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Hydrogeology and Water Quality of Significant Sand and Gravel Aquifers

in parts of Aroostook, Hancock, Penobscot, Piscataquis, and Waldo Counties, Maine

by

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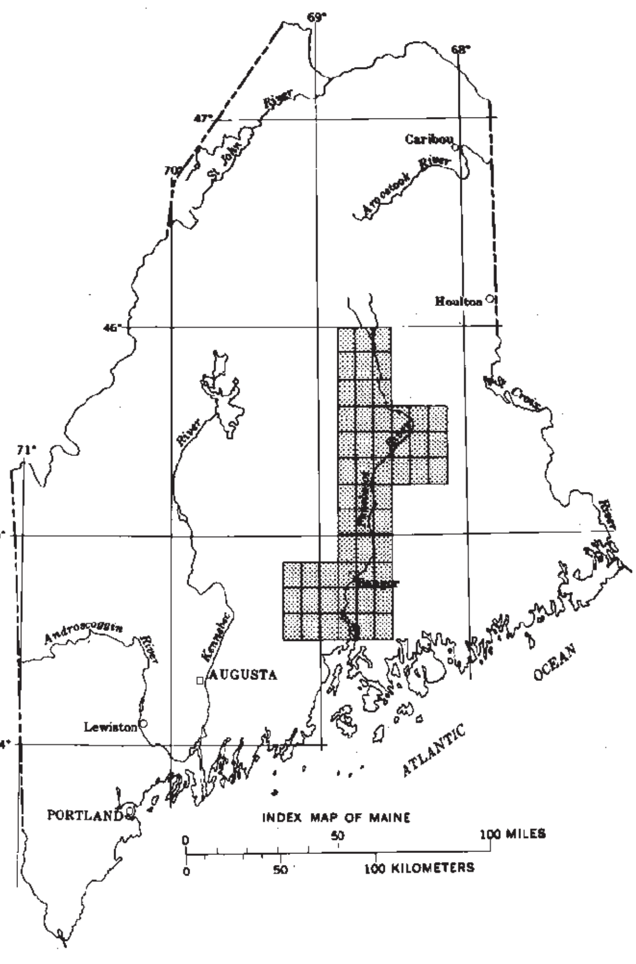

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CONTENTS

ASSOCIATED MAPS

(Available separately)

Significant sand and gravel aquifers maps associated with this report are available for the following quadrangles:

Quadrangle Name	Open-File No.
Bangor	92-3
Branch Lake	92-4
Brewer Lake	92-5
Brooks East	92-6
Brooks West	92-7
Bucksport	92-8
Carmel	92-9
Cedar Lake	92-10
Chemo Pond	92-11
Deasey Mountain	92-12
Dixmont	92-13
East Dixmont	92-14
East Millinocket	92-15
East Winn	92-16
Endless Lake	92-17
Green Lake	92-18
Greenbush	92-19
Hampden	92-20
Hardy Pond	92-21
Hermon	92-22
Howland	92-23
Katahdin Lake	92-24
Kingman	92-25
Lagrange	92-26
Lee	92-27
Lincoln Center	92-28

Quadrangle Name	Open-File No.
Lincoln West	92-29
Lookout Mountain	92-30
Mattamiscontis Mountain	92-31
Mattaseunk Lake	92-32
Mattawamkeag Lake	92-33
Medunkeunk Lake	92-34
Millinocket	92-35
Mount Waldo	92-36
Nine Meadow Ridge	92-37
Nollesemic Lake	92-38
Olamon	92-39
Old Town	92-40
Orland	92-41
Otter Chain Ponds	92-42
Passadumkeag	92-43
Plymouth	92-44
Pushaw Lake	92-45
Seboeis	92-46
Snow Mountain	92-47
South Lagrange	92-48
Springfield	92-49
Stacyville	92-50
Trout Mountain	92-51
Veazie	92-52
Weir Pond	92-53
Whetstone Mountain	92-54

ILLUSTRATIONS

TABLES

APPENDICES

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
	Length	
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
area(mi^2)	2.590	square kilometer (km^2)
	Velocity	
foot per second (ft/s)	0.3048	meter per second (m/s)
foot per day (ft/d)	0.3048	meter per day (m/d)
	Flow	
gallon per minute (gal/min)	0.06308	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	Transmissivity	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

OTHER ABBREVIATIONS USED IN THIS REPORT

S/cm, microsiemens per centimeter at 25 degrees Celsius
mg/L, milligrams per liter
g/L, micrograms per liter
Temperatures in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows: °F = 1.8° C + 32

Chemical concentrations and water temperature are given in metric units. Chemical concentration is given in milligrams per liter or micrograms per liter. Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water; 1,000 g/L (micrograms per liter) is equivalent to 1 mg/L (milligram per liter). For concentrations less than 7,000 mg/L, the numerical values are the same as concentrations in parts per million.

Specific-conductance data are reported in S/cm (microsiemens per centimeter at 25 degrees Celsius). Identical units are used for this analysis in the inch-pound and metric systems of measurement.

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, formerly called Sea Level Datum of 1929.

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ABSTRACT

A reconnaissance-level hydrogeologic study was made of 2,843 square miles in Aroostook, Hancock, Penobscot, Piscataquis, and Waldo Counties in Maine. Maps 28, 29, 41, 49, 50, and 61 of the Sand and Gravel Aquifer Map Series published by the Maine Geological Survey cover the study area. The significant sand and gravel aquifers consist of glacial ice-contact, ice stagnation, outwash, and alluvial deposits found primarily in the valleys of the major river systems and their tributaries and near other surface-water bodies. By definition, significant aquifers are capable of yielding more than 10 gallons per minute to a properly constructed well. Significant aquifers comprise approximately 84.6 square miles (3 percent) of the study area; well yields estimated to exceed 50 gallons per minute are believed to be available from only 3.1 square miles (less than 1 percent) of this area. Typically, the water table is within 15 feet of land surface. On the basis of well records, the greatest known depth to bedrock is 190 feet in a domestic well in Alton. According to seismic-refraction data, the greatest depth to bedrock is approximately 168 feet. The greatest known well yield is approximately 900 gallons per minute from a gravel-packed well operated by the Orono Water District. The regional ground-water quality ranges from acidic to quite basic; silica, calcium, and sodium are the most abundant cations; bicarbonate is the most abundant anion; and the water generally is soft. In some locations, concentrations of iron and manganese are large enough to limit the suitability of untreated water for some uses.

INTRODUCTION

Significant sand and gravel aquifers are the primary ground-water source for satisfying the needs of municipalities and industry throughout Maine. They also are a major source of water for domestic wells and may provide recharge to the underlying fractured-bedrock aquifer. The term “aquifer” has various connotations, but may best be defined as a “geologic deposit that yields useful quantities of ground water to wells and springs” (Caswell, 1987). The Maine State Legislature (38 MRSA Chapter 3, Section 403) defines a significant aquifer as one which is capable of producing 10 gal/min (gallons per minute) or more to a properly constructed well.

In recognition of the value of significant sand and gravel aquifers, the Maine State Legislature has adopted a number of provisions that restrict the siting of activities that may discharge contaminants to the aquifers. Many local governments and planning boards have passed zoning ordinances to protect the significant sand and gravel aquifers. To assist local and State governments in developing aquifer-protection laws and ordinances, the Maine Geological Survey (MGS), in cooperation with the U.S. Geological Survey (USGS) and with financial cooperation from the Maine Department of Environmental Protection (MDEP), has carried out reconnaissance investigations of sand and gravel aquifers throughout much of the State. These investigations, conducted during 1978-80, resulted in the production of 59 maps at a scale of 1:50,000 that delineate approximate aquifer boundaries, potential well yields, and potential point sources of contamination.

These original sand and gravel aquifer maps provide a valuable source of information, but are limited in accuracy because of the large area mapped in a short period of time. Also, the maps contain little information on aquifer thickness and stratigraphy and no information on water quality. To correct these shortcomings, the Maine State Legislature directed the MDEP and MGS to update the sand and gravel aquifer maps to provide additional information on depth to bedrock, depth to water table, stratigraphy, and water quality (38 MRSA Chapter 3, Section 403). In 1979, the Legislature instructed the MDEP and MGS to delineate all significant sand and gravel aquifers. These new maps are referred to as Significant Sand and Gravel Aquifer Maps.

A cooperative, detailed aquifer-mapping project was initiated in June 1981 by the MGS, USGS, and the MDEP to satisfy the demand for more accurate, complete, and current hydrogeologic information concerning sand and gravel aquifers in Maine. The mapping first was conducted in densely populated and rapidly developing areas and subsequently has been extended to other areas of the State (Tolman and others, 1983; Tepper and others, 1985; Williams and others, 1987; Adamik and others, 1987; Weddle and others, 1988; Locke and others, 1989). The study area locations for the Significant Aquifers Project are shown in Figure 1. Significant Sand and Gravel Aquifer Maps for the 1981-86 study areas were published at a scale of 1:50,000. Beginning with this (the 1987-88) study area and for subsequent years, Significant Sand and Gravel Aquifer Maps for the study areas designated on Figure 1 will be published at a scale of 1:24,000.

This report presents the results from the seventh and eighth years of the mapping project (1987-88 field seasons) and updates the Sand and Gravel Aquifer Map Series for maps 28, 29, 41, 49, 50, and 61. These maps have been modified locally on the basis of new data, are compiled onto 1:24,000 scale topographic base maps, and are available separately. The maps can be used as a base for detailed hydrogeological siting studies and planning. Furthermore, they provide a variety of information on aquifer favorability and vulnerability, as well as a preliminary estimate of well yield in certain areas.

Purpose and Scope

The purpose of this report is to describe the physical characteristics of sand and gravel aquifers in the area covered by Sand and Gravel Aquifer Maps 28, 29, 41, 49, 50, and 61 in parts of Aroostook, Hancock, Penobscot, Piscataquis, and Waldo Counties, Maine. A secondary objective is to describe the water quality in the aquifers and to identify areas where development may be limited by unsuitable water quality or by the presence of possible sources of contamination.

The scope of the investigation included —

(1) surficial geologic mapping to define the boundaries of the glacial deposits;

(2) presentation of supplemental information about the glacial geology of the area;

(3) seismic-refraction investigations to determine the depth to water, depth to bedrock, and bedrock-surface topography;

(4) a well inventory to supplement existing data on the depth to water, depth to bedrock, and well yields;

(5) observation-well and test-boring drilling to determine aquifer stratigraphy, thickness, and grain size (used to estimate transmissivity);

(6) water-quality sampling and analysis to characterize the regional ground-water chemistry;

(7) identification of potential sources of ground-water contamination, and

(8) location of municipal-well fields.

Previous Investigations

Surficial and bedrock geologic mapping conducted in the study area provided information on bedrock outcrops and the areal extent of sand and gravel deposits (Borns, 1981; Borns and Thompson, 1981; Borns and others, 1981; Caldwell and others, 1982; Genes and Newman, 1986; Griffin, 1971 a-c, 1976 a-e; Hanson, 1986; Holland, 1981, 1986 a,b; Kenoyer, 1979; Lowell, 1980; Ludman, 1985; Newman, 1980, 1981, 1986; Newman and Genes, 1986; Newman and Holland, 1981, 1986; Pankiwskyj, 1976; Roy, 1981; Smith and Thompson, 1986 a,b; Thompson, 1977; Thompson and others, 1982). General geologic relations are presented on the bedrock and surficial geologic maps of Maine (Osberg and others, 1985; Thompson and Borns, 1985). Prescott, 1964, 1966, published additional information on surficial geology, well depth, yield, ground-water levels, stratigraphy, estimated yield zones, and water quality. Prescott's reports were used as a basis for Sand and Gravel Aquifer Maps 28, 29, 41, 49, 50, and 61 (Tolman and Lanctot, 1981 a-f).

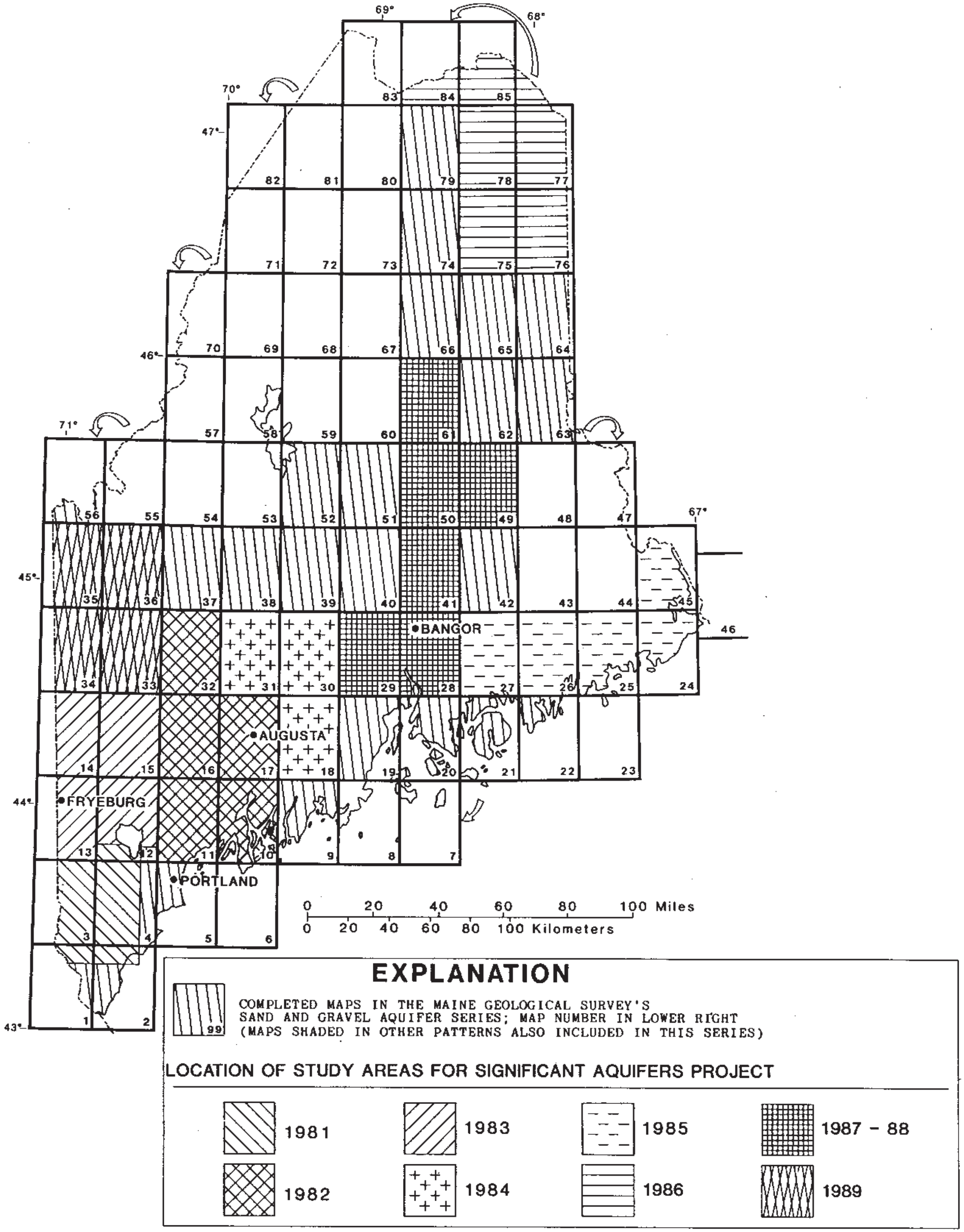

Figure 1.—Location of study areas for the significant aquifers project and index to sand and gravel aquifer map series.

METHODS OF STUDY

Approach

The methodology of this investigation included —

(1) recompilation of all existing hydrogeologic data from each 1:50,000-scale map onto 1:24,000-scale maps;

(2) collection of information on existing domestic, municipal, and monitoring wells, boring logs, and test pits;

(3) identification of sites of potential ground-water contamination;

(4) verification of the original sand and gravel aquifer map boundaries by re-mapping surficial deposits;

(6) seismic-refraction surveys;

(7) test borings and observation-well installation;

(8) development and water-quality sampling of wells;

(9) monthly water-level measurements; and

(10) compilation of all data on 1:24,000-scale maps.

Details concerning several of these steps are given below.

Identification of Sites of Potential Ground-Water Contamination

Potential ground-water contamination sites located on or near significant aquifers are shown on the associated maps[1]. These sites were identified primarily from files of the MDEP Bureaus of Land Quality Control, Water Quality Control, and Oil and Hazardous Materials Control. The locations of State-owned salt and salt-sand storage lots were determined from Maine Department of Transportation records.

The sites shown on the maps include waste-disposal areas and salt-sand storage piles. Sources of potential ground-water contamination not shown include septic systems, road de-icing activities, fertilized fields, pesticides use, underground fuel storage tanks, small-quantity generators of hazardous wastes, and other agricultural, industrial, or commercial sites.

Surficial Mapping Techniques

The aquifers were mapped by field determination of boundaries between significant sand and gravel deposits and materials such as compact till or bedrock outcrops. All known borrow pits and other exposures of sand and gravel deposits were examined, with particular attention to the thickness and texture of the deposits, and to any water in the pit. Shovel and auger holes were used to identify surficial materials in areas where exposures were lacking. Off-road areas were mapped by foot traverse and examination of aerial photographs.

In compiling the boundaries of the significant aquifers shown on the associated maps, some land-surface contacts between aquifers and surrounding materials were shifted slightly into the aquifers to indicate that the tapering margins of some aquifers are unlikely to yield 10 gal/min or more. Many pit exposures within the mapped aquifers do not intersect the water table, and the pit floors are dry. In these cases, the aquifer was mapped on the basis of the known or inferred saturated thickness, and confirmed where possible by well, boring, or seismic data. The boundaries of the aquifer deposits are shown as solid lines where data substantiate the contacts, and are shown dashed where data are sparse.

Seismic-Refraction Surveys

Seismic-refraction techniques were used to obtain profiles showing the depth to water table, depth to bedrock, and topography of the bedrock surface. In seismic exploration, seismic waves are generated at the surface by a small explosion or hammer blows. The waves travel at different velocities through different materials—the denser the material, the faster the wave velocity. If the generalized geology of an area is known, the velocity of seismic waves through a material can be used to characterize its composition. In this study, seismic refraction was used to distinguish between dry sand and gravel, saturated sand and gravel, and bedrock. To permit these distinctions, the seismic velocity must increase with depth and there must be a significant velocity contrast between layers.

A 12-channel, EG&G Geometrics Nimbus ES-1210F seismograph[2] was used to determine saturated thickness and bedrock surface topography in areas where the depth to bedrock was estimated to be more than 75 ft (feet). The seismic lines varied from 450 to 1,375 ft long. Elevations of the shot points and geophones were surveyed where land surface relief exceeded 5 ft 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 and bedrock surface beneath each line. Wherever possible, data from any nearby private wells and project borings were used to verify seismic results. In total, eighty-nine 12-channel lines were run (59,572 ft). Forty-two of these lines (27,372 ft) provided reliable data for interpretation.

Single-channel Soiltest MD9A, MD11, or EG&G ES 125 seismographs were used in areas where the depth to bedrock was estimated to be less than 75 ft. Information was obtained on depth to water table, depth to bedrock, and dip of the bedrock surface between the ends of each line. The single-channel seismic lines varied from 80 to 240 ft long. Data were analyzed and interpreted according to methods developed by Mooney (1980) and Zohdy and others (1974). In total, 365 single-channel lines

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[1] The use of industrial firm or local town names in this report and on the maps is for location purposes only, and does not impute responsibility for any present or potential effects on natural resources.

2 Use of trade names in this report is for descriptive purposes only and does not constitute endorsement by the Maine Geological Survey, the U. S. Geological Survey, or the Maine Department of Environmental Protection.

were run (48,910 ft), and 68 of these lines (9,440 ft) provided reliable data.

Drilling and Stratigraphic-Logging Methods

Thirty-four borings were made to determine the thickness of deposits, to collect sediment samples, and to verify depth to water table and bedrock as determined from seismic data. For the purpose of this report, the term "test boring" (TB) refers to a boring that was backfilled after test information was obtained. The term "observation well" (OW) refers to a boring where a monitoring well was installed. Borings are identified first by the appropriate OW or TB designation, followed by a number corresponding to the year in which it was drilled, and concluding with a sequential number in the order in which the borings were drilled. The observation wells were used to obtain water levels and water-quality samples during the period of investigation.

A 6-inch-diameter hollow-stem auger rig was used for drilling. Overburden material penetrated above the water table was 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 undisturbed sediment samples ahead of the drill stem. Samples were collected according to guidelines established by the Federal Interagency Work Group (1977, Chap. 2). Thirty-three borings were drilled to refusal, which occurred when either bedrock, compact sediments, or sediments containing cobbles larger than 6 inches were encountered. One boring was terminated before reaching refusal because the material drilled was beyond the capabilities of the drill equipment. Stratigraphic logs and screened intervals of observation wells are presented in Appendix 1 (at end of report).

Observation-Well Installation and Development

Sixteen borings were cased with 2-inch inside-diameter, schedule 40 PVC (polyvinyl chloride) pipe to collect water samples and to measure water levels. PVC screens with slot widths of 0.006 to 0.010 in. were used. Casing sections were connected either with couplings, fastened with 3/8-inch zinc-plated steel sheet-metal screws, or, if flush threaded casing pipe was used, simply screwed together. The casing and screen were placed inside the hollow stem auger, and the boring was allowed to collapse around the casing as the drill stem was withdrawn. Bentonite pellets were backfilled from 1 ft below ground surface to the ground surface to prevent water from infiltrating directly around the casing.

At most sites, immediately after the casing was installed, water was bailed from the observation well to aid well development. All observation wells were thoroughly developed 2 to 3 weeks after installation by surging and pumping with compressed air, using the well casing as an air-lift pump shaft, and removing at least 10 well volumes of water from each well. This procedure removed the fine materials from the screen and developed the hydraulic connection with the aquifer.

Procedures for Water-Quality Sampling and Analysis

Fifteen observation wells and two municipal wells were sampled to determine water quality. To ensure that water samples were representative of the geochemical environment, the observation wells were pumped with an ISCO model 2600 bladder pump or a Fultz model SP-202 positive-displacement pump or bailed with a PVC bailer until the pH, temperature, and specific conductance measurements stabilized and at least three well volumes of water were removed. Field measurements of pH, alkalinity, dissolved oxygen concentration, and specific conductance were made with portable meters (Leeds and Northrup model 7417 for pH and alkalinity, Fisher model 152 for specific conductance, YSI Model 54A for dissolved oxygen).

Unfiltered samples for nitrate, chloride, sulfate, and total organic carbon analyses were collected in plastic containers rinsed three times with sample water. Samples for dissolved-metal analyses also were collected in rinsed plastic containers but were filtered and then acidified with nitric acid. All samples were kept on ice and delivered to the USGS laboratory within 48 hours after collection.

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, 1985).

HYDROGEOLOGY

Surficial Geology

Maine probably was covered by continental glaciers several times during the Pleistocene Epoch, which occurred from approximately 2,000,000 to l0,000 years B.P. (before present). The last ice sheet, known as the Laurentide Ice Sheet, reached its maximum southern extent about 20,000 to 22,000 years B.P., in late Wisconsin time. It flowed southeastward and eastward beyond the present coastline and into the Gulf of Maine.

Glacial History

After the peak of the late Wisconsin glaciation, the margin of the Laurentide Ice Sheet began to retreat from its terminal position on the continental shelf. By about 13,000 years B.P., the ice margin was approximately at the present coast of Maine (Stuiver and Borns, 1975; Smith, 1985). The weight of the ice depressed the earth's crust enough to allow the sea to follow the retreating ice margin inland. The inland extent and elevation of the deposits laid down in the sea during this time mark what is known to geologists as the marine limit. At about this time or slightly later, marine waters transgressed up the St. Lawrence lowland in Canada as far inland as Ottawa, and a residual ice cap, separate from the Laurentide Ice Sheet was created, centered over northwestern Maine (Borns, 1985). Evidence of the existence of the separate ice cap is documented by the presence of ice-directional features indicative of glacial flow northwestward from the Quebec-Maine border toward the St. Lawrence River (Chauvin and others, 1985; Lowell, 1985; Lowell and Kite, 1986 a,b,c; Lowell and others, 1990). This residual ice cap, also termed the Appalachian Ice Complex of the Laurentide Ice Sheet (Prest, 1984; Dyke and Prest, 1987), is responsible for deposition of most of the surficial aquifer materials in the study area.

As deglaciation continued, glacial sediments were deposited, recording the style and pattern of glacial retreat in Maine. Glacial deltas in eastern Maine formed close to the inland marine-limit elevation (Thompson and Borns, 1985), where the ice retreat became slow enough for large volumes of sediment to accumulate. Below the marine limit, other glacial deposits are associated with an extensive silt and clay deposit, the Presumpscot Formation (Bloom, 1960). Radiocarbon-age dates, determined largely from fossil shells of marine mollusks recovered from the Presumpscot Formation, bracket Maine's marine deglacial history to between 13,200 and 11,000 years B.P. (Stuiver and Borns, 1975; Smith, 1985). When the ice retreated beyond the reach of the sea, large amounts of meltwater reworked the glacial sediment and laid down stream deposits and shoreline sediments over the Presumpscot Formation.

As the ice margin retreated, the marine waters removed much of the ice volume and where the ice margin was well inland of the marine limit, widespread stagnation and downwasting of ice probably occurred (Lowell and Kite, 1986b). In the study area, which occurs within and near the extent of the marine limit, the sand and gravel deposits consist primarily of sediments deposited in the sea, glacial-stream deposits laid down on or near the glacier, glacial-lake deposits, and stream deposits laid down after the ice left the area (Thompson and Borns, 1985).

Surficial Materials in the Study Area

As the glacier advanced, it eroded soil and rock debris and incorporated it into the ice. This material, deposited directly from the ice as a discontinuous layer on the bedrock surface, is called "till." The till was deposited at the base of the ice (lodgement 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 pebbles, cobbles, and boulders in a sandy silt or clayey silt matrix. It can be very compact to very loose and usually is not a productive aquifer. Although till usually is a poor ground water producer, its hydrological qualities and areal extent affect the amount of natural recharge to the region. A poorly sorted, compact, clayey till with low permeability will not have as rapid an infiltration rate as a well-sorted, less compact, sandy till. Large amounts of runoff from upland till areas can recharge adjacent stratified-drift deposits.

Till deposits in the State generally are not more than 10 ft thick. Thick deposits of streamlined, till-covered hills known as drumlins are common in southern Maine. An example of a drumlin in the study area is found on the Veazie quadrangle. It is located 0.75 miles west of Clewleyville Corners along the Brewer and Holden town line. Examples of other glacially streamlined hills in the study area are shown on the Brooks East quadrangle, south of Swan Lake in Swanville. The long axes of these hills and the drumlins trend south-southeast, parallel to the direction of flow of the last ice sheet that covered the region.

In places, linear ridges of sediment were deposited either in front of or beneath the ice at or near the terminus of the glacier. These ridges are termed moraines; examples are found northeast of Millinocket Lake in T2R8 (Trout Mountain quadrangle), and north of Bucksport Center on the east side of the Penobscot River Valley (Hampden quadrangle). The moraines are comprised predominantly of sand and gravel interbedded with till. Some of the moraines were formed above the marine limit; however, some are found below the marine limit and are generally small topographic features.

As the ice margin retreated in Maine, meltwater streams transported and deposited quantities of sand and gravel, mainly in the valleys. Coarse sediments, transported by the streams, accumulated in channels within or beneath the ice, between the ice and adjacent valley walls, or in the sea at or near the glacier front. Typical "ice-contact" stratified-drift deposits include such features as eskers (long, sinuous ridges formed as tunnel fillings within the ice), crevasse fillings (ridges formed as fillings in cracks on the ice surface), subaqueous fans (irregularly shaped hills formed by streams from ice tunnels entering a water body below the water surface), and deltas (flat-topped or irregularly shaped hills formed by streams entering a water body and building to the water surface). Sediments deposited by meltwater streams in valleys adjacent to or beyond the ice margin are termed fluvial outwash or outwash-plain deposits, respectively, and commonly display pitted surfaces as a result of the burial and subsequent melting of blocks of ice.

The study area is mostly within the Penobscot River drainage basin. Prominent features representing glacial drainage are the large esker systems found in the Penobscot River Valley (Thompson and Borns, 1985, Figure 2). An example of an esker can be found on the Passadumkeag quadrangle. This feature is known locally as the Enfield Horseback. The esker systems are comprised of segments of esker-fed deltas or fans, which were deposited at the ice marginal position at the time that the esker segment was forming (Clinch and Weddle, 1989).

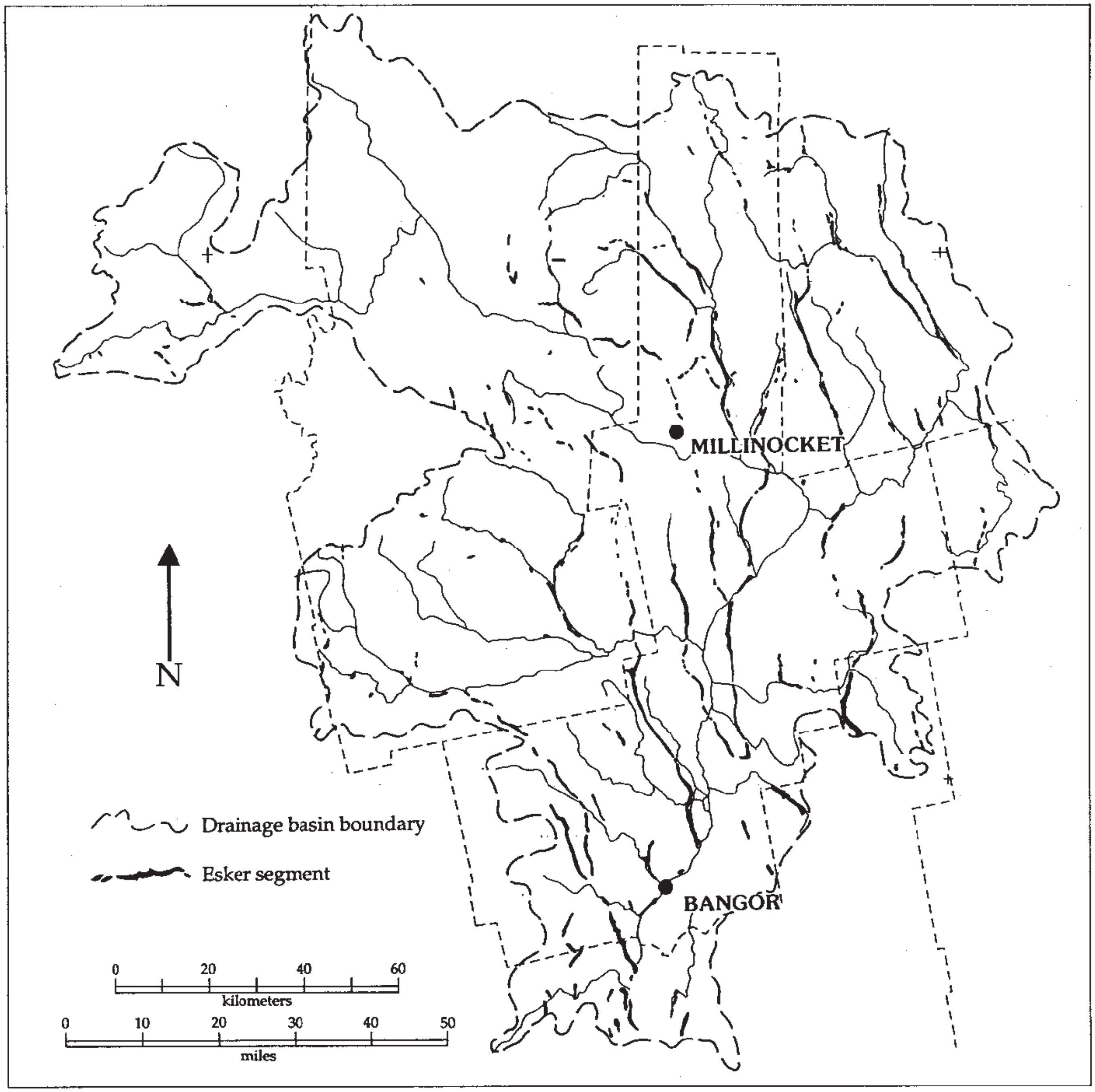

Figure 2.—Esker systems in the Penobscot River drainage basin.

Deltas are found where meltwater streams entered a body of water, in the study area most likely into the sea at or near the ice margin. Well developed deltas with characteristic lobe-shaped form are not as common in the upper part of the Penobscot River Valley as they are in southwestern and southeastern Maine. An example is the flat-topped landform on the northwestern shore of Dolby Pond in East Millinocket and Grindstone (Millinocket quadrangle). Another example is a delta in Medway south of the Penobscot River on the northwestern corner of the Mattaseunk Lake quadrangle about 0.5 miles south of transmission lines that cross the esker system. The topset- foreset contact represents the point where streams enter the water body and is a good approximation of the marine limit at this site, about 340 ft above sea level. Figure 3 is a photo of the topset-foreset contact in the delta.

In the southern part of the study area, examples of deltas are found in the northeast part of the Brooks East quadrangle. The most southerly delta is northwest of Swan Lake and east of Irish Hill and Clement Hill, referred to by Thompson and others (1989) as the Irish Hill Delta. It is an example of a leeside delta, situated on the lee side of a ridge that extended above the ocean surface during the marine submergence. Here the feeder stream for this delta flowed through the gap between Irish and Clement Hills and deposited the delta on which Robertson and Mt. Solitude Cemeteries are found. Another leeside delta is found about 2.5 miles north of the Irish Hill Delta and just north of the village of Monroe.

Outwash deposits are differentiated into two categories, subaqueous outwash and fluvial outwash. The subaqueous outwash is primarily found at elevations below the marine limit and is associated with the lobe-shaped parts of the esker systems. The lobe-shaped features are usually fan deposits which were deposited by meltwater streams emanating from tunnels in the ice. As noted previously, the lobe-shaped areas of the Enfield Horseback are good examples of subaqueous fans. Fluvial outwash is generally restricted to areas at elevations above the marine limit, which increases from about 315 to 370 feet above sea level from south to north in the Penobscot River valley study area. Outwash deposits in Brooks (Brooks West quadrangle) in the Marsh Stream valley constitute aquifer material in that area; but these deposits often are thin material over bedrock and are not shown as significant aquifers. Outwash in the Martin Stream valley and adjacent to Cates Meadows in Dixmont (Dixmont quadrangle) is characteristic of these deposits.

Wetland deposits occur in swamps and bogs, and are typically underlain by till or fine-grained stratified deposits. Many of the wetlands are characterized by compact peat deposits. These deposits generally are not aquifers, but are often found adjacent to esker systems and may be hydrogeologically connected to the system. Some large wetlands include Sunkhaze Meadows (Otter Chain Ponds quadrangle), Caribou Bog (Pushaw Lake quadrangle), Alton Bog (Greenbush quadrangle), and Sargent Bog (South Lagrange quadrangle).

Eolian deposits of fine-grained sand and silt occur throughout the study area, generally as a cap not more than a few feet thick over other glacial deposits. These wind-blown deposits are not aquifers; however, they may overlie water-bearing strata.

Recent alluvial deposits generally consist of interbedded sand, gravel, silt, and cobble gravel, and occupy much of the flood plain of the major rivers in the study area. As previously noted, alluvial deposits of late glacial and early post-glacial age may be difficult to differentiate from glacial outwash, however, post-glacial alluvium is generally deposited at lower elevations than outwash.

Stratigraphy of Glacial Deposits

Figure 4 is a schematic diagram that shows the generalized regional stratigraphic relations of glacial deposits in Maine. In general, surficial stratigraphy in the study area is best represented by the left and central parts of the schematic figure. Not all of the units shown on this figure will necessarily be found in any one place.

Figure 4 indicates the relative age of the deposits. Bedrock is overlain by till, which is overlain by sand and gravel in the form of ice-contact stratified drift, glacial outwash and glacial-lake sediments. The youngest surficial deposit, a thin veneer of sand and gravel overlying the glacial deposits, may represent a late outwash deposit or alluvium.

Hydrology of the Significant Sand and Gravel Aquifers

The significant sand and gravel aquifers consist of coarse glaciolacustrine and glaciomarine sediments, ice-contact, ice-stagnation, and glaciofluvial-outwash deposits, and Holocene stream alluvium. The largest yields available are from wells in coarse-grained deposits near surface water bodies that may serve as sources of induced recharge. These aquifers are located in ice-contact stratified-drift or coarse-grained alluvial deposits—for example, the Penobscot River valley sediments.

The most productive and highly-developed aquifer is located in ice-contact and outwash deposits in Orono (Old Town quadrangle). The largest reported single well yield is from this aquifer, 900 gal/min, from a municipal well operated by the Town of Orono.

Significant sand and gravel aquifers are shown on the maps as areas with moderate to good potential water yield (greater than 10 gal/min to a properly constructed well), and areas with good to excellent potential water yield (greater than 50 gal/min to a properly constructed well). Areas with moderate to low or no potential water yield (generally less than 10 gal/min to a properly constructed well) are shown as surficial deposits with less favorable aquifer characteristics. These areas include regions underlain by surficial deposits such as till, alluvium, swamps,

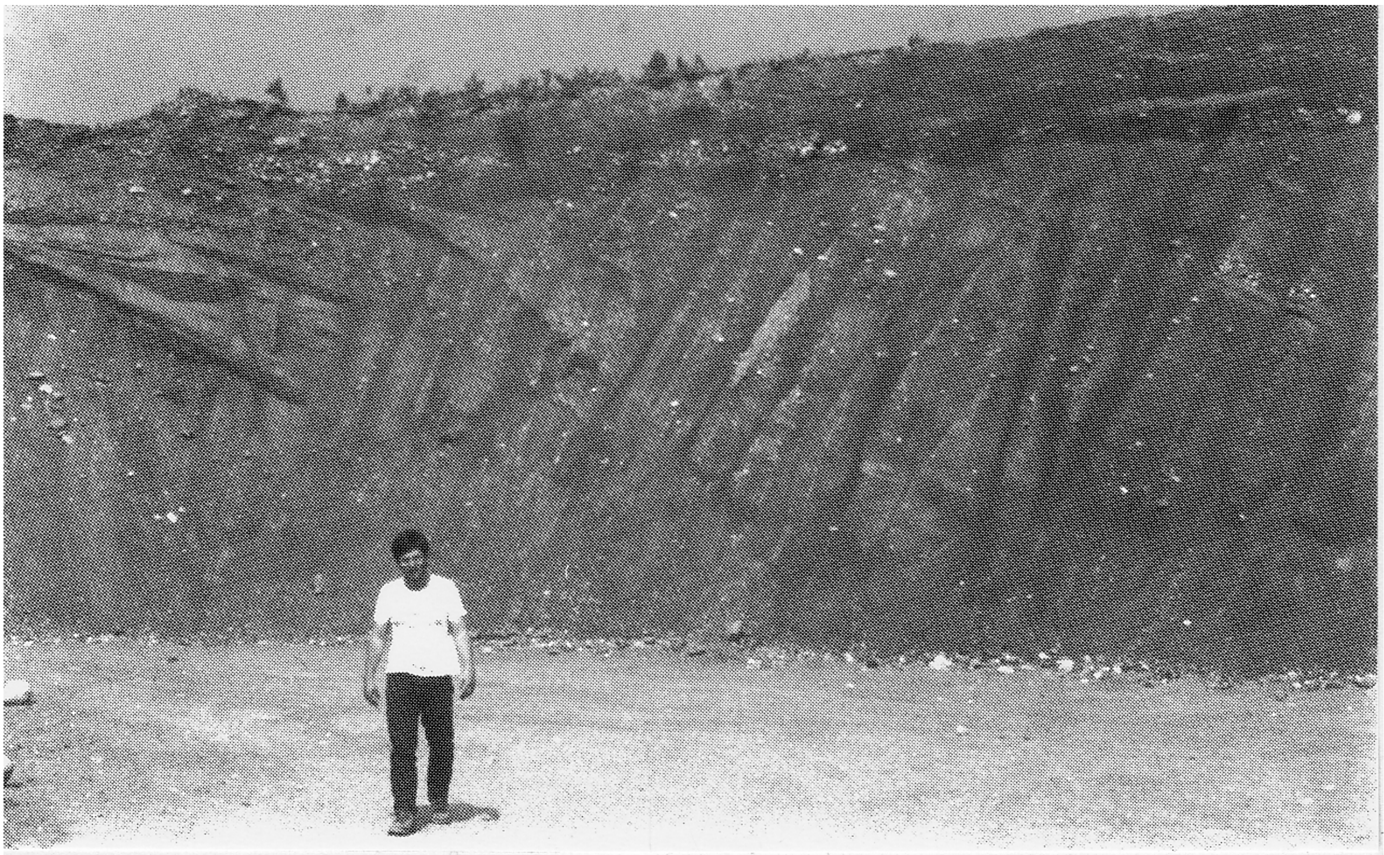

Figure 3.—Topset - foreset contact in delta, Medway, Maine (Mattaseunk Lake quadrangle).

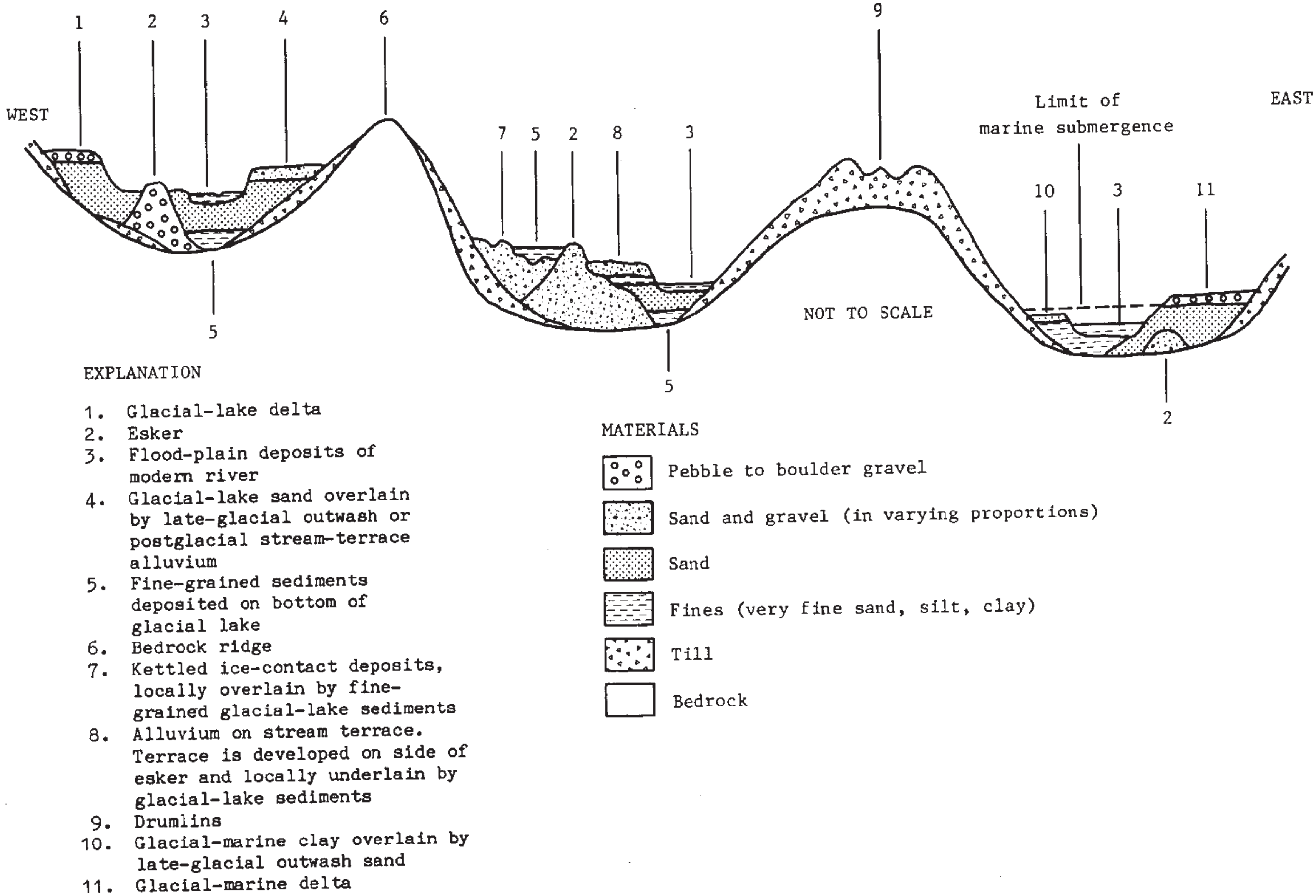

Figure 4.—Generalized regional stratigraphic relation of glacial deposits.

and thin glacial sand and gravel deposits. Bedrock wells shown on these maps record only the depth to bedrock of the well. The aquifer boundaries and estimated yield zones shown on the associated maps are based on available information and are subject to modification as additional data become available.

Major surface-water drainage-basin boundaries are identified on the maps. In general, ground-water divides coincide with surface-water divides. The horizontal direction of ground-water flow generally is away from surface-water divides and toward surface-water bodies.

Hydraulic Properties

Hydraulic Conductivity:

Hydraulic conductivity is a measure of the rate at which water will flow through aquifer materials. It depends 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 usually the most important hydraulic property of sediments for assessing ground-water flow and well yield (Caswell, 1987).

Hydraulic conductivity 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. For this study, the median particle diameter (in millimeters) and the degree of sorting of representative sediment samples were determined by grain-size analyses. These analyses were performed at the USGS laboratory in Harrisburg, Pennsylvania, using a dry-sieve method (Folk, 1974). The results of these analyses (Table 1) were used to to estimate horizontal hydraulic conductivity, using nomographs published by Masch and Denny (1966) that relate mean grain size and degree of sorting to hydraulic conductivity. The range of horizontal hydraulic conductivities, expressed in ft/d (feet per day), are 0.000001 to 0.001 for marine clay, 0.0000001 to 0.01 for till, 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, 1979). The horizontal hydraulic conductivities estimated for selected aquifer materials sampled in this study have much less variation, from 11 ft/d to 83 ft/d (Table 1).

Transmissivity:

Transmissivity is a measure of the rate at which water or another liquid is transmitted through an aquifer or confining bed. 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 horizontal hydraulic conductivity multiplied by the saturated thickness. Driscoll (1986), suggests that aquifers with transmissivities of less than 130 ft^2/d (feet squared per day) can only supply enough water for domestic wells or other low yield uses. Aquifers with transmissivities of 1,700 ft^2/d or greater are capable of transmitting adequate quantities of water for industrial, municipal, or irrigation purposes.

Approximate transmissivities were calculated at 16 sites from the complete stratigraphic logs of observation wells. Sediment from each interval in the saturated part of the exploration boring (Appendix 1, at end of report) was assigned a horizontal hydraulic conductivity, on the basis of sample description, grain size, and sorting (Table 1). This hydraulic conductivity was multiplied by the interval thickness to obtain an interval transmissivity. The interval transmissivities were then summed to give a total transmissivity for that part of the aquifer penetrated by the exploration boring.

The transmissivities estimated by this method range from 294 to 1,584 ft^2/d and are presented in Table 2.

Estimated Well Yields

The significant sand and gravel aquifers consist of deposits that have sufficient areal extent, horizontal hydraulic conductivity, and saturated thickness to sustain a yield of 10 gal/min or more to a properly installed well. Yields available from wells constructed in the aquifers were obtained from yields reported by well drillers, well owners, and previously published studies, and from estimates based on saturated thickness, transmissivity, and areal extent of the aquifers. Aquifer transmissivity determined through aquifer tests was not in the scope of this study. Therefore, a method developed by Mazzaferro (1980) was used to estimate well yields in a water-table aquifer. This method is based on transmissivity (T), in ft^2/d, and saturated thickness (B), in ft, where (T x B)/750 = well yield in gallons per minute. Yields calculated for selected observation wells range from 7 to 162 gal/min (Table 3). Areas where wells are estimated to yield more than 10 gal/min and more than 50 gal/min are shown in separate shading patterns on the maps. Areas where wells may yield less than 10 gal/min constitute the remaining unshaded portion of the map.

Although the total study area covers 2,843 mi^2, areas mapped as significant sand and gravel aquifers include only about 84.6 mi^2 (3 percent) of this area. Yields exceeding 50 gal/min are estimated to be obtainable in only 3.1 mi^2 (less than 1 percent) of the study area.

The greatest yields are obtainable in areas where the deposits are coarse grained, have a thick saturated zone, or are hydraulically connected to an adjacent body of surface water that is a source of induced recharge. The largest reported well yield in the sand and gravel deposits is 900 gal/min from a municipal well in Orono (Old Town quadrangle). Other large well yields in the area include municipal wells in Hampden, 500 gal/min, (Bangor quadrangle), and in Lincoln, three wells with a combined yield of 2,000 gal/min, (Lincoln West quadrangle) and two industrial wells in Prospect, each yielding 700 gal/min (Bucksport quadrangle).

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

Sample description	Observation well or test boring number	Depth of interval sampled (feet)	Median diameter (phi)[1]	Degree of sorting[2]	Estimated horizontal hydraulic conductivity (feet per day)[3]
Silt to very fine sand					
Silty fine sand	OW88-2	33-35	3.5	poor	11
Very fine sand, silt	OW88-12	37.5-38.5	4.2	moderate	11
				Average	**11**
Very fine to fine sand					
Very fine to fine sand, some silt	OW88-13	58-59	3.7	poor	12
Very fine to fine sand, silt	OW88-4	27-29	3.7	poor	11
Very fine sand, some silt	OW88-1	23-24	3.6	moderately well	13
Very fine to fine sand, some silt	OW88-10	12.7-13.3	3.5	moderate	13
Very fine to fine sand, some silt	OW88-2	68	3.4	moderate	13
Very fine sand, some fine sand	OW88-6	38.3-39	3.3	moderately well	15
Very fine to fine sand, some silt	OW88-13	28-29	2.9	poor	11
Very fine to fine sand	TB88-7	23-23.7	2.8	moderate	16
Fine sand, some very fine sand	OW88-5	48-49	2.6	moderate	17
Fine sand, some very fine sand, little medium sand	TB88-8	63.5-64	2.6	moderate	19
Very fine to fine sand, silt, some medium sand	TB88-15	23-23.7	2.4	poor	15
				Average	**14**

[1] Phi is the negative log (base 2) of the particle diameter in millimeters
[2] Sorting classified by Inclusive Graphic Standard Deviation

greater than 1.0	- poor
0.75 - 1.0	- moderate
0.50 - 0.75	- moderately well
less than or equal to 0.50	- well

[3] Masch and Denny (1966)

Table 1.—Grain-size analysis, sorting, and estimated horizontal hydraulic conductivity of aquifer materials, (cont).

Sample description	Observation well or test boring number	Depth of interval sampled (feet)	Median diameter (phi)[1]	Degree of sorting[2]	Estimated horizontal hydraulic conductivity (feet per day)[3]
Very fine; fine to medium sand					
Very fine to medium sand	OW88-1	18.5-19	2.7	poor	17
Very fine to medium sand	OW88-3	18-19	2.6	poor	17
Fine to medium sand, little silt	OW88-2	38.5-39	2.5	poor	15
Fine to medium sand	OW88-2	63	2.3	poor	12
Fine to medium sand	OW88-9	73-74	2.3	poor	20
Fine to medium sand	OW88-11	57-59	2.2	moderate	21
Fine to medium sand	OW88-12	17-19	2.1	moderate	28
Fine to medium sand	OW88-5	57.5-59	2.0	moderate	25
Fine to medium sand	OW88-9	78-78.5	1.9	moderate	29
Fine to medium sand	OW88-16	18-19	1.8	moderate	28
Fine to medium sand	OW88-6	68.5-69	1.8	moderate	27
Fine to medium sand, little coarse sand	OW88-3	13.5-14	1.7	poor	18
Fine to medium sand	OW88-13	27-28	1.6	moderate	36
				Average	**23**
Fine to coarse sand	OW88-10	17-18.5	1.6	poor	**25**
Fine to coarse sand	OW88-14	88-89	1.6	poor	**21**
Medium sand, some fine sand	OW88-6	68-68.5	1.8	moderate	**28**
Medium sand, some fine sand	OW88-9	58-59	1.6	poor	**33**
Medium to coarse sand	OW88-7	27.5-28	1.3	poor	**37**
Medium to very coarse sand, little fine sand	OW88-6	58.2-58.8	.95	poor	**20**
Coarse sand, some gravel	OW88-9	87.5-89	.85	moderately well	**83**

[1] Phi is the negative log (base 2) of the particle diameter in millimeters
[2] Sorting classified by Inclusive Graphic Standard Deviation

greater than 1.0 - poor
0.75 - 1.0 - moderate
0.50 - 0.75 - moderately well
less than or equal to 0.50 - well

[3] Masch and Denny (1966)

Table 2.— Estimated transmissivity values of aquifers based on stratigraphic logs of observation wells.

Quadrangle	Observation well number	Estimated transmissivity, in feet squared per day
Branch Lake	OW 88-1	339
Brooks East	OW 88-2	821
Snow Mountain	OW 88-3	332
Brooks East	OW 88-4	446
Olamon	OW 88-5	660
Olamon	OW 88-6	1184
Lincoln Center	OW 88-7	962
Mattawamkeag	OW 88-8	294
Nine Meadow Ridge	OW 88-9	1584
Nollesemic Lake	OW 88-10	600
Lincoln West	OW 88-11	708
Lookout Mountain	OW 88-12	1192
Lookout Mountain	OW 88-13	1560
Stacyville	OW 88-14	1279
Millinocket	OW 88-15	345
Millinocket	OW 88-16	656

Table 3.—Estimated well yields for selected observation wells.

Quadrangle	Observation well number	Estimated well yield (gallons per minute)[1]
Branch Lake	OW 88-1	9
Brooks East	OW 88-2	44
Snow Mountain	OW 88-3	9
Brooks East	OW 88-4	16
Olamon	OW 88-5	37
Olamon	OW 88-6	92
Lincoln Center	OW 88-7	33
Mattawamkeag	OW 88-8	8
Nine Meadow Ridge	OW 88-9	101
Nollesemic Lake	OW 88-10	19
Lincoln West	OW 88-11	45
Lookout Mountain	OW 88-12	114
Lookout Mountain	OW 88-13	162
Stacyville	OW 88-14	94
Millinocket	OW 88-15	7
Millinocket	OW 88-16	27

[1] Yields calculated from the methodology of Mazzaferro (1980), yield (gallons per minute = T, in ft^2/d, x B, in ft/750).

Depths to the Water Table and Bedrock Surface

Depths to the water table and bedrock surface in the significant sand and gravel aquifers were determined from seismic-refraction surveys, water-level measurements, well inventory, test drilling, mapping of bedrock outcrops, and previous investigations. In the study area, the seismic velocity in unsaturated overburden materials ranges from 800 to 2,935 ft/s (feet per second), with an average velocity of 1,572 ft/s. Saturated overburden materials have velocities of 4,135 to 6,910 with an average velocity of 5,371 ft/s. Bedrock seismic velocities in the study area vary from 11,075 to 28,248 ft/s with an average velocity of 15,298 ft/s. In the significant sand and gravel aquifers, the depth to the water table differs considerably areally, but, typically is within 15 ft of the land surface. The greatest depth to bedrock determined by seismic-refraction is approximately 168 ft, along seismic line LOO-9, (Lookout Mountain quadrangle). Well records indicate that bedrock is at a depth of 190 feet in a domestic well drilled in Alton (Greenbush quadrangle).

Determinations of depths to the water table and bedrock surface are necessary to provide a three-dimensional picture of aquifer geometry. Saturated thickness at selected points can be determined by subtracting the depth to water table from the depth to bedrock. Depth to bedrock data and bedrock surface profiles can be used to estimate the amount of casing required in overburden for bedrock well construction and to locate buried valleys, which may contain water-bearing sediments. A summary of the information collected with the single-channel seismographs is presented in Table 4. Hydrogeologic sections from seismic-refraction surveys conducted with the 12-channel seismograph are presented in Appendix 2 (at end of report). The locations of 68 single-channel and 42 twelve-channel seismic-refraction lines conducted throughout the study area are shown on the associated maps.

Water-Level Fluctuations

Monthly water-level measurements at 16 observation wells in the study area are shown in Table 5. Water-level measurements were made once a month from January 1989 through December 1989. Water levels over a 12-month period in all observation wells fluctuated within a range of approximately 1 to 6.5 ft (Table 6). Hydrographs from selected observation wells are shown in Figure 5. The mean depth to the water table in the 16 wells ranged from 6.19 to 46.55 ft below land surface over a 12-month period. In most of the wells, the water table is less than 15 ft from the surface. This thin unsaturated zone renders the ground water potentially vulnerable to contamination originating at the land surface.

Average monthly precipitation data from National Oceanic and Atmospheric Administration Stations at Bangor, Orono, Ellsworth, Waterville, Millinocket, Springfield, and Patten are compared with water-level data in Figure 5. Regional recharge generally occurs in the fall and winter months, when there is little plant growth to intercept precipitation as it infiltrates the aquifer. Most water levels decline slowly but steadily between these recharge events.

GROUND-WATER QUALITY

<u>Factors Influencing Water Quality</u>

The chemical quality of water in sand and gravel aquifers is determined by a number of factors. The primary control is the mineralogy of the sand and gravel. Most sand and gravel in the study area is derived from calcareous mudstone, sandstone, limestone, and granite which generally release calcium as a dominant cation to ground water. Chemical reactions that occur as water passes through the soil zone can also affect ground- water chemistry. Where the flow path of water from the recharge zone to the discharge zone is long, more time is available for the dissolution of soluble material in the aquifer (Caswell, 1987). Residence time also depends on hydraulic conductivity, hydraulic gradient, and the porosity of the unconsolidated deposits.

Contamination by human activities may increase concentrations of many compounds in ground water. Activities that can significantly alter the quality of ground water include the following:

(1) Landfill disposal of household and industrial wastes, which may include petroleum derivatives and hazardous material.

(2) Storage and spreading of road salt. An investigation conducted in the Province of New Brunswick, Canada, indicated that as much as 57 percent of the salt in an uncovered salt-sand storage pile may leach in a year (Environment New Brunswick, 1978).

(3) Introduction of human wastes into ground water through septic tanks, disposal of septic wastes, or by spreading or landfilling of sludge from municipal sewage treatment systems.

(4) Agricultural activities, which include stockpiling and spreading of manure, spreading of commercial fertilizers, and spraying of pesticides. From 1985 to 1988, the Maine Geological Survey collected samples from 47 overburden wells within agricultural areas underlain by sand and gravel; water from eight of these wells contained detectable concentrations of pesticides. Furthermore, water from seven of these wells contained nitrate concentrations exceeding the State drinking water standard of 10 mg/L (milligrams per liter) (Neil and others, 1989). More than 100 wells in Aroostook County contaminated by aldicarb, an agricultural chemical used extensively for potato farming, have also been documented (unpublished data, Rhone-Poulenc Agricultural Products Company).

Table 4.—Depth to water table and depth to bedrock based on single-channel seismic data, [>, greater than].

Seismic-line identifier [1]	Quadrangle	Town	Length of line (feet)	Depth to water table (feet)		Depth to bedrock, (feet)		Comments
				A [2]	B [2]	A [2]	B [2]	
BHL-D	Branch Lake	Prospect	180	9	7	43	59	Water in pond 8 feet below line.
BKP-H	Bucksport	Ellsworth	150	22	20	56	64	70 feet of material removed
BWL-F	Brewer Lake	Bucksport	180	6	7	54	59	
HAM-G	Hampden	Hampden	150	8	7	46	40	50-60 feet of material removed
CMO-B	Chemo Pond	Clifton	130	6	4	30	28	
VEZ-D	Veazie	Bangor	100	5	4	33	45	
ORL-E	Orland	Orland	160	9	8	59	66	Stream 8 feet below line
ORL-L	Orland	Orland	140	6	7	35	33	
ORL-O	Orland	Orland	160	8	7	44	50	
BKE-H	Brooks East	Jackson	130	8	7	29	40	8 feet of material removed
BKE-K	Brooks East	Swanville	160	7	5	40	30	
BKE-P	Brooks East	Monroe	130	11	8	27	38	
BKW-C	Brooks West	Knox	100	6	6	33	24	
BKW-L	Brooks West	Thorndike	130	4	4	21	15	
DIX-I	Dixmont	Plymouth	110	9	8	14	23	
EDM-A	East Dixmont	Monroe	150	7	6	37	24	
EDM-B	East Dixmont	Newburgh	150	6	6	39	34	35 feet of material removed
HER-P	Hermon	Hampden	140	7	9	17	28	
HER-G	Hermon	Levant	140	8	7	27	31	
HER-N	Hermon	Carmel	140	10	7	24	34	
PLY-G	Plymouth	Newport	100	6	6	16	23	Pond 8 feet below line
SNO-L	Snow Mountain	Hampden	110	10	9	33	35	Pond 7 feet below line

[1] Location of all seismic lines are shown on plates.

[2] Refers to orientation of line: A is the western end of the line; B is the eastern end of the line.

Table 4.—Depth to water table and depth to bedrock based on single-channel seismic data, [>, greater than], (cont.).

Seismic-line identifier [1]	Quadrangle	Town	Length of line (feet)	Depth to water table (in feet)		Depth to bedrock (feet)		Comments
				A [2]	B [2]	A [2]	B [2]	
LAG-A	Lagrange	Medford	80	13	7	31	27	
LAG-B	Lagrange	Medford	100	12	11	26	26	'B' end-65 feet material removed
LAG-D	Lagrange	Lagrange	190	14	17	70	57	
HOW-B	Howland	Edinburg	110	9	8	29	32	20 feet of material removed
GBH-D	Greenbush	Alton	200	10	10	49	60	'A' end-30 feet material removed
GBH-E	Greenbush	Alton	210	11	12	55	54	'A' end-30 feet material removed
PUS-D	Pushaw Lake	Glenburn	160	8	8	35	42	
MTS-A	Mattaseunk Lake	Medway	110	8	4	33	40	
MTT-C	Mattawamkeag	Macwahoc	120	15	20	46	40	
MTT-F	Mattawamkeag	Mattawamkeag	100	21	21	41	51	
SPR-A	Springfield	Springfield	110	9	7	38	34	
EWN-N	East Winn	Lee	100	4	3	26	30	
EWN-R	East Winn	Winn	140	6	8	44	34	Stream 5-10 feet below line
LCW-C	Lincoln West	Lincoln	210	9	11	65	60	
LCW-C	Lincoln West	Lincoln	120	16	14	41	38	
LCW-P	Lincoln West	Enfield	200	24	25	53	67	30-50 feet of material removed
SEB-T	Seboeis	Enfield	150	13	13	32	41	
SEB-V	Seboeis	Howland	130	15	13	52	62	
SEB-X	Seboeis	Howland	90	9	9	21	32	15 feet of material removed
SEB-AA	Seboeis	Howland	120	10	10	33	35	
SEB-FF	Seboeis	Howland	150	8	10	70	41	
SEB-GG	Seboeis	Howland	110	11	8	20	28	
SEB-II	Seboeis	T1R7	200	7	6	53	47	

[1] Location of all seismic lines are shown on plates.

[2] Refers to orientation of line: A is the western end of the line; B is the eastern end of the line.

Table 4.—Depth to water table and depth to bedrock based on single-channel seismic data, [>, greater than], (cont.).

Seismic-line identifier [1]	Quadrangle	Town	Length of line (feet)	Depth to water table (feet)		Depth to bedrock (feet)		Comments
				A [2]	B [2]	A [2]	B [2]	
SEB-MM	Seboeis	Seboeis	110	16	16	43	43	
NMR-ZZ	Nine Meadow Ridge	T2R9	180	15	20	60	50	
NMR-FFF	Nine Meadow Ridge	Chester	130	7	5	31	29	
MTM-LLL	Mattamiscontis Mtn.	T2R8	180	18	16	33	46	
LCW-VVV	Lincoln West	T1R7	150	6	6	25	20	
SEB-WWW	Seboeis	T1R7	80	6	6	26	19	6 feet of material removed
MKK-B	Medunkeunk Lake	Woodville	170	27	28	67	71	
MKK-J	Medunkeunk Lake	T2R9	170	7	6	53	48	
NOL-P	Nollesemic Lake	Hopkins Academy	150	19	24	54	50	
MKK-XXX	Medunkeunk Lake	Medway	150	8	10	31	32	
HDY-B	Hardy Pond	Lakeview	150	8	10	54	41	
HDY-C	Hardy Pond	Lakeview	130	6	5	43	37	
HDY-F	Hardy Pond	Milford	170	9	8	49	50	‘A’ end-10 ft. of material removed
HDY-I	Hardy Pond	Medford	240	10	11	61	64	
MLL-C	Millinocket	T2R7	170	11	14	58	50	25 feet of material removed
MLL-D	Millinocket	East Millinocket	100	6	8	26	26	
MLL-H	Millinocket	Indian Purchase	190	7	8	67	63	
MLL-Q	Millinocket	T1R8	110	7	8	13	27	
MLL-W	Millinocket	Millinocket	120	12	11	27	25	40 feet of material removed
MLL-X	Millinocket	Millinocket	130	7	8	34	34	
STA-B	Stacyville	T2R7	180	8	9	50	54	
DYM-K	Deasey Mtn.	T3R7	210	11	7	59	50	
DYM-V	Deasey Mtn.	T3R7	210	26	25	82	79	

[1] Location of all seismic lines is shown on plates.

[2] Refers to orientation of line; A is the western end of the line, B is the eastern end of the line.

Table 5.—Water-level data for observation wells in the study area, January 1989 through December 1989.
[Depth to water table in feet below land surface; —, no water level measured during this period]

Observation Well Number	Town	Jan 9-11	Feb 1-2	Mar 1-2	Apr 5-6/21*	May 3-4	June 7	July 7	Aug 2-4	Sept 6	Oct 3	Nov 8-9	Dec 5-6
OW88-1	Ellsworth	6.15	6.75	6.78	5.25	3.90	4.05	5.60	7.39	7.92	8.10	5.90	6.44
OW88-2	Monroe	20.00	20.30	19.88	18.70	18.70	18.65	18.90	20.20	20.81	20.70	19.86	20.20
OW88-3	Hampden	6.95	8.42	8.46	6.45	5.75	5.60	6.40	7.59	8.23	8.55	—	7.65
OW88-4	Monroe	11.20	16.15	16.58	15.55	13.90	11.45	11.10	12.77	14.60	15.50	16.09	15.65
OW88-5	Greenbush	35.60	35.65	35.65	35.70	35.20	34.40	35.50	34.30	34.50	34.40	34.67	35.19
OW88-6	Greenbush	27.56	27.77	27.81	27.65	26.95	26.20	27.70	26.75	26.93	27.18	27.10	27.35
OW88-7	Chester	11.85	12.00	10.60	10.70	7.87	11.65	12.85	10.70	12.65	12.75	12.26	—
OW88-8	Macwahoc	8.15	8.88	9.09	6.65	3.60	5.35	7.30	8.70	8.20	8.50	7.62	7.20
OW88-9	Chester	47.15	47.04	47.10	47.10	46.82	46.15	48.20	45.65	45.55	45.60	45.64	46.57
OW88-10	Hopkins Academy Grant	8.79	8.99	9.07	8.29*	8.04	8.19	8.74	8.79	8.51	8.49	8.42	8.93
OW88-12	T3R7	12.00	12.40	12.42	9.95*	9.08	11.35	12.15	12.50	12.05	12.00	11.75	—
OW88-13	T4R7	11.80	9.03	9.24	5.35*	5.30	7.05	8.70	9.35	8.80	9.10	8.65	—
OW88-14	T2R7	29.10	30.35	29.65	28.90*	28.40	26.70	27.35	26.95	28.20	28.50	28.80	29.22
OW88-15	TAR7	30.80	30.38	31.00	31.10	30.70	28.20	28.30	28.80	29.24	29.60	30.17	30.72
OW88-16	T3 Indian Purchase	7.90	8.18	7.98	5.60	4.95	—	—	—	—	—	—	—
EM-1	Medway	—	29.40	29.60	28.65	24.80	26.97	29.05	28.90	29.24	29.70	—	29.11

Table 6.— Statistical analysis of water-level data for observation wells in the study area, January 1989 to December 1989.

of Observation Well Number	Town	Number of Measurements	Mean (feet)	Standard deviation	Maximum depth to water (in feet below land surface)	Minimum depth to water (in feet below land surface)	Range values (feet)
OW88- 1	Ellsworth	12	6.19	1.29	8.10	3.90	4.20
OW88-2	Monroe	12	19.74	0.76	20.81	18.65	2.16
OW88-3	Hampden	11	7.28	1.05	8.55	5.60	2.95
OW88-4	Monroe	12	14.21	1.98	16.58	11.10	5.48
OW88-5	Greenbush	12	35.06	0.54	35.70	34.30	1.40
OW88-6	Greenbush	12	27.25	0.47	27.81	26.20	1.61
OW88-7	Chester	11	11.44	1.38	12.85	7.87	4.98
OW88-8	Macwahoc	12	7.44	1.54	9.09	3.60	5.49
OW88-9	Chester	12	46.55	0.80	48.20	45.55	2.65
OW88-10	Hopkins Academy Grant	12	8.60	0.32	9.07	8.04	1.03
OW88-12	T3R7	11	11.60	1.05	12.50	9.08	3.42
OW88-13	T4R7	11	8.40	1.79	11.80	5.30	6.50
OW88-14	T2R7	12	28.51	1.04	30.35	26.70	3.65
OW88-15	TAR7	12	29.92	1.01	31.10	28.20	2.90
OW88-16	T3 Indian Purchase	5	6.92	1.36	8.18	4.95	3.23
EM-1	Medway	10	28.54	1.44	29.70	24.80	4.90

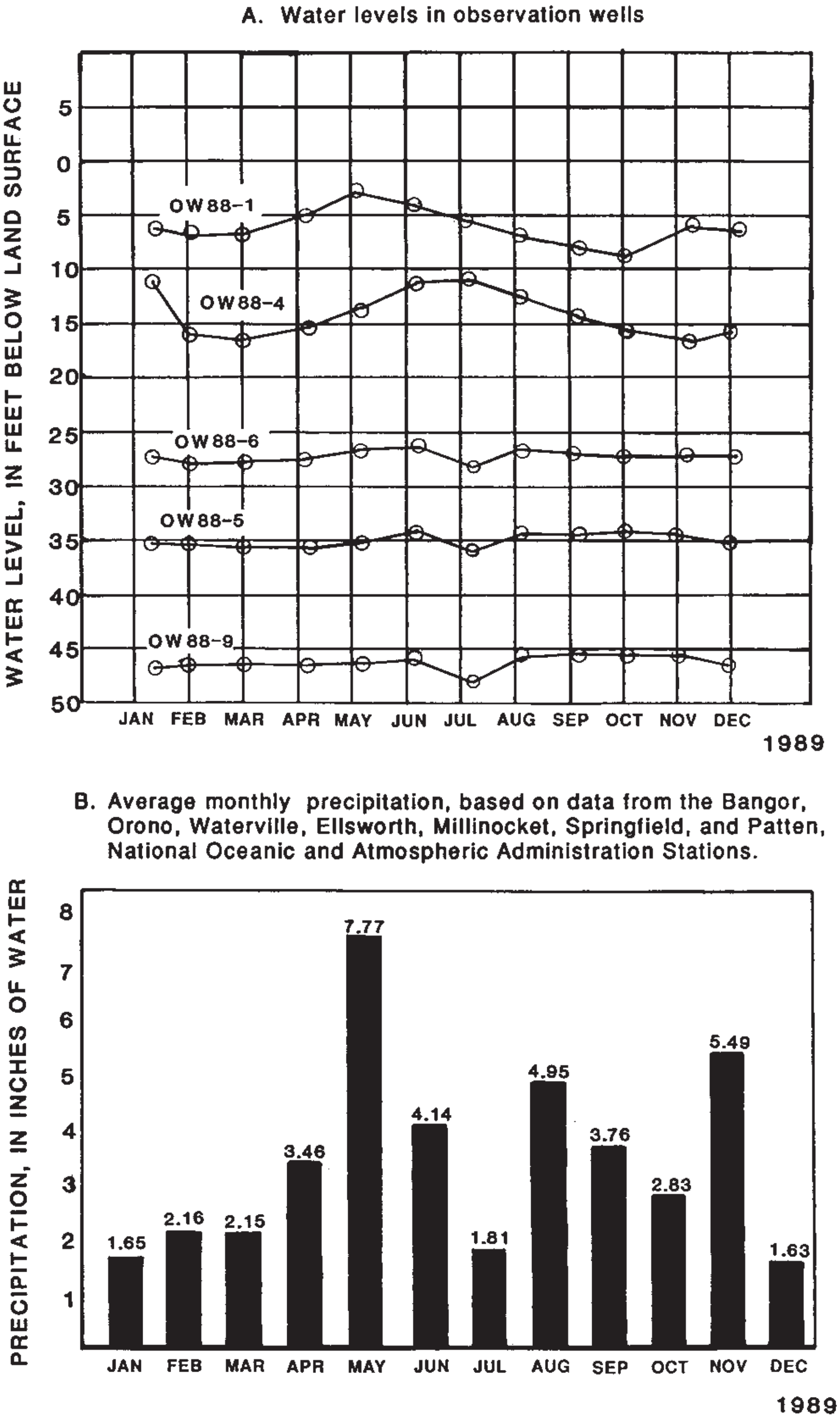

Figure 5.—Ground-water levels in selected observation wells and average monthly precipitation, January 1989 through December 1989.

(5) Leaking waste-storage or disposal lagoons.

(6) Leaking fuel- or chemical-storage tanks. The MDEP Bureau of Oil and Hazardous Materials Control has documented concentrations of gasoline as high as 600,000 parts per billion in a well installed in a sand and gravel aquifer downgradient from a leaking underground fuel tank (Garrett and others, 1986). Underground fuel tank leaks were documented at 158 locations in Maine from 1979-83. In total, 76 wells were found to be contaminated, most commonly by gasoline that leaked from buried tanks and connecting pipes at retail and nonretail commercial establishments (Caswell, 1987).

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

(8) Contaminants in precipitation. In the northeastern United States “acid rain” has been reported to cause a 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). Continued research has failed to document this finding conclusively (Steve Kahl, University of Maine, personal communication, April 26, 1990).

Common indicators of ground-water contamination are elevated levels of nitrate, a contaminant derived from sewage, animal waste, fertilizer, and landfill waste; chloride, a contaminant introduced by road-salt application, saltwater intrusion, fertilizer application, and landfill wastes; and specific conductance, which indicates the presence of dissolved ionic compounds.

Background Water Quality

The following discussion is based on analyses of samples collected from 15 observation and two municipal wells within the study area. Characteristics of these wells are given in Table 7. Water-quality analyses of samples from these wells are provided in Table 8. Data for all properties are reported in standard metric units used for these analyses. These wells are located in areas that are believed to be upgradient from sources of contaminants other than agricultural activities.

A summary of the water-quality information collected from mapped sand and gravel aquifers from previous studies in southern and central Maine (Tolman and others, 1983; Tepper and others, 1985; Williams and others, 1987; Adamik and others, 1987; Weddle and others, 1988), and from northern Maine, (Locke and others, 1989), is shown in Table 9 and is compared with the data from this study area. In previous study areas in other parts of Maine, the wells were sited to minimize any influence by man-induced contamination. Variations in water quality are attributed to natural geologic and geochemical factors and to the effect of agricultural practices on ground water. Volatile organic compounds (VOC’s) were analyzed for in earlier project field seasons (1981-84), but they were not analyzed for in 1985-88 seasons because analyses of previously collected water samples did not detect them. VOC’s are not likely to be found in wells installed for measurement of background water quality.

Graphic summaries of selected water-quality properties and constituents are presented as box plots in Figures 6 and 7. The summaries are based on analyses of water samples collected from earlier studies mentioned above and from this study area. Percentiles of some of the constituents are compared to the U.S. Environmental Protection Agency (USEPA) (1986) and Maine Department of Human Services (MDHS) drinking-water standards (1983) in Figure 7. The maximum containment levels (MCL’s) are health-related and are legally enforceable. The secondary maximum contaminant levels (SMCL’s) apply to aesthetic qualities and are recommended guidelines, but are not legally enforceable.

Temperature

The temperature of ground water normally has a small seasonal fluctuation and remains within a few degrees of the mean annual air temperature in a given area. In Maine, ground-water temperatures are typically 4.4 to 10.0 ^{o}C (Caswell, 1987). The temperature of ground water in the study area varies from 6.0 to 9.0 ^{o}C, with a median of 7.0 ^{o}C (Table 8). This is lower than the median ground-water temperature of 9.0 ^{o}C in wells from southern and central Maine, but similar to the median ground-water temperature of 7.0 ^{o}C in wells in northern Maine (Table 9, Figure 6).

Specific conductance

The specific conductance (electrical conductivity) of water is a measure of its capacity to conduct an electrical current. The presence of charged ions makes water conductive; as the ion concentration increases, so too does the specific conductance. 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 is no drinking-water standard for specific conductance, the U.S. Department of Health, Education and Welfare (1962) has recommended a maximum concentration of 500 mg/L for dissolved solids in drinking water. The concentration of dissolved solids, in milligrams per liter, can be estimated by multiplying the specific conductance value, in S/cm (microsiemens per centimeter at 25 degrees Celsius), by a factor dependent on water chemistry, usually from 0.55 to 0.75 (Hem, 1985). These estimated dissolved-solids concentrations can be compared with the laboratory calculated values in Table 8.

Specific conductance of the water-quality samples from the study area range from 64 to 310 mS/cm, with a median of 126 mS/cm (Table 8, Figure 6). Converting to dissolved solids (using the high-end factor of 0.75 for a worst-case estimate), a range of 48 to 233 mg/L and median of 95 mg/L is estimated for dissolved-solids concentration. The estimated dissolved-solid concentrations in the study area are therefore less than the recommended maximum concentration of 500 mg/L. The spe-

Table 7.—Characteristics of observation and municipal wells in the study area sampled for background water quality.

Observation Well Number	Town	Latitude	Longitude	Altitude[1]	Depth [2]	Predominant Land Type Around Well
OW88-1	Ellsworth	44°31'01"N	68°31'08"W	360	21	Gravel Pit
OW88-2	Monroe	44°34'22"N	69°05'14"W	340	65	Gravel Pit
OW88-3	Hampden	44°42'33"N	68°52'47"W	305	30	Gravel Pit
OW88-4	Monroe	44°34'07"N	69°02'09"W	315	33	Field
OW88-5	Greenbush	45°02'34"N	68°31'47"W	200	60	Gravel Pit
OW88-6	Greenbush	45°04'34"N	68°35'55"W	170	62.5	Gravel Pit
OW88-7	Chester	45°24'25"N	68°29'50"W	185	32	Gravel Pit
OW88-8	Macwahoc	45°36'48"N	68°15'43"W	320	31	Gravel Pit
OW88-9	Chester	45°24'27"N	68°31'45"W	294	67	Gravel Pit
OW88-10	Hopkins Academy Grant	45°34'44"N	68°40'02"W	370	25	Forest
OW88-12	T 3 R 7	45°55'50"N	68°36'43"W	372	32	Forest
OW88-13	T 4 R 7	45°57'53"N	68°37'03"W	378	35	Forest
OW88-14	T 2 R 7	45°46'02"N	68°34'46"W	340	40	Forest
OW88-15	T A R 7	45°39'49"N	68°38'11"W	379	42	Forest
OW88-16	T 3 Indian Purchase	45°40'57"N	68°42'07"W	381	31	Gravel Pit
Municipal Wells						
E. Millinocket	Medway	45°38'31"N	68°33'11"W	260	—	Forest
Lincoln	Lincoln	45°19'27"N	68°34'59"W	224	69.5	Gravel Pit

[1] Altitude of observation well at land-surface datum, in feet.

[2] Depth of observation well in feet below land-surface datum.

Table 8.—Background water quality in sand and gravel aquifers in the study area.
[All values in milligrams per liter (mg/L) except as noted;
S/cm, microsiemens per centimeter at 25° Celsius;
,—, value not determined, <, less than]

Observation well number	Date	Specific conductance (S/cm)	pH (standard units)	Temperature, water (degrees C)	Oxygen, dissolved (mg/L)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
OW88-1	12-06-88	248	5.9	8.0	5.7	14	4.3	0.86	39
OW88-2	12-05-88	94	7.2	6.0	10.7	40	13	1.8	2.3
OW88-3	12-06-88	247	7.5	9.0	8.15	120	42	3.0	3.5
OW88-4	12-05-88	94	7.2	6.0	11.5	41	13	2.0	4.4
OW88-5	12-09-88	308	8.0	7.0	4.24	130	35	10	12
OW88-6	12-07-88	121	7.0	7.0	12.7	31	9.3	1.9	8.6
OW88-7	12-07-88	132	7.7	7.0	11.7	52	15	3.5	4.7
OW88-8	12-08-88	176	7.2	7.0	4.40	63	19	3.7	5.7
OW88-9	12-07-88	72	9.2	8.0	14.0	28	9.1	1.4	2.5
OW88-10	12-07-88	92	7.0	7.0	5.00	39	12	2.1	5.3
OW88-12	12-06-88	—	7.2	6.5	7.60	100	32	5.9	2.9
OW88-13	12-06-88	310	7.6	6.0	9.90	150	44	9.8	8.8
OW88-14	12-07-88	94	7.4	6.5	12.0	47	16	1.7	2.4
OW88-15	12-07-88	246	6.6	6.0	—	43	11	3.7	32
OW88-16	12-07-88	64	6.5	9.0	4.8	15	4.6	0.83	2.6
E. MILLINOCKET	12-08-88	74	6.7	6.0	8.60	30	9.8	1.4	2.3
LINCOLN	12-08-88	186	8.5	6.5	8.84	81	27	3.4	5.0
MINIMUM		64	5.9	6.0	4.20	14	4.3	0.83	2.3
MAXIMUM		310	9.2	9.0	14.00	150	44.0	10.00	39.0
MEDIAN		126	7.2	7.0	8.70	43	13.0	2.10	4.7
MEAN		160	—	7.0	8.73	60	18.6	3.35	8.5
STANDARD DEVIATION		87	—	1.0	3.22	41	12.6	2.78	10.6

Table 8.—Background water quality in sand and gravel aquifers in the study area.
[All values in milligrams per liter (mg/L) except as noted;
,—, value not determined, <, less than]

Observation well number	Potassium, dissolved (mg/L as K)	Carbonate, water dissolved incremental titration field (mg/L as CO_3)	Bicarbonate, water dissolved incremental titration field (mg/L as HCO_3)	Alkalinity, water whole total fixed endpoint titration field (mg/L as $CaCO_3$)	Alkalinity, water dissolved total incremental titration field (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)
OW88-1	1.4	0	11	10	9	4.4	63	0.1	6.1
OW88-2	2.0	0	52	43	42	5.3	1.8	0.1	9.7
OW88-3	1.4	0	143	115	117	6.9	2.1	0.1	9.5
OW88-4	0.7	0	52	44	43	5.5	2.4	0.1	8.2
OW88-5	3.0	0	139	114	114	27	11	0.2	9.7
OW88-6	1.3	0	23	21	19	4.8	19	0.1	12
OW88-7	1.6	0	61	51	50	6.6	3.8	0.1	12
OW88-8	1.3	0	93	77	76	7.2	4.3	0.2	13
OW88-9	0.7	4	26	28	28	5.9	0.7	0.1	14
OW88-10	1.1	0	52	43	43	3.3	1.0	0.3	16
OW88-12	0.5	—	—	—	—	12	0.9	0.1	9.5
OW88-13	0.8	0	183	149	150	13	0.8	0.1	7.6
OW88-14	0.5	0	52	44	43	5.1	0.7	0.1	11
OW88-15	1.9	0	14	13	11	7.5	67	0.1	16
OW88-16	0.7	0	24	21	22	11	1.3	0.3	15
E. MILLINOCKET	0.5	0	33	28	27	6.2	1.0	0.1	9.8
LINCOLN	1.2	2	91	79	78	8.0	3.6	0.1	12
MINIMUM	0.5	0	11	10	9	3.3	0.7	0.1	6.1
MAXIMUM	3.0	4	183	149	150	27.0	67.0	0.3	16.0
MEDIAN	1.2	0	52	44	43	6.6	2.1	0.1	11.0
MEAN	1.2	0.4	66	55	54	8.2	10.8	0.1	11.2
STANDARD DEVIATION	0.7	1.1	51	41	42	5.5	20.9	0.1	2.9

Table 8.—Background water quality in sand and gravel aquifers in the study area.
[All values in milligrams per liter (mg/L) except as noted;
,—, value not determined, <, less than]

Observation well number	Solids, residue at 180° C dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO_2 + NO_3 total (mg/L as N)	Phosphorous, total (mg/L as P)	Iron, total recoverable (mg/L as Fe)	Iron, dissolved (mg/L as Fe)	Manganese, total recoverable (mg/L as Mn)	Manganese, dissolved (mg/L as Mn)	Carbon, organic total (mg/L as C)
OW88-1	139	126	<0.10	<0.01	2.60	0.390	0.740	0.820	0.9
OW88-2	73	62	< .10	.03	44.00	.084	1.000	.070	2.8
OW88-3	129	137	1.00	.02	4.30	.014	.260	.018	.7
OW88-4	65	63	< .10	.73	74.00	.150	1.700	.041	1.6
OW88-5	176	177	< .10	.03	11.00	.120	.750	.580	3.8
OW88-6	77	70	< .10	.46	93.00	.031	4.900	.012	—
OW88-7	75	78	< .10	.02	.96	.007	.050	.008	.7
OW88-8	104	105	< .10	.75	110.00	.190	11.000	4.600	5.4
OW88-9	60	51	.10	.01	3.60	.042	.160	< .001	.9
OW88-10	60	67	< .10	.48	45.00	.089	4.900	.390	1.8
OW88-12	122	126	.30	.80	56.00	.320	3.200	1.100	6.1
OW88-13	177	176	< .10	.41	16.00	.042	1.800	1.300	1.8
OW88-14	82	64	.20	.04	5.00	.043	.520	.017	.9
OW88-15	149	147	.20	.32	37.00	.110	.970	.220	1.8
OW88-16	73	57	< .10	.14	14.00	7.900	.400	.380	2.1
E. MILLINOCKET	56	48	< .10	.01	4.80	.039	.230	.004	1.1
LINCOLN	110	108	1.30	<.01	.47	.013	.020	.010	1.4
MINIMUM	56	48	< .10	<0.01	<0.47	0.007	0.020	< .001	0.7
MAXIMUM	177	177	1.30	.80	110.00	7.900	11.000	4.600	6.1
MEDIAN	82	78	< .10	.04	11.00	.084	.750	.070	1.7
MEAN	102	98	.25	.25	26.77	.564	1.918	.563	2.1
STANDARD DEVIATION	41	43	.35	.30	33.30	1.894	2.	1.119	1.6

Table 9. — Background water quality in sand and gravel aquifers in previous study areas.

Background water quality in sand and gravel aquifers in southern Maine[1]

[All values in milligrams per liter except as noted]

	Temperature (°C)	Conductance (microsiemens/cm)	pH	Alkalinity as $CaCO_3$	Chloride, dissolved	Nitrate + nitrite as N	Sulfate, dissolved	Sodium, dissolved	Potassium, dissolved	Calcium, dissolved	Magnesium, dissolved	Hardness as $CaCO_3$	Iron, dissolved	Manganese, dissolved	Total Organic Carbon
Number	84	84	83	80	83	82	83	84	84	84	84	84	84	83	59
Minimum	6.5	17	5.3	4	.5	.01	3.0	1.3	.3	.2	.08	1.0	.02	<.005	<1.0
Maximum	15.0	234	8.6	97	15.0	8.00	18.0	20.0	4.8	33.0	10.00	109	10.00	1.500	83.0
Median	9.0	65	6.6	15	2.0	.06	5.6	4.6	1.2	5.6	1.15	19	.07	.061	1.0
Mean	9.2	75	NA[2]	22	3.5	.38	6.9	5.3	1.6	8.2	1.70	27	.52	.174	5.4
Standard Deviation	1.6	45	NA[2]	20	3.1	1.10	3.3	3.3	1.0	6.8	1.61	22.5	1.54	.284	12.3

[1] Tolman and others, 1983; Tepper and others, 1985; Williams, Tepper, Tolman, and Thompson, 1987; Adamik and others, 1987; Weddle and others, 1988.

[2] Not analyzed

Background water quality in sand and gravel aquifers in northern Maine[1]

[All values in milligrams per liter except as noted]

	Temperature (°C)	Conductance (microsiemens/cm)	pH	Alkalinity as $CaCO_3$	Chloride, dissolved	Nitrate + nitrite as N	Sulfate, dissolved	Sodium, dissolved	Potassium, dissolved	Calcium, dissolved	Magnesium, dissolved	Hardness as $CaCO_3$	Iron, dissolved	Manganese, dissolved	Total Organic Carbon
Minimum	6.0	110	5.8	41	<0.5	0.02	5.0	1.4	0.36	10	1.3	38	<.03	<.005	<1.0
Maximum	10.5	530	8.0	202	20	5.3	54.0	29.0	3.2	85	18.0	260	4.2	.850	62.0
Median	7.0	270	6.9	125	9.0	1.5	17.0	4.1	1.00	39	5.6	130	.05	.290	7.0
Mean	7.3	283	H6.5	128	8.8	1.95	23.3	7.4	1.15	47	6.7	145	0.60	.342	12.4
Standard Deviation	1.1	121	—	63	6.3	2.00	14.8	6.8	0.84	25	4.4	75	1.33	.275	16.9

[1] Locke and others, 1989

[2] H - Mean pH value calculated from hydrogen ion concentration

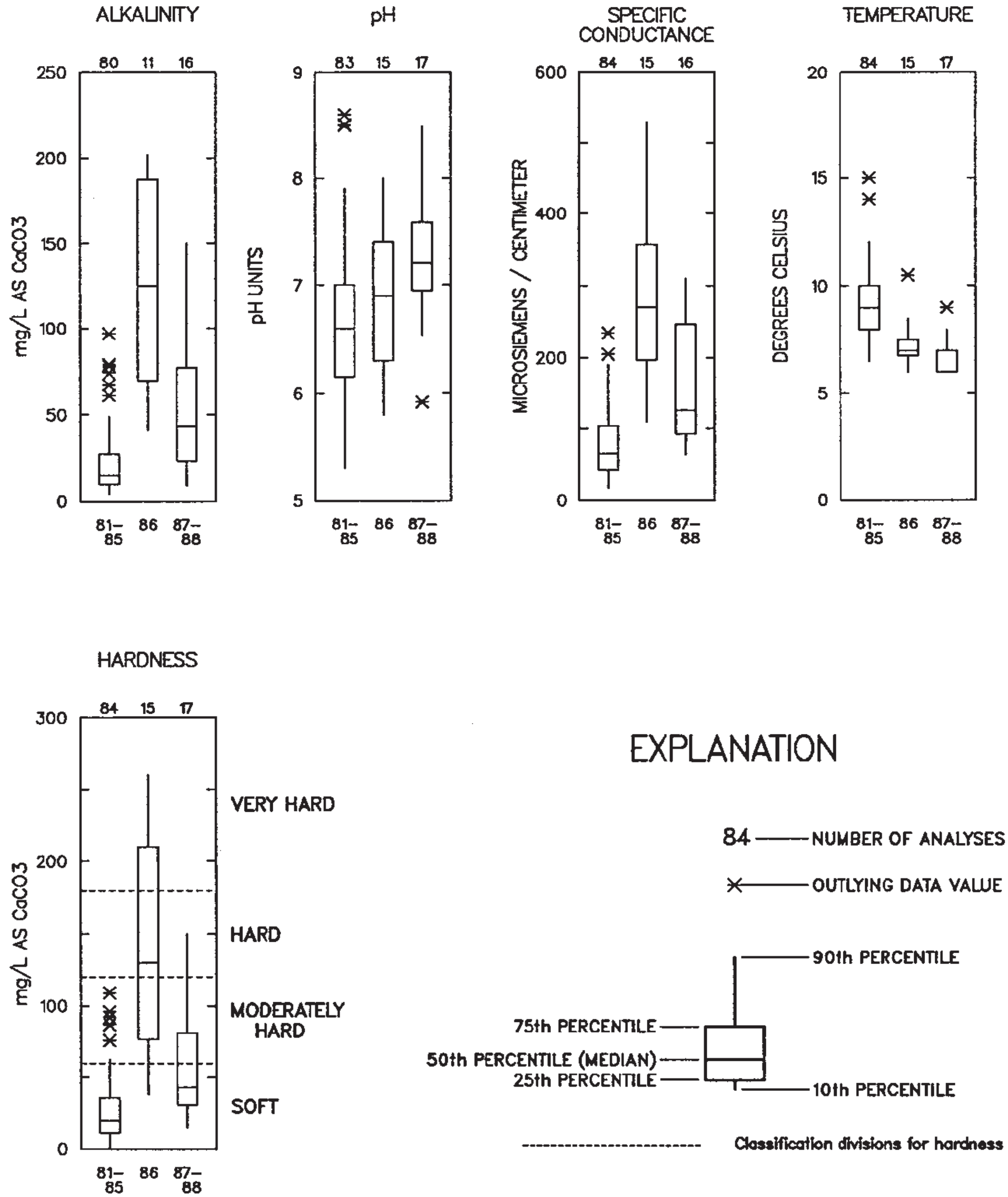

Figure 6.—Box plots of selected water-quality properties for 1981-85, 1986, and 1987-1988 study areas.

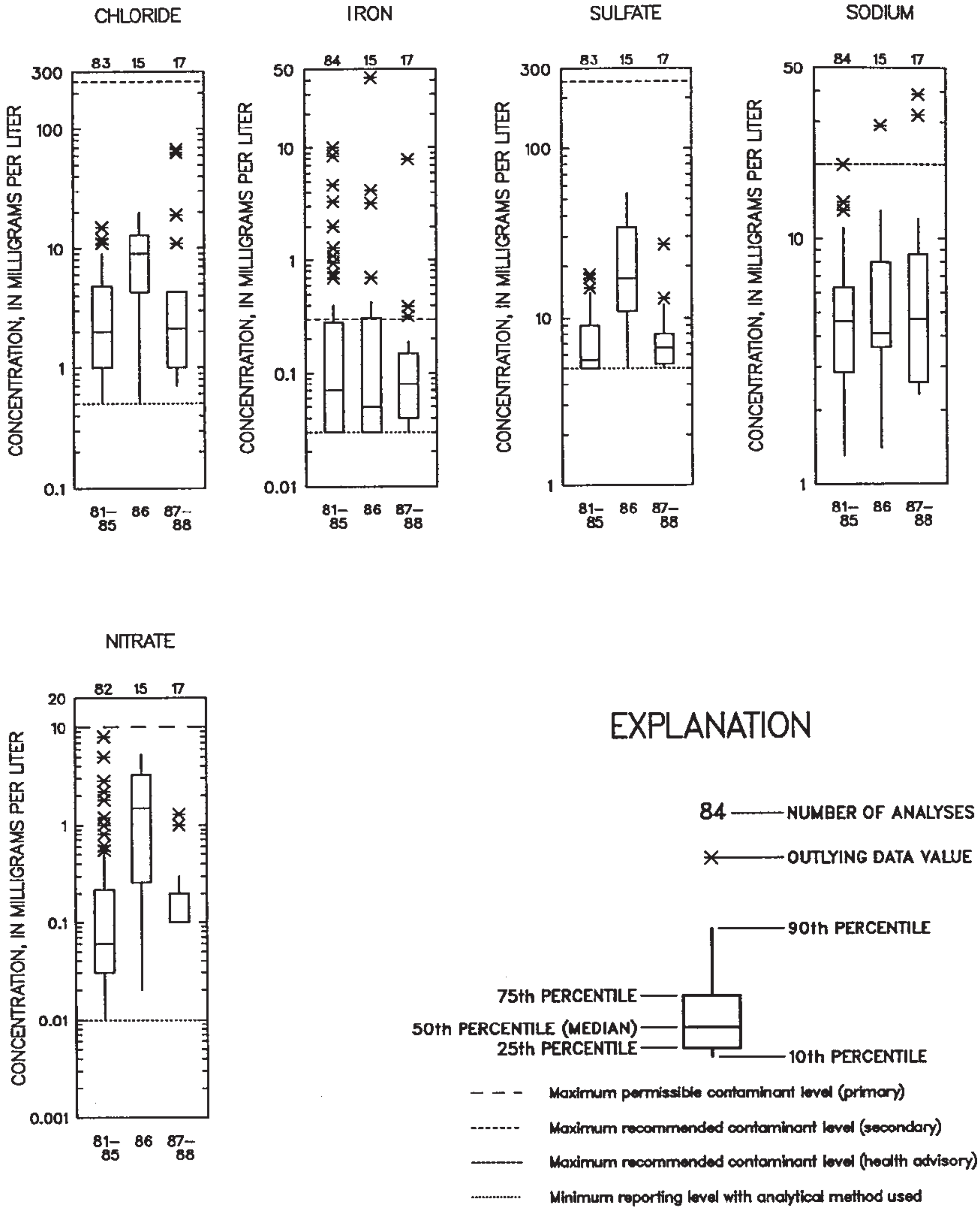

Figure 7.—Box plots of selected water-quality constituents for 1981-85, 1986, and 1987-1988 study areas with U. S. Environmental Protection Agency and Maine Department of Human Services drinking-water standards.

cific conductance of background water-quality samples in the southern and central Maine study areas ranges from 17 to 234 S/cm, with a median of 65 S/cm; the specific conductance of background water-quality samples in the northern Maine study area range from 110 to 530 S/cm, with a median of 270 S/cm (Table 9, Figure 6). The dissolved-solids concentration estimated from specific-conductance values from southern and central Maine study areas range from 13 to 176 mg/L, with a median of 49 mg/L. The dissolved-solids concentration estimated from specific-conductance values from the northern Maine study area range from 83 to 398 mg/L, with a median of 203 mg/L.

pH

The pH of water is a measure of hydrogen-ion activity (concentration). Each unit increase in the pH 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. The primary control on pH in ground water involves interaction of soil and rocks with gaseous carbon dioxide and with bicarbonate and carbonate ions. The pH in the background water-quality samples from the study area ranges from 5.9 to 9.2, with a median of 7.2 (Table 8, Figure 6). This is slightly higher than pH values found in previous study areas, which range from 5.3 to 8.6, with a median of 6.6, for the southern and central Maine study areas, and from 5.8 to 8.0, with a median of 6.9, for the northern Maine study area (Table 9, Figure 6). The USEPA (1986) has recommended a pH range for drinking water of from 5 to 9.

Alkalinity

Alkalinity is a measure of the capacity of a solution to neutralize acid. This capacity depends on the concentrations of carbonate (CO^{-2}), bicarbonate (HCO_3^-), and hydroxyl (OH^-) ions. Under equilibrium conditions, pH can be used to indicate the distribution of the different carbonate species (Hem, 1985). Thus, for ground water with pH in the range found in the study area, bicarbonate is the dominant anion. Alkalinity is reported in terms of equivalent calcium carbonate ($CaCO_3$) concentration. The alkalinity concentrations within the study area range from 9 to 150 mg/L, with a median of 43 mg/L (Table 8, Figure 6). The alkalinity concentrations in the wells in the southern and central Maine study areas are generally lower, with a range of 4 to 97 mg/L, with a median of 15 mg/L, whereas the alkalinity concentrations in the wells in northern Maine are generally higher, with a range of 41 to 202 mg/L and a median of 125 mg/L (Table 8, Figure 6). This alkalinity variation is likely caused by the predominance of calcareous mudstone and limestone in the northern Maine study area, whereas crystalline rocks with little or no carbonate content underlie the southern and central Maine study areas, and the study area discussed in this report.

Chloride

Because chloride is a highly mobile ion and is not readily sorbed, it can be used to trace contamination from applied road salt, sand-salt storage piles, landfills, and septic tanks. The USEPA (1989) has set an SMCL of 250 mg/L for chloride. High chloride concentrations in water can contribute to the deterioration of plumbing, water heaters, and water-works equipment. High chloride concentrations in water may also be associated with high sodium concentrations. Chloride concentrations in the background water-quality samples from the study area range from 0.7 to 67 mg/L, with a median concentration of 2.1 mg/L (Table 8, Figure 7). Chloride concentrations in the wells in the 1981-85 study areas in southern and central Maine are commonly lower, with a range of less than 0.5 to 15 mg/L, and a median of 2.0 mg/L. Chloride concentrations in the wells in the 1986 study area in northern Maine are generally higher, with a range of less than 0.5 to 20 mg/L, but with a median concentration of 9.0 mg/L (Table 9, Figure 7).

Nitrate Plus Nitrite

Nitrate and nitrite commonly are derived from plant and animal materials but can also be contributed by fertilizers. Nitrate is the most common nitrogen compound in ground water. Because nitrate is weakly adsorbed by soil, it is a good indicator of contamination from septic systems and waste-disposal sites. Nitrate can be converted to nitrite in the stomach; this may lead to the onset of methemoglobinemia in infants, a potentially lethal disease (National Research Council, 1977). Because of this, the USEPA (1986) established an MCL for nitrate-nitrogen (NO_3-N) of 10 mg/L in drinking water. High nitrate levels are also potentially lethal to cattle and other ruminants.

Nitrate plus nitrite concentrations in the background water-quality samples from the study area range from less than 0.1 to 1.3 mg/L, with a median of less than 0.1 mg/L (Table 8, Figure 7). These values are similar to those for the southern and central Maine study areas, which range from less than 0.01 to 8 mg/L, with a median of 0.06 mg/L, but are much lower than the values for the northern Maine study area, which range from 0.02 to 5.3 mg/L, with a median of 1.5 mg/L. (Table 9, Figure 7).

Sulfate

Sulfate is one of the major anions in natural waters. 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 at levels as low as a few tenths of a milligram per liter. The USEPA (1989) has set an SMCL for sulfate of 250 mg/L in drinking water; at concentrations above this, sulfate can have a laxative effect.

Sulfate concentrations in the background water-quality samples from the study area range from 3.3 to 27.0 mg/L, with a median of 6.6 mg/L (Table 8, Figure 7). Water samples from the southern and central Maine study areas have lower sulfate concentrations, ranging from less than 3.0 to 18 mg/L, with a median of 5.6 mg/L. Water samples from the northern Maine study area have higher sulfate concentrations, ranging from 5.0 to 54 mg/L, with a median of 17 mg/L (Table 9, Figure 7).

Sodium and Potassium

Sodium and potassium are among the major cations in ground water in Maine. The USEPA (1989) has not set a maximum limit for potassium in drinking water. For sodium, a drinking water standard of 20 mg/L has been set by the Maine Department of Human Services (1983) to protect individuals on restricted sodium diets. These diets usually are recommended for people with heart, hypertension, or kidney problems.

Concentrations of sodium in the background water-quality samples from the study area range from 2.3 to 39 mg/L, with a median of 4.7 mg/L (Table 8, Figure 7). Concentrations of potassium in the study area range from 0.5 to 3.0 mg/L, with a median of 1.2 mg/L (Table 8). These values are similar to those found in the 1981-85 and 1986 study areas. Sodium concentrations in the 1981-85 study areas in southern and central Maine range from 1.3 to 20 mg/L, with a median of 4.6 mg/L (Table 9, Figure 7); potassium concentrations range from 0.3 to 4.8 mg/L, with a median of 1.2 mg/L (Table 9). Sodium concentrations in the 1986 study area in northern Maine range from 1.4 to 29 mg/L, with a median of 4.1 mg/L (Table 9, Figure 7); potassium concentrations range from 0.36 to 3.2 mg/L, with a median of 1.00 mg/L (Table 9).

Calcium, Magnesium, and Hardness

Because calcium is widely distributed in the common minerals of rocks and soil, it is the principal cation in most freshwater (Hem, 1985). Magnesium also is a common cation in ground water. The Maine Department of Human Services (1983) has not recommended any maximum limits for calcium, magnesium, or hardness in drinking water.

Concentrations of calcium, the principal cation in the background water-quality samples, range from 4.3 to 44.0 mg/L in the study area, with a median of 13 mg/L (Table 8). Calcium concentrations in the southern and central Maine study areas range from 0.2 to 33 mg/L, with a median of 5.6 mg/L. Calcium concentrations in the northern Maine study area are considerably higher, ranging from 10 to 85 mg/L, with a median of 39 mg/L (Table 9). The high median concentration for calcium in the northern Maine study area likely reflects the abundance of calcareous bedrock underlying the northern Maine study area.

Magnesium concentrations in the study area range from 0.83 to 10 mg/L, with a median of 2.1 mg/L (Table 8). This is similar to magnesium concentrations in the southern and central Maine study areas (0.08 to 10 mg/L, with a median of 1.15 mg/L), but lower than magnesium concentrations in the northern Maine study area (1.3 to 18 mg/L, with a median of 5.6 mg/L.) (Table 9). Again, this difference likely reflects the bedrock geology of the northern Maine study area.

Hardnesss is a measure of the abundance of cations, mainly calcium and magnesium, that react with soap to form insoluble compounds or precipitate from heated water to form encrustations (Hem, 1985). Other divalent cations, including strontium, iron, and manganese, also can contribute to hardness. Hard water requires considerable amounts of soap to produce a foam or lather and is the cause of scale in hot-water pipes, heaters, boilers, and other units that use hot water.

Hardness in study-area water samples was calculated by Standard Method 314A (American Public Health Association, 1985) and is expressed in terms of an equivalent concentration of calcium carbonate. 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, 1985). Ground-water samples from the study area have hardness ranging from 14 to 150 mg/L (Table 8, Figure 6). This indicates that hardness of water in the region is variable, spanning the hardness scale from soft to hard. The median hardness for the study area is 43 mg/L, indicative of soft ground water. Southern and central Maine study-area ground water has a median hardness of 19 mg/L, also indicative of soft water. Median hardness for the northern Maine study area water is 130 mg/L, indicative of hard ground water (Table 9, Figure 6).

Iron and Manganese

Elevated iron and manganese concentrations can cause 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. Iron and manganese can stain clothes and plumbing fixtures and can cause problems in water-distribution systems by supporting growth of iron bacteria. Even at very low concentrations, iron in water can impart an objectionable taste, which is commonly described as rusty or metallic. When exposed to the air, water that contains dissolved iron and manganese can become turbid because of the formation of colloidal precipitates.

Dissolved-iron concentrations in the study area samples range from 0.007 to 7.9 mg/L, with a median of 0.084 mg/L (Table 8). These concentrations are similar to those found in previous study areas; the median iron concentration is 0.07 mg/L in the southern and central Maine study areas and 0.05 mg/L in the northern Maine study area (Table 9, Figure 7). The median concentrations for iron in all the study areas are less than the SMCL of 0.3 mg/L for drinking water recommended by the USEPA (1989).

Dissolved-manganese concentrations in the project area range from less than 0.001 to 4.6 mg/L, with a median of 0.07 mg/L (Table 8). Water samples from the southern and central Maine study areas have manganese concentrations ranging from less than 0.005 to 1.5 mg/L, with a median of 0.061 mg/L. Northern Maine study-area water samples have manganese concentrations ranging from less than 0.005 to 0.85 mg/L, with a median of 0.29 mg/L (Table 9). Median dissolved manganese concentrations in all study areas exceed the SMCL of 0.05 mg/L recommended for drinking water by the USEPA (1989).

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

Total Organic Carbon

TOC (total organic carbon) is a bulk indicator of all organic chemicals present in water. The TOC-measurement technique does not distinguish between toxic and nontoxic organic species. Natural organic species derived from soils can cause anomalously high TOC concentrations. The TOC concentrations in the background water-quality samples from the study area range from 0.7 to 6.1 mg/L, with a median of 1.7 mg/L (Table 8). Previous study-area TOC values range from less than 1.0 to 83 mg/L, with a median of 1.0 mg/L in the southern and central Maine samples, and from less than 1.0 to 62 mg/L, with a median of 7.0 mg/L in the northern Maine study area (Table 9). Most of the TOC values in the northern Maine study area exceed the detection limit of 1.0 mg/L, but many of the TOC concentrations in the southern and central Maine study areas and the study area described in this report are less than the detection limit.

SUMMARY

The significant sand and gravel aquifers in the study area consist of glacial ice-contact, ice-stagnation, outwash, and stream-alluvium deposits. These primarily occur in the valleys of the major river systems and their tributaries, or are associated with other surface-water bodies.

Although the study area includes 2,843 mi^2, areas mapped as significant aquifers cover only 84.6 mi^2. Yields exceeding 50 gal/min are estimated to be available in only 3.1 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. The largest reported well yield is 900 gal/min. from a municipal well operated by the Town of Orono.

The water table in the significant sand and gravel aquifers typically is within 15 ft of the land surface. On the basis of well-record data, the greatest known depth to bedrock is 190 ft in a domestic well in Alton.

On the basis of field relations, logs of observation wells, and interpretation of the geologic history, the following generalized stratigraphic relations have been determined: bedrock is overlain by till, which locally is overlain by ice-contact and outwash deposits, which may be overlain by and locally interbedded with glaciolacustrine or glaciomarine deposits. These deposits in turn, may be overlain by sand and gravel deposits of mixed origin. The thickness of the deposits and stratigraphic units varies considerably, depending on landform and local depositional controls during deglaciation and postglaciation.

The background water quality in sand and gravel aquifers in the study area has the following characteristics: the median pH is 7.2; calcium, sodium and silica are the most abundant cations, bicarbonate is the dominant anion, and the water is generally soft. According to water-quality data for the study area and the established USEPA and State drinking water-standards, the regional water quality generally is suitable for drinking and most other uses. However, in some localities, concentrations of iron and manganese may limit the use of untreated water.

Solid-waste facilities and salt-sand storage areas are the most common potential sources of ground-water contamination identified on or near sand and gravel aquifers in the study area. No municipal water-supply wells are known to have been contaminated by these sources.

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Appendix 1

Observation-Well and Test-Boring Logs [1]

Identification number: composed of three elements:

OW (Observation Well installed for collection of water-level and water-quality data) or TB (test boring drilled but no observation well installed); year well was drilled in; and a sequential number in the order the exploration borings were drilled.

Location: Latitude and longitude are specified; observation wells and test borings are located on the plates.

Site description: A brief site description is given.

Description of materials: Logs of observation wells and test borings, based on the Wentworth scale, in Pettijohn (1975).

Terms used in logs of exploration borings:

Sand and Gravel—Sorted sediment varying in size from boulders to very fine sand.

Silt—sediment particles ranging in size from 1/16 mm to 1/256 mm.

Clay—Sediment particles 1/256 mm and smaller in size.

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

Loam—A mixture of sand, silt and clay particles which exhibits light and heavy properties in roughly equal proportions.

End of Boring—Depth of bottom of exploration boring in which bedrock or refusal was not reached.

Refusal—Depth at which drill equipment could not penetrate further. If it is fairly certain that a boulder was encountered, the word "boulder" is shown in parentheses after the word "refusal". If it is fairly certain that the bedrock surface was encountered, the word "bedrock" is shown in parentheses after the word "refusal".

PVC — Polyvinyl chloride

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[1] See tables 1, 2, and 3 for information on grain-size analyses and estimated transmissivities and well yields.

OW 88-1. Latitude: 44°31’01" N., Longitude: 68°31’08" W.

Located on the Branch Lake quadrangle in Ellsworth near the western edge of a gravel pit off Route 1 in West Ellsworth .2 mile east of Birch Grove Cemetery. Water is approximately 7 feet below land surface.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, fine to medium	0 - 3	3
Sand, medium to very coarse and gravel up to 1/2" in diameter	3 - 7	4
Sand, very fine to fine	7 - 13	6
Sand, fine to medium, trace silt	13 - 17	4
Sand, very fine to medium	17 - 22	5
Sand, very fine to fine with occasional layer of silty clay 1/4" thick	22 - 28	6
Till	28 - 38	10
Refusal (bedrock)	38	—

OW 88-1 is screened from 16-21 feet below land surface with a 0.006-inch slotted PVC screen.

OW 88-2. Latitude: 44°34’22" N., Longitude: 69°05’14" W.

Located on the Brooks East quadrangle in Monroe in southeast end of gravel pit near Marsh Stream. Gravel pit is east of Route 139 approximately .2 miles north of the Brooks-Monroe townline. Water is approximately 32 feet below land surface.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Silt, very fine to medium sand, some coarse to very coarse sand, granules	0 - 10	10
Silt, very fine to medium sand, very compact	10 - 15	5
Sand, very fine to coarse, silt	15 - 27	12
Sand, fine to coarse, some silt	27 - 32	5
Sand, very fine to fine, some silt	32 - 38	6
Sand, fine to medium, little silt	38 - 67	29
Sand, very fine to fine, some silt	67 - 72	5
Till	72 - 75	3
Refusal (bedrock)	75	—

OW 88-2 is screened from 60-65 feet below land surface with a 0.006-inch slotted PVC screen.

OW 88-3. Latitude: 44°42’33" N., Longitude: 68°52’47" W.

Located on the Snow Mountain quadrangle in Hampden in east end of gravel pit off Monroe Road, approximately 0.7 miles south of junction with Kennebec Road. Depth to water is approximately 10 feet.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Gravel, granules, silt (fill) sand, medium to coarse	0 - 7	7
Sand, medium to coarse, silt, very compact (fill)	7 - 13	6
Sand, fine to medium, interbedded with medium to coarse sand, little fine sand	13 - 29	16
Till	29 - 33	4
Refusal (bedrock)	33	—

OW 88-3 is screened from 25 to 30 feet below land surface with a 0.006-inch slotted PVC screen.

OW 88-4. Latitude: 44°34’07" N., Longitude: 69°02’09" W.

Located on the Brooks East quadrangle in Monroe in a field approximately 2.1 miles north of Nickerson Mills. Water is approximately 22 feet below land surface.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, loam, gravel	0 - 7	7
Sand, fine to coarse, granules	7 - 12	5
Sand, medium to coarse, some very coarse sand, granules	12 - 27	15
Sand, very fine to fine, silt	27 - 37	10
Silt, some very fine sand	37 - 47	10
Silt, clay in layers, some very fine sand, gray	47 - 48	1
Refusal (bedrock)	48	—

OW 88-4 is screened from 28 to 33 feet below land surface with a 0.006-inch slotted PVC screen.

OW 88-5. Latitude: 45°02’34" N., Longitude: 68°31’47" W.

Located on the Olamon quadrangle in Greenbush in gravel pit off Greenfield Road, .8 mile west of Greenfield-Greenbush-Milford townline. Water is approximately 26 feet below land surface.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, fine to medium, some silt, some coarse sand	0 - 12	12
Silt, fine sand	12 - 14	2
Sand, fine, some medium sand	14 - 20	6
Sand, very fine to fine, some silt	20 - 32	12
Silt, clay, interbedded with very fine to fine sand, blue	32 - 53	21
Sand, fine to medium, some very fine sand	53 - 68	15
Till	68 - 69	1
Refusal (bedrock)	69	—

OW 88-5 is screened from 55 to 60 feet below land surface with a 0.006-inch slotted PVC screen.

OW 88-6. Latitude: 45°04’34" N., Longitude: 68°35’55" W.

Located on the Olamon quadrangle in Greenbush in gravel pit off Cardville Road approximately 2.7 miles south of junction with Route 2. Water is approximately 30 feet below land surface.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Loam, sandy, with gravel, cobbles, (fill)	0 - 5	5
Sand, medium to very coarse, granules, gravel 1/2-2" in diameter	5 - 13	8
Sand, fine, silt, some clay	13 - 18	5
Sand, very fine, silt, blue	18 - 27	9
Sand, very fine, silt, interbedded with layers of very fine to medium sand	27 - 38	11
Sand, very fine to fine, silt, brown	38 - 48	10
Sand, fine to medium, interbedded with medium to coarse sand, very little silt throughout	48 - 88.5	40.5
Till	88.5- 90	1.5
Refusal (till)	90	—

OW 88-6 is screened from 57.5 to 62.5 feet below land surface with a 0.006 inch slotted PVC screen, however, when well was developed fine gravel was brought up. The screen was probably broken during installation.

OW 88-7. Latitude: 45°24’25" N., Longitude: 68°29’50" W.

Located on the Lincoln Center quadrangle in Chester approximately 3.0 miles northeast of Chester-T2R8NWP townline off Route 116 in gravel pit near Penobscot River. Water level is at approximately 17 feet below land surface.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, very fine to fine, some medium sand	0 - 4	4
Sand, very fine to coarse, pebbles	4 - 7	3
Sand, medium to very coarse, granules, pebbles, some fine sand	7 - 43	36
Refusal (bedrock)	43	—

OW 88-7 is screened from 27 to 32 feet below land surface with a 0.008-inch slotted PVC screen.

OW 88-8. Latitude: 45°36’48" N., Longitude: 68°15’43" W.

Located on the Mattawamkeag quadrangle in Macwahoc in gravel pit approximately .2 mile west of Route 170 and .6 mile north of Kingman-Macwahoc townline. Water level is 19 feet below land surface.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, medium to very coarse	0 - 17	17
Rock, broken, 1/4" - 1", some silt fine sand, till (?)	17 - 40	23
Refusal (bedrock)	40	—

OW 88-8 is screened from 26 to 31 feet below land surface with a 0.006-inch slotted PVC screen.

OW 88-9. Latitude: 45°24’27" N., Longitude: 68°31’45" W.

Located on the Nine Meadow Ridge quadrangle in Chester in gravel pit approximately 1 mile north of Route 116 between Keene Bog and Medunkeunk Stream. Water level is 50 feet below land surface.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Loam, very fine sand	0 - 15	15
Sand, very fine to fine, some silt	15 - 50	35
Sand, medium to coarse, interbedded with very fine sand, silt layers	50 - 98	48
Refusal (bedrock)	98	—

OW 88-9 is screened from 62 to 67 feet below land surface with a 0.006-inch slotted PVC screen.

OW 88-10 Latitude: 45°34'44" N., Longitude: 68°40'02" W.

Located on the Nollesemic Lake quadrangle in Hopkin's Academy Grant on east end of road cut through esker, west of Mud Brook. Water level is 14 feet below land surface.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, very fine to medium, fill (?)	0 - 7	7
Sand, very fine to fine, silt	7 - 13	6
Sand, fine to coarse, some layers of very fine sand, silt	13 - 20	7
Sand, fine to very coarse, granules pebbles, silt	20 - 38	18
Refusal (till)	38	—

OW 88-10 is screened from 20 to 25 feet below land surface with a 0.008-inch slotted PVC screen.

OW 88-11. Latitude: 45°21'33" N., Longitude: 68°32'13" W.

Located on the Lincoln West quadrangle in Lincoln 800 feet southwest of the south end of the airstrip in the Lincoln Municipal Airport. Water was found at 20 feet below land surface in this confined aquifer.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Silt, some very fine sand	0 - 17	17
Silt, blue, some very fine sand	17 - 50	33
Sand, very fine to medium, layered with medium to very course sand, pebbles	50 - 68	18
Silt, blue	68 - 88	20
Refusal (bedrock?)	88	—

OW 88-11 is screened from 55 to 60 feet below land surface with a 0.006-inch slotted PVC screen, however, during development there was a blockage in the well at 40 feet, probably due to broken casing. The well was not used for any further data collection.

OW 88-12. Latitude: 45°55’50" N., Longitude: 68°36’43" W.

Located on the Lookout Mountain quadrangle in T3R7 approximately 3.9 miles north of Hunt Camp. Water level is approximately 13 feet below land surface.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, very fine to fine, some medium sand, silt	0 - 3	3
Sand, fine to very coarse, granules pebbles	3 - 10	7
Sand, medium to very coarse, granules, pebbles, little silt	10 - 17	7
Sand, fine to medium, occasional layer of silt	17 - 37	20
Sand, very fine to fine, silt, blue	37 - 47	10
Clay, silt, blue	47 - 68	21
Clay, silt, blue, with very thin layer of very fine sand	68 - 77	9
Sand, very fine to fine, silt, blue	77 - 85	8
Weathered bedrock or till	85 - 90	5
Refusal (bedrock)	90	—

OW 88-12 is screened from 27 to 32 feet below land surface with a 0.006-inch slotted PVC screen.

OW 88-13. Latitude: 45°57’53" N., Longitude: 68°37’03" W.

Located on the Lookout Mountain quadrangle in T4R7 east of the Seboeis River along a logging road approximately .8 mile south of the bridge over the Seboeis River. Water level is 21 feet below land surface.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, medium to very coarse, granules, pebbles 1/4 to 4" diameter, sub-rounded	0 - 17	17
Sand, fine to medium, some coarse sand, interbedded with very fine to fine sand, little silt	17 - 47	30
Sand, very fine to fine layered with silt, 1/8" to 1/16" thick, blue	47 - 99	52
Till	99 -103.5	4.5
Refusal (till)	103.5	—

OW 88-13 is screened from 30 to 35 feet below land surface with a 0.006-inch slotted PVC screen.

OW 88-14. Latitude: 45°46'02" N., Longitude: 68°34'46" W.

Located on the Stacyville quadrangle in T2R7 (Soldiertown) south of outlet from Round Pond and west of confluence with Penobscot River, also across the Penobscot River from Hay Brook. Water level is approximately 37 feet below land surface.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Loam, sandy	0 - 3	3
Sand, fine to medium, some coarse sand	3 - 25	22
Sand, fine to very coarse, granules pebbles	25 - 38	13
Sand, medium to very coarse	38 - 48	10
Sand, very fine to very coarse	48 - 68	20
Sand, medium to very coarse, some fine sand, silt	68 - 78	10
Sand, very fine to very coarse, silt, granules	78 - 88	10
Sand, fine to coarse, some very fine sand, blue	88 - 92	4
Refusal (till)	92	—

OW 88-14 is screened from 35 to 40 feet below land surface with a 0.006-inch slotted PVC screen.

OW 88-15. Latitude: 45°39'49" N., Longitude: 68°38'11" W.

Located on the Millinocket quadrangle in TAR7, approximately 300 feet south of Route 157 on a dirt road west of Dolby Pond and .3 mile east of intersection of Route 157 and road going south to Rice Farm. Water level is 30 feet below land surface.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, medium to very coarse, some fine sand	0 - 13	13
Sand, fine to medium, some coarse sand, interbedded with very fine to fine sand	13 - 45	32
Till, silt to very coarse sand, rock fragments	45 - 63	18
Refusal (till)	63	—

OW 88-15 is screened from 37 to 42 feet below land surface with a 0.006-inch slotted PVC screen.

OW 88-16. Latitude: 45°40’57" N., Longitude: 68°42’07" W.

Located on the Millinocket quadrangle in T3 Indian Purchase in gravel pit on the east side of Millinocket Steam, approximately .3 mile north of the bridge over Millinocket Stream. Water level is 14 feet below land surface.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, fine to medium	0 - 28	28
Sand, very fine to medium, little silt	28 - 33	5
Silt, fine sand, blue, very compact	33 - 45	12
Refusal (bedrock)	45	—

OW 88-16 is screened from 26 to 31 feet below land surface with a 0.008-inch slotted PVC screen.

TB 88-1. Latitude: 44°45’47" N., Longitude: 68°51’36" W.

Located on the Bangor quadrangle in Hampden in a field along Paper Mill Road, 0.8 miles west of the junction of Cold Brook Road and Paper Mill Road or .1 mile west of the bridge over the Souadabscook Streamon Paper Mill Road.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Silt, some clay	0 - 7	7
Loam, silt	7 - 12	5
Silt, some clay, brown	12 - 17	5
Silt, some clay, gray	17 - 25	8
Silt, some clay, blue-gray	25 - 35	10
Silt, some clay, blue-gray, drier	35 - 45	10
Sand, fine, silt, dry	45 - 49	4
Refusal (hard drilling)	49	—

No well was installed.

TB 88-2. Latitude: 44°31’01" N., Longitude: 68°31’08" W.

Located on the Branch Lake quadrangle in Surry in a field on North Bend Road 1.5 miles north of Surry. Boring was dry.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, medium to coarse, gravel	0 - 9	9
Sand, fine, some coarse sand and gravel 1/4 - 1/2" in diameter	9 - 12	3
Sand, very fine to fine, interbedded with layers of medium to very coarse sand, dry	12 - 50	38
Till	50 - 54	4
Refusal (bedrock?)	54	—

No well was installed.

TB 88-3. Latitude: 44°31’45" N., Longitude: 68°50’03" W.

Located on the Bucksport quadrangle in Stockton Springs by the side of gravel road off Muskrat Road, 1.3 miles northwest of junction with Route 1. Depth to water was approximately 12 feet below land surface.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Loam	0 - 2	2
Silt, brown	2 - 18	16
Silt, clay, blue	18 - 23	5
Till	23 - 29	6
Refusal (bedrock)	29	—

No well was installed.

TB 88-4. Latitude: 44°31’37" N., Longitude: 68°49’55" W.

Located on the Bucksport quadrangle in Stockton Springs in gravel pit approximately .2 mile farther southeast along the gravel road from TB 88-3. About 10-100’ feet of gravel has been removed in pit. Depth to water approximately 36 feet.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, very fine to medium	0 - 6	6
Sand, fine to medium, some coarse sand	6 - 10	4
Sand, very fine to medium, some coarse sand, granules, pebbles 1/4" to 1 1/2", cobbles at 16 and 22 feet	10 - 37	27
Till	37 - 39	2
Refusal (bedrock)	39	—

No well was installed.

TB 88-5. Latitude: 44°31’54" N., Longitude: 68°50’51" W.

Located on the Bucksport quadrangel in Stockton Springs in gravel pit near Muskrat Road approximately 1.1 miles south of junction with Route lA. Boring was dry.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, very fine to fine with some silt, brown	0 - 5	5
Sand, very fine to medium. granules, pebbles	5 - 10	5
Sand, medium to very coarse, some fine sand, granules, pebbles	10 - 29	19
Silt, some medium to very coarse sand; granules	29 - 35	6
Silt, little fine to medium sand	35 - 40	5
Silt, little fine to medium sand, some granules, pebbles	40 - 43	3
Refusal (till)	43	—

No well was installed.

TB 88-6. Latitude: 44°31’12" N., Longitude: 69°05’05" W.

Located on the Brooks East quadrangle in Brooks in a field .8 mile north of Route 131 in Waldo, and 6 mile from Waldo Station Road. Boring was dry.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, fine to coarse. silt, granules, gravel	0 - 32	32
Refusal (bedrock)	32	—

No well was installed.

TB 88-7. Latitude: 44°37’53" N., Longitude: 69°00’25" W.

Located on the East Dixmont quadrangle in Monroe in a field off Dalia Farm Road, .3 mile west of Monroe-Winterport townline. Boring was dry.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Gravel, loamy, pebbles 1/2" to 2" in diameter	0 - 8	8
Gravel, 1/4 - 1" in diameter, medium to coarse sand	8 - 17	9
Sand, fine to coarse, gravel 1/4" to 1/2" in diameter	17 - 20	3
Sand, fine to medium	20 - 23	3
Sand, very fine to fine, silt	23 - 37	14
Sand, very fine, silt, gray	37 - 46	9
Till	46 - 49.5	3.5
Refusal (bedrock)	49.5	—

No well was installed.

TB 88-8. Latitude: 45°02’45" N., Longitude: 68°44’26" W.

Located on the Greenbush quadrangle in Alton in field off Route 16 approximately 5.8 miles south of South Lagrange. Sediments were wet at 52 feet but depth to water table is uncertain.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, medium, some coarse sand and gravel	0 - 7	7
Sand, medium, some fine sand	7 - 37	30
Sand, fine, some medium sand	37 - 47	10
Sand, very fine to fine, silt in layers	47 - 77	30
Sand, very fine, silt	77 - 95	18
Till	95 - 98	3
Refusal (till)	98	—

No well was installed.

TB 88-9. Latitude: 45°06’00" N., Longitude: 68°47’56" W.

Located on the South Lagrange quadrangle in Alton in field off Route 16, 0.1 mile south of the LaGrange-Alton townline. Water level is 65 feet below land surface.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, fine to very coarse, some silt	0 - 3	3
Sand. very fine to fine, silt	3 - 57	54
Sand, medium to very coarse	57 - 67	10
Sand, medium to very coarse, granules, pebbles, rock fragments, very little silt (till?)	67 -103	36
Refusal (bedrock?)	103	—

No well was installed.

TB 88-10. Latitude: 45°25'37" N., Longitude: 68°28'33" W.

Located on the Lincoln Center quadrangle in Chester approximately 4.7 miles northeast of the Chester-T2R8NWP townline off Route 116 near the Penobscot River. Perched water table at 6 feet and confined aquifer water level at 16 feet.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, medium to very coarse, pebbles, cobbles	0 - 2	2
Sand, medium to very coarse, granules, pebbles	2 - 11	9
Clay, blue	11 - 18.5	7.5
Clay, rock fragments	18.5- 23	4.5
Refusal (bedrock)	23	—

No well was installed.

TB 88-11. Latitude: 45°30'40" N., Longitude: 68°19'39" W.

Located on the Mattawamkeag quadrangle in Mattawamkeag in the forest on the north side of Mattawamkeag River approximately 1.5 miles east of Route 2A in Mattawamkeag. Perched water table around 20 feet. Very little water in boring.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, fine to very coarse, pebbles	0 - 37	37
Till	37 - 38	1
Refusal (bedrock)	38	—

No well was installed.

TB 88-12. Latitude: 45°35'40" N., Longitude: 68°28'14" W.

Located on the Mattaseunk Lake quadrangle in Medway in gravel pit southeast of Route 157 at confluence of the Penobscot River and Salmon Stream. Boring was dry.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, very fine to fine, some medium to very coarse sand, pebbles, silt	0 - 22	22
Silt, fine sand, some medium to coarse sand, few pebbles, blue-gray, dry	22 - 41	19
Refusal (bedrock)	41	—

No well was installed.

TB 88-13. Latitude: 45°23’12" N., Longitude: 68°31’25" W.

Located on the Nine Meadow Ridge quadrangle in Chester in gravel pit approximately .2 miles downstream of the confluence of the Medunkeunk Stream and the Penobscot River. Boring was dry.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, gravel, fill	0 - 5	5
Sand, medium to very coarse, pebbles, some silt	5 - 83	78
Sand, medium to very coarse, pebbles, tight drilling	83 -103	20
Refusal	103	—

No well was installed.

TB 88-14. Latitude: 45°18’26" N., Longitude: 68°51’18" W.

Located on the Hardy Pond quadrangle in Medford .2 mile west of Scutaze Trail, 1.2 mile north of Scutaze Trail’s junction with Route 16. Boring was dry.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, very fine to fine	0 - 5	5
Sand, fine, some medium sand, granules	5 - 8	3
Sand, fine to medium, pebbles	8 - 18	10
Refusal, large cobbles or boulders	18	—

No well was installed.

TB 88-15. Latitude: 45°58’24" N., Longitude: 68°39’50" W.

Located on the Deasey Mountain quadrangle in T4R7 in gravel pit north and east of the East Branch Penobscot River 0.3 mile south on a dirt road that is 2.0 miles west of bridge over Seboeis River. Water level was at 20 feet when boring was drilled.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Fill, gravel, sand	0 - 5	5
Sand, very fine to fine, silt, few pebbles	5 - 24	19
Silt, blue, gray	24 - 27	3
Refusal (bedrock)	27	—

No well was installed.

TB 88-16. Latitude: 45°54’00" N., Longitude: 68°36’59" W.

Located on the Lookout Mountain quadrangle in T3R7 near the confluence of the Wassataguoik and the East Branch Penobscot Rivers.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Cobbles, pebbles, granules	0 - 7	7
End of boring, material is too difficult to drill in with available drilling equipment	7	—

No well was installed.

TB 88-17. Latitude: 45°38’52" N., Longitude: 68°41’45" W.

Located on the Millinocket quadrangle in Millinocket in gravel pit across the road from the entrance to the Millinocket airport. Some perched water at 22 feet below land surface.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, fine	0 - 12	12
Sand, very fine to fine, some silt, few pebbles at 25 feet	12 - 25	13
Sand, very fine to very coarse, black rock fragments	25 - 33.5	8.5
Refusal (till)	33.5	—

No well was installed.

TB 88-18. Latitude: 45°40’57" N., Longitude: 68° 42’07" W.

Located on the Millinocket quadrangle in TlR7 (Grindstone) in reclaimed gravel pit west of Dolby Pond after crossing bridge over Schoodic Stream. Perched water at 7 feet.

MATERIAL	DEPTH (feet)	THICKNESS (feet)
Sand, very fine to fine, silt	0 - 7	7
Sand, very fine to fine, silt, few pebbles	7 - 15	8
Sand, very fine, silt	15 - 17	2
Sand, very fine to fine, some medium to very coarse sand	17 - 20	3
Till	20 - 27	7
Refusal (till)	27	—

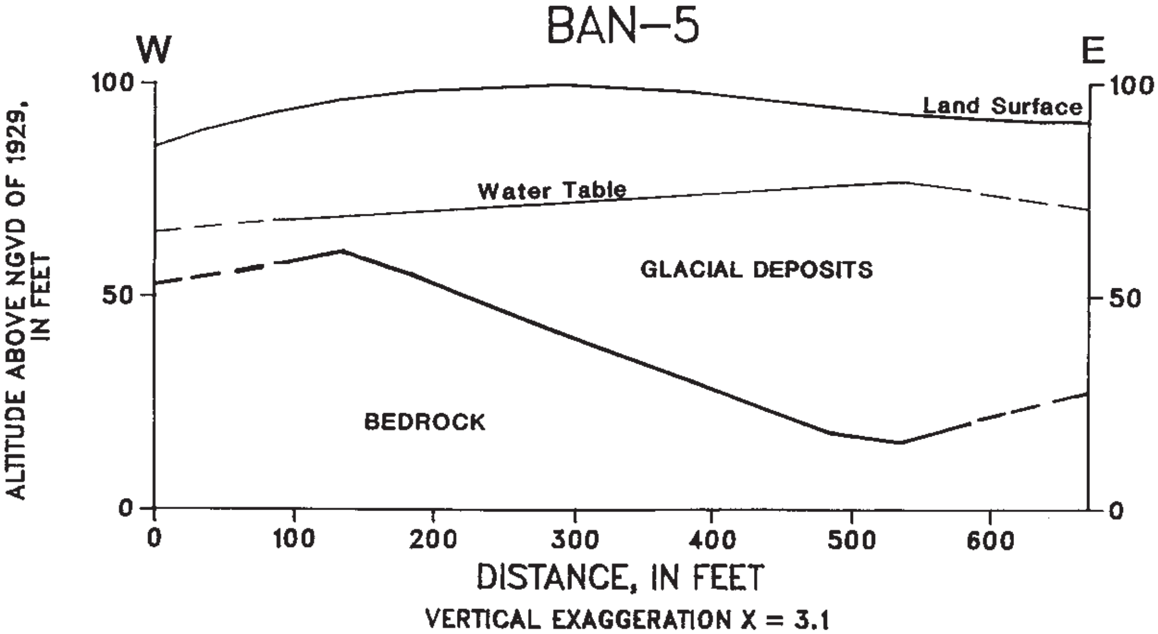
No well was installed.

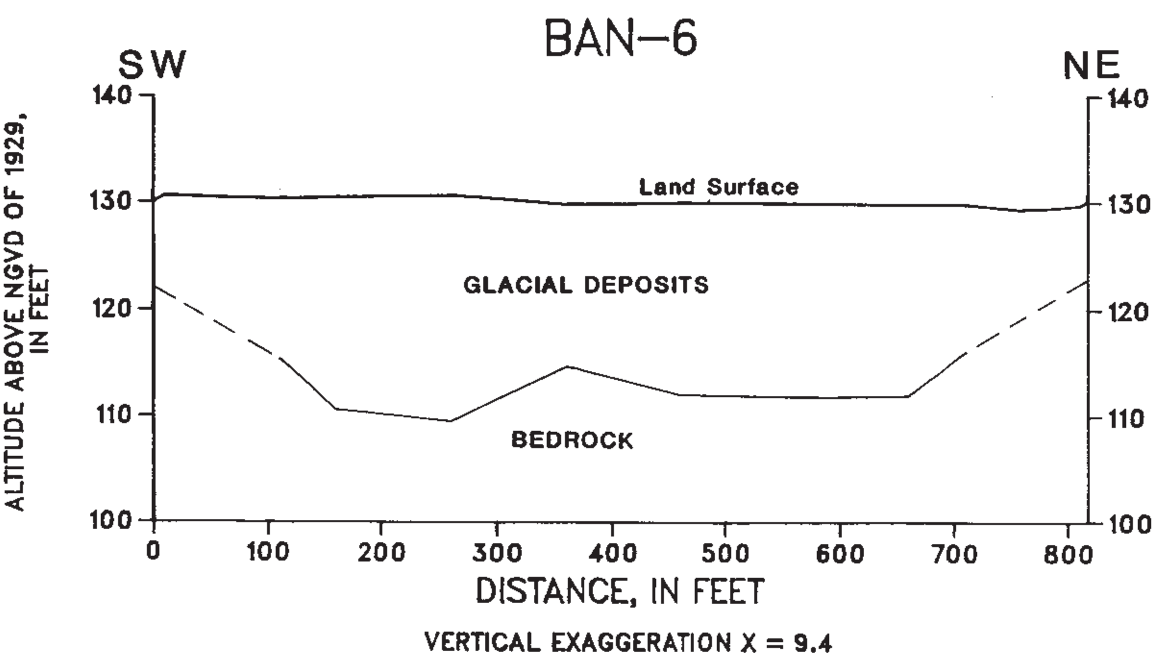
Appendix 2

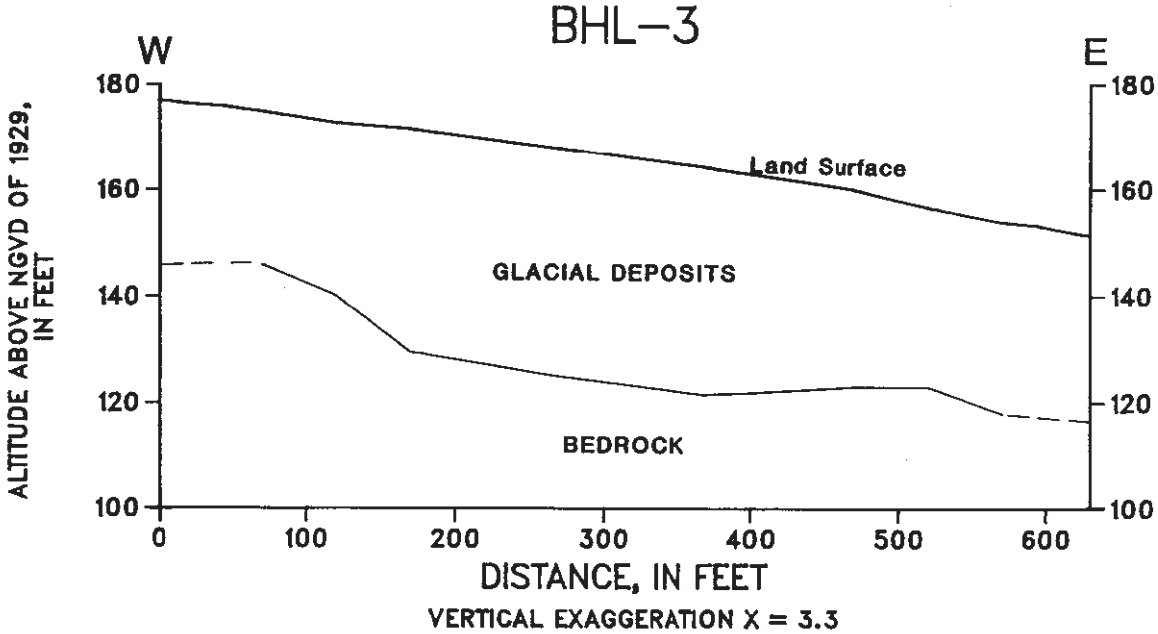
12-Channel Seismic-Refraction Profiles

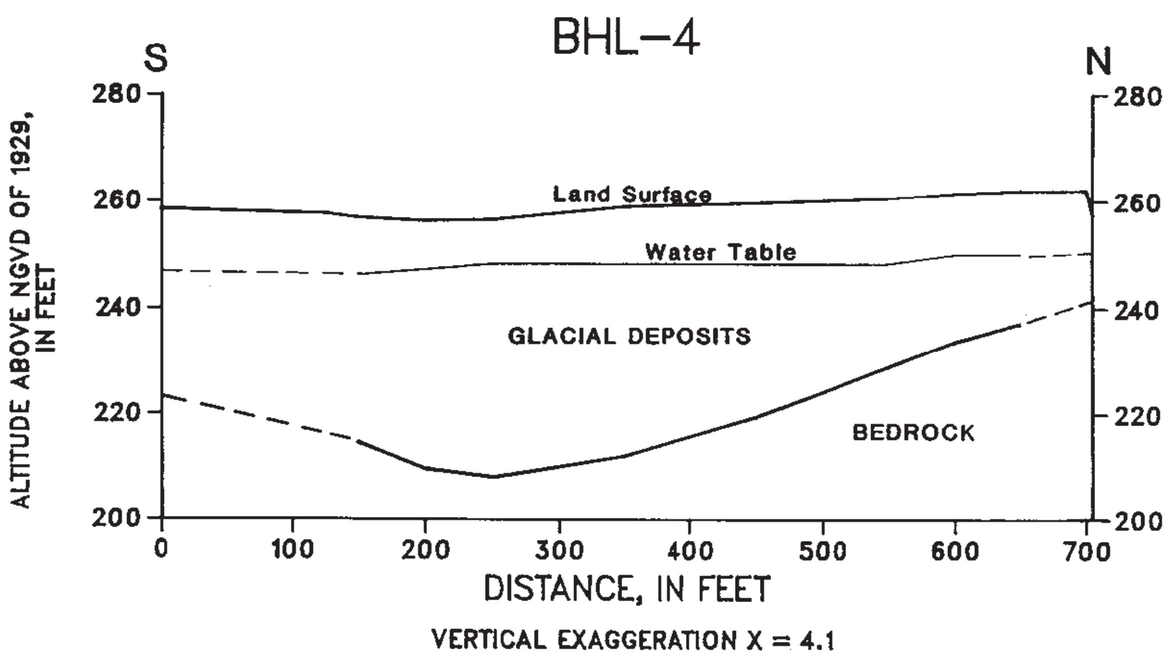
The following are hydrogeologic cross sections interpreted from seismic-refraction surveys conducted by the Maine Geological Survey and the U.S. Geological Survey during 1987-1988. Data interpretation is based on a computer modeling program described by Scott and others (1972). Distances shown on the x-axes are measured from geophone number 1. In places, the altitude of the water table and bedrock surfaces have been shown with dashed lines to emphasize the relative unreliability of the interpretation at the extreme ends of the line. Not all seismic lines shown on the associated maps have corresponding profiles in this appendix. Locations of individual profiles are shown on the quadrangle indicated by the three letter quadrangle code identifying the seismic line. A list of these quadrangle codes is given below.

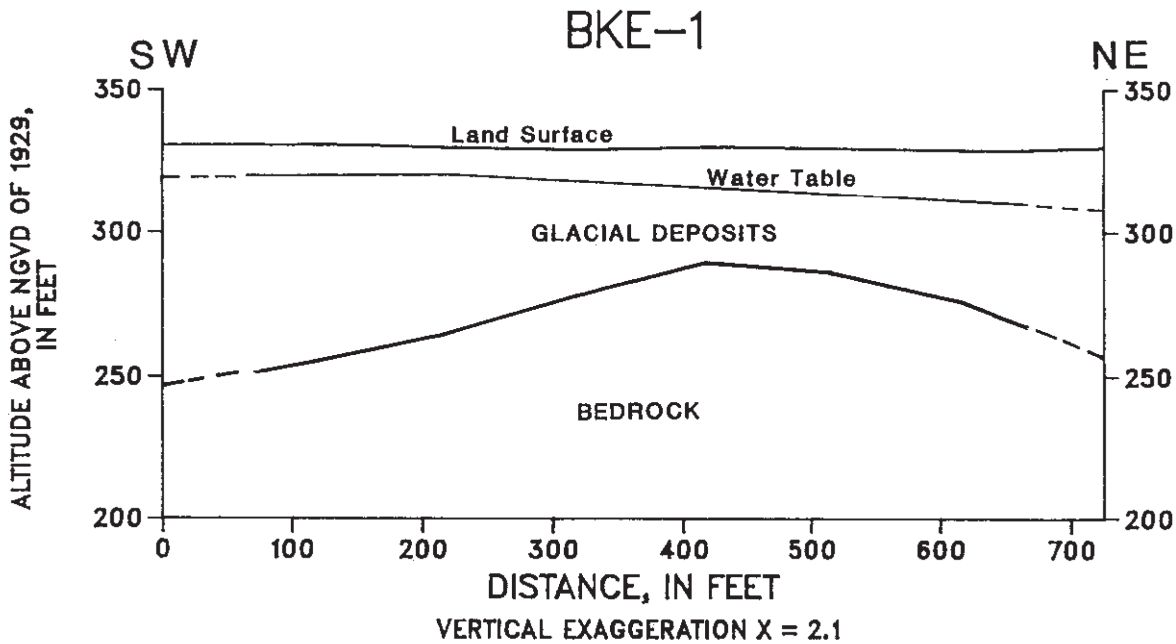
CODE	QUADRANGLE	CODE	QUADRANGLE
BAN	Bangor	LCC	Lincoln Center
BHL	Branch Lake	LCW	Lincoln West
BKE	Brooks East	LOO	Lookout Mountain
BKW	Brooks West	MKK	Medunkeunk Lake
EDM	East Dixmont	MTT	Mattawamkeag
GBH	Greenbush	NMR	Nine Meadow Ridge
GRE	Green Lake	NOL	Nollesemic Lake
HAM	Hampden	OLD	Old Town
HER	Herman	SNO	Snow Mountain
KNG	Kingman	STA	Stacyville
LAG	Lagrange	TRT	Trout Mountain

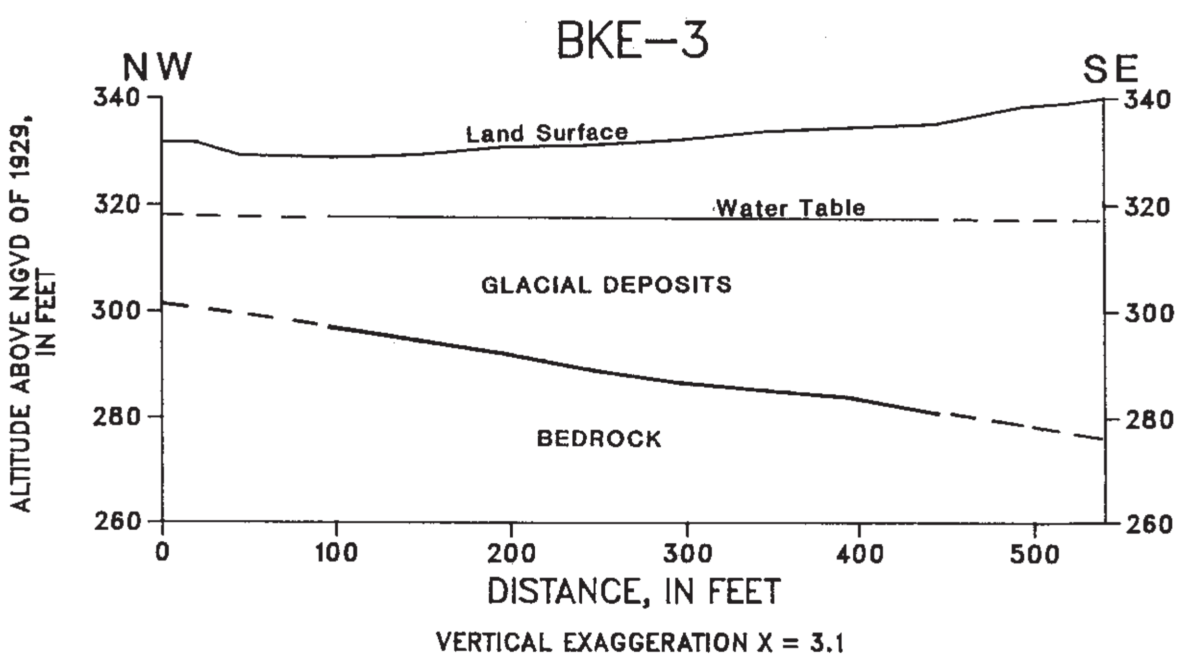

BAN–5
W
E
ALTITUDE ABOVE NGVD OF 1929, IN FEET
100
50
0
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
0
100
200
300
400
500
600
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 3.1

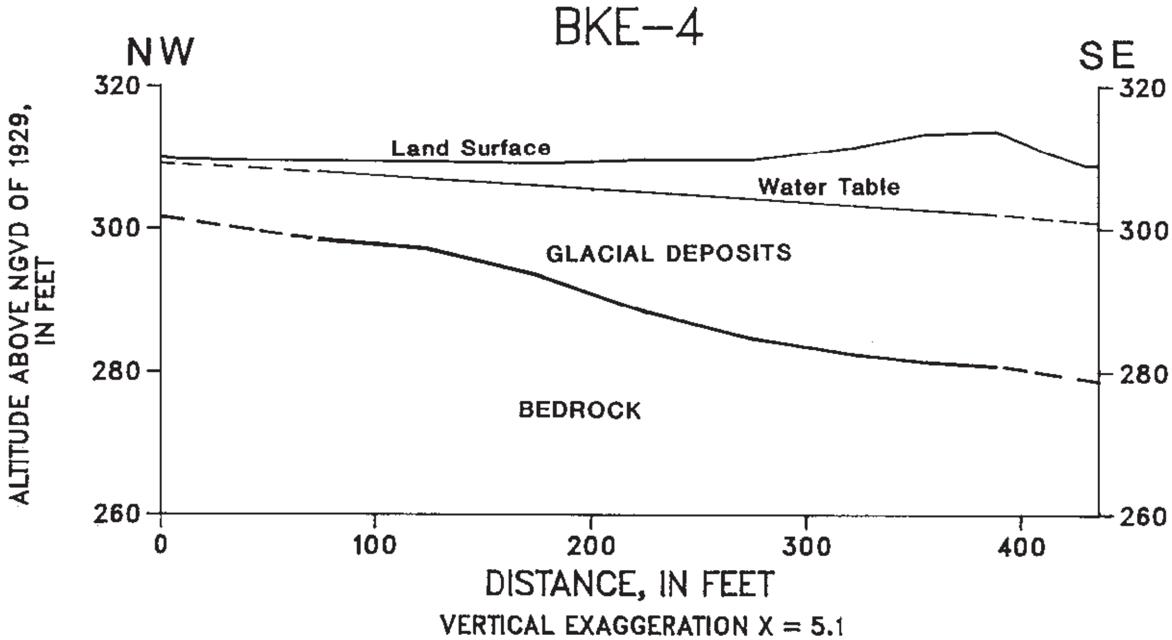

BAN–6
SW
NE
ALTITUDE ABOVE NGVD OF 1929, IN FEET
140
130
120
110
100
Land Surface
GLACIAL DEPOSITS
BEDROCK
0
100
200
300
400
500
600
700
800
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 9.4

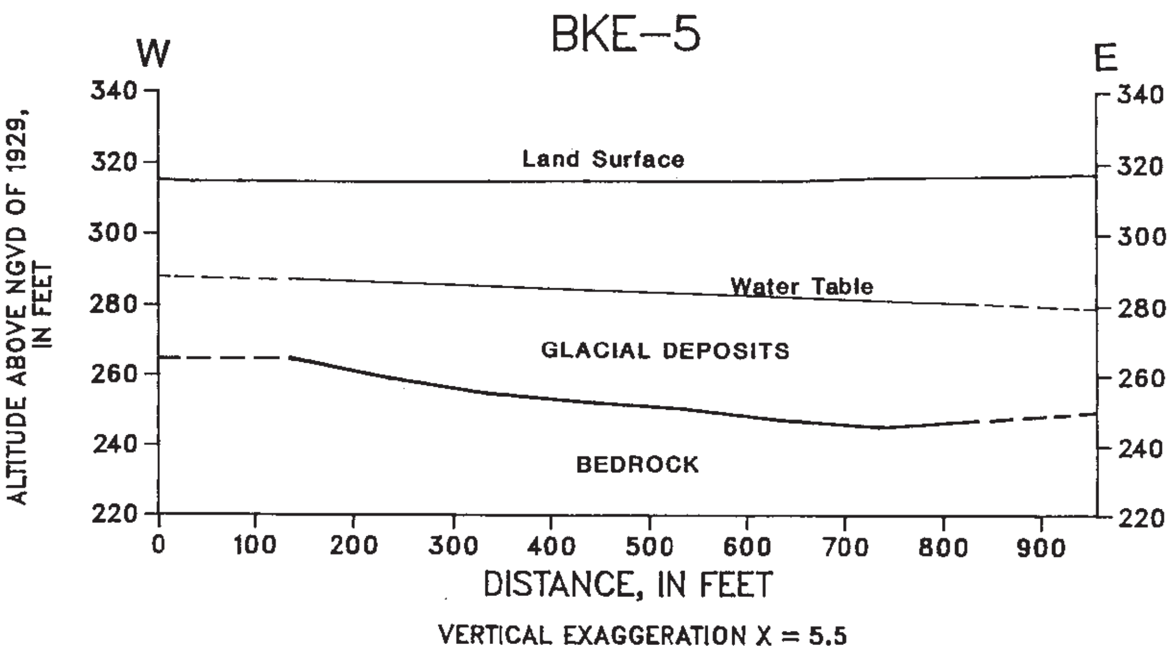

BHL-3
W
E
180
160
140
120
100
Land Surface
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
0
100
200
300
400
500
600
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 3.3

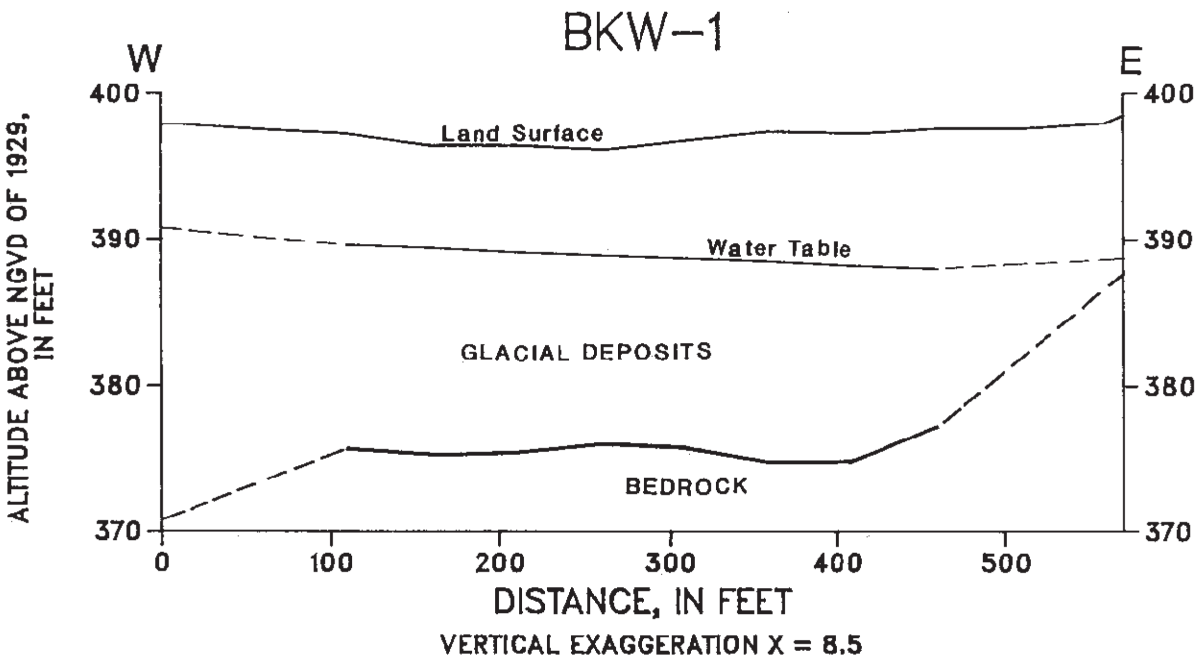

BHL-4
S
N
280
260
240
220
200
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
0
100
200
300
400
500
600
700
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 4.1


BKE-1
SW
NE
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
350
300
250
200
0
100
200
300
400
500
600
700
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 2.1

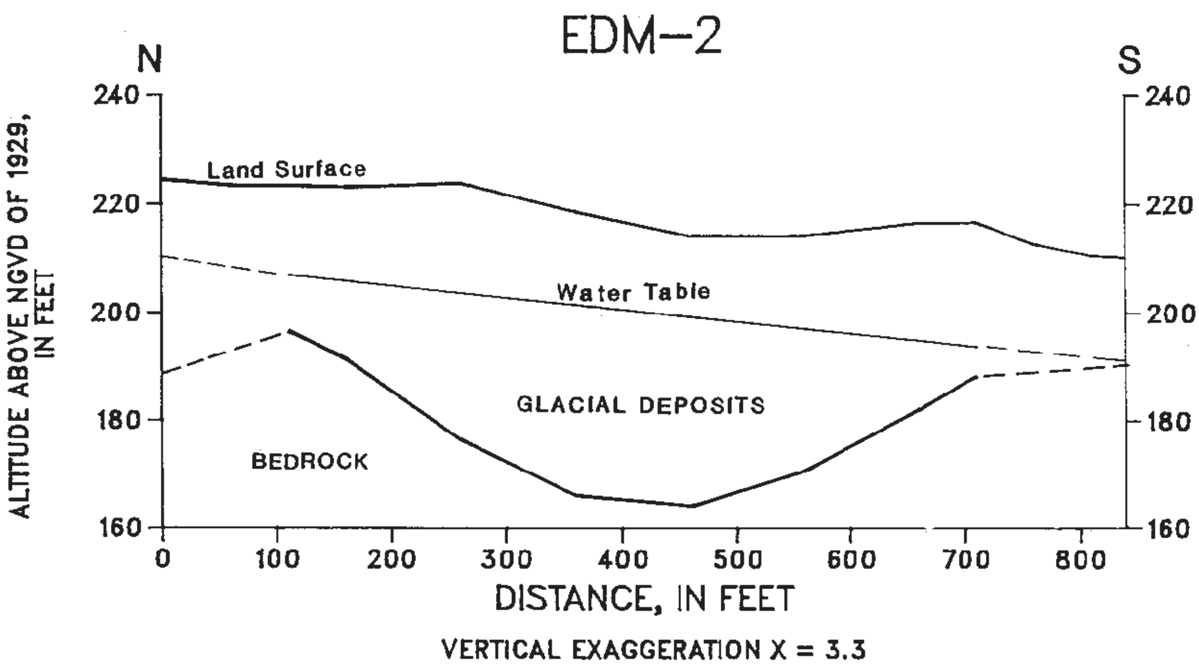

BKE-3
NW
SE
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
340
320
300
280
260
0
100
200
300
400
500
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 3.1


BKE-4
NW
SE
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
320
300
280
260
0
100
200
300
400
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 5.1

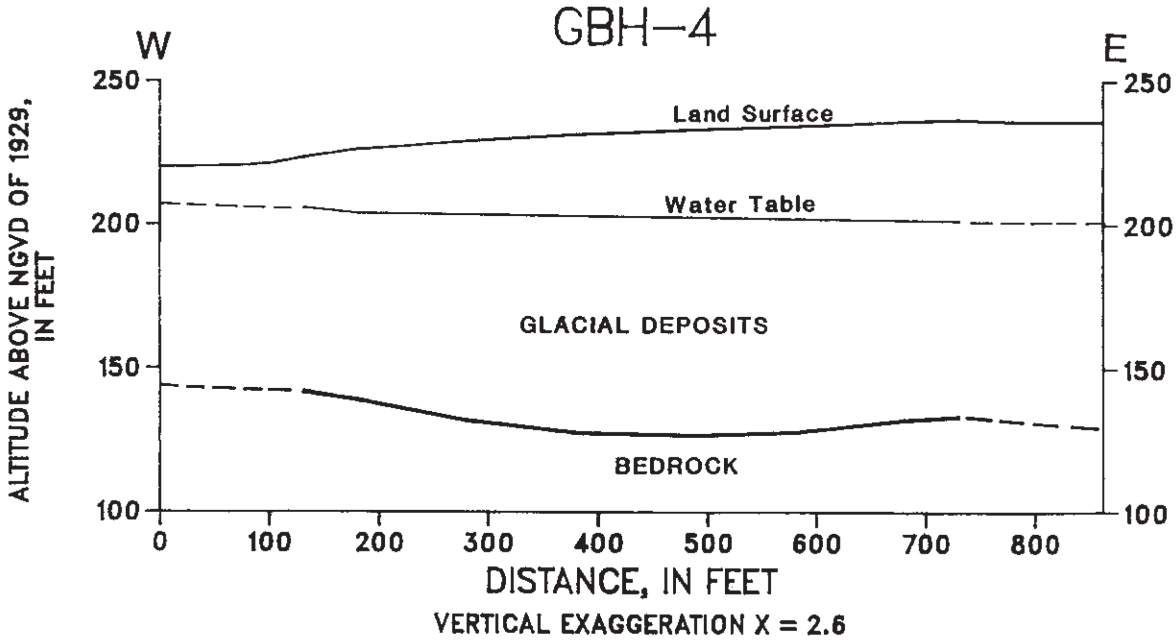

BKE-5
W
E
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
340
320
300
280
260
240
220
0
100
200
300
400
500
600
700
800
900
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 5.5



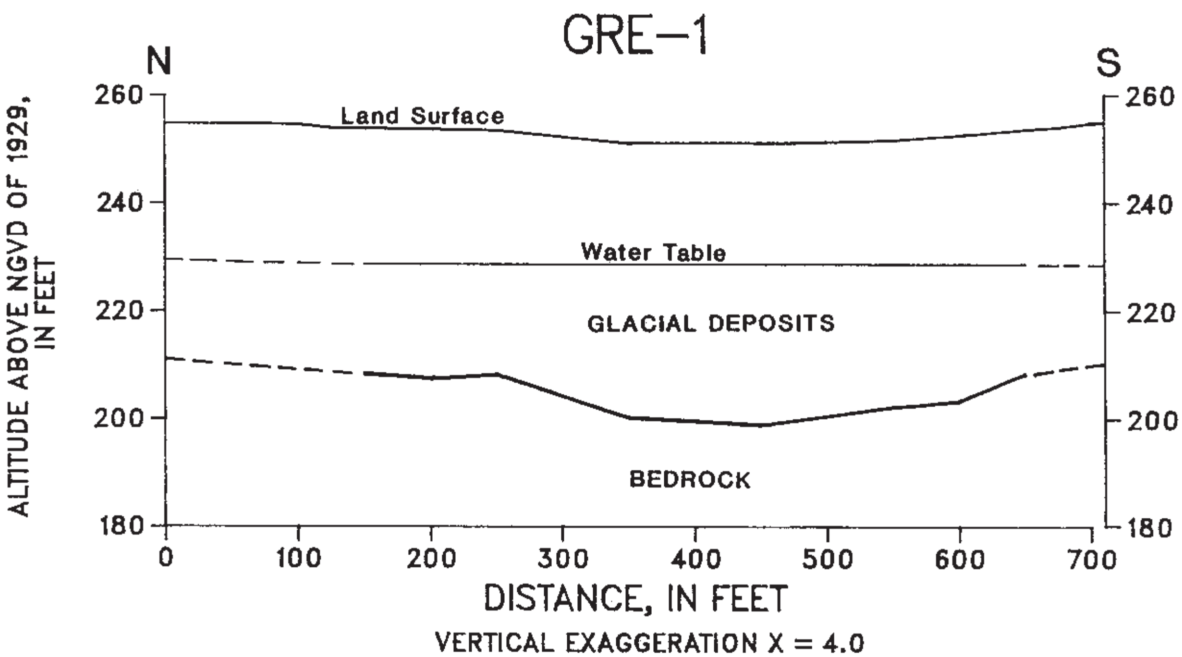
BKW-1
W
E
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
400
390
380
370
0
100
200
300
400
500
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 8.5



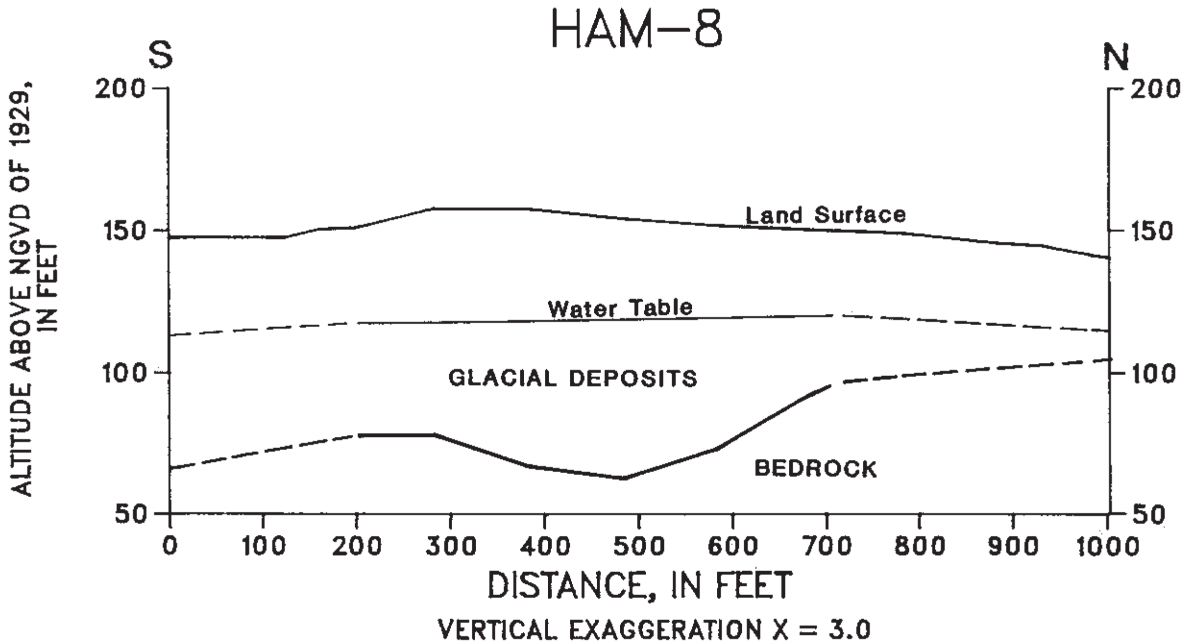
EDM-2
N
S
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
240
220
200
180
160
0
100
200
300
400
500
600
700
800
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 3.3

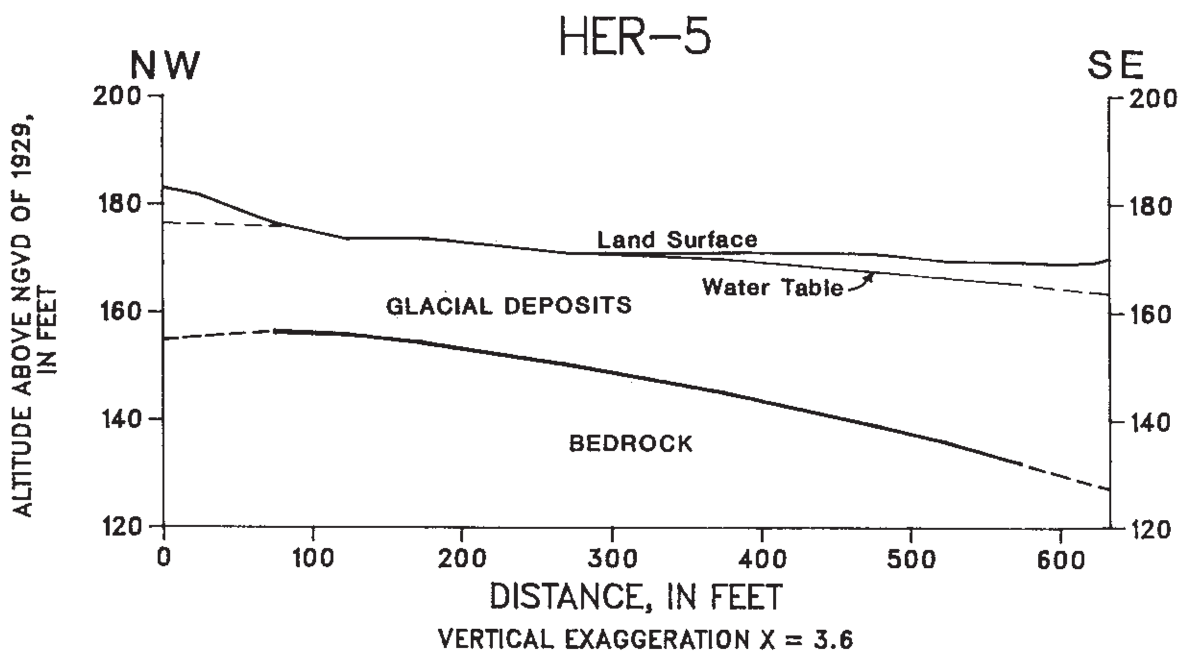


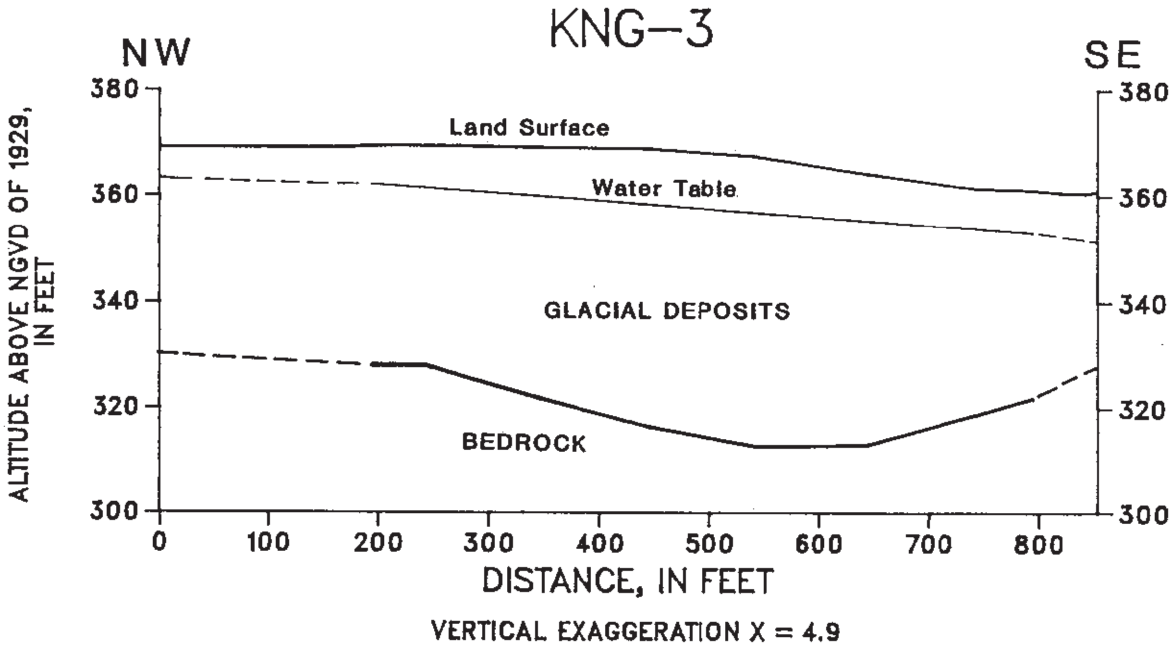
GBH-4
W
E
250
200
150
100
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
0
100
200
300
400
500
600
700
800
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 2.6

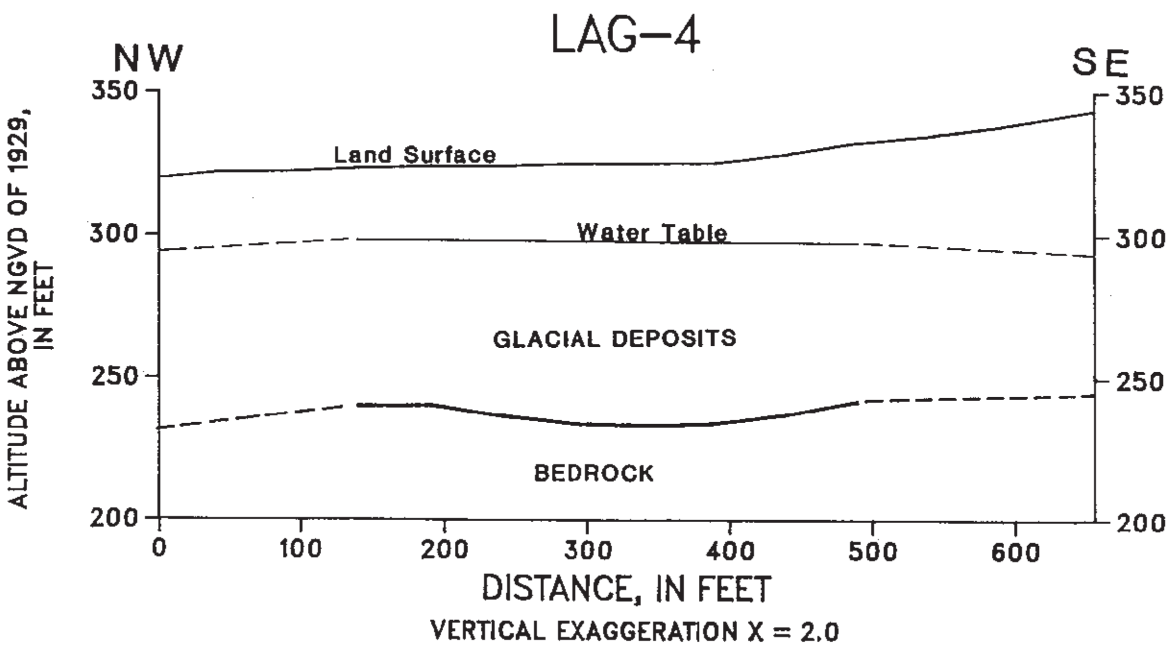


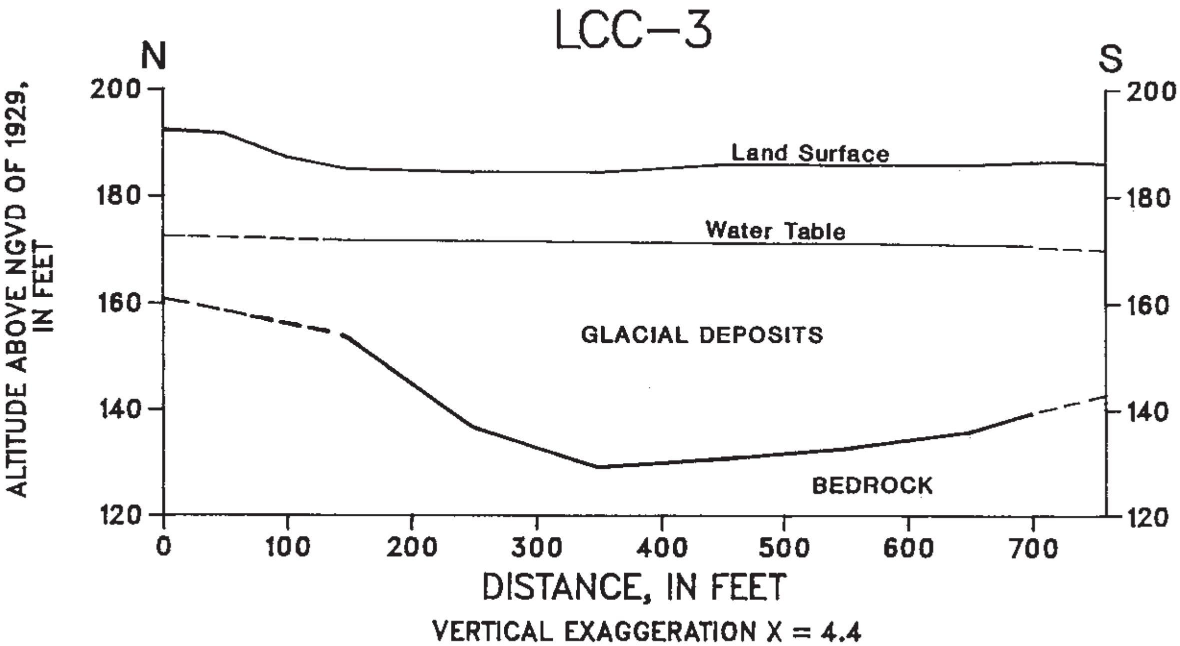
GRE-1
N
S
260
240
220
200
180
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
0
100
200
300
400
500
600
700
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 4.0

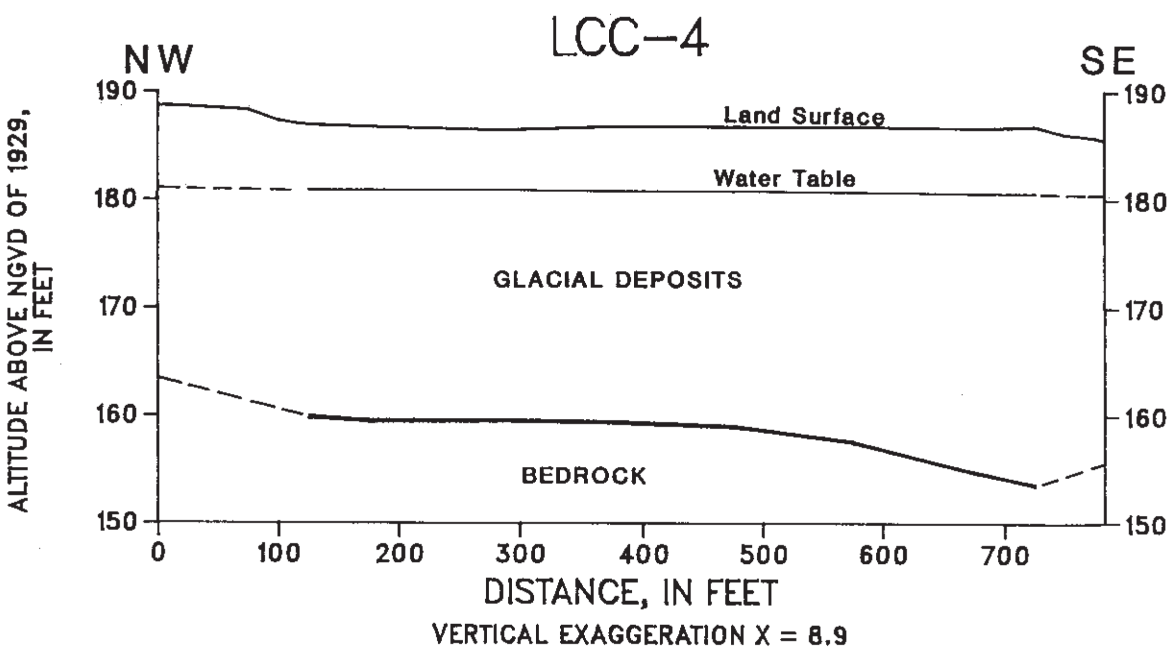

HAM–8
S
N
ALTITUDE ABOVE NGVD OF 1929, IN FEET
200
150
100
50
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
0
100
200
300
400
500
600
700
800
900
1000
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 3.0

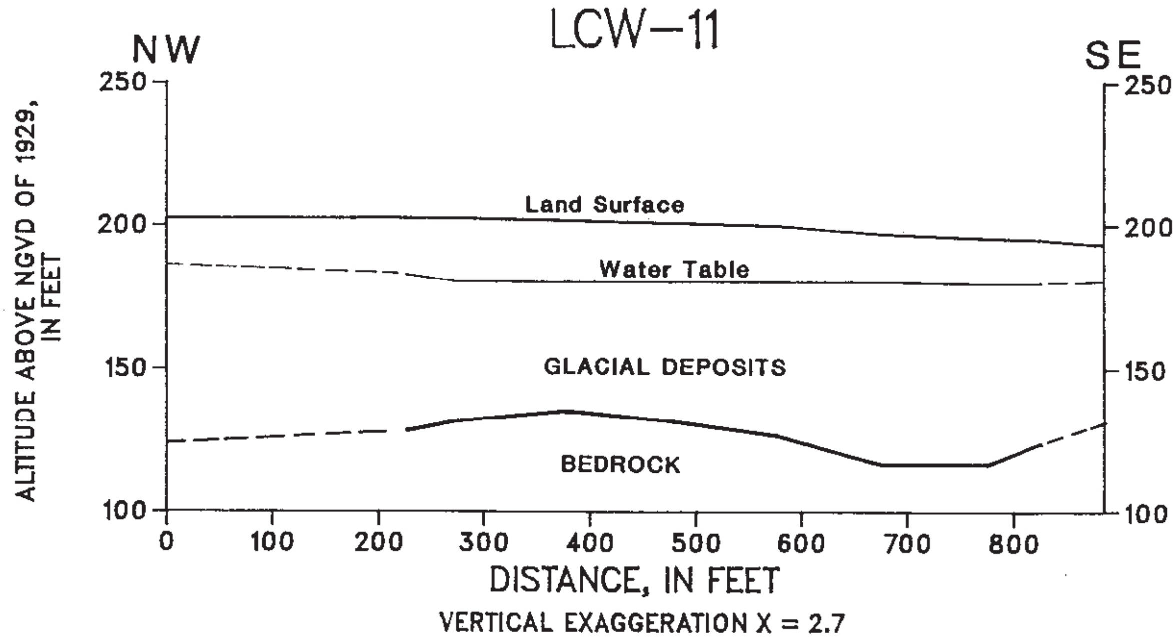

HER–5
NW
SE
ALTITUDE ABOVE NGVD OF 1929, IN FEET
200
180
160
140
120
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
0
100
200
300
400
500
600
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 3.6

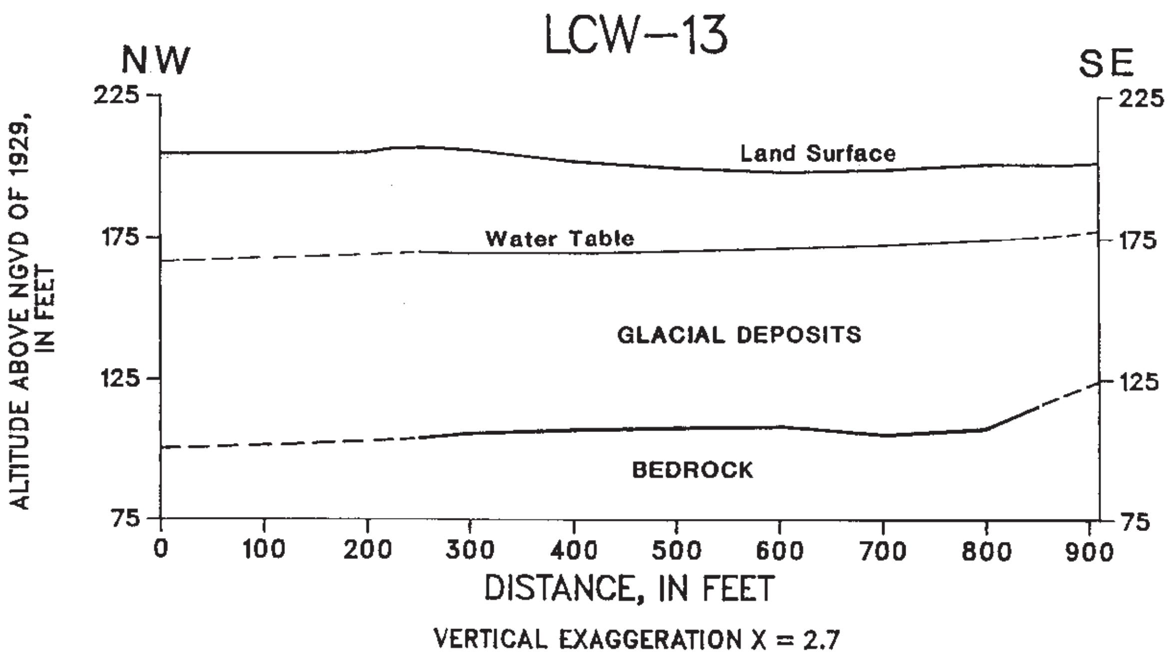

KNG-3
NW
SE
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
380
360
340
320
300
0
100
200
300
400
500
600
700
800
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 4.9

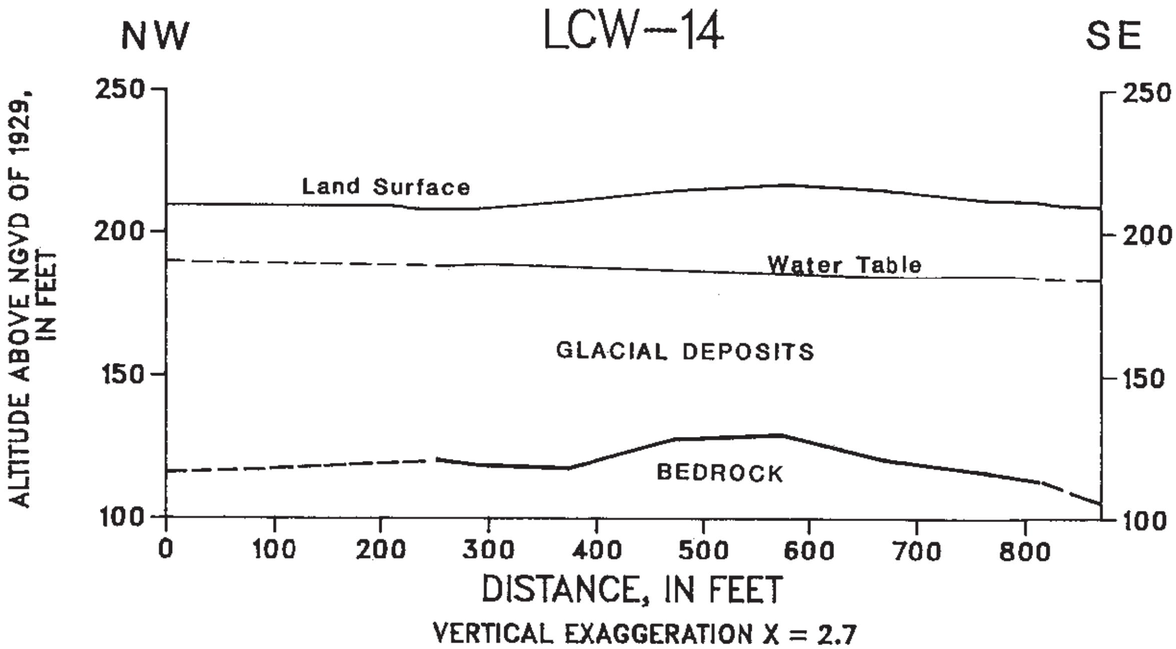

LAG-4
NW
SE
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
350
300
250
200
0
100
200
300
400
500
600
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 2.0

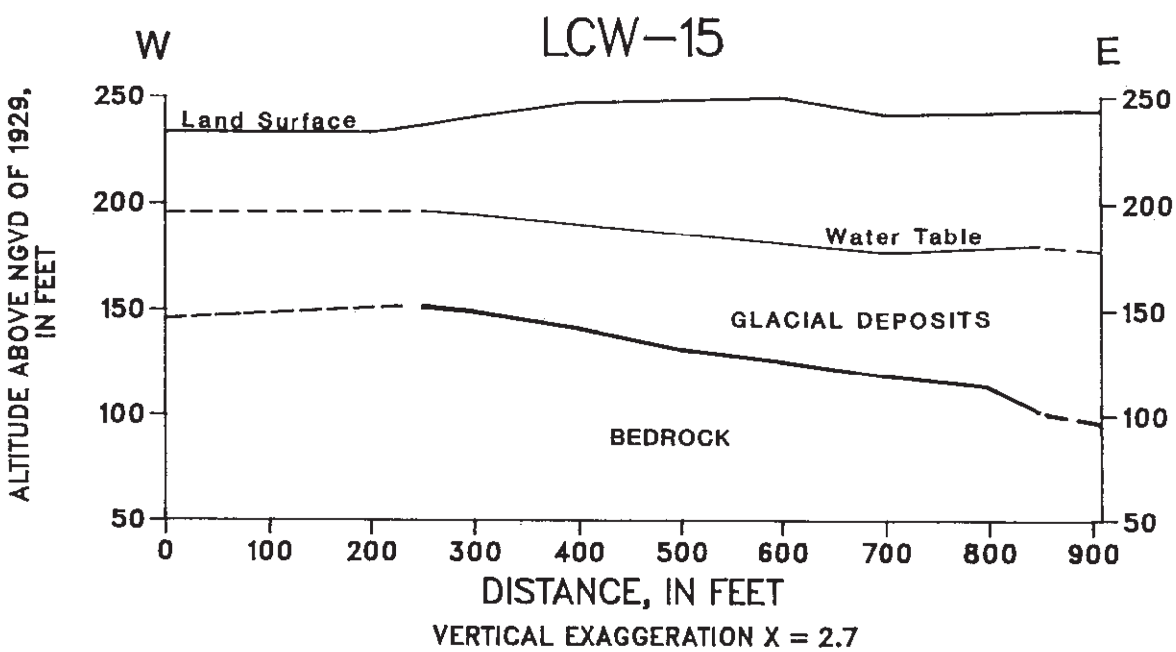

LCC–3
N
S
200
180
160
140
120
ALTITUDE ABOVE NGVD OF 1929, IN FEET
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
0
100
200
300
400
500
600
700
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 4.4

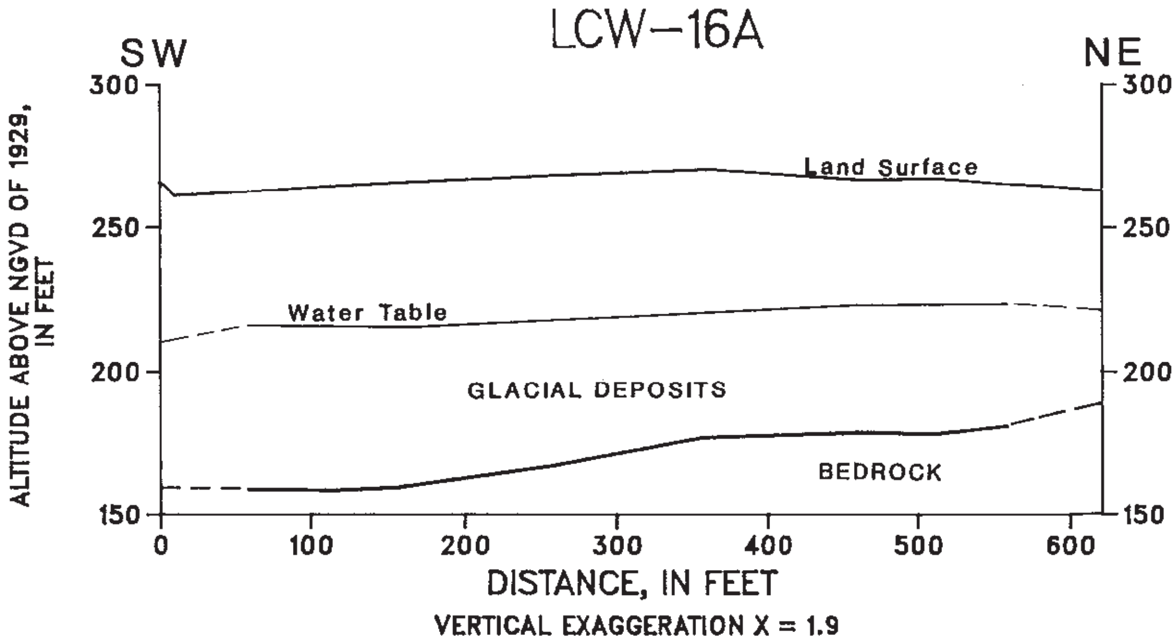

LCC–4
NW
SE
190
180
170
160
150
ALTITUDE ABOVE NGVD OF 1929, IN FEET
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
0
100
200
300
400
500
600
700
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 8.9

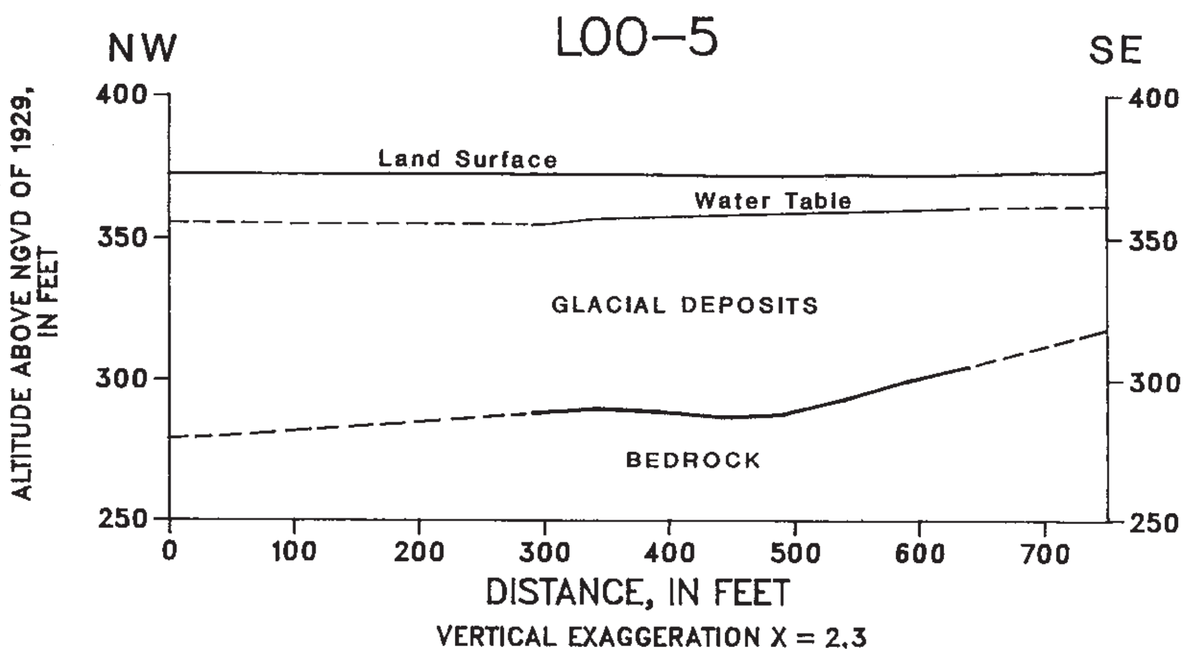

LCW–11
NW
SE
250
200
150
100
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
0
100
200
300
400
500
600
700
800
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 2.7

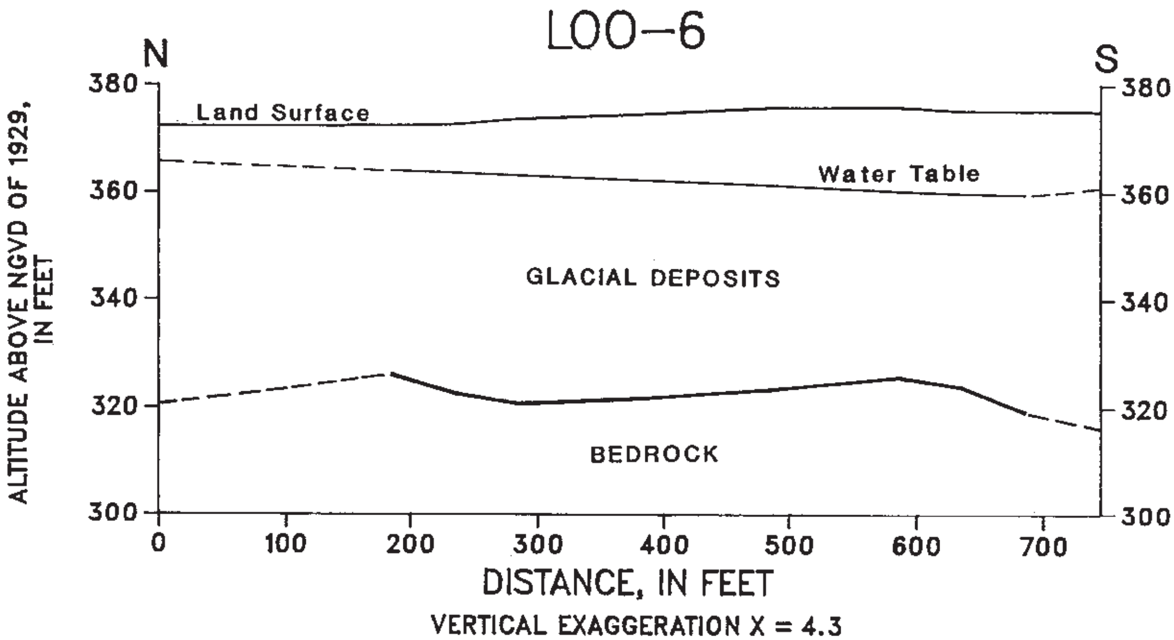

LCW–13
NW
SE
225
175
125
75
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
0
100
200
300
400
500
600
700
800
900
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 2.7

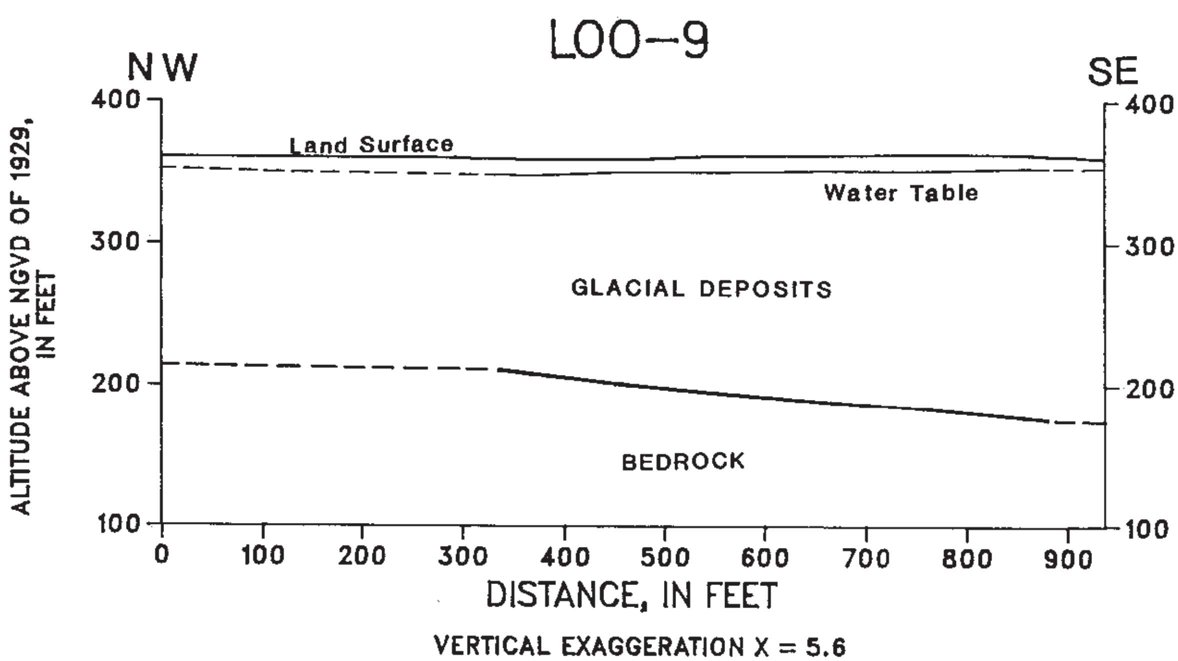

NW
LCW—14
SE
ALTITUDE ABOVE NGVD OF 1929, IN FEET
250
200
150
100
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
0
100
200
300
400
500
600
700
800
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 2.7

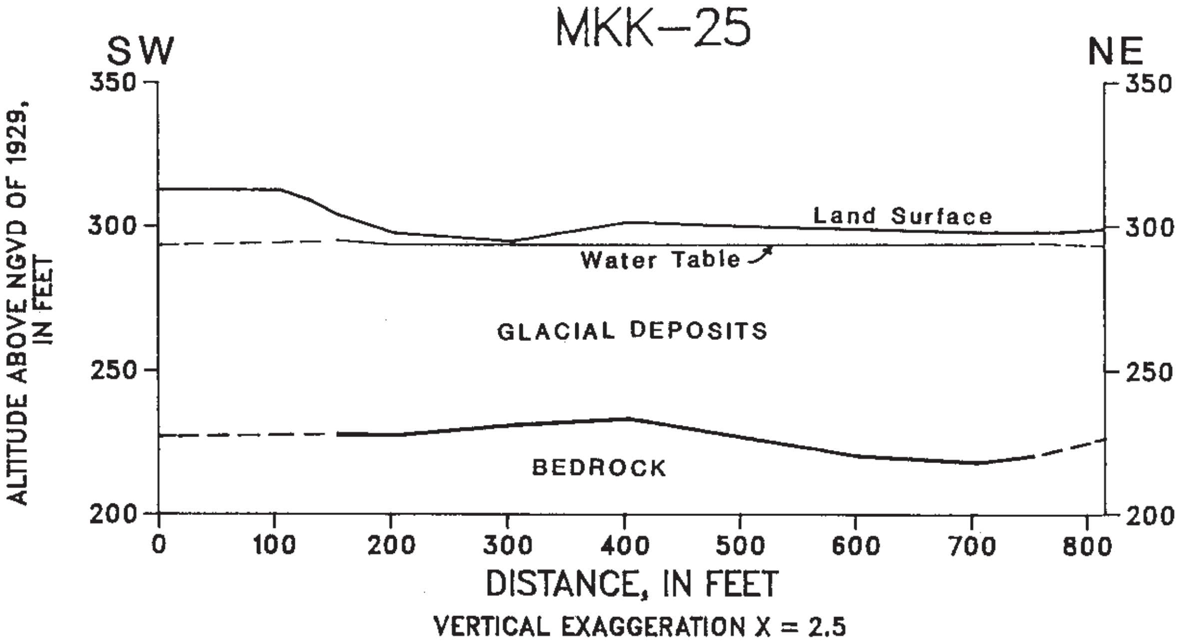

W
LCW—15
E
ALTITUDE ABOVE NGVD OF 1929, IN FEET
250
200
150
100
50
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
0
100
200
300
400
500
600
700
800
900
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 2.7

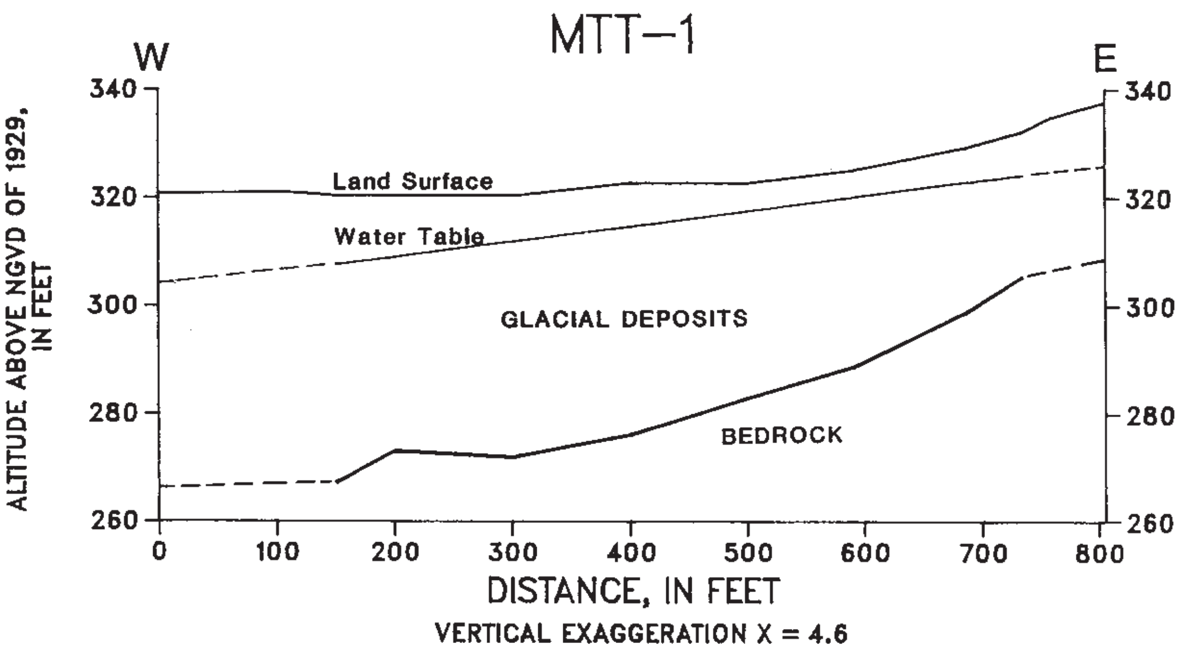

LCW-16A
SW
NE
300
250
200
150
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
0
100
200
300
400
500
600
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 1.9

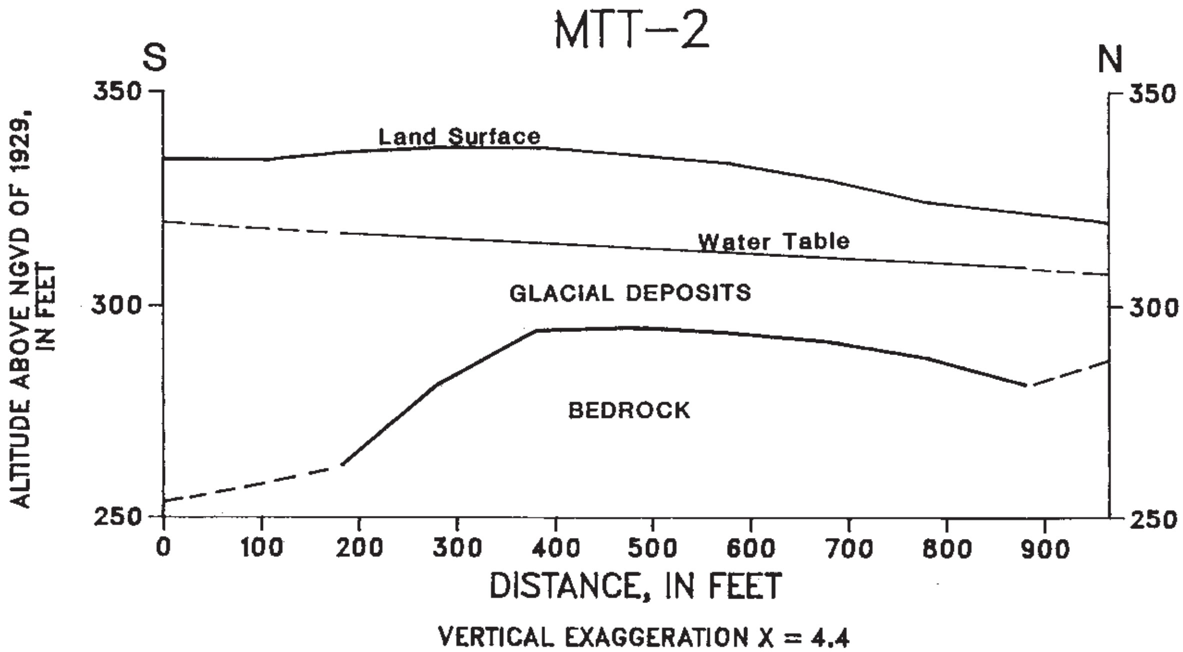

LOO-5
NW
SE
400
350
300
250
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
0
100
200
300
400
500
600
700
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 2.3

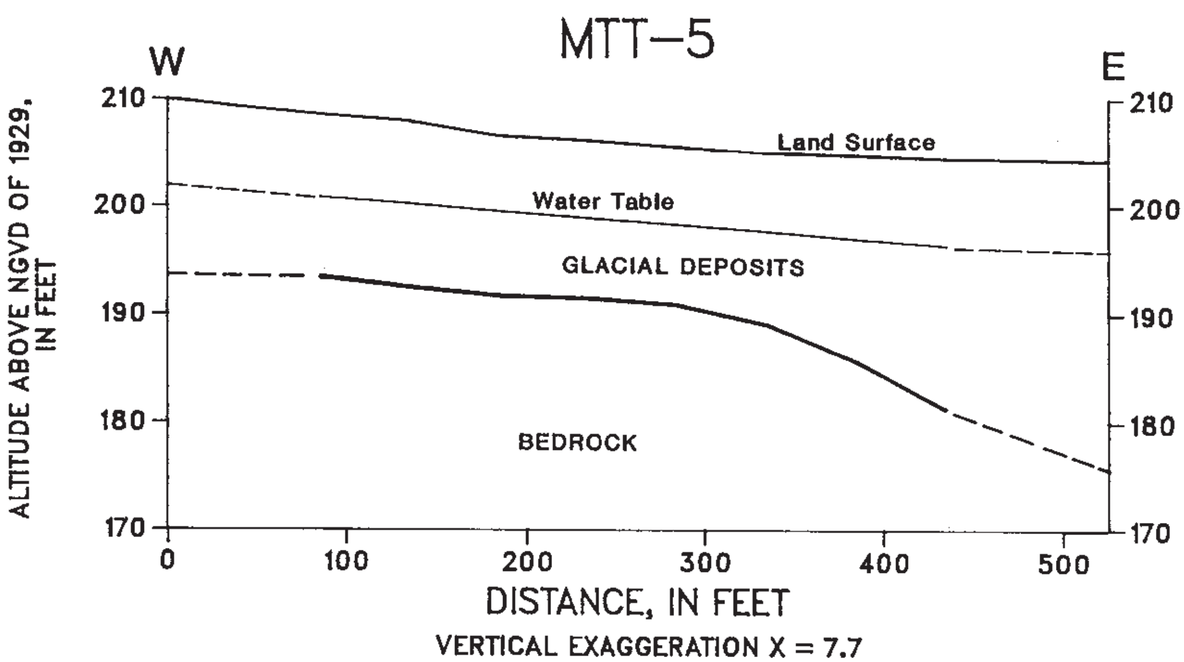

LOO—6
N
S
ALTITUDE ABOVE NGVD OF 1929, IN FEET
380
360
340
320
300
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
0
100
200
300
400
500
600
700
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 4.3

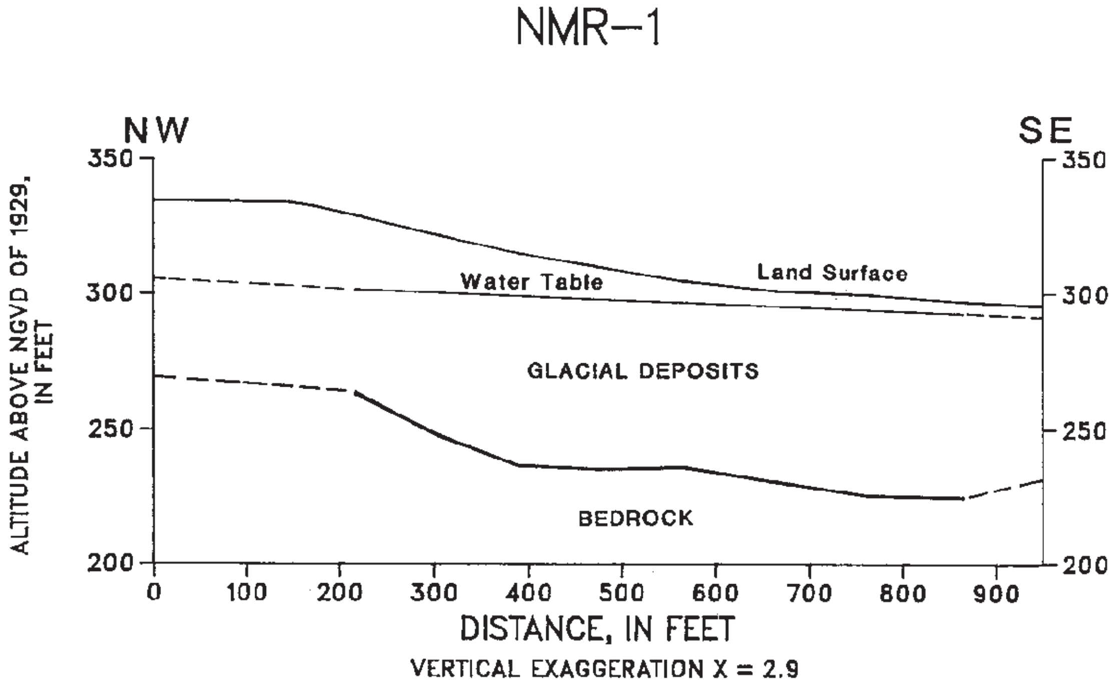

LOO—9
NW
SE
ALTITUDE ABOVE NGVD OF 1929, IN FEET
400
300
200
100
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
0
100
200
300
400
500
600
700
800
900
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 5.6

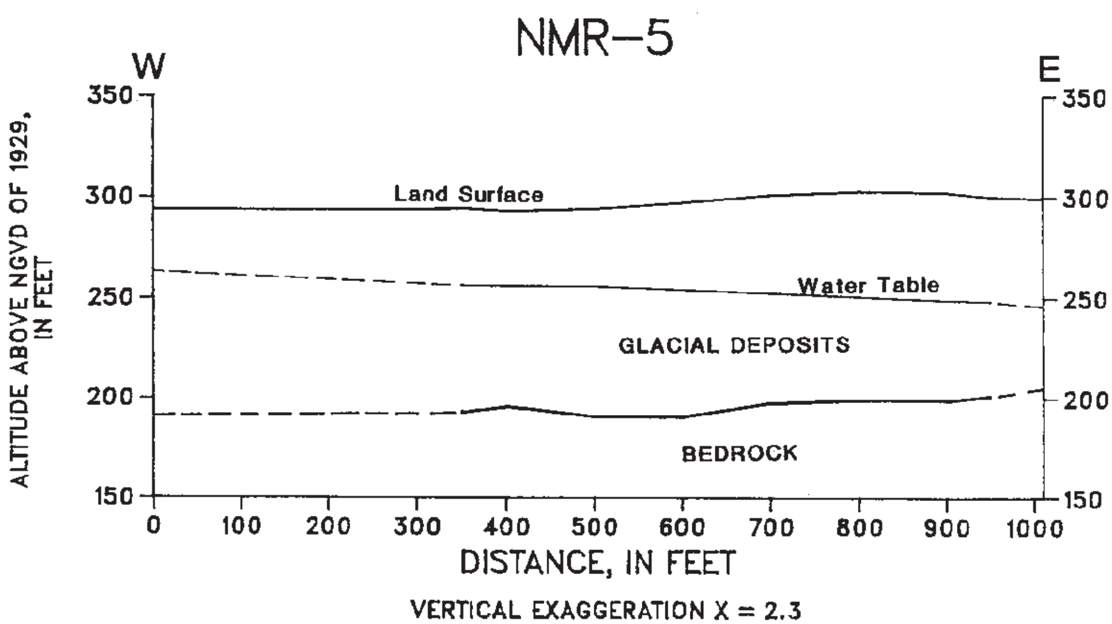

MKK–25
SW
NE
350
300
250
200
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
0
100
200
300
400
500
600
700
800
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 2.5

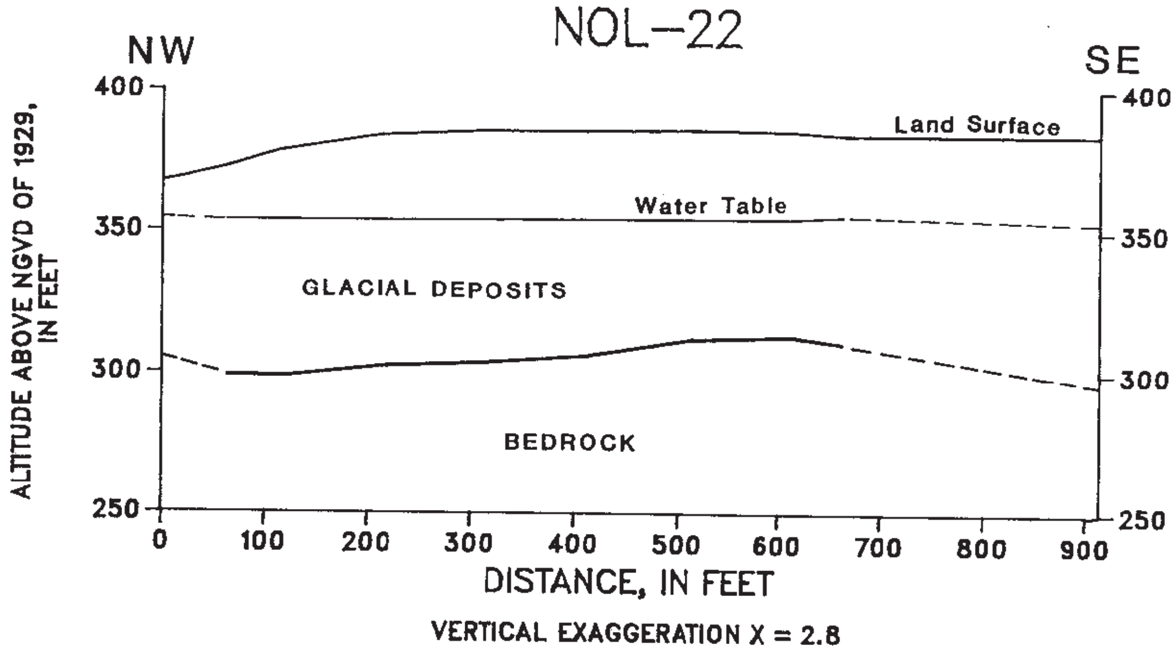

MTT–1
W
E
340
320
300
280
260
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
0
100
200
300
400
500
600
700
800
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 4.6

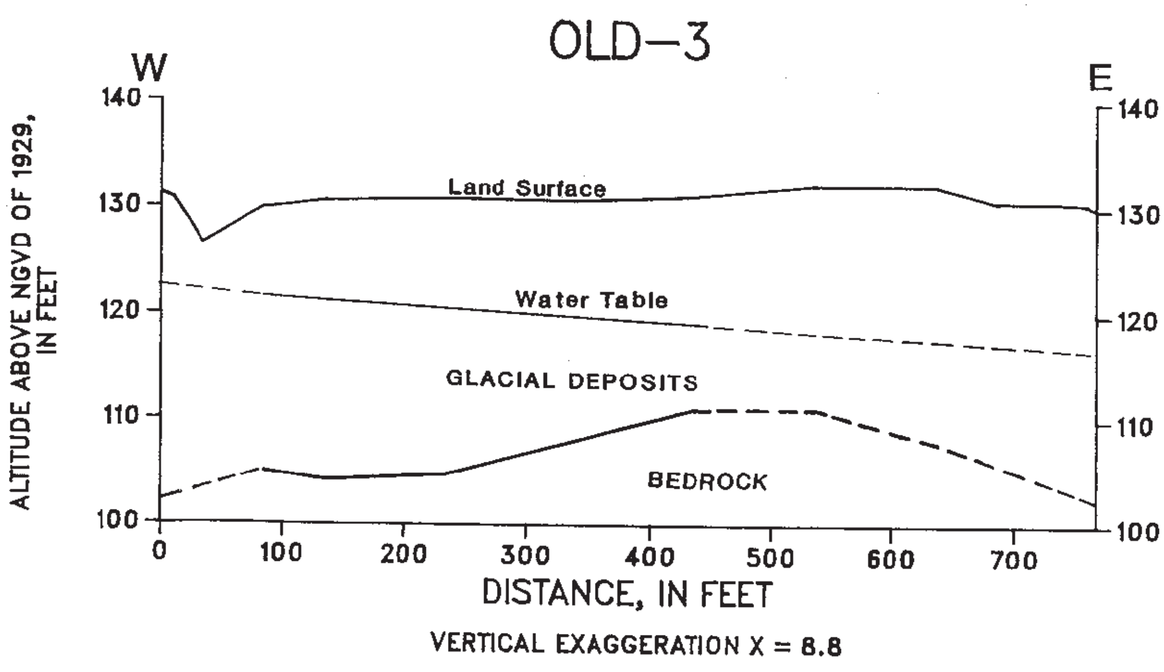

MTT–2
S
N
350
300
250
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
0
100
200
300
400
500
600
700
800
900
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 4.4

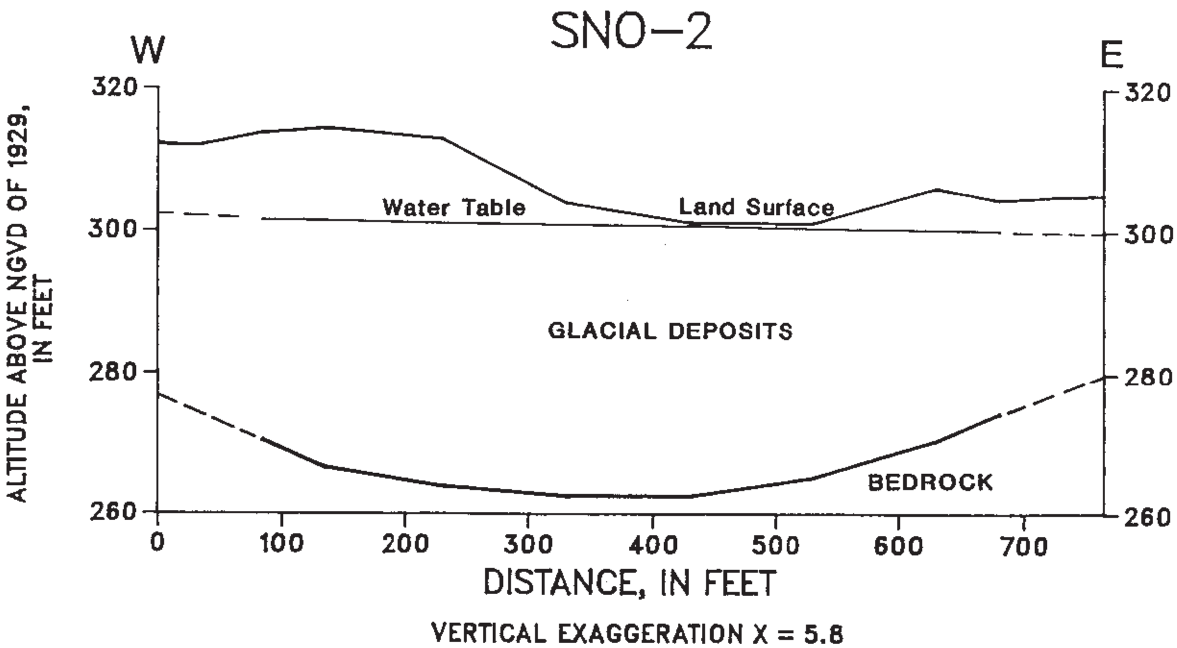

MTT–5
W
E
210
200
190
180
170
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
0
100
200
300
400
500
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 7.7

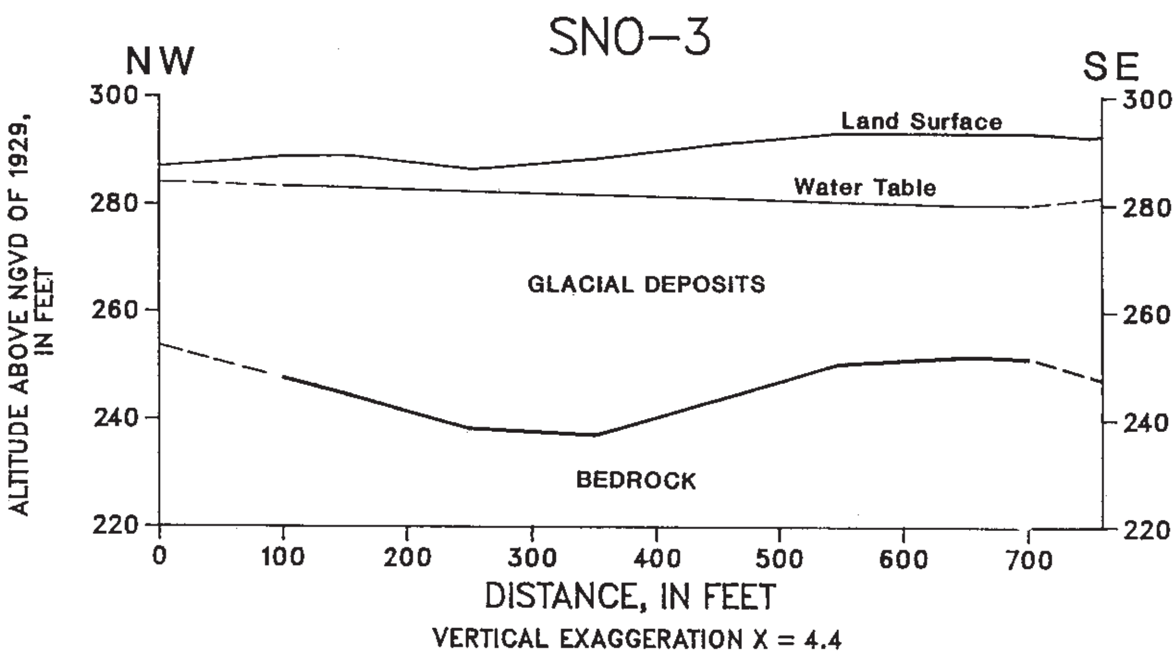

NMR–1
NW
SE
350
300
250
200
ALTITUDE ABOVE NGVD OF 1929, IN FEET
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
0
100
200
300
400
500
600
700
800
900
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 2.9

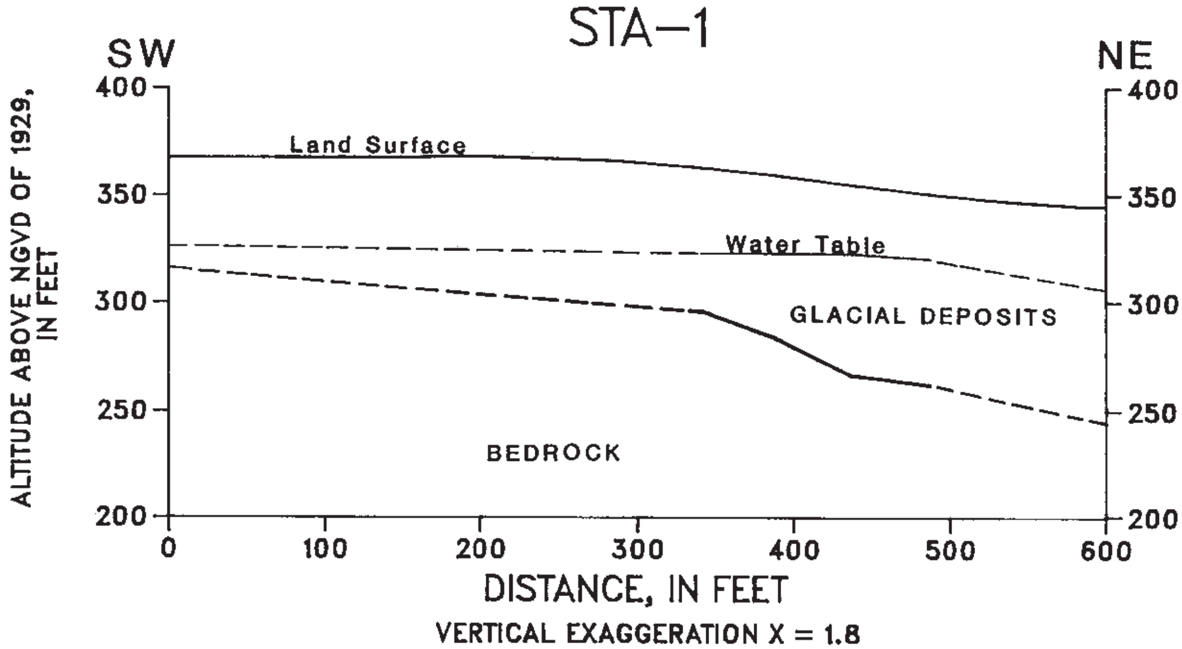

NMR–5
W
E
350
300
250
200
150
ALTITUDE ABOVE NGVD OF 1929, IN FEET
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
0
100
200
300
400
500
600
700
800
900
1000
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 2.3

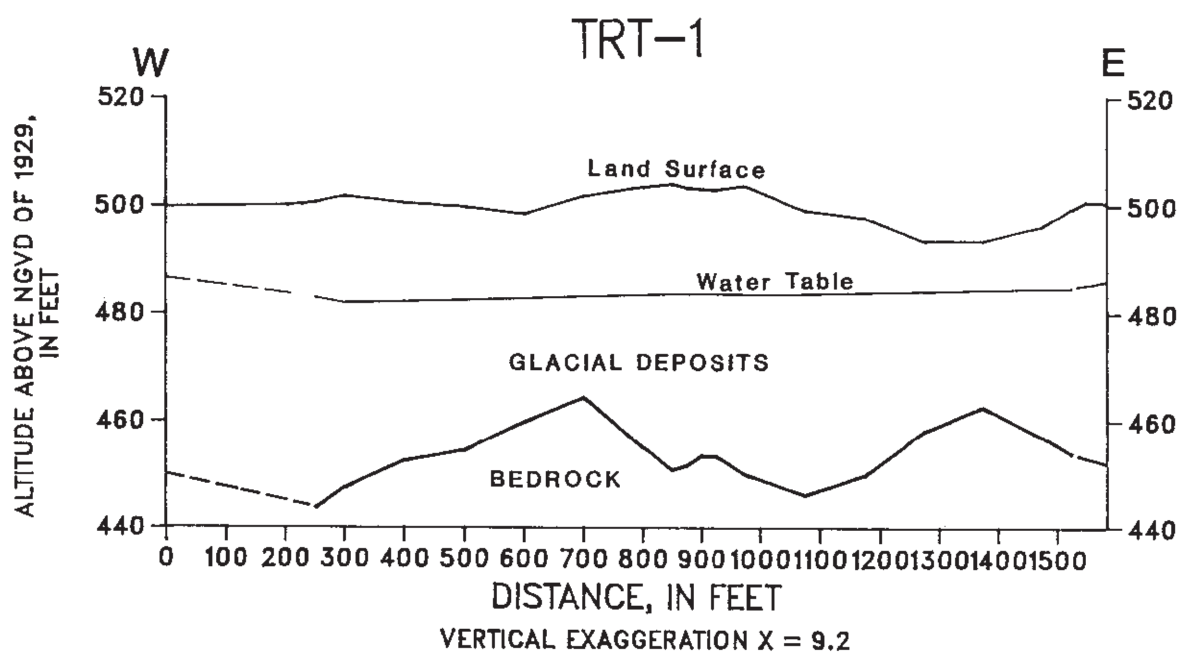

NOL-22
NW
SE
ALTITUDE ABOVE NGVD OF 1929, IN FEET
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
400
350
300
250
0
100
200
300
400
500
600
700
800
900
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 2.8

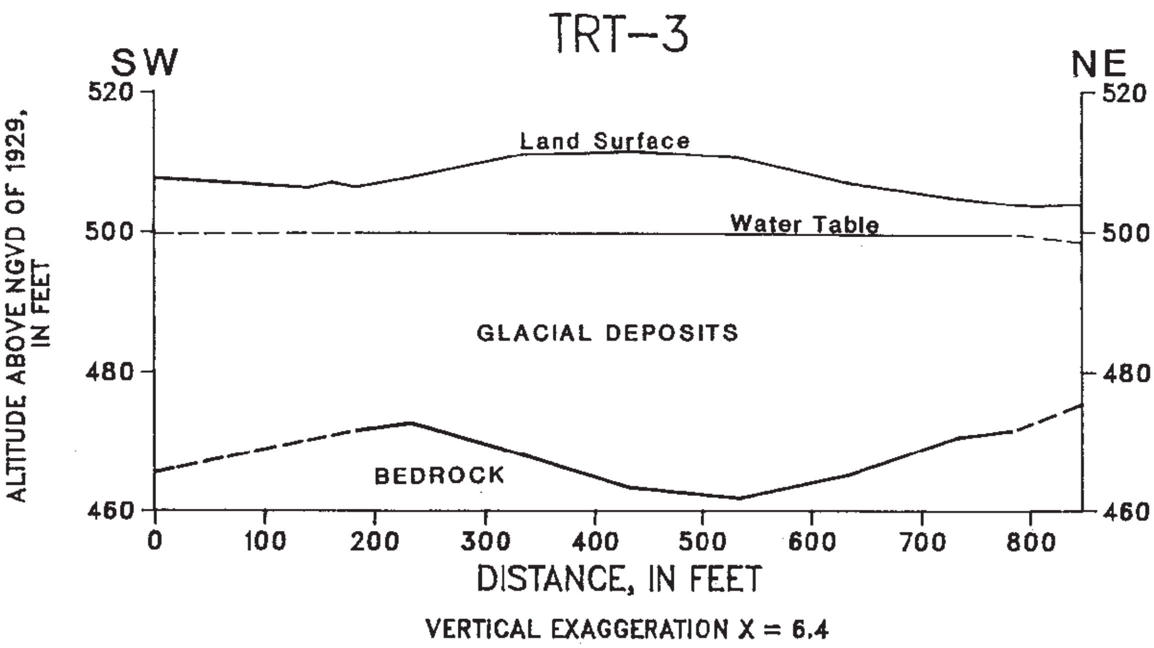

OLD-3
W
E
ALTITUDE ABOVE NGVD OF 1929, IN FEET
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
140
130
120
110
100
0
100
200
300
400
500
600
700
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 8.8


SNO—2
W
E
320
300
280
260
ALTITUDE ABOVE NGVD OF 1929, IN FEET
Water Table
Land Surface
GLACIAL DEPOSITS
BEDROCK
0
100
200
300
400
500
600
700
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 5.8


SNO—3
NW
SE
300
280
260
240
220
ALTITUDE ABOVE NGVD OF 1929, IN FEET
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
0
100
200
300
400
500
600
700
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 4.4


STA-1
SW
NE
400
350
300
250
200
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
0
100
200
300
400
500
600
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 1.8


TRT-1
W
E
520
500
480
460
440
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 9.2



TRT-3
SW
NE
Land Surface
Water Table
GLACIAL DEPOSITS
BEDROCK
ALTITUDE ABOVE NGVD OF 1929, IN FEET
520
500
480
460
0
100
200
300
400
500
600
700
800
DISTANCE, IN FEET
VERTICAL EXAGGERATION X = 6.4