INTRODUCTION

The Browns Mills quadrangle is in the Pine Barrens region of the New Jersey Coastal Plain, in Burlington County and a small bit of Ocean County, in the south-central part of the state. Outcropping geologic materials in the map area include surficial deposits of late Miocene to Holocene age that overlie the Cohansey and Kirkwood formations, which are shallow-marine and coastal deposits of early and middle Miocene age. In the subsurface, unconsolidated marine and fluvial sediments ranging in age from Early Cretaceous to Eocene underlie the Cohansey and Kirkwood formations. The surficial deposits include stream, wetland, hillslope, and windblown sediments.

Summaries of the resources provided by the formations, and of the history of the map area as recorded by the Coastal Plain bedrock formations and surficial deposits and landforms, are provided below. The age of the deposits and episodes of valley erosion are shown on the correlation chart. Table 1 shows the formations penetrated by selected wells and borings as interpreted from drillers' descriptions and geophysical well logs. These data were used to construct the cross sections, which show formations to a maximum depth of about 700 feet (elevation -600 feet). Four wells in the quadrangle are deeper (wells 1, 190, 217, and 218), extending to total depths of 887, 1,025, 900, and 1,025 feet, respectively. Formations below elevation -600 feet in these wells are listed in table 1 and described in Owens and others (1998) and Sugarman and others (2010). Although no wells in the quadrangle reached basement rock beneath the Coastal Plain formations, wells and seismic data in adjacent areas indicate that basement is probably at a depth of about 1,000 feet in the northwest corner of the quadrangle, deepening to about 2,000 feet in the southeast (Volkert and others, 1996). Basement rocks in this area are chiefly gneiss and schist of Middle and Late Proterozoic and early Paleozoic age. Carbonate rock may occur in the southeastern part of the quadrangle (Volkert and others, 1996, p. B15). The basement rocks are commonly weathered to saprolite with thicknesses of as much as 100 feet beneath the basal Cretaceous sediments.

The outcrop extent of the Cohansey and Kirkwood formations in the Browns Mills quadrangle was mapped at 1:24,000 by Minard and Owens (1963) based on exposures and 40 power-auger holes drilled to depths of 25 to 30 feet. Using the same data, Owens and Minard (1975) mapped the surficial geology of the quadrangle and adjacent areas extending north and west to Trenton at 1:48,000. The present map updates these efforts by adding subsurface interpretations based on lithologic and geophysical logs from 220 wells and borings and by mapping surficial deposits using LiDAR imagery, aerial photography, and approximately 1,300 five-foot hand-auger holes. These data also allow for minor adjustments to the Cohansey-Kirkwood contact in outcrop, and the mapping of clay beds in the Cohansey.

RESOURCES

Groundwater is pumped mostly from two aquifers in the quadrangle: (1) the Kirkwood-Cohansey aquifer system, consisting of sands in the Kirkwood (unit Tkw) and Cohansey (Tchs) formations, and (2) the Wenonah-Mount Laurel aquifer, consisting here of sand primarily in the Mount Laurel Formation (Kml) (Zapecza, 1989; Sugarman and others, 2018). Most domestic and irrigation wells in the southeastern part of the quadrangle, where the Kirkwood and Cohansey together are between 100 and 250 feet thick, tap sand in the Kirkwood-Cohansey aquifer at depths between 50 and 120 feet. Most of these wells produce from the Cohansey Formation, which contains medium-to-coarse sand, because the Kirkwood in the quadrangle is mostly very fine-to-fine sand. Most wells in the northwestern part of the quadrangle tap the Mount Laurel Formation at depths between 250 and 450 feet. Here, the Kirkwood and Cohansey together are less than 100 feet thick and the more permeable Cohansey sands are generally less than 50 feet thick, so the Mount Laurel is the shallowest usable aquifer.

Several other sands are major aquifers in the quadrangle. These include: (1) the upper and …

SURFICIAL DEPOSITS AND GEOMORPHIC HISTORY

After the Cohansey Formation was deposited in the middle Miocene, sea level in the New Jersey region began a long-term decline. As sea level lowered in the middle and late Miocene, between about 15 to 5 million years ago (15-5 Ma, Ma = million years ago), the inner continental shelf emerged as a coastal plain. River drainage was established on this plain. The oldest surficial deposits in the quadrangle are gravels deposited by these rivers. This drainage eroded valleys into an earlier, higher fluvial gravel known as the Beacon Hill Gravel, which formerly covered the Brown Mills quadrangle at elevations above 200 to 250 feet from south to north (Stanford, 2010a). It has been eroded away in this quadrangle but remains as a cap on the highest hills and uplands to the east, north, and south of the map area. Erosion from spring seepage, on hillslopes, and in stream channels, reworked the gravel and deposited it in floodplains, channels, and pediments in valleys that had been cut down between 100 and 150 feet below the level of the former Beacon Hill plain. These deposits are mapped as upland gravel, high phase (unit Tg). They cap the uplands east of Four Mile in the southeastern part of the quadrangle and the upland in the northwestern corner of the quadrangle (fig. 2). The base of these deposits in the southeastern part of the quadrangle declines from an elevation of 160 to 170 feet just south and southeast of the quadrangle border (Stanford, 2010b, 2012) to about 135 feet near Four Mile and between 140 and 150 feet east of McDonald. This slope indicates northwesterly stream flow (purple arrows on fig. 2). The deposits in the northwest corner have a base between 140 and 160 feet in elevation. They are the southernmost part of an upland gravel with a base that rises to the north and northeast to an elevation of 190 to 200 feet near Jacobstown, about eight miles north of the town of Browns Mills (Owens and Minard, 1975). This slope indicates southerly to southwesterly stream flow. Together, these northern and southern upland gravels record a late Miocene drainage pattern like that of the present-day Rancocas basin.

A renewed period of lowering sea level in the late Pliocene and early Pleistocene, approximately 2 Ma to 800,000 years ago (800 ka, ka = thousand years ago), led to another period of valley deepening. Spring seepage, channel, and hillslope erosion reworked the upland gravel, high phase and deposited the upland gravel, lower phase (unit TQg) in shallow valleys 20 to 50 feet below the higher gravels. These deposits today cap hilltops and interfluves, and form upland plains. In the southern half of the quadrangle the base of the lower-phase deposits descends from between 130 and 140 feet in elevation in the southeast, adjacent to remnants of the high-phase deposits, to between 90 and 100 feet to the west and northwest, indicating northwestward stream flow (blue arrows on fig. 2). In the northern half of the quadrangle the base of the lower-phase deposits descends from between 120 and 130 feet in the northwest adjacent to the remnants of the high-phase deposits, to between 70 and 80 feet on the upland located south of Browns Mills (blue arrows on fig. 2), indicating southwesterly to southerly stream flow. As with the high-phase deposits, the low-phase deposits record a Pliocene and early Pleistocene drainage pattern like that of the present-day Rancocas basin.

Further deepening of valleys in the middle and late Pleistocene (about 800 to 20 ka), primarily during periods of low sea level, formed the present-day valley network (white areas on fig. 2). Fluvial sediments laid down in these valleys include upper and lower terrace deposits (units Qtu, Qtl, and Qtll) and floodplain and wetland deposits (Qals, Qald) in valley bottoms. Colluvium deposited at the base of hillslopes on the edge of the valleys (Qcu) grades to the upper terraces. Like the upland gravels, the terrace, hillslope, and floodplain deposits represent erosion, transport, and redeposition of sand and gravel reworked from older surficial deposits and the Cohansey and Kirkwood formations by streams, spring seepage, and hillslope erosion. Wetland deposits are formed by accumulation of organic matter in swamps and bogs.

Upper terrace deposits (Qtu) form terraces and pediments with surfaces 10 to 30 feet above present-day floodplains. The terrace deposits were laid down chiefly during periods of cold climate in the middle Pleistocene. During cold periods, permafrost was widespread and forest was replaced by tundra-like grassland. The permafrost impeded deep infiltration of rainfall and snowmelt during thaws, increasing runoff and spring seepage, and the shallow roots of grassland vegetation provided less anchoring of surface sediments than did the deeper roots of forest cover. The volume of sand washing into valleys increased, producing the terrace deposits. Some of the deposits may have been laid down during periods of temperate climate when sea level was high, because downstream in the Rancocas valley the upper terraces grade to the Cape May Formation, unit 2 estuarine terrace in the Willingboro area, 15 miles west of the town of Browns Mills. This topographic equivalence indicates that some of the upper terrace deposits aggraded during the sea-level highstand at 125 ka, when unit 2 of the Cape May Formation was deposited (Stanford and others, 2016).

Upper terraces cross present-day drainage divides in several places (green arrows on fig. 2). South of Mount Misery the upper terrace crosses the divide between the South Branch of Mount Misery Brook and the Gum Spring and McDonalds Branch valleys. This pattern indicates that the North, Middle, and South branches of Mount Misery Brook flowed eastward into the Gum Spring and McDonalds Branch valleys during deposition of the upper terrace. This flow was captured by Mount Misery Brook east of Mount Misery during Wisconsinan incision. The extent of this incision is shown with black lines on figure 2. This capture was facilitated by a thick clay-sand bed in the Cohansey Formation at a depth of 30 to 50 feet below the lowland northeast of Mount Misery Brook, which is shown on cross section CC' and on cross sections in the Whiting quadrangle to the east (Stanford, 2016). As streams in this lowland, including the downstream reach of Mount Misery Brook, incised during the Wisconsinan, this clay bed impeded downward groundwater flow in the Cohansey, instead directing flow above the clay laterally and thereby increasing streamflow. Active seepage at the edge of the incised Mount Misery valley east of Mount Misery, marked by well-developed seepage theaters (fig. 3), record this groundwater discharge. South of Mount Misery the clay-sand bed is not present (cross sections AA' and BB') and thinner, more discontinuous clays higher in the Cohansey and in outcrop (fig. 1) lie mostly above the limit of Wisconsinan incision and intercept less groundwater from smaller catchment areas.

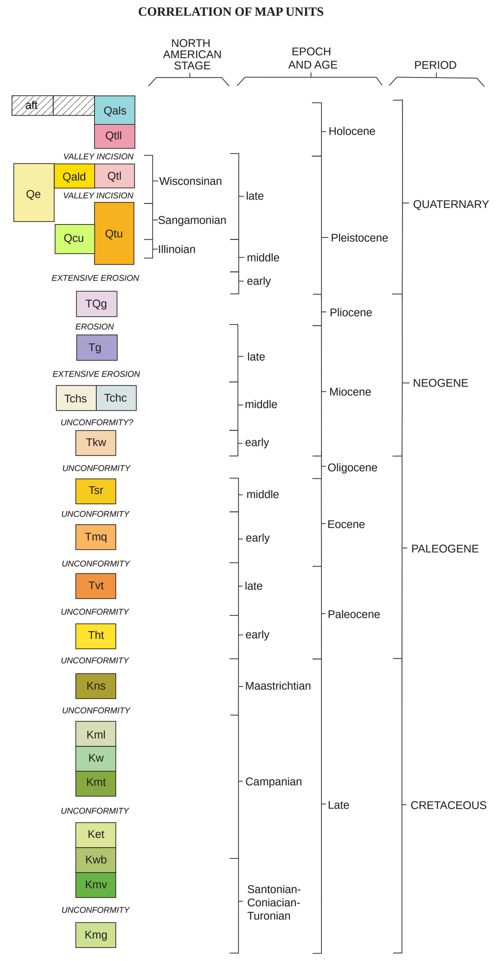
In one place, though, this higher clay may have facilitated another stream capture like that at Mount Misery. The upper terrace crosses the McDonalds Branch-South Branch divide in the southeastern corner of the quadrangle (fig. 2), indicating that McDonalds Branch captured part of the South Branch drainage during Wisconsinan incision. The outcropping clay bed near the capture site intercepted groundwater from the adjoining Neogene uplands (gray areas on fig. 2), increasing streamflow in McDonalds Branch as it incised.

Another capture occurred along the northern edge of the quadrangle, where a tributary of Jacks Run intercepted a stream that formerly flowed south to the east of the Jacks Run valley. Here, the Kirkwood Formation, which crops out in the Jacks Run valley (fig. 1) but not in the shallower valley to the east, may have impeded and directed groundwater into the tributary to Jacks Run during Wisconsinan incision in a manner like that in the two instances described above.

Lower terrace deposits (Qtl) form terraces with surfaces generally less than 15 feet above present-day floodplains. They formed from stream and spring-seepage erosion of the upper terrace deposits, and, in places, older deposits, chiefly during the last period of cold climate corresponding to the late Wisconsinan glacial stage between 33 and 11 ka. Small valleys on uplands that contain thin deposits of sand and gravel (Qald) and that do not conduct water under present-day conditions, lead out onto lower terraces in places and are likely of the same age. Organic-rich clayey fine sand within lower terrace deposits in the headwaters of the Burrs Mill Brook valley in the Chatsworth quadrangle about three miles south of Four Mile yielded a radiocarbon date of 20,350±80 yrs BP (Beta 309764) (24.2-24.7, median 24.4, calibrated ka), indicating deposition in the late Wisconsinan (Stanford, 2012). (All radiocarbon dates are calibrated using Reimer and others (2020) and the Calib 8.20 computer program. Calibrated dates are stated with two-sigma uncertainty.) Organic silt at the base of lower terrace deposits east of the quadrangle in the Manasquan and Metedeconk river valleys yielded radiocarbon dates of 29,050±150 yrs BP (Beta 471459) (33.1-34.1, median 33.6, calibrated ka) from a site near Siloam in the Adelphia quadrangle and a date of 35,570+3,180-2,270 (GX-24257) (33.5-49.8, median 39.6, calibrated ka) from a site near Farmingdale in the Farmingdale quadrangle (Stanford and others, 2002). These dates confirm deposition of the overlying terrace sediments in the late Wisconsinan. As with the upper terrace deposits, permafrost and tundra vegetation led to an increase of sediment entering valleys. This influx led to the development of shallow braided channels (blue lines on map) on the lower terrace as streams were clogged with sand, causing channels to branch and shift.

Lower terraces include broad wetlands in headwater areas like the Jade Run valley on the western side of the quadrangle, the lowland south of Mirror Lake, the Bucks Cove Run and Cranberry Brook valleys around Whitesbog, the headwaters of Baffin Brook southeast of Route 70 on the eastern side of the quadrangle, and the McDonalds Branch, Cooper Branch, and Shinns Branch valleys upstream of Lebanon Lake in the southwestern part of the quadrangle. In these areas the lower terraces are inset generally less than five feet into upper terraces and present-day floodplains are likewise inset only one to three feet into the lower terraces. The lower terraces in these headwaters were formed chiefly by spring-seepage erosion of the upper terrace. In some places this erosion is enhanced by the presence of low-permeability sediments at shallow depth, such as silty fine sand of the Kirkwood Formation in the Jade Run valley and Mirror Lake area and clay beds of the Cohansey Formation in the Whitesbog area, the Baffin Brook valley, and parts of the Shinns, Cooper, and McDonalds Branch valleys. This seepage continues today at the contact of the lower and upper terraces, which generally corresponds to the transition from a dry upland supporting pine and oak forest on the upper terrace to a wet lowland supporting pine, scattered cedar, and maple forest on the lower terrace. The present-day floodplain is wetter still and supports cedar and maple forest and marsh grasses in the wettest areas.

CORRELATION OF MAP UNITS



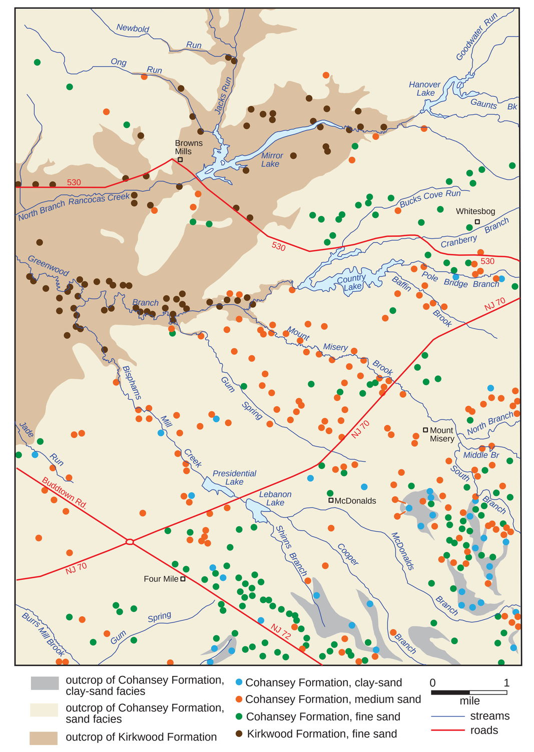


Figure 1. Outcrop areas and grain size of the Kirkwood and Cohansey formations in the Browns Mills quadrangle.

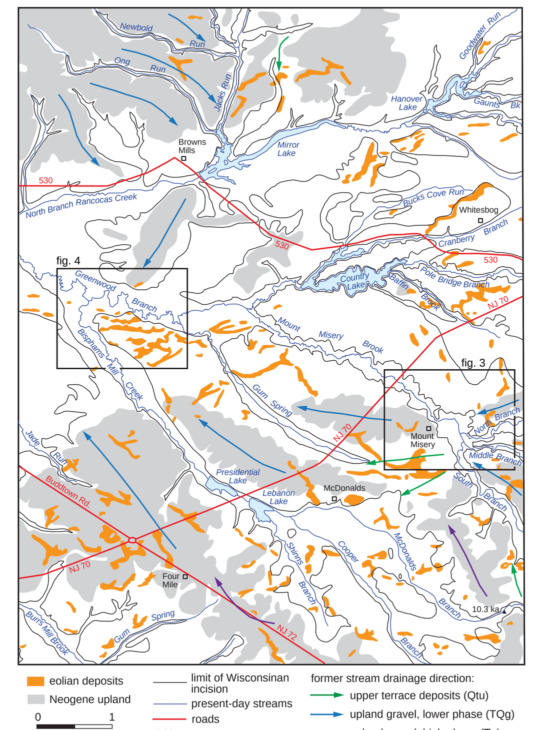


Figure 2. Geomorphic features, extent of eolian deposits, and former drainage directions of streams in the Browns Mills quadrangle.

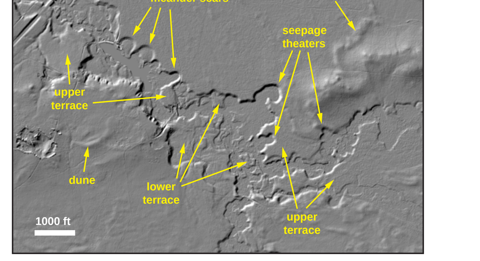


Figure 3. Hillshade image showing seepage theaters in the Mount Misery Brook valley.

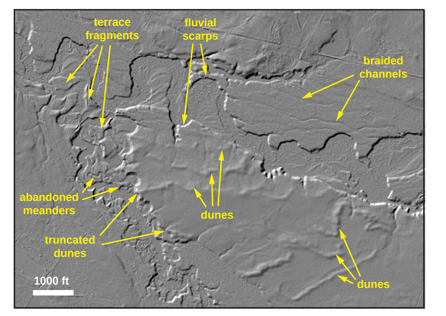


Figure 4. Hillshade image showing fluvial landforms and dunes in the Greenwood Branch and Bighams Mill Creek valleys.

Figure 5. Sand and gravel of the lower terrace, low phase (Qtl).

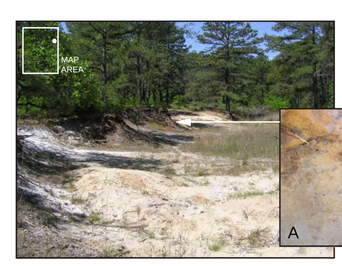


Figure 6. Former sand pit dug into a paleodune near Whitesbog.

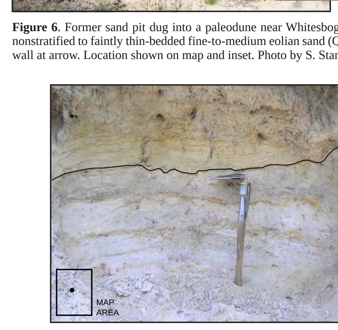
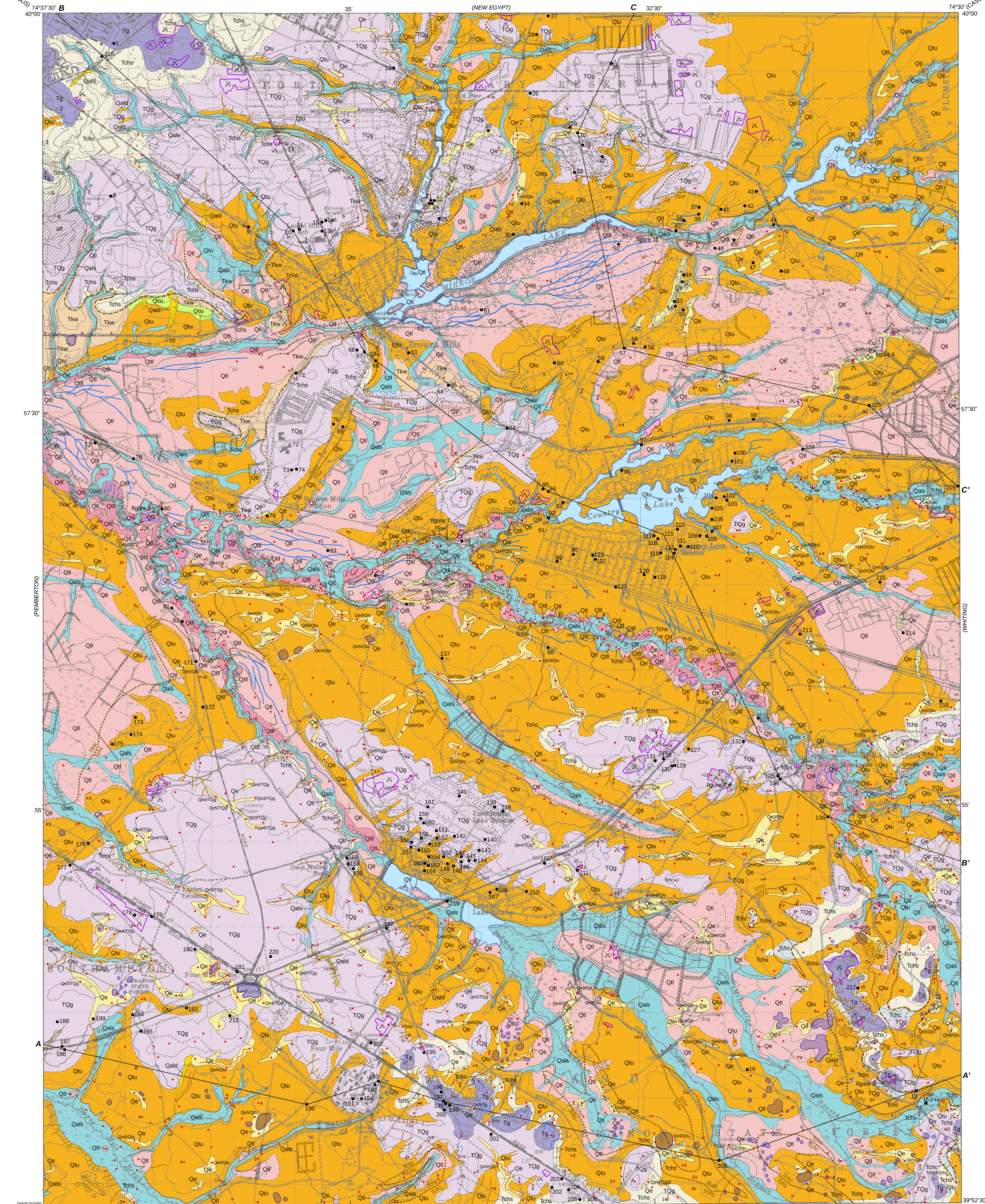
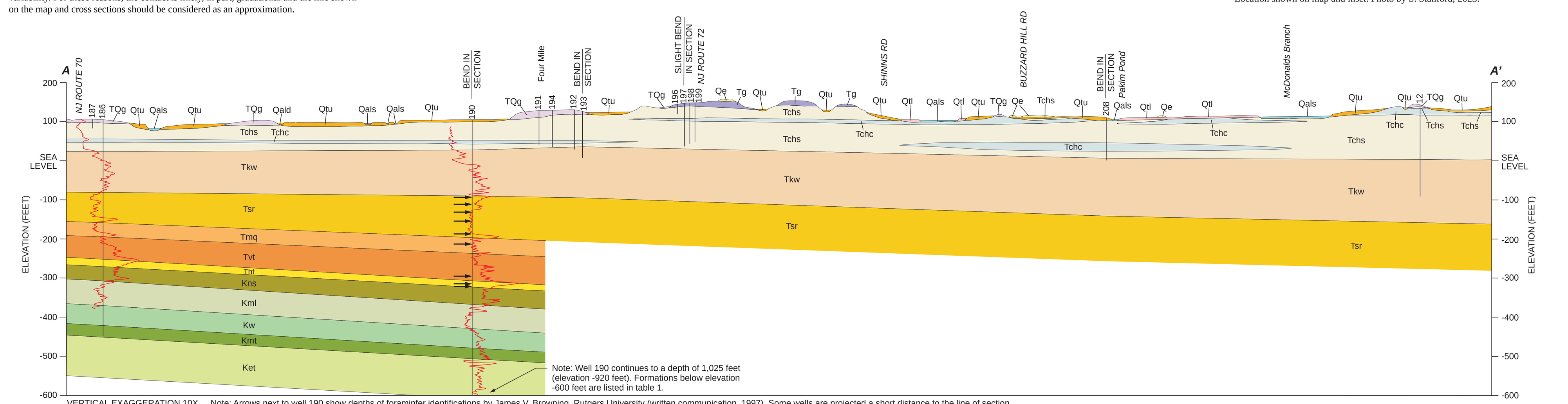


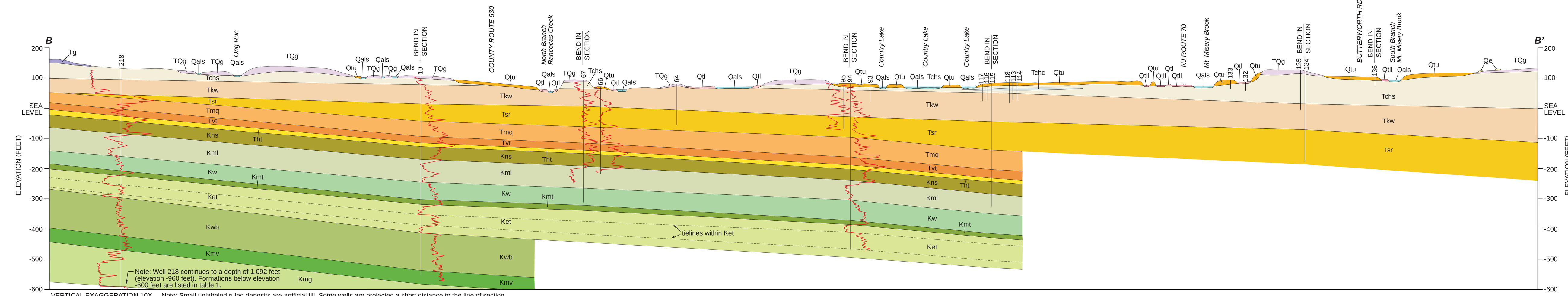
Figure 7. Sand and gravel of the upper terrace deposit (Qtu, above line).

DESCRIPTION OF MAP UNITS

MAP SYMBOLS







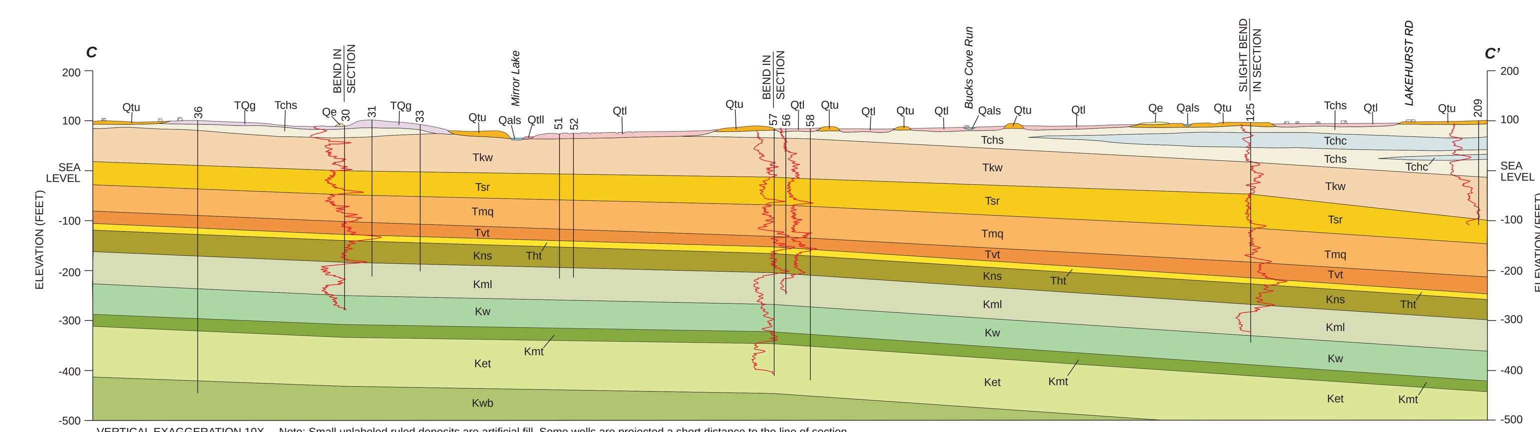


Figure 8.

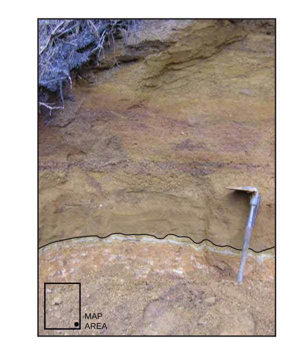


Figure 9.

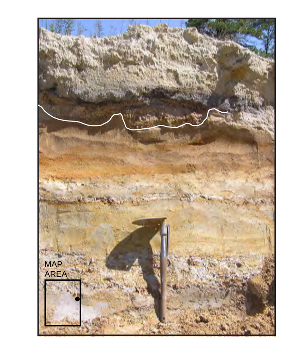


Figure 10.

Figure 11.

GEOLOGY OF THE BROWNS MILLS QUADRANGLE BURLINGTON AND OCEAN COUNTIES, NEW JERSEY

By
Scott D. Stanford
2023

Geology of the Browns Mills Quadrangle
Burlington and Ocean Counties, New Jersey

New Jersey Geological and Water Survey
Open-File Map OFM 157
2023

pamphlet with table 1 to accompany map

Table 1. Selected well and boring records. Well numbers in boldface indicate that the well is shown on the cross section listed after the well number. Footnotes are at the end of the table (p. 5).

Well Number	Identifier[1]	Formations Penetrated[2]
1	52-8, G	40 Tch 105 Tkw 150 Tsr+Tmq 180 Tvt 195 Tht 220 Kns 300 Kml 380 Kw 400 Kmt 460 Ket 590 Kwb 610 Kmv 745 Kmg 785 Kr 887 Kp
2	19694	22 Tchs 76 Tkw
3	8379	34 Tchs 50 Tkw
4	19756	40 Tchs 64 Tkw
5	8381	10 s or Tchs 36 Tchs 40 Tkw
6	8377	14 s or Tchs 34 Tkw
7	19765	43 Tchs 64 Tkw
8	22302	12 s or Tchs 32 Tchs 47 Tkw
9	MO1	20 Tch 25 Tkw
10 BB’	18309+18451, G	30 Tch 90 Tkw 145 Tsr 200 Tmq 220 Tvt 235 Tht 270 Kns 350 Kml 405 Kw 420 Kmt 515 Ket 640 Kwb 660 Kmt
11	18441	15 Tchs 23 Tchc+Tchs 27 Tchs 29 Tchc 57 Tchs+Tchc 102 Tkw 274 Tsr+Tmq+Tvt+Kns 320 Kml 407 Kw 419 Kmt 511 Ket 532 Kwb
12 AA’	USGS 5-1560	11 Tchs 12 Tchc 19 Tchs 21 Tchc 117 Tchs 140 Tchs+Tchc 235 Tkw
13	143	12 Tchs 74 Tkw 98 Tkw or Tsr 178 Tsr+Tmq+Tvt 196 Tht 275 Kns 303 Kml
14	526	37 Tchs 89 Tkw 249 Tsr+Tmq+Tvt+Tht+Kns 305 Kml
15	6929	38 Tchs 77 Tkw 107 Tkw or Tsr 285 Tsr+Tmq+Tvt+Tht+Kns 315 Kml
16	MO33	25 s 30 Tch
17	138	48 Tchs 105 Tkw 140 Tsr
18	MO37	10 Tch 25 Tkw
19	13	60 Tkw 262 Tsr+Tmq+Tvt+Tht+Kns 282 Kml
20	301	10 s 20 Tchs 80 Tkw 110 Tsr
21	14520	42 Tchs 77 Tkw 255 Tsr+Tmq+Tvt+Tht+Kns 288 Kml
22	15759	42 Tchs 77 Tkw 255 Tsr+Tmq+Tvt+Tht+Kns 288 Kml
23	15758	42 Tchs 77 Tkw 255 Tsr+Tmq+Tvt+Tht+Kns 288 Kml
24	14315	42 Tchs 77 Tkw 255 Tsr+Tmq+Tvt+Tht+Kns 288 Kml
25	MO3	10 Tch 25 Tkw
26	MO35	22 Tch 25 Tkw
27	MO36	15 Tch 25 Tkw
28	USGS 5-1416	47 Tchs 80 Tkw 260 Tsr+Tmq+Tvt+Tht+Kns 290 Kml
29	14400	4 s 7 Tchc 20 Tchs 22 Tchc 34 Tchs 52 Tkw
30 CC’	15968+15670, G	20 Tchs 90 Tkw 130 Tsr 185 Tmq 215 Tvt 230 Tht 275 Kns 340 Kml 363 Kw
31 CC’	10219	47 Tchs 90 Tkw 170 Tsr+Tmq 315 Tvt+Tht+Kns+Kml
32	12693	20 Tchs 31 Tchc 45 Tchs 60 Tkw
33 CC’	14167	37 Tchs 77 Tkw 260 Tsr+Tmq+Tvt+Tht 292 Kns+Kml
34	15400	12 s 55 Tkw
35	6	60 Tkw 221 Tsr+Tmq+Tvt 336 Tht+Kns+Kml
36 CC’	USGS 5-754	17 Tchs 86 Tkw 297 Tsr+Tmq+Tvt+Tht+Kns 395 Kml 447 Kw+Kmt 518 Ket 545 Kwb
37	12365	4 s 90 Tkw 280 Tsr+Tmq+Tvt 312 Tht+Kns+Kml

Well Number	Identifier[1]	Formations Penetrated[2]
38	15311	86 Tkw 269 Tsr+Tmq+Tvt 315 Tht+Kns+Kml
39	11532	32 s+Tchs 62 Tkw
40	11945	70 Tkw 100 Tsr 270 Tmq+Tvt+Tht 307 Kns+Kml
41	11165	15 Tchs 90 Tkw 195 Tsr+Tmq 280 Tmq+Tvt+Tht 325 Kns+Kml
42	15441	20 Tchs 94 Tkw 248 Tsr+Tmq 290 Tmq+Tvt+Tht 320 Kns+Kml
43	11375	10 Tchs 125 Tkw 230 Tsr+Tmq 271 Tmq+Tvt 292 Tvt+Tht 325 Kns+Kml
44	MO40	6 s 15 Tch 25 Tkw
45	10819	20 Tchs 110 Tkw 210 Tsr+Tmq 325 Tvt+Tht+Kns+Kml
46	15038	21 Tchs 93 Tkw 231 Tsr+Tmq 275 Tmq+Tvt 315 Tht+Kns+Kml
47	13088	30 Tchs+Tkw 90 Tkw 220 Tsr+Tmq 302 Tmq+Tvt+Tht 360 Kns+Kml
48	10564	20 Tchs 80 Tkw 215 Tsr+Tmq 285 Tmq+Tvt+Tht 315 Kns+Kml
49	15084	34 Tchs 92 Tkw 222 Tsr+Tmq 278 Tmq+Tvt+Tht 320 Kns+Kml
50	14907	24 Tchs 92 Tkw 222 Tsr+Tmq 278 Tmq+Tvt+Tht 310 Kns+Kml
51 CC'	274	109 Tkw 257 Tsr+Tmq+Tvt+Tht 286 Kns+Kml
52 CC'	950	78 Tkw 220 Tsr+Tmq 280 Tvt+Tht 288 Kns+Kml
53	15562	37 Tchs 115 Tkw 282 Tsr+Tmq+Tvt+Tht 328 Kns+Kml
54	15561	37 Tchs 115 Tkw 238 Tsr+Tmq 282 Tmq+Tvt+Tht 328 Kns+Kml
55	438	3 Tchs 76 Tkw 130 Tsr 190 Tmq 300 Tvt+Tht 306 Kns+Kml
56 CC'	775, G	20 Tchs 100 Tkw 150 Tsr 205 Tmq 235 Tvt 245 Tht 280 Kns 348 Kml 368 Kw
57 CC'	22560, G, E	20 Tchs 100 Tkw 150 Tsr 210 Tmq 240 Tvt 250 Tht 290 Kns 350 Kml 410 Kw 430 Kmt 480 Ket
58 CC'	24732	15 Tchs 100 Tkw 150 Tsr 210 Tmq 240 Tvt 250 Tht 290 Kns 350 Kml 410 Kw 430 Kmt 501 Ket
59	819, G	55 Tchs 100 Tkw 150 Tsr 210 Tmq 235 Tvt 245 Tht 280 Kns 340 Kml 364 Kw
60	14513	8 Tchs 9 Tchc 20 Tchs 51 Tchs+Tkw 83 Tkw 267 Tsr+Tmq+Tvt+Tht 305 Kns+Kml
61	17219, G	65 Tkw 110 Tsr 170 Tmq 190 Tvt 210 Tht 245 Kns 310 Kml 329 Kw
62	776	3 s 122 Tkw 226 Tsr+Tmq+Tvt+Tht 240 Kns 266 Kml 348 Kw 368 Kmt
63	MO4	10 s 25 Tkw
64	234	85 Tkw 134 Tsr+Tmq
65	MO5	10 s 25 Tkw
66 BB'	378, G	10 Tchs 65 Tkw 125 Tsr 190 Tmq 215 Tvt 230 Tht 265 Kns 284 Kml
67 BB'	386, G	30 Tchs 85 Tkw 145 Tsr 205 Tmq 230 Tvt 245 Tht 285 Kns 355 Kml 410 Kw
68	28317	30 Tchs 105 Tkw 277 Tsr+Tmq+Tvt+Tht 334 Kns+Kml
69	421	80 Tkw 142 Tsr
70	396	10 Tchs 80 Tkw 132 Tsr
71	MO2	10 Tch 25 Tkw
72	486	41 Tchs 62 Tkw 205 Tsr+Tmq+Tvt 227 Tht 312 Kns+Kml
73	12359	33 Tchs+Tchc 92 Tkw 237 Tsr+Tmq+Tvt 280 Tht+Kns 320 Kml
74	22041	21 Tchs 76 Tkw 265 Tsr+Tmq+Tvt+Tht 312 Kns+Kml
75	550	5 s 70 Tkw 255 Tsr+Tmq+Tvt+Tht 280 Kns+Kml 300 Kml
76	1218	10 s 55 Tkw 95 Tsr+Tmq
77	23123	12 s 40 Tkw 240 Tsr+Tmq+Tvt+Tht 280 Kns+Kml
78	MO14	7 s 25 Tkw
79	397	90 Tkw 200 Tsr+Tmq+Tvt
80	MO13	17 s 25 Tkw
81	MO15	9 s 25 Tkw
82	MO16	13 s 25 Tkw
83	MO 12	10 s 25 Tkw
84	MO6	5 s 15 Tch 25 Tkw
85	MO11	8 s 12 Tch 25 Tkw
86	MO18	13 s 20 Tch 25 Tkw
87	MO17	5 s 8 Tch 25 Tkw
88	MO23	18 s 25 Tch
89	8667	30 Tchs 75 Tkw
90	14048	12 Tchs 14 Tchc 22 Tchs 52 Tkw
91	199	50 Tkw 200 Tsr+Tmq+Tvt 220 Tht 260 Kns 310 Kml+Kw
92	MO9	6 s 14 Tch 25 Tkw
93 BB'	15251	20 Tch 110 Tkw
94 BB'	27282, G	20 Tchs 110 Tkw 160 Tsr 240 Tmq 270 Tvt 285 Tht 320 Kns 380 Kml 450 Kw 465 Kmt 545 Ket

Well Number	Identifier[1]	Formations Penetrated[2]
95 BB'	27280, G	20 Tchs 110 Tkw 155 Tsr
96	383	28 Tchs 106 Tkw 260 Tsr+Tmq+Tvt+Tht 329 Kns 345 Kml
97	MO7	5 s 25 Tch
98	654	7 s 40 Tchs+Tkw 75 Tkw
99	15237	38 Tchs 115 Tkw 337 Tsr+Tmq+Tvt+Tht 395 Kns+Kml
100	13382	4 Tchs 67 Tkw
101	14536	7 Tchs 14 Tchc 19 Tchs 77 Tkw
102	12706	9 Tchs 12 Tchc 18 Tchs 60 Tkw
103	14369	12 Tchs 14 Tchc 22 Tchs 52 Tkw
104	11778	19 Tchs 21 Tchc 30 Tchs 63 Tkw
105	14399	9 Tchs 12 Tchc 21 Tchs 22 Tchc 28 Tchs 62 Tkw
106	11634	19 Tchs 20 Tchc 28 Tchs 60 Tkw
107	11633	18 Tchs 21 Tchc 30 Tchs 62 Tkw
108	11632	20 Tchs 23 Tchc 40 Tchs 64 Tkw
109	MO10	4 s 25 Tch
110	15694	14 Tchs 32 Tchs+Tchc 40 Tchs 99 Tkw
111	14058	15 Tchs 18 Tchc 34 Tchs 52 Tkw
112	10016	6 Tchs 8 Tchc 12 Tchs 13 Tchc 23 Tchs 64 Tkw
113 BB'	13332	17 Tchs 21 Tchc 29 Tchs 52 Tkw
114 BB'	12466	5 Tchs 25 Tchc 34 Tchs 58 Tkw
115 BB'	7870	47 Tchs 127 Tkw 272 Tsr+Tmq 295 Tvt 367 Tht+Kns 404 Kml
116 BB'	13779	8 Tchs 11 Tchc 15 Tchs 19 Tchc 26 Tchs 52 Tkw
117 BB'	14117	17 Tchs 19 Tchc 27 Tchs 52 Tkw
118 BB'	11317	8 Tchs 12 Tchc 40 Tchs 67 Tkw
119	15523	9 Tchs 24 Tchc 35 Tchs 52 Tkw
120	13977	16 Tchs 18 Tchc 29 Tchs 60 Tkw
121	MO19	18 s 25 Tch
122	13614	15 Tchs 17 Tchc 29 Tchs 60 Tkw
123	13331	30 Tchs 60 Tkw
124	MO8	23 s 25 Tch
125 CC'	17621, G	20 Tchs 50 Tchc 80 Tchs 140 Tkw 210 Tsr 275 Tmq 310 Tvt 320 Tht 360 Kns 422 Kml 440 Kw
126	8	60 Tchs+Tkw 80 Tkw 291 Tsr+Tmq+Tvt+Tht 337 Kns+Kml
127	18026	10 Tchs 18 Tchs+Tchc 55 Tchs 100 Tkw
128	MO24	7 s 25 Tch
129	14705	17 Tchs 19 Tchc 47 Tchs 52 Tchc 69 Tchs
130	23809	14 Tchs 17 Tchc 40 Tchs 43 Tchc+Tchs 52 Tchs 57 Tchc 68 Tchs
131	14492	8 s 62 Tchs 67 Tchco 71 Tchs 73 Tchco 95 Tchs
132 BB'	MO39	5 s 25 Tch
133 BB'	MO38	13 s 25 Tch
134 BB'	E201217349	10 s +Tchs 14 Tchc 83 Tchs+Tchc 108 Tchs 192 Tkw 300 Tsr
135 BB'	17439	32 Tchs 49 Tchc+Tchs 135 Tchs
136 BB'	MO34	10 s 25 Tch
137	MO22	8 s 25 Tch
138	15560	81 Tchs 86 Tchc 105 Tchs
139	12748	81 Tchs 87 Tchs 98 Tchs
140	13145	25 Tchs 27 Tchc 40 Tchs 43 Tchc 65 Tchs 69 Tchc 97 Tchs
141	3320	20 Tchs 23 Tchc 53 Tchs
142	13114	26 Tchs 49 Tchc+Tchs 56 Tchco 87 Tchs 90 Tchco 103 Tchs 110 Tchs+Tchc
143	10766	10 Tchs 60 Tchs+Tchc 63 Tchc 83 Tchs
144	14516	26 Tchs 30 Tchc 59 Tchs 64 Tchs+Tchc 99 Tchs
145	14469	28 Tchs 31 Tchc 60 Tchs 66 Tchc+Tchs 105 Tchs
146	13964	28 Tchs 33 Tchc 56 Tchs 61 Tchc 82 Tchs
147	14943	22 Tchs 47 Tchc 62 Tchs
148	9010	100 Tchs
149	15113	60 Tchs 66 Tchc 115 Tchs
150	12846	14 Tchs 17 Tchc 27 Tchs 32 Tchc 57 Tchs 67 Tchc 82 Tchs
151	14362	26 Tchs 28 Tchc 61 Tchs 65 Tchc+Tchs 123 Tchs 192 Tkw 412 Tsr+Tmq+Tvt+Tht+Kns

Well Number	Identifier[1]	Formations Penetrated[2]
		433 Kml
152	8663	50 Tchs+Tchc 70 Tchco+Tchs 105 Tchs
153	10758	10 Tchs 35 Tchs+Tchc 43 Tchc 72 Tchs 79 Tchc+Tchs
154	14967	64 Tchs 70 Tchc 105 Tchs
155	13726	23 Tchs 26 Tchc 31 Tchs 34 Tchc 50 Tchs 56 Tchc 75 Tchs
156	3127	10 Tchs 25 Tchs+Tch 60 Tchs
157	13598	16 Tchs 25 Tchs+Tchc 70 Tchs 72 Tchs+Tchc
158	8669	85 Tchs 105 Tchs+Tchc
159	14898	60 Tchs 67 Tchc 100 Tchs
160	20729	60 Tchs 80 Tchs+Tchc 100 Tchs
161	15671	62 Tchs 69 Tchc 103 Tchs
162	12743	20 Tchs 22 Tchc 60 Tchs 66 Tchco 74 Tchs
163	13608	28 Tchs 31 Tchc 50 Tchs 56 Tchc 80 Tchs
164	9158	105 Tchs
165	MO25	8 s 25 Tch
166	1552	34 Tchs 42 Tchc 52 Tchs
167	1557	34 Tchs 42 Tchc 52 Tchs
168	13304	23 Tchs 45 Tchc+Tchs 49 Tchc 76 Tchs 84 Tchc+Tchs 95 Tchs+Tchco 102 Tkw
169	14197	68 Tchs 73 Tchc+Tchs 100 Tchs
170	14363	70 Tchs 75 Tchc+Tchs 100 Tchs
171	MO20	5 s 18 Tch 25 Tkw
172	MO21	32 Tch 35 Tkw
173	E201114233	32 Tchs 110 Tkw 310 Tsr+Tmq+Tvt+Tht+Kns 350 Kml
174	27236	40 Tchs 100 Tkw 300 Tsr+Tmq+Tvt+Tht+Kns 330 Kml
175	E202012067	45 Tchs 110 Tkw 300 Tsr+Tmq+Tvt+Tht+Kns 320 Kml
176	23817	4 s 24 Tchs
177	20485	29 Tchs 40 Tchc 80 Tchs
178	27311	32 Tchs 43 Tchc 70 Tchs
179	28716	14 s 74 Tchs 91 Tchs+Tchc 98 Tchs 149 Tkw 385 Tsr+Tmq+Tvt+Tht+Kns 432 Kml
180	27071	30 Tchs 35 Tchc 71 Tchs
181	MO27	4 s 25 Tch
182	MO26	3 s 25 Tch
183	MO29	5 s 25 Tch
184	20147	6 Tchs 13 Tchc+Tchs 76 Tchs 80 Tchco+Tchs
185	13278	4 Tchs 6 Tchc 12 Tchs 14 Tchc 25 Tchs 28 Tchc 59 Tchs 64 Tchc 97 Tchs
186 AA’	1240, G	50 Tchs 60 Tchc 80 Tchs 180 Tkw 260 Tsr 295 Tmq 350 Tvt 370 Tht 410 Kns 470 Kml 525 Kw 550 Kmt
187 AA’	MO30	5 s 25 Tch
188	17883	13 Tchs 17 Tchc 23 Tchs 25 Tchc 36 Tchs 46 Tchc 53 Tchs 57 Tchc 62 Tchs 65 Tchc 78 Tchs
189	24593	5 Tchs 12 Tchc 18 Tchs+Tchc 47 Tchs 53 Tchco 80 Tchs
190 AA’	21804+22005, G	50 Tchs 60 Tchc 80 Tchs 195 Tkw 295 Tsr 340 Tmq 410 Tvt 425 Tht 470 Kns 530 Kml 580 Kw 610 Kmt 705 Ket 765 Kwb 880 Kmv 955 Kmg 1,025 Kr
191 AA’	8580	62 Tchs 65 Tchs+Tchc 77 Tchs 86 Tchs+Tchc
192 AA’	1315	88 Tchs 104 Tkw
193 AA’	6083	7 Tchs+Tchc 12 Tchs 45 Tchs+Tchc 47 Tchc 53 Tchs+Tchc 73 Tchs 87 Tchs+Tchc 120 Tkw
194 AA’	8688	16 Tchs 31 Tchs+Tchc 57 Tchs 61 Tchs+Tchc 72 Tchs 95 Tchs+Tchc
195	MO31	4 s 25 Tchs
196 AA’	MO32	3 s 25 Tch
197 AA’	30034	20 Tchs 40 Tchs+Tchc 110 Tchs
198 AA’	19550	105 Tchs
199 AA’	26465	40 Tchs 50 Tchc 100 Tchs
200	20648	62 Tchs 78 Tchc 105 Tchs
201	25824	17 Tchs+Tchc 19 Tchc 52 Tchs+Tchc 63 Tchco 72 Tchs 75 Tchc 98 Tchs
202	24674	17 Tchs 19 Tchc 26 Tchs 52 Tchs+Tchc 63 Tchc 72 Tchs 75 Tchc 92 Tchs
203	130	32 Tchs 36 Tchs+Tchc 65 Tchc 77 Tchs 78 Tchc
204	15106	17 Tchs 26 Tchc 30 Tchs 33 Tchc 35 Tchs 48 Tchc 59 Tchs 66 Tchc 95 Tchs
205	26707	5 Tchs 19 Tchc+Tchs 38 Tchs 51 Tchc 80 Tchs

Well Number	Identifier[1]	Formations Penetrated[2]
206	125	20 Tchs 30 Tchc+Tchs 45 Tchco 55 Tchs 60 Tchc 69 Tchs+Tchc
207	699	15 Tchs 16 Tchc 105 Tchs
208 AA'	726	41 Tchs 62 Tchs+Tchc 88 Tchc 101 Tchs 107 Tkw or Tchs+Tchc
209 CC'	581, G	30 Tchs 36 Tchc 48 Tchs 56 Tchc 64 Tchs 75 Tchc 110 Tchs 250 Tkw
210	14044	60 Tchs 64 Tchc 85 Tchs
211	USGS 5-1597	6 s 17 Tchs+Tchc 20 Tchs 80 Tchs+Tchc 100 Tchs 139 Tchs+Tchc 195 Tkw 200 Tsr or Tkw
212	MO28	4 s 25 Tch
213	29026	110 Tchs
214	P200800761	12 Tchc+Tchs 30 Tchs 38 Tchc 60 Tchs
215	P200800885	55 Tchs 70 Tchc 85 Tchs
216	29860	17 Tchs 20 Tchc 56 Tchs 60 Tchc 72 Tchs 74 Tchc 85 Tchs
217	Transco 6, E	160 Tch 240 Tkw 580 Tsr+Tmq+Tvt+Tht+Kns 675 Kml 730 Kw+Kmt 770 Ket 900 Kwb+Kmv
218	E201501347, G	40 Tchs 95 Tkw 135 Tmq 160 Tvt 175 Tht 220 Kns 290 Kml 340 Kw 360 Kmt 430 Ket 550 Kwb 600 Kmv 730 Kmg 770 Kr 1,092 Kp
219	DOT 52983	17 s 62 Tchs
220	DOT 52978	10 s 50 Tchs

[1]Identifiers that are one- to five-digit numbers are N. J. Department of Environmental Protection well-permit numbers. All are preceded by the prefix "32-." Identifiers of the form "52-xx", "E20xxxxxxx" and "P20xxxxxxx" (where "x" indicates numbers) are also N. J. Department of Environmental Protection well-permit numbers. Identifiers of the form "USGS 5-xxxx" are U. S. Geological Survey unique well numbers with logs in Fiore (2019) and in the U. S. Geological Survey GeoLog locator database, at https://webapps.usgs.gov/GeoLogLocator/#!/search (accessed March 2023). Identifiers of the form "MOxx" are power-auger borings from Minard and Owens (1963). The total depths of these borings are not reported in Minard and Owens (1963) but are estimated from the depths of contacts they reported for the borings. Identifiers of the form "DOT xxxxx" are N. J. Department of Transportation boring log identification numbers from the N. J. Department of Transportation Geotechnical Data Management System at https://geoapps.nj.gov/dot_gdms/ (accessed June 2023). The identifier "Transco 6" refers to a well drilled for the Transcontinental Gas Pipeline Company in 1951 with a list of formations penetrated provided in Kasabach and Scudder (1961). A "+" indicates two wells drilled at the same location. A "G" following the identifier indicates that a gamma-ray log is available for the well. An "E" following the identifier indicates that an electric log (resistivity and/or spontaneous potential) is available for the well.

[2]Number is the depth (in feet below land surface) of the base of the unit indicated by the abbreviation following the number. The final number is the total depth of the well rather than the base of unit. For example, "Tchs 12 Tchc 34 Tchs 62" indicates Tchs from 0 to 12 feet below land surface, Tchc from 12 to 34 feet, and Tchs from 34 to bottom of hole at 62 feet. Abbreviation "s" indicates surficial deposits (units Qals, Qald, Qtll, Qe, Qtl, Qtu, Qcu, TQg, and Tg). Drillers' descriptive terms used to infer the surficial units are: yellow, white, tan, brown, red, orange, gray sand and gravel. Note that in most drillers' and geophysical logs, surficial deposits cannot be distinguished from the uppermost Cohansey or Kirkwood formations, and are not separately identified in the table. Drillers' terms for bedrock units are: Tchs = white, yellow, gray, brown (minor red, orange) fine, medium, and coarse sand (and minor fine gravel) of the Cohansey Formation, sand facies; Tchc = yellow, white, gray (minor red, orange) clay, silty clay, and sandy clay of the Cohansey Formation, clay-sand facies; Tchco = black clay of the Cohansey Formation, clay-sand facies, with high organic content; Tch = Cohansey Formation, facies undifferentiated or not identified. Tkw = gray, brown, and black, minor white and yellow, clay, hard clay, silt, fine sand, sandy clay, silty clay, clayey sand, muddy sand, and sand of the Kirkwood Formation. Tsr, Tmq, Tvt, Tht, Kns = green, black, brown, blue clay, silt, sand, marl, glauconite of the Shark River, Manasquan, Vincentown, Hornerstown, and Navesink formations. Generally, these five formations cannot be distinguished on lithologic logs, although descriptions of shell beds may indicate the

Vincentown or Navesink formations, and descriptions of hard green clay may indicate the Hornerstown Formation. These formations are separated in the table only where gamma-ray logs are available for the well or for an adjacent well. Kml = green, white, gray, black sand, “pepper sand” of the Mount Laurel Formation. Kw = gray, green fine sand, silty fine sand of the Wenonah Formation. Kmt = green clay, sand, black clay of the Marshalltown Formation. Ket = gray sand, sandy clay of the Englishtown Formation. Kwb = gray clay and silt of the Woodbury Formation. Formations below the Woodbury are identified from gamma-ray logs only. These include the Merchantville (Kmv), Magothy (Kmg), Raritan (Kr), and Potomac (Kp) formations. The Raritan and Potomac formations were penetrated in only three wells (1, 190, and 218) and are not shown on the cross sections or described in the Description of Map Units. The Raritan is gray to grayish brown silty clay with minor fine-to-medium sand of Late Cretaceous (Cenomanian-Turonian) age. The Potomac is red, gray, white, and light gray interbedded clay, clayey silt, and fine-to-coarse sand with minor gravel of Early to earliest Late Cretaceous (Barremian-early Cenomanian?) age. Detailed descriptions of the Raritan and Potomac formations are provided in Sugarman and others (2010). A “+” sign indicates that the units are mixed, interbedded, or cannot be separately identified from the information provided in the log for that depth interval. An “or” indicates two possible unit interpretations for the description. Units are inferred from drillers’ or geologists’ lithologic descriptions on well records filed with the N. J. Department of Environmental Protection, or provided in the cited publications, and from geophysical well logs where available. Units shown for wells may not match the map and sections due to variability in drillers’ descriptions and drilling techniques.