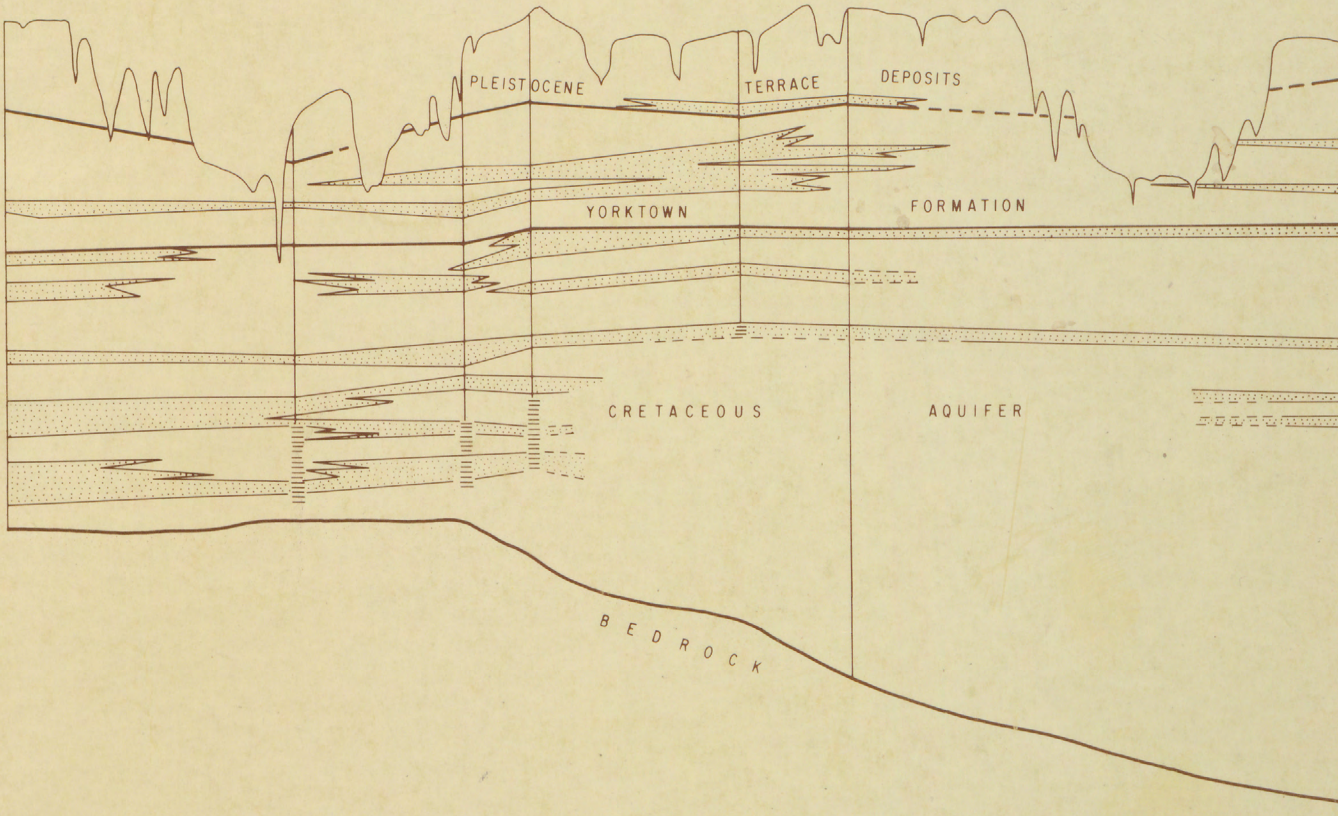
GROUND-WATER RESOURCES OF WILSON COUNTY, NORTH CAROLINA



U S GEOLOGICAL SURVEY
WATER RESOURCES INVESTIGATIONS 76-60

PREPARED IN COOPERATION WITH THE
WILSON COUNTY BOARD OF COMMISSIONERS
AND THE
NORTH CAROLINA DEPARTMENT OF NATURAL
AND ECONOMIC RESOURCES

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No.
4. Title and Subtitle Ground-water resources of Wilson County, North Carolina			5. Report Date June 1976 6.
7. Author(s) M. D. Winner, Jr.			8. Performing Organization Rept. No. USGS/WRI 76-60
9. Performing Organization Name and Address U. S. Geological Survey Water Resources Division P. O. Box 2857 Raleigh, N. C. 27602			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address U. S. Geological Survey Water Resources Division P. O. Box 2857 Raleigh, N. C. 27602			13. Type of Report & Period Covered Final 14.

15. Supplementary Notes

Prepared in cooperation with the Wilson County Board of Commissioners and the North Carolina Department of Natural and Economic Resources.

16. Abstracts

The most significant sources of ground water for Wilson County, North Carolina are (1) the sand beds of the Cretaceous aquifer system in the Coastal Plain section in the eastern part of the county and (2) the bedrock aquifer system in the Piedmont section in the western part of the county. Individual wells could sustain yields up to about 500 gallons per minute (32 litres per second) in the eastern part of the county where the Cretaceous aquifer is thickest, but wells pumped at these rates would rapidly increase the rate of water-level decline throughout the aquifer. In the Piedmont section, it is estimated that a maximum sustained yield of about 125 gallons per minute (7.9 litres per second) may be expected from properly constructed and developed wells in favorable topographic locations where fractures in the bedrock are likely to be more numerous and a nearby perennial stream is available as a recharge source. Pleistocene terrace deposits occur throughout the county as surficial sands mixed with clay and silt. Detailed maps depict the geology and hydrology of each geohydrologic unit in the county.

17. Key Words and Document Analysis. 17a. Descriptors

*Ground-water movement, *Potentiometric levels, *Water-level fluctuations, *Specific capacity, *Geohydrologic units, *Water supply, Ground-water recharge, Hydrology, Aquifers, Ground water, Specific yield, Surface-ground-water relationships, Transmissivity, Storage coefficient, Water table, Hydraulic conductivity, North Carolina.

17b. Identifiers/Open-Ended Terms

*Ground-water availability, Wilson County, Well yields.

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 93
No restriction on distribution	20. Security Class (This Page) UNCLASSIFIED	22. Price

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Prepared in cooperation with the
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June 1976

UNITED STATES DEPARTMENT OF THE INTERIOR

THOMAS S. KLEPPE, Secretary

GEOLOGICAL SURVEY

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June 1976

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USE OF INTERNATIONAL SYSTEM UNITS

The U.S. Geological Survey has recently adopted a policy of including metric or International System (SI) units in all reports. In most instances, the SI equivalent follows the English unit in the text. For convenience of the reader, the following table gives the factors used in converting from English to SI units:

Multiply English units	by	to obtain SI units
inches (in)	25.40	millimetres (mm)
feet (ft)	.3048	metres (m)
miles (mi)	1.609	kilometres (km)
square feet (ft^2)	.0929	square metres (m^2)
square miles (mi^2)	2.59	square kilometres (km^2)
feet per mile (ft/mi)	.1894	metres per kilometre (m/km)
feet per day (ft/d)	.3048	metres per day (m/d)
feet squared per day (ft^2/d)	.0929	metres squared per day (m^2/d)
gallon (gal)	3.785	litre (l)
	.0038	cubic metre (m^3)
gallons per square mile (gal/mi^2)	.0015	cubic metre per square kilometre (m^3/km^2)
gallons per minute (gal/min)	.0631	litres per second (l/s)
gallons per foot (gal/ft)	12.418	litres per metre (l/m)
gallons per minute per foot [(gal/min)/ft]	.207	litres per second per metre [(l/s)/m]
gallons per minute per foot per foot ([(gal/min)/ft]/ft)	.679	litres per second per metre per metre ([(l/s)/m]/m)
gallons per day (gal/d)	.0038	cubic metre per day (m^3/d)
gallons per day per square mile [(gal/d)/mi^2]	.0015	cubic metres per day per square kilometre [(m^3/d)/km^2]
Gallons per foot per square mile [(gal/ft)/mi^2]	.0005	cubic metres per metre per square kilometre [(m^3/m)/km^2]

GROUND-WATER RESOURCES OF

WILSON COUNTY, NORTH CAROLINA

By M. D. Winner, Jr.

ABSTRACT

The most important sources of ground water for Wilson County, North Carolina are (1) the sand beds of the Cretaceous aquifer system in the Coastal Plain section in the eastern part of the county and (2) the bedrock aquifer system in the Piedmont section in the western part of the county.

The Cretaceous aquifer is recharged from leakage through overlying beds composed primarily of clay. This leakage rate is estimated to average about 67,000 gallons per day per square mile (100 cubic metres per day per square kilometre). Present withdrawals from the Cretaceous aquifer in the county average about 740 gallons per day per square mile (1.1 cubic metres per day per square kilometre), or about 1 percent of the amount of water available to the aquifer. Most of the withdrawals from the Cretaceous aquifer are in the Saratoga-Stantonsburg area in eastern Wilson County around which a widespread decline in water level has occurred in the aquifer. Since 1942, the rate of decline has averaged nearly 1.5 feet (0.45 metre) per year in the center of the pumping area.

Individual wells can yield as much as 500 gallons per minute (32 litres per second) in the easternmost part of the county where the aquifer is thickest, but wells pumped continually at this rate would increase the rate of water-level decline throughout the aquifer.

Availability of water to the bedrock aquifer ranges from about 67,000 gallons per day per square mile (100 cubic metres per day per square kilometre) in the Coastal Plain section of the county to about 630,000 gallons per day per square mile (945 cubic metres per day per square kilometre) in the Piedmont section. Present pumpage from the bedrock aquifer in the Piedmont section of the county is estimated to be about 2,300 gallons per day per square mile (3.4 cubic metres per day per square kilometre).

In the Piedmont section an estimated maximum sustained yield of about 125 gallons per minute (7.9 litres per second) may be expected from individual wells in locations where fractures in the bedrock are numerous and a nearby perennial stream is a recharge source. The stream valleys of Contentnea Creek and its larger tributaries west of the City of Wilson approximate these conditions. Elsewhere in the interstream areas in the Piedmont section, maximum sustained yields are not likely to exceed about 50 gallons per minute (3.2 litres per second).

Maximum yield of individual wells open to the bedrock aquifer in the Coastal Plain section of the county is estimated to be 100 gallons per minute (6.3 litres per second) on a sustained basis, however, the chance for a successful well at any given location is less predictable than in the Piedmont section of the county.

Pleistocene terrace deposits occur throughout the county as surficial sands mixed with clay and silt and are up to 35 feet (10 metres) thick in some places. Sustained yields from individual wells are estimated not to exceed 25 gallons per minute (1.6 litres per second); however, the deposits usually will yield enough water to wells for domestic supplies.

The Yorktown Formation of Tertiary age, which overlies the Cretaceous beds in the Coastal Plain, functions mainly as a confining bed due to its composition of clay, silt, marl, and shell beds. No large water supplies can be developed from this formation, and enough water for domestic supplies can be obtained only in a few localized areas where sandy zones can be tapped.

Ground-water quality is generally good in the Cretaceous and bedrock aquifers, except iron concentrations in the water exceed 0.3 milligrams per litre nearly everywhere in the county. Of the two aquifers, the bedrock aquifer in the Piedmont appears to yield water containing the least amount of iron. Deeper wells in the bedrock aquifer in the eastern half of the county have yielded residual sea water having chloride concentrations exceeding 5,000 milligrams per litre. Salt water in the bedrock aquifer occurs randomly along the western margin of the Coastal Plain section but becomes more definitive in occurrence eastward below depths of 200 feet (61 metres).

Development of large ground-water supplies from either the bedrock aquifer or the Cretaceous aquifer are possible, but each supply should be developed on the basis of detailed hydrologic testing at the site. Continual assessment of the system should be supervised by skilled ground-water hydrologists, and provision also should be made for the regular collection of data vital to the proper management of the system.

INTRODUCTION

This report is the result of a study begun in September 1972 aimed toward a detailed understanding of the ground-water resources of Wilson County, North Carolina, so that this valuable resource may be better managed and developed for the maximum benefit of the people of the county. The report provides specific information about water-bearing strata within the county and areas where ground-water supplies can be feasibly and economically developed, and it identifies areas most favorable for additional ground-water development.

Previous investigations of the ground-water resources in the county (Clark and others, 1912; Mundorff, 1946) were made as part of reconnaissance-type studies of larger areas. Although specific details about the ground-water regime were lacking in these reports, they provide the geologic and hydrologic framework upon which this study was built. These reports also provide a valuable source of historic water-level measurements with which to compare recent measurements. The present study was conducted and the report was prepared by the U.S. Geological Survey in cooperation with the Wilson County Board of Commissioners and the North Carolina Department of Natural and Economic Resources.

Many well owners, water-system managers, well drillers, and county officials generously allowed access to their wells and records. The help of Mr. Roland Gardner of Stantonsburg, Mr. Irvin Gardner of Saratoga, and Mr. W. R. Bunn of Black Creek, all of whom cooperated in allowing pumping tests utilizing their town wells, is gratefully acknowledged. Mr. Cecil Hildebrand was most helpful in supplying records of wells drilled under his supervision.

PHYSICAL SETTING

Wilson County is in east-central North Carolina astride the fall line which separates the Piedmont and Coastal Plain physiographic provinces (fig. 1). The fall line is generally recognized as being marked by the last downstream occurrence of falls or rapids on streams. The fall line is also defined by Fenneman (1938) as, "the inner edge of Cretaceous (or younger rocks)" that comprise the Atlantic and Gulf Coastal Plain sediments. For purposes of this report, the fall line in Wilson County is the

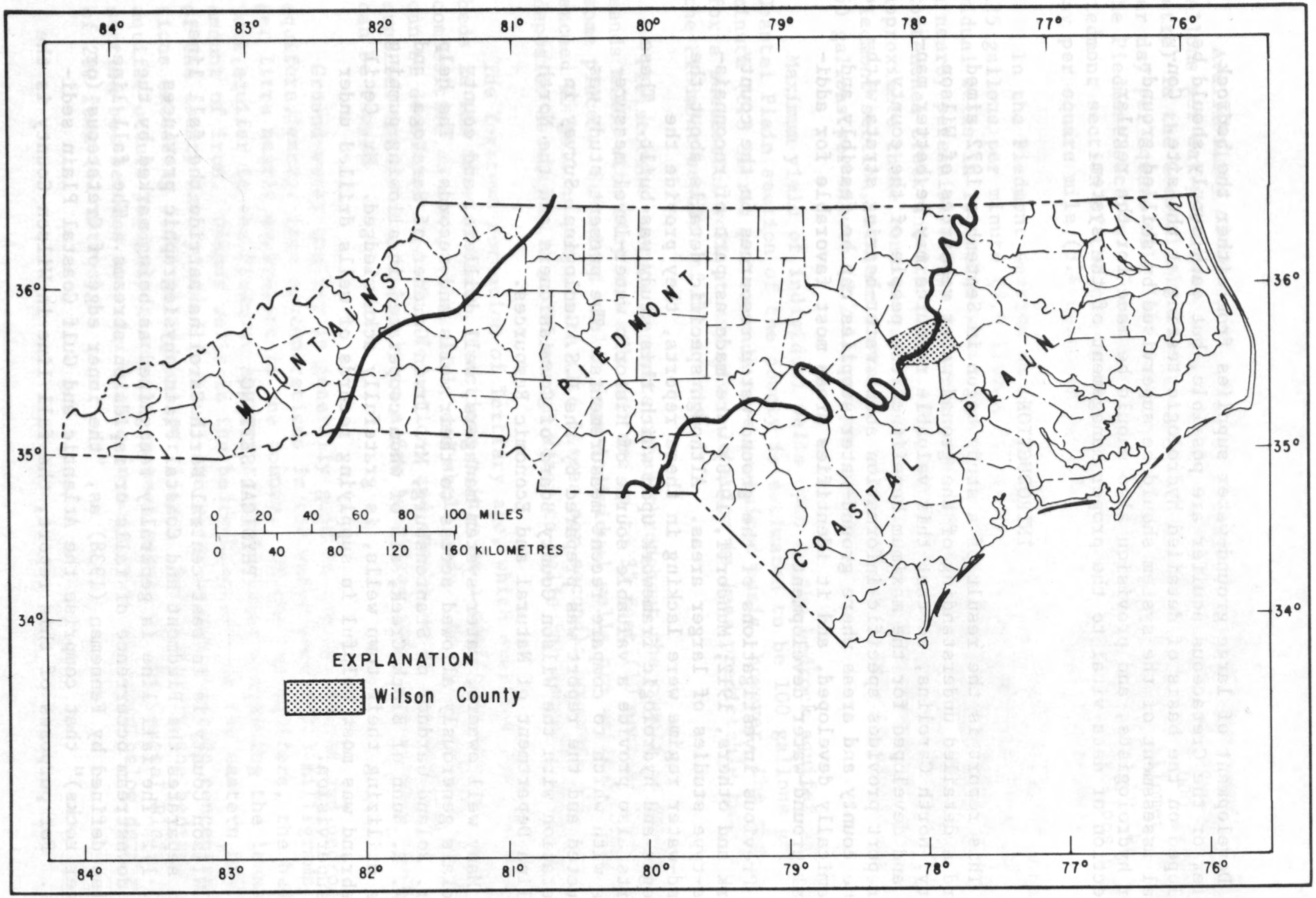


Figure 1.--Wilson County and physiographic provinces of North Carolina.

western limit of the Tertiary Yorktown Formation, which is marked by a meandering line which enters the county about 3 miles (4.8 km) northwest of Elm City, passes through the western edge of Wilson, and leaves the county about 4 miles (6.4 km) south of Lucama. (See fig. 17.) The Coastal Plain province as thus defined covers about 65 percent of the county.

There is no distinct topographic break between the Piedmont and the Coastal Plain provinces. In general, the topography of the Piedmont section of the county is characterized by gently rolling hills having a maximum relief of up to 140 ft (43 m) between the ridges and the larger streams such as Contentnea Creek. The eastward slope of the land surface of the Piedmont section is 60 to 90 ft/mi (11 to 17 m/km). It gradually lessens to 12 to 15 ft/mi (2.3 to 2.8 m/km) in the Coastal Plain section where the maximum relief is about 60 ft (18 m).

Pleistocene terrace deposits consisting of unconsolidated gravels, sands, silts, and clays cover all of the county (fig. 2) except where streams have removed these deposits. The Pleistocene terraces gently slope eastward from an altitude of about 300 ft (91 m) in the western part of the county to about 75 ft (23 m) in the eastern part. Several escarpments have been identified on the Pleistocene surface in Wilson County and have been interpreted as evidence for still-stands or short-term transgressions of the sea during Pleistocene time (Daniels and others, 1972). These Pleistocene deposits constitute the chief water-table aquifer in the county.

In the Coastal Plain section of the county, the Yorktown Formation of Tertiary age underlies the Pleistocene terrace deposits, forming a distinctive series of unconsolidated blue and gray sediments containing numerous shell and marl beds. The Yorktown, in turn, is underlaid by unconsolidated sediments of Cretaceous age. The Cretaceous aquifer system in Wilson County (fig. 2) has been correlated with the Tuscaloosa Formation of Late Cretaceous age as formerly used by Cooke (1936). Sumsion (1970) indicated that sediments of Early Cretaceous age may extend westward from Pitt County into Wilson County. These beds thin to the west and probably cannot be distinguished hydrologically from the Upper Cretaceous sediments in Wilson County. Brown and others (1972, Section E-E', pl. 27) divide the Cretaceous sediments into Cretaceous Units D and F at Stantonsburg. All of the Cretaceous sediments will be referred to as the Cretaceous aquifer system, or more simply, Cretaceous aquifer in this report, because they are virtually a single geohydrologic unit in the county.

Metamorphic and igneous crystalline rocks make up the basement complex that underlies all of Wilson County. In the Piedmont section of the county, these consolidated rocks and their uppermost weathered portions (saprolite) are partially exposed at land surface in the stream valleys and are overlain by the Pleistocene deposits elsewhere. The bedrock surface dips eastward under the Coastal Plain sediments, reaching a depth

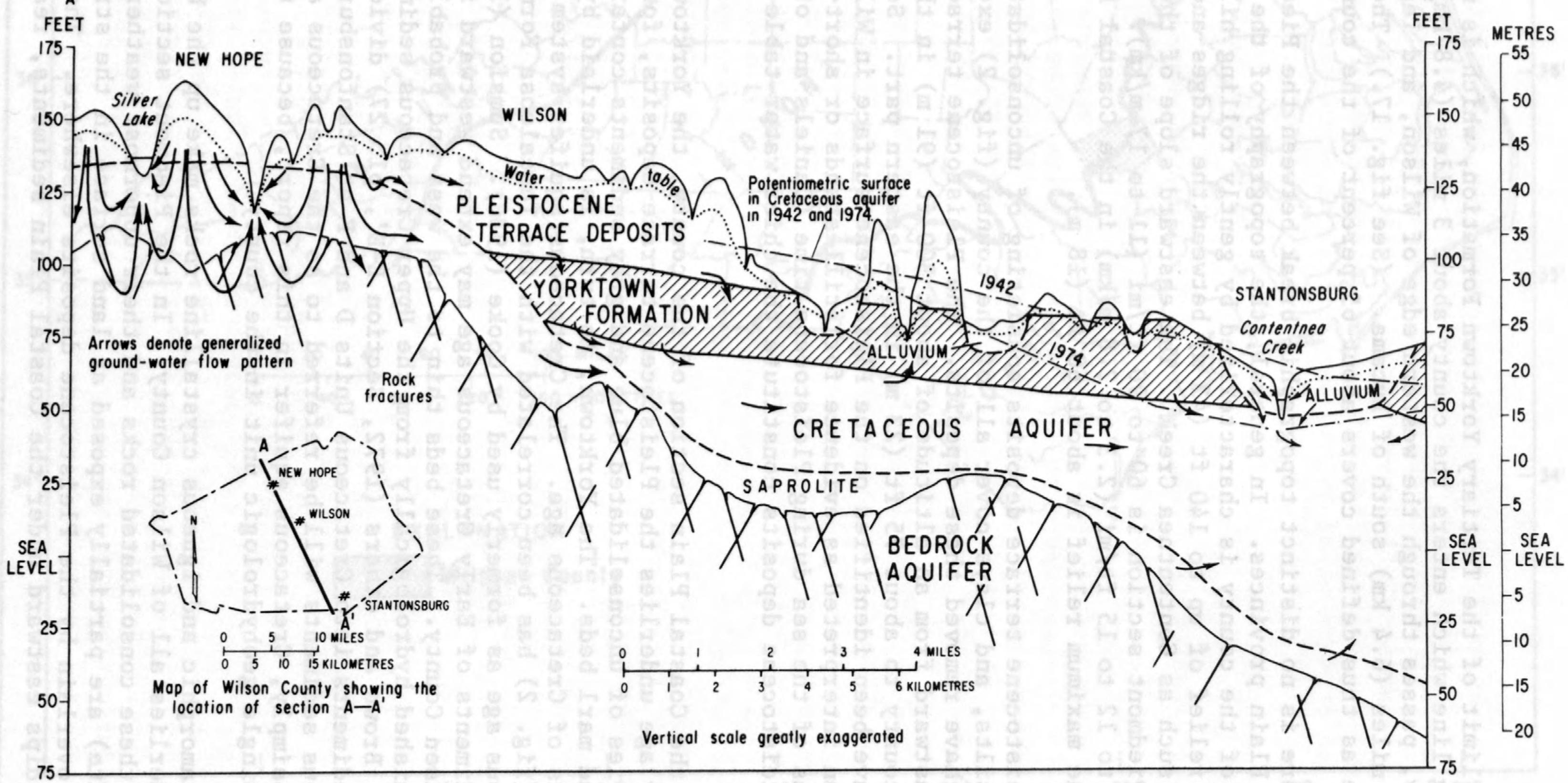


Figure 2.--Geology and generalized ground-water flow system in Wilson County, North Carolina.

of about 200 ft (61 m) below land surface in eastern Wilson County. These rocks, together with their saprolite cover, also form a major geohydrologic unit in the county; they will be referred to as the bedrock aquifer system, or the bedrock aquifer, in this report.

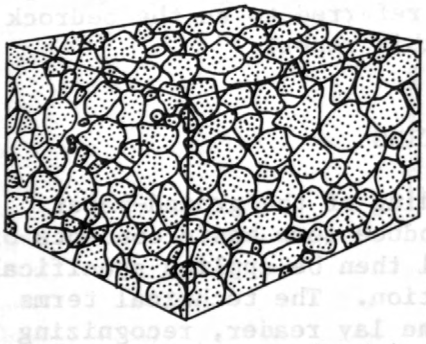
HYDROLOGIC SETTING

In order to achieve a better understanding of the ground-water resources of the county, we must first introduce some basic concepts of ground-water hydrology. These concepts will then be applied specifically to Wilson County and its ground-water situation. The technical terms will be defined as simply as possible for the lay reader, recognizing that some of these definitions may lack the precision normally required for scientific and engineering uses. For exact meanings of the terms used in ground-water hydrology the reader is referred to definitions as given by Lohman and others (1972).

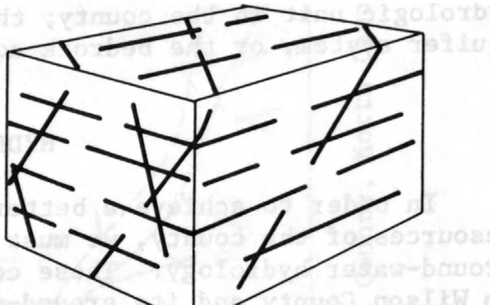
The Ground-Water System

To understand how water occurs in the ground, we need to look at the rocks that make up the ground-water reservoir. In this sense, the rocks themselves are not as important as are the openings that are found within them, which, when filled with water, constitute the ground-water reservoir.

Two types of openings exist in the rocks of Wilson County--pore spaces between mineral grains in unconsolidated rocks and thin, sheet-like fractures in the bedrock, both of which are illustrated in figure 3. For the unconsolidated rocks the pore spaces may amount to as much as 30 percent of the total rock volume, meaning that if these openings were completely filled with water (saturated) then nearly a third of the rock volume would consist of water. One can readily calculate that a huge quantity of water is stored in this type of ground-water reservoir. By contrast, the volume of fracture openings in the bedrock is only 0.1 to 1 percent of the total volume. The ratio between the volume of openings and the total rock volume is called porosity. Water from wells in Wilson County is derived from these pore spaces and fractures, not, as is believed by some people, from an underground river or stream.



Intergranular pore spaces are found in unconsolidated rocks such as the Pleistocene terrace deposits, the Coastal Plain sediments, and in the saprolite of the bedrock.



Sheet-like fractures are found in the bedrock such as the consolidated igneous and metamorphic rocks of the Piedmont.

Figure 3.--Idealized diagram showing two types of rock openings.

Because porosity is a measure of the water-storage capacity of a particular rock, we might expect to be able to recover all of the water in storage. This is not the case, however. A certain amount of water will cling to the mineral grains or to the walls of a rock fracture and remain behind as water is pumped from the rock. The amount of water recoverable from storage is called the specific yield, which is largely governed by the size of the pore spaces or fractures in the rock. A rock may have a high porosity and yet have a low specific yield because the pore spaces are very small (such as clay). Conversely, if the rock grains are fairly large, the porosity might be smaller, but the specific yield could be a relatively large percentage of the water in storage. Hence, the water-supply value of a saturated rock depends on its specific yield rather than its porosity. Estimated specific yields for the principal geohydrologic units of the ground-water system in Wilson County are given in table 1.

Table 1.--Estimated values of specific yield for the geohydrologic units in Wilson County

Geohydrologic units	Estimated specific yield (percent)
Pleistocene terrace deposits	5-10
Yorktown Formation	less than 5
Cretaceous aquifer	10
Saprolite	5-20
Bedrock	less than 1

In conjunction with their reservoir function, rock openings also serve as pipelines because water moves through them under the influence of gravity. This property of the rock openings which permits the movement of water within the ground-water system is known as permeability. The rate of movement of water through the openings, as controlled mainly by the size of the open spaces, is known as the hydraulic conductivity of the rock.

Rocks that have the largest pore openings or fracture widths will have the greatest hydraulic conductivity. These rocks are called aquifers because they are capable of yielding significant amounts of water to wells. The general range of hydraulic conductivity for aquifers in Wilson County is estimated to be from about 0.5 ft/d (0.15 m/d) in the unconsolidated Pleistocene terrance deposits to perhaps as much as 500 ft/d (152 m/d) for individual sand beds of the Cretaceous sediments.

Not all of the rocks of the ground-water system are aquifers. Rocks with low hydraulic conductivity will yield no water or very little water to wells; moreover, they serve to retard the movement of water into or out of adjacent aquifers. The term confining bed refers to rocks of this type and is applied more specifically to relatively thick, areally extensive beds having low hydraulic conductivity, such as clay or silt, that overlies or underlies an aquifer. The Yorktown Formation in the Coastal Plain sediments of eastern Wilson County is a confining bed (fig. 2) of thick clays and silts, which overlie the sand aquifers in the Cretaceous sediments.

To summarize briefly, a ground-water system has two functions: (1) the storage of water, and (2) the movement of water under the influence of gravity. Porosity is a measure of the amount of openings in the rock in which water may be stored. If water is to be recovered from the system, the specific yield of the rock is the important factor, because it is a measure of how much of the water stored in the openings can be drained from the rock.

The ground-water system in Wilson County consists of a number of identifiable rock units (fig. 2). Each unit has its own range of porosity, specific yield, and hydraulic conductivity; however, each rock unit is also connected hydraulically to the rest of the rock units in the ground-water system.

Recharge and Discharge

The ground-water system represents only one part of the vast unending circulation of the waters of the earth, which is called the hydrologic cycle. In order to better understand the function of the ground-water system within the hydrologic cycle, it is important to determine where ground water fits into the cycle.

Chiefly under the influence of solar radiation, water evaporates from the ocean, smaller bodies of water, and from the land surface. Returning to earth as rainfall, part of the water falls directly on the ocean and part falls on the land surface. Some of the water falling on the land surface ultimately returns to the ocean as overland runoff by way of streams, but some of the rainfall enters the soil and slowly percolates downward to fill the rock openings--this is known as recharge to the ground-water system.

The water table is the water surface in an unconfined aquifer bounded by atmospheric pressure. Given a sufficient amount of recharge, the water table rises until input is balanced by seepage or discharge into streams or ponds, or the rocks become too full to accept further recharge. A lag-time is thus introduced into this part of the hydrologic cycle because ground water is stored in rocks for a variable period of time until it is discharged from the system. Although we usually see variations in the amount of ground water in storage, even on an annual basis, the system is in balance over long periods of time, because ultimately, water discharged from the system will balance recharge to it.

Changes in the ground-water reservoir may be observed by measuring the depth to the water table in wells over a period of time. Fluctuations in the water table indicate changes in storage in the system due either to recharge or discharge. Figure 4A shows fluctuations of the water table that occurred in a shallow well near Wilson. During the winter months from December 1973 to March 1974 recharge from rainfall provided more water to the ground-water system than was discharged from it. Thus, the water level rose. From April 1974 through the end of the record (and presumably until the succeeding winter months again) recharge was not sufficient to balance discharge from the system and the water level gradually declined. If the decline rate during the summer of 1974 continued unchanged, by September the water level would be below that of the previous year, which would indicate that the recharge during the winter of 1973 was insufficient to balance the water which discharged from the system during the following summer. This shows how ground-water storage varies on an annual basis according to the amount of recharge received.

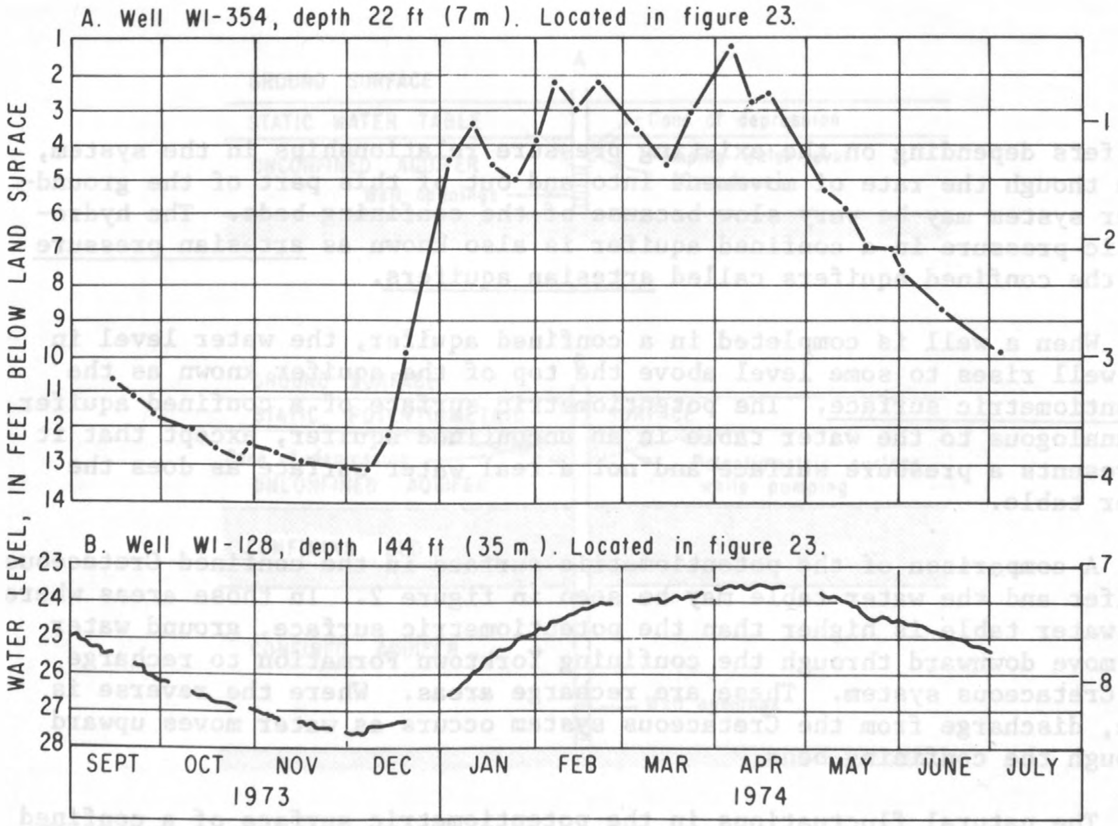


Figure 4.--Fluctuations in (A) the water table and (B) the potentiometric surface in the Cretaceous aquifer.

Discharge from the ground-water system is by seepage to streams and ponds, by evaporation from the land surface, and by transpiration from plants (evapotranspiration is the term for the combined processes of evaporation and transpiration). Evapotranspiration is greatest in areas where the water table is near land surface such as in stream valleys or swamps, and constitutes the largest volume of ground-water discharge. During the winter months, however, ground-water discharge by evapotranspiration is nil.

To this point the discussion has centered on recharge and discharge that occurs in the unconfined part of the ground-water system, where the bulk of this activity takes place. How does recharge and discharge occur in the confined parts of the ground-water system--in aquifers overlain by relatively impermeable confining beds? We have seen that water moves by gravity downward through confining beds in spite of their low hydraulic conductivity. Water that enters a confined aquifer continues to move under gravity, but because of the confinement a hydrostatic pressure is built up within the confined aquifer. When sufficient pressure is established water may move up against gravity, pass through the confining bed once more as it moves towards areas of lower head, and ultimately discharge into streams. Thus, water is able to move in or out of confined aquifers depending on the existing pressure relationships in the system, even though the rate of movement into and out of this part of the ground-water system may be very slow because of the confining beds. The hydrostatic pressure in a confined aquifer is also known as artesian pressure and the confined aquifers called artesian aquifers.

When a well is completed in a confined aquifer, the water level in the well rises to some level above the top of the aquifer known as the potentiometric surface. The potentiometric surface of a confined aquifer is analogous to the water table in an unconfined aquifer, except that it represents a pressure surface and not a real water surface as does the water table.

A comparison of the potentiometric surface in the confined Cretaceous aquifer and the water table may be seen in figure 2. In those areas where the water table is higher than the potentiometric surface, ground water may move downward through the confining Yorktown Formation to recharge the Cretaceous system. These are recharge areas. Where the reverse is true, discharge from the Cretaceous system occurs as water moves upward through the confining beds.

The natural fluctuations in the potentiometric surface of a confined aquifer occur in response to seasonal changes in storage in the overlying unconfined aquifer; fluctuations also may occur as a result of changes in barometric pressure, tides, earthquakes, and loading phenomena, which are of relatively minor importance. Figure 4B shows fluctuations of the potentiometric surface in a well open to the Cretaceous aquifer. Comparing this hydrograph with that in figure 4A (both wells being at the same location), we see that the potentiometric surface has less total range of fluctuation than the water table, and has a greater depth below land surface. Moreover, the fluctuations shown in this hydrograph (fig. 4B) are probably due in part to seasonal variations in regional pumpage from the Cretaceous aquifer.

The discharge from the ground-water system described thus far has been that which occurs within a naturally balanced system. Discharge from the ground-water system caused by pumping water from wells can have a significant and wide-ranging effect on the natural balance of the system. When a well is pumped, water is removed from storage in the ground-water reservoir. The water level in the pumped well declines due to the loss of water from storage in the aquifer around the well. This water-level decline is called drawdown. Continued pumping extends this drawdown outward from the well in an ever-widening shape resembling an inverted cone (called cone of depression) with the pumped well central to its lowest point (fig. 5).

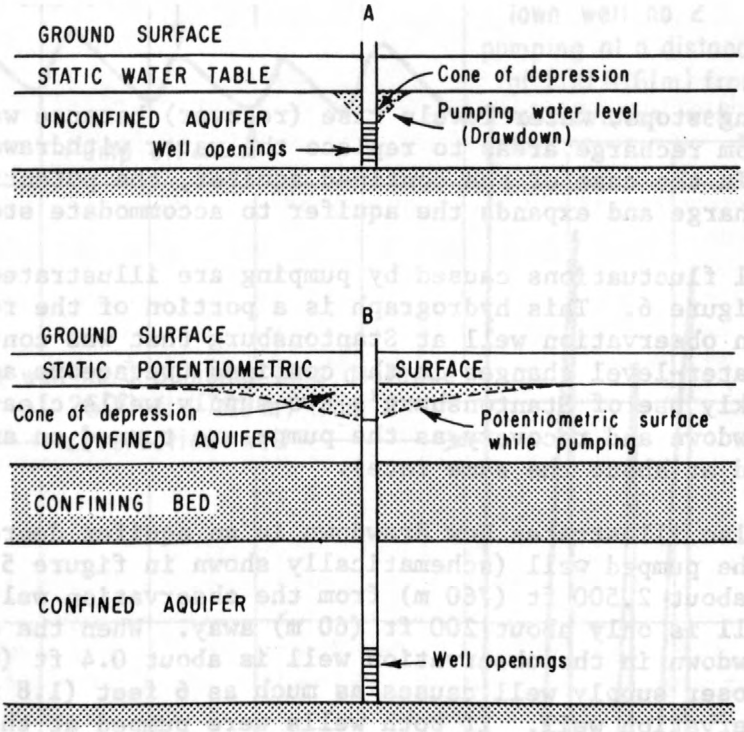


Figure 5.--Idealized sections showing comparative drawdown effects while pumping at the same rate from (A) an unconfined aquifer and (B) a confined aquifer.

Both the drawdown and the cone of depression operate in the same manner in confined and unconfined aquifers. However, there is a difference in how water is taken from storage in each type of aquifer situation. In the case of the unconfined aquifer in sketch A (fig. 5), water pumped from the aquifer is drained from the aquifer within the cone of depression. This part of the unconfined aquifer is no longer saturated with water.

In sketch B (fig. 5) (the confined aquifer situation), the potentiometric surface behaves similarly when water is pumped from this aquifer; however, the drawdown has not extended into the confined aquifer. The confined aquifer remains saturated with water although it continues to yield water to the well. Remembering that the potentiometric surface represents the hydraulic pressure in the confined aquifer and hence is not a true water surface, a pumping well will lower the pressure in the aquifer around the well. This partial release of internal hydraulic pressure is accompanied by a very small but definite compaction of the aquifer, which represents a small loss of storage space in the aquifer. In order to release a comparable amount of water to a well, the cone of depression in a confined aquifer must extend over a much larger area than the cone in an unconfined aquifer.

When pumping stops, water levels rise (recover) because water is still moving from recharge areas to replace the water withdrawn through the pumping well. In the case of the confined aquifer, the potentiometric head builds from recharge and expands the aquifer to accommodate storage.

Water-level fluctuations caused by pumping are illustrated by the hydrograph in figure 6. This hydrograph is a portion of the record obtained from an observation well at Stantonsburg that was continuously monitored for water-level changes in the confined Cretaceous aquifer. Alternating weekly use of Stantonsburg's two supply wells clearly shows patterns of drawdown and recovery as the pumps are turned on and off (both wells are pumped at about the same rate).

Figure 6 also illustrates how drawdown in an aquifer decreases with distance from the pumped well (schematically shown in figure 5). One supply well is about 2,500 ft (760 m) from the observation well, and the other supply well is only about 200 ft (60 m) away. When the distant well is pumping, drawdown in the observation well is about 0.4 ft (0.12 m), whereas, the closer supply well causes as much as 6 feet (1.8 m) of drawdown in the observation well. If both wells were pumped at the same time, we can easily understand that the cones of depression produced by each well would overlap, causing an additive effect (mutual drawdown interference) in the resultant drawdown in the aquifer. The combined drawdown at this observation well would be about 6.4 ft (1.9 m) if both supply wells were pumped at the same time.

Ground Water-Surface Water Relationship

Part of the hydrologic cycle involves the ultimate discharge of water from the ground-water system into surface-water bodies such as oceans, lakes, and streams because they are the lowest topographic features toward which water will gravitate. Flows in perennial streams like Contentnea Creek, Black Creek, and Toisnot Swamp are sustained by this ground-water discharge during rainless periods after overland runoff has ceased. Perennial streams are so-named because they flow year round. During unusually long periods of drought, a large proportion of ground-water discharge is lost through evapotranspiration along the stream valleys, leaving even smaller amounts of water for streamflow. Streamflow will cease when evapotranspiration demand equals or exceeds the rate of ground-water discharge to stream channels. Streams are said to be intermittent when streamflow ceases during dry periods.

Streamflow records can be used to estimate ground-water discharge to streams, thus providing an indication of ground water availability. Ground-water discharge to streams in Wilson County is estimated to be the amount of streamflow that is equalled or exceeded about 60 percent of the time. This estimate is based on studies in similar areas (Floyd and

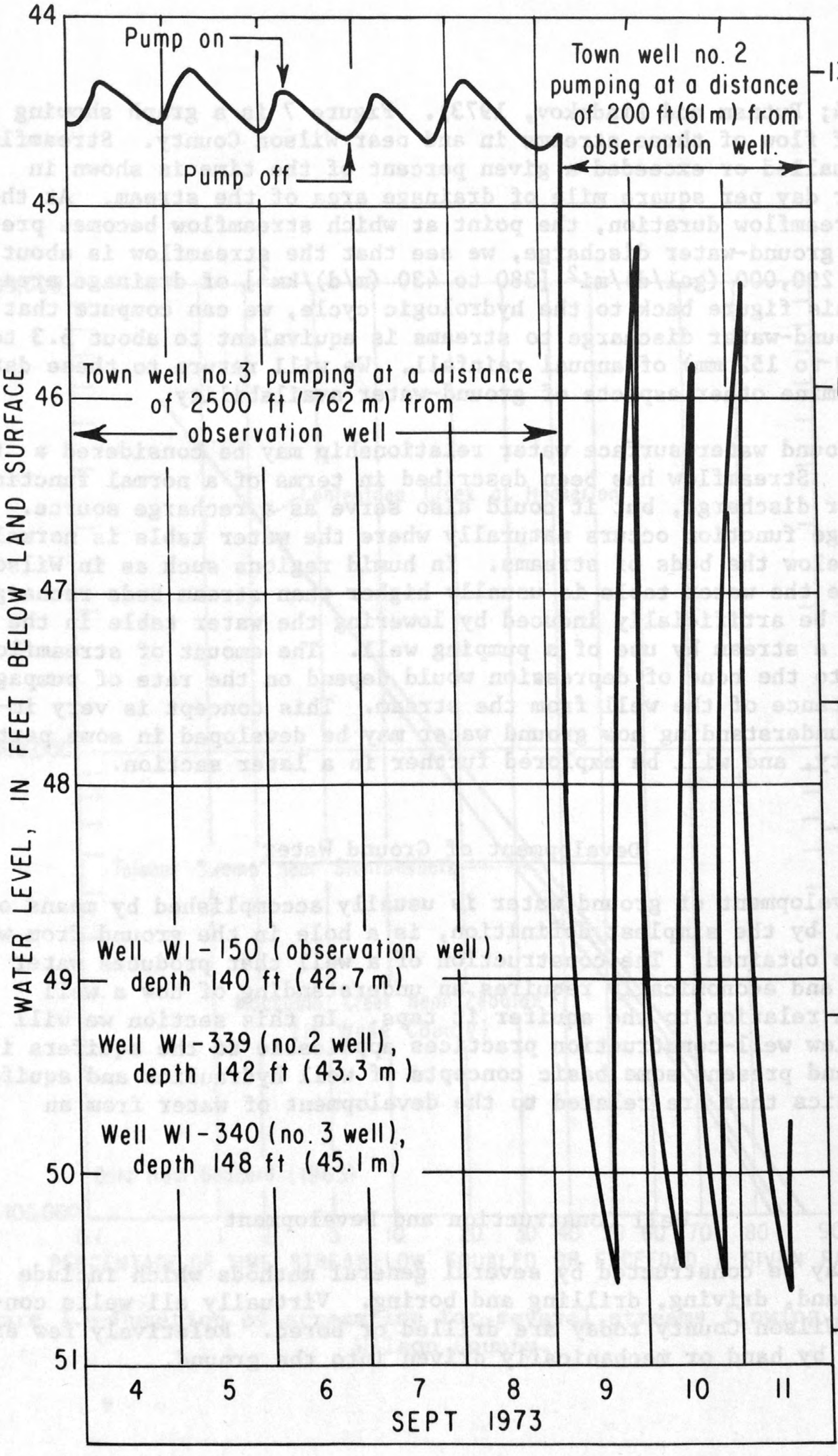


Figure 6.--Drawdown and recovery cycles in the Cretaceous aquifer due to pumping at Stantonsburg.

Peace, 1974; Putnam and Lindskov, 1973). Figure 7 is a graph showing the duration of flow of three streams in and near Wilson County. Streamflow that is equalled or exceeded a given percent of the time is shown in gallons per day per square mile of drainage area of the stream. At the 60 percent streamflow duration, the point at which streamflow becomes predominantly ground-water discharge, we see that the streamflow is about 250,000 to 290,000 $(gal/d)/mi^2$ [380 to 430 $(m/d)/km^2$] of drainage area. Relating this figure back to the hydrologic cycle, we can compute that the bulk of ground-water discharge to streams is equivalent to about 5.3 to 6.0 in (135 to 152 mm) of annual rainfall. We will return to these data when we examine other aspects of ground-water availability.

The ground water-surface water relationship may be considered a two-way street. Streamflow has been described in terms of a normal function of ground-water discharge, but it could also serve as a recharge source. This recharge function occurs naturally where the water table is normally many feet below the beds of streams. In humid regions such as in Wilson County where the water table is usually higher than stream beds recharge by streams may be artificially induced by lowering the water table in the vicinity of a stream by use of a pumping well. The amount of streamflow diverted into the cone of depression would depend on the rate of pumpage and the distance of the well from the stream. This concept is very important in understanding how ground water may be developed in some parts of Wilson County, and will be explored further in a later section.

Development of Ground Water

The development of ground water is usually accomplished by means of a well, which, by the simplest definition, is a hole in the ground from which water may be obtained. The construction of a well that produces water efficiently and economically requires an understanding of how a well functions in relation to the aquifer it taps. In this section we will briefly review well-construction practices applicable to the aquifers in the county and present some basic concepts of well hydraulics and aquifer characteristics that are related to the development of water from an aquifer.

Well Construction and Development

Wells may be constructed by several general methods which include digging by hand, driving, drilling and boring. Virtually all wells constructed in Wilson County today are drilled or bored. Relatively few exist that are dug by hand or mechanically driven into the ground.

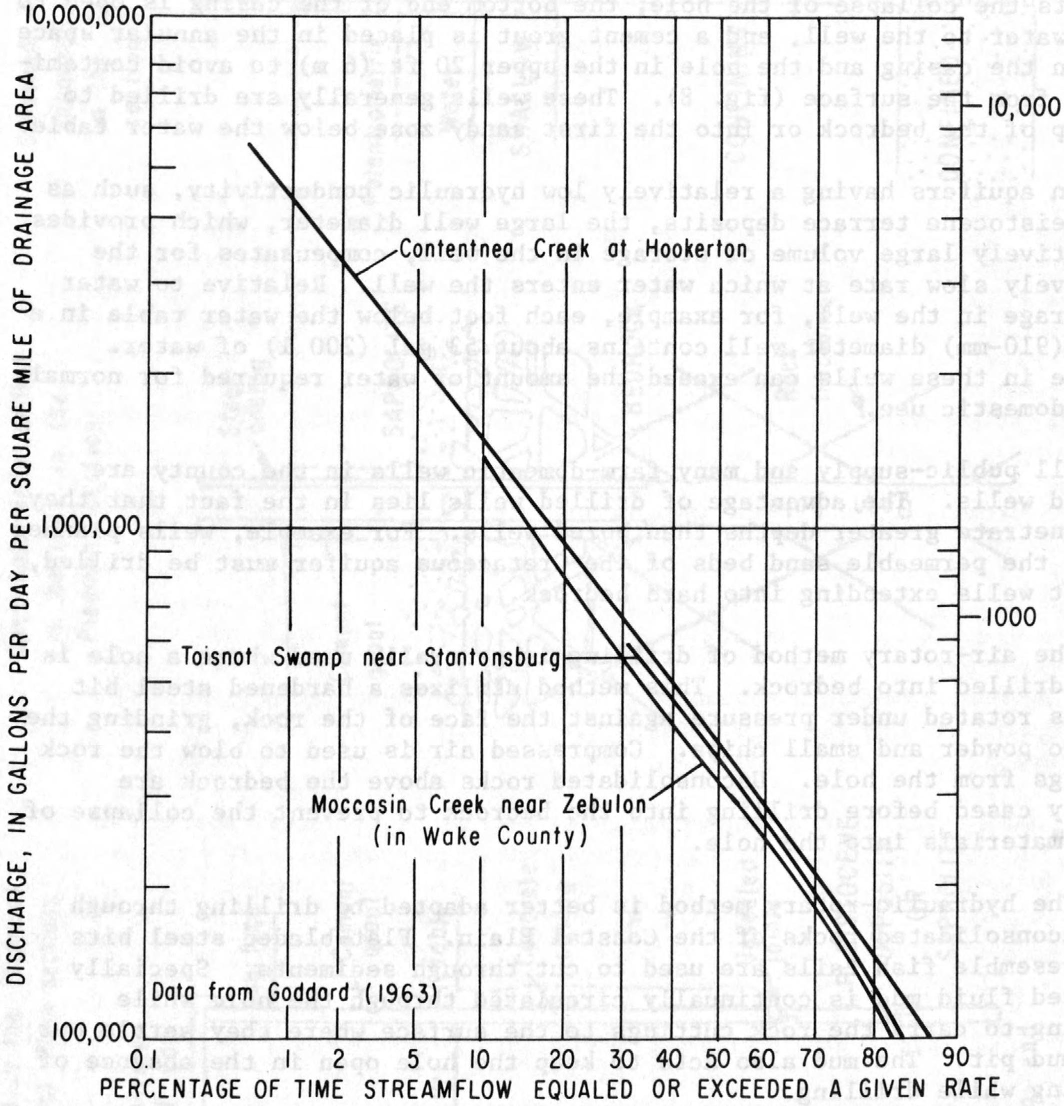


Figure 7.--Duration of streamflow for several streams flowing through Wilson County.

Most domestic wells are bored with large-diameter bucket-type augers into the shallow unconsolidated Pleistocene terrace deposits or the saprolite to depths that seldom exceed 50 ft (15 m). Some of these wells penetrate the Yorktown Formation in the Coastal Plain section. The wells are lined with 18- to 36-in (460- to 910-mm) diameter concrete casing that prevents the collapse of the hole; the bottom end of the casing is open to admit water to the well, and a cement grout is placed in the annular space between the casing and the hole in the upper 20 ft (6 m) to avoid contamination from the surface (fig. 8). These wells generally are drilled to the top of the bedrock or into the first sandy zone below the water table.

In aquifers having a relatively low hydraulic conductivity, such as the Pleistocene terrace deposits, the large well diameter, which provides a relatively large volume of storage in the well, compensates for the relatively slow rate at which water enters the well. Relative to water in storage in the well, for example, each foot below the water table in a 36-in (910-mm) diameter well contains about 53 gal (200 l) of water. Storage in these wells can exceed the amount of water required for normal daily domestic use.

All public-supply and many farm-domestic wells in the county are drilled wells. The advantage of drilled wells lies in the fact that they can penetrate greater depths than bored wells. For example, wells planned to tap the permeable sand beds of the Cretaceous aquifer must be drilled, as must wells extending into hard bedrock.

The air-rotary method of drilling is generally used where a hole is to be drilled into bedrock. This method utilizes a hardened steel bit that is rotated under pressure against the face of the rock, grinding the rock to powder and small chips. Compressed air is used to blow the rock cuttings from the hole. Unconsolidated rocks above the bedrock are usually cased before drilling into the bedrock to prevent the collapse of these materials into the hole.

The hydraulic-rotary method is better adapted to drilling through the unconsolidated rocks of the Coastal Plain. Flat-bladed steel bits that resemble fish tails are used to cut through sediments. Specially prepared fluid mud is continually circulated through the hole while drilling to carry the rock cuttings to the surface where they settle out in a mud pit. The mud also acts to keep the hole open in the absence of a casing while drilling.

Two basic types of wells are constructed by use of the above drilling methods--open-hole wells in bedrock and screened wells in unconsolidated aquifers. (See fig. 8.) Open-hole construction is used in bedrock because there is little or no tendency for rock to slump into the hole, and casing is needed only to prevent the collapse of the overlying unconsolidated material. The advantage of this type of construction is that all rock fractures intersected by the hole can contribute water to the well.

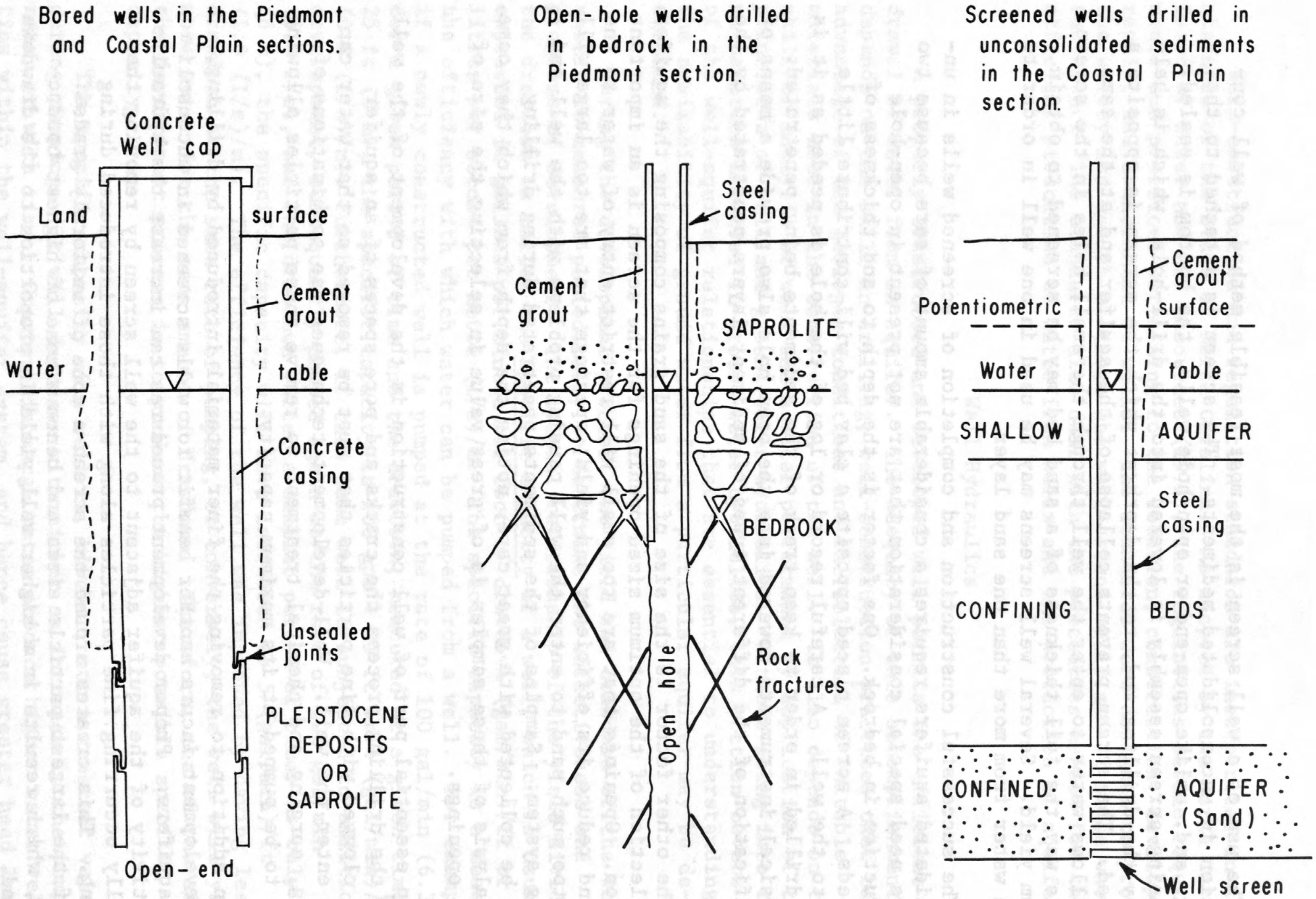


Figure 8.--Predominant types of well construction used in different hydrologic settings in Wilson County.

The use of a well screen is the most feasible method of well construction in unconsolidated sediments. The screen is attached to the casing, and, unlike open-end or open-hole wells, the bottom is sealed. The casing-screen assembly is lowered into the drill-hole, which is held open by the drilling mud, to the depth at which the screen is opposite a sand bed. The screen prevents collapse of the aquifer and at the same time allows water to enter the well through the small holes in the screen. In this way the full thickness of a sand bed may be screened to obtain maximum yield. Several well screens may be used in one well in order to obtain water from more than one sand layer.

The successful construction and completion of screened wells in unconsolidated aquifers requires a considerable amount of care because two factors need special consideration that are not present in open-hole construction in bedrock. One factor is the depth to and thickness of sand beds. A screen placed opposite a clay bed will contribute little water to the well. A careful record or log of the hole is needed as it is being drilled in order to keep track of the sediments being penetrated. Geophysical instruments lowered into the open hole also provide a means of identification of the different types of sediment layers penetrated by the well.

The other factor is the size of the sand grains composing the aquifer. The selection of the optimum sized openings for the screen is an important decision. Openings that are too small will restrict entry of water to the well and reduce its efficiency and yield; openings that are too large will allow too much sand to enter the well causing problems with the well and pumping system. Samples of the sediments penetrated during drilling should be collected with great care, noting the depth from which they come. The analysis of these samples is of great value in selecting the size of screen openings.

An essential part of well construction is the development of the well. During the drilling process the cracks and pore spaces of an aquifer become clogged with fine particles that must be removed so that water can freely enter the well. Well-development techniques use combinations of pumping, surging and chemical treatment to remove these particles allowing a well to be pumped at its maximum capacity.

In addition to removing the finer material introduced by drilling, well development incurs another benefit for wells screened in unconsolidated aquifers. Proper development procedures can increase the hydraulic conductivity of the aquifer adjacent to the well screen by removing the naturally occurring fine particles along with those introduced during drilling. This creates around the screen a zone of uniformly graded sand of the largest particle sizes and hence a zone of highest conductivity, which results in a higher well yield in proportion to the drawdown produced.

Well-construction and regulation standards are incorporated in the statutes of the State of North Carolina. As adopted by the North Carolina Board of Water and Air Resources (1971), the regulations define requirements and practices pertaining to the location, construction, development, repair, and abandonment of wells. The standards were designed to protect the safety and health of those who work around wells and of those who use the water. The standards also deal with the procedures needed for the efficient production of water from wells and the protection of aquifers.

Well Hydraulics

A properly constructed and developed well permits the efficient withdrawal of water from an aquifer. The adequacy of this accomplishment depends on the skill in drilling, well-construction practices that take advantage of the geologic conditions and the selection of suitable materials used in the construction of the well. It also depends on the skillful analysis of well and aquifer performance by application of the principles of well and ground-water hydraulics. Without going into the mathematics involved in ground-water hydraulics, this section covers some of the well-aquifer relationships that are essential to understanding how the availability of ground water from a particular aquifer may be determined.

During the development process, the yield and drawdown of the well should be measured periodically to determine the effectiveness and progress of development. The special relationship of the yield divided by the drawdown is called the <u>specific capacity</u> of a well, which is usually expressed in gallons per minute per foot of drawdown (gal/min)/ft or litres per second per metre (l/s)/m. The specific capacity is a measure of the efficiency with which water can be pumped from a well. For example, if a newly constructed well is pumped at the rate of 100 gal/min (6.3 l/s) for a given period of time and the drawdown, measured at a given time, is 25 ft (8 m), the specific capacity is 100 gpm ÷ 25 ft or 4 (gal/min)/ft (0.8 (l/s)/m). Furthermore, if this same well is subjected to additional development, subsequently pumped again at the rate of 100 gal/min (6.3 l/s), and the drawdown (after a similar period of time) is only 20 ft (6 m), the specific capacity will have increased to 5 (gal/min)/ft (1.0 (l/s)/m). The efficiency of the well was improved by having less drawdown at the same rate of pumping, or conversely, the well will yield more water for the same amount of drawdown. Therefore, one of the aims of the development process is to produce the highest possible specific capacity.

The specific capacity of a well is, however, not a constant value during pumping. It will decrease with either an increase in the pumping rate, or with time. Greater discharge rates produce higher water velocities within the well-aquifer system, and hence cause greater head loss due to increased friction. Thus, the drawdown produced in a well pumping at

100 gal/min (6.3 l/s) will be slightly more than doubled at 200 gal/min (12.6 l/s), with the difference accounted for by the increased head loss due to friction.

Specific capacity also slowly decreases with time. Drawdown in a pumped well is most rapid in the first few minutes after the pump is turned on. The drawdown increases with time until, in most cases, after a day's pumping perhaps 80 to 90 percent of the total drawdown is achieved, provided there is no change in the rate of discharge (fig. 9). For this reason specific capacity measurements taken after at least one day of pumping are generally accepted as the maximum nominal specific capacity for the well at the given pumping rate. By keeping a record of specific capacity tests, or by periodically making a test, problems such as declines in yield may be discovered and corrected; other well problems also may be diagnosed from the specific-capacity record of a well.

Production of ground water also depends on the hydraulic properties of the aquifer. A well will produce only as much water as the aquifer will yield to it. As previously defined, hydraulic conductivity is the rate of water movement through rock openings. By averaging the hydraulic conductivity values of the individual layers throughout the section of the aquifer and multiplying this average value by the thickness of the aquifer, we have the hydraulic property of the aquifer called <u>transmissivity</u>. Transmissivity is expressed in feet squared per day (or metres squared per day). Transmissivity is more convenient to use than hydraulic conductivity because it describes the average rate of water movement through the entire thickness of the aquifer. In actual practice the transmissivity of an aquifer is usually determined from the data collected during an aquifer test, and the average hydraulic conductivity is derived from the transmissivity and the aquifer thickness.

In addition to the transmissivity, the other important property of an aquifer, which was mentioned earlier, is the storage. The <u>coefficient of storage</u> is the volume of water stored in or released from an aquifer (or confining bed) per unit surface area per unit change in head. For unconfined aquifers the coefficient of storage is approximately the same as the specific yield and is equal to the amount of water yielded by gravity drainage--the range is generally about 0.05 to 0.2. In confined aquifers the coefficient of storage is much less than the specific yield and is related to the amount of contraction of the aquifer due to changes in the hydrostatic pressure. The usual range for the coefficient of storage for such aquifers is about 0.001 to 0.00001.

If both the transmissivity and the coefficient of storage can be determined for a particular aquifer, then predictions may be made about the amount of water that can be obtained from the aquifer. Such things as drawdown at various times and distances from a pumped well may be

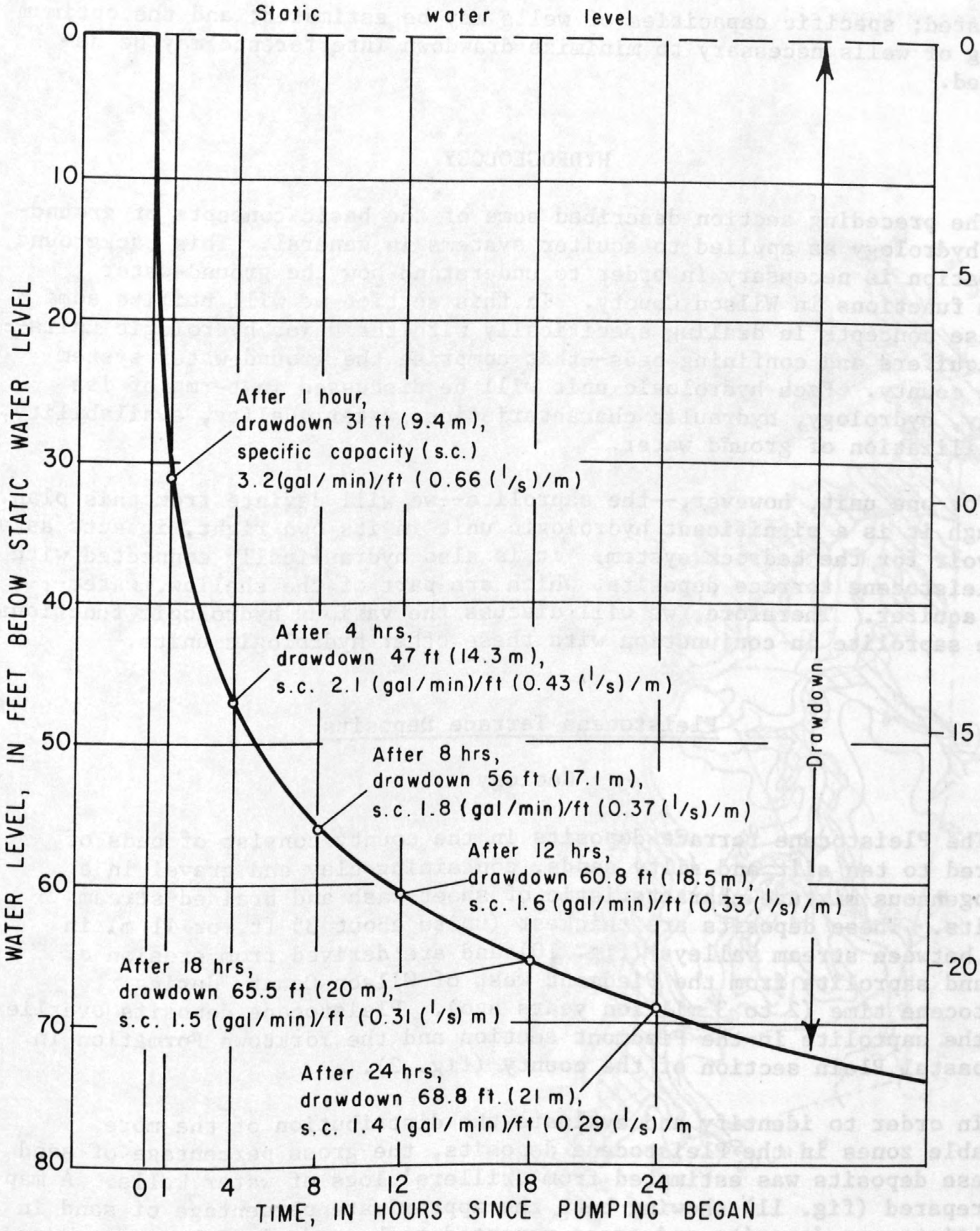


Figure 9.--Drawdown in a hypothetical well pumping at the rate of 100 gal/min (6.3 l/s) that shows how drawdown and specific capacity change with time.

calculated; specific capacities of wells may be estimated; and the optimum spacing of wells necessary to minimize drawdown interference may be determined.

HYDROGEOLOGY

The preceding section described some of the basic concepts of ground-water hydrology as applied to aquifer systems in general. This background information is necessary in order to understand how the ground-water system functions in Wilson County. In this section we will utilize some of these concepts in dealing specifically with the major hydrologic units--both aquifers and confining beds--that comprise the ground-water system in the county. Each hydrologic unit will be discussed in terms of its geology, hydrology, hydraulic characteristics, water quality, availability, and utilization of ground water.

For one unit, however,--the saprolite--we will deviate from this plan. Although it is a significant hydrologic unit in its own right, it acts as a reservoir for the bedrock system. It is also hydraulically connected with the Pleistocene terrace deposits, which are part of the shallow, water-table aquifer. Therefore, we will discuss the various hydrologic functions of the saprolite in conjunction with these other hydrologic units.

Pleistocene Terrace Deposits

Geology

The Pleistocene terrace deposits in the county consist of beds of rust-red to tan silt and silty sands, containing clay and gravel in a heterogeneous mixture characteristic of sheet-wash and braided-stream deposits. These deposits are thickest (up to about 35 ft, or 11 m) in areas between stream valleys (fig. 10) and are derived from erosion of rock and saprolite from the Piedmont west of Wilson County during Pleistocene time (2 to 3 million years ago). Pleistocene deposits overlie both the saprolite in the Piedmont section and the Yorktown Formation in the Coastal Plain section of the county (fig. 2).

In order to identify and evaluate the distribution of the more permeable zones in the Pleistocene deposits, the gross percentage of sand in these deposits was estimated from drillers' logs of water wells. A map was prepared (fig. 11) showing both the approximate percentage of sand in the Pleistocene deposits and areas reported to be underlaid by coarse sand and gravel beds. Those deposits containing the larger percentages of sand and the coarse sand and gravel beds are located in the western and northwestern sections of the county. Presumably they are there because a decrease in gradient as streams approached the Coastal Plain section caused the deposition of the coarser portion of the stream sediment load in those areas.

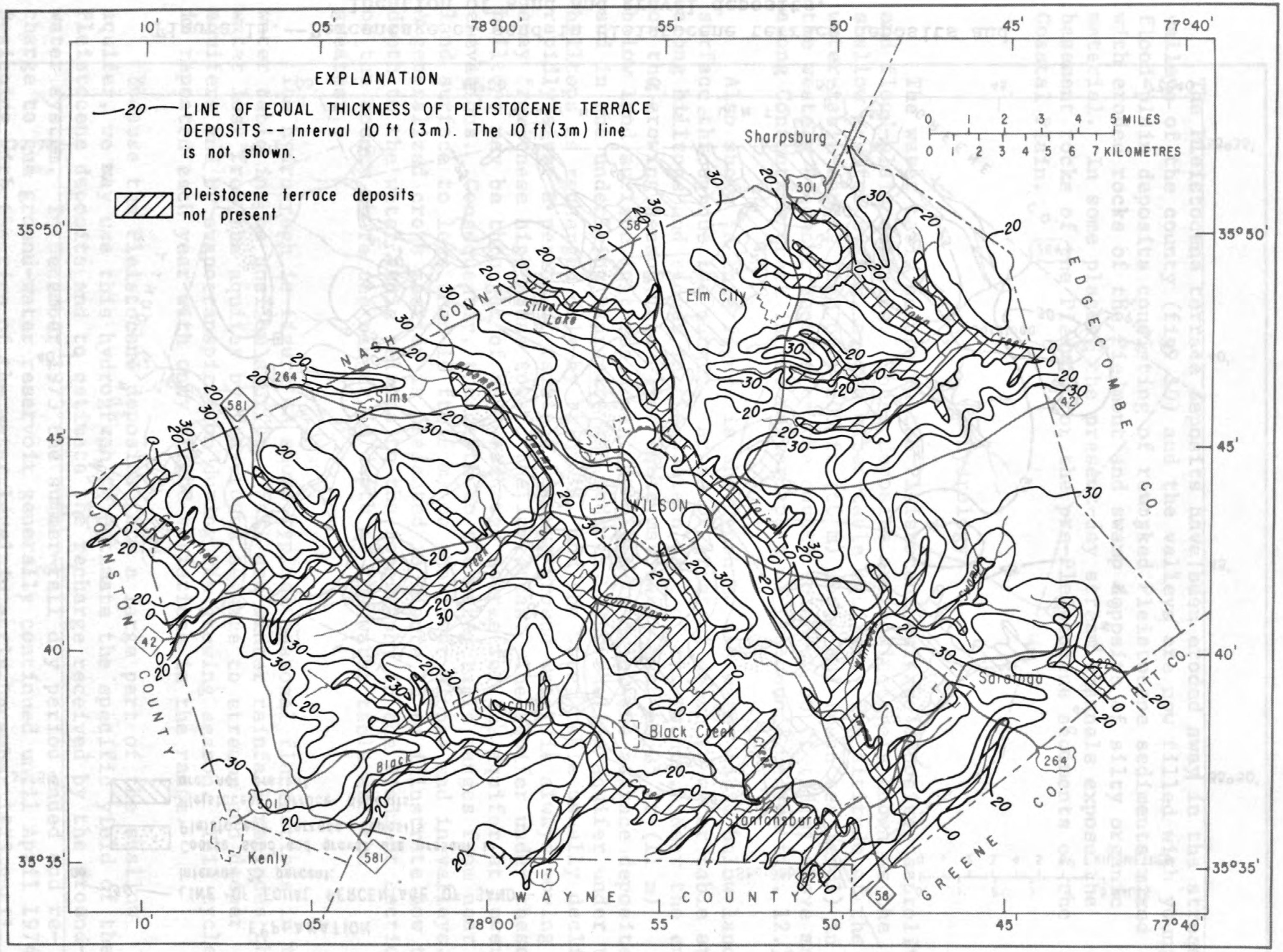


Figure 10.--Thickness of Pleistocene terrace deposits.

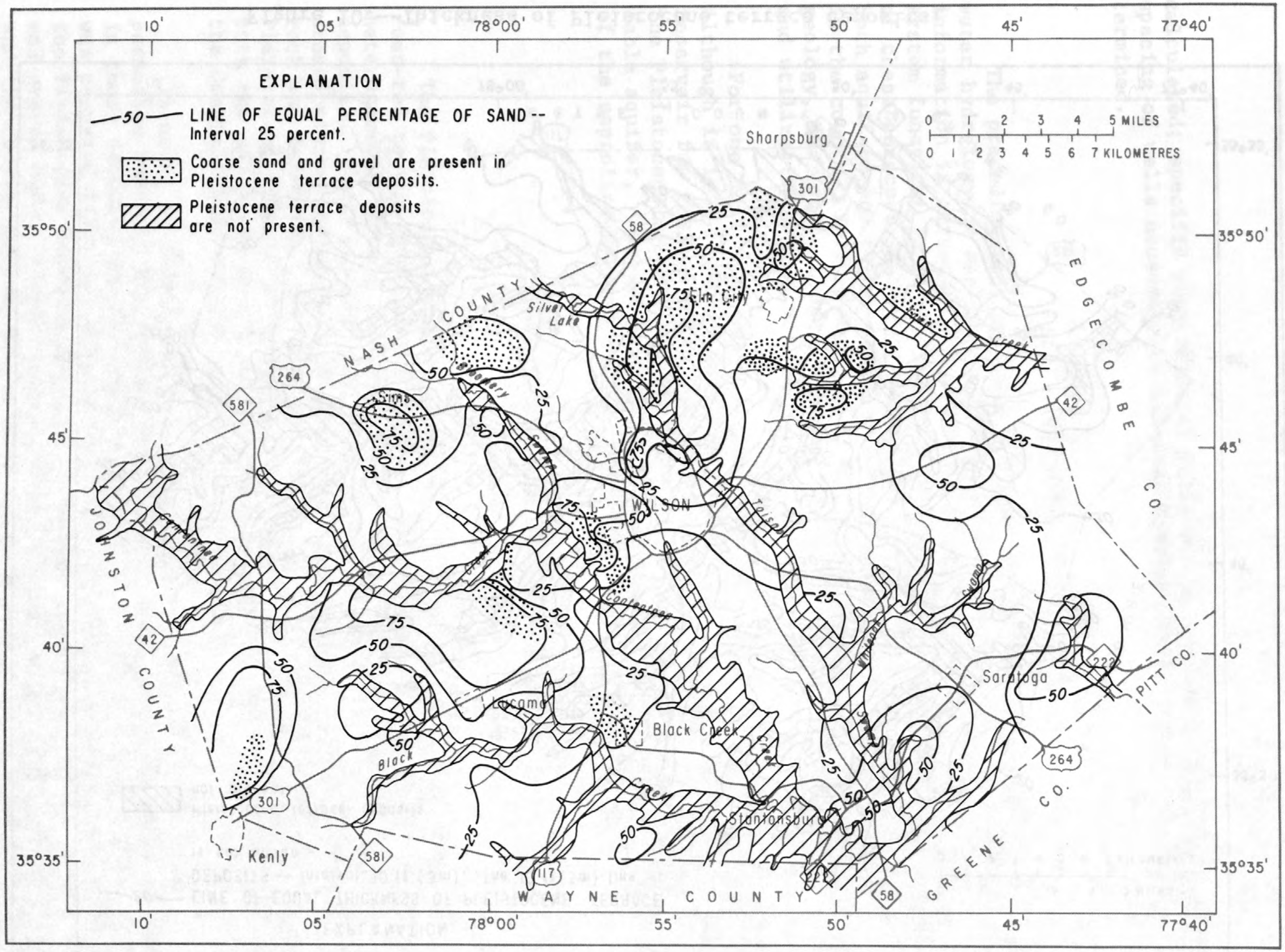


Figure 11.--Percentage of sand in Pleistocene terrace deposits and location of sand and gravel deposits.

The Pleistocene terrace deposits have been eroded away in the stream valleys of the county (fig. 10) and the valleys are now filled with younger flood-plain deposits consisting of reworked Pleistocene sediments mixed with eroded rocks of the Piedmont and swamp deposits of silty organic material. In some places, the present-day stream channels expose the basement rocks of the Piedmont or the pre-Pleistocene sediments of the Coastal Plain.

Hydrology

The water table occurs in the Pleistocene terrace deposits, saprolite, and flood-plain deposits. These deposits are collectively known as the shallow aquifer system, or the water-table aquifer. The altitude of the water-table ranges from over 200 ft (60 m) above msl (mean sea level) in the western Piedmont section of the county to about 50 ft (15 m) above msl along Contentnea Creek in the eastern part of the county. (See fig. 12.)

Also shown in this figure is the depth to the water table below land surface throughout the county. Areas of greatest depth to water table are along hilltops and ridges in the western part of the county. Near the end of the growing season, the water table may be as much as 35 ft (11 m) below land surface in these areas; it often is below the terrace deposits and in the underlying saprolite and bedrock. The shallow aquifer under the hilltops is recharged only by rainfall, and the water table usually declines rapidly after a period of rainfall because ground water is always moving away from these high areas toward the low areas. The aquifer under these hilltops may be throught of as a recharge source for the aquifer at lower elevations. Consequently, the depth to the water table ranges from near land surface to less than 10 ft (3 m) on the lower slopes and in valleys. A generalized cross section is presented in figure 13 to illustrate how the depth to the water table relates to the topography in the Piedmont section of the county where the ranges in depth to the water table are the greatest.

The hydrograph in figure 4A shows typical seasonal fluctuations in the water table in the shallow aquifer. Fall and winter rainfall replaces the water lost from the aquifer by year-round seepage to streams and deeper aquifers and by evapotranspiration during the growing season. This cycle is repeated each year with only slight variations in the range.

Because the Pleistocene deposits form a large part of the shallow aquifer, we may use this hydrograph to estimate the specific yield of the Pleistocene deposits and to estimate the recharge received by the ground-water system. In December 1973 the summer-fall dry period ended and recharge to the ground-water reservoir generally continued until April 1974. Beginning with the rise of the water level in early December 1973 until the end of the month, the water table rose about 7.25 ft (2.2 m). The National Weather Service at Wilson recorded 7.27 in (185 mm) of rainfall

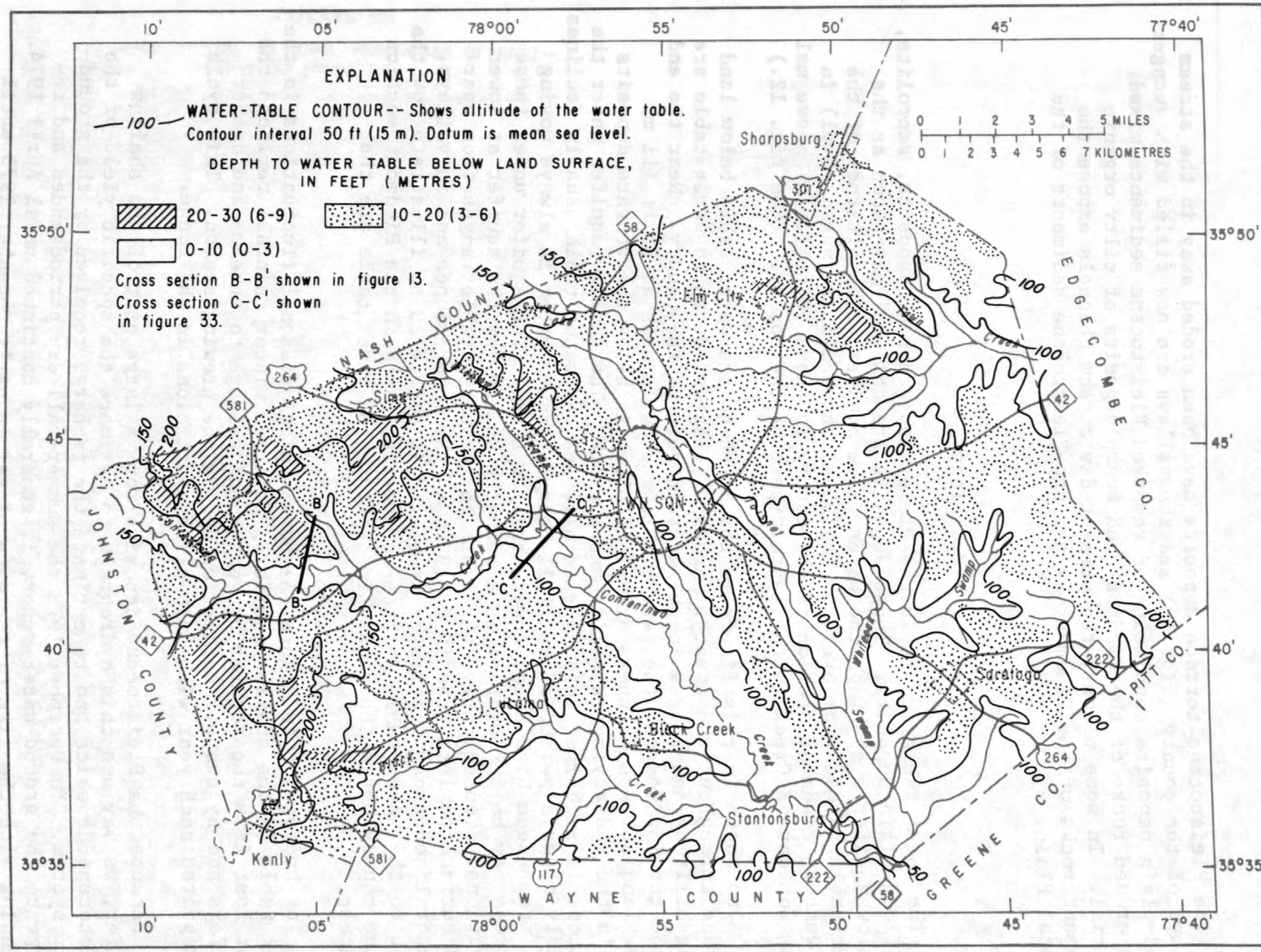


Figure 12.--Altitude of the water table and the depth to the water table below land surface in Wilson County, 1974.

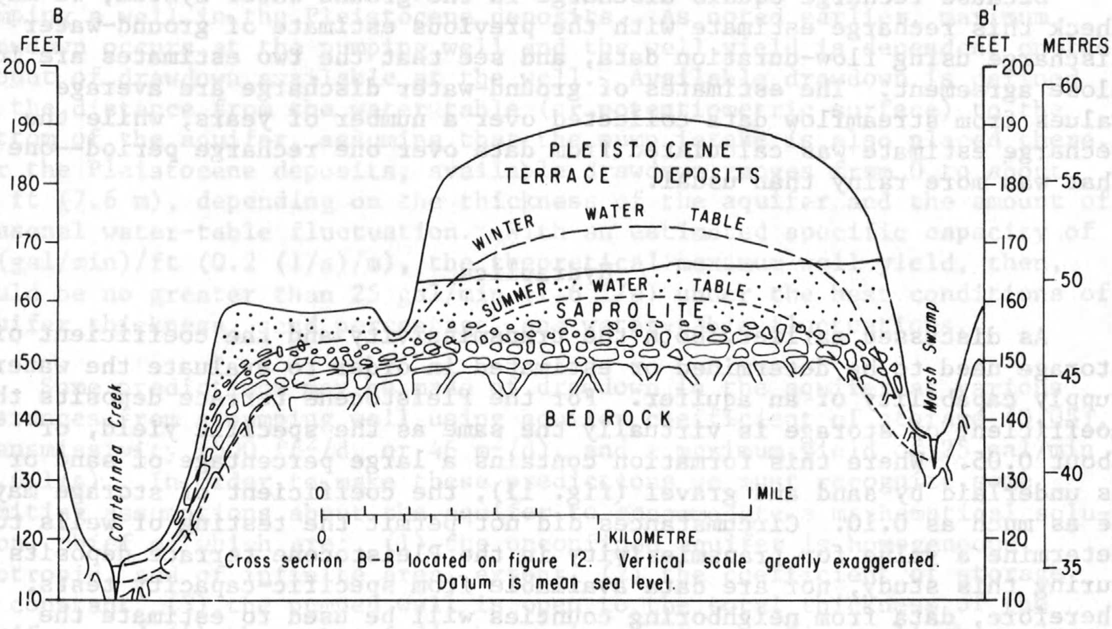


Figure 13.--Generalized cross section showing seasonal range in the water-table depth in the Piedmont section of Wilson County.

during that period. Remembering that the specific yield of an aquifer is the amount of water that can be drained by gravity (expressed as a percentage), the converse is true that the specific yield is also equivalent to the amount of water that the aquifer will accept as recharge. If we assume that the aquifer accepted all of the rainfall during this period, then the maximum value of the specific yield would be equivalent to the amount of rainfall divided by the amount of rise in the water table (both in inches), or about 8 percent. However, since rainfall intensities vary considerably, we may assume that some of the rainfall did not infiltrate to the aquifer but was retained in the soil zone or was diverted to streams as overland runoff. If we estimate that 60 percent of the rainfall enters the aquifer, then the specific yield would be about 5 percent (See table 1.)

The water table continued a general rising trend until April 1974, when it began to decline, marking the end to this recharge cycle. The maximum rise in water level due to recharge was about 12 ft (3.6 m). We may then calculate that the recharge required to produce this rise during this cycle is equivalent to the specific yield times the total amount of the rise, or a little over 7 in (178 mm) of equivalent rainfall.

Because recharge equals discharge in the ground-water system, we may check this recharge estimate with the previous estimate of ground-water discharge using flow-duration data, and see that the two estimates are in close agreement. The estimates of ground-water discharge are average values from streamflow data collected over a number of years, while the recharge estimate was calculated from data over one recharge period--one that was more rainy than usual.

Hydraulics

As discussed earlier, both the transmissivity and the coefficient of storage need to be determined or estimated in order to evaluate the water-supply capability of an aquifer. For the Pleistocene terrace deposits the coefficient of storage is virtually the same as the specific yield, or about 0.05. Where this formation contains a large percentage of sand or is underlaid by sand and gravel (fig. 11), the coefficient of storage may be as much as 0.10. Circumstances did not permit the testing of wells to determine a value for transmissivity in the Pleistocene terrace deposits during this study, nor are data available from specific-capacity tests; therefore, data from neighboring counties will be used to estimate the value for these deposits in Wilson County.

Based on one aquifer test in Martin County, Wyrick (1966, p. 39) indicated that the transmissivity of the Pleistocene deposits there would probably not exceed about 100 ft^2/d (9 m^2/d). Wyrick (1966) also reported that specific capacities of wells open to these deposits range from 0.3 to 0.5 (gal/min)/ft, or 0.06 to 0.1 (l/s)/m. However, data from one aquifer test are not necessarily indicative of the average hydraulic characteristics of an aquifer over a large area.

Geologically, the Pleistocene deposits in Martin County as described by Wyrick (1966) are similar to those in Wilson County, and the transmissivity determined there is presumed to apply to Wilson County. Martin County lies entirely in the Coastal Plain section, however, and because the Pleistocene deposits in the Piedmont section of Wilson County generally contain more sand and gravel than the deposits in the Coastal Plain section (fig. 11), any transfer of transmissivity values from Martin County to Wilson County would apply only to the Pleistocene deposits within the Coastal Plain of Wilson County. The presence of sand and gravel beds increases the average transmissivity of the Pleistocene deposits and enhances their water-supply characteristics. The transmissivity of the Pleistocene deposits in the Piedmont section is estimated to be as much as 500 ft^2/d (46 m^2/d); specific capacities of wells are estimated to be as much as 1 (gal/min)/ft (0.2 (l/s)/m).

Estimates may be made of the maximum well yield and the effects of pumping a well in the Pleistocene deposits. As noted earlier, maximum drawdown occurs at the pumping well and the well yield is dependent on the amount of drawdown available at the well. Available drawdown is defined as the distance from the water table (or potentiometric surface) to the bottom of the aquifer, assuming that the pump intake is also placed there. For the Pleistocene deposits, available drawdown ranges from 0 to about 25 ft (7.6 m), depending on the thickness of the aquifer and the amount of seasonal water-table fluctuation. With an estimated specific capacity of 1 (gal/min)/ft (0.2 (l/s)/m), the theoretical maximum well yield, then, would be no greater than 25 gal/min (1.6 l/s) under the best conditions of aquifer thickness, sand percentage, and water-table fluctuations.

Some predictions may be made of drawdown in the aquifer at various distances from a pumping well using aquifer coefficient of storage (0.05), transmissivity (500 ft^2/d, or 46 m^2/d), and a maximum yield of 25 gal/min (1.6 l/s). In order to make these predictions we must recognize some limiting assumptions about the aquifer to accommodate a mathematical solution, chief of which are: (1) the unconfined aquifer is homogeneous, isotropic, and of infinite areal extent, (2) the coefficient of storage is constant, (3) the pumped well is open to the total thickness of the aquifer, and (4) the rate of discharge is constant. Figure 14 shows drawdown of the water table at various distances and times under idealized conditions for the Pleistocene terrace deposits in response to a well pumping at 25 gal/min (1.6 l/s) and therefore, provides an estimate of the extent of the cone of depression in the aquifer under the best conditions that are likely to exist in the county. Because drawdown is proportional to the discharge, drawdowns at other yields may be determined. For example, drawdown caused by a well pumping 5 gal/min (0.3 l/s) would be one-fifth that shown in figure 14 at any given time or distance.

Quality of Water

Rainfall that enters the ground-water system in Wilson County has a very low dissolved-solids concentration, and among the constituents present are dissolved oxygen and carbon dioxide. As it infiltrates through the soil zone, the water dissolves additional carbon dioxide and small amounts of organic acids from decomposing organic matter. This acidic water dissolves certain minerals from the rocks through which it passes. It will also react with well casings and pump equipment with which it comes in contact. As seen in table 2, the Pleistocene deposits contain water with low hardness and dissolved-solids concentration. Since the water is corrosive, it might be expected to dissolve more mineral matter than is shown by the analyses. One explanation for the low dissolved-solids concentration is that the Pleistocene deposits have been leached by circulating ground waters since their deposition, and now only relatively small amounts of readily soluble minerals remain in the deposits.

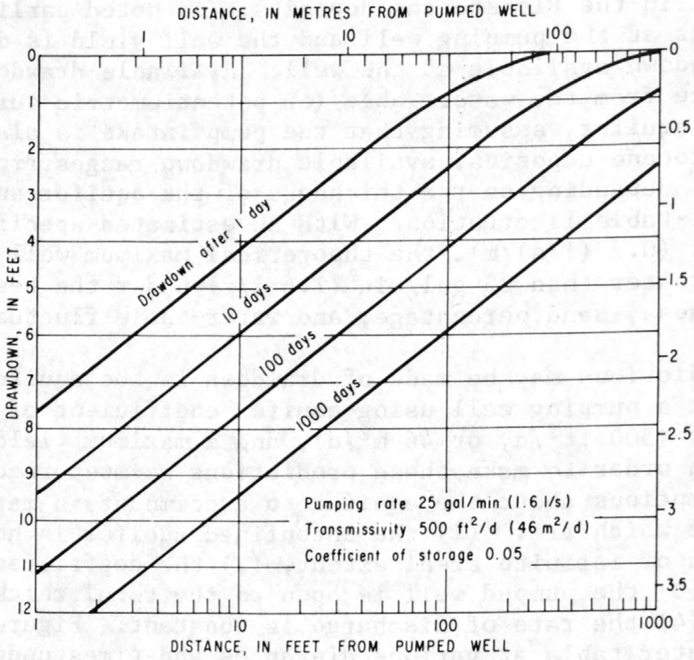


Figure 14.--Idealized distance-drawdown relationship in the Pleistocene terrace deposits.

Table 2.--Selected natural constituents and properties of ground water from the Pleistocene terrace deposits in Wilson and surrounding counties

[Average of 6 samples selected from Mundorff, 1946]

Constituents in milligrams per litre					
Silica (SiO_2)	Iron (Fe)	Bicarbonate (HCO_3)	Chloride (Cl)	Hardness	Dissolved solids
17	0.08	8.5	8	18	66

Dissolved iron is generally a troublesome constituent in many ground waters because concentrations in excess of 0.3 mg/l (milligrams per litre) tend to stain plumbing fixtures and laundry and impart a bitter taste to water (U.S. Environmental Protection Agency, 1973). Because the ground water from the Pleistocene deposits is slightly corrosive, the low iron concentration in the water is due in part to a lack of contact of the water with iron minerals in the deposits and iron and steel in modern well systems. Most of the shallow domestic wells in Wilson County are constructed with large diameter (18- to 36-in, or 460- to 910-mm) concrete or tile casing. The water is usually pumped through plastic lines from the well, stored in galvanized, glass-lined, or plastic-lined pressure tanks, and distributed for use through plastic or copper lines. One water sample from a shallow well with iron casing had an iron concentration of 1.8 mg/l; this analysis was not included in table 2.

Systems using galvanized iron may be subject to a gradual increase in the iron concentration in the water. The zinc coating of the galvanizing will also be dissolved by corrosive water. This action is not generally evident until the galvanized coating is partially removed.

Availability of Ground Water

The amount of ground water in the Pleistocene terrace deposits that is available by gravity drainage is estimated to be about 1.5×10^8 gal/mi^2 (2.2×10^5 m^3/km^2), based on a specific yield of 5 percent and an average saturated thickness of about 15 ft (4.6 m). In the Piedmont section where the saprolite is part of the shallow aquifer, each square mile could drain an additional 1.0×10^7 gal per foot of saturated thickness of saprolite, or for each square kilometre 5.0×10^3 m^3 per metre thickness.

Recharge by rainfall percolating into the shallow aquifer is a renewable source of water. Using the earlier estimate of 7 in (178 mm) per year of rainfall for ground-water recharge, we can estimate that about 330,000 (gal/d)/mi^2 [495 (m^3/d)/km^2] is generally available on an annual basis. This amount is considered the maximum quantity available in the shallow aquifer in hilltop areas because rainfall is the only source of recharge there. On hill slopes and in stream valleys the availability of water in the shallow aquifer is increased to the extent that additional recharge from streamflow and ground-water movement from the hilltops may be captured. Theoretically, this amount is the combined total of ground-water recharge, overland runoff to streams, and some salvaged evapotranspiration losses. Based on the average streamflow for Contentnea Creek near Lucama (U.S. Geological Survey, 1974) and neglecting evapotranspiration, the maximum availability of water to the shallow aquifer in stream valleys is estimated to be equivalent to about 13 inches (330 mm) of rainfall per year, or about 620,000 (gal/d)/mi^2 [930 (m^3/d)/km^2].

Well Yields and the Utilization of Ground Water

Between 6,000 and 7,500 water wells are estimated to be currently (1974) in use in Wilson County. Probably over 75 percent of these wells draw from the shallow aquifer for farm-domestic water supplies. A small number of commercial establishments use shallow wells, but no public supplies or industries presently use or are known to plan use of this ground-water source. Total pumpage from the shallow aquifer is estimated to be about 775,000 gal/d (2,950 m^3/d).

The average reported yield from wells in the Pleistocene terrace deposits is about 6 gal/min (0.4 l/s), with the highest yield being 22 gal/min (1.4 l/s), however, these yields probably were measured after less than an hour or so of pumping during well construction or pump installation operations. Maximum sustained yields of these wells when pumped 24 hours or longer probably range from 2 to 10 gal/min (0.1 to 0.6 l/s) due to the low estimated specific capacities, and depending on the available drawdown.

General areas most favorable for the development of water supplies from the Pleistocene terrace deposits are shown on figure 15. The areas are based on (1) the highest percentages of sand likely to be available, (2) the greatest thickness of the terrace deposits, (3) the depth of the water table below land surface, and (4) the use of the large-diameter, concrete-cased, open-end wells that are in most common use today for domestic supplies.

Areas A on the map (fig. 15) are the most favorable in terms of potential development sites. These areas occur mostly in the Piedmont section of the county where the terrace deposits are over 30 ft (9 m) thick, notably just west of Elm City and Lucama and to the north of Kenly. This thickness allows greater well depths and more drawdown. The deposits in these areas usually have a sand content exceeding 50 percent, or a gravel bed, which may be indicative of a greater potential specific capacity. Seasonal water levels generally fluctuate from between 10 to 20 ft (3 to 6 m) below land surface. The sustained yield (for 24 hours or longer) of a properly constructed and developed well may exceed 10 gal/min (0.6 l/s) in these areas.

Areas B, C, and D in figure 15 are less favorable than area A in terms of potential. Area B is very similar to Area A except that the terrace deposits are only 20 to 30 ft (6 to 9 m) thick. Shallower well depths decrease the potential for available drawdown, therefore sustained well yields will be less--probably not more than 10 gal/min (0.6 l/s).

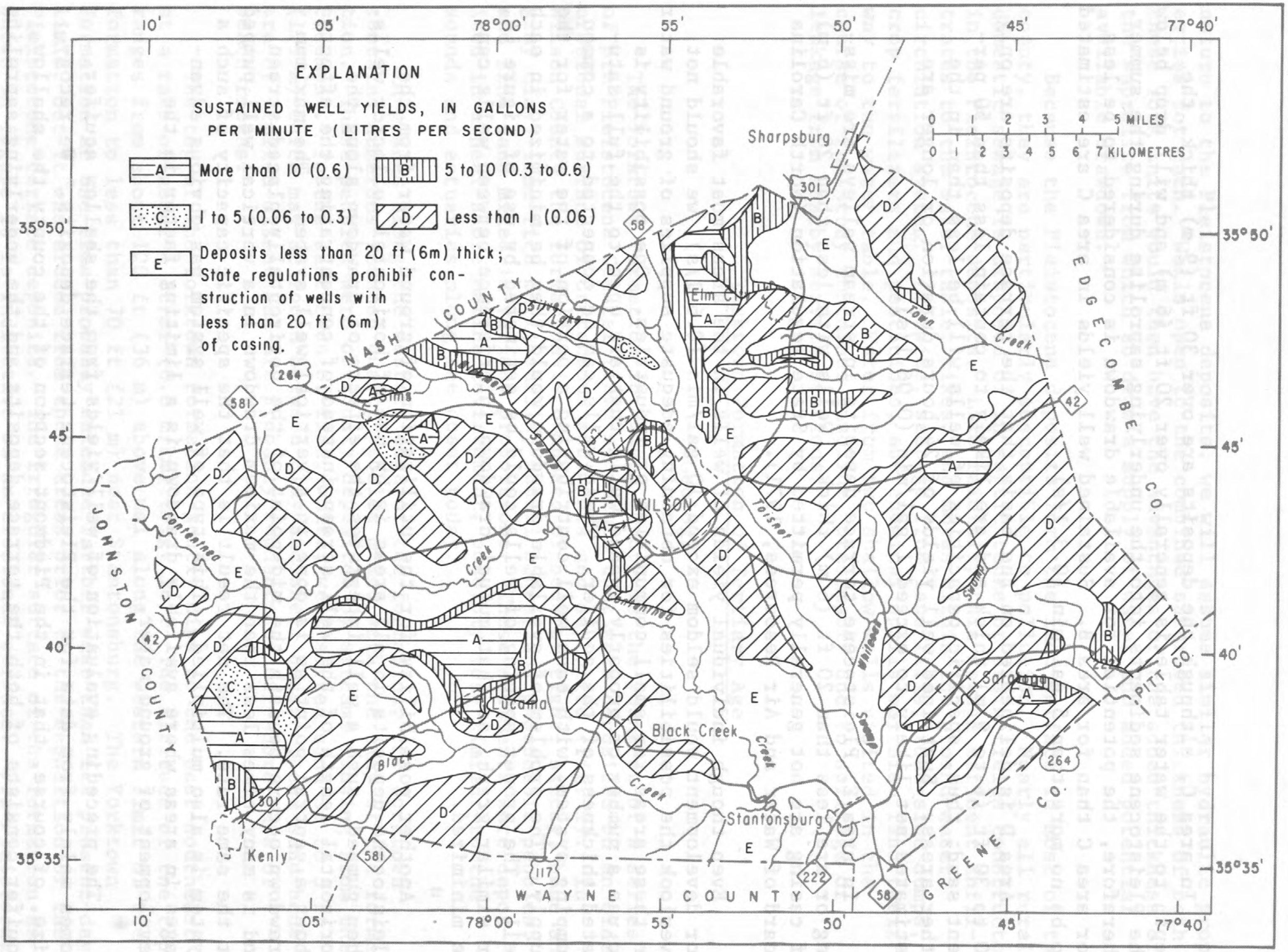


Figure 15.--Sustained yields to individual wells in the Pleistocene terrace deposits.

In area C, although the deposits are over 30 ft (9 m) thick, the depth to the water table is generally over 20 ft (6 m) and will drop below the Pleistocene sediments into the underlying saprolite during the summer. Therefore, the potential for available drawdown is considered to be less for area C than for area B. Sustained well yields in area C are estimated to be no more than 5 gal/min (0.3 l/s).

Area D is delineated on the basis that the terrace deposits are only 20 to 30 ft (6 to 9 m) thick and are likely to contain less than 50 percent sand; thus, specific capacities of wells will be less than in the other areas. Sustained well yields of 24 hours duration or longer are estimated not likely to exceed 1 gal/min (0.06 l/s).

In area E, Pleistocene terrace deposits in stream valleys are missing or are less than 20 ft (6 m) thick. Wells with less than 20 ft (6 m) of casing are not generally permitted by State regulation (North Carolina Board of Water and Air Resources, 1971).

Even though individual yields of wells in the areas most favorable for development would seldom exceed 10 gal/min (0.6 l/s), we should not overlook the possibilities for obtaining adequate supplies of ground water in these areas for small communities or industries. One possibility is to use a number of properly spaced wells that are open to the full saturated thickness of the aquifer. These wells can be connected to a common pumping system, with each well contributing a portion of the water for the supply. The problem of available drawdown would then be minimized in each well. The proper spacing of wells could be estimated by use of figure 14, or similar graph, so that mutual drawdown interference between wells can be minimized.

Another possibility for the utilization of ground water from the Pleistocene deposits in all areas is by use of horizontal collector wells. When pumped, such a well integrates the effects of drawdown along the horizontal length of the well screen instead of concentrating the effects about a central point as is done in a vertical well system. The maximum drawdown occurs beneath the mid-point of the horizontally-placed screen and is many times less than the maximum drawdown in a vertical well pumped at the same rate. The net result is that the specific capacity of such a system is also multiplied. This type of well system has obvious advantages in areas where available drawdown is a limiting factor in the development of ground water.

The preceding evaluation of well yields from the shallow aquifer comes mainly from data for the Pleistocene terrace deposits. We recognize, of course, that in the Piedmont section of the county the shallow aquifer consists of both the terrace deposits and the underlying saprolite (fig. 13). Because the materials comprising the saprolite are similar in nature to the Pleistocene deposits, we will assume similar hydraulic properties for each. Wells open to the combined saturated thickness of both these rock units would then have the advantages of the added thickness of the saprolite from which to draw a supply of water and added potential available drawdown.

Because the Pleistocene deposits form the land surface in most of the county, they are particularly susceptible to pollution. Nearly all rural-domestic sewage is disposed of in septic tanks or drain fields constructed in the Pleistocene deposits. Like rainfall, this sewage effluent infiltrates to the water table, mixes, and moves within the ground-water circulation system. Likewise, seepage from land-fills, road-side dumps, crop fertilizers and pesticides, and chemical spills may also find their way to the water table. Water from two shallow wells visited in the course of the study contained gasoline, presumably due to spillage or leakage from nearby service stations.

Yorktown Formation of Tertiary Age

Geology

The Yorktown Formation in Wilson County is the youngest of a series of pre-Pleistocene Coastal Plain sediments that were deposited on an older erosional surface of Cretaceous sediments and saprolite (fig. 2). In Wilson County the formation is composed of beds of tight, sticky, blue and gray clay; lime-rich marl; shells, fossil bones, and phosphatic pebbles; and fine sand mixed in various proportions. These sediments were deposited in a near-shore marine environment, possibly very similar to the sounds and estuaries along the coast today.

In places along the western edge of the formation, the Yorktown contains numerous rounded quartz pebbles mixed with the clay of the formation. These pebbles were obviously deposited by streams flowing from the Piedmont. To the east beds of fine, white, well-sorted sand up to 5 ft (1.5 m) thick may be found between clay and shell beds. These sand beds are of limited extent and are probably remnants of off-shore bars or beach ridges.

The top of the Yorktown Formation gently dips to the east-southeast at a rate of about 4 ft/mi (0.8 m/km) (fig. 16). The altitude of the top ranges from about 120 ft (36 m) above msl along the western limit of the formation to less than 70 ft (21 m) near Stantonsburg. The Yorktown Formation at one time probably extended farther west than its present-day limit, but it was eroded from those areas prior to the deposition of the Pleistocene terrace deposits. The irregular surface of the formation as shown in figure 16 is indicative of an erosional surface. Pre-Pleistocene stream erosion is also responsible for the removal of some of the Yorktown along Contentnea Creek and along Town Creek west of Elm City.

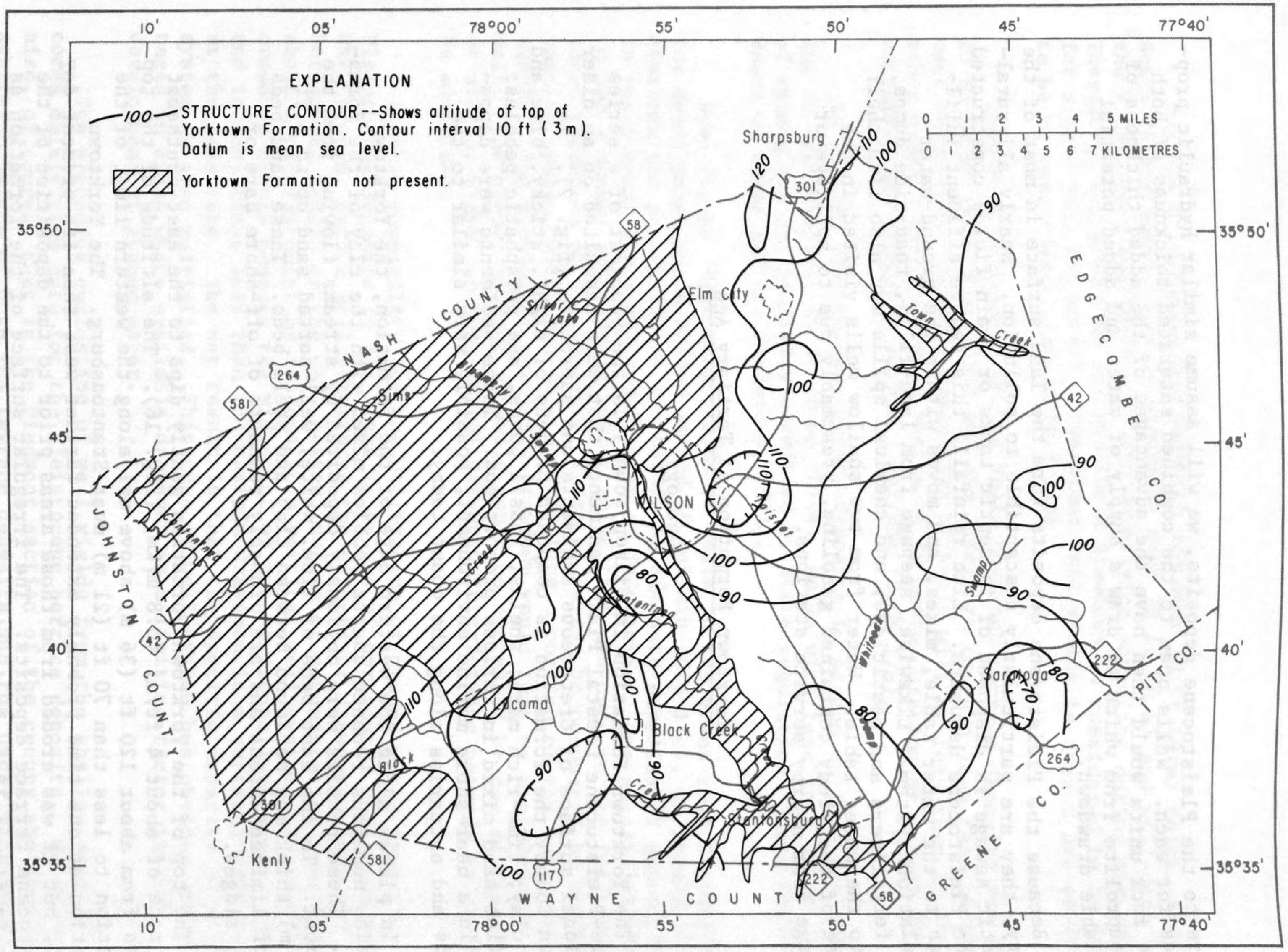


Figure 16.--Altitude of the top of the Yorktown Formation of Tertiary age.

The thickness of the Yorktown Formation, as shown in figure 17, increases in an eastward direction at a rate of nearly 4 ft/mi (0.8 m/km). The average thickness of the Yorktown Formation is about 30 ft (9 m); the maximum thickness is about 50 ft (15 m).

The small amount of sand in the Yorktown Formation (generally less than 25 percent) reflects its lack of potential as a major source of ground water in the county. Figure 18, which shows the distribution of sand in the formation, is based on drillers' logs and observations of well cuttings from a number of shallow wells penetrating the formation. The percentage of sand increases slightly towards the east and southeast. In a small area north of Saratoga, the formation consists of more than 50 percent sand. This may be due to the general thickening of the formation in this direction as well as a possible change in the environment of deposition of the sediments.

Hydrology

Because of its high percentage of clay and silt, the chief hydrologic significance of the Yorktown Formation in Wilson County is its role as a confining bed. The formation is relatively impermeable to the extent that it tends to impede the vertical movement of ground water (fig. 2). Consequently, the zone of greatest ground-water circulation remains above the Yorktown Formation in the shallow aquifer.

Head differences that exist between the water table and the deeper confined aquifers will cause small amounts of water to slowly move through the Yorktown Formation, a process generally known as leakage. Leakage through the Yorktown is an important source of recharge to the underlying Cretaceous aquifer, especially in the western part of the county where the formation contains larger percentages of sand. Except in stream valleys near the western margin of the Cretaceous subcrop, the water table is higher than the potentiometric head in the Cretaceous aquifer, and thus provides the driving force to move water downward through the Yorktown Formation. Assuming that the vertical hydraulic conductivity of the Yorktown is uniform, the amount of leakage through it would depend on the thickness of the formation and the amount of head difference between the water table and the potentiometric surface of the Cretaceous aquifer.

In a relatively narrow band along its western margin, the Yorktown lies directly on the saprolite (figs. 2 and 18). Leakage through the Yorktown here is not considered an important source of recharge to the underlying aquifer because the formation is composed largely of clay. The clay beds inhibit recharge to the saprolite and bedrock aquifer in these areas.

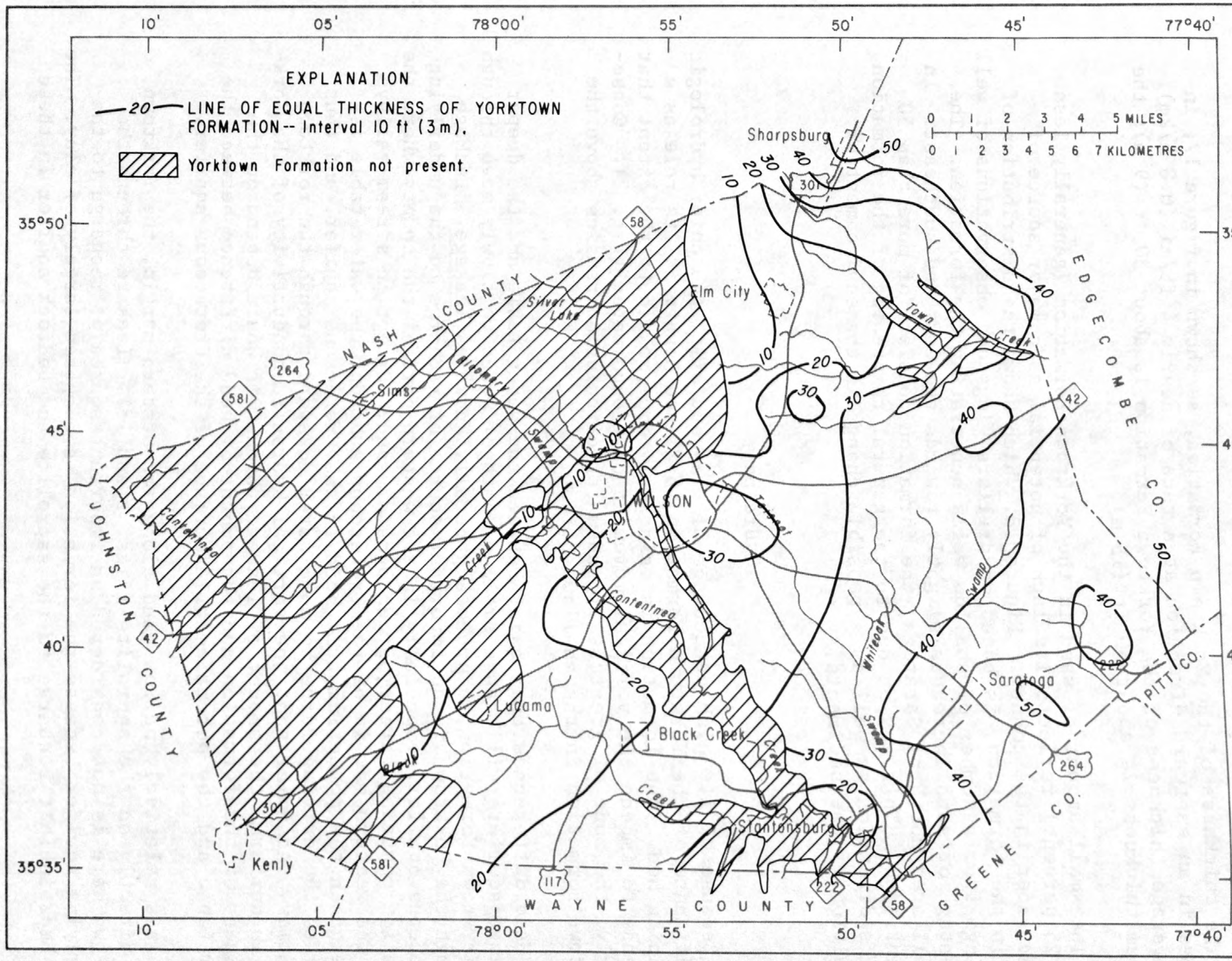


Figure 17.--Thickness of the Yorktown Formation of Tertiary age.

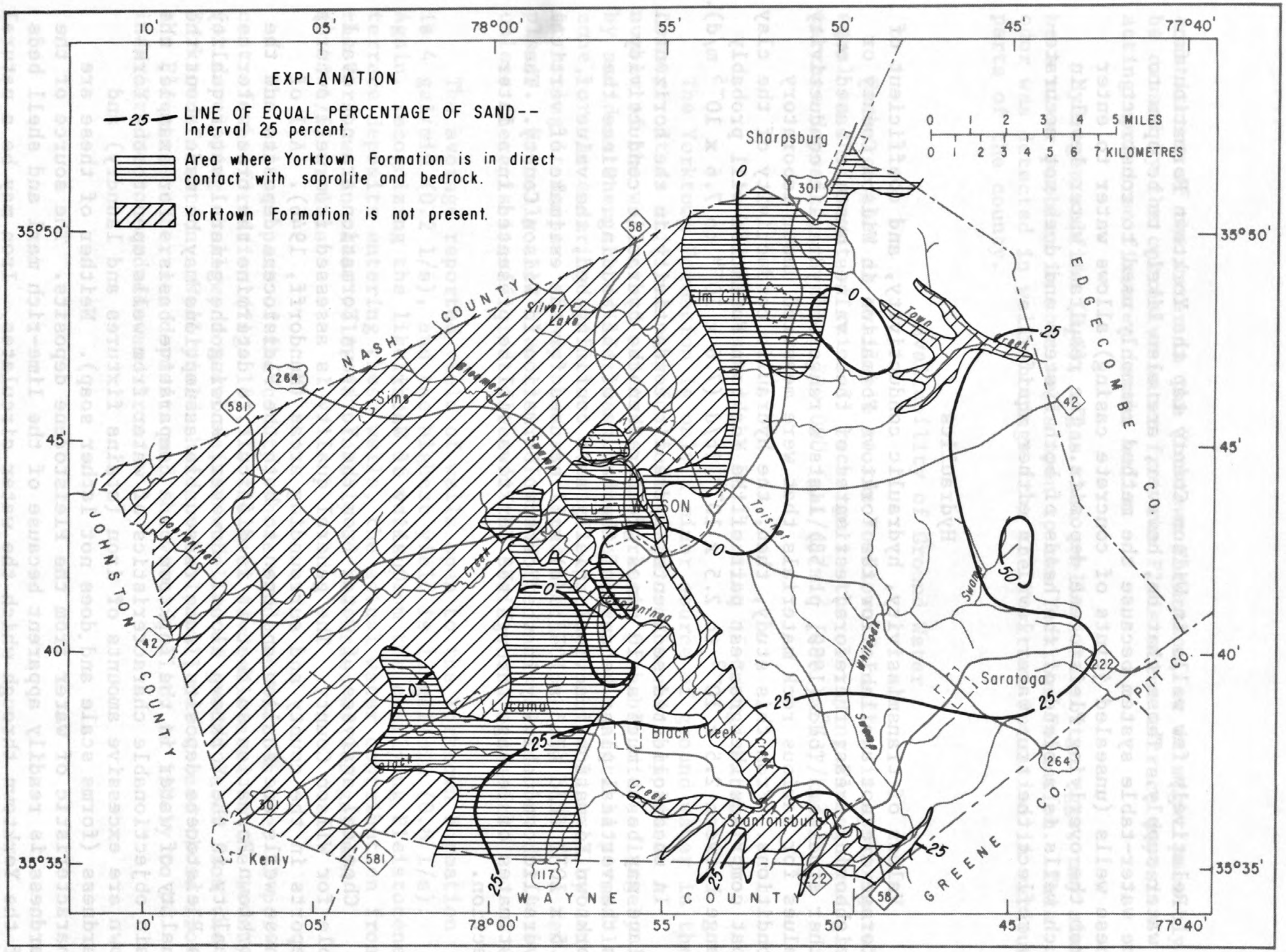


Figure 18.--Percentage of sand in the Yorktown Formation of Tertiary age.

Relatively few wells in Wilson County tap the Yorktown Formation for a water supply. Those that do, however, are also likely to be open to the water-table system because the method commonly used to construct these wells (unsealed joints of concrete casing) allows water to enter from the overlying Pleistocene deposits. The resultant water level in such wells is a blend of the heads of both systems and does not accurately reflect the true water level in either aquifer.

Hydraulics

Values of transmissivity, hydraulic conductivity, and coefficient of storage are not available for the Yorktown Formation in Wilson County or neighboring areas; therefore, estimates of these values must be based on other studies. Todd (1959, p. 53) lists a range of hydraulic conductivity values for various rock materials that were measured under laboratory conditions. From this study, then, the hydraulic conductivity of the clay that comprises the greatest part of the Yorktown Formation will probably range between 2.5×10^{-3} to 2.5×10^{-4} ft/d (7.6×10^{-4} to 7.6×10^{-5} m/d).

In unconsolidated sediments, hydraulic conductivity in the horizontal plane may be as much as 10 times greater then the hydraulic conductivity in the vertical plane because of the nature of the bedding. Since the Yorktown Formation functions chiefly as a confining bed, the value of 2.5×10^{-4} ft/d (7.6×10^{-5} m/d) will be used for the estimate of vertical hydraulic conductivity in the Yorktown Formation in Wilson County. The estimates of leakage through the Yorktown will be presented in a later section.

Quality of Water

Chemical analyses of water from the Yorktown Formation are not available for Wilson County. The general quality is assessed from well owner's reports in the county and surrounding areas (Mundorff, 1946). All of these wells are shallow and open to both the Pleistocene deposits and the Yorktown Formation so that it is difficult to determine the true water quality in the Yorktown alone. However, knowing the general water quality in Pleistocene deposits, some reasonable assumptions may be made about the quality of water in the Yorktown on a comparative basis. For example, the main objectionable characteristics of water from wells open to the Yorktown are excessive amounts of iron (stains fixtures and laundry) and hardness (forms scale and does not lather soap). Neither of these are characteristic of water from the Pleistocene deposits. The source of the hardness is readily apparent because of the lime-rich marl and shell beds of the Yorktown through which the water circulates. Iron may be a natural constituent of the water in the Yorktown Formation, or it might possibly be caused by the corrosive water from the Pleistocene terrace deposits acting upon iron fixtures in the wells.

Hydrogen sulfide (H_2S), a gas that smells like rotten eggs, may also be a minor problem in some wells open to the Yorktown Formation. This odor was detected in well cuttings from the Yorktown Formation in various parts of the county.

Availability of Ground Water

Recharge that is available to the Yorktown Formation is approximately equal to the amount of rainfall recharge to the overlying Pleistocene terrace deposits, or about 330,000 (gal/d)/mi^2 [495 (m^3/d)/km^2].

Well Yields and the Utilization of Ground Water

The Yorktown Formation is only a minor source of ground water in the county. It is utilized only for a few farm or domestic supplies. A number of the wells that penetrate the Yorktown probably did so largely by accident when the driller was boring in search of a suitable permeable zone, or was ensuring sufficient storage capacity within the well by constructing it deeper. Sandy beds are found in the Yorktown only in a few places. Normally the "blue clay" of the Yorktown is avoided by drillers unless there is insufficient water in the Pleistocene sediments.

The average reported yield of wells open to the Yorktown Formation is 4 gal/min (0.2 l/s), and the highest yield is 12 gal/min (0.8 l/s). Again, recognizing the likelihood of water from the overlying Pleistocene terrace deposits entering these wells, the actual water contribution from the Yorktown in these wells is probably on the order of 0.5 gal/min (0.03 l/s) or less.

The eastern part of the county, where sand constitutes over 25 percent of the formation (fig. 18), is the most favorable area in the county for developing shallow, domestic-sized supplies of ground water from the Yorktown Formation. Well yields here probably will not exceed those from the Pleistocene terrace deposits and the water quality is likely to be inferior due to hardness and iron.

Cretaceous Aquifer

Geology

In the eastern part of Wilson County the Yorktown Formation is underlain by the Cretaceous aquifer system. The Cretaceous aquifer is composed of interbedded, red and brown sands and clays that are believed to have been deposited under fluvial conditions similar to the Pleistocene terrace deposits. Individual beds are commonly heterogeneous mixtures of a wide range of particle sizes with one size range predominant to typify the bed as being a sand or a clay.

The top of the Cretaceous aquifer shown in figure 19 slopes to the east-southeast at an average rate of about 5 ft/mi (0.9 m/km). The depth to the top of the Cretaceous aquifer below land surface at any given place may be calculated by subtracting the altitude of the top of the Cretaceous aquifer (fig. 19) from the altitude of land surface taken from a topographic map. The Cretaceous aquifer pinches out just east of and generally parallel with the westernmost occurrence of the Yorktown Formation. The western limits of both series of sediments may be compared in figure 18.

The Cretaceous sediments, which contain the chief water-bearing sand beds in the county, attain their maximum thickness of about 150 ft (46 m) in the extreme eastern part of the county (fig. 20). Individual sand beds range from 5 to 15 ft (1.5 to 4.6 m) in thickness; however, due to the fluvial nature of these deposits, most beds are discontinuous from place to place and vary in thickness. The total accumulation of individual sand beds at any one place averages about 35 to 45 ft (11 to 14 m) in thickness, but may be as much as 60 ft (18 m) thick in some places.

A cross section (fig. 21) was prepared to show the general distribution of sand beds in the Cretaceous aquifer and overlying formations. The section lies in a northeast-southwest direction in eastern Wilson County, approximately along the strike of the sediments. The thickness and extent of individual sand beds was based on interpretations from both drillers' logs and gamma-ray logs of water wells.

The fluvial nature of the Cretaceous deposits is illustrated by the sand and clay beds. Several thin beds can merge to form one relatively thick bed; other beds apparently pinch out abruptly. Distinct, areally extensive sand or clay beds over 10 ft (3 m) thick are not common in the Cretaceous aquifer of Wilson County.

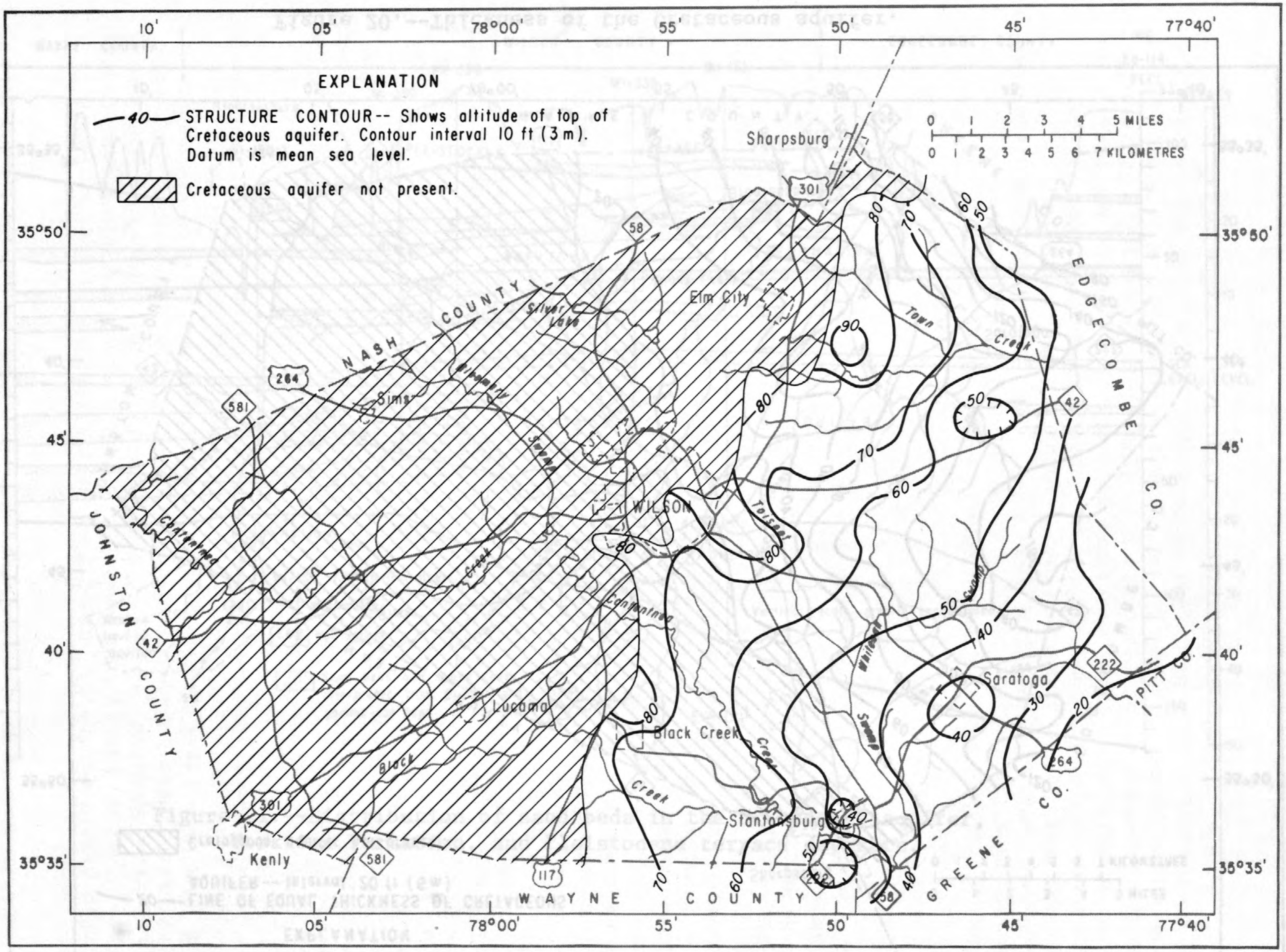


Figure 19.--Altitude of the top of the Cretaceous aquifer.

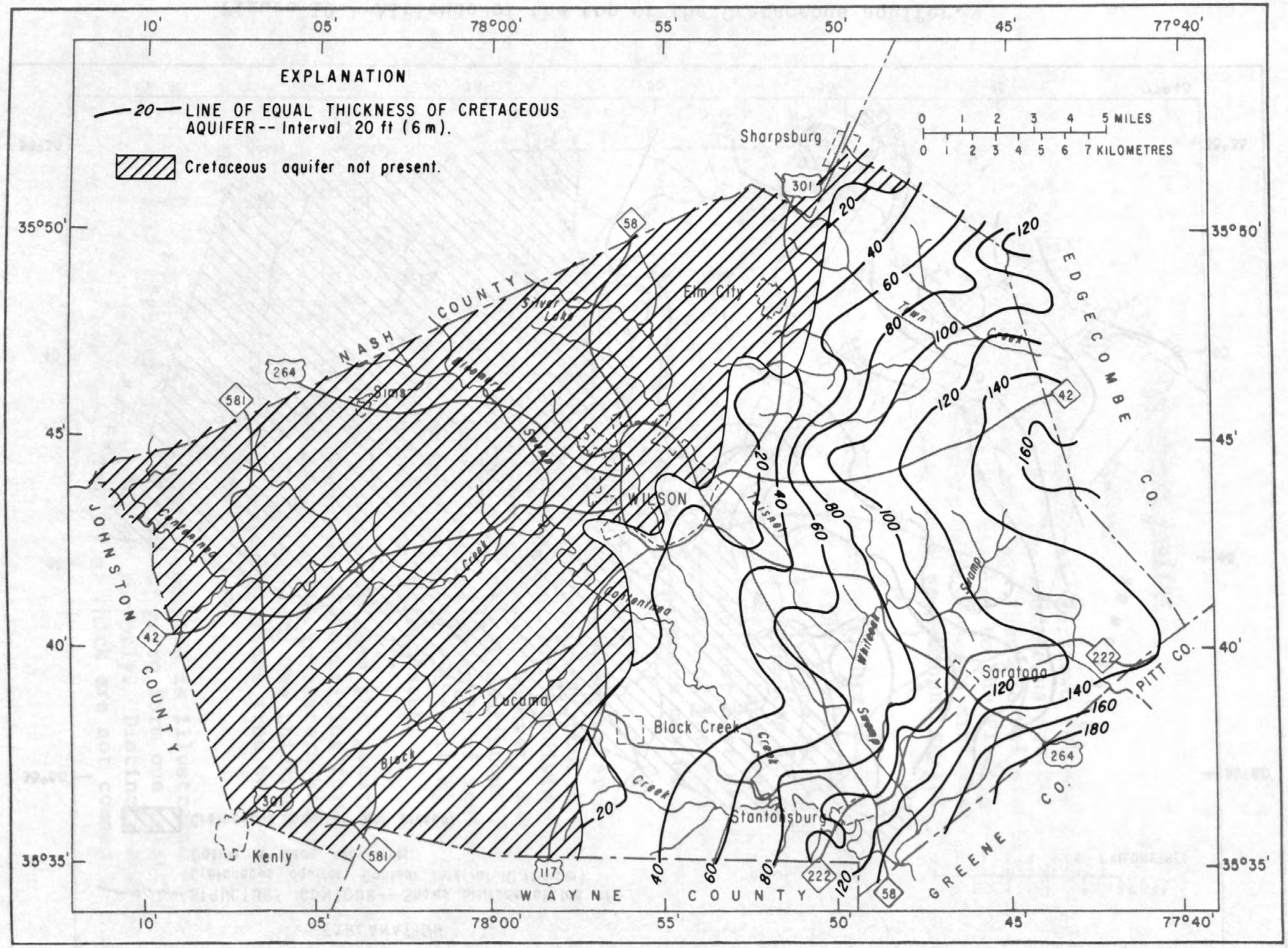


Figure 20.--Thickness of the Cretaceous aquifer.

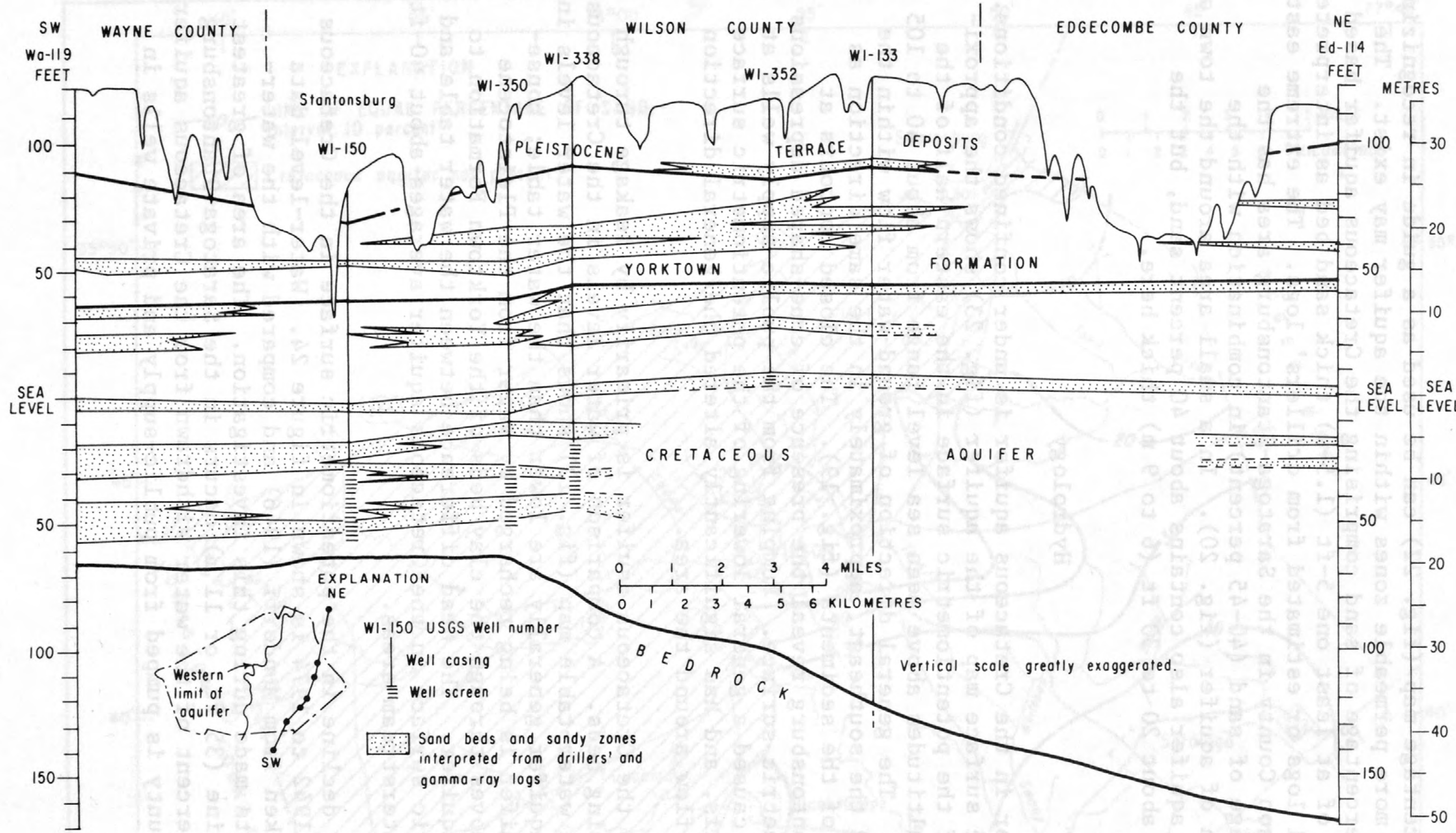


Figure 21.--Distribution of sand beds in the Cretaceous aquifer, Yorktown Formation, and Pleistocene terrace deposits.

A sand percentage map (fig. 22) can be used as a guide in recognizing areas where the more permeable zones within the aquifer may exist. The map shows the percentage of sand comprising the Cretaceous aquifer based on the presence of at least one 5-ft (1.5-m) thick sand bed as interpreted from geophysical logs or estimated from drillers' logs. The extreme eastern part of Wilson County in the Saratoga-Stantonsburg area has the highest percentage of sand (40-45 percent) in combination with the thickest section of aquifer (fig. 20). In a small area around the town of Black Creek the aquifer also contains about 40 percent sand, but the aquifer is only about 20 to 30 ft (6 to 9 m) thick here.

Hydrology

Ground water in the Cretaceous aquifer is under confined conditions. A potentiometric surface map of the aquifer (fig. 23) shows the approximate altitude of the potentiometric surface in the eastern half of the county. These altitudes above mean sea level range from about 40 to 105 ft (12 to 32 m). The general direction of ground-water flow within the system is toward the southeast, approximately in the same direction as the general dip of the sediments (fig. 19). The closed contours at Saratoga and Stantonsburg reveal the presence of cone-shaped depressions in the potentiometric surface. Pumping from the public-supply wells at these towns has caused a general lowering of the potentiometric surface around these wells, and has significantly altered the general direction of ground-water flow around the area.

Recharge to the Cretaceous aquifer is primarily by leakage through overlying confining beds. A comparison of water levels in the Cretaceous aquifer with the water-table map (fig. 12) shows that the water levels in the Cretaceous aquifer generally are lower than the water table; consequently, the aquifer is being recharged by water from the Pleistocene deposits which moves through the clay beds of the Yorktown Formation to the Cretaceous aquifer. The head difference between the water table and the potentiometric surface in the Cretaceous aquifer averages about 40 ft (12 m) in the interstream areas.

The general decline in the potentiometric surface in the Cretaceous aquifer between 1942 to 1974 is shown in figure 24. Water-level data for 1942 were taken from Mundorff (1946) and compared with the water-level measurements made during this investigation. The area of greatest water-level decline (35 ft, or 11 m) occurs in the Saratoga-Stantonsburg area. Over 90 percent of the water withdrawn from the Cretaceous aquifer within Wilson County is pumped from public-supply and private wells in this area.

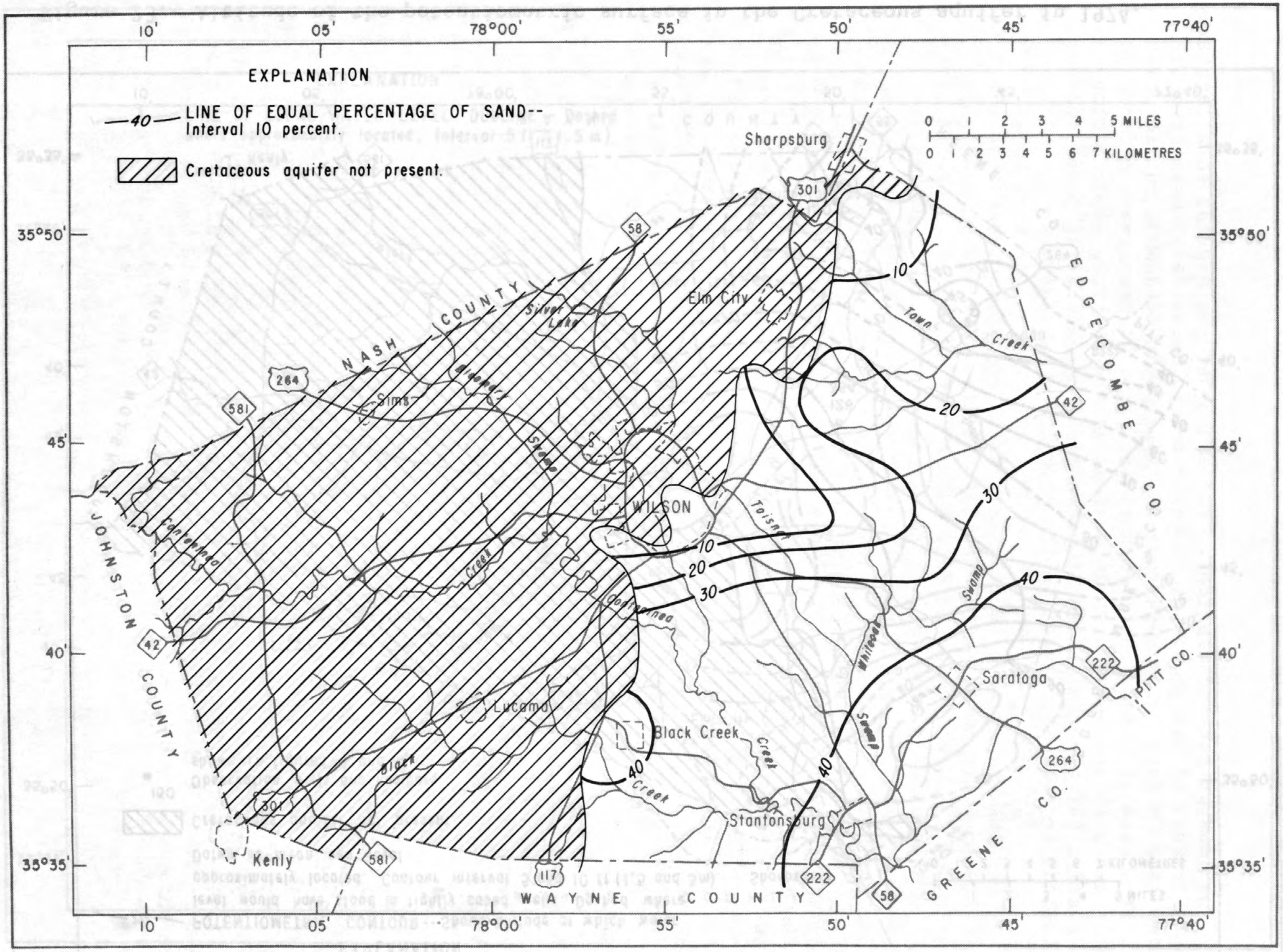


Figure 22.--Percentage of sand in the Cretaceous aquifer.

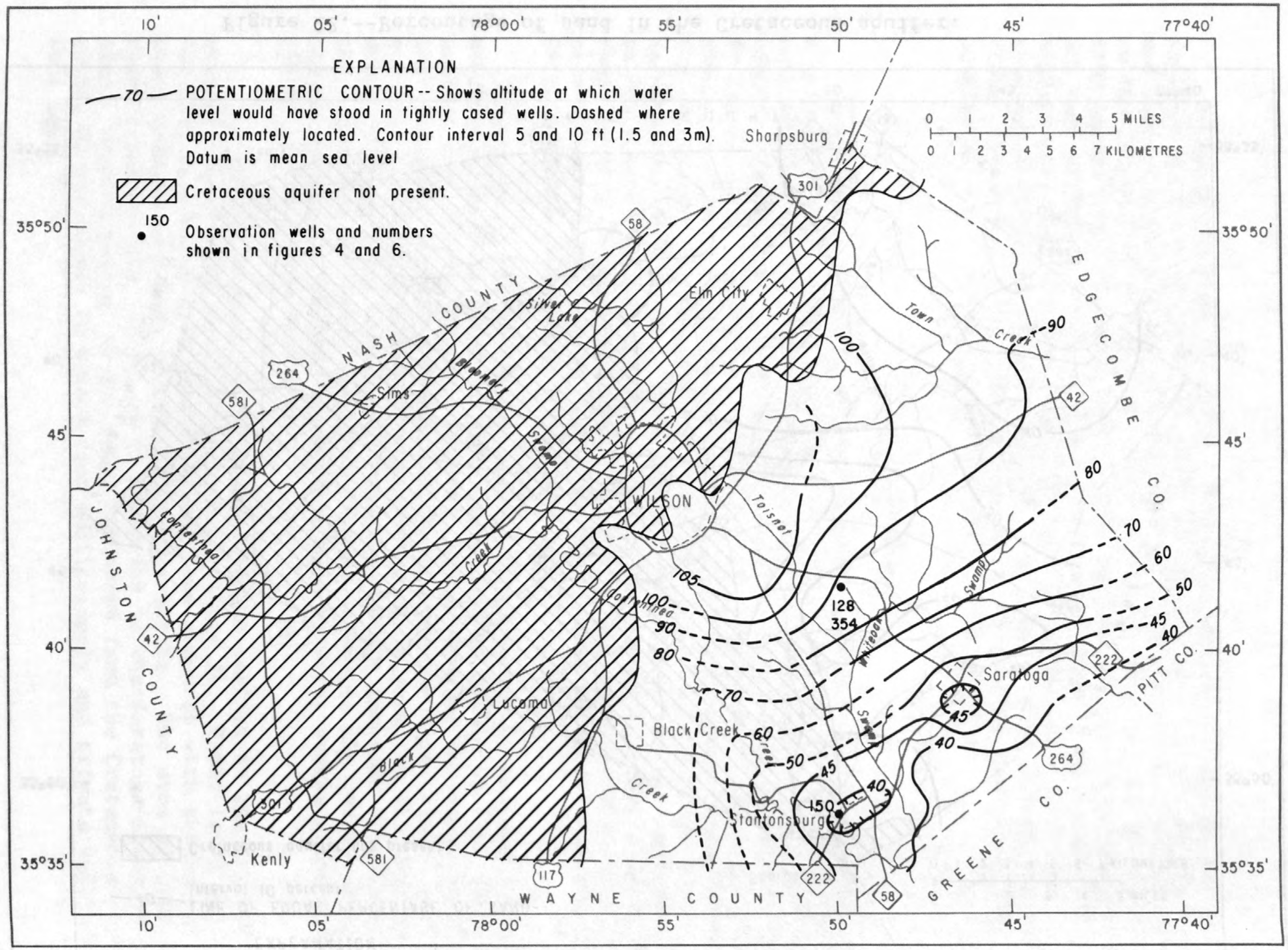


Figure 23.--Altitude of the potentiometric surface in the Cretaceous aquifer in 1974.

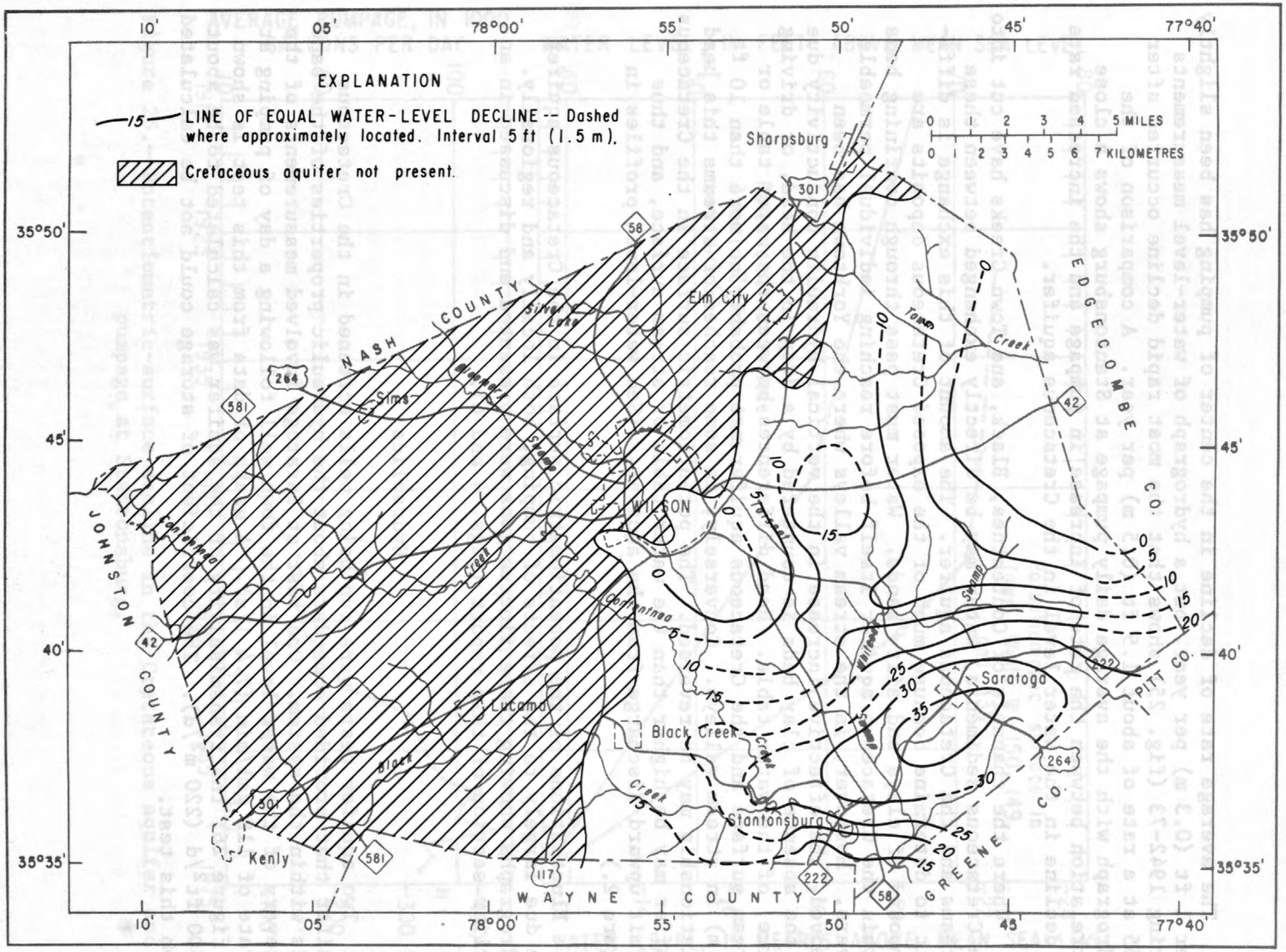


Figure 24.--Decline in the potentiometric surface in the Cretaceous aquifer between 1942 and 1974.

The average rate of decline in the center of pumping has been slightly over 1 ft (0.3 m) per year, but a hydrograph of water-level measurements during 1942-73 (fig. 25) shows that the most rapid decline occurred after 1955 at a rate of about 1.5 ft (0.5 m) per year. A comparison of the hydrograph with the average daily pumpage at Stantonsburg shows a close correlation between the rate of increase in pumpage and the increased rate of decline in the water level in the Cretaceous aquifer.

Where the channels of Contentnea, Black, and Town Creeks have cut into the Cretaceous sediments, water may be directly exchanged between these streams and the Cretaceous aquifer. The amount of this exchange is difficult to determine because much of the exposed Cretaceous deposits are composed of clays and silty sands. Water must pass through confining beds within the Cretaceous aquifer itself before reaching individual permeable layers. Moreover, in the stream valleys where the Yorktown has been removed, the effective increase in the vertical hydraulic conductivity due to the absence of clay beds is countered by a drop in the head, or driving force, of the water table. Head differences between the water table or stream surface and the Cretaceous aquifer are probably no more than 10 ft (3 m) in stream valleys. Conversely, in some reaches of streams this head relationship may be reversed. The potentiometric surface in the Cretaceous aquifer may be higher than the water table or stream surface, and thus permit upward discharge from the aquifer. (See water-level profiles in figure 2.)

Fluctuations of the potentiometric surface in the Cretaceous aquifer are due largely to the effects of pumping, both locally and regionally. Hydrographs showing these fluctuations were presented and discussed in an earlier section of this report (figs. 4 and 6).

Hydraulics

Two aquifer tests were run using wells screened in the Cretaceous aquifer that provided some data about the hydraulic properties of the sand beds within the system. One test at Saratoga involved measurements of the recovery of the water level in the town well following a day of pumping at a rate of 118 gal/min (7.4 l/s). A graph of data from this test is shown in figure 26; the transmissivity of the aquifer was calculated to be about 2,400 ft^2/d (220 m^2/d). The coefficient of storage could not be calculated from this test.

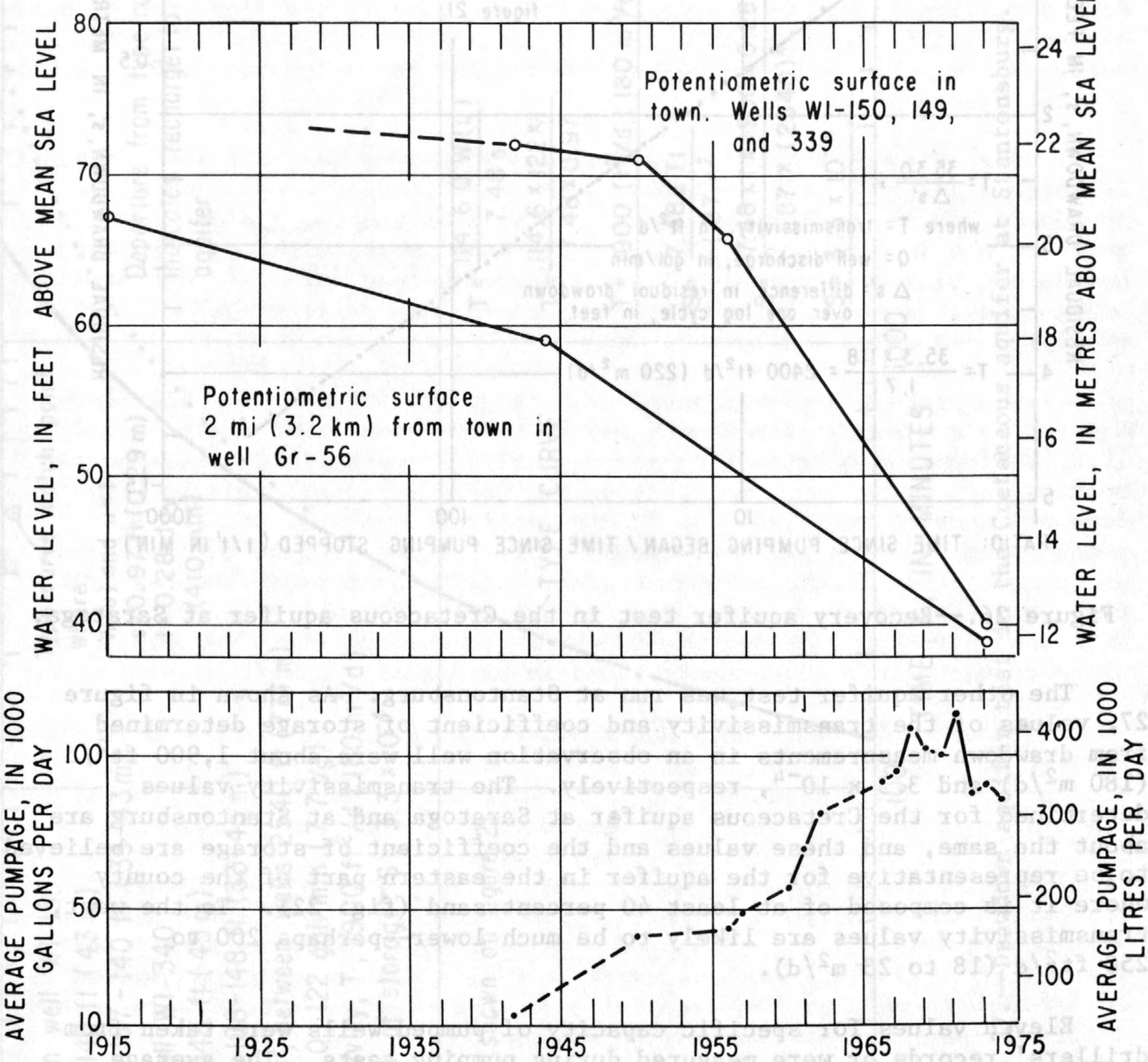


Figure 25.--Potentiometric-surface decline in the Cretaceous aquifer and pumpage at Stantonsburg.

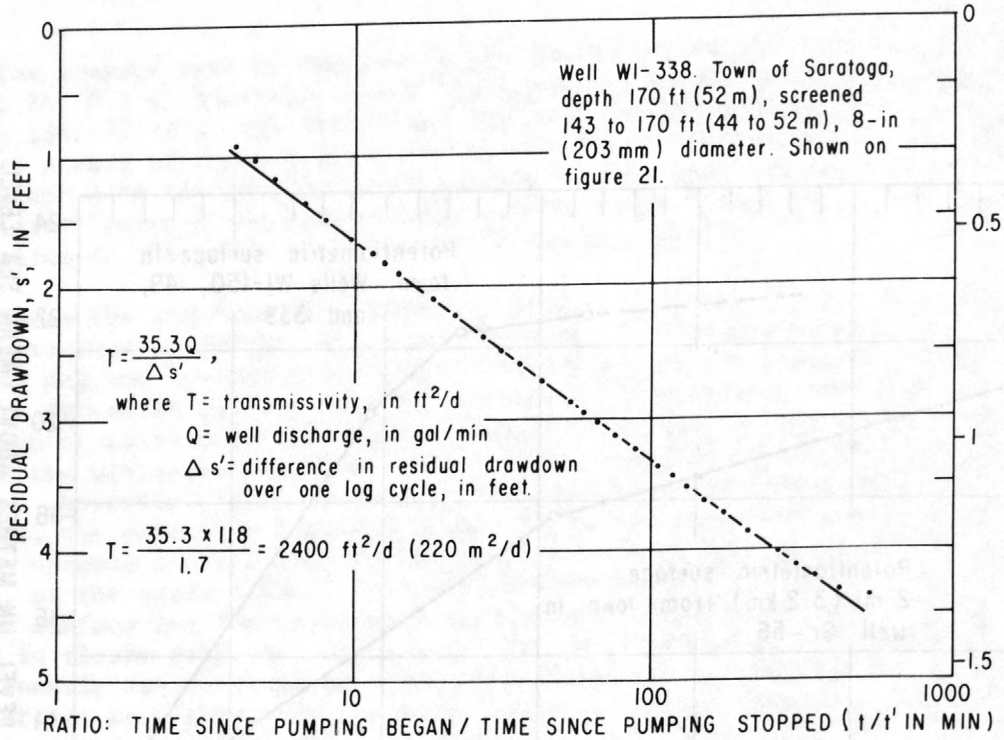


Figure 26.--Recovery aquifer test in the Cretaceous aquifer at Saratoga.

The other aquifer test was run at Stantonsburg. As shown in figure 27, values of the transmissivity and coefficient of storage determined from drawdown measurements in an observation well were about 1,900 ft^2/d (180 m^2/d) and 3.3×10^{-4}, respectively. The transmissivity values determined for the Cretaceous aquifer at Saratoga and at Stantonsburg are about the same, and these values and the coefficient of storage are believed to be representative for the aquifer in the eastern part of the county where it is composed of at least 40 percent sand (fig. 22). To the west, transmissivity values are likely to be much lower--perhaps 200 to 250 ft^2/d (18 to 23 m^2/d).

Eleven values for specific capacity of pumped wells were taken from drillers' records or were measured during pumping tests. The average specific capacity was 3.4 (gal/min)/ft, or 0.70 (l/s)/m, and the values ranged from 0.44 to 10 (gal/min)/ft, or 0.09 to 2.1 (l/s)/m. Pumping time for most of these tests exceeded 18 hours.

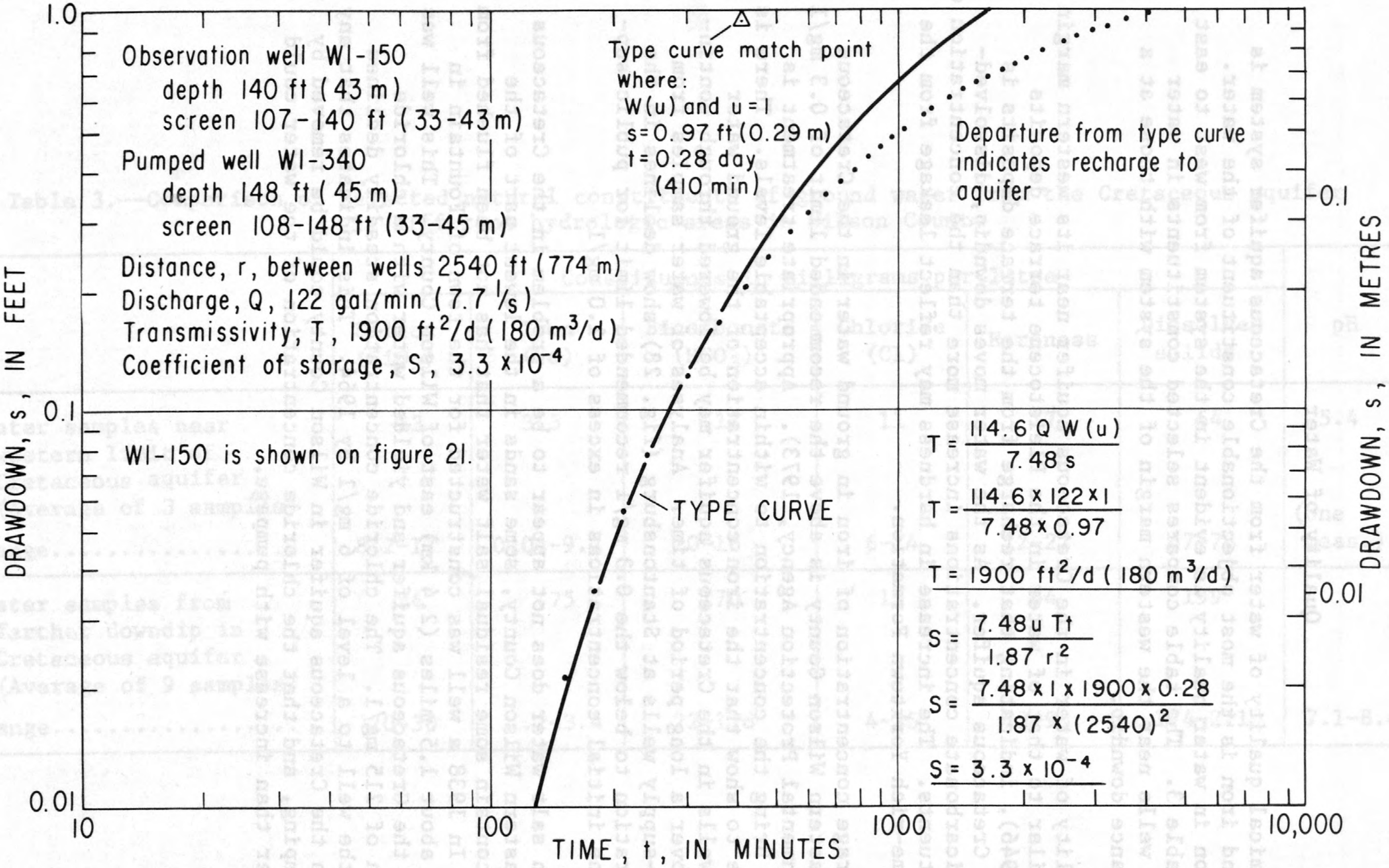


Figure 27.--Drawdown aquifer test in the Cretaceous aquifer at Stantonsburg.

Quality of Water

The chemical quality of water from the Cretaceous aquifer system is very good, and iron is the most objectionable constituent of the water. Some variation in water quality is evident in the system from west to east as seen in table 3. The table compares selected constituents in water samples from wells near the western margin of the system with those at a greater distance downdip.

The quality of water in the Cretaceous aquifer near its western margin is quite similar to that of water in the Pleistocene terrace deposits (Mundorff, 1946), indicating that recharge from the terrace deposits is entering the Cretaceous aquifer. As the water moves downdip, dissolved-solids and bicarbonate concentrations increase more than the concentration of other constituents. The increase in hardness may reflect leakage from the overlying lime-rich Yorktown Formation.

The average concentration of iron in ground water in the Cretaceous aquifer in eastern Wilson County is above the recommended limit of 0.3 mg/l (U.S. Environmental Protection Agency, 1973). Appropriate treatment is necessary to bring the concentration to within acceptable levels. There is some evidence to show that the iron concentration of the ground water pumped from wells in the Cretaceous aquifer may be lowered through continual pumping over a long period of time. Analyses of water samples from three public-supply wells at Stantonsburg (fig. 28) show declines in the iron concentration to below the 0.3 mg/l recommended limit for public supplies from the initial concentrations in excess of 1.0 mg/l.

Although salt water does not appear to be a problem in the Cretaceous aquifer of eastern Wilson County, some sands in the lowest part of the aquifer may contain some residual salt water that has not been flushed from the system. In 1938 a well was constructed for the town of Fountain in Pitt County, about 1.5 miles (2.4 km) east of Wilson County. This well was completed in the Cretaceous aquifer and yielded water with a chloride concentration of 215 mg/l. The chloride concentration steadily declined with use of the well to a level of 6 mg/l by 1964. This indicates that any salt water in the Cretaceous aquifer in Wilson County could be removed by long-term pumping, and that the chloride concentration of the water could decline rather than increase with pumpage.

Table 3.--Comparison of selected natural constituents of ground water from the Cretaceous aquifer in different hydrologic areas in Wilson County

	Constituents in milligrams per litre						
	Silica (SiO_2)	Iron (Fe)	Bicarbonate (HCO_3)	Chloride (Cl)	Hardness	Dissolved solids	pH
Water samples near western limit of Cretaceous aquifer (Average of 3 samples)	13	3.3	12	11	17	64	5.4
Range..................	8.2-17	0.04-9.2	10-16	6-14	12-22	47-78	(one meas.)
Water samples from farther downdip in Cretaceous aquifer (Average of 9 samples)	24	.75	170	12	84	199	
Range..................	20-30	.2-3.4	22-178	4-25	73-93	174-211	7.1-8.4

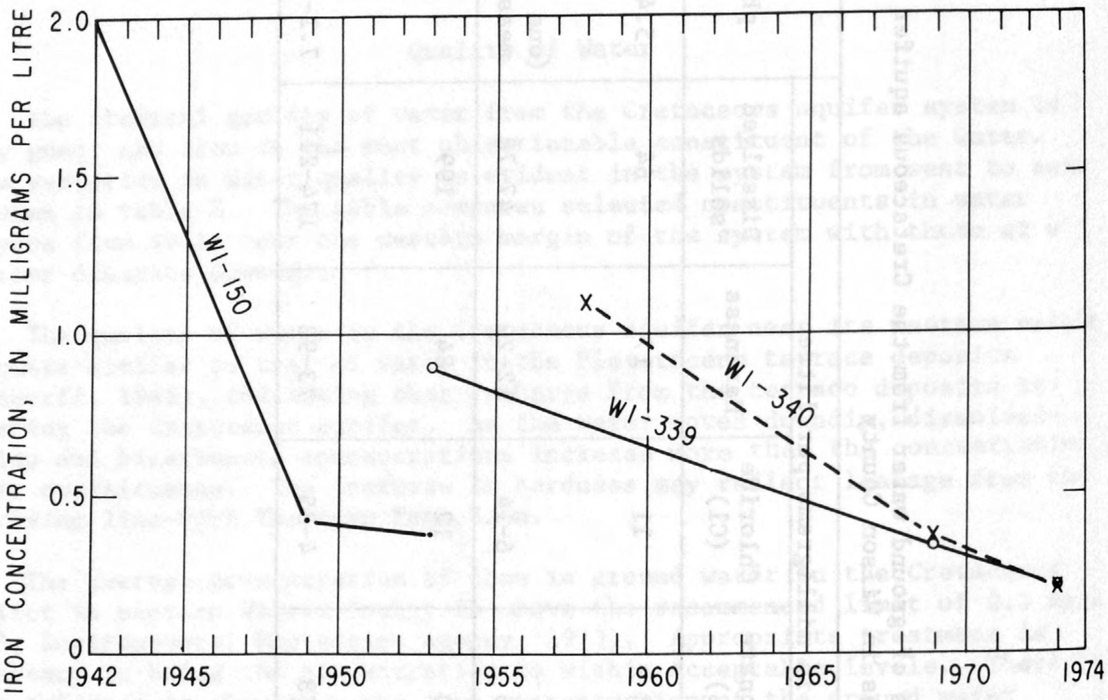


Figure 28.--Decline in the iron concentration of water from public-supply wells at Stantonsburg.

Availability of Ground Water

Because the Cretaceous aquifer cannot be recharged directly by rainfall, the availability of water in this aquifer depends largely upon leakage through overlying confining beds. The rate of leakage is controlled by the vertical hydraulic conductivity of overlying confining beds, the thickness of those beds, and the difference in head between the potentiometric surface in the Cretaceous aquifer and the water table in the shallow aquifer. The average rate of leakage into the Cretaceous aquifer can be estimated by using the following assumed values: (1) an average vertical hydraulic conductivity of the Yorktown Formation (primarily clay) is about 2.5×10^{-4} ft/d (7.6×10^{-5} m/d), (2) an average vertical hydraulic conductivity of the Pleistocene terrace deposits (sandy in nature) is about 2.5×10^{-3} ft/d (7.6×10^{-4} m/d), (3) the average thickness of the Yorktown Formation is 30 ft (9 m), (4) the average saturated thickness of the Pleistocene terrace deposits is 10 ft (3 m), and (5) the average head difference between the water table of the shallow aquifer and potentiometric surface of the Cretaceous aquifer is about 40 ft (12 m). These values give an estimated average rate of leakage into the Cretaceous aquifer of about 67,000 (gal/d)/mi^2 (100 (m^3/d)/km^2).

If the potentiometric head in the Cretaceous aquifer is lowered below the top of the aquifer, the relatively small coefficient of storage for the confined aquifer (3.5×10^{-4}) would change to a larger specific yield (about 0.1) for the unconfined conditions. More water then would become temporarily available through the dewatering process until storage is depleted. This additional amount of water available from storage in the Cretaceous aquifer is estimated to be about 3.1×10^{8} gal/mi^2 (4.6×10^{5} m^3/km^2) in eastern Wilson County where the aquifer contains 40 percent sand (fig. 22), assuming (1) that the water level is lowered no more than 50 ft (15 m) below the top of the aquifer and (2) that the vertical hydraulic conductivities of the sand and clay beds in the Cretaceous aquifer are similar to those in the Pleistocene terrace deposits and the Yorktown Formation.

Additional recharge might be induced into the Cretaceous aquifer along reaches of Contentnea Creek, Black Creek, and Town Creek where these streams have cut into the Cretaceous aquifer. The amount of water that may infiltrate from these streams is difficult to assess without further study.

Well Yields and the Utilization of Ground Water

The largest users of ground water from the Cretaceous aquifer in Wilson County are the towns of Stantonsburg and Saratoga. Average daily pumpage in 1974 for these public supplies was about 91,000 gal/d (346 m^3/d) and 32,500 gal/d (124 m^3/d), respectively. In addition to this amount, as much as 10,000 gal/d (38 m^3/d) may also be pumped from as many as 50 privately-owned domestic and farm wells which tap the Cretaceous aquifer in the eastern part of the county.

The highest reported yield from any individual well was measured in the town supply well at Saratoga when it was drilled in 1956. This well (W1-338) was reported to have been pumped at the rate of 600 gal/min (38 l/s) during a 24-hour test. At the end of the test, the drawdown was 120 feet (36 m), and the specific capacity was 5 (gal/m)/ft, or 1.0 (l/s)/m. The well was screened from 143 to 170 ft (44 to 52 m). A subsequent geophysical log of the well revealed an additional 25 ft (7.6 m) of sand in the Cretaceous aquifer above the 143-ft (44-m) level that also could have been screened (fig. 21).

Individual well yields from the Cretaceous aquifer in the easternmost part of Wilson County may exceed 500 gal/min (32 l/s). (See fig. 29.) The potential-yield areas were mapped on the basis that the potential yield will be influenced by (1) the thickness of the aquifer, (2) the percentage of sand likely to be available, (3) wells that will be constructed so that they are open to all sand beds present in the aquifer, and (4) wells that will be developed as fully as possible for the greatest efficiency.

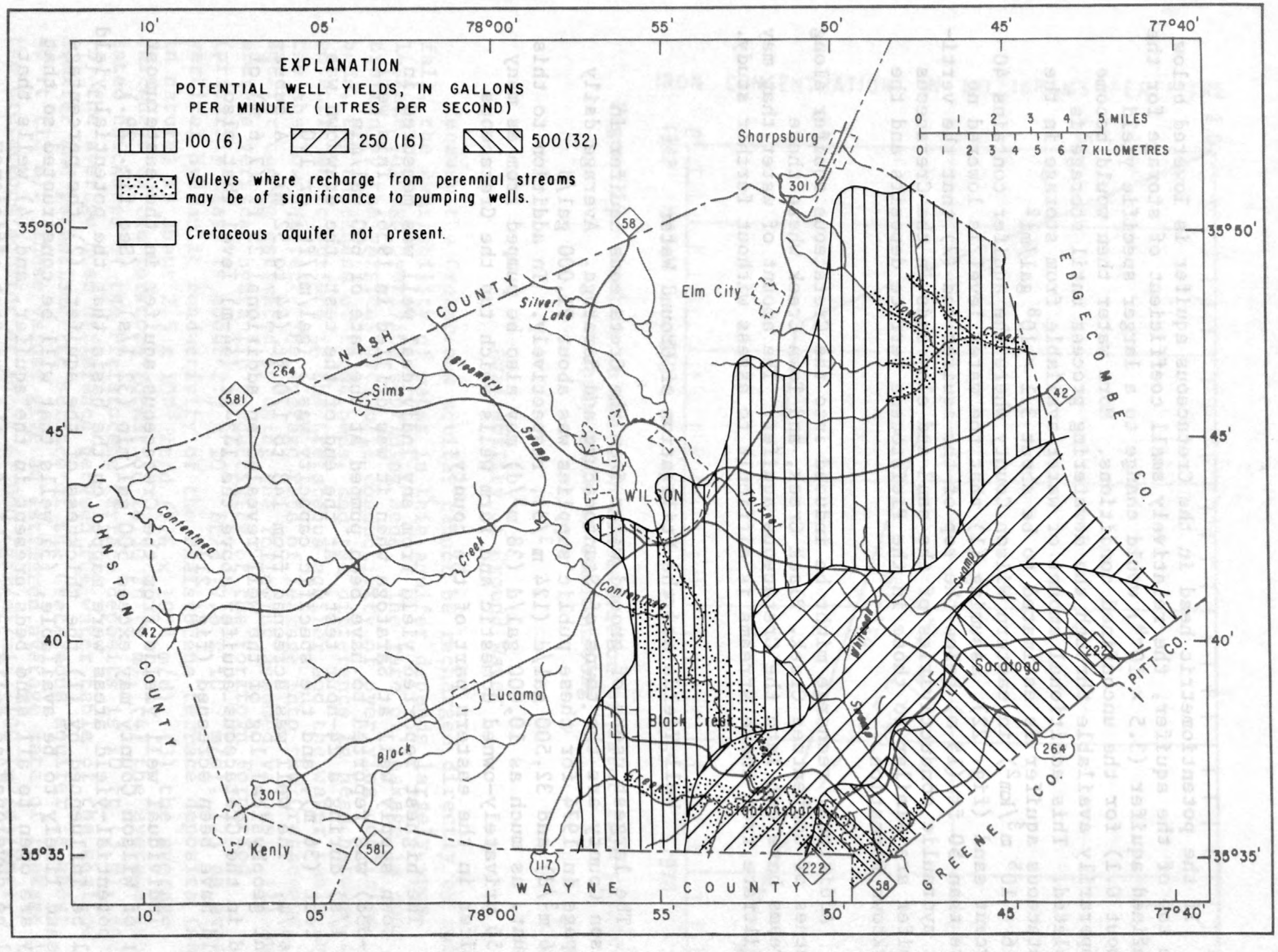


Figure 29.--*Areas of potential yield of individual wells in the Cretaceous aquifer.*

The most favorable area for large yields generally occurs southeast of a line between Stantonsburg and Saratoga. Here the aquifer exceeds 100 ft (30 m) in thickness and has a cumulative sand thickness of at least 40 ft (12 m). Less favorable areas are to the west where the aquifer is thinner and the percentage of sand declines. Also shown in figure 29 are valleys of streams whose channels have cut into the Cretaceous aquifer. These areas are significant because of the potential for artifically inducing recharge to wells located near the streams.

One might reasonably ask about the effects of pumping a Cretaceous-aquifer well at rates up to 500 gal/min (32 l/s), especially over a long period of time. Distance-drawdown effects in a confined aquifer, as noted earlier, are more areally extensive than those in the shallow unconfined aquifer. For example, the effects of pumping at the rate of about 100 gal/min (6.3 l/s) at Stantonsburg and Saratoga have produced cones of depression extending for some distance around these towns (fig. 23). In order to provide some means of estimating the effects of pumping at higher rates--up to 500 gal/min (32 l/s)--a distance-drawdown graph was prepared for the Cretaceous aquifer (fig. 30) similar to that for the Pleistocene terrace deposits (fig. 14), using aquifer coefficients obtained during the Stantonsburg test (fig. 27). A well pumping 500 gal/min (32 l/s) for 10 years would produce about 23 ft (7 m) of drawdown at a distance of 10,000 ft (3000 m) from the pumping well. This distance-drawdown relationship applies to the area southeast of Stantonsburg and Saratoga where the highest well yields are likely to occur in the Cretaceous aquifer (fig. 29).

It should be remembered that the same assumptions for an idealized aquifer mentioned earlier also apply to the drawdown curves calculated for the Cretaceous aquifer. Also, the graph is not adjusted for the effects of recharge, either by leakage through the Yorktown Formation or recharge from streams. These effects would reduce the amount of drawdown with both distance and time.

The effects of drawdown are additive as expanding cones of depression resulting from two or more pumping wells overlap one another. Figure 30 may also be used to estimate the appropriate distances for well spacing to minimize the amount of drawdown interference between two or more wells pumping from the aquifer.

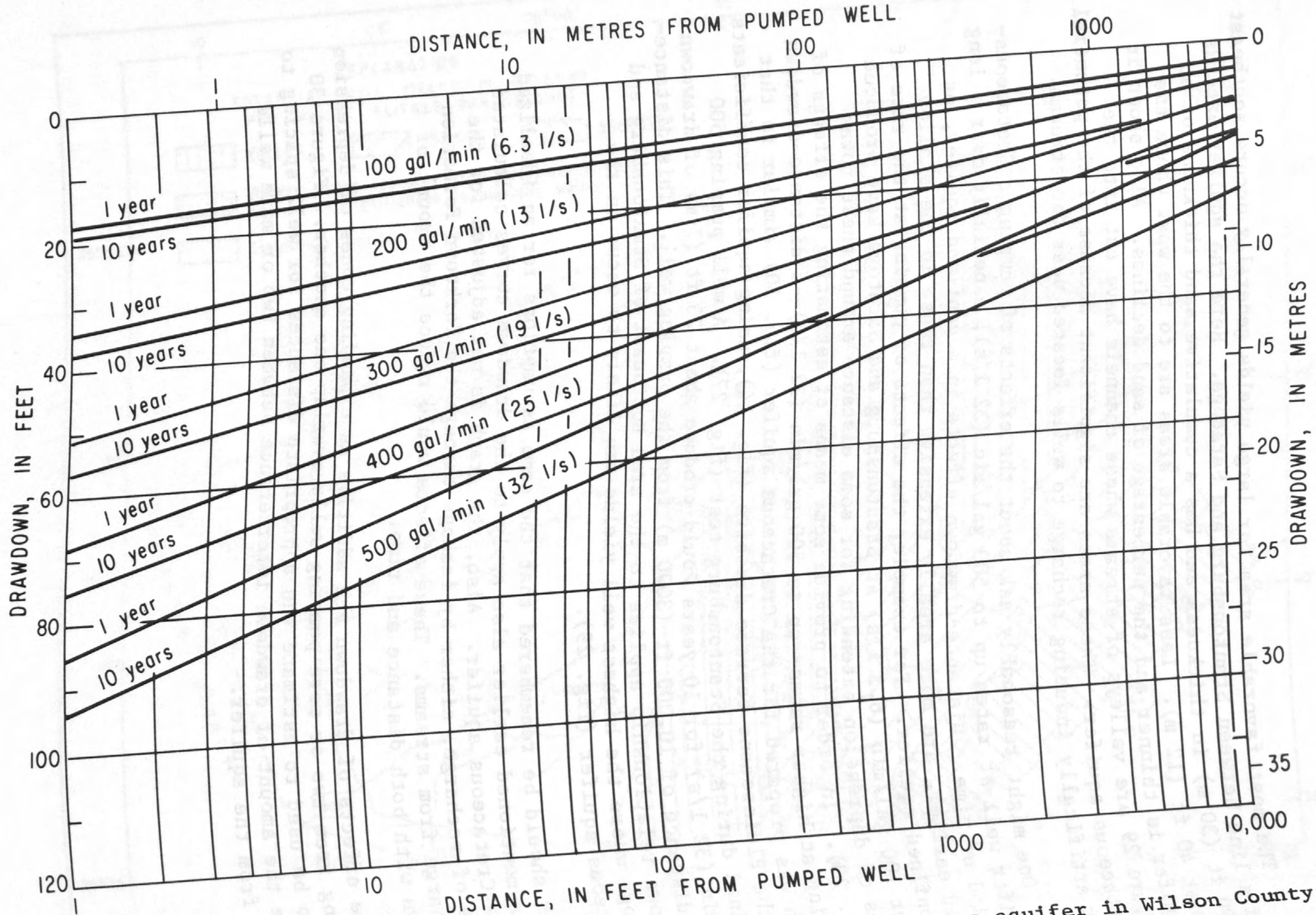


Figure 30.--Idealized distance-drawdown relationship in the Cretaceous aquifer in Wilson County after 1 and 10 years of pumping.

Bedrock Aquifer

Geology

The bedrock aquifer underlies all other geohydrologic systems in the county and is composed of igneous and metamorphic rocks of several varieties, the principal types of which are granite, slate, and schist. A geological map of the basement rocks (fig. 31) was prepared from drillers' records of well cuttings and from observations at rock outcrops. No attempt was made to distinguish between pink and gray types of granite, or granite-like rocks that occur in the eastern part of the county. All of these rocks were mapped as granite. Similarly, slate includes slate-like graywacke, and schist includes schist-like phyllitic rocks.

In several areas the occurrence of granite is shown below slate or schist; this was done in order to indicate the lateral extent of these intrusive granitic bodies. Granite is also reported to occur above other rocks in some wells. Few wells have been drilled to the basement rock in eastern Wilson County and the distribution of the various rock types is not known there.

The altitude of the top of the bedrock surface, based largely on well records, is shown in figure 32. Depth to the bedrock below land surface may be estimated with an accuracy of about ± 10 ft (3 m) by subtracting the rock surface altitude at a given place from the land surface altitude.

The bedrock surface in the western half of the county is irregular. It has many valleys and hills, the result of erosion by streams which have been acting upon the Piedmont rocks since they were exposed. The apparent uniformity of the bedrock surface in the eastern part of the county is due to a lack of data points rather than any effect of pre-burial erosion.

Hydrology

In the Piedmont section of the county the bedrock aquifer consists of two main zones, (1) an uppermost zone of clay and rock fragments formed by the weathering of the bedrock, and (2) the bedrock itself. The thickness of the weathered rock zone, or saprolite, depends upon the topography at any given site. Generally, the saprolite is thinner on hilltops and ridges, especially in areas of rock outcrops, than on the lower hill slopes and in valleys. However, a 15 to 20 ft (4.6 to 6 m) cover of Pleistocene terrace deposits makes assessment of saprolite thickness difficult based on post-Pleistocene topographic relationships.

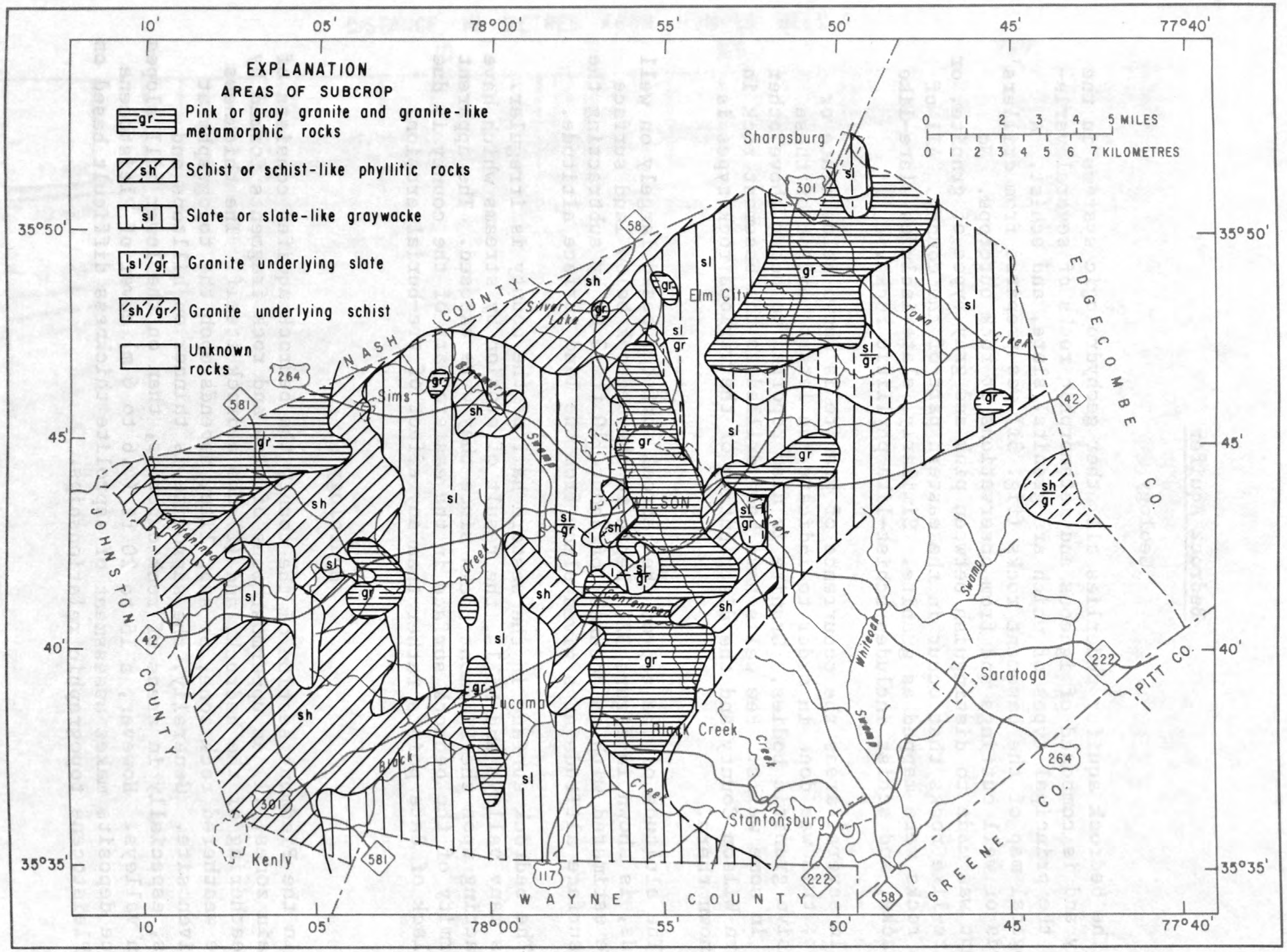


Figure 31.--General distribution of the major types of rocks in the bedrock aquifer.

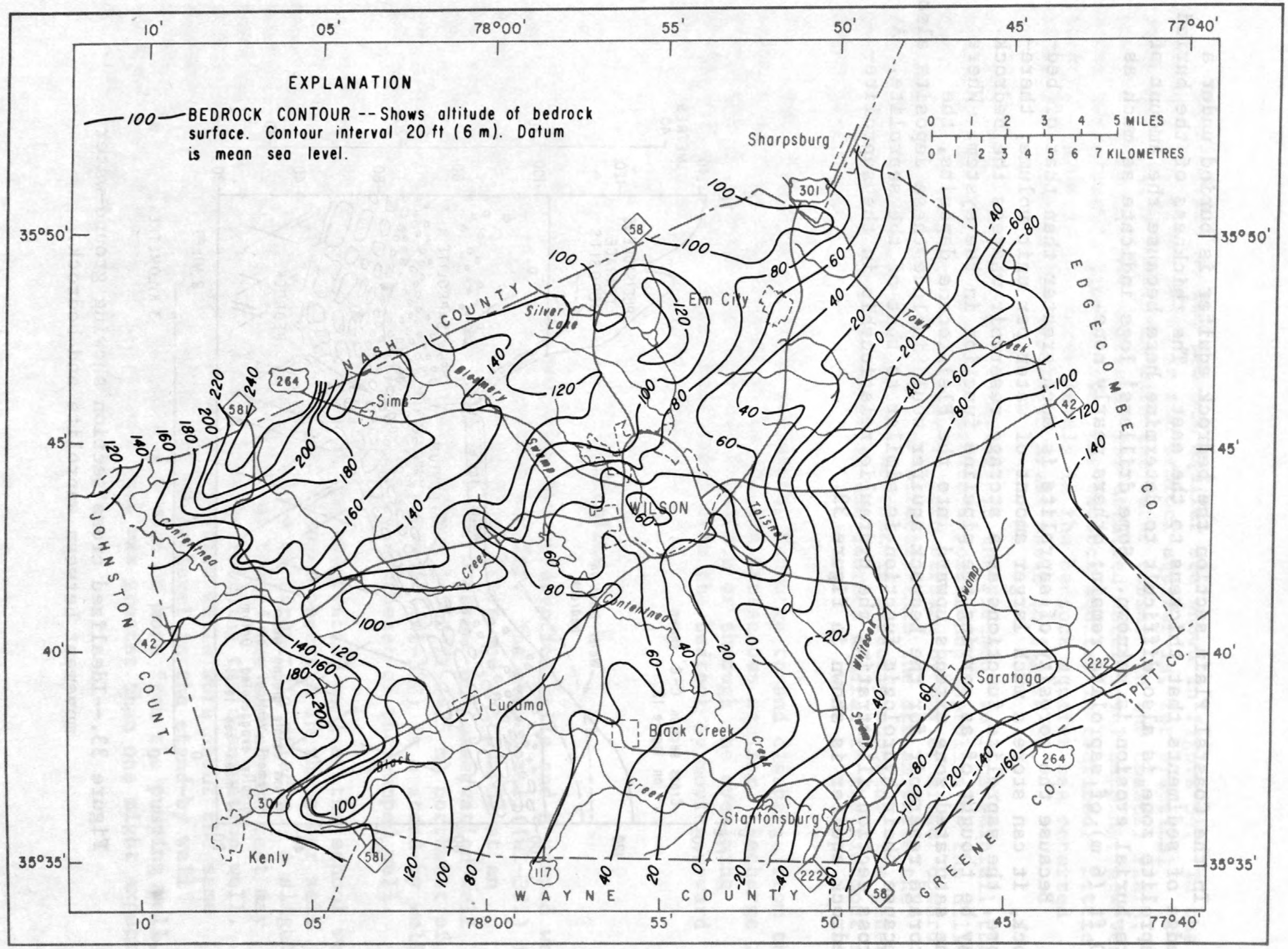


Figure 32.--Altitude of the top of the bedrock aquifer.

In the Coastal Plain section the bedrock aquifer is buried under a wedge of sediments that thickens to the east. The thickness of the buried saprolite zone is also difficult to determine here because the amount of pre-burial erosion is unknown. Some drillers' logs indicate as much as 20 ft (6 m) of saprolite remain; others nearly none.

Because the porosity of saprolite is much greater than that of bedrock, it can store a much larger amount of water per unit volume; therefore, the saprolite functions as a storage reservoir whereas the bedrock may be thought of as serving the pipeline function in the system. Where the saturated zone extends upward into the Pleistocene deposits, the storage reservoir for the bedrock aquifer would include these deposits also because their hydrologic function is similar to that of the saprolite. A cross section illustrating the hydraulic relationship in the saprolite-bedrock aquifer is shown in figure 33.

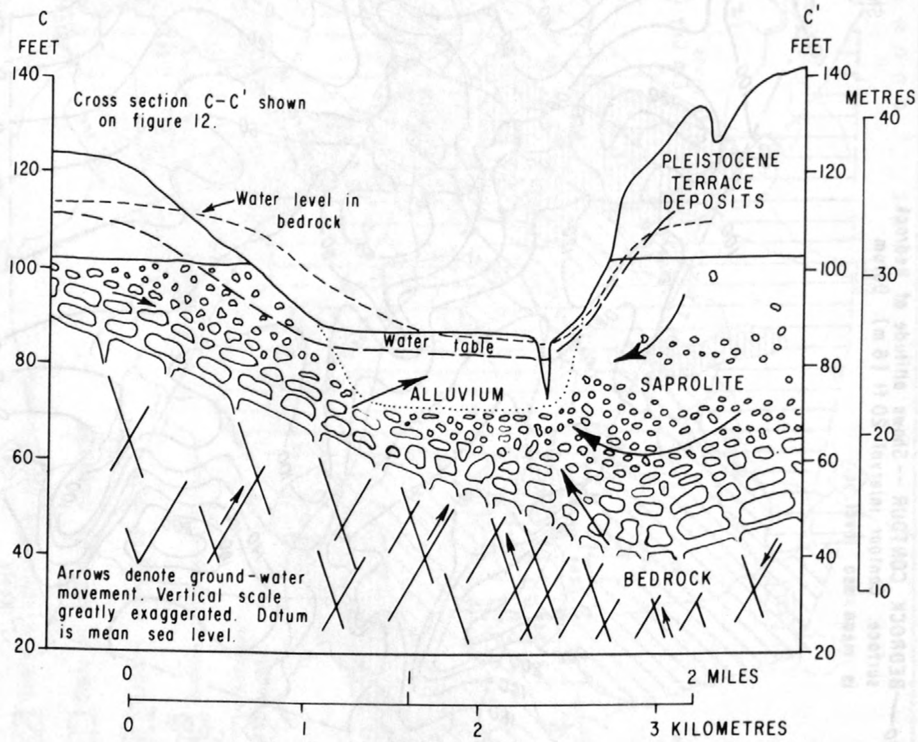


Figure 33.--Idealized cross section showing ground-water movement between saprolite and bedrock.

Water levels in the bedrock aquifer are shown in figure 34. In the Piedmont, the water level in the bedrock aquifer is, for practical purposes, nearly identical with the water table. In the Coastal Plain, however, data are not available for detailed water-level mapping; however, a few measurements suggest that the bedrock aquifer is confined. Little, if any, change in the water levels in the bedrock aquifer has occurred since 1942, except for the local areas shown in figure 34.

Recharge to the bedrock aquifer in the Piedmont is from rainfall that seeps through the Pleistocene terrace deposits and saprolite on the hilltops. In the valleys, discharge is into streams by way of either upward movement through the saprolite, or directly into the stream where the saprolite has been eroded and the bedrock is directly exposed. The general pattern of ground-water movement in the bedrock aquifer in the Piedmont is shown in figure 33.

Under the Coastal Plain sediments, recharge to and discharge from the bedrock is much the same as it is for the Cretaceous aquifer. Recharge is from leakage through the Yorktown Formation or through the overlying Cretaceous aquifer. Water discharges from the bedrock by moving upward into the Cretaceous aquifer (fig. 2).

Hydraulics

One aquifer test was run using two observation wells and a pumped well all of which are open to the bedrock aquifer. The pumped well (W1-331) is a public-supply well at the town of Black Creek and was pumped at an average rate of 104 gal/min (6.6 l s) for 3 days. One observation well (W1-159) is at the Lee Woodard High School 1,560 ft (475 m) northwest of the pumped well. The second observation well (W1-332) is a stand-by well for the town, and it is 1,780 ft (542 m) southeast of the pumped well.

The total drawdown measured in the observation well at the school was 22 ft (6.7 m). The only water-level changes observed in the other well were some minor fluctuations believed to be barometric effects. A slight downward trend of about 0.05 ft (0.02 m) toward the end of the test may have been the effects of pumping finally reaching the observation well. In other words, even though the two observation wells were about the same distance from the pumping well, the water level in the stand-by well reacted as if the well were perhaps a mile or more from the pumping well, whereas the drawdown in the school well was greater than one might expect at that distance from the pumped well.

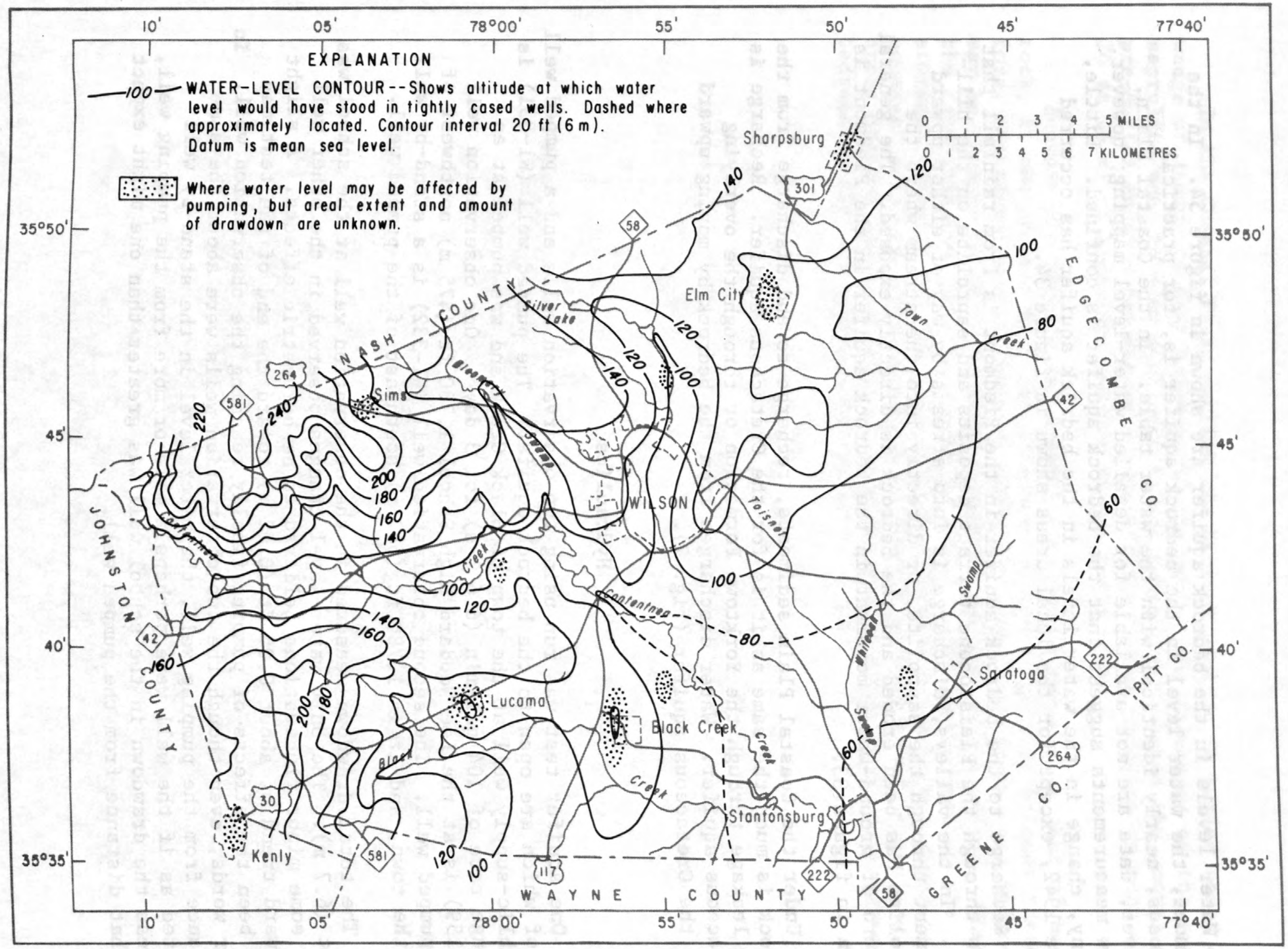


Figure 34.--Altitude of water levels in the bedrock aquifer during 1974.

This test is a good example of the directional nature of drawdown resulting from differences in hydraulic conductivity in different directions due to the fracture system of the bedrock. Instead of the roughly circular cone of depression around a pumping well in a granular aquifer, the drawdown was oriented along the fracture system in the bedrock roughly as an elliptically-shaped cone. A number of observation wells would be required to define the drawdown pattern. The orientation of the school observation well with respect to pumped well (N 18° W) roughly coincides with the main fracture direction for rocks in the Rocky Mount area (N 9° W), 22 mi (35 km) north of Black Creek, as reported by Mundorff (1946). These test data infer that north-south trending rock fractures extend under the Coastal Plain sediments.

The values for transmissivity and storage coefficient obtained through the test could be valid only for the fracture system between the pumped well and the observation well at the school. The transmissivity is about 160 ft^2/d (15 m^2/d) and the storage coefficient is about 2.5×10^{-5}. A plot of the drawdown in the observation well is shown in figure 35. A departure from the type curve after about 200 minutes of pumping indicates a recharge effect. The recharge occurs as leakage from the overlying Cretaceous aquifer which is composed of about 10 to 20 ft (3 to 6 m) of sand, gravel, and clay in this area.

About 130 values for specific capacity were obtained from drillers' records for wells open to the bedrock aquifer. Most of the wells are in neighboring counties in the Piedmont section. The data were grouped according to well diameter and rock type and were analyzed to determine if these factors affect the specific capacity of a well. The average specific capacity of all 8-in (200 mm) diameter wells was 1.15 (gal/min)/ft, or 0.24 (l/s)/m, and for all 6-in (150 mm) diameter wells, 0.42 (gal/min)/ft, or 0.09 (l/s)/m. However, the average productivity values (specific capacity divided by the length of hole open to the bedrock) were nearly identical--0.0048 gal/min ft^2, or 0.0032 l/s m^2, and 0.0052 gal/min ft^2, or 0.0035 l/s m^2, respectively. In general, 8-in (200 mm) wells are drilled mostly for public supplies and, therefore, are drilled deeper to intercept as many fractures as possible. The average depth of 45 of these wells was about 315 ft (96 m). Below this depth, we would expect the productivity per foot of depth to decline because of the decreasing number of fractures in the bedrock at great depths.

The productivity values for wells open to granite, slate, or schist were also differentiated. These values averaged 0.0046 and 0.0057 gal/min ft^2, or 0.0031 and 0.0039 l/s m^2, for wells in granite and slate, respectively. The values for wells in schist averaged somewhat higher, 0.0090 gal/min ft^2, or 0.0061 l/s m^2, but this may be due to a smaller number of wells for which data were available in this bedrock type (26 out of 130 wells).

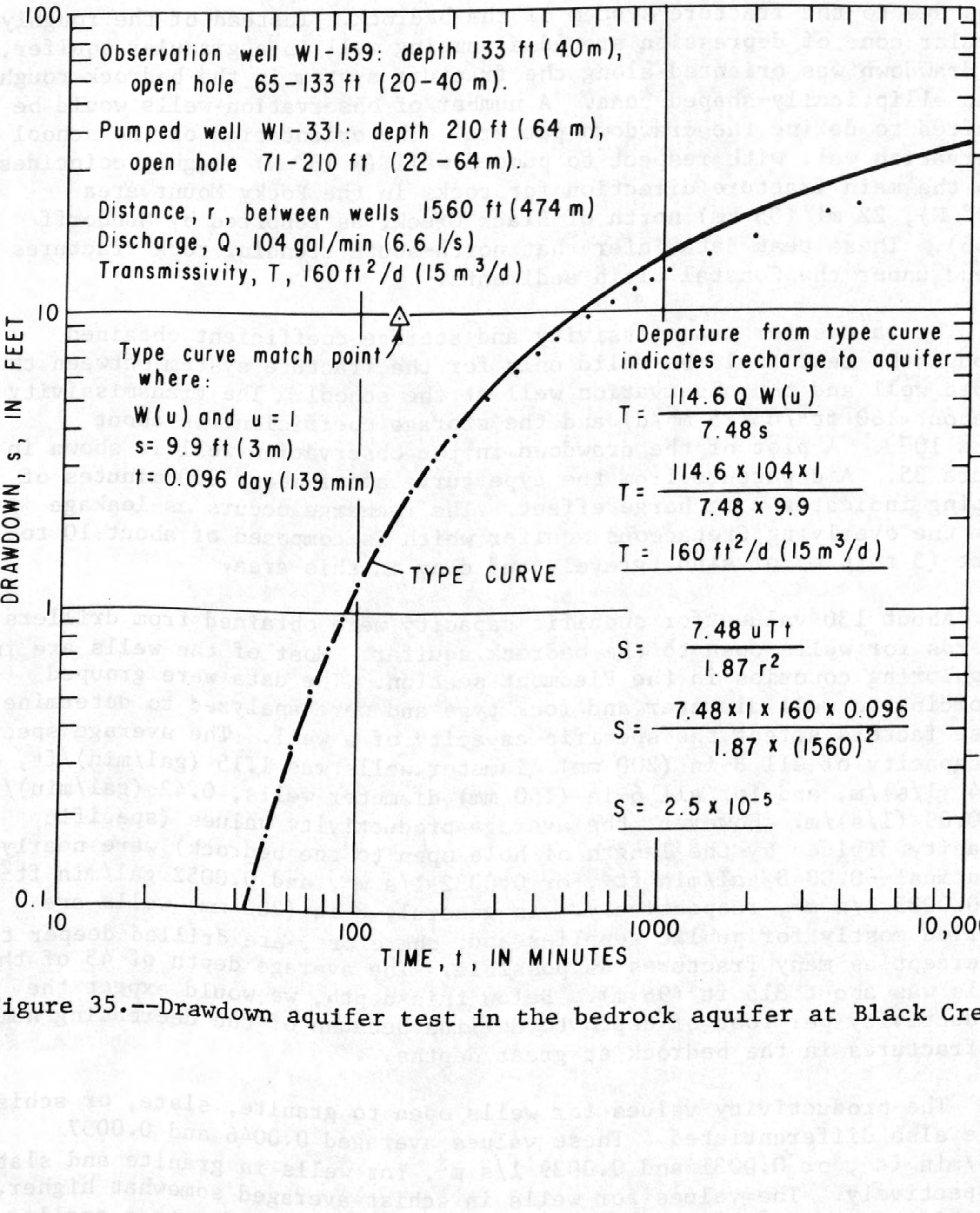


Figure 35.--Drawdown aquifer test in the bedrock aquifer at Black Creek.

Quality of Water

The chemical quality of water in the bedrock aquifer is generally good with the exception of the iron concentration, which in some areas may amount to several milligrams per litre. There is some variation in water quality, especially dissolved-solids concentration, which probably is due to the recharge source for the bedrock aquifer. Table 4 compares selected constituents and properties in water samples from wells tapping the bedrock aquifer in the Piedmont and Coastal Plain sections of the county. As seen in the table, bedrock underlying the Coastal Plain formations (and receiving recharge from them) yields water slightly more mineralized than does the bedrock in the Piedmont, which receives recharge from the saprolite and Pleistocene terrace deposits.

Where the Yorktown Formation lies directly on the bedrock aquifer, leakage through the lime-rich marl and shell beds of the Yorktown may contribute to an increased hardness of water from bedrock wells. For example, at Lucama where the Yorktown is in direct contact with the bedrock, the hardness of water from the bedrock aquifer is about 130 mg/l. At the town of Black Creek, where we have noted recharge to the bedrock aquifer as being from the Cretaceous aquifer, the water hardness is about 95 mg/l.

Salt water may occur in the bedrock aquifer underlying the Coastal Plain formations at depths as shallow as 140 ft (43 m) below msl. For example, the chloride concentration of water from one well near Saratoga was 460 mg/l (fig. 36). The highest chloride concentration measured was 5,420 mg/l. A similar occurrence of salt water in the bedrock along the fall line of northern Virginia has been described by Subitzky (1961).

The origin of the salt water is probably sea water which entered the bedrock aquifer when the sea covered Wilson County several times in the geological past. Since the last retreat of the sea, circulation of fresh water has been slowly flushing the salt water from the bedrock in this area.

In some places in the Coastal Plain section, long-term pumping from the bedrock aquifer has increased the chloride concentration of water from the supply well. The chloride concentration of water from the supply well (W1-335) for the community of Daniels Chapel (1.5 mi or 2.4 km northeast of Black Creek) increased from about 50 mg/l in 1970 to over 150 mg/l by 1974. The chloride increase as related to pumpage is shown in figure 37. At the present rate of pumpage, the chloride concentration may, within a few years, exceed the 250 mg/l limit recommended for public water supplies (U.S. Environmental Protection Agency, 1973). On the other hand, continual, but moderate, pumping of the well may eventually deplete the salt water in this particular fracture system, and the supply may actually become less salty with time. A similar situation occurred at the town of Fountain, as discussed earlier, where chloride concentration of water pumped from the Cretaceous aquifer declined with continued pumping.

Table 4.--Comparison of selected natural constituents and properties of ground water from the bedrock aquifer in the Piedmont and Coastal Plain sections

	Constituents in milligrams per litre						
	Silica (SiO_2)	Iron (Fe)	Bicarbonate (HCO_3)	Chloride (Cl)	Hardness	Dissolved solids	pH
Piedmont (Average of 15 samples)	24	0.30	81	6	65	117	
Range	4.8-40	0.01-1.1	36-145	2-16	11-131	59-192	6.6-8.2
Coastal Plain (Average of 40 samples)	31	1.3	152	20	111	184	
Range	7.6-46	0.03-2.3	98-190	3-160	39-203	53-246	5.8-8.3

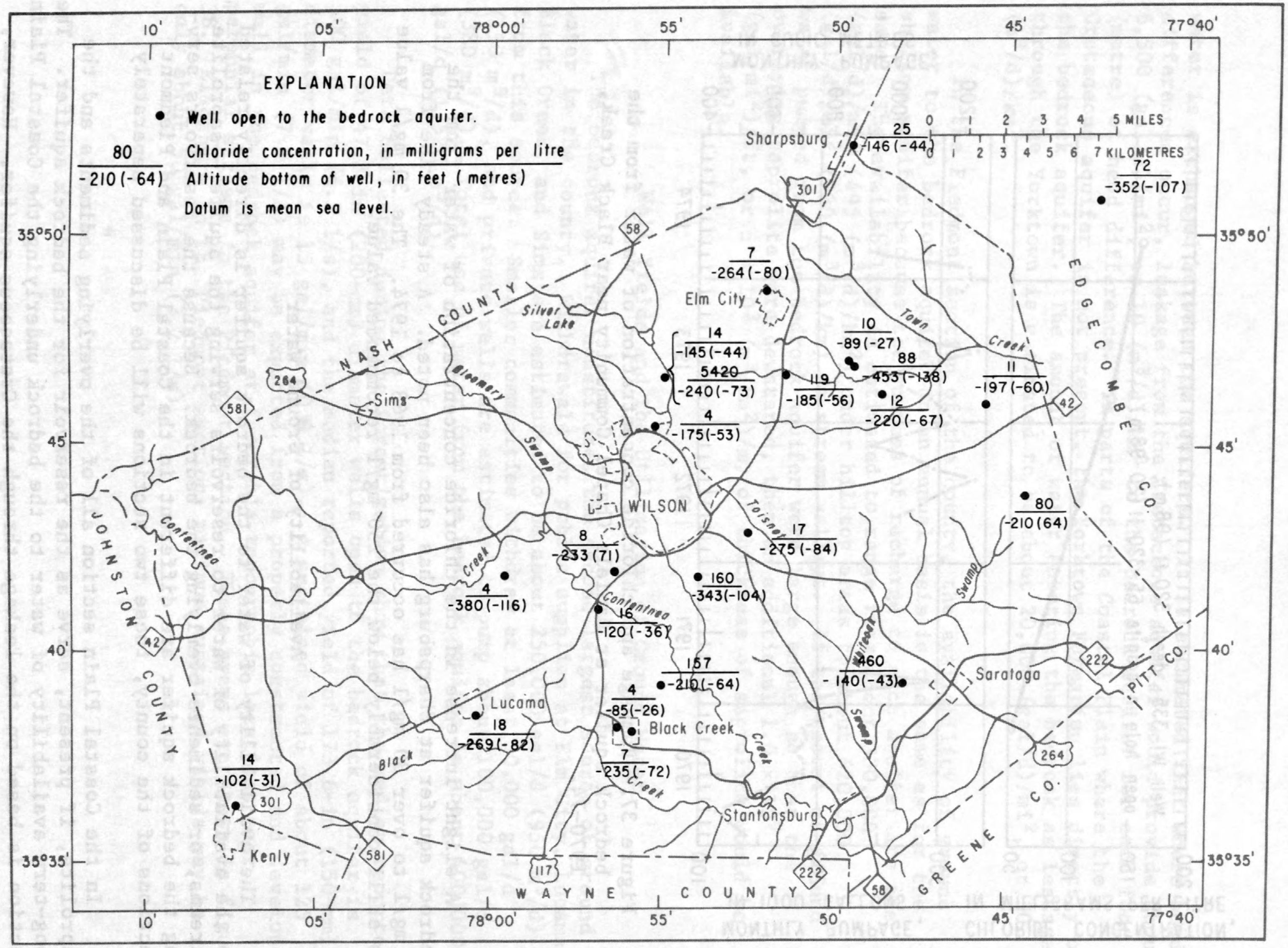


Figure 36.--Chloride concentration of water in the bedrock aquifer, 1974.

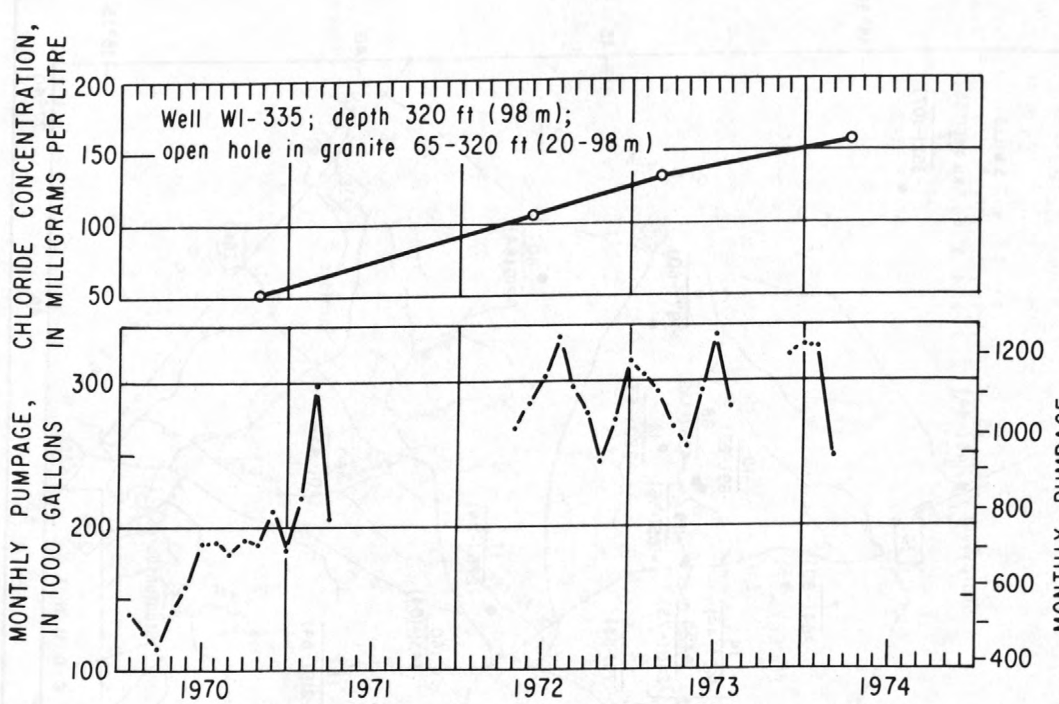


Figure 37.--Pumpage and chloride concentration of water from the bedrock aquifer at Daniels Chapel Community near Black Creek, 1970-74.

A slight increase in the chloride concentration of water from the bedrock aquifer at Sharpsburg has also been noted. A steady rise from 7 mg/l to over 30 mg/l has occurred from 1963 to 1974. The 30 mg/l value is still considerably below the 250 mg/l recommended value.

Availability of Ground Water

The availability of water to the bedrock aquifer is directly related to the availability of water to reservoirs serving the aquifer--saprolite, streams, or sediments overlying the bedrock. Because the reservoirs serving the bedrock aquifer are different in the Coastal Plain and Piedmont sections of the county, these two sections will be discussed separately.

In the Coastal Plain section all of the overlying sediments and the saprolite, if present, serve as the reservoir for the bedrock aquifer. The long-term availability of water to the bedrock underlying the Coastal Plain section is based on the leakage through the Cretaceous aquifer. However, the average head difference between the Cretaceous aquifer and the bedrock aquifer in eastern Wilson County is small so that a negligible amount of water is exchanged between the aquifers. It is estimated that where head differences occur, leakage from the Cretaceous aquifer would provide about 6,500 (gal/d)/mi^2, or 10 (m^3/d)/km^2 to the bedrock aquifer for each foot (metre) of head difference. In parts of the Coastal Plain where the Cretaceous aquifer is not present, the Yorktown Formation lies directly on the bedrock aquifer. The amount of water entering the bedrock as leakage through the Yorktown is estimated to be about 20,000 (gal/d)/mi^2, or 30 (m^3/d)/km^2.

In the Piedmont section of the county, the availability of ground water to the bedrock aquifer on an annual basis is the same as for the shallow aquifer because the sources of recharge to each aquifer are the same. The availability is estimated to range from about 330,000 (gal/d)/mi^2 (495 (m^3/d)/km^2) under hilltop areas to about 620,000 (gal/d)/mi^2 (930 (m^3/d)/km) in stream valleys. If the amount of ground water pumped from the bedrock aquifer were large enough so that the overlying saprolite were dewatered, then an additional 1.0×10^7 (gal/mi^2)/ft, or 5×10^3 (m^3/km^2)/m, of thickness of saprolite would be available.

Well Yields and the Utilization of Ground Water

The bedrock aquifer constitutes the second largest source of ground water in the county. Withdrawals for public supplies at Elm City, Lucama, Black Creek, and Sims are estimated to be about 250,000 gal/d (950 m^3/d) from this source. Smaller communities withdraw at least 50,000 gal/d (190 m^3/d), and private wells are estimated to pump about 100,000 gal/d (380 m^3/d). Total use of water from the bedrock aquifer is about 400,000 gal/d (1,520 m^3/d).

Data collected during the investigation show that the median reported yield of 47 8-in (200-mm) diameter wells open to the bedrock aquifer is 100 gal/min (6.3 l/s), and the median reported yield of 173 6-in (150-mm) diameter wells is 15 gal/min (0.9 l/s). A sustained yield of about 125 gal/min (7.9 l/s) may be expected from a properly constructed and developed well in the bedrock aquifer at favorable topographic locations near perennial streams in the Piedmont section. These areas are shown in figure 38. Elsewhere in the Piedmont section, maximum sustained yields may be only about 50 gal/min (3.2 l/s).

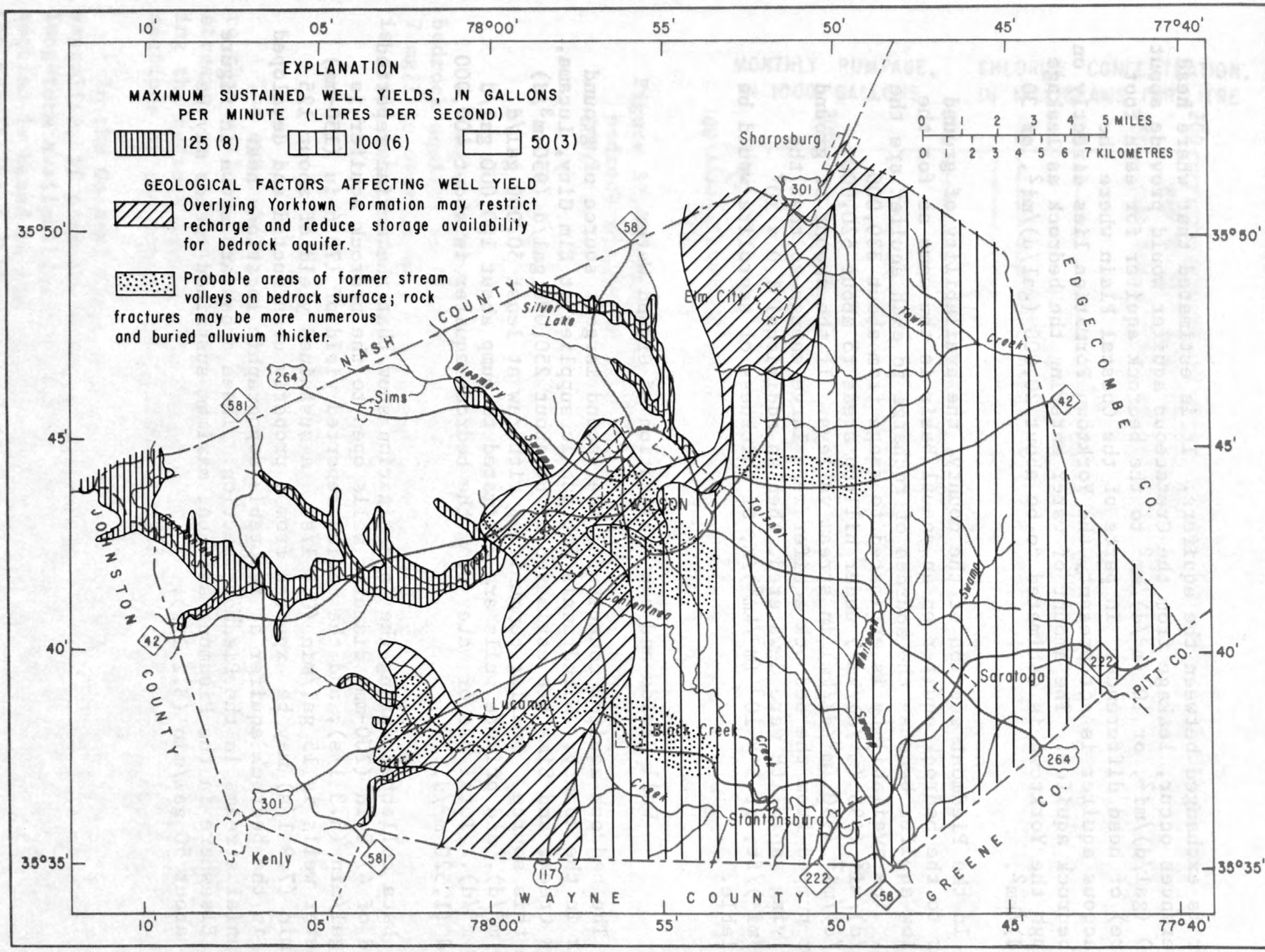


Figure 38.--Yields that may be expected from individual wells in the bedrock aquifer and geologic factors that may affect yields.

A yield of 600 gal/min (38 l/s) was reported from a bedrock well drilled for the Town of Lucama (W1-333). This yield was measured during a short-term test, and this high yield probably could not be sustained over a long period of time. Sustained yields somewhat greater than 125 gal/min (7.9 l/s) probably can be achieved occasionally, but only where a well would intercept intersecting sets of fractures, and the most favorable conditions exist for recharge near a perennial stream. Sustained yields of 100 gal/min (6.3 l/s) or more can often be developed in the bedrock aquifer under the Coastal Plain formations, but the chance for a successful well at any given location here is less predictable than it is in the Piedmont.

Along the westernmost margin of the Coastal Plain formations, the Yorktown Formation lies directly on the bedrock aquifer and may affect yields from the bedrock. Because it is a confining bed, the Yorktown inhibits recharge to the bedrock, and this results in lower yields from the bedrock aquifer in this area. (See fig. 38.)

In some places there is indication of former stream valleys that are now buried under the Coastal Plain sediments (fig. 38). These buried valleys appear to be the former valleys of Contentnea and Black Creeks and Toisnot Swamp, and they extend from these respective present stream valleys in the Piedmont section eastward under the Coastal Plain formations. Bedrock fractures may be more numerous and buried alluvium may be thicker in these areas, providing favorable hydrologic conditions for successful wells.

The most promising area for development of a large ground-water supply in the bedrock aquifer is in the valleys of Contentnea Creek and its larger tributaries west of the City of Wilson (fig. 38). A line of wells parallel to and as close as practical to the stream would take maximum advantage of the recharge from the stream. The success of this type of ground-water development would depend heavily upon the on-site test data and the individual characteristics of each supply well. According to the experience of local well drillers, two or three holes must be drilled for each successful supply well completed in a bedrock aquifer because of the random occurrence of enough fractures to supply the needed water to the well. The maximum practical depth of penetration of wells into the bedrock aquifer is about 300 ft (90 m) according to LeGrand (1967). Occasionally, however, a well drilled many hundreds of feet into bedrock will intersect a large fracture or fracture zone and produce a large yield. Unfortunately, the random occurrence of rock fractures and the cost of drilling a deep well are the main factors that tend to discourage the deep exploration for water in bedrock.

One of the most important benefits derived from the aquifer test at Black Creek was the demonstration of directional hydraulic conductivity of the bedrock fracture system. During the test drawdown was observed in one observation well and not the other, even though they both were about the same distance from the pumped well. The key to understanding this phenomenon lies in the fact that the observation wells were located in different directions from the pumped well, and hence presumably open to different fracture zones in the bedrock that are not hydraulically connected within the radius of the pumping effect. Since regional fracture patterns in bedrock are roughly parallel, it is presumed that two or more wells located at right angles to the fracture direction could intercept fracture zones that are not hydraulically connected, or are only slightly so. By taking advantage of this property of the bedrock aquifer, a group of wells could be located in hydrologically favorable areas--such as near a stream--so that they could be operated simultaneously without significantly affecting each other.

SUMMARY AND CONCLUSIONS

A summary of the water-supply characteristics of the hydrologic units in Wilson County is provided in table 5 as a reference to their features discussed in this report.

The most favorable areas for the development of water supplies in the shallow aquifer are in the stream valleys. Wells in these areas draw upon the maximum amount of rainfall recharge and streamflow capture. This recharge is estimated to be about 620,000 $(gal/d)/mi^2$, or 930 $(m^3/d)/km^2$. Present pumpage of water from the shallow aquifer by domestic and farm wells is estimated to be about 3,500 $(gal/d)/mi^2$, or 5.25 $(m^3/d)/km^2$, or about 0.5 percent of the maximum recharge potential.

Development of ground-water supplies in the shallow aquifer that utilize captured streamflow will modify the flow characteristics of the stream (Theis, 1941). Some reaches of a stream could become dry at times. In fact, any pumpage of water from the shallow aquifer results in a decrease in the amount of water available to streams. Any large-scale development of water supplies in the shallow aquifer should be planned with this fact in mind.

Table 5.--A summary of the water-supply characteristics of the major hydrologic units in Wilson County

Hydrologic unit	Description	Thickness of unit (ft)	Water-level range (ft below lsd)	Est. max. sustained yield per well (gal/min)	Highest reported yield (gal/min)	Specific capacity of wells [(gal/min)/ft]	Trans-missivity (ft^2/d)	Coefficient of storage	Water-supply characteristics
Pleistocene terrace deposits	Heterogeneous mixture of sand and gravel mixed with silt and clay; individual beds are thin, and of local areal extent.	0-35	0-35	25	22	0.1-1.0	50-500	0.05-0.2	Suitable for domestic-sized supplies; larger supplies possible from multiple well field installation; pollution potential high; water likely to be corrosive with iron problems.
Yorktown Formation	Blue and gray silty marine clay; shell and marl beds; thin beds of sand of limited extent.	0-50	20-30	0.5	12	Less than 0.1	Less than 50	1×10^{-4}	Not considered suitable for water supply; domestic supplies might utilize sandy facies in eastern Wilson Co.; water is very hard, contains some iron, and H_2S gas.
Cretaceous aquifer	Interbedded red and brown sand and silty clay; individual sand beds up to 15 ft thick.	0-180	0-50	500	600	1-10	1,000-2,500	2.5×10^{-4}	Sutiable for community or industrial supplies in eastern Wilson Co.; available drawdown may be limiting factor in development; water contains some iron.
Bedrock aquifer	Igneous and metamorphic rocks consisting mainly of granite, slate, and schist.	-------	0-35	125	600	0.05-3	100-500	0.05-0.2	Suitable for community or industrial supplies in Piedmont section along stream valleys; salty water occurs in aquifer under Coastal Plain sediments; water contains iron and may be slightly corrosive.

Because of the relatively low transmissivity of the shallow aquifer, individual well yields are not likely to exceed about 25 gal/min (1.6 l/s) on a sustained basis. Adequate supplies of ground water for small communities or industries may be obtained by the use of a number of wells in the shallow aquifer that may be pumped individually or connected by a common pumping system. The use of a horizontal collector well is an efficient means of obtaining large quantities of water with relatively little drawdown. Such an installation could be used effectively in the shallow aquifer, especially where available drawdown may be a limiting factor in supply development.

The quality of water in the shallow aquifer is generally excellent. Only the slightly acidic property of the water may be considered a problem, as it will cause iron or galvanized iron used in well systems to corrode. The use of non-ferrous materials in water-system construction or pH control with chemicals may alleviate this problem. Because most of the rural-domestic sewage eventually enters the shallow ground-water system, supply wells should be located as far as possible from these sources of pollution and preferably up the hydraulic gradient from them.

The Yorktown Formation consists mostly of clay and is of relatively little significance as a source of water supply. A few wells that are open to this formation pump water that is hard and often contains iron and hydrogen sulfide. Data are not available for the yields of wells solely in the Yorktown, as most wells tapping the Yorktown also are open to the shallow aquifer. Because of the low transmissivity of the formation, well yields are estimated to not exceed 0.5 gal/min (0.03 l/s).

As much as 500 gal/min (32 l/s) may be obtained from wells in the Cretaceous aquifer. The most favorable area for development is in the easternmost part of Wilson County where the aquifer is the thickest and contains the highest percentage of sand. The average rate of recharge to the Cretaceous aquifer is estimated to be about 67,000 (gal/d)/mi^2, or 100 (m^3/d)/km^2. In order to sustain a pumping rate of 500 gal/min (32 l/s) under this rate of recharge the amount of leakage available in an area of about 11 mi^2 (28 km^2) (radius 1.9 mi, or 3.1 km) would be required.

The Cretaceous aquifer underlies about 180 mi^2 (466 km^2) of Wilson County. Present pumpage from it is estimated to be about 134,000 gal/d (509 m^3/d), or an average of about 740 (gal/d)/mi^2, or 1.1 (m^3/d)/km^2 for the aquifer in Wilson County. Compared to the average rate of recharge, only about 1 percent of the recharge is currently being used in the county. Most of the ground-water recharge to the Cretaceous aquifer evidently moves eastward out of the county, where it discharges to other aquifers, to streams, and eventually to the ocean.

In general, the quality of water in the Cretaceous aquifer is very good, requiring treatment only for iron. The dissolved-solids concentration ranges from about 60 mg/l near the western limit of the aquifer to about 200 mg/l in the eastern part of the county.

The maximum sustained yield from a well in the bedrock aquifer is about 125 gal/min (7.9 l/s). This well would have to be drilled in a Piedmont valley where a perennial stream is available for a source of recharge. In hilltop areas of the Piedmont, maximum sustained yields are estimated to be about 50 gal/min (3.2 l/s). Under Coastal Plain formations the maximum sustained yield is estimated to be about 100 gal/min (6.3 l/s) because of the availability of leakage from the overlying sediments as a source of recharge.

On a sustained basis, the estimated amount of water available to the bedrock aquifer ranges from about 20,000 (gal/d)/mi^2, or 30 (m^3/d)/km^2, under Coastal Plain formations to about 620,000 (gal/d)/mi^2, or 930 (m^3/d)/km^2, in the most favorable locations in Piedmont valleys.

In the Piedmont section, only excess iron is a water quality problem. However, in the Coastal Plain salt water occurs in the deeper fractures of the bedrock, and chloride concentrations may be as much as 5,000 mg/l.

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Table 6.--Basic data for wells used in report

USGS well no.	Owner	Location N latitude	Location W longitude	Aquifer	Well depth (feet below land surface)	Well diameter (inches)	Interval open to aquifer (feet below land surface)	Static water level (feet below land surface)	Date measured	Well yield (gal/min)	Pumping water level feet below land surface)	Specific capacity [(gal/min)/ft]	Date measured	Remarks
						WILSON COUNTY								
W1-128	S. T. Wooten..............	35°41'35"	77°49'59"	Cretaceous	114	6 1/4	....	24.17	2/21/74	...	.....	....	....	Well no.128 (Mundorff, 1946, p.72); obs. well.
W1-133	Dr. A. F. Williams.........	35°43'52"	77°44'25"	Bedrock	333	5	233-333	51.45	2/21/74	5	.....	....	1942	Well no.133 (Mundorff, 1946, p.72); Cl 80 mg/l, 4/16/74.
W1-150	Town of Stantonsburg.......	35°36'15"	77°49'42"	Cretaceous	140	8	107-140	43.60	2/21/74	200	.....	....	1942	Well no.150 (Mundorff, 1946, p.73); obs. well.
W1-159	Lee Woodward High School...	35°38'25"	77°56'14"	Bedrock	133	6	65-133	18.28	2/14/74	8	.....	....	1942	Well no.159 (Mundorff, 1946, p.73); obs. well.
W1-203	Town of Elm City...........	35°48'08"	77°51'15"	Bedrock	450	6	60-450	....	....	32	.....	....	2/ 5/73	Well no.9a (Mundorff, 1946, p.68); no.3 town well.
W1-331	Town of Black Creek........	35°38'07"	77°56'07"	Bedrock	210	8	71-210	15.90	6/ 3/74	104	74.1	1.8	6/ 7/74	Aquifer test, June 1974; no.1 town well.
W1-332	Town of Black Creek........	35°38'02"	77°55'43"	Bedrock	360	8	76-360	7.38	6/ 3/74	122	120	1.1	5/20/68	Observation well; no.2 town well.
W1-333	Town of Lucama.............	35°38'37"	78°00'35"	Bedrock	402	8	32-402	16	3/1956	600	115	6.1	3/1956	No.2 town well.
W1-334	Town of Lucama.............	35°38'23"	78°00'20"	Bedrock	401	10	51-401	9	12/22/67	250	145	1.8	12/22/67	No.3 town well.
W1-335	Daniels Chapel Community...	35°39'05"	77°55'00"	Bedrock	320	6 1/4	65-320	16	10/22/66	50	67	1.0	10/22/66	Chloride 157 mg/l, 4/16/74.
W1-336	Oakdale Subdivision........	35°41'41"	77°59'21"	Bedrock	500	8	52-500	2	12/30/68	30	80	.4	12/30/68	
W1-337	Hyland Park Subdivision....	35°39'33"	77°56'11"	Bedrock	220	6 1/4	72-220	21	7/ 5/65	60	99	.6	7/ 5/65	
W1-338	Town of Saratoga...........	35°38'59"	77°46'28"	Cretaceous	170	8	143-170	75.45	4/16/74	118	94.6	6.2	4/17/74	Aquifer test, April 1974;test yield 600 gpm, June 1956.
W1-339	Town of Stantonsburg.......	35°36'14"	77°49"41"	Cretaceous	142	8	105-142	44.45	11/ 2/73	105	119.0	1.4	11/12/73	No.2 town well; gravel-wall construction reported.
W1-340	Town of Stantonsburg.......	35°36'22"	77°49'12"	Cretaceous	148	8	108-148	45.12	11/ 2/73	122	95.0	2.4	11/ 5/73	No.3 town well; aquifer test, Nov. 1973.

Table 6.--Basic data for wells used in report--Continued

USGS well no.	Owner	Location: N latitude	Location: W longitude	Aquifer	Well depth (feet below land surface)	Well diameter (inches)	Interval open to aquifer (feet below land surface)	Static water level (feet below land surface)	Date measured	Well yield (gal/min)	Pumping water level feet below land surface)	Specific capacity [(gal/min)/ft]	Date measured	Remarks
					WILSON COUNTY--Continued									
Wl-341	Lakeside Heights Sub-division	35°39'34"	78°00'09"	Bedrock	150	6 1/4	35-150	....	....	75	.....	....	Nov.1972	
Wl-345	Parkers Barbeque...........	35°41'50"	77°56'16"	Bedrock	348	8	49-348	18	5/11/66	70	200	.4	5/11/66	
Wl-352	J.Whitley Estate...........	35°42'07"	77°45'00"	Cretaceous	111	3 1/2	108-111	30	9/29/53	7	90	.1	9/29/53	
Wl-354	S. T. Wooten..............	35°41'35"	77°49'59"	Pleistocene	22	24	open-end	2.18	2/21/74	....	.....	....	....	Observation well.
Wl-362	Happy Valley Club..........	35°42'45"	77°52'35"	Bedrock	410	6	76-410	20	10/15/69	25	191	.2	10/15/69	Chloride 17 mg/l, 5/13/74.
Wl-366	Exxon Truck Stop...........	35°46'39"	77°51'21"	Bedrock	305	6	114-305	18	7/29/61	35	128	.3	7/29/61	Chloride 119 mg/l, 5/13/74.
Wl-367	Bruce Foods...............	35°41'44"	77°53'54"	Bedrock	453	8	98-453	9	6/20/69	62	116	.6	6/20/69	Chloride 160 mg/l, 3/16/71.
Wl-368	Town of Kenly.............	35°36'13"	78°07'16"	Bedrock	300	6 1/4	63-300	10.33	10/23/73	150	.....	....	June 1973	"7th Street well."
Wl-391	Speight School............	35°39'11"	77°47'42"	Bedrock	255	6	168-255	76.31	7/ 3/74	18	185	....	1950	Chloride 460 mg/l, 5/6/74.
Wl-392	Elizabeth Heights Sub-division	35°46'35"	77°54'49"	Bedrock	250	6 1/4	21-250	2	2/19/73	46	40	1.2	2/19/73	Chloride 5,420 mg/l at original depth of 345 ft.
Wl-402	Benson Hog Farm...........	35°46'45"	77°49'12"	Bedrock	189	6 1/4	92-189	0	2/10/70	50	26	1.9	2/10/70	No.1 well; chloride 10 mg/l, 5/13/74.
Wl-403	Benson Hog Farm...........	35°46'42"	77°49'10"	Bedrock	543	6 1/4	142-543	19	10/10/69	100	188	.6	10/10/69	No.2 well; chloride 88 mg/l, 5/13/74.
Wl-407	Town of Sims..............	35°45'41"	78°03'39"	Bedrock	255	8	47-255	5	6/18/64	23	166	.1	6/18/64	No.1 town well.
Wl-408	Town of Sims..............	35°45'30"	78°03'23"	Bedrock	165	6 1/4	20-165	18	6/ 7/65	38	45	1.4	6/ 7/65	No.2 town well.
					EDGECOMBE COUNTY									
Ed-114	Hazelwood Park Subdivision..	35°51'15"	77°41'15"	Bedrock	445	6 1/4	250-445	57.39	10/10/73	75	.....	....	10/ 9/73	Water reported salty.
Ed-120	Town of Sharpsburg..........	35°52'05"	77°49'40"	Bedrock	286	8	80-286	....	....	125	.....	....	1958	No.1 town well; chloride 33 mg/l, 11/7/73.
					GREENE COUNTY									
Gr-56	Camp Contentnea............	35°35'13"	77°47'21"	Cretaceous	130	1 1/2	....	16.13	6/11/73	...	.....	....	....	Observation well.
					WAYNE COUNTY									
Wa-119	Town of Eureka.............	35°32'22"	77°52'30"	Bedrock	704	6 1/2	194-704	24	1960	14	509	.03	1960	Not in use.

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