STATE OF WASHINGTON
DANIEL J. EVANS, Governor

DEPARTMENT OF ECOLOGY
JOHN A. BIGGS, Director

Water-Supply Bulletin No. 35

AVAILABILITY OF GROUND WATER IN WESTERN COWLITZ COUNTY, WASHINGTON

By
D. A. Myers

Prepared in cooperation with
UNITED STATES GEOLOGICAL SURVEY

1970

ERRATA SHEET

Department of Ecology
Water Supply Bulletin No. 35

1. Page 9, 2nd Paragraph, 5th line. "prophyritic" should be porphyritic.

2. Page 9, Last line - See page "13", not 16.

3. Page 12, Line 4 from bottom. hyphen after induced.

4. Page 22, Paragraph 2, last word should be measurably.

Plate 1.

Explanation

A. Tertiary Bracket should include Pliocene.

B. Tv - Volcanic Rocks, "prophyritic" should be porphyritic.

C. Tsv - "phyroclastic" should be pyroclastic.

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Per Copy Price $2.00
DEPARTMENT OF ECOLOGY
Airdustrial Park, Olympia, Washington

FOREWORD

Publication of Water Supply Bulletin No. 35 completes a sequence of reports which combined describe the geology and ground water resources of the Puget Lowland on a county basis. This area extends from Whatcom County on the north to Clark County on the south. Said area is the state's most densely populated area and is destined to become one of the west coast's major strip cities.

In recent years there has been a continuing demand from engineers, geologists and planners of both public and private agencies requesting geohydrologic information to assist them in evaluating and developing water supply projects to serve the needs of cities, industries and individuals of Cowlitz County.

This report was prepared to answer some of the questions raised and acquaint people with the geologic conditions of Cowlitz County which control the storage, movement and yield of ground water with the thought that an informed people can develop and utilize this valuable resource without exploiting it or causing damage to the local environment.

Water Supply Bulletin No. 35 is a product of our cooperative data gathering program with the U. S. Geological Survey designed to evaluate, describe and inventory the state's ground water resources.

Robert H. Russell
Water Resources Branch

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AVAILABILITY OF GROUND WATER IN WESTERN COWLITZ COUNTY, WASHINGTON

By

D. A. Myers

ABSTRACT

Cowlitz County is an area of major use of ground water in the State of Washington. Although the large towns in the area use surface sources for municipal supply, the major industries (wood products and aluminum) depend heavily on ground-water sources. The rural population of the county also depends primarily on individually owned wells for domestic water. A total of about 59 billion gallons, from all sources, is used annually in the county.

Wells in the county produce water from Tertiary sedimentary and igneous rocks and Holocene alluvial materials. The wells range in depth from less than 6 to more than 600 feet, and yields from these wells range from less than 1 to more than 3,000 gpm (gallons per minute). A wide variation in yields from alluvial aquifers is due primarily to the percentage of clay and silt they contain.

Wells near the Columbia River tap the most productive of alluvial aquifers. Water levels in these wells show a response to river stage that is almost immediate and of the same general magnitude as the range in tidal stage of the river.

Ground-water use in some parts of Cowlitz County is limited by the quality of the water. Observed dissolved-iron concentrations range from zero to 36.0 mg/l (milligrams per liter), and undesirably high concentrations are common in the densely populated areas. In most other respects, the chemical quality of the ground water is generally good.

INTRODUCTION

Purpose and Scope

The lowland of Cowlitz County is growing in both population and industrial development. The suburban population of the county is dependent mostly on ground water for domestic supply. In addition, ground water is being used in increasing amounts to meet industrial needs. However, the development of the ground-water resource is hampered by the limited extent of high-yield aquifers and by the high iron concentration in some of the water. The purpose of this report is to define the availability and quality of the ground water as a guide for the management and development of this resource.

This investigation consisted of a qualitative evaluation of the general ground-water conditions based on: (1) interpretation of the water-bearing characteristics of the various rock units; (2) extrapolation of information available for adjacent areas; (3) records of wells in the area; and (4) chemical analyses of ground-water samples. Information concerning the rock units was obtained in part from previous studies and in part by a geologic reconnaissance by the writer. The geologic reconnaissance and field inventory of wells were carried out during the period July 1967-June 1968.

Location

Cowlitz County is adjacent to the Columbia River in southwestern Washington (fig. 1) and lies within the Puget Trough as defined by Fenneman (1931, p. 443). The area of the study, approximately 830 square miles, is limited to the more heavily populated parts of the county.

Previous Investigations

A previous investigation of the availability of ground water in Cowlitz County was local in scope. This was a study made for the Cowlitz County Public Utilities District by Donald Birch, a consulting geologist, and covered ground-water conditions in the Longview area only.

Investigations of large areal extent were conducted previously to the north and south of Cowlitz County. Lewis County was studied during the period 1952-1959 (Weigle and Foxworthy, 1962), and Clark County was investigated during the period 1949-55 (Mundorff, 1964). Those studies provided substantial guidance to the course of the present investigation.

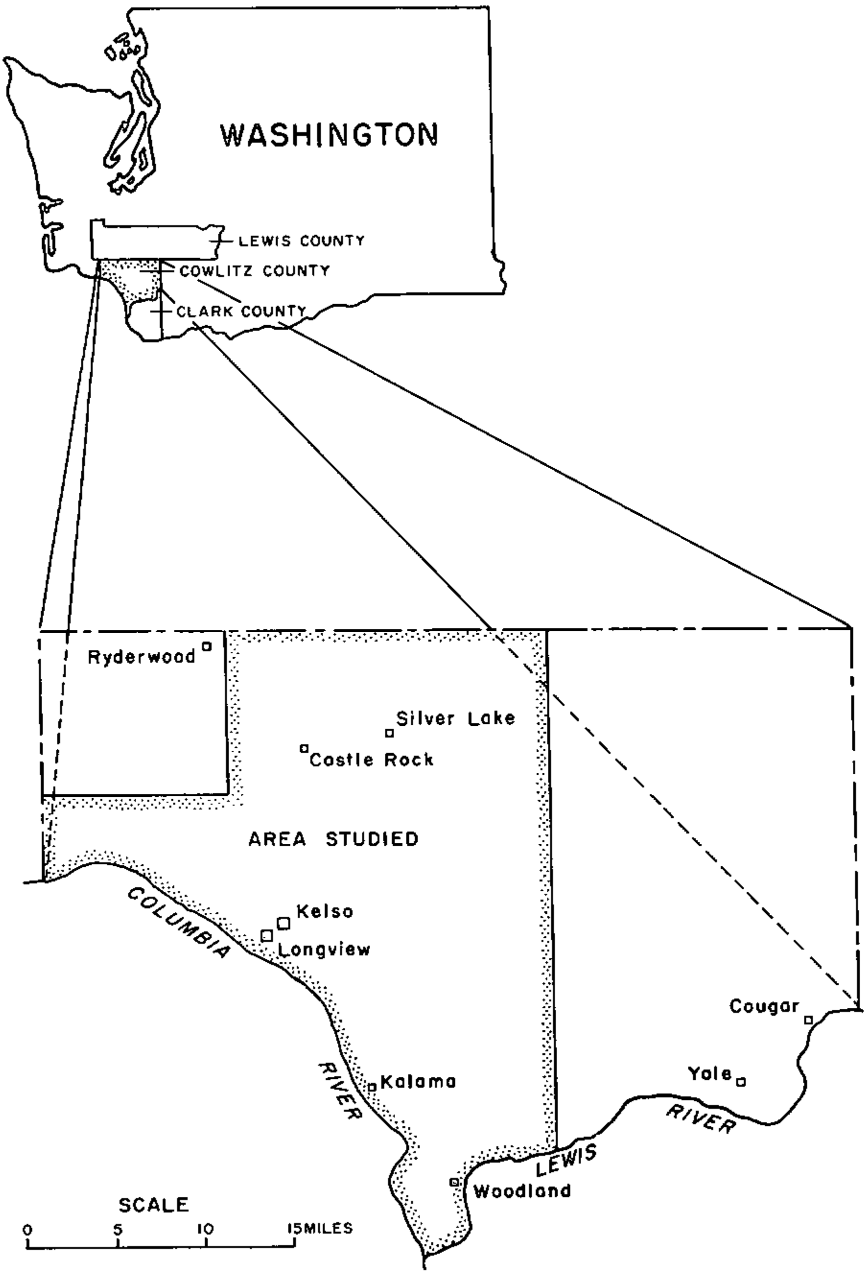

Figure 1.--Locations of Cowlitz County and area studied.

Geologic investigations have been made by Wilkinson, Lowry, and Baldwin (1946), Henricksen (1956), Roberts (1958), and Livingston (1966). However, these investigations did not include the entire area of this report, and it was necessary to supplement them with reconnaissance mapping.

Well-Numbering System

In this report, wells are designated by symbols that indicate their location according to the official rectangular public-land survey. For example, in the symbol 7/1-8B1, the part preceding the hyphen indicates the township and range (T. 7 N., R. 1 W.) north and west of the Willamette Base Line and Meridian. Because most of the wells listed are west of the meridian, the letter "W" is omitted; for wells located east of the meridian, the letter "E" is added. As the study area is entirely north of the base line, the letter "N" also is omitted. The first number after the hyphen indicates the section (sec. 8), and the letter B gives the 40-acre subdivision of the section as shown in figure 2. The last number is the sequence number of the well listed within the particular 40-acre tract. Thus, the well 7/1-8B1 is the first well canvassed in the NW 1/4 NE 1/4 sec. 8, T. 7 N., R. 1 W.

Records of representative wells in the study area are listed in table 6 and drillers' logs are in table 7. In both tables the wells are listed sequentially by township, range, section and 40-acre tract according to the well-numbering system.

Locations of the wells are shown on plate 2. There the well number is shortened to the notation for the 40-acre tract and sequence number (as B1) within the appropriate section of land.

Acknowledgments

This investigation was facilitated by the assistance of many individuals. Well data were supplied by well owners and users and by well drillers. Additional valuable assistance and information were given by the Reynolds Metals Company, International Paper Company, Robinson and Roberts (consulting geologists), and Karl Kanoke of Bechtel Corporation. Critical review of the manuscript was made by Robert H. Russell of the Washington State Department of Ecology, and by K. L. Walters and A. R. Leonard of the Geological Survey. The friendly cooperation of all is acknowledged.

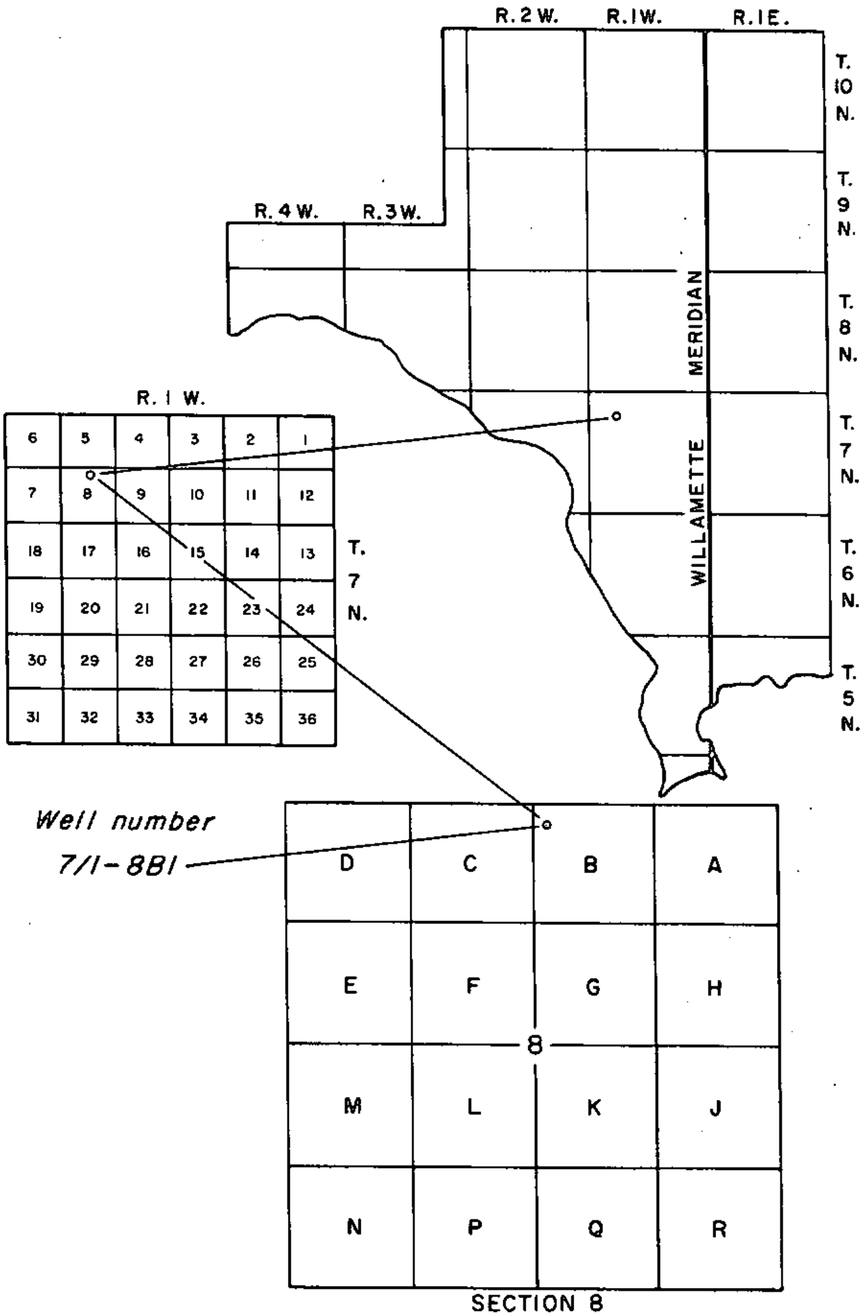

Figure 2.--Well-numbering system.

The study was under the direction of L. B. Laird, district chief of the Washington District of the U. S. Geological Survey, Water Resources Division. It was conducted in cooperation with the Washington State Department of Water Resources, directed by H. M. Ahlquist, now the Department of Ecology, J. A. Biggs, Director.

Climate

The climate of Cowlitz County is typical of western Washington. The chief characteristics are mild, wet winters and moderately warm, dry summers. Climatological data are available for several U. S. Weather Bureau stations in Cowlitz and adjacent counties (table 1).

Table 1.--Mean annual precipitation at weather stations in and near Cowlitz County, Washington

Station	Location	Mean annual precipitation (inches)
Toledo	Lewis Co., 12 miles north of Castle Rock	55
Castle Rock	Cowlitz Co., shown in figure 3	54
Longview	do.	45
Kalama	do.	64
Woodland	do.	46
Cougar	do.	110
Cathlamet	Wahkiakum Co., 20 miles west of Longview	74
Ridgefield	Clark Co., 8 miles south of Woodland	49

The areal distribution of precipitation in the county (fig. 3) reflects the orographic influence of the Cascade Range to the east. The average measured precipitation is least (45 inches per year) at Longview (elevation 12 feet) and greatest (110 inches per year) at Cougar (elevation 659 feet). Monthly precipitation is greatest in December and least in July. About three-fourths of the precipitation falls in the 6-month period October 1-March 31 during an average year.

The summer of 1967 was unusually dry in the Pacific Northwest. In Cowlitz County rainfall was below normal for 5 successive months; total deficiency from normal during this period amounted to 4.15 inches, or about 50 percent of the normal precipitation. As it was during this time that water levels were measured in many of the wells (table 6), the measurements probably reflect the extended dry season.

Air temperatures at lower altitudes in Cowlitz County are generally mild, Longview has a 30-year mean of 51.3°F, although the extreme range at that station is from -20°F to +103°F. The mean annual date of last killing frost at Longview is March 15.

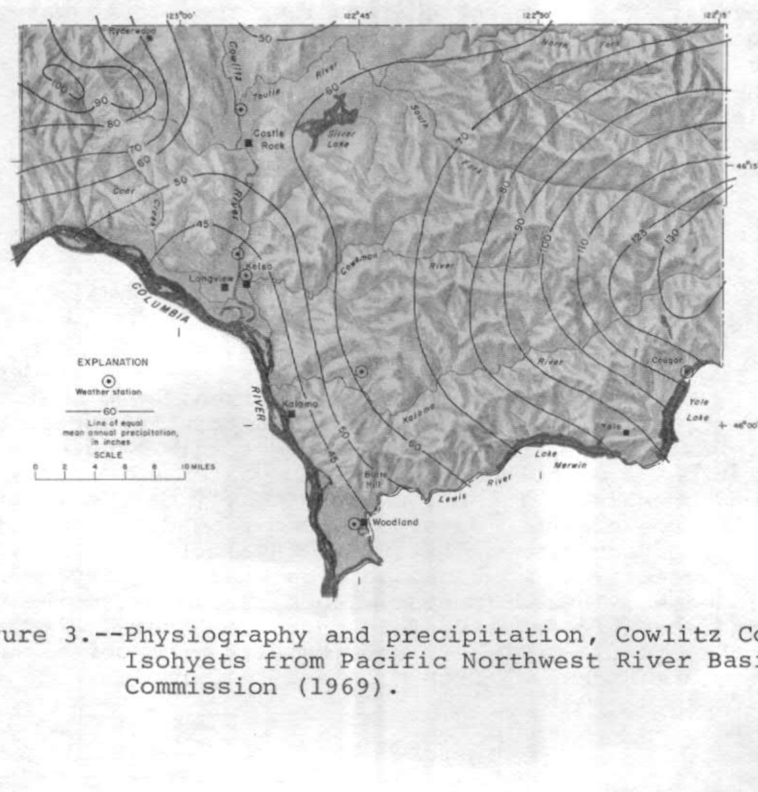

Figure 3.--Physiography and precipitation, Cowlitz County. Isohyets from Pacific Northwest River Basin Commission (1969).

Drainage

Cowlitz County is drained by six major streams: the Columbia, Cowlitz, Kalama, Lewis, Toutle, and Coweman Rivers (fig. 3). The Columbia receives discharge directly or indirectly from the others, then discharges into the Pacific Ocean about 40 miles west of the study area. Flow characteristics of the major streams in the county, excluding the Columbia River, are listed in table 2, and streamflow gaging sites within the mapped area are shown on plate 2. The flows of the Columbia, Cowlitz, and Lewis Rivers are regulated by hydroelectric dams.

GEOLOGIC UNITS AND THEIR WATER-BEARING CHARACTERISTICS

The geology of Cowlitz County closely controls the availability and chemical composition of the ground water. All the ground water comes from precipitation that has infiltrated the ground surface and then percolated downward through the openings in the rock materials. The rate of movement and availability of the ground water is controlled by the size and degree of interconnection of these openings. The chemical character of the ground water is largely controlled by the composition of the rocks and the rate of movement of the ground water through them. Because of this, it is necessary to understand the distribution and character of the rocks in order to plan development of a suitable water supply in the best possible location. The distribution of the various rock units in the county is shown on plate 1, and pertinent characteristics are discussed in the following pages.

Sedimentary and Volcanic Rocks of Eocene Age

In Cowlitz County, three formations of Eocene age are exposed, namely the Cowlitz Formation (Henricksen, 1956), the Goble Volcanic Series (Warren, Norbisrath, and Grivetti, 1945), and the Hatchet Mountain Formation (Roberts, 1958). For the purposes of this report these formations are included in the map unit "sedimentary and volcanic rocks." These rocks are mostly marine in origin but include brackish-water and nonmarine deposits. They consist of sandstone, siltstone, basalt flows, and volcanic breccia, and include some carbonaceous layers and coal seams. The sedimentary deposits are extensively weathered where exposed; feldspars are altered almost entirely to clay. Dense, dark basalts crop out along Interstate Highway 5 from Woodland to Carrolls.

The sedimentary and volcanic rocks of Eocene age are not an important aquifer because of their poor water-bearing characteristics. Movement of water at appreciable rates in the unit is restricted to joints, and numerous small springs issue where these joints intersect the land surface. In the southern part of the county, where younger rocks overlie the unit, springs issue from the younger rocks near the contact. Some springs have sufficient yield to supply individual homes; one spring supplies a small community. Ground-water availability and hydraulic conditions in these rocks are extremely variable. Yields range from 2-200 gpm (gallons per minute), and water levels in adjacent wells in the jointed sedimentary rocks may have differences of more than 100 feet. Differences of that magnitude imply that there is poor continuity in the ground-water system in those rocks, and that individual wells tap isolated water bodies rather than one large system.

Volcanic Rocks of Miocene Age

Volcanic rocks of Miocene age are exposed along the Columbia River and elsewhere in Cowlitz County and underlie much of the northeastern part of the study area, extending southward into the unmapped area (pl. 1). They consist mainly of flows of aphanitic basalt and prophyritic andesite. The rocks are dense and exhibit both columnar and blocky joints. The flow layers of the rock commonly are broken and vesicular near their contacts. These near-contact or interflow zones, plus joints within the flow layers, constitute the paths of ground-water movement within the unit.

In the western part of the area, the unit has been mapped as basalt of the Columbia River Group and may be as thick as 1,400 feet (Livingston, 1966). It is not tapped extensively by wells, but it may be a good potential source of ground water in much of the western part of the county. Several wells tapping the unit in that part of the county yield as much as 120 gpm, and one well (9/4-35D1) reportedly yields 450 gpm (table 6).

In the northeastern part of the area, the unit includes the "Tertiary volcanic rocks" of Roberts (1958) and ranges in thickness from 0-2,000 feet. There, the rocks of this unit underlie mostly unpopulated parts of the area and, consequently, do not supply water to any known wells. However, this extensive unit serves as an important ground-water reservoir which seasonally stores huge volumes of water from abundant high-altitude precipitation and gradually discharges it to the stream system. (See p. 16.)

Wilkes Formation

The Wilkes Formation, of late Miocene age, is exposed extensively in northern Cowlitz County. The formation consists of a sequence of nonmarine or brackish-water siltstone, sandstone, and conglomerate which ranges in thickness from 0-760 feet (Roberts, 1958, p. 34). Near Silver Lake, the Wilkes Formation is identified in drillers' logs by the occurrence of sandy layers.

The formation is tapped by many domestic wells in the northern part of the county, although the unit has generally poor water-bearing characteristics. The more productive wells draw most of their water from a few discontinuous layers of sand in the unit. Pumping yields of the wells are generally less than 10 gpm.

Troutdale Formation

Unconformably overlying the sedimentary and volcanic rocks of Eocene age is the Troutdale Formation (Hodge, 1938). Within Cowlitz County the Troutdale Formation, of Pliocene age, consists of interbedded sand, gravel, and clay, and ranges in thickness from 0-500 feet (Livingston, 1966). Materials of the formation are generally fresh in appearance and have undergone little alteration. The formation is not widespread but appears to be plastered on hillsides underlain by older rock.

The relatively small extent of the Troutdale Formation and its topographic position in Cowlitz County limit the usefulness of the formation as an aquifer. A few wells are completed in this unit but yields from them are low because of the thinness and limited areal extent of the formation. The formation is fairly permeable and readily absorbs infiltrating water from precipitation. Many springs issue from this formation at its contact with older consolidated rocks. In Clark County to the south the Troutdale Formation is extensive and the upper part is an excellent aquifer (Mundorff, 1964, p. 42).

Logan Hill Formation

The Logan Hill Formation, of early Pleistocene age (Roberts, 1958), is exposed in the northern part of the county. This unit ranges in thickness from 0-250 feet (Roberts, 1958) and is characterized by intensively weathered gravel, which has been altered mostly to clay. In exposures the gravel particles show as differentially colored globules which can be cut with a knife. It has been tentatively suggested (Weigle and Foxworthy, 1962, p. 30-31) that the Logan Hill Formation is correlative with the upper part of the Troutdale Formation in Clark County.

The Logan Hill Formation is tapped by many domestic wells in northern Cowlitz County. The clayey nature of the formation prevents the easy passage of ground water; consequently, yields from wells rarely exceed 10 gpm and the drawdown of water levels necessary to produce such yields generally is more than 50 feet below nonpumping levels.

Landslide Debris

Landslide debris of Pleistocene and Holocene age is common throughout the county. The debris consists of displaced Tertiary and Quaternary rock. Many of the landslide areas appear to be quite stable at present, and homes have been built on some of them.

The landslide debris has poor water-bearing characteristics. Wells tapping the unit rarely yield more than 5 gpm, and the drawdowns of water level to produce such yields may exceed 100 feet. Specific capacities range from about 2 gpm per ft. (gallons per minute per foot of drawdown) to 0.05 gpm per ft.

Alluvium

The lower reaches of all the major stream valleys in Cowlitz County are partly filled with alluvium, which in general consists of gravel, sand, and silt. As defined in this report, alluvium includes deposits in alluvial fans, flood plains, deltas, and terraces. The alluvium ranges in thickness from less than 10 feet in the uplands and small valleys to more than 300 feet near the mouth of the Cowlitz River.

The alluvial materials are the most productive sources of ground water in Cowlitz County and are tapped by the most wells. They are very permeable in most places but permeability decreases as the amount of clay and silt in them increases. Yields of wells tapping these materials are as great as 3,000 gpm, and drawdowns of the water level in pumping wells generally are no more than about 40 feet.

GROUND-WATER HYDROLOGY

General Occurrence

In Cowlitz County, ground water is obtained mostly from unconsolidated alluvial materials and to a lesser degree from the older, more indurated sedimentary and igneous rocks. In the unconsolidated deposits the ground water is contained in the pore spaces between individual particles. In the consolidated igneous rocks and indurated older sedimentary rocks the water occurs in small cracks and joints that generally are insignificant at depths greater than a few hundred feet.

Ground water in the county occurs under both unconfined and confined conditions. Most of the alluvial aquifers contain unconfined ground water in their upper parts, but confinement often occurs and increases with depth. Nearly all the water obtained from the older rock units is confined to some degree--in most cases ground water found in these rocks rises above the depths where first encountered during drilling.

Data on specific capacity are available for many of the wells in the county. Specific capacity is a measure of well production which relates the yield to the water-level change (drawdown) due to pumping; it is commonly expressed as gallons per minute per foot of drawdown. Values of specific capacity of wells in Cowlitz County range from 0.05 to 1,300 gpm per ft (table 6). The lower values are from wells drilled in the consolidated rocks or in alluvium that contains significant amounts of clay or silt. The higher values are from wells where inter-granular spaces in the aquifer materials are larger and mostly free of clay and silt.

Recharge and Movement

Ground water in Cowlitz County is recharged mainly by direct infiltration of water from precipitation. To a lesser extent, the streams of the county during their high stages help to recharge the ground water when some stream water infiltrates to the aquifers adjacent to the stream channels. Stream water also is being induced to infiltrate to the aquifers adjacent to the channel by heavy pumping of wells, and such induced infiltration can take place at any river stage. An induced infiltration well supplies the town of Woodland.

Rates of ground-water movement generally are less than 1 foot per day under natural gradients, but the movement is much more rapid in the vicinity of pumping wells.

The path of movement of ground water and the degree of interconnection of joints in the consolidated rocks of the county are largely indeterminate. This is best illustrated by the relations between two wells and a spring in Cowlitz County. Well 6/1-16M1 is 90 feet deep and was completed in highly jointed Eocene sedimentary rock. The well was drilled in 1967 and initially flowed at a rate of 18 gpm. Within 8 hours after the completion of this well, a spring about 600 feet away and about 50 feet higher in elevation reportedly stopped flowing. Conversely, the water level in another well, 6/1-16L1, which is 337 feet deep and located between the spring and well 6/1-16M1, was 316.5 feet below land surface and reportedly remained unchanged when the flowing well was completed. The vast difference in water level between adjacent wells is typical of the joint-controlled flow of ground water in the county.

Discharge

Ground water discharges as spring flow, seepage to streams, well discharge, and evapotranspiration. Springs which are common throughout Cowlitz County, are typically located at the contact of the present-day soil and the underlying, poorly permeable bedrock. Because of the small storage capacity of some of the weathered material overlying the bedrock, the water stored in the weathered material during the wet season drains out before the end of the following dry season, and many of the springs in the county flow during only the wet part of the year. Where a deep mantle of weathered material is available to store the seasonal recharge water, however, springs may flow the entire year. Two springs of this type serve the community of Pleasant Hill as a water supply. Many small springs issue where the joints in the bedrock intersect the land surface. The joint systems commonly drain a fairly extensive ground-water body and springs issuing from them generally flow perennially. Flows as great as 20 gpm have been reported from these joint-fed springs.

Most of the ground-water discharge in the county occurs as seepage to the stream channels. The late-summer low flow of the streams is maintained almost entirely by this seepage, although the flows of the Cowlitz and Lewis Rivers are augmented by releases of water from hydropower reservoirs. The effectiveness of a ground-water reservoir, depending on the storage capacity as well as the relative rates of intake and release of the ground water, can often be inferred from analysis of the low-flow characteristics of the streams draining it. The more effectively the rock materials of a basin function as a ground-water reservoir, the greater will be the base flow of a stream that drains it, in terms of the percentage of its mean annual flow, if all other factors are equal.

Flow-duration characteristics of three unregulated streams--the Coweman, Kalama, and Toutle Rivers--in Cowlitz County can be compared in figure 4, and from data in table 2. On the duration curves of figure 4 are plotted the points representing the average discharge and the lowest instantaneous discharge during 1967. A comparison of those points shows that the 1967 low flow of the Coweman River, in proportion to its average annual discharge, was much less than the low flow of either the Kalama or Toutle Rivers. The lower base flow of Coweman River also is shown by the steeper slope of the right end of the duration curve for that river. The relatively smaller base flows of the Coweman River also are indicated in table 2 by the column showing record low flow divided by mean annual discharge. The differences in the flow-duration curves are largely attributed to the differing nature of the rocks that underlie the drainage basins of the streams. The drainage basin of the Coweman River is underlain principally by indurated sedimentary rocks which have openings so small that water does not readily drain from them. The other streams are largely underlain by volcanic rocks that more readily absorb the water from precipitation and release it to the streams.

Discharge from wells in the county (pl. 2) averages 35 mgd (million gallons per day). This is about 22 percent of the estimated total water use of 59 billion gallons per year in Cowlitz County (Laird and Walters, 1967). Industrial plants at Longview use most of the surface and ground water in the county. High-yield wells provide water for the processing and cooling required by pulp, paper, and aluminum industries. Agriculture uses about 200 acre-feet (0.18 mgd) annually. Municipal uses of ground water include an estimated 0.5 mgd from six wells for the town of Castle Rock, while Woodland utilizes an induced-infiltration well beside the Lewis River with a capacity of 2 mgd. Domestic wells provide water for many residents of the county who are not served by municipal-water systems. Individual domestic wells yield from about 1 to 20 gpm and collectively produce about 2 mgd.

Evapotranspiration is a major form of ground-water discharge in the parts of the area having a shallow water table. In most of the cultivated lowland areas, irrigation is not necessary for most of the growing season because the

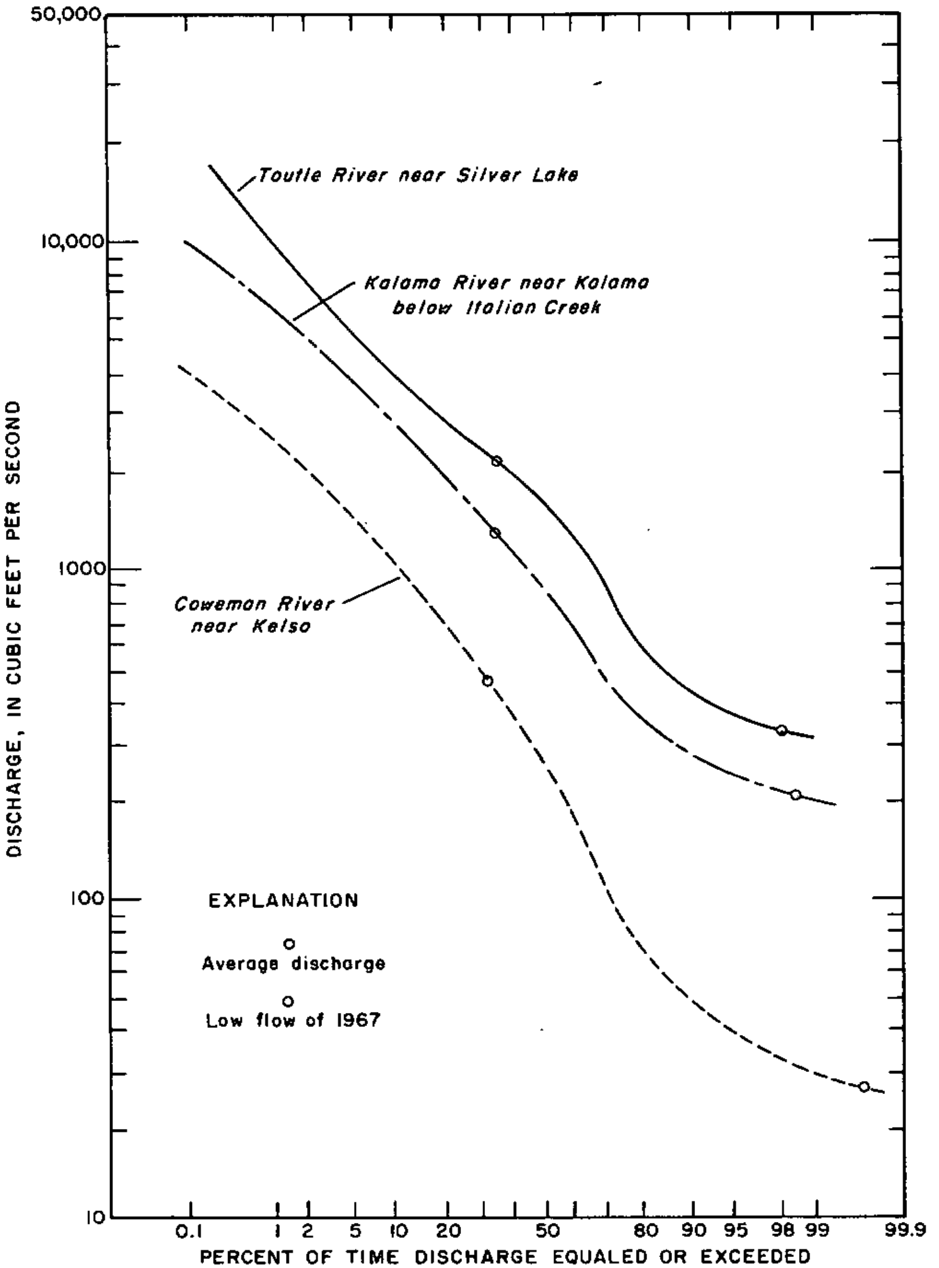

Figure 4.--Flow-duration curves for three unregulated streams in Cowlitz County.

Table 2.--Flow characteristics of major streams in Cowlitz County
(Locations of gaging stations shown on plate 2)

Stream and gaging stations	Average annual discharge (cfs) and periods of record	Record low flow (cfs) and date	Lowest flow during 1967 (cfs)	Average discharge per square mile (cfs/sq mi)	Ratio of record low flow to mean annual discharge	Drainage area (sq mi)
Cowlitz River a/ near Castle Rock	9,069 (1927-60)	998 11/7-8/35	--	4.05	0.11	2,238
Toutle River near Silver Lake	2,024 (1909-11, 1919-21, 1922-23, 1929-60)	240 11/21/29	327	4.27	.12	474
Coweman River near Kelso	436 (1950-60)	22 9/22/51	25	3.66	.05	119
Kalama River near Kalama	1,259 (1946-60)	155 10/3,5-7/58	205	6.26	.12	201
Lewis River b/ near Cougar	1,281 (1954-67)	175	--	5.64	.14	227

a/ Stream is regulated above station.

b/ Stream is regulated below station. Station is not in study area and not shown on plate 2.

roots of the plants can obtain water from the shallow ground water or the capillary water above the water table.

Water Levels in Wells

In Cowlitz County ground-water levels in the alluvial aquifer generally rise in response to recharge during the period between October 1 and March 31, when about three-fourths of the annual precipitation falls. During the late spring and summer months, water levels decline due to a decrease in recharge and, locally, to an increase in pumping from wells, and evapotranspiration.

Ground-water levels in the consolidated rock aquifers are generally stable throughout the year.

To verify the ranges and seasonal pattern of water-level fluctuations reported by well owners and from measurements made during the well inventory, continuous water-level recorders were installed on three selected wells (5/1-14K1, 7/1-33J1, and 8/3-25Q1) for periods ranging from 2 weeks to 8 months between October 1967 and June 1968. These short-term water-level records were then analyzed in comparison with longer-term records available from adjacent counties. It should be noted that, because the summer of 1967 was very dry in the northwest, water levels were probably at their lowest during this period of water-level measurements.

Well 5/1-14K1 (table 6, pl. 2) is typical of those completed in relatively shallow permeable deposits. The hydrograph of this well is compared with the longer term hydrograph of a similar well (11/1E-5H1) in Lewis County (fig. 5). The hydrographs show that the highest water levels usually occur in late winter or early spring and the lowest levels occur in summer or early autumn.

In contrast, well 7/1-33J1 (tables 6 and 7, pl. 2) is completed in relatively impermeable material near the bank of the Kalama River. Water levels in this well remained virtually constant until river flooding on February 3, 1967, inundated and filled the well.

Well 8/3-25Q1 (table 6, pl. 2) is an industrial well owned by the Reynolds Metals Company. The well taps highly permeable sand and gravel at a depth of 353 feet beneath the flood plain of the Columbia River about 2 miles west of Longview. The water-level fluctuations in the well probably are largely a reflection of the loading and unloading of the aquifer caused by tidal fluctuations of the Columbia River, as indicated by a comparison with the predicted tidal stages of the river at

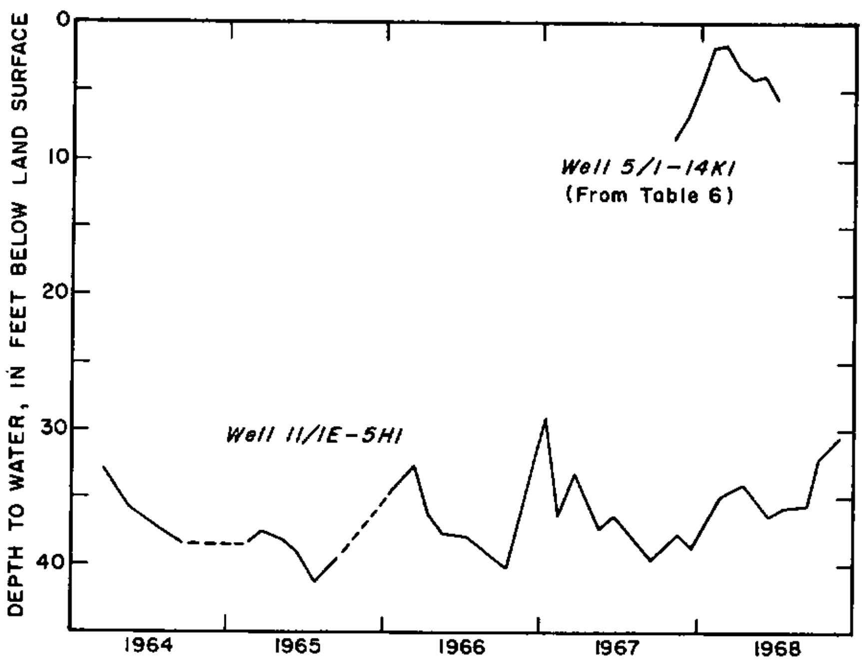

Figure 5.--Comparison of water levels in wells 5/1-14Kl in Cowlitz County and 11/1E-5H1 in Lewis County. Dashed lines indicate periods of missing records.

Longview (fig. 6). The apparent differences between times of extremes in the two hydrographs are probably due to slight errors in prediction of the time of river tidal fluctuation.

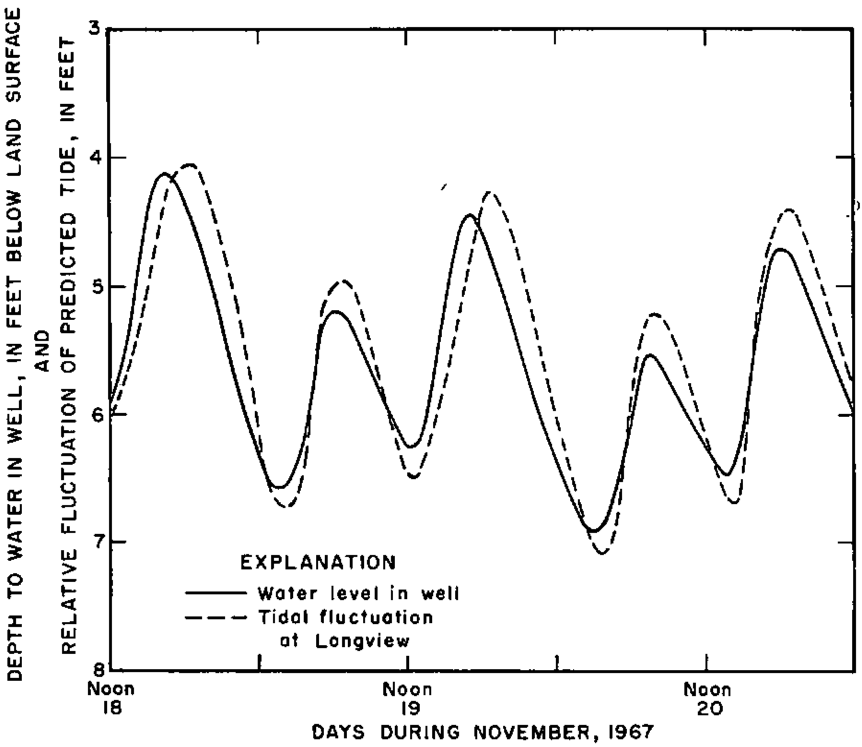

Figure 6.--Water level in well 8/3-25Q1, showing changes in response to predicted tidal fluctuations of Columbia River.

Ground-Water Occurrence in Subareas

Silver Lake Subarea

The Silver Lake subarea (pl. 2), which lies east of Castle Rock near the Toutle River, contains Silver Lake which has a surface area of 3,870 acres. The subarea is surrounded by low hills underlain by the Wilkes Formation and sedimentary and volcanic rocks of Eocene age (pl. 1).

Water supplies for most of the homes around the lake and in the adjacent area are from wells tapping aquifers in the Wilkes Formation (pl. 1). The wells are reported to be generally about 50 feet deep and are adequate to supply all or most domestic requirements. Yields of wells are generally less than 10 gpm and specific capacities range between 0.5 and 2 gpm per foot. Most wells in this subarea are reported to be adequate throughout the year; no wells were reported to have gone dry during the near-record dry summer of 1967.

Iron is a common constituent of the ground water in this area. In many cases treatment is required to reduce iron concentrations to tolerable levels.

Coal Creek Subarea

The Coal Creek subarea (pl. 2) occupies a rather narrow valley about 7 miles northwest of Longview. Most of the subarea is underlain by carbonaceous sedimentary rocks of Eocene age. Although some families obtain their domestic supplies directly from Coal Creek, most use wells that tap ground water in the underlying rocks. Most of the wells in the subarea are drilled to depths of about 100-250 feet. Pumping yields are as much as 20 gpm. No drawdown data were available, but pumping lifts are low and some wells have been reported to flow. (See table 6, well 8/3-2Q1.) Supplies are reportedly adequate, dependable, and of excellent quality.

Rose Valley Subarea

The Rose Valley subarea (pl. 2), about 4 miles south of Kelso and 2 miles east of Interstate Highway 5, is a small upland valley that drains to the Coweman and Columbia Rivers. The valley is floored by clayey alluvium underlain by sedimentary and volcanic rocks of Eocene age. The only source of water used in the area is ground water from springs or wells. As a rule, each home maintains its own water supply. Depths of wells range from 75 to 380 feet. Most of the ground water is derived from joints in the Eocene rocks. Although yields are generally low (on the order of 5 gpm) they are reported to be adequate, even during extended periods of no precipitation. However, some springs reportedly have ceased to flow during dry periods. The maximum reported yield in the vicinity is from an improved spring (well 7/1-15F2) with a pumping yield of 110 gpm (table 6, pl. 2).

Most of the water is of good quality. The only constituent that exceeds Public Health Service standards in any of the water is dissolved iron, which has concentrations ranging from 0.01 to 9.2 mg/l (milligrams per liter).

Woodland Subarea

The Woodland subarea (pl. 2) is on the flat delta of the Lewis River. It is bounded by the Columbia River on the west and by the Lewis River on the east and south. The area is underlain by sand and gravel. The town of Woodland derives its water from an induced-infiltration well (5/1E-18N2) on the bank of the Lewis River.

The subarea is a major agricultural district of the county. The farms there depend upon ground water for domestic and irrigation uses. Wells generally are 30 to 40 feet in depth, and most domestic supplies come from shallow driven wells that tap ground water in the alluvium. Yields from the larger irrigation wells range from about 200 to 500 gpm and specific capacities range from about 15 to 30 gpm per foot. Wells in this area are reported to yield adequate supplies at all times. However, iron is a common constituent in the ground water, concentrations are excessive in many places with values ranging up to 36 mg/l.

Longview Subarea

The Longview subarea (pl. 2) is made up of reclaimed flood plain along the Columbia River and at the mouth of the Cowlitz River.

The subarea is the major industrial district of the county. Ground water in the area is used in large quantities for industrial purposes. Wells tapping the thick alluvium underlying the flood plain are generally more than 200 feet deep and of large diameter (12-24 inches). Yields from wells range from 150 to 3,000 gpm, and specific capacities range from 40 to 1,000 gpm per foot. Some of the wells have been reported to flow during periods of high stage of the Columbia River.

Although deep wells generally tap ground water of good quality, shallow wells commonly tap ground water that contains concentrations of iron exceeding Public Health Service standards for drinking water.

QUALITY OF GROUND WATER

The chemical quality of a water supply largely determines the usefulness of the supply for domestic, industrial, or municipal purposes. Ground water has certain quality-related properties that make it preferable over surface water for some uses, including more constant temperature and chemical composition, and lower probability of bacterial contamination.

Ground water generally is subject to variation in quality both areally and with depth. This situation results primarily from differences in the chemical character of the rock materials through which the water passes and to differences in the length of time the water has had to react with the rock materials. Each time the environment of the water is altered, as when the water from precipitation infiltrates the soil and when it later percolates to the deeper rock materials, the water tends to adjust to the new conditions and its chemical character may change measuraby.

General Characteristics

Much of the ground water in Cowlitz County meets or exceeds the quality standards of the U. S. Public Health Service for drinking water (table 5), and is suitable for most uses without extensive treatment. Use of some of the ground water for municipal supply, however, is limited by the chemical composition of the water. The ground water in some of the more productive aquifers contains significant amounts of undesirable dissolved constituents which are difficult and expensive to remove. These include dissolved iron and ions such as calcium and magnesuim that contribute to the "hardness" of the water.

Dissolved iron is the only constituent that occurs widely in the ground water in concentrations greater than those recommended by the U. S. Public Health Service (1962). Excessive quantities of chloride also have been reported locally, but the condition does not appear to be widespread.

In 1963, the Cowlitz County Public Utilities District conducted an investigation in the county to locate a ground-water supply to meet its public-supply commitments. An extensive test-drilling and sampling program was carried out. The test wells tapped the alluvial aquifer in the vicinity of Longview and Kelso and averaged 107 feet in depth. Water from these wells

Table 5.--Selected drinking-water standards (after U. S. Public Health Service, 1962)

Chemical constituent	Recommended limit (mg/l)	Maximum allowable limit (mg/l)
Chloride	250	--
Fluoride[a]	.8-1.7	1.6-3.4
Iron	.3	--
Nitrate	45	--
Sulfate	250	--
Dissolved solids	500	--

[a] Amounts vary inversely with mean annual temperature.

showed an average dissolved-iron concentration of 3.8 mg/l. In 1966 and 1967, Bechtel Corporation had several wells drilled for the Longview plant of the Reynolds Metals Company. These wells averaged 353 feet in depth. Water from these wells showed an average of 1 mg/l dissolved iron.

Specific conductance, which measures the ability of the water to conduct an electrical current, in some cases can be used as an indicator of the total dissolved solids in the water. Chemically pure water has a very low electrical conductance. The presence of dissociated ions in solution, however, renders the solution conductive (Hem, 1959).

An examination of the data in table 4 indicates that the approximate dissolved-solids concentration, in milligrams per liter, is about 0.6 the value of the specific conductance, in micromhos per centimeter at 25°C. On this basis, the average concentration of dissolved solids in ground water in the study area probably is between 200 and 250 mg/l.

The standard chemical analyses of water from eight wells (table 4) indicate that the ground water generally is of either the calcium, magnesium bicarbonate or the sodium bicarbonate type. The only exception is the sample from well 5/1E-5F1, which penetrates 300 feet of landslide debris on Butte Hill near Woodland (pl. 2). Water from that well is a sodium chloride type that appears to be anomalous to the area (table 4).

Iron

Concentrations of total iron in the samples collected ranged from less than 0.01 to 36 mg/l. Although dissolved iron has no deleterious effects on human beings, it can be tasted and will discolor the water and objects in contact with the water when concentrations exceed about 0.3 mg/l. Dissolved iron is most common in water from the alluvium and, therefore, somewhat limits the use of these potentially productive aquifers in some parts of Cowlitz County (fig. 7).

Chloride

Concentrations of chloride ion in samples collected for comprehensive analysis ranged from 2.8 to 250 mg/l. Chloride limits recommended by the U. S. Public Health Service (1962) are based solely on the taste threshold--chloride can be tasted by some people at a concentration of about 300 mg/l. Only two wells that were sampled had concentrations at or above Public Health Service standards. One of these taps landslide debris near Woodland. The other well, which is completed in marine sedimentary rocks of Eocene age, is just west of the study area, near Ryderwood.

Hardness

The hardness of ground water, which determines the usefulness of the water for steam generation, laundering, and other purposes, is largely determined by the concentration of calcium and magnesium in the water. Ground water in Cowlitz County ranges in hardness from 5 to 160 mg/l, as $CaCO_3$, in the samples tested (table 4).

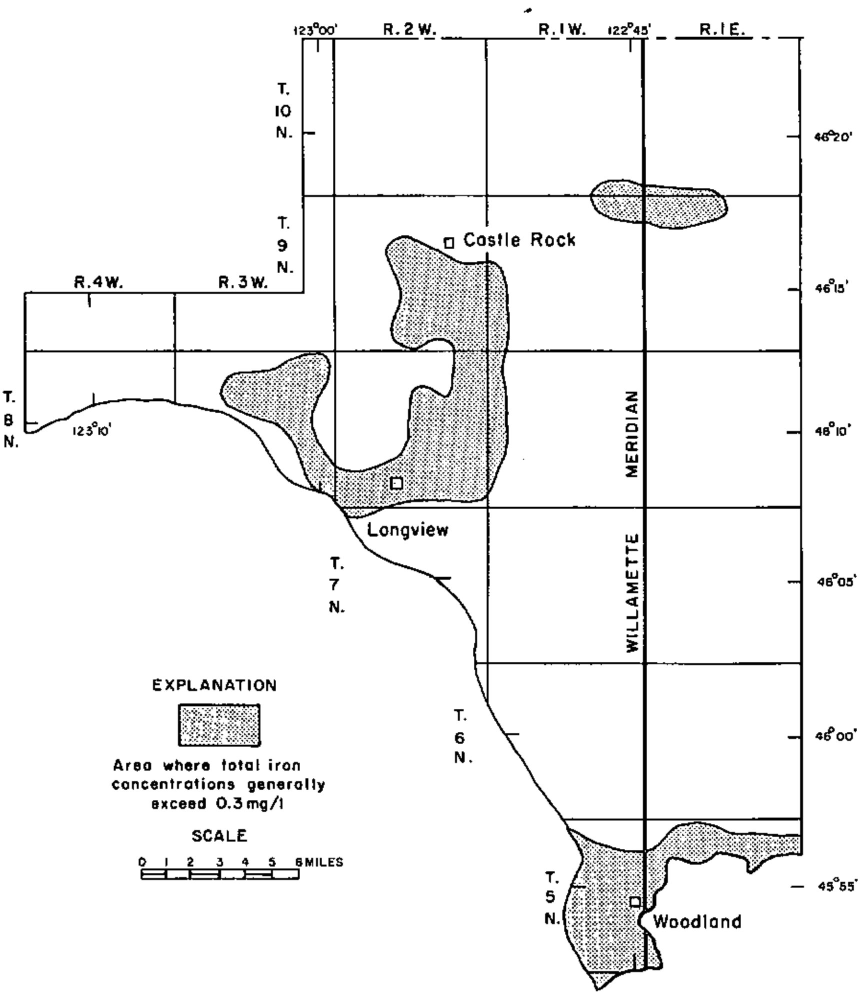

Figure 7.--Areas where total iron concentrations in ground water generally exceed 0.3 mg/l, the recommended limit set for drinking water by the Public Health Service (1962).

Temperature

The temperature of ground water is generally at or near the average annual air temperature in the area. Measurements of ground-water temperatures at wells in Cowlitz County ranged from 7.2°C (45°F) to 20°C (68°F) and averaged about 12°C (54°F). Temperatures varied with depth of the well and season of the year, the seasonal variation amounting to about 1°C (1.8°F).

ADDITIONAL DEVELOPMENT OF THE GROUND-WATER RESOURCE

Most of the wells drilled in Cowlitz County are for domestic use, whereas most of the ground-water pumpage is from industrial wells. Wells capable of yielding large quantities of water for industry and agriculture are limited in areal distribution by the extent of the highly productive aquifers. The delta of the Cowlitz River in and near Longview shows the greatest promise for additional development. The majority of the high-capacity wells, some of which have pumping yields as great or greater than 3,000 gpm, are located in this area. The gravel aquifers underlying the delta apparently have hydraulic connection with the Columbia River, and probably are recharged by the river when pumping withdrawals are sizable. The evaluation of Mundorff (1964, p. 93) for a similar lowland area near the Columbia River in Clark County also may be valid in this part of Cowlitz County: "With a very large source of recharge close at hand yields of about 50 to 100 mgd might be obtained per mile length of lowland along the [Columbia] river."

The lower Cowlitz River valley seems to be undergoing primarily suburban growth. Because many of the new homes lie outside the areas served by public-water systems, it is necessary for the home owners to develop individual water supplies. Even where springs might be developed, wells are the more common answer to household-supply needs, because of the possibility of contamination of a spring at or near the point of discharge. In areas where consolidated sedimentary rocks and basalt must be tapped for water, a well must intersect enough joints so that flow to the well will be sufficient to meet demands. However, the joints are closely spaced in most places, and thus the chances of successful completion of the well are enhanced. In the area west of Longview the volcanic rocks of Miocene age offer a potential source of water. The unit at present is not highly developed but some wells have reported yields as high as 450 gpm.

Where clayey alluvium must be explored as an aquifer, special attention should be given to any beds of clean sand that are penetrated, for these generally are the major sources of water in such alluvium. Water from the clayey alluvium, however, tends to have a high dissolved-iron content.

No available evidence indicates that ground water is being withdrawn faster than it is being recharged any place in the county, and large additional supplies can be obtained from the alluvium of most of the major stream valleys.

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Table 3.--Total iron and specific conductance in water from selected wells

Well number	Iron (mg/l)	Specific conductance (micromhos per cm at 25°C)	Well number	Iron (mg/l)	Specific conductance (micromhos per cm at 25°C)
5/1E-1J1	0.31	238	6/1-16Q1	0.00	139
3R1	11	99			
5C1	.11	42	20A1	.13	254
5F1	1.1	1,137	20H1	.12	428
5G1	3.5	956	21B1	1.6	304
5K1	.15	568	21E1	.02	200
5L1	.37	939	28B1	.26	1,020
7R1	12	87	28C1	.57	366
8A1	7.5	198	28C2	.04	129
5/2E-6M1	4.3	192	7/1-8P1	9.4	324
6M2	5.6	258	8R1	.49	234
5/1-11J1	.09	78	9M1	.27	326
14J1	3.1	189	9N1	.28	259
25F1	36	207	9N2	.12	273
6/1-16G1	.02	191	9P1	.01	271
16K1	.32	213	9P2	.09	280
16L1	.17	339	9P3	.04	393
16P1	.03	243	9Q1	.02	366

Table 3.--Total iron and specific conductance in water from selected wells--Continued

Well number	Iron (mg/l)	Specific conductance (micromhos per cm at 25°C)	Well number	Iron (mg/l)	Specific conductance (micromhos per cm at 25°C)
7/1-15F1	0.07	425	8/2-11B1	0.13	234
17A1	.08	198	12B1	.30	288
17B1	.87	425	12C1	1.9	281
17G1	.37	314	13C1	4.3	206
17G2	1.2	221	14C1	.61	266
17N1	.68	536	24K1	.05	282
17P1	.08	360	24L1	.18	70
20D1	.10	239	24M1	.09	147
30J1	.02	264	8/3-2Q1	.02	302
30J2	.03	393	2Q2	.82	387
30K1	.20	304	11N1	4.2	659
7/2-9L1	3.6	545	15A1	.12	379
8/2-1P1	.65	290	15A2	.37	392
1P2	4.4	279	36H1	.97	364
2Q1	.13	310	9/1E-6H1	.01	380
3G1	.04	802	7A1	.00	449
3G2	1.2	390	9/1-5M1	1.2	43
3Q1	.20	110	6N1	.21	28

Table 3.--Total iron and specific conductance in water from selected wells--Continued

Well number	Iron (mg/l)	Specific conductance (micromhos per cm at 25°C)
9/1-7M1	0.02	410
9/2-2P1	.00	212
5B1	.16	599
5J1	9.1	923
26J1	.01	263
27B1	.06	110
27B2	.01	356
28D1	.07	236
33D1	.07	332
33L1	.71	405
33M1	.37	150
33Q1	2.7	360
33Q2	.31	437
33Q3	.05	281
33R1	.09	433
33R2	1.1	488
33R3	2.8	1,530
34N1	.02	3,050
9/2-35A1	1.6	258
10/1-25J1		
(11/15/67)	3.2	241
(4/5/68)	.57	225
30F1	.08	279
31K1	.32	206
33B1	.71	56
33K1	.04	62
10/2-31H1s	.04	25
32M1s	.14	30
36A1	3.1	90
36E1	.00	118

TABLE 4 - CHEMICAL ANAYLSES

Table 4.--Chemical analyses of ground water.

Well number	Milligrams								
	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)
5/1E-5F1	18	1.1	38	8	189	1.4	172	2	51
7/1-17B2	25	.90	29	7.1	36	.8	203	0	3.4
8/1-19C1	41	.04	20	24	16	2.7	224	0	.4
8/2-11G1	36	.10	44	12	8.8	2.7	194	0	3.2
8/3-11F1	10	.09	4.7	.1	48	.2	90	4	31
9/2-11Q1	47	--	10	3.2	7.9	.9	53	0	.4
9/2-29R1	21	.16	2.0	.0	92	.5	122	20	6.2
10/1-25J1	61	3.2	17.0	7.5	17	2.9	136	0	.2

Analyses made by U. S. Geological Survey

per liter							
Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness (as $CaCO_3$)	Specific conductance (micromhos per cm at 25°C)	pH	Principal aquifer (as designated geologically on plate 1)
250	0.1	0	656	128	1,150	8.3	Landslide debris
11	.1	0	228	102	348	8.0	Alluvium
5.4	.1	0	228	149	353	7.9	Sedimentary and volcanic rocks of Eocene age
7.8	.3	1.2	219	160	347	7.8	Alluvium
4.5	.1	0	150	12	232	8.5	Sedimentary and volcanic rocks of Eocene age
3.3	.1	5.7	109	38	121	6.5	Alluvium
50	.3	0	254	5	428	9.1	Alluvium
2.8	.4	.1	168	74	219	6.6	Alluvium

Table 6.--Records of wells.

Well locations shown on Plate 2.

Explanation:

Altitude: Land-surface datum at well, in feet above mean sea level, interpolated from topographic maps.

Type of well: Dr, drilled; Dg, dug; Dn, driven; Bd, bored.

Depth of well: Recorded to the nearest foot below land-surface datum.

Water level: Measurements are in feet below land-surface datum. Those given in feet and decimal fractions of feet were made by the Geological Survey; measurements recorded to the nearest foot were reported by the owner, tenant, or driller. A flowing well whose static head is known has "+" preceding the water level, which is in feet above land-surface datum. A flowing well whose static head is not known is indicated by "Flows".

Type of pump: C, centrifugal; J, jet; N, none; P, piston; Sb, submersible; T, turbine.

Use of well: D, domestic; I, irrigation; C, industrial; U, unused; S, stock; P, public supply; X, destroyed; O, observation.

Principal aquifer: Qa, alluvium; Qls, landslide debris; Tw, Wilkes Formation; Tv, volcanic rocks of Miocene age; Tvs, sedimentary and volcanic rocks of Eocene age.

Remarks: Most of the information was supplied by driller or owner: dd, drawdown; gpd, gallons per day; gpm, gallons per minute; L, log in table 7. Pa, partial analysis; Ca, comprehensive analysis; H, hydrograph; mgd, million gallons per day.

Table 6.-Records of wells

Well No.	Owner or tenant	Altitude (feet)	Type of Well	Depth of Well (feet)	Diameter of Well (inches)	Water Level: Below land surface (feet)	Water Level: Date	Pump: Type	Pump: H. P.	Use of Water	Principal aquifer	Remarks
T. 5 N., R. 1 E.												
1A1	H. C. Fisher	280	Dr	190	6	59.6	8- 1-67	J	2	D	Qls	
1J1	J. W. McKinley	220	Dr	--	6	--	--	--	--	--	Qa	Pa.
3R1	Kouvos	80	Dr	60	6	14	8- 1-67	Sb	3/4	D	Qa	Pa.
5C1	W. J. Burroughs	520	Dg	6	30	1	8- 8-67	C	3/4	D	Qls	
5F1	Paul	320	Dr.	300	6	--	--	Sb	3/4	D	Qls	Ca.
5G1	Lavine	360	Dr.	510	6	170.9	8- 8-67	N	--	X	--	Pa, L.
5K1	Keith	280	Dr	395	6	--	--	J	2	D	Qls	Pa.
5L1	John Covington	360	Dr	310	6	--	--	Sb	1	D,S	Qls	Pumped 20 gpm, Pa.
7R1	Matilla	20	Dn	40	1½	8	8- 1-67	C	1	D	Qa	Pumped 15-35 gpm, Pa.
8A1	Max Altair	25	Dr	45	6	22	8-10-67	Sb	3/4	D	Qa	Pa.
8C1	U.S.G.S.	30	Dn	18	1½	15.32	6- 7-68	N	--	O	Qa	
8F1	U.S.G.S.	25	Dn	18	1½	11.32	6- 7-68	N	--	O	Qa	
8F2	U.S.G.S.	23	Dn	18	1½	8.73	6- 7-68	N	--	O	Qa	
18B1	Glen Blanchard	25	Dr	40	12	16.4	10-28-49	C	5	I	Qa	Pumped 400 gpm, dd 6 ft.

Table 6.-Records of wells - Continued

Well No.	Owner or tenant	Altitude (feet)	Type of Well	Depth of Well (feet)	Diameter of Well (inches)	Water Level		Pump		Use of Water	Principal aquifer	Remarks
						Below land surface (feet)	Date	Type	H. P.			
	T. 5 N., R. 1 E. - Continued											
18F1	Wayne Bozarth	33	Dr	58	8	9.2	8-21-67	--	--	I	Qa	Pumped 160 gpm, dd 10 ft. L.
18G1	L. B. Brown	25	Dr	40	12	20	3-30-52	C	7½	D,I	Qa	Pumped 300 gpm, dd 5 ft.
18N2	Town of Woodland	25	Dn	50	144	--	--	T	--	P	Qa	Induced infiltration well, capacity 2 mgd.
31F1	Lester Nelson	20	Dr	202	6	5.2	5-10-65	--	--	--	Qa	Pumped 70 gpm, dd 3 ft. L.
	T. 5 N., R. 2 E.											
6M1	C. Kerr	200	Dg	33	30	18.1	8- 1-67	P	3/4	U	Qa	Pa.
6M2	---do---	200	Dr	186	6	--	--	J	½	D,S	Qa	Pa.
	T. 6 N., R. 1 E.											
32N1	Armas Saastamo	960	Dr	180	8	50	12-20-52	T	7½	I	Tsv	Pumped 200 gpm, dd 125 ft. L.
	T. 6 N., R. 2 E.											
31P1	Simpson	480	Dr	400	6	150	6-15-67	Sb	2	D	Tsv	Well tends to fill with sand.

T. 5 N., R. 1 W.

2M1	Fred Love	10	Dr	220	6	2	10-28-49	C	1	S	Qa	
10A1	H. C. Bohnert	10	Dr	253	4	--	--	J	1	D,S	Qa	Flows during high river stage.
11J1	Floyd Chumbley	10	Dn	22	1¼	4	8- 4-67	J	3/4	D	Qa	Pa.
13M1	Dirk Kroon	10	Dr	30	12	--	--	C	10	I	Qa	Pumped 300 gpm.
13N1	---do---	10	Dr	30	12	9.8	10-24-49	C	--	I	Qa	Pumped 200+ gpm.
14A1	United Bulb Co.	10	Dr	38	12	4	8- 4-67	C	--	I	Qa	Pumped 300 gpm, dd 20 ft. L.
14B1	--- do---	10	Dr	30	12	4	8- 4-67	C	--	I	Qa	Pumped 300 gpm.
14F1	L. E. Nelson	10	Dr	40	8	6	2- 2-54	--	--	I	Qa	Pumped 250 gpm, dd 14 ft.
14J1	United Bulb Co.	10	Dr	30	12	9.1	8- 4-67	C	--	I	Qa	Pa. L.
14J2	---do---	10	Dr	30	12	9.2	8- 4-67	--	--	I	Qa	
14K1	---do---	10	Dr	30	12	9.2	10- 3-67	--	--	I	Qa	H.
14L1	J. E. Jackson	10	Dr	38	12	8	1-13-54	--	--	I	Qa	
15J1	N. E. Durgan	10	Dr	42	10	8	4- 8-68	C	20	I	Qa	Pumped 400 gpm, dd 26 ft.
22A1	N. J. Rogers	10	Dg	12	40	2	6-15-40	C	7½	I	Qa	Pumped 200 gpm, dd 4 ft.
22C1	L. D. Cuddleback	10	Dr	38	10	5.8	10-28-49	C	65	I	Qa	Pumped 450 gpm.
22K1	D. J. Weeks	10	Dr	34	12	6.3	10-28-49	C	--	--	Qa	Pumped 450 gpm.

Table 6.-Records of wells - Continued

Well No.	Owner or tenant	Altitude (feet)	Type of Well	Depth of Well (feet)	Diameter of Well (inches)	Water Level: Below land surface (feet)	Water Level: Date	Pump: Type	Pump: H. P.	Use of Water	Principal aquifer	Remarks
T. 5 N., R. 1 W. - Continued												
23N1	Earl Swett	10	Dr	38	12	8	3- -53	--	--	I	Qa	Pumped 500 gpm, dd 20 ft.
24M1	P. W. Olsen	10	Dr	35	12	10	1- -54	--	--	I	Qa	Pumped 400 gpm, dd 22 ft.
25F1	Donald Bros. Farm	10	Dr	40	12	10	8-12-67	C	25	I	Qa	Pumped 500 gpm.
25L1	D. C. Pittman	10	Dr	35	12	8	7- -52	--	--	I	Qa	Pumped 500 gpm, dd 18 ft.
T. 6 N., R. 1 W.												
16G1	R. B. Coulter	920	Dr	189	6	33.5	9-13-67	Sb	3/4	D	Tsv	Pa.
16K1	Ray Luhrs	760	Dr	61	6	--	--	Sb	1	D	Tsv	Pa.
16L1	Donald Payder	600	Dr	337	6	316.5	9-12-67	Sb	1	D	Tsv	Pa.
16M1	Albert Gould	560	Dr	90	6	+0.04	9-12-67	Sb	1	D	Tsv	Flows 20 gpm.
16P1	Hugo Holm	440	Dr	300	6	44.3	9-13-67	Sb	1½	D	Tsv	Pa.
16Q1	Charles Nash	650	Dg	4	60	2.0	9-13-67	N	--	D	Tsv	Pa.
18A1	Northern Pacific RR.	25	Dg	52	60	--	--	T	5	D	Qa	Pumped 135 gpm.

20A1	Neil Rosevear	250	Dr	215	6	22.1	9-18-67	Sb	1	D	Qls	Pa.
20H1	S. D. LaBonte	140	Dg	13	30	9.3	9-18-67	C	3/4	D	Qls	Pa.
20J1	Port of Kalama	25	Dr	631	10	--	--	—	--	P	Tsv	Pumped 20 gpm.
21B1	Lee Pitchforth	450	Dr	60	6	40±	9-12-67	J	½	D	Qls	Pumped 12 gpm. Pa.
21D1	Page Stewart	240	Dr	200	6	75	11- -55	J	--	D	Qls	Well pumps "dry" in 4 hr at 8 gpm.
21E1	E. G. Bruner	160	Dr	80	6	37.9	9-18-67	Sb	½	D,S	Qls	Pumped 30 gpm. Pa, L.
28B1	Robert Shelby	190	Dr	215	6	--	--	P	½	D	Qls	Pa.
28C1	George Confer	185	Dr	180	6	--	--	P	½	D	Qls	Pa.
28C2	William Mahlum	200	Dg	15	30	13.1	9-20-67	C	3/4	D	Qls	Pa.
35B1	L. W. Metzger	840	Dr	314	8	80	3- 6-53	--	--	--	Tsv	Pumped 50 gpm, dd 290 ft.
						T. 7 N., R. 1 W.						
8P1	T. E. Courser	270	Dr	169	6	82.9	8- 7-67	Sb	3/4	D	Qa	Pa.
8R1	J. L. Bodine	330	Dr	160	6	85.2	9-14-67	Sb	1½	D	Qa	Pa.
9D1	F. K. Swihart	280	Dr	380	6	20	4-10-68	Sb	1	D	Qa	
9M1	M. E. Keller	270	Dr	75	6	--	--	J	3/4	D	Qa	Pa.
9N1	S. Stangle	280	Dr	150	6	--	--	Sb	3/4	D	Qa	Pumped 18 gpm. Pa.
9N2	A. West	270	Dr	274	6	47.3	9-14-67	Sb	1	D	Qa	Pa.

Table 6. -Records of wells - Continued

Well No.	Owner or tenant	Altitude (feet)	Type of Well	Depth of Well (feet)	Diameter of Well (inches)	Water Level: Below land surface (feet)	Water Level: Date	Pump: Type	Pump: H. P.	Use of Water	Principal aquifer	Remarks
T. 7 N., R. 1 W. - Continued												
9P1	W. F. Williams	380	Dr	105	6	--	--	J	3/4	D,S	Qa	Pa.
9P2	D. C. Blaine	400	Dr	200	6	21.0	9-14-67	Sb	1	D,S	Qa	Pa.
9P3	N. Elliott	380	Dr	205	6	--	--	Sb	3/4	D,S	Qa	Pa.
9Q1	R. T. Huss	450	Dr	200	6	44.4	9-14-67	J	1	D	Qa	Pa.
15F1	K. Bayles	900	Dr	201	6	--	--	Sb	3/4	D,S	Tsv	Pa.
15F2	P. M. Jabusch	900	Dg	5	30	2	8- -59	J	¼	D	Qa	Pumped 110 gpm.
17A1	T. E. Courser	395	Dr	97	6	--	--	J	3/4	D	Qa	Pa.
17B1	R. G. White	280	Dr	--	6	--	--	J	1	D	Qa	Pa.
17B2	J. Herndon	275	Dr	125	6	15	1966	J	1	D	Qa	Ca.
17D1	E. Adams	220	Dr	210	6	44.8	6- 5-68	Sb	3/4	D	Qa	Pumped 10 gpm.
17G1	Julio Mendez	300	Dr	180	6	--	--	Sb	½	D	Qa	Pa.
17G2	T. E. Courser	280	Dr	97	6	--	--	J	3/4	D	Qa	Pa.
17N1	Perigo	260	Dr	90	8	--	--	J	1	D	Tsv	Pa.
17P1	R. Slavens	420	Dr	370	6	--	--	Sb	1	D,S	Qa	Can be pumped "dry" in 2 hr with present pump. Pa.

20D1	R. Hight	200	Dg	12	108	8	8-18-67	N	--	D,S	Tsv	Gravity flow to house. Pa.
22E1	S. J. Peterson	1,320	Dr	154	6	47.2	6- 4-68	Sb	1	D	Tsv	
23D1	K. Ostrem	1,120	Dr	60	6	35.0	8-16-67	J	½	D	Tsv	
30J1	J. E. Jacobs	755	Dr	218	6	57.2	8-16-67	Sb	½	D	Tsv	Pa.
30J2	R. C. Jacobs	740	Dr	180	6	50.2	8-16-67	Sb	3/4	D	Tsv	Pa.
30K1	H. V. Cook	600	Dr	238	6	163.9	8-16-67	Sb	1	D	Tsv	Pa.
33J1	Washington State Dept. of Fisheries	40	Dr	84	8	14.6	10-20-67	N	--	O	Qa	L.
33J2	---do---	35	Dr	26	16	7.5	10-24-67	N	--	U	Qa	
33J3	---do---	43	Dr	33	16	19.4	11- 9-67	N	--	U	Qa	
					T. 7 N., R. 2 W.							
6B1	Weyerhaeuser Timber Co.	15	Dr	201	12	--	--	T	--	C	Qa	L.
6B2	---do---	15	Dr	198	12	--	--	T	--	C	Qa	L.
8H1	Continental Grain Co.	15	Dr	309	16	24	1-12-54	T	--	C	Qa	Pumped 1,000 gpm, dd 29 ft. L.
9K1	International Paper Co.	10	Dr	218	14	11	10- 4-67	T	25	C	Qa	L.
9L1	---do---	10	Dr	215	14	10	10- 4-67	T	25	C	Qa	Pa.
					T. 8 N., R. 1 W.							
19C1	William Gottfryd	1,120	Dr	520	6	384.8	11- 8-67	Sb	2½	D	Tsv	Ca.

Table 6.-Records of wells - Continued

Well No.	Owner or tenant	Altitude (feet)	Type of Well	Depth of Well (feet)	Diameter of Well (inches)	Water Level: Below land surface (feet)	Water Level: Date	Pump: Type	Pump: H. P.	Use of Water	Principal aquifer	Remarks
T. 8 N., R. 2 W.												
1P1	W. R. Chancellor	50	Dr	165	6	.4	10-26-67	Sb	1	D	Qa	Pa.
1P2	J. H. Joplin	50	Dr	38	6	1.5	10-26-67	J	½	D	Qa	Pa.
2L1	Cowlitz County PUD	--	Dr	69	6	26	10- 1-63	--	--	X	Qa	Test hole. L.
2N1	---do---	--	Dr	96	6	30	9-28-63	--	--	X	Qa	Do.
2P1	---do---	--	Dr	118	6	12.5	12- 2-63	--	--	X	Qa	Do.
2Q1	Dorothy Adams	95	Dr	140	6	--	--	Sb	--	D	Qa	Pa.
2R1	Cowlitz County PUD	--	Dr	195	6	30	12- 5-63	N	--	X	Qa	Test hole. L.
3F1	E. MacWilliams	30	Dr	60	6	--	--	J	1	D	Qa	Pumped 12 gpm.
3G1	F. H. Belter	70	Dr	300	6	57.9	9-20-67	Sb	1	D	Qa	Pa.
3G2	Beasley	100	Dr	100+	6	--	--	J	½	D	Qa	Pa.
3Q1	R. Kiser	20	Dg	20	36	13.0	9-20-67	J	¼	D,S	Qa	Pa.
10J1	Bee Smith	25	Dr	50	8	12	5-10-50	C	5	I	Qa	Pumped 120 gpm, dd 2 ft.
11B1	Ed Rice	80	Dr	124	6	61.4	11- 3-67	Sb	1	D,S,I	Qa	Pa.
11E1	Cowlitz County PUD	--	Dr	90	6	25	10-15-63	N	--	X	Qa	Test hole. L.

11G1	Ostrander Water Co.	100	Dr	165	6	71.9	11- 1-67	Sb	3	P	Qa	Ca.
11L1	Cowlitz County PUD	--	Dr	93	6	20	10-11-63	N	--	X	Qa	Test hole. L.
12B1	Robert Brown	100	Dr	185	6	37.0	10-26-67	Sb	½	D	Qa	Pa.
12C1	Alder Wood Mobile Home Park	40	Dr	270	6	--	--	Sb	3	P	Qa	Pa.
13C1	R. Sockerson	400	Dr	165	6	--	--	Sb	1	D	Qa	Pa.
14C1	Lyle Caines	140	Dr	88	6	15	1966	J	1	D	Qa	Pumped 2 gpm.
24K1	R. D. Lemmons	480	Dr	319	6	--	--	J	1	D	Qa	Pa.
24L1	G. A. Jarvis	400	Dr	130	6	94.3	10-25-67	J	1	D	Qa	Pa.
24M1	K. G. Peterson	430	Dr	100+	6	--	--	Sb	--	D	Qa	Pa.
28D1	Washington Gas and Electric Co.	40	Dr	246	10	15	9- 1-38	--	--	X	Qa	
28D2	---do---	40	Dr	250	10	15	9- 1-38	--	--	X	Qa	
28D3	---do---	40	Dr	250	10	15	9- 1-38	--	--	X	Qa	
30L1	Fry Mint Farm	25	Dr	200	6	15	8- -53	T	7½	I	Qa	
31K1	Weyerhaeuser Timber Co.	20	Dr	233	12	11	4-30-63	--	--	C	Qa	L.
31P1	---do---	20	Dr	201	12	6	7- 5-37	T	100	C	Qa	Pumped 600 gpm, dd 12 ft.
34L1	Interstate Packers, Inc.	20	Dr	40	8	12	4-10-53	J	7½	C	Qa	Pumped 100 gpm.
34P1	Westport Chemical Co.	20	Dr	45	8	8	1-18-60	C	15	C	Qa	Pumped 150 gpm, dd 4 ft. L.

Table 6.-Records of wells - Continued

Well No.	Owner or tenant	Altitude (feet)	Type of Well	Depth of Well (feet)	Diameter of Well (inches)	Water Level: Below land surface (feet)	Water Level: Date	Pump: Type	Pump: H.P.	Use of Water	Principal aquifer	Remarks
T. 8 N., R. 3 W.												
2Q1	Vaughn Trailer Court	175	Dr	255	6	Flows	11-29-67	Sb	1	P	Tsv	Pa.
2Q2	---do---	175	Dr	65	6	3	11-29-67	J	1	P	Qa	Pa, L.
11F1	H. G. Lockwood	100	Dr	260	6	42.7	11-29-67	Sb	3/4	D	Tsv	Ca.
11N1	Earl Swett	150	Dr	213	6	103.1	11-29-67	Sb	1	D	Tsv	Pa.
15A1	C. F. Wood	50	Dr	120	6	50.0	11-28-67	Sb	3/4	D	Tsv	Pumped 20 gpm. Pa.
15A2	G. S. Shortlidge	65	Dr	108	6	57.3	11-28-67	Sb	½	D	Tsv	Pa.
25P1	Reynolds Metals Corp.	20	Dr	339	20	7	4- 3-67	T	--	C	Qa	Pumped 3,000 gpm, dd 49 ft. L.
25P2	---do---	20	Dr	353	20	7	4-18-67	T	--	C	Qa	Pumped 3,000 gpm, dd 11 ft. L.
25Q1	---do---	20	Dr	353	20	9.5	10-31-67	T	--	C	Qa	Pumped 3,000 gpm, dd 6 ft. H.
36B1	---do---	20	Dr	261	20	8	5-12-67	T	--	C	Qa	Pumped 3,000 gpm, dd 2.3 ft. L.
36B2	---do---	20	Dr	410	20	Flows	7- 6-67	T	--	C	Qa	Pumped 3,000 gpm, dd 15 ft. Flows during high river stage. L.

36H1	---do---	20	Dr	261	20	7	3-24-52	T	250	C	Qa	Pumped 3,000 gpm, dd 7 ft. Pa.
						T. 8 N., R. 4 W.						
11L1	E. G. Smith	60	Dr	128	6	45	2- 1-59	Sb	1	D	Tv	L.
						T. 9 N., R. 1 W.						
5H1	C. L. Robards	500	Dr	60	6	23.2	6-12-68	J	½	D	Qa	
5K1	L. A. Day	520	Dr	30	6	16.4	6-12-68	J	½	D	Qa	
5M1	Larry Kruckenberg	565	Dr	164	6	16.1	11-15-67	Sb	1	D	Tw	Pa.
6A1	Ralph Rider	640	Dr	265	8	--	--	J	1	D	Tsv	Can be pumped "dry" in 8-10 hr with present pump.
6A2	G. H. Campbell	650	Dr	124	6	68	6-12-68	J	1	D	Tsv	
6N1	Richard Carnine	720	Dg	40	48	21.6	11-16-67	J	1	D	Qa	Pa.
7M1	D. A. Barnett	860	Dr	339	6	270.6	11-16-67	Sb	1½	D,S	Tsv	Serves two homes. Pa.
22P1	Weyerhaeuser Timber Co.	880	Dr	175	8	30	5-23-60	Sb	3	P	Tsv	L.
22Q1	---do---	880	Dr	180	8	--	--	T	5	P	Tsv	
						T. 9 N., R. 2 W.						
1A1	G. A. Stitham	600	Dr	97	8	--	--	Sb	1	D,I	Qa	Pumped 67 gpm. L.
2E1	Orland Nelson	40	Dr	80	6	--	--	J	½	D	Qa	

Table 6.-Records of wells - Continued

Well No.	Owner or tenant	Altitude (feet)	Type of Well	Depth of Well (feet)	Diameter of Well (inches)	Water Level: Below land surface (feet)	Water Level: Date	Pump: Type	Pump: H. P.	Use of Water	Principal aquifer	Remarks
						T. 9 N., R. 2 W. - Continued						
2P1	Elgin Fiest	80	Dr	152	6	79.0	11-16-67	Sb	1	D	Qa	Pa.
5B1	H. P. Cole	160	Dr	220	8	--	--	Sb	1	D	Qa	Pa.
5J1	J. H. Puvogel	160	Dr	160	5	--	--	P	1	D	Qa	Pa.
10A1	J. E. Kalmbach	40	Dg	26	72	--	--	--	--	P	Qa	
10A2	---do---	40	Dg	26	72	--	--	--	--	P	Qa	
10B1	R. A. Lewellen	40	Dr	51	12	19	4- -65	--	--	P	Qa	L.
10C1	---do---	40	Dr	30	12	15	3-31-53	C	15	P	Qa	There are six wells in this vicinity that supply the town of Castle Rock with 500,000 gpd.
10C2	---do---	40	Dr	40	12	12	7- 1-51	C	--	P	Qa	
10D1	---do---	40	Dr	32	6	18	6- 1-52	C	5	P	Qa	Pumped 70 gpm, dd 4 ft.
10J1	J. E. Kalmbach	40	Dr	--	--	--	--	--	--	I	Qa	
10L1	Charles Uniker	40	Dr	44	12	12	10-16-52	--	--	--	Qa	Pumped 185 gpm, dd 25 ft.
10L2	Delbert Maddux	40	Dg	16	30	7	4- 4-53	--	--	--	Qa	Pumped 60 gpm, dd 4 ft.

11Q1	Cecil Eklund	100	Dr	132	6	64.7	4- 9-68	J	2	D	Qa	Ca.
14H1	C. W. Lane	150	Dr	180	8	129	4-10-65	--	--	--	Qa	Pumped 30 gpm, dd 2 ft. L.
22J1	C. A. Axtell	180	Dr	172	6	110	8- 6-65	--	--	--	Qa	L.
22K1	C. C. Church	180	Dr	415	6	90	9- -60	--	--	--	Tsv	L.
23B1	W. F. Larsen	45	Dr	41	8	8	5-14-65	--	--	--	Qa	Pumped 80 gpm, dd 0.0 ft. L.
23C1	F. C. Baker	40	Dr	30	12	9	10-28-43	C	5	--	Qa	
26J1	Milton Brown	100	Dr	140	6	--	--	J	1	D	Qa	Pa.
27B1	Weller	160	Dr	160	6	--	--	J	1	D	Qa	Pa.
27B2	E. A. Fettis	160	Dr	150	6	--	--	Sb	1	D	Qa	Pa.
27J1	G. M. Burris	80	Dr	36	6	--	--	P	½	D	Qa	Dug to depth of 8 ft. and then drilled to 36 ft.
27Q1	O. A. Dudonsky	40	Dr	43	12	8	8-25-50	C	5	I	Qa	Pumped 200 gpm.
28D1	W. Williams	160	Dr	150	6	--	--	J	1½	D	Qa	Pa.
29R1	D. F. Roland	140	Dr	100	6	--	--	Sb	½	D	Qa	Ca.
29R2	Stuart Busch	130	Dr	110	6	--	--	N	--	U	Qa	
33D1	---do---	120	Dr	95	6	15.9	9-21-67	Sb	1	D	Qa	Pa.
33L1	L. R. Bopp	140	Dr	125	6	--	--	P	3/4	D,S	Qa	Pa.
33M1	Harry Siverson	200	Dg	8	36	Flows	9-21-67	N	--	D	Qa	Gravity flow to house. Pa.
33Q1	Ralph Roggenback	95	Dr	68	6	8	9-21-67	J	1	D	Qa	Pa.

Table 6.-Records of wells - Continued

Well No.	Owner or tenant	Altitude (feet)	Type of Well	Depth of Well (feet)	Diameter of Well (inches)	Water Level: Below land surface (feet)	Water Level: Date	Pump: Type	Pump: H. P.	Use of Water	Principal aquifer	Remarks
						T. 9 N., R. 2 W. - Continued						
33Q2	J. G. Bales	180	Dr	35	6	.0	9-21-67	Sb	1	D	Qa	Pa.
33Q3	N. Beckers	100	Dr	60	6	--	--	J	1/3	D	Qa	Pa.
33R1	Archie Adirim	100	Dr	128	6	--	--	J	1	D	Qa	Pa.
33R2	G. L. Hedgson	110	Dr	90	6	--	--	Sb	3/4	D	Qa	Pa.
33R3	G. A. Hansen	115	Dr	100+	6	36.2	9-21-67	Sb	1	D	Qa	Pa.
34N1	W. V. Fritz	100	Dg	8	30	.0	9-21-67	C	½	D	Qa	Pa.
34R1	Cowlitz County PUD	20	Dr	70	6	30	9-17-63	--	--	X	Qa	Test hole. L.
35A1	G. H. Evans	80	Dr	85	6	--	--	J	1	D	Qa	
35G1	Charles Bond	120	Dr	138	6	75	9- -65	--	--	--	Qa	Pumped 50 gpm, dd 30 ft. L.
35N1	Cowlitz County PUD	20	Dr	110	6	30	9-15-63	--	--	U	Qa	Test hole. L.
						T. 9 N., R. 3 W.						
26A1	Kejerline	720	Dr	209	4	60.2	6-11-68	Sb	½	D	Tsv	Pumped 2 gpm.
26A2	R. L. Bosler	700	Dr	64	8	4	9- 1-58	--	--	D	Tsv	Pumped 160 gpm, dd 24 ft.

T. 9 N., R. 4 W.												
35D1	U. S. Department of the Interior	250	Dr	237	16	152	8-17-65	--	--	C	Tv	Used to maintain constant temperature of the water for salmon propagation studies. Pumped 450 gpm. L.
T. 9 N., R. 1 E.												
6H1	K. L. Taylor	520	Dr	95	6	47.0	11-14-67	Sb	1	D	Qa	Supplies three homes.
7A1	W. A. Tippary	560	Dr	145	6	--	--	J	1	D	Tv	
T. 10 N., R. 1 W.												
25J1	Virgil Carroll	480	Dr	400	6	3.2	11-15-67	J	1	D	Qa	Ca.
30A1	Byron Will	120	Dr	115	6	--	--	J	1	D,S	Tw	Pa.
30L1	Carl Brockman	360	Dr	109	6	12	4- 5-42	--	--	D	Tw	Pumped 35 gpm.
30N1	Jad Bunn	385	Dr	250	6	25.8	11- 9-67	J	1	D,S	Tw	
31J1	Ringold	675	Dg	30	72	--	--	J	1	D	Tw	Serves two homes.
31K1	David Smith	640	Dr	300	6	116.3	11-15-67	Sb	1	D,S	Tw	Pa.
33B1	M. C. Stevenson	470	Dg	35	48	13.1	11-17-67	J	½	D	Tw	
33K1	Donald Vernon	590	Dr	120	6	--	--	J	--	D	Tw	Pa.
35K1	Streeters' Resort	490	Dr	45	6	5.6	6- 8-68	J	1	C	Tw	
35R1	B. V. Williams	490	Dr	20	6	5.4	6- 6-68	J	3/4	D	Tw	

Table 6.-Records of wells - Continued

Well No.	Owner or tenant	Altitude (feet)	Type of Well	Depth of Well (feet)	Diameter of Well (inches)	Water Level: Below land surface (feet)	Water Level: Date	Pump: Type	Pump: H. P.	Use of Water	Principal aquifer	Remarks
						T. 10 N., R. 2 W.						
36A1	Paul Everdell	480	Dr	232	6	--	--	Sb	1	D,S	Tw	Pa.
36E1	B. A. Goodrich	360	Dg	18	36	6.1	11-16-67	J	½	D	Tw	Pa.

Table 7.--Drillers' logs of representative wells.

Drillers designations are edited for consistency of presentation but are otherwise unchanged. The altitudes shown are those of the land surface at the wells, in feet above mean sea level, interpolated from topographic maps.

Materials	Thickness (feet)	Depth (feet)
5/1 E-5G1. Lavine. Drilled by S. J. Peterson, 1967.		
Soil	2	2
Clay, gray	14	16
Clay, gray, and sand	29	45
Clay, green, and sand	10	55
Clay, gray, and sand	5	60
Clay, green, and sand	10	70
Clay, gray, sand and rock	42	112
Clay, brown	12	124
Sandstone, gray	72	196
Clay, tan	19	215
Sandstone, tan	9	224
Sandstone, green	14	238
Sandstone, brown	32	270
Ash, volcanic	74	344
Andesite	166	510
Altitude 360 ft.		
5/1 E-18F1. Wayne Bozarth. Drilled by G. Zent, 1967.		
Soil, sandy	1	1
Sand, fine to medium, some gravel	18	19
Sand and gravel, water-bearing	11	30
Sand, medium to coarse, water-bearing	4½	34½
Clay, fine, sandy, and silt	11½	46
Sand, fine, silty	12	58
Altitude 33 ft.		
5/1 E-31F1. Lester Nelson. Drilled by G. Zent, 1965.		
Soil	2	2
Sand and clay	21	23
Sand, water-bearing	1	24
Clay, sandy	36	60
Sand, fine, silty	5	65
Silt	48	113
Sand, wood, water-bearing	4	117

Table 7.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
5/1 E-31F1 - Continued.		
Clay, sandy	14	131
Silt	38	169
Sand, medium to coarse, water-bearing	2	171
Clay, sandy	29	200
Sand and gravel, water-bearing	2	202
Altitude 20 ft.		
6/1 E-32N1. Armas Saastamo. Drilled by F. McGhee, 1952.		
Clay	60	60
Gravel, cemented	70	150
Rock, shale, loose	30	180
Altitude 960 ft.		
5/1 W-14A1. United Bulb Co. Drilled by G. Zent, 1963.		
Soil, black	2	2
Silt, light gray	1	3
Sand, silty, gray-brown	4	7
Sand, very fine, gray	3	10
Sand, gray, water-bearing	25	35
Silt, gray	1	36
Silt, white	1	37
Silt, gray	1	38
Altitude 10 ft. Casing, 12-inch perforated from 15 to 35 ft.		
5/1 W-14J1. United Bulb Co. Drilled by G. Zent, 1946.		
Soil	2	2
"Quicksand," water-bearing at 10 ft.	18	20
Clay	1	21
Sand, water-bearing	9	30
Altitude 10 ft.		
6/1 W-21E1. E. G. Bruner. Drilled by W. Price, 1956.		
Clay and soil	20	20
Clay and rock	35	55
Water-bearing "strata"	2	57

Table 7.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
6/1 W-21E1 - Continued.		
Rock, solid	13	70
Sand and gravel, water-bearing	10	80
Altitude 160 ft.		
7/1 E-33J1. Washington State Dept. of Fisheries. Drilled by Robinson and Roberts, 1967.		
Silt, clay, very fine sand, brown	15	15
Sand, gravel, with silt, clay	14	29
Sand, pumiceous, and clay, contains pebbles and granules of pumice at 41 ft.	17	46
Sand, gravel, wood fragments, contains much interstitial silt and clay	10	56
Clay, green, with sand and silt, some imbedded gravel	9	65
Clay, soupy, with some silt, sand, and gravel	17	82
Rock, andesite	2	84
Altitude 40 ft.		
7/2 W-6B1. Weyerhaeuser Timber Co. Drilled in 1935. Driller unknown.		
Clay, sandy, brown	18	18
Sand	9	27
Clay, very sticky, red	37	64
Clay, silty, gray	28	92
Sand, silty, fine	20	112
Sand, fine	11	123
Sand, very hard	2	125
Sand	18	143
Sand, very hard, with rocks	3	146
Sand	12	158
Sand, very fine, silty	8	166
Clay, gray	20	186
Sand, coarse	8	194
Gravel	7	201
Rock, solid	--	
Altitude 15 ft.		
7/2 W-6B2. Weyerhaeuser Timber Co. Drilled in 1935. Driller unknown.		
Soil	6	6
Sand and clay	38	44

Table 7.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
7/2 W-6B2 - Continued.		
Sand, gray, and silt	30	74
Sand	5	79
Silt	7	86
Sand	15	101
Silt	6	107
Sand	2	109
Clay, brown, with sand	9	118
Clay, brown	22	140
Silt	41	181
Gravel and sand, black; some water	5	186
Gravel and sand, coarse	2	188
Gravel and sand	4	192
Rock "boulder"	1	193
Sand, fine, and clay	3	196
Gravel and boulders	2	198
Altitude 15 ft.		
7/2 W-8H1. Continental Grain Co. Driller unknown.		
Sand and silt; some "binder"	17	17
Sand and silt	8	25
Sand, packed	32	57
Clay, sandy	9	66
Sand, coarse, packed	41	107
Silt	9	116
Silt, sandy, and gravel	22	138
Gravel, cemented	41	179
Gravel with clay "binder"	9	188
Sand and clay	18	206
Clay, sandy; some gravel	17	223
Sand, dirty; small amount of gravel	28	251
Gravel, cemented	25	276
Shale, blue	33	309
Altitude 15 ft.		
7/2 W-9K1. International Paper Co. Drilled in 1935. Driller unknown.		
Sand and gravel	170	170
Clay, thin lenses	8	178
Sand and gravel	40	218
Altitude 10 ft.		

Table 7.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
8/2 W-2L1. Cowlitz County PUD. Drilled by D. McGhee, 1964.		
Clay, sandy	30	30
Sand, gravel, and clay	11	41
Clay, soft	16	57
Sand and gravel, water-bearing	6	63
Sand, water-bearing	5	68
Clay, blue	1	69
(Casing pulled, hole backfilled)		
8/2 W-2N1. Cowlitz County PUD. Drilled by D. McGhee, 1964.		
Clay, sandy	20	20
Sand	5	25
Clay, sandy	4	29
Sand, clay and gravel	28	57
Clay, soft, sandy	8	65
Gravel and silty sand	2	67
Gravel, heavy; sand, and silt	4	71
Clay, sandy	4	75
Clay, sandy; and gravel	1	76
Clay, sandy, gray	20	96
(Casing pulled, hole backfilled)		
8/2 W-2P1. Cowlitz County PUD. Drilled by D. McGhee, 1964.		
Clay, sandy	20	20
Sand and gravel	2	22
Mud, sand, and gravel	6	28
Gravel, sandy	3	31
Sand; some gravel	4	35
Sand and gravel	7	42
Sand, fine	4	46
Clay, soft	13	59
Sand and gravel	4	63
Sand	17	80
Sand, gravel, and clay	8	88
Sand and gravel	6	94
Clay, hard	24	118
8/2 W-2R1. Cowlitz County PUD. Drilled by D. McGhee, 1964.		
Clay, sandy	15	15
Sand; some gravel	10	25

Table 7.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
8/2 W-2R1 - Continued.		
Gravel, sand, and mud	17	42
Sand and gravel	15	57
Pumice, gravel, and sand	8	65
Pumice, and dark sand	10	75
Sand, dark	10	85
Sand, silt, and wood	35	120
Sand, clean, and pebbles	15	135
Sand	8	143
Sand, gravel, and clay	25	168
Sand; some gravel	15	185
Sand; some water	10	195
(Casing pulled, hole backfilled)		
8/2 W-11E1. Cowlitz County PUD. Drilled by D. McGhee, 1964.		
Clay, sandy	9	9
Sand and gravel	23	32
Sand, coarse	7	39
Sand; some gravel	6	45
Sand, coarse; some gravel; water-bearing	15	60
Clay	5	65
Sand, mud, and wood	14	79
Mud, silty	11	90
8/2 W-11L1. Cowlitz County PUD. Drilled by D. McGhee, 1964.		
Clay, sandy	10	10
Sand, gravel	8	18
Sand	10	28
Sand, gravel, and some mud	16	44
Clay, silty, blue	19	63
Gravel and sand	8	71
Gravel, sand, and clay	4	75
Gravel and sand	3	78
Sandstone, soft, with clay	15	93
8/2 W-31K1. Weyerhaeuser Timber Co. Drilled by E. W. Janson, 1962.		
"Sandfill"	30	30
Clay, soft, silty, blue	60	90
Sand, very fine, silty, blue	90	180
Sand streaks, coarse, and heavier clay	20	200

Table 7.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
8/2 W-31K1 - Continued.		
Rock streaks, broken, sand, and clay	18	218
Gravel and heavy cobbles	12	230
Cobbles, large	3	233
Altitude 20 ft.		
8/2 W-34P1. Westport Chemical Co. Drilled by D. McGhee.		
Clay, sandy	18	18
Sand and gravel, fine, water-bearing	27	45
Altitude 20 ft. Perforated, 20-45 ft.		
8/3 W-2Q2. Vaughn Trailer Court. Drilled by D. McGhee, 1966.		
Topsoil	8	8
Clay and gravel	12	20
Clay, soft, blue	8	28
Shale, caving, water-bearing	4	32
Clay, hard, sandy	33	65
Altitude 175 ft.		
8/3 W-25P1. Reynolds Metals Corp. Drilled by R. J. Strasser, 1967.		
Clay, brown, and sand	21	21
Silt, brown	81	102
Sand, gray, and silt	84	186
Sand, hard-packed	8	194
Clay, brown, and silt	9	203
Sand, hard-packed	38	241
Sand, packed	58	299
Clay, gray, and gravel	5	304
Gravel, water-bearing	35	339
Altitude 20 ft.		
8/3 W-25P2. Reynolds Metals Corp. Drilled by R. J. Strasser, 1967.		
Fill	4	4
Clay, brown, and silt	8	12
Sand, gray, and silt	30	42
Sand, blue, and silt	35	77
Sand, hard-packed	31	108
Silt, sandy, gray	78	186

Table 7.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
8/3 W-25P2 - Continued.		
Sand, hard-packed	118	304
Sand, coarse, gray	12	316
Sand and gravel, water-bearing	41	357
Altitude 20 ft.		
8/3 W-36B1. Reynolds Metals Corp. Drilled by R. J. Strasser, 1967.		
Fill	5	5
Silt, soft, brown	26	31
Silt, gray	41	72
Silt, brown	111	183
Sand, packed	26	209
Clay, sandy, dark-blue	5	214
Gravel, cemented	7	221
Gravel, water-bearing	40	261
Altitude 20 ft.		
8/3 W-36B2. Reynolds Metals Corp. Drilled by R. J. Strasser, 1967.		
Fill	2	2
Clay, sandy, gray	22	24
Silt, gray	36	60
Silt, brown; contains wood	79	139
Sand, packed	25	164
Sand, gray	31	195
Sand, hard-packed	6	201
Sand, gray	6	207
Sand, hard-packed	64	271
Clay, blue	3	274
Sand and silt	7	281
Sand; small amount of gravel	18	299
Sand	6	305
Gravel, large, and sand	10	315
Sand and gravel, water-bearing	80	395
Gravel, cemented	2	397
Shale, brown	13	410
Altitude 20 ft.		

Table 7.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
8/4 W-11L1. E. G. Smith. Drilled by S. J. Pederson, 1965.		
Clay, brown, and boulders	21	21
Basalt	107	128
Altitude 60 ft.		
9/1 W-22P1. Weyerhaeuser Timber Co. Drilled by S. J. Peterson, 1959.		
Clay, brown	10	10
Clay, blue	15	25
Clay, blue, and small stones	35	60
Clay, chocolate brown, and sandstone	30	90
Shale, reddish, and layers of blue shale	19	109
Soapstone	1	110
Rock, solid, gray	65	175
Altitude 880 ft.		
9/2 W-1A1. G. A. Stitham. Drilled by F. McGhee, 1967.		
Soil, brown	2	2
Clay, yellow	18	20
Clay, brown	20	40
Rock, black	57	97
Altitude 600 ft.		
9/2 W-10B1. R. A. Lewellen. Drilled by S. J. Peterson, 1965.		
Topsoil	5	5
Clay, pumice	7	12
Gravel and clay	10	22
Sand, pumice, and gravel (up to 2-inch)	29	51
Altitude 40 ft.		
9/2 W-14H1. C. W. Lane. Drilled by Williams Well Drilling, 1965.		
Topsoil	2	2
Clay, sandy, brown	38	40
Sand, "runny", blue	10	50
Clay, blue	5	55
Gravel, cemented	84	139
Sand and pea gravel, coarse, water-bearing	2	141
Gravel, cemented; some water	3	144
Sand, cemented	16	160

Table 7.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
9/2 W-14H1 - Continued.		
Clay, blue	5	165
Sand and blue rock, water-bearing	15	180
Altitude 150 ft.		
9/2 W-22J1. C. A. Axtell. Drilled by S. J. Peterson, 1961.		
Clay and silt	39	39
Silt and sand; some gravel	86	125
Sand, clean	10	135
Clay and sand	3	138
Sand, coarse to fine	27	165
Gravel, coarse	7	172
Altitude 180 ft.		
9/2 W-22K1. C. C. Church. Drilled by D. McGhee, 1960.		
Topsoil	3	3
Clay	47	50
Sand, clayey	40	90
Sand, clayey; some gravel	15	105
Clay and hard sand	310	415
Altitude 180 ft.		
9/2 W-23B1. W. F. Larsen. Drilled by Williams Well Drilling, 1966.		
Loam, sandy	4	4
Clay, sandy brown	16	20
Sand, fine	3	23
Gravel, cemented	7	30
Gravel and sand, water-bearing	11	41
Altitude 45 ft.		
9/2 W-34R1. Cowlitz County PUD. Drilled by D. McGhee, 1964.		
Clay, sandy	5	5
Sand and gravel	2	7
Sand	13	20
Sand and gravel	7	27
Sand, water-bearing	13	40
Clay, soft, blue	13	53
Clay, yellow	10	63

Table 7.--Drillers' logs of representative wells.--Continued

Materials	Thickness (feet)	Depth (feet)
9/2 W-34R1 - Continued.		
Sand and gravel	3	66
Clay, blue	4	70
Altitude 20 ft.		
9/2 W-35G1. Charles Bond. Drilled by D. McGhee, 1965.		
Clay, brown	10	10
Clay, sandy, soft	80	90
Clay, caving, sandy	19	109
Sand and gravel	11	120
Sand	4	124
Sandstone, soft	14	138
Altitude 120 ft.		
9/2 W-35N1. Cowlitz County PUD. Drilled by D. McGhee.		
Clay, sandy	10	10
Sand, coarse	13	23
Sand, coarse; and some gravel	14	37
Clay and some sand	7	44
Gravel	3	47
Sand and gravel	6	53
Clay, gray	43	96
Clay, dark	14	110
Altitude 20 ft.		
9/4 W-35D1. U. S. Dept. of the Interior. Drilled by R. J. Strasser, 1965.		
Fill	3	3
Boulders, sand, and gravel	9	12
Gravel and clay	2	14
Conglomerate	33	47
Sand, white	50	97
Sand, gravel, and clay	67	164
Rock, decomposed, brown	6	170
Basalt, hard, black	26	196
Rock, porous, black	28	224
Rock, broken	13	237
Altitude 250 ft.		