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NORTH CAROLINA
DEPARTMENT OF CONSERVATION AND DEVELOPMENT
WILLIAM P. SAUNDERS, *Director*

DIVISION OF MINERAL RESOURCES
JASPER L. STUCKEY, *State Geologist*

BULLETIN NUMBER 69

Ground-Water Resources
In North Carolina

By
H. E. LEGRAND, *Geologist*
United States Geological Survey

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PREPARED COOPERATIVELY BY THE GEOLOGICAL SURVEY,
UNITED STATES DEPARTMENT OF THE INTERIOR

1956

MEMBERS OF THE BOARD OF CONSERVATION AND DEVELOPMENT

LETTER OF TRANSMITTAL

Raleigh, North Carolina
January 23, 1956

To His Excellency, HONORABLE LUTHER H. HODGES
Governor of North Carolina

Sir:

I have the honor to submit herewith manuscript for publication as Bulletin No. 69, "Ground-Water Resources in North Carolina," by Harry E. LeGrand.

This report is another in the series being prepared on ground water in the State by the Department of Conservation and Development in cooperation with the United States Geological Survey. The purpose of this report is to indicate the ground-water resources in the different rock types of the State and to point out the importance of ground water as a source of supply for schools, municipalities, and industry.

Respectfully submitted,
WILLIAM P. SAUNDERS,
Director

Ground-Water Resources In North Carolina

By
H. E. LeGrand

INTRODUCTION

Ground water is one of North Carolina's most valuable natural resources. More than 2,500,000 people, or about 70 percent of the population, depend on wells as a source of water supply, and more than half the municipalities of the State get water from wells. The great rural population uses water from almost a million wells, perhaps as many as exist in any other State. Although a much larger volume of water for municipal and industrial uses comes from surface than from underground sources, the extremely large supplies drawn from surface sources by large cities and a few industries, such as those producing paper, tends to overshadow the more widespread use of ground water. Figure 1 shows the proportion of people using ground water in the counties of North Carolina.

Purpose

The purpose of this paper is to promote a better understanding of the ground-water resources of North Carolina. Cognizance is taken of the present and potential future importance of ground water in the State, and a discussion is given of some of the fundamental principles that control the occurrence and availability of ground water.

In spite of a general awareness of the importance of our water resources and of the limitations placed on the use of water locally during droughts, the public is largely uninformed on the conditions that control the movement and occurrence of underground water. The report that the water table is falling perennially in North Carolina is erroneous; yet, this belief is so firmly established in the minds of the people that it is not likely to be corrected soon. Droughts such as those experienced in North Carolina during 1953 and 1954 make us aware of our sources of water supplies and of the difficulties in getting an acceptable supply. As we look around and see our surface reservoirs and streams dwindling during long periods of fair weather, we wonder if the same thing is happening to our underground water supplies. It is during these times that we frequently hear some categorical statements about ground-water supplies that are not altogether true.

Investigations Being Made

Being aware of the need for more knowledge of the State's ground-water resources, the North Carolina Department of Conservation and Development in 1941 entered into an agreement with the Geological Survey, United States Department of the Interior; this agreement, which has been continuous to the present, provides for a cooperative investigation of the ground-water resources of

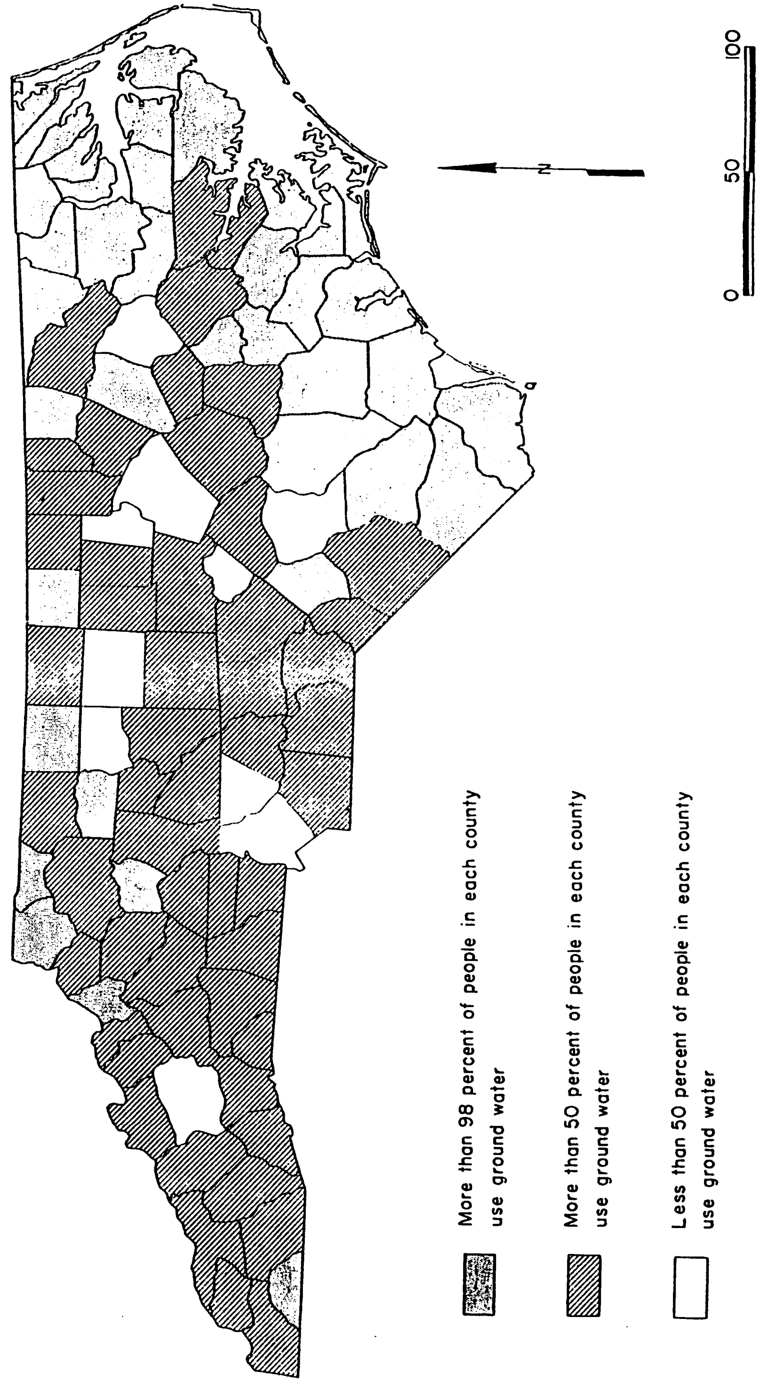

Figure 1.—Map showing the widespread use of ground water in North Carolina.

North Carolina. The Geological Survey and the Division of Mineral Resources of the Department of Conservation and Development have shared equally the expense connected with these investigations. The purpose of these investigations is to appraise and evaluate the ground-water resources of the State. Although the work has resulted in the accumulation of considerable data on the ground-water resources of the State, a great deal more remains to be learned. Several reports have been prepared, six of which were published as bulletins by the Division of Mineral Resources. Four of them (see fig. 2) cover areas of five or more counties each. The pressing need for information necessitated the preparation of reports including only a small part of the data that need to be collected. Consequently, the published reports do not represent the final word on the ground-water resources of the areas studied. Moreover, less than half the State has been the subject of study to date. The appraisal of our ground-water resources, although well begun, is certainly not half done.

RELATION OF GROUND WATER TO GEOLOGY

All ground water occurs in open spaces in the rock materials underground. In North Carolina there are many kinds of rocks, which differ considerably in the number, size, and shape of their open spaces. The nature of the open spaces determines the porosity, which is generally expressed as the percentage of total volume not occupied by solid material. Rocks of low porosity are not capable of absorbing, holding, or yielding much water. Rocks of high porosity absorb considerable water and may also yield much, although this is not necessarily true. For example, some sands and some clays have approximately the same porosity, but the sands will yield water to wells or springs more readily than will the clays. The difference lies in the ability of the clays to hold much water by molecular attraction and the corresponding ability of the sands to allow water to move by gravity through their larger pore spaces. Rock materials through which water moves by gravity are said to be permeable. Permeable rock materials are in effect vast underground reservoirs. Much more water is stored in them than in all the surface reservoirs and streams in North Carolina. The underground reservoirs are filled with water to a level known as the water table. Below the water table the pores are saturated with water under hydrostatic pressure; above it the water is held by capillarity and many of the pores are partly filled with air.

The amount of water that we can withdraw perennially from an underground reservoir is limited by the amount that can be replenished, or recharged, to that reservoir and not primarily by the amount of water in storage. Since our usable water is replenishable, we should give due consideration to the ability of water to move into, through, and out of the underground reservoirs.

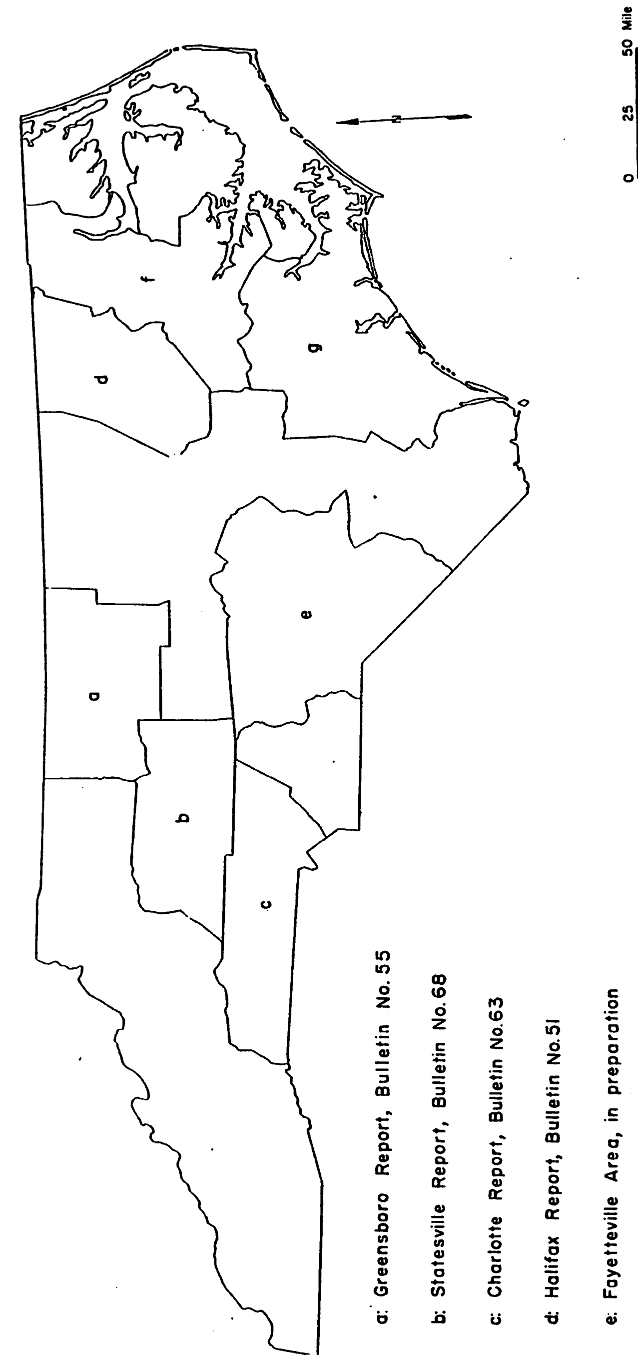

Figure 2.—Map showing areas covered by bulletins in preparation or bulletins published by the North Carolina Division of Mineral Resources.

GROUND-WATER LEVELS

During droughts we see evidence of a falling water table when many shallow wells go dry. We also can detect a lowering of the water table locally around wells from which water is pumped. The water table, or upper surface of the underground reservoir, continuously changes its position, reflecting changes in underground storage. There is a continual discharge of ground water by seepage into streams, by evaporation, and by transpiration through vegetation. The discharge causes a gradual lowering of the water table except during and immediately after periods of significant precipitation, when recharge to the underground reservoir exceeds the discharge from it and the water table rises. Figure 3 shows the trends of water-level fluctuation in a well at Mocksville, Rowan County. The water level in this well is controlled entirely by natural conditions, and its fluctuation is typical of that in the Piedmont and mountain sections of North Carolina. The decline of the water table covers a longer aggregate period during a year and is more gradual than the rise of the water table. In a year of normal rainfall the recharge to the underground reservoir is approximately equal to the discharge from it, so that the water table at the end of the year is at about the same level as at the beginning of the year.

So far the withdrawal of water by pumping of wells is not great in the State, and the lowering of the water table around individual wells does not affect the regional water table. There appears to be no evidence to support the general belief that the water table has been declining dangerously during recent years. Both the logical deductions from an understanding of the principles of ground-water occurrences and movement and the actual measurements of water levels during the past 20 years refute this belief and show, instead, that the water table in unpumped or lightly pumped areas has no trend except that associated with climate. An overall deficiency in rainfall that has accumulated since 1953 has caused water levels to fall below seasonal averages since that time. An accumulative deficiency in precipitation of about 37 inches in Salisbury since 1948 has caused the water table at Mocksville (fig. 3) to be lower than normal since that time. In much of the State this trend was reversed by the heavy rains associated with the recent hurricanes.

In North Carolina there is a characteristic change in the water table with the seasons. It generally begins to decline in April or May, owing to the increasing amount of evaporation and transpiration by plants, which not only consume ground water directly in some places but, much more importantly, reduce the amount of precipitation that can reach the water table, by removing water from the soil. Although interrupted by minor rises due to exceptionally heavy rainfall, this decline generally continues through summer and autumn, in spite of the abundant rainfall of July and August. In November or December, when much of the vegetation has become dormant, the precipitation first makes up the summer-

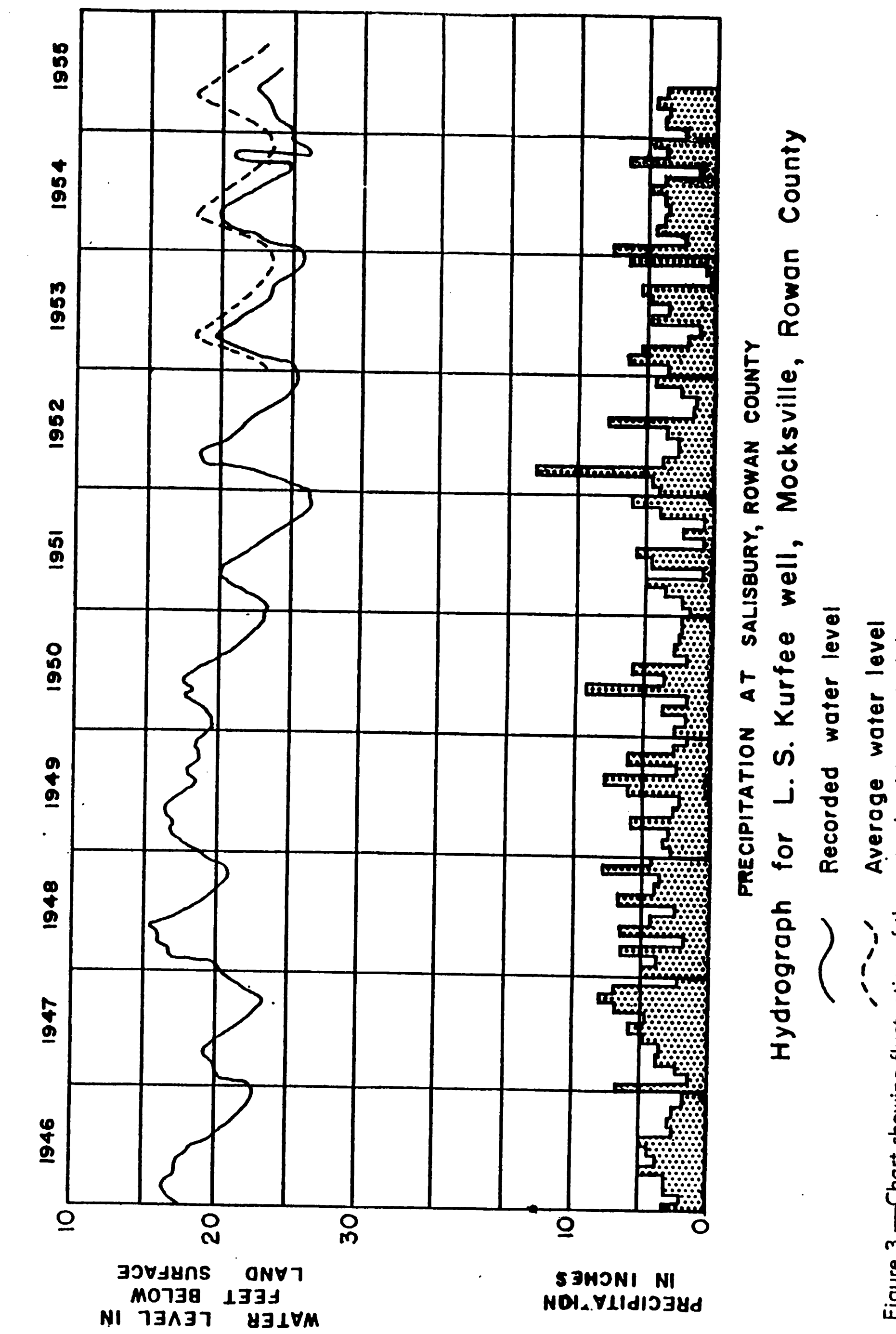

Figure 3.—Chart showing fluctuation of the water level in a typical dug well in the Piedmont Province. The well is 32 feet deep.

time soil-moisture deficiency and then again becomes effective in producing recharge, and the water table begins to rise. It reaches another high stage about April or May of the next year.

Beds of sand and limestone lying at depth in the Coastal Plain generally contain artesian water — that is, water that is under pressure because of the presence of relatively impermeable layers above it and because of intake areas at high levels. The water level of each bed differs somewhat from that of other beds. In most places the artesian water levels are within a few feet of the land surface. On low ground at many places on the Coastal Plain the artesian level is above the land surface, making flowing wells possible. Since the artesian beds are essentially full of water and do not, therefore, have the facilities for taking in all the water available from precipitation, or for discharging it relatively soon after it is recharged, artesian water levels under natural conditions vary less with the seasons than does the water table.

The water level is depressed around wells that are pumped, forming a "cone of depression". The lowest point in the water surface is in the well, and a hydraulic gradient is established which causes water to flow toward the well from roundabout. As pumping continues to lower the level of water in the well, the influences of the gradient extend farther away, allowing water to enter the well that naturally would have discharged elsewhere. If this intercepted water approximates in quantity that pumped out, the water level eventually will stop falling and reach a new state of equilibrium. With the pumping of additional nearby wells, the cone of depression of each well overlaps with others and becomes deeper, and a composite cone of depression is developed. Only a trained hydrologist is qualified to appraise the water levels in terms of future perennial withdrawal of water. A decline of the water level is not always detrimental. It is a natural consequence of the withdrawal of water and is necessary to induce a flow of water to the well.

GROUND-WATER PROVINCES

On the basis of types of ground-water reservoirs and movement of water in them, North Carolina may be divided into two major ground-water provinces: the Piedmont and mountain sections, considered here as one province, and the Coastal Plain as the other. The characteristics of these ground-water provinces are discussed on the following pages.

Piedmont and Mountain Regions

The ground-water provinces are shown in figure 4, in which the number 1 designates the Piedmont and mountain provinces. The Piedmont includes a wide belt of rolling land extending westward from the Coastal Plain to the mountains of western North Carolina. The region west of the Coastal Plain, except for the area numbered 2 in figure 4, is underlain by dense rocks broken by crevices and mantled by a layer of soil and soft, decayed rock. The rocks are very complex in character and occurrence, but for this

discussion they may be considered as of two types — massive granite-like rocks and bedded slatelike rocks. Many of the rocks have been deformed by earth movements, so that their beveled edges are observed at the land surface. The underground reservoir in the Piedmont and mountain provinces consists of two contrasting types, (1) the clayey and sandy soil and weathered material which underlies the surface to depths generally ranging from several feet to several tens of feet and (2) the underlying bedrock. In the soil and weathered rock, water occurs between the individual mineral grains, but in the underlying bedrock it occurs only in fractures. These fractures generally are not evenly distributed, so that they may be an inch or two or several feet apart. Many are interconnected sufficiently to allow ground water to circulate through them. In many places fracture openings are only a fraction of an inch wide, although there is a great variation in size of openings. The size and number of fractures appear to decrease with depth. As a result, most ground water occurs at a depth of less than 150 feet - much of it in the upper 30 feet of bedrock. Therefore, the lower limit of the reservoir is a thick, indefinite zone; the top, however, is a definite though fluctuating surface — the water table. It should be emphasized at this point that there are no underground streams or lakes in North Carolina.

Ground water moves slowly through the soil and fractures in the rock, always under the influence of gravity. After percolating downward through the pore space in the soil and mantle rock, ground water is restricted in circulation to fractures in the bedrock. The water does not generally move to great depths but instead is shunted almost laterally by "tight" or impermeable rocks to discharge points along the perennial streams. Thus, the movement of ground water from the recharge, or interstream, areas to the discharge areas follows, in general, a short, crooked path, the water flowing locally through interconnecting fractures.

If the underground reservoirs can store immense amounts of water and if replenishment is great enough to cause them to spill over, as attested by outflow of water as springs and seepage, then why do some wells yield so little water? As a rule, the rocks in the Piedmont and mountain provinces release water rather slowly to wells, and consequently wells capable of yielding less than 30 gallons a minute are common. Even where geologic conditions are somewhat similar, individual wells show a wide range in yield. One well is known to produce more than 600 gallons a minute, whereas many yield as little as 1 gallon a minute, the average yielding 25 to 40 gallons a minute. One well may yield too little water to pump while another 100 feet away may yield as much as 100 gallons a minute. This great variation in yield and our inability to predetermine the yield of a prospective well might suggest that getting a good well is a matter of luck or chance. If a single well is considered, chance appears to be the governing factor, but if many wells are considered then certain probabilities give us a clearer picture. For example, we know that, as regards municipal

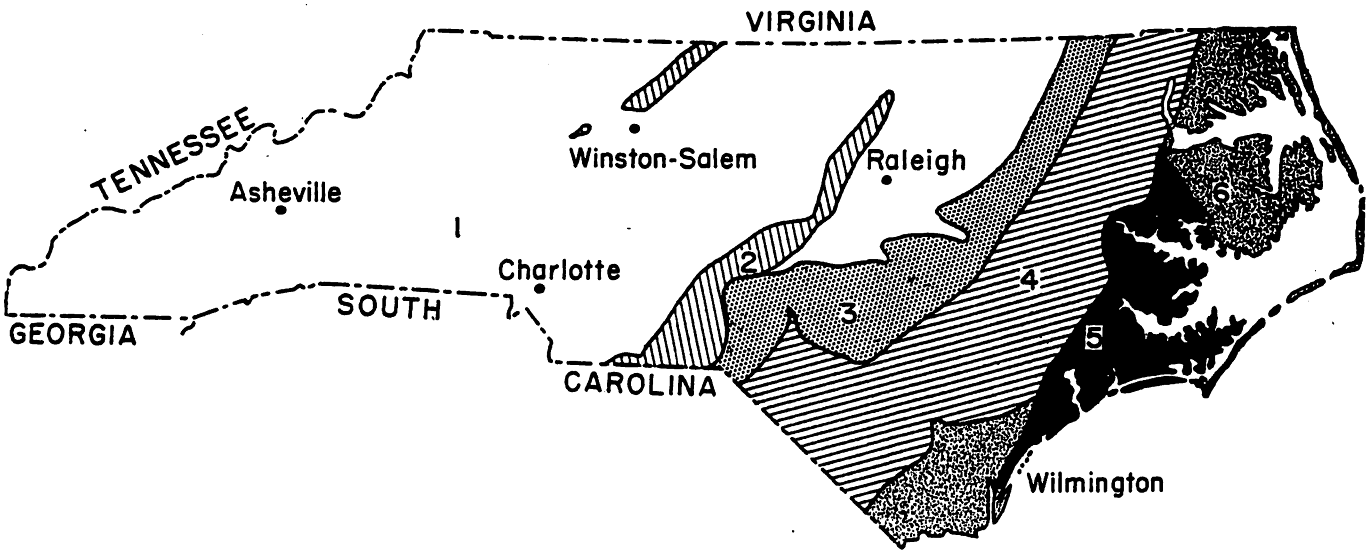

Figure 4.—Map showing the major ground-water regions in North Carolina.
(See following page for explanation)

EXPLANATION

1

Chiefly granite- and slate-like rocks beneath a layer of residual soil. Water occurs in the subsoil and in the fractures of the underlying rocks to depths rarely exceeding 300 feet. Favorably located wells may yield as much as 50 gallons a minute, but average is less. Range in yield is 0-200 gallons a minute, small municipal and industrial supplies being available almost everywhere. Water is generally soft and of good chemical quality.

2

Shale and sandstone - Wells yielding as little as 10 gallons a minute are common. Few yield more than 40 gallons a minute.

3

Lenticular beds of sand and clay, thickening eastward. Water available from sands, and also from fractures in the underlying slatelike rocks, which pass beneath the sand and clay from their exposures in the Piedmont to the west. Yields of individual wells commonly less than 50 gallons a minute.

4

Interbedded sands and clays. Completely developed wells in sands are capable of yielding 300-700 gallons a minute. Water generally is soft and of good chemical quality.

5

Chiefly limestone with subordinate amounts of sand. Wells generally capable of yielding more than 300 gallons a minute, commonly 10 to 60 gallons a minute for each foot of lowering of the water level. At greater depths salt water occurs and at some places may encroach toward wells that are pumped too heavily. Water is generally hard and may contain objectionable amounts of iron.

6

Wells obtain water chiefly from sands. Yields of wells range from 50 to 500 gallons a minute, depending on the character and thickness of sands above the salt-water body, which occurs at depth. Salt-water encroachment is possible if withdrawal of water is too concentrated.

and industrial wells in the Piedmont area, 60 percent yield at least 18 gallons a minute, 40 percent yield at least 33 gallons a minute, and 20 percent yield at least 54 gallons a minute. Such statistics on probabilities are not very satisfactory to a person interested in only his own well, but the situation parallels the plight of a sick man having a serious disease, who does not know whether he will live but can get from the doctor only an opinion as to his chances of survival, based on records of previous patients having the same disease. What appears to be luck regarding the water supply from a well actually represents undetermined geologic conditions.

The most important problem involves the selection of a site at which to drill the well. The probabilities of successful wells, shown above, were based on records of existing wells whose locations were selected for convenience. Most wells are located on hills where conditions for large supplies are unfavorable. In general, there is a greater likelihood of developing a large-yielding well in a draw, or other low ground where the soil zone is thick, than on a sharp hill where bare rock is exposed.

Another important consideration is the depth of the well. Since the water table generally lies in the zone of soft, decayed rock, shallow dug or bored wells can be developed a few feet below the water table in most places. These wells are normally adequate for domestic uses, but some of them go dry when the water table falls during droughts. Larger supplies can be obtained from deeper, drilled, wells that draw water directly from fractures in the bedrock. The yield of a drilled well does not increase in proportion to an increase in depth. Since most of the water-bearing fractures occur in a zone no deeper than 150 feet, it may not be economically wise to drill deeper than 150 feet if the yield is poor, nor deeper than about 300 feet in almost all cases.

Ground water is of good chemical quality almost everywhere in the Piedmont and mountain provinces. Some of the dark-colored rocks, overlain by dark-red or brown soils, yield moderately hard water containing objectionable amounts of iron, but, on the favorable side, these rocks generally give high yields to wells.

Coastal Plain Province

The Coastal Plain rises gradually from the coast, and its highest parts are only a few hundred feet above sea level. In the geologic past the sea has encroached upon the Coastal Plain several times, receiving sediments from the emerged land to the west. The accumulated sediments lie almost flat on a gently sloping floor of rocks that are similar to and form an extension of those exposed in the Piedmont. The sediments of the Coastal Plain are composed chiefly of poorly consolidated beds of sand, clay, and limestone. Considered as a whole, they represent a wedgelike body of sediments whose thin edge lies inland near Fayetteville and Rocky Mount and whose thicker part lies coastward. The greatest observed thickness of Coastal Plain sediments in North Carolina was nearly 10,000 feet in an oil-test well at Cape Hatteras. Geologists have grouped the sediments into formations, all of which slope gently toward the coast at a rate slightly greater than the slope of the land surface; as a result, the formations exposed at the surface at inland places are buried progressively deeper toward the coast.

The prevailing flat, sandy ground, the unconsolidated characteristics of the strata, and the presence of many permeable sand and limestone beds result in high infiltration and in the availability of prolific water-yielding beds at one or more levels beneath the surface. Coastward-dipping permeable sand and limestone beds alternate with impermeable clays, producing artesian conditions throughout much of the region except in beds near the surface. Water enters the artesian beds where they are exposed at the surface and then moves downward and coastward, becoming confined between beds of clay. The artesian water in the Coastal Plain areas does not originate in the mountains, as is commonly believed, but enters the ground at some point on the Coastal Plain, generally west of its point of discharge or withdrawal.

Only a very small part of the total amount of water available in the Coastal Plain is now used. This is partly because the total demand for water is still far below the quantity of ground water available and partly because the availability of ground water and the means of obtaining it are not generally understood.

The chief water-bearing strata of both sand and shell rock, or limestone, have a lateral extent that is considerable in comparison with rocks of the Piedmont and mountain provinces. Yet, the water-yielding strata of the Coastal Plain are not uniform. For example, wells at Kinston, New Bern, and Richlands each draw water from different strata. A major problem arises from the difficulty in obtaining sufficient data to disclose the depth, thickness, and hydrologic properties of each stratum.

Although it is known that some individual wells are capable of yielding as much as a million gallons of water a day, the maximum withdrawal that can perennially be assured at any one place has not yet been established. Water initially withdrawn from artesian beds has been in storage underground for a relatively long period of time. As more water is removed, the artesian water level continues to lower until the withdrawal is balanced by an increase in recharge or a decrease in natural discharge, or both. Before the balance between withdrawal and natural replenishment is reached, the water level may have lowered sufficiently in some places near the coast to cause salt water to move into the fresh-water body. In no place has overdevelopment of artesian water occurred in North Carolina, nor is overdevelopment likely as long as withdrawal of water is not concentrated. We should be aware that more water can be pumped perennially from widely spaced than from closely spaced wells.

Figure 4 shows the approximate limits of four areas in the Coastal Plain, each having underground reservoirs of different types. Several million gallons of water per day can be obtained at many places in areas 4 and 5. The perennial yield at any one place depends on local geologic conditions which should be studied prior to undertaking large-scale developments of ground water. The picture on the front cover shows a well owned by the city of Kinston, Lenoir County, being pumped at the rate of 1,500 gallons a minute.

The chemical character of water in the Coastal Plain varies greatly from place to place, as well as with depth at any place. As water moves downward through the atmosphere and soil it dissolves carbon dioxide and mineral matter. All natural waters contain some dissolved mineral matter. In view of the many uses of water and with the objections that some users have to excessive amounts of certain mineral constituents, it is essential that adequate chemical analyses be made to determine the character of the waters.

The shallow ground water in the surface sands of the Coastal Plain generally contains enough carbon dioxide to cause some corrosion of pipes, and the resulting dissolved iron may stain plumbing fixtures or laundry. This is a common problem because the use of well points in the shallow surface sand is prevalent throughout the Coastal Plain.

In much of areas 5 and 6 the water is hard enough to be objectionable for some purposes. Artesian water moving in area 4 passes through material which tends to make it hard, but on further movement it passes through certain other mineral aggregates that result in a natural softening. As a result, the water from the deep wells at Greenville, Kinston, and Richlands rates among the finest in the country because of its softness and because it has no mineral matter that is objectionable, so far as most uses are concerned.

In recent years many municipalities have added small quantities of fluoride to their water supplies in an effort to retard the decay of children's teeth. Many of the waters in the Coastal Plain contain small amounts of fluoride, but in a wide belt extending from eastern Pitt County through Williamston, Windsor, and Gatesville to the Virginia line, artesian waters containing appreciable amounts of fluoride occur. In most places in this belt the artesian water contains sufficient fluoride to inhibit the decay of children's teeth and in some places enough to mottle the enamel of their teeth.

Almost all the formations of the Coastal Plain contained sea water at one time or another. Water, originating as precipitation, has subsequently circulated through the formations to flush or greatly dilute the salty water. Unfortunately, the salty water has not been completely flushed out of all parts of the Coastal Plain. Consequently, we cannot use water from those beds that contain a significant amount of salt water. In the western part of the Coastal Plain all the beds contain fresh water, but, toward the coast, beds penetrated by some deep wells may yield salt water. The depth to salt water, which varies locally with complex geologic factors, is not adequately known. In some coastal counties the depth to salt water is less than 200 feet, limiting the withdrawal of water to near-surface beds.

Not only is the depth to salt water important, but so is the level to which the water level can be lowered without causing the salt water to rise from below or encroach laterally. Under natural conditions the fresh water tends to float on the salt water, and the depth to salt water is governed to a large extent by the height of the fresh water above sea level. When the ground-water level is depressed by withdrawal of water, salt water may move toward the wells unless the head remains high enough between the wells and the salt-water beds to prevent such movement. In coastal areas of some other States parts of some underground reservoirs have been contaminated by the encroachment of salt water. Fortunately, such has not yet occurred in North Carolina, and is not likely to occur so long as the withdrawal of water is not concentrated locally. Under present conditions the rate of withdrawal has not reached the perennially safe yield, and large additional supplies are still available if precautions are taken to prevent the encroachment of salt water.

Unlike surface water, which generally has to be treated, ground water throughout the State is usually of good sanitary and bacteriological quality. The water is filtered of impurities in passing through the soil and rocks. Although polluted waters may exist in the vicinity of shallow, poorly constructed wells located near sources of contamination, the well drillers and owners in North Carolina have generally been careful in the construction of wells to prevent the entrance of polluted water. As a result, problems of pollution of ground water in North Carolina are extremely rare.

CONCLUSIONS

An immense quantity of water is stored in the underground reservoirs of North Carolina — more water than occurs in all our streams and lakes combined. The underground reservoirs of the Piedmont and mountain sections yield water slowly to wells, whereas those of the Coastal Plain give up water much more readily.

In spite of the great number of wells, the ground-water resources have not been overdeveloped. In fact, North Carolina does not rank high, compared with other States, in the total use of ground water. This is due largely to the following reasons: (1) Surface-water supplies are readily available in many places for large municipal and large industrial uses where individual wells do not yield large amounts of water; and (2), more important, most people are not aware that adequate ground-water supplies may be available for their purposes.

In spite of an assured increase in demand for ground water in the future, the number of problems arising from its use can be greatly reduced. The responsibility for maintaining an adequate supply of water from wells rests with the well owner or operator. He should understand his well. He should have knowledge of the performance of the well and of its ability to draw water from the underground reservoir. Having this knowledge, he can foretell almost all approaching ground-water problems before they become a reality. Orderly and relatively inexpensive measures can then be taken to avoid them. Even though more than half the municipalities in North Carolina use ground water as a source of supply, the ground-water reservoir beneath each one has never been depleted of usable water, not even during severe droughts. Shortages of ground-water supplies that have been experienced in the past were almost entirely due to inadequacies of existing wells to draw sufficient water from the underground reservoir or to some extraneous factor, such as mechanical failure of power or pump. The possibility of spreading wells over the area of a city places municipalities in North Carolina in the fortunate position of having adequate amounts of water in the underground reservoir during severe droughts.

Contrary to popular belief, the underground reservoirs are not being depleted and the water table is not perenially falling. Even though people are using more ground water than ever before, the use is so small and so dispersed compared with the total ground water available that the withdrawal has no significant effect on the water table throughout the State.

A study of the ground-water resources of North Carolina is being made by the U. S. Geological Survey, in cooperation with the North Carolina Department of Conservation and Development. This study is intended to show where wells can be developed to produce various quantities of water and to determine the perennial supply available to each area. Considerable progress has been made but a great deal of intensive work remains to be done before the full picture will be known.

We hear much about conservation of our water supplies. Where does ground water fit into the picture? Under natural conditions the recharge of water to the underground reservoirs is in balance with discharge from them. Where water is pumped from wells we temporarily disturb this balance, but the reduction of natural discharge accompanying development will rarely affect anyone adversely, and the increase in recharge that commonly occurs is a gain from anyone's standpoint. The extent to which the population in North Carolina is dispersed over the State has had the effect that local withdrawals of ground water are only a fraction of that available. Nowhere in the State has there been any serious overdraft of the ground-water supply. So long as water leaks out of the underground reservoirs through seeps and springs, as is the case in all parts of the State, we can say confidently that we are not using it all. Failure to use ground water is not conservation. As with all renewable natural resources, wise and full use is the most productive form of conservation.