Prepared in cooperation with the
COMMONWEALTH OF MASSACHUSETTS, WATER RESOURCES COMMISSION,
BARNSTABLE COUNTY, and the NATIONAL PARK SERVICE

INTRODUCTION

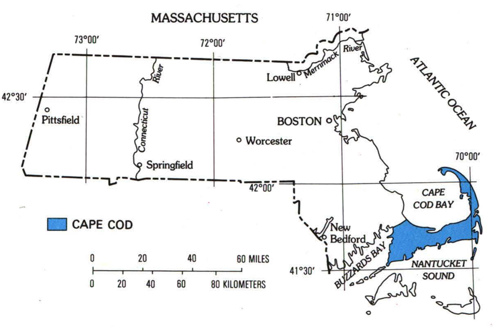


Figure 1.—Location of Cape Cod.

Cape Cod extends into the Atlantic Ocean from southeastern Massachusetts (fig. 1) and includes 15 towns in Barnstable County. The Cape measures about 40 miles from east to west (herein referred to as the inner and mid-Cape, fig. 2), and 25 miles from north to south (herein referred to as the outer Cape, fig. 2). The peninsula has an area of 440 mi^2 and a maximum land-surface altitude of 309 feet above sea level. More than 300 freshwater ponds dot the Cape, and the coast is lined by sandy beaches. On the outer Cape, the Cape Cod National Seashore includes over 44,000 acres of beaches, ponds, wetlands, and woodlands.

Cape Cod is separated from the mainland by a sea-level canal, and is completely surrounded by seawater. Residents of the Cape obtain freshwater for domestic, commercial, and industrial use from a sand and gravel aquifer system. Precipitation is the sole source of water to the aquifer.

The year-round population of Cape Cod grew 82 percent from 1960 to 1975, and the population triples during the summer (Cape Cod Planning and Economic Development Commission, 1978, p. 2-14). This growth is due chiefly to the popularity of the Cape as a resort and retirement area. Local, State, and federal officials responsible for managing and protecting water resources on the Cape are concerned that continued growth and development may result in excessive ground-water withdrawals and degradation of water quality. In 1982, the U.S. Environmental Protection Agency (1982) designated the aquifer as the sole source of supply for the Cape's residents.

The U.S. Geological Survey, in cooperation with the Massachusetts Water Resources Commission, Barnstable County, and the National Park Service, has studied the Cape Cod aquifer system to increase knowledge of ground-water flow, ground-water quality, and characteristics of the aquifer boundaries. This map report describes the aquifer and the ground-water flow system. Other reports prepared as a result of this investigation describe the chemical quality of ground-water (Frimpter and Gay, 1979) and digital models of ground-water flow (Guswa and LeBlanc, 1985). Additional information on the geology and hydrology of Cape Cod is available from the maps and publications listed in the references. Data on lithology, well testing and construction, water quality, and sediment size that were collected and analyzed for this investigation are available in the files of the U.S. Geological Survey, Boston, Massachusetts.

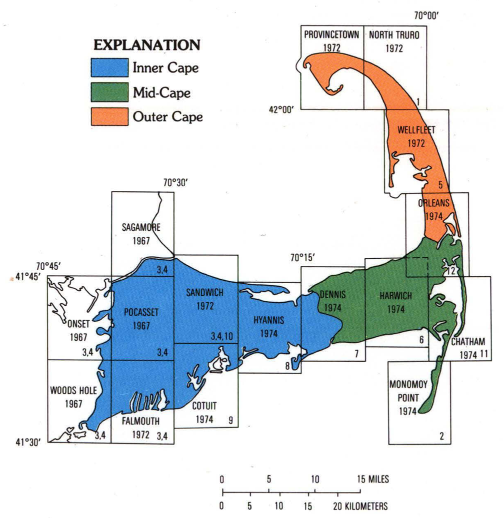


Figure 2.—Location of inner, mid-, and outer Cape Cod, and index to topographic and geologic maps. Topographic maps are 7.5-minute Geological Survey quadrangles. Name of quadrangle and date of latest topographic survey shown. Geologic maps keyed to references by numbers in lower right corner of quadrangles.

METRIC CONVERSION FACTORS

For use of readers who prefer to use metric (International System) units, conversion factors for terms used in this report are listed below.

Multiply	By	To obtain metric units
inch (in)	2.540	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
acre	0.4047	square hectometer (hm^2)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
gallon (gal)	3.785	liter (L)
million gallons (Mgal)	3,785	cubic meters (m^3)
billion gallons (Bgal)	3,785,000	cubic meters (m^3)
inch per year (in/yr)	25.4	millimeter per year (mm/a)
foot per day (ft/d)	0.3048	meter per day (m/d)
square foot per day (ft^2/d)	0.0929	square meter per day (m^2/d)
cubic foot per second (ft^3/s)	0.0283	cubic meter per second (m^3/s)
gallons per minute (gal/min)	0.06309	liters per second (L/s)
million gallons per day (Mgal/d)	3,785	cubic meters per day (m^3/d)
micromho (μmho)	1.000	microsiemens (μ S)

HYDROGEOLOGY AND GROUND-WATER AVAILABILITY

The Cape Cod aquifer is formed of unconsolidated sand (with some interbedded gravel, silt, and clay) that overlies crystalline bedrock. The bedrock under Cape Cod ranges from 80 to more than 900 feet below sea level (Oldale, 1969b). Bedrock is not part of the aquifer because it is much less permeable than the unconsolidated sediments.

The unconsolidated sediments were deposited by continental ice sheets near the end of the Pleistocene Epoch, from 14,000 to 15,000 years ago. Thickness of the sediments ranges from about 100 feet at the Cape Cod Canal to more than 1,000 feet in Truro. The map and sections shown in figures 3 and 4 illustrate the general areal and vertical variability of the sediments. The major hydrogeologic units are glacial outwash, lacustrine sediments, and moraines.

Outwash (fig. 3) forms gently sloping plains and is composed primarily of stratified sand and gravel that was deposited by meltwater streams. The outwash is as much as 200 feet thick at some locations. Layers of silt and clay are commonly interbedded in the sand and gravel between eastern Barnstable and Chatham on the inner and mid-Cape and between Eastham and Truro on the outer Cape. Silt and clay underlie the outwash in most areas of the inner and mid-Cape, especially within several miles of Nantucket Sound.

Outwash is the source of most public-water supplies because it is extensive, thick, and very permeable. Well yields of 2,000 gal/min have been reported, and 24-inch diameter gravel-packed wells with 10-foot-long screens commonly yield 250 to 1,000 gal/min.

Along the southern shore of Cape Cod Bay, lacustrine sediments (fig. 3) were deposited between a melting ice sheet in Cape Cod Bay and the Sandwich moraine in Sandwich and Barnstable and hummocky ice-contact and outwash deposits in Yarmouth, Dennis, and Brewster. Deltas and lake-bottom sediments underlie the hills, lowlands, and peninsulas of this area between the moraine and the bay. In these sediments, irregularly distributed sand and gravel deposits more than 150 feet thick in some areas are interbedded with silt and clay. Artesian conditions are common where the silt and clay overlie and confine the sand and gravel. The coarse-grained deposits are not consistently thick or extensive; however, water supplies for fish hatcheries and municipal use have been developed in the confined aquifer in Sandwich.

Moraines (fig. 3) that are composed mostly of sandy till form ridges with rugged topography on the inner Cape. Till is a poorly sorted mixture of sand, gravel, silt, clay, and boulders deposited at a recessional terminus of the ice sheet. Some sand and gravel deposits are interbedded with till in the moraines. Water supplies have been obtained from wells in some of the thicker sand and gravel deposits in the moraines, and well yields of over 1,000 gal/min have been reported. The yields of many wells are low owing to the abundance of poorly permeable material in the moraines and depths to water which exceed 100 feet in some areas.

Other sediments which yield freshwater are less common on the Cape. Very coarse sand and gravel that were deposited by meltwater either near or in direct contact with the ice sheets have been developed for public and private supplies in Mashpee. Beach and dune deposits formed by ocean currents, waves, and wind also have been developed for water supplies, but development has been limited to domestic wells because the deposits are small, near the ocean, and commonly contain water with elevated concentrations of iron, manganese, and sulfide.

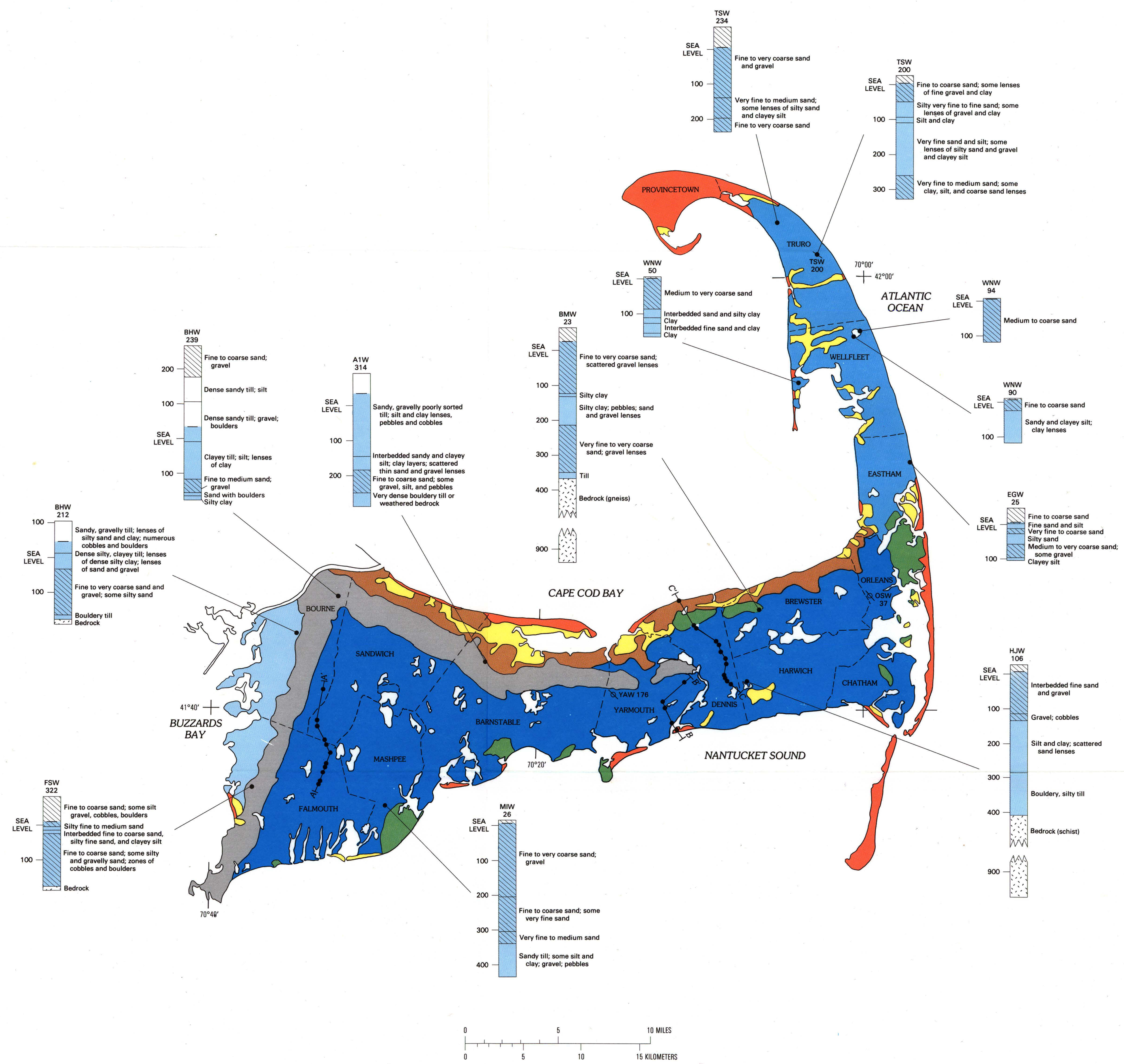
The hydraulic conductivity of the sand and gravel ranges from 100 to 500 ft/d. Hydraulic conductivity was determined from analysis of water-level drawdown during three pumping tests (table 1) and 265 specific-capacity tests (Guswa and LeBlanc, 1985, p. 5). The hydraulic conductivity of silt and clay was not measured during this study, but is estimated to be less than 1 ft/d. Because the sediments were deposited in layers, the vertical hydraulic conductivity across the layers is less than the horizontal hydraulic conductivity along the layers. In sand and gravel, the ratio of horizontal to vertical hydraulic conductivity is 10:1 or less (table 1), but the ratio can be much greater if very fine sand, silt, and clay are interbedded with the sand and gravel.

Table 1.—*Hydraulic conductivity measured by analysis of water-level drawdown around pumping wells in Truro, Orleans, and Yarmouth*

[Sources of data: Guswa and Londquist, 1976; U.S. Geological Survey, 1977; Guswa and LeBlanc, 1985]

Location	Well number in figures 3, 14, and 18	Lithology	Horizontal hydraulic conductivity, in feet per day	Ratio of horizontal to vertical hydraulic conductivity
Truro	TSW 200	Very fine to coarse sand	220	1:1 to 5:1
Orleans	OSW 37	Coarse to very coarse sand and very fine gravel, with some medium sand.	300	2:1
Yarmouth	YAW 176	Fine to medium sand	200	*

*Data were not adequate to determine ratio for this site.



EXPLANATION

BEST POTENTIAL FOR DEVELOPMENT OF LARGE SUPPLIES—Drilling generally easy for light rigs. Potential for seawater intrusion may limit development in coastal areas.

SAND AND GRAVEL OUTWASH, INNER AND MID-CAPE—Mostly fine to very coarse sand and gravel from land surface to a depth of 50 to 200 feet. In the northern half of the area, sand and gravel generally is thick and coarse and contains scattered boulders. In the southern half, the sand and gravel is finer; is underlain by thick silt, clay, very fine sand, and till; and, east of central Barnstable, commonly contains 10- to 40-foot-thick beds of silt and clay. The median specific capacity of 90 large supply wells (10 feet of 24-inch diameter screen) in the sand and gravel is 30 gal/min per foot of drawdown; 90 percent of the wells have specific capacities that range from 15 to 60 gal/min per foot of drawdown.

SAND AND GRAVEL OUTWASH, OUTER CAPE—Mostly fine to very coarse sand and gravel from land surface to a depth of 50 to 100 feet. The sand and gravel includes some silty sand, silt, and clay in lenses 5 feet to 50 feet or more thick. Boulders and lenses of till occur in widely scattered areas. Silt, clay, and very fine sand are commonly interbedded with sand and gravel at depths greater than 100 feet. Specific capacities of three large supply wells with 20 feet of 8-, 18-, and 24-inch diameter screen are 23, 74, and 18 gal/min per foot of drawdown.

SAND AND GRAVEL OUTWASH WITH SOME TILL—Fine to coarse sand and gravel that includes some sandy silt and clay lenses of variable extent and thickness. Bouldery till overlies sand and gravel at scattered locations, especially on the coastal peninsulas and headlands. Specific capacities of three large supply wells with 10, 10, and 15 feet of 24-inch diameter screen are 40, 44, and 116 gal/min per foot of drawdown.

ICE-CONTACT SAND AND GRAVEL—Mostly medium to very coarse sand and gravel that includes some silt and clay, till lenses, and scattered boulders. A well with 10 feet of 24-inch diameter screen has a specific capacity of 47 gal/min per foot of drawdown; a well with 5 feet of 8-inch diameter screen has a specific capacity of 33 gal/min per foot of drawdown.

FAIR TO GOOD POTENTIAL FOR DEVELOPMENT OF LARGE SUPPLIES—Drilling may be difficult for light rigs in moraine. Silt, clay, and till may limit development in some areas and extensive test drilling may be necessary to locate permeable zones. Potential for seawater intrusion may limit development in coastal areas.

LACUSTRINE SAND, GRAVEL, SILT, AND CLAY—Sand and gravel interbedded and interfingered with very fine sand, silt, and clay. Sand and gravel deposits commonly form hills and ridges, include some silt, clay, till, and boulders, and are as much as 150 feet thick. Very fine sand, silt, and clay commonly are adjacent to or overlap sand and gravel and are as much as 100 feet thick. Clay is particularly extensive in Barnstable. Beds of silt and clay commonly confine flow in underlying sand and gravel. Specific capacities of four large supply wells with 10 feet of 24-inch diameter screen range from 12 to 40 gal/min per foot of drawdown.

MORAINE OF SANDY TILL—Mostly poorly sorted sand and gravel that includes lenses of silt and clay, dense till (hardpan) as much as 100 feet thick, and some stratified sand and gravel as much as 100 feet thick. Large boulders and till are common within 30 feet of land surface, especially in Falmouth and Bourne. The specific capacity of one large supply well with 15 feet of 24-inch diameter screen is 16 gal/min per foot of drawdown.

POOR POTENTIAL FOR DEVELOPMENT OF LARGE SUPPLIES—Potential for seawater intrusion is great because of proximity to coast. Undesirable levels of iron, manganese, and hydrogen sulfide in ground water are commonly associated with organic matter in the deposits.

BEACH AND DUNE DEPOSITS—Mostly fine to coarse sand and some gravel that includes some silty sand, lenses of silt and clay, and some scattered cobbles. Layers of organic material are common in some areas. Sparse data show that the underlying sediments generally are similar to those at depth in adjacent areas. No large supply wells tap these deposits.

MARSH AND WETLAND ORGANIC SEDIMENTS—Peat and organic silt generally less than 30 feet thick that are mixed with varying amounts of silt and sand. Sparse data show that the underlying deposits generally are similar to those at depth in adjacent areas. No large supply wells tap these deposits.

WELL OR BORING USED TO DETERMINE AQUIFER LITHOLOGY

YAW 176 WELL USED FOR PUMPING TEST—Well number refers to table 1

A—A' SECTION LINE—Line of section shown in figure 4

TOWN BOUNDARY

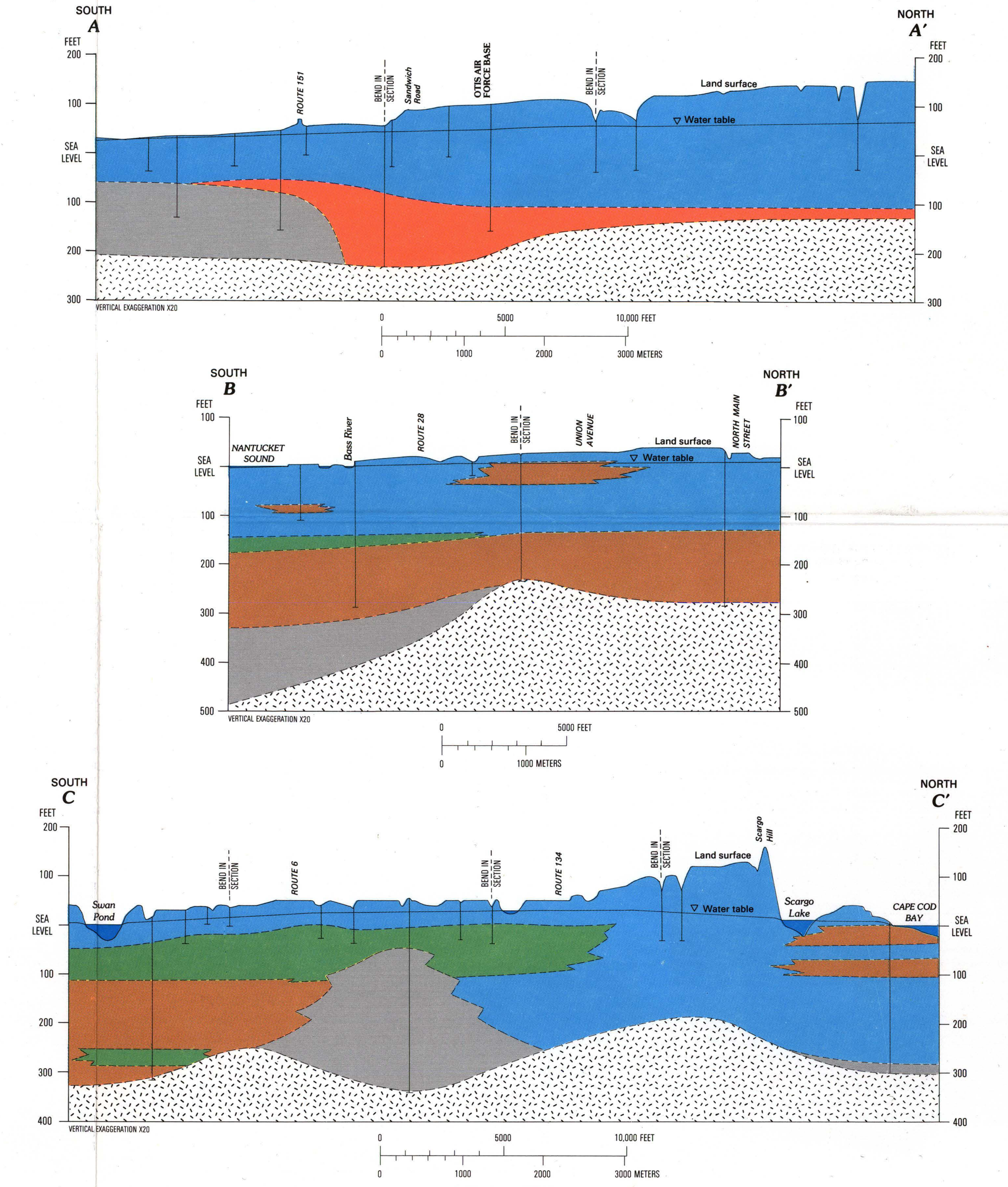
TSW 200 GEOLOGICAL SURVEY WELL NUMBER

SATURATED, UNCONSOLIDATED SEDIMENTS

COARSE-GRAINED ZONES—Mostly sand or sand and gravel

BEDROCK

Figure 3.—Hydrogeologic units of Cape Cod.



EXPLANATION

MODERATE TO HIGH PERMEABILITY—Yields water readily to properly constructed wells.

SAND AND GRAVEL—Mostly stratified sand or sand and gravel that include little silt and clay in most areas.

LOW TO MODERATE PERMEABILITY—Yields water readily to wells screened in the coarse layers. Sustained yields may be limited by the small extent of the coarse layers.

SAND AND GRAVEL WITH FINE-GRAINED BEDS—Sand or sand and gravel that includes lenses of silt, clay, and very fine sand with variable areal extent and thickness.

VERY LOW TO LOW PERMEABILITY—Does not readily yield water to wells.

FINE TO VERY FINE SAND AND SILT

VERY FINE SAND, SILT, AND CLAY—Includes scattered, probably discontinuous sand and gravel lenses in some areas.

TILL—Poorly sorted mixture of sand, gravel, silt, clay, and boulders that includes lenses of silt and clay and sand and gravel.

ESSENTIALLY IMPERMEABLE

BEDROCK—Altitude of bedrock surface is derived from seismic soundings (Oldale, 1969b) and test borings.

TEST BORING—Lithologic logs used to construct sections. Location of section lines shown in figure 3.

Figure 4.—Hydrogeologic sections of the inner and mid-Cape showing typical variations in lithology.

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INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1986

GROUND-WATER RESOURCES OF CAPE COD, MASSACHUSETTS

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