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Hydrogeology and Water Quality of Significant Sand and Gravel Aquifers

in parts of Hancock, Penobscot, and Washington Counties, Maine

Significant Sand and Gravel Aquifer Maps 24, 25, 26, 27, 45

by

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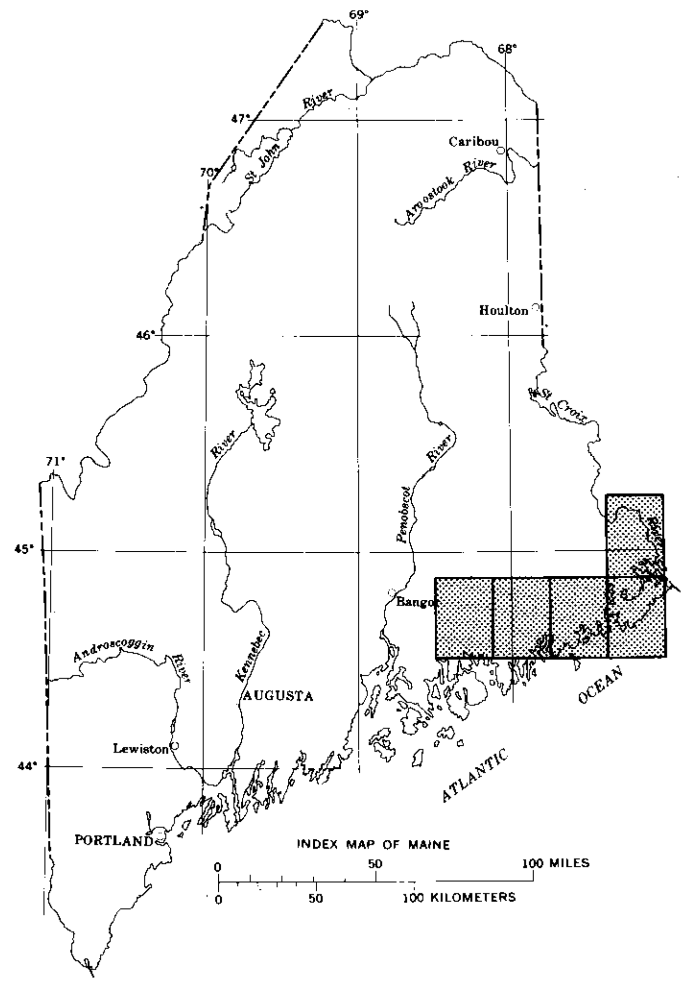

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DEPARTMENT OF CONSERVATION

HYDROGEOLOGY AND WATER QUALITY OF SIGNIFICANT SAND AND GRAVEL AQUIFERS IN PARTS OF HANCOCK, PENOBSCOT AND WASHINGTON COUNTIES, MAINE: SIGNIFICANT SAND AND GRAVEL AQUIFER MAPS 24, 25, 26, 27, AND 45

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CONVERSION FACTORS AND ABBREVIATIONS

For the convenience of readers who may prefer to use metric (International System) units rather than the inch-pound units used in this report, values may be coverted 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	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow	
foot per second (ft/s)	0.3048	meter per second (m/s)
foot per day (ft/d)	0.3048	meter per day (m/d)
gallon per minute (gal/min)	0.0630	liter per second (L/s)
million gallons per day (Mgal/d)	0.0438	cubic meter per second (m^3/s)
	Transmissivity	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

Other abbreviations used in this report

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

SEA LEVEL: In this report "sea level" refers to the 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 "Mean Sea Level of 1929".

HYDROGEOLOGY AND WATER QUALITY OF SIGNIFICANT SAND AND GRAVEL AQUIFERS IN PARTS OF HANCOCK, PENOBSCOT, AND WASHINGTON COUNTIES, MAINE: SIGNIFICANT SAND AND GRAVEL AQUIFER MAPS 24, 25, 26, 27 AND 45

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ABSTRACT

A reconnaissance-level hydrogeologic study was made of 1,715 square miles in Hancock, Penobscot, and Washington Counties in Maine. This area includes Maps 24, 25, 26, 27, and 45 of the Significant Sand and Gravel Aquifer Map Series published by the Maine Geological Survey. 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, the aquifers are capable of yielding more than 10 gallons per minute to a properly constructed well. Significant aquifers comprise almost 238 square miles (14 percent) of the study area, but yields that exceed 50 gallons per minute are estimated to be available from only 4 square miles (less than 1 percent) of this area. Typically, the water table is within 25 feet of land surface. On the basis of well records, the greatest known depth to bedrock is 235 feet. The greatest known well yield is approximately 350 gallons per minute from a gravel-packed well owned by a public-water supplier. The regional ground-water quality is slightly acidic to moderately basic, calcium and sodium are the most abundant cations, bicarbonate is the most abundant anion, and the water is soft. In some locations, concentrations of iron and manganese are large enough to limit the use of untreated water.

INTRODUCTION

Significant sand and gravel aquifers are commonly the only sources of ground water capable of supplying the large volumes of water needed by municipalities and industries in Maine. They also are the source of water for many domestic wells and may serve as a source of recharge to underlying bedrock aquifers. A significant sand and gravel aquifer, as defined by the Maine State Legislature (38 MRSA Chapter 3, Section 482, 4-D) is "...a porous formation of ice-contact and glacial outwash sand and gravel that contains significant recoverable quantities of water which is likely to provide drinking-water supplies."

Recognizing the value of significant sand and gravel aquifers, the Maine State Legislature has adopted a number of provisions to restrict the siting of activities that may discharge contaminants to ground water in the aquifers. Many local governments have also based zoning ordinances on the protection of significant aquifers. To aid local and State governments in these efforts, the Maine Geological Survey (MGS) and the U.S. Geological Survey (USGS), with funding from the Department of Environmental Protection (DEP), conducted a reconnaissance-level investigation of sand and gravel aquifers in most of the State. This investigation, conducted from 1978 through 1980, resulted in the production of 59 maps showing approximate aquifer boundaries, estimates of potential well yields, and locations of some potential point sources of contamination.

The 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. Additionally, the maps contain little information on aquifer thickness and stratigraphy, and no information on water quality. Recognizing these shortcomings, the Maine State Legislature directed the DEP and MGS to update the sand and gravel aquifer maps to provide more information on depth to bedrock, depth to water table, stratigraphy, and water quality (38 MRSA Chapter 3, Section 403). This bill instructed the DEP and MGS to delineate all sand and gravel aquifers capable of yielding more than 10 gallons per minute (gal/min) to a properly installed well. This new series of maps is referred to as Significant Sand and Gravel Aquifer Maps.

To meet the demand for more accurate, complete, and current hydrogeologic information concerning Maine's sand and gravel aquifers, a detailed cooperative mapping project was started in June 1981 by the MGS, the USGS, and the DEP. Mapping was first conducted in the most densely populated and fastest growing parts of the State and has continued throughout the State (Tolman and others, 1983; Tepper and others, 1985; Williams and others, 1987; Adamik and others, 1987). The location of these study areas and planned study areas are shown in figure 1.

This report presents the results from the fifth year of the mapping project (1985 field season), and updates the Sand and Gravel Aquifer Map Series for maps 24, 25, 26, 27, and 45. These maps have been locally modified on the basis of new data and are available separately or with this report as plates 1-5 (Significant Sand and Gravel Aquifer Maps 24, 25, 26, 27, and 45).

Purpose and Scope

The purpose of this report is to present predicted well yields of aquifers in areas covered by Significant Sand and Gravel Aquifer Maps 24, 25, 26, 27, and 45. 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 includes:

(1) surficial geologic mapping to define the boundaries of the glacial deposits;
(2) seismic-refraction investigations to determine the depth to water, depth to bedrock, and bedrock-surface topography;
(3) well inventory to supplement existing data on the depth to water, depth to bedrock, and well yields;
(4) observation-well and test-boring drilling to determine aquifer stratigraphy, thickness, and grain size (used to estimate transmissivity);
(5) water-quality sampling and analysis to characterize the regional ground-water chemistry;
(6) identification of potential sources of ground-water contamination, and
(7) location of municipal-well fields.

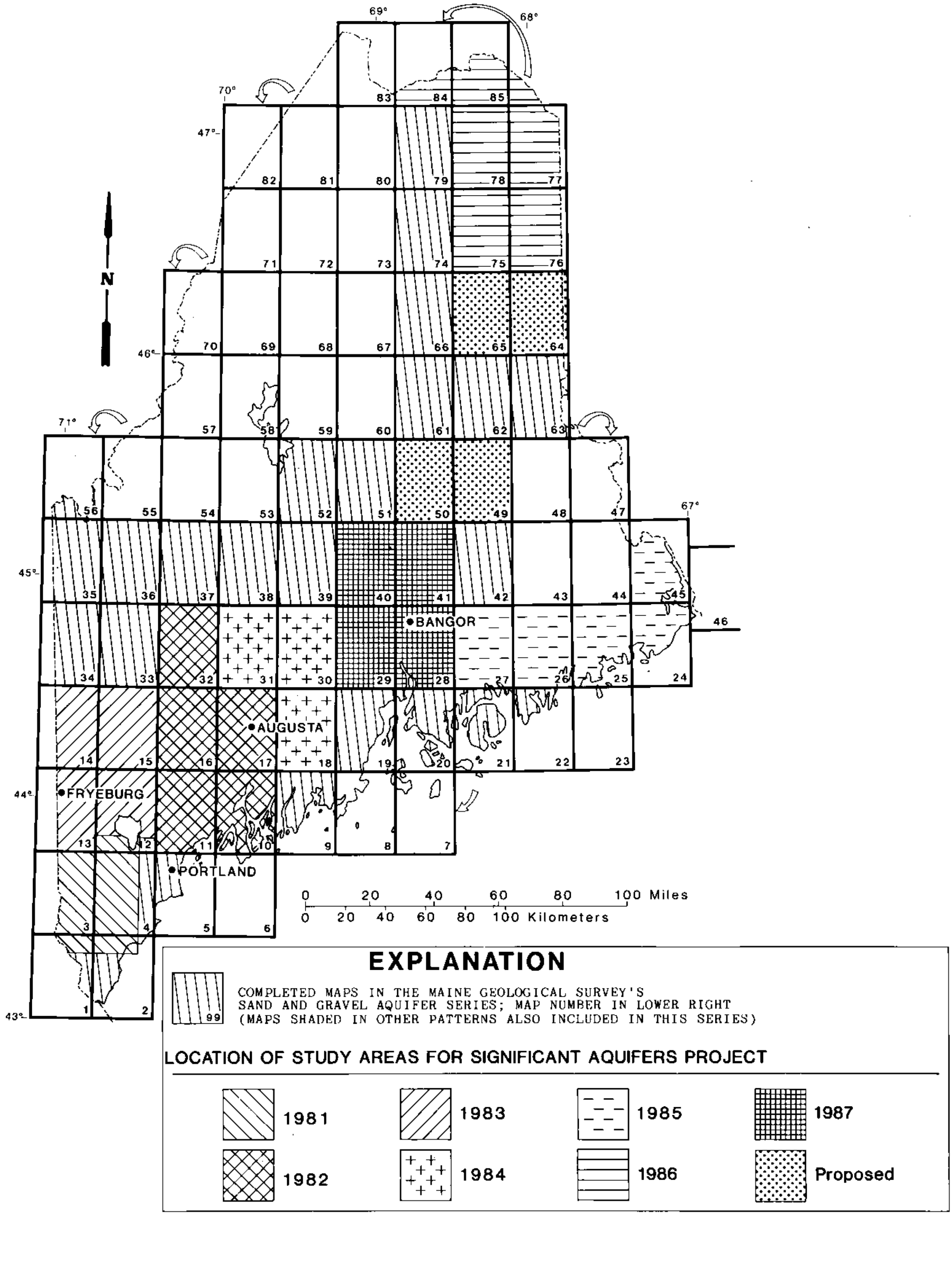

Figure 1. Location of study areas for Significant Aquifers Project.

Previous Investigations

Surficial and bedrock geologic mapping conducted in the study area provided information on bedrock outcrops, and on the areal extent of sand and gravel deposits (Borns, 1974a-j, 1975a-c; Borns and Andersen, 1982a-e; Gates 1961, 1978, 1981; Gilman, 1961; Griffin, 1976; Holland, 1981a-b, 1986; Holland and Borns, 1974; Ludman, 1985; Thompson 1977a-c; Westerman, 1981). General geologic relations are represented on the bedrock and surficial geologic maps of Maine (Osberg and others, 1985; Thompson and Borns, 1985). Prescott, (1973, 1974a-b) published additional information on surficial geology, well depth, yield, ground-water levels, stratigraphy, estimated yield zones, and water quality, and these reports were used as a basis for Sand and Gravel Aquifer Maps 24, 25, 26, 27, and 45 (Tolman and Lanctot, 1981a-e). Data collected for the present study were compiled on the same base as the old Sand and Gravel Aquifer Maps to produce the new maps, plates 1-5 in this report.

METHODS OF STUDY

Approach

The methodology of this investigation includes:

(1) compilation of all existing hydrogeologic data on each 1:50,000-scale map;
(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;
(5) seismic-refraction investigations;
(6) test borings and observation-well installation;
(7) development and sampling of wells;
(8) monthly water-level measurements; and
(9) compilation of all data on 1:50,000-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 maps[1]. These sites were identified primarily from files of the DEP Bureaus of Land, Water, and Oil and Hazardous Materials. The locations of State-owned salt-storage lots were determined from Maine Department of Transportation records. Letters were sent to town managers and local code-enforcement officers requesting their assistance in locating potential contamination sites. All site locations were field-checked.

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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.

The sites shown on the maps include waste-disposal areas and salt-storage piles. Other sources of potential ground-water contamination not shown include malfunctioning septic systems, roads that are salted in the winter, fertilized fields, and areas where pesticides are applied. Other possible point sources of contamination that are not included on the maps include underground gasoline or oil storage tanks, small-quantity generators of hazardous wastes, and other agricultural, industrial, or commercial sites.

Surficial Mapping Techniques

Mapping of the aquifer media was accomplished 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. Mapping of off-road areas was conducted by foot traverses and by examination of aerial photographs.

In compiling the boundaries of the significant aquifers shown on plates 1-5, some ground-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 has been mapped on the basis of the known or inferred saturated thickness at depth, and confirmed where possible by well, test-boring, or seismic data. The boundaries of the aquifer deposits are shown as solid lines where data substantiates the contacts, and are shown dashed where data are sparse.

Seismic-Refraction Investigations

Seismic-refraction techniques were used to obtain profiles showing 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 by 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, till and bedrock. To make 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 feet (ft). The

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[2] Use of trade names in this report is for descriptive purposes only and does not constitute endorsement by the MGS, the USGS, or the DEP.

seismic lines vary from 325 to 1,100 ft long. Elevations of the shot points and geophones were surveyed where relief on the land surface 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 test borings were used to verify seismic results. In total, 82 twelve-channel lines were run (58,366 ft), and 63 lines (42,841 ft) were determined to provide useful data.

A single-channel Soiltest MD9A seismograph was 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 seismic lines vary from 70 to 310 ft long. Interpretations and analyses were done according to methods developed by Mooney (1980), and Zohdy and others (1974). Seismic-refraction information was used in conjunction with well-inventory data and surficial mapping results to infer boundaries of sand and gravel deposits potentially capable of yielding 10 gal/min. In total, 134 single-channel lines were run (21,450 ft), and 67 lines (12,000 ft) were determined to provide useful data.

Drilling and Stratigraphic Logging Methods

Thirty-one exploration borings were drilled to obtain information on the thickness of the deposit, to collect sediment samples to determine grain size, 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 an exploration boring where the borings were backfilled after test information was obtained. The term "observation well" (OW) refers to an exploration boring where a monitoring well was installed. Exploration borings are identified first by the appropriate OW or TB designation, followed by the corresponding significant sand and gravel aquifer map number, and concluded by 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 drill rig was used for drilling. Samples of the sediment penetrated above the water table are brought to the surface by the rotation of the augers. Where detailed stratigraphic information was needed below the water table, a split-spoon sampler was used to collect undisturbed sediment samples ahead of the drill stem. Samples were collected according to established guidelines in Federal Interagency Work Group (1977, Chap. 2). Most wells were drilled to refusal, which may occur when either bedrock, compact sediments, or sediments larger than 6-inch cobbles are encountered. Several borings were terminated before reaching refusal because of depth limitations, equipment breakdown, or scheduling constraints. Stratigraphic logs and screened intervals of observation wells are included in tables 9-13 (at end of report).

Observation-Well Installation and Development

Twenty-six borings were cased with 2-inch-diameter, schedule 40 PVC (polyvinyl chloride) pipe to collect water samples and to measure water levels. PVC screens with slot widths varying from 0.006 to 0.010 in. were used. All casing couplings were fastened with 3/8-inch sheet metal screws rather than with PVC cement. The release of tetrahydrofuran from PVC cement can cause artifical increases in total organic carbon concentrations, thereby causing erroneous results in determinations of concentrations of volatile organic compounds (National Research Council, 1982). 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 powder was backfilled from 1.0 ft below ground surface to the ground surface to prevent water from infiltrating around the casing.

At most sites, immediately after the casing was in position, water was pumped down 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 from each well. This procedure removes the fine materials from the screen and develops the hydraulic connection with the aquifer.

Procedures for Water-Quality Sampling and Analysis

Twenty-six observation wells were sampled to determine water quality. To ensure that water samples were representative of the geochemical environment, the observation wells were pumped with in ISCO model 2600 bladder pump, or bailed with a PVC bailer until the pH, temperature, and conductivity measurements stabilized, and at least three well volumes of water were removed. Field measurements of pH and specific conductance were made with portable meters (Orion Model 231 for pH, Fisher 152 for specific conductance).

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. These samples were filtered and then acidified with 5 milliliter (ml) of nitric acid. All samples were kept on ice and delivered to the DEP 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 infarared technique (Standard Method 505, American Public Heath Association and others, 1976). Volatile organic analyses were done by using a purge-and-trap method on a gas chromatograph equipped with a mass spectrophotometer.

HYDROGEOLOGY

Surficial Geology

Maine probably was covered by continental glaciers several times during the Pleistocene Epoch, which occurred from approximately 2,000,000 to 10,000 years before present (B.P.). The last ice sheet, known as the Laurentide Ice Sheet, advanced into Maine from eastern Canada about 20,000 years B.P., in late Wisconsin time, and flowed southeastward beyond the present coastline and into the Gulf of Maine.

Glacial History

After the maximum 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 approximated 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.

As deglaciation continued, the remnant ice cap deposited glaciofluvial, glaciolacustrine, and glaciomarine sediments, which record the style and pattern of glacial retreat in coastal Maine. Most glaciomarine deltas in eastern Maine formed close to the island marine limit, where the ice retreat became slow enough for large volumes of sediment to accumulate. Below the marine limit, glacial landforms such as eskers, deltas, fans, and moraines are associated with a glaciomarine deposit, the Presumpscot Formation (Bloom, 1960). Radiocarbon dates, determined largely from 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, vast amounts of meltwater reworked the glacial sediment and deposited fluvial and shoreline sediments over the Presumpscot Formation.

The deglacial period of the study area also has a complex history of sea-level change. Following the ice advance, global climatic warming caused melting of the glaciers, and sea level began to rise worldwide. In coastal Maine, which was depressed by the weight of the ice, sea level approximately followed the receding ice margin inland as far as Millinocket. Almost as soon as the ice left, crustal rebound in coastal Maine occurred at a faster rate than worldwide sea-level rise, so the local sea-level in coastal Maine fell until rebound slowed, approximately 10,000 years B.P. Since then, sea level has been rising over most of the coast. The Passamaquoddy Bay area, however, is the site of a more rapid local sea-level rise, as a result of local crustal downwarping (Anderson and others, 1984).

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 heterogeneous 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 qualitites and areal extent, in part, determine the amount of natural recharge to the region. A poorly sorted, compact, clayey till with minimal permeability will not have as rapid an infiltration rate as a well-sorted, sandy, less compact till. Large amounts of runoff from upland till areas can recharge adjacent stratified-drift deposits.

Till deposits in the State differ in thickness areally but generally are not more than about 10 ft thick. On the southern side of some streamlined hills, known as drumlins, the thickness of till may exceed 100 ft. Examples of drumlins are shown on Map 27, Plate 4, in the northeastern part of the map; these include Hardwood Hill, Birch Hill and Pine Hill, although the thickness of till on those hills is not known. The long axis of these hills trends northwest-southeast, parallel to the direction of flow of the last ice sheet that covered the region.

The marine submergence during deglaciation was most extensive along the coastal lowland, but it also reached far into central Maine along the major river valleys. Marine sediments deposited during the submergence are regionally extensive in the low areas and generally consist of glaciomarine silt and clay, although, in places, the sediment are sandy. The glaciomarine sediments are collectively referred to as the Presumpscot Formation; it underlies areas below the marine limit, commonly overlies till, and is as much as 100 ft thick. It generally is not a productive aquifer.

In places, the ice margin paused in its retreat, and ridges of sediment were deposited into the sea in front of the ice. These ridges are termed moraines; an example is the Pineo Ridge moraine, north and east of Schoodic Lake (Map 26, Plate 3). Numerous smaller moraines such as the Pond Ridge moraine in Cutler (Map 24, Plate 4) are present throughout the study area as ridges with a similar trend as that of the Pineo Ridge moraine. In general, the moraines are comprised of sand and gravel with interbedded till and marine clay. Parts of the moraines are major aquifers in some locations.

As the ice margin retreated in Maine, meltwater streams transported and deposited quantities of sand and gravel, predominantly 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. These deposits are termed ice-contact stratified drift and include such features as eskers or crevasse fillings and subaqueous fans and kame deltas. Sediments laid down by meltwater streams in valleys beyond the ice margin are termed outwash-plain deposits, and commonly display pitted surfaces as a result of the burial and subsequent melting of blocks of ice. An example of an esker occurs in Aurora along Maine State Highway 9 (Air Line Road), Map 27, Plate 4. It is a long, sinuous ridge, known as the "whalesback".

An example of a delta is the southeastern part of Pineo Ridge--the large flat-topped feature south of Schoodic Lake (Map 24, Plate 1). Another example of a delta and associated subaqueous fans is present northeast of Columbia Falls (Map 25, Plate 2). These features commonly are found in association with a moraine complex. As the ice retreated, the delta and moraine were deposited in the sea in front of the ice; the sediments were released from the ice during melting. These deposits can be regarded as ice-marginal features, indicative of the location of the ice front as it retreated northward. Outwash deposits are present in river valleys, such as the Narraguagus and Machias Rivers (Maps 24 and 25, Plates 1 and 2, respectively).

Wetland deposits are present in swamps and bogs and are underlain by till, marine clay, or locally impermeable deposits in stratified drift. Many of the wetland areas are characterized by compact peat deposits. The wetland deposits generally have low permeability, however, porosity and storativity of the deposits can be high. Some large wetland areas include the Great Heath and Denbow Heath (Map 26, Plate 3).

Eolian deposits (sand dunes) are present throughout the study area--for example, on the Deblois sand plains (Map 26, Plate 3). These types of deposits generally are not used as aquifers.

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, including the St. Croix, Narraguagus, and Machias Rivers.

Stratigraphy of Glacial Deposits

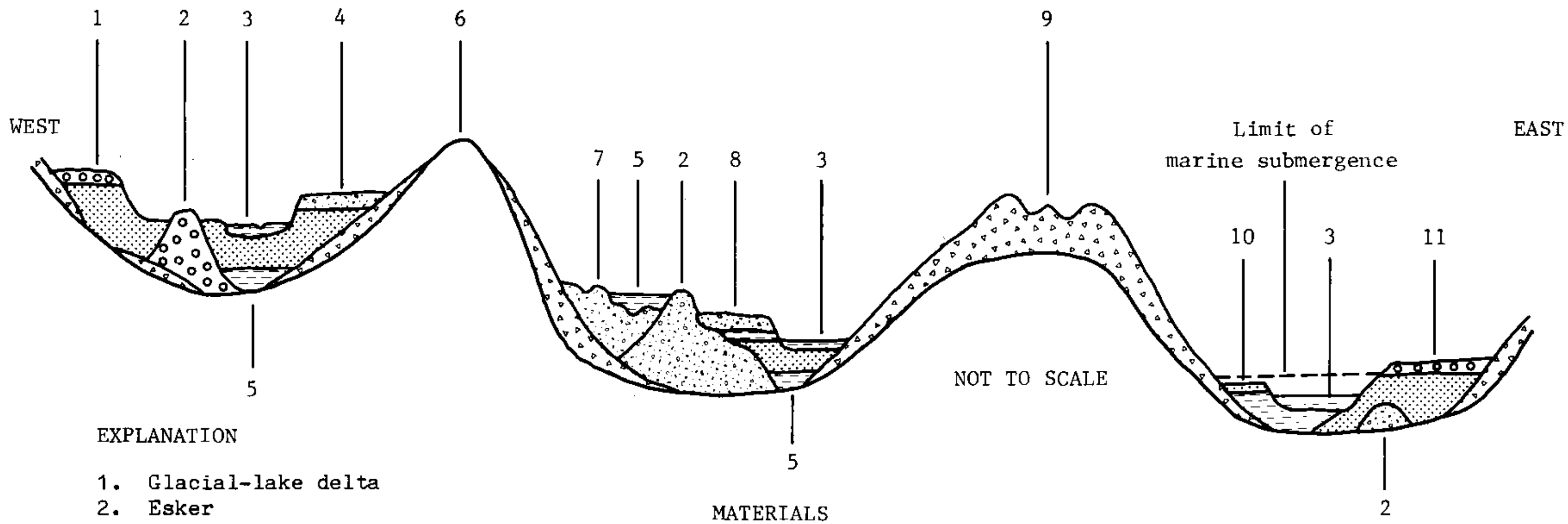
Figure 2 is an interpretive, schematic diagram that shows the generalized regional stratigraphic relation of glacial deposits in Maine. In general, surficial stratigraphy in the study area is best represented by the eastern part of the schematic figure, where glaciomarine deposits are extensive. This figure is based on field studies, test-boring logs (tables 9-13, at end of report) and seismic investigations conducted in the region. Not all of the units shown on this figure will necessarily be found in any one place.

The relative age of the deposits is indicated in figure 2. 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. This material generally is older than the overlying marine deposits; however, in places, these two units appear to be contemporaneous in age as shown by interbedding. A thin veneer of sand and gravel overlying the marine clay may represent a late outwash deposit, or could have been deposited by modern streams (alluvium); it is the youngest surficial deposit. Representative hydrogeologic sections of glacial deposits found in the study area are shown on figures 3, 4, and 5. Section A-A' (fig. 3) is a north-south transect through the Pineo Ridge delta in Columbia (Map 26, Plate 3).

Depth to the water table and bedrock in figure 3 is based on several 12-channel seismic lines (CHD-26, CHD-26A, CHD-11, and CHD-15), as well as logs from borings conducted in the area (R.G. Gerber, Inc. written commun., 1987) and project boring OW26-2 (Plate 3).

Section B-B' (fig. 4) is an east-west transect through outwash deposits north of Montegail Pond, T19MD (Map 26, pl.3). Subsurface data used to construct this section includes test-boring information supplied by E.C. Jordan Company (written commun., 1987).

Section C-C' (fig. 5) is an east-west transect through an esker-fan-delta complex east of Ellsworth (Map 27, plate 4). Subsurface data used to construct this section consists of three 12-channel seismic lines (ELL-7A, ELL-12, and HAN-1) and several nearby private well logs, located to the north and south of the section line.



EXPLANATION

1. Glacial-lake delta
2. Esker
3. Flood-plain deposits of modern river
4. Glacial-lake sand overlain by late-glacial outwash or postglacial stream-terrace alluvium
5. Fine-grained sediments deposited on bottom of glacial lake
6. Bedrock ridge
7. Kettled ice-contact deposits, locally overlain by fine-grained glacial-lake sediments
8. Alluvium on stream terrace. Terrace is developed on side of esker and locally underlain by glacial-lake sediments
9. Drumlins
10. Glacial-marine clay overlain by late-glacial outwash sand
11. Glacial-marine delta

MATERIALS

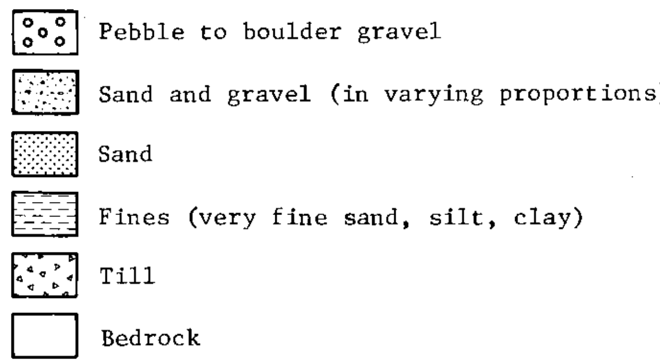


Figure 2. Generalized, regional stratigraphic relations in glacial deposits.

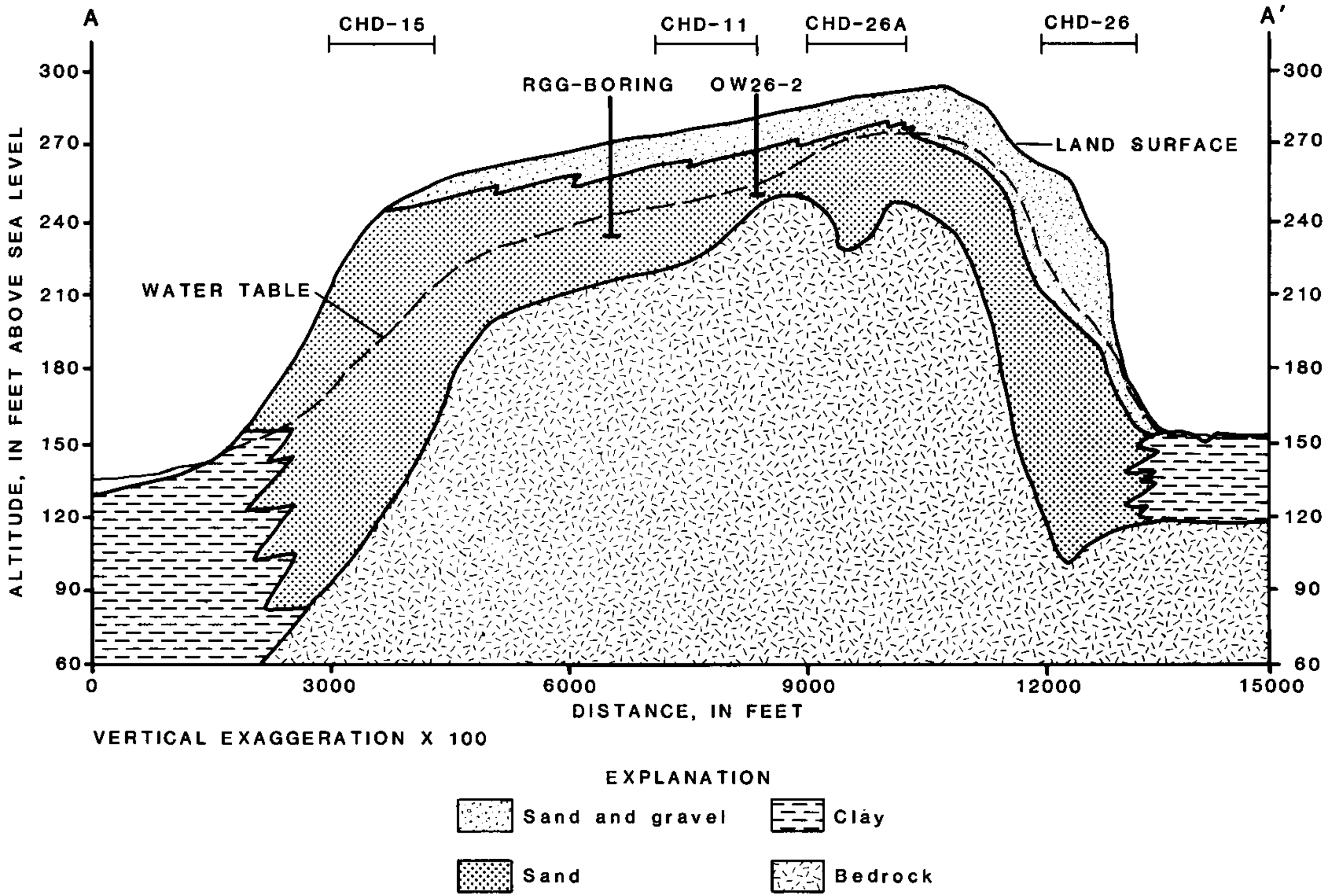


Figure 3. Hydrogeologic section through Pineo Ridge Delta, Columbia, Maine, line A-A' (based on 12-channel seismic data and logs), plate 3, map 26.

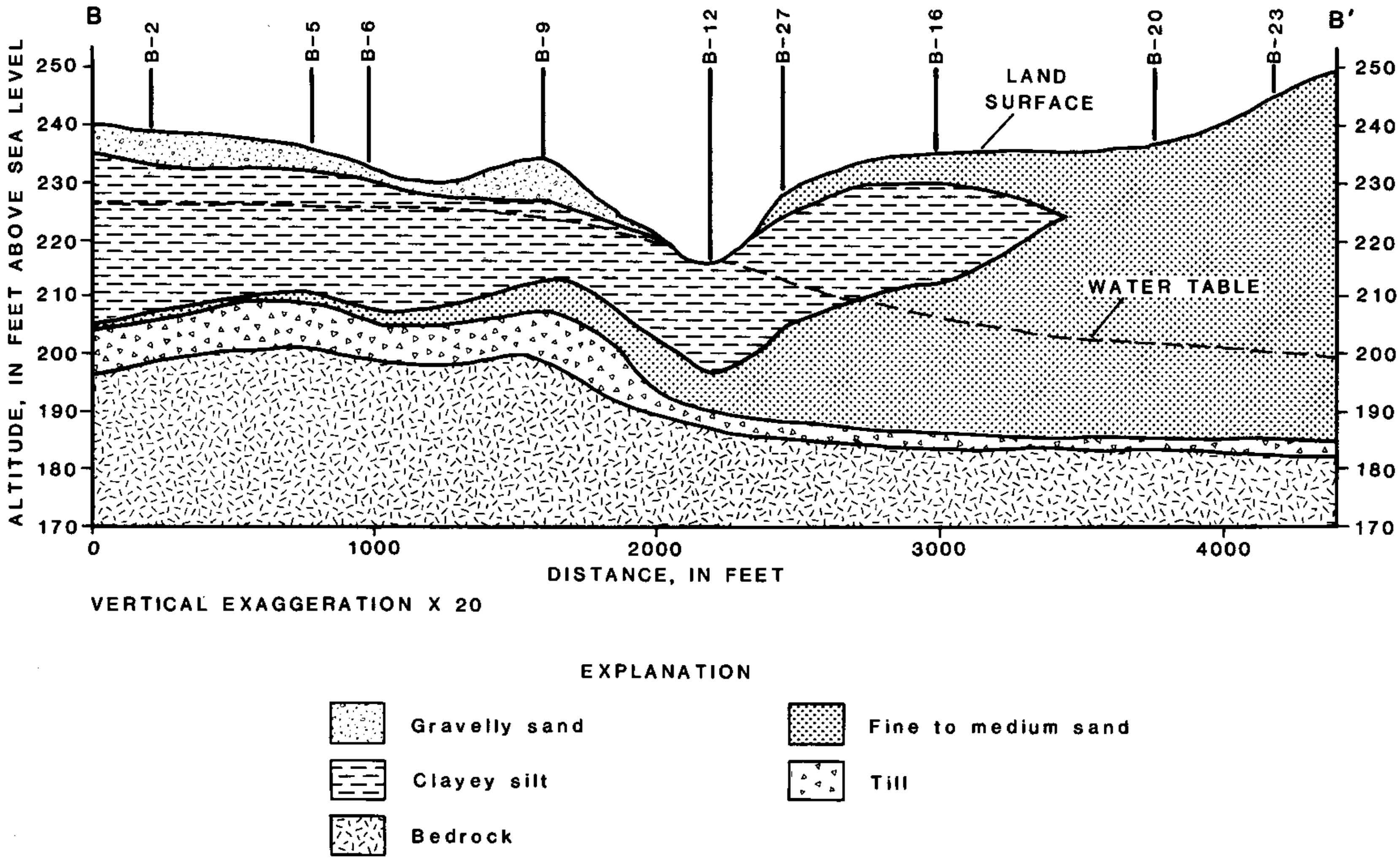


Figure 4. Hydrogeologic section through outwash deposits, T19MD, Maine, line B-B', plate 3, map 26. (Boring data from E. C. Jordan, Co., 1982 & 1983.)

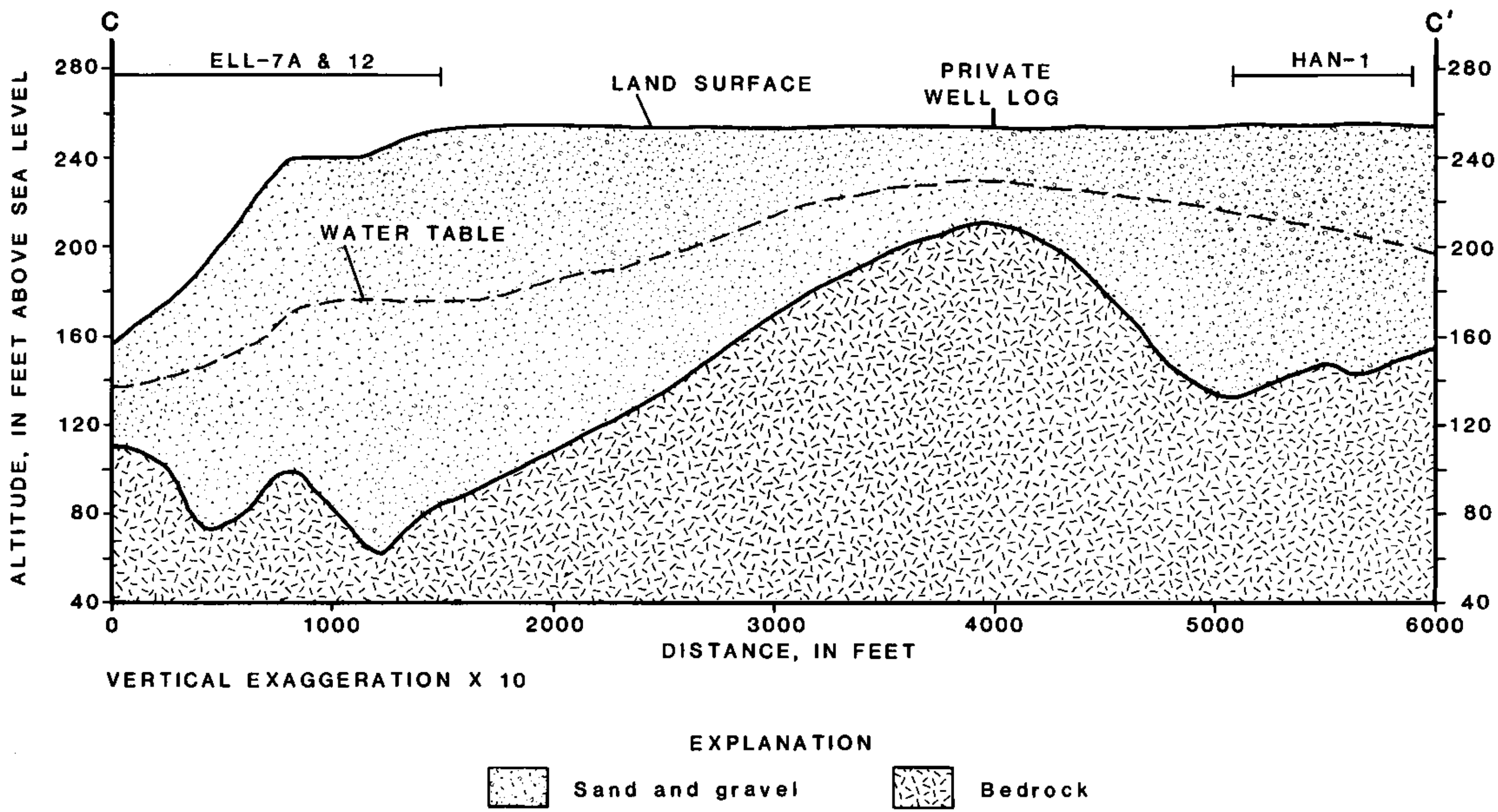


Figure 5. Hydrogeologic section through stratified drift, Hancock, Maine, line C-C' (based on 12-channel seismic data and logs), plate 4, map 27.

Hydrology of the Significant Sand and Gravel Aquifers

The significant sand and gravel aquifers consist of glaciomarine deltaic sediments; ice-contact, ice-stagnation, and glacial outwash deposits; and Holocene stream alluvium. Many of the deltas are found at higher elevations on interfluve areas rather than in stream valleys. The other deposits are present in association with the deltas or in the valleys of the major river systems and their tributaries, commonly near surface-water bodies that may serve as sources of recharge.

The major aquifers are located in glaciomarine deltaic deposits--for example, the Pineo Ridge delta (map 26, pl. 3). The largest yields are obtained from wells constructed in areas where coarse-grained deposits are located near freshwater bodies.

The most productive and most developed aquifer system is located in sand and gravel overlain by marine deposits in Machias (Machias Water Co., 208 gal/min; Map 25, pl.2). The largest reported yield in the area, 350 gal/min, is from a well in the Town of Pembroke (map 45, pl. 5) operated by the Passamaquoddy Water District.

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 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, marine deposits, alluvium, swamps, 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 plates 1-5 are based on available information and are subject to modification as additional data become available.

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

Hydraulic Conductivity

Hydraulic conductivity is a measure of the volume of water that will flow through a unit area of aquifer under unit hydraulic head in a unit amount of time (Heath, 1983). It dependents on a variety of physical factors, including porosity, particle size and distribution, shape of particles, and arrangement of particles (Todd, 1980). Hydraulic conductivity is the most important hydraulic property with respect to rates of ground-water flow and well yield (Caswell, 1978). Typical values of hydraulic conductivity (in a horizontal direction), expressed in feet per day (ft/d), 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). Horizontal hydraulic conductivities estimated for selected aquifer materials sampled in this study range from 10 ft/d to 180 ft/d (table 1).

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

The results of these analyses (table 1) were used to estimate horizontal hydraulic conductivity, using nomographs published by Masch and Denny (1966). Those nomographs relate mean grain size and degree of sorting to hydraulic conductivity. The median particle diameter (in millimeters) and the degree of sorting of representative observation-well sediment samples were determined by grain-size analyses. These analyses were performed at the USGS laboratory in Harrisburg, Pennsylvania, using a dry sieve method (Folk, 1974). The estimates, shown in table 1, are comparable to those of Morrissey (1983) for outwash sand (15 to 80 ft/d) and for coarse-grained materials (150 to 200 ft/d).

Transmissivity

Transmissivity is the rate at which water is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. 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. Freeze and Cherry (1979) suggest that transmissivities greater than 14,000 ft^2/d represent productive aquifers. However, aquifers with smaller transmissivity also are capable of transmitting usable quantities of water to properly constructed wells.

Approximate transmissivity values of sand and gravel aquifers were calculated at 24 sites from the complete stratigraphic logs of observation wells. Sediment from each interval in the saturated part of the exploration boring (tables 9-13, at end of report) was assigned a horizontal hydraulic conductivity, based on sample descriptions, grain size, and sorting (table 1). This hydraulic conductivity was multiplied by the interval thickness to obtain an approximate interval transmissivity. The interval transmissivity values were then summed to give a total transmissivity for that part of the aquifer penetrated by the exploration boring.

The transmissivity value are presented in table 2. The exploration borings for seven observation wells did not penetrate the entire aquifer thickness. Aquifer transmissivity at these wells was calculated based on properties of the known materials; actual transmissivity may be larger.

Depths to the Water Table and Bedrock Surface

Depths to the water table and bedrock surface in the significant sand and gravel aquifers have been determined from seismic-refraction investigations, well inventory, project drilling, mapping of bedrock outcrops, and previous investigations. In the significant sand and gravel aquifers, areally the depth to the water table differs considerably, but

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

Sample description	Observation well number	Depth of interval sampled (feet)	Median diameter (phi) [1/]	Degree of sorting[2/]	Estimated horizontal hydraulic conductivity (feet per day)[3/]
Clay to silt					
Silt to medium sand	OW 27-3	22- 24	5.6	poor	10
Silt to fine sand	OW 26-11	42- 44	4.5	poor	10
Clay to fine sand	OW 26-11	37- 39	3.8	poor	11
				Average	10
Very fine to fine sand					
Very fine to fine sand, few pebbles	OW 26-3	47- 49	3.0	poor	15
Fine sand	OW 27-4	77- 79	2.9	poor	11
Fine sand with some small gravel	OW 26-7	42- 44	2.7	poor	10
Very fine to fine sand	OW 26-6	32- 34	2.7	poor	17
				Average	13
Very fine; fine; to medium sand					
Fine to medium sand	OW 26-10	48- 49	2.6	poor	12
Fine to medium sand	OW 26-10	42- 44	2.6	moderate	17
Very fine to medium sand, some silt	OW 26-3	57- 59	2.6	poor	16
Fine to medium sand	OW 26-10	107-108	2.5	poor	17
Fine to medium sand	OW 27-2	102-104	2.5	poor	17
Very fine to medium sand	OW 45-2	48- 49	2.5	moderate	20
				Average	17

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

Sample description	Observation well number	Depth of interval sampled (feet)	Median diameter (phi) 1/	Degree of sorting 2/	Estimated Horizontal hydraulic conductivity (feet per day) 3/
Medium sand	OW 45-1	67- 69	2.6	poor	19
Fine to coarse; very coarse sand					
Fine to coarse sand	OW 25-2	32- 34	2.2	poor	23
Fine to coarse sand	OW 26-4	72- 74	2.0	poor	23
Fine to very coarse sand	OW 27-2	57- 59	2.2	poor	20
Fine to very coarse sand	OW 27-4	67- 69	1.0	poor	16
Fine to very coarse sand	OW 25-3	22- 27	1.1	poor	16
				Average	20
Medium to coarse sand					
Medium to coarse sand	OW 27-2	52- 54	1.8	poor	24
Medium to coarse sand	OW 45-1	37- 39	1.4	poor	22
Medium to coarse sand, some gravel	OW 25-5	22- 24	1.2	poor	20
Medium to coarse sand	OW 26-9	22- 24	1.7	moderate	33
Medium to coarse sand	OW 26-9	17- 19	1.5	poor	33
Medium to coarse sand	OW 26-10	108-109	0.8	poor	33
				Average	28

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

Sample description	Observation well number	Depth of interval sampled (feet)	Median diameter (phi) 1/	Degree of sorting 2/	Estimated horizontal hydraulic conductivity (feet per day) 3/
Medium to very coarse sand	OW 26-10	97- 99	1.1	poor	44
Very coarse sand	OW 45-1	17- 19	0.9	moderate	53
Very coarse sand	OW 45-2	17- 19	0.5	moderately well	117
Coarse to very coarse sand, some gravel to 1/8"	OW 26-9	12- 14	0.1	moderate	114
Medium to very coarse sand, some gravel	OW 26-12	17- 19	-0.5	poor	180

1/ Phi is the negative logarithm to the base 2 of the particle diameter in millimeters

2/ Sorting classified by Inclusive Graphic Standard Deviation
>1.0 - poor
.75-1.0 - moderate
.50-.75 - moderately well
<.50 - well

3/ Masch and Denny (1966)

Table 2.-- Estimated transmissivity of materials from selected observation wells.

Map	Observation well number	Transmissivity, in feet squared per day
24	OW 24- 1	470
25	OW 25- 1	1,200
	OW 25- 2	540
	OW 25- 3	750
	OW 25- 4	920
	OW 25- 5	1,120
26	OW 26- 1	>200
	OW 26- 2	>250
	OW 26- 3	1,050
	OW 26- 4	1,140
	OW 26- 5	510
	OW 26- 6	660
	OW 26- 7	190
	OW 26- 8	500
	OW 26-10	>1,680
	OW 26-11	>1,200
	OW 26-12	3,040
	OW 26-13	>660
27	OW 27- 1	170
	OW 27- 2	>1,420
	OW 27- 3	990
	OW 27- 4	700
45	OW 45- 1	1,440
	OW 45- 2	1,620

typically is 25 ft of the land surface. The greatest depth to bedrock determined by seismic-refraction data is approximately 215 ft, along seismic line CHD-32A, on the Pineo Ridge Delta in Columbia (map 26 pl. 3). Well records indicate that bedrock is at a depth of 235 feet in Columbia.

Seismic-refraction techniques were used extensively to determine both depth to water table and depth to bedrock. In the study area, the seismic velocity in unsaturated overburden materials ranges from 704 to 2,759 feet per second (ft/s), with an average velocity of 1,306 ft/s. Saturated overburden materials have velocities of 4,000 to 7,478 ft/s, with an average velocity of 5,915 ft/s. Bedrock seismic velocities in the study area vary from 10,735 to 70,573 ft/s. Bedrock velocities greater than 25,000 ft/s were considered unrealistic for the bedrock types in the area (granite, schist, and metavolcanics). An average velocity of 16,029 ft/s was determined by using values that ranged from 10,735 to 25,000 ft/s.

A summary of the information collected with the single-channel seismographs is presented in table 14 (at end of report). Hydrogeologic sections from seismic-refraction surveys conducted with the 12-channel seismograph are presented in figures 7-11 (at end of report). The locations of 67 single-channel and 63 twelve-channel seismic-refraction lines conducted throughout the study area are shown on plates 1-5.

Determinations of depths to the water table and bedrock surface are necessary to provide a three-dimensional hydrogeologic picture 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 (fig. 7-11, at end of report) 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.

Estimated Well Yields

The significant sand and gravel aquifers consist of ice-contact, ice-stagnation, outwash, and alluvial deposits, which have sufficient areal extent, hydraulic conductivity, and saturated thickness to sustain a yield of 10 gal/min or more to a properly installed well. Yields obtainable from wells constructed in various parts of the significant sand and gravel aquifers were estimated from yields reported by well drillers and well owners, previously published studies, and from estimates based on saturated thickness, transmissivity, and areal extent of the aquifers. A method used to estimate well yields in a water-table aquifer was developed by Mazzaferro (1980), and is based on transmissivity (T) and saturated thickness (B), where $(T \times B)/750 =$ well yield (gal/min). Using this method, with $T=8{,}020$ ft^2/d, $B = 30$ ft (Caswell and other, 1985) an estimated yield of 320 gal/min was calculated for the Passamaquoddy Water District well in Pembroke. Caswell and others (1985) estimated that the long-term yield of this well is greater than 300 gal/min. Estimated yields were calculated for selected observation wells and are presented in table 3. Areas where wells are estimated to yield more than 10 gal/min and more than 50 gal/min are shown as separate shading patterns on the maps. Areas where wells may yield less

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

Map	Observation well number	Estimated well yield (gal/min)
24	OW 24- 1	5
25	OW 25- 1	100
	OW 25- 2	20
	OW 25- 4	5
	OW 25- 5	100
26	OW 26- 1	>5
	OW 26- 2	>5
	OW 26- 3	60
	OW 26- 4	130
	OW 26- 5	20
	OW 26- 6	15
	OW 26- 7	5
	OW 26- 8	20
	OW 26-10	>240
	OW 26-11	>160
	OW 26-12	230
	OW 26-13	>15
27	OW 27- 2	>140
	OW 27- 3	110
	OW 27- 4	50
45	OW 45- 1	140
	OW 45- 2	130

than 10 gal/min constitute the remaining unshaded portion of the map. The maps can be used as a base for detailed hydrogeological siting studies, and in making environmentally sound decisions. Furthermore, they provide a variety of information on aquifer favorability and vulnerability, as well as a preliminary estimate of well yield in certain areas.

Although the total study area covers 1,715 mi^2, areas mapped as significant sand and gravel aquifers include only about 238 mi^2 (14 percent) of this area. Yields exceeding 50 gal/min are estimated to be obtainable in only 4 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 recharge. The highest reported well yield in the sand and gravel deposits is 350 gal/min from a Passamaquaddy Water District Well (Map 45, pl. 5). Other large yield wells in the area include municipal wells in Lubec (Lubec Water District, three wells with total capacity of 555 gal/min; Map 24, pl. 1) and in Machias (Machias Water Co., 208 gal/min; Map 25, pl. 2).

Water-Level Fluctuations

Monthly water-level measurements made at 24 observation wells installed in the study area are shown in table 4. Water-level measurements were made once a month from October 1985 through October 1986. Water-levels averaged over a 12-month period in all observation wells fluctuated within a range of approximately 1 to 10 ft (table 5). Selected hydrographs from these observation wells are shown in figure 6.

Maximum depth to water table is approximately 50 ft and minimum depth is approximately 2.5 ft, averaged over a 12-month period. In much of the area, the water table is less than 25 feet from the surface. Here, the thinness of the unsaturated zone renders the ground water vulnerable to potential contamination originating at the land surface.

Monthly precipitation data from National Oceanic and Atmospheric Administration's Jonesboro and Ellsworth stations are compared with water-level data in figure 6. Regional recharge generally occurs in response to seasonal precipitation in the spring and fall. Most water levels decline slowly but steadily between these recharge events. Local response to precipitation recorded by well water levels in the study area is presented in figure 6.

GROUND-WATER QUALITY

Factors Influencing Water Quality

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

Table 4.--Water-level data for observation wells in the study area, October 1985 through October 1986.
[Depth to water, in feet below land surface; --, no water level measured during this period].

Aquifer Map Number	Observation Well Number	Location	October 29-30	December 5-6	December 30-31	February 6-7	March 6	April 10-11	April/May 30, 1-2	May 28-29	June 26-27	July 30-31	September 3-4	October 1-2
24	OW24- 1	Lubec	10.74	10.12	10.15	9.41	9.93	9.01	7.43	7.18	7.72	8.81	7.79	8.10
25	OW25- 1	Jonesboro	17.78	17.41	17.81	17.44	17.75	17.04	17.14	17.20	17.42	16.80	17.21	17.43
25	OW25- 2	East Machias	21.28	20.96	21.15	20.40	20.79	19.80	19.42	19.30	19.64	20.18	20.28	20.58
25	OW25- 3	Whitneyville	3.24	--	--	--	--	--	--	--	--	--	--	--
25	OW25- 4	Jonesboro	4.86	4.21	--	4.26	4.64	4.11	4.11	4.18	4.77	3.80	4.46	4.71
25	OW25- 5	T25MD BPP	12.82	12.01	12.34	11.17	--	10.22	9.01	9.47	10.11	11.14	10.95	11.61
26	OW26- 1	Columbia	19.75	17.07	--	12.66	--	11.24	10.49	12.46	14.16	16.76	14.89	16.75
26	OW26- 2	Columbia	17.24	15.76	--	14.56	--	14.45	13.68	14.21	14.86	15.92	15.02	15.88
26	OW26- 3	T22MD	27.03	--	26.43	30.97	--	--	24.44	23.83	24.14	24.57	24.01	24.25
26	OW26- 4	Columbia	28.01	27.57	--	26.60	--	25.05	24.11	23.81	24.29	25.47	25.66	26.05
26	OW26- 5	T19MD BPP	46.99	46.65	--	46.28	46.63	46.07	46.12	46.15	46.34	47.54	46.49	46.52
26	OW26- 6	Columbia	25.48	24.79	--	22.73	--	20.06	18.69	19.38	20.82	22.80	22.46	23.04
26	OW26- 7	Deblois	32.72	32.35	32.34	31.74	--	30.35	30.02	29.82	30.57	30.90	30.56	30.26
26	OW26- 8	Beddington	22.09	20.71	21.18	19.43	--	17.62	17.84	19.15	20.40	21.29	20.36	21.18
26	OW26-10	T24MD BPP	16.42	15.64	15.72	13.99	--	13.07	11.66	13.63	14.69	15.67	15.55	16.03
26	OW26-11	Deblois	16.57	16.09	--	15.44	--	15.23	14.92	15.00	15.18	15.38	14.62	14.94
26	OW26-12	Deblois	12.95	12.43	--	11.16	--	9.56	8.63	9.16	9.90	10.92	10.37	10.97
26	OW26-13	T18MD BPP	21.43	21.56	--	20.09	--	18.89	18.63	18.58	19.01	19.51	19.65	19.86
27	OW27- 1	Franklin	32.44	32.36	32.09	31.66	31.46	31.19	30.95	30.75	31.05	31.42	31.49	31.68
27	OW27- 2	Hancock	46.66	46.91	47.05	46.83	46.27	45.76	45.27	44.79	44.43	44.70	44.78	45.77
27	OW27- 3	Otis	12.29	11.73	11.50	10.15	--	8.47	7.72	7.97	8.84	9.49	9.67	10.17
27	OW27- 4	Aurora	49.76	49.87	49.60	48.72	--	45.40	43.73	43.06	44.76	44.94	45.82	45.82
45	OW45- 1	Baring Plt.	3.64	3.20	3.47	--	3.33	2.55	2.34	2.52	2.84	3.13	3.10	3.28
45	OW45- 2	Meddybumps	5.58	5.31	5.31	4.27	4.61	3.45	3.72	3.75	4.18	4.37	4.65	4.85

Table 5.--Statistical analysis of water-level data for observation wells in study area, October 1985 to October 1986.

[--, not enough data collected to do statistical analysis]

Observation Well Number	Location	Mean (feet)	Standard deviation	Maximum depth to water (in feet below land surface)	Minimum depth to water (in feet below land surface)	Range of values (feet)
OW24- 1	Lubec	8.9	1.2	10.74	7.18	3.56
OW25- 1	Jonesboro	17.4	0.3	17.81	16.80	1.01
OW25- 2	East Machias	20.3	0.7	21.28	19.30	1.98
OW25- 3	Whitneyville	--	--	--	--	--
OW25- 4	Jonesboro	4.4	0.3	4.86	3.80	1.06
OW25- 5	T25MD BPP	11.0	1.2	12.82	9.01	3.81
OW26- 1	Columbia	14.6	3.0	19.75	10.49	9.26
OW26- 2	Columbia	15.2	1.0	17.24	13.68	3.56
OW26- 3	T22MD	25.5	2.3	30.97	23.83	7.14
OW26- 4	Columbia	25.7	1.4	28.01	23.81	4.20
OW26- 5	T19MD BPP	46.5	0.4	47.54	46.07	1.47
OW26- 6	Columbia	22.0	2.2	25.48	18.69	6.79
OW26- 7	Deblois	31.1	1.0	32.72	29.82	2.90
OW26- 8	Beddington	20.1	1.4	22.09	17.62	4.47
OW26-10	T24MD BPP	14.7	1.5	16.42	11.66	4.76
OW26-11	Deblois	15.3	0.6	16.57	14.62	1.95
OW26-12	Deblois	10.6	1.4	12.95	8.63	4.32
OW26-13	T18MD BPP	19.7	1.1	21.56	18.58	2.98
OW27- 1	Franklin	31.5	0.5	32.44	30.75	1.69
OW27- 2	Hancock	45.8	1.0	47.05	44.43	2.62
OW27- 3	Otis	9.8	1.5	12.29	7.72	4.57
OW27- 4	Aurora	46.5	2.5	49.87	43.06	6.81
OW45- 1	Baring Plt.	3.0	0.4	3.64	2.34	1.30
OW45- 2	Meddybemps	4.5	0.7	5.58	3.45	2.13

A. Water level in shallow water table observation wells (Depth to water less than 25 ft.)

B. Water levels in deep water table observation wells (Depth to water greater than 25 ft.)

C. Average monthly precipitation, based on data from the Ellsworth and Jonesboro NOAA stations.

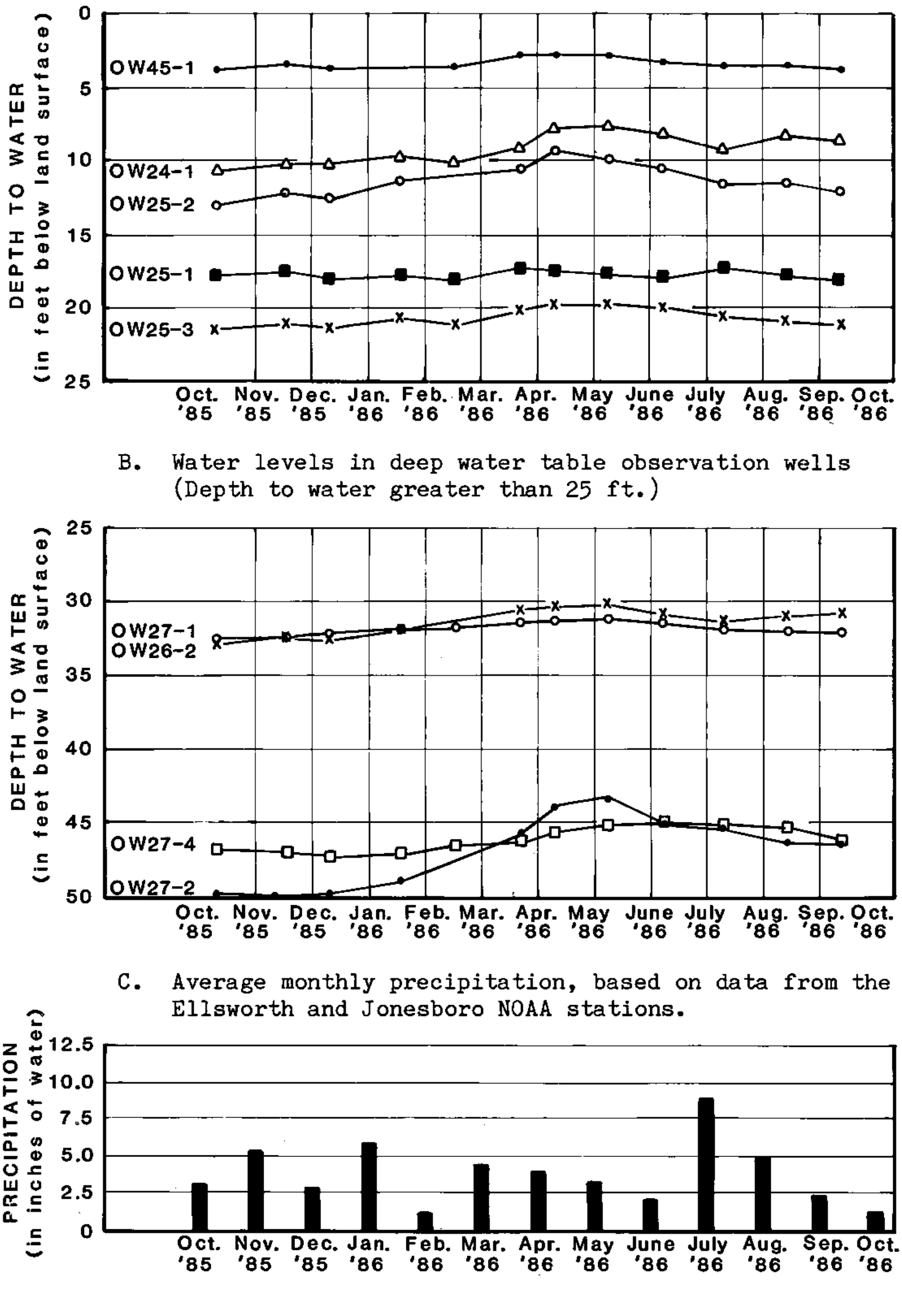


Figure 6. Groundwater levels and average monthly precipitation, October 1985 through October 1986.

Chemical reactions that occur as water passes through the soil zone also can affect ground-water chemistry. Where the saturated thickness of unconsolidated deposits is great, the water-flow paths are long; hence, greater time is available for the dissolution of soluable material in the aquifer (Caswell, 1978). Residence time also depends on hydraulic conductivity, hydraulic gradient, and the porosity of the unconsolidated deposits.

The chemical composition of precipitation also can affect ground-water quality. In coastal regions where precipitation contains sea salt, the concentrations of sodium and chloride in ground water typically are larger than in inland areas (Matthess, 1982). Elevated concentrations of sodium and chloride also can result from saltwater intrusion in coastal areas. There also are some aquifers in Maine where saline water is present, trapped during the late Wisconsinan marine submergence (Tepper, 1980).

Contamination by human activities can introduce elevated concentrations of many compounds into ground water. Activities that may greatly alter the quality of ground water include the following:

(1) landfill disposal of household and industrial wastes, which may include petroleum derivatives and hazardous and radioactive materials;
(2) storage and spreading of road-deicing salt;
(3) introduction of human wastes into ground water through septic tanks, disposal of septic wastes, or by spreading or landfilling of sludge from municipal sewer systems;
(4) agricultural activities, which include stockpiling and spreading animal wastes, spreading commercial fertilizers, and spraying pesticides;
(5) leaking waste-storage or disposal lagoons;
(6) leaking fuel- or chemical-storage tanks;
(7) spills of toxic or hazardous materials along transportation routes;
(8) large withdrawals from wells can induce saltwater intrusion in coastal areas or infiltration of degraded water quality where a well is near contaminated surface water;
(9) contaminants in precipitation may degrade ground water and surface water. For example, in the northeastern United States, "acid rain" has been reported to cause a lowering of pH and a subsequent increase in aluminum and trace-metal concentrations in ground water in New Hampshire and New York (Bridge and Fairchild, 1981).

The most commonly used indicators to detect ground-water contamination include above-background levels of nitrate, a contaminant derived from sewage, animal waste, fertilizer, and landfill waste; chloride, a contaminant introduced by road salt, saltwater intrusion, fertilizers and landfill wastes; and specific conductance, which indicates the presence of dissolved, ionized contaminants.

Background Water Quality

The following discussion is based on analyses of samples collected from 25 wells within the study area. Characteristics of these wells are given in table 6. Water quality of samples from these wells is given in table 7. Data for all parameters, including temperature, are reported in

Table 6.--Characteristics of observation wells in the study area sampled for background water quality.

Observation well number	Town	Latitude	Longitude	Elevation[1]	Depth[2]	Predominant land use around well	Date sampled
OW24- 1	Lubec	44°49'59"N	67°01'24"W	100	14	field	09-25-85
OW25- 1	Jonesboro	44°37'54"N	67°38'44"W	60	35	gravel pit	10-02-85
OW25- 2	East Machias	44°49'23"N	67°25'12"W	120	34	gravel pit	09-26-85
OW25- 3	Whitneyville	44°41'14"N	67°29'18"W	140	21	gravel pit	09-26-85
OW25- 4	Jonesboro	44°37'40"N	67°37'11'W	100	13	field	10-02-85
OW25- 5	T25MD	44°52'01"N	67°44'29"W	230	35	forest	10-09-85
OW26- 1	Columbia	44°40'41"N	67°51'52"W	260	25	field	10-03-85
OW26- 2	Columbia	44°40'25"N	67°51'15"W	270	27	field	10-03-85
OW26- 3	T22MD	44°46'44"N	68°04'40"W	270	50	field	09-24-85
OW26- 4	Columbia	44°40'38"N	67°52'06"W	260	42	field	10-03-85
OW26- 5	T19MD	44°45'12"N	67°46'50"W	250	66	field	10-02-85
OW26- 6	Columbia	44°40'38"N	67°51'55"W	260	37	field	10-03-85
OW26- 7	Deblois	44°45'44"N	68°01'48"W	240	47	field	09-24-85
OW26- 8	Beddington	44°50'10"N	68°04'43"W	280	35	gravel pit	10-04-85
OW26- 9	T24MD	44°52'27"N	67°52'01"W	260	30	field	10-09-85
OW26-10	T24MD	44°52'27"N	67°52'01"W	260	105	field	05-06-86 10-09-85
OW26-11	Deblois	44°43'07"N	67°59'09"W	200	35	field	10-08-85
OW26-12	Deblois	44°45'59"N	67°56'28"W	260	32	field	10-04-85
OW26-13	T18MD	44°42'58"N	67°54'36"W	230	30	field	10-03-85
OW27- 1	Franklin	44°34'23"N	68°12'05"W	20	37	field	10-08-85
OW27- 2	Hancock	44°33'15"N	68°23'00"W	200	70	forest	10-08-85
OW27- 3	Otis	44°44'01"N	68°27'23"W	250	35	forest	10-01-85
OW27- 4	Aurora	44°52'01"N	68°18'19"W	290	84	field	10-01-85
OW45- 1	Baring	45°04'10"N	67°16'33"W	130	20	forest	09-25-85
OW45- 2	Meddybemps	45°01'48"N	67°21'44"W	200	23	field	09-25-85

1 Elevation of observation well at land surface datum, in feet.
2 Depth of bottom of observation well in feet below land-surface datum.

Table 7.--Background water quality in sand and gravel aquifers in the study area
[all values in milligrams per liter (mg/L) except as noted; µs/cm, microsiemens per centimeter at 25° Celsius; --, value not determined.]

Observation well number	Temperature (°C)	Conductivity (µs/cm)	pH	Alkalinity, as $CaCO_3$	Chloride, dis solved	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
OW 24-1	12.0	460	7.00	450	10	0.200	28	19	4.4	63	11	200	0.07	0.560	72
OW 25-1	8.5	84	7.04	32	4.4	.056	<5.0	7.8	1.5	5.8	2.5	25	.05	.016	7.0
OW 25-2	8.0	46	6.78	15	3.4	.010	<5.0	11	0.33	0.20	0.08	1	.07	.006	<1.0
OW 25-3	9.5	93	7.75	35	5.8	.060	6.4	5.8	1.6	11	2.0	36	<.03	.023	14
OW 25-4	11.5	104	6.98	74	4.4	.014	8.8	20	3.4	7.0	2.8	29	4.70	.120	83
OW 25-5	7.0	68	6.58	29	1.0	<.010	<5.0	3.7	.60	8.4	1.2	26	.12	.480	1.0
OW 26-1	11.5	25	6.29	6.4	2.0	.011	<5.0	3.8	.80	1.3	.72	6	1.30	.018	<1.0
OW 26-2	9.0	31	6.60	7.5	2.0	.074	<5.0	5.7	.90	1.8	.92	8	.94	.038	<1.0
OW 26-3	8.5	25	6.98	7.5	1.0	.100	<5.0	2.7	.60	1.6	.49	6	.16	.005	<1.0
OW 26-4	11.5	30	6.30	6.4	2.0	.059	<5.0	2.6	.70	1.4	.64	6	.07	.057	<1.0
OW 26-5	8.0	47	7.29	21	2.0	.340	<5.0	14	.60	2.9	1.1	12	1.10	.016	2.0
OW 26-6	11.5	43	6.76	13	2.0	.023	<5.0	4.7	1.5	2.5	.81	10	.03	.082	<1.0
OW 26-7	11.5	150	7.89	78	2.0	<.010	<5.0	9.1	3.1	17	4.5	61	.04	.310	3.0
OW 26-8	12.0	33	5.73	5.4	2.0	.330	<5.0	2.9	.40	2.5	.70	9	<.03	.010	<1.0
OW 26-9	9.0	29	5.84	6.4	0.5	.010	<5.0	2.3	.30	1.3	.34	5	1.20	.036	<1.0
	8.0	15	5.90	8.0	1.5	--	1.4	2.8	.30	1.4	.40	5	1.40	.041	--
OW 26-10	8.0	27	6.56	16	1.0	.014	<5.0	3.3	1.0	3.4	.88	12	.08	.051	<1.0
OW 26-11	9.0	42	6.71	14	1.0	.490	<5.0	13	1.0	3.0	.86	11	<.03	.140	<1.0
OW 26-12	12.0	31	6.28	8.0	1.0	.130	<5.0	2.6	1.0	2.0	.77	8	.06	.078	1.0
OW 26-13	11.5	31	6.47	9.1	1.0	.036	<5.0	3.5	.60	1.9	.60	7	.03	.022	<1.0
OW 27-1	9.5	76	6.61	26	4.0	.170	6.5	4.5	1.2	4.2	1.3	16	.29	.022	3.0
OW 27-2	9.0	66	5.99	8.6	4.0	.507	10	5.3	2.2	5.6	1.0	18	<.03	.030	2.0
OW 27-3	9.5	44	6.85	22	1.0	.222	<5.0	7.2	.50	3.9	1.3	15	.70	.032	34
OW 27-4	8.5	43	6.46	14	1.0	.090	<5.0	3.2	.60	3.7	.84	13	<.03	.037	<1.0
OW 45-1	9.0	128	8.51	67	2.0	.090	5.6	2.7	1.3	22	2.0	63	.08	.006	<1.0
OW 45-2	10.0	117	7.60	48	2.0	.190	8.7	2.2	1.0	18	2.0	53	.03	.031	<1.0
With OW24-1 (25 wells)															
Minimum	7.0	22	5.73	5.4	0.5	<.010	<5.0	2.2	0.3	0.2	0.08	1.0	<0.03	0.005	<1.0
Maximum	12.0	460	8.51	450.0	10.0	.507	28.0	20.0	4.4	63.0	11.00	200.0	4.70	.560	83.0
Median	9.5	44	6.71	15.0	2.0	.119	<5.0	4.5	1.0	3.4	0.92	12.0	.07	.032	1.0
Mean	9.8	75	--	40.8	2.5	.130	6.6	6.5	1.2	7.8	1.65	26.2	.45	.089	9.4
Standard Deviation	1.6	88	--	87.9	2.1	.147	4.7	5.1	1.0	12.8	2.16	40.1	.98	.145	21.7
Without OW24-1 (24 wells)															
Minimum	7.0	22	5.73	5.4	0.5	.010	<5.0	2.2	0.3	0.2	0.08	1.0	<.03	.005	<1.0
Maximum	12.0	150	8.51	78.0	5.8	.507	10.0	20.0	3.4	22.0	4.50	63.0	4.70	.480	83.0
Median	9.3	43	6.66	14.5	2.0	.067	<5.0	4.1	0.9	3.2	0.90	12.0	.07	.031	1.0
Mean	9.7	58	--	23.7	2.2	.127	5.7	6.0	1.1	5.5	1.27	19.0	.47	.069	6.8
Standard Deviation	1.5	36	--	21.9	1.4	.149	1.4	4.5	0.8	5.8	0.96	17.6	1.00	.109	17.7

metric units. These wells are located in areas that are believed to be upgradient from any known sources of contaminants, and should, therefore, be representative of background water quality.

The samples were averaged both with and without data from OW24-1 (table 7). The water-quality characteristics of this well are different from the other well data. The data for OW24-1 is excluded in the written report as part of the average water-quality data of the study area for several reasons: (1) the screen is set partly in till and partly in sand and gravel; (2) when the well is bailed, it takes more than a day for the water level to recover; and (3) sample water from the well is turbid. These factors suggest that the hydraulic couple between the well in OW24-1 and the aquifer is not completely developed, or that the screen is an improper size for the material in which it is set. Based on these observations, the data from this well are considered significantly different from the other samples, warrant separation from the overall data, and are not included in the averages presented here. It is possible, however, that water quality in this well is representative of background water quality in tills.

A summary of the water-quality information collected throughout southwestern and south-central Maine from mapped sand and gravel aquifers (Tolman and others, 1983; Tepper and others, 1985; Williams and other, 1987; Adamik and others, 1987, table 8 this report) also is included in this discussion, and is compared with the data from southeastern Maine.

One category of water-quality characteristics that was omitted from this study, but was included in previous studies, is volatile organic compounds. This category was omitted because analyses of samples from the 1981-1984 field seasons did not detect any volatile organic compounds, and chances of finding randomly occurring volative organic compounds was subsequently considered unlikely.

Concurrent with the sand and gravel aquifer project, samples were collected and analyzed for pesticide concentration because of the intense blueberry cultivation in the study area. Of ten wells sampled, two (OW26-4 and OW26-12) contained detectable levels of the herbicide hexazinone (Neil and others, 1987; Williams and others, 1987).

Temperature

The temperature of ground water normally has a small seasonal fluctuation and is usually within a few degrees of the mean annual air temperature in a given area. In Maine, ground-water temperatures are typically between 4.4°C and 10.0°C (Caswell, 1978). The temperature of ground water in the background water-quality samples within the study area ranges from 7.0°C to 12.0°C, with a mean of 9.7°C. The mean ground-water temperature in wells throughout southwestern and south-central Maine is 8.9°C.

Table 8.--Background water quality in sand and gravel aquifers in southwestern and south-central Maine[1].
[All values in milligrams per liter (mg/L) except as noted; us/cm, microsiemens per centimeter at 25° Celsius]

	Temperature (°C)	Conductivity (us/cm)	pH	Alkalinity, as $CaCO_3$	Chloride, dis solved	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	60	60	59	56	59	58	59	60	60	60	60	60	60	59	35
Minimum	6.5	17	5.3	4.0	0.5	0.01	3.0	1.3	0.4	1.2	0.2	4	.02	.005	1.0
Maximum	15.0	234	8.6	97.0	15.0	8.00	18.0	13.0	4.8	33.0	10.0	109	10.00	1.500	30.0
Median	9.0	70	6.6	15.0	3.0	0.06	7.0	4.6	1.5	7.4	1.3	24	.07	.090	1.0
Mean	8.9	81	NA[2]	21.6	4.0	0.49	7.4	5.0	1.8	9.2	1.9	31	.54	.217	4.5
Standard Deviation	1.5	47	NA[2]	19.0	3.4	1.29	3.7	2.6	1.0	7.0	1.8	23	1.72	.321	6.6

1 Tolman and others, 1983; Tepper and others, 1985; Williams and others, 1987; Adamik and others, 1987.

2 Not Analyzed

Specific Conductance (Conductivity)

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

Although there are no drinking-water standards set for specific conductance, the Maine Department of Human Services (MDHS) (1983) has recommended a maximum concentration limit of 500 milligrams per liter (mg/L) of dissolved solids in drinking water. Specific conductance can be used to estimate dissolved-solids concentrations that were not measured directly. The concentration of dissolved solids, in mg/L, can be estimated by multiplying the conductivity value, in microsiemens per centimeter at 25° Celsius (μs/cm at 25°C), by a factor dependent on water chemistry, usually from 0.55 to 0.75 (Hem, 1985).

Specific conductance of the background water-quality samples within the study area range from 22 to 150 μs/cm at 25 °C, with a mean of 58 μs/cm. Adjusting the values using the factors given by Hem (here using the lower estimate of 0.55), a range of 12.1 to 82.5 mg/L and mean of 31.9 mg/L is estimated for dissolved solid concentrations, indicating that dissolved-solid concentrations in the study area are well below the recommended maximum level. Dissolved solids derived from specific conductance values from southwestern and south-central Maine range from 9.3 to 128.7 mg/L, with a mean of 44.6 mg/L. Using a conversion factor of 0.75 suggested by Hem to determine dissolved-solid concentrations, results of values are still well below the 500 mg/L limit in all study areas.

pH

The pH of water is a measure of hydrogen-ion activity (concentration). The pH scale ranges from 0 to 14; each unit increase in the scale represents a tenfold decrease in hydrogen-ion activity. A pH of 7 is considered neutral, less than 7 is acidic, and greater than 7 is alkaline. The primary control on pH in ground water involves interaction of soil and rocks with gaseous carbon dioxide, bicarbonate, and carbonate ions. The pH in the background water-quality samples within the study area ranges from 5.7 to 8.5, with a median of 6.7. The pH from southwestern and south-central Maine ranges from 5.3 to 8.6, with a median of 6.6. The U.S. Environmental Protection Agency (1979) has set a minimum pH drinking-water standard of 6.5 and a maximum of 8.5.

Alkalinity

Alkalinity is a measure of the capacity of a solution to resist a change in pH as an acid is added. The alkalinity is a measure of the concentrations of carbonate (CO^{-2}). bicarbonate (HCO_3^-), and (OH^-). In groundwater within the pH range found in the study area, the bicarbonate ion is the dominant anionic species. Alkalinity is reported in table 7 in terms of an equivalent quantity of calcium carbonate ($CaCO_3$). The alkalinity concentrations within the study area range from 5.4 to 78 mg/L, with a mean of 23.7 mg/L. The alkalinity concentrations in the wells throughout southwestern and south-central Maine range from 4.0 to 97 mg/L, with a mean of 21.6 mg/L.

Chloride

Because chloride is a highly mobile ion and is not readily sorbed, it can be used to trace contamination from road-salting operations, salt-storage piles, landfill, and septic tanks. Chloride concentrations in the background water-quality samples within the study area range from 0.5 to 5.8 mg/L, with a mean concentration of 2.2 mg/L. Chloride concentrations in the wells throughout southwestern and south-central Maine range from less than 0.5 to 15 mg/L, with a mean of 4.0 mg/L. These concentrations are all below the MDHS (1983) drinking-water standard of 250 mg/L.

Nitrate Plus Nitrite

Nitrogenous compounds 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 absorbed by soil, it functions as a good indicator of contamination from septic systems and waste-disposal sites. Nitrate can be converted to nitrite in the stomach of an infant; this may lead to the onset of methemoglobinemia, a potentially lethal disease (National Research Council, 1977). Because of this, the Maine Department of Human Service (1983) has established a limit of 10 mg/L nitrate-nitrogen (NO_3-N) in drinking water. Nitrate also is potentially lethal to cattle in similar doses. Nitrate concentrations in the background water-quality samples within the study area range from less than 0.01 to 0.51 mg/L, with a mean of 0.12 mg/L. The values in southwestern and south-central Maine range from less than 0.01 to 8.0 mg/L, with a mean of 0.49 mg/L.

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 containing only a few tenths of a milligram per liter of H_2S. The MDHS (1983) has recommended an upper limit for sulfate of 250 mg/L in drinking water; at levels above this, sulfate can have a laxative effect. Sulfate concentrations in the background water-quality samples within the study area range from less than 5.0 to 10.0 mg/L, with a mean of 6.6 mg/L. The mean is assumed because more than half the measured values are less than 5.0 mg/L--a value below detection limits. Sulfate concentrations in southwestern and south-central Maine have the same range, from less than 3.0 to 18.0 mg/L, with a mean of 7.4 mg/L.

Sodium and Potassium

Sodium and potassium are among the major cations in ground water in Maine. The MDHS (1983) has not set maximum limits for potassium in drinking-water. However, for sodium, a drinking water standard of 20 mg/L has been set 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 within the study area range from 2.2 to 20.0 mg/L, with a mean of 6.0 mg/L. Concentrations of potassium in the study area range from 0.3 to 3.4 mg/L, with a mean of 1.1 mg/L. Potassium concentrations in southwestern and south-central Maine range from 0.4 to 4.8 mg/L, with a mean of 1.8 mg/L, whereas sodium concentrations in southwestern and south-central Maine range from 1.3 to 13 mg/L, with a mean of 5.0 mg/L.

Calcium, Magnesium, and Hardness

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

Concentrations of calcium, the principal cation in the background water-quality samples, range from 0.2 to 22.0 mg/L in the study-area wells, and from 1.2 to 33 mg/L in the 60 wells in southwestern and south-central Maine. Mean calcium concentrations are lower within the study area (5.5 mg/L) than in the entire southwestern and south-central Maine area (9.2 mg/L). Magnesium concentrations are lower in the study area wells (0.8 to 4.5 mg/L; mean of 1.3 mg/L) than in all of southwestern and south-central Maine (0.2 to 10 mg/L; mean of 1.9 mg/L).

Hardness, a property associated with effects observed in the use of soap or with the encrustations left by some types of water when they are heated (Hem, 1985), is caused by divalent metallic cations, principally calcium and magnesium. Other divalent cations, including strontium, iron, and manganese, can also 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 was calculated by Standard Method 309a (American Public Health Association, 1976) and is expressed in table 7 in terms of an equivalent concentration of calcium carbonate in milligrams per liter. Water is considered soft if it contains 0 to 60 mg/L of hardness, moderately hard if it contains more than 60 to 120 mg/L, hard if it contains more than 120 to 180 mg/L, and very hard if it contains more than 180 mg/L (Hem, 1985). Ground water in the background water-quality samples within the study area, with a range of 0.97 to 63.0 mg/L is considered soft. Hardness concentrations in the entire southwestern and south-central Maine area are higher than those in the study area; the mean hardness concentration in southwestern and south-central Maine is 31 mg/L, which is considered soft.

Iron and Manganese

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

The mean iron concentration in the background water-quality samples within the study area is 0.47 mg/L, which is above the MDHS (1983) recommended limit of 0.3 mg/L for drinking water. Water from six wells in the area has iron concentrations exceeding this limit. However, water from the entire southwestern and south-central Maine area has a mean iron concentration of 0.54 mg/L, which is more than 1 1/2 times the recommended limit. The mean concentration for manganese in the study area is 0.07 mg/L; in southwestern and south-central Maine it is 0.22 mg/L. Both of these values exceed the maximum limit of 0.05 mg/L recommended for drinking water by the MDHS (1983).

Filtration units can be installed by individual well owners to help remove objectionable levels of iron and manganese. Treatment to remove iron and manganese from public-water supplies obtained from wells that tap sand and gravel aquifers might be necessary in some localities in the study area.

Total Organic Carbon

Total organic carbon (TOC) is a bulk indicator of all organic chemicals present in water. Some of these chemicals are highly toxic, although the TOC-measurement technique does not distinguish between toxic and nontoxic organic species. Natural organic species derived from soils can cause anomalously high concentrations. The TOC concentrations in the background water-quality samples within the study area range from less than 1 to 83 mg/L; over the entire southwestern and south-central Maine area, TOC values range from less than 1 to 30 mg/L. The mean TOC level in southwestern and south-central Maine is 4.5 mg/L. Most of the values from the study area are below detection limit, with an assumed mean value of 6.8 mg/L. These means are assumed because more than half of the measured values are below the detection limit (1.0 mg/L).

Characteristics of Sites of Potential Ground-Water Contamination

Potential sites of ground-water contamination in sand and gravel aquifers within the study area have been identified on the maps (plates 1-5). These sites include solid-waste facilities, salt-storage lots, and sewage and industrial waste lagoons. Ground-water contamination from many of the sites shown on the maps has been documented by the DEP. However, no domestic or municipal wells are known to have been affected by these activities. Many other potential contamination nonpoint sources, such as agricultural activities, and some point sources, including septic systems, roads that are salted in the winter, and leaking underground gasoline tanks are not shown on these plates.

SUMMARY

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

Although the study area includes 1715 mi^2, areas mapped as significant aquifers cover only 238 mi^2 (plates 1-5). Yields exceeding 50 gal/min are estimated to be available in only 4 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 as a source of recharge. The largest reported well yield in the sand and gravel deposits is 350 gal/min from the Passamaquoddy Water District well, adjacent to the Pennamaquan River.

The water table within the significant sand and gravel aquifers within 25 feet of the land surface. Based on well-record data, the greatest known depth to bedrock is 234 feet in Columbia.

Based on 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 deposits, outwash, and glaciomarine deltaic deposits: these deposits may be overlain by and sometimes interbedded with marine clay, which may be overlain by sand and gravel deposits of mixed origin. The thickness of the deposits and stratigraphic units differs 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 pH ranges from 5.7 to 8.5, calcium and sodium are the most abundant cations, bicarbonate is the dominant anion, and the water is soft. The regional water quality is suitable for drinking and most other uses, although in some localities, concentrations of iron and manganese are at levels sufficient to limit water use without treatment.

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

REFERENCES

Adamik, J. T., Tolman, A. L., Williams, J. S., and Weddle, T. K., 1987, Hydrogeology and water quality of significant sand and gravel aquifers in parts of Franklin, Kennebec, Knox, Lincoln, Penobscot, Somerset, and Waldo Counties, Maine; significant sand and gravel aquifer maps 18, 30, and 31: Maine Geological Survey, Open-File Report 87-24 a-d, 94 p., 3 pl., scale 1:50,000.

American Public Health Association, American Water Works Association, Water Pollution Control Federation, 1976, Standard methods for the examination of water and wastewater, 15th ed.: Washington, D. C., American Public Health Association, 1193 p.

Anderson, W. A., Kelley, J. T., Thompson, W. B., Borns, H. W., Jr., Sanger, D., Smith, D., Tyler, D. A., Anderson, R. S., Bridges, A., Crossen, K., Ladd, J., Andersen, B., and Lee, F., 1984, Crustal Warping in coastal Maine: Geology, v. 12, p. 677-680.

Bloom, A. L., 1960, Late Pleistocene changes of sea level in southwestern Maine: Augusta, Maine, Department Economic Development, 143 p.

Borns, H. W., Jr., 1974a, Reconnaissance surficial geology of the Bar Harbor quadrangle, Maine: Maine Geological Survey Open-File Map 74-1, scale 1:62,500.

_____1974b, Reconnaissance surficial geology of the Cutler quadrangle, Maine: Maine Geological Survey Open-File Map 74-2, scale 1:24,000.

_____1974c, Reconnaissance surficial geology of the Devils Head quadrangle, Maine: Maine Geological Survey Open-File Map 74-3, scale 1:24,000.

_____1974d, Reconnaissance surficial geology of the Machias quadrangle, Maine: Maine Geological Survey Open-File Map 74-4, scale 1:24,000.

_____1974e, Reconnaissance surficial geology of the Machias Bay quadrangle, Maine: Maine Geological Survey Open-File Map 74-5, scale 1:24,000.

_____1974f, Reconnaissance surficial geology of the Moose River quadrangle, Maine: Maine Geological Survey Open-File Map 74-6, scale 1:24,000.

_____1974g, Reconnaissance surficial geology of the Mount Desert quadrangle, Maine: Maine Geological Survey Open-File Map 74-7, scale 1:62,500.

_____1974h, Reconnaissance surficial geology of the Petit Manan quadrangle, Maine: Maine Geological Survey Open-File Map 74-8, scale 1:24,000.

_____1974i, Reconnaissance surficial geology of the Red Beach quadrangle, Maine: Maine Geological Survey Open-File Map 74-9, scale 1:24,000.

_____1974j, Reconnaissance surficial geology of the Robbinston quadrangle, Maine: Maine Geological Survey Open-File Map 74-10, scale 1:24,000.

_____1975a, Reconnaissance surficial geology of the Columbia Falls quadrangle, Maine: Maine Geological Survey Open-File Map 75-1, scale 1:62,500.

_____1975b, Reconnaissance surficial geology of the Eastport quadrangle, Maine: Maine Geological Survey Open-File Map 75-2, scale 1:62,500.

_____1975c, Reconnaissance surficial geology of the Roque Bluffs quadrangle, Maine: Maine Geological Survey Open-File Map 75-5, scale 1:24,000.

Borns, H. W., Jr. and Andersen, B., 1982a, Reconnaissance surficial geology of the Calais quadrangle, Maine: Maine Geological Survey Open-File Map 82-1, scale 1:62,500.

_____1982b, Reconnaissance surficial geology of the Cherryfield quadrangle, Maine: Maine Geological Survey Open-File Map 82-2, scale 1:62,500.

_____1982c, Reconnaissance surficial geology of the Ellsworth quadrangle, Maine: Maine Geological Survey Open-File Map 82-3, scale 1:62,500.

_____1982d, Reconnaissance surficial geology of the Gardner Lake quadrangle, Maine: Maine Geological Survey Open-File Map 82-4, scale 1:62,500.

_____1982e, Reconnaissance surficial geology of the Tunk Lake quadrangle, Maine: Maine Geological Survey Open-File Map 82-5, scale 1:62,500.

Bridge, J. E., and Fairchild, D. F., 1981, Northeast damage report of the long range transport and deposition of air pollutants: Boston, Mass., Northeast Regional Task Force on Atmospheric Deposition, 72 p.

Caswell, W. B., 1978, Ground water handbook for the State of Maine: Maine Geological Survey, 145 p.

Caswell, Eichler and Hill, Inc., 1985, Evaluation of Pennamaquan River gravel aquifer in Pembroke, Maine. Prepared for Passamaquoddy Water District.

Federal Interagency Work Group, 1977, National handbook of recommended methods for water-data acquisition: U.S. Geological Survey, Office of Water Data coordination, 192 p.

Fetter, C. W., Jr., 1980, Applied hydrogeology: Columbus, Ohio, Charles E. Merrill Publishing Co., 488 p.

Freeze, R. A., and Cherry, J. A., 1979, Groundwater: Englewood Cliffs, New Jersey, Prentice-Hall, 604 p.

Folk, R. L., 1974, Petrology of sedimentary rocks: Austin, Texas, Hemphill Publishing Co., 182 p.

Gates, Olcott, 1961, Geologic map of the Cutler and Moose River quadrangles, Washington County, Maine: Maine Geological Survey Open-File Map 61-1, scale 1:24,000.

_____1975, Geologic map and cross sections of the Eastport quadrangle, Maine: Maine Geological Survey, GM-3, 19 p., scale 1:48,000.

_____1978, Reconnaissance bedrock geology of the Gardiner Lake quadrangle, Maine: Maine Geological Survey Open-File Map 78-3, scale 1:62,500.

_____1981, Bedrock geology of the Machias, Columbia Falls, and Great Wass Island 15' quadrangles, Maine: Maine Geological Survey Open-File Map 81-11, scale 1:62,500.

Gilman, R. A., 1961, Reconnaissance bedrock geology of the Cherryfield 15' quadrangle, Maine: Maine Geological Survey Open-File Map 61-2.

Griffin, J. R., 1976, Reconnaissance bedrock geology of the Great Pond 15' quadrangle, Maine: Maine Geological Survey Open-File Map 76-22.

Haeni, F. P., 1986, Application of seismic-refraction techniques to hydrologic studies: U.S. Geological Survey Open-File Report 84-746.

Heath, R. C., 1984, Basic ground-water hydrology: U.S. Geological Survey Water-Supply Paper 2220, 84 p.

Hem, J. D., 1985, Study and interpretation of the chemical characteristics of natural water (3d ed.): U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Holland, W. R., 1981a, Reconnaissance surficial geology of the Great Pond quadrangle, Maine: Maine Geological Survey Open-File Map 86-62, scale 1:62,500.

_____1981b, Reconnaissance surficial geology of the Lead Mountain quadrangle, Maine: Maine Geological Survey Open-File Map 86-63, scale 1:62,500.

_____1986, Reconnaissance surficial geology of the Tug Mountain quadrangle, Maine: Maine Geological Survey Open-File Map 86-24, scale 1:62,500.

Holland, W. R., and Borns, H. W., 1974, Reconnaissance surficial geology of the Wesley quadrangle, Maine: Maine Geological Survey Open-File Map 86-26, scale 1:62,500.

Ludman, A., 1985, Pre-Silurian Rocks of eastern and southeastern Maine: Maine Geological Survey Open-File Report 85-78, 29p., 2 pl, scale 1:62,500.

Maine Department of Human Services, 1983, Rules relating to drinking water: Augusta, Maine, 47 p.

Masch, F. D., and Denny, K. J., 1966, Grain size distribution and its effect on the permeability of unconsolidated sands: Water Resources Research, v.2, no. 4, p. 665

Matthess, George, 1982, The properties of groundwater: New York, John Wiley and Sons, 406 p.

Mazzaferro, D.L., 1980, Ground water availability and water quality in Farmington, Connecticut; U.S. Geological Survey Water-Resources Investigations Open-File Report 80-751, 57 p.

Mooney, H. M., 1980, Handbook of engineering geophysics, volume 1: seismic: Minneapolis, Minn., Bison Instruments, Inc., 193 p.

Morrissey, D. J., 1983, Hydrology of the Little Androscoggin River Valley Aquifer, Oxford County, Maine: U.S. Geological Survey Water-Resources Investigations Report 83-4018, 79 p., 8 pl.

National Climatic Center, 1985, Climatological data for New England, January-November 1985: National Oceanic and Atmospheric Administration v. 97, no. 1-12.

National Research Council, 1977, Drinking water and health: National Academy Press, Washington, D. C., 939 p.

_____1982, Drinking water and health, volume 4: Washington, D. C., National Academy Press, 299 p.

Neil, C. D., Williams, J. S., and Weddle, T. K., 1987, Second Annual Report-Pesticides in Ground Water Study: Maine Geological Survey Open-file Report No. 87-29, 26 p.

Osberg, P. H., Hussey, A. M., II, and Boone, G. M., 1985, Bedrock geologic map of Maine: Augusta, Maine, Maine Geological Survey, scale 1:500,000.

Pettijohn, F. J., 1975, Sedimentary rocks: New York, N. Y.: Harper & Row, 628 p.

Prescott, G. C., Jr., 1973, Southern Washington County area: U.S. Geological Survey Open-File Report, Maine Basic Data Report No. 8, 40 p.

_____1974a, Ground water favorability and surficial geology of the Cherryfield-Jonesboro area, Maine: U.S. Geological Survey Hydrologic Investigations Atlas 529, 1 pl, scale 1:62,500.

_____1974b, Ground water favorability and surficial geology of the Machias-Lubec area, Washington County, Maine: U.S. Geological Survey Hydrologic Investigations Atlas 535 1 pl, scale 1:62,500.

Scott, J. H., Benton, L. T., and Burdich, R. G., 1972, Computer analysis of seismic refraction data: U.S. Bureau of Mines Report of Investigations 7995, 95 p.

Smith, G. W., 1985, Chronology of late Wisconsinan deglaciation of coastal Maine, in Borns, H W., Jr., and others, eds., Late Pleistocene history of northern New England and adjacent Quebec: Geological Society of America Special Paper 197, p. 29-44.

Stuiver, M., and Borns, H. W., Jr., 1975, Late Quateruary marine invasion in Maine: its chronology and associated crustal movement: Geological Society of America Annual Bulletin, v. 86, p. 99-104.

Tepper, D. H., 1980, Hydrogeologic setting and geochemistry of residual periglacial pleistocene seawater in wells in Maine: Orono, Maine., University of Maine, unpublished M.S. thesis, 126 p.

Tepper, D. H., Williams, J. S., Tolman, A. L., and Prescott, G. C., Jr., 1985, Hydrogeology and water quality of significant sand and gravel aquifers in parts of Androscoggin, Cumberland, Franklin, Kennebec, Lincoln, Oxford, Sagadahoc, and Somerset Counties, Maine: significant sand and gravel aquifer maps 10, 11, 16, 17, and 32: Maine Geological Survey Open-File Report 85-82a-f, 121 p., 4 pl., scale 1:50,000.

Thompson, W. B., 1977a, Reconnaissance surficial geology of the Cross Island quadrangle, Maine: Maine Geological Survey Open-File Map 77-27, scale 1:24,000.

______1977b, Reconnaissance surficial geology of the Harrington quadrangle, Maine: Maine Geological Survey Open-File Map 77-30, scale 1:24,000.

______1977c, Reconnaissance surficial geology of the Jonesport quadrangle, Maine: Maine Geological Survey Open-File Map 77-31, scale 1:24,000.

______1979, Surficial geological handbook for coastal Maine: Maine Geological Survey, 69 p.

Thompson, W. B. and Borns, H. W., Jr., eds., 1985; Surficial geologic map of Maine: Augusta, Maine, Maine Geological Survey, scale 1:500,000.

Thompson, W. B., Crossen, K. J., Borns, H. W., Jr., and Anderson, B. G., 1983, Glacial-marine deltas and late Pleistocene-Holocene crustal movements in southern Maine. in Thompson, W. B., and Kelley, J. T., eds., New England seismotectonic study activities in Maine during fiscal year 1982: Maine Geological Survey Report to U.S. Nuclear Regulatory Commission, p. 153-171.

Todd, D. K., 1980, Groundwater hydrology (2d ed.): New York, John Wiley, 535 p.

Tolman, A. L.; and Lanctot, E. M., 1981a, Sand and gravel aquifer map number 24, Washington County, Maine: Maine Geological Survey Open-File Map 81-56, scale 1:50,000.

______1981b, Sand and gravel aquifer map number 25, Washington County, Maine: Maine Geological Survey Open-File Map 81-57, scale 1:50,000.

_____1981c, Sand and gravel aquifer map number 26, Washington and Hancock Counties, Maine: Maine Geological Survey Open-File Map 81-58, scale 1:50,000.

_____1981d, Sand and gravel aquifer map number 27, Hancock and Penobscot Counties, Maine: Maine Geological Survey Open-File Map 81-59, scale 1:50,000.

_____1981e, Sand and gravel aquifer map number 45, Washington County, Maine: Maine Geological Survey Open-File Map 81-75, scale 1:50,000.

Tolman, A. L., Tepper, D. H., Prescott, G. C. Jr., and Gammon, S. O., 1983, Hydrogeology of significant sand and gravel aquifers, northern York and southern Cumberland Counties, Maine: Maine Geological Survey Open-File Report 83-1, 4 pl., scale 1:125,000.

U.S. Environmental Protection Agency (USEPA), 1979, National secondary drinking water regulations: Washington, D.C., office of Drinking Water EPA-570/9-76-000, 37 p.

Westerman, D. S., 1981, Reconnaissance bedrock geologic map of the Wesley quadrangle, Maine: Maine Geological Survey Open-File Map 81-90, scale 1:62,500.

Williams, J. S., Tepper, D. H., Tolman, A. L., Thompson, W. B., 1987, Hydrogeology and water quality of significant sand and gravel aquifers in parts of Androscoggin, Cumberland, Oxford, and York Counties, Maine: Sand and Gravel Aquifer Maps 12, 13, 14, and 15: Maine Geological Survey Open-File Report 87-1a, 121 p., 4 pl., scale 1:50,000.

Willaims, J. S., Neil, C. D., and Weddle, T. K., 1987, The influence of agricultural practices on ground water quality in Maine, in Proceedings of the focus on Eastern Regional ground water issues: a conference: National Water Well Association, Burlington, Vermont, July 14-16, 1987, p. 329-341.

Zohdy, A. A. R., Eaton, G. P., and Mabey, D. R., 1974, Application of surface geophysics to ground-water investigations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 2, chap. D-1, 116 p.

Table 9.--Observation-well and test-boring logs, Map 24 Area [1/].

Identification number: composed of three elements:

Code TB (Test Boring abandoned after data collection) or OW (Observation Well installed for collection of water-level and water-quality data); Significant Sand and Gravel Aquifer Map Number; 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 plate 1.

Site description: A brief site description is given.

Description of materials: Logs of observation well 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 boulder to very fine sand. "Poorly sorted" indicates approximately equal amounts, by weight, of all grain sizes.

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

Marine clay--Sorted, sometimes stratified sediment varying in size from clay to silt, deposited during the marine transgression during deglaciation, approximately 13,000 years before present. Color is typically light brown or blue-gray.

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 work "refusal". If it is fairly certain that the bedrock surface was encountered, the word "bedrock" is shown in parentheses after the word "refusal".

[1/] See tables 1, 2, and 3 for information on grain-size analyses and estimated transmissivity and well yield.

Table 9.--Observation-well log, Map 24 Area
[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 24-1. Latitude: 44°49'59" N., Longitude: 67°01'24" W.
Located in Lubec on an unimproved road, 0.3 mile southeast of the Lubec Airport. Depth to water is approximately 9 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Sand, brown; silt, and clay with cobble	0 - 2	2
Sand, very fine to very coarse; with some silt; granules; and pebbles	2 - 7	5
Sand, very coarse, with granules and pebbles	7 - 13	6
Till	13 - 14	1
Refusal (bedrock)	14	--

OW 24-1 is screened from 9 to 14 feet below land surface with a 0.006-inch slotted PVC screen.

Table 10.--Observation-well and test-boring logs, Map 25 Area [1/].

Identification number: composed of three elements:

Code TB (Test Boring abandoned after data collection) or OW (Observation Well installed for collection of water-level and water quality data); Significant Sand and Gravel Aquifer Map Number; 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 plate 2.

Site description: A brief site description is given.

Description of materials: Logs of observation well 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 boulder to very fine sand. "Poorly sorted" indicates approximately equal amounts, by weight, of all grain sizes.

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

Marine clay--Sorted, sometimes stratified sediment varying in size from clay to silt, deposited during the marine transgression during deglaciation, approximately 13,000 years before present. Color is typically light brown or blue-gray.

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 work "refusal". If it is fairly certain that the bedrock surface was encountered, the word "bedrock" is shown in parentheses after the word "refusal".

[1/] See tables 1, 2, and 3 for information on grain-size analyses and estimated transmissivity and well yield.

Table 10.--Observation well and test boring logs, Map 25 Area
[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 25-1. Latitude: 44°37'54" N., Longitude: 67°38'44" W.
Located in Jonesborough, in a gravel pit off woods road 80-25-0, 1.0 mile south of Carr Hill. Approximately 20 vertical feet of sand and gravel have been removed. Depth to water is approximately 18 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Granules; pebbles; and cobbles with some sand, fine to very coarse	0 - 26	26
Pebbles, angular and subangular; and granules with sand, very fine to very coarse, some silt	26 - 48	22
Subangular and subrounded granules and pebbles with sand, medium to very coarse	48 - 80	32
Till	80 - 84	4
Refusal (fractured rock)	84	--

OW 25-1 is screened from 29.5 to 34.5 feet below land surface with a 0.006-inch slotted PVC screen.

Table 10.--Observation-well and test-boring logs, Map 25 Area
(Continued)
[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 25-2. Latitude: 44°49'23" N., Longitude: 67°25'12" W.
Located in East Machias, in a gravel pit off of State Route 191, 4.4 miles north-northwest of Jacksonville. Water is approximately 21 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Sand, very fine to coarse, with some silt and clay	0 - 2	2
Sand, very fine to coarse, interbedded with some silt	2 - 37	35
Brown silt and clay interbedded with brown sand, very fine to coarse	37 - 42	5
Sand, fine to coarse, brown	42 - 48	6
Fractured rock (granite)	48 - 52	4
Refusal (bedrock)	52	--

OW 25-2 is screened from 29.4 to 34.4 feet below land surface with a 0.006-inch slotted PVC screen.

Table 10.--Observation-well and test-boring logs, Map 25 Area (Continued)

[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 25-3. Latitude: 44°41'14" N., Longitude: 67°29'18" W.

Located in Whitneyville in a gravel pit off U.S. Route 1, 2.35 miles southwest of Machias. Approximately 20 vertical feet of sand and gravel have been removed from this area. Water is approximately 3.0 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Cobbles; pebbles; granules; sand; very fine to very coarse; and silt	0 - 7	7
Sand, very fine to coarse, with some granules; pebbles; and silt	7 - 27	20
Sand, fine to very coarse	27 - 38	11
Compact layer of sand, very fine to very coarse, with angular rock fragments and silt	38 - 39	1
Sand, fine to very coarse	39 - 45	6
Till	45 - 46	1
Refusal (bedrock)	46	--

OW 25-3 is screened from 16.4 to 21.4 feet below land surface with a 0.008-inch slotted PVC screen.

Table 10.--Observation-well and test-boring logs, Map 25 Area (Continued)

[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 25-4. Latitude: 44°37'40" N., Longitude: 67°37'11" W.
Located in Jonesboro, on the northern perimeter of a blueberry field 1.85 miles southwest of the junction of U.S. Route 1 and State Route 187. Water is approximately 5 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Sand, medium to very coarse, brown	0 - 14	14
Clay, blue-grey	14 - 45	31
Pebbles; granules; sand, very fine to very coarse; and silt	45 - 52	7
Till	52 - 70	18
Refusal (bedrock)	70	--

OW 25-4 is screened from 8.4 to 13.4 feet below land surface with a 0.010-inch slotted PVC screen.

Table 10.--Observation-well and test-boring logs, Map 25 Area (Continued)

[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 25-5. Latitude: 44°52'01" N., Longitude: 67°44'29" W.
Located in T25MD off a woods road in the Sam Hill Barrens area, 2.6 miles north of Wigwam Rapids on the Machias River. Water is approximately 12 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Sand, coarse to very coarse, with granules and pebbles, brown	0 - 10	10
Sand, very fine to very coarse, some silt; granules; pebbles; stratified; and brown	10 - 33	23
Sand, interbedded very fine to coarse; grey	33 - 43	10
Sand, very fine to medium, interbedded with silt and clay, blue-grey	43 - 63	20
Clay, blue-grey	63 - 79	16
Till	79 - 85	6
Refusal	85	--

OW 25-5 screened from 29.9 to 34.9 feet below land surface with a 0.008-inch slotted PVC screen.

Table 10.--Observation-well and test-boring logs, Map 25 Area (Continued)

[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

TB 25-1. Latitude: 44°51'16" N., Longitude: 67°40'47" W.

Located in Centerville in field adjacent to blueberry barren, 2.0 miles northwest of Jonesboro Station. Water is approximately 9 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Sand, very fine to very coarse, with some granules and pebbles, brown	0 - 5	5
Silt, and clay, brown	5 - 15	10
Silt; sand, very fine to very coarse; granules; and pebbles, and minor amounts of silt	15 - 30	15
Sand, medium to very coarse; with granules; pebbles; and minor amounts of silt	30 - 38	8
Till	38 - 44	6
Refusal	44	--

A well was not installed. The sediments beneath the brown silt and clay were not saturated. The thinness and grade of the saturated sediments did not warrant well installation.

Table 10.--Observation-well and test-boring logs, Map 25 Area (Continued)

[--, an aquifer "thickness" value is not relevant for the "end of boring " depths.]

TB 25-2. Latitude: 44°49'52" N., Longitude: 67°33'29" W.
Located in Northfield on the northern edge of a field, along an unimproved road, 0.3 mile south of Bog Lake. Water is approximately 15 feet below land surface. (perched)

Material	Depth (feet)	Thickness (feet)
Silt; sand, very fine to very coarse; interbedded with granules and pebbles; brown	0 - 27	27
Interbedded clay, silt, and very fine sand, grey	27 - 34	7
Very fine sand to silt with some clay, brown	34 - 42	8
Sand, fine to medium, compact	42 - 73	31
Sand, very fine to very coarse, with angular granules and pebbles	73 - 81	8
End of boring	81	--

A well was installed from 45 to 50 feet below land surface with a 0.006-inch slotted PVC screen. Subsequent visits revealed a dry well. Apparently,the saturated material is perched on the sand, silt, and clay layers at 27-34 feet below land surface. Sediments are unsaturated below this layer.

Table 10.--Observation-well and test-boring logs, Map 25 Area (Continued)

[--, an aquifer "thickness" value is not relevant for the "end of boring " depths.]

TB 25-3. Latitude: 44°41'16" N., Longitude: 67°40'47" W.
Located in Centerville, in a field, 0.5 mile southeast of Centerville (proper). Boring was dry.

Material	Depth (feet)	Thickness (feet)
Brown silt	0 - 11	11
Silt and sand, very fine to fine	11 - 17	6
Very fine sand	17 - 30	13
Sand, very fine to very coarse, with granules and pebbles	30 - 62	32
End of boring	62	--

No attempt was made to install a observation well.

Table 11.--Observation-well and test-boring logs, Map 26, Area [1].

Identification number: composed of three elements:

Code TB (Test Boring abandoned after data collection) or OW (Observation Well installed for collection of water-level and water quality data); Significant Sand and Gravel Aquifer Map Number; 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 plate 3.

Site description: A brief site description is given.

Description of materials: Logs of observation well 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 boulder to very fine sand. "Poorly sorted" indicates approximately equal amounts, by weight, of all grain sizes.

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

Marine clay--Sorted, sometimes stratified sediment varying in size from clay to silt, deposited during the marine transgression during deglaciation, approximately 13,000 years before present. Color is typically light brown or blue-gray.

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 work "refusal". If it is fairly certain that the bedrock surface was encountered, the word "bedrock" is shown in parentheses after the word "refusal".

1/ See tables 1, 2, and 3 for information on grain-size analyses and estimated transmissivity and well yield.

Table 11.--Observation-well and test-boring logs, Map 26 Area (Continued)

[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 26-1. Latitude: 44°40'41" N., Longitude: 67°51'52" W.
Located in Columbia, on the blueberry barrens 4.9 miles west southwest of Epping. Water is approximately 18 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Sand, medium to very coarse; with granules; pebbles; and cobbles	0 - 6	6
Sand, coarse to very coarse; with granules	6 - 10	4
Sand, medium to very coarse; with granules; pebbles; and cobbles	10 - 11	1
Sand, coarse, with granules and pebbles	11 - 16	5
Medium sand	16 - 21	5
Sand, medium to very coarse; interbedded with layers of granules and pebbles	21 - 24	3
Till	24 - 45	21
Refusal (boulder?)	45	--

OW 26-1 is screened from 20.2 to 25.2 feet below land surface with a 0.006-inch slotted PVC screen.

Table 11.--Observation-well and test-boring logs, Map 26 Area (Continued)

[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 26-2. Latitude: 44°40'25" N., Longitude: 67°51'15" W.
Located in Columbia, on the blueberry barrens, 4.4 miles west-southwest of Epping. Water is approximately 16 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Humus with sand, granules, and pebbles, brown	0 - 3	3
Sand, very fine to very coarse; with granules; pebbles; and some silt	3 - 26	23
Sand, very fine to fine	26 - 30	4
Till	30 - 35	5
Refusal (boulder?)	35	--

OW 26-2 is screened from 22.4 to 27.4 feet below land surface with a 0.008-inch slotted PVC screen.

Table 11.--Observation-well and test-boring logs, Map 26 Area (Continued)

[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 26-3. Latitude: 44°46'44" N., Longitude: 68°04'40" W.
Located in T22MD, off a logging road, 3.45 miles south of the junction of State Route 9 and 193. Water is approximately 26 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Sand, medium to very coarse; with pebbles; granules; and humus	0 - 5	5
Sand, medium to very coarse; with pebbles and granules	5 - 40	35
Sand, very fine to very coarse, with some minor amounts of pebbles; granules; and silt	40 - 53	13
Sand, very fine to very coarse, with minor amounts of granules and silt	53 - 63	10
Clay, blue-grey, with some pebbles	63 - 71	8
Refusal (bedrock)	71	--

OW 26-3 is screened from 45.2 to 50.2 feet below land surface with a 0.006-inch slotted PVC screen.

Table 11.--Observation-well and test-boring logs, Map 26 Area (Continued)

[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 26-4. Latitude: 44°40'38" N., Longitude: 67°52'06" W.
Located in Columbia, 5.0 miles west-southwest of Epping. Water is approximately 27 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Sand, silt, and clay with pebbles and granules	0 - 2	2
Sand, very fine to very coarse; interbedded with granules; pebbles; and minor amounts of silt	2 - 68	66
Silt and sand, very fine to very coarse, interbedded	68 - 78	10
Clay, blue-grey interbedded with fine to very fine sand and silt	78 - 109	31
Till	109 - 112	3
Refusal (till?)	112	--

OW 26-4 is screened from 37 to 42 feet below land surface with a 0.006-inch slotted PVC screen.

Table 11.--Observation-well and test-boring logs, Map 26 Area (Continued)

[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 26-5. Latitude: 44°45'12" N., Longitude: 67°46'50" W.
Located in T19MD on blueberry barrens 200 feet west of Montegail Pond. Water is approximately 47 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Soil; sand, pebbles, and granules	0 - 5	5
Sand, fine to very coarse, with granules and pebbles	5 - 17	12
Sand, medium to very coarse, with granules and pebbles, and minor amounts of silt to fine sand	17 - 55	38
Sand, very fine to medium, with silt	55 - 73	18
Refusal (till)	73	--

OW 26-5 is screened from 60.6 to 65.6 feet below land surface with a 0.006-inch slotted PVC screen.

Table 11.--Observation-well and test-boring logs, Map 26 Area (Continued)

[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 26-6. Latitude: 44°40'38" N., Longitude: 67°51'55" W.
Located in Columbia, 4.8 miles west-southwest of Epping. Water is approximately 24 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Soil, sandy loam with granules and pebbles	0 - 2	2
Sand, medium to very coarse; interbedded with granules and pebbles; brown	2 - 30	28
Sand, very fine to very coarse; with some silt and clay, varies from brown to grey	30 - 36	6
Till	36 - 38	2
Refusal (bedrock)	38	--

OW 26-6 is screened from 31.8 to 36.8 feet below land surface with a 0.006-inch slotted PVC screen.

Table 11.--Observation-well and test-boring logs, Map 26 Area (Continued)

[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 26-7. Latitude: 44°45'44" N., Longitude: 68°01'48" W.
Located in Deblois, 5.3 miles south-southeast of the junction of State Routes 9 and 193. Water is approximately 32 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Soil, coarse to very coarse sand with granules and humus	0 - 5	5
Sand, coarse to very coarse; with pebbles and granules	5 - 10	5
Clay, blue-grey	10 - 40	30
Sand, very fine to very coarse; with minor amounts of pebbles; granules; silt; and clay	40 - 47	7
Till	47 - 52	5
Refusal	52	--

OW 26-7 is screened from 42.3 to 47.3 feet below land surface with a 0.006-inch slotted PVC screen.

Table 11.--Observation-well and test-boring logs, Map 26 Area
(Continued)
[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 26-8. Latitude: 44°50'10" N, Longitude: 68°04'43" W.
Located in Beddington, 0.6 mile northeast of the junction of State Route 9 and 193. Water is approximately 22 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Sand, medium to very coarse; with granules; pebbles; and cobbles; brown	0 - 2	2
Sand, very fine to very coarse; with minor amounts of pebbles; granules; and silt	2 - 36	34
Sand, very fine to very coarse; with pebbles; granules; and silt. Sediments are poorly sorted and compact	36 - 40	4
Sand, very fine to very coarse; with granules	40 - 48	8
Till	48 - 65	17
Refusal (till?)	65	--

OW 26-8 is screened from 30.3 to 35.3 feet below land surface with a 0.008-inch slotted PVC screen.

Table 11.--Observation-well and test-boring logs, Map 26 Area (Continued)

[--, an aquifer "thickness" value is not relevant for the "end of boring " depths.]

OW 26-9. Latitude: 44°52'27" N., Longitude: 67°52'01" W.
Located in T24MD, on a sand plain 750 feet north of Hadley Lakes. Water is approximately 6 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Sand, humus at surface; sand, coarse to very coarse; with granules and pebbles	0 - 2	2
Sand, coarse to very coarse, with granules	2 - 16	14
Sand, very fine to very coarse, with pebbles; granules; and minor amounts of silt	16 - 30	14
End of boring	30	--

OW 26-9 is screened from 24.7 to 29.7 feet below land surface with a 0.008-inch slotted PVC screen.

Table 11.--Observation-well and test-boring logs, Map 26 Area (Continued)

[--, an aquifer "thickness" value is not relevant for the "end of boring " depths.]

OW 26-10. Latitude: 44°52'27" N., Longitude: 67°52'01" W.
Located in T24MD, on a sand plain 750 feet north of Hadley Lakes. Water is approximately 16 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Soil; humus at surface; sand, coarse to very coarse; with granules and pebbles	0 - 2	2
Sand, coarse to very coarse, with granules	2 - 16	14
Sand, very fine to very coarse, with granules and minor amounts of silt	16 - 32	16
Sand, very fine to medium, brown-grey, interbedded and mixed with silt and clay, blue-grey	32 - 70	38
Clay and silt varying from brown to blue-grey	70 - 90	20
Sand, very fine to very coarse, with minor amounts of silt and granules varying from brown to blue-grey	90 - 120	30
End of boring	120	--

OW 26-10 is screened from 100.1 to 105.1 feet below land surface with a 0.008-inch slotted PVC screen.

Table 11.--Observation well and test boring logs, Map 26 Area (Continued)

[--, an aquifer "thickness" value is not relevant for the "end of boring " depths.]

OW 26-11. Latitude: 44°43'07" N., Longitude: 67°59'09" W.
Located in Deblois, on a blueberry barren 1500 feet south of the southern end of the runway of the Deblois Flight Strip. Water is approximately 16 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Humus	0 - 2	2
Sand, coarse to very coarse, with pebbles and granules	2 - 12	10
Sand, very fine to medium, interbedded with minor amounts of silt and clay, brown	12 - 48	36
Silt to very fine sand interbedded with clay, varies from brown to grey	48 - 58	10
Clay, blue-grey	58 - 117	59
End of boring	117	--

OW 26-11 is screened from 30.0 to 35.0 feet below land surface with a 0.006-inch slotted PVC screen.

Table 11.--Observation-well and test-boring logs, Map 26 Area (Continued)

[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 26-12. Latitude: 44°45'59" N., Longitude: 67°56'28" W.

Located in Deblois on a blueberry barren 0.5 mile east of Flynn Pond. Water is approximately 12 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Soil; humus layer at surface; sand, coarse to very coarse, with pebbles and granules	0 - 2	2
Sand, medium to very coarse, with pebbles and granules	2 - 24	22
Sand, very fine to very coarse; with pebbles; granules; and silt	24 - 34	10
Sand, medium to very coarse; with pebbles and granules; interbedded with clay to fine sand	34 - 44	10
Sand, very fine to coarse; brown, interbedded with silt and clay blue-grey to brown	44 - 67	23
Till	67 - 75	8
Refusal	75	--

OW 26-12 is screened from 27.2 to 32.2 feet below land surface with a 0.008-inch slotted PVC screen.

Table 11.--Observation-well and test-boring logs, Map 26 Area (Continued)

[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 26-13. Latitude: 44°42'58" N., Longitude: 67°54'36" W.
Located in T18MD, 100 feet north of East Pike Brook Pond. Depth to water is approximately 21 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Humus, silt, and medium sand	0 - 1	1
Sand, medium to very coarse; with granules; pebbles; and cobbles	1 - 7	6
Sand, medium to very coarse; brown with some granules; and pebbles	7 - 17	10
Sand, medium to very coarse; brown	17 - 30	13
Granules, pebbles, and cobbles	30 - 35	5
Refusal (boulder?)	35	--

OW 26-13 is screened from 25.2 to 30.2 feet below land surface with a 0.008-inch slotted PVC screen.

Table 11.--Observation-well and test-boring logs, Map 26 Area (Continued)

[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

TB 26-1. Latitude: 44°41'47" N., Longitude: 68°00'44" W.
Located in Deblois on a blueberry barren 3.0 miles south of the town center. Water is approximately 10 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Sand, fine to coarse, brown	0 - 12	12
Fine brown sand	12 - 19	7
Clay, blue-grey	19 - 91	72
Till	91 - 98	7
Refusal	98	--

A well was installed and screened from 12 to 17 feet below land surface with a 0.006-inch slotted PVC screen. Shortly after completion the site was vandalized and destroyed.

TB 26-2. Latitude: 44°44'30" N., Longitude: 67°54'53" W.
Located in T18MD 650 feet southwest of the mouth of Bog Stream. Boring was dry.

Material	Depth (feet)	Thickness (feet)
Humus	0 - 1	1
Sand, fine to very coarse; interbedded with layers of granules and pebbles.	1 - 53	52
Refusal (till)	53	--

No well was installed.

Table 11.--Observation-well and test-boring logs, Map 26 Area (Continued)

[--, An aquifer "Thickness" value is not relevant for the "End of Boring" depths.]

TB 26-3. Latitude: 44°46'40" N., Longitude: 67°55'55" W.

Located in T18MD, on a blueberry barren adjacent to the T24MD/T18MD town line in the east bank of the Colonel Brook. Hole was dry.

Material	Depth (feet)	Thickness (feet)
Soil; humus at surface; sand coarse to very coarse; with pebbles and granules	0 - 1	1
Sand, coarse to very coarse, with pebbles and granules	1 - 21	20
Sand, very fine to fine, inter-bedded with silt and clay; blue-grey	21 - 28	7
End of boring	28	--

A well was not installed.

Table 12.--Observation-well and test-boring logs, Map 27, Area [1].

Identification number: composed of three elements:

Code TB (Test Boring abandoned after data collection) or OW (Observation Well installed for collection of water-level and water quality data); Significant Sand and Gravel Aquifer Map Number; 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 plate 4.

Site description: A brief site description is given.

Description of materials: Logs of observation well 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 boulder to very fine sand. "Poorly sorted" indicates approximately equal amounts, by weight, of all grain sizes.

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

Marine clay--Sorted, sometimes stratified sediment varying in size from clay to silt, deposited during the marine transgression during deglaciation, approximately 13,000 years before present. Color is typically light brown or blue-gray.

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 work "refusal". If it is fairly certain that the bedrock surface was encountered, the word "bedrock" is shown in parentheses after the word "refusal".

1/ See tables 1, 2, and 3 for information on grain-size analyses and estimated transmissivity and well yield.

Table 12.--Observation-well logs, Map 27 Area
[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 27-1. Latitude: 44°34'23" N., Longitude: 68°12'05" W.
Located in Franklin in a field, 0.5 miles northwest of East Franklin. Water is approximately 32 feet.

Material	Depth (feet)	Thickness (feet)
Brown silt, mixed with blue-grey clay	0 - 1	1
Silt and clay, brown	1 - 6	5
Clay, green	6 - 19	13
Sand, medium to coarse, brown	19 - 30	11
Sand, medium to coarse, with pebbles and granules	30 - 38	8
Refusal (till)	38	--

OW 27-1 is screened from 32.0 to 37.0 feet below land surface with a 0.010-inch slotted PVC screen.

Table 12.--Observation-well logs, Map 27 Area
(Continued)

[--, An aquifer "Thickness" value is not relevant for the "End of Boring" depths.]

OW 27-2. Latitude: 44°33'15" N., Longitude: 68°23'00" W.
Located in Hancock, 2.0 miles east-northeast of Ellsworth. Water is approximately 46 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Sand, medium to coarse; and granules; brown	0 - 2	2
Sand, medium to coarse, brown	2 - 22	20
Sand, fine to coarse, brown	22 - 34	12
Sand, fine to medium, brown and grey	34 - 42	8
Sand, interbedded layers varying from very fine to very coarse with minor amounts of silt, brown	42 - 90	48
Sand, interbedded iron stained layers varying from very fine to coarse; with some minor amounts of brown silt and clay	90 - 117	27
End of boring	117	--

OW 27-2 is screened from 64.9 to 69.9 feet below land surface with a 0.008-inch slotted PVC screen.

Table 12.--Observation-well logs, Map 27 Area
(Continued)
[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 27-3. Latitude: 44°44'01" N., Longitude: 68°27'23" W.
Located in Otis, 1.5 miles north of the town center. Water approximately 12 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Sand, fine to very coarse, with pebbles and granules; brown	0 - 2	2
Sand, fine to very coarse; brown	2 - 20	18
Sand, very fine to fine, interbedded with silt and clay, brown	20 - 50	30
Clay, blue-grey, with some minor amounts of silt	50 - 94	44
Refusal (bedrock)	94	--

OW 27-3 is screened from 29.7 to 34.7 feet below land surface with a 0.006-inch slotted PVC screen.

Table 12.--Observation-well logs, Map 27 Area (Continued)
[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 27-4. Latitude: 44°52'01" N., Longitude: 68°18'19" W.
Located in Aurora 50 feet off the road to Dow Pines (USAF Reservation), 1.4 miles northeast of the town center. Water is approximately 49 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Sand, silt, and clay with some granules	0 - 2	2
Fine brown sand	2 - 8	6
Sand, medium to very coarse; with granules and pebbles; brown	8 - 15	7
Sand, very fine to medium; with silt and clay	15 - 20	5
Sand, medium to very coarse, with granules and pebbles	20 - 52	32
Sand, very fine to very coarse; poorly sorted with silt and subangular granules and pebbles, sediments are compact	52 - 65	13
Sand, very fine to very coarse; with some granules and silt, sediments are less compact	65 - 71	6
Sand, very fine to very coarse; with some granules; silt; and clay; brown	71 - 76	5
Sand, very fine to coarse; with silt and clay; brown	76 - 82	6
Sand, very fine to coarse; with silt and clay; varying from brown to blue-grey	82 - 92	10
Sand, very fine to medium; with silt; blue-grey	92 - 100	8
Till	100 - 104	4
Refusal (compact till)	104	--

OW 27-4 is screened from 79.0 to 84.0 feet below land surface with a 0.006-inch slotted PVC screen.

Table 13.--Observation-well and test-boring logs, Map 45, Area [1/].

Identification number: composed of three elements:

Code TB (Test Boring abandoned after data collection) or OW (Observation Well installed for collection of water-level and water quality data); Significant Sand and Gravel Aquifer Map Number; 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 plate 5.

Site description: A brief site description is given.

Description of materials: Logs of observation well 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 boulder to very fine sand. "Poorly sorted" indicates approximately equal amounts, by weight, of all grain sizes.

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

Marine clay--Sorted, sometimes stratified sediment varying in size from clay to silt, deposited during the marine transgression during deglaciation, approximately 13,000 years before present. Color is typically light brown or blue-gray.

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 work "refusal". If it is fairly certain that the bedrock surface was encountered, the word "bedrock" is shown in parentheses after the word "refusal".

[1/] See tables 1, 2, and 3 for information on grain-size analyses and estimated transmissivity and well yield.

Table 13.--Observation-well logs, Map 45 Area
[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 45-1. Latitude: 45°04'10" N., Longitude: 67°16'33" W.
Located in Baring in the Moosehorn National Wildlife Refugee in gravel pit near Youngs Road. Approximately 25 vertical feet of sand and gravel have been removed. Water is approximately 4 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Sand, medium to very coarse; with granules; pebbles; and cobbles; brown	0 - 2	2
Sand, very fine to very coarse; well sorted; with minor amounts of silt; brown	2 - 64	62
Sand, very fine to medium; well sorted; with minor amounts of silt; grey	64 - 74	10
Fractured bedrock	74 - 78	4
Refusal (bedrock)	78	--

OW 45-1 is screened from 15.2 to 20.2 feet below land surface with a 0.010-inch slotted PVC screen.

Table 13.--Observation-well logs, Map 45 Area
(Continued)
[--, An aquifer "Thickness" value is not relevant for the "Refusal" depths.]

OW 45-2. Latitude: 45°01'48" N., Longitude: 67°21'44" W.
Located in Meddybemps, in a gravel pit, 0.75 mile southwest of the source of the Dennys River at the outlet of Meddybemps Lake. Approximately 12 vertical feet of sand and gravel have been removed. Water is approximately 5 feet below land surface.

Material	Depth (feet)	Thickness (feet)
Sand, medium to very coarse, with granules and pebbles, brown	0 - 15	15
Sand, very fine to very coarse, with minor amounts of silt, brown	15 - 32	17
Sand, very fine to coarse, interbedded with silt and clay; predominantly grey	32 - 64	32
Till	64 - 67	3
Refusal	67	--

OW 45-2 is screened from 18.1 to 23.1 feet below land surface with a 0.008-inch slotted PVC screen.

Table 14.--Depth to water and depth to bedrock based on single-channel seismic data.
Locations of single-channel lines are shown on plates 1-5.
Depths - feet below land surface
A and B - refer to opposite ends of the seimic lines: A is northern or western end, B is southern or eastern end.
USGS refers to U.S. Geological Survey

Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location	Length	Depth to water (feet) A	Depth to water (feet) B	Depth to bedrock (feet) A	Depth to bedrock (feet) B
Map 24	CUT-B	Cutler 7.5	Cutler	0.7 mile north of Cutler on Route 191 turn left; travel almost 1.0 mile to dirt crossroad; turn right 0.2 miles.	150	12	9	>63	>49
Map 24	MSB-A	Machias Bay	Machias-port	South on Route 191 from East Machias to Whiting town line; backtrack 1.4 miles; take dirt road on right 0.2 mile.	150	6	5	48	55
Map 24	MSB-B	Machias Bay	Machias-port	South on Route 191 from East Machias to Whiting town line; backtrack 1.4 miles; take dirt road on right 0.4 miles.	140	4	6	31	39
Map 24	MSB-E	Machias	Whiting	South on Route 191 from East Machias cross Whiting town line; line 1.0 mile on left.	150	5	7	>51	>48
Map 24	WLU-A	West Lubec 7.5	Trescott	East on Route 189; left on Crow Neck Road; 0.1 mile before junction of Route 191; 2.8 miles to road on left, 0.2 mile.	160	9	10	54	55
Map 24	WLU-F	West Lubec	Lubec	East on Route 189 to intersection of North Lubec Road; turn right for 1.0 miles; bear right on dirt road for 0.9 mile.	200	3	5	>60	>54
Map 24	WTG-A	Whiting 7.5	Edmund	Using map of Moosehead Wildlife Refuge, go to east side of Wier Road beginning at Middle Brook towd Alder Brook.	200	3	6	35	32
Map 25	ADD-A	Addison 7.5	Addison	0.25 mile southwest of Tracy Corner	200	4	6	86	83
Map 25	CAF-B	Columbia	Columbia	4.7 miles north of Columbia Falls; 100 yards south of junction of Tibbettstown Road.	100	8	7	26	23
Map 25	CAF-E	Columbia	Centerville	Left off Route 1 in Columbia Falls; cross tracks, round corner and bear right; stay on main road for 4.0 miles; line just beyond right turn.	200	8	6	77	88
Map 25	GRL-B	Gardner	East Machias	North on Route 191, turn right onto dirt road 1.0 mile beyond bridge in Jacksonville. Line along this road.	170	5	5	29	45

Table 14.--Depth to water and depth to bedrock based on single-channel seismic data (Continued).

Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location	Length	Depth to water (feet) A	B	Depth to bedrock (feet) A	B
Map 25	JST-C	Jonesport	Jonesport	Route 1, 1.5 miles southwest of Jonesboro; go south on Route 187 for 3.5 miles; line is 0.125 mile beyond Southwest Creek.	190	6	8	72	66
Map 25	MHS-B	Machias 7.5	East Machias	Take Route 1 across river in E. Machias follow Route 191 south 0.4 mile; line at beginning of road to left.	90	7	7	26	21
Map 25	MHS-G	Machias 7.5	Machias	North on Route 1 from Machias; turn left 100 yards beyond East Machias town line; travel 200 yards northwest back across town line; line on left hand side of road.	170	4	3	46	28
Map 25	MHS-I	Machias 7.5	Machias	North on Route 1, 0.3 mile beyond road to Machias airport; turn right; go 7.5 miles south; line 200 yards before fork in road.	140	4	6	47	37
Map 25	MHS-J	Machias 7.5	Roque Bluffs	North on Route 1, 0.3 mile beyond road to Machias airport; turn right toward Roque Bluffs. Line is 0.75 mile beyond town line.	180	6	6	51	43
Map 25	MHS-Q	Machias 7.5	Roque Bluffs	From Jonesboro 3.5 miles from Route 1, take dirt road on left 100 yards before Roque Bluffs town line; go 1.1 miles to where road crosses town line again.	90	4	5	28	25
Map 25	WLY-H	Wesley 15	Northfield	North on Route 192 to Northfield; turn right for 1.75 miles; turn left 0.5 mile to shore of Fulton Lake.	120	5	4	>44	>47
Map 25	WYE-B	Whitneyville 7.5	Jonesborough	Route 1, 1.0 mile north of Bluebird Ranch, turn right 0.2 miles on Route 187.	150	4	5	37	29
Map 26	CRD-A	Cherryfield 7.5	Cherryfield	From junction of Routes 1 and 182 in Cherryfield, drive west on Route 182 0.9 miles; line across railroad tracks.	170	6	9	45	41
Map 26	CRD-J	Cherryfield 7.5	Steuben	South on Route 1 from Milbridge; turn left 0.85 mile beyond Steuben town line 0.55 mile on right.	110	7	3	30	35
Map 26	CHD-F	Cherryfield 15	Columbia	0.1 mile north of Epping on Tibbetts-town Road.	170	7	8	>51	>54

Table 14.--Depth to water and depth to bedrock based on single-channel seismic data (Continued).

Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location	Length	Depth to water (feet) A	Depth to water (feet) B	Depth to bedrock (feet) A	Depth to bedrock (feet) B
Map 26	CHD-K	Cherryfield 15	T 19 MD	Follow Tibbettstown Road to Green Spring; sign to airforce base; bear left at Cherryfield Foods depot; one road to south. (#19-SBR-2C-58)	200	58	53	>79	>84
Map 26	DSP-A	Cherryfield 15	Deblois	Left off Route 193, 2.8 miles north of Deblois town line.	200	14	16	>86	>82
Map 26	SPR-A	Cherryfield 15	Deblois	Take fish hatchery road across from Deblois flight strip; bear right at fork in road for 1.5 miles; line on right parallel to road.	200	45	44	>104	>104
Map 26	HAR-A	Harrington 7.5	Addison	North on Route 1 from Harrington; turn right on Back Road to Addison; line just before intersection at bottom of hill.	180	34	34	68	68
Map 26	HAR-B	Harrington 7.5	Addison	North on Route 1 from Harrington; turn right on the Back Road; turn right at top of hill; line perpendicular to end of road.	220	7	6	81	53
Map 26	LDM-C	Lead Mountain 15	Beddington	0.5 mile north on Route 9 from intersection of Route 193; road on right across from Maine DOT sand/salt pile.	200	11	13	66	52
Map 26	LDM-D	Lead Mountain 15	Beddington	North on Route 193; road on right, 1.0 mile before intersection with Route 9.	140	6	6	18	24
Map 26	LDM-F	Lead Mountain 15	Deblois	0.1 mile east of Route 193 in Delois, 0.5 mile south of Beddington town line.	200	13	13	78	67
Map 26	LDM-G	Lead Mountain 15	T 16 MD	Proceed to west branch of Narraguagus River via Big Hill area (see Wyman's Map).	200	6	9	56	60
Map 26	LDM-H	Lead Mountain 15	Deblois	Proceed to access road between Big Hill and Hen Coop II (see Wyman's map); at right angle bend in road, take snowmobile road 0.5 mile.	269	8	8	>98	>97

Table 14.--Depth to water and depth to bedrock based on single-channel seismic data (Continued).

Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location	Length	Depth to water (feet) A	Depth to water (feet) B	Depth to bedrock (feet) A	Depth to bedrock (feet) B
Map 26	TKM-A	Tunk Mountain 7.5	Deblois	North on Route 193 to Deblois; turn left beyond Deblois landfill, 1.2 miles turn right; line is 1.4 miles between Hen Coop II and Big Hill (see Wyman's Map).	310	7	8	123	141
Map 26	TKM-B	Tunk Mountain 7.5	Deblois	North on Route 193 to Deblois; turn left beyond Deblois landfill; 1.2 miles turn right; line is 0.9 mile (near Hen Coop II - see Wyman's map).	300	16	17	109	116
Map 26	TKM-C	Tunk Mountain 7.5	Deblois	North on Route 193 to Deblois; turn left beyond Deblois landfill; line is 0.5 miles in on this road.	270	7	10	124	102
Map 26	TKM-E	Tunk Mountain 7.5	Deblois	North on Route 193 to Deblois; turn left beyond Deblois landfill, 1.6 miles, turn left and go 3.0 miles, line just beyond left turn.	300	16	20	>120	>119
Map 26	TKM-F	Tunk Mountain 7.5	Deblois	From Deblois 0.5 mile south of Narraguagus River, turn right; go 0.8 mile; bear left at fork, 0.5 mile to road on left.	300	11	12	>116	>113
Map 26	GP5-A	Tunk Mountain 7.5	Deblois	Pit is east of Downeast Peat Co.; southwest of Deblois Landfill.	300	4	5	>74	>76
Map 26	TGM-A	Tug Mountain 15	Deblois	Proceed to Wilson area on Wyman Map from Route 193, north of Deblois Flight Strip.	200	36	36	77	76
Map 26	TGM-B	Tug Mountain 15	T 18 MD	Take road 0.4 mile beyond fish hatchery; bear right and go 0.25 mile left; turn right 0.1 mile for line.	300	18	18	>119	>123
Map 26	TGM-D	Tug Mountain 15	T 18 MD	Following Cherryfield Foods map, take Shadagee Ridge Road past Montegail Pond 0.1 mile; bear left; line is on right 0.4 miles beyond airforce bombing range.	120	7	8	46	47
Map 26	TGM-E	Tug Mountain 15	T 18 MD	Using DeLorme Atlas, take Shadagee Ridge Road (see TGM-D), 3.0 miles past Montegail Pond; line is on right 0.5 mile before Brewster Corner.	190	10	9	72	62

Table 14.--Depth to water and depth to bedrock based on single-channel seismic data (Continued).

Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location	Length	Depth to water (feet) A	Depth to water (feet) B	Depth to bedrock (feet) A	Depth to bedrock (feet) B
Map 26	TGM-F	Tug Mountain 15	T 24 MD	From TGM-E continue north on same road from Brewster Corner 6.0 miles to fork in road (0.15 mile beyond Grass Pond outlet); bear right for 1.25 miles; line between Duck and Goose Ponds.	150	9	9	47	48
Map 26	TGM-I	Tug Mountain 15	T 24 MD	Follow Shadagee Ridge Road 0.1 mile beyond outlet of Grass Pond to fork; go left 0.35 mile to another fork; turn right 2.1 miles to Pretty Pond; line on road at north end of pond.	250	9	10	66	67
Map 26	TGM-J	Tug Mountain 15	T 19 MD	Take right fork at Cherryfield Foods depot, 1.4 miles to dirt road on left.	150	30	31	>77	>80
Map 26	TGM-K	Tug Mountain 15	T 25 MD	Take right fork by Cherryfield Foods depot to Libby Brook; 1.9 miles on road running beside the radar installation to sharp left turn; go straight 0.2 mile.	200	3	6	>73	>75
Map 26	TGM-N	Tug Mountain 15	T 24 MD	Where Shadagee Ridge crosses outlet of Grass Pond, drive just over 0.1 mile to fork; go left 0.35 mile to another fork; go right for 4 miles past Pretty Pond to another fork go right 0.55 mile to short straightaway.	180	8	8	28	27
Map 26	TGM-R	Tug Mountain 15	T 25 MD	From TGM-K cross Mopang Stream 1.5 miles; line done 0.7 mile in from new road at Air Force Station.	130	19	18	35	51
Map 27	BHP-A	Beech Hill Pond 7.5	Otis	Go north on Route 180 to Floods Pond Road; turn left, go 0.15 mile and turn right for 1.4 miles; line on trail to right.	150	15	15	59	50
Map 27	BHP-B	Beech Hill Pond 7.5	Otis	From Mariaville follow Rocky Nubble Road to junction of Route 180; go 0.6 mile further to field on left near log cabin; line on road through field.	200	6	6	65	52

Table 14.--Depth to water and depth to bedrock based on single-channel seismic data (Continued).

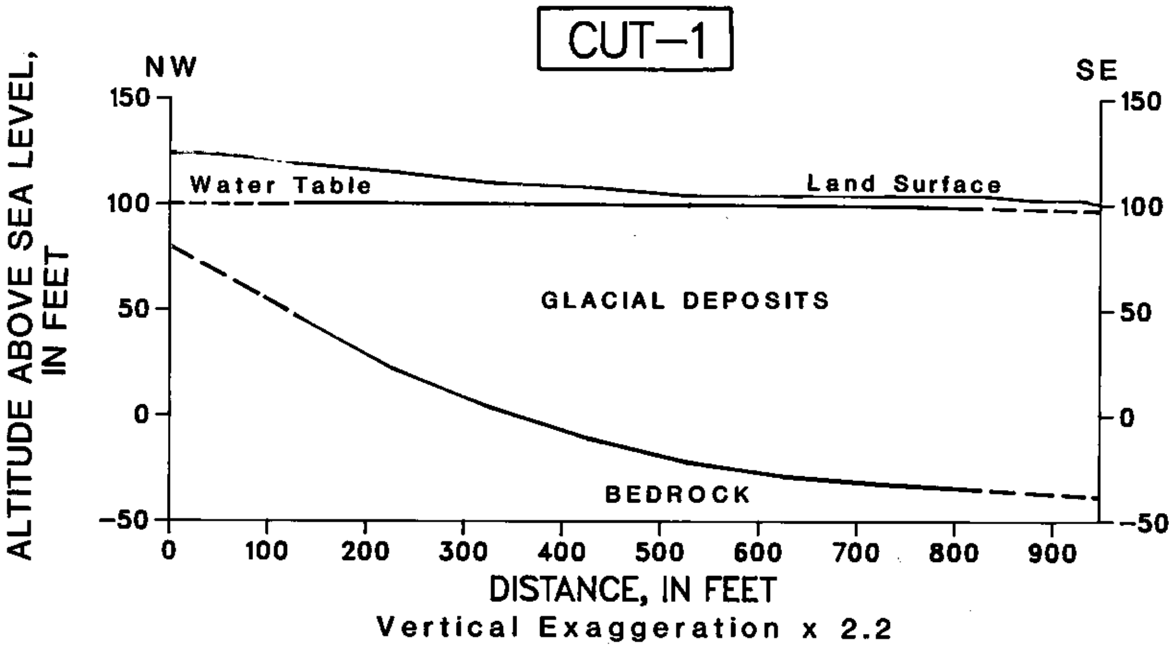
Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location	Length	Depth to water (feet) A	Depth to water (feet) B	Depth to bedrock (feet) A	Depth to bedrock (feet) B
Map 27	BHP-C	Beech Hill Pond 7.5	Otis	Gravel pit south of junction of Rocky Nubble Road and Route 180.	250	6	9	>95	>92
Map 27	BHP-D	Beech Hill Pond 7.5	Otis	From junction of Route 180 and Rocky Nubble Road head west 0.15 mile to Floods Pond Road; line is 0.6 mile.	200	7	4	79	82
Map 27	BHP-F	Beech Hill Pond 7.5	Mariaville	Left off Route 181 in Mariaville, 0.7 miles on Rocky Nubble Road to Pyles Cemetary.	290	17	11	105	96
Map 27	BHP-J	Beech Hill Pond 7.5	Mariaville	From junction of Routes 180 and 181, go north 0.4 mile to dirt road on right; go to gravel pit at end.	140	24	23	57	69
Map 27	EBK-E	Eastbrook 7.5	Eastbrook	North on Route 200 from Franklin; cross Georges Brook 0.25 mile.	100	6	9	25	18
Map 27	ELL-B	Ellsworth 7.5	Ellsworth	North of Ellsworth Falls, bear left on Route 180, 3.0 miles to Sunset Park Road on left.	180	5	5	61	60
Map 27	ELL-G	Ellsworth 7.5	Hancock	On Route 1 east of Ellsworth, cross Card Brook; go almost 0.2 mile and turn left beyond golf course; line in gravel pit 0.3 mile on right.	190	60	55	>67	>73
Map 27	GRP-H	Great Pond	Aurora	Road to right of Route 9, 0.75 mile east of road to Dow Pines Air Force Recreation Area.	150	13	13	>65	>62
Map 27	HAN-I	Hancock 7.5	Lamoine	Route 184, 1.1 miles north of Route 204 take right 0.2 miles to gravel pit.	100	10	9	34	33
Map 27	MSP-A	Molasses Pond 7.5	Eastbrook	0.4 miles up dirt road on left opposite Molasses Pond (0.1 miles beyond boat boat ramp).	100	12	14	39	43

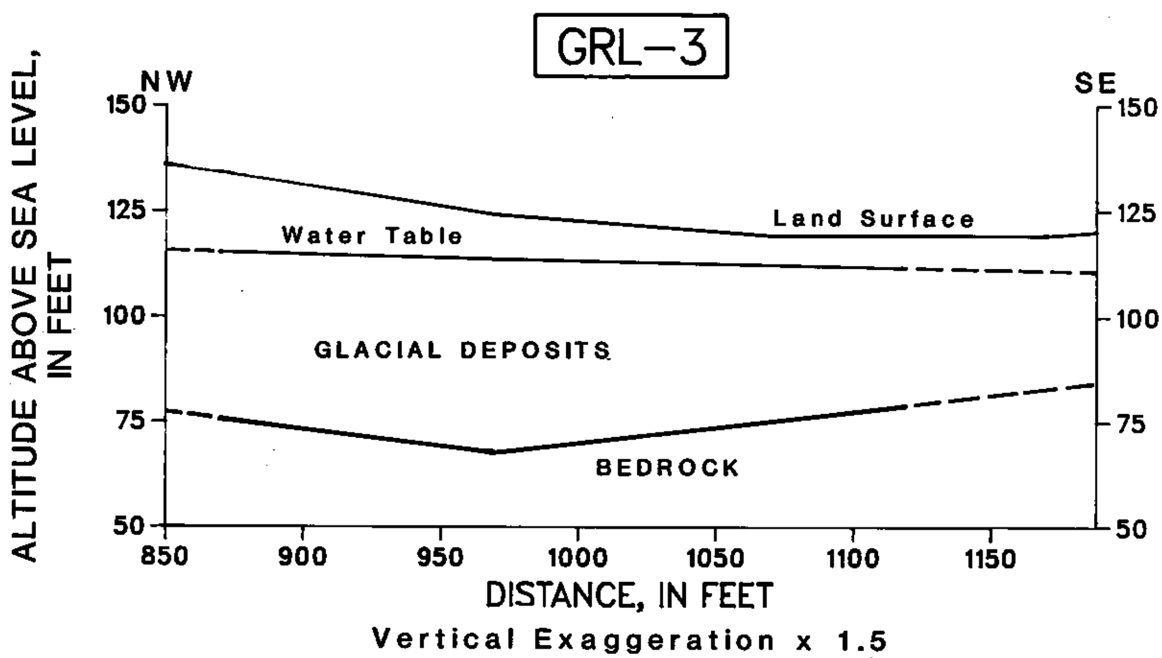
Table 14.--Depth to water and depth to bedrock based on single-channel seismic data (Continued).

Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location	Length	Depth to water (feet) A	Depth to water (feet) B	Depth to bedrock (feet) A	Depth to bedrock (feet) B
Map 27	SLN-A	Sullivan 7.5	Franklin	Road on left 0.9 mile beyond junction with Georges Pond Road on Route 182; line in gravel pit at end.	120	6	8	36	39
Map 27	SLN-D	Sullivan 7.5	Sullivan	Line on camp road to right at north end of Flanders Pond.	70	6	4	10	18
Map 27	SLN-E	Sullivan 7.5	Franklin	Left on Georges Pond Road from Route 182 east of Franklin; follow road to north end of Georges Pond before it crosses Georges Brook.	130	6	4	20	36
Map 45	CAL-A	Calais 7.5	Calais	1.45 miles north on Route 1 from Moosehorn, turn left; line on dirt road perpendicular to railroad tracks.	100	6	7	39	15
Map 45	CAL-C	Calais 7.5	Calais	Line on right to substation at intersection of Route 1 and Moosehorn.	130	5	5	43	46
Map 45	CLS-A	Calais 15	Meddybemps	Line is in Meddybemps 0.5 mile southwest of where Route 214 crosses Dennys River.	200	35	36	91	81
Map 45	RDB-A	Red Beach 7.5	Charlotte	Take Route 214 northwest from Rte. 1 in W. Pembroke to Blanchard Corner; turn right; line 2 miles (cross railroad tracks and Moosehorn Brook.)	250	6	10	40	51

Figure 7.--12-channel seismic-refraction profiles: Plate 1, Map 24 Area

Hydrogeologic sections from seismic-refraction surveys conducted by the U.S. Geological Survey in 1985. Location of individual profiles are shown on plate 1. Data interpretation is based on a computer modeling program described by Scott and others (1972). Distances shown on the X-axes are measured from shot #1. In places, the altitude of the water table and bedrock surfaces have been shown with dashed lines. This is to emphasize the relative unreliability of this data.





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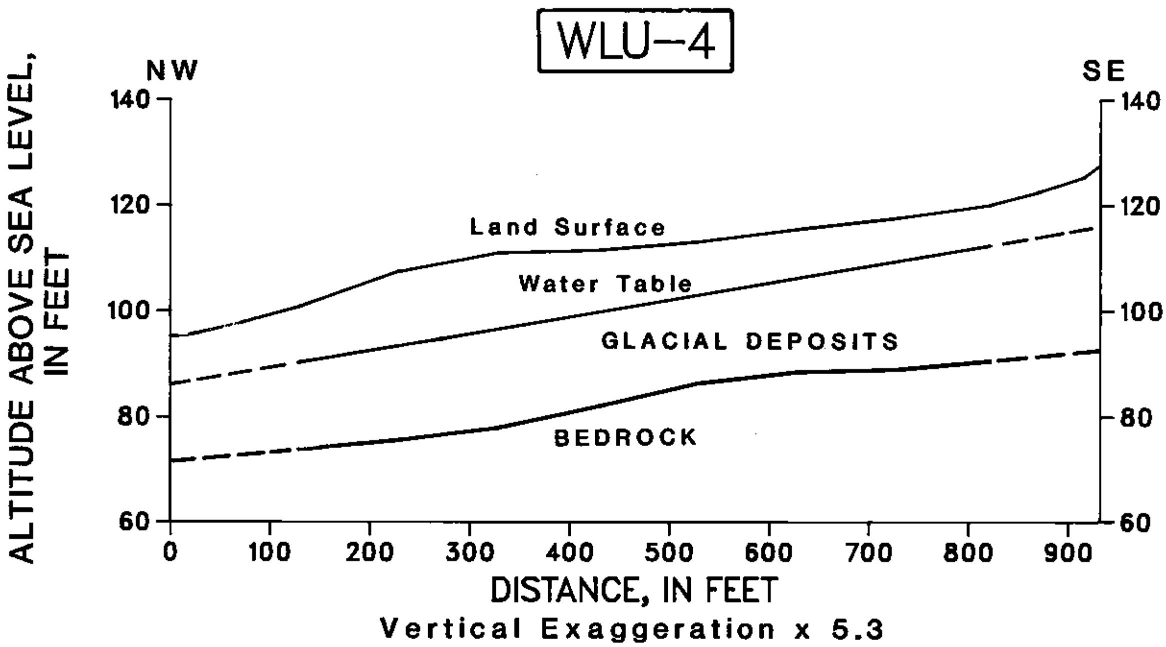

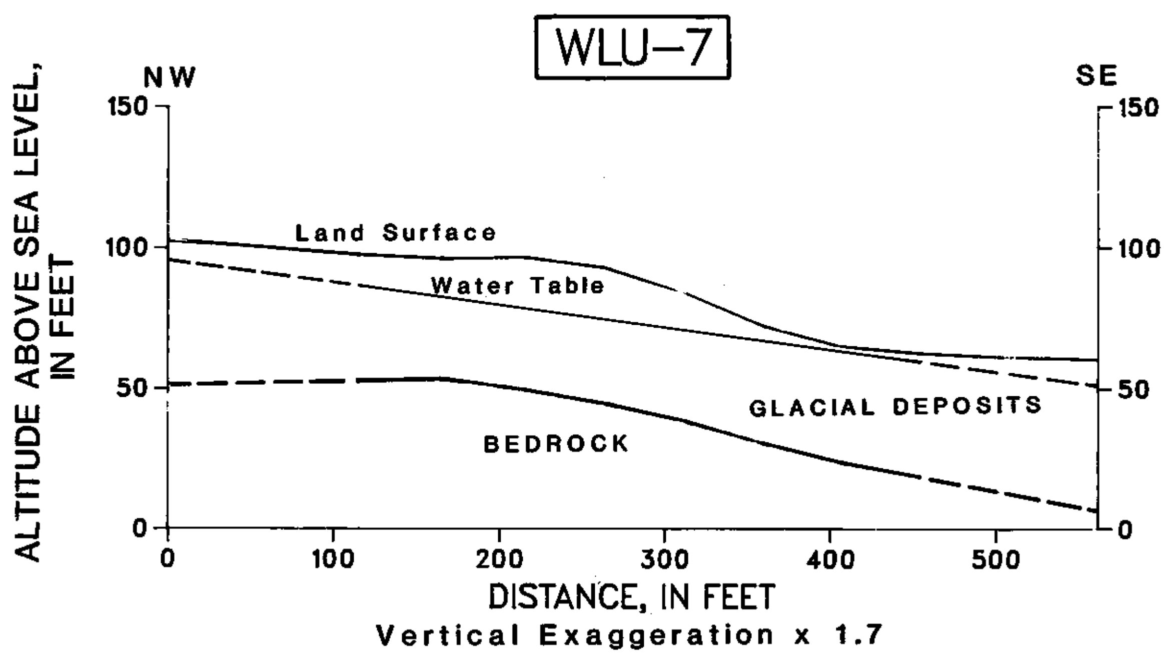

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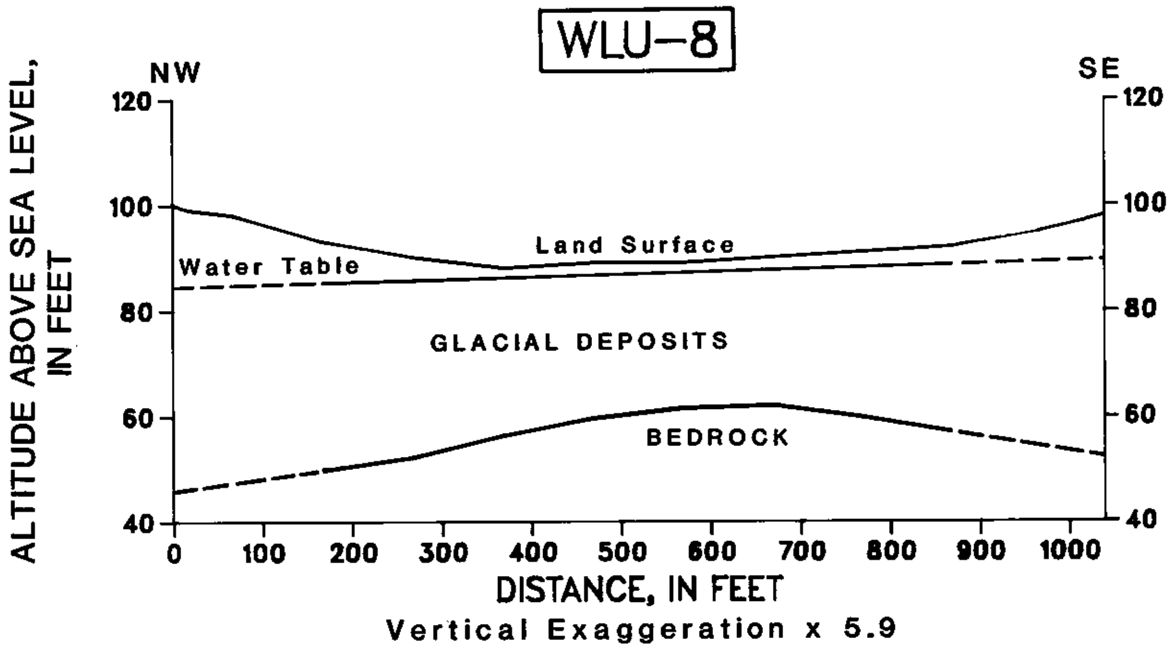

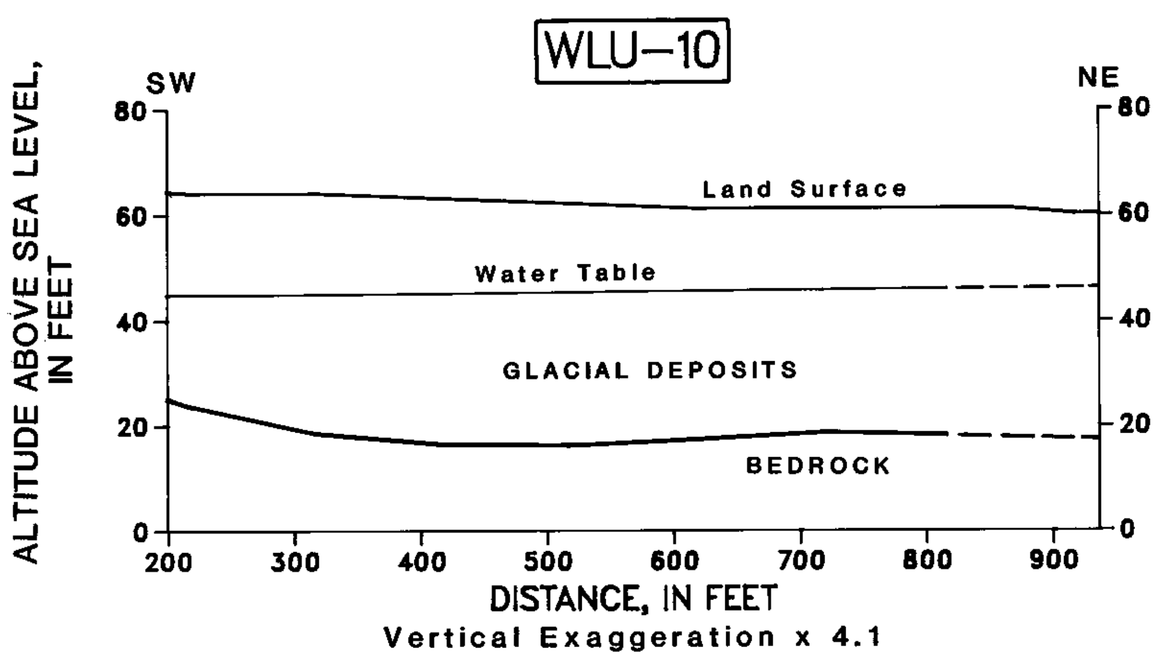

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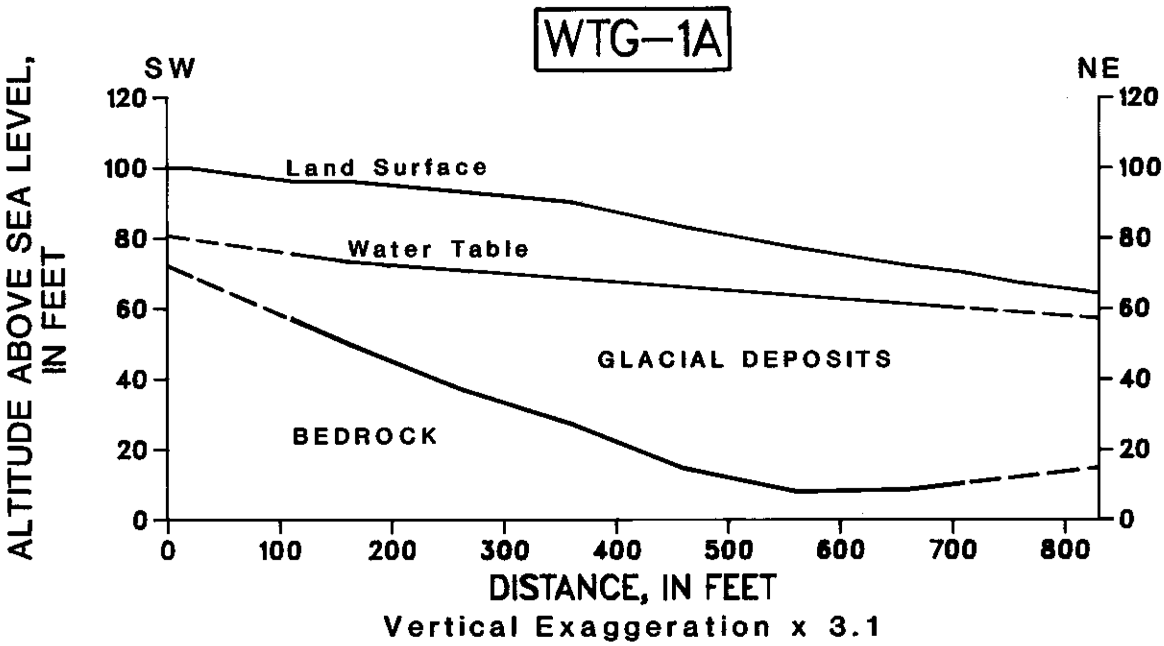

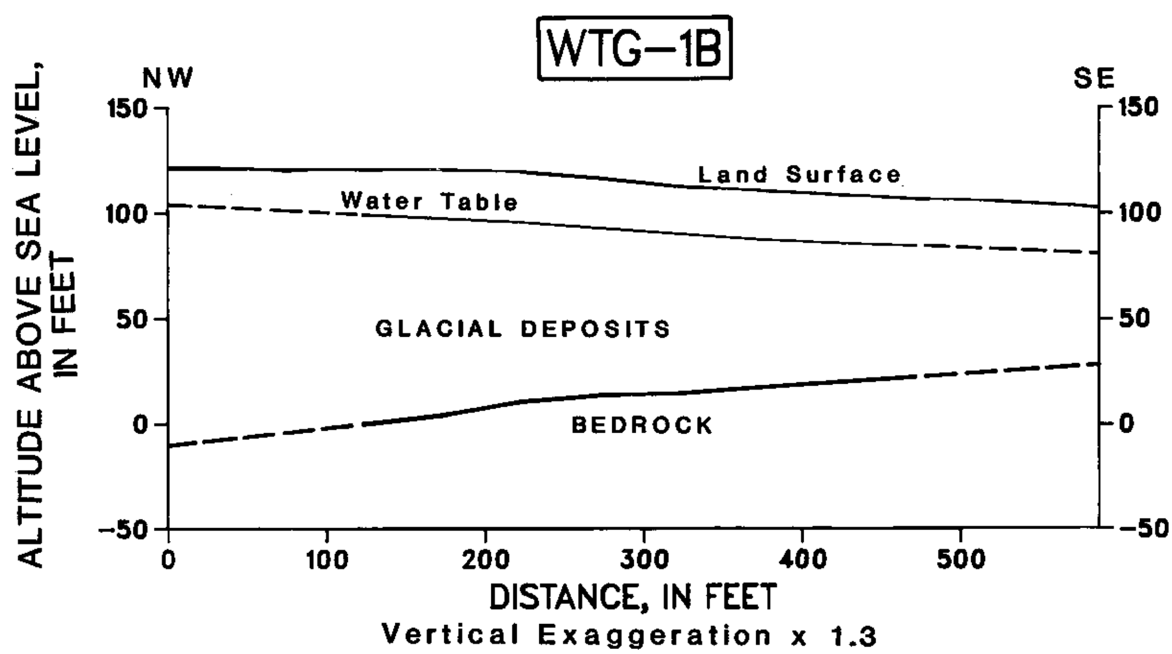

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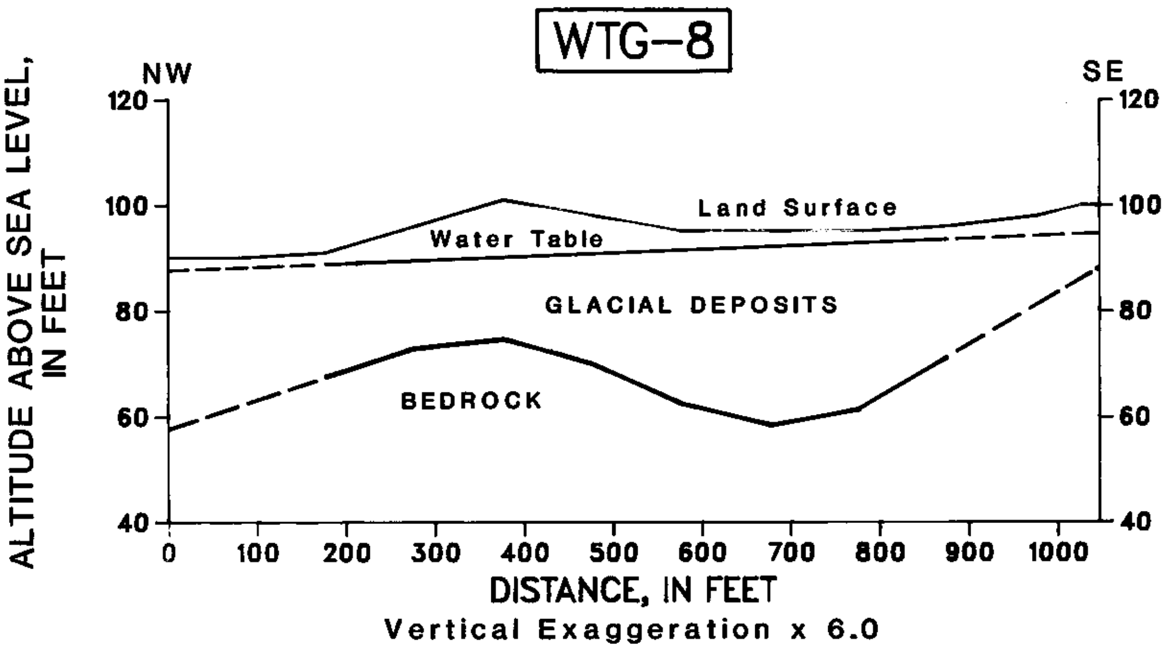

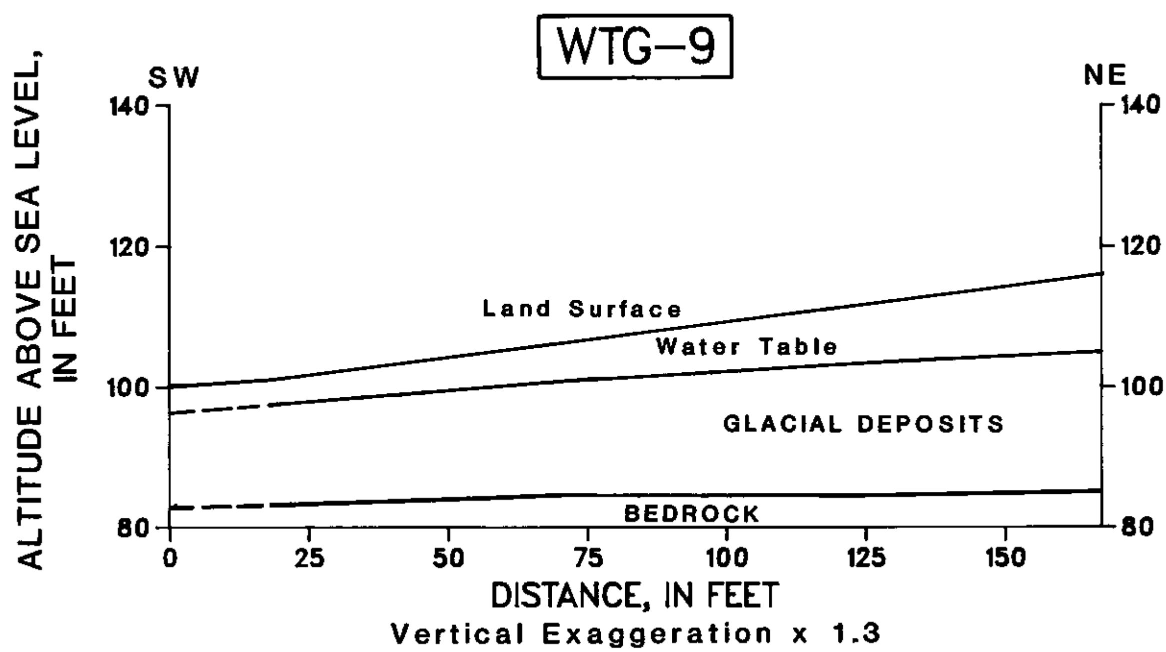

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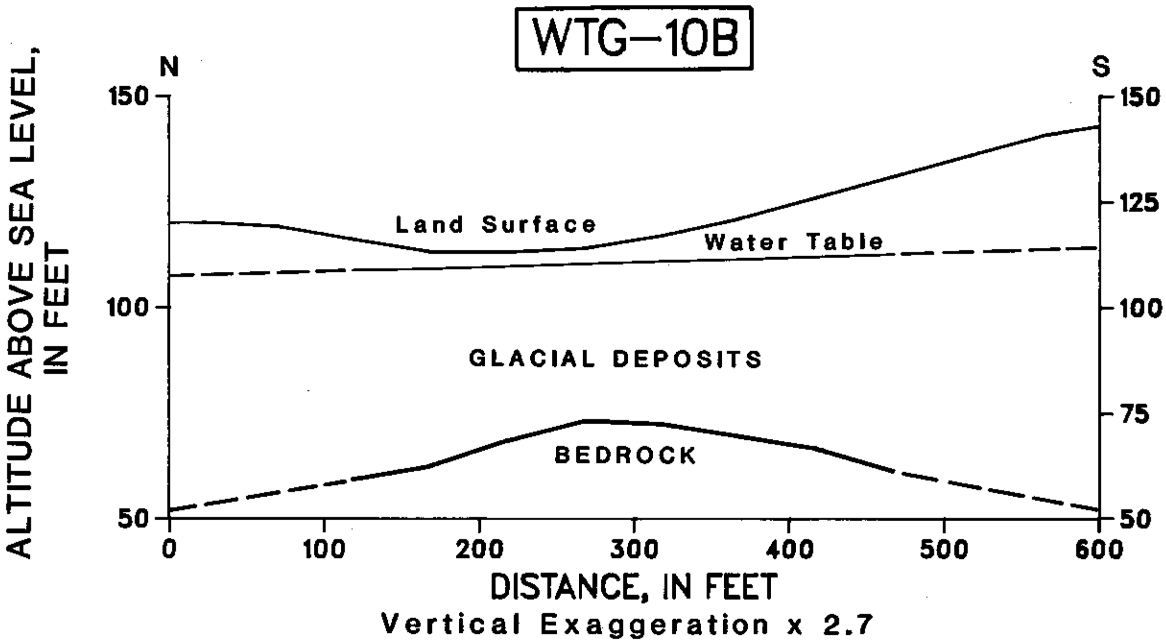
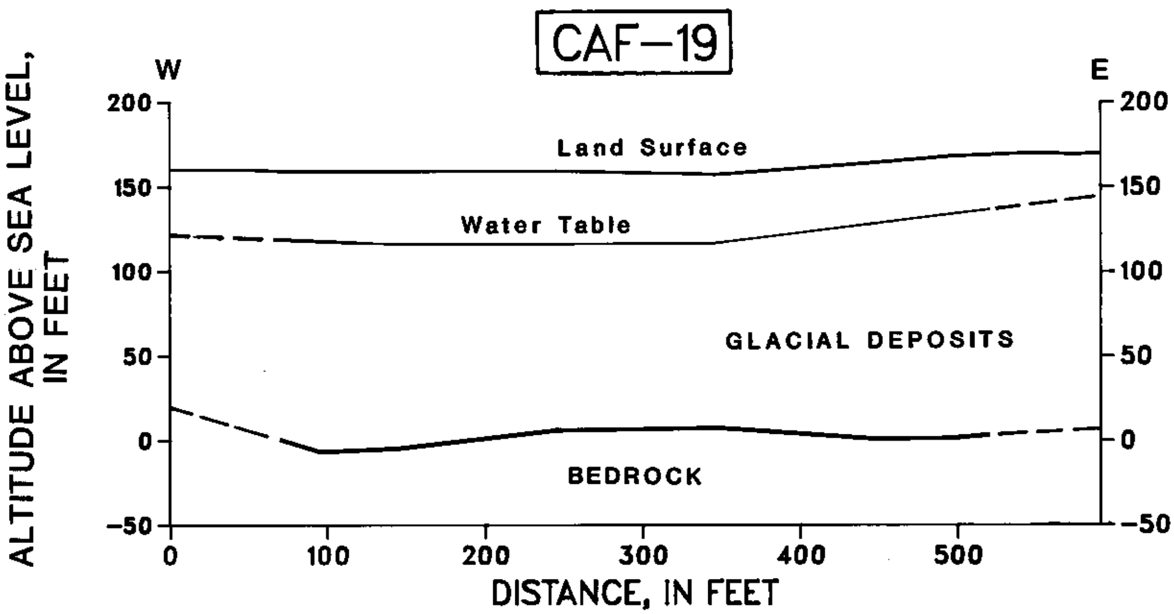
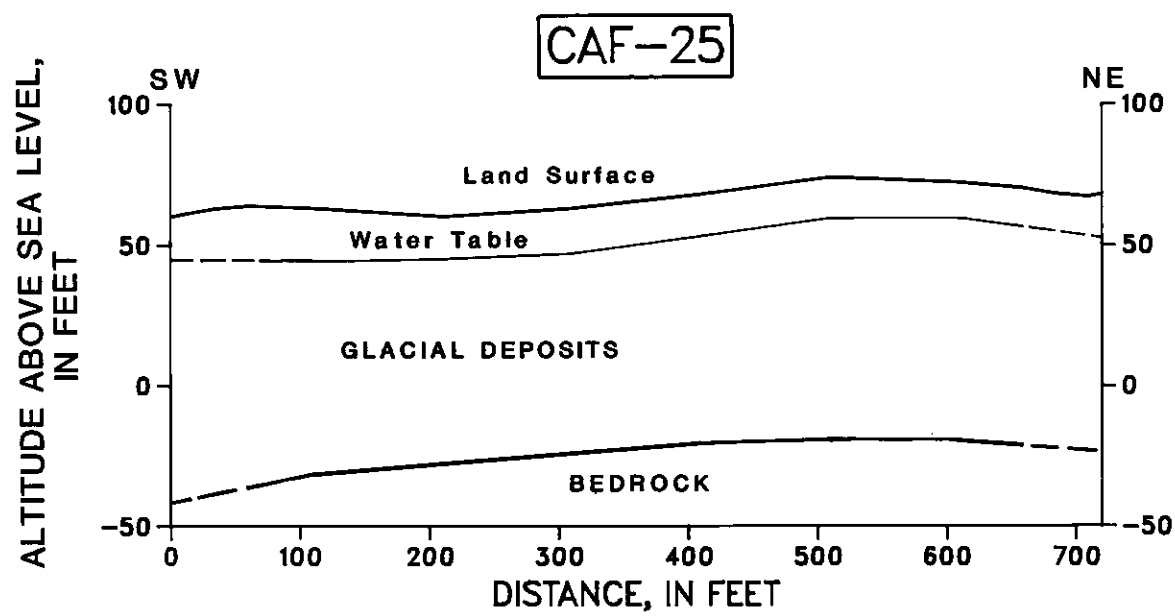


Figure 8.--12-channel seismic-refraction profiles: Plate 2, Map 25 Area

Hydrogeologic sections from seismic-refraction surveys conducted by the U.S. Geological Survey in 1985. Location of individual profiles are shown on plate 2. Data interpretation is based on a computer modeling program described by Scott and others in (1972). Distances shown on the X-axes are measured from shot #1. In places, the altitude of the water table and bedrock surfaces have been shown with dashed lines. This is to emphasize the relative unreliability of this data.



Vertical Exaggeration x 1.1



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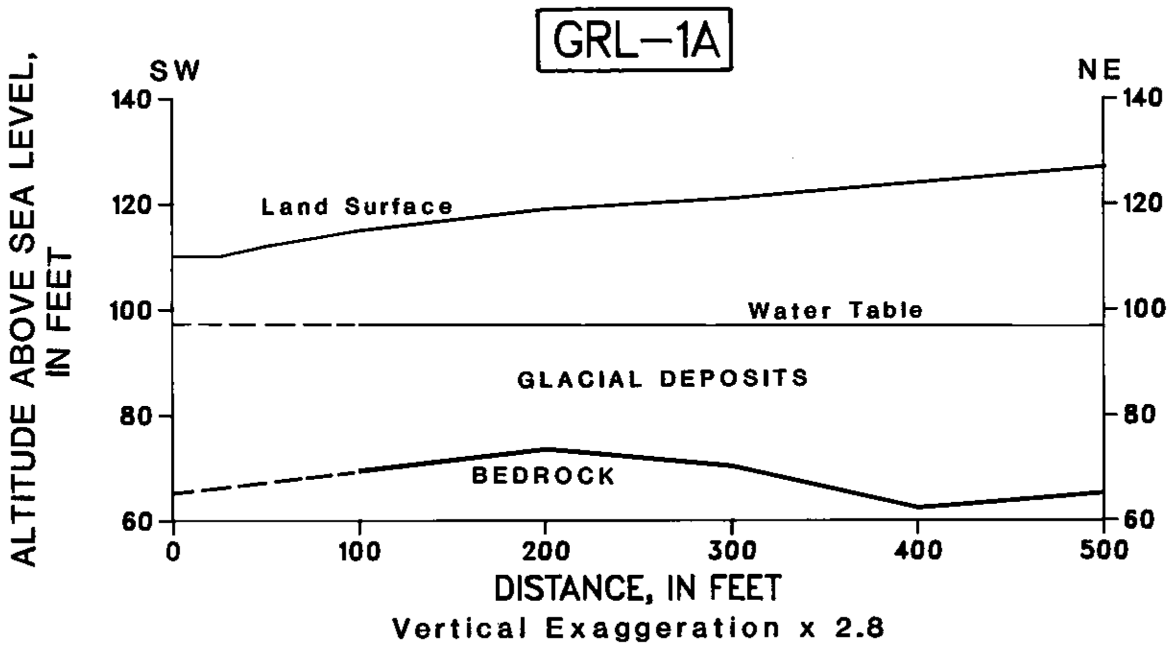

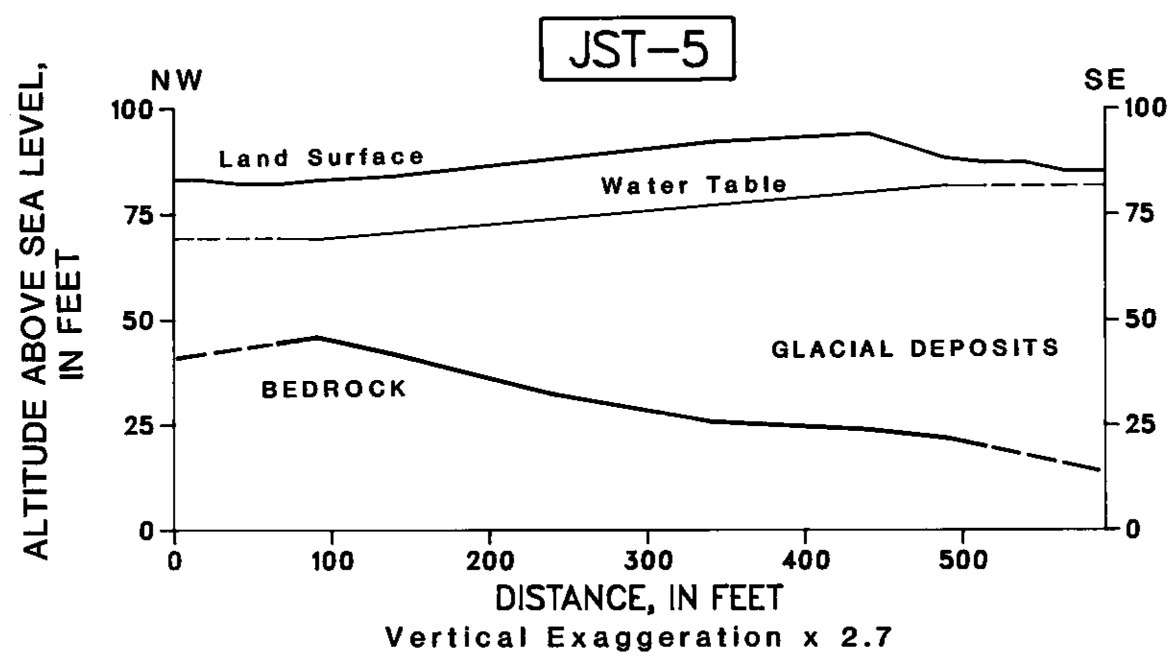

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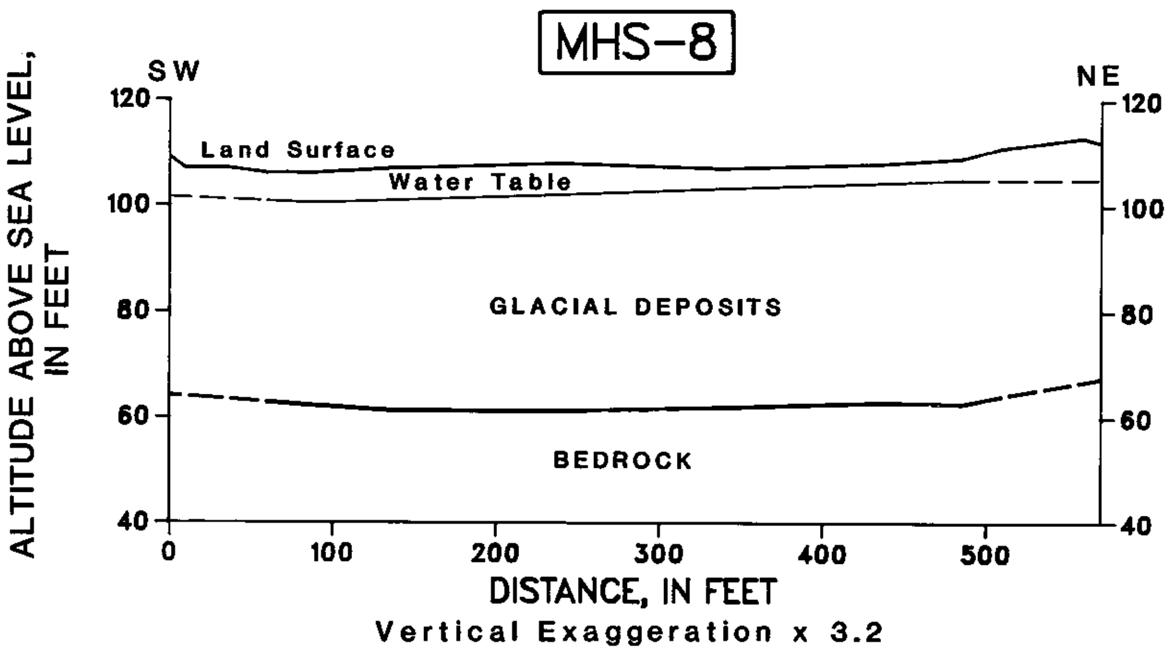

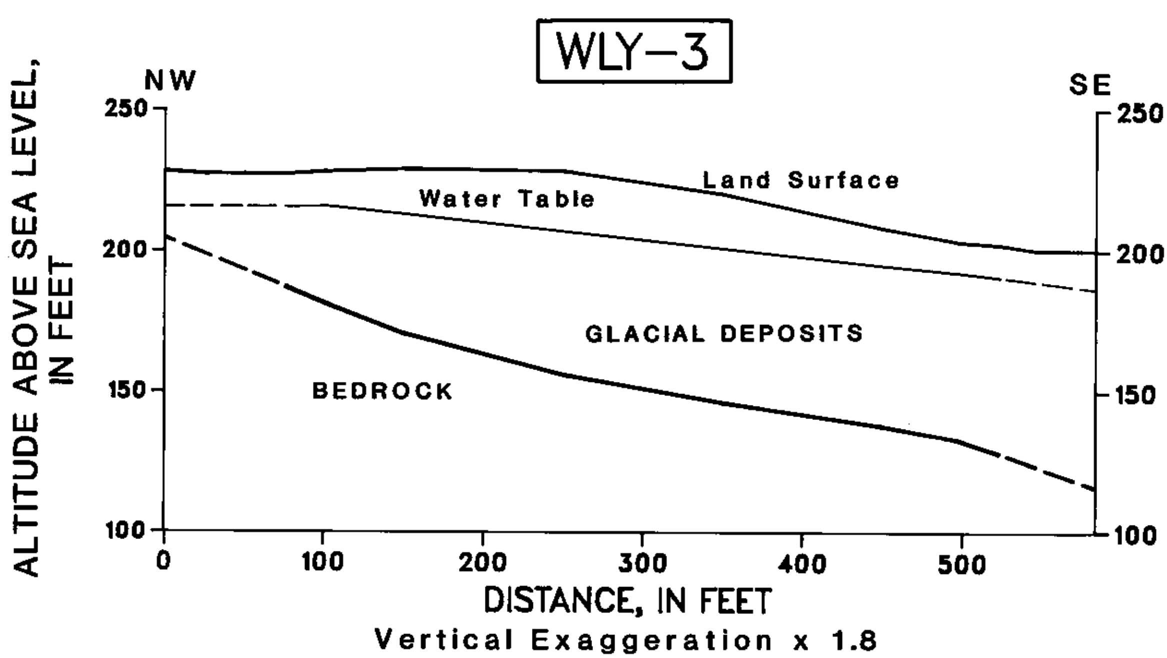

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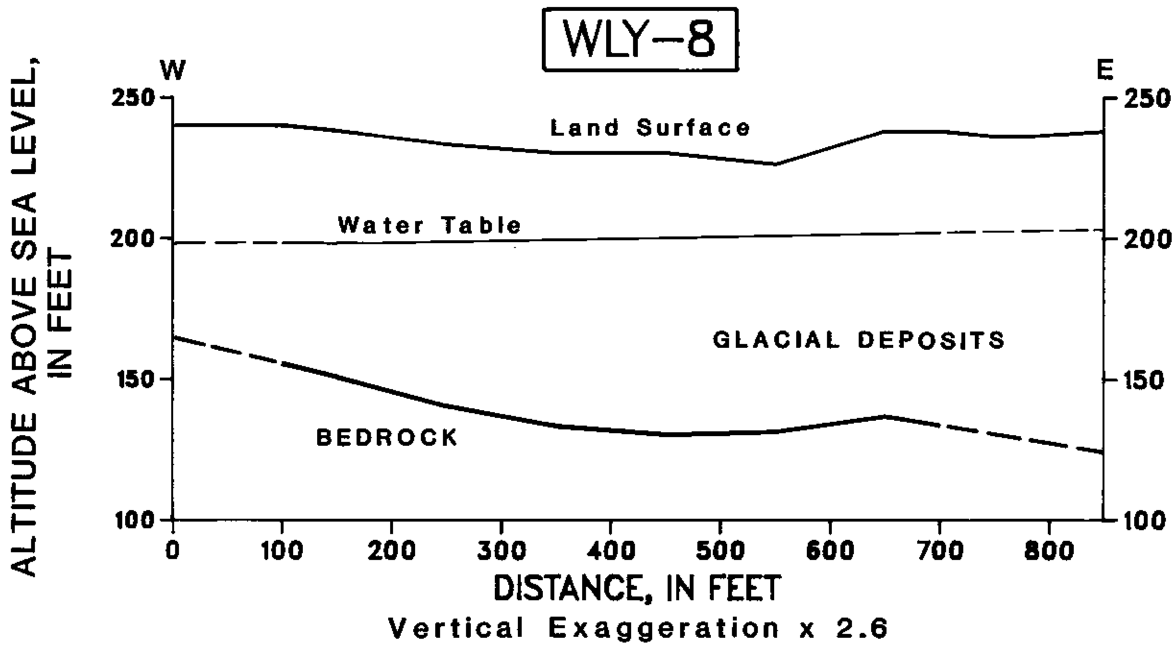

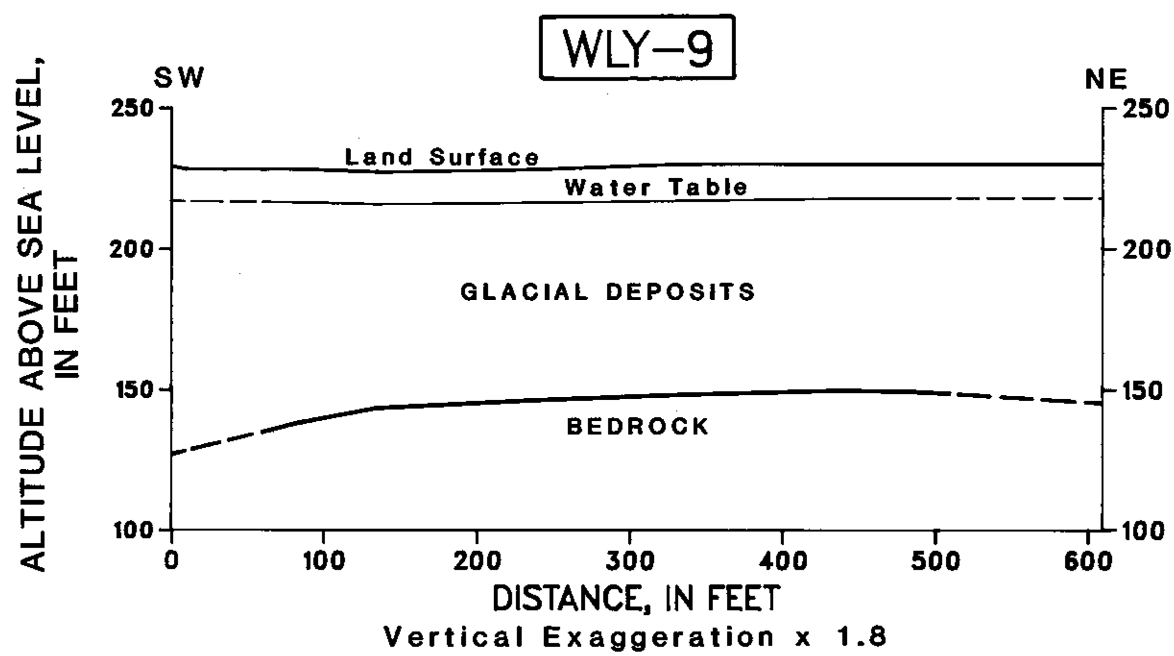

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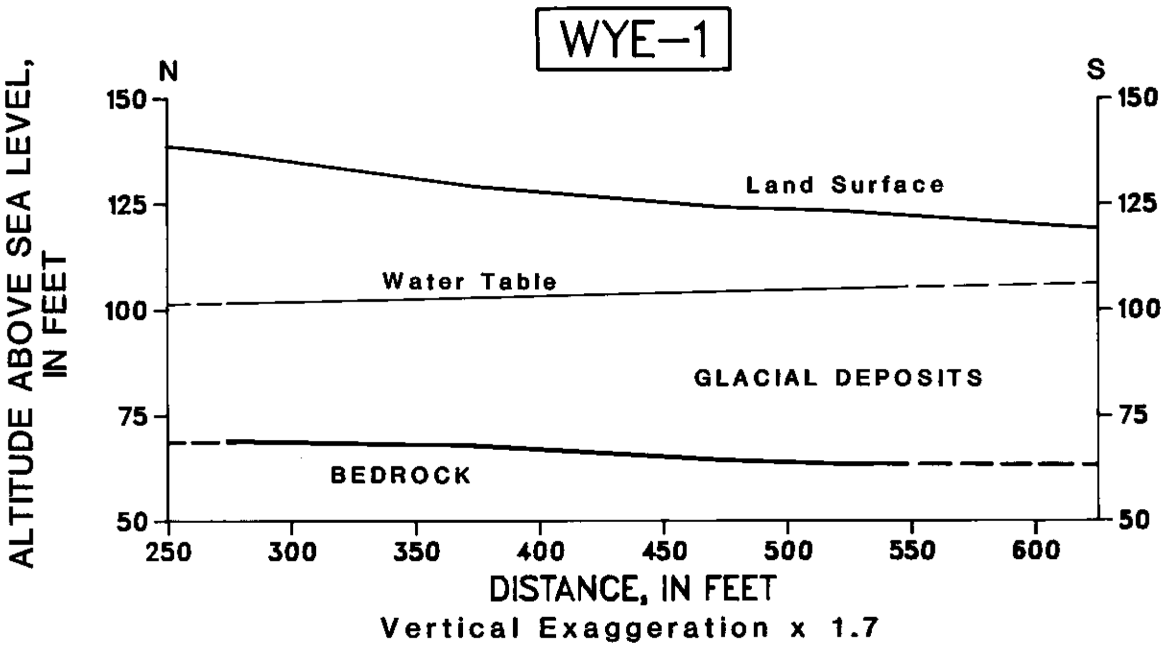


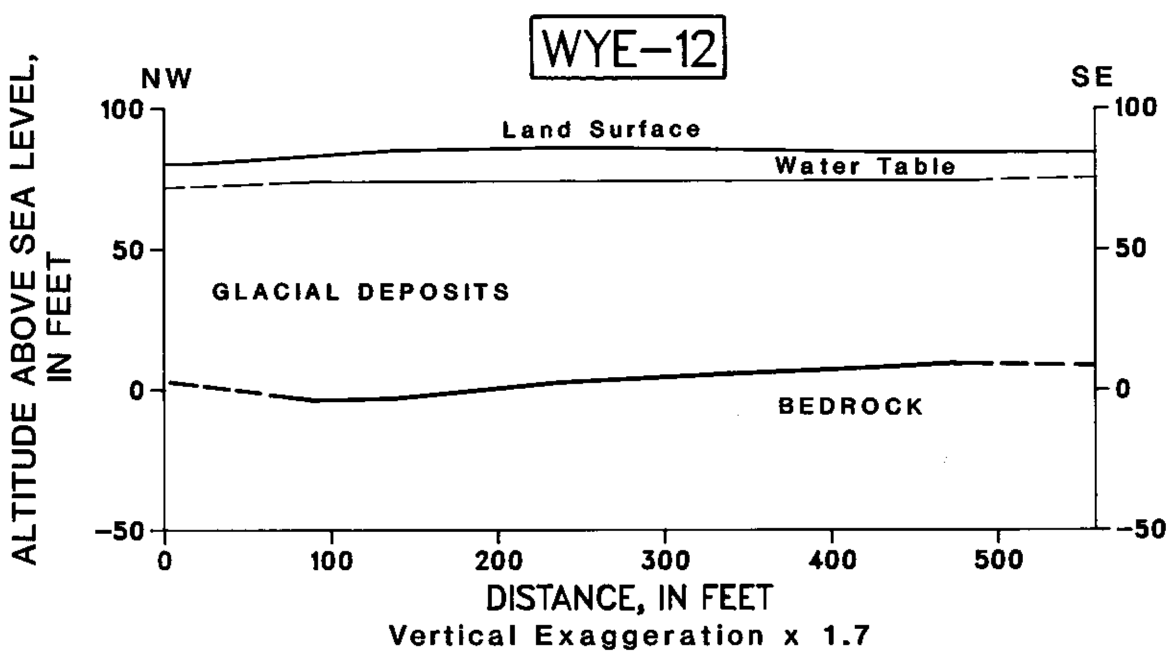
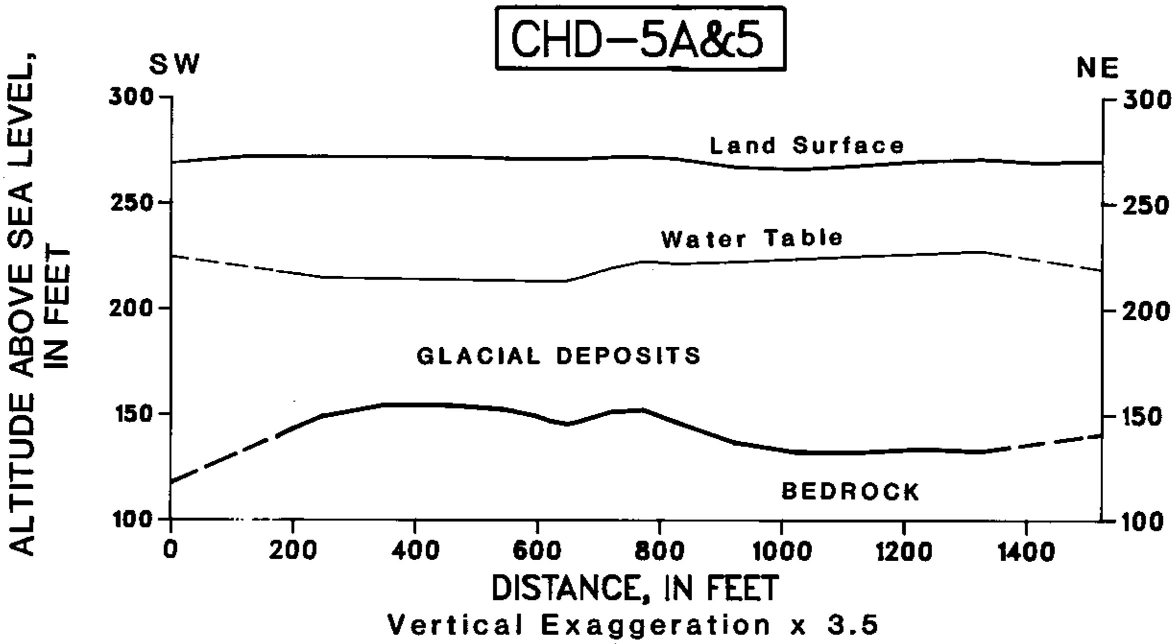
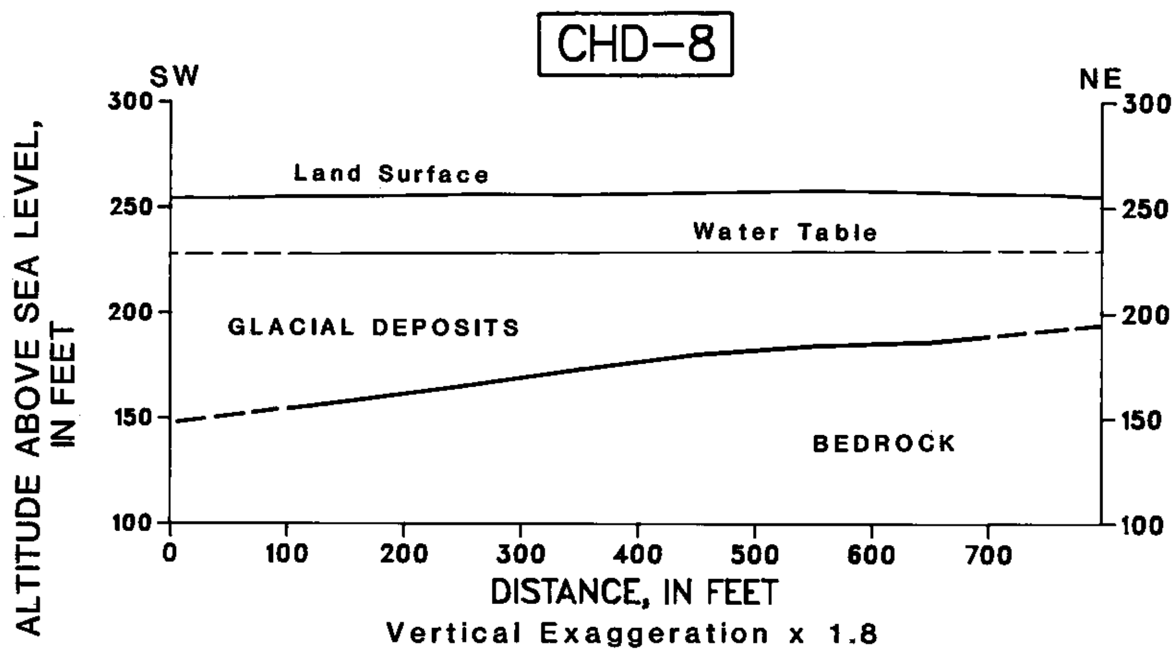


Figure 9.--12-channel seismic-refraction profiles: Plate 3, Map 26 Area

Hydrogeologic sections from seismic-refraction surveys conducted by the U.S. Geological Survey in 1985. Location of individual profiles are shown on plate 3. Data interpretation is based on a computer modeling program described by Scott and others (1972). Distances shown on the X-axes are measured from shot #1. In places, the altitude of the water table and bedrock surfaces have been shown with dashed lines. This is to emphasize the relative unreliability of this data.





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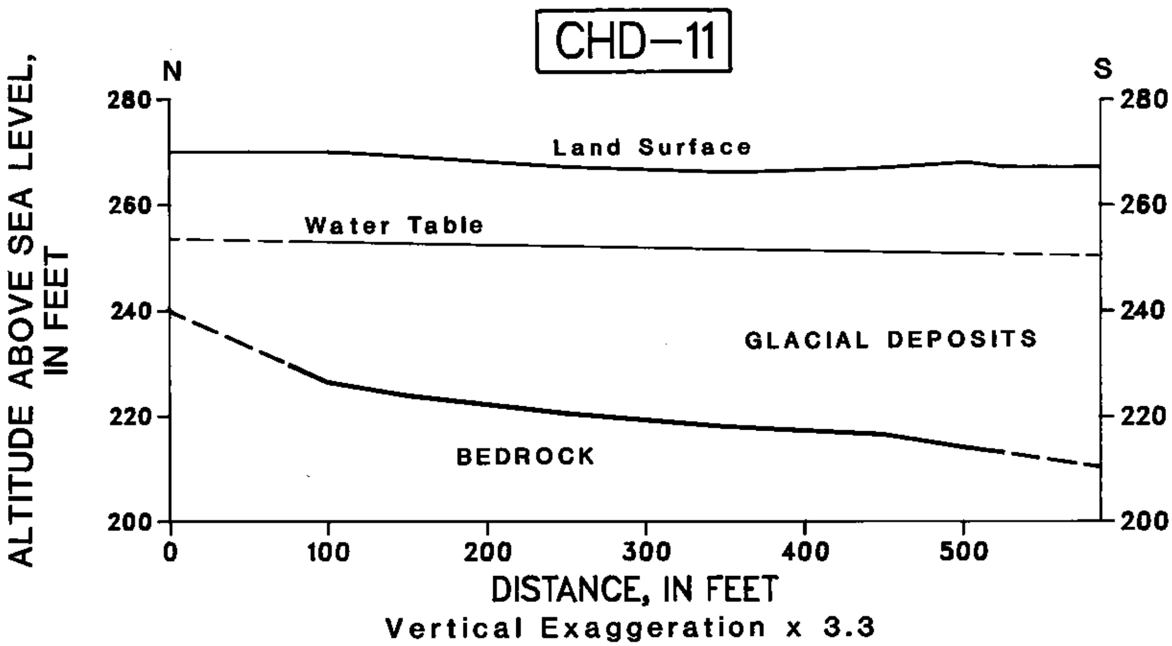

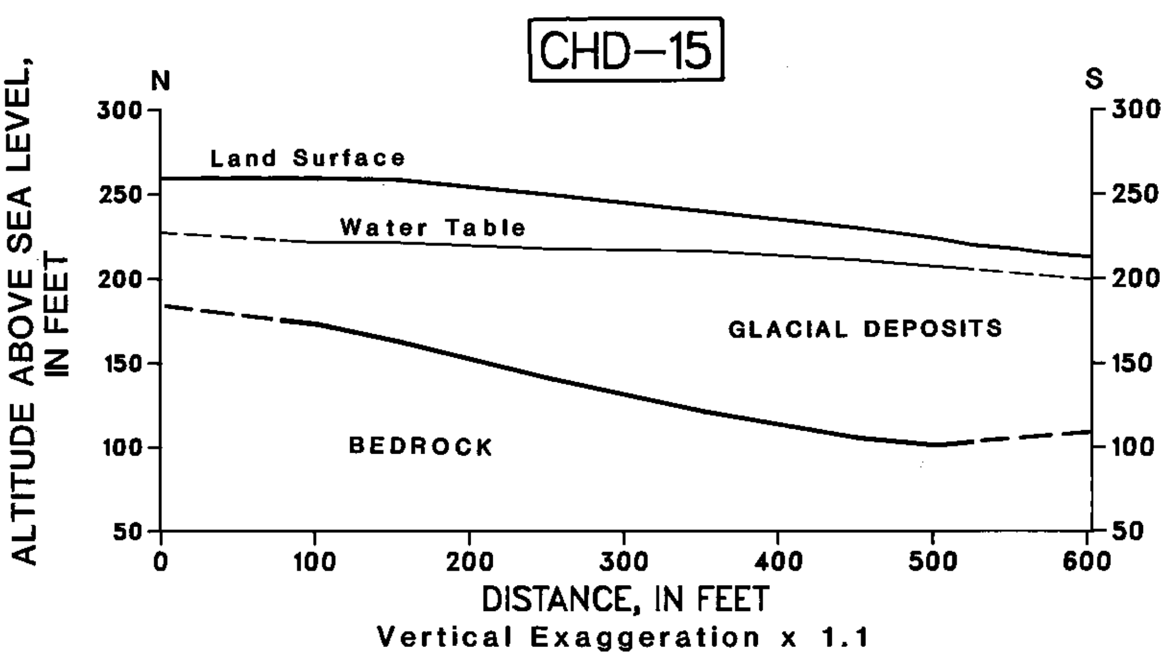

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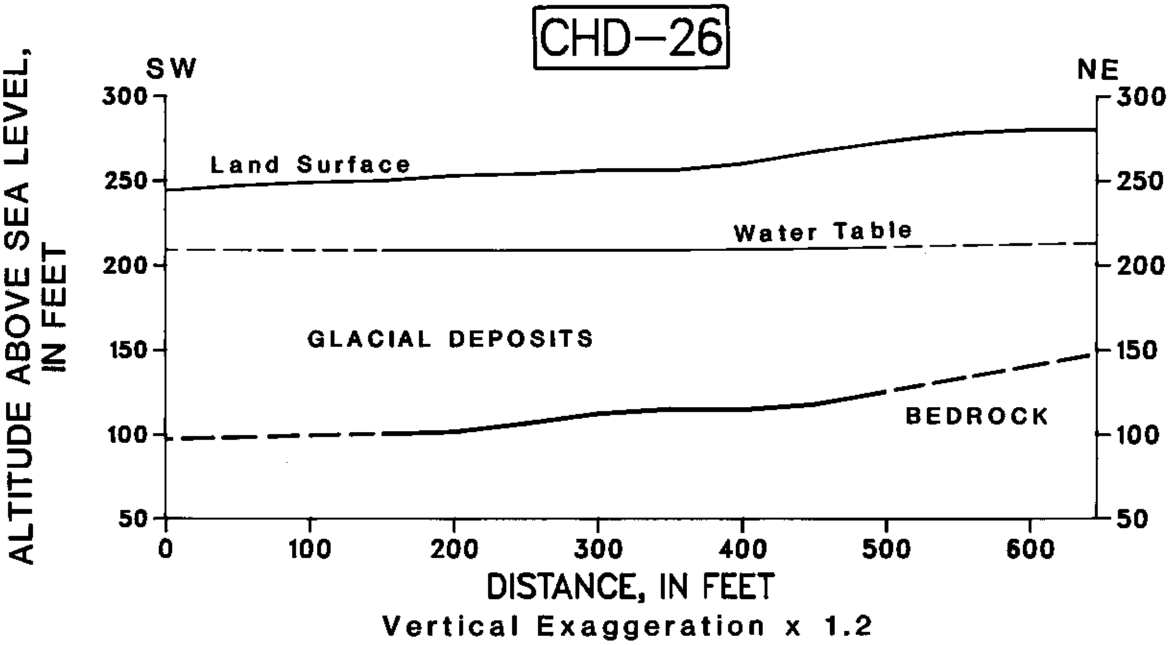

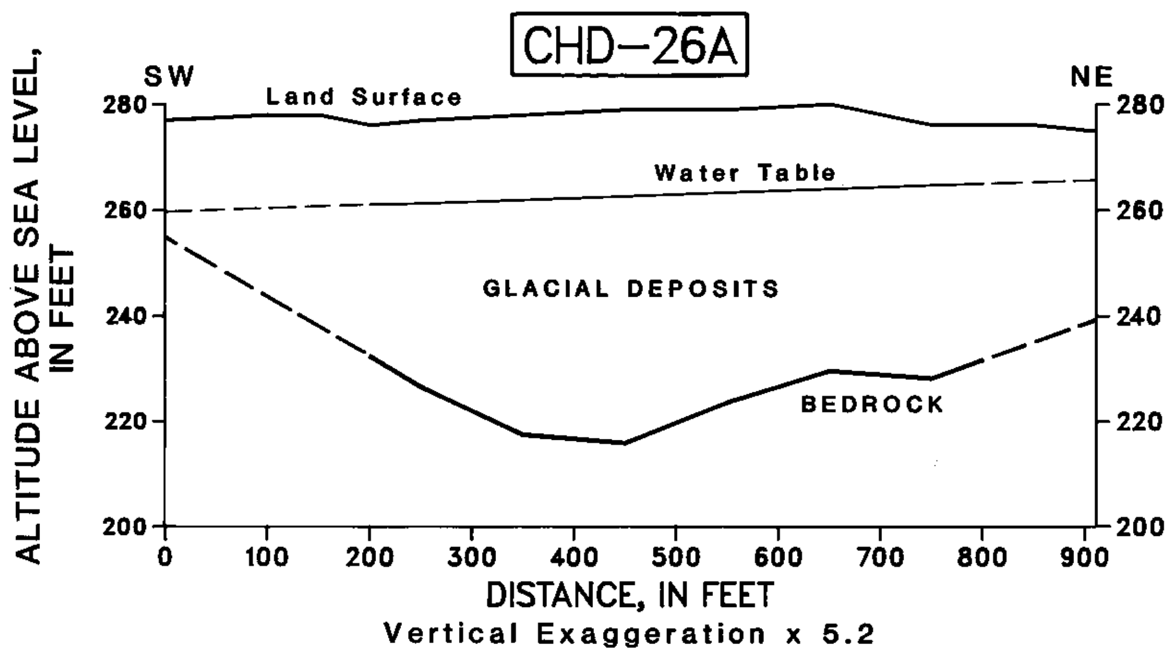

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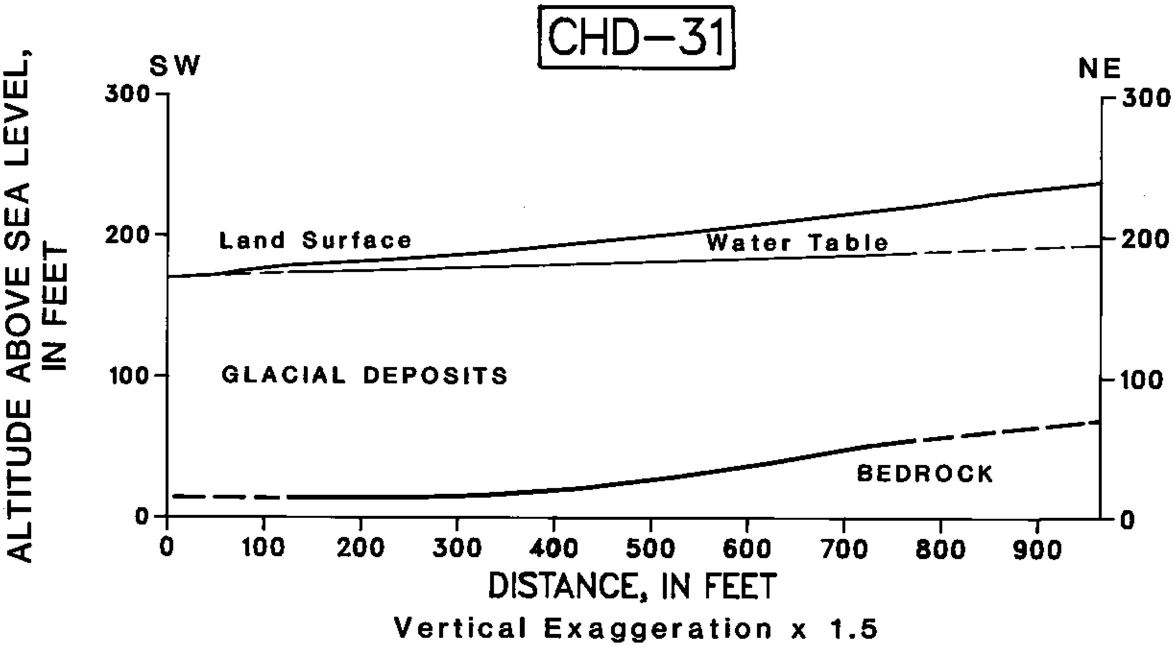

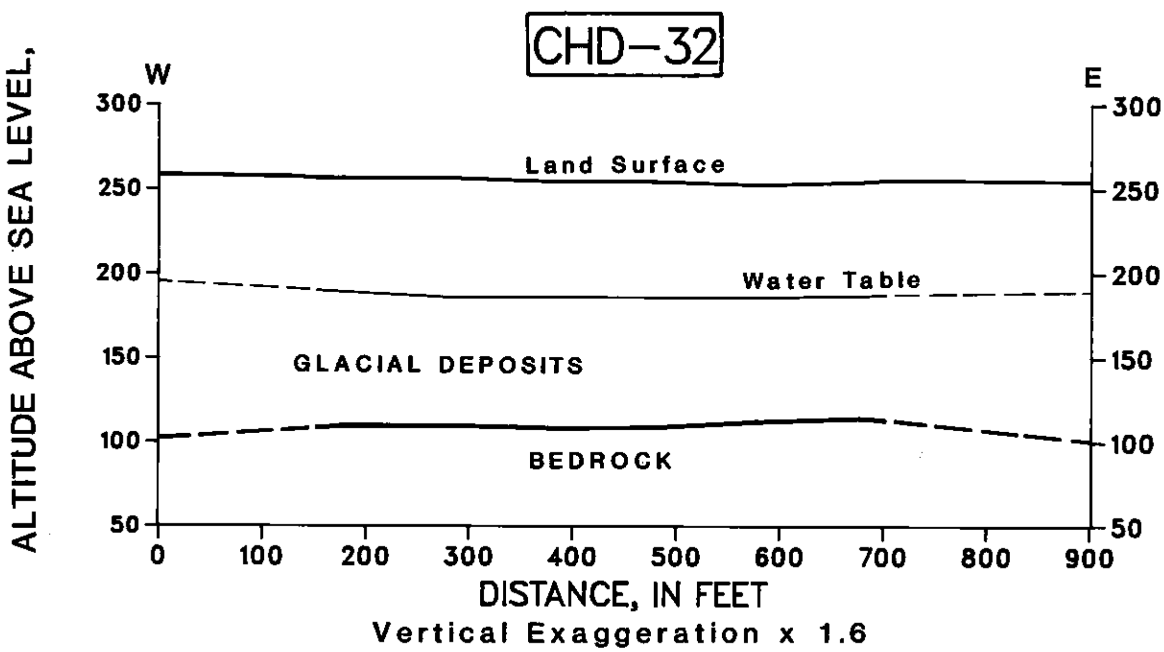

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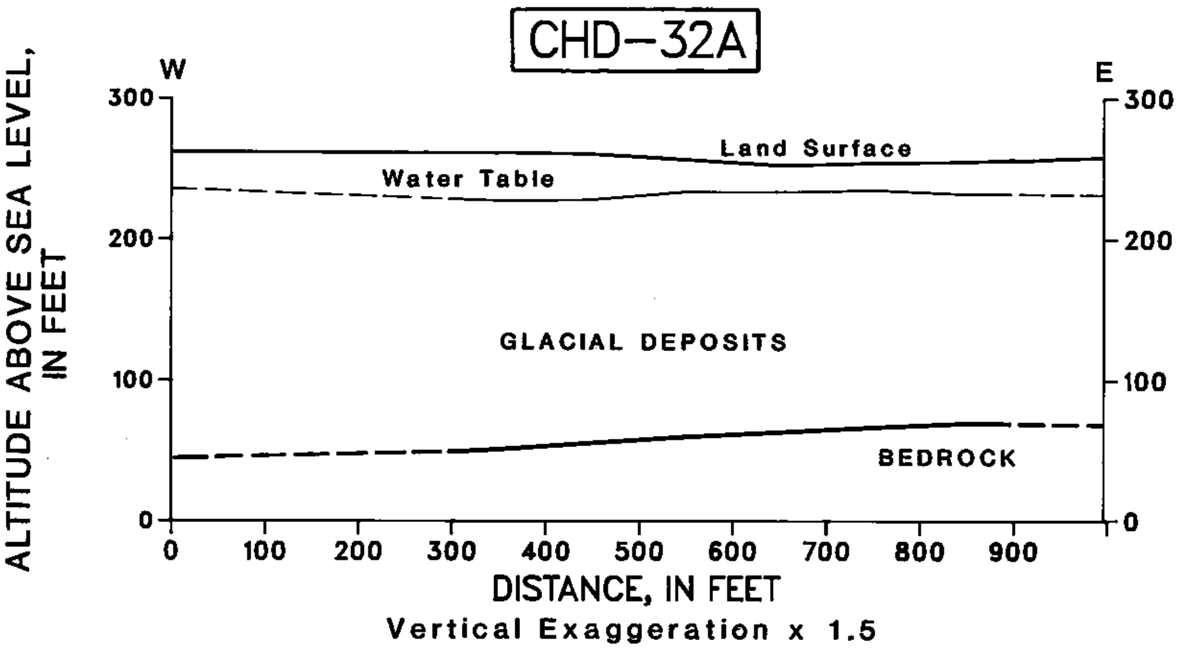

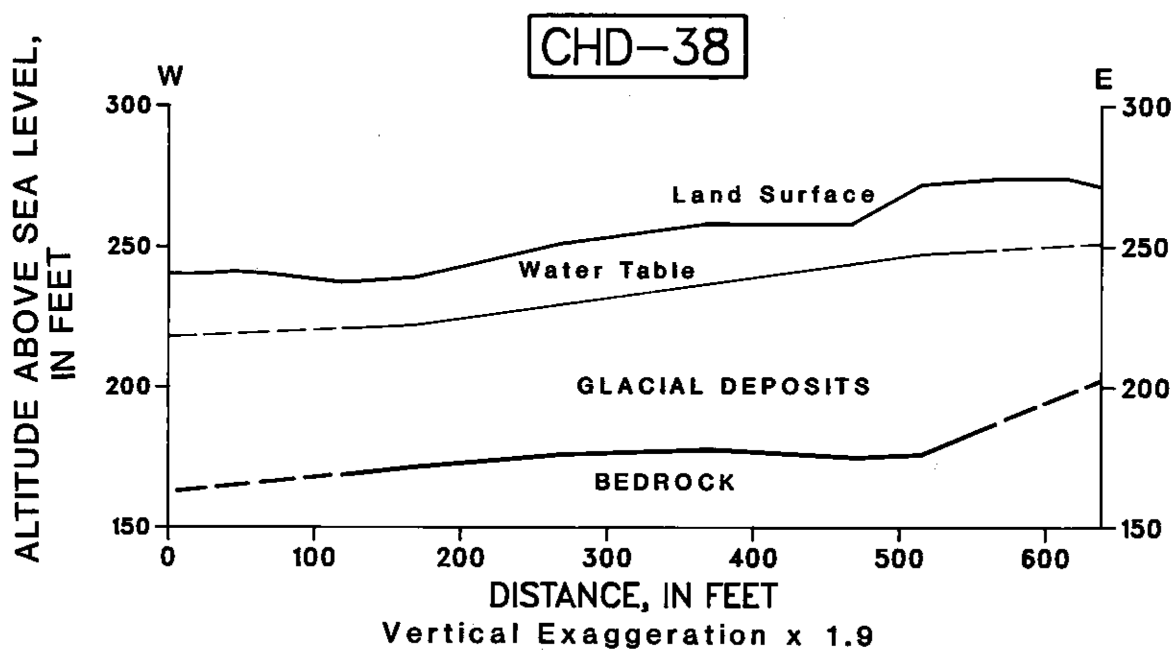

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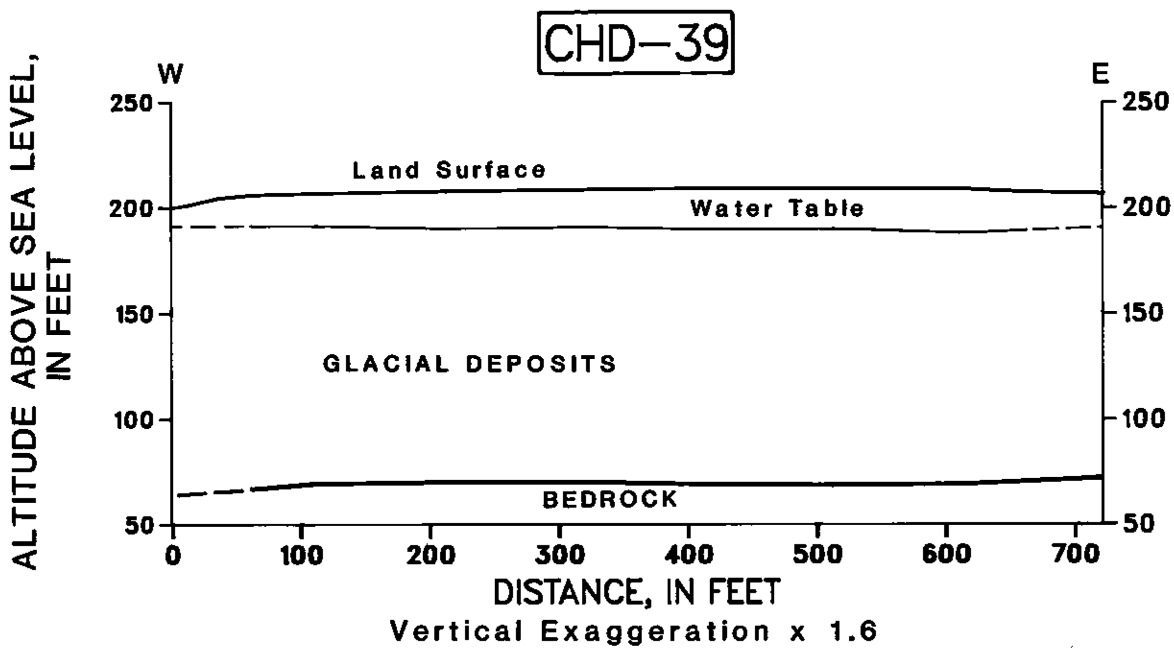

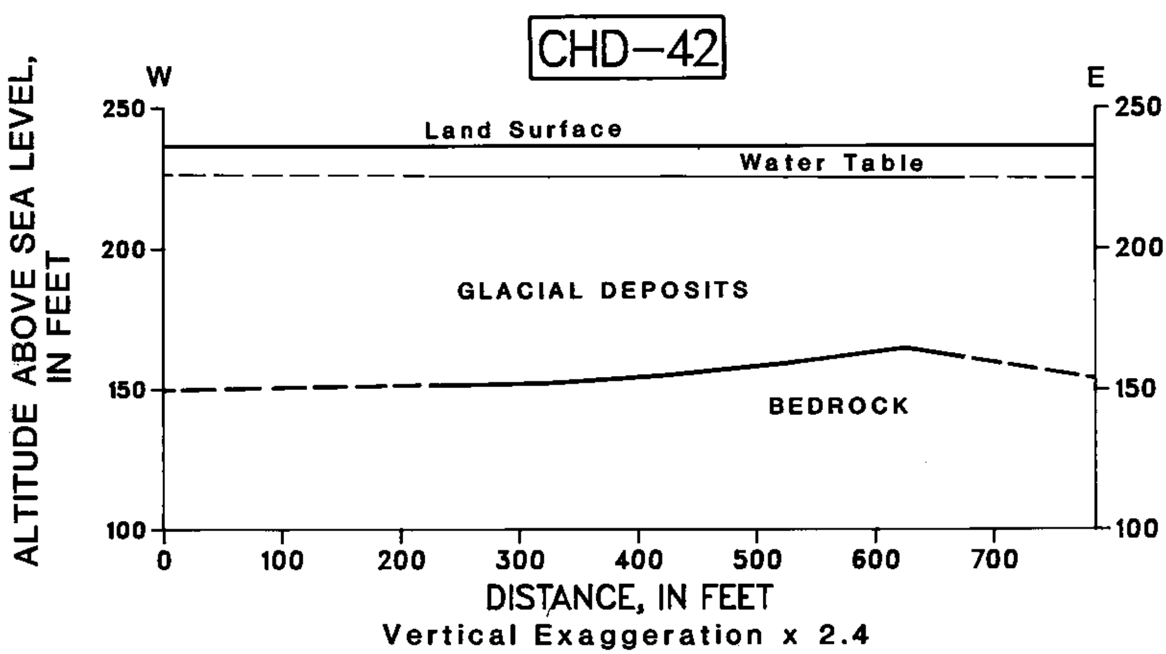

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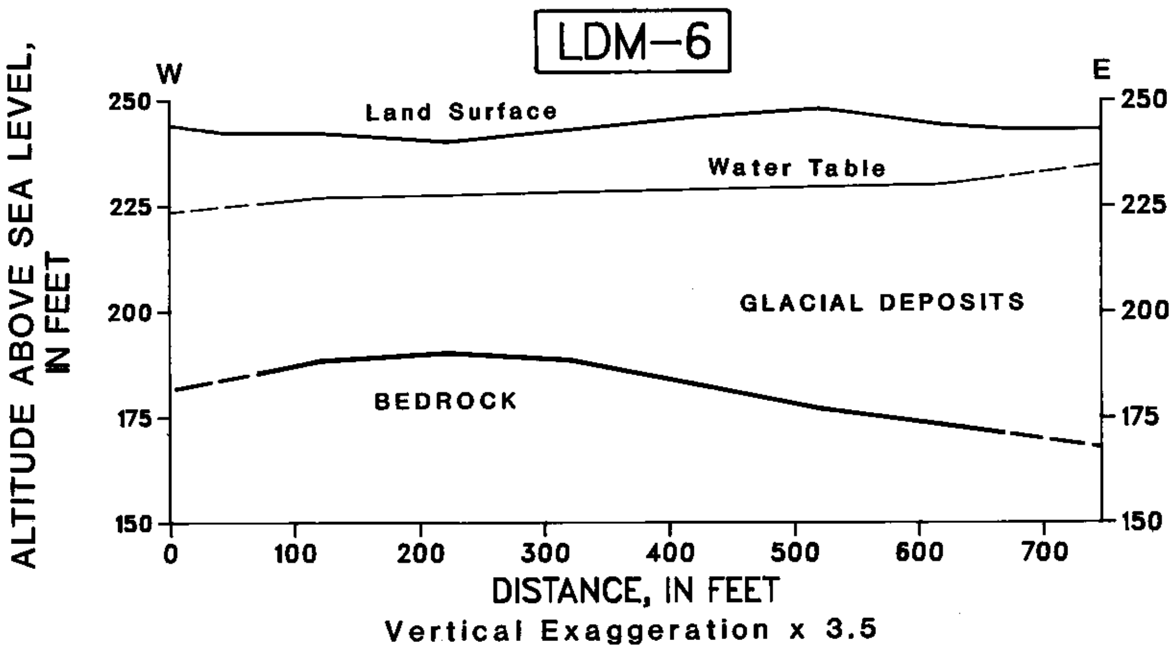

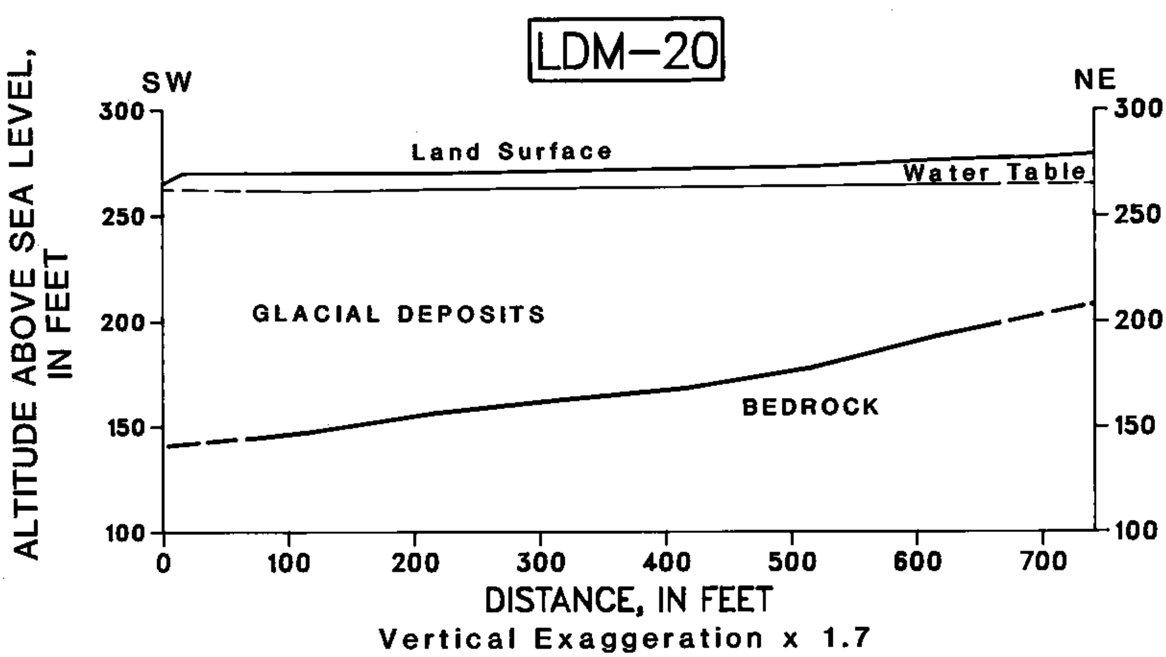

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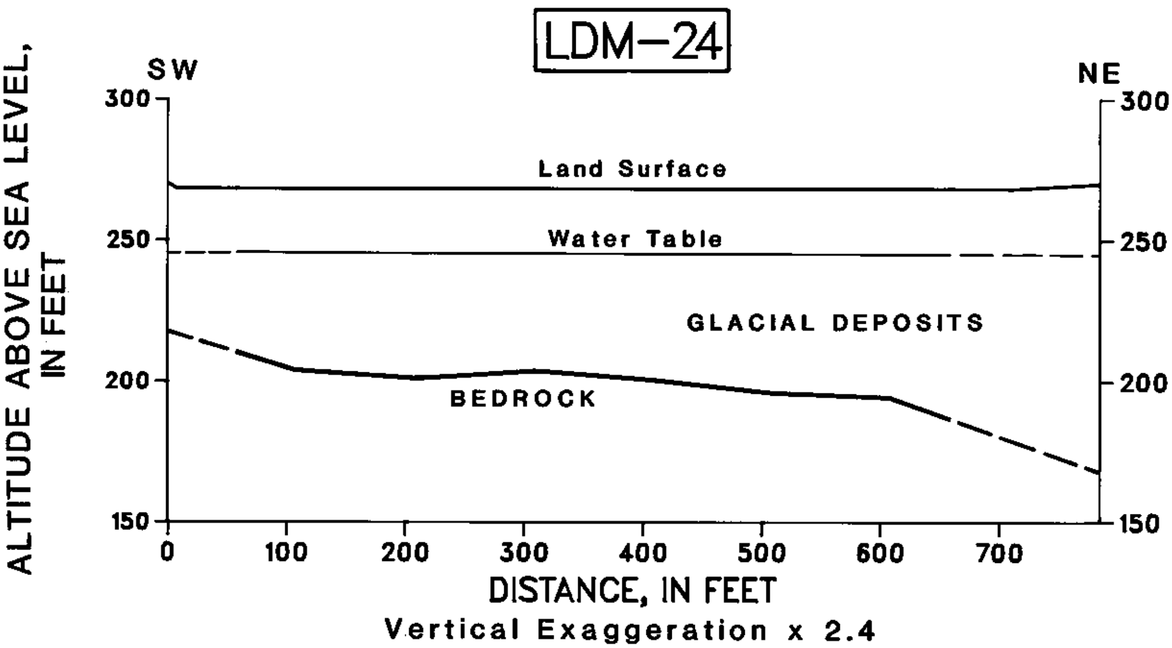

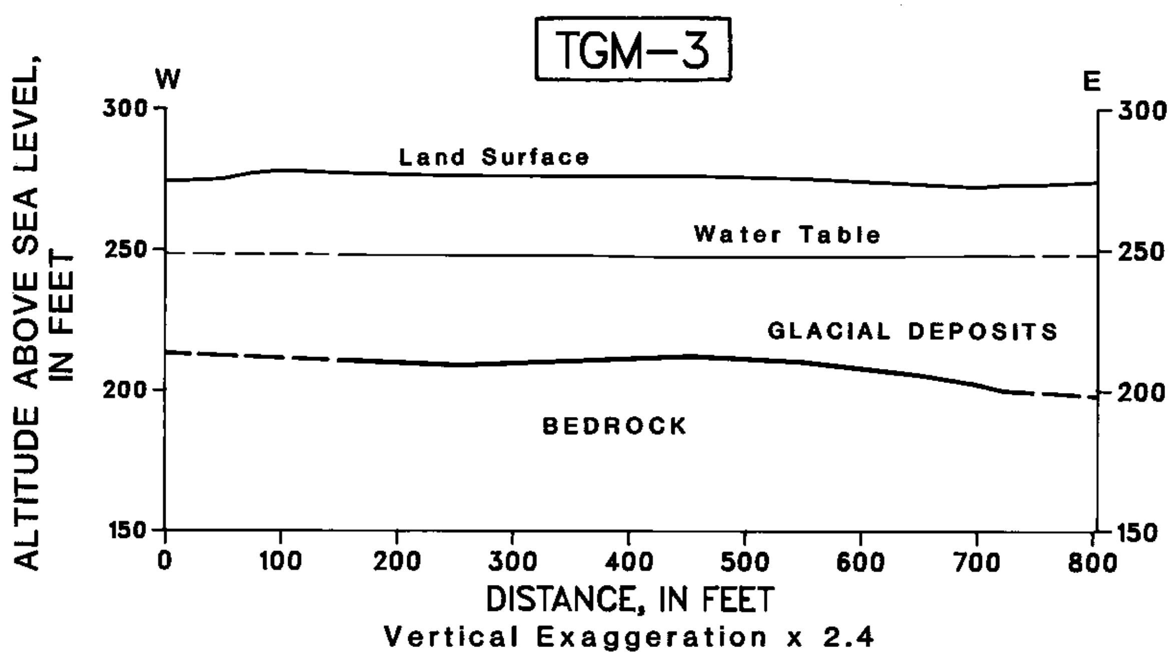

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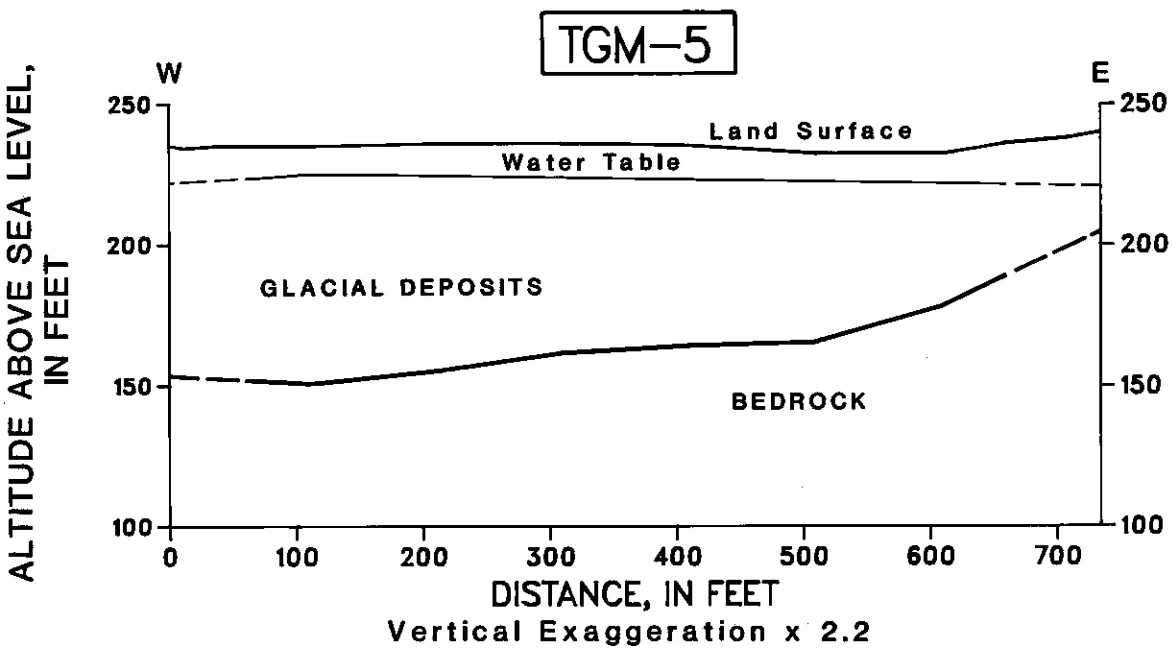

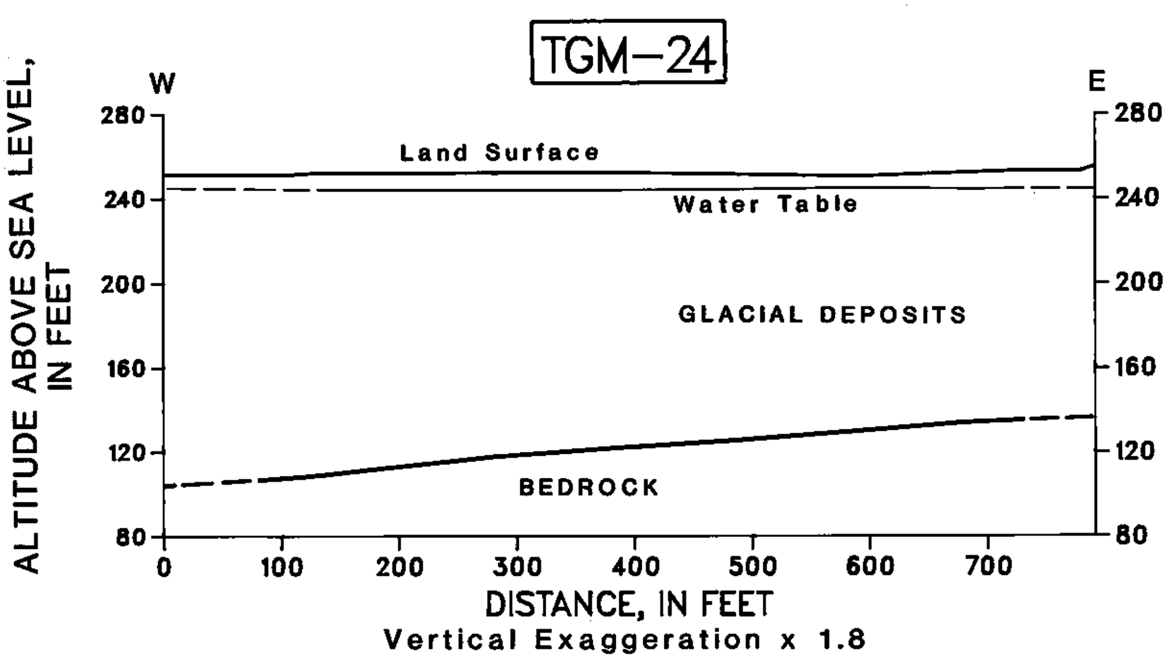

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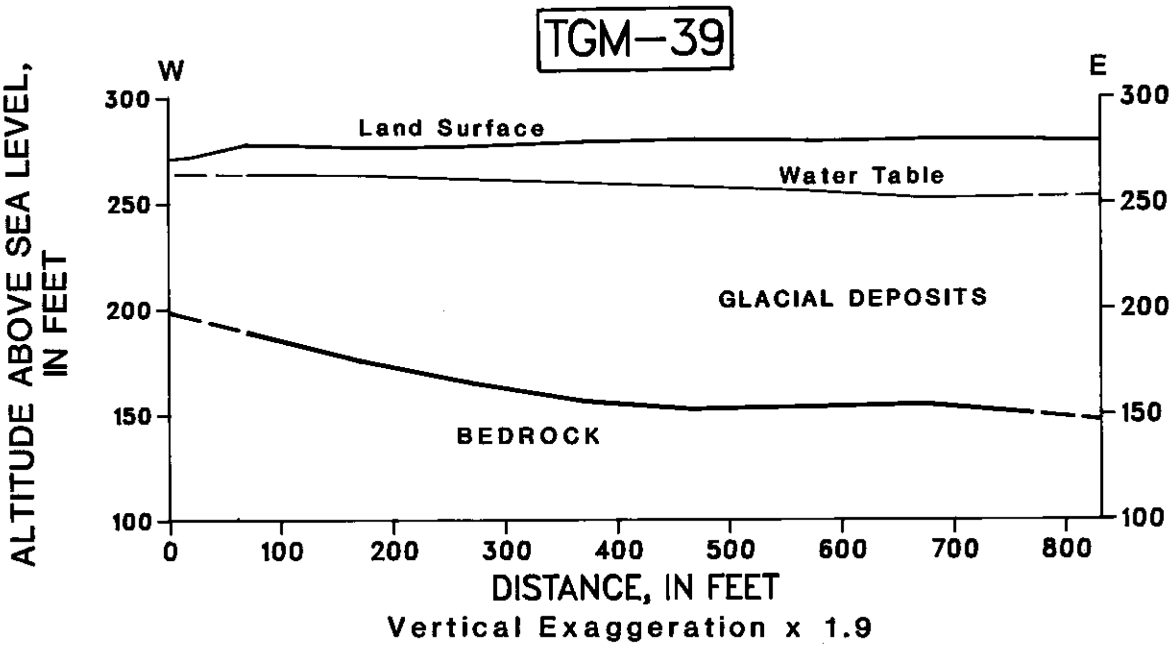

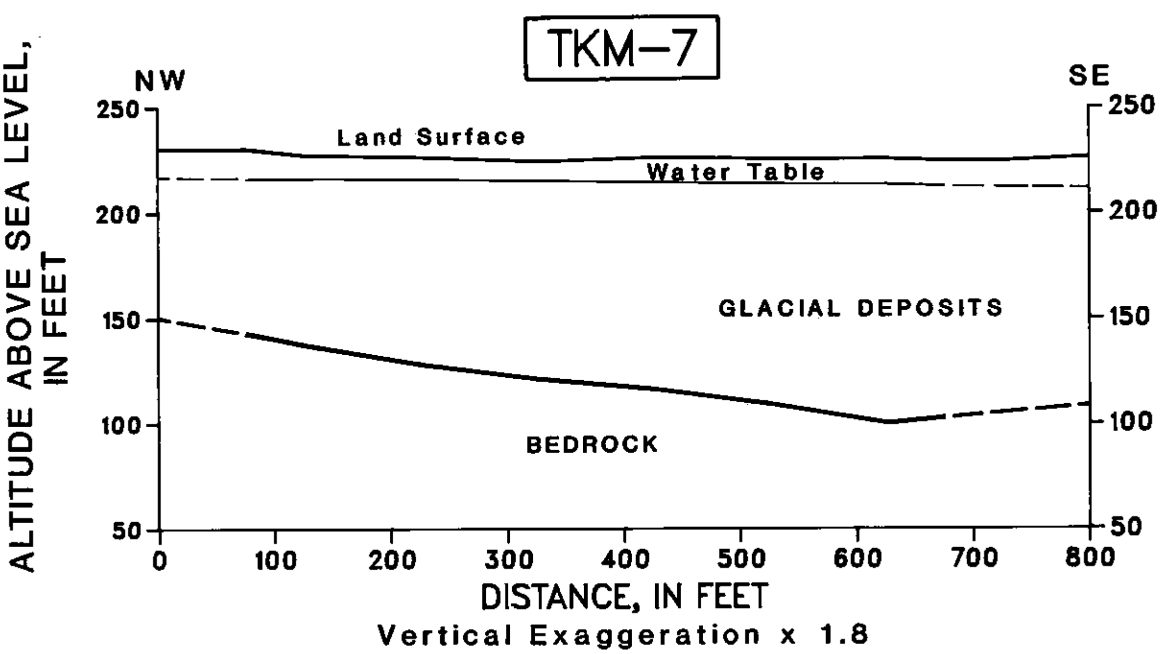

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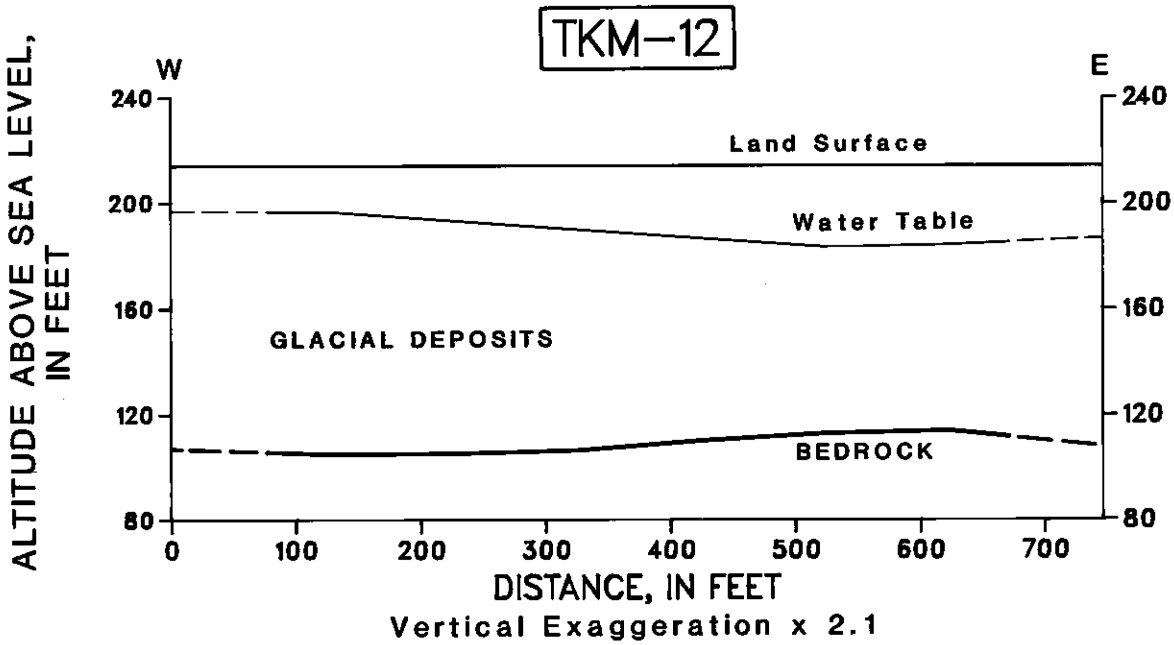
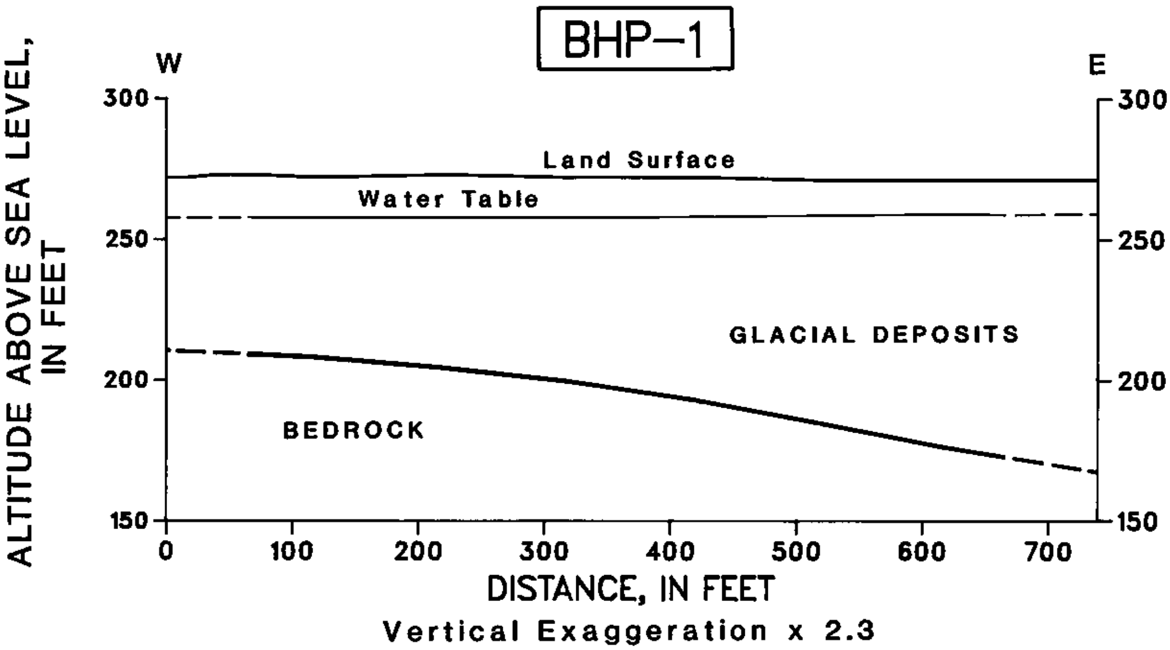
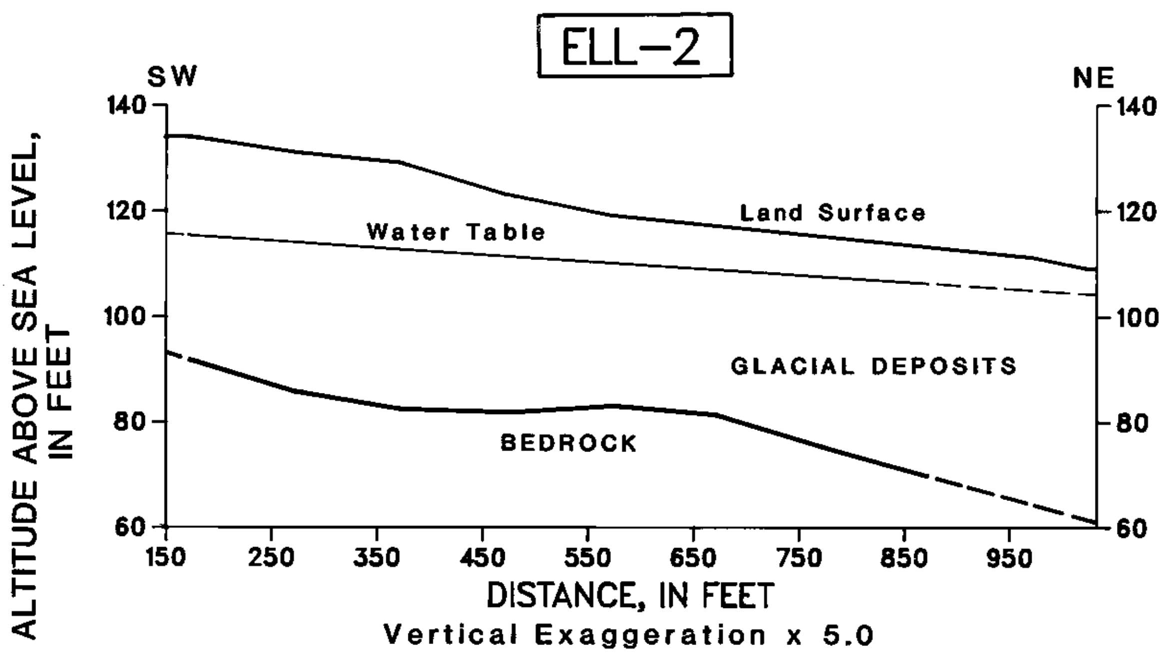


Figure 10.--12-channel seismic-refraction profiles: Plate 4, Map 27 Area

Hydrogeologic sections from seismic-refraction surveys conducted by the U.S. Geological Survey in 1985. Location of individual profiles are shown on plate 4. Data interpretation is based on a computer modeling program described by Scott and others (1972). Distances shown on the X-axes are measured from shot #1. In places, the altitude of the water table and bedrock surfaces have been shown with dashed lines. This is to emphasize the relative unreliability of this data.





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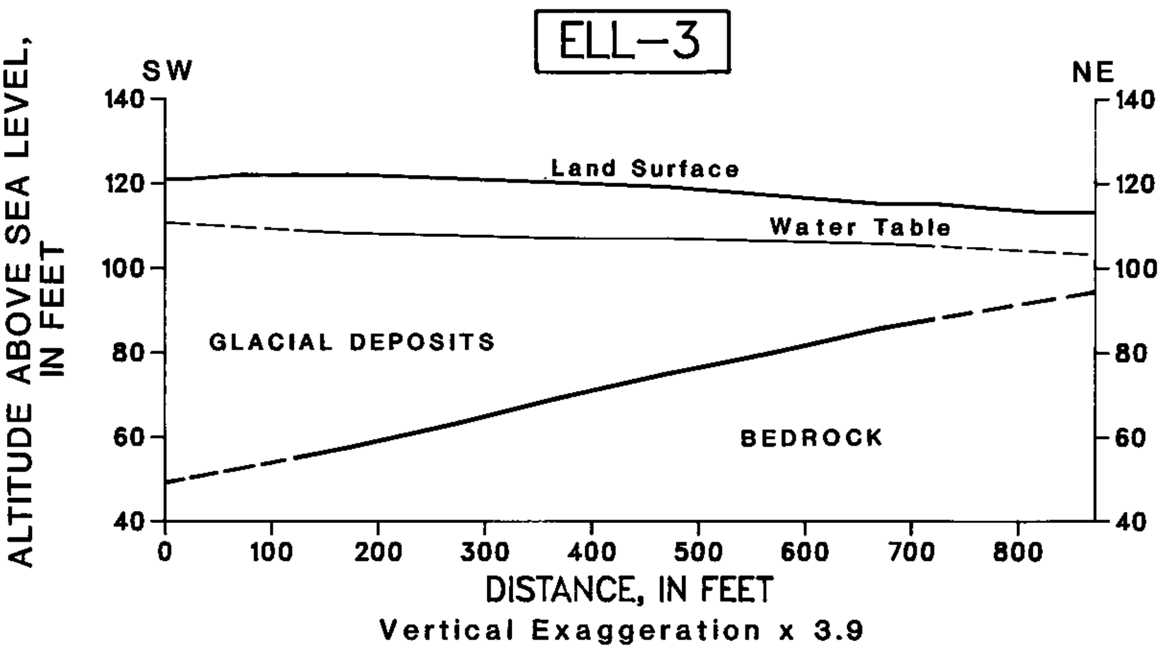

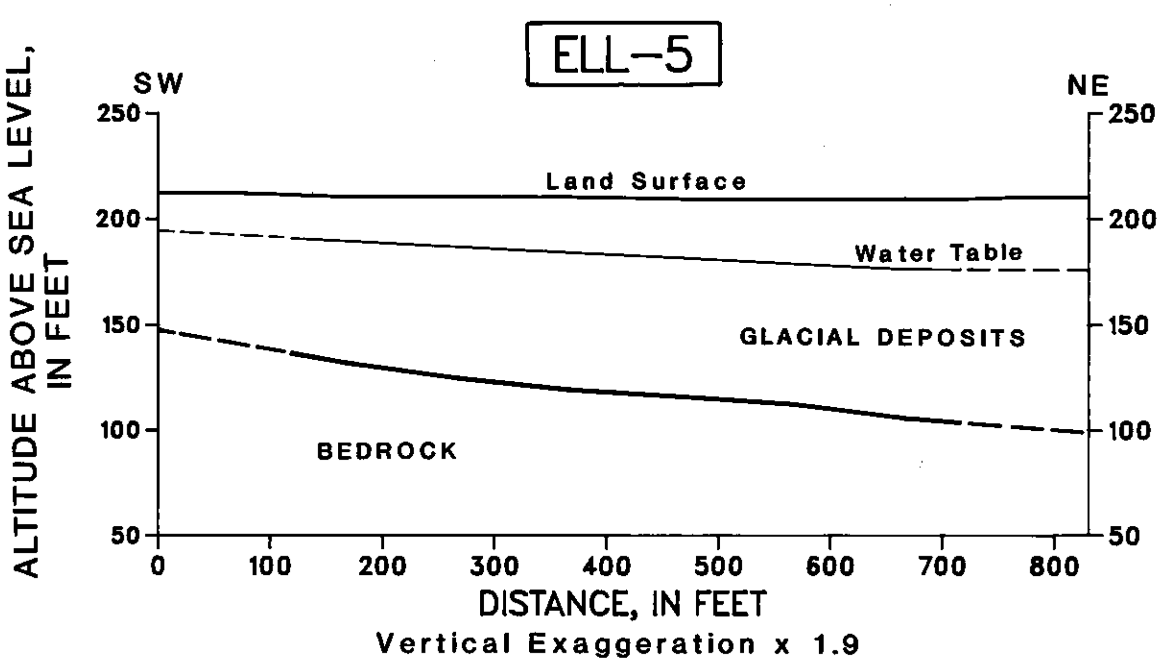

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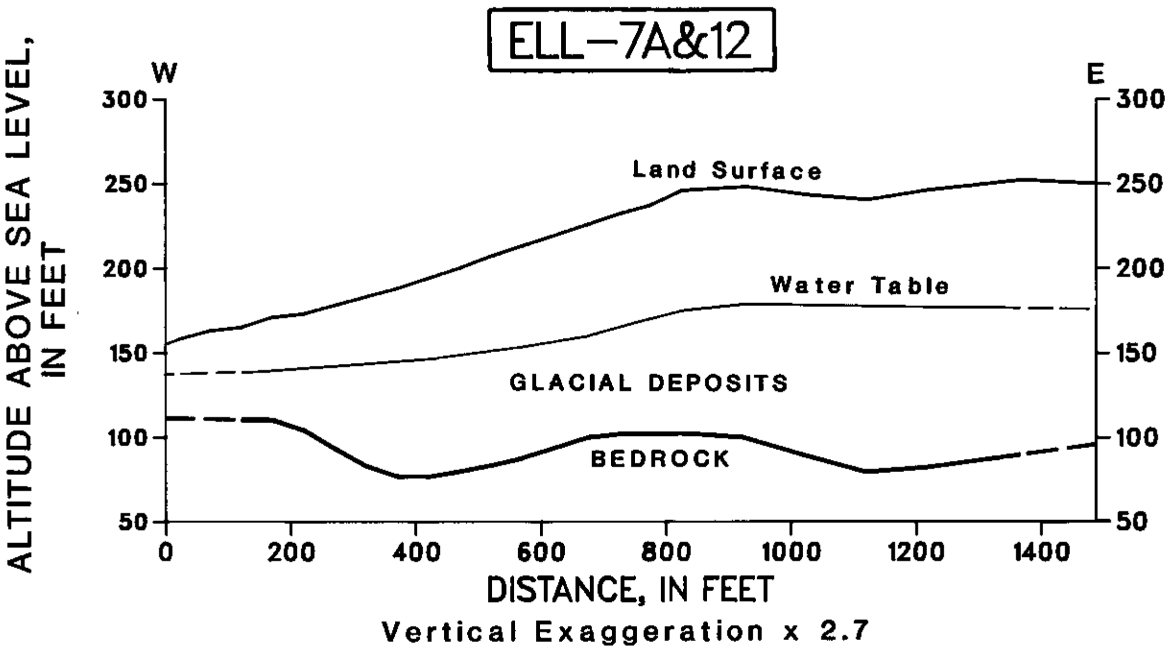

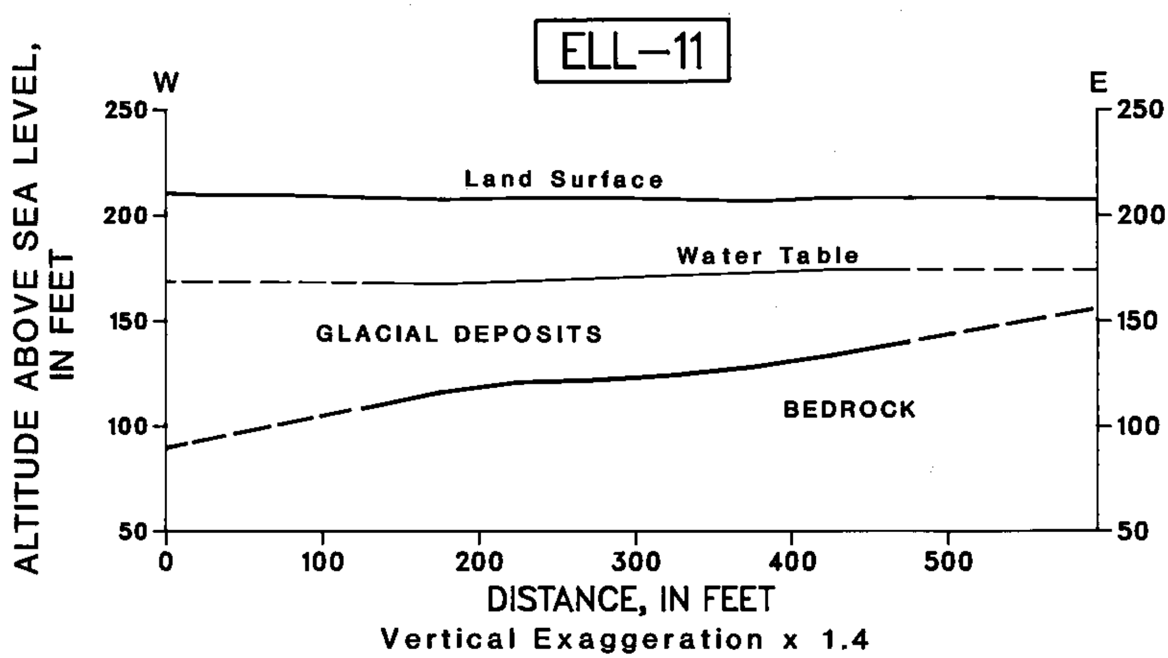

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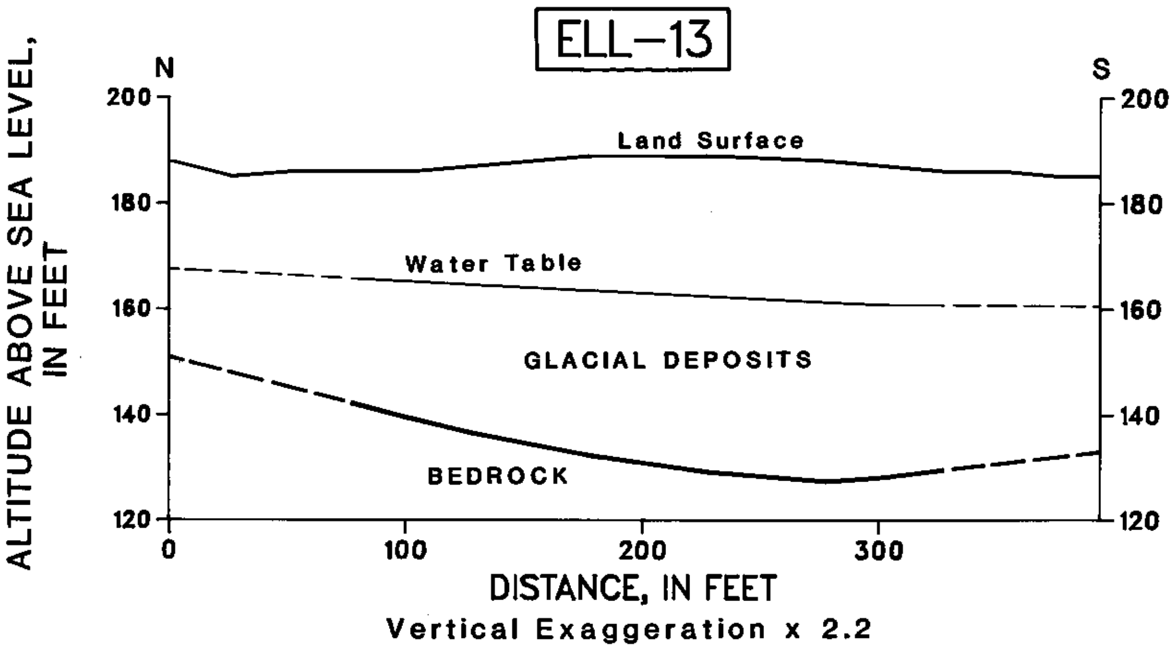

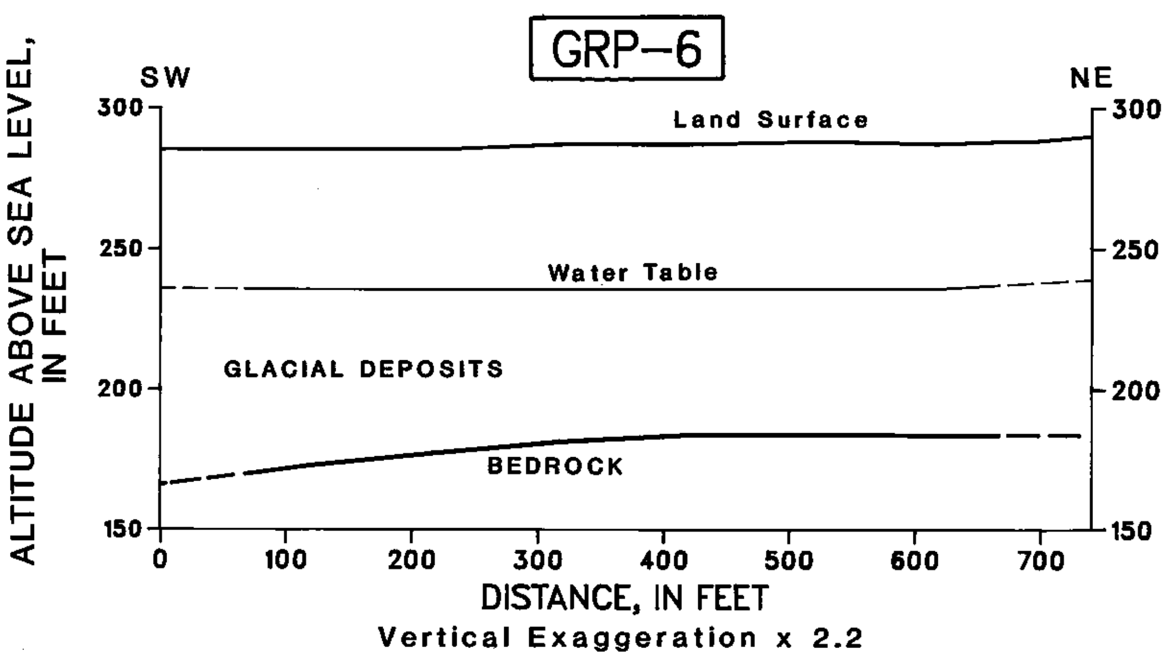

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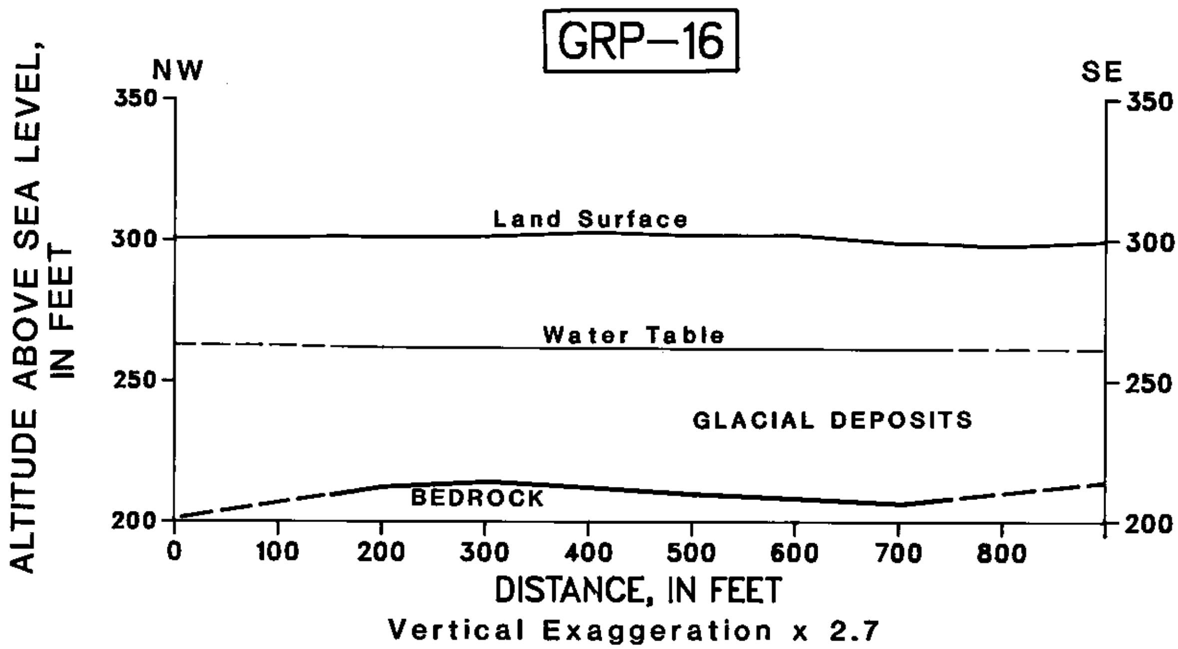

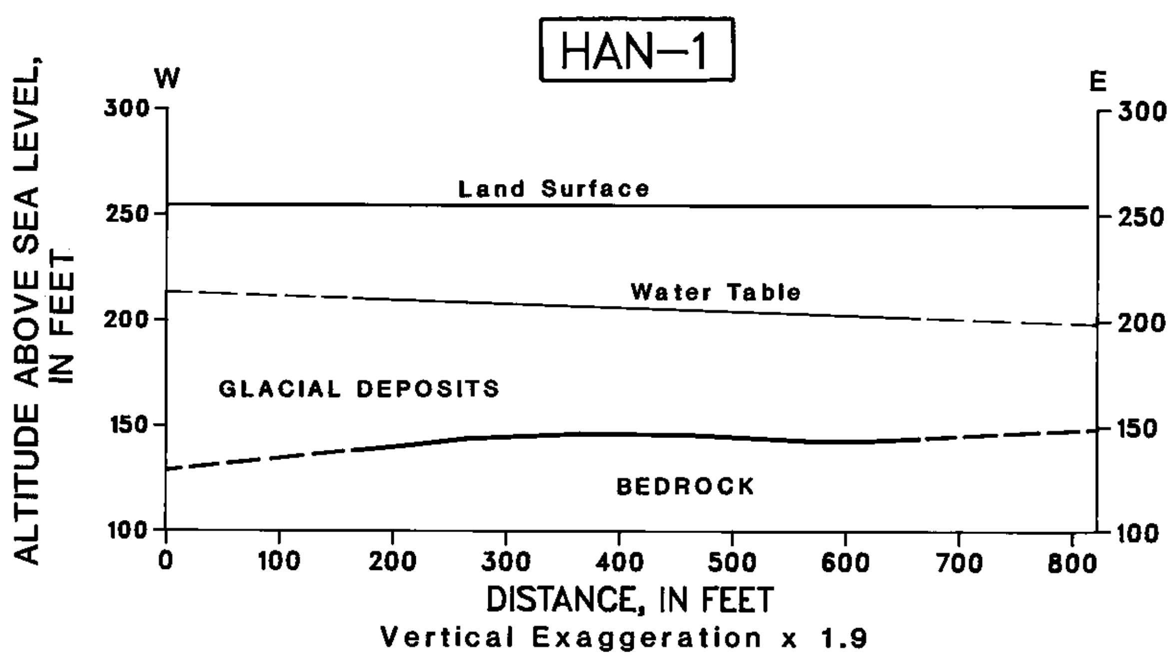

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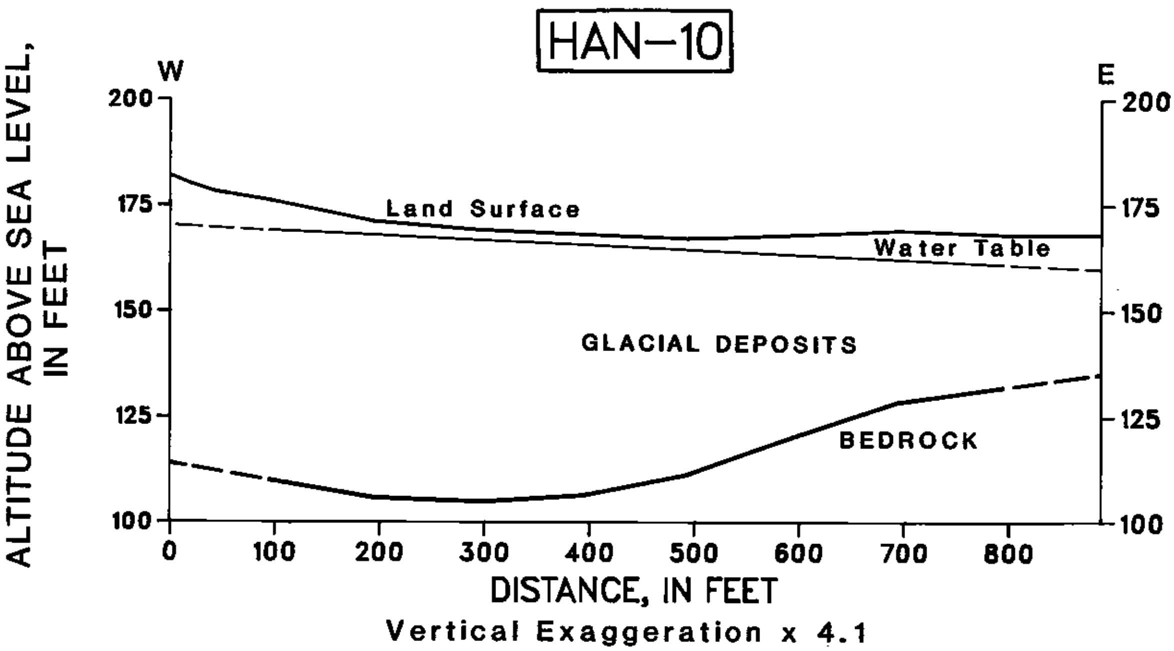

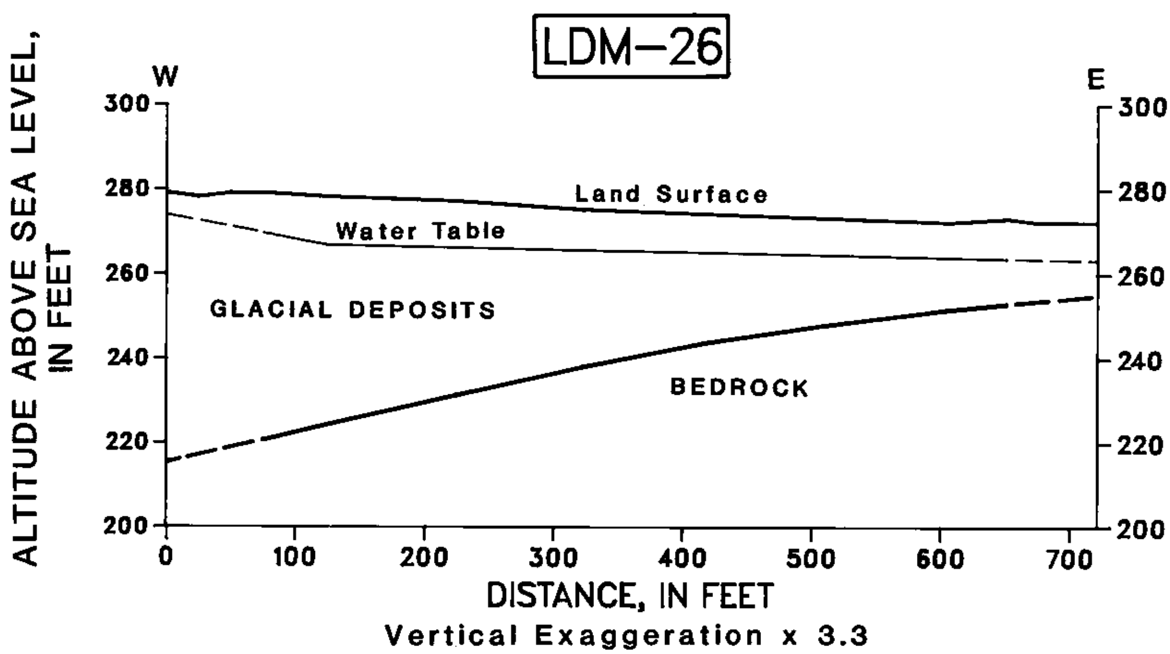

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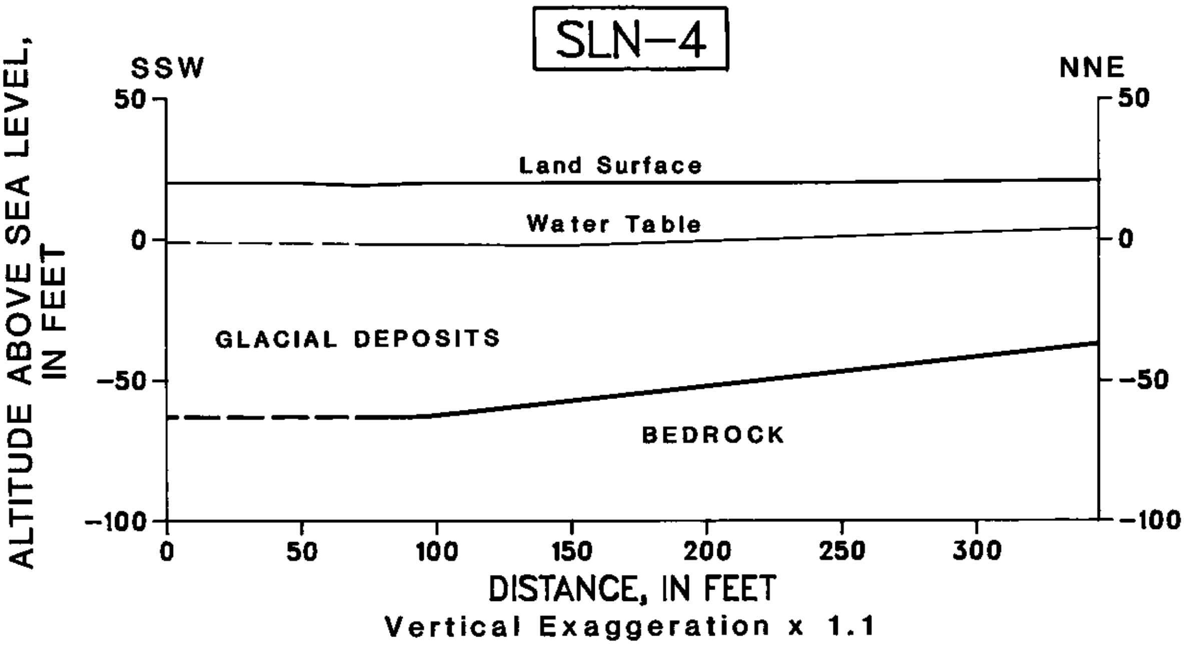
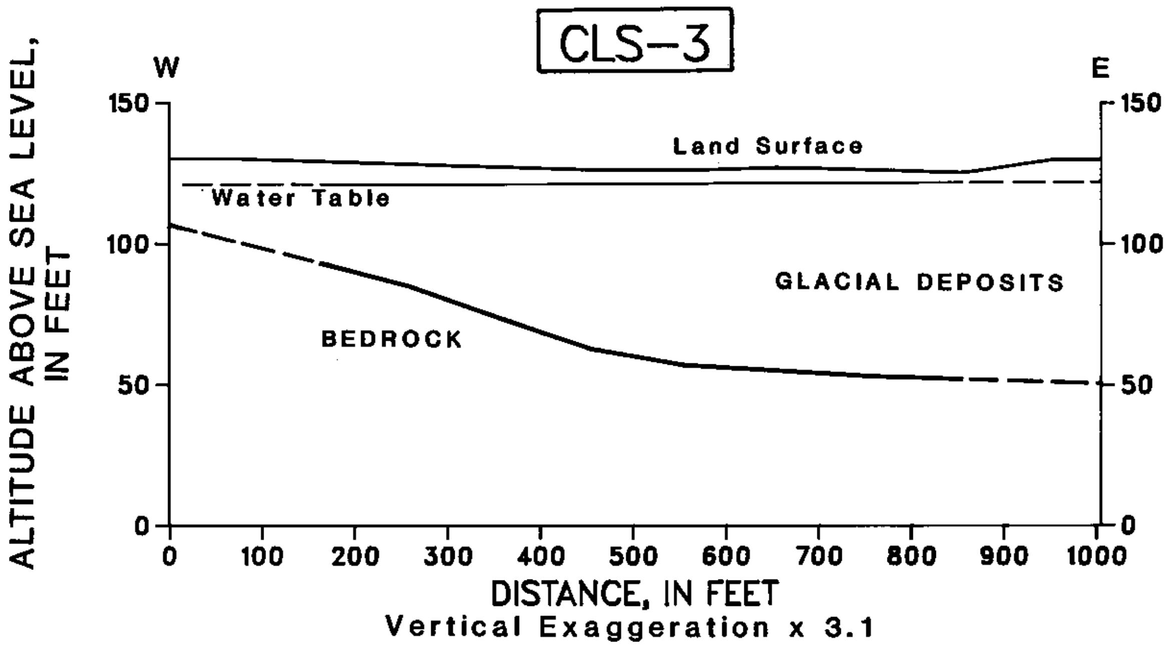


Figure 11.--12-channel seismic-refraction profiles: Plate 5, Map 45 Area

Hydrogeologic sections from seismic-refraction surveys conducted by the U.S. Geological Survey in 1985. Location of individual profiles are shown on plate 5. Data interpretation is based on a computer modeling program described by Scott and others (1972). Distances shown on the X-axes are measured from shot #1. In places, the altitude of the water table and bedrock surfaces have been shown with dashed lines. This is to emphasize the relative unreliability of this data.



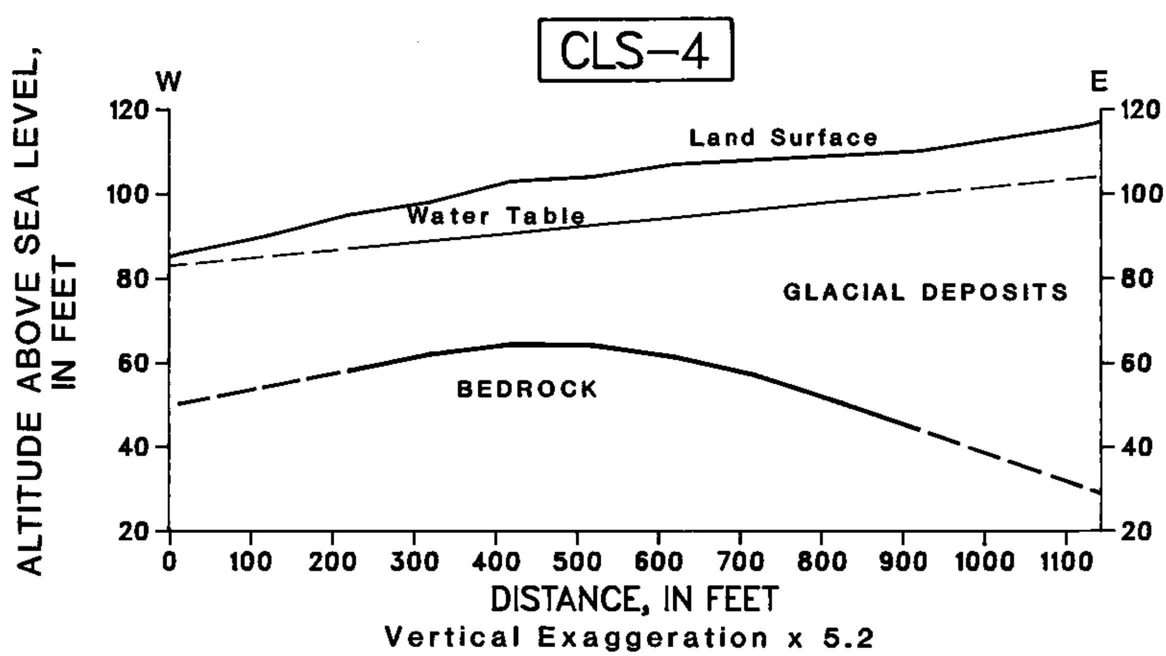
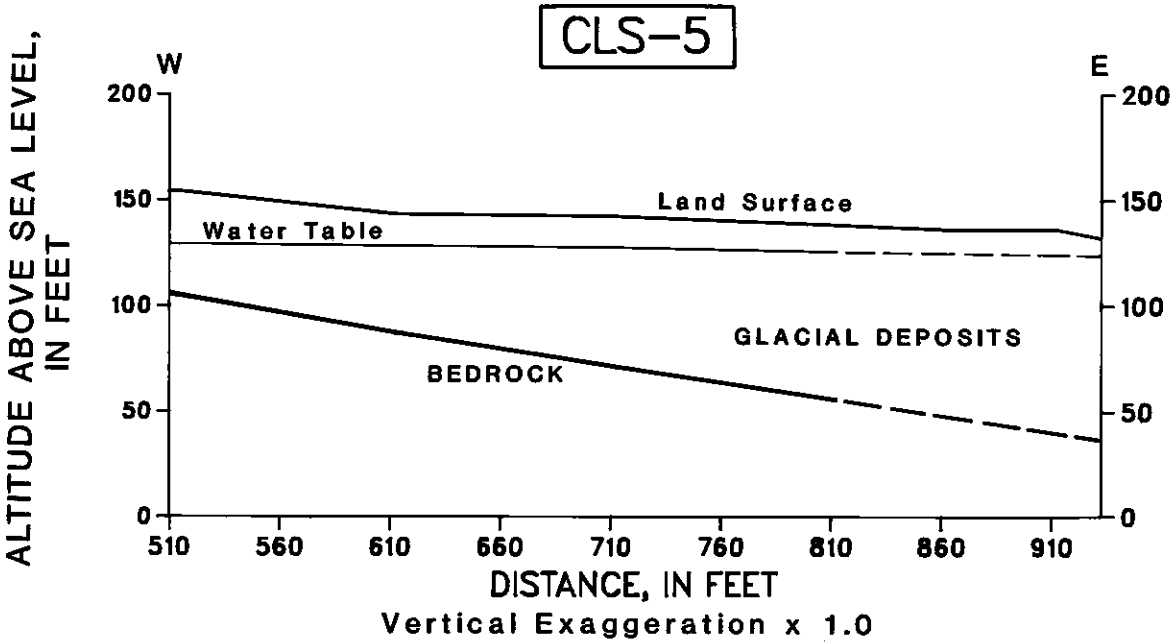


Figure 11. Continued.



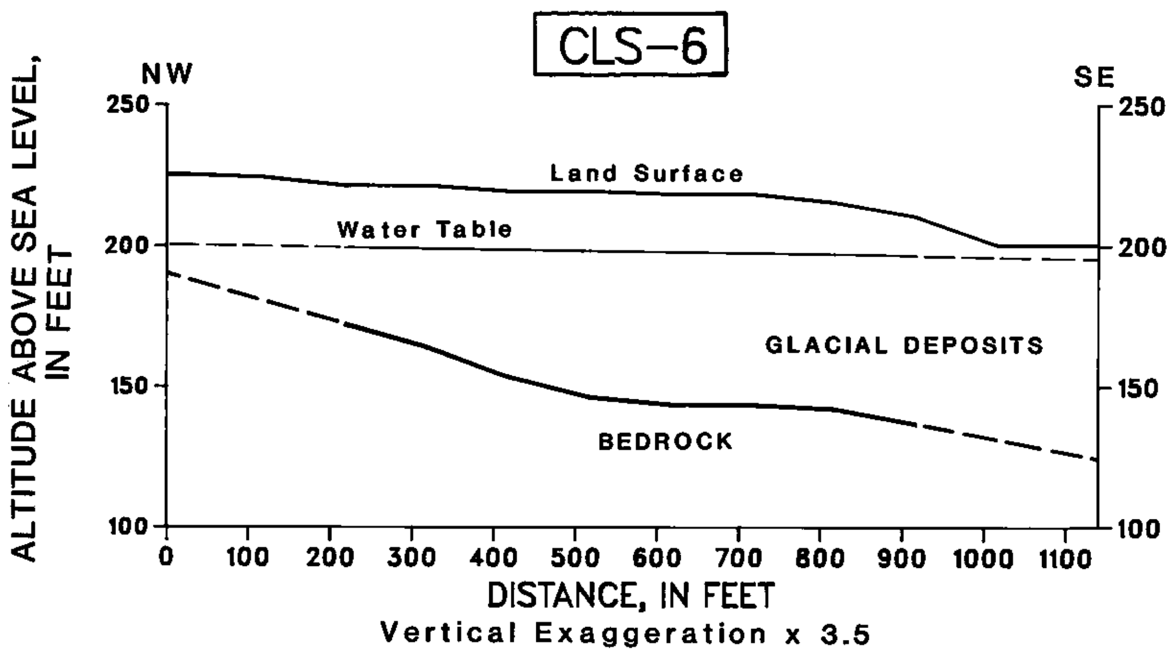


Figure 11. Continued.