Geology and Ground-Water Resources of the Upper Grande Ronde River Basin Union County, Oregon

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By E. R. Hampton and S. G. Brown

ABSTRACT

The upper Grande Ronde River basin is a 1,400-square-mile area in northeastern Oregon, between the Blue Mountains to the west and the Wallowa Mountains to the east. The area is drained by the Grande Ronde River, which flows northeast through this region and is tributary to the Snake River.

The climate is generally moderate; temperature extremes recorded at La Grande are 22°F. below zero and 108°F. above. The average annual precipitation ranges from 13 to 20 inches in the Grande Ronde Valley to more than 35 inches in the mountain highlands surrounding the valley.

The topography of the area is strongly controlled by the geologic structures, principally those related to block faulting. The terrain ranges from the nearly flat floors of the Grande Ronde and Indian Valleys, whose elevations are 2,600 to about 2,750 feet, to the mountainous uplands, whose average elevations are about 5,000 feet and which have local prominences exceeding 6,500 feet.

The rocks in the upper Grande Ronde River basin, from oldest to youngest, are metamorphic rocks of pre-Tertiary age; igneous masses of diorite and granodiorite that intruded the metamorphic rocks; tuff-breccia, welded and silicified tuff, and andesite and dacite flows, of Tertiary age; the Columbia River basalt of Miocene and possibly early Pliocene age; fanglomerate and lacustrine deposits of Pliocene and Pleistocene age; and younger deposits of alluvium, colluvium, and welded tuff.

In the graben known as the Grande Ronde Valley, which is the principal populated district in the area, the valley fill deposits are as thick as 2,000 feet. The valley is bordered by the scarps of faults, the largest of which have displacements of more than 4,000 feet.

Most of the wells in the area obtain small to moderate supplies of water from unconfined aquifers in the valley fill and alluvial fan deposits. Moderate to large quantities of water are obtained from aquifers carrying artesian water in the fan alluvium and the Columbia River basalt. The available supplies of ground water greatly exceed the relatively small amounts that are being used, and the natural supplies are adequate for foreseeable domestic, industrial, irrigation, and municipal requirements. Yields of future wells probably could be improved appreciably over those of present wells by exercising close attention to subsurface conditions during construction, and by greater use of well screens, gravel envelopes, and well-development techniques.

The chemical quality of the ground water in general is excellent. All waters sampled are potable and are within the desired ranges of hardness and salinity for most public, industrial, and irrigation uses. The average temperature of shallow ground water drawn from the alluvial fill was 3°F. above the mean annual air temperature. That of water obtained from the basalt is 6°F. above the temperatures computed from the "normal" gradient of 1.8°F. per 100 feet of increased depth.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

This report combines hydrologic information gathered under the federally financed program of the Geological Survey with the geologic information collected as a part of the continuing program in cooperation with the office of the Oregon State Engineer. The work was planned to derive the basic facts about the occurrence of ground water as they relate to irrigation, drainage, flood control, and water supply for various uses.

The investigation comprised an inventory of representative wells and springs, regular measurement of depth to water in observation wells, collection of well logs, chemical analysis of surface- and ground-water samples, a geologic study and mapping of the geology of the area, and the coordination of these data into this report. Base maps used for the project were those of the U.S. Forest Service, including planimetric maps of the Meacham Ranger District and planimetric maps of the La Grande, Telocaset, Elgin, and Wallowa quadrangles.

The investigation was started in May 1957 and the geologic work was begun in June of that year. The work was under the direct supervision of R. C. Newcomb, district geologist for Oregon.

ACKNOWLEDGMENTS

The cooperation of local residents, well drillers, and public officials greatly facilitated this investigation. Well drillers who contributed logs and information were Mr. J. P. Corriell of La Grande, Oreg., A. A. Durand & Son of Walla Walla, Wash., and Mr. O. C. Tandy of North Powder, Oreg. Information obtained from the Corps of Engineers, U.S. Army, consisted of logs of shallow drill holes and water-level records from many shallow wells near the Grande Ronde River. Information concerning an earlier irrigation and drainage study by the U.S. Bureau of Reclamation was made available to the authors by Mr. E. L. White, area engineer of the Bureau at Boise, Idaho.

Prof. W. H. Taubeneck, of the Department of Geology of Oregon State College, contributed valuable geologic information on the areas adjacent to the Wallowa Mountain and Bald Mountain batholiths.

General information on the geology of much of the area included in this report was freely extended by Mr. N. S. Wagner of the Oregon State Department of Geology and Mineral Industries.

LOCATION AND EXTENT OF THE AREA

This report is concerned with a major part of the drainage basin of the Grande Ronde River in Union County upstream from Gordon Creek, which enters the river about 2 miles downstream from Elgin. The area covers about 1,400 square miles and is roughly oval shaped (fig. 1 and pl. 1). It includes the separate valley segments commonly known as the Grande Ronde and Indian Valleys.

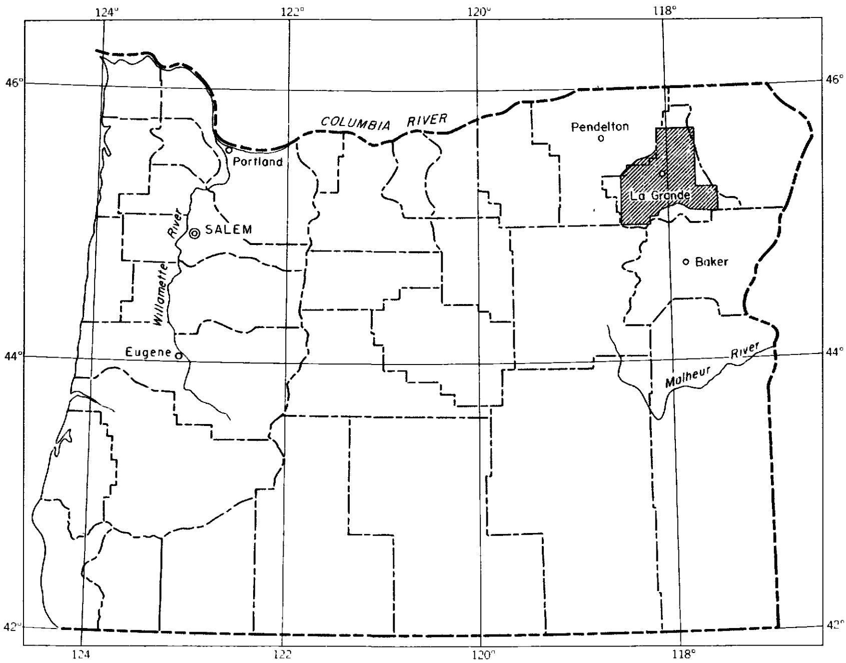

Figure 1.—Map of Oregon showing area covered by this investigation (shaded).

The principal centers of population (1960 census) in order of decreasing size are: La Grande; 9,014, Union, 1,490; Elgin, 1,315; Cove, 311; Island City, 158; Imbler, 137; and Summerville, 76. La Grande is the principal city and seat of Union County. The valley is served by a mainline transcontinental railroad, U.S. Highway 30, and State Highway 82. The valley plain and adjacent slopes can be reached by a good network of paved highways and all-weather roads. The distant headwater areas are reached only by forest roads or on foot.

Principal industries in the Grande Ronde Valley are agriculture and lumbering. Small grains, grass seed, fruit, dairy products, and livestock are the main agricultural commodities. Lumber mills at Elgin, Union, Cove, and La Grande process fir and pine timber cut in the nearby mountains, and Imbler is the center of a large grass-seed industry. The area provides excellent opportunities for outdoor recreation. A sizeable industry is concerned with service to tourists, campers, and sportsmen.

WELL-NUMBERING SYSTEM

Wells discussed in this report are numbered in accordance with the rectangular system of land subdivision. The part of the number before the hyphen indicates township and range; the numeral after the hyphen indicates the section; the letter indicates the 40-acre subdivision of the section, as shown in the diagram; and the final digit is the serial number of the well within that 40-acre tract. Locations in Oregon are referred to the Willamette base line and meridian. If no letter appears after the township number, the township lies south of the base line; if no letter appears after the range number, the range lies east of the meridian. Thus, well 3/38–25B1 is in the NW¼NE¼ sec. 25, T. 3 S., R. 38 E., and is the first well listed in this tract.

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

GEOGRAPHY OF THE AREA

CLIMATE

PRECIPITATION

In the lowland part of the upper Grande Ronde River basin the average precipitation ranges from 13.21 inches per year[1] at Union, at the south end of the Grande Ronde Valley, to 22.93 inches per year at Cove, at the east edge of the valley. The higher areas of the Blue Mountains receive more precipitation, and Meacham, at the northwest edge of the drainage basin, has an average annual precipitation of about 35 inches. These graphs show that, except at Elgin, precipitation is rather uniformly distributed during the months of

[1] The year commonly used for hydrologic studies (the water year) begins October 1 and ends September 30 of the following calendar year. The number used is that of the year in which the water year ends.

October through June, although that during November, December, and May is slightly more than the average for the other months. Throughout the rainy season the average variation in monthly precipitation, from the highest to the lowest, is about 0.3 to 0.6 inch, except for Elgin where the distribution is less uniform. Figure 2 shows the annual precipitation at La Grande, Union, and Cove and the accumulated deviation from the average precipitation for a 25-water-year base period at the same three stations. On these curves a rising line indicates a period of above-average precipitation and an opportunity for above-average contribution to ground-water storage, whereas a falling line indicates a period of below-average precipitation and a lesser opportunity for contribution to ground-water storage.

By June of the average water year 85 to 90 percent of the precipitation has fallen. Figure 3 shows the monthly average precipitation at La Grande, Cove, Union, Elgin, Starkey, and Hilgard. Altitude and yearly average precipitation for these six stations are as follows:

Station	*Altitude (feet)*	*Yearly average precipitation (inches)*
Elgin	2, 670	22. 55
Union	2, 765	13. 21
La Grande	2, 782	19. 70
Hilgard	2, 997	21. 31
Cove	3, 100	22. 93
Starkey	3, 400	17. 30

About one-third to one-half of the winter precipitation, November through March, falls in the form of snow. During an average winter, 2 or 3 storms, each producing 6 to 15 inches of snow and lasting 2 to 3 days, can be expected; depths of snow on the valley plains after such storms range from 8 to 12 inches. Prevailing westerly winds can melt 8 to 12 inches of snow in a few hours, and seldom does more than a few inches of snow stay on the valley plains for any great length of time. Seasonal snowfall totals have ranged from 6.5 inches to as much as 121.5 inches at La Grande.

In the mountains surrounding the Grande Ronde Valley most of the precipitation during the fall, winter, and spring is in the form of snow. Its melt water is the source of much of the streamflow in the spring and summer. By March 1 the water content of the snow sampled on 3 snow courses at high altitudes in the upper Grande Ronde River basin has ranged from as little as 10.5 inches to as much as 21.0 inches. Much of the summer precipitation occurs during thunderstorms but, because of the adequate vegetal cover, seldom results in runoff of the flash-flood type. Technical Paper 19 of the U.S. Weather Bureau shows that thunderstorms normally can be expected to occur on 10 days during the 3-month period June through August.

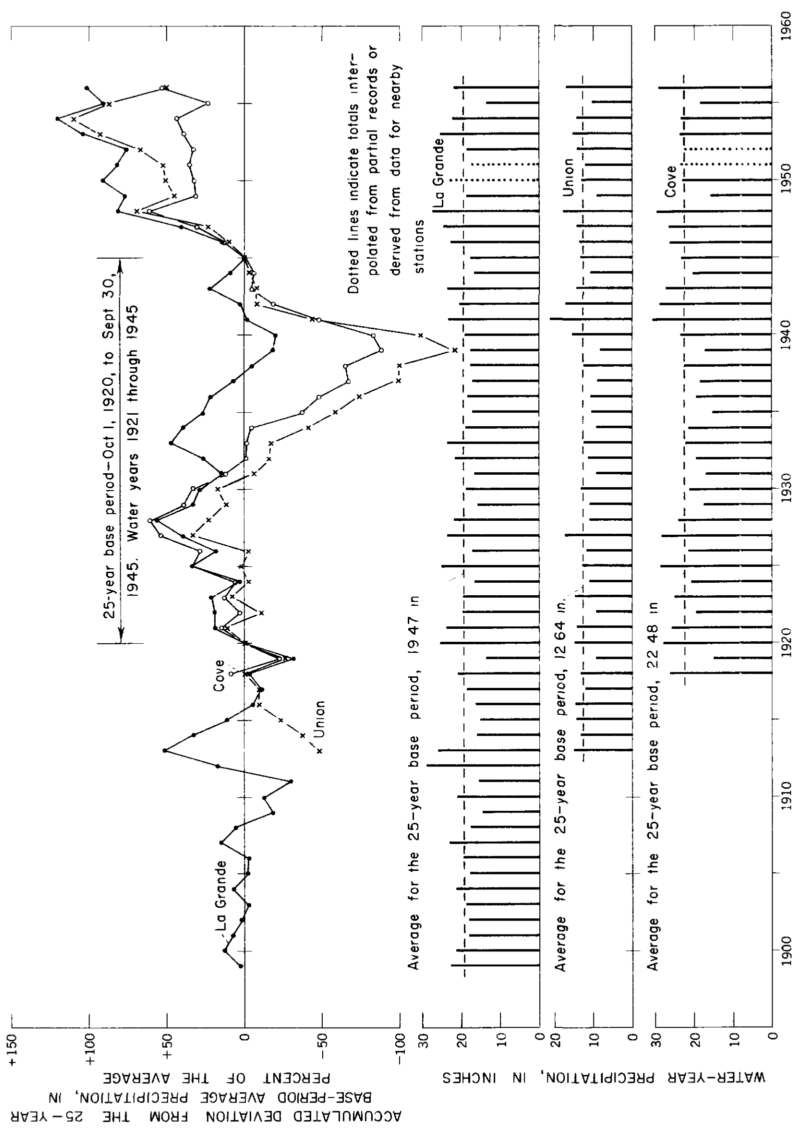

FIGURE 2.—Graphs showing precipitation for the period of record and the accumulated deviation from the base-period average at La Grande, Union, and Cove in the Grande Ronde Valley.

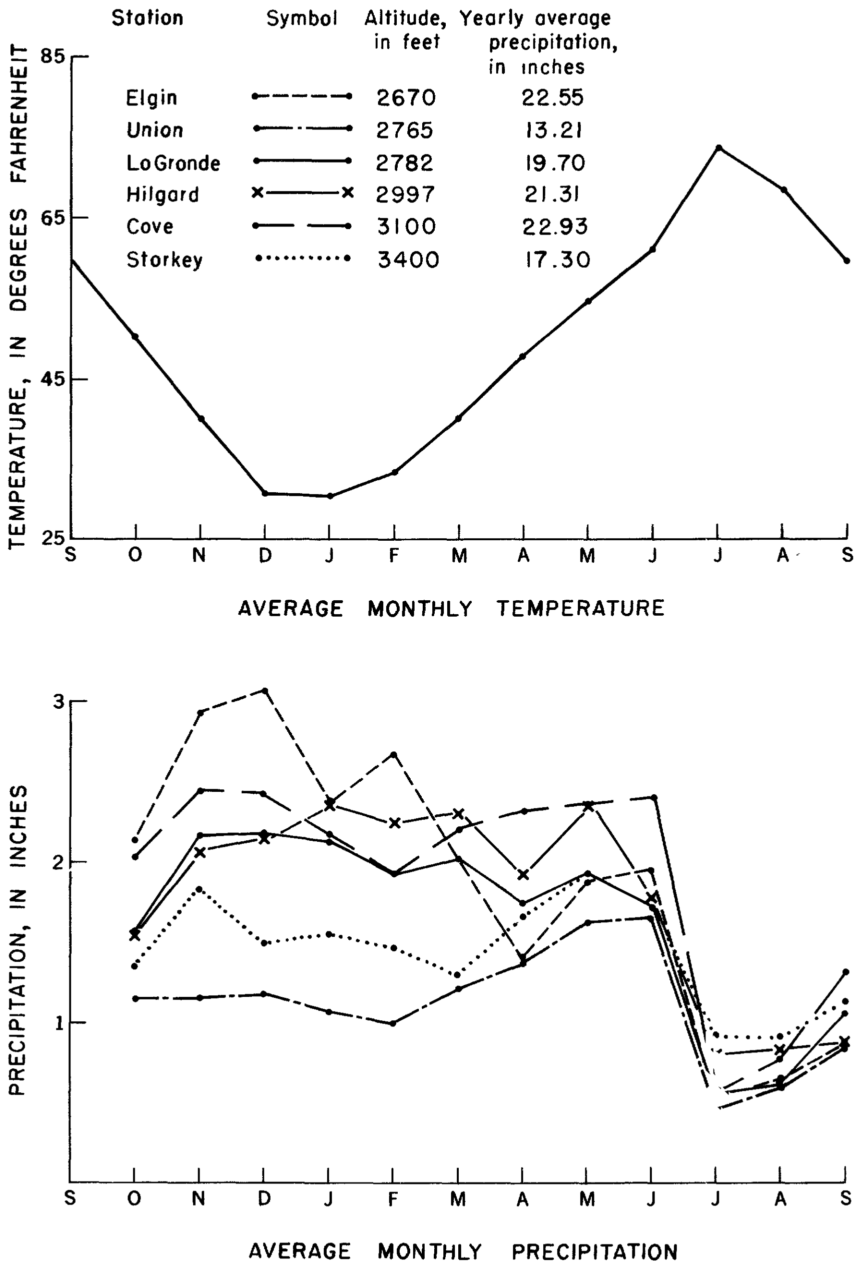

FIGURE 3.—Graphs showing average monthly temperatures at La Grande, and average monthly precipitation at six stations in the upper Grande Ronde River basin.

TEMPERATURE

In summarizing temperatures at La Grande (Climatography of the United States, Nos. 20–35), G. L. Sternes, State Climatologist of the U.S. Weather Bureau at Portland, has observed:

In the entire period of over sixty years for which temperatures are available for La Grande, these have ranged between extremes of 22° below zero to 108° above. In about two-thirds of those years a temperature at least as high as 100° has been recorded, and in 60 percent of them one as low as 0°. * * * Marine air moving in from the Pacific Ocean prevails over this area most of the time greatly moderating both the high temperatures of summer and lows of winter. As a result, neither extreme persists for a very long period. Nights the year around are cool, usually dropping down to between 50° and 60° even in the warmest weather. During the periods of highest temperatures, relative humidity reaches its lowest point, often reaching only 10–15 percent thus materially reducing the discomfort otherwise associated with the warmer temperatures. An average growing season of approximately 143 days permits the growing of a fair variety of crops on a commercial scale. Practically all temperate-climate fruits and vegetables can be grown. The probability for occurrence of temperatures of 32°, 28°, and 24° after specific dates in spring and before specific dates in fall is shown in the table below.

Mr. Sternes' tables, which are reproduced below, show the probability of occurrence of killing frosts.

Statistical likelihood (in percent) that temperatures of 32°, 28°, and 24° will occur in spring after dates indicated

Temperature (°F)	90	80	70	60	50	40	30	20	10
32	4/11	4/21	4/28	5/4	5/9	5/15	5/21	5/28	6/7
28	3/24	4/1	4/6	4/10	4/15	4/19	4/23	4/29	5/6
24	2/27	3/8	3/15	3/21	3/27	4/1	4/7	4/14	4/24

Statistical likelihood (in percent) that temperatures of 32°, 28°, and 24° will occur in fall before dates indicated

Temperature (°F)	10	20	30	40	50	60	70	80	90
32	9/11	9/17	9/22	9/26	9/29	10/3	10/7	10/11	10/17
28	10/1	10/10	10/13	10/18	10/22	10/26	10/30	11/4	11/11
24	10/13	10/18	10/25	10/31	11/6	11/11	11/17	11/24	11/29

TOPOGRAPHY AND DRAINAGE

The Grande Ronde River is formed by the confluence of streams draining the extensive upland southwest, west, and northwest of La Grande. It enters the Grande Ronde Valley at La Grande and receives the creeks flowing from the less extensive uplands to the east, south, and north of the valley. It passes out of the Grande Ronde Valley and into the smaller Indian Valley to the north. From there it flows northeast for 60 miles through the varied topography of canyons and valleys between the Blue Mountains and the Wallowa Mountains and enters the Snake River at a point about 25 miles above Clarkston, Wash. The whole of the Grande Ronde River basin lies within the Blue Mountain section of the Columbia Plateaus physiographic province (Fenneman, 1931, map and text). The part of the basin covered by this investigation ranges in altitude from 2,500 feet, its lower limit on the river at the mouth of Gordon Creek, to about 5,000 feet on the mountainous uplands above, and reaches a maximum of 7,161 feet on Mount Fanny.

The area investigated includes approximately the upper half of the entire Grande Ronde River basin. It is characterized by two distinct types of topography—valley plains and mountainous upland. There is little transitional slope between them.

THE GRANDE RONDE VALLEY

The valley plains are mostly in one large unit, roughly 250 square miles in extent, to which the proper name "Grande Ronde Valley" is applied. The smaller Indian Valley, just downstream, is separated by a short stretch of rockbound canyon through Pumpkin Ridge and is genetically and topographically similar to the larger unit of the valley plain.

The plains are underlain by alluvium, which in places is more than 2,000 feet thick. The alluvium was deposited by lakes and streams in a basin that had been formed by downfaulting and warping of blocks of the bedrock crust of the earth. The altitude of the valley plains rises evenly from 2,600 feet in the lower part of the Indian Valley to about 2,750 feet where it abuts abruptly against the bedrock escarpments and canyon walls in the upper parts of the Grande Ronde Valley. Though forming a smoothly regular surface in the large sense, the valley plains have local features, such as swales, stream valleys, low "ridges," and marginal slopes, which in part control the drainage and ground-water conditions of the valley.

The Grande Ronde River enters the valley just west of La Grande at an altitude of about 2,800 feet and flows down the surface of its alluvial fan to the low part along the east side of the valley. Ladd, Pyle, Catherine, Little, Mill, Willow, and Spring Creeks descend across the valley plains over alluvial fans. Pyle, Catherine, and Little Creeks form a composite alluvial fan, on which is situated the town of Union. At the northwest edge of the valley the fans formed by Willow and Spring Creeks also are partly coalesced. The surfaces of the alluvial fans slope as much as 20 to 100 feet per mile in their upper parts and flatten evenly to merge into the slope of 1 to 3 feet per mile that characterizes the alluvial plain along the Grande Ronde River through the low part of the valley. The alluvial fans are an important part of the valley plains, as they contain much of the best-drained land and the better townsites, and are underlain by the more permeable alluvial fill.

Through the lowest part of the valley, where the water gradient is very slight, the Grande Ronde River follows a sluggish course north to the controlling bedrock in the canyon cut through Pumpkin Ridge. Much of this land, particularly that north of Hot Lake in the south-central part of the valley, was shallow lake or marsh before drainage works were constructed. An 8-mile canal, called the State Ditch, bypasses about 40 miles of the old meander channel and assists in draining water from a large area of the valley north of Hot Lake. The flood-plain part of the valley is still marshy and wet during the parts of the year when runoff from the mountain watershed exceeds the transmission capacity of the river through this flat segment of its course.

A third type of landform in the valley plains consists of terraces above the general level of the streams. Small segments of terraces occur within and south of La Grande and also 3 miles northwest of La Grande; these are remnants of an older, higher alluvial fan of the Grande Ronde River. The largest terrace surface forms the feature known as Sand Ridge, which extends northward from Island City for about 10 miles, between the Willow Creek swale on the west and the Grande Ronde River's flood plain on the east. It stands 20 to 90 feet above the adjacent streams and is a gently rolling plain lacking permanent streams. Apparently, it is a remnant of a former higher level of the valley floor, perhaps of the valley floor that existed before the Grande Ronde River cut through the last 50 to 100 feet of the bedrock rim, at the Pumpkin Ridge outlet from the valley. The land is sandy, hence the name "Sand Ridge," and the precipitation percolates downward to the water table and then moves laterally, mostly eastward, toward the streams.

From its bedrock outlet at the northern end of the valley through Pumpkin Ridge, locally called the Elgin Gorge, the Grande Ronde River flows north through the smaller Indian Valley at a gradient of about 5 feet per mile. Below the second bedrock outlet, north of the mouth of Gordon Creek, the river flows at a much steeper gradient through the canyons beyond the area of this investigation. Indian Valley consists of about 10 square miles of plains which also abut against the sharp bedrock slopes of the mountainous upland to the west. The alluvial fans, like that of Phillips Creek on which Elgin is situated, and local talus slopes in places form transitional slopes between the valley plains and the upland.

The two main terrace levels in Indian Valley are a higher, older level about 100 feet above the river, and a younger one, which extends down to within a few feet of the flood plain. The higher terrace is about 2 square miles in extent; it is underlain by gravel and is eroded into rounded forms. The lower terrace level, about 4 square miles in extent, forms the greater part of the valley; it extends from a few feet to about 50 feet above the general river level and is undergoing dissection.

THE MOUNTAIN UPLANDS

The basaltic bedrock rises sharply from beneath the alluvial cover of the valleys and makes an ascent to the headwater drainage areas in a great diversity of mountain forms. Many of these mountains consist of fault blocks whose deformation was superimposed on broad regional warping. (See p. 27.)

The uplands, which drain to the Grande Ronde and Indian Valleys, comprise three general segments: (a) the linear block mountains on the east, (b) the smaller area draining north from the divide which separates the Grande Ronde Valley from the similar Baker and North Powder Valleys farther south, and (c) the extensive eastern slope of the Blue Mountains, herein called the Blue Mountain upland.

The belt of linear block mountains rises precipitously along the east sides of the valleys. The mountain crests attain some of the greatest heights in the basin—Mount Fanny, 7,161 feet; Bald Mountain, 6,823 feet; and Mount Harris, 5,372 feet. The sharp ridges trend generally northwest and their highest parts form an outlying ridge of the Wallowa Mountains. The northern and more linear part of the mountain upland is underlain by basaltic lava rocks and is drained by Indian and Clark Creeks to the Grande Ronde River in Indian Valley. The southern part, in which are the headwaters of Catherine, Little, and Mill Creeks, drains northwestward to the Grande Ronde Valley.

The upland area at the south end of the drainage basin consists of the southern part of the linear ridgelands east of the Grande Ronde Valley, the mountainous steplike slope of the Blue Mountains west of the valley, and the central area of linear blocks through which passes connect with the North Powder and Baker Valleys. The whole segment has a moderate north-trending linearity in conformity with the fault structure. The headwaters of Catherine, Little, and Ladd Creeks are the main streams draining north to the Grande Ronde River.

The most extensive of the mountain uplands, the Blue Mountain upland, consists of the eastern slope of the Blue Mountains, whose

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crest arcs northward and northeastward around the Grande Ronde and Indian Valleys and continues northeastward as the northwest flank of the lower Grande Ronde River basin. This broad mountainous upland area within the upper Grande Ronde River basin is roughly 25 miles wide and about 40 miles long, north to south; from the latitude of La Grande it continues northward for another 20 miles; its east-west width is only 5 to 15 miles. It ranges in altitude from about 3,500 to 6,000 feet. The upland surface is dissected by steep stream valleys and canyons, and only small parts of the original flattish surface remain on the ridges. The greater part of the upland area is in late youth or early maturity of the erosion cycle. In addition to the general inward slope of the mountainous upland eastward from the crest of the Blue Mountains, broad cross folds and many local variations in altitude and structural pattern were observed. The principal segments of the Blue Mountain upland consist of the northward slope of the Elkhorn Range of the Blue Mountains, which lies south and southwest of the area; the east-trending sag or synclinal warp, which is followed by the Grande Ronde River eastward to the Grande Ronde Valley, and the diverse block-mountain areas, such as that of Mount Emily and vicinity northwest of La Grande.

West of the Grande Ronde Valley, all the drainage from the Blue Mountain upland flows to the Grande Ronde River in the prominent east-trending downwarp called the Grande Ronde syncline and enters the valley near La Grande. The main stem of the Grande Ronde River starts with creeks draining the north slope of the Elkhorn Range of the Blue Mountains and receives the discharge of Chicken, Fly, Beaver, McCoy, Sheep, Meadow, and lesser creeks from the south and west, as well as of Spring, Railroad Canyon, Fivepoint, and smaller creeks from the north. Farther north, Willow Creek and other smaller creeks drain to the Grande Ronde River in the valley. North of Pumpkin Ridge, Phillips Creek drains the Blue Mountains slope to the Grande Ronde River in Indian Valley.

Most of the headwater creeks are intermittent, flowing strongly only during the fall and spring rains and during the spring thaw of snows accumulated in the winter months. During late summer these creeks consist generally of separate pools and local stretches of trickling surface flow. The larger and more deeply incised creeks include some that have continuous discharge, even during the summer and autumn when creek discharge is largely reduced to outflowing ground water. Many of the "dry" creeks are underlain by permeable deposits through which subsurface underflow passes.

The discharge of the Grande Ronde River at La Grande ranges from a minimum of 3.9 cfs (cubic feet per second), which occurred on August 26, 1940, to a maximum of 8,880 cfs, which occurred on

March 18, 1932. The average discharge for the 49-year period of record is 384 cfs. The period of large discharge is short and in most years is limited to the months February through May. The months July through October of most years are months of low streamflow. During that low-flow period, most of the creeks draining the older metamorphic and intrusive igneous rocks of the Elkhorn Range are dry. The creeks draining areas where the Tertiary volcanic rocks overlie the older metamorphic and igneous rocks maintain a rather constant, though small, flow even in the driest part of the summer. Other spring outflow that enters the river does so in the lower reaches of the creeks and in the part of the main stem that is underlain by the basaltic lava rocks.

The creeks in the Grande Ronde River drainage area above La Grande have two distinct drainage patterns. The creeks that drain the older metamorphic and igneous rocks have a dendritic (tree-like) drainage pattern, whereas the creeks and streams draining the layered Tertiary volcanic rocks have a trellis (roughly rectangular) drainage pattern.

The upland areas west and east of La Grande are underlain by lava rocks that discharge ground water from interflow zones. This outflowing ground water appears as numerous seeps and small springs on slopes and in declivities. Thus, moderate supplies of water are available for livestock and wildlife in these upland areas. Similar seeps and springs feed water to the lower reaches of the creeks and form the dry-season "base flow" which discharges from the uplands.

Many springs issue from the foot of the escarpments around the edge of the valley floor. Only the hot spring at Hot Lake, the Cove Spring, and a few others discharge significant amounts of water from single orifices. The lower parts of the alluvial fans contain many spring and seep areas, where the ground-water recharge farther up the fan emerges and drains to creeks and drainage ditches.

In general, the chief characteristics of the runoff of the upper Grande Ronde basin are the wide seasonal variation in discharge and the moderately high total water yield in comparison to most other streams in eastern Oregon.

GEOLOGY OF THE AREA

GENERAL DESCRIPTION AND RELATIONSHIP OF THE ROCK UNITS

The oldest rocks exposed in the upper Grande Ronde basin are pre-Teritary in age and consist of metamorphosed sedimentary and volcanic rocks that were intruded by igneous masses. These igneous intrusive rocks are a part of the Bald Mountain batholith described by Lindgren (1901, p. 574–594) and Taubeneck (1957), and the Wallowa Mountains batholith described in part by Smith and Allen (1941) and by Wagner (1955). The metamorphic and intrusive rocks are exposed over 30 square miles of mountainous terrain in the southwestern part of the area, and over 25 square miles of more rugged upland terrain in the southeastern part.

The pre-Tertiary rocks in the southwestern part of the area are unconformably overlain by tuff breccia and andesite flows tentatively considered by Gilluly (1937) to be of Miocene age, and by Taubeneck (1955, p. 95) to be of Eocene age. The tuff breccia and andesite flows underlie about 60 square miles and are unconformably overlain by basalt flows, which are part of the Columbia River basalt and associated volcanic rocks found in the southwestern part of the area.

The Columbia River basalt and associated volcanic rocks (hereafter referred to as the Columbia River basalt) are of Miocene and possibly early Pliocene age. They are the most widespread and important rock units in the area and are composed of basaltic and andesitic lava flows, interflow beds of lacustrine and fluvial sedimentary deposits, and scoriaceous tuff. These rocks crop out or closely underlie the surface of about 850 square miles of the area.

The Columbia River basalt is unconformably overlain by several types of sedimentary and volcanic rocks. These include lacustrine deposits in the Grande Ronde and Indian Valleys, fanglomerate, valley alluvium, the ejecta which composes volcanic cones, and scattered deposits of volcanic ash.

These geologic units are described in more detail below, and on the geologic maps (pls. 2 and 3).

PRE-TERTIARY ROCKS

METAMORPHIC ROCKS

The two general areas underlain by metamorphic rocks are described separately below but are combined into one metamorphic-rock unit on the geologic map of the area (pls. 2 and 3).

In the southwestern part of the area, schists, greenstones, and quartzite are exposed over about 3 square miles in the canyon of the Grande Ronde River in secs. 12, 13, and 24, T. 5 S., R. 35 E., and in secs. 7, 17, 18, and 19, T. 5 S., R. 36 E. They are best exposed in the walls and slopes of the river canyon near the Grande Ronde Guard Station.

The schist is light blotchy gray brown or red brown and forms sharp, shaly outcrops. The quartzite is mostly light yellow brown and forms blocky outcrops. The greenstone is light green to dark gray and forms rounded outcrops.

Although the schist is deeply weathered, its color has not been greatly altered, the freshly broken surfaces showing much the same appearance as the weathered rock. The schist has alternating light and dark bands, and the parting surfaces have a micaceous sheen. The dark bands are composed of biotite; the light bands are composed of quartz and some feldspar. Quartzite schist, composed of alternate bands of subrounded quartz grains and dark minerals, is common.

The greenstone weathers less rapidly than the schist. A freshly broken surface is dark gray green and shows the rock to be composed of plagioclase crystals set in a chloritic matrix.

In the southeastern part of the area marble, greenstone, and argillite are exposed over about 3 square miles of the Catherine Creek drainage basin in secs. 2 and 12, T. 5 S., R. 40 E., and secs. 21 to 28, T. 5 S., R. 41 E. They are best exposed in the lower walls and slopes of Catherine Creek canyon.

The marble is of two types: pink and white and coarsely crystalline; and dark gray and fine grained, containing white calcite veins. It forms rough, pock-marked outcrops.

The greenstone is gray green to black and forms massive, relatively smooth-faced outcrops. Exposures in roadcuts reveal the angular, blocky jointing of the greenstone, which breaks into sharp-edged, irregular blocks and fragments.

The argillite is dark gray, light gray, and brown and forms blocky outcrops. The layered structure of this rock is almost indistinguishable on freshly exposed surfaces but is readily apparent on weathering surfaces.

On all the metamorphic rocks except the marble, the soil is generally thin and rocky. In places the soil contains some residual material derived from the former cover of tuff breccia or basalt. The residual tuff-breccia rubble is especially common in the southwestern part of the basin; in the southeastern part the basalt rubble is common. In most places the marble is covered by a thicker soil zone than is present on the other metamorphic rocks. The metamorphic rocks as a whole are tight and poorly permeable.

INTRUSIVE ROCKS

The metamorphic rocks of the area are intruded by igneous masses having the general composition of diorite and a granular texture. The intrusive rocks crop out in the southwestern and southeastern parts of the area. Those in the southwestern segment are part of the Bald Mountain batholith and are exposed in the vicinity of the Grande Ronde Guard Station and in Tps. 5 and 6 S., R. 36 E., east of the confluence of Clear Creek and the Grande Ronde River. The exposure near the Grande Ronde Guard Station occupies an area of less than 2 square miles. The intrusive rocks exposed in

T. 6 S., R. 36 E., crop out in more than one-half of this township and in a few sections of T. 5 S., R. 36 E.—about 24 square miles in all.

Outcrops of the intrusive rocks, which are present in only a small part of the area, are generally bold and well rounded. These rocks are best exposed in stream canyons and roadcuts. One of the best exposures noted is adjacent to the channel of Limber Jim Creek, in sec. 26, T. 5 S., R. 36 E., where relatively fresh quartz diorite stands in a cliff about 20 feet high and 100 feet long. Here, the rock includes several dark-colored xenoliths, remnants of the roof material into which the diorite was intruded.

Most of the intrusive rocks weathered to a medium or dark gray though in some exposures they are dark reddish brown. The fresh rock is lighter, being a salt-and-pepper gray, and its darkness depends on the percentage of magnesium and iron minerals present.

Samples of the intrusive rocks were collected near the zone of contact with the greenstone in the NW¼NW¼ sec. 19, T. 5 S., R. 36 E. The rock is medium grained and contains about 25 percent dark minerals. A representative sample of biotite-quartz diorite from this outcrop is composed of about 60 percent andesine, 20 percent biotite, 10 percent quartz, 5 percent hornblende, 5 percent potassic feldspar, and traces of apatite and iron minerals. Quartz diorite in an outcrop farther from the contact (in the NE¼NE¼ sec. 27, T. 5 S., R. 36 E.) is light gray and coarse grained. This rock is composed of about 70 percent andesine, 20 percent quartz, 10 percent biotite, and traces of iron minerals.

South of the area included in this report the quartz diorite forms high, barren peaks, such as Anthony Butte. The granular rock weathers to a coarse, sandy rock waste (grus), which in turn decomposes to form soil. The sandy soil formed on this rock is generally less than 5 feet thick. The rock itself is massive, tight, and poorly permeable.

The intrusive rocks in the southeastern part of the area are part of the Wallowa Mountains batholith. The rocks are exposed in about 20 square miles of the headwater area of Catherine Creek, in the eastern half of Tps. 4 and 5 S., R. 42 E.

Outcrops of these intrusive rocks are generally bold and prominent knobs. In some places the diorite is capped by basalt flows, as it is at Mule Peak and Burger Butte, two of the high peaks of the western Wallowa Mountains (fig. 4). According to Staples, in Smith and Allen's report (1941, p. 15), most of the central intrusive mass of the Wallowa Mountains batholith consists of quartz diorite and granodiorite.

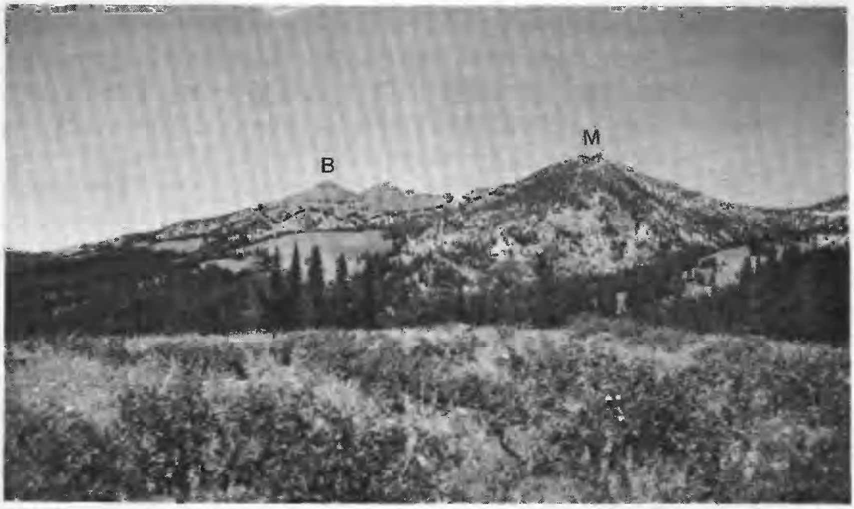

FIGURE 4.—View of Burger Butte (B) and Mule Peak (M) looking north from near the center of sec. 25, T. 5 S., R. 42 E. Dashed line marks approximate contact of the Columbia River basalt with the underlying granitic rocks of the Wallowa Mountains batholith.

Like the intrusive rocks of the Bald Mountain batholith, those of the Wallowa Mountains batholith have a weathered soil zone only a few feet thick on gentle slopes, and no soil on steep slopes. Many of the canyons tributary to Catherine Creek contain a 50-foot-thick fill of loose, permeable train of boulders derived from this intrusive rock, but the diorite in place is massive, tight, and poorly permeable.

OLD GRAVELS

The diorite of the Bald Mountain batholith, where it is exposed at the Camp Carson placers in the SE¼SW¼ sec. 15, T. 6 S., R. 36 E., is unconformably overlain by old gravel, sand, and silt. These sedimentary materials were laid down in a stream channel cut into the diorite. A sharply defined angular unconformity separates these old gravels from the overlying lavas of the andesitic volcanic rocks No wells are known to obtain water from this sedimentary unit.

TERTIARY ROCKS

ANDESITIC VOLCANIC ROCKS

The pre-Tertiary rocks—the so-called basement rocks—in the southwestern part of the area are unconformably overlain by tuff breccia and andesitic lava flows originally described by Pardee (1941) as andesite flows and tuff breccia. Pardee considered this unit to be of Tertiary age. As previously mentioned, this unit has been tentatively assigned to the Miocene by Gilluly (1937) and to the

Eocene by Taubeneck (1955). It is overlain by the Columbia River basalt and associated volcanic rocks of known Miocene and possibly early Pliocene age, and it contains fossils (described below) dated as of middle to late Miocene age; therefore, it will be referred to in this report as of Miocene age.

The tuff breccia and andesitic lava flows crop out in about 60 square miles in the southwest corner of the area. The surface exposures are in the form of cliffs up to 60 feet high. Some of these cliffs have been weathered and eroded into hoodoo and pinnacle forms, such as those 2 miles north of the Grande Ronde Guard Station. In this area tuff breccia is the predominant rock. This rock also forms the cliffs on the north slope of the Grande Ronde River valley immediately east and west of the mouth of Limber Jim Creek. Silicified tuff and welded tuff are the predominant rocks in this unit where it is exposed near Sheep Ranch, about 4 miles southwest of the Grande Ronde Guard Station. These tuffs form subdued, rounded hills where not capped by more resistant andesite or basalt.

Plant fossils collected from the silicified tuff in the SW¼SE¼ sec. 10, T. 6 S., R. 35½ E., were identified by the late Mr. Roland W. Brown of the U.S. Geological Survey (written communication, September 1958), who commented: "The composition and aspect of this collection indicate a middle to late Miocene age." The flora includes the following species identified by Brown:

Populus eotremuloides Knowlton
Quercus simulata Knowlton
Betula fairi Knowlton

The tuff breccia is light yellow buff and is composed of pebble- to boulder-size angular fragments of andesite embedded in a tuffaceous matrix. The breccia also includes many sandstone and siltstone interbeds, some of which are crossbedded. The silicified tuff is cream to buff and contains visible primary crystals of quartz and secondary veins of chalcedony. The fracture planes in this rock are coated by limonite.

The welded tuff is dark red brown or light red brown. It is flow banded and has thin tan bands between thicker dark-red-brown bands. The banding gives part of the rock an appearance that resembles fossilized wood. Some of the cavities and vesicles in this rock are lined by blue-green botryoidal chalcedony or hairlike zeolite minerals of the natrolite group. The sandstone interbeds exposed in several large hoodoolike pinnacles dip 9° in a direction N. 45° W. If this dip has not been disturbed by slumping, it indicates an angular unconformity between the tuff breccia and the directly overlying Columbia River basalt, which dips 4° in a direction N. 10° W. The rocks of the tuff breccia weather to light-yellow-buff clayey soil, which becomes very sticky when wet.

Most of the outcrops of lava in the area occupied by this unit show an andesitic type of rock, but some contain enough quartz to be considered dacite. Included under the general classification of andesite are calcic andesite, andesite porphyry, and lamprophyre of andesitic composition.

Calcic andesite crops out in about 12 square miles in the hills south of Sheep Ranch in T. 6 S., Rs. 35 and 35½ E. The lavas are well exposed on ridges and hilltops. The andesite porphyry is dark gray or red gray on a fresh surface and light buff or brown where weathered. It is composed of phenocrysts of plagioclase and hornblende set in a dense, glassy groundmass. Inclusions of fragments of fine-grained red andesite and greenish-gray tuff also are visible in hand specimens.

A lamprophyre dike in secs. 11 and 12, T. 6 S., R. 35 E., cuts through tuff breccia and is possibly a feeder conduit through which part of the lava of the andesite porphyry rose. The dike rock looks much like the andesite porphyry but does not have the flow structure that is fairly well developed in the porphyry. The andesite porphyry is composed of approximately 30 percent andesine phenocrysts, 50 percent felted andesine feldspar crystals, 10 percent iron minerals, 10 percent glass, and traces of quartz and hornblende. The lamprophyre dike is composed of approximately 30 percent andesine-labradorite feldspar, 10 percent quartz, 10 percent iron minerals, 5 percent hornblende, 5 percent chlorite, and 40 percent glassy groundmass.

Some of the andesitic lavas exhibit a distinct platy structure. The platy andesite is light blue gray and fine grained, and visible crystals of plagioclase are rare. It has a pronounced platy lamination, probably caused by flow banding.

Deep stream canyons separating narrow flat-topped ridges are eroded into the andesite. The andesite porphyry weathers to rounded knobs that occur on hill and ridge tops, whereas the platy andesite often forms bold cliffs 50 to 100 feet high. Good examples of the cliffs formed on this platy andesite are found at Johnson Rock, 2 miles north of Sheep Ranch. The platy andesite is more resistant than the underlying tuff breccia and in many places forms a protective caprock above the softer material.

On field examination of outcrops, the andesitic volcanic rocks appear to be relatively impermeable, and recognizable porous zones are lacking. These rocks probably will yield only small quantities of water to wells.

COLUMBIA RIVER BASALT AND ASSOCIATED VOLCANIC ROCKS

The tuff breccia and andesite flows described above are unconformably overlain by the Columbia River basalt. This basaltic lava is the main bedrock unit of the Grande Ronde River basin. Its age is considered to be Miocene in many areas of its occurrence. However, age assignment of plant fossils collected in the upper Grande Ronde River basin, and discussed later in this report, indicates that the uppermost flows may be early Pliocene age. The unit is composed of a thick series of accordantly layered basaltic lava flows. In the southern and eastern parts of the basin it is roughly divisible into two parts: a basal series of basalt flows and, overlying this in places, an upper series of calcic andesite flows. South of the basin, the calcic andesite part of the Columbia River basalt has been mapped by Pardee (1941) and by Gilluly (1937). Pardee called this material "younger basic lavas" and considered it to be of late Tertiary age. Gilluly mapped the same unit in the Baker quadrangle and included it within his Columbia River lava unit, which he considered to be of Miocene age.

In this report the basal basalt flows and the platy andesite flows are collectively referred to as Columbia River basalt and associated volcanic rocks (or, more briefly, the Columbia River basalt). Each of the two parts will be discussed in more detail below.

A sequence of basaltic lava flows makes up the lower part of the Columbia River basalt (fig. 5). This basalt section is the thickest and most widespread part of the unit. It crops out in more than 700 square miles in the area. The basalt is dark gray to black and is somewhat flinty in appearance on a freshly broken surface. The weathered rock is dark red brown. Most individual lava flows are 10 to 50 feet thick. In some places, the individual lava flows have a chilled fracture zone at the base, a thick, dense, massive middle zone, and an upper scoriaceous zone. In places, a thin layer of fossil soil occurs between some of the lava flows.

Internal structures within the massive part of the thicker flows consist mainly of the polygonal joint planes caused by cooling contraction. The commonest joint patterns in the basalt form hexagonal columns normal to the cooling surfaces (the tops and bottoms of most flows). However, the main jointing systems may form blocky and irregular cubes instead, especially in the thinner lava flows and at the tops and bottoms of the flows.

The basalt flows yield water to wells in amounts that range from small to large. The water comes into the wells from porous interflow zones. The water-bearing character of the basalt will be discussed in greater detail in the section on hydrology.

FIGURE 5.—View of accordantly layered basaltic lava flows of the Columbia River basalt, looking north from south side of the Grande Ronde River in NE¼NW¼ sec. 34, T. 2 S., R. 37 E., and upward at the canyon wall.

Most of the andesite unit occurs in the upland areas east of the western Grande Ronde Valley escarpment. Some areas at Mount Emily are underlain by basic platy andesite and, according to Hogenson (oral communication, Oct. 1958), Spring Mountain just northwest of the area (pl. 1), is composed of gray platy basalt that is very similar in appearance to the typical platy andesite of the southeastern part of the basin.

A thickness of about 300 feet of platy andesite is exposed in the Mount Harris and Mount Fanny escarpments. This thickness appears to be a single flow. About 120 square miles of the upper Grande Ronde area is underlain by this rock, and intercalated with the andesite over much of the area are some basalt flows.

The platy structure of the upper andesite is at places parallel to the base of the flows, but at other places it may be in almost any position with respect to the base of the flows. Thus, the platy layering is not everywhere a reliable indicator of the dip of the flow. Fresh exposures of this rock display rather poorly developed flow banding or flow fracturing. The platy andesite has no well-developed vertical joint system analogous to the hexagonal joint system of the basalt, but it has random, roughly vertical joints that are separated as much as 15 feet. This rock is light gray or buff on weathered surfaces, and dark blue gray on fresh surfaces.

The calcic platy andesites are relatively impermeable and probably will yield only small quantities of water to wells.

The topography developed in the Columbia River basalt is characterized by abrupt cliffs, steep-sided, narrow stream canyons, and rather broad, flat, interfluvial uplands. The soil developed on this rock in the upper Grande Ronde River basin is commonly red brown and in few places is more than a few feet deep.

Interflow deposits of gravel, fossiliferous fluvial-lacustrine sediments, and scoriaceous tuff are interlayered with some of the lava flows. A gravel interbed 2 to 4 feet thick is exposed in a roadcut in the NE¼SW¼ sec. 36, T. 3 S. R. 35 E. (fig. 6). The pebbles and cobbles in this gravel are andesite, basalt, greenstone, diorite, quartzite, and schist. This is the only interflow gravel bed noted in the area. A fluvial-lacustrine deposit is interbedded in the basalt in the NW¼NW¼ sec. 15, T. 3 S., R. 36 E., on the west side of the Grande Ronde River. It consists of bedded tuffaceous siltstone and some crossbedded medium-grained sandstone.

At least two interbeds of yellow-buff scoriaceous tuff, ranging from about 20 to 50 feet in thickness, crop out in the escarpments and benchlands between the North Fork of Clark Creek and Cricket Flat east of Indian Valley. The tuff beds underlie the surface in about 14 square miles and form the rich soils for which that upland district is noted. This material weathers more rapidly than the basalt and consequently occupies topographic depressions that are

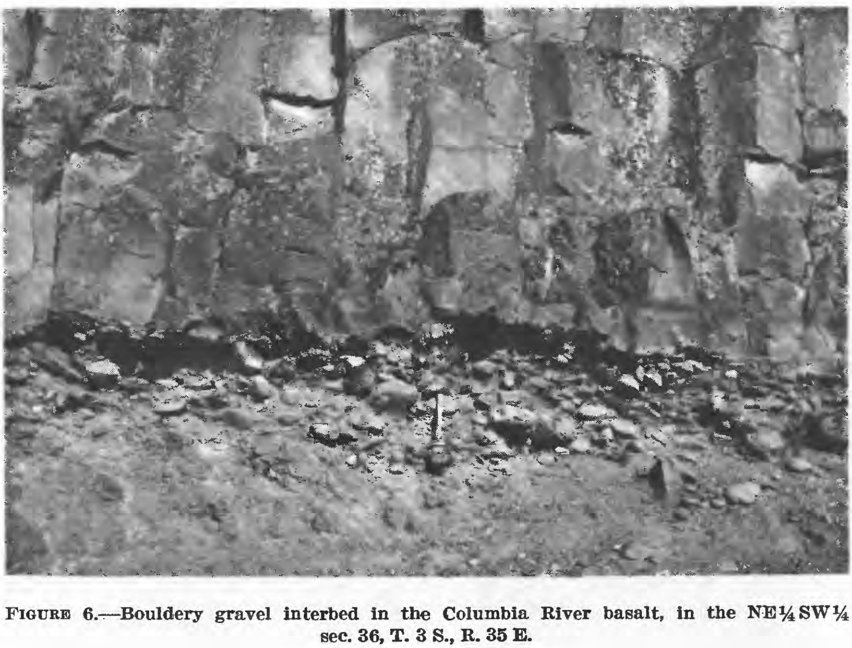

FIGURE 6.—Bouldery gravel interbed in the Columbia River basalt, in the NE¼SW¼ sec. 36, T. 3 S., R. 35 E.

bordered by steep erosional escarpments. A small amount of this scoriaceous tuff has been used as building stone.

Part of the siltstone in the interbed in sec. 15, T. 3 S., R. 36 E. contains terrestrial plant fossils. These fossils were identified by the late Mr. Roland W. Brown of the U.S. Geological Survey (written communication, January 1958), who tentatively dated them as of late Miocene or early Pliocene age. The flora includes the following species, identified by Brown:

Quercus browni Brooks
Salix, 2 spp.
Ulmus speciosa Newberry
Platanus dissecta Lesquereux
Acer glabroides Brown

The extension of the upper part of the Columbia River basalt into the early Pliocene also has been tentatively established in central Washington, where the upper part of the Yakima basalt, a locally named part of the Columbia River basalt, has been tentatively assigned to the early Pliocene on the basis of mammalian and molluscan fossils (Foxworthy, 1962, p. 16).

TERTIARY AND QUATERNARY ROCKS

FANGLOMERATE

The oldest rock unit that overlies the Columbia River basalt is an old fanglomerate which lies on basalt in the upland southwest of La Grande. The fanglomerate underlies an area of about 5 square miles near Starkey; its maximum thickness is about 250 feet. The fanglomerate, a conglomerate of gravel, sand, silt, and clay, is exposed in a gravel pit on the Starkey road in the NE¼SE¼ sec. 35, T. 3 S., R. 35 E., and in the Beaver Creek drainage basin in the SW¼NE¼ sec. 7, T. 4 S., R. 36 E. In the gravel pit on the Starkey road it consists of loosely cemented beds of coarse sand and silt and intercalated beds and lenses of conglomerate. Some of the material is crossbedded. The sand and silt units contain enough volcanic ash to be termed tuffaceous. The conglomerate consists of cobbles and pebbles in a matrix of silt and sand and is loosely cemented by limonite and silica. Several limonite-lined molds of tree limbs are present, some of the largest of which are 10 or 12 inches in diameter and up to 8 feet in length.

In the Beaver Creek basin the fanglomerate is exposed in a canyon wall that is at least 250 feet high. It is composed chiefly of boulders, cobbles, and pebbles in a matrix of sand and silt and is loosely cemented by silica. Rude stratification is present throughout this exposure.

Part of the fanglomerate was deposited against the upstream face of fault blocks. Therefore, most of this unit seems to postdate the main block faulting, which outlined the major features of the topography. There are, however, thin layers or patches of well-rounded pebbles and cobbles randomly scattered on both the upthrown and the downthrown fault blocks within the Grande Ronde syncline. From this evidence we can conclude that fanglomerate was being deposited in the syncline before and during the faulting, but that the greatest thickness of fanglomerate accumulated on the downthrown blocks after the fault displacements had started. The thicker deposits of fanglomerate probably include some reworked materials from earlier deposits of this type. Because of the relatively high permeability of the fanglomerate, few streams drain its surface; but several small springs occur at its edges. The cleaner beds of gravel or coarse sand may yield small to moderate quantities of water to wells, if these beds can be found beneath the regional, or a perched, water table. Most of the deposit now lies above the regional water table.

LACUSTRINE DEPOSITS

The sedimentary fill of the Grande Ronde Valley is mostly clay, silt and fine sand, deposited in quiet water. The coarser sediments of the alluvial fans and the colluvium underlying the talus slopes interfinger with the finer sediments along the borders of the basin. The highest remnant of the older valley fill is called the Sand Ridge and is about 150 feet higher than the present outlet of the valley. At the north and south edges of the valley floor the alluvial fill lies on the bedrock and progressively thickens from a featheredge in these locations to great depths near the center of the valley. The driller's log of well 3/39–5J1 (table 2) records 2,020 feet of sedimentary deposits. Apparently, this well was drilled entirely in the valley alluvium. The deposits include some gravel strata to a depth of 525 feet, which probably were deposited by the Grande Ronde River as it lost velocity and load-carrying ability upon entering the valley. The log of well 1/38–24R1 records only one thin gravel stratum at a depth of 412 feet. In that well the remainder of the sedimentary section consists of sand and clay strata to the top of the basalt at a depth of 665 feet.

The drillers' logs of water wells that were drilled more than 200 feet into the alluvium (see table 2) record a definite color change in the alluvial fill at depths ranging from 35 to 610 feet. The color change from yellow brown to blue or green does not occur at comparable altitudes over the entire valley. The top of the blue sediments ranges in altitude from 2,500 to 2,700 feet.

The alluvial fill in Indian Valley is analogous to that of the Grande Ronde Valley. The known depth of the alluvium ranges from 560 feet, as reported in the log of well 1N/39–22B1, to 267 feet, reported in the log of well 1N/39-15J1. These sedimentary deposits are composed of clay, silt, sand, and some gravel.

The younger sedimentary deposits that underlie the alluvial fans and talus slopes unconformably overlie the lakebed deposits in the Grande Ronde and Indian Valleys. The older parts of these coarse deposits of the alluvial fans and talus are presumably intercalated with the lacustrine deposits.

FAN ALLUVIUM

Five well-developed alluvial fans have formed in the Grande Ronde Valley at the mouths of the canyons cut by the Grande Ronde River; Willow Creek; Ladd Creek; Catherine, Little, and Pyle Creeks; and Mill and Warm Creeks. The Grande Ronde fan forms the southwestern part of the valley floor and its materials were deposited by the Grande Ronde River. It occupies an area of about 22 square miles and has an average gradient of about 25 feet per mile. The Union fan, at the southern end of the valley, was formed by the coalescing of deposits from Catherine, Little, and Pyle Creeks. It has an area of about 13 square miles and an average gradient of about 36 feet per mile.

The Willow Creek fan, in the northwestern part of the valley was formed by the deposits of Willow and Spring Creeks. Its area is about 6 square miles and its average gradient about 43 feet per mile. The Cove fan in the southeastern part of the valley was formed by material deposited by Mill and Warm Creeks. Its area is about 3 square miles and its average gradient about 96 feet per mile.

Alluvial fans are formed of material carried and subsequently deposited by their respective streams. This material ranges in size from boulders to clay and is deposited in rude layers. In this manner, alternating beds of clay, sand, and gravel are deposited across successive surfaces of the growing fans. A sand and gravel aquifer within the alluvial fan of the Grande Ronde River is noted in the logs of 20 wells. The depth of this aquifer below the land surface ranges from 6 feet at well 3/38-6K2 to 33 feet at well 3/38-3L2. Although this aquifer apparently underlies about 10 square miles of the fan, drillers' logs (table 2) show that its thickness is not constant and that it is discontinuous.

Other alluvial fans in the Grande Ronde Valley have a structure similar to that of the alluvial fan of the Grande Ronde River. The size and sorting of the component materials of an alluvial fan are largely dependent on the discharge and the sediment load (particularly the bedload) of the contributing stream or streams. Within any one layer of a fan a progressively finer grained phase is deposited outward from the apex. Thus, progressively less permeable materials are found toward the downstream edges of alluvial fans.

COLLUVIUM

The colluvial deposits that underlie the talus slopes are composed of weathered blocks and fragments of basalt and andesite indiscriminately mixed with soil and stream alluvium. This material is porous; hence, few of the numerous small streams that head above the talus slopes normally flow completely across them. The water that infiltrates from these streams moves slowly downgradient beneath the surface of the talus slope to reappear as springs in the lower part. The occurrence of springs and of ground water in the talus colluvium is discussed in the hydrology section beyond.

VOLCANIC CONE DEPOSITS

A small volcanic cone near Elgin in W½ sec. 4, T. 1 N., R. 39 E., and two cinder and lava cones south of Union, in secs. 30 and 31, T. 4 S., R. 40 E., and sec. 32, T. 4 S., R. 40 E., and sec. 5, T. 5 S., R. 40 E., are the only features of this type seen within the upper Grande Ronde River basin during this study. Cinders from the cone in secs. 30 and 31, T. 4 S., R. 40 E. are being used for road metal.

The Elgin cone is composed of red, buff, and gray porous welded tuff and overlies the lacustrine deposits of Indian Valley. This cone has a thin soil zone and supports a dense stand of second-growth conifers and brush.

The cones south of Union are composed principally of red cinders and basaltic scoria, and of vesicular basaltic lava.

VOLCANIC ASH

Deposits of light-gray volcanic ash of Recent age are exposed in White Horse and upper Ladd Canyons. Similar deposits occur over much of eastern Oregon and Washington. In the canyons cited the ash overlies the stream alluvium and attains a thickness of about 10 feet. The ash probably was windborne and deposited as a thin layer over most of the area. It was washed off the higher areas and has accumulated locally in the valleys and other depressions. Deposits of volcanic ash beneath the terraces along a mountain stream are commonly accompanied by a stand of western larch, locally called "tamarack," which apparently prefers the ash soil.

RECENT STREAM ALLUVIUM

The youngest geologic unit in the area is the Recent alluvium that underlies the floors of the larger stream canyons and valleys. The alluvium consists of river-washed sorted and unsorted sand and gravel which underlies low terraces along the streams and forms the beds over which the streams flow.

The alluvial fill in both the Beaver Creek and Spring Creek valleys is derived, in part, from the fanglomerate unit and forms small ground-water reservoirs of potential local importance. These are discussed further in the section on hydrology.

GEOLOGIC STRUCTURE

The Grande Ronde River basin is a compound structural depression between the Blue Mountains to the west and the Wallowa Mountains to the east. The main elements of the Blue Mountains are the Blue Mountain anticline, named by Hogenson (1957, p. 29), and the domed highland area of the Blue Mountains, called the Elkhorn Range by Fenneman (1931, p. 249). The Wallowa Mountains are an uplifted domal structure elongated in a general north-south direction. The deformation that resulted in these major structural features occurred after the extrusion of the Columbia River basalt. It predated, or was in part contemporaneous with, most of the deposits that have accumulated in the resultant structural valleys.

Because the tectonic structures that largely govern the occurrence and movement of ground water are strongly developed in the Tertiary lava rocks (fig. 7), these faults and folds are described in more detail below. The structures of the pre-Tertiary rocks were not studied in detail because these rocks bear virtually no water, and tectonic structures in them have little, if any, effect on the occurrence and movement of ground water.

FOLDS

The principal folds found partly or wholly within the upper Grande Ronde basin are (a) part of the Blue Mountain anticline, (b) the Grande Ronde syncline, and (c) the Indian Creek syncline. The Wallowa Mountains dome lies northeast of this basin and is not described in this report.

As described by Hogenson (p. 29), the Blue Mountain anticline is a broad, nearly flat-topped arch whose axis is recognizable from Arbuckle Mountain near Heppner northeastward to Kamela. Northeast of Kamela the location of the axis of this fold is obscured by a strong northwest-trending fault system as far north as Langdon Lake. The upland formed by the Blue Mountain anticline extends northeastward from Kamela to the Snake River in southeastern Washington and forms the western and northwestern boundary of the Grande Ronde River basin.

The basalt layers in the southern limb of the Blue Mountain anticline dip about 5° to 8° to the trough of the Grande Ronde syncline, which is in the upper Grande Ronde River basin (pl. 1). These

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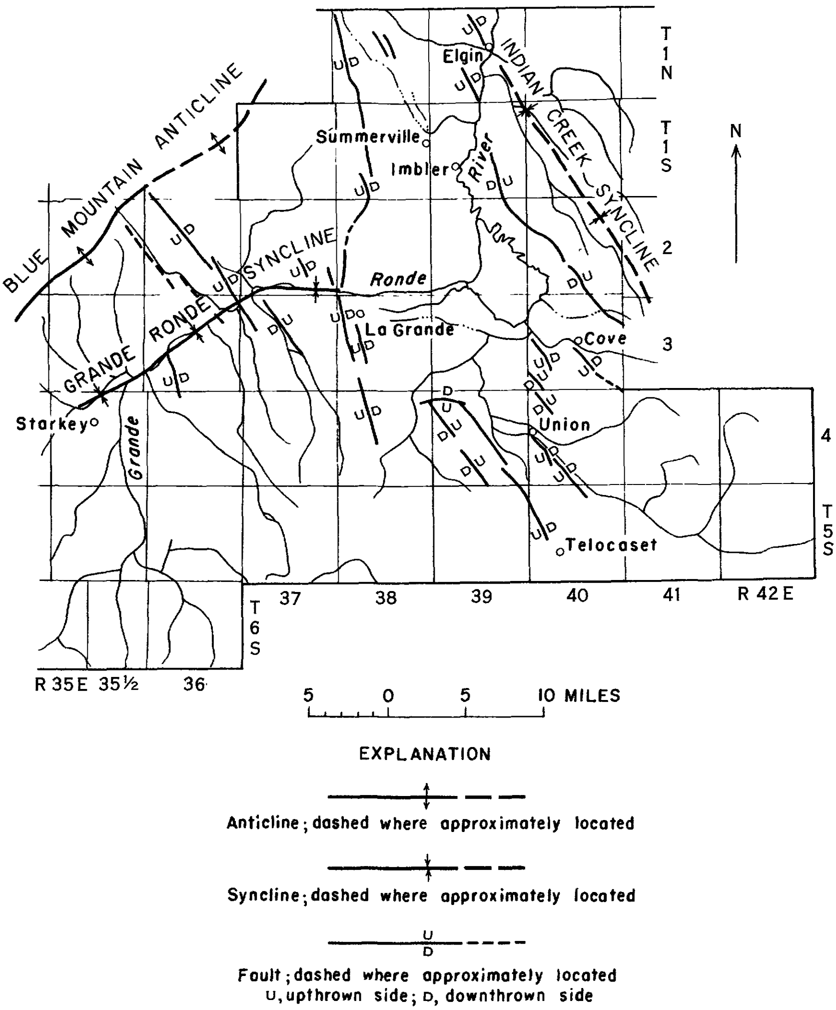

FIGURE 7.—Map of the Grande Ronde River basin above Elgin, Oreg., showing location of major structural features of the Columbia River basalt.

basalt strata in the southern limb of the Grande Ronde syncline descend at a maximum dip of 8° from the Elkhorn Range to the trough of the syncline. This syncline is a broad, gently downwarped trough whose axis is clearly recognizable from the fault scarp bordering the west side of the Grande Ronde Valley southwestward to Starkey, a distance of about 18 miles. It is intersected by numerous northwest-striking faults but retains its general downwarp shape as far as the large fault where the bedrock disappears beneath the Grande Ronde Valley.

A lesser fold within the upper part of the Grande Ronde River basin is the Indian Creek syncline. This structure occupies the area between the Minam River and the eastern escarpment of the Grande Ronde Valley, and between Mount Fanny and Elgin. The strata dip toward its axis at very low angles. Within this northward plunging syncline the streams flow parallel to its axis and empty into the Grande Ronde River near Elgin.

FAULTS

Of equal structural importance are the numerous normal faults that cut the rocks of Tertiary age. The faults having the largest displacement outline the Grande Ronde Valley and are a part of the northwest-trending system of faults found throughout northeastern Oregon. Great variation in the spacing and in the amount of vertical displacement is evident everywhere throughout the area. Many fault zones in the Columbia River basalt contain a clayey gouge that can act as a barrier to the lateral movement of ground water. Faults of large displacement in the Columbia River basalt apparently have relatively narrow gouge zones, whereas some faults having lesser displacements, especially those well exposed in the Grand Ronde River canyon near Red Bridge State Park, have vertical displacements of less than 100 feet and gouge zones 50 to 200 feet wide. This seemingly anomalous occurrence of wide gouge zones and relatively small vertical displacements along these smaller faults may indicate that horizontal as well as vertical movement occurred.

As stated above, the faults that have the greatest displacement border the downdropped block beneath the Grande Ronde Valley. Such a downdropped fault block is commonly termed a graben. The visible displacement along the east side of the graben is about 4,000 feet near Cove (fig. 8), and the displacement along the west side at Mount Emily is nearly 3,000 feet (fig. 9). The overall displacements are the sum of those along a large number of faults generally alined along the master zones. Some individual faults along the western escarpment have vertical displacements ranging from 200 to 1,500 feet, however.

The east side of the Grande Ronde Valley is bounded by a zone of faulting which includes one large and several lesser faults. The large fault extends about 6 miles northwest from a point near the village of Cove to a point about 1 mile west of Gasset Bluff. The trend of the escarpment of this single fault is broken by a step displacement near Mount Harris, which is a fault-block mountain bounded on the west and south by normal faults (fig. 10).

FIGURE 8.—View of fault escarpment near Cove (right center), looking east from the SW¼SE¼ sec. 18, T. 3 S., R. 40 E. Mount Fanny (alt. 7,161 ft) is the highest point along this escarpment. Dashed line delineates talus slope at base of escarpment.

FIGURE 9.—View of fault escarpment of Mount Emily (alt. 6,060 ft), looking northwest from the NE¼SW¼ sec. 15, T. 2 S., R. 38 E. Dashed line delineates talus slope at base of escarpment.

MAJOR FAULT ESCARPMENTS OF THE GRANDE RONDE VALLEY

FIGURE 10.—View of Mount Harris showing the step-fault escarpments at its southwestern side, looking north from the SE¼SW¼ sec. 7, T. 3 S., R. 40 E. Dashed line separates the escarpments of the step faults.

South of Cove, the major displacement at the east side of the Grande Ronde Valley fault gives way to a regional west-dipping monocline; this is cut by northwest-striking rotational faults which persist from the Wallowa Mountains west to Ladd Canyon. The fault density in this area is great, averaging in each mile 2 or 3 faults that have vertical displacements exceeding 100 feet. The faults having the greatest displacement are upthrown on the western side. The most striking examples of these are the High Valley, the Catherine Creek, and the Pyle Canyon faults, whose displacement ranges from 300 to 1,500 feet. Most of the larger faults in this vicinity are normal faults which have progressively greater displacement toward their northern ends.

Pumpkin Ridge is the northern terminus of the Grande Ronde Valley. It extends northwest from Rhinehart to the vicinity of Odessa Spring, near the crest of the Blue Mountain anticline. It is fractured by numerous curved fault zones at its southeastern end. These fault zones strike both northwest and northeast, and the angle of their intersection approaches 90°. The surfaces of the largest blocks composing the ridge dip to the southwest at maximum angles of 3° to 5°. The surface of the Willow Creek graben west of Pumpkin Ridge has a general southeast dip of 2° to 4°. Rocks of the Pumpkin Ridge blocks and the Willow Creek graben descend beneath the alluvial fill of the Grande Ronde Valley and are encountered at depth by the Wagner irrigation well (1/38–24R1) and the Summerville Cemetery well (1/39–18M2) farther south.

South and west of La Grande, in the Grande Ronde syncline, faults having a throw exceeding 100 feet are about 3,000 feet apart on the average. The intensity of the faulting in this area decreases progressively southward toward the Elkhorn Range. Only a few faults are recognizable near the Porcupine Guard Station and in the uppermost part of the drainage area of the Grande Ronde River. Most of the fault blocks within the Grande Ronde syncline were not tilted sufficiently to modify the dips originally imposed by the warping of this structure. Only the larger and more obvious faults or fault zones that cut the rocks immediately west of Mount Emily are shown on the geologic map (pls. 2 and 3).

The earth movements that created the structural features described are developed in lava rocks of known Miocene and possibly early Pliocene age. If these rocks were folded during the time of extrusion and deposition, angular discordances probably would be present in the strata. As these are lacking, it appears that the warping postdates the extrusion of the Columbia River basalt. No secondary structures, such as faulting or folding, are present in the rock units of post-Pleistocene age. Hogenson (1957, p. 37) has described an early upwarp of the Blue Mountain anticline as taking place in Pliocene time, before the deposition of the fanglomerate locally known as the McKay beds in the Agency syncline south of Pendleton. His evidence indicates that the uplift of this structure occurred in two stages. The earliest uplift was probably in the Pliocene epoch. Later, in middle to late Pleistocene time, more intense deformation occurred in the Umatilla Basin (Newcomb, 1958, p. 339). Because the Indian Creek syncline is in the same general structural complex as the large Blue Mountain crustal warps, the writers assume that the latest stage of deformation was basinwide in the upper Grande Ronde River drainage area and occurred in middle to late Pleistocene time.

The major system of northwest-striking faults was developed sometime after the broad warping was underway. The folds were displaced by many faults of this system. The fault scarps are relatively uneroded and, thus, geologically young. The fault system probably developed in about middle to late Pleistocene time.

GEOLOGIC HISTORY

An account of the geologic history emphasizes some of the features mentioned in other sections of this report and provide a chronological order for the descriptions of the water-bearing units from which ground water can be withdrawn.

In early Tertiary time the erosion surface of the pre-Tertiary metamorphic and intrusive rocks was covered by volcanic debris. The lava and breccia blocked the existing drainage in many places and caused ponding. Some of the breccia or tuff-breccia "flows," described on page 17, were laid down at this time and are composed, in part, of water-laid sediments. These deposits had been gently folded and erosion had produced some steep topography in them prior to out pouring of Columbia River basalt.

The Miocene was a time of great outpourings of fluid lava over the Columbia Plateau region. A thickness of thousands of feet of lava rocks was laid down on the early Tertiary erosion surface, attaining a maximum of at least 3,000 feet in the upper part of the Grande Ronde River basin. Few of the lava flows are deeply weathered or have well-developed soil zones on their upper surfaces. This absence of interflow soils suggests a geologically short time lapse between the successive flows. Interflow deposits of fluvial-lacustrine sediments, including river-washed gravel, show that some of the flows interrupted the drainage and that ponds and stream channels were present in places on the previous flows. The youngest Columbia River basalt was extruded during late Miocene or possibly early Pliocene time.

The earlier arching of the Blue Mountains anticline occurred during the Pliocene epoch after the outpouring of the Columbia River basalt. Because there are no deposits of middle or late Pliocene age in the upper Grande Ronde basin, this epoch is considered to have been largely a time of general, and probably mild, erosion in the area.

The Blue Mountains anticline was again arched in about middle Pleistocene time. Apparently, the greatest deformation of the Tertiary rocks and the greatest uplift of the Blue Mountains anticline occurred at this time. This deformation probably created the Grande Ronde syncline and shaped the large structural elements of the upper Grande Ronde River basin. Deposits of fanglomerate, possibly derived in part from early Pleistocene glacial outwash, accumulated in the trough of the Grande Ronde syncline. Although there is little or no direct evidence of Pleistocene glaciation within the Grande Ronde basin, the Wallowa Mountains to the east and the Elkhorn Mountains to the south of the basin are well known for the scars remaining from mountain glaciers.

The age of the main faulting in the upper Grande Ronde basin can be inferred from that in neighboring basins. The fault scarps along the northern Wallowa Mountains border are parallel to those in the Grande Ronde basin and presumably of the same age. The Wallowa Mountains scarps were crossed by the younger Pleistocene glaciers that lay in the present-day Wallowa Lake valley and Hurricane Canyon. Wallowa Lake lies astride one of the major fault zones. From this evidence gathered outside the Grande Ronde basin it is apparent that the regional faulting took place before the last advance of the Pleistocene glaciers—an advance considered by Lowell (Smith and Allen, 1941, p. 38) to represent the Wisconsin stage of glaciation, which was the last of the five great advances of continental glacial ice during the Pleistocene. Consequently, it is concluded that the later deformation in the upper Grande Ronde River basin occurred in about middle to late Pleistocene time.

The faulting deranged the drainage and created two major sediment-catching basins: the downdropped block (graben) of the Grand Ronde Valley and Indian Valley. These basins filled with water and existed as lakes until they were filled by sedimentary deposits. The presence of some coarse-grained beds at depth in the valley fill suggests that the sedimentation probably took place concurrently with the depression of the graben blocks. Thus, coarse-grained deposits were laid down by streams at intervals during the accumulation of the thick valley fill.

In Recent time, the erosive lowering of the bedrock outlets of these basins has drained the basin floors and caused some erosion of the valley fill. More than 100 feet of the finer grained materials that at one time filled the Grande Ronde Valley to an altitude of 2,800 feet has been removed. The Indian Valley has had a similar erosional history.

The volcanic Elgin cone was built upon one of the higher sedimentary terraces. It represents the most recent volcanic activity in or near the Grande Ronde Basin. The beds of volcanic ash in some of the upland canyons are similar to those present in much of eastern Oregon and Washington and are believed to have come from some of the volcanoes in the Cascade Range several hundred miles to the west. Since Pleistocene time the mountain uplands have been continuously eroded and the valleys in most places have been receiving sediment that in turn has been eroded away in a few places

These events have built the geologic framework that governs the occurrence of ground water and to some extent that of water on the surface as well. The effects of these geologic controls are described in the following section on ground-water resources.

GROUND-WATER RESOURCES

OCCURRENCE OF GROUND WATER

Below a certain depth the materials of the earth's crust are saturated with water under hydrostatic pressure. The depth at which the upper surface of this zone of saturation, the water table, lies is dependent upon the regional and local drainage, the relative abundance of precipitation, the topography, the geologic structure, and the composition of the earth materials. In shape the water table generally is a modified and subdued replica of the topography. In certain areas, such as the Grande Ronde Valley, the water table lies close beneath the surface of the valley; in the mountain uplands the water table may be at greater depths. The water table is region-wide, but locally other water tables of minor extent may occur at higher levels in saturated materials where ground water is perched on poorly permeable materials.

SOURCE OF GROUND WATER

The source of ground water is precipitation. On the land surface, precipitation is absorbed to satisfy the soil-moisture deficiencies, and plant and atmospheric requirements. As the capacity of the soil to hold moisture is reached (field capacity), water from additional precipitation runs off toward the streams and also moves downward in the earth through the pore spaces in the soil and rock materials. This water moves downward to the zone of saturation or to less permeable layers around which its percolation path is diverted. Precipitation on the mountainous uplands also supplies water to the streams. Water from the streams may infiltrate to the ground-water reservoir in significant amounts wherever the stream is above the level of the water table and the material on which the stream flows is permeable enough to permit infiltration. In a similar manner all ground water moves by gravity toward ultimate outlet to the surface. Surface water (all water in lakes, ponds, snow storage, and streams) and ground water (all water beneath the land surface within a zone of saturation) are intimately interrelated and form the total water resources of an area.

The interrelation of water on the surface and water in the ground is illustrated at many places in the upper Grande Ronde River basin. One example is found in the hillside rivulets which flow down the steep valley walls until the water infiltrates into the colluvium underlying the talus slopes. Farther down the slopes some of this water emerges as either perennial or wet-weather seeps or springs. Some of the water remains underground and moves downward to the main water table, from which position it ultimately moves to a stream or is discharged by evapotranspiration.

CONFINED AND UNCONFINED GROUND WATER

Ground water may be either confined or unconfined. Confined water occurs where a saturated water-bearing material is overlain by less permeable material, which confines the water and prevents it from escaping freely upward. Confined water is under pressure greater than that of the atmosphere and rises above the level at which it is encountered by a well or natural opening, whereas unconfined water has only atmospheric pressure at its surface. The imaginary surface coinciding with the level to which water from a confined aquifer will rise is called the piezometric surface.

In general, hydrologists use the word "artesian" to mean any confined water, whether or not it flows from wells. Most dictionaries still use the obsolete definition of water that flows at the surface. Some popular usage is still looser, meaning water from any deep well, or even any drilled well.

The saturated material from which ground water can be extracted in usable amounts is called an aquifer. The ability of an aquifer to transmit water is controlled and measured by the permeability and the thickness of the aquifer. Permeability is defined as the number of gallons of water per day at 60°F that will percolate through 1 square foot of the aquifer under a hydraulic gradient of 1 foot per foot. A sand or clay may have the same porosity (ratio of the volume of voids in the material to the total volume of the material) as a gravel, but the gravel will transmit water more easily than the sand or clay because of the greater size of its pore spaces; hence it is said to be more permeable or to have a greater permeability.

GROUND WATER IN THE ALLUVIUM

Throughout the upper Grande Ronde River basin the water table lies near or slightly above the level of the major drainage. It lies at shallow depth beneath the valley floor and slopes upward to the valley walls. In the mountain uplands it may be at great depth beneath some of the ridges. In the valley areas the water table in most of the alluvium has a shape that is a subdued replica of the land surface. The various materials of the valley fill have different water-storage and transmitting capabilities. These are partly dependent upon the manner of deposition and the physical characteristics, such as grain size, degree of grain sorting, and amount of consolidation by compaction and cementation. The more permeable zones in the valley fill are composed of the coarser grained gravel and sand, whereas the less permeable are the finer grained clay and silt. At most places in the Grande Ronde Valley the grain size of the valley fill decreases with depth. The coarser grained deposits are mainly at shallow depth beneath the alluvial fans, and in a much lesser amount in the upper 300 feet of the valley fill beneath the lower parts of the valley plains.

Within the valley are areas that have distinct topographic, lithologic, and hydrologic features. These are underlain by deposits having lithologically different zones, such as those in the lacustrine (lakebed) deposits, the alluvial-fan deposits, and the colluvium (material underlying talus slopes). These deposits are discussed further below.

LACUSTRINE DEPOSITS

The bulk of the valley fill consists of lakebed deposits, chiefly medium- to fine-grained sand mixed with much silt and clay. Few gravel strata have been encountered in well drilling, except where the lacustrine deposits interfinger with alluvial-fan deposits.

The yields of wells drilled in the lacustrine deposits range from almost nothing to 50 or 60 gpm (gallons per minute). (See table 1.) Of 9 wells for which adequate drillers' logs and test data are available, the yields obtained from 6- and 8-inch wells completed with only open-end casings ranged from 10 to 45 gpm.

A small artesian flow was obtained at a depth of about 200 feet from the lacustrine deposits beneath Sand Ridge by well 1/39–32D2. Well 1/39–17D1, a short distance north of Imbler, was reported to have flowed when first drilled in the early 1900's.

ALLUVIAL FANS

On entering the valley, the rivers and larger creeks flow across large alluvial fans, which are underlain by deposits of the coarser materials that the streams have brought from their mountain canyons. The coarse materials are deposited near the heads of the fans, and as the load-carrying ability of the stream decreases downstream, the finer materials are deposited toward the outer ends of the fans. Individual gravel or sand beds are not laterally continuous for any distance. The thickness of any single bed of coarse-grained material is extremely variable and decreases progressively outward from the apex of the fan. Gravel deposits beneath the Grande Ronde fan extend at least as far east as sec. 5, T. 3 S., R. 39 E., and a few wells north of the La Grande airport have encountered gravel at depths of 18 to 20 feet in sec. 12, T. 3 S., R. 38 E. The gravel yields 5 to 10 gpm to driven wells of 1½-inch diameter. (See table 1.)

The yields of wells tapping unconfined ground water from the sand and gravel average about 22 gpm and range from 2 to 400 gpm. The drawdown of the water levels in the wells at these pumping rates ranges from less than 1 foot to as much as 111 feet. The average drawdown is about 16 feet below the static water level. Thus, the average specific capacity of the wells is about 1.4 gpm for each foot of drawdown of the water level in the well. Such rude data suggest that the gravel and coarse sand are sufficiently permeable to yield water in moderate quantity to wells of larger diameter.

Some confined ground water occurs at places beneath the alluvial fans. Flowing water is tapped by well 4/39–11H1 in the gravelly beds beneath the alluvial fan of Catherine Creek. The well is reported to flow about 60 gpm at the land surface, and 3,000 gpm can be pumped when the water level in the well is drawn down to about 95 feet below the land surface. Wells 4/39–11G1, –2H1, –1B1, and

3/39–36K1, also on the Catherine Creek alluvial fan, obtain flowing water. It is reported that when well 4/39–11H1 is pumped for about 30 days at a rate of about 3,000 gpm, wells –11G1, –2H1, –1B1, and 3/39–36K1 stop flowing after 1 day, 2 weeks, 3 weeks, and 4 weeks, respectively.

COLLUVIUM

The rubbly, angular material underlying the talus slopes near the rock escarpments is composed of partly weathered blocks and fragments of basalt and andesite mixed with some sand and clay. The colluvium is poorly stratified and has yielded little water to the wells that have been drilled in it. In part, this lack of yield may be due to inadequate construction of wells in this difficult-to-drill material. Runoff from the higher areas and precipitation on the talus slopes infiltrates to the colluvium. The ground water that is not consumed by evapotranspiration moves slowly down the hydraulic gradient to the valley.

The average yield from 6 colluvium-tapping wells for which adequate information is available is about 9 gpm. The yields range from nearly zero to 20 gpm. The average specific yield of these wells is 0.5 gpm per foot of drawdown.

GROUND WATER IN THE COLUMBIA RIVER BASALT

The Columbia River basalt is a series of flows of basalt and andesitic lava and a few interbeds of tuff, as previously described. This rock unit underlies much of the mountain uplands and continues beneath the alluvial fill of the area. Between many of the individual lava flows is a zone of "cinders," "broken rock," or breccia, and these rubbly interflow zones are generally porous and permeable enough to transmit water. The permeable zones are saturated below the level of the regional water table and also in places where water is perched above the regional water table.

The dense central parts of the successive flows form hydraulic separations between the permeable zones and in places act as confining layers. Tight, less permeable alluvial and lacustrine deposits overlie the basalt and may also confine ground water within the basalt. In a few places joints and fissures may allow some movement of water between flows, though usually these fail to supply much water to wells. Where joints and fissures are exposed in excavations, many are seen to be filled with silt or with clayey decomposition products. Individual flows may be traced for several miles, but the permeable parts of the interflow zones may be discontinuous or at intervals along their length may contain impermeable zones. Because of these discontinuities, as has been observed in other areas where the Columbia River basalt is the principal aquifer, wells drilled to the same depth and relatively close together may obtain water from different interflow zones. Also, they may have different static water levels and, in general, different hydraulic characteristics.

In the mountain uplands where the basalt is cut by deep canyons, water within the interflow zones above the level of the major drainage escapes readily and provides the base flow of the Grande Ronde River system.

Normal geologic processes, most of which occurred after the outpouring of the lava, have produced certain conditions in the basalt that can interfere with the passage of ground water through the interflow zones of the basalt. These are (a) sharp folds or warps in the rock layers, which may drag flow over flow and grind the interflow material to a fine claylike material of poor permeability; (b) faults across which the continuity of the flows may be interrupted by fracturing and vertical or horizontal movement along the fault plane, resulting in the damming of water in the interflow zones by the fault-gouge material; and (c) the previously mentioned nonhomogeneity of the interflow zones themselves.

Eleven wells in the Indian and Grande Ronde Valleys are believed to obtain water from the Columbia River basalt. These wells are 1N/38–25R1, 1N/39–15J1, –J2, –16G1, –22B1, 1/38–24R1, 1/39–18M2, 3/38–5M1, –5M2, –6H1, and 6H2. Yields from these wells average about 700 gpm and range from 20 to 3,500 gpm (table 1). Where the lava flows are tilted and a stratigraphic or structural barrier closes the lower end of the aquifer, or where tight alluvial or lacustrine deposits confine the water, the porous interflow zones may contain water under relatively high artesian pressure. One or more of these situations apparently exist were the wells in the basalt obtain artesian water. Of the 11 wells cited above, 10 wells flow at the land surface, but some are pumped in order to obtain larger quantities of water. The average artesian flow from these 10 wells is about 630 gpm; the flow ranges from 40 to 3,500 gpm.

It has been stated by Newcomb (1959, p. 14):

> A compilation made by the writer in 1947, based on records of several hundred wells that penetrated 300 feet or more of the Columbia River basalt, shows that one gpm of water for each foot of well penetration below the regional water table is a fair overall average of the yield obtained by a 10- or 12-inch well when pumped at the common drawdown of 50 to 100 feet.

The authors tabulated the results of performance tests made by drillers on wells obtaining water from the Columbia River basalt. It was found that, according to probability of occurrence, there is a 50-in-100 chance of obtaining a yield of 1 gpm of water per foot of drawdown for each 100 feet of penetration of the basalt below the piezometric surface.

CHEMICAL QUALITY OF GROUND WATER

Except in a few places the quality of ground water in the upper Grande Ronde River basin is excellent. All waters sampled are potable and within the desirable ranges of hardness and salinity for public supply and most industrial uses. Samples of water from 19 wells and 3 springs within the area were analyzed by the Geological Survey. Chemical analyses of water samples from two wells were obtained from other sources. These 24 analyses are shown on table 4, along with 2 analyses of water from the Grande Ronde River.

HARDNESS

Certain constituents, especially calcium and magnesium, in water cause hardness, which affects the use of detergents and dyestuffs, causes the deposition of scale when the water is heated, and consumes soap in laundry operations. Water has been classified by the Geological Survey (1953) according to the following scale of hardness:

Hardness as $CaCO_3$ (parts per million)	*Class*
0–60	Soft
61–120	Moderately hard
121–200	Hard
More than 200	Very hard

The hardness of the water sampled in the upper Grande Ronde River basin ranged from a high of 156 ppm in well 3/39–7N1 to a low of 4 ppm in spring 3/40–22D1. The average hardness of the waters from 5 wells in the basalt is 18, whereas that of the water from 16 wells in the alluvium is about 93. Of the 3 springs sampled, the water from the 2 hot springs has an average hardness of 7 ppm, whereas the water from the cold spring has a hardness of 36 ppm.

CHLORIDE, SULFATE, AND NITRATE

The chloride content of the water sampled ranged from 0.2 to 129 ppm. That of water from the basalt averaged 2.0 ppm, and that of water from 16 wells in the alluvial fill, 4.2 ppm. The water of well 3/39–7N1, which was drilled into lacustrine deposits of the valley fill, contains 28 ppm of chloride. Hot Lake Spring (4/39–5K1) has the highest chloride concentration, 129 ppm, of all waters sampled in the Grande Ronde basin.

The sulfate and nitrate concentrations in the water analyzed are generally low. The highest sulfate concentration (56 ppm) occurs in the waters of Hot Lake Spring, and the lowest (0.3 ppm) occurs in well 1N/38–21C1. The average sulfate content of 17 ground waters sampled (excluding that of spring 4/39–5K1) is 5.4 ppm.

The highest nitrate concentrations in the 24 water samples so analyzed are 50 ppm for a sample from well 1/39–4N1 and 49 ppm in well 1/39–17L1. Both wells are north of Imbler and are drilled in the valley fill. The lowest concentration is 0.1 ppm or less. The average nitrate concentration of all samples is 6.4 ppm. Water from 3 wells drilled in the basalt has a very low nitrate concentration, ranging from 0.0 to 0.2, and in water analyzed from 16 wells drilled in the alluvium nitrate concentrations ranged from 0.1 to 50 ppm. The average concentration is 9.4 ppm.

MINOR CONSTITUENTS

BORON

A small amount of boron is required for plant growth; however, a slightly larger amount is harmful to many plants. According to Wilcox (1948), a concentration of less than 0.33 ppm is excellent for sensitive plants, whereas a concentration exceeding 3.75 ppm is unsuitable even for the most tolerant plants.

In the 12 samples analyzed for boron, the highest concentration (and the only one over 0.33 ppm) was 0.56 ppm from well 2/38–27R1, and the lowest, 0.02 ppm. The average boron concentration of all waters analyzed was 0.11 ppm; thus, all but one water analyzed was found suitable in this respect for even the most boron-sensitive plants.

FLUORIDE

Concentrations of about 1.0 ppm fluoride in drinking water are considered beneficial to children's teeth. Because concentrations of more than 1.5 ppm may cause mottling of tooth enamel, the Public Health Service (1946) recommends as a maximum limit 1.5 ppm of fluoride for drinking water.

Of the 18 waters analyzed for fluoride content, 2 slightly exceeded the recommended maximum concentration of 1.5 ppm. Well 1/38–24R1 taps water, confined in the basalt, whose fluoride concentration was 2.0 ppm; and the water from spring 4/39–5K1 contained 1.6 ppm of fluoride. The fluoride content of the remaining 16 analyzed samples ranged from 0.0 to 0.5 ppm.

IRON AND MANGANESE

A concentration limit of 0.3 ppm of iron, or of iron and manganese together, is suggested for water for domestic use. Greater amounts of iron or managanese may stain plumbing fixtures and laundry, thus making such water undesirable unless these constituents are removed. The iron concentrations in the 15 water samples analyzed ranged from 0.00 to 0.27 ppm and averaged 0.06 ppm.

SUITABILITY OF THE WATER FOR IRRIGATION

The characteristics most important in determining the quality of irrigation water have been stated by the U.S. Department of Agriculture (U.S. Salinity Laboratory Staff, 1954). They are (a) the total concentration of soluble salts, (b) the relative proportion of sodium to the principal cations as a whole, and (c) the concentration of boron (discussed previously) or other possibly toxic elements. Approximate concentrations of soluble salts can be determined by measuring the electrical conductivity of the water. Conductivity, usually expressed in micromhos, is a partial measure of the suitability of water for irrigation.

The sodium (alkali) hazard of an irrigation water is determined by the relative proportion of sodium to the other major cations, magnesium and calcium. If the relative proportion of sodium is high, the hazard is high; if calcium and magnesium predominate, the hazard is low.

A useful index for designating the sodium hazard is the sodium-absorption ratio (SAR), which is related to the absorption of sodium by the soil. This ratio may be determined by the following formula, in which all principal cations are expressed in equivalents per million:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

A diagram used for the classification of irrigation water, based on the sodium-absorption ratio and the electrical conductivity, is shown on figure 11. In this diagram, 16 types of irrigation water are classified, ranging from low sodium (S1) and low salinity (C1) to high sodium (S4) and high salinity (C4). Water classed as C1–S1 can be used to irrigate any type of crop on nearly all soils with little danger of harmful effects to either crops or soil. Water classified as C4–S4 is not suitable for irrigation of any crops in any soil, except under special conditions.

Of the 15 samples for which adequate data are available for computing the sodium-absorption ratio, 14 fall in either the C1–S1 or the C2–S1 class. These waters are generally suitable for irrigation of most crops on most soils. Water from spring 4/39–5K1 falls in the C2–S2 class, water that can be used for irrigation on permeable organic soils where moderate leaching occurs.

TEMPERATURE

The average temperature of rocks and of their contained water, at depths of 100 feet or less, in most places is at or within a few degrees Fahrenheit above the mean annual atmospheric temperature at the land surface. The average, or "normal," thermal gradient of the earth's crust is commonly taken to be about 1.8°F for each additional 100 feet of depth.

The temperature of the water from the alluvial fill of the Grande Ronde Valley averages about 3°F above the mean annual temperature of the atmosphere. This average includes water from depths

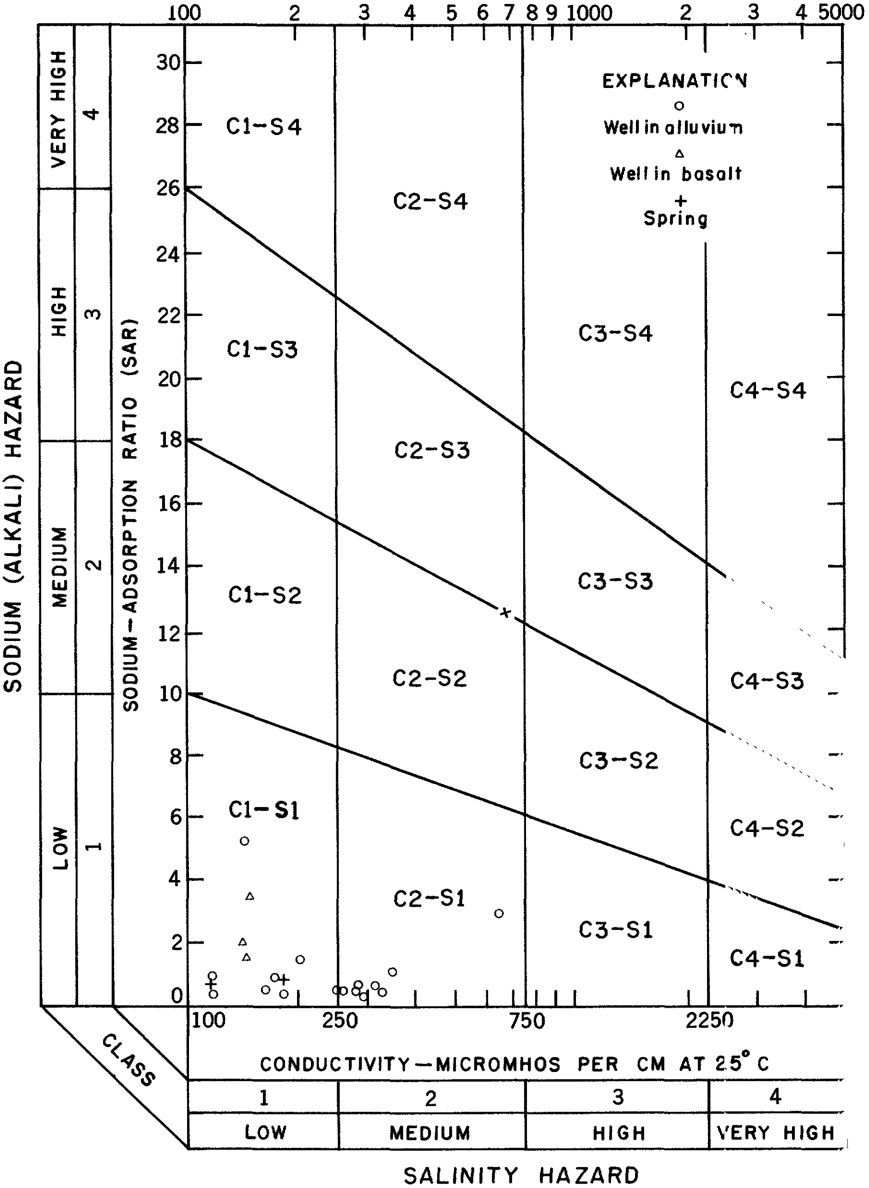

FIGURE 11.—Classification of irrigation waters. Diagram taken from U.S. Dept. Agriculture Handbook 60, Feb. 1954.

of 16 to 337 feet, and it accords with the general expectation. The temperature of the water from wells drilled into the basalt, however, ranges from 3.6° to 9.4°F and averages about 6°F above the temperatures computed fron the "normal" thermal gradient.

The water from well 1N/39-22B1, which is derived from basalt in Indian Valley, has a temperature 5.6°F lower than that computed for its reported depth of 665 feet. It would appear that (a) the above-average temperature noted in the deep wells in basalt in the Grande Ronde Valley is not present in the Indian Valley, (b) the water in well 1N/39-22B1 enters the well considerably above the bottom, or (c) the water percolates to its deep location so rapidly that it does not become warmed to the "normal" rock temperature.

The warmest ground water known in the upper Grande Ronde River basin flows from Hot Lake Spring at a temperature of 180°F The high temperature of this water may be due in part either to heat generated mechanically in the fault zone from which the spring issues or to heat gained during slow circulation of the water to great depth, followed by a more rapid rise during which the water does not have an opportunity to cool.

FLUCTUATIONS OF WATER LEVELS

Under natural conditions a balance exists between the water the aquifer receives (recharge) and the water it discharges. Minor variations occur in the amount of water in storage within an aquifer. These variations in storage are due to seasonal and long-term differences in the amount of water recharged and discharged and the rates at which these additions and losses take place. The differences in recharge and discharge show as changes in the altitude of the water table or piezometric surface (artesian head). The water table is not a stationary surface but constantly fluctuates by small or large amounts in accordance with the recharge to and discharge from the aquifer, and the permeability and porosity of the saturated materials. The piezometric surface, or pressure head, of a confined artesian aquifer likewise fluctuates because of the same factors. In addition, it is particularly subject to variation in hydrostatic pressure because of such factors as barometric changes, earth tides, and earthquakes. The fluctuations in the level of ground water are measured in order to learn some of the facts about how, when, and where the water enters and leaves underground storage.

Water-level fluctuations have been observed regularly in 2 water-table wells in the Grande Ronde Valley since 1936, in a third water-table well since 1940, and in 1 artesian well since 1950. Beginning in the summer of 1957, about 45 additional observation wells were measured periodically and a continuous water-level recorder was in operation from August 1957 to December 1958. Hydrographs of 10 of the short-term observation wells are shown on figures 12 to 14. Hydrographs of the 4 long-term observation wells are shown on plate 4 and on figures 15 and 16.

SHORT-TERM FLUCTUATIONS

The most readily noticeable and regularly observable water-level fluctuations are the annual or seasonal variations. Wells tapping the unconfined ground water show a pronounced low and high water level each year. Of the 49 wells in which depth to water was measured in 1957, the high water level occurred in 40 during the period May through July; 11 of these highs were measured in July; 1 was measured in June; and the remainder were measured in May. Low water levels occurred in the late summer and autumn, 35 in November and 9 in July. Two wells were reported dry during August and September. The annual lows occur several months after the rate of precipitation has reached the yearly low and before the new recharge from the autumn precipitation has had time to percolate to the water table.

As the rate of precipitation increases during the fall and winter months, the water table rises with the increasing infiltration, there being but a short time lag.

The hydrograph (fig. 15) of well 1/38–24R1, an artesian well in the Columbia River basalt, shows little annual variation in pressure head; the variations shown probably are caused by the withdrawal of water from the well.

Four factors that directly affect the water levels in wells tapping unconfined water are (a) infiltration of precipitation, (b) temperature (season of the year), (c) recharge from creeks and rivers which discharge onto the valley floor, and (d) discharge from the groundwater body to the land surface. Plate 4 shows the hydrograph of well 3/38–10B1 for the period of record and graphically compares it with the monthly precipitation, monthly average air temperature at La Grande, and monthly runoff of the Grande Ronde River near La Grande. Precipitation and temperature appear to have the greatest influence on the water level in this well. The discharge of the Grande Ronde River and any consequent water loss to the ground-water reservoir appear to have a lesser influence on the water level. The temperature is indicative of the amounts of evaporation from the soil and transpiration by plants which extract water from the zone of saturation. Hydrologists commonly combine the two terms into one, "evapotranspiration," when it is not possible to evaluate the processes separately. Hydrographs of wells drilled on the valley floor south of the Grande Ronde River have shapes similar to that of well 3/38–10B1, indicating that water levels in those wells are influenced by the same factors as the water level in well 3/38–10B1.

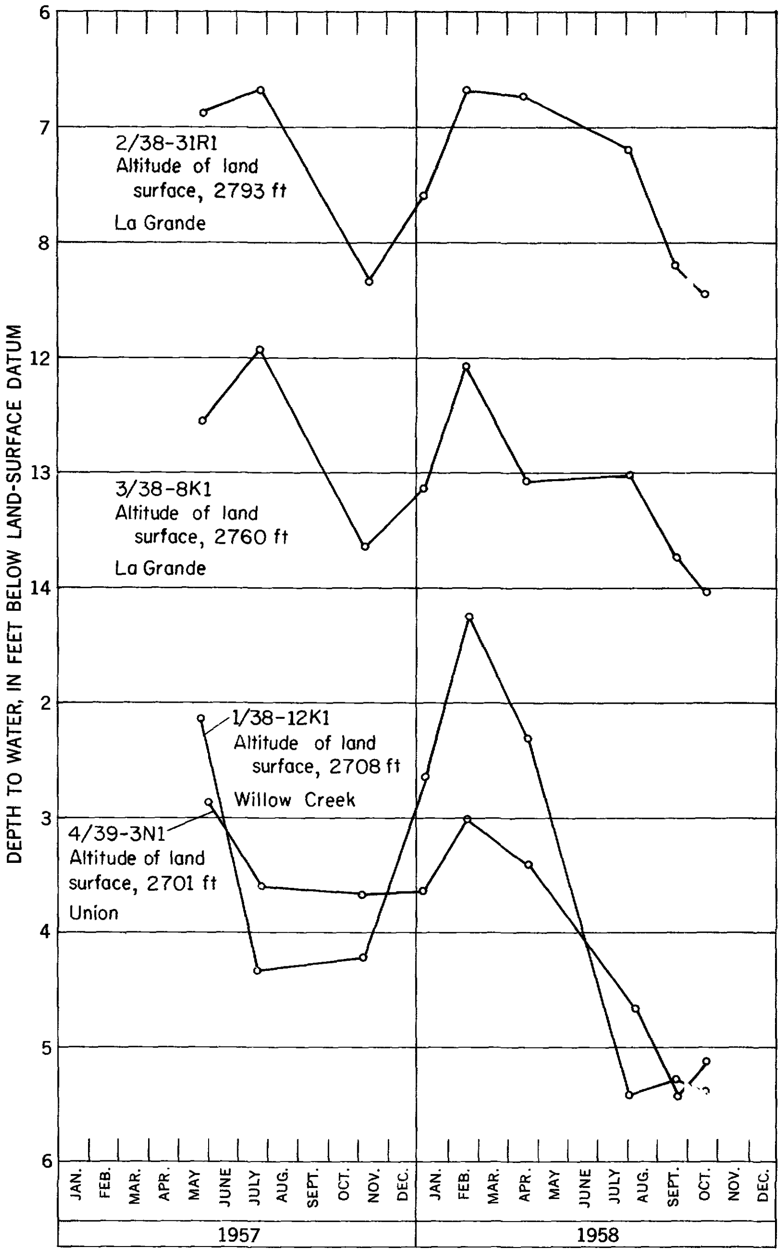

FIGURE 12.—Graphs showing water levels in wells drilled in the La Grande, Willow Creek, and Union alluvial fans.

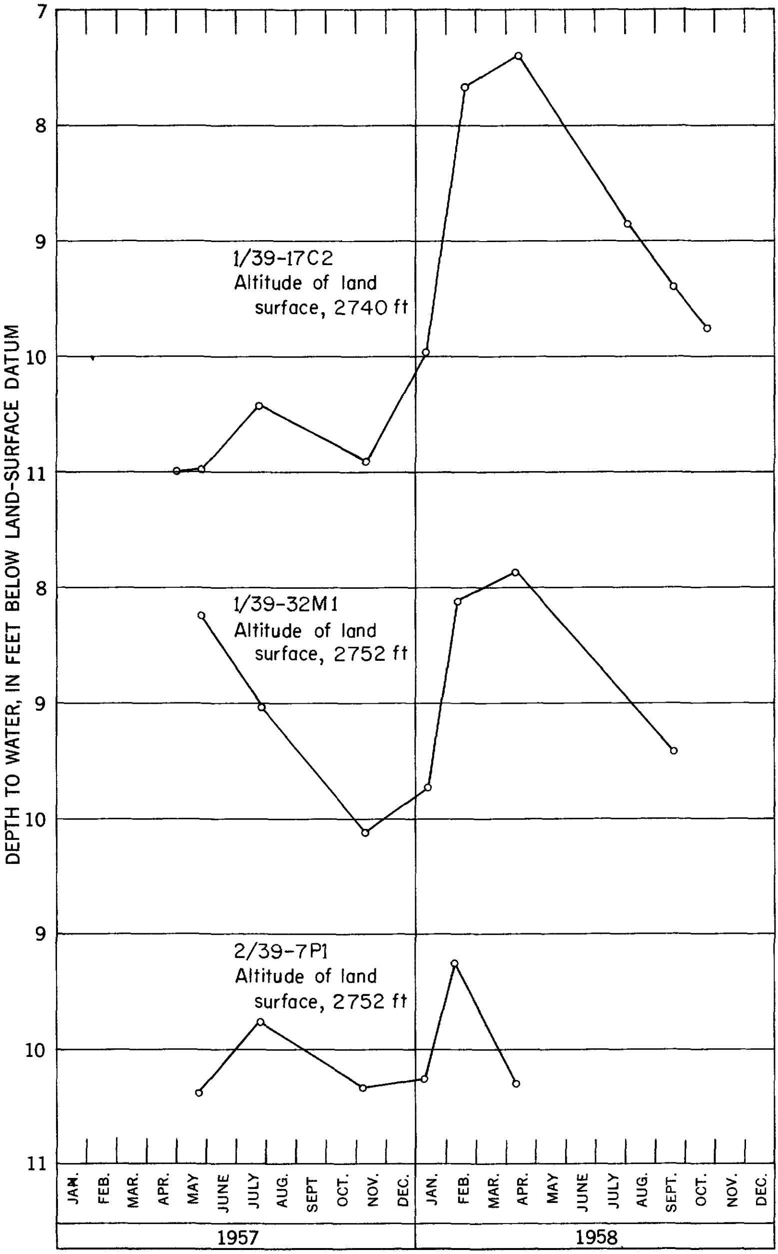

FIGURE 13.—Graphs showing water levels in wells drilled in "the Sand Ridge."

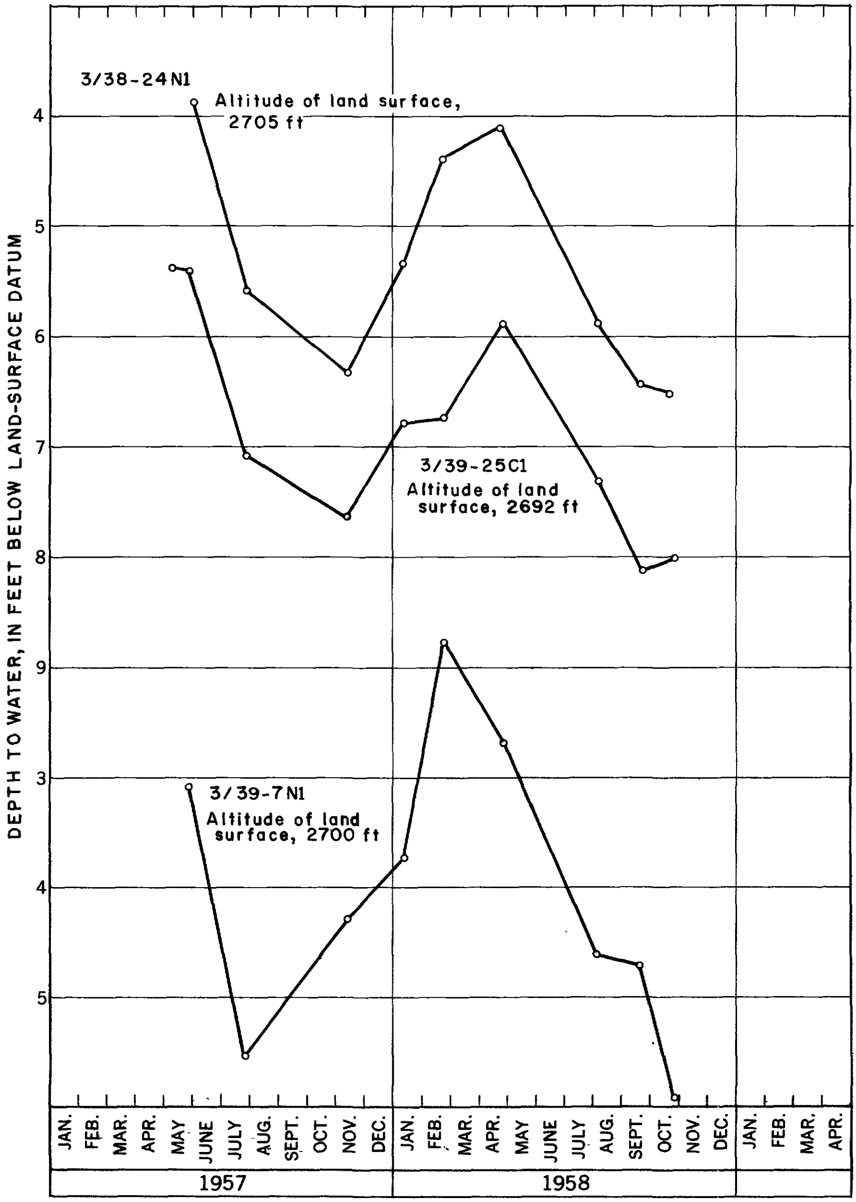

FIGURE 14.—Graphs showing water levels in wells drilled in the alluvium in the southern part of the Grande Ronde Valley.

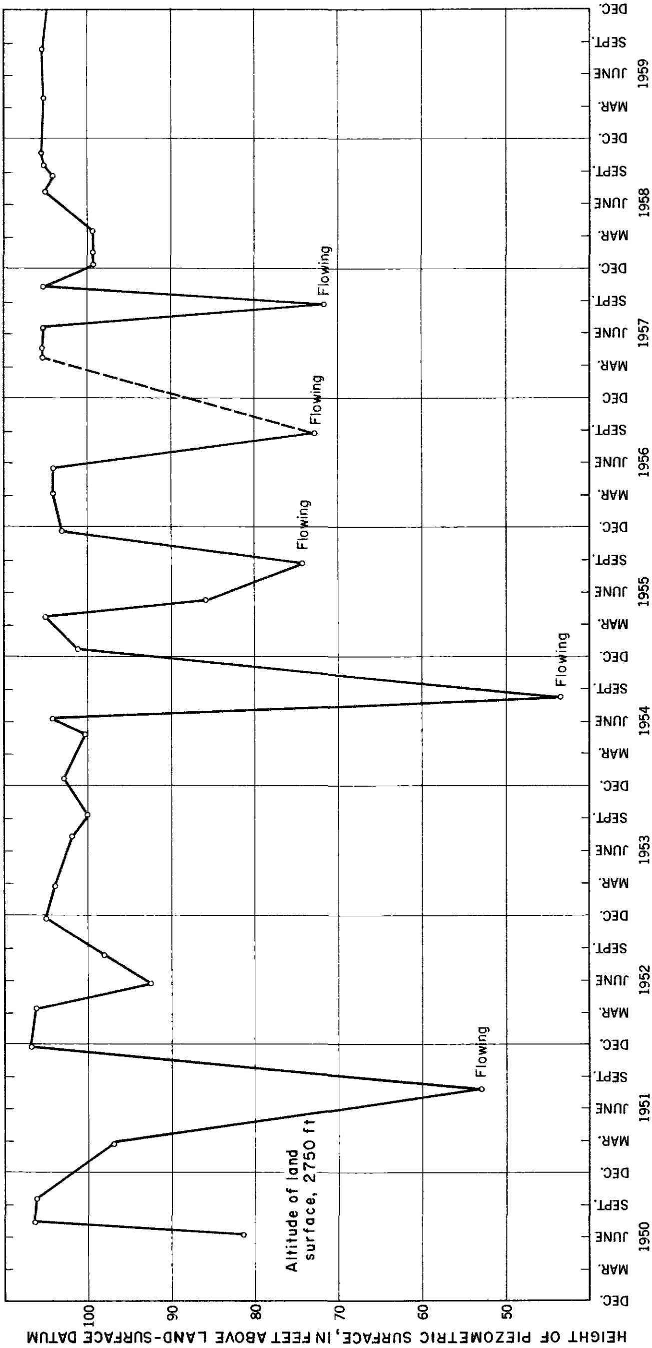

FIGURE 15.—Graph showing artesian pressure in well 1/38–24R1 drilled in the Columbia River basalt and associated volcanic rocks near Imbler, Oreg.

The hydrograph (fig. 16) of well 1/39–17L1, about 1 mile north of Imbler, shows a rather sudden rise in water level from July 1948 to February 1949. The rise of about 8.4 feet in 7 months suggests that at times the water table may respond quickly, with little lag, to the responsible meteorological factors. As shown on plate 4, the precipitation in December 1948, as measured at La Grande, was about 4.4 inches, and the monthly average temperature was less than 26°F. January 1949 was even colder, the monthly average temperature was less than 14°F, and slightly more than 1 inch of precipitation was measured at La Grande. In December 1948 and January 1949 most, if not all, of the precipitation accumulated on the ground as snow. The soil was well primed by the autumn and early winter rains; therefore water could be transmitted to the water table quickly. In February 1949 the monthly average temperature rose to 30°F and the daytime temperature was above freezing. Thus, as the snow began to melt, water was transmitted to the aquifer faster than it discharged from the aquifer to the Grande Ronde River, and the water table rose rapidly. It will be noted that wells 3/38–10B1 (pl. 4) and –25B1 (fig. 16) show similar but less pronounced rises in water level, followed by sharp declines through the spring and summer.

When recharge increases, the slope of the water table or piezometric surface is steepened toward the points of discharge. The discharge from the aquifer then increases. Also, if over a period of years the precipitation—and hence the recharge—are increased, the water table will rise and more water will be stored in transit within the aquifer. If the rate of recharge sufficiently exceeds the rate at which the ground water can percolate and discharge from the aquifer, the water table will rise until it approaches or intersects the land surface, and a waterlogged terrain may result. In the low areas along the channel of the Grande Ronde River, the low stage of the water table is controlled by the stage of the river.

LONG-TERM FLUCTUATIONS

In addition to seasonal and annual fluctuations, long-term changes in water levels occur. The hydrographs on plate 4 and figures 15 and 16 display several features of long-term fluctuations. The steady rise of the water level in well 1/39–17L1 (fig. 16) from a low of 25.5 feet below the land surface in October 1942 to a low of 11.2 feet in November 1957 is an example of such a long-term change. Annual high water levels observed during the period of record ranged from 25.0 feet below the land-surface datum in January 1942 to about 6.8

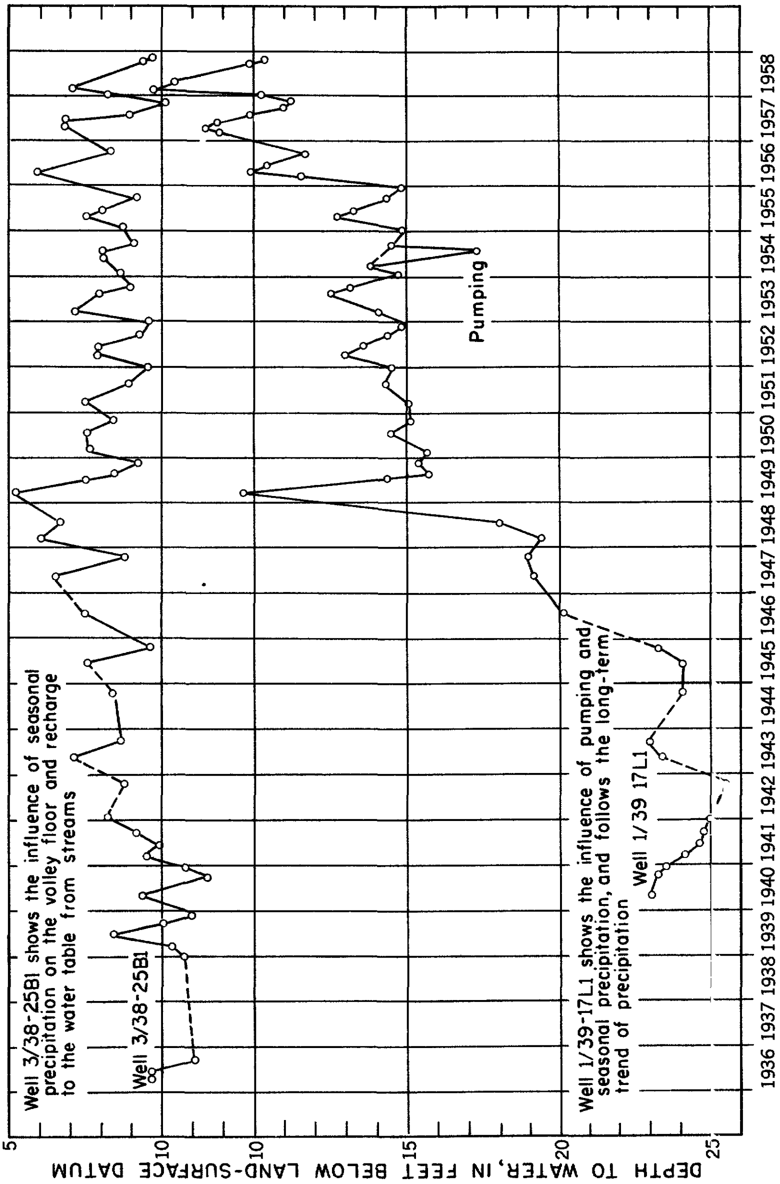

FIGURE 16.—Graphs showing water levels in well 3/38-25B1 near the La Grande airport and well 1/39-17L1 about 1 mile north of Imbler.

feet below in February 1958. This progressive rise in the water apparently coincides with greater annual recharge during years of greater than average rainfall, which have characterized the period since 1940, as shown on figure 2. The cumulative deviation from average rainfall reached a low in 1939 and then displayed a general rise to above average at the present time. The time lag between the lows of the precipitation deviation and the lows of the water levels spans the water years 1939 to 1942. Such a lag suggests that several years of increased precipitation may be necessary before a decline of the water table is halted and a general rise begins.

The hydrographs of wells 3/38–25B1 and –10B1, on La Grande alluvial fan, show no pronounced rise such as that shown by well 1/39–17L1. However, since 1939, water levels in these two wells have shown a rise of about 1 foot in both the annual high and the annual low water level.

WATER-TABLE MAPS

Plates 5 and 6, water-table maps of the Grande Ronde Valley for November 1957 and February 1958, show the approximate shape of the water table at both the low stage in November and the high stage in February. Certain features of the water table persist throughout the water year. The contours on the water-table map show also the general direction of movement of the ground water. As a ball rolls downhill at right angles to the contour lines of a hill, so ground water moves through the permeable material of the earth in the direction of the hydraulic gradient and at right angles to the contours on the water table.

From the point where the Grande Ronde River leaves its mountain canyon west of La Grande, it flows to a point about 3 miles west of Island City over a broad alluvial fan. Here the contours on the water table show that the river contributes water to the ground-water reservoir. Because of the lack of adequate data, such a loss or gain by the streams is shown less clearly on other alluvial fans of the valley.

In the southwest quarter of T. 1 S., R. 39 E., and extending into the northeast and northwest quarters of T. 2 S., Rs. 38 and 39 E., the water table is at an altitude at least 2,740 feet above mean sea level. The existence of this isolated high indicates that the level of the water table is maintained entirely by infiltration from local precipitation, and that the lateral movement of the ground water is away from this area, principally toward Willow Creek on the west and north and the Grande Ronde River on the east.

CONSTRUCTION OF WELLS

WELLS IN THE VALLEY FILL

In the Grande Ronde Valley a few driven pipe wells and some dug wells are in use. A few of the wells dug in gravelly beds provide moderately large quantities of water. Well 2/38–33N1, a dug well 12 feet deep in gravel, is reported to have been pumped at a rate of 400 gpm for 6 hours with 3 feet of drawdown. These dug wells are, in general, wide, shallow holes excavated either by hand or by mechanical excavator. Most are cribbed for only part of their depth.

Most of the wells in the Grande Ronde Valley are drilled by the cable-tool (percussion, churn-drill) method into one of the sand or gravel units of the valley fill and are cased for the full depth with 4- or 6-inch casing. The casing finish usually is of the nonperforated, open-end type. In this type of well all the water pumped must enter through the open bottom of the casing. If the casing is "bottomed" in sand, gravel may be placed in the bottom of the well to act as a filter. The yields of wells constructed in this manner in sand or gravelly sand are commonly less than 30 gpm, and considerable sand is found in the water pumped from the wells. When pumped at greater rates, most of the wells yield even larger amounts of sand. Because of the sand problem, most of the wells are pumped at restricted rates. The dissatisfaction arising from wells discharging sand in the water is so widespread that some comments on well construction in the valley alluvium are listed below.

In a few wells, the first length of casing installed is slotted by a cutting torch. The well is then drilled by customary cable-tool methods until a satisfactory water-bearing zone or a predetermined depth has been reached. In most such wells the slot openings of the preperforated casing are too coarse to screen out the sand from the well.

Little has been done with standard well-construction methods, such as perforation of the casing opposite an aquifer after the casing is in place, the use of well screens or machine-perforated pipe for sand aquifers, and the gravel packing of wells. In addition, the wells usually are not thoroughly developed and cleaned.

By using properly perforated casing, sand-free wells can be obtained in some of the alluvial fans. The process must be founded on an accurate log and correct samples kept by the driller. That is, the log must contain information on the depth and thickness of water-bearing gravel or sand strata and an accurate description of the grain size; and carefully collected samples of the water-bearing materials must be obtained and analyzed to permit selection of the most efficient perforation or screen opening.

After the well casing has been properly perforated, or the screen set, the well is bailed and surged until it yields sand-free water. Further cleaning and development usually is continued as long as the efficiency of the well is being increased.

Where the aquifers include fine sand, or even some types of fine sand mixed with gravel, only screened or gravel-packed or sand-packed wells will yield adequate quantities of sand-free water. A sand- or gravel-packed well is usually constructed by drilling a hole 10 to 24 inches in diameter and centering in it a smaller 6- to 16-inch perforated casing or well screen. Coarse sand or gravel of uniform size, properly selected after an analysis of the aquifer materials, is fed into the annular space between the casings and well bore while the well is surged and bailed. The surging and bailing settles and cleans the pack. The pack must be selected according to the size of the material in the formation. Sand will enter the well if the gravel pack is too coarse.

If the water-bearing formation contains material having a range of grain sizes, proper perforations or correctly sized well screens alone may be used to complete a sand-free well. The proper slot size of perforation or screen for a well in sand and gravel also must be determined from a sieve analysis of the water-bearing material. The size of opening selected is one that will allow the passage of about the finer grained three-fourths of the aquifer material. In the zone immediately surrounding the screen, nearly all the particles smaller than the slot size are drawn through the screen into the well and are pumped or bailed out during the period of development. Farther away from the screen, most of the finer particles are removed but some—the larger ones of this group—remain behind. Still farther from the screen, only the smallest particles are removed. Thus, in the natural gravel envelope developed from the formation, there is undisturbed material a certain distance from the screen, and a transition band of graded material that becomes progressively coarser toward the well.

The advantages of a properly developed natural gravel envelope, a screen, or a gravel pack in a well are: (a) sand-free water can be obtained, (b) drawdown within the well is reduced or well can be pumped at a higher rate at the same drawdown, (c) power and pump costs are lowered, (d) caving is prevented, and (e) the life of the well is lengthened.

Carefully designed wells in sand or sand and gravel can be drilled and developed so as to yield adequate water for economical irrigation. Proper well construction should permit the development and use of much now-unused ground water in the alluvium. Plant-efficiency tests show that even in the coarsest materials the nonperforated, nonscreened, open-end well—as now commonly used in the

Grande Ronde Valley—has greater drawdown, higher pumping and power costs, and a shorter useful life than an adequately designed and properly constructed screened or perforated well. The average well owner will find that he purchases a well like any other piece of equipment, and attention to some details of its construction will result in greater initial cost but long-term savings in its operation. Many technical bulletins are available at libraries and at offices of the Agricultural Extension Service to assist the prospective well owner to making a wise investment.

From the data listed for the present wells in the alluvium (tables 1 and 2), it is apparent that properly designed wells of 8- to 10-inch diameter will yield at least 100 gpm from the sand and gravel of the alluvium at many places in the valley.

WELLS IN THE COLUMBIA RIVER BASALT

Wells in the Columbia River basalt have been drilled by cable-tools. Casings ordinarily are driven through the alluvium and "landed" in the basalt bedrock. In order to prevent leakage from aquifers of higher water pressure to those of lower water pressure, a casing may be installed and pressure grouted with cement into the unweathered bedrock to isolate the aquifer that yields water under the higher pressure. Grouting is commonly used where it is anticipated that an artesian flow will be encountered. Some wells tapping confined water in the Columbia River basalt have lost their original pressure because of the lack of an adequate seal.

Cleaning and developing a well in basalt sometimes requires as much care and thought as developing a well in sand or gravel. Drilling mud, forced into or smeared over the interflow zones by hydrostatic pressure or the churning motion of the drill bit, may block off potential water-bearing zones. This mud can be removed by careful surging or bailing, and treatment with one of the common detergents or wetting agents. A careful record of the water levels observed during drilling will often reveal potential water-bearing or water-depleting layers.

The basalt is not an easy material in which to construct a good, straight well. Careful workmanship, after proper planning and design of these wells, pays dividends in better well performance, longer useful well life, and more economical operation.

USE OF GROUND WATER AND PROSPECTS FOR FUTURE DEVELOPMENT

MUNICIPAL USE

The cities of La Grande, Elgin, Union, and Cove are supplied entirely or in part by central water-distribution systems, whereas in the communities of Imbler and Island City individual wells supply each household. The supply for each community served by central distributing systems is described below.

LA GRANDE

Water for the municipal system of La Grande is obtained from both surface-water and ground-water sources: Beaver Creek and the two artesian wells, 3/38–6H1 and –6H2. About 3,100 service connections were in use in 1957, 2,700 of which were metered. The maximum dependable supply from the Beaver Creek watershed is 3.5 to 4 mgd (million gallons per day), and from the artesian wells combined, about 1.1 mgd. The wells are used mainly during the summer, a time of heavy demand and low runoff from the mountain watershed of Beaver Creek. When the wells are used the water is allowed to flow by artesian pressure to a "clear well" and is pumped from there to the mains and reservoir. The average output from both sources of the La Grande water system is 2 mgd.

ELGIN

The municipal system of Elgin obtains its water from two wells. The city owns a third well, but it is not used at present (1958). About 1,400 people are served by 456 metered connections. The capacity of the system is rated about at 2.4 mgd and the average output is about 0.2 mgd. The two wells used, 1N/39–15J1 and –22B1, have water levels slightly above the land surface but are pumped in order to obtain the quantities of water and the pressure needed for the mains and to supply the regulating reservoir. The pumps discharge about 1,700 gpm to the mains, and a 150,000-gallon reservoir provides storage and maintains pressure during periods of peak demand. The Elgin city wells are good examples of properly situated wells drilled into the Columbia River basalt. The water is of good quality and free from odor or taste. Table 4 gives a chemical analysis of a sample of water from well 1N/39–22B1.

UNION

The city of Union obtains water for its municipal system from Catherine Creek. It is the only municipality in the Grande Ronde Valley that relies entirely on surface water for its supply. Four hundred fifty metered connections serve 1,367 people. The system has a rated capacity of 0.86 mgd and an annual average output of about 0.17 mgd.

COVE

The privately owned supply system of Cove obtains its water from springs. According to records supplied by the Oregon State Board of Health, the system serves 39 houses and 117 people. The capacity of the system is about 6,000 gpd and the average output is reported to be about 3,000 gpd.

The following table summarizes the municipal supplies of the Grande Ronde and Indian Valleys.

Community	Population served (1956)	Source of supply	Capacity mgd	Average output 1957, mgd
La Grande	9,100	Beaver Creek	4.0	2
		2 artesian wells	1.1	1.1
		Subtotal	5.1	3.1
Elgin	1,400	2 wells	2.4	.2
Union	1,367	Catherine Creek	.86	.17
Cove	117	Springs	.01	.003
Total	11,984	All sources	8.4	3.5
		Surface water	4.9	2.2
		Ground water	3.6	1.3

GENERAL CONSIDERATIONS CONCERNING GROUND WATER AS A FUTURE SOURCE OF SUPPLY

A review of the data presented by this report shows that little use is now being made of the ground-water resources available in the upper Grande Ronde River basin. Well logs and water-level records indicate that large amounts of ground water can be obtained economically from the valley alluvium and from the basalt bedrock. Little of the ground water in the alluvium is now used, except for the relatively small amounts that are withdrawn for domestic and stock use. Wells 1/38–24R1 and 4/39–11H1 are the only major irrigation wells in the valley. Their combined yield is about 9 mgd.

At the points where the Grande Ronde River and the several lesser streams enter the valley, permeable sand and gravel underlying alluvial fans will yield large quantities of water to wells that are properly constructed and developed. A well of this type is irrigation well 4/39–11H1, which has been pumped at 3,000 gpm with a drawndown of about 100 feet. The sand and gravel beneath the alluvial fan of the Grande Ronde River have been penetrated by wells from land surface to depths as great as 540 feet in an area extending from the mountain front on the west eastward as far as sec. 5, T. 3 S., R. 39 E. The easternmost well was a deep exploratory well drilled about 4 miles east of Island City.

Most of the sedimentary deposits underlying the main valley floor are lacustrine in origin, and the most permeable are very fine sand and some silt. However, sand-free water for domestic and stock use may be obtained from properly designed screened, or screened and gravel-walled wells.

As previously described in the section on ground-water resources, the water table lies close beneath the land surface in much of the valley. Thus drawing the water table down by pumping water from wells would drain waterlogged land and would have additional beneficial effects. This lowering of the water level would induce more recharge from precipitation and would salvage some of the winter and spring runoff for ground-water recharge.

The colluvium underlying the talus slopes contains some irregularly bedded permeable zones, but it is a difficult material in which to drill successful wells. Only small amounts of ground water have been obtained from the colluvium, except from an occasional layer of clean gravel or boulders. In the area around Cove, drilling is difficult because of heaving sand and boulders and of poor water-yielding materials, such as sandy and gravelly clay.

Much additional ground water is available for development in the basaltic rocks underlying the valley. Beyond the points at which the bedrock disappears beneath the alluvium at the edges of the valley plain, the depth to bedrock is known in only a few places. Those wells which have reached and penetrated the basalt beneath the valley fill in the Grande Ronde and Indian Valleys have obtained large quantities of water. All these wells have relatively high water levels, and water flows from some of them. Wells in Indian Valley have encountered bedrock relatively near the surface. In the Imbler-Summerville area the basalt has been reached at depths of about 600 feet by 2 wells (table 1). Well 1/38–24R1 has been tested at a flowing yield of 3,500 gpm with about 95 feet of drawdown. In the La Grande area also, water is obtained from bedrock by 4 wells.

Certain factors should be recognized in the planning of a well to tap water in the Columbia River basalt beneath the valley floor. In few places is the depth to bedrock definitely known. Although the basaltic rocks are believed to underlie the alluvium throughout the valley, they do not do so at a uniform depth. The buried rock surface beneath the alluvium may be as irregular as some of the blocky uplands surrounding the valley. The northwest-trending linear fault system and its abrupt displacements of the rock surface probably continue in the basalt beneath the valley. Consequently, irregularities in the depth necessary to reach the basalt can be expected from place to place on the valley floor. The greatest depth now known is in excess of 2,000 feet in exploratory well 3/39–5J1 (tables 1 and 2), which was drilled 2,020 feet and, according to the driller's information in table 2, did not encounter the Columbia River basalt.

Although drilling into the basalt at some places beneath the valleys may involve considerable uncertainty as to the depth and condition of the basalt encountered, there are many places around the edges of the valleys, such as the south edge of Pumpkin Ridge, where wells can be drilled into the gently sloping basalt at relatively shallow depth beneath the valley alluvium.

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BASIC DATA

TABLE 1.—*Records of representative wells in the upper Grande Ronde River basin*

Well number: See p. 4 for description of well-numbering system.
Topography and approximate altitude: Af, alluvial fan; Fp, flood plain; Hs, hillside; Ts, talus slope; Vb, bottom of small valley; Vp, valley plain; Vt. valley terrace. Altitude of land-surface datum at well, in feet above mean sea level, from surveys by the U.S. Engineer Department, or interpolated from topographic maps of the U.S. Bureau of Reclamation.
Type of well: Bd, bored; Dg, dug; drilled; Dn, driven.
Ground-water occurrence: C, confined, artesian; U, uncomfined, water-table.
Water level: Depths given in feet and decimal fractions measured by the Geological Survey; those in whole feet reported by owners or driller. For flowing well whose static head is known, a "+" precedes the water level; a flowing well whose static head is not known is indicated by "Flows." All levels are related to land-surface datum at well.
Type of pump: C, centrifugal; J, jet; N, none; P, piston or plunger; S, submersible; T, turbine.
Use of water: D, domestic; Ind, industrial; Irr, irrigation; N, none; O, observation; PS, public supply; S, stock
Remarks: Ca, chemical analysis in table 4; dd, drawdown; ft, feet or foot; gpm, gallons per minute; H, hydrograph included in this report; L, log in table 2; Pf, perforated, perforations; Temp, temperature in degrees Fahrenheit. Remarks on the adequacy and dependability of water supply, general quality of water, and materials penetrated were reported by owners, tenants, drillers, and others.

Well	Owner or occupant	Topography and altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone (s)			Ground-water occurrence	Water level		Type of pump and yield (gallons per minute)	Use	Remarks
							Depth to top (feet)	Thickness (feet)	Character of material		Feet below datum	Date			
	T. 1 N., R. 38 E.														
21C1	Mr. Schmittle	Ts, 3,175	Dr	67	6	36			Gravel	U	10.45	5-25-57	P	D	Pumped 30 gpm, dd 24 ft. Ca.
22N1	F. M. Doles	Ts, 3,100	Dr	89	6	89				U	12.4	5-25-57		D	
22N2	C. Hamilton	Ts, 3,100	Dr	200	6	180			Clay, sandy				N		Drilled entirely in sandy clay.
22N3	do	Ts, 3,100	Dg	18	36	18			Gravel in clay	U	11.54	5-25-57	N		
25R1	L. R. Starr	Vb, 3,000	Dr	161	6	161	120	23	"Basalt, broken, and sand."	U	114	4- -48		D	Bailed 20 gpm, dd 26 ft. Pf 4 per ft from 125 to 150 ft. L.
28L1	J. Jarvis	Ts, 3,150	Dr	27	6	23.5	24	3	Sand, medium	U	14	2-19-53	3	D	Aquifer overlain by 24 ft of mixed gravel, boulders, and clay.
33J1	C. H. Hanson	Ts, 2,985	Dr	24	6	21	23	1	Sand	U	8	2-15-53	10	D	Aquifer overlain by 23 ft of gravel and clay.
34M1	Mike Royes	Af, 2,937	Dr	350	6	280				U	87	12- -49	N	N	L.
	T. 1 N., R. 39 E.														
2E1	Lloyd Wickens	Vb, 2,600	Dg	25	1.25					U			C	D	Well filled around 1¼-inch pipe.

3K1	Hanford Reed	Vt, 2,625	Dr	340	6	280				C	35		J	D, S	Owner reported artesian flow at about 130 ft, which was cased off; quicksand at 340 ft rose to 240 ft.
8A1	Clarence E. Merritt.	Ts, 2,900	Dr	440							37	1954	J	D	
9E1	W. S. Cobb	Ts, 2,800	Dr	123	6						20	1953	J	D	Pumping yield 3½ gpm.
15J1	City of Elgin (Well 2).	Af, 2,550	Dr	350	12	287.5	278	72	Basalt	C	Flows		T, 590	PS	Pumping of well 15J2, 50 ft distant, causes flow to stop. On 6/21/41 pumped 300 gpm, dd 38 ft; 438 gpm, dd 50 ft; 590 gpm, dd 62 ft. Flowed 85 gpm on that date. L.
15J2	City of Elgin (Well 1).	Af, 2,550	Dr	290	8		275	15	Basalt	C	Flows			PS	Now capped, formerly flowed 125 gpm. Influenced by 15J1. Pumped 400 gpm, dd 106 ft. Temp 52.
16G1	R. B. Kennedy	Af, 2,600	Dr	308	6	280	281	27	do	C	Flows			Ind	L, Temp 48.
16G2	David Clay	Af, 2,600	Dr	47	6	42	40	5	Gravel, fine	U	12	5-28-54		D	Aquifer overlain by 40 ft. of gravel, clay, and saudy clay. Pumped 1/3 gpm, dd 10 ft. Temp 48.
22B1	City of Elgin (Well 3).	Fp. 2,550	Dr	655	{20 16 12}	{61.8 429 620}	618	33	Basalt	C	Flows		T, 1,095	PS	Pumped 1,095 gpm, dd 87 ft; 552 gpm, dd 27 ft; flows 500 gpm when not pumped. Ca, L.
25N1	Peter Westenskow.	Vb, 2,700	Dr	143	6	80	136	7	Sand and gravel	C	Flows	2- 2-55		D	Flows 1½ gpm; pumped 10 gpm, dd 30 ft. L.
29E1	Mrs. Lois Barton	Vb, 3,100	Dr	60	6	51	49	11	Sand, yellow-green.	U	37	6-21-52	5	D	Pumped 5 gpm, dd 14 ft. Aquifer overlain by 49 ft of clay, rocks, and coarse sand.
30L1	H. C. McDonald	Hs, 3,000	Dr	114	6	102	{101 105}	4 9	Sand do	}U	50	8- -48	8	D	Pumped 8+ gpm, dd 50 ft. Hole filled gravel to 102 ft.
32P1	A. F. Hug	Hs, 3,000	Dg	17.5	36					U	11.5	5- 1-57	C, 10	D	
32P2	do	Hs, 3,000	Dg	10.4	36					U	1.65	5- 1-57	N	S	Flows at times.
32Q1	J. Works	Hs, 3,100	Dg		24					U	1.55	do	N	D, S	

TABLE 1.—*Records of representative wells in the upper Grande Ronde River basin*—Continued

Well	Owner or occupant	Topography and altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone (s): Depth to top (feet)	Water-bearing zone (s): Thickness (feet)	Water-bearing zone (s): Character of material	Ground-water occurrence	Water level: Feet below datum	Water level: Date	Type of pump and yield (gallons per minute)	Use	Remarks
	T. 1 S., R. 38 E.														
2C1	Howard Fisher	Af, 2,805	Dr	132	6	29	130	2	Sand	U	8	1-21-53	J	D	Pumped 30 gpm, dd 16 ft. L.
2R1	Fred Behrens	Af, 2,760	Dr	103	6	103				U	6	4- -48	J	D	Bailed 10 gpm. L.
4Q1	Albert Hopkins	Ts, 2,925	Dr	200	6	189			Clay and gravel.	U	18	10- 4-53		D	Casing blasted at 99 ft and 47 ft. L.
4R1	B. M. Cantrell	Ts, 2,890	Dr	99	6	N				U	20	7- -48		D	Bailed 3 to 5 gpm for 1 hr.
11F1	Lyle Slack	Af, 2,735	Dr	33	6	30.5	10	22	Gravel, coarse, and clay.	U				D	Pumped 17 gpm; 10 ft of topsoil and sandy clay overlies aquifer.
11F2	do	Af, 2,735	Dr	35	6	32	34	1	Sand	U				D	Pumped 4 gpm, dd 20 ft. L.
11L1	Marion Wagner	Af, 2,715	Dr	98	6	94	96	2	Sand, coarse, black.	U	9.75	7-10-52		D	Pumped 10 gpm, dd 24 ft. L, Temp 50.
12K1	Mrs. Correill	Af, 2,708	Dr	61	6	41	60	1	Sand	U	2.92	5-24-57	C, 10	D	Pumped 20 gpm, dd 12 ft. Ca, H, L.
12K2	Ivan Calhoun	Af, 2,705	Dr	23	4	20	9	14	Gravel	U	20		P	S	Pumped 10 gpm. L.
12L1	H. P. Billerbeck	Af, 2,712	Dr	67	6	67	62	5	Sand, fine	U				D	Do.
12Q1	Mrs. J. Ham	Af, 2,705	Dr	4	6-5	96	95	5	Sand, brown	U	8	11-10-54		D	Pumped 10 gpm, dd 50 ft. 5-inch Pf liner set 93 to 114 ft. L.
							105	9	Sand, gravel, some clay.						
12Q2	John Tuck	Af, 2,704	Dr	50	6	46	49	1	Sand	U	4	10-22-51		D	Pumped 33 gpm, dd 13½ ft. L.
15L1	Cleo Booth	Ts, 2,835	Dr	48.7	48				Gravel and sand.	U	21.31	5-25-57		D	Ca.
15Q1	Alfred Arnoldus	Ts, 2,820	Dr	95	6	93	94	2	Sand	U	26	7-19-52	J, 10	D	Pumped 10 gpm, dd 10 ft. Cemented gravel and clay from surface to aquifer. Temp 50.
16A1	J. P. Lively	Ts, 2,915	Dr	35	6	32	30	5	Sand and boulders.	U	12.4	5-24-57	J, 5	D	Pumped 5 gpm, dd 14 ft.
22C1	Harvey Frizzell	Ts, 2,840	Dr	60	6	46.5	51	4	Gravel	U	21	12-7-51		D	Pumped 10 gpm, dd 18½ ft. L.
22F1	Rudy Michel	Ts, 2,850	Dr	60	6	53	24	36	Sand and gravel in clay.	U				D	Pumped 30 gpm, dd 10 ft. 24 ft of clay and boulders overlying aquifer.

24R1	H. L. Wagner	Vt, 2,750	Dr	1,150	12 10 8	676 746 1,105	665	485	Basalt and andesite.	C	+100	8-9-50	Flows, 3,500	Irr	Flowed 3,500 gpm, dd 96 ft. Ca, H, L.
27N1	R. E. Vandermulen.	Ts, 2,825	Dg	9	60				Colluvium	U	5.8	7-27-57	P	D	Reported to go dry in late summer.
34C1	T. Teeter, Jr	Ts, 2,790	Dr	35					do	U			P	S	
	T. 1 S., R. 39 E.														
4N1	Don McKinnis	Hs, 2,750	Dr	23.0	6					U	13.62	5-1-57	J, 5	D	Ca.
5N1	James McKinnis	Vb, 2,725	Dr	60	8					U					Temp 54.
8B1	Cap Tuttle	Vt, 2,725	Dr	116	6	112				U	43.98	5-23-57	J	D	Owner reported "quicksand" at 45 to 49 ft, sand and clay to bottom. Temp 53.
8H1	Mr. Hauts	Vt, 2,710	Dr	300	6	300					4	1935	J	D	Formerly supplied schoolhouse.
8M1	George Royes	Vt, 2,730	Dr	150	6					U			J, 10	D	Finished in blue clay at 150 ft.
17C1	H. Huron	Vt, 2,745	Dr	65	6	65			Sand	U	30	1947	J	D	
17C2	do	Vt, 2,740	Dr	54	7	54			do	U	11.4	5-1-57	N		Supplied water for 1,700 sheep. H.
17D1	M. J. Goss	Vt, 2,738	Dr	70	6	54	68	2	do	C			10		Sand to 60 ft, clay to 68 ft; hole backfilled with gravel to 53 ft.
17K1	W. P. Rawlins	Vt, 2,730	Dr	72	6	48				U	6.89	5-23-57	J	D, S	Finished in blue clay.
17L1	A. F. Furman	Vt, 2,740	Dr	45.6	4				"Sand"	U	23.22	10-10-40	J	D	Ca, H.
17L2	Albert Quebbeman.	Vt, 2,735	Dr	960	8					C	12.00	5-23-57	J	D, S	Flowed when drilled in 1912; supplied water for 80 acres.
17P1	Clayton Fox	Vt, 2,733	Dr	750	4					C			J	D, S	Flowed when drilled about 1900. Pumps "dry" in 3 to 4 hrs.
18M1	Summerville Cemetery Dist.	Vt, 2,755	Dr	90	6					U			P	Irr, PS	Supplies water for two lawn sprinklers.
18M2	do	Vt, 2,755	Dr	960	6 5	960	600		Basalt?	C	Flows	9- -57	N	N	Flows 40 gpm; drilling in progress in 1957.
20F1	Olin Hopkins	Vt, 2,742	Dr	64	6	62	63	1	Sand	U	10	5- -53			Pumped 20 gpm, dd 15 ft. L.
20L1	Otto Geddes	Vt, 2,730	Dr	377	6					U			C, 20	S	Ca, L.
20L2	Dwight Hopkins	Vt, 2,720	Dr	135	6	94				U	13	2- -52	J	D	Pumped 13 gpm, dd 50 ft. L.
20Q1	Tom Ruckman	Vt, 2,717	Dr	126	8	85	119	7	Sand, blue	U	14	10- -52	J	D	Pumped 20 gpm, dd 27 ft. L, Temp 51.
29G1	U.S. Engineer Dept. (W-5).	Fp, 2,680	Dr	15	1.25	14				U	5.0	2-14-56	N	O	
29H1	U.S. Engineer Dept. (W-6).	Fp, 2,675	Dr	17.9	1.25	17.9				U	6.0	2-14-56	N	O	

TABLE 1.—*Records of representative wells in the upper Grande Ronde River basin*—Continued

Well	Owner or occupant	Topography and altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone (s): Depth to top (feet)	Water-bearing zone (s): Thickness (feet)	Water-bearing zone (s): Character of material	Ground-water occurrence	Water level: Feet below datum	Water level: Date	Type of pump and yield (gallons per minute)	Use	Remarks
	T. 1 S., R. 39 E.—Continued														
30A1	Mr. Osborne	Vt, 2,749	Dr	165	4					U			P	D, S	Supplied water for 1,700 sheep.
32D1	Wm. Ruckman	Vt, 2,745	Dg	15	9.5				Sand and gravel	U	5.22	5-24-57	N	D, S	
32D2	do	Vt, 2,745	Dr	250	6	250				C	+10.25	5-24-57	C	D, S	Static head of about 20 ft when drilled (1912?). Temp 49.
32E1	K. R. Brown	Vt, 2,750	Dr	64	6	49	63	1	Sand	U				D	L.
32M1	Otto Geddes	Vt. 2,752	Dr	74	6	57	73	1	Sand	U	8.24	5-24-57	C, 10	S, D	H, L.
32M2	do	Vt, 2,751	Dr	125	6	109	124	1	Sand, coarse	U			C, 20	D	Sand below 15 ft is water bearing. L.
	T. 2 S., R. 37 E.														
35E1	J. P. Baron		Dr	78	4	42	42	36	Basalt(?)	C	14	9- 3-58		D	Bailed 10 gpm for 1 hr, dd 8 ft. L.
	T. 2 S., R. 38 E.														
8R1	L. R. Hoxie	Ts, 2,975	Dr	125	5	89	68	28	Gravel	U	14	10-21-54		D	Casing Pf 20 to 30 ft and 70 to 80 ft. Pumped 2 gpm, dd 45 ft. L.
13D1	Harlow Speckhart	Vt, 2,760	Dr	120	6	80	120		do	U?	18	1950	J	D, S	Blue clay from 80 to 120 ft. Ca.
14K1	do	Vt, 2,710	Dr	71.0	6					U	5.95 4.65	5-27-50 2-18-58	P	S	
16C1	R. E. Hall	Ts, 2,875	Dr	175	6	118	170	5	Sand	U	36.64	5-27-57	J	D	Ca, L.
16C2	do	Ts, 2,875	Dr	309	6	50				U	20	8-10-57	N	N	L.
16P1	Ellis McCoy	Ts, 2,775	Dr	201	6	132	200	1	Sand	U	6	7- -55		D	Pumped at 20 gpm, dd 45 ft. L.
21C1	Lester Peach	Ts. 2,800	Dr	35	6	35	33	2	do	U	5	10- -57			Pumped 18 gpm for 24 hrs., dd 12 ft. L.
21N1	Harlan Long	Hs, 2,900	Dr	103									C	D, S	
25E1	L. V. Carter	Af 2,705	Dn	70						U			C	D	
25E2	do	Af, 2,705	Dg	6.9	36				"Boulders and clay"	U	4.61	7-29-57	C	Irr	Pumps "dry" in 1 hr.
26F1	Paul Gettle	Af, 2,715	Dn	12	2					U			C, 15	D, S	Water stains porcelain yellow.
27F1	R. C. Alexander	Af, 2,734	Dr		6					U			C	D	
27F2	do	Af, 2,734	Dg	14.0	48	14			Gravel	U	4.42	5-27-57	N	O	

27R1	S. H. Burleigh	Af, 2,725	Dr	95	6	94.8	64	31	Sand and gravel	U	6.06	7-26-57	J	D	Pumped 10 gpm, dd 40 ft. Ca, L.
28D1	G. L. Crane	Hs, 2,900	Dg	65	72				Gravel	U			C	D, S	Adequate for 2 lawn sprinklers. Temp 57.
28H1	C. W. Raney	Af, 2,775	Dr	61	6					U	13.7	7-27-57	C	D, S	Supplies water for 20 cattle.
28J2	Ralph Berry	Af, 2,755	Dr	41	6	41	22	19	Sand and gravel	U	20	5-25-57	J	D	Aquifer overlain by clay. Bailed 20 g for 1hr, dd 8 ft. Ca.
29R1	Dave Turner	Af, 2,815	Dr	95	8	95	88	7	Sand, coarse, and gravel.	U	60	4-19-57		D	Bailed 20 gpm, dd 17 ft. L, Temp 50.
31P1	Valley Sausage Co.	Af, 2,820	Dr	105	6	94	99	6	Sand, blue, and fine gravel.	U				Ind	L.
31R1	Harold Yoho	Af, 2,793	Dr	102	6 4	43 88	83	19	Sand, fine, with clay and streaks of coarse sand.	U	6.85	5-29-57	C	Irr	Pumped 14 gpm, dd 13 ft. H, L, Temp 54.
31R2	Mr. Worthington	Af, 2,798	Dr	200	6	169				U	25	8- -48		Irr	L.
32F1	Claude Wright	Af, 2,786	Dr	22	6	18	5	17	Clay, gravel, and sand.	U	11	6- 9-52			Pumped 30 gpm, dd 6 ft. Clay and soil overlie aquifer.
32L1	Garrett & Berry	Af, 2,785	Dr	34	6	31.5	26	6	Sand	U	9	10-23-52		D	Pumped 5 gpm, dd 20 ft. L.
33G1	Clyde C. Jones	Af, 2,756	Dg	12	72x96					U	4	1953	C, 180	Irr	Irrigated 2 acres, July to Sept. 1953.
33L1	W. E. Garrett	Af, 2,764	Dg	16	48x48		5	11	Sand and gravel	U	8	1954	C, 90	Irr	Pumped 80 gpm for 24 hrs., dd 4 ft. Black soil overlies aquifer.
33L2	Edward Patterson.	Af, 2,761	Dr	41	6	41	24 34	2 7	do do	U	11	12-27-56			L.
33N1	C. E. Primm	Af, 2,763	Dg	12	84x84		5	7	Gravel	U	8	1930	N	N	Pumped 400 gpm for 6 hrs., dd 3 ft. Aquifer overlain by soil. Pumped "dry" in August 1952.
33P1	Zack Chandler	Af, 2,758	Dr	48	6	45				U	14	11- -55			In sand, gravel, and clay; not yet completed when visited.
34G1	Claude Wright	Af, 2,735	Dr	34	6	33	33	1	Sand, coarse	U					Dug well to 15 ft; sandy clay and gravel from 15 to 33 ft.
34G2	do	Af, 2,735	Dg	14.5	48					U	1.62	7-26-57	C	S, Irr	
34G3	Frank Stewart	Af, 2,737	Dn	18	2				Gravel	U			C	Irr	Equipped with well-point screen.
34G4	do	Af, 2,737	Dn	18	2				do	U			C	D	In basement; flows in spring.
34K1	Rebekah Bond	Af, 2,737	Dg	16.0	36				do	U	1.92	5-26-57		Irr	Irrigated 30 acres of pasture. Temp 52.
34P1	S. B. Rasmussen	Af, 2,741	Dr	77	5	75			Sand and gravel	U			D		L.

TABLE 1.—*Records of representative wells in the upper Grande Ronde River basin*—Continued

Well	Owner or occupant	Topography and altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone (s)			Ground-water occurrence	Water level		Type of pump and yield (gallons per minute)	Use	Remarks
							Depth to top (feet)	Thickness (feet)	Character of material		Feet below datum	Date			
	T. 2 S., R. 39 E.														
3N1	U.S. Engineer Dept. (W-10).	Fp, 2,680	Dr	15.5	1.25	14.5			Silt, sandy	U	6	2-15-56	N	O	In sandy silt.
3N2	U.S. Engineer Dept. (W-9)	Fp, 2,680	Dr	13.9	1.25	13.9			do	U	3	2-15-56	N	O	Do.
5J1	Tom Ruckman	Vt, 2,725	Dr	65	6	62	63	2	Sand	U	15	2-12-52			Aquifer overlain by 63 ft of sand and clay. Pumped 8 gpm, dd 25 ft. Water brown and cloudy.
7J1	Alicel School Dist.	Vt, 2,743	Dr	59	4	59			do	U					
7K1	Tom Ruckman	Vt, 2,753	Dr	42	6					U	9.77	5-24-57	N		
7K2	Douglas Westenhaver.	Vt, 2,752	Dr	120	6	110	117	3	Sand	U	13.29	5-24-57	T	Ind	Pumped 45 gpm, dd 30 ft. L.
7L1	J. Michael	Vt, 2,760	Dr	100	4					U	10.62	5-24-57	J	D	
7P1	do	Vt, 2,752	Dr	105	8	101	101	4	Sand	U	11.29	5-25-57	T	Irr	Pumped 30 gpm, dd 22 ft. H, L.
13B1	Don Gray	Ts, 2,725	Dr	109	6	103	104 108	4 1	Gravel(?) Sand	U					L.
13M1	U.S. Engineer Dept. (W-11).	Fp, 2,682.0	Dr	21.5	1.5	19		21.5	Silt, sandy	U	6.6	12-20-55	N	O	In sandy silt.
14R1	U.S. Engineer Dept. (W-12).	Fp, 2,684.9	Dr	26	1.5	24		26	do	U			N	O	
16N1	U.S. Engineer Dept. (W-45).	Vt, 2,720	Dr	23.4	1.5					U	10.42	5-23-57	N	O	
17D1	M. J. Goss	Vt, 2,745	Dr	70	6	63				U	48	7-15-49			Filled with rock to bottom of casing.
18P1	Wren Case	Vt, 2,755	Dr	195	6	177	175 194	15 1	Sand Gravel, fine	U	20	4-21-50			Pumped 20 gpm, dd 32 ft. L.
23Q1	Darrel Lampkins.	Fp, 2,705	Dg	35	48x48				Sand	U			J	D, S	
25H1	U.S. Engineer Dept. (W-14).	Fp, 2,685.0	Dr	23	1.5	18		23	Silt, sandy	U	8.5	11-30-50	N	O	
25Q1	U.S. Engineer Dept. (W-15).	Fp, 2,684.3	Dr	24	1.5	19		24	do	U	4.44	12-6-55	N	O	

25R1	U.S. Engineer Dept. (W-13).	Fp, 2,685.3	Dr	26.3	1.5	21.9				U			N	O	
26B1	Darrell Lampkins.	Fp, 2,710	Dg	30	48x48				Sand	U			N	N	
26L1	U.S. Engineer Dept. (W-43).	Fp, 2,700	Dr	23	1.5	23				U	13.54	7-29-57	N	O	
28J1	Mr. Jones	Vt, 2,700	Dr	184	6	125			Sand	U	7.57	do	P	S	
30H1	Carl Perkins	Vt, 2,715	Dr	45.3	6					U	8.35	do	C	D	Ca.
	T. 2 S., R. 40 E.														
19P1	Elmer Bros.	Fp, 2,695	Dr	200	6				Sand and gravel	U	11	1956	C	D	Supplies two families. Water carries "black sand" when well is heavily pumped.
30R1	Clara Breshears	Fp, 2,685	Dr	250	6				Sand, black	U			J	D	Temp 55.
30R2	do	Fp, 2,685	Dr	250	6				do	U			P	S	Temp 55.
33C1	Mr. Hostadt	Ts, 2,475	Dr	330	6				Sand	C	Flows		J, 10	D, S	Flows when not being pumped.
	T. 3 S., R. 38 E.														
2L1	J. O. Anson	Af, 2,715	Dr	49	6	49	44	5	"Gravel, loose and flowing sand."	U	10	9-22-50	J	D	Soil, sand, and clay overlie aquifer.
3B1	R. Goodnough	Af, 2,736	Dg	25	8		4	16	Gravel	U	6	3- -34	P	Irr	Irrigates 3 acres. Pumped 300 gpm for 1 hr., dd 20 ft.
3L1	R. R. Leonard	Af, 2,729	Dg						do	U	4	12-28-56	C	Irr	Pit dug by the Oregon State Highway Dept. Supplied 5.5 acre-ft in 1956. Yielded 256 gpm, dd 2 ft.
3L2	C. Keller	Af, 2,732	Dr	34	6	32.5	33	1	Sand, coarse	U	2.5	11- -57			Yielded 30 gpm., dd 15 ft.
4E1	G. W. Andrews	Af, 2,762	Dg	18	8								C, 138	Irr	Irrigated 5 acres.
4E2	Manley Williams	Af, 2,762	Dr	44	5	32			Sand and gravel	U			C	D	Yielded less than 2 gpm. L.
4E3	George Ellis	Af, 2,763	Dr	20	6	20	16	4	Sand, coarse and fine.	U	7	4- 3-53	J	D	Aquifer overlain by 14½ ft of gravel. Pumped 5 gpm, dd 17½ ft. Pf 18 in. from boottm. Dynamited at 19-, 17-, and 16½-ft levels; surged dry ice.
4E4	do	Af, 2,763	Dr	80	6	37.5	38	1	Sand	U	10	10-16-52	J	D	Pumped 5 gpm, dd 10 ft. L.

TABLE 1.—*Records of representative wells in the upper Grande Ronde River basin*—Continued

Well	Owner or occupant	Topography and altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone (s): Depth to top (feet)	Water-bearing zone (s): Thickness (feet)	Water-bearing zone (s): Character of material	Ground-water occurrence	Water level: Feet below datum	Water level: Date	Type of pump and yield (gallons per minute)	Use	Remarks
	T. 3 S., R. 38 E.—Continued														
4F1	E. E. Halsey	Af, 2,758	Dr	43	6	36	42	1	Sand, coarse, hard.	U	12	4- 2-52	J	D	Pumped 40 gpm, dd 12 ft. L.
4F2	Leonard Spears	Af, 2,760	Dr	36	6	33	34	2	Sand	U	16	3- 6-52	J	D	Pumped 40 gpm, dd 6 ft. L.
4F3	do	Af, 2,760	Dr	44	6	39	40	4	do	U	17.5	3-19-52	J	D	Pumped 40 gpm, dd 15 ft. L.
4L1	J. P. Corriell	Af, 2,756	Dr	46	6	42	44	2	do	U	13	8- -55	J	D	Pumped 20 gpm, dd 1 ft. after 10 hrs. L, Temp 48.
4L2	Jones Bros. Heating.	Af, 2,756	Dr	40	6	38	40		do	U			J	D	Yields 10 gpm.
4L3	Wallace Cass	Af, 2,757	Dr	45	6	40	41	4	Sand, coarse	U	13.5	2- 7-52	J	D, PS	Yields 40 gpm, dd 5 ft. L.
4L4	do	Af, 2,757	Dr	42	6	40	38	4	Sand	U	15	1952	J	D, PS	L.
4M1	W. M. Jeffers	Af, 2,761	Dr	180	4 3	149 180	123 150 177 179	27 27 2 1	Sand, gravel, and clay. Clay, gray, and gravel. Gravel. Gravel and clay.	U	19	12-27-56	J	D	Bailed 9 gpm, dd 111 ft. Casing. Pf from 139 to 180 ft. L, Temp 53.
4M2	F. M. Novak	Af, 2,760	Dr	39	6	30	23 38	15 1	Gravel Sand	U	23	3- -51	J	D	Pumped 30 gpm, dd 4 ft. Gravel between soil and aquifer.
4M3	H. E. Luther	Af, 2,760	Dr	50	6	44	47	3	Sand and gravel, fine.	U	14	1- -52	J	D	pumps 7½ gpm, dd 21 ft. L.
4N1	Keith Pratt	Af, 2,758	Dr	31	6	27	23	7	Sand and gravel.	U	12.5	10- -53	J	D	pumped 30 gpm, dd 5 ft. L, Temp 55.
5F1	Floyd Akers	Af, 2,783	Dr	15	6	14	30 4	1 11	Sand Gravel and boulders.	U					Aquifer overlain by 4 ft of soil.
5M1	Union Pacific Ry	Af, 2,783	Dr	1,435	10 8 6 4.5 3	312 740 835 1,090 1,435	845	590	Basalt and tuff alternating layers of.	C	+135	1927	C	Ind	Flowed 280 gpm after drilling. Ca, L.

M2	do	Af, 2,782	Dr	1,536	18 16 12	1,016 1,336 1,536			do	C	+122	1942	Flows, 289.	Ind	At 1,490-ft depth flowed 900 gpm 2-20-42, 360 gpm 3-12-43; 171 gpm 12-28-44. At 1,523 ft flowed 334 gpm. At 1,528 ft flowed 355 gpm. At 1,531 ft flowed 400 gpm. At 1,536 ft flowed 435 gpm, 1-22-45; 256 gpm, 8-11-45; 235 gpm 8-22-45; 289 gpm 2- -48. Ca. L.
5P1	Hub City Food Center.	Af, 2,780	Dr	93	5	67.5	67 90	3 3	Gravel Sand	U	12	12- -48	J	Ind	Pumped 20 gpm, dd 5 ft. L.
5R1	Iver Masterson	Af, 2,764	Dr	57	6	43	56	1	Sand and gravel	U	9	1- -56	J	D	Pumped 20 gpm for 3 hrs., dd 8 ft. L.
5R2	Mr. Prouty	Af, 2,765	Dr	25	6	21	22	3	Sand	U				D	Soil, gravel, sand and clay overlie aquifer.
6H1	City of La Grande (Well 1).	Af, 2,790	Dr	1,035	14				Basalt?	C	+95	1925	N	PS	
6H2	City of La Grande (Well 2).	Af, 2,790	Dr	1,391	14				do	C	+118	1947	F	PS	Wells 6H1 and H2 flow 750 gpm, 1957. Ca.
6K1	Cherry's Florists	Af, 2,795	Dr	39	6	38	37	2	Sand	U	12	6- -55	J, 5	Irr	Pumped 7 gpm, dd 25 ft. L.
6K2	Tom Faulkner	Af, 2,795	Dr	64	6	30	6	30	Gravel and sand	U			J	D	Pumped 20 gpm, dd 5 ft. Casing Pf at 15 ft. L.
6Q1	Dr. Gilstrap	Af, 2,795	Dr	20.4	8	20				U	15.29	5-25-57	J	D	
7A1	L. L. Snodgrass	Af, 2,787	Dr	26	6	26	19	7	Sand and coarse gravel.	U	20	8- -57	J	D	Pumped 20 gpm for 24 hrs., dd 1/4 ft.
7H1	Zion Lutheran Church.	Vt, 2,820	Dr	74	6	25	69	5	Sand, blue	U	21	1- -56	J	D	L, Temp 47.
8A1	Mr. Miller	Af, 2,760	Dr	43	6	38.5	42	1	Sand	U	12	3-27-53		D	Pumped 40 gpm, dd 6 ft. L, Temp 51.
8A2	Frank Edwards	Af, 2,760	Dr	26	6	24	24	2	do	U	12	6- -57		D	Pumped 20 gpm, dd 4 ft. L.
8B1	J. Peterson	Af, 2,768	Dr	19	6	18	3	16	Gravel	U	12	8- -52		D	Pumped 20 gpm, dd 4 ft.
8B2	Mr. Evans	Af, 2,755	Dr	29	6	23.5	3	23	Gravel and sand	U	14	5- -54		D	Pumped 20 gpm, dd 10 ft.
8C1	Jack Hiatt	Af, 2,767	Dn	18	1.5	18	7	11	do	U			C	D	
8C2	do	Af, 2,768	Dn	18	1.5	18	16	2	Sand, brown	U			C	D	
8C3	Lee Johnson	Af, 2,767	Dr	18	6	17	4	13	Gravel	U	10	5- -53		D	Pumped ¼ gpm, dd 2 ft.
8E1	St. Josephs Hospital.	Vt, 2,810	Dr	86	6	80				U	16	1- -58	S	Ind	Bailed 25 gpm for 1 hr., dd 34 ft.

TABLE 1.—*Records of representative wells in the upper Grande Ronde River basin*—Continued

Well	Owner or occupant	Topography and altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone (s)			Ground-water occurrence	Water level		Type of pump and yield (gallons per minute)	Use	Remarks
							Depth to top (feet)	Thickness (feet)	Character of material		Feet below datum	Date			
	T. 3 S., R. 38 E.—Continued														
8H1	La Grande Auto Court.	Af, 2,758	Dr	19	6	16	2 16	14 3	Gravel Sand, cemented	U	11	6- -57		D	Pumped 20 gpm, dd 1 ft.
8J1	L. J. Haynes	Af, 2,757	Dr	71	6	68	70	1	Sand, coarse	U	13	4- -57		D	Pumped 45 gpm. L.
8J2	R. Hill	Af, 2,756	Dr	58	6 5	36.5 56.5	57	1	Sand	U	12	5- -55		D	Pumped 30 gpm, dd 5 ft. L.
8K1	E. E. Teuscher	Af, 2,760	Dg	16	36	16			Gravel?	U	12.53	5-26-57	C	D	Ca, H.
8K2	M. E. Young	Af, 2,760	Dg	15	48	20			do	U	11.69	5-26-57	C	D	
8K3	Clyde Winn	Af, 2,770	Dr	44	6	44	32	12	Gravel and sand	U	20	10- -57	J	D	Bailed 7 gpm, dd 15 ft. Temp 50.
8Q1	N. L. Jacobsen	Vt, 2,774	Dr	46	6	43	45	1	Sand, coarse, and fine gravel.	U	27	5- -52	J	D	Soil, clay, sand, and gravel overlie aquifer. Pumped 14 gpm, dd 16 ft.
8Q2	do	Vt, 2,775	Dr	59	6	54	42	17	Sand and gravel	U	37	5- -51	J	D, S	Cemented gravel overlies aquifer. Pumped 12 gpm.
8Q3	R. E. Badgley	Vt, 2,775	Dr	50	6	46	44	6	Gravel, sandy clay.	U	22	8- -51	J	D	Pumped 5 gpm, dd 24 ft. L.
8R1	J. H. Berry	Vt, 2,755	Dr	33	6	31	32	1	Sand	U	7	11- -52	J	D	Pumped 55 gpm, dd 5 ft. L.
9D1	D. Smith	Af, 2,757	Dr	45	6	40	44	1	do	U	11	5- -53	C	D	Pumped 30 gpm, dd 3 ft. L, Temp 50.
9D2	D. L. Hutchison	Af, 2,757	Dr	41	6	36	40	1	do	U	12	6- -57	C	D	Pumped 30 gpm, "no" dd. L.
9E1	Fred Kaup	Af, 2,756	Dr	44	6	38	43	1	Sand, hard	U	10	3- -57	J	D, S	Pumped 40 gpm, dd 5 ft. Temp 45.
10B1	Union County	Af, 2,728	Dg	14	12	14	2	12	Sand and gravel	U	6.58	5-15-56	N	O	USGS observation well. H.
12Q1	Joe Harrison	Vt, 2,703	Bd	20	1.25	20			Gravel	U			C, 5	D, S	Formerly supplied dairy; representative of 3 other wells. Temp 51.
14C1	J. R. Kidd	Af, 2,714	Dr	30					Sand?	U			C	D, S	Water carries sand; well occasionally "pumped dry." Temp 55.
14C2	do	Af, 2,714	Bd	60	2					U			C	Irr	Supplies water for lawn and garden only. Temp 50.

14D1	Charles Wing	Af, 2,719	Dn							U				D, S	Occasionally pumps sand. Temp 52.
14D2	do	Af, 2,718	Bd	6.6	3					U	3.34	5-31-57		Irr	Irrigates garden; goes dry occasionally.
15F1	Stevens and Green	Af, 2,726	Dr	75.0	6					U	6.11	5-31-57	J	PS, S	
16E1	La Grande Cemetery Maint. Dist.	Vt, 2,825	Dr	217	8	197				U	22	6- -57	J	Irr	Bailed 20 gpm, dd 34 ft.
17A1	J. Gurnee	Vt, 2,850	Dr	75	6	53	37	38	Sand and gravel	U			J	D	Pumped 17 gpm. L.
23D1	Willard Green	Af, 2,713	Dr	31	6	29	30	1	Sand	U	6	3- -54	N	N	Pumped 1/2 gpm, dd 6 ft.
23D2	Glen Muilenberg	Af, 2,713	Dr	31	6	28	29	2	do	U	6	4- -54	C	D	Pumped 50 gpm, dd 10 ft. L.
23D3	Vernon DeLong	Af, 2,714	Dr	100	4				Sand, fine	U			J	D, S	Temp 52.
24E1	Blue Mountain Air Service.	Vt, 2,708	Dr	86	6					U			J	D, PS	Supplies airport facilities.
24E2	do	Vt, 2,707	Dg	20	48					U	3.63	5-31-57	C	Irr	
24N1	do	Vt, 2,705	Dr	98	6	98	93	5	Sand and gravel	U	10	3- -48	N	O	Formerly supplied CAA station. H, L.
25B1	Union County	Vt, 2,707	Dg	13.4	12				do	U	9.66	5-15-36	N	O	H.
26A1	Mr. Stover	Vt, 2,705	Dg	5.5	62					U	2.30	5-28-57	T	D PS	Supplies water for restaurant and 2 homes. Temp 52.
	T. 3 S., R. 39 E.														
5J1	Frank LeRoux	Vt, 2,703	Dr	2,020											Well abandoned and casing pulled in 1958. L.
7N1	J. E. Anson	Vt, 2,700	Dr	68	4.5	68				U	3.08	5-31-57	C	D	Ca, H.
11C1	U.S. Engineer Dept. (W-20).	Vt, 2,693	Dr	23.5	1.5	23.5	0	23.5	Sand, silty	U	5.73	12-13-55	N	O	
11L1	U.S. Engineer Dept. (W-19).	Fp, 2,691	Dr	25.2	1.5	21	0	25.2	Silt, sandy	U	13.35	12-13-55	N	O	
11P1	U.S. Engineer Dept. (W-18).	Fp, 2,690.9.	Dr	24.5	1.5	21	0	24.5	do	U	8.04	12-13-57	N	O	
12A1	U.S. Engineer Dept. (W-21).	Vt, 2,689.8	Dr	25	1.5	21.5	0	25	do	U	4.76	12-20-55	N	O	
13E1	U.S. Engineer Dept. (W-17).	Fp, 2,692.6.	Dr	24	1.5	21	0	24	do	U	10.6	12-20-55	N	O	
13K1	U.S. Engineer Dept. (W-28).	Fp, 2,689.7.	Dr	22	1.5		0	22	do	U	13.99	12-16-55	N	O	
13Q1	U.S. Engineer Dept. (W-30).	Fp, 2,689.4	Dr	19	1.5		0	19	Silt, sandy	U			N	O	
14J1	U.S Engineer Dept. (W-29).	Fp, 2,692.3	Dr	18.2	1.5		0	18.2	do	U	9.53	12-16-55	N	O	
18G1	Grant Henderson	Vt, 2,700	Dr	60	5					U			C	D	Temp 53.
19C1	John Rayburn	Vt, 2,702	Dr	62	8					U	3.40	5-31-57	C	D	Temp 53.
19H1	Guy Spencer	Vt, 2,710	Dr	200						U			C	D	Temp 54.
23A1	U.S. Engineer Dept. (W-16).	Fp, 2,6930.0	Dr	21.5	1.5					U	8.37	12-19-57	N	O	
24Q1	W. H. Woodruff	Fp, 2,690	Dr		6					C	+0.29	5- 6-57	N		Flows sometimes about 2 ft above land surface.

TABLE 1.—*Records of representative wells in the upper Grande Ronde River basin*—Continued

Well	Owner or occupant	Topography and altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing zone (s): Depth to top (feet)	Water-bearing zone (s): Thickness (feet)	Water-bearing zone (s): Character of material	Ground-water occurrence	Water level: Feet below datum	Water level: Date	Type of pump and yield (gallons per minute)	Use	Remarks
	T. 3 S., R. 39 E.—Continued														
25C1	W. H. Woodruff	Fp, 2,692	Dr	17.5	1.5					U	5.17	5-6-57	N	O	H.
28N1	Gilbert Courtwright.	Vt, 2,694	Dr		6					U			P	N	Formerly supplied one-room school.
30B1	M. A. Heslop	Vt, 2,695	Dr	171.0	6					U	7.69	5-29-57	C	D	Ca.
36K1	W. H. Woodruff (Well 1).	Af, 2,700	Dr		4					C	Flows		C	D, S	Stops flowing about 30 days after pumping begins at well 4/39-11H1.
	T. 3 S., R. 40 E.														
4A1	N.P. Knight	Ts, 2,850	Dr	190	6	120	189	1	Sand	U	21	11- -56	S	D, S	Bailed 7 gpm for 1 hr, dd 60 ft. L.
7E1	U. S. Engineer Dept. (W-26).	Fp, 2,689.2	Dr	22.5	1.5		0	22.5	Silt, sandy	U	10.99	12-20-55	N	O	
7J1	U. S. Engineer Dept. (W-22).	Fp, 2,688.8	Dr	23.4	1.5		0 6.5	6.5 22.9	do Sand, silty, and gravelly.	U	1.28	12-20-55	N	O	
15N1	P. C. Curtis	Ts, 2,925	Dr	69	6 4	23.5 68	67	2	Sand	U			J	D	Bailed 15 gpm, dd negligible. L, Temp 47.
15P1	Tom Towle	Ts, 3,025	Dr	98	6	75	96	2	do	U	50	5- -57	S	D	
18E1	U.S. Engineer Dept. (W-27).	Fp, 2,685.0	Dr	20	1.5		0	20	Silt, sandy	U	11.06	12-16-55	N	O	
18F1	U.S. Engineer Dept. (W-23).	Fp, 2,689.6	Dr	24	1.5		0	24	do	U	8.00	12-20-55	N	O	
18Q1	U.S. Engineer Dept. (W-24).	Hs, 2,699.2	Dr	20	1.5		17	3	Clay, sandy	U	4.98	12-20-55	N	O	
21D1	Fir Pine Lumber Co.	Af, 2,785	Dr	105	10	100	40	65	Boulders, rock, broken.	U	7	1956	C	Ind	Bailed 50 gpm, dd 12 ft. L, Temp 48.
30B1	U.S. Engineer Dept. (W-25).	Vt, 2,702.8	Dr	24.5	1.5		0	24.5	Sand, clayey	U	11.23	12-20-55	N	O	
2H1	W. J. Loudermilk	Af, 2,775	Dr	34	6	32	32	2	Sand, gravel	U	20.5	7- -57			Pumped 9 gpm, dd 11 ft. L.

	T. 4 S., R. 39 E.														
1B1	W. H. Woodruff (Well 4).	Af, 2,709	Dr							C	Flows		N	D, S	
2H1	W. H. Woodruff (Well 3).	Af, 2,707	Dr								Flows				
3N1	O. C. Wilde	Vt, 2,701	Dr	87	6	85				U	3	6- -43	C	D, S	Pumped 16 gpm, dd 11 ft. Hole backfilled with 3½ ft of clean gravel; first water at 30 ft; blue clay 30 to 40 ft. H, Temp 53.
11G1	W. H. Woodruff (Well 2).	Af, 2,713	Dr	108						C	Flows		N	D, S	
11H1	W. H. Woodruff	Af, 2,718	Dr	337	14		310	27	Gravel, pea-sized, and sand.	C	Flows		T, 3,000	Irr, S	Pumped 1,150 gpm, dd 65 ft; 3,000 gpm, dd 95 ft. Flows 60 gpm. Requires 2 weeks for artesian flow to return after pumping for 30 days. Ca, L.
12J1	Leonard Huffman	Af, 2,753	Dr	570	6										Dry hole, rock at 570 ft.
13B1	M. C. Pyatt	Af, 2,755	Dr	107	6	107	98	9	Gravel and sand	U	20	8- -56	J	D, S	Pumped 21 gpm, dd 37 ft. L.
	T. 4 S., R. 40 E.														
7G1	Charles Brooks	Af, 2,763	Dr	24.5	6	24.5	24	.5	Sand	U	2	7- -55	J	D	
7H1	W. L. Ash	Af, 2,770	Dr	75	6	68	74	1	do	U	3.30	6- 1-57	J	D	Aquifer overlain by gravel, clay and sand. Ca.
30C1	Aaron Payne	Hs, 2,775	Dr	118	{8 6 5	60 80 92	91 }116	1 2	Sand, black do	}U	25.12	6- 1-57			Pumped 8 gpm, dd 45 ft.

TABLE 2.—*Drillers' logs of representative wells*

[Tentative stratigraphic designation by E. R. Hampton]

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
1N/38-25R1. L. R. Starr Drilled by A. A. Durand and Son, 1948					
Soil	3	3	Columbia River basalt and associated volcanic rocks—Con.		
Columbia River basalt and associated volcanic rocks:			Basalt, broken	15	135
Basalt, broken, and clay	40	43	Basalt, broken, and sand	8	143
Clay, sandy, yellow	6	49	Clay, sticky, white (tuff?)	18	161
Basalt, broken and clay	71	120			
1N/38-34M1. Mike Royes Drilled by J. P. Corriell, 1949					
Colluvium:			Colluvium—Con.		
Clay, sandy	17	17	Clay and "rock" (gravel?)	102	190
Clay, brown, blue; rock strata at 10- to 20-foot intervals	70	87	Lacustrine alluvium:		
Sand	1	88	Clay, green, with "rock" layers	160	350
1N/39-15J1. City of Elgin Drilled by A. A. Durand and Son, 1941					
Alluvial fan deposits:			Lacustrine deposits—Con.		
Clay, sand, gravel	6	6	Shale, green	33	267
Gravel	2	8	Columbia River basalt and associated volcanic rocks:		
Boulders, heavy	7	15	Shale, sandy, gray (weathered rock?)	11	278
Shale, gray	19	34	Basalt, black	5	283
Clay and boulders	14	48	Basalt, porous	1	284
Lacustrine deposits:			Basalt, black	17	301
Shale, gray	56	104	Basalt, brown	2	303
Shale, sandy, gray	16	120	Basalt, black, hard	20	323
Sand and gravel	5	125	Basalt, brown	4	327
Shale, blue	20	145	Basalt, black	23	350
Shale, gray	30	175			
Clay, sticky, blue	23	198			
Sand	15	213			
Sand and clay, blue	21	234			
1N/39-16G1. R. B. Kennedy Drilled by Roy French, 1955					
Alluvial fan deposits:			Lacustrine deposits:		
Clay and gravel	6	6	Clay, sandy, blue	17	65
Gravel	2	8	Clay, blue	216	281
Gravel and boulders	7	15	Columbia River basalt:		
Boulders, heavy	19	34	Basalt, black	27	308
Clay and heavy boulders	14	48			

TABLE 2.—*Drillers' logs of representative wells*—Continued

1N/39-22B1. City of Elgin
Drilled by A. A. Durand and Son, 1948

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvial fan deposits:			Lacustrine deposits—Con.		
Gravel and boulders	38	38	Clay, white	7	417
Lacustrine deposits(?):			Clay, blue	11	428
Clay, blue, and gravel	27	65	Clay, sandy, blue	52	480
Gravel	5	70	Clay, sticky, blue	80	560
Clay, gravel	45	115	Columbia River basalt and associated volcanic rocks:		
Clay, brown, and gravel	30	145	Basalt	8	568
Clay, yellow, and gravel	3	148	Clay, blue(?)	50	618
Clay, sticky, yellow	53	201	Basalt, water-bearing; water flows at land surface	25	643
Clay, blue	97	298	Rock, cinder, water-bearing; water flows at land surface	8	651
"Shell rock"	8	306	Basalt, hard	4	655
Clay, blue	29	335			
Clay, green and yellow	29	364			
Clay, greenish blue	26	390			
Silt, micaceous	4	394			
Clay, sticky, blue	16	410			

1N/39-25N1. Peter Westenskow
Drilled by J. P. Corriell, 1955

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Recent alluvium:			Recent alluvium—Con.		
Clay	30	30	Clay, blue, and fine gravel	9	96
Gravel	4	34	Clay, sandy, blue, and wood	40	136
Clay, brown	4	38	Sand and gravel, blue-green, some clay	7	143
Clay, sandy, blue	6	44			
Clay, blue, with gravel	21	65			
Clay, sandy, blue	11	76			
Clay, sandy, brown	11	87			

1/38-2C1. Howard Fisher
Drilled by J. P. Corriell, 1953

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	1	1	Clay and gravel	9	52
Gravel; water encountered at 18 ft	24	25	Clay, soft	2	54
Clay, brown	3	28	Clay, gravelly	26	80
Clay, gravelly, blue-green	12	40	Clay, soft, brown	18	98
Clay, sandy, soft, brown	3	43	Clay with gravel streaks	32	130
			Sand	2	132

1/38-2R1. Fred Behrens
Drilled by A. A. Durand and Son, 1948

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvial fan deposits:			Alluvial fan deposits—Con.		
Soil and clay	11	11	Gravel and sand	14	52
Gravel and boulders	6	17	Sand, "muddy"	8	60
Clay and boulders	8	25	Clay	6	66
Clay, sticky	8	33	Gravel and sand	17	83
Sand	2	35	Clay	5	88
Gravel	3	38	Sand, gravel, clay	15	103

TABLE 2.—*Drillers' logs of representative wells*—Continued

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
1/38-4Q1. Albert Hopkins Drilled by J. P. Corriell, 1953					
Colluvium:			Colluvium—Continued		
Soil and clay	9	9	Clay, soft, brown, and gravel streaks	11	47
Gravel, clay, and boulders	27	36	Clay, and gravel streaks	153	200
1/38-11F2. Lyle Slack Drilled by J. P. Corriell, 1952					
Alluvial fan deposits:			Alluvial fan deposits—Con.		
Soil and clay	14½	14½	Clay, blue, and sand	4	34
Clay, blue, and gravel	7½	22	Sand, water-bearing	1	35
Clay, brown, and gravel	8	30			
1/38-11L1. Marion Wagner Drilled by J. P. Corriell, 1952					
Alluvial fan deposits:			Alluvial fan deposits—Con.		
Clay, brown	16	16	Sand, water-bearing	4	60
Gravel, cemented	10	26	Clay, blue; with sand and gravel	36	96
Sand	1	27	Sand, coarse, black	2	98
Sand, blue-green	7	34			
Sand, blue	6	40			
Clay, sandy, blue; with some gravel	16	56			
1/38-12K1. Mrs. Corriell Drilled by J. P. Corriell, 1953					
Alluvial fan deposits:			Alluvial fan deposits—Con.		
Soil	4	4	Clay, brown and gray; with sand	21	55
Gravel; water-bearing at 20 feet	17	21	Clay, blue	5	60
Clay, blue	1	22	Sand, fine	1	61
Clay, with gravel	12	34			
1/38-12K2. Ivan Calhoun Drilled by J. P. Corriell					
Alluvial fan deposits:			Alluvial fan deposits—Con.		
Sand	9	9	Gravel, coarse	14	23
1/38-12L1. H. P. Billerbeck Drilled by J. P. Corriell, 1950					
Alluvial fan deposits:			Alluvial fan deposits—Con.		
Soil and sand	9	9	Clay, blue-gray, and gravel	14	62
Gravel, cemented	37	46	Sand, light gray, water-bearing	5	67
Clay, blue-gray	2	48			

TABLE 2.—*Drillers' logs of representative wells*—Continued

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
1/38-12Q1. Mrs. J. Ham Drilled by J. P. Corriell, 1954					
Alluvial fan deposits:			Alluvial fan deposits—Con.		
Soil and clay	10	10	Clay, blue	11	85
Gravel and clay	13	23	Clay, sandy, brown	10	95
Sand, "hard"	5	28	Sand, brown, water-bearing	5	100
Clay, soft	17	45	Clay, blue	5	105
Clay and fine gravel	9	54	Sand and gravel with some clay, water-bearing	9	114
Sand, white (heaves slightly), water-bearing	9	63			
Clay, brown	11	74			
1/38-12Q2. John Tuck Drilled by J. P. Corriell, 1951					
Alluvial fan deposits:			Alluvial fan deposits—Con.		
Soil	9	9	Gravel, cemented	12	32
Gravel	2	11	Clay, soft	8	40
Sand, water-bearing	1	12	Clay, blue	6	46
Gravel	5	17	Clay, sandy, brown	3	49
Clay	3	20	Sand, water-bearing	1	50
1/38-22C1. Harvey Frizzell Drilled by J. P. Corriell, 1951					
Colluvium:			Colluvium—Continued		
No record	25	25	Clay and fine gravel, water-bearing	8	51
"Gravel" (rock rubble), cemented	18	43	Gravel, cemented	4	55
			Clay, brown	5	60
1/38-24R1. H. L. Wagner Drilled by A. A. Durand and Son, 1949					
Lacustrine deposits:			Columbia River basalt and associated volcanic-rocks:		
Soil	4	4	Rock, broken	20	685
Clay, sandy, yellow	101	105	"Basalt," hard, gray	67	752
Clay, sticky, green	14	119	Basalt, broken, black	61	813
Shale, green	3	122	"Shale," red (interflow oxidized zone?)	5	818
Clay, blue, and sand	33	155	"Shale," green (tuff?)	31	849
Clay, sandy, black	21	176	Basalt, broken, and clay	26	875
Clay, blue	6	182	Basalt, black	57	932
Shale, sandy	108	290	"Basalt," gray	15	947
Clay, blue	7	297	Basalt, broken	13	960
Shale, sandy	33	330	Shale, blue	110	1,070
Clay, blue	31	361	Sand and wood	15	1,085
Shale, sandy	8	369	Shale, sticky	17	1,102
Clay, sticky, blue	39	408	Basalt, hard	9	1,111
Shale, sandy	4	412	Basalt, "hard and soft streaks"	39	1,150
Clay and gravel	5	417			
Clay, sticky, blue	95	512			
Sand, coarse, water-bearing; flowed 65 gpm at land surface	29	541			
Clay, green	59	600			
Sand, hard	12	612			
Clay, blue	42	654			
Sand, hard, and wood	11	665			

TABLE 2.—*Drillers' logs of representative wells*—Contin·ıed

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
1/39-20 F1. Olin Hopkins Drilled by J. P. Corriell, 1953					
Lacustrine deposits:			Lacustrine deposits—Con.		
Soil	3	3	Clay	6	63
Clay, sandy	54	57	Sand, water-bearing	1	64
1/39-20L1. Otto Geddes Drilled by J. P. Corriell					
Lacustrine deposits:					
Sand	30	30	Lacustrine deposits—Con.		
Clay, brown	47	77	"Rock" and layers of		
Sand	2	79	clay	26	273
"Sandstone," water-			Clay, sandy	5	278
bearing	1	80	Clay, gray, and coarse		
Clay, sandy	5	85	sand	10	288
Clay, brown	12	97	Clay, gray-brown, and		
Clay, brown and green	138	235	coarse sand	61	349
Clay, brown	12	247	Clay, green and blue	28	377
1/39-20L2. Dwight Hopkins Drilled by J. P. Corriell, 1950					
Lacustrine deposits:			Lacustrine deposits—Con.		
Sand	27	27	Clay, sandy, brown	27	97
Clay, brown-green	8	35	Clay, blue-green	32	129
Clay, sandy, brown	26	61	Sand, blue-green	5	134
Sand, water-bearing	9	70	Clay, blue-green	1	135
1/39-20Q1. Tom Ruckman Drilled by J. P. Corriell, 1953					
Lacustrine deposits:			Lacustrine deposits—Con.		
Sand, light brown,			Clay, sandy, green	1	74
and clay	65	65	Clay, sandy, blue-green	45	119
Sand, light brown,			Sand, blue-green,		
water-bearing	8	73	water-bearing	7	126
1/39-32E1. K. R. Brown Drilled by J. P. Corriell, 1949					
Lacustine deposits:			Lacustrine deposits—Con.		
Sand	43	43	Sand	1	64
Clay	20	63			
1/39-32M1. Otto Geddes Drilled by J. P. Corriell, 1950					
Lacustrine deposits:			Lacustrine deposits—Con.		
Sand, some clay	67	67	Sand	1	74
Clay	6	73			

TABLE 2.—*Drillers' logs of representative wells*—Continued

1/39-32M2. Otto Geddes
Drilled by J. P. Corriell, 1950

Materials	Thickness (feet)	Depth (feet)
Lacustrine deposits:		
Sand	29	29
Clay. sandy, brown	8	37
Sand, fine	44	81
Clay, brown	4	85
Lacustrine deposits—Con.		
Sand, fine	6	91
Clay, brown, some sand	33	124
Sand, coarse	1	125

2/37-35E1. P. J. Baron
Drilled by O. C. Tandy, 1958

Materials	Thickness (feet)	Depth (feet)
Topsoil and gravel	4	4
Gravel and clay	14	18
Columbia River basalt and associated volcanic rocks:		
Basalt, gray	15	33
Columbia River basalt and associated volcanic rocks—Continued		
Basalt, broken	9	42
Basalt, gray	26	68
Basalt, broken	10	78

2/38-8R1. L. R. Hoxie
Drilled by J. P. Corriell, 1954

Materials	Thickness (feet)	Depth (feet)
Colluvium:		
Soil	2	2
Clay and rocks	17	19
Clay	5	24
Clay and "gravel," water-bearing	6	30
Clay	5	35
Colluvium—Continued		
Clay and gravel	8	43
Clay, sandy	25	68
"Gravel," clay, water-bearing from 70 to 80 ft	28	96
Clay, sandy	29	125

2/38-16C1. R. E. Hall
Drilled by J. P. Corriell, 1954

Materials	Thickness (feet)	Depth (feet)
Colluvium:		
Gravel and clay	25	25
Clay	40	65
Clay, sandy	10	75
Clay and sand	10	85
Colluvium—Continued		
Clay, sand, and gravel	20	105
Clay, sandy	65	170
Sand, water-bearing	5	175

2/38-16C2. R. E. Hall
Drilled by J. P. Corriell, 1954

Materials	Thickness (feet)	Depth (feet)
Colluvium:		
Clay, gravelly	20	20
Gravel, small	40	60
Clay, sandy	41	101
Clay and gravel	11	112
Clay and fine sand	87	199
Clay, sandy, and gravel	4	203
Clay	11	214
Clay and gravel	6	220
Colluvium—Continued		
Clay, sandy	15	235
Gravel, fine, and clay	5	240
Clay	8	248
Clay, blue, and small gravel	57	305
Clay, blue, and large gravel	4	309

TABLE 2.—*Drillers' logs of representative wells*—Continued

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
2/38-16P1. Ellis McCoy Drilled by J. P. Corriell, 1955					
Colluvium:			Colluvium—Continued		
Soil	5	5	Clay	11	136
Clay and "rocks"	14	19	Clay, sandy	4	140
Clay	11	30	Clay, gravel	15	155
Clay, sandy	18	48	Clay, sandy	15	170
Gravel, and clay	12	60	Clay, blue	30	200
Clay, sandy	61	121	Sand, water-bearing	1	201
Sand, water-bearing	4	125			
2/38-21C1. Lester Peach Drilled by J. P. Corriell, 1957					
Colluvium:			Colluvium—Continued		
Soil	5	5	Clay, sandy	18	33
Clay and sand, water-bearing at 15 ft	10	15	Sand	2	35
2/38-27R1. S. H. Burleigh Drilled by J. P. Corriell, 1952					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	5	5	Sand, brown, soft	3	64
Gravel and sand	20	25	"Conglomerate," sand, gravel, and a little clay	31	95
Sand, brown	2	27			
Gravel, sand, and some clay	34	61			
2/38-29R1. Dave Turner Drilled by O. C. Tandy, 1957					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	10	10	Gravel, "clay-packed"	10	88
Clay, hard	4	14	Sand, coarse, and small gravel	7	95
Clay	42	56			
Gravel, broken	16	72			
Sand, gravel, "washed"	6	78			
2/38-31P1. Valley Sausage Co Drilled by J. P. Corriell, 1949					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	2	2	Clay	19	74
"Rocks, river" (cobble gravel?)	14	16	Sand, water-bearing	7	81
Clay, brown	11	27	Clay, sandy, blue	18	99
Sand, water-bearing	7	34	Sand, blue	5	104
Clay	19	53	Gravel, fine	1	105
Sand	2	55			

TABLE 2.—*Driller's logs of representative wells*—Continued

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
2/38-31R1. Harold Yoho Drilled by J. P. Corriell, 1953					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	2	2	Sand, fine; with clay and streaks of coarse sand	19	102
Gravel	11	13			
Boulders	2	15			
Gravel	9	24			
Clay, gravelly, brown	17	41			
Clay, gravelly with boulders, gray	42	83			
2/38-31R2. Mr. Worthington Drilled by J. P. Corriell, 1948					
Alluvial fan deposits:			Lacustrine alluvium:		
Gravel	56	56	Clay, blue; "soapstone-like" strata every 15 to 25 ft	133	200
Clay, brown	11	67			
2/38-32L1. Garrett and Berry Drilled by J. P. Corriell, 1952					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Gravel, loose	18	18	Sand, soft, water-bearing (5 gpm)	4	32
Sand, water-bearing	6	24	Clay, sandy	2	34
Clay, sand, and gravel	2	26			
Sand, hard, water-bearing (3 gpm)	2	28			
2/38-33L2. Edward Patterson Drilled by O. C. Tandy, 1957					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	5	5	Sand and gravel	2	26
Gravel	5	10	Gravel, clay-packed"	8	34
Gravel, "cementlike"	4	14	Sand and gravel	7	41
Sand and gravel	2	16			
Gravel and clay	8	24			
2/38-34P1. S. B. Rasmussen Drilled by J. P. Corriell, 1949					
Alluvial fan deposits:			Alluvial fan deposits—Con.		
Clay	3	3	Sand	11	39
Sand, white	7	10	Gravel	1	40
Gravel	3	13	Sand	11	51
Boulders	1	14	Gravel, "rocks"	2	53
Gravel	6	20	Sand	12	65
Sand	6	26	Clay, sandy	11	76
Gravel	2	28	Sand	1	77

TABLE 2.—*Drillers' logs of representative wells*—Continued

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
2/39-7K2. Douglas Westenhaver Drilled by J. P. Corriell, 1956					
Lacustrine deposits:			Lacustrine deposits—Con.		
Sand, fine, brown	40	40	Sand, water-bearing; "heaves up in well"	4	92
Sand, fine, brown, some clay	18	58	Clay, sandy	25	117
Sand, fine brown	12	70	Sand	3	120
Sand, fine, brown, some clay	18	88			
2/39-7P1. Mr. Michael Drilled by J. P. Corriell, 1952					
Lacustrine deposits:			Lacustrine deposits—Con.		
Sand, brown	82	82	Clay, sandy, brown	6	101
Clay, sandy, brown	3	85	Sand, water-bearing	4	105
Sand, brown	10	95			
2/39-13B1. Don Gray Drilled by J. P. Corriell, 1948					
Colluvium:			Colluvium—Continued		
Clay, brown, and soil	34	34	Gravel	1	71
Clay, hard, and gravel	1	35	Clay and gravel	4	75
"Rock," coarse (cobble gravel?)	3	38	Clay, sandy	29	104
Clay, brown	8	46	"Rock," coarse	4	108
Clay	24	70	Sand	1	109
2/39-18P1. Wren Case Drilled by J. P. Corriell, 1950					
Lacustrine deposits:			Lacustrine deposits—Con.		
Sand; water encountered at 30 ft	50	50	Sand, medium-grained, water-bearing	3	174
Clay, sandy	3	53	Clay, brown	1	175
Sand, water-bearing; heaving up the well	72	125	Sand, water-bearing	15	190
Clay, sandy; less sand with depth	27	152	Clay, soft	4	194
Clay, sandy; more sand with depth	18	170	Gravel, fine	1	195
Clay, brown	1	171			
3/38-4E2. Manley Williams Drilled by J. P. Corriell, 1949					
Alluvial deposits:			Alluvial deposits—Continued		
Soil	4	4	Sand and "rocks"	16	43
Gravel and large rocks	14	18	Sand, coarse	1	44
Gravel, fine	5	23			
Sand and gravel, water-bearing	4	27			

TABLE 2.—*Drillers' logs of representative wells*—Continued

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
3/38-4E4. George Ellis Drilled by J. P. Corriell					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	6	6	Clay, sandy, brown	9	51
Gravel	12	18	Gravel, coarse	2	53
Sand, water-bearing	6	24	Clay, sandy, brown	3	56
Gravel, cemented	14	38	Gravel, coarse	2	58
Sand, water-bearing	1	39	Clay, sandy, brown	22	80
Clay, sandy, brown	2	41			
Gravel, coarse	1	42			
3/38-4F1. E. E. Halsey Drilled by J. P. Corriell, 1952					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	5	5	Sand, coarse, hard, water-bearing	1	43
Sand and gravel	15	20			
Clay, gravel, and sand	22	42			
3/38-4F2. Leonard Spears Drilled by J. P. Corriell, 1952					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	5	5	Sand, water-bearing	2	36
Gravel and sand	15	20			
Clay, sandy, hard, with gravel	14	34			
3/38-4F3. Leonard Spears Drilled by J. P. Corriell, 1952					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	3	3	Sand, water-bearing	4	44
Gravel and sand	17	20			
Clay, sandy, hard, and gravel	20	40			
3/38-4L1. J. P. Corriell Drilled by J. P. Corriell					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	3	3	Sand, water-bearing	2	46
Sand, gravel, and clay	19	22			
Sand, cemented	22	44			
3/38-4L3. Wallace Cass Drilled by J. P. Corriell, 1952					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Sand and gravel, loose	19	19	Sand, hard, with clay	11	41
Sand, water-bearing	3	22	Sand, coarse, water-bearing	4	45
Gravel, with clay and sand	8	30			

TABLE 2.—*Drillers' logs of representative wells*—Continued

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
3/38-4L4. Wallace Cass Drilled by J. P. Corriell, 1952					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	2	2	Clay, sandy, hard	7	38
Gravel	20	22	Sand, water-bearing	4	42
Clay and gravel	9	31			
3/38-4M1. W. M. Jeffers Drilled by O. C. Tandy, 1956					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	6	6	"Rock," large	8	118
Clay with gravel	8	14	Sand	1	119
Gravel	4	18	"Rock," coarse	4	123
Gravel, cementlike	12	30	Sand and small gravel, mixed with greenish-gray clay	27	150
Sand and small gravel	16	46	Clay, gray, and coarse gravel	27	177
Gravel and clay	8	54	Gravel, small to medium	2	179
Gravel, loose	2	56	Gravel, clay-packed	1	180
Gravel, sand, and clay	14	70			
Gravel and clay	20	90			
"Muck," blue-gray, some sand and gravel	10	100			
Gravel and clay	10	110			
3/38-4M3. H. E. Luther Drilled by J. P. Corriell, 1952					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Gravel	18	18	Clay, sand	5	47
Gravel, clay increasing with depth	20	38	Sand, fine gravel, water-bearing	3	50
Clay, gravel decreasing with depth	4	42			
3/38-4N1. Keith Pratt Drilled by J. P. Corriell, 1953					
Alluvial fan deposits:			Alluvail fan deposits—Continued		
"Soil"	8	8	Sand and gravel	7	30
Gravel, water-bearing at 18 ft	15	23	Sand, water-bearing	1	31
3/38-5M1. Union Pacific Ry. Drilled by A. A. Durand					
Alluvial fan deposits:			Columbia River basalt and associated volcanic rocks:		
Gravel and boulders	200	200	"Rock" (basalt?)	151	996
Clay, yellow	123	323	"Clay" (?)	110	1,106
Gravel, fine	14	337	"Rock" (basalt)	224	1,330
Lacustrine deposits:			"Clay," blue (tuff?)	15	1,345
Clay, yellow	273	610	Basalt	40	1,385
Clay, blue	235	845	"Clay," blue (tuff?)	20	1,405
			"Rock," red (basaltic scoria)	30	1,435

TABLE 2.—*Drillers' logs of representative wells*—Continued

3/38-5M2. Union Pacific Ry.
Drilled by A. A. Durand, 1942

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvial fan deposits:			Columbia River basalt and associated volcanic rocks—Continued		
Soil	6	6	Basalt and clay	6	996
Gravel and boulders	16	22	Basalt, black	174	1,170
Gravel, boulders, and clay	158	180	Basalt and red "clay"	28	1,198
Lacustrine deposits:			"Clay," red	112	1,310
Clay, yellow	390	570	Basalt, red	25	1,335
Clay, blue	370	940	Basalt, hard, black	74	1,409
Columbia River basalt and associated volcanic rocks:			Basalt, brown	41	1,450
Boulders, basaltic, and clay	22	962	Basalt, hard, black	49	1,499
Clay, blue	28	990	Basalt, black	10	1,509
			Basalt, brown	15	1,524
			Basalt, hard, brown	12	1,536

3/38-5P1. Hub City Food Center
Drilled by J. P. Corriell

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Gravel	7	7	Gravel	1	68
Gravel and boulders	1	8	Gravel and "shale"	2	70
Gravel	23	31	Clay, gray and brown	20	90
Gravel and clay	9	40	Sand	3	93
Sand	27	67			

3/38-5R1. Iver Masterson
Drilled by J. P. Corriell, 1956

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	4	4	Gravel, clay	6	40
Gravel and "rocks"	15	19	Sand, cemented, hard	16	56
Gravel and sand	3	22	Sand and gravel, small	1	57
Clay, sandy	10	32			
Sand and gravel	2	34			

3/38-6K1. Cherry's Florists
Drilled by J. P. Corriell, 1955

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	5	5	Sand, hard; sloughs into well	1	24
Gravel and "rocks"	2	7	Gravel, clay, sand	13	37
Gravel and clay	15	22	Sand	2	39
Gravel, cemented	1	23			

3/38-6K2. Tom Faulkner
Drilled by J. P. Corriell, 1955

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	2	2	Gravel and clay	4	46
Sand and "fill"	4	6	Clay, sandy	18	64
Gravel and sand	30	36			
Sand with fine gravel	6	42			

TABLE 2.—*Drillers' logs of representative wells*—Continued

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
3/38-7H1. Zion Lutheran Church Drilled by J. P. Corriell, 1955					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	4	4	Clay, with gravel	21	52
Gravel, loose	2	6	Clay, sandy	17	69
Clay, with gravel	19	25	Sand, blue, water-bearing	5	74
Gravel, cemented and hard	6	31			
3/38-8A1. Mr. Miller Drilled by J. P. Corriell, 1953					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil, clay	4	4	Clay	3	42
Gravel	13	17	Sand, water-bearing	1	43
Sand, cemented	22	39			
3/38-8A2. Frank Edwards Drilled by J. P. Corriell, 1957					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	1	1	Clay	4	24
Gravel, loose	9	10	Sand	2	26
Gravel, cemented	10	20			
3/38-8J1. L. J. Haynes Drilled by J. P. Corriell, 1957					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil, "gumbo"	10	10	Sand and fine gravel, water-bearing	2	45
Clay, with some coarse gravel, water-bearing at 16 ft	21	31	Clay and sand	2	47
Sand, water-bearing	5	36	Sand, water-bearing	4	51
Clay and fine gravel	7	43	Clay and gravel	19	70
			Sand, coarse	1	71
3/38-8J2. R. Hill Drilled by J. P. Corriell, 1955					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	4	4	Clay, sandy, with some gravel	14	45
Gravel and clay	20	24	Gravel and clay	12	57
Gravel with some clay	7	31	Sand	1	58
3/38-8Q3. R. E. Badgley Drilled by J. P. Corriell, 1951					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
"Gumbo and rocks"	4	4	Gravel and sandy clay, water-bearing	6	50
Clay and some sand	13	17			
Gravel and clay	27	44			

TABLE 2.—*Drillers' logs of representative wells*—Continued

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
3/38-8R1. J. H. Berry Drilled by J. P. Corriell					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	2	2	Clay and gravel	9	32
Gravel	16	18	Sand	1	33
Sand	5	23			
3/38-9D1. D. Smith Drilled by J. P. Corriell, 1953					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	3	3	Clay with sand	7	44
Gravel	20	23	Sand, water-bearing	1	45
Clay with gravel	14	37			
3/38-9D2. D. L. Hutchison Drilled by J. P. Corriell, 1957					
Alluvial fan deposits:			Alluvial fan deposits—Con.		
Soil	4	4	Sand, water-bearing	5	30
Gravel	6	10	Clay	10	40
Sand, cemented	10	20	Sand	1	41
Clay	5	25			
3/38-17A1. J. Gurnee Drilled by J. P. Corriell, 1949					
Alluvial fan deposits:			Alluvial fan deposits—Con.		
Gravel, coarse	12	12	Sand, coarse, sloughing into well	5	50
Sand	12	24	Sand, hard	8	58
Sand, hard	1	25	"Sandstone"	1	59
Sand	3	28	Sand	15	74
Gravel, cemented	2	30	Gravel, fine	1	75
Sand, hard, and clay	7	37			
Sand	8	45			
3/38-23D2. Glen Muilenberg Drilled by J. P. Corriell, 1954					
Alluvial fan deposits:			Alluvial fan deposits—Con.		
Soil and clay	24	24	Sand	2	31
Clay with gravel	5	29			
3/38-24N1. Blue Mountain Air Service Drilled by A. A. Durand and Son, 1948					
Lacustrine deposits:			Lacustrine deposits—Continued		
Soil	3	3	Sand	1	74
Clay, sandy, yellow	19	22	Sand and fine gravel	12	86
"Mud," sandy, blue	7	29	Clay, yellow	7	93
Sand and gravel	22	51	Sand and gravel, water-bearing	5	98
Sand	20	71			
Clay, sticky	2	73			

TABLE 2.—*Drillers' logs of representative wells*— Continued

3/39-5J1. Frank LeRoux
Drilled by A. A. Durand & Son, 194 -57

Materials	Thickness (feet)	Depth (feet)
Lacustrine and alluvial fan deposits, undifferentiated:		
Soil, sandy	26	26
Clay, sandy, blue	12	38
Gravel, small, some large	9	47
Sand with some gravel, heaving into well	25	72
Sand, some silt	12	84
Gravel, small	6	90
Clay, brown and sticky	15	105
Sand	4	109
Clay, sandy	11	120
Sand with some gravel	20	140
Sand and blue silt	20	160
Clay, blue	5	165
Sand and gravel	32	197
Silt and sand	9	206
Clay, blue	30	236
Clay, sandy	16	252
Sand and coarse gravel	5	257
Gravel, pea-sized	10	267
Sand and gravel	8	275
Sand and clay	17	292
Sand, gray, heaving	6	298
Gravel	2	300
Sand and gravel, with clay streaks	7	307
Sand and gravel, heaving into well	5	312
Gravel, "coarse river"	18	330
Gravel, cemented	13	343
Clay, blue	177	520
Gravel, cemented, large	5	525
"Hard shell" (?)	14	539
Lacustrine deposits:		
Clay, blue	33	572
Lacustrine deposits—Con.		
Clay, sandy, white	3	575
Clay, sticky, blue	25	600
Clay, brown	25	625
Clay, sticky, blue	187	812
Clay, hard, brown	83	895
Clay, blue	40	935
Sand, coarse, hard, white	13	948
Sand and clay	25	973
Clay, blue, and sand	60	1, 033
Clay, blue, dark	280	1, 313
Sand, little clay	15	1, 328
Clay, sandy, blue	62	1, 390
Clay, sticky, blue	97	1, 487
"Hard shell"(?) and clay, sticky, blue	10	1, 497
Sand	2	1, 499
Clay, blue	26	1, 525
Clay and sand	22	1, 547
Clay, sticky, blue	100	1, 647
Clay, sandy, blue, and sand	40	1, 687
Clay, blue, and cemented gravel	6	1, 693
Clay, blue	82	1, 775
Sand, gray	15	1, 790
Sand, little clay	75	1, 865
Shale, blue, and sand	7	1, 872
Clay, sticky, gray	28	1, 900
Sand, heaving into well	59	1, 958
Sand	13	1, 971
Clay, red	2	1, 973
Sand, gray	2	1, 975
Clay, red	4	1, 979
Clay, red, and sand	6	1, 985
Clay, red, "caving bad"	35	2, 020

Final casing, 4-inch, driven to 2,026⅓ feet.

TABLE 2.—*Driller's logs of representative wells*—Continued

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
3/40-4A1. N. P. Knight Drilled by J. P. Corriell, 1956					
Colluvium:			Colluvium—Continued		
Soil	3	3	Clay, brown, "squeezing	24	115
Clay, brown	87	90	Clay, solid, brown	74	189
Sand, fine, brown, water-bearing	1	91	Sand, brown, water-bearing	1	190
3/40-15N1. P. C. Curtis Drilled by J. P. Corriell, 1955					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil and small boulders	7	7	Clay, sandy, hard	2	67
Clay, brown, with large boulders	49	56	Sand, medium fine, water-bearing	2	69
Clay, brown, and gravel	9	65			
3/40-21D1. Fir Pine Lumber Co. Drilled by O. C. Tandy, 1956					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Gravel, coarse, rounded	40	40	"Rock," broken	5	105
"Rock," broken	46	86			
Boulders, large	12	98			
Clay, and small rounded gravel	2	100			
4/38-2H1. W. J. Loudermilk Drilled by J. P. Corriell, 1952					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Boulders	20	20	Sand and fine gravel, water-bearing	2	34
Gravel, sand and clay	12	32			

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TABLE 2.—*Drillers' logs of representative wells*—Continued

Materials	Thickness (feet)	Depth (feet)	Materials	Thickness (feet)	Depth (feet)
4/39-11H1. W. H. Woodruff Drilled by Charles Moore, 1951					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil, brown	3	3	Clay and gravel, sticky, blue	8	204
Gravel and clay, hard, tan	23	26	Sand, fine, and clay, blue	18	222
Sand, gravel, and clay, tan	6	32	Clay and gravel (static water level, 1½ ft)	5	227
Sand and clay, tan	6	38	Clay and sand, blue	15	242
Gravel, pea-sized, and clay, tan	12	50	Clay and gravel (static water level, 1 ft.)	3	245
Gravel, cemented, tan	4	54	Sand, hard, and clay, blue	13	258
Sand and clay, tan	2	56	Clay, sticky, blue	12	270
Gravel, cemented, tan	12	68	Sand and clay, packed, blue	13	283
Clay and sand, tan	2	70	Clay, sticky, blue	15	298
Gravel, cemented, tan	10	80	Clay and sand, blue	11	309
Gravel and clay, tan	10	90	Sand, blue	1	310
Clay and sand, tan	6	96	Gravel, pea-sized, and blue sand	27	337
Gravel and clay, tan	25	121			
Clay and sand, sticky, tan	20	141			
Clay and gravel, tan	17	158			
Clay, sand, and gravel	31	189			
Sand and clay, blue	7	196			
4/39-13B1. M. C. Pyatt Drilled by O. C. Tandy, 1956					
Alluvial fan deposits:			Alluvial fan deposits—Continued		
Soil	3	3	Gravel, small, and clay	3	57
Gravel, coarse	21	24	Clay	28	85
Gravel, packed with clay	22	46	Gravel and clay	13	98
Gravel, large, and clay	8	54	Gravel, small, and sand	9	107

TABLE 3.—*Representative springs in the upper Grande Ronde River basin*

[Spring locations shown on plates 1 and 2]

Topography and altitude: Af, alluvial fan; Hs, hillside; Ts, talus slope; Vb, bottom of small valley; Vp, valley plain; Vh, abrupt slope at head of valley. Altitude of land surface at spring, in feet above mean sea level, interpolated from topographic maps of the U.S. Bureau of Reclamation.
Use of water: B, bath; D, domestic; Irr, irrigation; M, medical; N, none; S, stock.
Remarks: Ca, chemical analysis in table 4; Temp, temperature in degrees Fahrenheit. Remarks on adequacy, dependability, and general quality of water were reported by owners, tenants, and others.

Spring	Owner or occupant, and name of spring	Topography and altitude (feet)	Water-bearing material	Occurrence	Yield		Use	Remarks
					Gallons per minute	Date		
	T. 1 N., R. 40 E.							
7G1	Carl Long	Hs, 3,300	Columbia River basalt	Flows from interflow zone in basalt.		10- 3-57	D	Reservoir enclosing spring is a concrete box 3x4x8 ft.
	T. 1 S., R. 38 E.							
25P1	Mrs. Shaw	Vp, 2,750	Columbia River basalt (platy andesite).	Seeps from fractures in faulted rock.	1 to 3	7-29-58	S	
28R1	Lawrence Greiner	Ts, 3,200	Colluvium	Seeps from talus		7-27-57	D	Spring enclosed by concrete box and water piped to reservoir.
34C2	Thurman Teeter	Ts, 2,800	do	do	4	7-27-57	D	Enclosed by concrete box.
34M1	Mr. Hulse	Ts, 2,925	do	do		7-27-57	D	One of 5 springs in group.
	T. 1 S., R. 39 E.							
5H1	Verne Hug	Hs, 2,800	Soil overlying andesite	Seep	5 to 10	5- 1-57	D	Flow decreases in summer.
5N2	James McKinnis	Hs, 2,725	Sand	Flows through lacustrine sand from basalt.	50	5-23-57	S	Dam impounds flow from many "quicksand boils." Temp 54.
5N3	John H. McKinnis	Hs, 2,725	do	do		5-23-57	D	Curbed with concrete and metal at springhouse. Temp 51.
27C1	F. C. Hunt	Ts, 2,785	Colluvium	Flows from base of slump block.	200+	6- 2-57	D, Irr	Formerly supplied trout hatchery; Ca. Temp 55.
	T. 2 S., R. 38 E.							
20P1		Hs, 2,975	Colluvium overlying basalt and andesite.	Flows from colluvium at base of fault scarp.	1 to 4	7-27-57	S	Enclosed by concrete reservoir; water is roily. Temp 54.
29A1		Hs	do	do	4 to 6	7-27-57	S, Irr	Do.

TABLE 3.—*Representative springs in the upper Grande Ronde River basin*—Continued

Spring	Owner or occupant, and name of spring	Topography and altitude (feet)	Water-bearing material	Occurrence	Yield: Gallons per minute	Yield: Date	Use	Remarks
	T. 2 S., R. 40 E.							
33B1	Mr. Hostadt	Ts, 2,950	Colluvium	Seepage from talus		7-29-57	S, Irr	Flows to a 75,000-gallon reservoir; water runs 7½ hp Pelton wheel.
	T. 3 S., R. 35 E.							
12N1		Vh, 4,400	Columbia River basalt	Flows from fractured zone in basalt.	1±	10-25-57	S	Has a low yield; water roily.
	T. 3 S., R. 36 E.							
11M1	Tony Vey	Vb, 3,150	do	Seeps in soil and colluvium overlying basalt.	5 to 10	11-14-57	D	Enclosed by concrete box 2 x 2 x 3 ft.
	T. 3 S., R. 40E.							
17L1	Charles Smutz (Wagner Springs).	Af, 2,715	Alluvium	Seeps from fan materials		3-26-57	Irr	Representative of 6 springs at the location.
17Q1	G. L. Golay	Af, 2,740	do	do		3-26-57	Irr	
22D1	R. W. Borkgren (Cove Springs).			Seeps from alluvial material where it overlies a fault in the bedrock.	226	6- -57	B	Supplies water to public swimming pool; Ca, Temp 85.
	T. 4 S., R. 39 E.							
5K1	Dr. Roth (Hot Lake Springs)	Vp, 2,700	Andesite	Fault zone	170	5-10-57	M, B	Ca, Temp 180.
22H1	Miller	Ts, 2,850	Colluvium	Seeps from talus overlying fault zone.		5- 6-57	N	Temp 52.
23E1	P. Chadwick	Ts, 2,750	do	do		3-26-57	S, Irr	Owner has water right for 17 cfs to irrigate 13 acres.
	T. 5 S., R. 41 E.							
23D1		Ts, 3,300	Columbia River basalt	Flows and seeps from contact of Columbia River basalt with metamorphic rocks.	10 to 20	8-15-58		Representative of many springs similarly situated.
	T. 6 S., R. 35 E.							
12D1	U.S. Forest Service (Warm Mineral Spring).	Vb, 4,500	Valley fill overlying welded tuff and volcanic agglomerate.	Apparently flows from tuff adjacent to dike.	25 to 50	10-17-57	N	Water has sulfurous odor. Temp 83.

TABLE 4.—*Chemical analyses of water from wells and springs of the upper Grande Ronde River basin*

[In parts per million except first and last five items. Analyses by U.S. Geological Survey unless otherwise indicated]

Well, spring, or river / Date of collection	IN/38–21C1 4/19/58	IN/39–22B1 5/10/57	1/38–12K1 6/2/57	1/38–15L1 4/18/58	1/38–24R1 8/9/50	1/39–4N1 4/18/58	1/39–17L1 4/19/58	1/39–20L1 7/31/57	1/39–27C1 7/31/57	2/38–13D1	2/38–16C1	2/38–27R1 4/19/58	2/38–28J2 4/17/58
(Well or spring)	Well	Well	Well	Well	Well	Well	Well	Well	Spring	Well	Well	Well	Well
Temperature (°F)	41	52	51	45	84	50	39	56	55	53		51.5	55
Silica (SiO_2)	38	38	47	47	88	47	51	50	41	40	48	40	42
Iron (Fe):													
Total	.15	.03	.19	.07	.04	.01		.01		.09		.02	.27
In solution		.00	.05		.02			.00		.05			.01
Manganese (Mn)	.02	.04	.20	.02	.00	.02		.00		.06		.04	
Calcium (Ca)	5.5	5.2	16	11	3.6	27	28	16	8.7	26	11	29	27
Magnesium (Mg)	1.4	1.4	8.0	4.5	.8	14	14	6.6	3.6	11	4.8	14	12
Sodium (Na)	2.2	21	7.7	3.9	28	16	8.3	10	9.0	11	6.2	28	10
Potassium (K)	1.8	5.3	3.1	3.2	4.0	3.4	3.2	1.5	2.5	2.5	1.9	1.9	2.8
Bicarbonate (HCO_3)	35	82	111	58	62	137	99	93	61	162	76	209	156
Carbonate (CO_3)	0	0	0	0	4.9	0	0	0	0	0	0	0	0
Sulfate (SO_4)	.3	3.5	1.2	1.6	8.3	6.7	23	2.9		1.6		11	2.3
Chloride (Cl)	.2	.8	.2	1.8	3.1	2.5	3.0	1.2	1.5	.5	1.2	6.0	1.0
Fluoride (F)	.0	.4	.3	.0	2.0	.0	0	.2		.2		.0	.1
Nitrate (NO_3)	.2	.1	.1	11	.2	50	49	9.0	3.4	.1	.5	1.7	5.6
Boron (B)	.05		.02	.09	.10	.04	.22	.10		.05		.56	.02
Dissolved solids:													
Calculated	67		139	112	174	234	228	143		173		235	180
Residue at 180°C	75	111	140	118		235	236	155	109	181	116	246	195
Hardness as $CaCO_3$	20	19	73	46	12	124	126	67	36	110	47	130	115
Noncarbonate hardness	0	0	0	0	0	12	45	0	0	0	0	0	0
Sodium-adsorption-ratio (SAR)	.22	2.1	.39	.79	3.5	.63	.32	.53	.65	.46	.39	1.07	.41
Specific conductance (micromhos at 25°C)	61	140	173	125	148	317	296	174	117	248	123	359	260
pH	6.8	8.2	7.7	6.6	8.0	7.2	7.2	7.4	7.2	8.0	7.2	7.2	7.3
Color	15			0		0	0					10	0

TABLE 4.—*Chemical analyses of water from wells and springs of the upper Grande Ronde River basin*—Continued

Well, spring, or river Date of collection	2/39-30H1 4/17/58	3/38-5M1 1/21/55 [a]	3/38-5M2 1/21/55 [a]	3/38-6H2 5/10/57	3/38-8K1 7/31/57	3/39-7N1 7/31/57	3/39-30B1 7/31/57	3/40-22D1 6/2/57	4/39-5K1 5/10/57	4/39-11H1 8/22/57	4/40-7H1 7/31/57	Grande Ronde River 1 mi. below Five Point 4/19/58	Grande Ronde River at Rhinehart 4/19/58
(Well, spring, or river)	Well	Well	Well	Well	Well	Well	Well	Spring	Spring	Well	Well	River	River
Temperature (°F)	50	77	80	81		54	52	85	180	58		40	45
Silica (SiO_2)	53	72	84	71	43	42	44	29	81	34	36	31	31
Iron (Fe):													
Total	.02	Tr.	Tr.	.03				.03	.00	.00		.38	.49
In solution				.02				.00	.00	.00			
Manganese (Mn)	.02	0	0	.01						.03		.02	.02
Calcium (Ca)	30	4.8	5	10	30	36	14	1.6	3.6	11	25	5.0	5.5
Magnesium (Mg)	13	1.3	.3	.2	13	16	6.6	.0	.3	4.3	12	1.6	1.8
Sodium (Na)	13	30	27	19	15	87	15	30	128	25	16	3.1	3.4
Potassium (K)	1.9	5	5	5.0	4.0	5.8	4.6	.5	2.7	4.2	5.5	1.5	1.7
Bicarbonate (HCO_3)	185	63	(?)	84	135	134	118	5	0	104	181	31	34
Carbonate (CO_3)	0		0	0	0	0	0	32	31	0	0	0	0
Hydroxide									4				
Sulfate (SO_4)	1.2	4.8	3.3	4.5				8.8	56	7.4		.9	1.2
Chloride (Cl)	1.5	2.1	3.2	1.0	10	28	.8	5.0	129	8.8	.8	.2	.5
Fluoride (F)	.1	.5	.5	.5				.3	1.6	.3		.0	.0
Nitrate (NO_3)	2.0			.0	19	.4	.4	.0	.0	.4	.3	.3	.6
Boron (B)	.03							.08				.01	.02
Dissolved solids:													
Calculated	207	166	163					109		146		59	63
Residue at 180°C	201			146	238	421	146	112	461	152	186	76	79
Hardness as $CaCO_3$	130	15	18	26	128	156	62	4	10	45	112	19	21
Noncarbonate hardness	0			0	17	46	0	0	0	0	0	0	0
Sodium-adsorption ratio (SAR)	.50	3.1	3.1	1.6	.57	3.0	.82	5.3	12.4	1.6	.66	1.7	1.8
Specific conductance (micromhos at 25°C)	286			146	327	658	188	150	676	207	280	54	61
pH	8.2	7.9	7.9		7.1	8	7.4	9.8	9.5	8.0	7.5	7.2	7.2
Color	0	3	4									35	40

[a] By Oregon State Board of Health.

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[Italic page numbers indicate major references]

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