NORTH CAROLINA
DEPARTMENT OF CONSERVATION AND DEVELOPMENT
R. BRUCE ETHERIDGE, DIRECTOR

DIVISION OF MINERAL RESOURCES
JASPER L. STUCKEY, STATE GEOLOGIST

BULLETIN 47

PROGRESS REPORT

ON

GROUND WATER

IN

NORTH CAROLINA

BY
M. J. MUNDORFF

PREPARED IN COOPERATION WITH THE GEOLOGICAL SURVEY,
UNITED STATES DEPARTMENT OF INTERIOR

RALEIGH
1945

MEMBERS OF THE BOARD OF CONSERVATION AND DEVELOPMENT

LETTER OF TRANSMITTAL

Raleigh, North Carolina
October 24, 1945

To His Excellency, HON. R. GREGG CHERRY,
Governor of North Carolina.

SIR:

I have the honor to submit herewith, manuscript for publication as Bulletin 47 "Progress Report on Ground Water in North Carolina," by M. J. Mundorff.

During recent years there has been developing an increased need for information on the ground water resources of the State. In some areas of our State surface water supplies are inadequate and consumers are forced to turn to ground water for their needs. This was true in the case of several military camps built in North Carolina during World War II. In areas where surface waters are abundant it is often more economical for public schools, certain manufacturing plants and smaller towns to secure their supplies from ground water.

To meet these needs the North Carolina Department of Conservation and Development and the United States Geological Survey have begun a cooperative study of the ground water resources of the State. It is planned to prosecute the study as rapidly as possible and present other reports as worthwhile information is secured.

Respectfully submitted,

R. BRUCE ETHERIDGE,
Director.

CONTENTS

ILLUSTRATIONS

ABSTRACT

A program of ground-water investigations was begun in North Carolina in 1941 by the State Department of Conservation and Development in cooperation with the Geological Survey, U. S. Department of Interior. Systematic field work has been completed in 12 counties. A large number of investigations were also made, mostly in the Coastal Plain, in connection with the development of ground water supplies for military bases and in defense areas. During the course of this work, much valuable information has been obtained, part of which is presented in this report.

Five unit-areas in the Mountain and Piedmont sections and four in the Coastal Plain section have been distinguished on the basis of the hydrological properties of the rock formations.

The formations of the Mountain and Piedmont sections are not as prolific as those of the Coastal Plain, but many wells yielding 50 to 100 gallons a minute have been drilled in these sections, and a number of wells yield 200 to 300 gallons a minute. The schists, slates, sheared granites and some of the gneisses are among the better aquifers in the Mountain and Piedmont sections, whereas the massive granites, some gneisses, schists and quartzites, and, in places, the triassic rocks, are generally less satisfactory. The quality of the water obtained is determined largely by the nature of the rock. The slaty tuffs, some granites and certain types of gneisses and schists yield hard water, whereas water obtained from most schists and gneisses, and from some granites, is soft.

Large quantities of water can be obtained from the formations of the Coastal Plain at most places, and wells yielding 500 to 1,000 gallons a minute are not uncommon. The character of the water and the type, depth, and construction of the well depend upon the nature of the water-bearing formation.

Soft water can be obtained in approximately the western half of the Coastal Plain, whereas only moderately hard to very hard water can be obtained in most of the eastern half.

Brackish water is encountered in many places in the eastern half of the Coastal Plain, at depths ranging from 100 to 500 feet.

Problems concerning quality of water, including chloride, iron, and fluoride content, hardness and corrosiveness, are discussed in some detail.

The aquifers, or water-bearing formations, of the Coastal Plain are individually described.

The report includes (1) an index map of the State, (2) a map showing the five hydrologic unit-areas in the Mountain and Piedmont sections and the four unit-areas in the Coastal Plain, (3) a map showing the hardness of municipal and military ground-water supplies in the Coastal Plain, (4) a map showing the probable depth to water with a chloride content of 250 parts per million or more, (5) nine cross-sections of the Coastal Plain, (6) a map showing the location of these sections and wells used in their construction, and (7) a diagramatic cross-section along New River estuary showing probable relation of fresh and salt water.

PROGRESS REPORT ON GROUND WATER IN NORTH CAROLINA

INTRODUCTION

Ground water is one of the most valuable natural resources in North Carolina. Approximately 2,500,000 people, or 70 per cent of the total population of the State depend upon ground water for their water supply. Probably more than 99 percent of the rural population use water from wells or springs, and approximately 400,000 people are supplied with ground water by municipalities and military establishments.

Of the several million dollars a year spent in obtaining this water, a considerable part is spent in digging, boring, and drilling new wells. It is unfortunate that part of this money is used unnecessarily because of inadequate knowledge of the ground water conditions.

Plan and scope of project.—The present investigation of the ground-water supplies and resources of the State was begun in August, 1941, as a result of a cooperative agreement between the State Department of Conservation and Development and the U. S. Geological Survey. The cooperating agencies each bear half of the expenses of the project. The program is under the direction of Dr. O. E. Meinzer, Geologist in Charge of the Division of Ground Water, U. S. Geological Survey and Dr. J. L. Stuckey, State Geologist of North Carolina.

The purpose of the project is to determine the quantity and quality of water available in the various parts of the State from the underlying water-bearing formations; to develop criteria for choosing favorable locations for drilling and digging wells; to determine the chances of increasing the yield with increasing depth of the well; to ascertain the areas capable of supplying large quantities of water for industrial development, and to determine the quantity and quality of water available from each aquifer in such areas.

It was considered advisable to use the counties as the basic units for field work and to publish reports covering the investigations of areas consisting of one or more counties. The first area in which ground-water studies were undertaken is the Halifax Area, consisting of Northampton, Halifax, Nash, Edgecombe, and Wilson Counties. The report of this area has been completed and is being published as a Bulletin of the State Department of Conservation and Development. The second area is the Greensboro Area consisting of Alamance, Caswell, Guilford, Rockingham, Forsyth, and Stokes Counties. The field work in this area has been completed and the report is being prepared. These two areas were chosen because of the need for information on their ground-water resources and also because they are representative of a largt part of the State.

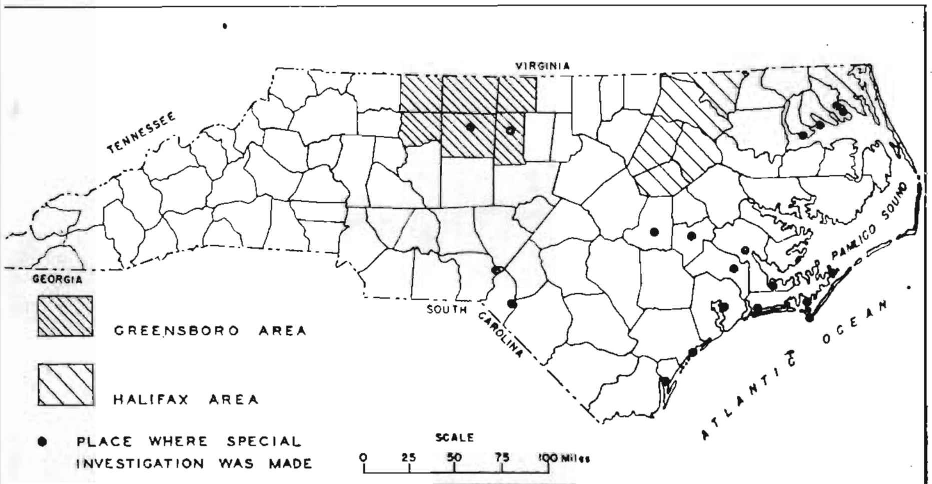


FIG. 1.—Index map of North Carolina showing areas where field work has been completed and places where investigations were made for military bases and in defense areas.

Because of the many military establishments built in the Coastal Plain of North Carolina, all of which utilize ground water, much time has been devoted to that area. A large amount of valuable data has been obtained, including well samples, well logs, and data on the quantity and quality of water available from the various aquifers.

Previous Investigations.—The only systematic investigation of ground water prior to the present one was a survey of the ground-water resources of the Coastal Plain, by L. W. Stephenson, B. L. Miller, and B. L. Johnson in 1905 and 1906[1]. Their report has served as a basis and guide for all subsequent work in this area.

In 1929 Dr. J. L. Stuckey[2] obtained data on 592 wells in the

[1]Clark, Wm. B.: Miller, B. L.: Stephenson, L. W.: Johnson, B. L.: and Parker, H. N.: The Coastal Plain of North Carolina, North Carolina Geol. and Econ. Survey, vol. III, part II, 1912.

[2]Stuckey, Dr. J. L., The ground water resources of the crystalline rocks of North Carolina, Journ. N. C. Water and Sewage Works Assoc., 1929-1930.

Piedmont section of the State, summarizing the data according to geologic formation, depth, and diameter of the well. The only other investigations have been of a local nature.

In 1928, W. N. White, of the U. S. Geological Survey, investigated the cause of the chloride contamination of the public-supply at New Bern. His report on this investigation was released in typewritten form. In 1932, S. W. Lohman, of the U. S. Geological Survey, investigated the ground-water resources of the area around Elizabeth City[3]. In 1941, D. G. Thompson, also of the U. S. Geological Survey, investigated the ground-water resources of the Wilmington Area for the town of Wilmington, and ground-water conditions around Jacksonville, North Carolina, for the Navy. These two reports have not been published.

GEOLOGY AND ITS RELATION TO GROUND WATER

There is a very close relationship between the geology of an area and the quantity and quality of water that can be obtained from wells in the area. Therefore, an understanding of the fundamentals of geology and the principles of the occurrence of ground water are of great value in estimating the ground water possibilities of a locality and in choosing the best possible location for drilling.

The principal source of ground water is precipitation as rain or snow. The water can enter and move through the soil and unconsolidated rocks only through the openings between the sand grains and clay particles, and in harder consolidated rocks, through fractures and joints. Ground-water moves because of gravity, and the point of discharge is always at a lower level than the point of recharge. In North Carolina, recharge occurs in interstream areas and the natural discharge is into stream valleys, lakes, swamps, and into the sea. Rain falling on the surface percolates vertically downward through the earth until it reaches the zone of saturation, below which the pores and openings of the rock are completely filled with water. The upper surface of the zone of saturation is called the water table and, in North Carolina, generally is from a few feet to about 100 feet below the land surface. Discharge of ground water is a continuous process so that the ground-water levels are receding except during and immediately following a period of rainfall at which time the ground-water supplies are replenished. For these reasons the water table is not a fixed surface but is continually fluctuating.

[3]Lohman, S. W.; Geology and ground-water resources of the Elizabeth City Area, North Carolina, U. S. Geol. Survey Water Supply Paper 773-A, 1936.

The amount of water in an aquifer depends upon the porosity of the rock. Porosity is defined as that percentage of the total volume of the rock that is occupied by pores or other openings. Natural rock materials differ greatly in porosity. The porosity of unconsolidated materials such as sand, clay, and gravel commonly is from 25 to 50 percent. The porosity of consolidated rocks is much less and is mainly in the joints, fractures, and solution channels.

A rock may have a large porosity and yet yield little water even though allowed to drain for a long time. A clay, for example, with a porosity of 50 percent, might not yield any water because of the smallness of the pores, the water being retained because of molecular attraction. The ratio of the volume of water a saturated rock will yield by gravity to the total volume of rock is called the specific yield and is stated as a percentage.

Porosity and specific yield are important properties of an aquifer, but permeability, that is the rate at which water can be transmittted, is the most important characteristic. The permeability of an aquifer depends upon the size and arrangement of the pores. In clays the pores are so small that water will be transmitted very slowly. A clean sand of moderate texture will transmit, and therefore yield, water relatively rapidly.

In rocks such as granite, slate, schist, gneiss, and some sandstone and shale, the water moves along bedding planes, joints, and cleavage planes so that the amount of water such a rock will yield depends on the size and number of these openings.

As rain is practically free of mineral matter, the mineral content of ground water depends on the minerals which are dissolved as the water percolates through the rock. Therefore, the mineral content of the water is largely determined by the kind of rock through which the water moves and by the length of time it is in contact with the soil and rock.

On the basis of the hydrologic properties of the underlying rocks the Mountain and Piedmont sections have been divided into five hydrological unit-areas. Each of these unit-areas has several different kinds of rocks which are more or less similar in their geology and water-bearing properties. The Coastal Plain has been divided into four hydrological unit-areas, each of which differs from the others in its geology and water-bearing properties. Plate 1 shows the five unit-areas in the Piedmont and Mountain sections and the four unit-areas in the Coastal Plain.

GEOLOGY AND GROUND WATER IN THE MOUNTAIN SECTION

Little detailed information is available regarding ground-water supplies and conditions in the Mountain section of the State. Surface supplies generally have been satisfactory in this area, but ground water has the advantage of a constant supply and temperature so that it is preferred at many places.

The rocks of the Mountain section of North Carolina have been divided into three main unit-areas on the basis of their hydrologic properties, and their distribution is shown on the accompanying map, Plate 1.

Unit-area 7 consists of rocks chiefly of sedimentary origin which have been only slightly or moderately metamorphosed. Included in these rocks are schists, phyllites, slates, shales, quartzites, sandstones, limestones, and marbles. Bedding planes are distinct in most of the formations of this group.

The rocks of this unit are fairly good aquifers. The harder and coarser grained formations generally yield larger supplies than those of softer and finer grain. Because a considerable amount of the water moves along the bedding and cleavage planes, the most productive wells are in areas where these planes are only moderately tilted. Thus a well of given depth will intersect more planes than it would in an area where the planes are steeper.

Unit-area 8 includes the highly metamorphosed mica gneisses and schists of the Carolina gneiss, and similar rocks which are also chiefly of sedimentary origin.

Because ground water occurs and moves in joints and other fractures, and along the cleavage and bedding planes in the rocks of western North Carolina, some of the best aquifers are the highly metamorphosed and sheared rocks included in the Carolina gneiss. The average yield of the eleven wells in this formation, listed in this report, is 77 gallons a minute. The more productive wells in this unit, as in unit-area 7, are generally located where the dip of the bedding and schistosity is moderately low.

Unit-area 9 consists of granites and gneisses of igneous origin, representing a wide range in age and a corresponding range in degree of metamorphism. The formations of this unit-area include the Whiteside, Yorkville, and similar granites which are only slightly, or moderately, metamorphosed; and the Cranberry, Bessemer, Beech, and Henderson granites and the Blowing Rock and Roan gneisses which have been greatly metamorphosed.

The range in the yield of wells in this unit-area is large. Generally the more intensely sheared rocks will yield the largest amounts; very often wells in unsheared granite will be failures. The areas of sheared and shattered rocks are more easily eroded than areas of unbroken rock and therefore, in granite areas, hills and ridges generally indicate that the rock beneath is relatively unfractured. Such locations are undesirable as well sites.

One possible source of ground-water supply in this part of the State has been generally overlooked; this is the gravel and sand of the flood-plain deposits, along the creeks and rivers. The logs of the wells of the Champion Fibre Company indicate a considerable thickness of sand and gravel in the valley of the Pigeon River at Canton, and it is probable that flood-plain deposits along many of the streams will yield moderate supplies of ground water. It is possible that several million gallons a day could be obtained in some of the larger stream valleys by utilizing groups or lines of shallow wells.

The yields of 16 industrial and municipal wells in western North Carolina are listed in the table of well data. The average yield is 64 gallons a minute. Fifteen wells from western North Carolina are included in Dr. Stuckey's report[1]. The average yield of these is 31 gallons a minute, which is about 5 gallons a minute more than the average well in the Piedmont area according to the same report.

An analysis of a sample of water from a well in the Carolina gneiss at Franklin, in Macon County, is given in the table of analyses. The water appears to be satisfactory for almost any use, none of the constituents being present in objectionable amounts. The total hardness is only 12 parts per million, which is unusually low. It is probable that most of the wells will yield somewhat harder water. The other analyses listed in the table are from wells in the Piedmont section, but wells in western North Carolina, drilled in comparable rocks, no doubt will yield water of similar quality.

GEOLOGY AND GROUND WATER IN THE PIEDMONT SECTION

In the Piedmont section are located the most thickly populated and highly industrialized areas of the State. Many thousands of wells have been drilled in this area and millions of gallons of ground water are used daily.

[1]Op. cit.

The rocks of the Piedmont section include not only those of the three unit-areas found in the Mountain section but also two additional types which are included in unit-areas 5 and 6. These are the sedimentary rocks of Triassic age and the pre-Cambrian (?) rocks of the so-called Carolina slate belt.

In the Piedmont the rocks of the first three unit-areas yield amounts of water comparable to those yielded by the same rocks in the Mountain section of the State.

The metamorphosed sedimentary rocks, of unit-area 7 in the Piedmont, as in the Mountain section, include schists, slates, shales, quartzites, sandstones, and limestones and form two narrow belts in the western part of the Piedmont. Wells drilled in favorable locations may yield as much as 50 gallons a minute or even more. At less favorable places, where the bedrock is close to the surface, where the bedding planes are vertical or dip very steeply, or where the rock has few joints or fractures, smaller yields are obtained.

The rocks of the unit-area 8 are chiefly mica-feldspar schist and gneiss similar to the Carolina gneiss, and crop out in extensive areas through the western Piedmont. Many of the more productive wells west of the Coastal Plain have been drilled in these rocks. The rocks are mostly of sedimentary origin and have been highly metamorphosed. They have been greatly sheared and fractured and are highly schistose. Because a considerable part of the ground water moves along the schistosity and bedding planes, the more productive wells are drilled in areas where the schistosity and bedding dip at a low angle, so that a well of given depth will intersect more planes than it would in an area where the planes are steeper. Yields of 50 to 150 gallons a minute are not uncommon from wells drilled in favorable locations in rocks of this group. The water is usually moderately hard to hard but usually has no other objectionable characteristics.

The granites and granite gneisses of the unit-area 9 include the Whiteside, Yorkville, and similar granites, and granite gneisses such as the Henderson granite and the Roan gneiss. These rocks occupy considerable areas in the Piedmont. Wells drilled in the more intensely sheared rocks usually yield from 10 to 40 gallons a minute, but wells in massive unfractured areas are among the poorest in the State. Yields of only a fraction of a gallon a minute are not uncommon at such locations.

Topography is a more important indication of the possible yield of wells in this type of rock than it is for other types. The areas of fractured and sheared rocks are more easily eroded than areas of massive rock so that hills and ridges in granite and granite gneiss usually indicate that the rock beneath is less fractured than the surrounding rock.

The rocks of the Carolina slate belt, included in unit-area 6, are a varied assortment, some being of volcanic origin and consisting chiefly of lava flows and ejecta, whereas others are of sedimentary origin.

The flows include both rhyolites and andesites, and the ejecta include breccias and tuffs. Much of the tuff is water laid and at many places considerable land waste is intermingled with the ash so that in some areas the rocks are of true sedimentary origin.

These rocks have been extensively metamorphosed by dynamic forces so that the tuffs and tuffaceous shales have developed a very pronounced slaty cleavage. The cleavage is usually much less well developed in the andesites and rhyolites than in the shales. However, the degree of metamorphism of these rocks appearently varies somewhat in different parts of the State as well, so that the rocks, classified by degree of metamorphism, include shale, slate, phyllite, and schist.

Wells drilled into the andesites, rhyolites, and more massive tuffs generally furnish small amounts of water. The slates and schists, with a better cleavage and schistosity, usually furnish larger supplies and some excellent wells have been drilled in these rocks, especially where quartz veins are encountered. Wells yielding up to 60 gallons a minute have been developed in favorable locations, but in unfavorable localities many wells furnish less than 10 gallons a minute. However, only very rarely does a well in this rock fail to yield less than 1 gallon a minute, which is about the minimum that is satisfactory for a domestic supply.

The water from the andesites and from the slaty tuffs usually is hard to very hard, but the water obtained from slates of sedimentary origin generally is much less hard, and the water yielded by sedimentary schists in many places is quite soft and relatively low in dissolved mineral matter. The iron content of the water from these rocks is excessive at some places.

The Triassic rocks of unit-area 5 are continental deposits and include sandstones, conglomerates, shales, mudstones, and limestones. The rocks are predominantly of a brownish or reddish color. The beds are lenticular and therefore usually pinch out in a short distance. The materials are poorly sorted, resulting in a low porosity and permeability which has been further reduced by compaction and cementation. The result is that the movement of ground water is practically confined to bedding planes, joints, and other fractures. Jointing and fracturing is generally more pronounced in the coarser and harder strata such as sandstone and conglomerate than it is in the shales and mudstones, so that the former usually furnish larger supplies. The Triassic sedimentary rocks have been intruded by many "trap" dikes which have fractured and baked the adjacent strata. Therefore, a well drilled near such a dike usually furnishes a larger water supply than a well drilled in the same strata at some distance from the dike.

According to Dr. Stuckey's report[1], 28 wells in the Triassic rocks of Rockingham, Anson, and Durham Counties yielded an average of about 25 gallons a minute. During the recent ground-water survey made in these counties, data were obtained on 20 industrial and municipal wells in Triassic rocks in Stokes and Rockingham Counties. The average yield of the 20 wells is 37 gallons a minute. However, many wells, especially in the eastern belt of Triassic rocks, will yield only a few gallons a minute. At the present time it appears that the Dan River Triassic belt, through Stokes and Rockingham Counties, will furnish larger amounts of water to wells than the eastern Triassic belt. However, not enough information regarding the yield of wells in the eastern Triassic belt is yet available to be certain of this.

GREENSBORO AREA

A detailed survey was made of the geology and ground-water supplies in Alamance, Guilford, Forsyth, Caswell, Rockingham, and Stokes Counties and records of about 1,300 wells were obtained. A complete report of the survey is being prepared. Data on many of the industrial and municipal wells are included in the present report.

Although the data obtained have not yet been fully analyzed, it appears that the gneisses and schists, including the greenstone schist in the vicinity of Greensboro, (unit-area 8) generally furnish the largest yields. Rocks of the Carolina slate belt (unit-area 6) appear to be second, Triassic rocks (unit-area 5) are third.

[1] Op. cit.

and the granite belt (unit-area 9) is fourth. Rocks of unit-area 7 are represented only in Stokes and northwestern Forsyth Counties where there are only a few domestic wells so that comparison of this group is difficult.

HALIFAX AREA

A report on the geology and ground water of Northampton, Halifax, Nash, Edgecombe, and Wilson Counties has been completed.

Wells in the schist and slate of this area yield, on the average, almost twice as much as wells in granite. The average yield from 128 domestic, municipal, and industrial wells in schist was 22 gallons a minute. The average yield of 78 wells in granite was about 10 gallons a minute. In neither group does drilling beyond about 400 feet appear to be advisable.

The water from the schist in this area on the average is less than half as hard as water from the granite, but frequently contains excessive iron whereas the water from granite usually does not.

GEOLOGY AND GROUND WATER OF THE COASTAL PLAIN

GEOLOGY

The formations of the Coastal Plain are very different from those of the Piedmont and Mountain sections of the State. In contrast with the hard, crystalline rocks of those areas, the formations of the Coastal Plain consist of unconsolidated and semiconsolidated sediments deposited in and along the margin of a sea that once covered the eastern part of the State.

GEOLOGICAL HISTORY

At the beginning of Cretaceous time the land had been worn down to a plain of low relief. The rocks were deeply decayed and a thick layer of weathered material covered the surface. At this time the land began to be tilted gently to the southeast so that eastern North Carolina was covered by a shallow sea which extended far up the broad valleys that had been developed in the crystalline rocks. The weathered and decayed material to the west was carried southeastward and deposited in the stream channels and adjacent flood plains, in the bays and estuaries, and along the sea margin, resulting in the basal sand and clay strata of

Cretaceous age. As these broad valleys were filled, subsidence continued so that in later Cretaceous time the land waste was carried into the sea, forming the marine deposits now known as the Black Creek and Peedee formations. At the end of the period the land was elevated relative to sea level so that a long period of erosion removed much of the material previously deposited.

In lower Eocene time the sea again encroached on the land, but only a few remnants of the sediments deposited in it have been found, and these are at relatively high levels along the western edge of the Coastal Plain. However, evidence of the presence of sand and clay strata of lower Eocene age, beneath the Miocene Yorktown formation in northeastern North Carolina, has recently been discovered. In later Eocene time the limestones and calcareous sands and sandstones of the Castle Hayne marl were deposited in southeastern North Carolina unconformably overlying the uppermost Cretaceous deposits. The Castle Hayne is not known to overlie the earlier Eocene deposits although it may do so in Beaufort County. The Coastal Plain of North Carolina appears to have remained above sea level in Oligocene time, but in lower Miocene time the sea again transgressed on the land, and the Trent marl was deposited unconformably over the Castle Hayne. In later Miocene time a more extensive submergence occurred, and the sea extended completely across the present Coastal Plain in the northern part of the State and most of the way across in the southern part. The formations of this period include the Yorktown in the north and the Duplin marl in the south.

Marine Pliocene deposits are found along the coast, but most of the Coastal Plain apparently remained above sea level during this period.

In Pleistocene time the sea rose to as much as 270 feet above its present level. The sea withdrew and advanced a number of times thereafter and at each successively lower stand formed a terrace, just as a terrace is being formed at the present time along the coast.

AREAL GEOLOGY AND STRUCTURE

The exact age of the basal Cretaceous beds in the northern half of the Coastal Plain has not yet been determined. They may belong either to the Patuxent formation, which is of Lower Cretaceous age, or to the Tuscaloosa formation of lower Upper

Cretaceous age, or in part to both formations. In the southern half of the Coastal Plain at least part of these basal strata have been correlated with the Tuscaloosa formation. The strata in both parts of the Coastal Plain, whether of Patuxent or Tuscaloosa age, or both, are lithologically similar and form a single lithologic unit, extending from the northern to the southern boundary of the State in an irregular belt immediately to the east of the Fall Zone.

Eastward, these strata pass beneath the Black Creek formation which in turn is overlain by the Peedee formation still farther to the east. The Black Creek and Peedee formations, of Upper Cretaceous age, extend southward beyond the South Carolina line but are not known to extend northward much beyond Greenville.

In the northeastern part of the Coastal Plain, strata of lower (?) Eocene age probably unconformably overlie the Cretaceous formations. These Eocene strata are not known to crop out in North Carolina. They apparently form a wedge thickening to the northeast from Pitt and Beaufort Counties. To the south, the Peedee formation dips to the southeast beneath the Castle Hayne marl of Eocene age, which forms a belt extending in a north-south direction from the Neuse River, between Goldsboro and Fort Barnwell, to the south of Wilmington. It in turn is overlain, to the east, by the Trent marl of Miocene age.

The upper Miocene formations were deposited on the erosion surface which beveled all older formations. The Yorktown formation underlies practically the entire Coastal Plain north of the Neuse River, extending from the Fall Zone to the coast. For a distance of 20 or 30 miles eastward from the Fall Zone, the dip is about the same as the slope of the land surface so that the thickness in this area is fairly uniform. Beyond this point, however, the dip becomes progressively greater. South of the Neuse River the Duplin marl, which apparently is about the same age as the upper part of the Yorktown formation, overlies the Trent and is in turn overlain by the Croatan sand of Pliocene age. Further south the Duplin occurs in thin isolated patches as far inland as Lumberton.

The Pleistocene terraces form a blanket usually about 20 or 30 feet thick over all the formations mentioned above and extend westward onto the crystalline rocks in the Fall Zone.

The average slope of the basement rock is about 13 feet to the mile in the southern part of the Coastal Plain and about 20 feet to

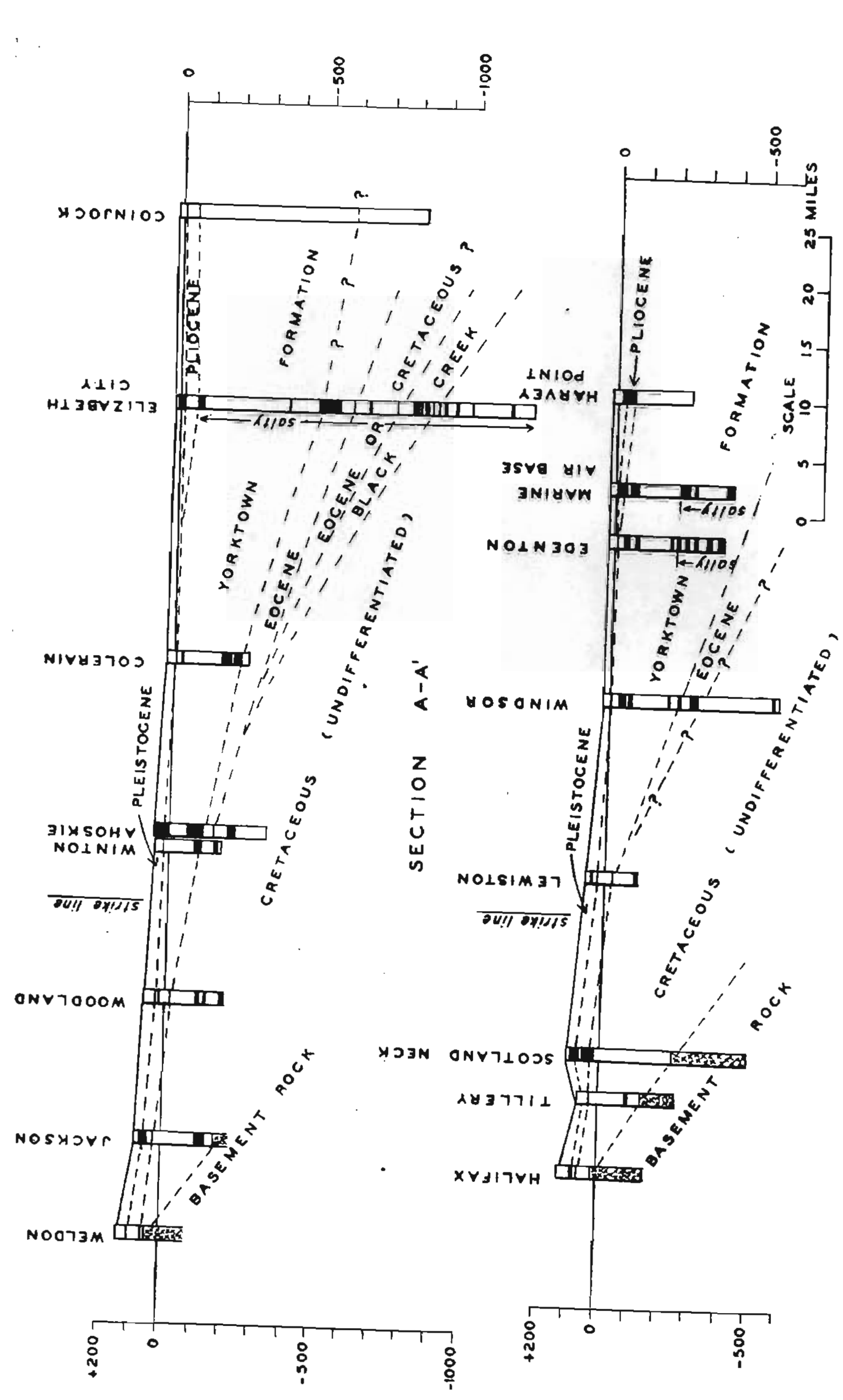


FIG. 2.—Cross sections along lines A-A' and B-B'. Water bearing horizons are shown in black. (see Plate 2)

the mile in the central part, crystalline rock being encountered in wells at 1109 feet at Wilmington, 1540 feet at Fort Caswell, and 2318 feet at Havelock, Craven County. The average dip of the overlying Cretaceous formations probably is not greatly different. However, the dip of the Cretaceous formations is usually steeper than that of the younger formations, and the dip in any one formation usually increases toward the coast.

The structure of the Coastal Plain is shown by cross sections in figures 2 to 6. The location of these sections and the wells whose logs were used in their construction are shown on plate 2. The position and thickness of the water-bearing horizons are shown on the sections in solid black.

Each section is in a straight line, and wells off the line were projected to the section line parallel to an arbitrary line which is approximately parallel to the strike of the basal Cretaceous formations. The contacts between successive Coastal Plain formations do not form perfect planes but have minor undulations in various directions. The depth to the formational boundaries therefore may not be exactly as shown on the sections. For example, the crystalline bedrock and the overlying Cretaceous formations not only dip to the southeast along the Cape Fear arch, but also have a southwestern component along its southern flank and a northeastern component along its northern flank. Therefore, when the well at Mullins, South Carolina, is projected northward to section K-K[1], the formational boundaries are shown deeper than they would be in a well drilled at the corresponding location along the line of the section.

Many of the well logs used in the construction of these sections were published[1] recently. Additional information, received since the compilation of these logs, has resulted in a few changes in the correlation of the formations. The most significant change is due to the finding, by Dr. H. G. Richards, of Eocene pelecypods in samples from a depth of about 110 feet in the well at Williamston. Presumably, the strata from 110 to 400 feet are of Eocene age. It is probable that some of the strata referred to the Miocene (Yorktown formation) or Cretaceous deposits in the logs of wells at Winton, Ahoskie, and Windsor also are of Eocene age.

[1]Mundorff, M. J., Selected well logs in the Coastal Plain of North Carolina, N. C. Dept. of Cons. and Dev., Information Circular 3, 40 pages, 1944.

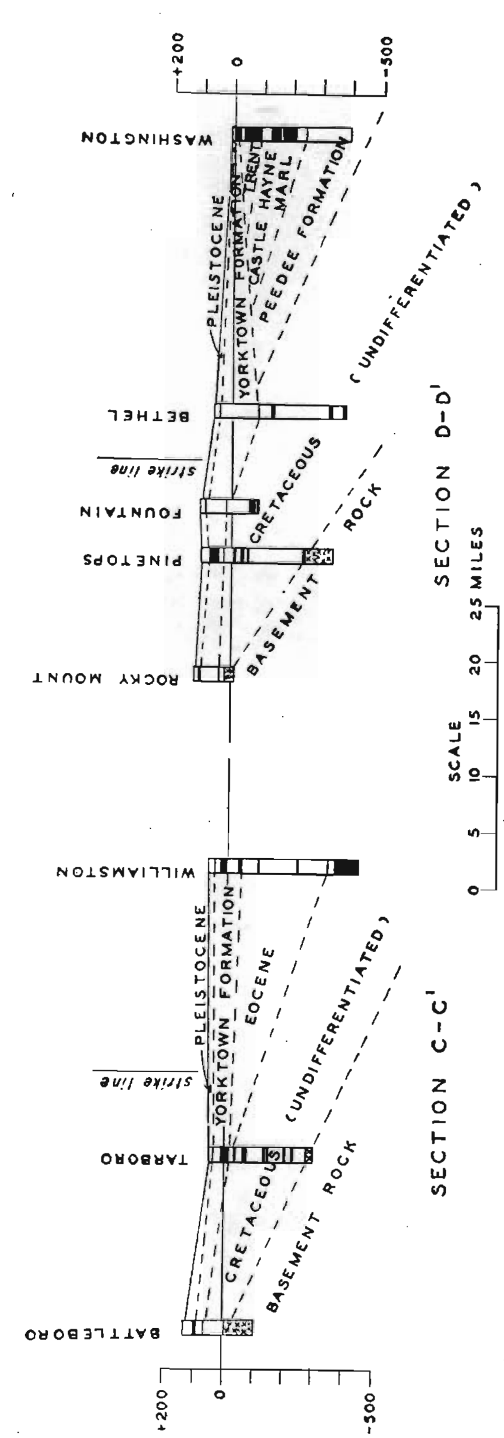


FIG. 3.—Cross sections along lines C-C' and D-D'. Water bearing horizons are shown in black. (see Plate 2)

GROUND WATER

GENERAL

In contrast with the Piedmont, most parts of the Coastal Plain will yield large quantities of water to wells. Supplies of several million gallons a day can be obtained at many places, and adequate supplies for most industrial uses can be obtained at almost any place in the Coastal Plain except along its western margin. A number of wells have been drilled that yielded 1000 or more gallons a minute, and many others which were tested at 300 or 400 gallons a minute with a drawdown of only a few feet undoubtedly would yield several times their tested capacity.

Because the amount of water withdrawn from the Coastal Plain has been small compared to the amount available, little attention has been given to the total perennial yield. Very few data are available regarding permeability of the formations, amount of recharge, or fluctuations of the water level.

Annual recharge in the eastern United States has been estimated by Meinzer[1] as about one-third of the precipitation. As annual rainfall averages about 45 inches in the North Carolina Coastal Plain, this would be about 15 inches and would be equivalent to about 700,000 gallons a day for each square mile. As the porosity of the soils of the Coastal Plain is considerably greater than the average for the eastern United States, it is possible that the recharge in this area may be closer to 1,000,000 gallons a day for each square mile. Because of losses through transpiration and evaporation and from discharge to streams, only a part of this is recoverable.

Although the yield of the deeper aquifers is determined by the transmissibility, which might be so low that part of the recharge would be rejected by these aquifers, the part rejected could be recovered from the surficial Pleistocene sands that practically blanket the Coastal Plain. Thus the total potential water supply in the North Carolina Coastal Plain is determined principally by the amount of recharge, and is probably several thousand million gallons a day.

At many places several million gallons a day can safely be removed from a small area, provided pumpage in adjacent areas is light, although probably not more than 500,000 gallons a day could safely be withdrawn per square mile, if each square mile were being pumped over a large area.

[1]Meinzer, O. E., Hydrology, p. 401, McGraw-Hill, 1942.

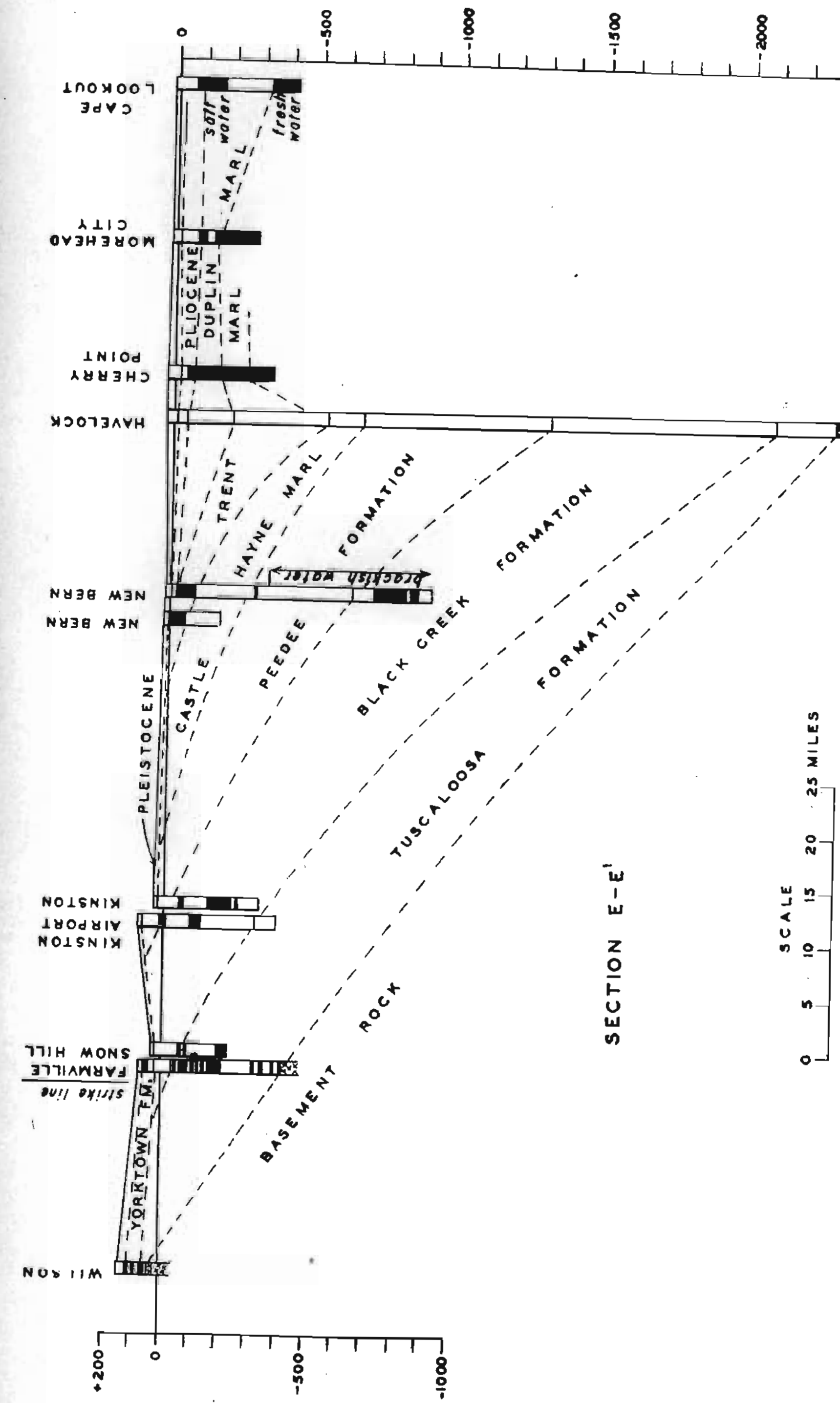


FIG. 4.—Cross section along line E-E'. Water bearing horizons are shown in black. (see Plate 2)

Permeabilities of the materials in the Coastal Plain vary greatly. The coefficient of permeability is defined as the number of gallons of water transmitted, perpendicular to the direction of flow, in one day through a section of the aquifer one mile long and one foot thick, under a hydraulic gradient of one foot per mile. Thus, an aquifer, that is 50 feet thick, and has a hydraulic gradient of 10 feet per mile and a coefficient of permeability of 500, will transmit 250,000 gallons of water daily through a section one mile long. The coefficient of permeability of a few samples of sand have been determined and these ranged from about 40 to 2200. The coefficient of some sands and gravels in the Coastal Plain probably is even higher. Some limestone and shell rock strata also are exceedingly permeable, but the clayey sands and clays have little or no permeability.

GROUND WATER OF THE DIFFERENT AREAS

The following is a summary of the ground-water conditions in each of the four unit-areas in the Coastal Plain shown on the map, Plate 1.

Unit-area 1.—Unit-area 1 is the northeastern part of the Coastal Plain. The Yorktown formation extends to 400 or more feet below the surface along the western edge of this area. Little information is available regarding its depth and thickness near the coast, but the base of the formation is probably 600 or more feet below the surface. Below it are Eocene and Cretaceous strata, but these generally cannot be used as a source of supply because the water has too high a salt content.

The Pliocene and Pleistocene deposits furnish good supplies in some places, some wells less than a hundred feet deep yielding 250 gallons a minute. Elizabeth City obtains its water by using a large number of shallow gravel-packed wells. The Yorktown formation will furnish large amounts of water, and yields of 1000 gallons a minute probably can be obtained at many places. However, as is shown on the map, plate 3, brackish water underlines the area so that in some places the water from this formation cannot be used. Some of the deeper wells near the southern boundary end in sand and shell rock which may belong to the Castle Hayne or Trent marls. The yields of these wells usually are large.

The water in this area is usually moderately hard to very hard, and the iron content, especially in the shallower beds, is apt to be high.

Unit-area 2.—Unit-area 2 is a relatively narrow strip in the southern corner of the eastern Coastal Plain but is much broader in the vicinity of the Neuse River. The limestone and calcareous sandstones of the Castle Hayne and Trent marls are at or near the

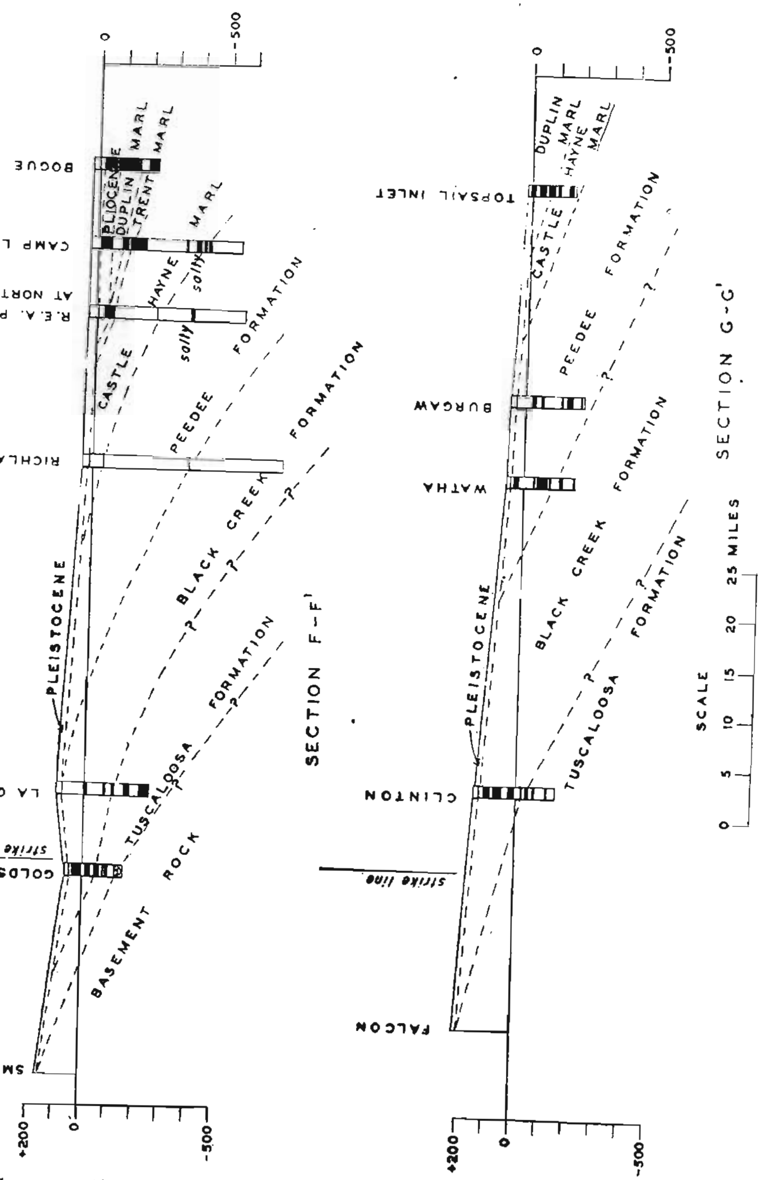


FIG. 5.—Cross sections along lines F-F' and G-G'. Water bearing horizons shown in black. (see Plate 2)

surface through most of the area, the Peedee formation underlying them at shallow depths along the western margin with the depth to it increasing eastward at the rate of 15 or 20 feet per mile.

Very large amounts of water are obtained from the limestones and shell rock strata of the Castle Hayne and Trent marls. Wells which will yield 50 to 100 gallons a minute for each foot of drawdown are not uncommon. However, the water is nearly always hard. In some places large quantities of water can also be obtained from the calcareous strata of the upper part of the Peedee formation. This water is also hard. The deeper sand strata in the Peedee formation contain softer water and will probably furnish moderate supplies, but in some places this water is brackish. In a few places, especially in the northeast corner of the area, in Craven and Carteret Counties, some of the wells obtain satisfactory supplies of water from the Duplin marl or Yorktown formation.

Unit-area 3.—This area includes approximately the inner half of the northern Coastal Plain. The Pleistocene terraces, which usually are 20 to 30 feet thick, are underlain by the marls, clays, and sands of the Yorktown formation. This formation averages 40 or 50 feet thick in the western half of unit-area 3 but becomes increasingly thicker eastward in the eastern half, reaching a thickness of nearly 350 feet at Edenton. Beneath the Yorktown are Eocene deposits and basal Cretaceous strata. Little is known of the extent or thickness of the Eocene deposits, but they probably are as much as several hundred feet thick and underlie most of the northeastern quarter of the Coastal Plain. The Cretaceous deposits increase in thickness from a feather edge along the Fall Zone to 400 feet at Farmville, and probably are thicker at the eastern edge of the area.

In some parts of the western half of the area, moderate amounts of water are available in sand lenses of the Yorktown formation. Yields of 300 or 400 gallons a minute are probably the most that can be expected, and at many places much less will be obtained. As the formation thickens to the east, greater amounts can be obtained, and along the eastern margin of the area many individual wells yield 400 or 500 gallons a minute. The water from many of the wells is hard.

A number of wells at Williamston probably obtain their water from Eocene strata, and wells at Everetts, Robersonville, Windsor, Winton, Gatesville, and Sunbury may also obtain water from

Eocene strata. The water from these wells is usually soft sodium bicarbonate water, high in fluoride.

Cretaceous strata along the western margin of the area will yield only small to moderate amounts of water to wells, but these strata become better producers toward the east. Yields of 200 to 500 gallons a minute probably can be obtained throughout most of the western half except in the strip just east of the Fall Zone and as much as 500 to 1,000 gallons a minute from wells in the

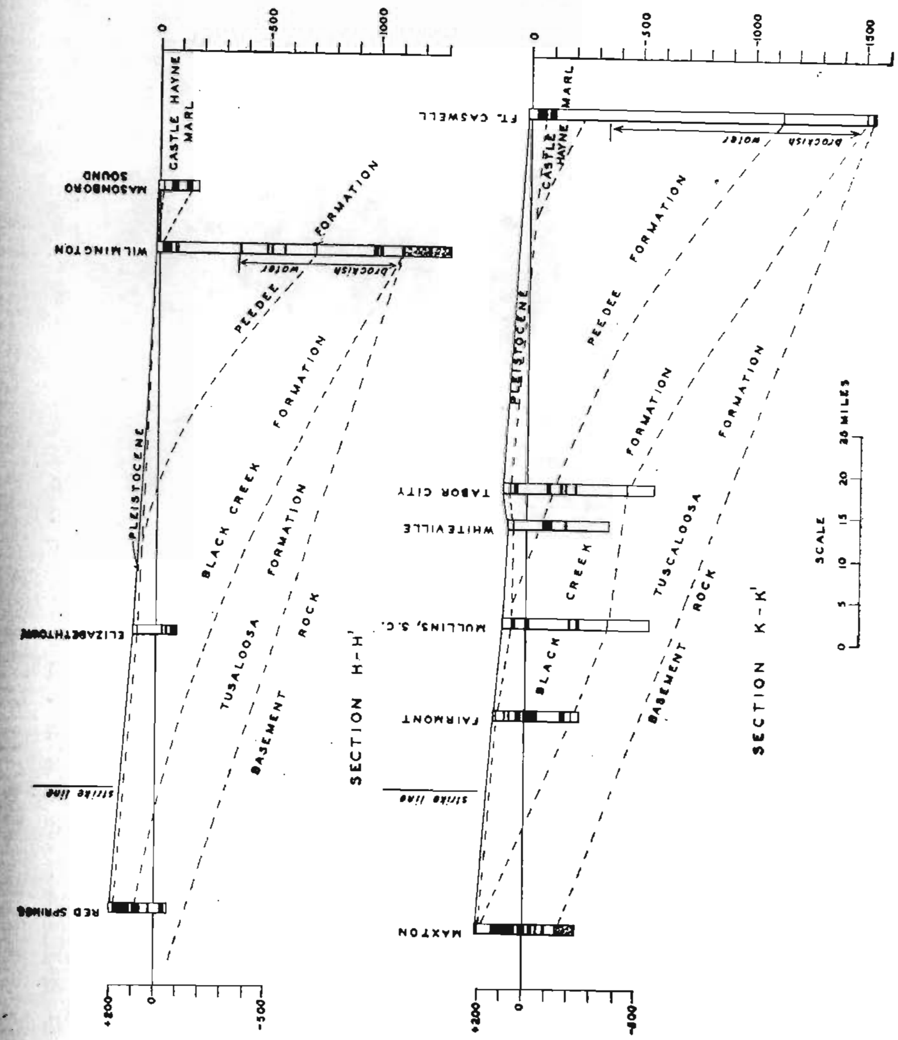


FIG. 6.—Cross sections along lines H-H' and K-K'. Water bearing horizons shown in black. (see Plate 2)

eastern half of the area. The water from the shallower beds at some places is moderately hard and may be somewhat corrosive. That from the deeper beds is soft and generally non-corrosive.

Unit-area 4.—This area includes about 75 percent of the southern half of the Coastal Plain. It is underlain by the Tuscaloosa, Black Creek, and Peedee formations of Cretaceous age. The strata consist chiefly of sands and clays and mixtures of the two, with some limestone and marl in the upper part of the Black Creek and in the Peedee. With the exception of a strip 10 to 15 miles wide along the western margin, yields of 500 to 1,000 gallons a minute probably can be obtained in most places from properly constructed gravel-packed or screened wells. Industrial supplies of several million gallons a day can thus be obtained at many places.

Soft water probably can be obtained in any part of the area although deeper drilling would be required in some parts of the eastern half of the area, where the water from the shallower strata of the upper Black Creek and Peedee formations is hard. In some areas the water has an objectionable amount of iron and in places it is corrosive.

QUALITY OF WATER IN THE COASTAL PLAIN

There are five important chemical constituents and characteristics of the ground water of the Coastal Plain that affect the quality of the water, some of which cause serious problems in parts of the Coastal Plain. These are chloride, iron and fluoride content, and hardness and corrosiveness.

CHLORIDE CONTENT

The chloride considered here is largely present as sodium chloride, or common salt. The usual chloride content of uncontaminated surface and shallow ground water ranges from a few parts per million along the Fall Zone to as much as 40 parts per million along the coast. The higher chloride content along the coast is probably caused by ocean spray being carried inland by the wind.

The U. S. Public Health Service[1] recommends that the chloride content of public water supplies should preferably not exceed 250 parts per million where other and more suitable supplies are available. Water with that amount of chloride in the form of sodium chloride has only a very slightly salty taste. At a concen-

[1]Public Health Service Drinking Water Standards, pages 69-82. Public Health Reports, vol. 58, no. 3, Jan. 15, 1943.

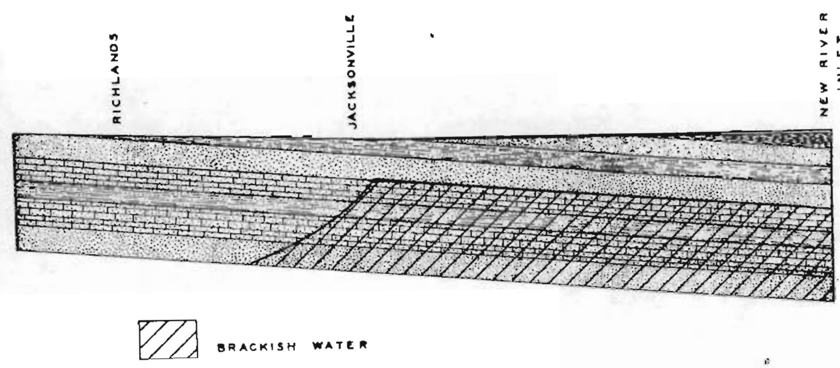


FIG. 7.—Generalized section along New River estuary showing relation of fresh and brackish water.

tration of about 500 parts per million a salty taste is generally noticeable, and it is doubtful whether water with more than that amount of chloride would be generally acceptable except for short periods. A number of towns, cities, and industries in North Carolina use water with a chloride content of 250 to 500 parts per million.

Water with an abnormally high chloride content originates in two general ways. First, as water that was trapped in the sediments at the time of their deposition or entered them during a later submergence and, second, by contemporaneous contamination from a nearby underground or surface body of salty water.

Connate and intrudent water.—Sea water that was trapped in the sediments at the time of their deposition is known as connate water. Subsequent to its entrapment the water may undergo considerable chemical change or may be greatly diluted or both, but is still considered connate water, even though greatly modified, if the outstanding chemical characteristics of the water are due to the original sea water.

Sea water that has entered the strata at some subsequent date (after deposition of the strata) due either to later submergence of the land or to a reversal of movement of the water in the aquifer, so that sea water enters the aquifer where it crops out in the sea, may be termed "intrudent" water. Like connate water, intrudent water is usually greatly changed from its original character. Connate and intrudent waters are both fossil waters. Water drawn in by pumping is not considered to be intrudent water.

It is probable that most or all of the strata of the Coastal Plain formerly contained connate or intrudent water. However, at most places this has been entirely flushed out or greatly diluted. The extent of the flushing and dilution depends chiefly upon the rate and amount of circulation which in turn depends upon several factors, the most important of which are permeability of the strata, ease of egress of the water from the strata and the difference in head between the points of recharge and discharge. The last mentioned factor is complicated where the aquifer has a submarine outcrop.

As sea water has a specific gravity of about 1.025, 40 feet of sea water will balance about 41 feet of fresh water. If the pressure head on the fresh water in the landward end of the system is greater than the pressure head of the seawater in the area of submarine outcrop, the fresh water will move down the aquifer, forcing out all of the connate and intrudent water and the aquifer will be freshened. However, if the pressure head of the sea water is greater, the connate and intrudent water will be flushed out only to some intermediate point. Changes in sea level, or in the water level in the area of recharge to the aquifer, or in the water level at some intermediate point due to change in rate of withdrawal of water will affect the salt water balance and result in a change of position of the fresh water-salt water contact.

It is apparent from the above discussion that a great deal of data and information are needed to permit prediction of the depth to brackish water and particularly the effect of increased pumpage in any area. However, enough data have been obtained to indicate that, in general, the chloride content of the brackish water at any particular place in the Coastal Plain increases with depth. Generally brackish water also occurs progressively closer to the surface southeastward in the Coastal Plain and usually the chloride content of the water in any aquifer will tend to increase down the dip.

Present distribution of connate and intrudent water.—Only in local areas has connate and intrudent water been encountered in the inner part of the Coastal Plain, and in these areas the chloride content is not more than a few hundred parts per million; but almost everywhere in the outer part they have been encountered at some depth. Where such salty water is once reached in any well, the chloride content apparently increases very rapidly with increasing depth of the well. At Edenton the stratum at 212 to 220 feet yields water with a chloride content of not more than

100 parts per million at the present time; at 230 feet the chloride content is about 700 parts per million. A test well at the Marine Corps Air Station, 4½ miles southeast of Edenton, yielded water with a chloride content of 900 parts per million at 250 feet, 2400 parts at 290 feet, and 3000 parts at 420 feet. At Plymouth a well drilled to 315 feet was reported to yield water "as salty as sea water." The casing was pulled back and the well plugged at 260 feet. The chloride content of a sample of water from that depth was 58 parts per million. The water from a 370-foot well at the Prison Camp, 5 miles northwest of Creswell, had a chloride content of 540 parts per million, and the water from a 410-foot well at Creswell had 760 parts. At Camp Lejeune, near Jacksonville, permanent supply well 1 is 195 feet deep and the water had a chloride content of 16 parts per million. Test well 3, 0.5 mile to the southwest, was 325 feet deep and the water had 580 parts per million; test well 5, 0.6 mile north of well 1, was 520 feet deep but apparently yielded water from strata between 320 and 440 feet, the water having a chloride content of 4900 parts per million.

The above examples illustrate the rapid increase in chloride content with increasing depth.

Plate 3 shows the probable depth to brackish (connate or intrudent) water containing 250 parts per million, or more, of chloride. Several significant facts are revealed by this map. In the first place, it is apparent that high chlorides are encountered at shallower depths along the major drainage channels than they are between these channels. Comparison of this map with Stephenson's[1] map of the coastal terraces shows a rather remarkable correlation between the areas in which high chlorides are found at shallow depth and the areal distribution of the lower Pleistocene terraces. It would seem plausible to assume that the strata in the areas submerged during later Pleistocene time became saturated with sea water. Because of the higher specific gravity of sea water and consequent greater pressure even though the head, in feet, was lower than that of the fresh water in adjacent areas, the salt water may also have been able to move into the strata for short distances beyond the margin of the Pleistocene seas.

Another factor influencing the localization of high chlorides is suggested by Cederstrom[2], who ascribes the localization of high chlorides in a wedge shaped area in eastern Virginia to a down-

[1]Clark, Wm. B.; Stephenson, L. W. (and others), The Coastal Plain of North Carolina: North Carolina Geol. and Econ. Survey, vol. III, pt. I, 1912.

[2]Cederstrom, D. J., Chloride in ground water in the Coastal Plain of Virginia, pp. 11-14, Va. Geol. Survey, Bull. 58, 1943.

warping of the area, resulting in a poorer circulation so that flushing of the strata has been slower. It may be that downwarping determined the course of the streams across the Coastal Plain of North Carolina, with later submergence occurring in these downwarped areas.

A second significant fact revealed by the map is that high chlorides occur at shallower depths at the heads of some of the bays than nearer the mouth of the bays. The following explanation may account for this apparent anomaly. At the end of the Pleistocene submergence, all the strata beneath the submerged areas were saturated with salt water. Upon emergence, fresh water began forcing out this intrudent water. The upper strata were freshened first. Because the dip of the strata is in the same direction as the elongation of the bays, the depth to any particular brackish water aquifer will be progressively greater toward the mouth of the bay. This explanation is illustrated by the cross-section in figure 7.

The abrupt increase in depth to high chlorides, west of the bay heads, apparently is due to the greater head of the fresh water in the strata in that direction which prevented the intrudent water water from moving up the dip. The intrudent water probably was confined to the strata beneath and immediately adjacent to the submerged areas.

The above discussion is not meant to suggest that all of the brackish water in the Coastal Plain dates from Pleistocene time. The Coastal Plain was submerged many times previous to this and doubtless salt water from every submergence is still contained at some place.

There are several places relatively far inland in the Coastal Plain where water with an abnormally high chloride content has been encountered. A deep well at Enfield and one at Fremont, both in the Fall Zone, yield water from the crystalline rock that is very hard and is high in sulfate and chloride. The chloride content of the well at Enfield has declined greatly, but it is not known whether the chloride content of the Fremont well has declined. Both of these wells are obviously yielding greatly diluted sea water that was trapped in the crystalline rock at some time when they were under the sea. There are probably other wells along the Fall Zone that yield such water.

The well supplying the town of Fountain yielded water containing more than 300 parts per million of chloride when first drilled. The chloride content declined steadily as the well was

used and was about 100 parts per million by 1944. The well undoubtedly penetrated a small pool of connate or intrudent water trapped by a dense granite mass which outcrops about 0.4 mile southeast of the well. Evidently this granite mass, being down dip from the well, impeded circulation in the Coastal Plain sediments. As water is withdrawn from the well, fresh water replaces it, and eventually the salty water will be entirely replaced by fresh water. As Fountain is 15 or 20 miles east of the Fall Zone, and the sediments there are about 400 feet thick, the granite mass evidently is a monadonock rising above the crystalline basement.

Besides the salty (connate or intrudent) water which is usually encountered several hundred feet below the surface along the coast, sea water is encountered at shallower depths on some of the bars, spits, and islands. If the materials are homogeneous, the fresh water, which has percolated downward from rainfall on the island, is in hydrostatic balance with the surrounding sea water. As sea water has a greater specific gravity than fresh water, the height of the column of fresh water must be greater than the height of the column of sea water. The specific gravity of sea water is about 1.025 so that 41 feet of fresh water will be needed to balance 40 feet of sea water. Thus, if the water table is 1 foot above sea level on a bar or island, the depth to sea water will be 40 feet below sea level. Because the water table on many of the bars and islands is less than one foot above sea level, wells drilled on them have encountered sea water at comparatively shallow depths. Such conditions are known to exist at Hatteras, Cape Lookout, on Bogue Banks, and on the bar at Sears Landing and Topsail Inlet and Wrightsville Beach. Fortunately, impermeable strata at depths ranging from 200 to 400 feet prevented deeper contamination by sea water, and comparatively fresh water was found below those depths. Apparently the depth to connate water was great enough at these locations that the fresh water was not entirely pinched out between the sea water above and the connate water below.

Chloride contamination.—In a few wells the chloride content has increased as the well was pumped. One way that this can occur is by lateral encroachment from a nearby body of salty water. Conditions which must be present to permit contamination of a well by lateral encroachment are: 1. A nearby body of salty water. 2. Access of the salty water to the strata from which the wells are drawing. 3. The cone of depression must extend to the body of salty water, so that a gradient is established from it to the wells.

Contamination has occurred in this way in the wells supplying the city of New Bern and in industrial wells in Wilmington.

A second way in which the chloride content will increase with pumping is by contamination from below. A lense of fresh water floating on salt water on an island or bar as described previously will theoretically extend about 40 feet below sea level for every foot that the water table is above sea level. If the water table is 2 feet above sea level, then salt water will not be encountered until 80 feet below the surface. However, if a shallow well is pumped sufficiently to lower the head on the fresh water to sea level, then the salt water will rise or "cone" up beneath the well. If the pumping level is maintained at such a level for a sufficient length of time, salt water will be drawn into the well. Contamination can also occur in this way along the beach as well as on islands and bars, and a number of examples are given from Connecticut by Brown[1].

It is probable that contamination has occurred in this way in some shallow domestic wells along the Coast of North Carolina although none has been reported.

An abnormal chloride content can also be caused by pollution from organic sources. The high chloride content then is usually accompanied by high nitrates. A number of shallow wells in populated areas have shown indications of such pollution.

HARDNESS

Hardness in water is due to the presence of certain compounds of calcium and magnesium, usually the carbonates, bicarbonates, and sulfates and occasionally chlorides or nitrates. Hardness of water is objectionable because it destroys soap, thus requiring a large amount to produce a lather and because of the scale formed by the precipitation of the minerals on the walls of any container in which the water is heated.

Hardness of the ground water in the Coastal Plain of North Carolina is usually due to the solution of calcium and magnesium carbonates by the water as it percolates downward through calcareous sediments. Occasionally part of the hardness is due to sulfates and rarely to chlorides or nitrates. Usually when sulfate is present in sufficient amount to cause any appreciable amount of hardness, the chloride content is also above normal.

[1]Brown, J. S., A study of coastal ground water with special reference to Connecticut: U. S. Geol. Survey Water Supply Paper 537, 1925.

The source of the sulfate and chloride in such waters is evidently connate water. The shallow water in the unit-areas 3 and 4 is usually soft but in some parts of unit-areas 1 and 2 it is as hard as the deep water. Wells ending in the calcareous Eocene and Miocene formations usually yield hard water as do wells ending in calcareous phases of the Peedee and Black Creek formations. Wells in the basal Cretaceous strata will yield soft water except from the upper part in areas where it is overlain by the Yorktown formation. In these areas, the water is hard when it leaves the Yorktown, but as it travels downward through the Cretaceous sands, base exchange minerals replace the calcium and magnesium of the bicarbonate with sodium, thus affecting a natural softening of the water so that deeper wells will yield softer water.

The map, plate 4, shows the hardness of municipal and military ground-water supplies in the Coastal Plain.

IRON

Some wells in nearly every part of the Coastal Plain yield water with objectionable amounts of iron, and it is probable that objectionable amounts of iron impair the value of more ground-water supplies than all other chemical factors combined. The principal objection to the presence of iron is that it causes staining of enameled ware and other utensils, bathroom fixtures, and clothing. The maximum amount of iron and manganese together permissible in public water supplies is 0.3 parts per million according to the U. S. Public Health Service[1]. However, water with 0.2 parts per million may cause some staining.

Iron in some form is present in practically all soils and rocks and may be dissolved by ground water. The presence of iron in ground water is seemingly quite erratic and of two wells only a few hundred yards apart and about the same depth, one will have a high iron content, whereas the other will have little or no iron.

Generally the deeper water has a lower iron content than the shallow water. The average iron content of wells between specified depths is shown in the following table:

AVERAGE IRON CONTENT OF WELLS BETWEEN SPECIFIED DEPTHS

Range in depth (feet)	0-50	51-100	101-150	151-200	above 200
Iron (parts per million)	2.2	1.14	1.23	0.75	0.51
Number of analyses considered	16	23	17	16	37

[1]Public Health Service Drinking Water Standards, pp. 69-82. Public Health Reports, vol. 58, no. 3, Jan. 15, 1943.

Iron can be removed quite simply in a treatment plant and therefore presents no insurmountable problem to the larger municipalities, but treatment is relatively more expensive for small municipalities and industries and is especially so for domestic supplies.

CORROSIVENESS

Oxygen and carbon dioxide are the principal constituents of ground water causing corrosion. Shallow ground water usually is much more corrosive than the deeper water. As the water percolates downward, the oxygen is quickly used up in oxidation of organic and inorganic materials. The carbon dioxide commonly reacts with carbonates to form bicarbonates. Because of this reaction, hard water is generally less corrosive than water of low mineral content and hardness.

Corrosion causes deterioration of the well casing, pump pipes, pumps, tanks, and water pipes in the distribution system. However, the deterioration is not as objectionable as is the presence of the iron which is dissolved, causing "red water" that stains utensils, plumbing fixtures, and the laundry. It is not always apparent whether the iron is in the water when it enters the well or whether it has been dissolved by corrosion of the well casing and pipes. The problems of iron and corrosiveness in ground water are closely related and both are serious problems for domestic and small municipal and industrial users in the Coastal Plain.

FLUORIDE

Fluoride in water in excess of about one part per million may cause the dental defect known as mottled enamel, if the water is used for drinking and cooking during the formation of the teeth. According to Dr. H. T. Dean[1], of the U. S. Public Health Service, the teeth will erupt showing a dull, chalky white appearance, later taking on a brown stain. The surface of the teeth may also be marked by pitting. Dr. Dean states that the mildest forms of mottled enamel will develop in about 10 percent of the children who continuallly use water with a fluoride content of about 1 part per million. The severity and percent of incidence increase markedly with an increase in fluoride content until at 6 parts per million an incidence of 100 percent is not unusual, and a large percentage of cases are classed as moderate or worse. Mottled enamel is a permanent physical disfigurement. It is the

[1]Dean, H. T., Chronic endemic dental fluorosis: Am. Medical Assoc. Jour., vol. 107, p. 1269, 1936.

teeth of children, only, that are affected. Normally calcified teeth do not become mottled later, regardless of the fluoride content of the drinking water.

Water containing small amounts of fluoride, however, is reported by Dean[2] to be beneficial in prevention of dental decay. It has been shown that school children using water containing about one part per million of fluoride experience only one-half to one-third as much dental decay as comparable groups using water that contains no fluoride.

Fluoride in excess of one part per million was found only in wells 100 or more feet deep. The following table lists all the wells from which analyses have shown a fluoride content of one part per million or more:

WELLS YIELDING WATER WITH A FLUORIDE CONTENT OF ONE PART PER MILLION OR MORE

County	Location	Owner	Depth (feet)	Parts Per Million		
				Fluoride	Bicarbonate	Total Hardness
Beaufort	Belhaven	Town (at the school)	250+	1.2	448	231
Bertie	Windsor	Town, municipal supply	334	3.0	432	18
Bertie	Windsor	Town, well across from Esso service station	325+	3.8	404	......
Chowan	Edenton	Freemason St. Well	291	1.6	670	176
Carteret	Atlantic Beach	Atlantic Beach and Bridge Co.	190	1.0	358	276
Columbus	Tabor City	Town, old well near tank	300+	1.0	343	9
Gates	Gatesville	Hotel	455	1.7	477	14
Gates	Sunbury	School	350	4.0	657	14
Gates	Roduco	E. D. Eure	155	1.0	471	82
Halifax	Littleton	Town	358	1.7	98	84
Hertford	Winton	Town	180	2.1	291	20
Hyde	Middleton	D. Miller	206	1.2	852	84
Martin	Williamston	Town	500	1.2	370	30
Martin	Williamston	Town	400–480	1.8	368	21
Martin	Robersonville	Town, well 1	390	1.0	404	15
Martin	Robersonville	Town, well 2	390	1.1	448	24
Martin	Everetts	Martin County Bottling Co.	300	2.8	358	16
Martin	Robersonville	S. Everett	185	1.6	402	18
Northampton	Rich Square	Town	100	1.3	24	10
Onslow	Jacksonville	State Prison Camp	138	1.0	498	36
Onslow	Ragged Point near Verona	Henry Grove	185	1.0	372	204
Onslow	Marines	T. G. Samworth	303	1.4	482	34
Onslow	Jacksonville	U. S. Marines,	184	2.4	524	76
		Tent Camp		1.8	528	60
Pitt	Pactolus	C. J. Saterthwaite	293	5.7+	340	14
Pitt	Stokes	M. H. Whichard	225	1.1	388	66
Pitt	Bethel	Town	375	1.0	370	24
Pitt	Bethel	J. L. Gurganus	192	1.7	186	27
Pitt	Farmville	Town	480	1.0	244	16
Pitt	Grimesland	J. L. Edwards	180+	1.3	306	88
Wilson	Bullucks School	Bullucks School	159	1.5	66	50

[2]Dean, H. T., Fluorine and dental health: Am. Assoc. Advancement of Sci. Bull., vol. 1, p. 47, 1942.

One source of the fluoride in ground waters of the southeastern United States is generally considered to be the phosphatic material present in some of the formations. In Florida the fluoride in some of the ground water is thought to have been derived from phosphatic pebbles in the Hawthorn formation[1]. C. W. Carlston[2] believes that the source of the fluoride in the Cretaceous area of Alabama is the phosphates at the top of the Eutaw formation and base of the Selma chalk. He also states that phosphates contain fluoride as a secondary product derived from volcanic debris, particularly bentonite.

Most of the wells in North Carolina that yield water high in fluoride apparently end in the basal Cretaceous deposits, the lower Eocene sands, or the Miocene marl. Phosphatic material has not been reported from the basal Cretaceous deposits of North Carolina, but it is not uncommon from the Castle Hayne marl (Eocene) and the Trent marl and Yorktown formation (Miocene). It is apparently most plentiful, however, in the Castle Hayne (Eocene) and Peedee formation (Upper Cretaceous).

It should be noted that the main area of high fluoride content extends northeast from near Greenville. It may be that most of the wells yielding high fluorides in this area obtain their water from the lower Eocene sands. It is possible also that some of them end in the basal Cretaceous sands.

Only a few wells from the Yorktown formation yield water high in fluoride, and these are in the eastern half of the Coastal Plain where the formation is thick. It may be that the phosphate is confined to the basal part of the Yorktown in the western half; and as most of the wells in the Yorktown end in more permeable strata above the basal part, most well supplies in that area are taken from above the phosphatic phases.

It is rather puzzling that although the Peedee formation has been reported to contain considerable phosphate, no wells ending in it, with the possible exception of the well at Grimesland, yield water high in fluoride. It is evident that phosphatic material in the strata does not always give the water a high fluoride content. Conversely, it is possible that the fluoride content of the water at some places is derived from other minerals than the phosphates.

[1]Black, A. P.; Stearnes, T. W.; McClane, H. H.; and McClane, T. K.; Fluorine in Florida waters: Mimeographed reprint, Florida section, Proceedings of the ninth annual convention of Amer. Water Works Assoc., pp. 22-23, 1935.

[2]Carlston, C. W., Fluoride in the ground water of the Cretaceous area of Alabama, Geol. Survey of Alabama, Bull. 52, pp. 16-20, 1942.

In Alabama, Carlston[1] shows a correlation between the amount of fluoride and the amount of bicarbonate in the water. He suggests that bentonite causing base exchange also contributes fluoride to the ground water or that the relation is due merely to the length of time the ground water is in contact with two different materials causing base exchange and contributing fluoride. However, in North Carolina there does not appear to be any relation between the amount of fluoride and bicarbonate, although most wells containing more than 1.0 part per million of fluoride are high in bicarbonate. Apparently the relation in this State is merely one of time and distance traveled, with phosphates furnishing the fluoride, and glauconite or some similar material causing base exchange. It should be noted that most wells in the Miocene formations, that have a high fluoride content, yield hard water, and base exchange has been much less.

Two wells drilled in crystalline rocks near the Fall Zone yield water with more than 1.0 part per million of fluoride. The well at Bullucks School, Wilson County, was drilled in granite and flows about 50 gallons a minute. The well supplying Littleton, Halifax County, was drilled in granite gneiss. The source of the fluoride of these two wells may be the mineral apatite which is present in most granites. However, it is difficult to explain why other wells in granite, for which analyses are available, show no unusual amount of fluoride.

FORMATIONS OF THE COASTAL PLAIN AND THEIR WATER-BEARING PROPERTIES

PATUXENT (?) AND TUSCALOOSA FORMATIONS

Geology.—The oldest formations in the Coastal Plain of North Carolina are the basal Cretaceous beds which were deposited directly upon the irregular erosion surface which had been formed on the crystaline rocks. In unit-area 4 these beds belong to the Tuscaloosa formation of early Upper Cretaceous age, and in unit-area 3 the beds either belong to the Patuxent formation of Lower Cretaceous age, or to the Tuscaloosa formation, or possibly to both. Whatever their age, these beds in unit-area 3 are similar lithologically and structurally to the Tuscaloosa formation in unit-area 4. These formations, which either crop out or are covered only by a thin layer of more recent sediments, lie to the southeast of the Fall Zone and extend northeastward from South

[1]Op. cit.

Carolina to Virginia in a belt 10 to 30 miles wide. In unit-area 4 the Tuscaloosa is exposed at the surface in many places. Where not exposed, it is covered by a few feet of Pleistocene sediments.

In unit-area 3 the Cretaceous beds are covered by 40 to 50 feet of Miocene marls, and 20 or 30 feet of Pleistocene sands, so that they crop out only where the larger streams have cut their channels through the overlying formations.

The Tuscaloosa and Patuxent (?) formations consist of sand, clay, and some gravel. Much of the sand is argillaceous, often containing enough clay to make it impermeable. The sands also are commonly cross-bedded and quite arcosic, containing much weathered feldspar and some mica. Interbedded with the above strata are layers of clean, permeable sand and gravel. Because this formation was deposited in broad valleys, estuaries, and bays by overloaded streams flowing across a low Coastal Plain, the strata occur as lenses and stringers rather than as continuous beds.

The underlying crystalline bedrock slopes southeastward at a rate of 15 or 20 feet to the mile so that the Tuscaloosa and Patuxent (?) thicken from a feather edge along the Fall Zone to about 300 or 400 feet along the eastern edge of the area of outcrop. Eastward the Tuscaloosa passes unconformably beneath younger formations and is encountered at progressively greater depths in wells drilled to the southeast. The dip of the formations varies considerably, but in general increases gradually southeastward from the Fall Zone. The average dip probably is 20 to 25 feet per mile.

Water supply.—The Tuscaloosa and Patuxent (?) formations are generally very satisfactory aquifers except along their thin western margin adjacent to the Piedmont. Gravel-walled wells yield 1000 gallons a minute at the Maxton Army Air Base and 400 to 600 gallons a minute at the Goldsboro Army Air Base. A number of municipalities use screened or gravel-walled wells ending in the Tuscaloosa, and yields range from 35 to 720 gallons a minute. The average yield of 38 wells, both gravel-walled and plain, 6 inches or more in diameter, furnishing municipalities and military establishments from these formations, is about 235 gallons a minute. Many of the smaller yields are from wells near the thin western margin or are from wells supplying small towns not needing a large amount of water.

It is especially noteworthy that, although both Maxton and Goldsboro had been considered as poorer than average locations at which to obtain satisfactory well supplies, the two gravel-packed wells at the Maxton Air Base yielded 1000 gallons a minute each, and the five screened wells yielded an average of 220 gallons a minute; and three gravel-packed wells at the Goldsboro Air Base ending in the Tuscaloosa formation yielded an average of 490 gallons a minute. It is probable that where a determined effort is made, yields of 300 to 1000 gallons a minute can be obtained nearly everywhere from wells in the Tuscaloosa and Patuxent (?) formations.

The total capacity of all wells supplying municipalities and military bases from the Tuscaloosa and Patuxent (?) formations is about 10,000 gallons a minute. It is probable that an equal, or greater, capacity is represented by industrial and domestic wells. However, the actual pumpage probably is not more than half the total capacity of the wells so that roughly about 15,000,000 to 20,000,000 gallons a day is withdrawn from the Tuscaloosa and Patuxent (?), which represents only a small fraction of the potential yield of the aquifer.

Recharge to the Tuscaloosa in unit-area 4 is by rainfall either directly on the formation in the area of outcrop or indirectly through the overlying Pleistocene terrace deposits. It is probable that recharge occurs with greater ease in this unit-area than in unit-area 3 where the deposits are for the most part covered by both Pleistocene and Miocene (Yorktown formation) deposits.

The determination of the permeability of ten samples of sand, from three wells drilled at the Maxton Air Base, furnish practically the only information available concerning the permeability of the formation. The permeabilities ranged from 95 to 2,250. The average transmissibility of the strata penetrated by the three wells was about 12,000. Because the materials are so greatly disturbed in withdrawing them from the well, the results do not always compare wtih the actual permeabilities of the material as it occurs underground. In this connection it should be noted that whereas the transmissibility at well 1 at the Maxton Airport was 8,000 according to the samples tested, calculation by means of the recovery formula based on the recovery after a 24-hour pumping test, showed a transmissibility of 27,500.

Although few data are available regarding the amount of recharge and permeability, it seems certain that only a small fraction of the potential yield of the Tuscaloosa and Patuxent (?) formations is being used, probably much less than 10 percent.

The water from most wells ending in these formations is soft. In unit-area 4 it is soft and low in total dissolved solids, but usually contains considerable carbon dioxide, is often corrosive, and frequently contains considerable iron. In unit-area 3 the water from the upper part of the formation is often moderately hard to hard, due to the solution of calcium and magnesium carbonate by the water as it passes down through the strata of the Yorktown formation. The calcium and magnesium are nearly always present in the water as bicarbonate.

However, as the water travels down through the Cretaceous beds, base exchange minerals, such as glauconite, exchange their sodium for the calcium and magnesium. Thus, although the bicarbonate content remains about the same, the water is softened. Usually neither the hard water nor the softened sodium bicarbonate water is corrosive. The difference in the chemical composition of the water from deep wells in unit-areas 3 and 4 is shown by analyses 2 and 4 in the table of analyses. Incidentally, this difference in the composition of water from wells of about the same depth in the basal Cretaceous formations is an additional indication that most of the recharge to the Cretaceous beds, in unit-area 3, is effected through the Yorktown formation.

BLACK CREEK FORMATION

Geology.—Southeast of the outcrop area occupied by the Tuscaloosa the Black Creek formation, of Upper Cretaceous age, lies uncomformably upon the eroded surface of the Tuscaloosa formation. The Black Creek forms an irregular belt extending from the South Carolina boundary, where it is 40 miles wide, to the Tar river near Greenville, where it is less than 10 miles wide. It passes conformably beneath the Peedee formation at the southeast margin of the belt.

The Black Creek formation is generally overlain by a thin blanket of Pleistocene deposits and in a few places is also overlain by patches of the Duplin marl.

The Black Creek consists chiefly of thinly laminated sands and clays. The clays are generally dark or black, the color being caused by carbonaceous matter. The sands are usually gray and are fine to medium grained and often contain lignitized wood. The strata are lenticular, so that the character of the material changes greatly from place to place. Many of the sand strata are cross-bedded. The upper part of the Black Creek contains considerable calcareous greensand (glauconite) and marine clay

and is known as the Snow Hill marl member. Some of these strata contain marine fossils.

The thickness and formational dip of the Black Creek vary somewhat. The greatest known thickness is reported in the well drilled at Havelock[1], where 790 feet of strata, between the depths of 1,335 and 2,125 feet, are referred to the Black Creek formation. The average dip, between Goldsboro and Havelock, is about 27 feet per mile. The lowest dip of the formation probably is along the Cape Fear arch where it is less than 17 feet per mile. It is quite possible also that the Black Creek is thinner along this arch than to the north or south. Stephenson[1] reported the thickness as 389 feet in a well at Wilmington and as 400 feet in a well at Fort Caswell. The Black Creek was presumed to be lying directly upon the crystalline basement at 1,109 feet at Wilmington as the Tuscaloosa was thought to be absent. However, it is possible that the bottom 28 feet belong to the Tuscaloosa formation, leaving 361 feet as the thickness of the Black Creek at that place. The bottom 30 feet of the well at Fort Caswell also may belong to the Tuscaloosa formation which would leave 370 feet as the thickness of the Black Creek at that place.

Water supply.—The Black Creek formation will furnish moderate to large supplies of water in most places. Two of the best wells are at Kinston. These are gravel-walled wells, one furnishing 700 and the other 860 gallons a minute. The four wells drilled in this formation at the Goldsboro Air Base yield an average of about 500 gallons a minute, and two wells at Clinton yield about the same amount. These are all gravel-walled wells, and the yield from ordinary screened wells is usually somewhat less. The yield of 31 wells, 6 inches or more in diameter, tabulated in this report, that supply municipalities and military bases from the Black Creek formation, ranges from 50 to 860 gallons a minute and averages about 245 gallons a minute. The lower yields are from wells supplying small towns which do not need large amounts of water. These wells usually have only a short length of screen, and it is probable that much larger supplies of water could be developed at these places if they were needed.

The total capacity of all wells supplying municipalities and military bases from wells drilled into the Black Creek formation is about 7,500 gallons a minute. Very likely, double that capacity

[1]Mansfield, W. C., Oil prospecting well near Havelock, North Carolina; Econ. paper No. 58, North Carolina Department of Conservation and Development.

[1]Clark, Wm. B.; Miller, B. L.; Stephenson, L. W.; Johnson, B. L.; and Parker, H. N.; The Coastal Plain of North Carolina: N. C. Geol. and Econ. Survey, vol. III, pp. 163-166, 1912.

is represented by industrial and domestic wells. The actual pumpage from this formation probably is about half this amount so that roughly 10,000 gallons a minute or 15,000,000 gallons a day is being withdrawn from the Black Creek formation. This amount represents only a small fraction of the total potential yield of the aquifer.

The Black Creek formation receives its recharge from rainfall which percolates downward through the layer of Pleistocene deposits that nearly everywhere cover it. The strata of the Black Creek formation are alternating layers of sand and clay so that as the water moves southeastward down dip it is confined and thus is under pressure. Practically no information is available on the amount of water that actually reaches the Black Creek formation, but the potential recharge is probably between 20 and 30 percent of the total rainfall over its area of outcrop.

Permeabilities have been determined of five sand samples from this formation. These ranged from 115 to 575 and averaged 350. It is probable that many of the sand strata have much higher permeabilities.

The water from the Black Creek formation, with the exception of that from wells ending in the Snow Hill marl member, is soft and has a low content of dissolved solids. It sometimes contains considerable carbon dioxide and is corrosive. In a few places the water contains an objectionable amount of iron. Water from wells ending in the Snow Hill marl member is usually moderately hard. Analysis 7, in the table of analyses, is typical of the soft water from the Black Creek, and analysis 8 is typical of water from the Snow Hill marl member.

PEEDEE FORMATION

Geology.—The Peedee formation is the youngest Cretaceous formation in North Carolina. It lies conformably upon the Black Creek, the separation of the two formations being based upon paleontologic and lithologic differences. The Peedee formation is at or near the surface in a belt extending northeastward from the South Carolina line to the Tar River, and lying to the southeast of the outcrop area of the Black Creek formation. The Peedee is about 25 miles wide at the southern end of the belt but narrows to a width of only a few miles at Greenville. Along the southeast edge of this belt the Peedee is unconformably overlain by the Castle Hayne marl which occurs in more or less isolated patches. Eastward the irregular surface of the Peedee dips more steeply and the Castle Hayne becomes thicker, forming a continuous sheet above the Peedee.

The Peedee formation consists of interbedded sands, clays, and marls. The sands are dark green to gray, most commonly fine grained, and often contain considerable glauconite. Many of the strata are calcareous, containing invertebrate fossils, and some are argillaceous. The clays are dark, sometimes green and are also commonly calcareous.

The greatest known thickness of the Peedee in North Carolina occurs in the well at Fort Caswell where 886 feet have been assigned to the Peedee formation. The thickness in the deep wells at Wilmington and at Havelock is 720 and 651 feet, respectively. As with the other formations of the Coastal Plain, the Peedee formation apparently has lower dips in its area of outcrop but dips more steeply as it passes beneath the Castle Hayne to the southeast. The dip increases from about 15 feet per mile to 25 or 30 feet per mile near the coast.

Water supply.—The Peedee formation will yield moderately large to very large amounts of water at most places. The shell rock yields very large amounts to ordinary cased wells. Screened wells in the coarser sand, and gravel-walled wells in the finer sand also will yield large amounts. A number of wells in the vicinity of Wilmington yield several hundred gallons a minute with only a few feet of drawdown. The gravel-walled well at Burgaw was tested at 150 gallons a minute with a drawdown of three feet. Stephenson[1] reported that a 10-inch well drilled at Chadbourn in 1907 for the Independent Ice Company was tested at 1800 gallons a minute with a rotary pump. This well was 135 feet deep, ending in a coarse sand stratum in the Peedee.

In this report 18 wells are listed that supply municipalities and military bases from the Peedee formation. The yield of these wells ranges from 80 to 300 gallons a minute, averaging about 190 gallons a minute. Most of these wells were tested with centrifugal pumps and had small drawdowns so that the actual capacity was never even approached. It is probable that some of them would yield a thousand or more gallons a minute. The 18 wells have a total capacity of 3,500 gallons a minute with probably 2,000 gallons a minute being used, more than 80 percent of this being from wells drilled in the immediate vicinity of Wilmington. The pumpage of these 18 wells probably is not more than 10 to 20 percent of the total amount withdrawn from the Peedee for-

[1] Op. cit.

mation, the total amount of water withdrawn from the Peedee is probably about 15 or 20 million gallons a day, which is only a small fraction of the total potential yield.

The only place at which the Peedee formation is overpumped is in the city of Wilmington. The effect has not been to decrease the available supply but rather to cause chloride contamination. The Peedee formation normally discharges into the Cape Fear River at Wilmington, but because of the considerable pumpage by commercial and industrial establishments the already low water table was depressed sufficiently further so that a gradient from the river toward the wells has been established. As the river is quite frequently invaded by salt water, the wells have been contaminated by lateral encroachment of salt water from the river. Wells drilled farther from the river can draw the water table down considerably below river level and still not become contaminated because the cone of depression will not reach the river. Therefore, a development of ground water in an area several miles from the river, equal to or greater than that within the city, could be made without danger of depletion of supply or contamination by lateral flow of salt water.

The water from the Peedee formation is usually moderately hard to hard. A few deeper than average wells yield soft water which has evidently been softened by base exchange. However, in some of these wells the increase in sodium bicarbonate content is accompanied by an increase in chloride, due to the presence of connate water. Analyses 8 and 9 are typical of the water obtained from the Peedee formation.

LOWER EOCENE DEPOSITS

Geology.—The presence of lower Eocene strata, except for a few very small isolated patches in or near the Fall Zone, has not previously been reported in North Carolina, although formations of the Pamunkey group are known to occur in nearby areas in southeastern Virginia.

D. J. Cederstrom reported[1] that a stratum of fossiliferous black sand, at a depth between 150 and 200 feet at Roduco in Gates County, appeared to be of Eocene age. The presence of Eocene strata is also suggested by the logs of several wells in northeastern North Carolina. However, the first positive proof of Eocene strata in this area was furnished by Dr. H. G. Richards[2], Associate Curator, Academy of Natural Science at Philadelphia, who has found several Eocene pelecypods in samples from a well at Williamston taken from a depth of about 110 feet. It is probable that the strata between 110 and 400 feet, at Williamston, are of Eocene age and that Eocene strata underlie most of the northeastern part of North Carolina.

[1]Personal communication.
[2]Personal communication.

Water supply.—Because so little is known regarding the distribution and thickness of these Eocene deposits, it is difficult to determine which wells are yielding water from these strata. However, since the strata between 110 and 400 feet at Williamston, and from 150 to an unkown depth at Roduco, are probably of Eocene age, it is probable that many drilled wells in Martin, Bertie, Hertford, and Gates Counties yield water from Eocene strata. The material from these strata at Williamston contained a large percentage of glauconite and phosphate grains, and the "black sand" from the well at Roduco undoubtedly did also. The Eocene strata in other States are noted for the presence of these two minerals. As the source of fluorides in ground water is generally considered to be the phosphatic material in the strata, it is highly significant that the high fluoride zone is practically coextensive with the known and inferred area of occurrence of Eocene strata. Also, most of the wells yielding high fluoride water in this area are of about the proper depth to be obtaining water from the Eocene. Windsor is probably the only town using water from these strata. The well is gravel packed and yielded, on test, 300 gallons a minute with a drawdown of 119 feet. The water is soft and has a fluoride content of 3.0 parts per million. The analysis is given in the table of analyses.

CASTLE HAYNE MARL

Geology.—The Castle Hayne marl, which is of upper Eocene age, lies unconformably upon the Peedee formation. In the vicinity of Wilmington and northward along its western margin, which extends almost due northward from Wilmington, it occurs in more or less isolated pockets and basins, but eastward it is continuous and becomes somewhat thicker. Although the Castle Hayne crops out over a fairly wide area in a belt extending northward from the Cape Fear River to the Neuse River, it apparently does not attain a thickness of more than 100 feet in this belt. The dip of the formation, therefore, is only a few feet per mile in that area. Eastward, near Pollocksville and Jacksonville, the dip increases and it passes beneath the Trent marl. The greatest known thickness of the Castle Hayne marl is in test well 4 at Camp Lejeune where 276 feet of strata between 138 and 414 feet have been referred to this formation. The regional dip of the Castle Hayne marl may be as much as 20 or 25 feet near the coast. The Castle Hayne marl consists chiefly of limestone, sandy limestone, calcareous sandstone, and calcareous sands or marls, all of which are usually fossiliferous.

Water supply.—The calcareous members of the Castle Hayne marl have undergone considerable solution so that frequently they are very porous and transmit large quantities of water. The Castle Hayne is one of the best aquifers in the Coastal Plain, although only a relatively small amount of water is being withdrawn from it. The 14 wells at Camp Davis, Onslow County, which are 8 inches in diameter, yielded, when first tested, an average of 220 gallons a minute with an average drawdown of 3.3 feet, a specific capacity of 66 gallons a minute per foot of drawdown. It is probable that most of these wells would yield 1000 gallons a minute. The wells in the main area at Camp Lejeune, which obtain part of their water from the Castle Hayne, yield an average of about 220 gallons a minute. A well drilled for the town of Jacksonville in 1942, was tested at 300 gallons a minute with a 7-foot drawdown, and a well near Pollocksville at the Auxiliary Air Base, yields 180 gallons a minute with 8.5 feet drawdown. Three of the wells at Fort Fisher were tested at an average of 260 gallons a minute with an average drawdown of 33 feet.

The average tested yield of the 32 wells ending in the Castle Hayne marl, tabulated in this report, is 203 gallons a minute. However, most of these wells had a drawdown of only a few feet so that the actual capacity is much larger. The specific capacity ranges from about 8 to 100 gallons a minute per foot of drawdown. The total tested capacity of the 32 wells is about 6,500 gallons a minute or nearly 10,000,000 gallons a day. The capacity of all other wells ending in the Castle Hayne marl probably is less than this amount, and as the wells are not pumped continuously nor at the tested capacity, the total amount of water used from the formation is probably not more than 10,000,000 gallons a day, which is probably less than 10 percent of the total potential yield.

Recharge to the Castle Hayne marl is from percolation of rain water through the overlying Pleistocene sands and clays. As recharge occurs in the area of outcrop (beneath the Pleistocene) much of which is in poorly drained areas such as White Oak pocosin, Great Sandy Run pocosin, Angola Bay and Holly Shelter Bay, where surface runoff is slow, it is possible that the ratio of recharge to rainfall is larger than elsewhere in the Coastal Plain.

No quantitative data are available regarding permeabilities of strata in the Castle Hayne marl. Because most aquifers are composed of more or less consolidated shell rock, the only practical method of determining permeability is by using some field method, preferably the discharging well methods.

The water from the Castle Hayne marl is usually hard and sometimes contains objectionable iron. Connate (or intrudent) water encountered at depth in some places is nearly always softer than the non-connate water. This soft, connate water is high in sodium bicarbonate. Depth of the well apparently is not the determining factor as both relatively shallow and deep wells yield soft, connate water. It is likely that the slowness of circulation of the diluting fresh water and the connate water, resulting in a much longer contact with the base exchange minerals, accounts for the softening. Limestone causing hardness, and the base exchange minerals causing a natural softening, are each present in both the areas of fresh water and connate water. Rain water entering the aquifer, being highly charged with carbon dioxide, dissolves calcium and magnesium carbonate very rapidly; whereas, the base exchange minerals act much more slowly. When all the carbon dioxide is used, solution of the carbonates apparently becomes very slow or ceases entirely, but the base exchange process continues slowly. In areas of fresh water, the circulation is fast enough that little or no softening occurs. However, if this hard water enters an area of connate water where circulation is very slow, then the base exchange process will continue while solution of additional carbonates will be much less, so that gradually all of the calcium and magnesium of the water is replaced by sodium. Analysis 11 in the table of analyses is typical of fresh water of the Castle Hayne marl, and analysis 12 is typical of a connate water of the formation.

TRENT MARL

Geology.—The Trent marl lies upon the eroded surface of the Castle Hayne. Eastward the Trent passes beneath the Duplin and Yorktown formations of upper Miocene age. The Trent marl is exposed along the Neuse River near New Bern, along the Trent

River between New Bern and Pollocksville, at Belgrade and Silverdale and along New River in Onslow County.

The lithology of the Trent marl is quite similar to that of the Castle Hayne marl. It consists of limestone, calcareous sandstone, and sand and marls. It generally is quite fossiliferous, the fossils usually being in the form of molds or casts.

The dip of the Trent marl appears to be about 10 feet per mile in the area of outcrop and for a few miles east, but farther east apparently becomes considerably less and even appears to be reversed between Cherry Point and Morehead City, the top of the Trent being at about 10 feet higher elevation at Morehead City than at Cherry Point. The greatest known thickness of the Trent is in the Havelock well where 333 feet, between the depths of 230 and 563 feet, have been referred to that formation. The usual thickness is much less, probably averaging about 100 feet.

Water supply.—The Trent marl is similar to the Castle Hayne in its water-bearing properties as well as in its lithology. Solution has made the semi-consolidated, sandy shell rock very porous and permeable in most places. Many wells in New Bern obtain water from the Trent. These wells are between 60 and 100 feet deep, have about 30 feet of casing, and are not screened or gravel packed. Several have yielded 800 to 1000 gallons a minute when pumped by a suction pump, and most of them will yield several hundred gallons a minute. The 12 supply wells at Cherry Point obtain most of their water from this formation. The average yield of the 12 was 310 gallons a minute with an average drawdown of 8.2 feet, which is an average specific capacity of 38 gallons a minute per foot of drawdown. Only two of these wells have screens. Some of the water at the New River Marine Base and at the Tent Camp south of Jacksonville is obtained from the Trent marl. The 32 main supply wells at these two places yield an average of more than 200 gallons a minute. However, because of the fineness of the sand, it has been necessary to gravel pack some of the wells at these places.

The average yield of 60 wells listed in this report is 235 gallons a minute, and the total capacity is 14,000 gallons a minute. Probably less than half this amount is actually used. A considerable number of industrial wells at New Bern, Morehead City, Washington, and elsewhere, and domestic wells over a considerable area, withdraw water from this formation. A fair estimate of the total amount of water withdrawn from this formation appears to be 20 to 25 million gallons a day, which is probably less than 20 percent of the total potential supply.

No quantitative data are available regarding the permeability of the Trent marl. Discharging well methods will be the most satisfactory for determining permeabilities in this formation. A considerable part of the outcrop area is in pocosins so that recharge may be somewhat greater than to formations in other areas.

Water from the Trent marl at nearly all places is hard and at some places it has objectionable amounts of iron. Connate water probably will be encountered at depths of 200 to 500 or more feet below the surface in various places. Analysis 12 in the table of analyses, is typical of water from the Trent marl.

YORKTOWN FORMATION

Geology.—The Yorktown formation is of upper Miocene age and was deposited on the erosion surface beveling all older formations. It presumably occurs mainly north of the Neuse River where it lies upon the beveled edges of the Trent, Peedee, Black Creek, and Patuxent (?) or Tuscaloosa (?) formations, overlapping them westward and lying directly upon the crystalline rocks along the Fall Zone. The area in which it crops out, or is overlain only by thin Pleistocene deposits, extends from the Neuse River to the Virginia State line; and from the Fall Zone extends 60 miles eastward to a line through New Bern and Edenton before the increasing dip carries it beneath the Pliocene and Pleistocene formations. Near the Fall Zone the dip is low, about 2 or 3 feet per mile, which is about the same as the slope of the land surface, and the formation is only 30 to 60 feet thick. Farther east, especially in the northern part, the dip increases so that the formation is about 400 feet thick along its eastern margin where it dips beneath the younger strata.

The Yorktown formation consists chiefly of interbedded sands and clays, which are usually calcareous, and frequently contain fossil shells. The upper part of the Yorktown, which occurs only in the eastern half of the area, also contains occasional layers of consolidated and semiconsolidated, fossiliferous sandy limestone.

Water supply.—Although the Yorktown formation covers a larger area than any other formation in the Coastal Plain, relatively few important supplies are obtained from it. Throughout most of the western half of the area it occupies, it is a relatively poor aquifer, and since the depth to the underlying Cretaceous is only 70 to 100 feet, most wells are drilled through the Yorktown to underlying strata. Farther east, as it becomes thicker, it becomes a better aquifer; but the water is hard, and water from the Cretaceous deposits is still preferred. Still farther east, near the eastern edge of its area of outcrop, the basal Cretaceous strata are 500 or more feet below the surface so that wells drilled into the Cretaceous strata would be expensive; and in addition the water in them is high in chloride. Therefore, at Edenton, Plymouth, and Belhaven the wells obtain water from the Yorktown formation; at those places the formation is thick enough so that good water-bearing strata usually will be found at some depth before encountering connate water with too high a chloride content for use.

The eight wells listed in this report yield an average of 285 gallons a minute. At Edenton the town's two gravel-packed wells yield 500 and 650 gallons a minute, and a number of other wells drilled for the town and for industries yield large amounts of water. The Plymouth city well yielded 500 gallons a minute and other wells at and near Plymouth are very satisfactory. Farther south, at and around Belhaven, Aurora, and Bayboro, satisfactory yields are also obtained. However, north and east of Edenton, at the Naval Air Base, four miles east of Edenton and at Hertford and Elizabeth City, the Yorktown appears to be less satisfactory as an aquifer. The strata for the first 150 or 200 feet are composed of clay and very fine argillaceous sands from which little water can be obtained, and the small amounts that are encountered are rather high in chloride. Below 200 or 250 feet better aquifers are encountered, but the water is too high in chloride for use. In this area it has been necessary to use wells of shallow or moderate depth, 30 to 100 feet, ending in Pleistocene or Pliocene formations.

The total capacity of the eight wells in the Yorktown formation is about 2,300 gallons a minute. Probably not more than 1,000 gallons a minute, or about 1,500,00 gallons a day is actually withdrawn by these eight wells. Domestic and industrial wells, mainly in Chowan, Washington, Tyrrell, Beaufort, Hyde, Craven, and Pamlico Counties, use possibly about twice as much more, which would make a total of not more than 5,000,000 gallons a day being withdrawn from the Yorktown formation. This is obviously only a small fraction of the total amount available.

The permeabilities of a few samples of sand from the Yorktown formation have been determined and show permeabilities

ranging from 25 to 650. However, the best aquifers are the shell rock strata and the permeability of these cannot be tested in the laboratory. Some of these strata apparently are very permeable and will transmit very large quantities of water.

The pressure head on artesian water in the Yorktown formation varies with the location, ranging from about sea level along the coast, to 100 or more feet above sea level near the Fall Zone. Generally the pressure is such that the water level in wells ranges from a few feet above, to 20 or 30 feet below the surface, depending upon the topographic location. Water from the Yorktown is generally hard, and as a rule the shallow water is as hard as the deeper. Water at depth in the outer half of the Coastal Plain usually has a high chloride content.

Analyses 13 and 14, in the table of analyses, are thought to be typical, respectively, of fresh and brackish water found in the Yorktown formation.

DUPLIN MARL

Geology.—The Duplin marl is about equivalent in age to the upper part of the Yorktown and is very similar lithologically and stratigraphically. As originally defined, it is confined to that part of the Coastal Plain south of the Neuse River. It consists of calcareous sands, clays, and marls and often contains a large amount of shell material. Some of the strata are semi-consolidated by cementation to form shell rock or limestone layers.

Like the Yorktown formation, the Duplin marl was deposited as a thin blanket over the beveled edges of the older formations, but whereas the Yorktown still is present as a nearly continuous blanket, the Duplin now occurs only in isolated patches, the largest of which is in western Duplin and eastern Sampson Counties. There is also one fairly large area in Robeson, one in Bladen, and one in Columbus Counties. These four areas, and a small area near Wilmington and one near New Bern, are the principal known areas of outcrop of the Duplin marl. However, nearer the coast it is found in wells drilled in Craven, Carteret, and Onslow Counties where it is below the Croatan sand of Pliocene age or the Pamlico formation of Pleistocene age. In these wells it lies unconformably upon the Trent or Castle Hayne marls.

The Duplin, in its areas of outcrop, is relatively thin, probably nowhere exceeding 100 feet, but a somewhat greater thickness has been encountered in wells drilled near the coast. At the

Havelock well, strata between 70 and 230 feet were referred to the Duplin marl and at both Atlantic and Cape Lookout, strata from 100 to 330 belong to that formation. The dip of the Duplin marl is very low, usually only a few feet per mile.

Water supply.—There apparently are no municipal supplies which are obtained from the Duplin marl. A few wells at the Cherry Point Marine Air Base and possibly at the New River Marine Base may draw part or all of their water from the Duplin marl. Shallow domestic supplies in the areas of outcrop in Duplin, Sampson, Robeson, Bladen, and Columbus Counties and a number of wells at Swansboro, Onslow County; Newport, Morehead City, and Beaufort, Carteret County probably obtain water from the Duplin. The total amount of water obtained from this formation is very small, probably not more than a few million gallons a day. The potential yield is probably several times this amout.

Water from the Duplin marl is generally hard and in some places contains an objectionable amount of iron. Analysis 15, in the table of analyses, is though to be fairly representative of the water from this formation.

WACCAMAW FORMATION AND CROATAN SAND

Geology.—Two formations, the Waccamaw and Croatan, comprise the Pliocene formations in North Carolina. The Waccamaw formation, consisting of shell marl and calcareous sands and clays, crops out only south of the Neuse River, occurring in a few relatively small areas along the Cape Fear River and a larger area in Brunswick County. The Croatan sand consists of fossiliferous sand and crops out chiefly along the Neuse River but has also been recognized in cuttings from wells at Cherry Point, Cape Lookout, Morehead City, Atlantic, Edenton Air Base, Harvey Point, and Elizabeth City.

Neither of these formations is more than about 50 feet thick, and the usual thickness is about 20 or 30 feet. The dip is nowhere more than a few feet per mile.

Water supply.—Relatively few wells obtain their water from the Pliocene formations, and most of these are small domestic supplies. The wells at Harvey Point, which yield an average of 150 gallons a minute each, and the wells at the Edenton Air Base, which also obtain part of their water from the Pamlico formation of Pleistocene age, furnish the most important supplies from the Croatan sand. The Patrol Plane Base and the Lend-Lease Base near Elizabeth City also obtain water from Pliocene strata which may be in the Croatan sand. The average yield from the four wells used at these two bases is about 200 gallons a minute, and the maximum tested yield of an individual well is 264 gallons a minute. The Croatan sand is an important aquifer in the northeastern Coastal Plain where deeper formations yield brackish water. Gravel-packed or screened wells will probably yield up to 300 gallons a minute.

The water from the Pliocene formations is generally moderately hard. Analysis 16, in the table of analyses, is believed to be typical of water from these formations.

FORMATIONS OF THE COLUMBIA GROUP

Geology.—Seven Pleistocene formations, belonging to the Columbia group, occur as a thin blanket over practically the entire Coastal Plain. Their surfaces form terraces taking the same name as the underlying formations. They form northeast-southwest belts, with the highest and oldest being in and parallel to the Fall Zone. The younger and lower formations crop out in successive belts to the southeast. The maximum thickness of any of these formations is about 75 feet and the average is about 25 or 30. The materials consist mostly of arenaceous clay, argillaceous sand and some clean sand and gravel.

Only the lower three formations contain marine fossils. The absence of marine fossils in the higher terraces suggests a continental origin, but the continuity, uniform altitude and thickness, flat surface, well-developed scarps, and universal development are strong arguments in favor of a marine origin for the higher terraces.

Water supply.—The majority of domestic ground-water supplies, and the supplies at several towns and military bases, are obtained from the Pleistocene formations.

Generally the yield per well is not large, the largest probably being from wells at the town of Manteo and the Naval Air Station at Manteo. These wells yield 45 to 60 gallons a minute each. However, at most places the individual yield of the wells is small, usually 5 to 15 gallons a minute. Where large supplies are desired, a number of wells are drilled in a group and pumped as a unit by a suction pump. The wells are finished with drive points and screens or are screened and gravel walled. At Elizabeth City, about 150 wells, covering an area of about 0.5 square mile, yield nearly a million gallons of water a day.

It is probable that in many places in the Coastal Plain supplies of 500,000 to 1,000,000 gallons of water a day can be developed from the Pleistocene formations by using batteries of small diameter wells.

The water from the older Pleistocene formations is usually very soft. It is low in dissolved solids but often contains objectionable iron and may be very corrosive. The water from the Pamlico formation, however, sometimes is as hard as the deeper water, and it also often contains objectionable iron.

Analyses 17 and 18 are thought to be typical of the soft and hard water, respectively.

TYPICAL ANALYSES OF GROUND WATER FROM CRYSTALLINE ROCKS IN NORTH CAROLINA

Analysed by E. W. Lohr, W. L. Lamar, and E. Holloman, U. S. Geological Survey

(parts per million)

	1	2	3	4	5	6
Silica (SiO^2)	12	....	26	40	31	....
Iron (Fe)	.07	0.18	.02	.01	1.3	0.00
Calcium (Ca)	1.9	....	37	16	95	....
Magnesium (Mg)	1.7	....	11	6.2	40	....
Sodium + Potassium (Na + K)	2.1	....	25	14	21	....
Carbonate (CO^3)	0	....	0	0	0	....
Bicarbonate (HCO^3)	12	78	178	110	304	53
Sulfate (SO_4)	3.9	14*	19	2	76	1*
Chloride (Cl)	1.0	1	16	2.5	85	4
Fluoride (F)	.0	0.1	.0	.0	.0	....
Nitrate (NO^3)	1.2	....	3.5	.0	.3	....
Total dissolved solids	30	....	217	129	544	....
Total hardness as $CaCO^3$	12	68	138	65	402	34
Date of collection	Dec. 1 1943	Nov. 30 1943	July 7 1942	July 10 1942	June 14 1943	June 17 1943

* By turbidity.

1 Town of Franklin, Macon County; 337 feet deep, Carolina gneiss.

2 Carnation Milk Co., Statesville, Iredell County; 503 feet deep, Carolina gneiss.

3 Copeland Fabrics, Inc., Hopedale (near Burlington), Alamance County; 470 feet deep; granite.

4 Town of Gibsonville, Guilford and Alamance County; 335 feet deep, schist.

5 Plantation Pipeline Co., Pleasant Grove, Caswell County; 485 feet deep, gneiss and schist?

6 Town of Stoneville, Rockingham County; 189 feet deep, shale (Triassic).

TYPICAL ANALYSES OF GROUND WATER FROM THE COASTAL PLAIN

Analysed by M. D. Foster, E. W. Lohr, M. S. Berry, W. L. Lamar, L. W. Miller, and E. Holloman, U. S. Geological Survey

(parts per million)

	1	2	3	4	5	6	7
Silica (SiO^2)			23	15	16		5.5
Iron (Fe)			2.0	.06	.02		.1
Calcium (Ca)			19	.8	2.9		5.2
Magnesium (Mg)			11	.7	2.6		2.1
Sodium + Potassium (Na+K)			36	79	255		14
Carbonate (CO^3)			0	0	0	8.9	2
Bicarbonate (HCO^3)	6.0	41	174	200	432	201	43
Sulfate (SO_4)	2*	4*	11	9.1	66	1*	4.8
Chloride (Cl)	3	4	12	3	100	4	10
Fluoride (F)			.2		3.0		
Nitrate (NO^3)			.25	.0	1.0		12
Total dissolved solids			199	208	670		88.5
Total hardness as $CaCO^3$	14	33	92	5	18	154	37
Date of collection	Jan. 21 1944	Jan. 20 1944	Jan. 29 1942	Mar. 26 1942	July 17 1942	Jan. 19 1944	July 13 1927

* By turbidity.
1 Town of Raeford, Hoke County; 75 feet deep, Tuscaloosa formation.
2 Town of Rowland, Robeson County; 269 feet deep, gravel-walled well, Tuscaloosa formation.
3 Town of Stantonsburg; Wilson County; 120 feet deep, gravel-walled well, Cretaceous deposits.
4 Town of Woodland, Northampton County; 264 feet deep, Cretaceous deposits.
5 Town of Windsor, Bertie County; 334 feet deep, gravel-walled well, Eocene (?) deposits.
6 Town of Wallace, Duplin County; 150 feet deep, Black Creek formation.
7 Town of Kinston, Lenoir County; 362 feet deep, gravel-walled well, Black Creek formation.

	8	9	10	11	12	13
Silica (SiO^2)			46	42	10	
Iron (Fe)	1.9		7.2	.23	.11	.19
Calcium (Ca)	42		85	17	61	
Magnesium (Mg)	9.1		6.7	8.1	3.6	
Sodium + Potassium (Na + K)	66		30	467	37	
Carbonate (CO^3)	0		0	0		
Bicabonate (HCO^3)	326	271	282	524	120	202
Sulfate (SO_4)	4.1	3*	4.9	126	35	3*
Chloride (Cl)	10	3	47	370	80	4
Fluoride (F)	.6	.6	.8	2.4		.4
Nitrate (NO^3)	.0		.0	.5	.60	
Total dissolved solids	319		390	1,297	308	
Total hardness as $CaCO^3$	142	36	240	76	167	142
Date of collection	Dec. 23 1941	Sept. 3 1941	Oct. 24 1941	Oct. 22 1941	Jan. 17 1933	Nov. 18 1943

* By turbidity.
8 Town of Burgaw, Pender County; 220 feet deep, gravel-walled well, Peedee formation.
9 Town of Richlands, Onslow County; 550 feet deep, Peedee formation.
10 Mike Medinas, Holly Ridge, Onslow County; 177 feet deep, Castle Hayne marl.
11 U. S. Marines, Tent Camp, Jacksonville, Onslow County; 184 feet deep, Castle Hayne marl.
12 Town of New Bern, Craven County; 100 feet deep, Trent marl.
13 Town of Colerain, Bertie County; 270 feet deep, Yorktown formation.

TYPICAL ANALYSES OF GROUND WATER FROM THE COASTAL PLAIN—*Continued*

Analysed by M. D. Foster, E. W. Lohr, M. S. Berry, W. L. Lamar, L. W. Miller, and E. Holloman, U. S. Geological Survey

(parts per million)

	14	15	16	17	18
Silica (SiO^2)	46	33	29		
Iron (Fe)	.05	4.1	.38	1.8	3.0
Calcium (Ca)	58	95	20	7.7	
Magnesium (Mg)	45	4.4	3.2	1.5	
Sodium + Potassium (Na + K)	547	7.4	13	6.7	
Carbonate (CO^3)	0	0	0	0	
Bicarbonate (HCO^3)	524	310	72	18	272
Sulfate (SO_4)	83	1.6	4.2	12	4*
Chloride (Cl)	710	10	18	9	44
Fluoride (F)	.6	.6	.1	.0	0.3
Nitrate (NO^3)	.0	.0	1.8	.0	
Total dissolved solids	1,738	327	132	73	
Total hardness as $CaCO^3$	330	255	63	25	270
Date of collection	Oct. 21 1942	Oct. 21 1941	Nov. 19 1943	Nov. 19 1941	Dec. 19 1941

* By turbidity.
14 Marine Air Station, Edenton, Chowan County; 267 feet deep, Yorktown formation.
15 U. S. Marine Air Base, Cherry Point, Craven County; 105 feet deep, Dulpin marl.
16 Naval Air Station, Harvey Point, Perquimans County; 82 feet deep, Pliocene sand.
17 Town of Whitakers, Nash County; 27.5 feet deep, Sunderland formation (Pleistocene).
18 Town of Hertford, Perquimans County; 25 to 35 feet deep, Pamlico formation (Pleistocene).

RECORDS OF WELLS IN WESTERN NORTH CAROLINA

Location	Owner	Depth (feet)	Diameter (inches)	Topographic Location	Chief Aquifer	Yield Gallons Per Minute	Remarks
Franklin, North of, ¼ mile from river	Town	337	6	Valley	Carolina gneiss	85	Temp. 58° F.; consumption about 200,000 gallons a day.
Franklin, at Creamery	Town	237	6	Slope	Carolina gneiss	55	
Franklin, near river, south of highway 64	Town	755	6	Valley	Carolina gneiss	35	
Hendersonville, 7 miles north of	Biltmore Hosiery Co.	100	6	Valley	Henderson (?) granite	25	
Hazelwood	Hazelwood Tannery	60?	6	Valley		30	Well originally 360 feet deep and supplied town of Hazelwood.
Hazelwood, near Golf Club	Town	400–500	6?	Valley	Roan (?) gneiss	0	Hit rock at 100 feet. No water below.
Canton, at E. B. Plant	Champion Fibre Co.	168 to 200	6	Valley	Carolina gneiss	av. 65	Four wells. Average 50 feet to rock.
Canton, at Sulfur storage plant	Champion Fibre Co.	86	6	Valley	Carolina gneiss	?	Earth-14 feet, sand-5 feet, gravel-40 feet, rock-27 feet.
Canton, at Sulfur storage plant	Champion Fibre Co.	202	6	Valley	Carolina gneiss	90	Soil, sand and gravel-27 feet; gravel and coarse sand-50 feet, sand-rock-125 feet.
Canton, south of Book Mill	Champion Fibre Co.	146 to 152	6	Valley	Carolina gneiss	?	Three wells average 35 feet earth and sand, 13 feet of gravel above rock.
Enka, 10 miles west of Asheville	American Enka Corp.	400 or 450	10	Valley	Carolina gneiss	300 (from 2 wells)	Two wells used for cooling, about 850 feet apart. Water from 175 to 200 feet.
Asheville	Eliada Orphanage	56	6		Carolina gneiss	20	Gray and bluish micaceous rock.
Crossnore, 20 yds. west of highway 194	Crossnore, Inc.	186	6	Valley	Shale (Cambrian ?)	70+	
Newland, ½ mile northwest of	Town	150	6	Slope	Shale (Cambrian ?)	60	Near base of hill.
Pineola	Marmon Estate	?	?		Shale (Cambrian ?)		
Linville, ½ mile south of	Linville Co.	600±	?	Low hill	Shale (Cambrian)		

RECORDS OF WELLS IN THE PIEDMONT AREA OF NORTH CAROLINA

Location	Owner	Depth (feet)	Diameter (inches)	Topographic Location	Chief Aquifer	Yield Gallons Per Minute	Remarks
Alamance County:							
Altamahaw	Altamahaw Mill	160	6	Valley	Schist	70	Used for drinking, soaking, humidifying.
Bellemont	Burlington Mills Corp.	80 to 185	2	Valley	Schist	2 to 6	Four wells, 80, 85, 90, and 185 feet deep.
Burlington, east edge of	Pepsi Cola Plant	162	6	Slope	Schist	84	
Burlington, N. Main and Gilmore Sts.	City	750	8	Draw	Granite	55	Not in use, capped.
Burlington, at City Power Plant	City	455	6	Draw	Granite	35	Not in use.
Burlington	Cherokee Flooring Co.	200	6	Flat	Schist	15	
Burlington	May Hosiery Mills	634	10-8	Draw	Granite?	200	Hardness 142 parts per million.
Burlington	Celanese Lanese Corp.	390	8	Flat	Granite	35	
Elon College	Town	300	8	Draw	Schist	150	
Elon College	Town	900	8	Ridge	Schist	23	
Gibsonville, east edge of	Town	335	8	Hill	Schist	112	Water from quartz veins.
Graham	City	1,005	10	Hill	Schist	30	Most of water in first 250 feet; temp. 63° F.
Graham	City	354–501	10 & 8	Valley	Schist	av. 40	Four wells, 354, 441, 465, and 501 feet deep.
Haw River, east side of river	Tabardrey Mfg. Co.	450	8	Slope	Schist	90	Quartz veins near well.
Haw River, west side of river	Tabardrey Mfg. Co.	600	8	Slope	Schist	75	Many quartz veins exposed near well.
Haw River, east edge of	Travora Mfg. Co.	61	8	Flat	Schist	20	
Hopedale	Copeland Fabrics Corp.	470	8	Valley	Granite	30?	Hardness 138 parts per million.
Mebane, north edge of	Town	735	8	Flat	Schist	25	Reported soft, much iron.
Mebane	Fitch-Riggs Lmbr. Co.	97	6	Flat	Schist	20	Reported soft, no iron.
Ossippee	Ossippee Weaving Co.	335	10	Slope	Schist	40	Temp. 60° F. Hardness by field test, 120 parts per million.
Saxapahaw	Sellars Mfg. Co.	168 & 204	6	Slope	Slate	av. 30	Two wells. Used for drinking and humidifying.
Swepsonville	Virginia Mills Co.	408	8	Valley	Diorite?	20?	Water level reported 265 feet below surface.

RECORDS OF WELLS IN THE PIEDMONT AREA OF NORTH CAROLINA—*Continued*

Location	Owner	Depth (feet)	Diameter (inches)	Topographic Location	Chief Aquifer	Yield Gallons Per Minute	Remarks
Alexander County:							
Taylorsville, 1 mile south of	Prison Camp	247	6			16	
Anson County:							
Lilesville	Town	290	?		Granite?	50	Hit rock at 60 feet.
Cabarrus County:							
Mt. Pleasant, 1 mile north of	Town	250	8–6	Hill	Slate	75	Much quartz float near wells.
Mt. Pleasant, 1 mile north of	Town	350	8–6	Hill	Slate	40	
Caldwell County:							
Granite Falls	Town	600±		Slope	Gneiss	60	
Granite Falls	Town	600±		Slope	Gneiss	40	
Caswell County:							
Milton	Town	312	6	Hill	Gneiss	75	Temp. 61° F. Hardness 138 parts per million.
Yanceyville	Sanitary District	400	8	Slope	Schist & gneiss	12	Temp. 61° F. Hardness 160 parts per million.
Yanceyville	Sanitary District	180	6	Flat	Schist & gneiss	15	Temp. 61° F.
Yanceyville, 1.2 miles north	C. C. C. Camp	183	6	Flat	Schist & geniss	75	
Pleasant Grove, 2.3 miles southeast of	Plantation Pipe Line Co.	485	8	Draw	Schist	55	Hardness 402 parts per million. 61° F.
Catawba County:							
Conover, at water tank	Town	600	6	Hill	Granite?	90	Temp. 62° F.
Conover, 300 yards southwest of highway crossing	Town	535	6	Draw	Granite?	76	Temp. 60° F.
Conover, 2 miles west of	Herman-Sipe Co.	416	6	Ridge	Granite	16	
Conover, 2 miles west of	Herman-Sipe Co.	165	6	Slope	Granite	11	Temp. 62° F.

RECORDS OF WELLS IN THE PIEDMONT AREA OF NORTH CAROLINA—*Continued*

Chatham County:							
Merry Oaks	Royal Crown Co.	90	6		Shale (Triassic)	8	
Siler City	Siler City Hosiery Co.	700	8		Slate	1½	
Cleveland County:							
Boiling Springs	College	115	6	Slope	Carolina gneiss	30	Near top of hill.
Lawndale, southeast edge of	Lawndale Cotton Mills	150	6	Valley	Carolina gneiss	60	Yields 60 gallons a minute from 2 wells.
Davidson County:							
Denton, west edge of	Town	230	8		Slate	23	
Denton, west edge of	Town	200	8		Slate	40	
Durham County:							
Rougemont	Carver Lumber Co.	101	6		Granite	5	
Forsyth County:							
Kernersville	Town	580	6	Flat	Granite	10?	Not used.
Kernersville	Town	150?	8	Flat	Granite	75?	Not used, reported to have failed.
Kernersville	Adams Millis Co.	308	6	Slope	Granite	18	Temp. 61° F.; hardness 88 parts per million.
Kernersville	Vance Knitting Co.	185	6	Flat	Granite	9	
Rural Hall	Sanitary District	350	8	Hill	Gneiss	125	
Winston-Salem (Ogburntown)	Smith-Reynolds Airport	200	8	Draw	Gneiss	50	Water level 14 feet below surface.
Winston-Salem (Tiretown)	R. J. Reynolds Co.	408	6	Draw	Gneiss	45	Bad iron stain.
Winston-Salem (Tiretown)	R. J. Reynolds Co.	320?	5	Draw	Gneiss	30	
Winston-Salem (Tiretown)	Garner Food Co.	200 & 400	6	Slope	Gneiss	av. 6	Two wells.
Winston-Salem, 6 miles north of	County Sanitarium	385	8	Hill	Gneiss	20	Temperature 61° F.
Winston-Salem, 7 miles north of	County Home	315	8	Slope	Gneiss	90	
Hanes (3½ miles west of Winston-Salem)	P. H. Hanes Knitting Co.	102	5 5-8	Ridge	Gneiss	15	
Winston-Salem, 2½ miles west of	Selected Dairies	348	6	Slope	Gneiss	13	

RECORDS OF WELLS IN THE PIEDMONT AREA OF NORTH CAROLINA—*Continued*

Location	Owner	Depth (feet)	Diameter (inches)	Topographic Location	Chief Aquifer	Yield Gallons Per Minute	Remarks
Winston-Salem, 2½ miles west of	Selected Dairies	410	6	Slope	Gneiss	30	
Winston-Salem, 2½ miles west of	Lasater (Smoke House)	538	6	Slope	Gneiss	50	Water in crevices at 73 and 150 feet.
Winston-Salem, 10th & Main Sts.	Peerless Ice Cream Co.	198	10	Valley	Gneiss	100	Temperature 61°; used for cooling.
Winston-Salem, S. Marshall St.	Crystal Ice & Coal Co.	140±	6	Slope	Gneiss	43+	Temperature 61°; used for cooling.
Winston-Salem	Taylor Mfg. Co.	420	6	Slope	Gneiss	21	
Winston-Salem, S. Marshall St.	Southern Dairies Co.	324	5 5-8	Slope	Gneiss	17½	Not in use; water reported hard.
Winston-Salem, S. Marshall St.	Brown-Williamson Co.	401	6	Slope	Gneiss	100	
Winston-Salem	Big Star Store	235	4	Hill	Gneiss	2-3	Not in use; insufficient water.
Winston-Salem, at Power Plant	R. J. Reynolds Co.	714	6	Valley	Gneiss	40	Hard water, 258 parts per million.
Winston-Salem, Foil Plant	R. J. Reynolds Co.	316	6	Valley	Gneiss	35	Foil plant closed, not used.
Winston-Salem	Carolina Narrow Fabric Co.	268	6	Slope	Gneiss	24	Hardness reported 4½ grains per gallon.
Winston-Salem	Hanes Hosiery Mills	211 to 1,097	8	Valley	Gneiss	0 to 65	Five wells; 211, 241, 405, 560, 1,097 feet deep. Use only one well.
Winston-Salem	Colonial Furniture Co.	67	6	Slope	Gneiss		Water slightly hard.
Franklin County:							
Louisburg	Louisburg Lumber Co.	200	6		Granite	3½	
Youngsville	Town	245	8	Slope	Granite	75	
Gaston County:							
Cherryville	Town	av. 200	8 & 6		Gneiss	av. 30	Nine wells in use from 132 to 238 feet deep, yield 20 to 75 gallons a minute.

RECORDS OF WELLS IN THE PIEDMONT AREA OF NORTH CAROLINA—*Continued*

Location	Owner	Depth (feet)	Diameter (inches)	Topographic Location	Chief Aquifer	Yield Gallons Per Minute	Remarks
Stanley	Town	350 to 500	8		Granite & gneiss	av. 25	Two wells 350 feet, one 500 feet deep.
Granville County:							
Camp Butner	Construction Wells	av. 130	6 & 5		Shales and dikes Traissic	av. 18	Nine wells 87 to 250 feet deep yield 3 to 50 gallons a minute.
Guilford County:							
Friendship	Airport	123	6	Hill	Schist	52	Drawdown 46 feet with 52 gallons a minute.
Friendship, 2 miles southeast of	Standard Oil Terminal	143	8	Draw	Schist	20	Most of water at 90 feet.
Friendship, 2 miles southeast of	Shell Oil Terminal	200	6	Slope	Schist	12	
Friendship, 2 miles southeast of	Plantation Pipeline Co.	204	8	Slope	Schist	71	Drawdown 147 feet with 71 gallons a minute.
Greensboro, west edge of	Pomona Terra Cotta Co.	65-120	3	Slope	Schist	15 to 20	Three wells.
Greensboro, west edge of	Pomona Mills Co.	302	8	Flat	Schist	60	Temperature 60° F.
Greensboro	Mock, Judson Voehringer Co.	438	8	Slope	Schist	200	Drawdown 200 feet with 200 gallons a minute.
Greensboro	Vick Chemical Co.	203	8	Slope	Schist	?	Good supply reported.
Greensboro	George C. Brown & Co.	120	6		Schist	15	
Greensboro, Whiteoak Mill	Proximity Mfg. Co.	322	8?	Valley	Schist	55	
Greensboro, Revolution Mill	Proximity Mfg. Co.	437	8	Valley	Schist	100	Not in use at present.
Greensboro, Revolution Mill	Proximity Mfg. Co.	402	8	Valley	Schist	100	
Greensboro, Print Works	Proximity Mfg. Co.	100	?	Valley	Schist	100	Hardness, 201 parts per million.
Greensboro, Hubbard St.	Proximity Mfg. Co.	274	8	Hollow	Granite?	100	Temperature 61°.
Greensboro, at Standpipe	Proximity Mfg. Co.	487	8	Slope	Granite?	70	Capped; not in use.
Greensboro, Revolution Mill	Proximity Mfg. Co.	858	8	Hill	Granite	5	Not used.
Greensboro	County Home	78	3		Granite	6	Two wells same size and yield.
Greensboro	County Home	100 & 250	8		Granite	4 & 6	Two wells.
Greensboro	Home Ice Plant	200	6		Granite	24	
Gibbsonville	Mineola Mfg. Co.	200 to 500	6 to 10	Flat	Schist	av. 40	Four wells.
Gibbsonville	Town	201	8?	Hill	Schist	100	Two wells, close together and interfere, only one is used.

LOCATION	OWNER	Depth (feet)	Diameter (inches)	Topographic Location	Chief Aquifer	Yield Gallons Per Minute	REMARKS
Greensboro, 10 miles east of	Palmer Institute	380	8	Hill	Schist	90	Just below top of hill.
Greensboro	Carolina By-Products Co.	521	8	Draw	Schist	100	
Greensboro	Carolina By-Products Co.	299	8	Slope	Schist	13	Temperature 61° F.
Greensboro	American Agr. Chem. Co.	433	8	Hill	Schist	35	Originally yielded 75 gallons a minute.
Greensboro	Armour Fertilizer Co.	271	6?	Valley	Schist	60	Drawdown is 35 ft. with 60 gallons a minute.
Sedgefield	Pilot Life Ins. Co.	308	8	Slope	Schist	65	Water reported slightly hard.
High Point	Adams Millis Corp.	120 & 124	4 to 6	Valley	Schist	50 & 75	Two wells.
High Point	Cloverdale Dye Plant	750	6	Hill	Slate	5	Yields of 20 gallons a minute at 60 feet shut out.
High Point	Highlands Cotton Mills, Inc.	190	6	Slope	Slate?	12	Most of water from above 100 feet.
High Point	Cloverbrand Creamery	96	6	Flat	Schist	13	
High Point	Crown Hosiery Mill	240	8	Flat	Schist	200	Pumped at 125 gallons a minute.
High Point	Logan Porter Mirror Co.	75	6	Flat	Schist	100	Temperature 62°. Hardness 111 parts per million.
Halifax County:							
Enfield	Town	350	10–8	Flat	Schist	200	Temperature 63°; hardness 206 parts per million.
Littleton	Town	358	8	Flat	Gneiss	120	Temperature 63°; hardness 84 parts per million.
Roanoke Rapids, west edge of	Johnson Laundry	65	4	Flat	Schist	100	Water from quartz vein.
Roanoke Rapids	Thompson Ice. Co.	65	6	Flat	Gravel?	24	
Roanoke Rapids	Colonial Ice Co.	140 to 190	8 & 6	Flat	Granite	10	Four wells yield 10 gallons a minute.
Roanoke Rapids, on river bank	Halifax Paper Co.	478	8	Valley	Gneiss & Schist	150	Hardness, 124 parts per million

RECORDS OF WELLS IN THE PIEDMONT AREA OF NORTH CAROLINA—*Continued*

Harnett County:							
Buies Creek	Buies Creek Academy	100	6		Slate?	17	
Lillington	Town	305	8?		Slate	41	Water from quartz veins.
Lillington, 1 mile south-east of	Prison Camp	85	6		Slate	35	
Iredell County:							
Statesville, west edge of	Carnation Milk Co.	503	10–8	Slope	Gneiss	500	Temperature 61°. Hardness 68 parts per million.
Johnston County:							
Selma	Town	300	8		Schist	250	Cased 61 feet.
Selma, 1 mile south of	Carolina Power and Light Co.	110	4	Flat	Sandstone?	8	Cased 83 feet.
Smithfield	Carolina Packing Co.	176	8		Slate	30	Cased 38 feet.
Smithfield	Carolina Packing Co.	197	8		Sandstone? and slate	60	Cased 31 feet.
Mecklenburg County:							
Charlotte	Shell Oil Co.	148	6		Granite or gneiss	36	
Montgomery County:							
Biscoe	Aileen Cotton Mills	300	8		Slate	30	Cased 59 feet.
Biscoe	Aileen Cotton Mills	400	8		Slate	22	No casing used.
Star	Town	356	8		Schist	25	
Troy	Smitherman Cotton Mills	200	8		Schist	22	Water from quartz veins.
Moore County:							
Carthage	Carthage Weaving Co.	123	4		Triassic	8	
Hemp	Standard Mineral Co.	178	8		Talc?	¼	
Hemp	Pinehurst Silk Mills	203	6		Slate	30	
West End	Sandhill Furniture Co.	175	6		Triassic	15	
Nash County							
Bailey, at school	Town	246	8	Slope	Schist	45	Water from hard vein (quartz?)
Bailey, at sawmill	J. W. Stone	158	6	Valley	Schist	25+	
Middlesex, at west edge of	Town	103	6	Draw	Schist	50+	Two wells, 50 gallons a minute each
Nashville	Town	239	8–6	Flat	Schist	300	

RECORDS OF WELLS IN THE PIEDMONT AREA OF NORTH CAROLINA—*Continued*

Location	Owner	Depth (feet)	Diameter (inches)	Topographic Location	Chief Aquifer	Yield Gallons Per Minute	Remarks
Nashville	Town	300	10–6	Flat	Schist	55	
Spring Hope	Town	507	6		Schist	155	
Spring Hope	Town	135	10		Schist	80	
Orange County:							
Hillsboro	Coca Cola Plant	53	6		Slate	10	
Hillsboro	Standard Oil Co.	54	6		Slate	10	
Randolph County:							
Franklinville	Randolph Mills, Inc.	109	6		Dike (Diabase?)	3	Rock, very hard.
Rowan County:							
Salisbury, 3½ miles south of	County Prison Camp	219	6		Granite	40	Seventy feet to rock.
Surry County:							
Pilot Mt.	Town	237	6		Schist	135	
Pilot Mt.	Town	300	6		Schist	50	
Stokes County:							
Pine Hall	Pine Hall Brick & Pipe Co.	40 to 95	4	Valley & slope	Shale (Triassic)	¼ to 15	About 18 wells.
Walnut Cove	Town	1,027	10	Valley	Triassic	150	
Rockingham County:							
Draper	Marshall Field & Co.	150 to 300	6	Valley	Shale (Triassic)	25 to 50	Three wells.
Leaksville, Bedspread Mill	Marshall Field & Co.	80	6	Valley	Triassic	10+	
Leaksville	Leaksville Woolen Mill	80	6	Valley	Triassic	8	
Spray, Woolen Mill	Marshall Field Co.	195	6	Valley	Triassic	9	
Spray, Suiting Mill	Marshall Field Co.	150	6	Valley	Triassic	9	
Spray	Spray Cotton Mills	100+	8	Valley	Triassic	15	
Reidsville	Edna Mills Corp.	160+	6	Valley	Gneiss	30	

RECORDS OF WELLS IN THE PIEDMONT AREA OF NORTH CAROLINA—*Continued*

Madison	Town	310	8	Valley	Triassic	75?	Not used. Tested at 140 gallons a minute but would not hold up to 90.
Madison	Town	300+	8	Draw	Triassic	75?	Not used, will not hold up to 90 gallons a minute.
Madison	Town	500	8	Slope	Triassic	50-15	Not used; yield decreased from 50 to 15 gallons a minute.
Madison	Town	700	8	Slope	Shale (Triassic)	50-15	Not used; yield decreased from 50 to 15 gallons a minute.
Mayodan	Washington Mills Co.	300	8?	Valley	Shale (Triassic)	15 to 45	Four wells; abandoned.
Mayodan	Washington Mills Co.	700	8	Valley	Shale (Triassic)	15	Abandoned.
Stoneville	Town	190	8	Valley	Shale (Triassic)	40	
Stoneville	Town	189	8	Valley	Shale (Triassic)	75	Temperature 61.5°.
Stoneville	Stoneville Furniture Co.	216	8	Valley	Shale (Triassic)	40	
Wentworth, Courthouse	County	588	6	Hill	Gneiss	30	Temperature 61°.
Wake County:							
Cary	Town	250	8		Gneiss	40	
Raleigh, 3 miles west of	Carolina Pines	150	8		Gneiss	12	
Raleigh	Central Prison	357	8		Gneiss	57	Rock at 47 feet.
Raleigh	Carolina Equip. Co.	112	6			18	
Raleigh-Durham Airport		252	8?		Shale (Triassic)	30	
Raleigh-Durham Airport		175	6		Shale (Triassic)	18	
Raleigh	Montlawn Mem. Asso.	258	6		Granite?	40	Cased 36 feet.

Records of Wells in the Coastal Plain

Location	Owner	Depth (feet)	Diameter (inches)	Chief Aquifer	Yield Gallons Per Minute	Hardness	Chloride	Remarks
Beaufort County:								
Belhaven	Town	101	8	Miocene shellrock (Yorktown?)	100			Screen.
Belhaven	Town	103	8	Mioceneshellrock (Yorktown?)	100	239	66	Screen.
Belhaven	Town	250	2	Miocene shellrock (Yorktown? or Trent?)	av. 10±	231	98	Fourteen flowing wells.
Washington	Town	173	10–8	Limestone (Trent and Castle Hayne?)	500	168	104	Gravel-walled well.
Washington	Town	100–170	3	Limestone (Trent and Castle Hayne?)	500±			About 15 wells.
Bertie County:								
Aulander	Town	135–187	3 & 2	Sand (Cretaceous)	av. 15±	168	5–28	Seven wells in use, screens.
Colerain	Town	270	8	Shellrock and sand (Yorktown)	65	142	4	Hole, 20 inches; gravel-walled.
Windsor	Town	334	8	Sand (Eocene?)	300	18	100	Gravel-walled.
Windsor	Town	325+	2	Sand (Eocene?)	½–1			Several wells; flow.
Bladen County:								
Bladenboro	Town	178	8	Sand (Black Creek)	230	25	4	Gravel-walled.
Elizabethtown	Town	199	8	Sand (Black Creek)	150	47	6	Gravel-walled.
Brunswick County:								
Southport	Town	150	8	Shellrock (Castle Hayne)	150	194	50	
Southport	Town	110	12	Shellrock (Castle Hayne)	50			
Fort Caswell	Army	125	6	Shellrock (Castle Hayne)	av. 50±			Four wells.
Cartaret County:								
Atlantic Beach	Atlantic Beach Co.	190	1¼	Shellrock? (Trent)	25	276	17	Two wells.
Beaufort	Tide Water Power Co.	440	10–8	Shellrock (Trent and Castle Hayne?)	500			Horizons at 300 and 440 feet.
Beaufort	Tide Water Power Co.	300	10	Shellrock (Trent)	?			
Morehead City	Tidewater Power Co.	av. 270	6	Shellrock (Trent)	av. 200	229	21	Four wells.

Records of Wells in the Coastal Plain—*Continued*

Location	Owner	Depth (feet)	Diameter (inches)	Chief Aquifer	Yield Gallons Per Minute	Hardness	Chloride	Remarks
Chowan County:								
Edenton	Town, Freemason St.	290	12	Sand and shell (Yorktown)	650	195	110	Gravel-walled.
Edenton	Town, Va. Road	358	10–8	Sand and shell (Yorktown)	500	204	116	Gravel-walled.
Edenton	Town, at Power Plant	212	8	Sand and shell (Yorktown)	200	210	120	
Edenton	Naval Air Base	40	6	Sand (Pleistocene)	40	47	16	Nine wells used. Average 40 feet deep.
Edenton	Naval Air Base	420	8	Sand and shellrock (Yorktown)				Salt water.
Edenton	Naval Air Base	269	8	Sand and shellrock (Yorktown)	250	330	710	Salty water at 248 feet.
Columbus County:								
Brunswick	E. L. Vinson & R. Gaskin	375?	4	Sand (Black Creek)	30±	141	5	
Chadbourn	Town	80±	8	Sand (Peedee)	300	134	14–30	Hardness 134, 1–2–41.
Fairbluff	Town	270	10 & 8	Sand (Black Creek)	115	9	16	
Tabor City	Town	210	8	Sand (Peedee)	80	51	5	
Tabor City	Town	250?	8–6	Black Creek & Peedee?	60	9	22	Drilled to 625 and pulled back.
Whiteville	Town	263	6	Sand (Black Creek)	600	110	4–23	
Craven County:								
Cherry Point	Marine Air Base	250 av.	8	Sand and shellrock (Duplin and Trent)	310 av.	190±	10±	Twelve wells in main system. Average drawdown 8 feet.
New Bern	City	80 to 110	18–8	Miocene limestone (Trent)	250 av.	200±	10±	Eight gravel-walled wells. Drawdown very small.
Cumberland County:								
Spring Lake	Sanitary District	75	6	Sand (Tuscaloosa)	50			Two wells
Dare County:								
Manteo	Town	45	6	Sand (Pleistocene?)	60 ea.	114		Two gravel-packed wells.
Manteo	Naval Air Base	60	6	Sand (Pleistocene?)	75 ea.	111 & 123	24 & 23	Two wells.
Duplin County:								
Faison	Town	200	8	Sand (Black Creek)	90 & 50	50	3	Two wells.
Kenansville	Town	198	8	Sand (Black Creek)	200	105	3	
Rose Hill	Town	186	8	Sand (Black Creek)	150	132	4	
Wallace	Town	150	10	Sand (Black Creek)	100	154	4	
Warsaw	Town	110±	8	Sand (Black Creek)	60 & 80	94	4	Two wells.

Records of Wells in the Coastal Plain—*Continued*

Location	Owner	Depth (feet)	Diameter (inches)	Chief Aquifer	Yield Gallons Per Minute	Hardness	Chloride	Remarks
Edgecombe County:								
Pinetops	Town	155	10 & 8	Sand (Cretaceous)	75 ea.	79	4	Two wells.
Gates County:								
Gatesville	Ice & Coal Co.	450	4	Sand (Cretaceous?)	30			Flows 30 gallons a minute.
Gatesville	Gatesville Hotel	455	3	Cretaceous?		14	156	Flows.
Sunbury	School	350	3	Sand (Eocene?)		14	60	
Greene County:								
Hookerton	Town	100±	1¼ to 4	Sand (Black Creek)	20±	48	5	Four flowing wells.
Snow Hill	Tidewater Power Co.	260	8	Sand (Cretaceous)	300	32	28	Flows 25 gallons a minute.
Walstonburg	Town	240	8	Sand (Cretaceous)	75	57	6	Gravel-packed well.
Halifax County:								
Enfield	Town	26	30 to 48	Sand (Pleistocene)	100	22	14	Three gravel-walled wells.
Enfield	Town	26	1¼	Sand (Pleistocene)				Eleven driven wells with screens.
Enfield	Town	350	10-8	Crystalline rock	200	206	36	
Halifax	Town	50	6	Sand (Yorktown)	15 ea.	11	11	Two gravel-walled wells.
Scotland Neck	Town	60, 80 & 96	8	Sand (Yorktown)	75, 200 & 205	20	14	Three gravel-walled wells.
Hertford County:								
Ahoskie	Town	290	8	Sand (Eocene?)	250 ea.	54	7	Two gravel-walled wells.
Murfreesboro	Town	228	3	Sand (Cretaceous)	50	10	6	Flowing well.
Winton	Town	155	6	Sand (Cretaceous? or Eocene)	50	20	21	
Hoke County:								
Raeford	Town	75	12	Sand (Tuscaloosa)	100 ea.	14	3	Two wells.
Hyde County:								
Englehard	Pamlico Ice & Light Co.	150 & 215	2 & 3	Sand (Miocene?)	100			Two wells.
Swanquarter	County Agr. Building	189	2	Sand (Miocene?)	20		15	

Records of Wells in the Coastal Plain—*Continued*

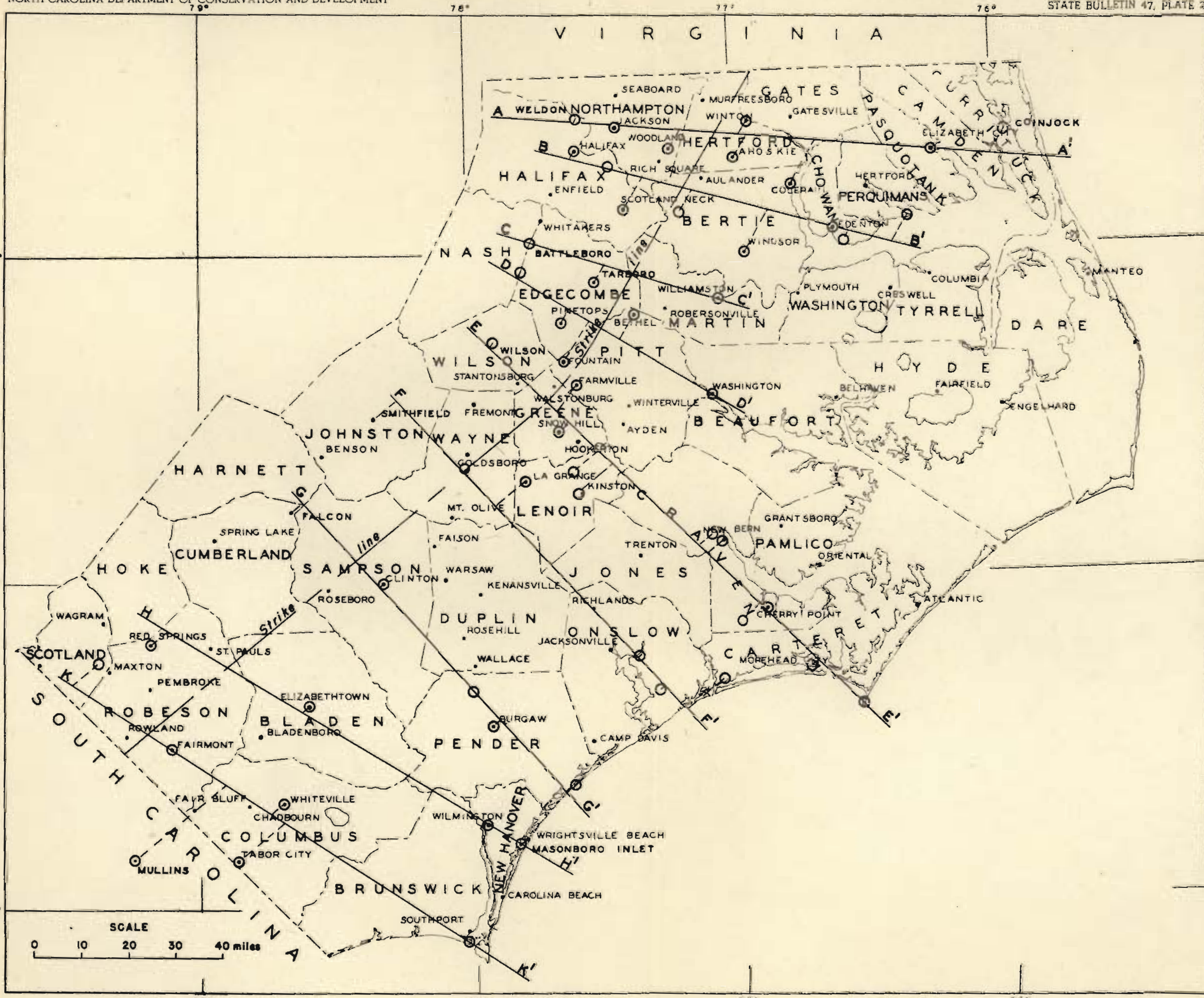
Johnston County:								
Benson	Town	550	10	Bedrock	240	70	9-47	
Jones County:								
Pollocksville	Naval Air Base	67	8	Limestone (Castle Hayne)	180			8.5 feet drawdown.
Pollocksville	Naval Air Base	54	8	Limestone (Castle Hoyne)	200			
Trenton	County	212	3	Limestone (Peedee)	35	138	7	
Lenoir County:								
Kinston	Town	375	8	Sand (Black Creek)	700 & 860	37	10	Two gravel-packed wells.
La Grange	Town	322	8	Sand (Tuscaloosa)	175	32	9	Eleven feet drawdown. Gravel-packed well.
Martin County:								
Robersonville	Town	390	10-8	Eocene or Cretaceous	125	15	16	Main supply.
Robersonville	Town	390	10-8	Eocene or Cretaceous	75	24	240	Auxiliary supply.
Williamston	Town	500	8	Sand (Cretaceous)	300	30	428	Gravel-packed well.
Moore County:								
Aberdeen	Town	30?	6?	Sand (Tuscaloosa)	?			?
Pine Bluff	Town	Springs		Sand (Tuscaloosa?)	40			Five or six springs.
Nash County:								
Whitakers	Town	27½	1¼	Sand (Pleistocene)	90	25	9	Thirty jetted wells.
Battleboro	Town	250	8	Granite	40			
New Hanover County:								
Carolina Beach	Town	200 av.	8	Shellrock (Castle Hayne)	250 av.	171	44	Three wells.
Fort Fisher	U. S. Army	175 av.	8	Shellrock (Castle Hayne)	250 av.	162	21	Five wells.
Sunset Park	Sunset Co.	125 av.	6 & 4½	Shellrock (Peedee)	100 av.	96	34	Eight wells; four in use.
Wilmington	Bluethenthal Field	100 av.	8	Shellrock (Peedee)	300 av.			Three wells.
Wilmington	Housing Project	175 av.	10 & 8	Sand (Peedee)	175 av.			Three wells.
Wilmington	Carolina Shipbuilding Co.	125 av.	8	Sand (Peedee)	275 av.	111	25	Five wells in use.
Wrightsville Beach	Town	165	8	Shellrock (Castle Hayne)	250 av.		176	Two wells.

LOCATION	OWNER	Depth (feet)	Diameter (inches)	Chief Aquifer	Yield Gallons Per Minute	Hardness	Chloride	REMARKS
Northampton County:								
Jackson	Town	40	1¼	Sand (Pleistocene)	75			Six wells.
Rich Square	Town	100	8	Sand (Cretaceous)	140	10	2	Main supply.
Rich Square	Town	70	8	Sand (Yorktown)	120	21	11	Auxiliary supply.
Seaboard	Town	154	8	Sand (Cretaceous)	46			
Seaboard	Town	85	8	Sand (Cretaceous)	60	21	4	
Woodland	Town	264	8	Sand (Cretaceous)	35	5	3	Screen.
Woodland	Town	182	8	Sand (Cretaceous)	60			Screen.
Onslow County:								
Camp Davis	U. S. Army	175 av.	8	Shellrock (Castle Hoyne)	220 av.			Average drawdown 3.3 feet.
Holly Ridge	Town	180	8	Shellrock (Castle Hayne)	330			Nine feet drawdown.
Jacksonville	Town	200	4	Shellrock (Castle Hayne)		204	27	Flows into reservoir.
Jacksonville	Town	185	8	Shellrock (Castle Hayne)	300			Seven feet drawdown.
Camp Lejeune	Marine Base	167 av.	8	Sand and shellrock (Trent and Castle Hayne)	220 av.	200	15	Twenty-one gravel-packed wells.
Camp Lejeune	Tent Camp	100 av.	8	Sand and shellrock (Trent)	175 av.	200	15	Eleven gravel-packed, two screened.
Richlands	Town	550	6	Sand (Peedee)	100	36	3	Soft water.
Pamlico County:								
Bayboro	County Court House	273	3	Yorktown or Trent?	6?	339	52	
Grantsboro	Fleishel Lumber Co.	275	6–4	Yorktown or Trent?	50	110	8	
Oriental	Town	270	2	Sand (Miocene)	1	288	15	Flows.
Pasquotank County:								
Elizabeth City	City	30 av.	1¼	Sand (Pleistocene)	5 av.	150	15	About 230 wells.
Elizabeth City	Consolidated Aircraft	105	8	Sand, Pliocene (Croatan?)	240 av.	198 to 240	44 to 67	Two wells.
Elizabeth City	Patrol Plane Base	85 av.	8	Sand, Pliocene (Croatan)	175 av.	49	15	Two wells.
Pender County:								
Burgaw	Town	220	8	Sand (Peedee?)	150	142	10	Gravel-walled well.

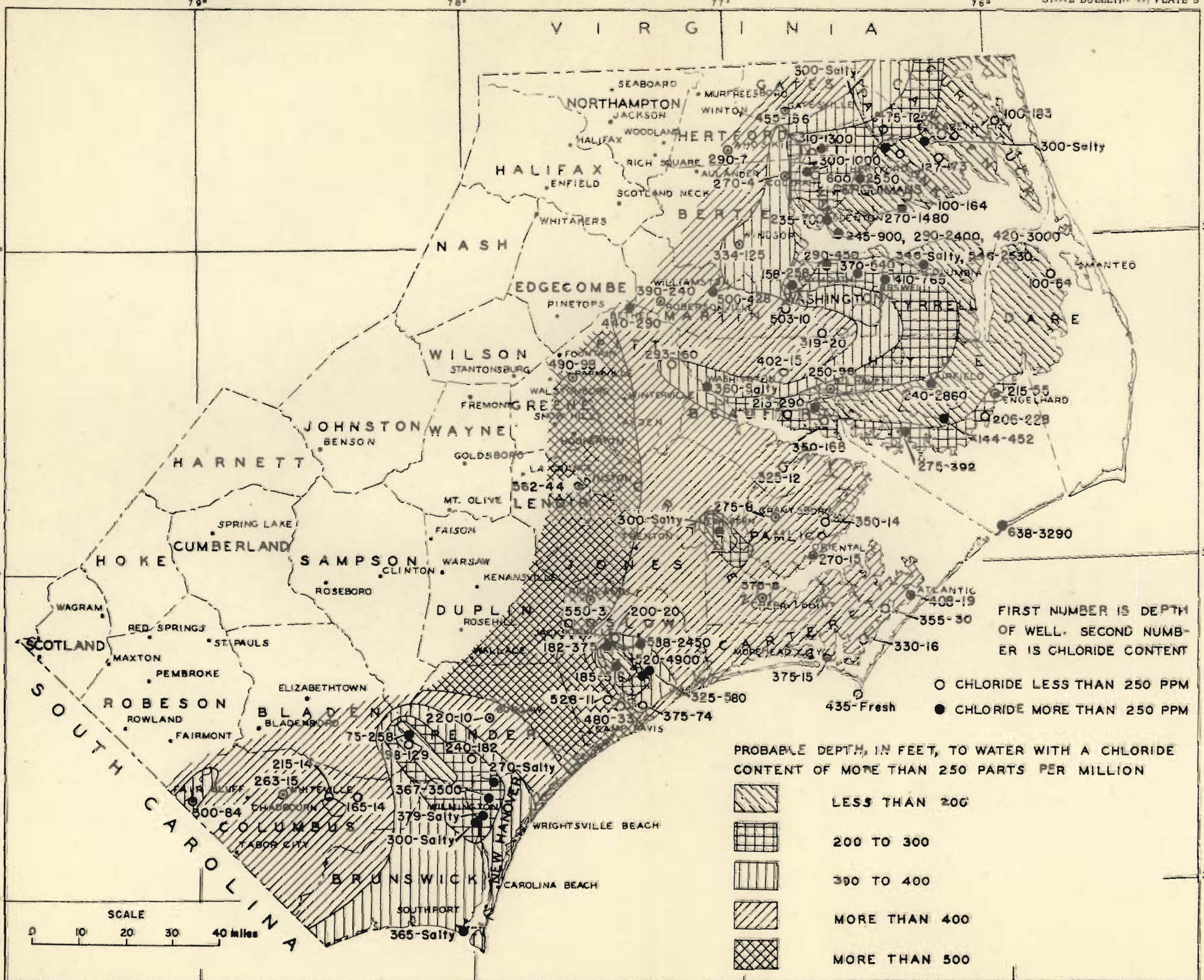
LOCATION	OWNER	Depth (feet)	Diameter (inches)	Chief Aquifer	Yield Gallons Per Minute	Hardness	Chloride	REMARKS
Perquimans County:								
Harvey Point	Naval Air Base	84 av.	8	Sand, Pliocene (Croatan)	135 av.	63	18	Two wells in use.
Hertford	Town	25 to 50	1¼ & 2	Sand (Yorktown)	5 to 10 ea.	270	44	Thirty wells in use.
Pitt County:								
Ayden	Town	152	8	Sand (Black Creek)	200	112	4	Gravel-packed, hard water.
Bethel	Town	445	8	Sand (Cretaceous)	100	24	290	Water from two horizons.
Farmville	Town	475 av.	8	Sand (Cretaceous)	325 av.	16	98	Three gravel-packed wells.
Fountain	Town	194	8	Sand (Cretaceous)	160	146	112	
Winterville	Town	157	6	Sand (Black Creek)	80	186	12	
Robeson County:								
Fairmont	Town	265 to 300	8	Sand (Black Creek)	75 av.	12	2	Three wells.
Fairmont	Town	380	8	Sand (Black Creek)	775	15	----	Gravel-packed; drawdown 28 feet.
Maxton	Town	50 to 70	6	Sand (Tuscaloosa)	75 av.	12		Three wells.
Pembroke	Town	93	8	Sand (Black Creek)	100	24	3	Screened from 85 to 93 feet.
Red Springs	Town	206	8	Sand (Tuscaloosa)	450			Gravel-packed wells.
Rowland	Town	269	8	Sand (Tuscaloosa)	160	33	4	Drawdown 40 feet, gravel-packed
Rowland	Town	250	8	Sand (Tuscaloosa)	775	27	----	Gravel-packed; drawdown 30 feet.
St. Pauls	Town	110	6	Sand (Black Creek)	100 ea.	6	10	Three wells.
Sampson County:								
Clinton	Town	260 av.	8	Sand (Black Creek)	450 av.	51	4	Two gravel-packed wells.
Roseboro	Town	45	1¼	Sand	10 av	20	23 to 85	Fourteen wells and points.
Scotland County:								
Gibson	Town	25	1¼	Sand (Pleistocene)	12 av.	30	8 to 20	Eight wells used.
Maxton	Army Air Base	150 av.	8	Sand (Tuscaloosa)	220 av.			Five screened wells average 75 feet drawdown.
Maxton	Army Air Base	260 av.	8	Sand (Tuscaloosa)	1,000 av.			Two gravel-packed wells average 38 feet drawdown.
Wagram	Town	30	1¼	Sand (Pleistocene)	5 av.	36	9 to 31	Twelve wells.

RECORDS OF WELLS IN THE COASTAL PLAIN—*Continued*

LOCATION	OWNER	Depth (feet)	Diameter (inches)	Chief Aquifer	Yield Gallons Per Minute	Hardness	Chloride	REMARKS
Washington County:								
Plymouth	Town	158	10	Shellrock (Yorktown)	500	232	258	
Wayne County:								
Fremont	Town	596	10	Crystalline rock	80	354	305	Hard water.
Fremont	Town	40	13	Sand (Tuscaloosa)	23	27	34	Gravel-packed.
Goldsboro	Army Air Base	115 av.	8	Sand (Black Creek & Tuscaloosa)	440 av.	22	5	Seven gravel-packed wells.
Pikeville	Town	255	6	Bedrock				
Pikeville, at school	Town	214	6	Bedrock	6	108	14	
Mount Olive	Town	174	10	Sand (Black Creek)	150	27	4	
Mount Olive	Town	135	10	Sand (Black Creek)	90			
Mount Olive	Town	170	10	Sand (Black Creek)	160			
Wilson County:								
Elm City	Town	187	6	Granite	100	124	10	
Stantonsburg	Town	120	8	Sand (Cretaceous)	300	92	12	



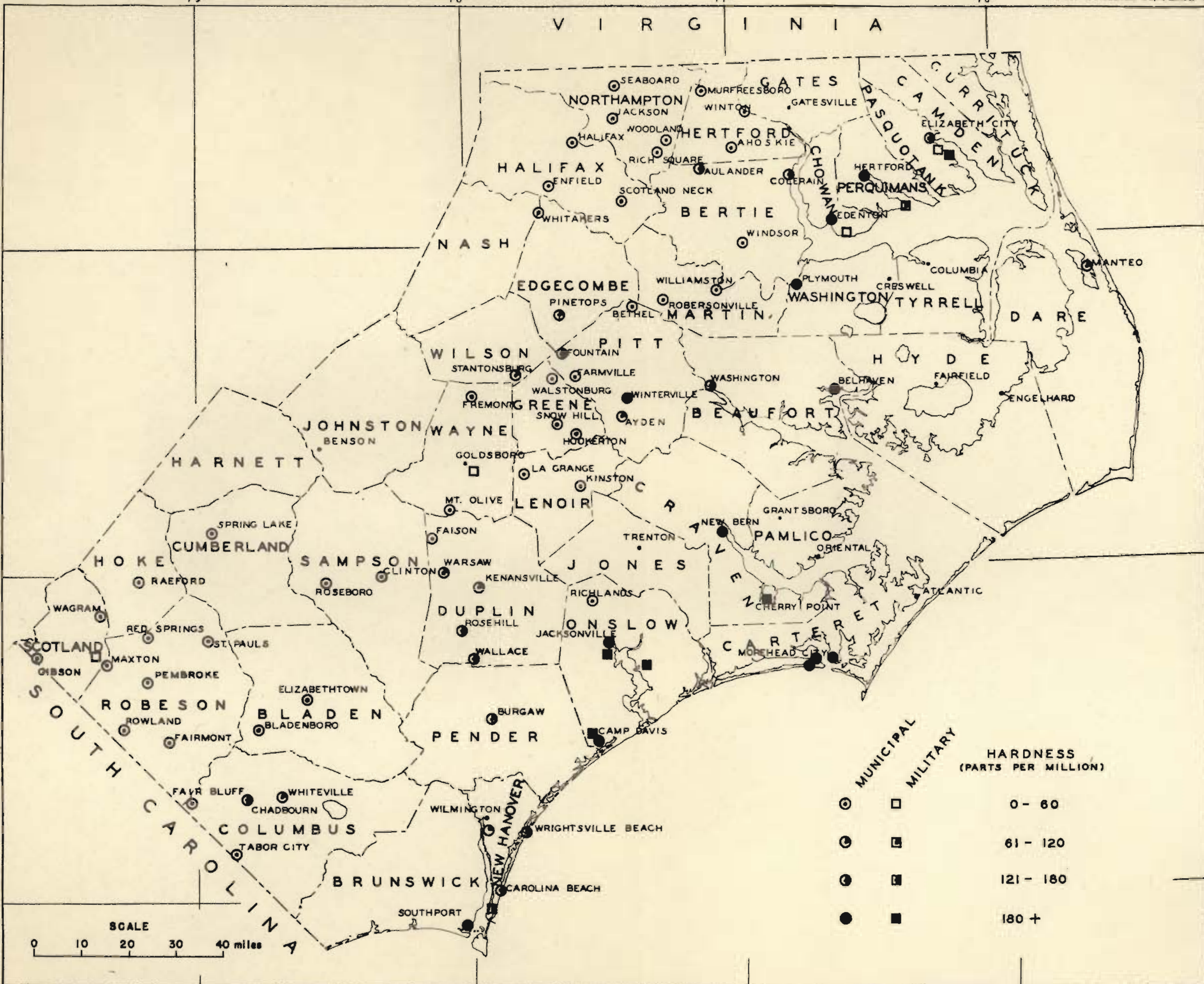
MAP OF THE COASTAL PLAIN SHOWING THE LOCATION OF CROSS SECTIONS AND THE WELLS USED IN THEIR CONSTRUCTION



MAP OF THE COASTAL PLAIN SHOWING PROBABLE DEPTH TO WATER WITH A CHLORIDE CONTENT OF 250 PARTS PER MILLION OR MORE

UNITED STATES DEPARTMENT OF THE INTERIOR, GEOLOGICAL SURVEY
IN COOPERATION WITH
NORTH CAROLINA DEPARTMENT OF CONSERVATION AND DEVELOPMENT

STATE BULLETIN 47, PLATE 4



MAP OF THE COASTAL PLAIN SHOWING THE HARDNESS OF GROUND WATER
USED BY MUNICIPALITIES AND MILITARY BASES