TABLE SUMMARIZING GEOLOGIC, HYDROLOGIC, AND ENGINEERING CONDITIONS

The Northeast Corridor is the highly urbanized area between Washington, D.C., and Boston, Massachusetts. The geologic conditions of part of the Northeast Corridor are summarized in a three-part report (Map I-514) of which this part, Coastal Plain and Surficial Deposits, consists of a map of these deposits with cross sections of the Coastal Plain deposits (sheets 1 through 5); cross sections of the surficial deposits (sheet 6); a table of geologic descriptions and engineering characteristics of each geologic map unit (sheet 7); a map showing published sources of data (sheet 8); and a list of selected additional references. Map I-514-A contains similar information on the bedrock geology, and Map I-514-C contains data on earthquake epicenters, geothermal gradients, and excavations and borings within the Northeast Corridor.

Purpose of Study

The Office of High Speed Ground Transportation, U.S. Department of Transportation (formerly Department of Commerce), asked the U.S. Geological Survey to summarize available information on the geology as it would affect building a proposed high-speed ground transportation facility between major cities of the Northeast Corridor. Construction of such a facility could involve surface construction methods, cut-and-cover, tunnels, or some combination of these. Because of the varied construction methods possible, economic solutions must be found and evaluated for a wide variety of problems, many of which are related to geologic and hydrologic conditions. Accordingly the report was prepared to provide a regional summary of the geology as required by planners, geologists, and engineers for early feasibility studies, and for subsequent planning of detailed investigations. It may, in addition, have wide application in planning other engineering projects, and it may have broad educational uses. The report is not intended for use in selecting actual alinements, or for supervision during construction. For these and similar purposes, detailed information at considerably larger scales is necessary.

Method of Study

Each map and its accompanying cross sections and table were compiled from existing published and unpublished data. These data consist primarily of geologic maps, reports, and information from governmental and private sources, principally the U.S. Geological Survey, the geological survey organizations of the several States, and various municipal agencies, universities, industrial concerns, and private consultants. Because the study was completed in a short period of time it was not possible to investigate and synthesize all sources rigorously. No original mapping or other investigations were made expresely for this report. Sources used range from detailed, accurate maps complete with explanatory texts to small-scale obsolescent reports of marginal utility to this report. Only a very few of the source reports evaluate engineering characteristics of the mapped earth and rock materials; most reports had to be interpreted with the aid of data from other sources.

The standard geological classifications of bedrock and surficial deposits used in source reports were broadly regrouped into map units having similar engineering characteristics. Because of disparate source data, and uncertainties in interpreting and correlating them, some of the regrouping, especially of bedrock units, was arbitrary, and perhaps was not always consistent between different parts of the map area. Although the engineering characteristics of the Coastal Plain deposits are broadly similar, local variation has made retention of the geologic classification desirable. The map scale of 1:250,000 was chosen because this scale permits comprehensive viewing of regional conditions, and because adequate base maps at this scale were available. The base map used here was adapted to the shape of the area from standard topographic 1:250,000 series maps published by the U.S. Geological Survey.

Cross sections through the bedrock were constructed along straight lines connecting major cities between Washington and Boston; additional cross-sections are included to better illustrate significant geologic relations. The data on which the cross-sections of bedrock are based are restricted largely to near-surface observations; deep subsurface portrayals are therefore highly interpretive, and in most cases, speculative. Cross-sections through the Coastal Plain and surficial deposits are based largely on subsurface data and were selected to show situations regarded as typical of more general geologic conditions. The accompanying tables summarize appropriate physical properties and selected engineering characteristics, including those of hydrologic nature.

The maps, cross-sections, and descriptive parts of the tables were compiled and prepared by Rachel M. Barker, Kathryn V. Dieterich, Jack B. Epstein, James P. Owens, Henry R. Schmoll, Howard E. Simpson, and David L. Southwick. Harold E. Gill compiled the hydrologic data to the maps and tables, and prepared the contours on the surface of the bedrock beneath the Coastal Plain deposits. The engineering data map, source data maps, and the engineering properties shown in the tables were prepared by Maxwell E. Gardner. Randolph W. Bromery supplied the geophysical data.

The authors appreciate the very generous support of their colleagues, both within and outside the U.S. Geological Survey, who provided many unpublished data printed here for the first time. It is not possible to credit these individuals here, but those not employed by the U.S. Geological Survey are named on Sheet 8, Index to data sources. The following State organizations also cooperated in every way possible: Connecticut Geological and Natural History Survey, Delaware Geological Survey, Maryland Geological Survey, New Jersey Bureau of Geology, New York State Museum and Science Service: Geological Survey, Pennsylvania Bureau of Topographic and Geologic Surveys, and Virginia Division of Mineral Resources. Moreover, many reports published by and credited to the U.S. Geological Survey in the Index to data sources were financed in part by State funds.

Geologic Setting

The mapped part of the Northeast Corridor may be broadly divided into three geologically distinct regions according to general types of geologic materials present. (1) Bedrock, which underlies the entire map area, is commonly found at or near the ground surface northwest of the Fall Line, a geographic line which extends through Washington, Baltimore, and Philadelphia to New York; information for this region is confined largely to I-514-A, Bedrock Geology. (2) Coastal Plain deposits cover the bedrock southeast of the Fall Line, and on Long Island; little is known of the bedrock in these areas, but its surface is portrayed on the bedrock map by contours. (3) Glacial deposits mantle the bedrock north of an east-west line through Raritan Bay, and on Long Island nearly conceal the Coastal Plain deposits. On the mainland the glacial deposits are so thin that bedrock crops out in many places and its nature is well known. Thus both bedrock and surficial deposits are mapped within this region.

In addition to these characteristic materials, each of the three geologic regions of the Northeast Corridor contains alluvium, minor accumulations of other surficial deposits, and local to widespread residual soils. The bedrock region has narrow belts of alluvium bordering nearly all rivers and streams, few of which are large enough to be mapped; elsewhere the rock is commonly mantled by thoroughly weathered and decomposed rock.

The Coastal Plain deposits form a thick wedge of nonindurated sediments dominantly of marine origin, which thicken seaward to a maximum of 3,500 feet in the map area. The basal unit (Potomac Group and equivalents) was deposited on a differentially warped, stream-eroded bedrock surface. The strata consist of gravel, sand, silt, and clay, which accumulated rapidly. The coarser grained materials are stream deposits, and have considerable directional permeability toward the southeast, parallel to the trend of major rivers. The silt and clay accumulated in slack-water or estuaries.

The overlying main body of the Coastal Plain deposits (Raritan Formation through Cohansey Sand) constitutes a succession of cyclic sediments deposited in transgressing and regressing seas. Individual formations accumulated under distinct environmental conditions during each cycle of advance and retreat of the sea, and comprise marine glauconite sand, silt-and-clay, and quartz sand facies. In any sequence the three facies grade laterally into one another.

The Coastal Plain deposits and some adjacent areas of bedrock were capped, after the last marine regression, by a series of alluvial terrace deposits. These represent several stages in the erosion and stripping of the Coastal Plain and bedrock by the major streams. The terrace deposits are divided into three map units shown by overprint patterns, and are characterized by differences in elevation, lithology and weathering.

The glacial deposits were laid down by at least two continental ice sheets that extended as far south as Long Island and northern New Jersey. The glaciers removed most of the preglacial soil mantle, and abraded the rock below, but left some scattered small areas of thoroughly weathered bedrock. Material eroded by the glaciers was transported and deposited by the ice as till, by melt-water streams as sand and gravel, and in lakes as silt and clay.

The till mantle (Qt) is unevenly distributed. It is thin or lacking on the crests and steep sides of many hills and ridges, and may be thicker on the lower slopes and beneath valley floors; some hills (drumlins) consist largely or entirely of till. Much of the till was compacted by overriding ice; part, however, is noncompacted material let down onto the surface of the underlying compact till as the ice melted.

Most till lies directly on bedrock, but in places, principally on Long Island, till is mapped separately where it overlies thick deposits of sand, gravel, and silt (Qto). A belt of morainal hills composed of thick till, sand, and gravel (Qe) extends across the Northeast Corridor from New Jersey to Rhode Island. This belt represents the terminus of the last continental glacier.

In New Jersey, south of the morainal belt, are scattered remnants of older till, sand, and gravel which are strongly and deeply weathered and somewhat altered (Qwt).

Glacial sand and gravel (Qsg), commonly of considerable thickness, partly fill valleys cut into bedrock. The thalweg (a line drawn through the lowest points of a valley) of several of these buried bedrock valleys is shown on the map, with elevation of the bedrock surface given for selected known points. A layer of till may separate the sand and gravel from the bedrock surface, which may be well below sea level in major valleys.

On Long Island, melt water that spilled southward from the ice margin built coalescing aprons of sand and gravel (Qo), forming the greater part of the island.

Lacustrine silt and clay (Qsc) accumulated in temporary lakes and ponds, and so is present locally at the base of, within, or on top of deposits of sand and gravel. Some of these deposits have since become buried by alluvium and swamp deposits. Known areas of buried or enclosed silt and clay are shown by an overprint pattern. Numerous small unknown areas probably exist also. The overprint pattern also shows buried marine clay in the vicinity of Boston.

The nonindurated or weakly indurated deposits beneath Long Island Sound have received much less study than those beneath the adjacent land surface. The position of the underlying bedrock surface, shown on the bedrock map as part of the extensive buried bedrock surface, was delineated in a general fashion by seismic data. Sparker traverses recently have permitted a much more detailed delineation of a buried surface beneath deposits of the Sound which is interpreted to be this same bedrock surface between the Connecticut shore and a line roughly 6 miles north of the central part of the Long Island shore; south of this line the sparker-traverse-determined surface probably represents the top of the Coastal Plain deposits.

Comparison of the "sparker" contours drawn on the bedrock–Coastal Plain (?) surface with depth-of-water contours (both are shown on the map accompanying this table) permits approximation of the thickness of the deposits directly underlying the sound. These deposits are interpreted to be dominantly glacial in origin; only a relatively thin upper part may be postglacial in origin.

Nonglacial surficial deposits within the glaciated area are relatively minor in extent and thickness. Streams have deposited alluvium along their courses since the last glacier receded. The deposits are large enough to be differentiated only along some major river valleys, but are actually present on a smaller scale in all but the very smallest valleys.

Beach deposits and adjacent sand dunes (Qb) are mapped along the ocean shore; scattered dunes of medium-grained sand also occur on the sand and gravel (Qsg) surface in areas too small to be mapped separately. A widespread but very patchy deposit of windblown silt and fine-grained sand, generally less than 3 feet thick, is commonly present over much of the area, east of stream-deposited sand, but is not differentiated from underlying deposits.

Extensive salt marshes border the beach and dune areas, the lagoons behind them, and some small streams. Many of these marshes have been covered by artificial fill, especially in and adjacent to major coastal cities. These fills are not differentiated on the map; they consist generally of mixed earth and trash. Poorly drained areas, many the remnants of late glacial lakes and ponds, now form swamps that contain variable thicknesses of peat and organic-rich silt. Only the larger of these are shown. Other quantitatively minor materials that are not differentiated include various kinds of colluvium, and the frost-, root- and plow-heaved soil.

Hydrologic Notes

The depth to the zone of saturation in the Northeast Corridor, where the annual precipitation averages between 40 and 45 inches, is generally 30 feet in the valleys and lowland areas.

The zone of saturation consists of two subzones: the subzone of unconfined ground water, below, and the subzone of continuous saturation, above. The two are separated by the water table, that surface within the zone of saturation where the water occurs at atmospheric pressure; this is the position at which water in an unconfined water body will stand in a well. The subzone of continuous saturation contains water under negative atmospheric pressure (capillary rise). The water table, and consequently the position of the subzone of continuous saturation, fluctuates with seasonal conditions. The thickness of this subzone is controlled by the size of the capillary openings, or, for practical considerations, the average particle size of the sediments; in fine-textured, nonindurated sediments it is as much as 10 to 15 feet thick. In rocks with low primary permeability the water table occurs near the top of the zone of saturation, and the subzone of continuous saturation is very thin.

For excavations within the zone of saturation, this zone must be locally dewatered; therefore cut-and-cover construction in nonindurated deposits in the Northeast Corridor will generally require high-capacity dewatering equipment.

GEOLOGIC DESCRIPTION

MAP UNIT OR SYMBOL AND DESIGNATION	LITHOLOGY	THICKNESS	ALTERATION	TOPOGRAPHY
Qt Younger ground moraine	Till (GM, GC, SM)[9]: Chiefly an unsorted mixture of clay, silt, sand, gravel, and boulders. Varies from a cohesive, moderately clayey material with embedded pebbles, cobbles and boulders (boulder clay) to a very well graded sand with gravel, cobbles, boulders, and minor silt derived mostly from nearby bedrock. Stratification generally lacking, poor to crude where present. Generally very compact, firm, and friable; upper few feet may be somewhat loose. Color varies with weathering (oxidation) and with color of dominant source bedrock. Generally gray when unweathered, buff to brown when oxidized; reddish brown in areas of reddish-brown bedrock. Locally contains or underlies thin lenticular sand and gravel. Overlain by many small, thin swamps containing muck and peat, and stream courses with postglacial alluvium that are not shown on map. Locally patchy; numerous bedrock exposures within unit not shown.	Very irregular, generally less than 25 ft. Unit normally thin to absent on hill crests and along major escarpments, thickens downslope to 50 ft or more on lower slopes. In drumlins may be 150 ft thick or more.	Upper 3–60 ft oxidized; most stones unweathered or nearly so.	A nearly ubiquitous mantle overlying the bedrock surface. Unusually thick till underlies streamlined hills, called drumlins, which may be as much as 150 ft high; some drumlins have a core of bedrock.
Qto Younger ground moraine over outwash	Four principal lithologic units, in stratigraphic sequence from top downward:			
	1. Till (GM, GC, SM): Chiefly an unsorted mixture of rock and soil fragments ranging from clay-size particles to boulders, derived from bedrock to the north and northwest. On southern Staten Island, clay and silt dominate the matrix, and there are few cobbles, and boulders. Elsewhere in New York City and also on eastern Long Island, particle-size distribution more equal, boulders numerous and commonly as much as 15 feet in diameter. On northern Long Island east of New York City, matrix sandy; pebbles and cobbles numerous and boulders rare (GM; GW–GM). Sorting and stratification generally lacking; poor to crude where present. Unit generally very compact, somewhat cohesive where clayey; upper few feet, and entire deposit where sandy, normally somewhat loose. Generally medium gray to pale buff, yellower near surface; medium reddish brown in New York City, and on eastern Long Island. Includes small, thin, and irregular, or locally extensive, bodies of gravel and sand, poorly to moderately well sorted and stratified (GW; SW). Locally overlain by deposits of muck and peat.	New York City and eastern Long Island generally 10–20 ft; locally as much as 100 ft on northern Staten Island and northwestern Long Island, and much as 60 ft on Montauk Peninsula. Generally less than 10 ft on central Long Island.	Upper 10–15 ft oxidized where sandy; oxidation less deep elsewhere. Most stones unweathered and hard.	Generally smoothly rolling hills and poorly defined valleys with local relief less than 50 ft. Bluffs along the north shore of Long Island are 50–200 ft high; on western Long Island long steep-sided valleys extend south from the north shore, producing a highly irregular coastline.
	2. Stratified sand and gravel, in part somewhat silty (SW, SP, GW, SM). Includes one fairly continuous bed of till and scattered lenses of silt. Color light gray to buff. Equivalent to map unit Qo.	Generally 100–200 ft.		
	3. Thin-bedded clay and silt (CL, ML); some lenses of sand and gravel; soft. Color gray-green to brown. Not present beneath Staten Island or parts of northern Long Island. (Gardiners Clay).	10–100 ft; absent in many places.		
	4. Stratified sand and gravel (SW; GW); some lenses of clay and silt. Sand and gravel loose to slightly firm; clay and silt compact. Color gray to brown. Present only beneath parts of western Long Island. (Jameco Formation). Underlain by Coastal Plain units Kmg and Kr.	Generally 30–60 ft; locally more than 100 ft.		
Qwt Older glacial deposits	Till (GM, GC): Compact unsorted mixture of clay, silt and sand containing pebbles, cobbles, and sparse boulders as much as 15 ft in diameter. Stones chiefly gneiss, quartzite and sandstone. Stratification generally absent. Unit also includes areas of clayey gravel and sand (GC, SC), with stones up to 8 in. in diameter; bedding fair to poor; poorly sorted. Very compact; ferruginous cementation common. Color generally yellowish brown throughout. Bedrock crops out locally, and underlies entire deposit.	Generally 15–20 ft; locally as much as 30 ft; absent in places.	Weathered throughout; quartzite resistant, other rocks decayed. Oxidized and leached throughout.	Discontinuous patches on low rolling terrain, and as low terraces. Local relief as much as 25 ft.
Qe End moraines	Till (GM): Chiefly an unsorted mixture of clay, silt, sand, gravel, and boulders. In most of northern New Jersey, stones and boulders comprise 50 percent of the till. In and near New York City, silt and clay dominate, with boulders less numerous but locally large. Eastward on Long Island, the matrix becomes progressively sandier, numerous areas of sand and gravel (SW; GW) present. On the eastern half of Long Island and in southern Rhode Island, principally gravel and sand (GW; SW), with local beds of silt and clay (ML); boulders common—as much as 50 ft in diameter. Till similar to Qt. Gravel and sand moderately well to poorly sorted, well to crudely stratified. Numerous surface depressions contain thin deposits of muck and peat. On Long Island, underlain by Qto units 2, 3, and 4 and by Coastal Plain units Kmg and Kr.	Generally 75–100 ft; locally as much as 200 ft in New York City, and 300 ft on eastern Long Island; commonly as little as 50 ft on central Long Island.	Little or no alteration; stones and boulders unweathered and hard. Oxidized at least 10 ft where matrix is sandy; may be leached 2 to 4 ft where calcareous.	Long narrow tract characterized by irregular to conical hills and subparallel, crudely arcuate ridges with intervening, generally nonconnecting elongate to equidimensional depressions. Relief generally 100–150 ft; 50–100 ft in central Long Island and part of Rhode Island; Hills more subdued in areas of till, more sharply crested in areas of gravel and sand. On western Long Island south edge of moraine forms relatively steep, regular escarpment.
Qsg Stratified glacial deposits and alluvium in valleys	Stratified sand and gravel, in part somewhat silty (SW, SP, GW); includes scattered lenses of till and well-sorted silt; may contain boulders locally. Sorting fair to poor, locally good. Sand and gravel loose; till commonly compact, firm, and friable. Commonly overlies till (Qt), which is also locally exposed at surface. In places overlies or encloses extensive deposits of silt and clay (Qsc, shown on map by overprint pattern). Locally overlain by alluvium (Qal), muck and peat, and silt and clay.	Generally less than 125 ft, locally as much as 300 ft; in small valleys commonly less than 40 ft; on Long Island, generally less than 10 ft.	Uppermost 5–15 ft oxidized. Stones and boulders unweathered and hard.	Partly fills bedrock valleys in northern New Jersey, New York, and New England. Valley floors flat to gently sloping. Valley sides in lower reaches and entire width in headward reaches characterized by irregular terraces, hills, and closed depressions. Local relief 25–75 ft. On northwestern Long Island, in part fills small channels and forms small hills.
Qo Outwash plains	Stratified sand and gravel (GW, GP) adjacent to map unit Qe, grading southward to sand with minor gravel (SW, SP); in New Jersey, grades southward to silt (ML). Sorting good to fair. Generally loose, noncemented. Color light gray to pale buff. Locally overlain by silt and clay. On southern Long Island underlain by Qto units 3 and 4, and by Coastal Plain units Kmg and Kr.	Generally 100–150 ft; in New Jersey may be as little as 50 ft.	Uppermost 10–15 ft oxidized. Stones unweathered and hard.	Broad plains, sloping gently south with gradients that range from 25–40 ft per mile in the north to less than 10 ft per mile in the south. Smooth surface broken at irregular intervals by shallow channels and by isolated or closely alined groups of depressions, 20–60 ft deep. In central Long Island, locally includes dissected remnants of older plains, now forming steep hills, with local relief 100–300 ft.
Qb Beaches and dunes	Sand, medium- to fine-grained (SP); coarse sand and gravel on parts of some beaches. Well sorted. Loose. Color white to very pale buff. Surface depressions in dunes commonly contain thin marshy accumulations of muck and peat. Commonly underlain by adjacent map unit; on southern Long Island, by Qo.	Beaches: probably less than 20 ft. Dunes: generally less than 50 ft.	Unaltered.	Beaches: smooth, very gently sloping narrow stretches along shores. Dunes: narrow ridges behind beaches and highly irregular hills with closed depressions and relief generally less than 50 ft.
Qal Alluvium	Shown in New England by map unit, south of New York City by stipple overprint pattern. Occurs in only a few areas large enough to be shown separately on the map, generally along major rivers. Sand, silt, clay, gravel, and organic material in differing proportions (SW, SM, ML); dominantly sand in New England, silt and clay in the south. Sorting good to fair. Loose to soft, in part semifluid. Color light to dark gray. In swamps overlain by thin deposits of muck and peat.	Generally 10–15 ft in New England; commonly thicker in the south, as much as 60 ft beneath and adjacent to Chesapeake Bay.	Unaltered in New England. Uppermost few feet oxidized and bleached in the south; locally, small iron oxide segregations present.	Nearly flat flood plains marked locally by terrace scarps, and curved, subparallel channel scars; local relief commonly less than 3 ft.
Lowland terrace deposits[10]	Clay, silt, sand, gravel, and scattered boulders as much as 6 ft in diameter, in differing proportions (ML; SM; SW; GW); gravel and boulders most abundant near the mouths of major rivers. Sorting good to fair. Bedding excellent to good, commonly thick, horizontal; sand and silt generally cross-stratified; clay beds massive, discontinuous. Gravel and boulders vary widely in composition; but quartz, quartzite, and locally chert predominate; sand and silt primarily of graywacke composition, with large concentrations of rock fragments; clay minerals also highly varied. Sand loose, silt and clay generally soft. Color light gray to buff; clay at depth blue gray. Shell beds common in upper part, especially along Chesapeake Bay south of Sparrows Point. Overlain by marshy accumulations of muck and peat where clayey beds are at or near surface. (Talbot and Cape May Formations)	Quite variable; as much as 200 ft beneath Chesapeake Bay and Delaware Bay.	Igneous and metamorphic boulders intensively weathered within several feet of surface. Iron oxide staining, and, locally, weak induration widespread in elevated terraces.	Broad, elevated terraces with gently rolling surfaces; only slightly dissected except along bays where steep 30-ft banks are common.
Intermediate terrace deposits[10]	Chiefly medium-grained sand (SW), with some thick interbeds of gravel (GW); boulders as much as 3 ft in diameter present locally; thin beds of clay scattered widely. Sorting generally good. Bedding well developed; large-scale cross-stratification common, strongly oriented south-southwest in New Jersey and Delaware. Sand typically arkosic, with feldspars extensively kaolinized; gravel chiefly quartz, quartzite and sandstone; boulders commonly tabular red sandstones; clays mainly kaolinite and illite. Generally compact, slightly firm to loose. Color typically light yellow. (Wicomico and Pensauken (part) Formations).	Generally 20–40 ft, locally, where not dissected as much as 120 ft.	Iron oxide staining common throughout; thick beds of ironstone common on highest hills; locally, iron oxide cementation forms large exotically shaped bodies through entire thickness.	In Delaware River Valley, occurs only in patches on highest hills. Between Delaware River and Chesapeake Bay forms gently rolling topography with relief generally less than 40 feet. West of Chesapeake Bay, occurs in isolated patches and in major river valleys.
Upland terrace deposits[10]	Chiefly medium- to coarse-grained sand (SW), with numerous interbeds of gravel (GW); boulders as much as 3 ft in diameter widely scattered. Sorting generally fair to good; sand and gravel in part silty. Bedding well developed; extensive very large scale cross-stratification. Sand arkosic in New Jersey between Trenton and Raritan Bay; elsewhere orthoquartzitic; gravel chiefly quartz and quartzite, most other rock types decayed. Generally compact, firm. Color yellow, or orange brown; black encrustations common on many grains. South of Washington, D. C., overlain by a loamy deposit up to 15 feet thick. (Bryn Mawr, Beacon Hill, Pensauken (part), and Brandywine Formations).	Typically about 50 ft; between Trenton and Raritan Bay, as much as 150 ft.	Oxidized throughout. Ironstone cementation of somce beds locally more than 10 ft thick. Between Trenton and Raritan Bay, bauxitization of the feldspars has occurred within several feet of the surface.	Extensive, nearly flat highlands south of Washington, D.C. and between Trenton and Raritan Bay; elsewhere occurs only in patches on the highest hilltops.
Qsc Lake-bottom and marine deposits[11]	Occurs at surface in only a few areas large enough to be mapped separately; widespread occurrence at depth shown by red dashed line overprint pattern in northern New Jersey, mainland New York, and New England. Chiefly well stratified clay and clayey silt (ML; CL); includes some very fine- to medium-grained sand (SM; SW). Stratification generally rhythmic (varved); individual beds less than 1 to 4 in. thick; commonly fine sand or coarse silt partings separate strata. Clay cohesive, moderately plastic. Light to medium gray and pink. In vicinity of Boston, silty clay and clayey silt (CL, ML). Stratification obscure. Upper 5–10 ft oxidized and stiff; remainder soft. Deposited in estuary rather than lake.	Quite variable; generally at least 20 ft; locally more than 100 ft.	Upper 10–20 ft may be oxidized.	Smooth nearly flat lowlands formerly occupied by lakes. May be dissected slightly by present drainage; local relief less than 5 ft.
Qm Marshes, swamps, estuaries, and artificial fill[11]	Interbedded silt, fine-grained sand, clay, and organic material in differing proportions (ML, OL, CL, CH, Pt); upper part dominantly organic. Sorting good to fair. Soft, noncompact, in part semifluid. Color light brown to black. In urban areas commonly overlain by artificial fill. In inland areas of New England and in northernmost New Jersey, underlain by till (Qt), or sand and gravel (Qsg). Elsewhere in New Jersey and along the coast, commonly underlain by silt and clay (shown by dashed red line overprint pattern, see Qsc).	Generally less than 15 ft thick; thins commonly to less than 3 ft near margins of unit, but thickens to as much as 40 ft along some seaward margins.	Unaltered.	Low flat areas along coasts, lagoons, estuaries, rivers, and rimming some lakes. Salt-marsh present below level of high tide; inland, water generally at surface.
Deposits beneath Long Island Sound	Uppermost 6 ft, data from numerous core samples: Sandy to clayey silt. Nonbedded. Silt 50–90 percent quartz; clay mostly illite and chlorite. Reducing conditions moderate, pH near 7. Soft, semifluid in places; firm and slightly friable when dry. Color greenish gray (wet), light gray (dry). Uppermost 1–2 in. black, odorous, rich in organic material. Deposited in present Sound. Characteristics of deposit at greater depth known only from sparker-survey profiles: Texture probably somewhat coarser than above; bedding characterized by cross-stratification, cut-and-fill structures, and differential-compaction folds. Most of the deposit probably somewhat similar to deposits described under map unit Qto. Underlain by Coastal Plain deposits, Kmg and Kr, in southern part of the Sound; by bedrock in northern part.	Generally 100–300 ft, thinning shoreward; 400–600 ft in a narrow belt 4–6 miles north of the central Long Island shore.	Unaltered.	General form of top of deposits gently concave upward; lowest areas generally lie along a line south of the middle of the Sound. Western and eastern parts channeled by marine currents; bars and flats present locally. Surface commonly ripple marked.
Tch Cohansey Sand	Chiefly quartz sand, with some clay and gravel. Sand medium-grained, well-sorted, cross-stratified, loose. Gravel beds more extensive in northwest, commonly cross-stratified, occur as well-defined channels in sand; dark, thick, massive, very carbonaceous and micaceous silt-clay beds in south. Sand is orthoquartzitic in north, arkosic in southwest. Pebbles in gravel well rounded, less than 2 in. in diameter; mostly quartz and quartzite, with metamorphic rock fragments common in south. Kaolinite and illite major clay minerals in clay-silt beds.	As much as 150 ft in north. Thickening to 200 ft to southeast.	Weathered throughout outcrop area: fresh in subsurface. Where unit crops out on high hills, massive ironstone beds as thick as 15 ft widely developed. Feldspar in arkosic beds extensively kaolinized.	Flat to gently rolling plain in central and southern New Jersey. In north-central New Jersey caps small, steep-sided hills with local relief of 200–250 ft.
Tcg Chesapeake Group and Tkw Kirkwood Formation	Chiefly fine-grained micaceous quartz sand, locally clayey or silty; interfingering with thick clay-silt to southeast. In northwest, mostly light yellow to white moderately to well sorted sand with scattered beds of fine-pebble gravel. Quartz, mica, and feldspar most abundant mineral constituents. In south, beds commonly darker in color because of finely divided organic matter. Minerals in clay-silt beds include quartz, montmorillonite (except in New Jersey), illite, and, less commonly, kaolinite.	Generally 0 to about 100 ft. Thickens to about 250 ft along southern boundary of Northeast Corridor area.	Locally, beds extensively stained but rarely cemented by iron oxides. Partial secondary silica cementation common in southern New Jersey. Organic matter removed where beds occur above the water table.	Typically underlie flat ground with very low relief. Poorly drained areas in valley bottoms common in the Kirkwood Formation because of its high silt content; less common in the Chesapeake Group. Along the west shore of Chesapeake Bay, form bluffs, some as high as 60 ft.
Tnj Nanjemoy Formation and Tmq Manasquan Formation	Silty, clayey glauconite sand, with interbedded silt-clay. Generally thick-bedded to massive. Basal 20 ft of Nanjemoy Formation consists of pink to drab brown silty clay, mostly kaolinite, illite, and quartz. In upper part of Manasquan Formation, sand interfingers with highly montmorillonitic clayey silt beds; lower part contains dark-brown apatite pellets, and siderite fragments; sand dominantly quartzose in lowest beds.	Nanjemoy Formation more than 50 ft in outcrop area, increasing to 170 ft near southern boundary of Northeast Corridor. Manasquan Formation 50 ft thick in New Jersey where only lower part exposed. Thickness increases to about 200 ft to southeast.	Clay beds at surface extensively stained by iron oxides. Glauconite beds weakly indurated by iron oxide.	Nanjemoy Formation commonly occurs in large river valleys, underlying smooth slopes and flat valley bottoms; swampy conditions widespread. Manasquan Formation underlies flat headwater stretches of large streams or flat coastal areas; swamps widespread.
Taq Aquia Formation and Tvt Vincentown Formation	Glauconitic quartz sand; primarily medium grained, light clolored; where fossiliferous, may be indurated. Mostly massive, but fossil beds are crudely stratified. Brightseat Formation is a thick, dark-gray, somewhat glauconitic quartz sand that occurs below the Aquia Formation south and west of Washington, D. C. Vincentown Formation consists of three sediment types: thick, glauconite quartz sand in northern New Jersey; a cemented quartzose lime sand with basal, dark glauconite quartz sand, like lower beds of Tmq, in west-central and southern New Jersey. In wells and borings to southeast, it is darker, more clayey, less sandy.	Aquia Formation: As much as 60 ft in outcrop; thickens to about 150 ft in subsurface along southern boundary of Northeast Corridor. Vincentown Formation: Varies from 100 ft in northern New Jersey to about 50 ft in southwest New Jersey thickens in subsurface to about 100 ft.	Where units topographically high, glauconite oxidized; local cementation of glauconitic beds very common. Fossiliferous beds locally leached, and fossils replaced by iron oxides.	Well-drained area of low, gently rolling hills.
Tht Hornerstown Sand	Glauconite sand; fine- to medium-grained; locally very silty and clayey. Poorly sorted and massive bedded. Sand particles almost all glauconite, but include some well-rounded quartz grains; in lower part of formation, some phosphatic pellets and bone fragments present. Silt-clay fraction mostly bright green finely divided glauconite, and some finely crystalline pyrite. Crops out from northern New Jersey to the eastern shore of Chesapeake Bay; not recognized west of Chesapeake Bay in Maryland, but may be equivalent to Brightseat Formation (in Taq).	Averages about 20 ft in outcrop and in subsurface.	Oxidizes readily, producing thin but widespread near-surface ironstone.	Generally underlies flat, poorly drained areas, but forms steep slopes where valley walls cut formation.
Kmo Monmouth Formation	Glauconitic, silty quartz sand, very clayey; dark gray, micaceous, feldspathic. Thin gravelly zone commonly found at base. Poorly sorted; bedding thick to massive. Clay complex mixture of all clay minerals; finely divided organic matter abundant.	In outcrop areas averages about 50 ft. Thickens in subsurface to 100 ft, though this thickness may include underlying Matawan Formation.	Intensely oxidized beds reddish brown; where less intensely oxidized, gypsum and jarosite locally very abundant.	Typically dissected terrain; surfaces poorly drained.
Krb Red Bank Sand	Chiefly quartz sand; massive to very thick bedded. Upper beds tough, mostly indurated, coarse-grained, dark quartz-glauconite sand. Beneath, in sequence, are beds of medium-grained quartz sand and fossiliferous sandy silt. To the southeast, beds become a dark, poorly sorted, micaceous glauconite sand. Quartz and feldspar major minerals, mica abundant in silt; clay minerals a complex mixture of all major types.	As much as 120 ft. Unit does not persist for any appreciable distance in the subsurface.	Where upper beds at higher elevations, siderite cement oxidized to iron oxides. Thin iron-oxide cementation widespread in upper beds.	Typically well-drained rolling topography of moderate relief and gentle slopes. Along Raritan Bay, entire unit exposed in steep bluffs that are broken by landslides.
Kns Navesink Formation	Clayey, silty glauconite sand; greensand, very silty and clayey; thickbedded; dark gray. Locally, particularly in north, contains several thick shell beds, especially at base of formation. Clay a complex mixture of all major clay minerals, finely comminuted organic matter, and finely crystalline pyrite.	Maximum 45 ft.	Gypsum and jarosite common in mildly oxidized beds; iron oxides cement strongly oxidized sands; fossil beds locally indurated through replacement of fossil material by iron oxides.	Underlies poorly drained gently rolling plains of low relief.
Kml Mount Laurel Sand	Glauconitic quartz sand; comprises three major lithofacies: (1) an upper, pebbly, medium-grained, poorly to moderately sorted feldspathic quartz sand, with glauconite sand filling many thin fossil borings; beneath this, northeast of Trenton, N. J., (2) thin-bedded, dark, very micaceous and carbonaceous silt-clay beds alternating with somewhat thicker, light-colored, micaceous glauconitic quartz sand beds, both containing widespread discontinuous layers of gray siderite concretions; and southwest of Trenton, (3) massive, moderately to well sorted feldspathic glauconitic quartz sand, medium-grained in New Jersey, coarsening southwestward, with shell beds like those in the Navesink Formation common locally.	Ranges from 30 to 170 ft; thickest between Delaware River and Chesapeake Bay. Upper pebbly bed rarely exceeds 10 ft; alternating silt-clay sand sequence as much as 40 ft; massive sand reaches 160 ft.	Most exposures oxidized; iron-oxide staining common; weakly cemented locally; rarely, well cemented.	Gently rolling, well-drained terrain of moderate relief. Some steep slopes where cemented beds crop out.
Kw Wenonah Formation	Glauconitic quartz sand; generally dark, micaceous, and feldspathic; locally very silty. Ranges from fine-grained at base to medium-grained at top. Poorly to moderately sorted; massive to thick-bedded. Sand-sized and finely divided carbonaceous matter locally abundant; pyrite content high.	As much as 70 ft in outcrop; thickest in west-central New Jersey: unit pinches out near Delaware River. Thickens to 100 ft in subsurface.	Where midly oxidized, dark color disappears; gypsum and jarosite locally developed. Thin platelets of iron oxides common in more intensely oxidized beds.	Poorly drained terrain of gentle slopes and low relief; marshes common.
Kmt Marshalltown Formation	Quartzose glauconite sand; fine-grained, very silty and clayey; massively bedded; dark colored. Very fossiliferous in southern New Jersey and northern Delaware. Mica, feldspar, and finely crystalline pyrite common; finely divided carbonaceous matter abundant. Clay is commonly mixture of all major clay minerals.	15–20 ft.	Same as Wenonah Formation.	Narrow belt of generally poorly drained terrain.
Ket Englishtown Formation	Glauconitic quartz sand; includes three major lithofacies: (1) upper, light-colored, well-sorted, fine- to medium-grained sand, extensively cross-stratified; beneath this, 2) interbedded sequences of clayey silt and light-colored sand containing numerous siderite concretions, except 3) thick, massive, dark clayey silt in southwest New Jersey. Silt beds contain considerable sand-sized carbonaceous matter and mica. All major clay minerals present. Minerals in sand are mostly quartz, feldspar, and mica; glauconite is minor constituent.	20–150 ft in outcrop area; thickest near Raritan Bay, thinnest in eastern Maryland.	Ironstone masses widespread in outcrop of first two lithofacies. Silty beds weather like the Wenonah Formation.	Hilly terrain with relief of 60 ft or more; slopes steep in places, particularly where sandy beds underlie the surface.
Kwb Woodbury Clay	Very clayey and somewhat micaceous dark-gray silt. Sorting very poor; bedding generally massive, crudely laminated at top. Contains abundant comminuted carbonaceous matter, and finely crystalline pyrite. Clay composition varied, but dominantly illite. Glauconitic at top in Trenton area. Siderite concretions as much as 3 in. in diameter common in northern outcrop area.	As much as 50 ft in west-central area; in subsurface, increases to about 100 ft.	Where weathered, commonly loses dark color, and contains gypsum and jarosite. Where intensively weathered, has iron-oxide masses, some of great size.	Flat to gently rolling, poorly drained terrain; relief negligible, but stream-cut banks commonly stand steeply.
Kmv Merchantville Formation	Chiefly clayey silt and glauconitic to quartzose sand; highly variable in lithology. Northern New Jersey: dark silt with interbedded gravel; thick, light-colored glauconite sand locally at base. Silt beds a mixture of quartz, mica, and carbonaceous fragments; stones in gravel; mostly reworked siderite concretions. West-central New Jersey: very micaceous clayey silt and glauconitic quartz sand. Thick-bedded; poorly sorted. Clay dominantly illite. Southwestern New Jersey and northern Delaware: micaceous quartz sand. Thick-bedded; poorly sorted. Eastern shore, Maryland: similar to beds in northern New Jersey, but sandier. Glauconite a minor constituent; no siderite concretions.	Maximum in subsurface 100 ft. In outcrop as follows for each area: 20 to 25 ft. About 60 ft. 50 ft. Averages 20 ft.	Sideritic concretions in conglomeratic beds weather readily to iron oxides; masses of ironstone common. Weathering fades glauconite and silty beds to lighter colors, and forms gypsum, jarosite, and iron oxides.	Rolling terrain with moderate relief; surface poorly to well drained, depending on lithology.
Kma Matawan Formation	Clayey, micaceous silt. Poorly sorted; massively bedded; dark colored; locally sandy (chiefly glauconite).	Maximum 50 ft; thins markedly southward.	Weathers like Woodbury Clay.	Hilly, rolling terrain with moderate relief; drainage poor to fair.
Kmg Magothy Formation[11]	Thin to thick interbeds of dark-colored clayey silt and light-colored quartz sand; mica and pyrite in small amounts. Clay minerals chiefly kaolinite and illite; contains large lignitized logs.	Thins and thickens along outcrop belt. Ranges from 150 ft near Raritan Bay to as little as 10 ft; as much as 200 ft thick in subsurface.	Massive cementation by iron-oxides common above the water table.	Where not concealed by gravel terrace deposits, forms rolling, highly dissected terrain, locally marked by ledges; local relief generally moderate, but strong in north. Surface well drained.
Kr Raritan Formation[11]	Chiefly massive, cross-bedded quartz sand, interbedded with thick beds of clayey silt and laminated clay and silt. Sand resembles Cohansey Sand in quartzose character and bedding. Massive clayey silt beds resemble Woodbury Clay but contain more beds of concretionary siderite. Laminated clay and silt layers horizontally stratified; generally similar to those of overlying Magothy Formation. Clay minerals dominantly kaolinite and illite.	About 200 ft in outcrop area; about 800 ft in subsurface along southern boundary of mapped area.	Extensive differential cementation; thick ironstone beds common under topographic crests. Tops of dark-colored beds commonly weathered red and white.	Generally covered by sand and gravel terrace deposits.
Kp Potomac Group	Chesapeake Bay to New Jersey: interbedded sand, gravelly sand, and clay, with abundant coarse lignitic material. Sand commonly moderately to well sorted, extensively cross-stratified, mostly quartz. Gravel fraction all quartz and quartzite; stones generally less than 5 in. in diameter. Clay chiefly kaolinite and illite; beds massive, locally crudely stratified, lenticular, with little lateral or downdip persistence; commonly black to red, white, or yellow. Vicinity of Washington, D. C.: mostly interbedded arkosic sand and clay, some gravel. Clay very montmorillonitic. Gravel composed of granitic and metamorphic rocks; rounded. Underlain by bedrock in all areas.	As much as 250 ft in outcrop area; thickens in subsurface to between 700 and 800 ft.	Cementation and staining by iron oxides common throughout formation; massive ironstone beds common under hill crests.	Mostly mantled by younger deposits. Where exposed generally underlies hilly terrain, with local relief as much as 400 ft. Southwest of Washington, D.C., terrain is similar, but relief is somewhat less. Surface generally well drained.
Kpa Patapsco Formation	Thick beds of clay interbedded with sand, locally with gravel. Sand chiefly quartz; locally mostly mica. Gravel consists of quartz and quartzite. Clay beds massive to crudely stratified; sand beds cross-stratified. Clay red, yellow, or white in color.	As much as 300 ft in outcrop; thickens in subsurface.	Weathering same as in Potomac Group.	Very hilly terrain of moderate relief; drainage poor.
Ka Arundel Formation	Very clayey and micaceous dark silt and silty clay. Contains siderite as thin concretionary beds, and, locally, masses weighing many tons; and coarse lignite fragments, some of log size. Clays mainly kaolinite and illite, mixed; small amounts of chlorite common. Crude horizontal stratification marked by siderite beds.	Ranges from 40 to 50 ft where exposed; reportedly as much as 200 ft in subsurface.	Siderite masses weather to iron oxide; formerly present at the surface, removed during urbanization.	Moderately hilly terrain of low relief; surface poorly drained.
Kpx Patuxent Formation	Interbedded gravel, sand, and clay. Gravel wholly of quartz and quartzite; stones rarely larger than 3 in. in diameter. Sand chiefly quartz; in part mica; feldspar rare. Clay minerals chiefly kaolinite and illite. Clay beds commonly contain large quantities of finely divided to very coarse carbonaceous matter. Color generally very light; red to black where unoxidized. Unit underlain by bedrock.	As much as 350 ft in outcrop area; somewhat more in subsurface.	Extensively cemented by iron oxides. Weathers to a very light color.	Very hilly terrain of moderate relief; slopes marked by massive ledges. Surface drainage generally good.
Uncolored area Residual soil	Residual soil and deeply weathered rocks. Occurs in scattered areas in north-central New Jersey, and extends as a nearly continuous mantle from Philadelphia southward to beyond Washington, D. C. Material developed varies with rock type but typically comprises three zones: (1) a thin upper zone—chiefly red silty to bouldery clay (CL, CL-ML) and yellowish brown clayey micaceous sand (SC, ML); (2) a thick intermediate zone of decomposed bedrock that retains the texture and structure of the original bedrock—a firm to punky mixture of clay- to boulder-size particles, with clay, silt, and fine sand (ML, SM) dominating the matrix; and (3) a lower, partly weathered bedrock zone—a mixture of sand- to boulder-size particles and remnant irregular bodies of hard, slightly weathered rock penetrating irregularly into bedrock, especially along faults and joints.	Upper zone is 0–5 ft thick. Decomposed bedrock as thick as 80 ft on granitic rocks (bedrock map, unit 6) in southern part of Northeast Corridor, but not more than 30 ft on similar rocks north of Philadelphia; less than 2 ft thick on serpentinites (bedrock map, unit 7). Weathering in bedrock along joints and faults as deep as 200 ft. Decomposed bedrock and upper zone commonly thickest on hilltops; thin or absent in valleys.	-------------------------------------	Rolling hills and generally broad valleys

ENGINEERING CHARACTERISTICS

MAP UNIT	FOUNDATION CONDITIONS[1]	EXCAVATION CHARACTERISTICS	SLOPE STABILITY[2]
Qt	Bearing capacity generally good because of high density and poor sorting. Expansion negligible.	Generally easy to moderately difficult to excavate with power equipment. Highly compacted till ("hardpan"), and very strong and bouldery till can be troublesome to excavate without special equipment.	Cuts higher than 40 ft generally require individual stability analysis. For lower slopes, 1½ on 1 to 2 on 1 generally considered safe. Vertical slopes up to 15 ft common, particularly in more cohesive clayey till.
Qto (units 1, 2, and 4)	Bearing capacity generally good for thicker till and coarser sand and gravel. Compressibility and expansion mostly negligible. (Units 1, 2, and 4).	Generally easy to excavate with power equipment. Compact till moderately hard to excavate.	Similar to Qt, but sandier material requires lower slopes or greater support.
Qto (unit 3)	Bearing capacity low. Precompressed by as much as 200 ft of overburden. Compressibility normally low under light load; may consolidate rapidly under dynamic or heavy loads. Expansion slight to moderate.	Rarely exposed at surface.	Crops out at places near base of bluffs on eastern Long Island where bluffs may be made unstable by addition of surcharge or by vibrations.
Qwt	Bearing capacities fair. Compressibility and expansion negligible.	Moderately hard to excavate with power equipment. Dense, indurated till may require blasting.	Stands in steep cut slopes and, in places, in vertical cut slopes with little or no support. Cut slopes ravel and spall by freezing and thawing.
Qe	Bearing capacity of till, sand, and gravel generally good. Compressibility and expansion negligible in sandy till. Local beds of silt and clay within sandy till moderately compressible; structures founded over small lenses may settle unevenly.	Easy to moderately hard to excavate with power equipment depending upon sand-clay ratio, stoniness, and precompaction.	Cuts higher than 40 ft generally require individual stability analysis. For lower slopes 1½ on 1 to 2 on 1 generally considered safe. Vertical slopes up to 15 ft common, particularly in more cohesive clayey till.
Qsg	Bearing capacity of sand and gravel fair to good; of silt and clay, less. Local artesian water pressure reduces bearing values. Vibratory loading on sand may cause settlement.	Easy to excavate by power equipment; in valleys of tidal rivers may be excavated by dredge.	Excavations below water table require support.
Qo	Bearing capacity generally fair for sand to good for gravel. Water table generally within 15 ft of surface.	Usually needs dewatering before excavation. Easy to excavate with power equipment.	Excavations below water table require support.
Qb	Bearing capacity poor to fair; improved by vibration.	Easy to excavate with power equipment. Beach sand to dredge.	Cut slopes stable to angle of repose; steeper slopes need lagging because sand is free running when dry; readily flows into excavations below water table.
Qal	Bearing capacity poor to fair in sandy alluvium; very poor to poor on silt, clay. Structures founded over small lenses of compressible clay or silt settle unevenly. Water table shallow. Compressibility and expansion negligible except in thick organic deposits.	Easy to excavate by power equipment; in rivers may by excavated by dredge.	Excavations below water table require support.
Lowland terrace deposits	Bearing capacity ranges from very poor in organic silt to fair in gravelly sand. Compressibility negligible to moderate; expansion negligible to slight. Structures founded over small lenses of compressible clay or silt may settle unevenly.	Easy to excavate with power equipment.	Clayey sand stands in moderate to steep natural slopes. Cut slopes in noncohesive material may ravel from wetting and drying. Vertical cuts and most cuts below water table need support. In deep excavations clay may fail along vertical joints.
Intermediate terrace deposits	Bearing capacity ranges from poor to fair. Compressibility and expansion negligible except locally in clayey sand.	Easy to excavate with power equipment.	Natural slopes usually gentle to moderate. Loose, dry sand free running; stable at angle of repose. Steep cut slopes in slightly cohesive material ravel rapidly.
Upland terrace deposits	Bearing capacity usually fair.	Easy to excavate with power equipment. Ironstone beds require blasting.	Stands on moderate cut slopes depending on cohesion and density. Steeper cut slopes ravel by wetting and drying.
Qsc	Bearing capacity generally poor. Where oxidized and preconsolidated, capacity fair. When confined and loaded, pore-water pressure increases and shearing strength decreases. Where saturated, dewatering may cause consolidation over large area. Compressibility high to low; expansion negligible to moderate.	Easy to excavate; wet conditions hamper construction equipment. "Quick" reaction to vibration in silt.	Generally unstable except in shallow dewatered cuts with gentle slopes. Support usually required. Clay is somewhat fissured and may fail along vertical joints. Sensitivity low.
Qm	Bearing capacity very poor. Compressibility high.	Easy to excavate by dredge or dragline.	Unstable; flows readily into underwater excavations.
Deposits beneath Long Island Sound	Size and texture of materials poorly known. Bearing capacity very poor in upper part, probably increasing at depth.	Easy to dredge. Soft-ground tunneling conditons unknown.	Upper part unstable; flows readily in excavations.
Tch	Bearing capacity of sand and gravel fair; low in silt and clay which are precompressed. Structures on small local lenses of silt, clay may settle unevenly.	Easy to excavate with power equipment.	Slopes stable to angle of repose of sand; angle of stable slopes increases as clay content increases. Dry, loose, poorly graded sand free running. Repeated wetting and drying may cause slopes in cohesive sand to ravel.
Tcg and Tkw	Bearing capacity fair in sandy beds; poor in clayey silt, even though somewhat precompressed. Compressibility low to medium; expansion negligible to moderate depending mostly on montmorillonite content.	Easy to excavate with power equipment; moderately difficult in cemented zones.	Stands in moderate slopes without support for long periods. Repeated wetting and drying may cause slopes in cohesive sand to ravel.
Tnj and Tmq	Precompressed; bearing capacity ranges from poor to fair. Compressibility, low to medium. Expansion generally slight; but may be high in montmorillonitic beds in Manasquan Formation.	Easy to excavate by power equipment. Wet conditions hamper excavation.	Stands for long periods in moderate slopes without support. Steeper slopes possible depending upon position of water table. Steep-sided excavations extending below water table need support.
Taq and Tvt	Clayey silt beds, precompressed. Bearing capacities range from fair in clayey sand to good in indurated beds. Compressibility and expansion generally slight to negligible.	Generally easy to excavate with power equipment. Hard limestones need blasting.	Cut slopes in sand ravel, but stable at angle of repose; angle of stable cut slopes generally increases as clay content increases. Indurated beds in shallow excavations stand for long periods in steep to near-vertical slopes.
Tht	Bearing capacity poor; very poor under water table conditions Compressibility, moderate; expansion, high.	Easy to excavate with power equipment. Wet conditions hamper excavation. Rebound probable after excavation.	Natural stream cuts form stable steep slopes. Steep cut slopes stable only when dry. Excavations with steep slopes extending below water table need support.
Kmo	Precompressed; bearing capacity poor to fair. Compressibility, low; expansion slight.	Easy to excavate with power equipment, except for scattered concretionary zones.	Natural stream cuts form moderate slopes. Steep cut slopes stable only when dry. Excavations with steep slopes extending below water table need support.
Krb	Bearing capacity of upper beds good; lower beds fair to poor.	Easy to excavate with power equipment except where indurated.	Along Raritan Bay, undermining of weaker beds has caused failure by massive spalling and slumping of overlying, indurated beds. If not undermined, steep to near-vertical cuts stable for long periods.
Kns	Bearing capacity poor; very poor under water-table conditions. Compressibility moderate; expansion high.	Easy to excavate with power equipment. Wet conditons hamper excavation. Probable rebound after excavation.	Natural stream cuts form stable moderate slopes. Steep cut slopes stable only when dry. Steep excavated slopes extending below water table need support.
Kml	Precompressed; bearing capacity ranges from poor to fair; silt-clay beds, very poor under water-table conditions. Compressibility in silt-clay beds low; expansion, moderate.	Easy to excavate with power equipment.	Ravels fast in cut slopes, but stable to angle of repose. Moderate to steep slopes stable, depending on cohesion and position of water table.
Kw	Bearing capacity poor to fair. Compressibility, negligible to low; expansion, negligible to slight.	Easy to excavate with power equipment.	Cohesive sand stable in high, steep natural stream cuts. Steep cut slopes stable only when dry. Steep excavations extending below water table need support.
Kmt	Precompressed; bearing capacity poor to fair. Compressibility, negligible to low; expansion, negligible to slight.	Easy to excavate with power equipment.	Cohesive sand stable in high, steep natural stream cuts. Steep cut slopes stable only when dry. Steep excavations extending below water table need support.
Ket	Clay-silt beds precompressed; bearing capacity ranges from fair in sandy beds to very poor in wet organic silt and clay. Compressibility, negligible to moderate; expansion, negligible to slight.	Easy to excavate with power equipment. Siderite concretions locally hinder excavation.	Cohesive sand and silt stable in moderate cut slopes when dry; ravel in steeper slopes. Noncohesive sand runs freely when dry; stable at angle of repose. Steep excavations extending below water table need support.
Kwb	Clayey silt precompressed; bearing capacity poor; very poor under water-table conditions. Compressibility negligible to moderate; expansion negligible to slight.	Easy to excavate with power equipment. Wet conditons hamper excavation.	Stable in short steep slopes along streams. Steep cut slopes stable only when dry. Steep excavations extending below water table need support.
Kmv	Precompressed; bearing capacity poor in clayey beds; better in sand and gravel.	Generally easy to excavate with power equipment. Conglomerate hinders excavation and may need blasting locally.	Natural and cut slopes in clayey beds similar to those in Woodbury Clay. Gravel and sand ravel in steep cut slopes.
Kma	Precompressed; bearing capacity poor to fair. Compressibility, low; expansion, slight.	Easy to excavate with power equipment.	Natural stream cuts form stable moderate slopes. Steep cut slopes stable only when dry. Steep excavations extending below water table need support.
Kmg	Bearing capacity variable, affected by artesian water pressure and cementation; decreases with depth where clayey silt beds confine artesian aquifers. Clay precompressed.	Mostly easy to excavate with power equipment; hard ironstone beds require blasting. Excessive rebound and boiling possible within deep excavations dug in clay that confines artesian aquifers.	Variable, depending on water conditions.
Kr	Bearing capacity variable, affected by artesian water pressure and cementation; decreases with depth where clay beds confine artesian aquifers. Clay precompressed.	Mostly easy to excavate with power equipment; hard ironstone beds require blasting. Excessive rebound and boiling possible within deep excavations dug in clayey silt beds that confine artesian aquifers.	Variable, depending on water conditions.
Kp	Bearing capacity variable, affected locally by artesian water pressure. Clay beds similar to those in Arundel Formation. Bearing capacity decreases with depth where clay beds confine artesian aquifers. Clay precompressed.	Usually easy to excavate with power equipment; hard ironstone beds may require blasting. Excessive rebound and boiling possible within deep excavations dug in clay beds that confine artesian aquifers.	Sandy beds ravel on steep cut slopes, but stable to angle of repose. Clayey beds usually stable at steeper angles, depending on water conditions.
Kpa	Bearing capacity variable, affected locally by artesian water pressure. Clay beds similar to those in Arundel Formation. Bearing capacity decreases with depth where clay beds confine artesian aquifers. Clay precompressed.	Usually easy to excavate with power equipment; hard ironstone beds may require blasting. Excessive rebound and boiling possible within deep excavations dug in clays that confine artesian aquifers.	Sandy beds ravel on steep cut slopes, but stable to angle of repose. Clayey beds usually stable at steeper angles, depending on water conditions.
Ka	Heavily precompressed, but preconsolidation pressures within range of fair bearing capacity. Compressibility normally low under light loads; may consolidate rapidly under heavy loads; expansion negligible to slight. In lower part of formation, where clay overlies artesian aquifers bearing capacity decreases with depth.	Easy to excavate with power equipment. Wet conditions and siderite concretions hamper excavation.	Stands in moderate slopes, particularly where siderite layers are present. Vertical or near vertical slopes in deep excavations have failed along vertical joints.
Kpx	Bearing capacity variable, affected locally by artesian water pressure. Clay beds similar to those in Arundel Formation. Bearing capacity decreases with depth where clay beds confine artesian aquifers. Clay precompressed.	Usually easy to excavate with power equipment; hard ironstone beds may require blasting. Excessive rebound and boiling possible within deep excavations dug in clay beds that confine artesian aquifers.	Sandy beds ravel on steep cut slopes, but stable up to angle of repose. Clayey beds usually stable at steeper angles, depending on water conditions.
Residual soil	Bearing capacity generally fair to good but locally very poor in bodies of cellular red clay having high void ratios. Red clay mostly associated with decomposed basalt, diabase, or metagabbro. Differential settlement under heavy structures common where bedrock surface and thickness of unit extremely irregular. Bearing capacity reduced by artesian-water pressure or high pore-water pressure. Compressibility depends on void ratio, but relationship to liquid limit may be inconsistent. Expansion generally negligible, except slight expansion because of wetting and drying in residual soils developed on mafic rocks.	Decomposed rock usually easy to excavate with power equipment. Residual soils on amphibolite, metagabbro, gabbro, and anorthosite (bedrock map units 2, 4, 5, and 8) contain large boulders which delay excavation. Rock pinnacles require blasting. Micaceous residual soil difficult to compact.	Above water table stands in steep cut slopes for short time without support; may fail locally along fractures inherited from bedrock; high moisture content reduces stability of cut slopes; soaking rains may cause sudden failure. Below water table steep cut slopes unstable and hazardous. Moderate slopes stable for long periods if dewatered and free of planar fractures sloping into cut.

MAP UNIT	SIGNIFICANT HYDROLOGIC FEATURES[3]	Yield of wells (gallons per minute): Range	Yield: Median	Coefficient of permeability (gallons per day per square foot): Range	Coefficient: Median	Specific capacity[5] (gallons per minute per foot): Range	Specific capacity: Median	Specific yield[6] (percent)	Free water content[7] (gallons per cubic yard)	Excavation permeability[8] (gallons per day per square yard)
	GENERAL HYDROLOGIC CONDITIONS[3,4]							WATER-TABLE CONDITIONS[3]		
Qt	Small domestic supplies obtained from dug wells. Unit functions as a confining layer over some bedrock aquifers.	1–15	6	0.02–4	----	----	----	5–17	10–35	1–35
Qto	Unit 1 lies above zone of saturation and as much as 200 ft above main water table, but contains discontinuous perched water bodies. Small yields.	----	----	----	----	----	----	----	----	----
	Data presented are for buried sand and gravel deposits (units 2 and 4).	6–1,700	1,000	150–3,000	----	33–221	----	19–30	38–60	1,350–27,000
Qwt	Low-permeability deposits. locally yield small supplies to domestic wells.	1–15	6	0.02–4	----	----	----	5–17	10–34	1–35
Qe	Same as Qwt.	1–15	6	0.02–4	----	----	----	5–17	10–34	1–35
Qsg	Major aquifer in New England. Median yield of wells from deeper sands in the Connecticut Valley north of Middletown, Conn. is 50 gpm. Water occurs mainly under water-table conditions; locally under artesian conditions.	6–2,400	100	60–3,200	----	0.7–195	7	14–30	28–60	540–28,800
	Water occurs under artesian conditions in northern New Jersey in the area indicated by thalweg in valleys.	20–2,200	502	180–5,180	----	0.24–500	30	----	----	----
Qo	Major aquifer. Water occurs under water-table conditions. Direct recharge from precipitation.	100–1,700	1,000	----	1,300	8–109	37	24	48	11,700
Qb	Greatest thickness of unit generally occurs above the zone of saturation, except in low coastal areas. Salt water prevalent in coastal areas.	1–20	6	3–200	----	----	----	5–17	10–34	27–600
Qal	Major aquifer when direct hydraulic connection present with stream or river.	5–200	50	3–200	----	----	----	5–17	10–34	50–1,000
Lowland terrace deposits	Water occurs mainly under water-table conditions. Direct recharge from precipitation. Clay layers in subsurface deposits act as confining beds, causing artesian conditions locally.	5–1,000	350	300–1,000	----	0.3–20	4.3	17–23	34–46	2,700–9,000
Intermediate terrace deposits	Deposits in many areas above zone of saturation.	5–200	50	3–200	----	----	----	5–23	10–46	50–1,000
Upland terrace deposits	Deposits almost entirely above main water table. Contains discontinuous perched water bodies.	----	----	3–1,000	----	----	----	5–17	10–34	50–9,000
Qsc	Deposits of low permeability. Small domestic supplies available locally from sand interlayered with clay and silt beds.	0–20	6	0.1–0.9	----	----	----	2–23	4–46	1–10
Qm	Very small yields to wells. Has high porosity (percentage of void space) but low permeability.	----	----	0.1–2	----	----	----	20–30	40–80	1–20
Deposits beneath Long Island Sound	-------------------------------------	----	----	----	----	----	----	----	----	----
Tch	Unconsolidated thick permeable aquifer, chiefly unconfined with direct recharge; locally artesian.	10–2,000	500	250–3,000	1,000	5–40	20	19–23	38–46	2,250–27,000
	Locally extensive clay horizons in Atlantic and Camden Counties, N. J.	----	----	----	0.001	----	----	2–5	4–10	36–90
Tcg and Tkw	Chesapeake group minor aquifer.	15–100	43	200–300	----	0.9–10	5	11	22	1,800–2,700
	Kirkwood Formation includes at least two significant aquifers which yield moderate to large supplies.	5–860	200	110–1,100	----	1.2–17.5	8.2	8–10	16–20	990–9,900
	Silty clay confining layers in both map units.	----	----	----	.01	----	----	2	4	0.9
Tnj and Tmq	Primarily a confining bed. Manasquan Formation locally supplies small yields to domestic wells in New Jersey.	3–60	----	0.3–120	6	0.2–1.2	0.6	5–10	10–20	2–54
	Nanjemoy Formation somewhat leaky becomes more permeable in Queen Annes County, Md.	----	----	0.1–100	----	0.2–1.2	0.6	5–10	10–20	0.09–900
Taq and Tvt	Aquia Formation major aquifer in Queen Annes County, Md.; Vincentown formation minor aquifer in Monmouth and Ocean Counties, N. J.	2–400	25	25–1,340	----	0.1–14.3	2.9	10–15	20–30	225–12,060
	Vincentown Formation minor aquifer in southwestern New Jersey and northern Delaware.	----	----	----	10	----	----	5	10	90
Tht	Functions primarily as a confining bed over artesian aquifers.	0–5	----	0.02–15	----	----	----	5–10	10–20	0.018–135
Kmo	Important aquifer in Kent County, Md.	7–750	40	200–3,000	----	0.2–8.0	1.8	10–15	20–30	1,800–27,000
	Confining bed over artesian aquifers.	----	----	0.007–0.1	----	----	----	5	10	0.063–0.9
Krb	Most of the permeable sands occur above water table in the Atlantic Highland of New Jersey.	2–25	----	1–100	----	----	----	5–8	10–16	9–900
Kns	Leaky confining bed; permeability increases to reported maximum in Salem County, N. J.	----	----	0.03–15	----	----	----	5–10	10–20	0.27–135
Kml	A minor aquifer in New Jersey; increases in importance in southern New Jersey and Delaware.	5–300	100	40–160	----	----	----	10–15	20–30	360–1,440
Kw	Unit functions as an aquifer, along with the Mount Laurel Sand	1–5	2	0.6–7	----	----	----	8–10	16–20	5–63
Kmt	Unit functions as a confining bed.	----	----	0.002–3	----	----	----	5	10	0.018–27
Ket	A minor aquifer in New Jersey and northern Delaware; most permeable and thickest in Monmouth County, N. J.	5–520	100	50–300	----	----	----	10–15	20–30	450–2,700
	Clayey silt in intercalated layers.	----	----	0.1–7	----	----	----	2–5	4–10	0.9–63
Kwb	Unit functions as confining bed, together with the Merchantville Formation.	----	----	0.002–0.2	----	----	----	2	4	0.018–1.8
Kmv	Functions mainly as a confining bed. Locally, in a narrow belt from Monmouth County to Gloucester County, N. J., sandy facies produces small domestic water supplies (5–10 gpm).	0–10	----	0.02–15	----	----	----	5	10	0.18–135
Kma	Functions as a confining bed.	----	----	0.007–0.1	----	----	----	2	4	0.063–0.9
	Functions as a minor aquifer where sand predominates.	7–180	37	100–200	----	0.2–9.5	1.5	10–12	20–24	900–1,800
Kmg	Moderate to highly permeable; yields large quantities of water from several zones. Water under artesian conditions in Long Island; some flowing wells in southern Long Island. Unit contaminated by salt water in southwestern Nassau and southeastern Queens Counties, N. Y. Data from Long Island.	10–2,200	1,500	50–1,450	950	1–80	35	25	50	450–13,050
	Data from New Jersey, Delaware, Maryland.	10–100	----	56–740	----	----	----	5–15	10–30	504–6,660
Kr	Individual aquifers range from a few feet to 70 or 80 ft in thickness. Sands crop out in the Raritan Bay area of Middlesex Co., N. J., and dip to the southeast. Water occurs under artesian conditions in the major part of the Northeast Corridor area; some wells flow. Aquifers contain some salt water in Raritan Bay area.	10–1,900	500	200–2,000	1,000	10–44	20	15–20	30–40	1,800–18,000
	Clay units locally thick and function as confining beds.	----	----	0.002–0.02	----	----	----	2	4	0.018–0.18
Kp	Individual aquifers range from a few feet to 100 ft in thickness; total thickness of sands probably about 250 ft near outcrop; data characteristic of area from New Jersey to Gun Powder River in Maryland. Unit contains salt water south and southeast of salt-water interface shown on sheets 1 and 2.	3–1,900	500	290–2,170	1,600	2.4–86	21	15–20	20–40	2,610–19,530
	Clay layers locally thick and function as confining beds.	----	----	0.007–0.02	----	----	----	2	4	0.063–0.18
	Minor aquifer south of Washington, D.C.	7–320	32	22–1,430	----	0.3–7.1	1.3	15–17	30–34	198–12,870
Kpa	Major aquifer; water occurs under artesian conditions downdip from outcrop area.	150–750	500	230–3,300	800	0.1–22.5	9.5	15–17	30–34	2,070–29,700
Ka	Major confining layer.	----	----	0.0001–0.001	----	----	----	1	2	0.0009–0.009
Kpx	Major aquifer; water occurs under artesian conditions.	3–1,000	375	22–1,430	900	1.3–19.6	7.9	15–17	30–34	198–12,870
	Water-table aquifer near outcrop.	----	----	22–380	100	0.3–10.2	2.8	8–12	16–24	198–3,420
Residual soil	See bedrock geology table.	----	----	----	----	----	----	----	----	----

[1]Bearing capacity—numerical values (tons per square foot) applied to qualifying adjectives:

Very poor	less than 1
Poor	1–4
Fair	4–8
Good	8–32
Excellent	greater than 32

Compressibility—volume decrease in a soil mass in response to an external load.
Expansion—volume increase that is a function of load, time, density, water content, and type of clay minerals.

[2]Cut slopes—numerical values, in degrees, applied to qualifying adjectives:

Vertical	90
Near vertical	80–89
Steep	45–80
Moderate	30–45
Gentle	0–30

[3]The well-yield data used in the preparation of this table are based on public-supply and industrial wells in which the maximum potential of the aquifer was being developed. (gpm: gallons per minute)

[4]Data given under general conditions should be used for calculations pertaining to artesian aquifers in tunneling or deep excavations where it may not be possible to dissipate the hydrostatic head.

[5]Specific capacity is the discharge expressed as a rate of yield per unit of drawdown. The data used in this column were selected to represent conditions of optimum well development and therefore reflect aquifer characteristics.

[6]The ratio of the volume of water which a saturated rock or soil will yield by gravity to its own volume, stated as a percentage. Values used in this table are laboratory determinations or estimates based on field experience.

[7]Gallons per cubic yard yielded by gravity drainage.

[8]Rate of flow of water in gallons per day through a cross section of 1 square yard under a unit hydraulic gradient at prevailing water temperatures.

[9]Unified Soil Classification System adopted by Corps of Engineers, U.S. Army (1953, The Unified Soil Classification System: Waterways Experimental Station, Vicksburg, Miss., Tech. Memo. 3-357, v. 1, 30 p., 9 pl.; v. 2, 11 p., 1 pl.). Based on grain-size, gradation, plasticity, and compressibility of soil. Symbols assigned are approximate, based upon limited test data.

[10]Shown in red line pattern on map.

[11]On Long Island, Staten Island and in adjacent New Jersey, dashed red line pattern on map shows areas where Magothy Formation and Raritan Formation are present beneath surficial deposits. Elsewhere, pattern shows areas where silt and clay are present within or beneath permeable surficial deposits; most of these bodies are lacustrine (Qsc), some are marine.

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