PRELIMINARY EVALUATION OF THE GROUND-WATER RESOURCES OF BAINBRIDGE ISLAND, KITSAP COUNTY, WASHINGTON

By N. P. Dion, T. D. Olsen, and K. L. Payne

With a section on geohydrologic units
by M. A. Jones

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CONVERSION FACTORS

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

Multiply inch-pound units	by	to obtain metric units
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon (gal)	0.003785	cubic meter (m^3)
acre	4,047	square meter (m^2)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
degree Fahrenheit (°F)	°C = 5/9 (°F-32)	degree Celsius (°C)

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "mean sea level of 1929."

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ABSTRACT

Bainbridge Island is underlain by as much as 1,600 feet of unconsolidated deposits of Quaternary age. Most domestic ground-water supplies are taken from two relatively coarse-grained geohydrologic units composed largely of glacial sand and gravel. Neither of these two aquifers, generally separated by a finer-grained semiconfining unit, is laterally continuous across the entire island.

Ground-water withdrawal on the island in 1984 was estimated to be 1,235 acre-feet. Of this amount, 60 percent (740 acre-feet) was withdrawn for public-supply purposes, 37 percent (460 acre-feet) for domestic purposes, and about 3 percent (35 acre-feet) for industrial purposes.

The chemical quality of ground water on Bainbridge Island generally is suitable for most uses, and most samples were within State drinking-water standards. However, 3 of 48 samples exceeded the criterion for iron and 19 exceeded the criterion for manganese. This is not considered to be a major water-quality problem and is probably due to natural causes.

Chloride concentrations in ground water were small in both sampling periods, April and September 1985, and changed little seasonally. These observations indicate that seawater intrusion currently is not a problem on Bainbridge Island.

The data now available are adequate to permit an assessment of the ground-water resources of the island, but only in a qualitative manner and only for the uppermost part of the thick unconsolidated deposits. The data are not adequate, however, to permit an assessment of the effects of additional ground-water development. This would require the construction of a mathematical model of the ground-water system, which in turn would necessitate extensive deep exploratory drilling.

INTRODUCTION

Background

Bainbridge Island, Washington, has no significant surface-water resources; therefore, the vast majority of residents are dependent on ground water for municipal and domestic supplies. Population growth has increased the demand for ground water, which occurs in finite quantity. Recent studies (Cline and others, 1982; Whiteman and others, 1983) have demonstrated that the hydrologic systems of similar islands in Puget Sound are sensitive to ground-water development.

Although some information about the geology, hydrology, and occurrence of ground water existed for Bainbridge Island, it was not known if the data base was sufficient to allow a comprehensive assessment of the ground-water resources to serve as an aid in the proper management, protection, and development of that resource. Consequently, the U.S. Geological Survey conducted a ground-water investigation of Bainbridge Island in cooperation with Kitsap County, the Washington Department of Ecology, Public Utility District No. 1, and the city of Winslow. This report is a summary of the results of that study.

Purpose and Scope

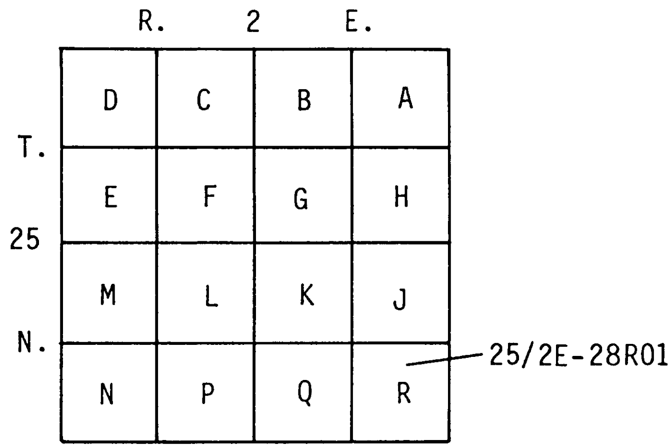
This report describes the results of a study to: (1) define, to the extent available data allow, the general lithology of the unconsolidated deposits of the island and the ground-water flow system within those deposits; (2) on the basis of data collected during the study, broadly define the present quality of ground water beneath the island; (3) identify ground-water quality problems where they exist; (4) design a monitoring network of wells for determining changes in ground-water levels and quality with time; and (5) determine whether the ground-water resources of the island can be assessed adequately using existing data and data collected as part of this study and, if not, what additional data would be required to do so.

Previous Investigations

The geology and ground-water resources of Bainbridge Island have been described in previous reports of broader geographic areas, such as Kitsap County or the entire Kitsap Peninsula. The first of these reports (Sceva, 1957) dealt only with the ground water of Kitsap County. A subsequent report by Garling, Molenaar, and others (1965) dealt with both the ground- and surface-water resources of the Kitsap Peninsula. More recently, Deeter (1979) described the geology and stratigraphy of Kitsap County, while Hansen and Bolke (1980) described ground-water availability on the Kitsap Peninsula. None of these reports, however, addressed the ground-water hydrology of Bainbridge Island specifically.

Well-Numbering System

In Washington, wells are assigned numbers that identify their location within a township, range, section, and 40-acre tract. Well number 25/2E-28R01 indicates that the well is in township 25 North and range 2 East (E) of the Willamette base line and meridian; the letter indicating north is omitted because all wells in Washington are north of the Willamette base line. The number immediately following the hyphen indicates the section (28) within the township; the letter following the section gives the 40-acre tract of the section, as shown in the sketch below. The two-digit sequence number (01) following the letter indicates that the well was the first one inventoried by U. S. Geological Survey personnel in that 40-acre tract. In several illustrations of this report, wells are identified only by the last part of the local well number, such as 28R01. In illustrations where the section number is plainly shown, well numbers are further abbreviated for the sake of clarity by dropping the section number (for example, R1).



Section 28

Acknowledgments

The authors wish to acknowledge the cooperation of many well owners and tenants who supplied information and allowed access to their wells and land during the field work; James Ach of Kitsap County Planning Department and Ted Wright of Public Utility District No. 1 for supplying numerous maps, tables, and data; J. D. Deeter for supplying unpublished geologic information; the owners and managers of the water companies on Bainbridge Island who supplied water-use data; and the Bainbridge Island Fire Department for providing work space in which to process water samples.

DESCRIPTION OF STUDY AREA

Geographic Setting

Bainbridge Island lies in the Puget Sound lowland of west-central Washington (fig. 1) and is bounded by Puget Sound on the east, Rich Passage on the south, Port Orchard (the water body) on the west, and Agate Passage on the north. The island is about 5 miles west of Seattle and is in Kitsap County, on the east side of the Kitsap Peninsula. The northwest end of the island is connected to the peninsula by a bridge across Agate Passage.

The island has an area of 28 square miles and is about 3.5 miles wide and 10.5 miles long. The land surface (fig. 2) is gently rolling, and altitudes range from sea level to about 400 feet above sea level. Numerous small ponds and reservoirs, and one lake (Gazzam), are present on the island. Surface drainage is generally by short, spring-fed streams that discharge directly to the sea.

Vegetative cover of uncleared land on the island is thick. The canopy vegetation consists chiefly of Douglas-fir, western hemlock, western red cedar, Pacific madrone, red alder, and bigleaf maple. The understory is a luxuriant growth of salal, oregon-grape, vine maple, and various ferns and berries.

Climate

Because of the lack of weather stations on Bainbridge Island, data collected by the National Weather Service during the period 1951 through 1980 in the city of Seattle, about 5 miles away, are used to describe the climate of the island.

The climate is of the mid-latitude, west-coast marine type, characterized by warm, dry summers and cool, wet winters (Phillips, 1968). Temperatures in the study area reflect the moderating influences of Puget Sound and the Pacific Ocean (fig. 3). The mean annual air temperature is 52.7 ^{o}F (degrees Fahrenheit); as shown in figure 3, July is the warmest month (65.3 ^{o}F) and January the coldest (40.6 ^{o}F). Afternoon temperatures are usually in the 70's in summer and from the upper 30's to lower 40's in winter.

The mean annual precipitation in the study area is about 39 inches; 74 percent of the precipitation falls in the 6-month period October to March. July has the least mean monthly precipitation (0.89 inch) and December the greatest (6.3 inches). Rainfall during the wet season is usually of light to moderate intensity.

Prevailing winds are from the south or southwest in winter and the west or northwest in summer. The number of clear or only partly cloudy days each month varies from 4 to 7 in winter to 20 or more in summer.

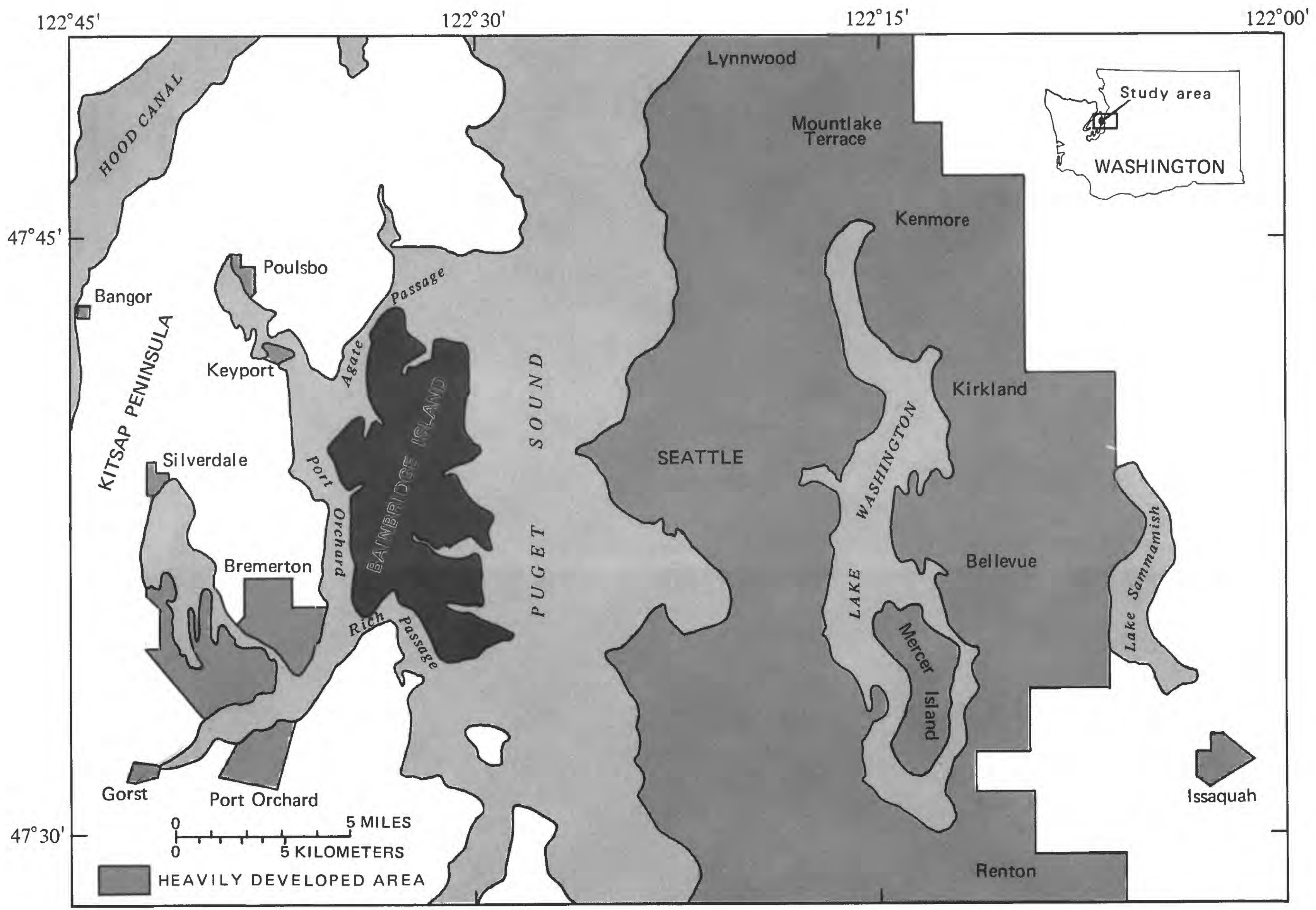


Figure 1.--Location of study area.

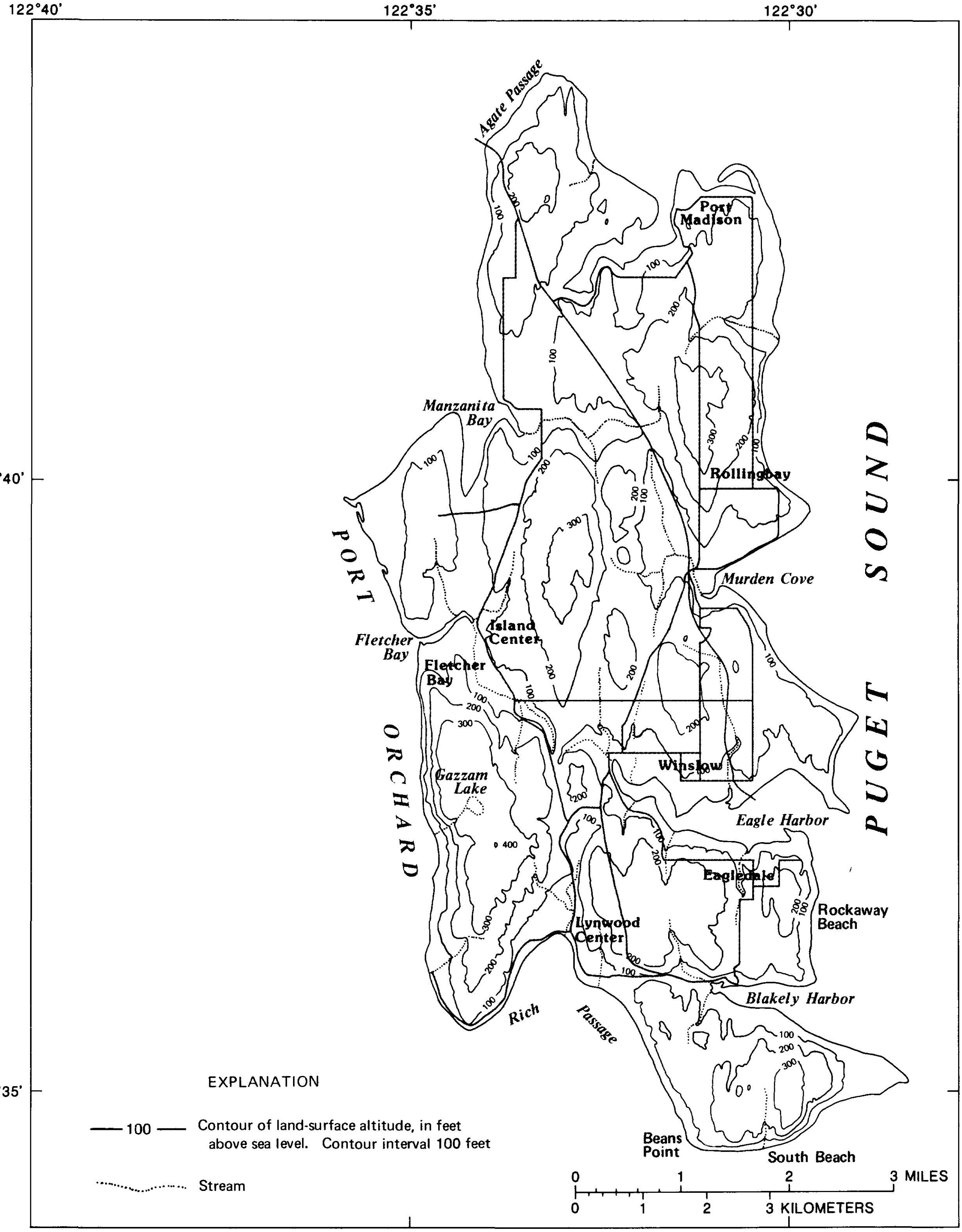


Figure 2.--Generalized topography and surface drainage.

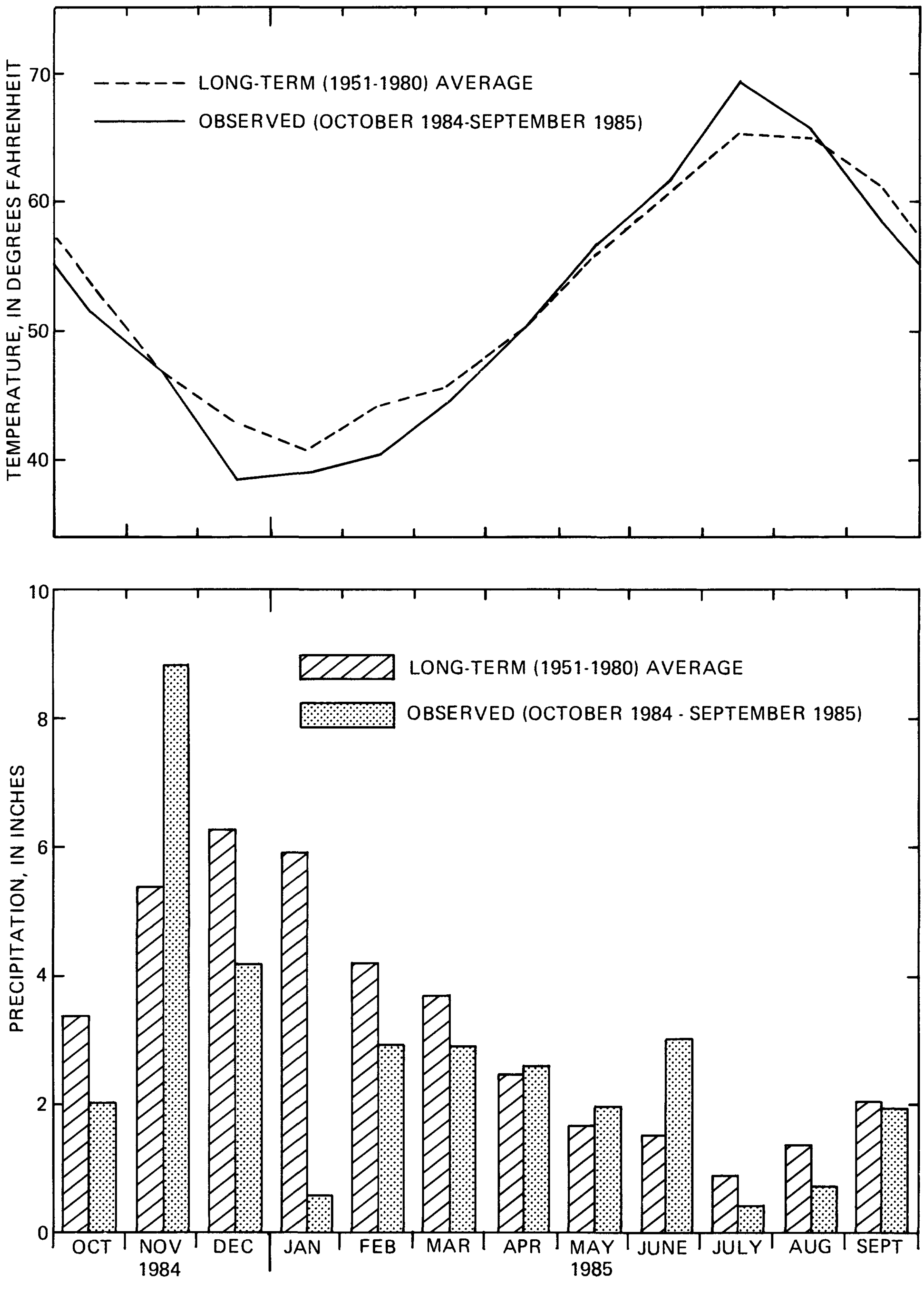


Figure 3.--Mean monthly and observed climatic conditions at Seattle, Washington.

Development and Population

The development of Bainbridge Island began in the 1850's when the island was first used as a summer resort for residents of Seattle. With time, an increasing number of people became year-round residents and the island gradually developed into a "bedroom" community for people working in Seattle or at the naval installations near Bremerton and Bangor (see fig. 1). Some of the factors responsible for this development include a pleasant, rural atmosphere that is close to a major metropolitan city, a large amount of easily developed waterfront property, and reliable ferry service. At present, about 75 percent of the island's work force commutes off the island daily.

Although the population has grown steadily (fig. 4), the rate of growth increased in the late 1970's in response to improved economic conditions in the Seattle area and establishment of a nuclear submarine base at Bangor. The population of the entire island is projected to be almost 15,000 by 1990 (Puget Sound Council of Governments, 1984).

Winslow (see fig. 1) is the principal center of population and commerce, and the ferry terminal is located there. Other areas of substantial residential development include Eagledale, Fletcher Bay, Island Center, Lynwood Center, Port Madison, Rolling Bay, and most of the shoreline. The upland areas of the island are only lightly developed. Lumbering and berry farming once thrived on the island, but both have now diminished greatly in importance. Agricultural pursuits on the island are currently restricted to a few scattered truck, Christmas tree, and holly farms.

The largest industry on Bainbridge Island is a wood-preserving plant at Eagledale, on the south side of Eagle Harbor, which specializes in pressure treating lumber, posts, and piles with creosote and other chemicals to retard decay. Other commercial endeavors worthy of note include a salmon-processing plant and a ship-repair facility at Winslow, an aquaculture concern at Beans Point, and several light manufacturing plants scattered across the island.

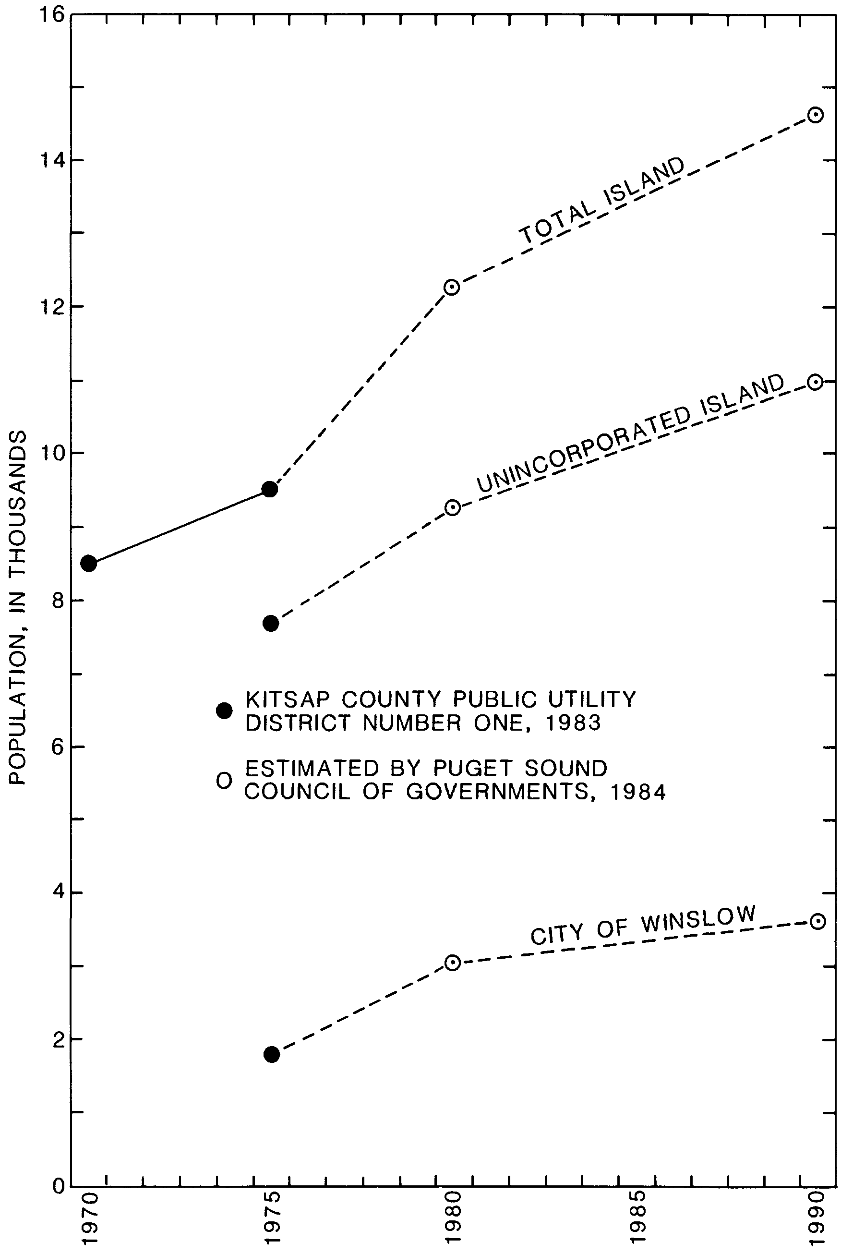


Figure 4.--Population trends for the City of Winslow and Bainbridge Island.

STUDY METHODS

The U. S. Geological Survey's ground-water study began with the compilation of existing well data. Approximately 600 well records from Geological Survey files were reviewed; about 250 of the wells were selected for field visits, beginning in October 1984. The locations of the wells visited are shown in figure 5 and their construction details and other information are provided in table 8. Selection of wells for field visits was based on several criteria: (1) existence of water-level and (or) water-quality data; (2) existence of drillers' lithologic logs; (3) geographic location; (4) depth; (5) geologic framework; (6) well use; and (7) permission from owner or tenant to include the well in this study.

The available data allowed a detailed study of the stratigraphy of the upper 200 feet of unconsolidated deposits that underlie Bainbridge Island, based on surface geology, geophysical data, and drillers' well logs. Well-yield and specific-capacity data were based on reports submitted by drillers to the Washington Department of Ecology.

About 210 wells were visited in April and in September 1985 to measure depth to water and to collect a water sample for analyses of specific conductance and chloride concentration. Forty-eight of the samples collected in April were analyzed for major cations and anions, nitrate, iron, manganese, and fecal-coliform bacteria; nine of the 48 water samples were also analyzed for trace metals. All analyses except fecal-coliform bacteria and specific conductance were done in the central laboratory of the U.S. Geological Survey at Arvada, Colorado. Samples for the analysis of fecal-coliform bacteria were processed in the field by project personnel within 4 hours of sampling. Colonies were counted within 22 $\pm$ 2 hours of sampling.

Water levels and (or) chloride concentrations were measured monthly in 24 selected observation wells (see fig. 5) to document the magnitude of seasonal fluctuations in those constituents. Water-quality data were compared with historical data in an attempt to identify areas where deterioration, especially seawater intrusion, has occurred with time. Bacteria and nitrate data were used as indicators of possible ground-water pollution from sources such as septic tanks and landfills. The results of the water-quality analyses are provided in tables 8 and 9 at the end of the report.

Water-system managers and industrial representatives were contacted by telephone to determine rates and temporal distribution of ground-water pumpage during 1984.

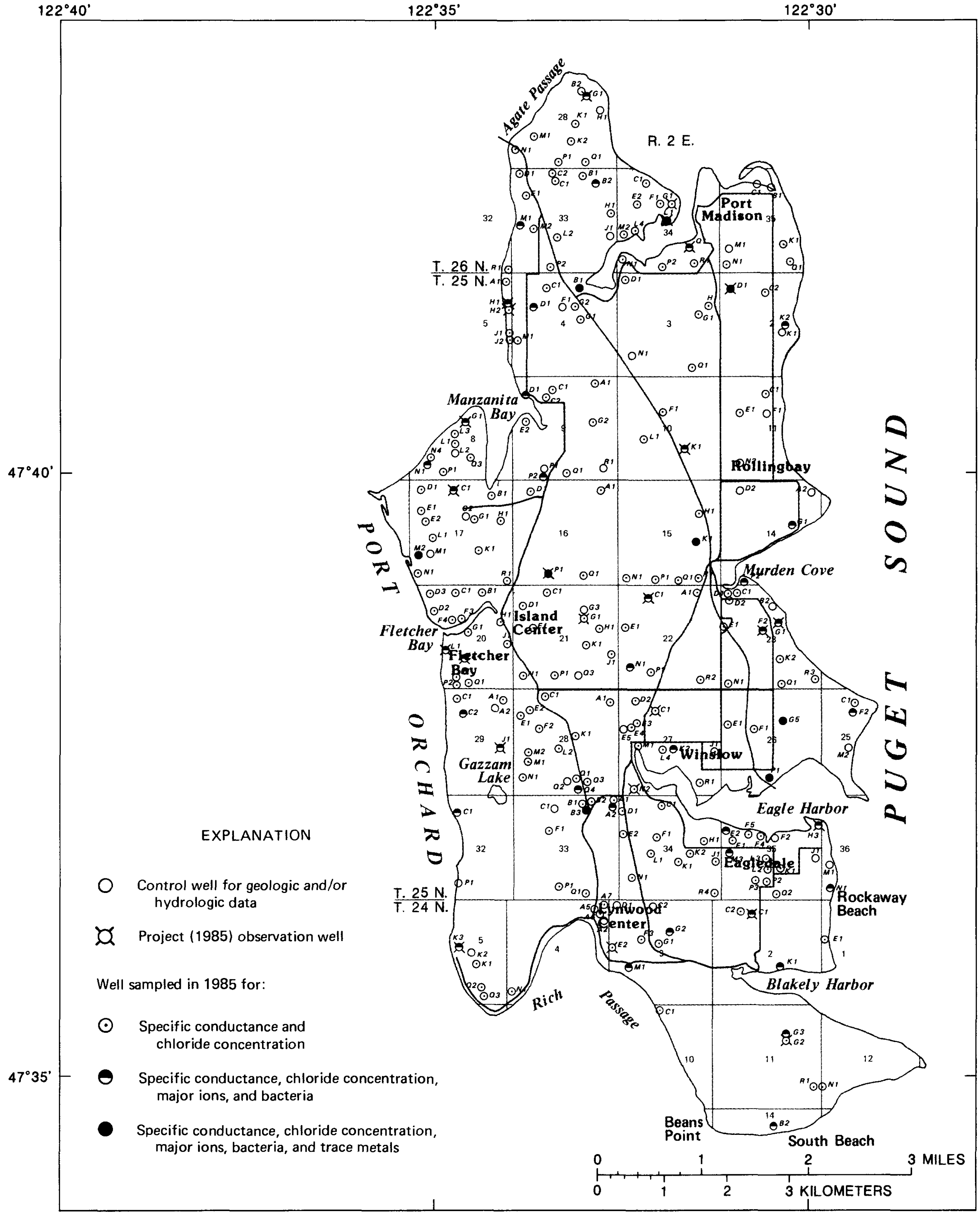


Figure 5.--Locations of wells used to collect geologic and hydrologic data (see page 3 for explanation of well-numbering system).

The Hydrologic Cycle

Water circulates continually between the ocean, the atmosphere, and the earth's surface in a process known as the hydrologic cycle (fig. 6). An understanding of the hydrologic cycle is helpful to the determination of ground-water conditions on Bainbridge Island.

Precipitation as rain or snow is the ultimate source of all freshwater. Once on the land surface, part of the precipitation runs off to streams and lakes, part infiltrates into the ground, and part is evaporated back to the atmosphere from the soil and from free-water surfaces such as ponds and lakes. Some of the water entering the soil is drawn up by plant roots and returns to the atmosphere by transpiration from leaves; the combination of evaporation and transpiration is called evapotranspiration. Some of the water that enters the ground continues to percolate downward to become ground water. Some of this ground water eventually returns to the land surface by seepage to springs, lakes, and streams, and some seeps directly to the sea. From the sea, water is evaporated back to the atmosphere, where it forms clouds and, eventually, precipitation.

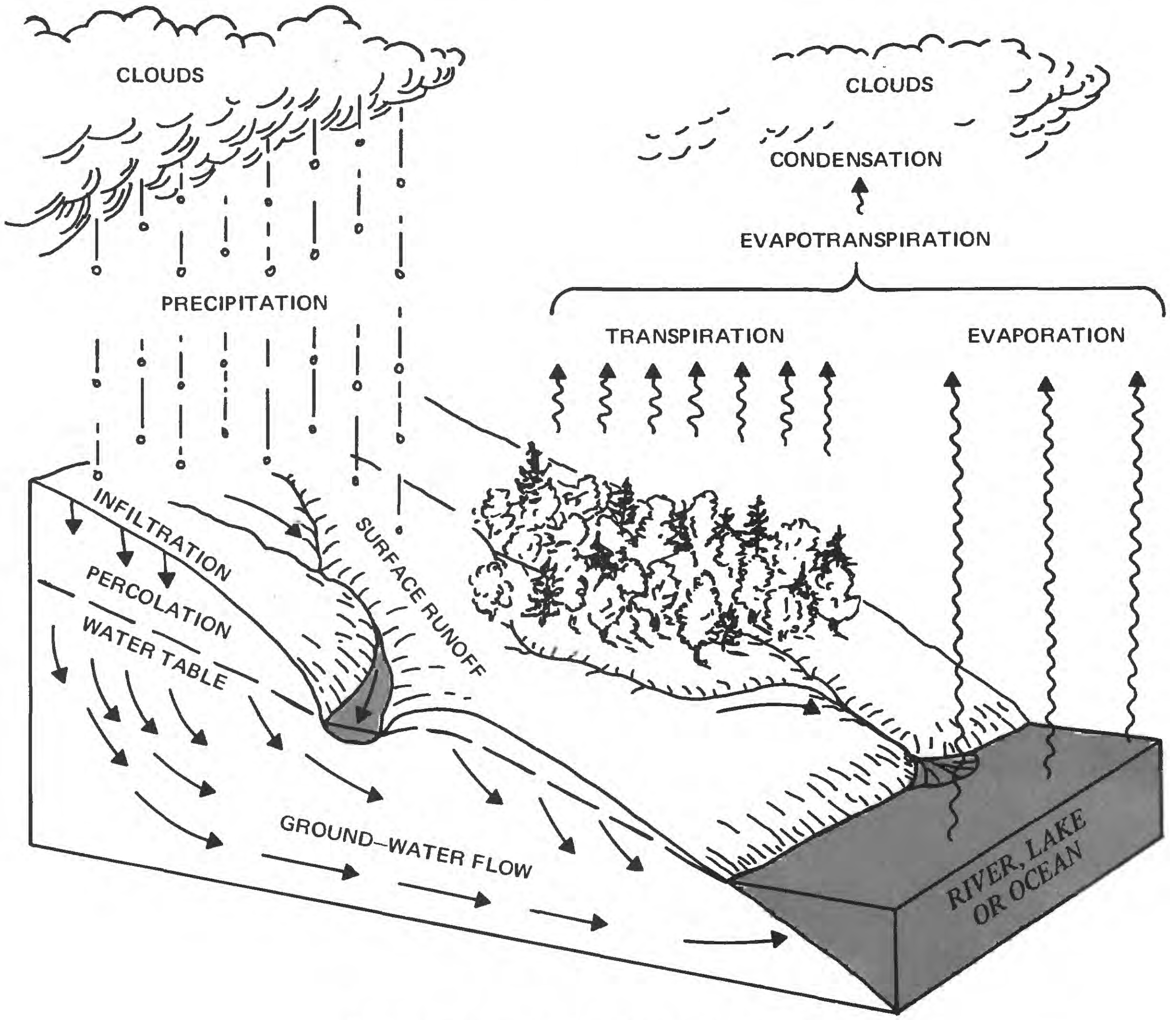


Figure 6.--The hydrologic cycle.

Ground-Water Occurrence

The basic principles of ground-water occurrence are described in a straightforward manner by Heath (1983). Although the abbreviated summary that follows is taken largely from that work, the reader is referred to Heath (1983) for a more comprehensive treatment of the subject.

From the standpoint of ground-water occurrence, all rocks that underlie the Earth's surface can be classified either as aquifers or as confining (or semiconfining) beds. An aquifer is a rock unit that will yield water in a usable quantity to a well or spring. A confining (or semiconfining) bed is a rock unit having very low permeability and that restricts the movement of ground water into or out of adjacent aquifers.

The manner of occurrence of ground water in bedrock and in unconsolidated deposits differs greatly. In dense, consolidated rock, the only movement of water is through interconnected joints, fractures, faults, and solution channels. In loose, unconsolidated materials such as silt, sand, or gravel, water moves through pore spaces separating the individual particles. Because these pore spaces are for the most part interconnected, there is relatively free movement of water within the deposits. Water moves more easily, however, through the larger spaces within deposits of well-sorted coarse sand and gravel than through the smaller spaces within clay, silt, and poorly sorted till.

Ground water occurs in aquifers under two different conditions. Where water only partly fills an aquifer, the upper surface of the saturated zone (the water table) is free to rise and fall with changes in recharge and discharge. The position of the water table is represented by water levels in unused, shallow wells. In this situation, the ground water is said to occur under "water table" or unconfined conditions.

Where water completely fills an aquifer that is overlain and underlain by a confining bed, ground water is said to occur under "artesian" or confined conditions. Wells that tap a confined aquifer (see fig. 19) encounter water that rises in the well to a height corresponding to the pressure "head" of the confined ground water. If the pressure is sufficient to raise the water above land surface, the well will flow and is called a flowing artesian well. Confined ground water has a pressure (potentiometric) surface analogous to the water table, but the pressure surface may differ greatly from that of an overlying water table. The potentiometric surface, like the water table, fluctuates in response to changing recharge-discharge relations.

Flowing wells may also be constructed in unconfined aquifers. The idealized ground-water flow pattern beneath an island of uniformly permeable material, as modified from Hubbert (1940), is depicted in figure 7. In the figure, the approximate flow paths are shown by dashed lines with arrows; the solid lines, which meet the flow lines at right angles, are lines of equal potential (pressure). Deeper cased wells located near the coast and finished in areas of upward-moving ground water tap water under greater head than do shallower wells at the same location. If the deep heads are sufficiently high, the deep wells will flow. Conversely, deeper cased wells near the middle of the island and finished in areas of downward-moving ground water tap water under lower head than do shallower wells at the same location. According to Freeze and Cherry (1979, p. 199), the primary control on the occurrence of flowing wells is not structure or stratigraphy but topography.

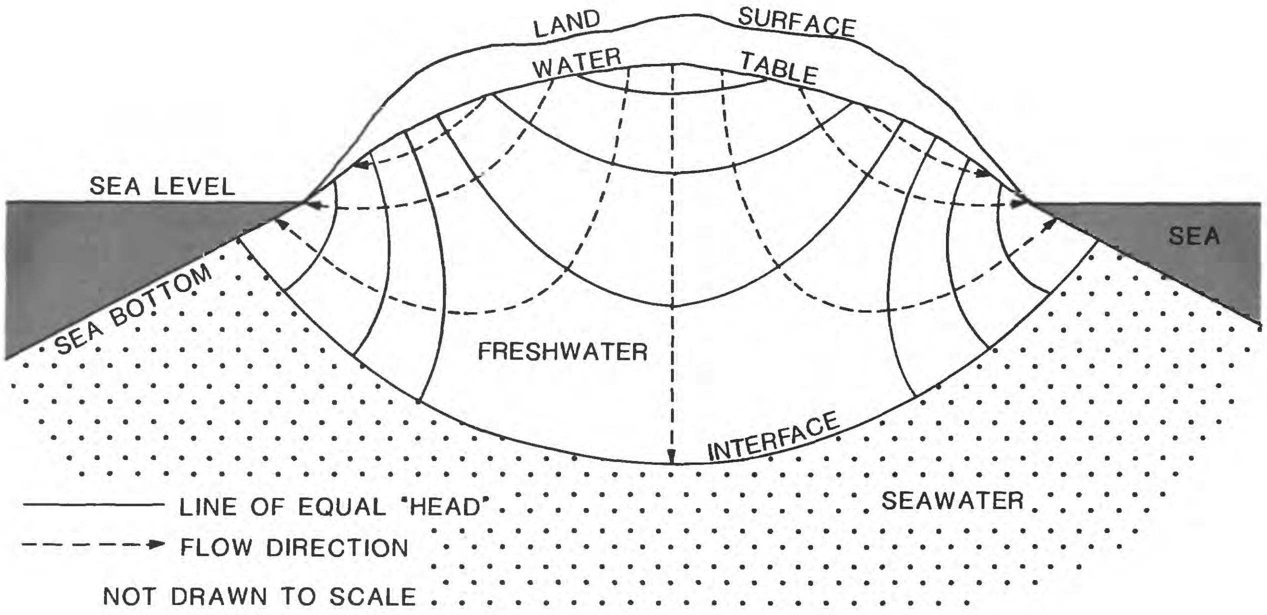


Figure 7.--Idealized head distribution and flow directions in a homogeneous unconfined island aquifer.

Geohydrologic Units

By M. A. Jones

A knowledge of the rock units that underlie Bainbridge Island and their hydrologic characteristics is important to understanding the occurrence and availability of ground water on the island. The distribution of the units at land surface is shown in figure 8.

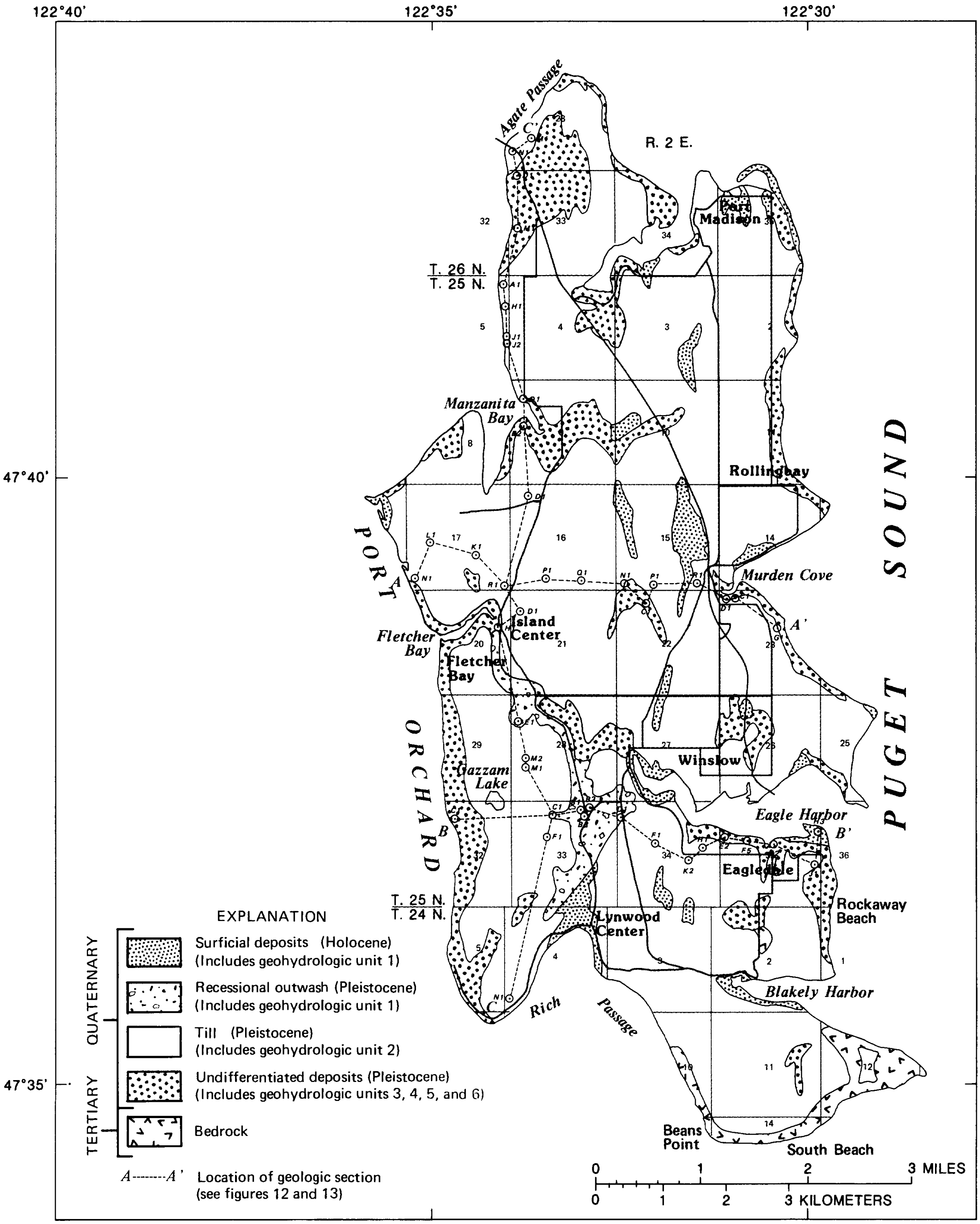


Figure 8.--Generalized surficial geology of Bainbridge Island (modified from Deeter, 1979).

The northern two-thirds of the study area is underlain by 1,000 to 1,600 feet of unconsolidated deposits (fig. 9) thinning southward (Yount and others, 1985). These deposits are absent at the south end of Bainbridge Island, where bedrock composed of older volcanic and sedimentary rocks is exposed. The upper several hundred feet of unconsolidated deposits are of glacial and nonglacial origin and of Quaternary age. Only those deposits extending from land surface to about 200 feet below sea level are well known, because most of the existing wells tap these deposits (see figs. 10, 11).

Identification and correlation of the Quaternary deposits in the Puget Sound region are extremely difficult. Investigators commonly disagree about the identification of individual deposits, and correlations over large areas have not been well established. For the purpose of this report, the unconsolidated Quaternary deposits are divided into three permeable, water-bearing units and three semiconfining units. The permeable, coarser-grained units are assumed to represent outwash deposited during glacial advances and retreats and (or) alluvium deposited during glacial interstades; the finer grained semiconfining units represent till and lake deposits. Because the units are mapped in this fashion, the geohydrologic units identified herein do not necessarily correspond to geologic time-stratigraphic units identified in previous reports that discuss the geology of Kitsap County and Bainbridge Island. A summarized description of the geohydrologic units is provided in table 1.

A network of 16 stratigraphic sections running north-south and east-west was constructed to identify, correlate, and map the continuity of permeable and semiconfining geohydrologic units present on Bainbridge Island. The stratigraphic-sections were based on drillers' lithologic logs, borehole geophysical logs, and on a map of surficial geology by Deeter (1979). Starting at land surface and moving downward through the unconsolidated Quaternary deposits, each unit (either permeable or semiconfining) was extrapolated laterally to the extent available data would allow. Generally, the thinner the unit the less certain is its correlation. Thickness and altitude of the individual units vary and altitudes of the uppermost units tend to reflect surface topography, as illustrated in the stratigraphic sections (fig. 12). The lithologic (drillers') logs of wells used in fig. 12 are provided in table 10.

Water levels, water chemistry, and specific capacities were used to try to identify unique characteristics of each aquifer; the differences were too small to distinguish between units. Specific-capacity data were used to describe the range of permeability in each unit.

A few shallow wells tap zones of higher permeability in the surficial deposits and recessional outwash of unit 1. For the most part, these materials occur at land surface along the longitudinal axis of the island (see fig. 8). Locally they yield water where they are sufficiently thick and saturated, but those instances are relatively uncommon.

Unit 2, a till, covers much of the surface of Bainbridge Island (fig. 8). The unit is generally less than 80 feet thick and is composed chiefly of unsorted and unstratified glacial sediments of clay-to-boulder size. The till (unit 2) and overlying recessional outwash (unit 1) yield small quantities of ground water to numerous shallow dug wells.

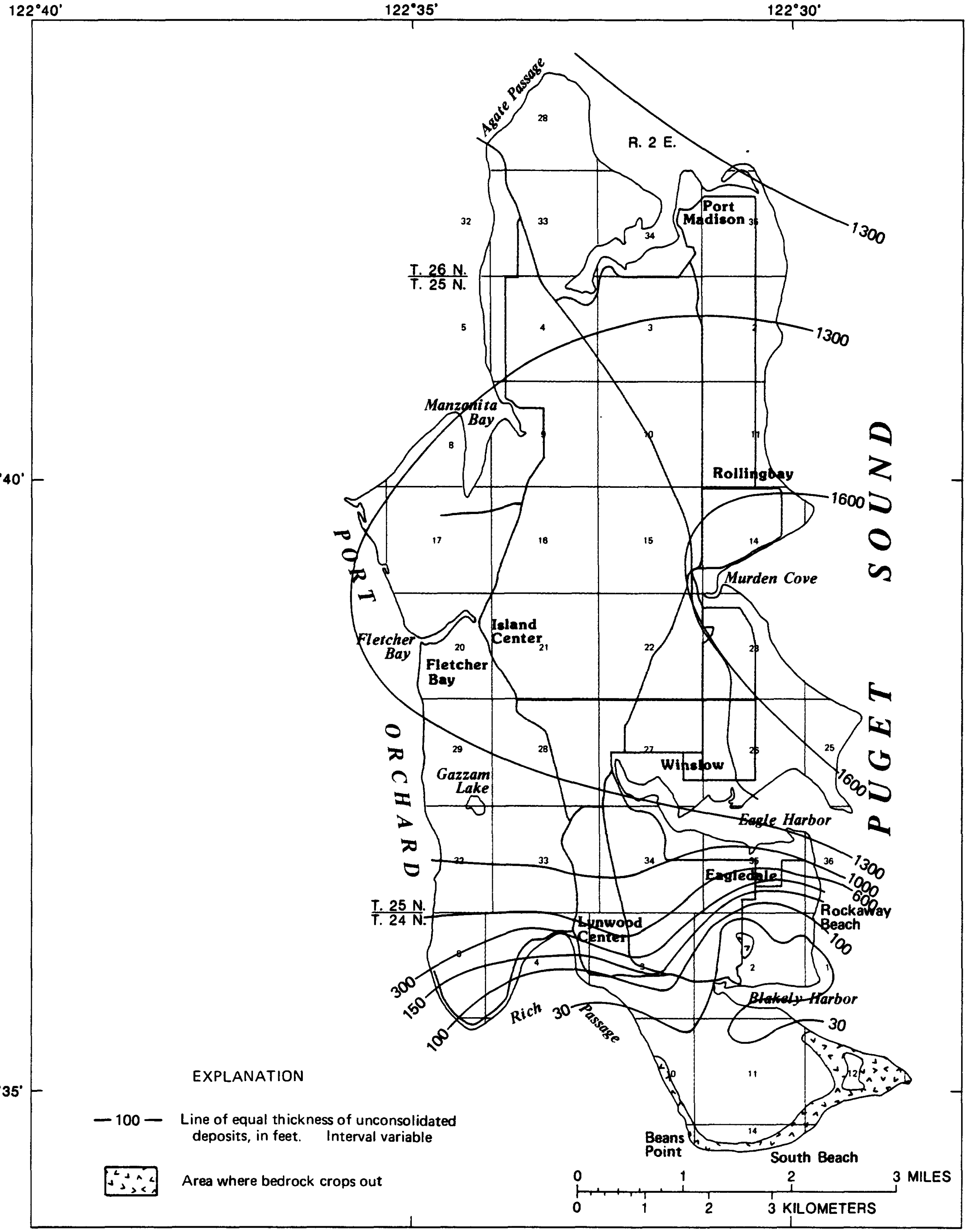


Figure 9.--Thickness of unconsolidated deposits on Bainbridge Island (modified from Yount and others, 1985).

NOTE: Ninety-three percent of all project wells on Bainbridge Island are completed above the -200' level.

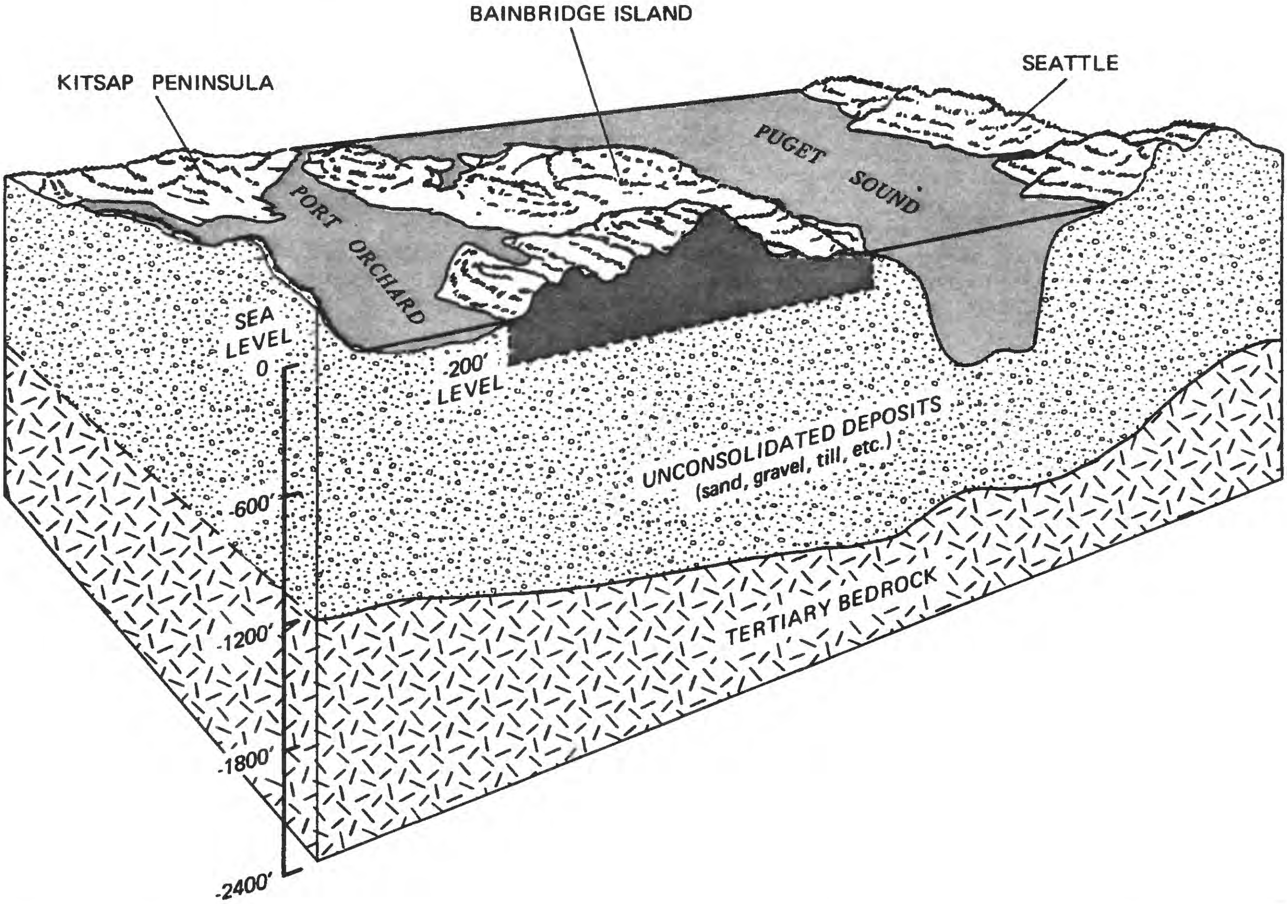


Figure 10.--Conceptual sketch showing relation of bedrock, unconsolidated deposits, and surface topography in the study area.

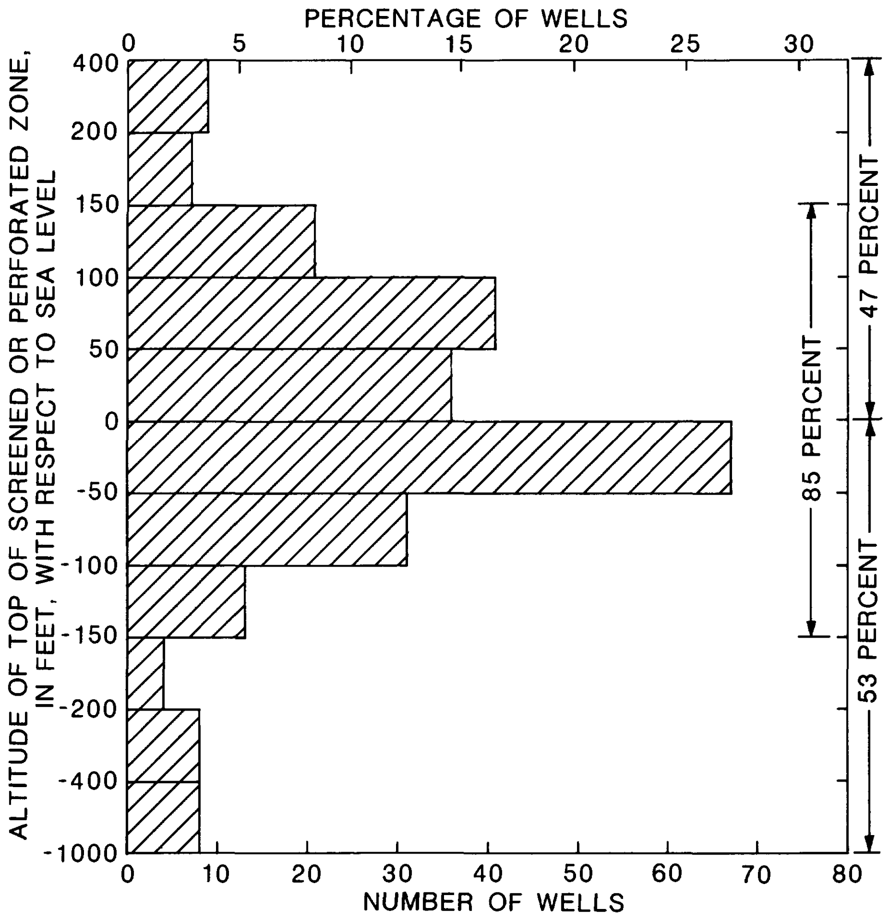
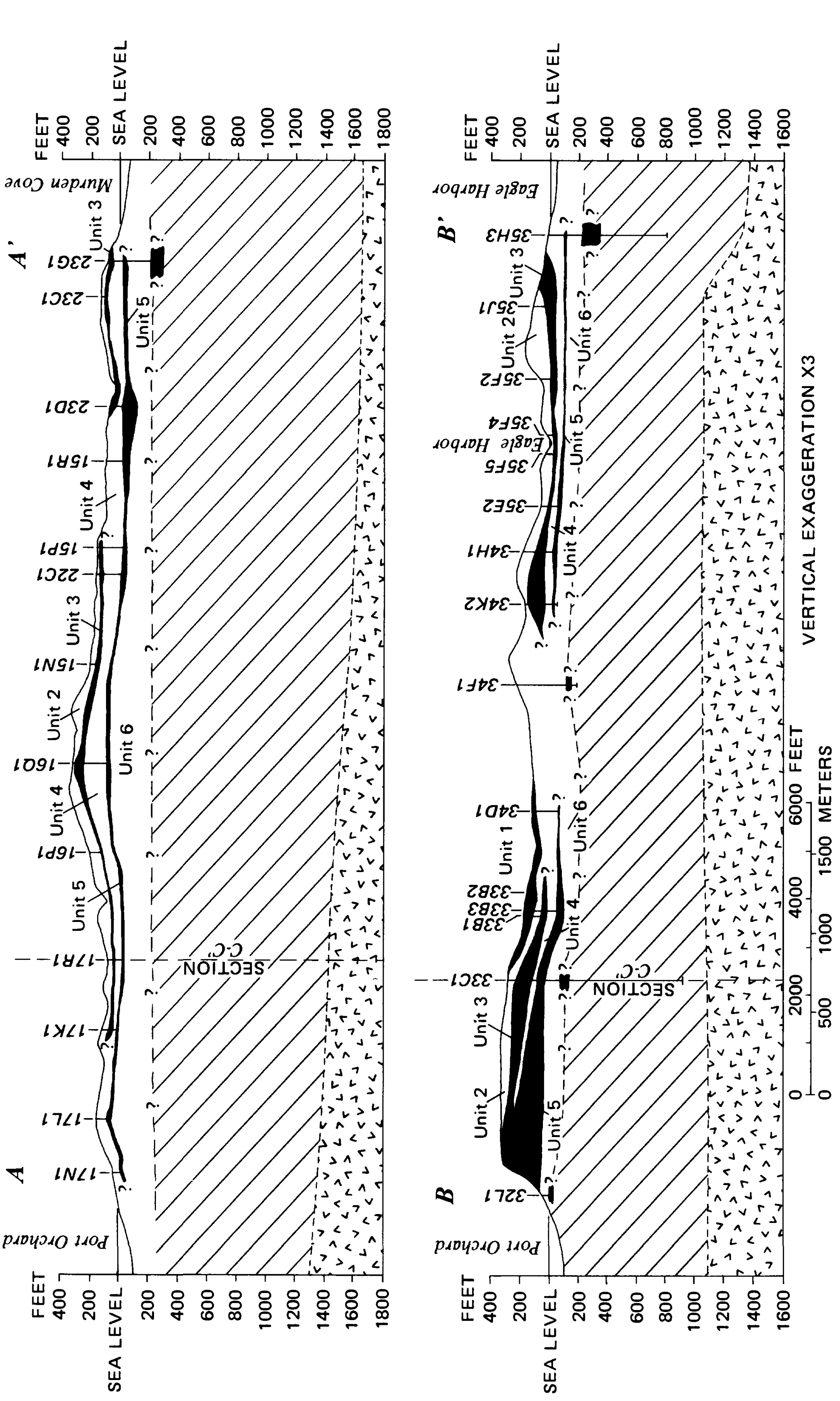


Figure 11.--Frequency distribution of depths of study wells on Bainbridge Island.



A
A'
B
B'
Port Orchard
Murden Cove
Eagle Harbor
FEET
SEA LEVEL
400
200
600
800
1000
1200
1400
1600
1800
17N1
17L1
17K1
17R1
16P1
16Q1
15N1
22C1
15P1
15R1
23D1
23C1
23G1
32L1
33C1
33B1
33B3
33B2
34D1
34F1
34K2
34H1
35E2
35F5
35F4
35F2
35J1
35H3
Unit 1
Unit 2
Unit 3
Unit 4
Unit 5
Unit 6
SECTION C-C'
VERTICAL EXAGGERATION X3
0
2000
4000
6000 FEET
0
500
1000
1500 METERS

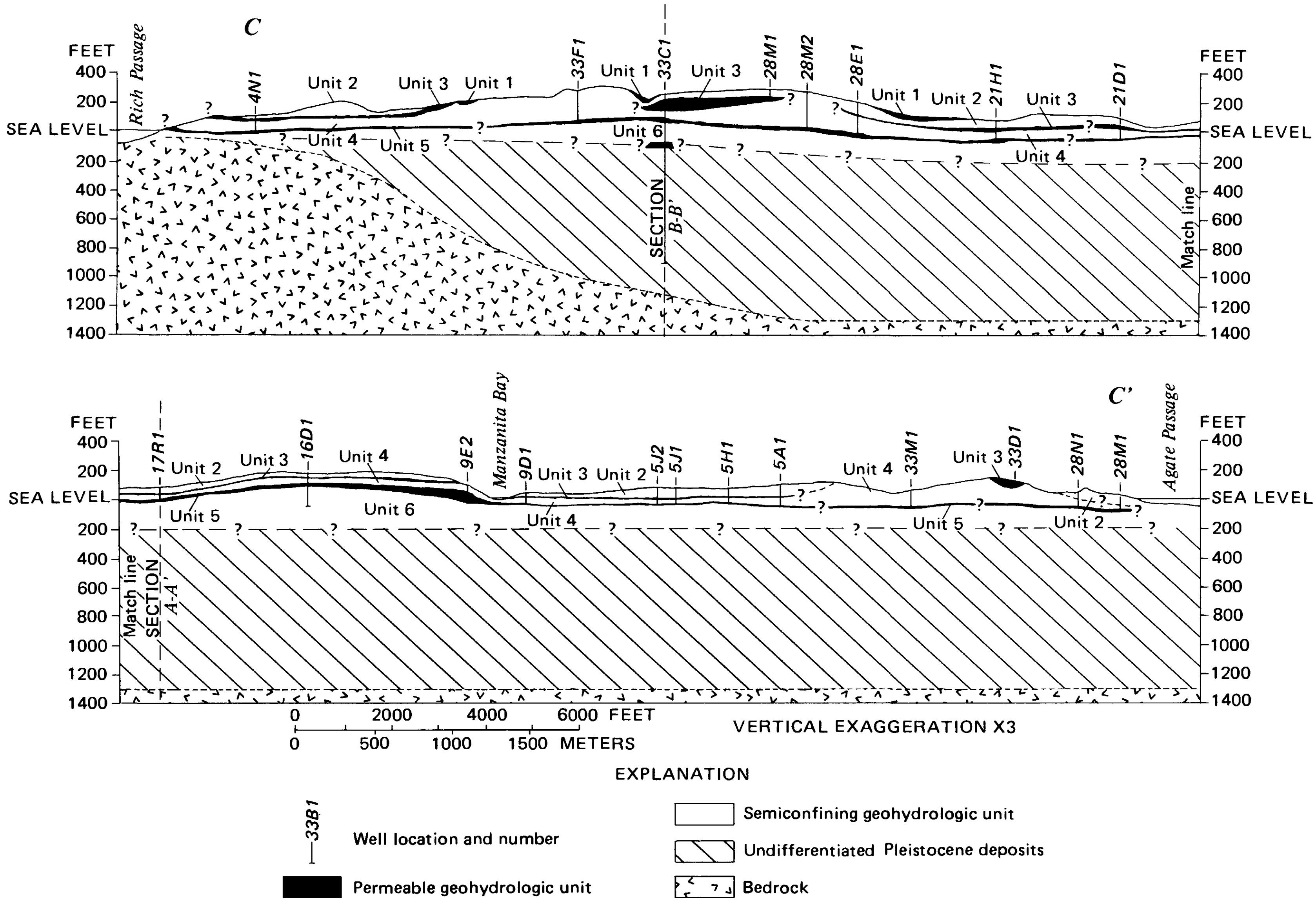


Figure 12.--Sketch of geologic sections A-A', B-B', and C-C' showing locations of major geohydrologic units.

TABLE 1.--Lithologic and hydrologic characteristics of the geohydrologic units beneath Bainbridge Island

Geohydrologic unit	Character and Extent	Median Thickness (feet)	Water-bearing Properties
1	Discontinuous bodies of alluvium and unconsolidated sand and gravel deposited by meltwater of the Vashon Glacier.	10	May yield small to moderate supplies of ground water for domestic use where deposits are generally thick.
2	Extensive till sheet that mantles most of the island. Till varies greatly in compaction and composition.	40	Essentially impervious but may yield small quantities of ground water. Generally acts as a semiconfining layer.
3	Predominately stratified sand. Contains irregular lenses of gravel and thin strata of clay and silt. In some places the sand is overlain by discontinuous silt, sand, and gravel. Deposited by meltwater streams.	30	A major water-bearing unit. Where base is below the water table, sand yields small quantities; gravel strata yield moderately large quantities. Data from wells in this unit indicate hydraulic conductivity ranges from 0.7 to 62 feet per day.
4	Interbedded silt and clay with occasional lenses of sand, gravel, and peat. Generally found exposed in steep bluffs adjacent to the shoreline.	70	Low permeability; generally yields little or no water. Acts as a semiconfining layer. Lenses of sand and gravel yield small quantities of water to wells.
5	Stratified sand and gravel. May be stained buff or orange-colored in outcrop. Slightly cemented. Contains some silt, clay, and till strata.	50	A major water-bearing unit. Yields small to large quantities of ground water, frequently under artesian pressure. Hydraulic conductivity ranges from 0.8 to 180 feet per day.
6	Predominantly massive blue clay and silt. Deformed in most places. Contains till, volcanic ash and peat or lignite.	90	Acts as a semiconfining layer.
Pleistocene deposits (undifferentiated)	Clay, silt, and till, generally underlain by sand and gravel. Top of unit is usually below sea level.	1,000 (?)	Clay, silt and till deposits yield little or no ground water. Sand and gravel deposits yield small to very large quantities of water.
Blakeley Formation of Weaver, 1916 (Tertiary)	Marine sedimentary conglomerate, sandstone, shale, and volcanic basalt. Rocks are steeply dipping, folded, fractured and jointed. Exposed on the southern end of the island	8,500 (?)	Unsatisfactory ground water source in quantity and quality.
Basalt (Tertiary)	Dark, fine grained basalt. Exposed at the southern coastline of Bainbridge Island.	6,700 (?)	Yields little to no ground water; available quantities are of poor quality

Unit 3 underlies the till and is a major water-bearing unit on Bainbridge Island. It is composed of sand and sand-and-gravel lenses and some thin strata of silt and clay. The thickness of unit 3 ranges from a few feet to 150 feet, with a median thickness of about 30 feet. The bottom of the unit is generally 50 feet or more above sea level. Thus, in most places where the present land surface is 50 feet or less above sea level, unit 3 is not found. Although the unit occurs throughout most of the study area and may have been continuous or nearly continuous at one time, subsequent erosion has dissected it in many places. The altitude and areal extent of unit 3 are shown in figure 13.

Unit 4 is a semiconfining layer underlying unit 3. It is composed almost entirely of silt and clay, with some lenses of peat, sand, and gravel. The unit is locally more than 200 feet thick and its median thickness is about 70 feet. Unit 4 is generally found at altitudes between sea level and 100 feet above sea level. Available drillers' logs indicate that this unit is not continuous over the entire study area.

Unit 5, shown in figure 14, underlies unit 4 and is a major water-bearing unit on Bainbridge Island. It is composed predominately of sand and sand-and-gravel layers with some thin layers of till, silt, and clay. The median thickness is 50 feet but the unit is locally as much as 150 feet thick. Altitudes of the top of this unit are generally between 30 feet above and 30 feet below sea level. Available drillers' well logs indicate that unit 5 is not continuous throughout the study area.

Below unit 5 lies a semiconfining layer, unit 6. This layer is composed of interbedded clay, silt, and fine-grained sand, with local thick lenses of peat. It is more massive and compact than unit 4 and is found exposed along the steep bluffs near the shoreline. Its average thickness is 90 to 100 feet and the unit is found at altitudes between 50 feet below and 50 feet above sea level.

The remaining unconsolidated deposits below unit 6 are collectively referred to here as undifferentiated glacial and nonglacial deposits of Pleistocene age. These deposits extend downward for more than 1,000 feet. The extent and thickness of the water-bearing units in these undifferentiated deposits are largely unknown and are not shown in figure 12.

Recharge and Discharge

Precipitation on Bainbridge Island is the sole source of recharge to its ground-water system. Although the system is probably recharged locally by filter-field leachate and excess lawn irrigation, the ultimate source of that water is also precipitation on the island. Factors determining the amount and location of recharge to the aquifers include distribution of precipitation in space and time, amount and type of vegetation, slope of the land, moisture-holding capacity of the soil, and vertical permeability of geologic materials above the aquifers.

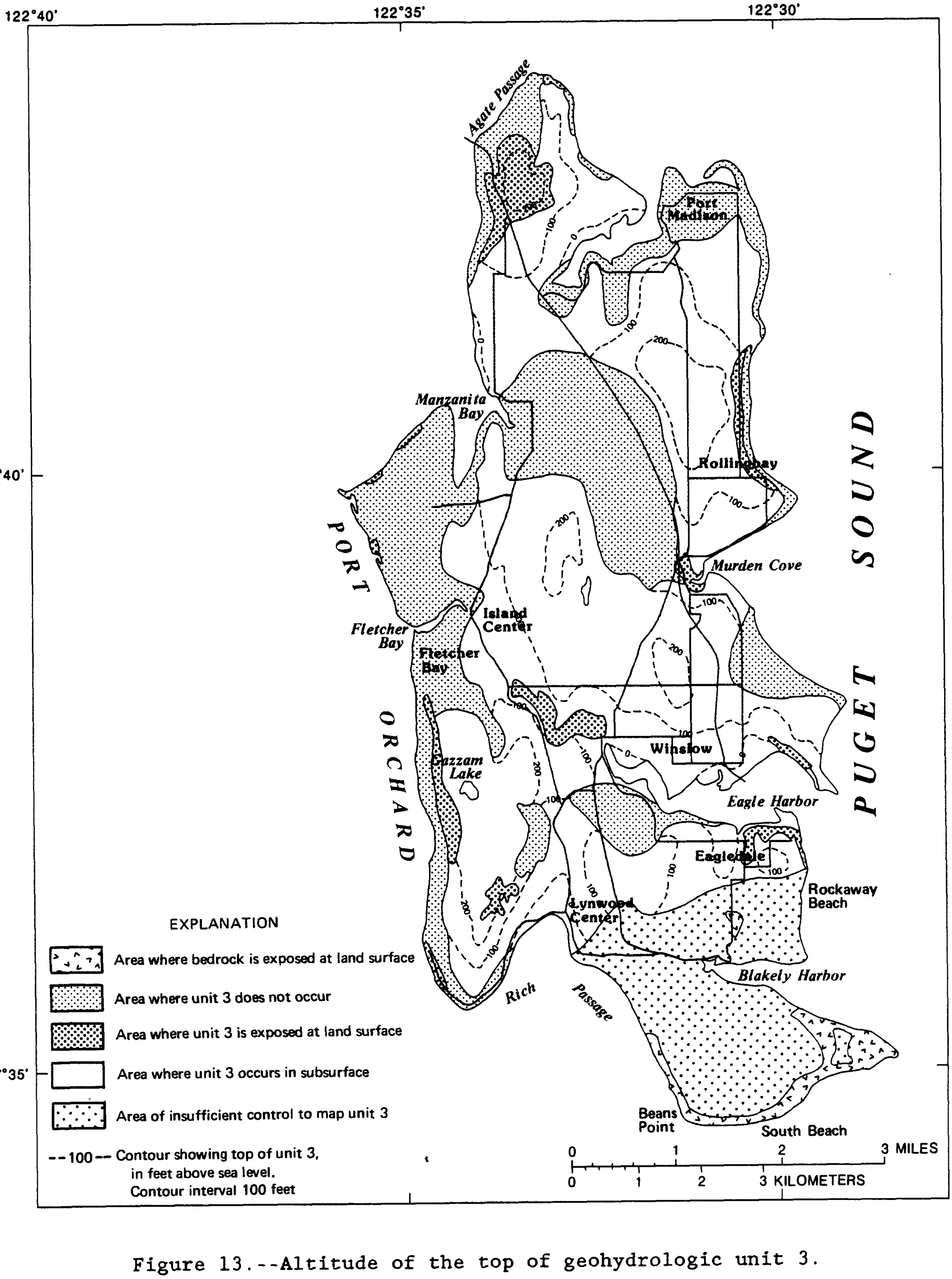


Figure 13.--Altitude of the top of geohydrologic unit 3.

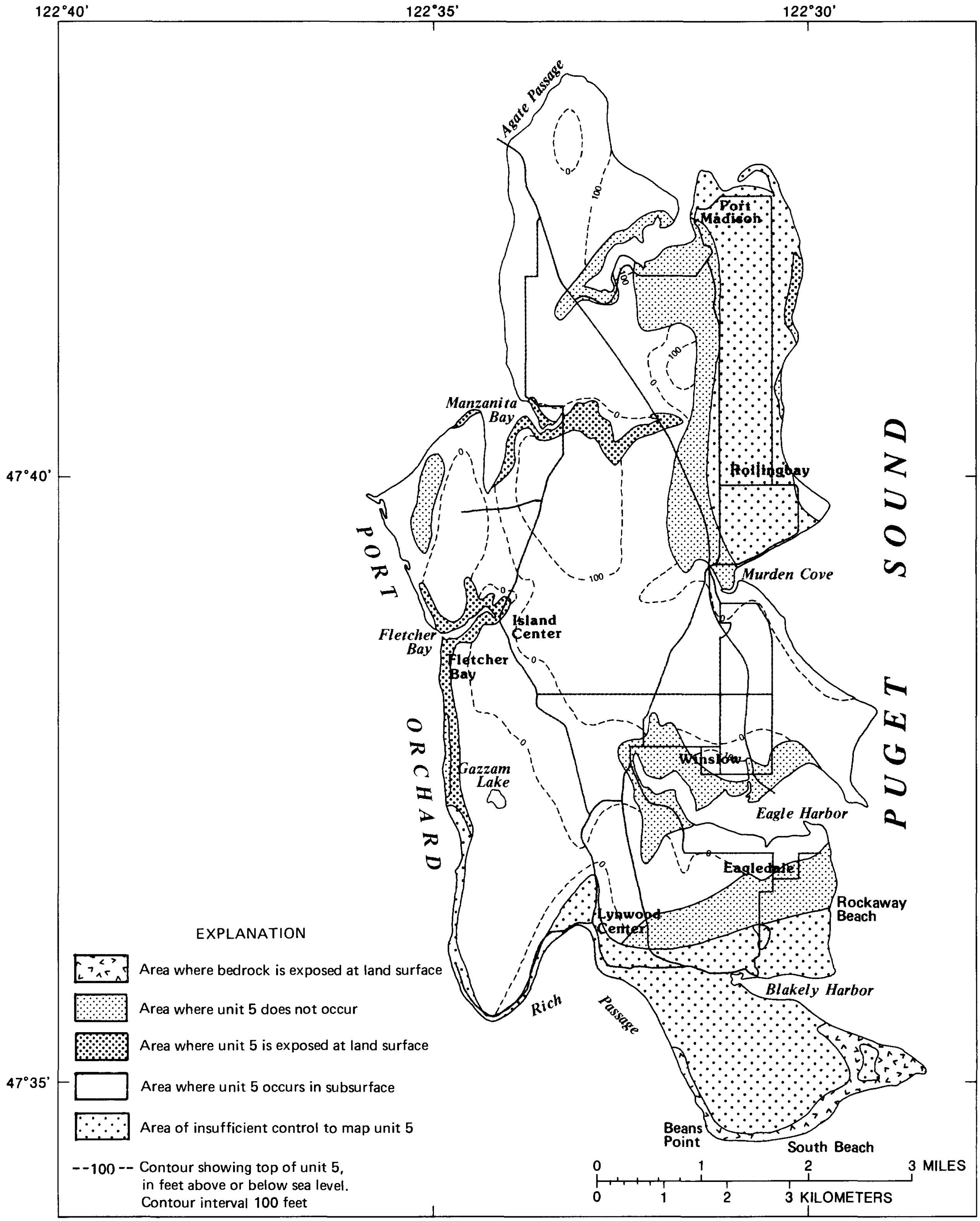


Figure 14.--Altitude of the top of geohydrologic unit 5.

Recharge to the Bainbridge Island ground-water system occurs over most of the island, with the possible exception of those areas covered by such impermeable, manmade materials as asphalt and concrete. Impermeable materials at land surface may only delay and redistribute the recharge process; precipitation that runs off impermeable surfaces may seep into the ground as soon as it encounters natural materials. In the city of Winslow, precipitation that might otherwise recharge the aquifer is diverted through storm drains to Eagle Harbor (see fig. 2), resulting in less recharge beneath Winslow than in areas without storm drains. Similarly, there is little or no recharge from filter-field leachate in Winslow because domestic sewage is diverted to a central sewage treatment plant (secondary treatment), and then to Puget Sound.

As pointed out previously, a large part of Bainbridge Island is capped by unit 2, a relatively impermeable glacial till (fig. 8) that tends to increase the amount of precipitation that runs off the land surface into small streams, thereby decreasing the amount of water that would otherwise infiltrate into the ground. The dense vegetation that covers much of the island retards runoff and allows more time for the precipitation to infiltrate, but it also results in greater transpiration. In those areas of Bainbridge Island where the till is absent and more permeable geologic units are exposed at land surface, recharge rates are probably higher than in areas capped by till. With the exception of the northern tip of the island, these areas of potentially greater recharge are for the most part near the periphery of the island (see fig. 8). Because the periphery is an area where ground-water discharge predominates, recharge in the periphery has a minimal effect on the amount of ground water in storage.

Unit 3, one of the major water-bearing units on the island, is recharged mostly by precipitation in areas where the unit crops out at land surface (see fig. 13), and by ground water that moves vertically through unit 2. Unit 5, another major water-bearing unit, is recharged in part by precipitation falling onto its outcrop areas (see fig. 14), and in part by ground water that moves vertically through unit 4.

Most recharge occurs during long rainy periods; in western Washington this is generally from October through March. Recharge also varies from year to year, depending on the amount of precipitation, its seasonal distribution, air temperature, land use, and other factors. The data currently available are insufficient to determine the exact amount of recharge to the island.

Even though the aquifers beneath Bainbridge Island discharge water to streams, springs, lakes, and wells, ground-water outflow to the sea accounts for most of the natural discharge from the island. As shown in figure 2, the perennial streams on the island are few in number and relatively short; surface-water discharge to the sea is correspondingly small. Many springs occur along the sea cliffs and shoreline of the island, but quantitative data pertaining to spring discharge are generally lacking. Although several of the springs are perennial and are the basis of private and public-supply systems, it is likely that others are formed by local perched ground-water bodies and cease flowing during dry periods. The withdrawal of ground water by wells is discussed later in this report.

Water-Level Fluctuations

The configuration of the water table is determined by (1) the hydraulic properties of the aquifer; (2) the distribution and temporal rates of recharge and discharge; and (3) the overall geometry of the ground-water system. Where recharge exceeds discharge, the quantity of water stored will increase and water levels will rise; where discharge exceeds recharge, the quantity of water stored will decrease and water levels will fall. Most of the annual recharge to Bainbridge Island occurs during the months of October through March, resulting in rising water levels during this period. Water levels generally fall during April through September. Water levels in shallow wells throughout western Washington generally follow the same pattern.

Along shorelines, water-level fluctuations also occur in response to tidal changes; these fluctuations are superimposed on the seasonal and long-term changes that are related to changing recharge-discharge relations. Water levels in deep wells generally respond much more slowly to recharge from precipitation than do water levels in shallow wells. In addition, the magnitude of fluctuation in deep wells is usually less than in shallow wells.

Water levels in observation wells on Bainbridge Island in 1985 (fig. 15) were generally at their highest in winter and early spring, and lowest in mid-summer (July through August). This pattern was most likely atypical in that the lowest water levels in a year of average precipitation would be expected to occur in September. The reasons for the pattern observed are probably that the months of May and June were wetter than normal (see fig. 3). Water-level measurements made in a year of more typical precipitation would presumably show a water-level fluctuation pattern more typical of western Washington.

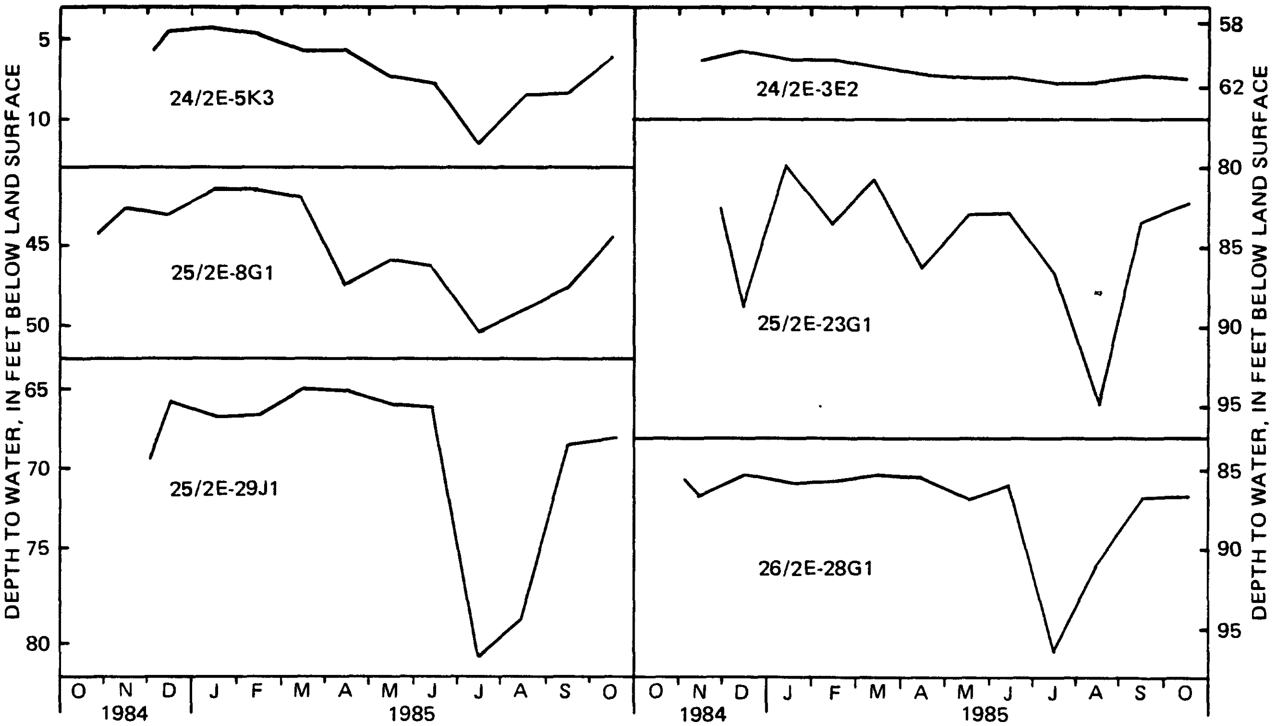


Figure 15.--Water levels in selected observation wells (see figure 5 for well locations).

Ground-water levels measured in mid-September were compared with those measured in mid-April to determine the direction and magnitude of seasonal water-level changes on Bainbridge Island. Of 147 paired measurements, water levels in 134 wells declined, 12 rose, and one remained unchanged. The changes ranged from a decline of 17.2 feet to a rise of 2.8 feet, and the mean net change in water level was a decline of 2.5 feet. No relation was found between individual water-level changes and well location or well depth.

The hydrographs of selected observation wells (fig. 15) indicate that water-level declines would have been far greater had the April measurements been compared to measurements made in July or August instead of September. Precipitation in July and August was significantly lower than the long-term average. Measurements made in future years will most likely show ground-water levels on Bainbridge Island to be lower in September than in July or August, as is typical of western Washington.

Although total precipitation from January to September of 1985 was below average, precipitation from mid-April to mid-September was actually 2.16 inches (29 percent) above average (fig. 3). Therefore, the 2.5-foot decline in ground-water levels observed over that period was most likely smaller than would be expected over a similar period of normal precipitation. All other factors being constant, the April-to-September change in water levels in a year of normal precipitation would be somewhat greater than the 2.5-foot decline observed in 1985.

Hydraulic Conductivity

The hydraulic conductivity of an aquifer is a measure of its ability to transmit water. For unconsolidated materials, hydraulic conductivity depends on the size, shape, and arrangement of the particles. It is necessary to know the hydraulic conductivity of an aquifer in order to calculate the drawdown that can be expected in a well under a given set of conditions. Although various methods of measuring the characteristic have been developed, most are difficult and time-consuming. Hydraulic conductivity can be estimated, however, using any of a number of mathematical techniques. For this study, hydraulic conductivity of the aquifer was determined by first calculating the value of transmissivity for the section of aquifer that the well is open to using specific-capacity data (Theis, 1963), and then dividing the resulting transmissivity value by the thickness of the open interval of the individual wells.

Specific capacity is the rate at which water is pumped from a well divided by the drawdown in water level caused by the pumping. The specific-capacity values used in calculating transmissivity (and hydraulic conductivity) were determined from drillers' records of well-yield tests, which are usually made upon completion of well drilling. In calculating specific capacity, care was taken to include only wells that were open to a single stratum of uniform lithology. In addition, only well-yield tests performed by pumping, as opposed to bailing, were included.

The hydraulic conductivity values determined using specific-capacity data from selected study wells are summarized by rock type and by geohydrologic unit in table 2. As shown in the table, hydraulic conductivity by rock type is largely determined by grain size; permeability is higher in the coarse-grained sediments than in the fine-grained. It should be noted that the results shown for the gravel unit may be biased by the sparcity of available control points.

Median hydraulic-conductivity values for units 3 and 5 were determined to be 41 and 14 ft/day (feet per day), respectively. Even though unit 4 is generally regarded as a fine-grained semiconfining layer, data from wells finished in coarse lenses within that formation indicate that the permeability of unit 4 (26 ft/day) is intermediate between that of the units above and below it. The value for unit 4, however, may not be typical of the unit as a whole.

TABLE 2.--Summary of hydraulic conductivity values for major rock types and geohydrologic units on Bainbridge Island

[Based on test pump data reported by well drillers.]

	Number of Tests	Hydraulic conductivity in feet per day		
		Range	Mean	Median
Rock type -				
- Fine sand	37	0.40 - 45	10	4.2
- Sand	49	.54 - 150	30	15
- Sand and gravel	52	3.6 - 310	61	38
- Gravel	4	13 - 1,160	480	800
Geohydrologic unit -				
- Unit 3	15	1.1 - 1,160	170	41
- Unit 4	34	1.5 - 310	40	26
- Unit 5	67	0.54 - 180	35	14

Well Yields and Drawdown

Well yield is determined in part by such well-construction factors as depth, diameter, and openings to the aquifer. Thus, wells can be designed and constructed in such a way as to maximize the expected yield from a particular aquifer. Well yield is also determined by the degree to which the water level in the well is lowered as a result of pumping.

When pumping of a well begins, the water level within the well drops from its static water level, the level of the undisturbed water table or potentiometric surface, to a pumping level. The difference between the static water level and the pumping water level is termed the "drawdown" (see fig. 16). The magnitude of the drawdown is dependent on the hydraulic conductivity of the aquifer and other factors.

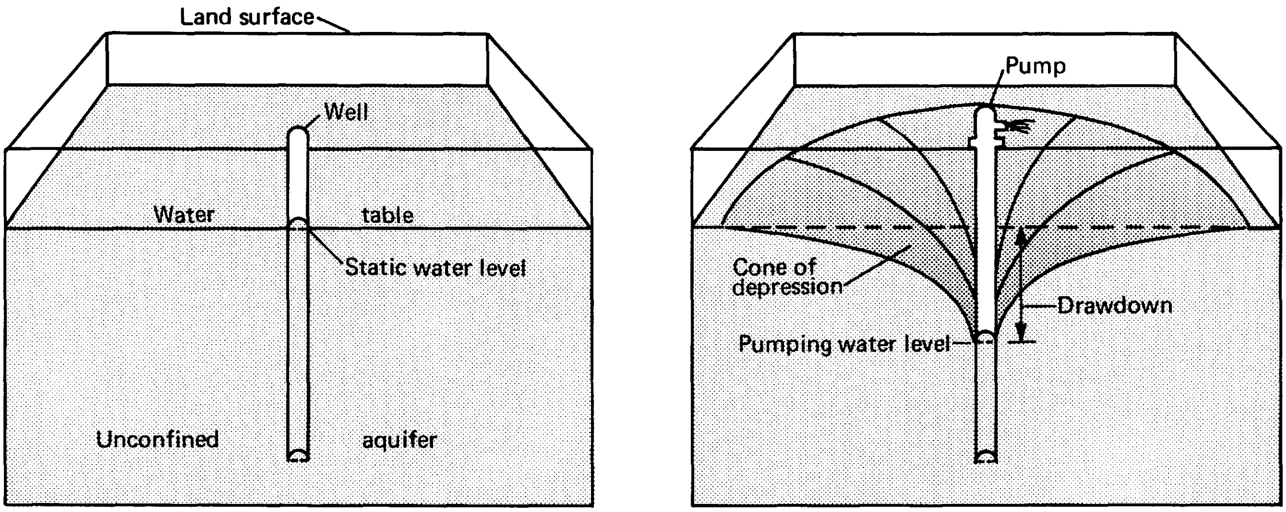


Figure 16.--Effects of pumping on configuration of water table.

The zone of water-level lowering around a pumping well takes the form of an inverted cone called the "cone of depression." The size and shape of the cone is determined by the hydraulic properties of the water-bearing materials, the quantity of water being pumped, and the duration of pumping. Water levels in non-pumping wells adjacent to a pumping well may be lowered because of the influence of the cone of depression surrounding the pumping well.

Most of the wells currently in use on Bainbridge Island yield small to moderate amounts of water that are generally sufficient for domestic purposes. According to drillers' reports, the test yields of 266 wells on the island are as follows:

Yield range (gallons per minute)		Wells in each category Number	Percent
0-5		40	15
6-10		79	30
11-20		98	37
21-50		37	14
greater than 50		12	4
	Total	266	100

The test yields in the foregoing table are presented without consideration of the testing method used (that is, pumping versus bailing), rock type, or test duration. As shown, 67 percent of the wells yielded 6 to 20 gal/min (gallons per minute). Most of the tests were conducted for no more than 4 hours; it is unlikely that the reported yields could be sustained indefinitely. In general, a yield of 10 gal/min is considered adequate for domestic purposes.

Water Use

Ground-water development on Bainbridge Island is dictated in large measure by land development and use. The principal land use on Bainbridge Island is residential; there is little industry and virtually no irrigation on the island. Hence, almost all water-use demands are generated by domestic and public-supply needs, which are met almost entirely with wells and, to a lesser extent, springs. Bainbridge Island residents are served by two large public-supply systems, Winslow and North Bainbridge, and approximately 105 smaller systems, more than half of which have fewer than six connections. Together, public-supply systems provided water to about 8,100 persons in 1984 (table 3), or about 61 percent of the island's population. The remaining 5,100 residents were served by privately owned wells.

TABLE 3.--Estimated ground-water withdrawals on Bainbridge Island, 1984

Use Category	Population Served	Percent of Population Served	Withdrawals (acre-feet)	Percent of Withdrawals
Public Supply				
Winslow	(4,500)	(34)	(410)	(33)
North Bainbridge	(2,600)	(20)	(240)	(20)
All others	(1,000)	(7)	(90)	(7)
Total	8,100	61	740	60
Domestic Supply	5,100	39	460	37
Industry	NA[1]	NA	35	3
Total	13,200	100	1,235	100

[1] NA = not applicable

The mainstay of the Winslow water system is a single deep well (25/2E-20L04) located near Fletcher Bay on the west side of the island; the well is capable of yielding 700 gal/min. This supply is augmented on demand by the output of several shallower wells located southwest of Winslow, near the head of Eagle Harbor. The North Bainbridge water system relies on three shallow wells and a spring.

Ground-water withdrawals for public-supply purposes were estimated by (1) totalling the withdrawals of the only public-supply system (Winslow) for which detailed, accurate records were kept in 1984, (2) determining the daily per capita rate of water usage by customers of the Winslow system, and (3) applying that rate, determined to be 81 gallons per person per day, to the population served by smaller water-supply companies that kept no records. For purposes of this study, a public water-supply system is defined as one that serves at least two homes, regardless of the number of wells or springs used to support that system. The ground-water withdrawal for domestic purposes was determined by multiplying the per capita public-supply rate by the number of residents served by privately owned wells.

Withdrawal values for the Winslow public-supply system include an undetermined amount of water that is used for commercial purposes, such as restaurants and laundries. This tends to raise the per capita rate above that which would be expected for domestic needs only. Nevertheless, the rate of 81 gallons per person per day agrees well with the results of previous investigations (for example, Dion and Lum, 1977).

A determination of ground-water withdrawals for industrial purposes was made by contacting all potential water-using industries on the island by telephone. Only two concerns use significant quantities of ground water in their processes. The wood-preserving plant at Eagledale is the largest industrial user of ground water on the island. An official of that company stated that the plant uses about 7.9 million gallons (about 24 acre-feet) of ground water per year from two deep, flowing wells for general plant needs, boiler and make-up water, fire fighting, and drinking. Water from the wells that exceeds the needs of the plant is sold to homeowners in the Rockaway Beach area for domestic use. An industrial concern near Beans Point uses about 2.2 million gallons (about 6.7 acre-feet) of ground water per year, which it buys from a local purveyor, for the preliminary processing of salmon. Further processing of the salmon takes place near Winslow, but the amount of ground water used is not monitored.

The total ground-water withdrawal on Bainbridge Island in 1984 was estimated to be 1,235 acre-feet (table 3). Of this amount, 60 percent (740 acre-feet) was withdrawn as public supply, 37 percent (460 acre-feet) was withdrawn for domestic purposes, and about 3 percent (35 acre-feet) was withdrawn for industrial purposes. Approximately 47 percent (348 acre-feet) of the public-supply water used in 1984 was withdrawn from a single deep well (25/2E-20L04) near Fletcher Bay. There is a marked seasonal variation in the withdrawal of water for public supply and domestic purposes. The greatest demand occurs in summer when temperatures are high, precipitation is at a minimum, and ground-water levels are relatively low.

GROUND-WATER QUALITY

The suitability of a water supply for a particular use is often dependent on the quality of the water. The effective management of water intended for domestic purposes, therefore, is enhanced by a knowledge of (1) the bacterial and chemical character of the water; (2) the relation of the water quality to current drinking-water criteria; and (3) areas where degradation of the water quality has occurred or is likely to occur in the future.

The quality of water in the ground-water system of Bainbridge Island was determined by studying the results of selected chemical and biological analyses of water samples collected in mid-April and mid-September 1985. The locations of the sampling sites are shown in figure 5 by type of analysis performed. The results of analyses of samples collected in September 1985 for specific conductance and chloride concentration only are included with the well data in table 8. The results of analyses of samples collected in April 1985 for specific conductance and concentrations of major ions and trace metals are shown in table 9.

The ground water on Bainbridge Island is of generally good quality and suitable for most purposes. With only a few exceptions, most water sampled in 1985 was within State drinking-water standards for the constituents selected for analysis.

General Character of Ground Water

The chemical character of water is illustrated by a trilinear diagram (fig. 17) which graphically depicts the major cations (positively charged particles) and anions (negatively charged particles) found in the water sample. The principal cations in ground water are usually calcium, magnesium, and sodium; the principal anions are sulfate, chloride, and bicarbonate (expressed as alkalinity in the analytical results of table 9).

Two triangles are used in the trilinear diagram--one for cations and one for anions--and all values are expressed as percentages of the principal ions in solution. Each vertex of the triangle represents 100 percent of a particular ion or combination of ions. Ions that are chemically similar, such as sodium and potassium, chloride and nitrate, and carbonate and bicarbonate, are combined for display purposes, even though one of the pair may be present in much higher concentration than the other. The composition of the water with respect to cations is indicated by a point plotted in the cation triangle, and the composition with respect to anions by a point in the anion triangle. The coordinates at each point within the triangle add up to 100 percent. The diamond plot depicts water quality with a single point for each sample by a projection of the points in the cation and anion triangles to an intersection in the diamond (for an example, see point "x" in figure 17).

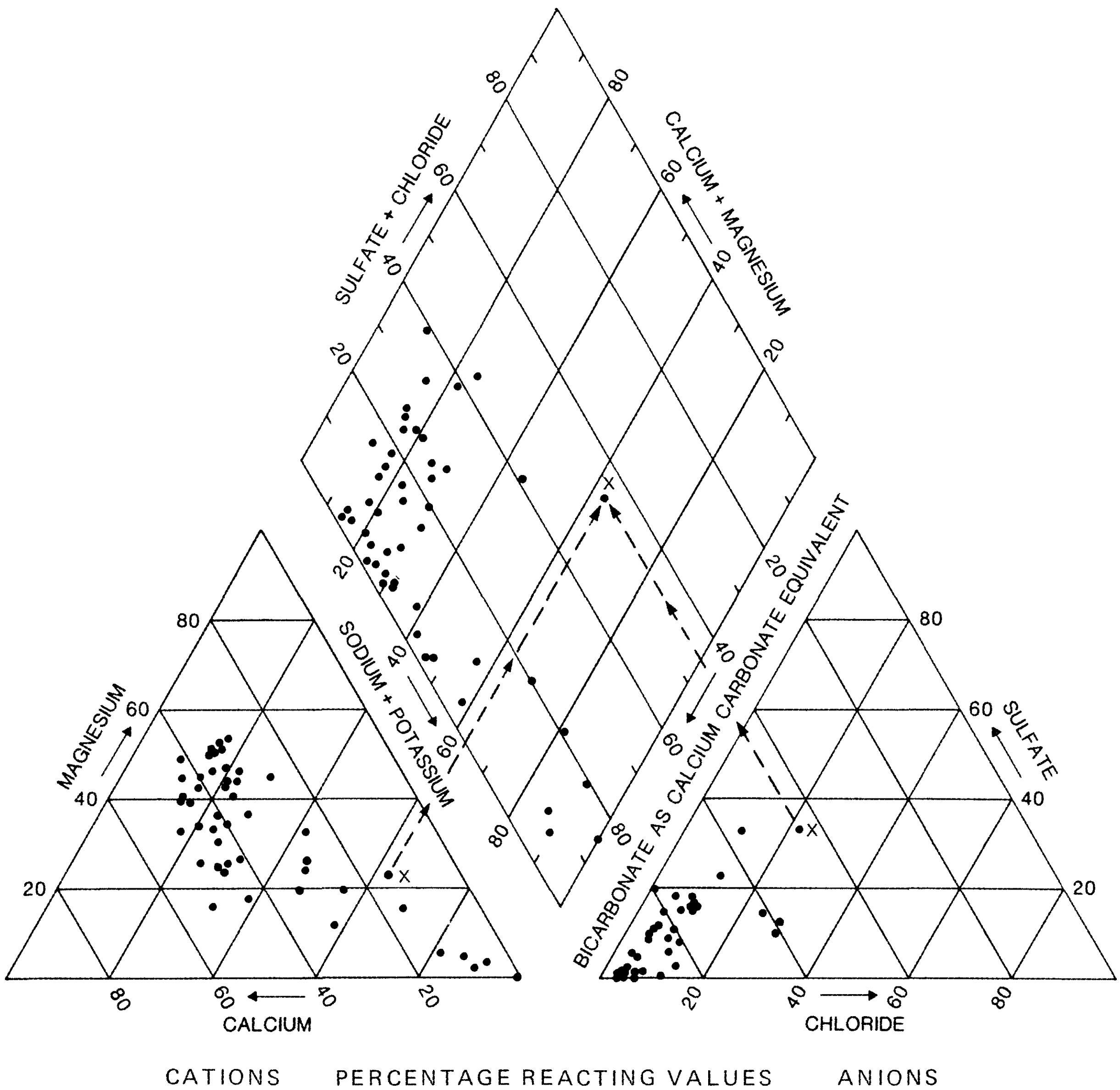


Figure 17.--Chemical character of water based on percentage of major ions.

Calcium and magnesium are the dominant cations in the ground water of Bainbridge Island, and bicarbonate (alkalinity) is the dominant anion. Of the 48 water samples analyzed in April 1985, 40 were of the calcium bicarbonate, magnesium bicarbonate, or calcium-magnesium bicarbonate type; the remaining eight were of the sodium bicarbonate type. The diversity in the chemical composition of the water is due to such factors as (1) the amount and chemical characteristics of the recharge water; (2) the pattern and velocity of ground-water movement; (3) the texture and mineral composition of the aquifer materials; and (4) the presence of contaminants. The only discernible pattern in the occurrence of ground-water types on Bainbridge Island is that six of the eight wells that yielded sodium bicarbonate water are located near the extreme southern end of the island. The reason for this pattern is most likely related to geology. Five of the six wells are finished at or near the contact of the consolidated bedrock and the overlying unconsolidated materials. Whiteman and others (1983) reported that sodium bicarbonate waters predominated in wells finished in bedrock in the San Juan Islands.

The "hardness" of water can be defined as its soap-consuming capacity. Suds will not be produced in a hard water until the minerals causing the hardness, chiefly calcium and magnesium, have been removed from the water by combining with the soap. The material that is removed by the soap forms an insoluble scum, such as the familiar ring on the bathtub. Some of the calcium and magnesium in hard water contributes to the incrustation that can develop when the water undergoes changes in temperature and pressure, such as in a water heater or hot-water pipe.

In general, Bainbridge Island ground water is classified as "moderately hard" according to the hardness classification proposed by Hem (1985, p. 159), which is reproduced below:

Hardness, as $CaCO_3$, in milligrams per liter	Degree of hardness	Wells in each category: Number	Wells in each category: Percentage
0-60	Soft	11	23
61-120	Moderately hard	32	67
121-180	Hard	5	10
>180	Very hard	0	0
	Total	48	100

The hardness values used in this report were calculated from calcium and magnesium concentrations, as described by Hem (1985, p. 158). Of the 48 samples analyzed, many of those classified as "soft" were of the sodium bicarbonate type. This would be expected because sodium does not contribute to hardness, and calcium and magnesium concentrations in these waters were very small.

The quality of ground water near the principal industrial concern of the island (the wood-preserving plant at Eagledale) and in the vicinity of an abandoned landfill (near the northwest quarter of section 33, T.25 N., R.2 E) was not different from the quality of ground water in other parts of the island for the constituents analyzed. The scope of this investigation, however, did not include testing for the organic chemicals typically associated with the preserving of wood products.

Suitability of Ground Water for Drinking

Standards have been established for many beneficial uses of water, but because the principal use of ground water on Bainbridge Island is for public supply and domestic purposes, drinking-water standards are used in this report for comparative purposes.

Some of the standards adopted by the Washington State Department of Social and Health Services (1978) for public water supplies are shown in table 4. Standards for bacteria, inorganic constituents, and physical properties are divided into primary and secondary categories. The primary constituents relate to human health, while the secondary constituents and properties relate to odor, appearance, and other esthetic qualities.

TABLE 4.--Median concentrations of selected constituents, and number of sampled wells that exceed the primary and secondary criteria for drinking water

[All concentrations expressed as milligrams per liter (dissolved), except for ug/L (micrograms per liter); number per 100 ml (milliliters)]

Constituent	Number of wells sampled	Median concentration	Water quality criterion[1]	Wells exceeding criterion: Number	Wells exceeding criterion: Percent
Primary					
Barium	9	0.015	1.0	0	0
Cadmium, ug/L	9	<1.0	10.	0	0
Fecal coliform bacteria, number per 100 ml	48	0[2]	1.	0	0
Fluoride	48	<0.1	2.0	0	0
Lead, ug/L	9	<10.	50.	0	0
Nitrate plus nitrite, as N[3]	48	<.10	10.	0	0
Secondary					
Chloride	209	4.3	250.	0	0
Copper	9	<.01	1.0	0	0
Dissolved solids[4]	48	142.	500.	0	0
Iron, ug/L	48	41.	300.	3	6
Manganese, ug/L	48	32.	50.	19	40
Sulfate	48	8.2	250.	0	0
Zinc	9	0.036	5.0	0	0

[1] From Washington State Department of Social and Health Services, 1978.

[2] Only one water sample contained fecal coliform bacteria.

[3] Analytical determination as nitrate plus nitrite; water-quality criterion as nitrate only.

[4] Residue on evaporation at 180° Celsius.

Because of the problems in detecting pathogenic (disease-producing) bacteria and viruses in water directly, normal intestinal bacteria are used as indicators of the degree of pollution by fecal wastes. If it can be shown that fecal contamination of the water has occurred, then it is assumed that pathogenic organisms may also be present.

The most commonly used indicators are fecal-coliform bacteria. As their name suggests, the primary source of fecal-coliform bacteria is the intestinal tract of warmblooded animals, including man. Their presence in ground water suggests strongly that the resource may have become contaminated by leachate from septic tanks, privies, landfills, farmland runoff, or feedlots. Soil can filter out many bacteria, but if a well is poorly sealed from the surface the ground water may not be adequately protected from bacterial contamination originating at or near land surface. In general, soil is ineffective in filtering out viruses.

Of the 48 ground-water sites sampled in April 1985, only one unused dug well (24/2E-14B02) tested positive for the presence of fecal-coliform bacteria, and the concentration in that well was only one colony per 100 ml. The almost total lack of detection of the bacteria suggests that, if the ground water is contaminated, the degree of contamination is not very severe. The possibility also exists that the one positive test result was spurious and that the well really is not contaminated.

Although in optimum concentrations fluoride reduces the incidence of tooth decay, especially in children, it can be of concern in high concentrations in water. At concentrations above 2 mg/L (milligrams per liter) the same element can cause the mottling and pitting of tooth enamel, and at concentrations above 4 mg/L it can cause changes in bone density. Concentrations in excess of 250 mg/L have been shown to be toxic to man (McNeeley and others, 1979). Fluoride concentrations in naturally occurring ground water are generally small, seldom exceeding 10 mg/L. Public water systems that artificially fluoridate their waters commonly maintain the concentration between 0.8 and 1.3 mg/L. Most ground-water samples analyzed as part of this study had fluoride concentrations below 0.1 mg/L. The largest concentration observed was 0.5 mg/L, and none exceeded the drinking-water criterion.

Nitrate is the principal form of combined nitrogen in natural waters because it is the most stable form. It is an important constituent in fertilizers and is present in relatively large concentrations in human and animal wastes. Because septic tanks, privies, landfills, and barnyards are rich sources of organic nitrogen that can readily oxidize to nitrate, large concentrations of nitrate in well water may indicate pollution from these sources.

The consumption of water high in nitrate decreases the ability of blood in infants to carry oxygen. Thus, the drinking-water criterion of 10 mg/L of nitrate nitrogen was established primarily to protect infants. As shown in table 4, the median nitrate concentration of waters from project wells was less than 0.10 mg/L. The largest concentration observed was 2.5 mg/L, and 33 wells out of 48 had concentrations below 0.10 mg/l. No water sample exceeded the drinking-water criterion, despite the fact that many of the 48 samples were collected from shallow wells in relatively dense residential areas served by septic tanks.

Chloride in ground water has many sources--sea spray in coastal areas, solution from soils and aquifer materials, seawater trapped in sediments at the time of deposition, contamination from numerous land-use activities, and seawater in contact with freshwater aquifers. As a result, chloride concentrations in ground water vary widely. Large concentrations of chloride increase the corrosiveness of water; seawater, which typically contains about 19,000 mg/L of chloride, is highly corrosive to metal. Large chloride concentrations also may adversely affect the use of water for food preparation or the irrigation of certain fruit crops and give water a salty taste. In addition, the sodium usually found in association with chloride may contribute to hypertension in some individuals.

The limits for the maximum concentration of chloride have been set largely by taste preferences. The criterion of 250 mg/L is the level at which most people can begin to detect a "salty" taste in water. The median concentration of chloride in 210 wells sampled in April 1985 was only 4.2 mg/L; concentrations at that time ranged from 1.9 to 35 mg/L and no sample exceeded the drinking-water criterion.

Dissolved-solids concentrations in ground water are an indicator of the degree of mineralization, or of the total amount of substances dissolved in the water. Large concentrations of dissolved solids limit the water as a desirable drinking source; the drinking-water criterion of 500 mg/L has been established largely with regard to taste rather than health effects. Industrial water users generally prefer that concentrations be less than 1,000 mg/L, but this requirement varies considerably among individual industries. Dissolved-solids concentrations were generally small throughout Bainbridge Island. Concentrations ranged from 62 to 365 mg/L and the median value was 142 mg/L. As shown in table 4, no dissolved-solids concentration exceeded the drinking-water criterion.

The specific-conductance value can be used to approximate dissolved-solids content. In natural waters, dissolved solids will vary from 55 to 75 percent of specific conductance (Hem, 1985, p. 67). On Bainbridge Island, the dissolved-solids concentration of ground water, in milligrams per liter, is approximately 64 percent of the specific-conductance value, in microsiemens per centimeter (μS/cm). Thus, a specific conductance of 250 μS/cm is approximately equal to 160 mg/L of dissolved solids. This relation is valuable because specific conductance is a much faster and less expensive measurement that can be completed in the field at the time of sampling.

Iron and manganese are derived naturally from the weathering of rocks and minerals. Even though manganese is much less abundant than iron in the Earth's crust, the two are similar in chemical behavior and are frequently found in association. The small oxygen concentrations commonly found in well water produce an environment that is favorable for the dissolution of both iron and manganese. Waters that are naturally colored are usually high in one or both elements.

High iron and manganese concentrations are objectionable in domestic waters because of taste, discoloration of clothes and porcelain plumbing fixtures, incrustation of well screens, and the formation of scale in pipes. These same elements are also objectionable in food processing, dyeing, bleaching, ice manufacturing, brewing, and certain other industrial processes (Heath, 1983). Iron in large concentrations produces a reddish-brown stain on porcelain and gives drinking water a bittersweet, astringent taste; manganese stains are dark brown or black and more difficult to remove than iron stains. Iron-bearing waters also encourage the growth of iron bacteria in wells and water pipes. These bacteria may eventually clog the pipes and reduce the flow rate. Frequently, the filamentous bacteria break loose in large clogging masses.

Ground water high in iron may be completely clear and colorless when first pumped from the well. Upon standing for a time, the dissolved iron is gradually oxidized by the atmosphere and the water sample becomes cloudy. Eventually, a rust-colored precipitate of iron oxide forms at the bottom of the container.

Three of the ground-water samples collected in April 1985 exceeded the drinking-water criterion for iron and 19 exceeded the criterion for manganese. There does not appear to be any pattern in the locations or depths of the wells from which these samples were taken. The largest iron and manganese concentrations observed, 1,300 and 460 μg/L (micrograms per liter), respectively, occurred in the same well (25/2E-29J01) in the southwestern part of the island. The island-wide median concentrations of iron and manganese, however, were 41 and 32 μg/L, respectively.

Sulfate is leached naturally from rocks, especially sedimentary rocks, but numerous industrial processes also can contribute significant amounts of sulfate directly to ground water. In addition, both wet and dry atmospheric deposition contain sulfate as a result of burning fossil fuels. Concentrations of sulfate above 250 mg/L may give water a bitter taste; in concentrations above 500 mg/L the water may have a laxative effect on humans. Livestock can usually drink water containing up to 1,000 mg/L of sulfate without adverse effects. In combination with calcium and magnesium, sulfate forms a hard scale in steam boilers.

Concentrations of sulfate in Bainbridge Island ground water were relatively low, ranging from 0.4 to 21 mg/L. The median concentration was 8.2 mg/L and no waters exceeded the drinking-water criterion.

Drinking-water standards have been established for those heavy (trace) metals known to be toxic to man. As part of this study, nine well-water samples were analyzed for the presence of barium, cadmium, copper, lead, and zinc. The median concentrations of those metals are given in table 4, and, as shown, none exceeded the drinking-water criteria.

WATER-QUALITY PROBLEMS

The vast majority of private well owners contacted during the course of this investigation had no complaints as to the quality of the ground water that satisfied their domestic needs. However, several owners complained of chronic staining of laundry and plumbing fixtures by water high in iron and manganese, and a smaller number of owners expressed concern about the "rotten-egg" smell of hydrogen sulfide gas in their water. Some owners remarked that the sulfide smell was perennial, while others contended it was noticeable only in certain seasons. Water-quality problems other than those discussed below, and which are related to constituents that were not studied, may exist.

Iron and Manganese

Even though many well waters exceeded the drinking-water criteria of the Washington State Department of Social and Health Services (1978) for iron and manganese, this is not a major water-quality problem on Bainbridge Island. The relatively large concentrations observed are most likely the result of natural causes such as the solution of iron-bearing minerals (Hem, 1985, p. 83), and to exceed these standards in the glacial drift of western Washington is common. In addition, the criteria exceeded pertain only to esthetics and not to human health. Both iron and manganese are among the most common elements in rocks and soil, and Hem (1985) points out that iron is usually more abundant in water than is manganese. In more than a third of the Bainbridge Island well samples analyzed in this study, however, manganese was more abundant than iron. Little is known about the exact source of the iron and manganese, or why so many of the water samples had manganese concentrations that were larger than the iron concentrations.

Numerous commercial water-treatment concerns provide equipment for decreasing iron and manganese concentrations in public and domestic water systems. The treatment usually involves oxidation by exposure to the atmosphere or to chemicals, and filtration to remove the resulting precipitate.

Seawater Intrusion

Wells in many coastal areas are in a fragile balance between rates of ground-water pumping that safely provide freshwater supplies, and increased pumping rates that might result in the intrusion of seawater into nearshore aquifers. Generally it is desirable to prevent or detect seawater intrusion. Excessive salts in drinking-water supplies produce unpalatable tastes and possible adverse physiological effects, are corrosive to plumbing, and may increase the cost of water treatment. Moreover, once seawater intrudes a coastal aquifer, it is difficult and expensive to control or reverse the condition. Because ground water moves slowly, remedial measures usually require several years to take effect.

Freshwater-Seawater Relations

In order for seawater intrusion to occur, the aquifers in coastal areas must be in hydraulic connection with the sea, and the hydraulic head of the fresh ground water must be decreased relative to that of seawater. Because the head reduction is usually an unnatural condition, intrusion is often the result of man-caused stresses, specifically pumping.

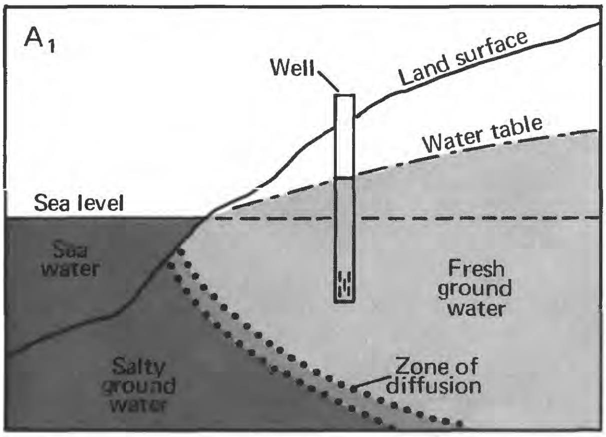
In about 1900, hydrologists working along coastal areas of Europe observed that seawater occurred beneath freshwater, not at sea level, but at a depth below sea level of about 40 times the height of the freshwater above sea level. The freshwater appeared to "float" on the seawater as a lens-shaped body (see fig. 7). This relation, known as the Ghyben-Herzberg principle after the two scientists who first described it, occurs because the density of freshwater (1.000) is slightly less than the density of seawater (1.025).

The Ghyben-Herzberg principle states that, at any particular location, for every 1 foot of altitude of the water table above sea level, fresh ground water will extend 40 feet below sea level. For example, if the water table at a given site is 3.0 feet above sea level, the freshwater-seawater interface is 120 feet below sea level. The thickness of the freshwater body is, therefore, 123 feet at that site. The principle also implies that if the water table in an aquifer is lowered 1 foot, the interface will rise 40 feet, thereby reducing the total thickness of the freshwater lens by 41 feet.

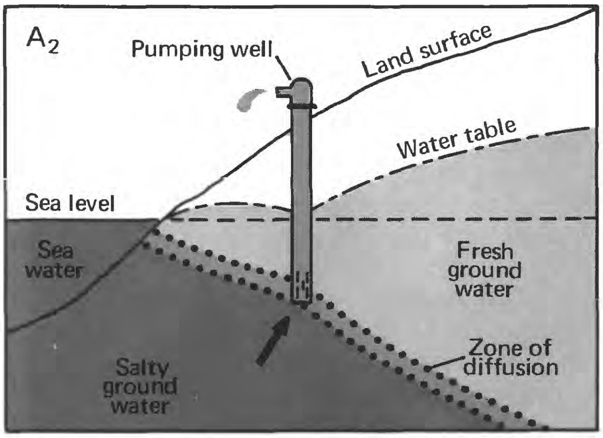
The waters of Puget Sound, however, are slightly more dilute and less dense than typical seawater (Wagner and others, 1957). Accordingly, the Ghyben-Herzberg principle, as it applies to Bainbridge Island, has to be modified in that fresh ground water will extend about 48 feet (instead of 40 feet) below sea level for every 1 foot of altitude of the water table above sea level.

In addition to the relative densities of freshwater and seawater, the position of the interface at any one time is also affected by tides, the seasonal position of the water table, the hydraulic characteristics of the aquifer, and recharge-discharge relations within the aquifer. Scientists have observed that the interface is seldom sharp, but rather a "zone of diffusion" in which the chloride concentration of the freshwater gradually increases with distance from the freshwater body until it reaches the salinity of the surrounding saline water body. This zone may be narrow or broad, depending on the hydraulic characteristics of the aquifer and other factors.

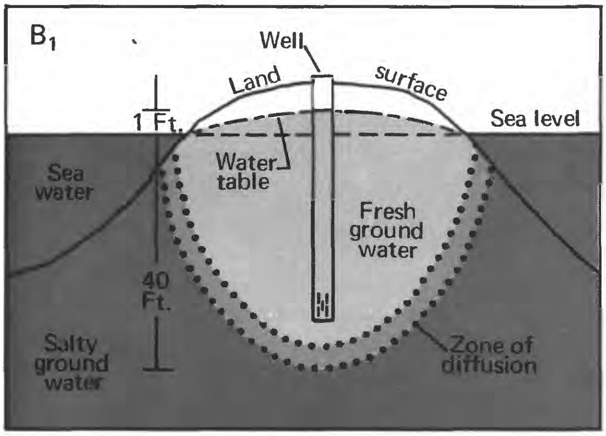
Under natural conditions, the altitude of the water table in a coastal area is higher than sea level and decreases toward the shoreline (fig. $18a_1$); if recharge and discharge are in equilibrium, the interface (zone of diffusion) is maintained in a relatively constant position. Freshwater under these conditions will move downgradient toward the sea and eventually, if not intercepted by pumping wells, discharge to low-lying coastal areas and to the sea. When the freshwater gradient is decreased or reversed, such as by pumping from wells (fig. $18a_2$), the seaward flow of freshwater is decreased and the interface begins to move landward and (or) upward. Conversely, when recharge is increased the interface moves seaward. Similar relations also apply beneath islands (fig. 18b).



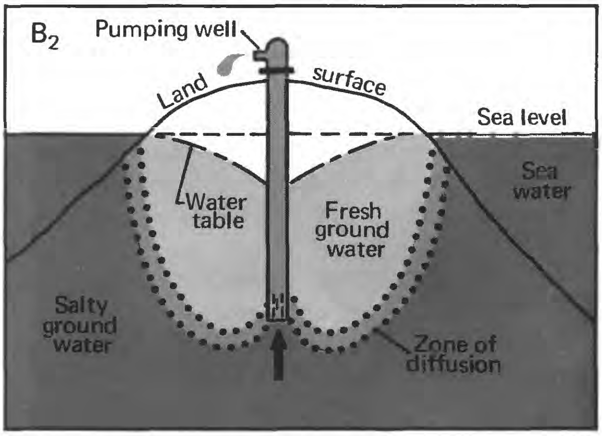
Well tapping an unconfined (water-table) aquifer under conditions of equilibrium--no intrusion has occurred.



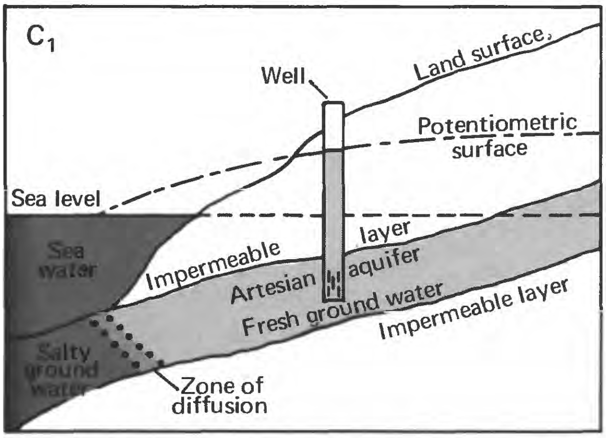
The same well under conditions of intensive pumping--intrusion has reached the well.



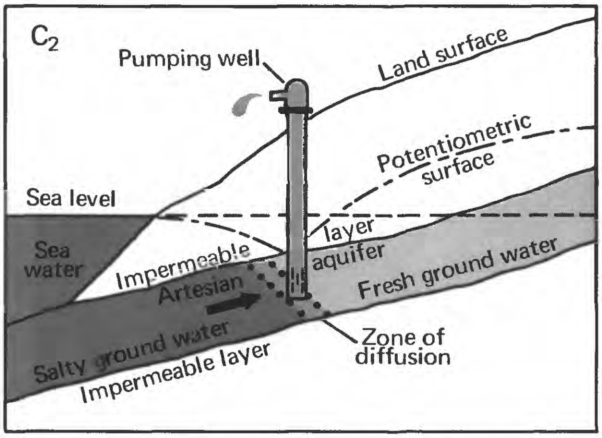
Well tapping an unconfined island aquifer under conditions of equilibrium--no intrusion has occurred.



The same well under conditions of intensive pumping--intrusion has reached the well.



Well tapping a confined (artesian) aquifer under conditions of equilibrium--no intrusion has occurred.



The same well under conditions of intensive pumping--intrusion has reached the well.

Figure 18.--Hypothetical hydrologic conditions before and after seawater intrusion.

As pointed out previously, the composition and configuration of geologic units beneath Bainbridge Island is complex and the units differ markedly in hydraulic properties. In addition, ground water is known to occur locally under artesian (confined) conditions. As shown in figure 18c, artesian aquifers can be intruded in much the same manner as unconfined aquifers. Because the position of the interface is a function of recharge, discharge, and the spatial variation of aquifer hydraulic characteristics, the Ghyben-Herzberg principle should only be used to provide an approximate position of the interface.

Criteria for Detecting Seawater Intrusion

The saline water surrounding Bainbridge Island typically contains approximately 15,000 mg/L of chloride (Wagner and others, 1957); uncontaminated ground water in most coastal areas of Washington generally contains less than 10 mg/L of chloride (Dion and Sumioka, 1984). Chloride is chemically stable and will move through the saturated zone of an aquifer at virtually the same rate as intruding seawater. For this reason, chloride serves as a good indicator of seawater intrusion. Chloride concentrations in excess of 10 mg/L, however, do not necessarily indicate seawater intrusion; higher concentrations or concentrations that increase over time may also be due to contamination introduced at or below ground surface, or to relict seawater in the aquifer.

Many occurrences of saline ground water in coastal areas are probably due to incomplete flushing of seawater from rock materials following the latest decline of sea level (Parker, 1955). At times during the Pleistocene (glacial) Epoch, sea level along the Washington coastline was higher than at present, and the interface between fresh and salty ground water was correspondingly higher. However, in situations where large chloride concentrations occur in deep coastal wells where water levels are at or below sea level, seawater intrusion is usually the cause.

For purposes of this investigation, two criteria were used as indicators of seawater intrusion: 1) water samples in which sodium and chloride are the dominant cation and anion, respectively; and 2) water samples having chloride concentrations in excess of estimated background levels.

The first determination could only be made for those 48 wells with complete cation and anion analyses. A study of the analytical results indicated that none of the 48 wells contained water of the sodium chloride type. In light of this fact, it was necessary to rely solely on the second criterion and to establish a limit for chloride concentration that effectively separated background from intruded (or contaminated) levels. Chloride concentrations in wells finished above sea level (and therefore immune to seawater intrusion) are usually less than 10 mg/L.

A conservative background level of 100 mg/L was chosen arbitrarily as the concentration above which seawater intrusion is indicated. The assumption was made that concentrations between 10 and 100 mg/L could more likely be the result of contamination from surface sources, the presence of relict seawater, sea spray, or causes other than true seawater intrusion (Dion and Sumioka, 1984).

Intrusion Conditions on Bainbridge Island

The most adverse conditions of seawater intrusion would normally be expected to occur in late summer or early autumn, when ground-water levels are at their seasonal lows and the freshwater-seawater interface is at its shallowest (most landward) position (fig. 19). In addition, as of mid-September 1985 the precipitation on Bainbridge Island for the previous 8.5 months was 40 percent below long-term (1951 to 1980) normal (fig. 3). Ground-water levels measured in September 1985 were probably below those for normal Septembers; therefore, chloride concentrations in wells finished below sea level were probably larger than in many previous Septembers.

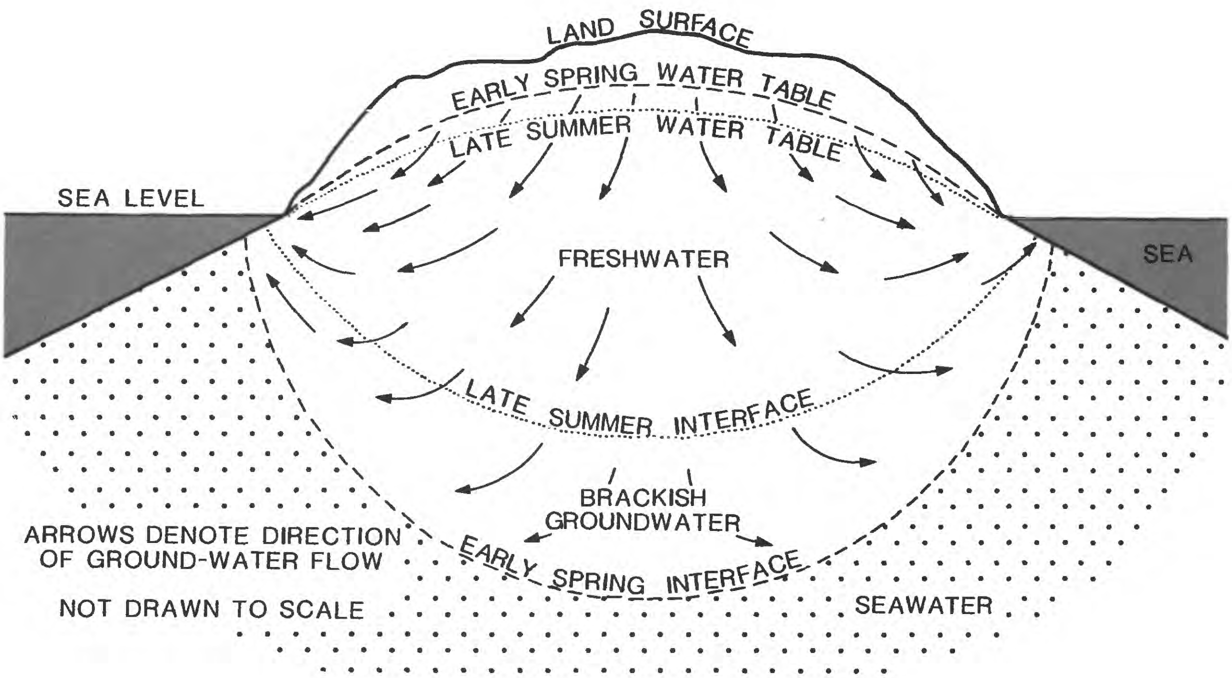


Figure 19.--Seasonal fluctuation of water table and freshwater-seawater interface in a homogeneous, unconfined island aquifer.

Despite these conditions and expectations, all 210 wells sampled in September 1985 had chloride concentrations of no more than 50 mg/L (table 8) and 95 percent had concentrations less than 11 mg/L (fig. 20). The largest concentration observed (50 mg/L) was from well 24/2E-14B02. This unused, dug well is situated near South Beach at the extreme southern tip of the island. Like well 25/2E-14P02 discussed earlier, the chloride concentration observed in September may have been temporary and influenced by tidal action. Indeed, the chloride concentration in well 24/2E-14B02 in April was only 16 mg/L. As shown in table 5, wells finished below sea level actually had smaller chloride concentrations in both April and September than wells finished above sea level, and the median concentration in all wells was unchanged from April to September. Had the average seasonal decline in water levels in 1985 been larger, as would be expected in a year of normal precipitation, chloride concentrations in September might have been somewhat larger. The amount of increase, however, would most likely be insignificant.

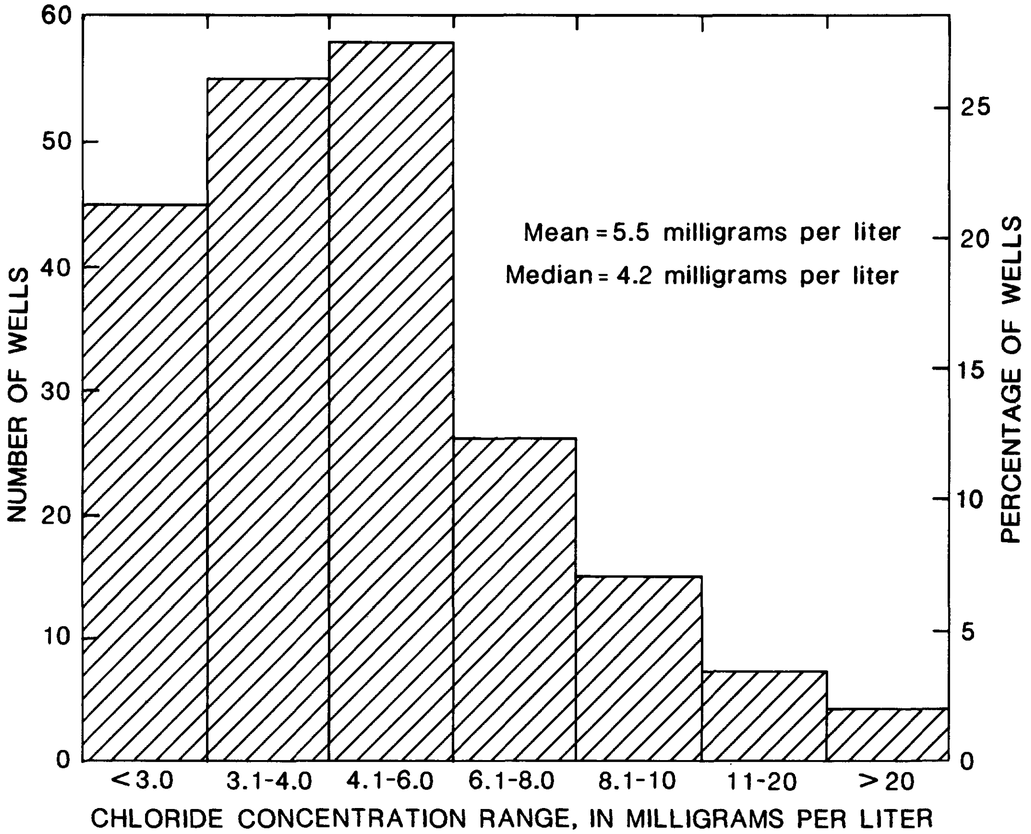


Figure 20.--Frequency distribution of chloride concentrations in Bainbridge Island ground water, September 1985.

TABLE 5.--Chloride concentrations in Bainbridge Island wells, April and September 1985

	APRIL 1985		SEPTEMBER 1985	
	Number of wells	Median Chloride Concentration, in milligrams per liter	Number of wells	Median Chloride Concentration, in milligrams per liter
Wells finished above sea level	98	4.5	97	4.5
Wells finished below sea level	112	3.8	113	3.8
All wells	210	4.2	210	4.2

Seasonal fluctuations in chloride concentrations were also determined by sampling 22 observation wells on a monthly basis from October 1984 to September 1985. The greatest fluctuation observed in a single well was 3.0 mg/L, in well 26/2E-34L01, and the mean fluctuation in all 22 wells was only 0.8 mg/L. Changes of this magnitude are considered insignificant. Well 26/2E-34L01 taps a horizon almost 1,000 feet below sea level.

Long-term changes in chloride concentration were assessed by comparing data collected in this study with data collected in studies completed in 1967 (Walters, 1971) and 1978 (Dion and Sumioka, 1984), as shown in table 6. With the exception of well 25/2E-14P02, concentrations do not appear to have changed substantially between 1967 and 1985. Well 25/2E-14P02 is situated near the shoreline of Murden Cove (see fig. 2), and the apparent increase in chloride in that well could be related to tidal fluctuations of seawater.

The results of studies on other islands (for example, Cline and others, 1982; Whiteman and others, 1983) suggest that, because of the physiography of the study area, seawater intrusion constitutes a potentially serious threat to the ground-water resources of Bainbridge Island. To detect the onset of seawater intrusion, should it develop, water levels and chloride concentrations could be monitored on a regular and continuing basis in an island-wide network of observation wells.

TABLE 6.--Seasonal and long-term changes in chloride concentration in selected wells

Well Number	Altitude Of Well Bottom[1]	Chloride concentration, in milligrams per liter			
		[2]May/June 1967	[3]August 1978	This study	
				April 1985	September 1985
24/2E-3M01	-50	6.0	9.4	6.8	6.2
25/2E-5H01	-17	6.5	6.8	7.4	---
-8G01	-98	6.5	5.3	6.5	6.3
-8N01	0	9.0	5.3	6.4	5.8
-8N04	-27	6.5	---	5.4	---
-9D01	-35	8.5	5.8	6.2	6.1
-14P02	+3	8.5	---	21.	22.
-17C01	-770	7.0	---	5.2	5.3
-18J01	-50	11.	9.9	9.6	7.9
-20B01	+5	---	3.3	4.0	4.0
-20G01	-1	6.5	---	4.4	4.6
-20L01	-6	5.5	---	6.1	4.8
-25C01	-14	10.	8.9	9.7	9.7
-26P01	-690	5.0	---	3.0	---
-27J01	+30	12.	11.	9.4	9.3
-27M01	-51	3.0	---	2.6	2.7
-33Q01	+5	6.5	7.6	5.5	5.4
-35H03	-680	7.0	---	4.7	4.9
-35K01	-18	7.0	5.6	7.5	7.8
-36N01	-584	18.	15.	16.	17.
26/2E-28N01	-50	---	27.	35.	33.
-32R01	-27	4.0	---	3.1	3.3
-33M01	-60	3.5	2.8	3.0	2.9
-34F01	-135	4.0	---	2.9	2.9
-34L01	-997	17.	15.	13.	14.
-34L04	-60	5.0	3.3	3.8	4.0

[1]in feet, with respect to sea level
[2]from Walters, 1971
[3]from Dion and Sumioka, 1984

NEED FOR OBSERVATION WELL NETWORK

Monitoring the ground-water conditions of Bainbridge Island could be accomplished by measuring water levels and chloride concentrations in selected observation wells completed both above and below sea level. An island-wide network of 38 such wells is presented in figure 21 and table 7. Water-level declines would provide an early warning of impending or incipient seawater intrusion, currently the most serious threat to the island's ground-water supply. Wells completed above sea level would be used to monitor background chloride levels, while wells finished below sea level would be used to monitor lateral and vertical shifts in the position of the freshwater-seawater interface. A gradual increase in chloride concentrations with time, or concentrations in excess of normal seasonal highs, would be interpreted as incipient intrusion.

As a long-term minimum level of effort, all 38 wells would be monitored every 2 to 3 years in spring and autumn, corresponding to times when water levels in shallow wells are at their seasonal highs and lows, respectively. As the ground-water fluctuation pattern beneath Bainbridge Island has not yet been adequately described, water-level measurements would be made in the proposed wells on a bimonthly basis for the first 2 to 3 years of the monitoring program, and water samples collected in April and September. If water-level measurements indicate that ground-water highs and lows occur at times other than April and September, the sampling schedule could be adjusted accordingly. Installations of continuous water-level recorders on a few unused wells would provide additional information and allow for greater accuracy. Once the seasonal water-level and chloride-concentration patterns have been determined, semi-annual monitoring would most likely be sufficient.

Even though many of the proposed wells in table 7 and figure 21 were used as short-term observation wells during this study, individual well owners may be unwilling to allow long-term access to their wells. If a proposed well should be unavailable, a similarly constructed well in the same general area could be substituted.

The proposed monitoring program could be reevaluated annually with respect to the number and locations of wells, and the frequency of their measurement and sampling. This evaluation would reflect changing cultural and hydrologic conditions. Modifications should be kept to a minimum, however, as the long-term success of a monitoring program is dependent in part on continuity. In selecting new or substitute observation wells, the following criteria need to be considered:

(a) location of the well
- Is it likely to be among the first affected by seawater intrusion?
- Is it in an area of extensive ground-water withdrawals?
- Is it in an area where water levels are near sea level?
- How close is the well intake to the freshwater-seawater interface?
- Is the well easily accessible?

(b) depth and construction of the well

Is the well completed above or below sea level?
To what horizon is the well open?
Is it open to a single horizon?
What is the nature of the openings?
Does the water level recover quickly after pumping has ceased?

(c) ease of measurement and sampling

Has the owner given his permission to measure and(or) sample the well?
Is access provided for water-level measuring equipment?
Is the well equipped with a pump to facilitate sampling?
Is water stored for long periods "upstream" of the sampling point, such as in a holding tank or cistern?

(d) use of well and its water

Is the well likely to be pumping for extended time periods and thereby unavailable for water-level measurement?
Is the well pumped often enough and long enough to provide a water sample representative of the aquifer?

(e) available data

Is a reliable driller's log of the well available?
Has the well been measured or sampled in the past?

TABLE 7.--Potential observation wells for long-term monitoring of water levels and chloride concentrations in ground water beneath Bainbridge Island

Well Number	Altitude	Depth	Intake[1]	Remarks[2]
	(in feet above or below sea level)			
24/2E-2C01	140	272	-119	P
-3E02	65	90	-25	P
-5K03	20	67	-43	P
-11G02	250	148	+179	L,P
25/2E-2D01	130	43	+91	P
-3N01	165	90	+80	L
-4D01	135	81	+61	
-8G01	50	148	-98	P
-9D01	25	60	-35	
-9P02	160	38	+127	
-10K01	140	302	-157	P
-11C01	220	22	+198	
-14G01	65	70	-5	
-14P02	15	12	+3	
-16P01	190	83	+112	P
-17C01	132	910	-770	P
-17G01	140	75	+71	
-20L04	93	1,030	-837	P,S
-20P02	110	134	-18	
-22C01	180	225	-40	P
-23E01	180	70	+116	
-23G01	100	397	+77	P
-25F02	125	160	-35	
-26P01	10	761	-690	S
-27E04	20	130	-100	S
-29J01	360	114	+251	P
-33B02	140	115	+32	
-35E02	70	133	-58	
-35H03	15	813	-680	P,S
-35M03	160	42	+118	
-36N01	20	604	-584	S
26/2E-28G01	90	190	-54	P
-28N01	50	105	-50	S
-33B02	175	52	+123	
-34G01	20	311	-264	P,S
-34L01	8	1,005	-997	P,S
-34Q01	70	523	-443	P,S
-35B01	20	155	-135	

[1]Top of well screen or perforations, or bottom of solid casing.
[2]L = Water level only.
P = Project observation well (1985).
S = Sample only.

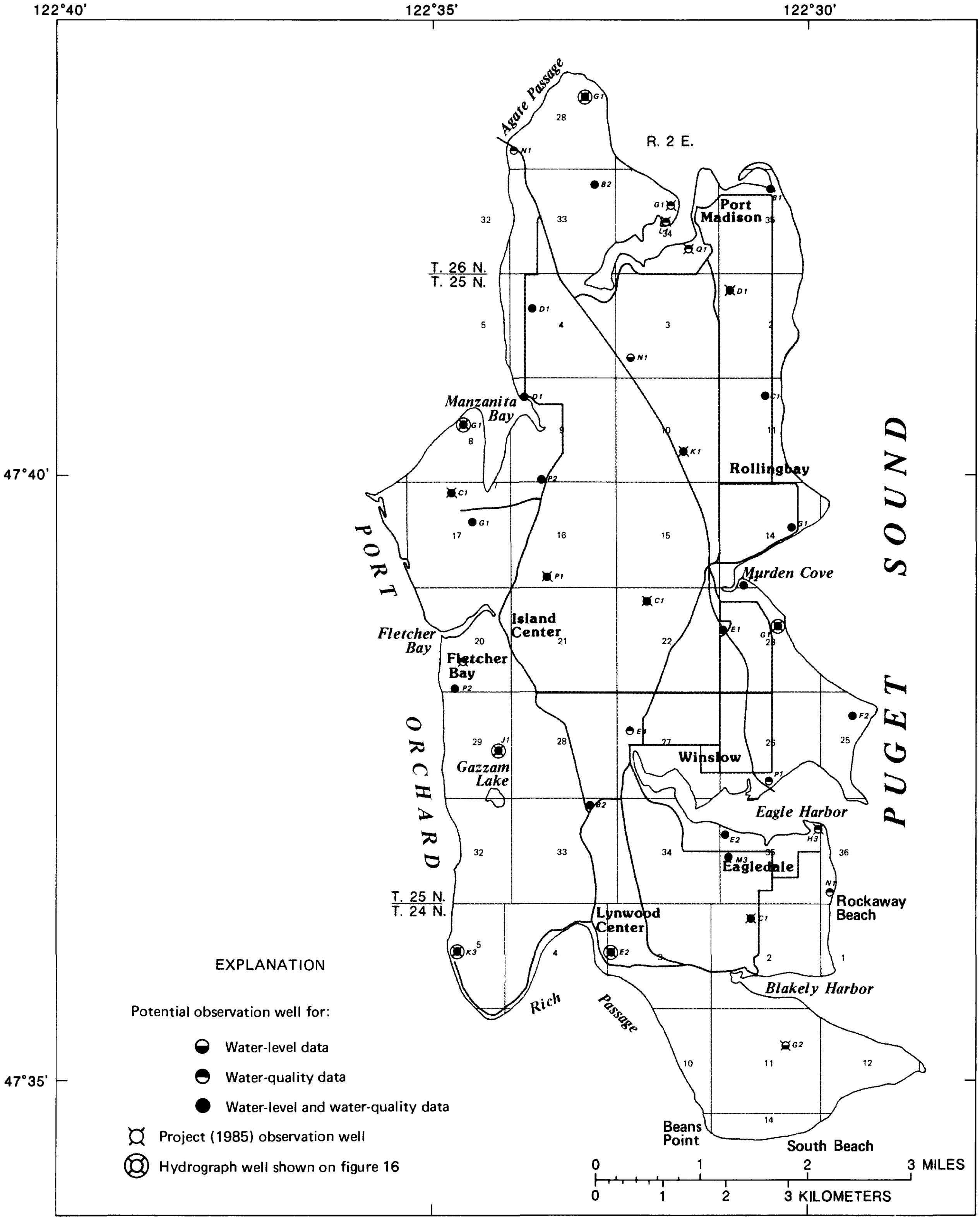


Figure 21.--Locations of potential observation wells (see page 3 for explanation of well-numbering system).

ADEQUACY OF EXISTING DATA

The geologic and hydrologic data now available are adequate to permit an assessment of the ground-water resources of Bainbridge Island, but only in a qualitative manner and only for the uppermost part of the thick unconsolidated deposits that underlie the island. As mentioned previously, only those deposits extending from land surface to about 200 feet below sea level have been described adequately.

Even though little is known about the lithologic or hydrologic characteristics of the remaining deposits, productive aquifers are known to occur within those deposits. Depending on the depth and extent of these and other aquifers, they could allow an expansion of ground-water development on Bainbridge Island. Also, it is likely that additional ground water is available for development in geohydrologic units described as part of this study, but the existing data do not permit a quantification of the amount available nor of the effects of pumping same on water levels, water quality, and the position of the freshwater-seawater interface. The position of the interface beneath Bainbridge Island under existing conditions has not been addressed. Production wells on the island are generally too shallow to have reached the freshwater-seawater interface, and any that may have reached it in the past have undoubtedly been abandoned because of the resulting water quality.

Existing data are not adequate to permit the calculation of a detailed water budget of Bainbridge Island. In order to do so, detailed, long-term data for the many facets of the hydrologic cycle on the island, such as precipitation, evaporation, transpiration, runoff, and infiltration would be needed.

The refinement, confirmation, and quantification of the preliminary concepts presented in this report would most likely require the construction of a mathematical model of the ground-water system. Many of the data required for such a model are currently unavailable. In particular, extensive and deep exploratory drilling would be needed to ascertain the hydrologic properties of stratigraphic units at depth and to delineate the position of the interface.

SUMMARY AND CONCLUSIONS

The major objectives of the study were to: (1) define the general lithology of the unconsolidated deposits of Bainbridge Island and the ground-water flow system within those deposits; (2) broadly define the present quality of ground water beneath the island; (3) identify areas and types of ground-water quality problems; (4) design a ground-water monitoring network; and (5) determine whether the ground-water resources of the island can be assessed adequately using existing data and data collected as part of this study and, if not, what additional data would be required to do so.

Bainbridge Island is underlain by as much as 1,600 feet of unconsolidated glacial and nonglacial deposits of Quaternary age. In general, the unconsolidated deposits are lithologically varied and most stratigraphic units have limited vertical and lateral extent. The vast majority of wells on the island, including those used to collect geologic and hydrologic data for this study, are completed in the uppermost 200 feet of the Quaternary deposits. This 200-foot sequence of deposits was divided into three permeable, water-bearing geohydrologic units (aquifers) and three semiconfining geohydrologic units.

On the basis of the depth distribution of producing wells on the island and the typical thicknesses of the geologic units, most domestic ground-water supplies are taken from the coarse-grained units 3 and 5. Neither aquifer is laterally continuous across the island. Water-level and water-quality data suggest that the units are hydraulically interconnected. Ground water occurs chiefly under water-table conditions in unit 3 and under semiconfined conditions in most of unit 5.

Recharge to the ground-water system occurs throughout most of the island, although recharge rates are undoubtedly higher where the less-permeable till (geohydrologic unit 2) is absent and more-permeable geologic units are exposed at land surface. These areas of potentially greater recharge are for the most part near the periphery of the island. Because the periphery is an area where ground-water discharge predominates, recharge in the periphery has a minimal effect on the amount of ground water in storage. Unit 3 is recharged chiefly by direct precipitation; unit 5 is recharged in part by precipitation and in part by leakage through the overlying unit 4, which acts as a semiconfining layer.

A comparison of water levels measured in April and in September 1985 indicates a mean seasonal decline of 2.5 feet during a period of greater-than-normal precipitation. The seasonal water-level decline would probably be greater in a more typical year.

Total ground-water withdrawal on the island in 1984 is estimated to be 1,235 acre-feet. Of this amount, 60 percent (740 acre-feet) was withdrawn as public supply, 37 percent (460 acre-feet) for domestic purposes, and about 3 percent (35 acre-feet) for industrial purposes.

Drillers' reports indicate that more than two-thirds of the study wells, as constructed, are capable of yielding from 6 to 20 gallons per minute. The median hydraulic conductivities of unit 3 and unit 5 are 41 and 14 ft/day, respectively; the hydraulic conductivity of the intervening unit 4, which generally serves as a semiconfining unit, is 26 ft/day.

Ground water on Bainbridge Island generally is suitable for most purposes. Most of the ground-water samples were classified as moderately hard, but were within State drinking-water standards. However, 3 of 48 samples exceeded the criterion for iron and 19 exceeded the criterion for manganese. The large concentrations observed are most likely the result of natural causes, and ground water that exceeds these standards is common in the glacial drift of western Washington. In addition, the criteria exceeded pertain only to esthetics and not to human health, hence the situation is not seen as a major water-quality problem.

Water samples for analysis of chloride concentration were collected in April, when ground-water levels are usually highest, and in September, when levels are usually lowest. Median chloride concentrations in September were essentially the same as in April, and wells finished below sea level contained water with slightly smaller chloride concentrations than water from wells finished above sea level. A comparison of chloride concentrations observed in 1985 with those observed in similar studies in 1967 and 1978 indicates that, of 26 wells, only one showed an increase in chloride concentration with time.

Because of the physiography of the study area, seawater intrusion constitutes a serious potential threat to the ground-water resources of Bainbridge Island. However, chloride concentrations in ground water are currently (1985) quite small and the concentrations change little seasonally. Seawater intrusion currently is not a problem on Bainbridge Island; ground-water development on the island to date has not been sufficient to induce the movement of seawater into the freshwater aquifers. Intrusion of seawater could occur in the future, however, if high-production wells were placed in areas where ground-water heads are low relative to sea level. In order to detect the onset of seawater intrusion, should it develop, a network of 38 potential observation wells could be used to monitor ground-water levels and chloride concentrations.

The data now available are adequate to permit an assessment of the ground-water resources of the island, but only in a qualitative manner and only for the uppermost part of the thick unconsolidated deposits. The data are inadequate to permit the calculation of a detailed water budget, to delineate the position of the freshwater-seawater interface, to determine the potential for additional ground-water development from known or unknown aquifers, or to assess the effects of such additional development. These questions could be addressed through the construction of a mathematical model of the ground-water system, which would require extensive deep exploratory drilling.

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Table 8.--Records of representative wells

[SURF ALT, surface altitude; CSG DIAM, casing diameter; CSG BTM, casing bottom; DATE MEAS, date measured; CHLR CONC, chloride concentration; SPEC COND, specific conductance; DATE SAMP, date sampled]

WELL-NUMBER	OWNER	WATER USE[1]	SURF ALT[2]	WELL DEPTH[3]	CSG DIAM[4]	CSG BTM[3]	WATER LEVEL[3]	DATE MEAS	CHLR CONC[5]	SPEC COND[6]	DATE SAMP	OTHER DATA[7]
24N/02E-01E01	WELD	U	40	30	36	--	7.40	04-16-85	7.8	325	04-16-85	--
							24.59	09-17-85	7.0	376	09-17-85	
24N/02E-02C01	NEWNHAM	H	140	272	6	261	75.81	04-17-85	3.0	298	04-17-85	D,I,O
							77.15	09-17-85	3.1	297	09-17-85	
24N/02E-02C02	FERGUSON	H	160	255	6	243	77.74	04-17-85	5.8	266	04-17-85	D
							117.58	09-17-85	6.1	277	09-17-85	
24N/02E-02K01	LUNDGREN	H	20	21	36	--	14.03	04-16-85	17.0	401	04-17-85	I
							17.53	09-17-85	9.3	312	09-17-85	
24N/02E-03C02	BAINBRIDGE SCH	T	275	286	5	286	164.71	04-15-85	--	--	--	D
							179.40	09-17-85	--	--	--	
24N/02E-03D01	FOSTER	H	150	159	6	154	126.25	04-16-85	--	--	--	D
							130.06	09-16-85	--	--	--	
24N/02E-03E02	BURKHOLDER	H	65	90	6	90	61.17	04-18-85	4.9	184	04-18-85	D,O
							61.20	09-17-85	5.2	197	09-17-85	
24N/02E-03F03	NICKUM	H	220	141	6	137	21.81	04-17-85	6.1	318	04-17-85	D
							32.78	09-17-85	6.7	318	09-16-85	
24N/02E-03G01	PT BLAKELY	P	270	750	6	750	--	--	4.8	260	04-17-85	D
							--	--	4.4	239	09-17-85	
24N/02E-03G02	KASPERSON	H	200	118	6	113	--	--	4.3	230	04-17-85	D,I
							72.28	12-05-84	4.5	235	09-16-85	
24N/02E-03M01	PRITCHARD	H	25	75	6	--	19.65	04-17-85	6.8	211	04-17-85	I
							22.28	09-17-85	6.2	257	09-17-85	
24N/02E-04A02	BLOSSOM CO	P	50	74	6	67	42.18	04-15-85	--	--	--	D
							43.32	09-16-85	--	--	--	
24N/02E-04A05	BLOSSOM CO	P	45	105	6	96	35.02	04-15-85	--	--	--	D
							41.94	09-16-85	4.7	287	09-16-85	
24N/02E-04A06	BLOSSOM CO	P	60	100	8	84	27.72	04-15-85	5.7	237	04-15-85	D
							31.22	09-16-85	5.7	226	09-16-85	
24N/02E-04A07	BLOSSOM CO	P	60	116	8	100	--	--	5.8	246	09-16-85	D
24N/02E-04N01	QUANRUD	H	130	142	6	136	--	--	3.5	248	04-18-85	D
							--	--	3.6	248	09-16-85	
24N/02E-05K01	SCHAGER	H	85	90	6	86	--	--	5.7	210	04-15-85	D
							59.99	09-16-85	6.5	220	09-16-85	
24N/02E-05K02	SCHAGER	U	105	320	6	320	99.50	04-15-85	--	--	--	D
							100.09	09-16-85	--	--	--	
24N/02E-05K03	STOWELL	H	20	67	6	63	5.79	04-15-85	4.2	210	04-15-85	D,I,O
							8.32	09-16-85	4.2	212	09-16-85	
24N/02E-05Q02	CONGER	H	110	201	6	198	57.82	04-18-85	10.0	354	04-18-85	D
							69.56	09-16-85	9.2	356	09-16-85	

Table 8.--Records of representative wells--continued

WELL-NUMBER	OWNER	WATER USE [1]	SURF ALT [2]	WELL DEPTH [3]	CSG DIAM [4]	CSG BTM [3]	WATER LEVEL [3]	DATE MEAS	CHLR CONC [5]	SPEC COND [6]	DATE SAMP	OTHER DATA [7]
24N/02E-05Q03	SOUTHWICK	H	60	77	6	71	29.70	04-18-85	6.1	147	04-16-85	D
							33.69	09-16-85	6.4	158	09-16-85	
24N/02E-10C01	MCGONAGLE	H	15	23	30	--	14.59	04-18-85	--	--	--	--
							12.73	09-17-85	20.0	399	09-17-85	
24N/02E-11G02	CARLSON	H	250	148	6	73	11.04	04-17-85	--	--	--	D,O
							23.56	09-16-85	--	--	--	
24N/02E-11G03	ODELL	H	250	109	6	99	--	--	5.7	428	04-18-85	D,I
							--	--	6.0	429	09-17-85	
24N/02E-11R01	COUNTRY CLUB	R	325	40	36	--	--	--	5.2	126	04-18-85	--
24N/02E-12N01	COUNTRY CLUB	R	275	40	36	--	--	--	6.0	162	04-18-85	--
24N/02E-14B02	BYRD	Z	20	22	36	--	2.72	04-15-85	16.0	234	04-15-85	I
							4.8	09-16-85	50.0	526	09-16-85	
25N/02E-02C02	BELLING	H	120	37	36	--	26.66	04-15-85	9.3	260	04-15-85	--
							28.62	09-16-85	9.0	265	09-16-85	
25N/02E-02D01	DEEBACH	H	130	43	6	39	29.56	04-15-85	5.5	250	04-15-85	D,M,O
							30.15	09-16-85	5.7	248	09-16-85	
25N/02E-02K01	BRAKENWOOD	Z	100	13	8	--	4.42	02-08-85	--	--	--	--
25N/02E-02K02	HOFFSTATER	H	40	52	6	--	--	--	2.9	274	04-17-85	I
							--	--	3.0	274	09-16-85	
25N/02E-03D01	HART	H	110	320	6	315	--	--	2.3	182	04-16-85	D
							--	--	2.6	185	09-16-85	
25N/02E-03G01	PEDERSON	H	220	139	6	136	121.82	04-16-85	6.0	223	04-16-85	D
							123.40	09-17-85	5.7	227	09-17-85	
25N/02E-03H01	PAINE	H	230	37	6	34	--	--	1.9	141	04-16-85	D
							--	--	1.8	142	09-17-85	
25N/02E-03N01	CLARKE	U	165	90	6	85	54.08	04-15-85	--	--	--	D
							54.08	04-15-85	--	--	--	
25N/02E-03Q01	ALMOJUELA	H	270	60	6	58	32.09	04-15-85	2.9	148	04-15-85	D
							41.80	09-17-85	3.8	168	09-17-85	
25N/02E-04B01	NORRIS	H	80	335	6	330	54.23	04-16-85	2.3	218	04-16-85	D,M
							55.48	09-16-85	2.4	219	09-16-85	
25N/02E-04C01	KOMEDAL	H	125	183	6	178	115.11	04-15-85	2.4	213	04-15-85	D
							115.84	09-16-85	2.5	214	09-16-85	
25N/02E-04D01	CHAMPENESS	H	135	81	6	74	45.40	04-16-85	6.8	222	04-16-85	D,I
							50.54	09-16-85	6.6	233	09-16-85	
25N/02E-04F01	NEWBERG	H	110	40	6	30	--	--	--	--	--	D
25N/02E-04G01	LAMPHERE	C	130	55	6	51	29.47	04-15-85	4.6	236	04-15-85	D
							31.64	09-16-85	5.1	232	09-16-85	
25N/02E-04G02	MACPHERSON	H	82	282	6	272	50.40	04-15-85	2.2	221	04-15-85	D
							52.44	09-16-85	2.4	225	09-16-85	

Table 8.--Records of representative wells--continued

WELL-NUMBER	OWNER	WATER USE[1]	SURF ALT[2]	WELL DEPTH[3]	CSG DIAM[4]	CSG BTM[3]	WATER LEVEL[3]	DATE MEAS	CHLR CONC[5]	SPEC COND[6]	DATE SAMP	OTHER DATA[7]
25N/02E-04M01	SWINBURNE	H	80	163	6	153	28.23	04-15-85	12.0	198	04-15-85	D
							33.22	09-16-85	11.0	202	09-16-85	
25N/02E-05A01	FAIRBANK	H	80	158	6	153	--	--	6.9	213	04-15-85	D
							--	--	3.3	199	09-16-85	
25N/02E-05H01	BERG	H	70	98	6	87	30.10	04-16-85	7.4	206	04-16-85	D,I,O
25N/02E-05H02	BERG	H	70	136	6	--	36.49	09-16-85	3.8	153	09-16-85	D,O
25N/02E-05J01	MYERS	H	80	113	6	108	--	--	8.2	205	04-15-85	D
							--	--	8.4	210	09-16-85	
25N/02E-05J02	HALL	H	70	114	6	109	52.91	04-15-85	10.0	220	04-17-85	D
							55.00	09-16-85	9.4	221	09-16-85	
25N/02E-08G01	DALY	H	50	148	8	--	47.25	04-15-85	6.5	255	04-15-85	D,I,O
							47.32	09-17-85	6.3	258	09-17-85	
25N/02E-08L01	KLOVEN	H	90	100	6	85	50.72	04-15-85	2.9	294	04-15-85	D
							51.70	09-17-85	3.1	304	09-17-85	
25N/02E-08L02	BENEDETTI	P	90	131	6	126	57.10	04-15-85	--	--	--	D
							57.35	09-17-85	--	--	--	
25N/02E-08L03	ROSENBAUM	H	70	200	6	190	--	--	4.6	288	04-15-85	D
							--	--	4.7	291	09-17-85	
25N/02E-08N01	LOWREY	H	80	80	6	--	64.33	04-16-85	6.4	304	04-16-85	D,I
							64.37	09-17-85	5.8	302	09-17-85	
25N/02E-08N04	PLUMMER	H	20	52	6	47	13.21	04-15-85	5.4	264	04-15-85	D
							14.07	09-17-85	--	--	--	
25N/02E-08P01	PEABODY	H	105	227	6	222	66.95	04-15-85	3.8	246	04-15-85	D
							66.13	09-17-85	3.6	247	09-17-85	
25N/02E-08Q03	TAYLOR	H	120	348	6	340	74.25	04-15-85	3.0	246	04-15-85	D
							72.70	09-17-85	3.0	253	09-17-85	
25N/02E-09A01	JAMES-WOLF	C	120	79	6	69	--	--	6.6	304	04-17-85	D
							36.47	09-17-85	7.5	322	09-17-85	
25N/02E-09C01	SMITH	H	50	67	6	62	1.38	04-15-85	11.0	190	04-16-85	D
							14.61	09-17-85	9.7	193	09-17-85	
25N/02E-09C02	TANGE	H	40	30	6	30	5.18	04-17-85	4.3	170	04-17-85	D
							9.04	09-17-85	--	--	--	
25N/02E-09D01	WOOLDRIDGE	H	25	60	5	--	14.00	04-16-85	6.2	228	04-16-85	D,I
							15.28	09-17-85	6.1	231	09-17-85	
25N/02E-09E02	OLYMPIC TERR	P	100	116	6	116	94.83	04-17-85	7.0	271	04-17-85	D
							--	--	8.1	296	09-17-85	
25N/02E-09G02	RODAL	P	110	118	8	103	--	--	10.0	230	04-16-85	D
							8.97	09-17-85	10.0	282	09-17-85	

Table 8.--Records of representative wells--continued

WELL-NUMBER	OWNER	WATER USE[1]	SURF ALT[2]	WELL DEPTH[3]	CSG DIAM[4]	CSG BTM[3]	WATER LEVEL[3]	DATE MEAS	CHLR CONC[5]	SPEC COND[6]	DATE SAMP	OTHER DATA[7]
25N/02E-09P01	GARCIA	H	140	30	6	25	10.47	04-16-85	--	--	--	D
							16.47	09-17-85	--	--	--	
25N/02E-09P02	TABAFUNDA	H	160	38	6	33	18.12	04-16-85	27.0	298	04-16-85	D,I
							24.12	09-17-85	24.0	293	09-17-85	
25N/02E-09Q01	HAYASHIDA	H	240	202	6	191	154.80	04-17-85	3.7	217	04-17-85	D
							156.25	09-17-85	3.9	225	09-17-85	
25N/02E-09R01	KOURA	U	260	160	8	--	155.75	04-17-85	--	--	--	D
							155.97	09-17-85	--	--	--	
25N/02E-10F01	CORPUZ	H	120	15	36	--	6.76	04-17-85	11.0	226	04-17-85	--
							7.50	09-17-85	9.4	226	09-17-85	
25N/02E-10K01	WHITNEY	H	140	302	6	297	96.35	04-17-85	2.9	232	04-17-85	D,I,O
							97.72	09-17-85	3.0	239	09-17-85	
25N/02E-10L01	CORPUZ	H	90	10	36	10	4.51	04-17-85	3.2	165	04-17-85	--
							--	--	3.3	178	09-17-85	
25N/02E-11C01	MIKKOLA	H	220	22	48	--	11.89	09-17-85	8.9	189	09-17-85	--
25N/02E-11E01	AQUINO	H	270	60	6	55	--	--	3.2	170	04-17-85	D
							43.74	09-17-85	3.0	169	09-17-85	
25N/02E-11F01	LOWELL	U	200	45	8	--	-0.25	04-17-85	--	--	--	--
25N/02E-11N02	LOUY	U	220	12	36	12	2.05	04-17-85	--	--	--	--
							5.95	09-71-85	--	--	--	
25N/02E-14A02	MSNGR HOUSE	H	98	230	8	--	119.13	10-25-84	--	--	--	D
25N/02E-14D02	WILSON	I	200	40	48	--	30.46	04-17-85	--	--	--	--
							35.88	09-17-85	--	--	--	
25N/02E-14G01	SNIDOW	H	65	70	6	--	33.33	04-15-85	4.5	171	04-15-85	I
							33.62	09-16-85	4.6	179	09-16-85	
25N/02E-14P02	CHIVERS	H	15	12	72	--	10.13	04-15-85	21.0	268	04-15-85	D,I
							10.62	09-16-85	22.0	260	09-16-85	
25N/02E-15H01	PIEHL	H	60	37	6	32	11.28	04-18-85	5.3	164	04-18-85	D
							14.04	09-16-85	7.1	205	09-16-85	
25N/02E-15K01	HERMANSON	H	50	116	6	111	12.20	04-15-85	2.2	182	04-15-85	D,M
							13.77	09-17-85	2.3	185	09-17-85	
25N/02E-15N01	GROVES	H	190	61	6	57	22.03	04-17-85	2.2	150	04-17-85	D
							22.57	09-17-85	2.4	154	09-17-85	
25N/02E-15P01	BUCKLEY	H	160	183	6	178	118.54	04-15-85	2.3	173	04-15-85	D
							119.05	09-17-85	2.3	177	09-17-85	
25N/02E-15Q01	EASON	H	70	123	6	119	44.24	04-15-85	2.4	192	04-15-85	D
							45.74	09-17-85	2.5	204	09-17-85	
25N/02E-15R01	WATTS	H	125	204	6	200	101.86	04-15-85	4.3	174	04-15-85	D
							107.27	09-17-85	4.4	180	09-17-85	
25N/02E-16A01	MEADOWMEER	R	240	171	8	151	116.43	04-18-85	3.7	212	04-18-85	D
							--	--	3.6	209	09-16-85	

Table 8.--Records of representative wells--continued

WELL-NUMBER	OWNER	WATER USE [1]	SURF ALT [2]	WELL DEPTH [3]	CSG DIAM [4]	CSG BTM [3]	WATER LEVEL [3]	DATE MEAS	CHLR CONC [5]	SPEC COND [6]	DATE SAMP	OTHER DATA [7]
25N/02E-16D01	BALLOU	H	170	91	6	86	--	--	4.7	138	04-16-85	D
							--	--	4.6	140	09-17-85	
25N/02E-16P01	JULIAN	H	190	83	6	78	51.17	04-17-85	6.5	196	04-17-85	D,M,O
							52.27	09-16-85	6.3	198	09-16-85	
25N/02E-16Q01	HEDDERLY-SMITH	H	315	236	6	232	48.50	04-15-85	2.9	148	04-15-85	D
							56.29	09-17-85	2.8	151	09-17-85	
25N/02E-17B01	COULTER	H	50	50	6	41	9.24	04-16-85	4.1	223	04-16-85	D
							11.25	09-16-85	4.2	226	09-16-85	
25N/02E-17C01	BATTLE PT PARK	I	132	910	6	930	101.54	04-16-85	5.2	224	04-16-85	D,I,O
							104.89	09-16-85	5.3	226	09-16-85	
25N/02E-17D01	SLATER	H	60	78	6	73	--	--	4.9	120	04-18-85	D
							55.59	11-28-84	4.9	127	09-16-85	
25N/02E-17E01	DEPEE	H	80	190	6	185	64.24	04-18-85	5.9	373	04-18-85	D
							100.34	09-16-85	6.0	375	09-16-85	
25N/02E-17E02	BROWN	H	95	148	6	143	87.02	04-18-85	3.5	221	04-18-85	D
							87.43	09-16-85	3.6	227	09-16-85	
25N/02E-17G01	RUSSELL	H	140	75	6	69	55.27	04-16-85	--	--	--	D
							58.71	09-17-85	2.8	151	09-17-85	
25N/02E-17G02	SPANGLER	H	145	83	6	83	--	--	--	--	--	D
25N/02E-17H01	RESSLER	H	70	50	6	46	--	--	3.5	158	04-16-85	D
							--	--	3.4	156	09-16-85	
25N/02E-17K01	LIUPAKKA	H	100	60	6	55	34.69	04-18-85	4.0	182	04-18-85	D
							38.32	09-16-85	4.7	186	09-16-85	
25N/02E-17L01	ANDERSON	H	150	80	6	76	56.73	09-17-85	5.7	212	09-17-85	D
25N/02E-17M01	BENNETT	H	35	59	6	54	18.12	04-17-85	--	--	--	D
							20.83	09-16-85	--	--	--	
25N/02E-17M02	JENSEN	H	30	80	6	--	--	--	9.6	255	04-18-85	D,M
							8.47	09-16-85	7.9	239	09-16-85	
25N/02E-17N01	BACKLAND	P	40	76	6	70	36.81	04-17-85	3.4	215	04-17-85	D
							37.63	09-16-85	3.7	220	09-16-85	
25N/02E-17R01	OKERMAN	P	75	100	6	96	--	--	3.0	179	04-17-85	D
							--	--	3.1	182	09-16-85	
25N/02E-20B01	WRIGHT	H	80	80	6	75	46.34	04-18-85	4.0	184	04-18-85	D
							47.06	09-16-85	4.0	187	09-16-85	
25N/02E-20C01	COMIN	H	130	152	6	147	--	--	4.1	192	04-18-85	D
							121.76	12-14-84	4.2	196	09-17-85	
25N/02E-20D02	KRAMER	H	110	134	6	128	109.95	04-18-85	2.3	200	04-18-85	D
							110.03	09-16-85	2.3	201	09-16-85	
25N/02E-20D03	HOUGHTEN	H	120	131	6	125	106.41	04-18-85	2.4	170	04-18-85	D
							107.07	09-16-85	2.4	173	09-16-85	
25N/02E-20F03	BARNETT	P	50	85	6	70	--	--	3.6	200	04-18-85	D
							--	--	3.7	199	09-16-85	

Table 8.--Records of representative wells--continued

WELL-NUMBER	OWNER	WATER USE[1]	SURF ALT[2]	WELL DEPTH[3]	CSG DIAM[4]	CSG BTM[3]	WATER LEVEL[3]	DATE MEAS	CHLR CONC[5]	SPEC COND[6]	DATE SAMP	OTHER DATA[7]
25N/02E-20F04	EPSTEIN	H	50	72	6	67	--	--	4.0	210	04-18-85	D
							--	--	4.1	214	09-16-85	
25N/02E-20G01	COCHRANE	H	45	46	6	--	35.69	04-18-85	4.4	246	04-18-85	D
							--	--	4.6	255	09-16-85	
25N/02E-20H01	COBLE	H	25	52	6	47	6.70	04-18-85	2.7	152	04-18-85	D
							10.17	09-16-85	2.7	153	09-16-85	
25N/02E-20J01	LOVERICH	H	90	106	6	101	68.25	04-17-85	7.8	293	04-17-85	D
							70.75	09-16-85	7.1	272	09-16-85	
25N/02E-20L01	HOOVER	H	40	46	6	--	38.50	04-17-85	6.1	286	04-17-85	D,I,O
							35.82	09-16-85	4.8	279	09-16-85	
25N/02E-20L04	KITSAP PUD	P	93	1030	24	930	--	--	3.6	206	04-17-85	D,I,O
							--	--	3.7	208	09-17-85	
25N/02E-20P01	LARSON	H	130	151	6	151	120.15	04-17-85	5.1	210	04-17-85	D
							122.80	09-16-85	4.6	215	09-16-85	
25N/02E-20P02	LARSON	H	210	139	6	134	123.53	04-17-85	3.4	138	04-17-85	D
							125.63	09-16-85	3.2	138	09-16-85	
25N/02E-20Q01	LUBOWICKI	H	200	138	6	135	118.06	04-17-85	3.2	135	04-17-85	D
							121.53	09-16-85	3.2	141	09-16-85	
25N/02E-21C01	SAVAGE	H	160	66	6	61	43.09	04-15-85	6.3	138	04-15-85	D
							44.55	09-16-85	6.0	170	09-16-85	
25N/02E-21D01	SUTHERLAND	H	80	55	6	50	--	--	5.4	156	04-15-85	D
							--	--	5.2	159	09-16-85	
25N/02E-21E01	NELSEN	H	135	86	6	86	48.35	04-15-85	7.3	161	04-15-85	D
							57.19	09-16-85	6.9	163	09-16-85	
25N/02E-21G01	MOLDSTAD	H	280	168	6	168	149.74	04-15-85	5.9	213	04-15-85	D,O
							151.09	09-16-85	5.3	207	09-16-85	
25N/02E-21G03	KITSAP PUD	U	295	402	8	383	195.54	04-15-85	--	--	--	D
							197.00	09-16-85	--	--	--	
25N/02E-21H01	KEMBALL	H	250	169	6	164	126.36	04-15-85	3.9	209	04-15-85	D
							130.70	09-16-85	4.0	209	09-16-85	
25N/02E-21J01	PILLER	H	180	98	6	93	--	--	3.0	132	04-15-85	D
							--	--	3.2	137	09-16-85	
25N/02E-21K01	ALLEN	H	255	193	6	188	138.86	04-15-85	7.8	179	04-15-84	D
							136.07	09-16-85	7.6	183	09-16-85	
25N/02E-21N01	DOSONO	H	90	153	6	149	--	--	2.3	162	04-15-85	D
							--	--	2.3	165	09-16-85	
25N/02E-21P01	GREGG	H	150	98	6	93	35.14	04-15-85	5.3	163	04-15-85	D
							37.08	09-16-85	5.1	166	09-16-85	
25N/02E-21Q03	LIPKIN	H	140	97	6	93	--	--	--	--	--	D
25N/02E-22A01	COLEMAN	H	160	93	6	--	72.41	04-15-85	4.4	194	04-15-85	--
							74.19	09-16-85	4.4	196	09-16-85	

Table 8.--Records of representative wells--continued

WELL-NUMBER	OWNER	WATER USE[1]	SURF ALT[2]	WELL DEPTH[3]	CSG DIAM[4]	CSG BTM[3]	WATER LEVEL[3]	DATE MEAS	CHLR CONC[5]	SPEC COND[6]	DATE SAMP	OTHER DATA[7]
25N/02E-22C01	BERG	H	180	225	6	220	94.41	04-16-85	2.3	185	04-16-85	D,I,O
							94.49	09-17-85	2.5	187	09-17-85	
25N/02E-22E01	OTTO	H	190	100	6	90	--	--	2.8	148	04-15-85	D
							--	--	2.7	155	09-16-85	
25N/02E-22N01	RUTTEN	H	180	72	6	67	45.13	04-15-85	3.6	99	04-15-85	D,I
							47.36	09-16-85	3.8	103	09-16-85	
25N/02E-22P01	PUTMAN	H	220	118	6	113	89.30	04-16-85	--	--	--	D
							93.56	09-17-85	6.8	233	09-17-85	
25N/02E-22R02	BAINBRIDGE SCH	T	250	264	12	191	--	--	2.4	185	04-15-85	D
							--	--	2.5	197	09-16-85	
25N/02E-23B02	FRIEDRICK	H	100	241	6	235	--	--	--	--	--	D
25N/02E-23C01	IHRIG	H	135	40	8	40	20.19	04-16-85	4.5	194	04-16-85	D
							25.00	09-16-85	4.2	107	09-16-85	
25N/02E-23D01	BLAKEY	H	60	180	6	176	--	--	2.9	159	04-16-85	D
							--	--	3.0	161	09-16-85	
25N/02E-23D02	TRICK	H	65	40	6	30	2.12	04-17-85	3.4	104	04-17-85	D
							5.15	09-16-85	3.8	188	09-16-85	
25N/02E-23E01	FIRE STA	H	180	70	6	66	32.15	04-17-85	10.0	279	04-17-85	D
							37.75	09-16-85	9.9	282	09-16-85	
25N/02E-23F02	MCGRATH	H	170	103	6	93	58.42	04-15-85	3.4	178	04-15-85	D,I,O
							60.89	09-16-85	3.6	185	09-16-85	
25N/02E-23G01	TROTTER	H	100	397	6	392	86.18	04-15-85	3.0	281	04-15-85	D,I,O
							83.09	09-16-85	3.0	303	09-16-85	
25N/02E-23K02	WALDRIP	H	150	71	6	66	--	--	3.8	195	04-17-85	D
							--	--	3.7	198	09-16-85	
25N/02E-23N01	ST CECELIA	H	200	110	6	--	66.18	04-17-85	4.0	176	04-17-85	--
							62.12	09-16-85	4.0	178	09-16-85	
25N/02E-23Q01	BAXTER	H	140	120	6	116	59.92	04-17-85	5.7	177	04-17-85	D
							62.12	09-16-85	5.5	181	09-16-85	
25N/02E-23R03	TARABOCHIA	H	180	195	6	190	--	--	7.1	236	04-17-85	D
							--	--	8.9	258	09-16-85	
25N/02E-25C01	YEOMALT PT	P	95	109	8	--	83.20	04-17-85	9.7	307	04-17-85	D
							92.07	09-16-85	9.7	311	09-16-85	
25N/02E-25F02	MADRONA WTR CO	P	125	160	8	160	96.46	04-16-85	7.2	217	04-16-85	D,I
							96.02	09-16-85	7.1	221	09-16-85	
25N/02E-25M02	DENNON	U	110	131	6	127	101.83	04-17-85	--	--	--	D
							102.15	09-16-85	--	--	--	
25N/02E-26E01	SELLAND	H	185	76	6	--	40.33	04-17-85	10.0	228	04-17-85	D
							42.24	09-16-85	9.9	235	09-16-85	
25N/02E-26F01	BENTRYN	C	150	127	6	122	78.88	04-17-85	3.3	206	04-17-85	D
							79.06	09-17-85	3.9	207	09-17-85	

Table 8.--Records of representative wells--continued

WELL-NUMBER	OWNER	WATER USE[1]	SURF ALT[2]	WELL DEPTH[3]	CSG DIAM[4]	CSG BTM[3]	WATER LEVEL[3]	DATE MEAS	CHLR CONC[5]	SPEC COND[6]	DATE SAMP	OTHER DATA[7]
25N/02E-26G05	DICK	H	125	40	18	--	5.46	04-16-85	4.9	119	04-16-85	M
							22.23	09-16-85	4.9	147	09-16-85	
25N/02E-26P01	TRASK	U	10	761	8	761	--	--	3.0	217	04-17-85	D,M
25N/02E-27C01	OKERMAN	H	100	74	6	69	2.71	04-17-85	2.7	161	04-17-85	D,O
							--	--	2.8	163	09-16-85	
25N/02E-27D02	DELORM	H	140	90	6	92	38.04	04-15-85	7.1	178	04-15-85	D
							41.95	09-17-85	6.0	179	09-17-85	
25N/02E-27E03	WINSLOW	P	30	149	8	149	-31.22	04-16-85	2.4	149	04-16-85	D
							-28.91	09-16-85	--	--	--	
25N/02E-27E04	WINSLOW	P	20	130	16	120	-30.22	04-16-85	2.9	155	04-17-85	D
							-21.90	09-16-85	3.4	165	09-16-85	
25N/02E-27E05	WINSLOW	P	40	163	6	142	--	--	--	--	--	D
25N/02E-27J01	DOMSEA FARMS	N	110	120	6	120	23.70	04-16-85	9.4	237	04-16-85	D
							30.90	09-16-85	9.3	258	09-16-85	
25N/02E-27K02	WINSLOW	P	25	150	12	134	-27.26	04-16-85	2.4	179	04-16-85	D,I
							-25.00	09-16-85	--	--	--	
25N/02E-27L04	RUDOLF	U	10	96	6	89	--	--	--	--	--	D
25N/02E-27M01	ADAMS	H	4	55	6	--	--	--	2.6	159	04-15-85	D
							--	--	2.7	184	09-16-85	
25N/02E-27N02	OKERMAN	H	80	170	6	166	--	--	2.9	181	04-15-85	D,O
							--	--	2.9	198	09-16-85	
25N/02E-27R01	CALLAHAM	H	60	45	48	--	27.54	04-17-85	7.6	168	04-17-85	--
							33.64	09-16-85	6.1	165	09-16-85	
25N/02E-28A01	POZNIAK	H	125	110	6	105	28.39	04-15-85	3.2	141	04-15-85	D
							31.66	09-16-85	3.1	146	09-16-85	
25N/02E-28C01	JENSEN	H	120	109	6	105	80.43	04-18-85	3.3	120	04-18-85	D
							80.54	09-17-85	3.3	233	09-17-85	
25N/02E-28E01	MORRISON	H	200	230	6	225	166.92	04-15-85	3.3	138	04-15-85	D
							173.70	09-17-85	3.2	139	09-17-85	
25N/02E-28E02	STONE	H	220	155	6	150	125.30	04-16-85	5.6	177	04-16-85	D
							128.45	09-17-85	5.3	179	09-17-85	
25N/02E-28F02	WETTLESON	H	210	154	6	149	123.93	04-15-85	--	--	--	D
							127.32	09-17-85	7.3	224	09-17-85	
25N/02E-28K01	BAGLEY	H	120	50	6	50	9.97	04-15-85	2.6	122	04-15-85	D
							11.22	09-17-85	3.0	121	09-17-85	
25N/02E-28L02	YENNE	H	240	30	36	--	24.60	04-16-85	2.5	108	04-16-85	--
							25.79	09-17-85	3.1	94	09-17-85	
25N/02E-28M01	SPOOR	H	290	65	6	60	30.43	04-16-85	--	--	--	D
							34.11	09-17-85	4.1	149	09-17-85	

Table 8.--Records of representative wells--continued

WELL-NUMBER	OWNER	WATER USE[1]	SURF ALT[2]	WELL DEPTH[3]	CSG DIAM[4]	CSG BTM[3]	WATER LEVEL[3]	DATE MEAS	CHLR CONC[5]	SPEC COND[6]	DATE SAMP	OTHER DATA[7]
25N/02E-28M02	HENDRICKSON	H	270	254	6	250	202.68	04-16-85	7.0	148	04-16-85	D
							207.30	09-17-85	3.9	152	09-17-85	
25N/02E-28N01	OREIRO	H	310	49	6	--	38.53	04-15-85	2.6	135	04-15-85	--
							43.81	09-17-85	2.9	138	09-17-85	
25N/02E-28Q01	PHILBROOK	H	175	55	30	--	48.46	04-16-85	2.8	106	04-16-85	--
							49.20	09-17-85	3.2	111	09-17-85	
25N/02E-28Q02	SWOLGAARD	H	200	105	6	99	68.50	04-16-85	--	--	--	D
							69.19	09-17-85	--	--	--	
25N/02E-28Q03	TURNER	H	170	70	6	70	47.41	04-16-85	--	--	--	D
							49.09	09-17-85	3.9	138	09-17-85	
25N/02E-28Q04	UGLES	H	170	294	8	279	108.52	04-16-85	7.3	167	04-16-85	D,I
							110.09	09-17-85	7.9	171	09-17-85	
25N/02E-29A01	FERBER	H	300	358	6	353	229.00	04-16-85	2.8	126	04-16-85	D
							231.75	09-17-85	3.4	130	09-17-85	
25N/02E-29A02	BECHTEL	H	190	305	6	301	--	--	--	--	--	D
25N/02E-29C01	JONAS	H	235	156	6	156	--	--	3.9	171	04-16-85	D
							--	--	4.0	176	09-17-85	
25N/02E-29C02	JOHNSTON	H	260	314	6	308	228.12	04-16-85	2.1	168	04-16-85	D,I
							227.50	09-17-85	2.3	166	09-17-85	
25N/02E-29J01	HEPPLER	H	360	114	6	109	64.99	04-16-85	2.2	218	04-16-85	D,I,O
							68.09	09-17-85	2.2	225	09-17-85	
25N/02E-32C01	LEIGH	H	50	62	6	57	40.23	04-17-85	2.5	225	04-17-85	D,I
							41.02	09-17-85	2.6	225	09-17-85	
25N/02E-32P01	CROWDER	U	30	34	36	--	13.66	04-16-85	--	--	--	--
							17.53	09-17-85	--	--	--	
25N/02E-33A01	MILES	H	105	9	30	--	2.49	04-16-85	--	--	--	--
							2.67	09-17-85	3.1	178	09-17-85	
25N/02E-33A02	HELLMUTH	H	120	150	6	--	39.58	04-16-85	3.0	174	04-16-85	I
							40.55	09-17-85	--	--	--	
25N/02E-33B01	OKERMAN	H	160	115	6	104	65.89	04-16-85	3.8	222	04-16-85	D
							69.28	09-17-85	4.0	226	09-17-85	
25N/02E-33B02	BUCKLIN	H	140	115	6	110	50.18	04-17-85	3.3	179	04-17-85	D,M
							53.33	09-17-85	3.4	181	09-17-85	
25N/02E-33B03	CHRISTENSON	H	270	242	6	238	120.73	04-17-85	4.5	193	04-17-85	D
							126.23	09-17-85	4.6	195	09-17-85	
25N/02E-33C01	KITSAP PUD	U	264	1,210	6	345	--	--	--	--	--	D
25N/02E-33F01	CROOKS	H	290	219	6	209	159.67	04-17-85	--	--	--	D
							160.22	09-17-85	4.4	202	09-17-85	
25N/02E-33P01	PETERS	H	180	12	24	--	1.58	04-17-85	3.3	184	04-17-85	--
25N/02E-33Q01	BURKE	H	40	35	36	--	20.08	04-16-85	5.5	160	04-16-85	--
							24.89	09-17-85	5.4	167	09-17-85	

Table 8.--Records of representative wells--continued

WELL-NUMBER	OWNER	WATER USE [1]	SURF ALT [2]	WELL DEPTH [3]	CSG DIAM [4]	CSG BTM [3]	WATER LEVEL [3]	DATE MEAS	CHLR CONC [5]	SPEC COND [6]	DATE SAMP	OTHER DATA [7]
25N/02E-34C01	SANDERSON	P	60	140	8	130	31.59	04-16-85	4.9	210	04-16-85	D
							34.02	09-17-85	4.9	215	09-17-85	
25N/02E-34D01	STOWELL	H	120	173	6	167	68.00	04-16-85	2.6	176	04-16-85	D
							70.88	09-16-85	2.8	179	09-16-85	
25N/02E-34E02	EUCHNER	H	195	182	6	177	117.34	04-16-85	5.8	262	04-16-85	D
							118.30	09-16-85	5.2	259	09-16-85	
25N/02E-34F01	LEON	H	210	380	6	370	--	--	2.4	174	04-17-85	D
							--	--	2.5	178	09-17-85	
25N/02E-34H01	HAWKINS	H	185	210	6	206	146.64	04-15-85	4.1	483	04-15-85	D
							147.56	09-17-85	--	--	--	D
25N/02E-34J01	LOWN	H	270	181	6	175	119.35	04-17-85	5.4	214	04-17-85	--
							120.27	09-17-85	5.3	215	09-17-85	
25N/02E-34K01	DERROR	H	260	310	6	310	128.82	04-17-85	3.4	187	04-17-85	D
							130.75	09-17-85	3.5	197	09-17-85	
25N/02E-34K02	AVERY	H	180	207	6	197	95.28	04-16-85	5.2	169	04-16-85	D
							94.87	09-17-85	5.4	172	09-17-85	
25N/02E-34L01	LADAU	H	285	377	6	372	227.05	04-16-85	3.3	227	04-16-85	D
							229.55	09-17-85	3.4	229	09-17-85	
25N/02E-34N01	IRVEN	H	260	245	6	241	221.37	04-17-85	4.4	164	04-17-85	D
							220.21	09-17-85	4.7	167	09-17-85	
25N/02E-34R04	DUCKWORTH	H	250	360	6	301	--	--	4.3	419	04-17-85	D
							--	--	4.3	420	09-17-85	
25N/02E-35E01	MCFARLAND	C	130	174	6	174	--	--	5.7	205	04-17-85	--
							--	--	5.6	206	09-17-85	
25N/02E-35E02	VIBRANS	H	70	133	8	128	39.33	04-17-85	3.0	271	04-17-85	D,I
							40.32	09-17-85	3.2	267	09-17-85	
25N/02E-35F02	MIRKOVICH	H	90	130	6	--	--	--	--	--	--	D
25N/02E-35F04	BURKE	C	40	78	6	78	26.15	04-17-85	5.4	183	04-17-85	D
							27.19	09-17-85	5.3	185	09-17-85	
25N/02E-35F05	STAFFORD	H	80	118	6	108	74.19	04-15-85	4.6	203	04-15-85	D
							74.96	09-17-85	4.6	207	09-17-85	
25N/02E-35H03	WYCKOFF CO	N	15	813	10	--	--	--	4.7	265	04-17-85	D,I,O
							--	--	4.9	269	09-17-85	
25N/02E-35J01	BILL PT	P	140	160	8	150	--	--	--	--	--	D
25N/02E-35K01	CLARK	H	180	198	6	--	168.01	04-15-85	7.5	308	04-15-85	D
							--	--	7.8	315	09-16-85	
25N/02E-35L02	WILLIS	H	125	365	6	360	51.45	04-15-85	3.8	366	04-15-85	D
							49.97	09-17-85	3.7	367	09-17-85	
25N/02E-35L03	MOYA	H	130	165	6	120	34.12	04-17-85	12.0	333	04-17-85	D
							35.18	09-17-85	12.0	336	09-17-85	

Table 8.--Records of representative wells--continued

WELL-NUMBER	OWNER	WATER USE[1]	SURF ALT[2]	WELL DEPTH[3]	CSG DIAM[4]	CSG BTM[3]	WATER LEVEL[3]	DATE MEAS	CHLR CONC[5]	SPEC COND[6]	DATE SAMP	OTHER DATA[7]
25N/02E-35M03	CHUKA	H	160	42	6	42	25.70	04-17-85	17.0	242	04-17-85	D,I
							29.07	09-17-85	14.0	223	09-17-85	
25N/02E-35P02	SIEVERTSON	H	130	175	6	148	27.12	04-17-85	5.3	305	04-17-85	D
							22.16	09-17-85	5.9	332	09-17-85	
25N/02E-35P03	SUTTON	H	125	192	6	187	--	--	11.0	313	04-18-85	D
							--	--	11.0	318	09-17-85	
25N/02E-35Q02	WARRICK	H	130	155	6	155	--	--	3.8	286	04-17-85	D
							--	--	3.8	287	09-17-85	
25N/02E-36M01	LEVINE	U	20	13	48	--	13.36	04-18-85	--	--	--	--
25N/02E-36N01	LINDSEY	H	20	604	6	--	-9.66	04-18-85	16.0	551	04-17-85	D,I
							-5.55	09-16-85	17.0	551	09-17-85	
26N/02E-28B02	SMITH	H	60	126	6	121	--	--	--	--	--	D
26N/02E-28G01	SCHADEL	H	90	190	8	144	85.44	04-16-85	2.3	198	04-16-85	D,I,O
							86.51	09-16-85	2.4	200	09-16-85	
26N/02E-28H01	CHESTERLEY	U	80	103	6	93	67.44	04-17-85	--	--	--	D
							67.02	09-16-85	--	--	--	
26N/02E-28K01	BAKER	H	135	186	6	176	125.82	04-17-85	3.3	195	04-17-85	D
							126.57	09-16-85	3.3	188	09-16-85	
26N/02E-28K02	PYKE	H	140	217	6	212	--	--	2.7	209	04-17-85	D
							--	--	2.9	211	09-16-85	
26N/02E-28M01	MCSHANE	H	20	105	6	95	14.53	04-17-85	4.3	371	04-17-85	D
							12.61	09-16-85	4.4	376	09-16-85	
26N/02E-28N01	GRANDY	H	50	105	6	99	--	--	35.0	658	04-17-85	D
							--	--	33.0	665	09-16-85	
26N/02E-28P01	PAYNE	H	255	294	6	290	--	--	3.2	367	04-17-85	D
							--	--	3.5	368	09-16-85	
26N/02E-28Q01	DUECK	P	220	237	6	231	186.59	04-17-85	2.9	344	04-17-85	D
							--	--	3.0	347	09-16-85	
26N/02E-32R01	RIELY	H	80	107	6	--	56.55	04-15-85	3.1	214	04-15-85	--
							56.87	09-16-85	3.3	215	09-16-85	
26N/02E-33B01	KIDDER	H	210	303	6	299	199.21	04-17-85	4.6	412	04-17-85	D
							200.06	09-16-85	4.7	412	09-16-85	
26N/02E-33B02	BLOEDEL	H	175	52	8	--	10.65	04-16-85	4.5	142	04-16-85	I
							12.80	09-16-85	4.7	143	09-16-85	
26N/02E-33C01	JURCA	H	235	103	6	98	45.40	04-17-85	3.2	165	04-17-85	D
							46.61	09-16-85	3.4	185	09-16-85	
26N/02E-33C02	GOMES	H	240	322	6	318	--	--	6.7	390	04-17-85	D
							--	--	6.7	391	09-16-85	
26N/02E-33D01	HART-ATKINSON	H	130	45	6	35	10.78	04-16-85	4.6	149	04-16-85	D
							12.64	09-16-85	4.6	151	09-16-85	

WELL-NUMBER	OWNER	WATER USE[1]	SURF ALT[2]	WELL DEPTH[3]	CSG DIAM[4]	CSG BTM[3]	WATER LEVEL[3]	DATE MEAS	CHLR CONC[5]	SPEC COND[6]	DATE SAMP	OTHER DATA[7]
26N/02E-33E01	SANFORD	H	170	64	6	50	--	--	3.7	149	04-16-85	D
							--	--	3.8	150	09-16-85	
26N/02E-33H01	PERSONIUS	H	110	546	6	541	88.37	04-16-85	3.3	261	04-16-85	D
							89.18	09-16-85	3.6	265	09-16-85	
26N/02E-33J01	ROBINSON	U	55	583	6	583	--	--	--	--	--	D
26N/02E-33L02	CALLAHAM	H	155	173	6	168	--	--	2.7	279	04-16-85	D
							--	--	2.8	281	09-16-85	
26N/02E-33M01	PRATT	H	60	120	6	--	--	--	3.0	380	04-16-85	D,I
							--	--	2.9	373	09-16-85	
26N/02E-33M02	PHILLIPS	I	160	168	6	163	--	--	2.8	371	04-16-85	D
							--	--	3.0	391	09-16-85	
26N/02E-33P02	PRINCIPE	H	175	162	6	159	--	--	5.4	190	04-15-85	D
							--	--	3.2	250	09-16-85	
26N/02E-34C01	TOLLEFSON	H	20	165	6	167	2.17	04-16-85	5.1	268	04-16-85	D
							15.71	09-16-85	5.0	271	09-16-85	
26N/02E-34E02	KIMBALL	H	50	227	6	217	32.10	04-16-85	2.3	207	04-16-85	D
							33.48	09-16-85	2.4	210	09-16-85	
26N/02E-34F01	JOHANNSEN	H	40	175	6	171	27.60	04-16-85	2.9	288	04-16-85	D
							28.44	09-16-85	2.9	283	09-16-85	
26N/02E-34G01	OLSEN	H	20	311	4	311	--	--	3.4	270	04-17-85	D,O
							--	--	3.5	272	09-16-85	
26N/02E-34L01	POWELL	H	8	1005	5	1005	--	--	13.0	297	04-17-85	D,M,O
							-3.3	09-16-85	14.0	304	09-16-85	
26N/02E-34L04	WADE	H	10	70	6	--	--	--	3.8	352	04-16-85	--
							--	--	4.0	383	09-16-85	
26N/02E-34M02	STRONG	H	50	109	6	56	--	--	7.1	253	04-16-85	D
							--	--	7.1	258	09-16-85	
26N/02E-34N01	LIVINGSTON	H	60	432	6	426	27.82	04-16-85	2.2	231	04-16-85	D
							33.76	09-16-85	2.3	232	09-16-85	
26N/02E-34P02	MARTIN	H	100	67	6	57	44.69	04-16-85	3.6	171	04-16-85	D
							45.88	09-16-85	3.8	180	09-16-85	
26N/02E-34Q01	THOMPSON	H	70	523	6	513	48.69	04-17-85	2.7	202	04-17-85	D,I,O
									2.8	203	09-16-85	
26N/02E-34R01	WILSON	H	100	234	6	221	61.34	04-16-85	2.5	238	04-16-85	D
							61.80	09-16-85	2.6	242	09-16-85	
26N/02E-35B01	MONROE PT	P	20	155	6	--	0.80	04-17-85	--	--	--	D
							0.51	09-17-85	--	--	--	
26N/02E-35C01	KNUDSEN	U	60	186	6	--	50.48	04-16-85	--	--	--	--
							51.74	09-16-85	--	--	--	

Table 8.--Records of representative wells--continued

WELL-NUMBER	OWNER	WATER USE[1]	SURF ALT[2]	WELL DEPTH[3]	CSG DIAM[4]	CSG BTM[3]	WATER LEVEL[3]	DATE MEAS	CHLR CONC[5]	SPEC COND[6]	DATE SAMP	OTHER DATA[7]
26N/02E-35K01	HARDING	H	120	72	6	--	54.66	04-16-85	6.3	232	04-16-85	--
							57.68	09-17-85	6.6	223	09-17-85	
26N/02E-35M01	PT MDSN WTR CO	P	110	31	6	26	13.58	09-17-85	--	--	--	D
26N/02E-35N01	WILLIAMSON	H	120	67	6	62	43.05	04-16-85	5.1	176	04-16-85	D
							44.18	09-16-85	5.0	185	09-16-85	
26N/02E-35Q01	SHORT	H	45	43	5	--	34.19	04-16-85	7.0	217	04-16-85	--
							34.62	09-17-85	6.8	219	09-17-85	

[1] C - Commercial
H - Domestic
I - Irrigation
P - Public supply
R - Recreation
T - Institution
U - Unused
Z - Other

[2] Feet above mean sea level.
[3] Feet below land surface. Negative water levels are above land surface
[4] Inches
[5] Milligrams per liter
[6] Microsiemens per centimeter at 25 C.
[7] D - Driller's log
I - Major ions and fecal coliform bacteria
M - Major ions, fecal coliform bacteria, and trace elements.
O - Project (1985) observation well

TABLE 9.--Ground-water quality at selected sites

[All concentrations are dissolved and in milligrams per liter unless otherwise stated.]

Well Number	Date	Specific conductance, micro-Siemens per centimeter	pH (units)	Hardness[1] (as $CaCO_3$)	Calcium	Magnesium	Sodium	Potassium	Alkalinity (as $CaCO_3$)	Sulfate	Chloride	Fluoride	Silica	Dissolved Solids[2]	Nitrate (as N)	Iron (Micrograms per liter)	Manganese (micrograms per liter)
24/2E-2C01	04-17-85	298	8.9	17	5.2	1.0	64	0.6	141	5.7	3.0	<0.1	17	176	<0.10	13	10
-2K01	04-17-85	401	8.0	20	4.5	2.0	86	1.1	158	16	17	.5	22	239	.82	73	<1
-3G02	04-17-85	230	8.2	108	29	8.7	5.5	.3	92	16	4.3	<.1	16	124	<.10	19	32
-3M01	04-17-85	211	7.1	35	6.8	4.3	33	2.0	83	11	6.8	<.1	24	132	.33	520	27
-5K03	04-15-85	210	8.3	89	16	12	9.0	2.9	88	9.5	4.2	<.1	33	128	<.10	30	52
-11G03	04-18-85	428	8.2	2.9	1.0	.10	96	2.9	182	21	5.7	.1	54	296	<.10	200	10
-14B02	04-15-85	234	7.0	24	6.3	2.0	44	2.6	63	21	16	<.1	19	157	<.10	530	18
25/2E-2D01[3]	04-15-85	250	7.2	83	21	7.4	14	.8	103	13	5.5	<.1	36	155	<.10	270	150
-2K02	04-17-85	274	8.1	130	27	15	6.4	4.6	130	0.7	2.9	<.1	47	166	<.10	64	66
-4B01[3]	04-16-85	218	8.5	83	21	7.4	14	4.1	105	.4	2.3	.1	36	128	<.10	7	6
-4D01	04-16-85	222	7.9	97	19	12	7.4	1.5	88	9.2	6.8	<.1	31	137	2.0	4	<1
-5H01	04-16-85	206	83	92	17	12	6.7	2.0	70	14	7.4	<.1	29	123	.13	36	13
-8G01	04-15-85	255	8.4	99	23	10	14	4.0	116	2.2	6.5	<.1	31	151	<.10	8	53
-8N01	04-16-85	304	7.8	145	22	22	8.7	1.6	130	18	6.4	<.1	33	172	<.10	3	92
-9D01	04-16-85	228	7.9	100	18	14	7.5	2.0	86	16	6.2	<.1	43	160	<.10	33	200
-9P02	04-16-85	298	6.9	140	25	18	6.2	.7	82	13	27	<.1	30	188	1.3	130	19
-10K01	04-17-85	232	8.2	65	16	6.1	22	6.9	107	.8	2.9	<.1	35	151	<.10	150	48
-14G01	04-15-85	171	7.5	73	9.4	12	6.6	2.0	58	14	4.5	<.1	42	127	.68	7	<1
-14P02	04-15-85	268	7.2	68	14	8.0	25	1.5	63	12	21	<.1	33	163	1.7	25	4
-15K01[3]	04-15-85	182	8.2	75	18	7.4	6.4	2.9	78	5.1	2.2	<.1	39	124	<.10	94	72
-16P01[3]	04-17-85	196	7.5	88	14	13	5.7	.9	67	15	6.5	<.1	24	117	.26	35	5
-17C01	04-16-85	224	8.4	73	21	5.1	20	3.1	101	.7	5.2	<.1	31	126	<.10	81	29
-17M02[3]	04-18-85	255	7.7	98	18	13	11	2.4	89	19	9.6	<.1	25	147	<.10	23	8
-20L01	04-17-85	286	7.4	140	27	17	8.1	1.4	120	15	6.1	<.1	26	163	.34	23	2
-20L04	04-17-85	206	8.3	77	23	4.8	14	2.7	91	1.9	3.6	<.1	38	141	<.10	20	34

TABLE 9.--Ground-water quality at selected sites--cont

[All concentrations are dissolved and in milligrams per liter unless otherwise stated.]

Well Number	Date	Specific conductance, micro-Siemens per centimeter	pH (units)	Hardness[1] (as $CaCO_3$)	Cal-cium	Magne-sium	Sodium	Potas-sium	Alka-linity (as $CaCO_3$	Sul-fate	Chlo-ride	Fluo-ride	Silica	Dis-solved Solids[2]	Nitrate (as N)	Iron (Micro-grams per liter)	Manganese (micro-grams per liter)
-22C01	04-16-85	185	7.5	65	17	5.6	11	2.3	87	1.1	2.3	.2	52	159	<.10	110	210
-22N01	04-15-85	99	6.5	36	8.1	3.8	4.9	.5	23	13	3.6	<.1	19	62	<.10	120	14
-23F02	04-15-85	178	8.2	82	13	12	6.0	1.1	66	15	3.4	<.1	27	109	.17	37	19
-23G01	04-15-85	281	7.7	79	17	8.8	29	4.6	138	1.1	3.0	<.1	47	171	<.10	120	100
-25F02	04-16-85	217	7.9	98	16	14	7.3	1.6	77	16	7.2	<.1	35	136	.10	---	---
-26G05[3]	04-16-85	119	6.4	40	11	3.1	5.6	.5	35	12	4.9	<.1	39	90	<.10	270	110
-26P01[3]	04-17-85	217	8.3	85	18	9.7	12	3.5	101	2.4	3.0	<.1	38	136	<.10	64	84
-27K02	04-16-85	179	8.0	74	17	7.8	6.8	3.1	79	2.2	2.4	.1	42	123	<.10	160	76
-28Q04	04-16-85	167	7.9	64	12	8.4	8.5	1.4	62	2.0	7.3	<.1	48	118	<.10	69	160
-29C02	04-16-85	168	8.3	38	11	2.5	23	2.1	77	1.7	2.1	<.1	33	122	<.10	19	24
-29J01	04-16-85	218	7.4	98	21	11	6.2	1.7	90	4.9	2.2	.2	52	156	<.10	1,300	460
-32C01	04-17-85	225	8.0	104	22	12	8.0	2.6	106	.5	2.5	<.1	42	143	<.10	92	110
-33A02	04-16-85	174	8.4	79	12	12	5.6	2.1	74	7.2	3.0	.1	37	126	<.10	84	120
-33B02[3]	04-17-85	179	8.0	70	10	11	5.6	2.2	71	10	3.3	<.1	39	116	<.10	270	110
-35E02	04-17-85	271	7.9	72	15	8.4	33	4.8	128	.9	3.0	<.1	34	164	.88	22	52
-35H03	04-17-85	265	8.3	100	20	13	18	2.1	121	6.7	4.7	<.1	27	150	<.10	15	33
-35M03	04-17-85	242	6.8	95	15	14	11	2.3	60	14	17	<.1	41	165	2.5	22	19
-36N01	04-17-85	551	8.3	38	10	3.1	120	2.2	262	5.7	16	<.1	38	365	<.10	84	24
26/2E-28G01	04-16-85	198	8.2	82	17	9.7	9.7	2.8	91	3.6	2.3	<.1	37	124	.13	21	5
-33B02	04-16-85	142	7.6	58	9.6	8.2	5.8	1.0	46	9.3	4.5	<.1	27	93	.91	35	14
-33M01	04-16-85	380	7.4	142	37	12	21	3.2	153	4.0	3.0	.2	40	216	<.10	15	840
-34L01[3]	04-17-85	297	8.3	68	15	7.3	35	7.3	128	.7	13	.1	45	185	<.10	41	32
-34Q01	04-17-85	202	8.4	74	18	7.1	13	5.2	93	1.8	2.7	.1	37	136	<.10	130	38

TABLE 9.--Ground-water quality at selected sites--continued

[All concentrations are dissolved and in micrograms per liter.]

Well Number	Date	Barium	Beryllium	Cadmium	Cobalt	Copper	Lead	Lithium	Molybdenum	Strontium	Vanadium	Zinc
25/2E-2D01	04-15-85	11	< .5	<1	<3	<10	<10	6	<10	80	<6	34
-4B01	04-16-85	17	<0.5	<1	<3	<10	<10	6	<10	110	<6	34
-15K01	04-15-85	15	< .5	<1	<3	<10	<10	8	<10	77	<6	36
-16P01	04-17-85	10	< .5	<1	<3	<10	<10	<4	<10	35	<6	170
-17M02	04-18-85	11	< .5	<1	<3	<10	<10	12	<10	110	<6	44
-26G05	04-16-85	15	< .5	<1	<3	<10	<10	8	<10	52	<6	88
-26P01	04-17-85	20	< .5	<1	<3	<10	<10	<4	<10	99	<6	13
-33B02	04-17-85	15	< .5	<1	<3	<10	<10	10	<10	52	<6	95
26/2E-34L01	04-17-85	19	< .5	<1	<3	<10	<10	<4	<10	100	<6	9

[1] As calculated according to Hem (1985, p. 158).
[2] Residue on evaporation at 180°C.
[3] Trace element analysis available.

TABLE 10.--Driller's lithologic logs of selected wells

Local Well Number	Altitude (feet)	Materials	Thickness (feet)	Depth (feet)	Tops of Geohydrologic Units
24N/02E-04N01	130	Topsoil	2	2	unit 2
		Hardpan	40	42	
		Fine sand	4	46	unit 3
		Hardpan	86	132	unit 4
		Gravel	10	142	unit 5
25N/02E-05A01	80	Rocky soil	5	5	unit 2
		Hardpan	55	60	
		Clay	11	71	
		Clay, silt, gravel	2	73	unit 3
		Clay	42	115	unit 4
		Clay and rocks	25	140	
		Silt and sand	7	147	unit 5
		Sand	11	158	
25N/02E-05H01	70	Gravel loam, sand	4	4	unit 1
		Glacial moraine, clay, with granite rocks	44	48	unit 2
		Gravel and sand	6	54	unit 3
		Glacial moraine, clay	41	95	unit 4
		Sand, silt, gravel	3	98	unit 5
25N/02E-05J01	80	Topsoil	3	3	unit 2
		Compact sand, gravel	77	80	
		Coarse gravel, water	10	90	unit 3
		Clay	5	95	unit 4
		Hardpan	10	105	
		Sand, water	8	113	unit 5
		Clay	---	---	
25N/02E-05J02	70	Clay and gravel	12	12	unit 2
		Hardpan	73	85	
		Sand and gravel	5	90	unit 3
		Hardpan	16	106	unit 4
		Water, sand, gravel	8	114	unit 5
25N/02E-09D01	25	Hardpan	11	11	unit 2
		Gravel	4	15	unit 3
		Loose sand	10	25	unit 4
		Hardpan	10	35	
		Clay and sand	10	45	
		Gravel	2	47	unit 5
		Sandy clay	9	56	
		Gravel, water-bearing	2	58	
		Sandy clay	2	60	

TABLE 10.--Driller's lithologic logs of selected wells--continued

Local Well Number	Altitude (feet)	Materials	Thickness (feet)	Depth (feet)	Tops of Geohydrologic Units
25N/02E-09E02	100	Sand and gravel	20	20	unit 3
		Hardpan	17	37	unit 4
		Fine sand (some gravel)	8	45	unit 5
		Fine sand	10	55	
		Fine sandy clay	7	62	
		Sand (dry)	48	110	
		Sand, water-bearing	6	116	
25N/02E-15N01	190	Topsoil	2	2	unit 2
		Hardpan	48	50	
		Coarse sand	11	61	unit 3
25N/02E-15P01	160	Sand and gravel	22	22	unit 3
		Sand, clay, and gravel	3	25	unit 4
		Granite boulder	5	30	
		Sand, clay, gravel	35	65	
		Clay	12	77	
		Sandy clay	17	94	
		Hard clay	26	120	
		Clay	58	178	
		Sand and gravel	5	183	unit 5
25N/02E-15R01	125	Topsoil	4	4	unit 2
		Hardpan	86	90	
		Sandy clay	50	140[A]	unit 4
		Silt	58	198	(?)
		Coarse sand	6	204	unit 5
		Clay	---	---	
25N/02E-16D01	170	Topsoil	1	1	unit 2
		Gravely hardpan	9	10	
		Hardpan	6	16	
		Cemented gravel	24	40	unit 3 (?)
		Sandy hardpan	15	55	unit 4
		Cemented sand, gravel	25	80	unit 5 (?)
		Sand and gravel	3	83	
		Sand, gravel, and water	8	91	
25N/02E-16P01	190	Topsoil	2	2	unit 2
		Hardpan	3	5	
		Cemented gravel	10	15	
		Claybound gravel	10	25	
		Cemented sand, gravel	10	35	
		Hardpan	10	45	
		Cemented gravel	24	69 (?)	unit 3
		Gravel and water	14	83	

TABLE 10.--Driller's lithologic logs of selected wells--continued

Local Well Number	Altitude (feet)	Materials	Thickness (feet)	Depth (feet)	Tops of Geohydrologic Units
25N/02E-16Q01	315	Topsoil	1	1	unit 2
		Hardpan	9	10	
		Sand	70	80	unit 3
		Sandy clay	38	118	unit 4
		Sand and gravel	15	133	
		Hardpan	13	146	
		Sand	4	150	
		Hardpan	30	180	
		Sandy clay	6	186	
		Hardpan	30	216	
		Sand, water-bearing	20	236	unit 5
25N/02E-17K01	100	Topsoil	2	2	unit 2
		Sandy clay with gravel	40	42	
		Sand, gravel, trace of clay	3	45	unit 3
		Sand, gravel, water	4	49	
		Sand and water	14	60	
		Fine sand and silt	---	---	
25N/02E-17L01	150	Dirt	2	2	unit 2
		Clay and gravel	16	18	
		Cemented gravel	5	23	unit 3 (?)
		Silty clay	15	38	unit 4
		Sandy clay and gravel	25	63	
		Clay, sand, gravel, water	17	80	unit 5
		Silty clay	1	81	unit 6
25N/02E-17N01	40	Gravely hardpan	31	31	unit 2
		Clay	14	45[A]	unit 4
		Hard till	17	62	
		Clay	9	71	
		Sand, gravel, water	5	76	unit 5
25N/02E-17R01	75	Topsoil	4	4	unit 2
		Hardpan	55	59	
		Coarse sand and water	6	65	unit 3
		Sand and water	4	69	
		Coarse sand and clay	3	71	unit 4
		Clay	19	90	
		Coarse sand and water	10	100	unit 5

TABLE 10.--Driller's lithologic logs of selected wells--continued

Local Well Number	Altitude (feet)	Materials	Thickness (feet)	Depth (feet)	Tops of Geohydrologic Units
25N/02E-21D01	80	Hardpan	32	32	unit 2
		Coarse sand, gravel, water	23	55	unit 3
		Gravel and clay	---	---	
25N/02E-21H01	250	Rocky hardpan	58	58	unit 2
		Fine sand	15	73	unit 3
		Clay	27	100	unit 4
		Hardpan	10	110	
		Clay	10	120	
		Sand	30	150	unit 5
		Soft clay, silt	5	155	
		Sand and water	14	169	
25N/02E-21N01	90	Topsoil	3	3	unit 2
		Hardpan	49	52	
		Clay	20	72	
		Silt, heaving	18	90	unit 3
		Clay	55	145	unit 4
		Peat	4	149	unit 5
		Sand, wood chuncks, quartz	3	152	
		Peat	---	---	
25N/02E-22C01	180	Hardpan	38	38	unit 2
		Cemented hardpan	4	42	
		Sand and gravel	4	46	unit 3
		Sandy mud	1	47	
		Cemented sand, gravel	3	50	(?)
		Hardpan	20	70	unit 4
		Till	13	83	
		Clay	47	130	
		Clay, sticky	22	152	
		Clay, gritty	8	160	
		Clay and rocks	15	175	
		Clay	9	184	
		Silt	22	206	
		Sand and silt	2	208	unit 5
		Sand	2	210	
		Clay	6	216	
		Sand	5	221	
25N/02E-23C01	135	Water bearing		---	unit 2
		Gravel strata	unk	40	unit 3 (?)

TABLE 10.--Driller's lithologic logs of selected wells--continued

Local Well Number	Altitude (feet)	Materials	Thickness (feet)	Depth (feet)	Tops of Geohydrologic Units
25N/02E-23D01	60	Topsoil	3	3	unit 4
		Sandy clay	95	98	
		Silty sand	47	145	unit 5
		Sand	10	165	
		Clay	2	167	
		Shale	1	168	
		Coarse sand, water-bearing	12	180	
25N/02E-23G01	100	Fill and clay	3	3	unit 2
		Hardpan	3	6	
		Clay	14	20	unit 3
		Silt	5	25	
		Clay	5	30	
		Silt	35	65	
		Clay	35	100	unit 4
		Hardpan	15	115	
		Cemented sand, gravel	15	130	unit 5 (?)
		Clay, sticky	70	200	unit 6
		Clay	50	250	
		Clay, sticky	66	316	
		Cemented sand, gravel	29	345[B]	
		Sandy silt	5	350	
		Clay	10	360	
		Gravely silt	20	380	
		Sandy silt	8	388	
		Fine sand	9	397	
		Clay	---	---	
25N/02E-28E01	200	Topsoil	1	1	unit 2
		Hardpan	17	18	
		Clay	17	35	
		Sand and gravel, clay filled	2	37	
		Sand, clay filled	27	64	
		Clay	16	80	
		Sand, water-bearing	5	85	unit 3
		Silt, clay filled	8	93	unit 4
		Clay	32	125	
		Sand, clay filled	12	137	
		Clay	88	225	
		Sand, water-bearing	5	230	unit 5

TABLE 10.--Driller's lithologic logs of selected wells--continued

Local Well Number	Altitude (feet)	Materials	Thickness (feet)	Depth (feet)	Tops of Geohydrologic Units
25N/02E-28M01	290	Topsoil	4	4	unit 2
		Hardpan	36	40	
		Sand and clay	10	50	
		Sand, water-bearing	15	65	unit 3
25N/02E-28M02	270	Topsoil	2	2	unit 2
		Clay	16	18	
		Clay, sand, gravel	28	46	
		Hardpan	15	61	
		Clay	5	66[A]	unit 4
		Clay and gravel	7	73	
		Clay, sticky	8	81	
		Clay	167	248	
		Sand, gravel, water	6	254	unit 5
		Fine sand	---	---	
25N/02E-32C01	50	Topsoil	1	1	unit 6
		Sandy clay	19	20	
		Clay	15	34	
		Hardpan	6	40	
		Sand	11	51[B]	
		Sand and gravel	11	62	
25N/02E-33B01	160	Hardpan	20	20	unit 2
		Sandy clay	85	105	
		Sand and water	10	115	unit 3
25N/02E-33B02	140	Topsoil	2	2	unit 1
		Sand	4	6	
		Sandy clay with gravel	11	17	
		Sand	43	60	
		Clay	9	69	unit 2
		Sandy clay	5	74	
		Silty clay	7	81	
		Clay	1	82	
		Silty clay	18	100	
		Sand, water-bearing	15	115	unit 3
		Clay	---	---	

TABLE 10.--Driller's lithologic logs of selected wells--continued

Local Well Number	Altitude (feet)	Materials	Thickness (feet)	Depth (feet)	Tops of Geohydrologic Units
25N/02E-33B03	270	Topsoil	2	2	unit 1
		Sand	78	80	unit 2
		Sandy clay	10	90	
		Silt	120	210[C]	
		Clay	10	220	unit 4
		Sandy clay	18	238	
		Sand, water-bearing	4	242	unit 5
25N/02E-33C01	264	Gray till	21	21	unit 2
		Pebbly sand	119	140	unit 3
		Pebbly silt	26	166	unit 4
		Pebbly sand	19	185	unit 5
		Silt to sand	50	235	
		Silt	102	337	unit 6
		Silty sand, gravel	48	385	
		Silt and clay	96	481[B]	
		Silt	20	501	
		Clay and silt	401	902	
		Silt and wood	5	907	
		Silt and clay	96	1,003	
		Silt	97	1,100	
		Clay and silt	4	1,104	
		Pebbly silt	49	1,153	
		Sand and silt	16	1,169	
		Silt	41	1,210	
25N/02E-33F01	290	Clay and gravel	5	5	unit 2
		Clay and sand	76	81	
		Clay	78	159	
		Clay and sand	115	196[A]	unit 4
		Sand and clay	7	203	
		Silty clay, sand	7	210	
		Sand and water	9	219	unit 5
25N/02E-34D01	120	Sand and gravel	3	3	unit 1
		Sandy clay	13	16	
		Sand	6	22	
		Sandy clay with gravel	4	26	unit 2
		Clay, sand, gravel	5	31[A]	
		Sandy clay	43	74	unit 4
		Silty clay	17	91	
		Clay	10	101	
		Clay with gravel	5	106	
		Silty clay	20	126	
		Clay	17	143	
		Silt and clay	4	147	
		Clay	21	168	
		Sand and water	5	173	unit 5

TABLE 10.--Driller's lithologic logs of selected wells--continued

Local Well Number	Altitude (feet)	Materials	Thickness (feet)	Depth (feet)	Tops of Geohydrologic Units
25N/02E-34F01	210	Clay and gravel boulders	8	8	unit 2
		Hardpan	27	35	
		Clay	57	92	
		Hardpan	17	109[A]	unit 4
		Sand, clay filled	26	135	
		Silty clay	45	180	
		Clay, sticky	39	219[D]	unit 6
		Clay	151	370	
		Water, sand, thin layers of clay	8	378[B]	
25N/02E-34H01	185	Topsoil	3	3	unit 2
		Hardpan	15	18	
		Clay	22	40	
		Sandy clay	20	60	
		Clay	50	110	
		Sandy silt	10	120	unit 3 (?)
		Hardpan	20	140	unit 4
		Sandy clay	30	170	
		Silt	35	205	
		Fine sand and water	5	210	unit 5
25N/02E-34K02	180	Clay and gravel	14	14	unit 2
		Sand	22	36	unit 3
		Sand and silt	94	130	
		Clay and sand	32	162	unit 4
		Fine sand	6	168	
		Clay and sand	18	186	
		Clay	11	197	
		Fine sand and water	10	207	unit 5
25N/02E-35E02	70	Gravel fill	3	3	unit 2
		Clay	47	50	
		Compacted silt	10	60	unit 3 (?)
		Clay	70	130	unit 4
		Sand	3	133	unit 5
		Clay	---	---	
25N/02E-35F02	90	Sand and clay	10	10	unit 2
		Clay and little sand	75	85	
		Sand, water-bearing	2	87	unit 3
		Sand	36	123	
		Sand and gravel, water-bearing	7	130	

TABLE 10.--Driller's lithologic logs of selected wells--continued

Local Well Number	Altitude (feet)	Materials	Thickness (feet)	Depth (feet)	Tops of Geohydrologic Units
25N/02E-35F04	40	Clay	3	3	unit 2
		Gravely hardpan	37	40	
		Gravel, sand, water	4	44	unit 3
		Sandy hardpan	11	55	
		Sand and water	12	63	
		Sandy hardpan	11	74	
		Sand, gravel, water	4	78	
25N/02E-35F05	80	Clay	39	39	unit 2
		Clay and sand	69	108	
		Sand and water	10	118	unit 3
25N/02E-35H03	15	Clay and gravel	98	98	unit 4
		Loose gravel	40	138	unit 5
		Clay and boulders	50	188	unit 6
		Clay and gravel	42	230	
		Sandy gravel	20	250[B]	
		Packed sand	50	300	
		Sand and boulders	52	352	
		Clay and boulders	9	361	
		Clay	84	445	
		Packed sand and boulders	59	504	
		Sand and gravel	4	508	
		Boulders	27	535	
		Clay	162	697	
		Sand, water-bearing	83	780	
		Clay	33	813	
25N/02E-35J01	140	Topsoil	2	2	unit 2
		Hardpan	21	23	
		Sandy clay	101	124	
		Hardpan	6	130	
		Sand and water	30	160	unit 3
26N/02E-28M01	20	Sandy hardpan	28	28	unit 2
		Gravelly hardpan	28	56	
		Sandy clay	41	97[A]	unit 4
		Sand and water	8	105	unit 5

TABLE 10.--Driller's lithologic logs of selected wells--continued

Local Well Number	Altitude (feet)	Materials	Thickness (feet)	Depth (feet)	Tops of Geohydrologic Units
26N/02E-28N01	50	Topsoil	5	5	unit 2
		Sand, gravel, clay	47	52	
		Sandy clay	12	64[A]	unit 4
		Hardpan	21	85	
		Sand and water	21	106	unit 5
26N/02E-33D01	130	Gravel	1	1	
		Claybound sand	24	25	unit 2
		Sand	18	43	unit 3
		Dirty sand	2	45	
26N/02E-33M01	60	Hardpan	20	20	unit 2
		Clay	90	110[A]	unit 4
		Gravel	10	120	unit 5

[A] unit 3 is absent.
[B] undifferentiated deposits.
[C] unit 3 absent or contained in silt deposit.
[D] unit 5 is absent.

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