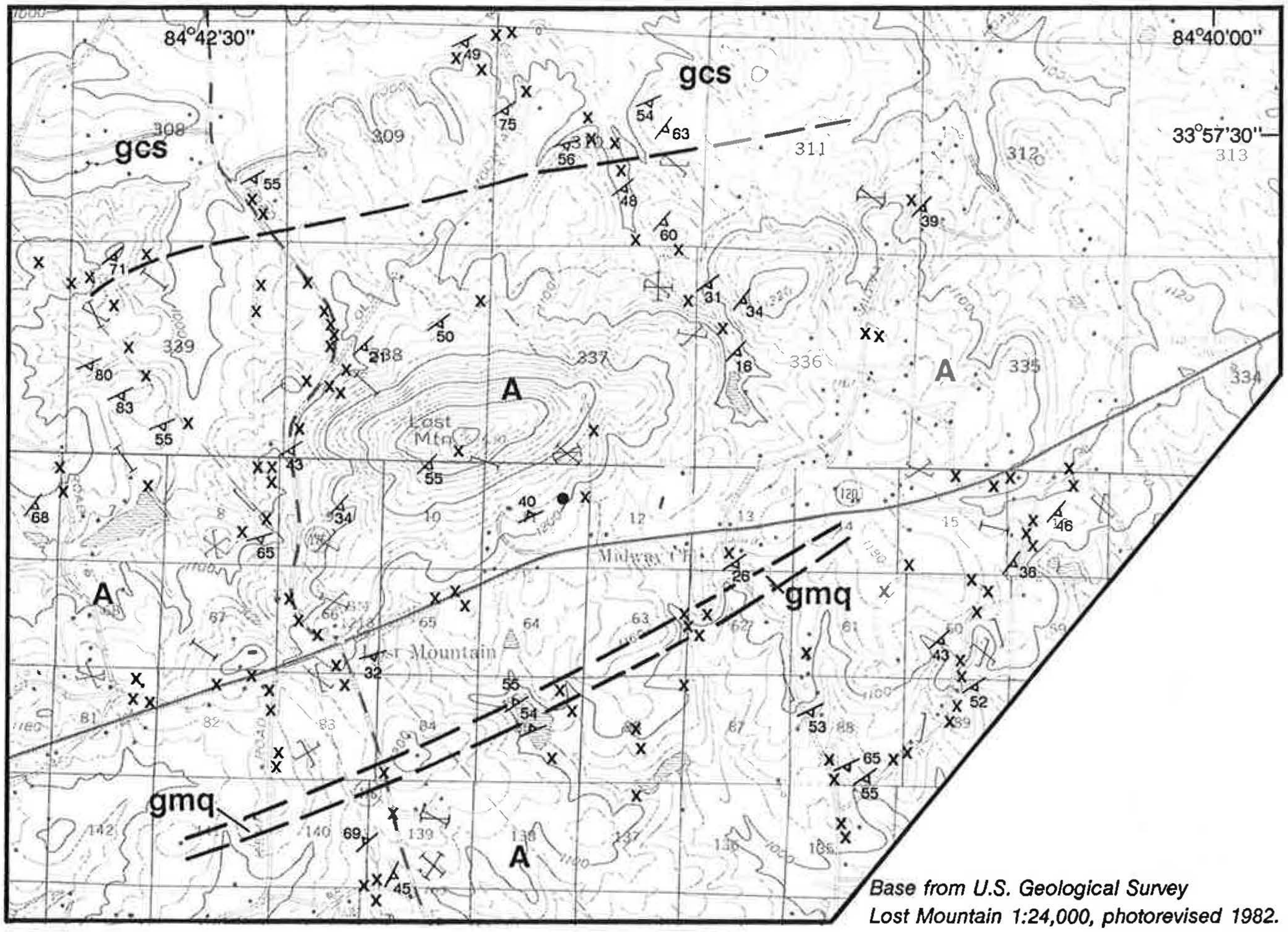


Figure 74. Drawdown and recovery curves for Locust Grove city well.



EXPLANATION

gmq	Garnet mica quartzite
A	Amphibolite, biotite gneiss
gcs	Garnet chlorite schist
45	Strike and dip of compositional layering
	Strike and dip of inclined joint
	Strike and dip of vertical joint
x	Outcrop
•	Well location
— —	Inferred contact

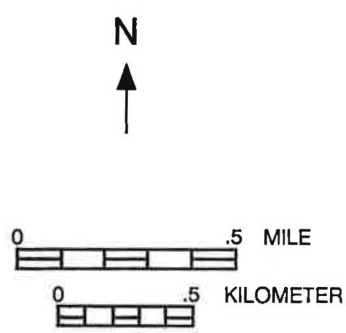


Figure 75. Geologic map of part of the Lost Mountain Quadrangle and location of the Lost Mountain well.

vertical and joints oriented N15°W dip 70°NE (Fig. 75).

HYDROLOGIC TESTING

A 24-hour step test was conducted on the Lost Mountain well using a submersible pump and generator supplied by the driller. No observation wells could be located for this test. The pumping rate during the test was very irregular due to intermittent failure of the generator, but averaged 60 gpm (Fig. 76). Pumping at this rate produced a total drawdown of only 9.5 ft during the test period. Drawdown and recovery curves generated from the test data are irregular and asymmetrical (Fig. 77). The curves are atypical in that they have a low slope and a linear shape. The well had not recovered to its pre-pumping water level after 6 days.

SUMMARY

The Lost Mountain well sustained an average pumping rate of 60 gpm for 24 hours. The drawdown was minimal, indicating that a considerable amount of water was stored in the bottom-hole fracture. However, full recovery of the well did not take place during the six days of monitoring. The very slow rate of recovery of this well was attributed to its high topographic position and limited recharge.

NEWNAN, COWETA COUNTY

INTRODUCTION

The city of Newnan is located in central Coweta County (Fig. 1). Newnan relies primarily on surface water to meet its municipal-supply needs, but withdraws ground water from three wells to supplement surface-water supplies. The Geologic Survey asked to be allowed to use one of these wells to conduct a pumping test because the other two wells could be used as observation wells. A 24-hour pumping test was conducted on well P, and wells S and NE (Geologic Survey designation) were used as observation wells (Fig. 78). Information on well construction was not available for any of these wells.

GEOLOGY

The city of Newnan lies in the Greenville Slope District (Clark and Zisa, 1976), a subdivision of the Piedmont Physiographic Province. Total relief in the Newnan area is approximately 200 ft (Fig. 78). Hilltops are gently convex, and stream valleys are gently concave. The largest streams in the area exhibit dendritic drainage patterns. Smaller intermittent streams have trellis-style drainage patterns. Straight valley segments identified on topographic maps near Newnan are oriented N29°W, N04°E, N74°W, and N40°E. The three municipal wells are all located in the valley of a northwest-trending tributary of Sandy Creek in an area of rolling topography.

The floodplain of the tributary where the wells are located is underlain by alluvium which in turn overlies the Clarkston Formation. The alluvium consists of tan, micaceous, sandy silt. The alluvium along the tributary to Sandy Creek ranges from 0 to 5 ft thick. A six-inch bed of colluvial and alluvial cobbles underlies the alluvium and marks the contact between the alluvium and bedrock.

The Clarkston Formation is the bedrock unit in which the Newnan city wells are completed. The formation consists of a tan to purple saprolite derived from a sillimanite-garnet-mica schist and a tan to purple saprolite derived from a biotite-plagioclase gneiss. These two lithologies are interlayered on a scale of one to several feet. The gneiss locally contains feldspar porphyroblasts and layers of manganese garnet quartzite and manganese garnet schist. Ocher-colored saprolite derived from a dark-green to black coarse-grained hornblende-plagioclase amphibolite also is present (Higgins and Atkins, 1981). Amphibolite layers are commonly less than one foot thick and comprise only about 5 percent of the outcrop area. All of these lithologies contain intrusions of granite and quartz-feldspar pegmatite in places.

The geologic map illustrates the northwest strike and northeast dip of the compositional layering (Fig. 78). Shearing parallels the compositional layering. Joints are spaced from one inch to several feet apart and persistence along strike varies from an inch to several feet (Table 7). Joint aperture in weathered rock is less than 0.1 in. Joint sets that strike E-W, N25°W, and N52°E all dip vertically. Joints striking N22°E dip 54°NW and some of the E-W joints dip 34°N.

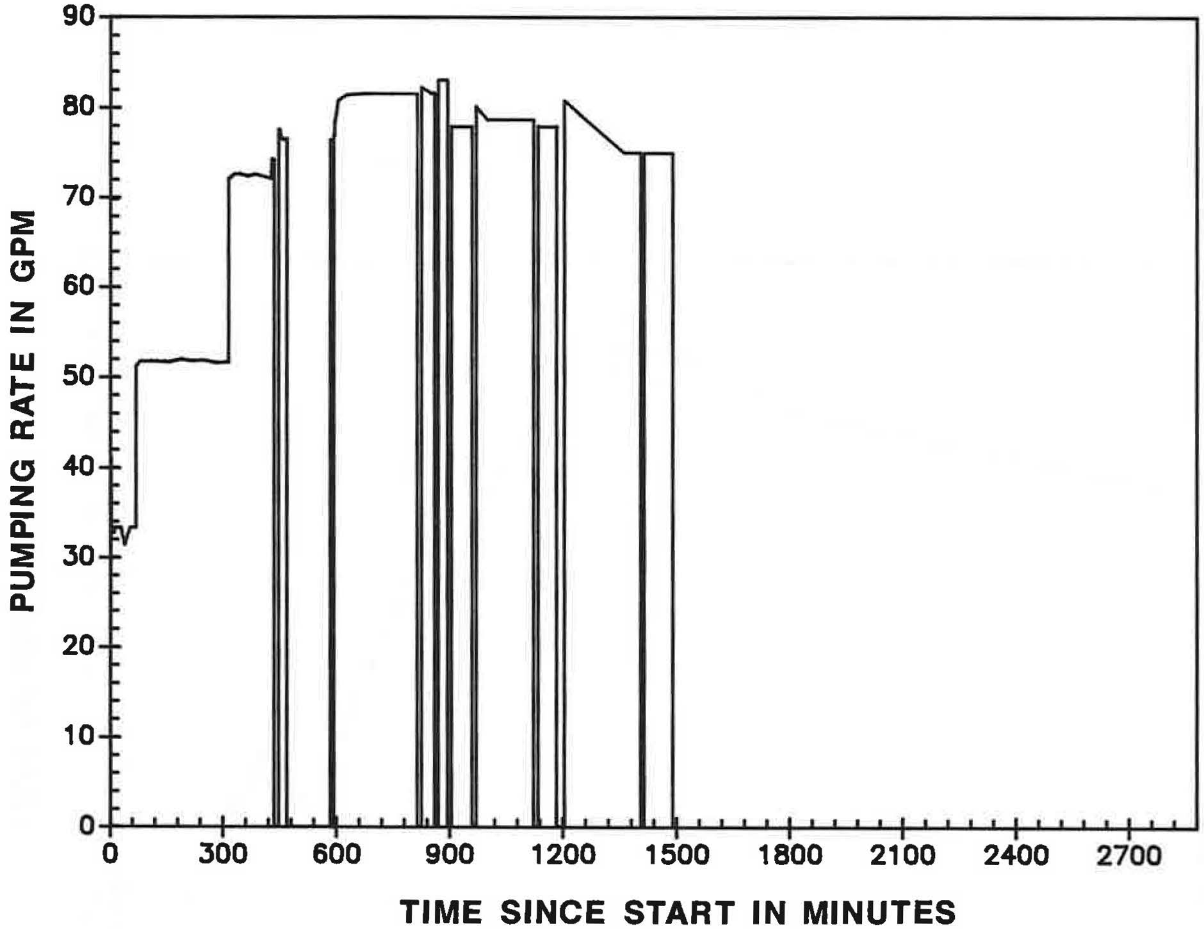


Figure 76. Pumping rate during test of Lost Mountain well.

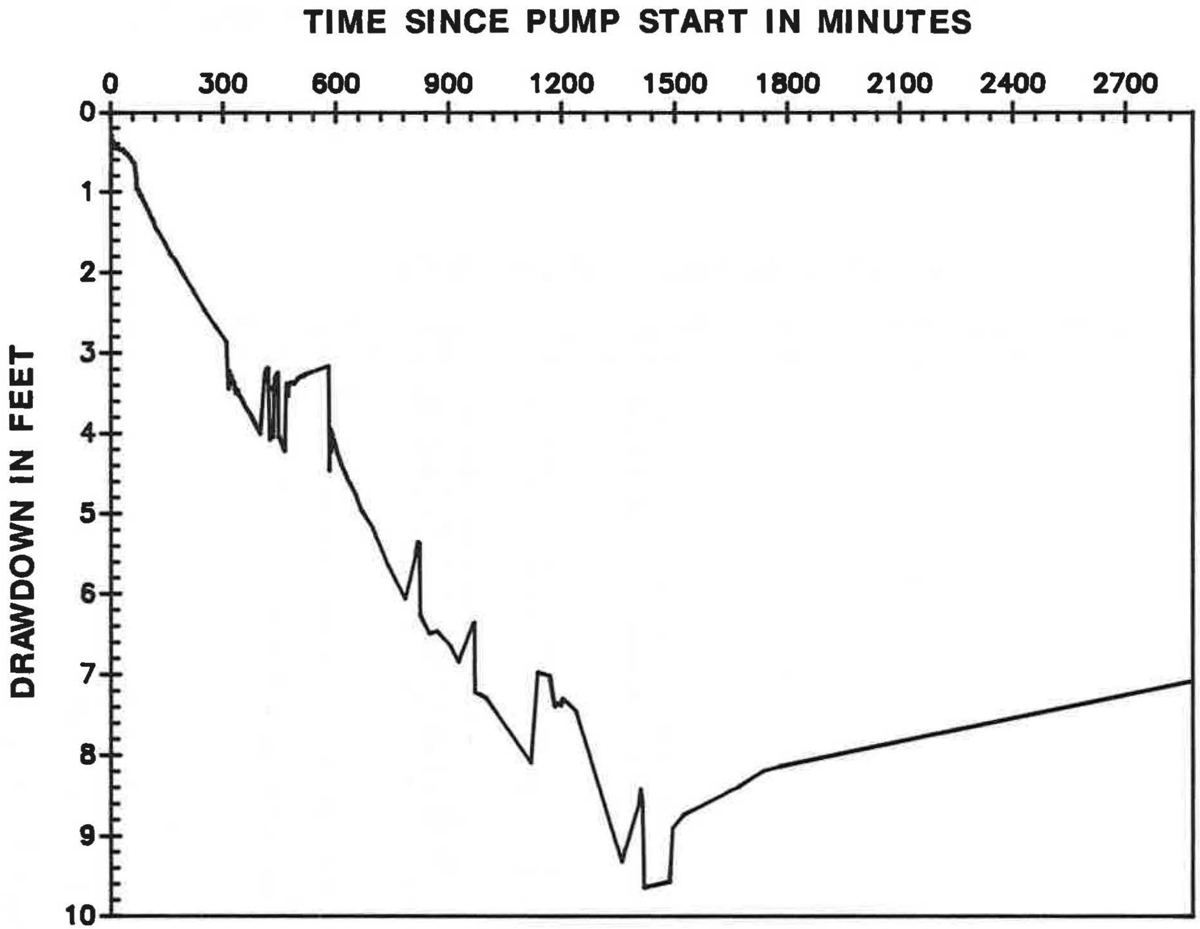
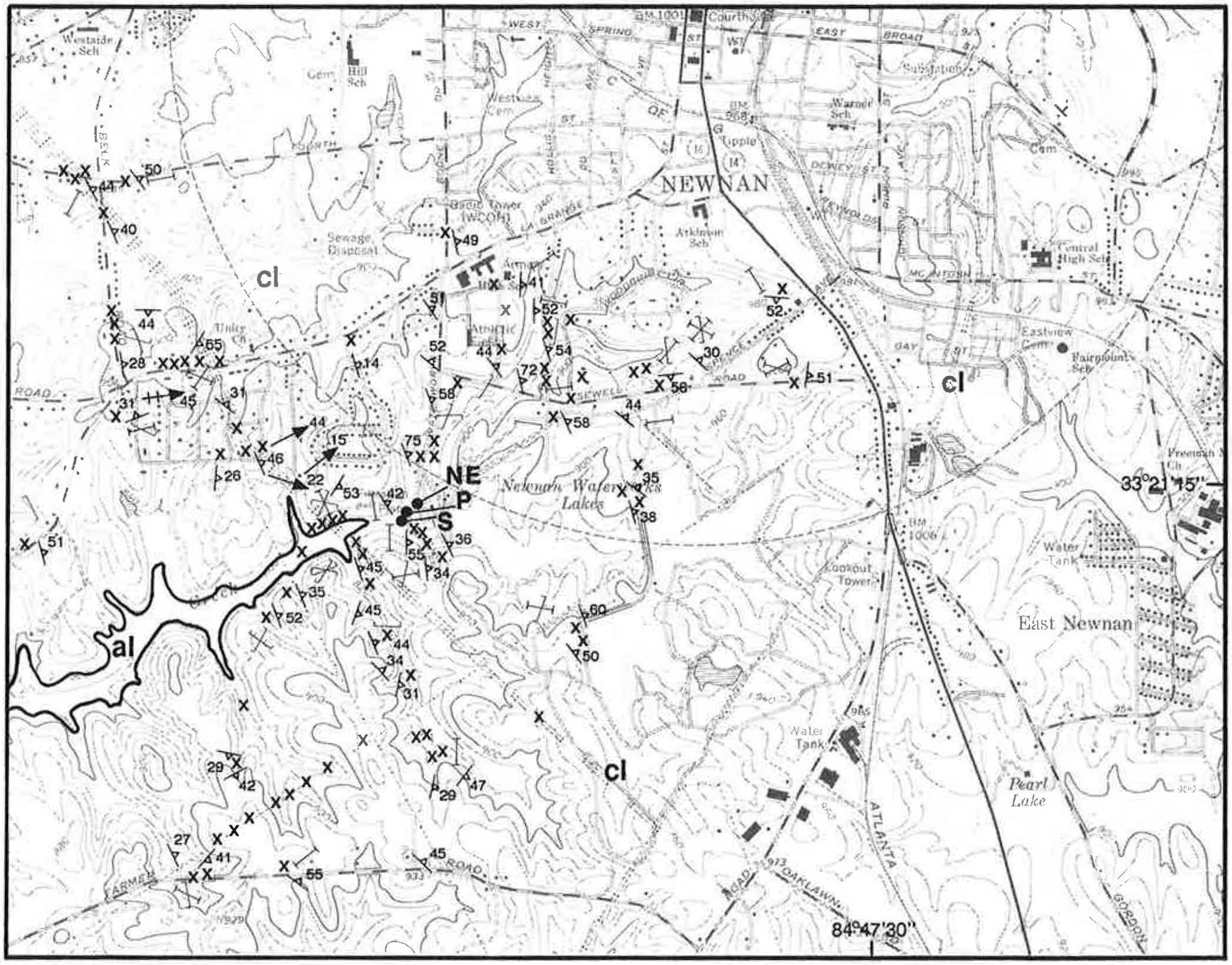


Figure 77. Drawdown and recovery curves for Lost Mountain well.



Base from U.S. Geological Survey
Newnan South 1:24,000, 1965.

EXPLANATION

al — Alluvium

cl — Clarkston Formation

Strike and dip of compositional layering

Strike and dip of inclined joint

Strike and dip of vertical joint

Trend and plunge of mineral lineation

Trend and plunge of fold axis

Well location

x — Outcrop

Contact

N

0 .5 MILE

0 .5 KILOMETER

Figure 78. Geologic map of part of the Newnan South Quadrangle and locations of the Newnan municipal wells.

Table 7. Newnan, joint orientations and descriptions.

Joint	Dip	Spacing	Surface	Coating
East-West	90°	2 in-1 ft	smooth to irregular curving	none
Northwest	"	"	smooth curving	manganese
Northeast	"	"	smooth	manganese
Northeast	NW	2 in	weathered surface	manganese
East-West	N	3-6 in	curving smooth	manganese

HYDROLOGIC TESTING

Two pumping tests were conducted at well P, a capacity test to measure the maximum pumping rate sustainable by the well over a period of four hours and a 24-hour constant-rate test during which the well was pumped at a rate of 30 gpm. Wells S and NE served as observation wells during these tests.

Drawdown in the pumping well could not be adequately measured because of cascading water (Fig. 79). The water level in well NE dropped over 2 ft in 24 hours while water level in well S dropped just over 0.5 ft in the same period of time (Figs. 80, 81). Recovery of wells NE and P was monitored after the constant discharge test. Recovery of well S was not recorded due to its limited drawdown during pumping. The test well has a sustainable pumping rate of 30 gpm after 24 hours of pumping.

SUMMARY

The Newnan well sustained a pumping rate of 30 gpm for 24 hours. Drawdown could not be recorded in well P due to cascading water. Only 2 ft of drawdown was noted in an observation well located 345 ft from well P and a little more than 0.5 ft of drawdown in a second observation well located 214 ft from P.

SHOAL CREEK SUBDIVISION, COWETA COUNTY

INTRODUCTION

Shoal Creek Subdivision, in Coweta County, is located about 35 miles south of Atlanta and 2 mi west of Peachtree City (Fig. 1). The Geologic Survey asked to be allowed to measure the hydrologic properties of Shoal Creek community-supply well 4 because of its high-yield potential.

GEOLOGY

The Shoal Creek Subdivision lies in the Greenville Slope District, a subdivision of the Piedmont Physiographic Province (Clark and Zisa, 1976). Hilltops in the area are convex to flat and are 800 to 1000 ft across (Fig. 82). The remaining area is gently sloping. Local relief is roughly 120 ft. Stream valleys in the vicinity of Shoal Creek are gently concave with floodplains between 200 and 400 ft wide. Drainage patterns range from dendritic to rectangular. Straight stream valley segments in the area, measured from topographic quadrangle maps, trend N35°W, N53°W, N13°E, N38°E, and N79°E. Shoal Creek Subdivision well 4 is located at the intersection of a northeast-trending intermittent stream and a northwest-trending segment of the valley of perennial Shoal Creek.

Two major geologic units are present in the Shoal Creek area, the Promised Land Formation and the Clarkston Formation (Higgins and others, 1987; Higgins and Atkins, 1981). The well is located at the contact between the two formations.

The Promised Land Formation crops out east of Shoal Creek. It consists of granite gneiss (approximately 90 percent) and amphibolite (approximately 10 percent). The granite gneiss is a light-colored, medium-grained, equigranular, foliated, biotite, quartz, plagioclase granite gneiss. The amphibolite is represented by a red-orange to ocher-colored amphibolite saprolite.

The Clarkston Formation crops out west of Shoal Creek. It consists of interlayered medium- to coarse-grained garnet, biotite, quartz, plagioclase gneiss; tan- to purple-weathering medium- to coarse-grained mica schist; and yellow- to ocher-weathering medium- to coarse-grained amphibolite. These metamorphic rocks were intruded by a coarse-grained equigranular biotite granite.

The study area is located in the southwestern nose of the Newnan- Tucker Synform, a northeast trending regional fold. This fold has been refolded by a north trending upright fold (Scott Creek fold generation; Higgins and Atkins, 1981; Atkins and Higgins, 1980). The general strike of the compositional layering is northeast with a southeast dip (Fig. 82). The rocks along Shoal Creek, however, strike northwest and dip to the northeast.

Joints are spaced from 2 to 6 in. apart, and persistence along strike varies from 1 in. to 70 ft (Table 8). Joint aperture in weathered and exposed rock is less than 0.1 in. Joints in the Shoal Creek area are commonly vertical and

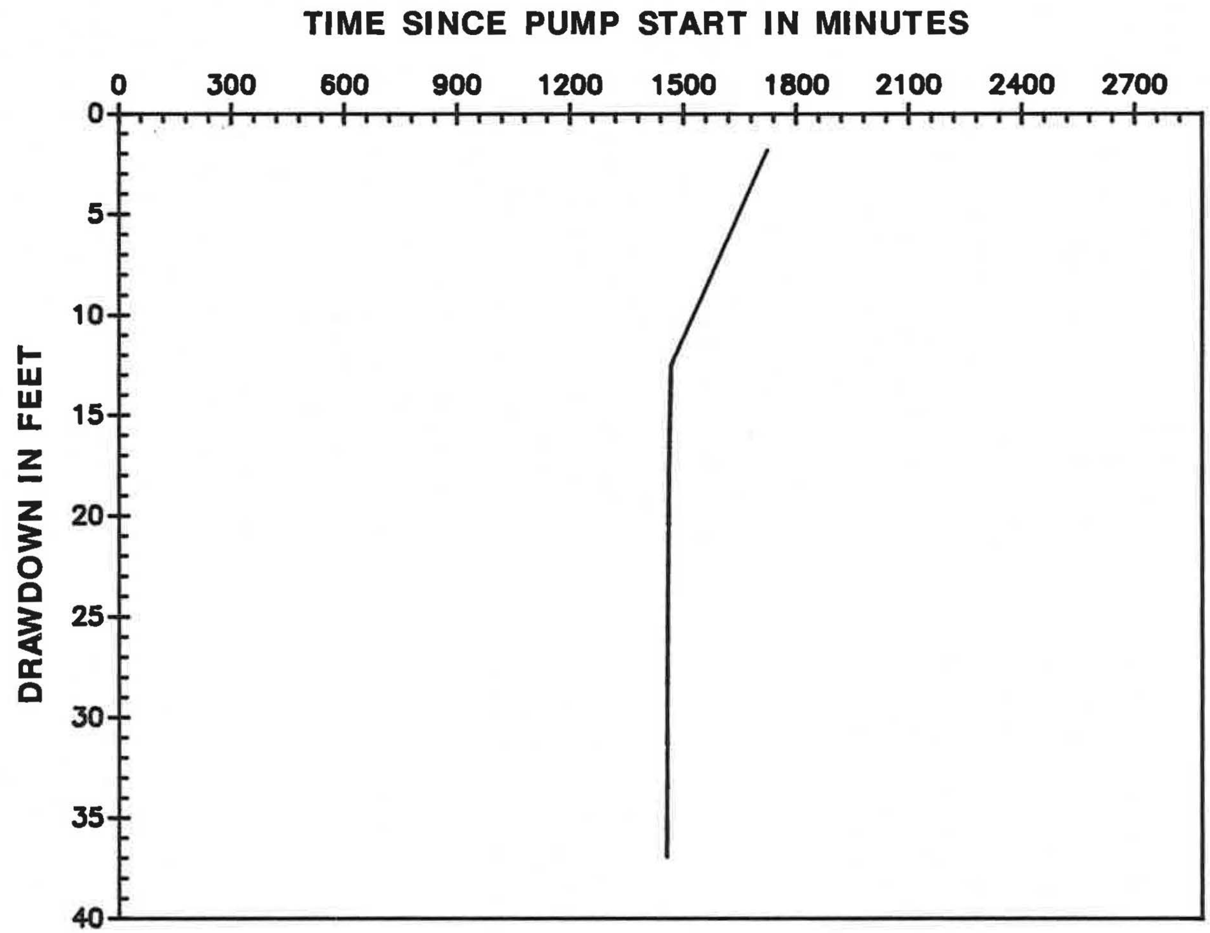


Figure 79. Drawdown and recovery curve for Newnan test well.

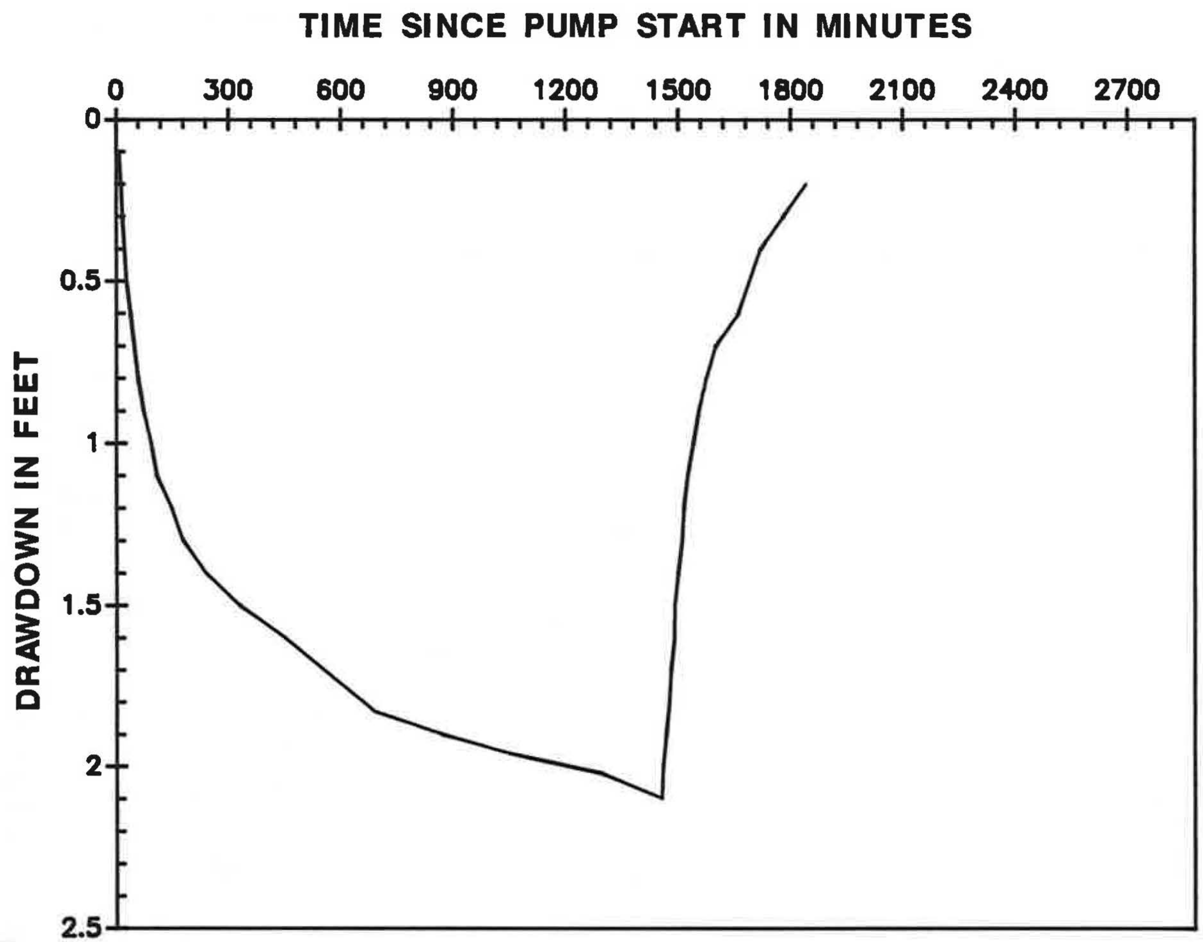


Figure 80. Drawdown and recovery curve for Newnan observation well NE.

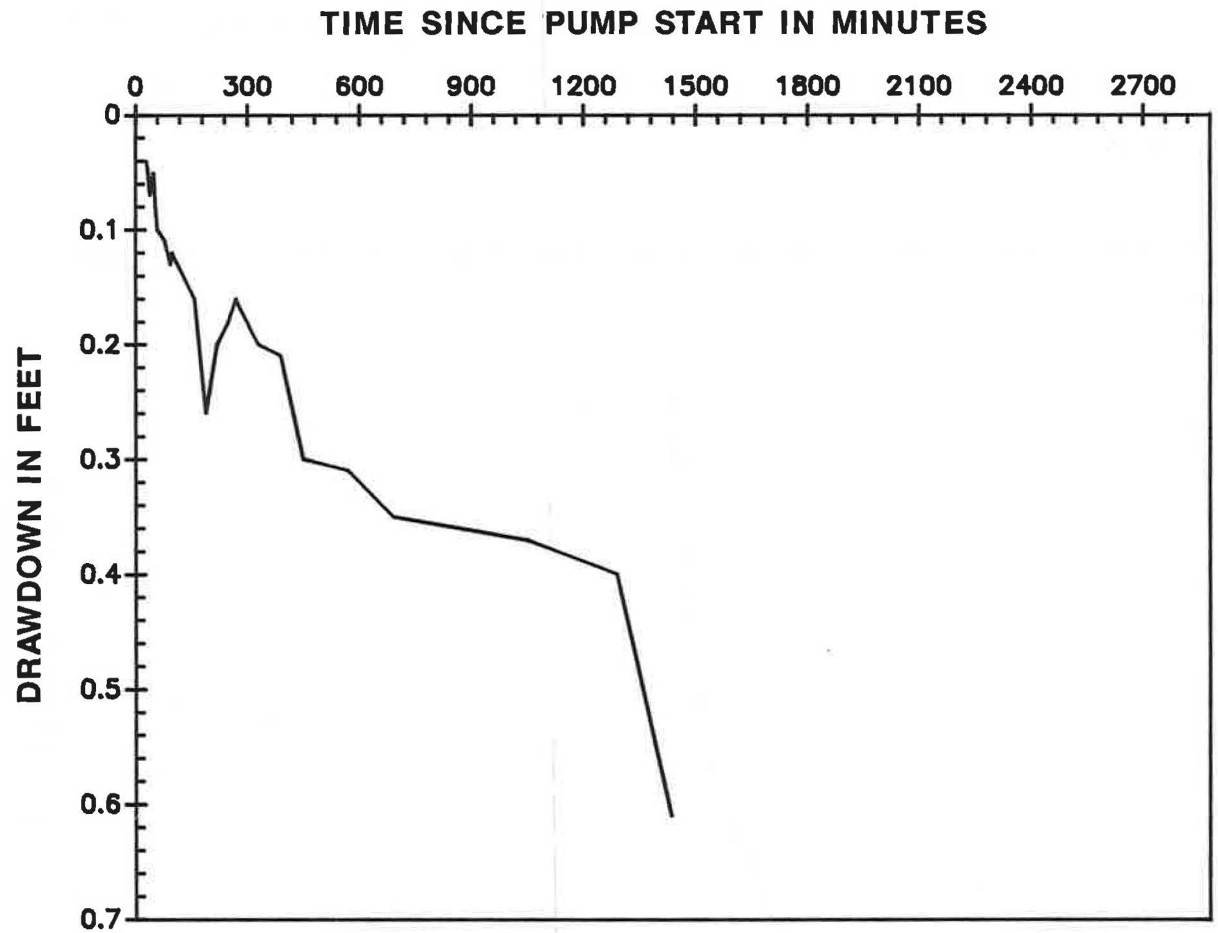
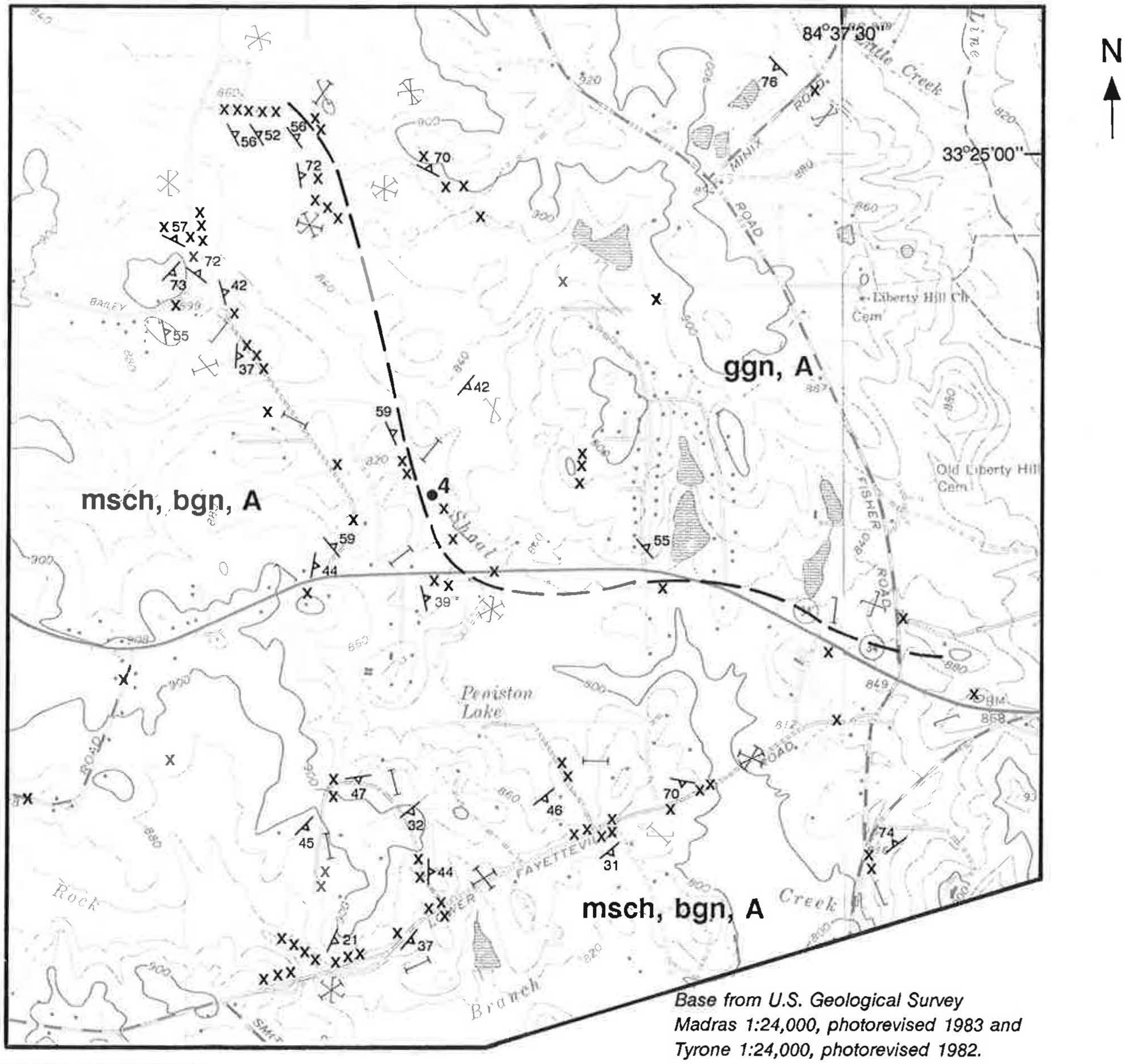


Figure 81. Drawdown and recovery curve for Newnan obsrvation well S.



EXPLANATION

ggn, A	Promised Land Formation: granite gneiss, amphibolite
msch, bgn, A	Clarkston Formation: mica schist, biotite gneiss, amphibolite
44	Strike and dip of compositional layering
	Strike and dip of inclined joint
	Strike and dip of vertical joint
x	Outcrop
•4	Well location
— — —	Inferred contact

0 .5 MILE

0 .5 KILOMETER

Figure 82. Geologic map of parts of the Madras and Tyrone Quadrangles and location of Shoal Creek Subdivision well 4.

Table 8. Shoal Creek, joint orientations and descriptions.

Joint	Length	Spacing	Surface	Coating
N55°E	50-60 ft	6 in-2 ft	smooth	none
N41°W	60-70 ft	4-6 in	curvo-planar	none
N35°E	1 in-5 ft	3-6 in	irregular	none

Table 9. Shoal Creek Subdivision well, water-quality analysis.

Parameters	Results	Parameters	Results
pH	8.0	Ni	nd
Ag	nd	Pb	nd
A	nd	Se	nd
Ba	nd	SO_4	nd
Cd	nd	Zn	0.009 mg/l
Cl	40 mg/l	Hardness	
Cr	nd	(as $CaC0_3$)	120 mg/l
Cu	0.016mg/1	Turbidity (NTU)	1.6
F	0.500 mg/l	Nitrate	nd
Fe	0.43 mg/l	Total Solids	
Mg	nd	(as NaCl)	259 mg/l
Mn	0.010 mg/l		
Na	0.009 mg/l		

nd = not detected

strike N55°E, N41°W, N35°E, and N59°W (Fig. 82).

WATER QUALITY

A water-quality analysis from Shoal Creek Subdivision well 4 indicates that the water is high in iron, turbidity, and hardness (Table 9). The Shoal Creek water analyses were performed by West Georgia Water Analysis of Carrollton.

GEOPHYSICAL TESTING

Surface Geophysics

A series of magnetic profiles were conducted at Shoal Creek Subdivision well 4 to determine whether any magnetic anomalies are associated with this high-yielding well. Measurements were conducted on a 330 x 330 ft (100 x 100 m) grid centered on the well and laid out by pace and compass (Fig. 83). Figures 84 and 85 show the drift in the base station during the measurement period.

The most prominent feature in the survey is the large magnetic anomaly produced by the well casing (Fig. 86). Figure 87 shows the data with the well casing anomaly removed. Figure 88 is a contour map of the cleaned magnetic data. The most prominent feature on the map is a magnetic anomaly in the southwest part of the survey area (Fig. 88). The magnitude of the anomaly is greater than 40 gammas, which is ten times the normal ambient variation in the magnetic field seen over the rest of the site. This anomaly suggests a consistent contrast in magnetic properties between the rocks to the southwest and those to the northeast of the survey area.

Borehole Geophysics

A suite of borehole geophysical logs, including caliper, temperature, spontaneous potential, acoustic velocity, single-point resistance and natural gamma logs were run at Shoal Creek Subdivision well 4 (Figs. 89-94). A water-bearing discontinuity was reported by the well driller at approximately 228 ft, corresponding with anomalies on borehole geophysical logs.

The caliper log (Fig. 89) suggests a relatively smooth borehole surface of constant diameter until about 220 ft. From 220 to 228 ft, the borehole diameter becomes smaller. The apparent reduction in hole diameter is caused by a pipe lodged in the borehole. The caliper log indicates a great increase in borehole diameter at 228 ft. Anomalies on the spontaneous potential and single-point resistance logs occur from about 210 to 230 ft (Figs. 91 and 93). These anomalies may be related to the water-bearing discontinuity at 228 ft. However, the metal pipe lodged in the borehole probably produced some of this activity. The acoustic velocity log (Fig. 92) shows one major anomaly at about 231 ft.

HYDROLOGIC TESTING

The Geologic Survey conducted two pumping tests, a stress test and a 24-hour constant-rate pumping test on Shoal Creek Subdivision well 4, using a four-inch shaft-driven turbine pump powered by a gasoline engine. Discharge from the test well was directed into Shoal Creek, 50 ft away, via a drainage ditch. No observation wells could be located near the site.

The appropriate pumping rate for the 24-hour constant-rate test was calculated from the results of a four-hour stress test. During the constant-rate test, the well sustained a pumping rate of 104 gpm for 24 hours (Fig. 95). The total drawdown observed during the constant-rate test was 143 ft. Drawdown and recovery curves generated by the data gathered from the constant-rate test are irregular but symmetrical (Fig. 96). The well was somewhat unusual in that, prior to pumping, the well had an artesian flow rate of 5 gpm. The well again began to flow several days after testing, but at a lower rate.

SUMMARY

The Shoal Creek Subdivision well is located at the contact between the Promised Land and Clarkston Formations. The well was test pumped at a rate of 104 gpm for 24 hours with a drawdown of 143 ft. A plot of drawdown versus recovery produced symmetrical curves.

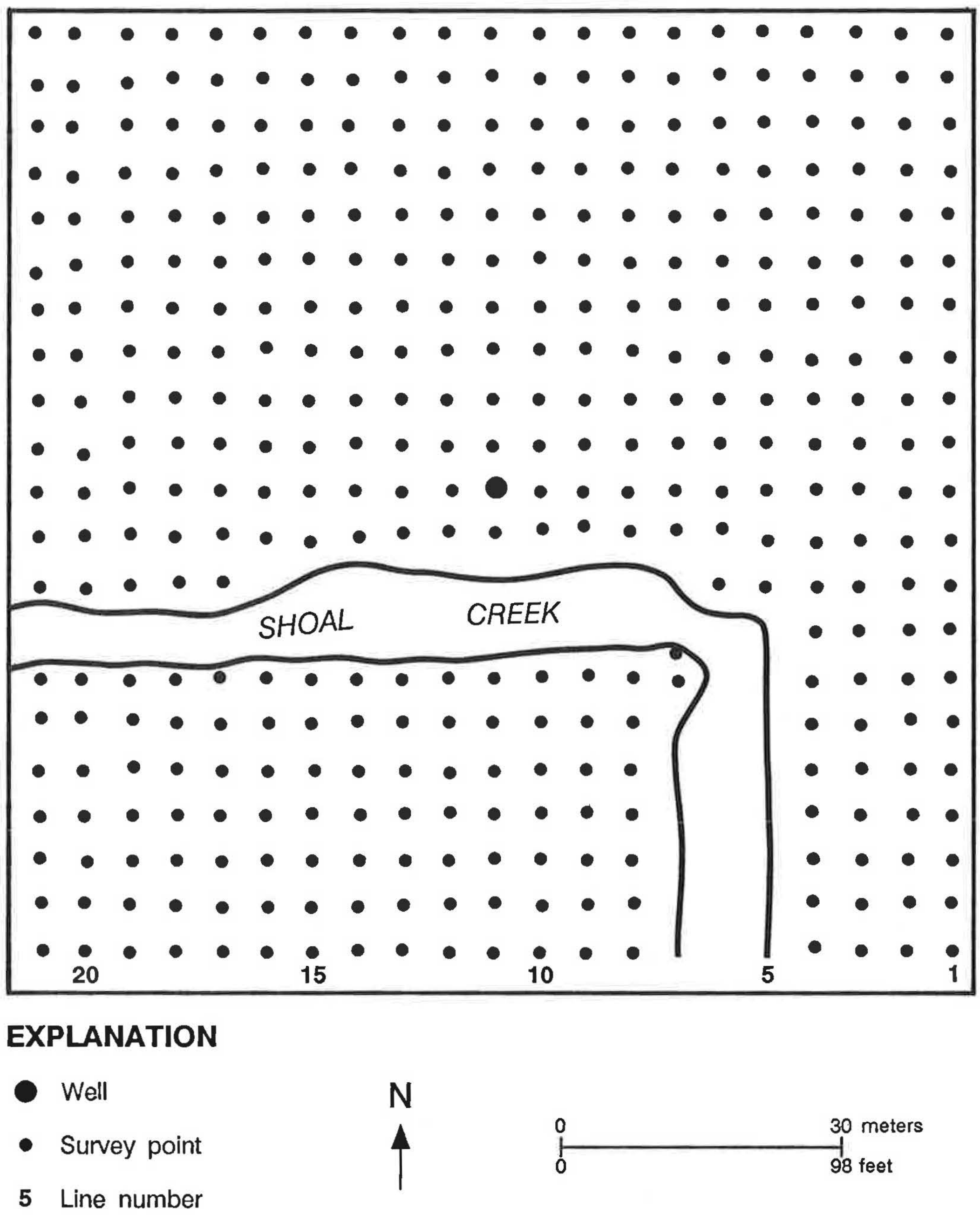


Figure 83. Magnetic survey grid at Shoal Creek Subdivision.

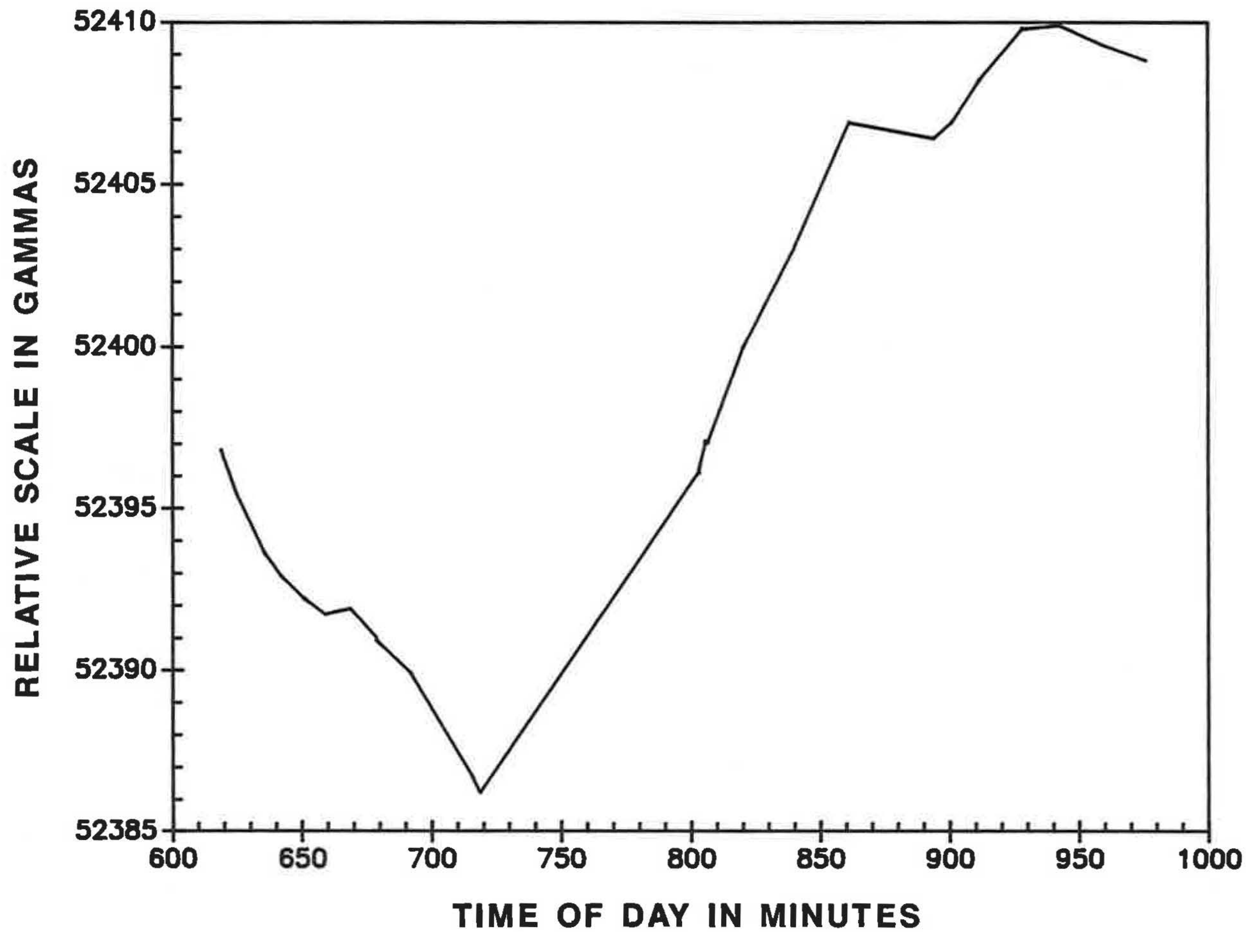


Figure 84. Changes in the magnetic field strength at the primary base station, Shoal Creek Subdivision site.

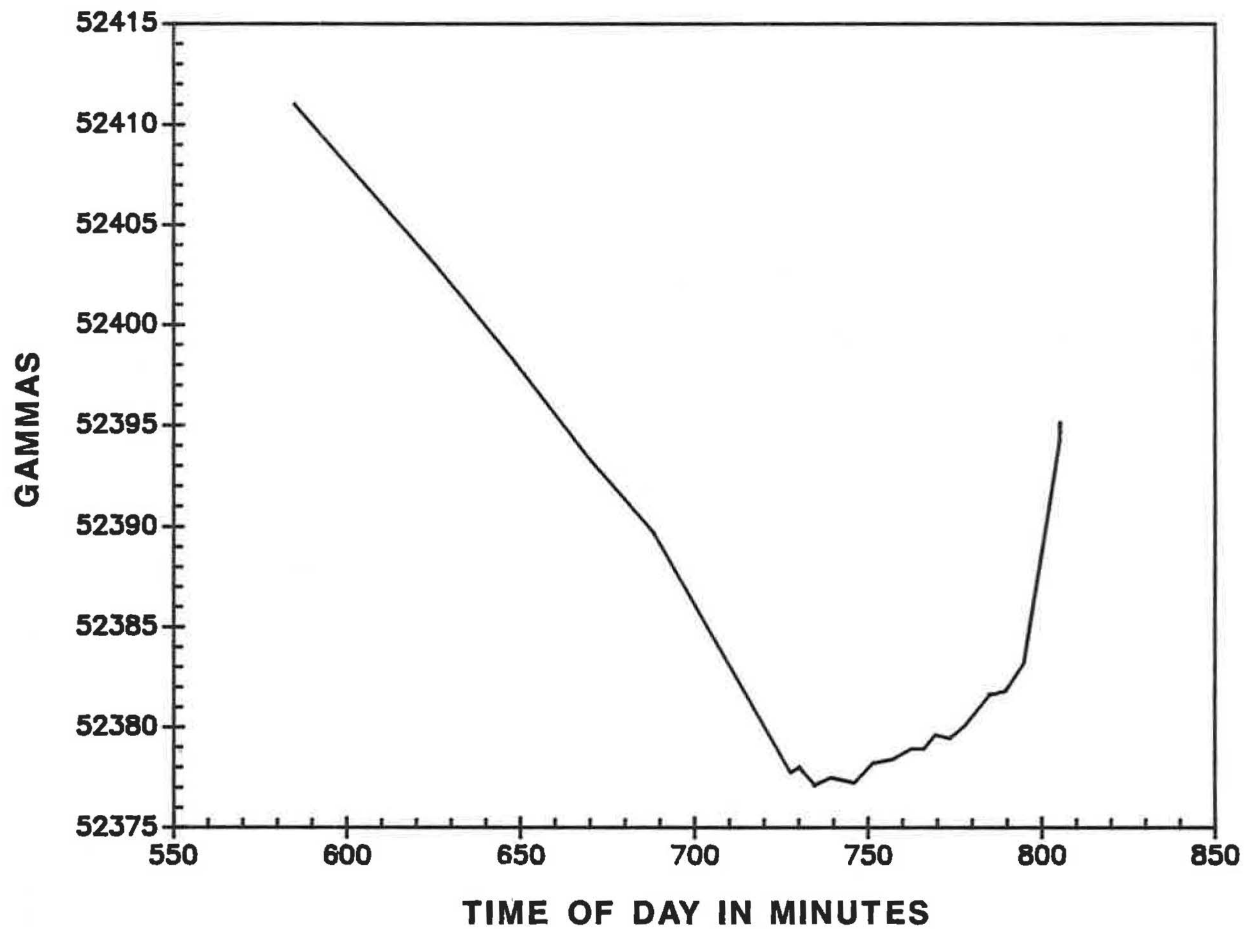


Figure 85. Changes in the magnetic field strength at the secondary base station, Shoal Creek Subdivision site.

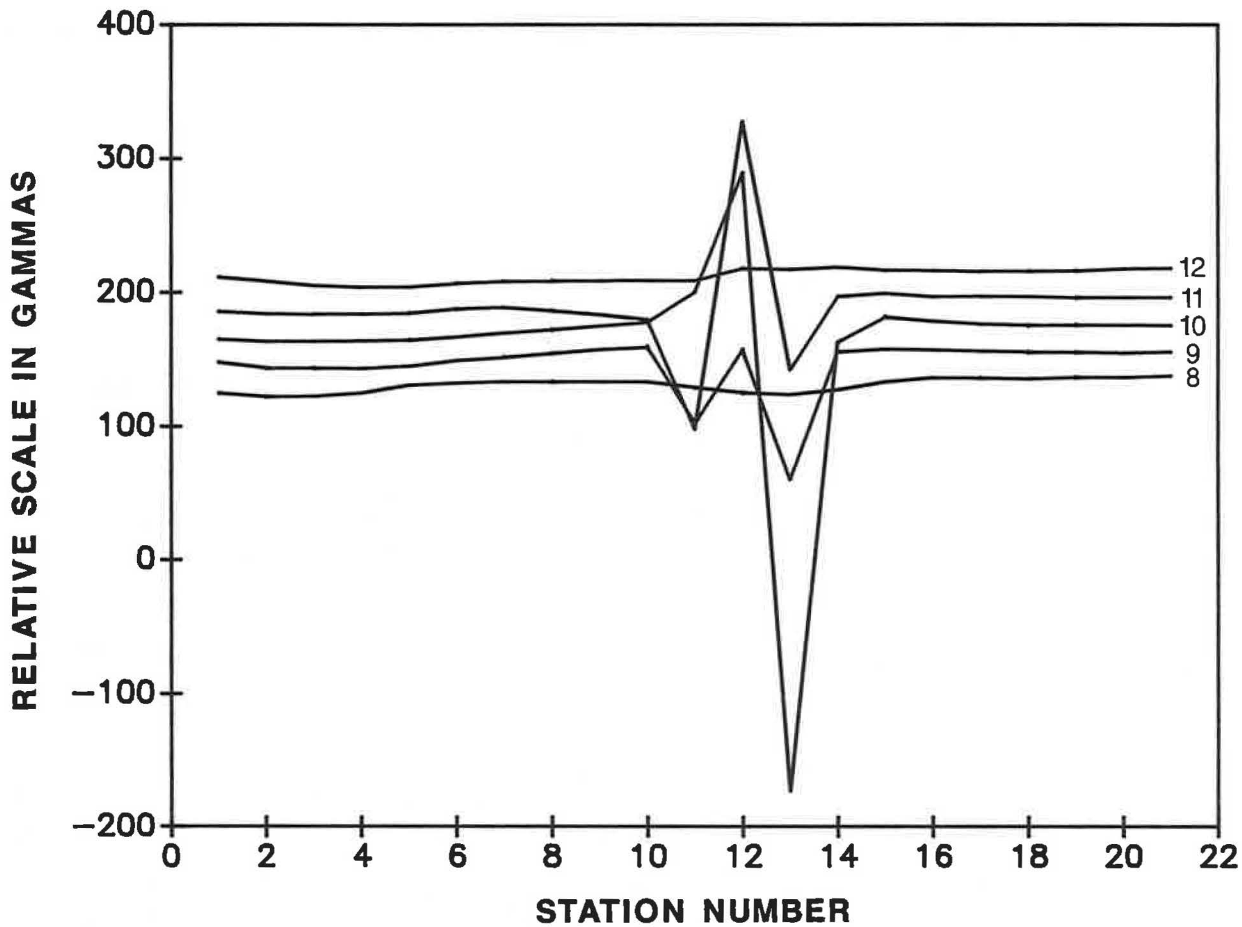


Figure 86. Magnetic survey showing the magnetic field caused by the well casing at the Shoal Creek Subdivision test site.

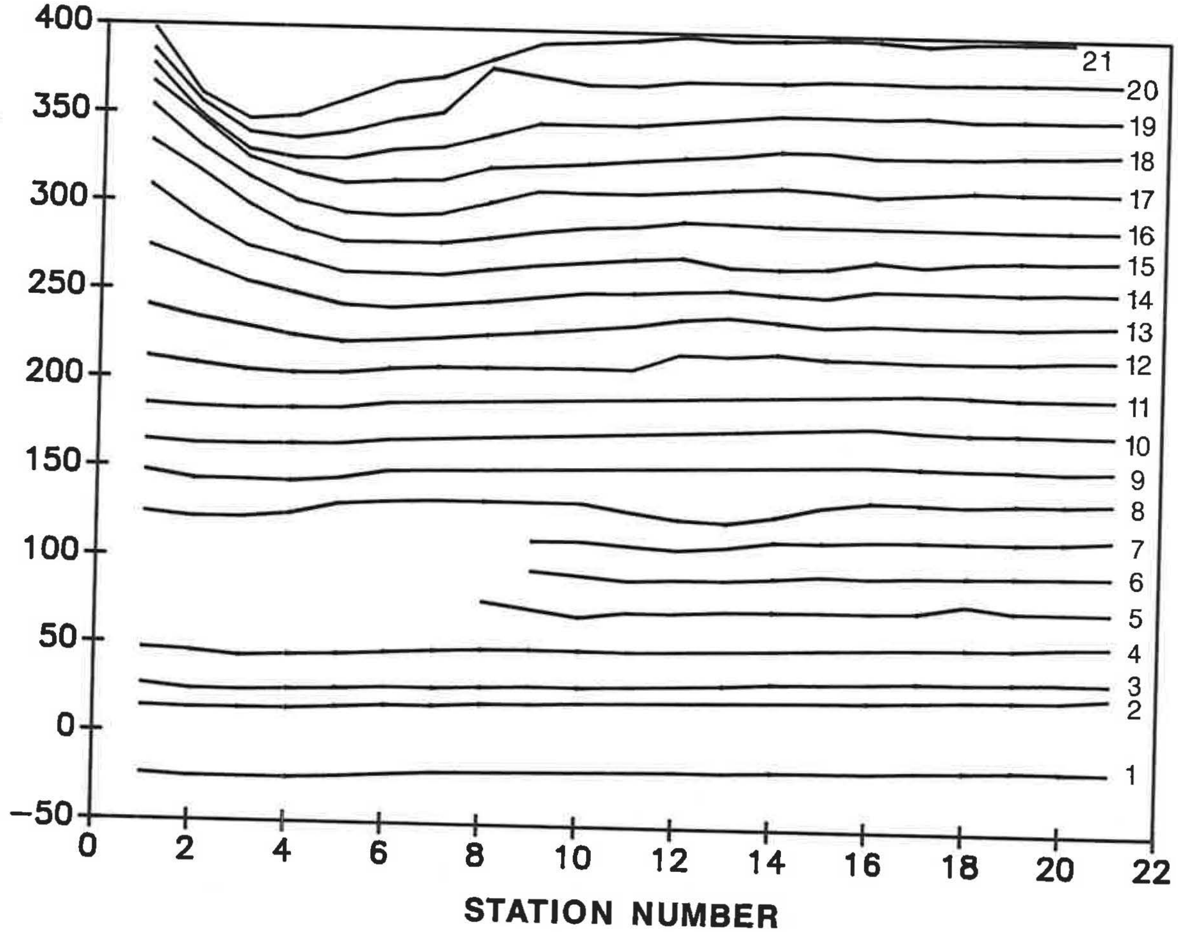


Figure 87. Magnetic survey showing the magnetic field with the influence of the Shoal Creek Subdivision well removed.

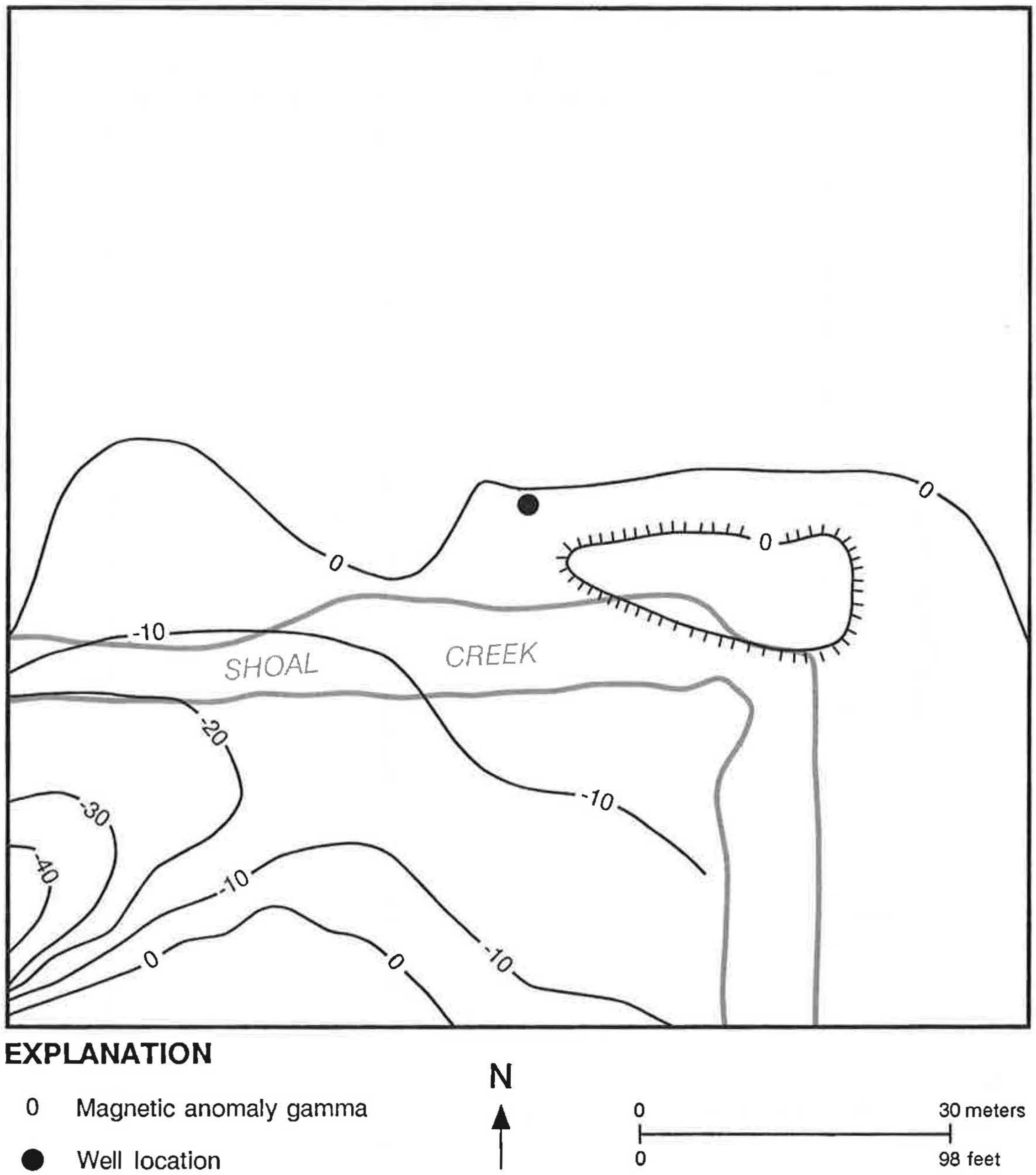


Figure 88. Magnetic anomaly map of the area around Shoal Creek Subdivision well 4.

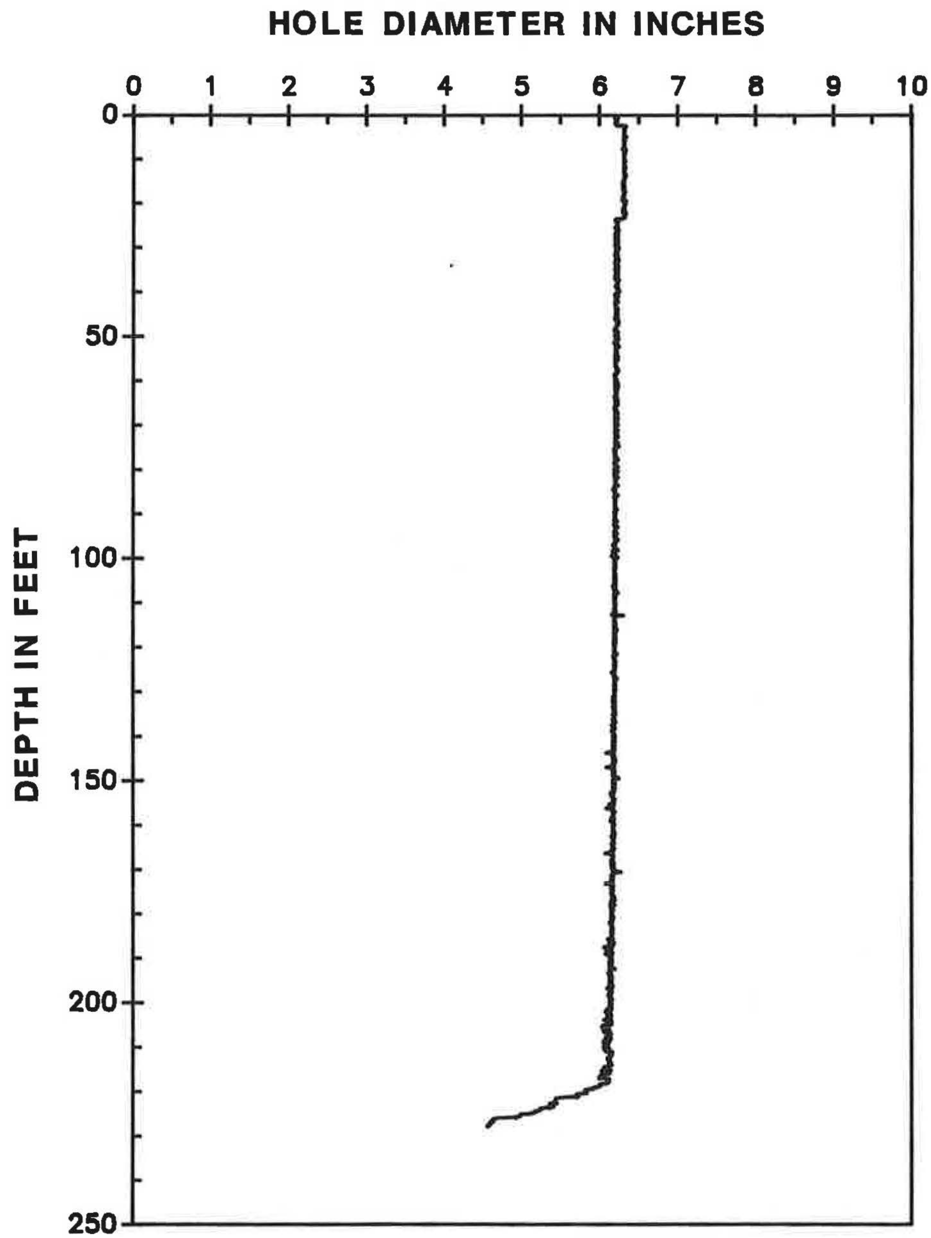


Figure 89. Caliper log of Shoal Creek Subdivision well 4.

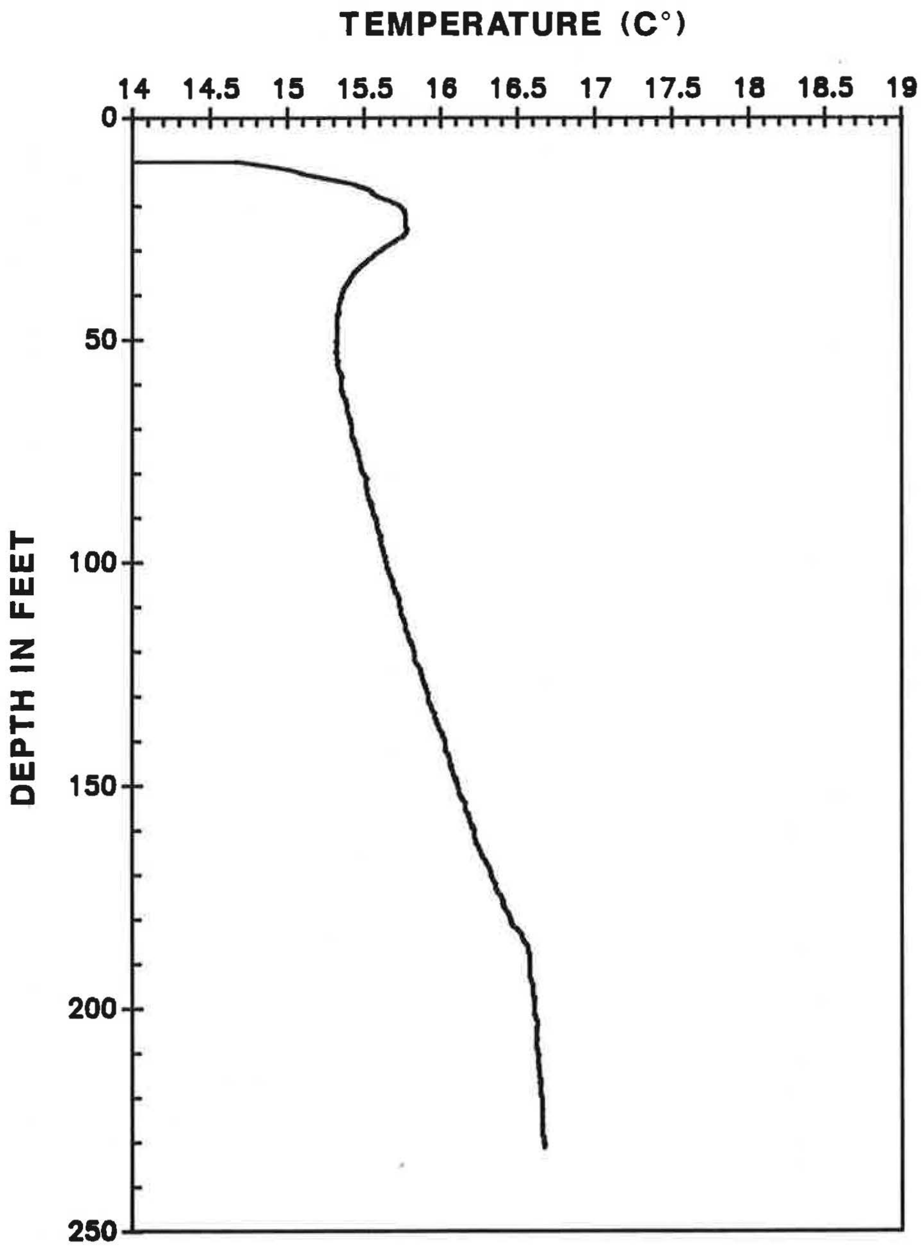


Figure 90. Temperature log of Shoal Creek Subdivision well 4.

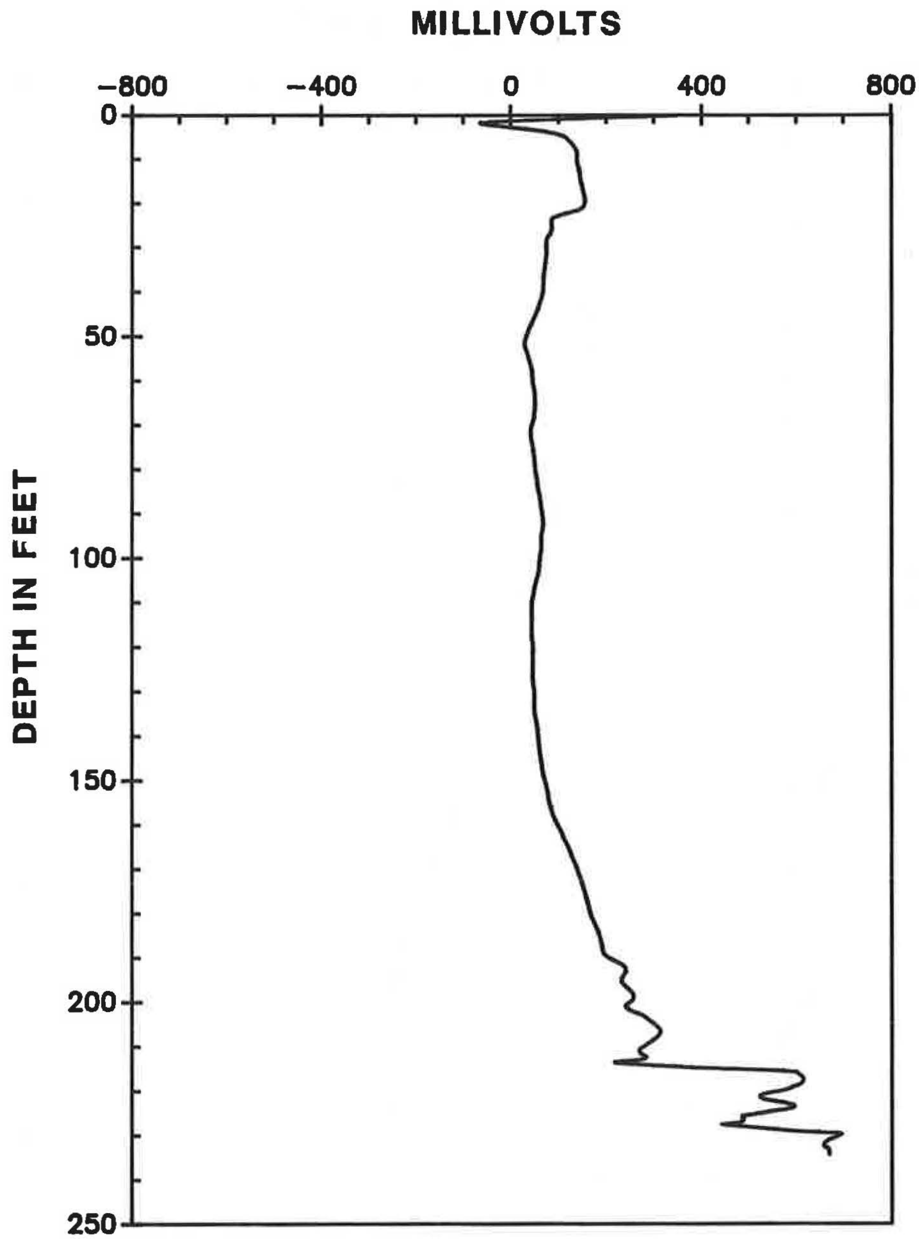


Figure 91. Spontaneous potential log of Shoal Creek Subdivision well 4.

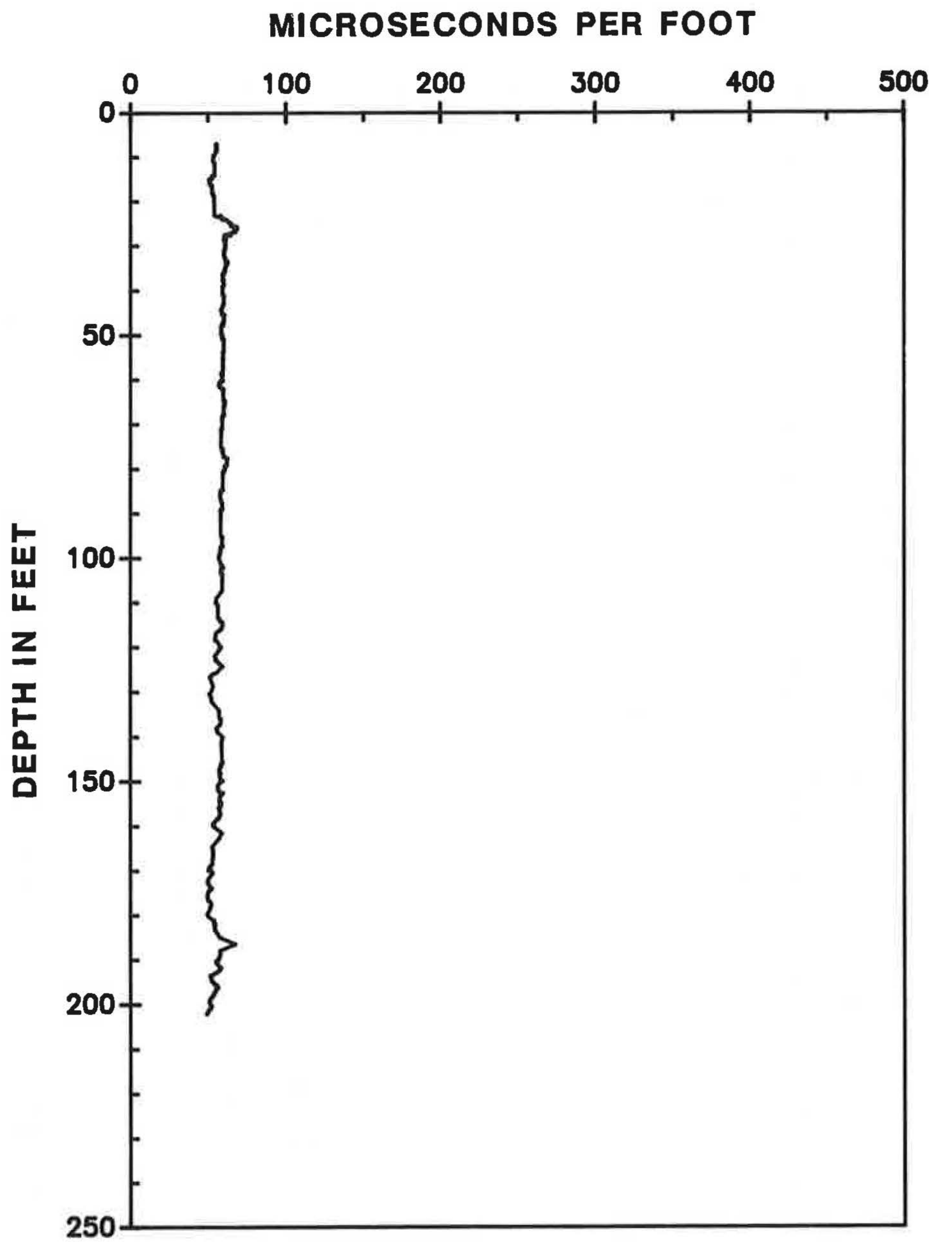


Figure 92. Acoustic velocity log of Shoal Creek Subdivision well 4.

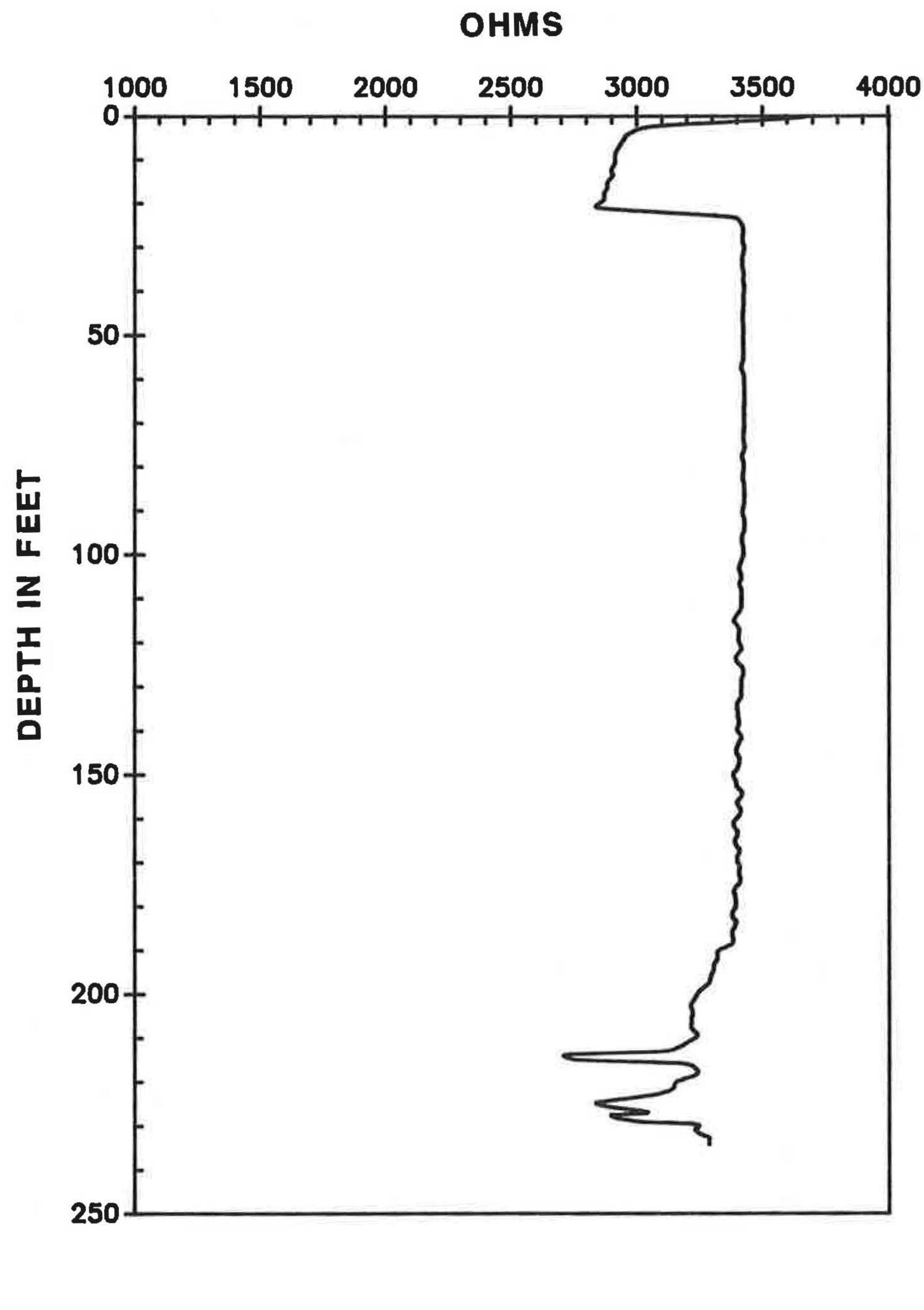


Figure 93. Single-point resistivity log of Shoal Creek Subdivision well 4.

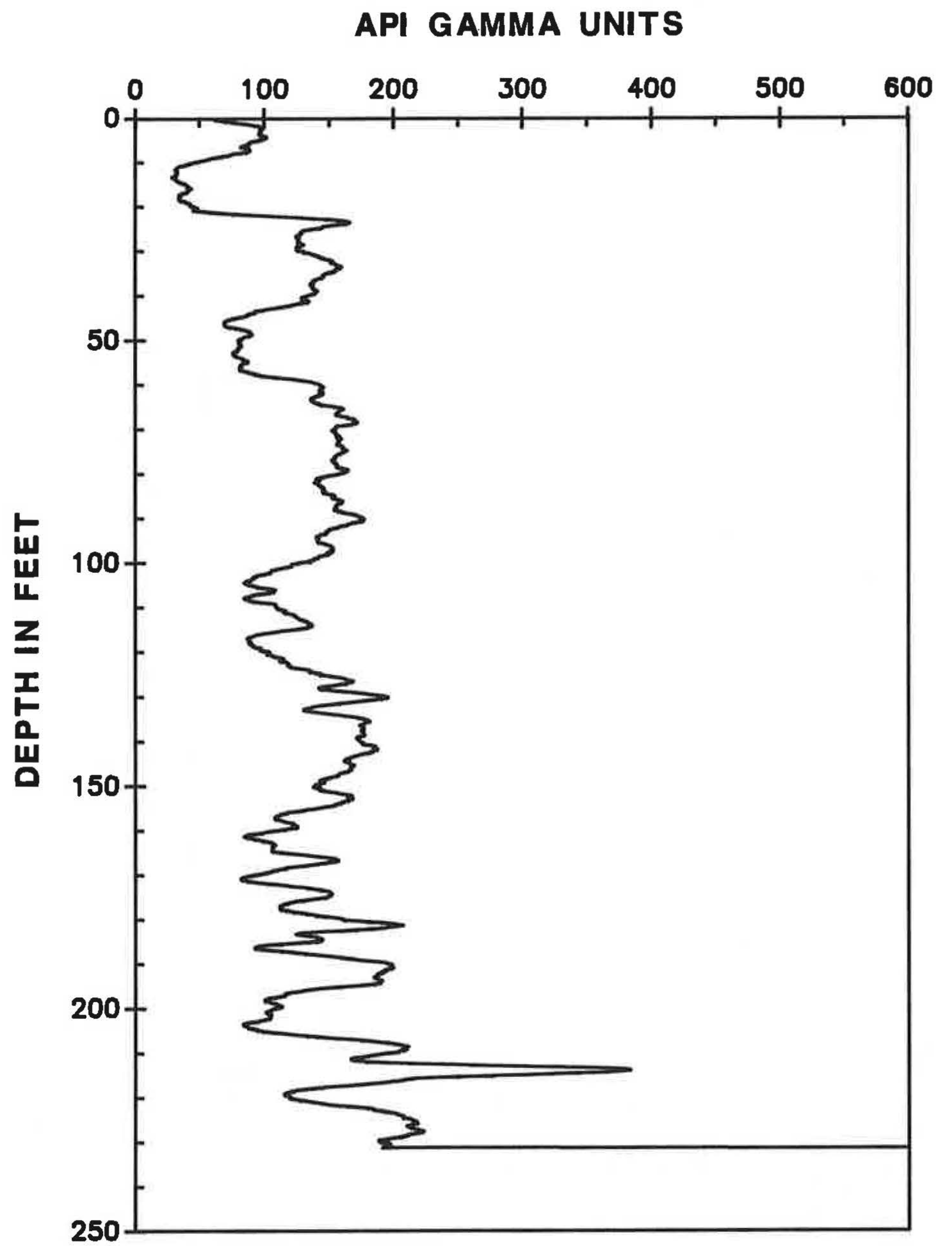


Figure 94. Natural gamma log of Shoal Creek Subdivision well 4.

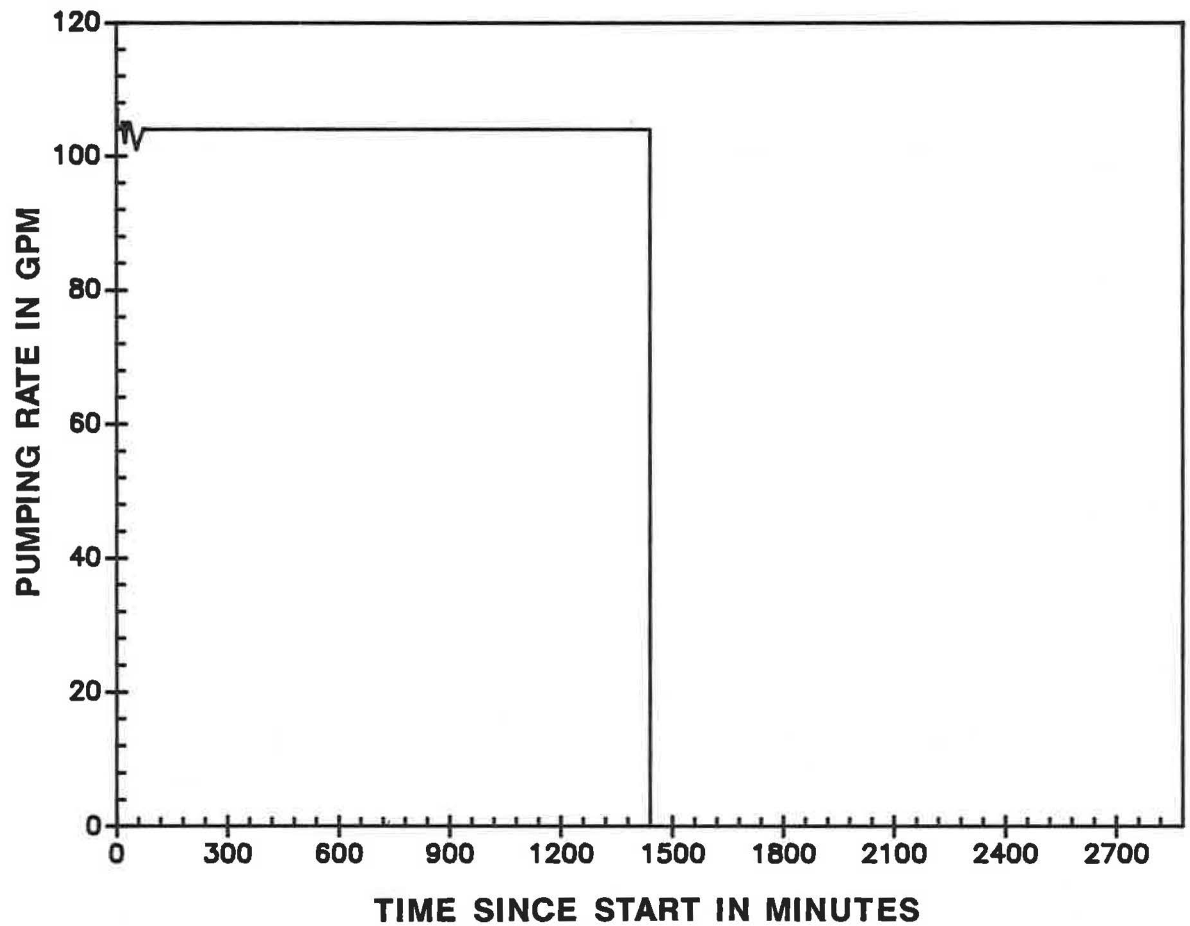


Figure 95. Pumping rate during test of Shoal Creek Subdivision well 4.

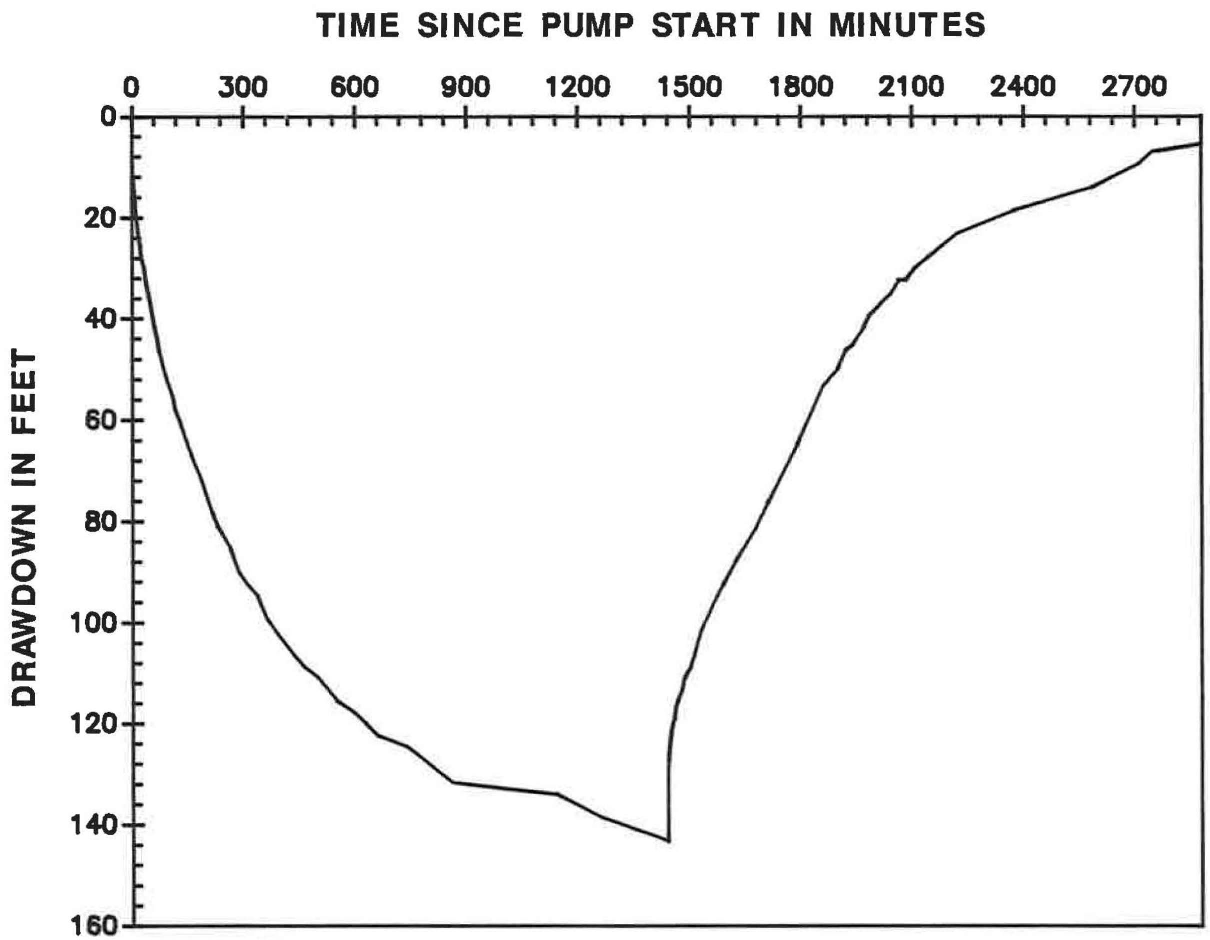


Figure 96. Drawdown and recovery curves for Shoal Creek Subdivision well 4.

UNICOI STATE PARK, WHITE COUNTY

INTRODUCTION

Unicoi State Park is located in northern White County, about 80 miles northeast of Atlanta (Fig. 1). The yield of the park's water-supply well 1 declined from approximately 100 gpm to 30 gpm during the summer drought of 1986, forcing the park to curtail activities for part of the summer. In an effort to obtain adequate supplies of potable water, the park drilled 4 new wells, two of which were sited by the Geologic Survey (wells 2 and 5). Two additional wells were sited, one by the well driller (well 3) and another by a dowser (well 4) (Fig. 97).

GEOLOGY

Unicoi State Park is located in the Blue Ridge Mountain District, a subdivision of the Blue Ridge Physiographic Province (Clark and Zisa, 1976). Ridges trend northeast and are steep-sided with small rounded hill tops (Fig. 97). Local relief is approximately 1200 ft. Most of the land surface is sloping. Many of the stream valleys in the vicinity of the park are v-shaped with little or no floodplain. Streams exhibit trellis-style drainage patterns. Straight stream valley segments near Unicoi State Park trend N50°W, N76°E, N48°E, and N10°E. Well 2 is located at the intersection of northwest- and northeast-trending tributary streams of Smith Creek. Well 5 is located south of Unicoi Lake in a straight, north-south-trending segment of the valley of Smith Creek. The park's original well (well 1) is located northeast of well 2 in a northeast-trending tributary of Smith Creek.

Three major mappable lithologic units can be identified in the vicinity of Unicoi State Park (Gillon, 1982, and German, 1985). Biotite gneiss consists of slabby, gray-weathering, coarse-grained biotite plagioclase gneiss with thin (1 in.) crenulated mica schist layers. Gneissic layering varies in thickness from one inch to several feet in this unit.

A second unit contains interlayered mica schist, biotite gneiss, and amphibolite.Tan- to silvery-weathering, coarse-grained mica schist is interlayered with coarse-grained biotite gneiss on a scale of 1 to 20 ft. One- to two-foot wide units of ocher-colored, coarse-grained amphibolite are also present. The occurrence of amphibolite distinguishes this sequence from the others.

The third unit is interlayered biotite gneiss and mica schist. Lithologies are a grayish-white weathering coarse-grained biotite feldspar gneiss interlayered with crenulated mica schist. Schist layers are 0.5 to 1 ft thick. The gneiss weathers to a distinct white sandy saprolite with feldspar porphyroblasts 0.5 in. in length. This sequence comprises 50 percent of the area studied.

The geologic map illustrates the northeast strike and the northwest and southeast dips of the compositional layering (Fig.97). Joints are spaced from one to several feet apart. Joints at Unicoi are straight to curvilinear with smooth surfaces. The joint sets strike N18°E, vertical; N05°E, SE dip; N50°W, vertical, and N-S with east or west dip.

WATER QUALITY

Water-quality analyses performed by the Georgia Environmental Protection Division Water Quality Laboratories indicate that well 2 is high in iron and that well 5 is high in calcium, sulfate, strontium, and zinc as compared to well 2 (Table 10). The sulfate content renders water from well 5 non-potable.

GEOPHYSICAL TESTING

Surface Geophysics

Nine vertical resistivity soundings and three magnetic profiles were conducted at the site of well 5. Electrical and magnetic surveys indicate anomalies parallel to the north-south topographic trend and parallel to a north-south joint set. Both resistivity and magnetic surveys support the existence of a narrow fracture zone. Schmitt and others (1991) describe the results of the surface geophysical investigations in the Unicoi area.

Borehole Geophysics

A suite of borehole geophysical logs, including sonic televiewer, caliper, temperature, spontaneous potential, acoustic velocity, single-point resistance and natural gamma logs were run on Unicoi Wells 2 and 5 (Figs. 98-114). Unicoi well 2 (Figs. 98-104) contains two potential water-bearing zones at 105 and 643-650 ft. The caliper log (Fig. 99) shows an increase in borehole diameter at 90-105 ft. The spontaneous potential and single-point resistance logs also show anomalies at 105 ft. A potential water-bearing zone at 643-650 ft is indicated by the televiewer log (Fig. 98). From 105 to 500 ft, resistance values are stable, and then the values decrease from 500 to 650 ft.

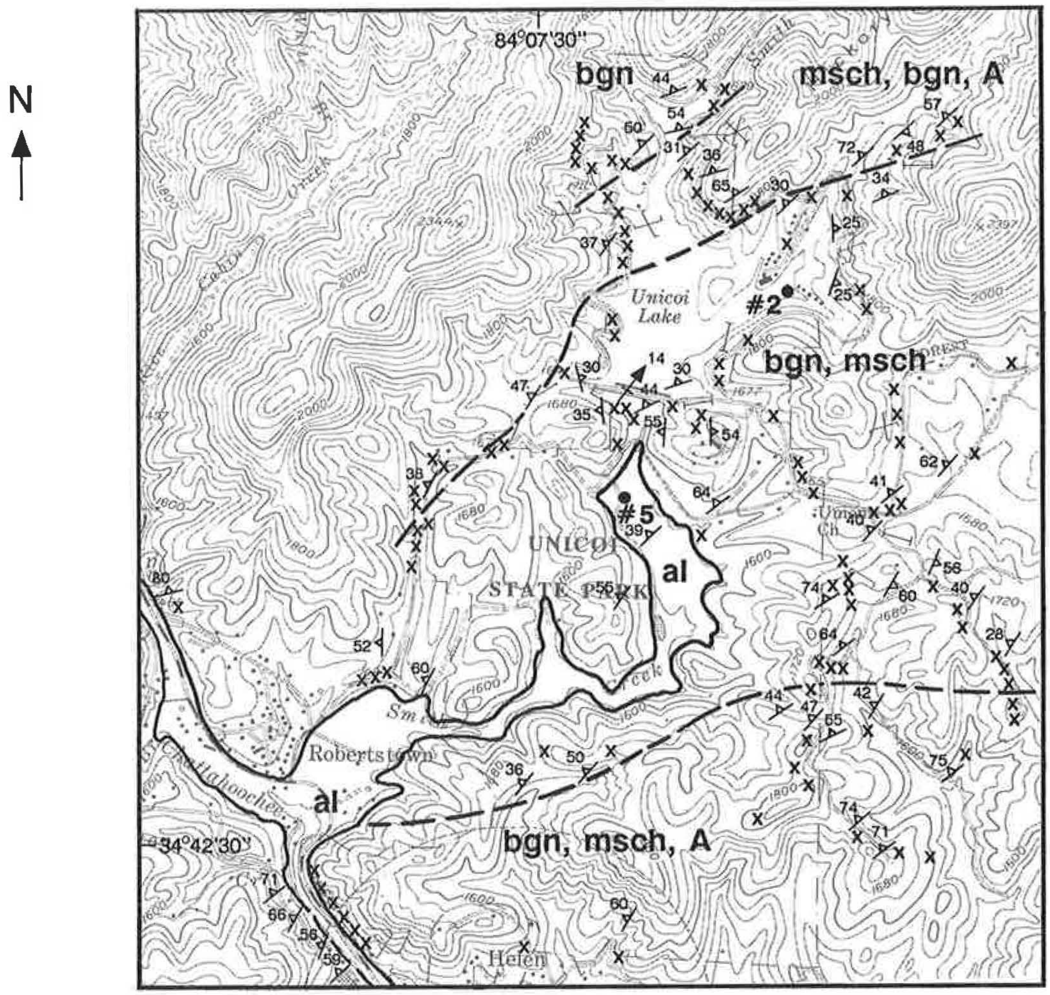
A flow meter was used at Unicoi well 5, in addition to borehole geophysical logs, in order to locate water-bearing zones. Several such zones were identified (Figs. 105-114). At 79-80 ft, the sonic televiewer log shows a discontinuity which the flow meter indicates to be water-bearing (Fig. 105). Borehole diameter also increases at this depth and anomalies occur on the single-point resistance and acoustic velocity logs. The sonic televiewer and caliper logs show a weathered discontinuity at 84-88 ft that also produces water. The single-point resistance and acoustic velocity logs show anomalies at this depth. Minor water-bearing zones were identified at 148-150 and 265-268 ft on the basis of sonic televiewer, caliper, single-point resistance, and acoustic velocity logs, along with flow meter data. The flow meter indicates the presence of another minor water-bearing weathered discontinuity at 301-342 ft. This zone is also indicated by changes in borehole diameter, single-point resistance and acoustic velocity. A more significant water-bearing zone is located at 345-352 ft. The flow meter and temperature log both indicate that ground water enters the borehole at this depth. The sonic televiewer log shows a weathered discontinuity, and the borehole diameter increases at this depth.

The orientation of subsurface discontinuities were measured from sonic televiewer logs of Unicoi wells 2 and 5. These orientations were plotted on equal area diagrams and compared with the orientations of compositional layering, joints, and straight valley segments mapped at the surface. Subsurface discontinuities in Unicoi wells 2 and 5 strike northeast. The strikes of the discontinuities in the two wells are within 9° of each other. Northeast-striking, northwest-dipping compositional layering was measured at the land surface. The strike and dip of the surface compositional layering are within 23° and 18°, respectively, of the strike and dip of northwest-dipping subsurface discontinuities measured from sonic televiewer logs. The subsurface discontinuities of this orientation may, therefore, be related to compositional layering. The three northeast-striking discontinuities observed in the sonic televiewer logs strike within 17° of a linear stream valley trend (N75°-80°E). The discontinuities from 148 to 150 ft and 265 to 268 ft in the Unicoi well 5 are water-bearing and dip about 55° and 59°, respectively, to the northwest. These dips correspond to the dip direction of compositional layering and may represent zones of differential weathering.

HYDROLOGIC TESTING

A total of four new wells were drilled at Unicoi State Park. Well 3 (driller) and 4 (dowser), sited without using geological or structural criteria, had air-lift yields of approximately 5 gpm. Well 2 was sited by the Geologic Survey on the basis of proximity to existing water lines at the request of park officials. A 24-hour constant-rate pumping test conducted on Unicoi well 2 utilized a submersible pump powered by utility power. The discharge from the well was directed into a nearby creek. The pumping rate was held constant at approximately 10 gpm except during the very early portion of the test (Fig. 115). Drawdown and recovery curves constructed from data gathered at well 2 illustrate the characteristics of the well (Fig. 116). Curves generated from the data on two observation wells (wells 3 and 4) are irregular and asymmetrical (Figs. 117 and 118).

Unicoi well 5 was sited by the Geologic Survey using geologic and structural criteria. It was test pumped at a constant rate of 130 gpm for 41 days, except when power was down, in an attempt to reduce sulfate levels in the ground water from this well. Testing was conducted using a submersible pump powered by utility power. The discharge from well 5 flowed into a nearby stream. Drawdown stabilized during the test and remained constant except during periods of interrupted power (Fig. 119). Sulfate levels did not decline significantly during the 41 days of pumping. Recovery was not monitored at well 5.



Base from U.S. Geological Survey Helen 1:24,000, photorevised 1985.

EXPLANATION

al	Undifferentiated cobbles of alluvium and colluvium sand and silt
bgn	Slabby, gray weathering coarse-grained biotite plagioclase gneiss with thin (1 inch) crenulated mica schist layers
msch, bgn, A	Tan to silvery weathering coarse-grained mica schist interlayered with coarse-grained biotite gneiss, locally contains 1-2 foot thick ocher-colored coarse-grained amphibolite
bgn, msch	Grayish-white weathering coarse-grained biotite feldspar gneiss interlayered with thin (<1 foot) crenulated mica schist
bgn, msch, A	Red-brown to gray weathering biotite gneiss (1-10 feet thick) and tan to silver to purple weathering quartz biotite schist (6 inches-1 foot thick), locally contains thin (1-2 feet) layers of ocher-colored amphibolite

56 Strike and dip of compositional layering
Strike and dip of vertical joint
Strike and dip of inclined joint
14 Trend and plunge of upright open fold

x Outcrop
● Well location
—— Contact
— — Inferred contact

0 .5 MILE
0 .5 KILOMETER

Figure 97. Geologic map of part of the Helen Quadrangle and the locations of the Unicoi State Park wells.

Table 10. Unicoi State Park wells 2 and 5, water-quality analyses.

Well Number	2	5	5	5	
Date Sampled	9/15/86	8/15/86	9/15/86	3/5/87	
Parameters			Results		Units
pH	4.5	5.0	5.2	7.2	
Spec. Cond.	50	1100	328	834	µmho/cm
Cl	1	1	3	1	mg/l
SO_4	<2	850	125	400	mg/l
NO_2+NO_3	<0.02	<0.002	<0.02	<0.5	mg.N/l
ICAP Screen					
Ca	6.2	250	56.6	185	mg/l
K	0.8	3.4	1.1		mg/l
Mg	0.6	1.4	0.6	1.2	mg/l
Na	3.2	24.7	8.9	21.7	mg/l
Ag	<10	<10	<10	<25	µg/l
Al	105	<20	<20		µg/l
As	<40	<40	<40	<25	µg/l
Au	<25	<25	<25		µg/l
Ba	<10	<10	<10	<50	µg/l
Be	<10	<10	<10		µg/l
Bi	<50	<50	<50		µg/l
Cd	<10	<10	<10	<5	µg/l
Co	<10	<10	<10		µg/l
Cr	<10	<10	<10	<25	µg/l
Cu	<10	<10	<10	<50	µg/l
Fe	23	20	<50		µg/l
Mn	40	68	49	40	µg/l
Mo	<10	<10	<10	<10	µg/l
Ni	<20	<20	<20		µg/l
Pb	<25	<25	<25	<25	µg/l
Sb	<50	<50	<50		µg/l
Se	<3	<8	<3	<5	µg/l
Sn	<50	<50	<50		µg/l
Sr	27	1230	270		µg/l
Ti	13	<10	<10		µg/l
Tl	<50	<50	<50		µg/l
V	<10	<10	<10		µg/l
Y	<10	<10	<10		µg/l
Zn	<10	87	135	120	µg/l
Zr	<10	<10	<10		µg/l

< = below laboratory detection limits

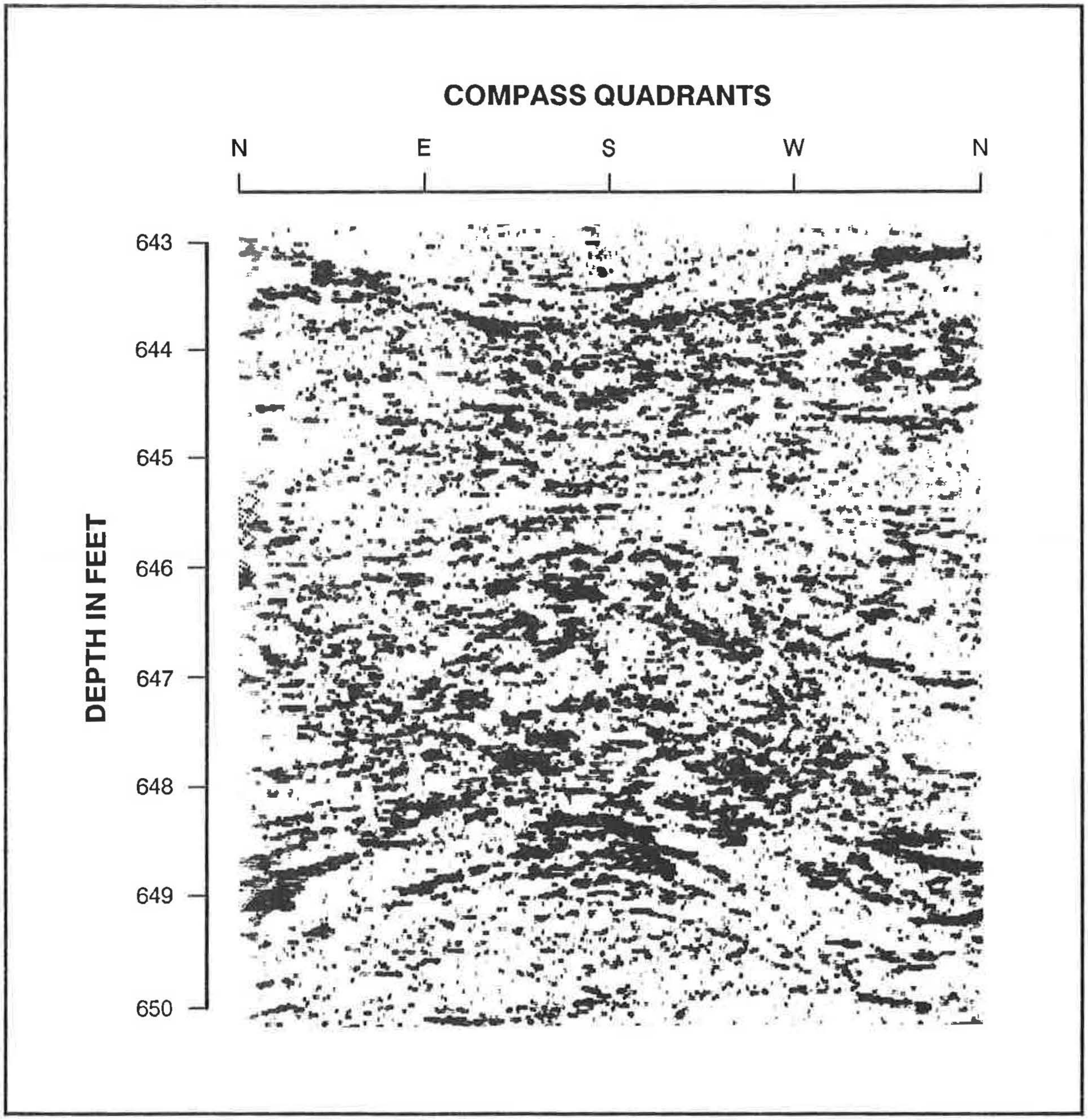


Figure 98. Sonic televiewer log of Unicoi State Park well 2, 643-650 ft.

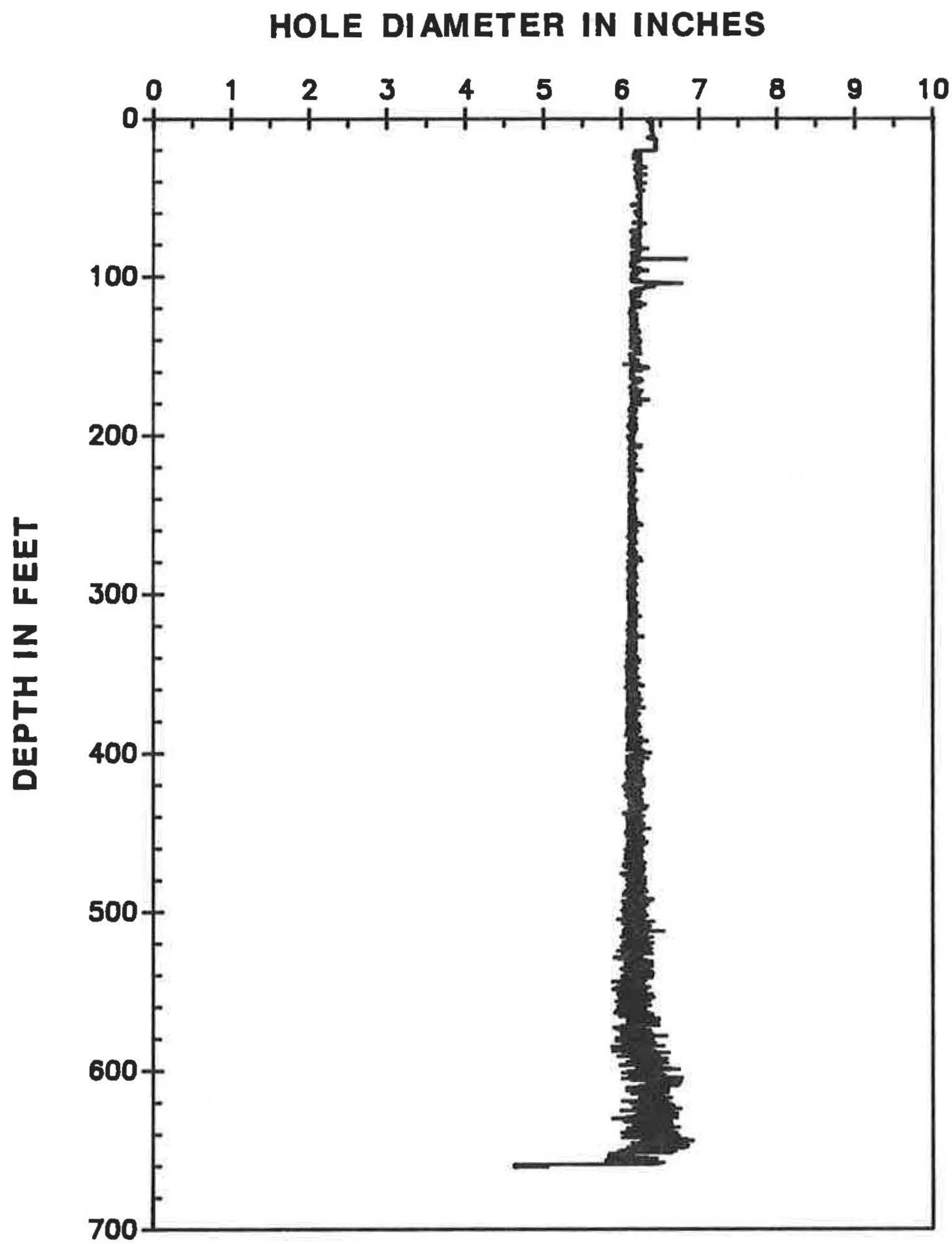


Figure 99. Caliper log of Unicoi State Park well 2.

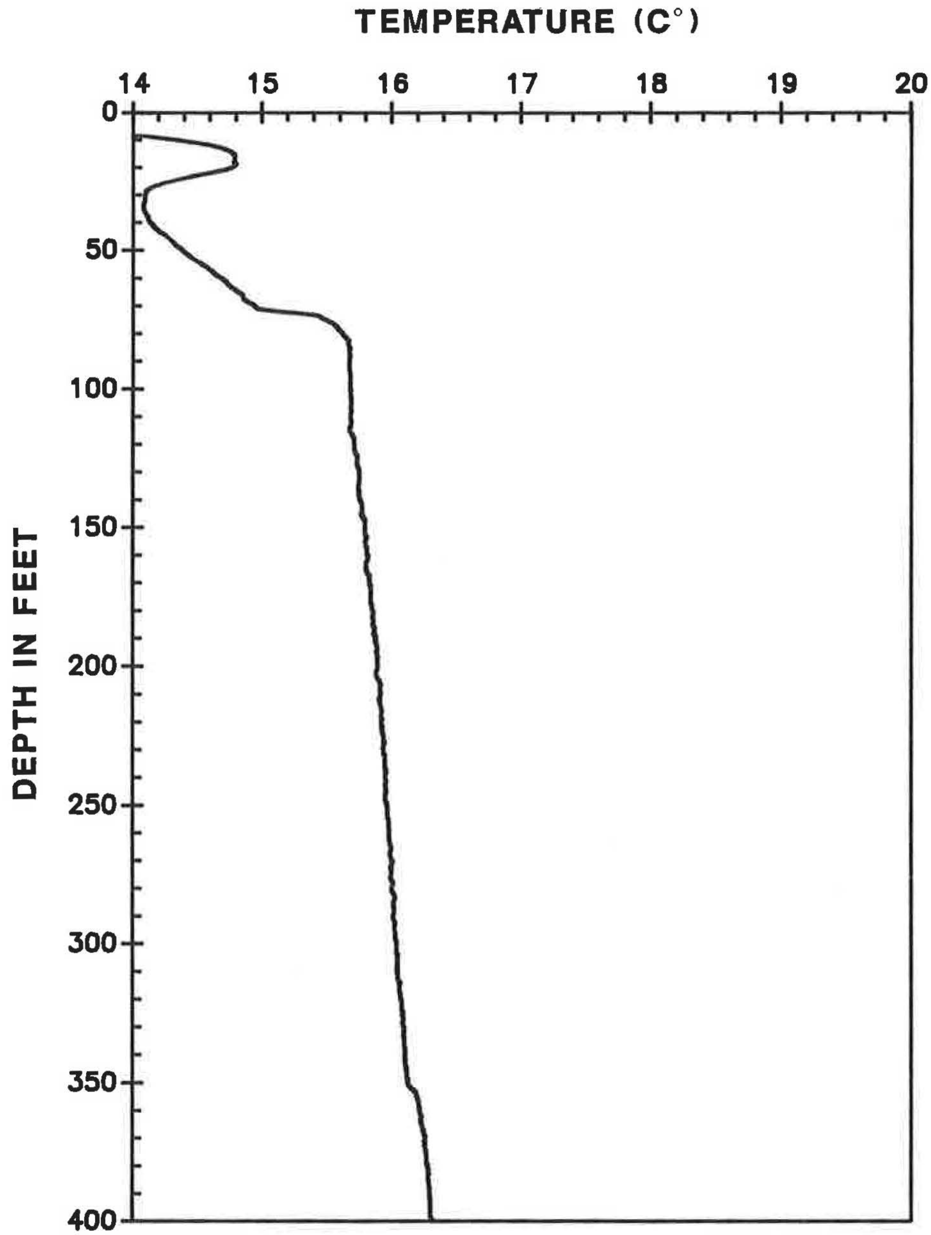


Figure 100. Temperature log of Unicoi State Park well 2.

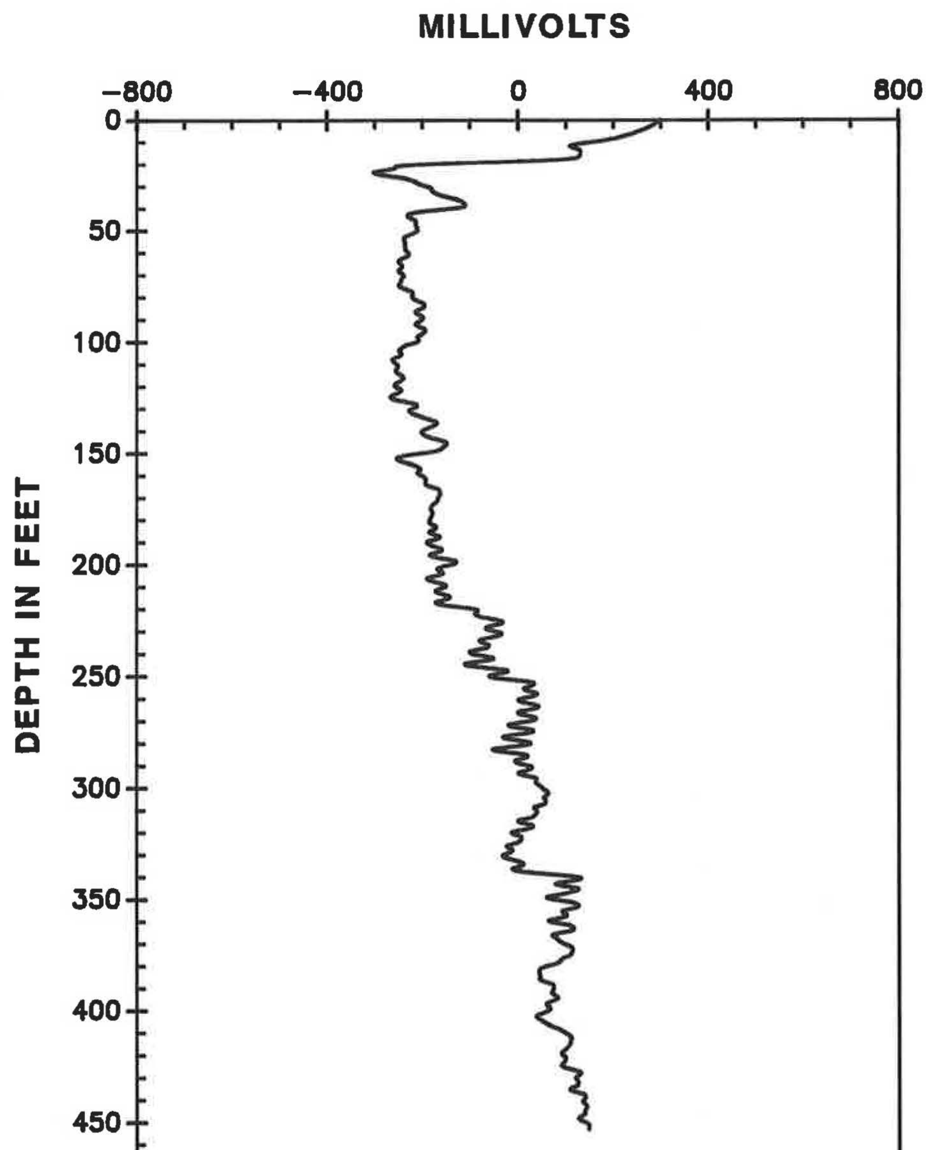


Figure 101. Spontaneous potential log of Unicoi State Park well 2.

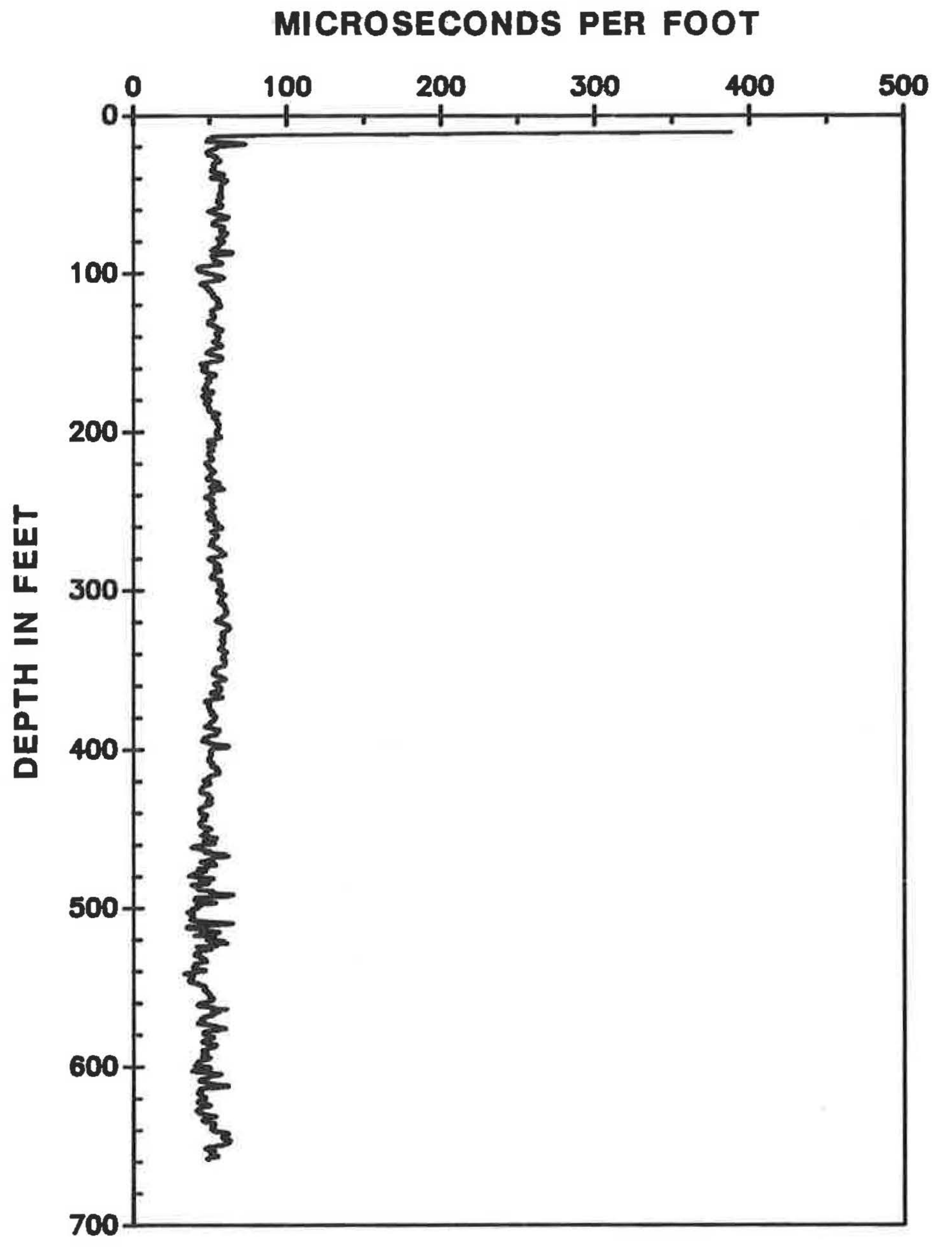


Figure 102. Acoustic velocity log of Unicoi State Park well 2.

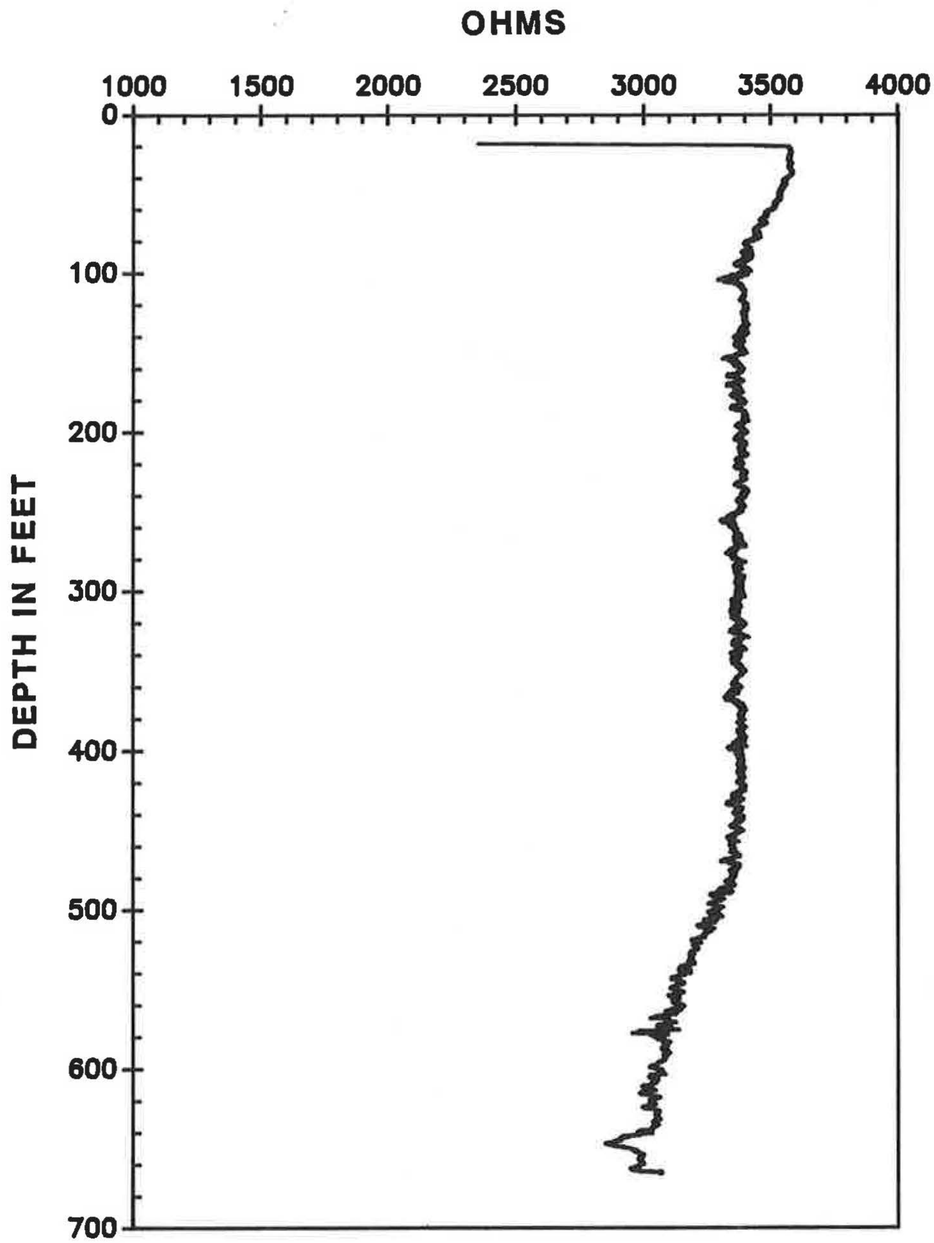


Figure 103. Single-point resistivity log of Unicoi State Park well 2.

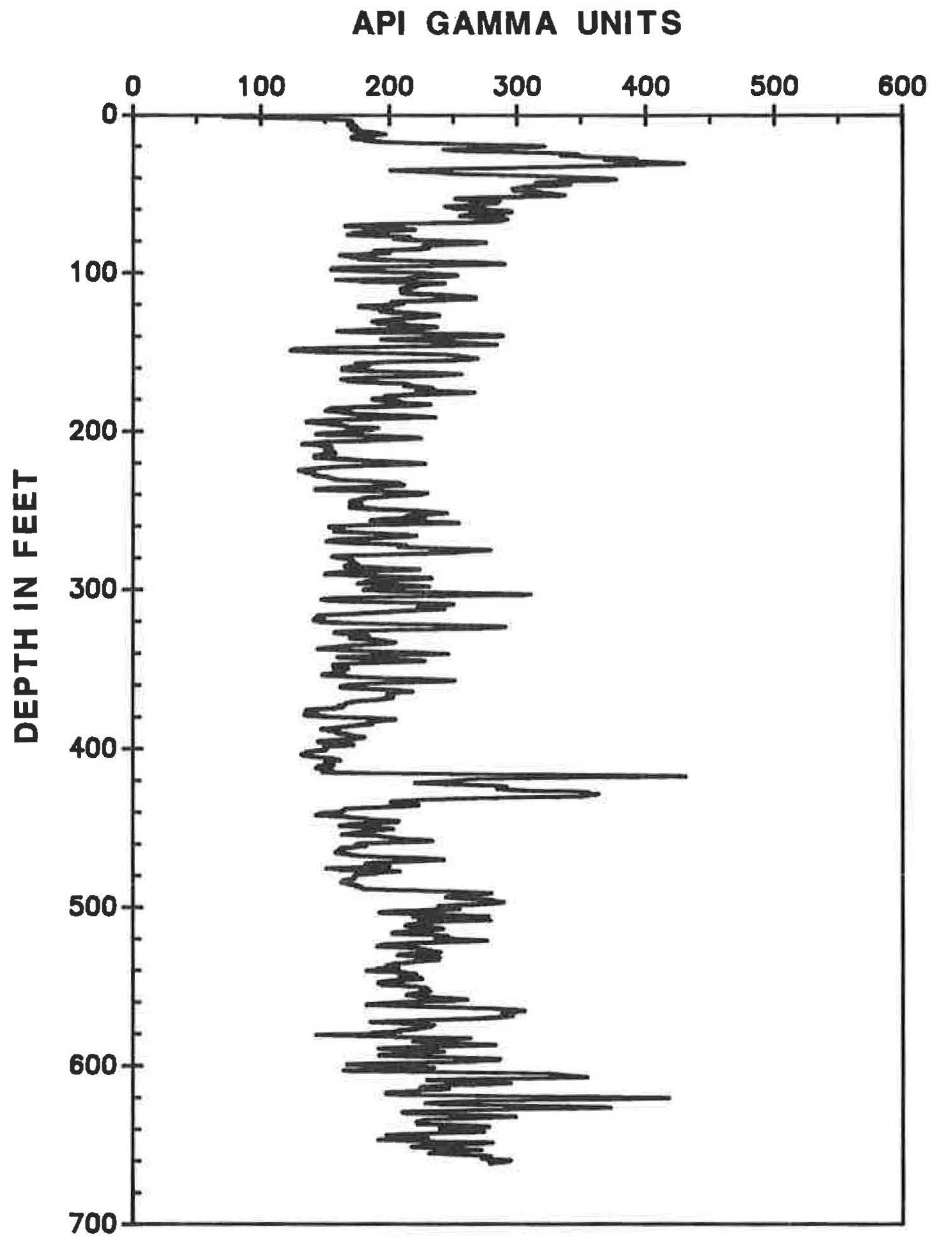


Figure 104. Natural gamma log of Unicoi State Park well 2.

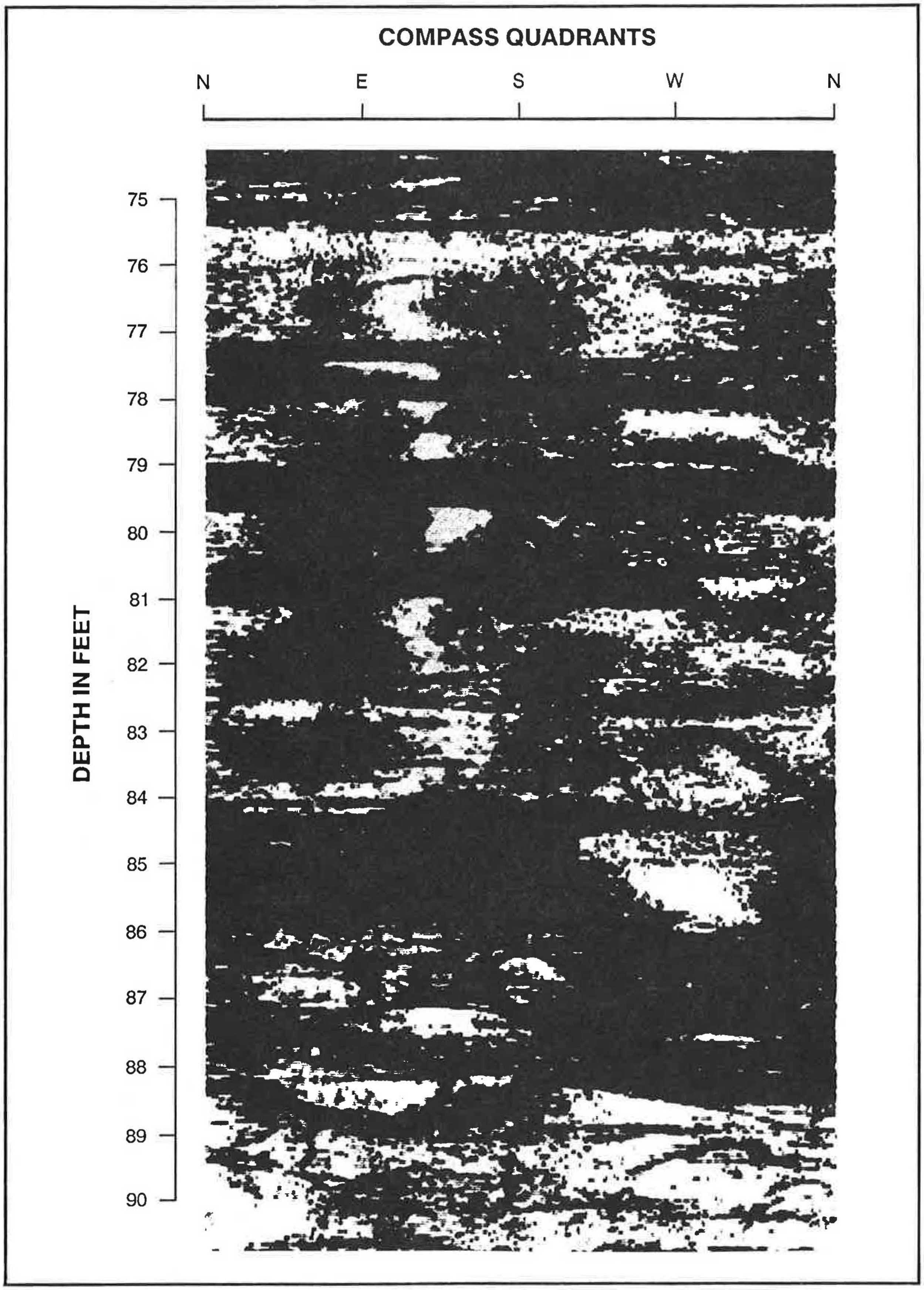


Figure 105. Sonic televiewer log of Unicoi State Park well 5, 75-90 ft.

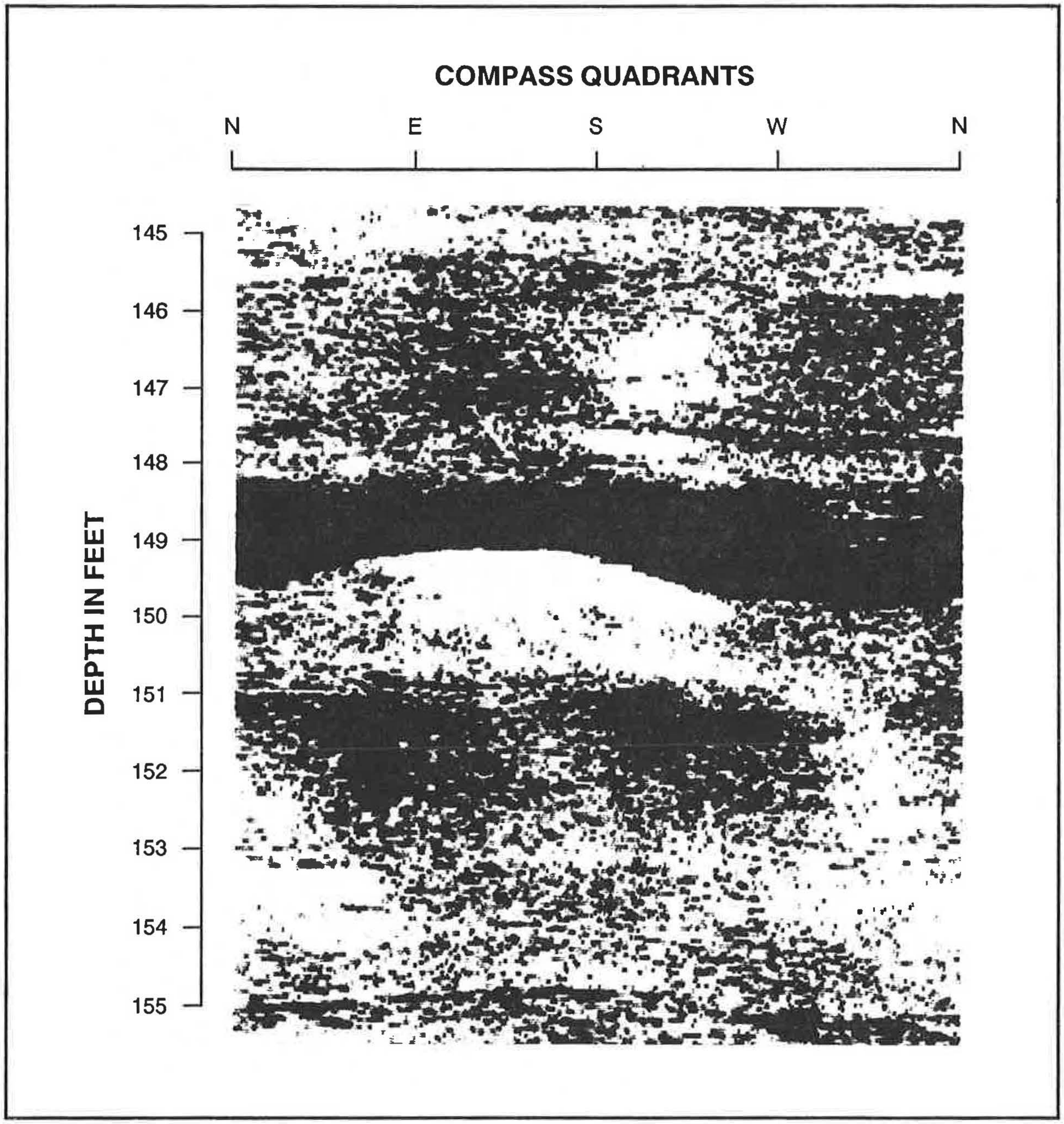


Figure 106. Sonic televiewer log of Unicoi State Park well 5, 145-155 ft.

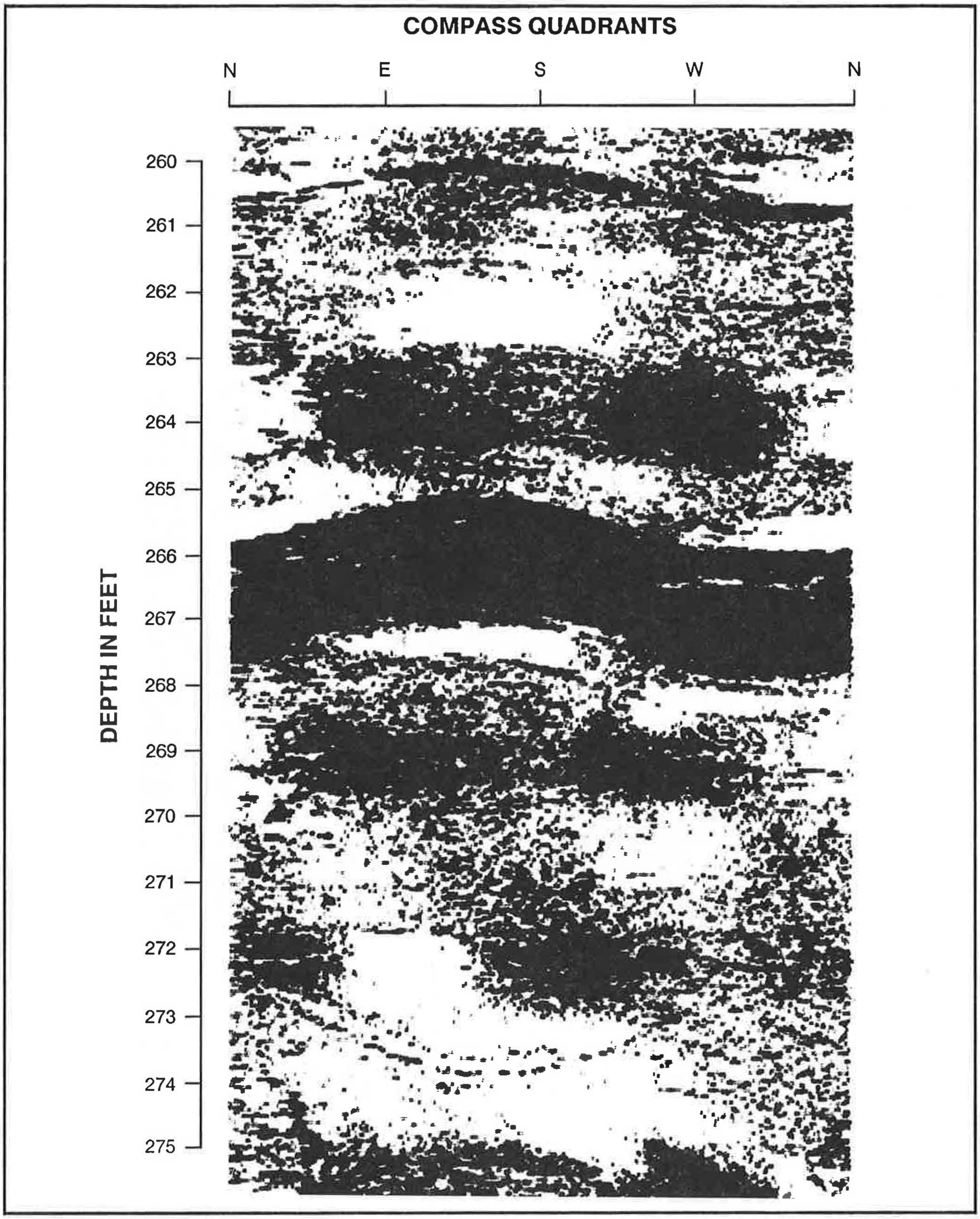


Figure 107. Sonic televiewer log of Unicoi State Park well 5, 260-275 ft.

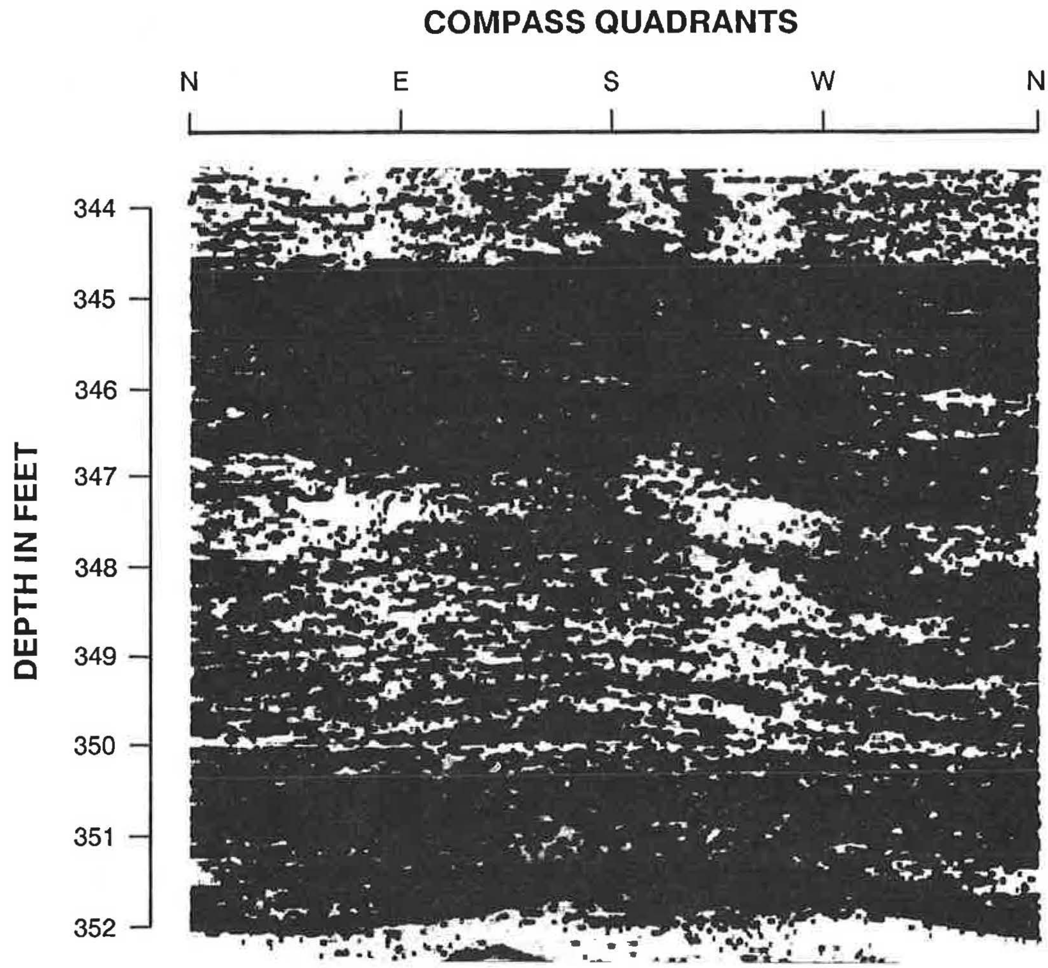


Figure 108. Sonic televiewer log of Unicoi State Park well 5, 344-352 ft.

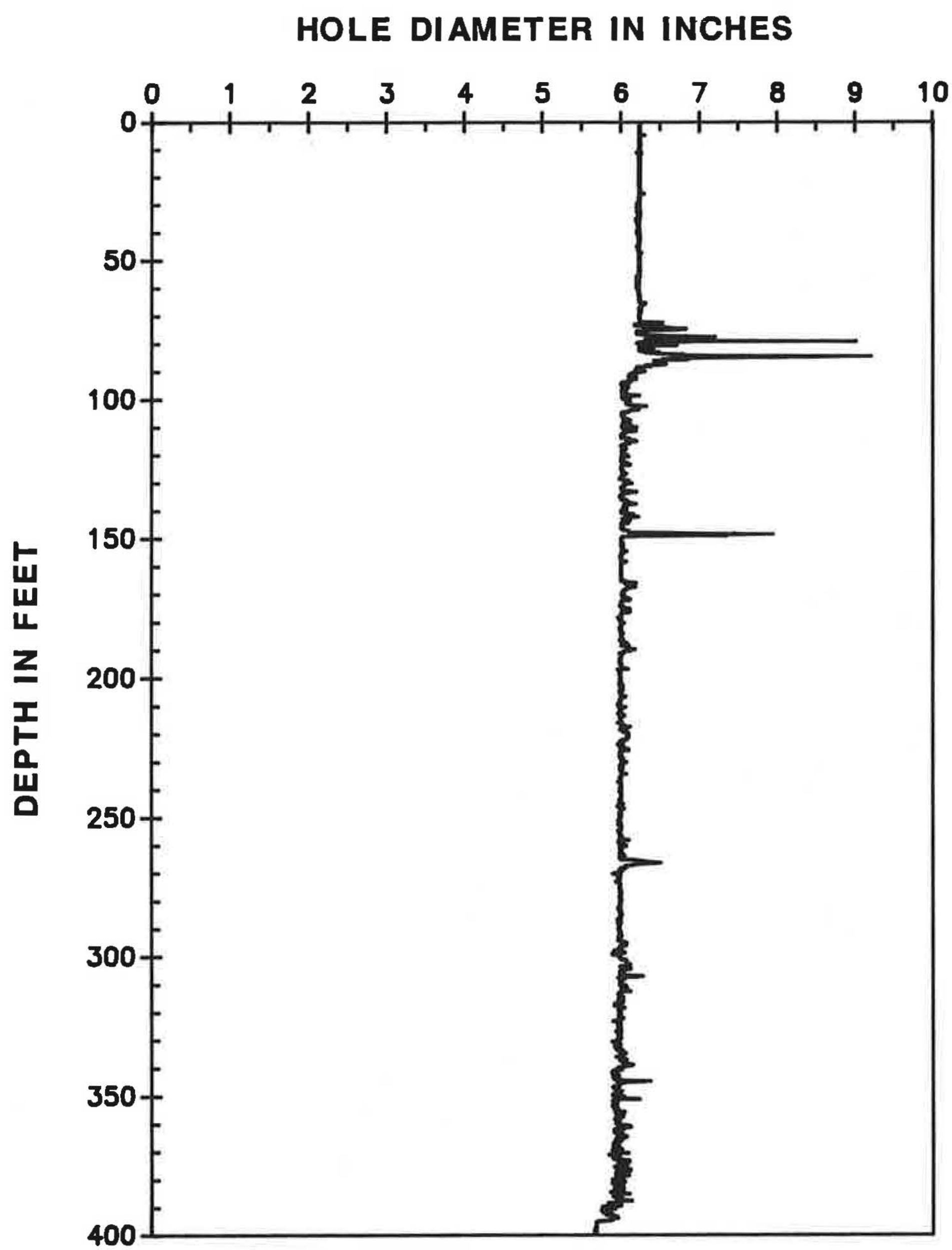


Figure 109. Caliper log of Unicoi State Park well 5.

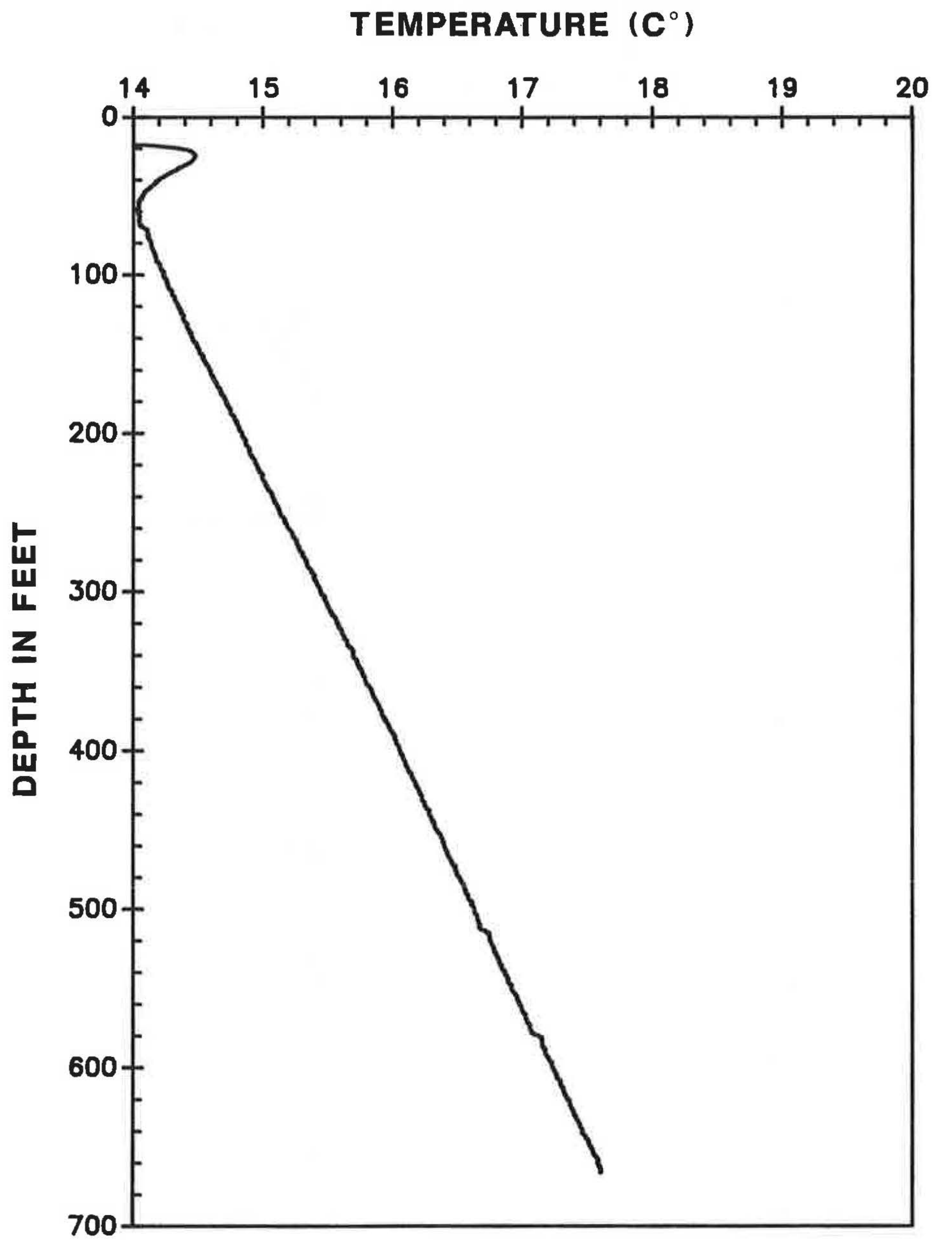


Figure 110. Temperature log of Unicoi State Park well 5.

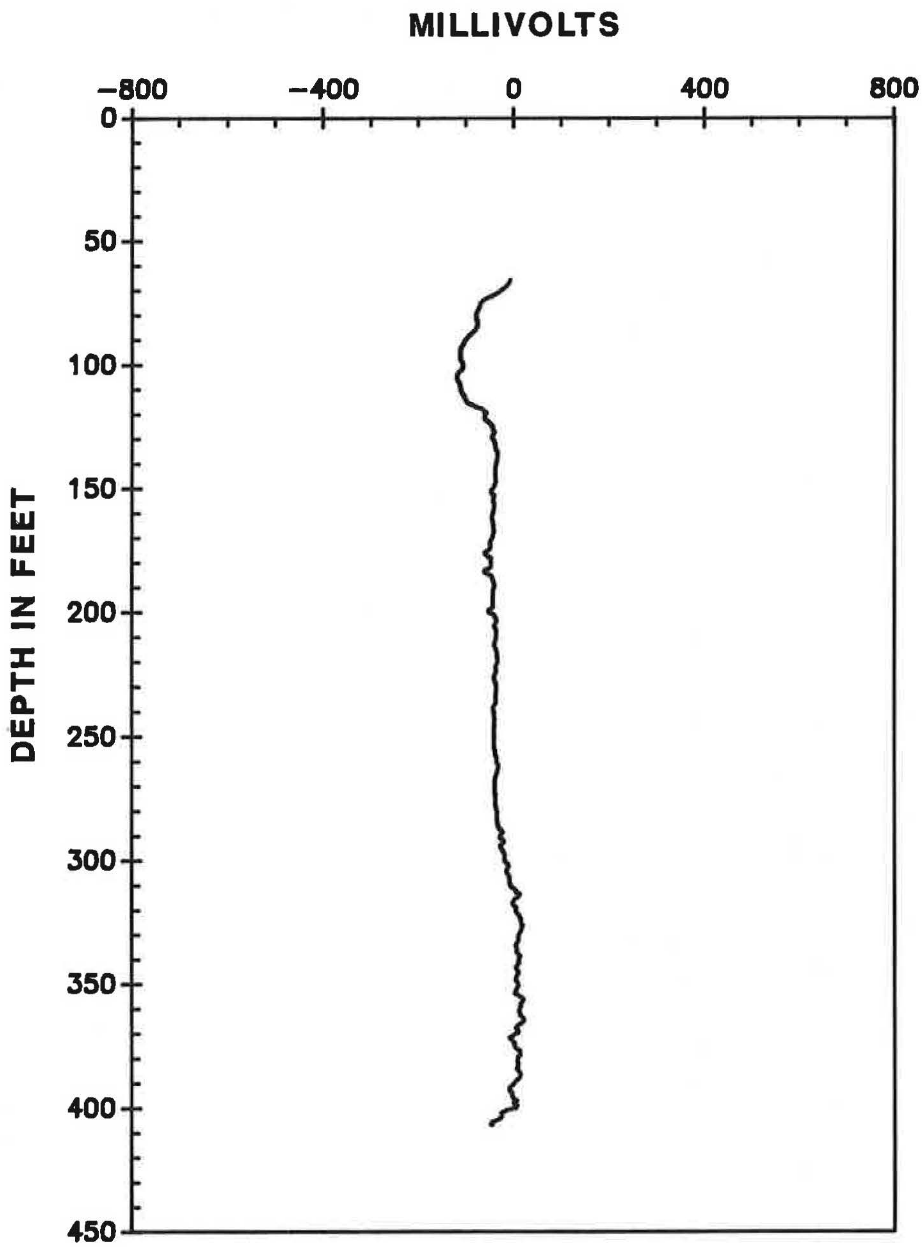


Figure 111. Spontaneous potential log of Unicoi State Park well 5.

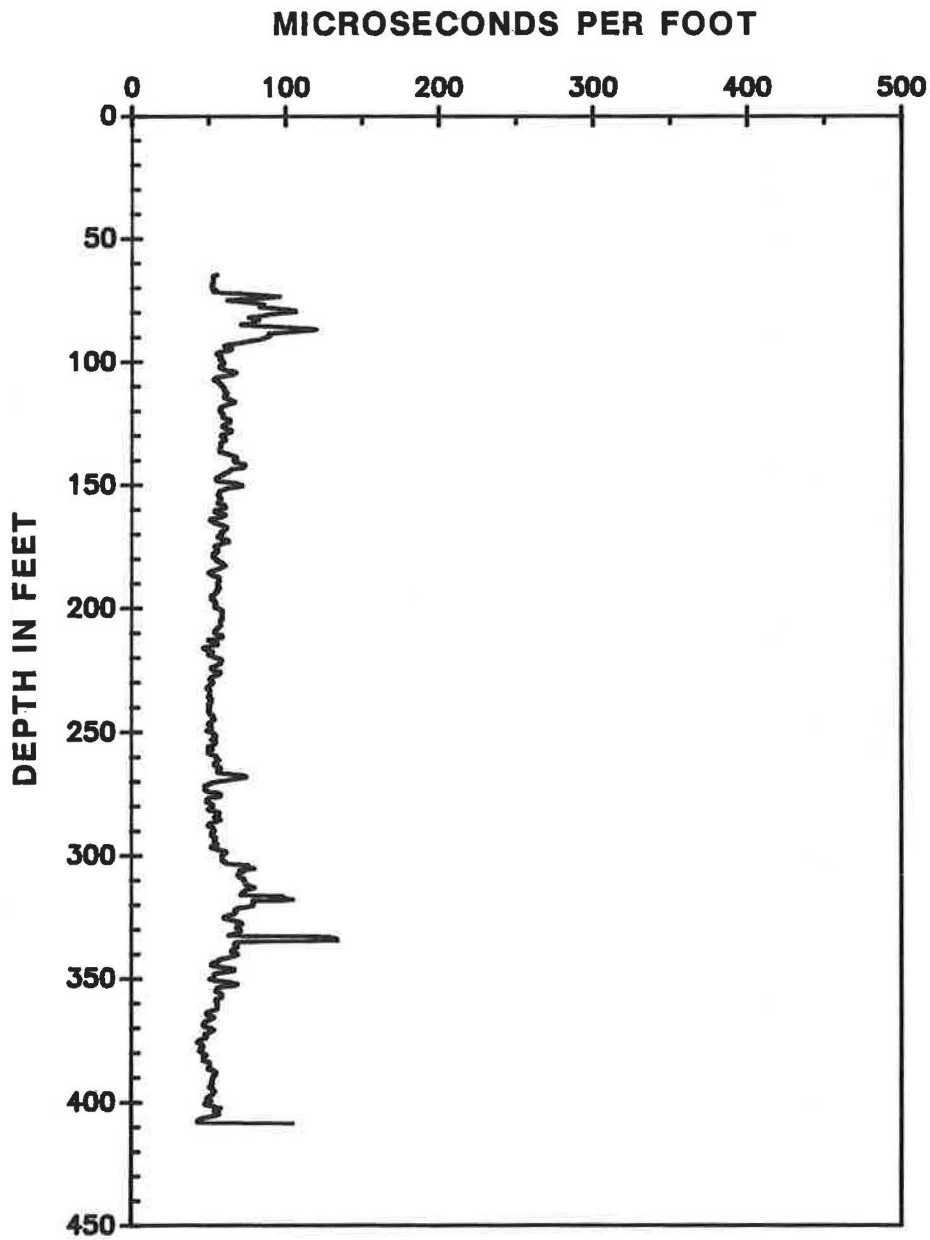


Figure 112. Acoustic velocity log of Unicoi State Park well 5.

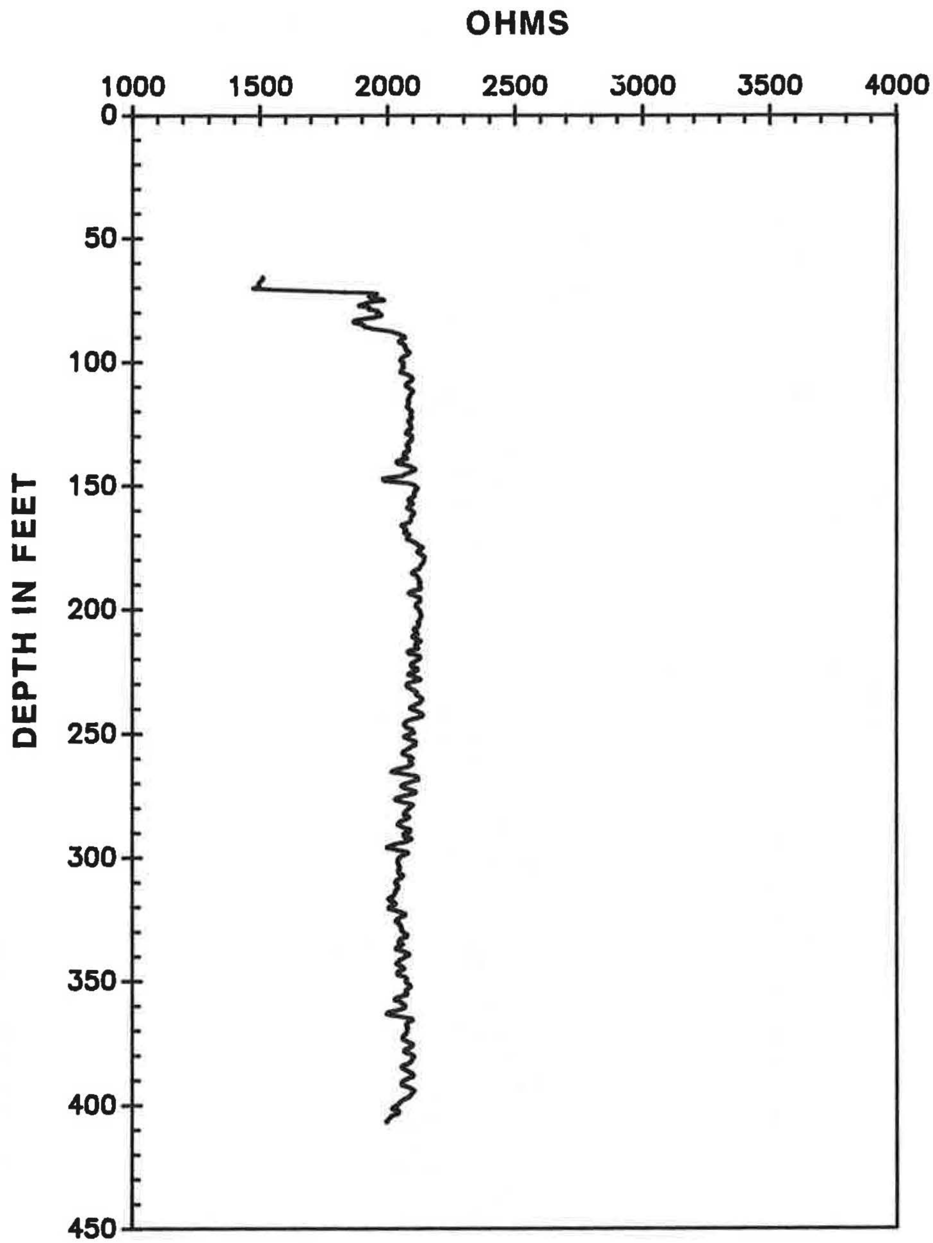


Figure 113. Single-point resistivity log of Unicoi State Park well 5.

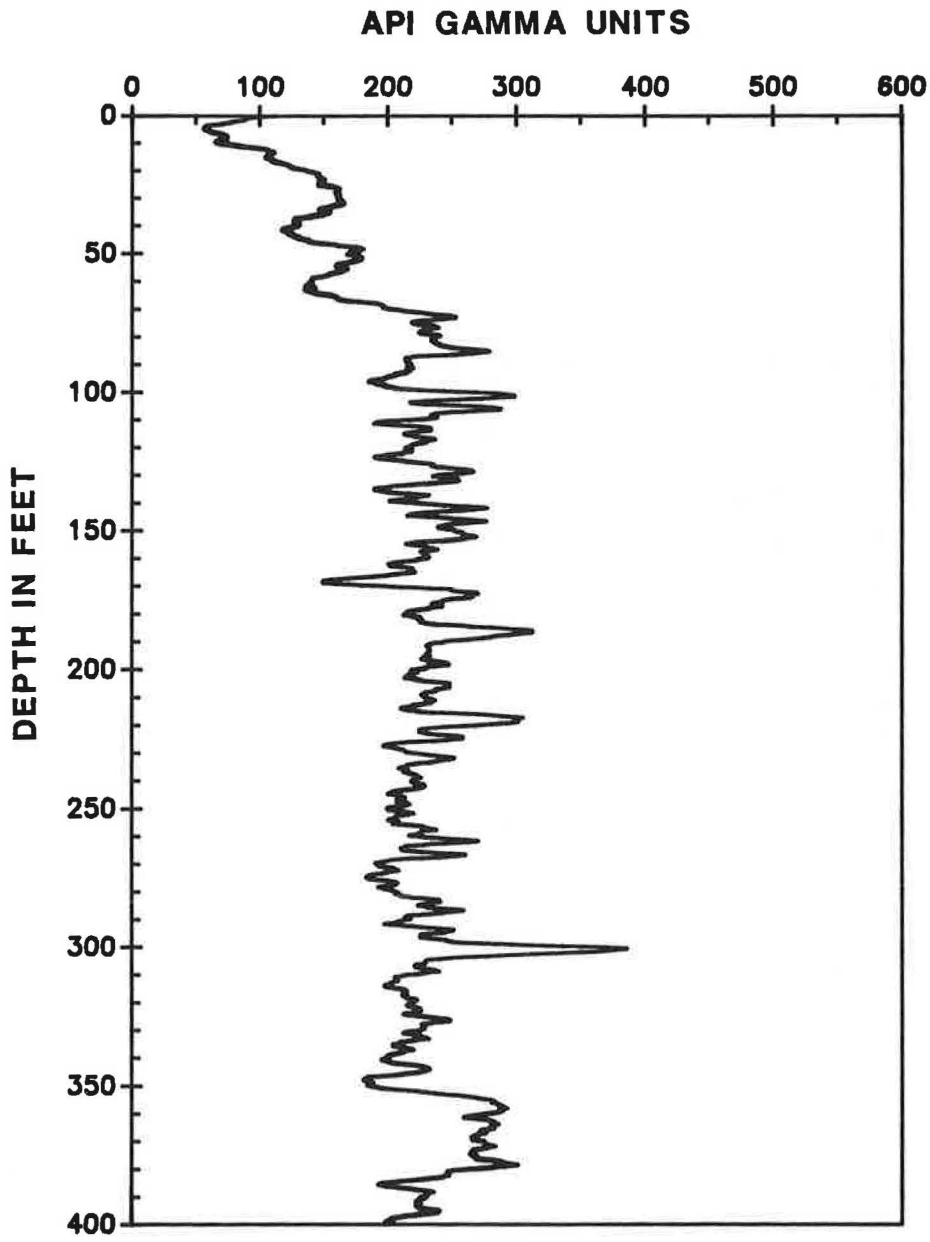


Figure 114. Natural gamma log of Unicoi State Park well 5.

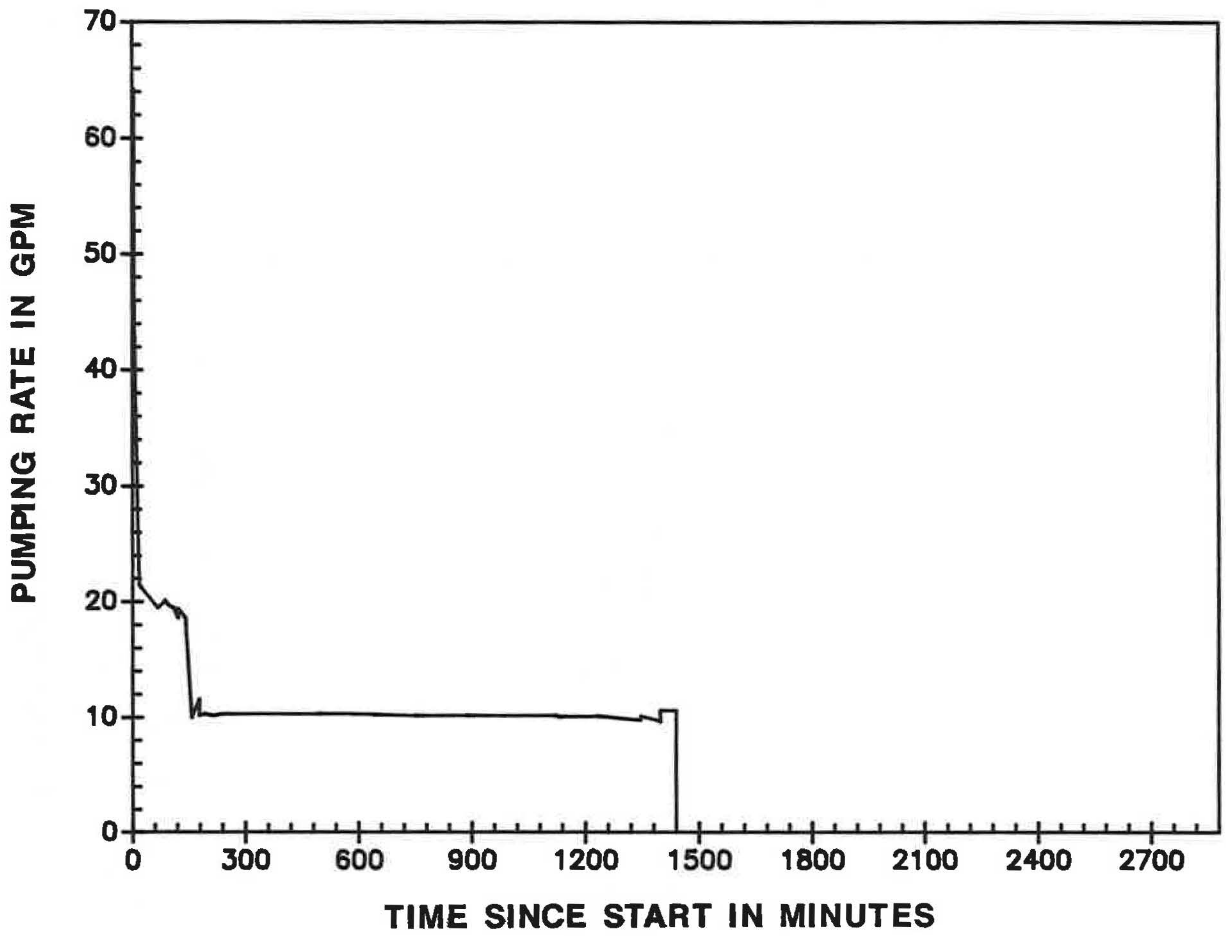


Figure 115. Pumping rate during test of well 2 at Unicoi State Park.

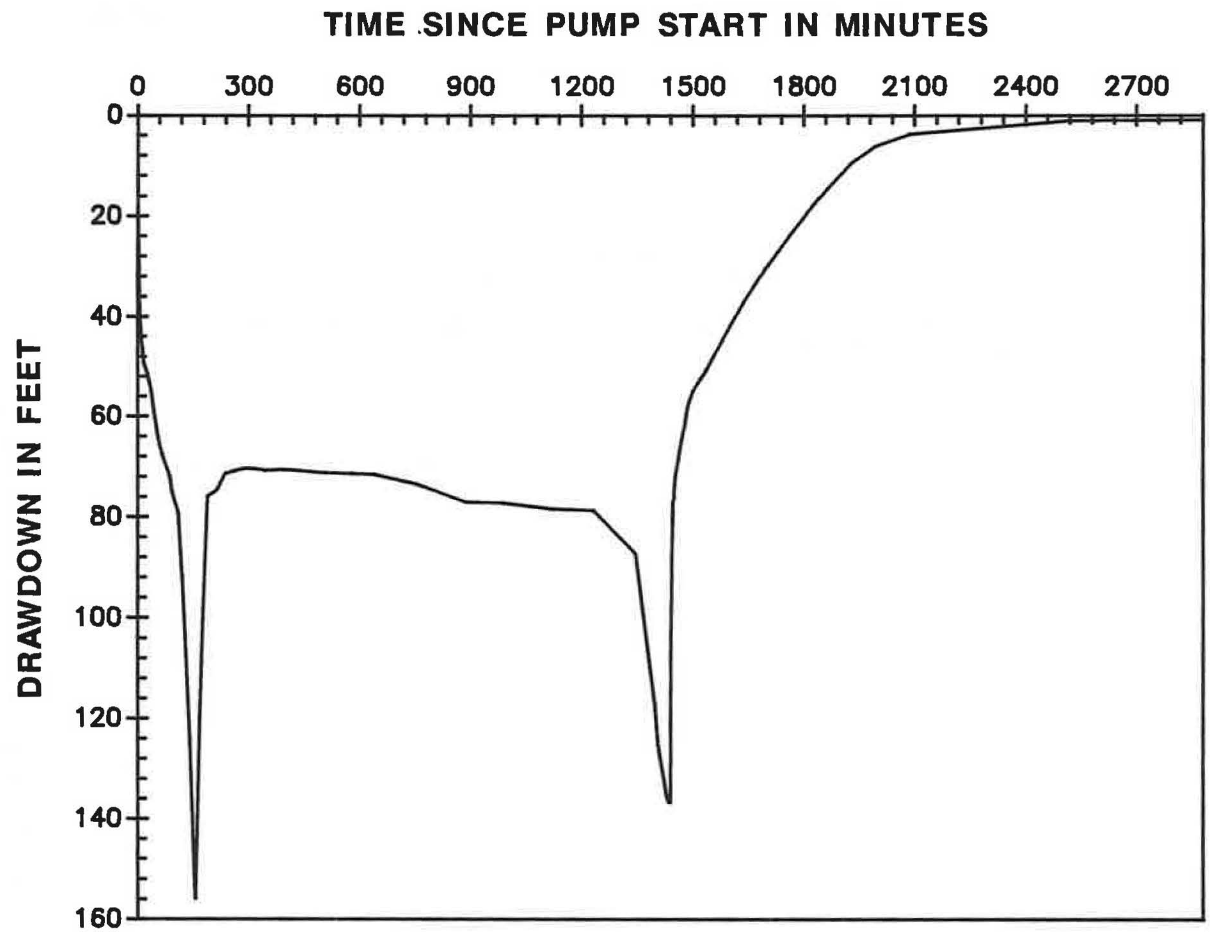


Figure 116. Drawdown and recovery curves for well 2 at Unicoi State Park.

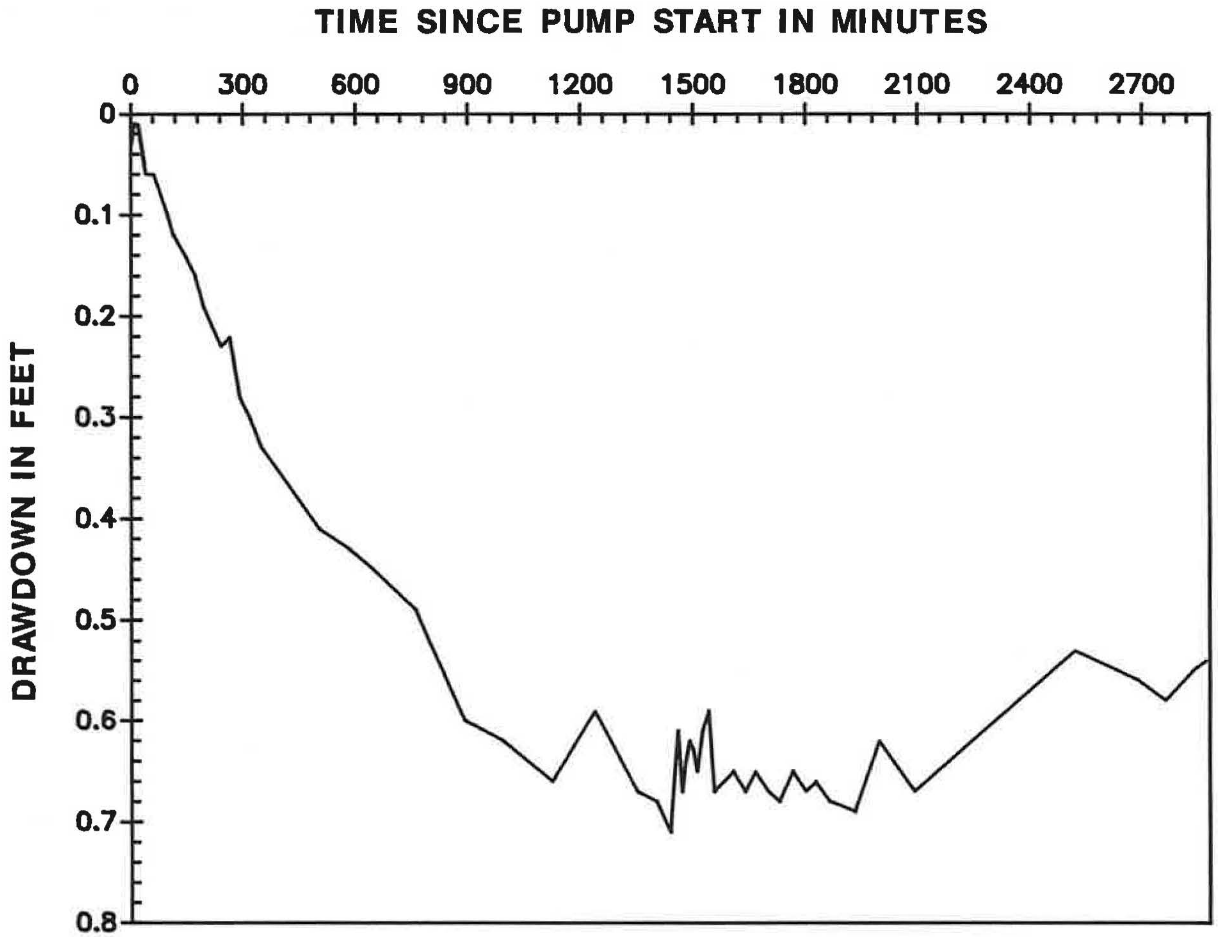


Figure 117. Drawdown and recovery curves for observation well 1 at Unicoi State Park.

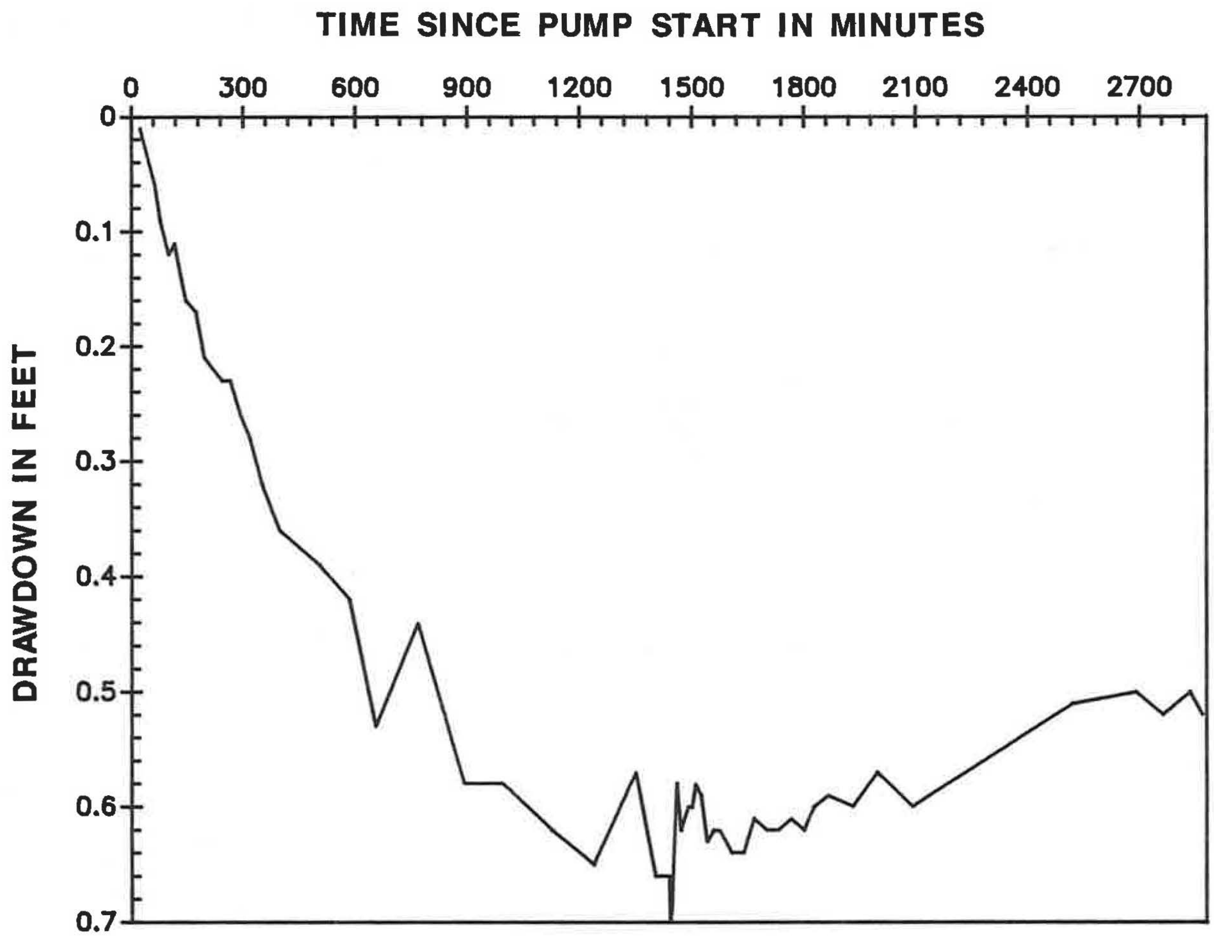


Figure 118. Drawdown and recovery curves for observation well 2 at Unicoi State Park.

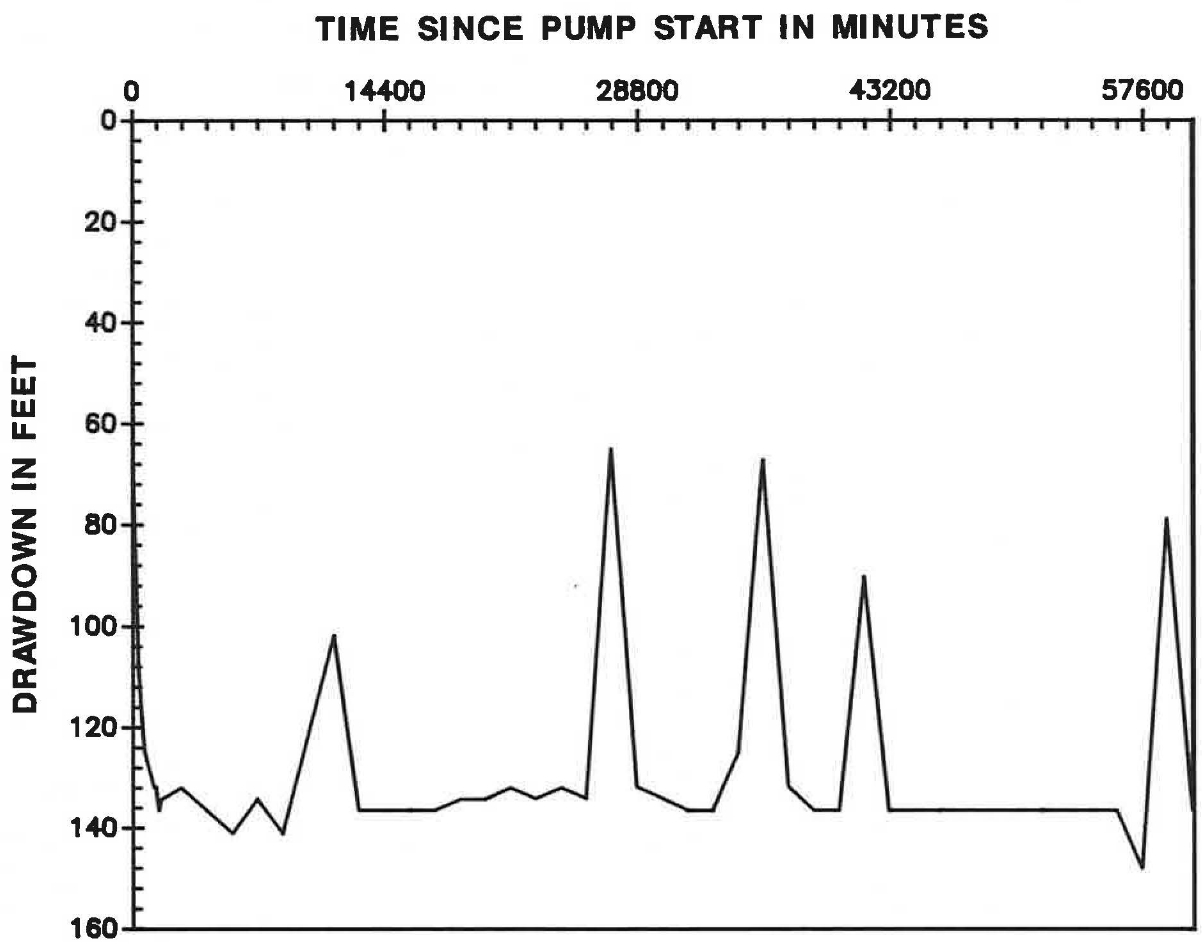


Figure 119. Drawdown curve for well 5 at Unicoi State Park during 41-day pumping test.

SUMMARY

The Georgia Geologic Survey sited two wells for Unicoi State Park, wells 2 and 5. Well 2 has a yield of 10 gpm after pumping for 24 hours. Wells 3 and 4, sited by others, had yields less than 5 gpm each and were used as observation wells during the pumping test of well 2. Well 5 produced 130 gpm from numerous discontinuities and it sustained this yield for over 4 months of pumping. Well 5 produces more than the amount of water needed to sustain the park; however, the water is not potable due to a high sulfate content.

WATKINSVILLE, OCONEE COUNTY

INTRODUCTION

A high-yield, private water-supply well owned by Oconee Well Drillers, located in Watkinsville, Oconee County, about 8 mi south of Athens, was made available to the Geologic Survey for testing to measure its hydrologic properties (Fig. 1). A second drilled well, located 400 ft northwest, and a shallow bored well, located 1000 ft southwest of the pumping well, were used as monitoring wells.

GEOLOGY

Watkinsville lies in the Winder Slope District, a subdivision of the Piedmont Physiographic Province. Stream valleys in the Watkinsville area are gently concave and hill tops are flat to gently convex. Valley floodplains are narrow, usually less than 100 ft in width (Fig. 120). Most of the land surface is gently sloping. Relief is approximately 100 ft. Intermittent streams exhibit trellis or rectangular drainage patterns. Straight stream valley segments near Watkinsville trend N40°W, N15°E, N50°E, and N78°E. The test well is located in the valley of an intermittent, northwest-trending tributary of southeast-flowing Porters Creek.

The study area is underlain by a red-weathering biotite gneiss, red- to tan-weathering mica schist, red-weathering biotite granite, and ocher- to yellow-brown weathering amphibolite. Biotite granite occurs as dikes and pods in the gneiss. Biotite schist is interlayered with the biotite gneiss on the scale of one inch to a few feet. Amphibolite occurs locally. Sillimanite mica schist occurs northeast of Watkinsville. Sillimanite mica schist and amphibolite are interlayered on a one foot scale.

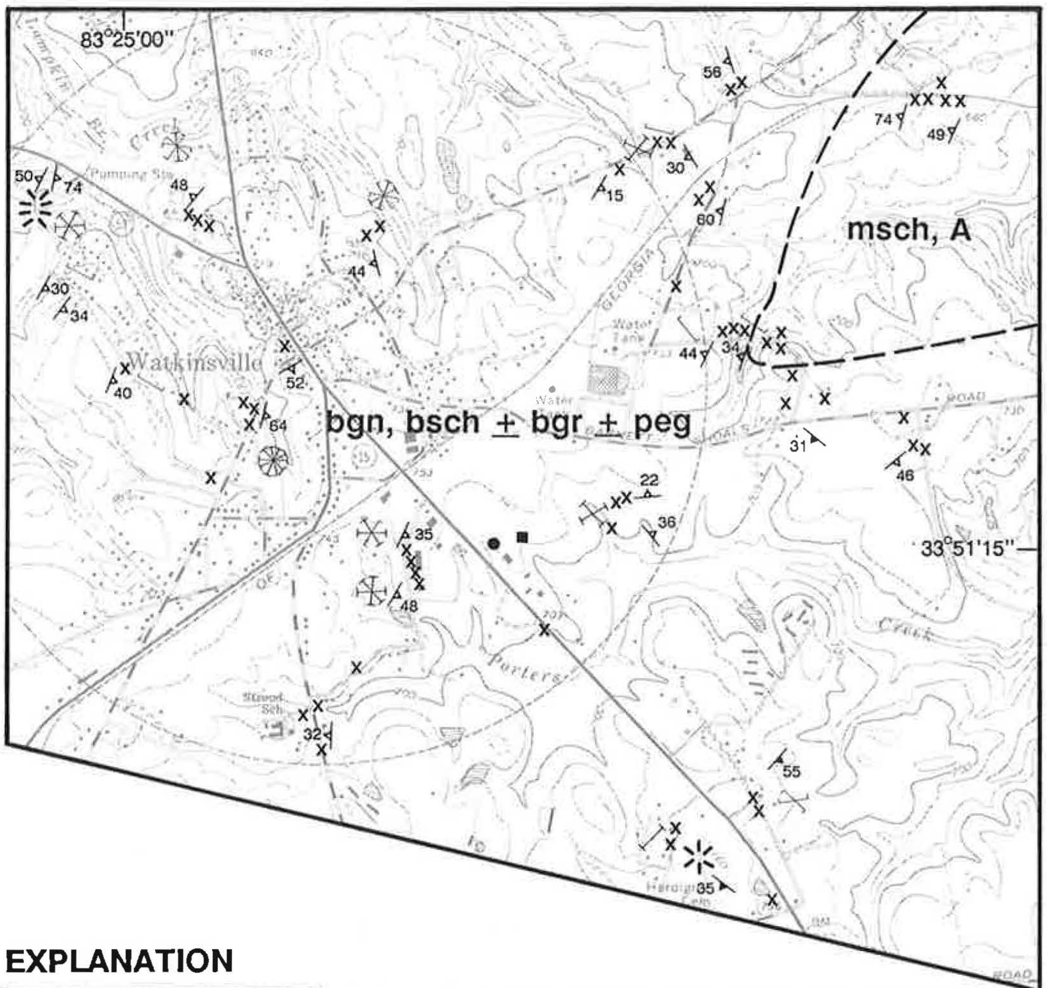
Rocks in the study area have been polydeformed. The geologic map (Fig. 120) illustrates the complexity of the structures. Compositional layering strikes northeast and dips to the southeast and northwest.

Joints are spaced from one inch to several feet apart and their persistence along strike varies from one inch to several feet. Joint aperture in weathered and exposed rock is less than 0.1 in. Joints strike N40°E, N60°-80°E, and N36°W and have vertical to near vertical dips (Fig. 120, Table 11).

BOREHOLE GEOPHYSICS

Geophysical logs, including sonic televiewer, caliper, temperature, spontaneous potential, acoustic velocity logs, single-point resistance, and natural gamma, were run at the Watkinsville well (121-127). Examination of the logs indicates the presence of water-bearing zones at depths of 140-146 ft, 150-152 ft, 347-348 ft, and 400-410 ft. Another water-bearing zone may be present at 20-21 ft.

The sonic televiewer log (Fig. 121a) and the caliper log (Fig. 122) indicate what appears to be a discontinuity at a depth of 20-21 ft. This, however, may actually be a zone where saprolite has "washed out" just below the base of the casing (16 ft). The sonic televiewer log indicates a potential water-bearing zone at 140-146 ft, consisting of a low-angle discontinuity dipping 29° SE, intersecting a high-angle discontinuity that dips 84°SW (Fig. 121b). This zone also is characterized by increased borehole diameter on the caliper log, decreasing water temperature, and by anomalies on the spontaneous potential, single-point resistance, and acoustic velocity logs (Figs. 122-126). Two other potential water-bearing zones appear at 150-152 and 347-348 ft on the sonic televiewer logs (Figs. 121b and 121c) and are also indicated by anomalies on the caliper, temperature, spontaneous potential, resistance, and acoustic velocity logs. A large anomaly at 400-410 ft on the single-point resistance log correlates with anomalies on temperature, natural gamma, and acoustic velocity



N

Base from
U.S. Geological Survey
Watkinsville 1:24,000,
photorevised 1986.

EXPLANATION

msch, A	Medium- to coarse-grained mica schist and medium- to coarse-grained amphibolite
bgn, bsch ± bgr ± peg	Coarse-grained contorted biotite gneiss and biotite schist intruded by coarse-grained porphyritic biotite granite and pegmatite
36	Strike and dip of compositional layering in metamorphic rock
35	Strike and dip of flow banding in granite
	Strike and dip of vertical joint
	Strike and dip of inclined joint
x	Outcrop
	Pavement outcrop
— — — —	Inferred contact
■	Pumping well
●	Observation well

0 .5 MILE

0 .5 KILOMETER

Figure 120. Geologic map of part of the Watkinsville Quadrangle and locations of the test well and observation well.

Table 11. Watkinsville, joint orientations and descriptions

Joint	Dip	Spacing	Surface	Coating
N40° E	90°	1-2 ft	curvilinear trend with smooth to irregular surface	none
N60° -80° E	90°	1-2 ft	curvilinear trend with irregular surface	none
N36° W	90°	2-6 in	curvilinear trend with smooth to irregular surface	none

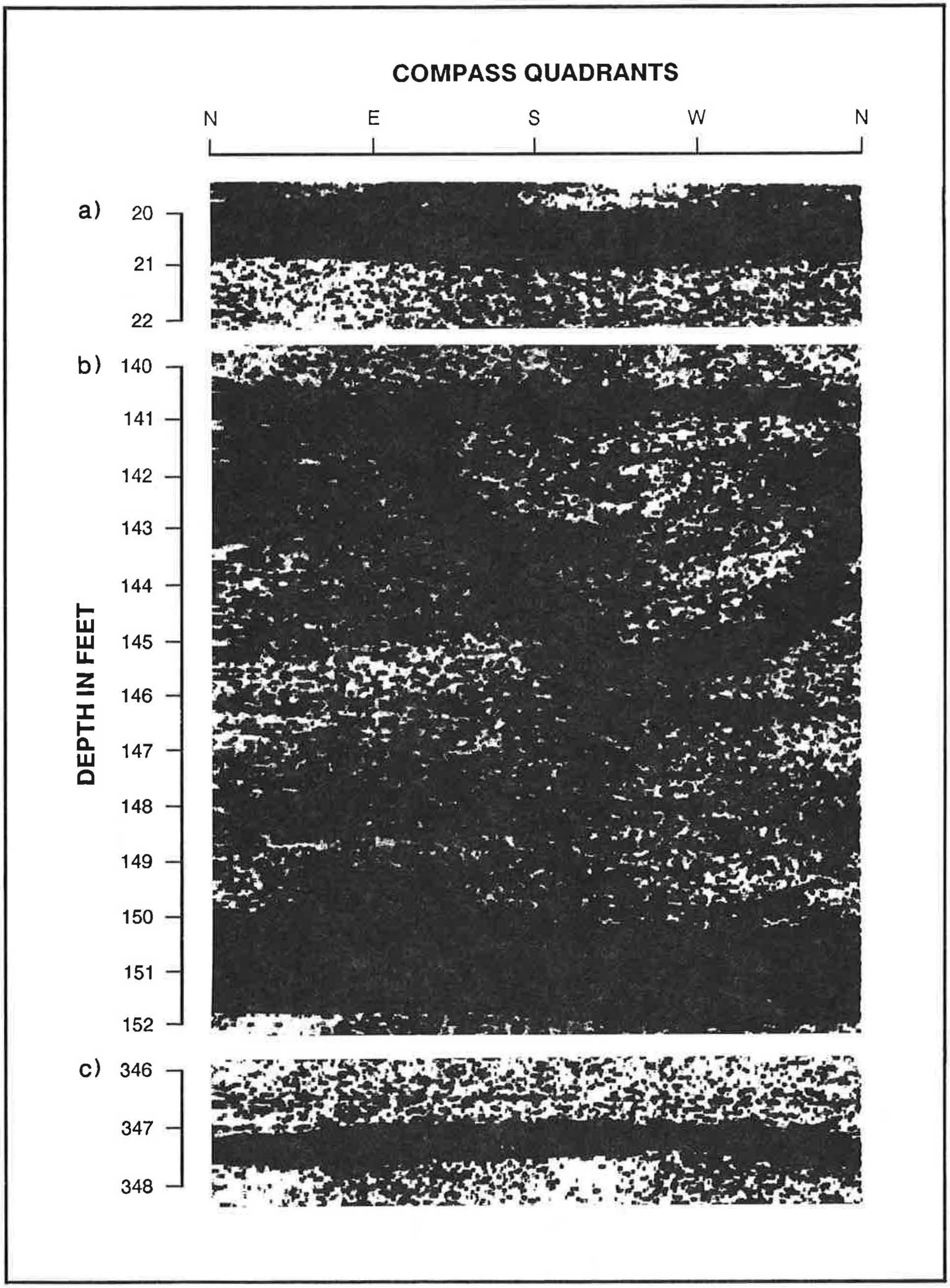


Figure 121. Sonic televiewer log of the Watkinsville well.

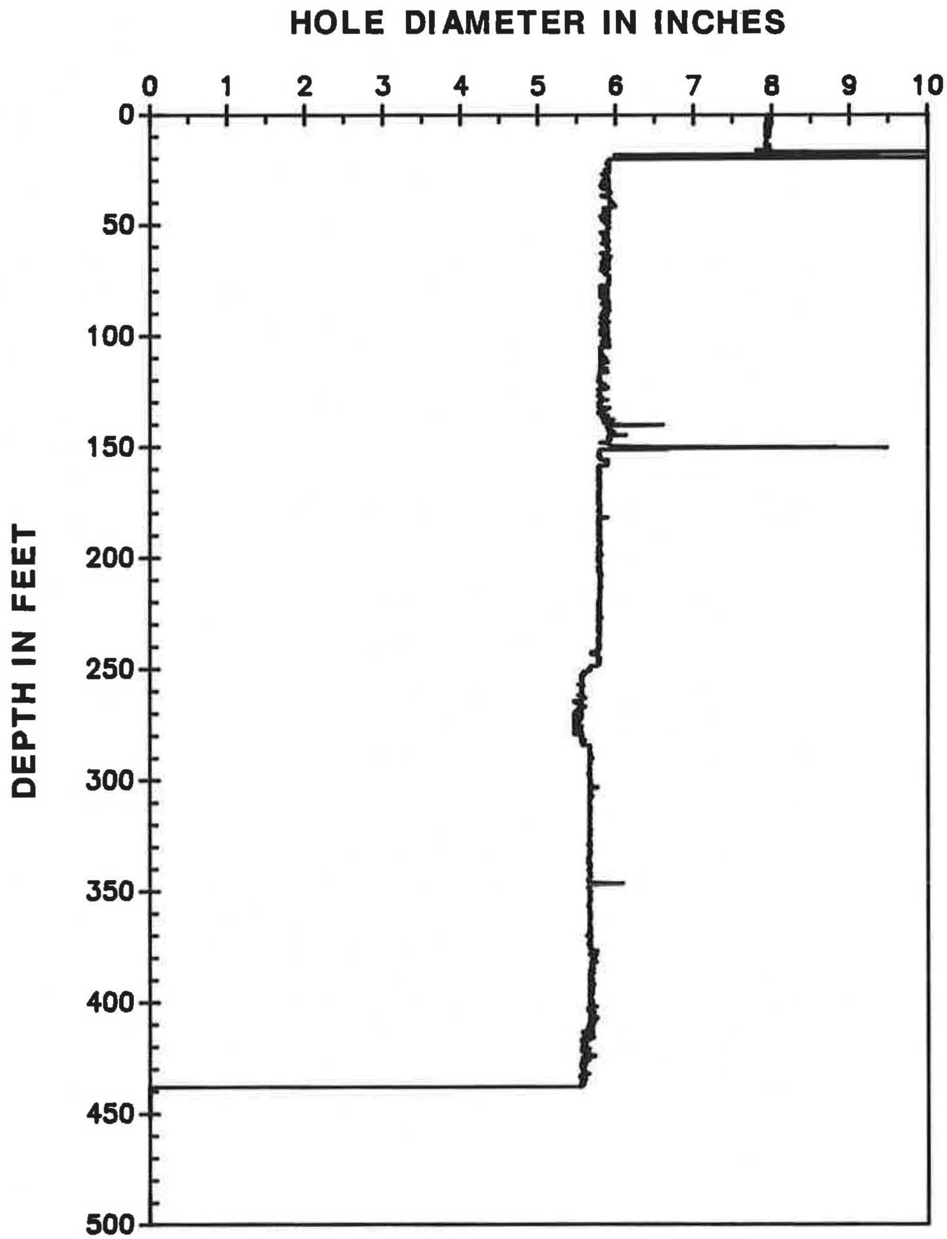


Figure 122. Caliper log of Watkinsville well.

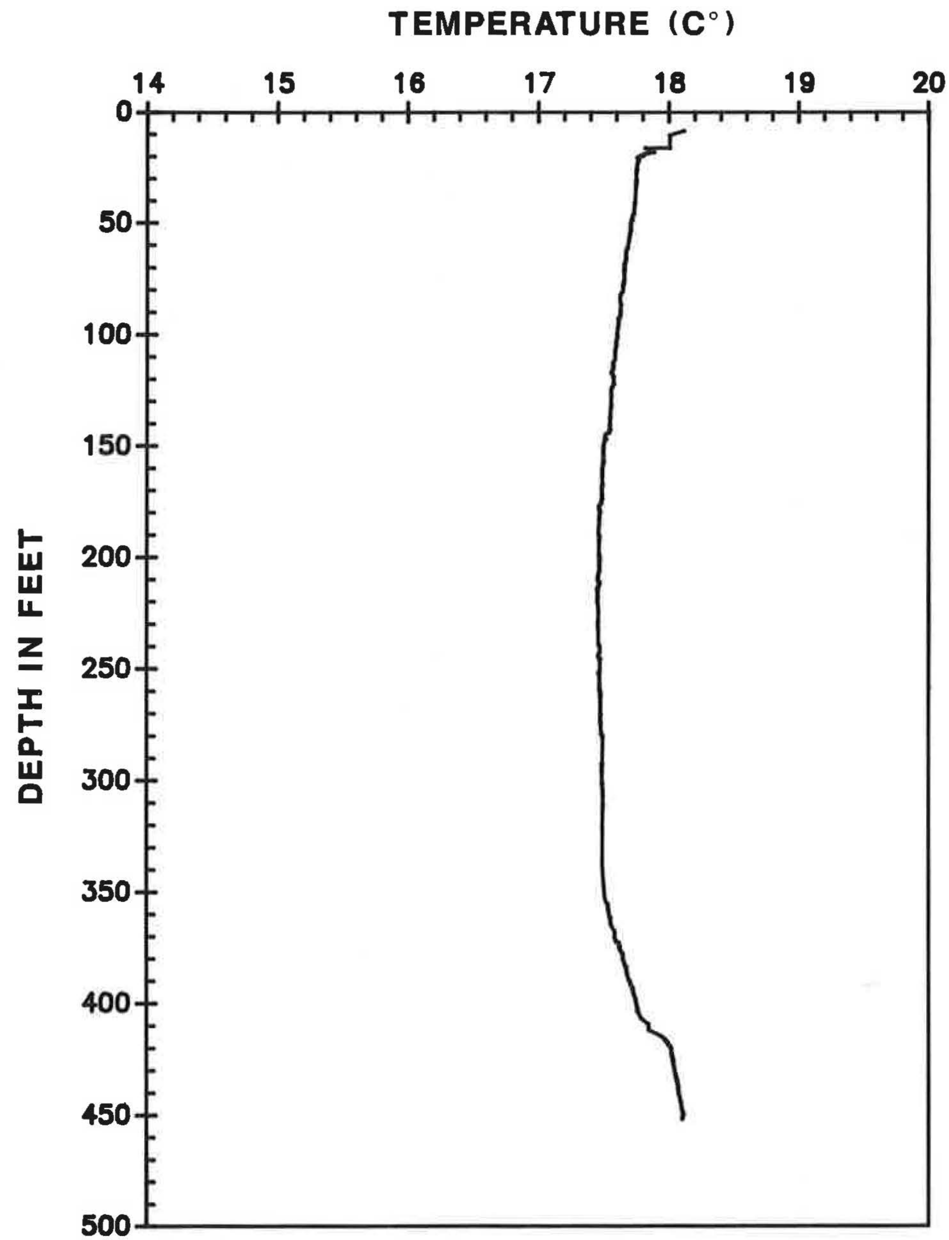


Figure 123. Temperature log of Watkinsville well.

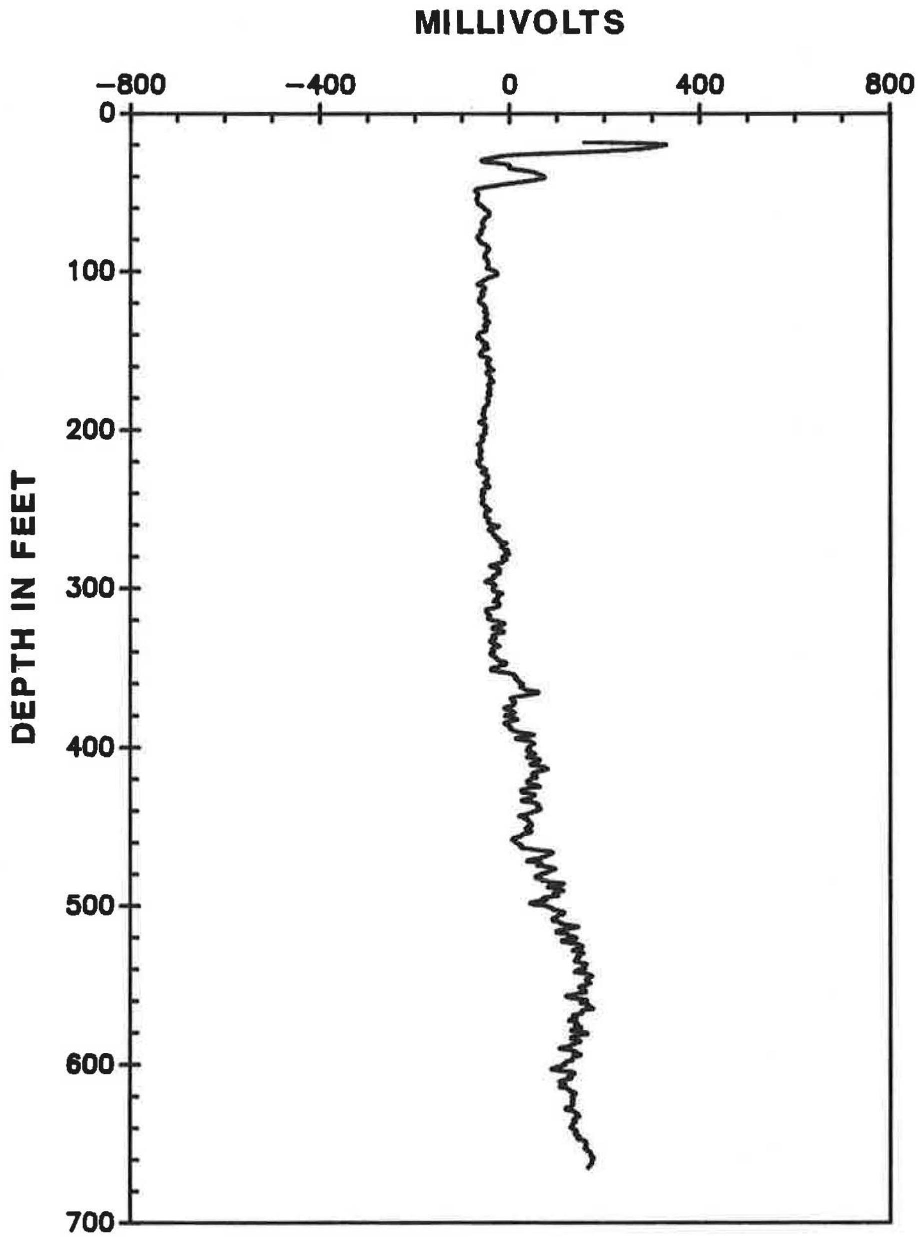


Figure 124. Spontaneous potential log of Watkinsville well.

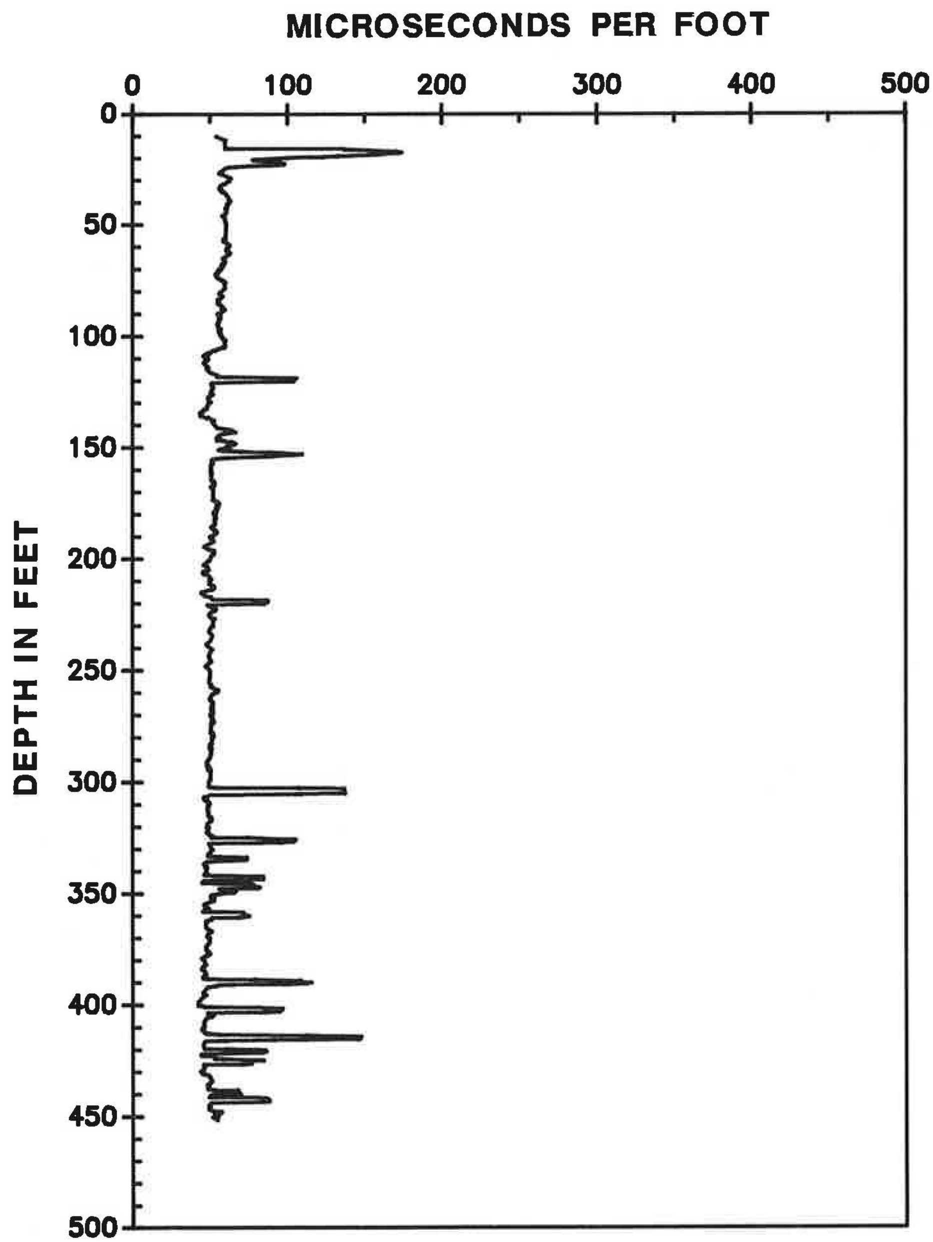


Figure 125. Acoustic velocity log of Watkinsville well.

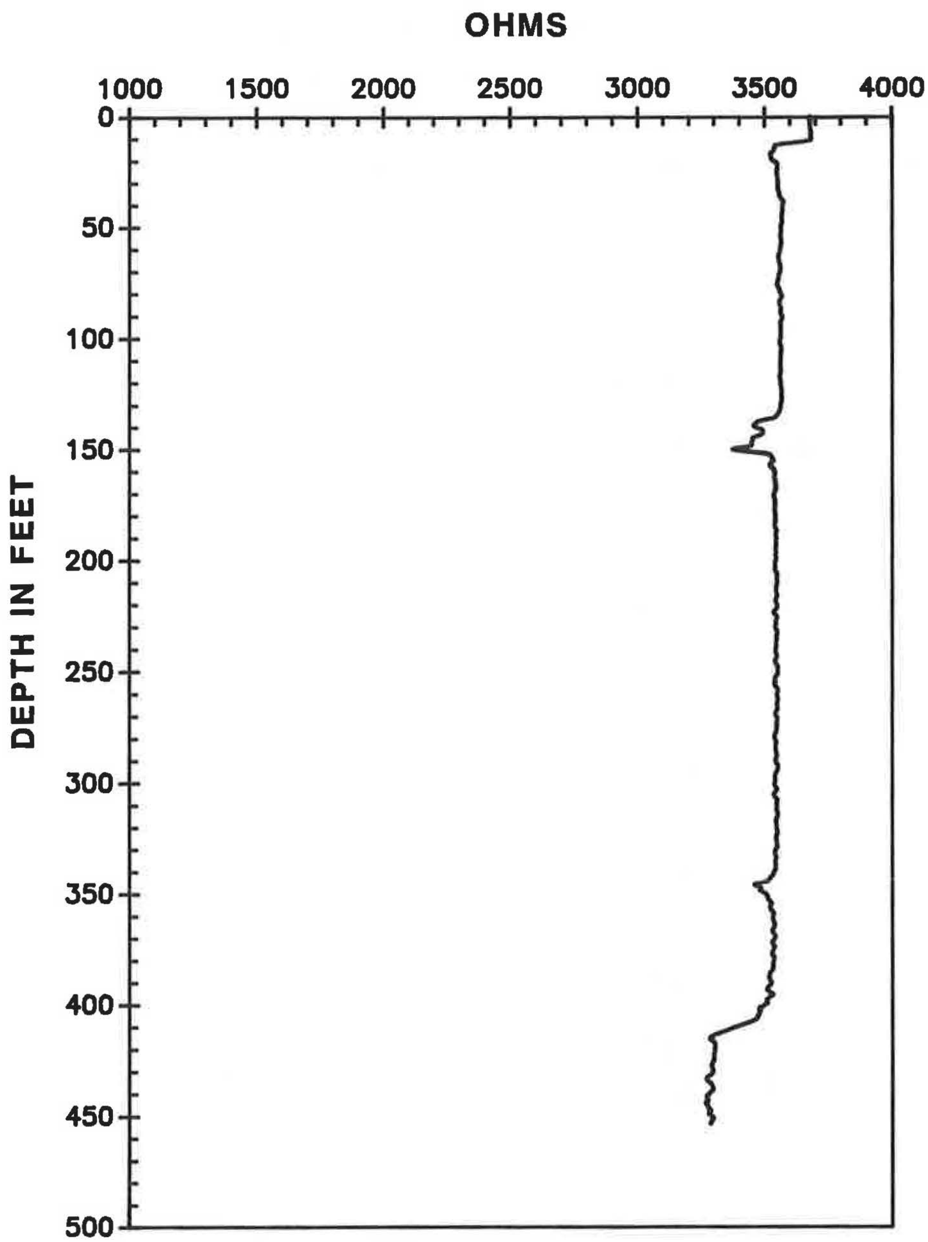


Figure 126. Single- point resistivity log of Watkinsville well.

logs, suggesting that this interval is another potential water-bearing zone not detected on sonic televiewer or caliper logs. Significant natural gamma anomalies occur at about 275, and 332 ft (Fig. 127); however, their relationship, if any, to water-bearing characteristics of the well are unknown.

The orientations of subsurface discontinuities were measured from the sonic televiewer log of the Watkinsville well. These orientations were plotted on equal area diagrams and compared with the orientations of compositional layering, joints, and straight valley segments measured at the surface. The strikes of discontinuities measured on the televiewer log (N75°E and N80°E) are parallel to the strike of one joint set (N60°-80°E) and nearly parallel to one linear stream valley trend (N80°-85$_0$E) mapped on the surface. This could indicate that the discontinuities observed on the sonic televiewer logs are joints and that the northeast-trending streams are structurally controlled. However, dips measured on the televiewer vary greatly (27°NW, 29°SE, and 84°SW) and generally are of lower angle than dips of the corresponding surface joint set.

HYDROLOGIC TESTING

A 24-hour constant-rate pumping test was completed on the Watkinsville well using a submersible production pump and utility power. Discharge from the well flowed into a valley head. A pumping rate of 83 gpm was used throughout the test (Fig. 128). Drawdown and recovery curves generated from the test well data are somewhat irregular and asymmetrical (Fig. 129). Curves generated from the drilled observation well data are more regular but also asymmetrical (Fig. 130). The bored observation well did not respond to the pumping.

SUMMARY

Hydrologic results indicate that the pumping well had a yield of 83 gpm for 24 the hours of the pumping test. Water was produced from discontinuities that were oriented parallel or subparallel to surface joint orientations but have varying degrees of dip.

GENERAL OBSERVATIONS

The Georgia Geologic Survey's efforts to locate high yield well sites and the testing of these and other wells in the Piedmont and Blue Ridge have yielded interesting preliminary hydrogeologic findings which merit comment and further investigation. The following is a discussion of some of the observations made during this phase of the project and of some of the possible future avenues for investigation.

WELL SITING

Certain factors have been identified which appear to aid in maximizing well yield when siting Piedmont wells. LeGrand (1967) described physiographic characteristics, such as topography and soil thickness, which appeared to correlate with high well yields in the Piedmont. Observations made during this study in the Piedmont and Blue Ridge confirm this relationship and have further refined well-siting methodology for these regions.

Wells completed in the crystalline rocks of the Blue Ridge and Piedmont Physiographic Provinces produce water from soil and saprolite and from voids in the unweathered rock. Ground water is channeled to wells via fractures, joints, weathered intervals, contacts or any other rock discontinuities intercepted by the well. The performance of a well, therefore, is controlled by the following factors:

1) the storage and transmission capabilities of the soil,
2) the storage and transmission capabilities of the discontinuity network, and
3) the hydraulic efficiency of the connection between the well bore and the discontinuities it intercepts.

An ideal Piedmont or Blue Ridge well would be constructed in a place where the well bore will intercept numerous discontinuities that are hydraulically connected to a thick, permeable regolith which is, in turn, hydraulically connected to one or more perennial streams. The ideal well would be of relatively large diameter (e.g., greater than 6 in.), in order to intercept a larger surface area of water-bearing discontinuities to allow more efficient transmission of water to the well.

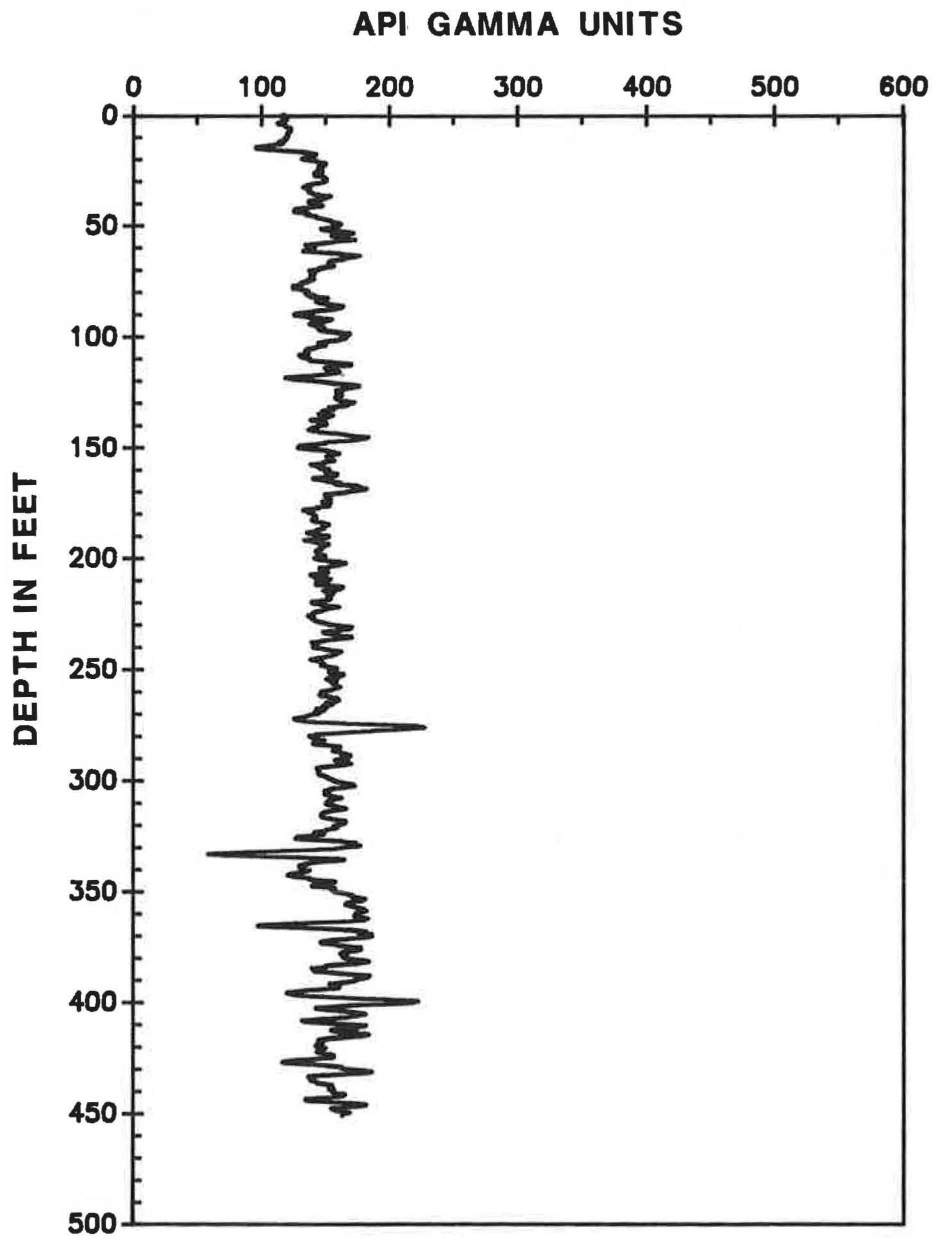


Figure 127. Natural gamma log of Watkinsville well.

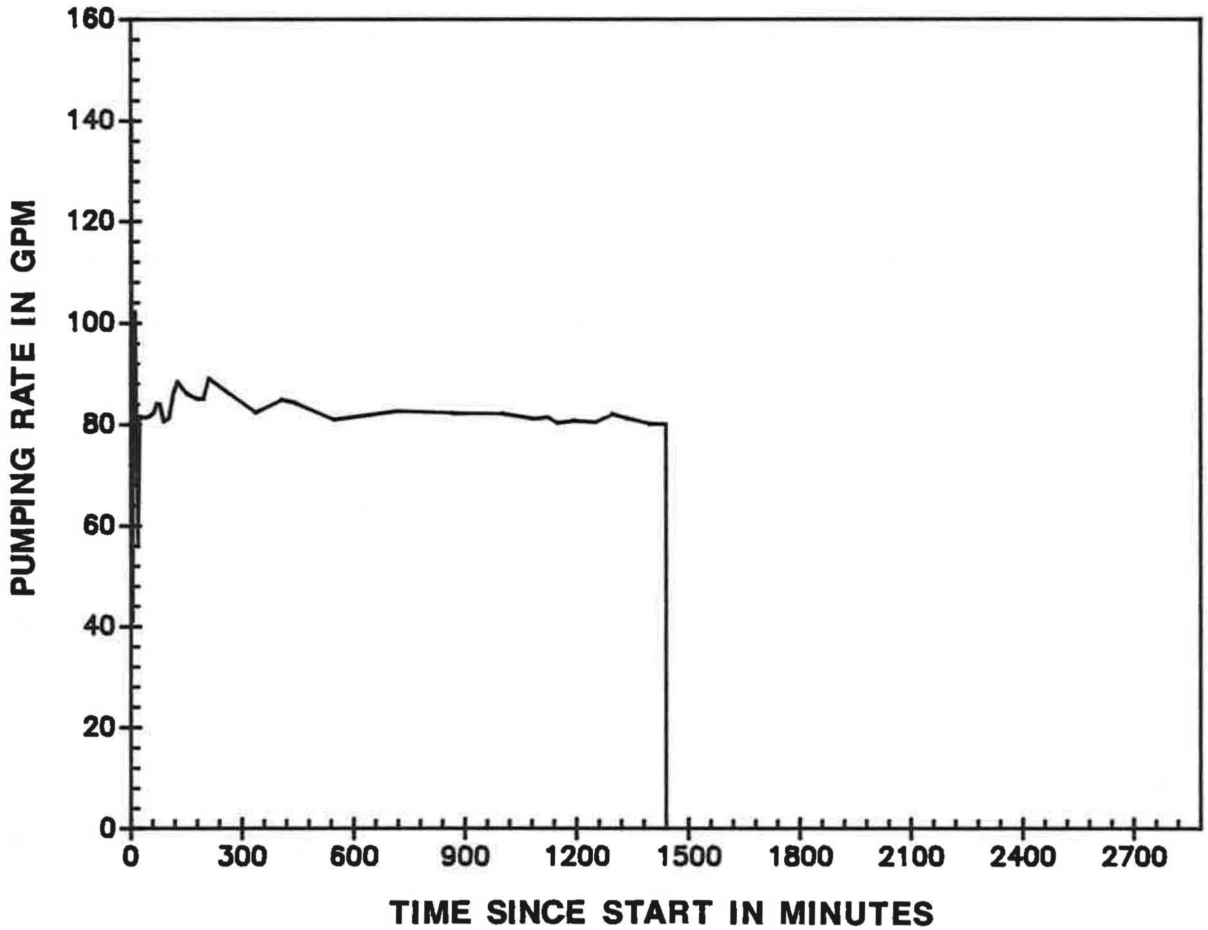


Figure 128. Pumping rate during test of Watkinsville well.

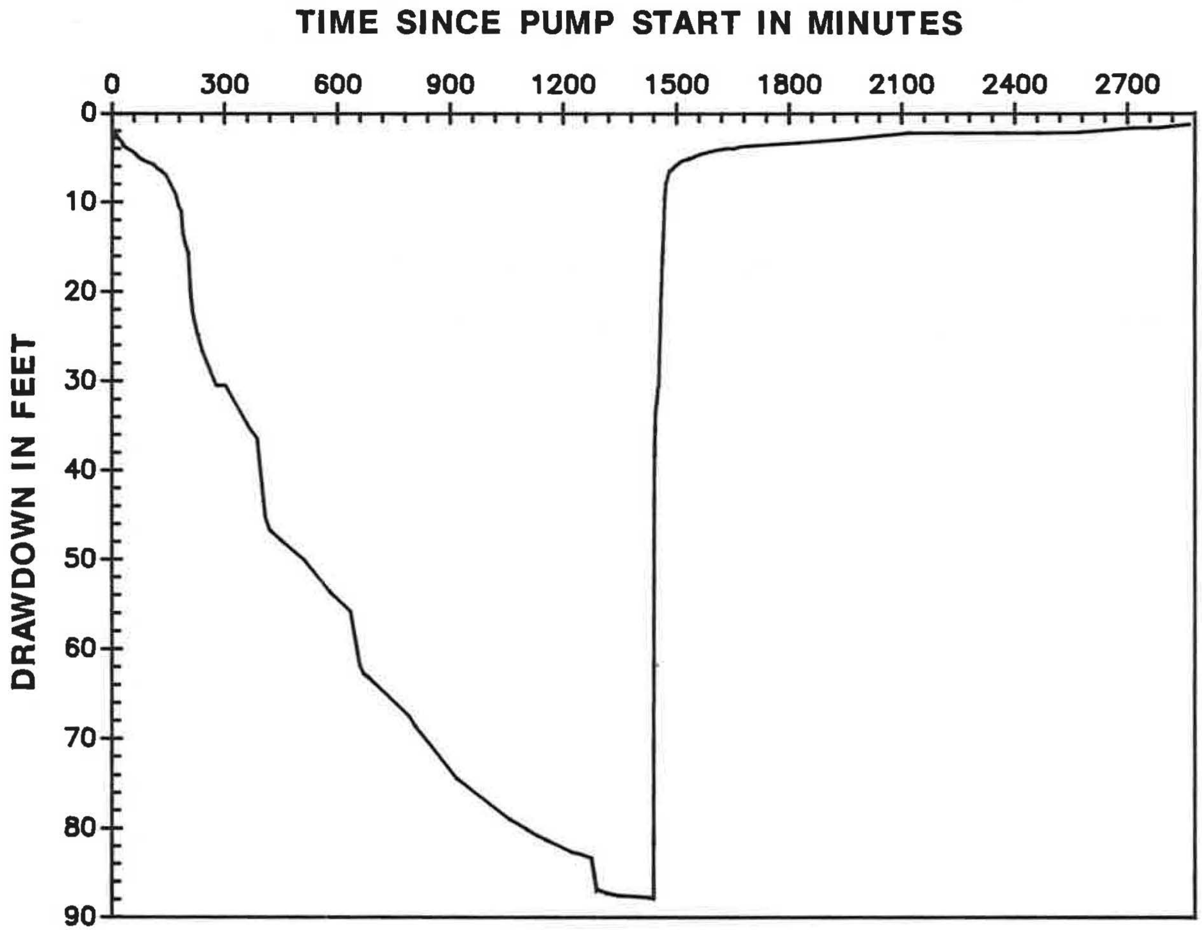


Figure 129. Drawdown and recovery curves for Watkinsville well.

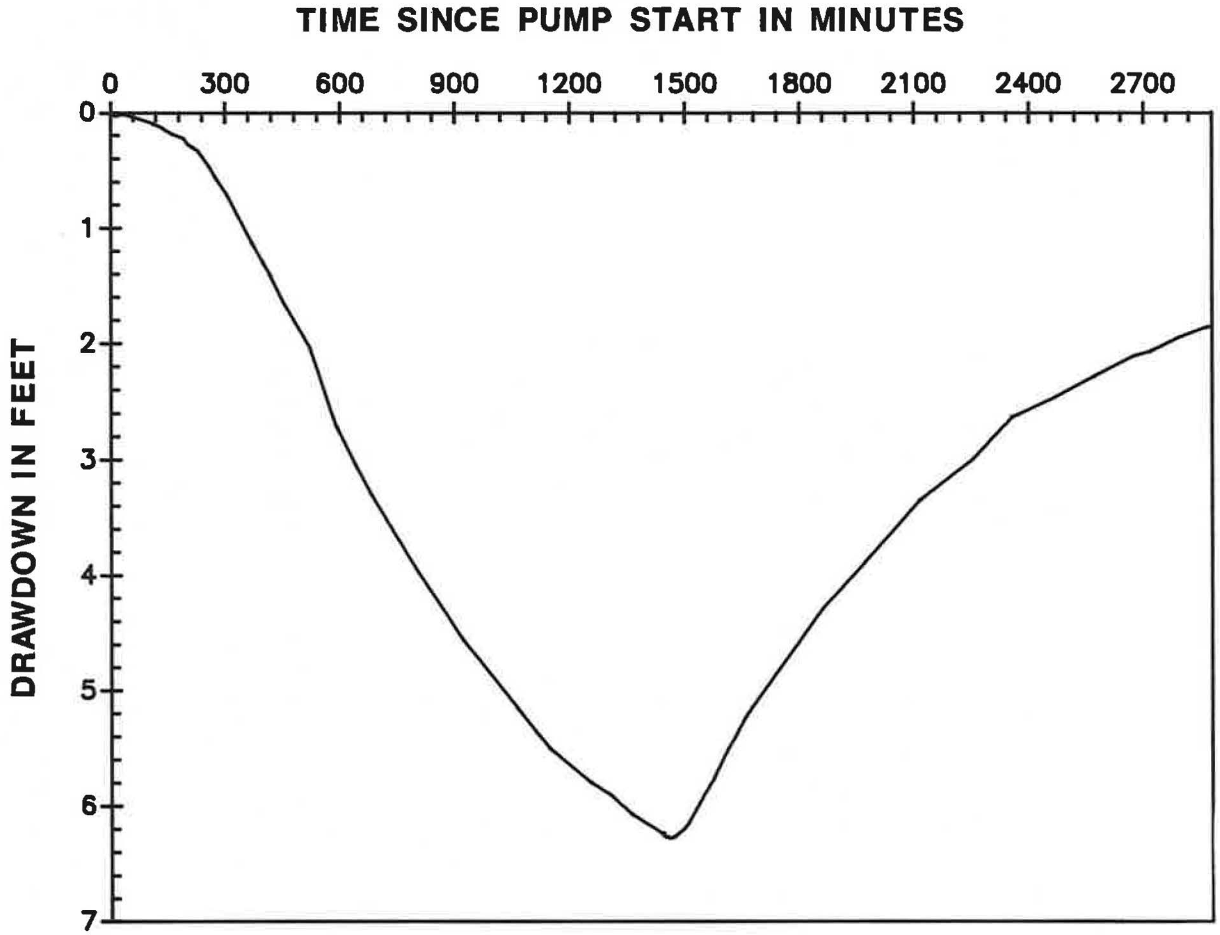


Figure 130. Drawdown and recovery curves for Watkinsville observation well.

This well also would be close enough to required utilities to reduce development costs, and it would be shallow (less than 400 ft) to minimize construction costs.

Ideal conditions rarely occur. Compromises are necessary, but the hydrogeologic siting criteria for the well system should not be the area for compromise. Wells must be properly placed if they are expected to produce high reliable yields. Almost certainly, wells sited on the basis of convenience will have lower yields.

Well performance factors, such as those discussed above, reflect soil and bedrock characteristics which can not be observed directly prior to completion of a well. Thus, well siting in the Piedmont and Blue Ridge Provinces is difficult, but possible, using a comprehensive geological approach. Methods of topographic analysis, such as the LeGrand Method, only indirectly address geologic factors critical to well performance. Geologic structure, compositional layering and the weathering characteristics of the rocks, which are observable and mappable in the field, must also be considered.

The topographic features of the Piedmont and Blue Ridge Provinces, when closely examined, reflect the geologic structure and weathering characteristics of the rocks on which they are developed. Areas of fractured and highly weathered rock are frequently expressed topographically as valleys and draws, serve to trap and channel water, and should be exploited in the placement of wells. The lowest elevations within these valleys appear to produce the highest yields, possibly due to a combination of high water table and, in many cases, a thick soil/saprolite or alluvium acting as a ground-water reservoir.

Rock discontinuities, such as foliations, compositional layering, joints and fractures, may serve to channel ground water from the soil/saprolite reservoir to the well. Locating wells at intersections of such discontinuities will generally maximize yield. Soil thickness at the well head itself, long regarded as a predictor of well yield, can not always guarantee a good yield. Wells located in areas of shallow soil may intercept discontinuities which drain ground-water reservoirs located some distance away or, conversely, a well may penetrate a thick soil which does not readily transmit water because of limited discontinuities in the underlying bedrock.

A structural analysis of rock discontinuities, along with topographic analysis, has been the most reliable method found by this study for siting wells in the Piedmont and Blue Ridge Provinces. The relationship between topography and bedrock characteristics is complex, but it must be understood if a well is to be optimally sited.

HYDROLOGIC TESTING

Pumping tests conducted by the Geologic Survey on wells in the Piedmont and Blue Ridge have yielded some interesting results. Each test yielded a unique set of results indicating the highly variable nature of the hydrogeologic system in the Piedmont and Blue Ridge Provinces. The importance of monitoring water-level recovery, rather than just drawdown, was demonstrated by pumping test results. Recovery response may present a truer picture of long term well yield than does the drawdown curve, because the effects of pump performance, variations in pumping rate, and turbulence caused by the pumping are not present. Drawdown and recovery curves demonstrate another significant aspect of crystalline rock hydrology: well behavior can not be reliably predicted using classical analytical methods. Since the assumptions governing the application of the Theis equation are not met, transmissivity and storativity have no clear physical meaning in aquifers formed of discontinuities in crystalline rocks. Further, such a well changes performance characteristics over time as the well is pumped and the discontinuities are de-watered.

RECOMMENDATIONS

This study demonstrates that ground water in the Piedmont and Blue Ridge Provinces has the potential to be a reliable source for public drinking water supplies and for light industrial and commercial uses. Further refinements in well-siting methodology are needed, as well as a more complete understanding of the performance characteristics of crystalline-rock wells. Development of ground water to provide or supplement water supplies in the future will depend on the accuracy with which high-yielding wells can be sited and on the degree to which the long-term performance of such wells can be predicted. Further research in crystalline-rock hydrology should address the question of how best to site high-yielding wells without the need for expensive preliminary investigations or testing.

Many drillers familiar with finding water in the Piedmont and Blue Ridge report that approximately 5-7 percent of randomly drilled domestic wells have a high yield potential (greater than 50 gpm). Observations from this study indicate that the high yield wells lie in identifiable geologic structures. The structures which can be identified as representing potential high-yield sites probably occupy only 5 percent of the land area or less. Thus, rational development of ground-water resources in the Piedmont/Blue Ridge may require developers of water supplies to obtain drilling sites or water rights in places more remote from their treatment or distribution systems than they usually have in the past.

Since almost all ground-water in the Piedmont/Blue Ridge can be considered as being part of the surface or water table aquifer, it is quite prone to pollution from man-made sources. Special ground-water protection efforts should be directed towards those geological environments in which the high yield well sites may be located.

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