SUMMARY OF GEOLOGY AND GROUND-WATER RESOURCES OF THE EASTERN SHORE PENINSULA, VIRGINIA

A Preliminary Report

ALLEN SINNOTT AND G. CHASE TIBBITTS, JR.

MINERAL RESOURCES CIRCULAR NO. 2

VIRGINIA DIVISION OF GEOLOGY

Commonwealth of Virginia

Department of Conservation and Development

DIVISION OF GEOLOGY

William M. McGill, State Geologist

Mineral Resources Circular No. 2

SUMMARY OF GEOLOGY AND GROUND-WATER RESOURCES OF THE EASTERN SHORE PENINSULA, VIRGINIA: A PRELIMINARY REPORT

By

Allen Sinnott
Geologist
U. S. Geological Survey

and

G. Chase Tibbitts, Jr.
Engineering Aid
U. S. Geological Survey

Prepared in Cooperation with the Geological Survey
of the United States Department of the Interior

Charlottesville, Virginia

1954

TABLES

Page

1. Description of rocks occurring in the Eastern Shore peninsula, Virginia..... 3

CONTENTS

	Page
Introduction	1
Purpose of investigation and method of field work	1
Previous investigations	2
Geomorphology	4
Terraces	4
Shorelines	4
Carolina bays	5
Geomorphic history	5
Occurrence of ground water	6
Water-level fluctuations	6
Exploratory drilling	7
General geology and water-bearing properties of the rock formations	8
Basement complex	8
Occurrence and lithology	8
Water-bearing properties	9
Cretaceous system	9
Occurrence and lithology	9
Water-bearing properties	9
Tertiary system	10
Paleocene series	10
Eocene series	10
Occurrence and lithology	10
Water-bearing properties	10
Miocene series	10
Occurrence and lithology	10
Water-bearing properties	11
Quaternary system	12
Pleistocene series	12
Occurrence and lithology	12
Water-bearing properties	12
Recent series	13
Quality of ground water	13
Water from Cretaceous and Eocene deposits	13
Water from Miocene deposits	13
Water from Pleistocene deposits	14
Suitability of ground water for irrigation	14
Preliminary conclusions	15
Relatively shallow wells (to about 80 feet)	15
Deeper wells (80-300 feet)	15
Aquifers deeper than 300 feet	15
References	17

SUMMARY OF GEOLOGY AND GROUND-WATER RESOURCES OF THE EASTERN SHORE PENINSULA, VIRGINIA: A PRELIMINARY REPORT

By Allen Sinnott and G. Chase Tibbitts, Jr.

INTRODUCTION

Purpose of Investigation and Method of Field Work

This investigation has been undertaken to describe the occurrence and relation to subsurface geology of ground water on the Eastern Shore peninsula. Particular reference has been made to the quantity and quality of the water, so that this resource may be utilized to best advantage for domestic, municipal, industrial, and agricultural purposes. The study has been made by the Federal Geological Survey in cooperation with the Division of Geology of the Virginia Department of Conservation and Development.

A detailed reconnaissance of representative existing wells was made by the Geological Survey in 1952-54, supplementing meager information already on file. Data were collected on wells selected partly on the basis of geographical distribution and partly to obtain information on the several stratigraphic horizons penetrated. Samples of the water from most of these wells were collected for preliminary chemical analysis. So far as known, virtually all the important high-yield wells on the Eastern Shore (Accomack and Northampton Counties) have been included in this reconnaissance.

A program of exploratory drilling resulted in three holes drilled to depths of about 450 feet below the land surface; a fourth hole was drilled to a depth of 100 feet, tapping a shallow gravel aquifer. Many drillers' logs were collected, and much information was given by hundreds of well owners. Most of these records were tabulated and released earlier during the course of the investigation. 1/

1/ Preliminary tabulation of factual data on water wells in Northampton County, Va. (January 1953); Preliminary tabulation of factual data on water wells in Accomack County, Va. (April 1953); U. S. Geological Survey open-file reports.

Previous Investigations

Samuel Sanford's comprehensive ground-water study (1913) of the Virginia Costal Plain was published by the Virginia Geological Survey as Bulletin 5. Although much less information was then available, Sanford nevertheless wrote creditable sections on the Eastern Shore counties in this early bulletin.

More detailed studies have been made on the subsurface geology of the Virginia Coastal Plain in recent years, including also geophysical investigations, but most of the results of these studies relate to the Western Shore counties. Nonetheless, stratigraphic correlations made during the course of these studies have been of some value as a guide in the Eastern Shore work.

Correlation studies on microfauna were made by Ruth Todd (1954) and I. G. Sohn (1954) of the U. S. Geological Survey. This microfauna was contained in the samples of the subsurface section down to about 450 feet in the three deep exploratory holes. Julia Gardner (1948), also of the Survey, identified the age of megafossils from a well at Cheriton. Significant data have also been obtained from microfossil studies by Doris Malkin (1947), formerly of the Shell Oil Co., and by J. D. McLean, Jr. (1950), on wells on Smith Island, Md., and at Crisfield, Md., respectively.

Practically all the deeper wells on the Eastern Shore tap aquifers of Miocene age (Table 1). In fact, even the relatively deep 450-foot test holes drilled for this investigation did not reach below the middle of the Miocene formations. Two of the three wells that had been drilled deeper than these exploratory holes obtained either little water or saline water and were never used. The third well, on Tangier Island, lies in an area where hydrologic conditions are more nearly like those of southeastern Maryland; satisfactory water for a fish-packing plant was obtained from this well from beds probably of Late Cretaceous age.

Table 1.—Description of rocks occurring in the Eastern Shore peninsula, Virginia

Geologic age		Lithology	Origin	Distribution	Water-bearing character
QUATERNARY	Recent	Silt, sand, and gravel	Wind, beach, lagoon, and stream deposits	Dunes; beaches, bars, and spits; deposits in creek beds	May yield small quantities of ground water of fair to good quality
	Pleistocene (Columbia group)	Unconsolidated yellow crossbedded sand and gravel, up to 100 feet thick	Marine shallow-water deposits	Underlie entire area; exposed at surface everywhere except where covered by Recent deposits	Small quantities of good quality ground water from many shallow, dug, and driven wells; large supplies from gravel-packed wells
TERTIARY	Miocene (Chesapeake group)	Largely clay, sand, and diatomite, with shells in upper part, up to 900 feet thick	Marine deposits, formed when seas extended west to Fall Zone	Underlie entire area; not exposed at the surface	Tapped for ground water by nearly all deep wells. Large supplies from gravel-packed wells. Below 300 feet, to 450 feet and probably deeper, water-bearing sands generally absent and quality of water poor
	Eocene (Lower portion may be Paleocene; upper portion probably represents Pamunkey group)	Glauconitic sand beds and interbedded clay; about 150 feet thick at north end of area, to 850(?) feet thick at Cape Charles	Marine deposits	Underlie entire area; not exposed at the surface	Tapped by Cobb Island well, yielding salty water
CRETACEOUS	Upper Cretaceous and Lower Cretaceous	Sand, clay, and minor gravel lenses; may exceed 1,500 feet in thickness	Fluvial deposits, chiefly deltaic; contain plant fossils	Underlie entire area; not exposed at the surface	Tapped by Tangier Island well, yielding satisfactory water; farther south on peninsula probably contain brackish water
Pre-Cambrian		Crystalline basement rocks	Schists, gneisses, and igneous intrusives	Underlie entire area; not exposed at the surface	Essentially non-water-bearing

GEOMORPHOLOGY

The land-forms of the Eastern Shore peninsula are subdued and generally inconspicuous--the total relief being only about 50 feet. However, the character of the shore-line is of interest, and two fairly well developed terraces can be seen along Kiptopeke Beach and locally elsewhere. Certain other features--the so-called "Carolina bays"--rarely appear on maps and are not usually apparent to ground observers but are readily visible on aerial photographs.

Terraces

The Columbia group of terrace deposits of Pleistocene age (Table 1) consists of a succession of nearly horizontal marine and estuarine formations that overlie the older rocks of the Virginia Coastal Plain. These formations are extensively developed on the mainland part of the Coastal Plain. However, on the Eastern Shore, only the three youngest--the Talbot, Pamlico, and Silver Bluff terraces--are believed to be represented. Topographic maps of suitably small contour interval are not available in this area for delineation of these terraces.

Stephenson (1912) first described the Pamlico terrace in North Carolina. In Virginia, Wentworth (1930, p. 81) found local development of a distinct lower terrace, whose shoreline is about 12 feet above sea level, which he named the Princess Anne Terrace. This terrace is evidently correlative with the widely-developed Silver Bluff terrace described by Parker and Cooke (1944) and others (Cooke, 1945; MacNeil, 1950), and the Silver Bluff name is retained in this report. The Silver Bluff terrace is believed to be a later phase of the Pamlico, whose shoreline is developed at about 25 feet above sea level.

The Talbot terrace, which lies above the Pamlico elsewhere in Tidewater Virginia, is not distinctly represented on the Eastern Shore. However, it is believed that the land surface above 25 feet on the Eastern Shore, and the underlying deposits, represent the Talbot terrace and formation, whose level characteristically is at an altitude of 42 feet. The escarpment of the Talbot terrace, found in many places elsewhere in Virginia, evidently was eroded away during the formation of the peninsula. The sediments above 42 feet on the Eastern Shore may represent either the deposits formed by longshore currents during Talbot time--the incipient land area of the Eastern Shore postulated by Wentworth (1930, p. 114)--or the eroded remnants of the Penholoway formation, whose shoreline averages 70 feet above the present level.

Shorelines

The Chesapeake Bay area shows features typical of shorelines of

submergence. It is evident that the base level of erosion must have been at one time considerably lower than at present--probably late in the Pleistocene epoch at the time of greatest expansion of the Pleistocene glaciation. Subsequently the region was in part submerged by the sea as its level rose to its present position.

Carolina Bays

In Accomack County, and to a lesser extent in Northampton County, many aerial photographs exhibit striking elliptical surface features, here referred to the so-called Carolina bays prevalent in the Coastal Plain areas of the Carolinas. These "bays" are broad, shallow, elliptical sand-rimmed depressions, some of which are truncated by other similar depressions. The origin of these features has been a matter of considerable geological controversy. The senior author considers the modified meteoritic hypothesis of Prouty (1952) as the most tenable (Sinnott, 1953). This theory postulates a shower of large extra-terrestrial bodies that must have struck the earth in a vast swarm centering in the Carolinas but with a broad fringe extending from New Jersey to Florida. The impact of the supposed meteorites must have taken place after the present general features of the Coastal Plain had already been developed--that is, in the Recent epoch of geologic time.

Geomorphic History

Prior to the deposition of the Talbot formation in late Pleistocene time, as a result of the advance of the Talbot sea, little or no land existed in the area of the Eastern Shore peninsula, according to Wentworth (1930, p. 114). During the advance of the Talbot sea, "the combined action of wave and shore currents built spits and barriers across the shore reentrant from the vicinity of Snow Hill, Maryland, to eastern Gates County, North Carolina, thus forming an enclosed area of lagoons and marshes similar to Pamlico and Albemarle Sounds."

In post-Talbot time, that is, after the retreat of the Talbot sea, "this barrier was sufficiently continuous to force the combined Potomac and Susquehanna drainage southward to its present outlet into the ocean." (Wentworth, op. cit.) It was during this time that the principal features of Chesapeake Bay and its tributaries were formed. The higher part of the Eastern Shore peninsula must have been modified also during this period, and during Pamlico and Silver Bluff time, to approximately its present form.

With the advance of the Pamlico sea, the deposition of the Pamlico formation took place, and the Pamlico terrace was formed by the strand-line erosion against the remnant of the Talbot formation. The Silver Bluff terrace, which is close to the present sea level, was probably formed during a pause or minor readvance of the Pamlico sea during its retreat in

late Pleistocene time. The Silver Bluff terrace in Virginia averages about 10 to 12 feet above the present mean sea level, and the shoreline of the Pamlico terrace about 25 feet above sea level.

During Recent time the present shoreline has been developed around the peninsula, and loose sand along the beaches has been locally gathered into dunes. Longshore currents have formed small spits, some of which have grown to form baymouth bars and associated lagoons.

OCCURRENCE OF GROUND WATER

In the Virginia Coastal Plain, water enters the ground from the surface, usually by infiltration from rainfall, but in part from water carried in streams and other surface-water bodies. It is drawn downward by gravity. Below a certain level, called the water table, the interstices of the rocks are completely filled with water, forming the zone of saturation.

Ground water has been defined by Meinzer (1923, p. 22) as the water in the zone of saturation, as distinguished from the water in the overlying zone of aeration. Water that is withdrawn from the ground by wells and springs occurs in the zone of saturation.

The occurrence and availability of ground water are dependent upon a source of supply of water, and on an important characteristic of the water-bearing portions of the rock, namely, permeability. Permeability of rocks will be discussed at length in a forthcoming report; for the present summary, it is sufficient to state that the size of the component grains of a water-bearing material bears a definite relation to the permeability. Thus, sand and gravel are permeable whereas clay, having a porosity as high as or higher than that of sand, is almost impermeable to water because the openings are so small that the water is locked in them by molecular attraction.

Relatively permeable rocks, overlain by rocks that are essentially non-water-bearing, frequently contain water under so-called artesian pressure, if the permeable rocks are exposed at the surface elsewhere at a higher elevation. Such water, when tapped by wells, rises above the base of the confining impermeable layer. If the level to which this water rises is above the land surface--as in certain low areas of the Eastern Shore peninsula--the wells will flow.

Water-Level Fluctuations

Ground water in the vicinity of the Naval Auxiliary Air Station near Chincoteague occurs essentially under water-table conditions. Through arrangement with the Navy Department, an observation well was established

at this station in 1948. Subsequently, this well was designated as Federal Observation Well Va-US-2, one of six such wells in eastern Virginia that are part of a network of key observation wells established throughout the nation. A recording gage was operated on this well until August 1949, giving a continuous record of water-level fluctuations. Single weekly measurements with a weighted steel tape have since been made up to the present time.

Although local variations of withdrawals at the Air Station affect the water level in this well, there is a seasonal fluctuation which has been apparent during at least the past three years. Beginning in 1952, the highest level--a little more than 27 feet below the land surface--has been recorded during the period April-June. The water level then declines to a low of about 28 feet below the surface during the winter months. This yearly pattern is probably characteristic of most water-table wells on the peninsula. A 3 1/2-foot decline from mid-1949 to mid-1951 evidently reflects increased pumping for the increased personnel at the base beginning in 1950. Subsequently, however, there has been a recovery of about 1 foot, and the cyclical fluctuations observed since that time appear to have become stabilized at about 27 to 28 feet below the surface.

EXPLORATORY DRILLING

In the spring of 1953 a contract for test drilling was awarded to the Sydnor Pump & Well Co., of Richmond, for exploratory holes to be drilled by the hydraulic rotary method on the Eastern Shore peninsula. Public lands at several schools were selected as drilling sites. Owing to limitations on funds, one of the holes, at the new high school at Machipongo, was held to about 100 feet in total depth when good water-bearing beds were encountered within that depth. This permitted the three other holes to be finished to total depths of about 450 feet. Accordingly, a test hole at the elementary school at Capeville, near the southern end of the peninsula, was drilled to a depth of 470 feet; two other test holes, at Central High School near Keller and at the Atlantic High School at Oak Hall near the Maryland boundary, were drilled to 450 and 451 feet, respectively.

Schlumberger electric logs were made on each of the four holes to assist in the determination of the water-bearing zones and with the regional geologic correlations.

The first 300 feet of section penetrated by the deeper holes is characterized by water-bearing sand and fine gravel with interbedded silty clay, clay, and silt. There are numerous shell beds throughout the section. Below about 300 feet, however, the material is much finer grained, with only minor thin lenses of silty sand and shell fragments.

As shown by the electric logs and drill cuttings, such thin sands as do occur below 300 feet are likely to be laden with silt and probably of low yield. Inasmuch as a wealth of information was already available on existing wells shallower than 300 feet, it was decided that the most useful information would be obtained by testing the best of these unexplored sands for yield, in order to determine whether they might be permeable enough to respond to development.

The geologic information obtained in the drilling program is discussed in later sections on the occurrence and lithology of the Miocene and Pleistocene rocks (p. 10 and 12, respectively). The unsuccessful attempts to develop adequate supplies from the unproved deposits in the deeper holes between 300 and 450 feet are summarized in a later section on water-bearing properties of rocks of Miocene age (p. 11).

GENERAL GEOLOGY AND WATER-BEARING PROPERTIES OF THE ROCK FORMATIONS

The sedimentary rocks underlying the Eastern Shore peninsula are nearly horizontal. Earlier studies elsewhere in Tidewater Virginia on the Western Shore indicate a gentle eastward dip of the beds of about 15 to 30 feet per mile. These strata consist of beds of sand and clay and minor gravel lenses, resting unconformably on an undulating surfact of crystalline, igneous, and metamorphic basement rocks. The sediments become progressively thinner westward in the Tidewater counties, and disappear as a feather edge along the eastern border of the Piedmont province. Eastward from the Western Shore, the wedge of sediments thickens beneath Chesapeake Bay; beneath the Eastern Shore peninsula the granitic basement complex probably lies at a depth of 3,000 feet or more below the surface. Farther east beyond the peninsula the sediments extend beneath the Atlantic Ocean for 60 to 70 miles to the edge of the continental shelf. According to Ewing and his associates (1937), geophysical evidence indicates that 60 miles east of Cape Henry the Coastal Plain sediments may exceed 12,000 feet in thickness.

Basement Complex

Occurrence and Lithology

The character of the basement complex beneath the Coastal Plain sediments has only been inferred from interpretation of geophysical studies. So far as known no deep wells on the Eastern Shore peninsula have penetrated to this bedrock, which probably consists largely of gneisses and schists.

Water-Bearing Properties

The basement rocks are too deep even to be considered as a possible source of ground water for the Eastern Shore. Indeed, in areas of the mainland where they are accessible, near the Fall Zone at the western fringe of the Coastal Plain, they are generally regarded as non-water-bearing, at least by comparison with the prolific Coastal Plain sediments.

Cretaceous System

Occurrence and Lithology

Sedimentary rocks of Cretaceous age immediately overlie the crystalline basement rocks throughout most of the Virginia Coastal Plain. These sediments are mostly unconsolidated, probably fluviatile and deltaic in origin, and consist of clay, sand, and gravel. Beneath the mainland, where these rocks have been adequately sampled during the drilling of deep wells, they have been subdivided into deposits of Late and Early Cretaceous age.

So far as known, only two wells on the Eastern Shore of Virginia penetrate rocks of Cretaceous age. One is a test hole drilled in 1910 at Cape Charles, to a depth of 1,810 feet, and the other is the 860-foot flowing well on Tangier Island, said to have been drilled about 1925 for use by a fish-packing plant. The 1,000-foot test well at Cobb Island, drilled by the U.S. Coast Guard, although deeper than the Tangier Island well, is in an area where the sedimentary beds are thicker, and consequently the well probably reached only into Eocene rocks. (See Table 1.)

Water-Bearing Properties

No good water-bearing zones were encountered during the construction of the old Cape Charles well, according to Sanford (1913, p. 246). Water from the deeper zones in Northampton County is probably brackish and unsuitable for most uses.

In the northern part of the area, however, it is likely that the Cretaceous sands would yield fresh ground water. This is suggested by information on wells on Smith Island and Crisfield, in southeastern Maryland. Furthermore, the deep Tangier Island well, when sampled in 1948, yielded water that was satisfactory although somewhat high in fluoride content.

Tertiary System

Paleocene Series

Data on the Eastern Shore are not sufficient to establish the presence or absence of beds of the Paleocene epoch, as the necessary deep formation samples are lacking. They may be present, however, as equivalents of the Mattaponi formation of Virginia, of Late Cretaceous and Paleocene age (Cederstrom, 1954), or the Brightseat formation of Maryland (Bennett and Collins, 1952).

Eocene Series

Occurrence and lithology. --The Pamunkey group of deposits of Eocene age in Virginia consists of the Aquia formation and the overlying Nanjemoy formation. These rocks consist of sand and interbedded clay and occur widely throughout the Virginia Coastal Plain. They have been described from many wells east of their outcrop area, which is near the Fall Zone. Characteristically they contain much glauconite, usually described as "black sand" or "green sand" in drillers' logs. They are apparently present in the subsurface section beneath the Eastern Shore, underlying the Miocene rocks.

Water-bearing properties. --Although it might be expected that the Eocene formations would yield adequate supplies on the basis of evidence from the Western Shore counties, neither the Cobb Island well nor the Cape Charles well was reported to penetrate significant water-bearing beds. Furthermore, results of recent test drilling, as well as data from the Cobb Island well, appear to confirm the suspicion that the deeper zones yield brackish water.

Miocene Series

Occurrence and lithology. --The Chesapeake group of Miocene age lies near the surface in the eastern portion of the Virginia Coastal Plain, and is covered only by the Columbia group of terrace deposits of Pleistocene age which in turn is covered, locally, by deposits of Recent age. Subsidence of the Coastal Plain region during Miocene time resulted in an advance of the early Miocene sea over the older rocks. In the northern part of the Coastal Plain, the westward advance of the sea apparently was not as great as in the southern part, as pointed out by Clark and Miller (1912, p. 213-214).

The Chesapeake group has been subdivided into four formations: the basal Calvert formation, overlain successively by the Choptank, St. Marys, and Yorktown formations. They consist largely of clay, sand, and diatomite, with interbedded shell fragments.

Three of the four exploratory holes drilled during the summer of 1953 reached approximately 450 feet below the surface. According to a study of the drill cuttings by Ruth Todd (1954) of the U. S. National Museum, the Foraminifera (small one-celled animals having calcareous shells) indicate, in the Miocene section, that the rocks were formed under shallow-water marine conditions, from the beach to probably not more than 50 fathoms. There are also indications that the area of deposition was open to the ocean and probably fairly close to the circulation of ocean currents.

Correlation among the wells in the Miocene section was not feasible because of the variations in abundance among the species of Foraminifera represented. On the other hand, a comparison with the electric logs made when the wells were drilled shows a very striking overall similarity throughout the entire 55-mile line of test holes. This is also true of the general lithologic descriptions made by the Geological Survey from the drill cuttings from the four holes.

Water-bearing properties.--Most wells deeper than about 100 feet on the Eastern Shore peninsula tap water in strata of Miocene age. These include wells at many of the larger homes and those drilled for farms. They constitute what are locally termed "deep" wells, and most of them have been constructed by the jetting method.

When larger quantities of water are required, as for municipal or industrial purposes, wells 6 or more inches in diameter drilled by the cable-tool or hydraulic-rotary method are generally employed. Most of the wells drilled by the rotary method are also constructed with a gravel envelope in order to increase their yield.

The maximum yield recorded from a well tapping beds of Miocene age is 746 gallons per minute (gpm) made during a test of a gravel-packed well 270 feet deep and 8 inches in diameter drilled by the Layne-Atlantic Co. for the Town of Exmore in the northern part of Northampton County. The specific capacity at this rate was about 20 gpm per foot of drawdown. The permanent pump installation of this well yields about 310 gpm, at which rate the specific capacity is 24 gpm per foot. Water is derived from quartz sand and mixed sand and gravel in the zone from 165 to 238 feet below the surface.

Results of the exploratory drilling in 1953 showed that there are several water-bearing beds 10 to 40 feet thick in the depth range of 100 to about 300 feet below the surface--one or more of which are tapped by many wells on the peninsula. Below about 300 feet, however, these beds are absent, and there are only a few thin beds of silty sand. These deeper beds were largely unproved;therefore, to test whether sands below about 300 feet might yield at least moderate supplies of ground water after development of the well, 5 feet of screen was set in each of the three deep holes at the beds below about 300 feet that would be most likely to yield some water.

Although the most promising material encountered among the exploratory holes in the untested section below 300 feet was at Capeville, where 22 feet of coarse sand was penetrated from 442 to 464 feet below the surface, even this well yielded less than a gallon a minute after extensive development. The other two deep holes, near Keller and at Oak Hall, yielded even less than the Capeville well.

In summary, it is believed that moderate yields for additional industrial, municipal, or irrigation needs--up to 250 gpm per well--are available from beds of Miocene age between 100 and 300 feet below the surface, from properly developed wells at least 6 inches in diameter. Larger yields should be obtainable by the construction of two or more wells, spaced as far apart as possible consistent with other requirements. Beds below about 300 feet were found by actual test to be essentially non-water-bearing.

Quaternary System

Pleistocene Series

Occurrence and lithology.--The Columbia group of terrace deposits forms a mantle over the older rocks of the peninsula. Except for localized deposits of Recent age, these Pleistocene beds are the only rocks exposed at the surface in this part of the Virginia Coastal Plain.

The Pleistocene formations consist largely of unfossiliferous cross-bedded sand and gravel, distinctively yellow in color as compared with the underlying Miocene rocks. The maximum thickness of the Pleistocene deposits is believed to be about 100 feet, being greatest in areas of high elevation.

In a study of the cuttings from the exploratory holes, Miss Todd (1954) found Pleistocene Foraminifera in hole no. 3 at Central High School near Keller. However, the samples of Pleistocene material were barren of fossils in hole no. 2 (Machipongo) and no. 4 (Oak Hall). Nevertheless, test hole no. 4 entered the Miocene at 115 feet. Samples for the first 65 feet of hole no. 1 at Capeville are being restudied for possible Pleistocene specimens.

Water-bearing properties.--There are many hundreds of shallow dug or driven wells in the Eastern Shore peninsula that tap the deposits of Pleistocene age. These wells yield small quantities of water--up to about 10 gpm. Among these wells, the shallowest generally yield water characteristically high in iron, and in many instances they are likely also to be polluted with organic wastes.

There are a few extensive water-supply developments from aquifers in the Columbia group. The most important of these is the muni-

cipal plant for the Town of Chincoteague in northeastern Accomack County. This plant is 3 1/2 miles west of the town, on the peninsula proper, and uses the combined yield of 28 wells, 50 to 60 feet deep, to obtain about 140,000 gallons of water per day. At the Naval Auxiliary Air Station, 5 miles west of Chincoteague, several 8-inch wells, ranging from 54 to 65 feet deep, each yield 50 to 85 gpm.

An irrigation well 63 feet deep and 8 inches in diameter, 2 miles east-southeast of Onancock, yields 450 gpm and has a specific capacity of 8 gpm per foot of drawdown. At present this well has the highest yield with permanent pumping equipment of any well on the peninsula.

Recent Series

Deposits of Recent age on the Eastern Shore peninsula are represented by alluvium in creek beds, lagoonal deposits, and deposits forming dunes, beaches, bars, and spits. Except for some of the beaches, the lateral extent of these deposits is limited and they are relatively thin.

So far as known, there are no wells in the area that tap ground water in Recent deposits, although relatively small supplies could probably be developed in a few favorable places, particularly in the beach deposits.

QUALITY OF GROUND WATER

Water from Cretaceous and Eocene deposits

The 1,000-foot Cobb Island well, tapping beds of Eocene age, yielded salty water and was never used. Electric logs of the deeper test holes suggest an increase in salinity with depth below 300 feet, and the deeper Miocene, Eocene, and Cretaceous rocks in Northampton County, and in southern Accomack County at least, are believed to contain water excessively high in chloride.

Water from Miocene deposits

In Accomack County, water from Miocene aquifers is generally high in bicarbonate, averaging a little more than 150 parts per million (ppm). The chloride content is generally less than 25 ppm, although a few well waters show higher concentrations. Sulfate and fluoride concentrations are generally low. Hardness commonly ranges between 80 and 150 ppm throughout the county; a few well waters, however, show a hardness of only 50 ppm.

Bicarbonate concentrations in samples of water from wells tapping Miocene beds in Northampton County range mostly from 100 to 200

ppm. As in Accomack County, chloride concentrations are low with but few exceptions, and concentrations of sulfate and fluoride also are low.

Water from Pleistocene deposits

In Accomack County, water from beds of Pleistocene age is sometimes found to contain iron in excessive amounts, but chloride concentrations are low to moderate, and fluoride is generally absent. These waters are not as hard as those from underlying Miocene rocks. Nitrate concentrations may be high in some well waters, especially those from dug wells, owing wholly or in part to improper well construction and to incomplete filtration of polluted surface waters.

In Northampton County, the hardness ranges up to 100 ppm, and a few well waters exceed even this. Sulfate and bicarbonate concentrations are moderately low, generally less than 50 ppm. Fluoride is generally either absent or present only in concentrations of a few tenths of a part per million. The chloride concentration may approach 100 ppm locally, presumably owing to contamination of the shallow ground waters with salt spray from the ocean. As in Accomack County, nitrate may be high among certain well waters, for reasons cited above. Iron also may be high, ranging from less than 1 to more than 5 ppm among ground waters analyzed.

Suitability of ground water for irrigation

The percentage of sodium among the cations is an important consideration in evaluating the suitability of water for use in irrigation. Excessive sodium percentages, particularly in soils that are not permeable or are poorly drained, adversely affect the structure of the soil, reducing permeability and crop yields.

Preliminary computations have been made of the sodium percentages for 14 complete analyses of ground waters from both counties. Of eight determinations for waters from Miocene aquifers, one was unsuitable, two were permissible, and the rest good to excellent, according to the classification of Scofield (1933). For waters tapping Pleistocene aquifers, of the six analyses evaluated, two were permissible, and the rest good to excellent. In general, the soils on the Eastern Shore peninsula are believed to be sufficiently permeable so that the adverse effect on the soil of high soluble-sodium percentages is minimized. Thus, provided sufficient water is obtained by proper well construction, the quality of the ground waters from Pleistocene and upper Miocene aquifers on the Eastern Shore is generally satisfactory for irrigation use.

PRELIMINARY CONCLUSIONS

Although the data obtained during the Eastern Shore investigation have not been completely evaluated, certain preliminary generalizations can be made at this time. Additional quantitative tests are planned that will augment and may in part modify some of the conclusions set forth in this summary.

Relatively Shallow Wells (to about 80 Feet)

The results of the test drilling, and logs of many shallow wells throughout both counties, indicate that relatively coarse water-bearing sand and fine gravel are widespread. Near Chincoteague, and at Bobtown, which is 5 miles south-southwest of Onancock, large supplies are obtained from Pleistocene beds from groups of shallow wells pumped as a unit. At Tasley, 2 miles west-southwest of Accomac, an 8-inch well yields 450 gpm.

Although locally the water from these shallow aquifers may be high in iron and not as desirable as deeper water for domestic purposes, nevertheless the quality is adequate or even preferred for irrigation.

Deeper Wells (80-300 Feet)

As a result of the field canvass, it has been ascertained that most of the larger yield wells in both counties of the Eastern Shore peninsula are drilled within the depth range of 80 to 300 feet. The largest yielding wells are generally 6 to 8 inches in diameter and are 200 to 300 feet deep; many of these are gravel packed. According to the electric logs and to other logs available, there are several water-bearing beds ranging in thickness from 10 to 40 feet between 80 and 300 feet below the surface. Thus, wells drilled below 80 feet are reasonably assured of adequate supplies from one or more of these water-bearing zones. The quality of this water is generally good. One exception was noted, at Exmore, where a 295-foot well was abandoned in 1952 because it yielded salty water.

It is believed that up to 250 gpm can easily be obtained from individual 6-inch wells tapping more than one aquifer in this depth range. Larger total yields may be obtained from two or more wells, spaced as far apart as possible consistent with other requirements.

Aquifers Deeper than 300 Feet

With the exception of the deep well on Tangier Island, and related wells on Smith Island and at Crisfield, Md., information obtained during the canvass of wells showed universally poor results from drilling deeper than about 300 feet for water. (A successful 317-foot well at the

cannery in New Church, obtains water from aquifers shallower than 300 feet.) The deep test hole at Cape Charles yielded inadequate supplies; the well on Cobb Island yielded salty water.

In an effort to determine at first hand the character of the sediments deeper than 300 feet, three of the exploratory holes constructed by the Geological Survey in the summer of 1953 were drilled to about 450 feet in depth, and the best of the questionable aquifers tested that occurred in the unproved deposits between about 300 and 450 feet. These zones were found to be virtually barren as a cource of supply. It is doubtful whether larger diameter wells, equipped with gravel envelopes, could be expected to yield more than a few gallons per minute from these zones below about 300 feet. Indications from the electric logs point to an increase in salinity with depth below about 300 feet. This is further supported by the information obtained on the 1,000-foot well on Cobb Island, which was never used because the water was salty.

It is thus concluded that, except on Tangier Island, the likelihood of finding suitable water-bearing sands below about 300 feet is extremely remote, and further, that the chemical quality of the water is likely to be unsuitable for most uses.

REFERENCES

1. Bennett, R. R., and Collins, G. G. (1952) Brightseat formation, a new name for sediments of Paleocene age in Maryland: Washington Acad. Sci. Jour., v. 42, p. 114-116.

2. Cederstrom, D. J. (1954) Geology and ground-water resources of the York-James peninsula, Virginia: U. S. Geol. Survey Water-Supply Paper (in preparation).

3. Clark, W. B., and Miller, B. L. (1912) The physiography and geology of the Coastal Plain province of Virginia: Virginia Geol. Survey Bull. 4, 274 p.

4. Cooke, C. W. (1945) Geology of Florida: Florida Geol. Survey Bull. 29.

5. Ewing, Maurice, and others (1937) Geophysical investigations in the emerged and submerged Atlantic Coastal Plain: Geol. Soc. America Bull., v. 48, no. 6, p. 753-812.

6. Gardner, Julia A. (1948) Megafossils from a well at Cheriton, Northampton County, Va.: U. S. Geol. Survey manuscript report.

7. MacNeil, F. Stearns (1950) Pleistocene shore lines in Florida and Georgia: U. S. Geol. Survey Prof. Paper 221-F, p. 95-106.

8. Malkin, Doris S. (1947) Sample descriptions and correlation of material from the Bradshaw well, Smith Island, Somerset County, Md.: Shell Oil Co. unpublished report, 2 p.

9. McLean, J. D., Jr. (1950) Stratigraphic study of well at Crisfield, Somerset County, Md.: Am. Assoc. Petroleum Geologists Bull., v. 34, no. 1, p. 133-138.

10. Meinzer, O. E. (1923) Outline of ground-water hydrology, with definitions: U. S. Geol. Survey Water-Supply Paper 494, 71 p.

11. Parker, G. G. and Cooke, C. W. (1944) Late Cenozoic geology of southern Florida: Florida Geol. Survey Bull. 27.

12. Prouty, W. F. (1952) Carolina Bays and their origin: Geol. Soc. America Bull., v. 63, no. 2, p. 167-224.

13. Sanford, Samuel (1913) The underground water resources of the Coastal Plain province of Virginia: Virginia Geol. Survey Bull. 5, 361 p.

14. Scofield, C. S. (1933) South Coastal Basin investigation, quality of irrigation waters: California Dept. of Public Works, Div. of Water Resources, Bull. 40, p. 21-24.

15. Sinnott, Allen (1953) Carolina Bays of the Coastal Plain of Virginia (abstract): Virginia Jour. Sci., Proceedings of the year 1952-53, v. 4, no. 4, p. 258.

16. Sohn, I. G. (1954) Ostracodes from rotary drill cuttings from test holes on the Eastern Shore peninsula, Va.: U. S. Geol. Survey manuscript report.

17. Stephenson, L. W. (1912) Quaternary formations: in North Carolina Geol. and Econ. Survey, v. 3, p. 266-290.

18. Todd, Ruth (1954) Smaller Foraminifera from rotary drill cuttings from test holes on the Eastern Shore peninsula, Va.: U, S. Geol. Survey manuscript report.

19. Wentworth, C. K. (1930) Sand and gravel resources of the Coastal Plain of Virginia: Virginia Geol. Survey Bull. 32, 146 p.