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Hydrogeology and Water Quality of Significant Sand and Gravel Aquifers

in parts of Androscoggin, Cumberland, Oxford, and York Counties, Maine

Significant Sand and Gravel Aquifer Maps 12, 13, 14, and 15

by

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DEPARTMENT OF CONSERVATION

HYDROGEOLOGY AND WATER QUALITY OF SIGNIFICANT SAND AND GRAVEL AQUIFERS IN PARTS OF ANDROSCOGGIN, CUMBERLAND OXFORD, AND YORK COUNTIES, MAINE: SIGNIFICANT SAND AND GRAVEL AQUIFER MAPS 12, 13, 14, AND 15

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CONVERSION FACTORS AND ABBREVIATIONS

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

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

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

$$°F = 1.8°C + 32$$

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

HYDROGEOLOGY AND WATER QUALITY OF SIGNIFICANT SAND AND GRAVEL AQUIFERS IN PARTS OF ANDROSCOGGIN, CUMBERLAND, OXFORD, AND YORK COUNTIES, MAINE: SIGNIFICANT SAND AND GRAVEL AQUIFERS MAPS 12,13, 14, AND 15

By John S. Williams, Dorothy H. Tepper, Andrews L. Tolman, and Woodrow B. Thompson

ABSTRACT

Significant surficial aquifers, capable of yeilding more than 10 gallons per minute to a properly installed well, were mapped in 1640 square miles in Androscoggin, Cumberland, Oxford, and York Counties in Maine. The area is included in Maps 12, 13, 14, and 15 of the Sand and Gravel Aquifer Map Series, published by the Maine Geological Survey.

The significant aquifers consist of ice-contact, ice-stagnation and outwash deposits. Significant aquifers comprise approximately 200 square miles, but yields that exceed 50 gallons per minute are estimated to be available within only 2 percent of the study area. Typically, the water table is within 20 feet of the land surface. The greatest known depth to bedrock is 290 feet. The greatest known well yield is 1300 gallons per minute. The regional ground-water quality is slightly acidic to slightly basic; calcium and sodium are the most abundant cations; bicarbonate is the most abundant anion; and the water is soft. Locally, concentrations of iron and manganese are too high to use the water without treatment.

Sixty-six sites were identified as potential point-sources of ground-water contamination. Monitoring wells near four landfills had high levels of many dissolved inorganic chemicals, and detectable levels of several volatile organic pollutants. Domestic wells near many sand-salt storage areas have been found to have levels of sodium and chloride exceeding background values.

INTRODUCTION

Significant sand and gravel aquifers are often the only sources of ground water capable of supplying the large volumes of water needed by municipalities and industries in Maine. They are also the source of water for many domestic wells, and may serve as reservoirs that recharge 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 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 that restrict 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 MGS (Maine Geological Survey) and the USGS (U.S. Geological Survey), with funding from the DEP (Maine Department of Environmental Protection) and EPA (U.S. Environmental Protection Agency) conducted a reconnaissance-level investigation of sand and gravel aquifers over most of the State. This investigation, conducted from 1978 to 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 (figure 1).

The original sand and gravel aquifers maps provide a valuable source of information, but are limited in accuracy due to the large area studied in a short 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 so they provide more information on depth to bedrock, depth to water table, stratigraphy of the surficial deposits, 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. This new series of maps is referred to as the Significant Sand and Gravel Aquifer Map series.

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 initiated in June, 1981 by the MGS, the USGS, and the DEP. Mapping was initiated in southern Maine (Tolman and others, 1983; Tepper and others, 1985) and has continued throughout the state (figure 1).

Purpose and Scope

This report presents the results from the third year of the mapping project (1983 field season). The study updates the Sand and Gravel Aquifer Map Series for Maps 12, 13, 14, and 15 (Prescott and others, 1979 a, b; Prescott and Dickerman, 1981 a,b). These maps have been locally modified on the basis of new data, and are available with this report as plates 1-4, respectively.

The primary objective of this study is to identify locations that are most favorable for development of water supplies and, therefore, in most need of protection in the area covered by Significant Sand and Gravel Aquifers Maps 12, 13, 14, and 15 . A secondary objective is to identify areas where development may be limited by poor water quality or by the presence of possible sources of contamination. The report provides information that can be used for water-resources planning, development and management by municipal, regional, State and Federal agencies. Consultants and homeowners will also find the report and maps useful in location of water supplies.

The scope of the investigation includes:

- Surficial geologic mapping to define the boundaries of the sand and gravel deposits
- Seismic-refraction investigations to determine depth to water, depth to bedrock, and bedrock-surface topography
- Well inventory to supplement existing data on depth to water, depth to bedrock, and well yields
- Observation-well and test-boring drilling to determine aquifer stratigraphy, thickness, and grain-size (used to estimate transmissivity)
- Water-quality sampling and analysis to characterize the regional ground-water chemistry
- Identification of potential sources of ground-water contamination
- Location of municipal well fields

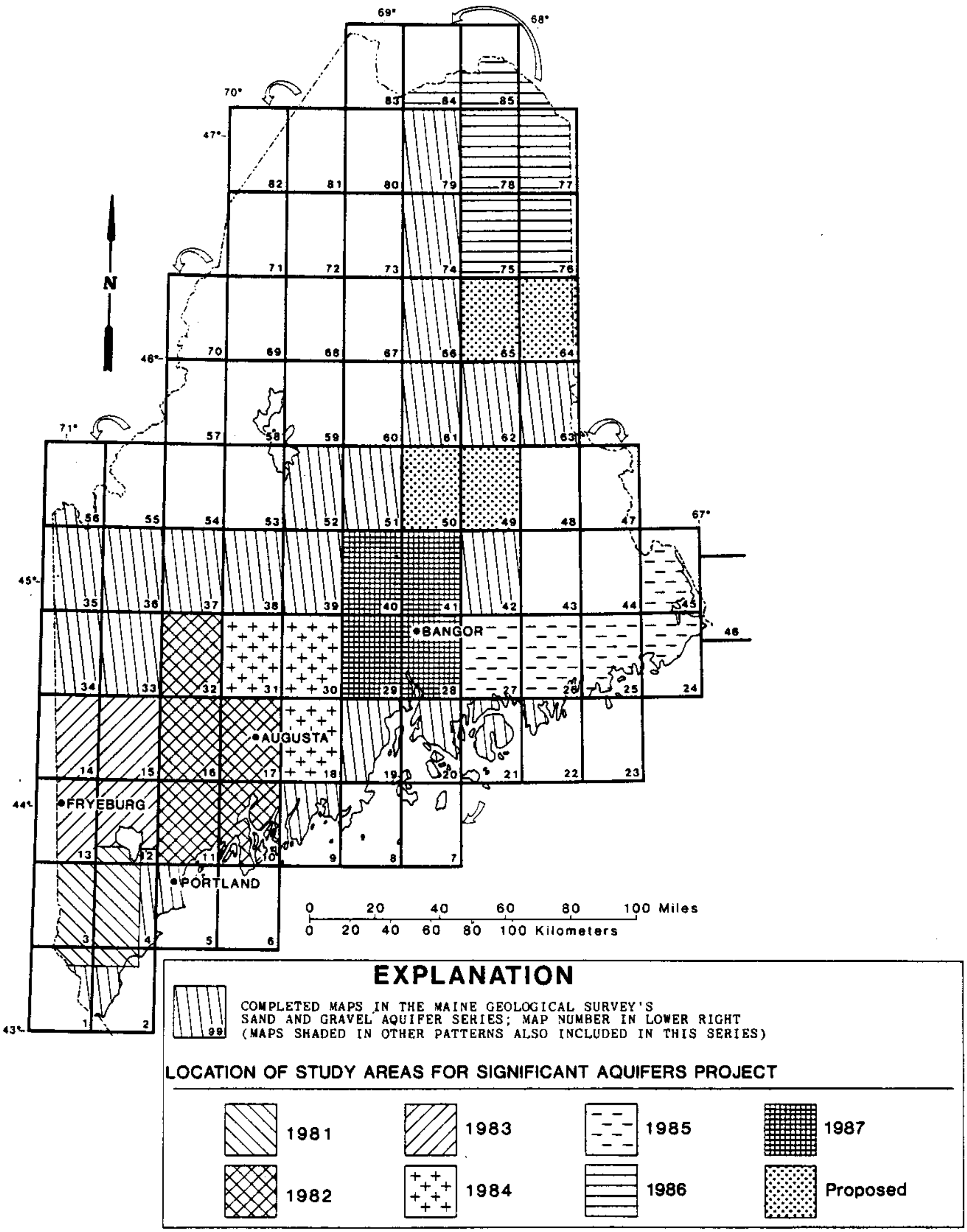

Figure 1. Location of study areas for Significant Aquifers Project.

Previous Investigations

Surficial geologic mapping conducted in the study area by the USGS, MGS, and others has provided information on the areal extent of glacial sand and gravel deposits (Prescott and Thompson, 1976; Thompson, 1976 a, b, c; 1977 a, b; Smith, 1977; Smith and Thompson, 1980; and Prescott and Drake, 1962). A series of hydrologic atlases and data reports (Prescott 1967, 1968a, 1976a,b, 1977, 1979, 1980a,b) include additional information on surficial geology, well depth, yield, ground-water levels, stratigraphy, estimated yield zones, and water quality.

These reports were used as a basis for Sand and Gravel Aquifer Maps 12-15 (Prescott and others, 1979 a,b; Prescott and Dickerman, 1981 a,b). Data collected for this study were added to information compiled on the original Sand and Gravel Aquifer Maps to produce plates 1-4.

METHODS OF STUDY

Approach

The approach used for this investigation was as follows:

1. Compile all existing hydrogeologic data onto each 1:50,000 scale map.
2. Collect information on existing domestic, municipal, and monitoring wells, boring logs, and test pits.
3. Identify sites of potential ground-water contamination.
4. Verify the original sand and gravel aquifer map boundaries by re-mapping surficial deposits.
5. Select locations for 12-channel and 1-channel seismic refraction lines, trying to obtain even distribution of data and fill in data gaps.
6. Conduct seismic refraction investigations.
7. Drill test borings and install observation wells at sites which appear to be good aquifers based on seismic data, which provide widespread areal coverage, and which are in suitable locations for water quality sampling.
8. Develop and then sample wells in the Fall.
9. Measure water levels in wells monthly.
10. Compile all data on 1:50,000 scale maps, and adjust aquifer boundaries as necessary.

Details concerning several of these steps are given below.

Identification of Sites of Potential Ground-Water Contamination

Potential ground-water contamination sites that are located on or near significant aquifers are shown on plates 1-4. These sites were identified primarily from files of the DEP Bureaus of Land, Water, and Oil and Hazardous Materials. The locations of State-owned salt-storage lots were determined from Maine Department of Transportation records. Letters were sent to town managers and local code-enforcement officers requesting their help in locating potential contamination sites. All site locations were field-checked.

The sites shown on plates 1-4 include most of the known major point sources of contamination. Non-point sources have not been shown. Non-point sources include malfunctioning septic systems, roads that are salted in the winter, manure piles and fertilized fields, and areas where pesticides are applied.

Surficial Mapping Techniques

Mapping of the significant aquifers was accomplished by determining the contacts between extensive sand-and-gravel deposits and non-aquifer materials such as till or bedrock outcrops. All known borrow pits and other exposures of sand and gravel deposits were examined, with particular attention paid to the thickness and textures of the deposits. Shovel and auger borings were used to identify surficial materials in areas where exposures were lacking. Mapping of off-road areas was conducted by traverses on foot in some places, and by examination of aerial photographs in others. Previously published maps and reports by the U. S. Geological Survey were utilized as a guide to field work (Prescott, 1967, 1968, 1979, 1980a, 1980b). Aquifer boundaries from a detailed study of the aquifer in the Little Androscoggin River valley (Morrissey, 1983) were incorporated in the compilation of Plates 1 and 4.

In compiling the boundaries of the significant aquifers shown on Plates 1-4, some of the land-surface contacts between the aquifers and surrounding materials were shifted slightly inwards towards the center of the aquifers to reflect the fact that the tapering margins of some of the sand-and-gravel aquifers are unlikely to have sufficient saturated thickness to yield 10 gal/min or more. Many pit exposures within the mapped aquifers do not intersect the water table. In these cases the aquifer has been mapped on the basis of the known or inferred saturated thickness at depth, confirmed where possible by well, test-boring, or seismic data.

Seismic-Refraction Investigations

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

A 12-channel EG&G Geometrics Nimbus ES-1210F seismograph 1/ was used to determine saturated thickness and bedrock surface topography in areas where the depth to bedrock was estimated to be more than 75 feet. The seismic lines vary from 220 to 1,100 feet in length. Several lines were run end-to-end to provide extended profiles over areas of particular interest. Altitudes of the shot points and geophones were surveyed where relief on the land surface exceeded 5 feet along the line. A computer program (Scott and others, 1972) was used to determine layer velocities and to generate a continuous profile of the water-table surface and the bedrock surface beneath each line. Wherever possible, data from nearby wells and test borings were used to verify the results.

A single-channel Soiltest MD9A seismograph was used in areas where the depth to bedrock was estimated to be less than 75 feet. Information was obtained on depth to water, depth to bedrock, and dip of the bedrock surface vary at each end of the lines, which varied from 100 to 200 feet long. Interpretations and analyses were done according to methods developed by Mooney (1980), and Zohdy and others (1974). These results were particularly

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

useful in defining aquifer boundaries. Seismic-refraction information was used to determine where the saturated thickness of sand and gravel deposits was too thin to yield 10 gal/min or more to wells. These thinly saturated areas were excluded from consideration as significant aquifers.

Drilling and Stratigraphic Logging Methods

Thirty-five exploration borings were drilled to obtain information on thickness and grain-size of the glacial sediments, and to verify seismic data on the depth to water table and depth to bedrock. For the purposes of this report, the term "test boring" refers to an uncased exploration boring. These borings were backfilled after test information was obtained. The term "observation well" refers to a cased exploration boring. The observation wells were used to obtain water-levels and samples for water-quality analysis during the period of investigation.

A hollow-stem auger drill rig was used for drilling. In this method of drilling, fluted auger sections 5 feet in length and 6 inches in diameter are rotated in the boring, new auger sections are added at the drill head as drilling progresses. 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 sediment samples ahead of the drill stem. Most wells were drilled to refusal, which may occur from contacting either bedrock or large boulders, however several did not penetrate the entire thickness of unconsolidated deposits because of depth limitations of the drill rig and time constraints. Exploration borings were numbered sequentially in the order in which they were drilled.

Observation-well Installation and Development

Thirty-two borings were cased with 2-inch, schedule 40 PVC (polyvinyl chloride) plastic pipe, so that water samples could be collected and water-level measurements could be made. PVC screens with slot widths varying from 0.006 to 0.015 inches were used. All casing couplings were fastened with 3/8-inch sheet metal screws rather than with PVC cement because the release of tetrahydrofuran from PVC cement can cause artificial increases in total organic-carbon concentrations, and thereby cause erroneous results in determinations of concentrations of volatile organic compounds (National Research Council, 1982). The casing and screen were emplaced inside the hollow stem auger and the boring was allowed to collapse around the casing as the drill stem was withdrawn. Bentonite pellets were backfilled from about 1.0 ft below ground level to ground surface, to prevent surface water from infiltrating around the casing.

Immediately after the casing was emplaced, water was pumped down the observation well to aid well development. Observation wells were more thoroughly developed 1 to 2 weeks before water-quality samples were taken, by removing at least five well-volumes of water using a PVC bailer or submersible pump.

Procedures for Water-Quality Sampling and Analysis

Thirty observation wells were sampled to determine water quality. Fifteen of these wells were near potential contamination sources; the remaining fifteen wells were in relatively pristine locations. To ensure that water samples were representative of the geochemical environment, the observation wells were pumped with a Johnson-Keck model SP-81 submersible pump or bailed with a PVC bailer until 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 399 A with a glass electrode for pH, Beckman Solu-Bridge for specific conductance). Alkalinity was measured in the field using Standard Method 403, subsection 4c-4d (American Public Health Association and others, 1976).

Unfiltered samples for nitrate, chloride, sulfate, and total organic carbon determinations were collected in plastic containers rinsed three times with sample water. Samples for dissolved-metal analyses were also collected in rinsed plastic containers. These samples were filtered and then acidified with nitric acid. Samples for volatile organic analyses were collected in baked glass vials which were rinsed with sample water before collection. These bottles were immediately sealed with no air space remaining to prevent loss of gases. Samples for pesticide analyses were collected in 1-liter amber glass jars rinsed with sample water. All samples were kept on ice and delivered to the DEP laboratories within 48 hours after collection.

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

HYDROGEOLOGY

Surficial Geology

Maine was covered at least twice by continental glaciers during the Pleistocene Epoch, which occurred from approximately 2,000,000 to 10,000 years ago. The last ice sheet advanced into Maine from eastern Canada about 25,000 years ago, in late Wisconsin time. The ice sheet flowed southeastward beyond the present coastline and into the Gulf of Maine.

As the glacier advanced, it eroded soil and rock debris and incorporated it into the ice. This material, which was 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 (lodgment or basal till) as the glacier advanced, and from melting ice (ablation till) as the glacier stagnated and retreated (Thompson, 1979). Till is a poorly sorted, usually nonstratified mixture of clay, silt, sand, gravel, and rock fragments. Its color, which is dependent on composition, texture, degree of oxidation, and moisture content, is typically olive-gray or olive. Most of the rocks in the till are of local origin.

Till is the oldest and most widespread glacial deposit in the study area. It is typically exposed in the uplands and is buried beneath younger deposits in the valleys. Much of the till in the study area is unweathered and is presumed to be of late Wisconsin age. However, a second, more weathered till, which is probably older, also crops out in several localities. Two tills are known to be superimposed near the southwestern shore of Keewaydin Lake in Stoneham (Thompson, 1985). The age of the lower till in the Stoneham exposure is not known because of the absence of dateable organic material, but it may be equivalent to the lowest stratigraphic unit (the New Sharon Till) exposed along the banks of the Sandy River in New Sharon, Maine (Caldwell, 1959). The New Sharon Till has been dated as older than 52,000 years (Borns and Calkin, 1977). This till and its possible correlatives in central and southern New England are generally believed to be at least as old as early Wisconsin, but may be the products of an even earlier (Illinoian) glaciation (Koteff and Pessl, 1985).

As the climate warmed, the ice melted faster than the rate of glacial advance, causing the glacial margin to recede. This recession probably began 15,000 to 14,000 years B.P. (before present) in the southwestern part of the Gulf of Maine (Tucholke and Hollister, 1973). The ice margin rapidly retreated and was slightly inland of the present coastline of southwestern Maine by 13,800 years B.P.(Smith, 1985). Central Maine was deglaciated by approximately 13,000 years B.P. (Thompson and Borns, 1985).

Marine transgression accompanied deglaciation of coastal Maine, and the ice retreat was accomplished in large part by calving of ice blocks into the open sea. This marine submergence occurred because the weight of the ice sheet caused the earth's crust to be depressed by several hundred feet. The crustal depression resulted in a marine invasion which flooded low-lying areas in southern Maine. Marine submergence was most extensive in the coastal lowlands but it also reached far into central Maine along the major river valleys. The present altitude of the marine limit rises from about 220 feet on the outer coast to nearly 425 feet at Bingham (Thompson and others, 1983). The glacial ice had been thicker to the northwest, so both the amount of crustal depresssion and the subsequent uplift that followed deglaciation were greater in that direction, causing the observed seaward tilt of the plane of marine submergence.

In places where there was a pause in the retreat of the glacial margin, ridges of sediment were deposited along the ice front. These ridges are called end moraines. They are typically composed of a mixture of sand and gravel and till. Most of the moraines in Maine were deposited in the sea, and some of them contain lenses of marine clay.

Inland from the limit of marine submergence, there are local concentrations of hummocky to ridge-shaped deposits which consist of chaotic mixtures of bouldery till, gravel, and sand. Some of the ridges resemble end moraines; and their poor sorting, coarseness, and sedimentary structures suggest that these deposits formed in an ice-marginal environment. They are tentatively identified as ice-stagnation deposits that were emplaced in disintegrating marginal zones of the late Wisconsin ice sheet. However, it is possible that flowage of active ice may have played a role in supplying the sediments from which these deposits were constructed. Good examples of the hummocky terrain occur north of Denmark village, along the southwest side of Moose Pond.

As the ice margin receded, a large amount of water was released. Streams formed by this meltwater picked up and transported great quantities of sediment which were deposited downstream in areas of slower water velocity. The coarser sediments accumulated in channels within or beneath the ice, between the ice and adjacent valley walls, and at or near the front of the glacier. This type of deposit is termed "ice-contact stratified drift", and is composed of sand and gravel. Characteristic ice-contact landforms include eskers, which are sinuous ridges; crevasse fillings, which are also ridges but are not as extensive as eskers; kames, which are irregular hills; kame terraces, which are terraces along a valley wall or hillside; and deltas, which are flat-topped hills. Outwash plains formed where meltwater streams deposited sand and gravel on valley floors in front of the glacier margin.

Many large deltas, which were fed by meltwater streams, were built into the sea where sand and gravel accumulated along the retreating margin of the ice sheet. Very fine-grained sediments that washed out of the ice sheet ultimately settled to the sea floor, often at some distance from the ice, forming extensive deposits of glaciomarine silt and clay. This material is referred to as the Presumpscot Formation (Bloom, 1960), or as marine clay. Although it is not highly fossiliferous within the study area, the Presumpscot Formation locally contains remains of shells, seaweed, spruce trees, and other terrestrial plants (Thompson, 1982).

The Presumpscot Formation commonly overlies deposits of till or sand and gravel in areas below the marine limit. However, it also may be interbedded with or overlain by sand and gravel. It typically fills valleys and may have a thickness of 100 feet or more. The Presumpscot Formation ranges from brownish gray to bluish gray. It is usually massive but does show stratification in some outcrops.

In the eastern part of the study area, particularly in the Little Androscoggin River valley (Map 15), the Presumpscot Formation is overlain by fine to coarse sand and small amounts of gravel. At least some of this sand was deposited in the sea, but it is much coarser than typical Presumpscot sediment. It may be glacial outwash that was deposited in shallow water during the regression of the sea (Thompson, 1982), or it may have been washed into the sea by postglacial streams that eroded previously deposited glacial sediments.

Temporary glacial lakes existed in valleys inland from the marine limit, where meltwater drainage was obstructed either by the surrounding topography or by dams composed of glacial sediments and/or stagnant ice. Some of these lakes were located in short valleys that sloped toward the ice margin, such as the north-trending tributary valleys of the Androscoggin River. Here the level of the ponded meltwater rose until it drained through gaps in the hills to the south. Other lakes developed along sections of major river valleys, such as the Saco and Androscoggin, where masses of ice or stratified drift temporarily blocked the drainage. Glacial lakes of this type formed in the Fryeburg and Bethel areas. Thick deposits of sand, silt, and clay accumulated on the floors of these lakes, and deltas were graded to lake surfaces in a few places. Much of the lake-bottom sediment is now concealed by younger outwash and postglacial alluvium, as in the vicinity of Fryeburg village.

As deposits of glacial sand and gravel were formed during ice retreat, strong winds swept across the valley floors, eroding great quantities of sand and redepositing it in dunes on the downwind (east) sides of the valleys. Sizeable deposits of windblown sand locally mantle the walls of the Saco, Androscoggin, and other river valleys in the study area. These sand dunes probably formed very soon after deglaciation, before the vegetative cover was sufficiently developed to prevent wind erosion.

Stratigraphy of Glacial Deposits

Based on field relationships, observation-well and test-boring logs (tables 8-11, at end of report), and interpretation of the geologic history, a generalized stratigraphic section for the study area is shown in figure 2. Not all of the units shown on this section will be found in any one place.

The deposits shown in the eastern valley on figure 2 are representative of water-laid glacial sediments that accumulated in the sea during the late-glacial marine transgression. These deposits include deltas (11) and marine silty clay, which is locally overlain by sandy outwash (10). In this and other valleys, the meltwater deposits may rest directly upon bedrock, or they may be separated from the bedrock by a layer of till.

The central valley shown in Figure 3 contains deposits that are typical of the Crooked River valley north of Sebago Lake (plate 1). Here the eskers and other ice-contact deposits are locally overlain by fine-grained glacial-lake sediments. The glacial deposits have been incised by postglacial stream activity, with deposition of stream-terrace and modern floodplain alluvium.

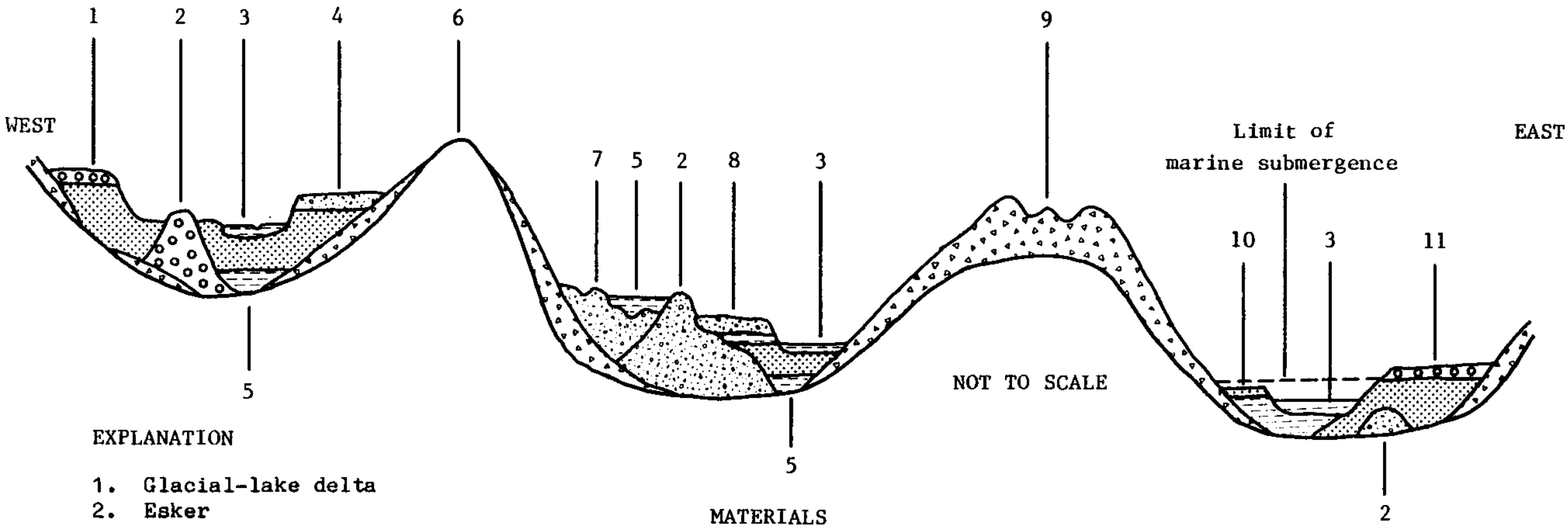
The western valley shown in figure 2 is a composite of the upper Saco and Androscoggin valleys and their tributaries where sand, silt, and clay were deposited in temporary glacial lakes. These lake sediments commonly have been covered by gravelly or coarse-sandy glacial outwash and stream-terrace alluvium, as well as modern flood-plain deposits.

Actual geologic sections from each of the map areas, based on seismic refraction and test-boring data, are shown in figures 3-6. Figure 3 shows a cross-section of a glacial-marine delta near North Windham (southeast part of plate 1). The surface gravel layer that is typical of most deltas is absent here, or perhaps has been removed. However, test boring 12-4 (table 8) penetrated a section that is representative of deltaic sediments that are coarser toward the ground surface. Note the absence of till at the bottom of this boring.

A section of glacial-lake sediments in the Saco River valley north of Fryeburg (near the north edge of plate 2) is shown in figure 4. The log from test boring 13-9 (table 9) reveals lake-bottom clay overlain by sand. The latter unit in turn is buried beneath fine-grained flood-plain sediments. Elsewhere in this part of the Saco Valley, sandy outwash covers the thick lake deposits. Till may occur at the base of the section, but its presence is speculative.

A section through another sequence of glacial-lake sands, located next to the Androscoggin River in West Bethel (northern part of plate 3) is shown in figure 5. This deposit is finer-grained at depth, and may be a delta that was built into the Pleasant River valley just south of here. It is probably underlain by till, which occurs abundantly on nearby hillsides.

Figure 6 shows a section through a thick sand deposit in the Crooked River valley in Waterford (southwest part of plate 4). This sequence appears to be yet another glacial-lake deposit, though an upper portion of undetermined thickness may be outwash. The log from test-boring 15-1 (table 11) indicates that till is present between the sand and underlying bedrock.



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

- Pebble to boulder gravel
- Sand and gravel (in varying proportions)
- Sand
- Fines (very fine sand, silt, clay)
- Till
- Bedrock

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

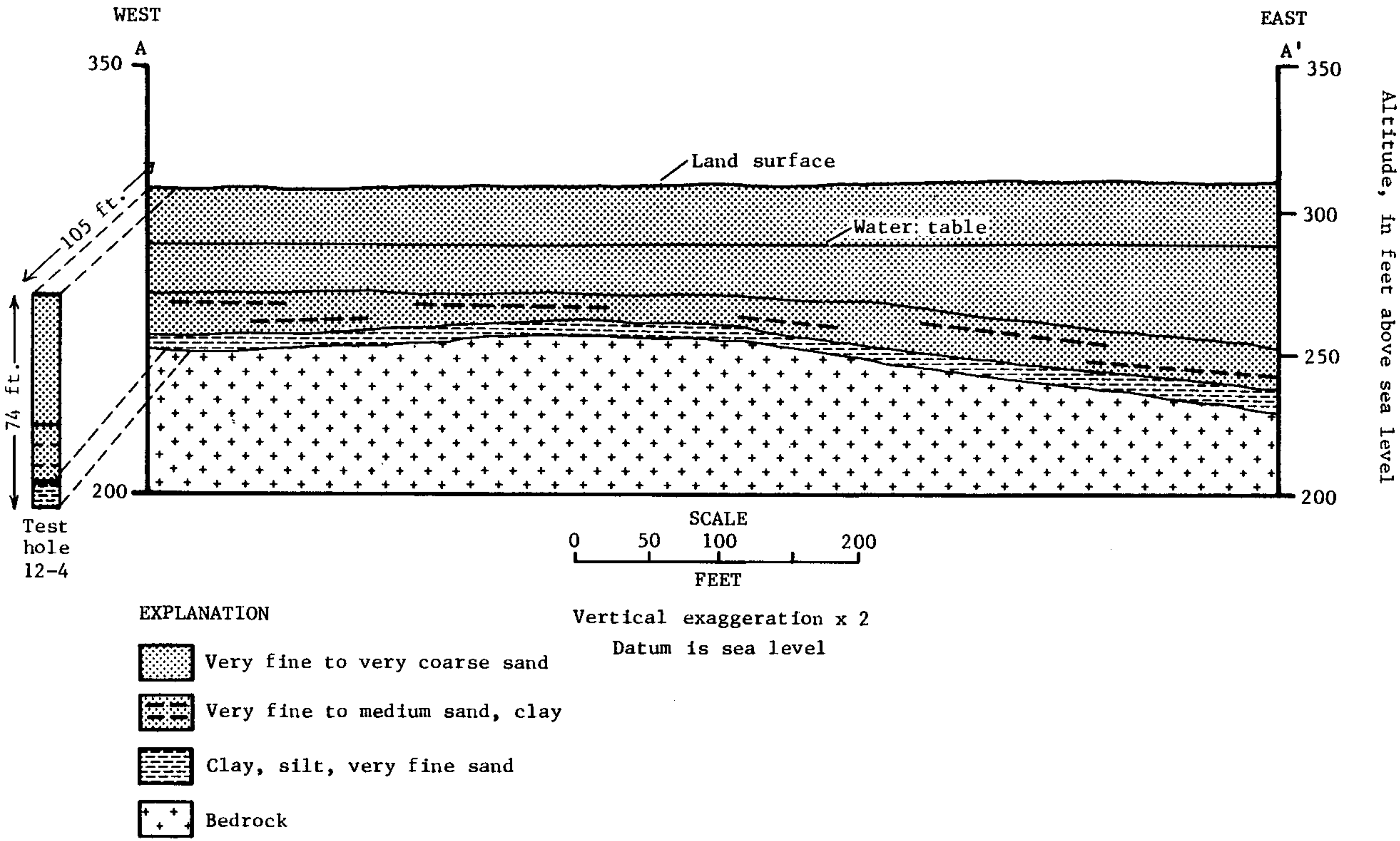


Figure 3. Geologic section along A-A' shown on Plate 1. The profiles of the water table and bedrock surface are based on data from seismic line NWI-4. Test hole 12-4 is located approximately 100 feet south of the seismic line. The stratigraphic relationships in the test hole have been extrapolated to the plane of the cross-section.

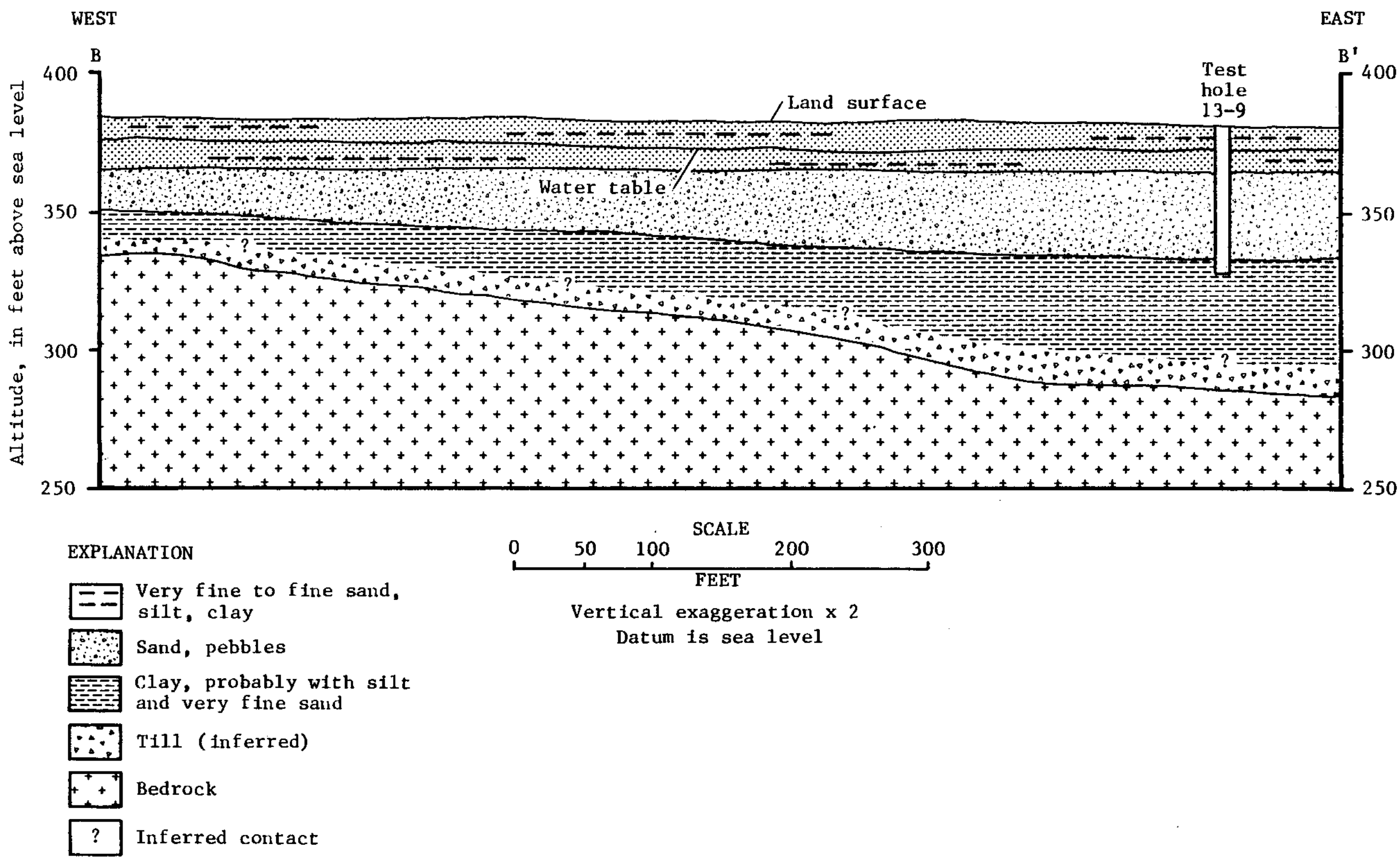


Figure 4. Geologic section along B-B' shown on Plate 2. The profiles of the water table and bedrock surface are based on data from seismic line FR-8B. Test hole 13-9 is located approximately 300 feet north of the seismic line. The stratigraphic relationships in the test hole have been extrapolated to the plane of the cross-section.

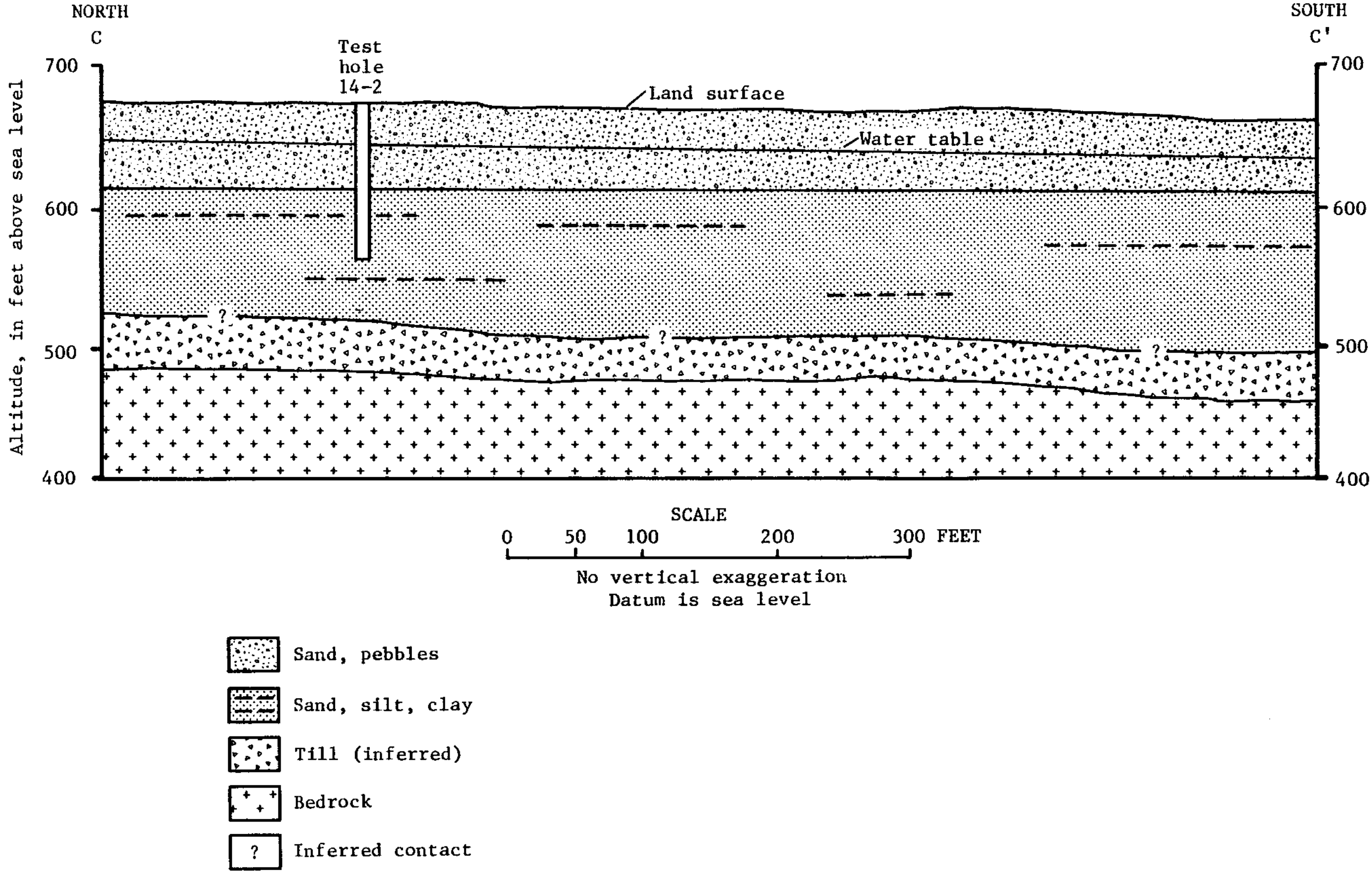


Figure 5. Geologic section along C-C' shown on Plate 3. The profiles of the water table and bedrock surface are based on data from seismic line BET-5B. Test hole 14-2 is located approximately 30 feet east of the seismic line. The stratigraphic relationships in the test hole have been extrapolated to the plane of the cross-section.

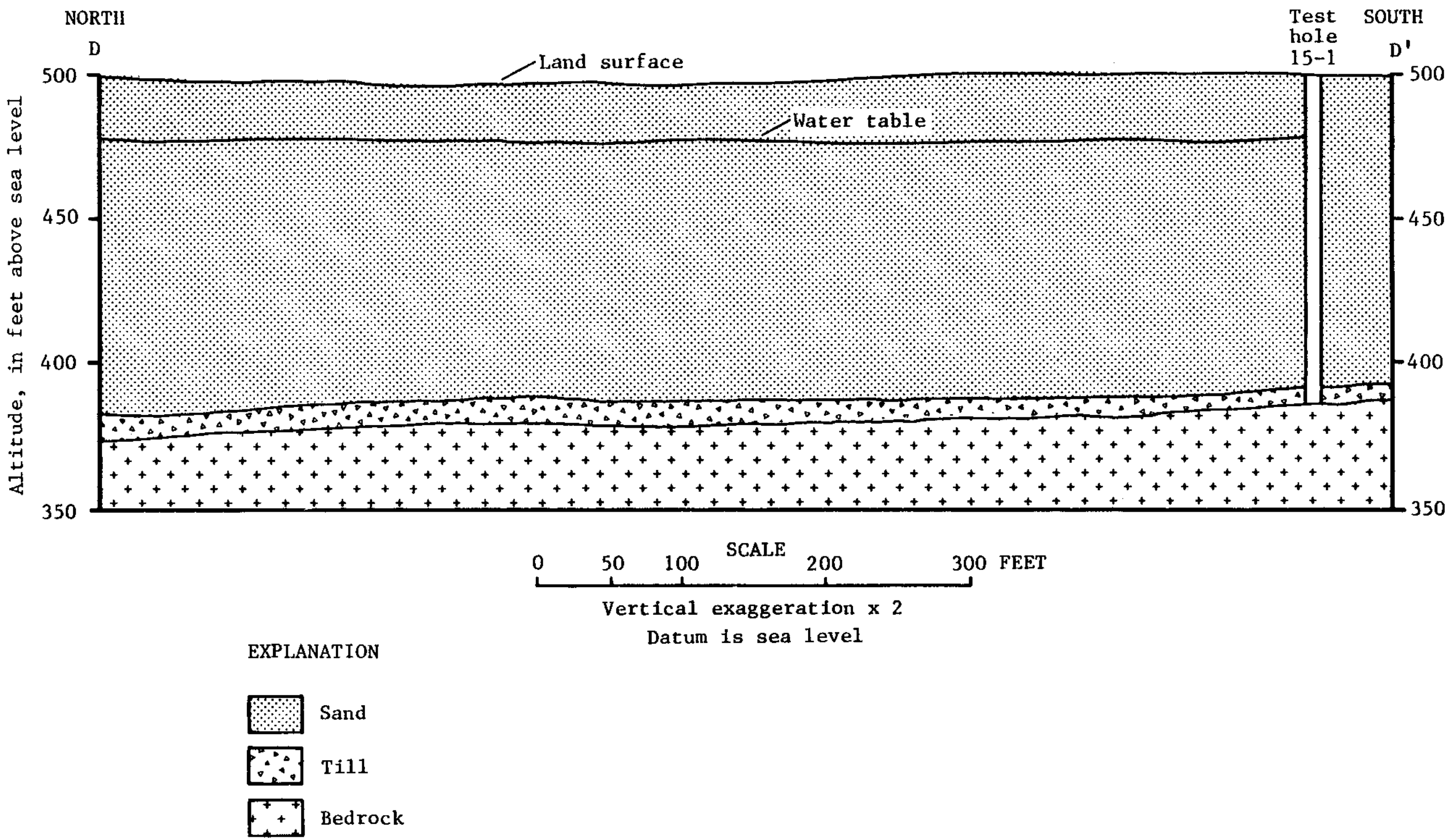


Figure 6. Geologic section along D-D' shown on Plate 4. The profiles of the water table and bedrock surface are based on data from seismic line NOR-2. Test hole 15-1 is located approximately 500 feet west of the seismic line. The stratigraphic relationships in the test hole have been extrapolated to the plane of the cross-section.

Hydrology of the Significant Sand and Gravel Aquifers

The significant sand and gravel aquifers consist of ice-contact, ice-stagnation, and outwash deposits which occur primarily in the valleys of the major river systems and their tributaries or near other surface water bodies that can serve as sources of recharge. The aquifer boundaries and estimated yield zones shown on plates 1-4 are based on available information and are subject to modifications as additional data become available.

The major aquifers are located in valley-train deposits associated with the Androscoggin and Little Androscoggin Rivers. The highest yields are obtainable from wells constructed in areas where coarse-grained deposits, commonly eskers, are located in proximity to these rivers or to lakes.

The most productive and most developed aquifer system is located along the Little Androscoggin River in the Poland-Paris area. More information about this aquifer is available in a modeling study performed by the USGS and MGS (Morrissey, 1983). The highest reported yield in the area, 1300 gal/min, is from a well in this aquifer operated by the Norway Water District

Hydraulic Properties

Hydraulic Conductivity

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

Because the hydraulic conductivity depends, in part, on the size, shape, and arrangement of sediment particles, it is best measured directly in the field on an undisturbed section of aquifer. When field measurements are impractical, the hydraulic conductivity of the aquifer material can be estimated in the laboratory. The mean particle diameter (in millimeters) and the degree of sorting of representative observation-well sediment samples were determined by grain-size analyses. These analyses were performed at the USGS laboratory in Harrisburg, Pennsylvania, using a dry sieve method (Folk, 1974). The results of these analyses (table 1) were used to estimate hydraulic conductivity, using nomographs published by Masch and Denny (1966). Those nomographs relate mean grain size and degree of sorting to hydraulic conductivity. The estimates, shown on table 1, are comparable with those of Morrissey (1983) for outwash sands (15-80 ft/d). They are, however, lower than his estimates for coarse-grained ice-contact materials (150-200 ft/d).

Transmissivity

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

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

Sample description	Observation-Well	Depth of interval sampled (feet)	Median Diameter phi 1/	Degree of sorting 2/	Estimated hydraulic conductivity (feet/day)3/
Coarse silt	14-7	11	4.1	poor	10
Very fine sand	12-2	21-23	3.6	moderately well	15
Fine sand	12-4	21	2.4	poor	17
Very fine to fine sand	14-7	26	3.0	moderately well	20
Fine sand	12-3	16-18	2.4	well	27
Fine to medium sand	14-8	6	2.0	moderate	30
Medium sand	12-1	53-55	1.5	moderate	50
Medium to very coarse sand	14-5	16	1.7	moderate	54
Medium to coarse sand with some fines	14-3	11-16	0.7	poor	54
Medium to coarse sand	12-3	6	1.2	moderate	60
Medium to coarse sand	13-5	21	0.5	poor	60
Coarse to very coarse sand	12-2	66-68	0.2	poor	60
Coarse sand	12-5	21	0.5	poor	77
Coarse sand with some fines	12-1	41	0.5	moderate	94
Coarse to very coarse sand with some fines	13-9	16-18	-0.4	poor	100
Very coarse sand	14-6	76-78	-0.7	poor	100

1/ phi is the negative log (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 Denney (1966)

Approximate transmissivities of sand and gravel aquifers were calculated at 31 sites from the stratigraphic logs of observation wells using the following method. Sediment from each interval in the saturated portion of each observation well (tables 8-11 at end of report) was assigned a value of hydraulic conductivity estimated from relationships given in table 1. This hydraulic conductivity value was multiplied by the interval thickness to obtain an approximate interval transmissivity. The interval transmissivities were summed to give a total transmissivity for that part of the aquifer penetrated by the observation well. The transmissivities are presented in table 2. Fourteen of the sampled observation wells did not penetrate the entire aquifer thickness. Aquifer transmissivities at these wells were calculated based on the known materials; actual transmissivities may be higher.

Depths to the Water Table and Bedrock Surface

Depths to the water table and bedrock surface in the significant sand and gravel aquifers have been determined from seismic refration investigations, well inventory, observation-well and test-borings, mapping of bedrock outcrops, and previous investigations. In the significant sand and gravel aquifers the water table varies considerably, but is typically within 20 feet of the land surface. Based on seismic data, the greatest depth to bedrock, which was encountered in the Fryeburg area, is 290 feet.

Seismic-refraction techniques were used extensively to determine both depth to water table and depth to bedrock. In the study area, the velocity of sound in unsaturated sand and gravel ranged from 700 to 1,500 ft/s, with an average velocity of 1,100 ft/s. Saturated sand and gravel had velocities ranging from 4,300 to 5,700 ft/s, with an average velocity of 5,000 ft/s. Till had velocities ranging from 6,000 to 9,000 ft/s, with an average velocity of 7,500 ft/s. Bedrock in the study area had seismic velocities ranging from 12,000 to 28,000 ft/s, with an average velocity of 16,600 ft/s.

A summary of the information collected with the single-channel seismograph is presented in table 3. Hydrogeologic sections from seismic-refraction surveys conducted with the 12-channel seismograph are presented in figures 8-11 (back of the report). The locations of the 74 single-channel lines and the 87 twelve-channel lines run in the study area are shown on plates 1-4.

Determinations of depths to the water table and bedrock surface are necessary to provide a three-dimensional hydrogeologic picture. Saturated thickness at selected points can be determined by subtracting the depth to the water table from the depth to bedrock (plates 1-4). Depth-to-bedrock data and bedrock surface profiles (fig 8-11, at back of report) can be used to estimate the amount of casing required for construction of bedrock wells and to locate bedrock valleys that may be filled with water-bearing sediments.

Estimated Well Yields

The significant sand and gravel aquifers consist of ice-contact and outwash deposits which have sufficient areal extent, hydraulic conductivity, and saturated thickness to sustain a yield of 10 gal/min (gallons per minute) or more to any properly installed well. Yields obtainable from wells constructed in different parts of the significant sand and gravel aquifers were estimated from yields reported by well drillers and well owners, previously published studies (for example, Prescott, 1976a) and from estimates

Table 2.--Approximate transmissivities at selected observation wells.

Map 12

Observation Well	Transmissivity (ft /day)
12-1	2900
12-2	1600
12-3	1/ > 500
12-4	1000
12-5	> 2000
12-6	1300
12-7	> 500
12-8	> 200
12-9	> 500

Map 13

Observation Well	Transmissivity (ft /day)
13-1	DRY
13-2	600
13-3	1800
13-4D	4600
13-5	6200
13-6	2000
13-7	> 1100
13-8	> 3900
13-9	> 1900

Map 14

Observation Well	Transmissivity (ft /day)
14-1	2200
14-2	> 2800
14-3	> 1300
14-4	5400
14-5	600
14-6	4000
14-7	> 800
14-8	800

Map 15

Observation Well	Transmissivity (ft /day)
15-1	4100
15-2	> 6000
15-3	> 700
15-4	2800
15-5	> 600

1/ Observation wells not drilled to refusal; therefore, values represent minimum transmissivities.

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

Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location[1]	Depth to WATER (FEET)[2] A	Depth to WATER (FEET)[2] B	Depth to BEDROCK(FEET)[2] A	Depth to BEDROCK(FEET)[2] B
Map 12[8]	A-3	Steep Falls	Limington	On Skip Road 0.5 miles of Horne Pond	10	10	87	109
Map 12[8]	A-6	Steep Falls	Standish	0.1 miles east of the fire station in Steep Falls	7	6	60	75
Map 12[8]	A-8	Steep Falls	Standish	Line runs west from Manchester Road 1.7 miles south of Steep Falls	10	10	73	63
Map 12[8]	A-9	Sebago Lake	Standish	Line on dirt road 0.3 miles south of Little Watchic Pond	5	9	20	28
Map 12	MF-A	Mechanic Falls	Oxford	0.5 miles north from Valley Road on camp road between Whitney and Hogan Ponds.	30	30	96	96+
Map 12	MF-B	Mechanic Falls	Oxford	0.2 miles south from Valley Road on camp road east of Green Pond.	23	23	73	73
Map 12	MF-C	Mechanic Falls	Poland	Approx. 300' in on woods road, 0.2 miles from north end of Pine Grove Cemetery.	BZP ssg 32-42	BZP ssg 33-45	BZP br 42-60	BZP br 45-61
Map 12	NOR-E	Norway	Harrison	On road 0.2 miles west of bridge in Scribners Mill.	DRY	DRY	35 (bedrock)	25 till
Map 12	NOR-F	Casco	Harrison	On banks of Crooked River 1.6 miles south of Scribners Mills	12	15	52	42
Map 12	NOR-G	Norway	Bridgton	Behind DOT Garage in Bridgton, 470 feet north of road.	4	7	44	42
Map 12	NOR-H	Norway	Bridgton	On dirt road 0.3 miles southwest of Sandy Creek Cemetery.	5	6	46	58
Map 12	NOR-I	Norway	Naples	On dirt road just south of Cold Brook, 1.6 miles north of Edes Falls.	16	13	78+	69+
Map 12	NOR-J	Norway	Naples	On dirt road 0.3 miles north of Burgess Brook, 0.9 miles north of Edes Falls.	6	8	76+	77+
Map 12	SL-A	Sebago Lake	Naples	500' in on dirt road 0.2 miles southwest of Route 302.	12	11	82+	81+
Map 12	SL-B	Sebago Lake	Naples	On dirt road 0.25 miles south of Thompson Point Rd.	10	9	68	65
Map 12	SL-C	Sebago Lake	Naples	On dirt road 0.25 miles east of Thompson Point Rd.	10	8	79+	77+
Map 12	SL-D	Sebago Lake	Baldwin	On dirt road 500 feet east of Route 11, northeast of intersection with Route 107.	8	7	33	31

1 Locations of single-channel seismic lines are shown on plates 1-4.

2 Datum is land surface.

3 Refers to end of the seismic line: A is the north or west end of the line, B is the south or east end.

4 Minimum depth to bedrock (calculated).

5 BZP: Blind Zone Problem: An intermediate layer (usually the saturated zone) was too thin to be detected using the seismic method. If the presence of this layer was suspected, calculations were done according to Mooney (1980) to determine the minimum and maximum possible thickness of this layer. The symbol "ssg" refers to saturated sand and gravel, "t" refers to till, and "br" refers to bedrock. For example on line MF-C, the symbol ssg 32-42 means that the depth to saturated sand and gravel, if present, is between 32 and 42 feet.

6 Till was encountered rather than sand and gravel deposits or bedrock. This is based on the assumption that the velocity of sound in till ranges approximately from 6000 to 9500 ft/sec.

7 DNU: data not useable.

8 Depth to water and depth to bedrock were calculated from seismic data collected during the 1981 field season (Tolman and others, 1983)

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

Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location	Depth to water (feet) A	Depth to water (feet) B	Depth to bedrock (feet) A	Depth to bedrock (feet) B
Map 13	FR-A	Fryeburg	Sweden	10 feet in on dirt road approximately 0.5 miles south of substation.	6	9	75+	78+
Map 13	FR-B	Fryeburg	Fryeburg	Southwest of Horseshoe Pond, 0.5 miles northwest of covered bridge.	12	12	81+	81+
Map 13	FR-B	Fryeburg	Fryeburg	Along edge of field approximately 0.1 miles east of FR-B.	10	12	40	57
Map 13	FR-C	Fryeburg	Fryeburg	On road beside potato field, south of Rt. 113, 0.3 miles from Maine/New Hampshire state line.	16	11	101+	96+
Map 13	FR-D	Fryeburg	Fryeburg	On dirt road 0.15 miles from Rt. 5, just north of Fryeburg Academy.	5	12	84+	90+
Map 13	FR-E	Fryeburg	Fryeburg	On Fryeburg Dump road, 0.2 miles south of railroad tracks.	19	19	87+	82
Map 13	HI-A	Hiram	Denmark	0.5 miles in on dirt road, south of Long Pond.	18	15	85+	82+
Map 13	HI-C	Hiram	Denmark	In gravel pit south of Rt. 160 near Brownfield/Denmark town line.	10	8	76+	75+
Map 13	KF-A	Kezar Falls	Hiram	On Camp Hiawatha road south of Trafton Pond.	16	18	85	65
Map 13	KF-B	Kezar Falls	Hiram	On northern neck of Stanley Pond.	14	14	61	66
Map 13	KF-C	Kezar Falls	Hiram	On southern neck of Stanley Pond.	31	28	93+	91+
Map 13	KF-D	Kezar Falls	Porter	At south end of Bickford Pond.	5	5	70	46
Map 13	KF-E	Kezar Falls	Porter	0.3 miles in on jeep road approx. 0.6 miles south of Bickford Pond.	18 till	18 till	75+	75+
Map 13	KF-F	Kezar Falls	Parsonsfield	On logging road, northwest of Edgecomb Cemetery.	9	11	38	47
Map 13	KF-G	Kezar Falls	Parsonsfield	On Huntress Cemetery road, approx. 1.5 miles from Maine/New Hampshire state line.	17	20	64	58
Map 13	KF-H	Kezar Falls	Parsonsfield	On jeep road approx. 0.2 miles south of Huntress Cemetery Road.	4	4	91+	82+
Map 13	KF-I	Kezar Falls	Parsonsfield	Approx. 0.7 miles in on jeep road east of Great Brook.	8	8	74+	73+
Map 13	KF-J	Kezar Falls	Parsonsfield	Approx. 0.8 miles in on jeep road, north of North Parsonsfield.	6	5	54	29
Map 13	PM-A	Pleasant Mountain	Sweden	Approx. 1000 feet in on dirt road southeast of Popple Hill Brook.	17	21	83+	86+
Map 13	PM-B	Pleasant Mountain	Sweden	0.25 miles in on jeep road, 0.4 miles northwest of Gammay Cemetery.	BZP ssg 21-28	BZP ssg 18-22	BZP br 28-38	BZP br 22-34
Map 13	PM-C	Pleasant Mountain	Bridgton	On dirt road, 0.8 miles north of Rt. 302, near Elkins Brook	26	26	80	75
Map 13	PM-D	Pleasant Mountain	Fryeburg	In gravel pit near Elkins Brook, northwest of McLucas Cemetery.	4	3	46	50
Map 13	PM-E	Pleasant Mounain	Fryeburg	0.2 miles in on dirt road, 0.5 miles from East Fryeburg.	33	33	96+	96+
Map 13	PM-F	Pleasant Mountain	Fryeburg	0.6 miles in on jeep road which starts 0.2 miles southeast of E. Fryeburg.	11	12	80+	80+
Map 13	PM-G	Pleasant Mountain	Denmark	On dirt road just west of Liberty Corner.	6	6	75+	74+
Map 13	BRF-A	Brownfield	Fryeburg	0.2 miles in on dirt road south of Round Pond.	18	BZP ssg 27-31	93+	BZP br 31-47
Map 13	BRF-B	Brownfield	Fryeburg	0.6 miles in on new road, near southeast end of runway.	9	14	64	50
Map 13	BRF-C	Brownfield	Fryeburg	Approx. 0.9 miles in on new road east of Clays Pond.	6	8	35	54

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

Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location	Depth to water (feet) A	Depth to water (feet) B	Depth to bedrock (feet) A	Depth to bedrock (feet) B
Map 13	BRF-D	Brownfield	Brownfield	On dirt road approx. 1000 feet from Rt. 5/113, just south of Hiram/ Fryeburg town line.	7	6	20	21
Map 13	BRF-E	Brownfield	Brownfield	Packed road along edge of field approx. 0.3 mile south of East Brownfield.	13	12	81+	81+
Map 13	BRF-F	Brownfield	Hiram	0.1 miles in on northern road to Clemons Pond.	DRY	DRY	14	12
Map 13	COR-A	Cornish	Hiram	Approx. 0.5 miles in on dirt road, west of Ingalls Pond.	12	13	63	66
Map 13	COR-B	Cornish	Hiram	0.2 miles in on dirt road, 1.8 miles south of Great Falls Dam.	22	24	78	75
Map 13	COR-C	Cornish	Hiram	Approx. 0.5 miles in on dirt road between Durgintown and the Ossipee River.	24	25	97+	97+
Map 13	COR-D	Cornish	Cornish	In gravel pit near Saco River, west of Cornish Station.	BZP ssg 32-37	BZP ssg 25-38	BZP br 37-57	BZP br 38-44
Map 13	COR-E	Cornish	Cornish	In gravel pit between Rt. 25/117, and Saco River, 0.6 miles southeast of Drive-in.	BZP ssg 11-13	4	BZP br 13-18	46
Map 13	COR-F	Cornish	Cornish	300' in on dirt road between Rt. 5 and Little River, northeast of Pendexter Cemetery.	7	6	60	44
Map 13	COR-G	Cornish	Cornish	In small gravel pit west of Day Cemetery.	BZP ssg 31-59	BZP ssg 34-62	BZP br 59-76	BZP br 62-84
Map 14	BET-A	Bethel	Newry	1.25 miles northwest of covered bridge.	10	10	54	45
Map 14	BET-B	Bethel	Bethel	Across Androscoggin River from Newry, 0.2 miles in on woods road.	39	35	94+	91+
Map 14	BET-C	Bethel	Bethel	In field 0.2 miles northwest of Middle Intervale.	36	36	95+	95+
Map 14	BET-D	Bethel	Bethel	Approx. 0.15 miles in on dirt road, 0.9 miles south of Middle Intervale.	9	10	76+	77+
Map 14	BET-E	Bethel	Bethel	Just east of Bethel, off Rt. 35.	5	6	65	49
Map 14	BET-F	Bethel	Bethel	In gravel pit 0.5 miles south of West Bethel.	6	8	75+	76+
Map 14	CL-A	Center Lovell	Stow	On field road past gravel pit, north of Emerson Cemetery.	7	6	31	39
Map 14	ES-A	East Stoneham	Mason	On tree farm road west of confluence of East and West branches of Pleasant River.	34	27	97+	91+

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

Aquifer map number	Seismic line identifier	USGS topographic quadrangle	Town	Location	Depth to water (feet) A	Depth to water (feet) B	Depth to bedrock (feet) A	Depth to bedrock (feet) B
Map 14	ES-B	East Stoneham	Albany	Off Rt. 5 at south end of Songo Pond.	7	5	49	59
Map 14	ES-C	East Stoneham	Albany	0.1 miles in on road to Little Papoose Pond.	11	13	77	42
Map 14	ES-D	East Stoneham	Albany	In gravel pit off of Rt. 5/35, southeast of Little Papoose Pond.	18	18	69	47
Map 14	GIL-A	Gilead	Gilead	On cemetery road west of Gilead, just beyond railroad tracks.	28	36	90+	96+
Map 14	GIL-B	Gilead	Gilead	Approx. 1000 feet in on Wheeler Brook trail.	43	46	103+	107+
Map 14	GIL-D	Gilead	Gilead	At beginning of dirt road off North Road, approx. 0.55 miles east of Chapman Cemetery.	19	15	88+	84+
Map 14	NWA-A	North Waterford	Waterford	Near Crooked River, along dirt road 0.2 miles northwest of intersection of Rts. 118 and 35.	18-21	13-17	21-32	17-25
Map 14	NWA-B	North Waterford	Waterford	On gravel pit road northeast of Five Kezar Ponds.	6	9	62	35
Map 14	NWA-C	North Waterford	Lovell	On logging road north of Dan Charles Pond.	BZP 14-17	BZP 11-13	BZP br 17-25	BZP br 13-19
Map 14	SM-A	Speckled Mountain	Batchelders Grant	On dirt road, 0.1 miles south of Hastings.	7	9	77+	78+
Map 15	NOR-A	Norway	Waterford	0.1 miles in on camp road, north of Papoose Pond.	26	26	100+	100+
Map 15	NOR-B	Norway	Waterford	Near Crooked River approx. 0.8 miles north of East Waterford.	16	11	86	62
Map 15	NOR-C	Norway	Waterford	0.5 miles in on camp road, southeast of East Waterford.	16	15	120+	120+
Map 15	NOR-D	Norway	Waterford	1.1 miles in on dirt road, south of Sodom.	6 till	5 till	49	53

based on saturated thickness, transmissivity, and areal extent of the aquifers. Areas where wells are estimated to yield between 10 to 50 gal/min and more than 50 gal/min are shown in separate shading patterns on plates 1-4. Additional shading patterns are used to denote areas where fine-grained deposits may overlie sand and gravel aquifers capable of yielding 10 to 50 gal/min.

Although the study area includes 1640 mi^2, areas mapped as significant sand and gravel aquifers include only about 200 mi^2 (12 percent of the total area). Yields exceeding 50 gal/min are estimated to be obtainable in only 30 mi^2 (2 percent) of the study area. The highest yields are obtainable in areas where the deposits are coarse grained, have a thick saturated zone, and are hydraulically connected to an adjacent body of surface water, which can be a source of recharge. The highest reported well yield in the sand and gravel deposits is 1,300 gal/min from the Norway Water District well adjacent to the Little Androscoggin River. Other high yield wells in the area include municipal wells in Paris (6 wells with yields ranging from 350 to 1,000 gal/min), Oxford (325 gal/min), Rumford (2 wells, 375 and 175 gal/min), Fryeburg (210 gal/min), and West Paris (150 gal/min).

In addition to the 200 mi^2 of significant aquifers discussed above, another 20 mi^2 of the study area consists of fine-grained deposits which may overlie significant sand and gravel aquifers. These areas have not been included as significant aquifers because their existence is only speculative; there is no subsurface data available. However, based on glacial history and regional stratigraphy, there may be coarse deposits present at depth capable of yielding 10 or more gallons per minute.

Water-level Fluctuations

Monthly water-level measurements made at 31 of the observation wells installed in the study area are shown in table 4a; selected hydrographs from these observation wells are shown on figure 7. Water-level measurements were made once a month from November 1983 through October 1984. Water levels in most shallow observation wells fluctuated within a 6-foot range (table 4b), which is greater than the water-level fluctuation for the Survey's monitoring well in Bethel (plate 3) during this period. The Bethel well is located on a valley flat, proximal to surface water. Water level fluctuations were least in the deepest observation wells, OW 13-6 and OW 14-2, which fluctuated approximately 3.5 ft over the 11-month period.

Monthly precipitation data from National Oceanic and Atmospheric Administration stations in Bridgton and East Hiram are compared with water-level data in figure 7. Recharge (rising water levels) occurred in response to seasonal precipitation in November-December and again in April-May. Most water levels declined steadily between these two recharge events.

Maximum depth to water was within 30 feet of ground surface, shallow enough for suction lift pumps, in all but five wells (table 4b). Fifteen wells had minimum depths to water of 5 feet or less. The thin unsaturated zone renders the ground water vulnerable to contamination in these areas.

Table 4a.--Water level data for observation wells.

Depth to water (in feet below land surface)

Observation-well number	Location	November 22, 23, and 30	December 29,30, 83 Jan 17, 84	January 30, and Feb 1,2	Mar 1, and 2	March 26, 27, and 28	April 26, 30, May 1	May 29, and 30	June 26,28, and 29	July 24, 27, and 31	August 21 and 28	October 5
12-1	Oxford	38.80	38.80	39.70	38.84	38.57	38.06	38.44	38.60	40.15	40.32	41.40
12 2	Naples	11.66	10.71	12.66	11.39	10.96	10.19	10.89	11.49	13.27	14.29	15.36
12-3	Naples	7.90	5.39	6.05	6.24	6.25	4.05	3.98	4.22	5.56	6.57	8.52
12-4	Windham	21.80	21.17	22.40	22.00	21.80	20.77	21.15	21.05	22.05	22.29	22.75
12-5	Windham	26.90	27.66	28.42	28.25	27.93	27.32	27.90	27.62	28.13	28.80	29.10
12-6	Bridgton	0.90	0.79	1.54	0.93	0.45	0.92	-0.05	1.43	1.73	3.10	3.10
12-7	Bridgton	1.60	2.25	2.81	2.17	2.02	2.29	0.75	3.20	4.18	4.40	3.50
12-8	Casco	3.30	3.34	2.02	3.19	2.94	3.04	2.48	3.25	3.97	4.19	4.55
12-9	Windham	6.60	5.93	8.10	6.02	6.12	5.77	5.96	7.39	8.72	9.68	10.75
13-1	Cornish	DRY	DRY	DRY	DRY	DRY	DRY	DRY	NM	NM	NM	DRY
13-2	Cornish	20.32	17.82	17.86	18.05	17.81	16.02	16.18	15.63	17.26	18.20	19.54
13-3	Porter	0.83	1.36	2.09	0.86	0.58	1.15	0.44	2.41	3.57	4.05	NM
13-4D	Brownfield	7.26	6.19	6.48	6.08	5.90	4.55	4.13	4.01	4.92	5.45	6.48
13-4S	Brownfield	7.20	6.19	6.50	6.07	5.77	4.61	3.99	4.08	5.03	5.54	6.47
13-5	Brownfield	20.76	18.58	19.88	18.70	18.35	16.90	17.78	18.10	19.95	20.52	21.25
13-6	Fryeburg	79.11	78.43	78.10	78.27	76.50	76.28	76.39	75.63	76.18	77.05	78.35
13-7	Sweden	2.25	1.23	2.48	0.64	0.55	0.55	-0.15	1.65	2.95	4.05	5.10
13-8	Fryeburg	15.55	13.23	13.78	12.47	10.80	8.70	8.75	NM	NM	NM	NM
13-9	Fryeburg	4.90	6.20	7.51	NM	3.95	4.18	4.33	6.37	7.64	7.95	NM
14-1	Stow	5.70	5.95	7.90	6.42	5.60	4.95	4.62	6.55	7.30	7.60	7.90
14-2	Bethel	47.00	44.84	45.10	NM	44.12	43.68	45.35	45.65	46.17	46.80	47.10
14-3	Bethel	20.62	19.01	19.55	NM	20.61	18.25	20.03	20.25	21.12	21.45	21.70
14-4	Gilead	6.15	4.50	4.80	NM	6.03	4.15	5.65	6.25	5.35	7.22	7.15
14-5	Albany	10.40	10.81	11.73	10.96	10.10	9.37	NM	10.33	11.27	11.70	11.75
14-6	Albany	30.90	30.35	31.62	30.50	29.29	29.23	29.85	30.38	31.48	32.05	32.40
14-7	Sweden	30.80	30.30	29.85	29.73	30.17	27.73	26.33	25.02	24.10	23.70	24.30
14-8	Stow	4.40	3.80	4.95	3.30	4.55	3.20	3.53	4.30	6.80	6.12	6.30
15-1	Waterford	18.54	15.90	17.05	17.07	16.32	13.72	14.73	14.60	16.00	17.35	18.60
15-2	Rumford	8.90	NM	9.55	NM	8.32	6.80	8.38	8.03	9.07	9.85	10.15
15-3	Rumford	20.15	18.15	19.25	NM	17.96	15.25	19.00	19.45	20.35	21.40	21.45
15-4	*Peru	* -0.15	* -0.55	* -0.71	NM	* -1.25	* -0.40	* -0.03	0.35	1.10	1.25	1.40
15-5	Buckfield	6.00	5.50	6.55	6.10	5.96	5.60	5.35	5.67	6.60	7.15	7.75

* Although the measurements show water above ground level this was not observed. Water levels were measured from top of casing; it is assumed that the casing in this well has settled through frost action or some other means.

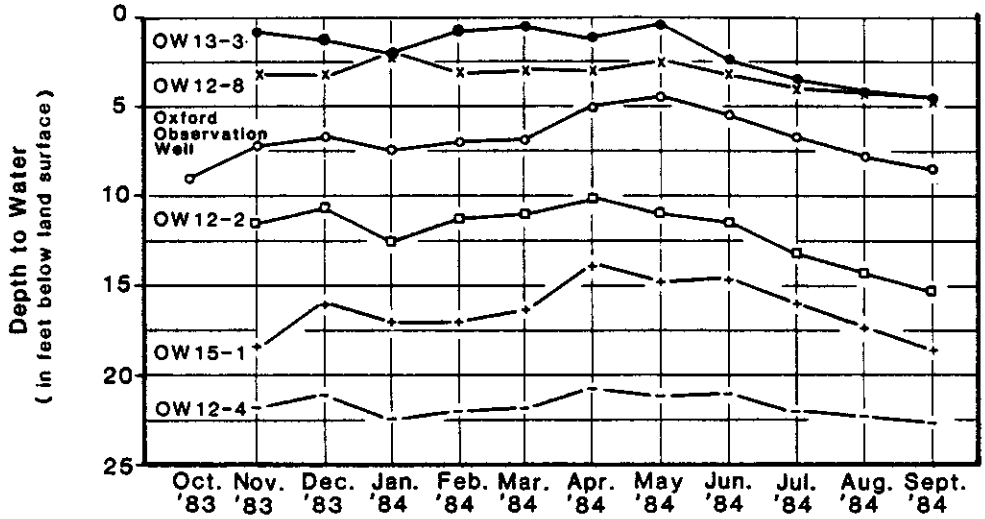
NM = Not Measured

Table 4b.--Statistical data for water levels in observation wells: November 1983 to September 1984.

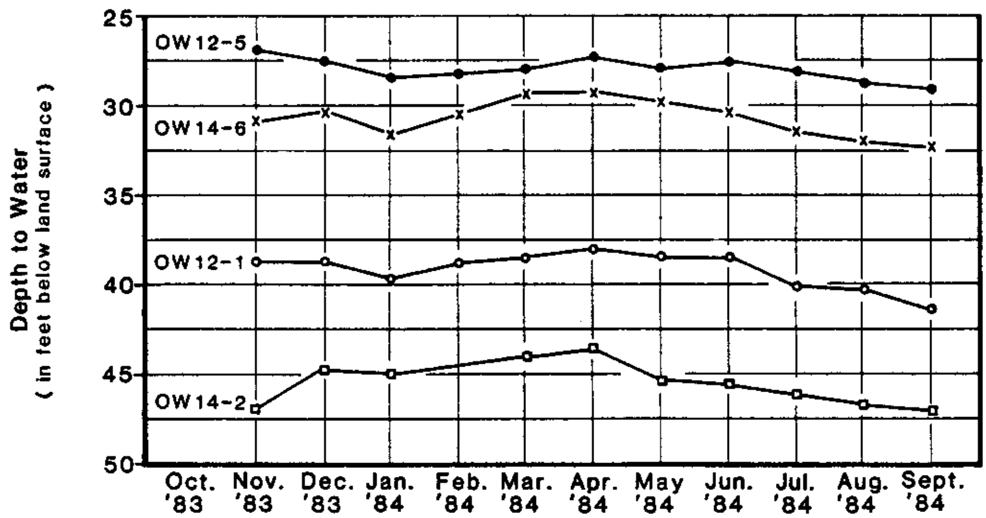
Observation well Number	Location	Mean depth to water (feet)*	Standard deviation	Maximum depth to water (feet)*	Minimum depth to water (feet)*	Range of values (feet)*
12-1	Oxford	39.2	1.0	41.40	38.06	3.34
12-2	Naples	12.0	1.6	15.36	10.19	5.17
12-3	Naples	5.8	1.5	8.52	3.98	4.54
12-4	Windham	21.7	0.6	22.75	20.77	1.98
12-5	Windham	28.0	0.6	29.10	26.90	2.20
12-6	Bridgton	1.4	1.0	3.10	-0.05	3.15
12-7	Bridgton	2.7	1.1	4.40	0.75	3.65
12-8	Casco	3.3	0.7	4.55	2.02	2.53
12-9	Windham	7.3	1.7	10.75	5.77	4.98
13-1	Cornish	> 40	--	--	--	--
13-2	Cornish	17.7	1.4	20.32	15.63	4.69
13-3	Porter	1.7	1.3	4.05	0.44	3.61
13-4D	Brownfield	5.5	1.1	7.26	4.01	3.25
13-4S	Brownfield	5.5	1.0	7.20	3.99	3.21
13-5	Brownfield	19.1	1.4	21.25	16.90	4.35
13-6	Fryeburg	77.3	1.2	79.11	75.63	3.48
13-7	Sweden	1.9	1.6	5.10	-0.15	5.25
13-8	Fryeburg	11.9	2.6	15.55	8.70	6.85
13-9	Fryeburg	5.9	1.6	7.95	3.95	4.00
14-1	Stow	6.4	1.2	7.90	4.62	3.28
14-2	Bethel	45.6	1.2	47.10	43.68	3.42
14-3	Bethel	20.3	1.1	21.70	18.25	3.45
14-4	Gilead	5.7	1.0	7.22	4.15	3.07
14-5	Albany	10.8	0.8	11.75	9.37	2.38
14-6	Albany	30.7	1.1	32.40	29.23	3.17
14-7	Sweden	27.5	2.8	30.80	23.70	7.10
14-8	Stow	4.8	1.2	6.80	3.20	3.60
15-1	Waterford	16.4	1.6	18.60	13.72	4.88
15-2	Rumford	8.7	1.0	10.15	6.80	3.35
15-3	Rumford	19.2	1.8	21.45	15.25	6.20
**15-4	Peru	0.1	0.9	1.40	-1.25	2.65
15-5	Buckfield	6.2	0.7	7.75	5.35	2.40

* Statistics on this well are questionable because the casing has apparently settled.
**Datum is land surface.

A. Water levels in shallow water table observation wells and the Oxford observation well.



B. Water levels in deep water table observation wells.



C. Average monthly precipitation, based on data from the Hiram, Lovell, Rumford and West Paris NOAA stations.

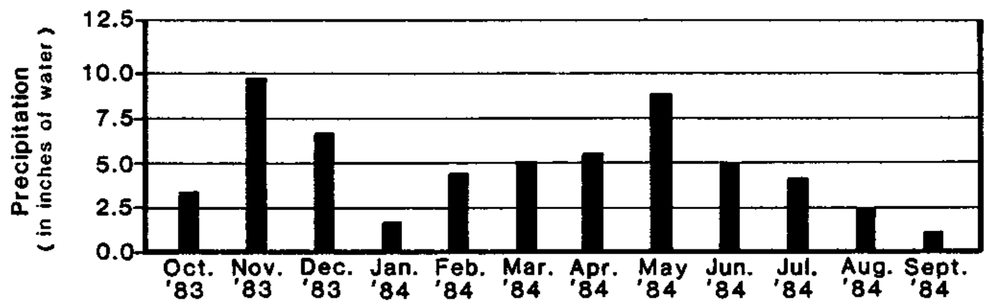


Figure 7. Ground-water levels and average monthly precipitation, October 1983 through September 1984.

GROUND-WATER QUALITY

Factors Influencing Water Quality

The chemical quality of ground water in sand and gravel aquifers is determined primarily by 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 low solubility. Ground water in regions with this type of bedrock tends to have low concentrations of dissolved solids (Matthess, 1982).

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

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

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

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 salt water intrusion in coastal areas or infiltration of poor quality water where a well is near contaminated surface water.
9. Contaminants in precipitation may degrade both ground water and surface water.For example, in the northeastern United States, "acid rain" has been reported to cause a lowering of pH and subsequent increase in aluminum and trace metal concentrations in ground water in New Hampshire and New York (Bridge and Fairchild, 1981).

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

Physical and Chemical Characteristics of Samples

Background Water Quality

The following discussion is based on analyses of samples collected in October and November, 1983 from 15 background water-quality wells (table 5). These wells are located in areas that are believed to be upgradient of any known souces of contamination other than atmospherically-derived contaminants. Water quality from wells located adjacent to or downhill from potential point or non-point sources of contamination are discussed later in this report. The background water-quality well locations were selected to provide a widespread areal distribution of water quality sampling points and to provide verification for seismic refraction soundings discussed earlier in this report.

Statistical data can be used to characterize the background water quality and to compare concentrations of constituents in a given sample to the mean concentration of all other samples. The mean and the standard deviation of analyzed constituents are presented in table 5, part B. The mean is equal to the sum of the measurements divided by the number of measurements; it is the average concentration for a given constituent. The standard deviation is a numerical expression of how much variation there is from the mean value.

The statistical data presented here must be interpreted cautiously, as only a limited number of wells were sampled.

Temperature

The temperature of ground water normally has a small seasonal fluctuation and is usually within a few degrees of the mean annual air temperature in a given area. In Maine, ground-water temperatures are typically between 4.4 and 10.0°C (Caswell, 1978). The mean temperature of ground water in the background water-quality samples ranged from 8.0 to 15°C, with a mean of 9.6°C.

Specific Conductance (conductivity)

The specific conductance of water is a measure of its capacity to conduct an electrical current. The presence of charged ions makes water conductive; 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 conductance, the Maine Department of Human Services (1983) has recommended a maximum concentration limit of 500 mg/L of dissolved solids in drinking water. Specific conductance can be used to estimate dissolved solid concentrations, which were not measured directly. The concentration of dissolved solids, in milligrams per liter, can be estimated by multiplying the conductivity value by a factor usually between 0.55 and 0.75 (Hem, 1970).

Table 5a.--Characteristics of observation wells sampled for background water-quality data.

Observation well number	Town	Latitude	Longitude	Altitude 1/	Depth 2/	Predominant Land-use around well	Date sampled
12-1	Oxford	44°06'16"	70°27'35"	335	53	Forest	10/31/83
12-2	Naples	44°00'46"	70°34'50"	320	70	Field	10/31/83
12-3	Naples	43°55'23"	70°34'58"	270	61	Forest	10/31/83
13-3	Porter	43°47'33"	70°57'05"	385	16	Field	11/01/83
13-4S	Brownfield	43°56'09"	70°57'14"	495	18	Field	11/01/83
13-4D	Brownfield	43°56'09"	70°57'14"	495	51	Field	11/01/83
13-5	Brownfield	43°55'48"	70°53'27"	405	37	Field	11/01/83
14-1	N. Fryeburg	44°12'12"	70°59'59"	405	22	Field	10/27/83
14-2	W. Bethel	44°24'01"	70°52'05"	685	65	Campground	10/27/83
14-4	Gilead	44°24'24"	70°55'38"	665	28	Forest	10/27/83
14-5	Albany	44°15'48"	70°47'32"	560	22	Gravel Pit	10/28/83
14-8	Stow	44°09'35"	70°58'40"	390	25	Gravel Pit	10/27/83
15-1	Waterford	44°13'40"	70°42'16"	495	38	Forest	10/28/83
15-2	Rumford	44°28'30"	70°38'30"	620	25	Field	10/27/83
15-4	Peru	44°26'58"	70°24'24"	575	51	Field	10/26/83

1/ Altitude of observation well at land surface datum in feet

2/ Depth of bottom of observation well in feet below land surface datum

Table 5b.--Background water-quality in sand and gravel aquifers in southwestern Maine

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

Observation well number	Temperature (°C)	Conductivity (microsiemens /cm)	pH units	Alkalinity (as $CaCO_3$)	Chloride Dissolved	Nitrate/Nitrite 1/	Sulfate Dissolved	Sodium Dissolved	Potassium Dissolved	Calcium Dissolved	Magnesium Dissolved	Hardness (as $CaCO_3$)	Iron Dissolved	Manganese Dissolved	TOC 2/	VOP 3/
12-1	9.0	65	6.6	15.6	4.5	0.03	3.0	6.5	1.20	4.6	0.88	15.3	0.10	NA	30	<1
12-2	9.0	58	6.6	18.6	1.5	.04	<3.0	3.8	0.94	5.2	1.40	18.9	.04	0.014	4	<1
12-3	8.0	46	6.0	11.8	2.5	.03	<3.0	4.8	.60	3.3	.75	11.5	.07	.110	7	<1
13-3	15.0	47	5.4	11.5	1.0	.03	7.0	4.6	.68	4.3	.84	14.5	.13	.088	1	<1
13-4S	9.5	17	5.8	4.4	<0.5	.05	<3.0	1.7	.53	1.2	.21	3.9	< .03	.038	3	<1
13-4D	9.0	24	5.7	8.3	<0.5	.02	<3.0	1.7	.44	1.6	.27	7.5	1.30	.076	12	<1
13-5	8.0	43	6.2	9.7	2.0	.28	6.0	4.3	1.30	3.2	.52	10.7	.03	.016	17	<1
14-1	9.0	29	5.9	3.4	3.0	.06	<3.0	5.1	.50	1.6	.42	6.0	.07	.014	1	<1
14-2	8.0	103	7.0	33.7	1.0	.09	10.0	9.2	4.30	8.9	2.70	33.8	.15	.490	19	<1
14-4	9.0	65	5.6	8.8	7.4	.20	<3.0	7.4	.91	5.0	1.40	18.8	.12	.260	3	<1
14-5	14.0	38	6.0	16.5	<0.5	.13	4.0	4.7	.74	3.9	.88	13.7	.06	.028	13	<1
14-8	10.0	65	6.4	23.0	0.5	.17	4.0	13.0	1.20	5.4	2.20	23.2	.17	.072	2	<1
15-1	8.0	58	6.1	18.7	2.0	.04	6.0	4.6	1.20	6.6	1.10	21.0	< .03	.320	2	<1
15-2	9.0	55	6.1	14.0	0.5	.14	6.0	5.8	2.60	4.6	1.30	17.3	.09	.050	<1	<1
15-4	9.3	123	7.5	52.0	1.5	.06	4.0	7.4	2.50	16.0	3.20	53.3	.04	.120	<1	<1
NUMBER	15	15	15	15	15	15	15	15	15	15	15	15	15	14	15	15
MINIMUM	8.0	17	5.4	3.4	<0.5	0.02	<3.0	1.7	0.44	1.2	0.21	3.9	<0.03	0.014	<1	--
MAXIMUM	15	123	7.5	52	7.4	0.28	10.0	13.0	4.30	16.0	3.20	53.3	1.30	0.49	30	<1
MEAN	9.6	56	4/6.0	16.7	1.9	0.09	4.0	5.6	1.31	5.0	1.20	18.0	0.16	0.12	8	--
STD DEV	2.1	28	--	12.4	1.9	0.08	2.5	2.9	1.06	3.6	0.88	12.3	0.32	0.14	9	--

1/ Nitrate plus Nitrite in mg/L as nitrogen

2/ TOC = Total organic carbon

3/ VOP = Volatile organic pollutants, in micrograms per liter

4/ Mean calculated from hydrogen ion concentration

NA = Not analyzed

The maximum specific conductance in the background water-quality samples was 123 microsiemens/cm. Using the range of factors given by Hem, a range of 68 to 92 mg/L was estimated for dissolved solids, indicating that dissolved solids concentrations in the study area are well below the recommended maximum level.

pH

The pH of water is a measure of hydrogen ion activity (concentration). The pH scale ranges from 0 to 14; each unit increase in the scale represents a tenfold decrease in hydrogen-ion activity. A pH of 7 is considered neutral, less than 7 is acidic, and greater than 7 is alkaline. The primary control on pH in most ground water involves interaction of soil and rocks with gaseous carbon dioxide, bicarbonate, and carbonate ions. The pH in the background water-quality samples ranged from 5.4 to 7.5, with a mean (calculated from hydrogen ion concentration) of 6.0. The USEPA (1979) has set a minimum pH drinking water standard of 6.5 because increased solution of metal from pipes can occur at lower pH values. Only four of the 15 background water-quality samples meet this standard.

Alkalinity

Akalinity is a measure of the capacity of a solution to resist a change in pH as an acid is added. The alkalinity is a measure of the concentrations of carbonate (CO), bicarbonate (HCO), and hydroxide (OH). In ground water within the pH range found in the study area, the bicarbonate ion is the dominant anionic species. Alkalinity is reported in table 5 in terms of an equivalent quantity of calcium carbonate (CaCO). The alkalinity concentrations ranged from 3.4 to 52 mg/L with a mean of 17 mg/L in the background water-quality samples.

Chloride

Because chloride is a highly mobile ion and is not readily sorbed, it can be used to trace contamination from road-salting operations, salt-storage piles, landfills, and septic tanks. Chloride concentrations in the background water-quality samples ranged from less than 0.5 to 7.4 mg/L, with a mean concentration of 1.9 mg/L. These concentrations are all below the Maine Department of Human Services (1983) drinking-water standard of 250 mg/L.

Nitrate plus nitrite

Nitrogenous compounds are commonly derived from plant and animal materials but can also be contributed by fertilizers. Nitrate is the most commonly occurring form in ground water. Because nitrate is weakly adsorbed 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 stomachs of infants; this may lead to the onset of methemoglobinemia, a potentially lethal disease (National Research Council, 1977). Because of this the Maine Department of Human Services (1983) has established a limit of 10 mg/L nitrate-nitrogen (NO -N) in drinking water. Total concentrations of nitrate plus nitrite in the background water-quality samples ranged from 0.02 to 0.28 mg/L, with a mean of 0.09 mg/L.

Sulfate

Sulfate is one of the major anions in natural waters. The Maine Department of Human Services (1983) has recommended an upper limit for sulfate of 250 mg/L in drinking water; at levels above this sulfate may have a laxative effect. Sulfate concentrations in the background water-quality samples ranged from less than 3 to 10 mg/L, with a mean of 4 mg/L. Sulfate can be reduced under anaerobic conditions to hydrogen sulfide gas (H_2S). The rotten-egg odor of this gas can be detected in water containing only a few tenths of a milligram per liter of H_2S. Hydrogen sulfide gas is a common problem in ground water from wells drilled into bedrock containing sulfide minerals (pyrite and pyrrhotite), but generally it is not a problem in unconsolidated aquifers.

Sodium and potassium

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

Concentrations of sodium in the background water-quality samples ranged from 1.7 to 13 mg/L, with a mean of 5.6 mg/L. Concentrations of potassium in these samples ranged from 0.4 to 4.3 mg/L, with a mean of 1.3 mg/L.

Calcium, magnesium, and hardness

Because calcium is widely distributed in the common minerals of rocks and soil, it is the principal cation in most natural freshwater (Hem, 1970). Magnesium is also frequently among the major cations in ground water. The Maine Department of Human Services (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, ranged from 1.2 to 16 mg/L, with a mean of 5.0 mg/L. Concentrations of magnesium in these samples ranged from 0.2 to 3.2 mg/L, with a mean of 1.2 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, 1970), is caused by divalent metallic cations-principally calcium and magnesium. Other divalent cations, including strontium, iron and manganese, may also contribute to hardness. Hard water requires considerable amounts of soap to produce a foam or lather and can cause scale in hot water pipes, heaters, boilers, and other units that use hot water.

Hardness was calculated by Standard Method 309a (American Public Health Association, 1976) and is expressed in table 5 (part B) in terms of an equivalent concentration of calcium carbonate in mg/L. Water is considered soft if it contains 0 to 60 mg/L of hardness, moderately hard if it contains 60 to 120 mg/L, hard if it contains 121 to 180 mg/L, and very hard if it contains more than 180 mg/L (Hem, 1970). Ground water in the background water-quality samples, with a range of 3.9 to 53 and a mean value of 18 mg/L, 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 was 0.16 mg/L, which is below the Maine Department of Human Services (1983) recommended limit of 0.3 mg/L for drinking water. However, the water from OW 13-4D had an iron concentration of 1.3 mg/L, which is more than four times the recommended limit. The mean concentration for manganese in this sample group was 0.12 mg/L, which exceeds the maximum limit of 0.05 mg/L recommended for drinking water by the Maine Department of Human Services (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 also be necessary in some localities in the study area.

Total organic carbon

TOC (total organic carbon) is a bulk indicator of all organic chemicals present in water. Some of these chemicals may be highly toxic, although the TOC measurement technique does not distinguish between toxic and non-toxic organic species. TOC concentrations in the background water-quality samples ranged from less than 1 to 30 mg/L.

Volatile organic pollutants

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

None of the 15 background water-quality samples contained detectable levels of volatile organic pollutants.

Comparison to other studies

The statistical data for the 15 wells sampled to determine background water-quality statistics for this study are quite similar to those determined in other studies of water-quality in sand and gravel aquifers in southern Maine (table 6). Mean conductivity and chloride, nitrate, sulfate, potassium, calcium and hardness concentrations are slightly lower than those found in Oxford County, Maine (Morrisey, 1983), York County, Maine (Williams and others, 1985), and Cumberland and Androscoggin Counties, Maine (Tepper and others, 1985). Total organic carbon values are higher in this study. Mean

Table 6. Comparison of water quality data to those in other published reports. All data are from monitoring wells or springs in sand and gravel aquifers in Southern or Western Maine. Mean values are shown.

Report	Area	Number Wells of Sampled	Conductivity (microsiemens /cm)	pH units	Alkalinity (mg/L as CaCO)	Chloride (mg/L)	Nitrate (mg/L as N)	Sulfate (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness (mg/L as CaCO)	Iron (mg/L)	Manganese (mg/L)	TOC (mg/L)	VOC (ug/L)
This Study	South-Western Maine	15	56	6.0	12	1.9	0.09	4.0	5.6	1.3	5.0	1.2	18	0.16	0.12	8	<1
Morrisey 1983	South-Western Maine	38	92	N/R	N/R	8.8	.88	6.0	7.0	1.5	7.7	1.1	24	.06	.018	1.1	N/R
Williams and Others, 1985	Southern Maine	24	69	6.0	2.3	4.3	.12	7.0	5.7	2.1	9.2	1.7	31	1.2	.44	N/R	N/R
Tepper and Others, 1985	South-Central Maine	16	99	N/R	15	6.0	1.4	7.0	4.2	1.7	12	1.9	37	.09	.083	<1	<1

Mean calculated from hydrogen ion concentration.

Total organic carbon.

Volatile organic carbon compounds.

N/R not reported

alkalinity, pH, sodium, magnesium, iron and manganese are within the range of those determined in the other three studies.

Ground-Water Quality Near Some Potential Contamination Sources

The water quality in 15 observation wells installed for this project is believed to be influenced by land-use activities (Table 7). Six wells were installed near municipal landfills. These wells had conductivity values ranging from 210 to 1860 microsiemens/cm, with correspondingly high concentrations of most inorganic chemicals. All of these wells exceeded State Drinking-Water Standards (Maine Dept. of Human Services, 1983) for sodium and manganese; four of the six exceeded the standards for iron. Five of the wells had total organic carbon values exceeding the maximum found in the background water-quality wells. Several volatile organic pollutants were detected in these wells, with toluene being the most concentrated (1,100 ug/L in well OW 13-6).

Five wells were installed in corn or potato fields which are heavily fertilized. The mean concentration of chloride, nitrate, sulfate, sodium, potassium, calcium, magnesium, hardness, iron, and magnesium were higher in these five wells than in the background water-quality wells. Nitrate concentrations in these five wells averaged 2.34 mg/L in the Fall, and 5.13 mg/L in the spring. These levels do not exceed the State Drinking-Water standard of 10 mg/L, but are well above the range of nitrate concentrations (0.02 to 0.28 mg/L) found in the background water-quality wells.

Three wells were installed near small housing developments. One of these wells had higher than background levels of chloride and calcium, while the other two wells had nitrate levels that were above background. The concentrations of all other constituents analyzed were within the range found in the observation wells used to determine background-water-quality.

One well, OW 13-7, was installed approximately 250 feet from Route 93, which is salted in the winter months. The quality of water from this well appears to be affected by salt from highway de-icing operations. The sample collected in the fall had 13 mg/L chloride, which is slightly above the background water-quality maximum, and 9.9 mg/L sodium, which is within the range of values found in the background water-quality wells (table 5). In the spring, chloride and sodium concentrations increased 2 to 3 fold in this well, to 34 and 18 mg/L, respectively.

Characteristics of Sites of Potential Ground-Water Contamination

Sixty six sites that may be degrading water quality in sand and gravel aquifers within the study area have been identified on plates 1-4. These sites include 34 sand-salt-storage lots, 21 solid-waste facilities (five of which have been closed or converted to transfer stations), 7 sewage and industrial waste lagoons (including 4 which have been closed), 3 sludge or septage disposal sites, and one former oil-waste disposal site. Many potential contamination sources, including septic systems, roads that are salted in the winter, agricultural activities, and leaking underground gasoline tanks are not shown on these plates because of their widespread occurence.

Ground-water contamination from many of the sites shown in plates 1-4 has been documented by the DEP and the USGS (for example, Morrissey, 1983). Several domestic wells are known to have been affected by the leaching of salt from sand-salt storage piles in the study area (D.B. Locke, Maine Dept. of Environmental Protection, pers. comm., 1986). However, no water supply wells are known to have been affected by sites in the other categories listed above.

Table 7.--Water quality near sites of potential ground-water contamination.
Part A: Wells near landfill activities.
(All values in mg/L unless noted)

Observation well number	Town	Latitude	Longitude	Altitude (feet) 1/	Depth (feet)2/	Date sampled	Temperature (°C)	Conductivity (uS/cm)	pH units	Alkalinity as CaCO	Chloride (dissolved)	Nitrate + Nitrite (as N)	Sulfate (dissolved)
OW 12-6	Bridgton	44°01'34"	70°42'09"	410	21.0	11-07-83	11.0	1380	6.6	535	110	0.11	NA
						05-09-84	11.0	1380	6.6	NA	170	.09	NA
OW 12-7	Bridgton	44°01'40"	70°42'04"	410	20.0	11-07-83	10.5	320	6.3	129	23	.03	<3.0
OW 12-8	Casco	43°59'23"	70°32'45"	330	11.0	11-07-83	11.0	1080	6.4	440	120	.22	<3.0
						05-09-84	10.0	1120	6.4	NA	170	.07	5.6
OW 12-9	Windham	42°51'35"	70°27'24"	320	17.0	11-07-83	14.0	1270	6.4	355	100	.08	57
						05-09-84	11.0	1340	7.0	NA	110	.02	45
OW 13-6	Fryeburg	43°58'37"	70°57'20"	500	94.5	11-07-83	9.5	1620	6.6	526	78	.33	NA
						05-08-84	9.0	1860	6.4	NA	140	.19	NA
OW 14-6	Albany	44°15'12"	70°47'26"	560	48.0	10-28-83	10.0	210	5.6	56.3	13	2.80	12
Fall Maximum		--	--	--	--	--	14.0	1620	6.7	535	120	2.80	57
Fall Mean		--	--	--	--	--	11.0	980	6.2	408	74	.59	18
Background Maximum*		--	--	--	--	--	15.0	123	7.5	52	7.4	.28	10

Observation well number	Date sampled	Sodium (dissolved)	Potassium (dissolved)	Calcium (dissolved)	Magnesium (dissolved)	Hardness (as CaCO)	Iron (dissolved)	Manganese (dissolved)	Total organic carbon	Ethyl-Benzene (ug/L)	Xylenes (ug/L)	Toluene (ug/L)	Other Volatile Organic Compounds (ug/L)
OW 12-6	11-07-83	68	26	110	22	460	55	13	50	10	30	40	4
	05-09-84	130	52	140	31	610	74	15	56	<10	<10	<10	<10
OW 12-7	11-07-83	26	4.4	26	4.2	83	0.24	5.2	<1	< 1	< 1	< 1	< 1
OW 12-8	11-07-83	41	7.0	79	23	560	150	25	190	20	40	150	4
	05-09-84	64	29	89	30	630	160	53	100	<10	80	300	<10
OW 12-9	11-07-83	81	59	66	55	400	2.4	0.55	68	< 1	< 1	< 1	< 3
	05-09-84	75	54	79	69	480	1.4	0.52	100	<10	<10	<10	<10
OW 13-6	11-07-83	56	39	73	23	580	170	28	250	1	1	200	10
	05-08-84	110	60	120	30	1050	350	34	600	40	80	1100	<10
OW 14-6	10-28-83	11	16	17	6.1	73	0.12	0.22	40	< 1	< 1	< 1	< 1
Fall Maximum		81	59	110	55	580	170	28	250	20	40	200	10
Fall Mean		47	25	62	22	360.	63	12	100	6	15	78	4
Background Maximum*		13	4.3	16	3.2	58.	1.3	0.49	30	< 1	< 1	< 1	< 1

1/Altitude of observation well at land surface datum in feet
2/Depth of bottom of observation well in feet below land surface datum
NA = not analysed
* maximum level found in background water-quality wells in fall sampling period.

Table 7.--Water chemistry near sites of potential ground-water contamination -Continued.
Part B: Wells in agricultural areas.
(All values in mg/L except as noted)

Observation well number	Town	Latitude	Longitude	Altitude (feet) 1/	Depth (feet)2/	Date sampled	Temperature (°C)	Conductivity (uS/cm)	pH units	Alkalinity as CaCO)	Chloride(dissolved	Nitrate + Nitrite (as N)	Sulfate (dissolved)
OW 13-8	Fryeburg	44°02'05"	70°58'26"	390	30	10-28-83	9.0	150	5.9	17.6	12	3.00	19.0
						05-08-84	8.0	212	6.0	NA	12	5.00	16.0
OW 13-9	Fryeburg	44°07'28"	70°56'27"	385	23	10-28-83	9.0	128	5.5	11.5	13	4.50	7.0
						05-08-84	7.0	220	5.8	NA	11	8.00	4.7
OW 14-3	Bethel	44°24'51"	70°51'07"	662	33	10-27-83	10.0	93	5.9	10.0	11	0.90	4.0
OW 15-3	Rumford	44°29'43"	70°40'23"	630	37	10-26-83	7.6	125	5.9	13.4	8.9	2.50	<3.0
OW 15-5	Buckfield	44°17'47"	70°23'31"	375	21	10-26-83	9.0	76	5.5	3.8	10	0.78	6.0
						05-09-84	10.0	110	NA	NA	15	2.40	5.7
Fall Mean		--	--	--	--	--	8.9	114	5.7	11.3	11	2.34	7.5
Spring Mean		--	--	--	--	--	8.3	220	5.9	--	13	5.13	8.8
Background Mean*		--	--	--	--	--	9.6	56	6.0	16.7	1.9	0.09	4.0

Observation well number	Date sampled	Sodium (dissolved)	Potassium (dissolved)	Calcium (dissolved)	Magnesium (dissolved)	Hardness (as CaCO)	Iron (dissolved)	Manganese (dissolved)	Total organic carbon	Volatile Organic Compounds (ug/L)	Aldicarb (ug/L)	Dinoseb (ug/L)
OW 13-8	10-28-83	7.8	2.0	16	2.7	60	1.80	2.70	7	< 1	NA	NA
	05-08-84	6.1	2.3	18	3.1	67	<0.03	1.20	9	NA	< 10	< 10
OW 13-9	10-28-83	8.9	3.5	11	1.9	47	1.70	0.59	4	< 1	NA	NA
	05-08-84	11.0	3.9	13	2.2	56	<0.03	0.33	4	NA	< 10	< 10
OW 14-3	10-27-83	9.6	1.7	5.3	1.1	20	0.04	0.064	3	< 1	NA	NA
OW 15-3	10-26-83	4.6	3.7	11	1.7	39	0.13	0.055	19	< 1	NA	NA
OW 15-5	10-26-83	9.1	1.1	3.1	1.7	16	0.06	0.017	3	< 1	NA	NA
	05-09-84	7.7	1.4	4.2	2.6	26	<0.03	0.049	6	NA	< 10	< 10
Fall Mean		8.0	2.4	9.3	1.8	36	0.75	0.69	7	< 1	--	--
Spring Mean		8.3	2.5	12	2.6	49	0.01	0.53	6	< 1	--	--
Background Mean*		5.6	1.3	5.0	1.2	18	0.16	0.12	8	< 1	--	--

1/Altitude of observation well at land surface datum in feet
2/Depth of bottom of observation well in feet below land surface datum
NA = not analysed
* mean level found in background water-quality wells in fall sampling period.

Table 7.--Water Chemistry near sites of potential ground-water contamination - Continued.
Part C: Wells near housing developments, highways.
(All values in mg/L except as noted)

Observation well number	Town	Latitude	Longitude	Altitude1/	Depth2/	Land Use	Date Sampled	Temperature (°C)	Conductivity (uS/cm)	pH units	Alkalinity (as CaCO)	Chloride(Dissolved)
OW 12-4	Windham	43°50'40"	70°26'18"	305	38	Residential	11-02-83	8.0	239	8.11	53.5	23.0
OW 12-5	Windham	43°49'06"	70°25'29"	260	44	Residential	11-02-83	8.5	84	5.50	9.0	1.5
							05-09-84	11.0	122	5.60	NA	2.4
OW 13-2	Cornish	43°47'23"	70°46'02"	310	28	Residential	11-01-83	8.0	51	5.78	8.7	4.5
							05-09-84	8.0	94	6.00	NA	5.8
OW 13-7	Sweden	44°07'22"	70°53'05"	410	20	Highway	10-28-83	10.0	80	6.21	17.7	13.0
							05-08-84	7.0	240	6.20	NA	34.0

Observation well number	Date sampled	Sodium (dissolved)	Potassium (dissolved)	Calcium (dissolved)	Magnesium (dissolved)	Hardness (mg/L as CaCO)	Iron (dissolved)	Manganese (dissolved)	Total organic carbon	Volatile Organic Compounds (ug/L)	Nitrate + Nitrite (as N)	Sulfate (Dissolved)
OW 12-4	11-02-83	14	2.60	25.0	3.00	75.7	0.06	0.098	11	< 1	0.43	8.0
OW 12-5	11-02-83	3.7	1.00	8.0	1.50	33.3	0.05	.020	33	< 1	3.90	<3.0
	05-09-84	5.5	1.10	8.2	1.50	34.2	<0.03	.014	10	NA	4.20	5.8
OW 13-2	11-01-83	5.8	0.91	3.2	0.57	15.6	0.08	.024	9	< 1	2.80	3.0
	05-09-84	7.1	0.77	3.8	0.60	14.3	<0.03	.008	2	NA	1.30	4.0
OW 13-7	10-28-83	9.9	2.10	6.6	2.10	25.4	0.14	.280	2	< 1	0.04	4.0
	05-08-84	18	3.40	7.2	2.60	31.9	1.80	.710	6	NA	NA	5.0

1/Altitude of observation well at land surface datum in feet
2/Depth of bottom of observation well in feet below land surface datum

SUMMARY

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

Although the study area includes 1640 mi^2, areas mapped as significant aquifers include only about 200 mi^2 (plates 1-4). Yields exceeding 50 gal/min are estimated to be available in only 30 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 which is a source of recharge. The highest reported well yield in the sand and gravel deposits is 1300 gal/min from the Norway Water District well adjacent to the Little Androscoggin River.

The water table within the significant sand and gravel aquifers is typically within 20 feet of the land surface. Based on seismic data, the greatest known depth to bedrock, which was encountered in the Fryeburg area, is 290 feet.

Based on field relationships, logs of 35 test borings and observation wells, and interpretation of the geologic history, the following general stratigraphic relationships have been determined: bedrock is overlain by till, which is overlain by ice-contact deposits (including glacial marine or glacial lake deltas, eskers, kames, and kame teraces) and outwash deposits, which in places may be overlain by marine clay or fine-grained glacial-lake deposits, and finally overlain by sand and gravel deposited as late outwash or recent stream alluvium. The thickness of the deposits differs considerably depending on landforms and local depositional controls during deglaciation.

Estimated hydraulic conductivities, based on grain-size analyses, vary from 10 to 30 ft/d for coarse silt to fine sand, 30 to 77 ft/d for medium to coarse sand, and 60 to 100 ft/d for coarse to very coarse sand. Estimated transmissivities at observation wells in the study area vary from 600 to 6220 ft^2/d.

The background water quality in sand and gravel aquifers in areas relatively unaffected by man has the following characteristics: The pH varies from 5.4 to 7.5; 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 high enough to limit use of the water without treatment.

Solid-waste facilities and sand-salt storage sites are the most common of the 66 potential ground-water contamination sites identified on or near sand and gravel aquifers in the study area. Several domestic wells near sand-salt storage facilities have higher than background chloride and sodium levels. No water supply wells are known to have been contaminated by activities at other sites in the study area. However, observation wells installed near four of the landfills had elevated levels of many dissolved inorganic chemicals, and detectable levels of several volatile organic pollutants.

Non-point contamination sources, including agricultural activities, road-salting, and housing developments, are also degrading ground-water quality in some areas. Increased levels of nitrates, chlorides, and other dissolved solids have been found in wells installed near such sources.

SELECTED REFERENCES

American Public Health Association, American Water Works Association, Water Pollution Control Federation, 1976, Standard methods for the examination of water and wastewater, 14th ed.: Washington, D.C., American Public Health Association, 1193 p.

Bloom, A. L., 1960, Late Pleistocene changes of sea level in south-western Maine: Augusta, Maine, Maine Geological Survey, 143 p. Borns, H. W., Jr., and Calkin, P. E., 1977, Quaternary glaciation, west-central Maine: Geological Society of America Bulletin, v. 88, p. 1773-1784.

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.

Caldwell, D. W., 1959, Glacial lake and glacial marine clays of the Farmington area, Maine: origin and possible use as a lightweight aggregate: Augusta, Maine, Maine Geological Survey, Special Geological Studies Series No. 3, 48 p.

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

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

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.

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water (2d ed.): U.S. Geological Survey Water-Supply Paper 1473, 363 p.

Koteff, C. and Pessl, F., Jr., 1985, Till stratigraphy in New Hampshire: correlations with adjacent New England and Quebec, in Borns, H. W., and others, eds., Late Pleistocene history of northern New England and adjacent Quebec: Geol. Soc. Amer. Spec. Paper 197, p. 1-12.

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 665-677.

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

Mooney, H. M., 1980, Handbook of engineering physics, 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: Augusta, Maine, U.S. Geological Survey Water-Resources Investigations Report 83-4018.

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

______ 1982, Drinking water and health, volume 4: National Academy Press, Washington, D. C., 299 p.

Prescott, G. C., Jr., 1963, Geologic map of the surficial sits of southwestern Maine and their water-bearing characteristics: U.S. Geological Survey Hydrologic Investigations Atlas HA-76.

______ 1967, Records of selected wells, springs, and test borings in the lower Androscoggin River basin: U.S. Geological Survey Open-File Report, Maine Basic-Data Report No. 3, 63 p.

______1968, Ground-water favorability areas and surficial geology in the lower Androscoggin River basin, Maine: U.S. Geological Survey Hydrologic Investigations Atlas HA-285.

______ 1976a, Records of selected wells and test borings in the Windham-Freeport-Portland area of Cumberland County, Maine: U.S. Geological Survey Open-File Report, Maine Basic-Data Report No. 9, 48 p.

______ 1976b, Ground-water favorability and surficial geology of the Portland area, Maine: U.S. Geological Survey Hydrologic Investigations Atlas HA-561.

______ 1977, Ground-water favorability and surficial geology of the Windham-Freeport areas, Maine: U.S. Geological Survey Hydrologic Investigations Atlas HA-564.

______ 1979, Records of selected wells, springs, and test borings in the Royal, upper Presumpscot, and upper Saco River basins, Maine: U.S. Geological Survey Open-File Report 79-1169, Maine Hydrologic-Data Report No. 10, 53 p.

______ 1980a, Ground-water availability and surficial geology of the Royal, upper Presumpscot, and upper Saco River basins, Maine: U.S. Geological Survey Water-Resources Investigations Report 79-1287, 3 sheets.

______ 1980b, Records of selected wells, springs, and test borings in the upper Androscoggin River basin in Maine: U.S. Geological Survey Open-File Report 80-412, 84 p.

Prescott, G. C., Jr., and Drake, J. A., 1962, Records of selected wells, test borings, and springs in southwestern Maine: U.S. Geological Survey Open-File Report, Maine Basic-Data Report No. 1, 35 p.

Prescott, G. C., Jr., Brewer, T., and Genes, A. N., 1979a, Sand and gravel aquifers Map 12, Cumberland, Androscoggin and York Counties, Me: (Compiled by W. B. Caswell), Augusta, Maine; Maine Geological Survey Open-File Report, 79-10, 5p., 1 map.

_____ 1979b, Sand and gravel aquifers map 13, Oxford, York and Cumberland Counties, Maine: (compiled by W.B. Caswell), Augusta, Maine; Maine Geological Survey Open-File Report 79-11, 5p., 1 map.

Prescott, G. C., Jr., and Dickerman, D. C., 1981a, Sand and gravel aquifers map 14, Oxford County, Maine: (compiled by A. L. Tolman and E. M. Lanctot): Augusta, Maine, Maine Geological Survey Open-File Report 81-50, 6 p., 1 map.

_____ 1981b, Sand and gravel aquifers map 15, Oxford, Cumberland, and Androscoggin Counties, Maine: (compiled by A.L. Tolman and E. Melanie Lanctot), Augusta, Maine; Maine Geological Survey Open-File Report 81-51, 6p., 1 map.

Prescott, G. C., Jr., and Thompson, W. B., 1976 Surficial geology of the Kezar Falls Quadrangle, Maine: Maine Geological Survey Open-File Report 77-14, 1 plate, scale 1:24,000.

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., 1977, Reconnaissance surficial geology of the Kezar Falls Quadrangle Maine: Augusta, Maine, Maine Geological Survey Open-File Report 77-14, 1 map, scale 1:24,000.

_____ 1985, Chronology of late Wisconsinan deglaciation of coastal Maine, in Borns, H.W. and others, eds., Late Pleistocene history of northern New England and adjacent Quebec: Geol. Soc. Amer. Spec. Paper 197, p. 29-44.

Smith, G. W., and Thompson, W. G., 1980, Reconnaissance surficial geology of the Poland 15' Quadrangle, Maine: Augusta, Maine, Maine Geological Survey Open-File Report 80-25, 1 map, scale 1:62,500.

Tepper, D. H., 1980, Hydrogeologic setting and geochemistry of residual periglacial Pleistocene seawater in wells in Maine: Orono, Me., 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: Sand and Gravel Aquifer Maps 10, 11, 16, 17, and 32: Augusta, Maine, Maine Geological Survey Open-File Report 85-82 a-f.

Thompson, W. B., 1976a, Surficial geology of the Cornish Quadrangle, Maine: Maine Geological Survey Open-File Report 76-44, 1 plate, scale 1:24,000.

_____ 1976b, surficial geology of the Pleasant Mountain Quadragle, Maine: Maine Geological Survey Open-File Report 76-46, 1 plate, scale 1:24,000.

_____ 1976c, Reconnaissance surficial geology of the Gray 15' Quadrangle: Augusta, Maine, Maine Geological Survey Open-File Report 76-45, 1 Map, Scale 1:62:500.

_____ 1977a, Surficial geology of the Norway Quadrangle, Maine: Maine Geological Survey Open-File Report 77-34, 1 plate, Scale 1:62,500.

_____ 1977b, Surficial geology of the Sebago Lake Quadrangle, Maine: Maine Geological Survey Open-File Report 77-45, 1 plate, scale 1:62,500

_____ 1979, Surficial geology handbook for coastal Maine: Augusta, Me., Maine Geological Survey, 69 p.

_____ 1982, Recession of the late Wisconsinan ice sheet in coastal Maine, in Larson, G. J., and Stone, B. D., eds., Late Wisconsinan glaciation of New England: Dubuque, Iowa, Kendall/Hunt, p. 211-228.

_____ 1985, Glacial geology of the Fryeburg-Bethel region, southwestern Maine, Augusta, Me., Maine Geological Survey,Geological Society of Maine field trip, July 27, 1985: field trip guide, 14 p.

Thompson, W. B. and Borns, H. W., Jr., 1985, editors, 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 Andersen, 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: Augusta, Maine, 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, 535p.

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: Augusta, Maine, Maine Geological Survey, Open-File Report 83-1, 4 plates.

Tucholke, B. E., and Hollister, C. D., 1973, Late Wisconsinan glaciation of the southwestern Gulf of Maine: new evidence from the marine environment: Geological Society of America Bulletin, v. 84, p. 3279-3296.

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

Williams, J. S., Tolman, A. L., and Fontaine, C. W., 1985, Water quality in sand and gravel aquifers in York County, Maine: Augusta, Maine, Maine Geological Survey Open-File Report 85-77, 91 p.

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 8.--Observation well and test boring logs, Map 12 Area 1/

Identification number: Exploration boring were numbered sequentially in the order in which they 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, by the U.S. Geological Survey.

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 B.P. 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 word "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 and 2 for information on grain-size analyses and estimated transmissivities.

Table 8.--Observation well and test boring logs, Map 12 Area - Continued

OW 12-1. Latitude: 44°06'16"N, longitude: 70°27'35"W. Located in Oxford, on dirt road on eastern shore of Green Pond, off Valley Road. Depth to water approximately 42 feet.

Material	Depth (feet)	Thickness (feet)
Sand, medium to coarse	0-6	6
Sand, medium to very coarse	6-11	5
Sand, coarse to very coarse; granules and pebbles	11-26	15
Sand, fine to medium	26-31	5
Sand, coarse to very coarse; granules and pebbles	31-36	5
Sand, coarse to very coarse	36-46	10
Sand, fine to coarse	46-51	5
Sand, fine to medium, well-sorted, stratified, micaceous, iron-stained	51-61	10
Sand, fine to coarse, grey, poorly sorted; granules and pebbles	61-72	11
Sand, very fine to fine, stratified, micaceous, iron-stained	72-81	9
Sand, fine to very coarse, poorly sorted, micaceous; granules and pebbles	81-82	1
Sand, very fine to medium, micaceous	82-91	9
Sand, fine to very coarse, moderately sorted, stratified, micaceous	91-106	15
Sand, coarse to very coarse	106-107	1
Till	107-108	1
End of boring	(108)	--

OW 12-1 is screened from 51 to 53 feet below land surface with 0.006-inch slotted PVC screen.

Table 8.--Observation well and test boring logs, Map 12 Area - Continued

OW 12-2. Latitude: 44°00'46"N, longitude: 70°34'50"W. Located in Casco, on Jugtown Plains, off Edes Falls Road. Depth to water approximately 14 feet.

Material	Depth (feet)	Thickness (feet)
Sand, medium to coarse	0-6	6
Sand, fine to medium	6-16	10
Sand, fine, micaceous	16-21	5
Sand, fine, iron-stained; stratified silt and clay	21-26	5
Sand, very fine to medium, stratified, iron-stained	26-28	2
Sand, fine, micaceous, iron-stained	28-36	8
Sand, fine; clay; some iron-staining evident throughout sample	36-46	10
Sand, very fine to fine; laminated clay	46-56	10
Sand, fine to very coarse, well-sorted, stratified; clay interbedded with fine sands; some iron-staining evident throughout sample	56-66	10
Sand, very fine to very coarse, well-sorted, stratified	66-68	2
Sand, fine to very coarse, moderately well-sorted	68-71	4
Refusal (bedrock)	71	--

OW 12-2 is screened from 67 to 70 feet below land surface with 0.008-inch slotted PVC screen.

Table 8.--Observation well and test boring logs, Map 12 Area - Continued

OW 12-3. Latitude: 43°55'23"N, longitude: 70°34'58"W. Located in Naples off Thompson Point Road in Sebago Lake State Park. Depth to water approximately 10 feet.

Material	Depth (feet)	Thickness (feet)
Sand, medium to coarse	0-6	6
Sand, fine to medium	6-16	10
Sand, fine to medium, micaceous, moderately sorted	16-21	5
Sand, very fine to medium, stratified, iron-stained	21-23	2
Sand, very fine to medium, moderately sorted, stratified, iron-stained; silt; clay	23-31	8
Clay, massive, grey-green	31-41	10
Sand, medium to very coarse; poorly sorted clay; some broken rock fragments	41-51	10
Sand, medium to very coarse with granules and pebbles; clay with granules and pebbles	51-61	10
Sand, medium to very coarse, granules and pebbles	61-63	2
End of boring	(63)	--

OW 12-3 is screened from 56 to 61 feet below land surface with 0.015-inch slotted PVC screen.

Table 8.--Observation well and test boring logs, Map 12 Area - Continued

OW 12-4. Latitude: 43°50'40"N, longitude: 70°26'18"W. Located in North Windham, on private property off Smith Road. Depth to water approximately 24 feet.

Material	Depth (feet)	Thickness (feet)
Sand, fine to medium	0-6	6
Sand, very fine to fine	6-11	5
Sand, medium to very coarse	11-16	5
Sand, fine to medium	16-26	10
Sand, medium to coarse, moderately well-sorted	26-34	8
Sand, very fine to medium, moderately well-sorted, stratified	34-46	12
Sand, very fine to medium, grey, moderately well-sorted, weakly stratified; clay	46-56	10
Sand, and clay, laminated; sand is very fine to medium, moderately sorted, stratified	56-66	10
Clay, massive; interbedded with silt and very fine sand	66-74	8
Refusal (bedrock)	74	--

OW 12-4 is screened from 36 to 38 feet below land surface with 0.006-inch slotted PVC screen.

Table 8.--Observation well and test boring logs, Map 12 Area - Continued

OW 12-5. Latitude: 43°49'06"N, longitude: 70°25'29"W. Located in Windham in Blue Rock gravel pit on west side of Varney's Mill Road, near intersection with Route 302. Depth to water approximately 29 feet.

Material	Depth (feet)	Thickness (feet)
Sand, medium to coarse	0-11	11
Sand, coarse	11-16	5
Sand, coarse to very coarse	16-21	5
Sand, coarse	21-26	5
Sand, fine to medium	26-31	5
Sand, medium to very coarse	31-40	9
Sand, medium to coarse, moderately well-sorted, stratified	40-42	2
Sand, medium to very coarse	42-44	2
End of boring	(44)	--

OW 12-5 is screened from 39 to 44 feet below land surface with 0.008-inch slotted PVC screen.

OW 12-6. Latitude: 44°01'34", longitude: 70°42'09". Located in Bridgton, at Bridgton Dump. Depth to water within 6 feet of the land surface.

Material	Depth (feet)	Thickness (feet)
Sand, fine to medium	0-11	11
Sand, medium to very coarse	11-16	5
Sand, fine to very coarse, moderately sorted, stratified; granules and pebbles	16-21	5
Sand, medium to very coarse, moderately sorted, stratified	21-26	5
Sand, medium to very coarse, moderately sorted, stratified, iron-stained; gravel and broken rock fragments	26-33	7
Refusal (bedrock)	33	--

OW 12-6 is screened from 16 to 21 feet below land surface with 0.008-inch slotted PVC screen.

Table 8.--Observation well and test boring logs, Map 12 Area - Continued

OW 12-7. Latitude 44°01'40", longitude: 70°42'04". Located in Bridgton, at Bridgton Dump. Depth to water approximately 5 feet.

Material	Depth (feet)	Thickness (feet)
Sand, coarse to very coarse, brown; gravel; some artificial road material	0-3	3
Sand, fine to medium	3-13	10
Sand, coarse	13-16	3
Sand, medium to very coarse, tan	16-20	4
End of boring	(20)	--

OW 12-7 is screened from 16 to 20 feet below land surface with 0.008-inch slotted PVC screen.

TH 12-8. Latitude 43°59'23", longitude: 70°32'45". Located in Casco, at Casco Dump.

Material	Depth (feet)	Thickness (feet)
Sand, fine to medium	0-16	16
Peat; dense silt and clay	16-26	10
Sand, silty, brown; clay, brown and grey	26-28	2
End of boring	(28)	--

No casing was installed in this boring because the boring would not cave in to the desired depth for setting the screen. OW 12-8 was drilled nearby instead.

OW 12-8. Latitude: 43°59'23", longitude: 70°32'45". Located in Casco, at Casco Dump. Depth to water within 5' of the surface.

Material	Depth (feet)	Thickness (feet)
Sand, fine to medium, silty, grey	0-9	9
Sand, fine, silty, brown and grey	9-11	2
End of boring	(11)	--

OW 12-8 is screened from 6 to 11 feet below land surface with 0.008 inch slotted PVC screen.

Table 8.--Observation well and test boring logs, Map 12 Area - Continued

OW 12-9. Latitude 42°51'35", longitude: 70°27'24". Located in Windham, off Route 302, at Windham Incinerator site. Depth to water approximately 12 feet.

Material	Depth (feet)	Thickness (feet)
Sand, fine to medium, tan and brown; cobbles and boulders	0-2	2
Sand, medium to very coarse; granules, pebbles, and cobbles	2-6	4
Sand, coarse to very coarse; granules and pebbles	6-11	5
Sand, coarse, well-sorted, brown	11-16	5
Refusal (boulder)	17	--

OW 12-9 is screened from 14.5 to 17 feet below land surface with 0.015-inch slotted PVC screen.

Table 9.--Observation well and test boring logs, Map 13 Area 1/

Identification number: Exploration borings were numbered sequentially in the order in which they 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, by the U.S. Geological Survey.
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 B.P. 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 word "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 and 2 for information on grain-size analyses and estimated transmissivities.

Table 9.--Observation well and test boring logs, Map 13 Area- Continued

OW 13-1. Latitude: 43°48'19", longitude: 70°50'08". Located in Cornish, in gravel pit on north side of Route 25, near Co-Hi Apple Packers Plant.

Material	Depth (feet)	Thickness (feet)
Sand, coarse; granules and pebbles	0-10	10
Sand, fine to coarse	10-20	10
Sand, fine, tan	20-25	5
Sand, silt, tan	25-30	5
Silt, tan, compact	30-36	6
Till, grey, compact, contains phyllite	36	--
End of boring	(36)	--

OW 13-1 is screened from 28 to 33 feet below land surface with 0.006-inch slotted PVC screen.

TH 13-2A. Latitude: 43°48'41", longitude: 70°51'21". Located in Hiram, in northeast side of large gravel pit near Ossipee Valley Fairgrounds. Dry boring.

Material	Depth (feet)	Thickness (feet)
Sand, coarse; some gravel	0-10	10
Sand, medium, brown	10-15	5
Sand, medium to coarse, reddish-brown; gravel	15-23	8
Till	23-24	1
Refusal (probably on boulder)	24	--

No casing was installed in this boring because no water was encountered. A second attempt was made at TH 13-2B. This attempt was also unsuccessful. An observation well was installed at the OW 13-2 site.

Table 9.--Observation well and test boring logs, Map 13 Area- Continued

TH 13-2B. Latitude: 43°48'41", longitude: 70°51'21". Located in Hiram in northeast side of large gravel pit near Ossipee Valley Fairgrounds. Dry boring.

Material	Depth (feet)	Thickness (feet)
Sand, coarse, brown; cobbles	0-5	5
Sand, coarse; cobbles and smaller gravels	5-15	10
Sand; granules	15-23	8
Refusal	23	--

No casing was installed in this boring because no water was encountered. Because this attempt was unsuccessful, an observation well was installed at the OW 13-2 site.

OW 13-2 Latitude: 43°48'19", longitude: 70°51'21". Located in Cornish, on private property in housing development 0.6 miles south of the Drive-in Theater on Rt. 25. Depth to water approximately 23 feet.

Material	Depth (feet)	Thickness (feet)
Sand, coarse	0-3	3
Gravel	3-4	1
Sand, medium, well-sorted	4-29	25
Gravel	29-31	2
Sand, very fine to fine	31-36	5
Till	36-37	1
Refusal (bedrock)	37	--

OW 13-2 is screened from 23 to 28 feet below land surface with 0.006-inch slotted PVC screen.

Table 9.--Observation well and test boring logs, Map 13 Area- Continued

OW 13-3. Latitude: 43°47'33", longitude: 70°57'05". Located in Porter, in field off Route 25, near the intersection of Rt. 25 and Rt. 160. Depth to water approximately 3 to 5 feet.

Material	Depth (feet)	Thickness (feet)
Sand, coarse, well-sorted	0-3	3
Sand, medium, well-sorted	3-16	13
Sand, fine to medium, well-sorted; silt and clay, greenish-grey	16-26	10
Sand, very fine; silt and clay, greenish-grey	26-76	50
Till, sandy	76-80	4
Refusal (bedrock)	80	--

OW 13-3 is screened from 10 to 16 feet below land surface with 0.008-inch slotted PVC screen.

Table 9.--Observation well and test boring logs, Map 13 Area- Continued

OW 13-4D and OW 13-4S. Latitude 43°56'09", longitude: 70°57'14". Both wells located in Brownfield, on private property, northwest of Merrill Corner. Depth to water approximately 5 feet.

Material	Depth (feet)	Thickness (feet)
Sand, coarse, well-sorted	0-6	6
Sand, coarse to very coarse, well-sorted	6-16	3
(Gravel)	(10-11)	(1)
Sand, medium, well-sorted	16-26	10
Sand, fine to medium, well-sorted	26-36	10
Sand, very fine to very coarse, moderately well-sorted, stratified	36-46	10
Sand, coarse to very coarse	46-56	10
Sand, very fine to very coarse, moderately well-sorted, stratified	56-66	10
Sand, very fine to coarse, well-sorted, stratified	66-71	5
Till	71-74	3
Refusal (bedrock)	74	--

OW 13-4D is screened from 46 to 51 feet below land surface with 0.010-inch slotted PVC screen. OW 13-4S; as drilled 2 feet away from OW 13-4D and is screened from 13 to 18 feet with 0.008-inch slotted PVC screen.

Table 9.--Observation well and test boring logs, Map 13 Area- Continued

OW 13-5. Latitude 43°55'48", longitude: 70°53'27". Located in Brownfield, on private property, in clearing northwest of Burnt Meadow Road. Depth to water approximately 23 feet.

Material	Depth (feet)	Thickness (feet)
Sand, medium, well-sorted	0-6	6
Sand, fine	6-11	5
Sand, very fine to fine, grey	11-16	5
Sand, very coarse, iron-stained	16-21	5
Sand, very coarse; granules and pebbles	21-31	10
Sand, coarse to very coarse; granules and pebbles	31-41	10
Sand, very coarse	41-51	10
Sand, medium to coarse, moderately well-sorted	51-61	10
Sand, coarse to very coarse, moderately well-sorted	61-71	10
Sand, medium to very coarse, moderately well-sorted; gravel	71-96	25
Sand, fine to very coarse, moderately well-sorted, stratified; granules and pebbles	96-106	10
Refusal (bedrock)	106	--

OW 13-5 is screened from 33 to 38 feet below land surface with 0.015-inch slotted PVC screen.

Table 9.--Observation well and test boring logs, Map 13 Area-- Continued

OW 13-6. Latitude 43°58'37", longitude: 70°57'20". Located in Fryeburg, at Fryeburg Dump. Depth to water approximately 75 to 80 feet.

Material	Depth (feet)	Thickness (feet)
Sand, coarse to very coarse	0-6	6
Sand, coarse, well-sorted	6-11	5
Sand, coarse to very coarse; granules and pebbles	11-16	5
(Cobbles)	(14)	
Sand, medium	16-26	10
Sand, coarse to very coarse	26-31	5
Sand, medium, well-sorted	31-41	10
(Cobbles)	(33)	
Sand, medium to very coarse, poorly sorted	41-46	5
Sand, coarse	46-51	5
Sand, coarse to very coarse	51-61	10
(Cobbles)	(60)	
Sand, coarse to very coarse; granules and pebbles	61-81	20
(Cobbles)	(62)	
Sand, coarse to very coarse	81-88	7
Sand, very coarse with very thin interbeds of fine sand; granules and pebbles	88-95	7
broken rock fragments	95-96	
Refusal	96	--

OW 13-6 is screened from 85 to 95 feet below land surface with 0.010-inch slotted PVC screen.

Table 9.--Observation well and test boring logs, Map 13 Area- Continued

OW 13-7. Latitude 44°07'22", longitude: 70°53'05". Located in Sweden, near Lovell town line, in field off Wrights Hill Road. Depth to water approximately 5 feet.

Material	Depth (feet)	Thickness (feet)
Sand, medium to coarse	0-6	6
Sand, fine to medium	6-21	15
Sand, very fine to fine	21-26	5
Sand, very fine to fine, with laminations of silt and clay	26-81	55
End of boring	81	--

OW 13-7 is screened from 15 to 20 feet below land surface with 0.006-inch slotted PVC screen.

Table 9.--Observation well and test boring logs, Map 13 Area- Continued

OW 13-8. Latitude 44°02'05", longitude: 70°58'26". Located in Fryeburg, in field owned by Green Thumb Corporation, east of Rt. 113.

Material	Depth (feet)	Thickness (feet)
Sand, medium, well-sorted	0-6	6
Sand, fine to medium	6-11	5
Sand, very fine; silt	11-21	10
Sand, coarse to very coarse, well-sorted	21-26	5
Sand, medium to very coarse, moderately well-sorted, stratified	26-31	5
Sand, medium to coarse	31-36	5
Sand, fine to very coarse, moderately well-sorted, stratified	36-46	10
Sand, medium, well-sorted	46-56	10
Sand, fine to medium	56-66	10
Sand, very fine to medium, moderately well-sorted, stratified	66-76	10
Sand, fine to medium, grey	76-96	20
Sand, fine to coarse, grey, moderately sorted, stratified	96-106	10
Sand, very fine to fine, with faint laminations of silt and clay	106-108	2
End of boring	(108)	--

OW 13-8 is screened from 25 to 30 feet below land surface with 0.008-inch slotted PVC screen.

Table 9.--Observation well and test boring logs, Map 13 Area- Continued

OW 13-9. Latitude: 44°07'28", longitude: 70°56'27". Located in Fryeburg near the intersection of McNeil Road and River Road. Depth to water approximately 8 feet.

Material	Depth (feet)	Thickness (feet)
Sand, very fine to fine; silt; clay	0-16	16
Sand, medium to very coarse; granules and pebbles	16-20	4
Sand, medium to very coarse, moderately sorted, stratified	20-31	11
Sand, medium to very coarse, iron-stained; granules and pebbles	31-41	10
Sand, fine to medium, grey, well-sorted, micaceous	41-48	7
Clay, massive, grey-green	48-53	5
End of boring	(53)	--

OW 13-9 is screened from 20.5 to 23 feet below land surface with 0.010-inch slotted PVC screen.

Table 10.--Observation well logs, Map 14 Area 1/

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

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

Site description: A brief site description is given.

Description of materials: Logs of observation well based on the Wentworth scale, by the U.S. Geological Survey.

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

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

Table 10.--Observation well logs, Map 14 Area - Continued

OW 14-1. Latitude 44°07'28", longitude: 70°56'27". Located in Stow, in field off Rt. 113 near Maine-New Hampshire state line. Depth to water approximately 9 feet.

Material	Depth (feet)	Thickness (feet)
Granules, pebbles, and cobbles	0-11	11
Sand, medium to very coarse; granules and pebbles	11-16	5
Sand, coarse to very coarse; granules and pebbles	16-21	5
Sand, medium to very coarse; granules and pebbles	21-26	5
Sand, medium, well-sorted	26-36	10
Sand, fine to coarse, poorly sorted; granules and pebbles	36-46	10
Sand, fine to coarse, well-sorted, stratified, iron-stained, interbedded with clay	46-56	10
Clay, blue and green, interbedded with some moderately sorted, fine to medium sand	56-66	10
Clay, interbedded with very fine sand and silt	66-72	6
Refusal (bedrock)	72	--

OW 14-1 is screened from 18 to 23 feet below land surface with 0.010-inch slotted PVC screen.

Table 10.--Observation well logs, Map 14 Area - Continued

OW 14-2. Latitude: 44°24'01", longitude:70°52'05". Located in West Bethel, off Route 2, in Pleasant River Campground. Depth to water approximately 50 feet.

Material	Depth (feet)	Thickness (feet)
Sand, medium to very coarse; granules and pebbles	0-6	6
Sand, medium, well-sorted	6-16	10
Sand, medium to coarse	16-21	5
Sand, medium, well-sorted	21-26	5
Sand, medium to coarse, well-sorted	26-41	15
Sand, medium to very coarse; granules and pebbles	41-51	10
Sand, coarse to very coarse	51-56	5
Sand, fine to very coarse, moderately well-sorted, stratified; some organic(?) material	56-61	5
Sand, medium to coarse, iron-stained	61-66	5
Sand, fine to very coarse, moderately well-sorted, stratified, interbedded with silt/clay	66-76	10
Sand, very fine to very coarse, well-sorted, stratified	76-86	10
Sand, very fine to very coarse, moderately well-sorted, stratified, micaceous, interbedded with silt/clay layers;	86-96	10
Sand, medium, grey, micaceous	96-111	15
Sand, very fine to medium, moderately well-sorted, stratified, some very fine stratified sand and silt, micaceous	111-113	2
End of boring	(113)	--

OW 14-2 is screened from 60 to 65 feet below land surface with 0.008-inch slotted PVC screen.

Table 10.--Observation well logs, Map 14 Area - Continued

OW 14-3. Latitude: 44°24'01", longitude:70°52'05". Located in field in Bethel, off Old Route 2, near Androscoggin River. Depth to water approximately 20 feet.

Material	Depth (feet)	Thickness (feet)
Sand, very coarse; granules, pebbles, and cobbles	0-6	6
Sand, coarse to very coarse; granules and pebbles	6-16	10
Sand, coarse to very coarse	16-33	17
Sand, very fine to fine	33-35	2
End of boring	(35)	--

OW 14-3 is screened from 28 to 33 feet below land surface with 0.006-inch slotted PVC screen.

Table 10.--Observation well logs, Map 14 Area - Continued

OW 14-4. Latitude: 44°24'24", longitude:70°55'38". Located in Gilead, off North Road, near Portland Pipe Line, near Whites Brook. Depth to water approximately 11 feet.

Material	Depth (feet)	Thickness (feet)
Sand, fine to very coarse; granules and pebbles	0-17	17
(Cobbles)	(8)	
Sand, medium to coarse, well sorted	17-22	5
Sand, fine to coarse, moderately well-sorted, weakly stratified, iron-stained	22-27	5
Sand, fine to very coarse, moderately sorted, stratified	27-32	5
Sand, very fine to medium, moderately well-sorted, stratified	32-37	5
Sand, very fine to very coarse, moderately sorted, weakly stratified, some medium to very coarse sands are iron-stained	37-42	5
Sand, very fine to very coarse, moderately well-sorted, stratified, interbedded with silt and clay	42-47	5
Sand, very fine to fine	47-52	5
Sand, coarse to very coarse	52-57	5
Sand, very coarse; gravel	57-58	1
Sand, medium, well-sorted	58-67	9
Sand, very coarse; granules and pebbles	67-68	1
Sand, medium, well-sorted	68-77	9
Sand, very fine to very coarse, moderately well-sorted, stratified	77-113	36
Refusal (bedrock)	113	--

OW 14-4 is screened from 24 to 28 feet below land surface with 0.008-inch slotted PVC well screen.

Table 10.--Observation well logs, Map 14 Area - Continued

OW 14-5. Latitude: 44°15'48", longitude:70°47'32". Located in Albany, on west side of Route 5, 5 miles south of the intersection of Route 5 and Route 35. Depth to water approximately 16 feet.

Material	Depth (feet)	Thickness (feet)
Sand, medium to very coarse; granules, pebbles	0-11	11
Sand, coarse to very coarse, granules, pebbles	11-22	11
Refusal	22	--

OW 14-5 is screened from 17 to 22 feet with 0.015-inch slotted PVC screen.

Table 10.--Observation well logs, Map 14 Area - Continued

OW 14-6. Latitude: 44°15'12", longitude: 70°47'26". Located in Albany, on east side of Route 5, at Albany/Waterford Dump. Depth to water approximately 34 feet.

Material	Depth (feet)	Thickness (feet)
Sand, coarse to very coarse; gravel	0-6	6
Sand, coarse to very coarse	6-21	15
Sand, coarse to very coarse; granules and pebbles	21-36	15
Sand, medium to very coarse	36-41	5
Sand, medium to very coarse; abundant granules and pebbles	41-46	5
Sand, fine to very coarse; granules and pebbles	46-56	10
Sand, coarse to very coarse; granules and pebbles	56-57	1
Sand, medium to very coarse, iron-stained	57-76	19
Sand, medium to very coarse; granules and pebbles	76-86	10
Sand, medium to very coarse; rock fragments	86-87	1
Refusal (bedrock)	87	--

OW 14-6 is screened from 45 to 48 feet with 0.008-inch slotted PVC screen.

Table 10.--Observation well logs, Map 14 Area - Continued

OW 14-7. Latitude: 44°07'52", longitude: 70°52'21". Located in Sweden, in a gravel pit on north side of Route 93, approximately 1 mile east of the Lovell/Sweden town line.

Material	Depth (feet)	Thickness (feet)
Sand, medium to coarse	0-6	6
Sand, very fine to fine	6-21	15
Sand, fine	21-45	24
Sand, fine to medium; organic(?) debris	45-47	2
Sand, fine, iron-stained	47-56	8
Sand, fine, well-sorted	56-57	11
Sand, fine to medium, moderately well-sorted, stratified, interbedded with silt and clay	57-76	19
Sand, very fine to medium; some silt and clay	76-78	2

End of boring

OW 14-7 is screened from 45 to 50 feet with 0.006-inch slotted PVC screen.

Table 10.--Observation well logs, Map 14 Area - Continued

OW 14-8. Latitude: 44°09'35", longitude: 70°58'40". Located in Stow, in gravel pit on north side of New Road, near the intersection with Route 113. Depth to water approximately 10 feet.

Material	Depth (feet)	Thickness (feet)
Sand, medium, well-sorted	0-6	6
Sand, medium to coarse	6-16	10
Sand, fine to very coarse	16-18	2
Clay, with thin laminations of well-sorted very fine to medium sand	18-23	5
Sand, fine to medium; granules and pebbles	23-24	1
Sand, fine to very coarse, poorly sorted; granules and pebbles	24-26	2
Clay, grey; stratified with layers of moderately well-sorted fine to coarse sand; coarser sand layers are iron-stained	26-32	6
Till	32-37	5
Refusal (bedrock)	37	--

OW 14-8 is screened from 22.5 to 25 feet below land surface with 0.006-inch slotted PVC screen.

Table 11.--Observation well logs, Map 15 Area 1/

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

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

Site description: A brief site description is given.

Description of materials: Logs of observation well based on the Wentworth scale, by the U.S. Geological Survey.

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 B.P. 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 word "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 and 2 for information on grain-size analyses and estimated transmissivities.

Table 11.--Observation well logs, Map 15 Area- Continued

OW 15-1. Latitude: 44°13'40", longitude: 70°42'16". Located in Waterford, off south side of Route 118, in Papoose Pond Campground. Depth to water approximately 21 feet.

Material	Depth (feet)	Thickness (feet)
Sand, medium to coarse	0-3	3
Sand, coarse	3-6	3
Sand, coarse to very coarse	6-11	5
(Gravel)	(9)	
Sand, fine to medium, grey, well-sorted	11-21	10
Sand, fine, micaceous	21-32	11
Sand, medium to very coarse, poorly sorted, iron-stained	32-51	19
Sand, coarse to very coarse, iron-stained, with one 1/2" interbed of grey-green silt	51-61	10
Sand, medium to coarse, micaceous	61-71	10
Sand, medium, micaceous	71-82	11
Sand, fine to medium, micaceous	82-91	9
Sand, fine, micaceous	91-106	15
Till	106-112	6
Refusal (bedrock)	112	--

OW 15-1 is screened from 33 to 38 feet below land surface with 0.010-inch slotted PVC screen.

Table 11.--Observation well logs, Map 15 Area- Continued

OW 15-2. Latitude: 44°28'30", longitude: 70°38'30". Located in Rumford, off east side of Rt. 232, approximately 1 mile north of the Milton/Rumford town line. Depth to water approximately 15 feet.

Material	Depth (feet)	Thickness (feet)
Sand, medium to coarse, tan, brown; granules and pebbles	0-6	6
Sand, medium, reddish-brown, well-sorted; gravel	6-11	5
Sand, very coarse, reddish-brown, moderately well sorted	11-21	10
Sand, coarse to very coarse, reddish-brown, well sorted	21-31	10
Sand, medium to very coarse, tan, grey, red, moderately sorted; granules and pebbles	31-41	10
Sand, fine to coarse, moderately sorted; granules and pebbles	41-51	10
Gravel; sand, dense, poorly sorted	51-61	10
Gravel; mostly granitic granules and pebbles, angular, in matrix of grey silty sand	61-105	44
Refusal	105	--

OW 15-2 is screened from 21 to 26 feet below land surface with 0.010-inch slotted PVC screen.

OW 15-3. Latitude: 44°29'43", longitude: 70°40'23". Located in Rumford in a field on the east side of Route 232, near the Androscoggin River. Depth to water approximately 23 feet.

Materail	Depth (feet)	Thickness (feet)
Sand, fine to medium, tan; gravel	0-6	6
Sand, medium, brown; granules and pebbles	6-11	5
Sand, medium, brown, well-sorted; granules and pebbles	11-36	25
End of boring	(36)	

OW 15-3 is screened from 30 to 35 feet with 0.008-inch slotted PVC screen.

Table 11.--Observation well logs, Map 15 Area- Continued

OW 15-4. Latitude: 44°29'43, longitude: 70°40'23". Located in East Peru on north side of Worthley Road in Honey Run Campground, at southern end of Worthley Pond. Depth to water approximately 1 foot.

Material	Depth (feet)	Thickness (feet)
Clay, grey; silt	0-4	4
Gravel	4-6	2
Sand, medium	6-10	4
Sand, fine	10-11	1
Sand, medium	11-12	1
Sand, coarse to very coarse	12-21	9
Clay, with layers of fine sand	21-29	8
Sand, fine to very coarse, moderately well sorted, stratified, iron-stained, a few clay interbeds	29-32	3
Clay; sand, fine to coarse, moderately well-sorted, stratified, in layers 1/4 to 1/2" thick	32-36	4
Sand, medium to coarse, moderately well sorted, stratified with few clay interbeds	36-41	5
Sand, fine to coarse, well-sorted, stratified, clay interbeds	41-46	5
Sand, medium to coarse, well-sorted	46-47	1
Sand, coarse to very coarse, well-sorted, 1 1/4" - thick clay layer	47-47.5	0.5
Sand, very coarse; angular granules and pebbles	47.5-56.5	9
Sand, medium to coarse, grey; granules and pebbles	56.5-62	5.5
Till, densely packed, very fine to fine sand with quartz rock fragments	62-65	3
Refusal (bedrock)	65	--

OW 15-4 is screened from 46 to 51 feet below land surface with 0.006-inch slotted PVC screen.

Table 11.--Observation well logs, Map 15 Area- Continued

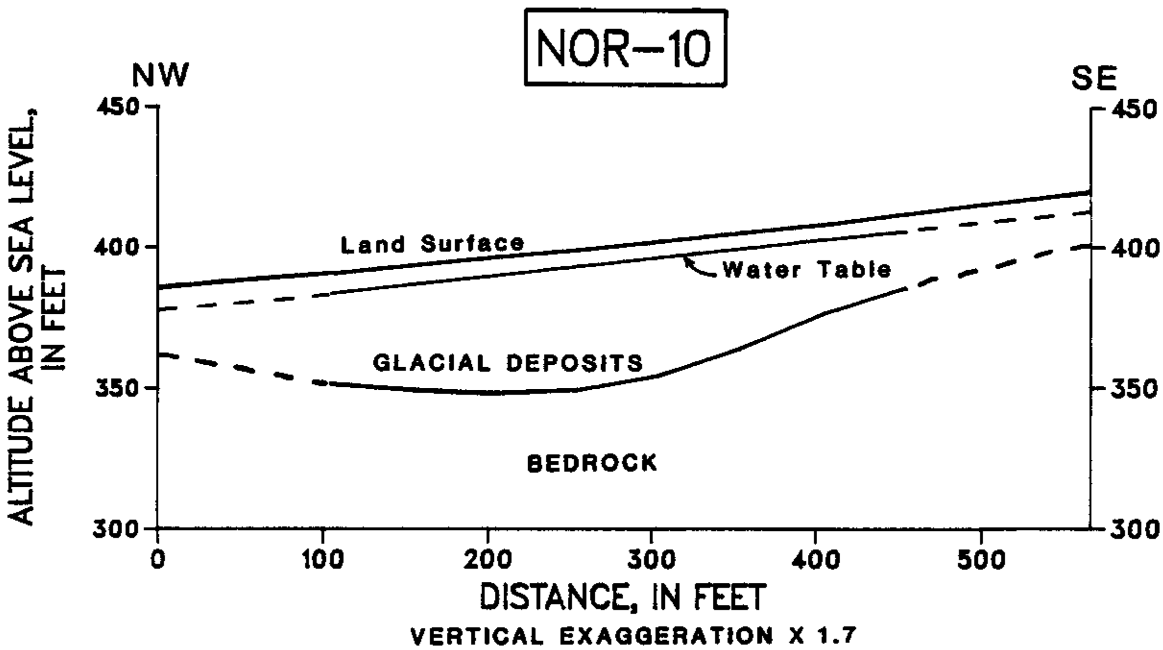
OW 15-5. Latitude: 44°17'47, longitude: 70°23'31". Located in Buckfield, in field on south side of Paris Hill Road, near the Nezinscot River.

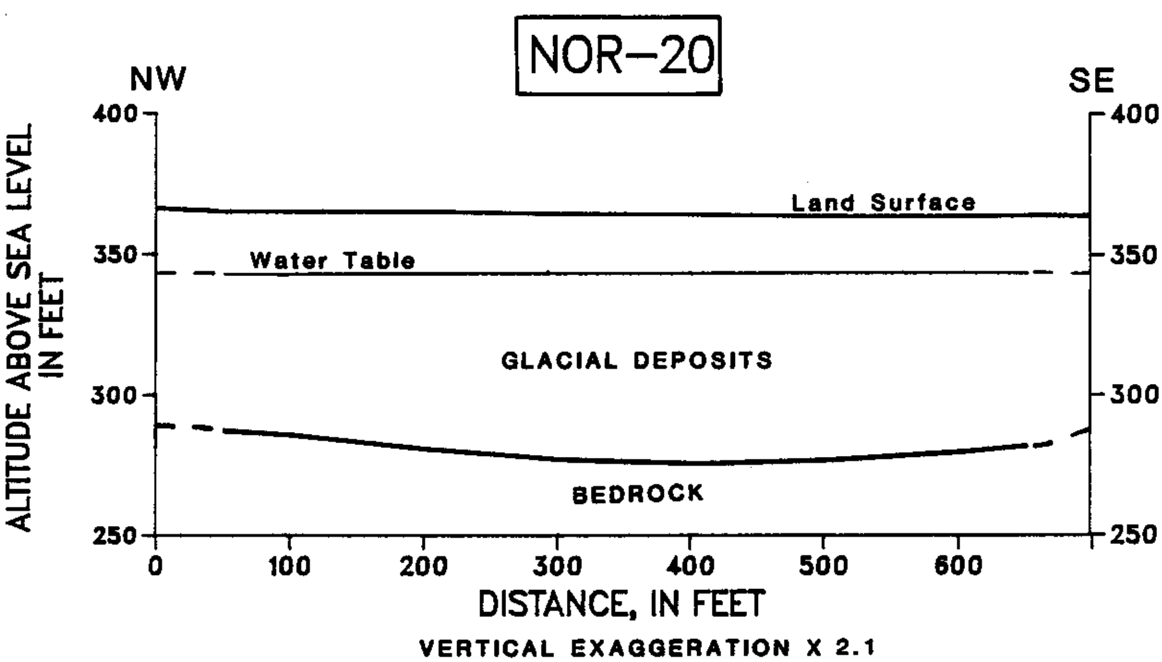
Material	Depth (feet)	Thickness (feet)
Sand, coarse, well-sorted	0-6	6
Sand, medium, well-sorted	6-11	5
Sand, fine to medium, well-sorted	11-21	10
End of boring	(21)	

OW 15-5 is screened from 16 to 21 feet below land surface with 0.008-inch slotted PVC screen.

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

Hydrogeologic sections from seismic-refraction surveys conducted by the U.S. Geological Survey in 1983. Locations 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 x-axes are measured from shot #1. At the ends of each profile, the altitudes of the water table and bedrock surface have been shown with dashed lines to emphasize the relative unreliabilty of this data as compared with the central portion of the profile.





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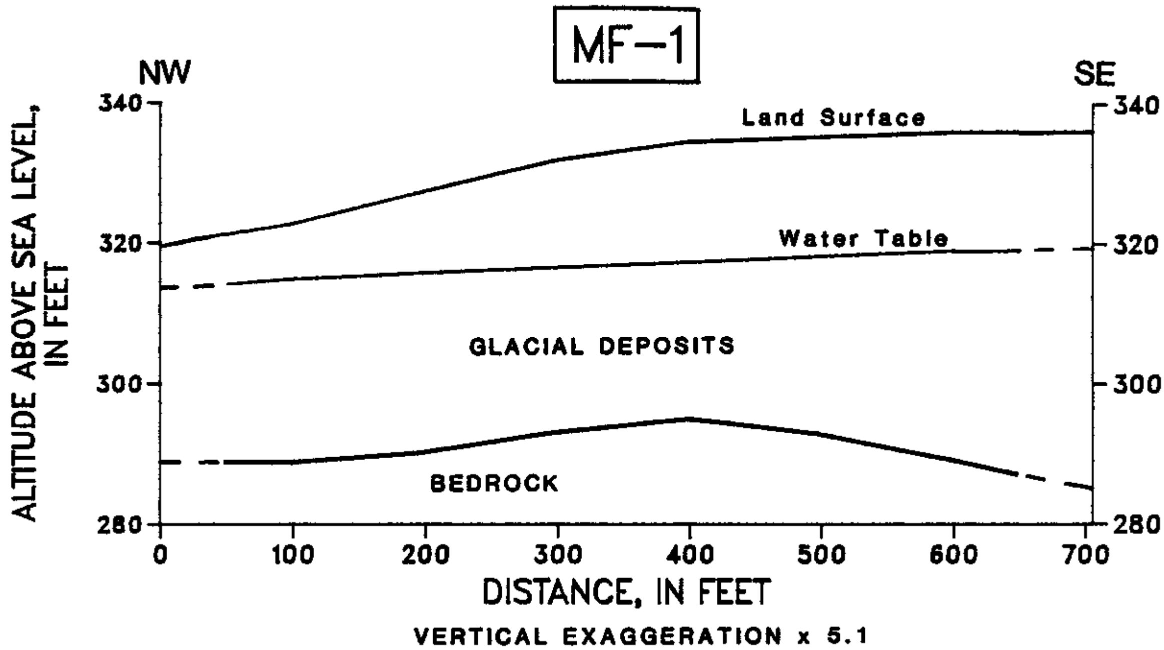

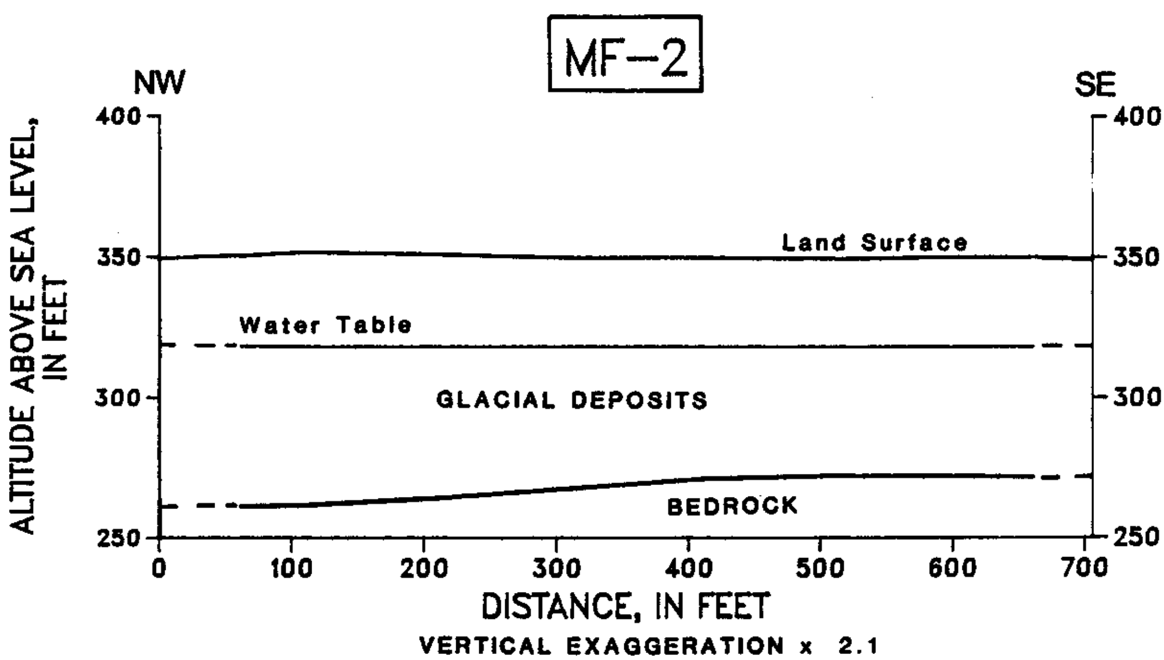

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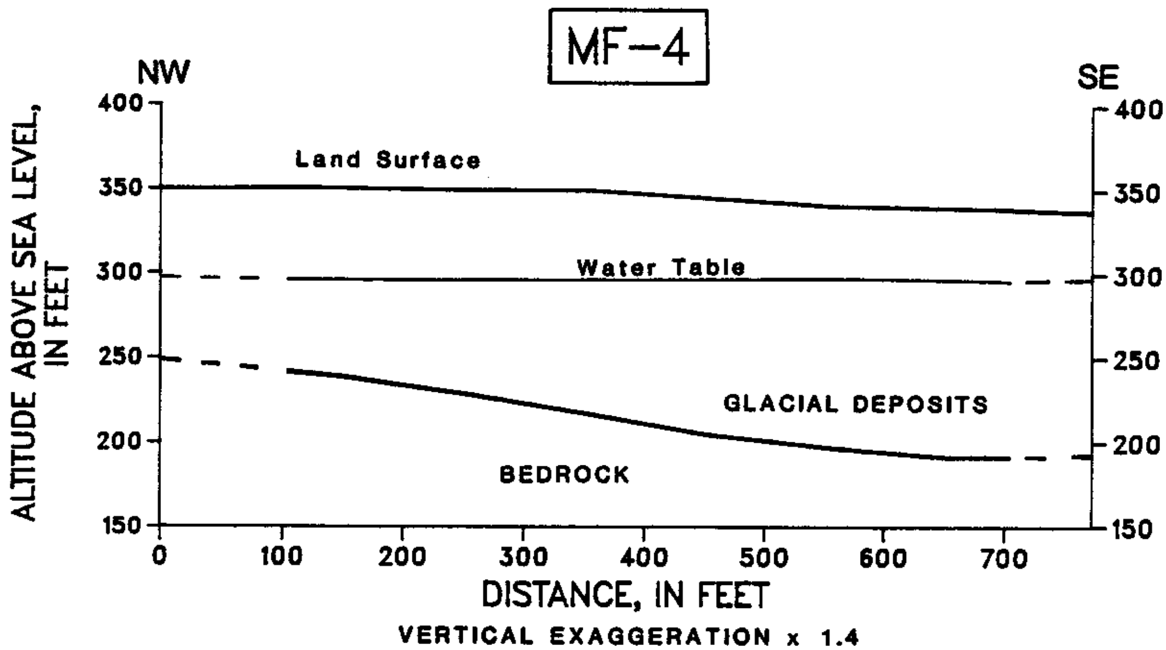

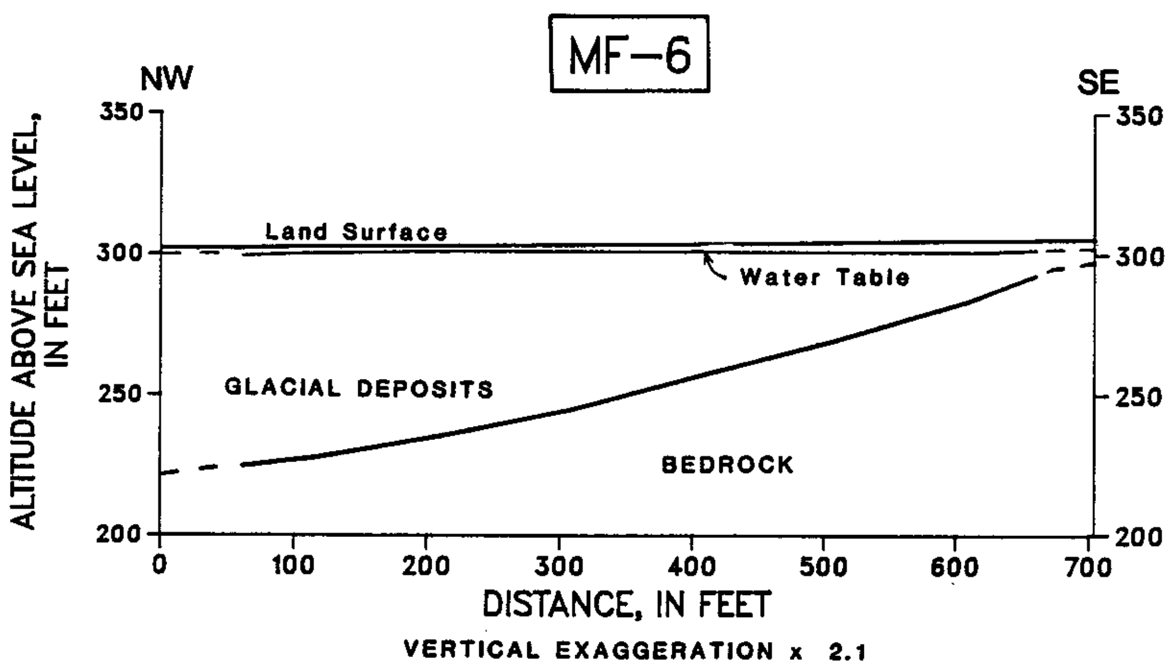

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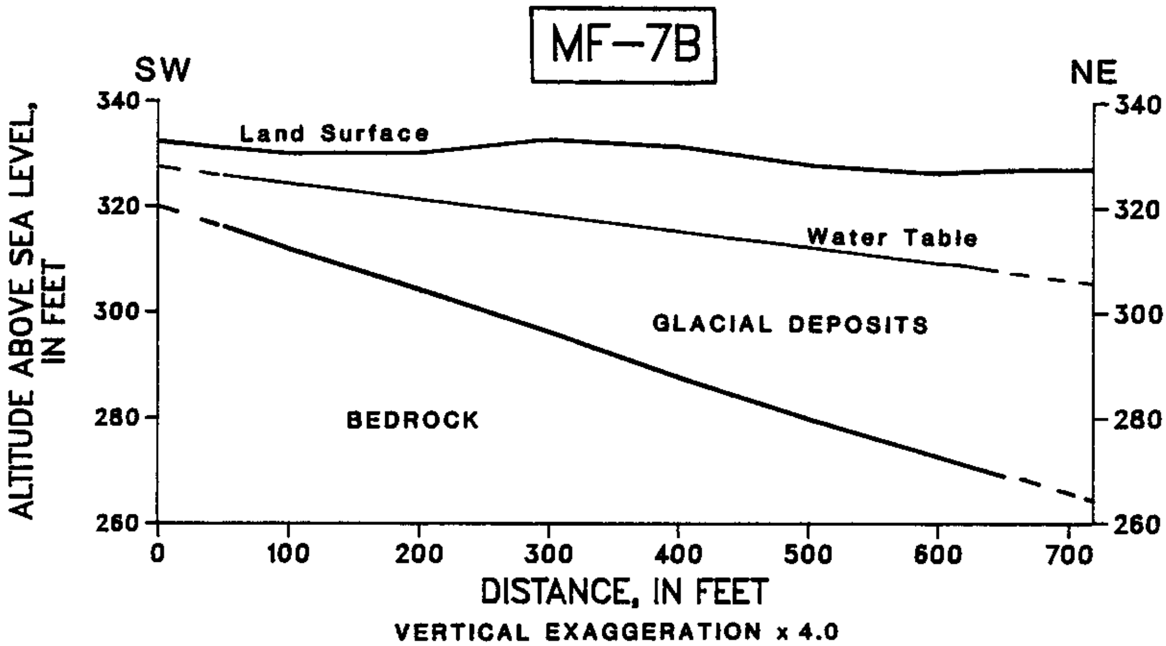

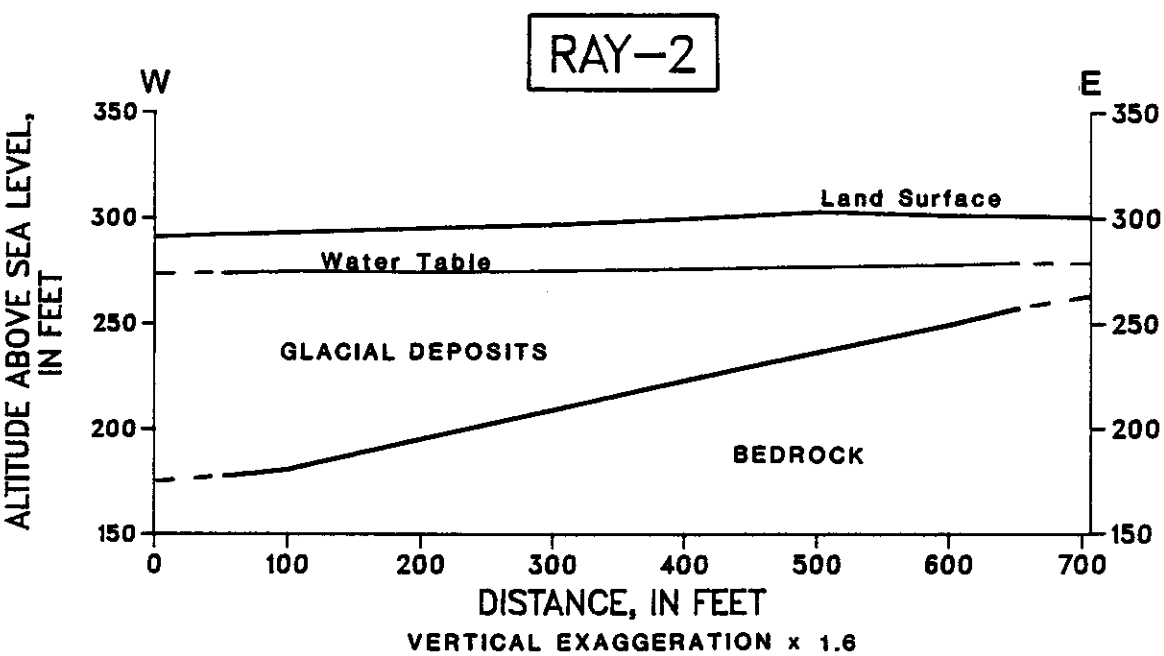

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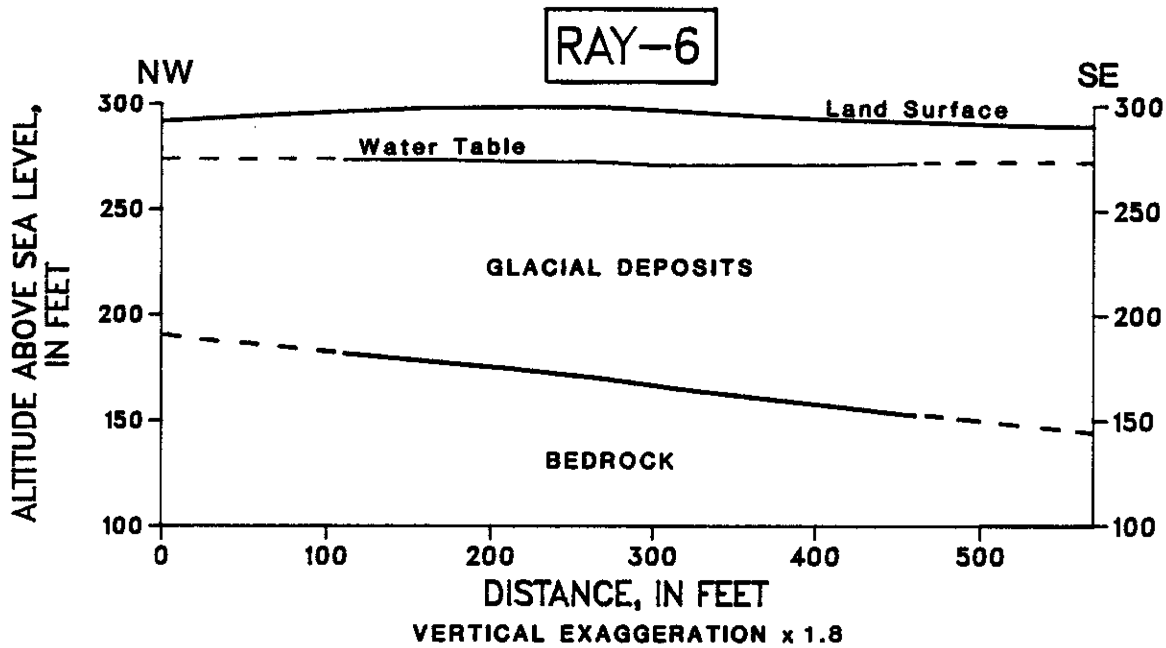


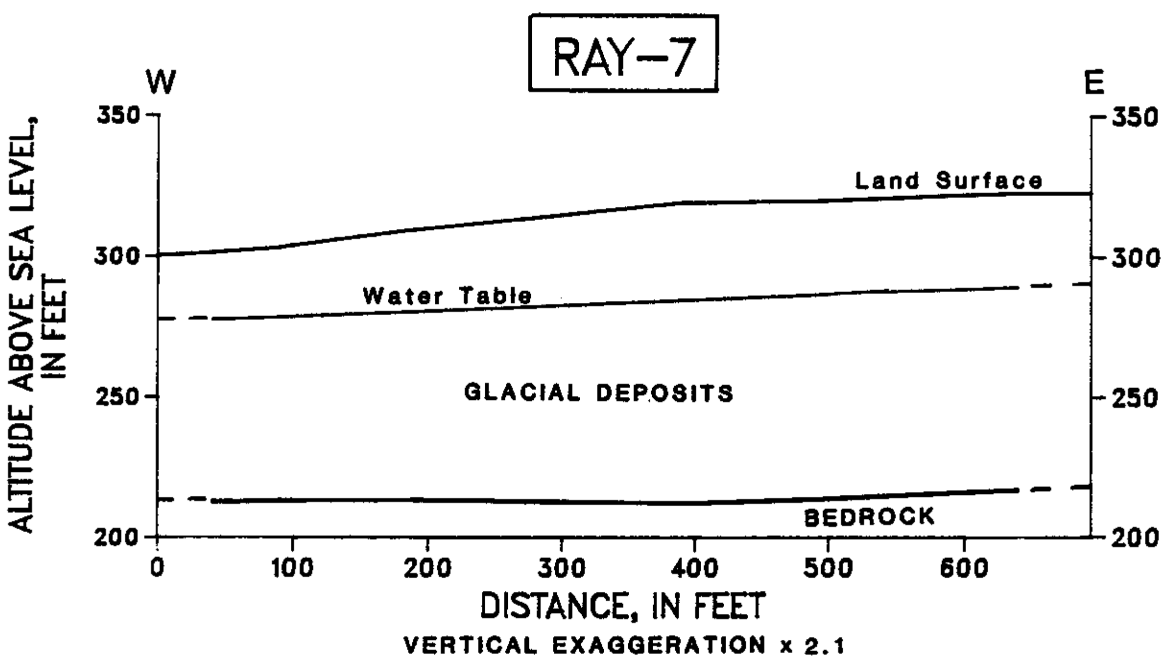
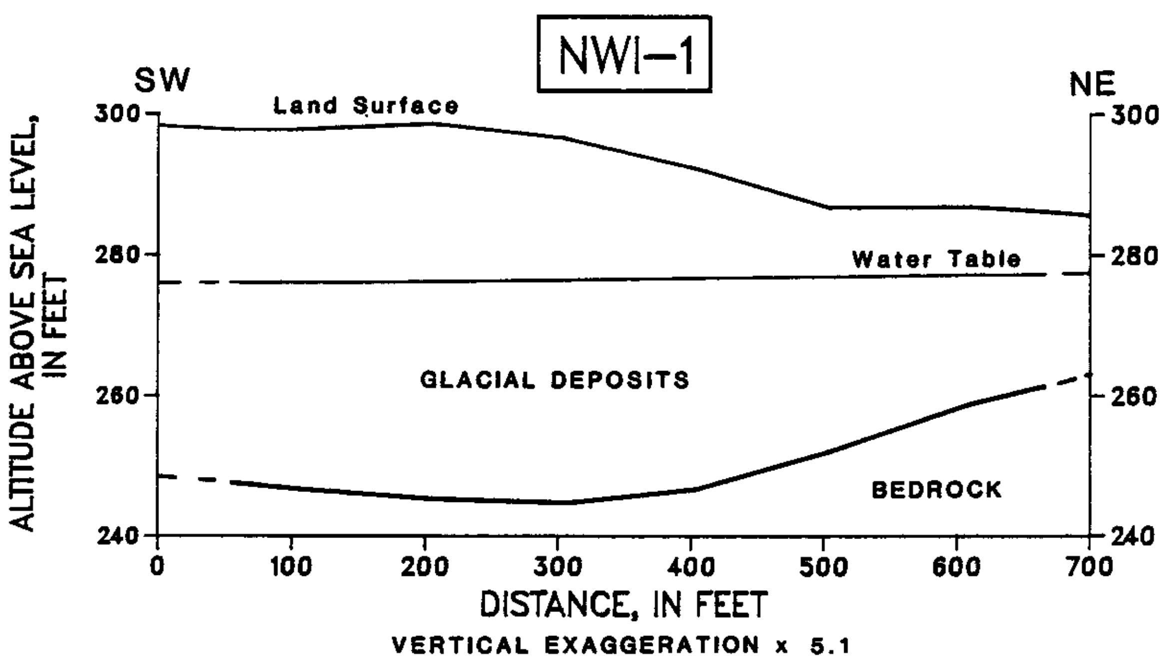


Figure 8. Continued.

NWI–O

No profile is shown for NWI-O because a blind zone problem was encountered on the northwestern end of the line. On this end, a 15-foot thick saturated section (if present), under 20 feet of unsaturated material, could not be detected with seismic refraction. The true depth to bedrock is somewhere between 23 feet and 34 feet and the saturated section (if present) is between 0 and 15 feet thick. On the southeastern end of the line, depth to water is approximately 4 feet and depth to bedrock is approximately 35 feet.



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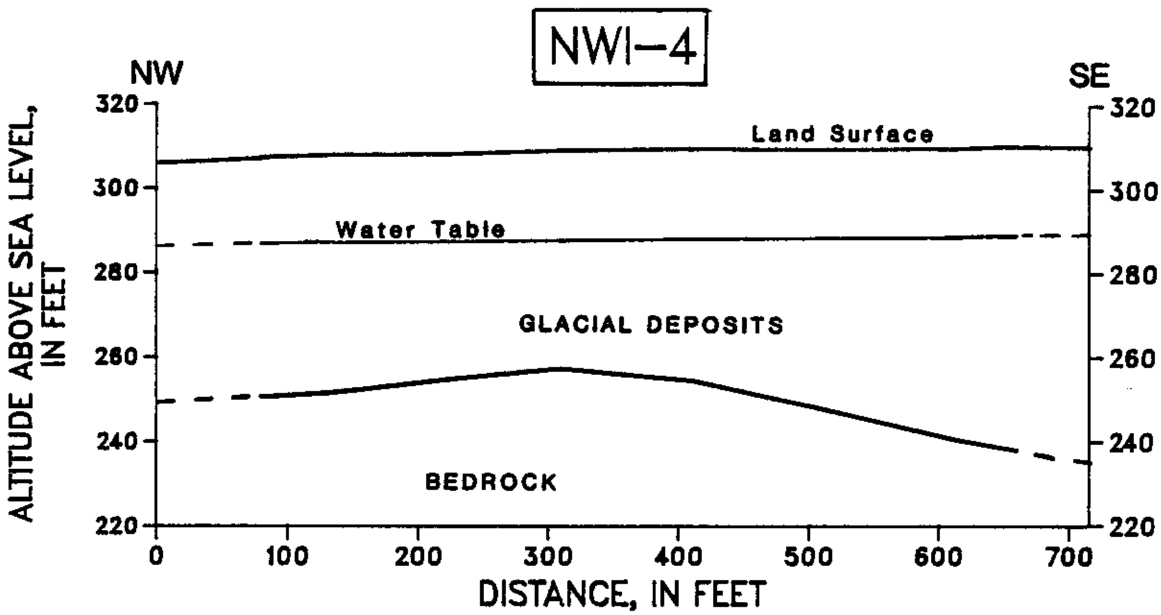
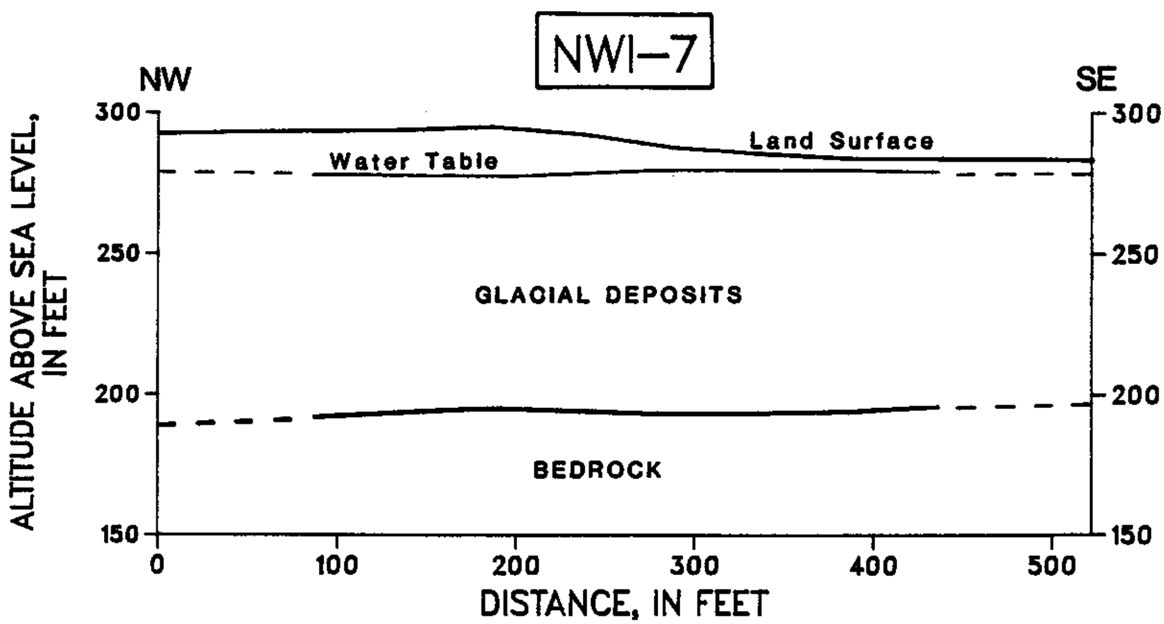
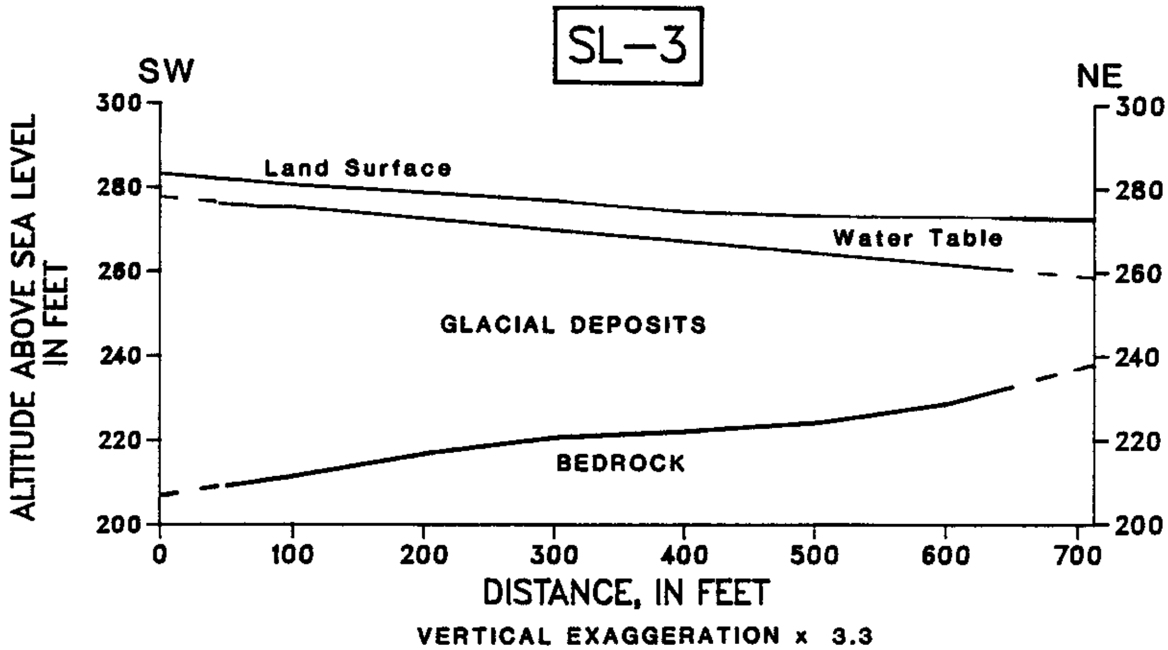


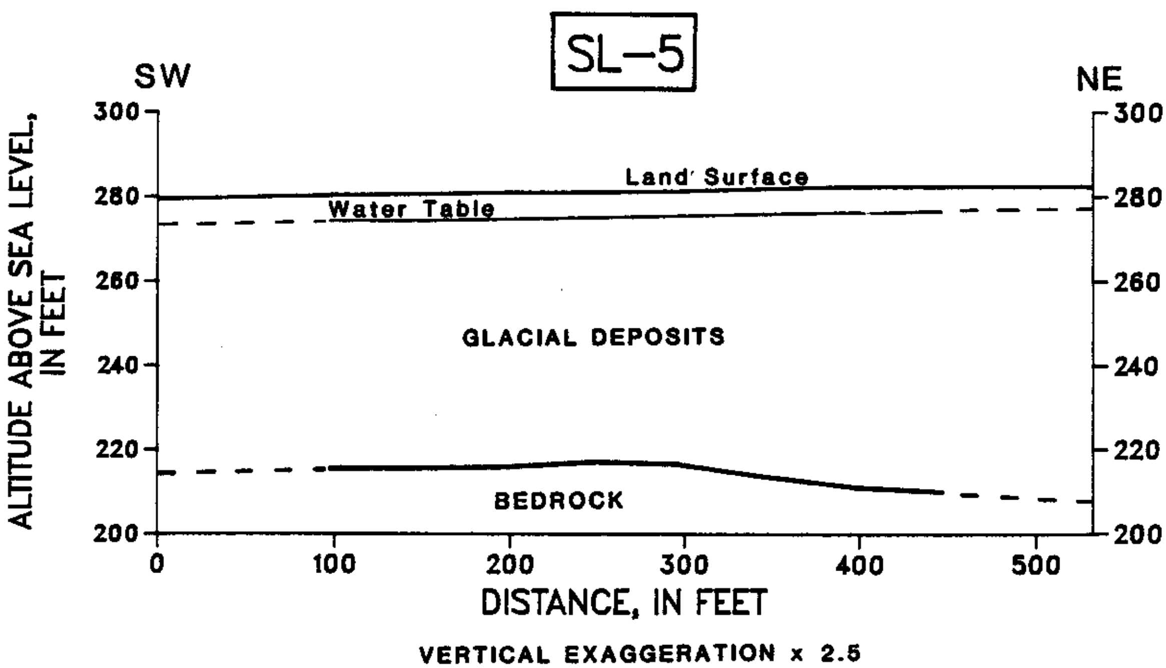
VERTICAL EXAGGERATION x 3.2



VERTICAL EXAGGERATION x 1.6

Figure 8. Continued.





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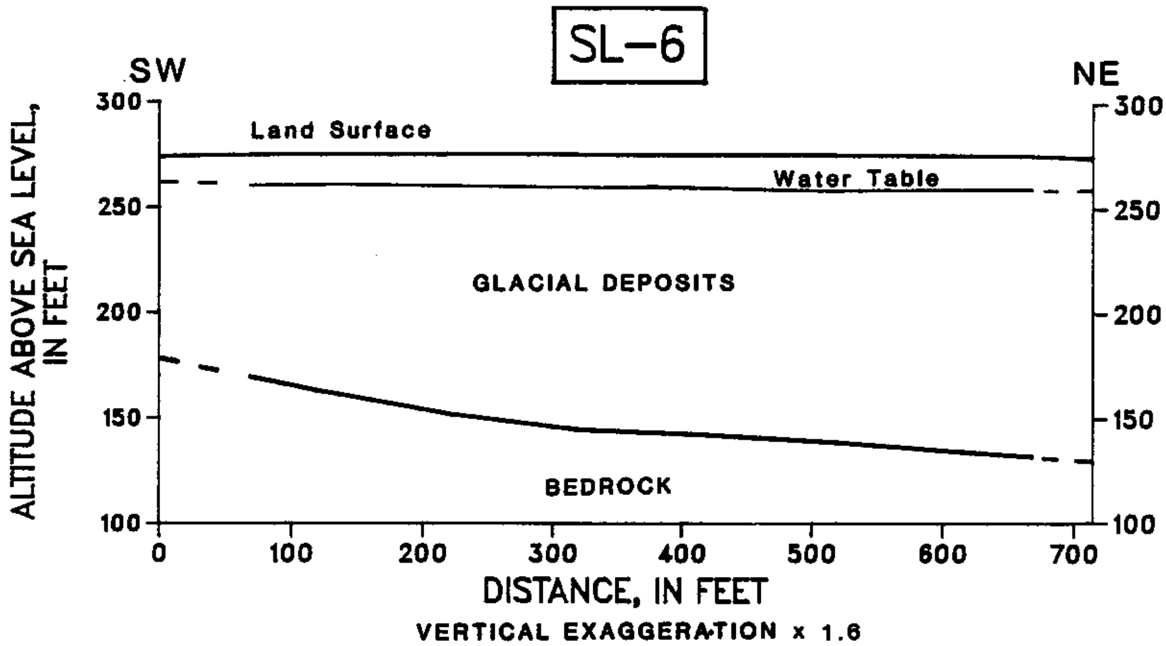
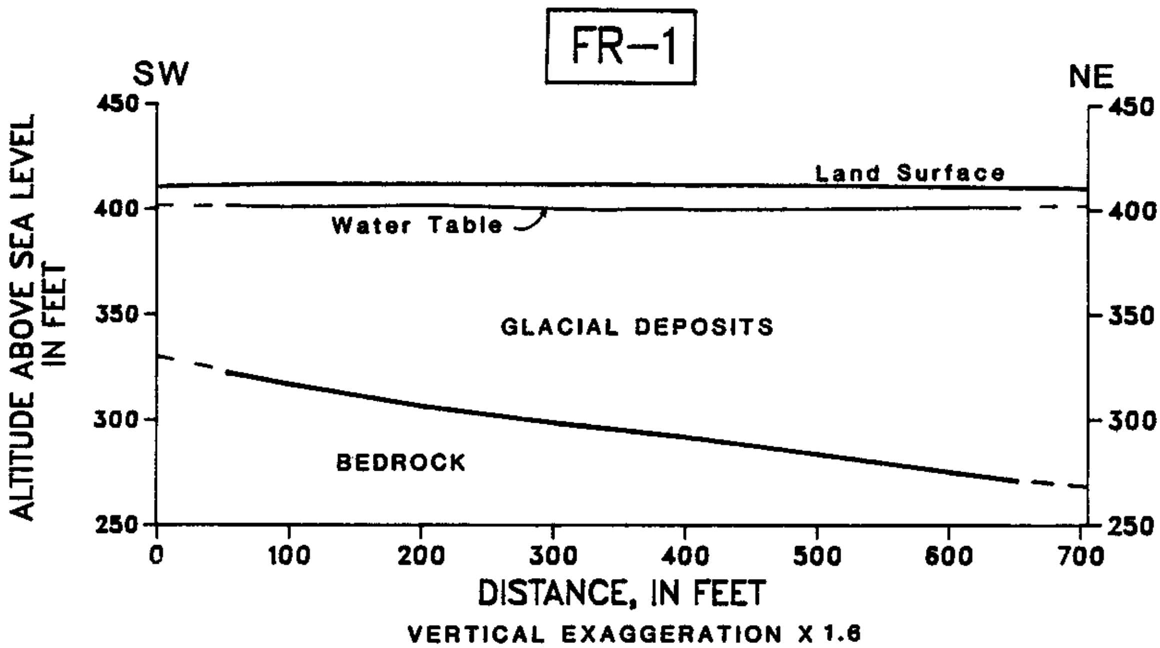
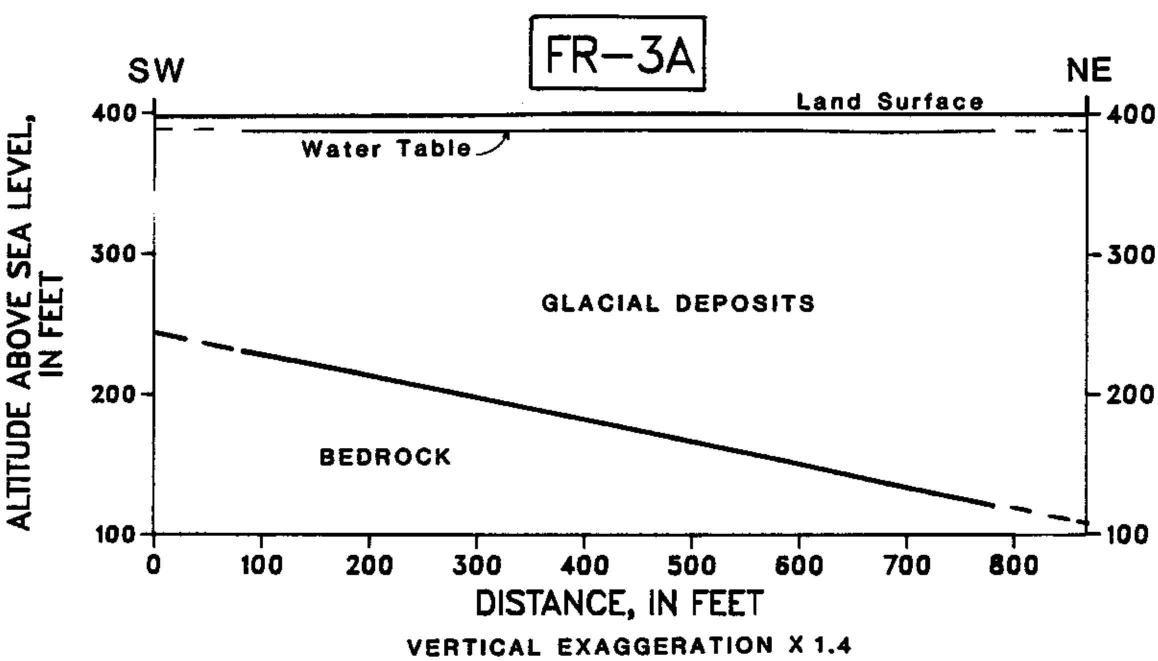


Figure 9.--12-channel seismic-refraction profiles: Map 13

Hydrogeologic sections from seismic-refraction surveys conducted by the U.S. Geological Survey in 1983. Locations of individual profiles are shown on plate 2. Data interpretation is based on a computer modeling program described by Scott and others (1972). Distances shown on x-axes are measured from shot #1. At the ends of each profile, the altitudes of the water table and bedrock surface have been shown with dashed lines to emphasize the relative unreliability of this data as compared with the central portion of the profile.





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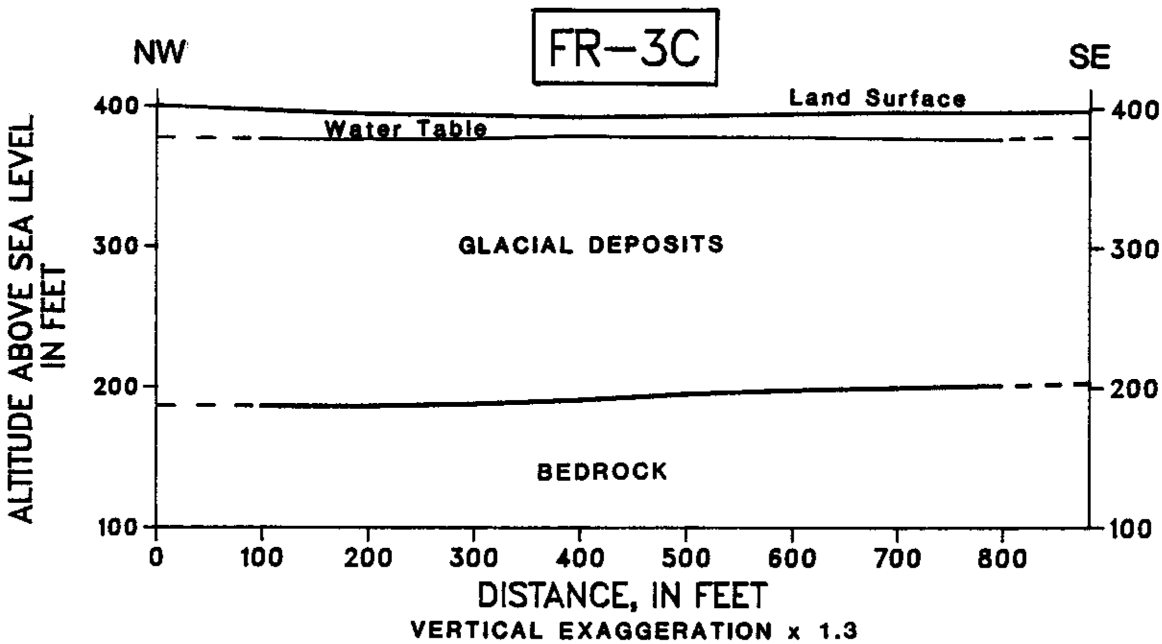

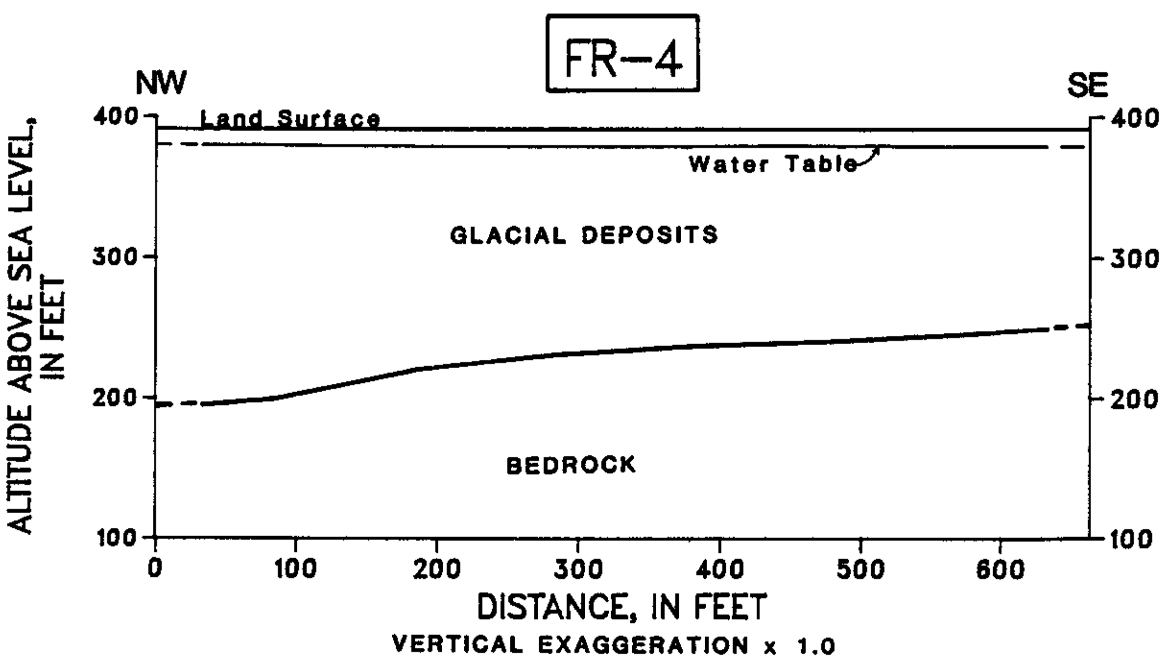

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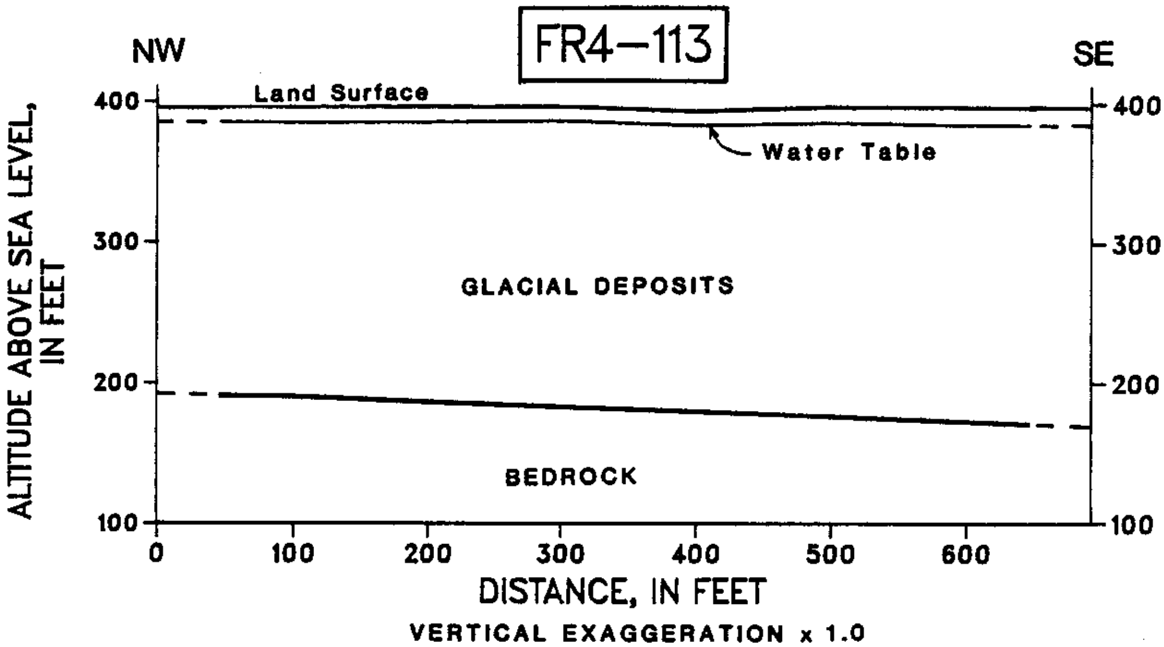

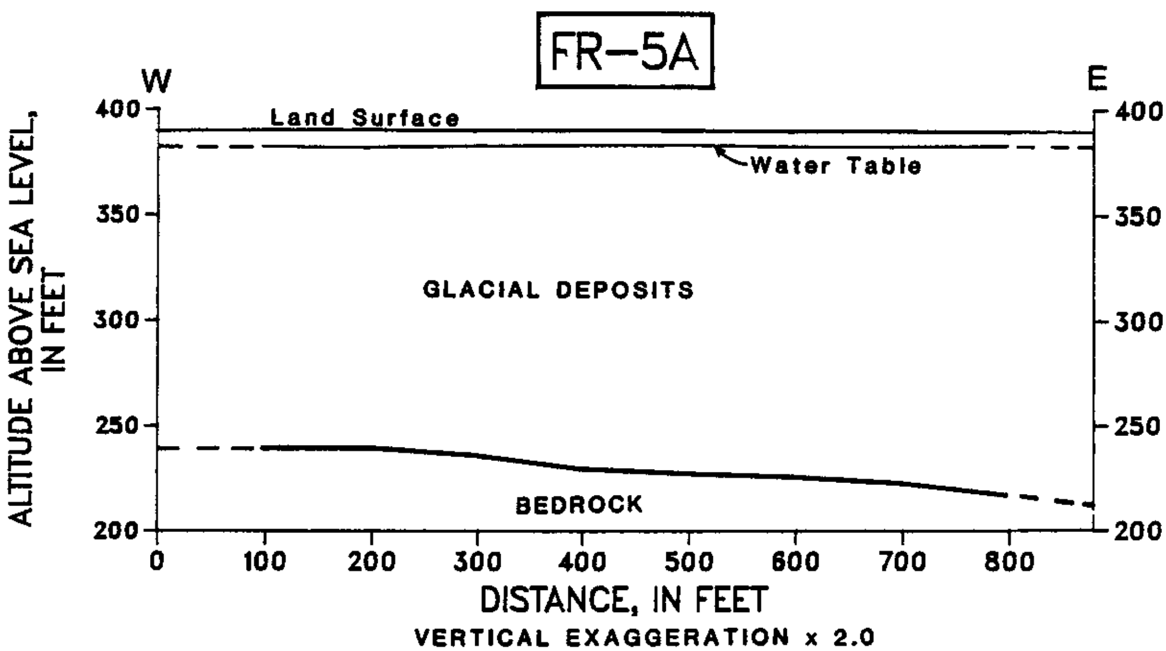

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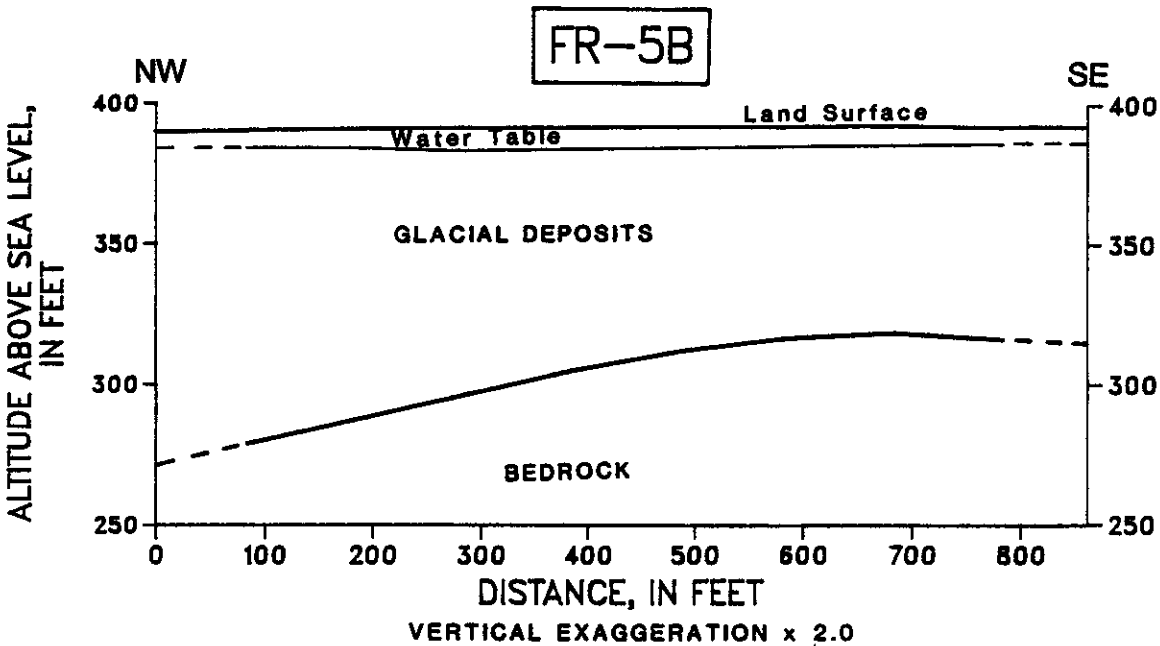

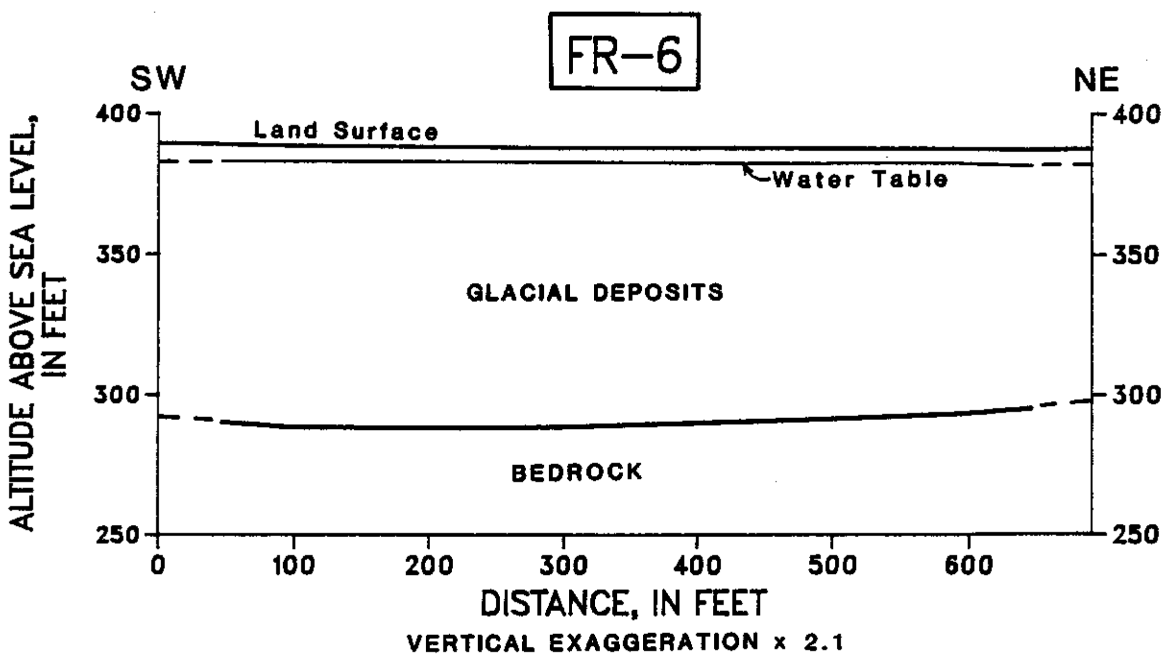

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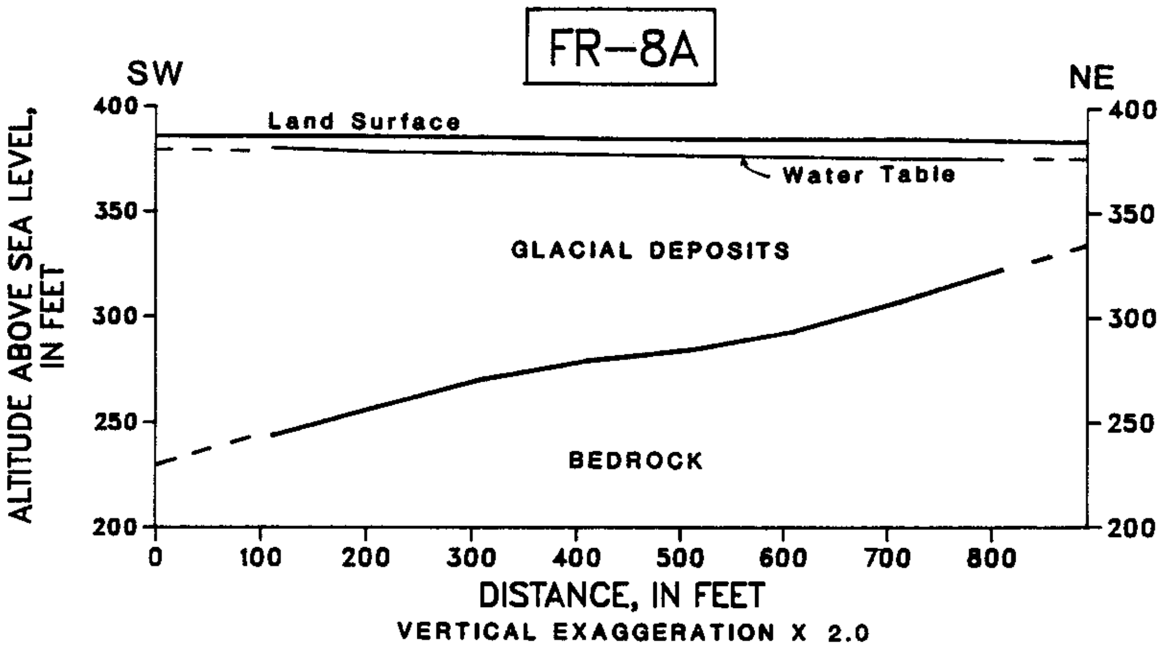

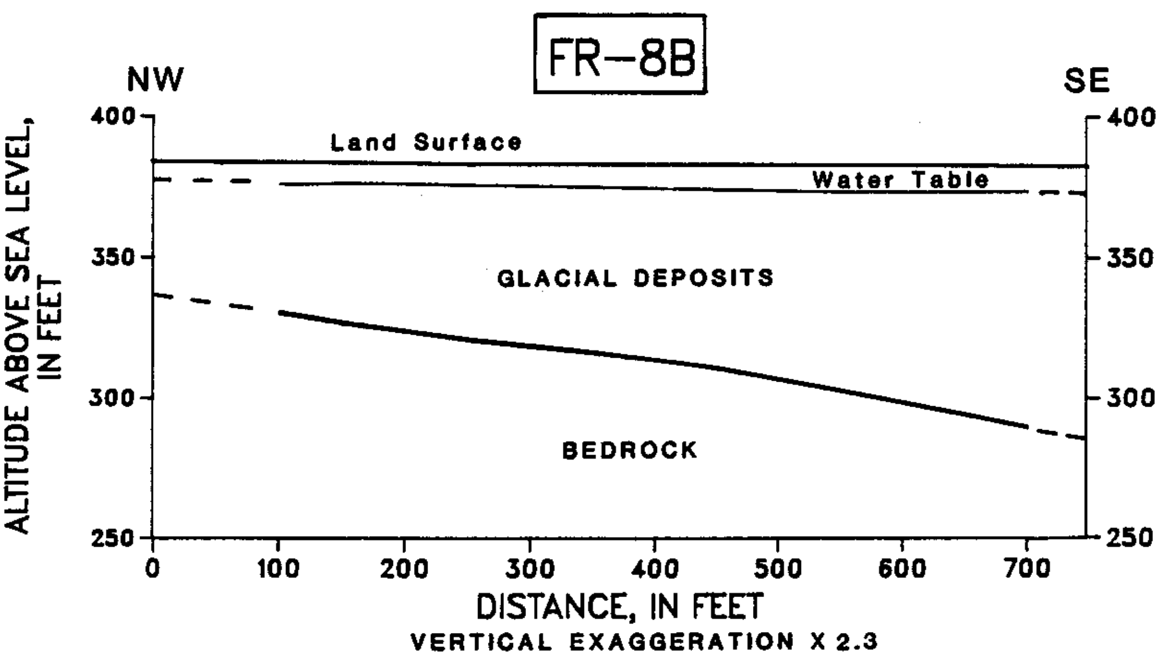

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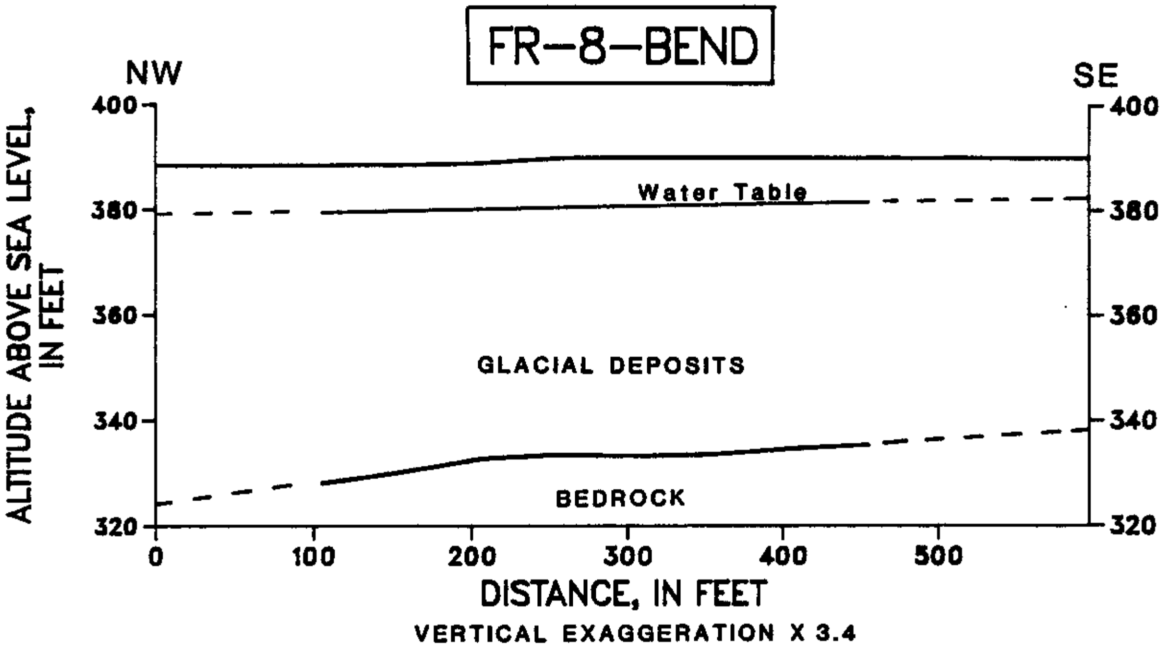

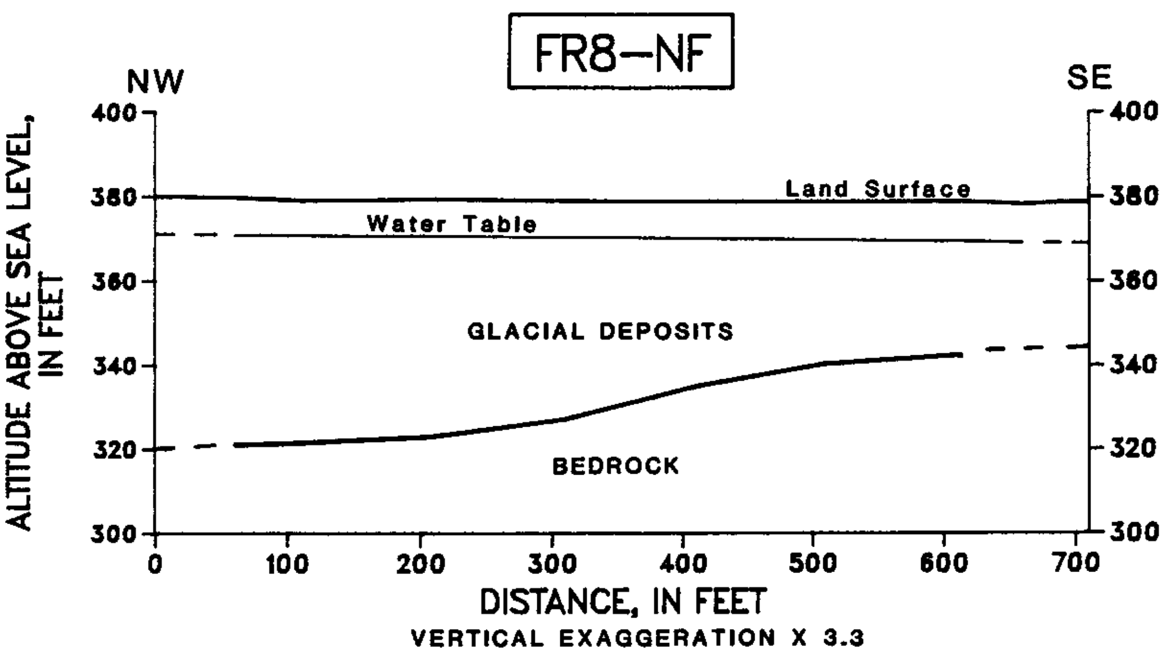

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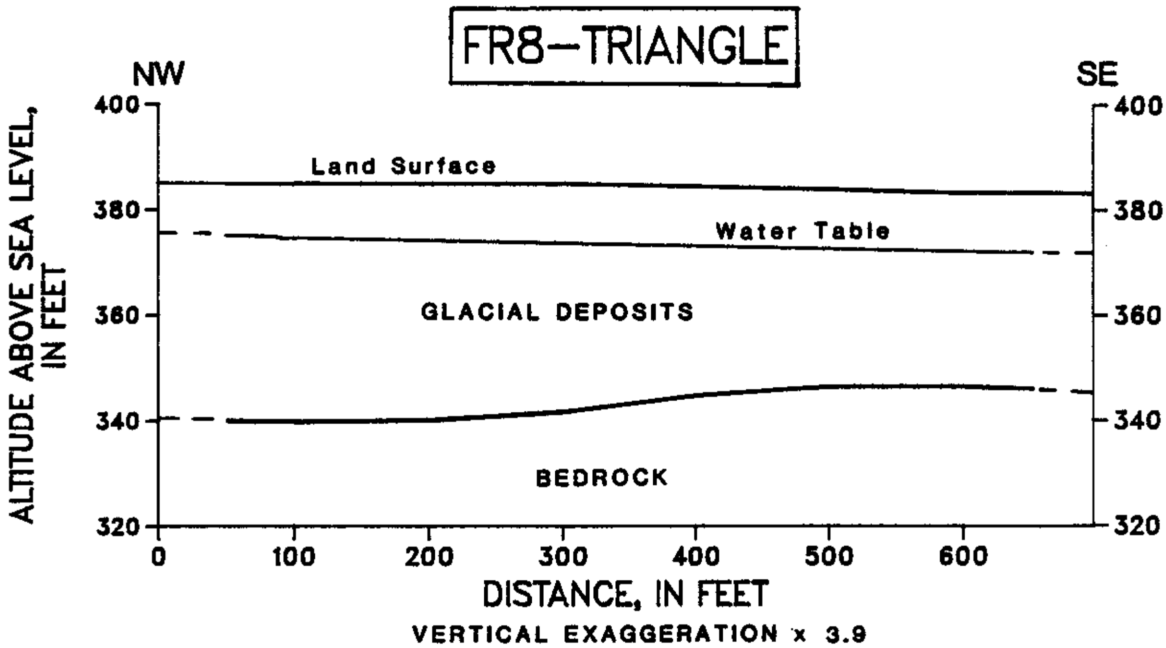

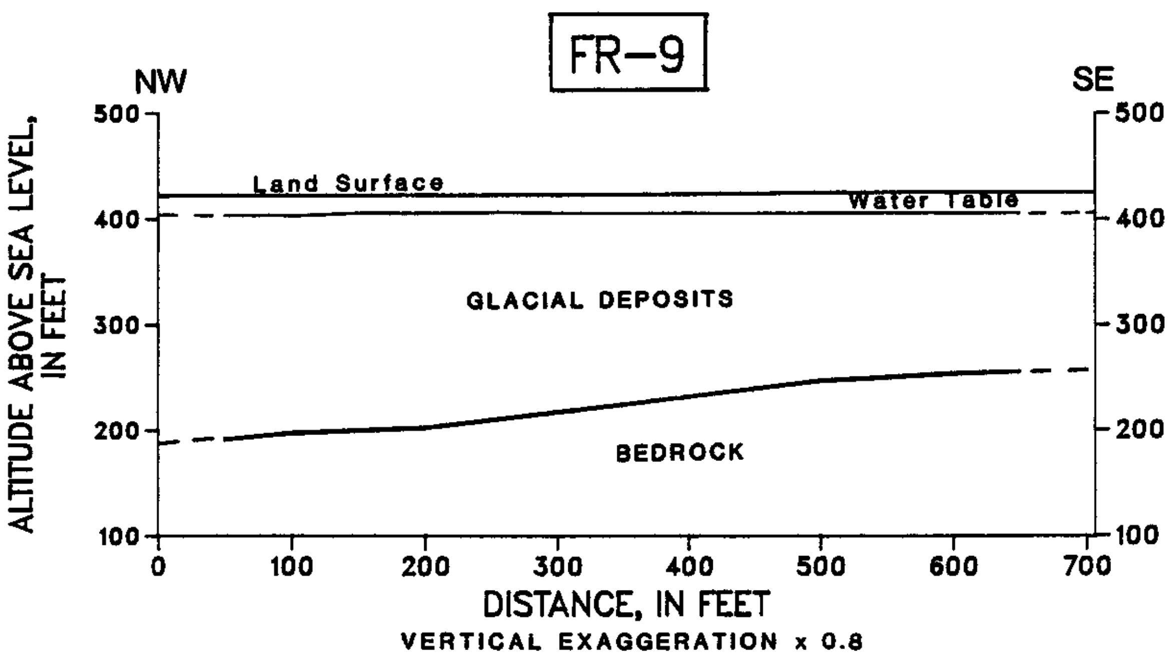

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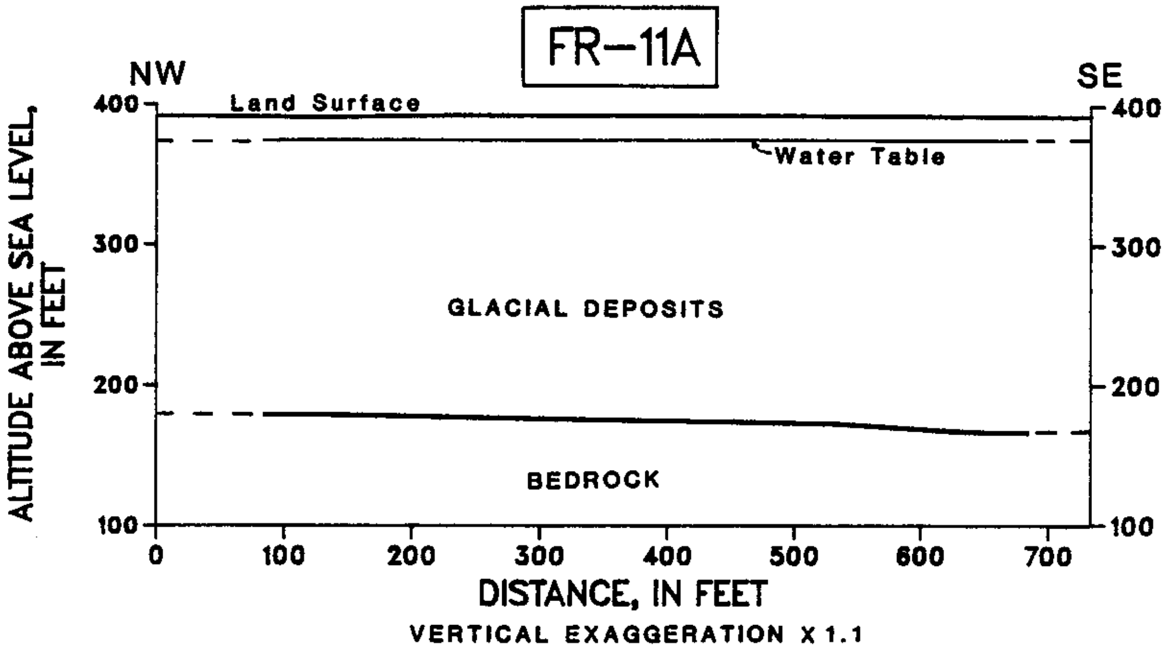

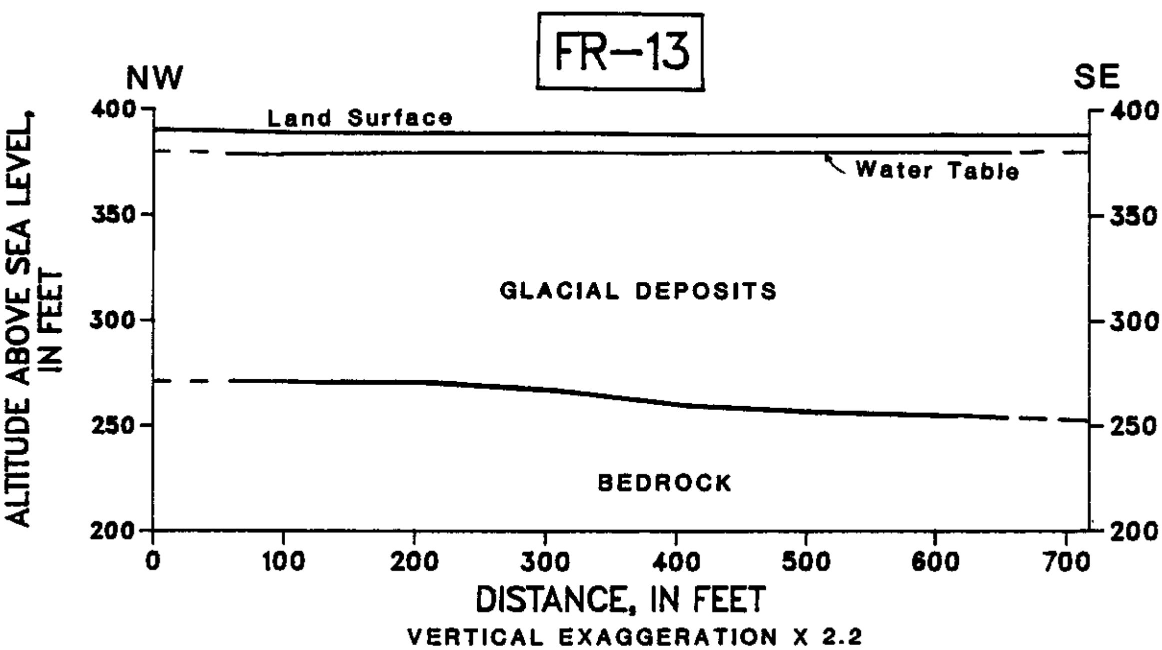

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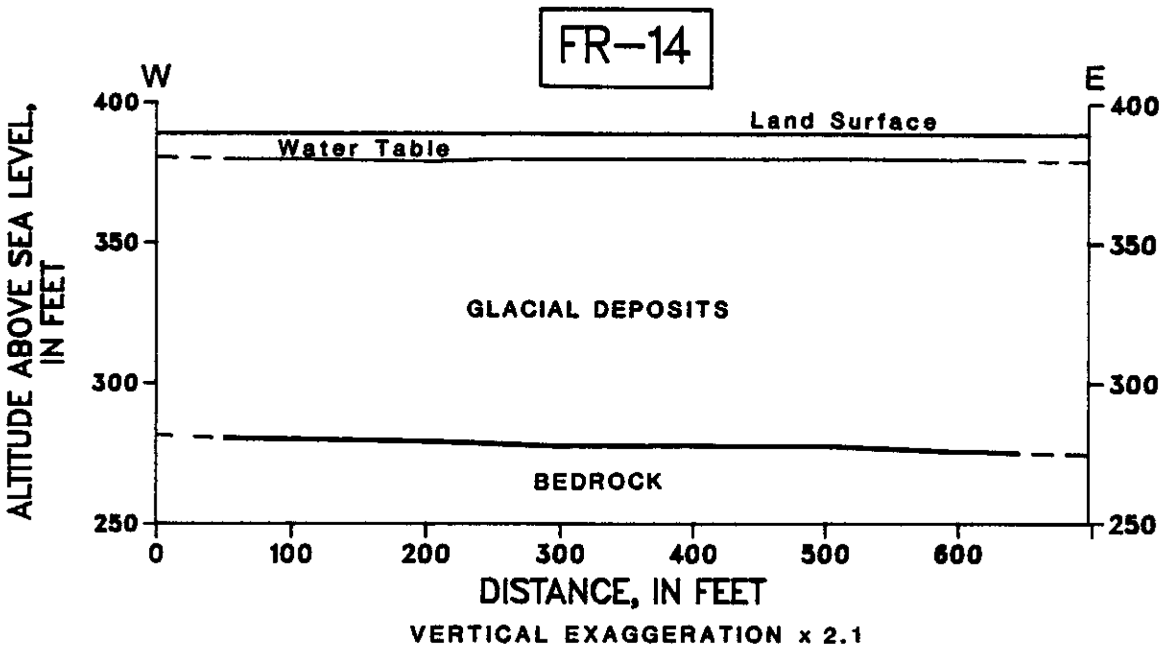

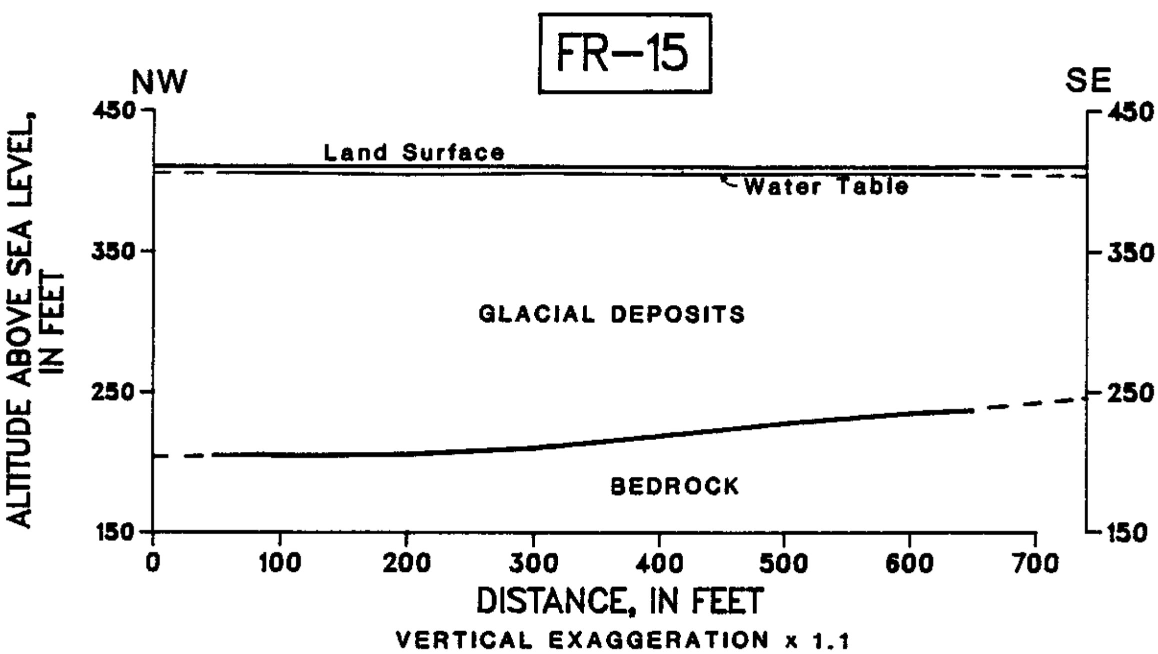

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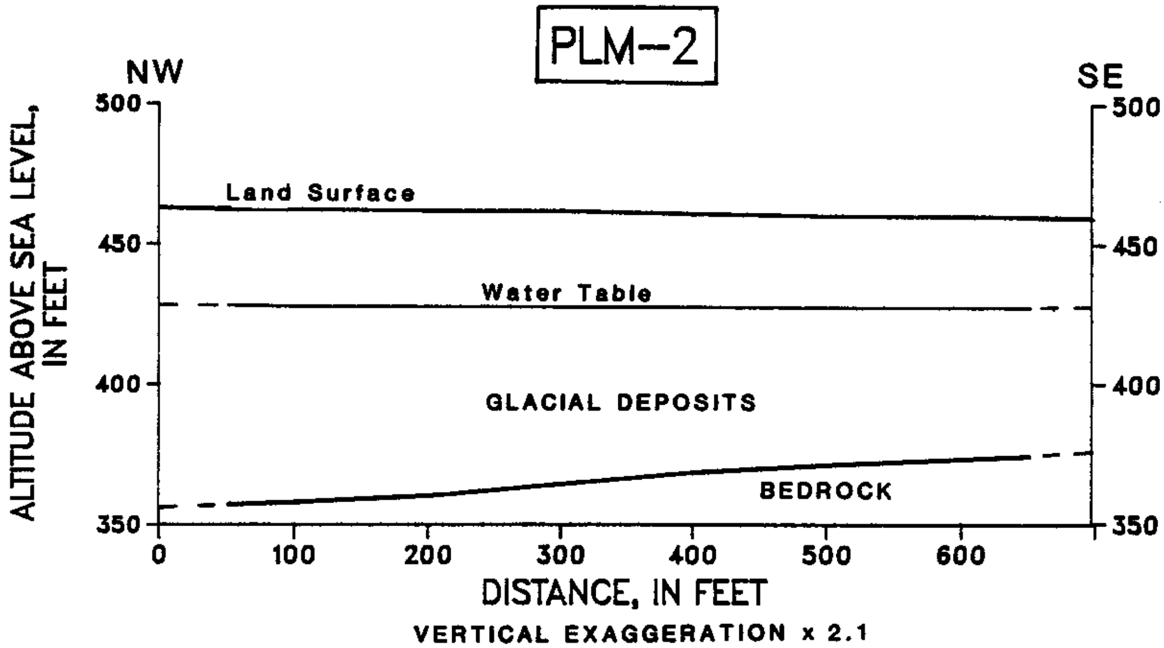

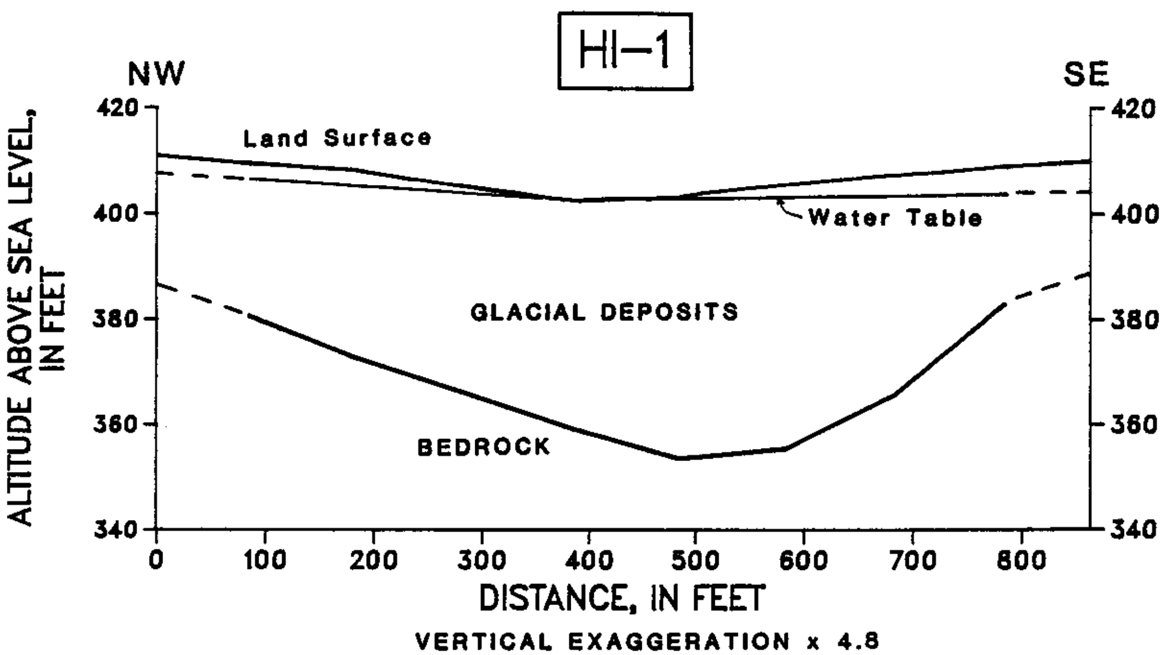

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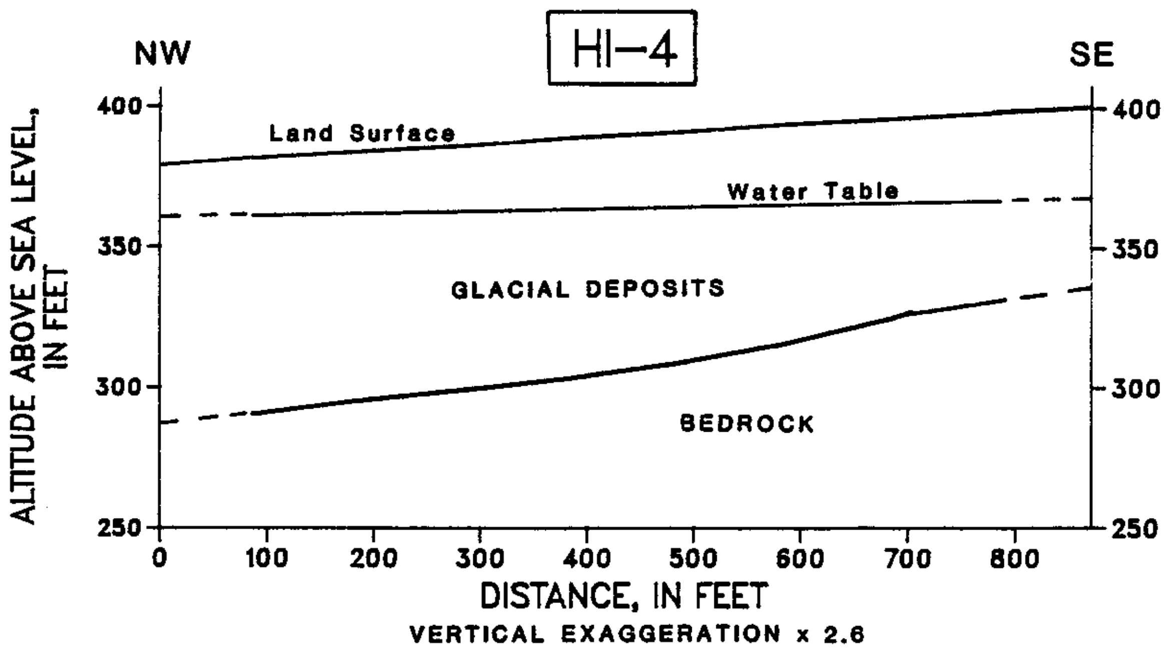

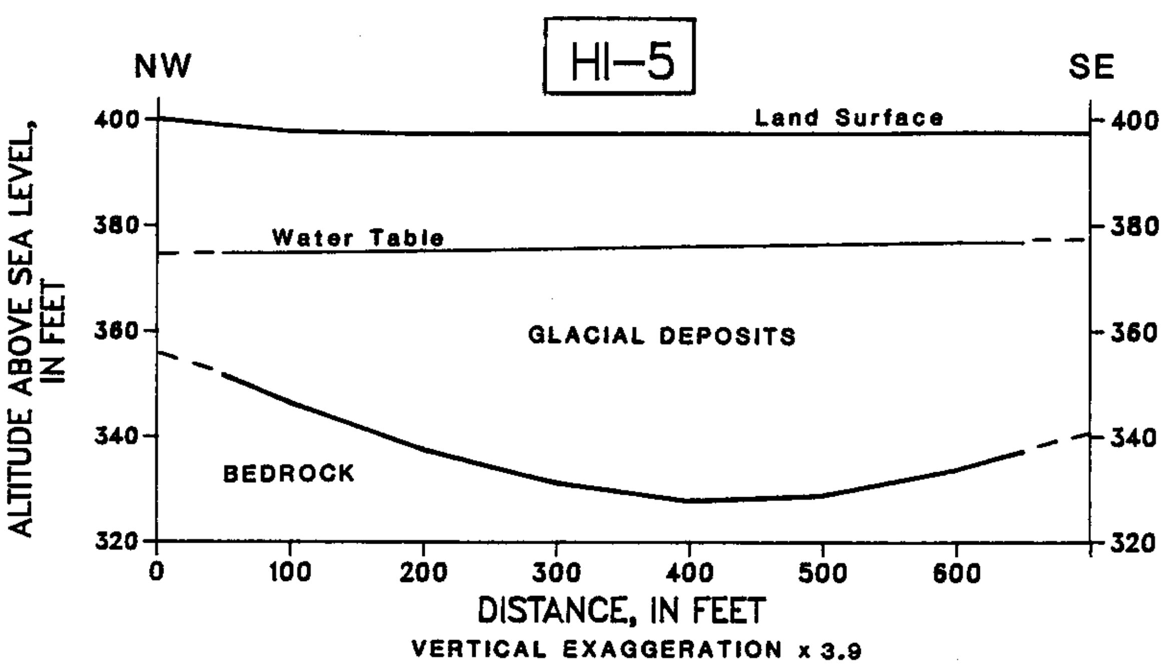

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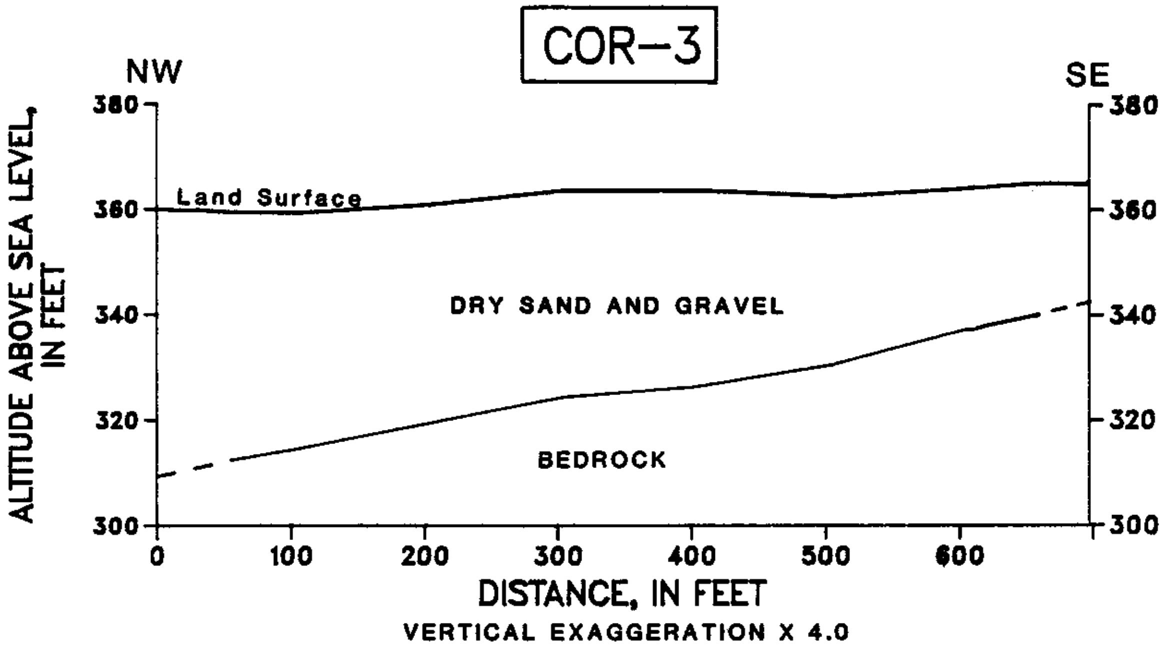

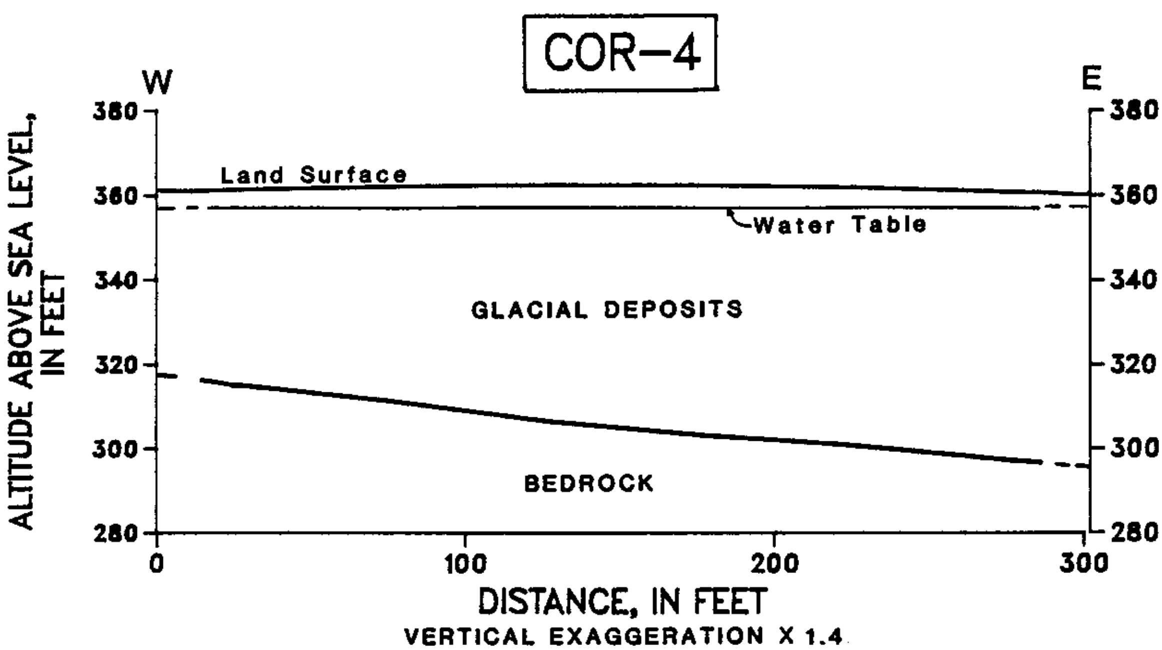

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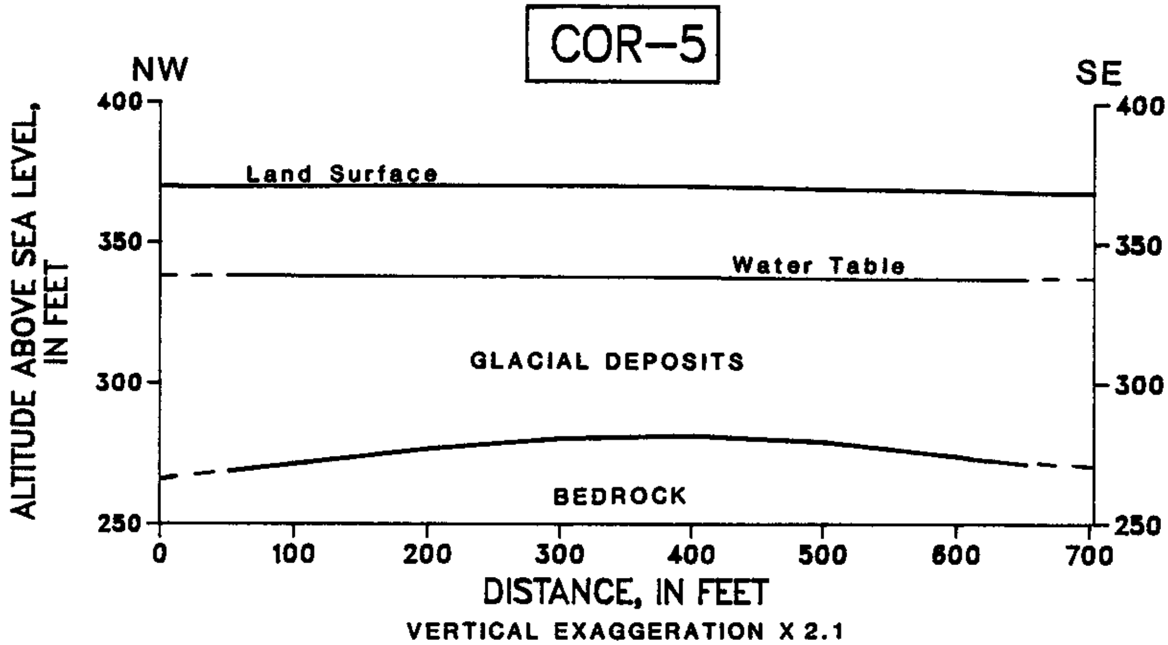
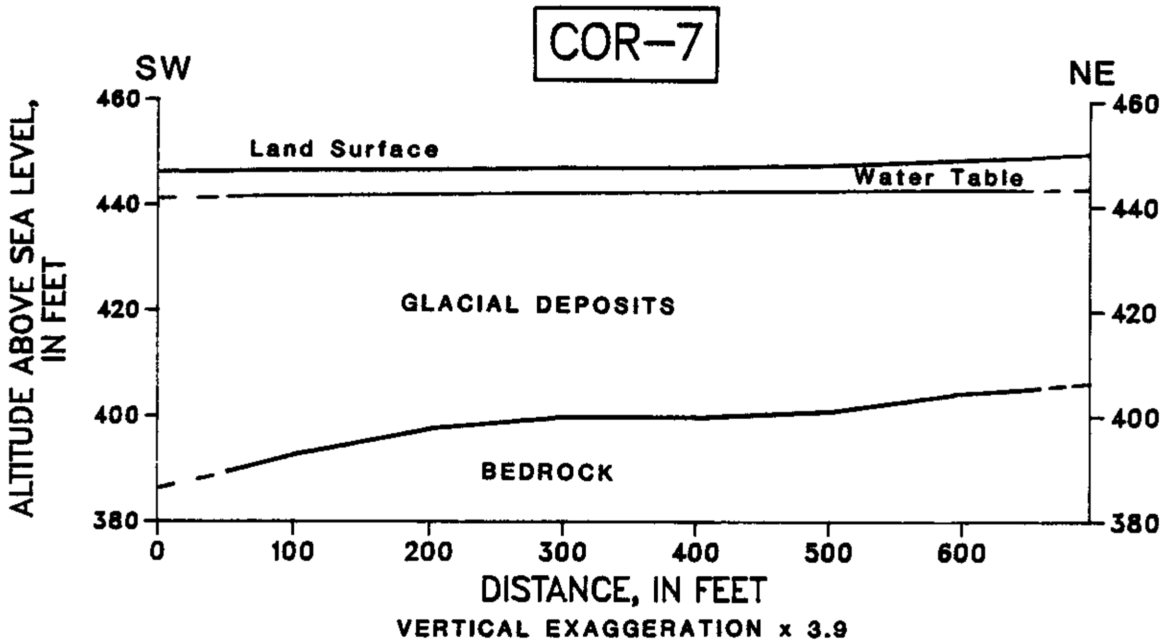
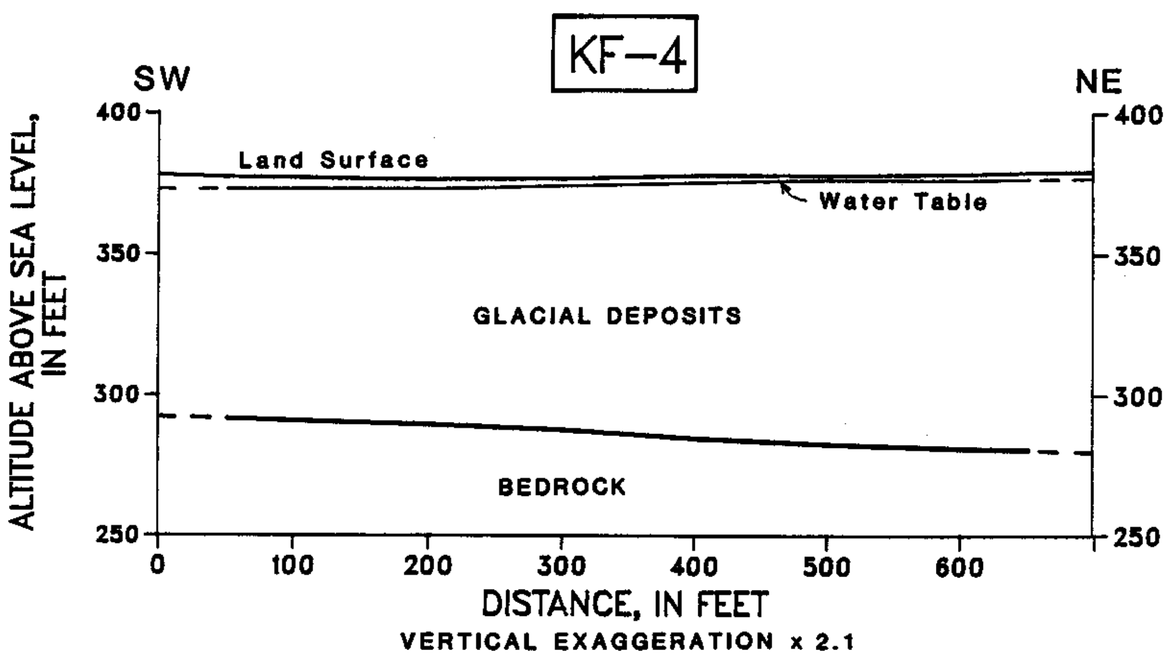


COR-6

No profile is shown for COR-6 because a blind zone problem was encountered on the northwestern end of the line. On the southeastern end, the depth to the water table is approximately 31 feet and the depth to the bedrock surface is approximately 100 feet. On the northwestern end of the line, a 14-foot thick saturated section (if present), under 19 feet of unsaturated material, could not be detected with seismic refraction. The depth to bedrock is somewhere between 22 feet and 33 feet and the saturated section (if present) is between 0 and 14 feet thick.

Figure 9. Continued.





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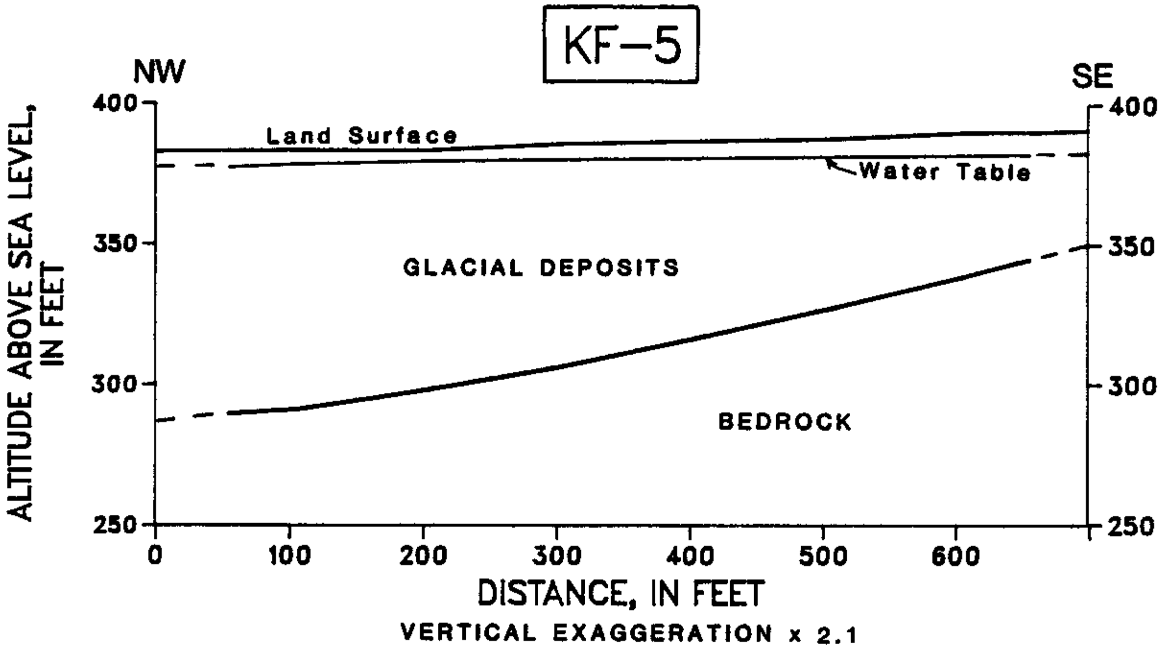

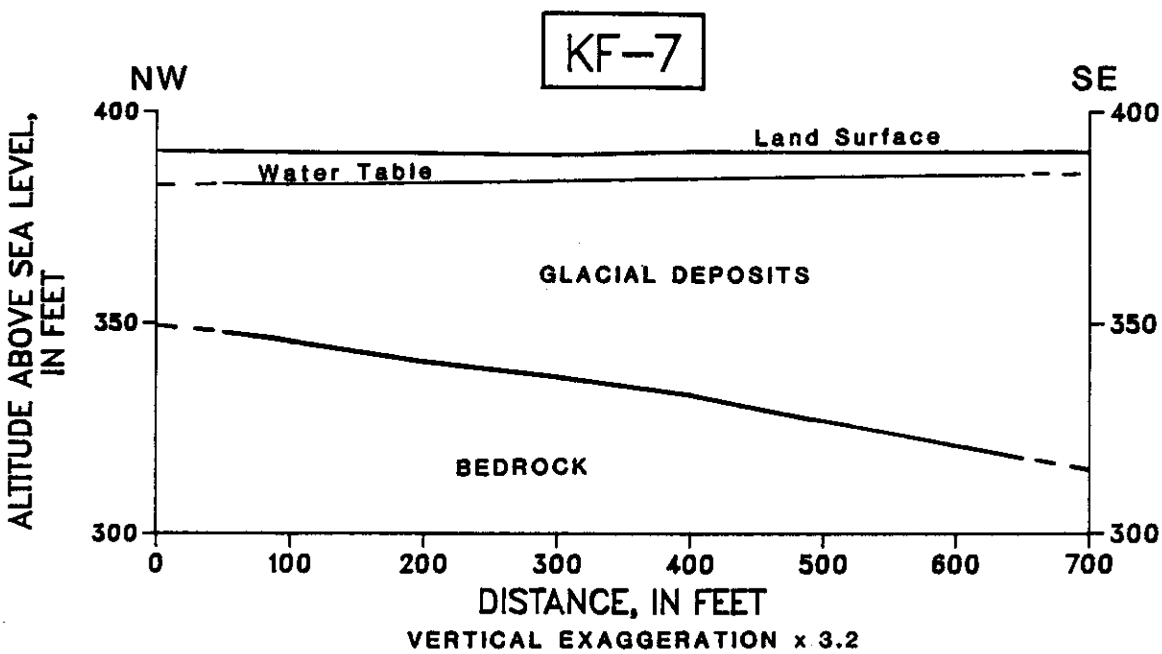

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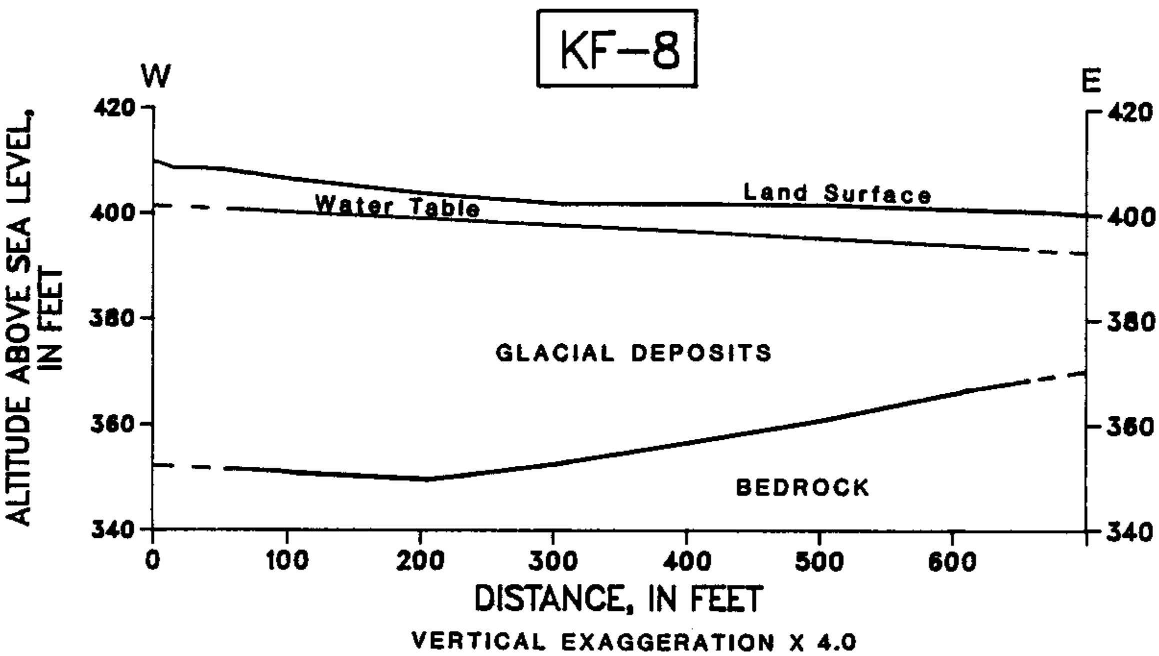

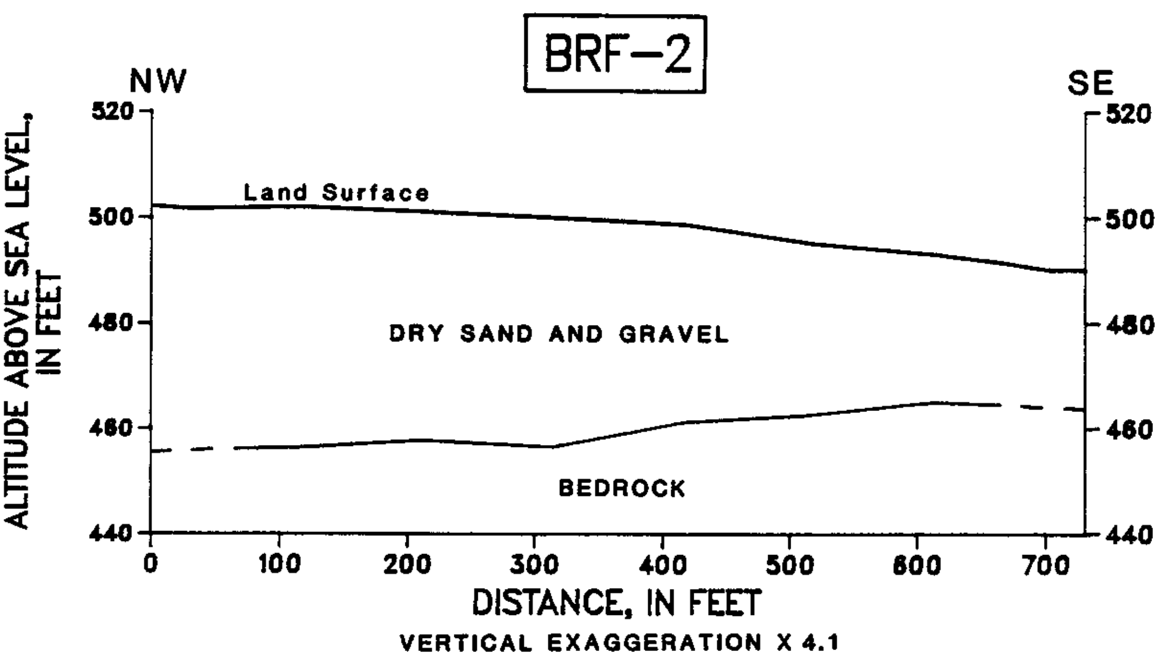

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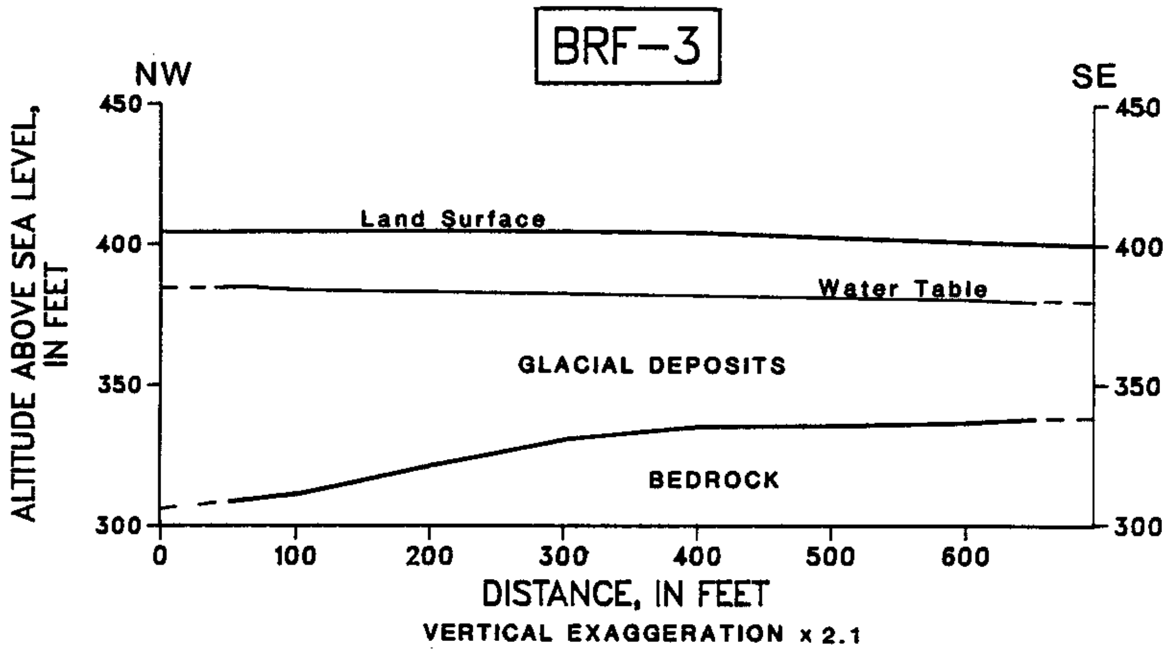

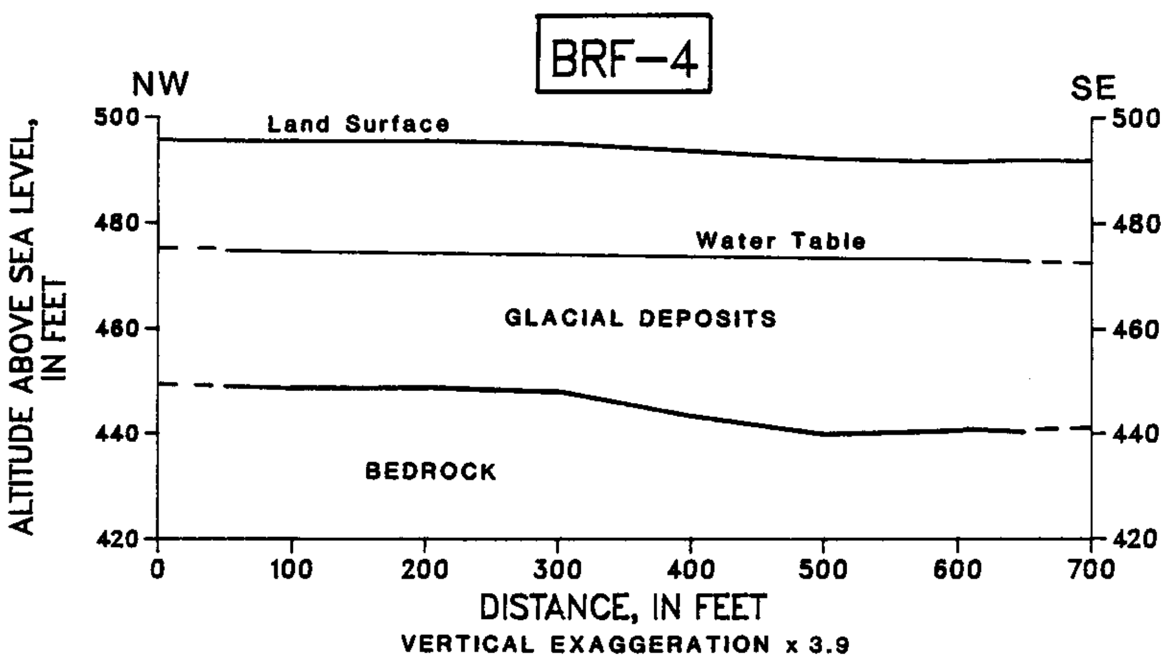

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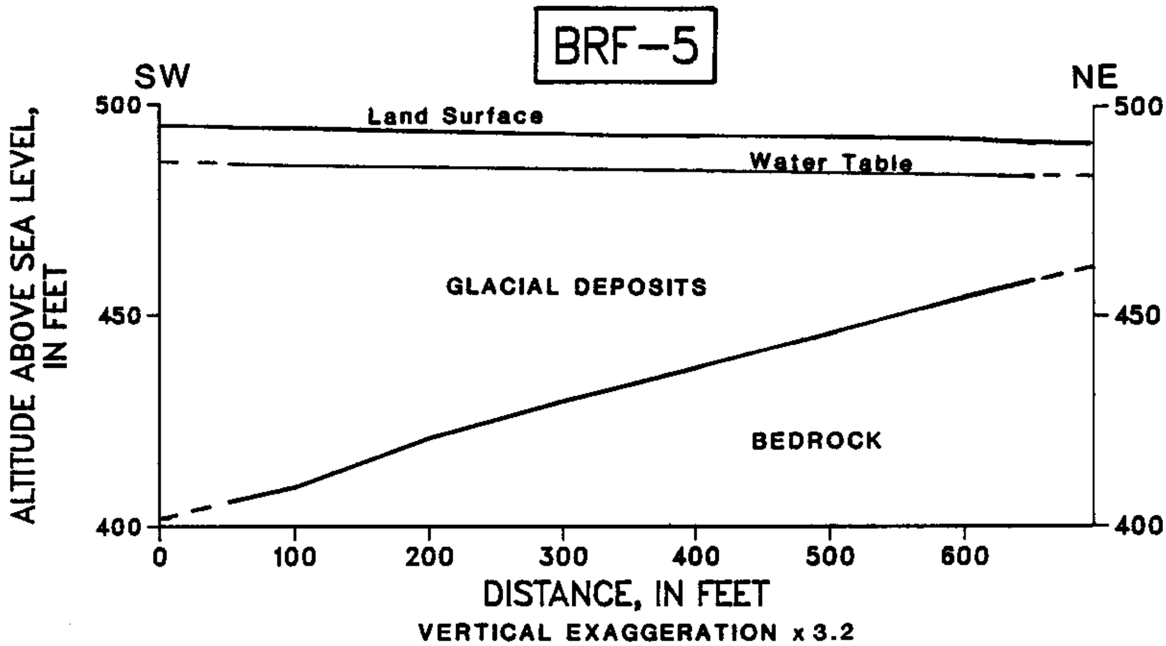


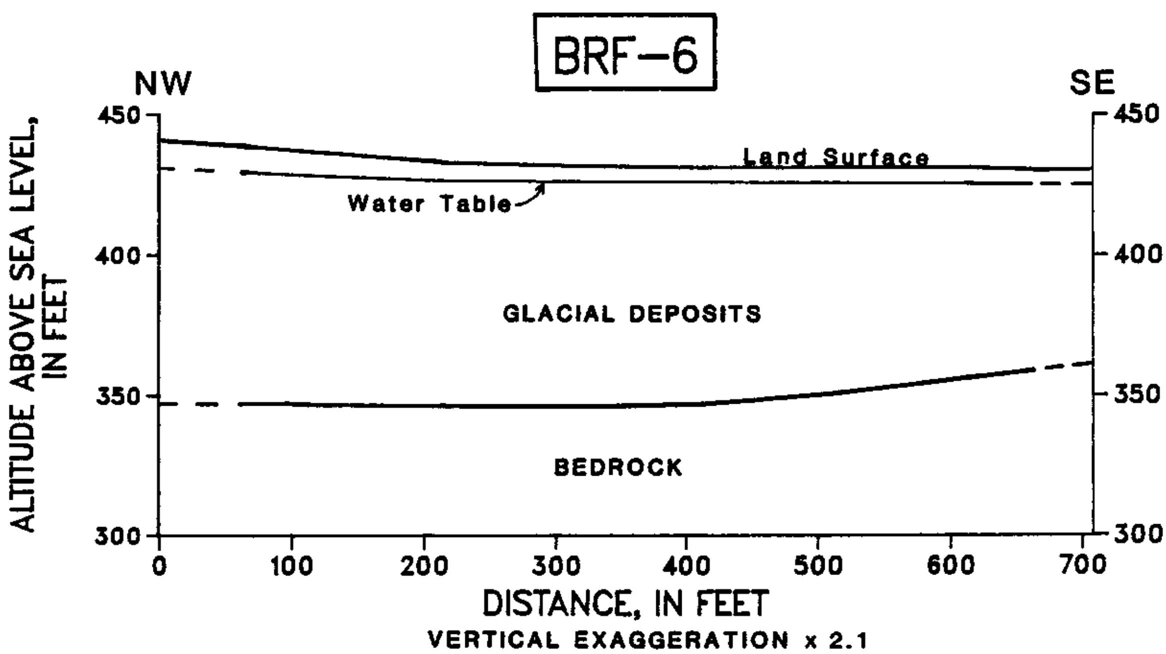
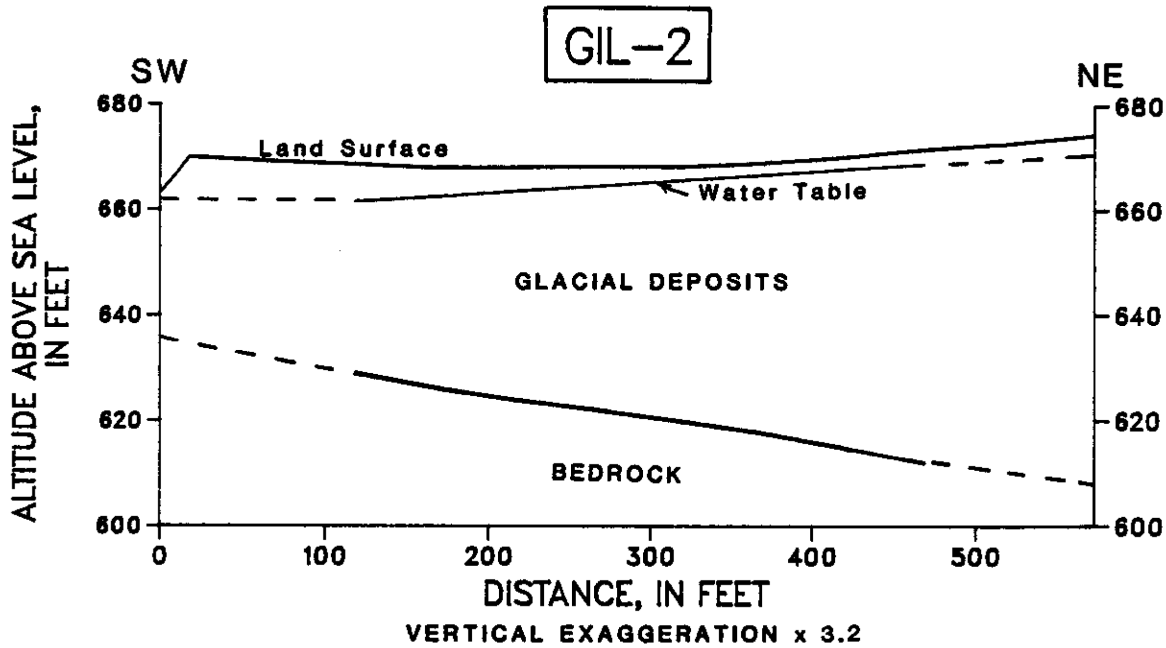
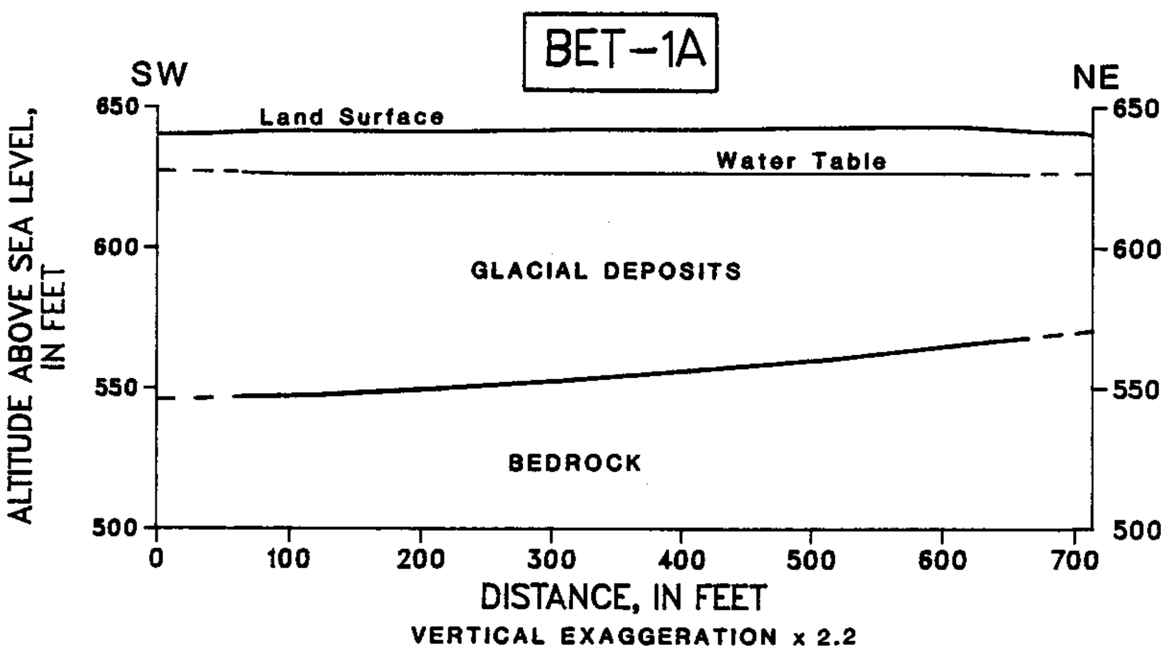


Figure 10.--12-channel seismic-refraction profiles: Map 14

Hydrogeologic sections from seismic-refraction surveys conducted by the U.S. Geological Survey in 1983. Locations 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 x-axes are measured from shot #1. At the ends of each profile, the altitudes of the water table and bedrock surface have been shown with dashed lines to emphasize the relative unreliability of this data as compared with the central portion of the profile.





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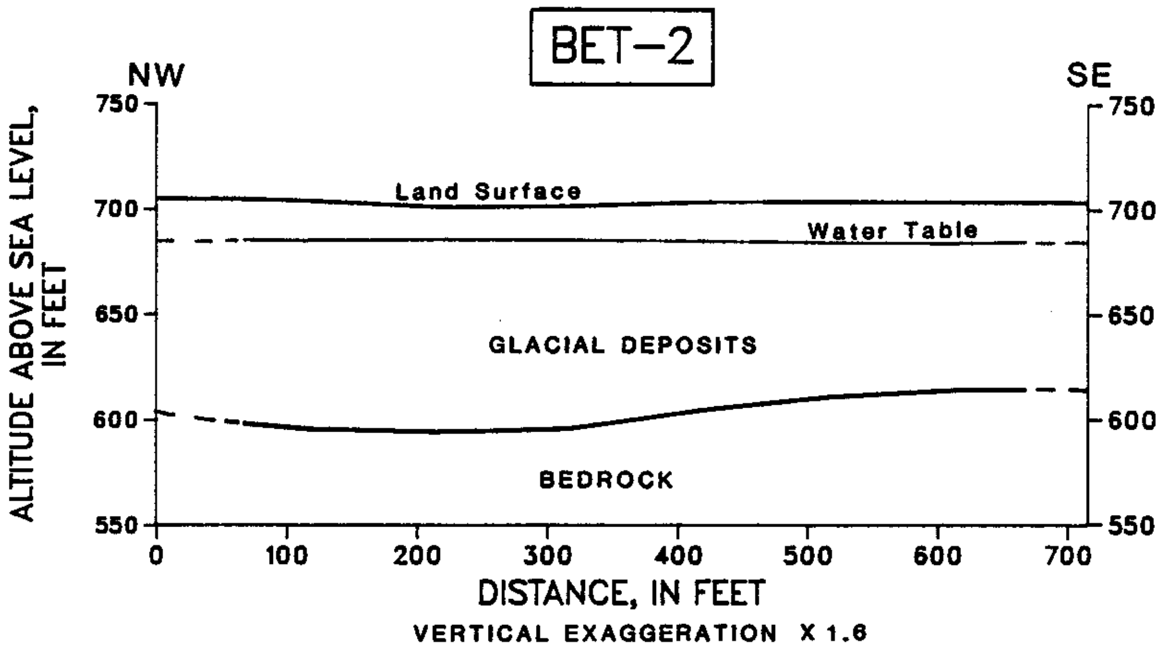

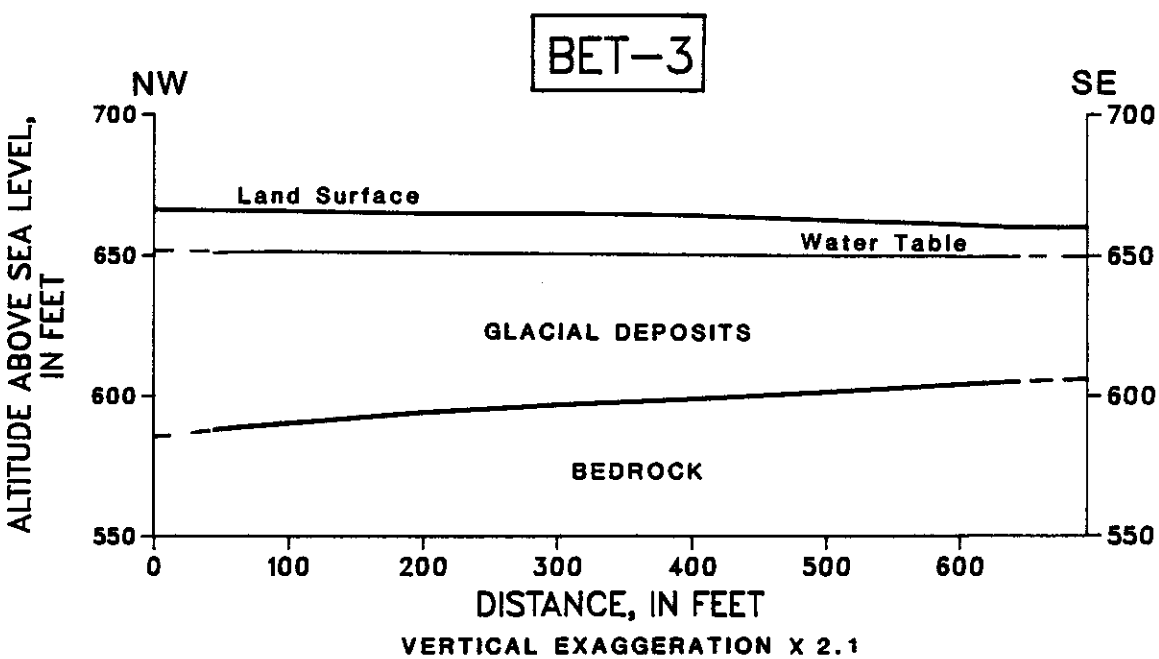

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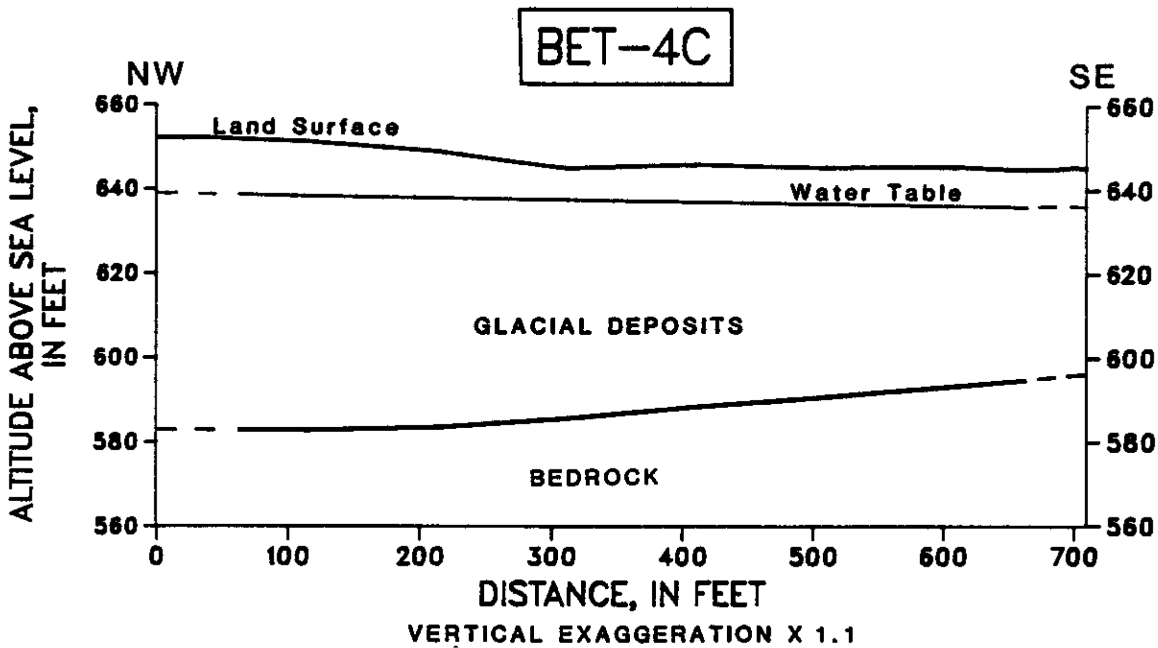

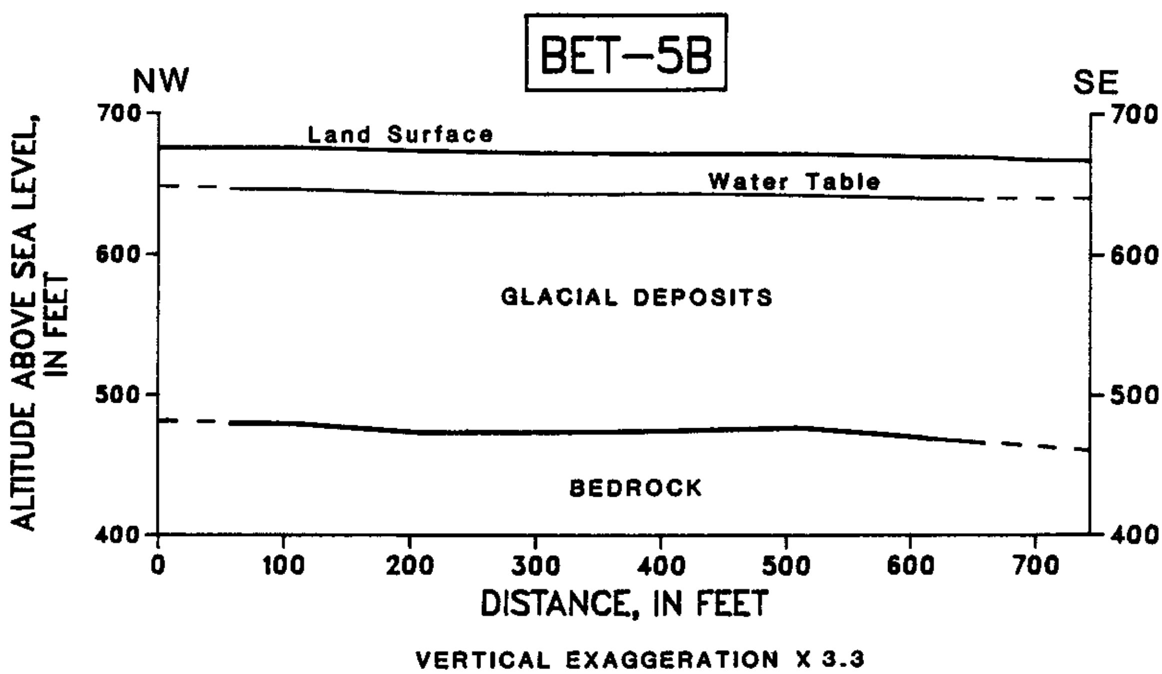

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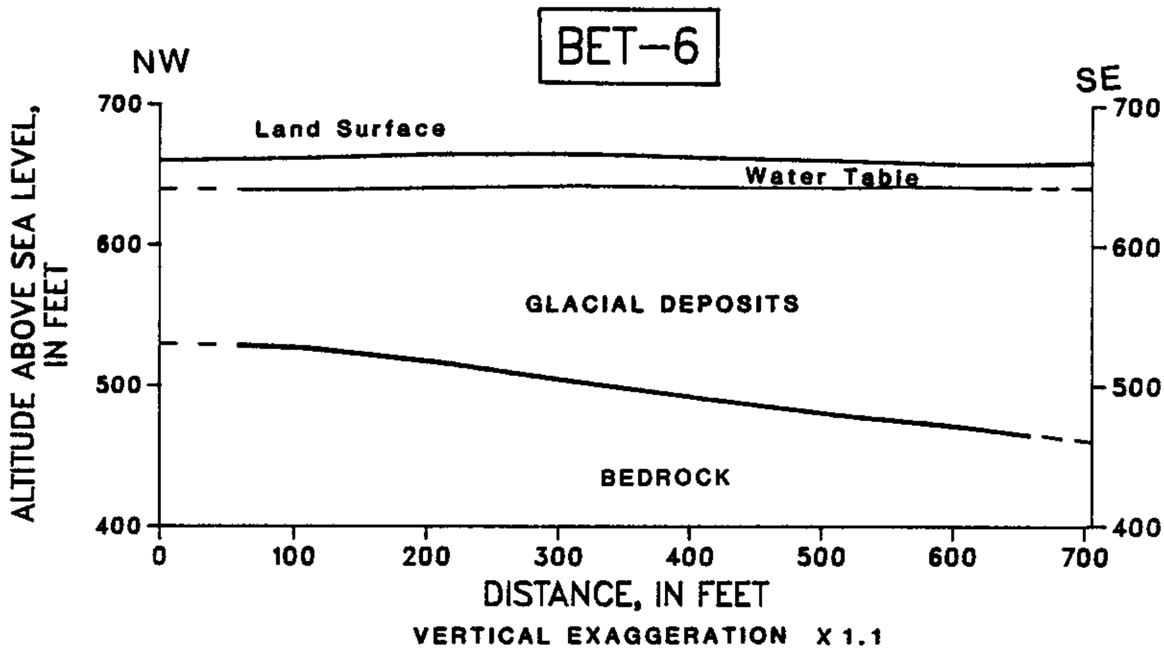

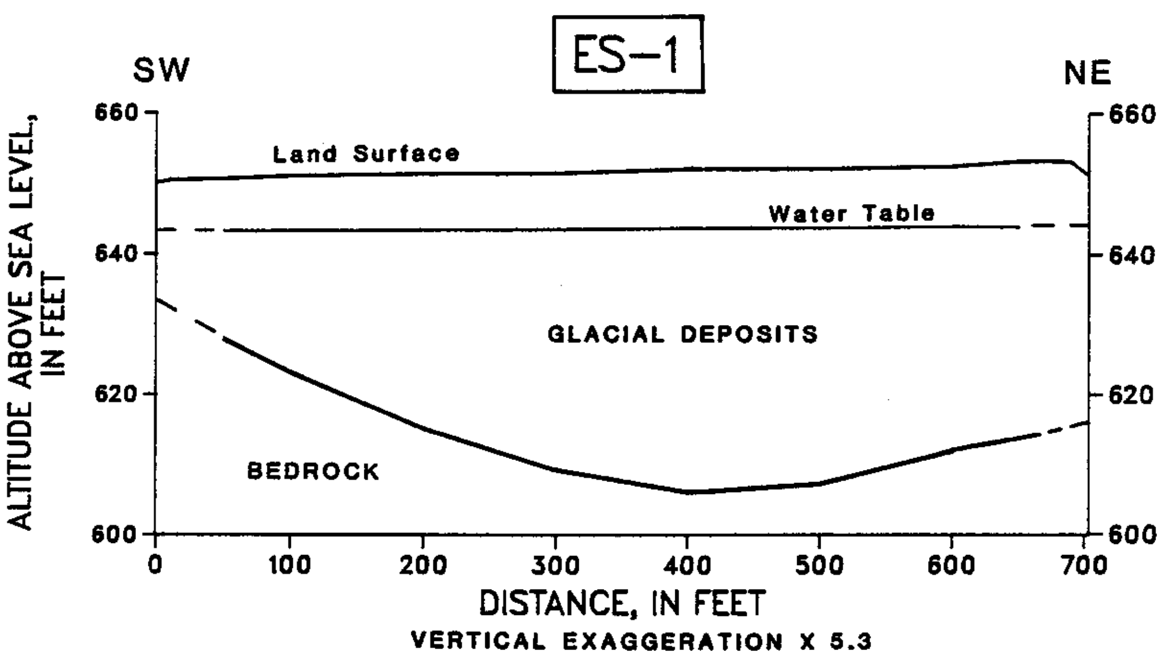

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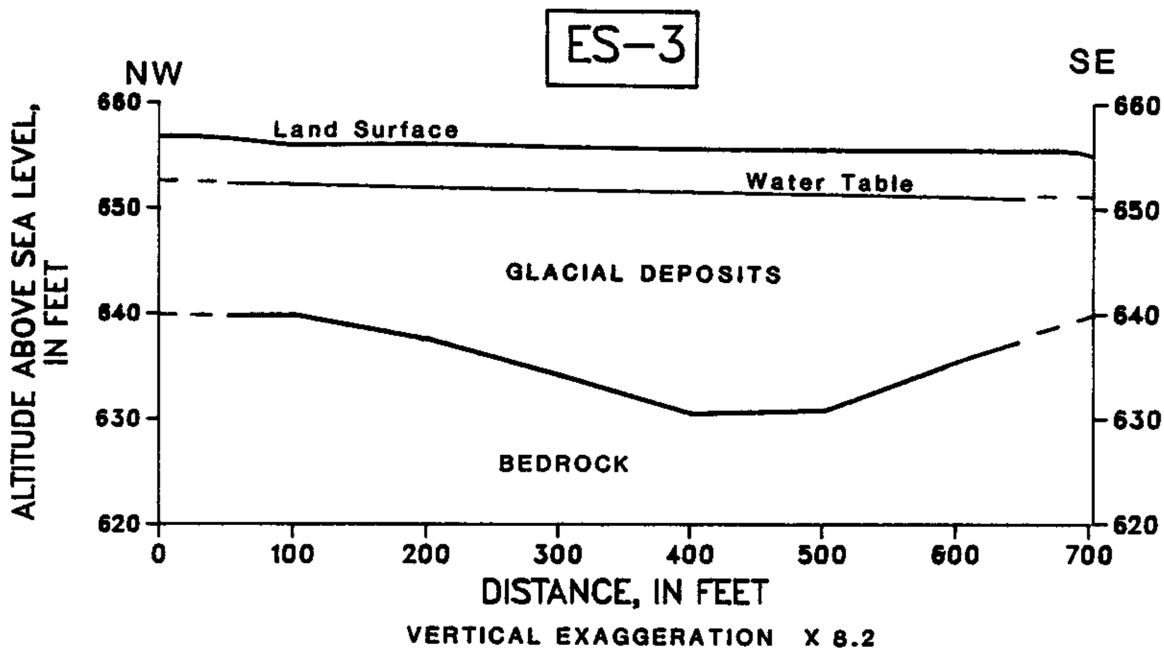

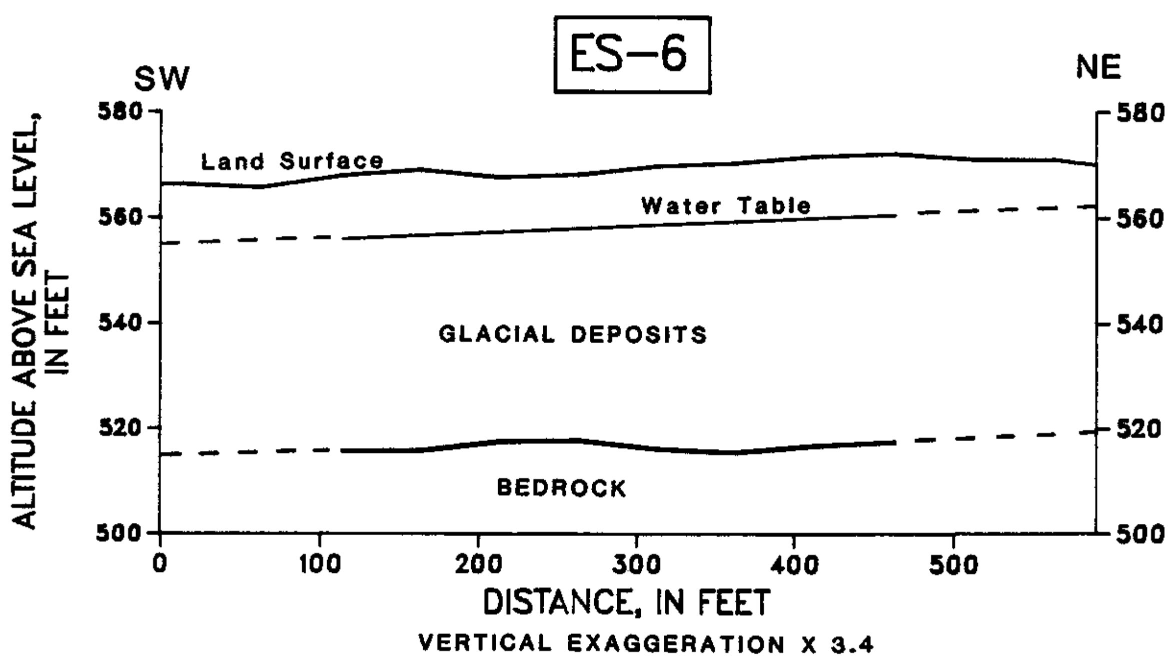

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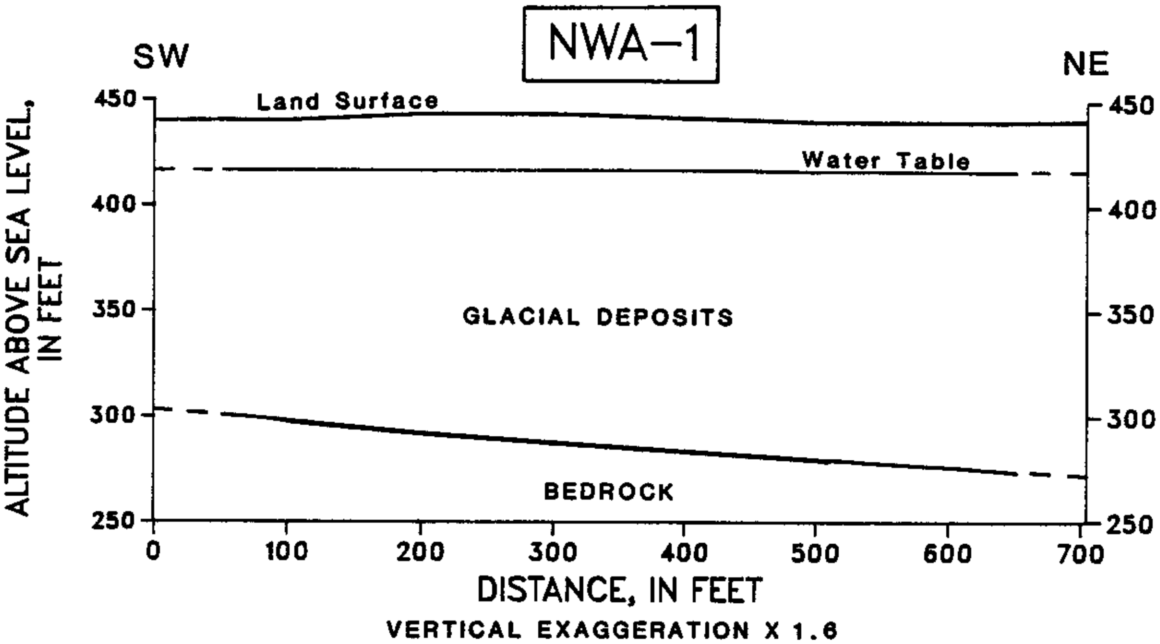

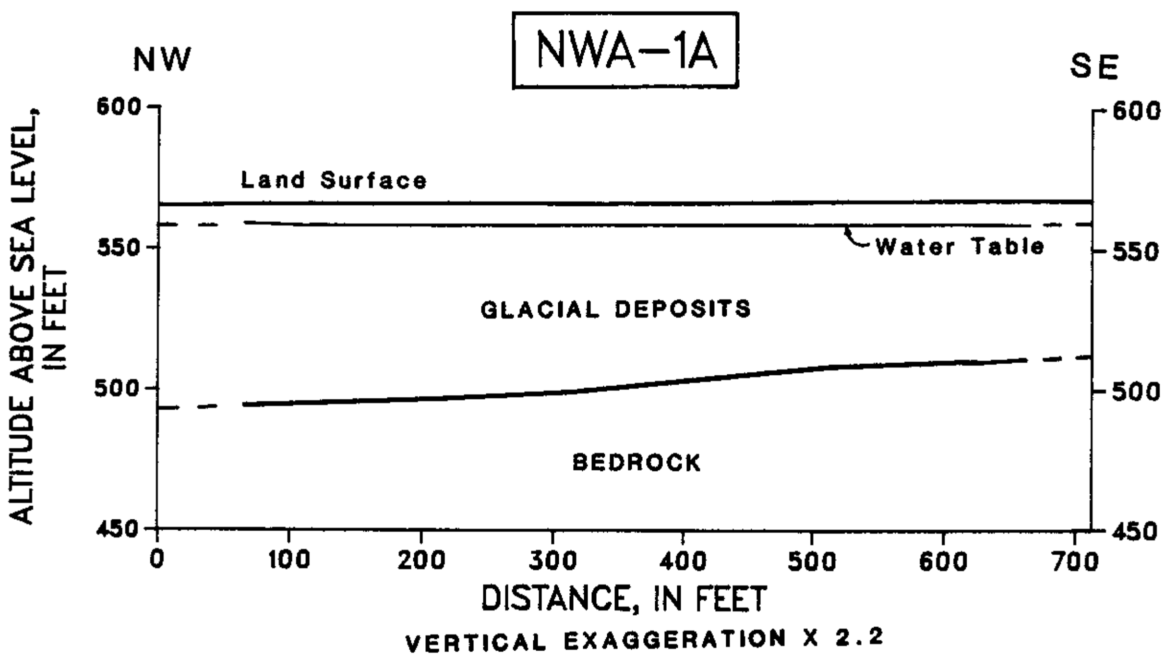

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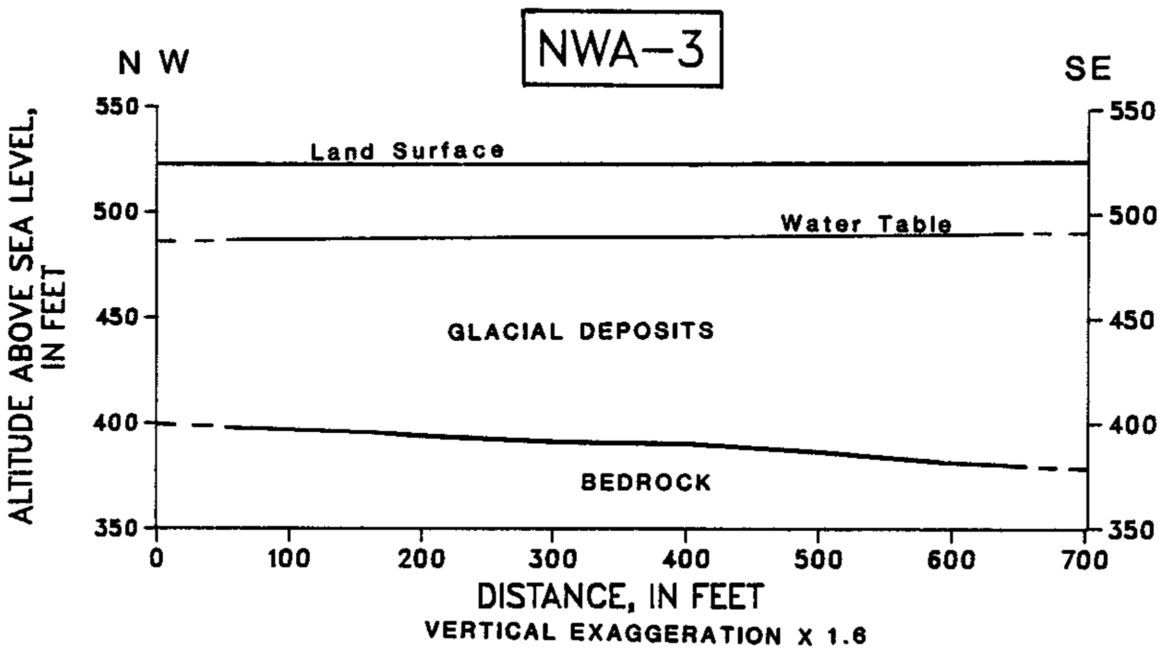

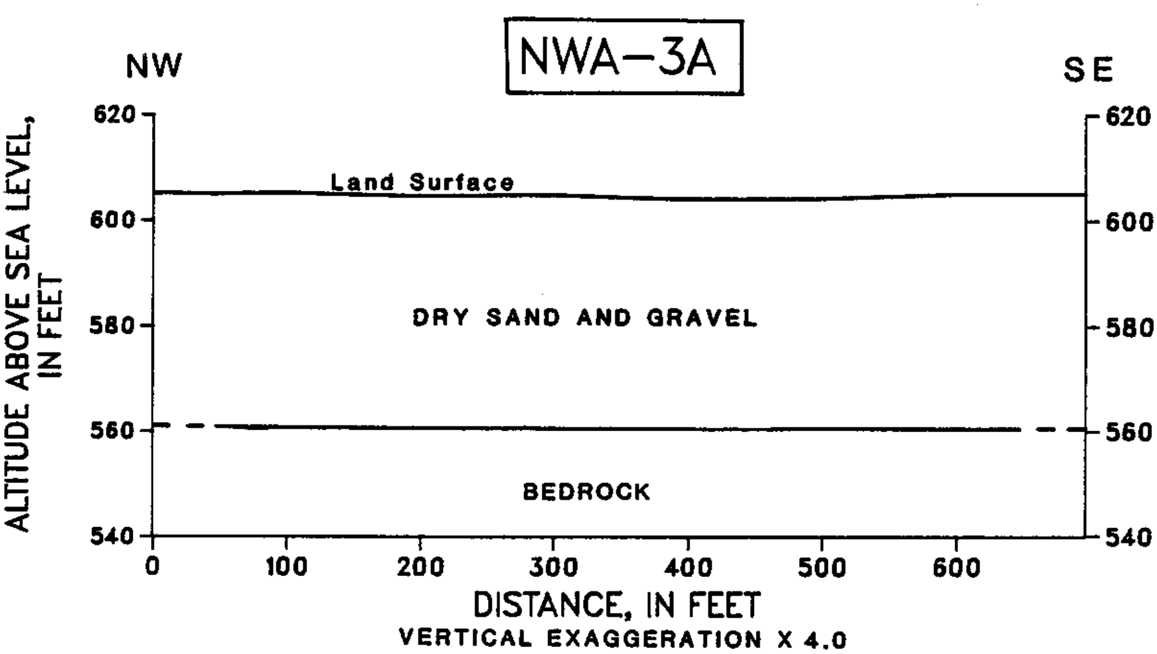

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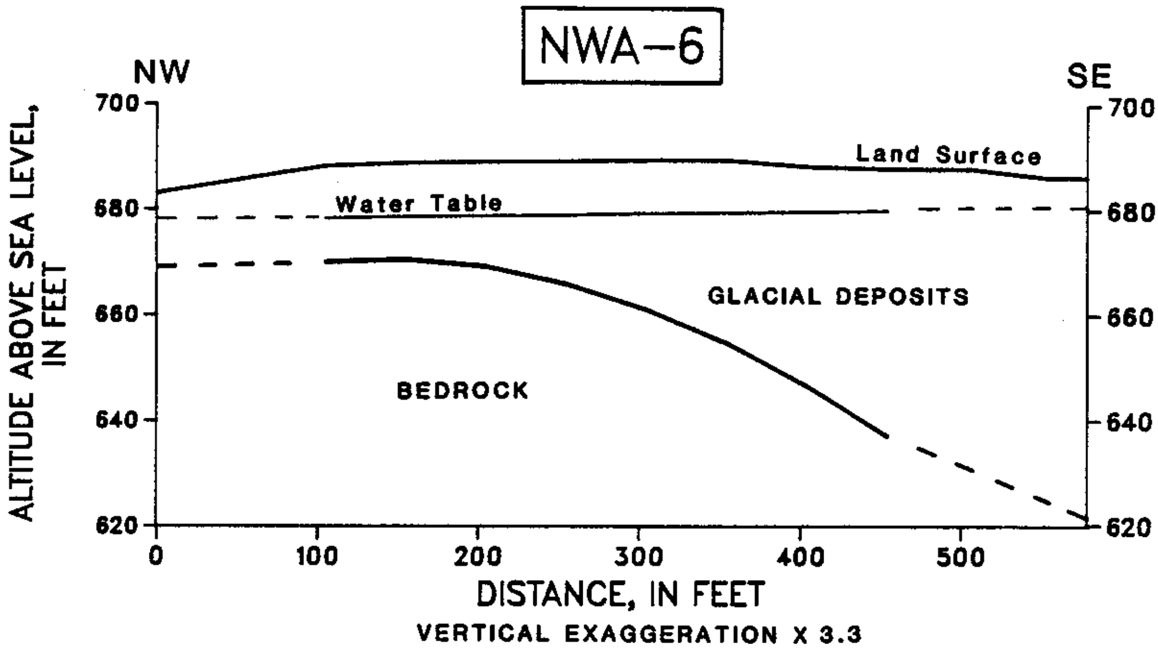

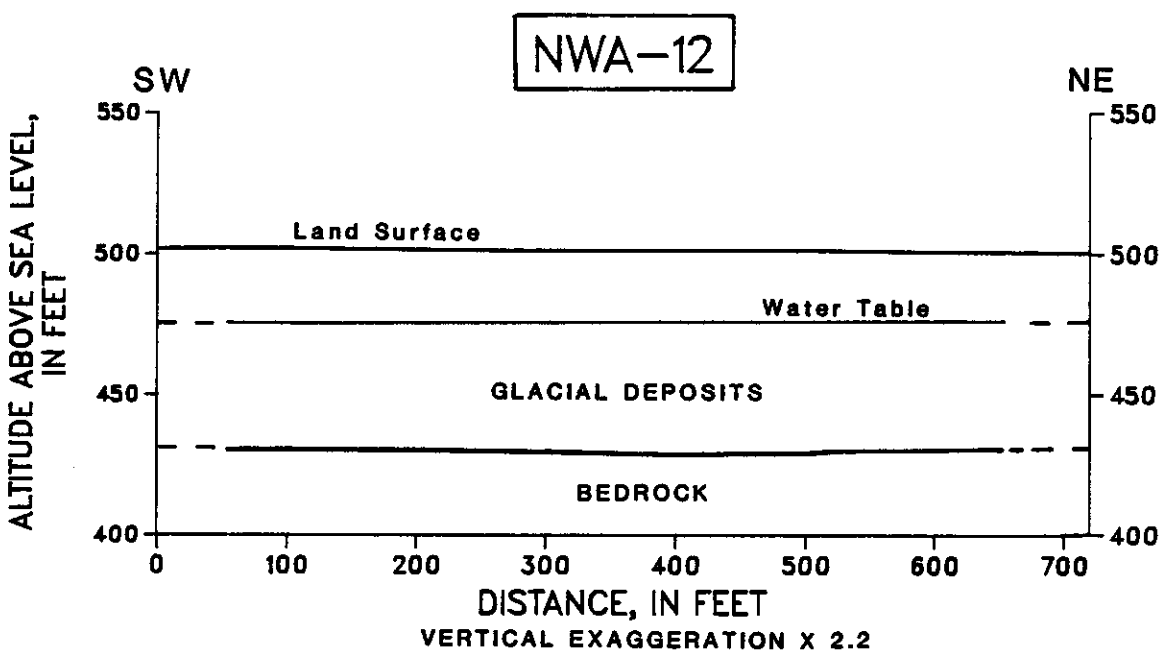

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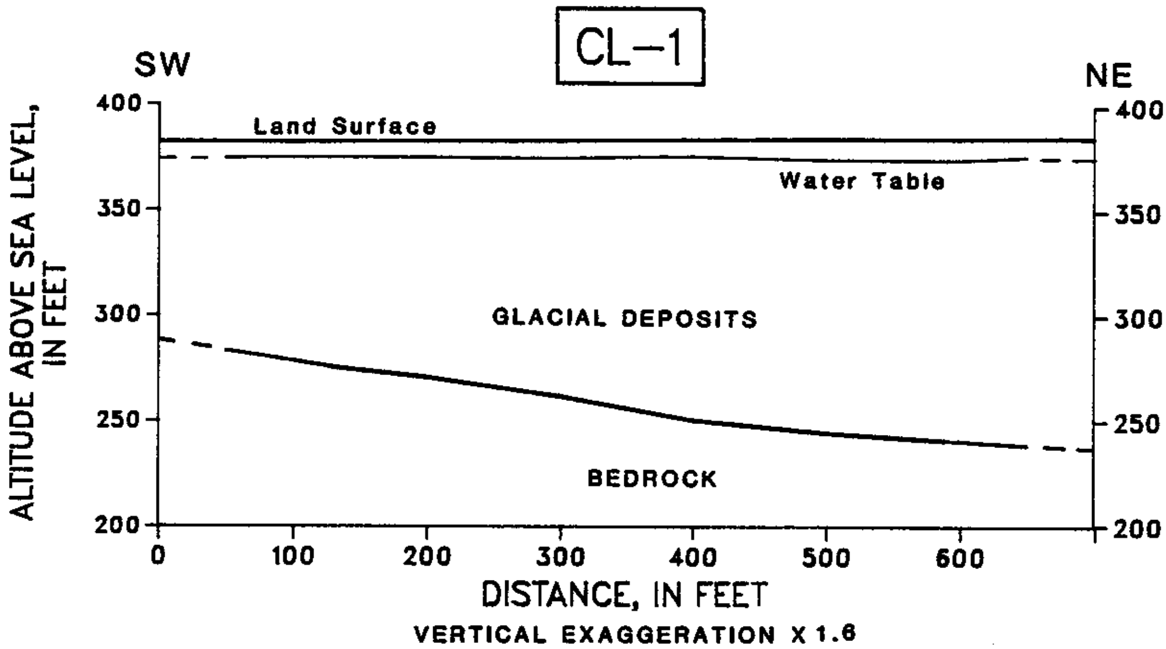

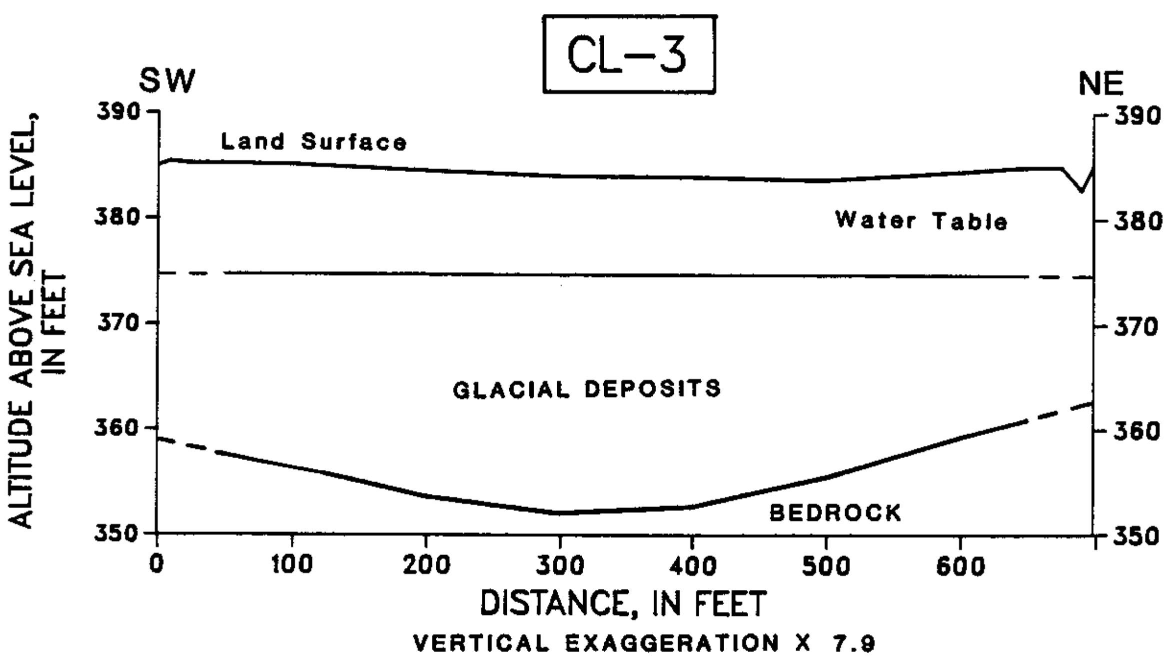

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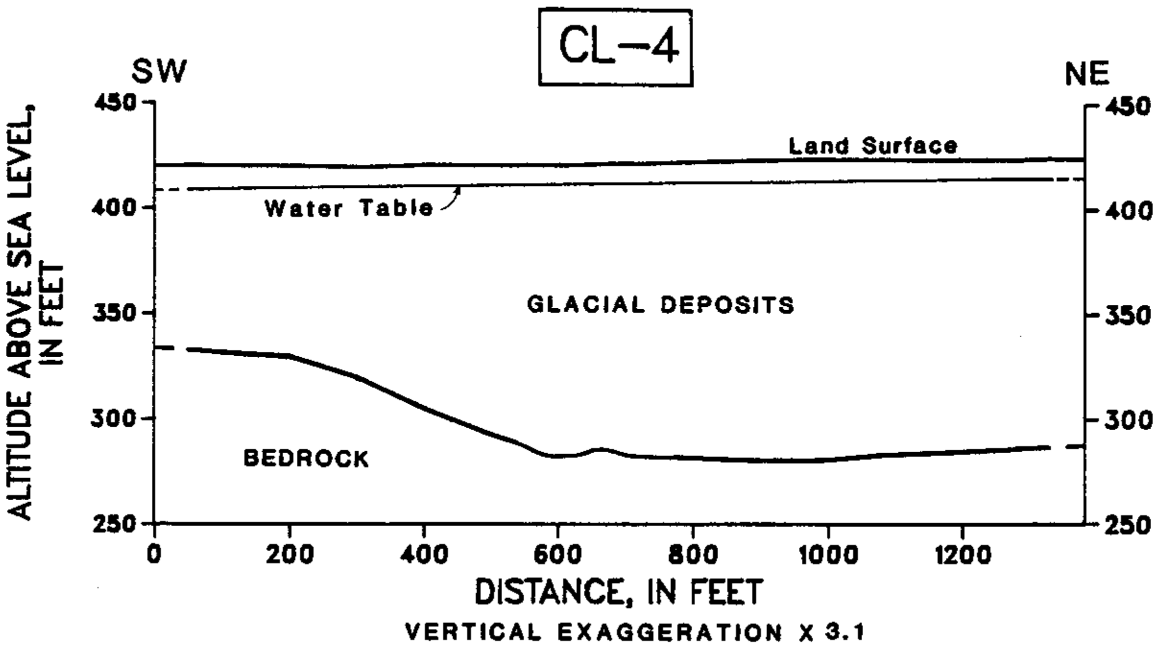

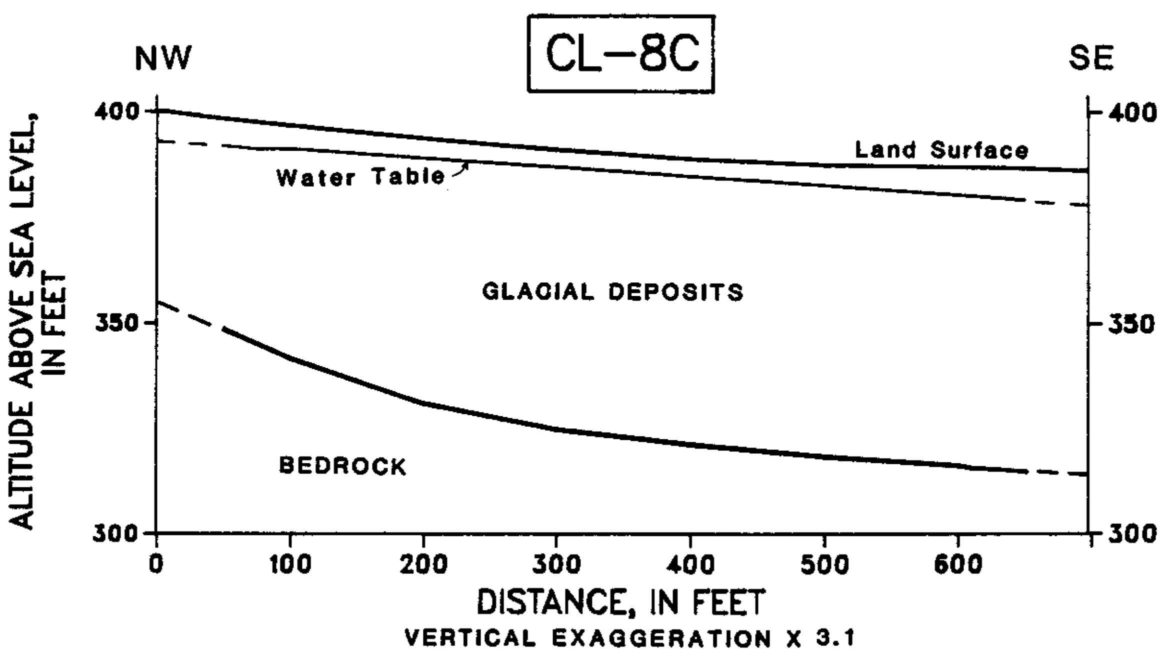

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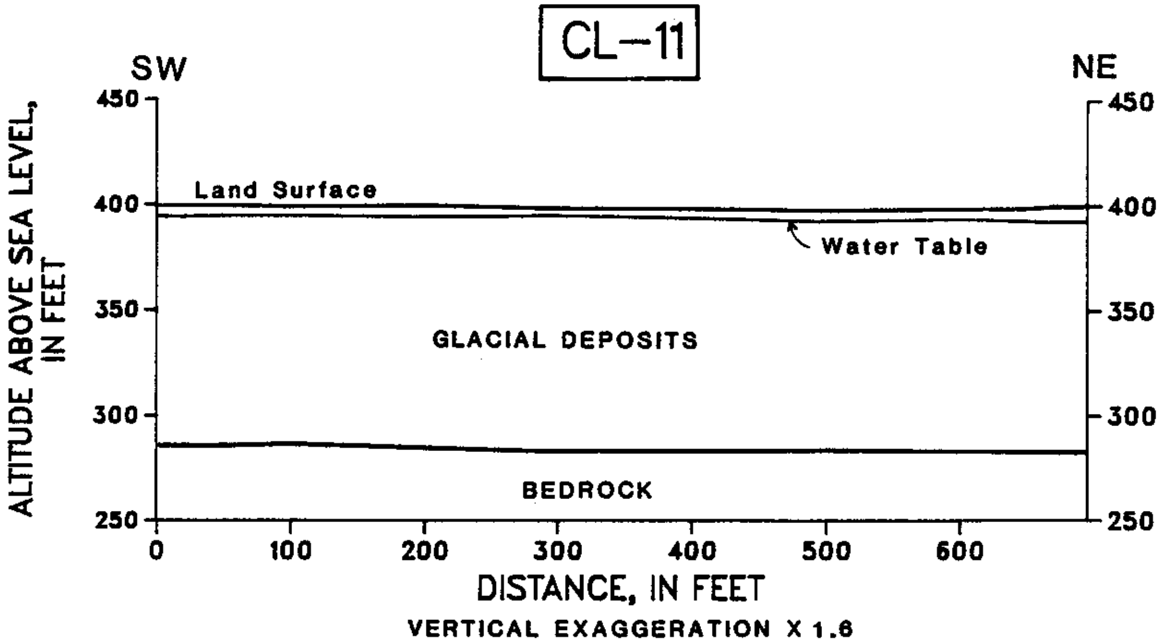
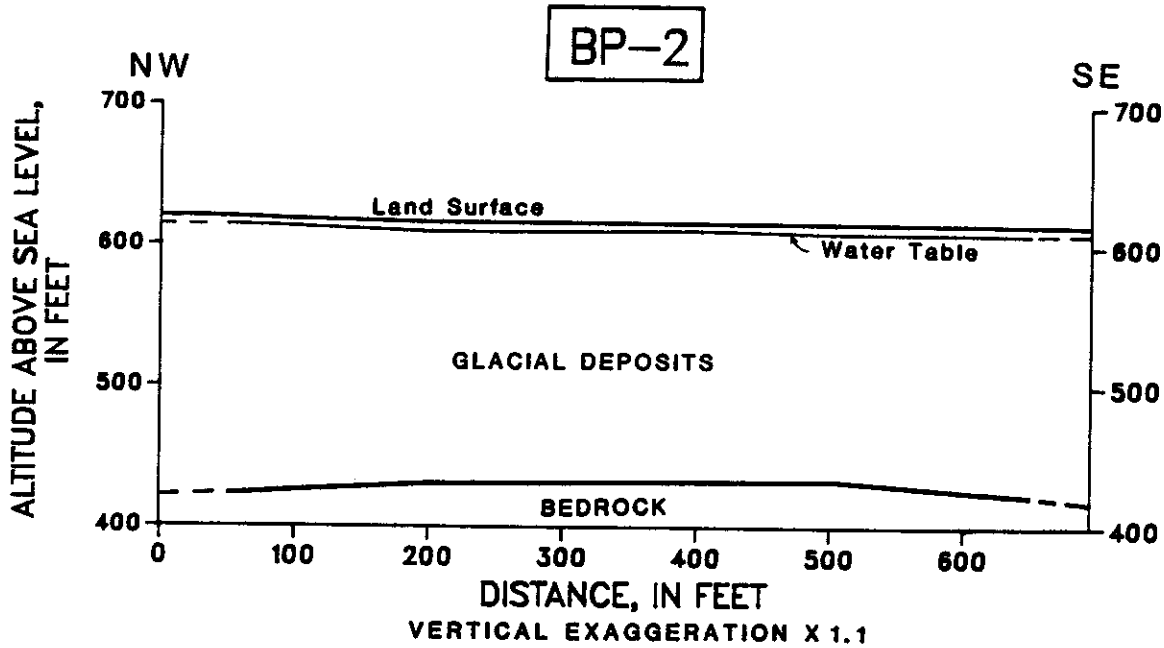
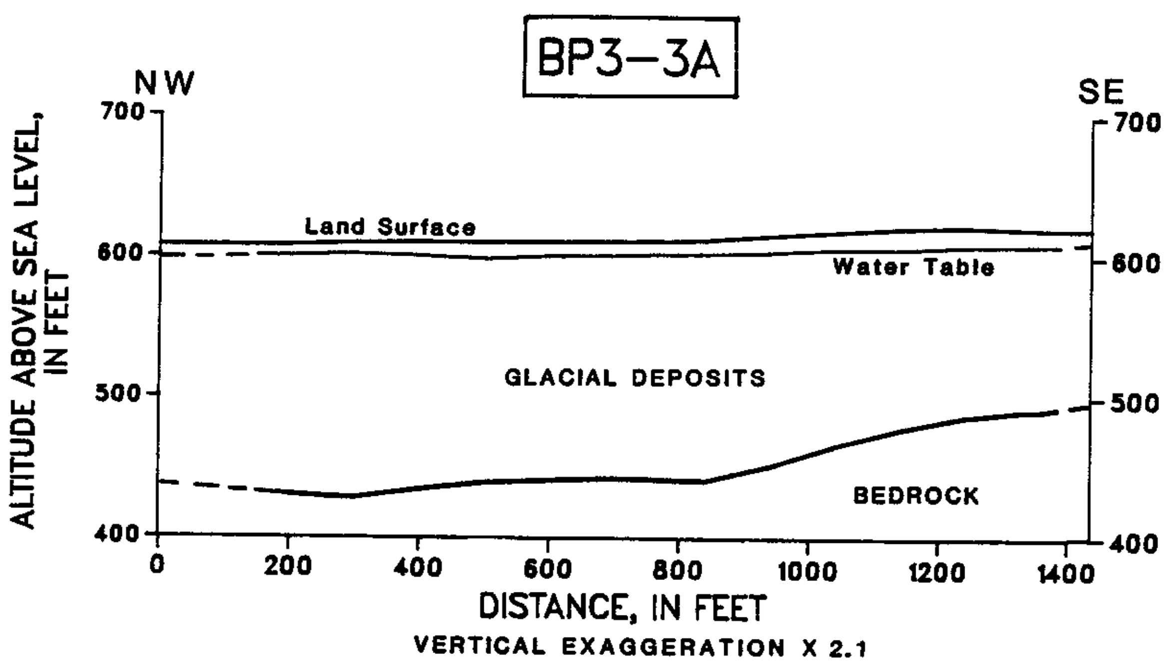


Figure 11.--12-channel seismic-refraction profiles: Map 15

Hydrogeologic sections from seismic-refraction surveys conducted by the U.S. Geological Survey in 1983. Locations 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 x-axes are measured from shot #1. At the ends of each profile, the altitudes of the water table and bedrock surface have been shown with dashed lines to emphasize the relative unreliability of this data as compared with the central portion of the profile.





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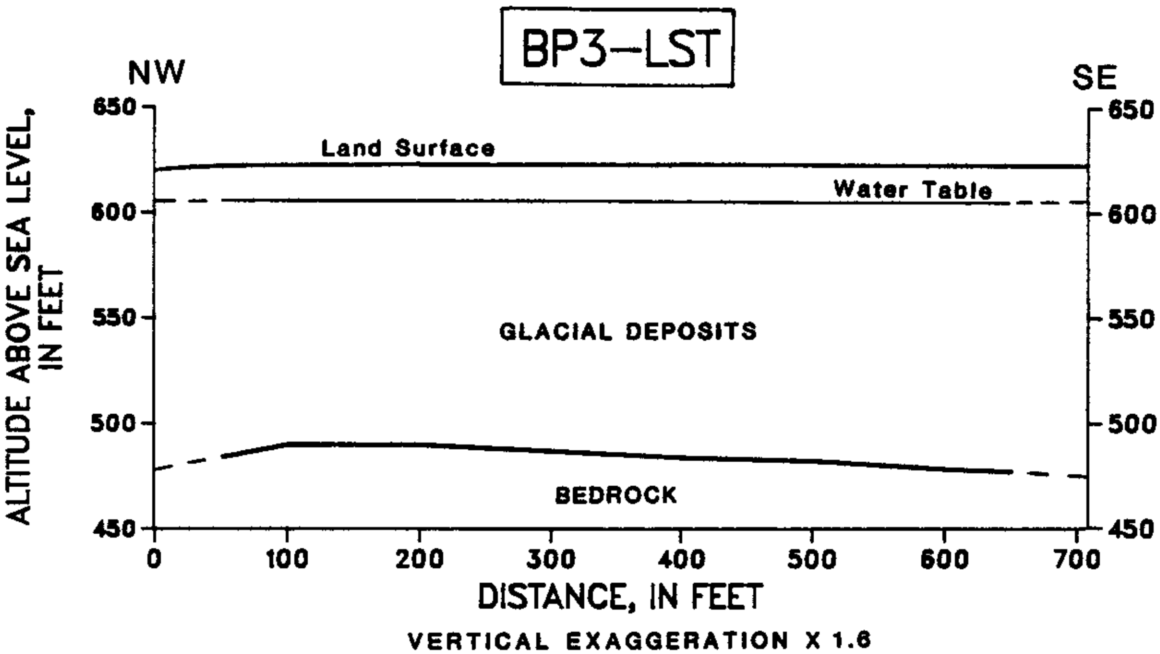

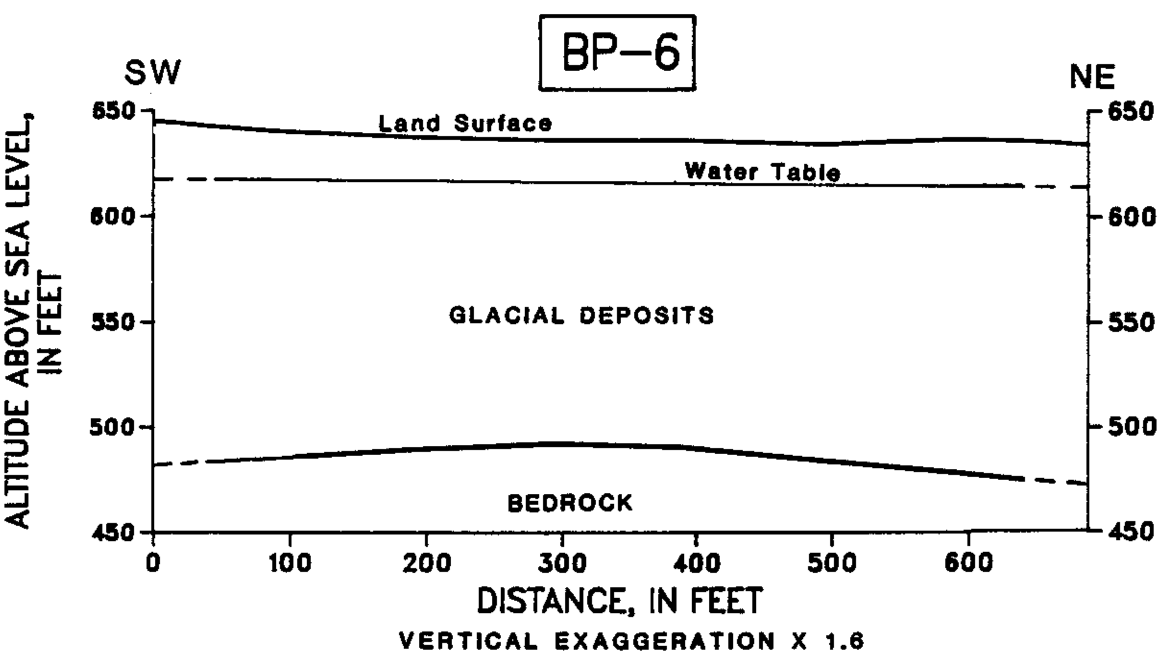

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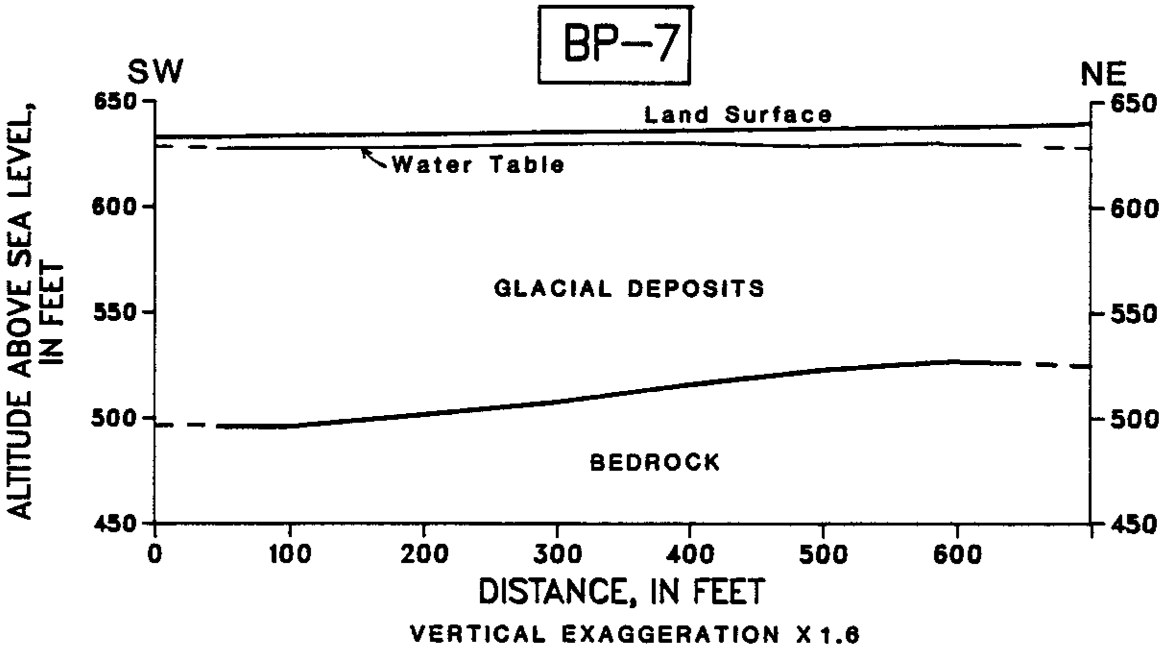

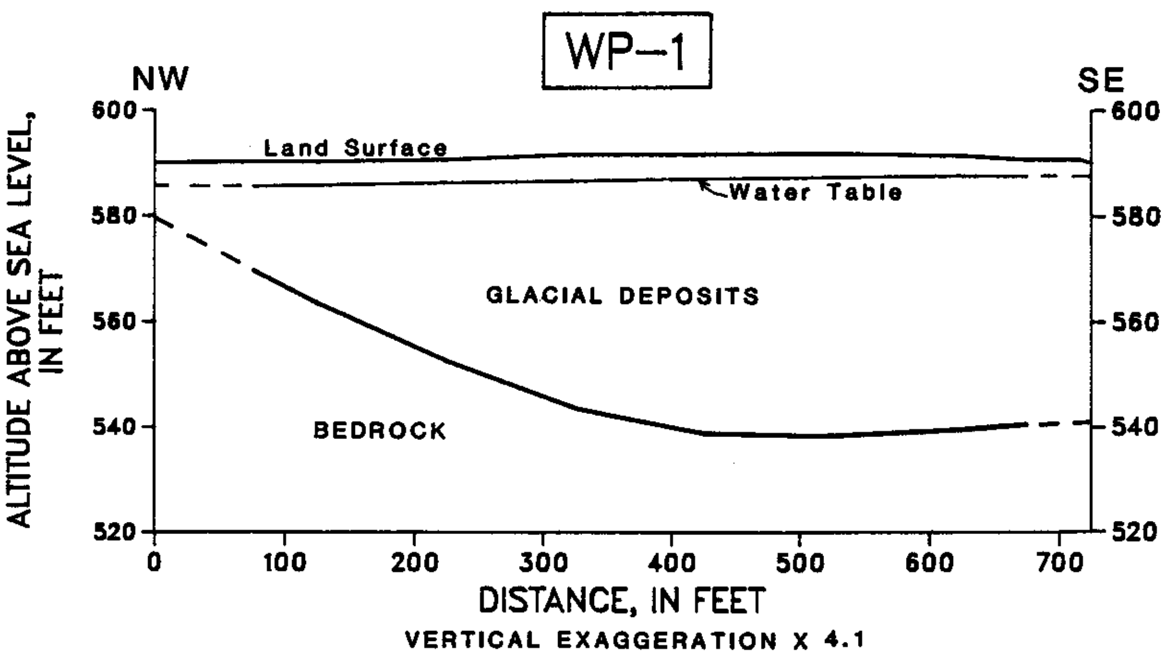

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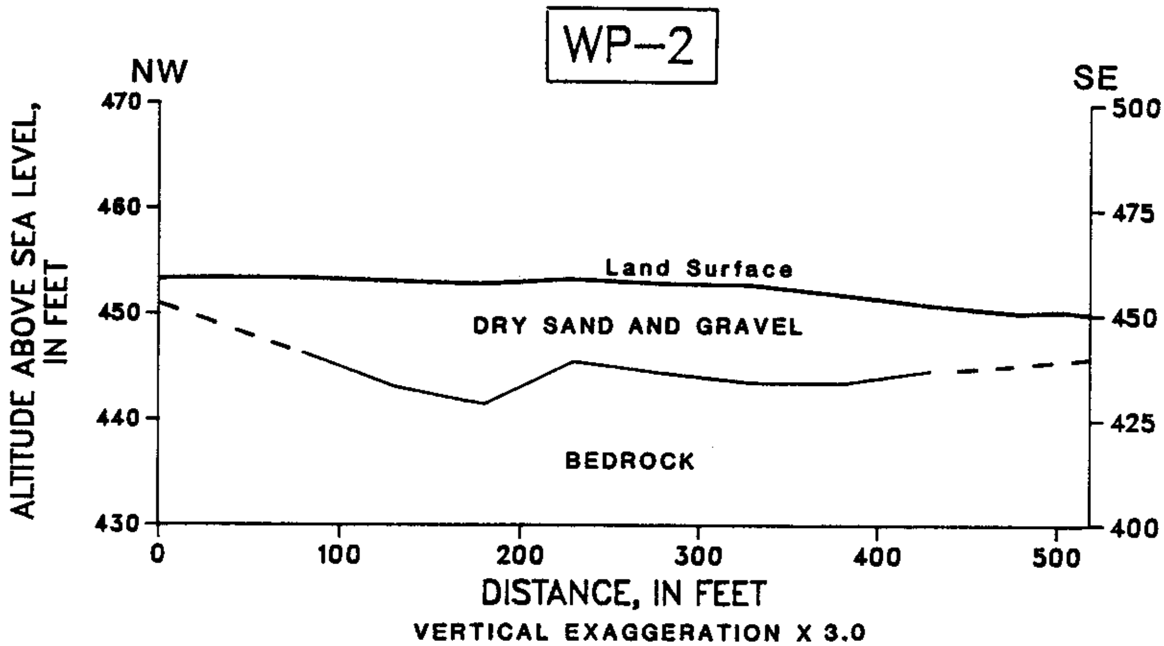

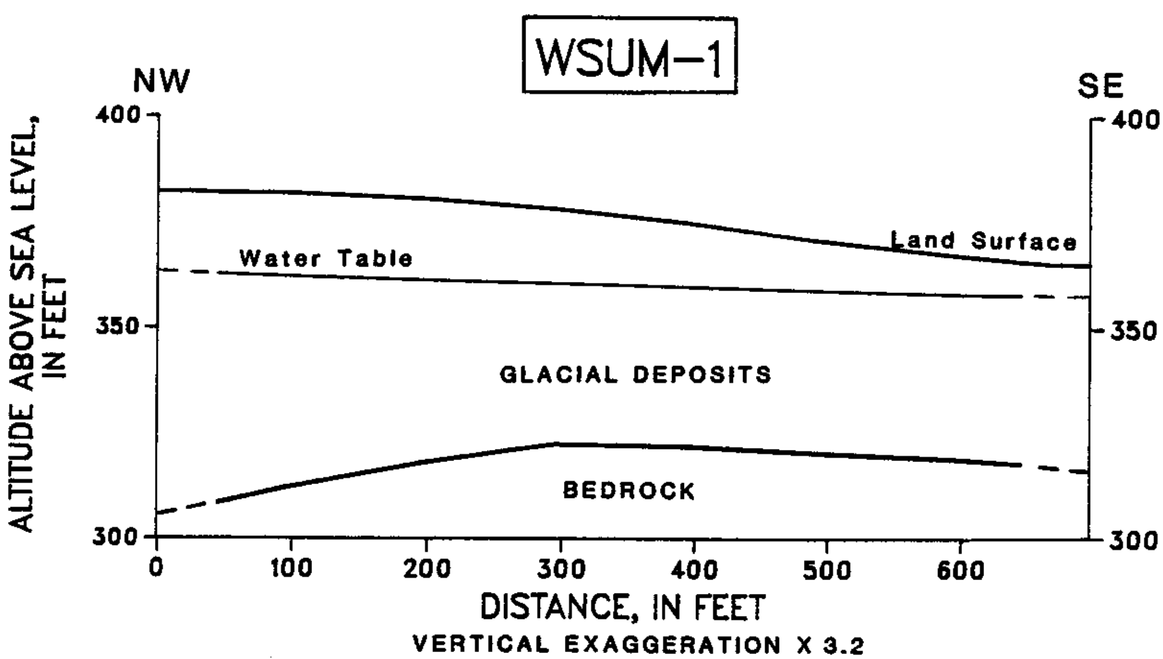

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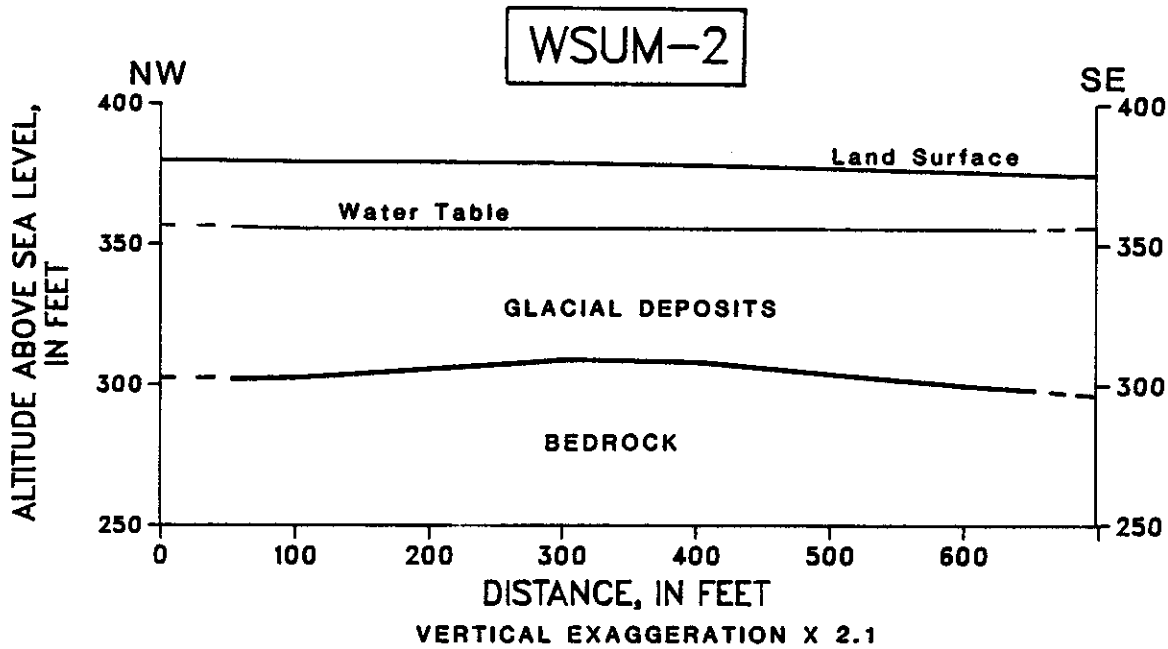

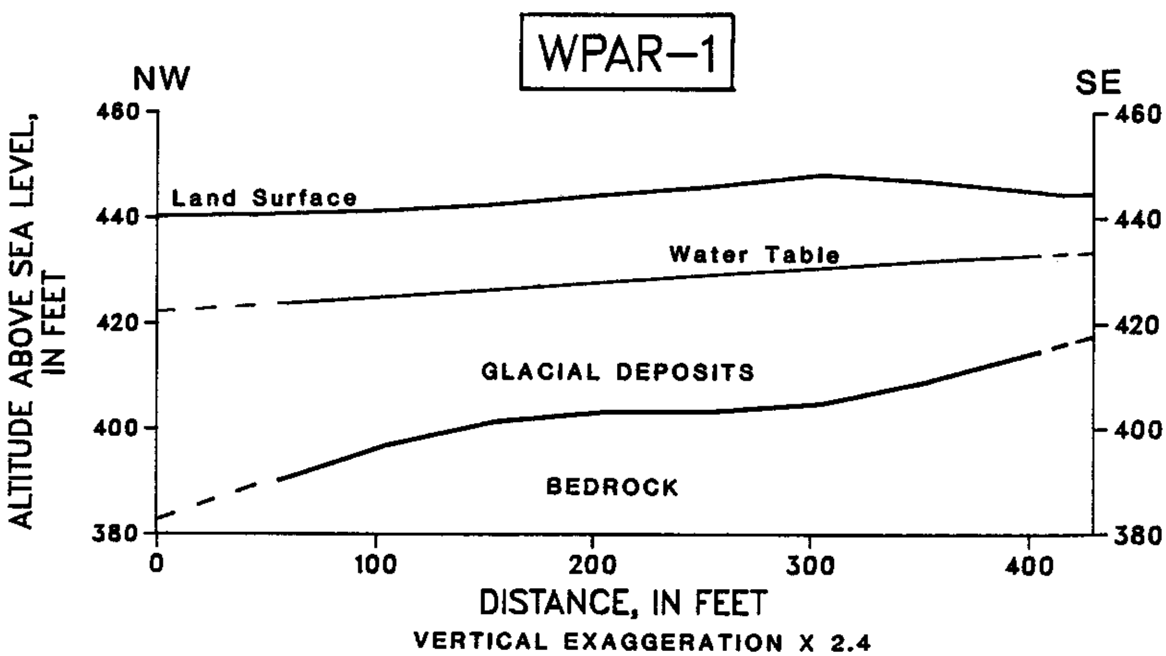

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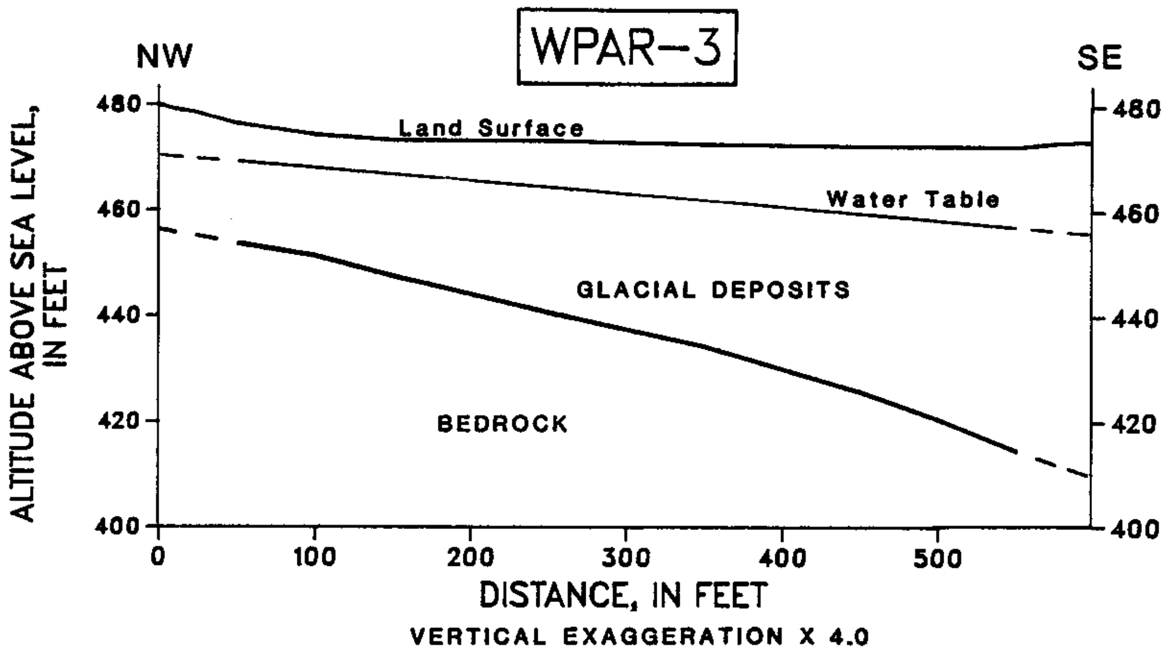

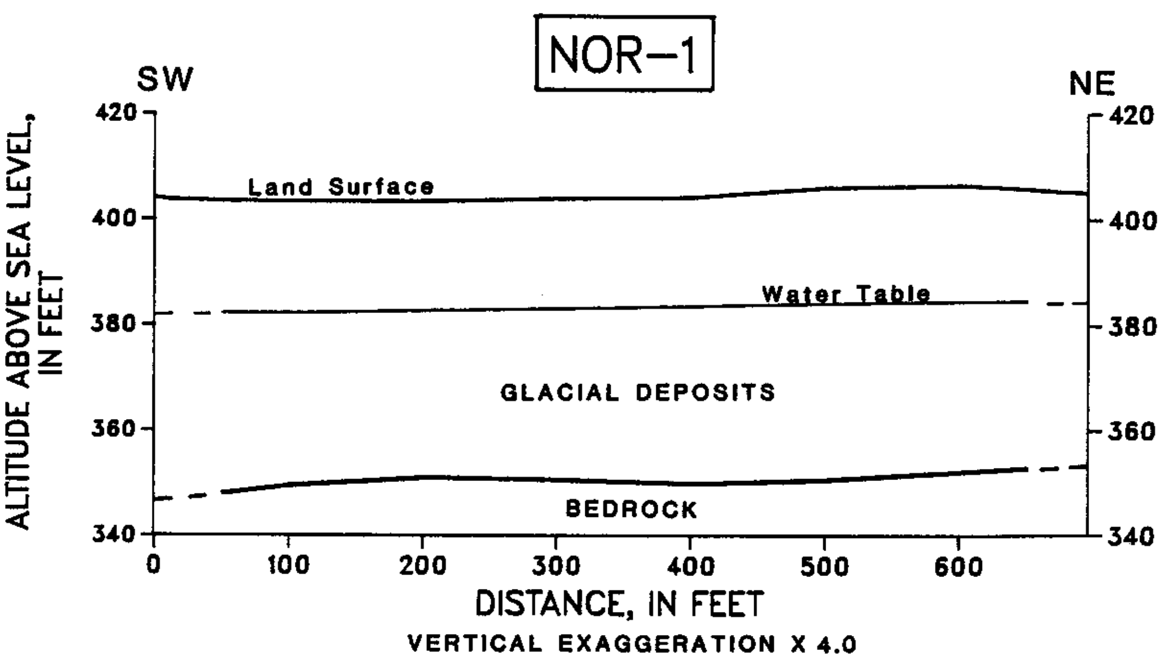

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