GROUND-WATER HYDROLOGY OF JAMES CITY COUNTY, VIRGINIA

By John F. Harsh

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Cecil D. Andrus, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

For additional information write to:

U.S. Geological Survey
200 W. Grace Street, Room 304
Richmond, Virginia 23220

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS--Continued

PLATES

PLATES--Continued

TABLES

CONVERSION FACTORS

Factors for converting Inch-Pound Units to International System (SI) Units, and abbreviations of units.

Multiply Inch-Pound Units	By	To obtain SI units
	Length	
inch (in)	25.4	millimeters (mm)
feet (ft)	.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow	
gallons per minute (gal/min)	.06309	liters per second (L/s)
million gallons per day (Mgal/d)	43.81	liters per second (L/s)
gallons per day per foot (gal/d/ft)	.00014	liters per second per meter (L/s)/m
	Hydraulic Units	
feet squared per day (ft^2/d)	.0929	meters squared per day (m^2/d)
feet per day (ft/d)	.3048	meters per day (m/d)
feet per mile (ft/mi)	.1894	meters per kilometer (m/km)

DEFINITION OF TERMS

Aquifer.--A water-bearing stratum (or combination of strata) of permeable earth material that will yield significant quantities of water to wells and springs.

Aquifer characteristics (storage coefficient and transmissivity).--Terms that describe, respectively, the ability of earth materials to store and transmit ground water.

Base flow.--The part of runoff derived from ground-water discharge.

Confined aquifer.--An aquifer that contains water under sufficient pressure to cause water levels in wells tapping it to rise above top of the aquifer.

Confining bed.--A body of relatively impermeable material stratigraphically adjacent to one or more aquifers.

Drawdown.--The difference between the nonpumping water level and the pumping level.

Effective porosity.--The fraction of the bulk volume of subsurface material made up of interconnecting pores for fluid transmission.

Evapotranspiration.--Water withdrawn from a land area by evaporation from water surfaces and moist soil and by plant transpiration.

Geohydrologic unit.--An aquifer, a confining bed, or a combination of aquifers and confining beds that compose a framework for a reasonably distinct hydraulic system.

Head, static.--The height above a standard datum of the surface of a column of water that can be supported by the static water pressure at a given point.

Hydraulic conductivity.--The volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

Hydraulic gradient.--The change in static head per unit of distance in the direction of flow.

Permeability, intrinsic.--A measure of the relative ease with which a porous medium can transmit a liquid under a potential gradient.

DEFINITION OF TERMS (Continued)

Potentiometric surface map.--A map that shows the altitude of the water table or, in a confined aquifer, the level to which water would rise in a well.

Saturated thickness.--The thickness of aquifer material through which ground water flows.

Specific capacity.--The rate of discharge of water from a well divided by the drawdown of water level within the well.

Storage coefficient.--Volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

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ABSTRACT

Urbanization and increase in water demand prompted a 2-year study of ground-water availability and quality in the county of James City. The Coastal Plain sediments, parts of which underlie James City County, are the largest source of ground water in Virginia.

The average rate of ground-water recharge from precipitation is estimated to be 70 million gallons per day (Mgal/d) compared with total current pumpage of about 8 Mgal/d. Shallow ground-water discharge to streams is estimated to be 65 Mgal/d, and 10 Mgal/d moves downward to the confined Eocene-Paleocene and Cretaceous aquifers.

Four aquifers form the complex aquifer system. Hydraulic characteristics vary from aquifer to aquifer and from place to place. The Cretaceous aquifer, which is the most productive water-yielding unit, furnishes nearly all the ground water for industrial and municipal needs in the study area. Movement of water in the Cretaceous aquifer is toward the cones of depression formed by withdrawal centers at Colonial Williamsburg and Dow Badische Company. All aquifers contain water that generally meets State standards for drinking water. Water in the Cretaceous aquifer is a sodium chloride bicarbonate type, generally with less than 1,000 milligram per liter (mg/L) dissolved solids. The concentrations of dissolved solids and chloride are greater in the deep aquifers.

Saline water (more than 250 mg/L chloride) is present in the deeper parts of the Eocene-Paleocene and Cretaceous aquifers, particularly in the eastern part of the county. Concentrated ground-water withdrawals in this area are likely to increase the potential for saline water to move toward parts of the aquifer containing fresh water.

The amount of water stored in the coastal sediments beneath the county is estimated to be 650-1,300 billion gallons. An increase in withdrawal to accomodate the expected daily demand of 9.8 Mgal/d in year 2,000 is feasible provided pumpage centers are distributed over the county. The optimum withdrawal rate of the ground-water reservoir cannot be determined during this study without evaluation of interaction between layered aquifers by modeling.

INTRODUCTION

Population growth and planned urban development in James City County are likely to cause a substantial increase in water demand in the near future. The county now depends on surface water purchased from the cities of Williamsburg and Newport News for most public water supplies. In addition, several private water companies and the James City Service Authority supply ground water locally to numerous subdivisions. Because present sources may not be adequate or continue to be available in the future, the county is studying the potential for developing additional water supplies from various sources, including ground-water supplies within the county as well as supplemental surface water from the Newport News System.

In the summer of 1977, the county of James City requested the U.S. Geological Survey to study the hydrologic characteristics of the Coastal Plain aquifers underlying the county and to determine the availability of ground water to augment current water supplies.

Purpose and Scope

The purpose of the study was to determine present ground-water conditions and evaluate alternative plans for development and management of the ground-water resources of the county. Objectives of the study are:

(1) Establish a network of observation wells to obtain sufficient data to define present water-level and water-quality conditions of individual aquifers and to provide a baseline for comparing future hydrologic data.

(2) Determine the direction of ground-water movement, quantity, and availability of ground water.

The county study is intended for use in designing future data-collection programs and to help in formulating local programs for ground-water management and land use.

Cooperation and Acknowledgments

The study was made by the U.S. Geological Survey in cooperation with the county of James City. Cooperation and assistance were provided by Eric Zicht and Wayland Bass of the James City Department of Public Works. Thanks is given to Eugene Rader, Virginia Division of Mineral Resources, for providing geologic information.

Location and Description of Study Area

James City County comprises an area of 148 square miles, stretching across the York-James Peninsula from the York River on the north to the James River on the south in southeast Virginia (fig. 1). It is bounded on the west by the Chickahominy River and Diascund Creek and on the north by Ware Creek and the York River. The southern part is bounded by the James River. The York River and York County form the eastern boundary.

That part of the county along the divide between the James River and the York River is underlain by moderately dissected terrace deposits, ranging in altitude from 130 feet above the National Geodetic Vertical Datum of 1929 (NGVD) in the western part to 80 feet above NGVD in the eastern part. Lower terrace deposits, 10 to 40 feet above NGVD, are widespread along the James River and the mouth of the Chickahominy River.

Average annual precipitation in the study area is 42 inches. Precipitation is distributed fairly evenly throughout the year, with slightly higher averages during October, November, and December. In a given year, however, any month can be either excessively wet or excessively dry. Winters are mild; average monthly air temperatures seldom fall below 32°F, and the summers are warm, with average monthly air temperatures often exceeding 70°F (NOAA, 1977).

Previous Investigations

Major contributors to the literature on the geology in southeast Virginia Coastal Plain are Richards (1945, 1948), Spangler and Peterson (1950), Johnson (1972), Brown and others (1972), and Teifke (1973). In addition, many reports such as those of Darton (1896); Sanford (1913); Cederstrom (1945); Leggette, Brashears, and Graham (1966); Geraghty and Miller (1967, 1978a, 1978b); and Virginia State Water Control Board (1974) discuss and interpret the ground-water resources. Cederstrom (1957), Bick and Coch (1969), Virginia State Water Control Board (1973), and Lichtler and Wait (1974) describe the geology and ground-water resources of the study area. Cederstrom (1943, 1946a, 1946b) and Back (1966), respectively, made studies of the genesis of ground waters and the hydrochemical facies of the ground-water system that describe a part of the study area. Malcolm Pirnie Engineers (1975) evaluated the growth patterns and availability of public facilities and services within James City County as part of a program for developing additional water supplies.

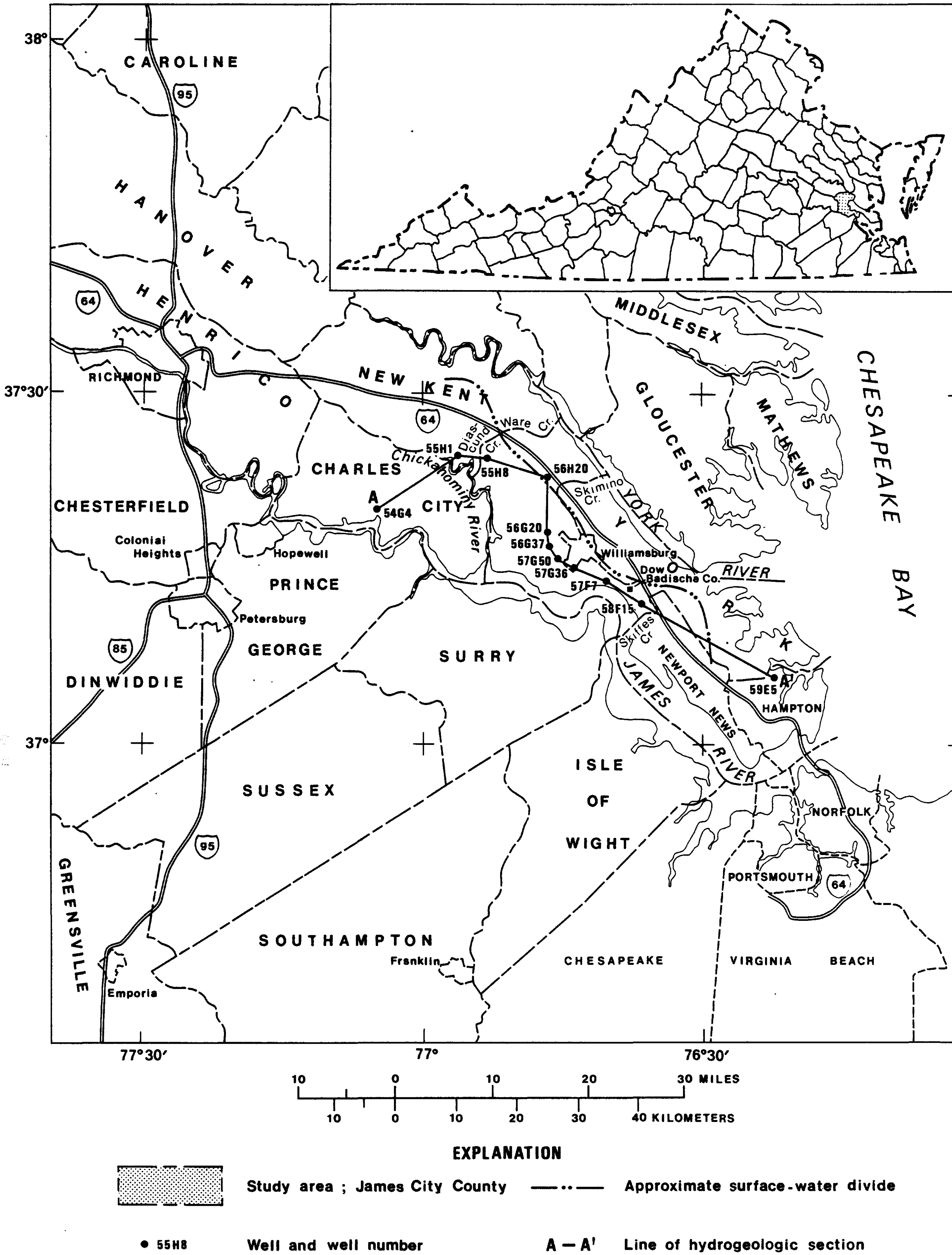


Figure 1. - Location of study area.

Methods of Investigation

Data for this study were collected and analyzed during June 1977 to August 1979.

First steps entailed a literature review and a study of earlier concepts of the geologic framework of James City County and of the hydrologic system. A well inventory was made to identify all pumping centers and to locate wells that would be accessible for measurement and water-quality sampling. Appendix 1 gives detailed information on the wells.

Geologic and hydrologic data from earlier studies were compiled, and new data were collected. Hydraulic characteristics of selected aquifers were estimated from several aquifer tests outside the study area and from specific-capacity data. Specific-capacity data provided the principal basis for estimating transmissivity. The transmissivity values determined from specific-capacity data are only approximations because the pumped wells differ in: (1) efficiency, (2) diameter, (3) percentage of penetration of the aquifer(s), (4) period of pumping, and (5) recharge effects caused by vertical leakage through confining beds. The locations of wells are shown in figure 2. The information reviewed and collected was used to prepare hydrogeologic sections and maps of the ground-water quality, to evaluate effects of pumping, and to estimate potential well yields.

Water-level measurements at observation wells and private wells were made in June and July 1978 to define the potentiometric surfaces of selected aquifers and to determine direction of ground-water movement, quantity, and availability.

GEOLOGY

Geologic Setting

James City County is within the Northern Atlantic Coastal Plain province. The geology is characterized by a series of southeastward dipping beds of marine and nonmarine sand, silt, clay, and gravel. This wedge of unconsolidated deposits ranges in thickness from 1,100 feet in the western part of the county to 1,900 feet in the eastern part (Brown and others, 1972).

Detailed subsurface mapping of geologic units was not attempted. However, the major sand bodies that function as aquifers were delineated. Four aquifers--the Quaternary, the Yorktown, the Eocene-Paleocene, and the Cretaceous--were

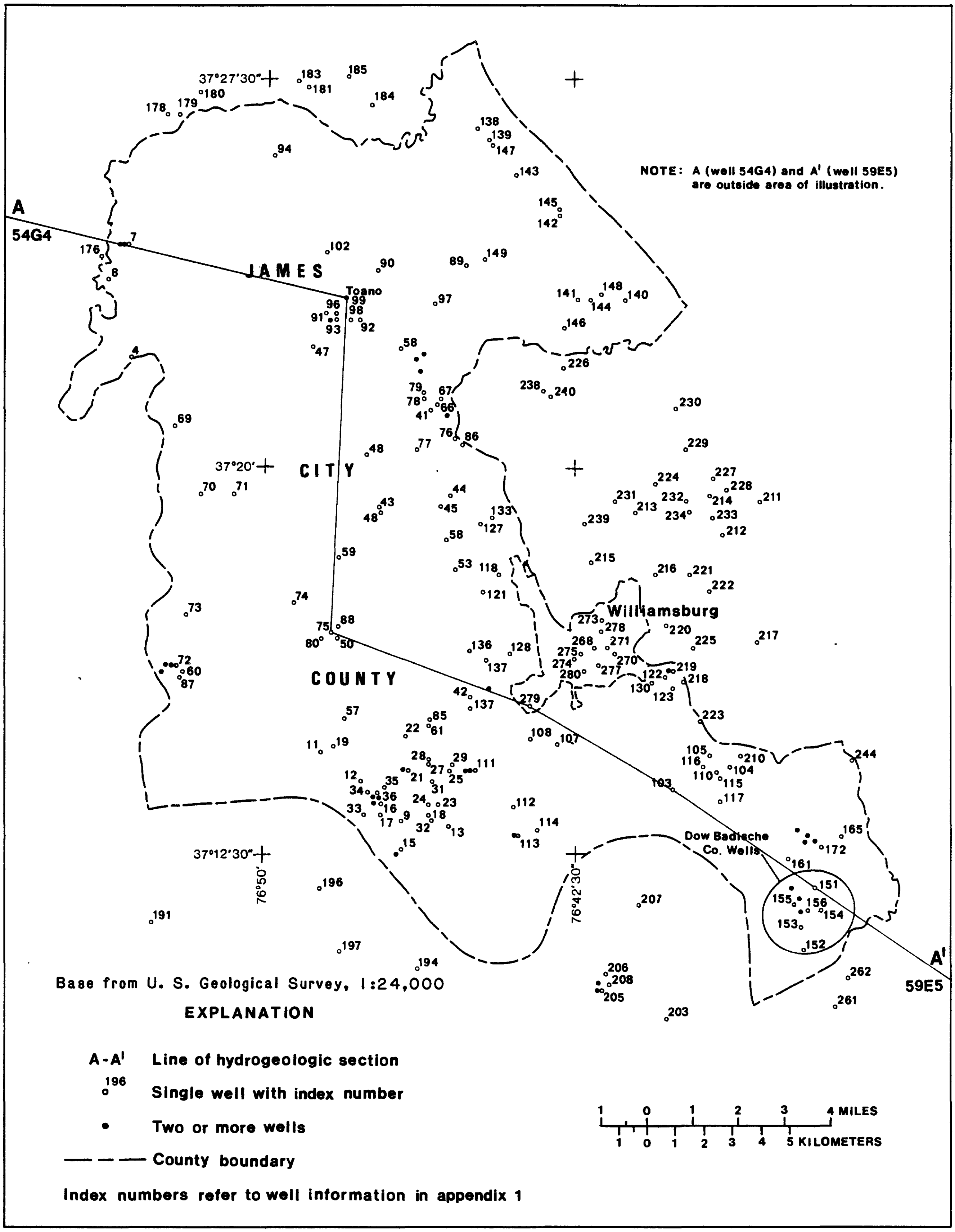


Figure 2. - Locations of well sites and hydrogeologic section

identified, and their approximate stratigraphic positions are indicated in table 1 and figure 3. The aquifer names used in this report are informal and may not be applicable elsewhere.

Correlation of aquifers was based on the study of drillers', geologic, and geophysical logs from 278 wells in the county and in adjacent areas. Because many geophysical logs did not provide a clear demarkation between units, correlations were made through lithologic characteristics.

Quaternary Sediments

A mantle of Quaternary sediments overlies the truncated surfaces of the older unconsolidated deposits. The Quaternary sediments are composed of two principal types: (1) sand and gravel of alluvial origin, and (2) clay, silt, and sand of littoral and shallow-marine origin. The alluvial deposits consist of beds of tan and brown iron-stained sand and gravel that are believed by Sanford (1913) to represent the coarse sediment loads of braided and coalescing streams. The littoral and shallow-marine beds are composed of tan and gray sand along with some layers of silt and clay.

Pliocene and Miocene Sediments

Marine Pliocene and Miocene sediments underlie the Quaternary deposits. The Pliocene and Miocene sediments consist of light-gray to bluish-gray quartz sand and dark-brown to greenish-brown silt and clay. Shells and shell fragments may be found throughout the deposits, and some beds are composed almost entirely of shell debris in sand. Diatomaceous material is common, particularly in the basal part. Glauconite is present only in subordinate amounts.

Eocene-Paleocene Sediments

Marine sediments of Eocene and Paleocene age underlie the Pliocene and Miocene sequence. These sediments consist of multicolored clay, silt, and sand with thin beds of shell and dense limestone and subordinate amounts of gray and blue marl. Glauconite is commonly the principal constituent of the sandy units.

Cretaceous Sediments

The Cretaceous age sediments are a thick and geologically complex series of nonmarine deposits overlying crystalline

Table 1.--Generalized coastal-plain stratigraphic nomenclature and geohydrologic units of James City County, Virginia

System	Series	Stratigraphic units	Informal unit name used in this report	Range in thickness (feet)	Geohydrologic unit name used in this report	Lithologic character	Water-yielding characteristics and hydrology
Quaternary	Holocene						
	Pleistocene	Columbia Group	Quaternary sediments	40-60	Quaternary aquifer	Light-colored oxidized alluvial terrace deposits; mainly a fining upward sequence of sand and gravel, silt, sandy clay, and clay.	Functions as a water-table aquifer, permits water to percolate downward to underlying units. Provides water locally for rural wells, well yields range from less than 10 gal/min to more than 30 gal/min.
Tertiary	Pliocene						
	Miocene	Chesapeake Group	Pliocena and Miocene sediments	50-225	Yorktown aquifer and undifferentiated confining beds.	Yorktown aquifer consists of beds and lenses of fine to coarse sand, some gravel, and shells. Confining beds consist of blue-gray clay, marl, sandy clay and diatomaceous silty clays.	Aquifer contains water confined under artesian pressure. Water enters squifer mainly by downward leakage from overlying units and by lateral flow from the west. Yields small quantities of hard water to wells. Well yields range from less than 10 gal/min to 100 gal/min.
	Eocene and Paleocene	Pamunkey Group undifferentiated	Eocene and Paleocene sediments	75-150	Eocene-Paleocene aquifer and undifferentiated confining beds	Eocene-Paleocena aquifer consists of beds and lenses of fine to coarse quartz-glauconite sands, thin beds of shell material and limestone. Confining beds are characterized by beds of glauconitic silts and clay, and by interbeds of bright variegated fine grained clastics. Thin beds of shell and limestone are present.	A potentially important artesian aquifer system with hydrologic properties similar to Cretaceous aquifer. Moderately productive where utilized with proper development methods.
Cretaceous	Lower	Potomac Group undifferentiated	Cretaceous sediments	100-1500	Cretaceous aquifer and undifferentiated confining beds	Cretaceous squifer is composed of interbedded gravel, sand, silt, sandy clay, and clay. Beds of clay divide the aquifer into several permeable zones.	Comprises the principal artesian aquifer system. Water-yielding sands are highly productive. Recharge is slow downward leakage from overlying aquifers and confining beds. Discharge is mainly toward centers of heavy pumping. Water quality ranges from fresh to saline. Large diameter multiscreened wells yield more than 750 gal/min. Aquifer is saline in southeastern part of county and eastward.

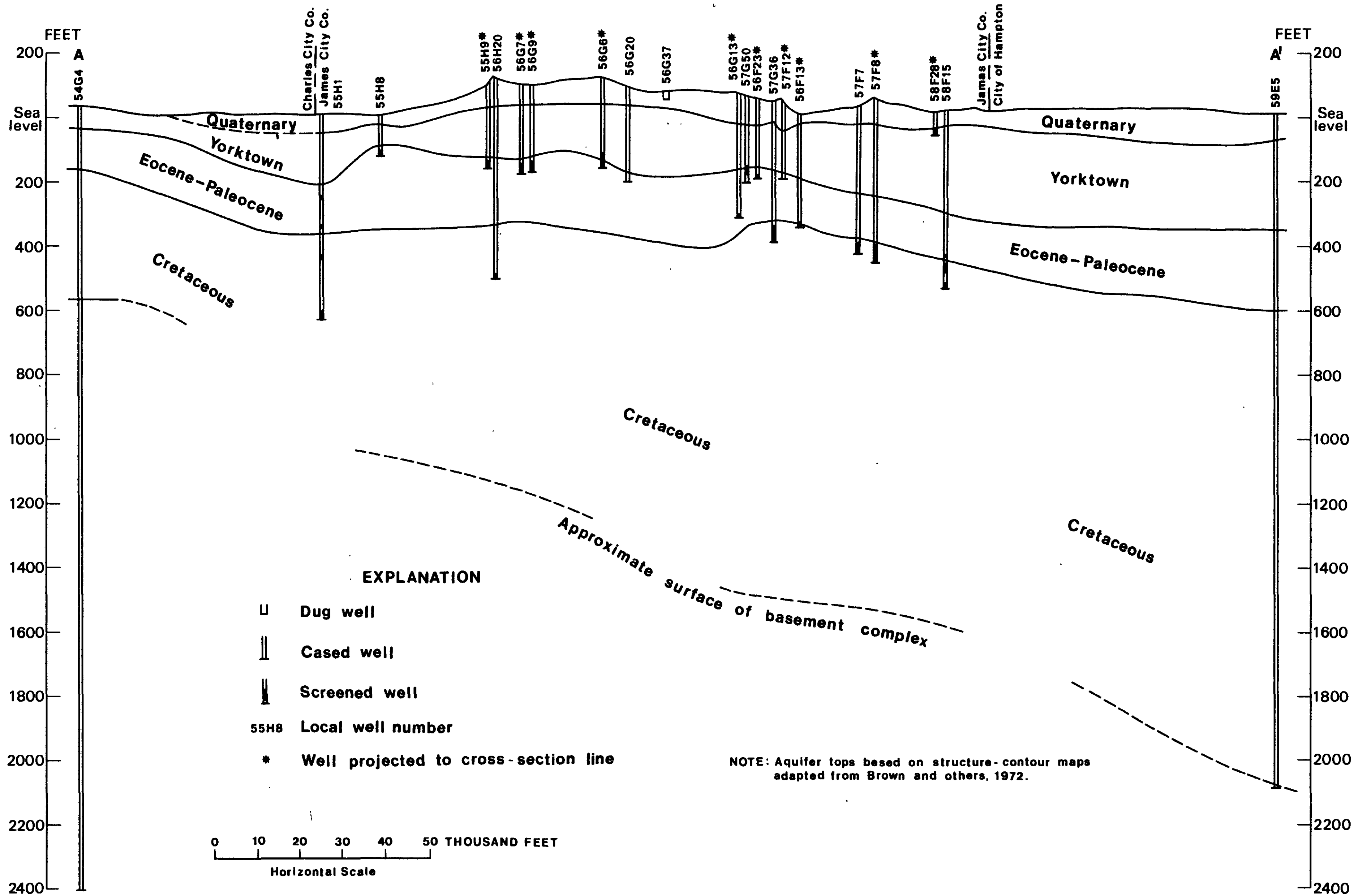


Figure 3. - Generalized hydrogeologic section across James City County, Virginia.

bedrock. These sediments consist of a series of interbedded lenses of quartz sand, silt, and clay that constitute approximately three-fourths of the total volume of unconsolidated material in the coastal plain. The hydrogeologic section (fig. 3) shows that the altitude of the top of the Cretaceous ranges from less than 200 feet below NGVD to more than 400 feet below NGVD. The estimated thickness of these deposits ranges from 500 feet to more than 1,400 feet.

GROUND-WATER HYDROLOGY

Geohydrologic Units

Water occurs under leaky artesian conditions in the multilayer aquifer system of the Coastal Plain province of Virginia. Geohydrologic units generally correspond to geologic units, but, in places, aquifers and confining beds transgress stratigraphic boundaries through facies changes. In addition, several stratigraphic units may occur within a geohydrologic unit. Maps of the formation tops of the Yorktown, Eocene-Paleocene, and Cretaceous aquifers, modified from structure-contour maps of Brown and others (1972), are shown on figures 4, 5, and 6, respectively.

The principal hydraulic characteristics of an aquifer are hydraulic conductivity, saturated thickness, and storage coefficient. Vertical leakage occurs between adjacent aquifers through confining beds. The rate of vertical flow is proportional to difference in heads in adjacent aquifers and vertical hydraulic conductivity. With concentrated pumping and increased head differentials, vertical leakage becomes a major contributor of water to aquifers being pumped.

Quaternary Aquifer

The Quaternary aquifer consists of the saturated Quaternary sediments that cover most of James City County. The upper surface of the water table ranges from several feet to as much as 40 feet or more below land surface. The aquifer thickness ranges from 10 to 70 feet and averages 50 feet (fig. 7).

Aquifer characteristics

Hydraulic characteristics of the Quaternary aquifer can not be defined with the available data. The aquifer, principally the sand zones, is tapped for small water supplies for miscellaneous uses. Individual well yields range from a few gallons

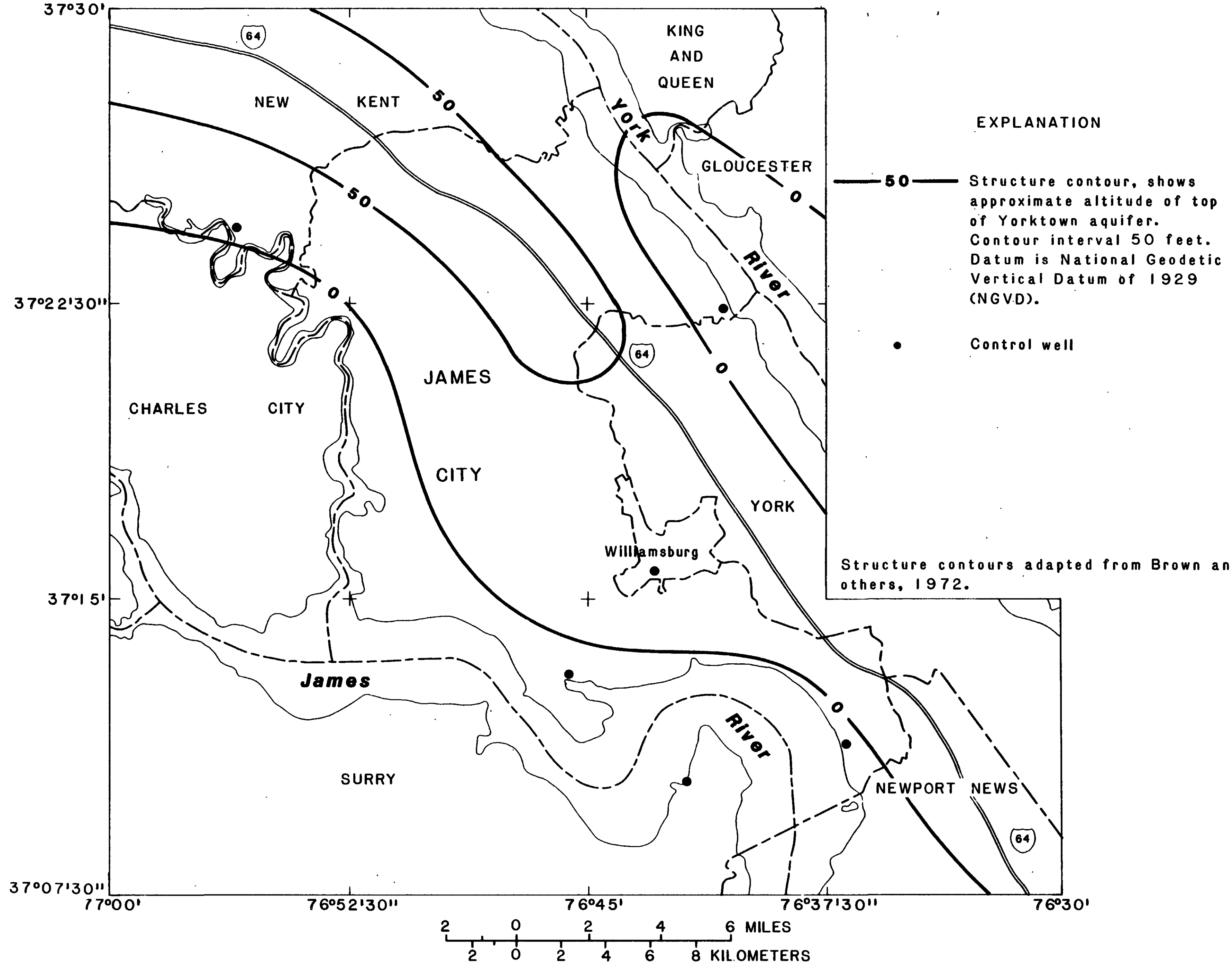


Figure 4. - Approximate configuration of top of the Yorktown aquifer, James City County, Virginia.

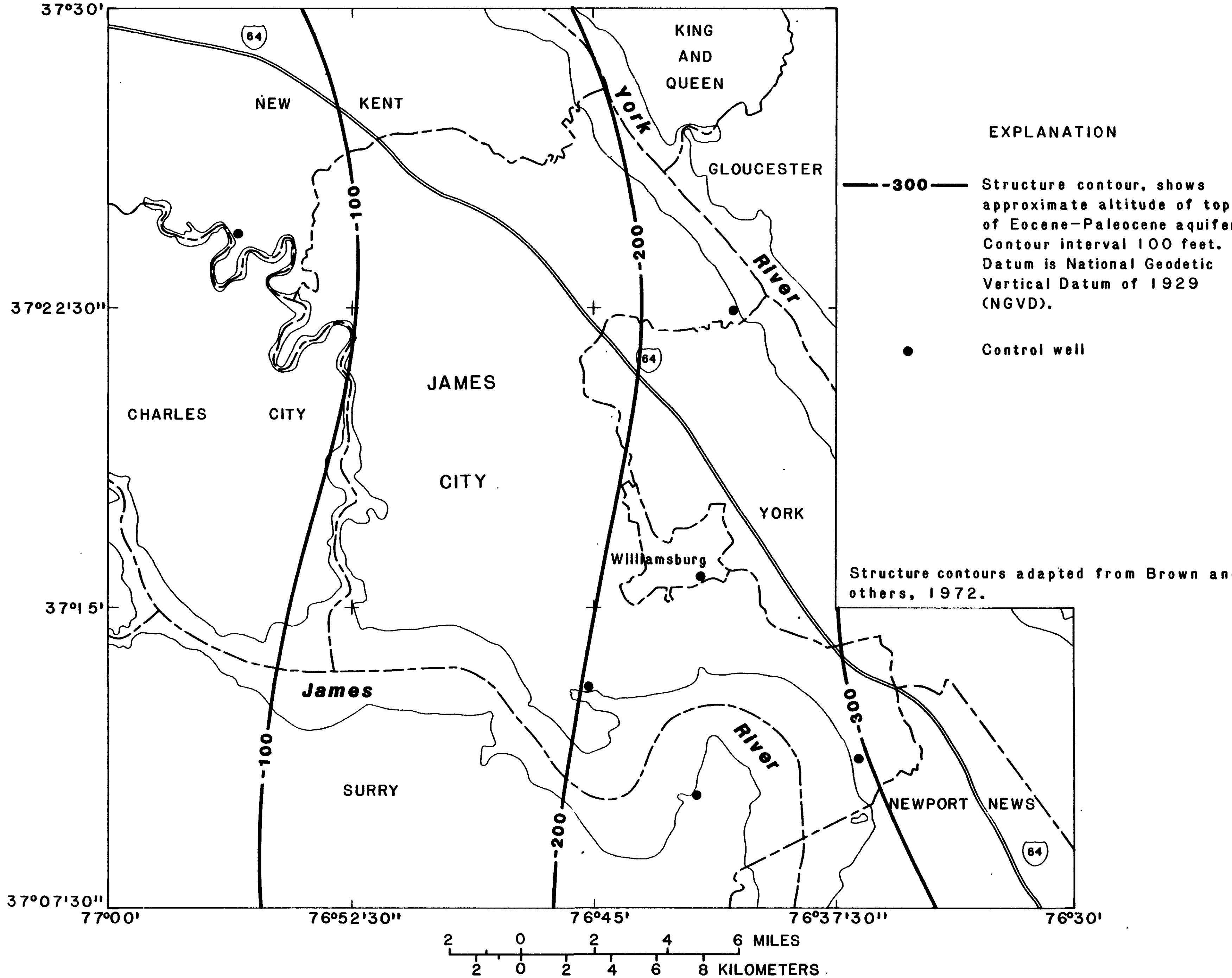


Figure 5. - Approximate configuration of top of the Eocene-Paleocene aquifer, James City County, Virginia.

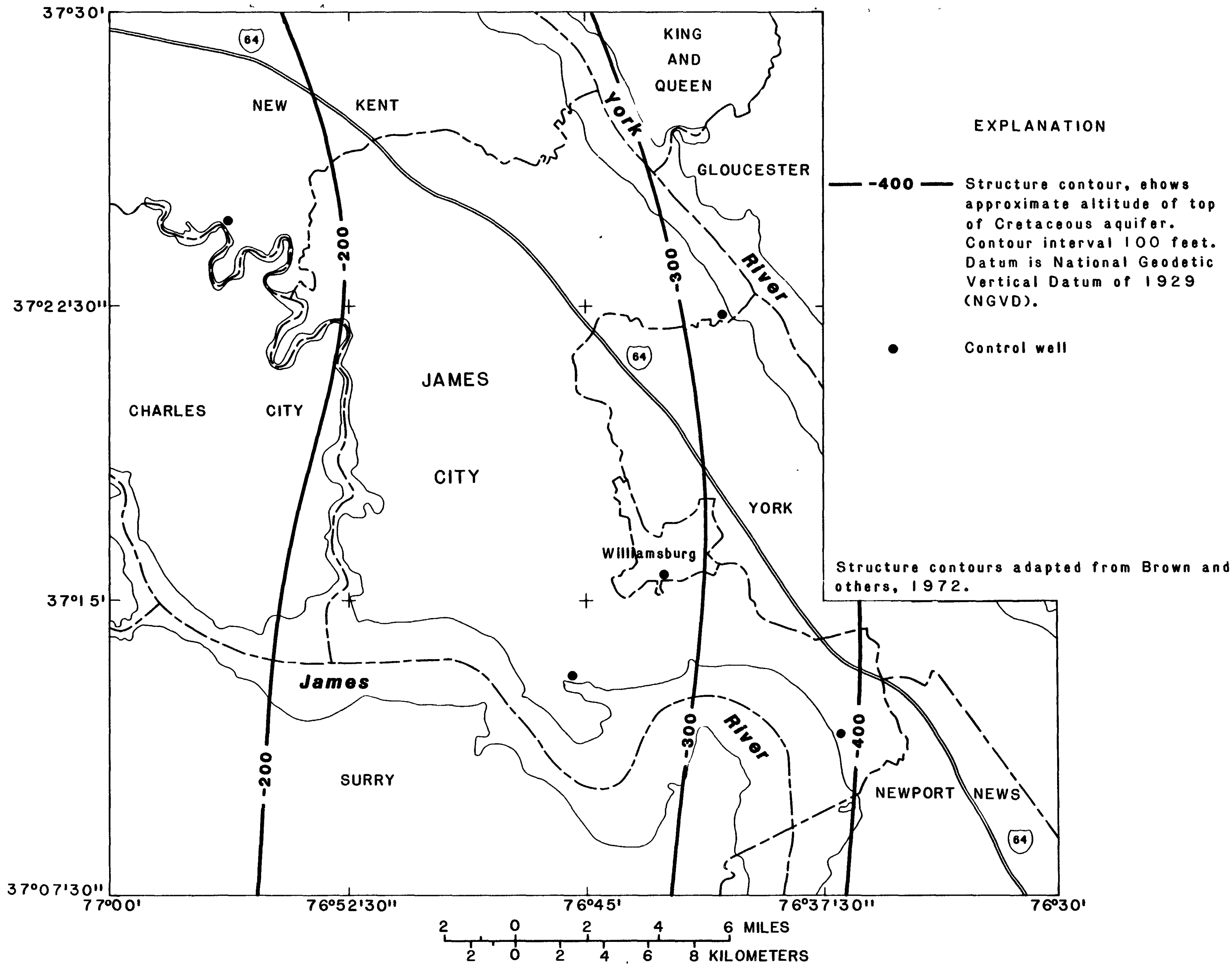


Figure 6. - Approximate configuration of top of the Cretaceous aquifer, James City County, Virginia.

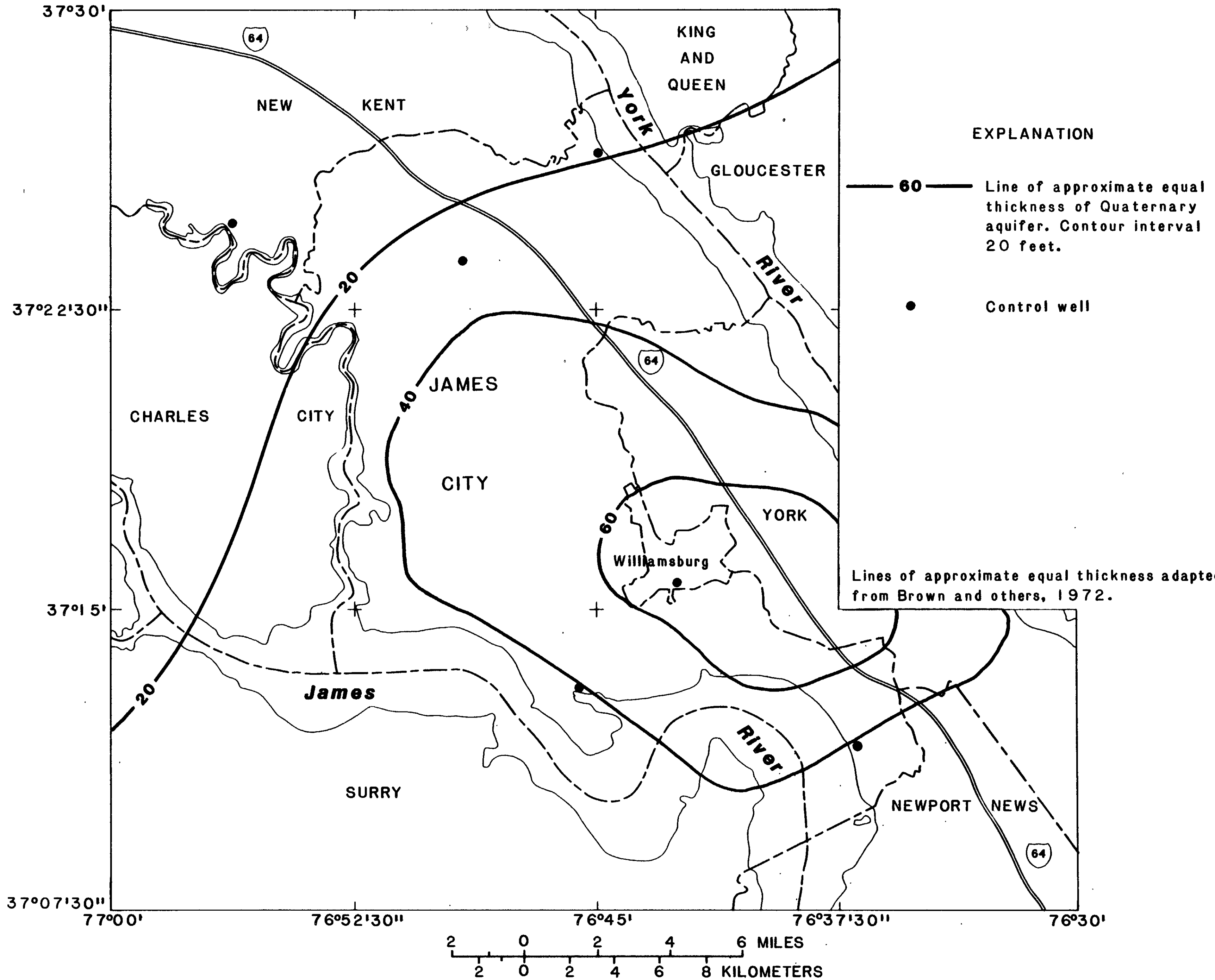


Figure 7. - Approximate thickness of Quaternary aquifer, James City County, Virginia.

per minute to 30 gal/min (Lichtler and Wait, 1974). Total pumpage is not known but is probably several thousand gallons per day. The Quaternary aquifer contains 25 to 60 billion gallons of water in storage (table 2). This estimate is based on an assumed effective porosity of 5 to 10 percent. Water levels have not declined significantly because of pumping.

Table 2.--Estimated quantities of ground water stored in the aquifers of James City County, Virginia, (based on an assumed effective porosity of 5 to 10 percent).

Geohydrologic unit		Estimated maximum amounts of ground water in storage (billion of gallons)
Quaternary aquifer		25-60
Yorktown aquifer		45-100
Eocene-Paleocene aquifer		35-90
Cretaceous aquifer		545-1050
	TOTAL	650-1300

Recharge, movement, and discharge of ground water

Because the Quaternary aquifer is mostly sand and lies at the surface, it is recharged directly by precipitation. Discharge is by evaporation and transpiration, seepage into streams, downward leakage to confined aquifers, and pumping. Water in the aquifer is largely unconfined. Water in the aquifer moves from areas of high water levels (generally corresponding to land-surface highs) toward streams, lakes, and swamps (generally corresponding to land-surface lows). The Quaternary aquifer is an important part of the hydrologic system because it is a source of recharge to the underlying multilayer aquifer system.

Water quality

The chemical quality of water in the Quaternary aquifer probably reflects that of precipitation concentrated by evapotranspiration and subsequent reaction with calcareous material. Because most of the water moves toward discharge points along short flow paths, opportunities for mineral solution are restricted. Lichtler and Wait (1974) report the dissolved-solids content of the water is low and is generally soft (less than 50 mg/L hardness). Where wells penetrate sediments containing calcareous material, the water may be slightly hard, and the bicarbonate content increases (Lichtler and Wait, 1974).

Water in the Quaternary aquifer is susceptible to pollution from septic systems and from fertilizer and pesticide application on lawns and farmlands. Such water commonly contains high concentrations of nitrate and organic constituents.

Yorktown Aquifer

Marine Pliocene and Miocene sediments form the Yorktown aquifer. The Yorktown aquifer overlies the Eocene-Paleocene aquifer and is generally separated from it by a sandy marl interval of Miocene sediments. The Yorktown aquifer is overlain by the Quaternary aquifer and is generally separated from it by an upward fining sequence of silt and clay with some gravel near the base of the Quaternary aquifer. The estimated thickness of the Yorktown aquifer ranges from 50 feet to 225 feet (fig. 8).

The Yorktown aquifer in the study area has not been used as a primary source of water supply because greater well yields have been developed from the underlying aquifers. Several shallow wells drilled in the Yorktown aquifer are used for domestic water supply at Williamsburg and Norge, Va. Many private wells have been abandoned because water is provided by the James City Service Authority.

Aquifer characteristics

Through the use of specific-capacity tests of wells completed in the Yorktown aquifer of the York-James Peninsula and outside the study area, Geraghty and Miller (1978a) estimated transmissivities of 1,300 to ft^2/d (table 3).

Individual well yields range from 10 to 100 gal/min, and specific capacities of wells range from 1 to 20 gal/min per foot of drawdown (Lichtler and Wait, 1974). The Yorktown aquifer contains from 45 to 100 billion gallons of water in storage (table 2).

Recharge, movement, and discharge of ground water

Water enters the Yorktown aquifer by downward vertical leakage from the Quaternary aquifer and by ground-water flow from the west along the Fall Line and the outcrop of Pliocene

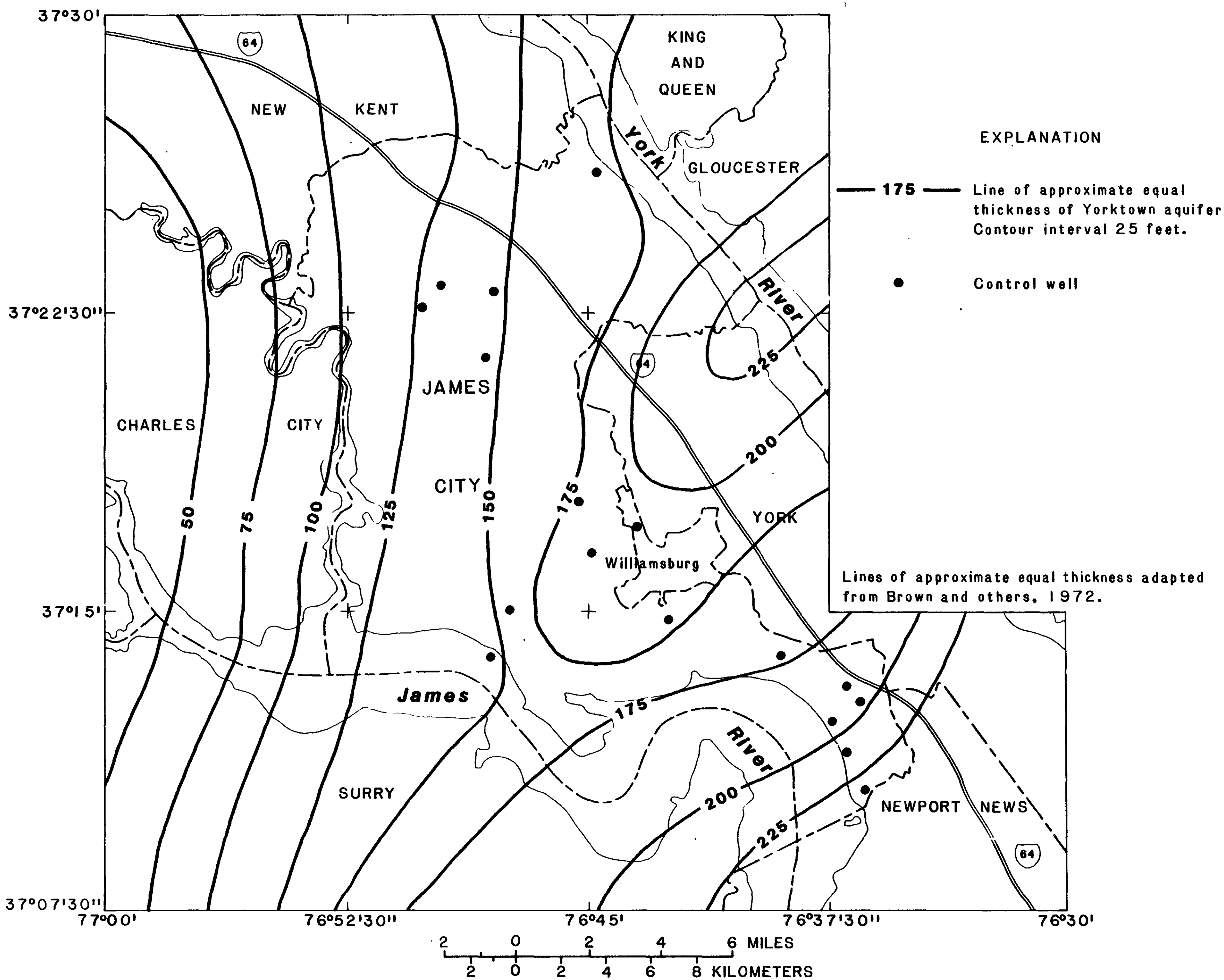


Figure 8. - Approximate thickness of Yorktown aquifer, James City County, Virginia.

Table 3.—Summary of aquifer data, James City County and vicinity, Virginia

Local Well No.	Specific capacity (gal/min/ft)	Pumping Time (hours)	Screened Intervals (ft)	Transmissivity (square feet/day) using Specific-capacity data	Recovery data	Residual drawdown data	Drawdown data	Aquifer formation
56F16	5.2	24	405-430 438-448 460-470 480-485	2200	5400	5800	—	Cretaceous
57F7	14.1	24	424-438 444-454 457-463	5800	8400	8400	—	Cretaceous
57F8	19.1	24	451-461 465-500	9200	9000	8700	—	Cretaceous
56H22	0.4	39	545-555 570-610	—	—	4400	6000	Cretaceous
57G34	4.0	24	400-415 423-438 458-473	1500	—	—	—	Cretaceous
56J16	23.2	24	400-415 420-440 668-678 682-692 696-711	9000	7500	6600	5500	Cretaceous
56J19	17.0	48	344-384 390-420	6700	—	4200	4900	Cretaceous
56J12	10.9	11	366-393 405-425 430-444 524-536 621-645 715-729	4500	—	—	5300	Cretaceous
56G4	11.0	24	225-260 264-274	4600	6700	7500	—	Eocene-Paleocene
57G29	10.6	8	242-282	4200	9000	9000	—	Eocene-Paleocene
55H6	28.0	48	198-238	12500	13500	12600	—	Eocene-Paleocene
55H7	21.6	48	198-238	9000	12000	12500	—	Eocene-Paleocene
56G3	23.7	24	225-240 262-277	8000	4600	4400	—	Eocene-Paleocene
56G6	48.0	24	225-240 262-277	20000	8500	9000	—	Eocene-Paleocene
58F29	18.4	12	78-88 98-118	7300	—	—	—	Yorktown

and Miocene sediments. Discharge is likely by underflow toward the east and to surface-water bodies, slow downward vertical leakage to underlying aquifers, and by pumping. Underflow entering the area is estimated to be 1 Mgal/d. Data are not available to determine pumpage.

Water quality

Water in the Yorktown aquifer varies from the calcium bicarbonate type, containing about 5 mg/L dissolved chloride, to the sodium bicarbonate type, containing about 70 mg/L dissolved chloride (table 4). The concentration of bicarbonate is about 120 mg/L, and the concentration of dissolved solids is generally low, less than 250 mg/L.

Eocene-Paleocene Aquifer

The Eocene-Paleocene aquifer overlies the Cretaceous aquifer and is overlain by the Yorktown aquifer. Water-level data indicate the individual sand units in this aquifer are hydraulically connected. However, this hydraulic connection may be interrupted in places, so that water in individual sand units may have different hydraulic heads. The thickness of this aquifer ranges from 75 feet to more than 150 feet (fig. 9). In some areas, this sand aquifer is in hydraulic continuity with the underlying Cretaceous aquifer.

The Eocene-Paleocene aquifer supplies water to domestic wells in an area from Jamestown to the mouth of the Chickahominy River and along the east bank of the Chickahominy River and Diascund Creek. Several wells along these streams are topographically low and flow under tidal loading. Wells in the aquifer provide water to residental subdivisions at Toano, Norge, Jamestown, and Williamsburg. Lichtler and Wait (1974) report that silty zones in the sand beds are generally unstable and tend to cause problems in wells.

Aquifer characteristics

Results of aquifer tests and specific-capacity tests of wells in the Eocene-Paleocene aquifer of the York-James Peninsula indicate the transmissivity ranges from 4,200 to 20,000 ft^2/d (table 3). A representative storage coefficient is estimated to be 0.0001.

Reported specific capacities of wells in the aquifer range from about 5 to 25 gal/min per foot of drawdown (fig. 10). The Eocene-Paleocene aquifer contains from 35 to 90 billion gallons of water in storage (table 2).

Table 4.--Concentrations of major chemical constituents from selected wells completed in the Yorktown aquifer, James City County, Virginia

STATION NUMBER	DATE OF SAMPLE	DEPTH OF WELL, TOTAL (FEET)	DEPTH TO TOP OF WATER-BEARING ZONE (FT)	DEPTH TO BOTTOM OF WATER-BEARING ZONE (FT)	TEMPERATURE (DEG C)	PH (UNITS)	SPECIFIC CONDUCTANCE (MICROMHOS)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)	SILICA, DISSOLVED (MG/L AS SIO2)	IRON, TOTAL RECOVERABLE (UG/L AS FE)	CALCIUM DISSOLVED (MG/L AS CA)
371401076390501	77-12-12	126	106	126	15.0	8.8	109	118	3.0	--	17
	78-06-02	126	106	126	22.0	6.9	300	177	9.9	--	55
371543076443401	77-08-11	85	75	85	17.0	5.1	220	151	16	--	46
	77-12-19	85	75	85	5.0	5.6	251	144	18	--	44
371655076473001	71-07-14	60	--	--	18.0	7.1	645	422	9.7	--	99
371730076432401	46-06-15	68	--	--	--	7.3	--	122	18	120	34
371805076473001	72-12-07	147	--	--	--	8.6	340	218	22	--	4.5
372206076460702	46-06-15	88	50	56	--	7.3	--	108	11	8100	32
372248076481801	47-11-06	50	20	50	--	7.5	--	264	10	30	83

Table. 4.--Concentrations of major chemical constituents from selected wells completed in the Yorktown aquifer, James City County, Virginia--Continued

DATE OF SAMPLE	MAGNESIUM, DISSOLVED (MG/L AS MG)	SODIUM, DISSOLVED (MG/L AS NA)	POTASSIUM, DISSOLVED (MG/L AS K)	BICARBONATE (MG/L AS HCO3)	CARBONATE (MG/L AS CO3)	SULFATE DISSOLVED (MG/L AS SO4)	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)	NITROGEN, NITRATE DISSOLVED (MG/L AS NO3)
77-12-12	1.4	4.4	5.8	51	0	9.4	5.5	.1	.00
78-06-02	1.1	4.8	1.8	160	0	11	4.3	.1	.10
77-08-11	.7	4.3	2.0	140	0	2.2	5.2	.1	.80
77-12-19	.9	11	2.0	140	0	3.2	10	.1	1.1
71-07-14	5.8	22	2.7	232	0	8.2	71	.2	21
46-06-15	.9	--	--	96	--	10	5.0	.1	--
72-12-07	1.1	70	7.3	196	4	11	3.7	.9	.10
46-06-15	.8	--	--	93	--	9.9	3.1	.1	--
47-11-06	3.9	--	--	246	--	12	20	.0	--

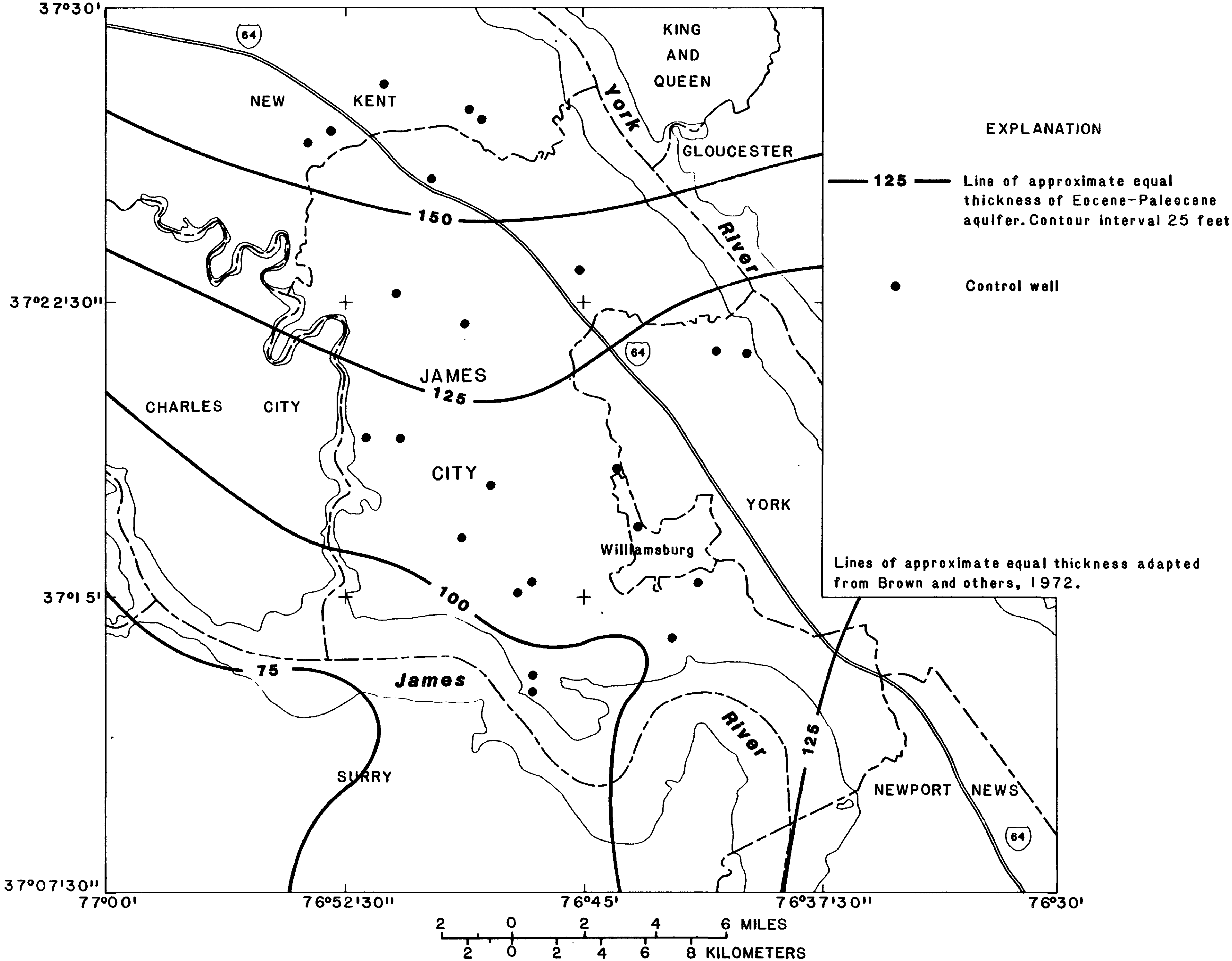


Figure 9. - Approximate thickness of Eocene-Paleocene aquifer, James City County, Virginia.

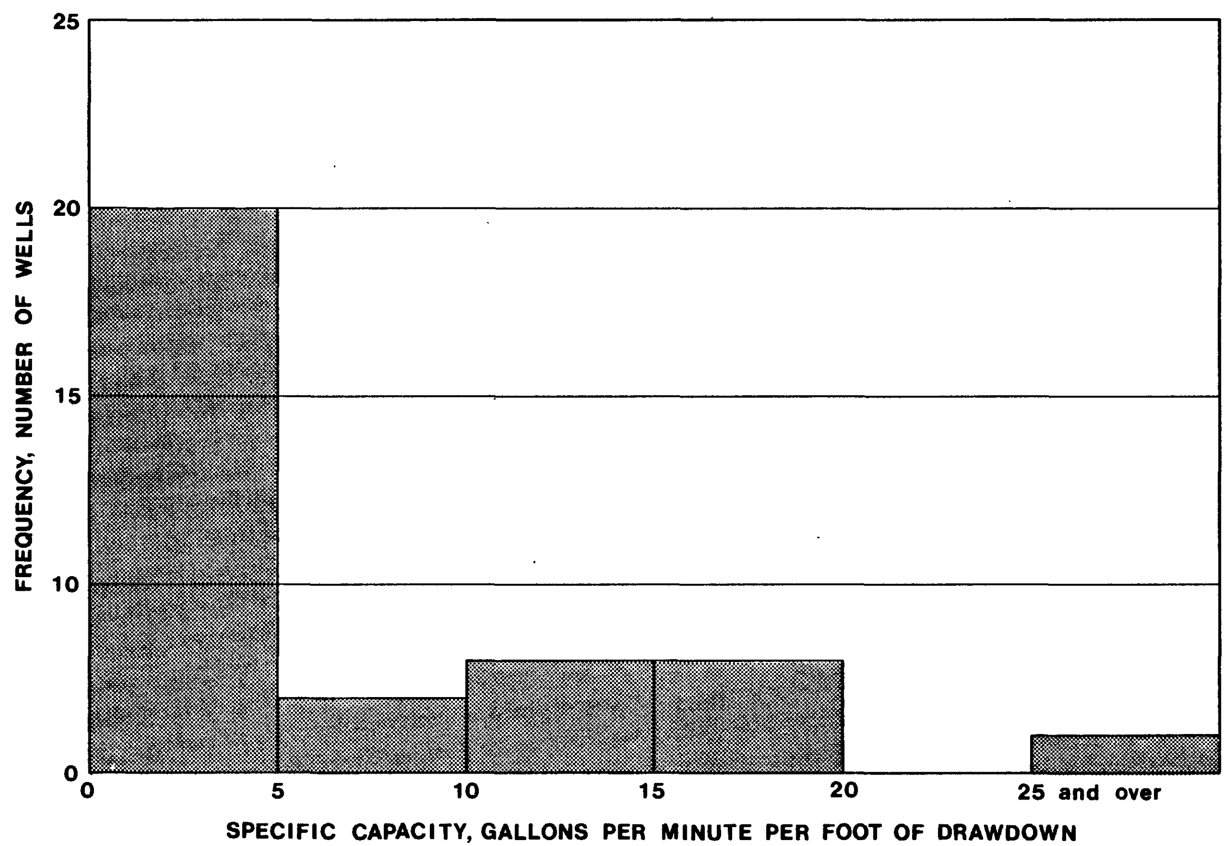


Figure 10. - Frequency distribution of specific capacities of 24 wells in Eocene - Paleocene aquifer.

Recharge, movement, and discharge of ground water

The Eocene-Paleocene aquifer receives recharge mainly from slow vertical leakage from overlying aquifers and confining beds and from lateral flow. The aquifer is discharged by slow lateral movement out of the area and by pumping. The following assumptions are made to estimate the discharge of underflow from the west into James City County through the 12-mile profile A-A' (see pl. 1): (1) the transmissivity is estimated to be 4,200 ft^2/d (31,400 gallons per day per foot), and (2) the hydraulic gradient is estimated to be 8 feet per mile. The quantity of underflow entering the area is calculated to be 3 Mgal/d. Total pumpage is estimated to be less than 1 Mgal/d.

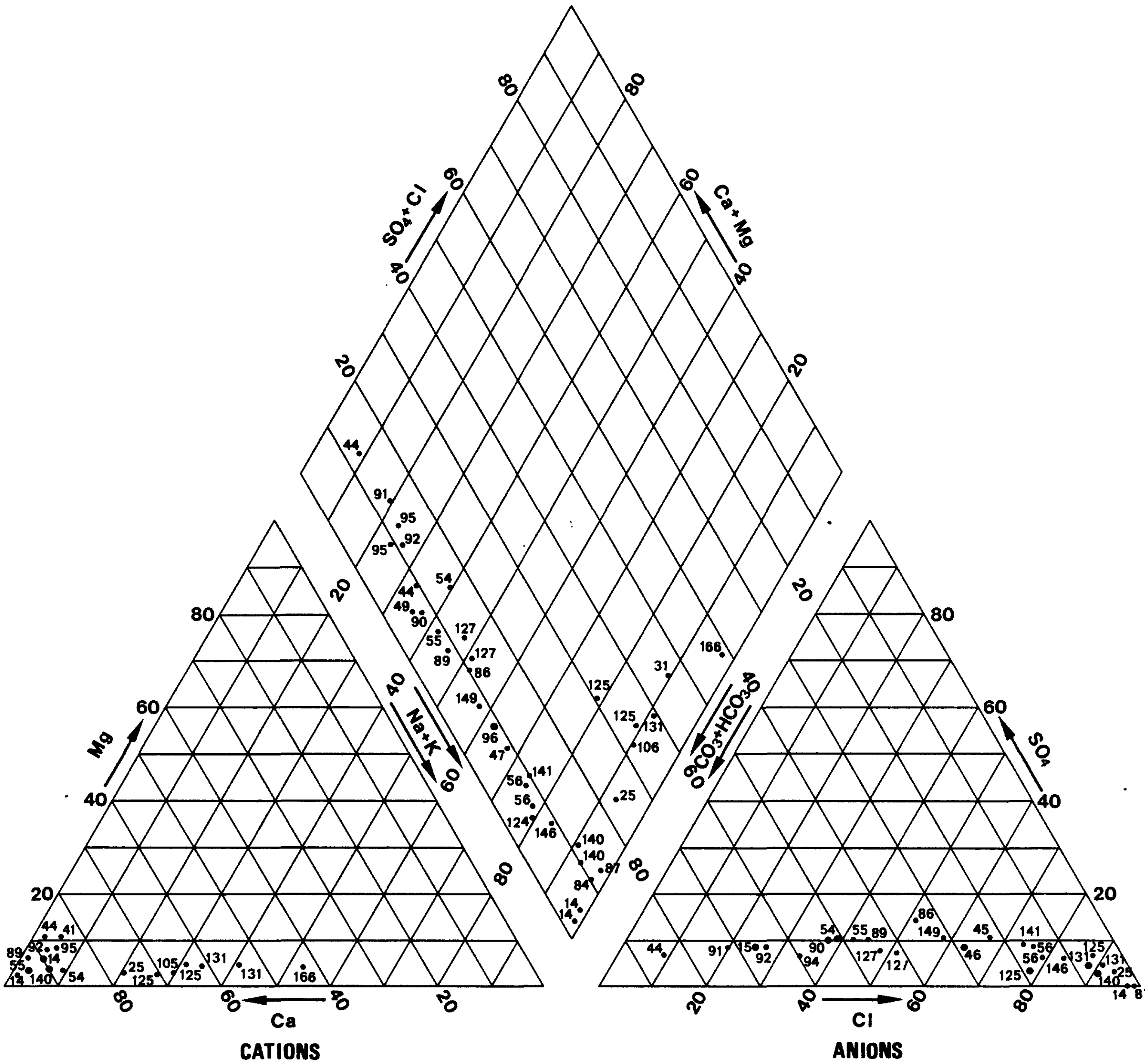
Few available data indicate that the altitude of water level in the Eocene-Paleocene aquifer (pl. 1) is generally below the altitudes of water levels in the Yorktown aquifer and above those in the Cretaceous aquifer. The potentiometric surface of the Eocene-Paleocene aquifer is about NGVD, except near pumping centers, where it is below NGVD. In the study area, the distribution of water levels suggests water in the Eocene-Paleocene aquifer is flowing toward cones of depression formed by pumping.

Water quality

Water in the Eocene-Paleocene aquifer varies in chemical quality from a calcium bicarbonate type, containing less than 250 mg/L dissolved solids, to a sodium bicarbonate type, containing more than 250 mg/L dissolved solids (table 5 and pl. 2). Figure 11 illustrates the composition of water in the Eocene-Paleocene aquifer. With increasing depth, water is characterized by increasing bicarbonate and sodium concentrations and decreasing calcium and magnesium hardness. Chemical data for wells 57G9, 58F41, and 58F42 indicate the lower parts of this aquifer contain water that is higher in sulfate, sodium, and chloride concentrations and dissolved solids than the upper part (table 5). Chloride concentrations increase generally from west to east and range from 1.2 mg/L to 120 mg/L (fig. 12). Lichtler and Wait (1974) report some water has unpleasant taste and odor. Flouride concentrations exceed the State standards for drinking water.

Cretaceous Aquifer

The most productive and extensive source of ground water in the York-James Peninsula is the Cretaceous aquifer. It consists of a series of interbedded sand, silt, and clay layers as well as a small amount of gravel. The individual sand



EXPLANATION

All analyses given in table 5
Index numbers given in appendix 1

125 Index number

• Single well

• Two or more wells

Figure 11. - Water analyses diagram for the Eocene-Paleocene aquifer.

Table 5.--Concentrations of major chemical constituents from selected wells completed in the Eocene-Paleocene aquifer, James City County, Virginia

STATION NUMBER	DATE OF SAMPLE	DEPTH OF WELL, TOTAL (FEET)	DEPTH TO TOP OF WATER-BEARING ZONE (FT)	DEPTH TO BOT-TOM OF WATER-BEARING ZONE (FT)	TEMPER-ATURE (DEG C)	PH (UNITS)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	SILICA, DIS-SOLVED (MG/L AS SIO2)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)	CALCIUM DIS-SOLVED (MG/L AS CA)
371228076464301	77-08-02	300	--	--	20.0	7.1	585	313	25	--	1.4
	77-12-12	300	--	--	11.0	8.0	481	320	24	--	1.4
371406076445701	77-08-11	206	196	206	18.0	6.3	655	383	35	--	7.3
	77-12-19	206	196	206	16.0	6.4	626	385	31	--	7.2
371410076453101	77-08-11	204	188	204	17.0	5.6	510	345	23	--	4.5
	77-12-19	204	188	204	5.0	6.3	572	331	24	--	4.8
371411076450601	77-08-11	246	236	246	18.0	6.7	690	395	35	--	6.9
	77-12-19	246	236	246	7.0	6.8	644	396	30	--	7.6
371500076473001	71-07-12	290	290	--	21.0	7.6	285	196	48	--	20
371505076473001	71-07-15	257	237	257	25.5	7.5	300	216	56	--	46
371520076473001	71-06-29	261	221	261	20.0	7.4	250	178	40	--	28
371522076453201	72-11-29	252	212	252	--	7.9	880	476	35	--	8.9
	79-02-05	252	212	252	17.0	8.3	710	445	31	--	7.5
371543076443402	77-08-11	280	270	280	18.0	6.2	745	427	37	--	10
	77-12-19	280	270	280	5.0	6.5	703	425	32	--	9.1
	78-06-01	280	270	280	19.0	7.4	543	340	30	--	21
371635076473001	72-11-29	228	--	--	--	7.4	285	195	53	--	37
371700076473001	71-07-14	210	--	--	26.5	7.9	458	284	38	--	.8
371708076431901	46-06-15	348	--	--	--	7.6	--	663	27	80	10
371710076473001	71-07-15	350	--	--	22.0	7.7	1840	1020	20	--	3.8
371715076473001	71-07-15	400	--	--	24.0	7.9	1900	1050	19	--	3.8
371740076473001	72-11-29	233	--	--	--	7.7	295	198	52	--	30
371750076473001	73-01-05	300	--	--	--	7.9	285	236	66	--	11
371755076473001	72-12-07	293	--	--	--	8.3	310	238	61	--	7.8
371800076473001	72-12-07	292	280	292	--	8.1	265	208	51	--	18
371804076434202	46-11-20	282	268	282	--	--	--	--	--	60	--
371815076473001	72-12-01	220	--	--	--	8.4	440	292	44	--	.8
371820076473001	72-02-07	325	--	--	--	8.1	260	205	60	--	25
	72-02-07	325	305	325	--	--	--	--	--	--	--
371834076453601	77-08-19	277	255	277	16.0	6.3	320	211	44	--	10
	77-12-21	277	255	277	16.5	8.4	296	203	44	--	8.9
371850076444601	77-08-19	282	242	282	19.0	6.5	310	196	33	--	25
	77-12-21	282	242	282	14.0	7.2	285	189	33	--	27
	78-06-01	282	242	282	18.0	6.8	300	208	42	--	8.4
371905076471201	77-08-19	277	225	277	16.5	5.9	295	187	35	--	17
	77-12-21	277	225	277	16.5	8.1	282	186	35	--	16
371909076471101	77-08-19	277	--	--	15.0	6.9	265	150	13	--	48
371910076454301	77-08-19	270	--	--	16.0	6.7	298	197	44	--	14
	77-12-21	270	--	--	15.5	8.0	281	206	43	--	15
371916076440701	78-06-01	280	265	--	18.0	7.6	335	238	41	--	4.6

Table 5.--Concentrations of major chemical constituents from selected wells completed in the Eocene-Paleocene aquifer, James City County, Virginia--Continued

DATE OF SAMPLE	MAGNESIUM, DISSOLVED (MG/L AS MG)	SODIUM, DISSOLVED (MG/L AS NA)	POTASSIUM, DISSOLVED (MG/L AS K)	BICARBONATE (MG/L AS HCO3)	CARBONATE (MG/L AS CO3)	SULFATE DISSOLVED (MG/L AS SO4)	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)	NITROGEN, NITRATE DISSOLVED (MG/L AS NO3)
77-08-02	.3	120	5.6	310	0	6.2	3.5	2.7	.60
77-12-12	.4	120	5.7	300	0	8.2	3.6	2.5	.60
77-08-11	3.4	130	12	260	0	5.2	68	1.1	1.5
77-12-19	3.4	130	11	260	0	5.5	69	1.1	1.5
77-08-11	1.9	130	9.0	270	0	2.6	46	1.5	.00
77-12-19	1.9	120	8.5	270	0	4.3	44	1.2	1.1
77-08-11	3.3	140	12	260	0	6.1	74	.9	1.3
77-12-19	3.4	140	11	260	0	6.5	77	1.1	1.5
71-07-12	4.7	30	7.7	158	0	8.0	4.8	.5	.00
71-07-15	2.8	12	4.9	162	0	14	5.3	.2	.40
71-06-29	3.4	19	5.7	144	0	6.0	1.2	.3	.00
72-11-29	4.2	160	17	272	0	16	120	1.1	1.5
79-02-05	3.6	150	12	280	0	14	92	.9	.00
77-08-11	4.3	140	13	270	0	13	78	1.0	.90
77-12-19	4.4	140	11	280	0	14	78	1.0	1.3
78-06-01	2.9	100	9.0	240	0	6.6	56	.7	.60
72-11-29	2.7	14	5.9	148	0	9.8	3.0	.2	.40
71-07-14	.5	100	4.6	237	0	8.0	12	5.5	.00
46-06-15	5.3	--	--	336	--	25	185	1.2	1.0
71-07-15	1.6	380	13	444	0	38	330	3.2	.00
71-07-15	1.8	380	12	431	0	41	350	3.0	.50
72-11-29	3.3	19	8.0	156	0	6.6	2.4	.3	.60
73-01-05	3.2	45	13	162	0	8.9	4.0	.6	.40
72-12-07	2.4	53	19	178	0	9.1	3.2	.7	.40
72-12-07	3.7	33	10	164	0	5.4	4.1	.5	.30
46-11-20	--	--	--	268	--	8.0	7.0	1.2	--
72-12-01	.2	100	5.4	237	4	8.3	9.2	4.8	.00
72-02-07	3.5	24	8.9	152	0	7.1	2.4	.4	.70
72-02-07	--	--	--	--	--	--	--	--	--
77-08-19	2.8	46	9.5	160	0	5.9	4.3	.6	.00
77-12-21	2.5	50	8.0	170	0	6.0	4.2	.6	.00
77-08-19	3.2	32	6.8	160	0	9.8	4.8	.4	.90
77-12-21	2.8	30	5.4	160	0	9.1	5.2	.3	1.7
78-06-01	2.8	55	9.0	170	0	6.4	4.6	.5	.00
77-08-19	2.6	37	7.4	150	0	6.7	4.1	.5	.50
77-12-21	2.7	38	7.5	150	0	6.7	3.8	.4	.10
77-08-19	1.1	2.4	1.4	130	0	10	2.6	.0	.90
77-08-19	3.5	41	8.8	160	0	8.0	3.4	.6	1.6
77-12-21	3.7	39	8.1	150	0	7.4	4.5	.5	1.2
78-06-01	1.5	75	9.0	200	0	6.0	4.7	.8	.00

Table 5.--Concentrations of major chemical constituents from selected wells completed in the Eocene-Paleocene aquifer, James City County, Virginia--Continued

STATION NUMBER	DATE OF SAMPLE	DEPTH OF WELL, TOTAL (FEET)	DEPTH TO TOP OF WATER-BEARING ZONE (FT)	DEPTH TO BOTTOM OF WATER-BEARING ZONE (FT)	TEMPERATURE (DEG C)	PH (UNITS)	SPECIFIC CONDUCTANCE (MICROMHOS)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)	SILICA, DISSOLVED (MG/L AS SIO2)	IRON, TOTAL RECOVERABLE (UG/L AS FE)	CALCIUM DISSOLVED (MG/L AS CA)
371925076452801	77-08-19	274	225	274	15.0	6.7	240	132	16	--	39
371934076441401	72-11-29	285	240	285	--	8.1	340	224	40	--	13
372102076460001	46-06-15	350	350	--	--	7.4	--	198	48	80	20
372148076461101	77-08-11	280	260	280	19.0	5.6	280	194	55	--	26
372201076461701	78-05-16	280	268	280	16.0	6.7	280	198	52	--	28
372213076485001	77-08-19	258	238	258	15.5	6.7	205	118	17	--	34
372251076482401	77-08-19	246	226	246	17.0	6.7	245	195	53	--	38
	77-12-21	246	226	246	17.0	7.7	264	192	53	--	38
	78-06-01	246	226	246	17.5	7.0	265	20	51	--	37
372309076420501	78-06-01	310	290	310	14.0	7.4	345	240	42	--	10
372310076411301	69-08-11	258	238	258	--	8.7	445	277	27	--	7.2
	72-12-07	258	238	258	--	8.6	415	268	38	--	4.4
372601076495301	72-12-01	265	245	265	--	8.0	288	226	66	--	37

Table 5.--Concentrations of major chemical constituents from selected wells completed in the Eocene-Paleocene aquifer, James City County, Virginia--Continued

OATE DF SAMPLE	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SODIUM, DIS-SOLVED (MG/L AS NA)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	BICAR-BONATE (MG/L AS HCO3)	CAR-BONATE (MG/L AS CO3)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	FLUO-RIDE, DIS-SOLVED (MG/L AS F)	NITRO-GEN, NITRATE DIS-SOLVED (MG/L AS NO3)
77-08-19	1.8	3.6	2.2	120	0	10	2.8	.1	.10
72-11-29	1.7	61	7.2	194	0	7.3	3.2	.8	.00
46-06-15	3.7	--	--	160	--	7.1	3.4	.4	--
77-08-11	3.6	23	7.0	150	0	5.3	3.2	.4	.40
78-05-16	3.5	21	6.5	150	0	5.9	10	.3	.00
77-08-19	1.1	3.3	1.5	93	0	9.8	3.5	.1	.00
77-08-19	2.4	12	5.0	140	0	9.0	3.9	.2	.00
77-12-21	2.5	13	4.6	140	0	8.5	2.8	.2	.00
78-06-01	2.3	12	4.8	140	0	6.6	3.2	.2	.00
78-06-01	2.6	65	10	170	0	9.6	14	.5	.10
69-08-11	1.0	97	7.8	231	13	11	9.9	.9	.80
72-12-07	.9	93	7.0	236	8	11	7.9	.9	20
72-12-01	2.6	20	6.3	168	0	8.3	4.0	.2	.40

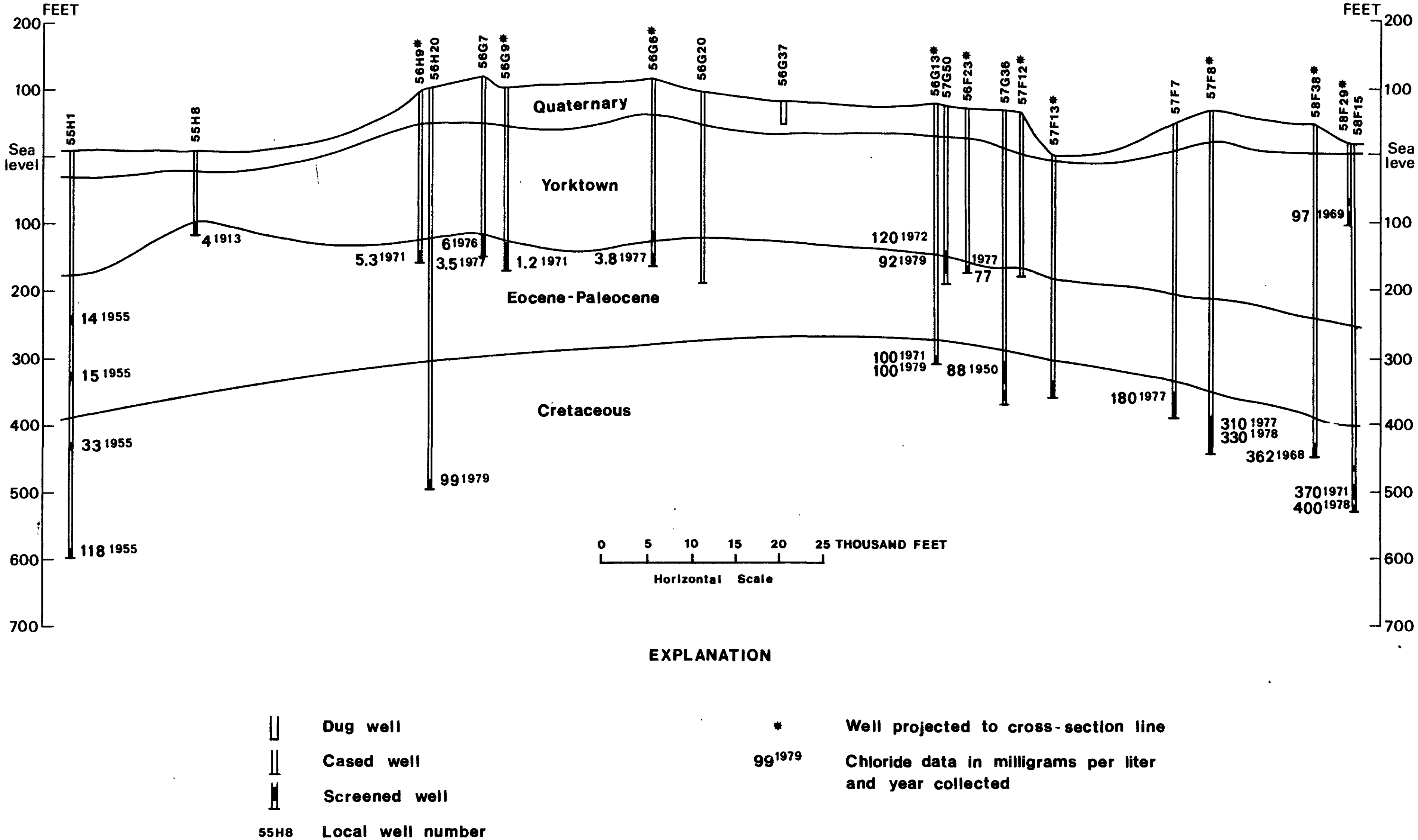


Figure 12.- Generalized hydrogeologic section across James City County, Virginia showing chloride concentrations of ground water.

units seem to have similar hydraulic properties; therefore, they are considered a hydrologic unit. Locally, relatively impermeable material may interrupt hydraulic continuity, causing head difference in the individual sand units. The estimated thickness of the aquifer ranges from 1,000 feet to 1,500 feet (fig. 13).

The Cretaceous aquifer overlies the basement rocks and is overlain by the Eocene-Paleocene aquifer in James City County. In the southeastern part of the county, about 30 square miles, part of the aquifer contains saline water. The aggregate sand and clay thickness penetrated by wells in the saline-water section of the aquifer is about 200 feet. In places, an individual sand unit may be slightly thicker than 75 feet.

Lower sand units probably contain saline water, but data are not available to define either the thickness and extent of the lower units or to determine the relation of fresh water to saline water.

Aquifer characteristics

Results of tests of the Cretaceous aquifer indicate that transmissivity ranges from 1,500 to 9,200 ft^2/d (table 3). In 1979, an aquifer test was made by the Geological Survey near Toano, Va. Well 56H21, screened at 545-555 and 570-610 feet, was pumped at 34 gal/min and obtained water from layers of sand and sandy clay. Wells 56H20 and 56H22, 10 and 100 feet from well 56H21, were used to observe water-level decline and recovery. The observation wells are screened, respectively, at 580-600 and 625-645 feet in the Cretaceous aquifer.

Analysis of drawdown and recovery data from wells 56H20 and 56H22 indicates transmissivity of 100 and 6,000 ft^2/d, respectively. The transmissivity of 6,000 ft^2/d which was calculated from the observation well 56H22, 100 feet from the pumped well, is considered representative of the aquifer and is least affected by partial penetration. In contrast, the transmissivity of 100 ft^2/d, which was computed from the effect of pumping on the water level of observation well 56H20, 10 feet from the pumped well, is most likely affected by partial penetration and poor well efficiency and is anomously low. A representative storage coefficient is estimated to be 0.0001. The storage coefficient of most confined aquifers is estimated to be 0.000001 per foot of thickness (Lohman, 1972).

Reported specific capacities of wells in the aquifer range from about 5 to 30 gal/min per foot of drawdown (fig. 14). Reported well yields range from 100 to 1,000 gal/min. The Cretaceous aquifer contains 545 to 1,050 billion gallons (estimated), of water in storage (table 2).

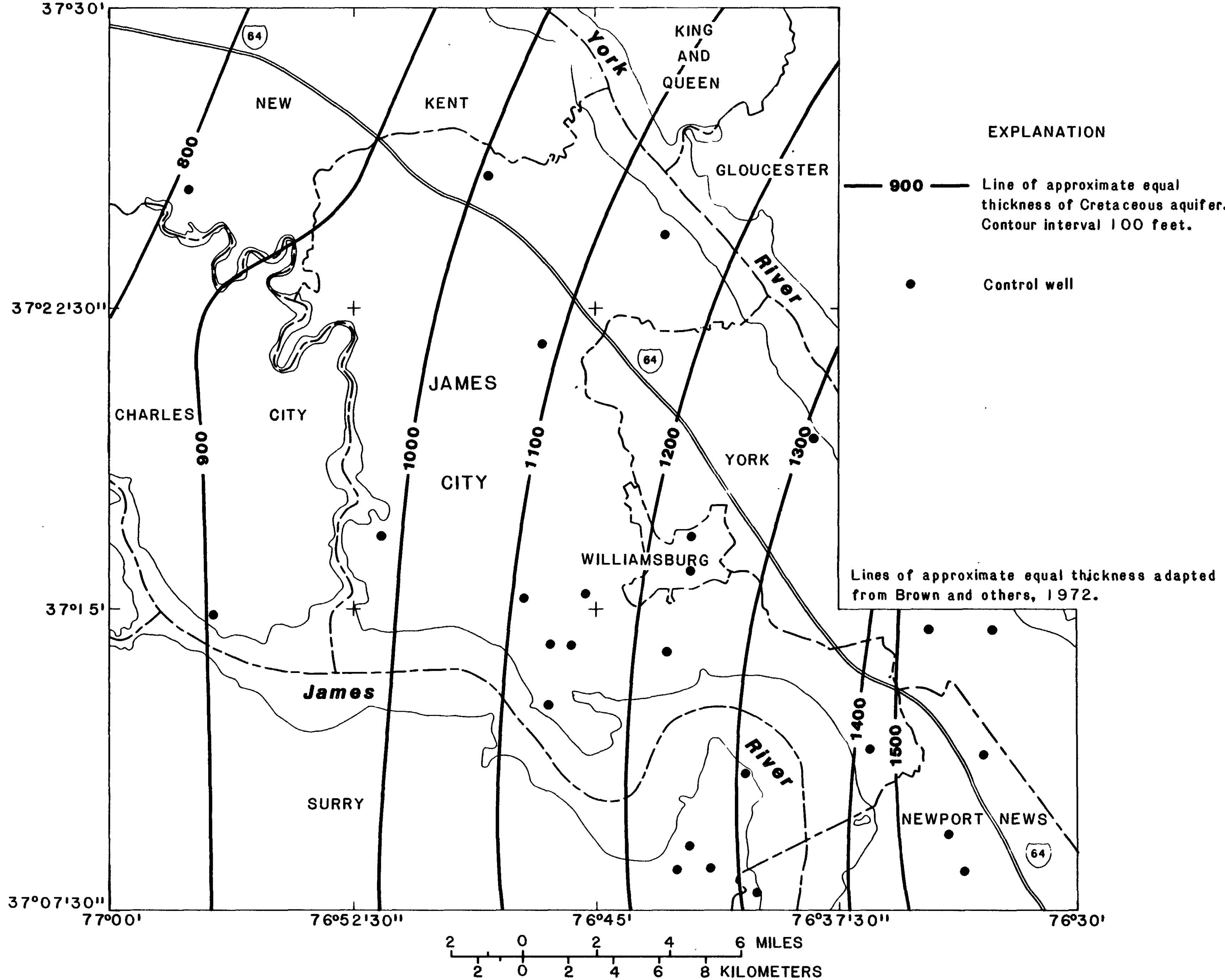


Figure 13.- Approximate thickness of Cretaceous aquifer, James City County, Virginia.

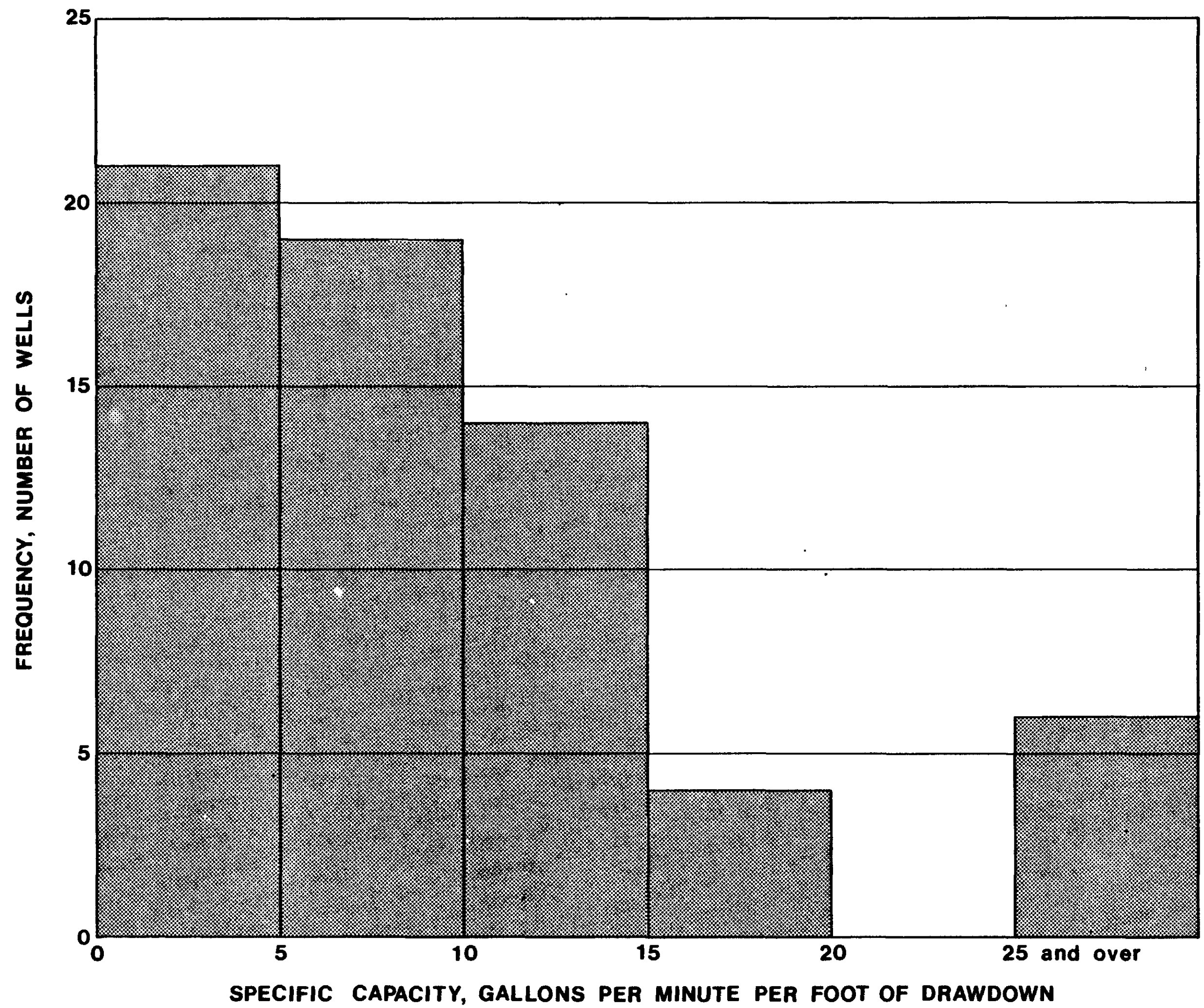


Figure 14. - Frequency distribution of specific capacities of 64 wells in the Cretaceous aquifer.

Recharge, movement, and discharge of ground water

The Cretaceous aquifer receives recharge by vertical leakage of fresh water from overlying aquifers and confining beds and by lateral movement of ground water from the west, where Cretaceous sediments crop out along the Fall Line. An undetermined amount of recharge takes place in and near the outcrop area, where deposits are more permeable. Recharge also takes place from streams incised into these deposits wherever the ground-water level is below stream level.

The permeability of a side-wall core, obtained from well 56H20 near Toano, was tested in the laboratory and had an average permeability of 2.42×10^{-4} feet per day. The sample is from a clay layer in the Cretaceous aquifer 523 feet below land surface. In the Toano area, the head difference between the Eocene-Paleocene aquifer and the Cretaceous aquifer is 70 feet. The confining unit is estimated to have a thickness of 85 feet. By Darcy's law and the above-discussed vertical permeability, vertical leakage over 1 square mile is computed to be 40,000 gallons per day or 6 Mgal/d over the entire county. This value is less than the estimated value of 10 Mgal/d shown in figure 15 because the permeability of the core sample used in the computation is only representative of the immediate testing area.

Estimated underflow to the entire county is computed to be 7 Mgal/d by areal flow-net analysis of the drawdown cone (fig. 16). Of the total estimated underflow, 3 Mgal/d is computed to occur through the 14-mile section A-A' (fig. 16).

Total pumpage in 1978 is estimated to be 7 Mgal/d (fig. 17); however, this estimate does not include the presumably negligible pumpage from private wells. Data on withdrawal from the Cretaceous aquifer by two municipal and industrial users were obtained from pumpage records. The major pumping centers are the Dow Badische Co. and Colonial Williamsburg well fields (fig. 2 and pl. 3). Average pumping rates in 1978 at these two sites were 4.5 and 2.5 Mgal/d, respectively. The present (1978) potentiometric surface slopes toward the cones of depression formed by the pumping (pl. 3). From 4 to 7 Mgal/d is pumped from centers north and south of James City County (fig. 15).

Water quality

The aquifer contains both fresh and saline waters. The water is predominantly sodium bicarbonate; chloride concentrations range from about 35 mg/L to 400 mg/L (table 6 and fig. 12). Figure 18 illustrates the composition of water in the Cretaceous aquifer.

EXPLANATION

A Quaternary aquifer

B Yorktown and Eocene–Paleocene aquifers

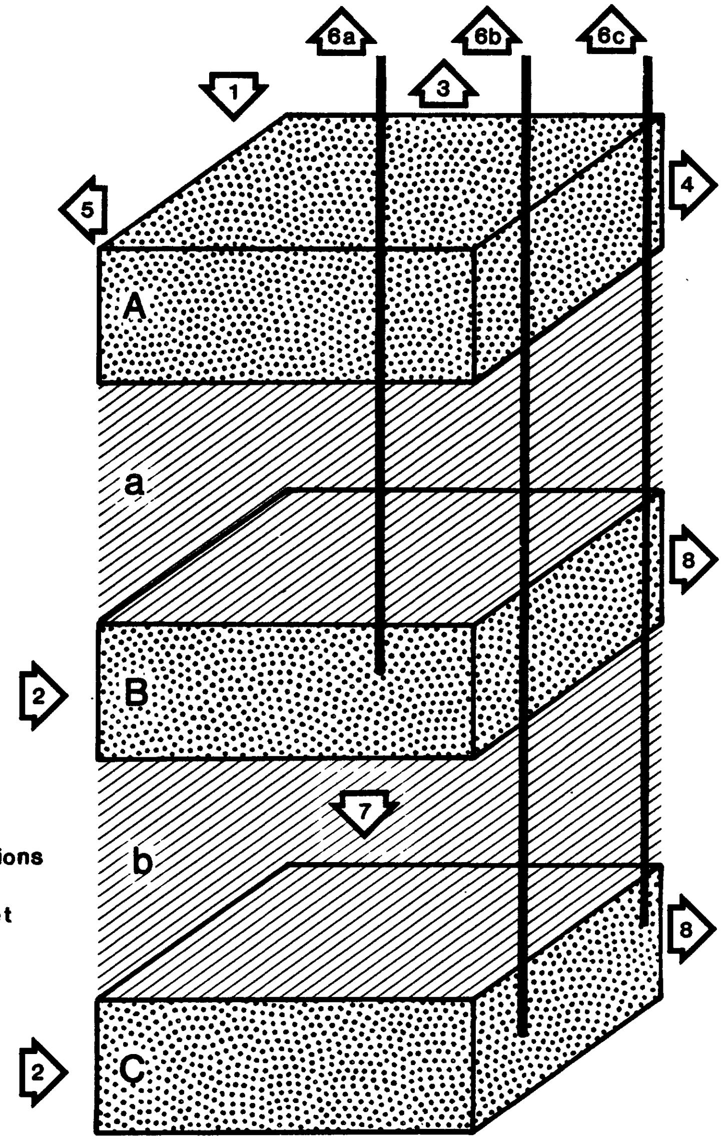
C Cretaceous aquifer

a, b Confining beds

5 Component of water budget

NOTE :

Ground–water underflow is from all directions toward a cone of depression created by pumping (the flow is computed by flow net method).

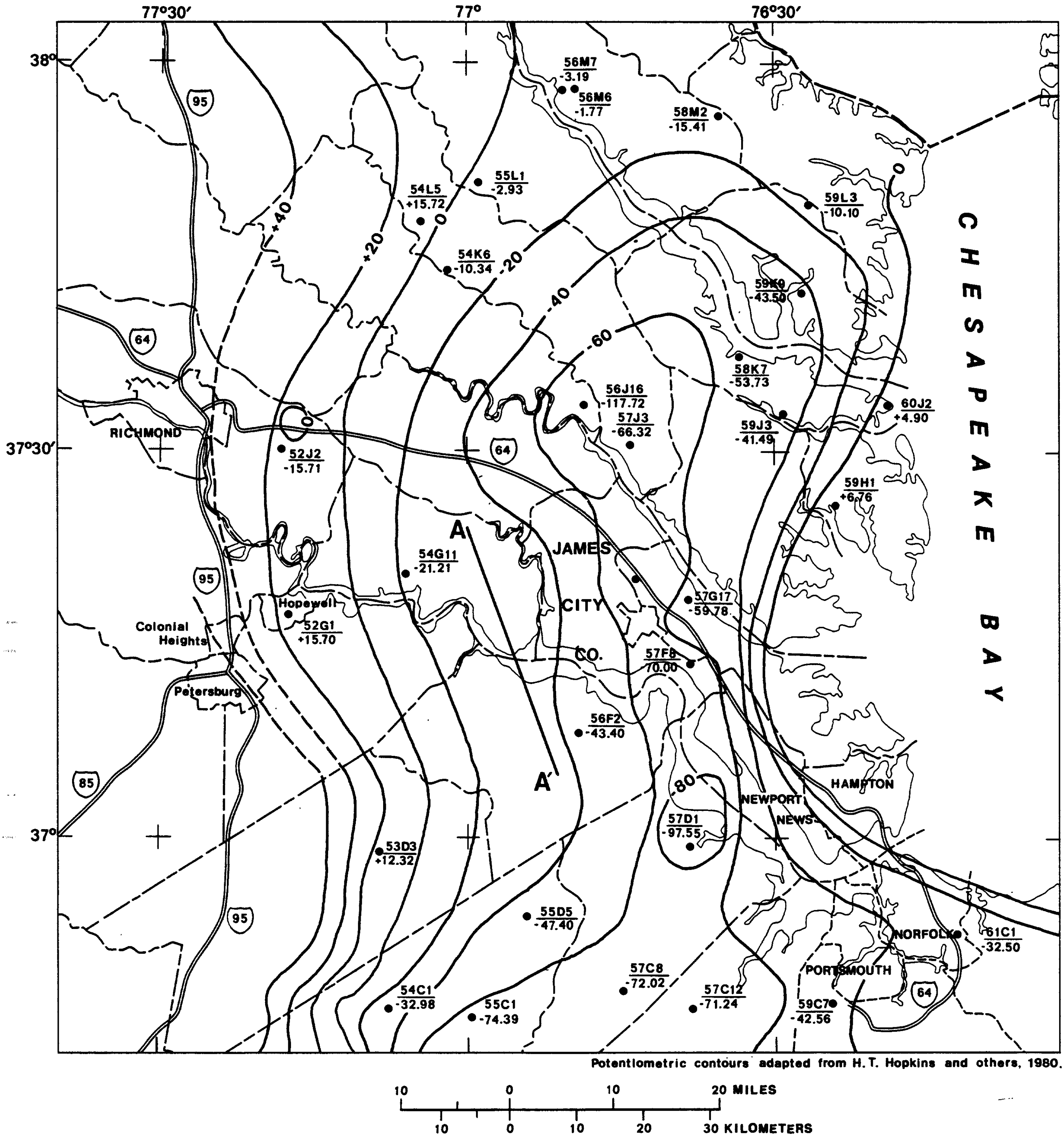


OVERALL ESTIMATED WATER–BUDGET ANALYSIS

		Mgal/d
INFLOW		
1 Precipitation		310
2 Underflow		10
	Total	320
OUTFLOW		
3 Evapotranspiration		190
4 Ground–water seepage to streams		65
5 Overland runoff		35
6 Pumpage to wells		15
a James City County	1 Mgal/d	
b Colonial Williamsburg and Dow Badische Company	7 Mgal/d	
c Adjacent pumping centers	7 Mgal/d	
7 Vertical leakage		10
8 Underflow		5
	Total	320

1 in/yr≈7 Mgal/d averaged over the area of the county, 148 mi^2

Figure 15. - Diagram showing estimated water balance for study area.



EXPLANATION

———-20———— Potentiometric contour—Shows altitude of potentiometric surface; dashed where approximate. Contour interval 20 feet. Datum is National Geodetic Vertical Datum of 1929 (NGVD).

Generalized flow line

• Well

55D5 / -47.40 Local well number and water level in reference to NGVD

A–A′ Section used to determine part of the underflow.

Figure 16. - Potentiometric surface map of Cretaceous aquifer showing generalized flow lines, Virginia Coastal Plain.

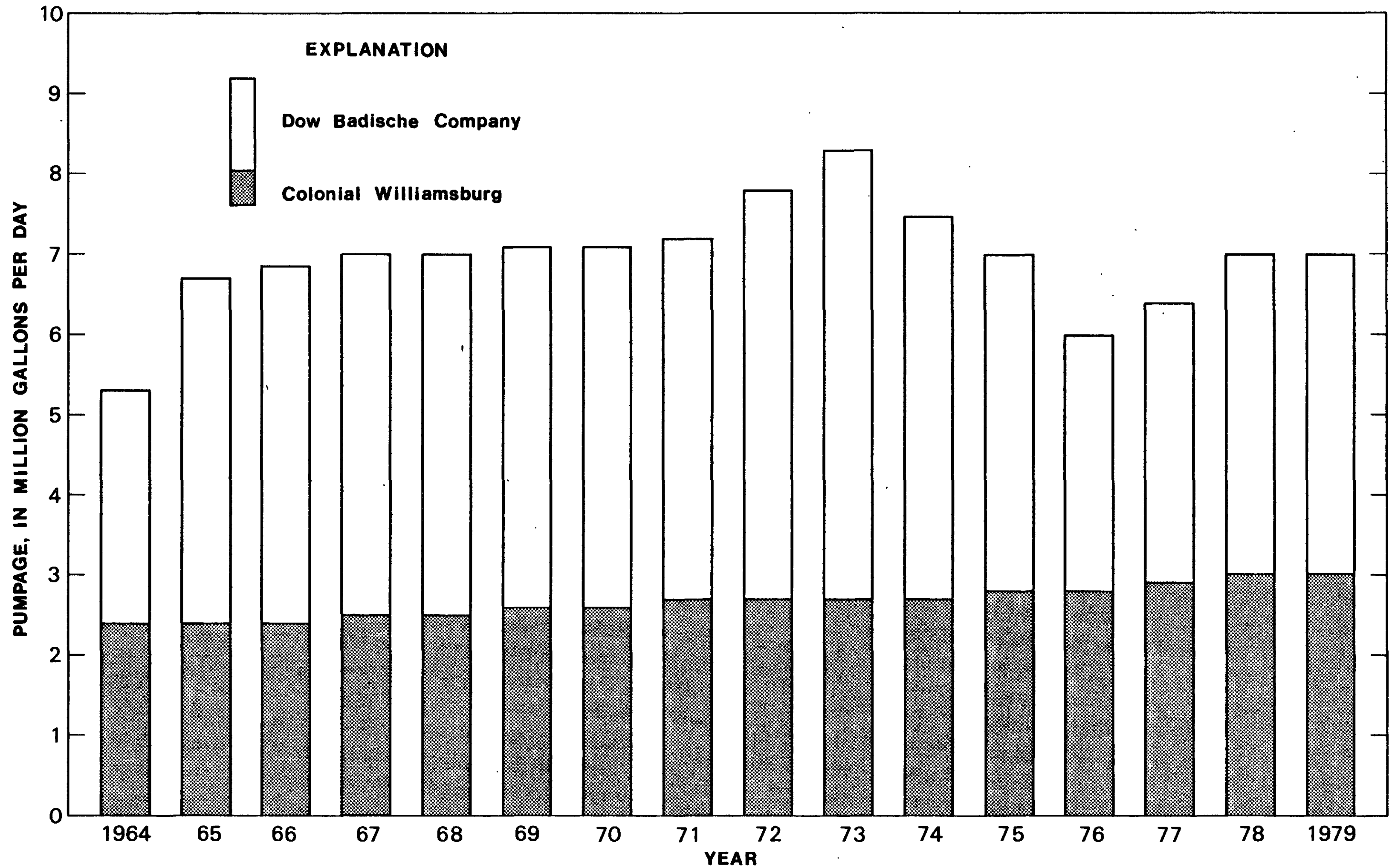


Figure 17. - Historic pumpage from the Cretaceous aquifer, James City County, Virginia.

Table 6.--Concentrations of major chemical constituents from selected wells completed in the Cretaceous aquifer, James City County, Virginia

STATION NUMBER	DATE OF SAMPLE	DEPTH OF WELL, TOTAL (FEET)	DEPTH TO TOP OF WATER-BEARING ZONE (FT)	DEPTH TO BOTTOM OF WATER-BEARING ZONE (FT)	TEMPERATURE (DEG C)	PH (UNITS)	SPECIFIC CONDUCTANCE (MICROMHOS)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)	SILICA, DISSOLVED (MG/L AS SIO2)	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)
371125076370401	69-10-27	524	444	524	--	8.0	1490	862	20	2.7	.9
	71-07-14	524	444	524	22.0	7.8	1500	860	25	2.8	1.1
371151076363801	69-10-27	545	450	545	--	8.1	1860	1030	21	3.0	1.1
	71-08-02	545	450	545	21.5	7.9	1870	1060	24	3.8	1.3
	78-06-02	545	450	545	21.0	6.9	1890	1090	24	3.3	1.1
371233076464001	71-07-20	340	331	340	22.0	7.9	650	402	25	.7	.3
	77-08-02	340	331	340	--	--	582	--	--	--	--
371250076355801	78-05-16	545	525	545	11.0	8.5	2140	1180	14	5.5	1.9
371250076365201	71-07-14	495	475	495	16.5	7.7	1400	795	21	30	2.2
371311076463601	72-04-27	337	325	337	13.0	7.4	1000	572	6.8	22	10
	79-02-02	337	325	337	6.0	6.4	1210	571	3.4	33	14
371314076460001	77-08-02	337	327	337	20.0	7.3	740	427	27	1.0	.2
371316076472701	77-08-02	370	360	370	19.0	6.9	600	371	26	.8	.1
371325076470701	71-07-01	336	309	336	21.5	8.0	500	322	23	1.1	.4
	77-08-02	336	309	336	19.0	6.7	615	333	23	.8	.1
	78-01-27	336	309	336	17.5	8.5	535	355	22	1.0	.2
371331076455801	77-08-19	315	285	315	17.0	7.6	595	358	20	1.4	.4
	77-12-21	315	285	315	17.0	8.3	550	362	19	1.3	.4
	78-06-02	315	285	315	22.0	7.7	555	355	13	3.2	1.1
371343076400801	77-08-02	470	347	463	20.0	6.7	1190	685	18	2.8	6.0
371353076473601	71-07-12	310	300	310	21.0	8.0	525	342	35	.8	.5
371405076463001	77-08-19	405	375	405	19.0	7.2	530	362	36	.7	.2
	77-12-21	405	375	405	17.5	7.6	545	352	35	.6	.2
371406076384301	77-08-02	500	451	500	20.0	6.0	1790	944	18	3.3	1.1
	78-06-02	500	451	500	20.0	7.8	1700	948	18	3.3	1.1
371424076391101	77-08-11	460	450	460	20.0	7.0	1600	892	17	4.2	1.5
	77-12-12	460	450	460	15.0	8.8	1510	875	8.8	3.3	1.0
371427076483701	71-07-07	460	374	441	18.5	8.0	700	412	32	7.9	3.9
	72-11-29	460	374	460	--	8.1	540	330	37	.3	.2
371447076463501	77-08-19	390	360	390	17.0	7.4	845	495	19	1.9	.6
	77-12-21	390	360	390	18.0	8.2	800	501	18	1.9	.6
	78-06-01	390	360	390	24.0	7.8	975	436	16	1.7	.5
371510076473001	71-07-14	210	--	--	21.0	8.0	460	280	38	.8	.5
371525076473001	69-10-27	520	460	520	--	8.5	1465	834	20	2.5	.8
	71-07-14	520	460	520	24.0	7.8	1460	820	23	2.0	1.2
371530076473001	69-10-27	530	470	530	--	8.5	1410	808	21	2.1	.7
	69-10-27	530	470	530	--	8.5	1410	808	21	2.1	.7
	71-07-14	530	470	530	21.0	7.9	1460	830	26	2.8	1.1
371535076473001	69-10-27	510	--	--	--	8.1	1850	1092	21	3.3	1.2
	71-07-14	510	--	--	22.0	7.8	1950	1090	24	3.6	1.9

Table 6.--Concentrations of major chemical constituents from selected wells completed in the Cretaceous aquifer, James City County, Virginia--Continued

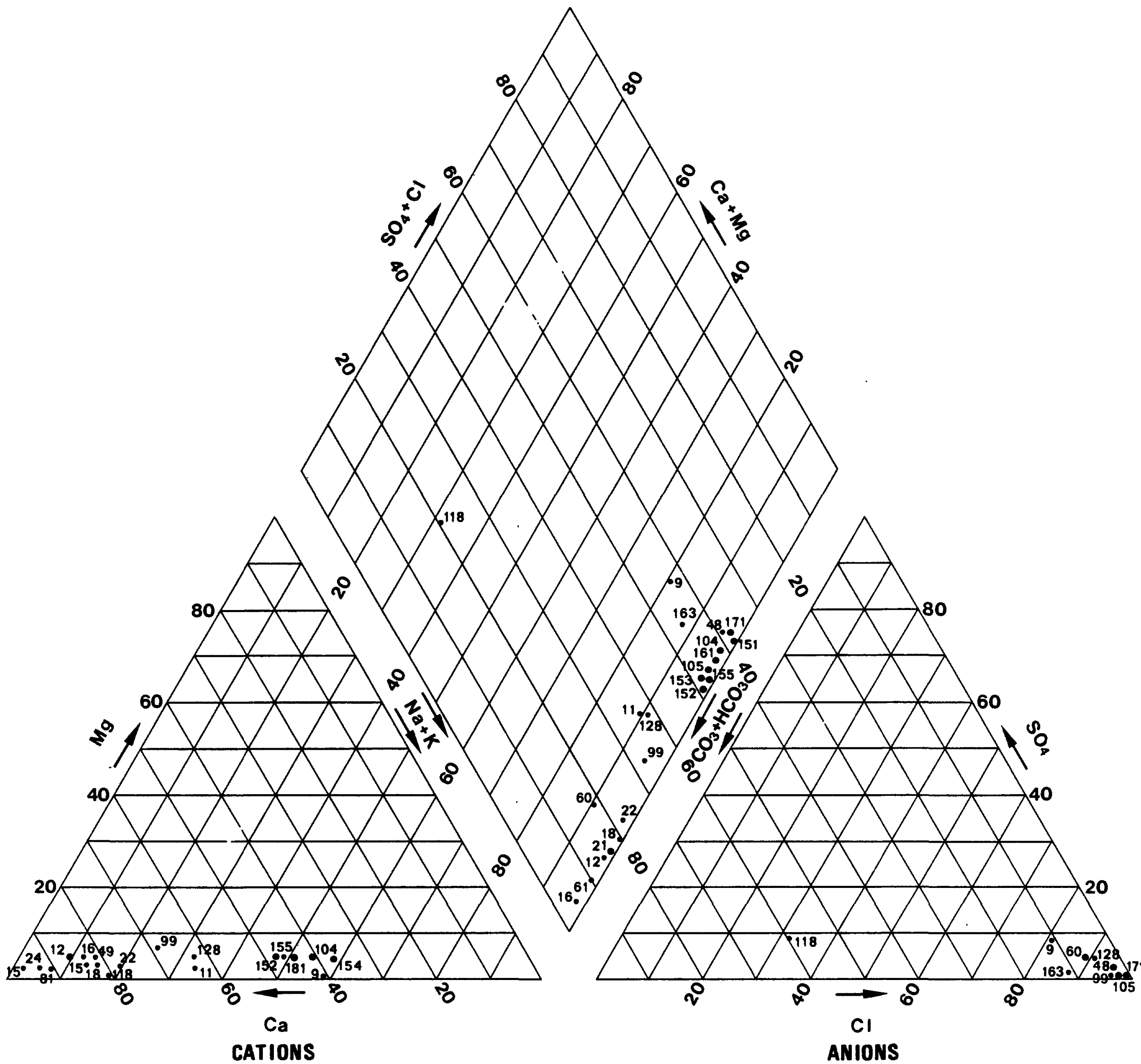
DATE OF SAMPLE	SODIUM, DIS- SOLVED (MG/L AS NA)	POTAS- SIUM, DIS- SOLVED (MG/L AS K)	BICAR- BONATE (MG/L AS HCO3)	CAR- BONATE (MG/L AS CO3)	SULFATE DIS- SOLVED (MG/L AS SO4)	CHLO- RIDE, DIS- SOLVED (MG/L AS CL)	FLUO- RIDE, DIS- SOLVED (MG/L AS F)	NITRO- GEN, NITRATE DIS- SOLVED (MG/L AS NO3)
69-10-27	314	13	410	0	28	252	2.9	.10
71-07-14	320	9.7	415	0	29	250	3.2	.20
69-10-27	402	16	416	0	35	360	2.7	--
71-08-02	400	10	415	0	38	370	2.9	--
78-06-02	420	10	420	0	33	400	2.4	.00
71-07-20	150	7.3	335	0	9.0	34	3.5	--
77-08-02	--	--	--	--	--	--	--	--
78-05-16	490	13	480	0	62	420	2.4	.00
71-07-14	270	8.7	373	--	27	240	2.0	--
72-04-27	180	13	258	0	2.0	200	1.8	4.9
79-02-02	190	15	250	0	1.6	240	.9	2.3
77-08-02	160	7.5	360	0	10	40	3.1	.60
77-08-02	150	5.6	330	0	8.5	22	3.2	.00
71-07-01	120	7.1	313	0	5.6	3.5	3.0	--
77-08-02	140	5.2	340	0	7.1	13	3.2	.20
78-01-27	140	4.7	340	0	7.8	12	3.4	.00
77-08-19	140	6.0	340	0	5.8	9.9	3.5	.00
77-12-21	140	5.0	350	0	6.1	9.3	2.9	.00
78-06-02	140	6.7	330	0	4.0	17	2.7	.90
77-08-02	280	7.5	420	0	18	180	2.3	1.2
71-07-12	120	4.3	273	0	12	19	3.8	.00
77-08-19	140	4.5	300	0	9.0	28	4.2	.00
77-12-21	140	4.1	300	0	8.2	27	3.8	.00
77-08-02	390	11	420	0	33	310	2.2	.10
78-06-02	380	10	420	0	28	330	2.3	--
77-08-11	360	12	430	0	31	280	2.6	.10
77-12-12	360	10	430	10	23	270	2.1	1.0
71-07-07	140	13	264	0	8.0	83	1.0	.70
72-11-29	120	4.1	267	0	8.1	19	3.8	--
77-08-19	190	8.2	400	0	11	60	2.5	.00
77-12-21	200	8.0	400	0	11	61	2.7	.00
78-06-01	180	7.0	470	0	8.7	55	2.3	.00
71-07-14	100	4.8	241	0	6.2	11	5.5	.00
69-10-27	314	13	398	12	26	250	3.0	.10
71-07-14	300	9.1	407	0	30	250	3.6	.00
69-10-27	314	13	400	10	25	235	3.1	--
69-10-27	314	13	400	10	25	235	3.1	.10
71-07-14	320	9.4	413	0	27	240	3.2	.10
69-10-27	402	17	412	0	34	367	2.6	.00
71-07-14	400	12	417	0	41	370	2.6	.10

Table 6.--Concentrations of major chemical constituents from selected wells completed in the Cretaceous aquifer, James City County, Virginia--Continued

STATION NUMBER	DATE OF SAMPLE	DEPTH OF WELL, TOTAL (FEET)	DEPTH TO TOP OF WATER-BEARING ZONE (FT)	DEPTH TO BOT-TOM OF WATER-BEARING ZONE (FT)	TEMPER-ATURE (DEG C)	PH (UNITS)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	SILICA, DIS-SOLVED (MG/L AS SIO2)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)
371538076400601	72-11-29	495	420	460	--	8.0	1950	1020	18	4.2	1.6
371550076401801	72-11-29	493	459	493	--	8.0	1900	1020	19	3.7	1.5
371550076473001	71-06-29	465	425	455	24.0	7.8	1680	940	19	3.0	1.1
371605076420301	71-07-13	470	408	466	--	--	1560	730	18	3.8	1.2
	75-05-20	470	--	--	19.0	--	1150	745	18	3.8	1.3
	77-12-12	470	--	--	18.0	7.8	1210	708	17	3.2	1.1
371618076413301	72-12-19	470	--	--	--	8.2	1600	940	18	4.6	1.7
371618076422301	71-07-13	438	409	432	--	8.0	1300	735	23	6.2	1.9
	77-12-12	438	--	--	18.0	7.5	1400	714	19	4.4	1.6
371623076420501	72-12-19	471	399	471	--	8.2	1600	930	18	4.4	1.6
	77-12-12	471	--	--	18.0	7.3	1390	855	17	3.9	1.3
371625076473001	71-07-08	440	420	440	22.0	7.9	820	480	29	8.5	4.1
371628076414501	72-12-19	445	350	445	--	8.0	1680	964	18	4.2	1.5
	75-05-20	445	--	--	20.0	--	1500	935	18	4.2	1.3
	77-12-12	445	--	--	18.0	7.6	2000	935	18	4.4	1.4
	78-06-01	445	--	--	20.0	7.8	1650	957	17	4.2	1.4
371630076473001	71-07-01	275	--	--	24.0	8.0	550	352	22	.5	.3
371640076473001	71-07-08	382	371	382	22.0	7.9	800	464	31	8.5	4.2
	79-02-05	382	371	382	17.0	8.3	772	453	33	9.3	4.2
371645076473001	71-08-02	475	--	--	20.0	7.8	1950	1090	21	4.2	1.4
371650076473001	71-07-14	475	--	--	23.5	7.8	2000	1100	22	4.8	1.4
371705076473001	71-07-14	400	370	400	18.5	8.0	440	260	31	5.6	1.7
371749076441801	67-03-20	550	410	550	--	8.1	--	1067	33	9.6	1.2
	72-03-29	550	410	550	15.0	7.9	155	89	1.0	18	1.3
371810076473001	72-12-01	490	480	490	--	8.1	1570	900	28	6.5	2.0
372313076480401	79-02-02	660	580	600	11.0	7.6	1050	573	32	6.1	.7
372313076480402	79-06-19	645	545	610	20.0	7.5	900	644	34	2.5	.4

Table 6.--Concentrations of major chemical constituents from selected wells completed in the Cretaceous aquifer, James City County, Virginia--Continued

DATE OF SAMPLE	SODIUM, DIS-SOLVED (MG/L AS NA)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	BICAR-BONATE (MG/L AS HCO3)	CAR-BONATE (MG/L AS CO3)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	FLUO-RIDE, DIS-SOLVED (MG/L AS F)	NITRO-GEN, NITRATE DIS-SOLVED (MG/L AS NO3)
72-11-29	400	12	423	0	37	330	2.4	1.2
72-11-29	400	12	427	0	37	320	2.5	.20
71-06-29	350	13	426	0	36	290	3.0	.20
71-07-13	280	11	422	--	24	190	2.6	--
75-05-20	280	11	430	--	21	190	2.3	.00
77-12-12	290	9.6	420	0	29	180	2.4	1.2
72-12-19	350	14	417	0	34	280	2.0	1.4
71-07-13	270	13	408	--	23	200	2.1	--
77-12-12	280	10	410	0	25	180	2.0	1.8
72-12-19	350	14	419	0	37	280	2.0	1.4
77-12-12	340	10	420	0	38	250	1.7	1.4
71-07-08	160	15	306	0	15	94	1.1	.60
72-12-19	360	14	427	0	37	300	2.2	--
75-05-20	360	12	433	--	29	300	2.2	.00
77-12-12	380	11	430	0	44	300	1.8	1.3
78-06-01	380	12	420	0	30	330	1.9	.00
71-07-01	130	7.0	338	0	9.8	7.9	3.5	.00
71-07-08	150	14	270	0	14	100	1.1	.60
79-02-05	150	13	270	0	15	100	.9	.00
71-08-02	400	11	431	0	39	370	2.9	.70
71-07-14	410	12	428	0	40	380	2.9	.50
71-07-14	84	9.4	216	0	9.0	23	1.1	.30
67-03-20	390	8.0	353	--	38	453	1.2	--
72-03-29	10	1.5	76	0	.6	10	.1	.10
72-12-01	330	16	367	0	45	300	1.4	1.5
79-02-02	240	8.6	460	0	37	99	1.6	--
79-06-19	220	6.9	450	0	31	79	1.9	.00



EXPLANATION

All analyses given in table 6
Index numbers given in appendix 1

152	Index number
•	Single well
•	Two or more wells

Figure 18. - Water-analyses diagram for the Cretaceous aquifer.

In western James City County, the concentration of dissolved solids in the upper parts of the aquifer ranges from 250 to 450 mg/L (table 6). As depth increases, the concentration of dissolved solids of water from multiscreened wells, particularly in Colonial Williamsburg and Jamestown, increases and ranges from 880 mg/L to 1,200 mg/L. A body of saline water in the aquifer is probably the source of this increase.

The areal distribution of concentration of dissolved solids and chloride and fluoride is shown in Plate 4. The variation in quality of water within the Cretaceous aquifer is most likely related to the historic pumping pattern, lithology, mineralogy, and presence of saline water. The variation of water quality is largely determined by the ground-water flow pattern, which is controlled partly by head distribution between different geohydrologic units within the multilayer aquifer system.

Hydrologic Budget Equation

The progress of a particle of water from the atmosphere to the land masses and oceans and its return to the atmosphere is termed the hydrologic cycle.

Water enters the study area mainly as infiltration from precipitation and to a smaller extent as streamflow and ground-water underflow. Water leaves the area by evaporation, transpiration, streamflow (including surface-water and ground-water runoff components), and ground-water underflow. In addition, water is discharged through wells.

A hydrologic budget is a convenient means to study ground water. An annual hydrologic budget without pumping can be written as:

$$P = ET \pm RO \pm U + \Delta S_g + \Delta S_s$$

where:

P = total precipitation

ET = evapotranspiration

RO = difference between stream outflow (-) and inflow (+)

U = ground-water outflow (-) and inflow (+)

ΔS_g = change in ground-water storage, both unsaturated and saturated

ΔS_s = change in storage of surface-water reservoirs

Normal annual precipitation is 42 inches. Of this total, 14 inches is discharged by runoff, and 28 inches is evapotranspiration and ground-water recharge under steady-state conditions (fig. 15). About 9 inches of the total runoff is derived from seepage of shallow ground water into streams, and 5 inches is overland runoff.

Elsewhere in the Atlantic Coastal Plain, the estimated ground-water recharge is between 25 and 50 percent of the average annual precipitation (Geraghty and Miller, 1978b). Through the use of the lowest estimate, ground-water recharge for the 148-square-mile area of James City County would be 10 inches per year, or 70 Mgal/d. As stated earlier, 9 inches, or 65 Mgal/d, seeps into streams as base flow from the shallow aquifer. Thus, recharge to the deep confined aquifers is estimated to be 1 inch per year, or 10 Mgal/d, and evapotranspiration is estimated to be 190 Mgal/d.

About 15 Mgal/d of water is discharged through wells; of this amount, 4 to 7 Mgal/d is estimated to discharge from pumping centers north and south of James City County. A small amount of the pumped water is used consumptively in crop production and manufactured goods. Lateral ground-water flow entering the study area is 10 Mgal/d, and 2 to 5 Mgal/d leaves the area; therefore, 5 to 8 Mgal/d of water from underflow supplements available ground water in the study area (fig. 15). Underflow was estimated by Darcy's law and the flow-net method.

DEVELOPMENT AND UTILIZATION OF GROUND-WATER RESOURCES

Substantial quantities of ground water underlie the entire study area and can be readily pumped. Except for zones of highly mineralized water (pls. 2 and 4), ground-water quality is acceptable for most uses. The most extensive and productive source of ground water is the Cretaceous aquifer.

Although surface water has been developed extensively on the York-James Peninsula, further development is not expected because: (1) potential reservoir sites have been utilized, and (2) few sites are available for small impoundments that would store water and augment low flows.

Size of Ground-Water Reservoir

The ground-water reservoir of James City County ranges in thickness from about 1,100 feet in the western part of the county to about 1,900 feet in the eastern part (fig. 3). Total volume of saturated sediments beneath James City County is about 40 cubic miles.

Estimated porosity is 30 percent; therefore, the estimated storage of ground water beneath the county is 12 cubic miles, or 13 trillion gallons. However, the amount of water that could be pumped from wells would be considerably less than the estimated amount, even if water levels were lowered to the bottom of the aquifers, because a certain amount of water would be retained by sediments. If the effective porosity is assumed to be 5-10 percent, the storage is between 650 to 1,300 billion gallons (table 2).

Potential Well Yield

Specific capacity is commonly an indicator of well potential. Observed specific capacities were used to develop a specific-capacity index to determine the quantity of water available in individual aquifers. A specific-capacity index is defined as the specific capacity of the well divided by the thickness of the interval that contributes water to the well. Aquifer thicknesses can be estimated from structure-contour maps. The observed specific capacities were not corrected for partial penetration, effective well radius, and well efficiency. The specific-capacity indices were plotted against percentage of wells for three different aquifers to obtain the relationship (fig. 19). The graph can be used to estimate yields of wells constructed in a specific aquifer with an estimation of the thickness of the interval that contributes water to the well. For example, if the estimated penetration in the Cretaceous aquifer is 100 feet, then the probability that a well has a specific capacity equal to or greater than 2 gal/min/foot drawdown is 9 percent or less, as shown in figure 19.

If transmissivity and storage coefficient are known, theoretical water-level declines (drawdown) caused by a constant pumping rate at any point and at any time can be calculated by the following Theis (1935) nonequilibrium equation:

$$s = \frac{Q}{4\pi T} W(u) \qquad (1)$$

and

$$u = \frac{r^2 S}{4Tt}, \qquad (2)$$

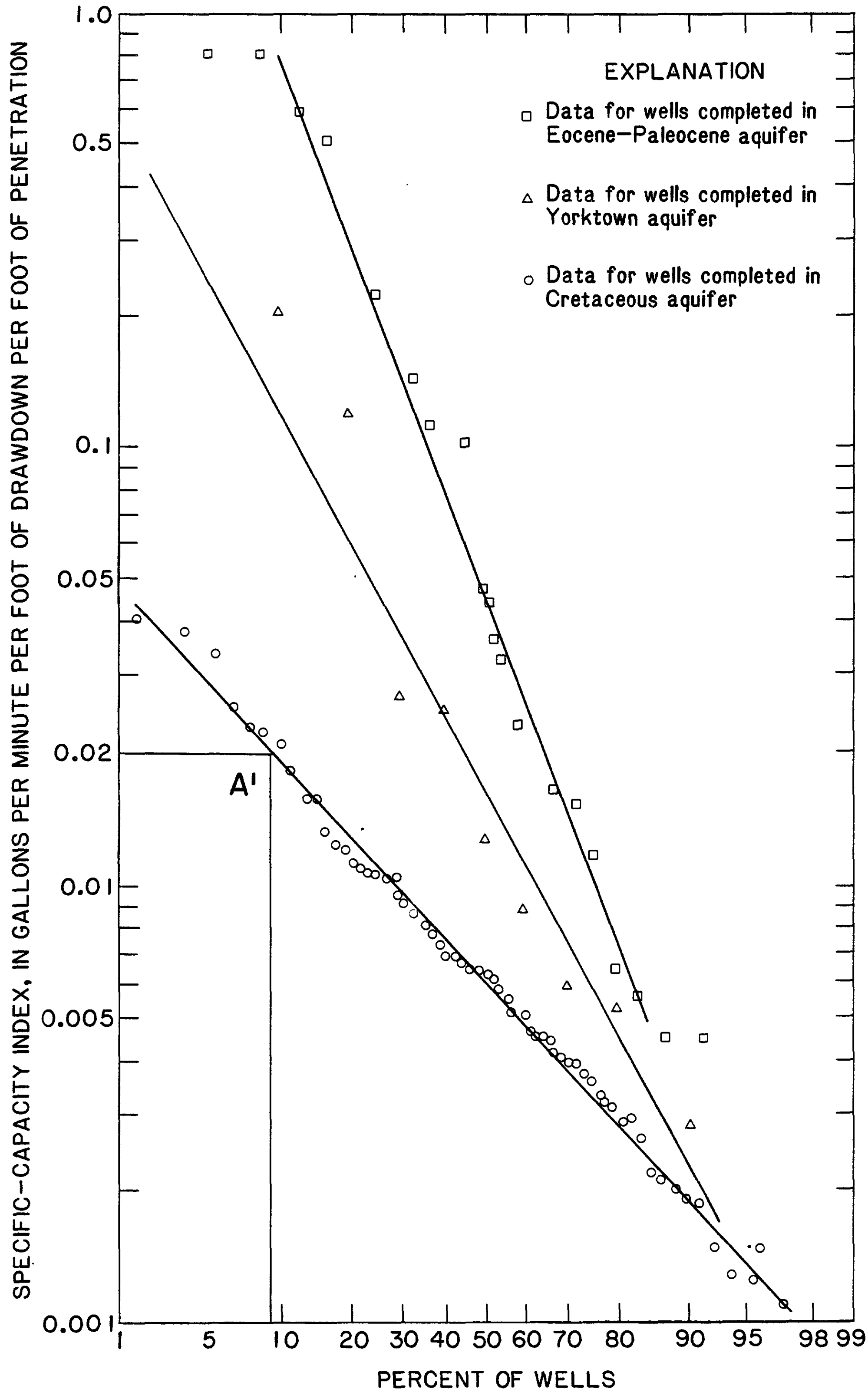


Figure 19. - Specific-capacity frequency graph for wells , James City County, Virginia.

in which s is drawdown at a radial distance (r) from the pumping well;

Q is well discharge $[L^3T^{-1}]$;

T is transmissivity $[L^2T^{-1}]$;

S is storage coefficient [dimensionless];

t is time since pumping started [t];

W(u) is known as the well function of u [dimensionless].

The assumptions of the equation, stated by Theis (1935) are: (1) the discharging well penetrates the entire thickness of the aquifer; (2) the well has an infinitesimal diameter; (3) the aquifer has infinite areal extent; (4) the water removed from storage is discharged instantaneously with decline in head; and (5) the aquifer is homogeneous and isotropic. These assumptions are seldom satisfied; nevertheless, the Theis equation is useful for an analytical solution to ground-water problems.

From equation 1, drawdowns at any distance produced by a well with a pumping rate of 1,000 gal/min during 3 time periods 1, 10, and 100 days are computed and shown in figure 20. Drawdowns induced by wells with a pumping rate other than 1,000 gal/min can also be obtained from figure 20, because drawdown is directly proportional to pumping rate. (See eq. 1.)

The drawdown of a single well pumping can be estimated with the aid of figure 21, which was constructed through the use of equation 1. For example, if a well is pumping for 100 days at a rate of 1,000 gal/min, the drawdown in an observation well caused by a pumping well at a distance of 1,000 feet is determined from figure 21 to be 19 feet.

Figure 21 can be used to estimate the cumulative effect of multiwell pumping. The cumulative effect of pumping two wells for 100 days at 1,000 gal/min, each at a distance of 1,000 feet from the same observation well, would be 19 feet for each well (fig. 21) for a total of 38 feet of drawdown.

The examples indicate how optimum well spacing can be determined. Note, however, few wells are 100 percent efficient and fully penetrate the aquifer; therefore, drawdowns will probably be somewhat greater than those estimated by this method.

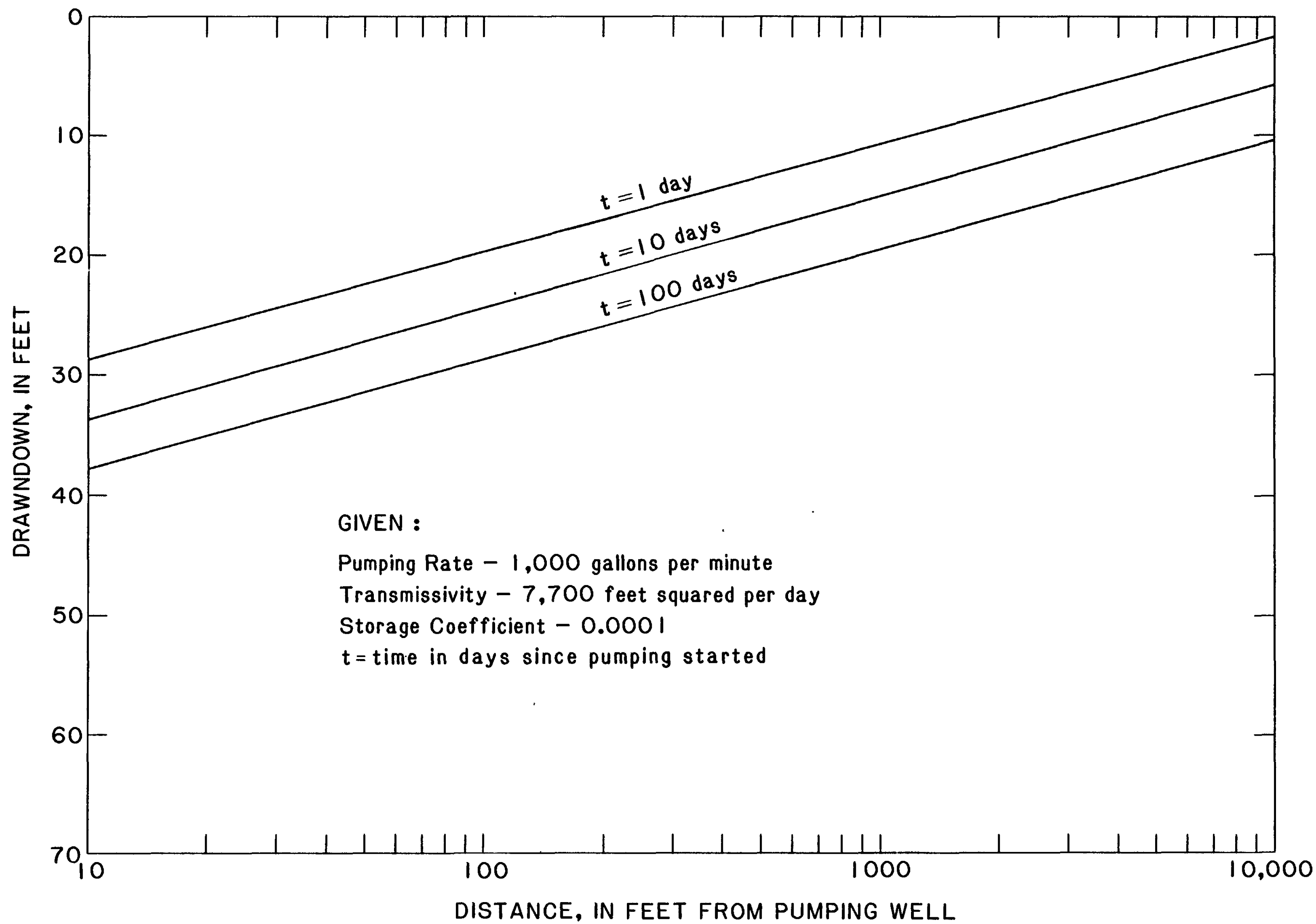


Figure 20. - Distance-drawdown graph showing effects of pumping from an ideal aquifer.

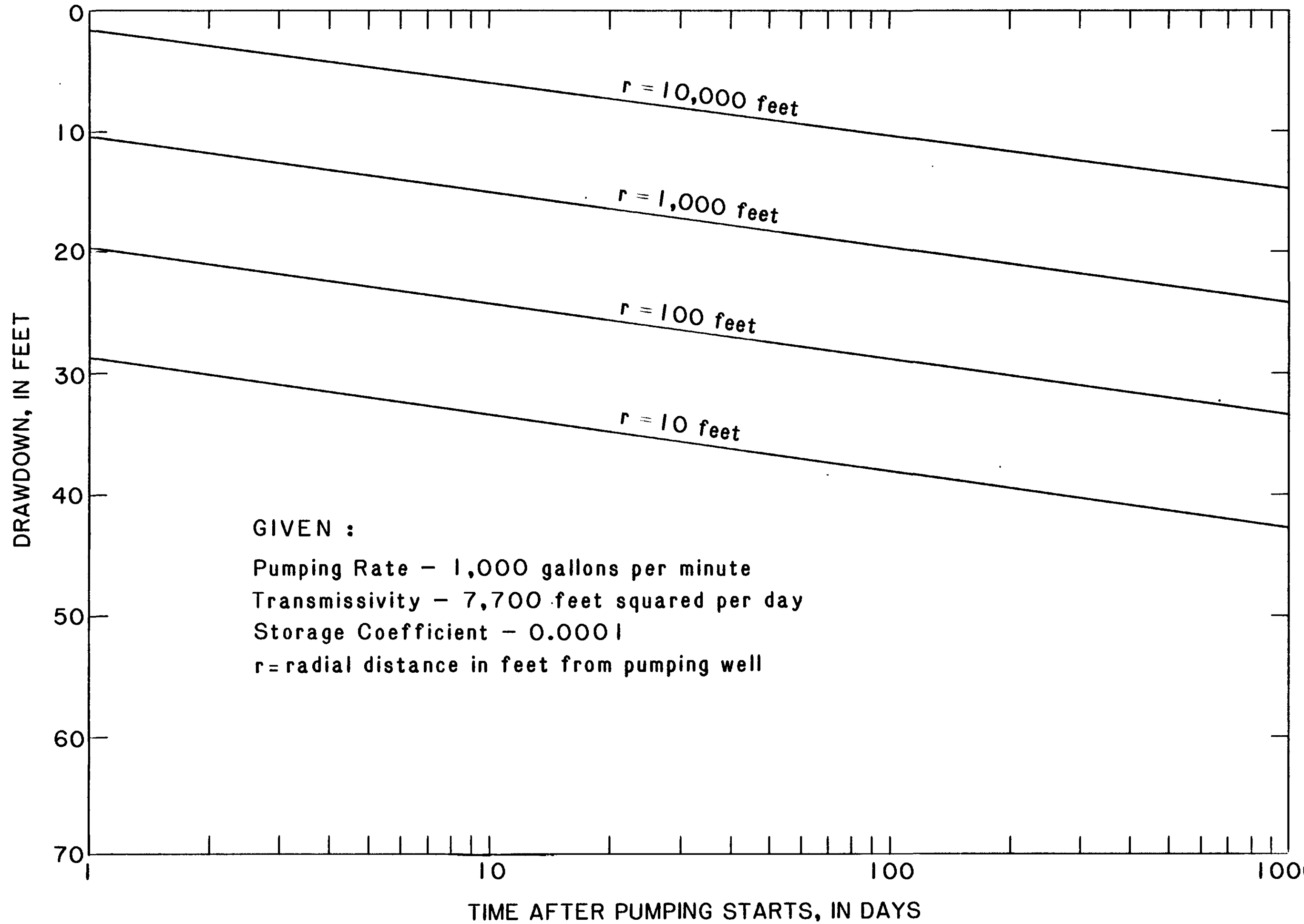


Figure 21 - Time-drawdown graph showing effects of pumping from an ideal aquifer.

Yield of the Ground-Water System

The yield of the multilayer aquifer system is dependent on recharge and discharge and the water stored in sediments. Before development, the system is under equilibrium--that is, recharge and discharge are equal. Ground-water levels have seasonal variations, yet long-term records indicate equilibrium.

The rate of ground-water recharge from precipitation in James City County is approximately 70 Mgal/d, compared to a total pumpage of 8 Mgal/d. About 65 Mgal/d seeps into streams from the shallow aquifer, and 10 Mgal/d is vertical leakage to the confined aquifers. Underflow is estimated to be 10 Mgal/d (fig. 15). From 4 to 7 Mgal/d of ground water moves toward pumping centers outside the county.

Current pumping (1978) has reduced the amount of ground water in storage. If pumping centers are distributed over the entire county, it is feasible to accomodate the expected daily demand of 9.8 Mgal/d in the year 2000. However, water will be withdrawn from storage, thus lowering water levels, or pumping may increase recharge through vertical leakage, thus reducing base flow in streams. The impact on the hydrologic system owing to increase in withdrawal cannot be evaluated in detail without a flow model.

RELATION OF SALINE WATER TO FRESH WATER

Saline water is present beneath fresh ground water in parts of the Eocene-Paleocene and Cretaceous aquifers. There is no sharp contact line between fresh and saline water because of diffusion. The fresh-saline water interface is defined by the 250 mg/L chloride contour line in this study.

Distribution of Fresh and Saline Water

According to water samples collected from wells 58F41 and 58F42 that are completed in the Eocene-Paleocene aquifer, saline water (250 mg/L or more) is penetrated about 300 feet below land surface southeast of Williamsburg.

Plate 4 shows the areal distribution of chloride and dissolved solids in the Cretaceous aquifer, and figure 12 shows a section of the contact between saline and fresh water. Saline water probably occupies the full thickness of the Cretaceous aquifer beneath Colonial Williamsburg and areas to the south and east. The western contact of saline and fresh water is marked by the position of the 250 mg/L chloride contour line. Fresh water probably overlies saline water beneath the north and west parts of the county.

Movement of Saline Water

Before pumping stresses were imposed the saline water in the Cretaceous aquifer probably was under equilibrium with fresh water.

The present study indicates that the position of the 250 mg/L chloride contour line in the Cretaceous aquifer closely corresponds with that mapped by Sanford in 1913 and Cederstrom in 1943. A comparison of the chloride concentration in selected wells indicates the position of the 250 mg/L chloride contour line in the county has been relatively stable since 1913.

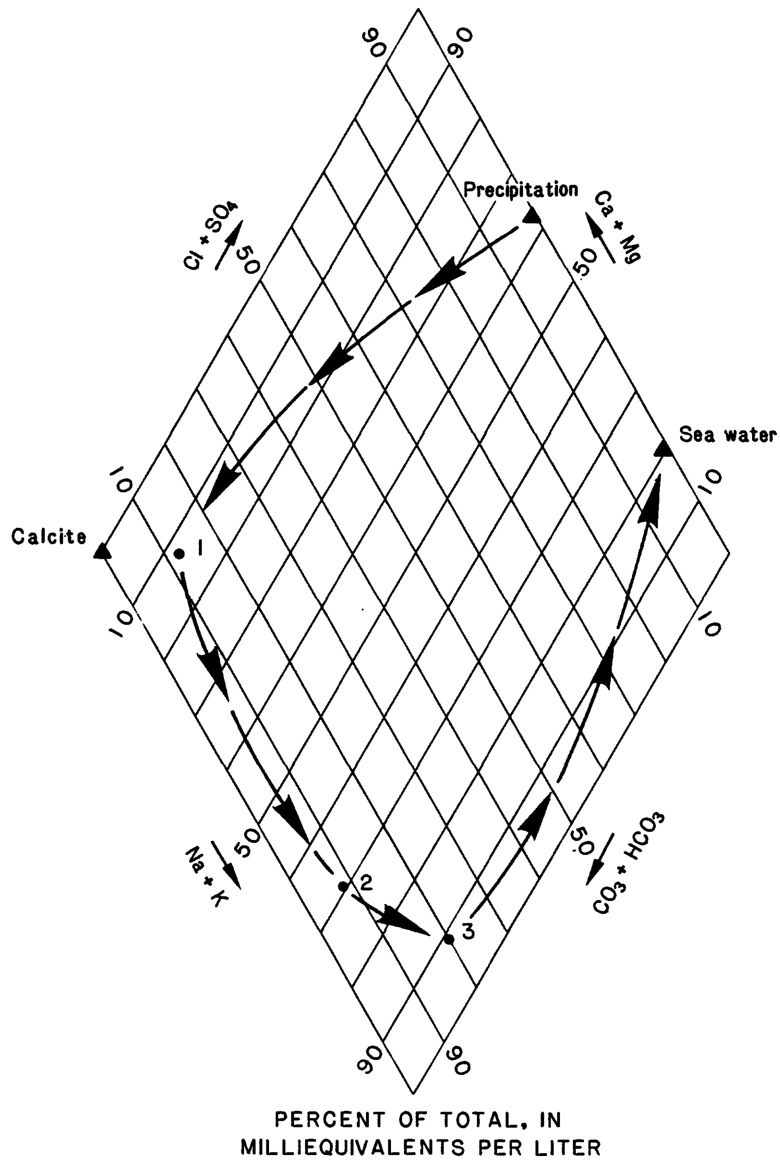
In areas of concentrated pumping, especially near Colonial Williamsburg and Dow Badische Co. well fields, the cone of depressions favor the movement of saline water toward the fresh-water part of the aquifers laterally and vertically.

Changes in Chemical Character of Ground Water

Water is changed chemically as it moves through sediments and reacts with minerals. The changes with depth from land surface through Quaternary to Cretaceous aquifer(s) of the major cations and anions are indicated by the arrows in figure 22.

The principal mineral dissolved in ground water of James City County is calcium carbonate. Solution of calcium carbonate from shell and limestone causes ground water to become enriched in calcium and bicarbonate and also raises the pH of the water (analysis 1, fig. 22). At some point, calcium in solution is exchanged for sodium held on mineral surfaces in the deposits. The removal of calcium by the exchange reaction generally continues as long as the ground water is not in equilibrium with the available calcite (Back, 1966). Bicarbonate is the dominant anion, but, as the exchange reaction continues, sodium replaces calcium as the dominant cation (analysis 2, fig. 22).

Saline sodium chloride water occurs in the deeper parts of the Eocene-Paleocene and Cretaceous aquifers. As fresh ground water mixes with saline water, it becomes enriched with sodium and chloride (analysis 3, fig. 22). The addition of chloride tends to decrease the relative percentage of bicarbonate. Magnesium, potassium, and sulfate may also be added to



EXPLANATION

← Direction of change in chemical character of ground water

ANALYSIS	SITE	DISSOLVED SOLIDS (mg/L)	AQUIFER
1	Well 57G27	150	Yorktown
2	Well 57H7	250	Eocene-Paleocene
3	Well 56G21	1000	Cretaceous

Figure 22. - Changes in chemical character of water in aquifers underlying James City County, Virginia.

ground water because of the mixing of fresh ground water with deep saline water (Cederstrom, 1946a).

The fluoride content is generally less than 1 mg/L and may be dependent upon the pH. Fluoride occurs in minor amounts in accessory minerals in most Coastal Plain sediments. These minerals have a low solubility. In water of high pH, for example water in the Cretaceous aquifer, hydroxide may be exchanged for fluoride on some mineral surfaces (Hem, 1970). The exchange of hydroxide for fluoride may account for the relatively high concentrations of fluoride (1-5 mg/L) in parts of the Eocene-Paleocene and Cretaceous aquifers, where the pH is close to 8. The increase in fluoride content may also be related to changes in the mineralogy of the deposits.

SUMMARY

The ground-water resources in James City County were studied to determine hydrologic characteristics of aquifers and to determine the effects of withdrawals on the ground-water resources and on the quality of water.

Normal annual precipitation is 42 inches. Of this total, 14 inches is discharged by runoff and 28 inches is ground-water recharge and evapotranspiration (fig. 15). About 9 inches of the total runoff seeps from the shallow aquifer into streams, and 5 inches is overland runoff. An estimated 27 inches is lost through evaporation and transpiration. Thus, recharge to the deep aquifers is about 1 inch per year.

Four aquifers underlie James City County and form a complex multilayer aquifer system. The Cretaceous aquifer is the most extensive and productive source of ground water. From 545 to 1,050 billion gallons of water is estimated to be stored in the aquifer. Current (1978) pumpage is 7 Mgal/d. The present (1978) potentiometric surface slopes toward the cones of depression formed by pumping centers at Colonial Williamsburg and Dow Badische Co. From 4 to 7 Mgal/d of ground water moves to pumping centers outside the county.

Specific-capacity indices were developed and used to estimate the potential well yield for a unit thickness of aquifer to be penetrated. Water-level declines at pumping centers can be estimated by the nonequilibrium equation of Theis (1935). This equation can also be used to evaluate interference between wells and to select optimum well spacing.

Water in the Eocene-Paleocene and Cretaceous aquifers is a calcium sodium bicarbonate chloride type and generally meets State standards for drinking water. The most likely threat to the quality of ground water is the potential of saline water, which occurs in the deeper parts of the Eocene-Paleocene and Cretaceous aquifers, to move toward the areas of concentrated pumping, particularly near Colonial Williamsburg and Dow Badische Co.

The amount of water stored in the entire multilayer aquifer system is estimated to be 650 to 1,300 billion gallons. If pumping centers are distributed over the county, the whole multilayer aquifer system can probably supply the projected pumping rate of 9.8 Mgal/d in year 2000 without seriously depleting the aquifer. Additional, detailed studies, involving a ground-water model, will be necessary to determine optimum well spacing and pumping rates.

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APPENDIX 1.--RECORDS OF WELLS, JAMES CITY COUNTY, VIRGINIA
[Depths are in feet below land surface]

INDEX NO. SHOWN IN FIG.2	STATION NUMBER	LOCAL WELL NUMBER		LATITUDE	LONGITUDE	DRILLER	OWNER OR NAME	DATE COMPLETED
4	372200076532101	55G 2		37 22 00 N	076 53 21 W	GRIFFITH	FARLEY, FRED	1965
--	372414076532801	55H 8		37 24 14 N	076 53 28 W	HAZELWOOD	HAZEWOOD, ROY E	1930
6	372411076533401	55H 9		37 24 11 N	076 53 34 W	HAZELWOOD	HAZELWOOD, RUBY	1913
7	372414076232401	55H 10		37 24 14 N	076 53 24 W	M HAZELWOOD	HAZELWOOD, MELBURN	1961
5	372417076532801	55H 11		37 24 17 N	076 53 28 W	GRIFFIN	HAZELWOOD, MELBURN H	1960
--	372532076533601	55H 12		37 25 32 N	076 53 36 W	HAZELWOOD	BOGAN, GERALD K	1939
--	372530076533401	55H 13		37 25 30 N	076 53 34 W	FETTERHOLF	LIBERTY, BAPTIST CH	1924
--	372527076533301	55H 14		37 25 27 N	076 53 33 W	S FETTERHOLF	LIBERTY, BAPTIST CH	1930
8	372333076535201	55H 15		37 23 33 N	076 53 52 W	UNKNOWN	WILKERSON, GORDON M	--
9	371311076463601	56F 1	SOW 18	37 13 11 N	076 46 36 W	MAGETTE R L	NATIONAL, PARK SERV	1958
10	371406076475701	56F 4		37 13 35 N	076 47 12 W	F CARMAN	WATTS, R B	1906
11	371427076483701	56F 8		37 14 29 N	076 48 38 W	SYDNOR HYDRO	FIRST COLONY NO. 1	08/27/1963
12	371353076473601	56F 9		37 13 53 N	076 47 36 W	BRENNEMAN	WHITE III, ALBERT L	03/ /1967
13	371300076453001	56F 10		37 13 00 N	076 45 30 W	CONOCO	CONOCO	11/21/1966
14	371228076464301	56F 11		37 12 28 N	076 46 43 W	SYDNOR HYDRO	VPVA	1930
15	371233076464001	56F 12		37 12 33 N	076 46 40 W	R L MAGETTE	NAT'L PARK, SERVICE	1956
16	371325076470701	56F 13		37 13 25 N	076 47 07 W	SYDNOR HYDRO	JAMESTOWN, FOUNDATION	03/28/1956
17	371316076472701	56F 14		37 13 16 N	076 47 07 W	R L MAGETTE	NAT'L PARK, SERVICE	12/18/1960
18	371314076460001	56F 15		37 13 14 N	076 46 00 W	R L MAGETTE	NAT'L PARK, SERVICE	1956
19	371434076481501	56F 16		37 14 34 N	076 48 15 W	SYDNOR HYDRO	COLONY SUBDIVISION NO. 2	03/03/1977
20	371406076463101	56F 17		37 14 06 N	076 46 31 W	DOUGLAS	JAMESTOWN 1607 NO. 1	02/ /1974
21	371405076463001	56F 18		37 14 05 N	076 46 30 W	DOUGLAS	JAMESTOWN 1607 NO. 2	03/22/1974
22	371447076463501	56F 19		37 14 47 N	076 46 35 W	W H GAMMON	ST. GEORGE HUNDRED	07/16/1973
23	371326076154201	56F 20		37 13 26 N	076 45 42 W	W H GAMMON	POWHATAN SHORES NO. 1	04/03/1976
24	371331076455801	56F 21		37 13 31 N	076 45 58 W	W H GAMMON	POWHATAN SHORES NO. 2	04/16/1976
25	371410076453101	56F 22		37 14 10 N	076 45 31 W	MITCHELL	RALEIGH SQUARE	04/03/1963
26	371411076450601	56F 23		37 14 11 N	076 45 06 W	MITCHELL	LAKEWOOD	05/12/1958
27	371415076480601	56F 24		37 14 15 N	076 46 06 W	H H SHAW	WALTHRID, LARRY T	1972
28	371422076455701	56F 25		37 14 22 N	076 45 57 W	H H SHAW	ARMSTEAD, ROBERT T	1957
29	371413076452501	56F 26		37 14 13 N	076 45 25 W	H H SHAW	NORMAN, RUSH N	1965
30	371325076471901	56F 27		37 13 25 N	076 47 19 W	GREENLEAF	VERMILLION, THOMAS R	1956
31	371352076455501	56F 28		37 13 52 N	076 45 55 W	W H GAMMON	CARTER, JOHN R	1972
32	371309076465601	56F 29		37 13 09 N	076 45 55 W	M S JEWETT	NAT'L PARK, SERVICE	1915
--	371354076470001	56F 30		37 13 54 N	076 47 00 W	VA DEPT HWYS	HIGHWAYS, VA DEPT OF	10/ /1977
33	371316076473501	56F 31		37 13 16 N	076 47 35 W	VA DEPT HWYS	HIGHWAYS, VA DEPT OF	10/ /1977
34	371335076471201	56F 33		37 13 35 N	076 47 12 W	MITCHELL	VERMILLION, THOMAS R	08/ /1942
35	371348076470201	56F 34		37 13 48 N	076 47 02 W	W H GAMMON	VERMILLION, THOMAS R	08/ /1969
36	371344076471201	56F 35		37 13 44 N	076 47 12 W	BRENNEMAN	VERMILLION, THOMAS R	1962
37	371337076471601	56F 36		37 13 37 N	076 47 16 W	BRENNEMAN	VERMILLION, THOMAS R	1963
38	371337076464801	56F 37		37 13 37 N	076 46 48 W	BRENNEMAN	VERMILLION, THOMAS R	1966

Note.--See "Explanation of abbreviations" on page 73.

APPENDIX 1.--RECORDS OF WELLS, JAMES CITY COUNTY, VIRGINIA
[Depths are in feet below land surface]

LOCAL WELL NUMBER		ALTITUDE OF LAND SURFACE (FEET)	DEPTH OF WELL (FEET)	CASING DIAM-ETER (INCHES)	DEPTH CASED	DEPTH TO FIRST OPENING (FEET)	SPECIFIC CAPACITY (GPM/FT)	DEPTH TO WATER (FEET)		DATE WATER LEVEL MEASURED	PUMP INTAKE SETTING (FEET)
55G 2		3	205.00	2	205	205	--	--		--	21
55H 8		3	115.00	2	105	105	--		F	09/27/1943	--
55H 9		3	128.00	2	105	105	--	7.00+		1913	--
55H 10		3	123.00	2	123	123	--	--		--	--
55H 11		3	106.00	2	106	106	--	1.29+		03/09/1978	--
55H 12		1	111.00	--	--	--	--	--		--	--
55H 13		10	144.00	--	--	--	--	--		--	--
55H 14		3	124.00	--	--	--	--	--		--	--
55H 15		6	216.00	--	--	--	--	2.67+		05/15/1978	--
56F 1	SOW 18	10	337.00	4	325	325	--	24.00		03/13/1969	--
56F 4		23	320.00	--	--	--	--	17.00+		1906	--
56F 8		18	467.00	4	467	374	19.4	20.00		08/26/1963	180
56F 9		20	310.00	4	300	300	--	41.43		12/06/1971	--
56F 10		15	370.00	--	--	--	--	--		--	--
56F 11		5	300.00	4	300	--	--		F	1930	--
56F 12		7	340.00	6	331	331	--		F	1956	252
56F 13		13	343.00	6	343	309	2.3	9.00		03/28/1956	--
56F 14		11	370.00	6	360	360	1.8	17.00		12/18/1960	216
56F 15		13	337.00	6	327	327	1.5	6.00		1956	125
56F 16		30	490.00	4	490	405	5.2	71.84		03/21/1977	200
56F 17		22	414.00	3	414	377	3.5	65.00		02/27/1974	--
56F 18		22	409.00	2.50	409	375	3.7	65.00	R	03/22/1974	--
56F 19		33	390.00	6	360	360	36.0	70.00		07/16/1973	168
56F 20		16	345.00	6	345	296	7.3	63.00		04/03/1976	--
56F 21		4	335.00	6	335	285	8.3	60.00		04/16/1976	--
56F 22		31	204.00	4.25	187	188	0.5	44.00	R	04/03/1963	--
56F 23		72	246.00	6	236	236	1.1	75.00		05/12/1958	--
56F 24		3	100.00	4	100	--	--	25.77	R	05/16/1978	--
56F 25		30	200.00	--	200	140	--	--		--	140
56F 26		39	220.00	4	220	--	--	64.24		09/20/1978	--
56F 27		5	400.00	--	--	--	--	--		--	--
56F 28		12	370.00	6	370	320	--	50.00		1972	--
56F 29		14	310.00	--	--	--	--	33.00+		1918	--
56F 30		25	172.00	--	--	--	--	--		--	--
56F 31		10	101.00	--	--	--	--	--		--	--
56F 33		23	376.33	4.02	376	--	6.3	16.00		08/ /1942	--
56F 34		23	321.00	4	301	301	--	--		--	--
56F 35		23	315.00	--	--	--	--	--		--	--
56F 36		30	315.00	--	--	--	--	73.12		04/20/1978	--
56F 37		15	315.00	--	--	--	--	65.05		04/20/1978	--

Note.--See "Explanation of abbreviations" on page 73.

APPENDIX 1.--RECORDS OF WELLS, JAMES CITY COUNTY, VIRGINIA
[Depths are in feet below land surface]

LOCAL WELL NUMBER		LITHOLOGY OF PRINCIPAL AQUIFER	TYPES OF LOGS AVAILABLE	OTHER DATA AVAILABLE QW	WL	LG	CK
55G 2		--	--				C
55H 8		SAND	--				C
55H 9		SAND	--		I		C
55H 10		SAND	--				C
55H 11		SAND	--		I		C
55H 12		SAND	--				C
55H 13		--	--				C
55H 14		--	--				C
55H 15		--	--		I		C
56F 1	SOW 18	--	C,E,J	H	I	G	C
56F 4		SDGL,RED SOIL	--		I		C
56F 8		CLAY,LIGHT GRAY	D,E		I	G	C
56F 9		SAND	--		I		C
56F 10		CLAY,GRAVEL	E,G,J			G	U
56F 11		--	--	H	I		C
56F 12		CLAY,RED	D	B	I	G	C
56F 13		SDGL,CLAYEY	D	A	I	G	C
56F 14		--	--	B	I		C
56F 15		CLAY,SANDY	D	B	I	G	C
56F 16		SAND,CLAYEY SILTY	D		I	G	C
56F 17		SAND,CLAYEY, SILTY	D,G		I	G	C
56F 18		SAND,FINE TO MEDIUM	D	B	I	G	C
56F 19		CLAY,RED	D	A	I	G	C
56F 20		SAND	D		I	G	C
56F 21		SAND,RED, CLAYEY	D	A	I	G	C
56F 22		CLAY	D		I	G	C
56F 23		SDGL	D	A	I	G	C
56F 24		--	D		I	G	C
56F 25		--	D			G	C
56F 26		--	--		I		C
56F 27		--	--				C
56F 28		--	--		I		C
56F 29		--	--	B	I		C
56F 30		SAND,SILTY BROWN	D			G	C
56F 31		CLAY,ORGANIC, SILTY	D			G	C
56F 33		--	D		I	G	C
56F 34		--	--				C
56F 35		--	--				C
56F 36		--	--		I		C
56F 37		--	--		I		C

Note.--See "Explanation of abbreviations" on page 73.

APPENDIX 1.--RECORDS OF WELLS, JAMES CITY COUNTY, VIRGINIA
[Depths are in feet below land surface]

INDEX NO. SHOWN IN FIG.2	STATION NUMBER	LOCAL WELL NUMBER	LATITUDE	LONGITUDE	DRILLER	OWNER OR NAME	DATE COMPLETED
--	371430076470201	56F 38	37 13 32 N	076 47 03 W	O BRENNEMAN	4-H CAMP	1935
39	371630076473001	56F 39	37 13 41 N	076 47 29 W	O BRENNEMAN	JAMESTOWN, 4-H CAMP	1946
--	371341076472901	56F 43	37 13 41 N	076 47 29 W	O BRENNEMAN	JAMESTOWN, 4-H CAMP	09/ /1967
40	371231076464201	56F 44	37 12 31 N	076 46 42 W	SYDNOR HYDRO	NAT'L PARK, SERVICE	1905
41	372102076460001	56G 1	37 21 02 N	076 46 00 W	MITCHELL	MASSIE, JACK L	1940
--	371613076503001	56G 19	37 16 13 N	076 50 30 W	H H SHAW	JONES, WILLIAM	12/16/1968
43	371909076471101	56G 3	37 19 09 N	076 47 11 W	SYDNOR HYDRO	FOREST GLEN NO. 2	12/29/1972
44	371925076452801	56G 4	37 19 26 N	076 45 28 W	SYDNOR HYDRO	LONG HILL NO. 2	06/28/1973
45	371910076454301	56G 5	37 19 10 N	076 45 43 W	SYDNOR	LONG HILL NO. 1	06/14/1973
46	371905076471201	56G 6	37 19 05 N	076 47 12 W	SYDNOR HYDRO	FOREST GLEN NO. 1	06/20/1972
47	372213076485001	56G 7	37 22 13 N	076 48 50 W	W H GAMMON	TOANO NO. 2	08/30/1976
48	371810076473001	56G 8	37 20 08 N	076 47 32 W	R L MAGETTE	PEN SCOUT, RESERVATION	11/ /1965
49	371520076473001	56G 9	37 21 49 N	076 46 12 W	SYDNOR HYDRO	JAMES CITY, SCHOOL BRD	10/13/1966
51	372200076460701	56G 10	37 22 06 N	076 46 07 W	SYDNOR HYDRO	C&O RAILRD	1909
52	372206076460702	56G 11	37 22 06 N	076 46 07 W	VA MACH WELL	C&O RAILRD	1944
53	371758076452301	56G 12	37 17 58 N	076 45 23 W	MITCHELL	WILLIAMSBG, WEST CORP	03/ /1968
42	371640076473001	56G 13	37 15 34 N	076 45 01 W	SYDNOR HYDRO	INDIGO PARK	07/25/1955
54	372201076461701	56G 14	37 22 01 N	076 46 17 W	BRENNEMAN	NORGE, WATER CO	02/16/1955
55	372148076461101	56G 15	37 21 48 N	076 46 11 W	R L MAGETTE	BRUNK, MECHANICAL	11/09/1972
56	371834076453601	56G 16	37 18 34 N	076 45 36 W	MITCHELL	WINDSOR FOREST	08/ /1971
57	371509076480301	56G 17	37 15 09 N	076 48 03 W	R L MAGETTE	BOANSCOMBE, ROBERT	04/12/1963
58	372213076464301	56G 18	37 22 13 N	076 46 43 W	--	BARNETT, JOHN B	1930
59	371810076431201	56G 20	37 18 10 N	076 48 12 W	H H SHAW	JAMES RIVR, BAPTIST CH	1962
60	371705076473001	56G 21	37 15 57 N	076 52 00 W	W H GAMMON	MIDKIFF, DORTHY F	10/ /1970
61	371502076455901	56G 22	37 15 02 N	076 45 59 W	GAMMON	SAUNDER, EDMUND	1971
62	372055076453301	56G 23	37 20 55 N	076 45 33 W	GAMMON	WILLIAMSBG, POTTERY	1970
63	372055076453302	56G 24	37 20 55 N	076 45 33 W	GAMMON	WILLIAMSBG, POTTERY	1970
64	372100076454201	56G 25	37 21 00 N	076 45 42 W	GAMMON	WILLIAMSBG, POTTERY	1971
65	372105076454601	56G 26	37 21 05 N	076 45 46 W	W H GAMMON	WILLIAMSBG, POTTERY	1970
66	372109076454801	56G 27	37 21 09 N	076 45 48 W	W H GAMMON	WILLIAMSBG, POTTERY	1976
67	372113076454501	56G 28	37 21 13 N	076 45 45 W	W H GAMMON	MILLER, ROBERT E	04/ /1977
68	372201076461702	56G 29	37 22 01 N	076 46 17 W	O BRENNEMAN	NORGE, WATER CO	02/16/1955
69	372041076521701	56G 30	37 20 41 N	076 52 17 W	UNKNOWN	MENZEL, GARY J	1935
70	371924076513601	56G 31	37 19 24 N	076 51 36 W	T P BINNS	RICHARDSON, JOHN C	1920
71	361927076504801	56G 32	37 19 27 N	076 50 48 W	T P BINNS	RICHARDSON, JOHN C	1920
72	371606076521001	56G 33	37 16 06 N	076 52 10 W	T P BINNS	HOLIDAY, INN CAMPGD	1938
--	371538076520301	56G 34	37 15 38 N	076 52 03 W	T P BINNS	TERRELL CO, JOSEPH	1939
73	371701076515701	56G 35	37 17 07 N	076 51 57 W	T P BINNS	BROWN, R M	1920
74	371718076491801	56G 36	37 17 18 N	076 49 18 W	T P BINNS	HEATH, EARL M	1915

Note.--See "Explanation of abbreviations" on page 73.

APPENDIX 1.--RECORDS OF WELLS, JAMES CITY COUNTY, VIRGINIA
[Depths are in feet below land surface]

LOCAL WELL NUMBER	ALTITUDE OF LAND SURFACE (FEET)	DEPTH OF WELL (FEET)	CASING DIAM-ETER (INCHES)	DEPTH CASED	DEPTH TO FIRST OPENING (FEET)	SPECIFIC CAPACITY (GPM/FT)	DEPTH TO WATER (FEET)		DATE WATER LEVEL MEASURED	PUMP INTAKE SETTING (FEET)
56F 38	10	280.00	--	--	--	--	--		--	--
56F 39	20	275.00	--	--	--	--	--		--	--
56F 43	20	308.00	4	288	288	--	--		--	--
56F 44	10	267.00	6	267	--	--	31.00+		1905	--
56G 1	110	350.00	4.50	350	--	0.8	105.00		1940	185
56G 19	15	320.00	4	319	319	--	--		--	--
56G 3	115	282.00	6	282	225	23.7	116.00		12/29/1972	--
56G 4	123	274.00	6	280	225	10.9	117.67	T	06/29/1973	--
56G 5	88	276.00	6	276	200	3.3	91.67		06/14/1973	--
56G 6	120	282.00	6	282	225	48.0	115.58	R	06/21/1972	214
56G 7	121	270.00	6	270	238	6.8	110.00		08/30/1976	--
56G 8	143	490.00	4	480	480	--	160.00		11/ /1965	189
56G 9	103	273.00	6	273	221	12.5	121.00		10/13/1966	121
56G 10	100	418.00	--	--	--	--	--		--	--
56G 11	100	86.00	6	50	50	--	--		--	--
56G 12	65	246.00	6	225	225	11.4	82.00		03/ /1968	--
56G 13	83	389.00	4.50	389	371	3.9	77.00		07/25/1955	--
56G 14	113	280.00	4	268	268	--	--		--	--
56G 15	103	280.00	6	260	260	5.0	105.00		11/09/1972	--
56G 16	104	277.00	--	--	255	10.9	110.00	T	08/ /1971	--
56G 17	24	360.00	--	--	--	--	--		--	--
56G 18	105	54.00	24	54	--	--	38.29		07/27/1978	--
56G 20	97	285.00	4	285	--	--	106.52		09/20/1978	150
56G 21	23	400.00	6	370	370	--	61.94		05/16/1978	--
56G 22	72	414.00	3	414	374	--	--		--	--
56G 23	103	290.00	4	290	--	--	--		--	--
56G 24	103	290.00	4	290	--	--	120.46		09/20/1978	--
56G 25	112	285.00	4	285	--	--	--		--	--
56G 26	112	280.00	4	280	--	--	129.72		06/23/1978	--
56G 27	108	290.00	4	290	--	--	--		--	--
56G 28	103	280.00	4	280	--	--	121.38	T	04/20/1978	--
56G 29	113	280.00	4	268	268	--	--		--	--
56G 30	7	117.00	--	--	--	--	--		--	--
56G 31	1	126.00	2	126	--	--	5.80+		09/23/1943	--
56G 32	8	126.00	2	126	--	--	--		--	--
56G 33	2	125.00	2	125	--	--		F	1938	--
56G 34	1	105.00	2	105	--	--	--		--	--
56G 35	1	212.00	2	212	--	--	3.50+		09/23/1943	--
56G 36	3	130.00	2	130	--	--	--		--	--

Note.--See "Explanation of abbreviations" on page 73.

APPENDIX 1.--RECORDS OF WELLS, JAMES CITY COUNTY, VIRGINIA
[Depths are in feet below land surface]

LOCAL WELL NUMBER	LITHOLOGY OF PRINCIPAL AQUIFER	TYPES OF LOGS AVAILABLE	OTHER DATA AVAILABLE QW	WL	LG	CK
56F 38	--	--				C
56F 39	MARL,SHELLS, SANDY	--	B			C
56F 43	--	--				C
56F 44	--	--	B	I		C
56G 1	CLAY,RED, SANDY	D	B	I	G	C
56G 19	--	--				C
56G 3	SAND,SILT	D,E,G	B	I	G	C
56G 4	SAND,TAN, CLAY	D	B	I	G	C
56G 5	SAND,SHELLY,SILTY	D		I	G	C
56G 6	SAND,YELLOW-TAN CLAY	D	B	I	G	C
56G 7	SAND,CLAY	D		I	G	C
56G 8	--	--	B	I		C
56G 9	SAND,CLAY BROWN WHITE	D	B	I	G	C
56G 10	CLAY,RED SANDY	--	B			C
56G 11	SDCL,YELLOW	D	B		G	C
56G 12	CLAY,RED AND BROWN	D		I	G	C
56G 13	CLAY,GRAVELLY SAND	D	B	I	G	C
56G 14	CLAY,SAND	D	B		G	C
56G 15	--	--	B	I		C
56G 16	SAND,CLAYEY RED	--	B	I		C
56G 17	--	E			G	C
56G 18	--	--		I		C
56G 20	--	--		I		C
56G 21	--	--	B	I		C
56G 22	--	--				C
56G 23	--	--				C
56G 24	--	--		I		C
56G 25	--	--				C
56G 26	--	--		I		C
56G 27	--	--				C
56G 28	--	--		I		C
56G 29	CLAY,BROWN AND YELLOW	D			G	C
56G 30	--	--				C
56G 31	--	--		I		C
56G 32	--	--				C
56G 33	--	--		I		C
56G 34	--	--				C
56G 35	--	--		I		C
56G 36	--	--		I		C

Note.--See "Explanation of abbreviations" on page 73.

APPENDIX 1.--RECORDS OF WELLS, JAMES CITY COUNTY, VIRGINIA
[Depths are in feet below land surface]

INDEX NO. SHOWN IN FIG.2	STATION NUMBER	LOCAL WELL NUMBER		LATITUDE	LONGITUDE	DRILLER	OWNER OR NAME	DATE COMPLETED
75	371643076482001	56G 37		37 16 43 N	076 48 20 W	UNKNOWN	HOGGE, HINTON E	1901
76	372028076452401	56G 38		37 20 28 N	076 45 24 W	JOHN TRUMBLE	CHESAPEAKE, POTOMAC CO	1977
77	372016076451601	56G 39		37 20 16 N	076 46 16 W	MAGETTE	BRUNK, MECHANICAL	05/29/1970
78	372115076460801	56G 40		37 21 15 N	076 46 08 W	G H GRIFFITH	WARE, DAVID	1967
79	372123076461001	56G 41		37 21 23 N	076 46 10 W	G H GRIFFITH	WARE, DAVID N	1972
80	371640076483901	56G 42		37 16 40 N	076 48 39 W	GRIFFTH	WALTRIP, DUDLEY S	1975
--	371637076482801	56G 43		37 16 37 N	076 48 28 W	GRIFFTH	WALREP, DUDLEY S	1967
81	371510076473001	56G 44		37 15 57 N	076 52 28 W	--	HOLIDAY, INN CAMPGD	1901
82	371602076522901	56G 45		37 16 02 N	076 52 29 W	--	HOLIDAY, INN CAMPGD	1901
83	371605076522401	56G 46		37 16 05 N	076 52 24 W	--	HOLIDAY, INN CAMPGD	1901
84	371815076473001	56G 47		37 16 05 N	076 52 14 W	--	HOLIDAY, INN CAMPGD	1901
85	371505076460101	56G 48		37 15 05 N	076 46 01 W	O BRENNEMAN	SAUNDERS, EDMUND H	1965
86	371500076473001	56G 49		37 20 21 N	076 45 12 W	O BRENNEMAN	JAMES YORK, DEVELOP CO	1963
87	371700076473001	56G 50		37 15 56 N	076 52 06 W	D BRENNEMAN	HOLIDAY, INN CAMPGD	1901
88	371652076481101	56G 51		37 16 52 N	076 48 11 W	G H GRIFFIN	COLEMAN, ROY	11/ /1972
89	371820076473001	56H 7		37 23 55 N	076 45 08 W	GRIFFITH	HIGHWAYS, VA DEPT OF	03/ /1965
90	371740076473001	56H 8		37 23 48 N	076 47 19 W	GRIFFITH	CARTER, FREDERICK R	03/ /1957
91	371505076473001	56H 9		37 22 53 N	076 48 30 W	GRIFFITH	JAMES CITY, COUNTY	11/ /1966
92	371635076473001	56H 13		37 22 46 N	076 47 41 W	O BRENNEMAN	HUGES, FRANK	1947
93	372248076481801	56H 14		37 22 48 N	076 48 18 W	--	TOWN OF TOANO	1876
94	372601076495301	56H 15		37 26 03 N	076 49 53 W	W H GAMMON	HAZELWODD, DONALD A	1972
95	372251076482401	56H 16		37 22 51 N	076 48 24 W	W H GAMMON	TOWN OF TOANO, NO. 1	08/11/1976
96	372258076481801	56H 17		37 22 58 N	076 48 18 W	W H GAMMON	MALCOLM, INDUSTRIES	1969
97	372305076455101	56H 18		37 23 05 N	076 45 51 W	MITCHELL	HIGHWAYS, VA DEPT OF	08/ /1974
98	372250076475801	56H 19		37 22 50 N	076 47 58 W	FETTERHOLF	SHELDON, MIKE E	1950
99	372313076480401	56H 20	OW	37 23 13 N	076 48 04 W	DELMARVA	TOANO TEST WELL	01/25/1979
100	372313076480402	56H 21		37 23 13 N	076 48 04 W	DELMARVA	TOANO TEST WELL	02/ /1979
101	372314076480401	56H 22		37 23 14 N	076 48 04 W	DELMARVA	TOANO TEST WELL	1979
102	372406076483201	56H 23		37 24 06 N	076 48 32 W	O BRENNEMAN	ANDERSON, JAMES M	1959
103	371343076400801	57F 7		37 13 43 N	076 40 08 W	SYDNOR HYDRO	BUSCH, PROPERTIES	07/22/1973
104	371406076384301	57F 8		37 14 06 N	076 38 43 W	SYDNOR HYDRO	BUSCH, GARDENS	01/ /1975
105	371424076391101	57F 9		37 14 24 N	076 39 11 W	MAGETTE	ANHEUSER, BUSCH INC	1969
106	371406076445701	57F 10		37 14 06 N	076 44 57 W	MITCHELL	COLONY SUBDIVISION	12/ /1954
107	371436076424701	57F 11		37 14 36 N	076 42 57 W	H H SHAW	WALTRIP, DUDLEY C	1950
108	371440076433501	57F 12		37 14 40 N	076 43 35 W	H H SHAW	WALTRIP, DUDLEY C	1950
109	371251076435901	57F 13		37 12 51 N	076 43 59 W	W H GAMMON	GOSPEL, SPREADING	05/14/1975
110	371401076390501	57F 14		37 14 01 N	076 39 05 W	W H GAMMON	BUSCH, GARDENS	06/ /1973
111	371409076445501	57F 15		37 14 09 N	076 44 55 W	MITCHELL	THE COLONY, SUBD	10/04/1941
112	371323076440201	57F 17		37 13 23 N	076 44 02 W	G H GRIFFITH	GOSPEL, SPREADING	1964

Note.--See "Explanation of abbreviations" on page 73.

APPENDIX 1.--RECORDS OF WELLS, JAMES CITY COUNTY, VIRGINIA
[Depths are in feet below land surface]

LOCAL WELL NUMBER		ALTITUDE OF LAND SURFACE (FEET)	DEPTH OF WELL (FEET)	CASING DIAM-ETER (INCHES)	DEPTH CASED	DEPTH TO FIRST OPENING (FEET)	SPECIFIC CAPACITY (GPM/FT)	DEPTH TO WATER (FEET)		DATE WATER LEVEL MEASURED	PUMP INTAKE SETTING (FEET)
56G 37		81	30.00	36	30	--	--	18.58		02/07/1978	--
56G 38		122	300.00	4	262	262	--	137.61	R	02/09/1978	168
56G 39		88	260.00	4	250	250	--	83.95	R	06/20/1978	--
56G 40		120	257.00	4	245	245	--	126.81		09/19/1978	147
56G 41		94	270.00	4	256	256	--	--		--	147
56G 42		71	216.00	4	216	216	--	85.07		09/20/1978	189
56G 43		73	233.00	4	222	222	--	95.89		04/20/1978	147
56G 44		6	210.00	--	--	--	--	--		--	--
56G 45		11	210.00	--	--	--	--	--		--	--
56G 46		11	215.00	--	--	--	--	--		--	--
56G 47		16	220.00	--	--	--	--	22.53		09/20/1978	--
56G 48		74	270.00	--	--	--	--	93.98	R	06/02/1977	--
56G 49		129	290.00	4	290	290	--	144.26		09/20/1978	--
56G 50		17	210.00	--	--	--	--	21.50		12/15/1978	--
56G 51		93	258.00	--	--	--	--	--		--	--
56H 7		101	325.00	4	305	305	--	120.90	R	08/20/1976	168
56H 8		82	233.00	--	--	--	--	95.16		08/20/1976	--
56H 9		100	257.00	4	243	237	--	--		--	210
56H 13		102	228.00	4	228	--	--	116.52		04/20/1978	--
56H 14		105	50.00	139.50	50	--	--	22.82	T	08/25/1977	--
56H 15		110	265.00	4	245	245	--	110.00		01/ /1972	--
56H 16		102	270.00	6	270	226	11.7	110.00	R	08/11/1976	--
56H 17		92	272.00	6	252	252	--	108.23		09/19/1978	120
56H 18		107	318.83	8	278	279	2.1	123.00		08/ /1974	--
56H 19		96	180.00	--	--	--	--	--		--	--
56H 20	OW	105	602.60	2	580	580	--	156.86		02/02/1979	--
56H 21		105	645.00	--	--	545	--	154.96		03/07/1979	--
56H 22		105	645.00	2	625	625	--	155.27		03/07/1979	--
56H 23		109	250.00	--	--	--	--	--		--	--
57F 7		53	470.00	8	470	424	13.4	118.00		07/23/1973	265
57F 8		73	510.00	8	510	451	19.1	143.58	P	01/22/1975	250
57F 9		82	460.00	4	450	450	--	145.96	T	12/12/1977	168
57F 10		48	206.00	5	196	196	--	40.00		12/ /1954	84
57F 11		9	150.00	4.25	150	--	--	--		--	--
57F 12		73	250.00	4.25	250	--	--	90.00		1950	--
57F 13		5	354.00	--	334	334	--	64.72	S	07/08/1977	130
57F 14		85	126.00	4	106	106	2.0	25.00		06/ /1973	--
57F 15		73	354.00	6	344	344	--	113.73	T	02/24/1978	--
57F 17		19	205.00	--	194	194	0.3	65.04		02/24/1978	125

Note.--See "Explanation of abbreviations" on page 73.

APPENDIX 1.--RECORDS OF WELLS, JAMES CITY COUNTY, VIRGINIA
[Depths are in feet below land surface]

LOCAL WELL NUMBER		LITHOLOGY OF PRINCIPAL AQUIFER	TYPES OF LOGS AVAILABLE	OTHER DATA AVAILABLE QW	WL	LG	CK
56G 37		--	--		I		C
56G 38		CLAY,SANDY	--		I		C
56G 39		SAND,AND CLAY	D		I	G	C
56G 40		--	--		I		C
56G 41		--	--				C
56G 42		--	--		I		C
56G 43		--	--		I		C
56G 44		--	--	B			C
56G 45		--	--				C
56G 46		--	--				C
56G 47		--	--	B	I		C
56G 48		--	--		I		C
56G 49		--	--	B	I		C
56G 50		--	--	B	I		C
56G 51		--	--				C
56H 7		--	--	B	I		C
56H 8		--	--		I		C
56H 9		--	--	B			C
56H 13		--	--	B	I		C
56H 14		CLAY,MARL	--	B	I		C
56H 15		--	--	B	I		C
56H 16		CLAY,RED YELLOW SANDY	D	B	I	G	C
56H 17		--	--		I		C
56H 18		SILT,CLAYEY	D		I	G	C
56H 19		--	--				C
56H 20	Dw	SDCL,TAN & BROWN	C,E,G,J	B	I	G	C
56H 21		SDMN,UNDESCRIBED	G		I	G	C
56H 22		SDCL,TAN & BROWN	--		I		C
56H 23		--	--				C
57F 7		SAND,CLAY LT BROWN	D		I	G	C
57F 8		CLAY,BROWN, SAND	D		I	G	C
57F 9		--	--		I		C
57F 10		SDGL	D	B	I	G	C
57F 11		CLAY,RED	D			G	C
57F 12		CLAY,RED	D		I	G	C
57F 13		--	--		I		C
57F 14		CLAY,RED, SANDY	--	B	I		C
57F 15		CLAY,YELLOW	D		I	G	C
57F 17		--	--		I		C

Note.--See "Explanation of abbreviations" on page 73.

APPENDIX 1.--RECORDS OF WELLS, JAMES CITY COUNTY, VIRGINIA
[Depths are in feet below land surface]

INDEX NO. SHOWN IN FIG.2	STATION NUMBER	LOCAL WELL NUMBER		LATITUDE	LONGITUDE	DRILLER	OWNER OR NAME	DATE COMPLETED
113	371248076435501	57F 18		37 12 48 N	076 43 55 W	--	GOSPEL, SPREADING	1937
115	371351076385801	57F 21		37 13 51 N	076 38 58 W	LYN ATLANTIC	BUSCH, PROPERTIES	05/01/1973
116	371410076392101	57F 22		37 14 10 N	076 39 21 W	SYDNOR HYDRO	ANHAEUSER, BUSCH	09/27/1977
117	371331076385901	57F 23		37 13 31 N	076 38 59 W	--	BUSCH, PROPERTIES	1901
118	371749076441801	57G 1	SOW 1	37 17 49 N	076 44 18 W	LYN ATLANTIC	EASTERN ST, HOSPITAL	02/28/1967
119	371708076431901	57G 9		37 17 24 N	076 43 24 W	MITCHELL	CAROLYN, TOURIST CT	1940
120	371804076434201	57G 10		37 18 04 N	076 43 42 W	O BRENNEMAN	WILLIAMSBG, TOURIST CT	01/17/1945
121	371732076444801	57G 11		37 17 33 N	076 44 42 W	VA MECH WELL	EASTERN ST, HOSPITAL	1937
122	371550076401801	57G 14		37 15 50 N	076 40 18 W	SYDNOR HYDRO	JAMES TERRACE	08/ /1950
123	371538076400601	57G 21		37 15 38 N	076 40 06 W	SYDNOR HYDRO	JAMES TERRACE NO. 2	03/16/1961
124	371934076441401	57G 22		37 19 34 N	076 44 14 W	SYDNOR HYDRO	OLD STAGE MANOR	07/23/1965
125	371543076443402	57G 26		37 15 43 N	076 44 34 W	MITCHELL	CANTERBURY NO. 2	12/ /1959
126	371543076443401	57G 27		37 15 43 N	076 44 34 W	MITCHELL	CANTERBURY NO. 1	10/26/1959
127	371850076444601	57G 29		37 18 50 N	076 44 46 W	SYDNOR HYDRO	OLD TOWN RD NO. 1	12/07/1973
128	371625076473001	57G 37		37 16 20 N	076 44 06 W	R L MAGETTE	JAMES CITY, SCHOOL BRD	12/22/1964
129	371730076432401	57G 38		37 17 30 N	076 43 24 W	MITCHELL	ABERDEEN, BARN	1941
130	371549076403501	57G 39		37 15 49 N	076 40 35 W	MITCHELL	FT MAGRUDE, HT WATER W	04/22/1939
131	371522076453201	57G 50		37 15 21 N	076 44 57 W	SYDNOR HYDRO	WHITE OAKS, NO. 1	11/15/1965
132	371804076434202	57G 56		37 18 04 N	076 43 42 W	SYDNOR HYDRO	WILLIAMSBG, TOURIST CT	02/ /1952
133	371900076442701	57G 57		37 19 00 N	076 44 27 W	MITCHELL	SPRING, LAND CORP	05/ /1967
134	371916076440701	57G 58		37 19 16 N	076 44 07 W	SYDNOR HYDRO	SOUTHERN, MATERIALS	02/06/1961
136	361627076445801	57G 63		37 16 27 N	076 44 58 W	TRUMBLE	BENTLY, DON	1956
137	371614076443901	57G 64		37 16 14 N	076 44 39 W	H H SHAW	JONES, JANET Y	12/20/1974
138	371805076473001	57H 4		37 26 34 N	076 44 55 W	G H GRIFFITH	MIHACLOE, CHARLIE H	04/ /1970
139	372610076443201	57H 5		37 26 10 N	076 44 32 W	MITCHELL	DANA, MARY B	03/11/1943
140	372310076411301	57H 6		37 23 10 N	076 41 14 W	R L MAGETTE	TIDEWATER, WATER CO	04/ /1964
141	371750076473001	57H 7		37 23 10 N	076 42 27 W	G H GRIFFITH	CHANDLER, LARRY B	06/ /1970
142	372447076424901	57H 8		37 24 47 N	076 42 51 W	W H GAMMON	COMNWEALTH, OF VIRGINA	03/04/1977
143	372535076435501	57H 9		37 25 35 N	076 43 55 W	W H GAMMON	COMNWEALTH, OF VIRGINA	04/28/1977
144	372309076420502	57H 10		37 23 09 N	076 42 05 W	W H GAMMON	VIRGINIA, CMNWLTH OF	03/15/1977
145	372455076425101	57H 11		37 24 55 N	076 42 51 W	W S REYNOLDS	VIRGINIA, CMNWLTH OF	1930
146	371755076473001	57H 12		37 22 32 N	076 42 43 W	W H GAMMON	CHANDLER, CAMEON M	1953
147	372609076443001	57H 13		37 26 09 N	076 44 30 W	UNKNOWN	DANA, MARY B	1901
148	372315076415001	57H 14	SOW 95	37 23 15 N	076 41 50 W	VASWCB	VASWCB	09/21/1978
149	371800076473001	57H 15		37 24 01 N	076 44 45 W	G H GRIFFITH	SAWYER, L	10/ /1972
150	371120076365401	58F 3		37 11 20 N	076 36 54 W	LYN ATLANTIC	DOW, BADISCHE	06/25/1968
151	371151076363801	58F 15		37 11 51 N	076 36 38 W	LYN ATLANTIC	DOW, BADISCHE	03/12/1965
152	371530076473001	58F 16		37 10 35 N	076 36 54 W	LYN ATLANTIC	DOW, BADISCHE	05/13/1957
153	371525076473001	58F 22		37 11 01 N	076 37 00 W	LYN ATLANTIC	DOW, BADISCHE	06/20/1957
154	371122076362801	58F 23		37 11 22 N	076 36 28 W	LYN ATLANTIC	DOW, BADISCHE	04/17/1963

Note.--See "Explanation of abbreviations" on page 73.

APPENDIX 1.--RECORDS OF WELLS, JAMES CITY COUNTY, VIRGINIA
[Depths are in feet below land surface]

LOCAL WELL NUMBER		ALTITUDE OF LAND SURFACE (FEET)	DEPTH OF WELL (FEET)	CASING DIAM-ETER (INCHES)	DEPTH CASED	DEPTH TO FIRST OPENING (FEET)	SPECIFIC CAPACITY (GPM/FT)	DEPTH TO WATER (FEET)		DATE WATER LEVEL MEASURED	PUMP INTAKE SETTING (FEET)
57F 18		16	350.00	--	--	--	--	--		--	130
57F 21		95	504.00	--	--	--	--	51.55		08/30/1978	--
57F 22		63	505.00	6	505	--	--	--		--	--
57F 23		70	444.00	--	--	--	10.5	140.00		09/05/1973	--
57G 1	SOW 1	92	555.00	8	555	--	27.8	115.00		03/20/1967	--
57G 9		103	348.00	--	--	--	0.5	102.00		1940	--
57G 10		94	265.00	2	265	245	--	85.00		01/17/1945	--
57G 11		71	632.00	6	632	582	6.9	52.00		1937	--
57G 14		70	503.00	6	503	459	--	65.00		08/ /1950	--
57G 21		80	502.00	4	502	420	12.8	90.00		03/16/1961	216
57G 22		100	305.00	6	305	240	10.5	117.92		11/29/1972	--
57G 26		100	280.00	6	270	270	12.0	105.00		12/ /1959	140
57G 27		100	84.75	6	74	75	0.8	31.00	R	10/26/1959	60
57G 29		105	288.00	6	288	242	10.5	124.50		12/07/1973	215
57G 37		103	440.00	6	420	420	5.0	90.00		12/22/1964	170
57G 38		100	68.00	6	68	--	0.3	31.00		1941	--
57G 39		82	435.00	6	435	405	--	81.00		04/22/1939	166
57G 50		85	270.00	4	270	212	1.0	87.00		11/15/1965	--
57G 56		94	282.17	4.50	268	269	3.0	87.00		02/05/1952	--
57G 57		111	302.00	6	282	282	16.0	122.00		05/ /1967	--
57G 58		100	286.83	4	265	266	--	104.00	S	02/06/1961	--
57G 63		95	90.00	--	--	--	--	35.00		1956	--
57G 64		92	266.00	4	266	266	--	--		--	--
57H 4		35	147.00	--	--	--	--	--		--	--
57H 5		73	225.00	3.50	225	--	--	64.25		03/11/1943	--
57H 6		50	258.00	6	238	238	--	60.00		04/ /1964	189
57H 7		100	300.00	--	--	--	--	--		--	147
57H 8		41	270.00	6	270	206	0.2	80.00		03/04/1977	--
57H 9		60	250.00	4	230	230	2.5	70.00		04/28/1977	--
57H 10		85	312.00	4	290	290	1.1	120.00	R	03/15/1977	--
57H 11		3	323.00	--	308	308	--	85.00		1930	--
57H 12		88	293.00	--	--	--	--	--		--	--
57H 13		73	47.42	36	47	--	--	44.21		06/22/1978	--
57H 14	SOW 95	93	123.00	4	118	118	--	45.00		09/21/1978	--
57H 15		100	292.00	4	280	280	--	--		--	--
58F 3		22	1465.00	6	1435	600	--	--		--	--
58F 15		20	545.00	8	535	450	42.0	55.00		12/11/1965	130
58F 16		26	530.00	8	510	470	30.5	32.00		08/05/1957	140
58F 22		26	520.00	8	480	460	50.6	28.00	P	06/25/1957	--
58F 23		20	510.00	8	470	445	31.2	45.50	P	04/23/1963	--

Note.--See "Explanation of abbreviations" on page 73.

APPENDIX 1.--RECORDS OF WELLS, JAMES CITY COUNTY, VIRGINIA
[Depths are in feet below land surface]

LOCAL WELL NUMBER		LITHOLOGY OF PRINCIPAL AQUIFER	TYPES OF LOGS AVAILABLE	OTHER DATA AVAILABLE QW	WL	LG	CK
57F 18		--	--				C
57F 21		SAND	D,E,G		I	G	C
57F 22		CLAY,SHELLS	D			G	U
57F 23		SAND,GRAY-ORANGE SILT	--		I		C
57G 1	SOW 1	SAND,MDN TO CRS	D,E,G		I	G	C
57G 9		CLAY,SILTY	D	B	I	G	C
57G 10		SAND,CLAYEY	D		I	G	C
57G 11		CLAY,RED	D		I	G	C
57G 14		SAND,MDM TO CRS	D		I	G	C
57G 21		CLAY,SANDY SOME GRVL	D,E	B	I	G	C
57G 22		LMSN,SHELLY & SANDY	D,E,G		I	G	C
57G 26		CLAY,SAND	D	B	I	G	C
57G 27		CLAY,RED	D	B	I	G	C
57G 29		SAND,CLAYEY AND SILTY	D	B	I	G	C
57G 37		SAND,CLAY STREAKS	D	B	I	G	C
57G 38		SDCL,RED	D	B	I	G	C
57G 39		--	D	B	I	G	C
57G 50		SAND,AND LIMESTONE	D,E,G		I	G	C
57G 56		CLAY,YELLOW	D	B	I	G	C
57G 57		SDCL,ORANGE	D,G		I	G	C
57G 58		CLAY,YELLOW	D	B	I	G	C
57G 63		--	--		I		C
57G 64		LMSN,SANDY	D,G			G	C
57H 4		--	--	B			C
57H 5		SAND,RED	D	B	I	G	C
57H 6		SAND,RED CLAY	D	B	I	G	C
57H 7		--	--	B			C
57H 8		SAND,SHELL & MUD	--		I		C
57H 9		--	D		I	G	C
57H 10		SDGL,RED MUD	D	B	I	G	C
57H 11		--	--		I		C
57H 12		--	--	B			C
57H 13		--	--		I		C
57H 14	SOW 95	SAND,RED-BROWN, CLAYEY	D,E		I	G	C
57H 15		--	--	B			C
58F 3		SDCL,BROWN-YELLOW	D,E,G,I,U,Z			G	C
58F 15		SAND,CRS	D		I	G	C
58F 16		CLAY,SANDY	D		I	G	C
58F 22		SAND,FINE TO CRS	D		I	G	C
58F 23		SAND,FINE TO CRS	D		I	G	C

Note.--See "Explanation of abbreviations" on page 73.

APPENDIX 1.--RECORDS OF WELLS, JAMES CITY COUNTY, VIRGINIA
[Depths are in feet below land surface]

INDEX NO. SHOWN IN FIG.2	STATION NUMBER	LOCAL WELL NUMBER	LATITUDE	LONGITUDE	DRILLER	OWNER OR NAME	DATE COMPLETED
155	371125076370401	58F 24	37 11 26 N	076 37 08 W	LYN ATLANTIC	DOW, BADISCHE	12/20/1956
156	371123076365201	58F 25	37 11 23 N	076 36 52 W	SYDNOR HYDRO	DOW, BADISCHE	01/15/1965
157	371150076371501	58F 26	37 11 50 N	076 37 15 W	LYN ATLANTIC	DOW, BADISCHE	05/23/1969
158	371135076370701	58F 27	37 11 35 N	076 37 07 W	SYDNOR HYDRO	DOW, BADISCHE	05/02/1960
159	371151076371701	58F 28	37 11 51 N	076 37 17 W	UNKNOWN	DOW, BADISCHE	07/16/1942
160	371125076365601	58F 29	37 11 25 N	076 36 56 W	SYDNOR HYDRO	DOW, BADISCHE	03/04/1969
161	371550076473001	58F 33	37 12 22 N	076 37 20 W	SYDNOR HYDRO	WILLIAMSBG, COLONIAL	06/18/1928
162	371135076370702	58F 37	37 11 35 N	076 37 07 W	W H GAMMON	DOW, BADISCHE	03/ /1973
163	371250076365201	58F 38	37 12 50 N	076 36 52 W	R L MAGETTE	HITCHENS, MYERS B	01/21/1965
164	371615076473001	58F 39	37 12 50 N	076 36 52 W	R L MAGETTE	HITCHENS, MYERS B	01/21/1965
165	371250076355801	58F 40	37 12 51 N	076 35 58 W	W H GAMMON	VA DEPT OF, HIGHWAYS	10/11/1974
166	371710076473001	58F 41	37 12 56 N	076 37 05 W	--	HOOKER, O M	1970
167	371715076473001	58F 42	37 12 52 N	076 37 04 W	--	HOOKER, O M	09/ /1970
168	371244076365701	58F 43	37 12 44 N	076 36 57 W	O BRENNEMAN	SMITH, BOYD J	1957
169	371650076473001	58F 44	37 12 39 N	076 36 38 W	O BRENNEMAN	GIBSON, BROTHERS	--
170	371655076473001	58F 45	37 12 39 N	076 36 38 W	--	GIBSON, BROTHERS	--
171	371645076473001	58F 46	37 12 39 N	076 36 38 W	O BRENNEMAN	GIBSON, BROTHERS	--
172	371236076362801	58F 47	37 12 36 N	076 36 28 W	R L MAGETTE	CHISMAN, CONCRETE	1960
269	371623076420501	57G 12	37 16 23 N	076 42 05 W	SYDNOR	WILLIAMSBG, COLONIAL	03/31/1965
270	371618076413301	57G 13	37 16 18 N	076 41 33 W	SYDNOR HYDRO	WILLIAMSBG, COLONIAL	04/19/1955
271	371628076414501	57G 24	37 16 28 N	076 41 45 W	SYDNOR HYDRO	WILLIAMSBG, COLONIAL	03/07/1961
272	371605076420301	57G 25	37 16 05 N	076 42 03 W	SYDNOR HYDRO	WILLIAMSBG, COLONIAL	09/04/1962
273	371656076415101	57G 30	37 16 56 N	076 41 51 W	SYDNOR HYDRO	WILLIAMSBG, COLONIAL	02/ /1967
274	371610076423001	57G 31	37 16 10 N	076 42 30 W	SYDNOR HYDRO	WILLIAMSBG, COLONIAL	1924
275	371618076422301	57G 32	37 16 18 N	076 42 23 W	SYDNOR HYDRO	WILLIAMSBURG, COLONIAL	04/29/1940
276	371605076420302	57G 33	37 16 05 N	076 42 03 W	SYDNOR HYDRO	WILLIAMSBG, COLONIAL	04/07/1952
277	371604076415401	57G 34	37 16 04 N	076 41 54 W	SYDNOR HYDRO	WILLIAMSBG, COLONIAL	05/28/1953
278	371648076415201	57G 35	37 16 48 N	076 41 52 W	SYDNOR	WILLIAMSBURG, COLONIAL	03/15/1956
279	371520076433501	57G 36	37 15 20 N	076 43 35 W	SYNDOR HYDRO	WALSINGHAM, ACADEMY	08/09/1950
280	371559076421501	57G 53	37 15 59 N	076 42 15 W	SYDNOR HYDRO	VIRGINIA, STATE OF	1903

Note.--See "Explanation of abbreviations" on page 73.

APPENDIX 1.--RECORDS OF WELLS, JAMES CITY COUNTY, VIRGINIA
[Depths are in feet below land surface]

LOCAL WELL NUMBER	ALTITUDE OF LAND SURFACE (FEET)	DEPTH OF WELL (FEET)	CASING DIAM-ETER (INCHES)	DEPTH CASED	DEPTH TO FIRST OPENING (FEET)	SPECIFIC CAPACITY (GPM/FT)	DEPTH TO WATER (FEET)		DATE WATER LEVEL MEASURED	PUMP INTAKE SETTING (FEET)
58F 24	25	524.00	8	514	444	54.2	25.00	P	12/20/1956	130
58F 25	20	119.00	6	119	98	31.6	24.00	S	01/15/1965	86
58F 26	12	495.00	8	450	430	18.1	72.42	S	05/23/1969	--
58F 27	27	116.67	4	104	104	0.4	26.00	S	05/02/1960	60
58F 28	11	62.00	2	49	49	--	8.00	S	--	--
58F 29	22	123.00	8	123	78	18.4	36.00	S	03/04/1969	55
58F 33	25	465.00	6	465	425	--	--		--	280
58F 37	26	126.00	4	106	106	2.0	25.00	S	03/ /1973	84
58F 38	42	495.00	2	475	475	2.5	106.16	S	03/09/1978	126
58F 39	50	72.00	6	72	50	1.0	8.00	S	01/21/1965	--
58F 40	55	545.00	3	525	525	--	138.00		10/11/1974	--
58F 41	61	350.00	4	350	--	--	--		--	--
58F 42	51	400.00	--	--	--	--	100.00		09/ /1970	--
58F 43	60	500.00	3	480	480	--	--		--	--
58F 44	63	475.00	--	--	--	--	--		--	--
58F 45	63	60.00	--	--	--	--	--		--	--
58F 46	63	475.00	--	--	--	--	--		--	--
58F 47	58	500.00	--	--	--	--	--		--	--
57G 12	70	471.00	8	464	399	9.2	101.00		03/31/1965	260
57G 13	81	470.00	6	459	417	3.0	77.00		04/20/1955	230
57G 24	70	449.67	8	449	410	7.3	68.50		03/07/1961	150
57G 25	70	470.00	8	470	408	12.2	166.05	P	12/12/1977	190
57G 30	55	455.00	6	455	369	10.9	95.00	P	02/20/1967	295
57G 31	80	442.00	8	442	395	--	60.00		07/ /1924	250
57G 32	80	438.00	6	410	409	4.6	75.00	P	04/29/1940	91
57G 33	70	481.00	5	481	431	6.1	72.00		04/07/1952	120
57G 34	68	476.00	6	480	397	4.0	62.00	P	05/28/1953	90
57G 35	65	453.00	8	453	396	3.1	55.00	P	03/15/1956	160
57G 36	68	437.00	6	437	380	0.7	53.00		08/09/1950	--
57G 53	55	280.00	8	280	--	1.6	80.00		1903	--

Note.--See "Explanation of abbreviations" on page 73.

APPENDIX 1.--RECORDS OF WELLS, JAMES CITY COUNTY, VIRGINIA
[Depths are in feet below land surface]

LOCAL WELL NUMBER	LITHOLOGY OF PRINCIPAL AQUIFER	TYPES OF LOGS AVAILABLE	OTHER DATA AVAILABLE QW	WL	LG	CK
58F 24	CLAY,SANDY	D	B	I	G	C
58F 25	CLAY,SANDY	D		I	G	C
58F 26	--	--		I		C
58F 27	CLAY,YELLOW-GRAY CLAY	D		I	G	C
58F 28	CLAY,SANDY	--		I		C
58F 29	CLAY,BROWN-BLUE	D		I	G	C
58F 33	--	D	B		G	C
58F 37	CLAY,SANDY	D		I	G	C
58F 38	SAND,CLAYEY, BROWN	D,E	B	I	G	C
58F 39	CLAY,BROWN SAND	D	B	I	G	C
58F 40	SAND,MDM TO CRS	--		I		C
58F 41	--	--	B			C
58F 42	--	--	B	I		C
58F 43	--	--	B			C
58F 44	--	--	B			C
58F 45	--	--	B			C
58F 46	--	--	B			C
58F 47	--	--				C
57G 12	SAND,SILTY	D,E		I	G	C
57G 13	CLAY,SAND YELLOW	D	B	I	G	C
57G 24	SAND	D,E		I	G	C
57G 25	CLAY,SANDY RED	D	B	I	G	C
57G 30	CLAY,SANDY ORANGE	D,G	B	I	G	C
57G 31	--	D	B	I	G	C
57G 32	CLAY	D,G		I	G	C
57G 33	--	--		I		C
57G 34	CLAY,YELLOW	--		I		C
57G 35	CLAY,YELLOW	--		I		C
57G 36	CLAY,SANDY, YELLOW	D		I	G	C
57G 53	--	--	B	I		C

Note.--See "Explanation of abbreviations" on page 73.

Explanation of abbreviations

C = caliper log
E = electric log
J = gamma log
D = driller's log
G = geologist log
I = induction log
U = gamma gamma log
R = reported
S = steel tape
T = electric tape
F = flowing well
OW = observation well
SOW = State observation well
SR = steel tape, recently pumped
TR = electric tape, recently pumped

RR = reported, recently pumped
RT = reported, nearby recently pumped
ST = steel tape, nearby recently pumped
TP = electric tape, pumping
RP = reported, pumping
RS = reported, nearby pumping
SS = steel tape, nearby pumping
M = manometer
QW = water quality
WL = water level
CK = data reliability
C = field checked
B = chemical analysis
I = intermittent
O = one time only