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GROUND-WATER RESOURCES OF THE LOWER SANTIAM RIVER BASIN, MIDDLE WILAMETTE VALLEY, OREGON

BY

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U. S. GEOLOGICAL SURVEY

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FACTORS FOR CONVERTING ENGLISH UNITS TO INTERNATIONAL SYSTEM UNITS (SI)

Factors for converting English units to metric units are shown to four significant figures. However, in the text the metric equivalents are shown only to the number of significant figures consistent with the value for the English units.

English	Multiply by	Metric
	Length	
in. (inches)	25.4	mm (millimeters)
ft (feet)	.3048	m (meters)
mi (miles)	1.609	km (kilometers)
	Area	
acres	4047	m^2 (square meters)
	.4047	ha (hectares)
	.004047	km^2 (square kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)
	Volume	
acre-ft (acre-feet)	1233	m^3 (cubic meters)
	.001233	hm^3 (cubic hectometers)
	.000001233	km^3 (cubic kilometers)
	Flow	
ft^3/s (cubic feet per second)	.02832	m^3/s (meters per second)
gal/min (gallons per minute)	.06309	l/s (liters per second)
Mgal/d (million gallons per day)	3785	m^3/d (cubic meters per day)
	Other	
(gal/min)/ft (gallons per minute per foot)	.2070	(l/s)/m (liters per second per meter)
ft/mi (feet per mile)	.1894	m/km (meters per kilometer)
lb/in^2 (pounds per square inch)	.04	kg/mm^2 (kilograms per square millimeter)
°F (degrees Fahrenheit)	5/9 (°F -32)	°C (degrees Celsius)

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By D. C. Helm and A. R. Leonard

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ABSTRACT

As used in this report, the lower Santiam River basin includes the lower valleys of the North and South Santiam Rivers and the alluvial valley westward from their confluence to the Willamette River. The study area occupies about 600 mi^2 (1600 km^2) in the middle part of the Willamette River valley and in the adjacent foothills of the Cascade Range. About 200 mi^2 (500 km^2) are alluvial plains where agriculture is the principal occupation.

Volcanic and marine sedimentary rocks that are exposed in the foothills and in isolated buttes in the valley lowland range in age from Eocene to Pliocene. The volcanic rocks include lava flows, tuffs, mudflows, and intrusive rocks. In the foothills, interflow zones in the Columbia River Basalt Group locally yield water adequate for irrigation supplies. However, where pumping is concentrated, water levels in the basalt are declining progressively with time. Wells that tap other consolidated volcanic and sedimentary rocks tend to have small yields, adequate only for domestic and stock needs. In places, water in the marine rocks and volcanic rocks of the Sardine Formation is too mineralized for use.

Alluvial deposits that underlie the valley plains are the most productive aquifers, the best being those along the North Santiam and Willamette Rivers. The younger alluvium has a maximum thickness of about 65 ft (20 m), but is less than 50 ft (15 m) thick in most places. The older alluvium ranges from 30 to 300 ft (9 to 90 m) in thickness. These aquifers are hydraulically connected with the South Santiam and Willamette Rivers and possibly to other major streams.

The alluvial aquifers contain about 2 million acre-ft (2.5 km^3) of water in storage, and the seasonal change in storage is estimated to be 190,000 acre-ft (230 hm^3). Seasonal fluctuations of water levels in those deposits range from about 2 ft (0.6 m) near major streams to 14 ft (4.3 m) along interstream divides. The aquifer is fully recharged by winter precipitation, even in relatively dry years. In places, January water levels are above land surface. Aquifers discharge water naturally by evapotranspiration and by seepage to streams.

Water in the lower Santiam basin generally is chemically suitable for drinking, irrigation, and most other uses. An exception is saline water from consolidated rocks, noted above, and iron concentrations exceeding recommended limits in water from some wells tapping alluvial deposits.

In 1967, 30,000 acre-ft (37 hm^3) of ground water was pumped for irrigation. Of that, an estimated 23,000 acre-ft (28 hm^3) was evaporated and consumed by crops; the remainder percolated back to the ground-water reservoir. Pumpage of ground water for other uses, such as domestic, stock, industrial, and public supply, totaled 5,000 acre-ft (6 hm^3). In addition, 24,000 acre-ft (30 hm^3) was withdrawn from streams for irrigation, about 52,000 acre-ft (64 hm^3) for industrial use, and 23,000 acre-ft (28 hm^3) for public supply. Total withdrawals from ground- and surface-water sources in 1967 were about 134,000 acre-ft (165 hm^3).

The alluvial aquifers in the area can sustain large increased withdrawals, at the expense of decreases in local evapotranspiration and in ground-water seepage to streams. The most favorable areas for additional withdrawals of water are where alluvial deposits are thick, as in the eastern part of the Lebanon-Albany plain, the Stayton Basin, and near the Willamette and Santiam Rivers. Withdrawals from the Columbia River Basalt Group perhaps can be increased in places, although at some locations it is presently being dewatered because of small storage capacity and recharge.

INTRODUCTION

The lower Santiam basin, in western Oregon's Willamette Basin, is one of the more productive and intensively irrigated agricultural areas of Oregon. During the growing season rainfall is insufficient for many crops, and irrigation is required although the total annual precipitation is moderately high. Because of the increase in total acreage under cultivation and the expanding urban and suburban industry and population, the demand for water grows.

This growing demand for water requires a better understanding of the quantity and quality of the resources in the area. To meet this need, a ground-water investigation was made from 1966 to 1968 by the U.S. Geological Survey in cooperation with the Oregon State Engineer (now Oregon Water Resources Department).

Purpose and Scope

The purpose of this investigation is to make available to water users and managers information on the occurrence, availability, and quality of the ground-water supplies in the lower Santiam basin. Quantitative estimates were made of recharge, runoff, ground water stored in major aquifers, ground water pumped for all uses, and additional ground water available for future use.

Investigational Procedures

Most of the fieldwork was done in 1966 and 1967. The basic data were compiled and combined with published information on geology, streamflow, climatology, and census statistics to prepare the present report.

Fieldwork included the collection of records for 991 wells used for irrigation, industry, and public supply, and records for an additional 213 wells used for domestic, institutional, stock, test, and unreported uses. Hydraulic characteristics of major aquifers were estimated from these records.

A network of 45 observation wells was established for periodic water-level measurements. Water levels were measured in 109 wells in January and October 1967 to estimate the seasonal variation in ground-water storage. To supplement prior records, chemical analyses were made of samples of ground water collected from 36 wells and 1 spring.

Measurements of the flow of the Santiam River and its major tributaries and diversions were made at 26 sites during low stage in September 1966 to identify reaches of significant ground-water inflow or seepage losses. Electric power-consumption records were collected for estimating pumpage from wells, and data supplied by well drillers and owners were used in computing water-bearing properties of rock units.

Geologic fieldwork consisted primarily of checking previous surficial geologic maps (Allison, 1953; Allison and Felts, 1956; Hampton, 1972; Mundorff, 1939; Peck and others, 1964; Smith, 1958; Thayer, 1939).

Previous Investigations and Related Studies

The ground-water resources of the lower Santiam basin were included in a reconnaissance ground-water study of the Willamette Valley by Piper (1942). More recently a brief hydrologic study was made of the effect that raising the height of the North Santiam River had on yields of wells tapping alluvium in the vicinity of Jefferson (Wolfe, 1959). A report (Helm, 1968) gives records of several hundred wells, drillers' logs of materials penetrated, and water quality in the lower Santiam basin.

Related ground-water investigations have been made in neighboring regions to the north and south. They include the French Prairie area (Price, 1967a), a few miles to the northwest; the Molalla-Salem Slope area (Hampton, 1972), directly north of the northeast boundary of the study area; the Eola-Amity Hills area (Price, 1967b), adjacent to and west of the French Prairie area; and the Corvallis-Albany area (Frank, 1974), immediately southwest of the study area.

Acknowledgments

The authors express appreciation to well drillers, owners, and operators, whose cooperation made collecting data an enjoyable task.

Special thanks are extended to Mr. Neal Hollingsworth for allowing a continuous water-level recorder to be installed in his well, and to Mr. Maynard Eckhart of Consumer Power, Inc., and Mr. John Reed and other officials of the Pacific Power & Light Co., for furnishing power-consumption data from which estimates of ground-water pumpage for irrigation were made.

GEOGRAPHY

Location and Extent of the Area

Most of the project area is in the northwestern part of the Santiam River drainage basin in the central Willamette River basin. The area (fig. 1) covers about 600 mi^2 (1600 km^2) and extends from the foothills of the Cascade Range westward to the Willamette River and from Salem-Waldo Hills southward to the drainage divide between Oak Creek and the Calapooia River, and is called the lower Santiam basin. The area lies entirely within Linn and Marion Counties between lat 44°23' N. and 44°52' N. and long 122°35' W. and 123°09' W.

The study area includes subareas that are adjacent to but outside the Santiam drainage basin. These are the 60-mi^2 (155 km^2) Stayton Basin (fig. 1), about 75 mi^2 (190 km^2) of the valley plain between Albany and Lebanon, and a few square miles between Roby Hill and the Salem Hills.

Topography and Drainage

The lower Santiam basin area has two dominant landforms, the valley plains in the west and the foothills of the Cascade Range toward the east. In the south the change from plains to foothills is sharp. In the north the transition is more gradual and complex and therefore is considered to be a third type of landform called the transitional slope. Figure 1 shows the boundaries of the several geographic subareas.

The flat, terraced plains of the valley occupy about 200 mi^2 (520 km^2) of the study area and include three distinct subbasins: Stayton Basin, Lebanon-Albany plain, and Ankeny Bottom, which are separated from one another by an interbasin area of low hills and tree-studded buttes.

The convergence of the North and South Santiam Rivers near Jefferson forms the Santiam, which flows about 12 mi (19 km) across the Ankeny Bottom to the Willamette River. The North Santiam River heads high in the Cascade Range, enters the study area near Mehama, and flows across the Stayton Basin. The South Santiam also heads in the Cascade Range, joins the Middle Santiam River near Foster, and flows across the Lebanon-Albany plain to join the North Santiam. In the study area, topography controls the general course of the streams, all of which are incised in the terraced plains of the Willamette Valley.

The valley plain is a slightly irregular surface crossed by many small streams which provide local drainage. Surfaces of the flood plains, adjacent to the major streams, are a few feet lower than the older alluvial plain, the area mapped as older alluvium on the geohydrologic map (pl. 1).

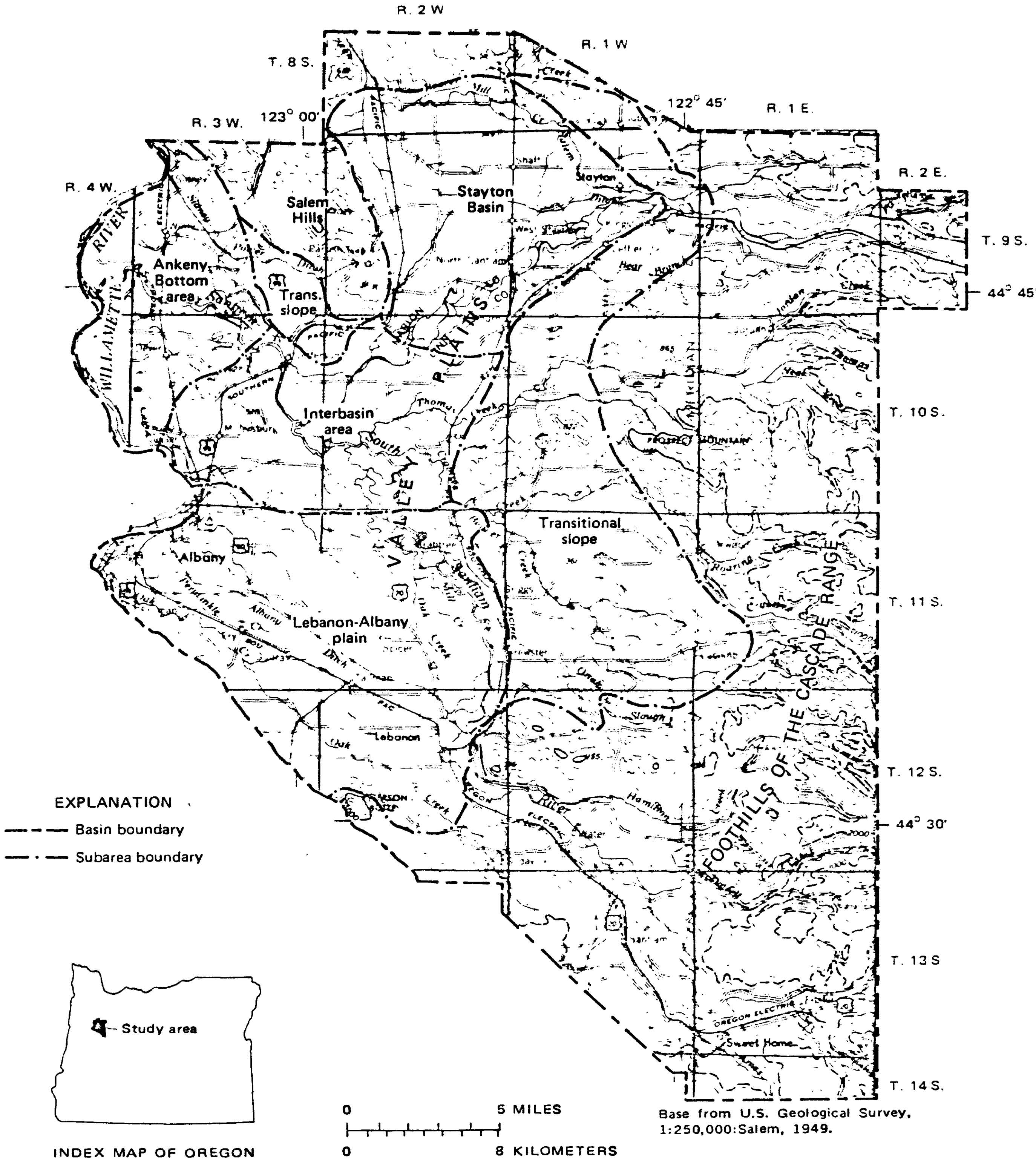


Figure 1. – Boundaries and general physiographic and cultural features of the lower Santaim River basin, Oregon.

Stayton Basin

Stayton Basin is a roughly triangular area of approximately 60 mi^2 (155 km^2). Its land surface declines westward almost uniformly at a rate averaging 15 to 20 ft/mi (2.8 to 3.8 m/km) from an altitude of about 450 ft (140 m) near the foothills of the Cascade Range to 275 ft (85 m) south of Marion.

The North Santiam River enters Stayton Basin at Stayton, flows 17 mi (27 km) southwestward, and joins the South Santiam River near Jefferson. The basin is largely drained by intermittent streams, most of which flow westward and then northward toward Mill Creek, or into Marion Creek which parallels the North Santiam River.

At Stayton, water from the North Santiam River is diverted into Mill Creek via Salem Canal. Two other diversions from the North Santiam River are (1) Stayton District Canal which empties into Stayton Basin and (2) Sidney Canal which skirts the south edge of the Salem Hills and carries irrigation water across Ankeny Bottom.

Lebanon-Albany Plain

The Lebanon-Albany plain of approximately 100 mi^2 (260 km^2) slopes gently and almost uniformly at a rate of about 11 ft/mi (2 m/km) from the foothills of the Cascade Range near Lebanon to the Willamette River.

The South Santiam River enters the Lebanon-Albany plain at Lebanon and flows northwestward 18 mi (29 km) to join the North Santiam River. Creeks on the Lebanon-Albany plain are mostly intermittent and drain northwestward directly into the Willamette River. Albany Ditch diverts water from the South Santiam River at Lebanon to the Willamette River at Albany.

Oak Creek rises at the west edge of the foothills of the Cascade Range south of Lebanon, flows northwestward across the Lebanon-Albany plain north of Peterson Butte, and enters the Calapooia River south of Albany, near the point where the Willamette River enters the study area.

Ankeny Bottom and Interbasin Areas

Ankeny Bottom is a 35-mi^2 (90-km^2) gently rolling area that slopes generally toward the Willamette River at about 10 ft/mi (2 m/km).

The interbasin area, in the heart of the valley plains, separates the three subbasins previously described. This area occupies roughly 40 mi^2 (100 km^2), about one-third of which is a complex of four main hills. Knox Butte, altitude 634 ft (193 m), is the highest; the Hardscrabble Hill complex reaches 520 ft (158 m); and Hale Butte reaches 427 ft (130 m). A small unnamed hill, lying about a mile southwest of Hale Butte, has an altitude of slightly more than 350 ft (107 m). The valley floor surrounding these hills is flat and has an average altitude of 225 ft (68 m).

The North and South Santiam Rivers join in the interbasin area to form the 12-mi-long (19 km) main stem of the Santiam River. The Santiam flows northward along the eastern foot of Hardscrabble Hill for about 2 mi (3 km) before meandering around Hale Butte at Jefferson and continuing northwestward across the Ankeny Bottom area to its junction with the Willamette River. The interbasin area has few small streams, but two major tributaries, Crabtree and Thomas Creeks, flow into the South Santiam River just south of its confluence with the North Santiam River.

The Willamette River, which flows mainly northward, picks up the waters of the Santiam 10 river mi (16 km) downstream from Albany and leaves the project area 18 river mi (29 km) downstream from Albany.

Because of the flat terrain, the major streams of the Santiam River system in the lowland area meander in belts ranging from 1/2 mi to 3 mi (0.8 to 5 km) wide. Abandoned channels, some with seasonal pools of water, are characteristic of the lower 5 mi (8 km) of the Santiam River. Abandoned channels also occur along the Willamette River and along the North Santiam River below Stayton and along the South Santiam River below Lebanon.

Channels of intermittent streams and local depressions in Stayton Basin, Lebanon-Albany plain, and the Ankeny Bottom area that are not connected to the Santiam River system fill with water during the rainy winter season when the water table rises to near or above land surface. Locally, clay lenses at shallow depth maintain semimarshy conditions during the early dry season even after the water table has declined.

Transitional Slopes and Foothills of the Cascade Range

In some places, the land-surface slope changes so abruptly that there is in effect no gradation from broad terraced plains to the foothills of the Cascade Range. Examples are the steep-sided mountainous region near Lebanon, the hills directly north of Ankeny Bottom, and those north and west of Stayton Basin between Marion and Aumsville. However, where the change from valley-plain to foothill topography is gradual, the areas are termed "transitional slopes."

One transitional slope covering about 10 mi^2 (16 km^2) borders the northeastern flank of Ankeny Bottom. It stretches northward from a few unnamed low-lying hills north and west of Jefferson to Looney Butte.

The second transitional slope borders the valley plains on the east and covers an area of about a hundred square miles. Rolling hills with altitudes ranging from 425 to 700 ft (130 to 210 m) extend southward from Sublimity through Kingston toward Scio. South of Scio lie Franklin Butte (alt 891 ft, or 272 m) and Hungry Hill (alt 651 ft, or 198 m). South of these two hills, high gravel terraces rise eastward at a rate of about a hundred feet per mile and reach an altitude of 800 ft (240 m) east of Lacomb. East and south of Lebanon, foothills border the valley plains with no intervening transitional slope.

The rolling foothills of the Cascade Range cover 250 mi^2 (650 km^2) in the study area. They are characterized by comparatively smooth uplands which eastward attain altitudes of as much as 2,000 ft (600 m) and are dissected to narrow steep-sided valleys separated by fingerlike ridges which point westward toward the valley plains.

Climate

General Features

The lower Santiam basin has a mild and temperate climate with dry summers and wet winters (fig. 2). About 80 percent of the total precipitation falls during October to May--little rain falls between mid-June and early September. In winter, rain usually comes in long, gentle showers accompanied by considerable fog and cloudiness. Snowfall is light, averaging 7.6 in. (193 mm) at Albany, and usually melts soon after falling.

The mean annual temperature at Albany (fig. 2) is 53.1°F [11.7°C (Celsius)]. The hottest month is July with an average temperature of 67°F (19.5°C), and the coldest month is January with 39°F (4°C).

The average date for the last killing frost is March 30 and for the earliest is November 6. The average frost-free season at Albany is 221 days. In parts of the upland areas of transition from valley to foothills, the frost-free season is longer because of the unrestricted movement of cooler air and its tendency to settle at lower altitudes (Kocher and others, 1924).

Precipitation

The isohyetal map of the lower Santiam basin showing mean annual precipitation (fig. 3) is based on National Weather Service records from five current climatological stations and one discontinued station within the study area and from seven stations adjacent to the study area.

Annual precipitation in the lower Santiam basin increases from 40 in. (1,020 mm) along the Willamette River to more than 70 in. (1,780 mm) in the foothills, and averages 46 in. (1,170 mm) over the valley plains.

Figure 4 shows the total annual precipitation at Albany for each year from 1931 through 1971. It has ranged from a high of 57.4 in. (1,460 mm) in 1937 to a low of 24.3 in. (620 mm) in 1944. Figure 4 also shows the cumulative departure from the average annual precipitation--that is, the accumulative excesses and deficiencies of precipitation for the years 1931-71. On the departure graph a falling line indicates a period of below-normal precipitation and a rising line a period of above-normal precipitation.

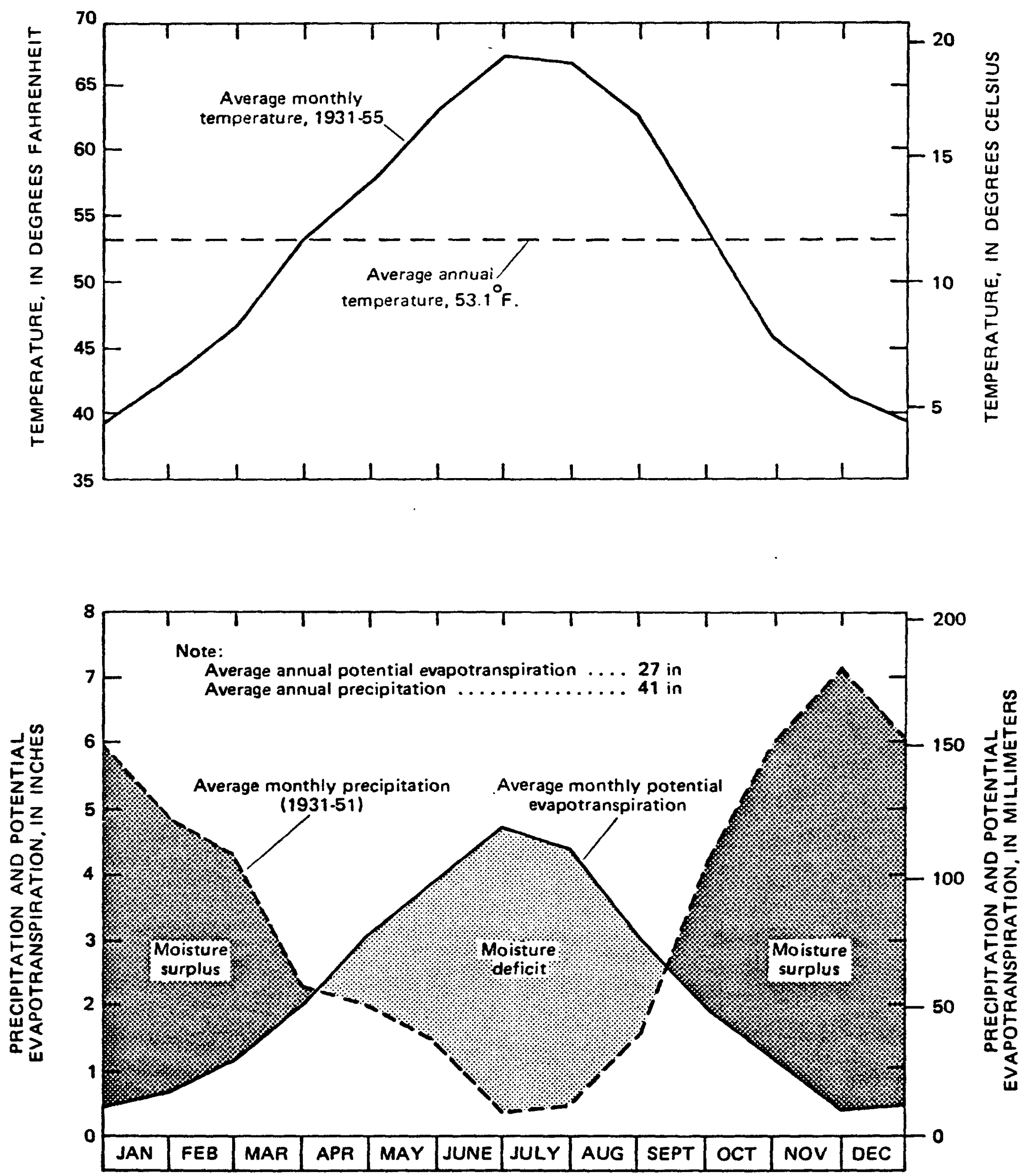


Figure 2.—Average monthly temperature, precipitation, and potential evapotranspiration at Albany, Oreg. Adapted from Johnsgard (1963).

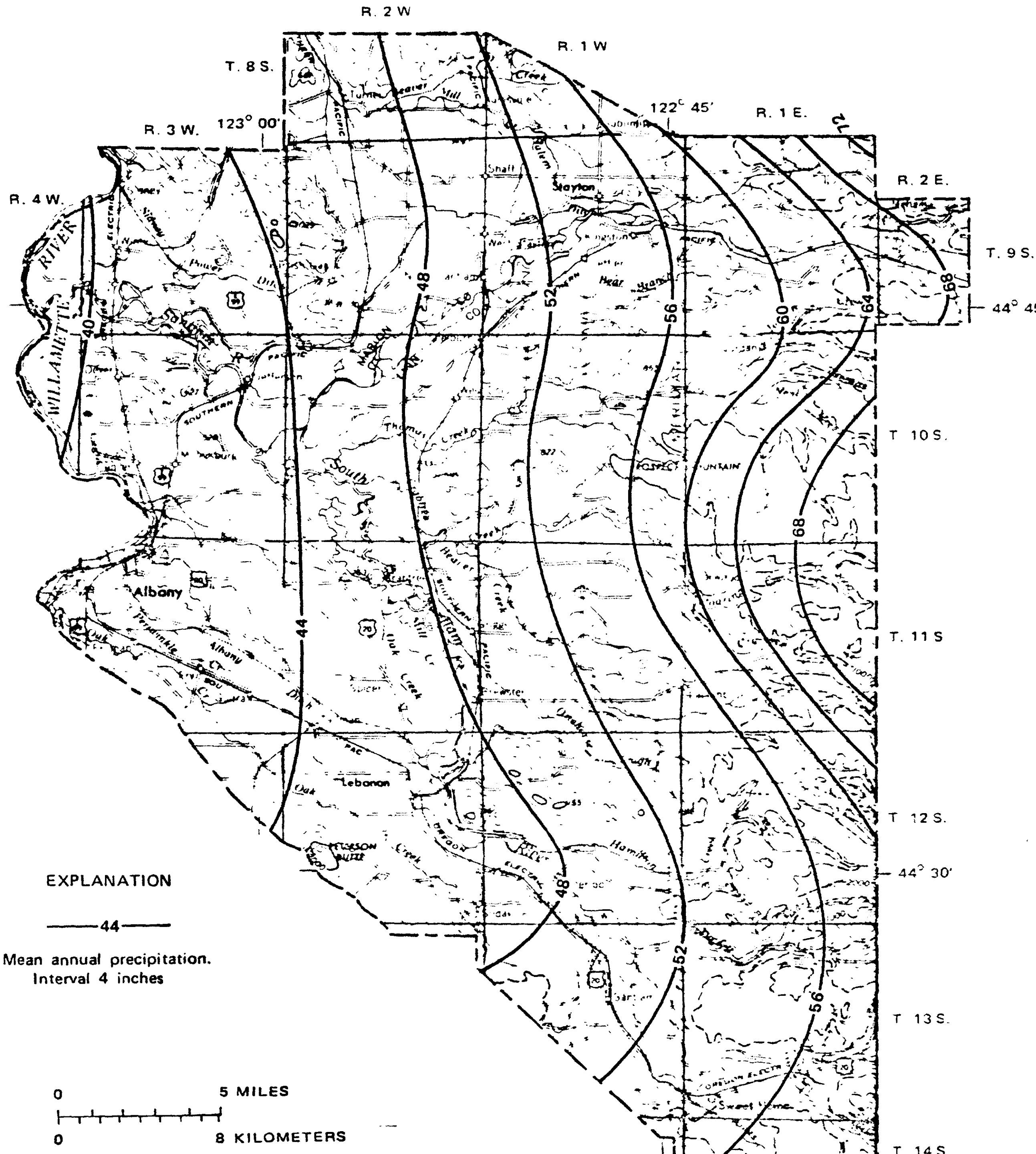


Figure 3. – Mean annual precipitation in the lower Santiam River basin.

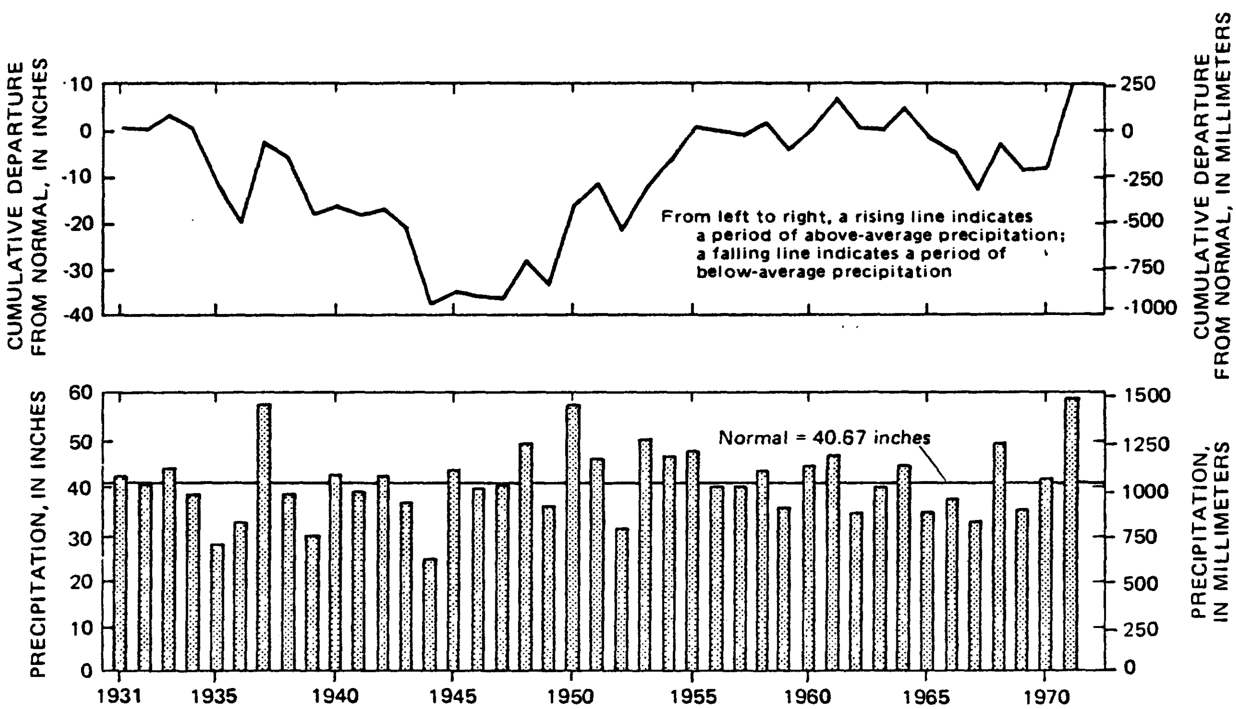


Figure 4. — Annual precipitation, 1931-71, and cumulative departure from normal at Albany, Oreg. (Data from National Weather Service)

Evapotranspiration

Moisture is transferred from surface and subsurface sources to the atmosphere by direct evaporation and by transpiration from plants. Because rainfall adds more moisture to the land surface than evapotranspiration can withdraw, there is a moisture surplus of about 27 in. (690 mm) in the Santiam basin from October through April. From May through September, when evapotranspiration exceeds rainfall, there is generally a moisture deficit which totals more than 13 in. (330 mm) (fig. 2).

Potential evapotranspiration is a theoretical maximum value, calculated on the assumption that an unlimited supply of water is available, and was estimated by the Thornthwaite-Mather method (Johnsgard, 1963) to average 27 in. (690 mm) at Albany (fig. 2). Estimates of the actual evapotranspiration for agricultural crops are given in the section on water use. Actual evapotranspiration is less than potential evapotranspiration, because during summer the soil moisture in the lower Santiam basin falls below the level that would allow maximum evapotranspiration.

Population and Industry

The population in the lower Santiam basin is more than 70,000. The 1970 population figures of incorporated cities and towns in the area total about 37,500 and are listed below. Albany, the county seat of Linn County, nearly tripled in population from 1940 to 1970.

Town	1970 population[1/]	Town	1970 population[1/]
Albany	18,181	Scio	447
Aumsville	590	Stayton	3,170
Jefferson	936	Sublimity	634
Lebanon	6,636	Sweet Home	3,799
Lyons	645	Turner	846
Mill City	1,451	Waterloo	186

1/ Taken from 1970 census.

Diverse crops flourish in the lower Santiam basin. Vegetables and other crops that require irrigation grow abundantly in the valley bottoms. Terraces and rolling foothills produce grass seed, hay, and small grains. The fringes of the valleys are used primarily for pasture for beef cattle, sheep, and goats. Dairy and poultry farms are scattered throughout the area, but tend to be concentrated near towns and markets.

Poultry, milk, cattle, sheep, and hogs are processed and marketed locally within the Willamette Valley. Vegetables, fruits, nuts, berries, and specialty crops are processed locally and marketed throughout the Nation. Salem, 8 mi (13 km) north of the study area, is recognized as the Nation's second largest center for fruit and vegetable canning and freezing.

Timber-related industries provide the largest single source of income for Linn County. Sand, gravel, and building stone are mined in the Santiam basin. Rare-metals research and manufacturing is centered in Albany. Many people are employed in service establishments, wholesale and retail trades, and in State and county institutions at Salem and Albany.

GEOLOGIC UNITS AND THEIR WATER-BEARING PROPERTIES

Ground-water occurrence in the lower Santiam area is directly related to the geology. Geologic features control the location and rate of recharge, the movement of water through the rocks, and the volume of water that can be pumped from wells.

Rock units exposed in the study area are either (1) consolidated volcanic or marine rocks of Tertiary age or (2) unconsolidated stream deposits, principally sand, gravel, and clay of Quaternary age. The surface distribution of the various geologic units is shown on plate 1.

Consolidated Tertiary Rocks

The consolidated Tertiary rocks range in age from Eocene to Pliocene and include marine sedimentary rocks, the Little Butte Volcanic Series, the Columbia River Basalt Group, the Sardine Formation, and intrusive igneous rocks. In general, the consolidated rocks form the higher parts of the area; that is, the foothills of the Cascade Range, the Salem Hills, and small hills such as Peterson and Knox Buttes which rise above the valley lowland.

Marine Sedimentary Rocks

The oldest rocks in the study area are marine sedimentary rocks of Eocene to middle Oligocene age, which are exposed over about 25 mi^2 (65 km^2) in the lower Santiam basin (pl. 1). In this report they are not assigned to a named geologic unit, although others have assigned exposures of these rocks in the southwestern part of the area to the Eugene Formation (Allison, 1953; Frank, 1974).

The marine sedimentary rocks generally are exposed along the steep slopes of hills, such as Knox and Peterson Buttes, that have cores of intrusive rock or that are capped by younger basalt (Salem Hills, Ridgeway Butte). These rocks also extend beneath the valley fill and underlie most of the younger consolidated rocks at depth.

Generally these rocks consist of tuff and tuffaceous sandstone, but they also include shale, siltstone, and minor lenses of fine conglomerate. They are massive to thin bedded and are composed largely of volcanic material, much of which weathers readily to clay. To the east and northeast, the marine rocks interfinger with beds of the Little Butte Volcanic Series. Elsewhere they are unconformably overlain by the Columbia River Basalt Group or are intruded locally by igneous plugs, dikes, and sills.

The total thickness of marine rocks in the study area is about 2,000 ft (600 m), as shown by the log of oil-test well 10/3W-10R1. Only a few hundred feet of these rocks are exposed in most outcrops, and the maximum exposed thickness is about 600 ft (180 m) in the southern part of Salem Hills.

The marine sedimentary rocks underlie alluvial deposits at shallow depths in the western part of the study area. At Albany, near Jefferson, and in the Ankeny Bottom, the top of the marine rocks is at less than 30 ft (9 m) in many wells. The depth to these rocks becomes greater eastward and southward in the Lebanon-Albany plain and is at least 135 ft (42 m) in the southeastern part of T. 11 S., R. 3 W. Under the eastern part of Lebanon-Albany plain, the depth to these rocks is unknown and may be more than 200 ft (60 m). In the Stayton Basin, the marine rocks lie at depths of several hundred feet. The irregular top of the marine beds suggests a surface that was carved by subaerial erosion prior to and during deposition of the overlying alluvial deposits.

Marine sedimentary rocks generally yield only small quantities of water to wells. The yields of wells reported by drillers and well owners are averaged in table 1 according to geologic unit. The wells used in preparing the averages were selected at random from among records of representative producing wells. Records of additional wells are available in an earlier report (Helm, 1968).

Water of poor chemical quality, unsuitable for drinking and most other uses, occurs at depth in the marine rocks. Mineralized water has been reported in the valley plain at depths ranging from 210 ft (64 m) near Lebanon (well 12/2W-23B2) and 206 ft (63 m) at Albany (well 11/4W-1R2) to 90 ft (27 m) west of Millersburg (well 10/3W-19K1).

Table 1.--Physical and hydrologic characteristics of wells, lower Santiam River basin

Number of wells	Depth of well (feet) Range	Depth to top of water-bearing unit (feet) Range	Depth to top of water-bearing unit (feet) Average	Yield (gal/min) Range	Specific capacity [(gal/min)/ft] 1/ Range	Specific capacity [(gal/min)/ft] 1/ Average, all selected wells	Specific capacity [(gal/min)/ft] 1/ Average, irrigation wells
MARINE SEDIMENTARY ROCKS							
16	70-398	20-230	69	1.5-97	0.01-3.0	0.9	--
LITTLE BUTTE VOLCANIC SERIES							
30	40-250	19-180	48	2.5-120	.04-8.0	1.5	--
COLUMBIA RIVER BASALT GROUP							
Transitional slope							
20	58-460	24-368	112	1-670	.01-122	11.8	24
Foothills							
11	74-442	30-319	140	7-550	.06-16	3.2	3.5
Salem Hills							
7	71-335	33-243	112	4-60	.1-4	.9	--
SARDINE FORMATION							
4	51-123	40-54	46	11-32	.2-1.0	.6	--
OLDER ALLUVIUM							
Foothills (along the North and South Santiam Rivers)							
7	42-194	35-100	53	30-550	.8-10	5.3	--
Valley plains							
102	21-330	4-130	44	4-720	.2-66	5.9	7.8
YOUNGER ALLUVIUM							
Transitional slope							
2	50-50	5-8	7	30-40	1.5-20	10.7	10.7
(Foothills (along the North and South Santiam Rivers)							
6	19-60	14-39	27	15-200	.4-50	9.8	17
Valley plains							
83	18-65	5-50	18	20-1,000	2-600	151	151

1/ Specific capacity is a well-performance characteristic expressed as rate of yield per unit of drawdown, generally gallons per minute per foot of drawdown.

Little Butte Volcanic Series

The volcanic rocks called the Little Butte Volcanic Series are exposed in an area of about 140 mi^2 (360 km^2) in the foothills of the Western Cascade Range, principally between the North and South Santiam Rivers (pl. 1). These rocks also underlie alluvial deposits in the Stayton Basin and stream valleys in the eastern part of the project area.

The Little Butte Volcanic Series consists of tuffaceous sandstone and siltstone, volcanic flows and pyroclastics, and a few lenses of pebble conglomerate. All these rocks are of volcanic origin and were deposited in a terrestrial environment, but beds in the lower part of the series interfinger with beds of similar lithology that were deposited in a marine embayment. Rocks forming the series were erupted from numerous vents in the western part of the Cascade Range; Peterson Butte is the remnant of such a vent (Peck and others, 1964, p. 21).

Most of the series is well stratified, but massive tuffs several hundred feet thick are exposed near Mehama. The tuff weathers readily to clay and commonly is reported in drillers' logs as claystone or shale. The sandstone and conglomerate range from thin bedded to massive, tend to be well sorted, and locally are crossbedded (Hampton, 1972, p. 15). The volcanic flows include both basalt and andesite, and commonly are jointed. Individual flows range from a few tens to 100 ft (30 m) in thickness.

The base of the Little Butte Volcanic Series is not exposed in the area and the top is eroded, so the thickness of the unit is not known, but oil-test wells in the area show the unit to be at least a few thousand feet thick. The maximum exposed thickness, on the sides of Franklin Butte, Hungry Hill, and other slopes is 500-600 ft (150-180 m).

The volcanic flows and breccias and the coarser sedimentary rocks all serve as aquifers. In most places, wells in the Little Butte produce sufficient water for domestic and stock supplies; locally yields are adequate for irrigation (well 12/1W-29N1).

Columbia River Basalt Group

Lava flows assigned to the Columbia River Basalt Group are exposed over about 80 mi^2 (210 km^2), principally in the western part of the Cascade Range foothills and in the Salem Hills. In the lower Santiam area, the Columbia River Basalt Group is largely of Miocene age; farther to the northeast, part of the unit is of Pliocene age (Newcomb, 1969, p. 3).

Much of the rock is true basalt, dark gray, and dense; some is andesitic. The basalt is at least 300-500 ft (90-150 m) thick, as shown by well logs; individual flows range from 10-100 ft (3-30 m) in thickness. In outcrop, the flows characteristically are flat lying or have gentle dips and most have well-developed columnar jointing. Successive flows commonly are separated by a scoriaceous rubbly interflow zone which, when saturated, yields water to wells. Dense centers of individual basalt flows are poorly permeable and prevent vertical movement of water from the surface to the permeable interflow zones. Where segments of the lava have been tilted or eroded and a porous interflow layer is intersected by land surface, precipitation can infiltrate directly into the porous zone and thereby recharge the aquifer. The highly permeable interflow zones are potentially important sources of water, and yields of some wells tapping them are as much as several hundred gallons per minute (for example, well 9/1W-14Q1).

Rubbly interflow parts of the Columbia River Basalt Group underlie slopes (transitional slope, fig. 1) between the valley plains and the foothills of the Cascade Range. In that area, the group is an important aquifer, particularly beneath the transitional slopes near Sublimity and Stayton. The average specific capacity of 20 wells that tap the group in that area is 11.8 (gal/min)/ft [2.4 (l/s)/m]. However, rubbly zones constitute only a small percentage of the total volume of the rock unit; therefore, the volume of water stored and the rate of recharge may be small. Because of the small storage capacity and the high permeability of these aquifers, it is possible to deplete them by pumping large-yield wells.

Near and southward from Scio, much of the Columbia River Basalt Group lies above the regional water table and the unit is suitable only for development of small supplies from local perched zones.

Intrusive Rocks

Intrusive rocks form the cores of several buttes or crop out in the hills in the interbasin area and southern part of the Salem Hills. Most exposures of these rocks are dikes and sills of basaltic or andesitic composition; they generally are dense and fine grained, but may be porphyritic or coarse grained. The intrusive rocks are not known to yield water to wells. Their areal extent beneath the alluvial deposits and any impeding effect on groundwater movement are not known, but probably are restricted to small local areas.

Sardine Formation

The term "Sardine Formation," as used in this report, follows the usage by Peck, Griggs, Schlicker, Wells, and Dole (1964) and by Hampton (1972). The formation crops out in about 80 mi^2 (210 km^2) of the study area, generally in the eastern part and north of the Stayton Basin (pl. 1). The main outcrop area extends 20 to 30 mi (32 to 48 km) east of the area shown in plate 1. The Sardine Formation includes coarse andesitic agglomerate, volcanic mudflow breccia, massive welded tuff, and flows of various compositions. The tuff and breccia in the lower part of the unit are somewhat similar to those in the Little Butte Volcanic Series, but are younger and are separated from them by the Columbia River Basalt Group. The Sardine Formation thickens eastward--from about 500 ft (150 m) on the east side of Stayton Basin to a few thousand feet east of the project area.

The best aquifers in the formation are the jointed lava flows and welded tuffs which yield moderate quantities of water to wells; yields from mudflow deposits generally are small (table 1). The supply of water is usually adequate for household and stock uses, but the formation has little potential as a source of water for irrigation.

Unconsolidated Quaternary Deposits

Unconsolidated deposits in the study area have been subdivided into three units: (1) terrace deposits, (2) older alluvium, and (3) younger alluvium. All are predominantly of fluvial origin, but may contain lacustrine beds locally. Principal source of these materials is the Cascade Range to the east, from which the deposits were eroded by westward-flowing streams.

Terrace Deposits

The terrace deposits include stream-deposited clay, gravel, and sand of different ages which have been mapped separately in detailed geologic studies (Allison, 1953; Allison and Felts, 1956). Although they represent several episodes of erosion and deposition, these deposits are grouped together in this report because of their similar lithology and hydrologic properties.

Terrace deposits are exposed in an area of about 45 mi^2 (120 km^2) in the lower Santiam basin at altitudes ranging from about 250 to 875 ft (75 to 270 m). For the most part, they occur in elevated positions flanking streams that originate in the Cascade Range, on remnant hills of the transitional slope northeast of Jefferson, and in the interbasin zone southwest of Jefferson. At most places, the terrace deposits consist of coarse gravel that ranges up to cobble size in a sand or clay matrix. The high proportion of clay where the deposits lie at the highest altitudes has been attributed (Allison and Felts, 1956) to weathering of the less resistant volcanic rock fragments.

In most places, the maximum thickness of the terrace deposits is 30 to 50 ft (9 to 15 m). Thickness may be more than 100 ft (30 m) locally near Millersburg and north of Lebanon, and in the Lacomb area they are 100 to 150 ft (30 to 45 m) thick. Where the deposits are thickest, drillers commonly report that the lowest layers are cemented gravel or sand and gravel.

In most places, the terrace deposits lie above the regional water table and, therefore, in spite of moderate permeability, yield no water to wells. An exception is the Millersburg area, where these deposits yield quantities of water adequate for domestic supplies. Elsewhere, a few wells obtain small supplies locally from these deposits where they are thickest, especially east of Lacomb. Also, near Lacomb a few wells obtain domestic supplies at relatively shallow depths, probably from perched zones in the terrace deposits.

Older Alluvium

Deposits mapped as older alluvium are exposed in more than 150 mi^2 (390 km^2) of the valley plain and probably underlie large areas of the younger alluvium. As used in this report, the older alluvium includes the Linn Gravels of Allison (1953), the overlying Willamette Silt and undifferentiated alluvial deposits that underlie those units in the valley plain.

The older alluvium consists of lenticular beds of sand and gravel, silt, clay, and locally cemented gravel. In general, these deposits contain a high proportion of sand and gravel in the eastern part of the area, particularly the Stayton Basin and eastern part of the Interbasin area and Lebanon-Albany plain. In the western part of the Interbasin area and Lebanon-Albany plain and Ankeny Bottom, clay and silt beds predominate and gravel layers are less common.

In many places, a thick bed of blue clay occurs at the base of the deposits directly overlying consolidated Tertiary rocks. The Willamette Silt, which consists of as much as 15 ft (4.5 m) of thin-bedded sandy silt, forms the surface of the older alluvium in the western part of the valley plain and in the Stayton Basin.

The thickness of the older alluvium varies widely and erratically, reflecting both the irregular bedrock surface on which deposits rest and the somewhat dissected top of the deposits. In the Stayton Basin, the thickness ranges from 92 ft (28 m) in well 9/2W-5E1, to 222 ft (67.7 m) in well 9/2W-27A2, and 319 ft (97 m) in well 9/1W-10M4. In other areas the thickness ranges from less than 100 ft (30 m) in the western part of the valley plain (well 10/3W-33K2) to at least 150 ft (46 m) (well 11/3W-26A1) and possibly 200 ft (60 m) in the central part of the Lebanon-Albany plain.

In most places, the older alluvium is highly permeable, so that precipitation infiltrates readily and ground water is transmitted freely through the unit. The water table lies at a shallow depth in most of the outcrop area, and water may collect in depressions on the irregular surface during the wet season.

The older alluvium is the principal aquifer in much of the study area. It supplies water to many domestic and stock wells that range in depth from less than 50 to about 100 ft (15-30 m). These deposits also are a major source of water for irrigation wells, which range from less than 100 ft (30 m) to more than 300 ft (90 m) in depth and yield as much as 700 gal/min (44 l/s).

Younger Alluvium

Younger alluvium underlies the flood plains of the Santiam River and its tributaries and the Willamette River and crops out over an area of nearly 100 mi^2 (260 km^2). Along the major rivers, the younger alluvium consists of gravel, sand, and some silt and clay, whereas along minor streams, silt and clay are more common. The thickness of the deposits ranges from a few feet along the smaller tributaries to a few tens of feet along the Willamette and Santiam Rivers. Along the narrow flood plains of small streams, the younger alluvium has been mapped with the older alluvium which is of similar lithology and character (pl. 1).

Porosity and permeability are high, and where the saturated thickness is great enough, the younger alluvium yields large quantities of water to wells (table 1). This aquifer, which is hydraulically connected to streams, supplies water to the wells of highest yields and specific capacities in the lower Santiam basin. Wells that tap alluvium along the Santiam River are generally less than 65 ft (20 m) deep.

GROUND WATER

Occurrence and Movement

Ground water is the term used for water that completely saturates the voids among particles of gravel, sand, silt, and clay; occupies vesicles in lava flows; and fills pores and fractures in consolidated rocks. Rock units that yield usable quantities of ground water to wells and springs are called aquifers.

The source of ground water in the area is precipitation, mostly within the local area. Most of the precipitation evaporates from the soil, some is transpired by vegetation, some runs off in surface channels, and some infiltrates into the ground. After saturating the soil, rainwater or snowmelt either becomes surface runoff which enters the various streams or percolates downward through porous earth materials to a saturated zone beneath the surface. The top of this saturated zone is called the water table, and a permeable saturated zone is called a ground-water reservoir. The water table is observed as the level of water in wells that tap unconfined aquifers, such as alluvium and terrace deposits.

In the Santiam basin, the water table is regionwide, but other minor water tables, called perched-water tables, occur locally. A perched-water table may form where a bed of limited areal extent and low permeability, such as a clay lens, impedes the downward percolation of water through the unsaturated zone to the main ground-water body. The water that collects in the porous material immediately above the impermeable lens is thereby perched above the regional water table. Most perched-water bodies are thin and of small extent, so that the yields of wells tapping them are small. Wells producing water from perched zones may yield water only during the wet seasons or until the water drains from the perched saturated zone.

Perched-water bodies occur locally in the Tertiary rocks in the transitional slopes and foothills of the Cascade Range and in terrace deposits near Lacomb.

Unconfined ground water characteristically moves downgradient approximately at right angles to the water-table contours and toward the nearest stream or other point of discharge. In the lower Santiam basin the water table slopes generally westward toward the Willamette River (pl. 1). Under the valley plains the water table has a configuration similar to that of the land surface, but more subdued. In detail, there are many local variations, some of which change with time of year.

Across the Stayton Basin, ground water flows westward, and its divide corresponds approximately with the surface-water divide. Part of the ground water flows northwestward toward Turner Gap and part flows southwestward toward McKinney Bottom.

During winter, the ground-water divide beneath the Lebanon-Albany plain approximates the surface-water divide in position. During summer, however, the water level declines so that near Lebanon there is a stronger northwestward component than in winter when part of the ground-water flow is parallel to the South Santiam River.

The flow through the interbasin and Ankeny Bottom areas is generally westward toward the Willamette River.

An aquifer that contains water under hydrostatic pressure because of an overlying unit of low permeability is called a confined aquifer. Water in it is said to be confined and not under water-table conditions. A confined aquifer commonly receives recharge from a somewhat distant location because rainwater cannot percolate downward through the impermeable layer to the underlying aquifer. When a well penetrates the confining bed, the water under pressure in the underlying porous zone will rise in the well to a level called the potentiometric surface.

In the lower Santiam basin, confined conditions are found in two general environments. The first, which is perennial, is in aquifers in the Columbia River Basalt Group. There, dense basalt flows, which greatly retard the vertical movement of water, separate permeable interflow zones and cause water in the aquifers to be under pressure in downdip areas. The dense basalt layers also severely restrict the volume of local recharge to the aquifers. Therefore, where confined conditions occur in the basalt, recharge and storage are small, and extensive pumping causes reduction of pressure which is reflected in hydrographs of wells (fig. 8). The fact that heads do not recover seasonally to the levels prevailing the previous year suggests that more water is being extracted from the aquifers than is being recharged. Therefore, although well yields may be large, the overall resource in the basaltic aquifers is not great.

The second type of confined occurrence is seasonal. In low-lying areas in the plains, especially on or near the toes of alluvial fans impinging on the plains from the hills, recharge from winter rains completely fills the unconsolidated aquifers. In late winter and early spring, pressure in shallow aquifers weakly confined by strata of lesser permeability builds to the point that water rises in some wells to above land surface (fig. 6, well 11/3W-13A1). However, during other seasons those same wells behave as do others that do not flow. The system, then, functions mostly as an unconfined aquifer, and for much of the year water levels in all wells in the valley plain are typical of a regional water table.

Water-Level Fluctuations

The water table rises and falls seasonally, as indicated by the water levels of wells whose hydrographs are presented in figures 5 and 6. Levels are highest during winter (January-March) and spring when rainfall is greatest, and lowest during early autumn when rainfall is least. The approximate seasonal change in water levels is shown in figure 7. Water levels in wells start to rise about in November as precipitation and infiltration increase. By January or February, in most years, water levels are at their highest and they decline slightly during the next few months. Declines of water levels generally accelerate about May when the precipitation rate becomes small and pumping for irrigation begins. Generally water levels are lowest in September or October.

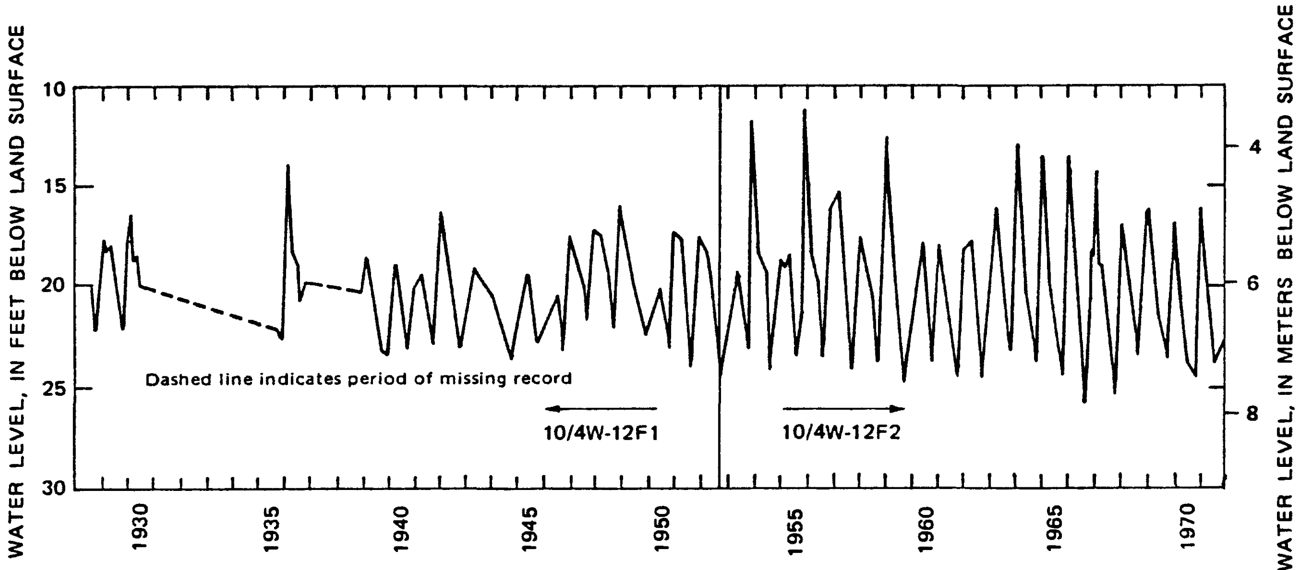


Figure 5.—Combination hydrograph of wells 10/4W-12F1 and 12F2, 1928-71.

In the alluvial aquifers, water levels recover fully each winter, even following years such as 1967, when annual rainfall is low and pumpage is high. This is illustrated by figure 5, which shows the successive hydrographs of wells 10/4W-12F1 (1928-52) and 12F2 (1952-71) in a heavily pumped alluvial aquifer, and by hydrographs (fig. 6) of wells that also tap alluvial aquifers. Figure 5 also shows that the seasonal pattern of water-level fluctuations has not changed in more than 40 years.

Annual fluctuations of water levels in wells tapping alluvial aquifers range from 2 to 14 ft (0.6 to 4.3 m) and average about 8 ft (2.5 m) (fig. 7). As shown by figure 6, water levels in some wells rise in the winter to or above land surface.

Pressure heads in wells that tap basalt aquifers east and south of Stayton show the progressive decline mentioned above (fig. 8, wells 9/1W-2R1, 14Q1, and 23P1). Water levels in wells that tap basalt north of Stayton (fig. 8, well 8/1W-28G1) do not yet show persistent declines.

Relation of Ground Water to Streamflow

In the Cascade Range foothills, the Santiam River streams flow in channels cut into poorly permeable bedrock. Where they cross the valley plains, those channels become incised into alluvium and seasonally the streams lose some of their flow to the ground. The amount lost is small, however, because replenishment from local precipitation keeps the alluvial aquifers well filled with water.

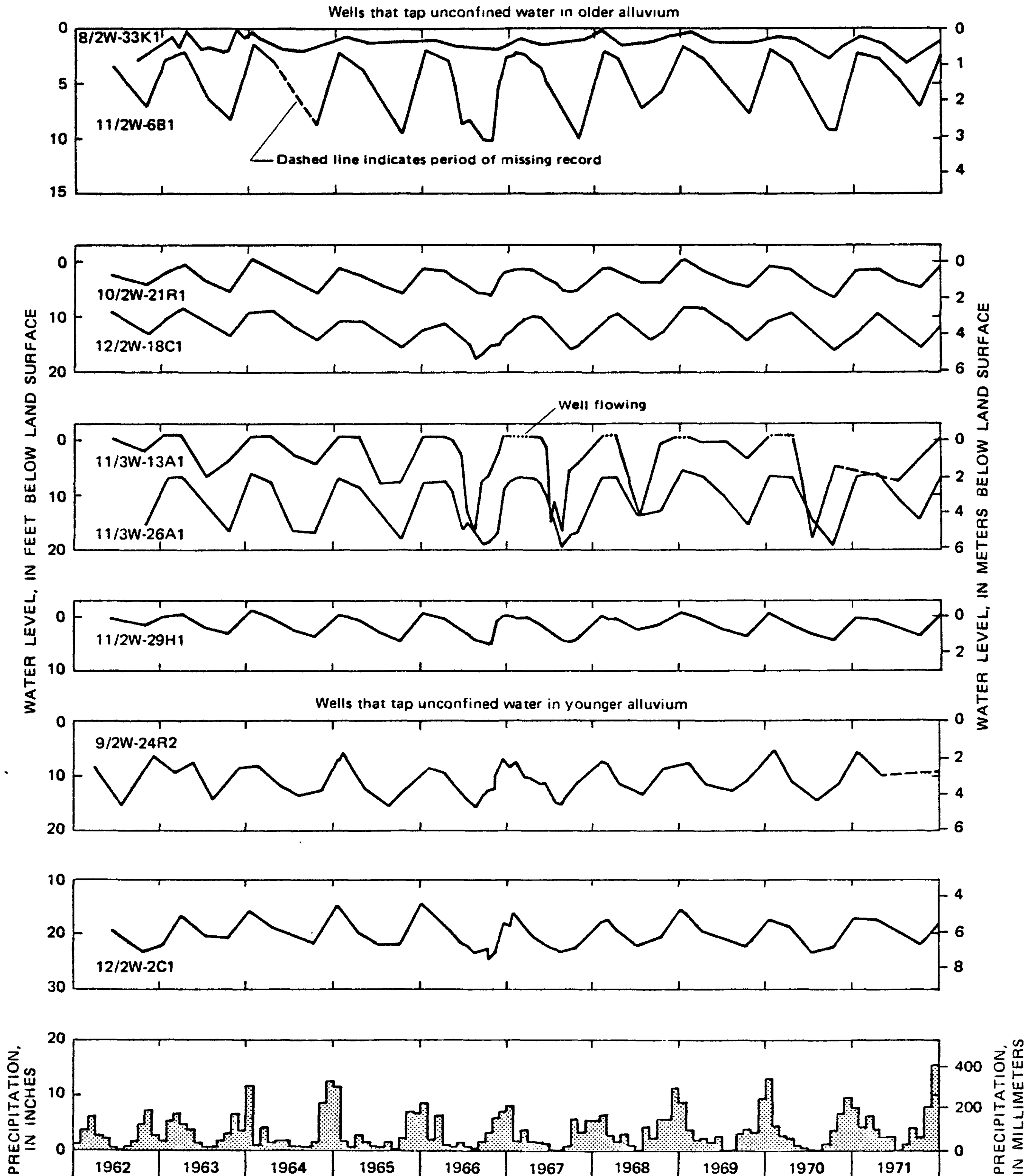


Figure 6.—Hydrographs of selected wells in the lower Santiam River basin and monthly precipitation at Albany, Oreg., 1962-71.

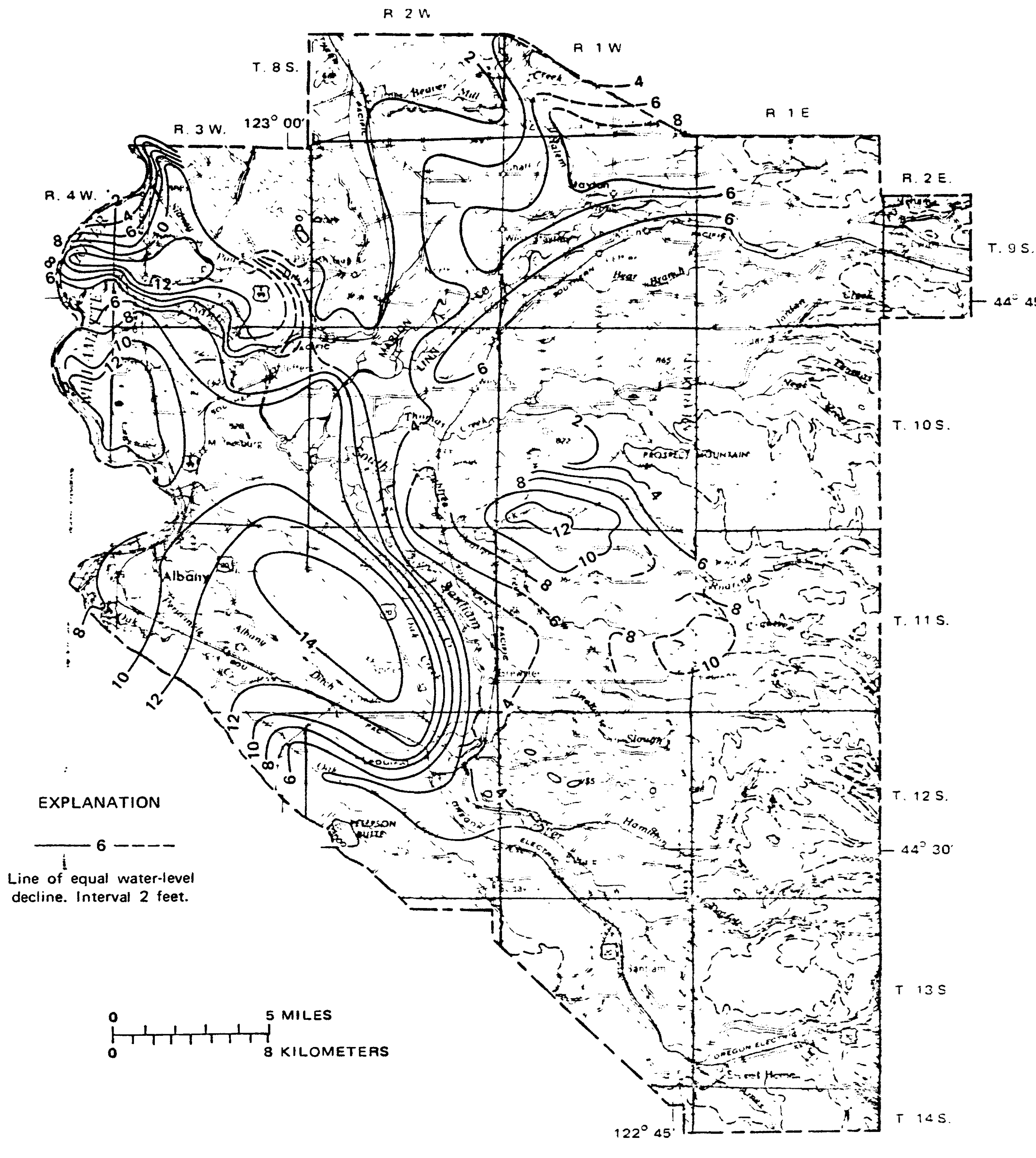


Figure 7.--Seasonal water-level declines in the lower Santiam River basin, February-September 1967.

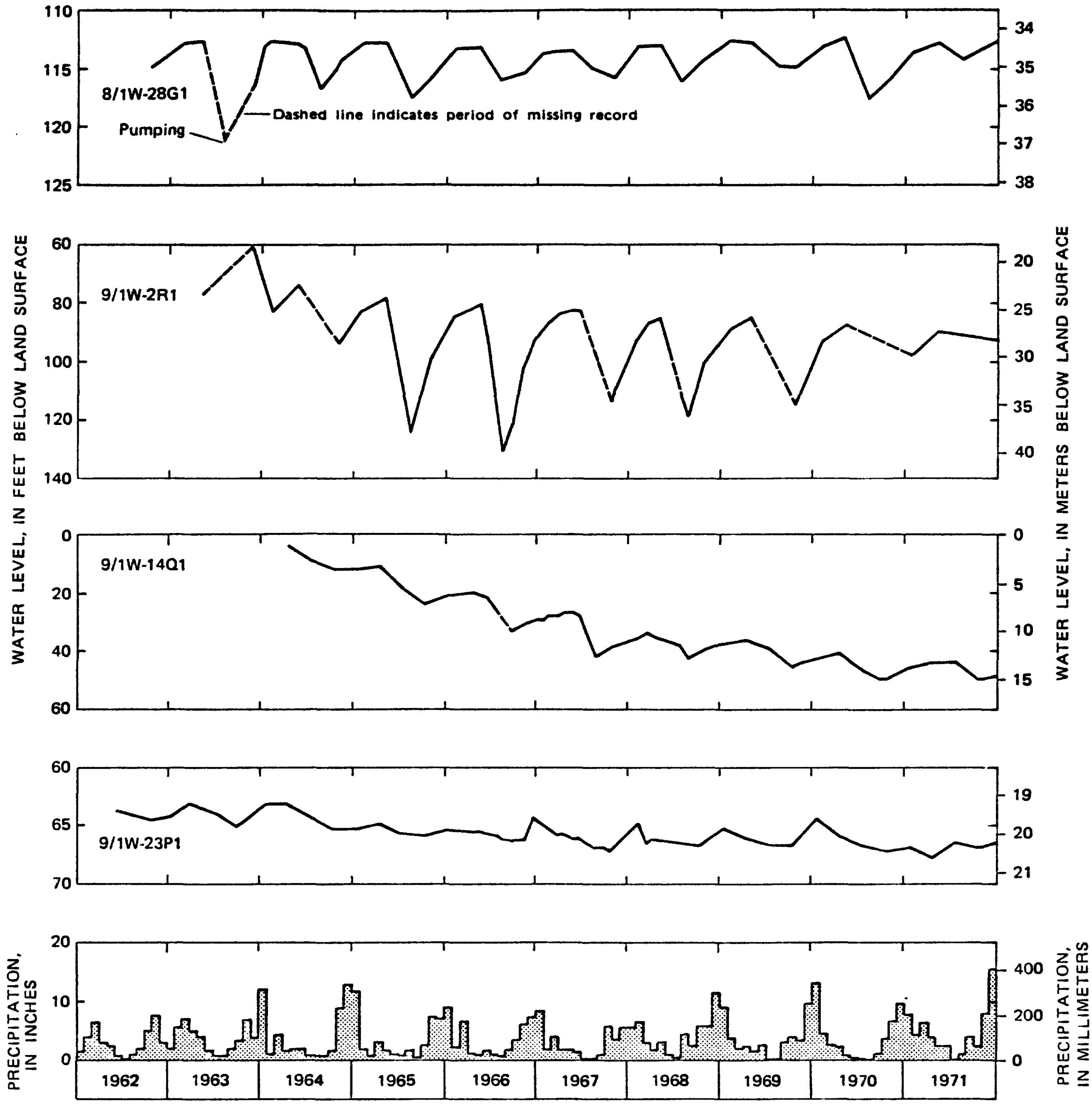


Figure 8. — Hydrographs of selected wells tapping the Columbia River Basalt Group in the lower Santiam River basin and monthly precipitation at Albany, Oreg., 1962-71.

As in other parts of the Willamette Valley lowland, water in the Santiam basin moves readily from streams into the alluvial aquifers and from the ground into streams. Water-level contours on plate 1 indicate that ground water moves generally northwestward toward the Willamette River, but also has a component toward the other major streams. Those contours depict the shape of the water table during winter when it is near its highest level. During dry seasons, ground-water movement still is generally toward the Willamette River, but some streams in the Santiam River system lose water locally to the alluvial aquifers.

Locally, where poorly permeable rock occurs at shallow depths, water in the alluvial deposits near the stream will be forced into the stream. This occurs on the flanks of Hardscrabble Hill, where impermeable marine rocks underlie the stream at depths of 15 to 20 ft (4.5 to 6 m). These rocks form a barrier which forces much of the ground water into the river, so that nearly all the water from upstream can be measured at the gaging station, Santiam River at Jefferson.

The relations between ground water in the alluvial deposits and streamflow are complex. Figure 9 shows the average monthly runoff, in acre-feet,

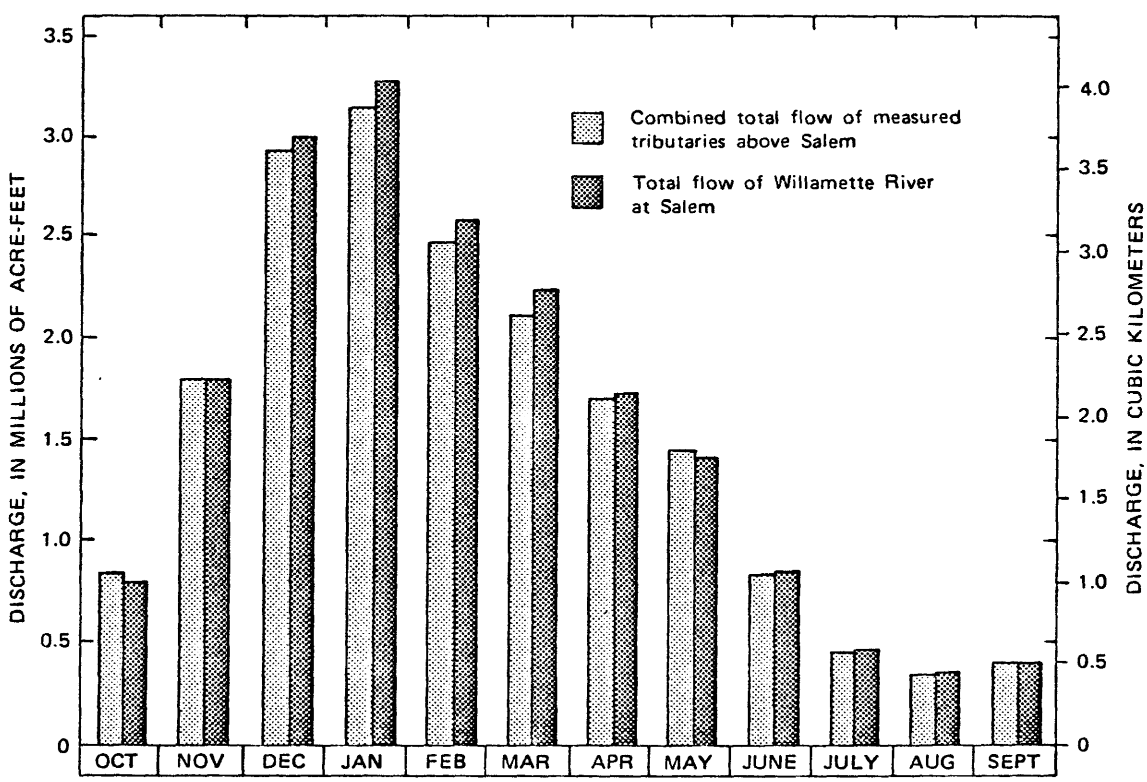


Figure 9. — Average monthly discharge for Willamette River at Salem, Oreg., and the combined total monthly discharge of tributaries measured above Salem, 1951-66.

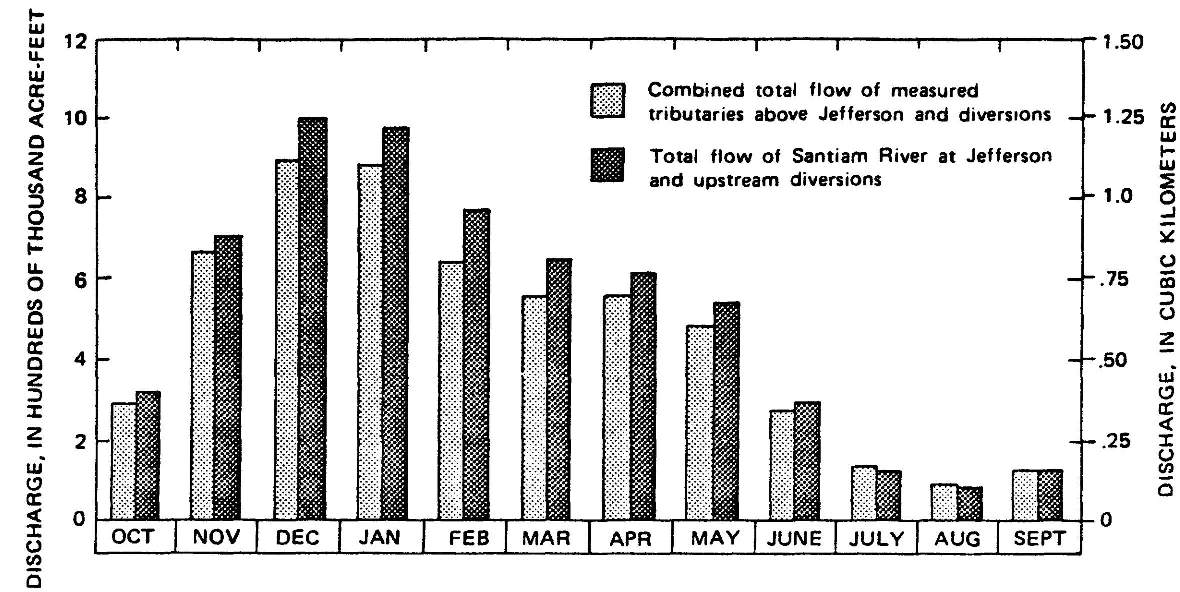


Figure 10. – Average monthly discharge of Santiam River, at Jefferson, Oreg., and combined total monthly discharge of tributaries measured above Jefferson, 1951-66.

of Willamette River at Salem and the sum of the major tributaries above Salem for the 16-year period 1951-66. Figure 10 gives similar information for the streamflow of the Santiam River system above Jefferson. On the average, there was a net increase in streamflow of about 400,000 acre-ft (500 hm^3) annually upstream from Jefferson along the Santiam River system and about 500,000 acre-ft (600 hm^3) along the Willamette River system between Albany and Salem. As figures 9 and 10 indicate, most of the gain in streamflow in both reaches is during the months of November to April when precipitation and direct runoff are greatest. In contrast, there was a net loss in flow along both rivers during the dry months of August and September. That loss results from a combination of factors, such as little rainfall, pumpage from the rivers for irrigation, and local seepage from the rivers into ground-water reservoirs.

The gain in streamflow for the area above the Jefferson gage is about 2 ft (0.6 m) of water over the valley-plain area, nearly the same as the estimated runoff for the area (Oster, 1968). Part of this runoff probably is cycled through the ground-water system, but the amount can be estimated only roughly. As shown in the following section, the annual change in ground water in storage was estimated to be 190,000 acre-ft (230 hm^3), two-thirds of which may be discharged into the Santiam and Willamette Rivers.

Figure 7 shows that ground-water levels fluctuate less near streams than along stream divides. Consequently, ground-water gradients toward streams are steeper during wet seasons than during dry ones. The steeper gradients allow ground water to move toward the streams at a faster rate in winter than in summer. Hence, a large part of the ground water contributed to streams probably is during the wet season.

Seepage measurements made during a period of low flow in September 1966 showed that the South Santiam River was losing about 25 ft^3/s (0.7 m^3/s) to alluvium near Lebanon. This net loss totals approximately 10,000 acre-ft (12 hm^3) during months when the water table adjacent to the stream is below stream level. Streams also may lose water in summer into alluvial ground-water reservoirs in the Ankeny Bottom area north and south of the mouth of the Santiam River. The water table declines significantly in these two areas during summer, causing a gradient away from the river. The natural loss of water from streams to alluvial aquifers is increased when controlled releases of water from upstream reservoirs result in above-normal streamflow during dry seasons. Locally, the condition is further magnified when pumping of irrigation wells draws the water table down near major streams, such as the Willamette River.

An unusual phenomenon occurs near Jefferson where the Santiam River loops around three sides of a segment of younger alluvium (pl. 1). At the upstream part of the loop, near Green's Bridge in sec. 18, T. 10 S., R. 2 W., the river loses water into the alluvial aquifer. On the opposite side of the meander loop, near Jefferson in sec. 11, T. 10 S., R. 3 W., water moves from the aquifer back into the stream. Wolfe (1959) made a detailed investigation of this phenomenon, particularly the relation between the yield of irrigation wells in the meander loop and the stage of the Santiam River.

Storage in the Alluvium

The water in an aquifer can be considered to be stored in an underground reservoir whose contents fluctuate with time and from which the water can be withdrawn for use by man.

Not all the water in a saturated porous zone is available to a well that penetrates the aquifer; some water adheres to the surfaces of granular material. The usable storage capacity of an aquifer can be calculated by multiplying the volume of saturated rocks by their estimated average specific yield. The specific yield of a rock or soil is the ratio of (1) the volume of water that the rock or soil, after being saturated, will yield by gravity to (2) the volume of the rock or soil (Meinzer, 1923, p. 28). The definition implies that gravity drainage is complete.

Specific Yield

The average specific yield is estimated for the two major aquifers of the valley plains--the older and younger alluvium. The most descriptive well logs in each township were used. Because of a lack of information for deeper wells, estimates of average specific yield are less reliable for the deeper depth ranges than they are for the shallower ranges. Almost without exception, the younger alluvium is less than 50 ft (15 m) thick. The deposits forming the older alluvium are divided into two depth intervals: (1) Average water table to 50 ft (15 m), and (2) 50 to 100 ft (15 to 30 m). The specific yield is estimated for each by the method described by Davis, Green, Olmsted, and Brown (1959, p. 199) and modified by Price (1967a). In the French Prairie, the assigned specific yields of valley-plain aquifer materials were confirmed by laboratory determination (Price, 1967a, p. 26). The average specific yield of each lithological category used in the French Prairie is judged to be directly applicable to alluvial deposits in the lower Santiam basin. Lithologic descriptions in drillers' logs are grouped into five categories, each with an assigned specific yield, as follows:

Category	Drillers' description	Assigned specific yield (percent)
G	Gravel, cobbles, and boulders	25
S	Sand, sand and gravel	25
Cs	Sandy clay, silt and sand, clay with sand lenses, sand with clay lenses	20
Cg	Clay and gravel, gravel with clay binder, conglomerate, cemented gravel, clay with gravel lenses	15
C	Clay, silt, silt and clay, shale, hard clay, sticky clay, tuff, sandstone	5

Figure 11 shows the geographic distribution of average specific yields by township and subbasin according to the two depth intervals. As the figure shows, the average specific yield of the younger alluvium ranges from 14 percent near the Willamette River south of Albany to 22 percent near the Santiam River in the Ankeny Bottom and Interbasin areas. The average specific yields of the older alluvium in the interval between the water table and the 50-ft (15-m) depth ranged from 12 to 21 percent and in the interval 50 to 100 ft (15 to 30 m), from 5 to 18 percent.

In general, average specific yield decreases with depth. The decrease, however, is small in much of the southern and western parts of the Lebanon-Albany plain and in the western part of the Stayton Basin.

Total Storage Volume

The volume of ground water stored in the several depth intervals was determined for the aquifers beneath the valley plains by the equation:

Volume stored (acre-ft) = area (acres) x thickness of interval (feet) x specific yield

The last column of table 2 lists the estimated quantity of water in each storage unit in the valley plains. The total ground-water storage capacity above a depth of 100 ft (30 m) is the sum of these, or about 2 million acre-ft (2.5 km^3). The storage capacity between the average water table and a depth of 50 ft (15 m) is 1 million acre-ft (1.2 km^3). The quantity in storage fluctuates seasonally as recharge and discharge alternate.

Table 2.--Summary of average specific yield and estimated ground-water storage capacity in the valley plains of the lower Santiam River basin

[All totals rounded]

Depth zone (feet)[1/]	Average specific yield (total)	Area (acres)	Volume saturated (acre-feet)	Volume of ground water in storage (acre-feet)
STAYTON BASIN				
W.T.-50	17	42,140	1,660,000	300,000
50-100	14		2,100,000	320,000
LEBANON-ALBANY PLAIN				
W.T.-50	18	81,680	2,600,000	450,000
50-100	15		3,410,000	570,000
INTERBASIN AREA				
W.T.-50	17	19,000	700,000	120,000
50-100	10		950,000	90,000
ANKENY BOTTOM AREA				
W.T.-50	18	23,420	800,000	150,000
50-100	10		870,000	100,000

1/ W.T., water table.

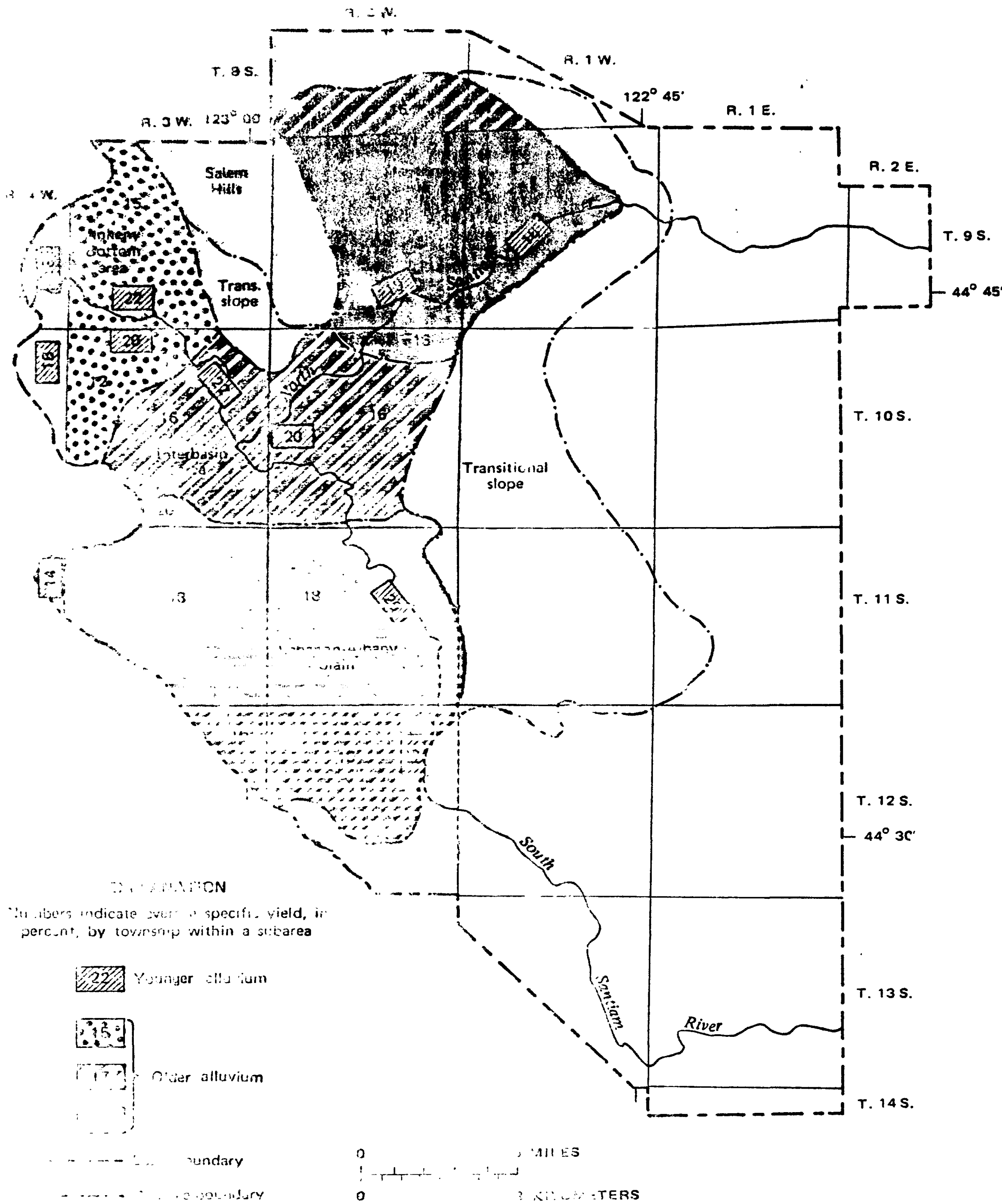
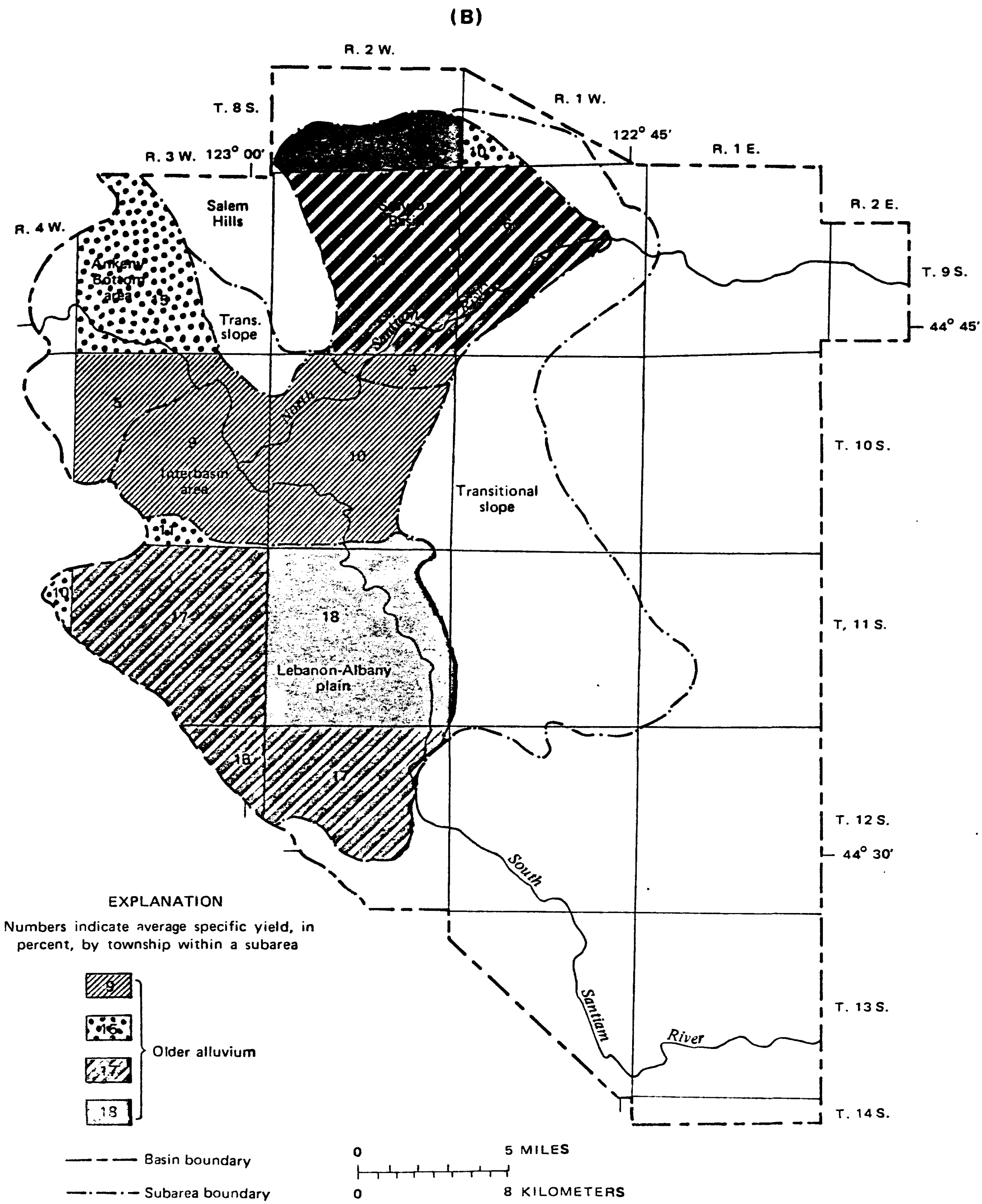


Figure 11. — Average specific yield [illegible] the valley plains of the lower Santiam River basin



in the (A) water-table-to-50-foot-depth interval and (B) 50-to-100-foot depth interval

Seasonal Change in Storage Volume

The net seasonal change in ground-water storage is the volume of water that drains from an aquifer as the water table declines from its high level in winter to its low position in late summer. Figure 7 shows the water-level decline beneath the valley plains from February to September 1967. The map was drawn by joining points of equal water-level change interpolated from measurements of 109 observation wells, most of which are in the younger and older alluvium.

The seasonal change in ground-water storage is calculated by multiplying the volume of the dewatered thickness of the aquifer by the average specific yield of the sediment dewatered. The volume was determined by multiplying the area between adjacent contour lines of ground-water decline within a township by the appropriate average ground-water decline and summing the products over the entire township or part of a township within a subarea. The volumes within a township were then multiplied by the corresponding average specific yield and listed in table 3.

Table 3.--Estimated seasonal change in ground-water storage volume beneath the lower Santiam River basin, 1967

[All numbers rounded]

Location	Change in ground-water storage (acre-ft)
VALLEY PLAINS	
Stayton Basin	28,000
Lebanon-Albany plain	95,000
Ankeny Bottom area	40,000
Interbasin area	28,000
Total	190,000
TRANSITIONAL SLOPES	
	43,000
Grand total	230,000

The net volume of water drained from the valley plains in 1967 was about 190,000 acre-ft (230 hm^3) or less than 10 percent of the volume in storage above a depth of 100 ft (30 m). This volume is equivalent to about 14 in. (0.36 m) over the valley plains of the area. It represents a minimum volume of recharge over the plains. Actual recharge would be somewhat greater, because some ground water is discharged from the aquifer system as water levels rise, and the system receives additional recharge as water levels begin to decline in late winter.

Specific Capacities of Wells in the Valley Plains

Specific capacities of wells that tap rock units in the study area are summarized in table 1. In this section the specific capacities of wells that tap terrace deposits and alluvium in the valley plains are discussed in greater detail.

Figure 12 shows, by townships within subbasins, the average specific capacities of wells finished in the younger and older alluvium, the major aquifers in the valley plains. Ranges of specific capacities, well depths, and yields for the four subbasins are listed in table 4.

Table 4.--Well-performance characteristics, lower Santiam River basin, by geographic location

[Wells tap older alluvium]

Subbasin and depth range, in feet	Number of wells	Depth of well (feet) Range	Yield (gal/min) Range	Specific capacity [(gal/min)/ft] Range
Stayton Basin area				
Less than 100	15	21-83	20-220	0.5-12
More than 100	14	100-330	40-600	.9-66
Lebanon-Albany plain				
Less than 100	32	27-96	4-500	.8-25
More than 100	17	100-171	40-720	1.2-20
Ankeny Bottom area				
Less than 100	8	31-81	45-235	1.8-14
More than 100	None			
Interbasin area				
Less than 100	10	30-94	5-75	.5-8.3
More than 100	6	127-250	25-600	.2-32

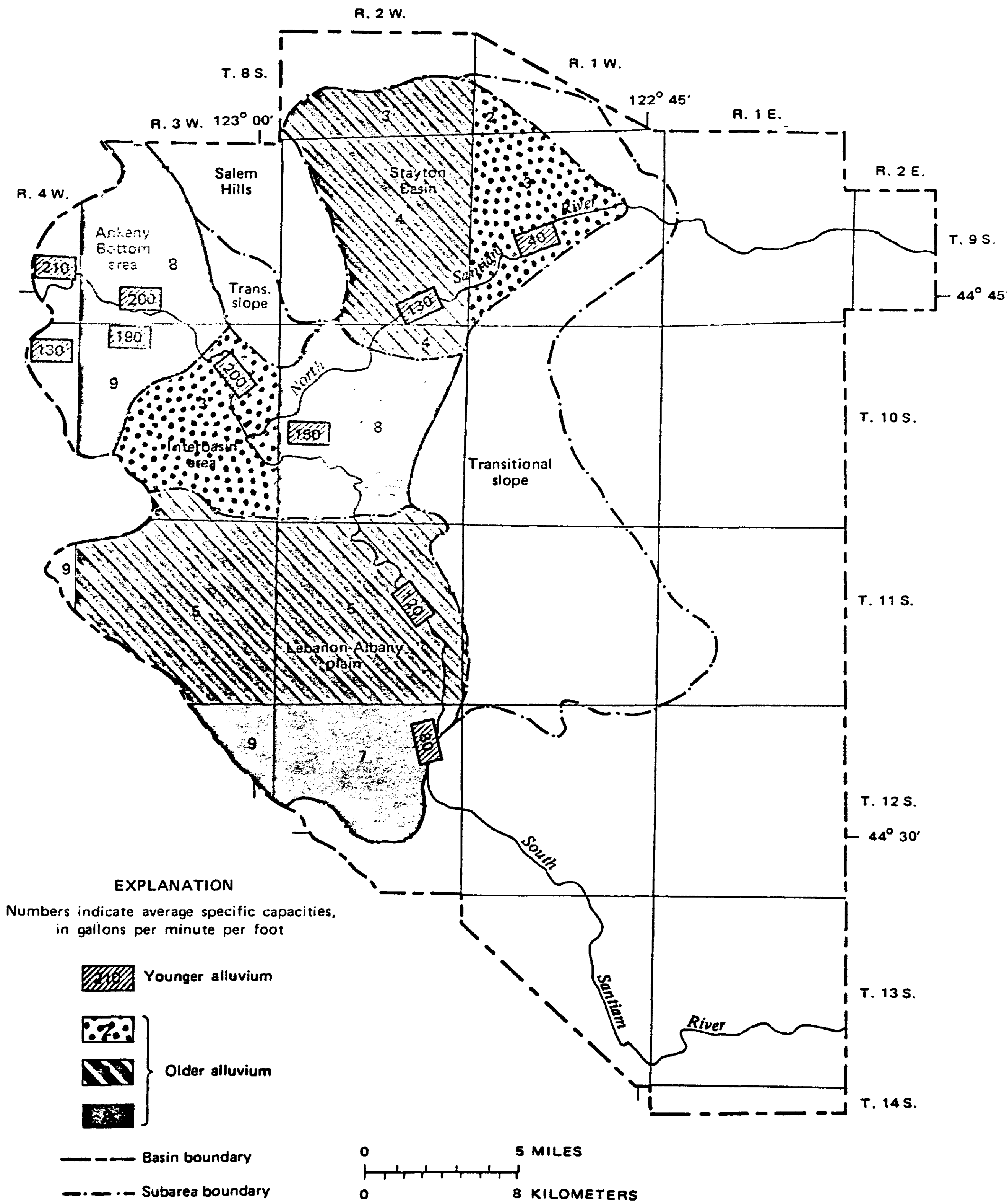


Figure 12. — Average specific capacities of wells tapping alluvium

Variations in specific capacity among individual wells are shown in table 4, and figure 12 depicts the general areal variation. However, the specific capacity of individual wells depends on factors other than aquifer characteristics, such as well construction and development. The areal trend in average specific capacity in each subbasin reflects the general aquifer characteristics and therefore is more significant than the variations among individual wells or the areal pattern.

Older alluvium.--Forty mi^2 (100 km^2) of the Stayton Basin is underlain by deposits of older alluvium. These deposits thicken westward toward the Salem Hills and the average specific capacity of wells increases westward. The higher specific capacities are found in wells more than 100 ft (30 m) deep. Obviously, the deeper wells tap a greater thickness of saturated material which yields water, and this greater saturated thickness is reflected in higher specific capacities.

The average specific capacity of 49 representative wells tapping older alluvium in the Lebanon-Albany plain is 6.2 (gal/min)/ft [1.3 (l/s)/m]. Depth does not affect the specific capacities of the wells by more than 10 percent (table 4). Irrigation wells generally have larger diameters and are more carefully and fully developed than are nonirrigation wells. Sixteen of the 26 shallow wells at low elevation are irrigation wells whose specific capacity averaged 11 (gal/min)/ft [2.3 (l/s)/m], whereas 10 are nonirrigation wells and averaged 2.6 (gal/min)/ft [0.54 (l/s)/m]. Figure 12 shows that the average specific capacity increases slightly toward the south and west.

The older alluvium underlies about 10 mi^2 (26 km^2) in the Ankeny Bottom area. The average specific capacity of wells that penetrate those deposits is 8.5 (gal/min)/ft [1.8 (l/s)/m], which is somewhat higher than it is in other areas. Well depths are generally less, and the likelihood of penetrating high-yielding sand and gravel below 100 ft (30 m) depth is less than in the Stayton or Lebanon-Albany subbasins.

The interbasin area can be roughly separated into two parts. One is the interbasin hills in T. 10 S., R. 3 W. The other is in T. 10 S., R. 2 W., and includes some lower slopes of the foothills of the Cascade Range and the lower valleys of the South Santiam and North Santiam Rivers where they converge. The specific capacity of wells in older alluvium in T. 10 S., R. 2 W., averages 7.8 (gal/min)/ft [1.6 (l/s)/m] of drawdown, which is high compared with 2.6 for the average specific capacity of wells in those deposits in T. 10 S., R. 3 W.

Younger alluvium.--The aquifer that yields the most water to wells in the Stayton Basin is the relatively thin deposit of younger alluvium along the North Santiam River. Permeable sand and gravel of the younger alluvium extend as a belt from the east corner to the south corner of Stayton Basin and underlie about 20 mi^2 (52 km^2).

Wells in the Stayton Basin that produce water solely from the younger alluvium are generally shallow; the deepest such well is only 54 ft (16 m) deep (table 5). On the average, in T. 9 S., R. 1 W., and T. 9 S., R. 2 W., only the lower 25 ft (7.6 m) of the younger alluvium is saturated, and, locally, the aquifer is not very permeable because the gravel and sand contain

Table 5.--Well-performance characteristics, lower Santiam River basin, by geographic location

[Wells tap younger alluvium]

Subbasin	Number of wells	Depth of well (feet) Range	Yield (gal/min) Range	Specific capacity [(gal/min)/ft] Range
Stayton Basin area	20	19-54	20-550	2-300
Lebanon-Albany plain	21	20-65	20-700	2.5-400
Ankeny Bottom area	30	20-46	40-1,000	8.3-600
Interbasin area	12	18-50	80-600	4.2-600

much interstitial clay. Therefore, the yields of individual wells vary locally and range from moderate (20 gal/min, or 1.3 l/s) to high (550 gal/min, or 35 l/s). For the same reason, specific capacity varies locally. In the Stayton Basin the specific capacity of wells in younger alluvium ranges from 2 to 300 (gal/min)/ft [0.4 to 60 (l/s)/m]. Specific capacity increases toward the southwest, the same direction as the flow of the North Santiam River. Figure 12 shows that the average specific capacity of representative wells in T. 9 S., R. 1 W., is 40 (gal/min)/ft [8.3 (l/s)/m], whereas in T. 9 S., R. 2 W., it is 130 (gal/min)/ft [27 (l/s)/m].

The few wells that tap alluvium of Mill Creek in the northern part of Stayton Basin have an average specific capacity of only 1.7 (gal/min)/ft [0.35 (l/s)/m]. The younger alluvium there is thin and probably lies above the water table; hence, the material that yields water to wells may actually be older alluvium. The potential for development of high-yield irrigation wells in Mill Creek alluvium is not promising.

Most of the younger alluvium on the Lebanon-Albany plain is in a 21-mi^2 (54-km^2) strip along the east edge of the plain parallel to the South Santiam River.

Younger alluvium deposited by the Willamette River occurs along the west border of the study area and yields moderate quantities of water. Oak Creek and intermittent streams have deposited small amounts of younger alluvium on the floor of the plain, but because this alluvium is thin, it is of little hydrologic significance. Along minor streams, wells must penetrate the underlying older alluvium to obtain water in quantities sufficient for irrigation.

The younger alluvium covers a 25-mi^2 (65-km^2) fan-shaped area (the Ankeny Bottom), where the flood plains of the Santiam and Willamette Rivers coalesce. The average specific capacity of wells in the younger alluvium is 205 (gal/min)/ft [42 (l/s)/m] and is higher in the Ankeny Bottom area than it is in any other part of the study area. The specific capacity generally increases westward from an average of 173 (gal/min)/ft [36 (l/s)/m] for wells at altitudes above 200 ft (60 m) to 216 (gal/min)/ft [45 (l/s)/m] at altitudes below 180 ft (55 m).

The average specific capacity of wells in the interbasin area in the younger alluvium is 177 (gal/min)/ft [36.6 (l/s)/m], increasing westward from 149 (gal/min)/ft [31 (l/s)/m] along the North and South Santiam Rivers to 196 (gal/min)/ft [41 (l/s)/m] along the main stem of the Santiam River.

Variations in specific capacity.--The data presented show that (a) younger alluvium generally yields more water to wells per foot of drawdown than does the older alluvium, and (b) there is a poorly defined east-to-west trend toward higher specific capacities in wells westward across the study area. The relation between depth and specific capacity is erratic, but wells tapping older alluvium that are more than 100 ft (30 m) deep tend to yield more water than those less than 100 ft (30 m) deep.

The well characteristics of yield and specific capacity are governed by the nature of the deposits forming the aquifers. For unconsolidated alluvial aquifers, the size of the grains and the degree of sorting are most important. Thus, a gravel layer will yield water to a well more readily and with less drawdown than will sand or silt. In addition, a well-sorted gravel or sand will transmit water more freely than will a layer that is a mixture of several sizes. The younger alluvium along the Willamette River is generally coarser and better sorted than the younger alluvium in other parts of the area. Younger alluvium deposited by the Santiam River also may be coarser near its mouth because its gradient has flattened there, causing the stream to deposit the coarsest part of its sediment load.

The apparent westward increase in specific capacity of wells tapping the older alluvium is more difficult to explain. In general, those deposits are thickest in the eastern part of the valley plain, and well logs indicate an increase in the proportion of clay toward the west. Perhaps the higher specific capacity toward the west results from the more favorable local occurrence of coarse, well-sorted channel deposits at the well sites. Another possibility is that those wells tap channels filled with material deposited by the Willamette River as it meandered over the valley plain and that such material is better sorted than the deposits from streams of the Santiam River system.

Relation of specific capacity to transmissivity.--Transmissivity is the rate at which water is transmitted through a unit width (1 ft, or 1 m) of an aquifer under a unit hydraulic gradient (1 ft/ft, or 1 m/m) (Lohman and others, 1972, p. 13). Although it is considered to be an aquifer property, transmissivity refers to the entire saturated thickness of the aquifer through which ground water is moving. For the valley plains area of this study, transmissivity would refer to the section of alluvial deposits between the water table and the impervious bedrock underlying the valley.

There is a direct relationship between transmissivity and the specific capacity of a well. Because of that relationship, transmissivity values can be estimated by multiplying the numerical value for specific capacities of wells in the lower Santiam basin by the factor 270. The applicability of that factor was confirmed by field tests, by the senior author, on several wells near Jefferson. It also was confirmed by tests on similar deposits in the French Prairie area (Price, 1967a).

The westward increase in specific capacity, noted above, indicates a similar increase in transmissivity. As the transmissivity increases westward, the alluvial deposits have a greater capacity to transmit water which allows the accommodation of the additional increment of water added by recharge on the valley plains. The flattening of the water-table gradient west of Jefferson also is a reflection of increased transmissivity, because as transmissivity increases, the same amount of water can move with a reduced gradient.

The practical application of transmissivity values in planning the development of ground water is discussed briefly in a later section of the report, "Effects of ground-water development."

CHEMICAL QUALITY

Chemical analyses of 18 surface-water samples from five streams and 45 ground-water samples from 43 wells, 1 infiltration trench, and 1 spring are included in table 12. Spectrographic analyses were made on six of these samples and are included in table 13.

One sample (13/2-15Cr) of surface water from the Middle Santiam River was collected upstream about 4 mi (6.4 km) east of the study area. It is included because the chemical characteristics of the water are probably representative of the river in the study area.

Relation to Geology

Quality of water varies from place to place and may be influenced by the geologic formations from which the water is derived. Table 6 is arranged according to geologic units and lists the average concentrations and ranges of some of the chemical constituents (silica, iron, chloride, fluoride, and boron) that affect man's use of water. Water from wells such as 10/3W-15M1 and P1 that penetrate elevated marine sedimentary rocks at shallow depth is of generally good quality, containing less than 200 mg/l (milligrams per liter) of dissolved solids. Saline or brackish water was trapped in these beds when they were initially deposited. Since continental uplift of the beds, circulation has displaced the saline water from the upper part of the formation and replaced it with fresh water. At depth, however, and under certain local conditions such as in the interbasin area (well 10/3W-19K1) and near Lebanon (well 12/2W-23B2), the water of the marine beds is reported to be saline and unsuitable for domestic and most other uses.

Water from wells that tap volcanic rocks varies in quality. Water from the Columbia River Basalt Group is generally of good quality, containing from 72 to 191 mg/l of dissolved solids. The dissolved-solids concentration ranges from 70 to 362 mg/l in the Little Butte Volcanic Series and from 129 to

Table 6.--Average[1/] and range of concentration of selected minerals in waters of the lower Santiam River basin

Source of water sample		Concentration, in mg/l				
		Silica	Iron	Chloride	Fluoride	Boron
Surface water						
Santiam River system	Avg	13	[2/] 0.53	1.3	0.1	--
	Range	9.6-16	--	.5-3.5	.0-0.2	--
Willamette River	Avg	17	.13	2.8	.1	--
	Range	15-19	.00-0.25	1.8-8	.1-0.2	--
Ground water						
Younger alluvium	Avg	28	.05	5.3	.1	0.02
	Range	17-46	.01-0.16	1.0-28	.0-0.2	0.00-0.09
Older alluvium	Avg	31	.34	6.3	.2	--
	Range	23-38	.01-0.93	1.8-27	0-0.4	.00-0.26
Terrace deposits	Range	20-37	.01-0.79	1.8-9.2	.1-0.2	.04-0.05
Sardine Formation	Range	27-36	.02-1.6	1.2-300	.1-0.2	.00-2.4
Columbia River Basalt Group	Avg	40	.61	4.9	.2	--
	Range	23-48	.01-1.6	1.0-10	.1-0.4	.00-0.04
Little Butte Volcanic Series	Range	20-60	.01-3.6	1.8-26	.0-0.2	.00-0.65
Marine sedimentary rocks	Range	35-44	.02-13	3.8-11	.1-0.2	.00-0.02

1/ Averages not given for terrace deposits, Sardine Formation, Little Butte Volcanic Series, and marine sedimentary rocks because too few samples were analyzed.

2/ Only one iron determination made.

956 mg/l in the Sardine Formation. Locally, water from some wells in the Little Butte Volcanic Series and the Sardine Formation is hard and has objectionable concentrations of some minerals, including arsenic and iron. (See table 12.) Volcanic rocks are a common source of silica in water. In the Santiam basin, where there is much volcanic material, the silica concentration is generally high and in water samples from the Columbia River Basalt Group and Little Butte Volcanic Series ranged from about 20 to 60 mg/l.

Water from streams and from wells that tap alluvium and terrace deposits is of good chemical and biological quality for drinking and for most other uses. Dissolved-solids concentrations range from 24 to 73 mg/l for samples from streams and from 43 to 273 mg/l for samples from wells that tap alluvium and terrace deposits. Information on biologic quality is not presented in this report, but can be obtained from the Oregon Department of Public Health.

Relation to Use

Suitability for Domestic and Industrial Use

Water in the Santiam basin is suitable for most domestic and industrial uses. Drinking-water standards were recommended by the Federal Water Pollution Control Administration (1968) based on those of the U.S. Public Health Service (1962). The suggested maximum concentrations of some of the more common chemical constituents are listed in table 7.

Table 7.--Recommended limits of selected chemical constituents in drinking water

Constituent	Recommended (max concentration) (mg/l)	Range in concentration in lower Santiam basin (mg/l)	
		Ground water	Surface water
Dissolved solids	500	43-956	24-73
Iron (Fe)	.3	.01-13	0-0.53
Sulfate (SO_4)	250	0-43	0.2-10
Chloride (Cl)	250	1-300	0.5-3.8
Fluoride (F)	1/ .9	0-0.4	0-0.2
Nitrate (NO_3)	44	0-52	0-0.8
Arsenic (As)	.05	0-0.12	--

1/ Based on average temperature in lower Santiam River basin.

The recommendation for a dissolved-solids total of less than 500 mg/l was an upper limit for water to be used in interstate carriers; however, water containing as much as 1,000 mg/l is acceptable if no other source is available. The dissolved-solids concentration was less than 40 mg/l in samples from the Santiam River system and less than 75 mg/l for the Willamette River. Of the 46 ground-water samples collected in the lower Santiam basin, 42 contained less than 250 mg/l of dissolved solids, and water from only one well (13/2-36Q1, table 12) contained more than 500 mg/l. Two samples from this particular well contained dissolved-solids concentrations of 683 and 956 mg/l.

The occurrence and importance of several critical properties and dissolved constituents of ground water in the Santiam basin are described below.

Iron.--Iron is not considered to be injurious to health, but concentrations of more than 0.3 mg/l in water can stain plumbing fixtures, cooking utensils, and laundry; may cause unpleasant taste; and can make water unsuitable for some industrial uses. The iron concentration of surface water was less than 0.25 mg/l, except 0.53 mg/l in one sample collected from the Middle Santiam River. Sixteen of the 47 ground-water samples had concentrations of iron in excess of 0.3 mg/l. Water from well 10/3W-15P1 had the highest concentration, with 13 mg/l.

Chloride.--The chloride concentrations of all surface-water samples were less than 10 mg/l, and only two ground-water samples exceeded 28 mg/l. Both of these samples were from well 13/2-36Q1 and had concentrations of 164 and 300 mg/l.

Fluoride.--Small concentrations of fluoride in drinking water reduce tooth decay in growing children. Higher concentrations may cause mottling and chalking. The most beneficial concentration of fluoride in drinking water depends on the maximum average daily air temperature. In the lower Santiam basin, the optimum concentration of fluoride in drinking water is 0.9 mg/l, and a concentration of more than 1.8 mg/l is sufficient reason to reject the water supply (U.S. Public Health Service, 1962, p. 8). The concentrations of fluoride in water samples collected in the study area were all well below the optimum beneficial level. The highest concentrations were 0.2 mg/l in surface-water samples and 0.4 mg/l in ground-water samples.

Arsenic.--Small concentrations of arsenic may occur naturally in water, and residues of certain insecticides and herbicides may be an additional source. Arsenic occurs naturally in ground water in an area near Cottage Grove and Eugene, Oreg., south of the project area (Goldblatt and others, 1963). According to the U.S. Public Health Service (1962, p. 9), concentration of arsenic in excess of 0.05 mg/l is sufficient reason to reject the water as a drinking supply. Such concentrations were found in three wells in the lower Santiam basin: 0.08 mg/l in well 12/1W-11H1, 0.07 in well 12/1W-29N1, and 0.12 mg/l in well 13/2-36Q1. The samples from a fourth well, 13/1-35K1, had a concentration of 0.01 mg/l of arsenic, which is recommended as the upper limit allowable for drinking water (U.S. Public Health Service, 1962). The arsenic concentration in surface water was not measured.

Silica.--The concentration of silica in water samples ranged from about 20 mg/l in both the Columbia River Basalt Group and Little Butte Volcanic Series to 60 mg/l in the Little Butte Volcanic Series. Water with this degree of silica concentration would be unsuitable for use in high-pressure boiler tanks (Moore, 1940) and would limit a few industrial enterprises, such as ice manufacturing (Hem, 1959, p. 253).

Hardness.--Hardness is caused mainly by dissolved calcium and magnesium which, like silica, form a scale in boilers and cooking utensils. Hardness indicates the soap-consuming capacity of the water and is classified by the Geological Survey as follows:

Hardness range (as $CaCO_3$) (mg/l)	Rating
0-60	Soft
61-120	Moderately hard
121-200	Hard
More than 200	Very hard

The maximum hardness of stream water in the area was 42 mg/l. Twenty-nine of the 46 ground-water samples were classified as soft, 10 moderately hard, 6 hard, and 1 very hard, with 270 mg/l of hardness. The very hard sample was from well 13/2-36Q1. The six samples classified as hard ranged from 121 to 156 mg/l of hardness.

Suitability for Irrigation

Perhaps the most important factor in determining suitability of water for irrigation is the total soluble salts which, in general, is indicated by the electrical conductivity (specific conductance) of the water. If the water is saline, it will have a correspondingly high specific conductance. High salinity is a hazard for irrigation.

A second index of the suitability of water for irrigation is the relative proportion of sodium to other cations in the water, as indicated by the SAR (sodium-adsorption-ratio). If the proportion of sodium is high, the alkali hazard is considered to be high, because the sodium cations in the water tend to replace the calcium and magnesium ions in the soil to which the water is applied. The result may be deflocculation of the soil and a loss of permeability.

Irrigation water may be grouped into 16 classifications (U.S. Salinity Lab. Staff, 1954, p. 80), from low salinity and low sodium (C1-S1) to very high salinity and sodium (C4-S4).

All surface-water samples are of excellent quality for irrigation (C1-S1). Water from rivers and streams in the lower Santiam basin can therefore be applied to almost any soil with no harmful effects on soil or crops. Water samples from all but 11 wells are in the same category. Eight of the samples are in the low sodium (alkali) hazard (S1) and medium salinity hazard (C2) class. Two samples from only one well, 13/2-36Q1, were classified as having medium sodium (alkali) hazard (S2) and high salinity hazard (C3).

Boron concentration is another index of the suitability of water for irrigation. Certain crops, including navy beans and most deciduous fruit and nut trees, are sensitive to excessive boron. The boron concentration of surface water was not measured. With one exception, samples of ground water in the lower Santiam basin would be rated excellent for semitolerant crops and good for sensitive crops (Scofield, 1936). The exception was the water from well 13/2-36Q1, which has a boron concentration of 2.39 mg/l, suitable only for tolerant crops.

In general, surface and ground water in the lower Santiam basin is excellent for irrigation and good for drinking and industrial purposes.

WATER USE

Water is used in the lower Santiam basin for irrigation, domestic, stock, industrial, and public supply. The main use of ground water has been and is for irrigation. The need of ground water for industrial and public supplies will increase with the growth of population and industries in the urban and suburban areas. Table 8 lists the pumpage from ground- and surface-water sources during 1967 in the lower Santiam basin.

Table 8.--Pumpage from the lower Santiam River basin, 1967

[All numbers rounded]

Use	Withdrawals (acre-feet)		
	Ground water	Surface water	Combined
Irrigation	30,000	24,000	54,000
Domestic and stock	3,000	Negligible	3,000
Industrial	2,000	1/ 52,000	54,000
Public supply	200	1/ 23,000	23,000
Total	35,000	99,000	134,000

1/ Diversion in study area; used in Salem outside study area.

Irrigation

In 1967 about 54,000 acre-ft (67 hm^3) of surface and ground water was pumped for irrigation. The volume of water pumped for irrigation varies each year depending on rainfall during the growing season, types of crops, and the acreage under cultivation. In 1962, 33,000 acres (13,000 ha) was under irrigation within the project area and almost half (16,000 acres, or 6,500 ha) was irrigated with ground water (U.S. Dept. Agriculture, 1962). In 1965 the total cropland irrigated was 55,000 acres (22,000 ha), almost half of which was irrigated with ground water (Willamette Basin Task Force, Irrigation Appendix F, 1969, p. II-4).

In 1966, records of 919 irrigation wells in the lower Santiam basin were on file in the office of the Oregon State Engineer. Plate 1 shows the distribution of irrigation wells within the project area, and data for the wells are presented by Helm (1968). Most of the wells are along the Santiam River, where alluvium yields large volumes of water.

Of the approximately 900 irrigation wells in the study area, 672 were used during the 1967 growing season. The volume of water pumped from irrigation wells was estimated from records supplied by electrical-power companies. A ratio of water pumped per kilowatt-hour was derived for each aquifer by assuming an average pump efficiency of 70 percent, a pressure of 65 lb/in^2 (2.6 kg/mm^2) to operate an average sprinkler system, and an average pumping lift of 20 ft (6 m) for wells in younger alluvium, 75 ft (23 m) for wells in older alluvium, and 175 ft (53 m) for wells in consolidated rocks (such as the Columbia River Basalt Group). In estimating the volume of ground water pumped, this ratio was multiplied by the total 1967 kilowatt-hour consumption for irrigation wells in each aquifer type.

In 1967, 24,000 acre-ft (30 hm^3) of ground water was pumped for irrigation from younger alluvium, 5,000 acre-ft (6 hm^3) from older alluvium, and 600 acre-ft (0.7 hm^3) from consolidated rock.

Pumpage from streams, ponds, and infiltration trenches totaled about 24,000 acre-ft (30 hm^3) in 1967. This figure was derived for 1967 by modifying 1964 estimates made by the Oregon State Water Resources Board (written commun., 1967). The total volume of surface and ground water pumped in 1967 for irrigation is therefore roughly 54,000 acre-ft (67 hm^3). Of this total, about 43,000 acre-ft (53 hm^3) was probably discharged by evapotranspiration and the remainder percolated to the water table.

Blaney and Criddle (1950) developed a formula by which the volume of water actually consumed by crops can be estimated from variables such as temperature, length of growing season, and monthly percentage of daytime hours. Tileston and Wolfe (1951) and Watts, Dehlinger, Wolfe, and Shearer (1968) experimentally determined consumptive-use coefficients for many crops in different parts of Oregon, including the part of the Willamette Valley within which the lower Santiam basin lies. Table 9 gives the water requirements for growing major crops in the lower Santiam basin as well as the estimated acreage of each crop. Using the Blaney-Criddle method, the total volume of water

Table 9.--Estimated water consumption by crop in the lower Santiam River basin, 1965

Crop	Irrigated acreage[1]	Net irrigation requirements[2] (inches)	(feet)	Total water needed for irrigation (acre-feet, rounded)
Pasture grass	12,700	15.27	1.27	16,300
Truck crops		5.02		
Onions		9.73		
Peas	11,300	1.54	.65	7,300
Tomatoes		10.46		
Potatoes		11.79		
Alfalfa		20.02		
Legume seed	7,300	14.99	1.04	7,600
Grass seed		2.66		
Mint	7,200	9.46	.79	5,700
Berries	4,000	11.10	.92	3,700
Corn	3,900	13.32	1.11	4,300
Beans (pole)	2,000	15.82	1.32	2,600
Spring grains		10.19		
Fall-seeded grains	1,400	15.85	1.08	1,500
Orchards	1,000	13.87	1.15	1,100
Orchards (with cover)	1,000	19.98	1.66	1,700
Beans (bush)	500	6.99	.58	300
Other	3,100	1.00	.08	200
Total (rounded)	55,000			52,000

1/ Total acreage irrigated in the lower Santiam basin was calculated in the field during the 1965 growing season by personnel of the U.S. Bureau of Reclamation (David Gangler, oral commun., 1967). Estimates of acreage under cultivation according to crop are made from modifications of a report by the U.S. Department of Agriculture (1962).

2/ Net irrigation requirements is the moisture required for plant consumption in addition to precipitation during the growing season of each crop, and is calculated by the Blaney-Criddle method.

consumed through irrigation in 1965 was estimated to be about 52,000 acre-ft (64 hm^3). According to Johnsgard (1963), the Blaney-Criddle method gives estimates that are usually higher than those for actual evapotranspiration. Therefore, the estimate of 43,000 acre-ft (53 hm^3) consumed through irrigation during 1967 seems reasonably accurate.

Domestic and Stock

Virtually all the water used for domestic and stock purposes in rural areas is pumped from privately owned wells. On the basis of records of water pumpage and number of persons served in rural areas near Portland (Price, 1967a, p. 58), the rural per capita requirement of the area is, by analogy, about 75 gal/d (280 l/d). The 30,000 persons in rural and suburban districts of the Santiam basin, therefore, probably used about 2.5 Mgal/d (9,500 m^3/d), or nearly 3,000 acre-ft (3.5 hm^3) in 1967, for domestic and stock supplies.

Industrial

In 1964 the Oregon State Water Resources Board made a survey in the Santiam basin of the volume of water pumped for industrial supplies, which included water for gravel washing, wood- and paper-products manufacturing, and lumber and food processing. According to the survey, about 1,600 acre-ft (2 hm^3) was pumped from wells in 1964. Slightly more ground water was probably pumped in 1967. The same survey reported that 51,600 acre-ft (64 hm^3) of river water from the lower Santiam basin was used by industries, largely in Salem 8 mi (13 km) north of the study area.

Public Supplies

The volume of water used for public supplies was estimated from U.S. Public Health Service records (1964) and from information furnished by owners and operators of small public-supply facilities. A total of about 23,000 acre-ft (28 hm^3) of water was pumped for public supplies in the lower Santiam basin during 1967. Less than 1 percent (about 200 acre-ft, or 0.2 hm^3) of this total was from ground-water sources. The principal users of ground water for public supplies are the towns of Jefferson, Aumsville, and Sublimity. Other towns in the area use surface water for public supplies. The city of Salem diverts about 15,000 acre-ft (18 hm^3) of water each year from the North Santiam River near Stayton and is the largest municipal user of water from the lower Santiam basin.

Consumptive Use

Of the water withdrawn for irrigation, about four-fifths is discharged to the atmosphere by evaporation and transpiration, and one-fifth percolates to the water table. Therefore, 80 percent of irrigation withdrawals is used consumptively--removed from the local system. Much of the total withdrawn by industry is returned as waste water to streams or to ground water, although some part is discharged by evaporation or is incorporated--especially in food and beverage industries--in the product. Most of the waste water is discharged impaired in quality or containing an added thermal load, or both. Water for public supply and private, domestic, or stock use is partly used consumptively and partly returned as sewage effluent to streams or to ground water from septic tanks and cesspools. The proportional distribution between consumptive use and effluent is poorly defined.

Of the 134,000 acre-ft (165 hm^3) (table 8) withdrawn in 1967, possibly 80,000 acre-ft (100 hm^3) reentered the system as effluent or as irrigation return flow degraded in quality by use.

OUTLOOK FOR THE FUTURE

Effects of Ground-Water Development

As ground water is more fully developed in the lower Santiam basin, mutual interference may occur between discharging wells that are closely spaced or that tap confined aquifers such as the Columbia River basalts. The magnitude of interference can be estimated from the drawdown and cone of depression of a pumping well.

Figure 13 shows distance-drawdown relations in the vicinity of a pumping well, schematically, and figure 14 as the relations change with time and with pumping rates. The drawdown, s, of the water table at a particular distance, r, from the discharging well depends on several variables, such as:

Q = rate of discharge, in gallons per minute,

t = length of time well has been pumped, in days,

T = transmissivity of the aquifer, in $feet^2$/day,

S = storage coefficient; taken as identical with specific yield in unconfined, granular aquifer.

Figure 14 is based on the nonequilibrium, or Theis, equation (Theis, 1935) which can be used for unconfined aquifers when the drawdown is small compared to the total saturated thickness (Todd, 1959, p. 97).

Various techniques have been used to calculate the effect of pumping on water levels, the spread of cones of depression around pumping wells, and the effect of pumping wells on a nearby stream. Some of the methods have been compiled by Bentall (1963), and the methodology is not elaborated on in this report.

The diagrams in figure 14 illustrate how the cone of depression for a pumping well can increase the ground-water gradient from the stream toward the well. As the drawdown effect increases with time, the proportion of the pumped water diverted from the stream also would increase.

Aquifers in the Columbia River Basalt Group are confined and have characteristics of low storage and high transmissivity that tend to make well interference a problem. The residual year-to-year drawdowns observed in wells tapping those aquifers suggest that interference problems will intensify seriously if more wells are drilled.

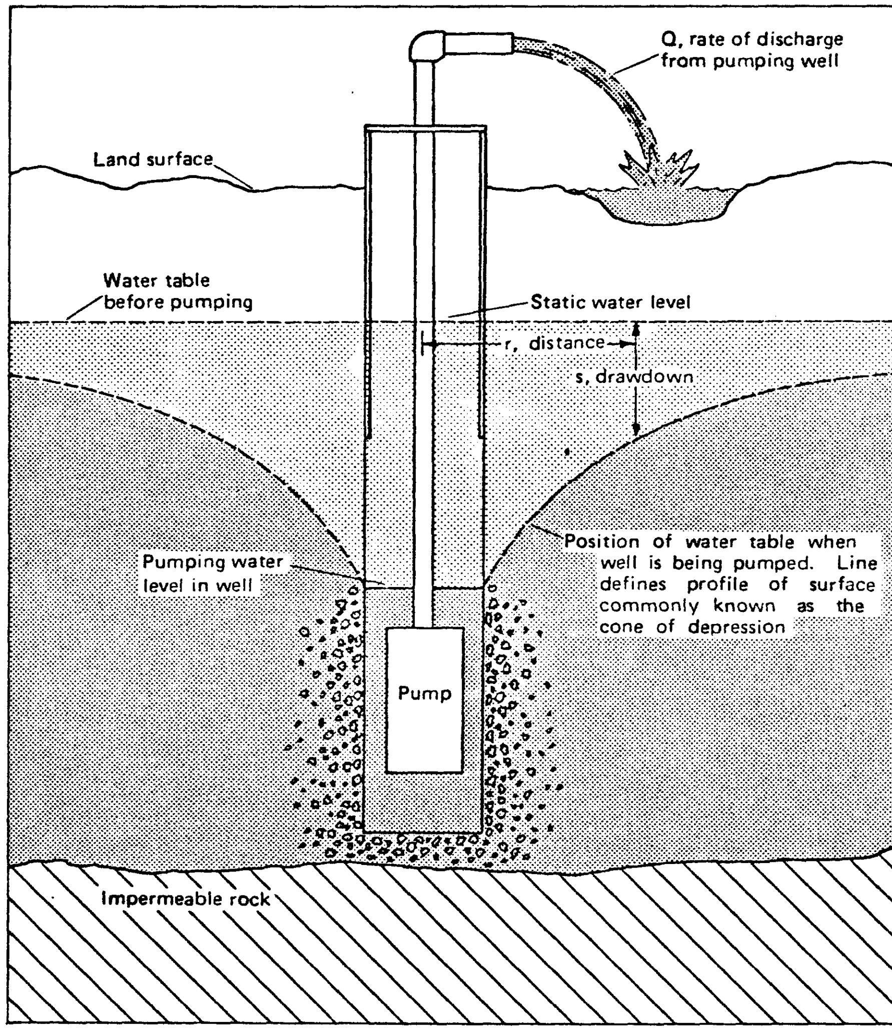


Figure 13. — Diagram illustrating distance-drawdown relations near a pumping well.

Provided the wells are spaced far enough apart, aquifers in alluvial deposits can sustain additional withdrawals without causing significant interference between wells. In general, the alluvial aquifers have high storage and transmissivity and are recharged fully each year--characteristics that should allow reasonably close spacing of wells in the study area without mutual-interference problems. Mutual interference between wells is unlikely where aquifers are hydraulically connected to the rivers, because there discharging wells may intercept some flow from the streams.

The possibility of waste water and irrigation return flow degrading both ground and surface water has been mentioned. No widespread contamination of ground water has yet been reported; however, the potential will remain unless these wastes are treated to prevent contamination.

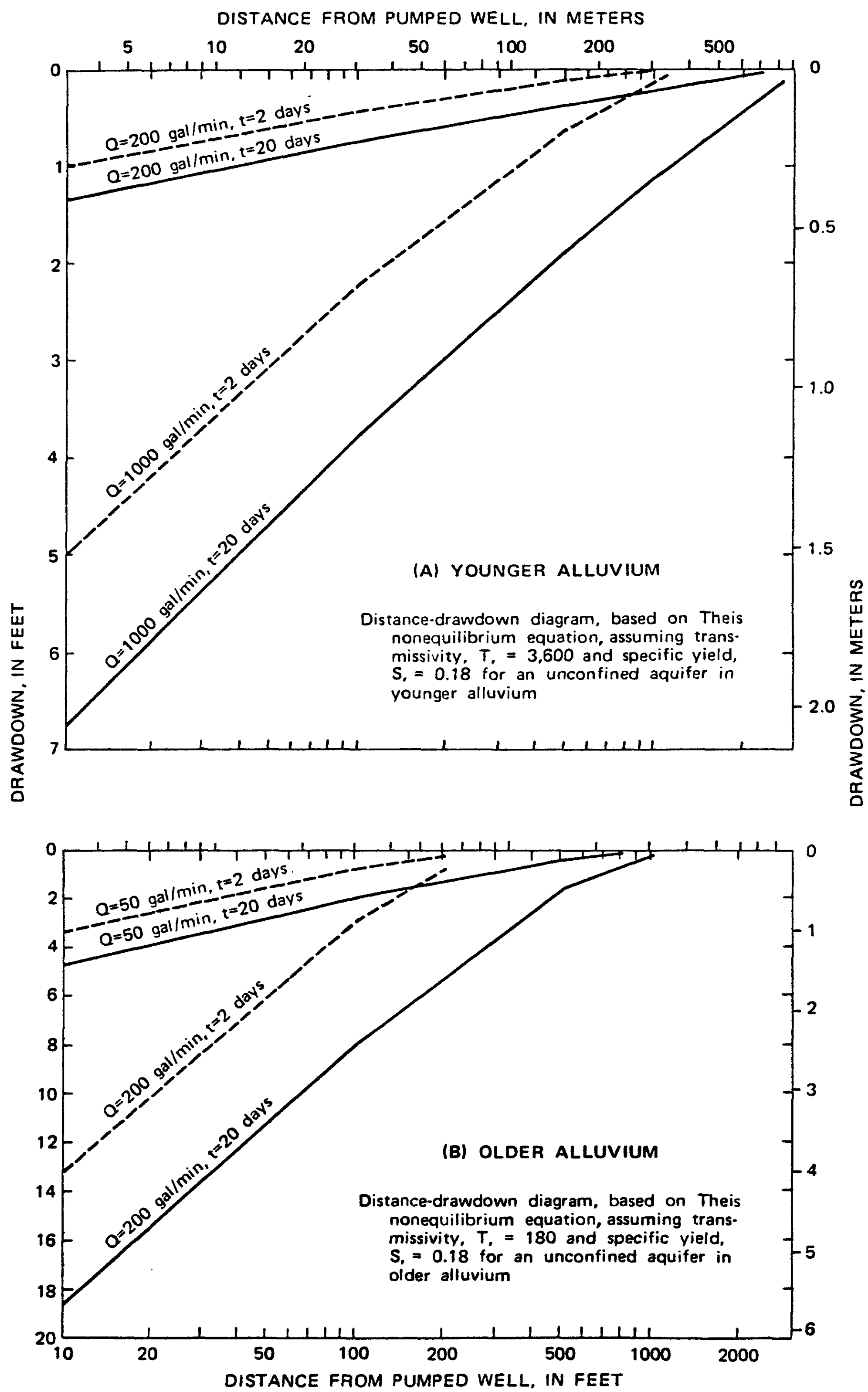


Figure 14. — Distance-drawdown relations in (A) younger alluvium and (B) older alluvium.

Locally, aquifers in marine sedimentary rocks, the Little Butte Volcanic Series, and the volcanic rocks of the Sardine Formation yield water that contains excessive salinity or concentrations of arsenic. If withdrawals from overlying aquifers are excessive, water from these sedimentary and volcanic rocks may be induced to move vertically or laterally to contaminate water now of acceptable quality.

Chemical fertilizers and insecticides are potential contaminants of ground water as well as of streams. If used excessively in areas where irrigation water percolates to the water table, those chemicals may contaminate the aquifers. The potential is greatest where the water table is fairly near the land surface.

Potential for Additional Development

Much additional ground water can be developed in the lower Santiam basin without seriously depleting ground-water storage. Records of water levels, depicted in figure 5, indicate that storage has been replenished each year despite a progressive increase in pumpage. Examination of various aspects of ground-water occurrence in the study area suggests that the ground-water system could readily accommodate withdrawals at several times the 1967 rate. Because ground-water pumpage for all uses (about 35,000 acre-ft, or 43 hm^3, per year), is only a small fraction of the cyclical storage volume, additional ground water is available for irrigation or other uses.

Assurance that a particular rate of withdrawal can be sustained requires: (1) evidence that available ground-water storage is sufficient to meet all foreseeable periods of shortage, and (2) evidence that the reservoir will be recharged at a rate at least equal to the annual rate of withdrawal. If these conditions are assured, the remaining considerations are whether the lowering of water levels and the interception of streamflow are acceptable.

About 2 million acre-ft (2,500 hm^3) of ground water in the lower Santiam basin is stored at a depth of less than 100 ft (30 m). Most of the water is in the younger and older alluvium which together underlie nearly 300 mi^2 (770 km^2) in the report area. These aquifers are highly to moderately permeable and hence are good sources for water. They are readily recharged by precipitation during winter and, locally, by streams during summer. Annual net change in storage in the alluvial aquifers of the valley plains is about 190,000 acre-ft (230 hm^3), less than 10 percent of the total storage. Annual recharge is estimated to be about 18 in. (46 mm), which is equivalent to about 250,000 acre-ft (300 hm^3). The large volume of water in storage and the rate of annual recharge clearly indicate that the first conditions for additional ground-water withdrawal have been met.

Studies by the U.S. Department of Agriculture (1962) show that land in the lower Santiam basin, suitable for irrigation, is about three times the area being irrigated in 1967. Ground water stored in the alluvial aquifers is a potential water source for irrigating much of that land. The most favorable areas for the development of additional ground water are areas where pumping already is greatest, such as in the Ankeny Bottom area and along the North Santiam River. Other favorable areas are the western part of Stayton

Basin and the central part of the Lebanon-Albany plain where the older alluvium is thickest and contains a large proportion of good water-bearing material.

Where wells are already concentrated, new wells should be located as far as possible from others in order to minimize problems of mutual interference Graphs similar to figure 14 will aid in determining the spacing of wells.

Increasing the withdrawal rate would lower water levels during the pumping season to depths greater than past seasonal lows. Lowered levels would reduce evapotranspiration and the seepage contribution to streams, because most of the seasonal fluctuation is discharged in those ways. The concentration of heavy ground-water pumping near streams, in areas where summer water levels are below stream level, would also intercept part of the streamflow at a time when flow is most critical for other uses. In places, water levels might fall below the bottom of shallow wells used for domestic and stock supplies.

Outside the valley plains, the most promising areas for developing additional ground-water supplies are areas that are underlain by the Columbia River Basalt Group, such as the uplands surrounding the eastern part of Stayton Basin. However, east of Sublimity, Stayton, and Kingston, water levels in basalt-aquifer wells are declining annually, and the aquifer in that area probably could not support large additional withdrawals of water. West of those towns and at places where the Columbia River Basalt Group is overlain by terrace deposits, ground-water levels in the Columbia River Basalt Group are not declining, and there the basalt may support a few high-yielding wells.

The Sardine Formation, Little Butte Volcanic Series, and marine sedimentary rocks locally produce sufficient water for domestic and stock use, but have small potential as sources for large ground-water supplies.

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BASIC DATA

Water-Source Numbering System

In this report, wells are identified by a numbering system that indicates their location according to the official rectangular subdivision of public lands. For example, 10/1-15G1 identifies a particular well. The two numbers that precede the hyphen and are separated by a slash indicate respectively the township and range (T. 10 S., R. 1 E.) south and east of the Willamette base line and meridian. Because most of the State lies south of the Willamette base line and east of the Willamette meridian, the letters indicating the directions south and east are omitted but the letters "W" and "N" for wells lying west of the meridian and north of the base line are used. The numeral after the hyphen designates the section (sec. 15) and the letter (G) indicates the 40-acre subdivision of that section in which the well is located, as shown in figure 15. The final digit is the serial number of that particular well as recorded by Helm (1968). Thus, well 10/1-15G1 is in the SW¼NE¼ sec.15, T. 10 S., R. 1 E., and is the first well listed in the 40-acre tract. It is identified on the map (pl. 1) by the letter and serial number that follow the section number--that is, G1. A final letter "s" indicates the source is a spring, "r" indicates the source is a river. These final letters are used in table 12 to designate non-ground-water sources of samples.

The well-numbering system used in this report is the same as that used in the basic-data report for the area (Helm, 1968). This differs, in the method of subdividing sections, from the system used in more recent reports for the southern Willamette Valley and other Oregon areas.

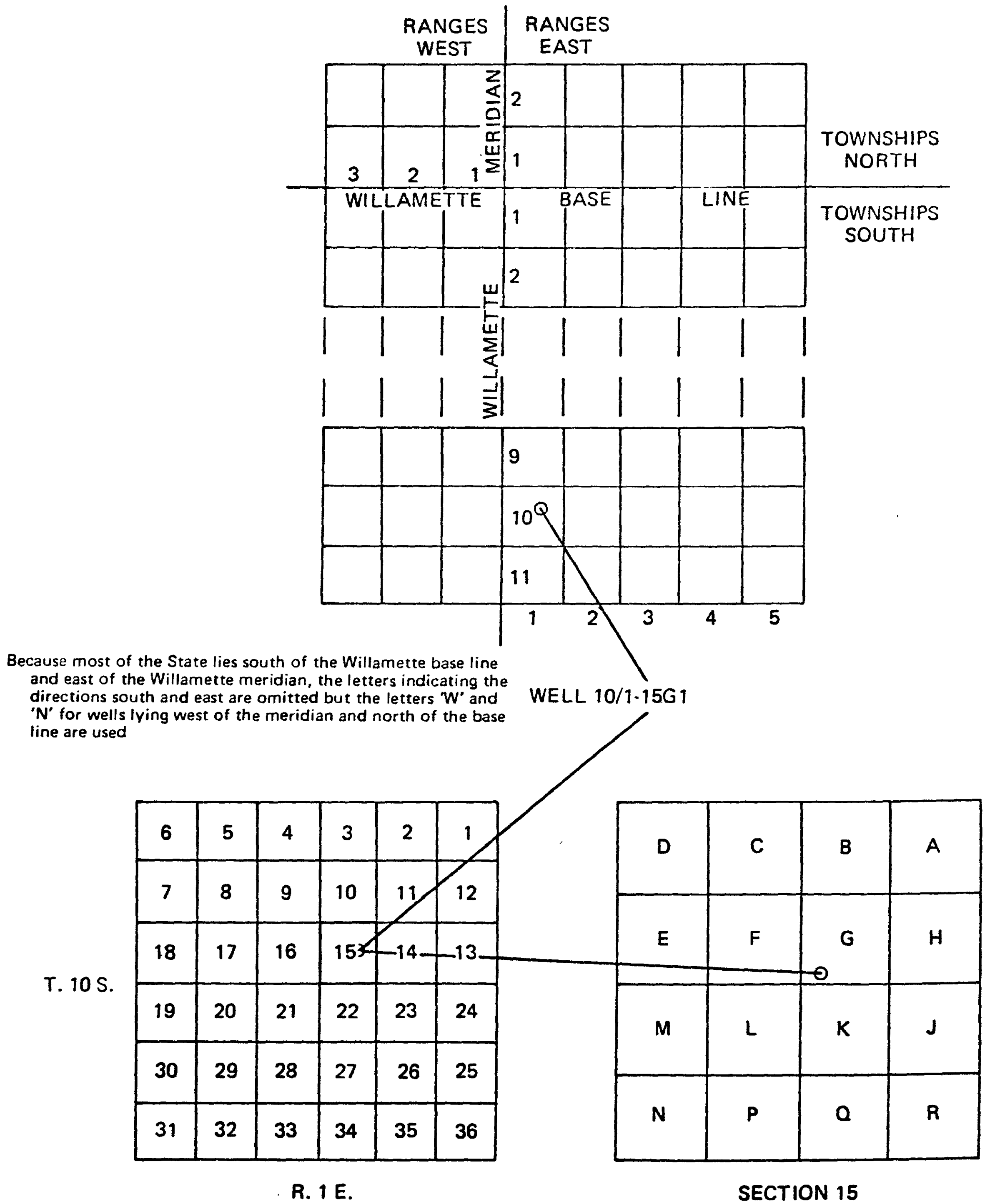

Figure 15. — Water-source numbering system.

Table 10.--Records of representative wells

Well number: The well number for each well is identical to the one that appears in the basic-data report (Helm, 1968). See page 57 for description of well-numbering system.
Type of well: Bd, bored; Dg, dug; Dr, drilled; Dn, driven.
Year completed: p, prior to.
Finish: B, open bottom (casing unperforated); P, casing perforated. Depth interval of perforations given in feet below land surface at well.
Water-bearing zones(s): Depth to top: Indicates top of saturated zone as reported by driller for most unconfined aquifers and top of water-producing interval(s) for confined aquifers. Thickness: <, less than; >, more than.
Altitude: Altitude of land surface at well, in feet above mean sea level, interpolated from topographic maps.
Water level: Depths to water given in feet and decimal fractions were measured; those given in whole feet were reported by well owner, driller, or pump company.
Type of pump: C, centrifugal; H, hand; J, jet; N, none; S, submersible; T, turbine.
Well performance: Yield, in gallons per minute, and drawdown, in feet below nondischarging water level, reported by owner, operator, driller, or pump company. Bailed yield is indicated by "b," flowing yield by "f," owner's estimated yield by "e."

Use: D, domestic; Ind, industrial; Inst, institutional; Irr, irrigation; PS, public supply; S, stock; T, test; U, unused.
Acres irrigated: Information was supplied in part by farmers and extracted from water-right records held by the Oregon Water Resources Department, Salem, Oreg.; total acreage irrigated by a group of wells is listed opposite one of those wells.
Remarks: CA, chemical analysis in table 12; FC, well located in field by U.S. Geological Survey personnel; H, hydrograph included in this report; L, driller's log of well included in table 11; Li, driller's log of well included in basic-data report (Helm, 1968); Lo, driller's log of well available at the offices of the Oregon Water Resources Department, Salem, Oreg., and the U.S. Geological Survey, Portland, Oreg.; Pp, pumped or bailed for the indicated number of hours when drawdown was measured; Temp, temperature of water in degrees Celsius, followed by temperature in degrees Fahrenheit within parentheses; TW, oil test well records available at office of the Oregon Department of Geology and Mineral Industries, Portland, Oreg.; SpA, spectrographic analysis in table 13; WS, water-level measurements available at the offices of the Oregon Water Resources Department, Salem, Oreg., and the U.S. Geological Survey, Portland, Oreg. Remarks on the adequacy and dependability of water supply, general quality of water, and materials penetrated were reported by owners, tenants, drillers, or others.

Well number	Owner	Type of well	Year completed	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Water-bearing zone(s): Depth to top (feet)	Water-bearing zone(s): Thickness (feet)	Water-bearing zone(s): Character of material	Altitude (feet)	Water level: Feet below datum	Water level: Date	Type of pump and hp	Well performance: Yield (gal/min)	Well performance: Drawdown (feet)	Use	Acres irrigated	Remarks
									T. 8 S., R. 1 W.										
28G1	Josephine Gerpecher	Dr	1960	178	6	122	B	122	56	Basalt	450	112	4- 7-60	S, 5	90	48	D,Irr	--	L, FC, WL, Temp 12 (54), H.
30J1	Francis Hendricks	Dr	1960	270	8	117	B	116	154	do	425	67 70.51	5-18-60 8-14-62	S, 25	220	82	D,Irr	--	L, FC.
34L1	Town of Sublimity	Dr	1960	317	10	191	B	182	135	do	530	68	10-21-60	S, 20	300	122	PS	--	CA, Lo, Temp 13 (55).
									T. 8 S., R. 2 W.										
28A1	D. L. Morlin	Dr	1958	205	6	45	B	160	45	Sandstone	400	53	9-20-58	S, 1	b, 10	55	D	--	FC, CA, Lo, Temp 13 (56).
									T. 9 S., R. 1 W.										
1E1	Etzel Bros.	Dr	1958	259	8	--	B	--	--	Basalt	510	26½	2-24-58	C, 15 T, 25	330	108	Irr	--	Li, FC, WL, Pp 1 hr, Temp 11 (51).
2F1	A. Hessler	Dr	1956	147	8	16	B	135	12	Crevices in andesite	470	½	12-13-56	C, 20	550	4½	Irr	30	Li, FC, Pp 1½ hr, Temp 12 (54).
2R1	Etzel Bros.	Dr	1962	289½	10	69	B	26½	263	Basalt	525	77	4- 4-62	T	400	140	Irr	--	L, FC, CA, WL, Pp 2 hr, Temp 14 (57), H.
4N1	Northwest Natural Gas Co.	Dr	1963	362	10	20	B	20	10	Boulders and sand	420	--	--	N	--	--	--	--	L, FC; well used to bury electric cables.
10C1	Regis High School	Dr	1964	250	10	92	P 45-70	45	25	Gravel, cobbles, and boulders	447	9	8-28-64	--	78	83	Irr	--	L, FC; no increase in yield below 70 ft.
10M4	Stayton Canning Co. Coop.	Dr	1954	485	12	319	P 40-319	--	--	--	440	--	--	T, 40	450e	--	Ind	--	L.

Table 10.--Records of representative wells--Continued

Well number	Owner	Type of well	Year completed	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Water-bearing zone(s): Depth to top (feet)	Water-bearing zone(s): Thickness (feet)	Water-bearing zone(s): Character of material	Altitude (feet)	Water level: Feet below datum	Water level: Date	Type of pump and hp	Well performance: Yield (gal/min)	Well performance: Drawdown (feet)	Use	Acres irrigated	Remarks
									T. 9 S., R. 1 W.--Continued										
11C1	Walter Miller	Dr	1965	275	6	95	B	155	5	"Rock, honey-combed"	500	63	3- 3-65	--	80	160	Irr	--	L, FC, Pp 2 hr.
								166	6	do									
								257	18	Andesite, hard, "broken"									
12B1	William Ripp	Dr	1963	460	6	343	P 40-53	51	1	"Rock," brown, seamy	690	91 226	8-22-55 8- 1-63	S, 2	35	127	D,Irr	--	L, FC, WL, Pp 8 hr, H.
								368	2	Basalt, vesicular									
								408	< 1	do									
								452	< 1	Bottom of basalt									
13D1	Salem City Water Dept.	Dr	1939	60	16	60	--	16	3	Gravel	466	12	--	T, 15	1,775e	--	PS	--	Li, CA.
								26	2	do									
13D2	do	Dr	1940	60	14	--	--	--	--	--	466	12	--	T, 10	1,550a	--	PS	--	CA.
13D3	do	Dr	1940	60	12	--	--	--	--	--	466	12	--	T, 10	1,100e	--	PS	--	CA.
14Q1	John Fery	Dr	1964	326	10	19½	B	57	269	Basalt flows	550	3	3-19-64	T, --	600	62	Irr	--	L, FC, CA, WL, Pp 3 hr, H.
15B1	Town of Stayton	Dg	1955	25	48	--	Infiltration trench	--	--	--	440	5	--	T, 45	1,000	18	PS	--	CA; 60 ft of infiltration line at 18-ft depth.
22E1	Raymond Frey	Dr	1966	162	6	59	B	35	6	Gravel, partly cemented	455	45	12- 1-66	--	35b	20	D	--	L, Pp 1 hr.
								145	17	Basalt									
23P1	Charles Hecht	Dr	1951	93	10	15	B	68.5	25	"Rock"	550	68.5	6-15-66	T, ½	30	30	Irr	--	Lo, FC, WL, H.
24B2	Jim Adams	Dr	1966	248	6	19	B	70	< 1	Basalt	685	86	5- 9-66	S, 1	7½	150	D	--	Li, Pp 1 hr.
								110	< 1	do									
								200	< 1	do									
29R1	John Tarr	Dr	1966	49	6	49	B	48	1	Sand, coarse	510	15	3-30-66	S, 1	50b	9	D	--	Li, FC, CA, Pp 3 hr, Temp 12 (53).
									T. 9 S., R. 2 W.										
4J1	Ollie Runions	Dr	1964	66	10	66	P 40-64	37	29	Sand and gravel	315	2.2	1-18-67	C, 10	125	10	Irr	18	Li, FC, Pp 6 hr.
5E1	A. S. Dreger	Dr	1950	121	8	94	P --	54	12	Gravel and sand	301	1	--	T, 15	170	110	Irr,S	62.7	L.
								69	21	Sand									
								90	2	Gravel and sand									
24L3	Boyd Hilton	Dr	1962	140	10	138	P 15-138	23	117	do	370	10	10-19-62	T, 30	300+	117	Irr	--	Li, FC, CA, WL, Pp 4 hr.

Table 10.--Records of representative wells--Continued

Well number	Owner	Type of well	Year com-pleted	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Water-bearing zone(s): Depth to top (feet)	Thick-ness (feet)	Character of material	Alti-tude (feet)	Water level: Feet below datum	Date	Type of pump and hp	Well performance: Yield (gal/min)	Draw-down (feet)	Use	Acres irri-gated	Remarks
T. 9 S., R. 2 W.--Continued																			
24M2	Albert Krenz	Dr	1963	54	6	54	P 50-53	50	4	Gravel and sand	358	15	12-27-63	--	50b	7	D,Irr	3½	Li.
24R2	A. F. Keithley	Dr	1946	23	6	23	P 17-23	12	11	Gravel	365	12	--	N	170e	--	U	--	Lo, FC, WL; originally irrigated 19.8 acres.
26A1	Glenn Tierce	Dr	1955	42	8	42	P 10-42	--	--	--	346	9-10	--	T, 10	290e	--	Irr	43.9	FC, WL.
27A2	E. F. Schermacher	Dr	1958	2,426	10 8	200 640	P 50-200	50 60 82 104 183	6 5 6 32 39	Sand and gravel do Gravel do Gravel and sand	330	3	4-22-63	--	600 500 300	91 72 47	Irr and test	--	L, Pp 3½ hr) Pp 4 hr) TW. Pp 4½ hr)
T. 9 S., R. 3 W.																			
8C1	J. L. Payne	Dr	1965	81	12	74	P 42-68	41	27	Sand and gravel	202	36.7	2-10-67 10- 1-65	S, --	160	26	Irr	--	Li, FC, CA, WL, Pp 16 hr, Temp 13 (55).
14E1	Portland Gas & Coke Co.	Dr	1936	3,617	--	--	--	--	--	--	305	--	--	--	--	--	T	--	TW.
18D1	G. E. Lamp	Dr	1961	33½	12	33½	P 20½-31½	15	18½	Sand and gravel	170	15½	5-25-61	C, 15	750	2	Irr	--	Li, FC, CA, Pp 3 hr.
18L1	do	Dr	1957	46	12	46	P 30-42	22	24	do	176	24	7-26-57	T, 15	480	14	Irr	--	Li, FC, WL, Pp 2 hr.
23R1	M. L. Vickery	Dr	1960	140	6	135½	B	129	11	Sand, gravel, and sandstone	260	3.5 8	4-15-66 9-16-66	T, 3	20b	70	O	--	Li, FC, WL, Pp 1 hr.
30E1	Delmar Davidson	Dr	1959	30	10	30	P 24-29	14	16	Gravel and coarse sand	175	6 15.2	12-19-66 9-16-66	C, 15	600e	--	Irr	--	Li, FC, WL, Temp 10 (50).
30L3	do	Dr	1957	30	12	30	P 24-29	16	14	do	180	12	5-19-66	C, 15	500	2	Irr	--	Li, FC, CA, Temp 11 (51).
34J1	Posel	Dr	1961	398	8	72	P 66-70	68	1	Break between yellow clay and blue shale	210	22	5-12-66	T, 1	45b 80	45 200	Irr	--	L, FC, WL, Pp 2 hr.
34K4	Ralph Nelson	Dr	1960	34	8	33	P --	12	22	Gravel	200	12	6-29-60	C, 20	--	--	Irr	--	Li, FC, CA.
T. 9 S., R. 4 W.																			
24E1	Portland Gas & Coke Co.	Dr	1935	2,845	--	--	--	--	--	--	176	--	--	--	--	--	T	--	"Buena Vista" TW.
26A1	Gayle Gilmour	Dr	1965	40	8	40	P 24-39	14	23	Sand and gravel	170	20	7-24-66	N	40b	3	Irr	--	Li, FC, Pp 1 hr.
35B1	D. E. Turnidge	Dr	1938	30	10	30	P 15-30	14	16	do	174	14	--	C, 10	350	--	Irr	25	Li.

Table 10.--Records of representative wells--Continued

Well number	Owner	Type of well	Year com-pleted	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Water-bearing zone(s): Depth to top (feet)	Thick-ness (feet)	Character of material	Alti-tude (feet)	Water level: Feet below datum	Date	Type of pump and hp	Well performance: Yield (gal/min)	Draw-down (feet)	Use	Acres irri-gated	Remarks
T. 9 S., R. 1 E.																			
3E1	Etzel Bros.	Dr	1964	400	10	60	B	58	333	Basalt and ash	1,160	61	4-24-64	T, 40	325	232	Irr	--	Li, FC, WL, Pp 3½ hr.
16B1	L. B. Jenota	Dr	1965	40	6	40	P 28-40	29	11	Gravel, medium	550	7.3	4-13-66	J, ½	20b	10	D	--	Li, FC, WL, Pp 1 hr.
25E1	Ervin Robertson	Dr	1965	273	6	20	B	220	20	"Rock," black, "broken"	1,465	150	6-15-65	J, 1½	7b	110	D	--	Li, FC, CA, Pp 1 hr.
T. 10 S., R. 1 W.																			
4J1	Carl Limbeck	Dr	1957	139	6	4	B	90 110 124 133	12 2 8 4	Basalt, seamy do do Sand, black	675	48	12-13-57	J, 2	10b	All	D,S	--	Li, FC, CA, Temp 12 (50).
5L1	A. M. Hendrickson	Dr	1951	225	10	110	P 0-110	147 218	< 1 < 1	Gravel in "rock" do	400	35.13	6-15-66	T, 30	670	28	Irr	70	L, FC, WL.
28F1	Grant Ferris	Dr	1958	172	8	27	B	50	100	Sandstone	340	5.56	do	J, 1	35b	40	S	--	Li, FC, WL, Pp ½ hr.
T. 10 S., R. 2 W.																			
1B1	Alice Music	Dr	1966	35	6	35	B	25	10	Gravel, cemented	342	4	5-27-66	T, 3/4	40b	16	D	--	Li, FC, CA, Pp 2 hr, Temp 12 (54).
7N2	S. B. Ferguson	Dr	1951	26	10	26	P 16-26	6	20	Gravel	248	6	--	C, 30	460e	--	Irr	112.7	Lo.
8N2	William Uppstad	Dr	1957	21	10	21	P 15-20	17	4	Gravel and sand	253	14	8-22-57	C, 15	450	1½	Irr	--	Li, FC, CA, WL, Pp 1 hr, Temp 10 (50).
18D1	O. D. Stephenson	Dr	1940	20	8	20	--	--	--	--	245	--	--	C, 10	300e	--	Irr	14.3	
19Q2	N. D. Bradley	Dr	1966	22	10	22	P 18-22	15 19	1 3	Gravel and sand do	230	5	5-12-66	C, 10	300	1½	Irr	10	Li, FC, CA, Pp 1 hr.
21R1	H. C. Robertson	Dr	1960	94	8	60	P 25-59	34 41 55	2 7 4	Sand and gravel Gravel Sand and gravel	262	3.94	6-15-66	N	60b	12	U	--	L, FC, WL, Pp 1 hr, H.
30N1	Zelma Bond	Dr	1965	140	10	52	P 39-52	45	6	Sand, black, and gravel	230	4 12.2	6- 7-65 11-11-65	--	48	50	Irr	--	L, FC, Pp 1 hr.
T. 10 S., R. 3 W.																			
2B1	Lewis Earll	Dr	1964	280	6	208	P 29-30	23 255	7 5	Sandstone, brown Shale, brown	226	8	10-17-64	--	8b	12	D	--	L, FC, Pp 1 hr.
5K4	Jack Pesheck	Dr	1959	25	6	25	P 21-24	19	6	Gravel	180	12.6	8- 6-65	C, 5	200	8	Irr	--	Li, FC, CA.
7A2	M. W. Fletcher	Dr	1966	35	10	34	P 23-34	20	12	do	178	14½	5-31-66	--	300	7	Irr	--	Li, Pp 1 hr.

Table 10.--Records of representative wells--Continued

Well number	Owner	Type of well	Year completed	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Water-bearing zone(s): Depth to top (feet)	Water-bearing zone(s): Thickness (feet)	Water-bearing zone(s): Character of material	Altitude (feet)	Water level: Feet below datum	Water level: Date	Type of pump and hp	Well performance: Yield (gal/min)	Well performance: Drawdown (feet)	Use	Acres irrigated	Remarks
								T. 10 S., R. 3 W.--Continued											
7N2	Gordon Hoefer	Dr	1967	130	10	40	P 28-40	22	17	Gravel and sand	180	10	5-27-67	--	100b	0	Irr	--	L, Pp 2 hr, Temp 13 (56).
10R1	H. J. Miller	Dr	1962	4,951	6 7	23 510	P 19½-21	20	3	Gravel and coarse sand	215	8	8- 1-62	C, 1½	40	10	T	--	Lo, FC, Pp 2 hr. Temp 11 (51); TW.
11R1	Martha Looney	Dr	1943	29	8	29	P 14-29	14	15	Gravel, coarse	215	14	--	C, 15	400	3	Irr	26½	Lo.
12N3	Town of Jefferson	Dr	1951	124	8	--	P 24-30	--	--	Sand and gravel	227	--	--	T, 20	200e	100±	PS	--	L; chlorinator attached.
13C1	E. W. Hart	Dr	1952	35	8	34	--	24	10	Clay and river rock	235	14.13	6-14-66	N	200	10	U	--	Lo, FC, WL; formerly irrigated 30 acres.
13F1	do	Dr	1949	21	8	21	P 8-21	8	13	Gravel and sand	225	4.50	2-10-67	C, 20	400	0	Irr	60	FC, CA, WL. Temp 11 (52).
15H1	Peterson	Dr	1959	255	6	40	B	240	5	Sand, black	310	94.85	8-17-65	S, 1	36b	20	D	--	Li, FC, CA, Pp 4 hr, Temp 12 (54).
15P1	G. K. Miller	Dr	1965	70	8	50	B	51	19	Sandstone, yellow	465	0	1- 3-66	S, 3/4	19b	All	D	--	Li, FC, CA, Pp 1 hr, Temp 13 (55).
19K1	Lester Conser	Dr	p1929	160	4	--	--	25 90	7 1	Gravel Sandstone	199	--	--	N	--	--	U	--	L, FC; abandoned; water reported to be saline.
20K1	Eldon Chowning	Dr	1959	150	6	150	P 105-110, 120-126, 142-148	105	45	Clay, sandy	227	27.7	8-20-65	J, 2	30	4	D	--	Li, FC, CA, WL, Pp 2 hr, Temp 13 (56).
21Q1	Engineering Management, Inc.	Dr	1962	250	6	154	P 17-26, 144-154	17 144	9 10	Gravel Clay, brown	235	27	4-30-62	S, ½	25b	105	Ind	--	L, FC, Pp 1 hr.
28K1	Tidewater Oil Co.	Bd	1959	86	6	24	B	75	10	Clay, blue, and sand	245	40.75	4- 3-66	J, --	< 5	All	Ind	--	L, FC.
28Q1	Shell Oil Co.	Dr	1959	185	6	185	B	178	7	Clay, gray	225	40	9- -59	--	2½e	--	Ind	--	L, FC.
33K2	C. Bean	Dr	1963	90	6	77	P 70-77	70 77	7 8	Clay, blue Sand, brown, and gravel	210	7	4-26-63	J, 1	40b	20	D	--	L, FC, Pp 1 hr.
36C1	George Lines	Dn	1959	50	1¼	50	B	26	24	Gravel, yellow	245	+3 -10	Winter 7- -63	H	4e	--	S	--	Li, FC, CA, Temp 13 (55).
								T. 10 S., R. 4 W.											
1C2	Ammon Bros.	Dr	1959	39	10	39	P 27-39	27	12	Gravel	175	15	11-13-59	C, 30	600	1½	Irr	--	Li.
11A1	A. A. Chambers	Dr	1960	32	8	32	P 21-31	12	20	do	170	7.35	8- 6-65	C, 15	1,000e	3.4	Irr	--	Li, FC, CA.

Table 10.--Records of representative wells--Continued

Well number	Owner	Type of well	Year com-pleted	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Water-bearing zone(s): Depth to top (feet)	Water-bearing zone(s): Thick-ness (feet)	Water-bearing zone(s): Character of material	Alti-tude (feet)	Water level: Feet below datum	Water level: Date	Type of pump and hp	Well performance: Yield (gal/min)	Well performance: Draw-down (feet)	Use	Acres irri-gated	Remarks
								T. 10 S., R. 4 W.--Continued											
12F1	Henry Hoefer	Dg	p1928	24½	24	24	Concrete tile	19	5	Gravel	185	22.95	9- 7-28	N	--	--	U	--	Lo, FC, WL, H.
12F2	do	Dr	--	32	8	--	--	--	--	do	186	21.85	6-14-66	N	--	--	U	--	FC, WL, H.
								T. 10 S., R. 1 E.											
7E1	J. L. Klundt	Dr	1956	37	6	37	B	20	< 17	Rock, blue	440	23.94 25	2-25-66 9-10-56	J, ½	6b	0	D	--	Li, FC, WL.
9L2	Bennie Silbernagel	Dr	1960	221	6	52	B	53 158 210	1 1 1	Sandstone, brown Tuffstone, gray Shale, gray	740	65	6-24-65	S, 1½	24b	--	D	--	Li, FC, CA.
								T. 11 S., R. 1 W.											
2C1	George Rice	Dr	1962	88	6	25	B	25	63	Sandstone and claystone	355	3.21 3.5	2-28-66 4-24-62	J, 1	30b	45	D	--	Li, FC, WL, Pp 1 hr.
6B1	I. S. Marshall	Dr	1956	50	6	18½	B	--	--	--	290	2.60	2-10-67	T, ½	--	--	D	--	FC, WL.
20N1	Seth Downer	Dr	1963	225	6	221	--	218	5	Sand and gravel	365	56	1- 1-63	S, 1	30b	20	D	--	Li, FC, WL, Pp 1 hr, Temp 12 (54).
25C1	Archie Wolfenberger	Dr	1961	54	6	53	B	50	4	Sand and gravel, loose	650	20	7-29-61	J, ½	10b	22	D	--	Li, FC, CA, Pp 1 hr, Temp 12 (54).
32D1	Linn County Oil Development Co.	Dr	1958	4,529	--	--	--	--	--	--	345	--	--	--	--	--	T	--	Lo, FC; "Barr 1" TW.
								T. 11 S., R. 2 W.											
3D1	Sam Looney	Dr	1957	107	10	107	P, 0-107	38 70	32 37	Gravel, fine Gravel and boulders	260	10	11-10-57	T, 15	500 150	67 28	Irr	--	Li, FC, CA, WL, Temp 11 (52).
5P1	George Dwyer	Dr	1966	126	8	99½	B	52	53	Sand, black, and gravel	260	6	4-19-66	S, 10	120	34	Irr	17	L, FC, Pp 3 hr.
6B1	G. C. Scheler	Dr	1956	74	8	74	P, 62-74	70	4	Gravel	249	8.71	6-17-66	T, 5	--	--	Irr	--	Li, FC, CA, WL, Temp 12 (56), H.
9E1	Arvid Backman	Dr	1957	120	10	108	P, 50-70, 92-108	45 94 104	21 3 3	Sand, black, and gravel Sand, black Sand, black, and gravel	265	9	9-27-59	T, --	265	84	Irr	--	L, FC, Pp 3 hr.

Table 10.--Records of representative wells--Continued

Well number	Owner	Type of well	Year completed	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Water-bearing zone(s): Depth to top (feet)	Water-bearing zone(s): Thickness (feet)	Water-bearing zone(s): Character of material	Altitude (feet)	Water level: Feet below datum	Water level: Date	Type of pump and hp	Well performance: Yield (gal/min)	Well performance: Drawdown (feet)	Use	Acres irrigated	Remarks
T. 11 S., R. 2 W.--Continued																			
22H1	Lauree Cunningham	Dr	1951	21	8	20	P 14-20	14	7	Gravel and sand	290	7	--	C, 15	350	1	Irr	12	Lo, FC, CA, Temp 11 (52).
24B1	Griggs School	Dr	p1928	73½	4	--	--	--	--	--	305	5.15	8- 3-28	--	< 5e	--	Inst	--	FC, CA, Temp 12 (54).
29H1	Neal Hollingsworth	Dr	1959	145	8	93	P 50-87	40	50	Gravel and clay	290	2.41	6-14-66	T, 15	400	57	Irr	--	L, FC, WL, Pp 3 hr, H.
T. 11 S., R. 3 W.																			
4C1	Albany Floral Co.	Dr	1928	44	1-3/4	44	--	27 33	1 8	Gravel, "tight" Gravel, loose	206	18	8- 2-28	--, 1	15e	--	Irr	--	FC, CA; irrigates hothouses.
4G1	A. H. Ropp	Dr	1961	59	6	59	B	57½	1½	Gravel, loose, and sand	215	7 12.82	1-21-61 11-10-65	J, ½	40b	13	D	--	Li, FC, CA, WL, Pp 1 hr, Temp 14 (57).
5J2	D. E. Nebergall Meat Co.	Dr	1936	96	8	96	P 78-96	86	10	Sand, black	200	18	--	T, 7½	125	60	Ind	--	L.
13A1	L. A. Nelson	Dr	1953	92½	6	92	P 83-92	70	22	Sand and gravel	255	256	6-14-66	T, 3	450	18	Irr	17.3	L, FC, CA, WL, Temp 13 (55), H.
15C1	Sam Kennel	Dr	1952	142	8	132	P 75-132	123	9	Sand, dark, and gravel	243	18	--	T, 10	135	115	Irr	48	Li, FC, WL.
17F2	J. T. Anderson	Dr	1960	70	6	66	P 32-38, 58-64	29	37	Sand and gravel	226	14.49	11- -65	C, 1½	40b	½	D, Irr	--	Li, FC, CA, WL, Pp 2 hr, Temp 13 (56).
26A1	Leonard Roth	Dr	1952	151	8	151	P 74-90, 112-120, 132-151	74 90 144	16 46 7	Gravel Gravel and clay do	272	14	11- 6-52	T, 10	225 120	120 70	Irr	29	L, FC, CA, WL, Temp 13 (56), H.
T. 11 S., R. 4 W.																			
1R2	Albany Creamery Assoc.	Dr	1922	540	4 3	200 500	--	206	--	Sandstone in shale	210	26	7-27-28	N	2-15e	--	U	--	FC; salty taste.
1R3	do	Dr	p1938	210	12	--	--	125	5	Shale with gravel	210	--	--	--	10e	--	--	--	L, FC.
23K1	Northwest Natural Gas Co.	Dr	1960	250	10	211	B	38	5	Gravel	205	--	--	--	--	--	--	--	L, FC; used as grounding bed.
T. 11 S., R. 1 E.																			
29D1	Lacomb Brengus Farm	Dr	1964	250	6	91	B	180	10	Shale, black	800	30	8-31-64	S, 1	7b	120	D	--	Li, FC, WL, Pp 1 hr.

Table 10.--Records of representative wells--Continued

Well number	Owner	Type of well	Year completed	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Water-bearing zone(s): Depth to top (feet)	Water-bearing zone(s): Thickness (feet)	Water-bearing zone(s): Character of material	Altitude (feet)	Water level: Feet below datum	Water level: Date	Type of pump and hp	Well performance: Yield (gal/min)	Well performance: Drawdown (feet)	Use	Acres irrigated	Remarks
T. 12 S., R. 1 W.																			
4P1	W. R. Gage	Dr	1965	148	6	20	B	35	78	Conglomerate, blue	440	12.77 19	4-13-66 6-27-65	N	8b	36	D	--	Li, FC, WL, Pp 1 hr, Temp 12 (54).
7P1	Reserve Oil & Gas Co.	Dr	1962	8,603	10	891	B	--	--	--	460	--	--	--	--	--	T	--	Lo, FC; "Esmond 1" TW.
11H1	Allan Todd	Dr	1965	92	6	35	B	70	20	Conglomerate, blue	490	27	10-25-65	S, ½	10b	18	D	--	Li, FC, CA, WL, Pp 1 hr, Temp 14 (57).
21J1	Gary Kieper	Dr	1964	150	6	98	B	97	53	Sandstone and clay	405	8	9-20-65	S, 1	16b	110	D	--	Li, FC, WL, Pp 1 hr.
29N1	Pineway Golf Course, Inc.	Dr	1957	201	8	131	P 80-120	100 136	4 15	Sand, soft Basalt, vesicular	410	8.56	5-12-66	C, 50	700	100	Irr	--	Li, FC, CA, SpA, WL, Pp 3½ hr, Temp 13 (55).
29P1	H. J. Griffiths	Dr	1958	60	6	54.7	P 21-24	21 37	3 23	Boulders, cemented Gravel, fine, and sand	410	5	9- 6-58	S, --	40b	40	Irr	--	Lo, FC, WL, Pp 5 hr.
30R1	Pineway Golf Course, Inc.	Dr	1957	442	8	75½	B	219	10	"Rock," red	435	16.11	6-14-66	N	15½	108	U	--	Li, FC, WL, Pp 1 hr.
T. 12 S., R. 2 W.																			
2C1	Kenneth Watters	Dr	1957	100	10	38	P 20-23, 30-37	20 25 81	5 11 19	Clay, brown, and gravel Gravel, blue Sand, black, and gravel	335	21.48	6-14-66	T, 5	300	22	Irr	--	L, FC, WL, Pp 3 hr, Temp 12 (54), H.
11N1	Mountain States Power Co.	Dr	1918±	115	6	85	--	85	30	Sand, coarse	340	5	8- 2-28	--, ¼	130	2	Inst	--	Lo, FC, CA, Temp 12 (54).
18C1	Henry DeManette	Dr	1958	175	10	92	B	86	21	"Rock, broken"	310	12	10- 2-58	T, 10	135	95	Irr	--	L, FC, CA, WL, Pp 24 hr, Temp 13 (56), H.
23B2	U.S. Plywood Corp.	Dr	1963	260	8	210	B	210 210	> 1 48	Bottom of blue clay, sand, and gravel Sandstone	360	30	9-23-63	--	1½b	All	U	--	L, FC; high salinity.

Table 10.--Records of representative wells--Continued

Well number	Owner	Type of well	Year completed	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Water-bearing zone(s): Depth to top (feet)	Water-bearing zone(s): Thickness (feet)	Water-bearing zone(s): Character of material	Altitude (feet)	Water level: Feet below datum	Water level: Date	Type of pump and hp	Well performance: Yield (gal/min)	Well performance: Drawdown (feet)	Use	Acres irrigated	Remarks
T. 12 S., R. 3 W.																			
7E1	City of Tangent	Dn	p1928	45	1¼	36 or 40	Screen at base	42	3	Gravel	245	10.75	8- 2-28	--	30e	--	PS	--	Li, FC, CA, Pp 6-7 hr; water is hard.
12A1	G. L. Jackson	Dr	1962	157	10	125½	B	128	7	Sand, black, and gravel	295	2	7- 2-62	--	720	70	Irr	--	L, FC, Pp 16 hr.
T. 13 S., R. 1 W.																			
3N1	Nylund Lumber Co.	Dr	1961	55	8	55	P 45-55	33 54	21 2	Gravel, loose Gravel and brown sand, loose	470	3	3-27-61	T, 2	40b	18	Ind	--	Li, FC, WL, Pp 1 hr.
T. 13 S., R. 1 E.																			
28R1	U.S. Forest Service	Dr	1963	205	10 8	35 46½	B	45 46½	1½ 158½	Sand and gravel Claystone, sandy	625	16 11	6-18-65 12-23-63	S, 2	15	All	Ind	--	Li, FC, CA, SpA, Pp 4 hr, Temp 11 (52).
35K1	Bobby Thedford	Dr	1963	122	6	23½	B	23½	98½	Sandstone	670	40.1	6-23-65	C, 1(?)	9b	75	D	--	Li, FC, CA, SpA, Pp 1 hr, Temp 13 (55).
T. 13 S., R. 2 E.																			
36Q1	U.S. Forest Service	Dr	1958	100	8	36	B	54	46	Tuff, lavender and green	795	7.5	3-19-58	--	32	82½	D	--	Li, FC, CA, SpA, Pp 8 hr, Temp 12 (53.5).

Table 11.--Drillers' logs of representative wells

Materials	Thickness (feet)	Depth (feet)
8/1W-28G1. Josephine Gerpacher. Alt 475 ft. Drilled by Robinson Drilling & Supply, 1960. Casing: 6-in. diam to 122 ft		
Sardine Formation:		
Clay, red, and soil	3	3
Tuff, decomposed, yellow	22	25
Tuffstone, gray	40	65
Tuff, brown to black, with wood fragments	10	75
Tuff, light-gray	25	100
Gravel, cemented in a green matrix	10	110
Gravel, cemented, with dark-green matrix	5	115
Gravel, cemented, with black matrix	7	122
Columbia River Basalt Group:		
Basalt	43	165
Clay, red-brown (weathered basalt?)	5	170
Basalt, vesicular, graduating to solid basalt	8	178
8/1W-30J1. Francis Hendricks. Alt 425 ft. Drilled by Robinson Drilling & Supply, 1960. Casing: 8-in. diam to 117 ft		
Soil	2	2
Terrace deposits(?):		
Clay, yellow	20	22
Gravel	1½	23½
Sardine Formation:		
Volcanic ash, weathered	31½	55
Volcanic ash, carboniferous	11	66
Basalt, andesitic, fresh	12	78
Volcanic ash, green	25	103
Volcanic ash, carboniferous	13	116
Basalt, andesitic, fresh	20	136
Columbia River Basalt Group:		
Clay, red	1	137
Basalt, gray, vesicular	33	170
Basalt, gray, fresh	74	244
Basalt, gray, vesicular	26	270
8/1W-34L1. Town of Sublimity. Alt 530 ft. Drilled by R. Stadeli & Sons, 1960. Casing: 10-in. diam to 191 ft		
Soil, brown	3	3
Sardine Formation:		
Clay, brown	27	30
Clay, gray	40	70
Clay, reddish-brown	6	76
Clay, light-gray	4	80
Shale, grayish-green, sticky	9	89
Rock, grayish-blue, medium-hard	56	145
Rock, gray, medium-hard, mixed with quartz and silica	3	148
Rock, gray, medium-hard, with quartz, silica, and decayed wood	21	169
Shale, light-gray, sandy, soft, sticky	3	172
Shale, gray, firm	2	174
Shale, gray, soft, sticky	8	182
Columbia River Basalt Group:		
Rock, black, hard	8	190
Rock, dark-gray, very hard	15	205
Rock, black, very hard	10	215
Rock, black, medium-hard	3	218
Shale, gray, soft	4	222
Rock, black, medium-hard, porous, water-bearing	29	251
Rock, black, hard	14	265
Shale, gray, medium-hard	10	275
Rock, dark-gray, very hard	37	312
Rock, black, very hard	5	317
9/1W-2R1. Etzel Bros. Alt 525 ft. Drilled by Miller-Robinson Well Drilling, 1962. Casing: 10-in. diam to 69 ft; unperforated		
Soil	2½	2½
Sardine Formation:		
Clay, orange	1½	4
Tuff, light-brown	16	20
Tuff, blue	6½	26½
Columbia River Basalt Group:		
Basalt, fresh, crevices	88½	115
Tuff and claystone	14	129
Basalt, fresh	1½	130½
9/1W-2R1.--Continued		
Columbia River Basalt Group:--Continued		
Sandstone, with wood and some leaf fossils; old land surface	5	135½
Basalt, fresh	4½	140
Basalt, fresh, very hard	32½	172½
Basalt, vesicular	1½	174
Basalt, fresh, hard	41	215
Basalt, vesicular	30	245
Claystone and siltstone, with wood fragments; old land surface	10	255
Basalt, vesicular	34½	289½
9/1W-4N1. Northwest Natural Gas Co. Alt 420 ft. Drilled by Hanson Drilling Co.(?), 1963. Casing: 10-in. diam to 20 ft; unperforated		
Older alluvium:		
Boulders and sand, water at 20-30 ft	30	30
Rock, gray, "broken"	15	45
Boulders and sand	92	137
Sardine Formation:		
Clay, gray	183	320
Sand, medium	15	335
Columbia River Basalt Group:		
Basalt, hard	27	362
9/1W-10C1. Regis High School. Alt 447 ft. Harry A. Robinson Well Drilling, 1964. Casing: 10-in. diam to 92 ft; perforated 45-70 ft		
Soil	2	2
Older alluvium:		
Gravel, cobbles, and boulders	100	102
Sardine Formation:		
Clay, light-brown	18	120
Clay, dark-brown	5	125
Clay, red cinder	35	160
Clay, gray-green	25	185
Siltstone	3	188
Columbia River Basalt Group:		
Rock, brown, hard	17	205
Rock, black, hard	45	250
9/1W-10M4. Stayton Canning Co. Coop. Alt 440 ft. Drilled by J. W. Beck Well Drilling, 1954. Casing: 12-in. diam to 319 ft; perforated 40-319 ft		
Younger alluvium:		
Soil	4½	4½
Gravel, loose	27½	32
Older alluvium:		
Gravel, cemented	287	319
Sardine Formation:		
"Rock"	12	331
Shale, brown	20	351
Shale, blue, hard and soft	129	480
Sand, green, with "quartz"	5	485
9/1W-11C1. Walter Miller. Alt 500 ft. Drilled by Miller-Robinson Well Drilling, 1965. Casing: 6-in. diam to 95 ft; unperforated		
Soil	2	2
Sardine Formation:		
Clay, brown	11	13
Clay, red	23	36
Clay, brown	10	46
Clay, orange	39	85
Columbia River Basalt Group:		
Rock, decomposed	7	92
Basalt, very hard	63	155
Rock, "honeycombed"	5	160
Claystone, blue	6	166
Rock, "honeycombed"	6	172
Basalt, very hard	85	257
Andesite, hard, "broken"	18	275

Table 11.--Drillers' logs of representative wells--Continued

9/1W-12B1. William Ripp. Alt 690 ft. Drilled by R. Stadeli & Sons, 1963. Casing: 6-in. diam to 343 ft; perforated 40-53 ft. Water level dropped from 140 ft to 226 ft during winter 1962

Materials	Thickness (feet)	Depth (feet)
Soil, red	5	5
Columbia River Basalt Group:		
Basalt, reddish-brown, weathered	43	48
Rock, light brown	3	51
Rock, light-brown, seamy, water-bearing	1	52
Rock, light-brown and gray	24	76
Rock, black, hard	26	102
Rock, black, hard, water-bearing	2	104
Rock, dark-gray, hard	6	110
Rock, black, medium-hard to hard	70	180
Rock, black, soft, water-bearing (26 gal/min)	1	181
Rock, black, hard to very hard	16	197
Rock, gray, very hard	8	205
Rock, black, hard	23	228
Basalt, gray, hard to medium-hard	32	260
Basalt, black, medium-hard to hard	108	368
Cavity (no change in water level; static level 135 ft)	2	370
Basalt, black	18	388
Basalt, black, very hard and abrasive (crevice at 408 ft; no change in water level)	35	423
Basalt, gray, hard	8	431
Basalt, gray, medium-hard, some water at 452 ft	21	452
Little Butte Volcanic Series:		
Claystone, gray, medium-hard	10	462
Claystone, brick-red, firm	23	485
No record, caving	15	500
Clay, brown, sticky (drove plug and rocks into hole and left a depth of 460 ft)	6	506

9/1W-14Q1. John Fery. Alt 550 ft. Drilled by Miller-Robinson Well Drilling, 1964. Casing: 10-in. diam to 19½ ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	2	2
Columbia River Basalt Group:		
Clay, orange	6	8
Boulders	2	10
Basalt, very hard	47	57
"Old land surface" (red clay)	3	60
Basalt, gray	18	78
Volcanic ash, blue, and "old land surface"	6½	84½
Basalt	15½	100
Basalt, angled fractures	80	180
Basalt, very hard	20	200
"Old land surface" (red clay)	5	205
Basalt, vesicular, "honeycombed"	10	215
Basalt, hard	9	224
Basalt, vesicular, "honeycombed"	3	227
Basalt, hard	5½	232½
Basalt, vesicular, "honeycombed"	1½	234
Basalt, hard	2	236
Basalt, vesicular, "honeycombed"	2	238
Basalt, hard	47	285
Basalt, "broken," very hard	30	315
Basalt, very hard, crevices on angle	11	326

9/1W-22E1. Reymond Frey. Alt 455 ft. Drilled by Miller-Robinson Well Drilling, 1966. Casing: 6-in. diam to 59 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Older alluvium:		
Clay, brown, with gravel	4	4
Gravel, brown, coarse, partly cemented, water-bearing	37	41
Sardine Formation:		
Claystone, gray	79	120
Columbia River Basalt Group:		
Basalt, black, with layers of hard claystone	10	130
Basalt, gray, very hard	15	145
Basalt, black, seamy	17	162

9/2W-5E1. A. S. Drager. Alt 301 ft. Drilled by Duffield Bros. Well Drilling, 1950. Casing: 8-in. diam to 94 ft; perforated at unknown depth

Materials	Thickness (feet)	Depth (feet)
"Dug hole"	9	9
Older alluvium:		
Gravel and sand, cemented	2	11
Gravel and sand, loose	7	18
Sand, "hard-packed," with occasional gravel	16	34
Gravel and sand, cemented	12	46
Clay, blue	8	54
Sand, loose, water-bearing	12	66
Gravel and sand, loose	3	69
Sand, loose, water-bearing	21	90
Gravel and sand, water-bearing	2	92
Sardine Formation:		
Clay, green	2	94
Sandstone, red	18	112
Sand, "hard-packed," water-bearing	8	120
"Hard formation"	1	121

9/2W-27A2. Schermacher. Alt 330 ft. Drilled by West Well Drilling, 1958. Casing: 10-in. diam to 200 ft; perforated 50-200 ft

Materials	Thickness (feet)	Depth (feet)
Soil and loose gravel	3	3
Older alluvium:		
Gravel, partly consolidated	18	21
Gravel, coarse, and sand, loose, water-bearing	9	30
Gravel, lightly cemented, water-bearing	15	45
Clay, brown	3	48
Clay and gravel	2	50
Sand and gravel, loose, water-bearing	6	56
Gravel, cemented	4	60
Sand and gravel, loose, water-bearing	5	65
Gravel, cemented	17	82
Gravel, coarse, loose	6	88
Gravel, partly cemented	6	94
Clay, blue	3	97
Clay, blue, and cemented gravel	7	104
Gravel, cemented, with some loose layers, water-bearing	32	136
Clay, brown, sandy	8	144
Gravel, cemented, with clay layers	39	183
Gravel and sand, brown, mostly unconsolidated; strips of sandy clay of various colors; mineral stain; water-bearing	32	215
Gravel, rusty, rough, with clinging particles of clay and shale, water-bearing	7	222
Sardine Formation:		
"Volcanics"	133	355
Columbia River Basalt Group:		
Basalt, "broken"	30	385
Basalt, with some large fractures	110	495
Andesite, may be partly tuffaceous	235	730
Marine sedimentary rocks:		
Shale, blue, soft	8	738
Shale	44	782
Shale and interbedded sand	78	860
Shale, hard	205	1,065
Shale	184	1,249
Sand, black	20	1,269
Shale, silty	761	2,030
Shale, chalky, with a few thin sand interbeds	50	2,080
Shale, silty	339	2,419
Sandstone, fine, silty	7	2,426

9/3W-34J1. Posel. Alt 210 ft. Drilled by Burr Rambo Well Drilling, 1961. Casing: 8-in. diam to 72 ft; perforated 66-70 ft

Materials	Thickness (feet)	Depth (feet)
Older alluvium:		
Clay, yellow	30	30
Clay, blue	14	44
Sand, blue	4	48
Clay, blue	12	60
Clay, yellow	8	68
Marine sedimentary rocks:		
Shale, blue	222	290
Rock, blue	108	398

Table 11.--Drillers' logs of representative wells--Continued

10/1W-5L1. A. M. Hendrickson. Alt 400 ft. Drilled by J. S. Studebaker, 1951. Casing: 10-in. diam to 110 ft; perforated 0-110 ft

Materials	Thickness (feet)	Depth (feet)
Soil	4	4
Sardine Formation:		
Shale, harder with depth	106	110
Columbia River Basalt Group:		
Rock, gravel in rock, water-bearing at 147 and 218 ft	115	225

10/2W-21R1. H. C. Robertson. Alt 262 ft. Drilled by Harry A. Robinson Well Drilling, 1960. Casing: 8-in. diam to 60 ft; perforated 25-59 ft

Materials	Thickness (feet)	Depth (feet)
Clay, "heavy"	4	4
Older alluvium:		
Clay, sand, with some gravel	4	8
Sand, cemented, and coarse gravel	24	32
Sand and gravel, loose, water-bearing	2	34
Gravel, cemented, with layers of tan clay	7	41
Gravel, partly cemented, with layers of clean gravel	7	48
Clay	7	55
Sand and gravel, unconsolidated	4	59
Clay, blue, with sandy layers	35	94

10/2W-30N1. Zelma Bond. Alt 230 ft. Drilled by Merle Warren Well Drilling, 1965. Casing: 10-in. diam to 52 ft; perforated 39-52 ft

Materials	Thickness (feet)	Depth (feet)
Soil	3	3
Older alluvium:		
Clay	11	14
Clay and gravel	11	25
Gravel	10	35
Clay, blue, and gravel	10	45
Sand and gravel, black	6	51
Clay, blue, and gravel	1	52
Clay, blue	30	82
Clay, brown	9	91
Clay, blue	49	140

10/3W-2B1. Lewis Earll. Alt 226 ft. Drilled by Pete Tolmasoff Well Drilling, 1964. Casing: 6-in. diam to 208 ft; perforated 29-30 ft

Materials	Thickness (feet)	Depth (feet)
Soil	3	3
Older alluvium:		
Cobbles, small, and clay	9	12
Clay, brown, soft	11	23
Sandstone, brown, firm, water-bearing	7	30
Clay, blue, soft	135	165
Marine sedimentary rocks:		
Shale, brown	5	170
Shale, blue, firm layers	50	220
Shale, brown, firm, water-bearing	5	225
Shale, gray, firm to hard	55	280

10/3W-7N2. Gordon Hoefer. Alt 180 ft. Drilled by Crispin Well Drilling, 1967. Casing: 10-in. diam to 40 ft; perforated 28-40 ft

Materials	Thickness (feet)	Depth (feet)
Soil	2	2
Alluvium (undifferentiated):		
Clay, yellow	6	8
Clay, brown, with gravel	14	22
Sand and gravel	7	29
Gravel, coarse, water-bearing	10	39
Clay, blue, no water	91	130

10/3W-12N3. Town of Jefferson. Alt 227 ft. Drilled (driller unknown), 1951. Casing: 8-in. diam to unknown depth; perforated 24-30 ft

Materials	Thickness (feet)	Depth (feet)
Younger alluvium:		
Sand and gravel	33	33
Marine sedimentary rocks:		
Shale, soft	32	65
Rock, hard, sedimentary (sandstone?)	55	120
Shale, hard	4	124

10/3W-19K1. Lester Conser. Alt 199 ft. Drilled by C. E. Gardenier prior to 1929. Casing: Casing pulled; well abandoned

Materials	Thickness (feet)	Depth (feet)
Soil	3	3
Older alluvium:		
Clay, yellow	22	25
Gravel	7	32
Clay, blue	8	40
"Sandrock" (sandy clay?), blue	50	90
Marine sedimentary rocks:		
Sandstone, porous, water-bearing, salty	1	91
Sandstone, blue	69	160
Water-bearing, very saline	--	--

10/3W-21Q1. Engineering Management, Inc. Alt 235 ft. Drilled by Merle Warren Well Drilling, 1962. Casing: 6-in. diam to 154 ft; perforated 17-26 ft, 144-154 ft

Materials	Thickness (feet)	Depth (feet)
Soil	3	3
Terrace deposits:		
Clay	14	17
Gravel	9	26
Clay, blue	41	67
Clay, brown	8	75
Clay, yellow	10	85
Sand, gray	40	125
Marine sedimentary rocks:		
Clay, brown	50	175
Sandstone, gray	1	176
Clay, brown	15	191
Clay, hard	3	194
Sandstone	3	197
Clay, brown	9	206
Sandstone, gray	4	210
Clay, brown	40	250

10/3W-28K1. Tidewater Oil Co. Alt 245 ft. Bored by Andy M. Jannsen Well Drilling, 1959. Casing: 6-in. diam to 24 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Clay, dry	24	24
Terrace deposits:		
Clay, blue, wet	4	28
Clay, blue	23	51
"Hardpan"	9	60
Clay, blue	15	75
Clay, blue, and sand	10	85
Marine sedimentary rocks(?):		
"Rock" (shale?), sandy	1	86

10/3W-28Q1. Shell Oil Co. Alt 225 ft. Drilled by Robinson Drilling & Supply, 1959. Casing: 6-in. diam to 185 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Terrace deposits:		
Clay, yellow and light-brown	10	10
Clay, orange and light-brown	20	30
Clay, dark-brown, with wood fragments and leaves	2	32
Clay, blue and dark-gray	38	70
Marine sedimentary rocks:		
Sandstone, light-blue, soft, water-bearing at 100 ft (2½ gal/min)	75	145
Clay, black, with wood fragments	25	170
Clay, brown	8	178
Clay, gray	7	185

Table 11.--Drillers' logs of representative wells--Continued

Materials	Thick-ness (feet)	Depth (feet)
10/3W-33K2. C. Bean. Alt 210 ft. Drilled by Merle Warren Well Drilling, 1963. Casing: 6-in. diam to 77 ft; perforated 70-77 ft		
Soil	3	3
Older alluvium:		
Clay	7	10
Gravel	32	42
Clay, sandy	18	60
Clay, blue	17	77
Sand, brown, and gravel	8	85
Marine sedimentary rocks(?):		
Sandstone	5	90
11/2W-5P1. George Dwyer. Alt 260 ft. Drilled by Pyle & Salisbury, 1966. Casing: 8-in. diam to 99½ ft; unperforated		
Soil	5	5
Older alluvium:		
Gravel, cemented	23	28
Send and gravel	4	32
Sand and clay, brown	3	35
Sand and gravel, brown	13	48
Sand and gravel, blue	4	52
Sand and gravel, black	53	105
"Limestone"	13	118
Mud seam, blue	4	122
"Limestone"	4	126
11/2W-9E1. Arvid Backman. Alt 265 ft. Drilled by West Well Drilling, 1957. Casing: 10-in. diam to 108 ft; perforated 50-70 ft, 92-108 ft		
Younger alluvium:		
Sand and gravel, unconsolidated, rusty, and containing much silt	25	25
Grevel, cemented, with layers of tan clay	11	36
Sand and gravel, unconsolidated, rusty, and silty	4	40
Older alluvium:		
Gravel, tan, cemented	2	42
Clay, blue	3	45
Sand and gravel, black, lightly cemented with blue clay, water-bearing	21	66
Clay, blue	2	68
Gravel, cemented with blue clay	3	71
Clay, blue	23	94
Sand and gravel, black, unconsolidated, water-bearing	3	97
Sand, black, cemented with blue clay	7	104
Send and gravel, black, unconsolidated, weter-bearing	3	107
Cley, brown	13	120
11/2W-29H1. Neal Hollingsworth. Alt 290 ft. Drilled by Art Clinton Well Drilling Co., 1959. Caaing: 8-in. diam to 93 ft; perforated 50-87 ft		
Soil	2	2
Older alluvium:		
Clay, brown	6	8
Boulders	32	40
Grevel and clay	50	90
Clay, blue	55	145
11/3W-5J2. D. E. Nebergall Meat Co. Alt 200 ft. Drilled (driller unknown), 1936. Casing: 8-in. diam to 96 ft; perforated 78-96 ft		
Older alluvium:		
Cley	10	10
Clay and grevel	32	42
Sand and gravel	28	70
Shale	16	86
Sand, bleck	10	96

Materials	Thick-ness (feet)	Depth (feet)
11/3W-13A1. L. A. Nelson. Alt 255 ft. Drilled (driller unknown), 1953. Casing: 6-in. diam to 92 ft; perforeted 83-92 ft		
Soil	2	2
Older alluvium:		
Clay	6	8
Clay and gravel	16	24
Sand and gravel	2	26
Clay and shale	24	50
Clay, sandy	10	60
Clay and gravel	10	70
Sand and gravel	16	86
"Sandrock" (sandy shale?)	6½	92½
11/3W-26A1. Leonard Roth. Alt 272 ft. Drilled (driller unknown), 1952. Casing: 8-in. diam to 151 ft; perforated 74-90 ft, 112-120 ft, 132-151 ft		
Older alluvium:		
Clay, light-colored	11	11
Clay and gravel, light-colored	31	42
Sand and clay	15	57
Clay, dark	17	74
Gravel, dark	16	90
Clay and gravel, dark	46	136
Sand and clay, dark	8	144
Gravel and clay, dark	7	151
11/4W-1R3. Albany Creamery Assoc. Alt 210 ft. Drilled by A. M. Jannsen Drilling Co., prior to 1938. Casing: 12-in. diam to unknown depth; unknown finish		
Younger alluvium:		
Soil and clay	5	5
Sand, dry	18	23
Marine sedimentary rocks:		
Shale	102	125
Shale and a little gravel	5	130
Shale	80	210
12/2W-2C1. Kenneth Watters. Alt 335 ft. Drilled by Ace Drilling Co., 1957. Casing: 10-in. diam to 38 ft; perforated 20-23 ft, 30-37 ft		
Alluvium (undifferentiated):		
Soil and clay, sandy	11	11
Clay, brown, and gravel	14	25
Gravel, blue	11	36
Clay, dark-brown, and gravel	2	38
Clay, derk-brown	32	70
Clay, blue	11	81
Sand and gravel, black	19	100
12/2W-18C1. Henry DeManette. Alt 310 ft. Drilled by W. E. Pyle Drilling Co., 1958. Casing: 10-in. diem to 92 ft; unperforated		
Older alluvium:		
Soil, sand, and clay	20	20
Gravel and clay	22	42
Shale, blue, and gravel	40	82
Sand and muck, water-beering	4	86
Marine sedimentary rocks:		
Rock, "broken," water-bearing	21	107
"Soapstone"	17	124
Shale, green	25	149
Rock, blue	26	175

Table 11.--Drillers' logs of representative wells--Continued

Materials	Thick-ness (feet)	Depth (feet)
12/2W-23B2. U.S. Plywood Corp. Alt 360 ft. Drilled by Willamette Irrigation & Equipment Co., 1963. Casing: 8-in. diam to 210 ft; unperforated; unused because of salinity		
Soil	15	15
Alluvium (undifferentiated):		
Sand, large boulders, and yellow clay	115	130
Sand and gravel	6	136
Clay, blue, and sand and gravel	74	210
Marine sedimentary rocks:		
Sandstone, hard	48	258
Lava	2	260

Materials	Thick-ness (feet)	Depth (feet)
12/3W-12A1. G. L. Jackson. Alt 295 ft. Drilled by Pyle & Salisbury, 1962. Casing: 10-in. diam to 125½ ft; unperforated		
Soil	5	5
Older alluvium:		
Sand and gravel, cemented	20	25
Clay, brown, and large boulders	20	45
Clay, brown, and gravel, water-bearing (55 gal/min)	10	55
Marine(?) sedimentary rocks:		
Rock, blue, "broken"	20	75
Sand and gravel, brown, water-bearing (15 gal/min)	6	81
"Lime," black, "broken"	24	105
Sand, black, water-bearing	23	128
Sand and gravel, black, and brown mud, water-bearing	7	135
"Lime," black	22	157

Table 12.--Chemical analyses of water from ground- and surface-water sources

[Analyses by the U.S. Geological Survey, Portland, Oreg., unless otherwise noted]

Location number[2]	Source[3]	Depth of water-bearing zone(s) (feet)	Date of collection	Temperature (°C)	Temperature (°F)	Milligrams per liter[1]: Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Arsenic (As)	Dissolved solids: Calculated	Dissolved solids: Residue on evaporation at 180°C	Hardness: As $CaCO_3$	Hardness: Noncarbonate	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos/cm at 25°C)	pH	Color	Remarks[4]
7/3W-22Lr[5]	WR	--	11-27-50	9	48.5	17	--	--	4.0	2.1	[6]5.1	--	24	0	4.1	3.8	--	0.6	--	--	--	--	--	19	0	0.5	48	--	--	
8/1W-34L1	Tcr	182-317	4-10-61	--	--	41.5	0.42	<0.05	8.8	8.8	12	2.0	66	0	13.4	5.8	0.3	<.05	0.42	--	--	125	119	58	--	.7	136	7.3	2	OBR.
Do	Tcr	182-317	6- 5-62	13	56	41	1.1	--	10	4.4	14	1.6	80	0	4.2	3.5	.4	.0	.45	0.04	--	120	--	43	0	.9	143	7.8	--	
8/2W-28A1	Tcr and Tm	160-205	6- 8-62	14	57	44	.07	--	12	1.5	44	.6	126	0	23	3.8	.1	.0	.10	.00	--	191	--	36	0	3.2	253	7.5	--	
9/1W-2R1	Tcr	77-289	5-25-66	14	57	48	1.6	--	8.6	4.5	12	1.9	70	0	4.2	5.0	.2	.1	.42	.01	0.00	121	--	40	0	.0	135	7.2	5	
9/1W-13D1, 2, 3	Qyal	12-25	6-14-51	18	64	17	.03	--	4.9	1.1	3.2	2.6	31	0	1.7	1.0	.0	.1	--	--	--	47	45	17	0	.3	54.4	7.3	5	I.
9/1W-14Q1	Tcr	57-326	6-23-66	13	56	45	.48	--	5.7	3.6	9.9	1.3	60	0	2.8	1.0	.1	.1	.50	.03	.00	101	--	29	0	.9	102	7.5	5	
9/1W-15B1	Qyal	18	1-20-55	--	--	20	<.05	0	7.6	3.4	3.2	.5	27	0	1.7	2.8	.0	--	.05	--	--	56	63	25	--	.2	34	7.2	3	ORH, I.
9/1W-29R1	Qt	48-49	5-20-66	12	53	20	.22	--	2.7	1.2	2.5	1.0	12	0	.0	1.8	.1	7.5	.08	.04	.00	43	--	12	2	.3	41	6.2	5	
9/2W-24L3	Qoal	15-140	6-23-66	11	52	26	.75	--	10	4.3	5.7	.8	46	0	2.4	4.0	.1	12	.12	.00	.00	89	--	43	6	.4	117	7.1	5	
9/3W-8C1	Qoal	41-68	6-17-66	13	55	31	.05	--	32	10	17	2.0	194	0	.0	3.5	.3	.1	3.5	.00	.00	194	--	121	0	.7	290	7.9	5	
9/3W-18D1	Qyal	15-33.5	6-24-66	12	54	46	.01	--	23	12	19	1.1	86	0	18	10	.2	52	.45	.02	.00	224	--	105	34	.8	303	7.3	0	
9/3W-30L3	Qyal	16-30	5-19-66	11	51	36	.16	--	20	9.6	7.8	.6	80	0	13	3.5	.1	30	.08	.01	.00	160	--	90	24	.4	224	6.4	0	
9/3W-34K4	Qyal	12-22	6-24-66	12	54	24	.01	--	17	6.6	7.7	.8	62	0	8.0	6.5	.0	21	.04	.05	.00	123	--	70	18	.4	183	6.6	5	
9/1-25E1	Ts and Tcr	220-240	5-25-66	12	53	36	.32	--	18	5.5	21	3.2	136	0	5.4	1.2	.1	.3	.05	.00	.00	158	--	68	0	1.3	224	7.4	5	
9/2-18Er	NSR	--	3-13-51	--	--	--	--	--	--	--	--	--	19	0	2.8	2.5	--	--	--	--	--	--	--	11	0	--	41	7.1	--	
Do	NSR	--	1-14-59	6	42	9.6	--	--	3.0	.3	1.6	.1	14	0	1.1	.8	.1	.1	--	--	--	24	22	9	0	.2	24	6.9	5	
Do	NSR	--	5-12-59	9	49	11	--	--	3.5	.4	1.5	.3	16	0	1.4	.5	.2	.2	--	--	--	27	27	10	0	.2	30	6.6	5	
Do	NSR	--	9- 4-59	11	52	16	--	--	4.0	.7	2.1	.6	22	0	1.2	.5	.1	.0	--	--	--	36	32	13	0	.3	38	7.3	0	
10/1W-4J1	Tcr	90-102, 110-112, 124-137	5-25-66	12	54	23	.01	--	4.9	3.0	7.8	1.0	25	0	1.2	10	.1	8.8	.13	.00	.00	72	--	24	4	.7	96	6.8	5	
10/2W-1B1	Qoal	25-35	6-27-66	12	54	38	.01	--	9.3	4.7	7.9	2.1	72	0	.0	2.5	.1	.2	.49	.05	.00	100	--	42	0	.5	123	7.1	5	
10/2W-8N2	Qyal	17-21	5-18-66	10	50	20	.01	--	7.4	2.5	3.3	.4	32	0	3.8	1.5	.0	4.3	.14	.01	.00	59	--	29	3	.3	76	6.6	5	

See footnotes at end of table.

Table 12.--Chemical analyses of water from ground- and surface-water sources--Continued

Location number[2/]	Source[3/]	Depth of water-bearing zone(s) (feet)	Date of collection	Temperature (°C)	Temperature (°F)	Milligrams per liter[1/]: Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Arsenic (As)	Dissolved solids: Calculated	Dissolved solids: Residue on evaporation at 180°C	Hardness: As $CaCO_3$	Hardness: Noncarbonate	Sodium-adsorption ratio (SAR)	Specific conductance (micromhos/cm at 25°C)	pH	Color	Remarks[4/]
10/2W-19Q2	Qyal	19-22	6-24-66	11	52	24	0.04	--	21	7.2	7.0	0.9	62	0	18	5.5	0.1	23	0.03	0.09	0.00	138	--	82	31	0.3	210	6.6	5	
10/3W-5K4	Qyal	19-25	6-23-66	--	--	22	.14	--	12	3.4	4.2	.7	46	0	7.8	1.8	.1	6.4	.05	.00	.00	82	--	44	6	.3	110	6.5	0	
10/3W-11Jr	SR	--	11-27-50	8	47	13	--	--	--	--	--	--	24	0	2.3	3.5	--	.4	--	--	--	--	--	16	0	--	35.6	--	--	
Do	SR	--	2-20-51	6	42	16	--	--	--	--	6/4.2	--	24	0	2.5	1.8	--	.5	--	--	--	--	--	16	0	.2	40.8	--	--	
Do	SR	--	4-21-60	7	45	12	--	--	4.0	.2	1.8	.4	18	0	1.0	.5	.0	.2	--	--	--	29	33	11	0	.2	36	7.1	10	
Do	SR	--	6-15-60	14	57	13	--	--	4.0	.8	2.3	.5	22	0	1.2	1.0	.0	.1	--	--	--	34	37	13	0	.3	39	7.2	5	
Do	SR	--	8-16-60	15	59	14	--	--	4.0	2.3	2.5	.5	23	0	3.2	.5	.0	.2	--	--	--	38	38	20	0	.2	48	7.2	5	
10/3W-13F1	Qyal	8-21	6-17-66	11	52	22	.01	--	13	4.2	4.6	.8	47	0	10	2.0	.1	11	.05	.05	.00	91	--	50	12	.3	124	6.9	5	
10/3W-15M1	Tm	240-245	5-19-66	12	54	36	.02	--	24	13	11	1.1	153	0	6.2	5.0	.2	.1	.14	.00	.00	170	--	114	0	.1	260	7.5	0	
10/3W-15P1	Tm	51-70	5-25-66	13	55	35	13	--	2.9	2.1	7.9	1.1	16	0	.8	11	.1	1.4	1.2	.02	.00	72	--	16	3	1	74	5.3	50	
10/3W-20K1	Qt	105-150	6-17-66	13	56	37	.79	--	13	7.7	10	1.3	80	0	14	7.0	.2	.0	.05	.05	.00	129	--	64	0	.5	171	6.9	15	
10/3W-35Qe	Ti	--	5-20-66	13	56	14	.01	--	2	1.1	2.4	.1	12	0	0	2.5	.0	1.9	.03	.00	.00	30	--	10	0	.3	33	5.8	0	
10/3W-36C1	Qoal	26-50	5-25-66	13	55	32	.44	--	38	15	37	2.4	288	0	0	4.0	.4	.6	1.6	.00	.00	273	--	156	0	1.3	445	7.3	5	
10/4W-11A1	Qyal	12-32	6-23-66	12	53	30	.01	--	27	7.9	18	.8	74	0	19	28	.2	19	.14	.00	.00	186	--	100	40	.6	294	6.6	0	
10/4W-14Jr	WR	--	4-27-61	--	--	17	.14	0.0	5.5	1.5	3.4	.3	30	--	.2	1.8	.1	.1	--	--	--	--	50	20	0	.3	55	7.4	--	
10/1-9L2	Tlb	53, 158, 210	6-24-65	12	54	28	.48	--	4.8	1.4	8.8	1.3	40	0	3.2	1.8	.1	.5	.11	.00	.00	70	82	18	0	.9	79	6.4	0	SpA.
11/1W-25C1	Qt	50-54	5-24-66	12	54	26	.01	--	8.3	3.8	5.1	1.0	24	0	0	9.2	.1	19	.10	.05	.00	85	--	36	16	.4	110	5.9	0	
11/2W-3D1	Qyal	38-107	6-23-66	11	52	28	.03	--	19	6.9	15	.5	108	0	6.2	5.5	.1	5.5	.38	.02	.00	140	--	76	0	.7	214	6.8	0	
11/2W-6B1	Qoal	70-74	6-17-66	13	56	28	.83	--	13	6.5	37	1.9	122	0	1.2	27	.1	3.5	1.9	.26	.00	180	--	59	0	2.1	278	7.5	5	
11/2W-22H1	Qyal	14-21	5-24-66	11	52	26	.06	--	19	6.6	5.7	.5	74	0	14	3.7	.1	9.9	.13	.00	.00	121	--	74	14	.3	180	6.4	0	
11/2W-24B1	Qoal	Above 73	10-12-28	12	54	25	.93	--	7.1	3.5	38	2.2	132	0	3.0	5.5	--	1.0	--	--	--	150	150	32	--	2.8	--	--	--	
11/3W-4C1	Qyal	33-41	do	--	--	38	.05	--	12	6.9	5.7	1.6	71	0	4.4	2.4	--	6.7	--	--	--	113	116	58	--	.3	--	--	--	
11/3W-4G1	Qyal	57.5-59	5-24-66	14	57	42	.08	--	7.4	4.6	17	1.2	84	0	1.0	2.5	.1	.8	1.7	.02	.00	119	--	38	--	1.2	143	7.5	5	
11/3W-6Hr	WR	--	11-27-50	9	48	18	--	--	4.2	1.8	6/7.4	--	29	0	4.9	3.2	--	.8	--	--	--	55	--	18	0	.8	51.6	--	--	

See footnotes at end of table.

Table 12.--Chemical analyses of water from ground- and surface-water sources--Continued

Location number[2/]	Source[3/]	Depth of water-bearing zone(s) (feet)	Date of col-lection	Temper-ature (°C)	Temper-ature (°F)	Milligrams per liter[1/]: Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Arsenic (As)	Dissolved solids: Calculated	Dissolved solids: Residue on evaporation at 180°C	Hardness: As $CaCO_3$	Hardness: Noncarbonate	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos/cm at 25°C)	pH	Color	Remarks[4/]
11/3W-6Nr	WR	--	2-20-51	7	44	19	--	--	--	--	[6/]5.1	--	30	0	3.5	2.3	--	0.8	--	--	--	--	--	21	0	--	51.1	--	--	
Do	WR	--	6- 8-52	--	--	16	--	--	--	--		--	30	0	--	--	0.2	--	--	--	--	--	--	17	0	--	46.8	--	--	
11/3W-13A1	Qoal	70-92	6-23-66	13	55	23	0.05	--	12	4.6	16	0.7	98	0	.2	2	.1	.3	0.43	0.01	0.00	85	--	49	0	1	158	7.7	5	
11/3W-17F2	Qoal	29-66	6-17-66	13	56	33	.37	--	33	17	14	1.0	213	0	1.4	4.5	.3	.2	.81	.11	.00	210	--	152	0	.5	330	7.8	5	
11/3W-26A1	Qoal	74-90, 144-151	do	13	56	30	.77	--	23	13	15	1.0	162	0	.6	6.0	.1	2.3	.35	.00	.00	172	--	111	0	.6	260	8.0	10	
12/1W-11H1	Tlb	70-90	do	14	57	23	.26	--	39	11	84	1.4	390	0	4.6	5.5	.2	.1	.20	.47	.08	362	--	142	0	3.1	580	8.2	5	
12/1W-28Er	SSR	--	2-20-51	--	--	14	--	--	--	--	[6/]4.4	--	22	0	3.0	1.6	--	.2	--	--	--	--	--	14	0	--	35.8	--	--	
12/1W-29H1	Tlb(?)	100-104, 136-151	6-24-65	13	55	60	3.6	--	10	6.8	51	2.4	154	0	2.0	26	.1	.2	.93	.65	.07	240	256	53	0	3.1	329	6.8	5	SpA.
12/2W-11N1	Qoal	85-115	10-12-28	12	54	36	.03	--	12	5.1	6.3	1.4	74	0	3.5	2.0	--	.25	--	--	--	103	98	51	0	.4	--	--	--	
12/2W-11R1	Qoal	--	4-14-58	13	56	38	.03	0.10	9.6	1.9	27	1.0	96	0	4.1	6.0	0	0	.24	--	--	135	139	32	0	2.1	169	8.2	0	SpA.
12/2W-18C1	Ts(?)	86-107	6-27-66	13	56	27	.02	--	11	5.0	23	1.0	98	0	1.6	9.5	.2	1.8	.52	.08	.00	129	--	48	0	1.4	189	7.9	5	
12/3W-7E1	Qoal	42-45	4-18-29	11	51	35	.08	--	31	18	14	1.1	193	0	2.1	13	--	3.8	--	--	--	213	204	151	--	.5	--	--	--	
13/1-28R1	Qoal and Tlb	45-205	6-18-65	13	56	31	.03	--	6.8	1.9	8.8	.4	49	0	.2	1.8	.1	3.3	.59	.01	.00	79	91	25	0	.8	88	7.6	0	SpA.
13/1-35K1	Qyal and Tlb	23½-122	6-23-65	13	55	20	.01	--	13	.8	36	.3	132	0	1.4	3.2	.0	.0	.60	.09	.01	140	135	36	0	1.9	213	8.2	0	Do.
13/2-15Cr	MSR	--	8-18-64	17	62	11	.53	--	5.0	1.5	2.8	.5	27	0	3.0	.5	.1	.2	.02	--	--	--	33	19	0	.3	52	7.4	5	
13/2-36Q1	Ts	46-100	3-18-58	11	52	35	.60	.01	46	9	200	2.1	414	0	25	164	.2	.3	--	1.1	--	683	--	152	0	7.1	1,170	6.9	0	
Do	Ts	46-100	6-23-65	12	54	34	1.6	--	80	17	257	2.6	443	0	43	300	.1	.0	.13	2.39	.12	956	965	270	0	6.4	1,670	7.0	5	SpA.

1/ < indicates less than amount shown.
2/ Location number is the same as the well number. See page 57 for description of the well-numbering system. The letter "s" indicates source is a spring; "r" indicates source is a river.
3/ Stream--WR, Willamette River; SR, Santiam River; NSR, North Santiam River; SSR, South Santiam River; MSR, Middle Santiam River. Aquifer--Qyal, younger alluvium; Qoal, older alluvium; Qt, terrace deposits; Ts, Sardine Formation; Tcr, Columbia River Basalt Group; Tlb, Little Butte Volcanic Series; Tm, marine sedimentary rocks; Ti, intrusive rocks.
4/ OBH, sample analyzed by the Oregon State Board of Health; I, infiltration trench; SpA, spectrographic analysis included in table 13.
5/ Ten miles north of the Santiam River basin area.
6/ Includes potassium.

Table 13.--Spectrographic analyses of water from wells

[Analyses by the U.S. Geological Survey, Portland, Oreg., unless noted otherwise]

Location number[2/]	Source[3/]	Micrograms per liter[1/]																		Micromicrocuries per liter[1/]	
		Aluminum (Al)	Beryllium (Be)	Bismuth (Bi)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Gallium (Ga)	Germanium (Ge)	Iron (Fe)	Lead (Pb)	Manganese (Mn)	Molybdenum (Mo)	Nickel (Ni)	Titanium (Ti)	Uranium (U)	Vanadium (V)	Zinc (Zn)	Beta-gamma activity	Radium (Ra)
10/1-9L2	Tlb	13	<0.57	<0.29	< 1.4	< 1.4	< 1.4	34	< 5.7	< 0.29	40	< 1.4	13	1.4	0.51	1.4	--	1.4	429	--	--
12/1W-29N1	do	7.4	< .57	< .29	< 1.4	< 1.4	< 1.4	< 1.4	< 5.7	< .29	6.9	< 1.4	4.9	≤ .29	≥.29	< .57	--	.69	< 5.7	--	--
12/2W-11R1	Qoel	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.3±0.1	--	--	< 7	<0.1
13/1-28R1	Qoel and Tlb	5.7	< .57	< .29	< 1.4	< 1.4	< 1.4	< 1.4	< 5.7	< .29	3.7	< 1.4	< 1.4	< .29	.37	< .57	--	12	> 1,000	--	--
13/1-35K1	Qyel and Tlb	<1.4	< .57	< .29	< 1.4	< 1.4	< 1.4	< 1.4	< 5.7	< .29	>1,000	< 1.4	< 1.4	≤ .29	≤ .29	34	--	< .29	< 5.7	--	--
13/2-36Q1[4/]	Ts	8.3	< .57	< .29	< 1.4	< 1.4	< 1.4	< 1.4	< 5.7	≤ .29	1.2	< 1.4	> 1,000	≤ .29	≥.29	< .57	--	.89	< 5.7	--	--

1/ > more than amount indicated, ≥ more than or equal to amount indicated. < less than amount indicated, ≤ less than or equal to amount indicated.

2/ See page 57 for a description of the well-numbering system.

3/ See footnote 3 for table 12.

4/ Well is 6 miles east of study area; however, because of the interesting chemical characteristics of its water, a spectrographic analysis is included in this table.