DEPARTMENT OF ENVIRONMENTAL PROTECTION
WATER RESOURCES MANAGEMENT
NEW JERSEY GEOLOGICAL AND WATER SURVEY

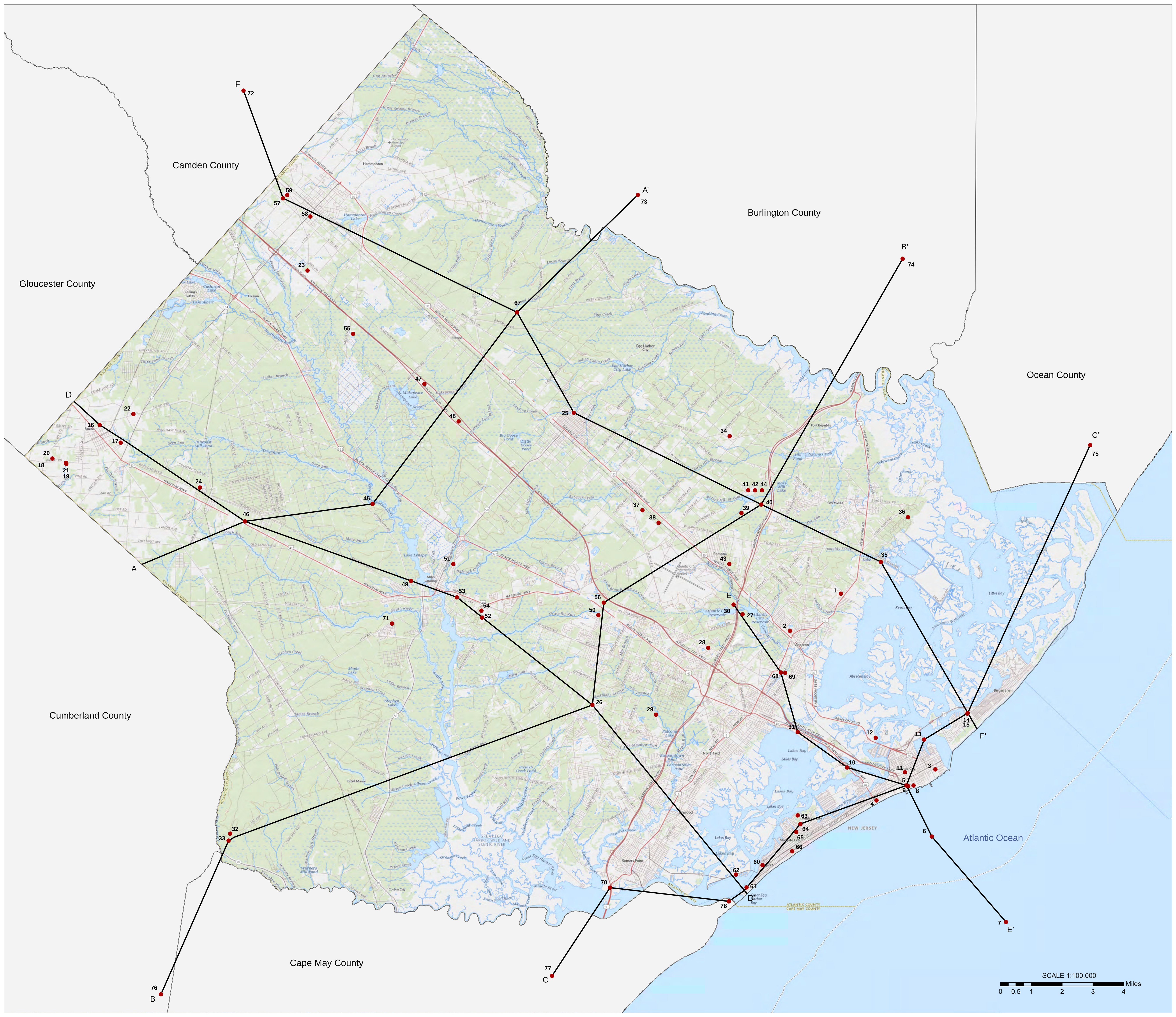

Figure. 1 Geologic Map of Atlantic County showing locations of hydrogeologic cross-sections and wells used in constructing the cross-sections.

FRAMEWORK AND PROPERTIES OF AQUIFERS IN ATLANTIC COUNTY, NEW JERSEY

by
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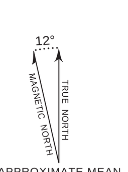


Introduction

Atlantic County is the third largest county in New Jersey by area (approximately 610 square miles), and the fifteenth most populated. It borders Cape May, Cumberland, Gloucester, Camden, Burlington, and Ocean Counties (Figure 1). Based on the 2017 Census Bureau estimate, it has a population of 269,918. Population is more concentrated in the eastern part of the county, especially in the summer, when tourists visit the shore communities. Egg Harbor Township is the most heavily populated area of the county as of 2017 (estimated at 43,296).

Since 1990 groundwater demands in Atlantic County have increased modestly (Figure 2). However, in the last ten years they have remained essentially flat. From 2007 through 2016 an annual average of 18 billion gallons of groundwater were withdrawn of which about 73 percent was used for drinking water (Figure 3). Irrigation, mostly for agriculture, but also for golf and other non-agricultural uses, accounted for another 22 percent of total groundwater withdrawals. Industrial uses made up most of the remaining groundwater withdrawals.

The Kirkwood-Cohansey aquifer accounts for nearly 72 percent of all groundwater withdrawals in Atlantic County, while the Atlantic City "800-foot" sand aquifer provided roughly 25 percent of the groundwater withdrawn in 2016 (Figure 2). The Piney Point aquifer and Rio Grande water-bearing zone contribute minimal groundwater withdrawals to meet the remaining demand in Atlantic County.

With gambling legalized in Atlantic City starting in 1976, and to plan for increased tourism and demand on water resources, new studies were initiated into the aquifer framework of Atlantic County, with special emphasis on supplying water to the barrier island communities where tourism is concentrated. The prime focus of these studies was: 1) delineating the Atlantic City 800-foot sand and the extent of its overlying confining unit (termed the Wildwood-Belleplain confining unit by Sugarman, 2001); 2) map water levels and groundwater flow in the principal aquifers; 3) investigate groundwater quality (Clark and Paulachok, 1989; Barton and others, 1993; McCauley and others, 2001); and 4) update well records (Mullikin, 1990). Of major concern was the potential for salt-water intrusion in the Atlantic City 800-foot sand aquifer due to excess withdrawals of groundwater, and surface contamination of the Kirkwood-Cohansey aquifer system.

This map continues the update of the hydrostatrigraphic framework of Atlantic County, in addition to providing new hydrologic data for the major aquifers that are pumped for potable water in this region. It also ties into the existing and surrounding county aquifer maps published by the New Jersey Geological and Water Survey for Monmouth and Ocean County (Sugarman and others, 2013), Burlington County (Sugarman and others, 2018), Salem, Gloucester, Cumberland and Camden Counties (Sugarman and Monteverde, 2008), and Cape May County (Sugarman and others, 2016). New information provided includes groundwater withdrawals by use type (for the past 10-years) and by specific aquifer for approximately the past 25 years, summary of aquifer tests, water quality data for the major aquifers, and six hydrostratigraphic cross sections showing the distribution and extent of the major aquifers in the county as defined by Zapecza, 1989. The major aquifers in Atlantic County include the Kirkwood-Cohansey aquifer system, and the Atlantic City 800-foot sand. The minor aquifers include the Piney Point aquifer and the Rio Grande water-bearing zone.

Methods

Using geophysical logs from a compilation of existing water wells (Table 1), along with continuously cored stratigraphic test holes, six revised and updated hydrostratigraphic cross-sections were developed for Atlantic County (Sheet 2; Figures. 5-10). High resolution stratigraphic test wells include the ACGS-4 site (Owens and others, 1988), Atlantic City Leg 150X site (Miller and others, 1994), Millville 174AX site (Sugarman and others, 2005; Cumberland County), Ancora 174AX site (Miller and others, 1999; Camden County), and Bass River 174AX site (Miller and others, 1998; Burlington County). In addition, well data from two sites offshore of Atlantic City (Mullikin, 1990) allow for extending aquifer correlations offshore (Figure 9). Well records including geophysical logs are from files at the New Jersey Geological and Water Survey (Table 1).

Geophysical logs are the primary means of correlation used in this map. Downhole geophysical logs have proven invaluable in the delineation and evaluation of New Jersey Coastal Plain aquifers and confining units (Zapecza, 1989; Zapecza, 1992; Sugarman, 2001; Sugarman and others, 2005; Sugarman and Monteverde, 2008; Sugarman and others, 2013; Sugarman and others, 2016; Sugarman and others, 2018). They are generally more reliable than descriptions of cuttings from rotary wells and allow correlation over long distances. Aquifers and confining units display distinctive patterns and contrasts on gamma-ray and electric-logs that clearly delineates the boundaries between them (Sugarman, 2001). Of the many kinds of downhole geophysical logs, natural gamma and electric have proven to be the most effective in subsurface mapping and, used in combination, are helpful in the identification of lithologies encountered in boreholes. Thorough discussions of the relationship between borehole geophysical measurements and lithologies are in Keys (1990) and Rider (2002).

The natural gamma tool measures gamma radiation from radioactive minerals in the surrounding sediments and is especially useful because it can measure through well casings. Elevated gamma readings generally correlate with the clays of confining units due to the higher concentration of potassium, uranium and thorium in clays than in quartz sands (Keys and MacCary, 1971). Care must be taken to differentiate the increased gamma levels in clay layers from unusually high levels in some sands due to glauconite (a sand-to-clay size mineral). Rider (1990) warned against the use of gamma logs to characterize grain-size differences because of the unique response of sands based on mineralogic composition. Confirming the applicability of gamma logs to New Jersey Coastal Plain sediments, Lanci and others (2002) show that the radioactive signatures of the Coastal Plain clay and sand mixtures and, where present, glauconite are consistent with those observed in gamma logs. Two different units of measurement are used for gamma response: American Petroleum Institute (API) units and counts per second (cps). CPS units are more commonly used in local investigations where curve matching allows unit identification and were used in this study.

Electric logs are commonly used in combination with natural gamma logs in groundwater studies (Keys,1990). Combining gamma and electrical data enables one to decipher the lithological makeup and therefore differentiate between aquifers and confining units. The single point resistance logs shown on the cross sections measure the electrical potential drop between two electrodes, one at the surface and the second within the tool. Results are measured in millivolts and subsequently converted to ohms (Keys and MacCary, 1971; Keys, 1990). Resistance values decrease as porosity and formation water content increase. In contrast to natural gamma values, which are generally higher in clays, resistivity values are generally lower in clays because the clays have higher overall conductivity. Quantitative measurements of porosity and/or salinity, though, cannot be calculated from single-point resistance probes because the current's travel path parameters are not defined (Keys, 1990). If borehole fluid is homogeneous, variations in resistance are caused by lithology. Increasing pore water salinity will cause a decrease in resistance.

Aquifer Properties

Aquifer tests data used to estimate the hydraulic properties of aquifers are from information in applications to the New Jersey Geological and Water Survey (NJGWS) in support of Water Allocation Permits. Data evaluation is based on: 1) hydrogeology of the area, 2) screen lengths of the pumping and observation wells, 3) test duration, 4) number of pumping and observation wells, 5) proximity of observation wells to the pumping wells, 6) influence of other pumping wells, and 7) data reliability. Results of the 29 aquifer tests available for Atlantic County are summarized in Table 1. Additional information for each test is in the NJGWS hydro database (Mennel and Canace, 2002).

Water Quality

The United States Geological Survey groundwater site inventory and New Jersey Department of Environmental Protection data were used to evaluate the water quality of Atlantic County's principal aquifers - the Kirkwood-Cohansey aquifer system and the Atlantic City 800-foot sand. The Piney Point aquifer has limited use in Atlantic County consisting of only three large public supply wells. Water quality results from 21 observation and public supply wells that were analyzed for major ion composition are shown in Table 2.

Hydrogeologic Units

The generalized stratigraphic framework of aquifers and confining units (Figure 4) consists of major sand beds (aquifers) and clay-silt beds (confining units). The hydrostratigraphic framework of Atlantic County is depicted in six cross sections (Sheet 2; Figure 5-10), three of which are strike sections (Figure 5-7) and three of which are dip sections (Figure 5-10). Four aquifers are depicted on the cross-sections, from oldest to youngest: 1) Piney Point aquifer; 2) Atlantic City 800-foot sand; 3) Rio Grande water-bearing zone; and 4) Kirkwood-Cohansey aquifer system. Three confining units are also shown on the cross-sections, from oldest to youngest: 1) Composite Confining Bed; 2) "leaky confining unit"; and 3) Wildwood-Belleplain confining unit.

In Atlantic County, aquifer boundaries may not correspond directly to the boundaries of the geologic formations. The Piney Point is correlative with sands in the Atlantic City Formation. The Atlantic City 800-foot sand has an upper and lower sand that is separated by a thin (10-20 ft thick where present) "leaky confining unit". The lower sand is found in the upper part of the Brigantine Member of the Kirkwood Formation, while the upper sand is found in the upper part of the Shiloh Marl Member of the Kirkwood Formation. The Rio Grande water-bearing zone is generally the sand found in the upper part of the Belleplaine Member of the Kirkwood Formation. The majority of the Kirkwood-Cohansey aquifer system is sands of the Cohansey Formation, but in places sands from the Kirkwood Formation can make up a substantial part of the lower part of the aquifer system.

Kirkwood-Cohansey aquifer system

The Kirkwood-Cohansey aquifer system is mainly semi-confined (Table 1), and unconfined to a lesser extent in some areas. It reaches a maximum thickness of just over 400 feet in Atlantic City (Zapecza, 1989). It consists of the upper predominantly sandy part of the Belleplain Member of the Kirkwood Formation, the medium-to-coarse sands of the Cohansey Formation, and coarser-grained material within surficial units where present. Where the Wildwood-Belleplain confining unit is absent, sands in the Brigantine and Shiloh Marl members are contained within the aquifer. Within the Cohansey Formation local clay beds reaching tens of feet thick can create perched water tables and semi-confined conditions (Rhodehamel, 1973).

Along the coast extending several miles inland, the base of the Kirkwood-Cohansey aquifer system overlies the top of the Wildwood-Belleplain confining unit. Where this confining unit is absent to the west, the aquifer system extends down to the lower composite confining unit and incorporates sands correlative with the Atlantic City 800-foot sand (Sugarman, 2001; figs. 4, 7, and 9).

Groundwater quality samples from five (5) unconfined Kirkwood-Cohansey wells were collected from 1997 to 1999 (Table 2). Water from the Kirkwood-Cohansey Aquifer exhibited pH in the range of 4.3 to 6.4. Low pH values (4.3 - 4.4) are most likely the result of the acidic effect of the shallow natural organic layers within the aquifer and acid precipitation. The New Jersey secondary drinking water standard for pH is 6.5 to 8.5. Water with pH lower than 6.5 must be adjusted to meet the standard pH range before being delivered to the public. Elevated Iron concentrations of up to 3.7 mg/L are reported in groundwater samples from this aquifer. Concentrations greater than 0.3 mg/L (NJ secondary standard) would require iron removal treatment before being delivered to the public. Groundwater quality results indicate that water from the Kirkwood-Cohansey is predominantly of good quality and can be characterized as Na-SO_4-Cl type with the occasional low pH and elevated iron concentration in some samples.

Wildwood-Belleplain Confining Unit

The Wildwood-Belleplain conining unit is a thick clay-silt bed between the Atlantic City 800-foot sand and the Kirkwood-Cohansey aquifer system. It is composed largely of the Wildwood Member of the Kirkwood Formation, and the lower part of the Belleplain Member of the Kirkwood Formation. It is rich in diatioms ("Great Diatom Bed" of Woolman, 1892; 1895). It reaches a maximum thickness of 300 feet just to the south of Atlantic City, and then can be over 400 feet thick in Cape May County (Sugarman, 2001).

Rio Grande Water-Bearing Zone

The Rio Grande water-bearing zone is contained within the Wildwood-Belleplain confining unit and is of minor importance in Atlantic County. It is found along the coastal region where it is a maximum of 40 feet thick (Zapecza, 1989). Its silt content increases north and west of Atlantic City, limiting its utility as an aquifer (Sugarman, 2001). It is, however, used for water supply in parts of southern Cape May County. It reaches a maximum thickness of approximately 60 feet in south central Atlantic County near its border with Cumberland and Cape May counties.

Atlantic City 800-foot sand aquifer

The Atlantic City 800-foot sand is the principal confined aquifer supplying water to Atlantic City, and 25% of Atlantic County. It contains sands from the Brigantine and Shiloh Marl members of the Kirkwood Formation. The aquifer typically has a lower and upper sand separated by a leaky, relatively thin (10-20 ft thick) confining unit. The lower sand corelates with sands in the Brigantine member; the upper sand with sands in the Shiloh Marl member. The aquifer is about 150 feet thick along the coast in Atlantic County (Zapecza, 1989; Sugarman, 2001).

Groundwater quality samples from eight (8) Atlantic City 800-foot sand aquifer wells were collected from 1992-2012. Water from the AC 800-foot sand aquifer has pH in the range of 5.4 to 8.7 with the mean pH calculated at 7.1. Overall, groundwater from the AC 800-foot sand can be divided into three types: Na-Ca-Cl, Na-Ca-SO_4, Ca-Na-HCO_3 with a few exceptions (Table 2). Contamination by sea water is a concern for the AC 800-sand aquifer, especially near the barrier island communities. Two major AC 800-foot sand users within Atlantic County (Ventnor and Brigantine Cities) have created two areas exhibiting cones of depression. During the summer months, water levels drop to 90 feet below sea level in these areas (McCauley and others, 2001), which can potentially provide a hydraulic pathway for seawater migration. Production wells in these areas are sampled annually for chloride. Historical chloride data collected by USGS and NJ DEP for the past 30 years indicate no significant changes in chloride levels. The AC 800-foot sand consists of good quality groundwater. Groundwater quality results from eight (8) AC 800-foot sand wells indicate the chloride concentrations from 1.82 to 8.9 mg/L with a mean concentration of 3.58 mg/L and are well below the secondary standard of 250-mg/l.

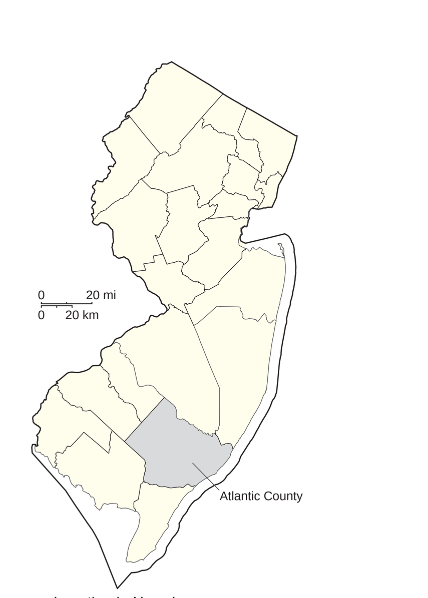
Composite Confining Unit

The composite confining unit consists of Late Cretaceous to Miocene deposits overlying the Wenonah-Mount Laurel aquifer and underlying the Atlantic City 800-foot sand. It can incorporate fairly permeable sands which form the Piney Point aquifer in Atlantic County.

Piney Point aquifer

A minor aquifer in Atlantic County. It is developed in Buena Borough where it is about 70 feet thick (Barton and others, 1993). A drillers log from the Buena Borough MUA well (Permit no. 35-4559) describes the aquifer lithology as fine to coarse sand with gravel, clay streaks, and containing a hard clay at 440-448 ft (Mullikin, 1990). An exploratory well drilled by the US Geological Survey at Margate City contained about 80 feet of the Piney Point aquifer (Atlantic City Formation), although the water is brackish at this site (Barton and others, 1993). This correlative sand is found in the ACGS#4 borehole from 485-575 ft (ACGS Beta unit), where it is typically a silty fine to medium glauconite quartz sand with shell fragments that is upper Oligocene age (Owens and others, 1988). A similar sand was identified in the 150X Atlantic City borehole from 937-1001 ft (Miller and others, 1994).

Groundwater quality samples from four (4) Piney Point observation wells were collected from 1994 to 2012. Only three (3) production wells use the Piney Point aquifer in Atlantic County. Water quality results presented here are based on data collected from four (4) observation wells. These data indicate that the groundwater is characterized by high pH of 8.2 to 9 and is predominantly Na-Cl type (Table 2). The samples collected from observation wells exhibit arsenic concentrations in the range of <0.003 to 6 µg/L and boron concentrations in the range of 0.42 to 2.24 mg/L. The Piney Point data indicate chloride concentrations range from 29 mg/L to 329 mg/L and is significantly higher than the chloride concentrations reported for the AC 800-foot sand. Three production wells (located in Buena Boro) are sampled annually for chloride with the reported concentrations in these wells ranging from 25 mg/L to 39 mg/L which is below the secondary standard of 250-mg/l.



Location in New Jersey.

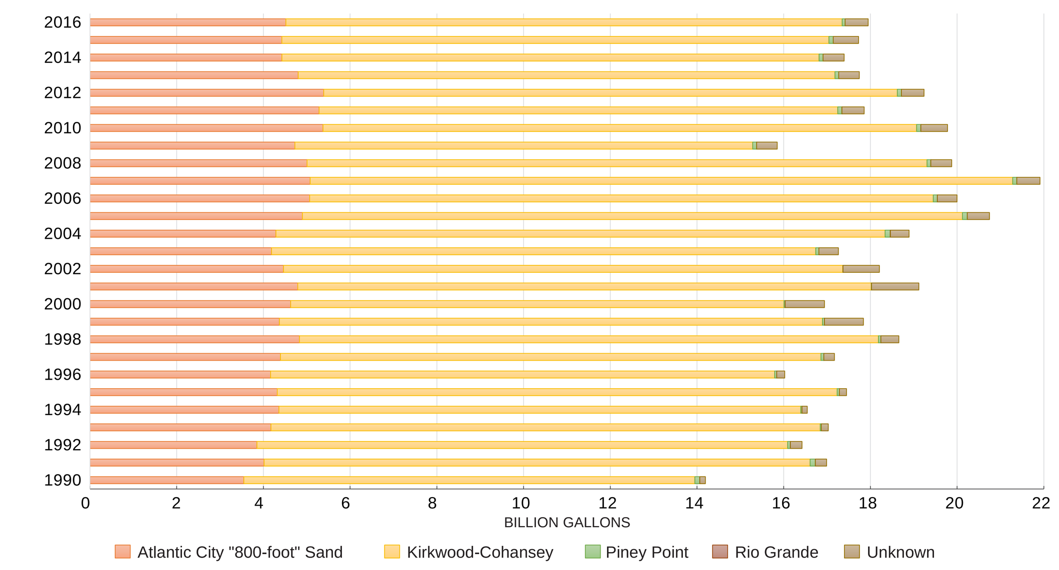


Figure 2. Annual Atlantic County groudwater withdrawals by aquifer. Data collected from 1990-2016.

NJGWS Hydro Database File Number	BWA Permit Number	Aquifer	Formation	Test Length (minutes)	Aquifer Characterization	Transmissivity (ft²/day)	Storativity	Leakance
7	5208	Kirkwood-Cohansey aquifer system	Cohansey Formation	4,400	Semi-confined	3,102.00	0.0010930	0.006970
8	5278	Kirkwood-Cohansey aquifer system	Kirkwood Formation - Belleplain Member	7,116	Semi-confined	9,559.22	0.0005980	0.000660
9	5306	Kirkwood-Cohansey aquifer system	Cohansey Formation	4,320	Semi-confined	500.35	0.0010200	0.000805
10	5306	Kirkwood-Cohansey aquifer system	Cohansey Formation	4,320	Semi-confined	6,548.00	0.0006094	0.000000
22	2418E	Kirkwood-Cohansey aquifer system	Cohansey Formation	4,008	Semi-confined	12,505.00	0.0001600	0.001690
33	5034	Kirkwood-Cohansey aquifer system	Cohansey and Kirkwood Formations	4,320	Semi-confined	15,221.00	0.0003200	0.003070
43	5275	Piney Point aquifer - lower sand	Shark River Formation - Toms River Member	4,320	Confined	2,235.00	0.0002500	0.000000
44	5208	Atlantic City "800-foot" sand aquifer	Kirkwood Formation - lower member	4,225	Confined	6,242.00	0.0000720	0.000000
45	5208	Atlantic City "800-foot" sand aquifer	Kirkwood Formation - lower member	4,320	Semi-confined	8,784.00	0.0001300	0.000020
59	2300P	Atlantic City "800-foot" sand aquifer	Kirkwood Formation - lower member	4,320	Confined	5,949.00	0.0002400	0.000000
133	5034	Kirkwood-Cohansey aquifer system	Cohansey Formation	4,540	Unconfined	14,520.00	0.0014700	0.000000
134	5034	Atlantic City "800-foot" sand aquifer	Kirkwood Formation - lower member	4,330	Semi-confined	6,254.00	0.0004100	0.000002
194	2519P	Kirkwood-Cohansey aquifer system	Cohansey & Kirkwood Formations	4,320	Semi-confined	19,656.00	0.0006780	0.007280
220	2506P	Kirkwood-Cohansey aquifer system	Cohansey & Kirkwood Formations	4,300	Semi-confined	6,858.00	0.0007280	0.001340
242	5275	Piney Point aquifer - upper sand	Atlantic City Formation	4,320	Confined	1,319.00	0.0004630	0.000000
244	5208	Kirkwood-Cohansey aquifer system	Cohansey Formation	4,320	Semi-confined	14,153.00	0.0003500	0.002900
245	5208	Atlantic City "800-foot" sand aquifer	Kirkwood Formation - lower member	4,320	Semi-confined	6,781.00	0.0002630	0.000066
250	2531P	Atlantic City "800-foot" sand aquifer	Kirkwood Formation	4,320	Semi-confined	6,356.00	0.0001320	0.000010
253	2533P	Kirkwood-Cohansey aquifer system	Kirkwood Formation - Belleplain Member	4,320	Semi-confined	9,777.00	0.0003400	0.000940
285	2529P	Kirkwood-Cohansey aquifer system	Cohansey and Kirkwood Formations	4,353	Unconfined	6,110.00	0.0007820	0.000000
289	2556P	Kirkwood-Cohansey aquifer system	Cohansey Formation	4,310	Semi-confined	5,148.00	0.0003300	0.000660
306	2312P	Kirkwood-Cohansey aquifer system	Cohansey Formation	4,320	Semi-confined	17,488.00	0.0008600	0.003900
311	5322	Atlantic City "800-foot" sand aquifer	Kirkwood Formation - Shiloh Marl Member	1,440	Confined	4,134.00	0.0001456	0.000000
330	5035	Atlantic City "800-foot" sand aquifer	Kirkwood Formation - lower member	4,330	Semi-confined	14,239.57	0.0003101	0.000040
331	5035	Atlantic City "800-foot" sand aquifer	Kirkwood Formation - lower member	4,330	Semi-confined	31,645.00	0.0002716	0.000155
332	5035	Atlantic City "800-foot" sand aquifer	Kirkwood Formation - lower member	4,330	Semi-confined	9,867.00	0.0007339	0.000739
333	5365	Kirkwood-Cohansey aquifer system	Cohansey and Kirkwood Formations	4,350	Semi-confined	8,760.00	0.0013840	0.012510
338	5322	Atlantic City "800-foot" sand aquifer	Kirkwood Formation - Shiloh Marl Member	4,320	Semi-confined	3,739.00	0.0003888	0.000140
371	2277P	Kirkwood-Cohansey aquifer system	Cohansey Formation	4,400	Semi-confined	4,134.00	0.0005337	0.002399

Table 1. Summary of aquifer tests in Atlantic County on file at the New Jersey Geological and Water Survey.

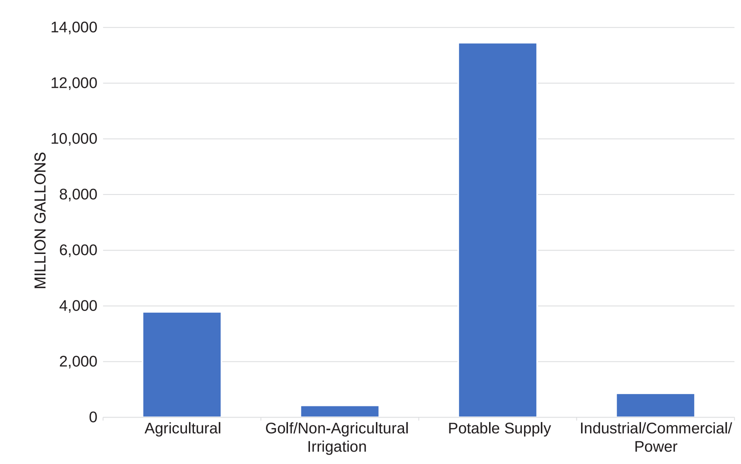


Figure 3. Annual average Atlantic County groundwater withdrawals by use type. Data collected from 2007 to 2016.

Kirkwood-Cohansey	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Iron	Hardness	pH
Minimum	0.54	0.52	2.60	0.90	2.60	0.48	0.03	3.77	3.90
Maximum	5.60	1.44	3.74	1.83	6.25	12.00	3.70	17.70	6.40
Arithmetic Mean	1.88	0.87	3.21	1.41	4.83	6.71	1.24	9.14	4.76
Atlantic City 800-foot sand	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Iron	Hardness	pH
Minimum	2.29	1.32	1.98	1.51	1.82	7.00	0.00	11.50	5.70
Maximum	16.50	3.11	20.50	3.34	8.90	11.60	0.70	54.00	8.70
Arithmetic mean	8.23	1.90	12.80	2.50	3.58	9.23	0.25	28.87	7.10
Piney Point	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Arsenic (µg/L)	Boron	pH
Minimum	4.86	3.90	87.40	6.71	29.10	0.50	0.03	0.42	8.00
Maximum	10.50	5.73	386.00	19.00	321.00	51.50	6.00	2.24	9.00
Arithmetic Mean	6.80	4.88	220.50	11.37	147.70	23.37	2.49	1.36	8.50

Table 2. Water quality of Atlantic County's aquifers. Parameter concentrations in mg/L unless otherwise indicated.

Label Number	Permit Number	Depth (ft)	County	Municipality	Latitude	Longitude	Cross Section
1	36-6288	239	Atlantic	Absecon Twp	39° 26' 58"	74° 28' 31"	
2	36-299	204	Atlantic	Absecon Twp	39° 25' 54"	74° 30' 24"	
3	56-00071	840	Atlantic	Atlantic City	39° 21' 52"	74° 24' 59"	
4	36-00220	865	Atlantic	Atlantic City	39° 20' 58"	74° 27' 11"	
5	36-01084	884	Atlantic	Atlantic City	39° 21' 24"	74° 26' 04"	C-C'; E-E'
6	36-05615	931	Atlantic	Atlantic City	39° 19' 55"	74° 25' 07"	E-E'
7	36-05972	1025	Atlantic	Atlantic City	39° 17' 26"	74° 22' 21"	E-E'
8	56-00088	830	Atlantic	Atlantic City	39° 21' 24"	74° 25' 48"	
9	56-00089	823	Atlantic	Atlantic City	39° 21' 23"	74° 26' 00"	
10	36-26186	826	Atlantic	Atlantic City	39° 21' 55"	74° 28' 17"	E-E'
11	36-28884	200	Atlantic	Atlantic City	39° 21' 48"	74° 26' 06"	
12	56-00065	1004	Atlantic	Atlantic City	39° 22' 47"	74° 27' 13"	
13	36-16845	1452	Atlantic	Atlantic City	39° 22' 44"	74° 25' 24"	C-C'
14	E201501897	793	Atlantic	Brigantine City	39° 23' 30"	74° 23' 45"	C-C'; F-F'
15	56-00012	840	Atlantic	Brigantine City	39° 23' 29"	74° 23' 47"	
16	35-04559	474	Atlantic	Buena Boro	39° 31' 49"	74° 56' 18"	D-D'
17	35-14298	2006	Atlantic	Buena Boro	39° 31' 22"	74° 55' 24"	
18	35-22078	580	Atlantic	Buena Boro	39° 30' 41"	74° 57' 33"	
19	35-21008	493	Atlantic	Buena Boro	39° 30' 42"	74° 57' 34"	
20	35-21009	495	Atlantic	Buena Boro	39° 30' 50"	74° 58' 05"	
21	35-21101	290	Atlantic	Buena Boro	39° 30' 40"	74° 57' 33"	
22	31-05832	196	Atlantic	Buena Vista Twp	39° 32' 08"	74° 55' 03"	
23	31-23070	549	Atlantic	Buena Vista Twp	39° 36' 19"	74° 48' 32"	
24	35-26915	586	Atlantic	Buena Vista Twp	39° 30' 01"	74° 52' 31"	D-D'
25	32-00477	507	Atlantic	Egg Harbor City	39° 32' 12"	74° 38' 32"	F-F'
26	36-05091	678	Atlantic	Egg Harbor City	39° 23' 44"	74° 37' 49"	B-B'; D-D'
27	36-00454	691	Atlantic	Egg Harbor City	39° 26' 22"	74° 32' 12"	
28	36-00428	232	Atlantic	Egg Harbor City	39° 25' 24"	74° 33' 29"	
29	36-01828	235	Atlantic	Egg Harbor City	39° 23' 27"	74° 35' 26"	
30	36-05092	608	Atlantic	Egg Harbor City	39° 26' 39"	74° 32' 32"	E-E'
31	36-05339	661	Atlantic	Egg Harbor City	39° 22' 57"	74° 30' 08"	E-E'
32	35-04904	73	Atlantic	Estell Manor City	39° 19' 52"	74° 51' 12"	
33	35-04903	600	Atlantic	Estell Manor City	39° 19' 46"	74° 51' 25"	B-B'
34	36-19837	202	Atlantic	Galloway Twp	39° 31' 32"	74° 32' 41"	
35	36-00294	1002	Atlantic	Galloway Twp	39° 27' 53"	74° 27' 01"	F-F'
36	36-11760	560	Atlantic	Galloway Twp	39° 29' 11"	74° 26' 00"	
37	36-00418	208	Atlantic	Galloway Twp	39° 29' 23"	74° 35' 57"	
38	36-00422	208	Atlantic	Galloway Twp	39° 29' 01"	74° 35' 21"	
39	36-03110	175	Atlantic	Galloway Twp	39° 29' 08"	74° 32' 13"	
40	36-04982	680	Atlantic	Galloway Twp	39° 29' 33"	74° 31' 30"	B-B'; F-F'
41	36-16159	402	Atlantic	Galloway Twp	39° 29' 33"	74° 32' 00"	
42	36-16160	610	Atlantic	Galloway Twp	39° 29' 33"	74° 31' 46"	
43	36-16750	603	Atlantic	Galloway Twp	39° 27' 50"	74° 32' 40"	
44	36-05551	336	Atlantic	Galloway Twp	39° 29' 33"	74° 31' 30"	
45	35-04274	945	Atlantic	Hamilton Twp	39° 29' 33"	74° 46' 04"	A-A'
46	35-04656	577	Atlantic	Hamilton Twp	39° 29' 02"	74° 50' 51"	A-A'; D-D'
47	32-00474	186	Atlantic	Hamilton Twp	39° 33' 02"	74° 44' 08"	
48	36-01865	172	Atlantic	Hamilton Twp	39° 31' 57"	74° 42' 51"	
49	36-00391	371	Atlantic	Hamilton Twp	39° 27' 09"	74° 44' 42"	D-D'
50	36-17655	650	Atlantic	Hamilton Twp	39° 26' 20"	74° 37' 36"	
51	36-26422	460	Atlantic	Hamilton Twp	39° 27' 49"	74° 43' 02"	
52	28-08310	378	Atlantic	Hamilton Twp	39° 26' 28"	74° 41' 59"	D-D'
53	36-28907	381	Atlantic	Hamilton Twp	39° 26' 51"	74° 42' 54"	D-D'
54	36-28242	165	Atlantic	Hamilton Twp	39° 26' 23"	74° 41' 58"	
55	31-23070	550	Atlantic	Hamilton Twp	39° 34' 29"	74° 46' 49"	
56	36-16546	801	Atlantic	Hamilton Twp	39° 26' 42"	74° 37' 24"	B-B'
57	31-19462	298	Atlantic	Hammonton Town	39° 38' 25"	74° 49' 28"	F-F'
58	51-00140	304	Atlantic	Hammonton Town	39° 37' 59"	74° 48' 24"	
59	31-12437	298	Atlantic	Hammonton Town	39° 38' 28"	74° 49' 32"	
60	36-00402	840	Atlantic	Longport Boro	39° 19' 05"	74° 31' 27"	
61	56-00080	803	Atlantic	Longport Boro	39° 18' 21"	74° 32' 08"	C-C'; D-D'
62	36-21179	770	Atlantic	Longport Boro	39° 18' 47"	74° 32' 33"	
63	36-05032	840	Atlantic	Margate City	39° 20' 32"	74° 30' 08"	
64	36-10548	1055	Atlantic	Margate City	39° 20' 17"	74° 30' 02"	C-C'
65	36-11871	800	Atlantic	Margate City	39° 20' 03"	74° 30' 11"	
66	36-15426	805	Atlantic	Margate City	39° 19' 30"	74° 30' 20"	
67	32-10935	540	Atlantic	Mullica Twp	39° 35' 07"	74° 40' 40"	A-A'; F-F'
68	56-00091	565	Atlantic	Pleasantville City	39° 24' 40"	74° 30' 36"	
69	36-28192	695	Atlantic	Pleasantville City	39° 24' 41"	74° 30' 46"	E-E'
70	36-00295	1002	Atlantic	Somers Point City	39° 18' 26"	74° 37' 09"	C-C'
71	36-4463	135	Atlantic	Weymouth Twp	39° 26' 05"	74° 45' 18"	
72	31-53332	1170	Camden	Winslow Twp	39° 41' 32"	74° 50' 58"	F-F'
73	32-01525/12D	370	Burlington	Washington Twp	39° 38' 32"	74° 36' 08"	A-A'
74	32-21761	1956	Burlington	Bass River Twp	39° 36' 41"	74° 26' 12"	B-B'
75	36-20855	1012	Ocean	Little Egg Harbor Twp	39° 31' 16"	74° 19' 10"	C-C'
76	35-04640	600	Cumberland	Maurice River Twp	39° 15' 18"	74° 53' 55"	B-B'
77	36-17000	770	Cape May	Upper Twp	39° 15' 52"	74° 39' 18"	C-C'
78	36-29739	923	Cape May	Ocean City	39° 17' 28"	74° 33' 53"	C-C'

Table 3. Well reference table for Figure 1.

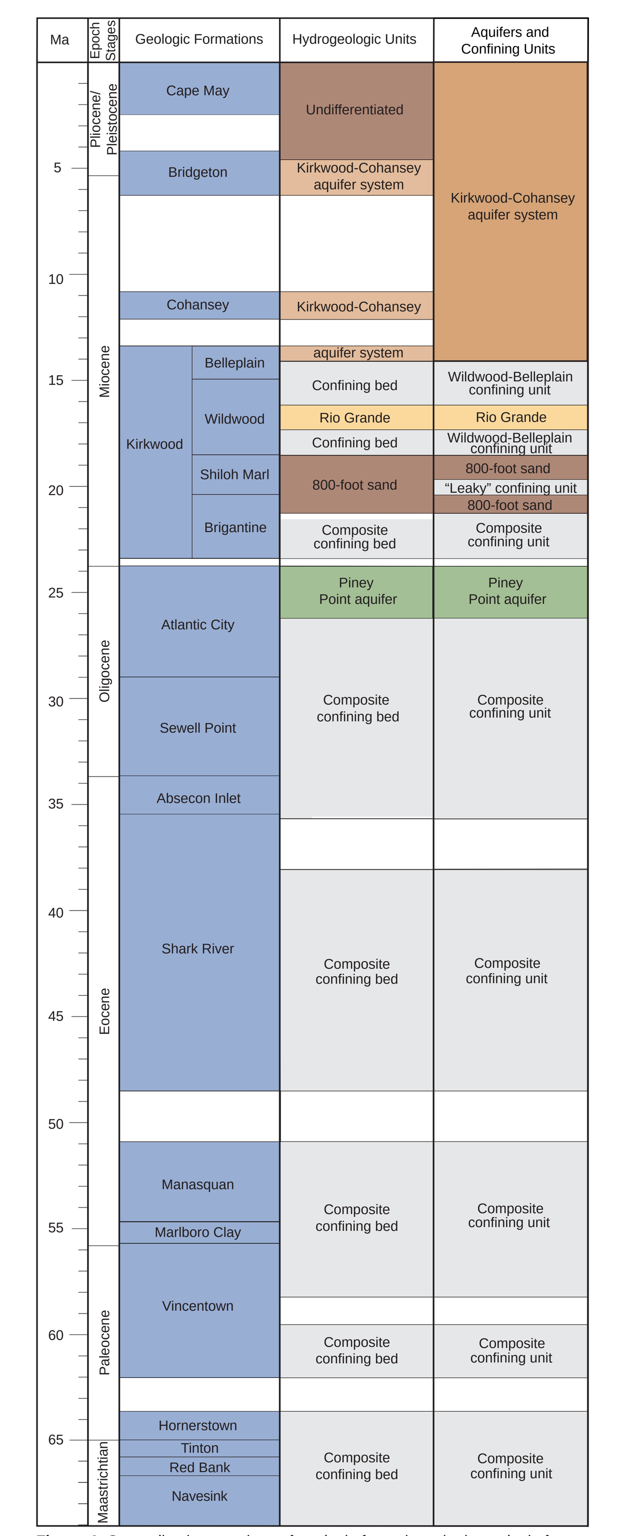


Figure 4. Generalized comparison of geologic formations, hydrogeologic framework (modified from Zapecza, 1989), aquifers, and confining units in the study area.

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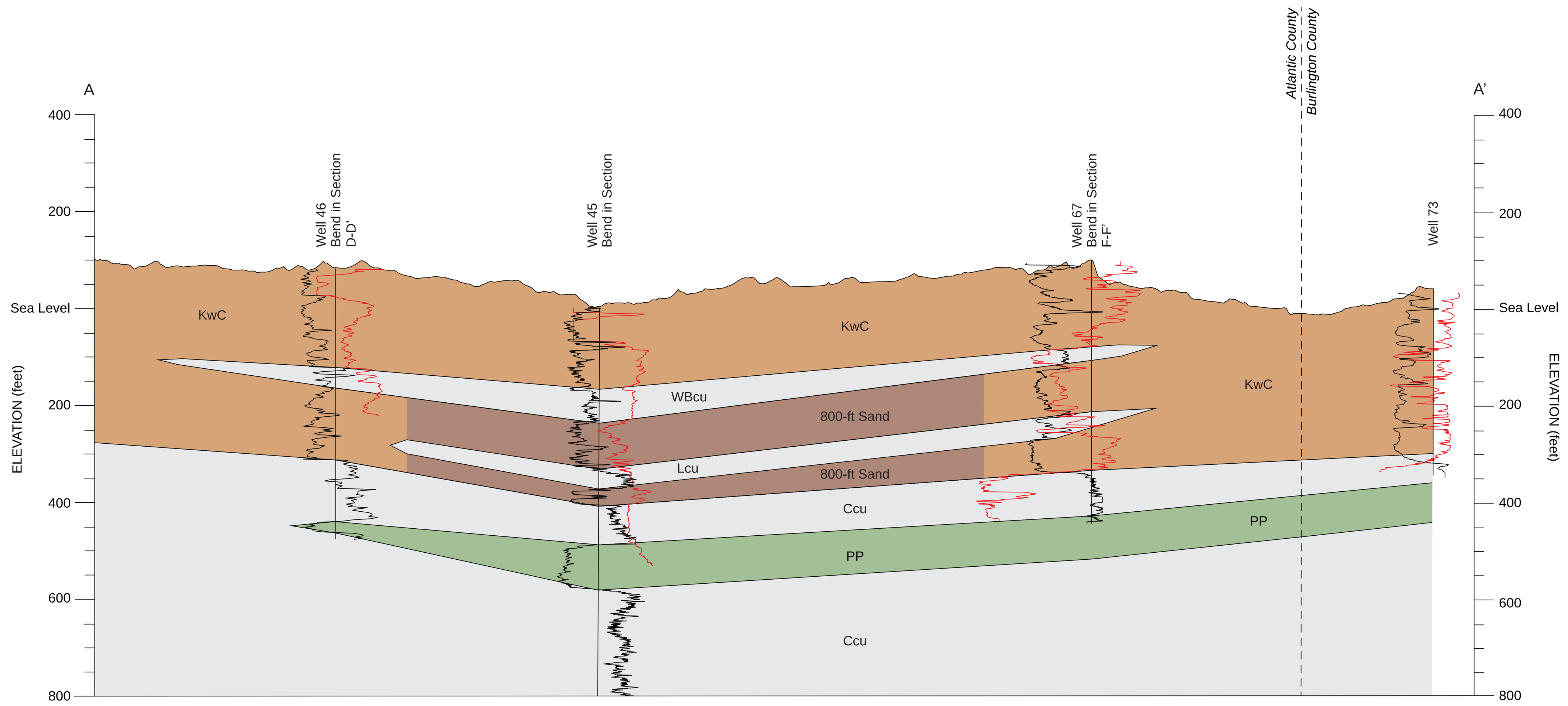


Figure 5. Hydrogeologic cross-section A-A'.

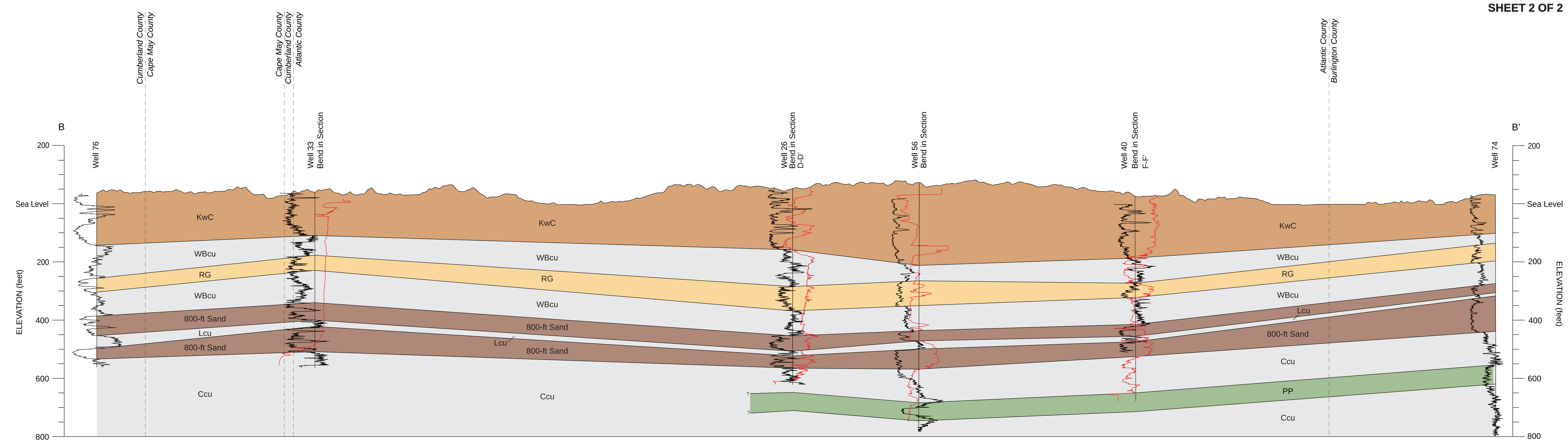


Figure 6. Hydrogeologic cross-section B-B'.

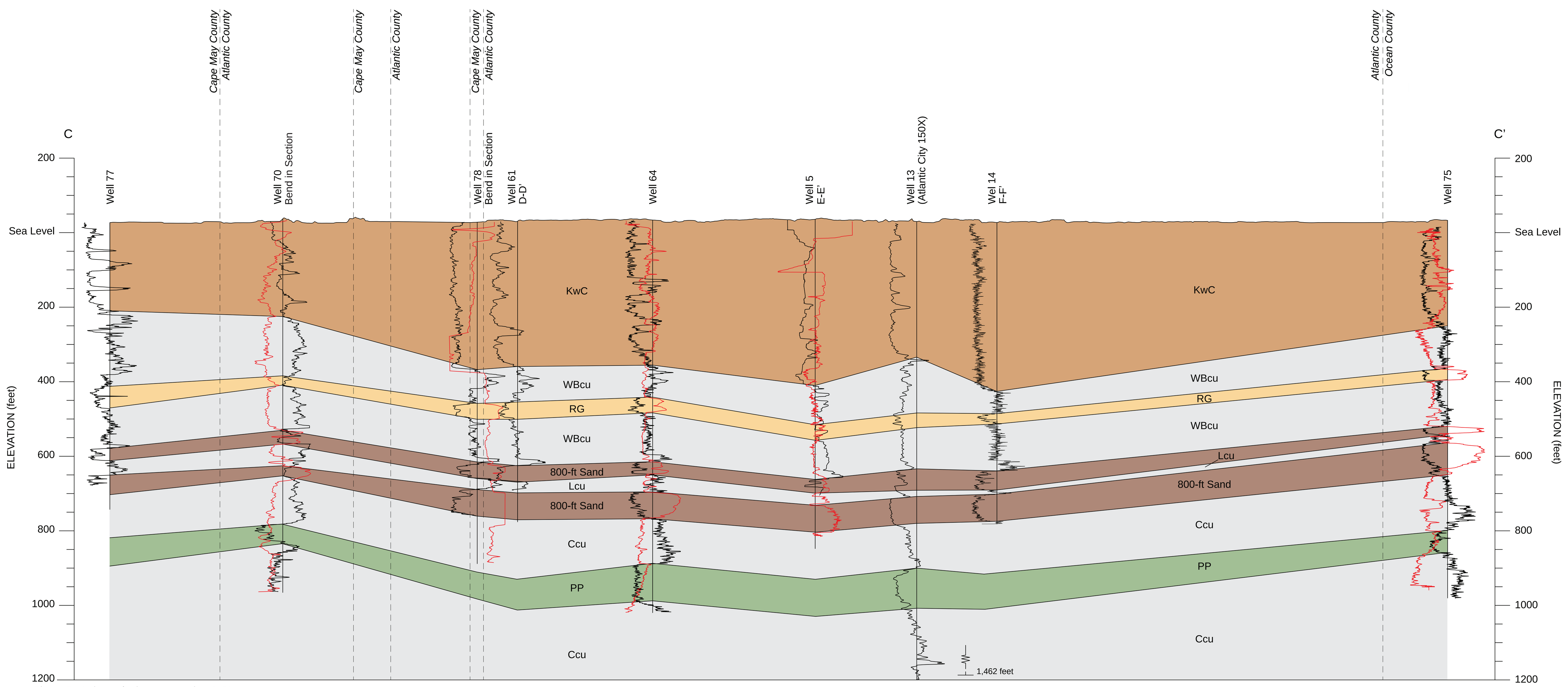


Figure 7. Hydrogeologic cross-section C-C'.

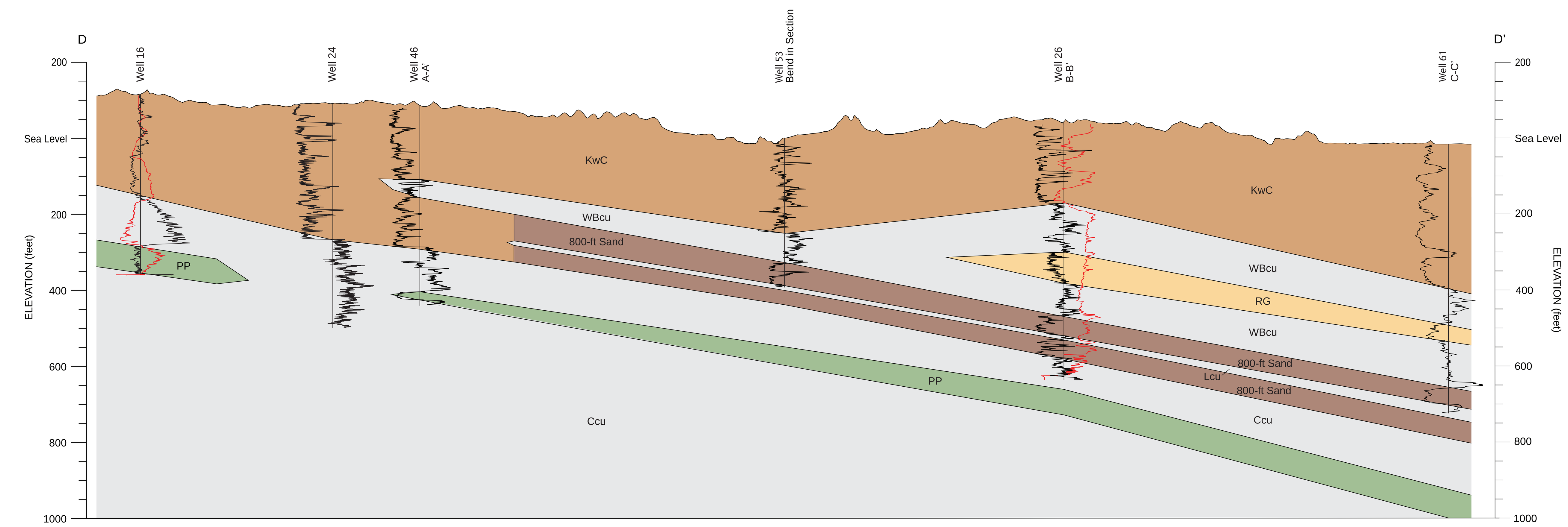


Figure 8. Hydrogeologic cross-section D-D'.

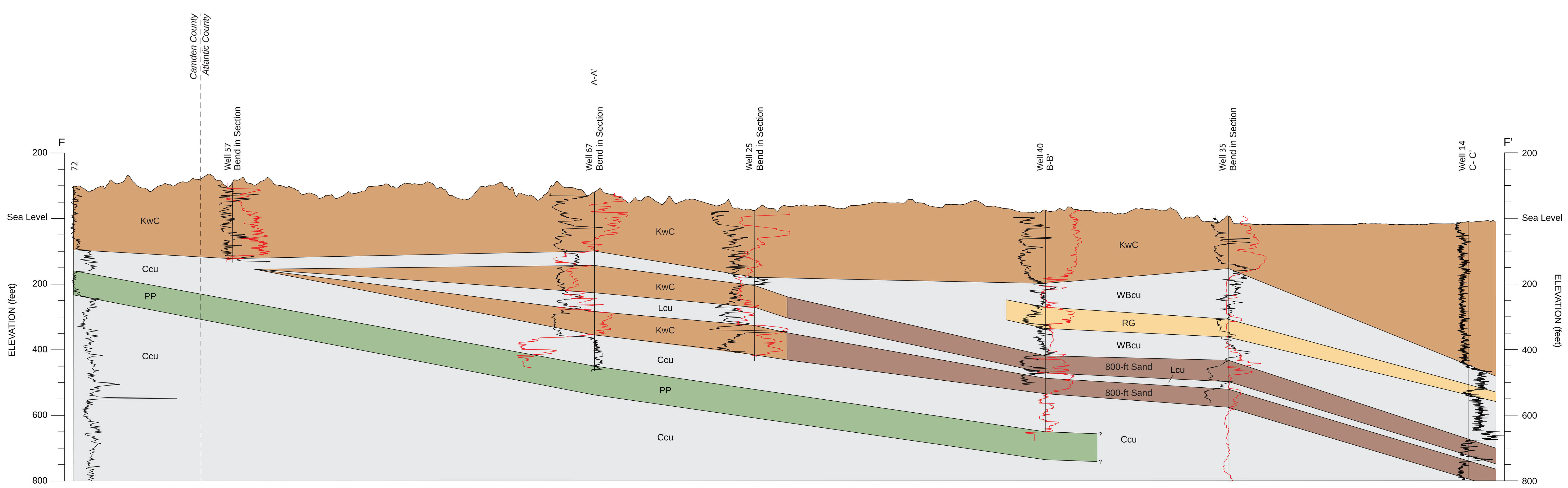


Figure 9. Hydrogeologic cross-section F-F'.

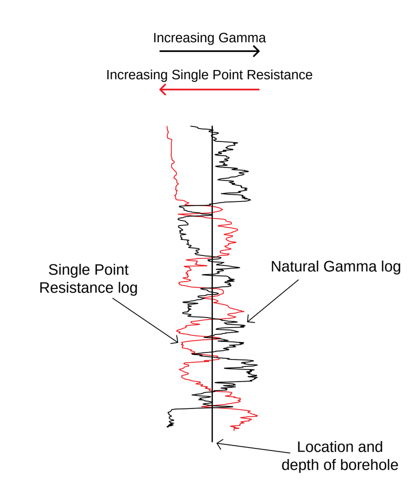
Description of Aquifer Units

- KwC — Kirkwood-Cohansey aquifer system
- RG — Rio Grande water-bearing zone
- WBcu — Wildwood-Belleplain confining unit
- Lcu — Leaky confining unit
- 800-ft Sand — Atlantic City 800-foot sand
- PP — Piney Point aquifer
- Ccu — Composite confining unit

Description of Map Symbols

- Contact
- Inferred aquifer contact
- Total depth of well
- Well location

Explanation of Geophysical Logs



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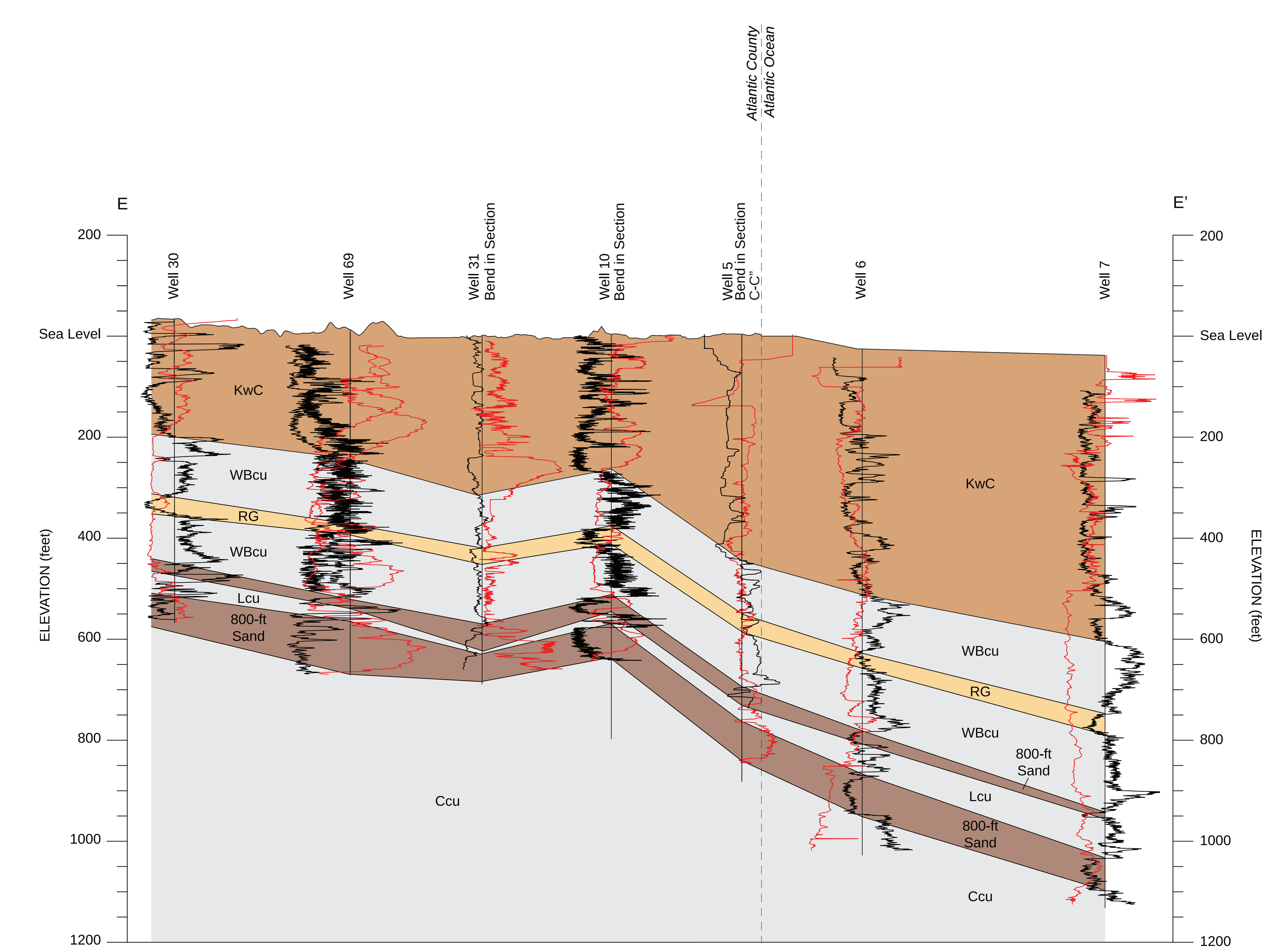

Figure 10. Hydrogeologic cross-section E-E'.