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

# INTRODUCTION

The Tuckerton and Beach Haven quadrangles are in the Barnegat Bay and Great Bay region of the New Jersey Coastal Plain, in the southeastern part of the state. The surficial deposits that crop out in these quadrangles are of late Miocene to Holocene age and overlie the Cohansey and Kirkwood formations, which are marginal marine deposits of Miocene age. The Atlantic City and Sewell Point formations are shelf deposits of early Oligocene age that underlie the Miocene deposits. The surficial deposits consist of estuarine, river, marine, eolian, wetland and hillslope deposits.

The Kirkwood Formation was deposited in marine delta and shallow shelf settings in the early and middle Miocene. The Cohansey Formation was deposited in coastal settings in the middle and late Miocene, when sea level was significantly higher than at present in this region. As sea level lowered after deposition of the Cohansey, rivers flowing on the emerging Coastal Plain deposited fluvial gravel. Continued lowering of sea level caused streams to erode into the gravel and the Cohansey Formation. During the latest Miocene, Pliocene, and Pleistocene, about 8 million years ago (Ma) to 11 thousand years ago (ka), stream and hillslope sediments were deposited in several stages as valleys were progressively deepened by stream incision, and widened by seepage erosion, coinciding with lowering sea level. During at least two interglacial periods in the middle and late Pleistocene, when sea level was higher than at present, estuarine sediments were laid down in terraces in the northwestern parts of the Tuckerton quadrangle. Most recently, alluvial and wetland deposits were laid down during the Holocene (11 ka to present).

A summary of the stratigraphy of the Kirkwood and Cohansey formations in these quadrangles and the geomorphic history of the map area as recorded by surficial deposits and landforms is provided below. The age of the deposits, erosional episodes and unconformities are shown on the correlation chart. Table 1 lists the formations penetrated by wells and borings in the map area. These formations are interpreted from drillers' descriptions and geophysical well logs, including gamma and single point resistance logs. These logs were used to infer the extent of formations in the map area as well as map the depth of formations in the cross-sections.

Cross section A-A' shows materials to a depth of 700 feet below sea level, which includes the Cohansey Formation and the Kirkwood Formation. This cross-section runs northeast-southwest along Long Beach Island. Cross-section B-B' shows materials to a depth of 1,000 feet below sea level, which includes the Atlantic City and Sewell Point Formations below the Kirkwood Formation. It runs from the mainland out into the marsh and bay area along Great Bay Boulevard.

Most domestic water wells in the quadrangles produce water from the Kirkwood-Cohansey aquifer at depths between 70 and 250 feet. A thick aquifer in the Kirkwood Formation known as the "Atlantic City 800-foot sand" provides water to several public-supply wells in these quadrangles (Zapecza, 1989). A thinner water-bearing sand in the Kirkwood, known as the Rio Grande water bearing zone (aquifers shown by blue stippling on the cross sections) is shallower but is not tapped by public-supply wells in one of six observation wells drilled in confined aquifers of the New Jersey Coastal Plain in 1996-1997. This well was drilled to 1,012 ft below land surface just north of Little Sheepshead Creek along the west side of Great Bay Boulevard. Sr-isotopic analyses from split spoon samples taken from this well provides age dates for upper Oligocene and lower most Miocene sequences (Pekar and others, 1997). Notes taken from this well state that the Rio Grande and the 800-foot sand aquifers appear to have the best water quality while there appears to be salt water in the Kirkwood-Cohansey aquifer, based on the resistance log. Formations below an elevation of -800 feet are also described in Owens and others (1998).

## KIRKWOOD FORMATION

The Kirkwood Formation consists of six marine delta and shallow-shelf units as described in the Island Beach corehole (Miller and others, 1994). This corehole is located approximately 18 miles northeast of Beach Haven. These units can be traced using geophysical well logs in the map area and to the north in the Ship Botton and West Creek quadrangles (Schagrin and others, 2021; Stanford, 2014). Unit 1 is the uppermost Kirkwood unit (Miller and others, 1994) and consists of interbedded clay and sand that lacks definitive ago control and is mapped in the southern most part of cross-section A-A'. Throughout the rest of the map, unit 1 is placed in the Cohansey Formation due to its lithologic similarities to the Cohansey Formation. Unit 2 in the corehole is described as a uniform gray to grayish-brown marine clay. It is as much as 80 feet thick and denotes the top of the Kirkwood Formation as picked from well logs, where the transition from interbedded, generally oxidized, medium-to-coarse sands and thin clays in the Cohansey to gray, fine sand and thicker clays in the Kirkwood is taken as the contact. Diatoms in this unit in the Island Beach corehole indicate a late to early Miocene age 18-17 Ma (Miller and others, 1994), corresponding to the Kirkwood 2 sequence of Sugarman and others (1993), or Wildwood member of Owens and others (1998). Unit 3 in the corehole is medium-to-coarse sand with minor thin clay beds, as much as 110 feet thick, but in the map area gamma logs show that unit 3 consists of a clay-over-sand unit as much as 80 feet thick below an upper 30-foot thick sand. This upper sand is the Rio Grande aquifer shown in the blue stipple on both cross sections. Unit 4 is gray clay with a few thin sand beds and is shown to be as much as 140 feet thick. Unit 5 is sand with a 10 to 20 foot thick clayey interval in the middle of the unit. Unit 5 is as much as 150 feet thick and the upper sandy part of this unit contains the Atlantic City 800 foot sand shown in the blue stipple on both cross sections. The lower sand in the 800 foot aquifer is thicker than the upper sand in the map area. Unit 6 is a silty clay to sandy silt and is up to 80 feet thick. In the Island Beach corehole, unit 6 contains shells giving a strontium stable-isotope ratio age of 21.8 Ma (Miller and others, 1994), placing the clay within the Kirkwood 1 sequence of Sugarman and others (1993), or the lower member of

#### COHANSEY FORMATION

Owens and others (1988).

The Cohansey Formation consists of stacked successions composed of beach and shoreface sand overlain by interbedded sand and clay deposited in tidal flats, bays, and coastal swamps (Carter, 1972, 1978). The Cohansey Formation in the Tuckerton and Beach Haven quadrangles is divided into a sand (Tchs) and a clay (Tchc) facies and was deposited when sea level was significantly higher than at present in the map area. Pollen and dinoflagellates recovered from peat beds in the Cohansey at Legler, in northern Ocean County, are indicative of a coastal swamp-tidal marsh environment (Rachele, 1976). The Legler pollen (Greller and Rachele, 1983), and for pollen recovered from a corehole near Mays Landing, New Jersey (Owens and others, 1988), and dinocysts obtained from coreholes in Cape May County, New Jersey leVerteuil, 1997; Miller and others, 2001), indicate a middle to early late Miocene age for the Cohansey. The Cohansey generally lacks datable marine fossils, particularly in updip areas where it has been weathered. As discussed above, lower parts of the Cohansey in updip settings like in the map area may be age-equivalent to the upper Kirkwood downdip (for example, Kirkwood sequence 2, about 17-15 Ma, and sequence 3, 12-14 Ma (Sugarman and others, 1993), and may represent the coastal facies of the Kirkwood shallow-shelf deposits. The clayey strata are generally about 5 to 10 feet thick (Figure 1) but may be as much as 40 feet thick.

# SURFICIAL DEPOSITS AND GEOMORPHIC HISTORY

Following the deposition of the Cohansey Formation the sea level in the region began a long-term decline. As sea level lowered, the inner continental shelf emerged as a coastal plain. River drainage was established on this plain. The Beacon Hill Gravel, which caps some of the highest elevations in the Coastal Plain, is the earliest record of this drainage. It is absent in the map area but caps elevations above 165 to 180 feet to the north of the Tuckerton quadrangle. The Beacon Hill is quartz-chert gravel deposited by rivers draining southward from the Valley and Ridge province in northwestern New Jersey and southern New York (Stanford, 2009). In the Beacon Hill, and in upland gravels reworked from the Beacon Hill, rare chert pebbles containing coral, brachiopod, and pelecypod fossils of Devonian age indicate that some of these rivers drained from north of what is now Kittatinny and Shawangunk mountains,

where chert- bearing Devonian rocks crop out. Continued decline of sea level through the late Miocene and early Pliocene (approximately 8 to 3 Ma) caused the regional river system to erode into the Beacon Hill plain. As it did, the river system shifted well to the west of the map area into what is now the Delaware River basin. The map area became an upland from which local streams drained eastward to the Atlantic Ocean. These local streams eroded shallow valleys into the Beacon Hill Gravel. Groundwater seepage, slope erosion, and channel erosion reworked the gravel and deposited it in floodplains, channels, and pediments, between 40 and 60 feet below the level of the former Beacon Hill plain. These deposits are referred to as upland gravel, high phase. They are not present on the Tuckerton or Beach Haven quadrangles. The upland gravel, high phase is found to the north on the West Creek quadrangle (Stanford, 2014). Today, due to topographic inversion, they cap ridgetops above an elevation of between 100 and 130

A renewed period of lowering sea level in the late Pliocene and early Pleistocene (approximately 3 Ma to 800 ka) led to another period of valley incision. Groundwater seepage and channel and slope 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 interfluves above elevations of 55 to 65 feet in the map area. These deposits are found in the northwestern part of the Tuckerton guadrangle.

During at least two periods of higher-than-present sea level in the middle and late Pleistocene, beach and estuarine deposits were laid down in terraces throughout most of the Tuckerton quadrangle. These

marine deposits are grouped into the Cape May Formation. The Cape May includes an older, eroded terrace (Cape May Formation, unit 1, Qcm1) with a maximum surface elevation of 65 feet, a younger, less eroded terrace with a maximum surface elevation of 35 feet (Cape May Formation, unit 2, Qcm2), and the youngest beach and estuarine deposit (Cape May Formation, unit 3, Qcm3) which has a maximum surface elevation of 15 feet. There is only a small part of Qcm3 present here in the southwestern part of the Tuckerton quadrangle. Proceeding to the northeast is the Cape May 2 platform deposit (Qcm2p), which slopes seaward and is onlapped along the bayshore by modern marsh deposits. In places below the Cape May 2 platform deposit are the Cape May 2, fine-grained clay, silt and sand deposits (Qcm2f). These deposits are only present in the subsurface and were mapped in cross-section BB'. The Cape May 1 deposit lies within wide valleys that were shallower and broader at the time of deposition than they are today. The base of the Cape May 1 is higher than that of the upper and lower terrace deposits, and of modern floodplain sediments. Amino-acid racemization ratios (AAR), optically stimulated luminescence ages, and radiocarbon dates from the Delaware Bay area (Newell and others, 1995; Lacovara, 1997; O'Neal and others, 2000; O'Neal and Dunn, 2003: Sugarman and others, 2007; Stanford and others, 2016) suggest that the Cape May 1 is of middle Pleistocene age (possibly oxygen-isotope stage 11, around 420 ka, or stage 9, around 330 ka, or older), that the Cape May 2 is of Sangamonian age (stage 5, 125-80 ka) and the Cape May 3 is of late Sangamonian, or possibly middle Wisconsinan (stage 3) age. AAR data from vibracores on the inner continental shelf off Long Beach Island northeast of the quadrangles indicate that the Cape May correlate there is of Sangamonian age (Uptegrove and others, 2012).

Continuing incision in the middle and late Pleistocene (about 800 to 11 ka) formed the modern valley network. Fluvial sediments laid down in modern valleys include upper and lower terrace deposits (units Qtu and Qtl), and active floodplain and wetland (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 Cohansey Formation by streams, groundwater seepage, and slope processes. Wetland deposits are formed by accumulation of organic matter in swamps and bogs.

Most terrace deposits were laid down chiefly during periods of cold climate in the Pleistocene. During cold periods, permafrost impeded the infiltration of rainfall and snowmelt and this, in turn, accelerated groundwater seepage, runoff, and slope erosion, increasing the amount of sediment entering valleys, leading to terrace deposition. Only one area of upper terrace is within the map area along Mill Branch north of Pohatcong Lake. Regionally the upper terraces are 5 to 25 feet above modern loodplains and in this map area they are inset into the Cape May 2 Formation indicating a slightly younger age than the Cape May 2 Formation. Lower terrace deposits are present in the map area along Tuckerton and Jesses creeks. Near Manahawkin, north of the quadrangles, sand and gravel of the lower terrace overlie an organic silt dated to 34,890±960 radiocarbon years (GX-16789-AMS, Newell and others, 1995) (38,410-40,550 calibrated years with one sigma error, calibrated using Reimer and others, 2013). In the Chatsworth quadrangle the map area (Sugarman and others, 2019). Well number 48 on to the northwest of the Tuckerton quadrangle, organic sediment within cross-section B-B' is known as the Great Bay Observation Well and was lower terrace sand dated to 20.350±80 radiocarbon years (Beta 309764. Stanford, 2012) (24,450-24,150 calibrated years with one sigma error). These dates indicate deposition of the lower terrace deposits in the late Wisconsinan.

> Another feature related to permafrost are thermokarst basins. These are shallow closed basins, circular to oval in shape, generally less than an acre in area, and less than 5 feet in depth (symbolled on map). In the Tuckerton quadrangle, the mapped thermokarst basins occur on the surface of the edge of the Cape May 2 deposit. Most formed when ice-rich lenses at shallow depth in the frozen sediments melted, leaving small depressions (Wolfe, 1953; French and others, 2005).

> Modern floodplain and wetland deposits (unit Qals) were laid down within the past 10 ka, based on radiocarbon dates on basal peat in other alluvial wetlands in the region (Buell, 1970; Florer, 1972; Stanford, 2000). Pollen in organic silt at a depth of 4 feet in unit Qals on the Oswego Lake quadrangle, to the northwest of Tuckerton, contains 50% spruce, 38% birch, 3% pine, 1% oak, and 6% herb (Watts, 1979). This pollen assemblage indicates an age no younger than about 10 radiocarbon ka (about 12,000 calibrated years) for the onset of deposition of the alluvial deposit here, based on the youngest occurrence of spruce in the region (Sirkin and others, 1970).

An inland windblown deposit (Qe) is found in the northwest corner of the Tuckerton quadrangle and forms a dune ridge 4-8 feet tall. The axis of this ridge is oriented east-west and conforms to the regional pattern that suggests the dunes were laid down by winds blowing from the west and northwest. Regionally east-west dunes tend to be more linear forming longitudinal dunes parallel to the prevailing winds like the one here. Regionally, most windblown deposits are on the upper terrace deposits and the Cape May 2 however some are on the Cape May 1 which is the case in the Tuckerton quadrangle. This regional distribution indicates that these dune ridges were mostly deposited during the Wisconsinan Stage which was a period of intermittently cold climate between 80 and 11 ka.

Within the last 10 ka, sea-level rise of about 60 feet led to the deposition of the most recent deposits in the map area (Miller and others, 2009; Psuty, 1986; Uptegrove and others, 2015). Extensive salt-marsh peat and muddy to sandy bay deposits (Qm) underlie the modern bayshore and bay. They thicken seaward and are overlain by tidal-delta and barrier overwash sand (Qbo) in the Beach Haven and southeast part of the Tucketon quadrangles. Overwash deposits were visible on aerial imagery and while conducting fieldwork on the southern part of Holgate (figure 2). This area is the Holgate Unit of E.B. Forsythe National Wildlife Refuge and is uninhabited. Based on measurements made using aerial photos the beach has migrated approximatly 200 yards inland since the 1940's when the construction of groins and jetties began to shore up the inhabited parts of beachfront in Holgate (figure 3).

The Beach Haven quadrangle encompasses a part of Long Beach Island, where the tidal-delta and barrier overwash sands are overlain by beach and dune sands (Qbs, Qbe). Residential development on the bayshore and barrier island created large areas of filled marshland. This fill (af, shown on map as ruled pattern) consists largely of dredged sand and mud from unit Qm and, on Long Beach Island, from grading of units Qbo and Qbe. Sand and mud dredged from navigation channels is also disposed in diked impoundments on islands and along the bayshore (afd). The extent of fill on the bay side of Long Beach Island, and on the western bayshore, is based in part on marsh limits visible on aerial photographs from 1930.

### DESCRIPTION OF MAP UNITS

- Artificial Fill—Sand, silt, gravel, clay; gray to brown; demolition debris (concrete, brick, wood, metal, etc.), cinders, ash, slag, glass, trash. Unstratified to weakly stratified. As much as 20 feet thick, generally less than 15 feet thick. In highway and railroad embankments and filled wetlands and flood plains. Small areas of fill, particularly along streams in urban areas, are not mapped.
- Dredge Spoil—Fine sand, silt, clay, minor medium-to-coarse sand and gravel; gray to brown. Contain variable amounts of organic matter and mica, and minor amounts of man-made materials. As much as 10 feet thick. In diked impoundments, from dredging of channels.
- 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 10 feet thick. Sand and gravel consist chiefly of 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 alluvial wetlands on modern valley bottoms.
- **Qs** Freshwater Swamp and Marsh Deposits—Peat and gyttja, black to brown, with wood pieces in places. As much as 10 feet thick. Deposited in areas of groundwater seepage along the bay shore and upstream of salt-marsh deposits.
- **Qm** Salt-Marsh and Estuarine Deposits—Peat, clay, silt, fine sand; brown, dark-brown, gray, black; minor medium-to-coarse sand and pebble gravel. Contains abundant organic matter and shells. As much as 50 feet thick; deposits at the surface along the eastern bayshore are generally less than 5 feet thick and overlie the Cape May Formation. Deposited in salt marshes, tidal flats and bays during Holocene sea level rise, chiefly within the past 10 ka in the map area, based in part on 8 radiocarbon dates ranging from 8.1 to 0.5 ka from depths of 30 to 7 feet in unit Qm along Great Bay Boulevard (Psuty, 1986; Miller and others, 2009).
- Qald **Dry Valley Alluvium**—Fine-to-medium sand and pebble gravel, minor coarse sand; very pale brown, light gray. As much as 5 feet thick. Sand and gravel consist of quartz. Deposits are relict and lack channels or other signs of surface water flow.
- **Eolian Deposits**—Fine-to-medium quartz sand; very pale brown, white. As much as 8 feet thick. Form an elongate dune ridge on the Cape May terrace. Likely formed during one or more periods of cold climate in the Wisconsinan when terrace sands were exposed to wind erosion.
- QtI Lower Terrace Deposits—Fine-to-medium sand, pebble gravel, minor coarse sand, light gray, brown, dark-brown. As much as 15 feet thick. Sand and gravel are quartz. Form terraces and pediments in valley bottoms with surfaces 2 to 10 feet above modern wetlands. 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 is more abundant in the lower terrace deposits than in upper terrace deposits due to removal of sand by seepage erosion.
- **Upper Terrace Deposits**—Fine-to-medium sand, pebble, gravel, minor coarse sand; very pale brown, brownish-yellow, yellow. As much as 15 feet thick. Sand and gravel are quartz. Form terraces and pediments with surfaces 5 to 20 feet above modern wetlands. Include stratified stream-channel deposits and poorly stratified to unstratified deposits laid down by groundwater seepage on pediments.
- Barrier-Beach Deposits—Sand and minor gravel deposited by waves (Qbs), wind (Qbe, Qbu) and tidal and storm flows (Qbo, Qbu) during the Holocene. Deposits on the Holgate peninsula on the south end of Long Beach Island are based on 2018 fieldwork and aerial photographs taken in 2017.
- Qbs Beach Sand—Fine-to-medium sand with few (1-5%) shells and shell fragments and minor (<1%) to few fine-to-medium quartz pebbles; very pale brown, white, light gray. Bedding is typically planar laminations that dip gently seaward. As much as 15 feet thick. Gravel is more common on mainland bay beaches than on ocean beaches or barrier bay beaches.
- Qbe **Dune Sand**—Fine-to-medium sand with a few coarse sand grains and shell fragments; white, light gray, very pale brown. May include netting, fencing, wood and other human-made materials placed to trap sand and stabalize dunes. As much as 30 feet thick.
- Qbo Overwash and Tidal-Delta Sand—Fine-to-medium sand, few shells and shell fragments, minor coarse sand and fine-to-medium pebble gravel, and a trace (<1%) of rip-up clasts of peat; light gray, very pale brown. Unstratified to laminated to trough- and planar-tabular cross bedded. As much as 60 feet
- Dune and Overwash Sand, Undivided—Sand as in units Qbe and Qbo graded and mixed during urban development. May include artificial fill. As much as 15 feet thick.
- Cape May Formation—Fluvial-estuarine and beach sand and gravel deposits of middle and late Pleistocene age forming an upper (Qcm1), middle (Qcm2), and lower (Qcm3) marine terrace, and fine-grained estuarine deposits (Qcm2f).



**Cape May Formation, Unit 3**—Fine-to-medium sand, pebble gravel, minor coarse sand; yellow, very pale brown, yellowish-brown. Sand and gravel are quartz. As much as 15 feet thick. Forms eroded terraces with a maximum surface elevation of 15 feet. Includes beach, dune, tidal-flat, tidal-channel, and shoreface sediment.

**Qcm2** Cape May Formation, Unit 2—Fine-to-medium sand, pebble gravel, minor coarse sand; yellow, very pale brown, yellowish-brown. Sand and gravel are quartz. As much as 30 feet thick. Forms eroded terraces with a maximum surface elevation of 30 feet. Includes beach, dune, tidal-flat, tidal-channel, and shoreface sediment.

- Cape May Formation, Unit 2, Fine-Grained Facies—Clay, silt. fine sand, minor organic matter; light gray to gray. As much as 30 feet thick. In subsurface only, inferred from well records (section BB'). Deposited in a bay during sea-level rise to the Cape May 2 highstand
- Cape May Formation, Unit 2, Platform **Deposit**—Fine-to-medium sand, with pebbles in places, minor clayey sand to sandy clay; very pale brown, light gray, yellowish-brown. As much as 40 feet thick. In places, the platform deposit is overlain by discontinuous black to dark brown freshwater peat and organic silt of Holocene age, generally less than 3 feet thick, that accumulate from groundwater seepage. Forms a platform that gently slopes bayward from the foot of the Cape May 2 terrace and extends beneath Holocene salt-marsh and estuarine deposits to the inner shelf. Includes beach, shoreface, and minor fluvial deposits laid down during sea-level decline from the Cape May 2 highstand. Upper part of this unit beneath unit Qm may include younger deposits of stage 5 and stage 3 age, as indicated by a radiocarbon date of 40.1 ka (Miller and others, 2009) at a depth of 47 feet in boring 49 at the southern end of Great Bay Boulevard.
- Cape May Formation, Unit 1—Fine-to-medium sand, pebble, gravel, minor clayey sand to sandy clay, and coarse sand; yellowish-brown, yellow, very pale brown. As much as 20 feet thick. Sand and gravel are quartz with minor weathered chert Forms eroded terraces with a maximum surface elevation of 65 feet. Includes beach, dune, tidal-flat, tidal-channel, and shoreface sediment.
- Upland Gravel, Lower Phase—Fine-to-medium sand, clayey in places, and pebble gravel; minor coarse sand; yellow, very pale brown, reddish-yellow. Sand and gravel are quartz with a few (<5%) with brown weathered chert in the coarse sand-to-pebble fraction. Clay is chiefly from weathering of chert. As much as 20 feet thick, generally less than 10 feet thick. Occurs as erosional remnants on interfluves between 55-90 feet in elevation. Includes stream-channel deposits, poorly stratified deposits laid down by groundwater seepage on pediments, and pebble concentrates formed from older surficial deposits and the Cohansey Formation as sand is removed by groundwater sapping or surface runoff.

Cohansey Formation—Fine-to-medium quartz sand, with some strata of medium- to-very coarse sand, very fine sand, and and inner-shelf settings. The Cohansey is here divided into two map units: a sand facies and a clay-sand facies, based on gamma-ray well logs, exposures, and excavations. Total thickness of the Cohansey in the map area is as much as 190 feet.

- Sand Facies—Fine-to-medium sand, some medium-to-coarse sand, minor very fine sand, minor very coarse sand to very fine pebbles, trace fine-to-medium pebbles; very pale brown, brownish-yellow, white, reddish-yellow, rarely reddish-brown, red, and light red. Well-stratified to unstratified; stratification ranges from thin, planar, subhorizontal beds to large-scale trough and planar crossbedding. Sand is quartz; coarse-to- very coarse sand may include as much as 5% weathered chert and a trace of weathered feldspar. Coarse-to-very coarse sands commonly are slightly clayey; the clays occur as grain coatings or as interstitial Florer, L.E., 1972, Palynology of a postglacial bog in the New Jersey infill. This clay-size material is from weathering of chert and feldspar rather than from primary deposition. Pebbles are chiefly pebbles are light gray, partially weathered, pitted, and partially decomposed; some are fully weathered to white clay. In a few places, typically above clayey strata, sand may be hardened or cemented by iron oxide, forming reddish-brown hard sands or ironstone masses. Locally, sand facies includes isolated lenses of interbedded clay and sand like those within the clay-sand facies described below. The sand facies is as much as 190 feet thick.
- Clav-Sand Facies— Clay interbedded with clayey fine sand, very fine-to-fine sand, fine-to-medium sand, less commonly with medium-to-coarse sand and pebble lags. Clay beds are commonly 0.5 to 3 inches thick but are as much as 4 feet thick (figure 1); sand beds are commonly 1 to 6 inches thick but are as much as 2 feet thick. Clays are white, yellow, very pale brown, reddish-yellow, light gray; sands are yellow, brownish-yellow, very pale brown, reddish- yellow. Rarely, clays are brown to dark-brown and contain organic matter. As much as 40 feet thick.
- Kirkwood Formation— Fine sand, fine-to-medium sand, coarse sand, sandy clay, and clay, minor medium-to-coarse sand; gray, dark gray, brown. Sand is quartz with some mica and lignite. In subsurface only. Approximately 550 feet thick in the eastern part of the map area. The Kirkwood consists of 6 clay- sand units traceable on gamma-ray logs and sampled in the Island Beach corehole (Miller and others, 1994, see discussion under "Kirkwood Formation" above). These units are shown by tie lines on both cross sections. The Kirkwood in the quadrangle is of early to middle Miocene age, based on strontium stable-isotope ratios and diatoms (Miller and others, 1997).

- Atlantic City Formation—Silty, clayey, glauconitic (as much as 10%) fine-to-medium quartz sand, minor coarse sand; olive, olive-brown, brown, dark gray; with mica, shells, and shell fragments. In subsurface only. As much as 70 feet thick in the eastern portion of the map area. Assigned to Atlantic City Formation of Pekar and others (1997) based on the presence of this formation in the Bass River corehole (Miller and others, 1998). Of early Oligocene age, based on strontium stable-isotope ratios and calcareous nannofossils (Miller and others, 1994, 1998; Pekar and others, 1997).
- Sewell Point Formation—Fine-to-coarse glauconitic sand and minor clay; olive green, olive, gray; with some shells. As much as 170 feet thick. Of Oligocene age, based on planktonic foraminifera and strontium stable-isotope ratios (Pekar and others, 1997).

### **EXPLANATION OF MAP SYMBOLS**

- Contact—Solid where well-defined by landforms as visible on LiDAR imagery, dashed where approximately located. Dotted within excavations.
- Material penetrated by hand-auger hole or observed in exposure or excavation. Hand-auger holes were dug to five feet or until refusal. Material descriptions of each hand-auger hole are written in field notes, on file at NJGWS.
- Well or test boring—Location accurate to within 200 feet. Log of formations penetrated shown in table 1. Dominant grain size of bay-bottom sediment in 6-foot
- sand

vibracore—Data on file at NJGWS

- sand and clay-silt clay-silt

Sand pit—Inactive in 2017

- Well with geophysical log- Gamma-ray log is shown by black line, with radiation intensity increases to right. single point resistance log is shown by red line, with resistance increasing to right.
- Shallow topographic basin—Line at rim, pattern in basin. Includes thermokarst basins formed from melting permafrost.
- Excavation perimeter—Line encloses excavated area.

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Sea Level







#### GEOLOGY OF THE TUCKERTON AND BEACH HAVEN QUADRANGLES ATLANTIC AND OCEAN COUNTIES. NEW JERSEY **OPEN-FILE MAP SERIES OFM 147** pamphlet containing table 1 accompanies map



**Figure 1.** Cohansey clay layer approximately 4 feet thick with Cohansey sand above and below the clay (located between the red lines). Clay was predominately white-yellow in color with some pale brown zones. This clay was exposed in former sand pit east of Otis Bog Road. Location shown on map. Photo by M. Castelli.



**Figure 2.** This photo shows an overwash (Qbo) deposit located on the Holgate natural area. You can see the vegetated dune deposits to the left and right of the individual in the middle of where the sea broke through the dune and deposited Qbo on the inland part of the barrier island. Based on aerial photography this barrier overwash likely occurred in 2012 during Hurricane Sandy. Location shown on map. Photo by M. Castelli.



Figure 3. This photo was taken in October of 2018 in Holgate, the southern most inhabited part of Long Beach Island. This scouring of the dune (Qbe) occurred from a nor'easter and cut into the dune leaving an approximately 15 foot drop down to the beach (Qbs). This photo is looking south, documenting that the Holgate Unit of the E.B. Forsythe National Wildlife Refuge has migrated approximately 200 yards inland since the 1940's when the construction of groins and jetties began to shore up the inhabited parts of beachfront in Holgate (based on aerial photos). Photo by M. Castelli.

#### Geology of the Tuckerton and Beach Haven Quadrangles Atlantic and Ocean Counties, New Jersey

New Jersey Geological and Water Survey Open File Map OFM 147 2022

pamphlet with table 1 to accompany map

Table 1. Selected well and boring records, bolded well numbers are depicted in cross-section

Well		
Number	Permit Number <sup>1</sup>	Formations Penetrated <sup>2</sup>
1	32-26171	25 Tchs, 35 Tchc, 80 Tchs
2	32-26404	12 Q, 23 Tchs, 30 Tchc, 100 Tchs
3	32-17281	10 Q, 20 Tchs ,28 Tchc, 90 Tchs
4	E201402716	47 Q + Tchs, 60 Tchc, 100 Tchs
5	E201306404	21 Q, 116 Tchs, 126 Tchc, 151 Tchs
6	32-27920	10 Q, 35 Tchs, 47 Tchc, 100 Tchs
7	E201403045	44 Q + Tchs, 61 Tchc, 85 Tchs, 91 Tchc, 127 Tchs
8	32-22287	32 Tchs, 45 Tchc, 80 Tchs
9	32-26604	30 Q+Tchs, 35 Tchc, 137 Tchs, 141 Tchc, 166 Tchs
10	32-26605	17 Q, 137 Tchs, 145 Tchc, 168 Tchs
11	32-26606	17 Q, 139 Tchs, 143 Tchc, 166 Tchs
12	32-22190	10 Q, 20 Tchs ,25 Tchc, 80 Tchs
13	32-21615	12 Q, 25 Tchs, 35 Tchc, 80 Tchs
14	32-21363	13 Q, 23 Tchs, 30 Tchc, 100 Tchs
15	33-25201	BB' 162 Q+Tchs, 167 Tchc, 230 Tchs, 480 Tkw
16	33-25210	BB' 162 Q+Tchs, 167 Tchc, 230 Tchs, 480 Tkw
17	32-15207	54 Tchs, 73 Tchc, 223 Tchs, 579 Tkw
		BB' 2 af, 41 Qm, 95 Tchs, 97 Tchc, 110 Tchs, 122 Tchs, 251 Tchs
18	32-9809	570 Tkw
19	E201405938	60 Q+Tchs, 67 Tchc, 280 Tchs, 555 Tkw
20	32-14034	22 Qcm2, 38 Tchs, 39 Tchc, 60 Tchs
21	31-19727	22 Qcm2, 30 Tchs, 45 Tchc, 55 Tchs, 66 Tchc, 75 Tchs
22	32-23484	60 Q+Tchs, 135 Tchs, 140 Tchc, 185 Tchs, 200 Tchc
23	32-25265	12 Qcm2, 23 Tchs, 30 Tchc, 100 Tchs
24	32-8612	45 Tchs

25	32-45123	BB' 10 Q, 40 Tchs, 45 Tchc, 57 Tchs, 60 Tchc
26	33-40330	3 af, 10 Qbu, 11 Qm
27	E200912694	AA' 3 af, 12 Qm, 90 Qbo+Qcm2p, 234 Tchs, 275 Tkw
28	E201702521	22 Qbo, 55 Qm, 100 Qcm2p, 200 Tchs
29	E201416219	AA' 19 af, 30 Qm, 36 Qbo
30	33-30127	AA' 2 Qbu, 4 Qm, 30 Qbo, 40 Qm
31	E201402343	12 af, 75 Qm, 100 Qcm2p+Tchs
32	E201509212	14 af, 40 Qm, 120 Qbo+Tchs, 150 Tchc, 200 Tchs
		9 Qbu, 64 Qbo, 70 Qm, 90 Qcm2p, 140 Tchs, 160 Tchc, 220 Tchs, 588
33	33-42143	Tkw
34	33-40083	6 af, 17 Qm, 42 Qbo
35	E201808394	AA' 5 af, 40 Qm+Qbo, 60 Qm, 100 Qcm2p
36	33-32306	15 Qbu, 40 Qm, 110 Qbo+Qcm2p, 265 Tchs
37	33-1023/4	40 Qcm2, 80 Tchs, 90 Tchc, 160 Tchs, 215 Tkw
38	32-25614	17 Qcm2, 185 Tchs, 505 Tkw
39	32-00447, G	12 Qcm2, 185 Tchs, 550 Tkw
40	32-00224	16 Q, 66 Tchs, 90 Tchc, 192 Tchs, 340 Tkw
41	32-9809	2 af, 41 Qm, 79 Qcm2p, 95 Tchs, 122 Tchc, 200 Tchs, 570 Tkw
42	32-00479, R	BB' 190 Q+Tchs, 568 Tkw
43	32-22508, G	143 Q+Tchs, 190 Tchs, 202 Tchs, 503 Tkw
44	32-22509, G	BB' 143 Q+Tchs, 190 Tchs, 202 Tchs, 546 Tkw
45	52-33	18 Q, 60 Tchs, 180 Tchc+Tchs, 331 Tkw
46	GB-1	31 Qm, 34 Qcm2p
47	56-24756	24 Qm, 60 Qbo, 115 Tchs, 136 Tchc, 217 Tchs, 797 Tkw
40	22 20055 C	BB' 85 Q, 105 Tchs, 125 Tchc, 275 Tchs, 825 Tkw, 890, Tac, 1007
48	32-20855, G	
49	GB-2	28 Qm, 60 Qcm2p BB' 45 Om 47 Ocm2p 54 Ocm2f 107 Tehs 138 Tehe 272 Tehs
50	53-00130	605 Tkw
		AA' 55 Qbo, 101 Qm, 135 Qcm2p, 153 Tchc, 170 Tchs, 181 Tchc,
51	33-40378	210 Tchs, 220 Tchc, 265 Tchc, 476 Tkw
52	33-01051	85 Qbo, 130 Qcm2p, 143 Tchs, 174 Tchc, 255 Tchs, 452 Tkw
50	52 00120	AA' 55 Qbo, 90 Qm, 115 Qcm2p, 135 Tchs, 150 Tchc, 280 Tchs, 575
53	53-00129	1 KW A A' 30 Obo 72 Om 122 Ocm2n 148 Tebs 184 Tebs 287 Tebs
54	33-2451	751 Tkw
55	33-39413. G	AA' 3 Obu, 65, Om, 78 Ocm2p, 250 Tchs, 656 Tkw
56	33-01275. R	AA' 54 Obo. 67 Om. 83 Ocm2p. 252 Tchs. 697 Tkw
57	33-40839. G	AA' 31 O. 98 Obo+Ocm2p, 258 Tchs, 647 Tkw
58	33-13836. G	AA' 3 af, 6 Om, 73 Obo, 93 Ocm2n, 234 Tehs, 616 Tkw
59	33-24693. G	AA' 24 Om. 86 Obo. 106 Ocm2p, 226 Tchs. 610 Tkw
60	32-22507, G	BB' 30 Qcm2, 50 Tchs, 60 Tchc, 145 Tchs, 193 Tchc+Tchs, 534 Tkw

<sup>1)</sup> Numbers of the form 33-xxxxx, 53-xxxxx, 56-xxxxx, 32-xxxx, 52-xxx or Exxxxxxx are N. J. Department of Environmental Protection well-permit numbers. GB-1 and GB-2 refer to coreholes drilled in Miller and others, 2009. A "G" following the identifier indicates that a gamma-ray log is available for the well, an "R" indicates that a Single Point Resistance log is available.

<sup>2)</sup> Number is depth (in feet below land surface) of base of unit indicated by abbreviation following the number. Final number is total depth of well rather than base of unit. For example, "88 Tchs 94 Tchc 120 Tchs 145 Tkw" indicates Tchs from 0 to 88 feet below land surface, Tchc from 88 to 94 feet, Tchs from 94 to 120 and Tkw from 120 to the bottom of the hole at 145 feet. Formation abbreviations and the corresponding drillers' descriptive terms used to infer the formation are: Q=yellow and white sand and gravel surficial deposits, undifferentiated west of the bayshore area (units TQg, Qtu, Qtl, Qals, Qcm1, Qcm2, Qcm3). Stacked surficial units along the bayshore and on the barrier beaches are differentiated as follows: Qcm2 (includes Qcm2 and Qcm2p), Qbe, Qbs=yellow, white, gray sand and gravel, Qm=peat, meadow mat, and gray to brown mud, Qcm2f=gray to brown clay, silt, fine sand. Bedrock formations 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; Tkw=gray and brown clay, silt and sand of the Kirkwood Formation. A "+" sign indicates that units are mixed or interbedded. For wells with gamma-ray or resistance logs, units are shown on the cross section indicated.

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, or from geophysical well logs where lithologic descriptions are not available or are of poor quality. Units shown for wells may not match the map and sections due to variability in drillers' descriptions and the thin, discontinuous geometry of many clay beds. In many well logs, surficial deposits cannot be distinguished from Cohansey sands; thus, the uppermost Tchs unit in well logs generally includes overlying surficial deposits.