DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 76-83
SHEET 1 OF 5

INTRODUCTION

The Lower Cretaceous aquifer is the most extensive and most productive aquifer in the Virginia Coastal Plain. Several industries and cities obtain their principal water supplies from this aquifer. Other cities use it as a stand-by supply in case of drought.

The largest withdrawals of water from the Lower Cretaceous aquifer are made in the Franklin area of southeastern Virginia. Because of its importance, the aquifer in the Franklin area is the subject of a cooperative study by the U. S. Geological Survey and the Virginia State Water Control Board. The study has resulted in two reports on the aquifer in the Franklin area; Brown and Cosner (1974) presented the geology and ground-water hydrology of the Lower Cretaceous aquifer in the Franklin area, and Cosner (1975) described the development and the verification of a computer model of the aquifer in the Franklin area. As part of this study, annual synoptic water-level measurements have been made since 1970 in wells tapping the Lower Cretaceous aquifer in the Franklin area. These measurements are presented as water-level contour maps in the above-mentioned reports through December 1972. The purpose of this report is to make available the maps of simulated and measured water levels for the period 1973-1974. Included in the report are the well data and water-level measurements that were used to produce these maps.

In addition to the above-mentioned purpose, it is necessary to check the computer model periodically to see that its predicted water levels are reasonably close to the measured ones for a given time period. So, another purpose of this report is to compare the simulated water-level contour maps generated by the computer with the actual water-level contoured maps based on measured water levels.

RESUME OF GEOLOGY AND HYDROLOGY

The model area is entirely within the Coastal Plain of Virginia and North Carolina. (See location map.) The area is underlain by unconsolidated sediments that rest on a massive body of hard rock called the basement complex. The Lower Cretaceous sediments, which constitute the aquifer of this study, are confined below by the basement complex and above by younger sediments. The aquifer forms a wedge that deepens and thickens from west to east; its thickness at Franklin is about 600 ft (180 m); at Norfolk about 2,600 ft (792 m).

It is composed of interbedded clay sandy clay, and sand. Plant remains and variegated clay are common. Individual sand and clay beds are commonly not more than 40 ft (12 m) thick but may be as thick as 100 ft (30 m). The thick sand beds are the major water-bearing units.

Precipitation is the source of all fresh ground water in the Coastal Plain. A part of the precipitation that soaks into the ground recharges the aquifers. A small amount of the recharge to the Lower Cretaceous aquifer occurs directly on the outcrops along the Fall Line, but, as these outcrops are of small areal extent, most of the recharge is by downward percolation from shallower ground-water bodies that overlie the Lower Cretaceous aquifer. Lateral ground-water flow through the weathered and fractured zone of the basement rocks that underlie the aquifer may contribute a small amount of recharge, but it is insignificant compared to leakage from the upper aquifers.

Prior to the withdrawal of ground-water the potentiometric surface in the Lower Cretaceous aquifer had a continuously decreasing gradient from the Fall Line eastward to the sea. Before ground-water withdrawal, water moved downgradient to a point where the static head in the aquifer became greater than the head in the overlying aquifers. From this point eastward, water also moved upward through the semipermeable confining beds into the overlying aquifers and eventually discharged at land surface. The average recharge was balanced by this natural discharge.

Ground-water withdrawal at Franklin disturbed this dynamic equilibrium and lowered the potentiometric surface of the Lower Cretaceous aquifer below the heads of the upper aquifers. At that time the upward movement of water from the Lower Cretaceous aquifer ceased, and water from the upper aquifers began moving downward to recharge the Lower Cretaceous aquifer. The cone of depression created by ground-water withdrawal in the Franklin area extends over an area in excess of 5000 mi^2 (12,950 km^2) and has caused all ground-water flow within this area to be diverted toward this center of pumping.

As shown by the water-level maps, the gradient of the potentiometric surface is gentle to the east of Franklin and steeper to the west. This difference in steepness is caused mainly by an eastward increase in thickness and in transmissivity of the aquifer. Transmissivity increases in approximate proportion to the increase in thickness for a few miles east of Franklin then remains fairly constant for about 20 to 30 mi (32 to 48 km) to the east, to the vicinity of Suffolk, Va. From Suffolk eastward the transmissivity probably decreases gradually to the edge of the Continental Shelf due to a change in character of the Lower Cretaceous sediments from alluvial fill to marine deposits. Although no data are available from offshore, it is probable that a complete gradation from very coarse terrestial sediments to fine-grained marine sediments occurs within the Lower Cretaceous from the Fall Line to the edge of the Continental Shelf.

PUMPAGE

Two significant changes in pumpage occurred between December 1972 and December 1974. The city of Norfolk wells at Lake Prince were pumped for about 10 weeks in the fall of 1973, and the Union Camp Corporation at Franklin shut down most of its wells for a month in July and August of 1974. The prorated withdrawal rates, along with the corresponding dates used to make the three model runs, are given in the table of pumpage.

HYDROGRAPHS AND POTENTIOMETRIC MAPS

Hydrographs of simulated and measured water levels in three observation wells for January 1940 through November 1974 are shown. The maps of the measured potentiometric surfaces on sheets 3, 4, and 5 are from water-level measurements made in selected wells. The locations and the numbers of these wells are shown on the well-location map, and the water levels and other well data are given in the well table (sheet 2).

The water-level data in the well table gives the altitude of the potentiometric surface at the well. The altitude of land surface at each well site was determined from 7-1/2-minute topographic maps with a contour interval of 10 feet. The maximum error in altitude should not exceed 10 ft, and the average error is probably less than 5 ft. From this it can be seen that some mismatching of contours between simulated and measured surfaces could be caused by the error in the determination of land-surface altitude at the well. However, this error is within the degree of accuracy expected from the simulated maps and is not considered to be a problem at this time.

MODEL SIMULATIONS

The period December 1972 to December 1974 was divided into three pumping cycles. The factor that dictated the choice of pumping cycles was the time at which synoptic water-level measurements were made in the area. The simulated and measured maps conform to these times. They are December 1973, August 13, 1974, and December 1974.

The simulated maps for each of these times check well with the measured maps for each respective time, indicating that the model is simulating hydrologic conditions satisfactorily. It is possible that in years to come the simulated maps may not compare as closely to the measured maps. It will then be necessary to make some adjustments in the model in order to achieve a closer comparison, but for the present the model seems adequate.

SELECTED REFERENCES

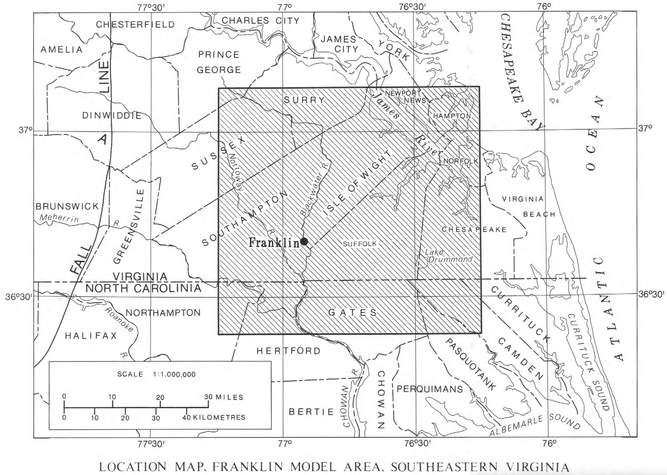
Brown, G. A., Cosner, O. J., 1974, Ground-water conditions in the Franklin area, Southeastern Virginia: U.S. Geol. Survey Hydrol. Inv. Atlas HA 538.

Cosner, O. J., 1975, A predictive computer model of the Lower Cretaceous aquifer, Franklin area, Southeastern Virginia: U.S. Geol. Survey Water-Resources Inv. 51-74, 62 p.

Pinder, G. F., 1970, An iterative digital model for aquifer evaluation: U.S. Geol. Survey open-file report, 44 p.

FACTORS FOR CONVERTING ENGLISH UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

Multiply English Units	By	To obtain SI Units
feet (ft)	0.3048	metres (m)
miles (mi)	1.609	kilometres (km)
gallons (gal)	3.785	litres (l)
cubic feet per second (cfs)	28.32	litres per second (l/s)

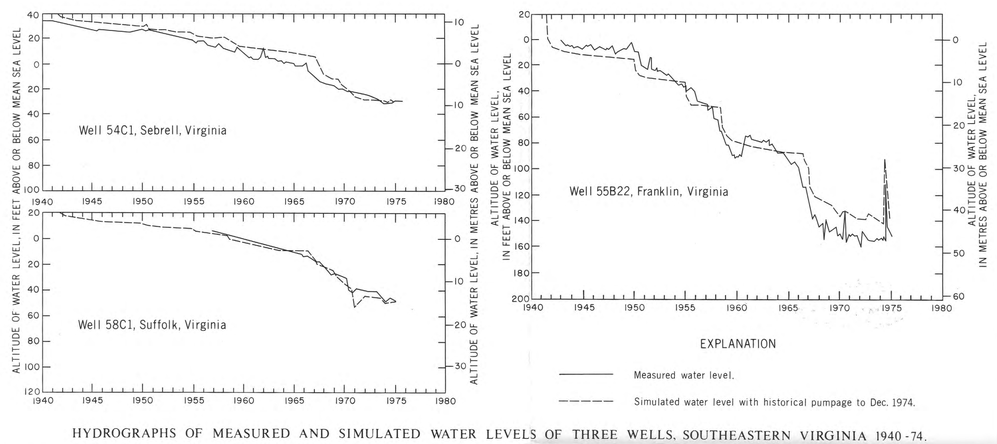


LOCATION MAP, FRANKLIN MODEL AREA, SOUTHEASTERN VIRGINIA

PRORATED WITHDRAWAL RATES, IN CUBIC FEET PER SECOND, FOR PUMPING PERIODS USED IN THE LOWER CRETACEOUS AQUIFER MODEL

Pumping Center		Model Run 4			Model Run 5		Model Run 6	
		December 1972 – December 1973			December 1973 – August 1974		August 1974 – December 1974	
		XII	XIII	XIV	XV	XVI	XVII	XVIII
	From	12-1-72	9-18-73	11-1-73	12-1-73	7-22-74	8-13-74	8-23-74
	To	9-18-73	11-1-73	12-1-73	7-22-74	8-13-74	8-23-74	12-7-74
City of Norfolk (Lake Prince Wells)			5.85					
Hercules, Inc.		8.85	8.85	8.85	8.85	8.85	8.85	8.85
Wakefield		.15	.15	.15	.15	.15	.15	.15
Waverly		.23	.23	.23	.23	.23	.23	.23
Smithfield		5.00	5.00	5.00	5.00	5.00	5.00	5.00
Chesapeake Corp. West Point		25.00	25.00	25.00	25.00	25.00	25.00	25.00
Dow-Badische near Williamsburg		9.44	9.44	9.44	9.44	9.44	9.44	9.44
Adjacent to James River 1/		4.65	4.65	4.65	4.65	4.65	4.65	4.65
Boykins		.69	.69	.69	.69	.69	.69	.69
Courtland		.23	.23	.23	.23	.23	.23	.23
Franklin		1.64	1.64	1.64	1.64	1.64	1.64	1.64
Williamsburg		2.00	2.00	2.00	2.00	2.00	2.00	2.00
Union Camp Corp. Franklin		54.48	54.58	54.48	55.70	8.92	8.92	57.28

1/ Estimated.



HYDROGRAPHS OF MEASURED AND SIMULATED WATER LEVELS OF THREE WELLS, SOUTHEASTERN VIRGINIA 1940-74.

Cartography by C.J. Blankenship

MEASURED AND SIMULATED GROUND-WATER LEVELS IN THE FRANKLIN AREA, SOUTHEASTERN VIRGINIA, 1973-74.

by
Oliver J. Cosner

1976