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Hydrogeology and Water Quality of Significant Sand and Gravel Aquifers

in parts of Androscoggin, Cumberland, Franklin, Kennebec, Lincoln, Oxford, Sagadahoc, and Somerset Counties, Maine

Significant Sand and Gravel Aquifer Maps 10, 11, 16, 17, and 32

by

Dorothy H. Tepper
U.S. Geological Survey

John S. Williams
Maine Department of Environmental Protection

Andrews L. Tolman
Maine Geological Survey

Glenn C. Prescott, Jr.
U.S. Geological Survey

Walter A. Anderson, State Geologist
Maine Geological Survey
DEPARTMENT OF CONSERVATION

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AUTHORS

Dorothy H. Tepper, U.S. Geological Survey
John S. Williams, Maine Department of Environmental Protection
Andrews L. Tolman, Maine Geological Survey
Glenn C. Prescott, Jr., U.S. Geological Survey

COMPILATION ASSISTANTS

E. Melanie Lanctot, Maine Geological Survey
Gloria L. Morrill, U.S. Geological Survey

FIELD ASSISTANTS

James T. Adamik, U.S. Geological Survey
Melissa C. Whitaker, Maine Geological Survey
Laurie A. Sparrel, Maine Geological Survey
Patricia A. Pierce, Maine Geological Survey
Jane C. Biggs, Bates College
E. Melanie Lanctot, Maine Geological Survey
Cheryl W. Fontaine, Maine Department of Environmental Protection

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Walter A. Anderson, State Geologist

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CONVERSION FACTORS AND ABBREVIATIONS

For the convenience of readers who may prefer to use metric (International System) units rather than the inch-pound units used in this report, values may be converted by using the following factors:

Multiply inch-pound unit	By	To Obtain Metric Unit
inch (in)	25.40	millimeter (mm)
foot (ft)	.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
foot per second (ft/s)	0.3048	meter per second (m/s)
foot per day (ft/d)	0.3048	meter per day (m/d)
foot squared per day (ft^2/d)	0.0929	meter squared per day (m^2/d)
gallons per minute (gal/min)	0.0630	liter per second (L/s)
million gallons per day (Mgal/d)	0.0438	cubic meter per second (m^3/s)

Temperatures in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows:

$$°F = 1.8°C + 32$$

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, called NGVD of 1929, is referred to as sea level in this report.

HYDROGEOLOGY AND WATER QUALITY OF SIGNIFICANT SAND AND GRAVEL AQUIFERS IN PARTS OF ANDROSCOGGIN, CUMBERLAND, FRANKLIN, KENNEBEC, LINCOLN, OXFORD, SAGADAHOC, AND SOMERSET COUNTIES, MAINE: SAND AND GRAVEL AQUIFER MAPS 10, 11, 16, 17, AND 32

By Dorothy H. Tepper, John S. Williams, Andrews L. Tolman, and Glenn C. Prescott, Jr.

ABSTRACT

A reconnaissance-level hydrogeologic study was made of 2,408 square miles in Androscoggin, Cumberland, Franklin, Kennebec, Lincoln, Oxford, Sagadahoc and Somerset Counties in Maine. This is the area included in Maps 10, 11, 16, 17, and 32 of the Sand and Gravel Aquifer Map Series published by the Maine Geological Survey.

The significant sand and gravel aquifers, defined as yielding 10 or more gallons per minute to a properly installed domestic well, consist of glacial ice-contact and outwash deposits which occur primarily in the valleys of the major rivers and along their tributaries. Significant aquifers comprise almost 109 square miles but yields that exceed 50 gallons per minute are estimated to be available within only 21 percent of this area. Typically, the water table is within 20 feet of the land surface. Based on seismic data, the greatest known depth to bedrock is 340 feet.

The regional ground-water quality has the following characteristics: It is slightly acidic to slightly basic; calcium and sodium are the most abundant cations; bicarbonate is the most abundant anion; and the water is soft. In some localities, concentrations of iron and manganese are high enough to limit use of the water without treatment.

Sixty-six sites, including 32 solid-waste facilities and 18 salt-storage lots, were identified as potential sources of ground-water contamination to the sand and gravel aquifers in the study area.

INTRODUCTION

Significant sand and gravel aquifers are the primary sources of ground water capable of supplying the large volumes of water needed by municipalities and industries in Maine. They are also the source of water for many domestic wells and may serve as major recharge areas for underlying bedrock aquifers. A significant aquifer, as defined by the Maine State Legislature (38 MRSA Section 6, 482, 4-D), is one that will produce 10 gal/min or more of water to a properly installed domestic well.

This report describes the hydrogeology and water quality of significant sand and gravel aquifers in parts of Androscoggin, Cumberland, Franklin, Kennebec, Lincoln, Oxford, Sagadahoc, and Somerset Counties, Maine.

The 5 plates (listed on page iii) which accompany this text are available under separate cover from the Maine Geological Survey.

Previous Investigations

Surficial mapping conducted in the study area has provided information on the areal extent of glacial sand and gravel deposits. Results are published in reports by Caldwell (1975), Prescott and others (1976), Prescott and Thompson (1977 a,b), Thompson (1976), Thompson and Smith (1977), Smith (1976 a-d, 1977), and Smith and Thompson (1980 a,b).

A series of hydrologic atlases and data reports (Prescott 1967, 1968a,b, 1969, 1976, 1977, 1979a, 1980a,b) include information on surficial geology, well depth and yield, water levels, stratigraphy, estimated yield zones, and water quality.

From 1978 to 1980, the Survey (U.S. Geological Survey) and the MGS (Maine Geological Survey), with partial funding from the DEP (Maine Department of Environmental Protection) conducted a reconnaissance-level investigation of sand and gravel aquifers in the populated areas of Maine. The Sand and Gravel Aquifer Map Series (fig. 1) presented the results of this investigation. The maps were compiled based on available well data and reconnaissance mapping of the surficial geology. Information presented in this map series, published at a scale of 1:50,000, includes approximate aquifer boundaries, estimated yields, and locations of some potential point sources of contamination.

The study area for the present investigation includes Maps 10, 11, 16, 17, and 32 of the Sand and Gravel Aquifer Map Series (Brewer and others, 1979; Prescott, 1979b, 1981; Prescott and others, 1979; Prescott and Dickerman, 1981).

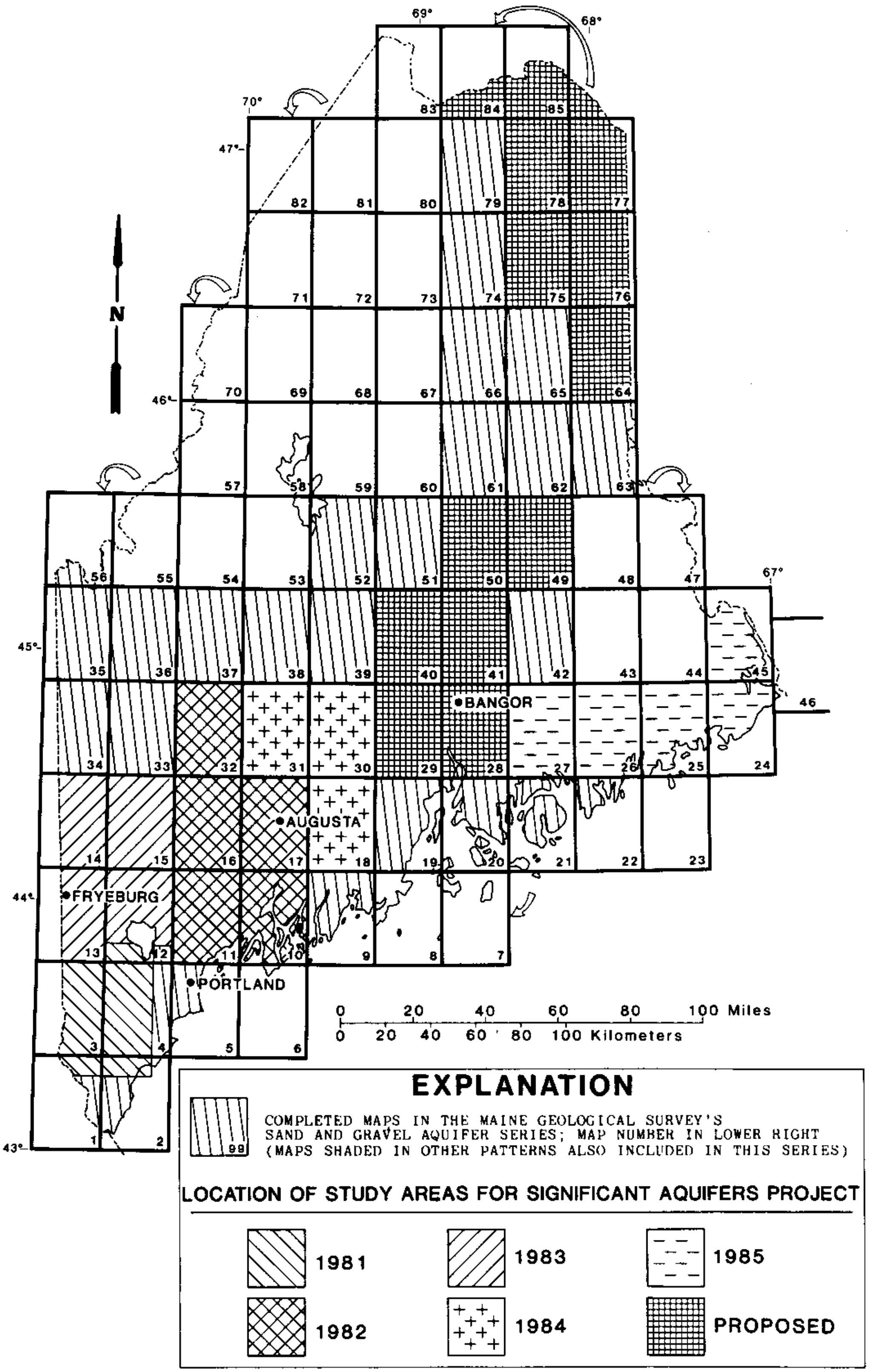

Figure 1. Index to Sand and Gravel Aquifer Map Series and location of study areas.

Purpose and Scope

To meet the demand for more accurate, complete, and current hydrogeologic information required to evaluate, manage, and protect Maine's ground-water resources, a detailed, cooperative mapping project was initiated in June 1981 by the MGS, the Survey, and the DEP. Significant aquifers in northern York and southern Cumberland Counties were investigated during the 1981 field season (Tolman and others, 1983). The locations of that study area and subsequent study areas are shown on figure 1.

This report presents the results from the second year of the mapping project (1982). It identifies areas most favorable for development of water supplies and, therefore, in most need of protection. In addition, it identifies areas where development may be limited by poor water quality or the presence of possible sources of contamination. The report provides water-resources planning and management information for the use of State and Federal agencies, regional planning commissions, municipal governments, consultants, and homeowners.

The scope of the investigation includes:

Surficial geologic mapping to define the boundaries of the glacial deposits

- Seismic-refraction investigations to determine depth to water, depth to bedrock, and bedrock-surface topography

- Well inventory to supplement existing data on depth to water, depth to bedrock, and well yields

- Observation-well and test-hole drilling to determine stratigraphy, aquifer thickness, and lithology (used to estimate transmissivity)

- Water-quality sampling and analysis to characterize the regional ground-water chemistry

- Location of potential sources of ground-water contamination

- Location of municipal well fields

Location of Study Area

Significant aquifers in maps 10, 11, 16, 17, and 32 of the Sand and Gravel Aquifer Map Series were investigated during the 1982 field season. The study area (2408 mi^2), which includes portions of Androscoggin, Cumberland, Franklin, Kennebec, Lincoln, Oxford, Sagadahoc, and Somerset Counties, (fig. 2) was selected because it has the second highest aquifer and population density in Maine.

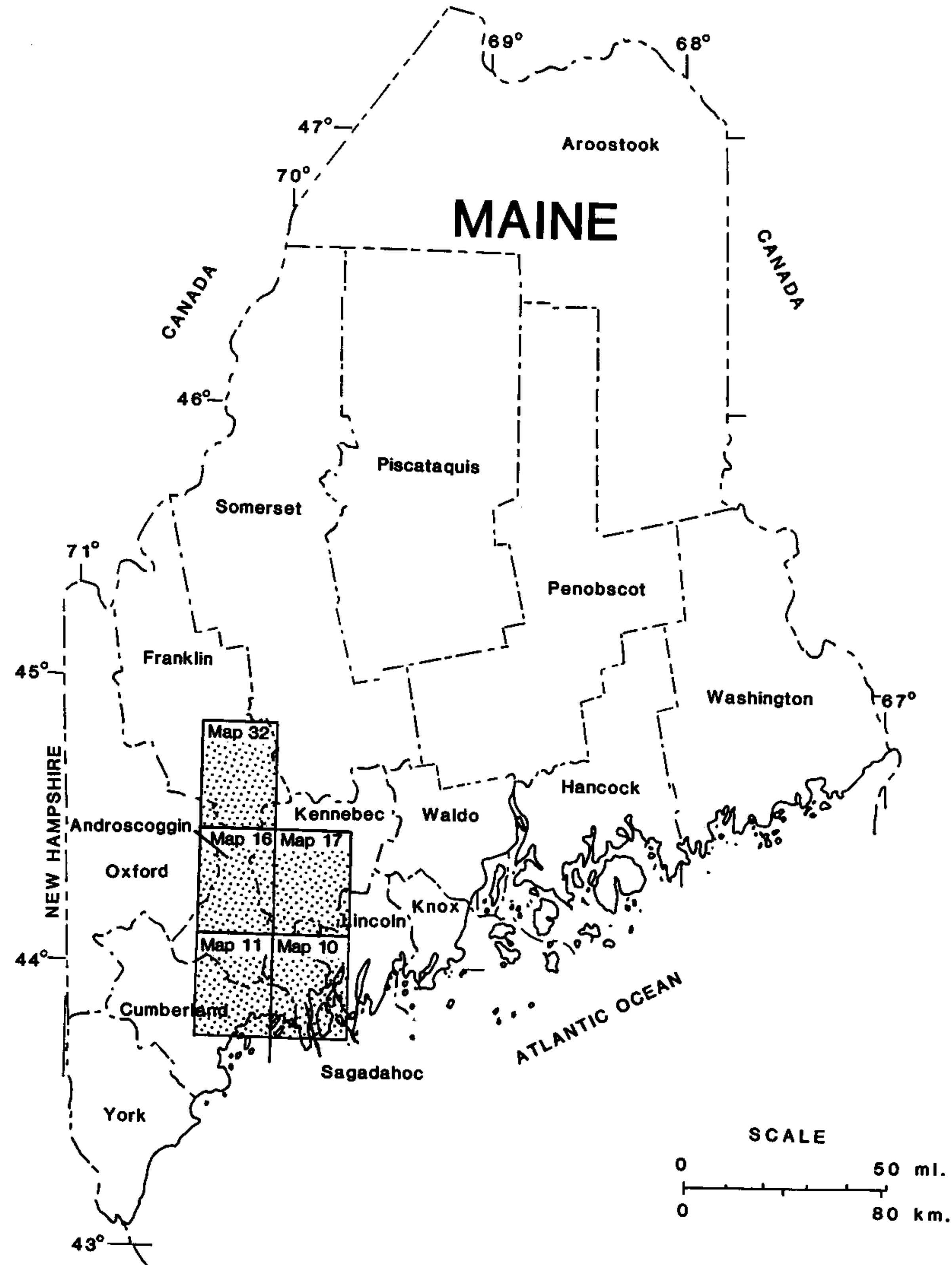

Figure 2. Location of study area.

METHODS OF STUDY

Mapping of Significant Sand and Gravel Aquifer Boundaries

The aquifer boundaries as shown on the maps of the Sand and Gravel Aquifer series were used as the initial boundaries for this investigation. Reports from previous investigations (see Previous Investigations section) were reviewed to verify these boundaries, which were then field-checked for accuracy on the basis of the distribution and type of surficial deposits exposed. Aquifer boundaries as shown on plates 1-5 (in pocket) are the result of modifications based on surficial mapping, and on data obtained during well inventories, geophysical investigations, and test drilling. However, in areas where no additional data were collected, the aquifer boundaries were not modified.

Seismic-Refraction Investigations

Seismic-refraction techniques were used extensively to determine depth to water table, depth to bedrock, and bedrock-surface topography. In seismic exploration, sound waves are generated at the surface by a small explosion or hammer. The waves travel at different velocities through different materials; the denser the material, the faster the wave velocity. The velocity of sound through a material can be used to identify whether it is dry or saturated sand and gravel, till, or bedrock.

A twelve-channel EG&G Geometrics Nimbus ES-1210F seismograph [1/] was used to determine saturated thickness and bedrock surface topography in areas where the depth to bedrock was estimated to be more than 75 feet. The seismic lines ranged from 240 to 1,200 feet in length. Several lines were run end-to-end to provide extended profiles over areas of particular interest. Altitudes of the shot points and geophones were surveyed where relief on the land surface exceeded 5 feet along the line. A computer program (Scott and others, 1972) was used to determine layer velocities and to generate a continuous profile of the water-table surface and the bedrock surface beneath each line. Wherever possible, nearby well and test-hole information were used to verify the results.

A single-channel Soiltest MD9A seismograph was used in areas where the depth to bedrock was estimated to be less than 75 feet. Information was obtained on depth to water, depth to bedrock, and dip of the bedrock surface at each end of the lines, which ranged from 100 to 200 feet long. Interpretations and analyses were done according to methods developed by Mooney (1980) and Zohdy (1974). These results were particularly useful in definition of aquifer boundaries. Based on seismic-refraction information, sand and gravel deposits which lacked sufficient saturated thickness to yield over 10 gal/min were excluded from consideration as significant aquifers.

1/ Use of trade names in this report is for descriptive purposes only and does not constitute endorsement by the Survey, the MGS, or the DEP.

Observation-well and Test-hole Data Collection

Drilling and Stratigraphic Logging Methods

Twenty-five exploration holes were drilled in selected aquifers to obtain information on water quality, thickness and lithology of the geologic units, and to determine the depth to water table and depth to bedrock. For the purpose of this report, the term "test hole" refers to an uncased exploration hole. These holes were destroyed after test information was obtained. The term "observation well" refers to a cased exploration hole. These holes were used to obtain water-level and/or water-quality observations during the period of investigation.

A hollow-stem auger drill rig was used for exploration hole drilling. In this method of drilling, fluted auger sections 5 feet in length and 6 inches in diameter are rotated in the hole. New sections are added at the drill head as the hole progresses. Samples of the sediment being penetrated above the water table are brought to the surface by the rotation of the augers. Where detailed stratigraphic information was needed below the water table, a split-spoon sampler was used to collect sediment samples ahead of the drill stem.

Observation-well Construction

Twenty of the exploration holes were cased with 2-inch, schedule 40 PVC (polyvinyl chloride) plastic pipe so that water samples could be collected and water-level measurements could be made. PVC screens with slot widths ranging from 0.006 to 0.015 inches were used. Because the release of tetrahydrofuran from PVC cement can cause artificial increases in total organic-carbon concentrations and thereby cause erroneous results in determinations of concentrations of volatile organic compounds, all casing couplings were fastened with 3/8-inch sheet metal screws rather than with PVC cement. The casing and screen were emplaced inside the hollow stem auger and the hole was allowed to collapse around the casing as the drill stem was withdrawn. Bentonite pellets were used at the surface to prevent water from infiltrating around the casing. No casing was installed in the remaining five exploration holes either because refusal was reached before the water table or only material of low permeability was encountered. Eleven exploration holes did not penetrate the entire thickness of unconsolidated deposits because of depth limitations of the drill rig and time constraints.

Observation-well Development

Immediately after the casing was emplaced, water was pumped down the observation well to aid well development. Observation wells were more thoroughly developed later by alternately adding clean water and then pumping, with either a suction or submersible pump until the water in the observation well appeared free of sediment. Development was completed by pumping several volumes of water from each observation well where yields were sufficient to allow continued pumping.

Procedures for Water-Quality Sampling and Analysis

Fifteen of the observation wells were sampled to determine background water quality. To ensure that water samples collected were as representative as possible of the geochemical environment, 11 of the observation wells were pumped with a Johnson-Keck model SP-81 submersible pump at a rate of 1 gal/min until pH, temperature, and conductivity measurements stabilized. Yields in the remaining four observation wells were too low to permit pumping. Samples from these observation wells were collected with a PVC bailer that was filled with well water and emptied three times prior to sampling.

Water samples from existing sources were collected to supplement the water-quality data from the observation wells. A small-diameter well at the Sabbatus Water District was sampled using a Horizon Ecology model 7570 peristaltic pump. Samples of untreated water were collected from public-supply wells in Bowdoinham, Gardiner, and Strong. In addition, a grab sample was collected from the Augusta Fish Hatchery Spring.

Field measurements of pH and conductivity were made with portable meters (Orion Model 399 A with a glass electrode for pH, Beckman Solu-Bridge for conductivity). Alkalinity was measured in the field using a gran-plot titration method (Stumm and Morgan, 1970).

Unfiltered samples for nitrate, chloride, sulfate, and total organic carbon determinations were collected in plastic "Cubitainers" rinsed three times with sample water. Samples for dissolved-metal analyses were also collected in rinsed "Cubitainers". These samples were filtered and then acidified with nitric acid. Samples for volatile organic analyses were collected in rinsed glass vials and immediately sealed to prevent loss of gases. All samples were kept on ice and delivered to the DEP laboratories within 48 hours.

Metals were analyzed by atomic-absorption spectrophotometry. Chloride was analyzed by the Argentometric Method (Standard Method 408A, American Public Health Association and others, 1976), nitrate-nitrite and sulfate by an automated Technicon method, and total organic carbon by a combustion-tube infrared technique (Standard Method 505, American Public Health Association and others, 1976). Volatile organic analyses were done using a purge and trap method on a gas chromatograph equipped with a mass spectrophotometer.

Identification of Sites of Potential Ground-Water Contamination

Potential ground-water contamination sites that are located on or near significant aquifers are shown on plates 1-5. These sites were identified primarily from files of the DEP Bureaus of Land, Water, and Oil and Hazardous Materials. The locations of State-owned salt-storage lots were determined from Maine Department of Transportation records. Letters were sent to town managers and local code-enforcement officers requesting their help in locating potential contamination sites. All site locations were field-checked.

Although the sites shown on plates 1-5 include most of the known major point sources of contamination, certain point and non-point sources have not been shown because of their widespread occurrence. These sites include malfunctioning septic systems, roads that are salted in the winter, manure piles and fertilized fields, areas where pesticides are applied, and leaking underground storage tanks.

HYDROGEOLOGY

Geologic Setting

Lithologies in the study area consist of highly deformed Paleozoic metasedimentary and granite rocks that are overlain by as much as 340 feet of unconsolidated late Wisconsinan glacial sediments. Structurally, the area is located within the Merrimack synclinorium.

Bedrock Geology

Map 10

The bedrock in this area consists primarily of a sequence of metasedimentary and metavolcanic rocks. Much of the area is underlain by a Cambrian and Ordovician sequence of gneiss, amphibolite, marble, schist, granulite, quartzite and metachert. The metamorphic grade of most of these rocks is sillimanite or higher. Granite intrusives and pegmatites also crop out in some localities (Hussey, 1981 a, b; Hussey and Pankiwskyi, 1975).

East of the Kennebec River, these rocks are overlain by younger rocks which consist of metashale, metasandstone, quartzite, and biotite-garnet-sillimanite schist. Numerous small granite and pegmatite plutons of Devonian age are exposed in this area (Newberg, 1981; Pankiwskyj, 1976).

The stratified rocks in the Map 10 area were affected by two major periods and several minor episodes of deformation (Hussey, 1981a). Several major faults trend southwest-northeast through the area.

Map 11

The bedrock of this area consists of a eugeosynclinal sequence of metasedimentary and metavolcanic rocks from Cambrian to Silurian age, intruded in places by Devonian granite (Hussey, 1981a). Cambrian and Ordovician rocks, which are present in the southeastern corner of this map, include gneiss, amphibolite, marble, schist, metachert, and feldspathic and micaceous quartzite.

A Silurian and Ordovician sequence of granofels and schist, with small outcrops of marble, trends northeast to southwest. The northwest section of this map is dominated by an early to middle-Silurian sequence of calc-silicate gneiss and schist which is interlayered with biotite granofels and meta-pelite (Creasy, 1979). Devonian granite and pegmatites intrude many of the units described above. The western third of Map 11 is occupied by the largest granite pluton in Maine (Hussey, 1981a).

The stratified rocks in this area have been affected by two major periods and several minor episodes of deformation. Several major faults trend southwest-northeast through the southeastern section of Map 11 (Hussey, 1981a).

Map 16

The bedrock in the Map 16 area consists of highly-deformed Silurian and Devonian metasedimentary rocks and Devonian granite (Osberg and others, 1984). The Silurian rocks include metapelite, metasiltstone, metasandstone, and metagraywacke. The Devonian rocks include metalimestone, metapelite, metasiltstone, metasandstone, and metaconglomerate.

In terms of structural setting, the area is located on the southeast limb of the Merrimack synclinorium (Pankiwskyj and others, 1976). The regional strike is predominantly northeast-southwest. Additional information concerning the bedrock lithology and structure can be obtained in Creasy (1979), Hodge and others (1982), Hussey (1983), Moench and others (1982), Pankiwskyj and others (1976), and Warner and others (1965).

Map 17

The bedrock consists of highly deformed Ordovician, Silurian, and Devonian metasedimentary rock and Devonian granite (Osberg et. al., 1984). The Ordovician rocks are primarily melange, and are restricted to the southern part of the area. Silurian rocks, which are predominant in the area, include metapelite, metasiltstone, metasandstone, and metagraywacke. The Devonian rocks include metalimestone, metapelite, metasiltstone, metasandstone, and metaconglomerate. The exposed granite and granodiorite are also of Devonian age.

The Map 17 area is located in the central portion of the Merrimack synclinorium (Newberg, 1981). The regional strike is northeast-southwest. Additional information concerning the bedrock and its structure can be obtained in Newberg (1981).

Map 32

The bedrock in the Map 32 area consists of highly deformed Silurian and Devonian metasedimentary rock and Devonian granite (Pankiwskyj and Hussey, 1980; Pankiwskyj, 1979). The Silurian rocks, which crop out only in the eastern section of the area, include metapelite, metasiltstone, metasandstone, and metagraywacke. Devonian rocks, which are predominant in the area, include metalimestone, metapelite, metasiltstone, metasandstone, and metaconglomerate. The exposed granitic rocks of the New Hampshire plutonic series are also of Devonian age.

The area is located in the central portion of the Merrimack synclinorium (Pankiwskyj, 1975). The regional strike is northeast-southwest. Additional information concerning the bedrock lithology and structure can be obtained in Pankiwskyj (1965, 1978a, 1978b, 1978c, 1979).

Surficial Geology

Glacial History

Maine was covered at least twice by continental glaciers during the Pleistocene Epoch, which occurred from approximately 2,000,000 to 10,000 years ago. The last ice sheet advanced into Maine from eastern Canada about 20,000 years ago, in late Wisconsinan time (Schafer and Hartshorn, 1965). The ice sheet flowed southeastward beyond the present coastline and into the Gulf of Maine.

As the glacier advanced, it eroded soil and rock debris and incorporated it into the ice. The material which was deposited directly from the ice as a discontinuous layer on the bedrock surface is termed "till". The till was deposited at the base of the ice (lodgment or basal till) as the glacier advanced and from melting ice (ablation till) as the glacier stagnated and retreated (Thompson, 1979). Till is a poorly sorted usually nonstratified mixture of clay, silt, sand, gravel, and rock fragments. Its color, which is dependent on composition, texture, degree of oxidation, and moisture content, is typically dark to light gray or brown. Most of the rocks in the till have been locally derived.

Till is the oldest and most widespread glacial deposit in the study area. It is typically exposed in the uplands and is buried beneath younger deposits in the valleys. Most of the till in the study area is unweathered and is presumed to be of late Wisconsinan age. However, a second, more weathered till, which is probably older, also crops out in several localities. Two tills are known to be superimposed at Winthrop (Map 17) and New Sharon (Map 32). The lower till in the Winthrop exposure has not been dated because of the absence of dateable organic material, but it may be equivalent to the older till exposed along the banks of the Sandy River in New Sharon (Thompson, 1980). The lower till at New Sharon has been dated as older than 52,000 years (Borns and Calkin, 1977).

As the climate warmed, the ice melted faster than the rate of glacial advance, causing the glacial margin to recede. This recession probably began 15,000 to 14,000 years B.P. (before present) in the southwestern part of the Gulf of Maine (Tucholke and Hollister, 1973). The ice sheet rapidly retreated and had withdrawn to a position parallel to and slightly inland of the present coastline by 13,200 years B.P. (Smith, 1982). Central Maine was deglaciated by approximately 12,700 years B.P. (Stuiver and Borns, 1975).

Deglaciation was contemporaneous with a marine transgression, and the ice retreat was accomplished, in large part, by calving of ice blocks into the open sea. Based on the present altitude of the marine limit in central Maine, the weight of the ice sheet caused an isostatic depression of about 790 feet in the crust (Stuiver and Borns, 1975). This depression and the subsequent release of glacial meltwater resulted in a marine invasion which flooded low-lying areas in southern Maine. This marine transgression was most extensive in the coastal lowlands but it also reached far into central Maine along the major river valleys. The marine limit averages approximately 300 feet in altitude over most of southern and central Maine; the highest known altitude is 425 feet at Bingham. As a result of differential rebound of the land as the ice receded, the altitude of maximum submergence is higher to the north and northwest of the coast. The ice was also thicker to the northwest, causing greater depression and allowing greater potential rebound.

In places where there was a temporary pause in the retreat of the glacial margin, ridges of sediment were deposited along the ice front. These ridges are termed "moraines." They are often composed of a mixture of sand and gravel and till.

As the ice margin receded, a large amount of water was released. Streams formed by this meltwater picked up and transported large amounts of sediment that were deposited downstream in areas of slower water velocity. These deposits accumulated in channels within or beneath the ice, between the ice and adjacent valley walls, and at or near the front of the glacier. This type of deposit is termed "ice-contact stratified drift", and is composed of sand and gravel. Characteristic ice-contact landforms include eskers, which are sinuous ridges; crevasse fillings, which are also ridges but are not as extensive as eskers; kames, which are irregular hills; kame terraces, which are terraces along a valley wall or hillside; and kame deltas, which are flat-topped hills. Outwash plains were formed where sediments were deposited by streams at some distance from the ice margin. Some of these ice-contact and outwash deposits have sufficient areal extent and saturated thickness to be considered significant sand and gravel aquifers.

Many large deltas, which were fed by meltwater streams, were built into the sea along the retreating margin of the ice sheet. Very fine-grained sediments that washed out of the ice sheet ultimately settled to the sea floor and formed extensive deposits of glaciomarine fine sand, silt, and clay. This material is referred to as the Presumpscot Formation (Bloom, 1960), or as marine clay. Although it is not highly fossiliferous within the study area, the Presumpscot Formation may locally contain remains of shells, seaweed, spruce trees, and other terrestrial plants.

The Presumpscot Formation, where present, typically overlies deposits of till or sand and gravel. However, it may locally be interbedded with or overlain by sand and gravel. It typically fills valleys and may reach thicknesses of 100 feet or more. The Presumpscot Formation is usually brownish gray to bluish gray. It is usually massive but does show stratification in some outcrops.

In parts of the study area, the Presumpscot Formation is overlain by fine to coarse sand and small amounts of gravel. This type of deposit may have resulted from increased rates of melting of the glacial ice or from slight readvances during the withdrawal of the sea. At least some of it was deposited in the sea, but it is much coarser than typical Presumpscot sediment. Some investigators have considered this coarser-grained unit to be a sandy facies of the Presumpscot Formation but it may be outwash that was redeposited in the shallow water during the regression of the sea (Thompson, 1982).

As some of the larger, sand-covered plains were exposed during the marine regression, wind action became dominant and dunes were formed on some valley floors. Dune formation is still active in local areas where the vegetation cover has been destroyed. An example of this is the "Desert of Maine" in Freeport. An area in Wayne, known locally as the "Desert of Wayne," consists of sand dunes that were formed shortly after deglaciation of the area (Caldwell, 1965). The sand may have been derived from deposits bordering the Androscoggin River. It probably was transported by the wind approximately 12,000 years ago, before enough vegetation and soil cover developed to prevent extensive wind erosion.

Stratigraphy of Glacial Deposits

Based on field relationships, observation-well and test-hole logs (tables 6 - 9, at end of report), and interpretation of the geologic history, a generalized stratigraphic section has been established for the study area (fig. 3). This entire section is usually not exposed in any given locality; instead, what is observed in the field depends on the local depositional conditions during the Pleistocene and on how much of the resultant sequence has been exposed to erosion. Thickness of the glacial units can vary considerably among different types of deposits. The greatest known thickness in the study area, based on seismic evidence, is 340 feet.

Actual geologic sections from the southeastern corner of Map 11 (plate 2), the central portion of Map 17 (plate 4), and the southeastern corner of Map 32 (plate 5) are presented in figures 4a,b, 5, and 6. Figures 4a and 4b show an actual geologic section through a glacial delta and figures 5 and 6 show actual geologic sections through esker-delta complexes.

Hydrology of the Significant Sand and Gravel Aquifers

The significant sand and gravel aquifers consist of ice-contact and outwash deposits which occur primarily in the valleys of the major river systems and their tributaries or near other surface water bodies that can serve as sources of recharge. The aquifer boundaries and estimated yield zones shown on plates 1-5 are based on available information and are subject to modifications as additional data become available.

In the Map 10 area, most of the aquifers are located along the Androscoggin River near Brunswick. Extensive outwash deposits and valley-fill deposits along the Androscoggin and Sabattus Rivers in the northeastern part portion of Map 11 constitute the major aquifers. Valley fill deposits along the Androscoggin River and its tributaries, including the Nezinscot and the Dead Rivers, are the significant aquifers in the Map 16 area. The Belgrade and the Kennebec esker systems constitute the major aquifers in the Map 17 area. Most of the significant sand and gravel aquifers within the map 32 area consist of deposits in the valley of the Sandy River and along its tributaries. In this area, aquifers estimated to yield more than 50 gal/min are located adjacent to the Sandy River, with the exception of the aquifer which includes the Chesterville esker.

Hydraulic Properties

Hydraulic Conductivity

The term hydraulic conductivity describes the rate at which water can move through a permeable medium (Fetter, 1980). It is dependent on a variety of physical factors including porosity, particle size and distribution, shape of particles, and arrangement of particles (Todd, 1980). The hydraulic conductivity is the most important hydraulic property of sediments to be considered when discussing ground-water flow and well yield (Caswell, 1978). Typical hydraulic conductivity values, expressed in feet per day, are 0.000001 to 0.001 for marine clay, 0.001 to 10 for silt, 0.1 to 100 for silty sand, 1 to 1,000 for clean sand, and 500 to 100,000 for gravel (Freeze and Cherry, 1981).

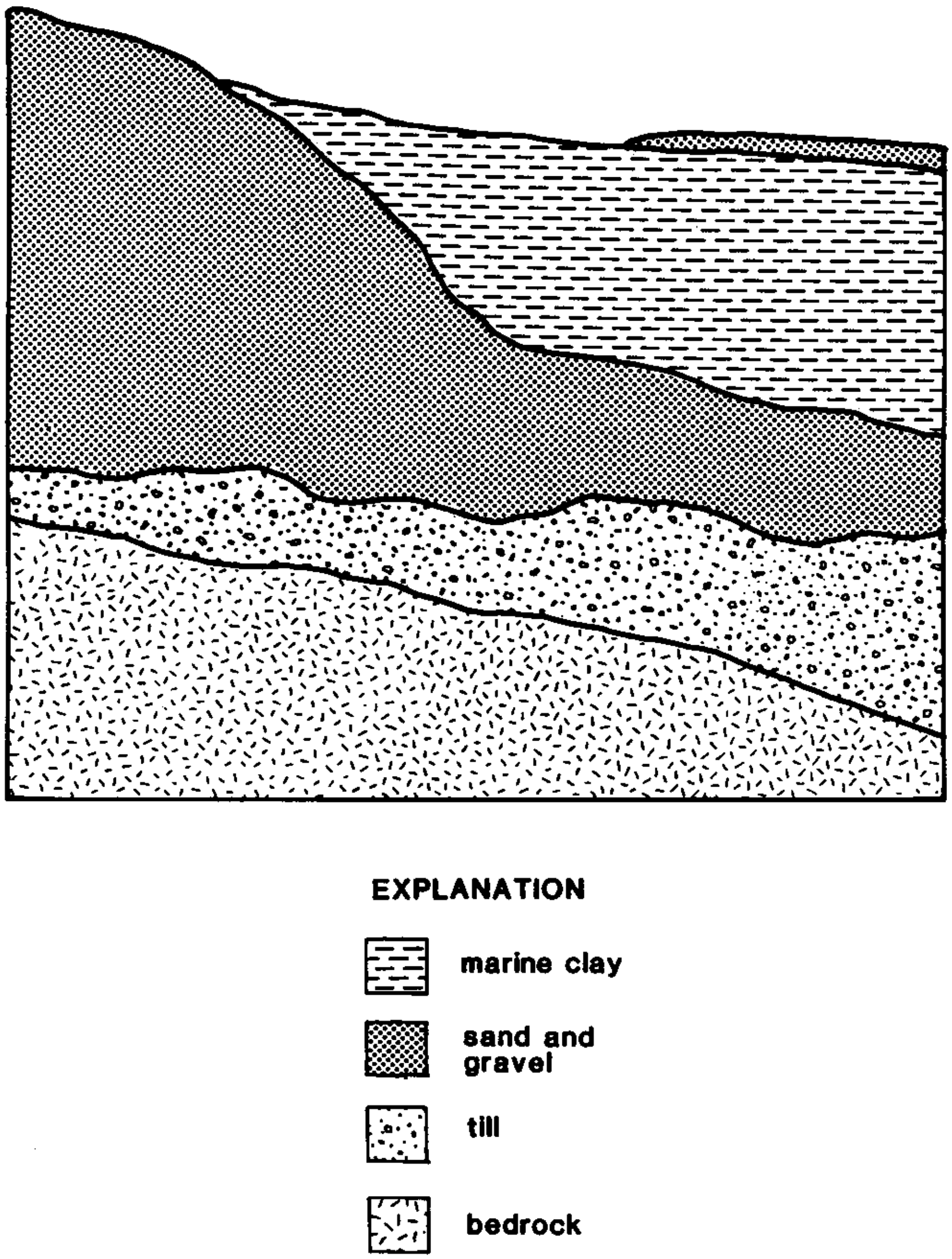

Figure 3. Geologic section showing generalized, regional stratigraphic relationships in glacial deposits (not to scale).

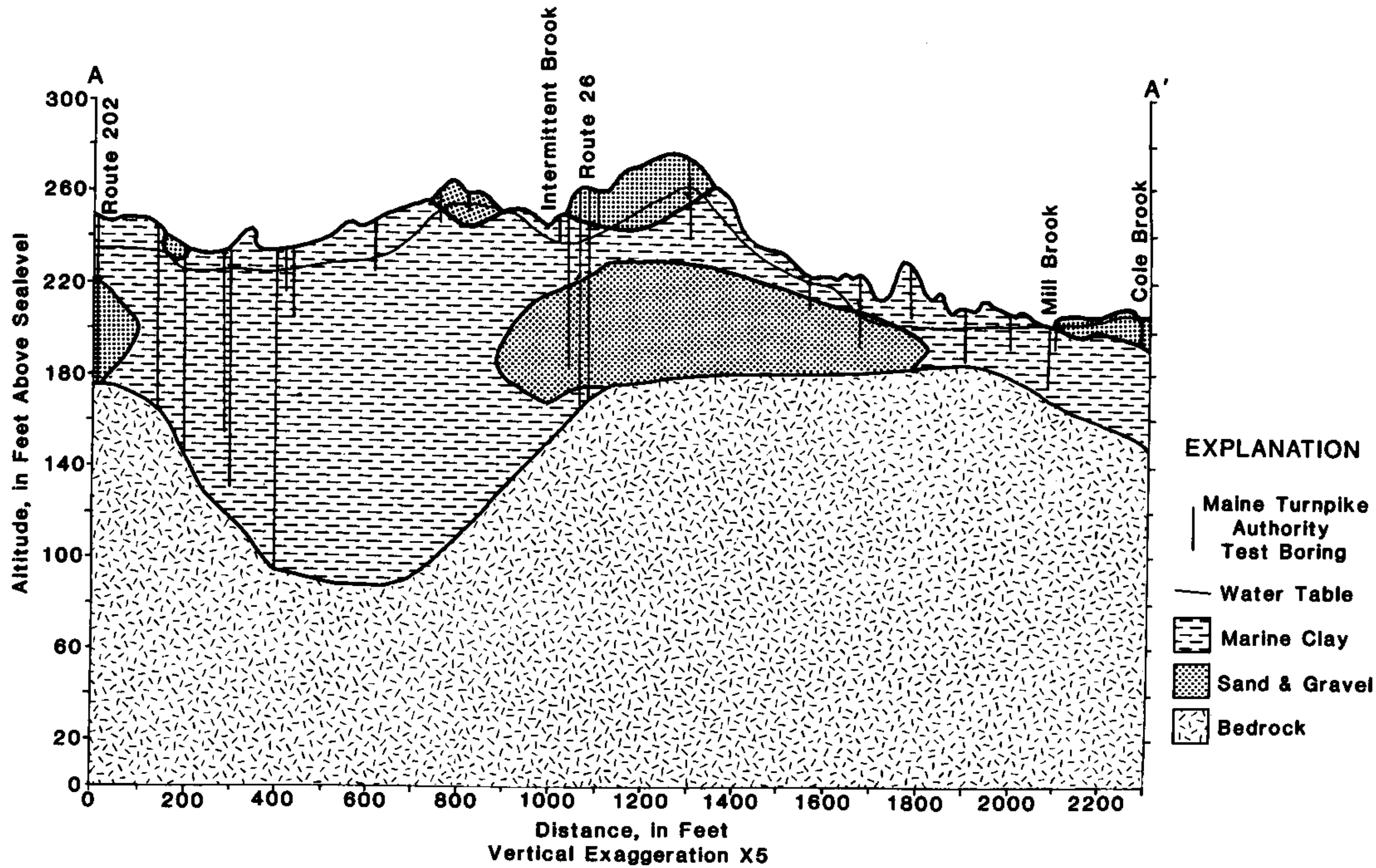

Figure 4a. Geologic section A-A' along the Maine Turnpike from Route 202 to Cole Brook (trace of section shown on plate 2). The profiles of the water table and bedrock surface are based on data from Maine Turnpike Authority borings.

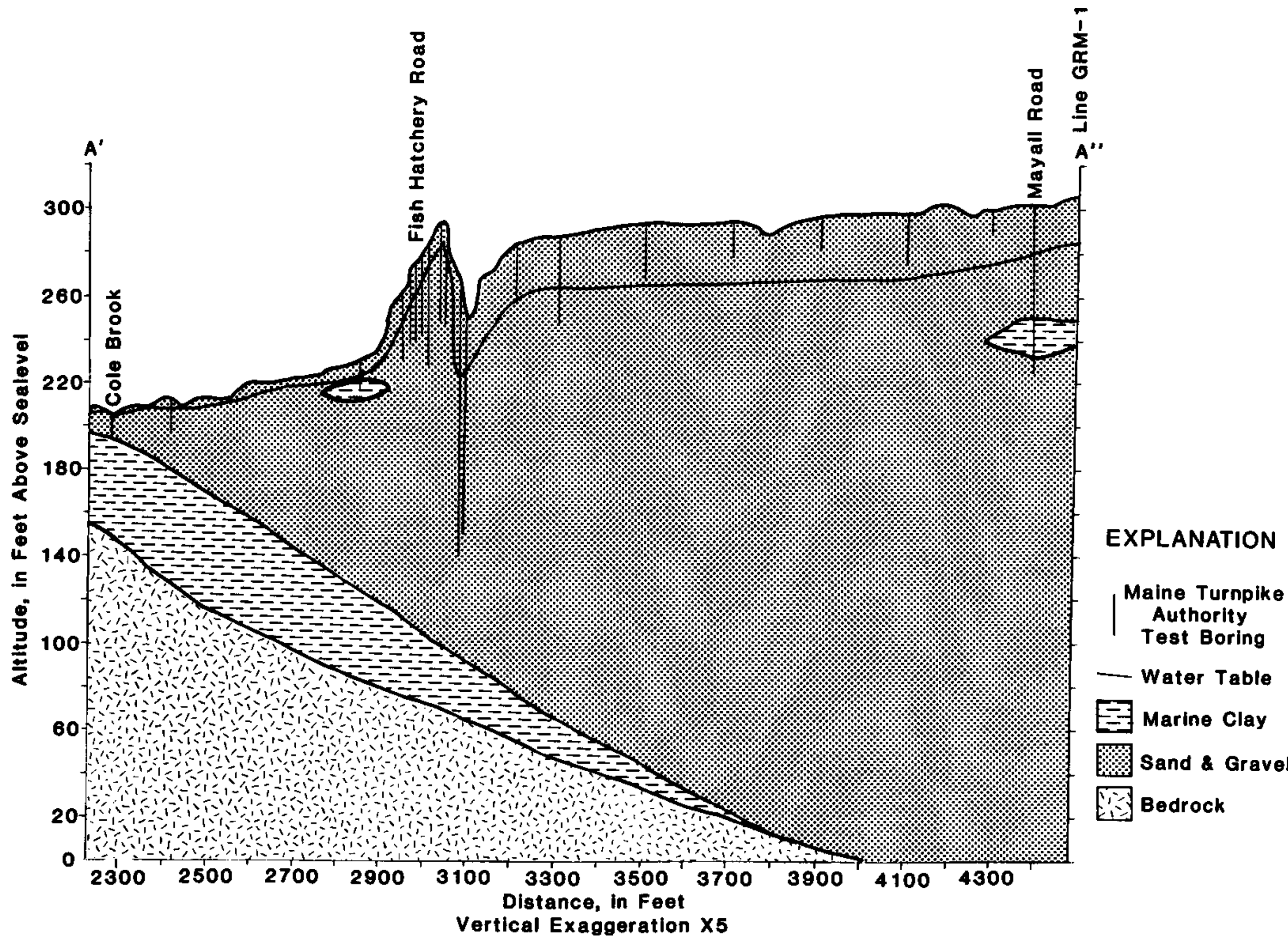

Figure 4b. Geologic section A'-A" along Maine Turnpike from Cole Brook to Mayall Road (trace of section shown on plate 2). The profiles of the water table and bedrock surface are based on data from Maine Turnpike Authority borings.

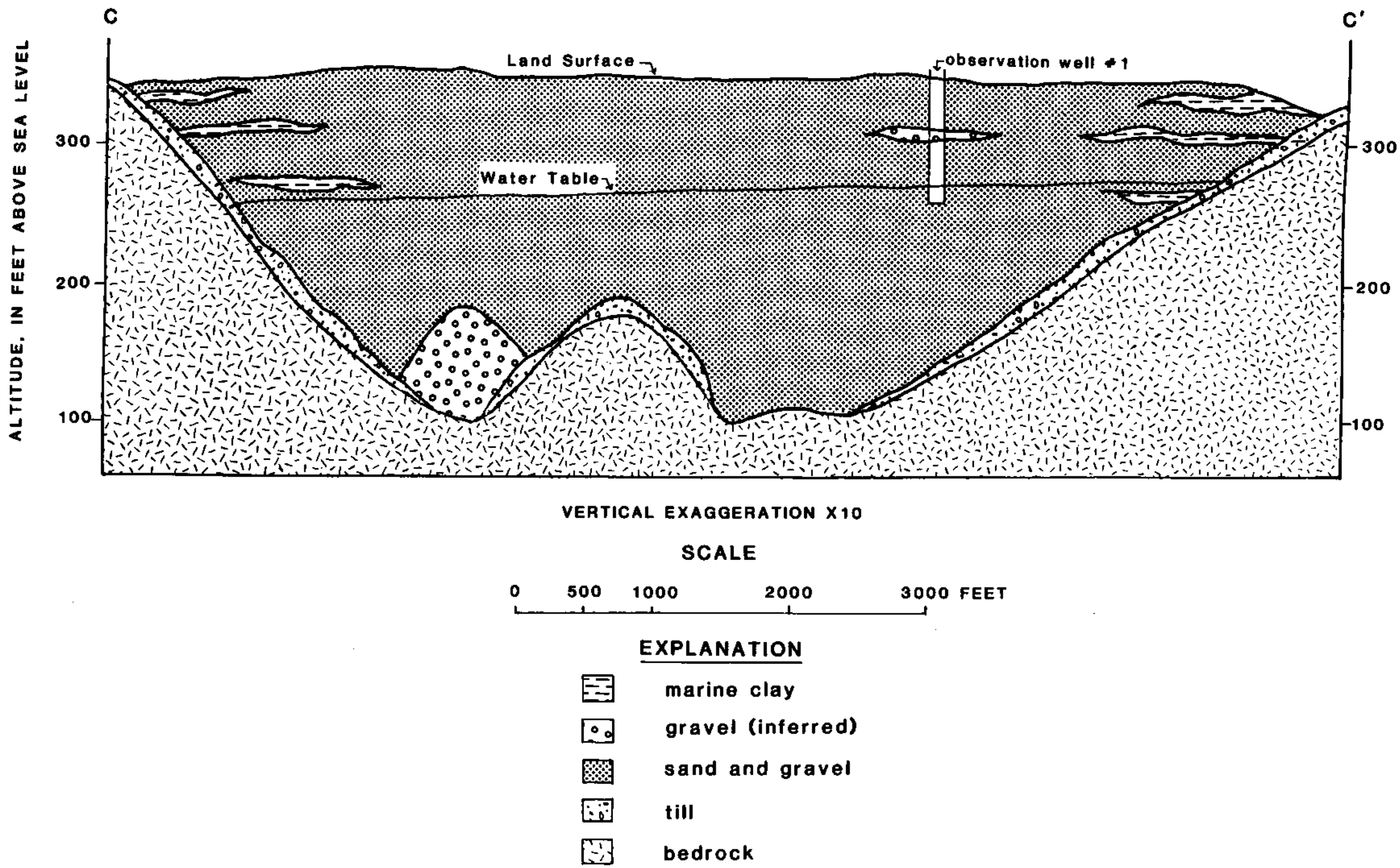

Figure 5. Geologic section C-C' (trace of section shown on plate 4). The profiles of the water table and bedrock surface are generalized from seismic lines AU-4/5 and BE-1A-C (fig. 10). Observation well #1 is located approximately 300 feet north of the seismic line. Data from observation well #1 (table 8) and nearby well-inventory information have been generalized for the section.

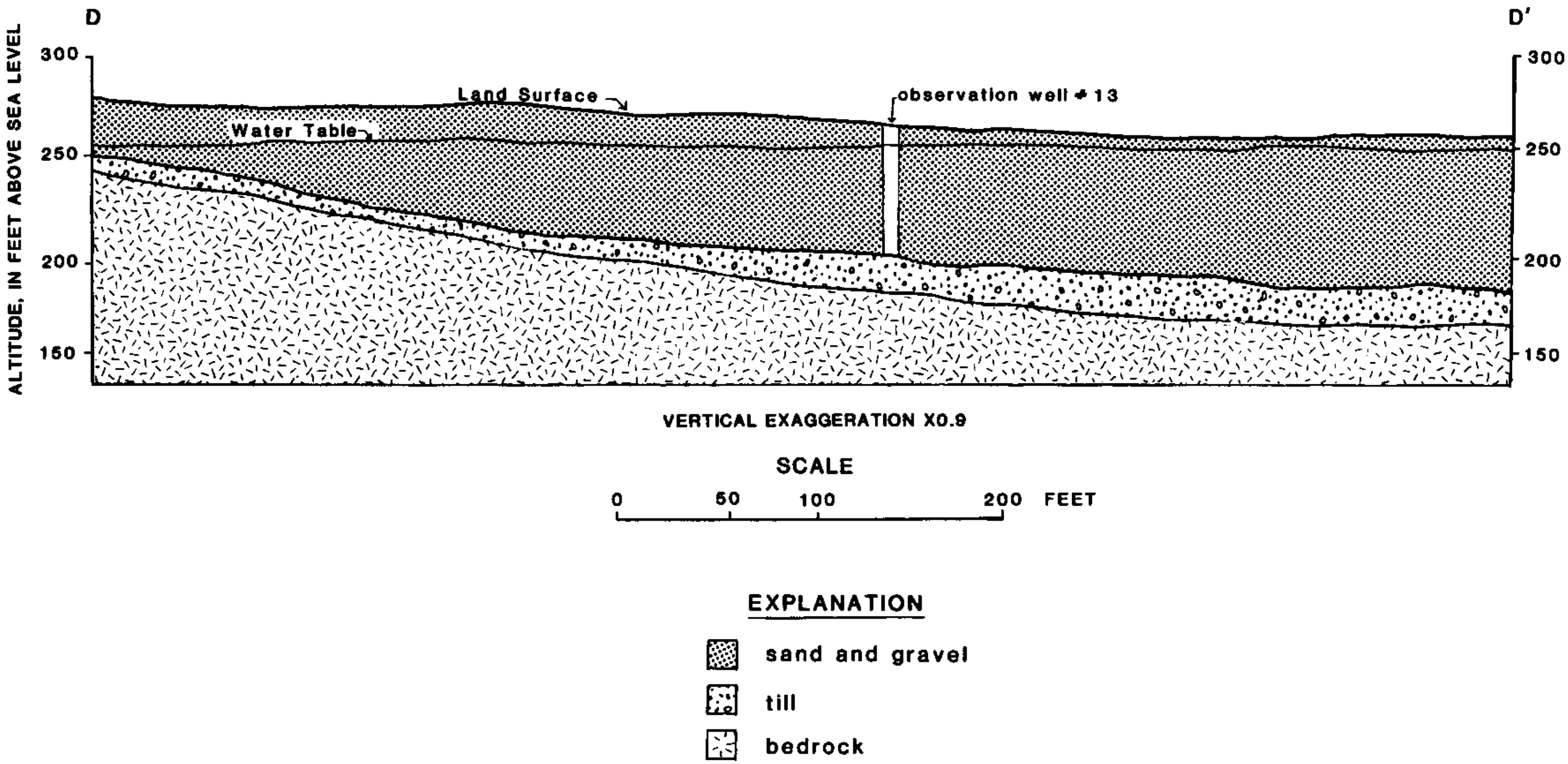

Figure 6. Geologic section D-D' (trace of section shown on plate 5). The profiles of the water table and bedrock surface are based on data from seismic line FF-2 (fig. 11). Observation well #13 is located approximately 200 feet west of the seismic line. Data from observation well #13 (table 9) have been generalized for the length of the profile.

Because the hydraulic conductivity depends, in part, on the size, shape, and arrangement of sediment particles, it is best measured directly in the field on an undisturbed section of aquifer. When field measurements are impractical, the hydraulic conductivity of the aquifer material can be estimated in the laboratory.

The mean particle diameter (in millimeters) and the degree of sorting of representative observation-well sediment samples were determined by grain-size analyses. These analyses were performed at the University of Maine at Orono, using a dry sieve method (Folk, 1974). The results of these analyses (table 1) were used to estimate hydraulic conductivity according to the method in Elzeftaway and Cartwright (1981).

Transmissivity

Transmissivity is the rate at which water flows through a unit width of an aquifer or confining bed under a hydraulic gradient of one. It is a function of properties of the liquid, the porous media, and the thickness of the porous media (Fetter, 1980). The transmissivity is equal to the average hydraulic conductivity multiplied by the saturated thickness. Freeze and Cherry (1981) suggest that transmissivity values greater than 14,000 ft^2/day represent good aquifers for water-well construction. However, aquifers with lower transmissivity values may also be capable of transmitting large quantities of water.

An approximate transmissivity was calculated by the following method for the 20 exploration holes that encountered saturated sand and gravel. Sediment from each interval in the saturated portion of each observation well and test hole (tables 8-11, at end of report) was assigned the estimated hydraulic conductivity value of the sediment sample in table 1 most similar to it. This hydraulic conductivity value was multiplied by the interval thickness to obtain an interval transmissivity. The interval transmissivities were summed to give a total transmissivity for each observation well and test hole. The transmissivities values are presented in table 2. Nine of the sampled exploration holes did not penetrate the entire aquifer thickness. Transmissivities for these exploration holes were calculated based on the known materials but the actual transmissivities are higher.

Depths to the Water Table and Bedrock Surface

Depths to the water table and bedrock surface in the significant sand and gravel aquifers have been determined from geophysical investigations, well inventory, observation well and test-hole drilling, mapping of bedrock outcrops, and previous investigations (see Previous Investigations section). In the significant sand and gravel aquifers, the water table is typically within 20 feet of the land surface. Based on seismic data, the greatest depth to bedrock, which was encountered in the New Gloucester area, is 340 feet.

Seismic-refraction techniques were used extensively to determine both depth to water table and depth to bedrock. The velocity of sound through a material can be used to identify whether it is dry or saturated sand and gravel, till, or bedrock. In the study area, the velocity of sound in unsaturated sand and gravel ranged from 700 to 2,000 ft/sec, with an average velocity of 1,200 ft/sec. Saturated sand and gravel had velocities ranging from 4,000 to 6,000 ft/sec, with an average velocity of 4,900 ft/sec. The seismic velocity of till ranged from 6,300 to 8,300 ft/sec, with an average velocity of 7,200 ft/sec. Bedrock in the study area had seismic velocities ranging from 10,000 to 32,700 ft/sec, with an average velocity of 16,300 ft/sec.

Table 1.--Grain-size analysis, sorting, and estimated hydraulic conductivity of aquifer materials

Sample description	Observation well number	Depth of interval sampled (feet)	Mean Diameter (millimeters)	Degree of sorting 1/	Estimated hydraulic conductivity (feet/day) 2/
Very fine sand, silt	OW11	41-43	0.10	moderately well	20
Powdery very fine sand	OW22	11-16	.11	moderately well	25
Fine to medium sand	OW6	21-26	.23	poor	25
Poorly sorted fine to medium sand, gravel	OW6	28.5-30	.35	poor	40
Medium sand	OW26	11-16	.28	moderate	70
Medium to coarse sand	OW11	11-16	.48	poor	80
Poorly sorted medium to very coarse sand	OW33	31-40	.51	poor	80
Medium to coarse sand and gravel	OW32	0-7	.52	poor	80
Coarse sand, gravel	OW13	6-11	.71	poor	90
Very coarse sand	OW32	11-16	.72	poor	90
Very coarse sand, gravel	OW13	26-28	1.7	poor	100
Very coarse sand, gravel	OW26	5-11	2.4	very poor	100
Fine to medium gravel	OW33	0-4	2.7	poor	100
Coarse gravel, some silt	OW16	16-21	13.8	poor	1,000

1/ as defined by Folk (1974)
2/ Elzeftaway and Cartwright (1981)

Table 2.--Approximate transmissivities at selected observation wells and test holes in study area

Map 11

Identification Number	Transmissivity (ft²/day)
OW24	> 4,200 1/
OW26	> 4,900
OW27	1,050
OW28	460
OW29	> 390
OW32	1,000
OW33	2,700

Map 16

Identification Number	Transmissivity (ft²/day)
OW6	3,200
TH7	> 900
OW10	360
OW11	1,400
OW12	1,100
TH20	> 630
OW22	> 1,300

Map 17

Identification Number	Transmissivity (ft²/day)
TH1	> 820
OW2	28,000

Map 32

Identification Number	Transmissivity (ft²/day)
OW13	4,800
OW15	> 1,000
OW16	>10,000
OW19	880

1/ These exploration holes were not drilled to refusal; therefore, values represent minimum transmissivities.

A summary of the information collected with the single-channel seismograph is presented in table 3. Hydrogeologic sections from seismic-refraction surveys conducted with the 12-channel seismograph are presented in figures 8-11 (back of the report). The locations of the 81 single-channel lines and the 72 twelve-channel lines run in the study area are shown on plates 1-5.

Determinations of depths to the water table and bedrock surface are necessary to provide a three dimensional hydrogeologic picture. Saturated thickness at selected points can be determined by subtracting the depth to the water table from the depth to bedrock (plates 1-5). Depth-to-bedrock data and bedrock surface profiles (figures 8-11 at back of report) can be used to estimate the amount of casing required for construction of bedrock wells and to locate bedrock valleys that may be filled with water-bearing sediments.

Estimated Well Yields

The significant sand and gravel aquifers consist of ice-contact and outwash deposits which are of sufficient areal extent and saturated thickness to yield 10 or more gallons per minute to a properly installed domestic well.

Ice-contact deposits consist largely of sand and gravel with varying amounts of silt, clay, and cobbles. These deposits differ in their permeability because of differences in sorting and grain size but generally are very permeable, and where saturated, can yield large quantities of ground water.

Outwash consists of sand and gravel, with sand predominating. Although outwash deposits in the study area are generally less permeable than ice-deposits, they are an important source of water for many domestic wells, particularly dug and driven (point) wells.

Well yields in the significant sand and gravel aquifers were estimated on the basis of information obtained during well inventory, review of previous investigations, test drilling, and geophysical surveys, as well as from knowledge of the lithology, saturated thickness, transmissivity, and areal extent of the aquifers. Areas where wells are estimated to yield between 10 to 50 gal/min and more than 50 gal/min are shown in separate shading patterns on plates 1-5. A third shading pattern is used to denote areas where marine deposits may overlie sand and gravel aquifers capable of yielding 10 to 50 gallons per minute.

Although the study area includes 2,408 mi^2, areas mapped as significant aquifers include only about 109 mi^2. Yields exceeding 50 gal/min are estimated to be available in only 22.6 mi^2 of these significant aquifers. The highest yields are obtainable in areas where the deposits are coarse grained, have a thick saturated zone, and are hydraulically connected to an adjacent body of surface water, which is a source of recharge. The highest reported well yield in the sand and gravel deposits is 2,000 gal/min from the Brunswick-Topsham Water District well adjacent to the Androscoggin River in Topsham.

Water-level Fluctuations

Monthly water-level measurements made at 16 of the observation wells installed in the study area are shown in table 4; and selected hydrographs from these observation wells are shown on figure 7. Water-level measurements were made once a month from October 1982 through April 1983.

Table 3.--Depth to water and depth to bedrock based on single-channel seismic data.

Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location[1]	Depth to water (feet)[2]		Depth to bedrock (feet)[2]	
					A[3]	B	A	B
Map 10	BR-A	Brunswick	Brunswick	Approximately 0.3 miles south of St. Joseph's Cemetery, along paved road by fence surrounding football field	15	16	53	39
Map 10	WIS-A	Wiscasset	Wiscasset	In gravel pit on Bradford Road	Dry	Dry	27	27
Map 10	RI-A	Richmond	Dresden	On woods road at old cemetery near Courthouse Point	10	10	33	47
Map 10	RI-B	Richmond	Dresden	In gravel pit on west side of Rt 128, 0.1 miles north of the intersection of Rt 128	7	8	59[4]	59+
Map 10	RI-D	Richmond	Bowdoinham	On extension of Pork Point Road in vicinity of Abagadasset Point	10	8	80+	78+
Map 11	CC-A	Cumberland	N. Yarmouth	On old railroad grade, due north of the intersection of Rt. 231 and Rt. 115.	8	8	80+	70
Map 11	CC-B	Cumberland	W. Cumberland	In gravel pit on the southwest side of the intersection of Skillings Rd. and the Maine Turnpike.	12	13	79+	80+
Map 11	YA-A	Yarmouth	N. Yarmouth	On farm road 0.3 miles northwest of Crockett Corner.	7	13	61+	40
Map 11	YA-B	Yarmouth	N. Yarmouth	On east side of Rt. 231, northwest Westcutgo Hill, just past intersection with the railroad tracks.	8	DNU[5]	30 till[6]	DNU

1 locations of single-channel seismic lines are shown on plate 1-5.

2 feet below land surface.

3 A and B refer to opposite ends of the seismic line: A is the north or west end of the line, B is the south or east end.

4 The number shown is the minimum depth to bedrock (calculated).

5 Data not useable.

6 Till was encountered rather than sand and gravel deposits or bedrock. This is based on the assumption that the velocity of sound in till ranges approximately from 6300 to 8300 ft/sec.

7 Blind Zone Problem: An intermediate layer (usually the saturated zone) was too thin to be detected using the seismic method. If the presence of this layer was suspected, calculations were done according to Mooney (1980) to determine the minimum and maximum possible thickness of this layer. In the table the symbol "ssg" refers to saturated sand and gravel, "t" refers to till, and "br" refers to bedrock. For example on line LFS-A, the symbol t27-30' means that the depth to till, if present is between 27' and 30'.

Table 3.--Depth to water and depth to bedrock based on single-channel seismic data--Continued.

Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location	Depth to water (feet) A	Depth to water (feet) B	Depth to bedrock (feet) A	Depth to bedrock (feet) B
Map 11	YA-C	Yarmouth	N. Yarmouth	On east side of the North Rd., approximately 0.5 miles south of Dunns Corner.	5	6	68	67
Map 11	YA-D	Yarmouth	N. Yarmouth	In gravel pit in Walnut Hill area.	9	10	70	49
Map 11	YA-E	Yarmouth	Cumberland	On old railroad grade, approximately 0.6 miles north of Tuttle Rd.	11	10	41	47
Map11	FRE-A	Freeport	Freeport	In gravel pit in Pleasant Hill area, south of lane Cemetery, on west side of Pleasant Hill Rd.	6	9	39	27
Map 11	LFS-A	Lisbon Falls South	Topsham	In pit on eastern side of Androscoggin River, opposite the Androscoggin/Cumberland/Sagadahoc County boundaries.	BZP[7] t27-30	BZP t19-21	BZP br30-43	BZP br21-31
Map 11	LFS-B	Lisbon Falls South	Topsham	In gravel pit north of Elmlawn Cemetery.	6	2	22	24
Map 11	LFS-C	Lisbon Falls South	Topsham	In gravel pit on east bank of the Androscoggin River, approximately 0.9 miles south of Pejepscot.	10	14	59+	42
Map 11	LFS-D	Lisbon Falls South	Durham	Near Gerrish Cemetery, approximately 1.0 miles north of Rabbit Rd., on the east side of the road to South West Bend.	6	5	78+	77+
Map 11	LFS-E	Lisbon Falls South	Freeport	In gravel pit on west side of Rt. 125 approximately 0.5 miles south of the intersection with Curtis Pond.	BZP ssg18-21	14	BZP br21-31	42
Map 11	LFS-F	Lisbon Falls	Freeport	On road to gravel pits, on west side of Rt. 125, approximately 0.6 miles north of the North Freeport Cemetery.	6	11	72	46
Map 11	NP-A	North Pownal	W. Durham	In gravel pit on west side of Rt. 9, 0.2 miles north of the intersection with Rabbit Road.	Dry	Dry	69	73

Table 3.--Depth to water and depth to bedrock based on single-channel seismic data--Continued

Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location	Depth to water (feet) A	Depth to water (feet) B	Depth to bedrock (feet) A	Depth to bedrock (feet) B
Map 11	GR-A	Gray	New Gloucester	In pit on west side of Rt. 231, approximately 0.2 miles west of the intersection with the Maine Turnpike	DNU	4	DNU	92+
Map 11	GR-B	Gray	New Gloucester	In pit on road to north of Shaker Road, approximately 0.6 miles west of the intersection of Shaker Road with the Maine Turnpike.	5	3	31 till	39 till
Map 11	GR-C	Gray	New Gloucester	In gravel pit on north side of Shaker Road, approximately 0.4 miles west of the intersection of Shaker Road and Snows Hill Road.	8	6	30	23
Map 11	MI-A	Minot	Auburn	On dirt road across from Auburn-Lewiston Municipal Airport. Dirt road is on north side of Lewiston Jct. Road, approx. 0.3 miles east of the railroad track crossing.	6	6	58+	58+
Map 11	MI-B	Minot	Poland	In Range Pond State Park, on road to northeast off southern extension of Bailey Hill Road, approximately 0.1 miles south of Frenchman Beach.	6	5	38	53
Map 11	MI-C	Minot	Poland	On road leading into gravel pit on southern side of Rt. 122, approximately 0.1 miles southeast of the intersection of Empire Road and Rt. 122.	15	BZP ssg15-18	65+	BZP br18-20
Map 11	LE-A	Lewiston	Lewiston	On western side of Webster Rd., approximately 0.5 miles northwest of the intersection of Webster Rd., and the Maine Turnpike.	3	4	48 till	33 till
Map 11	LE-B	Lewiston	Durham	On dirt road on east side of Rt. 136 approx. 0.1 miles south of the Auburn/Durham town lines.	8	8	60+	60+
Map 11	LFN-A	Lisbon Falls North	Sabattus	In gravel pit west of Furbush Cemetery, off Furbush Rd., approximately 0.3 miles west of the intersection of Furbush Rd., with Old Furbush Rd.	41	38	88+	85+

Table 3.--Depth to water and depth to bedrock based on single-channel seismic data--Continued

Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location	Depth to water (feet)		Depth to bedrock (feet)	
					A	B	A	B
Map 11	LFN-B	Lisbon Falls North	Sabattus	In gravel pit southwest of Furbush Cemetery, off Furbush Rd., approx. 0.1 miles west of the intersection of Furbush Rd. with Old Furbush Rd.	DNU	13	DNU	61
Map 11	LFN-C	Lisbon Falls	Lisbon	On dirt road paralleling Little River, north of Rt. 125, approx. 0.4 miles east of Higgins Corner.	5	6	40+	41+
Map 16	MO-A	Monmouth	Monmouth	In gravel pit southeast of Bonny Pond, west of Route 202	6	6	70	47
Map 16	MO-B	Monmouth	Litchfield	On Maxwell Cemetery Road, just north of intersection with Route 197	7	9	31	25
Map 16	LAW-A	Lake Auburn West	Hebron	On old railroad grade across from Saunder's Store, in Hebron Station.	6	5	75+	74
Map 16	LAW-B	Lake Auburn West	Turner	In gravel pit southwest of Black Pond.	9	9	60+	60+
Map 16	LAW-C	Lake Auburn West	Turner	In gravel pit northwest of Mud Pond.	10	14	55	36
Map 16	LAW-D	Lake Auburn West	Turner	On dirt road on top of esker between Mud Pond and Sandy Bottom Pond.	33	31	79+	77+
Map 16	W-A	Wayne	Leeds	On dirt road to Bishop Hill, southeast of Leeds.	12	11	81+	79+
Map 16	W-B	Wayne	Leeds	On woods road near gravel pit, northwest of Curtis Corner.	17	14	DNU	DNU
Map 16	TC-A	Turner Center	Livermore Falls	On edge of road, in front of Stricklands Cemetery.	5	10	50 till	59+ till
Map 16	TC-B	Turner Center	Turner	On paved road next to Nezinscot River, just past Keens Mills Cemetery.	10	8	23	35
Map 16	TC-C	Turner Center	Turner	On gravel road southwest of Pleasant Pond.	6	5	74+	73+

Table 3.--Depth to water and depth to bedrock based on single-channel seismic data--Continued

Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location	Depth to water (feet)		Depth to bedrock (feet)	
					A	B	A	B
Map 16	F-A	Fayette	Fayette	In gravel pit approximately 0.3 miles south of Twelve Corners.	DNU	11	DNU	37
Map 16	F-B	Fayette	Fayette	On dirt road in East Livermore Campgrounds, near Schoolhouse Pond.	4	3	23	14
Map 16	LF-A	Livermore Falls	Livermore	In gravel pit northwest of Hillman Cemetery.	12	10	50	76
Map 16	LF-B	Livermore Falls	Livermore Falls	In gravel pit on west side of Route 106, 0.6 miles south of the intersection with Route 133.	11	9	62+	61+
Map 16	LF-C	Livermore Falls	Livermore Falls	In gravel pit on west side of Route 106, 1.0 miles south of the intersection with Route 133.	15	14	33	34
Map 16	C-A	Canton	Canton	In field on west bank of Androscoggin, opposite McCollister Hill.	9	12	35	43
Map 16	C-B	Canton	Canton	On railroad grade, northeast of Canton, off east side of Route 140.	7	6	42	77
Map 16	C-C	Canton	Livermore	On dirt road between gravel pits, southwest of Brettuns Pond, near intersection of Route 4 and Route 108.	12	7	42	68
Map 16	BU-A	Buckfield	Livermore	On dirt road east of the Oxford/Androscoggin County line, west of Martin Stream.	4	5	27	27
Map 16	BU-B	Buckfield	Turner	In gravel pit on east side of Route 4, approximately 1.0 miles south of North Turner.	5	6	43	34
Map 16	BU-D	Buckfield	Buckfield	In gravel pit on west side of Route 117, approximately 0.6 miles southeast of Buckfield.	5	5	28	23+

Table 3.--Depth to water and depth to bedrock based on single-channel seismic data--Continued

Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location	Depth to water (feet)		Depth to bedrock (feet)	
					A	B	A	B
Map 17	WIN-A	Winthrop	Readfield	On dirt road off Beaver Dam Road, 0.25 miles east of Whittier Cemetery.	4 till	3	52+	51+
Map 17	WIN-B	Winthrop	Winthrop	In gravel pit on west shore of Annabessacook Lake, on east side of Annabessacook Road, 0.5 miles south of the intersection of Annabessacook Road and Route 202.	12	10	40	39
Map 17	WIN-C	Winthrop	Winthrop	On dirt road on western shore of Annabessacook Lake, 0.1 miles north of the Winthrop/Monmouth town line.	7	5	37	57
Map 17	PU-A	Purgatory	Monmouth	In 0.3 miles on dirt road that parallels west side of Jug Stream, near the intersection of 135 and Sanborn Road.	8	10	35	31
Map 17	EP-A	East Pittston	Whitefield	In gravel pit, 0.2 miles west of the intersection of Palmer Road and Route 218.	18	69+	17	68+
Map 17	GA-A	Gardiner	Pittston	In gravel pit on eastern side of Kennebec River, slightly northeast and opposite Eastman Point.	BZP ssg34-42	37	BZP br42-62	97
Map 17	GA-B	Gardiner	Dresden	On dirt road west of Everson Road, 0.2 miles south of the Kennebec/Lincoln County line.	6	4	57	64+
Map 17	RE-A	Readfield	Readfield	On road to Readfield Dump, off North Road, in vicinity of Readfield Depot.	Dry	Dry	6	6
Map 17	RE-B	Readfield	Readfield	At Readfield Dump, northeast of Readfield Depot.	5 till	4 till	19	23
Map 17	VA-A	Vassalboro	Vassalboro	On Mill Hill Road, approximately 0.2 miles east of the Kennebec River.	27 till	29 till	84+	82+
Map 17	BE-A	Belgrade	Belgrade	On western side of Pinkhams Cove, on Great Pond.	5	10	40+	44+

Table 3.--Depth to water and depth to bedrock based on single-channel seismic data--Continued

Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location	Depth to water (feet) A	Depth to water (feet) B	Depth to bedrock (feet) A	Depth to bedrock (feet) B
Map 17	BE-B	Belgrade	Belgrade	In gravel pit behind Belgrade Town Office, at the intersection of Route 135 and Route 27.	28	23	96+ till	72 till
Map 17	BE-C	Belgrade	Belgrade	In gravel pit on road west of Route 27, 0.4 miles north of Gagne and Son Concrete Blocks Company.	24	23	93	95+
Map 17	AU-A	Augusta	Augusta	In gravel pit on western shore of Kennebec River, northeast of Kling Cemetery.	49	DNU	118+	DNU
Map 17	AU-B	Augusta	Hallowell	On road between 2 gravel pits, approximately 150 yards west of the Kennebec Valley Training Center	BZP ssg12-14	BZP ssg12-14	BZP br14-20	BZP br14-19
Map 17	AU-C	Augusta	Chelsea	In gravel pit on eastern side of Kennebec River, opposite Hallowell Boat Ramp.	5	BZP ssg14-16	38+	BZP br16-25
Map 32	FA-A	Farmington	Farmington	Prescott Athletic Field-University of Maine	7	7	56+	56+
Map 32	FA-B	Farmington	Farmington	Riverview Terrace area, south of Rt.27, near town sand pit, southeast of Fairview Cemetery	13	13	51	59
Map 32	FF-A	Farmington Falls	Chesterville	In gravel pit on Ridge Road, southeast of Norcross Pond	5	3	73+	71+
Map 32	FF-B	Farmington Falls	Chesterville	On dirt road along north shore of Norcross Pond	13	10	45	61
Map 32	FF-C	Farmington Falls	Chesterville	In gravel pit near intersection of Ridge Road and Mace Road	DNU	DNU	10	13
Map 32	KI-A	Kingfield	Freeman	Bean Brook area, west of True Hill	8	6	26	38

Table 3.--Depth to water and depth to bedrock based on single-channel seismic data--Continued

Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location	Depth to water (feet)		Depth to bedrock (feet)	
					A	B	A	B
Map 32	ED-A	East Dixfield	Wilton	Near Interval Cemetary, off Rt. 156	10	6	60+	57+
Map 32	ED-B	East Dixfield	Dixfield	Dirt road south of Rt. 17, Southeast of East Dixfield.	7 till	4 till	DNU	DNU
Map 32	WI-A	Wilton	Jay	Behind trailer park near Stubbs Mill cemetery, northwest of Parker Pond	4	6	52+	48
Map 32	WI-B	Wilton	Jay	Northeast of boat ramp on Parker Pond	7	6	39	51

Table 4.--Water-level data for observation wells in study area

Depth to water (in feet below land surface)

Aquifer Map Number	Observation well Number	Location	October 7-25	November 16-17	December 14-16	January 11-13	February 15-16	March 16-17	April 13-18
11	OW24	Poland	41.3	41.3	41.7	41.9	40.8	39.6	35.1
11	OW26	New Gloucester	9.5	9.5	9.9	9.7	9.2	8.4	7.2
11	OW27	Gray	49.4	50.0	51.1	52.1	52.9	52.5	43.6
11	OW28	Durham	6.3	5.3	5.4	6.8	6.5	3.9	2.2
11	OW29	Pownal	--	3.5	3.8	2.5	2.7	1.6	2.0
11	OW32	North Yarmouth	9.6	9.7	9.8	9.9	10.2	9.4	8.5
11	OW33	Cumberland	15.1	15.2	15.4	15.7	15.9	--	13.1
16	OW6	Greene	16.0	16.4	16.0	15.7	16.0	15.2	14.1
16	OW11	Livermore Falls	16.2	16.7	17.4	17.3	17.3	16.6	15.0
16	OW20	Canton	11.9	11.1	11.3	9.6	8.8	9.3	8.7
16	OW22	Turner	18.3	18.4	18.6	18.7	18.4	17.6	16.0
17	OW2	Belgrade	44.8	--	44.4	44.3	44.4	43.8	42.9
32	OW13	Chesterville	1.9	1.5	1.8	0.8	1.0	1.0	0.3
32	OW15	New Sharon	15.3	--	10.8	13.7	--	--	--
32	OW16	Farmington	18.2	17.3	17.3	16.3	15.1	15.3	14.2
32	OW19	Jay	3.2	2.8	0.9	2.4	3.2	1.8	1.4

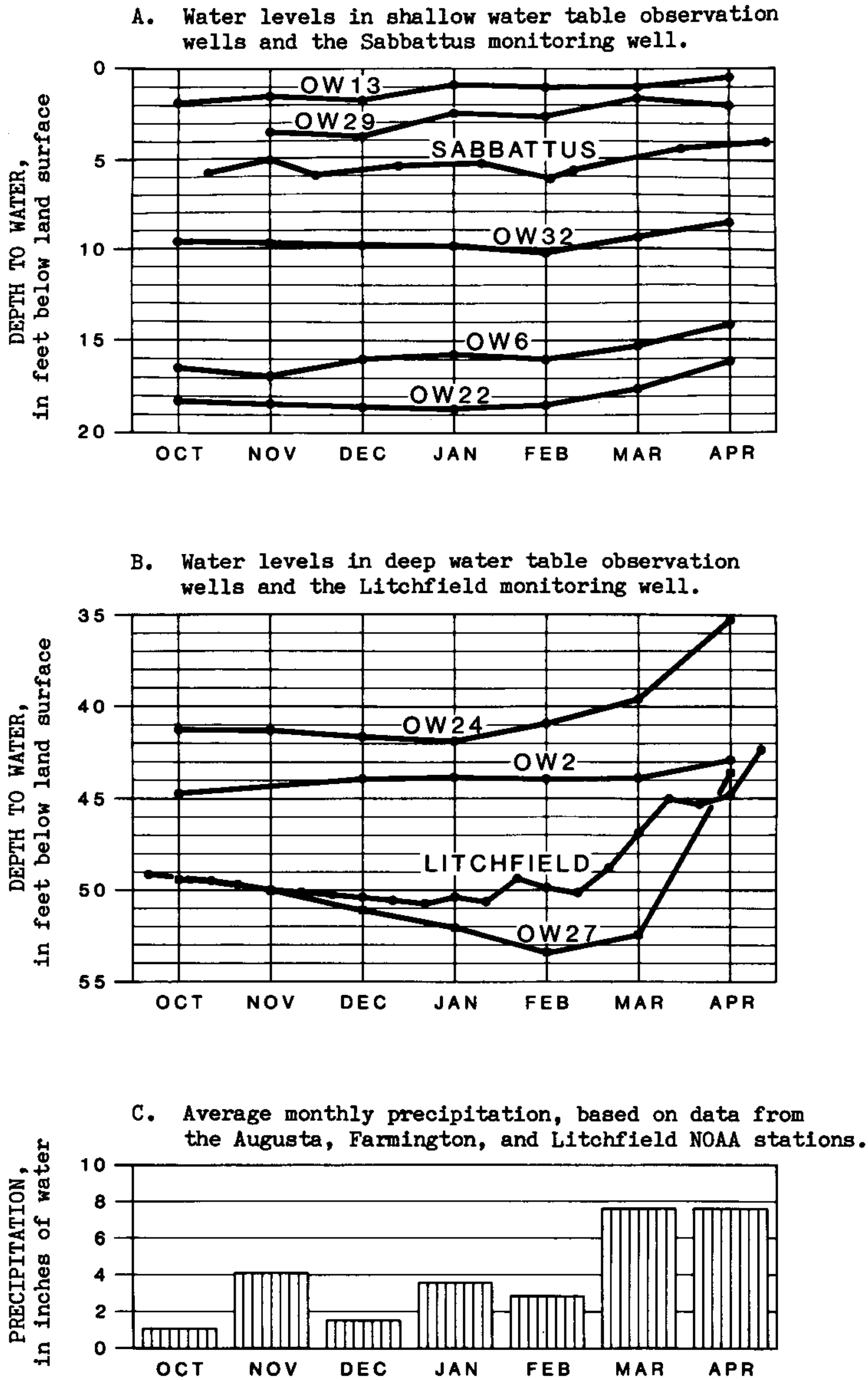

Figure 7. Groundwater levels and average monthly precipitation, October 1982 through April 1983.

Water levels in most shallow observation wells fluctuated within a 3-foot range, which is close to the range at the Survey's monitoring well in Sabattus (Map 11) during this period (fig. 7). The water level in OW-15, which was inaccessible during most of the winter, had a large fluctuation (5 feet). Water-level fluctuations were greatest in the deep observation wells, OW-24 and OW-27, which fluctuated 6 and 9 feet respectively, over the 7 month period. The Survey's water-level monitoring well in Litchfield (Map 17), where the water table is also deeper, showed similiar fluctuations during this period. Monthly precipitation data from NOAA (National Oceanic and Atmospheric Administration) stations in Augusta, Farmington, and Lewiston were averaged for comparison with water-level data (figure 7).

GROUND-WATER QUALITY

Background Water Quality

The background water-quality in the significant sand and gravel aquifers was characterized by analyzing 20 samples from supply wells, springs, and observation wells (table 5).

Additional background ground-water chemistry data for south-central Maine can be found in Tolman and others (1983) and in reports by Prescott (1963, 1967, 1968a, 1968b, 1969, 1976, 1977, 1979, 1980a, 1980b, and 1981), Prescott and Drake (1962), and Prescott and Dickerman (1981).

Factors Influencing Background Water Quality

The chemical quality of ground water in sand and gravel aquifers is determined by a number of natural factors. The primary control is the chemical composition of the sand and gravel and associated marine clay. Most of the sand and gravel is derived from noncalcareous, crystalline bedrock, which generally, consists of silicate minerals of low solubility. Ground water in regions with this type of bedrock tends to have a low dissolved-solids content (Matthess, 1982).

Many other natural factors influence water chemistry in sand and gravel aquifers. Chemical reactions that occur as infiltrating water passes through the soil zone can also affect ground-water chemistry. Where the saturated thickness of unconsolidated deposits is great, the flow paths are long and the water may have a long time to dissolve soluble material in the aquifer (Caswell, 1978). Residence time is also dependent on hydraulic conductivity, hydraulic gradient, and the porosity of the unconsolidated deposits.

The chemistry of precipitation can also affect ground-water quality. In coastal regions where precipitation contains sea salt, the concentrations of sodium and chloride in ground water are typically higher than in inland areas (Matthess, 1982). Elevated concentrations of sodium and chloride can also result from salt-water intrusion in coastal areas or from the entrapment of sea water in regions of relatively stagnant ground-water flow, which occurred during the late Wisconsinan marine submergence (Tepper, 1980).

Table 5.--Ground-water chemistry in significant sand and gravel aquifers

Part A. Observation well characteristics

Identification number	Town	Map number	Land use around well	Depth (feet)	Estimated yield (gal/min)	Date sampled	Sampling device
1. Background water-quality samples from observation wells developed in sand and gravel							
W1*	Bowdoinham	10	forest	35	85	10/29/82	faucet
W2*	Sabattus	11	forest	60	--	10/29/82	peristaltic pump
OW24	Poland	11	forest	71	>1	10/21/82	submersible pump
OW26	New Gloucester	11	power line	20	5	10/21/82	-Do-
OW32	North Yarmouth	11	gravel pit	20	>5	10/25/82	-do-
OW33	Cumberland	11	fairground	41	>5	10/25/82	-do-
OW6	Greene	16	gravel pit	29	1	10/07/82	-do-
OW11	Livermore Falls	16	forest	24	2	10/07/82	-do-
OW12	Chesterville	16	gravel pit	15	5	10/07/82	-do-
OW22	Turner	16	gravel pit	32	>5	10/18/82	-do-
S2*	Augusta	17	forest	spring	--	10/20/82	grab sample
W3*	Gardiner	17	forest/road	85	800	10/29/82	faucet
OW2	Belgrade	17	forest/g. pit	56	>1	10/20/82	submersible pump
W4*	Strong	32	field	69	300	10/19/82	faucet
OW13	Chesterville	32	gravel pit	18	3	10/07/82	submersible pump
OW15	New Sharon	32	field	24	1	10/19/82	-do-
2. Background water-quality samples from observation wells developed in marine clay							
OW28	Durham	11	forest	27	<1	10/25/82	PVC bailer
OW29	Pownal	11	campground	12	<1	10/25/82	-do-
OW10	Livermore	16	forest/agri.	63	<1	10/07/82	-do-
OW19	Jay	32	forest/agri.	29	<1	10/18/82	-do-

W1* Bowdoinham Water District well
W2* Sabattus Water District well
W3* Gardiner Water District well
W4* Strong Water District well
S2* Augusta Fish Hatchery Spring

Table 5.--Ground-water chemistry in significant sand and gravel aquifers--Continued

Part B. Chemical Characteristics (all values in milligrams per liter (mg/L) except as noted)

Identification number	Temperature (°C)	Conductivity (microsiemens /cm)	pH units	Alkalinity (mg/L as $CaCO_3$)	Chloride Dissolved	Nitrate Total (mg/L as N)	Sulfate Dissolved	TOC 1/	VOP 2/ (ug/L)	Sodium Dissolved	Potassium Dissolved	Calcium Dissolved	Magnesium Dissolved	Hardness (mg/L as $CaCO_3$)	Iron Dissolved	Manganese Dissolved
1. Background water-quality samples from observation wells developed in sand and gravel																
W1	9.0	98	6.6	13	5.0	0.61	9	--	<1	3.8	1.1	11	2.2	37	0.04	<0.005
W2	9.0	112	7.6	22	4.5	.32	9	--	<1	4.1	1.5	17	2.0	51	< .03	< .005
OW24	9.5	52	6.0	4	6.5	< .01	7	1	<1	4.2	.5	4	.8	13	.07	.022
OW26	10	86	7.3	11	11	8.0	8	1	<1	2.6	1.5	11	1.1	32	.10	.048
OW32	10	140	6.6	9	8.5	2.8	17	1	<1	8.2	2.0	12	2.7	41	< .03	< .005
OW33	10	120	7.3	10	15	2.2	7	<1	<1	5.4	1.2	11	2.5	38	< .03	.045
OW6	9.0	112	8.5	23	1.5	.55	<5	<1	<1	2.6	4.5	16	1.4	46	.10	.064
OW11	7.0	77	7.3	17	< .5	.05	<5	4	<1	1.9	1.2	11	1.6	34	.06	.31
OW12	10	72	6.9	13	2.0	.17	<5	<1	<1	2.2	2.4	10	1.3	30	.03	.017
OW22	9.0	131	6.5	21	7.0	.80	10	2	<1	6.4	1.6	17	1.9	50	.02	.036
S2	8.5	65	7.5	18	5.0	--	<5	--	<1	3.3	1.1	14	1.2	40	.14	.012
W3	9.0	205	7.3	31	12	5.0	15	--	<1	7.8	3.1	23	4.5	76	< .03	.12
OW2	8.0	58	6.8	13	1.0	.03	7	2	<1	1.9	1.5	9	1.0	27	< .02	.061
W4	9.0	70	6.3	8	4.5	.13	5	<1	<1	3.7	.9	7	1.1	22	.04	.018
OW13	11	73	6.8	6	8.5	.05	<5	<1	<1	3.5	2.2	9	.9	26	.05	.038
OW15	7.5	108	6.0	14	5.0	< .01	9	<1	<1	6.2	1.2	9	3.0	35	.76	.54
Minimum	7.0	52	6.0	4	< .5	< .01	<5	<1	<1	1.9	.5	4	.8	13	< .03	< .005
Maximum	11	205	8.5	31	15	8.0	17	4	<1	8.2	4.5	23	4.5	76	.76	.54
Median	9.0	92	6.9	13	5.0	.55	7	<1	<1	3.8	1.5	11	1.6	36	.04	.037
Mean	9.1	99	--	15	6.0	1.4	7	--	<1	4.2	1.7	12	1.9	37	.09	.083
Standard Deviation	1.0	38	--	7	4.0	2.2	4	--		2.0	1.0	5	1.0	14.	.18	.14
2. Background water-quality samples from observation wells developed in marine clay																
OW 28	8.0	110	6.3	12	8.5	0.17	13	7	<1	4.6	0.6	12	1.8	37	0.04	0.72
OW 29	10.0	273	7.1	75	14	8	21	47	<1	9.0	1.9	46	11	160	5.2	3.0
OW 10	9.0	330	8.9	71	8.5	.04	11	8	<1	34	2.5	6	2.3	24	.19	.05
OW 19	8.5	135	6.0	21	2.0	.14	7	15	<1	4.4	1.1	8	1.4	26	8.6	.97
Minimum	8.0	110	6.0	12	2.0	.04	7	7	--	4.4	0.6	6	1.4	24	.04	.045
Maximum	10.0	330	8.9	75	14	8	21	47	--	34	2.5	46	11	160	8.6	3.0

1/TOC = total organic carbon
2/VOP = volatile organic pollutants

Physical and Chemical Characteristics of Samples

The following discussion is based on sample analyses from all background water-quality sampling sites. This discussion is a general characterization of water chemistry in areas influenced only by natural factors.

The presence of marine clay can affect water quality. Therefore, the four background water-quality samples showing this influence (table 5, part B, sec. 2) have been separated from the group (16 samples) which are influenced by the composition of the sand and gravel (table 5, part B, sec. 1). Chemical characteristics of these two groups will be presented separately in the following discussion.

Statistical data can be used to characterize the background water quality and to compare concentrations of an element in a given sample to all other samples. The "mean", "median", and the "standard deviation" are presented in table 5, part B, sec. 1 for the background water-quality samples influenced by sand and gravel. The "mean" is equal to the sum of the measurements divided by the number of measurements; it is the average concentration for a given element. The "median" is the value that falls in the middle when the measurements are arranged in order of magnitude. This parameter is more useful than the mean when extremely high or low concentrations influence the mean (Byrkit, 1972). The "standard deviation" is a numerical expression of how much variation there is from the mean value.

Temperature

The temperature of ground water normally has a small seasonal fluctuation and is usually within a few degrees of the mean-annual air temperature in a given area. In Maine, ground-water temperatures are typically between 4.4 and 10.0°C (Caswell, 1978). The mean temperature of ground water in the samples from observation wells developed in sand and gravel was 9.1°C. The temperature in the samples affected by marine clay ranged from 8.0 to 10.0°C.

Specific conductance (conductivity)

The specific conductance of water is a measure of its capacity to conduct an electrical current. The presence of charged ions makes water conductive and as the ion concentration increases, so does the conductivity. Dissolved inorganic salts are the source of most ionic species and make up a large part of the total dissolved solids in most natural waters.

Although, there are no drinking-water standards for conductance, the Maine Department of Human Services (1981) has recommended a maximum concentration limit of 500 mg/L of dissolved solids in drinking water. Specific conductance can be used to provide a general index of dissolved solid concentrations, which were not measured directly. The concentration of dissolved solids, in milligrams per liter (mg/L), can be estimated by multiplying the conductivity value by a factor usually between 0.55 and 0.75 (Hem, 1970).

The maximum specific conductance in the background water-quality samples from observation wells developed in sand and gravel was 205 microsiemens/cm. Using the range of factors given by Hem, this is equivalent to 113 to 154 mg/L of dissolved solids. The maximum specific conductance in the samples influenced by marine clay was 330 microsiemens/cm, which converts to 182 to 248 mg/L of dissolved solids. Weakly-sorbed salts or pore water from the clay probably are responsible for the relatively high specific conductance values in the latter group. These conservative estimates of dissolved solids concentrations are well below the recommended maximum level.

pH

The pH of water is a measure of hydrogen ion activity (concentration). The pH scale ranges from 0 to 14; each unit increase in the scale represents a tenfold decrease in hydrogen-ion activity. A pH of 7 is considered neutral, less than 7 is acidic, and greater than 7 is alkaline. At pH values below 6.5, some metal in metallic piping will dissolve, imparting a metallic taste to the water in some instances (USEPA, 1979). The primary control on pH in most ground water involves interaction of soil and rocks with gaseous carbon dioxide, bicarbonate, and carbonate ions. The pH in the samples from observation wells developed in sand and gravel ranged from 6.0 to 8.5; pH in the samples influenced by marine clay ranged from 6.0 to 8.9.

Alkalinity

Akalinity is a measure of the capacity of a solution to resist a change in pH as an acid is added. The alkalinity is a measure of the concentrations of carbonate (CO_3=), bicarbonate (HCO_3^-), and hydroxide (OH^-). In ground water within the pH range found in the study area, the bicarbonate ion is the dominant anionic species. Alkalinity is reported in table 5 in terms of an equivalent quantity of calcium carbonate ($CaCO_3$). The alkalinity concentrations range from 4 to 31 mg/L (as $CaCO_3$) with a mean of 15 mg/L (as $CaCO_3$) in the samples from observation wells developed in sand and gravel. In the samples influenced by marine clay, the alkalinity concentrations range from 12 to 75 mg/L (as $CaCO_3$).

Chloride

Because chloride is a highly mobile ion and is not readily sorbed, it can be used to trace contamination from road-salting operations, salt-storage piles, landfills, and septic tanks. Chloride concentrations in the samples from observation wells developed in sand and gravel ranged from less than 0.5 to 15 mg/L, with a mean concentration of 6.0 mg/L. In the samples influenced by marine clay, chloride concentrations ranged from 2.0 to 14 mg/L. These concentrations are all below the Maine Department of Human Services (1981) drinking water standard of 250 mg/L.

Nitrate

Nitrogenous compounds are commonly derived from plant and animal materials but can also be contributed by fertilizers. Nitrate is the most commonly occurring form in ground water. Because nitrate is weakly absorbed by soil, it functions as a good indicator of contamination from septic systems and waste-disposal sites. The Maine Department of Human Services (1981) has established a limit of 10 mg/L nitrate-nitrogen (NO_3^-N) in drinking water. Nitrate concentrations in the samples from observation wells developed in sand and gravel ranged from less than 0.01 to 8.0 mg/L, with a mean of 1.4 mg/L. Nitrate concentrations in the clay-rich samples ranged from 0.04 to 0.17 mg/L.

Sulfate

The sulfate ion is one of the major anions in natural waters. The Maine Department of Human Services (1981) has recommended an upper limit for sulfate of 250 mg/L in drinking water. Sulfate concentrations in the samples from observation wells developed in sand and gravel ranged from less than 5 to 17 mg/L, with a mean of 7 mg/L. In the samples influenced by marine clay, sulfate concentrations ranged from 7 to 21 mg/L. Sulfate can be reduced under anaerobic conditions to hydrogen sulfide gas (H_2S). The rotten-egg odor of this gas can be detected in water containing only a few tenths of a milligram per liter of H_2S. Hydrogen sulfide gas is a common problem in ground water from wells drilled into bedrock containing sulfide minerals (pyrite and pyrrhotite), but generally it is not a problem in unconsolidated aquifers.

Total organic carbon

TOC (total organic carbon) is a bulk indicator of all organic chemicals present in water. Some of these chemicals may be highly toxic, although the TOC measurement technique does not distinguish between toxic and non-toxic organic species. Only 6 of the 12 samples from observation wells developed in sand and gravel had TOC concentrations above the detection limit of 1 mg/L. The four samples influenced by marine clay had much higher TOC concentrations, which ranged from 7 to 47 mg/L. Elevated TOC concentrations in ground water seem to be correlated with high concentrations of clay in the aquifer material because the organics adsorb readily onto clay particles (National Academy of Sciences, 1980).

Volatile organic pollutants

Volatile organics are a group of chemicals which include trichloroethane, trichloroethylene, tetrachloroethane, toluene, xylenes, benzenes, and fluorocarbons among many others. The presence of these compounds is usually associated with a spill or the disposal of oily material, gasoline, pesticides, or industrial solvents and cleaners. These compounds are not found in uncontaminated ground water.

The volatile organic pollutant analysis will indicate if any of the compounds is present. None of the 20 background water-quality samples contained a detectable level of volatile organic pollutants.

Sodium and potassium

Sodium and potassium are usually among the major cations in ground water. The Maine Department of Human Services (1981) has not set maximum limits for potassium in drinking water. However, a drinking-water standard of 20 mg/L has been set for sodium to protect people with heart, hypertension, or kidney problems.

Concentrations of sodium in the samples from observation wells developed in sand and gravel ranged from 1.9 to 8.2 mg/L, with a mean of 4.2 mg/L. In the samples influenced by marine clay, sodium concentrations ranged from 4.4 to 34 mg/L.

Concentrations of potassium in the samples from observation wells developed in sand and gravel ranged from 0.5 to 4.5 mg/L, with a mean of 1.7 mg/L. In the samples influenced by marine clay, potassium concentrations ranged from 0.6 to 2.5 mg/L.

Calcium, magnesium, and hardness

Because calcium is widely distributed in the common minerals of rocks and soil, it is the principal cation in most natural freshwater (Hem, 1970). Magnesium is also frequently among the major cations in ground water. The Maine Department of Human Services (1981) has not set any recommended maximum limits for these constituents in drinking water.

Concentrations of calcium, the principal cation in the samples from observation wells developed in sand and gravel, ranged from 4 to 23 mg/L, with a mean of 12 mg/L. In the samples influenced by marine clay, calcium concentrations ranged from 6 to 46 mg/L.

Concentrations of magnesium in the samples from observation wells developed in sand and gravel ranged from 0.8 to 4.5 mg/L, with a mean of 1.5 mg/L. In the samples influenced by marine clay, magnesium concentrations ranged from 1.4 to 11 mg/L.

The property of hardness has been associated with effects observed in the use of soap or with the encrustations left by some types of water when they are heated (Hem, 1970). Hard water requires considerable amounts of soap to produce a foam or lather and can cause scale in hot water pipes, heaters, boilers, and other units that use hot water.

Hardness is caused by divalent metallic cations--principally calcium and magnesium --but strontium, iron, and manganese may also contribute to hardness. Hardness has been expressed in table 5 (part B) in terms of an equivalent concentration of calcium carbonate (in mg/L). Water is considered soft if it contains 0 to 60 mg/L of hardness, moderately hard if it contains 61 to 120 mg/L, hard if it contains 121 to 180 mg/L, and very hard if it contains more than 180 mg/L (Hem, 1970). Ground water in the background water-quality samples from observation wells developed in sand and gravel, with a mean value of 37 mg/L, is considered soft. Ground-water in the samples influenced by marine clay was also soft, with the exception of that from OW-29, which was hard.

Iron and manganese

Elevated iron and manganese concentrations have caused some problems for municipal water systems and individual well owners in the study area. Humans are not known to suffer any harmful effects from drinking water that contains excessive iron. However, concentrations of only a few tenths of a milligram per liter of iron and a few hundredths of a milligram per liter of manganese can make water unsuitable for some uses. Both iron and manganese may stain clothes and plumbing fixtures, and can cause problems in distribution systems by supporting growth of iron bacteria. Even at very low concentrations, iron in water can impart an objectionable taste, which is often described as rusty or metallic. When exposed to the air, water that contains dissolved iron and manganese may become turbid and unacceptable from an aesthetic viewpoint as a result of the formation of colloidal precipitates.

The mean iron concentration in the samples from observation wells developed in sand and gravel was 0.09 mg/L, which is below the Maine Department of Human Services (1981) recommended limit of 0.3 mg/L for drinking water . However, the water from OW-15 had an iron concentration of 0.76 mg/L, which is more than twice the recommended limit. The mean concentration for manganese in this sample group was 0.083 mg/L, which exceeds the maximum limit of 0.05 mg/L recommended for drinking water by the Maine Department of Human Services (1981). Two of the samples influenced by marine clay had iron concentrations above 0.3 mg/L; four had manganese concentrations of 0.05 or greater.

Filtration units can be installed by individual well owners to help remove objectionable levels of iron and manganese. Treatment to remove iron and manganese from public water supplies might also be necessary in some localities in the study area.

Effects of Contamination on Water Quality

Contamination by human activities can introduce high concentrations of many compounds into ground water. The most commonly used indicators to detect ground-water contamination include above-background concentrations of: nitrate, a contaminant derived from sewage, animal wastes, fertilizers, and landfills; chloride, a contaminant introduced by road salt, salt water intrusion, fertilizers and landfill wastes; and specific conductance, which indicates the presence of dissolved, ionized contaminants.

Activities that may greatly alter the chemistry of ground water include:

1. Landfill disposal of household and industrial wastes, which may include petroleum derivatives and hazardous radioactive materials.

2. Storage and spreading of road-deicing salt.

3. Introduction of human wastes into ground water through septic tanks, disposal of septic waste, or by spreading or landfilling of sludge from municipal sewer systems.

4. Agricultural activities, which include stockpiling and spreading animal wastes, spreading commercial fertilizers, and spraying pesticides.

5. Leaking waste-storage or disposal lagoons.

6. Leaking fuel-or chemical-storage tanks.

7. Spills of toxic or hazardous materials along transportation routes.

8. Overpumping of wells can induce saltwater intrusion in coastal areas or infiltration of poor quality water where a well is near contaminated surface water.

9. Contaminants in precipitation may degrade both ground water and surface water. For example, in the northeastern United States, "acid rain" apparently has caused the lowering of pH and subsequent increase in aluminum and trace metal concentrations in ground water in New Hampshire and New York (Bridge and Fairchild, 1981).

Characteristics of Sites of Potential Ground Water Contamination

Sixty-six sites that may be degrading water quality in sand and gravel aquifers have been identified on plates 1-5. The majority of these sites (41) are in the map 11 and 16 areas. These areas have relatively high population densities and extensive sand and gravel deposits.

The most abundant potential ground-water contamination sites in the study area are solid waste facilities (dumps, landfills, and transfer stations) and salt storage lots. Thirty-two solid-waste facilities and 18 salt-storage sites are identified on plates 1-5. Malfunctioning septic systems, roads that are salted in the winter, agricultural activities, and leaking underground gasoline tanks are not shown on these plates because of their widespread occurence.

The McKin hazardous waste site in East Gray (Map 11), an oil and industrial waste-disposal lagoon, has been the single most extensive source of aquifer contamination in the study area. Thirty-three domestic wells were replaced with a municipal water line after elevated concentrations of industrial solvents were discovered in many of the wells in 1974 (Camp, Dresser and McKee, 1983). The Sabattus Municipal Water Supply Well (map 11) was replaced in 1976 due to contamination from the nearby salt storage lot. Domestic wells near several of the salt-storage facilities shown on plates 1-5 have also been contaminated (Maine Department of Transportation Well Claims files). No wells are known to be contaminated by solid-waste facilities in the study area.

SUMMARY

The significant sand and gravel aquifers in the study area consist of glacial ice-contact and outwash deposits which occur primarily in the valleys of the major rivers or along their tributaries.

Although the study area includes 2408 mi^2, areas mapped as significant aquifers comprise only about 109 mi^2. Yields exceeding 50 gal/min are estimated to be available in only 22.6 mi^2 of these significant aquifers. The highest yields are obtainable in areas of thick, coarse-grained, saturated deposits that are hydraulically connected to an adjacent body of surface water that is a source of recharge. The highest reported well yield in the sand and gravel deposits is 2,000 gal/min from the Brunswick Topsham Water District well adjacent to the Androscoggin River.

The water table the significant sand and gravel aquifers is typically within 20 feet of the land surface. Based on seismic data, the greatest known depth to bedrock, which was encountered in the New Gloucester area, is 340 feet.

Based on field relationships, observation well and test-hole logs, and interpretation of the geologic history, the following stratigraphic relationships have been determined: bedrock is overlain by till, which is overlain by ice-contact and outwash deposits, which are overlain by marine clay, which is overlain by sand and gravel deposits of mixed origins. The thickness of the deposits differs considerably depending on landforms and local depositional controls during deglaciation.

Estimated hydraulic conductivities, based on grain-size analyses, ranged from 20 to 70 ft/day for fine to medium sand, 80 to 90 ft/day for medium to coarse sand, and 90 to 1000 ft/day for very coarse sand to coarse gravel. Estimated transmissivities at exploration holes in the study area ranged from 360 to 28,000 ft^2/day.

The background water quality in sand and gravel aquifers in the study area has the following characteristics: The pH ranges from 6.0 to 8.5; calcium and sodium are the most abundant cations; bicarbonate is the dominant anion; and the water is soft. The regional water quality is excellent although, in some localities, concentrations of iron and manganese are elevated enough to limit use of the water without treatment.

The water quality from samples influenced by marine clay has the following characteristics: The pH ranges from 6.0 to 8.9; calcium and sodium are the most abundant cations; bicarbonate is the dominant anion; and the water is soft, with the exception of one sample which was hard. The water quality is good and suitable for most uses, although there may be some local problems with elevated concentrations of iron and manganese. These problems may be severe enough to limit the practical uses of this water without treatment.

Solid-waste facilities and salt-storage sites are the most common of the 66 potential ground-water contamination sites identified on or near sand and gravel aquifers in the study area. Although no wells are known to be contaminated by solid-waste facilities, wells in sand and gravel aquifers near several salt storage sites and near the McKin hazardous-waste disposal site have been contaminated.

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Table 6.--Observation well logs, Map 11 Area [1/]

Identification number: Exploration holes were numbered sequentially in the order in which they were drilled.

Location: Latitude and longitude are specified; observation wells are located on plate 2.

Site description: A brief site description is given.

Description of materials: Logs of observation wells, based on the Wentworth scale, by the Maine Department of Environmental Protection.

Terms used in logs of exploration holes:

Sand and gravel--Sorted sediment varying in size from boulder to very fine sand. "Poorly sorted" indicates approximately equal amounts, by weight, of all grain sizes.

Till--A predominantly nonsorted, nonstratified sediment deposited directly by a glacier and composed of boulders, gravel, sand, silt, and clay.

Marine clay--Sorted, sometimes stratified sediment varying in size from clay to silt, deposited during the marine transgression during deglaciation, approximately 11,000 years B.P. Color is typically light brown or blue-gray.

End of hole--Depth of bottom of exploration hole in which bedrock or refusal was not reached.

Refusal--Depth at which drill equipment could not penetrate further.

[1/] See tables 1 and 2 for information on grain-size analyses and estimated transmissivities.

Table 6.--Observation well logs, Map 11 Area - Continued.

OW 24. Latitude: 44°01'54"N, longitude: 70°20'58"W. Located along Bailey Hill Road at southeastern end of Range Pond State Park. Depth to water 40 feet.

Material	Depth (feet)	Thickness (feet)
Sand, medium	0-11	11
Sand, medium to coarse	11-41	30
Sand, medium to coarse, some gravel	41-71	30
Sand, fine to medium	71-76	5
Sand, fine to coarse	76-86	10
Sand, medium to coarse	86-96	10+
End of hole	96	--

OW 24 is screened from 66 to 71 feet with 0.008 - inch slot PVC screen.

OW 26. Latitude: 43°56'54"N, longitude: 70°20'20"W. Located in a power line clearing along the Mayall Road in New Gloucester. Depth to water 8 feet.

Material	Depth (feet)	Thickness (feet)
Sand, very coarse; gravel; cobbles	0-11	11
Sand, medium	11-16	5
Sand, medium to coarse	16-31	15
Sand, coarse; gravel	31-33	2
Sand, medium to coarse	33-56	23
Sand, fine to medium, grey; silt	56-96	40
End of hole	96	--

OW 26 is screened from 16 to 20 feet with 0.020 inch slot PVC screen.

Table 6.--Observation well logs, Map 11 Area - Continued.

OW 27. Latitude: 43°53'55"N, longitude: 70°20'48"W. Located approximately 300 feet northeast of the Gray landfill, off Route 26 in Gray. Depth to water 50 feet.

Material	Depth (feet)	Thickness (feet)
Sand, brown; gravel; pebbles	0-6	6
Sand, brown, medium to coarse	6-16	10
Sand, coarse; gravel, fine; pebbles	16-21	5
Sand, medium to coarse	21-56	35
Sand, fine to coarse	56-61	5
Sand, fine to medium	61-68	7
Till	68-70	2
Refusal	70	--

OW 27 is screened from 59 to 65 feet with 0.008 - inch slot PVC screen.

OW 28. Latitude: 43°56'48"N, longitude: 70°08'05"W. Located along Rabbit Road approximately one mile east of Route 9 in Durham. Depth to water 5 feet.

Material	Depth (feet)	Thickness (feet)
Sand, fine, gray; silt, cobbles	0-6	6
Sand, fine to medium	6-13	7
Sand, fine, gray; silt; clay; gravel	13-20	7
Sand, fine; silt	20-26	6
Till, sandy	26-28	2
Refusal	28	-

OW 28 is screened from 23 to 27 feet with 0.008-inch slot PVC screen.

Table 6.--Observation well logs, Map 11 Area - Continued.

OW 29. Latitude: 43°54'36"N, longitude: 70°08'37"W. Located in Blueberry Pond Campground off of Goddard Road in Pownal. Depth to water 3 feet.

Material	Depth (feet)	Thickness (feet)
Sand, brown; clay	0-3	3
Sand, fine, brown	3-6	3
Sand, medium, brown	6-8	2
Sand, fine	8-11	3
Sand, very fine; silt	11-14	3
Sand, fine; silt; clay	14-16	2
Clay, marine	16-40	24
End of hole	40	--

A new hole was drilled to a depth at 12 feet adjacent to the first hole. OW 29 installed in this second hole is screened from 7 to 12 feet with 0.008 - inch slot PVC screen.

OW 32. Latitude: 43°48'24"N, longitude: 70°14'12"W. Located in Portland Water District gravel pit midway between Greely Road and Route 115 in Yarmouth. Approximately 30 vertical feet of sand and gravel have been removed from the area. Depth to water 10 feet.

Material	Depth (feet)	Thickness (feet)
Sand, medium, orange-brown; gravel to 1-inch diameter	0-7	7
Sand, coarse to very coarse, tan; gravel	7-20	13
Refusal--till or large cobble	20	--

OW 32 is screened from 16 to 20 feet using 0.020-inch slot PVC screen.

Table 6.--Observation well logs, Map 11 Area - Continued.

OW 33. Latitude: 43°48'44"N, longitude: 70°17'24"W. Located in small gravel pit 300 feet northwest of Cumberland County Fairground. Approximately 20 vertical feet of sand and gravel have been removed from the area. Depth to water 15 feet.

Material	Depth (feet)	Thickness (feet)
Sand, very coarse; gravel	0-4	4
Silt, brown; clay; gravel	4-6	2
Silt, gray; clay	6-11	5
Clay; gravel	11-13	2
Clay; silt; sand, fine to medium	13-23	10
Sand, coarse to very coarse	23-41	18
Sand, medium to very coarse; gravel to one-inch diameter	41-54	13
Till	54-61	7
Refusal	61	--

OW 33 is screened from 37 to 41 feet with 0.020-inch slot PVC screen.

Table 7.--Observation well and test hole logs, Map 16 Area [1/]

Identification number: Exploration were numbered sequentially in the order in which they were drilled.

Location: Latitude and longitude are specified; observation wells and test holes are located on plate 3.

Site description: A brief site description is given.

Description of materials: Logs of observation wells and test holes, based on the Wentworth scale, by the Maine Department of Environmental Protection.

Terms used in logs of exploration holes:

Sand and gravel--Sorted sediment varying in size from boulder to very fine sand. "Poorly sorted" indicates approximately equal amounts, by weight, of all grain sizes.

Till--A predominantly nonsorted, nonstratified sediment deposited directly by a glacier and composed of boulders, gravel, sand, silt, and clay.

Marine clay--Sorted, sometimes stratified sediment varying in size from clay to silt, deposited during the marine transgression during deglaciation, approximately 11,000 years B.P. Color is typically light brown or blue-gray.

End of hole--Depth of bottom of exploration hole in which bedrock or refusal was not reached.

Refusal--Depth at which drill equipment could not penetrate further.

[1/] See tables 1 and 2 for information on grain-size analyses and estimated transmissivities.

Table 7.--Observation well and test hole logs, Map 16 Area - Continued.

OW 6. Latitude: 44°12'19"N, longitude: 70°05'27"W. This observation well is located in an unused section of the Town of Greene gravel pit, near Leeds Junction. The observation well is immediately north of and approximately 15 vertical feet above a boggy area where sand and gravel had once been mined to below the water table. As much as 30 feet of sand and gravel were removed from the area where the observation well is located. The water table is 16 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Sand, fine	0-21	21
Sand, fine to medium, poorly sorted	21-28	7
Sand, fine to medium, poorly sorted; gravel	28-36	8
Sand, interbedded fine to coarse; gravel	36-62	26
Clay	62-63	1
Sand, fine; some silt	63-89	26
Till	89-95	6
Refusal (bedrock)	95	--

OW 6 is screened from 26 to 29 feet with 0.008-inch slot PVC screen.

Table 7.--Observation well and test hole logs, Map 16 Area - Continued.

TH 7. Latitude: 44°14'23"N, longitude: 70°05'22"W. This test hole is located at the eastern end of a gravel pit belonging to Blue Rock Industries, off of the Hartford Road in Leeds. Approximately 10 vertical feet of sand and gravel have been removed from the area.

Material	Depth (feet)	Thickness (feet)
Sand, coarse; gravel and pebbles to 2-inch diameter	0-14	14
Sand, coarse	14-16	2
Sand, medium to coarse	16-25	9
End of hole	25	--

Casing was installed but was destroyed by vandalism before any water samples were taken.

TH 8. Latitude: 44°16'58"N, longitude: 70°06'25"W. This test hole is located at the northern end of an inactive gravel pit belonging to Blue Rock Industires, northwest of Curtis Corner in Leeds. Approximately 15 vertical feet of sand and gravel have been removed from the area.

Material	Depth (feet)	Thickness (feet)
Sand, fine; some gravel	0-3	3
Gravel, cobbles	3-10	7
Refusal (cobbles or till)	10	-

No casing was installed because refusal was encountered before the water table was reached.

Table 7.--Observation well and test hole logs, Map 16 Area - Continued.

TH 9. Latitude: 44°19'27"N, longitude: 70°07'54"W. This test hole is located in an inactive small gravel pit immediately west of the Leeds town landfill in North Leeds. Approximately 10 vertical feet of sand, gravel, and cobbles have been removed from the area.

Material	Depth (feet)	Thickness (feet)
Sand, medium to coarse	0- 6	6
Sand, medium, well-sorted	6-11	5
Sand, fine to medium	11-18	7
Gravel, pebbles to 2-inch diameter	18-21	3
Sand, medium; gravel, cobbles	21-27	6
Refusal (large cobbles or till)	27	--

No casing was installed because refusal was encountered before the water table was reached.

OW 10. Latitude: 44°22'09"N, longitude: 70°10'17"W. This test hole is located on the northern side of the Strickland Ferry Road, approximately one mile west of the Androscoggin River in Livermore. The water table is 2 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Loam, coarse; sandy	0- 2	2
Silt	2-11	9
Clay; silt	11-16	5
Silt; some clay	16-21	5
Clay, marine	21-23	2
Clay, marine, interbedded with silt	23-54	31
Sand, fine to coarse; some silt; some gravel	54-63	9
Refusal	63	--

OW 10 is screened from 59 to 63 feet with 0.008-inch slot PVC screen. The observation well has a poor yield; it was pumped dry on October 22, 1982 and did not fully recover until January of 1983.

Table 7.--Observation well and test hole logs, Map 16 Area - Continued.

OW 11. Latitude: 44°26'08"N, longitude: 70°07'12"W. This observation well is located on the southern side of an abandoned dirt road near the Fayette town line in Livermore Falls. The well is approximately 1/5 mile southwest of Round Pond, 1/5 mile northeast of Turner Pond, and 1/5 mile northeast of Schoolhouse Pond. The water table is 16 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Sand, very fine	0- 4	4
Sand, fine to medium	4-11	7
Sand, medium	11-16	5
Sand, coarse	16-21	5
Sand, medium to coarse	21-25	4
Sand, fine to medium	25-31	6
Clay; silt	31-32	1
Sand, fine	32-33	1
Clay, interbedded with silt and sand	33-41	8
Sand, very fine; silt	41-51	10
Silt; fine sand	51-56	5
Till	56-57	1
Refusal (till or bedrock)	57	--

OW 11 is screened from 19 to 21 feet with a 0.020-inch slot PVC screen, and from 21 to 23 feet with a 0.008-inch slot PVC screen.

Table 7.--Observation well and test hole logs, Map 16 Area - Continued.

OW 12. Latitude: 44°29'34"N, longitude: 70°05'32"W. This observation well is located in a gravel pit in an esker north of Mosher Pond in Chesterville. Approximately twenty feet of sand and gravel has been removed from the area where the observation well is situated. The water table is 2 feet below land surface.

Materials	Depth (feet)	Thickness (feet)
Sand, coarse; gravel and cobbles up to 3-inch diameter	0-2	2
Sand, fine; silty	2-3	1
Sand, medium	3-11	8
Sand, medium to coarse	11-15	4
Sand, coarse; gravel and cobbles	15-17	2
Refusal (till)	17	-

OW 12 is screened from 13 to 15 feet with a 0.008-inch slot PVC screen.

OW 20. Latitude: 44°27'48"N, longitude: 70°18'17"W. This observation well is located between corn and potato fields immediately northwest of the Androscoggin River bridge on Route 40 in Canton. The water table is 11 feet below land surface.

Materials	Depth (feet)	Thickness (feet)
Loam, sandy	0-6	6
Silt, fine sand	6-11	5
Sand, fine; silty	11-19	8
Sand, coarse; gravel to 1/2-inch diameter	19-24	5
Sand, fine	24-25	1
End of hole	25	-

OW 20 is screened from 19 to 20.75 feet with a 0.020-inch slot PVC screen and from 20.75 to 23 feet with a 0.008-inch slot PVC screen.

Table 7.--Observation well and test hole logs, Map 16 Area - Continued.

OW 22. Latitude: 44°11'58"N, longitude: 70°14'59"W. This observation well is located immediately east of the Blue Rock Industry gravel pit in Turner. The water table is 18 feet below land surface.

Materials	Depth (feet)	Thickness (feet)
Loam; sandy, some gravel	0-1	1
Sand; very fine	1-16	15
Sand, fine	16-17	1
Silt, fine sand	17-18	1
Sand, medium to coarse	19-26	7
Sand, very coarse; gravel to 1-inch diameter	26-33	7
End of hole	33	-

OW 22 is screened from 28 to 32 feet with a 0.008-inch slot PVC screen.

Table 8.--Observation well and test hole logs, Map 11 Area [1/]

Identification number: Exploration holes were numbered sequentially in the order in which they were drilled.

Location: Latitude and longitude are specified; observation wells are located on plate 4.

Site description: A brief site description is given.

Description of materials: Logs of observation wells, based on the Wentworth scale, by the Maine Department of Environmental Protection.

Terms used in logs of exploration holes:

Sand and gravel--Sorted sediment varying in size from boulder to very fine sand. "Poorly sorted" indicates approximately equal amounts, by weight, of all grain sizes.

Till--A predominantly nonsorted, nonstratified sediment deposited directly by a glacier and composed of boulders, gravel, sand, silt, and clay.

Marine clay--Sorted, sometimes stratified sediment varying in size from clay to silt, deposited during the marine transgression during deglaciation, approximately 11,000 years B.P. Color is typically light brown or blue-gray.

End of hole--Depth of bottom of exploration hole in which bedrock or refusal was not reached.

Refusal--Depth at which drill equipment could not penetrate further.

[1/] See tables 1 and 2 for information on grain-size analyses and estimated transmissivities.

Table 8.--Observation well and test hole logs, Map 17 Area - Continued.

TH 1. Latitude: 44°22'13"N, longitude: 69°48'56"W. This test hole is located at the northeastern edge of the Robert Lyon gravel pit off Sanford Road in Augusta, Maine.

Material	Depth (feet)	Thickness (feet)
Sand, medium	0-11	11
Sand, medium to coarse	11-16	5
Sand, coarse	16-21	5
Sand, medium to fine	21-26	5
Sand, fine	26-31	5
Sand, fine to medium	31-36	5
Sand, very fine; silty	36-41	5
Sand, fine to medium	41-46	5
Sand, medium	46-49	3
Gravel	49-50	1
Sand, medium	50-66	16
Sand, fine to medium	66-71	5
Sand, very fine; silt	71-86	15
Sand, fine to medium	86-91	5
Sand, medium	91-100	9
End of hole	100	--

No casing was installed because of the 86 foot depth to water at this location.

Table 8.--Observation well and test hole logs, Map 17 Area - Continued.

TH 2. Latitude: 44°25'18"N, longitude: 69°50'00"W. This observation well is located in a forested area across from the Gagne Gravel Pit off Penney Road, Belgrade, Maine. Depth to water is 46 feet.

Material	Depth (feet)	Thickness (feet)
Sand, medium	0-16	16
Sand, coarse	16-21	5
Sand, coarse; cobbles to 3-inch diameter	21-31	10
Sand, medium to coarse; cobbles	31-36	5
Gravel	36-46	10
Gravel, cobbles	46-51	5
Gravel, cobbles	51-56	5
Gravel, cobbles; very coarse sand	56-73	17
Refusal (cobbles?, till?, bedrock?)	73	--

OW 2 is screened from 54 to 56 feet with 0.020-inch slot PVC screen.

TH 3. Latitude: 43°53'55"N, longitude: 70°20'48"W. This test hole is located at the northwestern edge of the Hammond gravel pit off Route 27 in Belgrade, Maine.

Material	Depth (feet)	Thickness (feet)
Sand, medium; cobbles	0- 6	6
Sand, coarse; gravel	6-21	15
Sand, medium; gravel	21-26	5
Sand, medium to coarse	26-31	5
Refusal (till?)	31	--

No casing was installed in TH 3 because refusal was encountered before reaching the water table.

Table 8.--Observation well and test hole logs, Map 17 Area - Continued.

TH 4. Latitude: 44°23'57"N, longitude: 69°43'21"W. This test hole is located immediately west of the Crane Service Gravel Pit off Route 201 in Vassalboro, Maine.

Material	Depth (feet)	Thickness (feet)
Clay, silty	0-11	11
Clay, marine	11-23	12
Clay; gravel	23-26	3
Silt; fine sand; clay	26-31	5
Sand, coarse	31-35	4
Sand, fine to medium	35-48	13
Sand, medium to coarse; gravel	48-65	17
Refusal (till?)	65	--

A perched water table was penetrated at 26 feet, but the casing which was installed was screened below this perched water table where the sand and gravel were unsaturated.

Table 9.--Observation well and test hole logs, Map 32 Area [1/]

Identification number: Exploration holes were numbered sequentially in the order in which they were drilled.

Location: Latitude and longitude are specified; observation wells are located on plate 5.

Site description: A brief site description is given.

Description of materials: Logs of observation wells, based on the Wentworth scale, by the Maine Department of Environmental Protection.

Terms used in logs of exploration holes:

Sand and gravel--Sorted sediment varying in size from boulder to very fine sand. "Poorly sorted" indicates approximately equal amounts, by weight, of all grain sizes.

Till--A predominantly nonsorted, nonstratified sediment deposited directly by a glacier and composed of boulders, gravel, sand, silt, and clay.

Marine clay--Sorted, sometimes stratified sediment varying in size from clay to silt, deposited during the marine transgression during deglaciation, approximately 11,000 years B.P. Color is typically light brown or blue-gray.

End of hole--Depth of bottom of exploration hole in which bedrock or refusal was not reached.

Refusal--Depth at which drill equipment could not penetrate further.

[1/] See tables 1 and 2 for information on grain-size analyses and estimated transmissivities.

Table 9.--Observation well and test hole logs, Map 32 Area - Continued.

OW 13. Latitude: 44°31'57"N, longitude: 70°04'57"W. Located along edge of an extensive esker in a gravel pit immediately west of Horseshoe Pond and north of Fellows Pond in Chesterville. Depth to water 2 feet.

Material	Depth (feet)	Thickness (feet)
Sand, medium to coarse	0-6	6
Sand, coarse	6-26	20
Sand, very coarse; gravel to 1/2-inch diameter	26-36	10
Sand, medium, poorly sorted; gravel to 1/4-inch diameter	36-46	10
Sand, medium to coarse	46-56	10
Sand, medium	56-57	1
Sand, fine	57-58	1
Till, silty; gravel	58-63	5
Refusal	63	--

OW 13 is screened from 16 to 18 feet with 0.020-inch slot PVC screen.

TH14. Latitude: 44°36'37"N, longitude 70°05'44"W. Located along Route 156 in Farmington, west of Wilson Stream, south of the Sandy River. Depth to water 3 feet.

Material	Depth (feet)	Thickness (feet)
Sand, fine	0-3	3
Sand, fine; silt; clay	3-16	13
Sand, fine	16-26	10
Clay, marine	26-76	50
End of hole	76	--

No casing was installed in TH14 because of the predominantly fine-grained material encountered.

Table 9.--Observation well and test hole logs, Map 32 Area - Continued.

OW 15. Latitude: 44°38'04"N, longitude: 70°02'44"W. Located at the northern edge of a hay field in a sharp meander of the Sandy River in New Sharon. Depth to water is 13 feet.

Material	Depth (feet)	Thickness (feet)
Loam, silty-sandy, brown	0- 6	6
Sand, very fine	6-11	5
Sand, fine	11-12	1
Sand, medium to coarse	12-22	10
Sand, very coarse; gravel to 3/8-inch diameter	22-25	3
Clay, marine	25-33	8
End of hole	33	--

OW 15 is screened from 22 to 24 feet with 0.020-inch slot PVC screen.

OW 16. Latitude: 44°39'04"N, longitude: 70°08'18"W. Located at the southern edge of a hayfield north of the Sandy River, adjacent to the Farmington Sewage Treatment Plant.

Material	Depth (feet)	Thickness (feet)
Loam, sandy, brown	0- 6	6
Loam, sandy, silty	6-12	6
Sand, fine to medium; gravel 1/4 to 2-inch diameter	12-16	4
Gravel, granules and pebbles, 1/8 to 2-inch diameter, in silty matrix	16-27	11
Clay, gray	27-28	1
Gravel, 1/4 to 1.5-inch diameter, in clay, silt, and sand matrix	28-51	23
End of hole	51	--

OW 16 is screened from 23 to 25 feet with 0.008-inch slot PVC screen. It is also screened from 25 to 27 feet with 0.125-inch slot PVC screen.

Table 9.--Observation well and test hole logs, Map 32 Area - Continued.

OW 19. Latitude: 44°33'01"N, longitude: 70°15'40"W. Located at western edge of field, immediately east of unnamed stream and marsh in North Jay. Depth to water is 2 feet.

Material	Depth (feet)	Thickness (feet)
Sand, fine; silt; clay	0- 6	6
Silt, gray-brown; clay, gray-blue	6-24	18
Sand, very fine to medium; silt; clay	24-64	40
Till, silty	64-75	11
Refusal	75	--

OW 19 is screened from 25 to 29 feet with 0.008-inch slot PVC screen.

Figure 8.--12-channel seismic refraction profiles: Map 11.

Hydrogeologic sections from seismic refraction surveys conducted by the U.S. Geological Survey in 1982. Locations of individual profiles are shown on Plate 2. Interpretation of field data is based on a computer modeling program described by Scott and others (1972). Distances shown on x-axes are measured from shot #1 for all profiles.

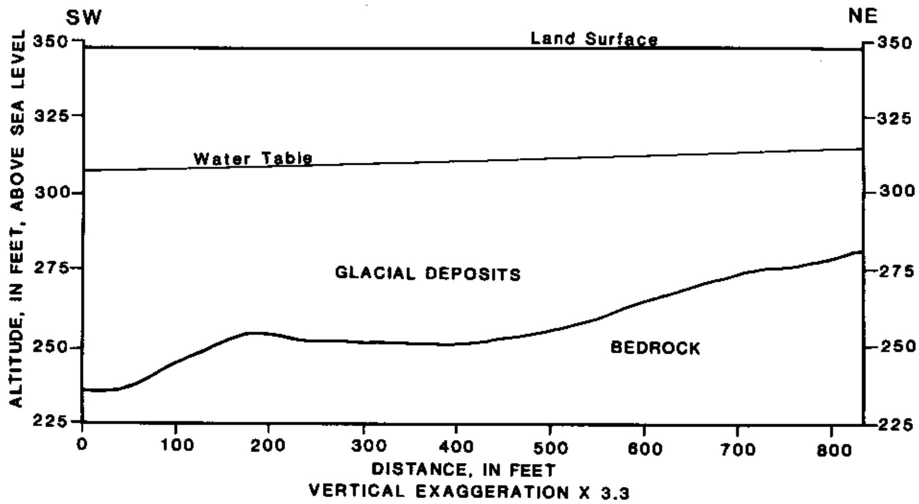

Figure 8a. Line MINOT-2. Minot 7.5' Quadrangle. Line of section in Range Pond State Park, on southern extension of Bailey Hill Road, approximately 0.3 miles southeast of Frenchman Beach, in Poland.

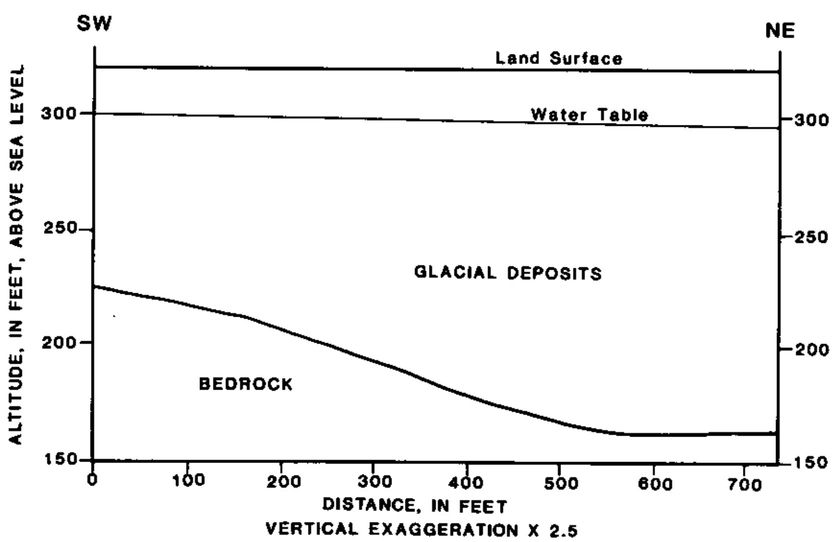

Figure 8b. Line MINOT-3. Minot 7.5' Quadrangle. Line of section on Bailey Hill Road, approximately 0.1 miles north of the intersection with the Plains Road, in Poland.

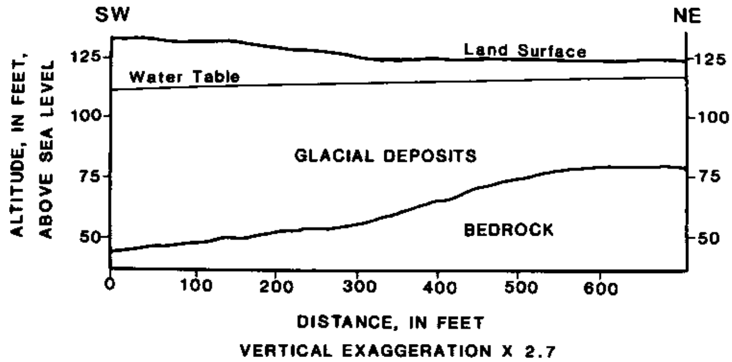

Figure 8c. Line LE-1. Lewiston 7.5' Quadrangle. Line of section in cornfield next to Androscoggin River, near the intersection of River Road and Ferry Road, in Lewiston.

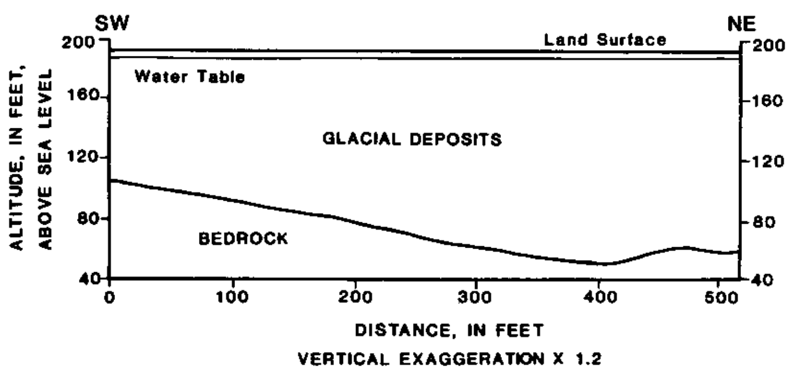

Figure 8d. Line LE-2. Lewiston 7.5' Quadrangle. Line of section in field on southern side of Rt. 196, 0.2 miles east of the Lewiston/Lisbon town line, in Lisbon.

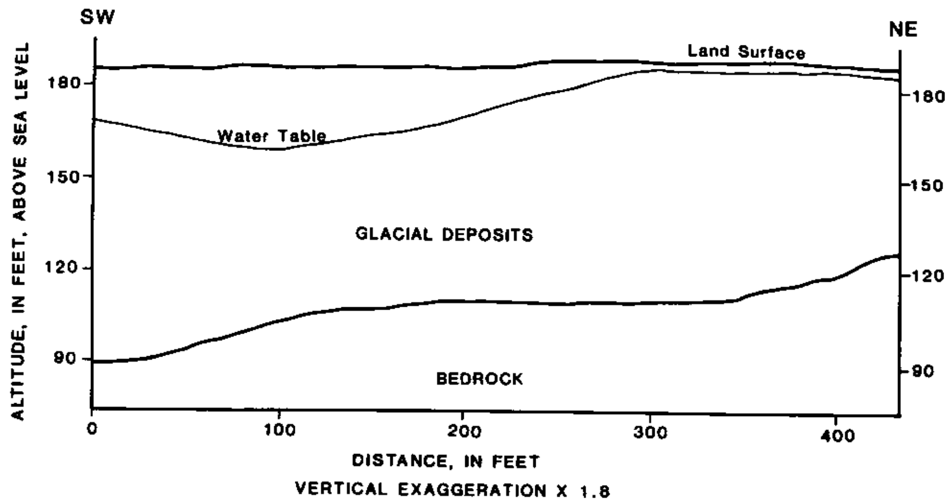

Figure 8e. Line LE-3. Lewiston 7.5' Quadrangle. Line of section in Brewer Park, Moody Road, in Lisbon.

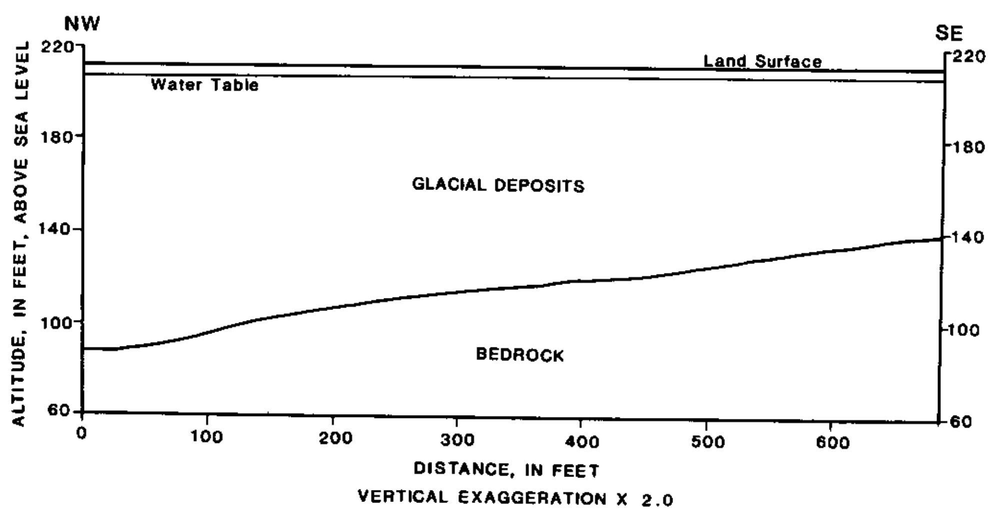

Figure 8f. Line LFN-1. Lisbon Falls North 7.5' Quadrangle. Line of section on Bowdoin Road, at Maxwell Brook, in Sabattus.

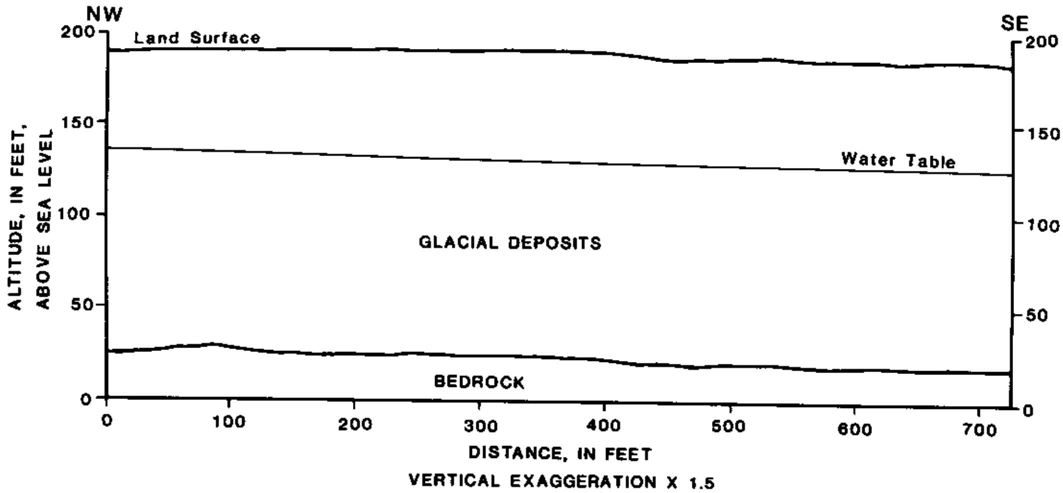

Figure 8g. Line LFN-2. Lisbon Falls North 7.5' Quadrangle. Line of section on Old Furbush Road, near intersection with Pleasant Hill Road, in Sabattus.

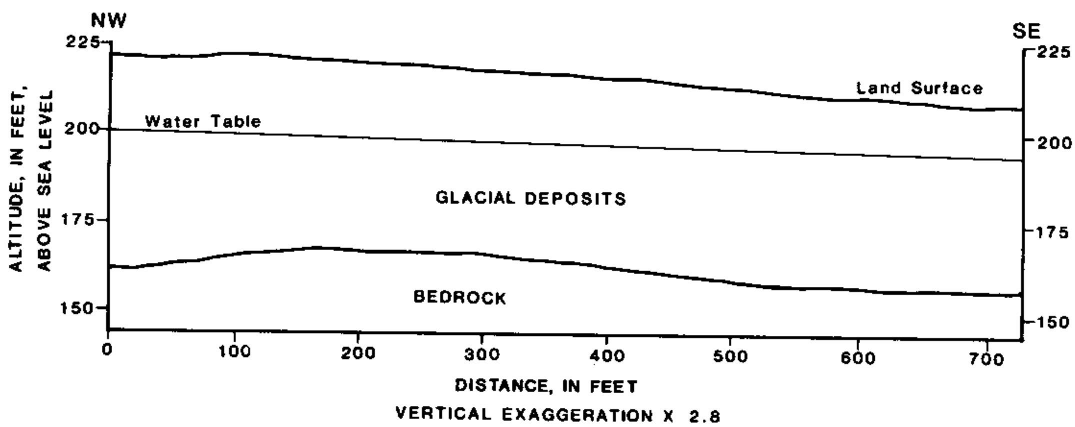

Figure 8h. Line LFN-4. Lisbon Falls North 7.5' Quadrangle. Line of section on Kettlebottom Road, near Woodland Cemetery, in Bowdoin.

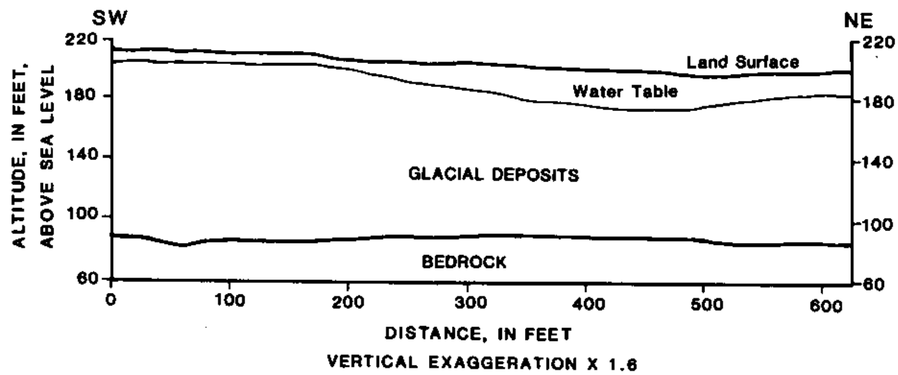

Figure 8i. Line NP-1. North Pownal 7.5' Quadrangle. Line of section on Davis Road, 0.4 miles north of intersection with Fickett Road, in Durham.

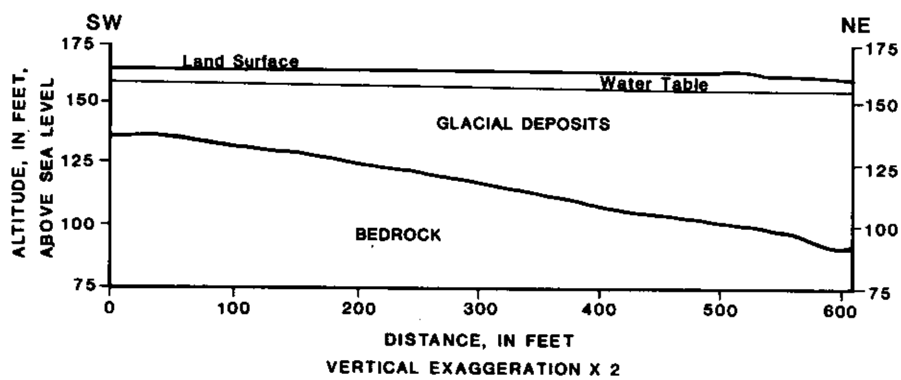

Figure 8j. Line NP-2. North Pownal 7.5' Quadrangle. Line of section on Rabbit Road, 0.7 miles east of intersection with Route 9, in Durham.

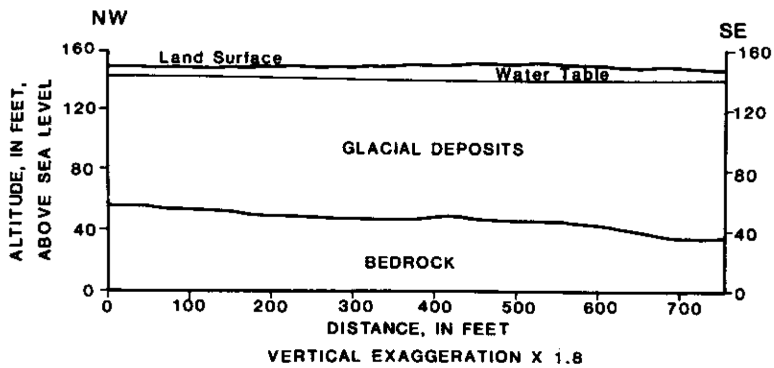

Figure 8k. Line NP-3. North Pownal 7.5' Quadrangle. Line of section on Goddard Road, 1.2 miles east of intersection with Route 9, in Pownal.

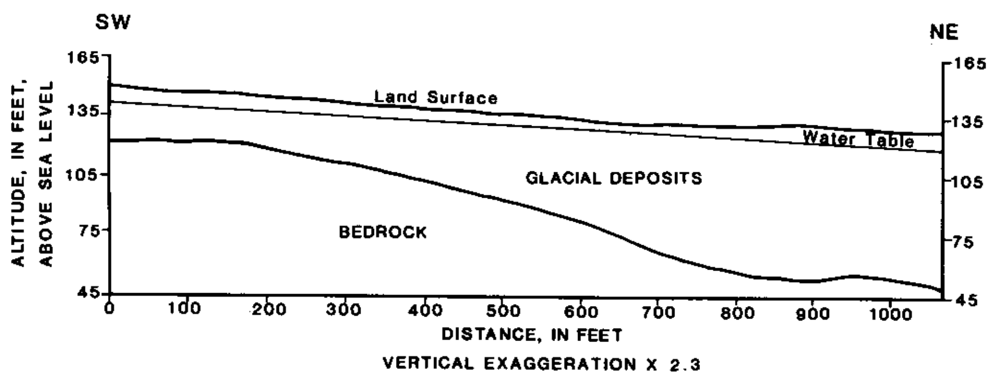

Figure 8l. Line NP-5. North Pownal 7.5' Quadrangle. Line of section on Verrill Road, 0.25 miles north of the intersection with Dyer Road, in Pownal.

Figure 8m. Line GR-1. Gray 7.5' Quadrangle. Line of section in Gray Landfill, off Seagull Road, in Gray. No profile is shown for GR-1 because a blind zone problem was encountered on each end of the line. On the southwestern end of the line, a 44-foot thick saturated section (if present), under 51 feet of unsaturated material, could not be detected with seismic refraction. The true depth to bedrock is somewhere between 51 feet and 95 feet and the saturated section (if present) is between 0 and 44 feet thick. On the northeastern end of the line, a 43-foot thick saturated section (if present), under 50 feet of unsaturated material could not be detected. The true depth to bedrock is somewhere between 50 feet and 93 feet and the saturated section (if present) is between 0 and 43 feet thick.

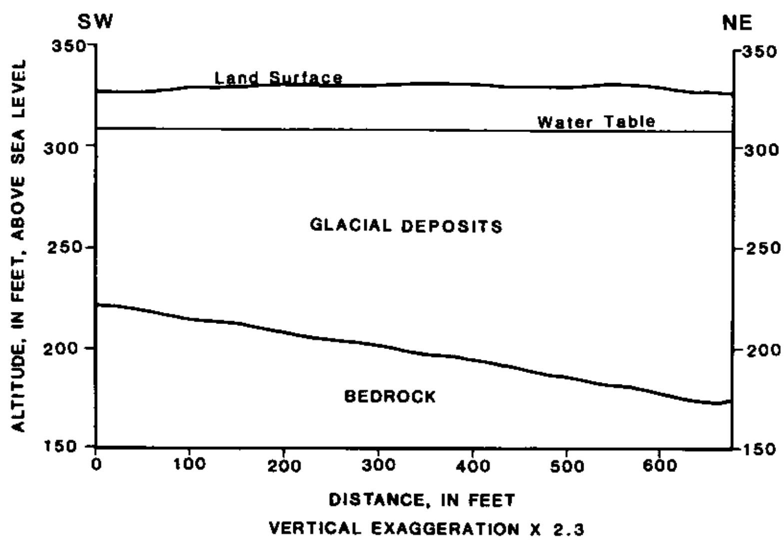

Figure 8n. Line GR-3. Gray 7.5' Quadrangle. Line of section on Swamp Road, 0.3 miles north of the intersection with Bennett Road, in New Gloucester.

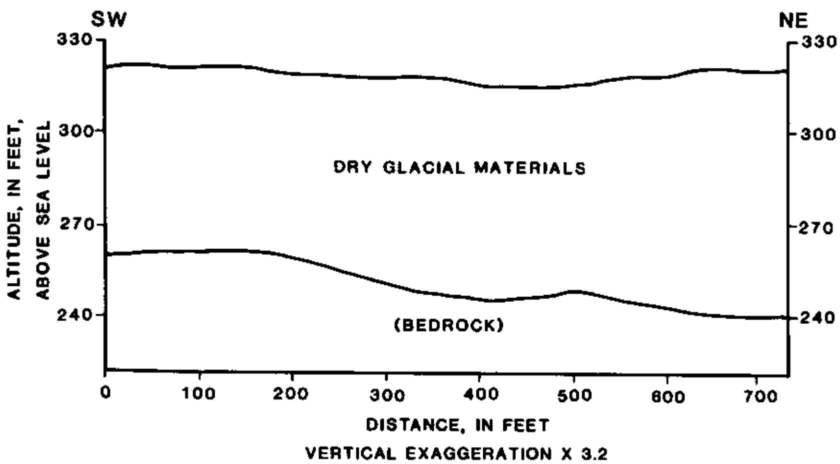

Figure 8o. Line GR-4. Gray 7.5' Quadrangle. Line of section on Sunset Shores Road, at intersection with Snows Hill Road, in New Gloucester.

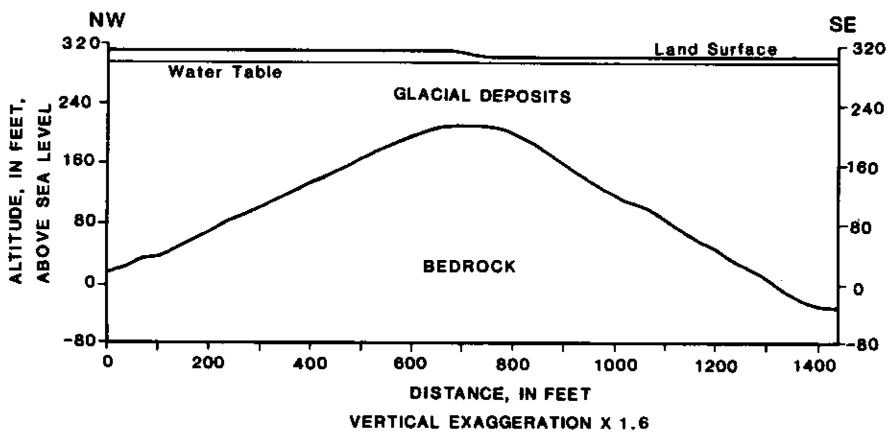

Figure 8p. Line GR-M-1/2. Gray 7.5' Quadrangle. Line of section on Mayall Road, 2.0 miles south of the intersection with Route 26, in New Gloucester.

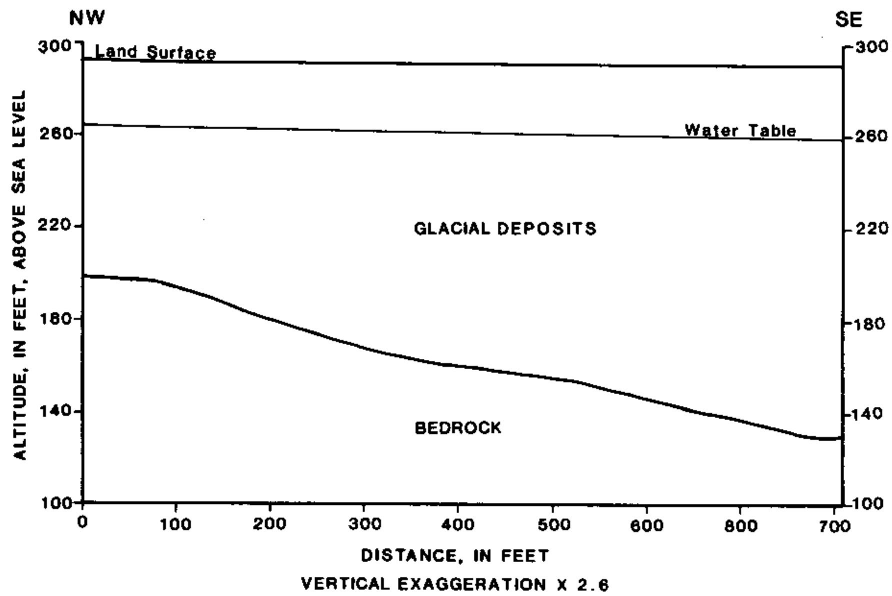

Figure 8q. Line GR-M-3. Gray 7.5' Quadrangle. Line of section on Mayall Road, 2.0 miles south of the intersection with Route 26, in New Gloucester.

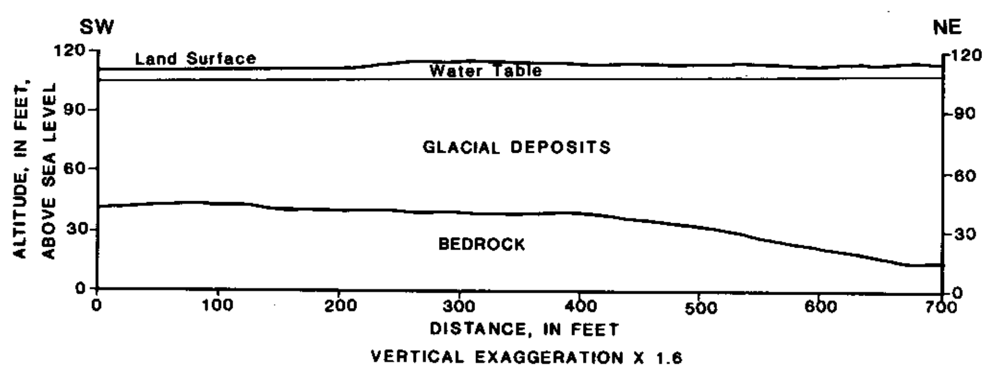

Figure 8r. Line CC-2. Cumberland Center 7.5' Quadrangle. Line of section on Mill Road, at railroad tracks, near Royal River, in North Yarmouth.

Figure 8s. Line YA-4/6. Yarmouth 7.5' Quadrangle. Line of section on dirt road in Walnut Hill area, near Yarmouth Water District wells, in North Yarmouth. No profile is shown for YA-4/6 because a blind zone problem was encountered on each end of the line. On the northwestern end of the line, a 50-foot thick saturated section (if present), under 54 feet of dry sand and gravel, could not be detected with seismic refraction. The true depth to bedrock is somewhere between 87 and 104 feet and the saturated section (if present) is between 0 and 50 feet thick. The water table, if there is one, may vary between 54 and 87 feet below land surface. On the southeastern end of the line, a 62-foot thick saturated section (if present), under 66 feet of dry sand and gravel, could not be detected. The true depth to bedrock is somewhere between 62 and 128 feet and the saturated section (if present) is between 0 and 62 feet thick. The water table, if there is one, varies between 62 and 66 feet below land surface.

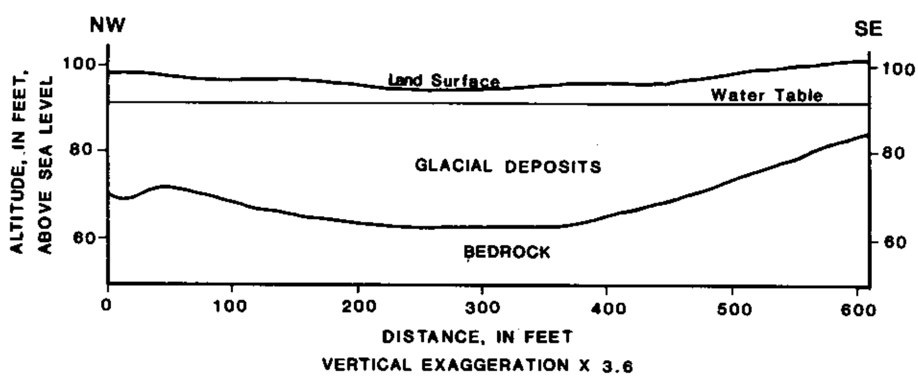

Figure 8t. Line YA-8. Yarmouth 7.5' Quadrangle. Line of section on Toddy Road, approximately 0.4 miles east of the intersection with Route 9, in North Yarmouth.

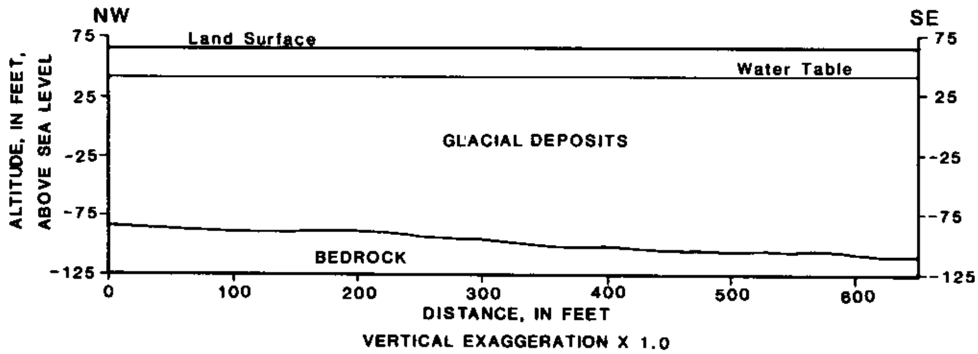

Figure 8u. Line YA-13. Yarmouth 7.5' Quadrangle. Line of section on Webster Road, just north of Webster Cemetery, in Freeport.

Figure 9.--12-channel seismic refraction profiles: Map 16

Hydrogeologic sections from seismic refraction surveys conducted by the U.S. Geological Survey in 1982. Locations of individual profiles are shown on Plate 3. Interpretation of field data is based on a computer modeling program described by Scott and others (1972). Distances shown on x-axes are measured from shot #1 for all profiles.

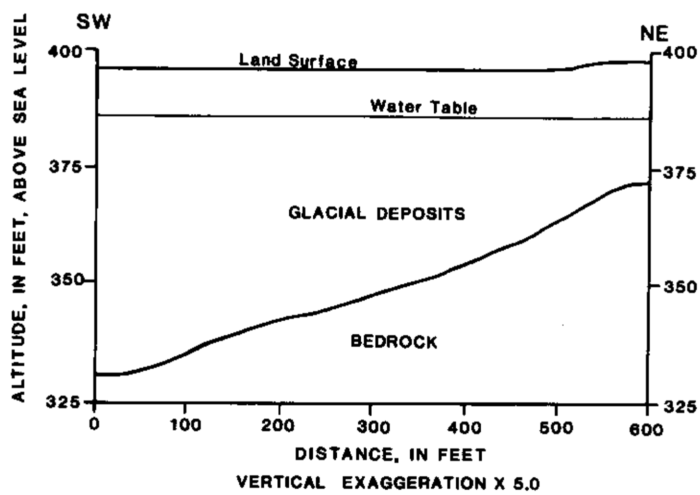

Figure 9a. Line C-1. Canton 7.5' Quadrangle. Line of section on dirt road between gravel pits off unnamed road that connects Rt. 4 and Rt. 108, south of Brettuns Pond, in Livermore.

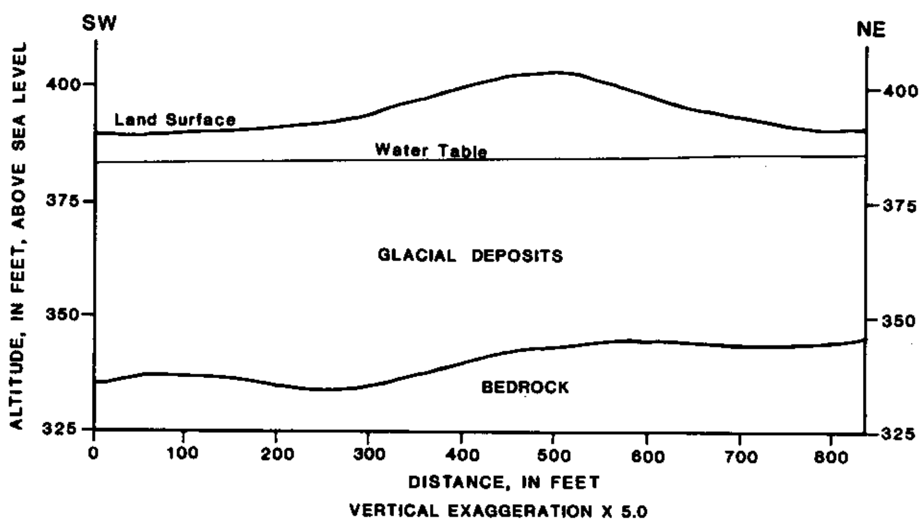

Figure 9b. Line C-2. Canton 7.5' Quadrangle. Line of section just east of Bog Brook on road that intersects Rt. 108, approximately 1.2 miles southeast of the intersection of Rt. 108 and Rt. 140, in Canton.

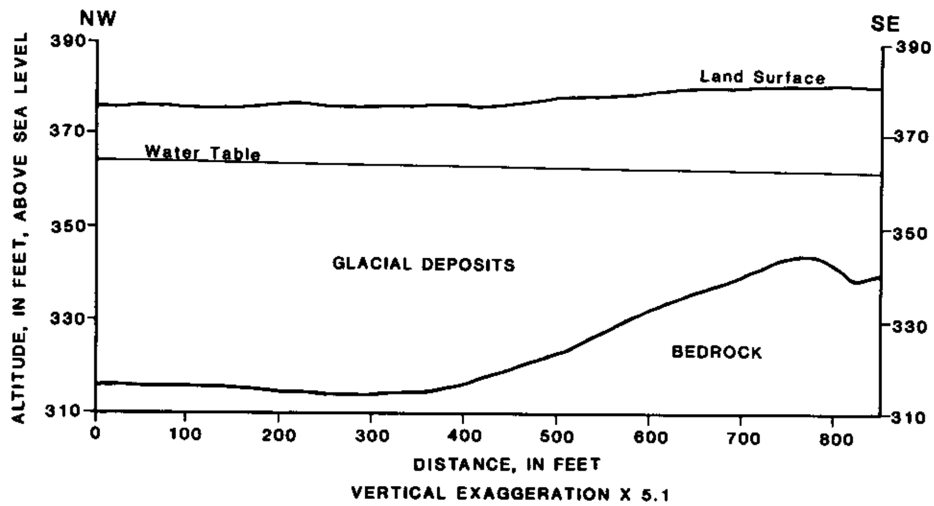

Figure 9c. Line C-4. Canton 7.5' Quadrangle. Line of section in field immediately to the west when heading north after crossing bridge over the Androscoggin River on Rt. 140, in vicinity of Canton Point.

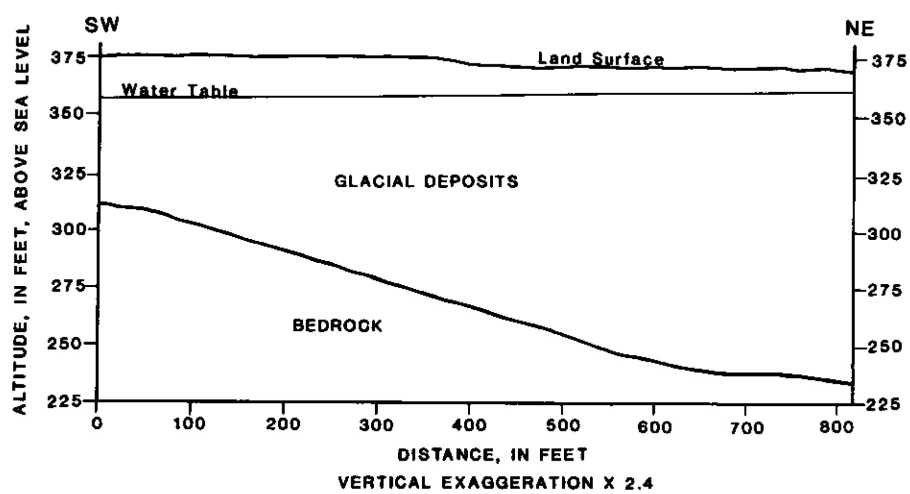

Figure 9d. Line C-5. Canton 7.5' Quadrangle. Line of section in field on western side of Rt. 140, 1.35 miles north of the bridge over the Androscoggin River, in vicinity of Canton Point.

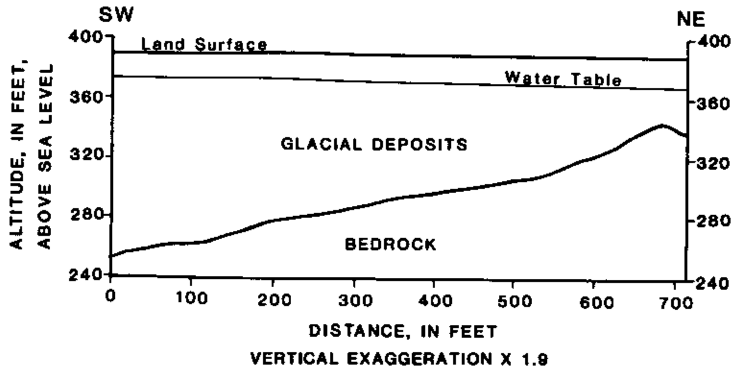

Figure 9e. Line C-6. Canton 7.5' Quadrangle. Line of section on Wainwright property on west bank of Androscoggin River, opposite McCollister Hill in Canton.

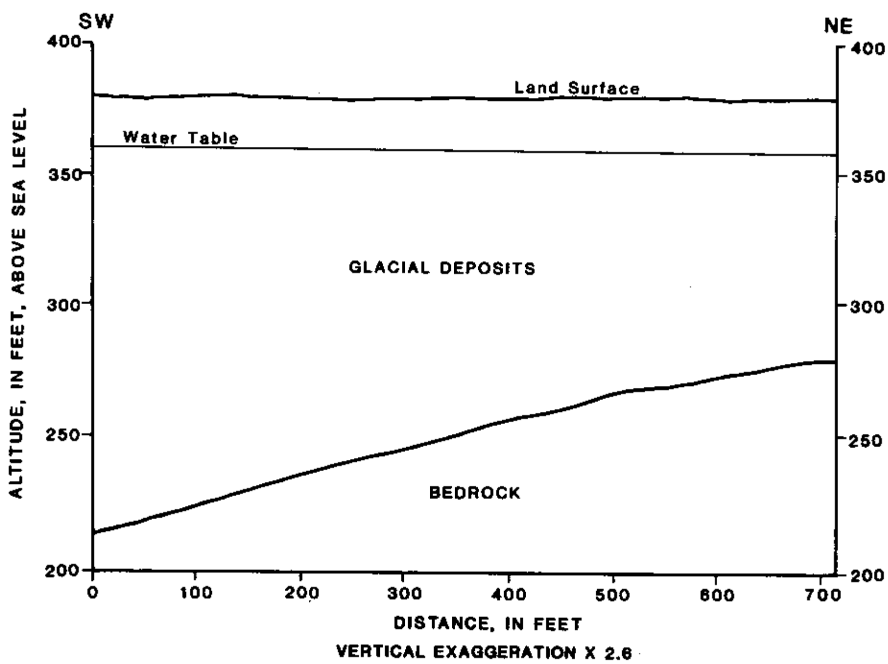

Figure 9f. Line LF-2. Livermore Falls 7.5' Quadrangle. Line of section in Souther's field, on east side of road to Warren Hill, 0.35 miles north of the intersection of this road and Rt. 17 in Livermore Falls.

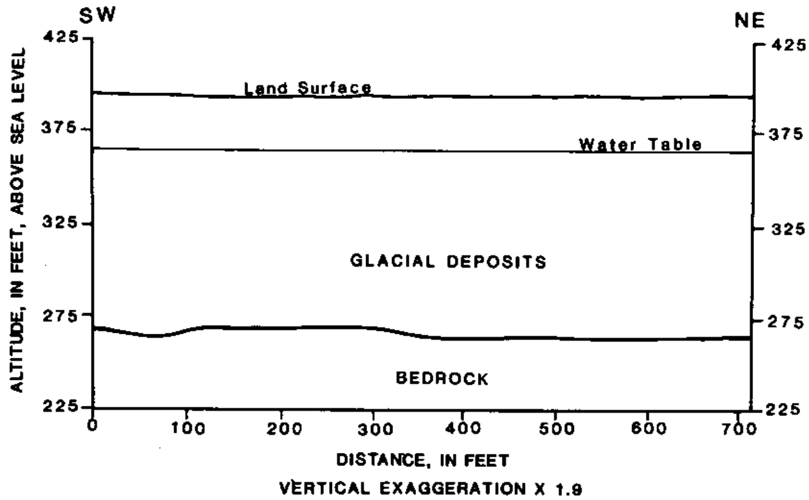

Figure 9g. Line F-1A. Fayette 7.5' Quadrangle. Line of section on western end of road trending east-west between Turner Pond and Schoolhouse Pond in Livermore Falls.

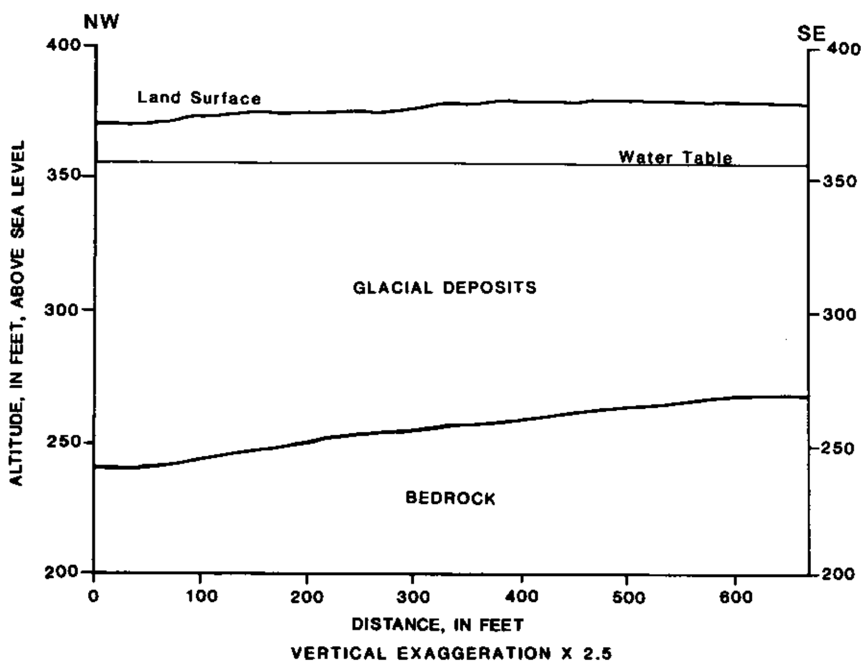

Figure 9h. Line F-2A. Fayette 7.5' Quadrangle. Line of section 0.7 miles north of the Chesterville/Fayette town line on eastern side of road which trends northeast from Twelve Corners on Rt. 17, towards Mosher Pond.

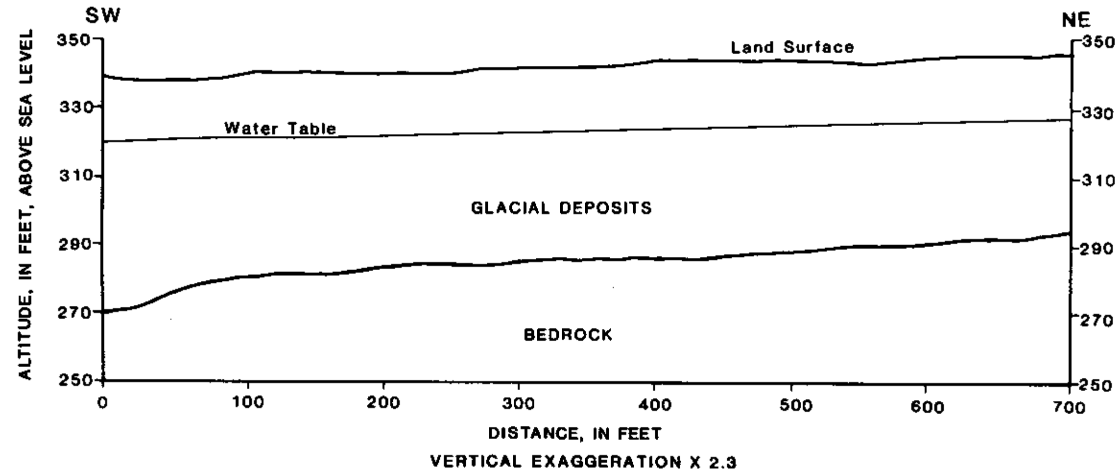

Figure 9i. Line B-1. Buckfield 7.5' Quadrangle. Line of section on dirt road east of Crystal Pond in Turner.

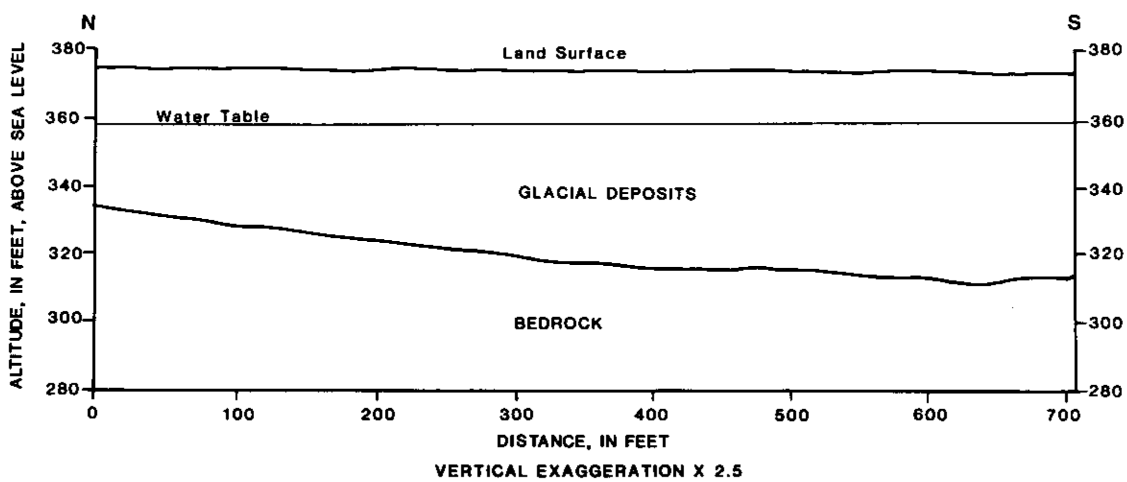

Figure 9j. Line BU-2. Buckfield 7.5' Quadrangle. Line of section on an abandoned railroad grade 0.9 miles south from the intersection of the railroad grade and the road to Howard Cemetery in Sumner. Railroad grade is on the west side of the East Branch of the Nezinscot River, in Buckfield.

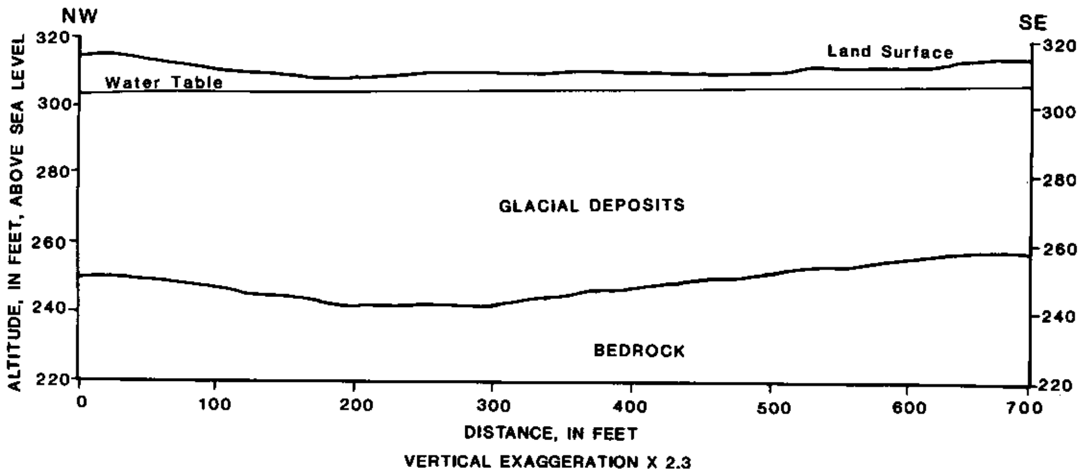

Figure 9k. Line BU-3. Buckfield 7.5' Quadrangle. Line of section in gravel pit owned by K & K Excavations, south of Rt. 117 and Riverside Cemetery in the Chase Mills area of Turner.

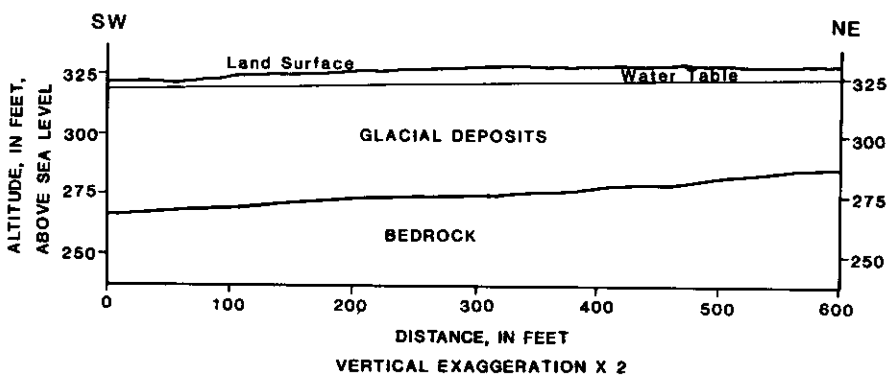

Figure 9l. Line BU-4. Buckfield 7.5' Quadrangle. Line of section south from intersection of Rt. 117 and road that trends southwest towards Lowell Cemetery, 1.2 miles west of the Buckfield/Turner town line.

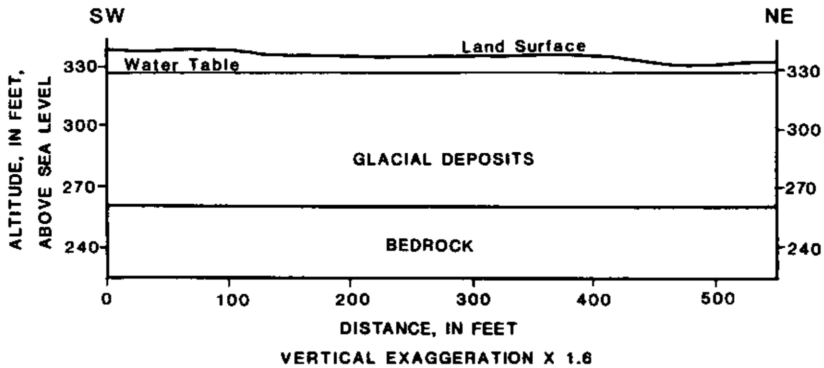

Figure 9m. Line BU-6. Buckfield 7.5' Quadrangle. Line of section in auto junkyard area on floodplain of Martin Stream, east side of Rt. 4, 0.9 miles south of the intersection of Rt. 219 and Rt. 4 in North Turner.

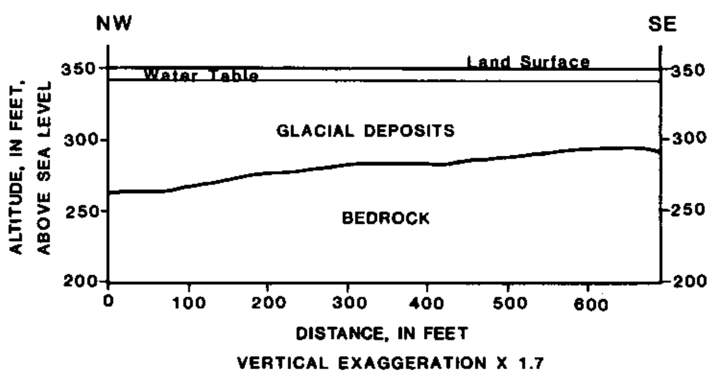

Figure 9n. Line TC-1. Turner Center 7.5' Quadrangle. Line of section on dirt road that crosses The Plains near the southern end of Pleasant Pond, in Turner. Line started 2.1 miles west of Rt. 117.

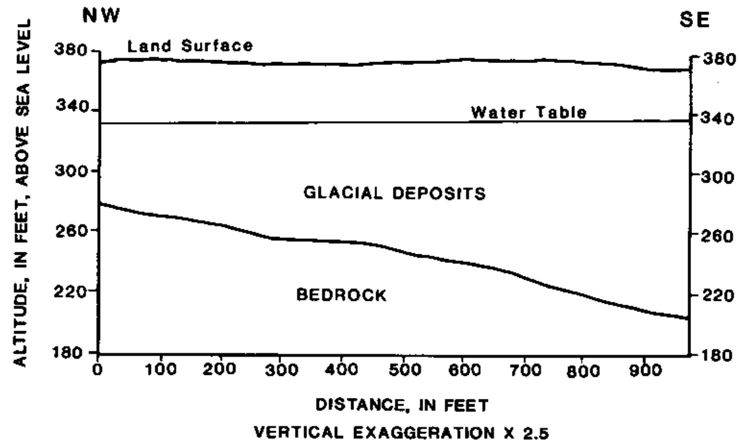

Figure 9o. Line TUC-1. Turner Center 7.5' Quadrangle. Line of section on road northeast of Monument Hill, 0.8 miles northwest of where this road intersects Rt. 106, 0.3 miles north of Leeds.

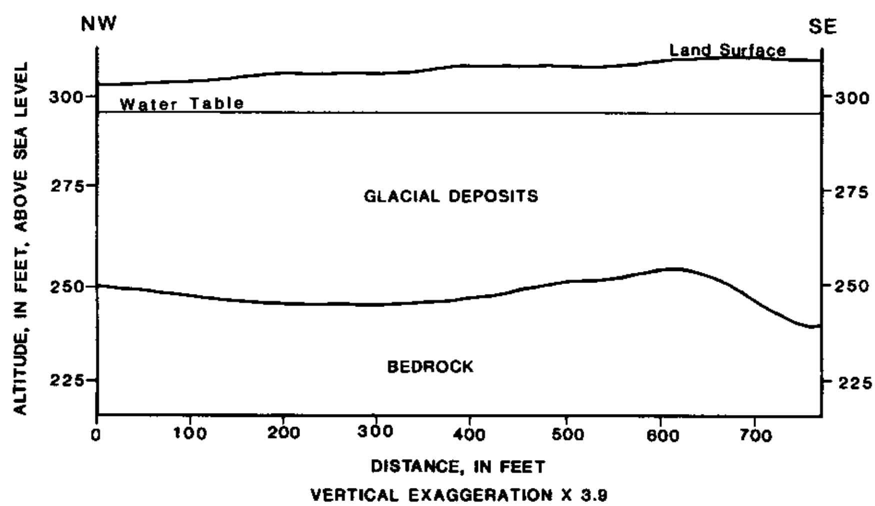

Figure 9p. Line TUC-2. Turner Center 7.5' Quadrangle. Line of section in 0.1 miles on road that intersects Rt. 106, 0.3 miles north of the intersection of Rt. 106 and Rt. 219 near the Dead River in Leeds.

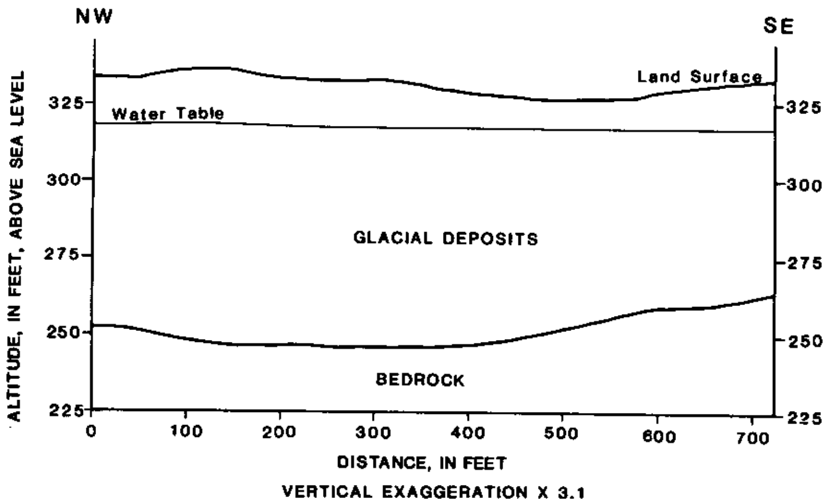

Figure 9q. Line W-1. Wayne 7.5' Quadrangle. Line of section on road connecting Rt. 202 and Rt. 106, 0.15 miles west of the Monmouth/Leeds town line, in the vicinity of Curtis Corner in Leeds.

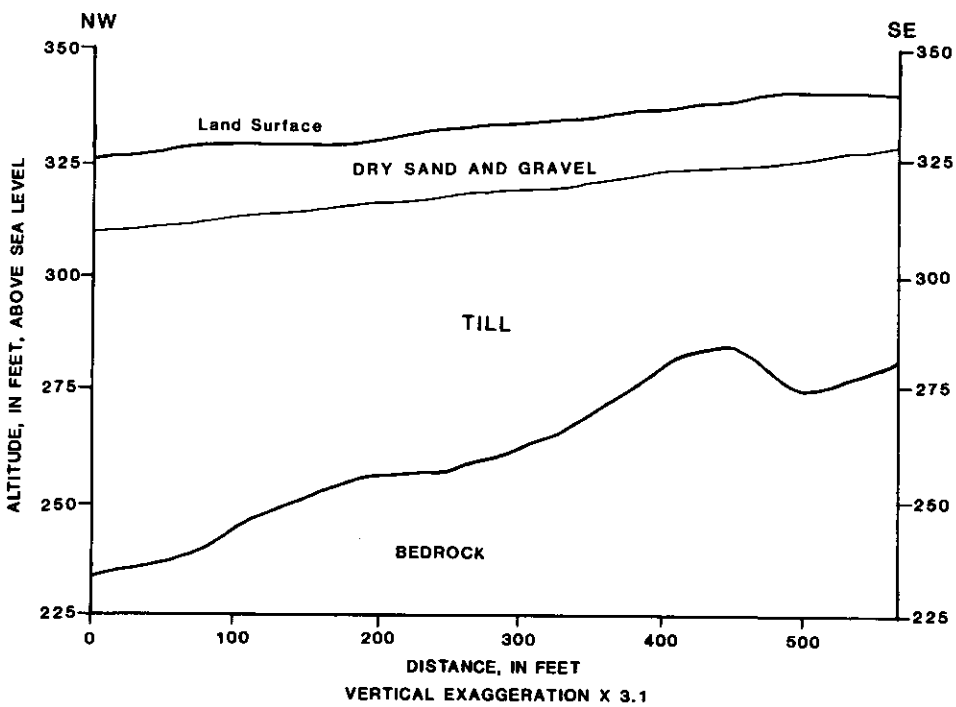

Figure 9r. Line W-2. Wayne 7.5' Quadrangle. Line of section in gravel pit off road that goes north from Rt. 106 towards Leeds, 0.7 miles northwest of Curtis Corner, in Leeds.

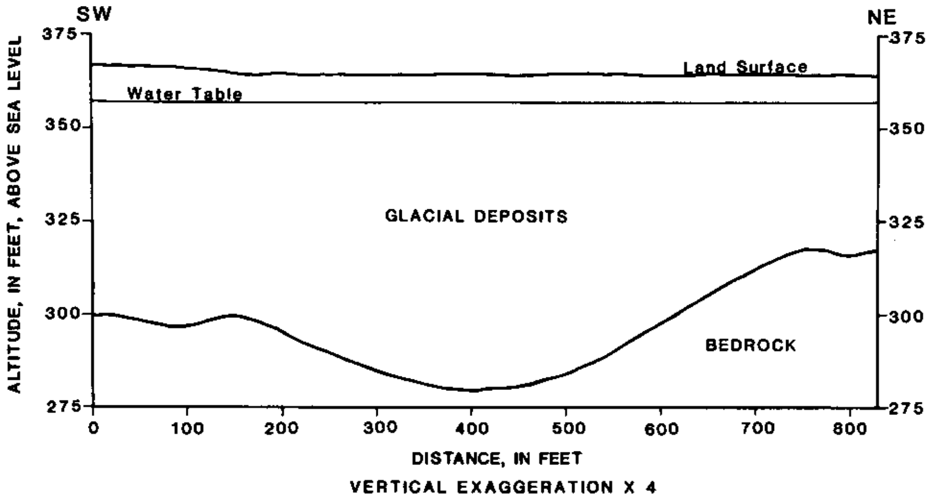

Figure 9s. Line LAW-4. Lake Auburn West 7.5' Quadrangle. Line of section 0.85 miles north of Hebron Station on old railroad grade.

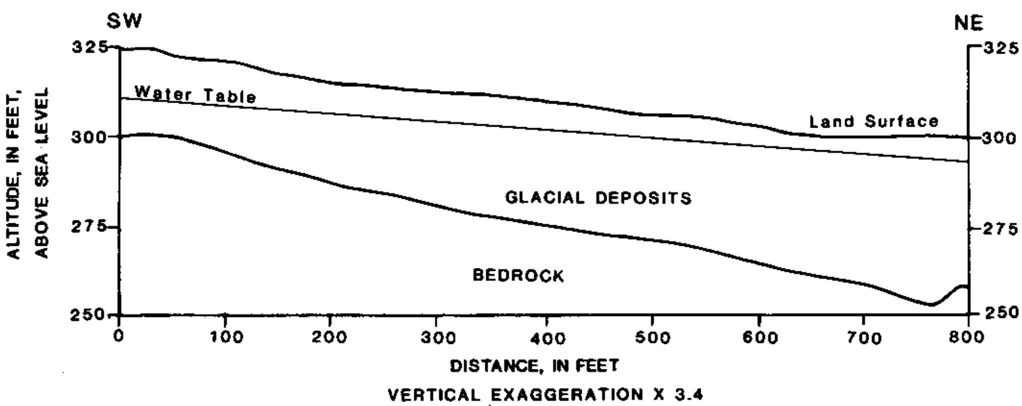

Figure 9t. Line LAW-5A. Lake Auburn West 7.5' Quadrangle. Line of section on Snell Hill Road 0.65 miles west of the intersection with Rt. 4 in Turner.

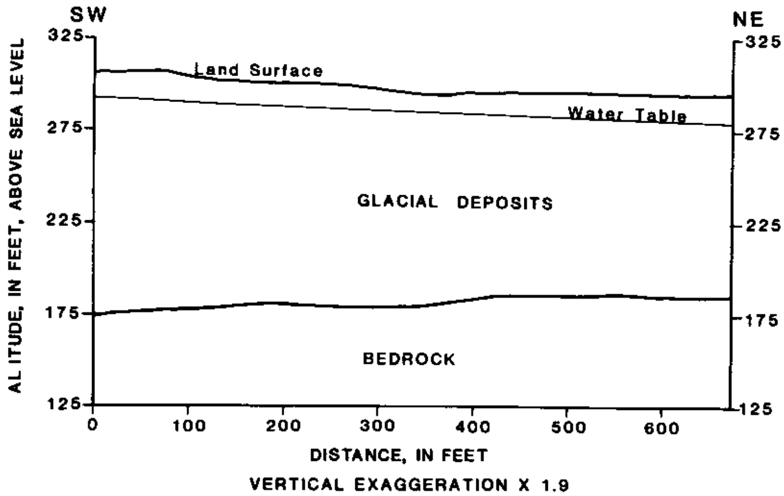

Figure 9u. Line MO-2. Monmouth 7.5' Quadrangle. Line of section on road that parallels railroad track west of Leeds Junction. Line run 0.45 miles west of the intersection of this road and Leeds Junction Road.

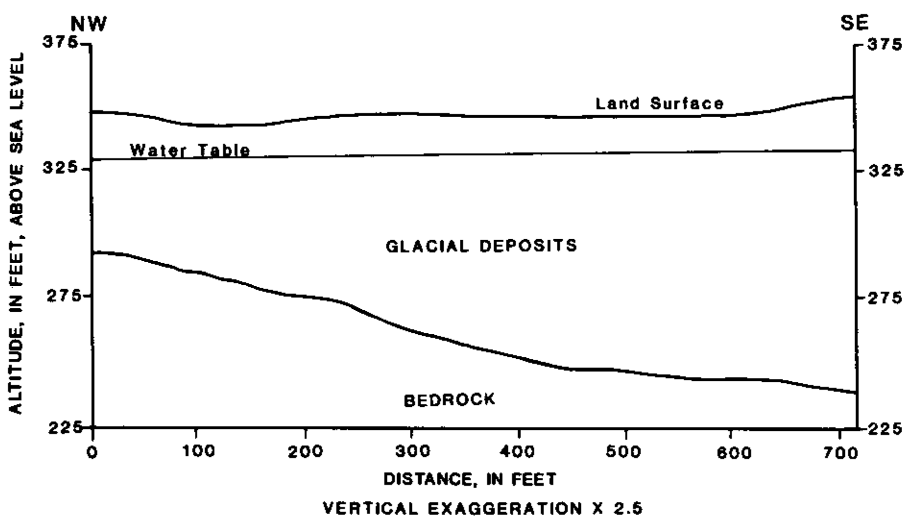

Figure 9v. Line MO-4. Monmouth 7.5' Quadrangle. Line of section in gravel pit immediately southwest of the intersection of Hartford Road and Rt. 106.

Figure 10.--12-channel seismic refraction profiles: Map 17.

Hydrogeologic sections from seismic refraction surveys conducted by the U.S. Geological Survey in 1982. Locations of individual profiles are shown on Plate 4. Interpretation of field data is based on a computer modeling program described by Scott and others (1972). Distances shown on x-axes are measured from shot #1 for all profiles.

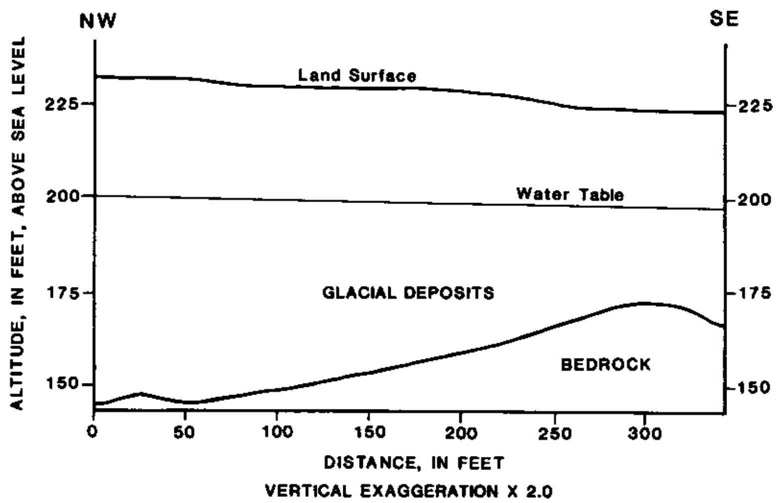

Figure 10a. Line PURG-1. Purgatory 7.5' Quadrangle. Line of section in Cyr's gravel pit, approximately 0.3 miles north of the intersection of Rt. 135 and the Tillson Road, in East Monmouth.

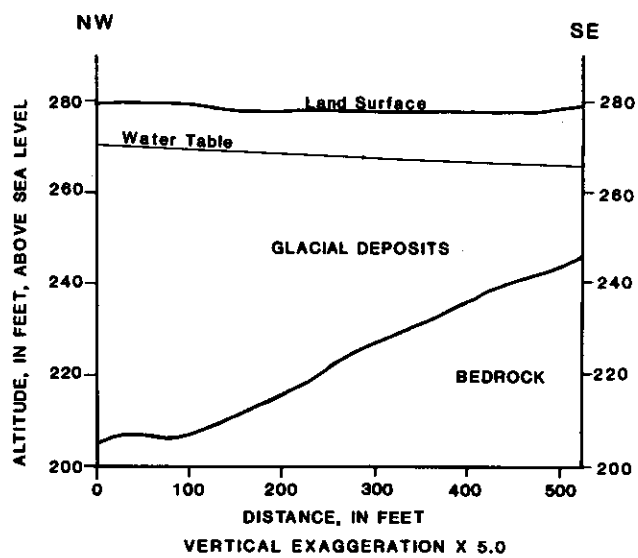

Figure 10b. Line PURG-2. Purgatory 7.5' Quadrangle. Line of section in gravel pit owned by Town of Litchfield, on east side of Hallowell Neck Road, approximately 0.4 miles north of the intersection with the Plains Road, in Litchfield.

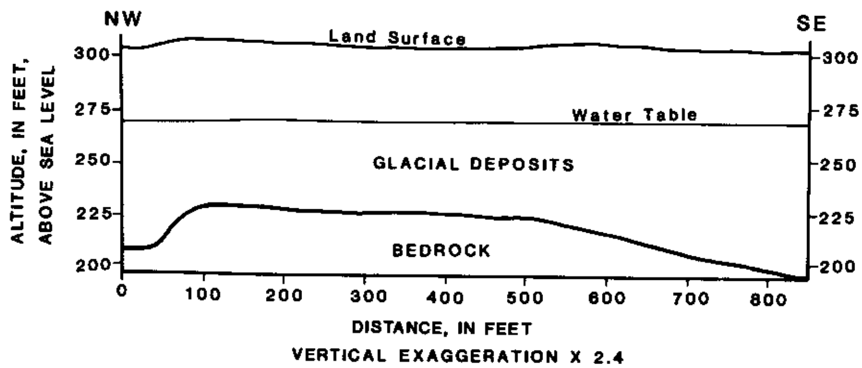

Figure 10c. Line PURG-3. Purgatory 7.5' Quadrangle. Line of section in Litchfield Fair Grounds, near intersection of Plains Road and Hallowell Neck Road, in Litchfield.

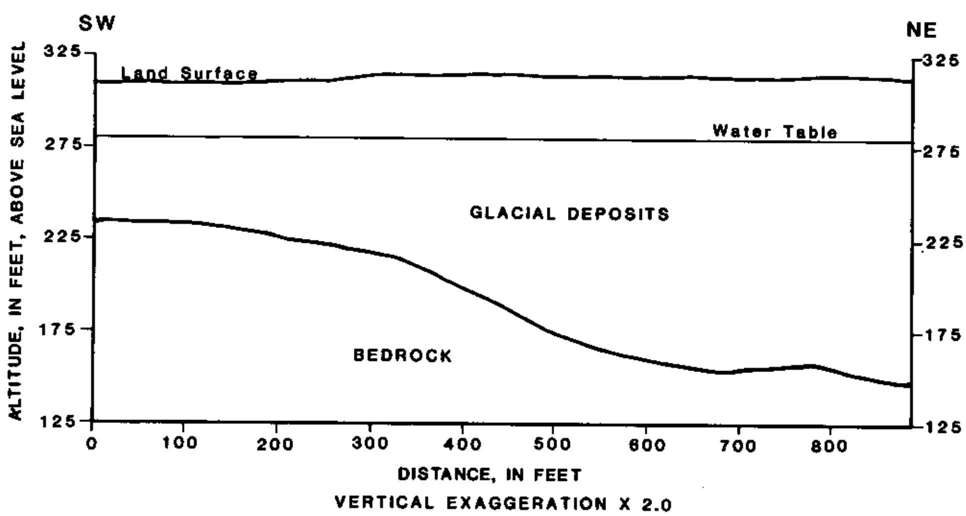

Figure 10d. Line PURG-4. Purgatory 7.5' Quadrangle. Line of section on Pine Tree Road, at intersection with Plains Road, in Litchfield.

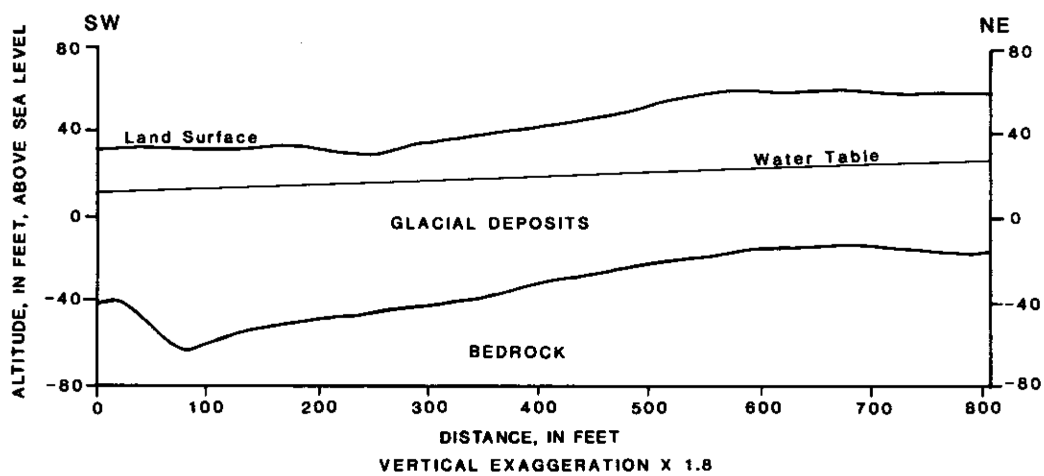

Figure 10e. Line V-1. Vassalboro 15' Quadrangle. Line of section in gravel pit adjacent to Kennebec River, in Vassalboro.

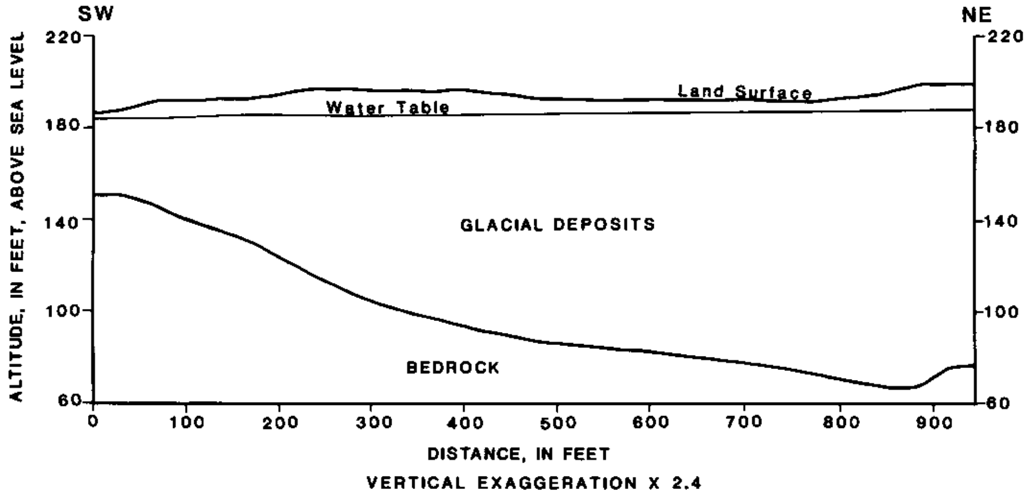

Figure 10f. Line AU-2. Augusta 7.5' Quadrangle. Line of section in field on east side of Mt. Vernon Road, 0.3 miles north of the intersection with Burns Road, in Augusta.

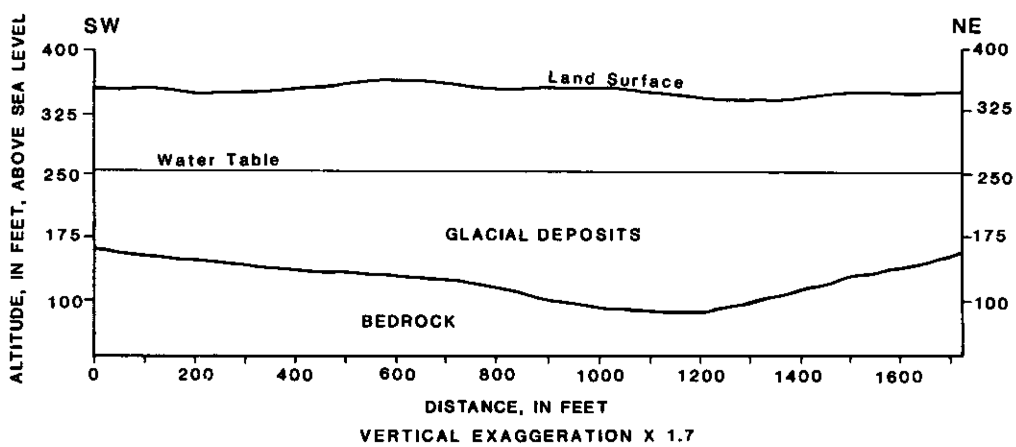

Figure 10g. Line AU-4/5. Augusta 7.5' Quadrangle. Line of section on Belgrade Road, 0.25 miles north of the intersection with Mt. Vernon Road, in Manchester.

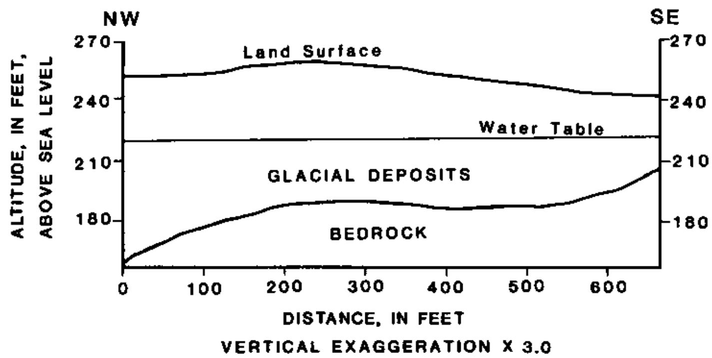

Figure 10h. Line WIN-1. Winthrop 7.5' Quadrangle. Line of section on camp road on southern shore of Annabessacook Lake, in Monmouth.

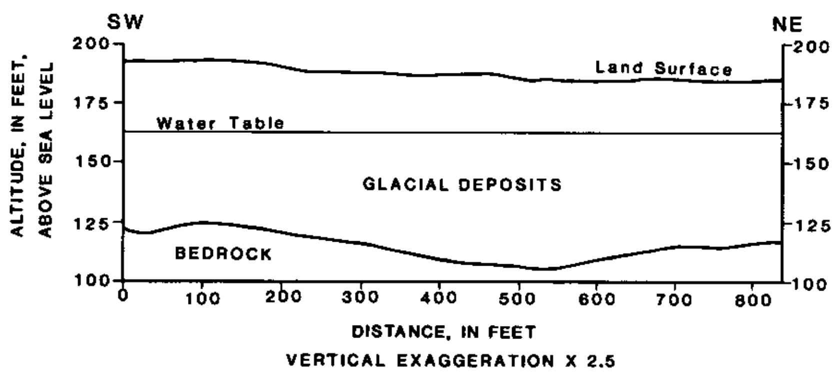

Figure 10i. Line BE-2. Belgrade 7.5' Quadrangle. Line of section in gravel pit near intersection of Penney Road and Route 27, in Belgrade.

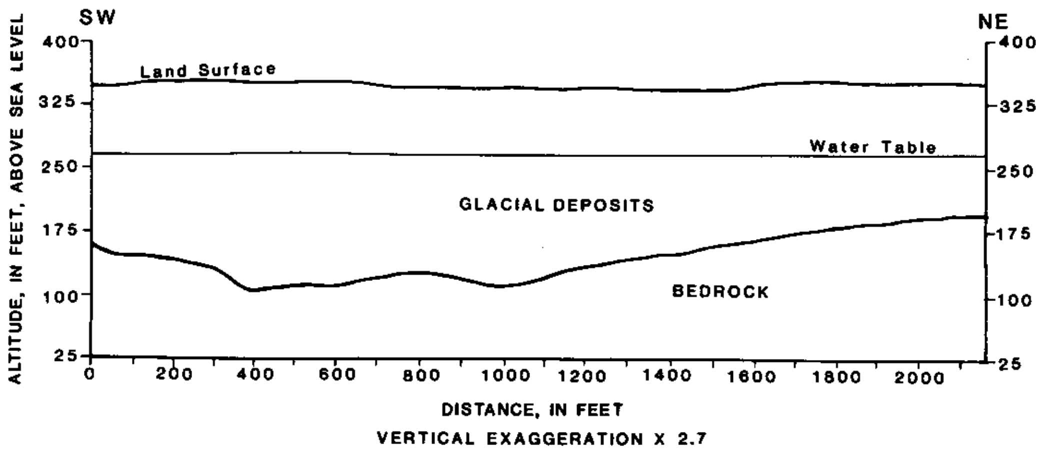

Figure 10j. Line BE-1A-C. Belgrade 7.5' Quadrangle. Line of section on Sanford Road, 0.4 miles southwest of the intersection with Summerhaven Road, in Augusta.

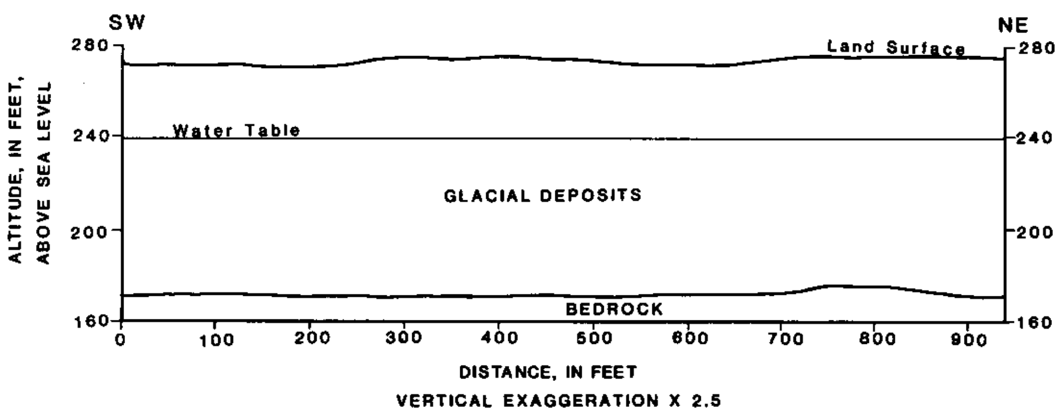

Figure 10k. Line BE-3. Belgrade 7.5' Quadrangle. Line of section on Foster Point Road, 1.3 miles north of the intersection with Route 27, in Belgrade.

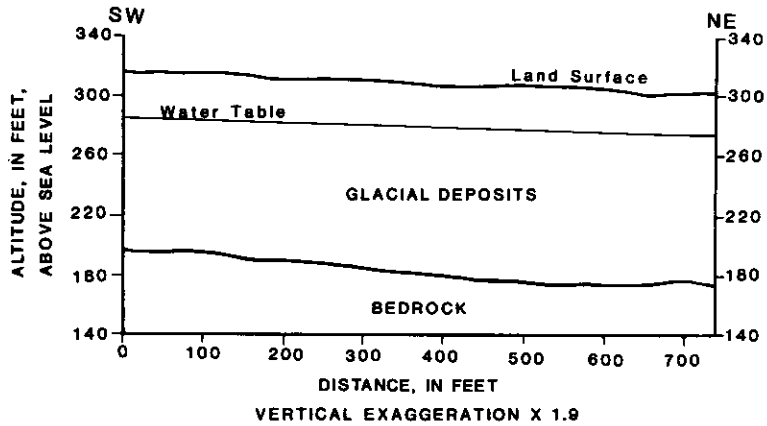

Figure 10l. Line BE-4. Belgrade 7.5' Quadrangle. Line of section on Route 135, 0.4 miles southwest of the intersection with Route 27, in Belgrade.

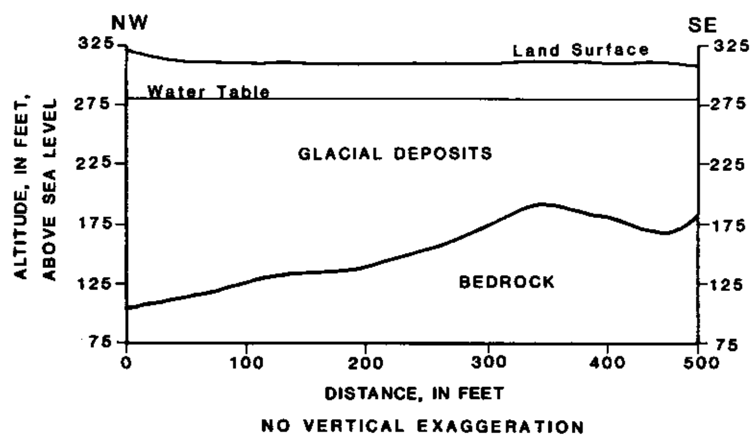

Figure 10m. Line BE-5. Belgrade 7.5' Quadrangle. Line of section in gravel pit on east side of Route 27, 0.05 miles north of the intersection with Route 135, in Belgrade.

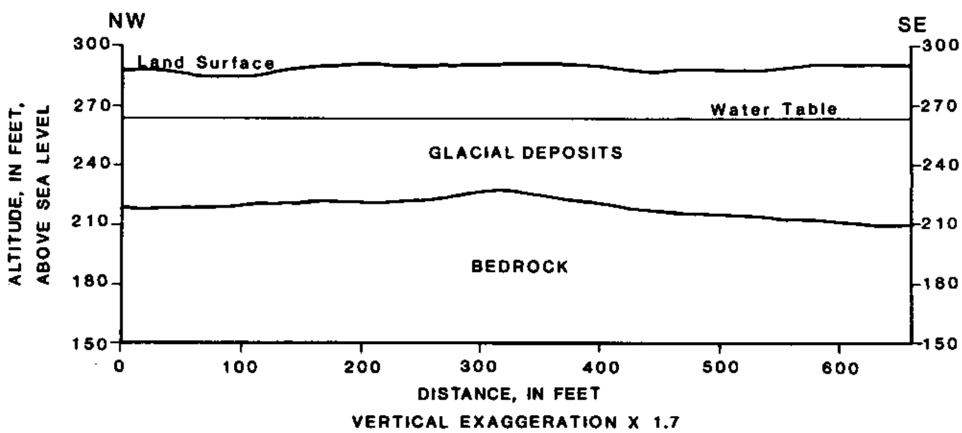

Figure 10n. Line BE-6. Belgrade 7.5' Quadrangle. Line of section in gravel pit behind Belgrade Town Office, at intersection of Route 135 and Route 27, in Belgrade.

Figure 11.--12-channel seismic refraction profiles: Map 32

Hydrogeologic sections from seismic refraction surveys conducted by the U.S. Geological Survey in 1982. Locations of individual profiles are shown on Plate 5. Interpretation of field data is based on a computer modeling program described by Scott and others (1972). Distances shown on x-axes are measured from shot #1 for all profiles.

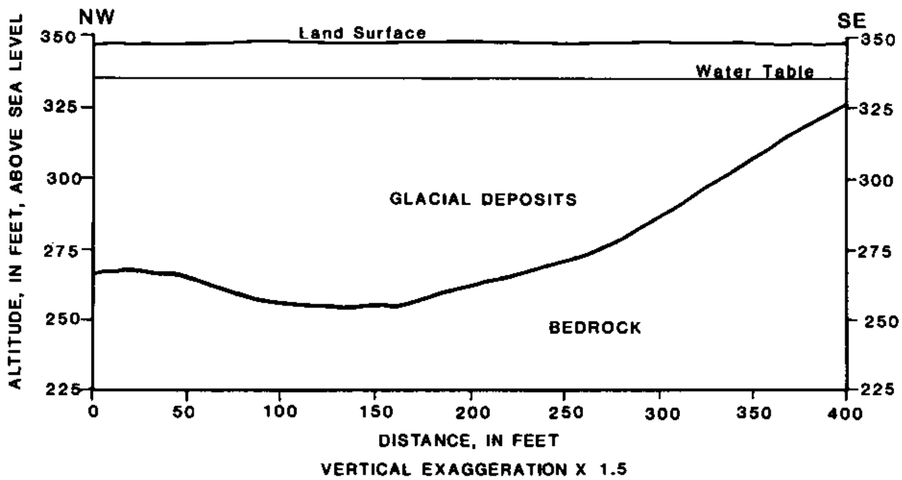

Figure 11a. Line FA-1. Farmington 7.5' Quadrangle. Line of section in gravel pit on west side of Rt. 4/27, 0.9 miles south of Fairbanks.

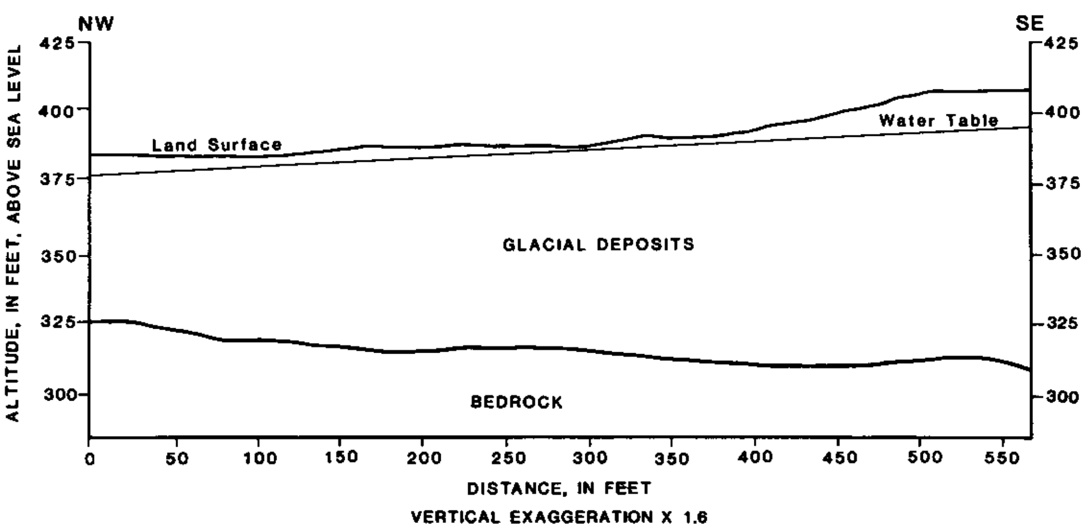

Figure 11b. Line FA-2. Farmington 7.5' Quadrangle. Line of section in gravel pit on west side of Rt. 149, 0.45 miles north of the intersection on Rt. 4 and Rt. 149, near Fairbanks.

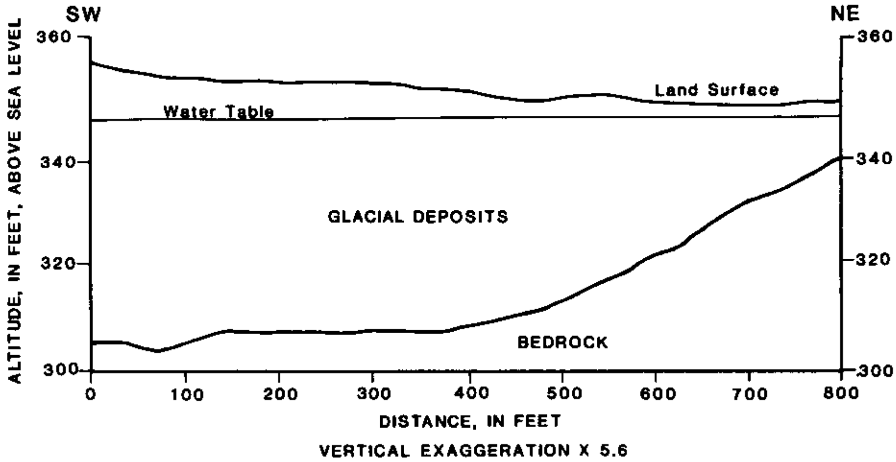

Figure 11c. Line FA-3. Farmington 7.5' Quadrangle. Line of section in gravel pit on eastern side of Town Farm Road, 1.55 miles south of the intersection of Town Farm Road and Rt. 4, near Fairbanks.

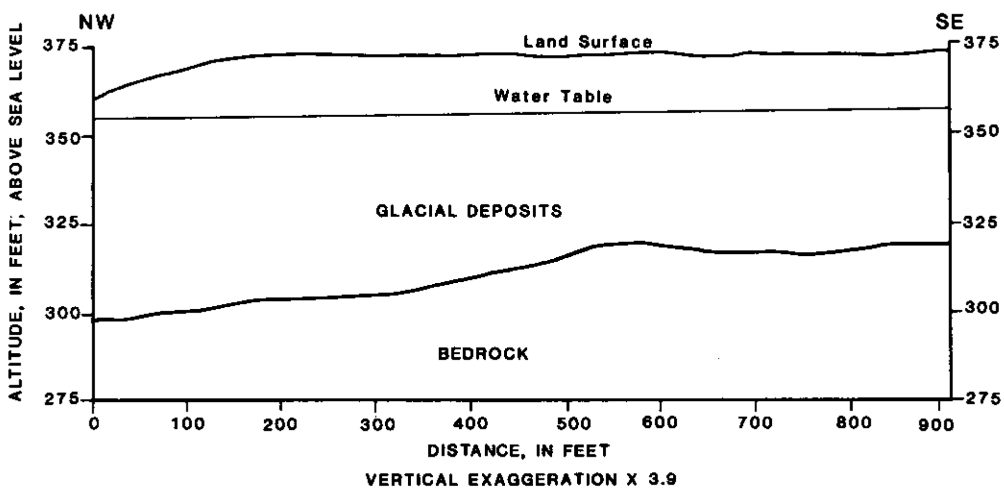

Figure 11d. Line FF-1. Farmington Falls 7.5' Quadrangle. Line of section on Heaward Road, westward from intersection of Heaward Road and Ridge Road, in Chesterville.

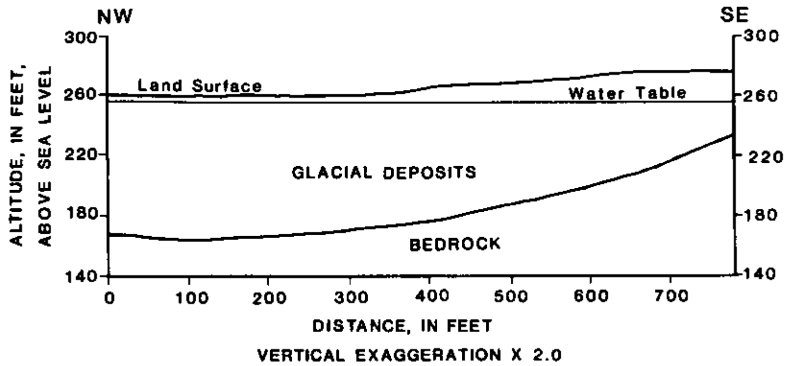

Figure 11e. Line FF-2. Farmington Falls 7.5' Quadrangle. Line of section adjacent to gravel pit on eastern side of Fellows Pond, off Ridge Road in Chesterville.

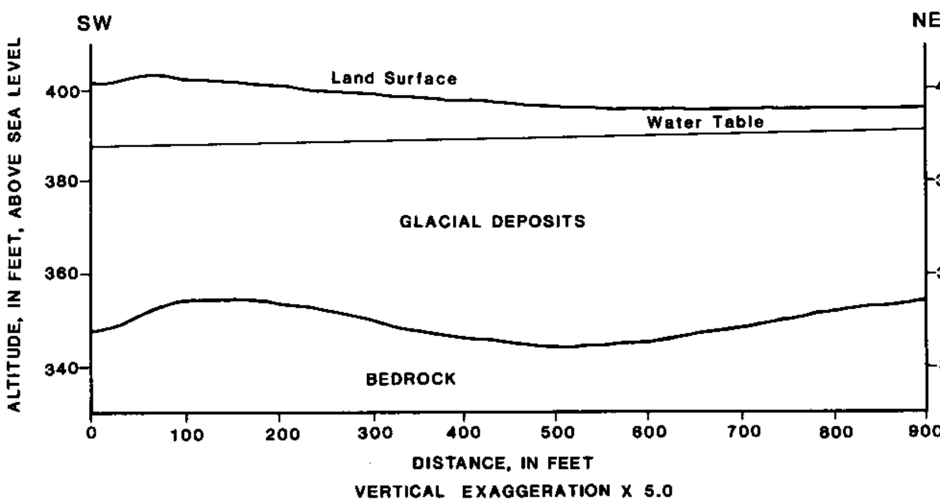

Figure 11f. Line FF-3. Farmington Falls 7.5' Quadrangle. Line of section on Adams Road, 0.45 miles east of intersection of Adams Road and Ridge Road in Chesterville.

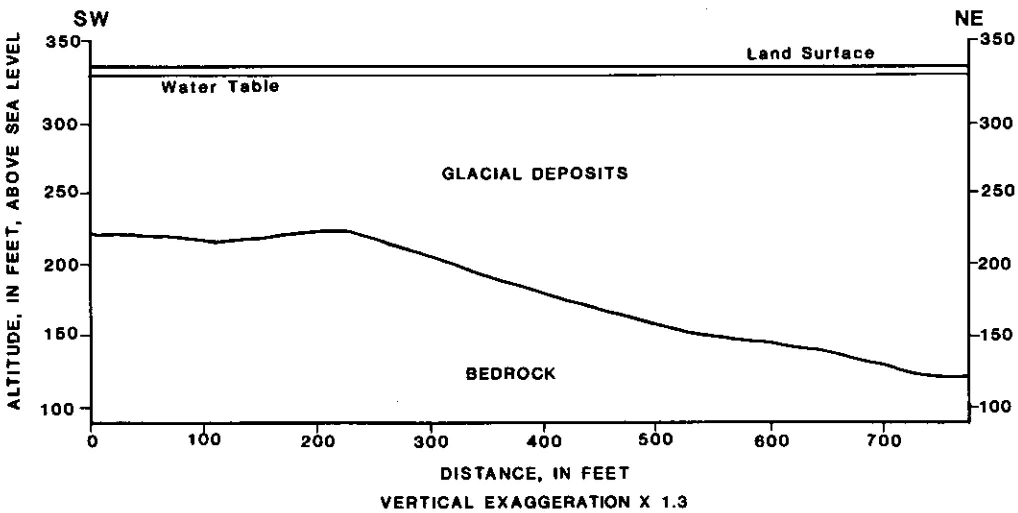

Figure 11g. Line FF-4. Farmington Falls 7.5' Quadrangle. Line of section on Rt. 156, 0.25 miles south of the intersection of Rt. 156 and Farmington Falls Road, near Farmington Falls.

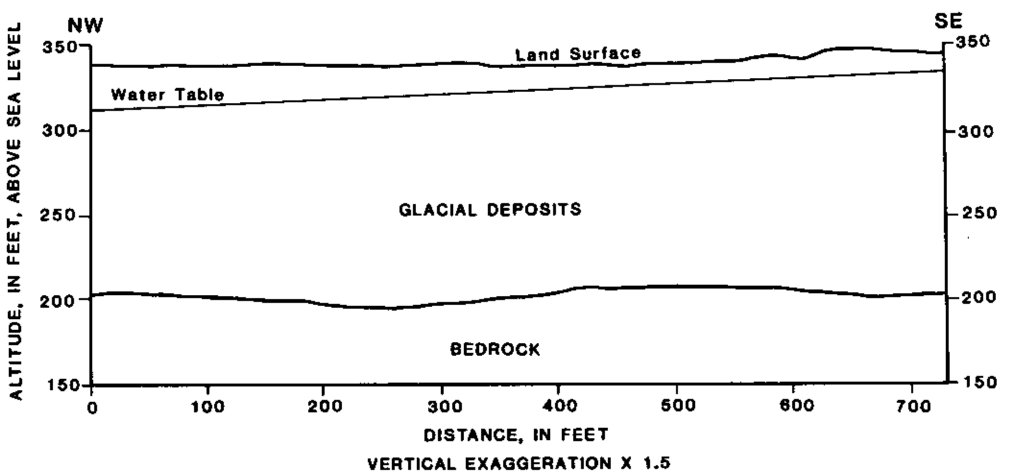

Figure 11h. Line FF-5. Farmington Falls 7.5' Quadrangle. Line of section on road to east of Farmington Falls connecting Rt. 41 and Rt. 134; line was run 1.45 miles east of the intersection of this road and Rt. 41.

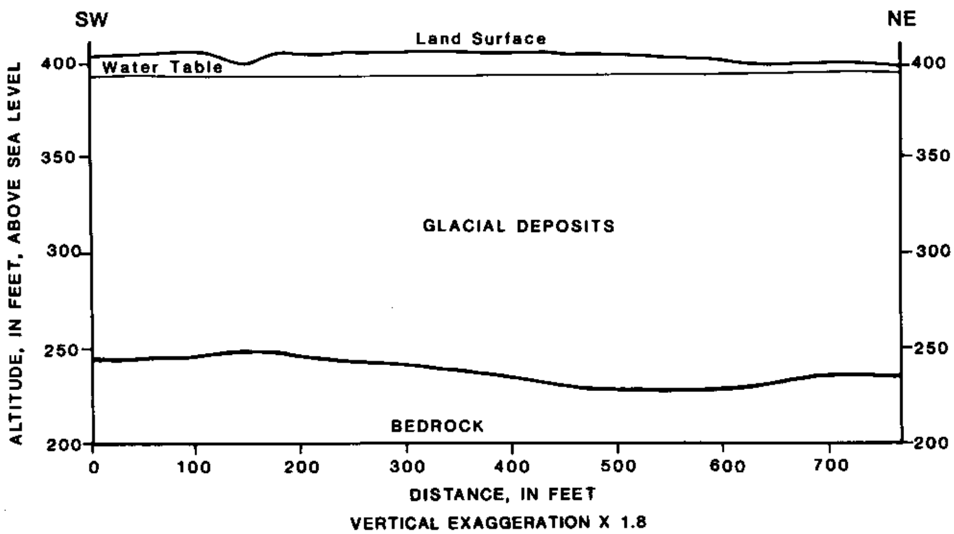

Figure 11i. Line KI-1. Kingfield 15' Quadrangle. Line of section on property of W. Hubbard, east of Rt. 4, south of Strong.

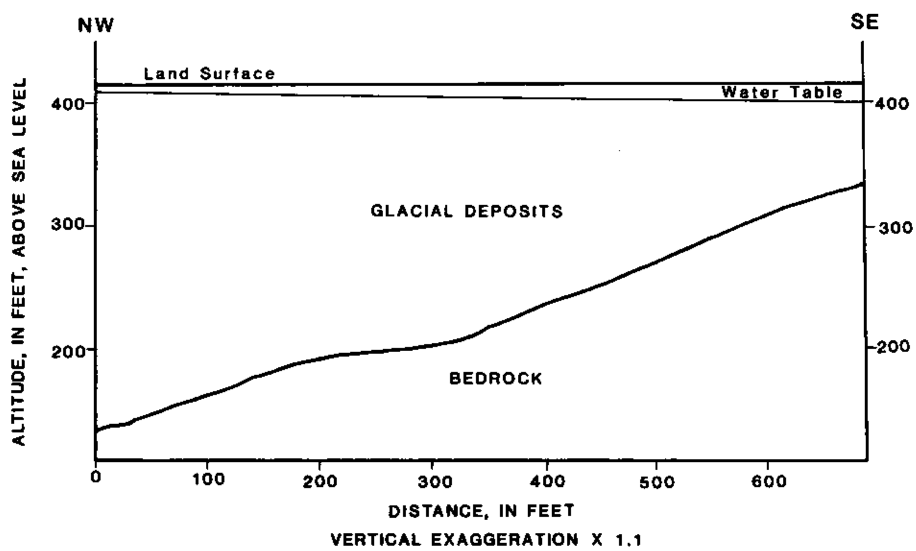

Figure 11j. Line KI-2. Kingfield 15' Quadrangle. Line of section on property of M. Richards, east of Rt. 4, south of Strong.

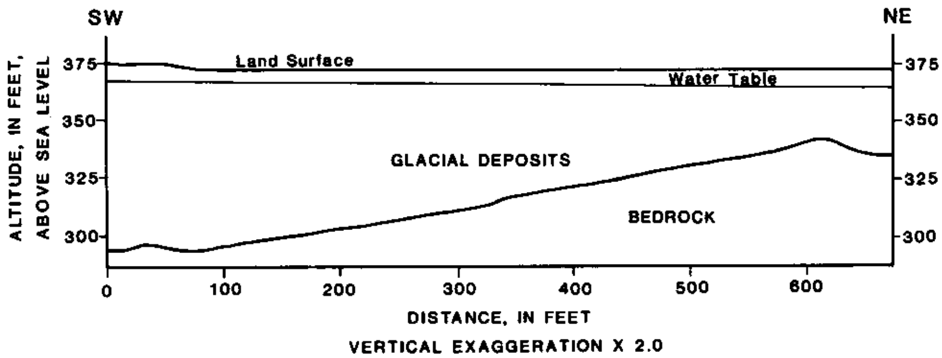

Figure 11k. Line ED-2. East Dixfield 7.5' Quadrangle. Line of section on Moss Hill Road, 0.3 miles west of the intersection of Moss Hill Road and Rt. 17, in Jay.

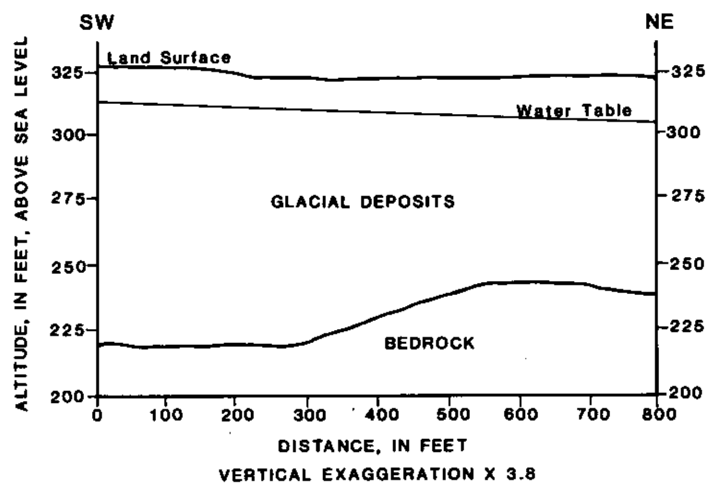

Figure 11l. Line NS-1. New Sharon 7.5' Quadrangle. Line of section on property of R. Davis, on south side of Rt. 27, near New Sharon.

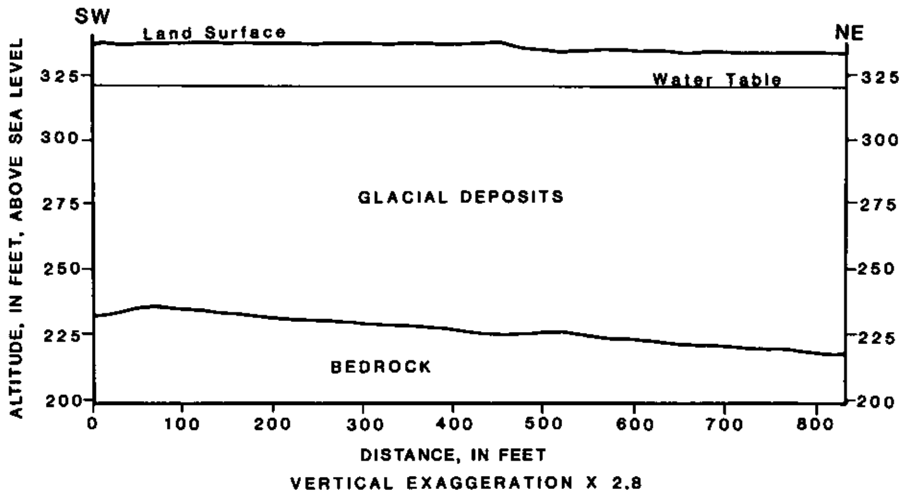

Figure 11m. Line NS-2. New Sharon 7.5' Quadrangle. Line of section on property of E. Lindberg, south side of Rt. 27, near Gower Cemetery in Farmington.

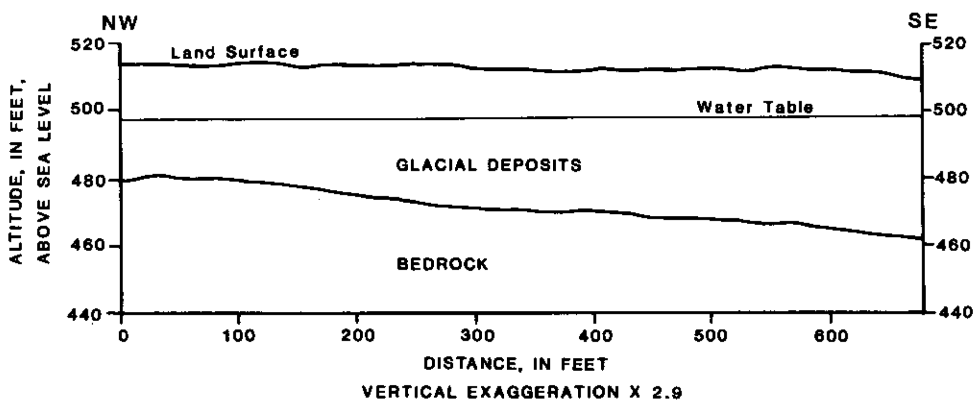

Figure 11n. Line PH-2. Phillips 15' Quadrangle. Line of section on property of T. Masterman, on west side of Rt. 149, southeast of Phillips.

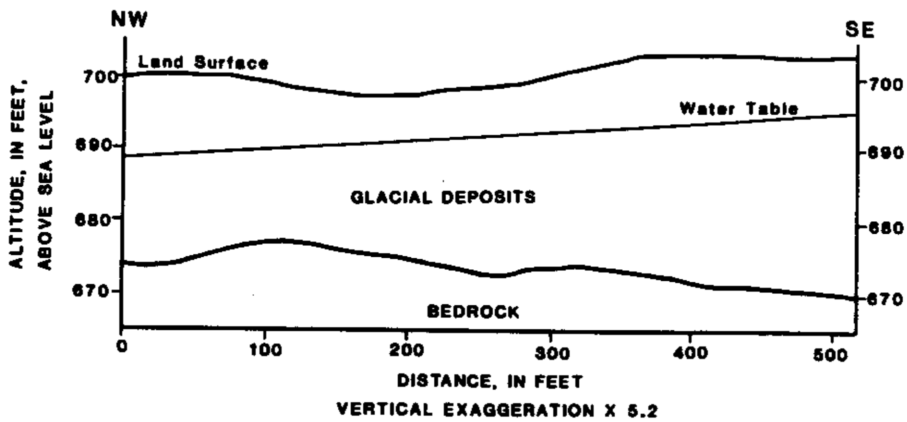

Figure 11o. Line PH-3. Phillips 15' Quadrangle. Line of section on property of R. Bredeau, on east side of Davenport Flats Road, in Phillips.