DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF SCIENCE, RESEARCH AND TECHNOLOGY
NEW JERSEY GEOLOGICAL SURVEY

INTRODUCTION

Surficial materials are the sediments and weathering products that overlie bedrock and Coastal Plain formations, and that are the parent material in which soils are developed. In Middlesex County they include fluvial, glacial, eolian, colluvial, swamp, beach, and estuarine deposits; weathered mudstone, sandstone, and diabase material; and man-made fill. They are as much as 140 feet thick but are commonly less than 50 feet thick, and are thin or absent throughout much of the county. The texture, bedding, and composition of these materials vary widely. This leads to significant differences in the ability of the materials to convey ground water into aquifers, to support structures, and to supply extractable resources. The purpose of this map is to provide information about these materials and their physical characteristics as an aid to land-use planning, ground-water studies, and engineering projects. The information presented here can be used as a preliminary guide to conditions likely to be present at a particular location, but the map should not be used as a substitute for the detailed study needed for site-specific projects. This map is based on field work, interpretation of aerial photographs, and compilation of well and test boring logs conducted by the author between 1986 and 1994. Detailed 1:24,000-scale surficial geologic maps, with complete listings of well and test-boring logs, are published for several 7.5-minute quadrangles (Stanford, 1992, 1995, in press; Stanford and others, in press). The other quadrangles are on file at the N. J. Geological Survey. Information about the soils developed on the surficial materials is provided in Powley (1987). Greater detail on the engineering properties of the surficial materials and associated soils is provided by Holman and Jumikis (1953). Bedrock geology is provided by Parker (1993), Owens and others (1995), and Drake and others (1996) ; Coastal Plain formations are mapped by Owens and others (1995).

The map and cross sections on sheet 1 show the extent and thickness of the surficial materials. Descriptions of the materials are provided in the "Description of Map Units" section, and the units are correlated on the "Geologic Age and Correlation of Map Units". A synopsis of the geologic history is provided below. On sheet 2, the hydrogeologic, engineering, and resource characteristics of the surficial materials are described in table 1. Table 2 provides records of selected wells and test borings to illustrate the subsurface distribution of the units and their water-bearing potential. Figures 1 through 7 show aspects of the surficial materials that are important for land-use planning, ground-water-resource management, and economic-resource assessment. The figures include maps showing thickness, sand-and-gravel resource potential, clay-and-peat resource potential, estimated permeability, and aquifer-recharge potential of the surficial materials; landforms and areas of potential slope instability in the county; and the general distribution of the underlying bedrock and Coastal Plain deposits. Figures 8 and 9 depict the grain-size distribution of till and the major sand and gravel deposits. A list of references is also provided on sheet 2.

GEOLOGIC HISTORY

The surficial deposits and landforms of Middlesex County are the result of geologic events that occurred primarily within the past 5 million years. They represent alternating periods of erosion and deposition that occurred in response to fall and rise of sea level, glaciation, and climate change. A brief discussion of these events follows. More complete discussions of the surficial deposits and the events they represent are provided by Davis and Wood (1890), Salisbury (1902), Salisbury and Knapp (1917), Johnson (1931), Campbell and Bascom (1933), MacClintock and Richards (1936), Wolfe (1953), Bowman (1966), Walters (1978), Owens and Minard (1979), Martino (1981), Psuty (1986), Stanford and Harper (1991), and Stanford (1993).

The landscape of Middlesex County began to form in the late Miocene (about 10 million years ago), when an extensive period of erosion began in response to worldwide lowering of sea level. By the Pliocene (about 5 to 2 million years ago) a large southwesterly-flowing river (the "Pensauken River"), which likely received drainage from both the Hudson River basin and from southwestern New England, had eroded a broad valley across all but the southeastern parts of the county. The erosion surface at the bottom of this valley is shown by contours on the geologic map. It includes a deep trough that extends from the vicinity of Milltown to the Plainsboro area. This trough includes fluvial scour features that extend below modern sea level, indicating that the valley may have been cut during a time of low sea level in the Pliocene. Tributaries to this main valley flowed northwesterly from the Coastal Plain highlands to join the main valley in the area of Jamesburg and Cheesequake. Fluvial sediments were deposited in the main and tributary valleys and gradually aggraded to form a broad plain over most of the county. This aggradation may have occurred during one or more periods of high sea level in the Pliocene. These deposits comprise the Pensauken Formation (Salisbury and Knapp, 1917).

Gravel in the Pensauken consists of well-rounded quartz, quartzite, chert, and ironstone, chiefly derived from recycled late Miocene deposits. In the main valley the Pensauken contains much feldspar in the sand fraction, and some sandstone, mudstone, gneiss, and schist in the gravel fraction, indicating that it was eroded from sedimentary and metamorphic bedrock to the northeast. This phase of the Pensauken is mapped as unit Tp. In the tributary valleys the Pensauken contains much glauconite in the sand fraction, which was eroded from glauconitic Coastal Plain formations to the southeast. This phase is mapped as unit Tpg. The two phases mix and interfinger along the southeastern edge of the main valley.

In the late Pliocene or early Pleistocene the Pensauken River was diverted southeastward in the vicinity of New York City. This probably occurred during the pre-Illinoian glaciation, which covered much of northern New Jersey. After this diversion a new drainage system was established on the now-abandoned Pensauken plain. The former tributaries to the Pensauken in the Jamesburg and Cheesequake areas formed the upper Millstone and South Rivers, respectively. The Raritan River established an eastward course across the northern edge of the county. During the early and middle Pleistocene (1.6 million to about 200,000 years ago) these rivers cut valleys as much as 100 feet deep into the Pensauken deposits and underlying bedrock and Coastal Plain formations. Much of the Pensauken deposit was eroded, particularly at the margins of the plain, where it was thin, and where it was underlain by shale or clay. Fluvial deposits along these streams (unit Qtu) are preserved today as isolated high terrace remnants in downstream areas where erosion has removed most of the deposits, or as broader, more continuous terraces in upstream areas where erosion has been slight. They are composed of material eroded from the Pensauken Formation and from underlying or adjacent Coastal Plain and bedrock formations.

During the middle and late Pleistocene, two glaciers entered northern New Jersey. The most recent, the late Wisconsinan, reached its terminal position slightly before 20,000 years ago and had retreated north of New Jersey by about 17,000 years ago. It covered the northeastern corner of Middlesex County. At its farthest advance it deposited till in the form of a prominent moraine (unit Qwtm). This feature is marked along much of its length by a frontal ridge or scarp as much as 120 feet tall, with a belt of gentle ridge, knoll, and swale topography extending back from the frontal ridge as much as 2 miles. Northeast of the moraine the glacier eroded the surface of bedrock and Coastal Plain formations into streamlined forms (refer to the bedrock-surface contours on the geologic map) and deposited a nearly continuous layer of till (unit Qwt) on the streamlined surface. The till is a reddish-brown silty sand to sandy clayey silt with many pebbles and cobbles and few boulders. The composition of the till reflects glacial erosion of the local red shale and mudstone, and Coastal Plain and Pensauken sediments, as well as metamorphic and sedimentary bedrock to the north. The sand, in contrast to the older surficial deposits, includes many rock fragments in addition to quartz, feldspar, and mica. The gravel is dominantly shale, mudstone, conglomerate, and gneiss, with lesser quartz and quartzite from the Pensauken Formation.

Meltwater from the glacier deposited sand and gravel (unit Qwf) in three outwash plains in front of the terminal moraine. The largest of these is the Plainfield outwash along the northwestern border of the county. This deposit, and part of the terminal moraine, filled the former Raritan valley with as much as 120 feet of glacial sediment and diverted the Raritan to a new southeasterly route. The Raritan thereupon eroded a narrow, gorge-like valley into shale bedrock from Middlesex to New Brunswick along this new route. East of New Brunswick it entered and deepened the existing valleys of Lawrence Brook and South River.

While meltwater deposited the outwash, nonglacial streams in the Millstone River, Lawrence Brook, Ambrose Brook, and South River basins, deposited stream terraces (unit Qtl). These deposits reflect increased slope erosion and sediment supply in the cold, tundra-like conditions prevailing during glaciation. In this environment there was little vegetation to stabilize slopes. During thaws, soils became waterlogged and flowed easily down gentle slopes when subsurface drainage was impeded by permafrost. In addition to alluviation along streams, colluvial material accumulated at the base of steep hillslopes (units Qcs, Qcn, Qca). Westerly winds blowing across newly-deposited alluvial and outwash plains, and, locally, unvegetated outcrops of Cretaceous sand, moved sand downwind from the terraces and outcrops, forming dunes and sand sheets (unit Qe).

As the glacier margin retreated from the terminal moraine, lakes occupied basins formed between the ice front and the moraine. Meltwater deposited sand and gravel in deltas in the lakes (unit Qwd) and silt, clay, and fine sand (unit Qwl) on the bottoms of the lakes. In two places, sand, gravel, and diamicton were deposited in small basins surrounded by glacial ice (unit Qwi).

Sea level slowly rose as the late Wisconsinan glaciers melted. The rising sea gradually drowned the lower reaches of valleys. By about 11,000 years ago the sea had encroached into the Raritan valley in what is now Raritan Bay. Continued rise extended the salt marsh farther inland into the Raritan, Rahway, and South River valleys, along the Arthur Kill, and into the Woodbridge, Cheesequake, Marquis, and Whale Creek valleys. Estuarine deposits (unit Qm) filled these drowned valleys. Waves and currents along Raritan Bay subsequently eroded low bluffs into the older surficial and Coastal Plain deposits and laid down beach deposits (unit Qb) along the base of the bluffs, and in spits across the mouths of intervening salt marshes.

The warming climate allowed vegetation to become reestablished. Slopes were stabilized and streams no longer carried large amounts of sediment. They thus incised into the outwash plains and stream terraces. After incision, larger streams deposited floodplain and channel sediment (unit Qal). Organic-rich deposits (unit Qs) accumulated in poorly drained areas. These areas include 1) small basins formed under permafrost conditions, 2) hummocky glacial topography, 3) larger areas on former glacial lake bottoms, 4) former stream valleys abandoned during drainage changes, and 5) low-lying areas dammed by glacial, eolian, or terrace deposits.

The most recent deposits and landforms have been the result of human activity, including mining of clay and sand, dredging of ship channels, and landfilling (units af, aft). These began on a large scale in the latter half of the nineteenth century. They have significantly altered the landforms and the distribution of surficial materials in parts of the county, particularly in the South River, lower Raritan River, and Arthur Kill valleys.

DESCRIPTION OF MAP UNITS

af ARTIFICIAL FILL--Gray, brown, white, yellow sand, silt, gravel, clay, and man-made material (concrete, brick, asphalt, cinders, ash, slag, and other construction or industrial materials). May contain wood, organic material, and trash. As much as 20 feet thick. Only large areas of fill are shown. Urban and suburban areas generally have a thin layer (generally less than 5 feet thick) of fill or mixed fill and natural material overlying the mapped surficial material.

aft TRASH FILL--Solid waste and other artificial materials mixed and covered with sand, gravel, silt, and clay. As much as 100 feet thick.

Qb BEACH DEPOSITS--Very pale brown to yellow sand and pebble gravel. Sand is chiefly quartz, with some glauconite, heavy minerals, mica, and rock fragments. Gravel is chiefly quartz, quartzite, chert, shells, and man-made materials, with some mudstone and sandstone. Well sorted and stratified. As much as 15 feet thick.

Qal ALLUVIUM--Gray, brown, reddish-brown, and yellowish-brown sand and silt, some pebble-to-cobble gravel and clay, with variable amounts of organic matter. Sand and gravel composition reflects that of surficial materials, bedrock, and Coastal Plain formations in the drainage basin. Nonstratified to moderately stratified, moderately sorted. As much as 15 feet thick.

Qca ALLUVIUM AND COLLUVIUM, UNDIVIDED--Gray, brown, and yellowish-brown sand and silt, some gravel and organic matter. Sand and gravel composition, stratification, and sorting as in units Qal and Qcn.

Qm ESTUARINE DEPOSITS--Gray, brown, and black peat and organic-rich clay and silt, minor white to gray sand and shell hash. Nonstratified to poorly stratified, moderately sorted. As much as 100 feet thick.

Qs FRESHWATER SWAMP AND MARSH DEPOSITS--Gray, brown, and black peat and organic-rich silt, sand, and clay. Nonstratified, moderately sorted. As much as 10 feet thick, but generally less than 5 feet thick.

Qtl LOWER STREAM TERRACE DEPOSITS--Yellow, yellowish-brown, reddish-yellow and reddish-brown sand, silt, and pebble gravel, minor cobble gravel. Sand is chiefly quartz, with glauconite and mica in the Millstone and South River basins, and feldspar and rock fragments in other deposits. Gravel is chiefly quartz, quartzite, and ironstone in the Millstone and South River basins, and mudstone, sandstone, quartz, and quartzite elsewhere. Moderately to well stratified and sorted. As much as 40 feet thick but generally less than 20 feet thick.

Qwl GLACIAL LAKE-BOTTOM DEPOSITS--Gray to reddish-brown silt, fine sand, and clay. Well stratified and sorted. As much as 20 feet thick. Occurs in places beneath unit Qm in the Rahway River, Arthur Kill, and Woodbridge Creek marshes.

Qwd GLACIAL DELTA DEPOSITS--Reddish-yellow to reddish-brown sand and gravel, minor silt. Sand is chiefly quartz, feldspar, and rock fragments. Gravel is chiefly mudstone, sandstone, quartz, quartzite, conglomerate, and gneiss. Well stratified and sorted. As much as 30 feet thick.

Qwi GLACIAL ICE-CONTACT DEPOSITS--Reddish-brown sand and gravel, minor diamicton. Sand and gravel composition as in unit Qwd. Moderately stratified and sorted. As much as 50 feet thick.

Qwf GLACIAL STREAM DEPOSITS--Reddish-brown to reddish-yellow sand and gravel, minor silt. Sand and gravel composition as in unit Qwd. Well stratified and sorted. As much as 100 feet thick.

Qwt TILL--Reddish-brown diamicton composed of a silty sand to sandy silt (refer to fig. 8, sheet 2, for grain-size distribution of matrix material), with some to many pebbles and cobbles, and few boulders. Sand and gravel composition as in unit Qwd. Boulders are chiefly conglomerate and gneiss. Nonstratified, poorly-sorted. As much as 60 feet thick.

Qwtm TILL OF THE TERMINAL MORAINE--Till as above, forming ridge-and-swale moraine topography. Includes some sand and gravel. As much as 130 feet thick.

Qe EOLIAN DEPOSITS--Very pale brown to reddish-yellow fine sand. Sand is chiefly quartz with some glauconite in the South River basin and some feldspar and rock fragments elsewhere. Nonstratified to moderately stratified, well sorted. As much as 20 feet thick in dunes but generally less than 10 feet thick.

Qtu UPPER STREAM TERRACE DEPOSITS--Reddish-yellow to brownish-yellow sand, silt, and pebble gravel. Sand and gravel composition as in unit Qtl. Nonstratified to moderately stratified, moderately sorted. As much as 20 feet thick.

Qcs SHALE COLLUVIUM--Reddish-brown diamicton composed of a clayey silt to sandy silt with some to many shale chips and flagstones and some quartz and quartzite pebbles. Nonstratified, poorly sorted. As much as 10 feet thick.

Qcn SAND AND GRAVEL COLLUVIUM--White, yellow, brown, gray diamicton composed of sand and pebble gravel, some silt and organic matter in places. Sand is chiefly quartz with some feldspar and mica, and with glauconite in the South River basin. Gravel is chiefly quartz, quartzite, and ironstone. As much as 10 feet thick.

Qsw WEATHERED SHALE, MUDSTONE, AND SANDSTONE (CHIEFLY OF QUATERNARY AGE)--Reddish-brown to yellow diamicton composed of silty clay to clayey silty sand with some to many shale, mudstone, and sandstone fragments and few to some quartz and quartzite pebbles and cobbles. As much as 30 feet thick but generally less than 10 feet thick.

Qdw WEATHERED DIABASE (CHIEFLY OF QUATERNARY AGE)--Yellow, reddish-yellow, gray, and brown diamicton composed of sandy silty clay with some to many diabase fragments and few to some quartz and quartzite pebbles and cobbles. As much as 10 feet thick.

Tp PENSAUKEN FORMATION--Reddish-yellow to yellow sand and pebble gravel, slightly silty and clayey; cobble gravel at base. Iron-cemented in places, particularly at base. Sand is chiefly quartz and feldspar, with some glauconite and mica. See Bowman (1966) and Owens and Minard (1979) for detailed descriptions of the sand and clay mineralogy of the Pensauken. Gravel is chiefly quartz and quartzite with some chert and ironstone, and minor weathered mudstone, sandstone, gneiss, diabase, and schist, particularly at base. Well stratified and well sorted. The upper 5 to 10 feet is generally nonstratified to poorly stratified, with more clay and silt than at depth, and is commonly cryoturbated. As much as 140 feet thick.

Tpg PENSAUKEN FORMATION, GLAUCONITIC PHASE--Reddish-yellow to yellowish-brown sand, pebble gravel, and silt. Sand is chiefly quartz, with some glauconite and mica. Gravel is chiefly quartz, quartzite, with some ironstone. As much as 40 feet thick.

Tpc PENSAUKEN FORMATION, CLAY PHASE--Dark gray silty clay. Nonstratified, well sorted. May contain some organic matter. As much as 15 feet thick (estimated).

Tug UPLAND GRAVEL--Reddish yellow to yellow sand, silt, and pebble gravel. Iron-cemented in places. Sand is chiefly quartz with some glauconite. Gravel is chiefly quartz and quartzite with some ironstone and weathered chert. Nonstratified, moderately sorted. As much as 10 feet thick.

Ks CRETACEOUS SAND--White, pink, yellow, and gray sand; minor silt and clay. Sand is chiefly quartz with some mica, lignite and, in places, glauconite and feldspar. Nonstratified to well stratified, moderately to well sorted. This unit marks outcrop areas of predominantly sandy Coastal Plain formations, which are as much as 150 to 200 feet thick. Overlain by thin, discontinuous alluvium, eolian sediment, and sand and gravel colluvium that are generally less than 3 feet thick.

Kc CRETACEOUS CLAY--Gray, brown, and olive clay and silt, minor sand. Nonstratified to moderately stratified, well sorted. This unit marks outcrop areas of predominantly clayey and silty Coastal Plain formations, which are as much as 120 feet thick. Overlain by thin, discontinuous alluvium, eolian sediment, and sand and gravel colluvium that are generally less than 3 feet thick.

Kdw WEATHERED DIABASE (CHIEFLY OF CRETACEOUS AND EARLIER AGE)--White, red, gray, olive, and brown diamicton composed of clay, silt, sand, and some diabase fragments. Nonstratified. poorly sorted. As much as 20 feet thick. In subsurface only, beneath Coastal Plain formations (see cross sections AA', CC', DD'). Generally more clayey and of more variable color than unit Qdw.

Ksw WEATHERED SHALE, MUDSTONE, AND SANDSTONE (CHIEFLY OF CRETACEOUS AND EARLIER AGE)--Red, reddish-brown, light gray, and olive diamicton composed of silty clay to sandy clay with some shale, mudstone, or sandstone fragments. Nonstratified to moderately stratified (may retain original bedding), well to poorly sorted. As much as 50 feet thick. Chiefly in subsurface, beneath Coastal Plain formations (see cross sections AA', CC', DD', EE'). Generally thicker, more clayey, and of more variable texture than unit Qsw.

MAP SYMBOLS

Contact--Dashed where based on base-map topography that has been extensively modified by excavation since the date of the topographic survey. Dotted where concealed by fill.

Large excavated area--Line shows limit; tick marks in area. Solid contacts within these areas show the approximate extent of materials in the excavation at the time of mapping. Dashed contacts show the inferred former extent of materials at the time the base-map topography was surveyed. In many places this topography has been substantially altered by excavation. Thickness values in these areas reflect pre-excavation conditions.

Sand, gravel, clay pit--Active in 1994.

Sand, gravel, clay pit--Inactive in 1994.

Quarry--Inactive in 1994.

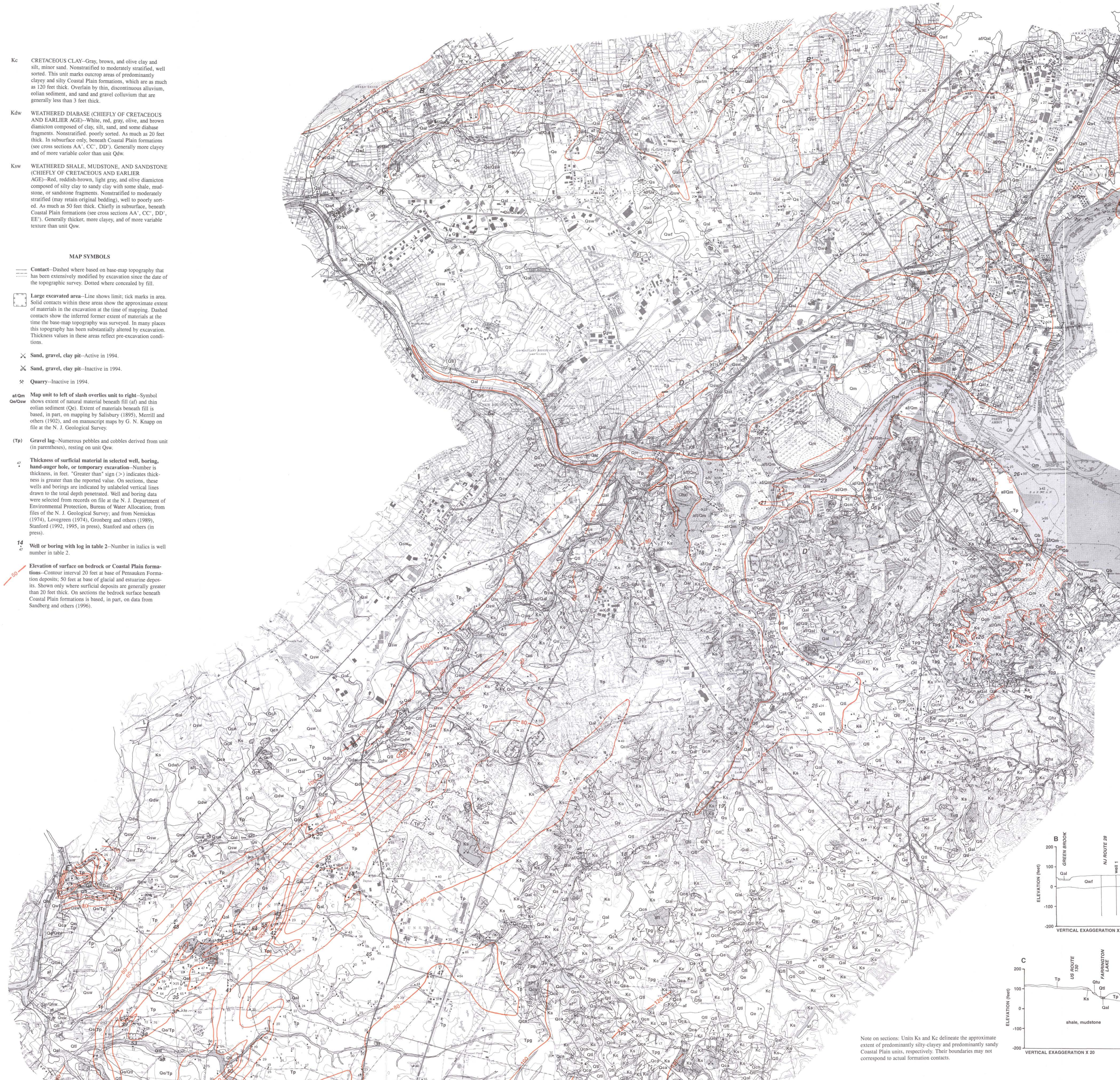
af/Qm Qe/Qsw **Map unit to left of slash overlies unit to right**--Symbol shows extent of natural material beneath fill (af) and thin eolian sediment (Qe). Extent of materials beneath fill is based, in part, on mapping by Salisbury (1895), Merrill and others (1902), and on manuscript maps by G. N. Knapp on file at the N. J. Geological Survey.

(Tp) **Gravel lag**--Numerous pebbles and cobbles derived from unit (in parentheses), resting on unit Qsw.

47 **Thickness of surficial material in selected well, boring, hand-auger hole, or temporary excavation**--Number is thickness, in feet. "Greater than" sign (>) indicates thickness is greater than the reported value. On sections, these wells and borings are indicated by unlabeled vertical lines drawn to the total depth penetrated. Well and boring data were selected from records on file at the N. J. Department of Environmental Protection, Bureau of Water Allocation; from files of the N. J. Geological Survey; and from Nemickas (1974), Lovegreen (1974), Gronberg and others (1989), Stanford (1992, 1995, in press), Stanford and others (in press).

14 47 **Well or boring with log in table 2**--Number in italics is well number in table 2.

50 **Elevation of surface on bedrock or Coastal Plain formations**--Contour interval 20 feet at base of Pensauken Formation deposits; 50 feet at base of glacial and estuarine deposits. Shown only where surficial deposits are generally greater than 20 feet thick. On sections the bedrock surface beneath Coastal Plain formations is based, in part, on data from Sandberg and others (1996).



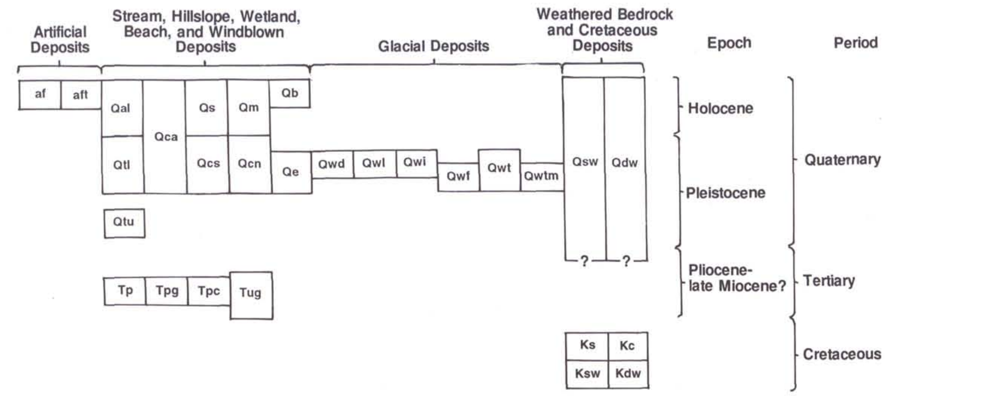
Base from U. S. Geological Survey Arthur Kill, Bound Brook, Freehold, Hightstown, Jamesburg, Keyport, Monmouth Junction, New Brunswick, Perth Amboy, Plainfield, Princeton, and South Amboy quadrangles, photorevised 1970-81.

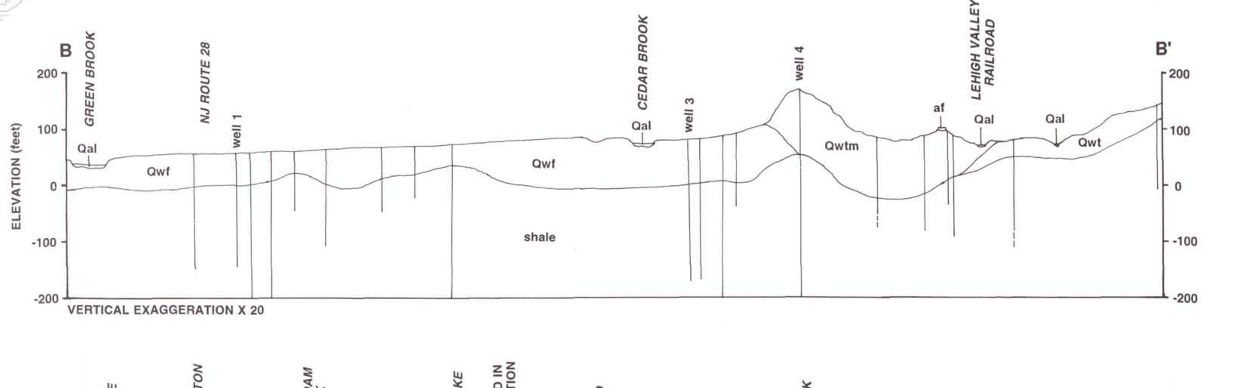
ENVIRONMENTAL GEOLOGY OF MIDDLESEX COUNTY, NEW JERSEY: SURFICIAL GEOLOGY

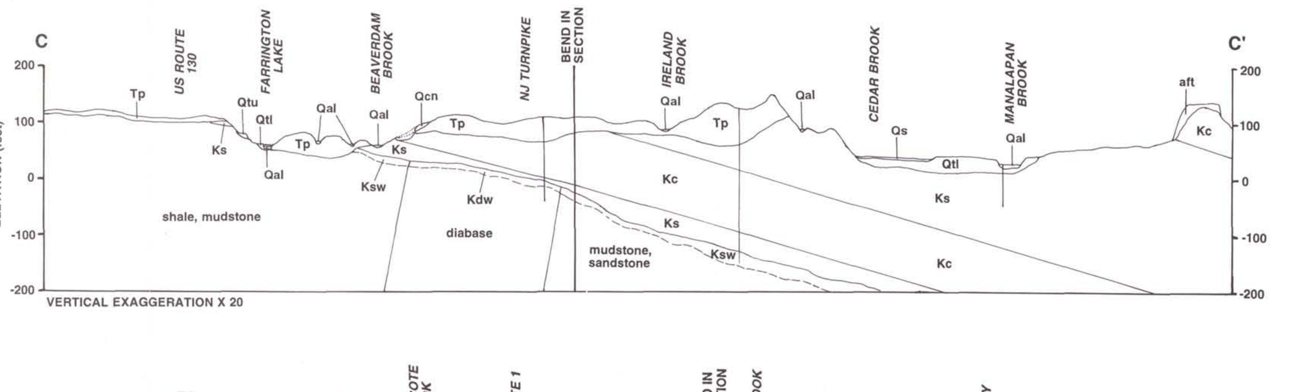
by
Scott D. Stanford
1999

SCALE 1:48000

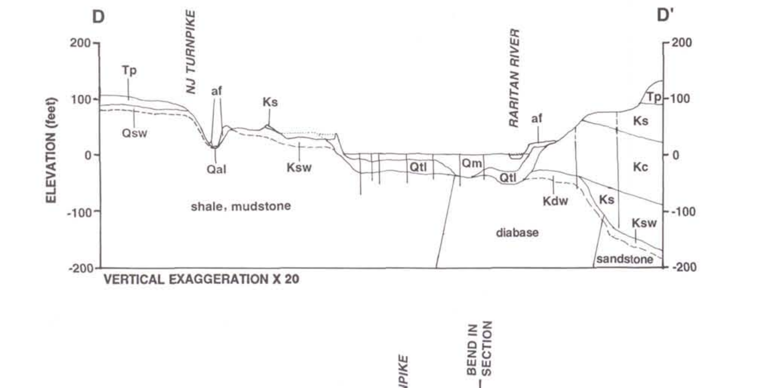
AGE AND CORRELATION OF GEOLOGIC UNITS

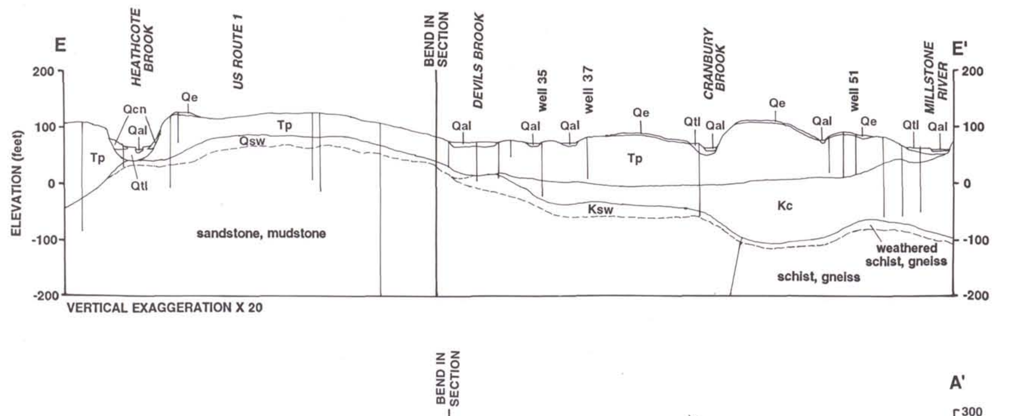


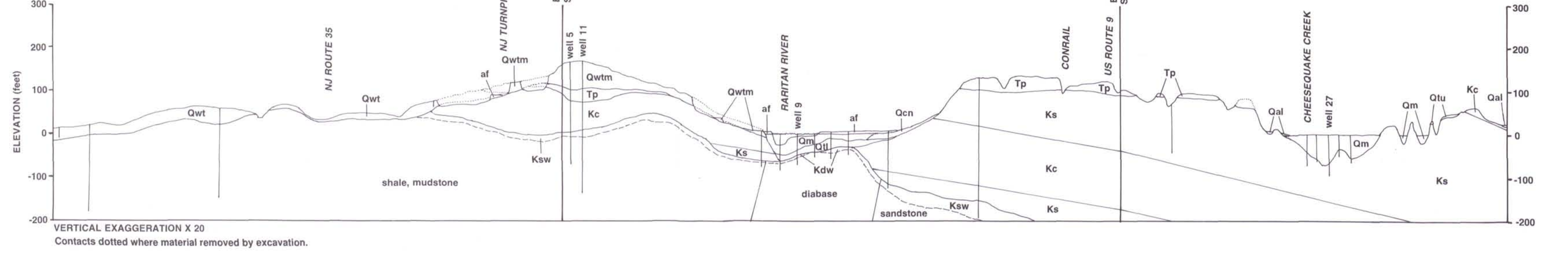




Note on sections: Units Ks and Kc delineate the approximate extent of predominantly silty-clayey and predominantly sandy Coastal Plain units, respectively. Their boundaries may not correspond to actual formation contacts.







Contacts dotted where material removed by excavation.

Table 1.--Hydrogeologic, Engineering, and Resource Characteristics of Surficial Materials in Middlesex County

Map Unit	Symbol	Hydrogeologic Properties[1]	Engineering Properties[2]	Material Resources	Associated Agronomic Soils[3]
ARTIFICIAL FILL	af	Variable depending on material and degree of compaction, but generally moderately to highly permeable. Some fill may contain ground-water contaminants.	Fill containing wood, organic debris, or trash, is subject to local collapse as the fill material decays. Steep slopes along edges of fill areas are subject to slump or gully erosion, particularly if water drains from the slope or if the slope is subject to stream or wave erosion. The variability of the material and emplacement method in fill result in widely variable strength properties. Fill that overlies estuarine, swamp, and alluvial deposits may be unstable due to low strength of underlying material.	Dredge spoils and highway and railroad fills may be a source of sand and gravel. Some demolition debris may be reclaimable.	Psamments Urban Land
TRASH FILL	aft	Material within trash fill is generally highly permeable, but surface cover material is of low permeability. Potential source of ground-water contamination.	Trash fill is subject to local collapse as fill material decays. Steep slopes are subject to slumping and gully erosion. Strength of material is variable but generally low. Generally unsuitable for permanent structures.	Potential source of methane gas and recyclable materials.	Psamments
BEACH DEPOSITS	Qb	Permeability is very high.	Subject to frequent wave and storm erosion and deposition. High water table. Unsuitable for permanent structures.	Potential source of sand and gravel.	Psamments
ALLUVIUM	Qal	Permeability is variable. Sand and gravel channel deposits are moderately to highly permeable; silt, sand, and clay floodplain deposits are of moderate to low permeability. Subsoil permeability ranges from 0.2 to 6.0 in/hr for fine-grained alluvium and from 6 to 20 in/hr for coarse-grained or peat-rich alluvium. Fine-grained alluvium may impede interchange of water between streams and underlying formations; coarse-grained alluvium and peat readily transmit water.	Subject to regular flooding and bank and channel erosion. High water table; generally saturated to within 1 to 2 feet of the surface. Unsuitable for permanent structures or septic systems. Three samples yielded liquid limits of 29, 32, and 30%, and plasticity indices of 11, 11, and 3%.	Potential minor source of sand, gravel, and peat in some places.	Humaquepts Hammonton Fallsington Manahawkin Rowland Atsion Woodstown Parsippany Elkton Keyport
ALLUVIUM AND COLLUVIUM, UNDIVIDED	Qca	Permeability is variable. Where unit overlies or occurs downstream from units Ks or Tp the deposits are sandy and permeability is moderate to high; elsewhere the deposits are of low to moderate permeability. Subsoil permeability ranges from 0.2 to 20 in/hr.	Generally high water table. Subject to local bank and gully erosion and flooding. Spring seepage present in places, causing soil instability. Generally unsuitable for permanent structures and septic systems.	Potential minor source of sand and gravel.	Elkton Fallsington Hammonton Holmdel Humaquepts
ESTUARINE DEPOSITS	Qm	Permeability is generally low to moderate, although sand, shell hash, and peat layers are moderately to highly permeable. Subsoil permeability ranges from 2 to 20 in/hr. Generally impedes interchange of water between the surface and underlying formations. Excavation and dredging of the deposits may facilitate saltwater intrusion into the underlying formations.	Subject to daily flooding. Saturated to surface. Material is unstable because of abundant organic matter, water content, and lack of compaction. Unsuitable for permanent structures and septic systems.	Potential minor source of peat and clay.	Manahawkin Sulfaquents Sulfhemists
FRESHWATER SWAMP AND MARSH DEPOSITS	Qs	Permeability is generally low although sand and clean peat are moderately permeable. Subsoil permeabilities range from 0.06 to 2.0 in/hr. Generally impedes interchange of water between the surface and underlying formations.	Subject to flooding. High water table; generally saturated to within 1 to 2 feet of the surface. Material is unstable because of abundant organic matter, high water content, and lack of compaction. Unsuitable for permanent structures or septic systems. Estimated liquid limits range from 18 to 41%, plasticity index ranges from non-plastic to 20%.	Potential source of peat. Generally, peat is too thin and impure for commercial exploitation.	Manahawkin Fallsington Mullica Parsippany
LOWER STREAM TERRACE DEPOSITS	Qtl	Permeability is moderate to very high. Subsoil permeability ranges from 0.06 to 20 in/hr. Barksdale and others (1943, p. 40) report hydraulic conductivity measurements (determined using laboratory methods) on 24 samples from unit Qtl in the Old Bridge-Runyon area. They range from 27 to 138 ft/d and average 54 ft/d (converted from coefficient of permeability values). Readily transmits water to underlying formations. Thin beds of gravel are generally more abundant near the base of the unit; these may be zones of lateral ground-water movement if the underlying material is of low permeability.	May be subject to rare flooding and high water table in places. Generally suitable for structures. Locally high water table may limit use of septic systems. Tests on 16 samples showed that 8 were non-plastic and had non-determinable liquid limits. The other 8 showed liquid limits ranging from 20 to 46%, with an average of 30%. Plasticity indices ranged from 3 to 18%, with an average of 8%.	Minor source of sand and gravel. Sand may require washing to remove silt and glauconite.	Klej Evesboro Hammonton Keyport Dunellen Lansdowne
GLACIAL LAKE-BOTTOM DEPOSITS	Qwl	Low to very low permeability. Measured hydraulic conductivity for similar material elsewhere in New Jersey is on the order of 10^{-5} ft/d (Vecchioli and others, 1962). Impedes movement of ground water into underlying formations.	Occurs in low areas, so subject to periodic inundation. High water table. Generally unsuitable for septic systems. Generally suitable for structures. Estimated liquid limit ranges from 20 to 30%; plasticity index ranges from 5 to 15%.	Potential minor source of clay.	Haledon, silt loam variant
GLACIAL DELTA DEPOSITS, GLACIAL STREAM DEPOSITS	Qwd, Qwf	Very high to high permeability. Measured hydraulic conductivities for similar material elsewhere in New Jersey are on the order of 10 to 10^2 ft/d (Stanford and Witte, in press). Subsoil permeability ranges from 0.06 to >6 in/hr. Readily transmit water into underlying formations. Where these materials exceed 50 feet in thickness they may provide domestic and community water supplies. A community- supply well yielding 1600 gpm (well 56, table 2) was completed in unit Qwf. Wells in bedrock aquifers overlain by these materials are generally more productive than wells drawing from uncovered bedrock (Barksdale and others, 1943, p. 54). This relationship indicates that Qwd and Qwf store and release water into the underlying bedrock under pumping conditions.	Low-lying areas of the deposits adjacent to units Qal and Qs may be subject to rare flooding and high water table. Generally suitable for structures and septic systems. Areas of high permeability may not be able to sufficiently attenuate effluent and so may be unsuitable for septic systems. Of 13 samples, 9 were non-plastic and had non-determinable liquid limits; 4 showed liquid limits of 27, 22, 19, and 26% and plasticity indices of 10, 4, 2, and 3%.	Potential source of sand and gravel.	Dunellen Haledon Nixon Boonton
GLACIAL ICE-CONTACT DEPOSITS	Qwi	Moderate to high permeability. Transmits water readily to underlying formations.	Suitable for structures and septic systems. One sample showed a liquid limit of 32% and plasticity index of 6%.	Potential minor source of sand and gravel.	Boonton
TILL, TILL OF THE TERMINAL MORAINE	Qwt, Qwtm	Moderate to low permeability. Small inclusions or lenses of sand and gravel may be of moderate to high permeability but they generally are not continuous or connected. Subsoil permeability ranges from 0.06 to 0.6 in/hr. Slows infiltration of water to underlying formations.	Fine-grained and low-lying parts of the deposits may have high water tables. Small basins on the surface of unit Qwtm may be subject to periodic inundation. Presence of boulders may hinder excavation. Otherwise, generally suitable for structures and septic systems. Liquid limits determined on 32 samples range from 16 to 36% and average 26%. Plasticity indices for the same samples range from 0 to 19% and average 7%.	Little to no resource potential.	Boonton Haledon
EOLIAN DEPOSITS	Qe	Moderate to high permeability. Subsoil permeability ranges from 2 to 20 in/hr. Readily transmits water to underlying formations. Where Qe is thick and overlies material of low permeability, ground water may travel laterally along the basal contact.	Low-lying parts of the deposits adjacent to units Qal and Qs may be subject to rare flooding and have high water tables. Areas of high permeability may not sufficiently attenuate effluent and so may be unsuitable for septic systems. Where deposits are thin and overlie low-permeability material, high water tables may be present, and septic systems may be unsuitable. Otherwise, generally suitable for structures and septic systems. Of four samples, two were nonplastic and had non-determinable liquid limits, two had liquid limits of 21 and 19%, and plasticity indices of 7 and 2%.	Minor source of sand. May require washing to remove silt and glauconite. Formerly, fine-grained parts of the unit provided molding sand.	Dunellen Ellington Klej Hammonton Atsion
UPPER STREAM TERRACE DEPOSITS	Qtu	Moderate to high permeability. Subsoil permeability ranges from 0.06 to 20 in/hr. Transmits water to underlying formations. Where Qtu overlies material of low permeability, water may move laterally along the basal contact.	Where deposits are in low-lying areas and where they are thin and overlie impermeable material (for example, in the southernmost part of the county around Bergen Mills), they may have high water tables and be unsuitable for septic systems. Otherwise, generally suitable for structures and septic systems. Of 6 samples tested, three were non-plastic and had non-determinable liquid limits, and 3 showed liquid limits of 33, 33, and 46% and plasticity indices of 12, 8, and 18%.	Potential minor source of sand and gravel. May require washing to remove glauconite and silt.	Woodstown Shrewsbury Fallsington Downer Nixon
SHALE COLLUVIUM	Qcs	Low permeability. Subsoil permeability ranges from 2 to 6 in/hr. Impedes movement of water into underlying formations.	May have high water table. May be subject to gully and bank erosion. Spring seepage present in places, causing soil instability and limiting suitability for structures. Generally unsuitable for septic systems. No measured liquid limits or plasticity indices, but likely similar to unit Qsw.	Little to no resource potential.	Klinesville
SAND AND GRAVEL COLLUVIUM	Qcn	Moderate to high permeability. Subsoil permeabilty ranges from 0.6 to 20 in/hr. Transmits water to underlying formations. Where Qcn overlies material of low permeability water may move laterally along the basal contact.	May have high water table, limiting suitability for septic systems in places. Spring seepage present in places, causing soil instability and limiting suitability for structures. Estimated liquid limits are less than 20%; estimated plasticity indices range from non-plastic to 13%.	Potential minor source of sand and gravel. May require washing to remove glauconite and weathered feldspar.	Woodstown Matapeake Mullica Hammonton
WEATHERED SHALE, MUDSTONE, AND SANDSTONE	Qsw, Ksw	Low to moderate permeability. Permeability is low on shale and mudstone bedrock and moderate on sandstone bedrock. Subsoil permeability ranges from 0.06 to 6.0 in/hr. Generally impede flow of water into underlying formations.	Where material is of low permeability septic systems may be unsuitable. Generally suitable for structures. Of 14 samples tested, one was non-plastic and had a non-determinable liquid limit; the others had liquid limits ranging from 19 to 51% and averaging 31% and plasticity indices ranging from 2 to 19% and averaging 10%.	Unit Qsw is a potential minor source of clay where it is formed from shale bedrock, although it generally contains shale fragments, pebbles, silt, and sand. Unit Ksw (the "Raritan fire and potters' clay" of Cook, 1878, and Ries and others, 1904) was formerly an important source of clay for pottery and brickmaking. It is still a potential source of high-quality clay.	Klinesville Reaville Ellington Lansdowne Elkton
WEATHERED DIABASE	Qdw, Kdw	Low permeability. Subsoil permeability for unit Qdw ranges from 0.06 to 6.0 in/hr. Generally impede flow of water into underlying formations.	Septic systems may be unsuitable due to low permeability. Generally suitable for structures. Material may include large boulders, or may be thin over unfractured, massive diabase bedrock, possibly requiring explosives for excavation. Three samples showed liquid limits of 34, 41, and 40% and plasticity indices of 14, 14, and 21%.	Unit Qdw is a potential minor source of clay, although it generally contains diabase fragments, pebbles, silt, and sand. Unit Kdw occurs in the subsurface only and has little to no resource potential.	Mount Lucas Watchung Keyport Woodstown
PENSAUKEN FORMATION	Tp	Moderately to highly permeable. The uppermost 5 to 10 feet of the deposit over much of the outcrop area is significantly less permeable than at depth because of accumulation of silt and clay in the soil zone. The basal 5 to 15 feet of the deposits, particularly where it is thickest, is generally a coarse gravel and so is is more permeable than the overlying material. In places, however, this zone is cemented with iron oxide compounds, forming ironstone masses as much as 3 to 4 feet thick and 10 feet in diameter. These masses will impede water movement. Once water moves past the upper soil zone it is readily transmitted to underlying formations. If the underlying material is of low permeability water may move laterally along the basal contact. Subsoil permeability ranges from 0.6 to 20 in/hr. Three samples from the Old Bridge-Sayreville area yielded laboratory-determined hydraulic conductivity values of 18, 29, and 29 ft/d (Barksdale and others, 1943, p. 41). The Pensauken is a domestic aquifer in the southern part of the county where it exceeds 50 feet in thickness (fig. 5). Driller's records of 15 domestic wells here, most of which are screened in the gravelly, lowermost 10 feet of the deposit, have yields ranging from 10 to 150 gpm and averaging 51 gpm (see table 2).	Generally suitable for structures and septic systems. In low-lying areas adjacent to units Qs and Qal, or where the unit is thin over low-permeability material, high water tables may limit use of septic systems. Small basins on the surface of this deposit may be subject to periodic inundation. Of 36 tested samples, 6 were non-plastic and had non-determinable liquid limits; in the others, liquid limit ranged from 17 to 36% and averaged 23%. Plasticity indices ranged from 2 to 18% and averaged 6%.	An important source of sand and pebble gravel. Sand may require washing to remove weathered feldspar, disseminated clay and silt, and glauconite. Gravel may include a trace to 1 or 2% of decomposed to partially decomposed mudstone, sandstone, gneiss, or schist clasts, which may need to be separated. Sand and gravel may be cemented with iron compounds.	Sassafras Downer Woodstown Nixon Fallsington Fort Mott
PENSAUKEN FORMATION, GLAUCONITIC PHASE	Tpg	Moderately to highly permeable. Subsoil permeability ranges from 0.6 to 20 in/hr. Will transmit water to underlying formations.	Generally suitable for structures and septic systems. In low-lying areas adjacent to units Qs and Qal, or where the unit is thin over low-permeability material, high water tables may limit use of septic systems. Of 10 tested samples, 3 were non-plastic and had non-determinable liquid limits; in the others, liquid limit ranged from 21 to 46% and averaged 32%, plasticity indices ranged from 0 to 15% and averaged 9%.	Minor source of sand and pebble gravel. Sand may require washing to remove glauconite, silt, and minor weathered feldspar.	Sassafras Woodstown Klej
PENSAUKEN FORMATION, CLAY PHASE	Tpc	Low to very low permeability. Impedes flow of water to underlying formations. Interbedded with unit Tp northeast of Plainsboro. May occur elsewhere within Tp in the subsurface, although it is not widely reported in records of wells and borings.	May be unsuitable for septic systems due to low permeability. Suitable for structures.	Minor source of clay. Clay may contain organic matter, sand, and silt.	Sassafras Woodstown
UPLAND GRAVEL	Tug	Highly permeable. Subsoil permeability ranges from 6.0 to 20 in/hr. Readily transmits water into underlying formations. May be locally cemented into ironstone, which may reduce permeability.	Generally suitable for structures and septic systems. Areas of high permeability, where Tug overlies high permeability Cretaceous sand, may not be able to sufficiently attenuate effluent and so may be unsuitable for septic systems.	Minor source of sand and gravel. May be cemented with iron compounds.	Evesboro
CRETACEOUS SAND	Ks	Very high to high permeability. Subsoil permeability is 0.6 to 20 in/hr. Readily transmits water into underlying formations. Locally, interbedded silt and clay may produce perched water tables and impede vertical flow. Map unit marks outcrop area of the Farrington Sand member of the Raritan Formation, and sand of the Magothy, Englishtown, and Wenonah Formations. Where thick enough, these units are aquifers. Hydraulic conductivities of these aquifers, as determined from 27 aquifer tests, range from 35 to 250 ft/d and average 112 ft/d (Pucci and others, 1989). Hydraulic conductivities determined using laboratory methods on 33 samples from the Farrington, Magothy, and Englishtown sands range from 0.075 to 527 ft/d and average 112 ft/d (Barksdale and others, 1943). For a detailed discussion of these aquifers, see Pucci and others (1994).	Generally suitable for structures and septic systems. Areas of high permeability may not be able to sufficiently attenuate effluent and so may be unsuitable for septic systems. In low-lying areas adjacent to units Qal and Qs, may have high water table and be unsuitable for septic systems and structures. Old pit walls and steep natural slopes are subject to gully erosion, particularly where water discharges atop clay beds. Five tested samples were non-plastic and had non-detectible liquid limits.	Major source of sand. May require washing to remove lignite, mica, clay, and glauconite.	Atsion Evesboro Lakehurst Fort Mott Lakewood Phalanx
CRETACEOUS CLAY	Kc	Low to very low permeability. Subsoil permeability less than 2 in/hr. Impedes movement of water into underlying formations. Locally, interbedded sand may increase permeability and permit horizontal flow. Jointing within clay units may also increase permeability and increase vertical water flow. Map unit marks outcrop area of the Woodbridge Clay member of the Raritan Formation and clay and silt of the Magothy, Cheesequake, Merchantville, and Woodbury Formations. These are all semi-confining units. The vertical hydraulic conductivity of these units, as estimated by hydrogeologic model results and laboratory tests on core samples, range from 4.1×10^{-6} to 0.47 ft/d, but are more generally in the 10^{-5} to 10^{-4} ft/d range (Nichols, 1977; Pucci and others, 1994). For a detailed discussion of these units, see Pucci and others (1994).	Low permeability and high water table severely restricts use of septic systems. Old pit walls, steep slopes, and streambanks are subject to slump failure, gully erosion, and water seepage. Generally suitable for structures away from the above locations. 12 samples yielded liquid limits ranging from 22 to 64% and averaging 39%, and plasticity indices ranging from 3 to 31% and averaging 13%.	Major source of clay. Was formerly mined for pottery and brickmaking in Woodbridge, Perth Amboy, Edison, East Brunswick, South River, Sayreville, South Amboy, and Old Bridge. Includes the Woodbridge Clay, South Amboy Fire Clay, and Amboy Stoneware Clay of Cook (1878) and Ries and others (1904). Presently mined for landfill and waste-site cover. May require processing to remove lignite, pyrite, iron concretions, mica, sand, and glauconite.	Elkton Keyport Klej

Footnotes for Table 1:

[1]Permeability is a property of a material, and describes the ability of that material to transmit any fluid (gas or liquid). It is units of length[2] (here in ft^2). Hydraulic conductivity describes the ability of a material to transmit water, and is more commonly used in hydrogeologic research. It is units of length/time (here, in ft/d). The terms "very high, high, moderate, low, very low" refer to the following estimated permeability ranges for materials beneath the soil zone:

very high= $k>10^{-9}$ ft^2
high=$10^{-9}>k>10^{-11}$ ft^2
moderate=$10^{-11}>k>10^{-13}$ ft^2
low=$10^{-13}>k>10^{-15}$ ft^2
very low=$k<10^{-15}$ ft^2

These estimates are based on comparison of known textural properties of the materials to published permeability values of similar materials (Davis, 1969; Freeze and Cherry, 1979).

The term "subsoil permeability" refers to the estimated field permeability values in the lower soil zone (generally at depths of 20 to 60 inches) reported by Powley (1987) for the agronomic soils associated with the surfical geologic materil unit. These values are reported in inches per hour (in/hr), and represent the number of inches per hour that water moves downward through saturated soil. For sand and gravel materials, soil formation generally lowers permeability. Thus, these materials will generally have greater permeability below the soil zone. For clay and silt materials, soil formation generally increases permeability. Thus, these materials will generally have lower permeability below the soil zone.

[2]Determinations of soil stability, septic suitability, flood susceptibility, and extent of wetlands, must be done on a site-specific basis. The descriptions here provide a preliminary assessment of conditions that may be encountered. Values for liquid limit and plasticity index are from Holman and Jumikis (1953). Estimated ranges for liquid limit and plasticity index are for associated agronomic soils and are from Powley (1987). The liquid limit of a soil is the lowest water content, expressed as a weight percentage, at which the soil behaves as a liquid. The plasticity index is the difference between the liquid limit and the plastic limit (the plastic limit is the lowest water content, expressed as a weight percentage, at which a soil behaves as a plastic material).

[3]These associations were determined by comparing the mapped extent of the soils in Powley (1987) with the mapped extent of the surficial materials on sheet 1. Some minor associated soils are not listed.

Table 2.--Selected well and boring logs

Well No.	Identifier[1]	Depth (feet)	Description (Driller's Log[2])
1	25-27396	0-60	sand and gravel (Qwf)
		60-200	shale
2	25-8170	0-80	sand (Qwf)
		80-125	shale
3	25-23756	0-70	sand and gravel (Qwf)
		70-75	clay (Qwl or Qsw)
		75-250	red rock
4	25-6839	0-109	red clay and stones (Qwtm)
		109-600	red shale rock
5	26-203		log by M. E. Johnson, N. J. Geological Survey, abbreviated here
		0-75	red clayey sand and gravel (Qwtm)
		75-100	yellow brown arkosic clayey sand and gravel (Tp)
		100-160	white, gray, buff clay and sand (Kc)
		160-235	red shale
6	26-5316		abbreviated log
		0-14	fill (af)
		14-18	brown peat (Qm)
		18-55	very dense red brown sand, trace silt, some gravel and cobbles (Qwt)
		55-73	very dense light gray medium-to-fine sand, trace fine gravel (Ks)
		73-96	hard gray to green clay, trace weathered diabase (Kdw)
7	NJGS files	0-48	silt (Qm)
		48-60	gray sand (Qm)
		60-65	coarse sand (Qwf)
		65-90	coarse brown sand (Qwf)
		90-95	clay, sand (Qwtm)
		95-105	hardpan (Qwtm)
		105-110	brown sand (Ks)
		110-111	fine gray sand and clay (Ks)
		111-117	coarse and fine sand (Ks)
		117-119	beach sand and clay (Ks)
8	N 26-41-275	0-69	silt (Qm)
		69-92	sand, rock or boulder at base (Qwf)
		92-100	clay (Kc)
		100-106	sand (Ks)
		106-125	mixed clay (Kc or Kdw)
		at 125	trap rock (diabase)
9	NJGS files	0-4	water
		4-39	organic silt with shells (Qm)
		39-49	gray sand, some silt and gravel (Qwf)
		49-56	decomposed rock (Kdw)
		56-66	rock (diabase)
10	26-320	0-12	red sandy clay and gravel (Qwt)
		12-22	red hardpan (Qwt)
		22-42	hard red clay with streaks of white clay (Qsw)
		42-102	red sand rock
11	26-1040		log by F. J. Markewicz, N. J. Geological Survey, abbreviated here
		0-60	reddish clayey sand and gravel (Qwtm)
		60-96	yellowish brown arkosic sand (Tp)
		96-157	gray lignitic micaceous clay, some sand (Kc)
		157-170	red clay (Ksw)
		170-302	red shale
12	N 26-32-411	0-6	gray clay and roots, medium-grained red sand (Qm)
		6-13	tough red silty clay (Qwt)
		13-19	fine-grained rusty red sand with shale pebbles (Qwt)
		19-21	slightly sandy and micaceous red shale
13	26-2082		log by Russell Mayer, N. J. Geological Survey, abbreviated here
		0-40	reddish brown clay with rounded to subangular quartz grains and pebbles, also shale and sandstone pebbles (Qwt)
		40-60	pale yellow fine sand and silt (Ks)
		60-80	light gray clayey sandy silt (Kc)
		80-100	dark gray lignitic sand and silt (Ks)
		100-140	light gray fine-to-medium sand (Ks)
14	boring on figure 12 in Lovegreen (1979)	0-20	water
		20-35	organic silt and shells (Qm)
		35-47	brown and gray sand (Qwf or Qal)
		47-52	gray laminated silt and clay with lignite (Kc)
		52-60	green, gray, yellow mottled desiccated clay (Kdw)
		at 60	diabase
15	N 25-44-539	0-8	water
		8-14	sand, broken shale (Qm and Qal)
		at 14	shale
16	25-11774		log by H. F. Kasabach, N. J. Geological Survey
		0-5	fill
		5-30	brown to gray silty clay with wood and lignite (Qm)
		30-40	brownish gray silty fine-to-medium sand with subrounded to subangular grains (Qtl)
		40-54	light gray fine-to-very coarse sand, rose quartz and a few chert grains (Ks)
		54-68	white to green clay (Kdw)
		68-74	diabase
17	SC--12H	0-30	yellow to light gray fine-to-coarse sand and gravel (Tp)
		30-102	white to light gray fine-to-coarse sand (Ks)
		102-109	compact gray to black clay (Ksw)
		109-126	hard, gray baked shale
18	SC--54	0-4	black to brown peaty clay (Qal)
		4-15	yellow clayey sand and small pebbles (Qtl)
		15-74	yellow to light gray fine-to-medium sand, a little lignite and clay (Ks)
19	well 23-131, Gronberg and others (1989)	0-15	yellow and brown sand and gravel (Qtl)
		15-80	white fine-to-coarse sand, some interbedded white and gray clay (Ks)
		80-87	blue tough clay (Kc)
20	SC--E17	0-18	brownish gray clay (Qm)
		18-29	yellowish brown clayey sand and gravel (Qtl)
		29-59	yellow to light gray arkosic fine-to-coarse sand (Ks)
21	SC--25E	0-20	soft gray clay and plant roots (Qm)
		20-32	medium sand, gray clay, and plant roots (Qm)
		32-41	brown fine-to-medium sand (Qtl)
		41-50	gray and brown slightly clayey medium sand (Qtl)
		50-54	disintegrated trap (Kdw)
		54-56	coarse-grained trap (diabase)
22	25-29613	0-8	sand and silt fill
		8-37	brown, red-brown, light gray sand, some gravel; gravel includes subrounded quartz, shale, and argillaceous rock fragments (Qtl)
23	well 23-848, Gronberg and others (1989)	0-12	black organic silt, trace gravel (af over Qm)
		12-18	gray fine-to-medium sand, trace silt and gravel (af over Qm)
		18-50	dark gray organic silt, trace sand and shells (Qm)
		50-60	dark gray sand, trace gravel and silt (Qtl)
		60-62	gray and white sand, some clay--weathered rock (Kdw)
		62-67	gray and white bedrock--diabase, gabbro
24	NJGS files	0-3	gray brown silty clay (Qm)
		3-13	gray silty clay (Qm)
		13-20	peat (Qm)
		20-24	brown fine silty sand (Qtl)
		24-29	green brown medium-to-fine silty sand (Qtl)
		29-41	gray silty clay (Kc)
25	SC--29	0-24	rusty brown sand and gravel (Qtl)
		24-64	white-to-yellow fine sand (Ks)
26	NJGS files	0-9	water
		9-29	black silt (Qm)
		29-70	soft gray clay (Qm)
		70-99	soft gray clay, some peat (Qm)
		99-100	gray very fine sand and dry black clay (Kc)
27	NJGS files	0-7	meadow bog and soft blue clay (Qm)
		7-70	medium soft blue clay (Qm)
		70-94	gray fine sand, little gravel (Ks)
28	SC--180	0-19	brown to gray clay and plant roots (Qm)
		19-43	soft gray clay with one or two shells (Qm)
		43-56	fine gray sand (Ks)
29	28-10261		abbreviated log
		0-64	orange brown silty sand and gravel (Tp)
		64-78	yellow brown to dark gray silty clay (Kc)
		78-95	gray silty and clayey sand (Ks)
		95-103	yellow-red-brown sand (Ks)
		103-107	saprolite (Ksw)
		107-112	green shale
30	28-2404	0-12	sand and gravel (Tp)
		12-25	muddy sand and gravel (Tp)
		25-50	sand and gravel (Tp)
			screened 45-48, yield 25 gpm
31	28-5603	0-60	yellow sand and gravel (Tp)
			screened 57-60, yield 25 gpm
32	28-2414	0-6	brown clay and gravel (soil in Tp)
		6-54	brown to yellow sand and gravel (Tp)
			screened 45-48, yield 10 gpm
33	N 28-2-887		abbreviated log
		0-16	yellow clay and gravel (Qwf)
		16-25	blue muddy clay (Qwf)
		25-43	yellow to gray clayey sand and gravel (Qwf)
		43-150	gray to red shale
34	28-927	0-74	sand (Tp)
		74-120	argillite
		120-145	black rock
35	NJGS files	0-10	gray silty to sandy clay (Tp)
		10-65	sand, generally orange-tan, mostly coarse-grained, contains gravel, pebbles, cobbles; silty to clayey (Tp)
		65-100	bluish gray sandy silty clay to clayey sand (Kc)
36	NJGS files	0-14	brownish gray sandy silt-clay (soil in Tp)
		14-79	orange-brown fine-to-medium sand, silty to clayey, contains a little gravel (Tp)
		79-81	dark dull red clay, very hard (Kc)
37	28-7792	0-5	brown silty sandy clay and gravel (Tp)
		5-77	brown coarse-to-medium fine sand (Tp)
			screened 55-60, yield 60 gpm
38	28-1015		log by F. J. Markewicz, N. J. Geological Survey, abbreviated here
		0-68	yellowish brown fine-to-coarse sand, slightly micaceous and glauconitic, and pebble gravel. Pebbles are mainly subangular to rounded quartz and chert, some shale (Tp)
			screened 58-68, yield 75 gpm
39	28-6143	0-93	yellow sand and gravel (Tp)
		93-101	brown and blue clay (Kc or Qsw)
		101-140	red, gray, green sandstone and shale
40	SC--102		abbreviated log
		0-14	clayey yellow-brown sand and gravel (Tp)
		14-90	fine-to-coarse brown sand with a little gravel (Tp)
		90-143	micaceous, lignitic gray clay (Kc)
41	28-6056	0-71	yellow sand and gravel (Tp)
			screened 68-71, yield 40 gpm
42	28-18561		abbreviated log
		0-100	brown, light brown, gray medium-to-coarse sand (Tp)
			screened 60-90, yield 150 gpm
43	28-9289		abbreviated log
		0-4	brown clay and gravel (Tp)
		4-60	brown medium-to-coarse sand, some gravel (Tp)
			screened 50-55, yield 60 gpm
44	28-2440		abbreviated log
		0-25	hard packed sand and gravel (Tp)
		25-58	muddy sand and gravel (Tp)
		58-65	sand and gravel (Tp)
			screened 54-57, yield 12 gpm
45	SC--82		abbreviated log
		0-10	light gray to yellow clayey sand and gravel (Tp)
		10-53	yellow micaceous clayey sand and gravel (Tp)
		53-95	brownish gray clay (Kc)
		95-155	brown and gray micaceous very fine clayey sand (Ks)
46	28-4589		log by Ian Walker, N. J. Geological Survey, abbreviated here
		0-50	yellow sand (Tp)
		50-140	light tan to light yellow fine-to-coarse sand, a little lignite (Ks)
		140-223	gray to white clay, some siderite and pyrite (Kc)
		223-315	gray to yellow coarse sand with chert and quartz granules (Ks)
		at 315	weathered schist
47	SC--3A		abbreviated log
		0-40	brown arkosic sand and gravel (Tp)
		40-49	brown sand and gravel (Tp)
		49-187	fine light gray micaceous sand to clayey sand (Ks)
48	28-8348	0-7	brown silty sandy gray clay (soil in Tp)
		7-20	red brown silty fine sand with some gravel (Tp)
		20-32	brown coarse-to-medium fine sand (Tp)
		32-60	decomposed rock (Qsw)
		60-65	blue hard rock
49	28-13976		abbreviated log
		0-6	orange medium sand with some clay (soil in Tp)
		6-88	yellow brown, orange brown, red medium-to-coarse sand with some ironstone (Tp)
		88-90	gray and light brown silty clay with some sand (Kc)
			screened 80-90, yield 60 gpm
50	SC--100		abbreviated log
		0-21	brown fine sand and gravel (Qtl)
		21-82	yellow brown clayey arkosic medium sand and gravel (Tp)
		82-128	gray clay (Kc)
51	28-15572	0-3	brown clay (soil in Tp)
		3-22	brown medium-to-fine sand with gravel (Tp)
		22-43	reddish brown medium-to-fine sand (Tp)
		43-55	brown clay with sand (Tp)
		55-78	brown coarse, medium, fine sand (Tp)
		at 78	gray clay (Kc)
			screened 70-78, yield 45 gpm
52	28-15267	0-2	topsoil
		2-15	brown sand with gravel (Tp)
		15-51	reddish brown medium-to-fine sand (Tp)
		51-57	reddish brown coarse, medium, fine sand (Tp)
		57-60	gray clay (Kc)
			screened 51-57, yield 25 gpm
53	28-6950	0-77	yellow sand and gravel (Tp)
		at 77	brown clay (Kc)
			screened 70-75, yield 30 gpm
54	28-13037		abbreviated log
		0-4	brown sandy clay (soil in Tp)
		4-91	fine, medium, and coarse orange brown to red brown sand (Tp)
		91-95	medium to coarse orange brown sand with red shale and trace of mica schists (Tp, possibly over shale bedrock)
			screened 82-90, yield 75 gpm
55	28-13073	0-4	brown sandy clay (soil in Tp)
		4-7	fine-to-medium brown sand with some clay and gravel (Tp)
		7-12	orange clay with fine brown sand (Tp)
		12-30	fine, medium, coarse brown sand and some pieces of fractured rock and gravel (Tp)
		30-60	fine, medium, coarse light brown sand and white sand (Tp)
		60-75	medium-to-coarse brown sand with red shale fragments and gray clay (Tp over Kc)
			screened 65-75, yield 75 gpm
56	25-9603		abbreviated log
		0-18	sandy hardpan with rocks (Qwf)
		18-38	fine sand (Qwf)
		38-40	silty clay (Qwf)
		40-42	fine sand (Qwf)
		42-49	silty clay (Qwf)
		49-70	sandy clay with stones, some sand layers (Qwtm?)
		70-99	fine-to-coarse sand and gravel (Qwf)
		99-100	shale
			screened 80-100, yield 1600 gpm

[1]Numbers of the form xx-xxxx are well permit numbers issued by the N. J. Department of Environmental Protection, Bureau of Water Allocation.

Numbers of the form N xx-xx-xxx are N. J. Atlas Sheet grid locations of entries in the N. J. Geological Survey permanent note collection.

Numbers of the form SC--xxx are borings made for a proposed ship canal in the 1930s. They are on file at the N. J. Geological Survey.

The notation "NJGS files" indicates borings or wells that are on file at the N. J. Geological Survey but that are not entered in the permanent note collection. Most of these borings were made for various construction or dredging projects.

Notations of the form "well 23-131, Gronberg and others (1989)" refer to logs provided in the cited publication.

[2]Inferred map units and comments in parentheses. Unless identified as "abbreviated" the descriptions are as they appear in the original source, except for minor format, spelling, and punctuation changes. Abbreviated logs have been condensed for brevity.

REFERENCES

Anderson, H. R., 1968, Geology and ground-water resources of the Rahway area, New Jersey: N. J. Department of Conservation and Economic Development Division of Water Policy and Supply Special Report 27, 72 p.

Appel, C. A., 1962, Salt-water encroachment into aquifers of the Raritan Formation in the Sayreville area, Middlesex County, New Jersey, with a section on a proposed tidal dam on the South River: N. J. Department of Conservation and Economic Development, Division of Water Policy and Supply Special Report 17, 47 p.

Barksdale, H. C., 1937, Water supplies from the No. 1 Sand in the vicinity of Parlin, New Jersey: N. J. Water Policy Supply Commission Special Report 7, 33 p.

Barksdale, H. C., Johnson, M. E., Baker, R. C., Schaefer, E. J., and DeBuchananne, G. D., 1943, The ground-water supplies of Middlesex County, New Jersey: N. J. State Water Policy Commission Special Report 8, 160 p.

Bowman, J. P., 1966, Petrology of the Pensauken Formation: unpublished Ph.D. thesis, Rutgers University, New Brunswick, N. J., 155 p.

Campbell, M. R., and Bascom, Florence, 1933, Origin and structure of the Pensauken gravel: American Journal of Science, v. 26, no. 153, p. 300-318.

Charles, E. G., Behroozi, Cyrus, Schooley, Jack, and Hoffman, J. L., 1993, A method for evaluating ground-water-recharge areas in New Jersey: N. J. Geological Survey Geological Survey Report GSR 32, 95 p.

Cook, G. H., 1878, Report on the clay deposits of Woodbridge, South Amboy, and other places: Geological Survey of New Jersey, Trenton, N. J., 380 p.

Davis, S. N., 1969, Porosity and permeability of natural materials, in DeWiest, R. J. M., ed., Flow through porous media: New York, Academic Press, p. 54-89.

Davis, W. M., and Wood, J. W., 1890, The geographic development of northern New Jersey: Proceedings of the Boston Society of Natural History, v. 24, p. 365-423.

Drake, A. A., Jr., Volkert, R. A., Monteverde, D. H., Herman, G. C., Houghton, H. F., Parker, R. A., Dalton, R. F., 1996, Bedrock geologic map of northern New Jersey: U. S. Geological Survey Miscellaneous Investigations Map I-2540-A, scale 1:100,000.

Freeze, R. A., and Cherry, J. A., 1979, Groundwater: Englewood Cliffs, N. J., Prentice-Hall, 604 p.

French, M. A., 1996, Ground-water recharge and aquifer recharge potential map for Middlesex County, New Jersey: N. J. Geological Survey Open File Map 21.

Gronberg, J. M., Birkelo, B. A., and Pucci, A. A., Jr., 1989, Selected borehole geophysical logs and drillers' logs, northern Coastal Plain of New Jersey: U. S. Geological Survey Open File Report 87-243, 133 p.

Hasan, Ashgar, Kasabach, H. F., and Malone, J. E., 1969, Water resources of the Sayreville area, Middlesex County, New Jersey: N. J. Department of Conservation and Economic Development, Division of Water Policy and Supply Water Resources Circular 20, 32 p.

Holman, W. W., and Jumikis, A. R., 1953, Engineering soil survey of New Jersey, report number 10, Middlesex County: New Brunswick, N. J., Rutgers University, College of Engineering, Engineering Research Bulletin no. 24, 106 p.

Johnson, D. W., 1931, Stream sculpture on the Atlantic slope: New York, Columbia University Press, 142 p.

Lovegreen, J. R., 1974, Paleodrainage history of the Hudson estuary: New York, Columbia University, unpub. M. S. thesis, 152 p.

Luzier, J. E., 1980, Digital-simulation and projection of head changes in the Potomac-Raritan-Magothy aquifer system, Coastal Plain, New Jersey: U. S. Geological Survey Water Resources Investigations 80-11, 72 p.

MacClintock, Paul, and Richards, H. G., 1936, Correlation of late Pleistocene marine and glacial deposits of New Jersey and New York: Geological Society of America Bulletin, v. 47, p. 289-338.

Martino, R. L., 1981, The sedimentology of the late Tertiary Bridgeton and Pensauken formations in southern New Jersey: New Brunswick, N. J., Rutgers University, unpub. Ph. D. thesis, 299 p.

Merrill, F. J. H., Darton, N. H., Hollick, A., Salisbury, R. D., Dodge, R. E., Willis, B., and Pressey, H. A., 1902, Geologic atlas of the United States, New York City folio: U. S. Geological Survey Geologic Atlas, folio 83, 19 p.

Nemickas, Bronius, 1974, Bedrock topography and thickness of Pleistocene deposits in Union County, New Jersey: U. S. Geological Survey Miscellaneous Investigations Map I-795, scale 1:24,000.

Nichols, W. D., 1977, Digital computer simulation model of the Englishtown aquifer in the northern Coastal Plain of New Jersey: U. S. Geological Survey Open File Report 77-73, 101 p.

Owens, J. P., and Minard, J. P., 1979, Upper Cenozoic sediments of the lower Delaware valley and northern Delmarva Peninsula, New Jersey, Pennsylvania, Delaware, and Maryland: U. S. Geological Survey Professional Paper 1067D, 47 p.

Owens, J. P., Sugarman, P. J., Sohl, N. F., Parker, R. A., Houghton, H. F., Volkert, R. A., Drake, A. A., Jr., Orndorff, R. C., 1995, Geologic map of New Jersey: central sheet: U. S. Geological Survey Open File Report 95-253, 60 p.

Parker, R. A, 1993, Stratigraphic relations of the sedimentary rocks below the Lower Jurassic Orange Mountain Basalt, northern Newark Basin, New Jersey and New York: U. S. Geological Survey Miscellaneous Field Studies Map MF-2208, scale 1:100,000.

Powley, V. R., 1987, Soil survey of Middlesex County, New Jersey: U. S. Department of Agriculture, Soil Conservation Service, 218 p.

Psuty, N. P., 1986, Holocene sea level in New Jersey: Physical Geography, v. 7, no. 2, p. 156-167.

Pucci, A. A., Jr., Gronberg, J. M., and Pope, D. A., 1989, Hydraulic properties of the middle and upper aquifers of the Potomac-Raritan-Magothy aquifer system in the northern Coastal Plain of New Jersey: N. J. Geological Survey Geologic Report Series GRS 18, 74 p.

Pucci, A. A., Jr., Pope, D. A., Gronberg, J. M., 1994, Hydrogeology, simulation of regional ground-water flow, and saltwater intrusion, Potomac-Raritan-Magothy aquifer system, northern Coastal Plain of New Jersey: N. J. Geological Survey Geological Survey Report GSR 36, 209 p.

Ries, Heinrich, Kummel, H. B., and Knapp, G. N., 1904, The clays and clay industry of New Jersey: N. J. Geological Survey Final Report of the State Geologist, v. 6, 548 p.

Salisbury, R. D., 1895, Surface geology--report of progress: N. J. Geological Survey Annual Report for 1894, p. 1-149.

Salisbury, R. D., 1902, The glacial geology of New Jersey: N. J. Geological Survey Final Report, v. 5, 802 p.

Salisbury, R. D., and Knapp, G. N., 1917, The Quaternary formations of southern New Jersey: N. J. Geological Survey Final Report, v. 8, 218 p.

Sandberg, S. K., Hall, D. W., Gronberg, J. M., Groenewold, J. C., and Pasicznyk, D. L., 1996, Geophysical investigation of the Potomac-Raritan-Magothy aquifer system and underlying bedrock in parts of Middlesex and Mercer counties, New Jersey: N. J. Geological Survey Geological Survey Report GSR 37, 33 p.

Stanford, S. D., 1992, Surficial geology of the Bound Brook quadrangle, Somerset and Middlesex counties, New Jersey: N. J. Geological Survey Open File Map 4, scale 1:24,000.

Stanford, S. D., 1993, Late Cenozoic surficial deposits and valley evolution of unglaciated northern New Jersey: Geomorphology, v. 7, p. 267-288.

Stanford, S. D., 1995, Surficial geology of the South Amboy quadrangle, Middlesex and Monmouth counties, New Jersey: N. J. Geological Survey Open File Map 18, scale 1:24,000.

Stanford, S. D., in press, Surficial geology of the Perth Amboy and Arthur Kill quadrangles, Middlesex and Union counties, New Jersey: N. J. Geological Survey Open File Map, scale 1:24,000.

Stanford, S. D., and Harper, D. P., 1991, Glacial lakes of the lower Passaic, Hackensack, and lower Hudson valleys, New Jersey and New York: Northeastern Geology, v. 13, p. 271-286.

Stanford, S. D., and Witte, R. W., in press, Geology of the glacial aquifers of New Jersey: N. J. Geological Survey Geological Survey Report.

Stanford, S. D., Monteverde, D. H., Volkert, R. A., Sugarman, P. J., Brenner, G. J., in press, Geology of the New Brunswick quadrangle, Middlesex and Somerset counties, New Jersey: N. J. Geological Survey Open File Map 23, scale 1:24,000.

Vecchioli, John, Gill, H. E., and Lang, S. M., 1962, Hydrologic role of the Great Swamp and other marshland in upper Passaic River basin: Journal of the American Water Works Association, v. 54, no. 4, p. 695-701.

Walters, J. C., 1978, Polygonal patterned ground in central New Jersey: Quaternary Research, v. 10, p. 42-54.

Wolfe, P. E., 1953, Periglacial freeze-thaw basins in New Jersey: Journal of Geology, v. 61, p. 131-141.

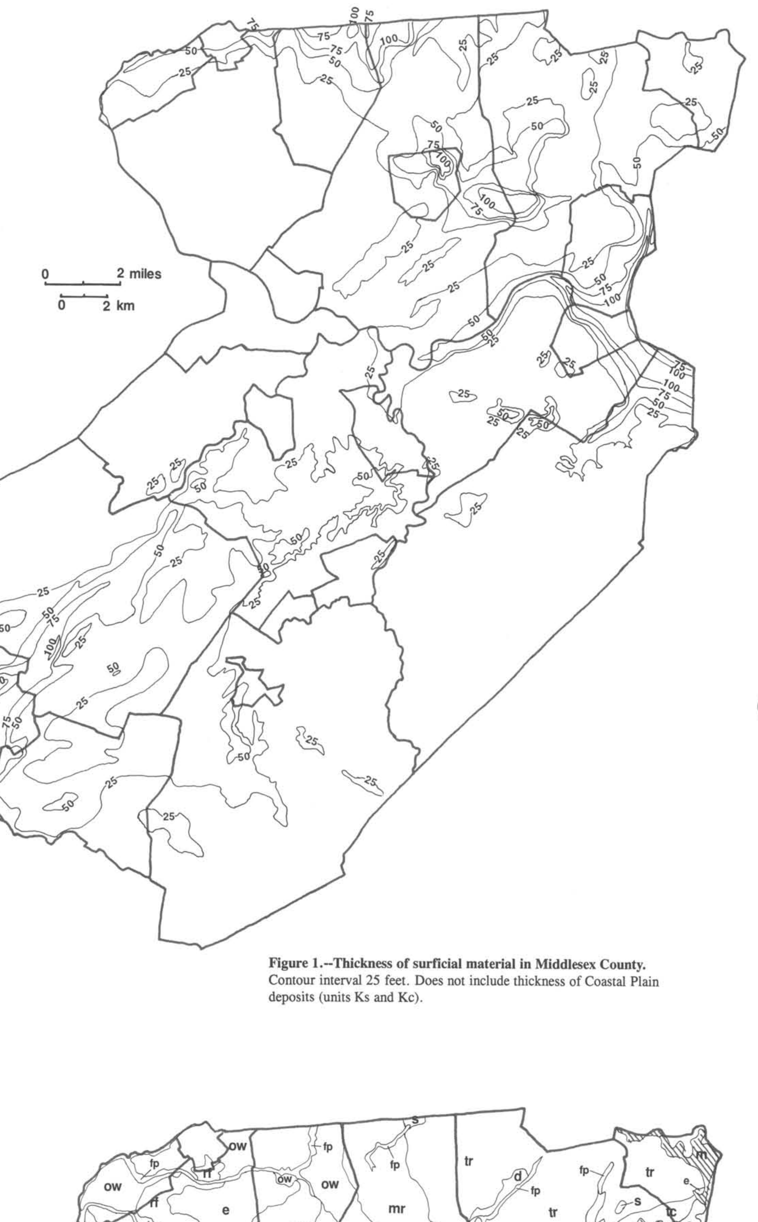


Figure 1.--Thickness of surficial material in Middlesex County. Contour interval 25 feet. Does not include thickness of Coastal Plain deposits (units Ks and Kc).

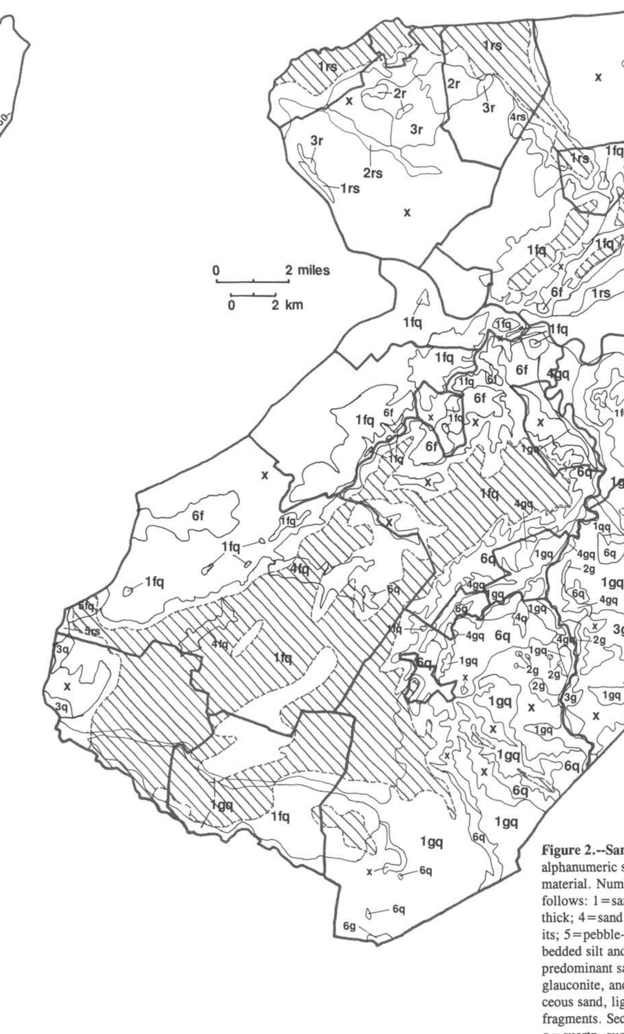


Figure 2.--Sand and gravel resources of Middlesex County. The alphanumeric symbol indicates the texture and composition of the material. Numbers indicate texture and associated information, as follows: 1=sand and pebble gravel; 2=sand; 3=sand, less than 6 feet thick; 4=sand and pebble gravel beneath swamp or estuarine deposits; 5=pebble-to-cobble gravel and sand; 6=sand, with some interbedded silt and clay, of Cretaceous age. First letter indicates the predominant sand mineralogy: f=quartz and feldspar; g=quartz, glauconite, and minor mica; q=quartz, minor mica and, in Cretaceous sand, lignite; r=quartz, shale, sandstone, and other rock fragments. Second letter indicates the predominant gravel lithology: q=quartz, quartzite, minor chert and ironstone; s=quartz, quartzite, shale, sandstone, gneiss. The letter "x" indicates areas without significant sand and gravel. Ruling indicates areas where sand and gravel deposits (excluding Cretaceous sand) are greater than 25 feet thick.

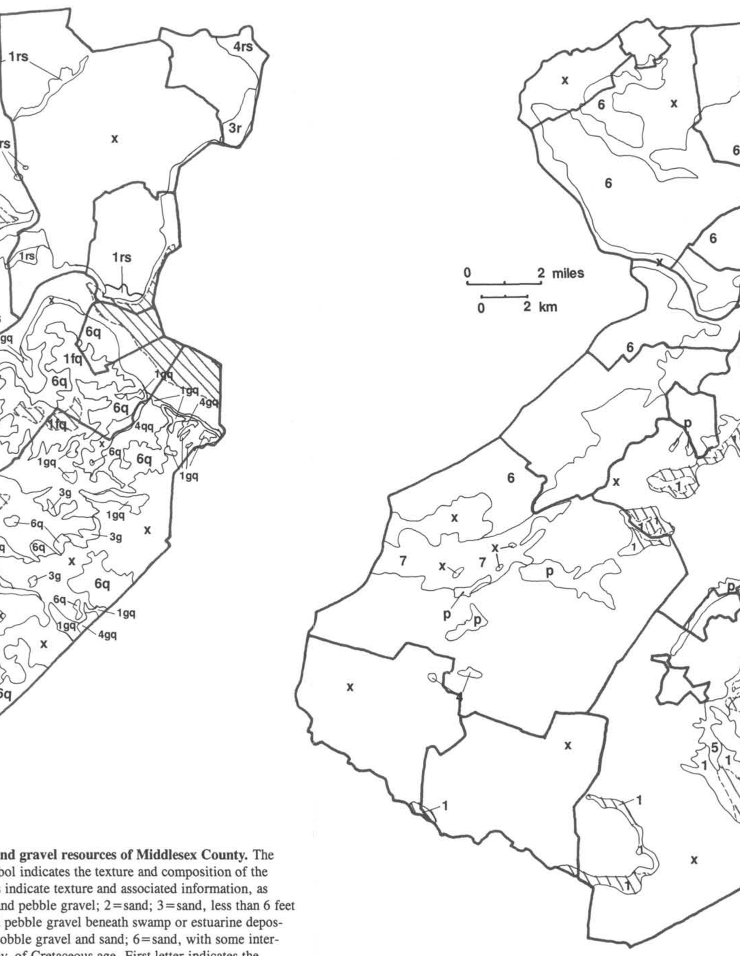


Figure 3.--Clay and peat resources of Middlesex County. The extent of clay deposits at or within 20 feet of the land surface is shown. The deposits are classed from 1 to 6, as follows:
1=Cretaceous clay--Dark gray to white, red, yellow, and pink clay with minor lignite, mica, pyrite, and fine quartz sand. Contains iron concretions, masses and crusts in places. As much as 100 feet thick.
2=Glacial lake-bottom clay--Gray to reddish-brown clay and silt, some fine sand. As much as 15 feet thick.
3=Deeply-weathered shale--Reddish-brown to gray silty clay. As much as 30 feet thick.
4=Clay within the Pensauken Formation--Dark gray to black silty clay with some organic matter. As much as 15 feet thick.
5=Cretaceous clay and silt--Olive brown, brown, and gray clay and silt with, in places, some glauconite, lignite, pyrite, and minor sand. Contains iron concretions forming masses and crusts. As much as 50 feet thick.
6=Weathered shale--Reddish-brown to gray clayey silt with shale and mudstone fragments and some quartz and quartzite pebbles. Generally less than 10 feet thick.
7=Weathered diabase--Reddish-yellow, yellow, and brown silty clay to clayey sandy silt with diabase fragments and some quartz and quartzite pebbles. Generally less than 10 feet thick.

Ruling shows areas where clay is covered by surficial materials less than 20 feet thick. Outcropping clay is unruled. The letter "p" indicates potential sources of peat. Many small peat deposits cannot be shown at this scale. Some of these small deposits are indicated by unit Qs on the geologic map (sheet 1). Peat is generally less than 5 feet thick, and may include organic-rich silt, sand, and clay. The letter "x" indicates areas without significant clay or peat resources.

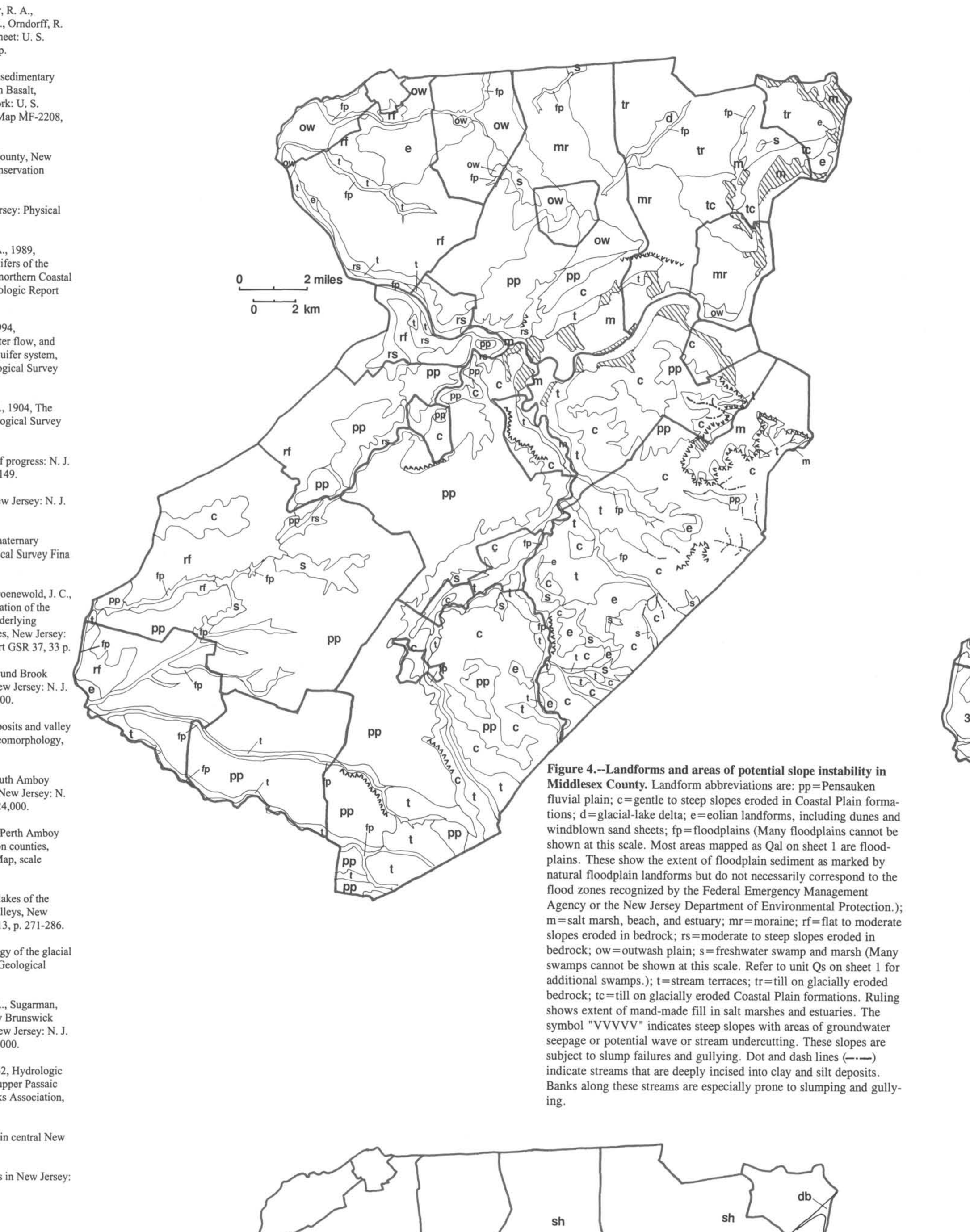


Figure 4.--Landforms and areas of potential slope instability in Middlesex County. Landform abbreviations are: pp=Pensauken fluvial plain; c=gentle to steep slopes eroded in Coastal Plain formations; d=glacial-lake delta; e=eolian landforms, including dunes and windblown sand sheets; fp=floodplains (Many floodplains cannot be shown at this scale. Most areas mapped as Qal on sheet 1 are floodplains. These show the extent of floodplain sediment as marked by natural floodplain landforms but do not necessarily correspond to the flood zones recognized by the Federal Emergency Management Agency or the New Jersey Department of Environmental Protection.); m=salt marsh, beach, and estuary; mr=moraine; rf=flat to moderate slopes eroded in bedrock; rs=moderate to steep slopes eroded in bedrock; ow=outwash plain; s=freshwater swamp and marsh (Many swamps cannot be shown at this scale. Refer to unit Qs on sheet 1 for additional swamps.); t=stream terraces; tr=till on glacially eroded bedrock; tc=till on glacially eroded Coastal Plain formations. Ruling shows extent of mand-made fill in salt marshes and estuaries. The symbol "VVVVV" indicates steep slopes with areas of groundwater seepage or potential wave or stream undercutting. These slopes are subject to slump failures and gullying. Dot and dash lines (-·-) indicate streams that are deeply incised into clay and silt deposits. Banks along these streams are especially prone to slumping and gullying.

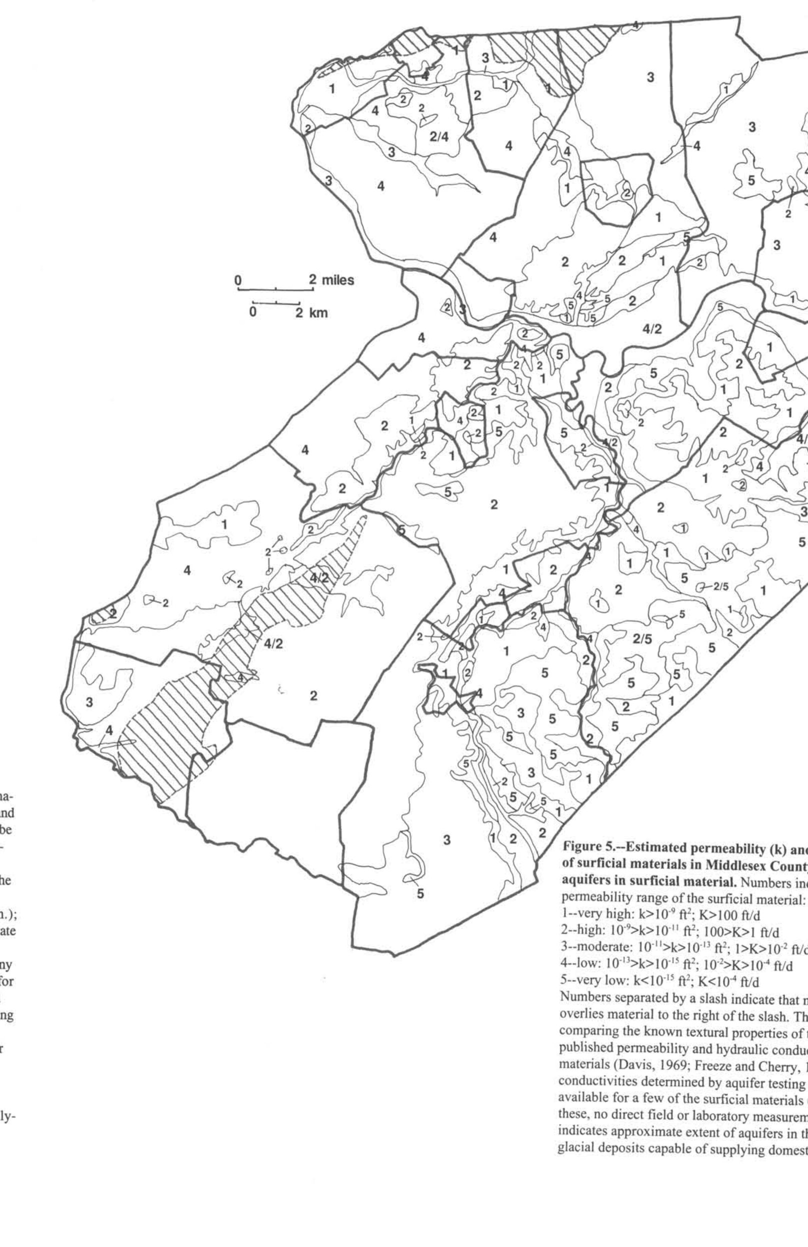


Figure 5.--Estimated permeability (k) and hydraulic conductivity (K) of surficial materials in Middlesex County, and extent of significant aquifers in surficial material. Numbers indicate the estimated permeability range of the surficial material:
1--very high: $k>10^{-9}$ ft^2; K>100 ft/d
2--high: $10^{-9}>k>10^{-11}$ ft^2; 100>K>1 ft/d
3--moderate: $10^{-11}>k>10^{-13}$ ft^2; $1>K>10^{-2}$ ft/d
4--low: $10^{-13}>k>10^{-15}$ ft^2; $10^{-2}>K>10^{-4}$ ft/d
5--very low: $k<10^{-15}$ ft^2; $K<10^{-4}$ ft/d
Numbers separated by a slash indicate that material to the left of the slash overlies material to the right of the slash. The ranges were estimated by comparing the known textural properties of the surficial materials to published permeability and hydraulic conductivity values for similar materials (Davis, 1969; Freeze and Cherry, 1979). Hydraulic conductivities determined by aquifer testing and laboratory methods were available for a few of the surficial materials (see table 1). Other than these, no direct field or laboratory measurements were made. Ruling indicates approximate extent of aquifers in the Pensauken Formation and glacial deposits capable of supplying domestic wells.

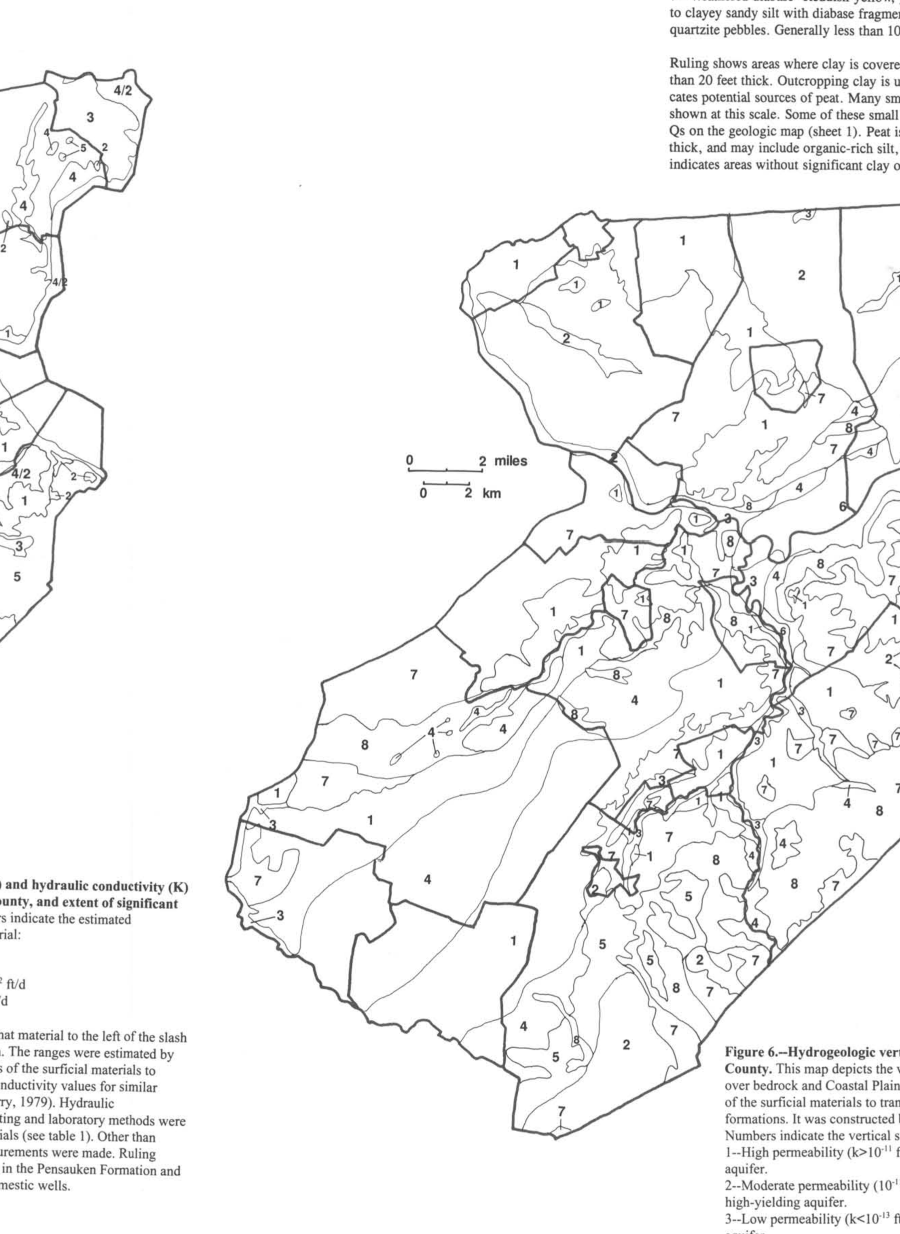


Figure 6.--Hydrogeologic vertical-sequence map of Middlesex County. This map depicts the vertical stacking of surficial materials over bedrock and Coastal Plain formations, and the resulting potential of the surficial materials to transmit ground water to the underlying formations. It was constructed by overlaying figure 5 on figure 7. Numbers indicate the vertical stacking as follows:
1--High permeability ($k>10^{-11}$ ft^2) surficial material over high-yielding aquifer.
2--Moderate permeability ($10^{-11}>k>10^{-13}$ ft^2) surficial material over high-yielding aquifer.
3--Low permeability ($k<10^{-13}$ ft^2) surficial material over high-yielding aquifer.
4--High permeability surficial material over low-yielding formation.
5--Moderate permeability surficial material over low-yielding formation.
6--Low permeability surficial material over low-yielding formation.
7--High-yielding aquifer at or within 10 feet of surface.
8--Low-yielding formation at or within 10 feet of surface.
High-yielding aquifers include Coastal Plain formations that are dominantly sand (Farrington Sand member of the Raritan Formation, Magothy Formation, Englishtown Formation, Marshalltown Formation, and the Mount Laurel-Wenonah Formations) and shale, mudstone, and sandstone bedrock (Passaic and Stockton Formations, part of the Lockatong Formation). Low-yielding formations include Coastal Plain formations that are dominantly clay and silt (Woodbridge Clay member of the Raritan Formation, Cheesequake Formation, Merchantville Formation, and the Woodbury Formation) and diabase and hornfels bedrock (including part of the Lockatong Formation).

The units shown on this figure can provide a general indication of the geologic control on recharge potential. The recharge potential of any specific area depends not only on the distribution of geologic materials beneath that area, but also on the land use, vegetation, soil type, meteorological conditions, and ground-water flow system. Charles and others (1993) provide a method for estimating the effects of the first four factors on recharge, and French (1996) provides a ground-water recharge map of Middlesex County based on this method. Ground-water flow systems in parts of Middlesex County are described in Barksdale (1937), Barksdale and others (1943), Appel (1962), Anderson (1968), Hasan and others (1969), Nichols (1977), Farlekas (1979), Luzier (1980), and Pucci and others (1994). Elsewhere, they must be determined on a site-specific basis.

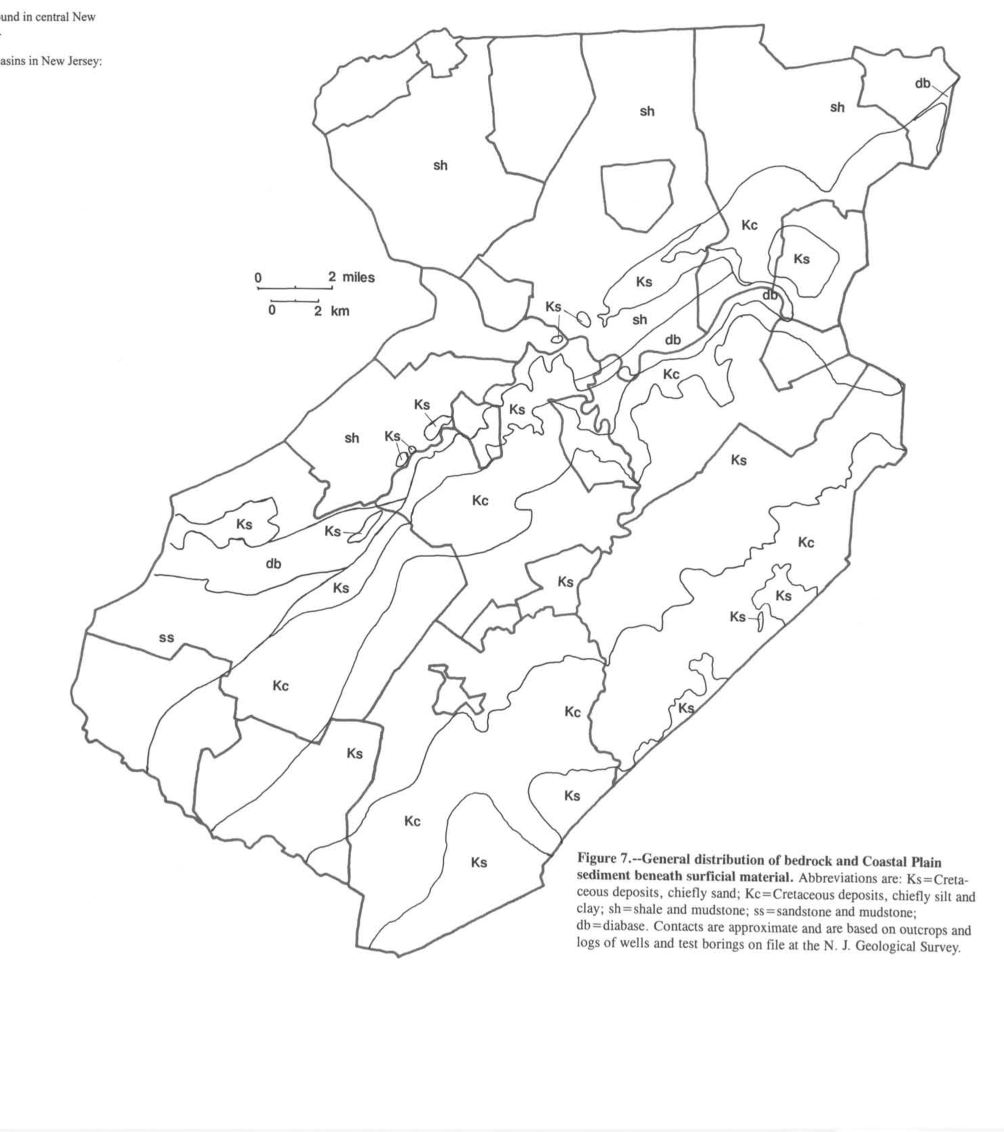


Figure 7.--General distribution of bedrock and Coastal Plain sediment beneath surficial material. Abbreviations are: Ks=Cretaceous deposits, chiefly sand; Kc=Cretaceous deposits, chiefly silt and clay; sh=shale and mudstone; ss=sandstone and mudstone; db=diabase. Contacts are approximate and are based on outcrops and logs of wells and test borings on file at the N. J. Geological Survey.

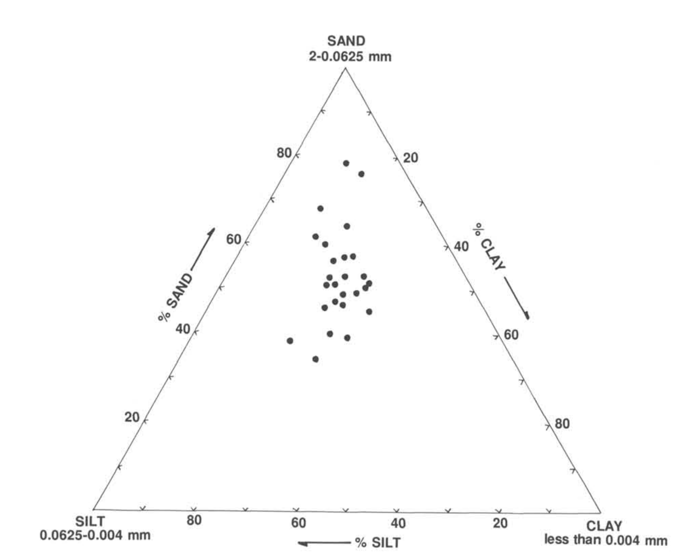


Figure 8.--Grain-size distribution of matrix sediment in till in Middlesex County (units Qwt and Qwtm). Data from Holman and Jumikis (1953). Samples are from depths ranging from 19 to 144 inches below the land surface.

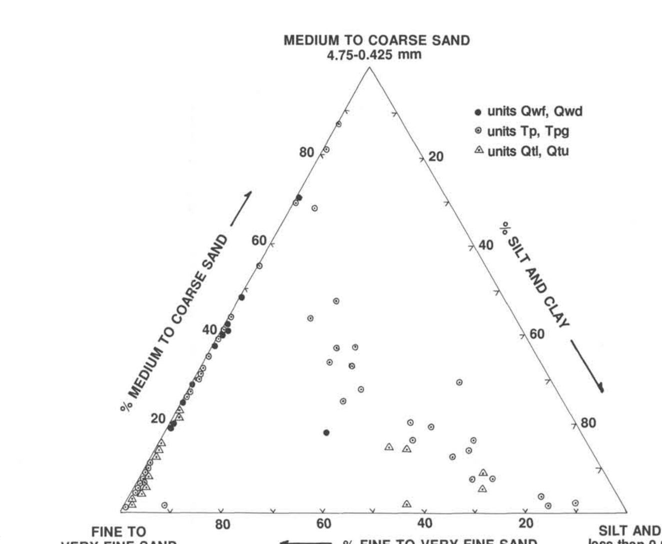


Figure 9.--Grain-size distribution of material finer than 4.75 mm (fine pebble gravel) for principal sand and gravel deposits in Middlesex County (units Qwd, Qwf, Tp, Tpg, Qtl, and Qtu). Data from Holman and Jumikis (1953). Samples are from depths ranging from 24 to 130 inches below the land surface. For units Tp and Tpg these samples are within surface soil horizons that are finer grained than less-weathered parts of the deposits at greater depth. Note the general absence of silt and clay in the younger surficial materials (units Qwd, Qwf, Qtl, Qtu) due to the absence of deep weathering in those units.