DEPARTMENT OF ENVIRONMENTAL PROTECTION
LAND USE MANAGEMENT
NEW JERSEY GEOLOGICAL SURVEY

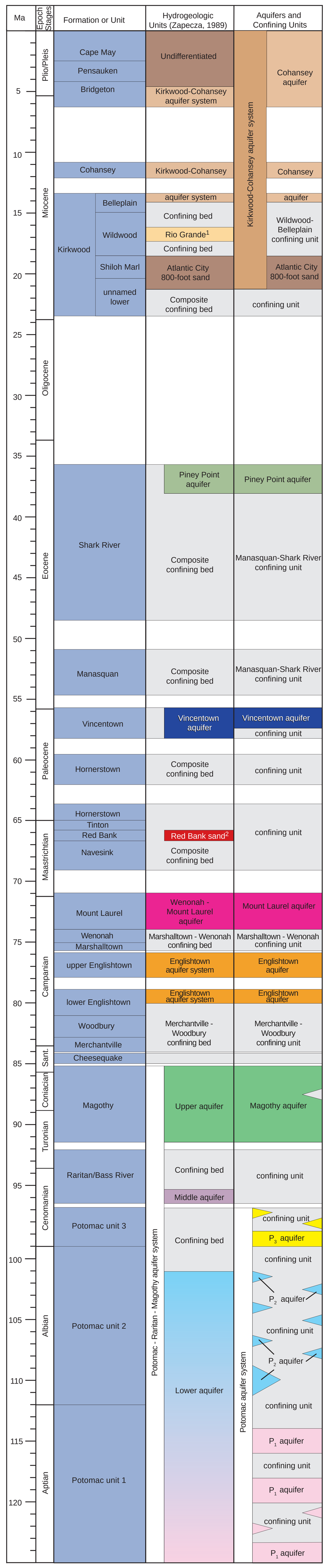

Figure 1. Generalized comparison of geologic formations, aquifers, and confining units in the study area. Also shown is the hydrogeologic framework modified from Zapecza (1989).

[1] Rio Grande water bearing zone - minor aquifer not mapped in this report.
[2] Red Bank sand - minor aquifer not mapped in this report.
[3] The Mount Laurel aquifer is used in this report in place of the Wenonah-Mount Laurel aquifer as defined by Zapecza (1989) based on data from continuously cored boreholes (e.g. Miller and others, 1999) that identifies medium-coarse aquifer sands only in the Mount Laurel Formation. The Wenonah contains only silty and clayey fine-grained sand and therefore is assigned to the upper part of the Marshalltown-Wenonah confining unit.

Introduction

Southwestern New Jersey is heavily dependent on ground water for potable water and irrigation. In 1999 about 67 billion gallons of ground water was withdrawn, 60 percent of total water withdrawals (Domber and Hoffman, 2004). These withdrawals have created significant water-level declines in the primary aquifers (Lacombe and Rosman, 2001). Critical issues face water-resource planners in this area, as in many areas of New Jersey, where demand for water is projected to increase significantly during the next 20 years. The Salem/Cumberland area is projected to be one of the five fastest growing areas in New Jersey (Cauller and others, 1999) highlighting the need for additional water resources, and careful water-resources planning.

Other issues face planners besides increased water use. A major aquifer system in the New Jersey Coastal Plain (NJCP), the Potomac-Raritan-Magothy (PRM) aquifer system (fig. 1), is susceptible to salt water intrusion in this region owing to its proximity to the Delaware estuary, and to heavy pumping in surrounding areas, resulting in salt water in the lower layers of the system. These issues have been addressed in the PRM aquifer system in northern Gloucester, Camden and Burlington Counties by the imposition of Water Supply Critical Area No. 2, along with strict restrictions on withdrawals (Hoffman and Lieberman, 2000). A more effective management strategy is to develop a comprehensive understanding of the geologic framework governing the aquifer system's ability to store and transmit water and prevent excess withdrawals by limiting pumpage to sustainable volumes.

These concerns initiated a study of the deep confined aquifers beneath the NJCP. The major focus of this study is to improve understanding of the hydrogeologic framework of the NJCP as developed by Zapecza (1989). In this study area (fig. 2), the primary focus is the geology and hydrostratigraphy of the PRM aquifer system, the main source of water for Salem, Gloucester, and Camden counties. Improvements in our understanding of the PRM aquifer system, and other deep confined aquifers, is based on the analysis and integration of stratigraphic data from continuous coreholes at Ancora (Miller and others, 1999), Clayton (Owens and others 1998), Fort Mott (Sugarman and others, 2004), and Millville (Sugarman and others, 2005a) with existing geophysical logs collected from regional water wells. Additionally, geologic maps of the study area by Owens and others (1998), Stanford and Sugarman (2004, 2005, 2006) and Stanford, Sugarman and Owens (2004) provided additional constraints for the hydrogeologic framework and cross sections.

Framework

The generalized hydrogeologic framework of aquifers and confining units (fig. 1) was developed by mapping major sand beds (aquifers) and clay-silt beds (confining units) within each geologic formation. In places, specific sand units are consistent and thick enough to be mapped as a single aquifer within a specific formation. For example, each of the following formations has one confined aquifer within the study area: the Shark River (Piney Point aquifer), Vincentown, Mount Laurel, Englishtown, and Magothy (figs. 3 to 8).

The geometry of aquifer sands and confining units in the Potomac Formation is more complex than in younger units. Because of the largely fluvial depositional environment of the Potomac Formation (Glaser, 1969), there are numerous thin-to-thick sand and clay-silt lenses in the Potomac Formation that commonly are laterally discontinuous within short distances. A further complication exists as Potomac units onlap against the southeast-dipping pre-Cretaceous basement such that older units occur only in the deeper, eastern sections of the study area. To facilitate mapping of geologic and hydrogeologic units in the Potomac Formation, a biostratigraphic subdivision consisting of mappable units: unit 3 (P3), unit 2 (P2), and unit 1 (P1; from youngest to oldest; fig. 1) has been employed (Owens and others, 1998). This subdivision is based on pollen zones of Doyle and Robbins (1977). Unit 3 (early Cenomanian) correlates with pollen Zone III, unit 2 (Albian) with pollen Zone II, and unit 1 (Aptian to early Albian) with pollen Zone I. P2 and P1 are entirely subsurface units in New Jersey (Owens and others, 1998).

Lithologic changes commonly observed along the Zone III/Zone II boundary have also been utilized in correlating hydrogeologic units. In Delaware, Benson (2006) mapped a sand body at the base of P3 (fig. 6) above a clay-silt marking the top of P2. The contact between this lower Zone III aquifer and the upper Zone II confining bed marks the Early Cretaceous-Late Cretaceous time line. This relationship is well documented at Fort Mott (figs. 6 and 7; Sugarman and others, 2004) where thick aquifer sands at the base of Zone III are above fine-grained confining beds assigned to Zone II. P3 contains a maximum of four distinct sand bodies (for example fig. 8). The lower one observed at Fort Mott appears to be regionally consistent and traceable throughout a large part of this study area, reflecting a possible delta front environment (Sugarman and others, 2005b). The overlying sand bodies appear to be discontinuous, reflecting their localized fluvial channel depositional environments.

Correlations of aquifer sands within the P2 and P1 aquifers are tenuous. P2 aquifer sands are generally 20-50 feet thick. The continuity of these sand bodies between wells is uncertain because of limited resolution from widely spaced boreholes and lack of biostratigraphic data for precise correlations. At certain boreholes such as Mantua and Monroe, aquifer sands within the P2 reach a maximum thickness of 100 feet. Where present, the P1 aquifer appears to be a continuous, thick sand throughout the region, but this requires verification.

Although this report identifies the location and distribution of aquifers in the Potomac and Magothy Formations, it should be pointed out that many of these sand units, especially the deeper ones, contain water with chlorides exceeding 250 mg/L established by the U.S. Environmental Protection Agency for national secondary drinking water standards. Consequently, water from these aquifer units would be unusable for potable supplies unless treated.

Hydrogeologic Correlations

Camden County

The major aquifers in Camden County are shown on northwest to southeast dip section A-A' (fig. 3). Sections E-E' (fig. 7) and F-F' (fig. 8) also provide information on these aquifers; E-E' is a strike section along the Delaware River whereas F-F' adds information on the geohydrology of the Potomac Formation in the deep subsurface from the New Brooklyn borehole. The most productive aquifers in the upper (northwestern) half of Camden County are the Magothy and P3 aquifer(s). The most important confined aquifer in Camden County besides the Magothy and P3 is the Mount Laurel aquifer. In the lower (southeastern) part of Camden County, the Cohansey is an important water-table aquifer. In the Devonshire, Ancora, and New Brooklyn boreholes, high chloride levels in the P3 and P2 aquifers limit their use for potable-water supply.

At the Camden City borehole, the Magothy Formation and P3 combine to form a ~200-ft-thick water-table-and-semiconfined (?) aquifer system (fig. 3). This is a prime recharge area for both the Magothy and P3 aquifer. A ~10-ft bed separates these two aquifers; because of its limited thickness, it probably has minor confining capabilities.

The Magothy aquifer thickens in the subsurface, increasing from 80-90 feet in outcrop to 120 feet at Ancora (fig. 3). In the wells downdip from Camden City borehole, thin (10 to 20-ft -thick) confining beds are present within the Magothy. At Haddonfield (slightly more than 4 miles downdip from Camden City) and Owens-Corning (~7 miles downdip), a 30 to 50-ft-thick confining bed is present between the Magothy and P3 aquifers. The confining bed thickens to 70-80 feet at Devonshire and Ancora (Miller and others, 1999), and correlates with the Bass River Formation (downdip Raritan) at Ancora. It is possible that the thin confining bed separating the Magothy and Potomac Formations at Haddonfield and Owens-Corning may also correlate with the Bass River Formation.

The thickness of the P3 aquifer is 80 to 100 ft on section A-A' (fig. 3). At the New Brooklyn well (section F-F'; fig. 8) the P3 is dominantly a clay-silt deposit, and the thick aquifer seen elsewhere in Camden County within P3 is absent. Instead, three 10-to-20-ft-thick sand units are separated by two confining beds – the upper one 30 ft thick and the lower one more than 60 ft thick.

The P2 and P1 were only penetrated in the New Brooklyn well in Camden County. Here, a thick 110-ft confining bed separates the lowermost aquifer in P3 from the uppermost aquifer in P2. This uppermost aquifer within P2 is 50 ft thick, and is separated from an upper 70-ft-thick P1 aquifer by a 40-ft-thick confining bed. In general, P1 is very sandy at this site. Six separate sand units were mapped, ranging in thickness from 20 to 80 ft. High chloride values in water from this interval in the Potomac limit its utility as an aquifer in this area.

The Englishtown and Mount Laurel confined aquifers are also water sources in Camden County. The Mount Laurel is more productive than the Englishtown in Camden County; the most productive water wells are located within 10 miles of the outcrop belt (Farlekas and others, 1976). The Englishtown is a minor aquifer closer to the Delaware River. It is thickest (25 ft) at Owens-Corning (fig. 3) where it is a silty-fine sand, typical of the Englishtown in this area (Nichols, 1977). Farlekas and others (1976) report that the most productive Englishtown wells are in the center of Camden County at Clementon. Downdip, at Ancora, the Englishtown sand is too thin to be an aquifer. The Mount Laurel is 50 feet thick between Devonshire and Ancora, where it is composed of silty, very fine to fine sand. In Camden County, the Piney Point aquifer is present only in the subsurface. It is thickest (80 ft thick) at the Ancora corehole, and is a potentially useful aquifer only in eastern Camden County.

The Cohansey forms a thick water-table aquifer is the eastern half of Camden County (fig. 3). It is more than 170 feet thick at the Ancora core hole and thins to approximately 100 feet towards the west, and pinches out 1.5 miles to the north-northwest of Devonshire.

Gloucester County

Several aquifers, depending on location, service Gloucester County's water needs as shown on sections B-B' (fig. 4), E-E' (fig. 7) and F-F' (fig. 8). The Magothy and P3 aquifers are the most important and productive aquifers in Gloucester County (Hardt and Hilton, 1969). These aquifers have elevated chlorides in the lower (southeastern) part of the county. The P2 is a productive aquifer closer to the Delaware River in the northwestern corner of Gloucester County, where chlorides are low enough so that the water is potable. The Mount Laurel aquifer is an important source of water for domestic use in the central part of Gloucester County. Where present in the eastern part of Gloucester County, the Cohansey is an excellent unconfined aquifer.

In northwestern Gloucester County, near the Delaware River (fig. 4), the Magothy is a relatively shallow, thick (~90 ft) confined aquifer. Less than 4 miles downdip, at Mantua, the Magothy aquifer is about 260 feet below the surface, and 90 ft thick. Farther downdip (~9 miles) at the Clayton 1 and Clayton 2 boreholes, its thickness (80-90 feet) is similar to that at the updip Mantua and Shell boreholes.

At the Shell borehole, a confining unit (~80 feet thick) separates the Magothy from aquifers within Potomac unit 3 (fig. 4). Two aquifers are within the P3 here; the upper one is ~40 ft thick, the lower one (sand) being the thinner (~15 ft). Only the lower P3 aquifer is interpreted as being continuous downdip all the way to Clayton 2. At West Deptford and Mantua, additional thin (5-10 ft) to thicker (20-30 ft) interbedded sands occur within P3. Owing to partial physical separation by a confining bed 10-25 ft thick between West Deptford and Mantua, the Magothy and P3 aquifers probably act as a single aquifer system. Four of the Mantua P3 sand beds project downdip to the Clayton 1 borehole. However, the P3 and P2 aquifers are at, or slightly above, the uppermost limit for chlorides in water at Clayton 1.

At Mantua a thick ~75-ft confining bed separates the lower P3 aquifer from aquifer sands within P2. The lower of two P2 sands penetrated in the Mantua well is nearly 100 ft thick and is potentially an excellent aquifer. This thick sand pinches out downdip before Clayton 1 where only a single thin (~15 ft thick) P2 sand was penetrated (fig. 4). Two deeper adjacent sand bodies form the P1 aquifer at Clayton 1. The P2 and P1 aquifers at Clayton, however, are not usable for potable water because of high chloride levels.

The Magothy, a confined aquifer, thins from 85 ft at Shell to 70 ft thick at Lopes, to 60 ft at Landtech, where the aquifer crops out and is unconfined to semiconfined (fig. 7). The P3 aquifers vary along strike in a similar way. From Shell and progressing southwesterly along strike (fig. 7), sands are more numerous and thicker in the upper part of P3. At Lopes, P3 consists of three main sand bodies. The upper sand bed is ~65 ft thick and probably forms a single aquifer with the Magothy as a result of limited separation by a 10 ft-thick confining bed. The lower P3 sands are 20-30 ft thick and also probably function as a single aquifer because of limited separation by a thin 10-ft-thick confining bed.

In the southeast part of the county, where the Clayton 1 borehole is located, the Mount Laurel aquifer is 60 ft thick, and is 80 ft thick at the Clayton 2 corehole downdip to the southeast (fig. 4). The Mount Laurel forms a confined aquifer in this area. The aquifer has been a satisfactory source of water for domestic wells in the north-central part of Gloucester County (Hardt and Hilton, 1969). Owing to restrictions on some confined aquifers below the Mount Laurel, pumpage of ground water from the Mount Laurel aquifer has increased (Cauller and others, 1999). A large cone of depression in central Gloucester and Camden counties indicates heavy pumpage from the Mount Laurel (Lacombe and Rosman, 2001). In this study the Englishtown is not recognized as an aquifer in Gloucester County because of its fine grained texture and limited thickness. In the vicinity of its outcrop, the Englishtown reportedly yielded water adequate for modest domestic use (Hardt and Hilton, 1969).

Cauller and others (1999) report large ground-water withdrawals from the unconfined Cohansey aquifer in the southeastern half of Gloucester County. At the Clayton 1 and 2 coreholes, the Cohansey ranges from 70 to 80 feet in thickness.

Salem and Cumberland Counties

The confined aquifers in Salem County are illustrated in sections C-C' (fig. 5) and D-D' (fig. 6), and part of section E-E' (fig. 7) and F-F' (fig. 8). Section C-C' is a cross section of the confined aquifers in the northwestern part of Salem County. The most productive confined aquifers in the county are generally the P3, P2, and the Magothy Formation (in the northern part of the county). The Mount Laurel is a productive confined aquifer in localized areas. The Cohansey water table aquifer is an important source of water in the in the southeastern third of Salem County. In Cumberland County, the unconfined Cohansey aquifer is the most important source of ground water (Rooney, 1971). The Kirkwood Formation's Atlantic City 800-foot sand is a productive confined aquifer in eastern Cumberland County (Sugarman, 2001). The confined Piney Point aquifer also supplies water at some domestic wells in eastern parts of Cumberland County.

A major change marks the Magothy aquifer as it thins to the southwest into Salem County. This change is very pronounced near the Magothy outcrop belt. The aquifer's thickness of 60 ft in the southwestern corner of Gloucester Counter at the Landtech borehole thins to just over 20 ft thick at Fort Mott (fig. 7). The Magothy is either cut out entirely by surficial deposits (Stanford and Sugarman, 2006), or is very thin (for example, less than 5 ft) at DuPont MW next to the Delaware River.

The boreholes at Woodstown, Pilesgrove, and DuPont Courses indicate that the most productive aquifers are in the Potomac Formation (fig. 5). At Woodstown, the lower P3 sand is at least 50 ft thick and is the most promising aquifer. At DuPont Courses and Woodstown, there is a 40-ft-thick aquifer at the top of P2. Below this aquifer is a confining unit more than 100 feet thick that separates the upper P2 aquifer from a 40-60-ft-thick lower P2 aquifer

Upsection, minor confined aquifers at shallower depths are the Mount Laurel and Englishtown. The Mount Laurel is 50 ft thick and is potentially a more productive aquifer than the 20-30-ft-thick, commonly silty and fine-grained Englishtown. Although the Englishtown is sufficient for domestic wells, the Mount Laurel is also adequate for industrial and community supply (Rosenau and others, 1969).

Farther downdip at Parvin and Millville, Cumberland County, the deep confined aquifers within the Magothy and the Potomac appear to be poor aquifers based on: 1) their limited thickness; 2) the occurrence of thick clay beds (Sugarman and others, 2005a); and 3) dissolved chlorides substantially exceeding 250 mg/L. At Millville, the Englishtown might possibly be a minor aquifer provided its water quality is suitable for potable supply. In these areas, water supply is primarily from the water-table component of the Kirkwood-Cohansey aquifer system, as well as from the deeper, confined, Atlantic City 800-foot sand aquifer. Water is also supplied here from the Piney Point aquifer. Although the Piney Point is 80 ft thick, numerous clay and silt interbeds cause large drawdowns during pumping (Lacombe and Rosman, 2001).

The confined aquifers at the western end of Salem County are shown on section D-D' (fig. 6). At Fort Mott, the Magothy is ~20-ft thick, and is much less productive than in Gloucester and Camden counties. An extensive confining bed (~150 ft thick) separates the Magothy from an excellent aquifer at the base of P3. This aquifer is almost 70 ft thick. Another extensive confining bed, almost 200 ft thick at Fort Mott, separates this P3 aquifer from a productive ~40-ft-thick aquifer in P2. Twenty feet below this aquifer is another 20-ft-thick P2 aquifer. Some thin (~10-ft thick) aquifers are shown in P1 at Fort Mott, although these semi-indurated sands might have limited porosity, limiting their ability to be productive water-bearing zones.

At the PSE&G borehole (figs. 6 and 8), the Vincentown (80 ft thick) and Mount Laurel (85-90 ft thick) are relatively shallow aquifers that are absent at Fort Mott. The Magothy thickens downdip from Fort Mott to ~60 ft at the PSE&G borehole. As with Fort Mott, the major aquifer at PSE&G is the sand body at the base of P3, where it is 80 ft thick. Unlike Fort Mott, three shallower sand bodies are in P3, their thicknesses are 15 ft, 20ft, and 30 ft respectively. Based on their geophysical characteristics, these sand bodies appear to be finer-grained than those in lower P3 aquifer, and their ability to transmit water might be limited by lower permeability.

P2 at PSE&G is a minimum of 300 ft thick, and consists mostly of fine-grained clays and silts that act as confining beds. Three separate sand beds in the P2 may be potential aquifers. Their thickness ranges from 20 to 35 ft.

P1 contains more numerous and thicker sand bodies than P2 at PSE&G, but their lithologic characteristics are unknown. The four upper sand bodies are 30, 50, 20 and 30 ft thick respectively. At the base of Potomac unit 1 in this well are two very thick sand bodies, each 80 to 100 ft thick. The lower three sand bodies might function as a single aquifer more than 250 feet thick. The PSE&G borehole is directly on the boundary of the 250 mg/L isochlor for the P3 aquifer.

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Drill-Site Name	Drill-Site Information	USGS 7 1/2' Quadrangle	NJ Permit Number	Elevation (feet above sea level)	Latitude	Longitude	Depth (ft)
Ancora	NJGS Ancora Site	Hammonton	31-53332	188	39° 41' 31.98"	74° 50' 56.46"	1170
Bellmawr	Bellmawr Water Department Well 4	Runnemede	31-04969	75	39° 51' 48.727"	75° 05' 41.792"	551
Camden City	NJ Water Company - Camden City Div 54 (7-547)	Camden	31-18944	35	39° 57' 04"	75° 04' 58"	210
Cherry Hill	Cherry Hill Murray Ave MW	Camden	31-37787	188	39° 55' 35"	75° 01' 32"	367
Clayton 1	USGS Clayton Deep Well (15-0999)	Pitman East	15-8013	142	39° 40' 31"	75° 06' 05"	1675
Clayton 2	Clayton Sewerage Authority USGS/NJGS TW1 (15-1035)	Pitman East	31-29933	108	39° 38' 38"	75° 06' 03"	1001
Devonshire	NJ American Devonshire ASR-1	Clementon	31-40750	188	39° 49' 10"	75° 32' 07"	1086
DuPont Courses	E.I. DuPont Courses Landing 2A (33-302)	Penns Grove		30	39° 40' 00"	75° 24' 39.1"	804
DuPont MW	E.I. DuPont de Nemours & Co. MW 45B	Penns Grove	30-01913-3	11	39° 41' 30.6"	75° 29' 25.5"	469
Fort Mott	NJGS Fort Mott State Park Site	Delaware City	30-14904	3.79	39° 36' 19.96"	75° 33' 07.18"	820
Haddon	Haddon Township Well 4A	Camden	31-59128	60	39° 54' 06.1"	75° 03' 34.85"	468
Haddonfield	Boro of Haddonfield Test Well (07-303)	Camden	31-04740	45	39° 54' 04"	75° 02' 02"	553
Landtech	Pureland Water Co. Test Hole 3 (Landtech Corp) (15-139)	Bridgeport	30-01223	7	39° 46' 07"	75° 21' 32"	345
Lopes	USGS Lopes Test Hole (15-621)	Bridgeport	30-03685	25	39° 47' 22"	75° 17' 31"	493
Mantua	USGS Mantua Township Maintenance Yard (15-742)	Woodbury		84	39° 46' 52"	75° 10' 04"	871
Millville	NJGS Millville Site	Millville	35-22816	89.7	39° 24' 10.32"	75° 05' 11.22"	1500
Monroe	Monroe MUA Observation #1 Corkery Lane	Williamstown	31-56306	150	39° 40' 5.58"	74° 58' 31.39"	2020
New Brooklyn	USGS New Brooklyn Park 1	Williamstown	31-4446	188	39° 42' 15"	74° 56' 17"	2090
Owens-Corning	Owens-Corning Test Hole 2 (7-0317)	Runnemede	31-04712	68	39° 51' 34"	75° 02' 51.1"	676
Parvin	NJGS Parvin State Park Site (33-841)	Elmer	35-17766	77	39° 30' 56.302"	75° 08' 35.838"	1135
Pennsville	Pennsville Twnsp Water Dept Test Hole 1-64	Delaware City		10	39° 37' 50"	75° 31' 49"	809
Pilesgrove	Delea Well IR-1, Pilesgrove	Penns Grove	30-13862	30	39° 39' 52.999"	75° 23' 33.000"	498
PSE&G	PSE&G Test Hole 1-80 (33-0401)	Taylors Bridge		20	39° 27' 51"	75° 32' 07"	1803
Shell	Shell Chemical Co. Test Hole 1 (15-287)	Woodbury	30-00862	30	39° 49' 20"	75° 12' 26.1"	445
Turnpike	NJ Turnpike Authority IN-1 (33-69)	Penns Grove	30-00067	40	39° 41' 39"	75° 23' 51"	331
W. Deptford	West Deptford MUA Well 8	Woodbury	30-14478	40	39° 48' 36.627"	75° 10' 47.336"	428
Woodstown	Borough of Woodstown	Woodstown	30-13120	45	39° 38' 44.874"	75° 19' 05.108"	1144

Table 1 – Boreholes (water wells and coreholes) used in the study.

Figure 2. Location map of study area showing boreholes used in cross sections.

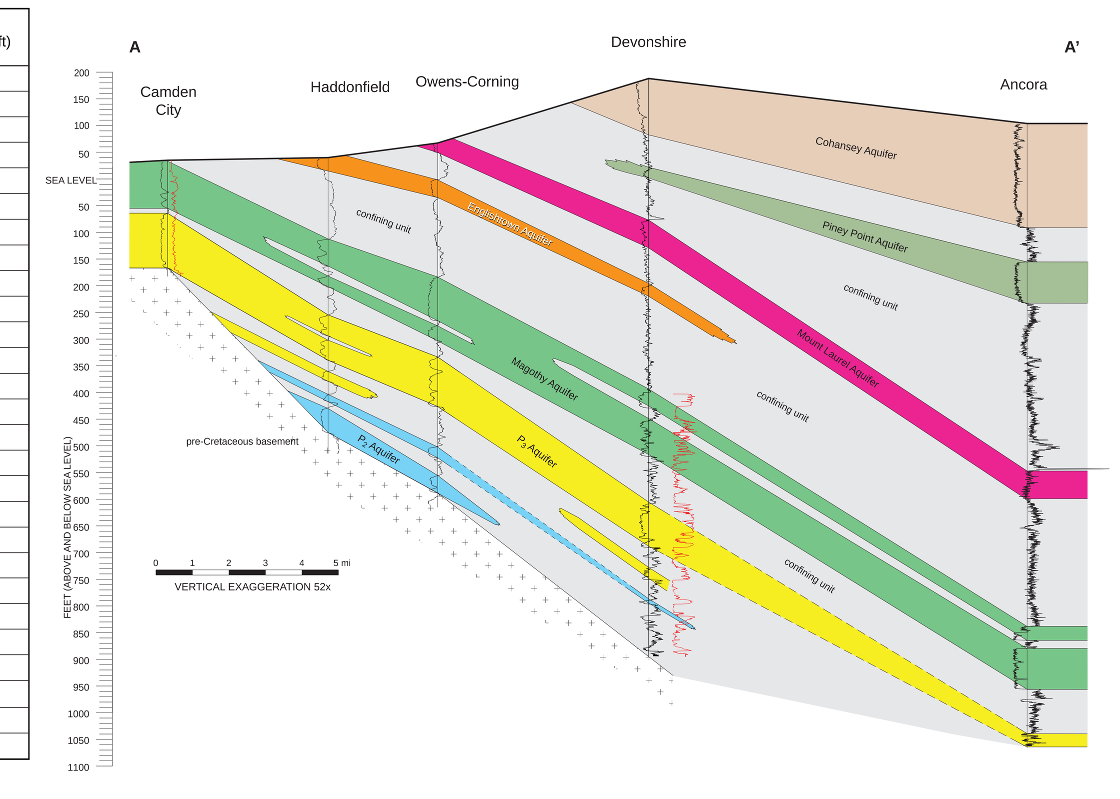


Figure 3. A-A': Hydrogeologic section down dip in most of Camden County.

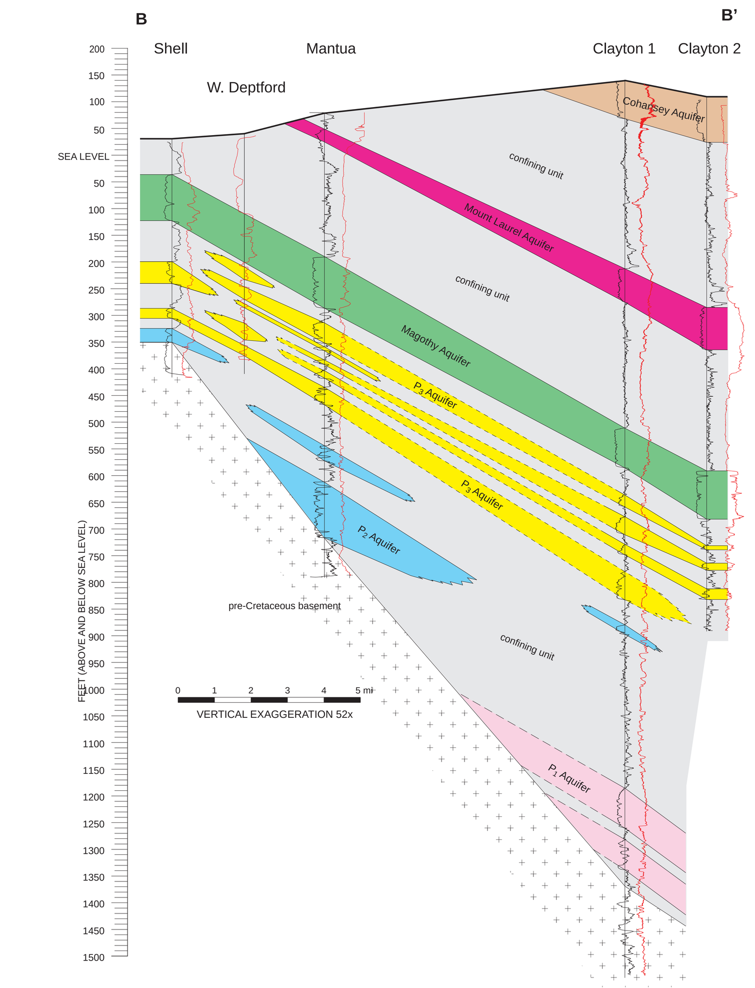


Figure 4. B-B': Hydrogeologic section down dip in Gloucester County.

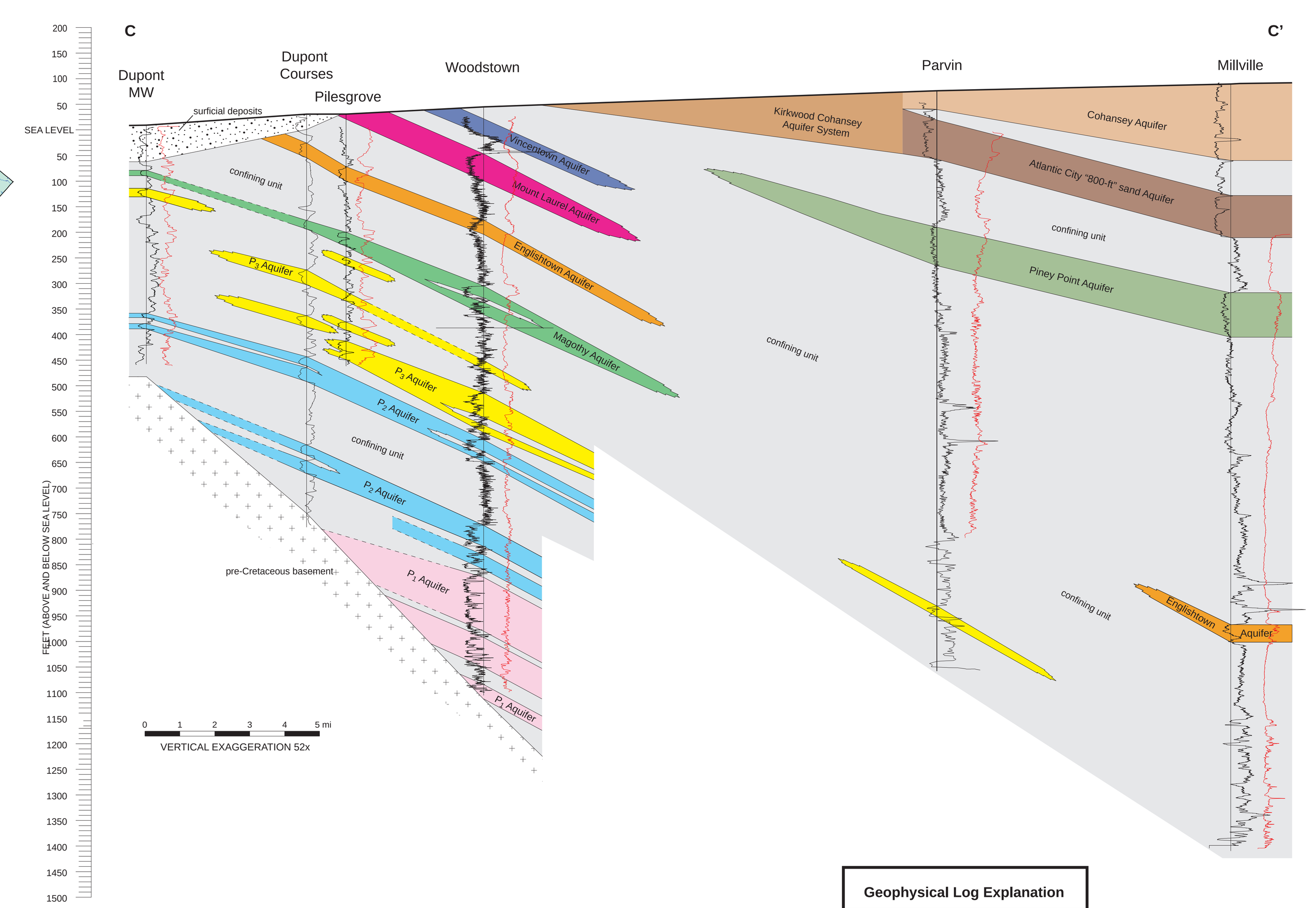


Figure 5. C-C': Hydrogeologic section down dip in Salem County and part of Cumberland County.

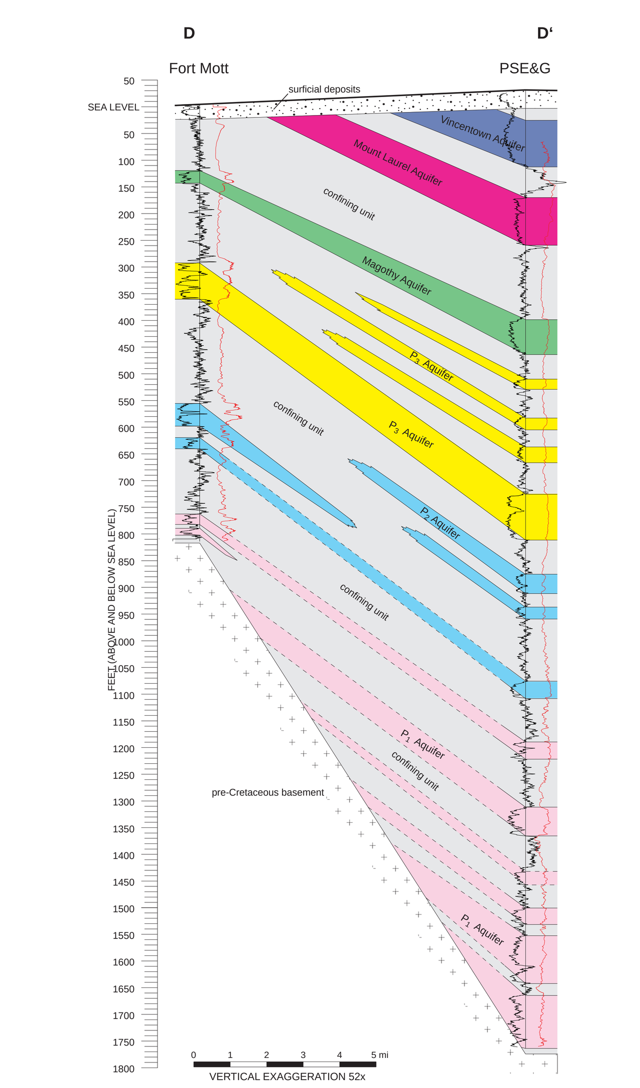
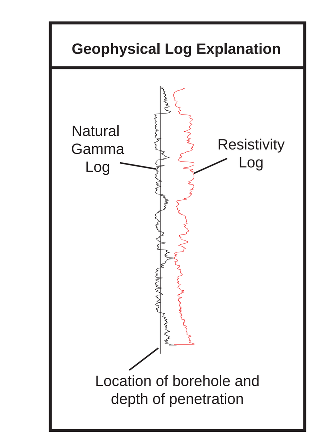


Figure 6. D-D': Hydrogeologic section down dip in Salem County.



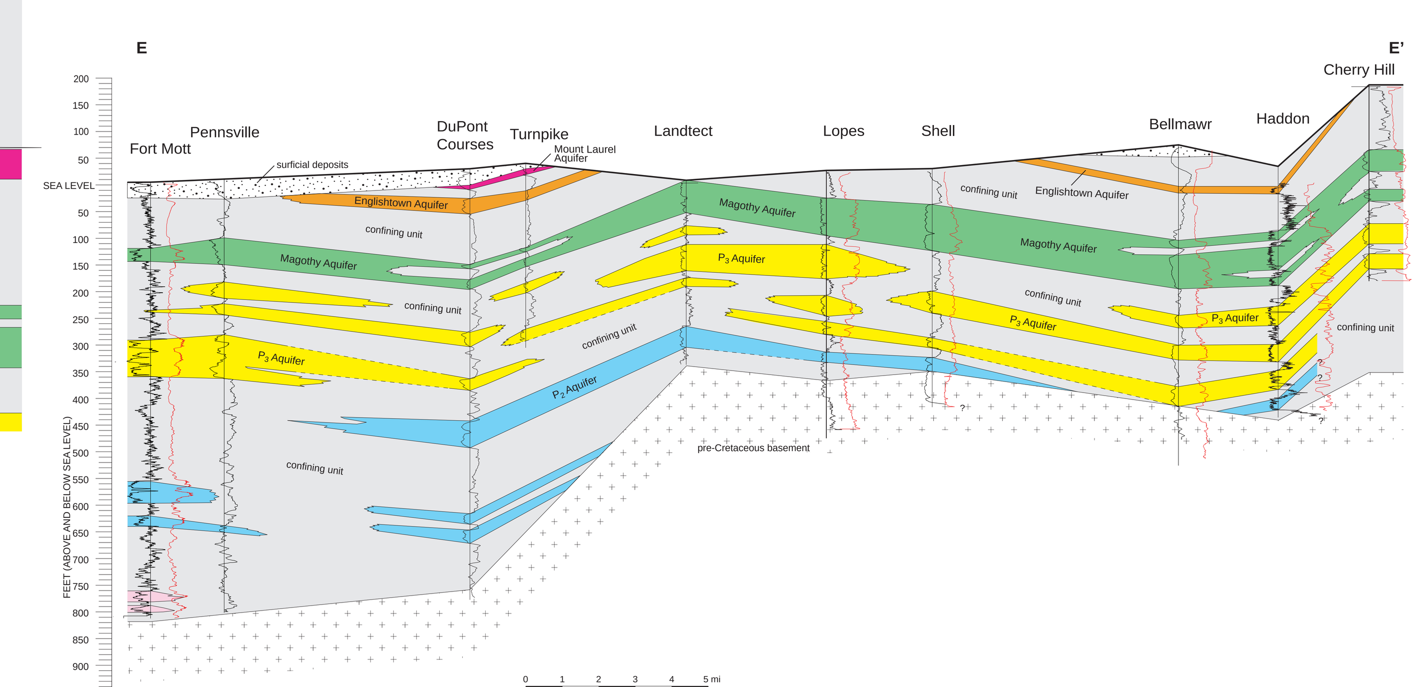


Figure 7. E-E': Hydrogeologic section along strike in Camden, Gloucester and Salem Counties near the Delaware River.

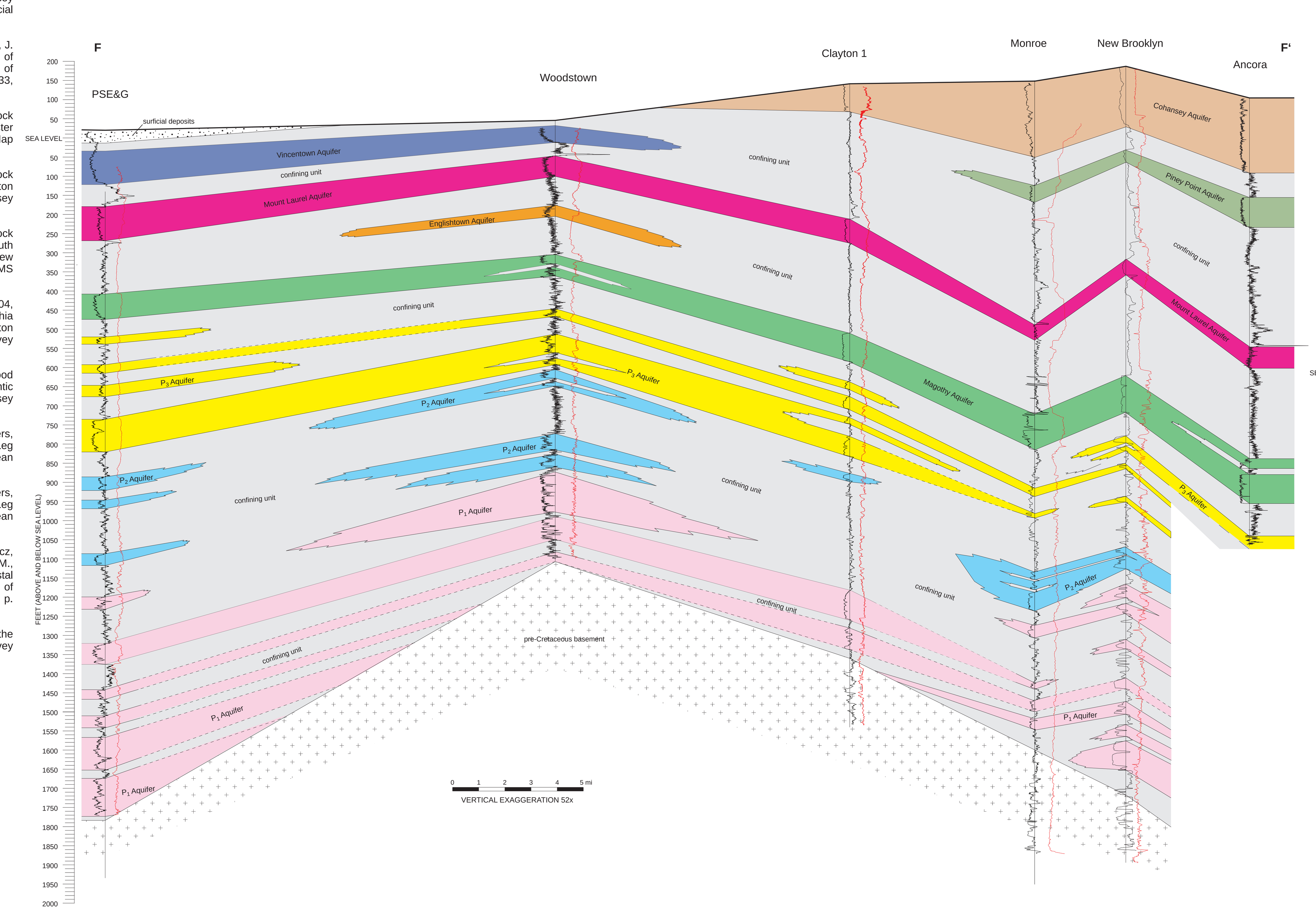


Figure 8. F-F': Hydrogeologic section along strike in Camden, Gloucester and Salem Counties.

Reviewed by P. McLaughlin, Jr., and O. Zapecza

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