PREPARED IN COOPERATION WITH THE
VIRGINIA STATE WATER CONTROL BOARD
BUREAU OF WATER CONTROL MANAGEMENT

WATER RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 80-965

INTRODUCTION

Purpose, Scope, and Areal Extent

The Atlantic Coastal Plain of Virginia includes 9,600 square miles--all or part of 40 counties east of the Fall Line (fig. 1). Undifferentiated Cretaceous sediments of the Virginia Coastal Plain form an aquifer that is the most productive and extensive source of ground water in the State. Large withdrawals for industrial and public supplies began more than 40 years ago. Pumpage has been greatest at Franklin, Suffolk, Smithfield, James City County, and West Point. Combined pumpage at these areas now exceeds 100 million gallons per day (Mgal/d). To determine the effect of withdrawals on the potentiometric surface, annual synoptic water-level measurements were begun in 1972. Water levels measured in 1978 were used to prepare the accompanying map, which shows the approximate present (1978) configuration of the potentiometric surface.

Cooperation and Acknowledgment

This report was prepared by the U.S. Geological Survey in cooperation with the Virginia State Water Control Board, R. V. Davis, Executive Secretary.

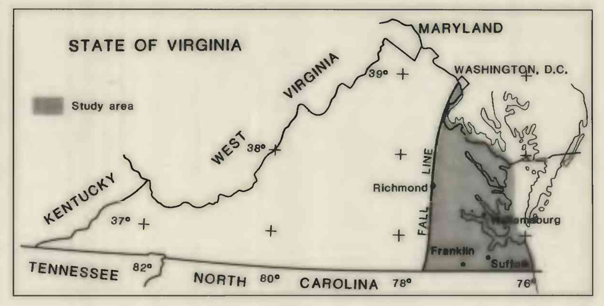

FIGURE 1. Location of study area.

GEOHYDROLOGIC SETTING

The Coastal Plain province of Virginia is underlain by unconsolidated sediments that range in age from pre-Cretaceous to Quaternary (Brown, Miller, and Swain, 1972). These sediments, which lie unconformably on crystalline rocks of the Piedmont province, range in thickness from a featheredge at the Fall Line to several thousand feet along the Atlantic Coast. This eastward-thickening wedge of sediments consists of stratified beds of sand and gravel interbedded with layers of silt and clay. The Cretaceous sediments crop out along the Fall Line and are overlain by progressively younger sediments to the east. The Cretaceous sediments are the principal source of ground-water supplies.

The primary source of recharge to the Cretaceous sediments is precipitation, but some water may flow laterally into the sediments from the generally underlying crystalline rocks. Part of the recharge enters the sediments at their outcrop along the Fall Line, but, because large-scale withdrawals have lowered the potentiometric surface significantly, most recharge may now enter by seepage from the overlying deposits (Cosner, 1974). The thickness, areal extent, and permeability of the silt and clay layers interbedded with the overlying sand and gravel layers control the rate of such vertical recharge (Virginia State Water Control Board, 1974).

POTENTIOMETRIC SURFACE

If the water-level elevations in wells completed in a confined aquifer are plotted on a map and contoured, the resulting surface, which is actually a map of the hydraulic head in the aquifer, is called the potentiometric surface. The slope of the potentiometric surface, or the rate of change of head (water level) per unit distance in a given direction, is the hydraulic gradient. The hydraulic gradient is greatest (steepest) where the contour lines are most closely spaced, such as near centers of pumping, and least (gentlest) where the lines are most widely spaced.

Before large-scale pumping of water from the Coastal Plain sediments of Virginia began, the slope of the potentiometric surface, and thus the direction of ground-water flow, was generally to the east and north. However, large withdrawals for public and industrial supplies, starting more than 40 years ago, have significantly altered the configuration of the potentiometric surface.

Sanford (1913) made one of the earliest ground-water studies in the Coastal Plain area of Virginia. Although he did not prepare a potentiometric-surface map, he did show the locations of flowing artesian wells along the major rivers of the Coastal Plain. These wells were drilled in the late 1800's and early 1900's and reportedly flowed for more than 50 years. The presence of such flowing wells indicates that the river valleys were natural discharge zones for ground water and implies a potentiometric surface that sloped toward the valleys of the James and other rivers of the Coastal Plain.

The earliest potentiometric-surface map prepared for the Coastal Plain of Virginia included the area south of the James River; this map (fig. 2) was compiled by D. J. Cederstrom (1945) from water-level measurements during 1937-39. The general direction of ground-water flow, based on the trend of the potentiometric contours, is to the east in the western part of the area and to the northeast near the James River. Water levels were relatively unaffected by pumping during the period represented by Cederstrom's map, and the decrease in hydraulic gradient from the Fall Line to the James River reflects the thickening of the aquifer system from west to east. Cederstrom's map does show small cones of depression--areas within which the potentiometric surface is lowered locally due to pumping--at Franklin in southwestern Isle of Wight County and at Hopewell in northwestern Prince George County.

Brown and Cosner (1974) compiled a potentiometric surface map for the Franklin area from water-level measurements in December 1971. This map shows the deepening of the cone of depression at Franklin. Cosner (1974) also showed cones of depression forming locally in the Lake Prince-Suffolk and Smithfield areas.

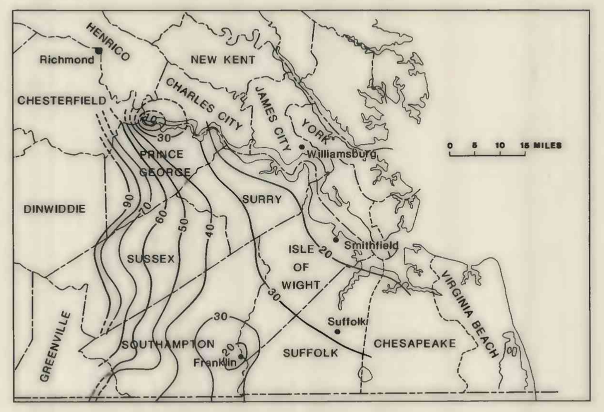

FIGURE 2. Potentiometric-surface map based on measurements from 1937 to 1939 of the undifferentiated Cretaceous aquifer, modified from Cederstrom (1945).

The potentiometric-surface map that accompanies this report (pl. 1) includes the entire Coastal Plain province of Virginia. This map was compiled from water-level measurements during January and February 1978. In 1978, seven local cones of depression could be identified, but they cannot all be portrayed at the contour interval used on the map in this report. Several of the individual cones of depression--those at Franklin, the Lake Prince-Suffolk area, Williamsburg, James City County, Smithfield and West Point--have coalesced to form a large regional cone of depression. This cone extends from south of the Virginia-North Carolina border northward beyond the Maryland-Virginia border at the Potomac River. The general slope of the potentiometric surface is toward the axis of the cone formed by large-scale ground-water withdrawals.

The cone of depression in southeastern Fairfax County developed due to local pumping, but its shape is affected by pumping at Indian Head, Md., about 25 miles to the south-southeast. The cone of depression at Hopewell seems to have remained relatively stable since it was first identified by Cederstrom (1945).

LAND SUBSIDENCE

In a study of vertical crustal movements in the Middle Atlantic Coastal Plain, Balazs (1974) indicated a rate of land subsidence of as much as 5 mm/yr in the Franklin area. The virtual coincidence of closed contour lines representing land subsidence and the cone of depression in the potentiometric surface at Franklin indicates that the subsidence is directly related to the ground-water withdrawals. A specially designed recording gage was installed on an observation well at Franklin in September 1979 to measure the amount and rate of land subsidence.

CONCLUSIONS

The potentiometric-surface map included in this report reflects the effects of withdrawal of ground water over more than 40 years. If compared with the earlier work of Cederstrom in the area south of the James River, it is apparent that the recharge-discharge relationship has been altered. The extent and depth of the cones of depression indicate that (1) continued ground-water withdrawals are causing a reduction of measured head in the confined aquifers, (2) the hydraulic gradient along the eastern part of the Coastal Plain has reversed, which may have caused the freshwater to saline water interface to move westward, (3) saline water may have migrated upward toward the freshwater zone, (4) former ground-water discharge to streams along the western and central parts of the area has been captured, and (5) water removed from storage may have caused land subsidence in the heavily pumped areas.

Available data are inadequate to quantify the effects of pumping or to define in detail the changes with time. Additional measurements of ground-water levels and monitoring of chemical quality of ground water are needed for such quantification and detail, particularly on the Eastern Shore, Middle and Northern Neck Peninsulas, and in the area south of the James River, to better define future patterns and trends. Additional data collection possibly could be coordinated with Maryland and North Carolina because of the potential effects of an expanding cone of depression.

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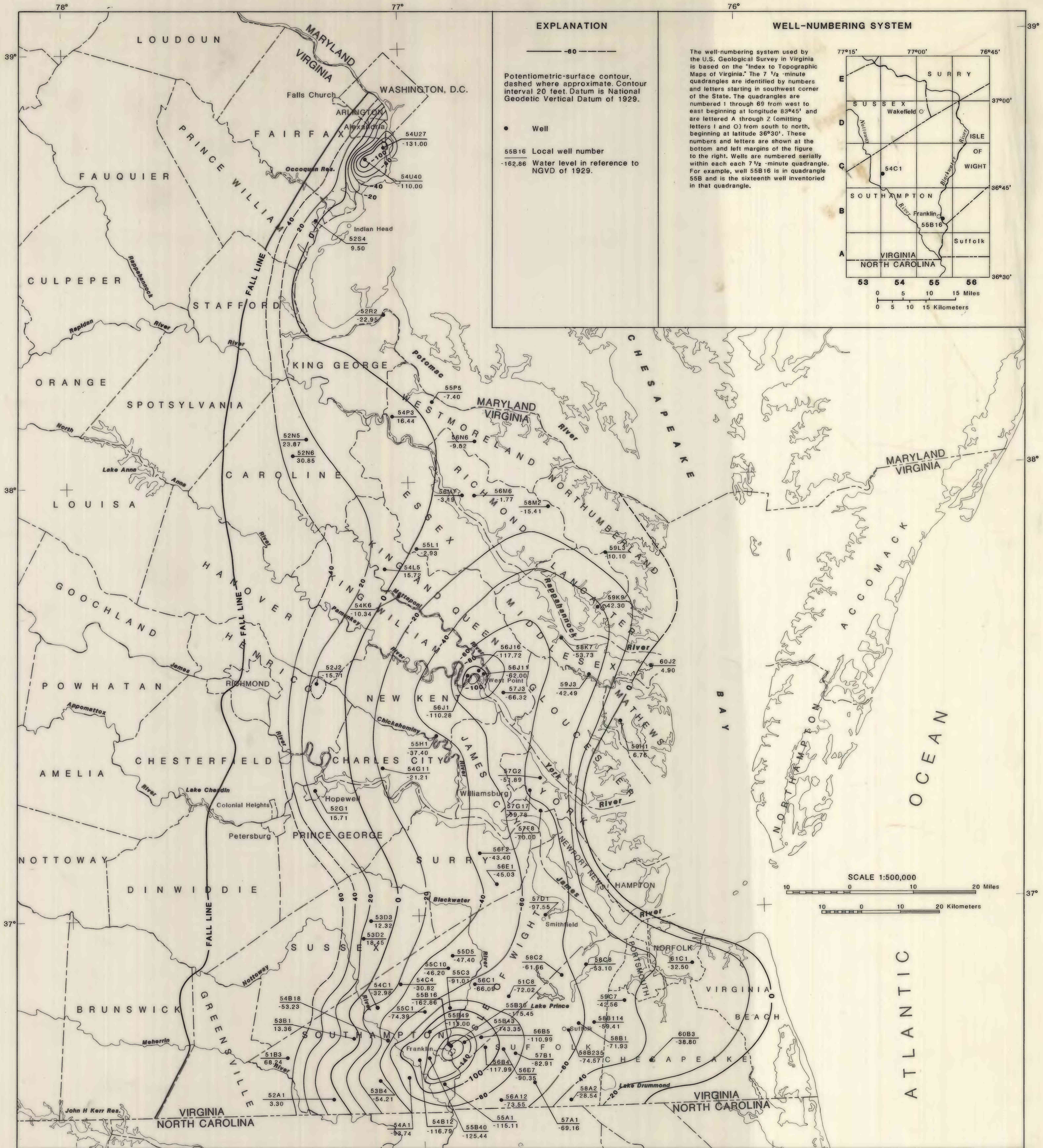
Conversion Factors

Factors for converting Inch-Pound to the International System (SI) Units.

Multiply inch-pound units	By	To obtain SI units
	Length	
inch (in)	25.4	millimeter (mm)
foot (ft)	.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
$mile^2$ (mi^2)	2.590	$kilometer^2$ (km^2)
	Flow	
gallon per minute (gal/min)	.06309	liter per second (L/s)
million gallons per day (Mgal/d)	43.81	$meters^3$ per second (m^3/s)



EXPLANATION

—— -60 ——

Potentiometric-surface contour, dashed where approximate. Contour interval 20 feet. Datum is National Geodetic Vertical Datum of 1929.

● Well

55B16 Local well number

-162.86 Water level in reference to NGVD of 1929.

WELL-NUMBERING SYSTEM

The well-numbering system used by the U.S. Geological Survey in Virginia is based on the "Index to Topographic Maps of Virginia." The 7 1/2 -minute quadrangles are identified by numbers and letters starting in southwest corner of the State. The quadrangles are numbered 1 through 69 from west to east beginning at longitude 83°45' and are lettered A through Z (omitting letters I and O) from south to north, beginning at latitude 36°30'. These numbers and letters are shown at the bottom and left margins of the figure to the right. Wells are numbered serially within each each 7 1/2 -minute quadrangle. For example, well 55B16 is in quadrangle 55B and is the sixteenth well inventoried in that quadrangle.

POTENTIOMETRIC-SURFACE MAP FOR THE CRETACEOUS AQUIFER, VIRGINIA COASTAL PLAIN, 1978

By H.T. Hopkins, R.F. Bower, J.M. Abe and John F. Harsh

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