Geology and Hydrology of the Hartford Research Center CANEL Site Middletown, Connecticut

GEOLOGICAL SURVEY BULLETIN 1133-G

Prepared in behalf of the U.S. Atomic Energy Commission and published with the permission of the Commission

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By J. A. BAKER, S. M. LANG, *and* M. P. THOMAS

STUDIES OF SITES FOR NUCLEAR ENERGY FACILITIES

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GEOLOGY AND HYDROLOGY OF THE HARTFORD RESEARCH CENTER, CANEL SITE, MIDDLETOWN, CONNECTICUT

By J. A. Baker, S. M. Lang, and M. P. Thomas

ABSTRACT

The Hartford Research Center, CANEL (Connecticut Advanced Nuclear Engineering Laboratory) site, is in the eastern part of Middletown in Middlesex County, Conn. It lies within a broad bend of the Connecticut River, which bounds it on the north and east. The site, which is about 1.75 square miles in area, is drained principally by the Connecticut River and two of its small tributaries, Maromas Brook and Hubbard Brook. The Connecticut River, trunk stream of the largest river system in New England, drains a region covering 10,880 square miles above the site. Since 1928 the weekly discharge has varied from about 2,860 to 190,000 cfs. (cubic feet per second), the average weekly flow being about 18,300 cfs. The reach of the river at the site is navigable and is affected by tides at low stages. The mean annual flood stage of the river at the CANEL site is about 11 feet above mean sea level and the maximum observed flood height, which occurred in March 1936, was about 24.3 feet above mean sea level.

Ground water occurs in alluvium, till, outwash, and bedrock. The alluvium is composed mostly of clay, silt, sand, some gravel, and intermixed organic material. The most extensive alluvial deposits occur along the Connecticut River flood plain and consist of as much as 40 feet of clay, silt, and fine-grained sand overlying an undetermined thickness of coarse sand and gravel. The uppermost fine-grained flood-plain deposits are relatively impermeable and act as a leaky aquiclude. The coarser grained underlying unit is included with the outwash aquifer in this report.

The glacial outwash, composed of beds and lenses of sand, gravel, and some silt is about 146 feet thick at maximum and is the most productive aquifer in the area. This aquifer yielded 12 gpm (gallons per minute) with a drawdown of about 45 feet to as much as 1,570 gpm with a drawdown of 13.7 feet during tests on individual wells. The largest yields are obtained from those wells along the Connecticut River where the outwash aquifer is susceptible to recharge from the river. Data from pumping tests on wells Mt 287 and Mt 288 in the outwash aquifer gave calculated values for coefficients of transmissibility of 2×10^5 and 3×10^5 gpd (gallons per day) per foot and coefficients of storage of 3.3×10^{-4} and 3.0×10^{-4}, respectively. The pumping tests show that the outwash beneath the Connecticut River flood plain is hydraulically connected to the river.

Till, as much as 15 feet thick, is composed of compacted, unsorted sand, gravel, silt, clay, and boulders. Because it is poorly sorted and compacted, the till is relatively impermeable and yields only small amounts of water to wells.

The bedrock is composed of metamorphic rocks of sedimentary and igneous origin. Most of the water in bedrock is contained in openings along joints and other fractures which neither store nor yield large amounts of water.

Practically all the ground water in the CANEL site is derived from local precipitation. The precipitation that is not evaporated or transpired moves ultimately to the Connecticut River by either overland or underground routes. Of the water in the hilly, western half of the area that is not evaporated or transpired, about half moves overland, some moves underground in till and bedrock, and some remains trapped in ponds and swamps for long periods. Of the water in the eastern, terrace half of the area that is not evaporated or transpired, most infiltrates to the zone of saturation and then moves underground through the glacial outwash material; most of the overland flow in the eastern half of the area originates in streams which rise in the western half of the area. The precise directions and rate of ground-water movement enroute to the river are not known. Under natural conditions, water in outwash may move at the rate of more than 100 feet per day beneath the central part of the high terrace but, owing to lower hydraulic gradient, at only about 2 feet per day beneath the Connecticut River flood plain.

A liquid spill at the surface anywhere in the site area would reach the Connecticut River eventually, faster overland and slower underground. Liquid spilled in the western half of the area would tend to move toward the river either overland or underground, and liquid spilled in the eastern half of the area would tend to move toward the river underground. Once in the river, movement and dilution of the spilled material would be influenced by the volume of river discharge and the tidal stage. During periods of low river discharge and high tidal stage, particularly, spilled material might travel a considerable distance upstream.

From past records it would appear that little danger to the facilities is to be expected from earthquakes.

Most water for domestic, municipal, or industrial supply in the area downstream from CANEL is obtained from ground water or from municipal reservoirs that are remote from the river. A few domestic wells are on the river flood plain and may receive inflow of river water during times of flood. One industrial plant about a mile upstream from CANEL obtains a moderate supply from wells in outwash immediately adjacent to the Connecticut River, and, in addition, pumps a small amount of water from the river to wash filters and for cooling. The Connecticut River is used for commercial navigation, recreational boating, fishing, and a limited amount of swimming and bathing.

INTRODUCTION

The Hartford Research Center, CANEL (Connecticut Advanced Nuclear Engineering Laboratory) site, is in the eastern part of the town of Middletown in Middlesex County, Conn. It is about 5 miles east of the main business district of Middletown, as located on the Middle Haddam U.S. Geological Survey topographic quadrangle (fig. 1). The site contains an area of 1.75 square miles and lies within a broad bend of the Connecticut River, which bounds it on the north and east.

In accordance with a request from C. V. Theis, former coordinator of the Geological Survey's water-resources studies for the Atomic Energy Commission, a reconnaissance study was made of the geology and hydrology of the government reservation near Middletown, Conn. (E. S. Simpson, September 1955). This study included a review of the facilities, a review of available data, consultations with responsible parties, and field inspection of the area to obtain background information for an appraisal of geologic and hydrologic conditions, and for an estimate of possible future need for data not then available.

Subsequently the Geological Survey was asked by the Atomic Energy Commission to make further field studies of the site. Accordingly, an investigation of the geology and ground-water conditions at the CANEL site began in March and continued through December 1956. The purpose and scope of the investigation were to collect, appraise, and report on the available geologic and hydrologic information in the vicinity of the site. Records, including 113 logs, were obtained for 148 wells and test holes; selected records are included in table 6. Periodic measurements of water levels were made in 10 wells. Con-

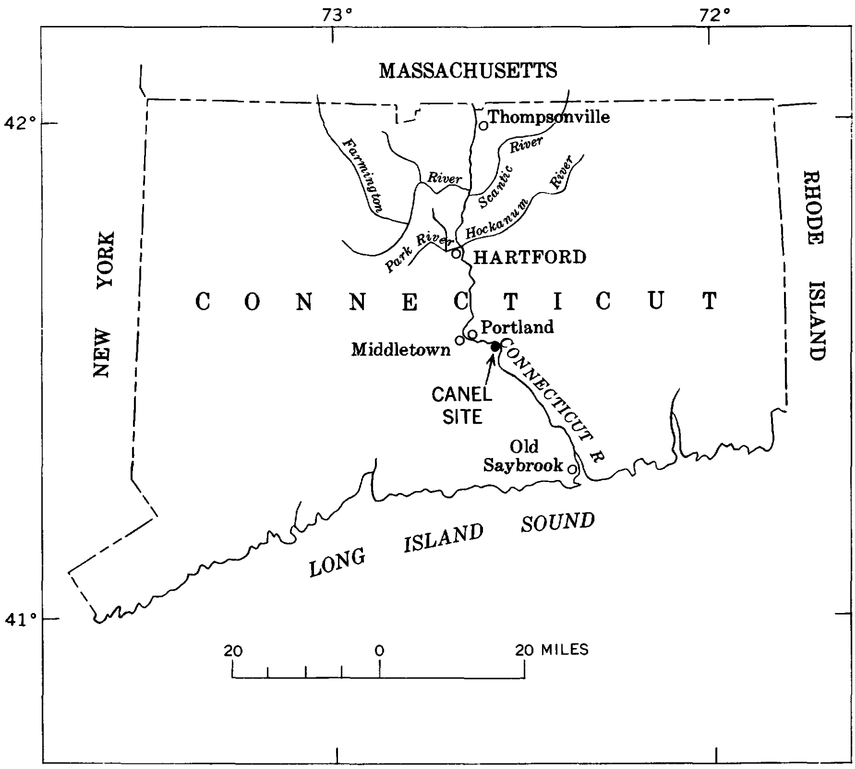

FIGURE 1.—Location of CANEL site.

tinuous records of water levels were obtained from 2 wells and the Connecticut River, and 19 surface-water discharge measurements were made at 6 sites (table 2) along Maromas Brook and its tributaries, and a synthetic record of the discharge of the Connecticut River during the period 1928–58 was prepared for the CANEL site. Aquifer tests were made at the sites of two proposed supply wells. Chemical analyses also were made of eight water samples from wells, one sample from the Connecticut River, and one from a quarry pond (table 4). In addition, surface contacts of the geologic units were mapped, and exposures were studied; particular attention was given to the water-bearing properties of the units.

Basic data collected during this investigation, but not incorporated in the report, may be examined at the office of the U.S. Geological Survey, Ground Water Branch, Room 204, Post Office Building, Middletown, Conn.

The work was done under the immediate supervision of J. E. Upson and G. C. Taylor, Jr., former district geologists. Surface-water data were collected and compiled by personnel of the Hartford office of the Geological Survey. N. J. Lusczynski, hydraulic engineer, planned and reviewed the results of the aquifer tests. The help of the personnel of Charles T. Main, Inc., prime contractor for CANEL activities, and of R. E. Chapman Co., Inc., drilling contractors, is also gratefully acknowledged.

PHYSICAL FEATURES

Topographically and geologically the CANEL site may be divided into two parts of approximately equal area. The dividing line coincides closely with the north-south access highway (River Road). The western half of the area, which reaches a maximum altitude of about 450 feet, is hilly and is underlain by consolidated rocks and a thin mantle of glacial till. The eastern half, which contains most of the structures, is mainly a high-level, flat-topped terrace which stands at an altitude of about 140 feet and is underlain by outwash. A low alluvial terrace, which is part of the Connecticut River flood plain, extends along the river at the base of the high terrace at an altitude of about 10 feet.

The CANEL site is drained principally by the Connecticut River and two of its tributaries on the site. Maromas Brook and its tributaries drain most of the hilly western half of the area and most of the high terrace; Hubbard Brook drains a small part of the extreme western half of the area and a small part of the southern extremity of the high terrace; several smaller streams drain the remainder of the area.

GEOLOGIC UNITS AND THEIR WATER-BEARING CHARACTERISTICS

The geologic units that store, transit, and confine water in the CANEL area are metamorphic rocks of Paleozoic or possible pre-Paleozoic age, glacial deposits of Pleistocene age, and fluvial deposits of Recent age. The units are described briefly in table 1, and their areal extent is shown on plate 1.

The metamorphic rocks comprise the Maromas Granite Gneiss and the younger Bolton Schist. Pegmatites intrude both formations but were not mapped separately for this report. The glacial deposits were formed during the Cary stade of the Wisconsin Glaciation (Flint, 1953, p. 900) ; they consist of till, unsorted material deposited directly by glacial ice, and younger outwash, sorted and stratified material deposited by melt-water streams. Alluvium of Recent age consists of deposits of existing streams. Swamp deposits of Recent age overlie all other units at places.

CONSOLIDATED ROCKS

MAROMAS GRANITE GNEISS

The Maromas Granite Gneiss was named from exposures in the Maromas quarries (Gregory, 1906, p. 115, 143) in the western part of the CANEL area. It crops out, or is thinly covered with till, in a large part of the western half of the area, and is overlain by till, outwash, and alluvium in most of the eastern half of the area beneath the high terrace and Connecticut River flood plain. The Maromas Granite Gneiss is overlain by the Bolton Schist in the northern and southwestern parts of the area.

In typical exposures the Maromas Granite Gneiss is a medium-grained gray granite gneiss. The chief minerals are feldspar, quartz, biotite, and hornblende, and minor amounts of pyrite and magnetite. The rock is massive in some places, but generally it is well foliated and jointed.

The granite gneiss has three sets of joints: one set strikes approximately north and dips vertically to steeply east; one set strikes approximately east and dips vertically to steeply south; the third set, which is about parallel to the foliation, strikes northwest and dips from about 10° to about 40° northeast toward the Connecticut River. Joint openings are less than 1 inch to as much as 4 feet wide at the surface, but most joint openings are probably much smaller at depth. The joints are spaced less than 1 foot to about 10 feet apart. Many of the vertical joints terminate at the low-dipping joints parallel to the foliation.

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TABLE 1—*Geologic units at the Hartford Research Center CANEL site and their water-bearing properties*

System	Series	Geologic unit	Physical character	Ground-water conditions
Quaternary	Recent	Swamps and areas periodically flooded	Silt, clay, and sand mixed with organic matter occupy the tidal swamp at the inner edge of the Connecticut River flood plain and other local depressions on the flood plain, terrace, and hilly upland areas; thickness generally is less than 10 ft.	Probably not important as an aquifer but locally may act as a confining layer.
		Dredged channel deposits	Medium to very coarse sand dredged from the channel of the Connecticut River and piled on the flood plain in the southeastern part of the area; overlies the upper silty zone of the alluvium; limited in areal extent; maximum thickness about 10 ft.	Relatively permeable; not a good source of water because of limited areal extent and thickness; transmits water readily. Water moves downward to contact with alluvium then along contact toward Connecticut River.
		Alluvium	Alluvial deposits of silt, clay, sand, and gravel deposited in the channel and flood plain of the Connecticut River and in the channels of the minor streams draining the western, hilly half of the area. Alluvium rests on bedrock, till, and outwash. The alluvium in the narrow, flat flood plain of the Connecticut River consists of an upper zone of silt and clay and a lower zone of sand and gravel. The thickest deposits are in the Connecticut River flood plain, but the maximum thickness is not known because of difficulty in distinguishing the lower zone of alluvium from the underlying outwash in well samples. The upper silty zone is 10 ft to 40 ft thick.	Upper silty zone relatively impermeable and not a source of water in this area; retards the downward movement of water to the outwash under the Connecticut River flood plain, and acts as a leaky confining layer to water in the outwash. Water-table conditions prevail. Water in the silty zone is under higher head than water in the outwash, and under natural gradients water is free to move into underlying outwash and toward the Connecticut River.
	Pleistocene	Outwash	Sorted and stratified glaciofluvial deposits of a valley-train type. Material consists of sand and gravel and some silt and boulders. Deposits are exposed in the flat terrace at an altitude of about 140 feet in eastern half of area. Outwash rests on till and on bedrock where till is missing. Well logs indicate that outwash extends under the Connecticut River flood plain and channel, and the outwash deposits exposed in the area are probably connected in the subsurface to outwash deposits on the east bank of the Connecticut River. Current cross-bedding and cut-and-fill structures are common.	Relatively permeable and the best soruce for development of large water supplies where saturated and connected hydraulically to the Connecticut River. Permeability varies with location. Test drilling is advisable to locate the more permeable zones. Water-table conditions prevail on the terrace area, but artesian conditions exist where outwash underlies the silty zone of Connecticut River alluvium. Where artesian conditions prevail, ground-water levels are affected by tidal changes in the Connecticut River. Under natural gradients water moves toward the Connecticut River. Under pumping

TABLE 1—*Geologic units at the Hartford Research Center CANEL site and their water-bearing properties*—Continued

System	Series	Geologic unit	Physical character	Ground-water conditions
Quaternary—Continued	Pleistocene—Continued	Outwash—Continued	Locally the bedding dips steeply and suggests collapse after melting of small ice blocks. No large-scale collapse is indicated. The thickness increases from a featheredge at the inner edge of the terrace to 146 ft at the outer edge of the terrace. The maximum thickness of outwash under the Connecticut River is not known, but at the south end of the reservation the log of well Mt 300 indicates a combined thickness of outwash and alluvium of more than 165 ft.	conditions along the Connecticut River flood plain gradients are reversed and water is free to move from the Connecticut River toward the pumped wells. Wells penetrating outwash under the Connecticut River flood plain have yielded 1,570 gpm with drawdown of 13.66 ft. At outer terrace edge, wells yielded as much as 110 gpm with drawdown of 1.5 ft. The range in yield is affected largely by well location and construction.
		Till	Nonstratified mixture of rock particles ranging in size from clay to boulders; exposed as discontinuous mantle overlying bedrock in western, hilly half of area, and apparently discontinuous on top of bedrock underlying outwash deposits on the terrace and under the Connecticut River flood plain; ranges from featheredge to more than 15 feet thick in exposures; is missing in some well logs but is as much as 15 ft thick in others.	Relatively impermeable because of poor sorting and compactness; impedes downward percolation of water and may act as confining layer for water in underlying bedrock; yields small supplies of water to a few domestic wells. Shallow wells likely to go dry in dry weather.
	Unconformity			
Paleozoic or Precambrian		Bedrock	Maromas Granite Gneiss: medium-grained gray granite gneiss with aplitic contact phases and minor pegmatite intrusions; crops out in western, hilly half of area; well jointed and well foliated. A set of vertical joints strikes roughly north and another set strikes roughly east. A set of gently dipping joints parallel to the foliation strikes generally northwest and dips east. This rock apparently forms core of an anticline and apparently is con cordant with the Bolton Schist; maximum thickness is not known. Bolton Schist: dark biotite schist, quartzite, sericite schist, banded gneiss, and impure marble with pegmatite intrusions; crops out along southwestern and northern margins of the Maromas Granite Gneiss body; well foliated but less well jointed than the gneiss; apparently forms synclines north and south of the site; maximum thickness is not known.	Water occurs in joints and fissures in bedrock. The joints and fissures do not store much water but act as conduits which transmit water. In some places, water in bedrock is under higher head than water in outwash, and water flows at the surface from some wells. Under natural gradients and where till does not impede movement, water may move upward into overlying outwash. Yields as much as 10 gpm to wells intersecting one or more water-bearing joints or fissures.

BOLTON SCHIST

The Bolton Schist was named from exposures in Tolland County in north-central Connecticut (Percival, 1842). The schist crops out, or is thinly covered with till in the northern and southwestern parts of the hilly western half of the area. In the eastern half of the area it is overlain by till, outwash, and alluvium beneath the northern and southern ends of the high terrace and the Connecticut River flood plain.

The Bolton Schist consists chiefly of dark biotite schist and contains garnet and staurolite. Other rock types include quartzite, sericite schist, banded gneiss, and impure marble. The schist is jointed and well foliated.

In contrast to the Maromas Granite Gneiss, which has three sets of joints, the Bolton Schist has only two sets. They correspond to the vertical or steeply dipping joints in the Maromas Granite Gneiss; one set strikes approximately north, and the other strikes approximately east. Unlike the Maromas, the Bolton does not have joints parallel to the foliation.

GEOLOGIC STRUCTURE

The structural relationships of the Maromas Granite Gneiss and the Bolton Schist are complex. The contact between gneiss and schist is covered throughout most of the area but is well exposed along Hubbard Brook beyond the southwestern boundary of the area. There the contact is parallel to the foliation of both the gneiss and the schist.

Minor folds in the gneiss and schist and drag folds in the schist suggest major folding of these formations, as does the foliation of the gneiss and schist which wraps around the northern "nose" of the gneiss body. The Maromas Granite Gneiss apparently forms the core of a major anticline, its axis striking northwest, plunging north, and overturned to the west.

No major faulting within the area is indicated, although small-scale faulting and displacement of a few inches between beds was observed in a minor fold of schist and gneiss in the western part of the area. Slippage along joints and displacement of a few inches was observed in an outcrop of gneiss along the western margin of the high terrace.

CONFIGURATION OF THE BEDROCK SURFACE

The exposed bedrock surface is highly irregular, and there is some evidence that the buried bedrock surface also is irregular. However, present information provides only a generalized idea of the configuration of the buried surface. (See pl. 1.) In particular, information is lacking for a broad belt beneath the outer part of the high terrace and beneath most of the building sites in the plant area. Near the boundary between the two parts of the area, the bedrock surface slopes generally eastward, passing beneath both the high-level and the low-level terraces. Beneath the low-level terrace on the west bank of the Connecticut River, the bedrock is about 77 feet below land surface at the northern edge of the area and more than 165 feet below land surface at the southern edge.

WATER-BEARING CHARACTERISTICS

Despite different lithologies, the two bedrock formations underlying the area are similar in water-bearing properties and constitute a single aquifer.

Ground water is stored in and moves through interconnecting joints in the bedrock. Although the joint openings range in width from less than 1 inch to about 4 feet at the surface, they close up at depth. The vertical joints probably remain open to greater depths than do the gently dipping joints parallel to the foliation, and deep wells probably obtain most of their water from vertical joint openings.

The bedrock is a source of small but usually dependable water supplies adequate for most domestic uses. One well, Mt 285, had a measured flow of about 1½ gpm (gallons per minute) and, by report, wells Mt 274 and Mt 271 flowed at rates of 5 gpm and 8 gpm, respectively. A fourth well, Mt 301, on being bailed "dry" by the driller, reportedly filled with water to the original level at the rate of about 4 gpm.

UNCONSOLIDATED DEPOSITS

TILL

Till is a poorly sorted, unstratified mixture of clay, silt, sand, gravel, and boulders deposited directly by glacial ice. The till in the CANEL area forms a discontinuous, thin mantle on the bedrock surface. It lies at land surface over much of the western half of the area and occurs discontinuously beneath outwash and alluvium under much of the eastern half of the area. The till ranges in thickness from a few inches to about 37 feet. Its greatest known thicknesses in the outcrop area are about 37 feet in well Mt 270 beyond the western limit of the site and about 25 feet in well Mt 279 beyond the southern limit of the site. Well data show that beneath the outwash in the eastern half of the area the till is missing in some places and is 1 to 15 feet thick in others.

Two types of till, of different color and composition, are exposed in the area. One type is gray-brown, is compact, breaks into chips when dry, and is semiplastic when wet. The other type is red to reddish-brown, is compact in some places but loose in others, and is friable. Both types are sandy, but the gray-brown till contains more clay and a greater proportion of angular rock fragments than the red till. In one exposure, the red till contains rounded quartz pebbles. In some exposures the gray-brown till rests directly on the bedrock, but no exposures were seen where the red till rests on bedrock, and no exposures were seen where the two types of till are in contact with each other. The two types seem to have no systematic areal distribution in the area; they were mapped as a single unit.

Quantitative data on the hydrologic characteristics of the till are lacking. However, because of its compactness, lack of sorting and stratification, and the presence of silt and clay, the till is relatively impermeable. Most wells in till are located where the till occurs at the surface; these wells yield small amounts of water from depths of about 4 to about 37 feet.

OUTWASH

The outwash consists of sorted and stratified sand, gravel, silt, and scattered boulders deposited as a valley train (Flint, 1953, p. 899) by melt-water streams and later trenched by the Connecticut River. The outwash rests on till and bedrock and is overlain by Recent alluvium.

The outwash underlies and forms the broad, flat-topped terrace in the eastern half of the area upon which most of the present buildings are located. The surface of the terrace is about 140 feet above mean sea level. The terrace extends beyond the northern and southern extremities of the area in an arc parallel to the Connecticut River. It is about 600 feet wide at the north end of the area, 3,100 feet wide at the center of the area, and about 1,100 feet wide at the south end of the area.

Well logs reveal that outwash is present beneath the Connecticut River flood plain (pl. 2), and probably underlies the Connecticut River. The outwash forming the high terrace and occurring beneath the flood plain and the river at the CANEL site probably is continuous with outwash on the east bank of the river.

The outwash ranges in thickness from a few inches to at least 146 feet. The thickest deposits underlie the high terrace near the riverward edge where thicknesses are 146 feet at well Mt 177, 145 feet at well Mt 311, and 136 feet at well Mt 178. The outwash underlying the high terrace pinches out against the valley wall; and, at the inner edge along River Road, it is only a few inches thick. (See sections *D–D′* and *E–E′*, pl. 2.) The maximum known thickness of outwash underlying the alluvium in the Connecticut River flood plain is about 77 feet in wells Mt 258–260 at the Hartford Electric Light Co. plant north of the area, and from 67 to 77 feet in well Mt 295 on the flood plain opposite the southeast end of Dart Island. The outwash underlying the flood plain may be much thicker in some places, inasmuch as the driller's log of well Mt 300 in the southeastern part of the area indicates a combined thickness of outwash and alluvium of more than 165 feet.

The upper part of the outwash, as exposed along the steep face of the high terrace and in pits and building excavations on top of the terrace, and as revealed in logs of wells on the terrace, forms a cap on the terrace 5 to 25 feet thick that consists predominantly of gravel interbedded with lenses and thin beds of sand and silt. Although variable in composition and thickness, this gravel cap can be traced over most of the terrace surface. The individual beds vary greatly in thickness and can be traced for only short distances. The gravel beds are poorly sorted and contain a large proportion of sand and some silt. The sand and silt lenses, on the other hand, generally are well sorted. The bedding, as exposed, is generally horizontal, but crossbedding within individual beds and cut-and-fill stratification are common.

The character of the lower part of outwash beneath the high terrace as revealed in well logs is variable. The logs of wells Mt 177 and Mt 178, at the riverward edge of the terrace show that beneath the 25-foot-thick gravel cap the terrace is underlain by 121 feet of outwash consisting chiefly of sand that contains thin beds of silt, some gravel, and scattered boulders. The logs of wells Mt 310 and 311, on the face of the terrace where the gravel cap has been eroded away, show that the outwash consists of about 22 and 82 feet, respectively, of sand and gravel underlain by 50 to 60 feet of silt and sand. At other places along the face of the terrace, as indicated by the logs of wells Mt 305–309, the outwash consists chiefly of alternating beds of sand and gravel.

The outwash underlying the alluvium along the Connecticut River flood plain, as shown in well logs, consists chiefly of beds of sand and poorly sorted gravel. Individual beds vary greatly in thickness and can be traced for only short distances. (See sections *A–A′* and *C–C′*, pl. 2.) Well logs show that the outwash beneath the alluvium at the north end of the flood plain consists chiefly of sand and some gravel. The outwash beneath the alluvium along the flood plain at wells Mt 287 and Mt 288 opposite the southeast end of Dart Island contains a large proportion of gravel.

The outwash gravels are the most permeable deposits in the area, and, where saturated, they yield large amounts of water to wells. In some places, however, fine-grained material impedes the movement of water, and wells may yield little or no water, even though the materials penetrated are saturated.

The permeability of the outwash was determined by aquifer tests (see p. G29) to be 3,000 to 4,000 gpd per ft² (gallons per day per square foot), and the coefficient of storage to be about 3.0×10^{-4}

ALLUVIUM

The alluvium consists of clay, silt, sand, and gravel deposited by the existing streams along their flood plains and in their channels. The small streams which flow from the western half of the area and cross the high terrace and Connecticut River flood plain have no well-defined flood plains. The alluvium along these streams consists mostly of thin channel deposits of small areal extent and are therefore not shown in plate 1. The alluvium overlies bedrock, till, and outwash and is Recent in age.

The alluvium along the Connecticut River consists of flood-plain and channel deposits. The channel deposits include those of Dart Island. The Connecticut River flood plain extends along the base of the high terrace and is about 3 miles long; parts of it are beyond the limits of the site; it narrows and disappears just upstream from the northern limit of the site and is also missing for a short distance south of the mouth of Maromas Brook. The average width is about 500 feet, but at the southern limit of the site the flood plain, including a large tidal marsh is about 1,100 feet wide.

The deposits exposed in the Connecticut River flood plain consist of a dense layer of clay, silt, and some sand containing organic material. Swamp deposits, principally muck, underlie swamps and small depressions mostly along the landward edge of the flood plain. (See pl. 1.) At the river edge of the flood plain the river has built a natural levee, the top of which is more than 10 feet above mean sea level. The surface of the flood plain slopes landward from the top of the levee to the base of the high terrace. The levee consists of fine- to medium-grained sand of undetermined thickness.

As exposed in an excavation for the main sewer line on the flood plain south of the CANEL loading dock, the flood-plain deposits consist of dark-gray medium- to fine-grained sand and silt in which numerous tree stumps, roots, twigs, and branches are buried. The exposed beds are massive to irregularly bedded. About 10 feet is exposed, the bottom of the excavation being about 11 feet below mean sea level. Overlying the flood-plain deposits at this place is about 5 feet of brown or brownish-gray, coarse- to very coarse-grained, well-sorted sand in horizontal layers a fraction of an inch to 3 inches thick. The brown sand is material dredged from the channel of the Connecticut River and deposited along the flood plain by the dredging equipment; it has been mapped as dredged channel deposits. Although partly obscured, the top of the flood-plain deposits at the contact with the overlying dredged channel deposits apparently is a soil zone, and roots, stumps, stems, and branches of small trees and bushes appear to be "growing" upward into the coarse sand.

As shown by well logs, the flood-plain deposits consist of an upper fine-grained layer of clay, silt, and fine-grained sand that contains some organic matter, and a lower layer of coarse-grained sand and gravel. The flood-plain deposits rest on outwash and are in turn partly covered by channel deposits of the river. The coarser grained lower layer of the flood-plain deposits is not easily distinguished in well logs from the outwash. It is shown in well logs and on cross section *C–C′* (pl. 2) as alluvium and outwash undifferentiated. For practical purposes it is included in the outwash aquifer. The fine-grained flood-plain deposits range in thickness from about 10 feet to about 40 feet (sections *A–A′ E–E′*, pl. 2).

The channel deposits, as exposed along the shoreline of the river, consist chiefly of well-sorted sand. Offshore, between the mainland and Dart Island, the river-bottom deposits consist of fine sand that has a large proportion of silt. The channel deposits cannot readily be distinguished from outwash in logs of wells drilled in the river bottom, and the thickness of the channel deposits is undetermined.

Dart Island, a river bar, is about half a mile long, about 250 feet wide at its upstream end, and about 60 feet wide at its downstream end. It extends northwestward from a point about a quarter of a mile upstream from the mouth of Maromas Brook. (See pl. 1.) The island was observed from shore to consist largely of sand and is mapped as part of the alluvium (pl. 1).

Because they are fine grained and dense at the surface, the flood-plain deposits are relatively impermeable and act as a partial barrier to the downward movement of water. The fine-grained flood-plain deposits also act as a leaky aquiclude which produces artesian conditions in the outwash aquifer beneath the Connecticut River flood plain. The channel deposits are comparatively coarse grained and probably are sufficiently permeable to permit movement of water from the river to underlying outwash. The dredged channel deposits contain ground water that is perched on the underlying flood-plain deposits. No wells draw water exclusively from alluvium in the CANEL area.

HYDROLOGY

SURFACE WATER

The dominant surface-water feature of the CANEL area is the Connecticut River, which forms the northern and eastern borders of the site (pl. 1). The Connecticut River not only supplies a large part of the water required for plant operation but also receives directly or indirectly liquid wastes discharged in the area. The regimen of this stream therefore is of importance in this study.

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The Connecticut River has its source in the Connecticut Lakes country in northernmost New Hampshire, whence it flows in a southerly direction, dividing the states of Vermont and New Hampshire and crossing western Massachusetts and central Connecticut to Long Island Sound at Old Saybrook, Conn. It is the greatest river system within the New England states, having a total length of watercourse of approximately 394 miles. Its watershed has a total area of 11,250 square miles, of which 10,880 square miles lies above the CANEL site. The lower river may be navigated by small oceangoing vessels as far as Hartford, and by smaller boats as far upstream as Holyoke, Mass.

At the CANEL site the river is affected by ocean tides. During periods of low discharge and rising tides the flow of water in the river is upstream. The upstream movement particularly is noticeable in the period from July to December and has been observed at the gaging station at Bodkin Rock and the U.S. Coast Guard station at Portland. No information is available on the maximum upstream distance above Portland that the low-water tidal currents may move.

The Connecticut River is extensively developed as a source of hydroelectric power for industrial use; it feeds several large power storage reservoirs. Major diversions from tributary watersheds are made for public water supply for Boston and Springfield, Mass., and Hartford, Conn. Seven primary flood-control reservoirs have been constructed in the Connecticut basin and four others are in process of construction.

The Connecticut River is gaged by the U.S. Geological Survey at Bodkin Rock near Middletown, Conn., about 3 miles upstream from the CANEL site, but tidal effects make accurate low-stage discharge computations impossible, and this gage therefore provides discharge data for periods of moderate to high stages only.

To supply the need for discharge data at the site, a synthetic record was computed on the basis of flow records for the Connecticut River at Thompsonville, Conn., and the four major tributaries, Scantic River, Farmington River, Park River, and Hockanum River, and adjustments made for runoff from intervening ungaged areas.

Streamflow varies greatly from day to day, week to week, season to season, and year to year, but no significant long-term trend toward either an increase or a decrease in the annual flow has been discerned during the period of record. A duration curve of weekly flow at the site, shown in figure 2, indicates the percentage of time that a specified weekly flow has been equaled or exceeded. It shows the cumulative frequency of occurrence of different rates of flow at the site. Average flow for the entire period of record was 18,300 cfs, or 11,800 mgd.

The flow-duration curve does not show whether the weeks of below-average flow will be consecutive nor does it show how frequently low

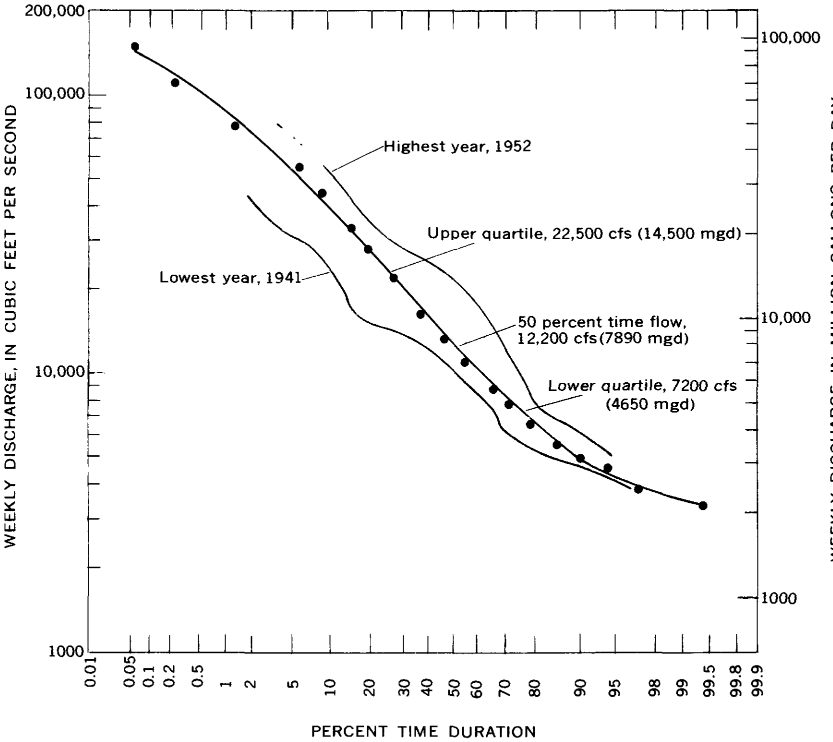

FIGURE 2.—Duration curve of weekly flow, of Connecticut River, 1929–58. Maximum weekly flow, 190,000 cfs (123,000 mgd), occurred March 15–21, 1936. Minimum weekly flow, 2,860 cfs (1,850 mgd), occurred August 30 to September 5, 1953. Flow is unadjusted for storage and diversion.

flows may occur. These facts are shown by a low-flow frequency curve and a curve for the maximum period of deficient discharge. The low-flow frequency curve, shown in figure 3, gives the average interval at which a specific weekly discharge may be expected to recur as the lowest flow in a climatic year (April 1 to March 31), and figure 4 shows the maximum number of consecutive weeks during which the weekly flow was less than a specified discharge. The regimen of flow at the CANEL site is affected to an appreciable extent by upstream storage and diversions, and by power and flood-control operations (see p. G14).

Frequency of occurrence of flood stages at the CANEL site are shown in figure 5. The curve is based on the 116-year (1843–1958) flood-stage record at Hartford and stage relationships at Hartford, Bodkin Rock, and CANEL. The curve has been extended to the maximum recorded stage of 24.3 feet for the flood of March 1936, historically the greatest flood that has occurred in the approximately

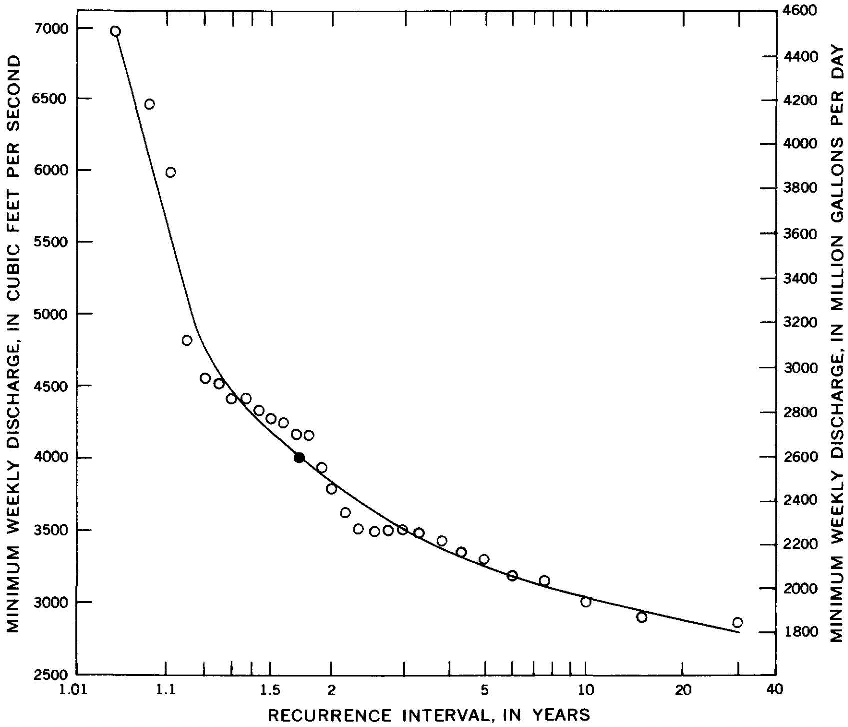

FIGURE 3.—Weekly low flows of Connecticut River, April 1, 1929 to March 31, 1958. Example: At the point on the graph indicated by the black circle, the lowest calendar weekly flow in a year may be expected to be less than 4,020 cfs (2,600 mgd) at average intervals of 1.7 years.

325-year period since settlement of the valley. This curve shows the average interval, in years, between floods that equal or exceed a given altitude.

A study of the salinity of the Connecticut River by the Works Progress Administration for Connecticut (1938) reveals that (1) there were no data to indicate sea-water intrusion as far as the Middletown bridge; (2) saline water collected in samples at the East Haddam bridge (10 miles downstream from the CANEL site) may represent sea-water intrusion as far upstream as this point; (3) the usual position of the saline water-fresh water contact is somewhere in the reach between Hadlyme and Essex (13 to 20 miles downstream from the CANEL site); (4) during flood flows saline water is flushed out of the river altogether; (5) the extent of sea-water intrusion will vary mainly owing to tides, tidal and nontidal currents, and discharge; and (6) there are broad seasonal fluctuations of sea-water intrusion upon which are superimposed daily and more frequent fluctuations. The location

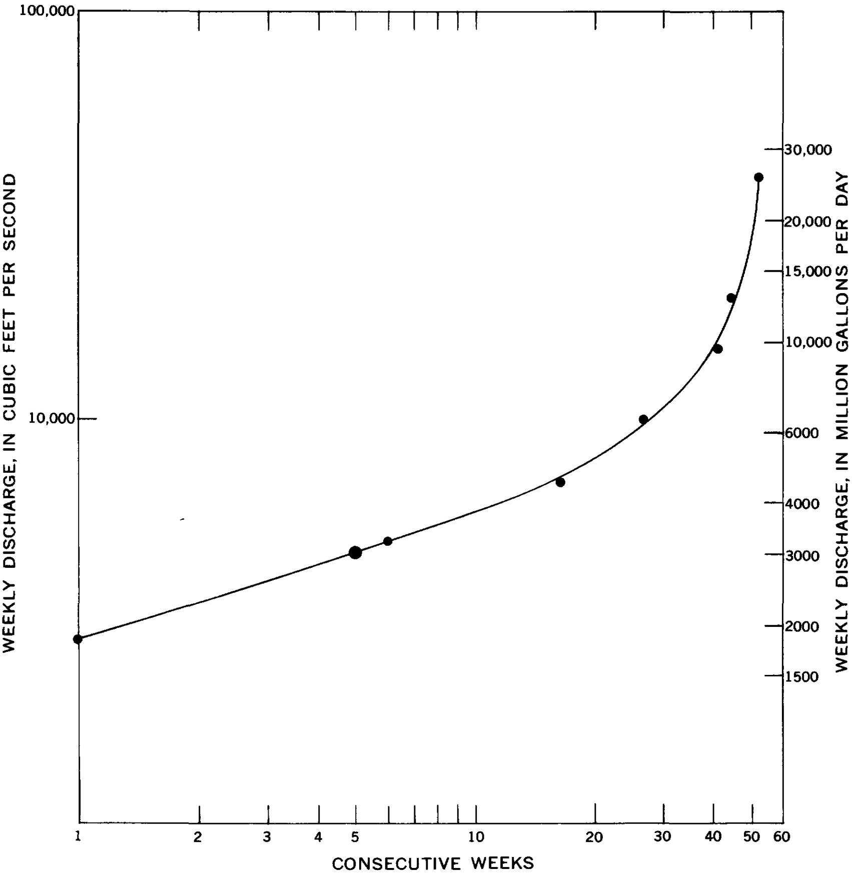

FIGURE 4.—Longest period of minimum weekly discharge of Connecticut River, 1930–58. Example: At the point on the graph indicated by the larger black circle, during a 29-year period similar to 1930–58 the weekly discharge of Connecticut River at CANEL site will not be less than 4,640 cfs (3,000 mgd) for longer than five consecutive weeks.

of the contact of fresh and saline water is important because of the precipitating effect of saline water on suspended sediment. The sediment probably would contain adsorbed radioactive material if such material were discharged into the river. Radioactive material may thus accumulate near the contact of fresh and saline water.

In addition to the Connecticut River, other bodies of surface water on the site are Maromas Brook, Hubbard Brook, two quarry ponds, and several intermittent brooks that flow from the western upland during wet weather. The intermittent streams are mostly north of the present main plant and are not likely to receive waste from proposed buildings and storage areas.

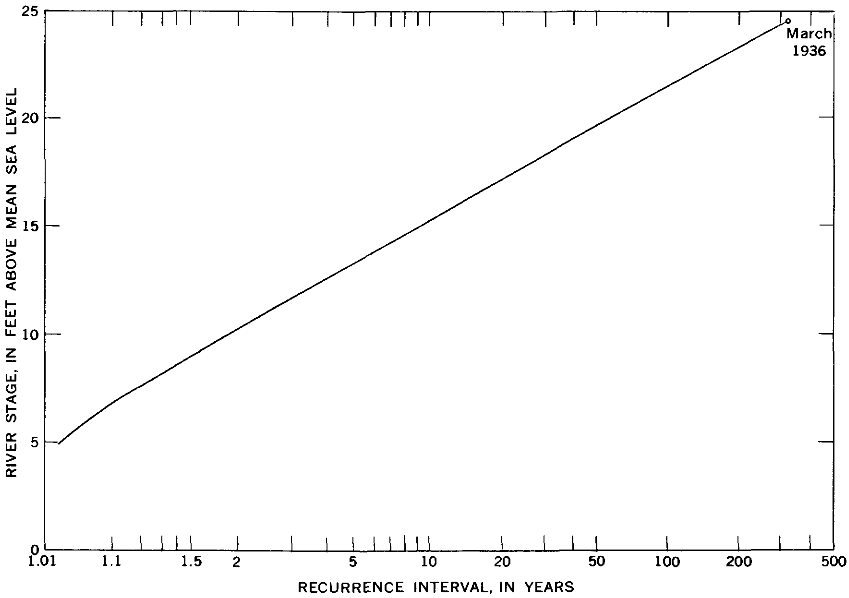

FIGURE 5.—Recurrence intervals of annual floods of Connecticut River, 1843–1958.

Maromas Brook, whose drainage area is about 1.33 square miles, heads up in two branches in the western half of the site. The two branches join near the center of the high terrace to form the main stream, which flows across the outer edge of the high terrace, crosses the Connecticut River flood plain, and empties into the river about a quarter of a mile downstream from the southeast tip of Dart Island. Between the four stream-measurement sites 4, 7, 12, and 13 (pl. 1) at the eastern margin of the high terrace and measurement site 6 near the center of the high terrace, Maromas Brook and its tributaries can be classed as influent streams which lose water to the ground. However, between sites 6 and 5 (pl. 1), Maromas Brook is an effluent or gaining stream. Four measurements made during the late spring and summer of 1956 (see table 2) indicate that the discharge of Maromas Brook did not exceed 0.42 cfs at measurement site 5 (pl. 1). The lowest flow at this site was 0.11 cfs.

The two branches of Maromas Brook were rerouted across the terrace. As a result of the rerouting, the existing channels across the terrace between River Road and the Connecticut River flood plain were abandoned. However, the existing channel across the flood plain still carries some ground-water discharge because Maromas Brook in this reach is an effluent stream. Adjustments of the water table along the present and proposed channels across the high terrace will probably take place as a result of the rerouting. The water table will probably decline in the vicinity of the existing channels and rise in the vicinity of the proposed new channels, provided the new channels and the water table are hydraulically interconnected.

Hubbard Brook heads in the extreme western part of the site, flows southeastward out of the site, and discharges into the swamp at the base of the high terrace beyond the southern limits of the site. Little is known of the hydrologic characteristics of this stream, but, under the plans for facilities at the site, the Hubbard Brook drainage is not likely to receive any wastes.

The two quarry ponds probably are fed by ground-water discharge from the surrounding bedrock and thus are outcroppings of the water table. The capacity of the quarry ponds to store and yield water are not known. There is no surface outlet for the water in the westernmost pond in the Hubbard Brook drainage; the water probably is discharged underground through cracks in the bedrock. The easternmost pond drains into a fork of the south branch of the Maromas Brook. Three measurements made during the late spring and summer of 1956 indicate that the maximum discharge of this fork of Maromas Brook was about 0.03 cfs (table 2). Water from this pond also may be discharged underground through the bedrock.

GROUND WATER

Ground water in the CANEL area occurs in fractures in the consolidated rocks and in intergranular pore spaces in the unconsolidated deposits. Conditions of ground-water storage and movement in these two contrasting types of rock differ greatly.

The unconsolidated deposits themselves (till, outwash, and alluvium) differ in character, extent, and thickness. Owing principally to these differences, two water-bearing zones occur in the unconsolidated deposits, but their difference in head is small under natural conditions, and aquifer tests in the outwash show the two zones to be hydraulically interconnected.

The system of interconnected fractures which store and transmit water in the bedrock was formed chiefly by earth movements and enlarged by weathering. The fractured zones in the rocks are not uniform and gradually disappear with depth. Ground water in bedrock appears to occur as a separate and irregular water body. The degree of interconnection between the water body in bedrock and the water body in unconsolidated deposits is not known.

ARTESIAN AND WATER-TABLE CONDITIONS

Ground water that is under sufficient pressure to rise above the level at which it is found in drilling a well is termed "artesian or confined water," and a well in which the water level rises above the top of the aquifer is an artesian well. Ground water that remains nearly at the level at which it is found in drilling a well is termed "unconfined water," and is said to be under water-table conditions. Water in bedrock in the CANEL site commonly rises above the level at which it is tapped in drilling the wells. Where observed, water levels in most bedrock wells stand higher than the bedrock surface and higher than the water table in overlying unconsolidated deposits. For example, water from five bedrock wells, Mt 262 and Mt 271–274, overflows either the casing or through bleeder pipes at or slightly below land surface; water from well Mt 285 overflows through a pipe in the casing about 3 feet above land surface; and water from well Mt 267, drilled into bedrock through the bottom of dug well Mt 267, at times overflows the casing about 0.8 foot above the water surface in the dug well and about 1.76 feet below land-surface datum. At other times the water level in drilled well Mt 267 stands more than 5 feet higher than the water level in dug well Mt 267. (See fig. 6) When well Mt 301 was drilled, the water level was about 24 feet below land-surface datum and about 5 feet above the bedrock surface. All these wells are located along the inner margin of the high terrace at the foot of the hilly western half of the area. Water in these wells probably comes from joints at some depth; the water enters joints in the area of rock outcrop in the high western half of the area and then moves along these linear openings toward the Connecticut River valley. When a water-bearing joint is intersected by a well, the water rises in the well under pressure, either because the water in the joint system stands at a higher level than the level at which the water was struck, or possibly because the water is confined in the joints by relatively impermeable till overlying the bedrock surface. Each well apparently reflects local conditions, and the available evidence does not indicate the presence of a widespread artesian aquifer in the bedrock.

Water in the unconsolidated deposits is unconfined at most places, but beneath the Connecticut River flood plain the fine-grained alluvium is relatively less permeable than the underlying coarse-grained alluvium and outwash, and causes some degree of confinement of the water in the lower part of the alluvium and the outwash. The coarse-grained alluvium cannot readily be distinguished from outwash in well logs, and together these two units form the artesian outwash aquifer. Water in till, where present beneath the Connecticut River flood plain, may occur under confined conditions also. The relatively impermeable, fine-grained alluvium acts as a leaky confining bed over the relatively permeable artesian outwash aquifer. The top of the artesian outwash aquifer ranges from 10 to 40 feet below the surface of the flood plain. Under natural conditions the pressure surface of the

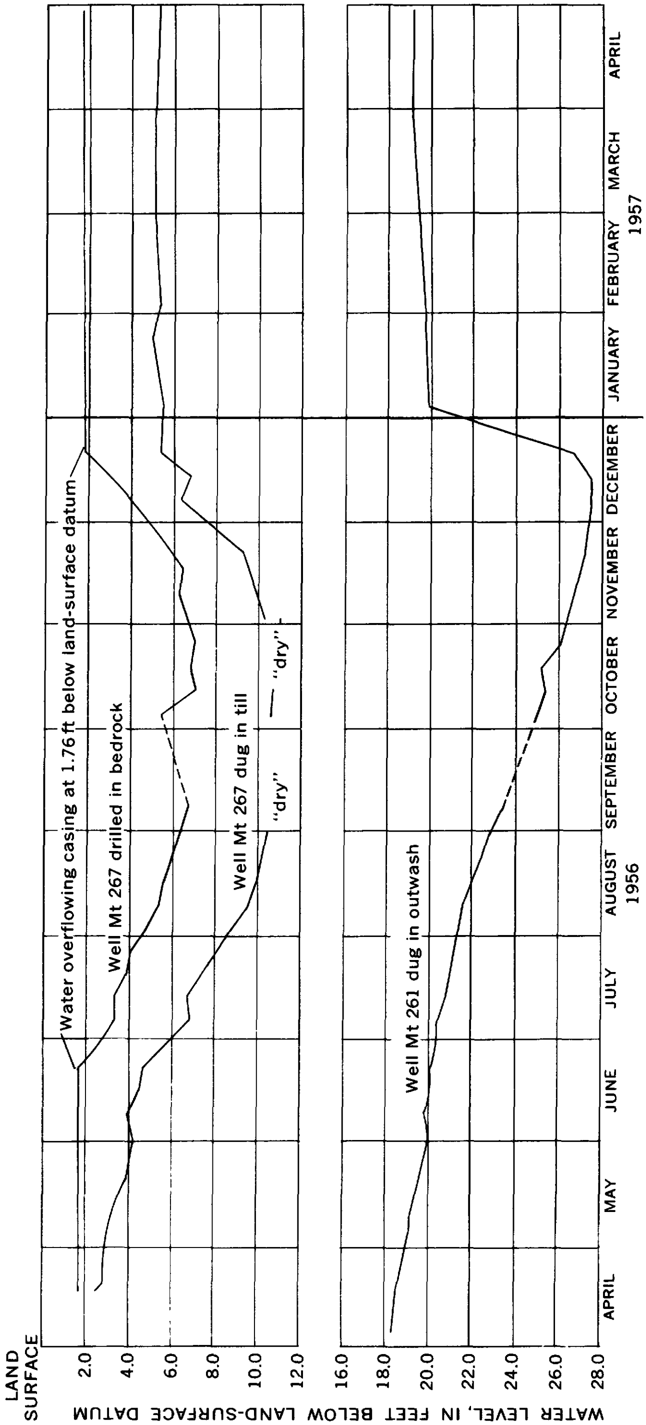

FIGURE 6.—Hydrographs showing water levels in wells.

confined water ranges from 0.5 foot to 10 feet below land surface, and, where covered by fine-grained alluvium, 1.5 to 3 feet below the water table in the alluvium. The pressure surface slopes toward the Connecticut River at a low gradient, 0.16 foot in a distance of 115 feet between wells Mt 291 and Mt 290. The pressure head of the water in the artesian outwash aquifer is controlled by the position of the water table in the unconsolidated deposits underlying the high terrace.

The available data show that the water table in the outwash underlying the high terrace and in the alluvium underlying the flood plain slopes toward the river from altitudes of 180 feet in the western half of the area to near sea level along the Connecticut River in distances ranging from less than 1,000 to more than 3,000 feet. The buried bedrock surface slopes generally in the same direction but at a somewhat steeper inclination.

The water table is at land surface, or only a few feet below land surface, in the alluvium of the Connecticut River flood plain and in till and outwash near the western edge of the high terrace. Near the riverward edge of the high terrace, depths to water of about 100 feet were measured in test holes Mt 177 and Mt 178.

The thickness of the zone of saturation in unconsolidated deposits ranges from less than 5 feet along the western edge of the high terrace to more than 150 feet along the Connecticut River flood plain at the southern end of the site. The saturated zone is about 45 feet thick beneath the riverward edge of the high terrace and about 50 to 80 feet thick in the outwash east of the railroad tracks near Maromas Brook.

NATURAL RECHARGE, DISCHARGE, AND MOVEMENT OF WATER

Under natural conditions, virtually all the surface and ground water in the CANEL area is derived from local precipitation. According to Knox and Nordenson (1955), the average annual precipitation in the CANEL area is about 47 inches. Of this amount about 23 inches is evaporated or transpired and about 24 inches either flows overland to the Connecticut River or percolates downward to the zone of saturation and then moves laterally to the river.

Of the precipitation in the western half of the area that is not evaporated or transpired, about half reaches streams and brooks as direct runoff or as ground-water discharge after first having percolated downward to the zone of saturation. Some water in the zone of saturation moves underground toward the Connecticut River, and some water is diverted to swamps and ponds en route to the streams and the river. Most of the western half of the area is in the Maromas Brook drainage system, and in that drainage area all the precipitation that is not evaporated or transpired moves ultimately, either in streams or underground, to the Connecticut River in the CANEL site. However, as indicated previously, some of the extreme western part of the area is in the Hubbard Brook drainage system, and in that part of the site all the precipitation that is not evaporated or transpired moves, either in streams or underground, to the Connecticut River downstream from the CANEL site.

Of the water in the eastern half of the area that is not evaporated or transpired, most infiltrates downward to the zone of saturation. Streamflow measurements show that some of the water flowing in Maromas Brook and tributaries originating in the western half of the area percolates downward into outwash as the streams cross the terrace. For example, on May 14, 1956, discharge measurements (table 2) on the four main branches of Maromas Brook indicated that 0.68 cfs of water was flowing from the western part of the area onto the terrace; at the powerplant near the center of the terrace a measurement of flow of only 0.21 cfs in Maromas Brook (pl. 1, S6) showed a loss of about 0.47 cfs of water by evapotranspiration and by percolation to the ground-water body underlying the terrace. A measurement of 0.38 cfs on Maromas Brook at the base of the terrace (pl. 1, S5) indicated a gain of about 0.17 cfs of water from the ground-water body to the stream. Thus, in the eastern half of the area, most of the water flows underground toward the Connecticut River and much of the overland flow originates in streams in the western half of the area that join to form Maromas Brook.

In the area of the well field opposite the southeast end of Dart Island, ground water normally moves toward the Connecticut River, but when water levels are drawn down by pumping, water moves toward the pumped wells. The average velocity of ground-water movement in the well field can be calculated from the Darcy equation $V=\frac{PI}{7.48\theta}$ (Wenzel, 1942), where V is velocity in feet per day, P is permeability in gallons per day per square foot, I is hydraulic gradient in feet per foot, and θ is effective porosity in percent.

TABLE 2.—*Miscellaneous measurements of stream discharge, in cubic feet per second, at six localities in the CANEL site*

[See pl. 1 for localities]

Date (1956)	S4	S5	S6	S7	S12	S13
May 14	0.33	0.38	0.21	0.01	0.09	0.25
June 13	.07	.11	.01	.004	.03	.13
29	.41	.42	.30	.03	.19	.45
Aug. 2	----------	.20	----------	----------	----------	----------

The permeability, *P*, of the outwash is 3,000 to 4,000 gpd per ft^2 as determined from pumping tests. The average of the observed drawdowns in the pumped wells during the tests was 15.3 feet. The effective distance from a line through the pumped wells to the area of recharge in the Connectitcut River was determined to be about 500 feet. Therefore, the average gradient is approximately 15.3/500, or about 0.03. The effective porosity of the outwash is estimated at 30 percent. These data indicate an average velocity of water moving from the river to a pumped well of 40 to 55 feet per day, when the well is pumped continuously at about 1,500 gpm. In this range of velocity, river water would arrive at a pumped well in 9 to 12 days under continuous pumping, and in a correspondingly longer time for interrupted pumping.

Static water levels observed in the well field indicate that the natural gradient is toward the river. A gradient of 0.0014 was determined from a 0.16-foot difference in water levels at wells Mt 290 and Mt 291, which are 115 feet apart. The permeability, *P*, of the outwash is about 3,000 to 4,000 gpd per ft^2. Hence, under natural conditions, the average rate of movement of water in the outwash is about 2 feet per day toward the river.

The estimates of hydraulic gradient indicate that the rate of movement of water under natural conditions in the outwash beneath the central part of the high terrace may be more than 100 feet per day.

During certain times of the year, recharge is sufficient to raise the water table to land surface along the base of the terrace, and ground water discharges directly into the swampy depression at the western margin of the Connecticut River flood plain. At medium to high stages of the Connecticut River, this swampy depression also receives tidewater. Most of the water thus collected drains to Maromas Brook, to a small unnamed stream near the loading dock, and to Hubbard Brook.

Most of the ground water in the Connecticut River flood plain moves toward the river. Essentially all the overland flow is water in Maromas Brook originating west of the flood plain and discharge from the water table along the swampy depression at the western margin of the flood plain.

MOVEMENT OF WATER BETWEEN GEOLOGIC UNITS

Movement of ground water toward the Connecticut River is probably continuous from one water-bearing unit to another, as a result of differences in pressure heads of the water in the units. Although data are lacking for most of the area, observations at the inner edge of the terrace along River Road indicate that under natural conditions water in bedrock is under higher head than water in overlying unconsolidated deposits (fig. 6). Thus, water may move upward from the bedrock into the unconsolidated deposits. Observations along the Connecticut River flood plain indicate that water in alluvium is under higher head (wells Mt 296–299, table 3) than confined water in the underlying outwash (wells Mt 237, Mt 286–295, table 3). Thus water is free to move downward from the alluvium into outwash as well as laterally to the river. The alluvium in turn receives water from precipitation and from the river during floods.

AQUIFER TESTS

In July 1956, two aquifer tests were conducted in cooperation with the drilling contractor; wells Mt 287 and Mt 288 were used as the pumped wells. The drilling contractor, R. E. Chapman Co., Inc., was concerned with defining the yield of the supply wells, which he constructed for the Corps of Engineers, U.S. Army. Geological Survey personnel were responsible for collecting sufficient data by which to determine the hydraulic characteristics of the outwash, the hydraulic connection of the water in the outwash with that in the river, the upward and downward leakage of water, and the extent of the cone of depression created by pumping the supply wells screened in the outwash.

Water-level data were collected at 2 supply wells and 13 observation wells before, during, and after the aquifer tests. The supply wells (Mt 287, 288) were 502 feet apart on the flood plain opposite Dart Island. Seven 3-inch-diameter observation wells (Mt 289–295) and one 8-inch-diameter observation well (Mt 286) were screened in the outwash at depths corresponding approximately to the centers of the 10-foot screen sections of the pumped wells, which were placed near the bottom of the outwash. Also available as an observation well in the outwash was an 8-inch-diameter test well (Mt 237) drilled in 1953 for the city of Middletown. Four shallow 6-inch open-end auger holes (Mt 296–299) were constructed in the fine-grained alluvium at the sites of four of the deep observation wells. Seven of the observation wells were approximately parallel to the river and in line with the supply wells; the other six were about at right angles to the river on the landward and riverward sides of the supply wells. Tidal and other changes in the level of the Connecticut River at the test area were monitored by means of a recording gage and a surface-water stilling well.

Except for the shallow auger holes (Mt 296–299), the locations of the wells used for the tests are shown on plate 1; well data and other pertinent information are presented in table 3; selected records are given in table 5 (p. 38).

TABLE 3.—*Summary of well and water-level data from*

Well	Depth (feet)	Diameter (inches)	Screen			Altitude of measuring point (feet)	Distance of measuring point above land-surface datum (feet)	Altitude of land-surface datum (feet)	Distance and bearing from pumped well Mt 287	
			Diameter (inches)	Length (feet)	Altitude of bottom (feet)				Distance (feet)	Bearing
Mt 237	85.0	8	8	10	−75.9	19.65	10.55	9.10	8	N 29° W
286	86.5	8	8	20	−76.1	11.87	1.50	10.37	511	S 56° E
287	84.9	12	12	20	−75.9	9.04	0	9.04	--------	--------
288	88.2	12	12	20	−78.4	9.76	0	9.76	502	S 57° E
289	76.8	3	3	2	−68.4	8.55	.30	8.25	150	N 57° W
290	75.6	3	3	2	−64.4	11.69	.50	11.19	72	N 27° E
291	75.9	3	3	2	−67.7	10.17	2.00	8.17	49	S 2° E
292	73.1	3	3	2	−63.5	12.56	3.00	9.56	251	S 57° E
293	76.3	3	3	2	−68.4	10.41	2.50	7.91	526	S 47° E
294	72.3	3	3	2	−62.6	14.18	4.50	9.68	641	S 57° E
295	74.2	3	3	2	−63.2	15.05	4.00	11.05	511	S 67° E
296	5.3	6	--------	--------	--------	10.95	2.4	8.55	39	S 16° E
297	6.8	6	--------	--------	--------	11.90	2.4	9.50	249	S 56° E
298	5.0	6	--------	--------	--------	11.48	3.3	8.18	511	S 48° E
299	12.0	8	--------	--------	--------	9.96	.20	9.76	--------	--------

Well Mt 287 was pumped (A test) by diesel engine for 48 hours and 5 minutes, from 12:28 p.m. on July 5 to 12:33 p.m. on July 7, 1956, at a constant rate of 1,570 gpm; during this time Mt 288 was used as an observation well. Well Mt 288 was then pumped (B test) by diesel engine for 48 hours, from 10:15 a.m. on July 11 to 10:15 a.m. on July 13, 1956, at a constant rate of 1,570 gpm; during this time Mt 287 was used as an observation well. The pumped water was conducted several hundred feet from the well sites to the edge of the river in an aluminum pipe.

Water-level readings were made by steel tape in the pumped wells. At all the observation wells and auger holes, and at the stilling well on the river, a continuous record was obtained by means of automatic recording gages. The first 3 to 4 hours of the drawdown and recovery was recorded on an expanded time scale by use of 4-hour clocks; after this period 24-hour clocks were used. In addition, the recorders on wells screened in outwash were equipped with float-tape gages so that water-level measurements could be taken quickly, even seconds apart, during the first few minutes of the drawdown and recovery periods.

The water levels at the pumped and observation wells screened in the outwash were affected not only by the pumping at the supply wells but also by river-level fluctuations and baromatic changes. Drawdowns observed at well Mt 290 during the A test are shown in figure 7 and at well Mt 295 during the B test in figure 8. The drawdown is the difference between the water level at the start of the test and that observed at given times throughout the pumping period.

pumping tests on wells Mt 287 and Mt 288 at the CANEL site

Distance and bearing from pumped well Mt 288		Measurements by recorder (R) or manual (M)	Pumping test well Mt 287				Pumping test well Mt 288			
			Altitude of water level (feet)		Drawdown (feet)		Altitude of water level (feet)		Drawdown (feet)	
Distance (feet)	Bearing		Start 12:28 p.m. 7-5-56	End 12:33 p.m. 7-7-56	Observed	Corrected	Start 10:15 a.m. 7-11-56	End 10:15 a.m. 7-13-56	Observed	Corrected
509	N 56° E	R	+1.81	−8.43	10.24	10.90	+1.58	+0.06	1.52	1.64
10.5	S 24° E	R	+1.80	+.84	.84	1.49	+1.59	−4.51	6.10	6.22
502	N 52° W	M	+1.80	−15.20	17.00	17.65	----------	----------	----------	1.64
----------	----------	M	----------	----------	----------	1.49	+1.52	−12.02	13.54	13.66
652	N 57° W	R	+1.84	−1.44	3.28	3.86	+1.65	+.23	1.42	1.50
514	N 49° W	R	+1.67	−2.17	3.84	4.57	+1.51	+.03	1.48	1.61
476	N 62° W	R	+1.83	−2.37	4.20	4.81	+1.64	−.17	1.81	1.90
252	N 56° W	R	+1.82	−.21	2.03	2.58	+1.59	−.81	2.40	2.51
96	S 23° W	R	+1.92	+.92	1.00	1.59	+1.72	−2.36	4.08	4.16
138	S 57° E	R	+1.84	+1.28	.56	1.21	+1.57	−1.61	3.18	3.30
85	N 33° E	R	+1.85	+1.01	.84	1.52	+1.53	−2.41	3.94	4.07
472	N 60° W	R	----------	----------	----------	----------	+4.92	+4.74	----------	----------
253	N 58° W	R	----------	----------	----------	----------	+4.68	+3.52	----------	----------
84	S 30° W	R	----------	----------	----------	----------	+4.78	+3.92	----------	----------
8	S 50° E	R	----------	----------	----------	----------	+2.96	+2.66	----------	----------

Changes in river stage due to tide and variations in flow are also shown in figures 7 and 8. Plus (+) values indicate changes to stages higher than the starting stage and minus (−) values indicate changes to stages lower than the starting stage. Shown the same way as the observed drawdowns and tidal changes in the river are the changes in barometric pressure (figs. 7 and 8), expressed in feet of water, which were determined by computing the difference between the pressure at the start of the test and the pressure at a given time after the test began. The observed drawdowns were corrected for tidal effects and river-level changes on the basis of the change in river stage. Corrections were made for barometric changes on the basis of pressure at the starting time as compared to that at the time of observed drawdown.

The amplitude of the tidal fluctuations in the observation wells in the outwash averaged about half that of the Connecticut River. This difference implies a tidal efficiency at the observation wells of about 50 percent. The sum of the tidal and barometric efficiencies equals unity, as demonstrated mathematically by Jacob (1950); the barometric efficiency is therefore also about 50 percent. The tidal effect is direct—rising or falling tide in the river produces corresponding rise or fall in ground-water levels. The barometric effect is inverse—an increase in barometric pressure depresses ground-water levels and a decrease in pressure allows water levels to rise. Inasmuch as tidal and barometric efficiencies are each approximately 50 percent, the correction applied to the observed drawdown is about half the tidal and about half the barometric change. The correction for a plus tidal change is added to, and the correction for a minus change is subtracted from, the observed uncorrected drawdown. The correction for a barometric pressure higher than that at the start of the test is subtracted from, and the correction for a pressure lower than at the start of the test is added to, the observed drawdown.

The method described is used for adjusting observed water levels for the river-level and barometric-pressure change during the drawdown and recovery periods. For all the observation wells screened in the outwash, the observed and corrected drawdowns at the end of the pumping periods in the two separate tests are listed in table 3.

The hydraulic characteristics of the outwash were computed from the corrected drawdown data by the nonequilibrium formula of Theis (1935), which is as follows:

$$s=\frac{114.6Q}{T}W(u)$$

where s=drawdown at any point, in feet,

Q=discharge of the pumped well, in gallons per minute,

T=coefficient of transmissibility of the aquifer, in gallons per day per foot,

$$W(u)=-0.5772-\log_e u+u-u^2/2.2!+u^3/3.3!-u^4/4.4!+---$$

$$u=\frac{1.87\,r^2S}{Tt}$$

where S=coefficient of storage of the aquifer, dimensionless,

r=distance from pumping well to point of observation in feet,

t=time since pumping began, in days.

The nonequilibrium formula is based on the following assumptions: (1) the aquifer is homogeneous and isotropic, (2) the aquifer has infinite areal extent, (3) the discharge well penetrates and receives water from the entire thickness of the aquifer, (4) the coefficient of transmissibility is constant at all times and at all places, (5) the well has an infinitesimal diameter, and (6) water removed from storage is discharged instantaneously with decline in head. Despite the assumptions on which it is based, the nonequilibrium formula can be applied to selected data for the aquifer tests in the CANEL area. The selected data are: (1) the corrected drawdown from start of pumping to 5 minutes after start, because the remainder of the drawdown was affected by boundaries due to river infiltration, (2) leakage, and (3) possible changes in groundwater inflow from the high terrace.

The Theis formula is solved graphically by matching the type curve to the curve obtained from test data. The type curve is a logarithmic plot of $W(u)$ against u values. Curves of drawdown against distance squared divided by time, at 2 minutes and at 5 minutes after start, are shown in figure 9 for the A test and in figure 10 for the B test.

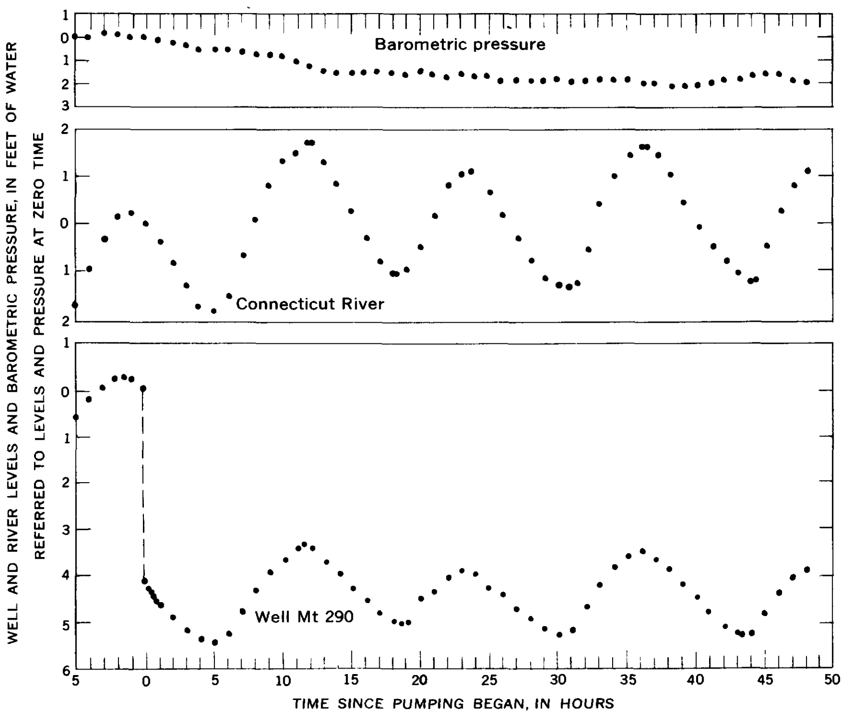

Figure 7.—Changes of barometric pressure and of water levels in the Connecticut River and well Mt 290 during pumping of well Mt 287.

For the best fit of the test data to the type curve, corresponding values of $W(u)$, u, s, and r^2/t were determined at selected match points to give the following results:

A test: $T=2.3\times10^5$ gpd per ft; $S=3.3\times10^{-4}$

B test: $T=3\times10^5$ gpd per ft; $S=3.0\times10^{-4}$

where T is the transmissibility and S is the coefficient of storage.

The difference in transmissibility computed from the A and B tests is due in part to the increase in thickness of the outwash in a downstream direction and, in part, to what is apparently more permeable material at and near well Mt 288 used for the B test. The effective thickness of the aquifer tested during the A test is about 60 to 70 feet, and that during the B test is about 70 to 80 feet. On this basis, the coefficient of permeability (transmissibility divided by the thickness of the aquifer) is about 3,000 gpd per ft² for the A test, and about 4,000 gpd per ft² for the B test.

If there were no boundaries under nearly ideal conditions, the drawdowns after about 7 minutes would plot on the extension of the straight line defined by the drawdowns between 1 and 7 minutes in a plot of drawdowns against log of time because the $W(u)$ against log u curve

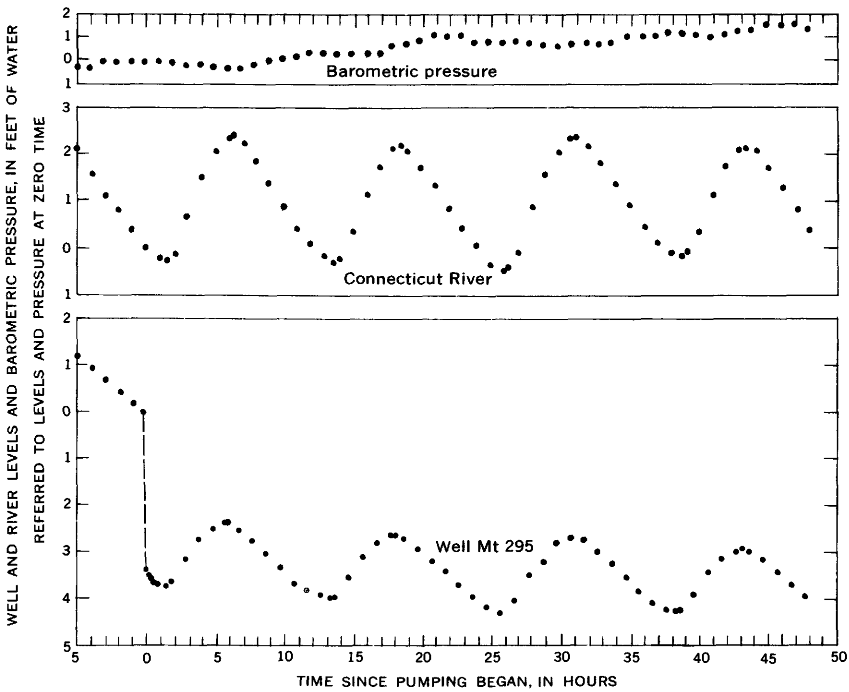

Figure 8.—Changes of barometric pressure and of water levels in the Connecticut River and well Mt 295 during pumping of well Mt 288.

approaches a straight line after u becomes greater than 0.02, as indicated by Jacob (1950) in his development of the modified Theis formula.

Departures from the straight line were noted at all the deeper observation wells during the two tests. These departures are illustrated in figure 11 by data for well Mt 290 located 72 feet riverward from well Mt 287, pumped for the A test, and, in figure 12, by data for well Mt 295 located 85 feet riverward from well Mt 288, pumped for the B test.

The departures from the straight line are attributable to the hydraulic connection of the outwash with the Connecticut River. They also reflect the combined effect of other boundaries: downward leakage to the outwash from the alluvium and possibly upward from the bedrock, change in thickness of the outwash, and perhaps changes in ground water inflow rates from the terrace.

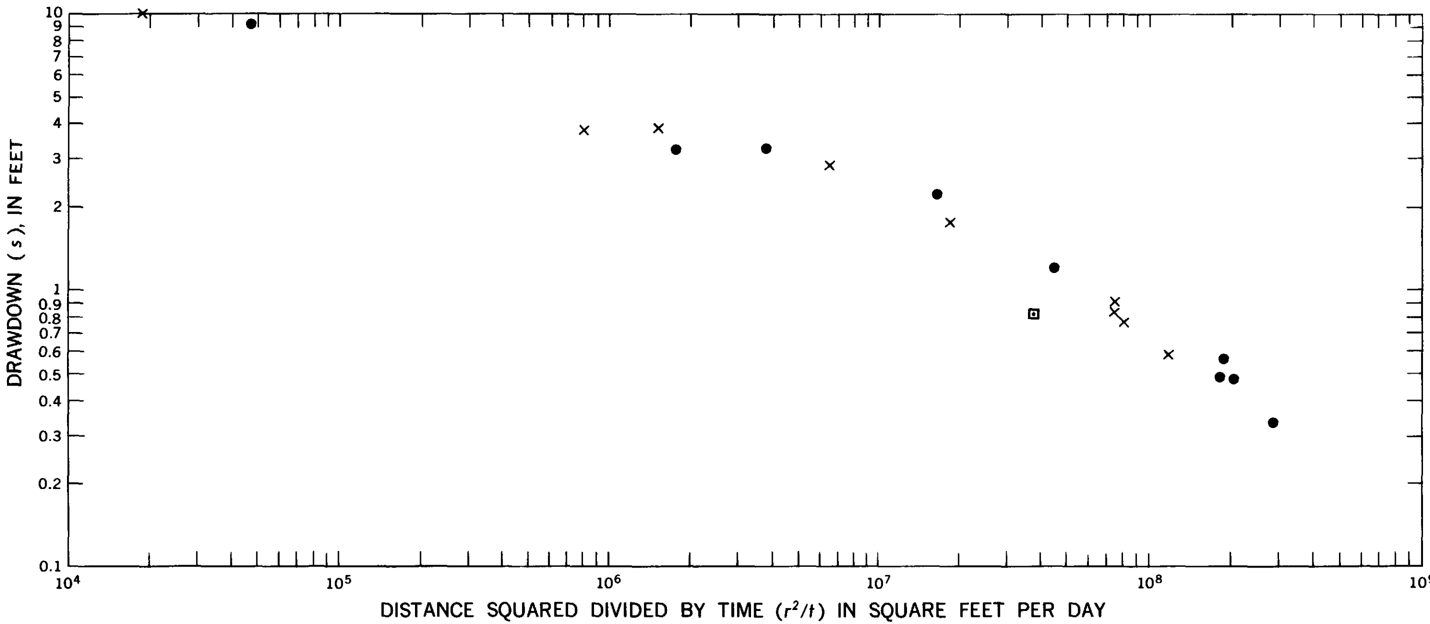

FIGURE 9.—Drawdowns 2 minutes and 5 minutes after start of pumping well Mt 287.

$$T=\frac{114.6\ QW(u)}{S}=\frac{114.6\times1570\times1}{0.79}=230{,}000 \text{ gpd per ft.}$$

$$S=\frac{uTt}{1.87r^2}=\frac{0.1\times230{,}000}{1.87\times3.7\times10^7}=3.3\times10^{-4}$$

Observed drawdown: ●, 2 minutes; x, 5 minutes; ⊡, match point. u=0.1; $W(u)=1$.

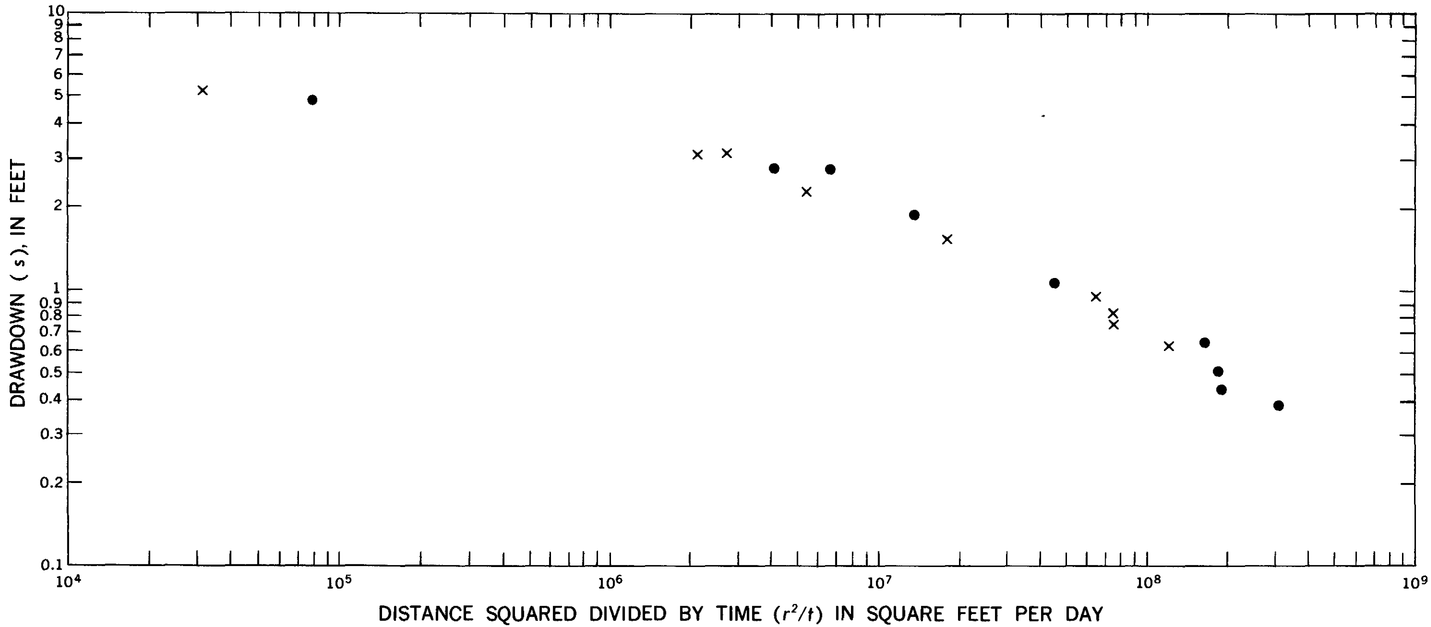

FIGURE 10.—Drawdowns 2 minutes and 5 minutes after start of pumping well Mt 288.

$$T=\frac{114.6\ QW(u)}{S}=\frac{114.6\times1570\times1}{0.60}=300{,}000 \text{ gpd per ft.}$$

$$S=\frac{uTt}{1.87r^2}=\frac{0.1\times300{,}000}{1.87\times5.4\times10^7}=3.0\times10^{-4}$$

Observed drawdown: ●, 2 minutes; x, 5 minutes. $u=0.1$; $W(u)=1$.

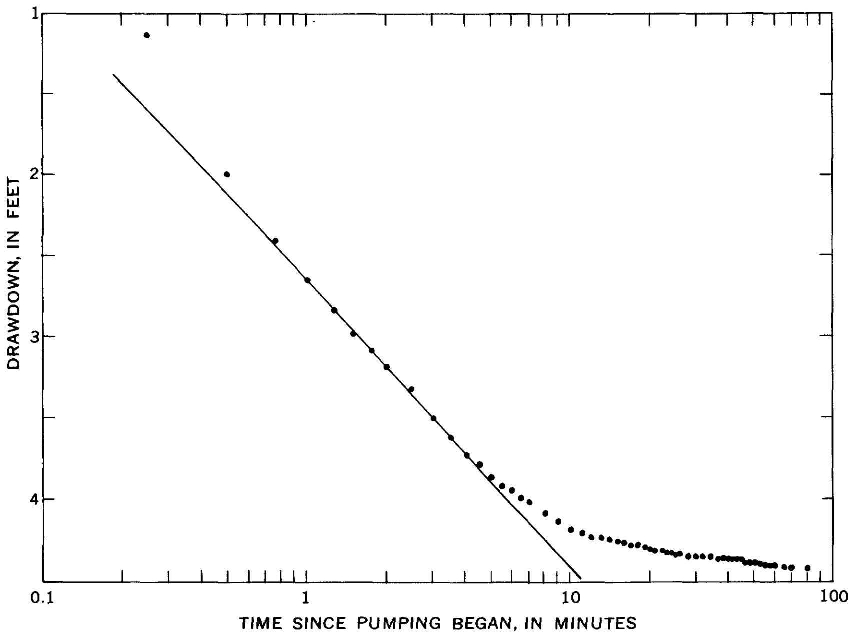

FIGURE 11.—Hydrograph showing drawdown in well Mt 290.

$S=\frac{0.3Tt_0}{r^2}$	$T=\frac{264Q \log t_2/t_1}{S_2-S_1}$
$=\frac{0.3\times240{,}000\times0.03}{5.84\times1440}$	$=\frac{264\times1570\times1}{4.41-2.66}$
$=0.00029$	$=240{,}000$ gpd per ft.

From the first departures, the effective distance to the river boundary is computed by the image-well method to be about 500 feet from wells Mt 287 and Mt 288. This departure of the test data from the straight line and the persistent flattening of the drawdown curve are confirmations of hydraulic connection of the outwash with the Connecticut River and the fact that the river is the principal boundary.

Downward leakage from the alluvium to the outwash, under natural and pumping conditions, is indicated by the difference in water levels observed at the pair of wells screened in the outwash and alluvium at each of four sites on the flood plain. (See table 3.) Under natural conditions, the head in the alluvium was 1.5 to 3 feet higher than the head in the outwash. During the two tests, the head in the alluvium was about 4 to 14 feet higher than that in the outwash and the greatest difference was in the vicinity of the pumped wells.

The change in water levels in the alluvium due to pumping during the A test cannot be determined because of heavy rainfall for several hours before and during the first test; the rainfall produced a change

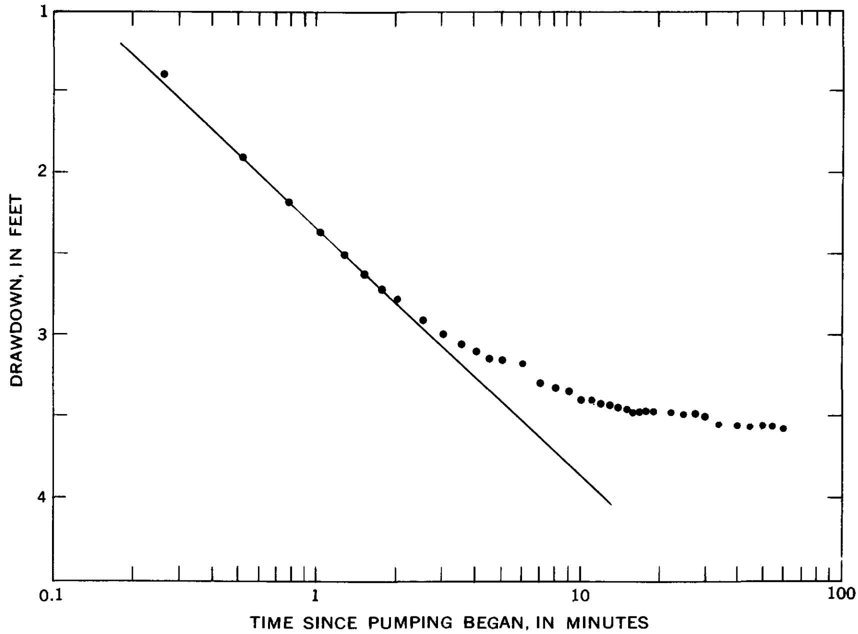

FIGURE 12.—Hydrograph showing drawdown in well Mt 295.

$S=\frac{0.3Tt_0}{r^2}$	$T=\frac{264Q \log t_2/t_1}{S_2-S_1}$
$=\frac{0.3\times 280{,}000\times 0.028}{7225\times 1440}$	$=\frac{264\times 1570\times 1}{3.85-2.35}$
$=0.00023$	$=280{,}000$ gpd per ft.

in shallow-water level opposite that produced by pumping. During the B test, water levels in the alluvium dropped 0.2 foot to 1.2 feet at the four pairs of wells.

The available data do not permit calculation of upward leakage from the bedrock under either natural conditions or pumping conditions. The general indications however, are that there is upward leakage, at least under pumping conditions.

Table 3 shows the amount of lowering of water levels at the end of the A and B tests in observation wells screened in the outwash. When well Mt 287 was pumped, water levels were lowered 1.49 feet at the idle supply well Mt 288 (502 ft away) and 1.21 feet at well Mt 294 (641 ft away). When well Mt 288 was pumped, water levels were lowered 1.64 feet at the then idle supply well Mt 287 and 1.50 feet at well Mt 289 (652 ft away). On the basis of these drawdowns, it is estimated that the cone of depression extends both upstream and downstream as much as 2,000 feet from the pumped wells when they are pumped singly at about 1,500 gpm, and that it may be as much as 3,000 feet when the two wells are pumped simultaneously at about 1,500 gpm each.

The uncorrected drawdowns in supply wells Mt 287 and Mt 288 after pumping for 48 hours were observed to be 17.00 and 13.54 feet respectively. The corrected drawdowns are 17.65 and 13.66 feet. The specific capacities for the corrected drawdowns are respectively 89 and 115 gpm per ft of drawdown.

From the standpoint of operation of the supply wells, the advantage of the several recharge boundaries, including the Connecticut River, is that the water levels in the pumped well are not as low as they would be under less optimum conditions. For example, the drawdown in supply wells Mt 287 and Mt 288 would have been several feet more than the 17.65 feet and 13.66 feet at the end of the 48-hour pumping period. Water levels at the end of the 48-hour period were virtually stabilized and would remain practically the same for an indefinite period provided the rate of pumping was constant.

WELL-FIELD CAPACITY

The results of the aquifer tests are as follows: (1) the outwash underlying the flood plain is capable of transmitting 3,000 to 4,000 gpd per ft^2 under a hydraulic gradient of 1 foot per foot, (2) the outwash is hydraulically connected with the Connecticut River and receives a major part of its recharge from the river when under pumping conditions, and (3) the effective distance to the river boundary from wells Mt 287 and Mt 288 is about 500 feet.

Computations utilizing the test results indicate that it is theoretically possible to increase the yield of each of the existing supply wells to 3,000 gpm without causing excessive drawdown—that is, without lowering the pumping levels below the bottom of the confining layer of alluvium. However, availability of pumps capable of efficiently producing 3,000 gpm from a 12-inch well—the size of the present supply wells—would likely be a limiting factor.

The geologic data from the well field indicate that the outwash aquifer thickens and becomes more permeable to the southeast. Thus, it is feasible to construct additional wells similar in design to the existing wells, each capable of producing 1,500 gpm. Because of the hydraulic connection between the aquifer and the river, the additional wells should be located about 250 feet apart and on an extension of the line between the existing supply wells. An alternative would be to construct wells of larger diameter—about 24 inches—at 500-foot intervals, each capable of producing about 3,000 gpm. It is estimated, on the basis of the area available for the installation of additional wells, that the well field has a potential capacity in excess of 20 mgd.

QUALITY OF WATER

Ten samples of water collected from six wells, the Connecticut River, and a quarry pond at the CANEL site were analyzed under the direction of F. H. Pauszek, district chemist of the Quality of Water Branch, U.S. Geological Survey, Albany, New York. The results of the analyses are given in table 4. Samples were collected also from five small ponds or reservoirs outside the limits of the CANEL site, but the results of these analyses are not given here.

The analyses in table 4 show that the water is low in total solids, and that the water from bedrock is more highly mineralized than water from the outwash, the Connecticut River, or the quarry pond. Water from bedrock and the Connecticut River contains iron in excess of 0.3 ppm, and two of the samples from bedrock and the sample from the river contained more than 1 ppm. Two samples of water collected from well Mt 288, which is in outwash, during a pumping test show that the iron content increased from 0.09 to 0.27 ppm after about 48 hours of pumping at the rate of 1,570 gpm. Otherwise, there was no significant change in the quality of the water as a result of the test.

USE OF WATER

The lower Connecticut River is used principally for commercial navigation, recreation, and fishing. No water is taken from the river for public supply. As far as is known, the only water withdrawn directly from the river for domestic, municipal, or industrial use is a small amount pumped by the Hartford Electric Light Co. for washing filters and for cooling at its steamplant at Benvenue, which is about a mile upstream from CANEL. Small supplies for these uses either are withdrawn from wells penetrating bedrock or unconsoli-

TABLE 4.—*Chemical analyses of water from wells, the*

[Analyses, in parts per million, by U.S. Geol.

Laboratory No.	Source of sample	Geologic unit	Date of collection (1956)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)
NYE 988	Well Mt 262	Maromas Granite Gneiss.	June 28	58	14	3.6	0.22	10	2.1	3.8	0.9
991	Well Mt 266	do	June 29	60	14	.51	.06	25	6.3	16	1.6
993	Well Mt 275	Bolton Schist	July 29	52	11	-----	-----	7.4	.6	32	1.7
992	Well Mt 285	Maromas Granite Gneiss.	July 28	50	24	1.4	.25	24	2.2	4.8	2.0
994	Well Mt 287	Outwash	July 7	51	12	-----	-----	26	2 4	3.2	1.1
989	Well Mt 288	do	June 27	52	14	.08	.06	24	1.2	3.3	1.4
996	do	do	July 11	51	14	.09	.08	22	2.6	3.5	1.1
995	do	do	July 13	51	13	.27	.06	23	1.8	3.2	.9
990	Connecticut River.		July 27	----	4.6	1.5	.06	12	1.8	5.9	1.4
896	Quarry pond	Maromas Granite Gneiss.	June 21	72	.8	.02	.00	3.1	1.0	2.2	1.0

dated deposits or from municipal reservoirs and wells located in areas remote from the river.

Commercial navigation is limited to the 45-mile reach of the Connecticut River below Hartford where a channel depth of 15 feet is maintained by the Corps of Engineers. Principal commodities transported are petroleum products and coal. Pleasure craft of all sizes use the river from June through October. Recreational boating is becoming more and more popular in Connecticut and boat ownership is increasing at the rate of at least 5 percent per year.

The river downstream from CANEL is used for swimming and bathing in the summer. This use probably is small at present but, as the State's effective pollution-abatement program progresses, there undoubtedly will be increased use of the river for swimming.

Fishing in the Connecticut River is on a small scale and includes both commercial and recreational fishing. Commercial fishing is restricted mostly to the taking of shad and alewives during the period from about April 1 to June 15, although yellow perch and eels are caught at other times of the year. The average annual commercial catch of shad as reported to the State Board of Fisheries and Game is about 100,000 fish. In addition, probably another 50,000 shad are caught by sportsmen, making the total value of the catch about $150,000. The average annual catch of alewives has been about 500 tons, and has been valued at about $18,000.

Domestic water supplies for farms and homes adjacent to the Connecticut River downstream from CANEL are obtained partly from ground water and partly from municipally owned reservoirs. Most wells penetrate terrace deposits and bedrock that are considerably above river level, but a few wells are located on the river flood plain.

Connecticut River, and a quarry pond at the CANEL site
Survey, Branch of Quality of Water]

Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$			Specific conductance at 25°C (micromhos)	pH	Color
						Total	Non-carbonate	Carbonate			
25	18	2.6	0.3	0.1	64	34	14	20	92.5	6.7	8
136	9.4	2.0	1.1	.1	137	88	0	88	234	7.7	3
96	6.7	2.3	1.1	.2	111	22	0	22	176	7.2	3
82	12	2.4	.5	.2	115	70	2	68	170	7.1	4
86	9.5	3.0	.0	.5	105	75	4	71	171	7.8	2
73	8.4	3.0	.0	.1	92	65	5	60	147	7.5	3
72	8.8	3.0	.1	.3	92	66	7	59	147	7.4	3
75	8.8	3.0	.0	.2	93	65	3	62	149	7.4	3
32	15	5.1	.0	2.0	77	38	11	27	120	6.4	9
6	9.1	2.5	.1	.2	27	12	7	5	41.4	6.8	7

TABLE 5.—*Records of selected*

Well and location: Wells in this report are numbered from 237. The number is preceded by the letter designation Mt for the city of Middletown. On the maps and cross sections the letter designation is omitted because all the wells are in Middletown. The well locations are indicated by coordinates of the grid shown on figure 2.
Owner or name: Name of present owner, or of individual or agency responsible for installation or operation of well.
Driller: Name of company, agency, or individual responsible for construction of well.
Date completed: Date or year when well was completed, if known.
Altitude of land-surface datum: Altitudes expressed in feet, tenths, and hundredths are instrumentally determined; those in whole feet are interpolated from topographic maps. Datum is mean sea level.
Type of well: DG, dug; DN, driven; DR, drilled.

Well	Location	Owner or name	Driller	Date completed	Altitude of land-surface datum (feet)	Type of well	Depth of well (feet)
Mt 237	N11,560:E32,110	City of Middletown No. 4.	E.H. Hartley	Dec. 1952	9.10	DR	85.0
261	N10,985:E30,515	S. L. Lebis			150	DG	27.6
262	N 9,015:E30,325	E. N. Dickinson	H. I. Stack	1949	155	DR	67
266	N 4,870:E30,005	J. C. Muller			135	DR	309
267	N10,920:E30,235				180	DG, DR	5 to 31
270	N 6,850:E26,050	Robert Day, Jr.	Robert Day, Sr.		375	DG, DN	13.8 to 36.9
271	N 5,830:E27,305	J. D. C. Waldon	H. I. Stack	1955	250	DR	70
272	N 5,750:E27,450	J. H. Curtis	do	1955	260	DR	72
273	N 4,850:E28,220	Stanley Pokorny	Rachbauer Brothers.	1948	200	DR	108
274	N 4,670:E28,585	Marian Pokorny	do	1930	175	DR	99
279	N 4,525:E28,960	W. G. Hannaford			160	DG	24.8
285	N 7,120:E30,435	J. M. Babor			135	DR	51
295	N11,275:E32,545	U.S. Air Force 7	R. E. Chapman Co.	June 22, 1956	11.05	DR	74.2
300	N 5,565:E32,535	Middletown Yacht Club.	A. J. Buczko	1944	10	DR	155
301	N 8,985:E31,355	B. F. Shaw Co.	Sima and Garigliano	June 1956	139	DR	143.6
310	N11,400:E31,450	U.S. Air Force 3.	R. E. Chapman Co.	Aug. 15, 1956	57	DR	87
311	N10,645:E32,375	U.S. Air Force 7A.	do	Aug. 23, 1956	70	DR	145

wells at the CANEL site

Depth of well: Depths expressed in feet and tenths are measured; those in whole feet are reported. Depths are below land-surface datum.
Water-bearing material: For explanation of geologic units from which water is drawn, see table 1. No entry is made if well does not penetrate the zone of saturation, or if the aquifer is not known.
Depth to bedrock: Depth to bedrock or, where number is followed by a question mark, depth to refusal, in feet below land-surface datum.
Water level: Water levels expressed in feet, tenths, and hundredths are measured; those in whole feet are reported or estimated. Measurements are depths below land-surface datum, except when preceded by a plus sign indicating that they are heights above land-surface datum.
Use: D, domestic; I, industrial; Obs, observation or water-test well; PS, public supply; S, stock; U, unused.
Remarks: A, well abandoned and destroyed; T, temperature of water in degrees Fahrenheit; method of lift indicated by pump type; gpm, gallons per minute; msl, mean sea level; lsd, land-surface datum.

Diameter of well (inches)	Principal water-bearing material		Depth to bedrock (feet)	Water level		Use	Remarks
	Type of material	Geologic unit		Depth (feet)	Date of measurement		
8	Sand and gravel.	Outwash	85.0	7.0	Jan. 5, 1953	Obs	Yield 450 gpm, drawdown of 4.5 ft after pumping 79½ hr. Drawdown not corrected for tidal fluctuations. A, Mar. 1 1957.
24	do	do		18.32	Apr. 5, 1956	Obs	
6	Bedrock	Maromas Granite Gneiss.	10			D	When completed in 1949, well flowed. Well now overflows at times through a bleeder pipe at top of casing which is below the surface. Chemical analysis in table 4. T 47°. Jet pump.
6	Bedrock	Maromas Granite Gneiss.	10?	62.28	Apr. 17, 1956	Obs	Chemical analysis in table 4. Jet pump.
24 to 6	Clay, silt, sand, gravel, boulders, and bedrock.	Till and Maromas Granite Gneiss.		2.40 and 1.60	Apr. 17, 1956	Obs	
24 to 2½	Clay, silt, sand, gravel, and boulders.	Till		5.28	Apr. 17, 1956	D	Suction pump.
6	Bedrock	Bolton Schist	0			D, S	Well flows at surface. Yield 8 gpm. Suction pump.
6	do	do				D	Well reportedly flows at surface.
6	do	do	6	4.08	Apr. 18, 1956	D, Obs	Well flows through bleeder line. Aquifer called "blue granite" by owner. Suction pump.
6	Bedrock, soft	do	0?			D	Well reportedly cased to bottom, reported to flow at rate of 5 gpm. Jet pump.
36	Clay, silt, sand, gravel, and boulders.	Till		.16	Apr. 18, 1956	D, Obs	Gravity flow.
6	Bedrock	Maromas Granite Gneiss.	30	+3	June 13, 1956	U	Chemical analysis in table 4. T 52°. Formerly used for domestic purposes, to supply swimming pool and fish pond. Water flows at rate of 1½ gpm from 2½-in. pipe at top of casing, which is about 3 ft above lsd. Lift pump.
3	Sand and gravel.	Outwash	87.5	9.57	July 14, 1956	Obs	T 51°. Continuous water-level record available.
	Gravel	do		10	1944	PS	Yield 50 gpm.
6	Bedrock	Maromas Granite Gneiss.	29	24.07	July 10, 1956	PS, I	Well bailed "dry" and rate of recovery measured at 3 to 4 gpm. Jet pump.
8			87			Obs	Driller reported "No water." A.
8	Sand and gravel.	Outwash	145	66	Aug. 24, 1956	Obs	A.

All wells are believed to obtain water from ground water that is moving toward the river. However, a few wells on the lower parts of the flood plain may receive inflow of river water when the flood plain is covered by backwater from the river during times of flood.

The only industrial supply wells immediately adjacent to the Connecticut River are the wells of the Hartford Electric Light Co. steamplant at Benvenue, about a mile upstream from CANEL. These wells are at the sites of test wells Mt 258 and Mt 260 shown on plate 1. An average of less than 50,000 gpd is pumped from these wells but the wells were rated at a total capacity of about one million gallons per day at the time they were installed. At the potential pumping rates it is possible that some water may be withdrawn from the Connecticut River by induced infiltration.

SUMMARY AND CONCLUSIONS

On the basis of data available for this report, the following conclusions are offered:

1. Virtually all the ground water in the CANEL site originates as precipitation on the immediate area, and most of the water that is not evaporated or transpired reaches the Connecticut River eventually, much faster overland than underground.
2. A liquid spill in the Hubbard Brook drainage area in the extreme western and southern parts of the site would reach the Connecticut River downstream from the site.
3. A liquid spill in the hilly western half of the site would tend to move toward the river either overland in streams or underground with the ground water.
4. A liquid waste reaching the zone of saturation in bedrock in the hilly western half of the area would tend to move toward the river with the ground water. However, enroute, contaminated water might be discharged to the surface by way of flowing bedrock wells or might move upward to overlying unconsolidated deposits in the eastern half of the area.
5. A liquid spill on the high terrace would tend to percolate to the zone of saturation in outwash and then move toward the Connecticut River in the ground water. In addition, contaminated water in streams originating in the western half of the area and crossing the high terrace would tend to percolate to the zone of saturation in outwash. Ground water in the outwash is probably prevented from moving downward into bedrock by the higher head of water in the bedrock.

6. The rate of movement of ground water in outwash may be as much as 100 feet per day beneath the high terrace and as little as 2 feet per day beneath the Connecticut River flood plain.
7. A liquid spill on the Connecticut River flood plain would tend to percolate downward to the zone of saturation in alluvium and then move laterally to the river or downward to the outwash.
8. The results of aquifer tests based on the geologic and hydrologic conditions at the CANEL well field as determined from observed data and test computations may be summarized as follows:
   a. A leaky artesian aquifer is present in the unconsolidated deposits beneath the Connecticut River flood plain at the Hartford Research Center. The water table in the fine-grained alluvium stands at a higher altitude than the piezometric surface of the outwash aquifer.
   b. The sustained yields of wells Mt 287 and Mt 288 (the production wells) during the tests satisfied the test specifications. These wells were each pumped for 48 hours at 1,570 gpm and specific capacities of 89 and 115 gpm per ft of drawdown, respectively. Pumping at well Mt 287 lowered the water level at Mt 288 by 1.49 feet, and pumping at well Mt 288 lowered the water level at Mt 287 by 1.64 feet. Therefore, mutual interference is small.
   c. The coefficients of T and S at wells Mt 287 and Mt 288 were computed to be 2.3×10^5 gpd per ft and 3.3×10^{-4} and 3×10^5 gpd per ft and 3.0×10^{-4}, respectively. The difference in the values of T is attributable largely to the greater effective thickness of the aquifer at well Mt 288. P was determined to be about 3,000 gpd per ft^2 and 4,000 gpd per ft^2 at the two wells.
   d. The outwash aquifer is in full hydraulic connection with the Connecticut River, and the effects of this recharge area are registered in observation wells within 5 minutes after the start of pumping at the rate of 1,570 gpm.
9. Pumping from outwash underneath the Connecticut River flood plain tends to draw water from the high terrace and the alluvium as well as from the river. The exact shape and extent of the cone of depression produced during two pumping tests on the floodplain could not be determined, and therefore it is not known from what parts of the terrace or the flood plain water might be drawn.
10. If ground-water requirements for the CANEL site are equivalent to the total yield of wells Mt 287 and Mt 288 during the pumping tests (4.5 mgd), most of the water would have to come from the river, for only about 1.7 mgd is available from local recharge furnished by precipitation without drawing from storage.

11. The velocity of flow of water from the river toward the wells under pumping conditions during the tests was about 20 times the velocity of flow of water from the wells toward the river under natural conditions.
12. The movement of a liquid spill or waste upon entering the Connecticut River would be considerably influenced by river currents, which would vary widely with river stage and the various phases of tidal fluctuation. This influence would be felt particularly at times of low flow when the tides often cause the usual downstream flow to reverse itself, and wastes might travel a considerable distance upstream. A precise study and definition of these currents has been proposed but was not undertaken as a part of the present investigation. A sizable catch of shad and alewives is taken annually from the Connecticut River by commercial fishermen and sportsmen. In addition, water from the river is used to a limited extent for other recreational purposes and for cooling and filter washing by a steam powerplant. Contaminants in the Connecticut River resulting from a liquid spill would be a potential hazard to each or all of the above users.

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