HYDROGEOLOGY AND ANALYSIS OF THE GROUND-WATER FLOW SYSTEM IN THE COASTAL PLAIN OF SOUTHEASTERN VIRGINIA

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Table 1.--Hydrogeologic column showing aquifers and confining units in model area

<table>
<tr><th rowspan="2">Period</th><th rowspan="2">Epoch</th><th rowspan="2">Stratigraphic formation</th><th colspan="5">Hydrogeologic units</th></tr>
<tr><th>This report</th><th>Cederstrom 1945</th><th>Geraghty and Miller 1979 a & b</th><th>Sludyla and others 1981</th><th>Harsh and Laczniak 1986</th></tr>
<tr><td>Quaternary</td><td>Holocene
Pleistocene</td><td>Undifferentiated sediments</td><td>Columbia aquifer</td><td>Sands of Recent deposits and the Columbia group</td><td>Water-table aquifer</td><td>Water-table aquifer</td><td>Columbia aquifer</td></tr>
<tr><td rowspan="13">Tertiary</td><td rowspan="2">Pliocene</td><td rowspan="2">Yorktown Formation</td><td>Yorktown confining unit</td><td rowspan="3">Sands and shells of the Yorktown Formation</td><td rowspan="12">Upper artesian aquifer system</td><td rowspan="3">Yorktown aquifer</td><td>Yorktown confining unit</td></tr>
<tr><td rowspan="2">Yorktown-Eastover aquifer</td><td rowspan="2">Yorktown-Eastover aquifer</td></tr>
<tr><td rowspan="4">Miocene</td><td>Eastover Formation</td></tr>
<tr><td>St. Marys Formation</td><td>St. Marys confining unit</td><td rowspan="4"></td><td rowspan="4"></td><td>St. Marys confining unit</td></tr>
<tr><td>Choptank Formation</td><td>Not present in model area</td><td>St. Marys-Choptank aquifer</td></tr>
<tr><td>Calvert Formation</td><td>Calvert confining unit</td><td>Calvert confining unit</td></tr>
<tr><td>Oligocene</td><td>Old Church Formation</td><td rowspan="3">Chickahominy-Piney Point aquifer</td><td rowspan="3">Chickahominy-Piney Point aquifer</td></tr>
<tr><td rowspan="4">Eocene</td><td>Chickahominy Formation</td><td rowspan="5">Glauconitic sands of the Pamunkey coup</td><td rowspan="5">Eocene-Upper Cretaceous aquifer</td></tr>
<tr><td>Piney Point Formation</td></tr>
<tr><td>Nanjemoy Formation</td><td rowspan="2">Nanjemoy-Marlboro confining unit</td><td rowspan="2">Nanjemoy-Marlboro confining unit</td></tr>
<tr><td>Marlboro Clay</td></tr>
<tr><td rowspan="2">Paleocene</td><td>Aquia Formation</td><td>Aquia aquifer</td><td>Aquia aquifer</td></tr>
<tr><td>Brightseat Formation</td><td>Not present in model area</td><td></td><td></td><td></td><td rowspan="5">Not present in Virginia</td></tr>
<tr><td rowspan="12">Cretaceous</td><td rowspan="6">Late Cretaceous</td><td rowspan="2">Peedee Formation (of North Carolina)</td><td>Peedee confining unit[1]</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="6">Eocene-Cretaceous aquifer</td></tr>
<tr><td>Peedee aquifer[1]</td></tr>
<tr><td rowspan="2">Unnamed deposits (Black Creek Formation equivalent) in Virginia</td><td>Virginia Beach confining unit</td><td rowspan="2">Sands of Late Cretaceous age</td><td rowspan="10">Lower artesian aquifer system</td></tr>
<tr><td>Virginia Beach aquifer</td></tr>
<tr><td rowspan="8">Potomac Formation</td><td>Upper Potomac confining unit</td><td rowspan="8">Sands of the Potomac Group</td><td>Upper Potomac confining unit</td></tr>
<tr><td>Upper Potomac aquifer</td><td>Upper Potomac aquifer</td></tr>
<tr><td rowspan="6">Early Cretaceous</td><td>Middle Potomac confining unit</td><td rowspan="6">Lower Cretaceous aquifer</td><td>Middle Potomac confining unit</td></tr>
<tr><td>Middle Potomac aquifer</td><td>Middle Potomac aquifer</td></tr>
<tr><td>Lower Potomac confining unit</td><td>Lower Potomac confining unit</td></tr>
<tr><td>Lower Potomac aquifer</td><td>Lower Potomac aquifer</td></tr>
</table>

[1]Not present in study area but used in model simulations of ground-water flow

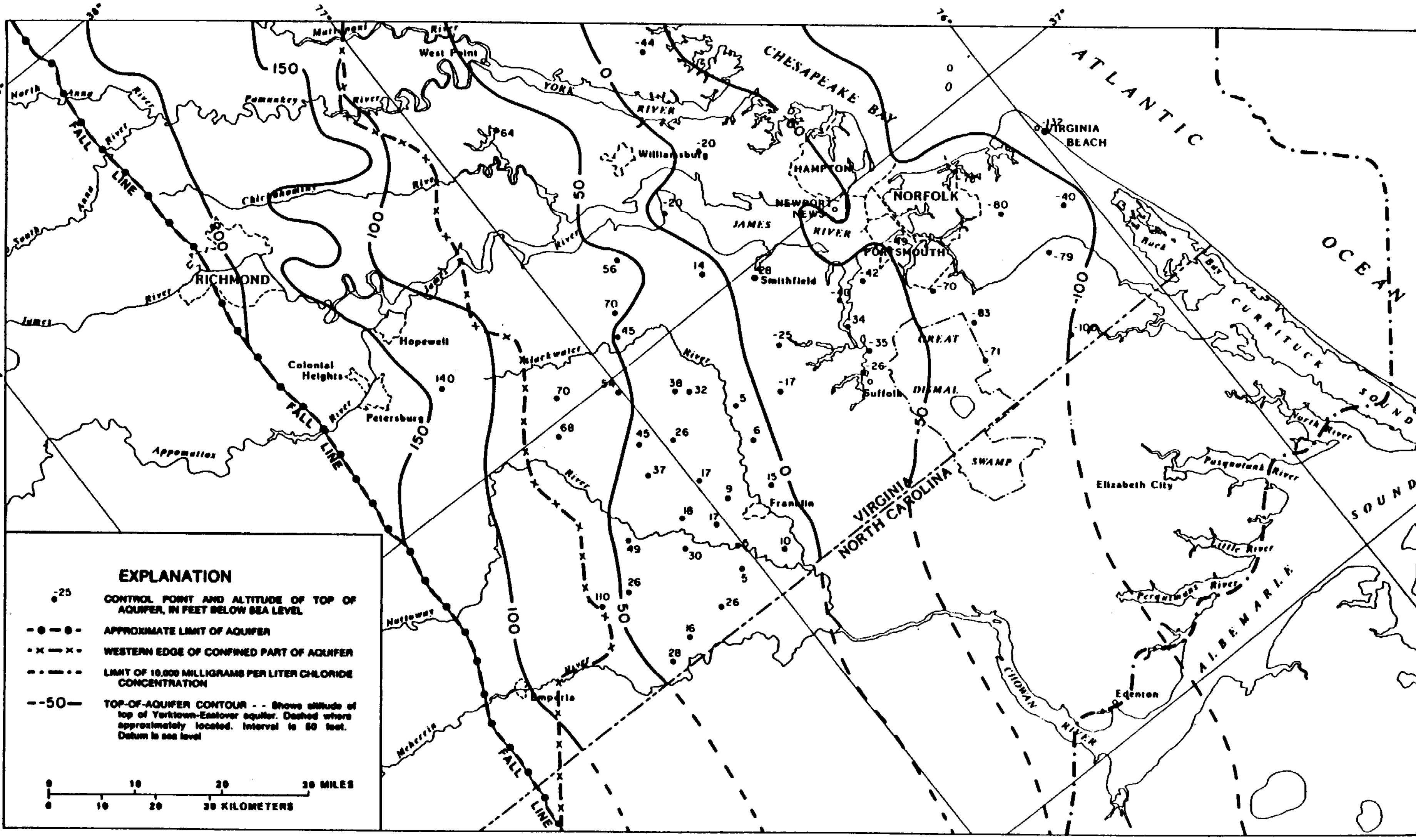

Figure 10.--Altitude of top and areal extent of Yorktown-Eastover aquifer.

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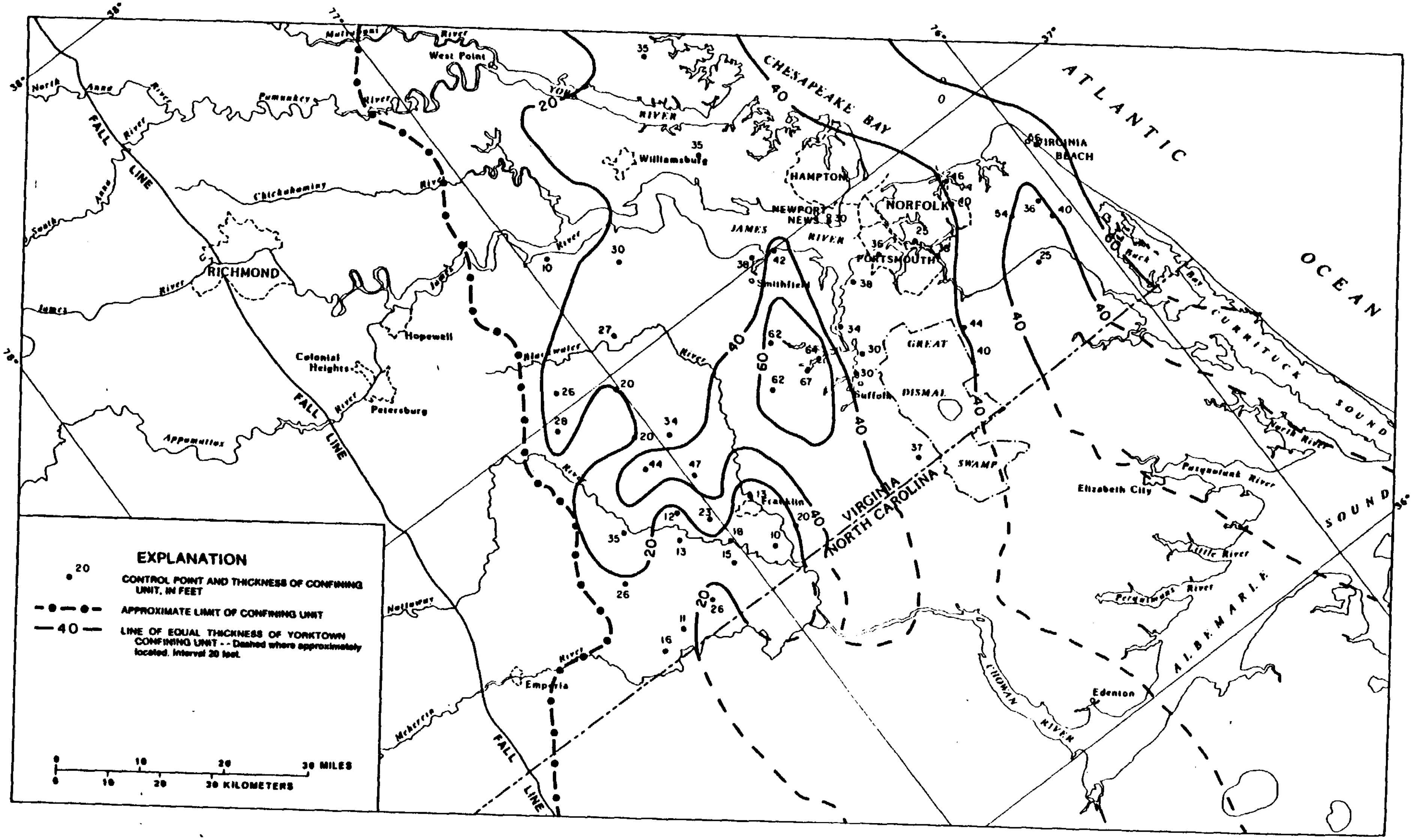

Figure 19.--Thickness and areal extent of Yorktown confining unit.

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Table 2.--Description of aquifers and well yields in model area
[Values in gallons per minute]

Aquifer name and description	Well Yield: Common range	Well Yield: May exceed	General remarks
Columbia aquifer: Sand and gravel, commonly clayey; interbedded with silt and clay. Fluvial to marine in origin; deposition resulted in terrace-type deposits from varying Pleistocene sea levels.	5-30	40	Generally unconfined, semi-confined locally. Most productive in eastern areas, very thin to missing in central and western areas. Water is very hard, calcium-bicarbonate type. Highly susceptible to pollutants from surface contamination. High concentrations of iron and nitrate in some areas. Possibility of salty water in coastal regions.
Yorktown-Eastover aquifer: Sand, commonly shelly; interbedded with silt, clay, shell beds, and gravel. Shallow, embayed marine in origin; deposition resulted in inter-fingering near-shore deposits from marine transgressions.	5-80	200	Multiaquifer unit. Mostly confined, unconfined updip in outcrop areas. Thickness dependent on altitude of land surface. Highest yields in eastern areas, thin to missing in western areas. Water is hard, sodium-calcium-bicarbonate type. Salty water in lower part of aquifer in eastern areas.
Chickahominy-Piney Point aquifer: Sand, moderately glauconitic, shelly; inter-bedded with silt, clay, and thin, indurated shell beds. Shallow, inner marine shelf in origin; deposition result of marine transgression.	10-110	200	Generally confined, except where it crops out along major stream valleys in the west. Important aquifer in central parts of Coastal Plain. Yields moderate to abundant supplies to domestic, small industrial, and municipal wells. Aquifer missing in western areas. Water is soft to hard, calcium-sodium-bicarbonate type and generally of good quality.
Aquia aquifer: Sand, glauconitic, shelly; interbedded with thin, indurated shell beds and silty clay intervals. Shallow, inner to middle marine shelf in origin; deposition result of marine transgression.	15-210	350	Generally confined, except where it crops out along major stream valleys in the west. Important aquifer in northern two-thirds of Coastal Plain. Yields moderate supplies to domestic, small industrial, and municipal wells. Aquifer missing in eastern areas. Water is soft sodium-bicarbonate type, with high iron, sulfide, and hardness locally.
Peedee aquifer: Sand, glauconitic and shelly; interbedded with dark, micaceous silt and clay. Near-shore marine in origin; deposition resulted from Late Cretaceous marine transgression.	5-40	50	Restricted to North Carolina Coastal Plain; not extensively developed. Yields small to moderate supplies to primarily domestic wells. Water is soft, sodium-bicarbonate type, with high chlorides in eastern areas.
Virginia Beach aquifer: Sand, fine- to medium-grained, glauconitic, micaceous, and lignitic; interbedded with thin clay layers and indurated zones. Shallow, inner marine shelf in origin; deposition result of marine transgression.	20-200	500	Multiaquifer unit. Restricted to south-eastern Virginia and North Carolina Coastal Plain. Yields moderate to abundant supplies to domestic and industrial wells. Water is soft, sodium-bicarbonate type, with high chlorides in eastern areas and areas of high fluoride and dissolved solids.
Upper Potomac aquifer: Sand, very fine to medium, micaceous, lignitic, and clayey; interbedded with silty clay. Shallow, estuarine and marginal marine in origin; sediments result of first major marine inundation of Cretaceous deltas.	20-400	1000	Multiaquifer unit. Confined, restricted to central and eastern areas. Yields second largest supply of water in Coastal Plain. Water is soft, sodium-chloride-bicarbonate type, with high chlorides in eastern areas.
Middle Potomac aquifer: Sand, fine to coarse, occasional gravel; interbedded with silty clay. Fluvial in origin; sediments result of deltaic deposition.	20-160	700	Multiaquifer unit. Generally confined, unconfined in outcrop areas of northwestern Coastal Plain and major stream valleys near Fall Line. Yields second largest supply of water in Coastal Plain. Water is moderately hard, sodium-chloride-bicarbonate type, with high chlorides in eastern half of Coastal Plain.
Lower Potomac aquifer: Sand, medium to very coarse, and gravel, clayey. Fluvial in origin; sediments result of deltaic deposition.	100-800	1,500	Multiaquifer unit. Generally confined, unconfined in outcrop areas of northwestern area of Coastal Plain. Yields third largest supply of water in Coastal Plain. Water is soft to very hard, and of sodium-bicarbonate to sodium-chloride type, with high chlorides in eastern half of Coastal Plain.

ground-water resource in the central part of the study area and yields moderate to abundant supplies to domestic, small industrial, and municipal users. The Chickahominy-Piney Point aquifer is overlain by the Calvert confining unit in the Calvert Formation. The confining unit forms an eastward-thickening wedge of dark-green clay interbedded with sandy clay and marl. It attains a maximum thickness in the study area of 460 feet in the city of Virginia Beach (well 63C1, fig. 17). It is overlain by the Yorktown-Eastover aquifer throughout the study area. In the north-central part of the model area, it is overlain by the St. Marys confining unit.

The St. Marys confining unit in the St. Marys Formation and basal part of the overlying Eastover Formation is present only in the north-central part of the model area and consists of shelly to laminated clay interbedded with very fine-grained sand. It ranges in thickness from near zero at its southern limit to approximately 88 feet in the northern part of the model area (well 58H4, fig. 18). It is overlain by the Yorktown-Eastover aquifer.

The Yorktown-Eastover aquifer in the lower part of the Yorktown Formation and upper part of the underlying Eastover Formation is the uppermost Tertiary aquifer. It is present throughout the study area, except in the middle and upper reaches of major stream valleys where it has been removed by erosion. The aquifer is unconfined in a broad area parallel to the Fall Line in the western part of the study area, and is confined in the central and eastern parts (fig. 10). It forms an eastward-thickening wedge of shelly, very fine- to coarse-grained sand, interbedded with silt, clay, shell beds, and gravel. Thickness in the study area ranges from near zero at its western and eroded limits to approximately 280 feet in the city of Virginia Beach (well 63C1). The aquifer is an important ground-water resource in southeastern Virginia for domestic, commercial, and light industrial use. It is an important source of recharge to the underlying confined system in the western part of the study area where it is unconfined. The Yorktown-Eastover aquifer is overlain by the Yorktown confining unit in the upper part of the Yorktown Formation. This unit consists of massive, well-bedded clay and silty clay, containing shells and fine-grained sand. It ranges in thickness in the study area from a featheredge at its western limit to approximately 56 feet in the city of Virginia Beach (well 63C1, fig. 19). Along its western limit, the confining unit is highly dissected. The unit is overlain by the Columbia aquifer in the eastern part of the study area.

The Columbia aquifer is the uppermost aquifer and is unconfined throughout its extent. It is present only in the central and eastern parts of the study area. The aquifer contains the youngest sediments of the Virginia Coastal Plain, consisting of interbedded gravel, sand, silt, and clay. The sediments range in thickness from 10 to 80 feet and represent Holocene sediments and terrace-type deposits laid down during Pleistocene time when sea levels fluctuated considerably. The aquifer is an important ground-water resource for rural and domestic users. It is also a major source of recharge to the underlying aquifer system.

Hydraulic Characteristics of Aquifers

Hydraulic characteristics describe the ability of an aquifer to transmit, store, or release water. The ability to transmit water is described in terms

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Table 7.--Estimated values for vertical hydraulic conductivity used in model analysis
[Values in feet per day]

Confining unit	Estimated vertical hydraulic conductivity
Yorktown	8.64×10^{-4}
St. Marys	4.15×10^{-4}
Calvert	3.89×10^{-5}
Nanjemoy-Marlboro	6.48×10^{-5}
Peedee	6.91×10^{-5}
Virginia Beach	7.34×10^{-5}
Upper Potomac	6.05×10^{-5}
Middle Potomac	6.48×10^{-5}
Lower Potomac	4.32×10^{-5}

Table 8.--Estimated minimum and maximum values for vertical leakance used in model analysis
[Values per day]

Confining unit	Estimated minimum vertical leakance	Estimated maximum vertical leakance
Yorktown	1.88×10^{-5}	9.60×10^{-3}
St. Marys	6.10×10^{-6}	4.15×10^{-3}
Calvert	5.40×10^{-8}	7.78×10^{-4}
Nanjemoy-Marlboro	1.16×10^{-7}	5.89×10^{-4}
Peedee	6.91×10^{-7}	9.87×10^{-6}
Virginia Beach	1.10×10^{-6}	2.29×10^{-5}
Upper Potomac	6.06×10^{-8}	1.89×10^{-4}
Middle Potomac	3.24×10^{-7}	5.40×10^{-4}
Lower Potomac	3.93×10^{-7}	5.40×10^{-6}

Values for vertical leakance generally decrease from west to east because of increased thickness of the confining unit (figs. 11 through 19) and decreased vertical hydraulic conductivity of the sediment. The deeper confining units are characterized by lower vertical leakance. Relatively high vertical leakance resulting from high vertical conductivity is present along major river valleys and Chesapeake Bay where original confining unit sediment was eroded and replaced with more permeable river deposits.

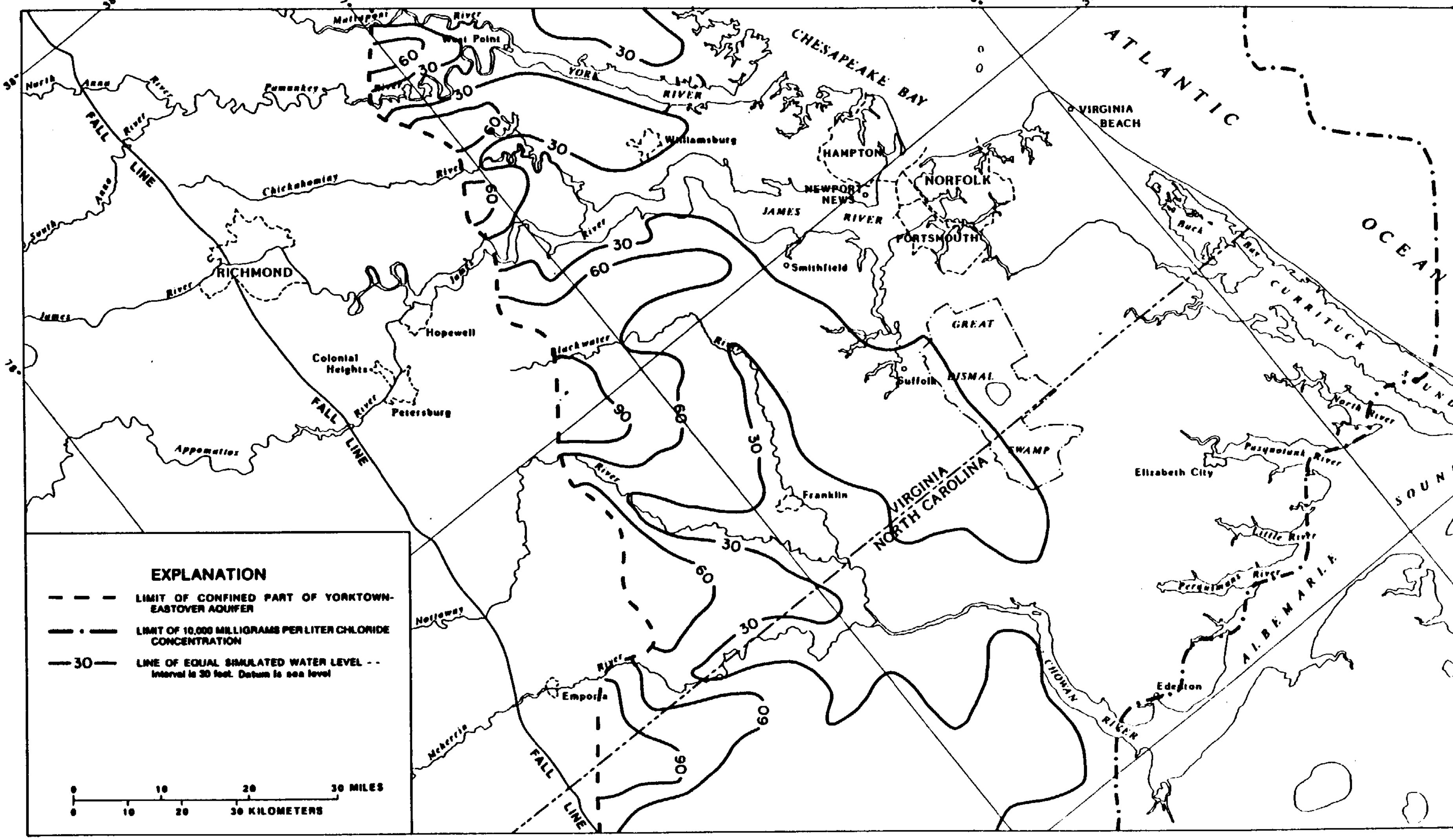

Figure 43.--Simulated water levels in the Yorktown-Eastover aquifer for prepumping conditions.

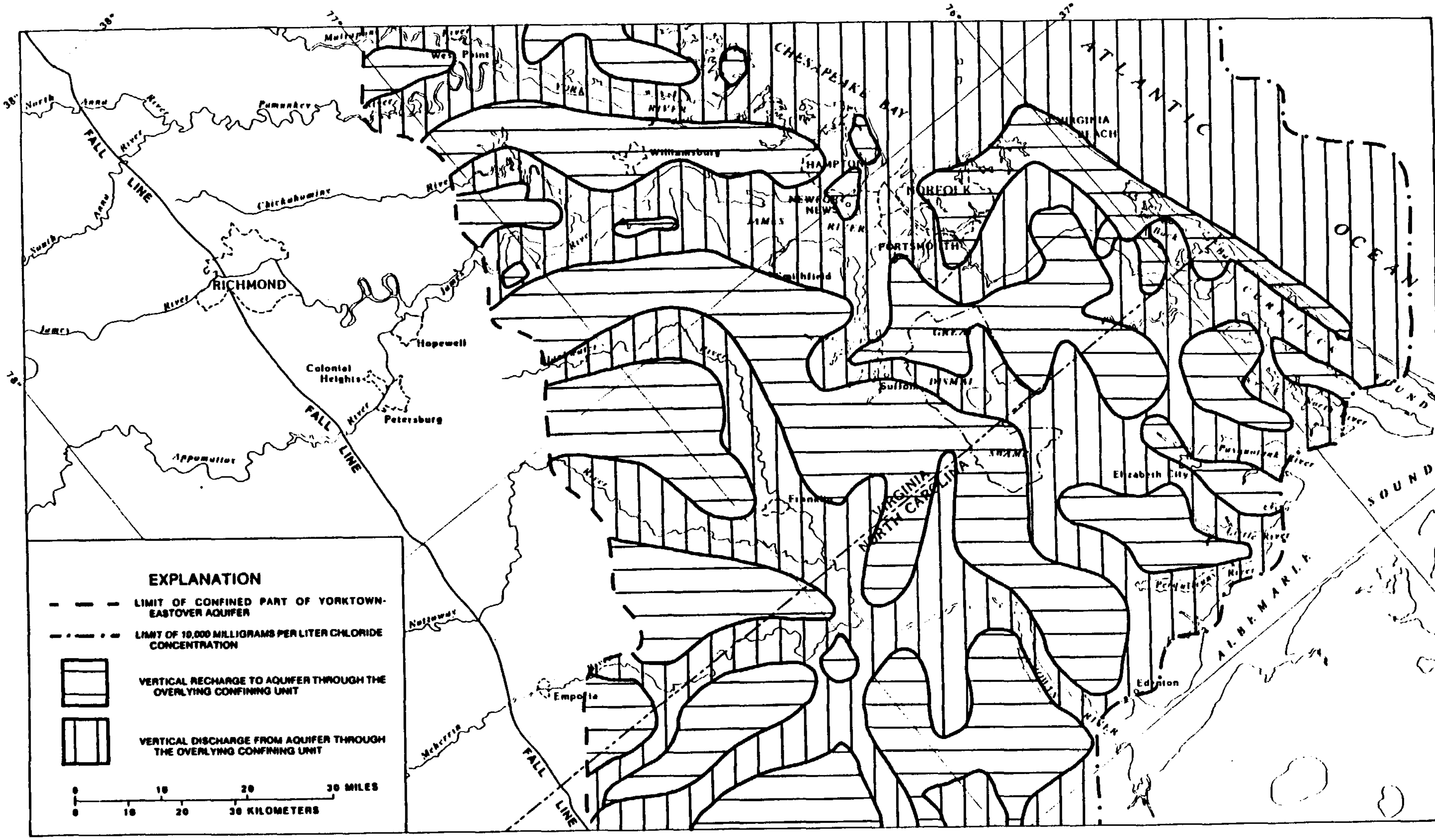

Figure 51.--Simulated areas of vertical recharge to and discharge from the Yorktown-Eastover aquifer through the overlying confining unit for prepumping conditions.