NORTH CAROLINA
DEPARTMENT OF WATER AND AIR RESOURCES

DIVISION OF GROUND WATER

REPORT OF INVESTIGATIONS NO. 5

GROUND-WATER SUPPLY OF CAPE HATTERAS NATIONAL SEASHORE RECREATIONAL AREA, NORTH CAROLINA

PART 4

By
ORVILLE B. LLOYD, JR. AND HUGH B. WILDER

RALEIGH, NORTH CAROLINA
1968

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GEORGE E. PICKETT, DIRECTOR

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HARRY M. PEEK, CHIEF

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U. S. Geological Survey

Prepared by the
UNITED STATES GEOLOGICAL SURVEY
in cooperation with the
NATIONAL PARK SERVICE

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June 24, 1968

The Honorable Dan K. Moore
Governor of North Carolina
Raleigh, North Carolina

Dear Governor Moore:

I am pleased to submit Report of Investigations No. 5, "Ground-Water Supply of Cape Hatteras National Seashore Recreational Area, North Carolina, Part 4," prepared by Orville B. Lloyd, Jr. and Hugh B. Wilder, United States Geological Survey, in cooperation with the National Park Service.

This report presents the results of the fourth phase of intensive studies by the Geological Survey to evaluate and aid in the development of ground-water supplies in the National Seashore Recreational Area. The data in this report was collected at the Fort Raleigh National Historical Site.

Respectfully submitted,

George E. Pickett

George E. Pickett

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INTRODUCTION

In 1957, the National Park Service requested that the U. S. Geological Survey determine the quality and quantity of available ground water at selected sites within the Cape Hatteras National Seashore Recreational Area. A series of reports, "Ground-Water Supply of Cape Hatteras National Seashore Recreational Area" by P. M. Brown (1960), "Ground-Water Supply of Cape Hatteras National Seashore Recreational Area, Part 2" by J. O. Kimrey (1960), and "Ground-Water Supply of Cape Hatteras National Seashore Recreational Area, Part 3" by W. H. Harris and H. B. Wilder (1964), have been prepared and transmitted to the National Park Service in compliance with their request.

In the spring of 1963, the Park Service requested the U. S. Geological Survey to determine whether or not adequate ground water could be obtained in the vicinity of Fort Raleigh National Historical Site to supply park headquarters, other administrative buildings, and ranger homes. The present report results from an investigation made in response to this request. The investigation is a part of the continuing cooperative program between National Park Service and the U. S. Geological Survey to evaluate the ground-water supply of the recreational area.

This report was prepared under the direct supervision of G. G. Wyrick, Ground Water Branch, and G. A. Billingsley, Quality of Water Branch, U. S. Geological Survey. It deals specifically with the appraisal of ground-water supplies to a

depth of about 155 feet below land surface in and near the Fort Raleigh area (fig. 1).

The field work for the present study was done during the period from July 15, to August 15, 1963. Methods of investigation consisted of 1) test drilling with a power auger; 2) collecting lithic samples at 5-foot intervals and water samples at 10-foot intervals from each of the test holes to determine the character of the sediments and the quality of water contained in them; 3) measuring yield at 10-foot intervals in each test hole; and 4) conducting a pumping test (fig. 2) in the most productive water-bearing zone.

Acknowledgment is due Mr. James Myers, former Superintendent, Cape Hatteras National Seashore Recreational Area, and the personnel of his staff, particularly Mr. Jerry Eubanks, Mr. Samuel Burrus, and Mr. Henry Hayward, for supplying pertinent maps, information, and materials during this investigation.

GEOGRAPHY

The area of study is located on the northern end of Roanoke Island (fig. 1 and 2), which is bounded on the north by Albemarle Sound, the south by Pamlico Sound, the east by Roanoke Sound and the west by Croatan Sound.

The sandy soil of the area supports a moderately dense stand of pine and scrub oak. The terrane slopes gently from about 20 feet above mean sea level at the top of the bluffs bordering Albemarle Sound, to 10 feet above mean sea level in the southern portions of the area.

Average annual rainfall is about 44 inches, and is greatest between the months of July and October. Surface runoff is small compared to the total amount of rainfall because the predominantly flat slopes and high permeability of the surface sands allows most of the precipitation to infiltrate the ground. When it occurs, runoff drains primarily to the south and southwest into Croatan Sound.

GEOLOGY

In general, the rock material that underlies the area of study consists largely of sand that was deposited in a marine

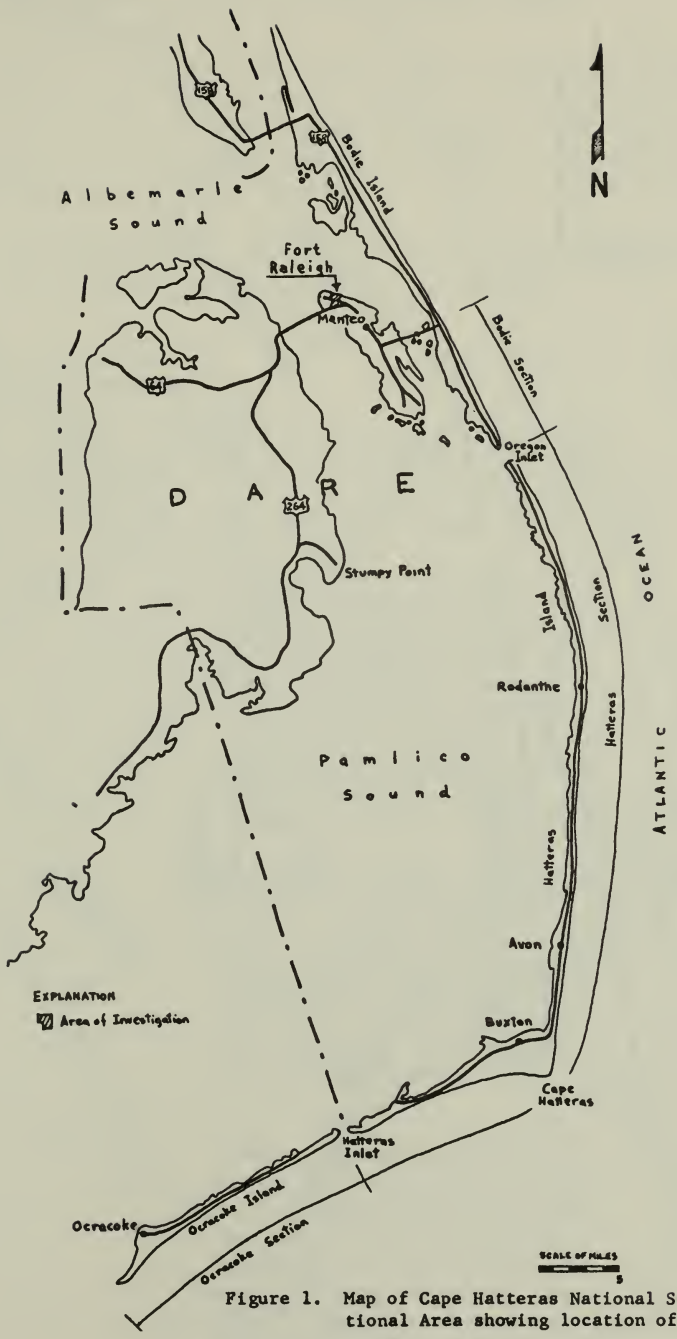

Figure 1. Map of Cape Hatteras National Seashore Recreational Area showing location of Fort Raleigh Area.

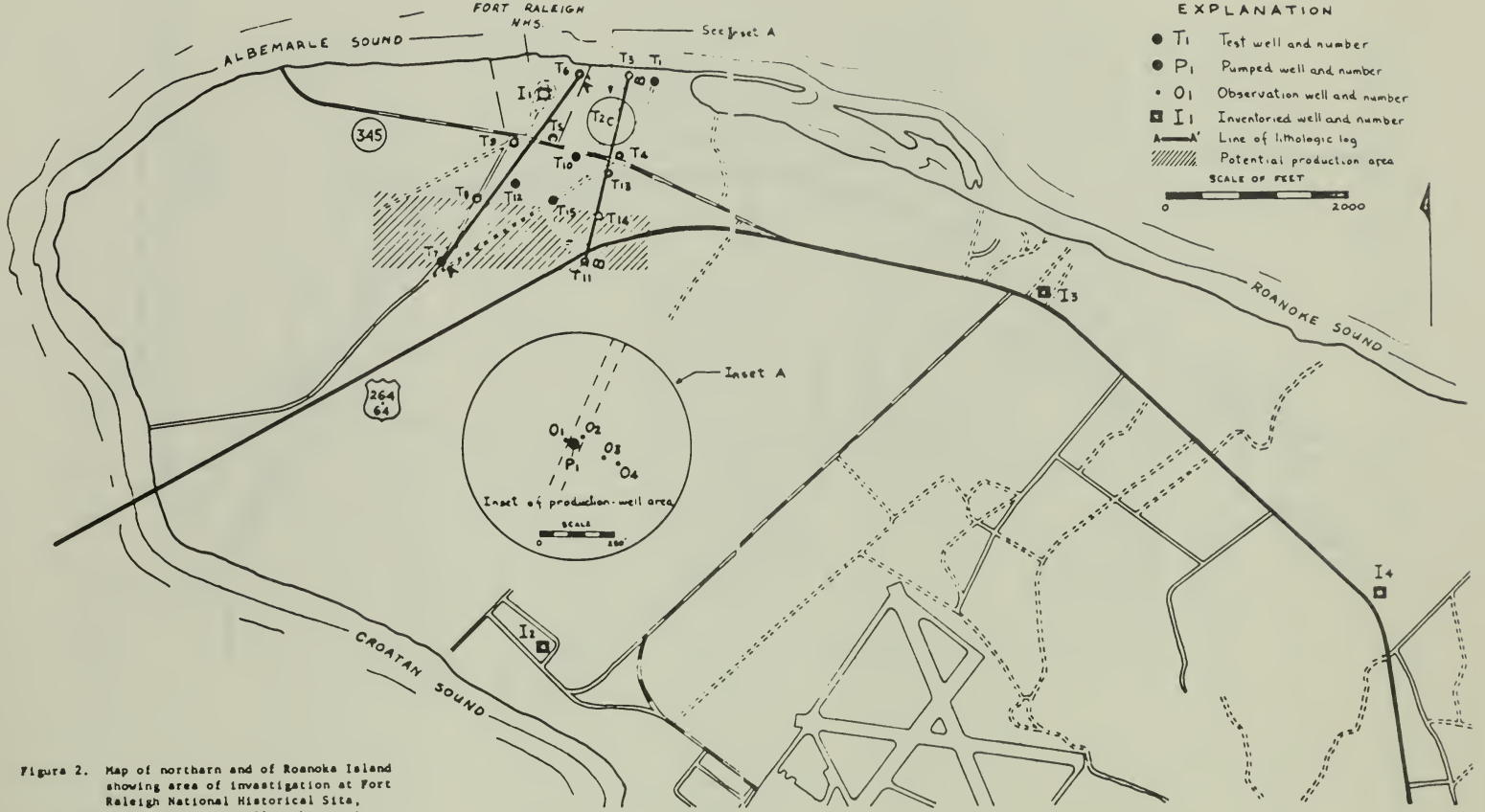

Figure 2. Map of northern end of Roanoke Island showing area of investigation at Fort Raleigh National Historical Site, location of test wells, observation wells, inventoried wells, line of lithologic logs, and potential production area.

environment. After the withdrawal of the sea the uppermost or youngest sediments were exposed to the weather, and wind blew the finer sand particles into dunes and ridges. These dunes line the northern shore of Roanoke Island today.

Fifteen (15) test holes (fig. 2) were drilled in and near Fort Raleigh National Historical Site to determine the nature and extent of the various underlying strata. The capacity of the power auger and the program description limited the depth of the holes to 157 feet or less.

Four (4) distinct lithologic units can be recognized in the area defined by the test holes, as follows:

Depth in feet (below land surface)		Thickness in feet
0-18	Sand, fine-grained, subangular quartz, tan; contains disseminated ilmenite throughout and clay in the upper 5 feet.	18
18-44	Sand, medium-grained, subangular quartz, orange-brown to brown, changes to greenish-brown in lower 10 feet; contains disseminated ilmenite, varying amounts of fine-grained quartz sand and gravel throughout, and disseminated shell fragments in the lower 10 feet.	26
44-96	Sand, fine-grained, subangular quartz, greenish-brown to green, changes to blue-green in the lower 25 feet; contains disseminated ilmenite, abundant disseminated shell fragments, silt and clay. Silt and clay content increases with depth.	52
96-157 +	Silty clay, blue-green, changes to blue-gray in the lower 50 feet; contains fine-grained quartz sand and disseminated shell fragments. Clay and sand layers alternate in the upper 40 feet, but little sand is encountered from 136 feet to 157 feet except in well T5.	61+

The depths and thicknesses given above are approximate because they represent arithmetic means based on samples collected from the fifteen (15) test holes drilled in the area.

The four (4) lithic units can be correlated from hole to hole and are continuous throughout the area. Although the depths to, and thicknesses of these units vary from place to place, there is little change in their physical character laterally. Two (2) lithologic logs (fig. 3), constructed along line A-A' and B-B' in figure 2, illustrate the lateral continuity and vertical relationships of these units.

A 5-foot thickness of fine-grained quartz sand was encountered between 145 and 150 feet below land surface in T5. This sand probably is in a lens of limited extent within the bottom lithic unit because it was not detected in the other test holes.

GROUND WATER

Most of the 44 inches of annual rainfall in the Fort Raleigh area seeps into the permeable surficial sand. It percolates downward, and recharges, or is added to, the zone of saturation -- the zone in which all pore spaces are filled with water. Thus, the available ground water (the available water that occurs in the zone of saturation) is stored in pore spaces between the grains of the subsurface material.

In general, the ground water in the area, to the depths tested, is under nonartesian or water-table conditions. Water-table conditions mean the upper surface of the zone of saturation is not confined by an impermeable bed or aquiclude; it is at atmospheric pressure, and it is free to rise and fall as water is added to or taken from the zone of saturation.

Aquifers

An aquifer is a formation, part of a formation, or group of formations that is water bearing. Coarse-grained, equigranular materials contain more immediately available ground water per unit volume than fine-grained materials. Therefore, the coarser materials (other factors being the same) constitute the more productive aquifers. In this report lithic units that did not produce a minimum of 2.5 gallons per minute during the preliminary yield tests are not considered aquifers.

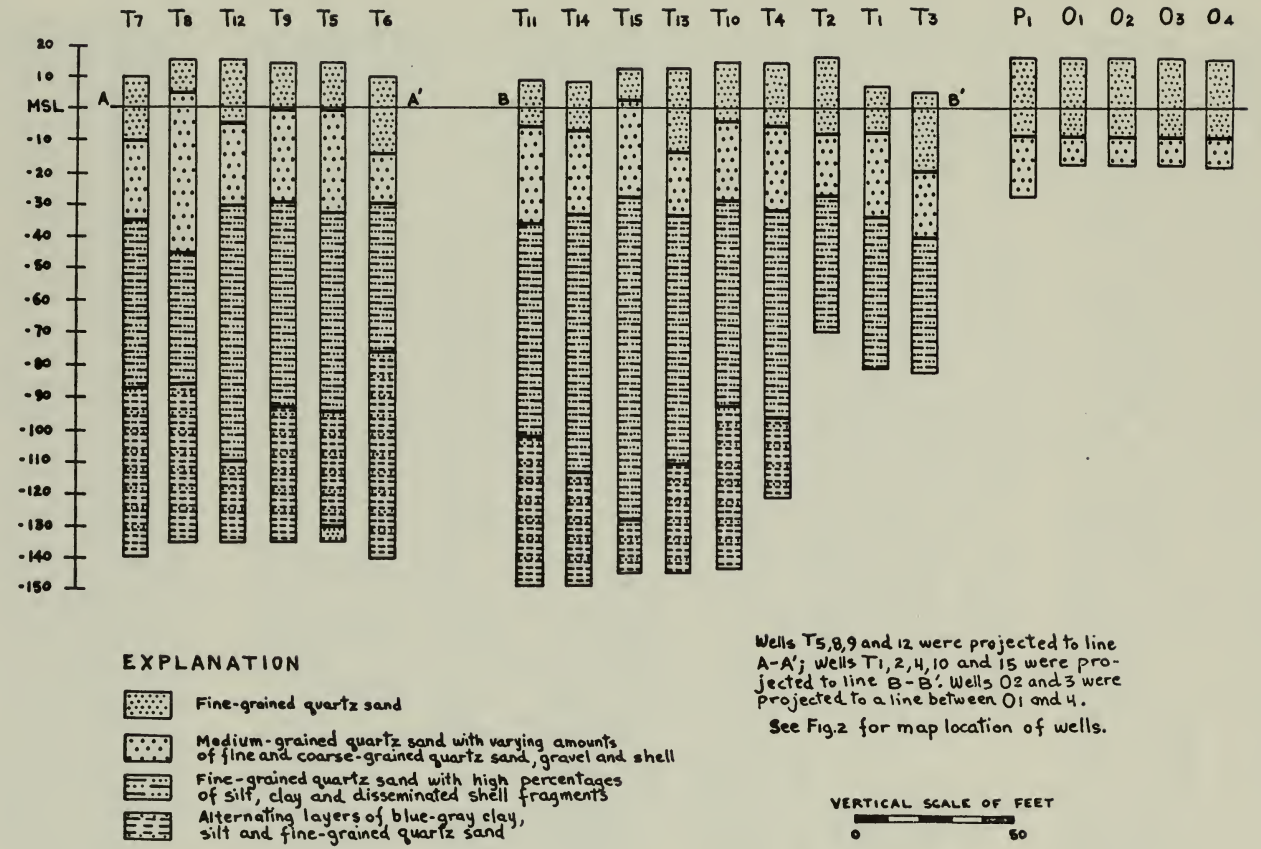

Figure 3. Lithologic logs showing material penetrated by test wells in the Fort Raleigh Area.

The coarsest and most productive material defined by the test drilling in the Fort Raleigh area was the unit between about 18 and 44 feet below land surface. The unit yielded from 2 to 6 gpm, and a mean value of 3 gpm is assigned for planning purposes. Water levels ranged from 2 feet above mean sea level near Albemarle Sound, to over 5 feet above mean sea level slightly south of Fort Raleigh. The material in this unit (see lithic log page 5) consists of medium-grained quartz sand which contains varying amounts of fine sand, fine gravel, and disseminated shell fragments.

This medium-grained sand unit is overlain and underlain mostly by fine-grained quartz sand. No measure of yield was obtained from the material between 0 and 18 feet below land surface because the drawdown at the pumping rates pulled the pumping level to below 18 feet almost immediately. It is assumed, therefore, that yields from the upper unit are less than those from the 18-44 foot zone because of the finer grain and consequent lower permeability of the shallower material. Water levels were the same as those described for the 18-44 foot zone.

The silt and clay fraction below the 18-44 foot zone, increases with the depth of hole until, at approximately 100 feet below land surface, the clay is concentrated in layers that alternate with thin beds of fine-grained and silty quartz sand. Yields from this material ranged from .25 to 2 gpm, and the mean value is about .7 gpm. Water levels were the same as those described for the 18-44 foot zone (p. 5).

Below 100 feet, layers of clay and small amounts of silty sand alternate to a depth of 157 feet below land surface. No water was produced from this zone except in test well T5 (fig. 3). Here a yield of .25 gpm was obtained from a 5-foot thickness of sand between 145 and 150 feet below land surface (see p. 6).

Other wells on Roanoke Island, including one of the water supply wells on Fort Raleigh National Historical Site proper, are open only to water-bearing strata from between 150 and 170 feet below land surface (see fig. 2 and appendix A). The yield from each of these wells is in excess of 2.5 gpm. These wells indicate one or more aquifers between 150 and 170 feet below

land surface. However, since no water-bearing strata were encountered between 100 and 157 feet during the test drilling in this area, (except in well T5), this water-bearing zone (or zones) is thought to be discontinuous lenses of sand or, if continuous, the zone (or zones) dips or plunges deeper than 157 feet in nearly all the area proposed for development.

Therefore (on the basis of the lithology defined by the test holes and the preliminary yield measurements), the water-bearing material between about 18 and 44 feet below land surface is the best zone to develop for a future source of ground water from the Fort Raleigh area.

Quantitative studies - Fort Raleigh

A pumping test was conducted at Fort Raleigh on August 7 and 8, to determine the amount of water that can be pumped from the water-bearing zone between 18 and 44 feet, and to detect any change in the quality of water during pumping.

The ability of the 18-44 foot zone to transmit and store water (which was determined from the pumping-test data) defines the limits of water production from the zone. These limits can be approached through any one of a variety of well diameters, well spacing, and pumpage rates. The following suggested specifications are practical for the hydrologic characteristics of the aquifer, but constitute only one of the possible combinations that may be used.

On the basis of pumping test data, 2-inch diameter wells, spaced at least 180 feet apart, and screened through the full thickness of the aquifer with #20 slot (30- to 40-gauge) screen will produce 20 gpm each for extended periods of pumping with negligible drawdown interference (fig. 4). The wells generally should be screened between about 18 and 44 feet, but screening should be adjusted to local thickening and thinning of the aquifer (fig. 3).

The production well, screened from 34 to 44 feet below land surface, was pumped for 18 hours at 15 gpm, and four (4) observation wells (0-1, 0-2, 0-3, and 0-4) were used to record water-level changes during the pumping test (Inset A, fig. 2). Figure 5 illustrates the drawdown in 0-1, 0-2, and 0-3 during each hour of the pumping test. The data for 0-4 are omitted

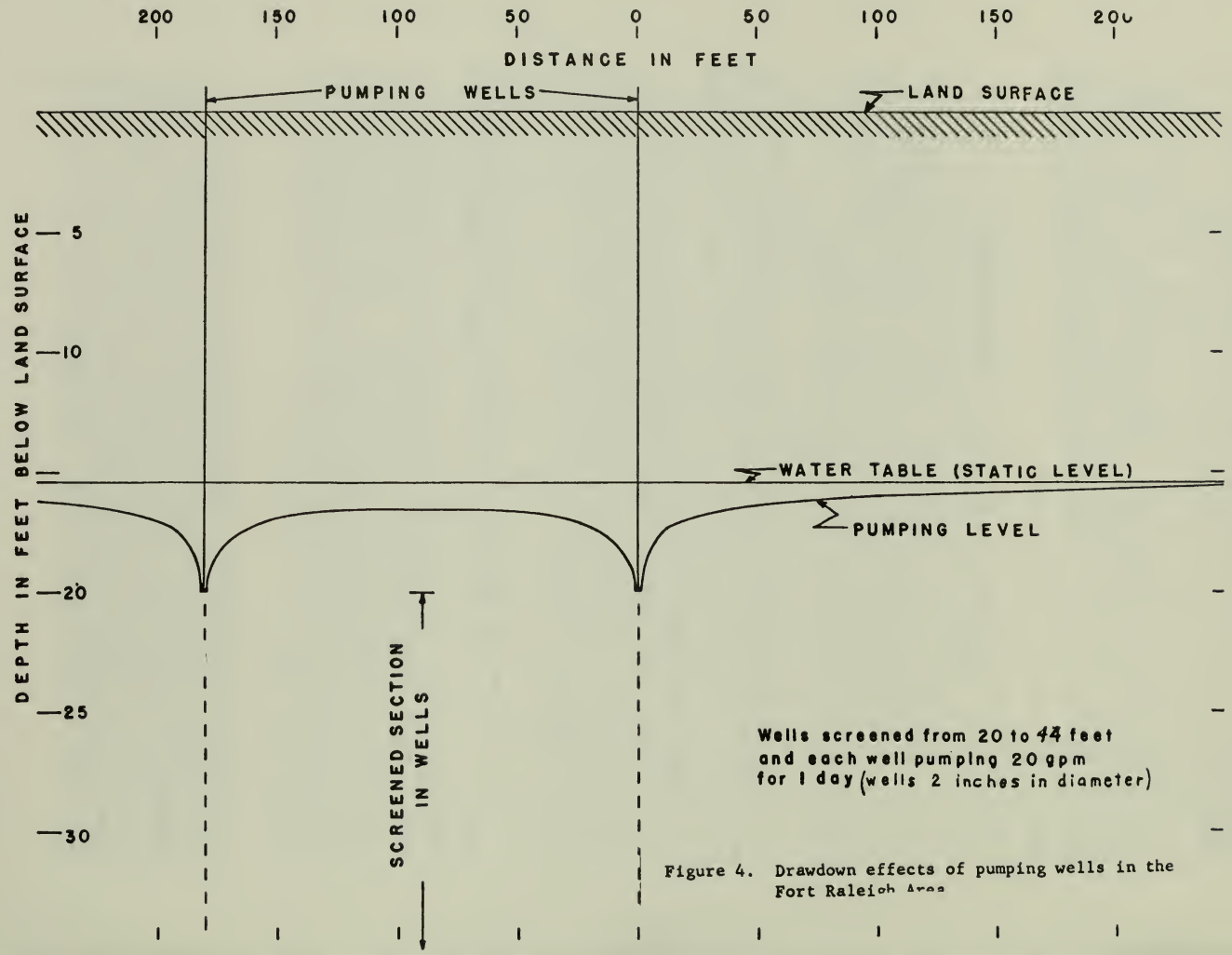

Figure 4. Drawdown effects of pumping wells in the Fort Raleigh Area

from the hydrograph because the drawdown in this observation well was negligible. The production well only partially penetrated the aquifer and this is taken into consideration in the final calculations and recommendations.

Although the pumping test was conducted at site T2, the permanent well field should be located farther from the sound, in a line parallel to the northern shore of Roanoke Island, to reduce the hazard of lateral salt-water encroachment. The change in location would not affect the specifications given above because the general uniformity of the material indicates that the hydrologic values obtained during the pumping test would be valid throughout the area defined by the test drilling.

Changes in chemical quality of water from the production well during the test are discussed in the section on water quality.

QUALITY OF GROUND WATER IN THE FORT RALEIGH AREA

Ground water, at depths of less than 100 feet, in the Fort Raleigh area is generally fresh, moderately hard to hard (see p. 14), and contains objectionable amounts of iron. Hydrogen sulfide was noticeable only in water samples collected from 40 feet in well T3 and 50 feet from well T10. This water can be made satisfactory for most purposes by control of iron with vitreous phosphate compounds or by removal of iron and hardness causing constituents with cation exchange treatment. A complete analysis for a typical ground water from the area is shown in table 1.

Chloride

Concentrations of chloride in 69 water samples collected from the 15 test wells in the area ranged from 19 to 54 ppm, and had a median value of 26 ppm. None of the wells penetrated the fresh water-salt water interface, which underlies the area, and to a depth of 145 feet no increase of chloride with depth was found. In addition, the chloride concentration did not increase during an 18-hour pumping test at the site of well T2. There appears to be little danger of vertical encroachment of salt water into wells screened above 100 feet.

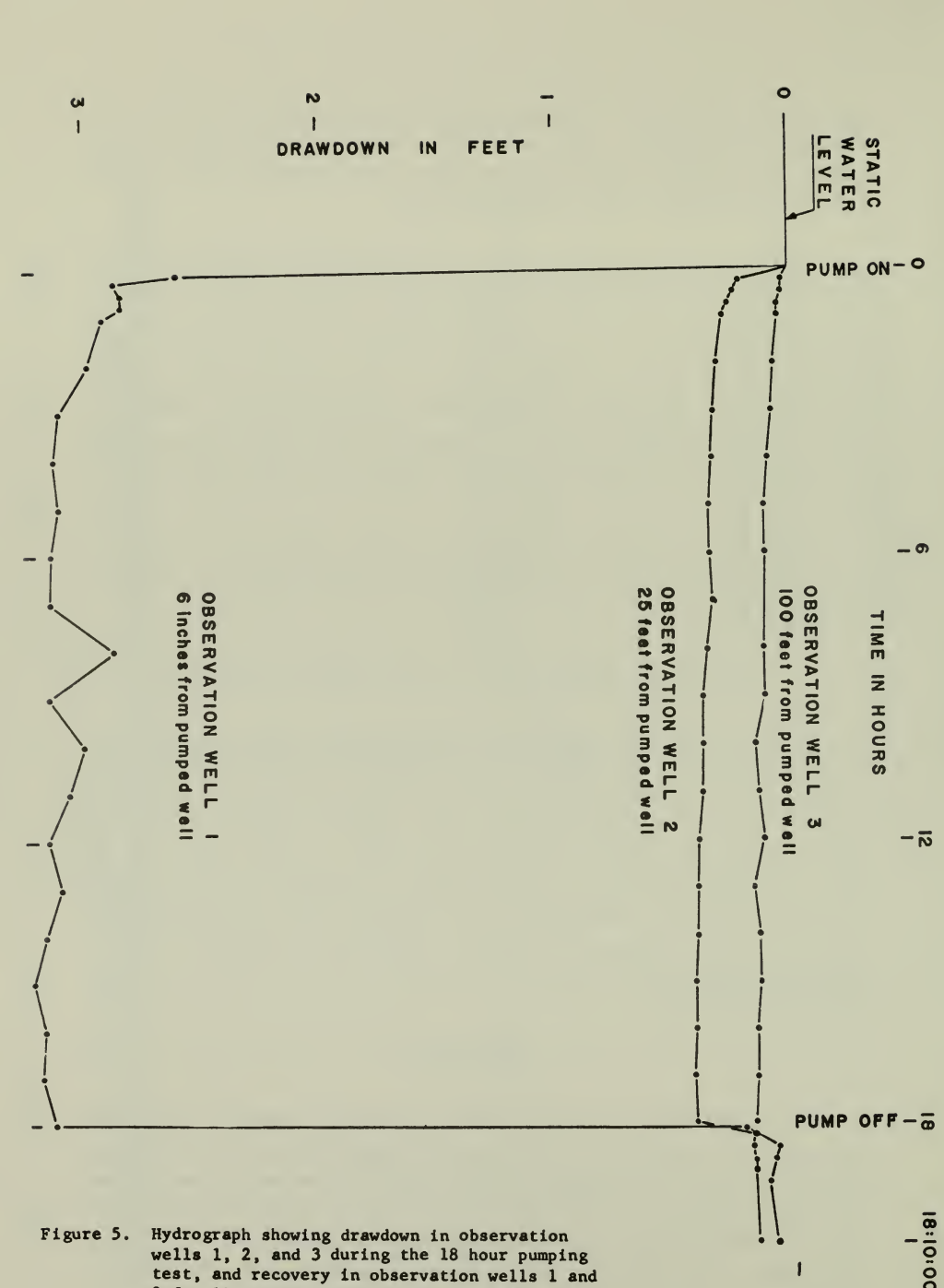

Figure 5. Hydrograph showing drawdown in observation wells 1, 2, and 3 during the 18 hour pumping test, and recovery in observation wells 1 and 2 for 10 minutes after the pump was shut off.

TABLE 1. CHEMICAL ANALYSIS IN PARTS PER MILLION OF A TYPICAL GROUND WATER FROM THE FORT RALEIGH AREA.

Date of collection	August 8, 1963
Silica (SiO_2)	7.1
Iron (Fe)	2.1
Manganese (Mn)	---
Calcium (Ca)	37
Magnesium (Mg)	3.5
Sodium (Na)	17
Potassium (K)	.7
Bicarbonate (HCO_3)	108
Carbonate (CO_3)	0
Sulfate (SO_4)	15
Chloride (Cl)	25
Fluoride (F)	.0
Nitrate (NO_3)	.6
Phosphate (PO_4)	.0
Dissolved solids	
Sum	161
Hardness as $CaCO_3$	106
Noncarbonate	17
Specific conductance (micromhos at 25°C)	267
pH	7.4

The amounts of chloride in all the samples analyzed were much lower than the 250 ppm maximum recommended for public supplies by U. S. Public Health Service. Except in the immediate vicinity of the sounds (fig. 1), where lateral encroachment of salt water is a possibility, excessive chloride is not a factor which must be considered in locating shallow wells in the Fort Raleigh area.

Hardness

Hardness is the term used to describe water which does not lather readily and which forms curds with soap. Most of the hardness of water is caused by dissolved calcium and magnesium ions. The shell material which is found in most of the water-bearing zones in the Fort Raleigh area is composed of calcium carbonate, and ground water in the area generally contains significant amounts of hardness-causing constituents. All of the hardness-causing constituents dissolved in a water are reported together as an equivalent amount of calcium carbonate ($CaCO_3$). The U. S. Geological Survey uses the following arbitrary scale to classify the hardness of waters.

Hardness as $CaCO_3$	Classification
0-60 ppm	Soft
61-120 ppm	Moderately hard
121-180 ppm	Hard
180+ ppm	Very hard

Hardness of ground water in the Fort Raleigh area ranged from 36 to 210 ppm, with a median value of 128 ppm. Most of the samples analyzed are classified as moderately hard or hard, and treatment for hardness is desirable to make these waters acceptable for domestic use.

Iron

When present in concentrations greater than about 0.3 ppm, iron in water causes reddish staining of laundry, porcelain household fixtures, and objectionable appearance of some foods cooked in the water. If present in sufficient quantities, it can also cause clogging of water systems, hot water heaters, and automobile radiators. The U. S. Public Health Service recommends that iron not be present in amounts greater than 0.3

ppm in waters to be used for public supplies. Iron concentrations in test samples from the Fort Raleigh area ranged from .00 to 3.0 ppm, with a median value of .67 ppm. Iron concentrations are generally greatest near the surface of the water table, and decrease gradually with an increase in depth. In the area north of Highway 345, water with less than 0.3 ppm of iron occurred at depths of 40 to 50 feet. However, during the 18 hour pumping test of this zone, at the site of well T-2, iron increased from .27 ppm to 2.1 ppm. This indicates that adequate supplies of low iron-bearing water cannot be obtained in the area of this investigation, and that treatment for iron will be necessary to make these waters satisfactory for domestic supplies.

Water Treatment

Treatment for iron will be required to make the ground water in the Fort Raleigh area suitable for domestic use. It may be possible to control the objectionable characteristics of the iron-bearing water by addition of vitreous phosphate compounds to the supply before any aereation occurs. A more satisfactory result would be obtained by removal of both iron and hardness from the water by cation exchange processes. The cost of such a treatment plant would not be prohibitive, and the maintenance necessary is less than that required for coagulation and filtration treatment processes.

SALT-WATER CONTAMINATION

Salt water (water that contains more than 250 ppm chloride) was not encountered during this investigation. However, Roanoke Island is surrounded by salt water and saline contamination is a threat if excessive fresh-water supplies are pumped from the ground.

The possibility of salt-water encroachment near the Historical Site is described in the report entitled "Ground-Water Supply of Cape Hatteras National Seashore Recreational Area, Part 2", by J. O. Kimrey, who states, "Fort Raleigh is in a protected area that is seldom, if ever, flooded. Thus, there is little danger of salt-water contamination of the fresh ground water by inundation. The relatively impermeable clayey zone that occurs below a depth of 110 feet below land surface should prevent vertical encroachment of salt water. However,

there is little difference in the lateral permeability of the sands underlying the area. Thus, lateral encroachment of salt water may occur if a well in the area were pumped until its drawdown reduced the head between the well and the salt-water body enough to induce salt-water encroachment above the clay layers."

Compliance with the suggested well and well field specifications (see p. 9 and 11), and the anticipated rate of recharge, should insure that the cone of depression will not reach the sound and permit lateral salt-water encroachment.

CONCLUSIONS

1. Four units of sand, silt, and clay underlie the Fort Raleigh area to depths of about 157 feet below land surface. The moderately coarse sand unit between approximately 18 and 44 feet below land surface is the best aquifer in which to develop future ground-water supplies in the area.

2. Two-inch diameter wells spaced no less than 180 feet apart and tapping the full thickness of the aquifer between approximately 18 and 44 feet will yield 20 gpm each. The length of screen should be adjusted to local thinning and thickening of the aquifer, and the screen openings should be #20 slot (30 to 40 gauge).

3. Future well fields should be located as far from the sounds as possible, (in the potential production area indicated on fig. 2), to decrease the possibility of lateral salt-water encroachment. The wells should be in a straight line that parallels the northern shore of Roanoke Island.

4. Water from wells in the area will require treatment to remove hardness-causing constituents and dissolved iron.

APPENDIX A

Four (4) wells 150 feet or deeper were inventoried on the northern end of Roanoke Island (fig. 2). Partial chemical analyses of ground water from these wells and the well records are given in the following tables.

TABLE 2. PARTIAL CHEMICAL ANALYSES OF GROUND WATER FROM INVENTORIED WELLS, NORTHERN END OF ROANOKE ISLAND.

Well number*	I1	I2	I3	I4
Iron (Fe) total	.15	.01	.90	.24
Bicarbonate (HCO_3)	230	414	201	217
Chloride (Cl)	16	14	22	24
Hardness as $CaCO_3$	95	34	130	128
Specific conductance (Micromhos at 25°C)	482	688	390	420
pH	7.7	8.1	7.9	7.6
Color	35	120	28	22
Date of collection	12-4-63	12-4-63	12-4-63	12-4-63

*See fig. 2 for well locations

The water-bearing stratum (or strata) that these four (4) wells penetrate was not defined during the investigation, (see p. 8). Thus no information is immediately available on the nature, extent, and hydrologic properties of this water-bearing material. In addition, no information is available on any change in water quality and/or the possibility of salt-water contamination after extended periods of substantial pumpage.

TABLE 3. RECORDS OF INVENTORIED WELLS, NORTHERN END OF ROANOKE ISLAND

Well* No.	Location	Owner	Type of well	Depth (ft.)	Diameter (in.)	Depth of casing	Water-bearing material	Water level (ft.)	Yield (gpm)	Drawdown (ft.)	Remarks
I1	Fort Raleigh National Historical site	National Park Service	Screen	150	2	-	Sand	-	15	-	---
I2	1 mile S. Fort Raleigh	F. Meekins	Screen**	160	2	150	Sand	10	8-15	26	Water level, depth, drawdown, and yield reported by driller.
I3	1 mile E.S.E. Fort Raleigh	F. Etheridge	Screen**	157	1¼	147	Sand	10	8-15	26	Water level, depth, drawdown, and yield reported by driller.
I4	2 miles E.S.E. Fort Raleigh	S. Bell	Screen**	170	1¼	160	Sand	10	8-15	26	Water level, depth, drawdown, and yield reported by driller.

*See fig. 2 for well locations

**Gauze screen #60 mesh

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