INTRODUCTION

Reverend William Blaxton, the first English settler of Shawmut (Boston) peninsula, established his homestead beside an excellent spring on the western slope of Beacon Hill in 1625. The crystal-clear spring water enticed Governor John Winthrop and colonists of the Massachusetts Bay Company to move from their brackish-water settlement in Charlestown in 1630. On September 7 of that year, Winthrop renamed the area Boston. For the next 165 years residents in the Beacon Hill area obtained water from springs and wells that tapped sand and gravel beds between till and clay beds. In 1795 the first of a series of ponds and reservoirs began to supply water to Boston through bored pitch-pine logs.

At the present time (1972), there are no springs or wells in the peninsula used for public water supply. The inhabitants are supplied by the Metropolitan District Commission with water from the Quabbin Reservoir system in central Massachusetts. Although ground water is no longer a significant source of water supply on the peninsula, it continues to be important. In filled land areas the position of the water table is critical for the structural safety of buildings built on wooden pilings driven through fill into underlying deposits. Since the late 1950's, large-scale urban-renewal projects, with their multistoried buildings and block-sized excavations, require extensive dewatering. Such activity potentially threatens wooden foundation pilings of nearby buildings, because the wood may deteriorate if exposed to air by lowering the water table.

Recognition of this problem led the Massachusetts Department of Public Works to request the assistance of the U.S. Geological Survey in monitoring ground-water levels before, during, and after dewatering associated with the construction of the proposed Inner Belt expressway across the peninsula. In addition to meeting this need, this report provides data on fluctuations of ground-water levels in the landfill areas where wooden pilings have been used. The water-table contour maps in this report compare low water of September 1967 and high water of March 1968, respectively, with composite low and high water tables from 1936 to 1940. This report will aid roadway and foundation engineers in scheduling ground-water-recharge programs to protect wooden piling during future construction projects and in assessing buoyancy factors in the design of "bathtub" and "floating" substructures.

GROUND-WATER RECHARGE AND DISCHARGE

Most of the precipitation is on buildings and pavement and is removed by overland runoff and storm drains. Direct recharge to ground-water reservoirs by infiltration of precipitation is greatest in parks, railroad rights-of-way, and other unpaved areas. Recharge is derived also from the Charles River Basin and Muddy River, which are kept at a relatively stable altitude of about 2.4 feet above mean sea level. Perhaps the greatest source of ground-water recharge is water-main leaks. Pitometer surveys indicate that water loss from 167 miles of water mains on the peninsula was about 2.5 mgd (million gallons per day) in the early 1940's, or 0.015 mgd per mile of water main (Boston Water Department, 1942, 1943, and 1945). Distributed evenly over the Boston peninsula, this recharge would be equivalent to 0.73 mgd per square mile.

Ground water discharges naturally to tidewater – the Charles River below the dam, Boston Harbor, Fort Point Channel, and South Bay. (Most of South Bay was filled land by 1967.) There is minor discharge to upper Muddy River, at the west edge of the peninsula, and perhaps for short periods to lower Muddy River and the Charles River Basin. Much ground water drains through breaks and openings in sewer mains and storm drains and into open-jointed underdrains (originally installed at a slightly lower level to keep trenches dry during installation of the other lines).

GROUND-WATER WITHDRAWALS

Dewatering for construction projects withdraws large amounts of ground water for short periods of time. Pumpage from leaky basements has accounted for small withdrawals of ground water in some areas. Use of water from the water-table aquifer is negligible. A small amount of water is withdrawn from a deeper sandy till aquifer and from bedrock, but this pumpage does not affect the water-table configuration.

GROUND-WATER MOVEMENT AND WATER-TABLE CONFIGURATION

Ground-water movement depends upon the water-transmitting characteristics (permeability) of the natural unconsolidated deposits. On the Boston peninsula these deposits display an exceedingly complex stratigraphy both vertically and horizontally. Except for a small area just north of Beacon Hill, these deposits are generally more than 70 feet thick and overlie a very irregular bedrock topography (Kaye and others, 1970). They are as thick as 200 feet under Beacon Hill and 230 feet in the Kenmore Square area. Little is known about the ground-water-flow system throughout this sequence because of the wide range of permeability.

Movement in the upper part of the ground-water system is better understood and can be related to the different types of unconsolidated deposits and artificial fill. Distribution and relative permeability of surface and near-surface deposits and fill are shown in figure 1.

The water table is highest in the original land area of the peninsula and the narrow neck of land that connected that area to the mainland to the southwest (fig. 1). The relatively high water table on Copps Hill reflects topography and the low permeability of the till. Not enough information is available to construct water-table contours for Beacon Hill. Springs in colonial days suggested a water table, perhaps perched, as high as 60 feet above mean sea level. Remains of wells on the eastern flanks of the hill suggest a former water table of at least 30 feet above mean sea level. At present the water table is lower than in colonial days because there is little ground-water recharge. Most precipitation runs off as storm drainage. The hill in the Fort Hill area was entirely excavated, but the relatively high water table reflects low permeability of till. Even though little topographic expression of the neck of land that connected Beacon Hill and Fort Hill to the mainland remains, a relatively high water table exists in the fine sand, silt, and clayey silt underlying the neck. Slower ground-water movement through these deposits than through adjacent coarser grained fill creates the ground-water mound. Water-table lows, or troughs, extend across this neck area, where ground-water flow is relatively rapid through permeable backfill along major sewers.

Landfill operations near the end of the peninsula in the early 1800's (fig. 1) utilized material from nearby Beacon, Fort, and Copps Hills. Most of this material was probably till with relatively low permeability. Although the water table in these filled areas is relatively low, small local water-table highs exist; these may reflect the variable permeability. Landfill along both sides of the Neck before 1851 was undocumented, and the source of fill for these areas has not been traced; permeability variations are probably extreme.

The mud-cored Mill Dam along present Beacon Street and Cross Dam may hinder ground-water movement except near the old Exeter Street gates. Railroad embankments completed in 1834–35 do not seem to affect ground-water movement at present.

The remainder of Back Bay, Fens East and West, and part of South Bay was filled systematically and extensively between 1858 and 1892 with sand and gravel from the town of Needham, about 9 miles to the southwest. Most of this fill has a moderate permeability. Ground-water movement through the fill is relatively rapid, and the water table is generally low. Where this fill is underlain by sand and gravel, such as old Gravelly Point (fig. 1), dewatering during construction can result in extensive lowering of ground-water levels.

Nearly watertight concrete tunnels, through which subways run, do not hinder ground-water movement if the subway line is parallel to the ground-water gradient (perpendicular to the water-table contours), such as along Huntington Avenue Subway near Prudential Center (old railroad yards) when there is no dewatering on old Gravelly Point; they will hinder movement if they are perpendicular to the ground-water gradient (parallel to the contours), such as along the Boylston Street Subway near Copley Square (J.R. Worcester Co., written commun., 1945).

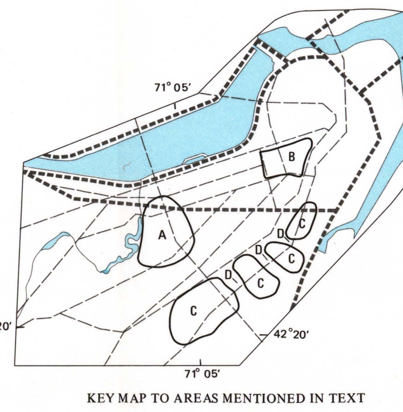
COMPOSITE LOW WATER–TABLE MAP, 1936-40

This map was constructed from the lowest recorded water levels measured during 1936–40, regardless of the month and year in which they occurred (Works Progress Administration, 1940). Although it differs in detail from the lowest water level of any one year, the water-table contours show that water from both the Muddy River and the Charles River Basin recharged the unconsolidated deposits along the north shore of the peninsula. Water flowed through these sediments and discharged into storm drains, sewers, and underdrains and into the permeable fill around these mains.

In 1902, two rows of wooden sheeting were driven through sand and gravel fill into the underlying organic silt to hold back ground water during construction of the large combined sewer and storm drain parallel to the shore of the Charles River Basin from the mouth of Muddy River to Charles River Dam; this sheeting was never removed. The contours indicate that perhaps this sheeting continued to hinder ground water moving southward to replace water drained by sewers and storm drains along Beacon Street.

Depression of ground-water levels in the old Gravelly Point area near Massachusetts Avenue in area A (key map) reflects dewatering by construction projects during 1936–40 as well as discharge into sewers and storm drains. Excavations exposed fill, silt and mud with low permeability, and underlying sand and gravel with relatively high permeability. Pumpage from these sites dewatered the upper part of the sand and gravel, and perched the original water table above the silt and mud. In this area contours reflect the lowest water levels in the sand and gravel. Lower water levels than shown on the map may have occurred along Huntington Avenue between Massachusetts Avenue and Exeter Street because of subway construction during this period, but available data cannot substantiate this conclusion.

The high water table at Boston Common (B) reflects above-average ground-water recharge caused by greater infiltration of precipitation than is possible in other areas. The generally high water table along Washington Street (C) reflects slow ground-water movement through fine-grained sediments. Movement is northward toward storm drains and sewers, southward toward South Bay, or toward permeable backfill (D) along major sewers that cross Washington Street.



KEY MAP TO AREAS MENTIONED IN TEXT

EXPLANATION

2376 — Observation well. *Number is well with hydrograph shown on sheet 2*

Observation well not used because of lack of data or apparent spurious water level

Observation well not used because it reflected perched water table

1 — Water-table contour. *Shows altitude of water table. Dashed where approximate; hachured indicates depression. Contour interval is 1 foot. Sea level datum of 1929*

Direction of ground-water movement near shores of the Charles River Basin and Muddy River

Channel of Muddy River under roadways

Area of perched water table because of dewatering during construction

Artificial pond (perched)

City of Boston major sewer and storm drain distribution system. *Where two intersecting lines are solid, sewers or drains are interconnected where two lines cross but are not interconnected; the solid line overlies the interrupted line. Only major sewers and drains are shown; minor ones underlie most streets but are not shown*

P — Metropolitan District Commission combined sewer and storm drain. P, pressurized line

Brook conduit

Interceptor and combined sewer

Sanitary sewer

Storm drain

Pumping station

Recharge in unpaved area or partly unpaved area

Possible recharge from water-main leak

Base from Boston Redevelopment Authority 1:9,600 city base, March 1969

SCALE 1:6 000

MEAN SEA LEVEL AND OTHER DATUM PLANES

See text for further details

	feet
Sea-level datum, Commonwealth Pier 5, 1921-23	0.00
Mean tide level, Commonwealth Pier 5, 1929	-.12
Mean low water, Boston Harbor, 1929	-4.84
Boston low water datum, 1929	-4.87
Boston City Base	-5.65
Metropolitan District Commission (sewers)	-105.62

SELECTED REFERENCES

Aldrich, H. P., Jr., 1970, Back Bay Boston, part 1: Boston Soc. Civil Engineers Jour., v. 57, no. 1, p. 1–33.

Boston Society of Civil Engineers, 1961, Boring data from greater Boston, Section 1: Boston Peninsula: Boston Soc. Civil Engineers Jour., v. 48, no. 1, p. 1–67.

———1969, Boring data from greater Boston, Section 1: Boston Peninsula: Boston Soc. Civil Engineers Jour., v. 56, no. 3–4, p. 131–293.

Boston Water Department, Pitometer water waste surveys—1942, 1943, and 1945.

Kaye, C.A., 1961, Pleistocene stratigraphy of Boston, Massachusetts, *in* Short papers in the geologic and hydrologic sciences, articles 1–146, Geological Survey Research, 1961: U.S. Geol. Survey Prof. Paper 424-B, p. B73–B76.

———1964, The upper limit of barnacles as an index of sea-level change on the New England coast during the past 100 years: Jour. Geology, v. 72, no. 5, p. 580–600.

Kaye, C.A., Barker, R.M., and Dieterich, K.V., 1970, Preliminary map of bedrock surface under parts of Boston, Cambridge, and Brookline, Massachusetts: U.S. Geol. Survey open-file report, 6 p., map, 1:6,000.

Marmer, H.A., 1951, Tidal datum planes: U.S. Coast and Geod. Survey Spec. Pub. 135, 142 p.

Massachusetts Geodetic Survey, 1942, Bench marks at water supply systems – In the counties of Barnstable, Bristol, Essex, Middlesex, Norfolk, Plymouth, Suffolk, Worcester, sea-level datum of 1929: Mass. Geod. Survey, 338 p.

Schureman, Paul, 1928, Tides and currents in Boston Harbor: U.S. Coast and Geod. Survey Spec. Pub. 142, 116 p.

Whitehill, W.M., 1968, Boston, a topographical history: Harvard University Press, 2d ed., 299 p.

Works Progress Administration, 1940, Ground-water-level survey, Building Department, City of Boston: W.P.A. Projects nos. 5325 and 18868.

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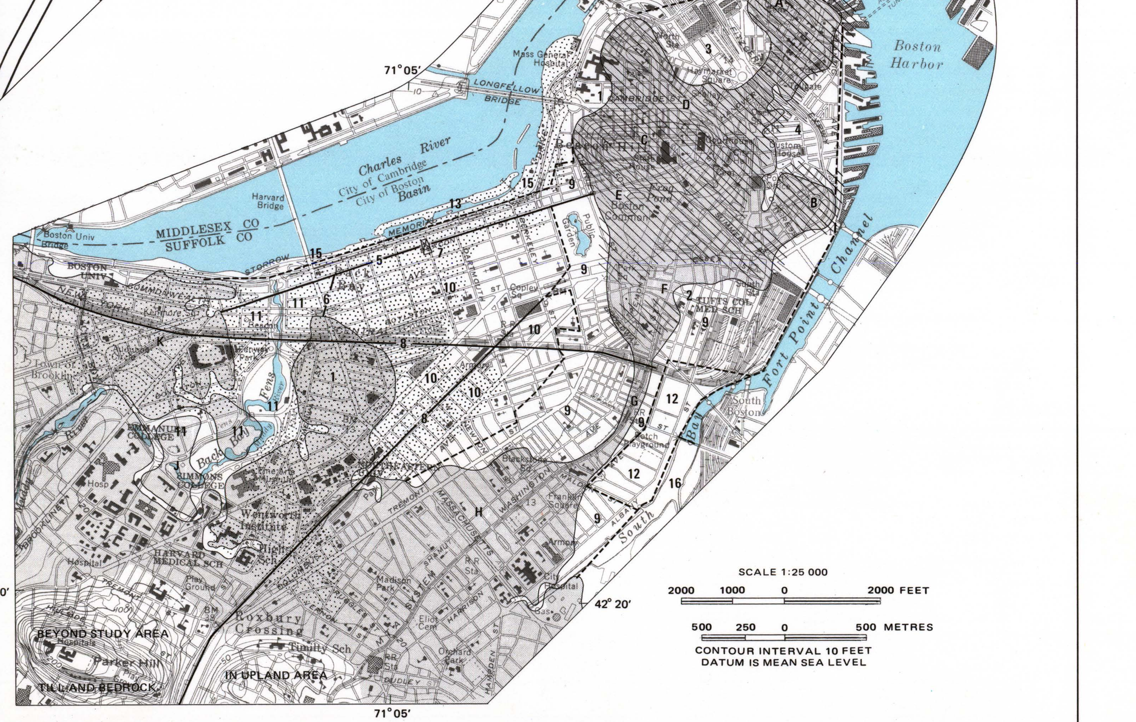
MEAN SEA LEVEL AND OTHER DATUM PLANES

Commonly used tidal datum planes are defined by Marmer (1951). Several different mean sea levels have been determined from different periods of record at Boston Harbor (Kaye, 1964, p. 583–589). The water-level altitude on all maps and hydrographs in this report are referred to the U.S. Coast and Geodetic Survey "Sea level datum of 1929"; determination of this datum for Boston Harbor is explained in Schureman (1928, p. 42) and is used as mean sea level by the U.S. Geological Survey. Some other datum planes (Massachusetts Geodetic Survey, 1942) commonly used in Boston (expressed in feet below "Sea level datum of 1929") are listed on each contour map. To convert altitudes in this report to Boston City Base, add +5.65 feet.



SCALE 1:25 000

2000 1000 0 2000 FEET

500 250 0 500 METRES

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

Base from U.S. Geol. Survey
Boston South quadrangle,
1:24,000, 1956

FIGURE 1.—MAP SHOWING ORIGINAL LAND AREA ABOVE MEAN HIGH TIDE, NEAR-SURFACE MATERIALS, AND SEQUENCE OF LANDFILL OPERATIONS.

EXPLANATION

About 50 percent of the present Boston peninsula is original land, but nearly 70 percent of that area was marshland which required additional fill (Aldrich, 1970; Boston Society of Civil Engineers, 1961, 1969; Whitehill, 1968). Wooden pilings were commonly used to support larger buildings in filled land areas.

ORIGINAL LAND AREA

Underlain by fine material (mud, clay, silt, and fine sand); relatively low permeability

Underlain by coarse material (sand and gravel) or less than 10 feet of silt and (or) mud over sand and gravel; relatively high permeability in sand and gravel; relatively low permeability in silt and sand

Underlain by till (nonlayered mixture of clay- to boulder-sized material) or complex lenses or layers of peat, clay, sand, and gravel; wide range of permeability

A Copps Hill (partly excavated); till; relatively low permeability
B Fort Hill (completely excavated); till; relatively low permeability
C Beacon Hill (partly excavated); till and sand and gravel; wide range of permeability
D Northern flank of Beacon Hill; silty clay, sand and gravel, and till thrust faulted into a complex sequence; wide range of permeability
E Western part of Boston Common; fill, peat, and till overlying folded clay, sand and gravel, and older till (Kaye, 1961); wide range of permeability
F South of Boston Common; fine sand, silt, and silty clay; relatively low permeability
G The Neck; fill, fine sand, silt, and silty clay; relatively low permeability
H Low-lying marshlands; fill, fine sand, silt, and clay; relatively low permeability
I Gravelly Point; fill and sand and gravel underlain by clay at depth; relatively high permeability in sand and gravel, very low permeability in clay
J Upper Back Bay Fens; fill and organic silt overlying clay; relatively high permeability in fill, low permeability in silt and clay
K Kenmore Square, Fenway West; thin fill and organic silt overlying sand and gravel; relatively high permeability

FILLED LAND AREA

Fill underlain by fine material (mud, clay, silt, and fine sand); relatively low permeability

Fill underlain by organic silt and mud over sand and gravel; silt and mud less than 10 feet thick except in areas 13 and 15 where it is 10 to 20 feet thick; relatively low permeability in silt and mud, relatively high permeability in sand and gravel

Fill underlain by till (nonlayered mixture of clay- to boulder-sized material) or complex lenses or layers of peat, clay, sand, and gravel; wide range of permeability

1. Charles Street, about 1800; fill from Beacon Hill (till?); relatively low permeability
2. Harrison Avenue, 1804; fill from Fort Hill
3. Mill Pond, 1807-24; fill from Beacon Hill
4. Town Cove, 1805-72; fill from Fort Hill and elsewhere
5. Mill Dam, 1818-21; mud core
6. Cross Dam, 1818-21
7. Old discharge gates in Mill Dam
8. Railroad embankment, 1834, 1835
9. Back Bay and South Bay, to 1851; fill from unknown sources; wide range of permeability
10. Back Bay, 1858-92; fill from Needham sand and gravel deposits; relatively high permeability
11. Back Bay Fens, 1858-92; fill from Needham sand and gravel deposits; relatively high permeability
12. South Bay, 1858-92; fill from Needham sand and gravel deposits; relatively high permeability
13. Charles River promenade
14. Charles River Dam, 1900-10
15. Storrow embankment, 1929-31
16. Rest of South Bay, 1965-67; about 60 percent coarse sand and gravel with relatively high permeability and 40 percent mixed material with wide range of permeability

Interior—Geological Survey, Reston, Va.—1975—W73230

GROUND–WATER LEVELS ON BOSTON PENINSULA, MASSACHUSETTS

By
John E. Cotton and David F. Delaney
1975

For sale by U.S. Geological Survey, Reston, Va. 22092