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SURFICIAL GEOLOGY OF THE LAKEWOOD QUADRANGLE
OCEAN AND MONMOUTH COUNTIES, NEW JERSEY
OPEN-FILE MAP OFM 141
pamphlet containing table 1 accompanies map

INTRODUCTION

The Lakewood quadrangle is on the northern edge of the Pine Barrens region of the New Jersey Coastal Plain, in the southeastern part of the state. Surficial deposits in the quadrangle include river, wetland, estuarine, hillslope, and windblown sediments of late Miocene to Holocene age. The surficial deposits overlie Coastal Plain bedrock formations (fig. 1), which are unconsolidated to semi-consolidated marine and coastal sediments that dip gently (10 to 50 feet/mile) to the southeast. Most of the quadrangle is underlain by the Cohansey Formation. The Cohansey is a middle Miocene quartz sand with a few thin clay beds. The Kirkwood Formation is a silty-clayey fine sand of early and middle Miocene age that underlies the Cohansey and crops out in valleys in the northern part of the quadrangle. The Cohansey is permeable and forms dry uplands vegetated by pine and oak and wet, seepage-fed lowlands vegetated by maple and cedar. The Kirkwood is less permeable and supports hardwood forest, or mixed hardwood and pine forest. Bedrock geology of the quadrangle was mapped by Sugarman and others (2018).

The Cohansey Formation includes beach, nearshore, bay, and marsh sediments deposited when relative sea level was more than 150 feet higher than at present in this region. As sea level lowered after the Cohansey was laid down, rivers flowing on the emerging Coastal Plain deposited the Beacon Hill Gravel, forming a broad regional river plain. With continued lowering of sea level, the regional river system shifted to the west of the quadrangle, and local streams began to erode into the Beacon Hill plain and rework the Beacon Hill Gravel. Through the late Miocene, Pliocene, and Quaternary, stream and hillslope sediments were deposited in several stages as valleys were progressively deepened by stream incision and widened by seepage erosion. In the middle and late Pleistocene, estuarine sediments were deposited at and below an elevation of 65 feet during two periods when sea level was higher than at present.

Summaries of the material resources and the history of the surficial deposits and geomorphology of the quadrangle are provided below. The age of the deposits and episodes of valley erosion are shown on the correlation chart.

MATERIAL RESOURCES

The surficial gravels and underlying Cohansey Formation sand have been mined for use as aggregate and fill in many pits in the quadrangle. These pits are shown by purple outline on the geologic map. Clay for brickmaking was mined from the Cohansey Formation in the early 20th century from a small pit east of Bay Avenue on the south edge of the quadrangle (N. J. Geological and Water Survey permanent note 29-42-585). All the pits were inactive at the time of mapping. Most have been converted to residential or commercial uses or landfills.

SURFICIAL DEPOSITS AND GEOMORPHIC HISTORY

Sea level in the New Jersey region began a long-term decline following deposition of the Cohansey Formation. As sea level lowered, the inner continental shelf emerged as a coastal plain and river drainage was established. The Beacon Hill Gravel is the earliest record of this drainage. The Beacon Hill is weathered quartz-chert gravel that caps the highest hills in the Coastal Plain. It formerly covered the Lakewood quadrangle but has been entirely eroded away. The base of the Beacon Hill is at an elevation of 290 feet in the Hominy Hills north of Farmingdale (Stanford, 2000), about 11 miles north of Lakewood, and at an elevation of 190 feet near Webbs Mills, 16 miles southwest of Lakewood (Stanford, 2016). This descending grade places the base of the Beacon Hill at an elevation between 260 and 220 feet from north to south across the quadrangle, which is above the present-day elevation of the highest hills. Regionally, cross-beds, slope of the deposit, and gravel provenance indicate that the Beacon Hill was deposited by rivers draining southward from the Valley and Ridge province in northwestern New Jersey and southern New York (Owens and Minard, 1979; Stanford, 2010).

Also indicative of southward flow are rare chert pebbles containing coral, brachiopod, and pelecypod fossils of Devonian age found in the Beacon Hill and in upland gravels reworked from the Beacon Hill. These fossils indicate that some of the rivers feeding the Beacon Hill drained from north of what is now Kittatinny and Shawangunk Mountains in northwestern New Jersey and adjacent New York state, where chert-bearing Devonian rocks crop out.

Continued decline of sea level through the late Miocene and early Pliocene (approximately 8 to 3 Ma; Ma = million years ago) caused the regional river system to erode into the Beacon Hill plain. As it did, it shifted to the west of the Lakewood quadrangle. The area of the quadrangle became an upland from which local streams drained southward. These local streams eroded valleys into the Beacon Hill Gravel. Groundwater seepage, slope erosion, and channel erosion reworked the gravel and deposited it in floodplains, channels, and pediments, more than 100 feet below the level of the former Beacon Hill plain. These deposits are mapped as upland gravel, high phase (unit Tg). Today, owing to topographic inversion, they cap hilltops and ridges above elevations of 90 to 130 feet. Overall, the base of these gravels descends to the south, recording the southerly paleoflow of streams at this time (purple arrows on figure 1).

The elevation and paleoflow direction of the upland gravels in the Lakewood quadrangle and adjacent areas indicate that the coastline in this region in the late Miocene and Pliocene was south of the quadrangle area and likely had a northeast-southwest trend. This geography began to change in the early Pleistocene when a glacial advance blocked the valley of a major river that formerly flowed southwesterly from the New York City area through central New Jersey. This river, which included the Hudson River and possibly rivers from southern New England, was diverted by the glacier to a southeasterly flow from the New York City area (Stanford, 2010). Fluvial and marine erosion in this new valley in the early Pleistocene formed the lowland now occupied by the New York Bight, which is the part of the Atlantic Ocean between New Jersey and Long Island. As the bight broadened, drainage in the Lakewood quadrangle and adjacent areas gradually shifted from the older southerly flow to an easterly flow leading to the now closer coast to the east.

A renewed period of lowering sea level in the latest Pliocene and early Pleistocene (approximately 3 Ma to 800 ka; ka = thousand years ago) led to another period of valley incision. Groundwater seepage and channel and slope erosion reworked the upland gravel and deposited the upland gravel, lower phase (unit TQg) in shallow valleys 20 to 50 feet below the upland gravel, high phase. These deposits today cap broad low divides and low hilltops and ridges and occur as thin fills in shallow headwater valleys on some uplands. The base of these deposits varies but in general descends from elevations of as much as 120 feet at the upland limits of the deposit to elevations as low as 60 feet at their downstream limits. Streamflow at this time, inferred from the elevation of the deposits, is shown by red arrows on figure 1. These flow directions show that eastward drainage to the New York Bight had been established in the Metedeconk River and Kettle Creek basins by the early Pleistocene, but that the older southward drainage persisted (as it does today) in the Toms River basin in the southwest corner of the quadrangle.

Continuing stream incision in the middle and late Pleistocene (about 800 to 15 ka) formed the modern valley network. Sediments laid down in modern valleys include upper, intermediate, and lower terrace deposits (units Qtuo, Qtu, Qti, and Qtl), upper and lower colluvium (Qcu, Qcl), units 1 and 2 of the Cape May Formation (Qcm1, Qcm2), inactive deposits in dry valleys (unit Qald), and active floodplain and wetland (Qal, Qals) deposits in valley bottoms. Like the upland gravels, the terrace and floodplain deposits represent erosion, transport, and redeposition of sand and gravel reworked from older surficial deposits and the Coastal Plain bedrock formations by streams, groundwater seepage, and slope processes. Seepage erosion was enhanced in places where clay beds in the Cohansey Formation increased groundwater discharge, for example in the valley north and west of Ocean County College and along Cotterals Brook (fig. 1). Wetland deposits are formed by accumulation of organic matter in swamps and bogs and tidal marshes. The Cape May Formation is an estuarine and beach sand and gravel deposited during two highstands of sea level in the middle and late Pleistocene.

Upper terrace deposits form terraces and pediments 5 to 40 feet above modern valley-bottom wetlands. They include sediments laid down during periods of cold climate, and during periods of temperate climate when sea level was high, in the middle and late Pleistocene. During cold periods, permafrost formed an impermeable layer at shallow depth, which increased runoff and slope erosion, which in turn increased the amount of sediment entering valleys. Aprons of colluvium (Qcu) along the base of steep slopes that grade to the upper terraces were also deposited primarily during periods of permafrost. During periods of high sea level, the lower reaches of streams in the quadrangle were close to sea level, favoring deposition.

During two interglacial periods in the Pleistocene, sea level was higher than at present in the New Jersey region. The earlier highstand was in the middle Pleistocene and reached an elevation of between 60 and 70 feet in the New Jersey area, submerging the downstream reaches of the Metedeconk and Toms River valleys, and most of the Kettle Creek and South Branch valleys, in the quadrangle (the extent of the submergence is shown by the light blue line on fig. 1). Estuarine and beach sand and gravel (Cape May Formation, unit 1, Qcm1) deposited during this highstand form eroded valley fills and, south of the Kettle Creek valley, a shorefront terrace, with a top elevation of 60 to 65 feet. The base of these deposits extends nearly down to the modern valley bottom, indicating that the valleys had been eroded to most of their present depth before this highstand. Amino-acid racemization (AAR) ratios of shells from the Cape May Formation in Cape May and Cumberland counties in southern New Jersey indicate that the Cape May 1 was deposited during either Marine Isotope Stage (MIS) 9 (peak highstand at 330 ka) or 11 (peak highstand at 400 ka) (Lacovara, 1997; O'Neal and others, 2000). Sea level during MIS 11 in the Bahamas and Bermuda (Olson and Hearty, 2009) was close to the maximum elevation of the Cape May 1, while MIS 9 sea level was lower, suggesting that the Cape May 1 is of MIS 11 age.

The next highstand occurred in the late Pleistocene and reached an elevation of about 30 feet in New Jersey. Estuarine and beach sand and gravel (Cape May Formation, unit 2, Qcm2) deposited during this highstand forms an eroded valley fill in the Metedeconk River valley and a shorefront terrace south of there, with a top elevation of 30 to 35 feet (the extent of this submergence is shown by the dark blue line on fig. 1). AAR ratios of shells from the Cape May 2 in Cape May County indicate an MIS 5 age (peak highstand at 125 ka) (Lacovara, 1997). Global sea level at this time (Spratt and Lisiecki, 2016) was close to that recorded by the Cape May 2.

In the Toms River valley two phases of the upper terrace are mapped: an older phase (Qtuo) forming erosional remnants with tops 15 to 20 feet higher than the more extensive main terrace (Qtu). The older upper terrace merges downvalley with the Cape May 1, which is at a similar height above the upper terrace, while the main upper terrace grades to, or is onlapped by, the Cape May 2 downvalley in the Toms River quadrangle (Stanford and Sugarman, 2017).

In the Metedeconk River valley most of the upper terrace grades topographically to the Cape May 1. Here, the upper terrace forms a broad plain between the North and South branches of the Metedeconk that continues north into the Haystack Brook valley in the Farmingdale quadrangle (Stanford, 2000). This plain, which extends across the present divide of the Metedeconk and Manasquan basins in the Farmingdale quadrangle, may be the combined product of both the Metedeconk and Manasquan rivers aggrading at the downstream ends of their valleys during the Cape May 1 highstand. In the valley of the South Branch of the Metedeconk River an intermediate terrace (Qti) is inset into the upper terrace, with a top surface between 5 and 15 feet below that of the upper terrace and 5 to 15 feet above that of the lower terrace. This intermediate terrace grades topographically downvalley to the Cape May 2 estuarine deposit.

Deposition of the Cape May 2 in the lower Metedeconk River valley may have altered earlier river drainage in this area. Before the Cape May 2 highstand and perhaps for a time after the highstand but before valley incision in the Wisconsinan stage (see below) the Metedeconk River may have flowed southward into what is now the Kettle Creek valley. This possibility is suggested by paleovalleys crossing the Metedeconk-Kettle Creek divide near Cedarwood Park (green arrows on fig. 1, see Stanford and others [2018] for the continuation of these features in the Point Pleasant quadrangle), and by the parallel southerly trends of the Metedeconk River and Kettle Creek valleys to the north and south, respectively, of the paleovalleys, and by the anomalously large size of the Kettle Creek valley downstream of the paleovalleys, which does not match the small drainage area of Kettle Creek. The southward route before the Cape May 2 highstand may indicate that the Metedeconk River was tributary to the Toms River paleovalley, which drained eastward across what is now the inner continental shelf from the Seaside Heights area, about 7 miles southeast of Cedarwood Park (Stanford and Sugarman, 2017; Stanford and others, 2018). Stream incision as sea level lowered after the highstand captured and diverted the Metedeconk River to a more direct easterly route to the Atlantic Ocean.

Another paleovalley near Williams (green arrow on fig. 1) is cut into Cape May 1 deposits and connects the North Branch of the Metedeconk River to the headwaters of Beaverdam Creek. It may be a route of the North Branch, taken after deposition of the Cape May 2 filled the Metedeconk River valley to the south. After the highstand, incision of the South Branch enabled capture of the North Branch to the west of Williams and left present-day Beaverdam Creek as an undersized stream in the former North Branch valley.

Sea level lowered after the Cape May 2 highstand, especially as cold climate set in around 80 ka and glaciers grew during a period known as the Wisconsinan (80-15 ka) in North American stage terminology. Sea level dropped as low as 300 feet below its present level during the peak of glacial expansion around 25 to 20 ka. During the period of lowered sea level in the Wisconsinan streams cut down into the upper and intermediate terraces and the Cape May deposits. The approximate limit of this incision is shown by black lines on figure 1.

Within these incised valleys, lower terrace deposits (Qtl) form terraces with top surfaces between 3 and 15 feet above modern floodplains and tidal marshes. The lower terraces are more distinct and higher above the modern floodplain along the mainstem channels of the Metedeconk River (figs. 2 and 3) and Toms River where discharge is greater and incision more vigorous than in tributary and headwater valleys. In headwater areas, such as the Watering Place Brook and Cotterals Brook valleys, the lower terraces are only 1 to 3 feet higher than the active floodplain and seepage wetlands. Here, the terraces are identifiable from vegetation patterns, with pine or mixed pine and cedar on the terraces and hardwood (chiefly maple) and cedar on the active wetlands. The lower terraces were deposited during or slightly after the last period of cold climate around 25 ka. Radiocarbon dates on organic silt at the base of the lower terrace deposits at Farmingdale and Siloam, 7 and 9 miles, respectively, northeast and northwest of Lakewood, yielded ages of 45.4-33.4 calibrated ka and 33.7-32.8 calibrated ka (Stanford and others, 2002, 2018; age range is 95% confidence interval), confirming a late Wisconsinan age for the overlying lower terrace sediments at those sites.

Braided channels (blue solid lines on map) scribe the lower terraces in one area in the Cotterals Brook valley and were likely present elsewhere before urbanization. These braided networks indicate that streams were choked with sand and gravel during deposition of the terraces, causing channels to aggrade and split. The high sediment supply indicates increased erosion by groundwater seepage and runoff, most likely when permafrost impeded infiltration. Dry-valley alluvium (unit Qald) and lower colluvium (Qcl), which grade to the lower terraces, were likely also laid down at this time. Arcuate meander scarps and channels (black ticked lines on map) were etched into the lower terrace during incision to the modern floodplain and are particularly evident along Toms River and the lower reaches of the North and South Branches of the Metedeconk (figs. 2 and 3). These features, and the meandering course of the present river channels, mark the transition from braided to single channel flow after permafrost melted and forest regrew, reducing the influx of sediment into valleys and causing incision into the lower terraces in postglacial time (15 ka to present).

Windblown deposits (Qe) form narrow individual dune ridges as much as 1,000 feet long (fig. 3) and dune fields. Most individual dune ridges are linear and east-west trending; a few are crescentic. Dune fields are larger areas consisting of numerous dunes of indistinct form, as viewed on stereo aerial photographs from 1961, although urbanization has now obscured these features. Individual dunes are up to 15 feet high but more commonly are 3 to 6 feet high. The orientations of the dune ridges indicate that winds were blowing from the north and northwest during their deposition. Most dunes occur on the Cape May 1 and 2 terraces; a few are on the upper terraces. None occur on the lower terraces in the quadrangle but do occur on lower terraces in adjacent areas, for example, upstream in the Toms River valley in the Lakehurst quadrangle (Stanford, 2020). Based on this distribution, the windblown deposits were laid down after deposition of the upper terraces and the Cape May 2 estuarine terrace, principally during the Wisconsinan stage.

Modern floodplain and wetland deposits (units Qal, Qals) were laid down within the past 10 ka, based on radiocarbon dates on basal peat in other alluvial wetlands in the Pine Barrens (Buell, 1970; Florer, 1972). Tidal-marsh and estuarine deposits (unit Qm) were laid down in the downstream ends of the Manasquan River, Kettle Creek, and adjacent local valleys in the southeast corner of the quadrangle as they were submerged during Holocene sea-level rise, chiefly within the past 5 ka in the map area.

During cold climates at glacial maxima in the middle and late Pleistocene, permafrost was present in the Pine Barrens region (Wolfe, 1953; French and others, 2005, 2007). During thaws, permafrost at depth acted as an impermeable layer and supported the water table at a higher elevation than in temperate climates. Streams cut channels that are dry today (brown lines on map) and deposited sand and gravel in valley bottoms that are dry and inactive today (Qald). Groundwater emerged in seeps in headwater areas that are dry today, eroding amphitheater-shaped hollows (outlined by blue dashed lines on map). Shallow depressions known as thermokarst basins formed when subsurface ice lenses melted (Wolfe, 1953). These basins (dark blue cross-hatching on map), which were more numerous before urbanization, typically form in sandy deposits in lowlands with high water table, for example, on upper terraces in the North Branch and Haystack Brook valleys that are underlain by low-permeability silt and fine sand of the Kirkwood Formation.

DESCRIPTION OF MAP UNITS

ARTIFICIAL FILL—Sand, pebble gravel, minor clay and organic matter; gray, brown, very pale brown, white. In places includes human-made materials such as concrete, asphalt, brick, cinders, and glass. Unstratified to poorly stratified. As much as 15 feet thick. In road and railroad embankments, dams, berms, dikes, and filled low ground. Extent of natural deposits beneath fill is based on aerial photographs taken in 1930 and 1940. Many small fills in urban areas are not mapped.

aft TRASH FILL—Trash mixed and covered with sand, silt, clay, and gravel. As much as 70 feet thick.

Qm TIDAL-MARSH AND ESTUARINE DEPOSITS—Peat, clay, silt, fine sand; brown, dark brown, gray, black. Contain abundant organic matter and shells. As much as 20 feet thick.

Qals WETLAND AND ALLUVIAL DEPOSITS—Fine-to-medium sand and pebble gravel, minor coarse sand; light gray, yellowish-brown, brown, dark brown; overlain by brown to black peat and gyttja. Peat is as much as 8 feet, but generally less than 4 feet, thick. Sand and gravel are chiefly quartz and are generally less than 3 feet thick. Sand and gravel are stream-channel deposits; peat and gyttja form from the vertical accumulation and decomposition of plant debris in swamps and marshes. In floodplains and wetlands on modern valley bottoms.

Qal ALLUVIUM—Fine-to-medium sand and pebble gravel, silt, fine sand, minor coarse sand and silty clay; gray, brown, yellowish-brown. As much as 10 feet thick. Sand is quartz with minor (<5%) mica; gravel is quartz with a trace (<1%) ironstone. Contains some wood and peat. Peat is not as thick and continuous as in unit Qals. Silty fine sand and clay are overbank deposits and typically overlie sand and gravel channel deposits.

Qald DRY-VALLEY ALLUVIUM—Fine-to-medium sand and pebble gravel, minor coarse sand; very pale brown, white, brown, dark brown, light gray. As much as 5 feet thick. Sand and gravel are quartz. In dry valley bottoms forming headwater reaches of streams.

Qe EOLIAN DEPOSITS—Fine-to-medium quartz sand; very pale brown, white. As much as 15 feet thick. Sand includes few (1-5%) opaque minerals and fine mica in places. Form dune ridges and dune fields. Sand is chiefly from wind erosion of the upper terrace deposits and the Cape May Formation.

Qtl LOWER TERRACE DEPOSITS—Fine-to-medium sand, pebble gravel, minor coarse sand; gray, brown, dark brown, yellowish-brown, brownish-yellow. As much as 15 feet thick. Sand and gravel are quartz. Sand includes minor mica and few to some (5-10%) opaque minerals. Gravel includes traces of ironstone in places. Form terraces and pediments in valley bottoms with surfaces 3 to 15 feet above modern floodplains. Include both stratified stream-channel deposits and unstratified pebble concentrates formed by seepage erosion of older surficial deposits. Sand includes gyttja in places, and peat less than 2 feet thick overlies the sand and gravel in places. The gyttja and peat are younger than the sand and gravel and accumulate due to poor drainage. Gravel generally is more abundant in lower terrace deposits than in upper terrace deposits due to winnowing of sand from the upper terrace deposits by seepage erosion.

Qcl LOWER COLLUVIUM—Sand and gravel as in unit Qtl forming footslope aprons on grade with lower terraces and the modern floodplain. As much as 10 feet thick. Weakly subhorizontally stratified to nonstratified. Includes sheetwash, alluvial-fan, and solifluction deposits and seepage lags.

Qti INTERMEDIATE TERRACE DEPOSITS—Sand and gravel as in unit Qtu forming terraces in the South Branch of the Metedeconk River valley with surfaces 15 to 20 feet above the modern floodplain. As much as 20 feet thick.

Qtu UPPER TERRACE DEPOSITS—Fine-to-medium sand, pebble gravel, minor coarse sand; very pale brown, brownish-yellow, yellow. As much as 45 feet thick but generally less than 25 feet thick. Sand and gravel are quartz. Sand includes few to some opaque minerals and minor mica. Gravel includes traces of ironstone in places. Form terraces and pediments with surfaces 5 to 40 feet above modern floodplains, and a few valley-bottom plains in headwater areas. Include stratified stream-channel deposits and poorly stratified to unstratified deposits laid down by groundwater seepage on pediments.

Qtuo UPPER TERRACE DEPOSITS, OLDER PHASE—Sand and gravel as in unit Qtu forming eroded terraces in the Toms River valley as much as 20 feet higher than adjacent upper terraces. As much as 25 feet thick.

Qcu UPPER COLLUVIUM—Sand and gravel as in unit Qtu forming footslope aprons on grade with upper terraces. As much as 10 feet thick. Weakly subhorizontally stratified to nonstratified. Includes sheetwash, alluvial-fan, and solifluction deposits and seepage lags.

Qcm2 CAPE MAY FORMATION, UNIT 2—Fine-to-medium sand, pebble gravel, minor coarse sand, a few thin beds of silty clay; yellow, very pale brown, yellowish-brown. As much as 40 feet thick but generally less than 20 feet thick. Sand is quartz with a few opaque minerals; pebbles are quartz and minor ironstone. Nonstratified to horizontally stratified, cross-bedded in places. Forms an estuarine terrace with a maximum surface elevation of 35 feet.

Qcm1 CAPE MAY FORMATION, UNIT 1—Fine-to-medium sand, minor coarse sand, pebble gravel, a few beds of sandy clay and silty clay; very pale brown, white, light gray, yellow. Sand is quartz with few opaque minerals and minor mica; pebbles are quartz with a few ironstones and white weathered cherts. As much as 30 feet thick. Unstratified to weakly horizontally stratified. Forms an eroded estuarine terrace with a maximum surface elevation of 65 feet.

TQg UPLAND GRAVEL, LOWER PHASE—Fine-to-medium sand, minor coarse sand, slightly clayey in places, and pebble gravel; yellow, very pale brown, reddish-yellow. Sand and gravel are quartz with few to some opaque minerals and a trace of white weathered chert in the coarse-sand-to-fine pebble gravel fraction. Sand and gravel are iron-cemented in places. Clay is chiefly from weathering of chert. As much as 30 feet thick but generally less than 20 feet thick. Occurs as erosional remnants on lower interfluves and hilltops, and as more continuous deposits in some headwater valleys, between 60 and 120 feet in elevation. Includes stratified stream-channel deposits, poorly stratified deposits laid down by groundwater seepage on pediments, and pebble concentrates formed by washing away sand from older surficial deposits and the Cohansey Formation by groundwater sapping or surface runoff.

Tg UPLAND GRAVEL, HIGH PHASE—Fine-to-medium sand, some coarse sand, clayey in places, and pebble gravel, trace fine cobbles; yellow, brownish-yellow, reddish-yellow, very pale brown. Sand and gravel are quartz, with a trace of chert and weathered feldspar in the coarse-sand-to-fine pebble gravel fraction. Sand and gravel are iron-cemented in places. Most chert is weathered to white and yellow clay; some chert pebbles are gray to dark gray and unweathered to partially weathered. Clay-size material chiefly is from weathering of chert and feldspar. As much as 25 feet thick. Occurs as erosional remnants on hilltops and ridges between 90 and 145 feet in elevation. Includes stratified and cross-bedded stream-channel deposits and poorly stratified to unstratified pebble concentrates formed by washing away sand and clay by groundwater sapping or surface runoff.

Qwcp WEATHERED COASTAL PLAIN BEDROCK FORMATIONS—Sand, clay, and silty sand of Coastal Plain bedrock formations (Cohansey and Kirkwood formations of Miocene age), variably oxidized during weathering in the Quaternary and Neogene. Upper several feet may include quartz pebbles left from erosion of surficial deposits, and patchy colluvial, alluvial, or eolian deposits less than 3 feet thick.

MAP SYMBOLS

Contact—Solid where well-defined by landforms as visible on 1:12,000 stereo airphotos and LiDAR imagery, long-dashed where approximately located, short-dashed where gradational or featheredged, dotted where reconstructed in excavations. Contacts in excavated and urbanized areas are based in part on stereo aerial photographs taken in 1961 and planimetric aerial photographs taken in 1930 and 1940.

8 Qe8/Qcm1 Material penetrated by hand-auger hole or observed in exposure or excavation—Number indicates thickness of surficial material, in feet, where penetrated. Symbols without a thickness value within surficial deposits indicate that the surficial material is more than 5 feet thick. Where more than one unit was penetrated, the thickness (in feet) of the upper unit is indicated next to its symbol and the lower unit is indicated following the slash.

Material formerly observed—Recorded in N. J. Geological and Water Survey files.

figure 4 Photograph location—For figures 4 through 7.

147 Well or test boring reporting thickness of surficial deposit—Location accurate to within 200 feet. Identifier, thickness of surficial deposit, and total depth shown in Table 1.

47 Well or test boring reporting thickness of surficial deposit—Location accurate to within 500 feet. Identifier, thickness of surficial deposit, and total depth shown in Table 1.

Dry channel—Line in channel axis. Marks inactive channels on dry uplands.

Abandoned channel—Line in channel axis. Marks braided-channel network on lower terraces.

Fluvial scarp—Line at top, ticks on slope.

Dune ridge—Line on crest.

Head of seepage valley—Line at top of slope. At head of small valleys and hillslope embayments formed by seepage erosion.

Paleocurrent direction—Arrow indicates direction of streamflow as inferred from dip of planar cross beds observed at point marked by "x".

Fe Iron-cemented sand—Extensive iron cementation in Cohansey Formation.

Shallow topographic basin—Line at rim, pattern in basin. Includes thermokarst basins formed from melting of permafrost, and deflation basins formed or enlarged by wind erosion.

Excavation perimeter—Line encloses excavated area. Contacts within these areas show units restored to the pre-excavated topography. In most large pits the surficial deposits have been removed and the Cohansey Formation is exposed.

Sand and gravel pit—Inactive.

C Clay pit—Inactive.

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Figure 4. Eolian sand (unit Qe) exposed in former pit. Color is from secondary weathering processes. White sand above the shovel is leached pedogenic A horizon. Brown and orange mottled areas below the A horizon are from deposition of iron and manganese oxides and hydroxides in the pedogenic B horizon. Location of photo shown on inset.

Figure 5. Upland gravel, lower phase (unit TQg) exposed in foundation excavation. Note weak subhorizontal bedding of gravel and faint cross bedding in sand at lower left. Location of photo shown on inset.

Figure 6. Upland gravel, lower phase exposed on a hilltop near Ocean County College. The deposit is sandy here and overlies a clay bed in the Cohansey Formation (below the lower, solid line). The upper part of the upland gravel (above the upper dotted line) is a yellow, leached, slightly pebbly sand with very faint cross bedding in places. The lower part of the upland gravel (below the dashed line) is a compact, massive, reddish sand with a few pebbles that is partly cemented by iron oxides deposited because ground-water drainage is impeded by the clay bed beneath. Location of photo shown on inset.

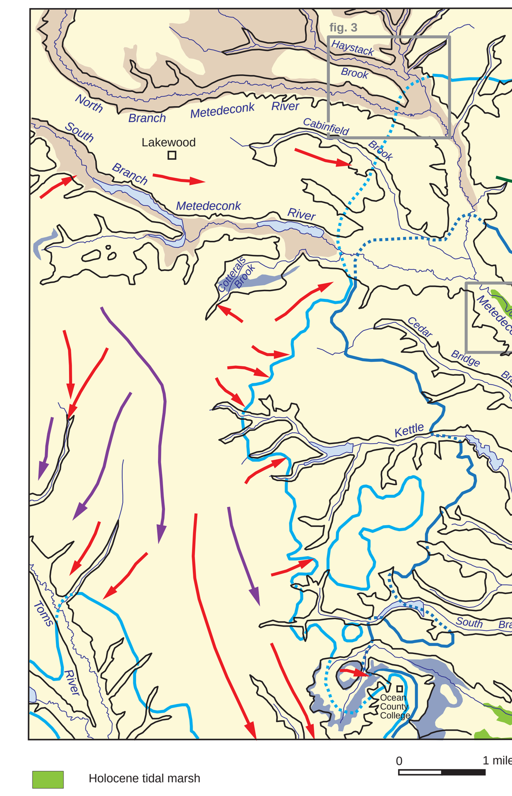


Figure 1. Limit of Wisconsinan valley incision, limits of marine submergences during deposition of the Cape May Formation, direction of stream drainage during deposition of upland gravels and before Wisconsinan incision, and outcrop areas of Coastal Plain bedrock formations, for the Lakewood quadrangle. Outcrop of Kirkwood Formation from Sugarman and others (2018). Areas of figures 2 and 3 shown in gray outline.

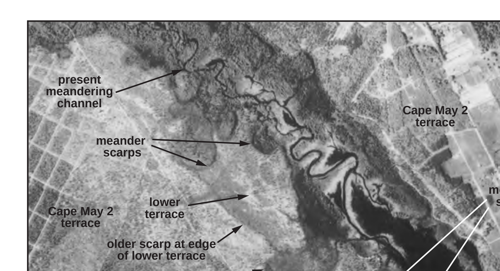


Figure 2. Aerial photograph taken in 1930 of a part of the Metedeconk River valley showing meander scarps cut into the lower terrace during incision of the river to the modern floodplain within the past 15 ka. The lower terrace is inset into the Cape May 2 terrace along an older straight scarp. Area of photo shown on figure 1.

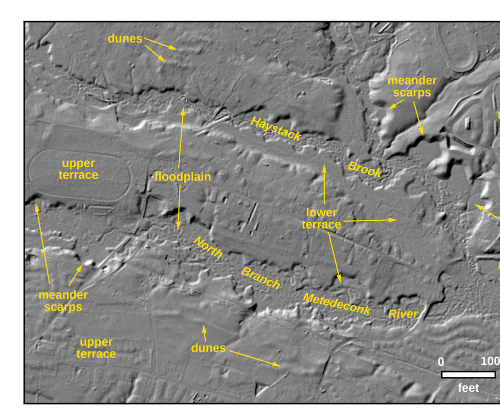
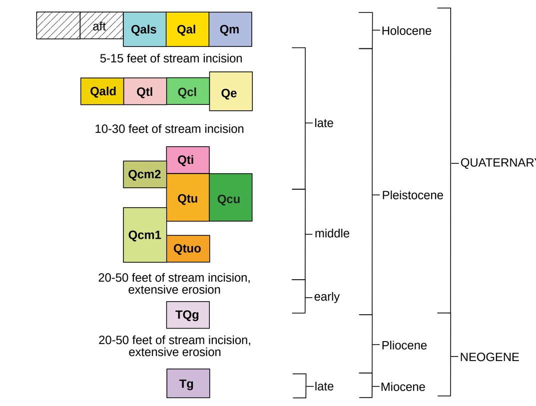
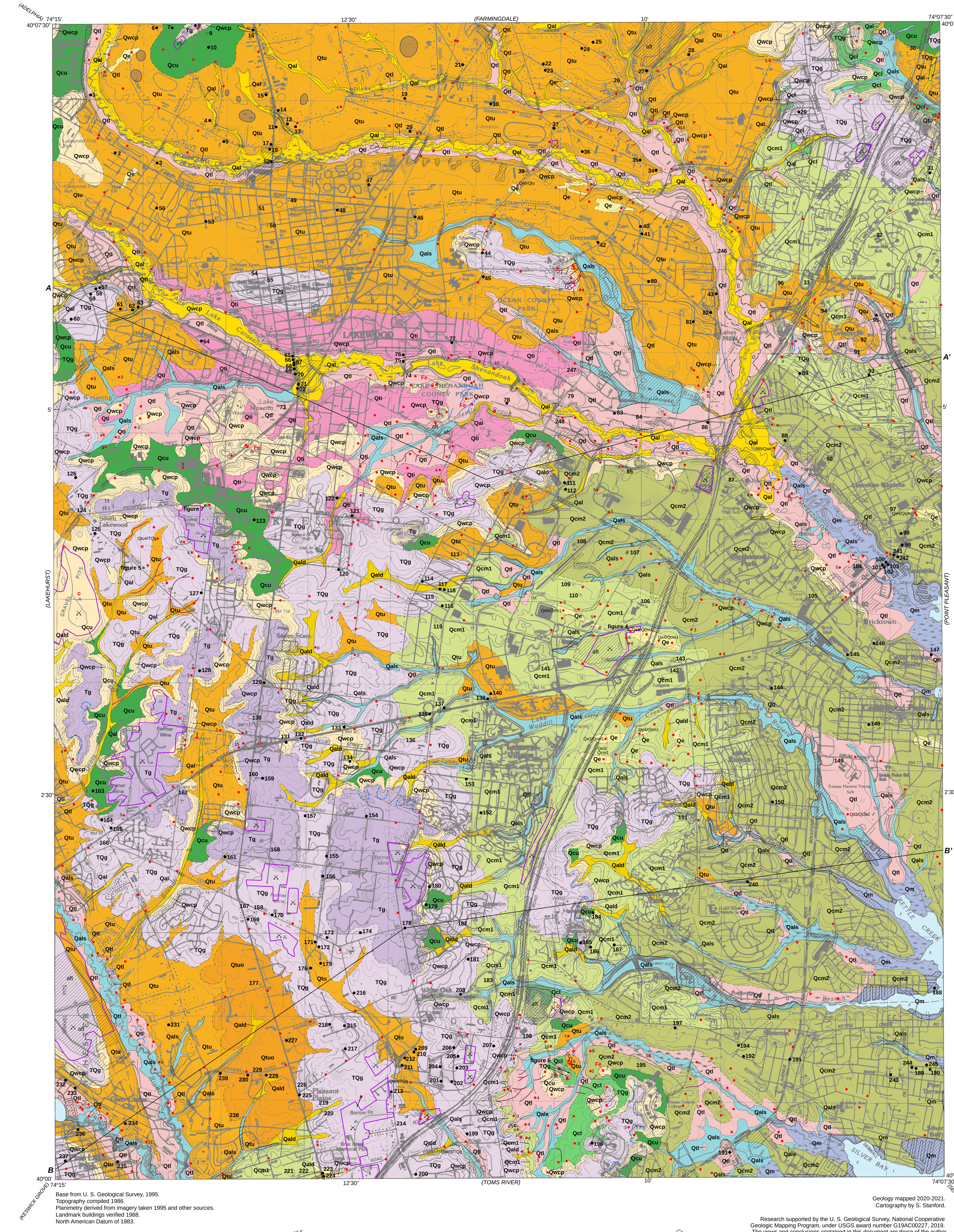


Figure 3. LiDAR hillshade image of a part of the North Branch of the Metedeconk River and Haystack Brook valleys showing upper and lower terraces, dune ridges, meander scarps at edge of lower terraces, and present-day floodplains. Area of image shown on figure 1.

Figure 7. Upland gravel, high phase (unit Tg, above shovel head) over sand of the Cohansey Formation. The upland gravel here is a structureless lag of quartz pebbles formed by washing away most of the sand and clay from the deposit. Location of photo shown on inset.

CORRELATION OF MAP UNITS





Base from U. S. Geological Survey, 1995.
Topography compiled 1986.
Planimetry derived from imagery taken 1995 and other sources.
Landmark buildings verified 1989.
North American Datum of 1983.

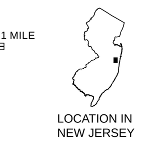
Geology mapped 2020-2021.
Cartography by S. Stanford.

Research supported by the U. S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number G19AC00227, 2019. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U. S. Government.

APPROXIMATE MEAN DECLINATION, 2021

SCALE 1:24 000

CONTOUR INTERVAL 5 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929



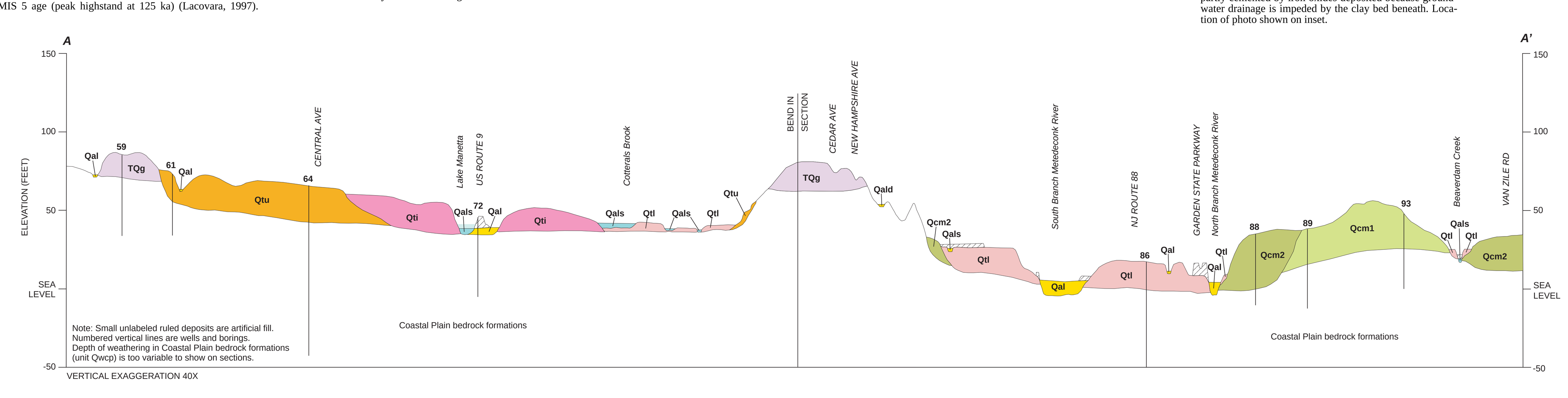
LOCATION IN NEW JERSEY

SURFICIAL GEOLOGY OF THE LAKEWOOD QUADRANGLE OCEAN AND MONMOUTH COUNTIES, NEW JERSEY

By

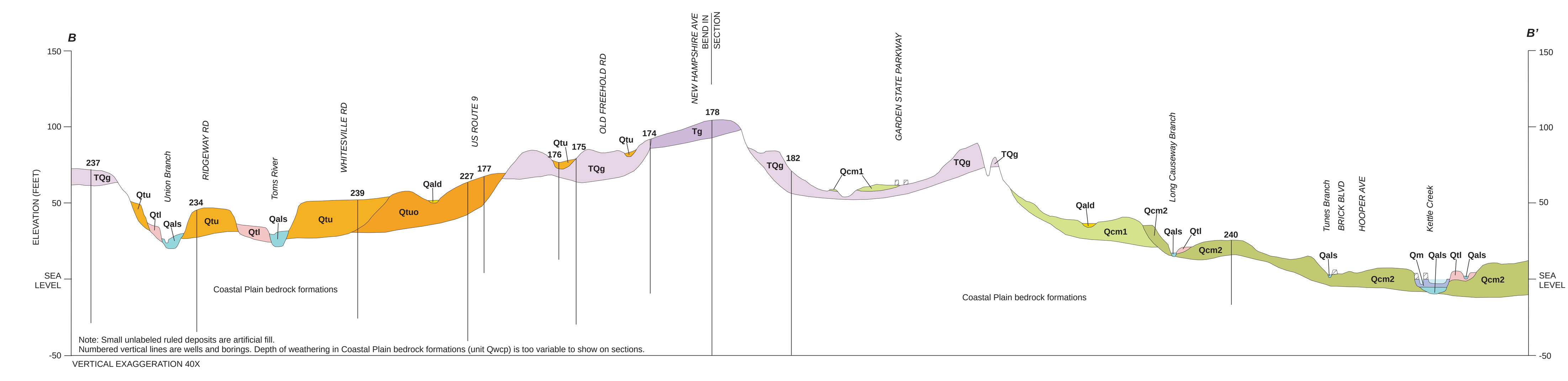
Scott D. Stanford

2021



Note: Small unlabeled ruled deposits are artificial fill.
Numbered vertical lines are wells and borings.
Depth of weathering in Coastal Plain bedrock formations (unit Qwcp) is too variable to show on sections.

VERTICAL EXAGGERATION 40X



Note: Small unlabeled ruled deposits are artificial fill.
Numbered vertical lines are wells and borings. Depth of weathering in Coastal Plain bedrock formations (unit Qwcp) is too variable to show on sections.

VERTICAL EXAGGERATION 40X

Surficial Geology of the Lakewood Quadrangle
Ocean and Monmouth Counties, New Jersey

New Jersey Geological and Water Survey
Open-File Map OFM 141
2021

Pamphlet with table 1 to accompany map

Table 1. Thickness of surficial deposits reported in well and boring logs. Well numbers in boldface indicate well and borings on cross sections.

Well Number	Identifier[1]	Thickness of Surficial Deposit[2]	Total Depth[3]
1	19969	18	70
2	5212	25	89
3	29070	5	30
4	16412	10	77
5	16073	10	81
6	26936	20	87
7	25154	11	103
8	10959	20	76
9	8207	20	76
10	15569	10	65
11	13635	18	568
12	14876	27	56
13	1732	20	26
14	8284	22	85
15	9115	28	94
16	DOT 269W-16	4 fill 9 Qals >11 Qtu	11
17	9914	30	403
18	17893	20	27
19	15053	10	90
20	14778	28	63
21	14892	21	41
22	17393	20	102
23	7128	8	37
24	13386	30	50
25	12717	18	445
26	4591	22	93
27	12543	8	37
28	23165	35	110
29	15500	22	60
30	3595	25	53
31	19492	4	80

Well Number	Identifier[1]	Thickness of Surficial Deposit[2]	Total Depth[3]
32	4136	30	140
33	19418	8	45
34	12558	30	55
35	17769	30	63
36	20039	34	100
37	13535	40	55
38	17655	36	402
39	18699	25	106
40	6418	35	63
41	6417	28	65
42	11396	30	116
43	19037	10	48
44	21659	20	75
45	14756	12	110
46	5496	16	823
47	17533	33	64
48	14377	10	38
49	1321	21	26
50	3791	10	25
51	5159	25	160
52	DOT 148W-7	15	106
53	3225	15	33
54	713	14	46
55	5012	10	116
56	19365	28	33
57	15646	20	104
58	17755	34	109
59	2009	14	53
60	24485	12	80
61	3903	18	42
62	16532	25	105
63	4379	11	91
64	24020	22	108
65	DOT 148W-23	6	51
66	DOT 148W-24	27	51
67	DOT 148W-16	15 fill 20 Qal	51
68	DOT 148W-25	18	48
69	DOT 148W-28	11	51
70	DOT 148W-17	21	51
71	DOT 148W-18	16	51
72	DOT 148W-27	11	51
73	14900	22	30
74	20048	14	20
75	15855	4	50
76	15857	6	26
77	14128	20	50
78	13574	18	140

Well Number	Identifier[1]	Thickness of Surficial Deposit[2]	Total Depth[3]
79	15249	10	115
80	14194	16	40
81	13991	25	120
82	16487	44	494
83	11489	10	106
84	L 211	7	9
85	L 205	4	14
86	21151	17	110
87	L 210	6	10
88	18155	40	45
89	16482	21	48
90	27264	26	34
91	13032	10	70
92	13121	10	76
93	20580	20	47
94	24680	10	40
95	112490	4 fill 9 Qtl	50
96	10064	21	150
97	734	18	37
98	27759	28	52
99	DOT 520W-6	16	36
100	DOT 64-847-F	36	67
101	DOT 64-847-A	28	63
102	DOT 64-847-C	23	62
103	DOT 64-847-H	18	66
104	5556	7	58
105	5499	40	568
106	L 208	2 Qe/ >7 Qcm2	7
107	L 203	1 Qe? 7 Qcm2	9
108	L 201	5	8
109	L 202	1 Qe? 5 Qcm2	7
110	29-42-231	1 Qe? >5 Qcm1	5
111	18410	25	140
112	19020	25	60
113	17619	28	54
114	9634	11	42
115	9796	16	53
116	9552	19	50
117	17765	18	50
118	7529	24	60
119	29-42-214	4 Qe? 6 Qcm1	9
120	18331	15	70
121	1545	10	58
122	10083	32	48
123	2996	16	43
124	682	13	52
125	26509	8	90

Well Number	Identifier[1]	Thickness of Surficial Deposit[2]	Total Depth[3]
126	18828	20	79
127	9608	20	75
128	15178	10	85
129	21378	5	81
130	12753	15	80
131	DOT 426W-43	0	11
132	DOT 426W-44	>11	11
133	DOT 426W-40	0	12
134	18143	0	110
135	DOT 426W-62	7	21
136	18815	12	100
137	DOT 426W-9	8	46
138	DOT 426W-10	9	41
139	DOT 426W-58	11	51
140	5110	6	767
141	29-42-228	4 Qe? >8 Qcm1	8
142	L 212	9	16
143	29-42-318	3	9
144	21067	22	60
145	25822	>18	18
146	24556	35	100
147	17620	28	110
148	20362	4	70
149	3525	30	795
150	16485	8	60
151	21408	33	100
152	2644	19	38
153	8417	21	57
154	17515	15	115
155	15190	26	81
156	10948	8	80
157	18689	25	89
158	18755	22	87
159	20009	40	100
160	15932	21	94
161	15530	20	78
162	15162	10	81
163	10498	20	54
164	31005	20	45
165	29076	19	50
166	L 107	>7	7
167	3991	30	70
168	20033	23	42
169	11417	21	82
170	17489	11	80
171	17656	6	70
172	18068	3	100

Well Number	Identifier[1]	Thickness of Surficial Deposit[2]	Total Depth[3]
173	20846	4	83
174	32013	18	100
175	15642	25	110
176	15499	10	65
177	6506	16	62
178	19535	11	103
179	20648	6	98
180	17069	0	141
181	15524	32	75
182	21554	14	145
183	19268	21	115
184	12906	21	65
185	10651	10	59
186	21428	3	50
187	19158	3	43
188	6012	20 fill over Qm >32 Qcm2	32
189	18062	36	55
190	21303	24	70
191	4218	8	62
192	13149	9	60
193	21764	7	15
194	9409	15	56
195	1247	12	220
196	19231	25	120
197	20209	18	74
198	3857	25	102
199	18201	0	100
200	17190	34	195
201	13752	20	110
202	15984	23	120
203	18637	14	181
204	12821	22	111
205	11744	14	144
206	11692	32	120
207	13742	28	101
208	16267	11	115
209	15484	20	115
210	13255	21	115
211	17924	3	100
212	20773	26	100
213	11417	12	180
214	17595	10	125
215	10303	10	169
216	11715	17	70
217	20932	25	120
218	19336	11	195
219	19362	15	85

Well Number	Identifier[1]	Thickness of Surficial Deposit[2]	Total Depth[3]
220	19356	15	135
221	4495	9	55
222	2434	31	60
223	DOT 148W-21	13	31
224	DOT 148W-19	9	36
225	1156	15	59
226	849	12	72
227	20837	25	105
228	21520	9	180
229	11551	27	170
230	10659	23	150
231	3533	10	67
232	14587	30	60
233	14588	30	123
234	19028	19	80
235	17446	25	80
236	10213	15	60
237	20579	11	100
238	20492	6	17
239	23253	21	77
240	17926	9	41
241	DOT 520W-7	8	26
242	DOT 520W-8	16	46
243	24973	15	55
244	P200906018	17	80
245	37422	9 Qcm2 18 peat bed in Qcm2	110
246	LK4	2 fill 8 Qtl	11
247	LK5	1 fill >21 Qti	21
248	LK6	16	21

[1]Identifiers numbered from "xxx" to "xxxxx" are N. J. Department of Environmental Protection well permit numbers. All are prefixed by "29-". Identifiers of the form "P2009xxxxx" are also N. J. Department of Environmental Protection well permit numbers. Identifiers prefixed by "DOT" are N. J. Department of Transportation soil borings accessed at https://www.state.nj.us/transportation/refdata/geologic/ . Identifiers of the form "29-xx-xxx" are N. J. Atlas Sheet coordinates of entries in the N. J. Geological and Water Survey permanent note collection. Identifiers of the form "L xxx" are borings made for an ilmenite-resource prospecting project in the 1950s, on file at the N. J. Geological and Water Survey (Markewicz, 1969). Identifiers of the form "LKx" are borings made by J. P. Owens (U. S. Geological Survey) and P. J. Sugarman (N. J. Geological and Water Survey) with logs on file at the N. J. Geological and Water Survey.

[2]Thickness, in feet, of surficial deposit overlying Coastal Plain bedrock formation. Surficial deposits are inferred from drillers' descriptions of "sand and gravel" or "sand and coarse gravel" or "coarse gravel" or "silty sand and gravel" or "coarse sand and gravel" or "heavy gravel" or "clay and large gravel" or "sand and stones", generally yellow or brown in color, or black or brown peat, overlying sand, clay, silt, or

sand and fine gravel, generally yellow, white, red, or gray in color, of Coastal Plain bedrock formations. Where more than one surficial deposit can be inferred from the well log, the depth of the base of the deposit is indicated, followed by the map unit abbreviation. A “>” sign indicates that the surficial deposit is greater than the indicated thickness, for well and borings that did not penetrate the surficial deposit. In some cases, the sand and gravel reported in the well log is in part sand and fine gravel of the Cohansey Formation (a Coastal Plain bedrock formation of Miocene age) rather than a surficial deposit, and therefore the inferred thickness of the surficial deposit is excessive. For this reason, the depth of the surficial deposits shown on sections AA’ and BB’ is in places less than that reported in the well logs where field data indicates that the inferred thicknesses are excessive.

[3]Total depth of well or boring, in feet below land surface.