Ground-Water Resources of the Coastal Sand-Dune Area North of Coos Bay, Oregon

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1619-D

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By S. G. BROWN *and* R. C. NEWCOMB

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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GROUND-WATER RESOURCES OF THE COASTAL SAND-DUNE AREA NORTH OF COOS BAY, OREGON

By S. G. Brown and R. C. Newcomb

ABSTRACT

The coastal region of Oregon is underlain by bedrock materials of Tertiary age that are impermeable or, at best, yield only small amounts of water to wells, springs, and streams. The meager supplies of water in the bedrock materials may be saline and unsuitable for most uses. At some places along the coast, as in the area north of Coos Bay, the bedrock in sizable lowland areas is overlain by extensive deposits of dune and beach sand. The sand is moderately permeable, and it absorbs and stores as fresh ground water a large percentage of the 61-inch average annual precipitation. In the 12-square-mile area studied, the water-bearing sand deposits are about 2 miles wide and extend to depths as great as 168 feet below sea level. No saline water was found during drilling of the wells in the area, even in those wells located near the ocean beach and in those that completely penetrated the sand.

Most of the ground water in the sand discharges naturally to the Pacific Ocean, Coos Bay, and North Slough through seeps and springs. A large part of that discharge could be salvaged by withdrawal from wells. It is estimated that throughout an area of about 8 square miles as much as 2,500 acre-feet of ground water per year per square mile might be available for withdrawal.

The water is soft and of generally good chemical quality; however, it is weakly acidic and at places contains sufficient iron to make removal necessary for some uses of the water. Ground water from shallow depth beneath a few swampy, low-lying areas contains excessive amounts of iron and has a brown color.

The most practical method of extracting water from the sand is by means of properly screened and developed vertical wells.

Any plan for near-maximum development of the ground-water resources should include provision for constructing and maintaining a network of deep wells near the edges of the dune sheet for periodic measurement of ground-water levels and chloride content of the ground water. These observations would be necessary in the maintenance of the water table at a high level along the margins of the dune sheet to prevent landward migration of sea water.

INTRODUCTION

PURPOSE OF THE INVESTIGATION

This investigation was made to determine the hydrologic and geologic character of part of the sand-dune area north of Coos Bay, the extent and quality of the ground water, and the availability of the ground water as a dependable supply.

Most of the coastal region of Oregon is underlain by rocks of low permeability, which, at best, store and yield only small quantities of ground water. Also, the meager supply of water from these rocks is of poor chemical quality. Because of the low permeability of these rocks, they discharge only a small amount of ground water to the streams. Consequently, the flow of rivers and creeks of the region, which normally is abundant during the wet seasons of the year, decreases greatly during the dry summer months. In many streams the summer flow ceases entirely.

At a few places along the coast, sizable lowland areas of dune sand catch and store water from precipitation and discharge this water by seeps and springs to the Pacific Ocean and to lakes and streams. Throughout most of the coastal region, the ground water in the sand holds a substantial perennial supply of water. The dune areas are also an important recreational resource.

This investigation is a part of the continuing program of studies of the Geological Survey aimed at appraising the Nation's water resources.

LOCATION AND EXTENT OF THE AREA

Between the mouth of Coos Bay and the mouth of the Umpqua River, about 23 miles to the north, a band of dune sand extends continuously at near sea level. This band is about 2 miles wide in its central part and diminishes in width to about 1.5 miles in its northern part. The southern part forms a spit (North Spit), about 1 mile or less in width, which extends along the seaward side of Coos Bay for a distance of 6 miles (fig. 1).

The principal area investigated is the central and widest part of the sand-dune area. This part extends from the vicinity of Jordan Cove to about 1 mile north of Hauser (pl. 1) and includes about 12 square miles. The area is in Coos County and mostly within the Siuslaw National Forest.

SCOPE AND METHODS OF STUDY

Fieldwork for this investigation was done during the period June 1954–January 1956. The extent of the sand deposit and the general character of the underlying rocks was determined, and hydrologic data were gathered (table 1). Seventeen shallow observation wells were constructed. Staff gages were installed in Beale and Spirit Lakes. The elevations of the wells and staff gages were established by third-order spirit leveling, and lake and ground-water levels were measured periodically. Representative samples of the sand at the surface were taken for laboratory determination of physical and hydraulic properties. Water samples were collected for chemical analyses. One

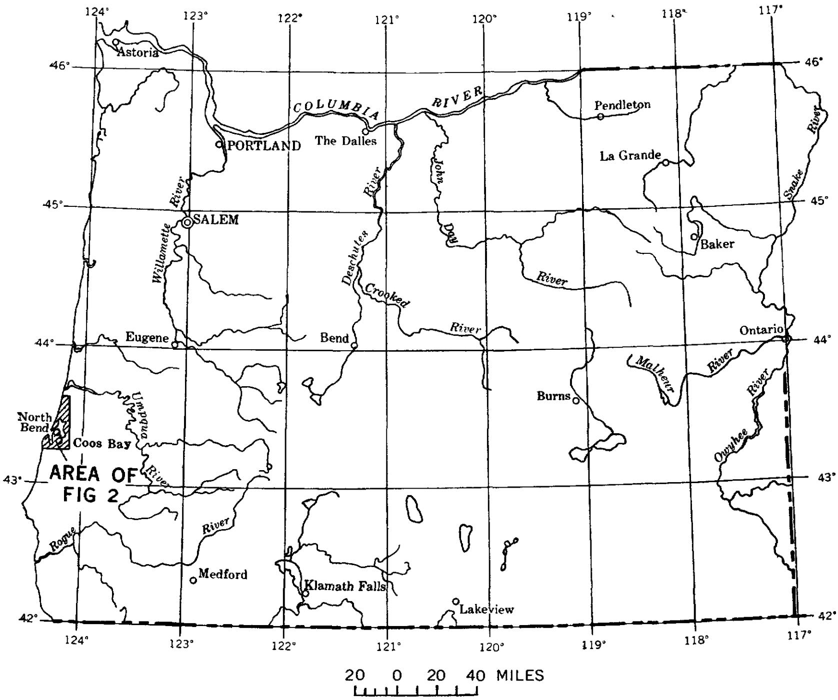

FIGURE 1.—Index map of part of southwestern Oregon, showing location of the sand-dune area.

aquifer test was made utilizing a group of seven small-diameter shallow wells.

Because of local interest in development of ground water from the sand deposit, a preliminary open-file version of this report was released by the Geological Survey in December 1956. Since then, important additional data have become available, largely through an intensive study of the area by the Pacific Power & Light Co. Through the gracious cooperation of that company some of these additional data are included in this report.

RELATED STUDIES

A study of the geology and coal resources of the Coos Bay area was made in 1943–44 by J. E. Allen and E. M. Baldwin (1944). The bedrock of the Coos Bay area, its general geologic structure, and the approximate extent of the unconsolidated deposits of Recent age, including the dune sand, are described briefly in their report.

A study of the coastal sand dunes of Oregon and Washington, including the dune sheet north of Coos Bay, was made by W. S. Cooper (1958). The report includes a description of the dune area, a discussion of the history, origin, and configuration of the dunes, and general information about the dune lakes.

In 1955 the Pacific Power & Light Co. began an intensive investigation of the quantity, quality, and best methods for development of ground water in the sand deposit. The principal purpose of the Pacific Power & Light Co. investigation was to determine whether ground water could be obtained in sufficient quantities to supply industry permanently and in turn create an additional market for electrical power. The investigation by that company started with the data contained in the 1956 open-file report of the Geological Survey.

POPULATION AND DEVELOPMENT

South of the area studied, across Coos Bay, is the important lumbering center that embraces the neighboring towns of Coos Bay and North Bend, with 1960 populations of 7,100 and 7,500, respectively. The port of Coos Bay is one of the largest lumber ports in the United States in quantity of lumber handled. Statistics of the North Bend and Coos Bay Chambers of Commerce show that 675 million board feet of lumber was shipped from the combined ports in 1953.

The east side of the Coos Bay sand-dune area is bounded by North Slough and a lowland area, which extends north to Hauser. The North Slough area is serviced by a railroad and a highway and has a population of about 50, most of whom live near the post office and railroad station at Hauser.

The sand-dune area itself is almost uninhabited. In the area of this study, only three houses were occupied during 1954. Cranberry bogs that probably total less than 7 acres in area and several hunting reserves account for nearly all the economic use that was made of the area during the period of field studies. The beaches and open dune areas were used also to a small extent for recreation.

Following a program of test drilling and pumping tests by the Pacific Power & Light Co., to demonstrate the feasibility of perennially withdrawing large amounts of ground water from the sand deposit, the Menasha Wooden Ware Co., in 1960, constructed a pulp mill on the dune area east of Jordan Cove. This plant is designed to produce 100 tons of paper pulp per day and is supplied with water from wells in the sand deposit.

CLIMATE

The climate of the Coos Bay area is generally cool and moist, and the area is under cloud cover much of the winter months. The winds normally are from the ocean; the prevailing winds blow from the northwest in the summer and from the southwest in the winter.

Precipitation and temperature data are collected at the U.S. Weather Bureau station at the North Bend Airport. The average annual precipitation at the North Bend station for the water years (years ending September 30) for the 25-year period 1921–45 was 61.2 inches. The minimum annual precipitation was 41.7 inches in water year 1924, and the maximum was 89.1 inches in water year 1916. Figure 2 shows a graph of the precipitation at North Bend for water years 1914–55.

Figure 2 also shows the cumulative departure, in percent, from the average annual precipitation for the 25-water-year base period 1921–45. This type of graph is used to show accumulated excesses and deficiencies of precipitation. Proceeding from the left end of the graph, a period of above-average precipitation is shown by a rising line, and a period of below-average precipitation by a falling line. This type of long-term graph is used because its rises and declines parallel the rise and decline of the water table with the cumulative ground-water storage effects of long-term weather conditions.

The graphs in figure 2 also show that the annual precipitation in the area was remarkably uniform during water years 1914–55. The annual precipitation deviated less than 50 percent from the average, and there were no prolonged periods of excessive or deficient precipitation.

The seasonal distribution of the precipitation is typical of coastal areas of the Pacific Northwest. Precipitation is at a minimum in July or the first part of August and is at a maximum in December. Approximately 40 percent of the annual precipitation occurs between October 1 and December 31, and by the end of March, about 80 percent of the precipitation for the average water year has occurred. The average monthly precipitation during the 25-year period October 1, 1920, to September 30, 1945, ranges from about 0.3 inches in July to 10.4 inches in December. Figure 3 also shows the average monthly temperature at North Bend. The temperatures are mild; they average about 44°F, in January, the coolest month, and about 60°F in August, the warmest month.

Because of the mild summer temperatures and the influx of moist air from the ocean, the evaporation in the area is low. From evaporation data obtained at Corvallis, 90 miles northeast of Coos Bay, it is estimated that evaporation from open-water surfaces at Coos Bay probably would not exceed 26 inches per year, and that about half the evaporation would occur during the months June through September. The period of greatest evaporation coincides generally with the period of least rainfall; therefore, evaporation would have its greatest effect on free-water surfaces and shallow ground water during that period. Also, the natural draft on the soil moisture and ground water by vegetative transpiration would be expected to be greatest during that period, which coincides with much of the growing season.

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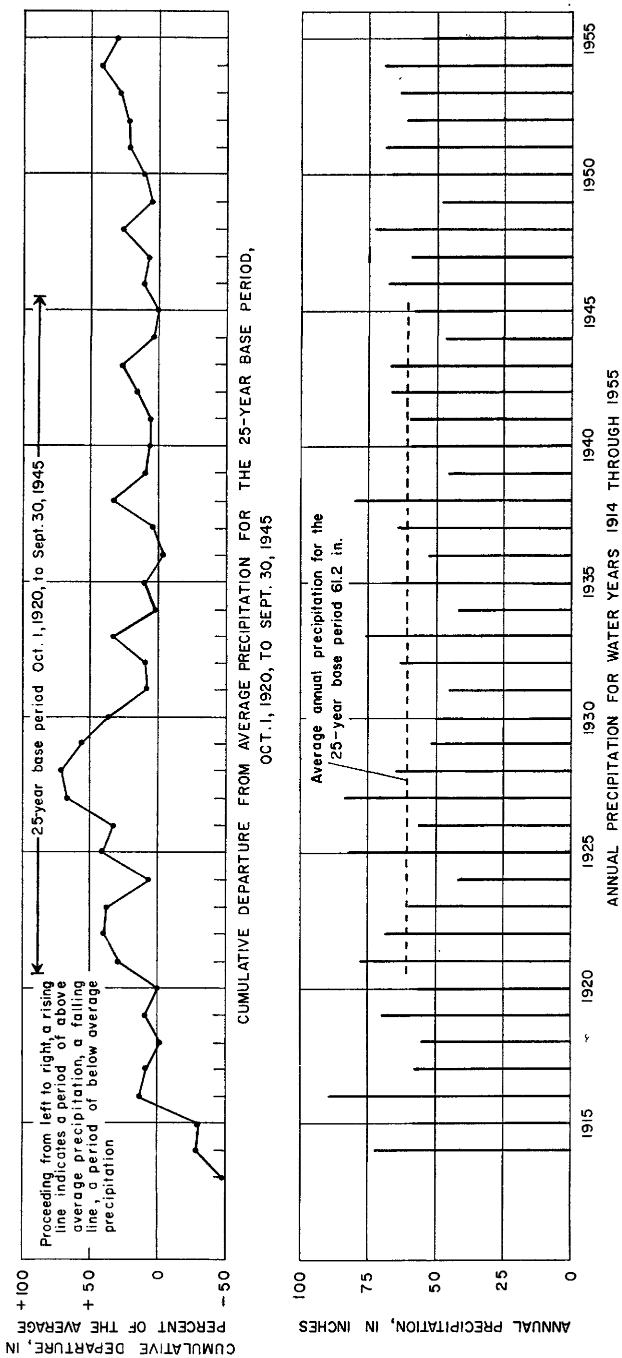

FIGURE 2.—Graphs showing annual precipitation at North Bend during water years (ending Sept. 30) 1914–55, and cumulative departure from average.

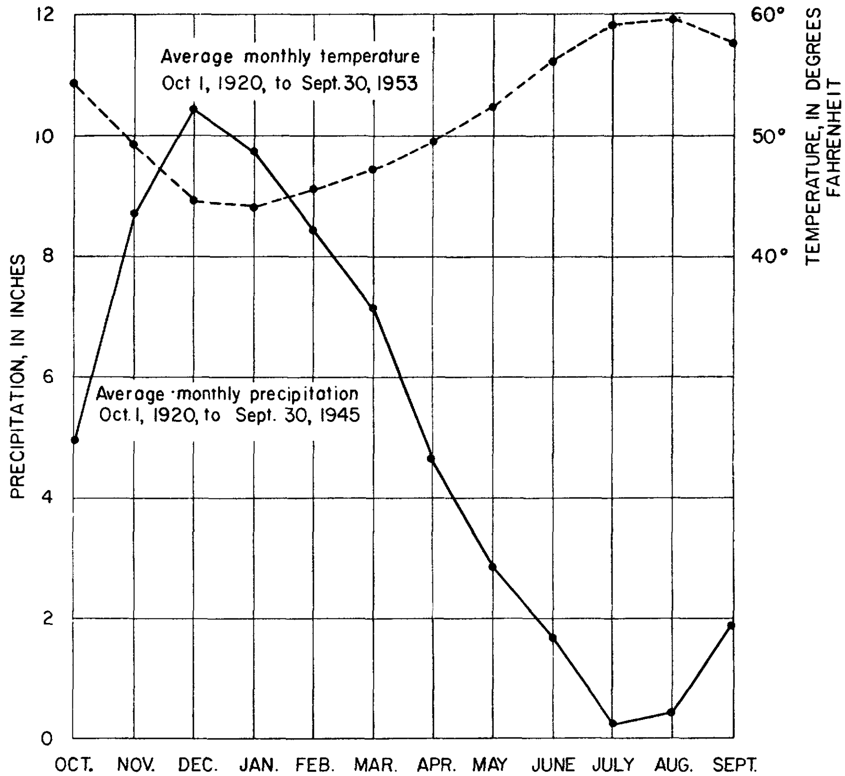

FIGURE 3.—Graphs showing average monthly temperature and precipitation at North Bend.

WELL AND SPRING NUMBERS

Wells and springs discussed in this report are numbered according to the location in the rectangular system of land division. In the symbol 24/13W–15R1, for example, the numbers and letter preceding the dash indicate respectively the township and range (T. 24 S., R. 13 W.) south and west of the Willamette base line and meridian. Because most of the State lies south of the Willamette base line, the letter indicating the direction south is omitted, but the letter W is included for wells lying west of the meridian. The first number after the dash indicates the section (sec. 15), and the letter (R) indicates a 40-acre subdivision of the section as shown in the diagram below (fig. 4). The final digit is the serial number of the well within that 40-acre tract. Thus, well 24/13W–15R1 is in the SE¼SE¼ sec. 15, T. 24 S., R. 13 W., and is the first well or spring in the tract to be listed.

A variation of this system, without the final serial number, is used in table 2 for a brief designation of the 40-acre tracts in which some water samples were taken from lakes.

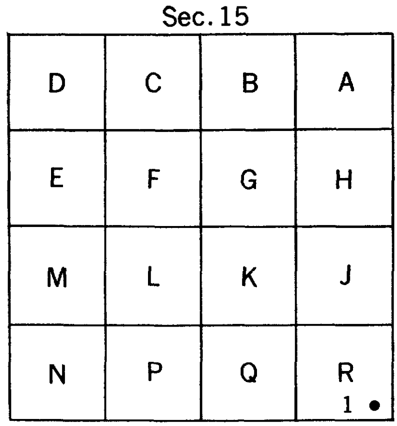

FIGURE 4.—Well-numbering system.

ACKNOWLEDGMENTS

This study was facilitated by the assistance of residents of the area and of others. Especial thanks are due Mr. and Mrs. Percy Philip, who made available their 9-year record of levels of Spirit Lake, and Mr. C. P. Davenport, engineer for the Pacific Power & Light Co., who supplied valuable data on wells, subsurface materials, and chemical quality of the ground water. The U.S. Forest Service granted permission for study and the construction of test wells in the part of the area that lies within the Siuslaw National Forest.

GROUND WATER

GEOLOGIC SETTING

The sand deposit north of Coos Bay rests on a broad surface cut into the sandstone and shale of the upper part of the Coaledo formation of late Eocene age, described by Allen and Baldwin (1944, p. 25–27). The Coaledo formation also underlies the hills that adjoin the east edge of the sand-dune area. The rocks of the Coaledo formation are principally sandstone, siltstone, and mudstone. The unit as a whole is poorly permeable; therefore, it is not described further in this report.

From the standpoint of water supply the sand deposit of Pleistocene and Recent age is the most important geologic unit in the area. The area of the sand extends from the shore of the Pacific Ocean on the west to North Slough or bedrock hills on the east, and passes north and south beyond the boundaries of the area studied. The thickness of the sand recorded in drillers' logs ranges from 83 to 172 feet (table 3). The sections in plate 2 show the general shape of the base of the sand unit.

The sand is composed principally of grains of quartz, but it contains minor amounts of olivine, magnetite, epidote, zircon, garnet, and unidentified rock fragments. In four samples collected during the study and analyzed in the Denver Hydrologic Laboratory of the Geological Survey, the particles ranged in size from clay and silt (<0.0625 mm) to very coarse sand (1.0–2.0 mm) but were predominantly within the size classifications of fine sand (0.125–0.25 mm) and medium sand (0.25–0.5 mm) (fig. 6).

The table opposite figure 5 illustrates the range in distribution of the particles in the various size classifications, in percentage by weight of the total sample.

The entire section of sand, with few exceptions, is loosely compacted and uncemented. The exceptions are thin, probably discontinuous, silty, clayey, or limonite-cemented layers that at places are seen at the surface or reported in drillers' logs.

The sand at and near the surface is all wind-deposited dune sand. At depth the windblown sand probably is interbedded with sand that was deposited in the littoral zone at lower levels of the sea during Pleistocene time. The presence of those littoral deposits is indicated by marine fossils reported in the logs of some of the deeper wells. However, because ground water in the dune and littoral sand is hydraulically continuous, both sand deposits are considered in this report as a single unit.

SHAPE AND EXTENT OF THE GROUND-WATER BODY

The ground-water body extends throughout the area of the sand deposit. It is bounded on the east by Coos Bay, North Slough, and by the impermeable bedrock hills that rise above the dune sheet. On the west it is bounded by the Pacific Ocean. It extends northward and southward beyond the area of this study.

Fresh water saturates the sand from the water table down to the underlying impermeable bedrock. Saline water has not been found in any of the wells in the sand-dune area, although at least 22 wells in and adjacent to the area have completely penetrated the sand. For example, wells 24/13W–9L1 and -32D1, both within 1,000 feet of the average shoreline of the ocean (pl. 1), entered the bedrock beneath the sand at depths of 133 feet and 168 feet, respectively, and did not encounter any saline water in the sand (C. P. Davenport, oral communication, 1960).

The upper surface of the ground water in the sand—the water table—is represented by the levels at which water will stand in wells that tap the ground-water body. The water table is a smoothly curved surface that reflects the larger elements of the dune land topography. It is highest in areas of recharge, where water replenishes the ground-water body, and lowest in areas of ground-water

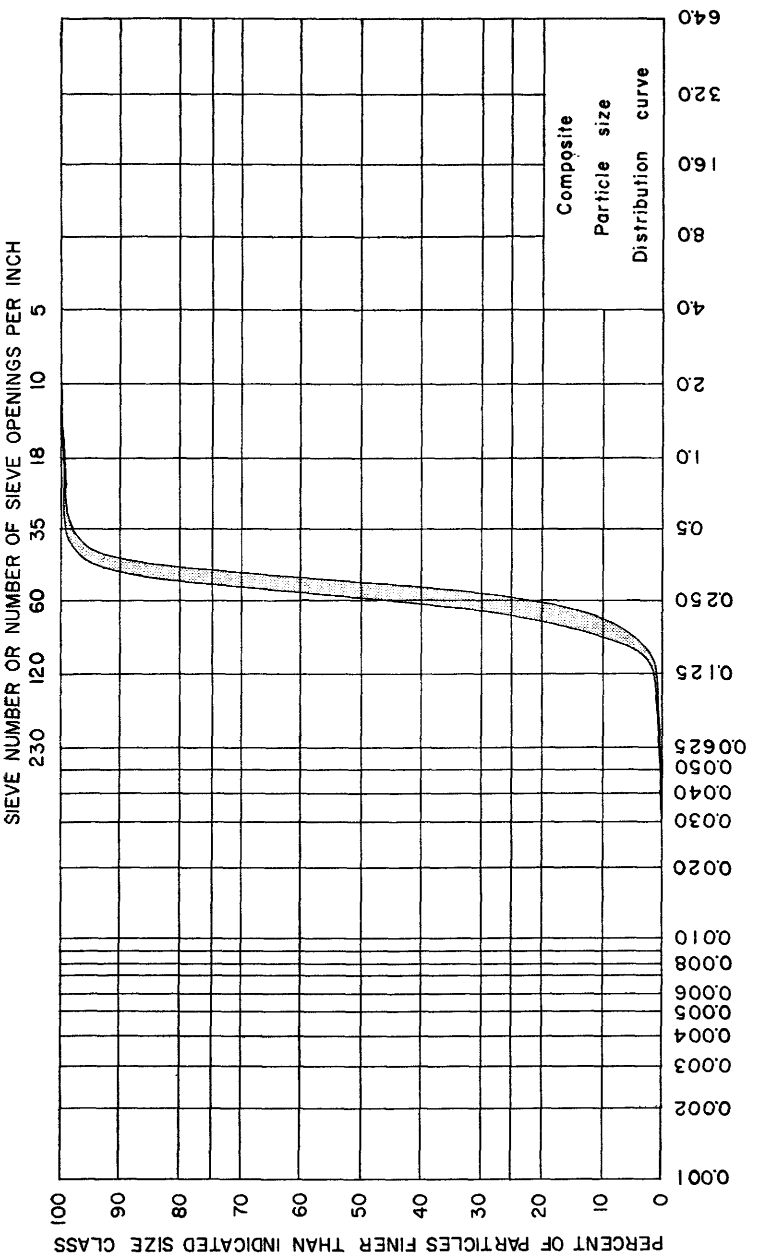

FIGURE 5.—Results of mechanical analyses of sand from the sand-dune area. The width of the curve gives the range limits in the four samples. See table on opposite page for the range in distribution of the particles in various size classifications.

Laboratory sample no. (see p. D14 for locations sampled)	Percent of total, by weight, of indicated particle size (mm)					
	Clay and silt (0.0625)	Sand sizes, in millimeters				
		Very fine (0.0625–0.125)	Fine (0.125–0.25)	Medium (0.25–0.5)	Coarse (0.5–1.0)	Very coarse (1.0–2.0)
56 ORE 1	0. 1	0. 3	33. 0	65. 7	0. 8	0. 1
56 ORE 2	. 2	. 2	19. 6	78. 5	1. 4	. 1
56 ORE 3	. 1	. 2	44. 9	54. 6	. 1	. 1
56 ORE 4	. 1	. 1	32. 8	66. 5	. 4	. 1

discharge. The water table rises and declines over a range of a few feet during the annual precipitation cycle.

The water table in the area studied lies generally within a few feet of the surface at low places, and it is probably at somewhat higher altitudes beneath the major dune ridges. The water table is highest in the vicinity of Beale Lake, where it has been measured at about 36 feet above mean sea level, and is lowest near its outer margins at the ocean, Coos Bay, and North Slough. The approximate shape of the water table along the lines of sections *A–A′* and *B–B′* is shown in plate 2.

A series of fresh-water lakes extends southward across the east half of the area. The larger named lakes are, from north to south, Beale, Snag, Sandpoint, Spirit, Horsefall, Bluebill, and Jordan Lakes. These are "ground-water" lakes—that is, their levels normally stand at or near the level of the adjacent water table. Beale Lake has the highest level, usually above an altitude of 33 feet, and the levels of the other lakes are progressively lower toward the south.

FLUCTUATION OF THE WATER TABLE

The fluctuation of the water table in the sand is principally a response to recharge—or lack of recharge—from precipitation. When the rains increase in intensity and frequency during the fall and early winter, the water table begins to rise. Abundant precipitation continues through the winter and early spring and the water table continues to rise. It rises above the land surface at low places and creates many lakes that exist only during the rainy season—in contrast to the permanent lakes that occupy the deepest depressions in the dune land. As the rains decrease in intensity and frequency during the late spring and the summer, the water table declines until the onset of the next rainy season. The relationship between fluctuation of the water table and recharge from precipitation is discussed more fully on pages D15–D20.

Data on the fluctuations of the water table were obtained by measuring water levels in a network of shallow observation wells constructed during the investigation and by periodically reading lake gages installed on Beale and Spirit Lakes. The fluctuation of water levels in the wells and lakes during this study is shown in figure 6. Records of additional levels of Spirit Lake for the period September 1945–June 1954 were obtained from Mr. and Mrs. Percy Philip and are shown in figure 9.

The hydrographs show that the water table usually is highest during the late winter or early spring and lowest during the fall. The hydrograph of Spirit Lake (fig. 9) shows that, for the 10 complete water years of record, the yearly low level in the lake occurred seven times in October, twice in September, and once in December. The yearly high levels occurred three times in February, three times in March, twice in April, and once each in January and May. The greatest fluctuation of ground-water levels measured during this investigation was 4.93 feet in well 24/13W–15R1. The lowest level in that well was 13.76 feet above mean sea level on October 22, 1954, and the highest was 18.69 feet above sea level on January 26, 1956. The maximum reported range of levels for Spirit Lake was about 5.4 feet—from a low of 16.6 feet on October 15, 1945, to a high of 22 feet above sea level on February 1, 1954.

The general accordance of the lake levels with the water table nearby is varied by the general regimen of the ground water from place to place within the area and by the rise and decline of the water table with the precipitation.

The levels of the major lakes normally stand slightly above the adjacent water table during the summertime periods of decline, stand a little below during the water table's rapid rise at the start of the rainy season, and are generally near the level of the water table during the other seasons. An example of the interplay of the lake and water-table levels, within minute dimensions, is shown by the curves for Spirit Lake and well 24/13W–28J2 on figure 7. During the summer season of 1954, the level of Spirit Lake was observed to lie one- or two-tenths of a foot above the water levels in this nearby observation well. That relative position remained through the dry season until a storm in the last week of August, at which time the water level in well 24/13W–28J2 rose to two-tenths of a foot above the level of Spirit Lake. The levels in the well and lake then fluctuated slightly above and below one another during the rainy season until April 1955, when the water levels began their seasonal decline and the water levels in the adjacent wells stood a little below the level of Spirit Lake. During the summer of 1955 the lake level remained about a quarter of a foot above the water table in well 24/13W–28J2.

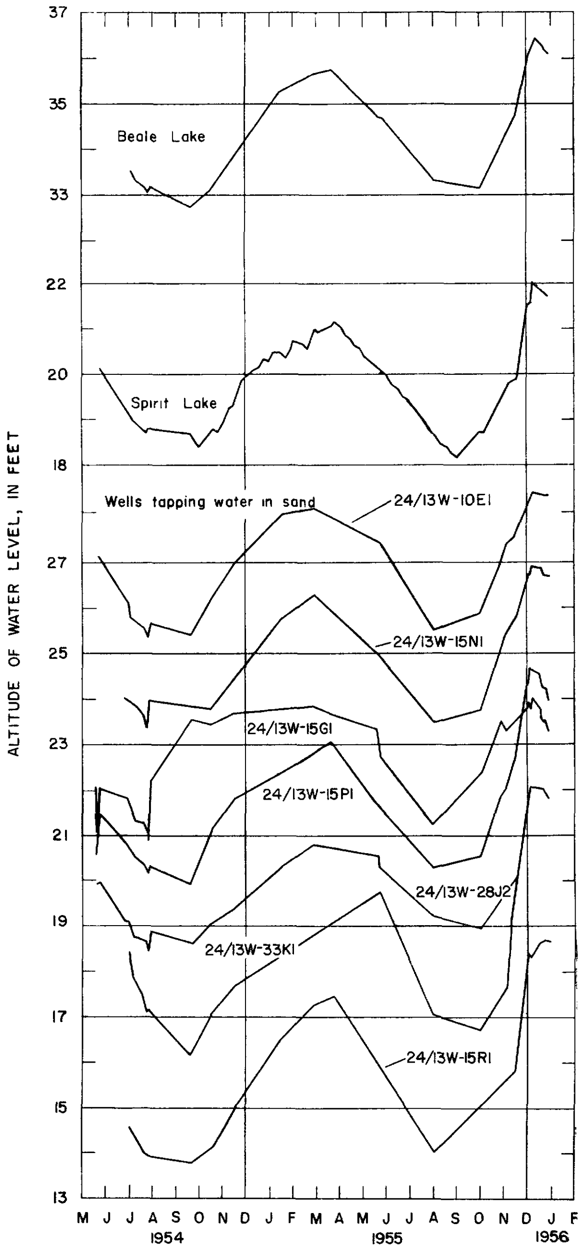

FIGURE 6.—Hydrographs of Beale Lake, Spirit Lake, and seven shallow wells tapping water in the sand-dune area north of Coos Bay, summer of 1954 to January 1956.

PROPERTIES OF THE AQUIFER

Definitions used in this report are as follows:

Permeability is the capacity of soil or rock materials to transmit water under pressure. A laboratory determination of permeability may be made by observing the rate of percolation of water through a sample of known length and cross-sectional area.

Coefficient of permeability is defined as the rate of flow of water, in gallons per day, through a cross-sectional area of 1 square foot under a hydraulic gradient of 1 foot per foot and at a water temperature of 60 degrees F.

Porosity is the ratio of the volume of the void spaces to the total volume of a rock or aggregate sample. When all voids are filled with water, porosity represents the upper limit of saturation—that is, the total water-holding capacity of soil or rock material.

Specific retention of a rock is the percentage of its volume that is occupied by water that will not drain from the rock by gravity and which therefore will not be yielded to wells.

Specific yield of a rock is the ratio of the volume of water that will drain from the rock by gravity to its own volume, stated as a percentage. The specific yield approximates the percentage of water that a given volume of rock will yield to wells. (The reader will note that the hydrologist and geologist for brevity include unconsolidated materials like sand under the inclusive term, rock.)

Coefficient of transmissibility is the rate of flow of water, in gallons per day, at the prevailing water temperature, through each vertical strip of aquifer 1 foot wide having a height equal to the thickness of the aquifer, under a unit hydraulic gradient (1 foot per foot).

Coefficient of storage of an aquifer is defined as the volume of water released from or taken into storage per unit of surface area of the aquifer per unit change in the component of head normal to that surface.

The hydrologic properties of the sand aquifer were tested by laboratory and field methods. Three disturbed samples of dune sand were taken from the surface of the sand, and one sand sample from the bottom of Beale Lake. The laboratory number and location of the sampling points appear below.

Laboratory No.	*Location*
56 ORE 1	Surface, SE¼SE¼ sec. 15, T. 24 S., R. 13 W.
56 ORE 2	Surface, SW¼NW¼ sec. 15, T. 24 S., R. 13 W.
56 ORE 3	Surface, SW¼NW¼ sec. 15, T. 24 S., R. 13 W.
56 ORE 4	Lake bottom, NE¼SW¼ sec. 10, T. 24 S., R. 13 W.

The samples were sent to the Hydrologic Laboratory of the Geological Survey at Denver, Colo., where they were tested for permeability, porosity, specific retention, specific yield, and, as previously mentioned, for grain-size distribution (fig. 5). The results of the laboratory tests are summarized below.

Laboratory No.	Specific retention (percent)	Porosity (percent)	Specific yield (percent)	Coefficient of permeability (gallons per day per square foot)
56 ORE 1	1.3	35.8	34.5	510
56 ORE 2	1.5	36.2	34.7	630
56 ORE 3	1.5	38.5	37.0	630
56 ORE 4	1.5	37.7	36.2	610
Average	1.5	37	36	600

To determine the coefficients of transmissibility and storage, a pumping test of the sand aquifer was made on June 26, 1955, by pumping well 24/13W-15G1 and observing the drawdown in six nearby observation wells. The pumped well and the observation wells penetrated only part of the aquifer. Graphs showing the drawdown and recovery of levels in two of the observation wells are given in figure 7. Using the nonequilibrium method of Theis (1935, p. 520), the coefficient of transmissibility was calculated to be about 27,000 gpd per ft (gallons per day per foot), and the coefficient of storage was calculated to be about 0.1.

Theoretically, the coefficient of transmissibility of the aquifer also can be determined by multiplying the coefficient of permeability obtained from the laboratory analysis (average about 600) by the total saturated thickness of the aquifer (average about 100 ft), which results in a value of 60,000 gpd per ft. This computed coefficient of transmissibility checks with the results of the field aquifer tests made by the Pacific Power & Light Co. on wells that nearly or completely penetrated the sand aquifer. According to C. P. Davenport, engineer for that company (oral communication, 1960), the coefficients of transmissibility determined from company tests generally ranged from about 40,000 to 60,000 gpd per ft.

The value for coefficient of transmissibility obtained from the pumping test on the shallow wells is undoubtedly low because the wells do not fully penetrate the aquifer.

RECHARGE

Recharge to the ground-water body in the area of this investigation is virtually all from precipitation that falls on the dune sheet. However, Beale Lake and the dune lands to the north receive some runoff from hills to the east.

Recharge normally begins and ground-water levels start to rise shortly after the beginning of a period of substantial precipitation.

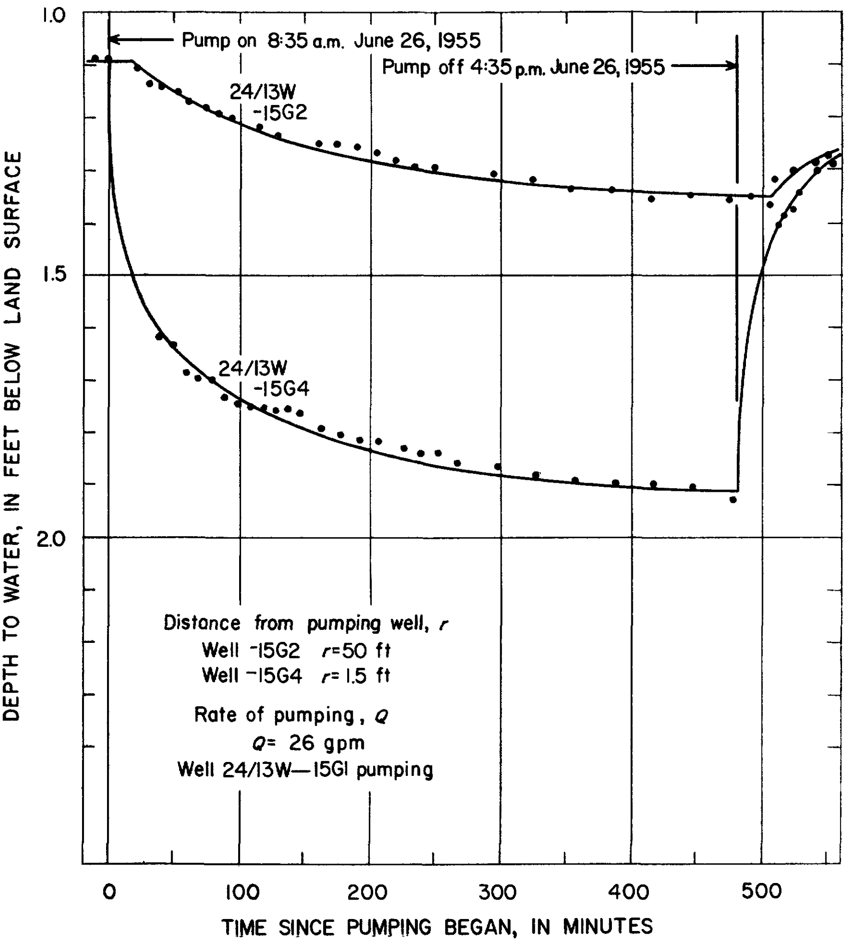

FIGURE 7.—Water levels in observation wells during a brief test of the sand aquifer at well 24/13W–15G1, near Hauser.

After a period of dry weather, the initial part of the precipitation is taken to enlarge the capillary film about each grain of sand and to bring the moisture content of the surficial sand up to field capacity. After the moisture of the sand reaches field capacity, additional water from precipitation can infiltrate and rapidly transfer to the water table. The delay, and subsequent rapid rise of the water table following the start of precipitation, is shown graphically in figure 8. As shown by this figure, the water levels in the wells were declining from July 29 to August 26, 1954, despite the small amount of precipitation that fell during that period. On August 27 about 1.37 inches of precipitation was recorded at the North Bend Airport, and the water levels in the lakes and the wells rose abruptly. The rapid

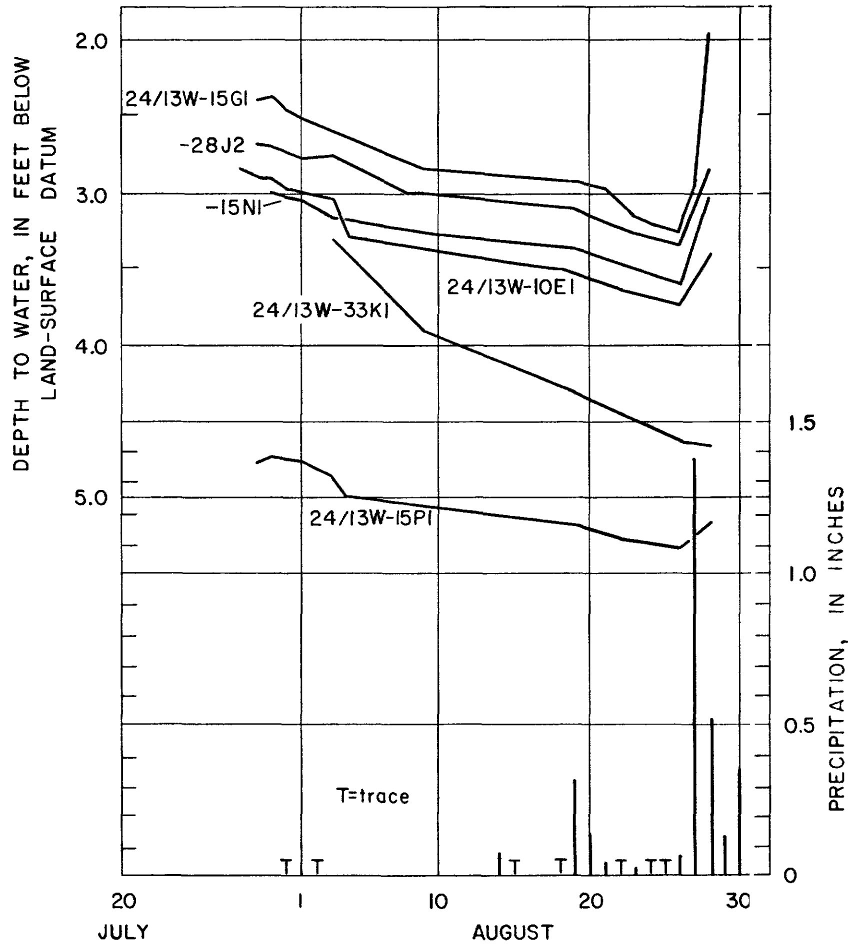

FIGURE 8.—Comparison of water levels in selected wells with precipitation at North Bend before and during the first storms of the season, July 20–Aug. 30, 1954.

rise of the water table at the beginning of the rainy season shows the excellent capacity of the sand for intercepting and storing water from precipitation.

The response of the water table to recharge from precipitation depends not only upon the distribution but also upon the intensity of the precipitation. A comparison of the monthly precipitation at North Bend with the fluctuations of water levels of Spirit Lake shows that in order for the level of Spirit Lake to rise from its low stage, the precipitation must exceed a rate of about 4 inches per month (fig. 9). As the water table rises, the hydraulic gradients steepen in the sand around the edges of the lake, and the ground-water discharge increases, tending to balance the additional recharge from

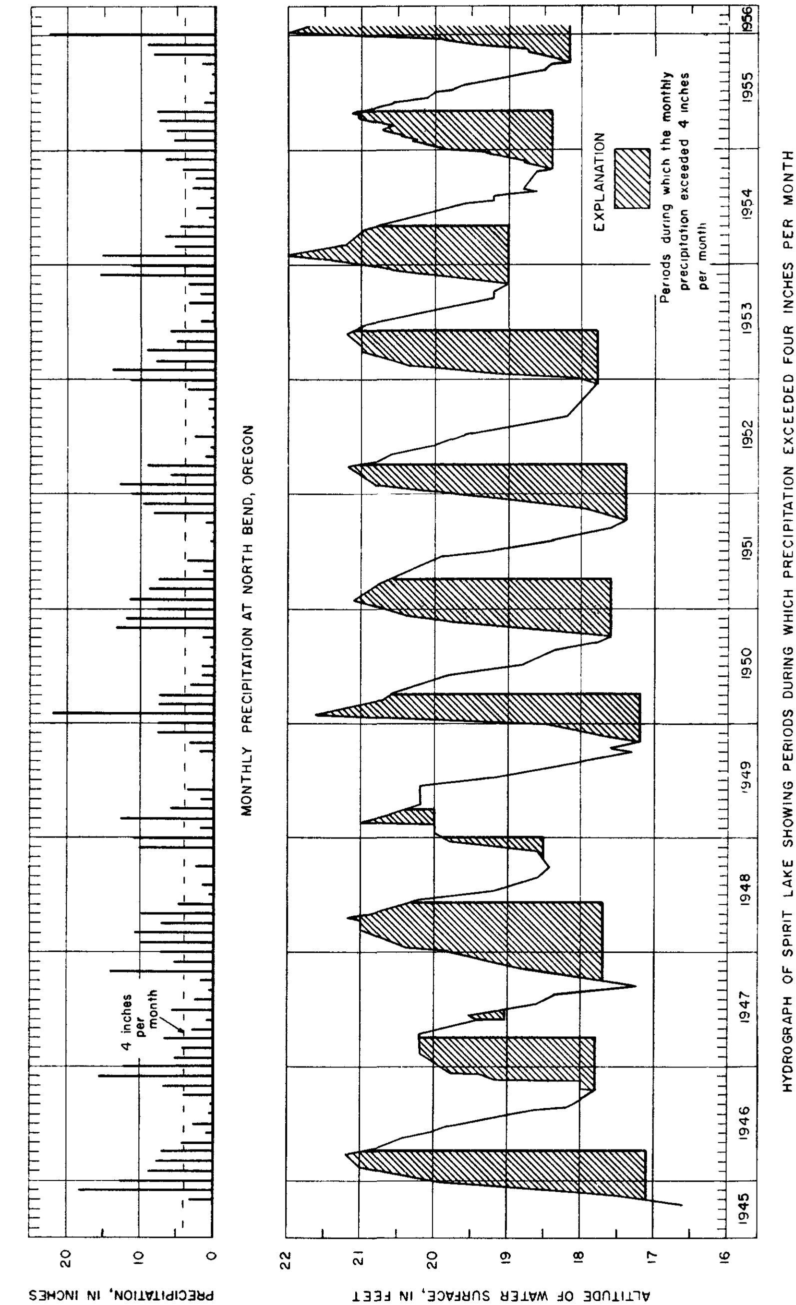

FIGURE 9.—Comparison of monthly precipitation at North Bend, Oreg., and the hydrograph of Spirit Lake for the period October 1945–January 1956.

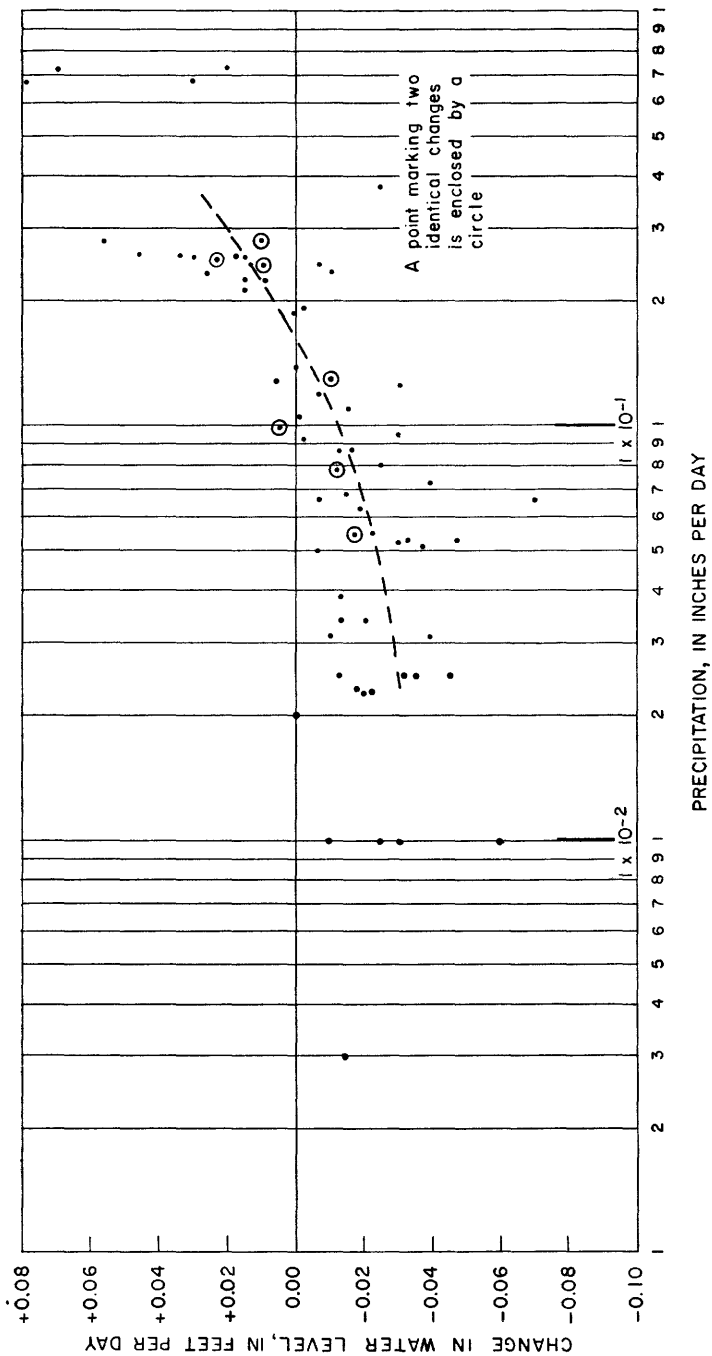

FIGURE 10—Scatter diagram showing the relation between small changes in the water levels in wells and precipitation at North Bend during the period June 1954–January 1956.

precipitation; thus, greater amounts of precipitation will be required to cause a further rise in ground-water levels. The hydrograph in figure 9 shows that, at the higher stages of Spirit Lake, recharge from a monthly rainfall of 4 inches is no longer sufficient to maintain the water table at its high level. Therefore, an infiltration of 4 inches per month, or 48 inches per year, is considered the minimum that would be required to maintain the water table within the range of levels observed during this study. This amount is equal to about 80 percent of the average yearly precipitation during the 25-water-year base period cited previously (fig. 2).

An additional estimate of the average yearly recharge to ground water in the sand-dune area was made by graphically comparing the changes in water levels in the observation wells with the precipitation that occurred between well measurements (fig. 10). Figure 10 shows a general correlation between the average daily change in water level in the wells and the average daily precipitation. An average line drawn through the scattered points on the diagram intercepts the line of zero change in water level at about 0.16 inch per day, which would amount to about 4.9 inches per month or 58 inches per year. That amount equals about 95 percent of the average yearly precipitation during the 25-water-year base period (fig. 2).

Thus, it appears that approximately 4 to 5 inches of precipitation per month is necessary to meet the evapotranspiration losses and the ground-water outflow from the area, and to maintain the water table within the range of altitudes observed during the investigation.

MOVEMENT

A ground-water divide trends north-south along a line generally through the lakes that occur interspersed from Spirit Lake to Beale Lake (pls. 1 and 2, section *A–A′*). Thus, the lakes are situated at about the highest points on the water table. East of the lakes the movement is generally to the south and east, toward North Slough and Coos Bay; west of the lakes the movement is south and west, toward Coos Bay and the ocean.

DISCHARGE

Most of the water that leaves the sand-dune area discharges from the ground-water body; there ordinarily is no surface runoff from the sand-dune area. A part of the precipitation that falls within the dune area—either on open sand, lakes, marshes, or vegetation—evaporates or is transpired by plants from the capillary zone above the water table. However, most of the precipitation percolates downward to the water table and begins to move toward points of discharge. Discharge of the ground water is principally through springs and seeps along the periphery of the dune sheet. At places where the water table is at shallow depth and the vegetation is dense, substantial ground-water discharge may occur during the growing season as evapotranspiration.

The few cases of water discharging on the surface from the area represent discharge of ground water. Ground water percolating south from Beale Lake is intercepted in a ditch system and conveyed southward to cranberry fields in sec. 10, beyond which it flows on the surface much of the year as an unnamed creek entering North Slough in the SE¼SE¼ sec. 15, T. 24 S., R. 13 W. Ground water moving from the north also flows to the surface in Henderson Marsh (a tidal marsh), and drains out with the ebb tide. Water emerging from beneath a ridge of high dunes that lies north of Jordan Cove discharges through a number of small seeps, and flows on the surface to a point at which it empties into Coos Bay.

After a prolonged period of wet weather a quicksand condition exists along the western slope of the "middle dune ridge" (pl. 2, section *A–A′*). The quicksand condition is caused by ground water percolating through the sand at or near the surface. Some of the water seeps west to the ocean through the beach ridge, and some drains south on the surface and discharges into the tidal water in Henderson Marsh.

Along the western face of the middle dune ridge, seepage discharge occurs only during the wet season, November to May, whereas along North Slough and in the Jordan Cove-Henderson Marsh area it occurs at all times. It is estimated that in the entire area the seepage discharge of ground water during the fall and winter increases to as much as 12 times that which occurs during the summer.

At places along the east side of the sand-dune area, small springs, spaced at intervals of about one-eighth mile, flow into North Slough. Spring 24/13W–15H2 is typical of the springs that flow from the east side of the sand-dune area. On June 18, 1954, the estimated flow of that spring was about 18 gallons per minute.

As surface runoff is negligible, ground-water discharge from the area through seeps and springs should approximately equal the amount of the precipitation minus the losses due to evaporation and transpiration.

Evaporation takes place from the sand near the surface but is greatest from the surface of the lakes. About 10 percent of the area is open-water surface, from which an estimated 26 inches of water per year evaporates. (See p. D5.)

Transpiration—the process by which plants transfer water to the atmosphere from the soil or from the ground-water body—probably accounts for most of the evapotranspiration losses. The vegetation, which covers about 40 percent of the area in fairly dense stands, consists largely of pine and hemlock trees; rye and Bermuda grasses; and huckleberry, willow, and salal brush. The densest vegetative cover is in the low places and around the permanent lakes, where the water table stands at shallow depth. The transpiration losses from the vegetation is not known precisely and can only be estimated by comparison with areas where transpiration rates for some types of plants have been determined experimentally. By this means, it is estimated that dense to moderately dense stands of vegetation in the area require between 30 and 36 inches of water per year—that is, between 2½ and 3 acre-feet of water per acre of vegetation.

On the basis of these estimates, an average evapotranspiration loss of about 15 inches per year could be expected for the area as a whole. If so, the total ground-water discharge through seeps and springs (equal to total precipitation minus total evapotranspiration) would average about 45 inches per year for the area as a whole. Probably about half of the total evapotranspiration is derived from moisture in the unsaturated zone above the water table; thus, of the estimated 15 inches of water lost annually through evapotranspiration, perhaps only 7 inches is derived directly from the ground-water body.

CHEMICAL QUALITY OF THE WATER

To appraise the general chemical quality of the water in the sand aquifer, eight samples of water were collected from wells, springs, and lakes and were analyzed by the Geological Survey. Two of the samples were analyzed for all the major constituents usually included in a complete water analysis; 1 was analyzed only for iron, bicarbonate, chloride, hardness, and specific conductance; 5 were analyzed only for bicarbonate, chloride, hardness, and specific conductance. The results of the analyses are presented in table 2. Table 2 also includes two analyses furnished by the Pacific Power & Light Co. Both analyses were of samples obtained from the combined discharge of the power company's three pilot wells (24/13W–33K2, L1, and Q1).

Except for the almost universal presence of undesirable amounts of iron, the waters sampled from wells, springs, and lakes were of generally good chemical quality for most domestic and industrial uses. All but 2 of the water samples were weakly acidic; the average pH of the 10 samples analyzed was 6.5, based on a scale where 7.0 is neither acidic or basic.

The highest iron content was 2.5 ppm (parts per million) in water from the combined discharge of the power company's pilot wells, and the lowest iron content, in Beale Lake water, was 0.06 ppm. A combined content of iron and manganese of 0.3 ppm or more is considered objectionable and should be removed from water for domestic and public supply. Water containing a greater concentration of iron is likely to cause a reddish-brown staining of plumbing fixtures and of clothing washed in it.

Most of the ground water is odorless and has a satisfactory taste, and its temperature is about the same as the mean annual air temperature; however, in parts of the area it is colored various shades of light brown. The brown color is common in the lakes and also occurs in the water from wells near the lagoons and marshy lakes. The water in some of the lakes, particularly the marshy ones, is the darkest observed in the area; however, some wells, even those near the marshy lakes, yield water that is clear or at least much lighter in color. The brown color probably is largely, if not entirely, due to dissolved organic matter.

The pH, iron content, and color are the known features detrimental to the quality of some of the water. The two samples analyzed by the Pacific Power & Light Co. (table 2) did not show the acid condition found in all the Geological Survey analyses; since the elapsed time between the collection and analysis of these two samples was not ascertained, the writers give preference to their data showing the waters to be slightly acid. Owing to its slight acidity, the water may be corrosive to metal pipes; the light-brown color, although entirely lacking at many places, is sufficiently obvious at other places to make treatment desirable if the water is used for domestic supply. The effects of all the detrimental properties of water quality can be removed or minimized by treatment. Corrosiveness of the water may necessitate the use of plastic or masonry pipe for the collection and conveyance of the raw water.

POTENTIAL SUPPLY FROM THE SAND-DUNE AREA

ESTIMATED AMOUNT

Most of the ground water that discharges through springs and seeps to the Pacific Ocean, North Slough, and Coos Bay could be salvaged by withdrawal from wells. As previously discussed, the average ground-water discharge through seeps and springs has been estimated to equal about 45 inches of water per year over the entire area. Thus, as much as 2,500 acre-feet of water per year per square mile, which now wastes from the sand-dune area, may be available for withdrawal. This is an average of more than 2 million gallons per day per square mile.

The area from which a substantial part of this discharge may be recovered probably is about 8 square miles within the part of the aquifer covered by this investigation. This area excludes a total of about 4 square miles of dune sand immediately adjacent to the

Pacific Ocean, North Slough, and Coos Bay, where large withdrawals from wells might produce sufficient drawdown to cause saline-water intrusion into the sand aquifer. A part of the area excluded—the low strip of sand just inside the beach ridge on the west side of the area—is occasionally overrun by the ocean waves during storms, and therefore, occasionally might, if the ground water was lowered there, contain water that was too saline for normal uses. Also excluded from the above 8-square-mile area is the northward continuation of the sand-dune area.

Inasmuch as the ground-water body extends beyond the area of this study, north of Beale Lake and southward toward North Spit, additional supplies of water should be available in those places. Beale Lake and the lakes to the north of the area studied receive some water as surface runoff from the hills to the east of the dune area. This runoff augments the recharge from direct precipitation and, thus, should add to the total recoverable supply of ground water in those localities.

PROBLEMS OF CHEMICAL QUALITY

The presence of more than 0.3 ppm of iron in all the samples of well water analyzed indicates that future wells in the area can be expected to yield water having undesirable amounts of iron. Thus, the water may require some iron-removal treatment before it would be suitable for uses requiring a low iron content. The ground water in the area is weakly acidic, and corrective treatment, such as filtration through limestone, possibly will be necessary to reduce the acidity and prevent excessive corrosion to transmission pipes and other fixtures of a water system.

Because the sand aquifer extends more than 100 feet below sea level, it must be in hydraulic contact with sea or brackish water west of the beach and beneath Coos Bay. It was probably also in contact with saline water near the bottom of North Slough prior to the recent closure of North Slough by a causeway. Therefore, the potential danger of intrusion of sea or brackish water into the aquifer should be recognized. The intrusion of highly saline water could result from excessive and prolonged drawdown of the water table by large concentrated pumping withdrawals. Because none of the existing wells penetrated salt water, the position of the interface between salt water and fresh water is not known, but presumably it is only a short distance offshore from the margins of the dune area. However, because the recharge to the sand a short distance inland from the beach apparently is ample to maintain the water table at least several feet above sea level throughout the year, the natural hydrostatic pressure and seaward movement of the fresh water should be sufficient to hold back the sea water, even if withdrawals farther inland lower the water table locally below sea level. Therefore, so long as the water table is maintained sufficiently high near the beaches, the sea water will be unable to migrate inland.

Any plans for large-scale development of the ground-water resources in the area should include provisions for (1) constructing and maintaining a network of deep wells near the edges of the dune sheet for monitoring the water level and chloride content of the ground water, and (2) maintaining the water table at least several feet above sea level around the periphery of the dune sheet to prevent intrusion of sea and brackish water into the aquifer.

GENERAL NATURE OF WITHDRAWAL WORKS

Experience gained during this investigation and the results of experiments made by the Pacific Power & Light Co. indicate that the most practical method of extracting water from the sand is by means of properly screened and developed vertical wells. For optimum efficiency, the wells should be screened through the full saturated thickness of the aquifer. The wells should be spaced to minimize the interference between wells and to prevent drawdown in any one part of the area.

REFERENCES CITED

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Cooper, W. S., 1958, Coastal sand dunes of Oregon and Washington: Geol. Soc. America Mem. 72, 169 p., 12 figs., 22 pls.

Theis, C. V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Am. Geophys. Union Trans., p. 519–524.

TABLE 1.—*Records of representative wells and springs in the sand-dune area north of Coos Bay*

[Location of wells is shown on pl. 1]

Topography: Bd, beach area in dune lands; Ed, edge of dune area; Ld, lagoon area within dune lands; Sd, sand dune.

Altitude of land-surface datum: Altitude of land-surface datum at well obtained by spirit leveling.

Type of well: B, bored; D, dug; Dn, driven; Dr, drilled; J, jetted.

Water level: Water levels expressed in feet and decimals were measured by the Geological Survey; those in whole feet were reported by the owner. All water levels are in feet above mean sea level (1929 datum adjusted).

Type of pump: C, centrifugal; N, none; P, plunger; T, turbine.

Use of well or spring: D, domestic; N, none; O, observation; S, stock.

Remarks: Ca, chemical analyses of water in table 2; dd, drawdown; gpm, gallons per minute; H, hydrograph included in this report; L, lithologic log of well in table 3; Temp, temperature of water in well (°F).

Well or spring	Owner or tenant	Topography	Altitude of land-surface datum (feet)	Type of well	Depth of well	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone(s): Depth to top (feet)	Water-bearing zone(s): Thickness (feet)	Water-bearing zone(s): Character of material	Water level: Feet above sea level	Water level: Date measured	Type of pump	Yield (gallons per minute)	Use	Remarks
T. 24 S., R. 13 W.																
9L1	Pacific Power & Light Co. (well 201).	Bd	10	Dr	155	2	-------	0	133	Sand	------	--------	N	-------	O	Piezometer set at 108 ft below land surface. L.
10E1	U.S. Forest Service	Ld	29	J	18	2	18	2	16	do	27.1	6-23-54	N	-------	O	Pumped 30 gpm; temp 54, 6-23-54. H.
10L1	Pacific Power & Light Co. (well 200).	Ld	35	Dr	505	2	121	0	107	do	------	--------	N	-------	O	L.
14D1	Kay Howard	Ed	50	D	45	24	45	------	------	do	------	--------	N	-------	D	Yields about 25 gpm.
15B1	do	Ld	30	Dr	12	1¼	12	------	------	do	------	--------	C	-------	D	
15G1	U.S. Forest Service	Ld	24	J	19	2	19	2	17	do	22.1	6-17-54	N	-------	O	Pumped 30 gpm; temp 55, 6-18-54. Ca, H.
15G2	do	Ld	25	J	19	1½	19	2	17	do	21.9	7-28-54	N	-------	O	Pumped 30 gpm; temp 56, 6-24-54.
15G3	do	Ld	24	J	10	1½	10	2	8	do	21.3	8-19-54	N	-------	O	
15G4	U.S. Forest Service	Ld	24	J	10	1½	10	2	8	Sand	21.3	8-19-54	N	-------	O	
15G5	do	Ld	24	J	10	1½	10	2	8	do	21.2	8-19-54	N	-------	O	
15G6	do	Ld	24	J	10	1½	10	2	8	do	21.4	8-19-54	N	-------	O	
15G7	do	Ld	24	J	10	1½	10	2	8	do	21.4	8-19-54	------	-------	O	
15G8	Pacific Power & Light Co. (Radio Direction Finder Station well 15G9).	Ld	23	B	85	2	-------	0	83	do	------	--------	------	-------	O	L.
15H1	Reuben Lyons	Ed	13	Dr	18	1¼	18	2	------	do	12	--------	P	-------	D	Supplies water to 2 houses.

15H2	U.S. Forest Service	Ed	15							do			N		S	Spring. Flow varies throughout the year; on June 18, 1954, it was 18 gpm. Ca.
15N1	Sand Point Lake Gun Club.	Ld	27	J	10	1½	10	2	8	do	24.0	7-30-54	N		O	Pumped 30 gpm; Temp 54, 6-18-54. H.
15P1	U.S. Forest Service	Sd	25	J	9	2	7	4	5	do	20.6	6-19-54	N		O	Pumped 25 gpm. Ca, H.
15R1	do	Sd	20	J	10	1½	10	4	6	do	14.6	7-30-54	N		O	Ca, H.
15R2	do	Ed	10							do					N	Spring. Flow varies throughout the year.
16N1	do	Bd	8	Dr	6	1½	6	2	4	do	5.7	7-31-54	N		O	
16Q1	do	Sd	23	Dr	10	1½	8.5	2.5	6	do	20.4	7-31-54	N		O	Water level varies from near surface in January to about 3½ ft below surface in August.
22D1	Sand Point Lake Gun Club.	Sd	24	Dr	10	1¼	10	4	6	do	18.2	7-28-54	P	4	D, O	Domestic water supply for hunting camp.
28J1	Percy Philip	Ld	22	Dr	8	1¼	8	0	8	Sand	20.0	6-22-54	N		O	Former domestic well; hardpan streak at 8 ft depth. Ca; Temp 54, 6-20-54.
28J2	do	Ld	20	J	19.5	1½	19.5	0.5	19	do	19.9	6-20-54	N		O	Temp 54. H.
28J3	do	Ld	22	Dr		1¼		0		do			P	4	D	L.
28P1	Pacific Power & Light Co. (well 204).		21	Dr	179	2		0	172	do			N		O	
29B1	U.S. Forest Service	Bd	7	J	5	1½	5	2	3	do	5.5	8- 1-54	N		O	Pumped 20 gpm. Temp 54, 8-1-54; well submerged during wet season.
31J1	do	Ld	5	Dr	6.5	1½	6.5	0	5.5	do	3.6	8- 3-54	N		O	
32D1	Pacific Power & Light Co. (well 205).	Bd	7	Dr	182	2		0	168				N		O	Piezometer in well at about 141 ft below land surface. L.
33K1	U.S. Forest Service	Sd	22	J	10.3	2	10.3	3	7	do	18.4	8- 3-54	N		O	Pumped 30 gpm. H.
33K2	Pacific Power & Light Co. (pilot well 3).	Sd	21	Dr	140	10		0	136	do			T	650		Proposed for industrial use. 10-inch screen set between 78 and 129½ ft. Ca, L.
33L1	Pacific Power & Light Co. (pilot well 2).	Sd	22	Dr	145	12		0	138	do			T			Proposed for industrial use. Double gravel-pack well with 12-inch-diameter screen set between 56½ and 135 ft; yields 8 gpm per ft dd. Ca, L.
33Q1	Pacific Power & Light Co. (pilot well 4).	Sd	26	Dr	142	10		0	138.5	do			T	650		Proposed for industrial use. Gravel-pack well with 10-inch screen set between 82 and 133 ft. Ca, L.

TABLE 2.—*Chemical analyses of water from wells, springs, and lakes of the sand-dune area*

[Analyses by U.S. Geological Survey except as indicated]

Well	Source	Date of collection	Temperature (°F)	Parts per million: Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Hardness as $CaCO_3$	Noncarbonate hardness	Units of color [1]	Specific conductance micromhos at 25°C	pH
24/13W-10L	Beale Lake	12-15-55	50	37	1.6	0.06	1.2	1.2	9.6	0.9	7	0	1.3	15	0.1	0.1	0.01	8	2	10	66	6.5
-15G1	Well	12-15-55	56	68	19	.92	2.4	2.5	8.3	1.4	28	0	0.4	10	.1	1.4	.05	16	0	175	80.6	6.3
-15H2	Spring	12-16-55	50	--	--	--	--	--	--	--	22	--	--	20	--	--	--	18	0	--	105	6.3
-15N	Sand Point Lake.	12-16-55	50	--	--	--	--	--	--	--	7	--	--	7	--	--	--	7	1	--	40.5	6.3
-15P1	Well	12-15-55	53	--	--	--	--	--	--	--	7	--	--	33	--	--	--	24	18	--	124	5.9
-15R2	Spring	12-15-55	50	--	--	--	--	--	--	--	14	--	--	24	--	--	--	16	5	--	121	6.3
-28H	Spirit Lake	12-16 55-	50	--	--	--	--	--	--	--	8	--	--	17	--	--	--	9	2	--	73.5	5.9
-28J1	Well	12-16-55	50	--	--	.36	--	--	--	--	20	--	--	10	--	--	--	17	1	--	73.3	6.3
-33K2, -33L1, -33Q1 [2]	Wells	8-8-58	--	148	22.7	2.5	32.5	3.4	9.7	4.9	11	0	2.9	16.4	.0	.1	--	95	--	--	--	7.6
-33K2, -33L1, -33Q1 [2]	do	4-7-59	--	[3] 162	20.2	2.44	30.8	4.9	11.5	6.0	12	0	3.0	18.3	.0	.0	--	97	--	--	--	7.8

[1] U.S. Public Health Service. Platinum chloride method.
[2] Sample collected from combined discharge of the 3 designated wells. Analyses by Charlton Laboratories, Portland, Oreg.
[3] Total dissolved solids include 0.04 ppm manganese (Mn), and 0.06 ppm aluminum (Al).

TABLE 3.—*Logs of wells*

24/13W–9L1

[Pacific Power & Light Co., well 201. Alt. 10 ft. Piezometer set in hole 108 ft. below land surface. Drilled in 1957]

Materials	Thickness (feet)	Depth (feet)
Quaternary deposits:		
Sand, unconsolidated	40	40
Sand, unconsolidated and semiconsolidated	30	70
Sand, having trace of clay	5	75
Sand	10	85
Sand, containing shell fragments	3	88
Sand, containing claystone fragments	2	90
Quaternary deposits—Con.		
Sand	14	104
Sand, containing few tiny rounded shale fragments	13	117
Sand, containing traces of mica and shells	16	133
Coaledo formation:		
Siltstone and mudstone, consolidated	22	155

24/13W–10L1

[Pacific Power & Light Co., well 200. Alt. 35 ft. Drilled in 1957]

Materials	Thickness (feet)	Depth (feet)
Quaternary deposits:		
Sand, consolidated and slightly consolidated	49	49
Sand, consolidated and slightly consolidated; thin clay lenses to ¼-in. thick	4	53
Sand	4	57
Sand, containing clay fragments to ½-in. diameter	2	59
Sand, and dark gray-green clay, intermixed	3	62
Sand, containing clay fragments to ¾-in. diameter	2	64
Sand, having numerous sandy clay fragments to ½-in. diameter	3	67
Sand, containing few small clay fragments	3	70
Sand	6	76
Sand, containing trace of mica; slightly fossiliferous	4	80
Sand	14	94
Sand; trace of clay and claystone fragments	3	97
Sand, containing mudstone fragments	9	106
Sand, containing pebbles of sandstone, siltstone, and chert	1	107
Coaledo formation:		
Clay and mudstone, dark-brown	14	121
Claystone, firm, dark-gray	19	140
Claystone, interbedded, firm, gray	10	150
Claystone, firm to well compacted, somewhat crumbly, dark-gray	10	160
Claystone, dark-gray; interbeds of soft green clay	30	190
Claystone, with thin streaks of sandy siltstone	10	200
Claystone, with some interbeds of soft olive-green clay; apparent dip is 30°	10	210
Coaledo formation—Con.		
Claystone, dark-gray to brown; hard drilling at 237 ft possibly chert	27	237
Claystone, light gray-blue	13	250
Claystone, silty to sandy, gray-green, fossiliferous; zones of fractured claystone	10	260
Claystone, well-indurated	22	282
Chert (?)	2	284
Claystone, well-indurated; interbedded soft streaks	16	300
Claystone, well-indurated; 6-in. bed of silty blue claystone; apparent dip 15° to 20°	10	310
Claystone and clay, interbedded, olive-drab	35	345
Claystone, well-indurated, fossiliferous; chert streaks	5	350
Claystone, well-indurated, light-gray to gray-green; apparent dip 15° to 20°	10	360
Claystone, hard and soft interbedded; 3-in. chert streak at 352 ft	27	387
Claystone, fossiliferous, hard; chert streaks	13	400
Claystone, well-indurated, various colors; dip 15° to 20°	10	410
Clay and claystone, interbedded	40	450
Claystone, well-indurated; dip 20° to 30°	10	460
Claystone, well-indurated with soft beds of olive-drab claystone	40	500
Claystone, well-compacted; soft olive-drab claystone	5	505

TABLE 3.—*Logs of wells*—Continued

24/13W-15G8

[Pacific Power & Light Co. Radar Cluster well 15G9. Alt. 23 ft. Auger drilled in 1957]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Quaternary deposits:			Coaledo formation:		
Topsoil and sand	2	2	Clay, having dark shale-like partings	2	85
Sand, gray	18	20			
Sand, brown and gray; hard silt streak at 22 ft.	10	30			
Sand, blue-gray; hard streaks at 62, 68, and 75 ft.	48	78			
Clay, sandy	5	83			

24/13W-28P1

[Pacific Power & Light Co., well 204. Alt. 21 ft. Drilled in 1957]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Quaternary deposits:			Quaternary deposits—Con.		
Dune sand, unconsolidated, buff	6	6	Sand, gray-black; some mica	4	136
Dune sand, unconsolidated, gray	14	20	Sand, gray-black; several small fragments of brown clay	4	140
Dune sand, unconsolidated, gray; some woody material	3	23	Sand, gray-black; some mica	4	144
Dune sand, unconsolidated; much decayed plant material	8	31	Sand, gray-black; some organic material	4	148
Dune sand, dark-gray	9	40	Sand, gray-black; very small clay fragments	5	153
Dune sand, dark-gray; several small clay fragments	2	42	Sand, gray-black, fossiliferous	3	156
Dune sand, dark-gray	4	46	Sand, gray-black, fossiliferous; clay particles containing shell fragments	2	158
Dune sand, dark-gray; few small clay particles	4	50	Sand, gray-black; clay fragments	3	161
Dune sand, dark-gray	25	75	Sand, gray-black, fossiliferous; few small to medium pebbles	3	164
Dune sand, dark-gray; few claystone pebbles	5	80	Sand, gray-black, fossiliferous; organic material and clay fragments	4	168
Dune sand, dark-gray; few small sandy, clayey fragments	29	109	Sand, gray-black; gray-green clay fragments	4	172
Dune sand, dark-gray; few clay fragments	15	124	Coaledo formation:		
Sand, gray-black, slightly fossiliferous	3	127	Claystone, gray-green	7	179
Sand, gray-black, woody material and mica	5	132			

24/13W-32D1

[Pacific Power & Light Co., well 205. Alt. 7 ft. Piezometer set in well at about 141 ft. below land surface. Drilled in 1957]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Quaternary deposits:			Coaledo formation:		
Sand, unconsolidated	160	160	Clay, soft, gray	14	182
Sand, inconsolidated; interbedded pebbles	8	168			

TABLE 3.—*Logs of wells*—Continued

24/13W-33K2

[Pacific Power & Light Co. pilot well 3. Alt. 21 ft. 10-inch screen set between 78 and 129½ ft. Drilled in 1957]

Materials	Thickness (feet)	Depth (feet)
Quaternary deposits:		
Sand, crossbedded, dominantly fine grained; winnowed in part and poorly sorted in part; contains thin irregular bands of clay	35	35
Sand, fine-grained, fossiliferous	20	55
Sand, crossbedded, coarser; few thin clay bands near top	15	70
Sand, crossbedded, medium- to coarse-grained, well-sorted, fossiliferous	5	75
Sand, crossbedded, medium- to coarse-grained, good to moderate sorting, fossiliferous	20	95
Quaternary deposits—Con.		
Sand, crossbedded, coarse-grained, medium sorting, fossiliferous	5	100
Sand, crossbedded, medium- to fine-grained, moderate to poor sorting, fossiliferous	5	105
Sand, crossbedded, medium- to fine-grained, relatively poor sorting, fossiliferous; may contain thin laminae of clay	25	130
Sand, coarse-grained; large shell and rock fragments	6	136
Coaledo formation:		
Clay, shale, or siltstone	4	140

24/13W-33L1

[Pacific Power & Light Co. pilot well 2. Alt. 22 ft. Double gravel-pack well with 12-in. screen set between 56½ and 135 ft. Drilled in 1957]

Materials	Thickness (feet)	Depth (feet)
Quaternary deposits:		
No sample	20	20
Sand, crossbedded, dominantly fine-grained; winnowed in part and poorly sorted in part; contains thin, irregular bands of clay	20	40
Sand, crossbedded, fine-grained; irregular bands of clay	15	55
Sand, crossbedded, coarser, fossiliferous	5	60
Sand, crossbedded, medium- to coarse-grained, well-sorted	15	75
Sand, crossbedded, medium- to coarse-grained, good to moderated sorting, fossiliferous	10	85
Quaternary deposits—Con.		
Sand, crossbedded, coarse-grained, medium sorting, fossiliferous	10	95
Sand, crossbedded, medium- to fine-grained, moderate to poor sorting, fossiliferous	25	120
Sand, crossbedded, medium- to fine-grained, relatively poor sorting, fossiliferous; may contain thin laminae of clay	15	135
Sand, coarse-grained; large shale and rock fragments	3	138
Coaledo formation:		
Clay, shale, or siltstone	7	145

TABLE 3.—*Logs of wells*—Continued

24/13W-33Q1

[Pacific Power & Light Co. pilot well 4. Alt. 26 ft. Gravel-pack well with 10-in. screen set between 82¼ and 133¾ ft. Drilled in 1957]

Materials	Thickness (feet)	Depth (feet)
Quaternary deposits:		
Sand, crossbedded, dominantly fine-grained; winnowed in part and poorly sorted in part; contains thin, irregular bands of clay	45	45
Sand, crossbedded, coarse-grained, fossiliferous	20	65
Sand, crossbedded, medium-to coarse-grained, well-sorted, fossiliferous	5	70
Sand, crossbedded, medium-to coarse-grained, good to moderate sorting, fossiliferous	20	90
Sand, crossbedded, coarse-grained. medium sorting, fossiliferous	10	100
Quaternary deposits—Con.		
No sample	5	105
Sand, crossbedded, coarse-grained, medium sorting, fossiliferous	15	120
Sand, crossbedded, medium- to fine-grained, poor sorting, fossiliferous	5	125
Sand, crossbedded, medium- to fine-grained, relatively poor sorting, fossiliferous; may contain thin laminae of clay	13.5	138.5
Coaledo formation:		
Clay, shale, or siltstone	3.5	142