HYDROGEOLOGY OF GREENE, MORGAN, AND PUTNAM COUNTIES

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DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION
GEORGIA GEOLOGIC SURVEY

INFORMATION CIRCULAR 60

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ABSTRACT

The metasedimentary and igneous rocks in Greene, Morgan, and Putnam Counties provide approximately 40 percent of the consumptive water-use in the area. Data from the files of local water-well contractors indicate that ground-water yields are highly variable from one location to the next. Maximum yield is approximately 300 gallons per minute, whereas yields of 1 to 2 gallons per minute are common. Depths for drilled wells range from 63 feet to a maximum of 700 feet. Well yields showed no apparent correlation with topography or rock type. Of the 145 high-yielding (20 gallons per minute or more) wells inventoried, approximately 110 obtained water moving through fractures within 400 feet of the surface. A total of 35 wells were drilled deeper than 400 feet. Of these 35, six were essentially dry before intercepting deep water-bearing zones. The water-producing interval was undetermined in the remaining 29 wells.

Streams valleys in the study area show a rectangular drainage pattern, a possible indication of structural control. Drainage may indicate zones of enhanced ground-water yield through fractures and foliation planes.

Water quality in the study area is generally within drinking water limits established by the Georgia Environmental Protection Division. Concentrations of total dissolved solids average less than 150 milligrams per liter, and do not exceed 270 milligrams per liter anywhere in the study area.

INTRODUCTION

Greene, Morgan, and Putnam Counties are located in the Piedmont Physiographic Province of north-central Georgia (fig. 1). The area is little more than a one-hour automobile drive from Atlanta, Macon, Augusta, or Athens. Census figures show that the population of the three-county area was 33,000 in 1980, a 17-percent increase over 1970. Because of the potential for further growth and development in the area, the Georgia Geologic Survey initiated a reconnaissance-level investigation of the geohydrology of Greene, Morgan, and Putnam Counties.

The study area is underlain by igneous (both plutonic and volcanic) and metamorphic rocks. Ground-water availability in these rocks is controlled primarily by the intensity of jointing and fracturing and thickness of the weathered zone overlying the bedrock. Most of the larger communities in the study area, those requiring more than about 100,000 gallons per day (gal/d) of water, rely entirely on streams as a source of water. These communities include Greensboro, Union Point and Eatonton. The City of Madison obtains approximately 75 percent of its water supply from streams and the remainder, approximately 217,000 gal/d from wells. Farms, rural residences, and smaller communities rely entirely on wells for water. Total water use in the three-county area, excluding thermoelectric and hydroelectric use, is approximately 6 mgal/d. An estimated 41 percent of this total is ground water. Of the 1.14 billion gal/d used for thermoelectric power, and 1.33 billion gal/d for hydroelectric power, none is from ground-water sources (Pierce, and others, 1982).

Goals of this investigation were:

1. define the geology, ground-water availability, and water quality of Greene, Morgan, and Putnam Counties; and
2. make recommendations for future hydrogeologic investigations based on the findings of this report.

Objectives leading to these goals were:

1. present the available geologic data on a base map;
2. plot available well data on a base map and relate well characteristics and water availability to geologic structure; and
3. determine the quality of ground water from existing chemical analyses, and relate analytical results to geologic conditions.

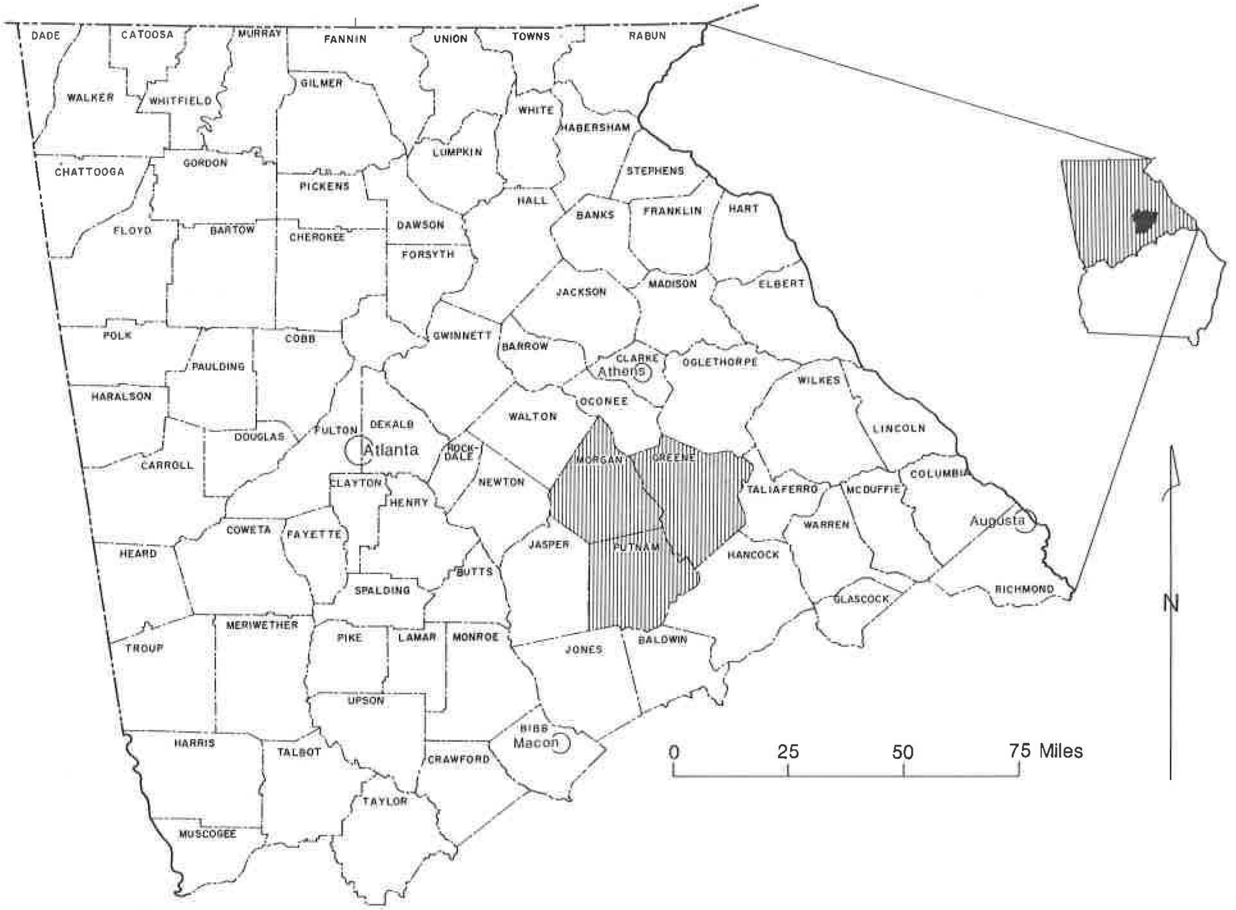

Figure 1. Map showing location of study area.

PREVIOUS INVESTIGATIONS

Several investigators have mapped the geology in Greene, Morgan and Putnam Counties. Myers (1968) and Libby (1969) mapped in Greene County; and Lawton (1966) mapped the Hard Labor Creek area of Morgan County. Davis (1980) suggested the existence of a cataclastic zone in parts of Greene and Morgan Counties. Vincent (1984) mapped the Siloam granite and vicinity in Greene and Putnam Counties.

GEOGRAPHY OF THE STUDY AREA

The study area occupies approximately 1,100 sq mi of the Piedmont Physiographic Province of Georgia. This area is characterized by a crystalline metamorphic and igneous bedrock overlain by weathered rock and soil. The topography of the area is probably the result of long-term erosion of a formerly smooth, broad plain. A large part of the area consists of broad ridges and long, smooth slopes. Streams have cut deep v-shaped valleys. Topographic-map data indicate that slopes range from 0 to more than 25 percent. Soils on uplands where the slope is less than 15 percent are generally deeper than soils on steeper slopes. Where the slope is 15 percent or more, erosion removes soil material almost as fast as it forms. Consequently, soil cover is thinnest where slope is steepest (Payne, 1965). Maximum topographic relief in the three-county area exceeds 350 ft, with altitudes ranging from over 700 ft near Madison in Morgan County to approximately 340 ft in the vicinity of Lake Sinclair in Putnam County.

Climate in the study area is characterized by warm to hot summers and mild winters. Precipitation averages about 48 in. per year. Ordinarily more precipitation occurs in spring than either summer or winter, and fall is the driest season of the year. The average precipitation in any month is more than 2 in. and less than 5½ in. Summer precipitation comes primarily from localized convective storms and is much less uniform in coverage than winter precipitation. The summer storms, though small in extent and of short duration, are often intense and can cause considerable runoff and erosion. Thunderstorms occur on an average of 50 or more days per year (Payne, 1965).

The economy of Greene, Morgan, and Putnam Counties is largely agricultural, with dairy production being the chief source of farm income. Light industry in the area includes the manufacture of aluminum cookware, garments, fertilizer, mobile homes and marine recreational products. Mineral production includes crushed granite, feldspar, dimension stone, sand and gravel.

GEOLOGY

The bedrock of the study area consists of igneous rocks and metamorphic rocks (plate 1) exhibiting multiple folding, fracturing, and lineation features. These rocks were divided into a series of northeast-southwest-trending belts by King (1955), and Overstreet and Bell (1965). They defined and delineated these belts on the basis of distinct lithologies, structures, and metamorphic grades. Within the study area, three of these belts, the Mobilized Inner Piedmont, Charlotte, and Carolina Slate belts, come together (fig. 2).

Mobilized Inner Piedmont Belt

The Mobilized Inner Piedmont belt consists of a broad zone of highly metamorphosed and migmatitic granite gneisses, biotite gneisses, and mica schists extending from Alabama to Virginia. It is bounded on the southeast and northwest by two northeast-trending shear zones with rock of lower metamorphic grade than that of the Inner Piedmont (Hatcher, 1972, 1978). The northwestern shear zone is the Brevard fault, and the southeastern zone is the Towaliga-Middleton-Lowndesville fault (Davis, 1980). In Greene, Morgan, and Putnam Counties, foliations and compositional layering resulting from metamorphism and deformation of Inner Piedmont lithologies exhibit steep dips toward the northwest and southeast.

Charlotte Belt

The Charlotte belt is an assemblage of metavolcanics and metasedimentary rocks extending from southern North Carolina to eastern Alabama (Hatcher, 1972). Lithologies include granite gneiss, metagabbro, metabasalt, quartzite, mica schist, and talc schist (Griffin, 1978). Metamorphic intensity is medium to high (amphibolite facies). Structurally, rocks in the Charlotte belt are interpreted to lie in an upright to slightly overturned anticlinorium cored by Precambrian basement rocks (Hatcher, 1972; Griffin, 1978).

Carolina Slate Belt

The Carolina Slate belt is a Late Precambrian assemblage of metavolcanic, metaplutonic, and metasedimentary rocks. It extends from southern Virginia into northeastern Georgia. In the study area, the Carolina Slate belt is bounded on the northwest, in part by the Towaliga-Middleton-Lowndesville fault, and in part by the Charlotte belt. To the south the boundary is the Charlotte belt. Dominant lithologies within the metamorphosed sequence include felsic pyroclastics, volcaniclastics, felsic to intermediate plutons, and metasediments. Structurally, rocks of the Slate belt are interpreted to lie in a northeast-southwest trending synclinorium. The nature of the boundary between the Charlotte belt and the Carolina Slate belt is controversial and presently unresolved. This contact is not exposed in the study area but is located near the junction of the Oconee and Apalachee Rivers.

Faulting

A major fault system extends through the study area (Davis, 1980). The Towaliga-Middleton-Lowndesville fault zone is proposed as an extension of the southern splay of the Towaliga fault to the southwest joining the Middleton-Lowndesville fault to the northeast. The Towaliga-Middleton-Lowndesville fault is an integral part of the boundary between the Inner Piedmont belt and the Charlotte and Carolina Slate belts (Davis, 1980). Geophysical data provide the best evidence for the existence of the Towaliga-Middleton-Lowndesville fault zone. Aeromagnetic maps published by the U.S. Geological Survey show a sharp break in aeromagnetic signatures across the fault boundary (Zietz, 1977). According to Davis (1980), the Towaliga-Middleton-Lowndesville fault indicates an early Paleozoic period of ductile deformation followed by a period of movement prior to the Triassic. This period of brittle faulting may be especially significant in terms of increased permeability and

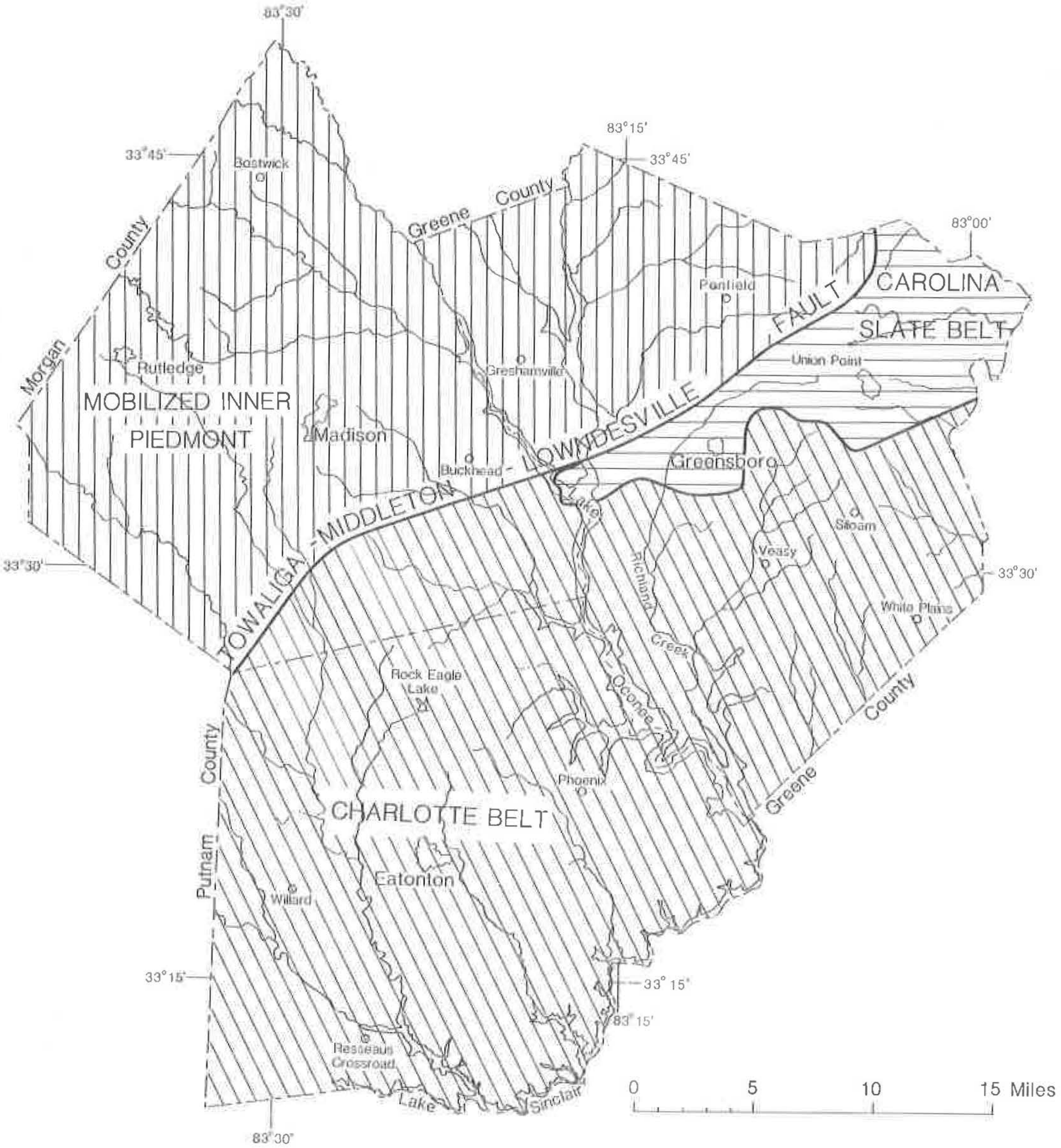

Figure 2. Map showing geologic subdivisions of the Piedmont Physiographic Province.

ground-water availability. Although jointing and fracturing are evident in outcrops and are suggested by drainage patterns, no systematic measurement of orientation was conducted in the study area.

Saprolite

Exposed crystalline rocks exhibit extensive changes resulting from physical and chemical weathering. Unweathered rock is exposed at only a few locations in the study area. What is most commonly seen in outcrop is saprolite and soil weathered from saprolite. Saprolite is rock weathered in place that retains some of the original structure of the rock. Thickness of the saprolite depends on the chemistry and degree of fracturing of the parent rocks, as well as drainage and climate. Well data demonstrate that saprolite thickness may vary significantly, even between two closely spaced drill holes. Thickness of the saprolite zone ranges from zero to more than 150 ft.

HYDROLOGY

Surface Water

Annual precipitation in Greene, Morgan, and Putnam Counties is approximately 48 in. per year (NOAA, Environmental Data and Information Service). Approximately 30 in. per year of the total annual precipitation is returned to the atmosphere by evapotranspiration (Peter W. Bush, U.S. Geological Survey, unpublished data). Subtracting evapotranspiration from total precipitation leaves 18 in. of water income. An estimate of surface runoff can be obtained by measuring the flow volume of the Oconee River upstream and downstream from the study area. Any addition to stream flow in this interval can be attributed to surface runoff. It is recognized that the boundaries of the study area do not correspond with the Oconee River watershed area, and that the flow of the Oconee River is regulated by dams; however, the results are within the limits of accuracy of this discussion. Surface runoff distributed evenly over the study area is equivalent to approximately 15 in. of precipitation per year (U.S. Geological Survey, 1981). Subtracting this amount from the water income leaves approximately 3 in. of the original 48 in. of annual precipation. This remaining 3 in. is assumed to represent the contribution to the ground-water regime.

The study area is drained by a network of streams of the Oconee, Ogeechee, and Little River drainage basins. Regional drainage patterns of streams in the study area are dendritic. Inspection of detailed maps of the area, however, reveals a smaller-scale drainage pattern that is trellised or rectangular, suggesting geologic control of drainage patterns. As the streams eroded into the crystalline Piedmont rocks, drainage may have begun to follow joints and fractures in the rock, resulting in the rectangular drainage patterns and linear stream beds common to the area.

Ground-Water Availability In The Piedmont

Geologic Controls

Ground-water availability in crystalline rocks is controlled primarily by the intensity and degree of interconnection of jointing and fracturing of the rock (fig. 3). Distribution of joints and fractures is a function of

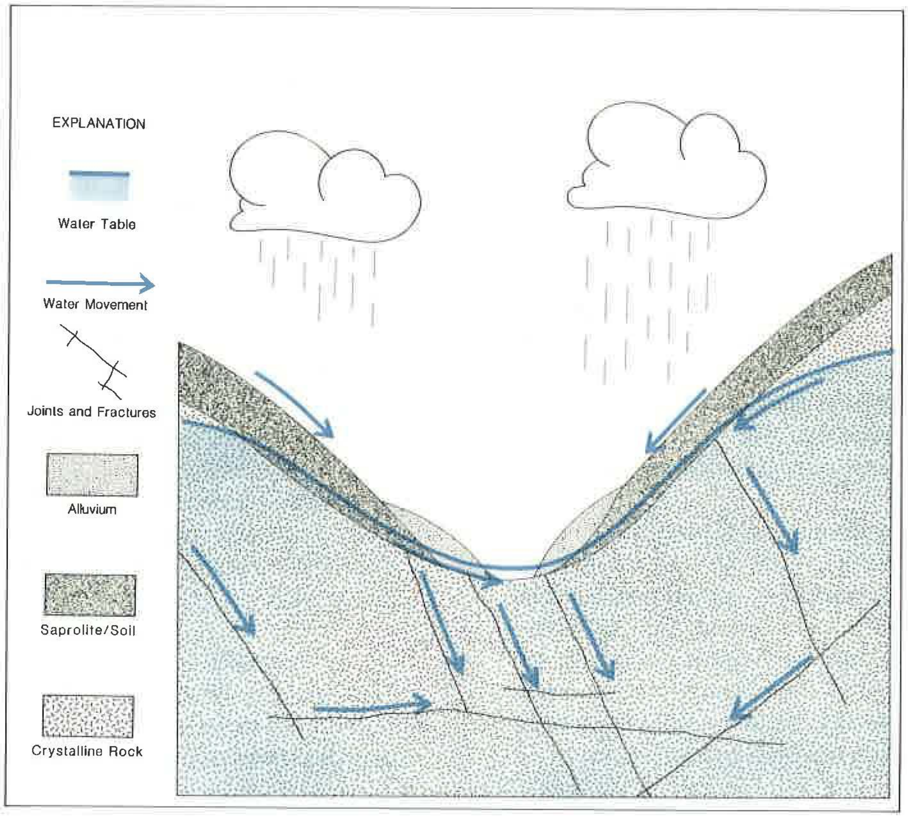

Figure 3. Schematic diagram of ground-water movement in a crystalline rock aquifer.

rock type, plus internal stress produced by tectonics, and stress relief from erosion, weathering, and metamorphism. Different types of rocks have different susceptibilities to jointing and fracturing. Some generalizations based on rock type can be used when evaluating aquifer potential in the Piedmont (Cressler and others, 1983):

1. Brittle rocks such as quartzite and rocks containing high percentages of feldspar and quartz are subject to fracturing and jointing, and the fractures are likely to be interconnected; these types of rock tend to provide good aquifer material.
2. Rocks such as gneiss and amphibolite tend to be variable in their susceptibility to fracturing and jointing, and are thus variable in aquifer capacity.
3. Rocks such as phyllite and schist tend to have tight, poorly connected joints and fractures; these rocks generally yield small quantities of water to wells.
4. Where rocks of contrasting character are in contact, different responses to stress and weathering can create zones of enhanced permeability.

Faults or cataclastic zones are features that can indicate fracturing, jointing and enhanced permeability of the rock. In the Piedmont, however, it is important to note the relative age of the last faulting event, and the type of faulting. Metamorphosis after faulting can "heal" fault fractures, thereby negating secondary permeability.

A second major influence on the availability of ground water in the Piedmont is the thickness and areal extent of the regolith, the layer of unconsolidated material, whether residual or transported, that overlies the more coherent bedrock. For purposes of this discussion, regolith includes soil, saprolite, and alluvium.

Because saprolite is often more permeable than the underlying coherent rocks, ground water tends to accumulate at the contact between saprolite and parent rock. Springs commonly form where the saprolite-bedrock interface is at land surface, as on a hillside. Many dug and bored wells in the Piedmont terminate at the bottom of the saprolite zone or penetrate only slightly into the top of the underlying hard rocks.

In addition to supplying water to springs, dug wells, and bored wells, the saprolite serves as a surficial mantle covering large drainage areas, absorbing surface water which would otherwise be lost to overland runoff. Much of the water absorbed by saprolite is released slowly to fractures in the underlying bedrock. In areas where a substantial thickness of saprolite is found, the water table is generally above the bedrock-saprolite interface. Therefore, aquifer storage capacity is significantly enhanced by thick saprolite. It is also generally correct to conclude that wells are more productive and tend to have more stable year-round yields where there is a thick mantle of saturated saprolite as opposed to where unweathered rock is near the surface.

Well Depth

Geology is the main influence on regional ground-water availability. However, at a specific location, well construction may be a major factor influencing water availability. Well depth is a subject of discussion among well drillers, ground-water geologists, and individuals seeking a reliable ground-water supply. Generally it was thought that beyond a depth of approximately 400 ft, ground-water yield decreased with increasing depth, presumably because increasing lithostatic pressure inhibited fracture formation or tended to close fractures.

Studies in other areas of the Georgia Piedmont, however, indicate that drilling deeper than 400 ft is justified in some instances. Water already available to a well is seldom lost by drilling deeper than 400 ft. Therefore, there is nearly always a chance of getting more water by increasing the depth of a well. Investigations into the feasibility of gas storage in crystalline rocks near the City of Jonesboro (Stewart, 1962) indicate that appreciable flows of water can occur in dense crystalline rocks at depths as great as 500 ft. The study described by Stewart deals with quartz-feldspar to hornblende-biotite gneiss similar to bedrock in much of the present study area. Horizontal permeabilities of 0.010 gpd/ft^2 were observed at a depth of 490 ft in one test hole. Stewart gives examples of other wells near Jonesboro with depths greater than 500 ft capable of yielding more than 20 gal/min.

In a study of ground-water availability in the metropolitan Atlanta area, Cressler and others (1983) noted numerous wells that derive 40 gal/min or more from fractures occurring at depths of 400 to 600 ft. They attribute the existence of deep fracture zones to the upward expansion of the rock column in response to erosional unloading. Because of the erosional mechanism of stress relief, topographic features indicating removal of large volumes of rock relative to specific areas may suggest areas where deep horizontal fracturing is likely to be found. Three distinct types of topographic settings which may indicate the presence of stress relief fracturing in the subsurface are cited (Cressler and others, 1983):

1. Points of land formed by streams converging at acute angles, or between subparallel tributaries entering a large stream.
2. Broad, relatively flat ridge areas, commonly on divide ridges, surrounded by stream heads.
3. Broad valleys formed by removal of large volumes of material relative to the land on either side.

Optimum Well Location

Optimum locations for higher-yielding wells in the Piedmont province are commonly in valleys where a fracture system or fault is present. The following reasons are given for drilling in valleys rather than hilltops or ridges (LeGrand, 1967):

1. Surface runoff is more rapid from hilltops and slopes resulting in less recharge than in lower, flatter areas.
2. Unconfined ground-water flow is from hill to valley; wells located in valleys can intercept a greater volume of natural ground-water flow.
3. The water table surface is generally a subdued image of the land surface (fig. 3); the water table is usually closer to the surface in lowland areas than on uplands.
4. The saprolite layer is generally thicker in valleys and lowland areas than on resistant hills and ridges; saprolite tends to enhance storage capacity of an aquifer, while retarding surface runoff.
5. Rocks underlying lowland areas often have a more effective system of openings to conduct ground water; commonly, highland areas exist because they are composed of rocks more resistant to erosion than lowlands; this resistance to erosion can often be attributed to the lack of a well-developed system of joints and fractures; penetration of water into fractures accelerates chemical and physical weathering, resulting eventually in a valley or lowland area.

Concerns of Ground-Water Users In The Piedmont

General

Ground water in the Piedmont is a valuable resource that is largely undeveloped. Potential ground-water users often would rather install expensive surface-water treatment plants than develop a ground-water system. Concerns most commonly expressed regarding ground-water supplies include low initial well yield, declining well yield, and susceptibility of the well to contamination. The following comments may help clarify these concerns.

Low Initial Well Yield

Drilling a water well involves a certain amount of risk. However, the majority of wells drilled in the Piedmont are sited without regard for hydrogeologic principles. Random site selection tends to increase the number of dry or nearly dry wells drilled. By taking advantage of available hydrogeologic knowledge and using properly designed multiple well systems, adequate municipal and industrial supplies of ground water can be developed in most areas of the Piedmont.

Declining Well Yield

The sustained yield predictions of a well in a crystalline rock aquifer must be based on a carefully executed pumping test. Specific capacity, the yield of a well per unit of drawdown, decreases as the pumping level is lowered below the water-producing fractures. The well continues to produce water, but at a reduced rate. Therefore, accurate specific capacities of a well should be determined when the well is pumped at its maximum rate. A 24-hour step-drawdown test should be used to find maximum pumping rate. This is followed by a pump test of at least 72 hours duration to establish aquifer characteristics (Caswell, 1982). Pumping tests should be based on one or more of the various techniques for evaluation of unconfined aquifers (Bouwer, 1978). The transmissivity value used to estimate long-term well capacity should be the lowest value obtained, thus providing a conservative estimate. When planning the construction of a high capacity well, it is important to note that pumping tests done in late summer through early fall provide more conservative values of transmissivity and storage than tests in late winter and early spring. The quantity of water stored in the aquifer reflects seasonal variations in precipitation.

Failure of a well is seldom a sudden occurrence. Most commonly, well failure is the cumulative result of one or more of the following (Cressler and others, 1983): an inadequate pumping test; pumping a well in excess of safe yield; a gradual decline of capacity due to improper maintenance and cleaning of the well and pump; the onset of a period of prolonged drought.

Contamination of Well Water

A concern of some ground-water users is that contaminants might travel for miles along water-bearing fractures in the rock, often in unknown directions. Direct entry of contaminants along fractures is not a likely problem, however, if a well has been properly located and constructed. Fracture zones yielding large quantities of water are usually associated with substantial thicknesses of an unconsolidated mantle of saprolite and alluvium. This unconsolidated mantle ordinarily provides adequate filtration of ground water.

Transport of contaminants along fractures in a crystalline rock aquifer can occur, especially within the area of influence of the well or upgradient of the well. Distances of contaminant transport are usually on the order of hundreds or thousands of feet, rather than miles as is sometimes suggested. A well normally obtains water from within an area of influence that can be defined by a pumping test and geologic analysis of the area.

Ground Water Availability in Greene, Morgan, and Putnam Counties

Geologic Controls

The search for geologic environments favorable for ground-water development was accomplished through a successive elimination process. During this process the size of the area under consideration was progressively reduced and study of the remaining area was intensified. Preceding sections of this report define the geology of the area and discuss the various geologic and well-construction controls on ground-water availability. Information presented to this point of this Information Circular is general and applies to all areas where ground water is controlled by fractures.

The best evidence of fracture systems in the study area is resultant from an analysis of stream valleys. Close examination of drainage patterns shows that many stream valleys exhibit a remarkable linearity. In addition, changes in stream direction often are angular. Such lineation and angularity of drainage are possible fracture zones in the bedrock. One of the most striking examples of geologic control of drainage is near the confluence of the Oconee and Apalachee Rivers (fig. 4), on the Buckhead 7½-minute quadrangle. Lineations also are evident on the Greensboro, Harmony, Liberty and Penfield 7½-minute quadrangles. Linear stream valleys are favorable drilling locations, as wells in these areas probably would intercept ground water flowing toward the stream through fractures.

The Towaliga-Middleton-Lowndesville fault zone is apparently the result of largely ductile deformation (Davis, 1980). Field inspection, however, reveals secondary brittle textures, suggesting possible postorogenic movement. Such brittle rock fabric probably would indicate an area of enhanced permeability.

Regolith in Greene, Morgan, and Putnam Counties is extensive. Most natural outcrops of unweathered rock are limited to some stream beds. Exceptions to this statement are found in the vicinity of the Siloam granite where boulders of unweathered granite and areas of pavement outcrops are common. Thickness of the regolith is generally greatest in river bottoms and least on crests of hills and ridges. Local variations in thickness can be extreme. Logs of wells in apparently similar geologic settings separated laterally by 200 or 300 ft can show differences in saprolite thickness of 100 ft or more.

Well Depth

The following conclusions are based on well data in the study area (table 2):

1. At depths less than 100 ft, the deeper the well is drilled the greater the productivity.
2. Between depths of 100 ft and 400 ft, well yield with increasing depth is not well defined; most Piedmont wells are within this depth range.
3. Between depths of 400 to 500 ft, if a well is relatively dry, and if no lithologic changes or fractures have been encountered, deeper drilling may not be advisable.

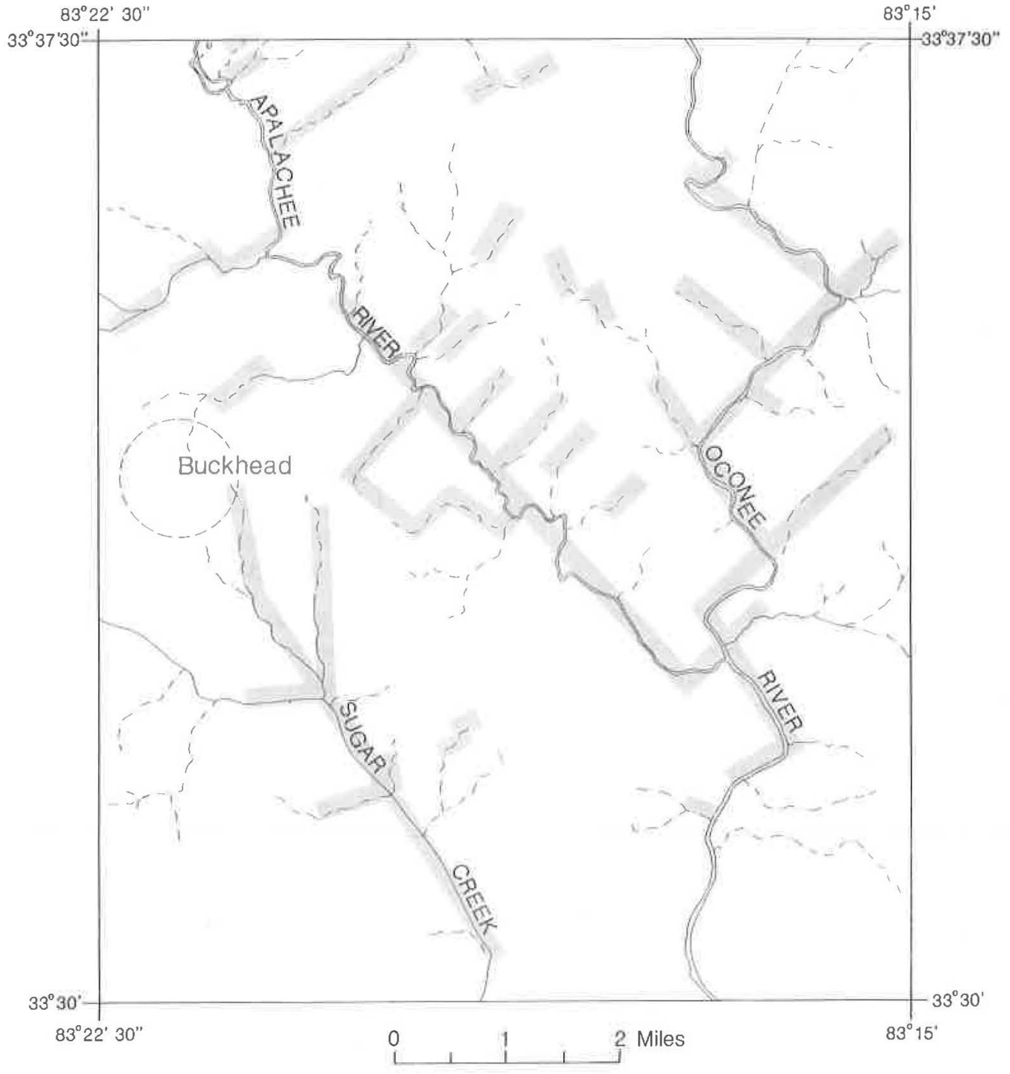

Figure 4. Map showing examples of the linear character of some stream beds.

4. It is often desirable to drill two wells of intermediate depth rather than continue a low-yielding well to extreme depth.

Of the wells inventoried for this report, only six were 100 ft deep or less, median well depth was 280 ft, and the maximum depth was 700 ft. Thirty-five of the wells inventoried were drilled to depths in excess of 400 ft. Of these 35 wells, at least six were essentially dry until penetrating water-bearing fractures near the bottom of the hole (William Martin, Virginia Supply and Well Co., oral commun., 1982). Nine of the 35 wells exceeding depths of 400 ft were drilled in areas considered optimum for drilling.

Ground-Water Favorability

By observing rock type, possible areas of extensive fracturing, saprolite thickness and well depth, Greene, Morgan, and Putnam Counties can be divided into three types of subarea based on relative favorability for water well drilling (plate 3). The favorability map does not imply the success or failure of a particular well. It merely takes into consideration the number of favorable criteria within a particular environment and attaches a weighted value. To make the best use of the favorability map, one would select several areas designated "Most favorable" and proceed with more detailed hydrogeologic investigation. Other examples of exploration techniques might include magnetometer surveys to detect areas of anomalous weathering associated with increased secondary permeability, and resistivity surveys to detect buried fracture systems. The final step in the exploration program would be test drilling.

Water Quality

Chemical quality of ground water is a complex function reliant in part on solubility of the reservoir rock, pH and temperature of the infiltrating water, and residence time of the water in the aquifer. Although rocks and minerals are only slowly soluble in water, residence time of ground water is commonly measured in tens to thousands of years. As a result, ground-water quality commonly reflects the character of the soluble components of the aquifer.

Chemical analyses of water from 19 wells in Greene, Morgan, and Putnam Counties show the water to be within normal ranges for ground water in the Piedmont. Concentrations of dissolved solids are low to moderate. Two distinctive chemical classes of ground water are present. The first includes soft, slightly acidic water, with low dissolved mineral content. Usually this type of water comes from light-colored rock of granitic composition. The second includes a hard, slightly alkaline water, comparatively high in dissolved solids. Water of this second category comes from dark rock such as gabbro, hornblende gneiss, and amphibolite. Except for occasional instances of high iron (table 1), concentrations of inorganic constituents are within drinking water standards recommended by the Environmental Protection Division (1977). Individual wells having unusually high levels of particular dissolved inorganic constituents are usually the result of water coming in contact with mineralized zones.

CONCLUSIONS

The following conclusions can be drawn regarding ground-water availability and water quality in Greene, Morgan, and Putnam Counties:

1. Specific aquifers cannot be delineated, based on available data. Water availability is affected by topography, saprolite thickness, well depth, and degree of fracturing, as well as rock type.
2. Rectangular drainage patterns are indicative of structural and lithologic control of drainage, and support the concept that permeability of the bedrock is higher in linear stream valleys.
3. Brittle rock fabric in the vicinity of the Towaliga-Middleton-Lowndesville fault zone probably indicates enhanced permeability in the immediate area of the fault.
4. Well yields are highly variable from one location to the next. Maximum yield is approximately 300 gal/min while yields of 1 to 2 gal/min are common. The sustained yield of most wells is less than 100 gal/min. Sometimes a few tens of feet separate a producing well from an essentially dry well. Therefore, average well-yield figures would be of little use in planning localized water supplies.
5. Most well sites in the area have been randomly located without regard for hydrogeologic principles. Convenience and/or economics are the most common considerations when choosing a well location. The incidence of "dry" holes could be minimized by using appropriate site-selection criteria as shown on the ground-water favorability map (plate 3).

Table 1. — SUMMARY OF WATER QUALITY ANALYSES
Values in milligrams per liter except pH

	Dissolved	pH	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (k)	Alkalinity ($CaCO_3$)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (Fl)	Nitrate (NO_3)
Maximum	270	8.7	55	0.3	161	11	15	4.0	113	149	110	22	1.0	17
Mean	142	6.8	36	0.05	22	4.5	10.7	2.4	76	72	14	8	0.3	2.9
Minimum	44	5.5	18	0	2	0.7	2.6	1.4	37	16	0.4	1.5	0.1	0.2
Number of Samples	18	17	15	11	13	14	18	12	9	14	15	18	16	13

6. Water quality in the three-county area is generally within limits for drinking water as defined by the Georgia EPD (1977). Aquifers of granitic composition commonly yield soft, slightly acidic water, while aquifers containing quantities of ferromagnesian minerals yield harder, slightly alkaline water.

RECOMMENDATIONS

Ground water can be an important water source in Greene, Morgan, and Putnam Counties. Increasing population will intensify demand for water, and at the same time, increase the risk of ground-water contamination. Information necessary for making effective decisions in ground-water management is not widely available in the crystalline rock areas of Georgia. The following activities are considered fundamental to a continuing ground-water reconnaissance program:

1. Detailed geologic mapping is essential to a ground-water study. Geologic maps provide information about rock type, rock origin, structure, and the existence of faulting, fracturing, and joint patterns.
2. Collection of well data is crucial to making accurate statements regarding ground-water availability. Necessary data include depth of the well, length of the casing in the well, and yield. Well data should be accompanied by accurate well locations.

In addition to the basic tasks of a ground-water program in a crystalline-rock area, the following suggestions could be used to augment a ground-water evaluation program in the Piedmont and Blue Ridge:

3. Standard geophysical surveys would enhance a geologic mapping program. Gravity and magnetometer surveys are effective methods for locating and delineating geologic structure which might be pertinent to water availability. Seismic refraction surveying is a rapid, accurate method of determining thickness of regolith. Resistivity surveys can help locate saturated fracture zones in bedrock.
4. Thorough aquifer testing should be done prior to putting a new well in service. Conservative well yields should be used in evaluating ground-water availability at a site. Well drawdown and yield should be monitored periodically to avoid "sudden" well failure.
5. A chemical analysis of raw water should be made when a new well is put into service. Periodic monitoring of raw water-quality should be done by trained personnel using standard techniques to obtain consistent results. The water should be analyzed for major dissolved constituents as well as trace elements. Common organic contaminants should be included in routine analyses.

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APPENDIX

Table 2 - WELL DATA

ID Number	Latitude & Longitude		Date Drilled	Diameter (in)	Cased to (ft)	Total Depth	Capacity (gal/min)
35	33 14 45	83 21 52	1973	10	108	500	6.3
36	33 14 42	83 21 48	1973	10	70	345	55
37	33 14 41	83 21 51	1974	10	75	425	108
38	33 14 40	83 21 53	1974	10	80	505	87
50	33 34 45	83 34 45	1968	6	66	500	47
51	33 36 08	83 39 36	1968	6	96	300	42
52	33 36 06	83 27 52	1978	6	93	346	203
55	33 35 02	83 28 46	1976	6	98	645	76
56	33 50 00	83 28 57	1980	6	85	605	63
57	33 19 42	83 22 42	1954	8	38	436	316
58	33 40 22	83 06 20	1980	6	110	605	50
59	33 36 59	83 04 25	1955	8	95	600	20
82	33 37 54	83 36 24	1967	6	94	360	30
84	33 40 35	83 06 40	1969	8	98	650	36
86	33 44 13	83 30 55	1963	6	60	494	—
95	33 37 45	83 36 32	1967	6	94	360	30
100	35 25 20	83 23 47	1952	6	67	414	75
101	33 13 24	83 18 05	1975	6	50	550	28
102	33 43 26	83 18 18	—	6	50	400	20
103	33 40 00	83 10 36	—	—	14	63	—
104	33 30 56	83 03 24	—	—	45	138	—
106	33 32 22	83 18 36	—	—	120	285	—
107	33 11 42	83 24 58	—	—	30	187	—
200	33 25 24	83 14 28	1980	6	50	405	22
201	33 29 38	83 16 01	1960	6	58	300	40
202	33 36 27	83 18 24	—	6	100	200	25
203	33 36 16	83 17 10	—	6	60	175	50
204	33 33 31	83 17 10	1969	6	70	436	200
205	33 35 57	83 17 20	1958	6	101	145	25
206	33 30 14	83 16 38	1981	6	60	265	60
207	33 33 09	83 17 20	1965	6	109	128	30
208	33 43 37	83 17 48	1962	6	50	400	20
210	33 41 44	83 19 47	1971	6	90	300	20
211	33 41 58	83 18 45	1974	6	60	233	40
212	33 36 12	83 18 00	1980	6	137	200	30
213	33 29 14	83 11 15	1973	6	60	345	60
214	33 29 11	83 11 04	1960	6	53	185	20
215	33 29 23	83 09 06	1980	6	110	505	40

Table 2 - WELL DATA (Continued)

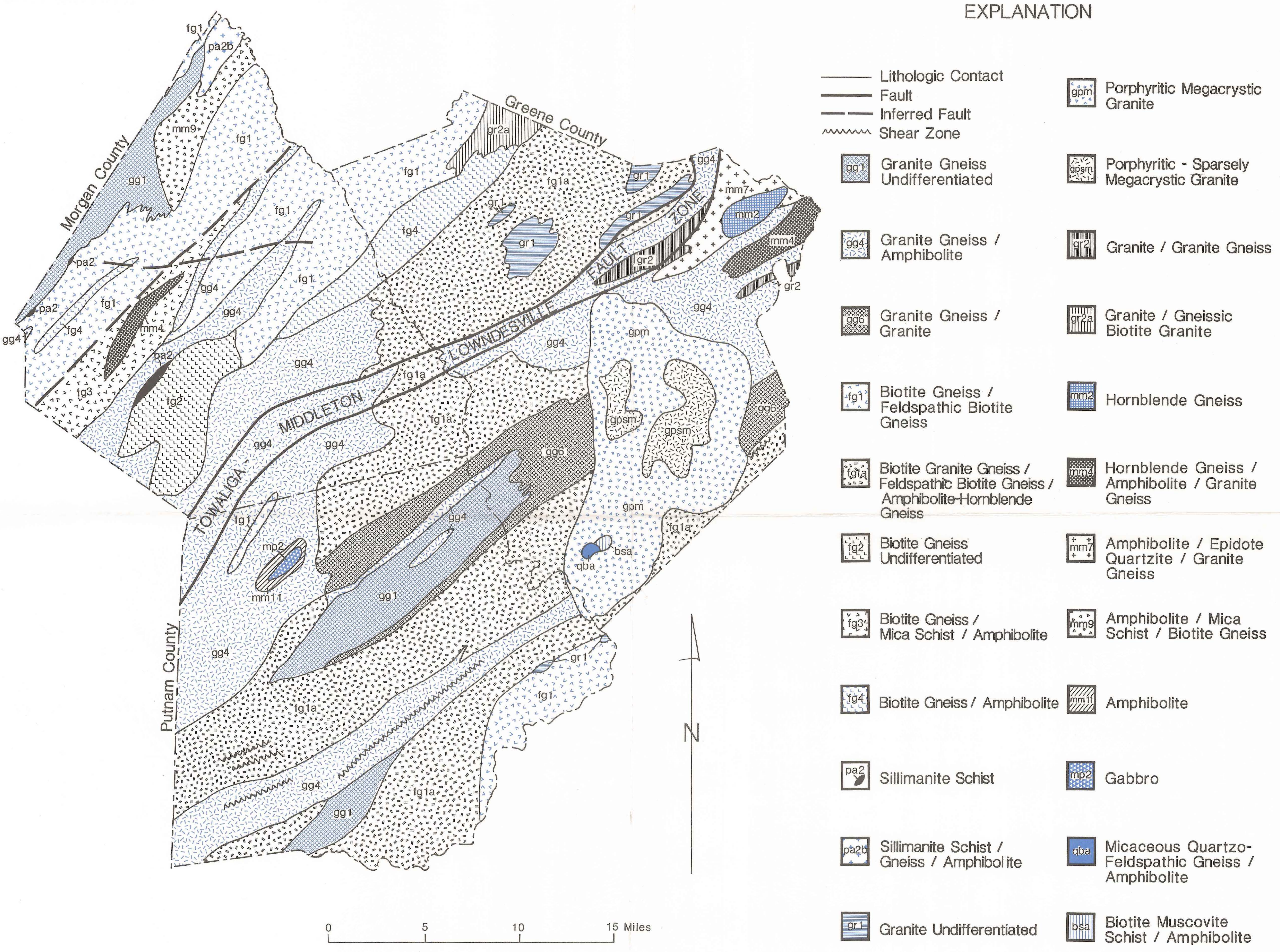
ID Number	Latitude & Longitude		Date Drilled	Diameter (in)	Cased to (ft)	Total Depth	Capacity (gal/min)
216	33 26 52	83 11 37	1977	6	120	515	25
217	33 26 43	83 10 31	1981	6	140	265	25
218	33 26 25	83 11 02	1978	6	76	425	60
219	33 26 39	83 11 03	1978	6	140	265	25
220	33 25 10	83 10 21	1981	6	45	225	25
221	33 24 13	83 10 30	1980	6	26	225	50
222	33 24 17	83 10 50	1980	6	120	185	30
223	33 25 47	83 14 15	1980	6	46	385	28
224	33 36 52	83 09 54	1958	6	62	168	44
225	33 36 01	83 08 57	1981	6	8	125	25
226	33 36 08	83 08 30	—	6	29	500	25
227	33 35 31	83 08 43	1981	6	8	65	60
228	33 35 03	83 09 44	1971	6	14	100	22
229	33 34 41	83 11 10	—	10	—	700	100
230	33 34 53	83 11 28	1948	8	151	450	53
231	33 35 33	83 12 32	1979	6	100	250	30
232	33 35 17	83 12 59	1970	6	58	120	30
233	33 33 39	83 13 23	1977	6	80	141	30
234	33 32 47	83 14 04	1981	6	138	230	110
235	33 32 10	83 13 00	1971	6	101	260	30
236	33 30 55	83 13 35	1959	6	96	165	44
237	33 30 57	83 11 03	—	6	90	150	20
238	33 30 17	83 08 44	1978	6	23	440	50
239	33 30 04	83 08 14	1979	6	40	200	30
240	33 32 20	83 07 38	1970	6	50	150	40
241	33 32 25	83 07 38	—	6	58	125	60
242	33 32 27	83 09 56	1977	6	20	173	30
243	33 36 04	83 07 34	1970	6	30	80	20
244	33 33 51	83 08 34	1953	6	194	167	35
245	33 34 03	83 09 04	1963	6	144	315	30
246	33 34 16	83 09 17	1964	8	29	365	22
247	33 33 57	83 09 19	1958	6	33	105	30
248	33 39 58	83 10 25	—	6	168	275	20
249	33 41 25	83 13 51	1975	6	—	145	45
250	33 28 25	83 01 05	1969	8	75	465	51
251	33 27 17	83 02 03	1977	6	18	203	40
252	33 29 02	83 02 15	1972	6	9	463	100
253	33 36 51	83 04 31	1948	8	—	—	22
254	33 30 53	83 03 17	1958	6	45	138	30
255	33 36 56	83 04 40	1943	8	221	600	40
256	33 36 41	83 03 53	1956	8	100	600	35

Table 2 - WELL DATA (Continued)

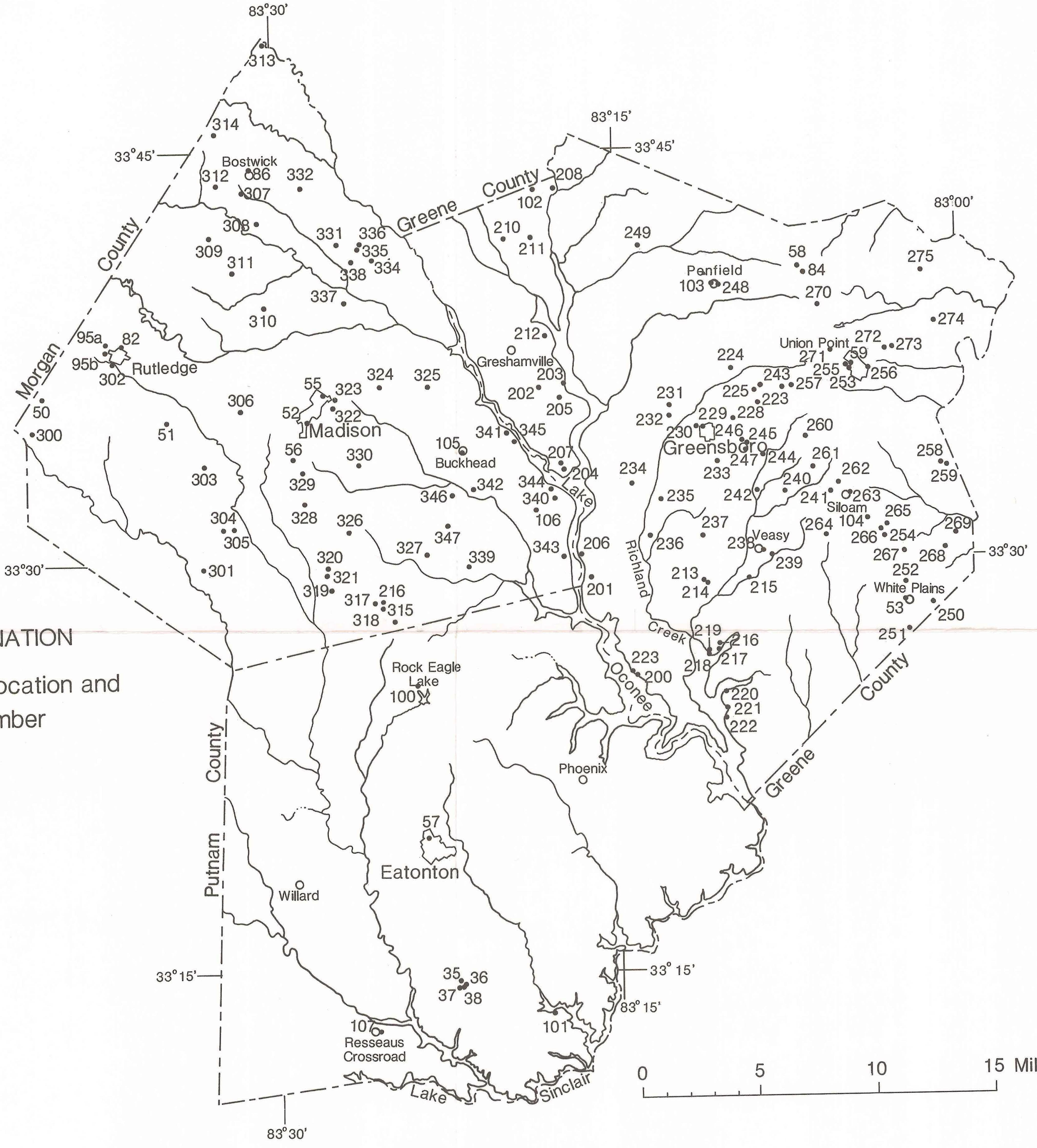
ID Number	Latitude & Longitude		Date Drilled	Diameter (in)	Cased to (ft)	Total Depth	Capacity (gal/min)
257	33 36 06	83 07 10	1974	6	25	100	200
258	33 33 24	83 00 49	—	6	135	275	20
259	33 33 23	83 00 37	—	6	121	275	20
260	33 34 19	83 06 38	—	6	90	105	75
261	33 33 17	83 06 13	1972	6	38	200	20
262	33 32 41	83 05 12	1954	6	47	124	25
263	33 32 19	83 04 53	1956	6	44	138	20
264	33 30 55	83 05 55	1975	6	30	209	100
265	33 31 04	83 03 27	1956	6	87	135	40
266	33 31 00	83 03 24	1958	6	87	141	25
267	33 30 05	83 02 29	1982	6	57	150	35
268	33 30 11	83 00 30	1972	6	19	68	40
269	33 30 53	83 00 02	1972	6	—	325	60
270	33 39 07	83 06 00	1956	6	132	186	30
271	33 37 32	83 05 32	1955	6	121	261	20
272	33 37 38	83 03 01	1969	6	51	140	25
273	33 37 41	83 02 51	1968	6	70	200	20
274	33 38 39	83 00 56	1972	6	98	200	20
275	33 40 13	83 01 27	1982	6	90	125	75
300	33 34 56	83 39 50	1972	6	35	45	60
301	33 29 59	83 33 12	1980	6	55	305	30
302	33 37 24	83 37 03	—	—	—	400	115
303	33 33 37	83 33 04	1968	6	52	100	25
304	33 31 07	83 32 11	1980	6	55	190	30
305	33 31 16	83 31 54	1969	6	100	280	30
306	33 35 31	83 31 30	—	6	73	173	70
308	33 42 18	83 31 46	1981	6	125	260	75
309	33 41 58	83 32 55	1981	6	40	200	35
310	33 39 20	83 30 23	1979	6	87	126	25
311	33 40 34	83 31 50	1961	6	41	160	48
312	33 43 55	83 32 35	1961	6	38	500	29
313	33 49 00	83 30 21	1975	6	34	263	200
314	33 45 32	83 32 34	1972	6	31	258	50
315	33 28 17	83 25 21	1965	6	117	150	26
316	33 28 25	83 25 29	1972	6	62	413	30
317	33 28 44	83 25 26	—	6	60	565	25
318	33 27 53	83 24 56	1977	6	60	565	25
319	33 29 00	83 27 36	1955	6	154	236	20
320	33 29 53	83 27 51	1971	6	75	185	75
321	33 29 39	83 27 51	1974	6	76	140	40
322	33 35 48	83 27 38	1980	6	66	335	125

Table 2 - WELL DATA (Continued)

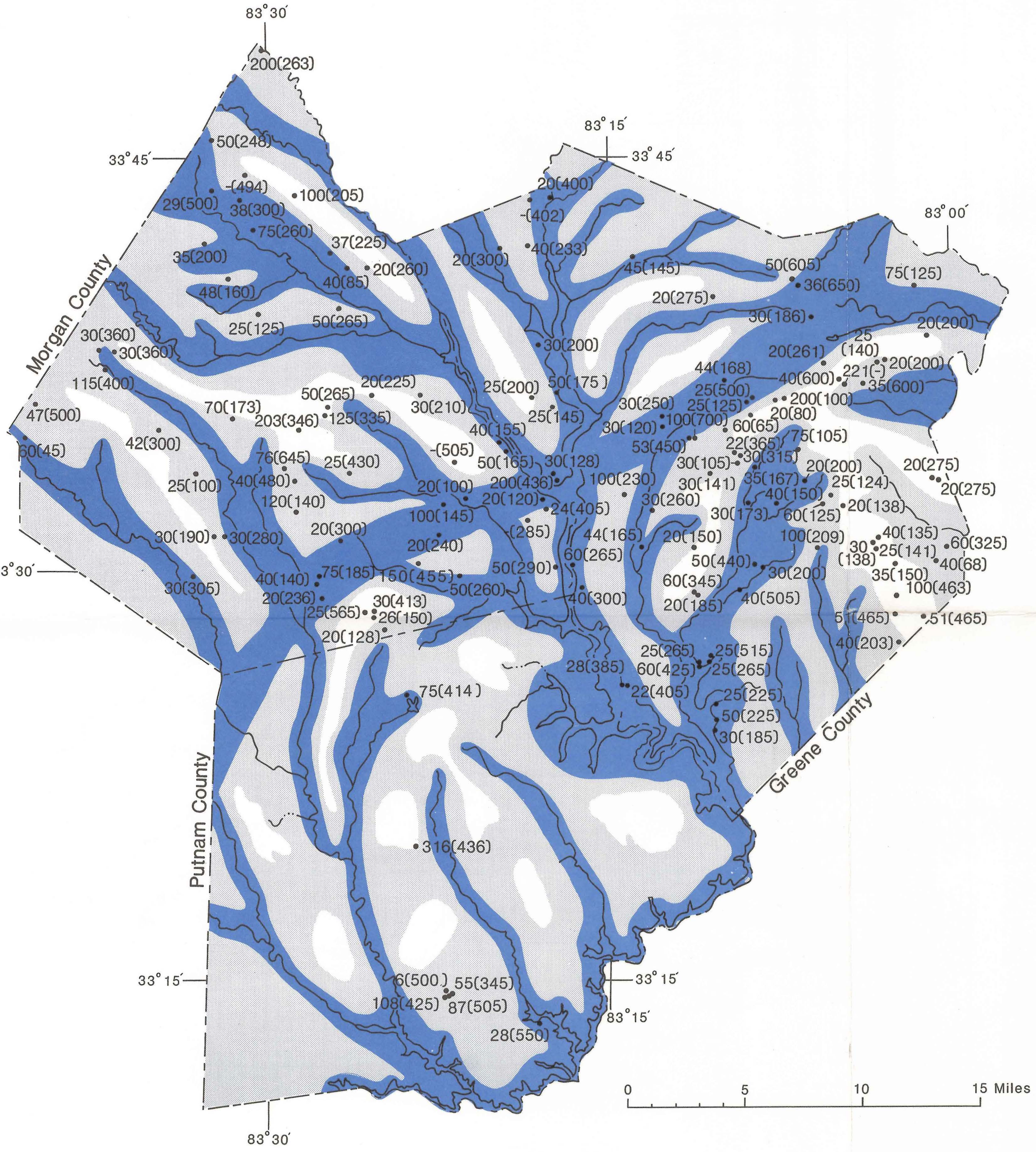
ID Number	Latitude & Longitude		Date Drilled	Diameter (in)	Cased to (ft)	Total Depth	Capacity (gal/min)
323	33 35 52	83 27 37	1980	6	104	265	50
324	33 36 26	83 25 26	1979	6	58	225	20
325	33 36 22	83 23 12	1961	6	109	210	30
326	33 31 04	83 26 48	1969	6	110	300	20
327	33 30 20	83 23 21	1981	6	91	455	150
328	33 32 09	83 28 45	1972	6	63	140	120
329	33 33 29	83 28 48	1981	6	95	480	40
330	33 33 30	83 26 24	1981	5	35	430	45
331	33 41 30	83 27 10	1974	6	84	225	37
332	33 43 25	83 28 53	—	6	52	205	100
333	33 42 10	83 27 42	1974	6	22	325	20
334	33 40 59	83 25 45	1970	6	173	260	20
335	33 41 27	83 26 12	1979	6	65	325	20
336	33 41 37	83 26 23	1982	6	126	485	60
337	33 39 39	83 26 57	1981	6	125	265	50
338	33 40 57	83 26 30	1981	6	40	85	40
339	33 29 52	83 21 29	1979	6	118	260	50
340	33 32 27	83 17 48	1981	6	126	405	24
341	33 34 39	83 19 47	—	6	65	155	40
342	33 32 44	83 21 05	1972	6	60	100	20
343	33 30 07	83 17 20	1974	6	70	290	50
344	33 32 44	83 17 52	1975	6	89	120	20
345	33 34 20	83 19 39	1981	6	68	165	50
346	33 32 31	83 22 06	—	6	95	145	100
347	33 31 18	83 22 20	1972	6	125	240	20



Geologic map of Greene, Morgan, and Putnam Counties.



Location of wells with data presented in Table 2.



EXPLANATION

20(200)
• Data Point
First number indicates well yield
Number in parentheses indicates well depth

🟦 Area of most favorable geologic criteria
Saprolite thickness - 20 to 150 feet
Slope- 0 to 15%
Probable jointing and fracturing of bedrock
Receives drainage from adjacent areas

▨ Area of moderately favorable geologic cr
Saprolite thickness - 10 to 60 feet
Slope - 8 to 25%
Possible jointing and fracturing of bedrock
Drainage is through the area

☐ Area of least favorable geologic criteria
Saprolite thickness - 0 to 60 feet
Slope - 15% or more
Bedrock resistant to jointing and fracturing
Drainage is away from area

Ground-water favorability map.

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