Quality of the Ground Water in Basalt of the Columbia River Group, Washington, Oregon, and Idaho

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1999-N

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By R. C. NEWCOMB

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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An analysis of constituents and physical characteristics of the ground water, including the effect of time on its quality

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QUALITY OF THE GROUND WATER IN BASALT OF THE COLUMBIA RIVER GROUP, WASHINGTON, OREGON, AND IDAHO

By R. C. NEWCOMB

ABSTRACT

The ground water within the 50,000-square-mile area of the layered basalt of the Columbia River Group is a generally uniform bicarbonate water having calcium and sodium in nearly equal amounts as the principal cations. The water contains a relatively large amount of silica.

The 525 chemical analyses indicate that the prevalent ground water is of two related kinds — a calcium and a sodium water. The sodium water is more common beneath the floors of the main synclinal valleys; the calcium water, elsewhere.

In addition to the prevalent type, five special types form a small part of the ground water; four of these are natural and one is artificial. The four natural special types are: (1) calcium sodium chloride waters that rise from underlying sedimentary rocks west of the Cascade Range, (2) mineralized water at or near warm or hot springs, (3) water having unusual ion concentrations, especially of chloride, near sedimentary rocks intercalated at the edges of the basalt, and (4) more mineralized water near one locality of excess carbon dioxide. The one artificial kind of special ground water has resulted from unintentional artificial recharge incidental to irrigation in parts of central Washington.

The solids dissolved in the ground water have been picked up on the surface, within the overburden, and from minerals and glasses within the basalt. Evidence for the removal of ions from solution is confined to calcium and magnesium, only small amounts of which are present in some of the sodium-rich water.

Minor constituents, such as the heavy metals, alkali metals, and alkali earths, occur in the ground water in trace, or small, amounts. The natural radioactivity of the ground waters is very low. Except for a few of the saline calcium sodium chloride waters and a few occurrences of excessive nitrate, the ground water generally meets the common standards of water good for most ordinary uses, but some of it can be improved by treatment. The water is clear and colorless and has a temperature slightly higher than would be indicated by the accepted "normal" earth gradient. A small amount of iron is present in some of the water and a slight amount of hydrogen sulfide gas is present in water from most wells.

Carbon-14 determinations indicate that the water has been underground for periods ranging from modern times to several tens of thousands of years. Generally, an increase in the age of the water corresponds to depth and with location in the central parts of the main structural basins. The evidence of correlations between chemical characteristics and the age of the water is limited to the excessive nitrate which occurs in young, shallow ground water and to the apparent base-exchange removal of calcium and magnesium that has occurred where the ground water is old.

INTRODUCTION

PURPOSE AND ARRANGEMENT OF THE REPORT

This report is prepared to compile the data on the quality of water in the Columbia River Group of basaltic rocks which underlie more than 50,000 square miles in the States of Washington, Oregon, and Idaho (fig. 1). The compilation, showing the types of water that occur in different parts of the basalt region, supplies data on the chemical conditions of the water in its natural state and gives information on some unnatural alterations of quality.

The report includes (1) data consisting of three tables of analyses of ground-water samples and a map of the basalt region in which the sampling sites are located (pl. 1) and (2) text describing the chemical characteristics of both the prevalent and special types of ground water shown by the data. The data include 525 standard chemical analyses of water samples (table 1), 100 partial analyses of minor elements (table 2), and 27 analyses of ground-water radioactivity (table 3). The data in the tables are arranged by State, so the State having the most information and the greatest area of basalt (Washington) is listed first and the State having the least (Idaho) is listed last. Fill-in analyses were made during this research project to supplement the main body of data which was contributed by many investigators. In substance, the data include all the analytical information on the ground water in the basalt.

The analyses of the ground water were made on samples which were not uniformly distributed throughout the region. A disproportionate number of the samples has come from valleys because more wells are located there (pl. 1). Consequently, a disproportionate number of analyses shows the sodium-rich ground water that occurs in the synclinal areas as described later in the report.

While most of the analyses in the tables are on representative samples of the ground water in the reported water-bearing zones, questions may be raised about the precise source of some of the samples analyzed. Owing to the stratigraphic arrangement of the individual aquifers in the basalt, some deep wells tap two or three water-bearing zones, one of which commonly yields more water than the others. In other wells (commonly unlined in most of their rock parts), different pressure heads occur in the separate aquifers, and circulation between aquifers takes place within the wells, especially when they are not being pumped. Also, in some valley areas where permeable sedimentary deposits overlie the basalt, well casings that don't have adequate sealing have been set to the top of the basalt; consequently, water from the overlying materials descends into the wells. Samples that are questionable with regard to their precise source, insofar as they could be identified by lack of uniformity in multiple samples and by other criteria, were omitted; however, several tens of analyses in table 1 may be questionable as to the accuracy with which they represent the ground water in the basalt or as to the particular zone shown to be producing the water. Nevertheless, the geologic and hydrologic requirements, met both by samples and analyses for inclusion in this report, make the data generally valid. An awareness of the sampling hazards, not to mention the higher grade of present-day well construction and completion, should make groundwater sampling more representative in the future.

ACKNOWLEDGMENTS

Many analyses have been taken from sources listed in the references. Other analyses, taken from the files of the Geological Survey in Washington, Oregon, and Idaho, were originally made through the Federal and cooperative programs between the Survey and State and local governmental agencies. Numerous analyses were contributed by the Oregon State Board of Health, the U.S. Army Corps of Engineers, the U.S. Bureau of Sport Fisheries and Wildlife, the U.S. Bureau of Reclamation, and the Idaho Board of Health. The source of each analysis is shown in the tables.

NUMBERING SYSTEMS FOR WELLS AND SPRINGS

Wells and springs from which water samples were taken for the analytical data discussed in this report are numbered in accordance with the rectangular system of land subdivision. In Washington and Oregon the township and range numbers are laid out from the Willamette base line and meridian; in Idaho, from the Boise base line and meridian. The custom of numbering wells using township and range designations, followed for many

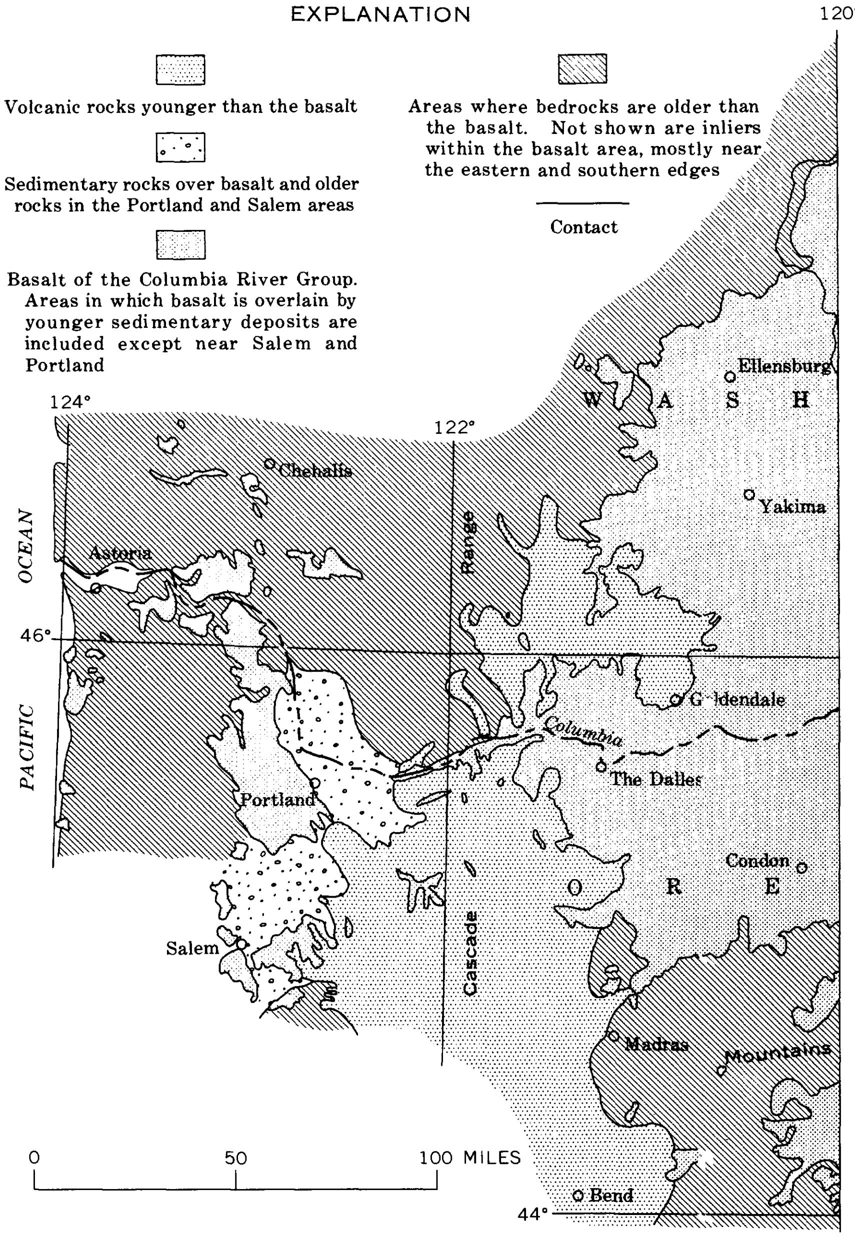
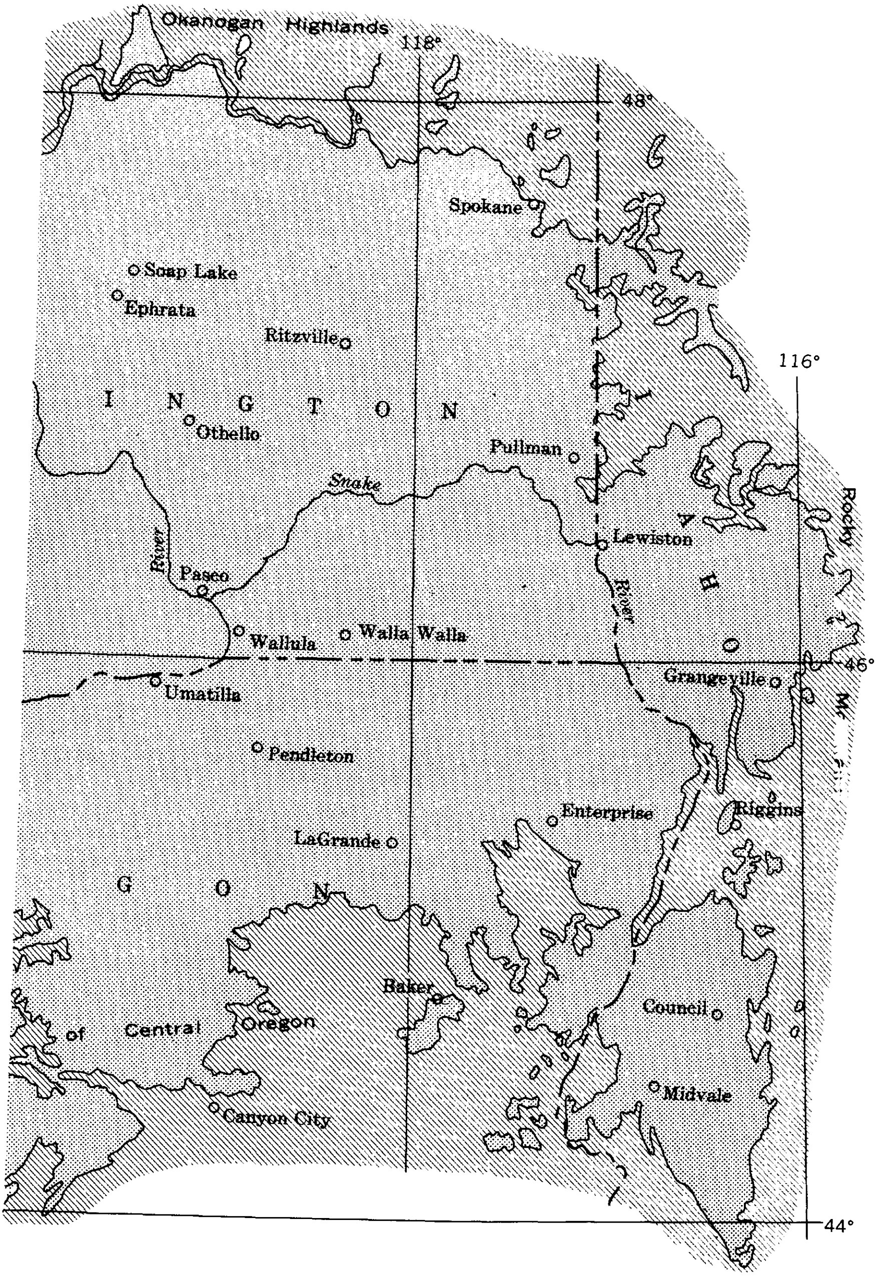


FIGURE 1. — Extent of the basalt

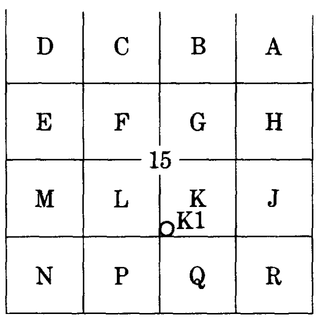
years in each State, is continued in this report. The letter "N" is dropped for townships north of the Willamette base line in Washington, because all townships are north of the base line. Like-



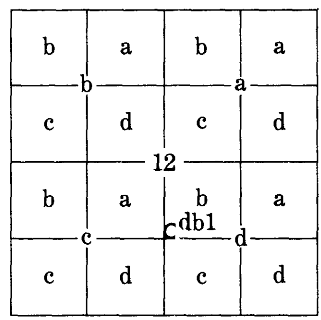
of the Columbia River Group.

wise, the letter "S" is dropped for townships south of the base line in Oregon, because most townships are south of the base line. In Idaho, all township and range designations retain their directional letters. This report contains no records of wells in Washington west of the Willamette meridian. Where dropping the directional letters for township and range identification of well and spring numbers in Oregon or Washington might cause confusion, the State name has been given.

The numbers preceding the dash indicate the township and range; the section number and 40-acre-tract subdivision, in that order, follow the dash. In Oregon and Washington, one letter indicates the 40-acre subdivision of the section, as shown in the diagram. In Idaho, two letters are used to designate a 40-acre tract.



Washington
and
Oregon



Idaho

Thus, a well numbered 10/30-15K1 in Washington is in the NW¼SE¼ sec. 15, T. 10 N., R. 30 E.; the same number in Oregon is in the same section subdivision but in T. 10 S., R. 30 E. Both wells would be the first wells numbered in their 40-acre tracts. In Idaho, a well numbered 16N/1W–12db1 would be the first one numbered in the NW¼SE¼ sec. 12, T. 16 N., R. 1 W., of the Boise base line and meridian, as shown in the diagram above.

The analyses in the tables are listed by township and range within each State. In Washington, listings are northward by township tiers within each of which the ranges follow successively eastward. In Oregon, each northward tier contains an eastward succession of ranges followed by a westward succession from the meridian; the southward tiers of townships are arranged in the same manner as the northern tiers. In Idaho, the ranges follow successively within each township tier northward from the base line.

A serial number from 1 to 525 is assigned to the analyses arranged by State and well numbers in table 1. These serial numbers are used for reference throughout this report.

GEOLOGIC CONDITIONS

The basalt of the Columbia River Group underlies a region of about 50,000 square miles in Washington, Oregon, and Idaho (fig. 1). The main body of the rock unit lies between the Rocky Mountains on the east and the Cascade Range on the west. In and south of the Columbia Gorge, the basalt crosses the Cascade Range and is interbedded with sedimentary and volcanic-sedimentary units north from the Salem, Oreg., area as far as the Chehalis River valley in Washington (pl. 1).

In the central part of the region, the basalt has a general thickness of 4,000-5,000 feet. It tapers out on the prebasalt surface at the edges, but the western and southern edges are complicated by the centrally located extension to the west and by the presence of other basaltic lavas of similar age to the south. In a few places west of the Cascade Range, the basalt reaches a thickness of 1,000 feet but is generally less than 500 feet thick.

The rock unit consists largely of accordantly layered basalt which accumulated as flow upon flow of highly fluid lava. The lava flows, which constitute the principal stratigraphic units, vary from 10 to 200 feet in thickness, averaging about 100 feet. The flows are made up of one or more arrivals of lava, called flow units; consequently, the stratigraphy of the layering varies considerably from place to place. Small amounts of interbedded sedimentary materials occur, especially in the top 1,000 feet in the west-central part of the basalt region and for the entire thickness at places around the edges of the basalt accumulation. For the most part, the interbedded materials are considered to be related to the Latah Formation at the northern edge, the Latah and Payette Formations at the eastern edge, the Mascall Formation at the southern edge, the Ellensburg Formation at the northwestern edge, and the Astoria Formation at the far western edge.

In certain vertical sections around the edges of the basalt, the interbedding of sedimentary layers is so great that the sedimentary materials predominate over basalt. Consequently, the quality of the ground water can differ from that sampled in other sections where the ground water has moved through exclusively basaltic materials.

The basalt is a largely uniform black or dark-gray rock. Seventy-five percent of the average basalt consists of crystals and microcrystallites of labradorite, augite, and magnetite. The remaining 25 percent, occupied by intercrystalline area, is composed of a glassy groundmass containing microlite beginnings of still smaller crystals. Olivine forms 1–5 percent of some of the lava flows. Apatite and cristobalite have been identified as accessory minerals, but primary fluorite has not been reported. Some lava flows are porphyritic and have megascopic labradorite and pyroxene crystals arranged in a distinctive habit (Irwin, 1946; Jones, 1950; Mackin, 1961).

Rubbly lava-breccia is largely confined to the tops of some lava flows, to pillow-palagonite occurrences where the lava has been chilled by flowage over or into water, and to rare occurrences of autobreccia wherein the lava has broken itself by movement during solidification. Cooling-contraction joints divide the basalt into blocks ranging from 1 inch to 10 feet across; some form of vertical hexagonal columnar jointing is the most prevalent joint system. The cooling joints are open cracks near the surface but are tightly closed at depth within the thick flows.

Joint-block surfaces of some lava flows are coated with iron oxide, but the rock is not deeply oxidized except near the land surface in some places. The lack of alteration in deep openings, drill cuttings, and other penetrations indicates that oxidation had not extended greatly downward from the surface, as anything more than a thin coating, before each successive flow was covered. Fresh, untarnished crystals of iron pyrite, observed on the sides of openings in some water-bearing zones, attest to strong reducing conditions in aquifers several hundred feet below the top of the basalt.

The integrated porosity sufficient to transmit ground water in quantities that will afford large yields, +1,000 gpm (gallons per minute), to wells is limited largely to the fractured tops of some flows, and stratigraphic zones of rubbly basalt (Newcomb, 1959, p. 4–6). These "adequately permeable" zones include only a small part of the basalt, probably comprising less than 6 percent of the top 1,500 feet of the basalt (Newcomb, 1969, p. 12).

The basalt was folded, warped, and faulted during the tectonic deformation of Pliocene and Quaternary time, the Cascadian orogeny (Newcomb, 1970). Tilting and fault displacement have exposed the permeable zones of anticlines and monoclines to recharge water from precipitation and streamflow; this recharge water migrates laterally to the downwarped parts of the basalt. Sharp folds and the crushed zones along faults generally constitute barriers to this lateral movement (Newcomb, 1961).

HYDROLOGIC CONDITIONS

The basalt underlies the land surface in areas that receive annual precipitation ranging from less than 10 inches to more than 100 inches. The average depths of water that passes through the soil and overburden and migrates downward to recharge the ground water in the basalt range from zero beneath some desert terrains to more than 1 foot in some river basins of the Blue Mountains (Newcomb, 1965, p. 18). The ease with which water at the surface may transfer downward in the basalt depends largely on the position in which the layers of basalt lie: if they are horizontal, the downward passage may be largely denied; if they are tilted, and the ends of permeable zones are exposed, the downward passage may be easy. The records of water levels in wells indicate that the natural recharge to ground water in the basalt is greatest where inclined layers of basalt are truncated by the land surface on which streams flow or abundant precipitation falls (Newcomb, 1959, p. 7–8).

From the recharge area, the water follows the courses afforded by the permeable openings in the basalt, and moves toward its ultimate discharge in response to the drive of the pressure gradient. Its life as ground water may be short or long depending on whether it entered a permeable unit beneath a mountain valley and was discharged a few months later from a hillside spring, or whether it drained deeply, to travel many thousands of years through the basalt beneath synclinal valleys. Its course may have been at shallow depths in cool rocks, or it may have penetrated the warmer parts of the basalt. The water may have circulated completely within a single stratigraphic zone, or it may have migrated from one aquifer to another by slow circuitous high pressure through stratigraphic overlaps, joints, or fault-shattered zones. It may have received an inflow of more concentrated solutions from greater depths, or it may have been diluted by less mineralized water. These and many other possible experiences in the subsurface passage of the water, both before and after it arrived in the basalt, can change the water's quality and affect the content of the dissolved materials carried by ground water.

The main natural mode of ground-water discharge from the basalt is through numerous springs, many of which inconspicuously feed streams. Single springs discharging more than 1,000 gpm are rare, though discharge from numerous small springs in an area of several tens of acres may add up to that quantity. Most springs discharge less than 10 gpm at single orifices which may be arranged at intervals of a few hundred feet along the base of the outcropping aquifer.

Passage of the ground water into the oxidizing environment of the atmosphere causes the precipitation of iron oxide at some springs, but there is a general absence of precipitates or incrustations at most springs where water flows from the basalt. Like-wise, the formation of incrustations and coatings is lacking at all but a few wells. Two wells (analyses 330 and 331 of table 1) at Mosier, 14 miles northwest of The Dalles, are the only ones known to the author that require periodic treatment to relieve yield-reducing incrustations.

QUALITY OF THE GROUND WATER

In general, the ground water of the basalt is satisfactory without treatment for most ordinary uses of water. Some of the water needs improvement for use in steam boilers, aeration to remove hydrogen sulfide gas, softening to lower soap consumption, or, in a few places, treatment to remove iron. From place to place, the dissolved solids in water from the basalt vary considerably; the common extremes range from less than 200 mg/1 (milligrams per liter) to as much as 500 mg/1. The most mineralized types of water have migrated into the basalt from other rocks and occur under specific sets of geologic conditions; these are described later in the report as some of the special types of ground water.

Most of the ground water discharged from springs and sampled at wells comes from the youngest part of the basalt, the top 2,000 feet. The average ground water in this top 2,000 feet is moderately hard, nearly iron free, and clear. Silica, calcium, sodium, and bicarbonate are the principal dissolved solids. Much of the ground water has a slight hydrogen sulfide odor that is easily removed by aeration, and, otherwise, the water is of generally good physical and chemical quality.

A general illustration of the composition of the dissolved solids is shown by bar graphs in figure 2 and by the compositional diagram in figure 3. Table 1 shows that a great majority of the analyses are on similar calcium sodium bicarbonate[1] waters of rather uniform characteristics. The calcium sodium bicarbonate water and a similar water having a predominance of sodium over calcium are considered to be the prevalent ground water of the basalt. In some of the descriptions appearing later in the report, this water is referred to as "the prevalent ground water" or "the ground water of the basalt."

Ground waters having peculiar amounts of dissolved solids are termed "special" types of ground water in this report. The special ground waters include (1) calcium sodium chloride waters rising

[1]The principal ions are used as adjectives in forming a brief designation for certain chemical characteristics of the ground waters. In these multi-word adjectives, the ion of greatest reacting concentration is listed first and progressively lesser ions follow, the anions listed after the cations.

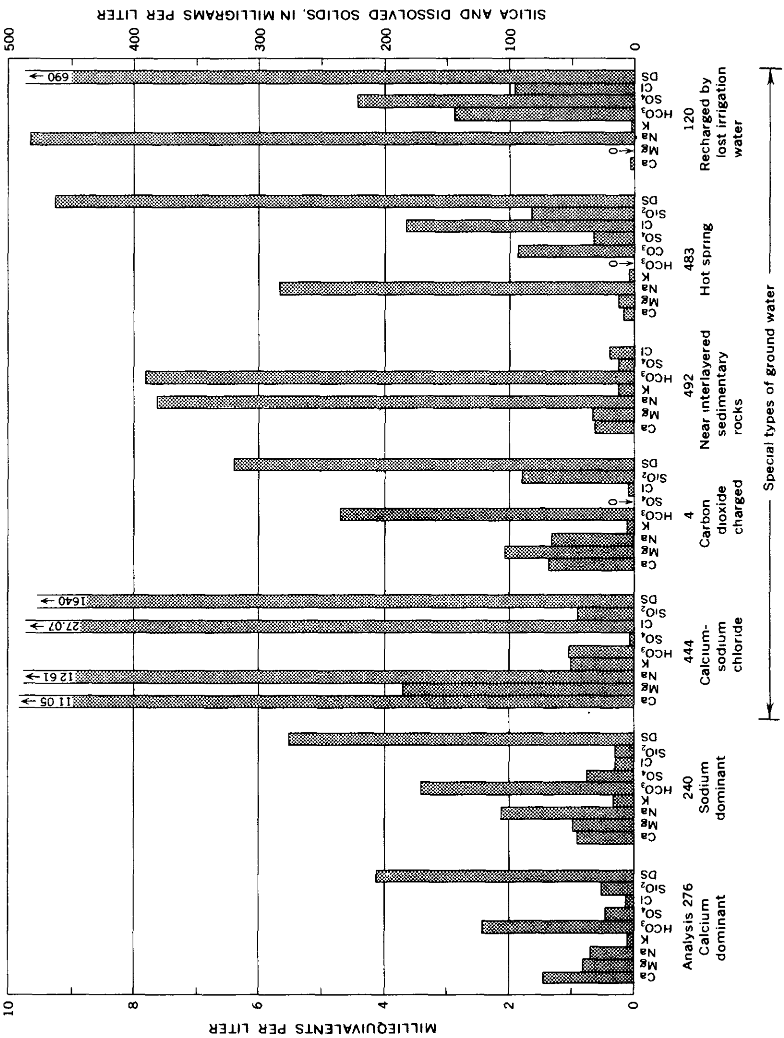


FIGURE 2. — Selected analyses of the prevalent and special types of ground water.

into the basalt from underlying sedimentary rocks west of the Cascade Range, (2) sodium- and calcium-rich sulfate chloride and

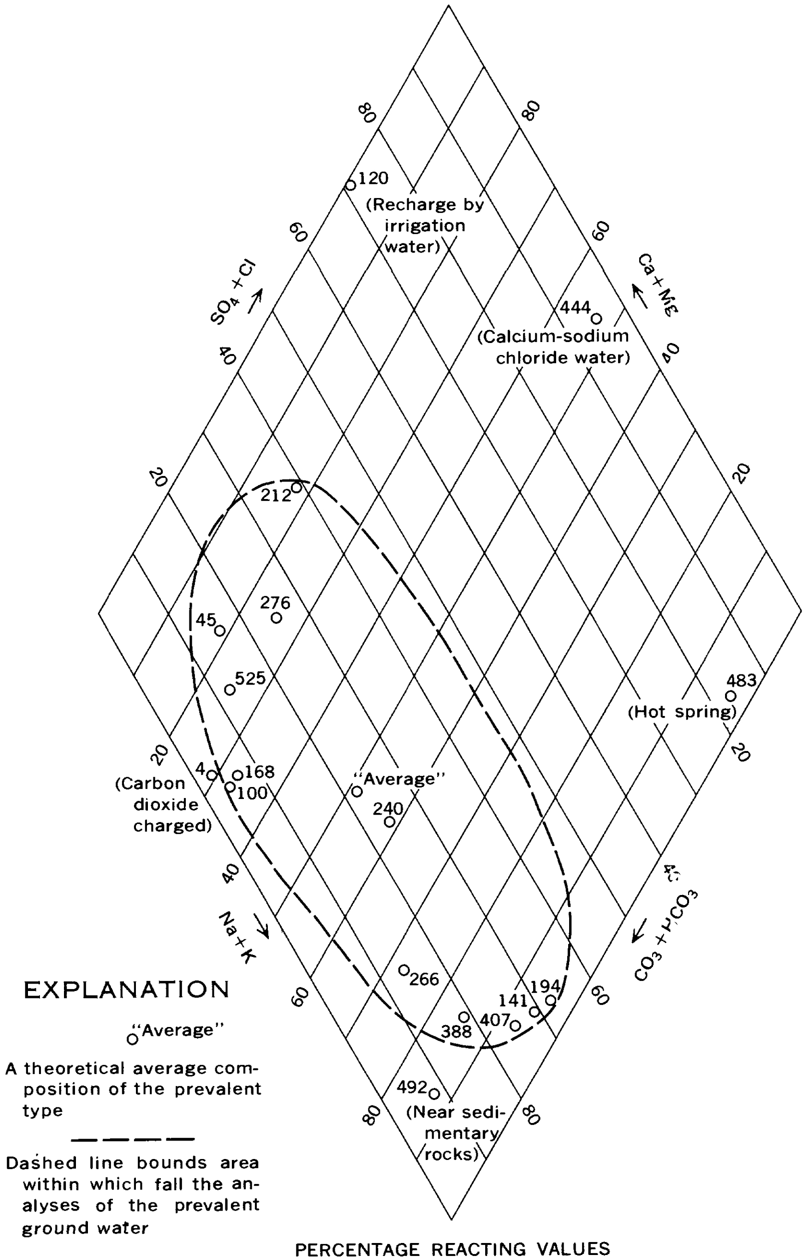


FIGURE 3. — Chemical character of the prevalent and special types of ground water.

bicarbonate waters recharged to dipping basalt layers by escaped irrigation water from the Columbia Basin Irrigation Project (between Pasco and Ephrata in central Washington), (3) mineralized water at or near warm or hot springs, (4) mineralized water at or near the carbon dioxide charged Klickitat Springs (in southern Washington, 16 miles north of The Dalles), and (5) water of various anomalous ion concentrations, especially chloride-rich waters, which occur within and near sedimentary rocks that are interlayered with the basalt around the edge of the basalt region.

The general composition of the ground water of the basalt is described further in the following section. The ranges and average concentrations of the principal ions of the dissolved solids, the distinctive features of their geologic occurrence in the ground water, and some of the effects of these ions on the uses of water are described to augment the data listed in the tables and shown in the illustrations.

DISSOLVED CONSTITUENTS

SILICA

In 381 analyses of the prevalent ground water, silica ranges from 18 to 121 mg/l (table 1). In most of the analyses, silica ranges from 40 to 80 mg/l and a value of about 55 mg/l is average. There is a general relation between the highest silica values and the temperature of the water, the highest silica values (121 and 115 mg/l) being from water of relatively high temperature (27.2°C, or 81.5°F). However, the comparative relation between temperature and silica content is not consistent; for example, the hottest water (analysis 483, 79.5°C, or 175°F) has only 81 mg/l silica. There is a lack of consistent relation between the silica content and the calcium or sodium content or the value of other characteristics, such as pH.

The general uniformity of the silica content in wells of all depths (ranging generally from 200 to 1,200 feet) indicates that the ground water reaches a silica equilibrium with the basalt fairly early in its underground history. Silica is of little significance in the quality of water for most uses, except that its deposition in boilers and other hot-water containers can cause undesirable scale.

IRON

Many of the values for iron listed in table 1 are from records of analyses in which the type of iron determination, whether iron in solution at time of sampling or at time of analysis, could not be ascertained. Those for which a total iron at time of sampling was definitely indicated are so shown as total iron in table 1.

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Of the 444 iron determinations, 377, or 85 percent, are less than 0.30 mg/l of iron, the content commonly taken as the point above which its presence in the water becomes detrimental for many water uses. Most of the 67 analyses in which iron equals or exceeds 0.30 mg/l range generally between that value and 2.4 mg/l, but one water sample from a faulted area (analysis 470) has 16.5 mg/l, and another from western Oregon (analysis 485) has 9.7 mg/l. One of the Gas-Ice Corp. wells (4/13–24H4) at Klickitat Springs has 11.0 mg/l, and one well (39N/15W–8aa2) at Moscow, Idaho, has 6.5 mg/l. Both of these latter waters are special types, respectively a carbon dioxide charged type and a water from basalt containing much interbedded sedimentary material.

The data indicate there is no correlation between the iron content and the depth of the aquifers, nor is there any geographical distribution of the iron content within the region, not even a consistent difference between the areas west and east of the Cascade Range. Differences in iron content have been noted between aquifers tapped during the drilling of a single well and between nearby wells drilled to the same aquifer. The 12 analyses (100–111 of table 1) listed for seven wells in the same general aquifers at Pullman, Wash., show a range from 0.03 to 0.50 mg/l. Some large concentrations of iron have been found to result from other influences—improperly sealed or rusted casing.

The average well water from the top 1,000 feet of the basalt, containing about 0.20 mg/l of iron, will lightly stain white cloth or porcelain plumbing fixtures but is generally satisfactory for other uses and does not ordinarily sustain heavy growths of iron bacteria in tanks and reservoirs. All observations known to the author indicate that the iron occurs in solution in the ferrous state in balance with bicarbonate anions; it is removable by aeration followed by filtration or by other common methods of iron removal.

PRINCIPAL CATIONS

Calcium and Magnesium

In the prevalent type of ground water, these major cations together usually range from 20 to about 100 mg/l. Within that range magnesium varies considerably but occurs at about one-fourth to one-half the milligrams-per-liter concentration of calcium, except in the waters in which sodium exceeds the calcium. In the sodium waters, the magnesium content may be only 1/10–1/4 that of calcium. Together they form the bulk of the elements that unite with soap to form the relatively insoluble compounds that are the principal effect of hard water.

Calcium ranges from 8 to 100 mg/l where it is the dominant cation in the prevalent ground water; it averages about 23 mg/l. In the waters which contain more sodium than calcium or equal amounts of the two, the calcium content ranges generally between 5 and 30 mg/l, averaging about 15 mg/l. Within the calcium waters there is a general lack of a consistent increase in calcium as the aquifer depth or the apparent time the water has been underground increases, indicating that the calcium content is present soon after water infiltrates and moves down. This would indicate that most of the calcium is picked up in the soil zone and the surficial weathered zones of the basalt. This relation also may indicate that the calcium in solution is not augmented by large additions from the decomposition of basaltic glass, labradorite, and pyroxene deep within the basalt. In the sodium waters, found mainly in the synclinal basins, calcium occurs at its lowest concentrations (2 and 1.5 mg/l in analyses 420 and 421 at Umatilla), indicating that base exchange with sodium may remove calcium from the ground waters progressively as the content of sodium increases. The greatest concentrations of calcium (200–600 mg/l, analyses 444 and 446) occur in a special type of ground water—the calcium sodium chloride waters that rise up into the basalt from underlying sedimentary rocks in Washington and western Oregon.

The magnesium content ranges from 0 to 106 mg/l and, in general, follows the variations of calcium content, previously described. Magnesium is entirely lacking in two analyses (120 and 337) of sodium-rich water taken from wells 15/28–24L1 in Washington and 2N/25–28D1 in Oregon. The sample from well 15/28–24L1 was taken after artificial recharge incidental to irrigation had converted the water to a sodium sulfate solution—the type of water in which the least amount of magnesium occurs. The two greatest concentrations of magnesium, both 106 mg/l, also occur in special types of water—the carbon dioxide charged water near Klickitat Springs (analysis 3) and the calcium magnesium sodium sulfate bicarbonate chloride water (analysis 89) resulting from flushing of salts downward by irrigation water.

The 1 : 3/8 ratio of calcium to magnesium content indicated for the prevalent ground water from the basalt, when converted to equivalents per million, gives a chemical-reacting ratio of about 2 : 1. This ratio is in the range given by Hem (1959, p. 82) as indicative that the source of the magnesium in the water lies in the solution of magnesium silicate minerals. Such a source for the magnesium in the ground water of the basalt would fit with the readily available mineral sources: the basaltic glass, pyroxene, and (in some of the lava flows) olivine.

Sodium and Potassium

In the prevalent ground water, sodium ranges from 6.2 to 100 mg/l and potassium from 0.4 to 26 mg/l. The sodium content varies greatly between the sodium waters that predominate beneath the synclinal basins[2] and the calcium-rich waters elsewhere. The ratio of sodium to potassium, in milligrams per liter, ranges from 15 : 1 to 3 : 1 and averages near 5 : 1. The average content of sodium in the calcium-rich waters is about 25 mg/l and within the sodium waters is about 50 mg/l; its average is about 32 mg/l in the prevalent ground water. Of 341 sources of the ground water (table 1) for which the analyses contain values for both calcium and sodium, 143 show a predominance of sodium over calcium by greater than 5 mg/l, as compared with 122 that show a similar predominance of calcium over sodium. There are 76 sources in which neither predominated by 5 mg/l. Overall, the analyses given in table 1 show sodium to be slightly predominant over calcium; but, because a disproportionately large percentage of these samples was taken in synclinal basins, where sodium is generally high, an evaluation of the regional conditions must allow for lack of full representation for the calcium-rich ground waters. In the sodium-rich ground waters of the synclinal areas of the basalt, concentrations of 50–110 mg/l of sodium are common (as in analyses 32–34, 140, 141, 358–360, and 368–391), and in these waters the milligrams-per-liter ratio of sodium to potassium is commonly near 10 : 1.

The analyses show no consistent relation between the content of sodium or potassium and the depth at which ground water is taken from the basalt. Possibly some correlation would show, if the samples from deep wells were from strictly separate water-bearing zones. Where the main aquifers are believed known, the analyses of some of the ground water at shallower depth in the basinal areas have greater sodium and potassium content than the deeper ground water. This relation is shown by analyses such as 139 and 140, where the deeper water (analysis 139) from "below 700 feet" has calcium and magnesium comparable to the combined milligrams per liter of sodium and potassium. In the shallower zone sampled from a depth of 170–304 feet (analysis

[2]The principal tectonic structures of the basalt, including the synclinal areas that are the main localities of this sodium-rich water, are shown on Miscellaneous Geologic Investigations Map I-587 (Newcomb, 1970).

140), the combined content of sodium (86 and 81 mg/l) and of potassium (26 and 12 mg/l) are nearly twice what they are in the deep zone (analysis 139); also, it is more than 10 times the combined milligrams per liter of the calcium and magnesium in the shallow zone (analysis 140). However, an opposite condition, a greater sodium and potassium concentration with greater depth, is shown by analyses 371–400 for the wells at the Umatilla Ordnance Depot. Outside the desert basins, in places where one well is believed to tap entirely deeper zones, analyses (such as 135 at Pullman) indicate that the sodium and potassium determinations of the deeper aquifers are nearly identical to those in the shallower zones (analyses 100 and 133).

Calcium sodium chloride water, a special type of ground water in the basalt at places in Washington and western Oregon, is the most common form of high-sodium water (analyses 326, 444, and 446). In the sodium-rich part of another special type of ground water, that newly recharged by irrigation water (analyses 120 and 261), the sodium is associated mostly with bicarbonate and sulfate and secondarily with chloride.

PRINCIPAL ANIONS

Bicarbonate and Carbonate

Bicarbonate is the principal anion of the prevalent ground water; it ranges from 50 to 300 mg/l in these waters, whereas the other major anions, sulfate and chloride, commonly amount to less than 10 mg/l. A value of 150 mg/l, slightly below the median of the range, is about the average. The total content of bicarbonate varies generally with the amount of dissolved solids. There is no obvious relation between the bicarbonate content and the depth at which the ground water occurs within the basalt.

Of 356 analyses, only 69 show any carbonate ions present. Of these 69 analyses, all but a few are sodium-rich waters. Of the 18 analyses having more than 8 mg/l of carbonate, 16 are water in which sodium greatly predominates over calcium.

In the special types of ground water, the bicarbonate and carbonate contents differ from those in the prevalent ground water. The carbon dioxide charged waters (analyses 3 and 4) at Klickitat Springs have bicarbonate concentrations as great as 1,060 mg/l. The chloride-rich connate waters rising up into the basalt in western Oregon (analyses 326 and 444) have insignificant amounts of bicarbonate. Bicarbonate is low in the warm ground waters and is entirely lacking in the Union Hot Springs (analysis 483). Two analyses of the newly recharged ground water in the Columbia Basin Irrigation Project (analyses 120 and 261) show

176 and 566 mg/l bicarbonate respectively. In these samples of recharge-modified ground water, the concentration of bicarbonate, in milligrams per liter, is less than the sulfate concentration but greater than the chloride concentration in analysis 120 and a little larger than the combined values for sulfate and chloride in analysis 261.

Sulfate

In the natural ground water of the basalt, sulfate occurs within the extremes of 1–130 mg/l and within a common range of 10–50 mg/l; it averages about 20 mg/l. Some of the analyses show that relatively large amounts of sulfate are present in some of the shallower aquifers beneath the synclinal basins (analyses 371 and 384), but that occurrence is not consistent. There seems to be no relation between the amount of sulfate in the natural ground water and the predominance of calcium or sodium, and it does not have a consistent relationship to the pH. The ground water in the basalt west of the Cascade Range is markedly lacking in sulfate compared with that beneath the drier areas to the east.

As is common with the first flushing of accumulated salts from the soils of semiarid basins, the local recharge of ground water as a result of deep escapement of irrigation water since the start of irrigation in 1952 has greatly increased the sulfate in the ground water of some parts of the Columbia Basin Irrigation Project (analyses 89, 120, 151, and 261). These newly recharged waters also have more calcium, sodium, and chloride (analyses 89, 120, 151, and 261) than the prevalent ground water.

The source of the sulfate in the prevalent ground water of the basalt could be from the small amounts of sulfate dissolved during the oxidation of iron sulfide in the upper parts of the basalt where oxygen is more available, from the release of sulfur during the breakdown of other minerals and glass of the basalt, or from sulfur-bearing minerals in the soils and overburden through which water passes on its descent to the ground water. The general uniformity between the amount of sulfate in the deep and shallow ground water of the basalt and the general absence of sulfate beneath the humid areas west of the Cascade Range, where evaporite concentrations at the surface are negligible, seem to indicate that leaching from the soils and overburden yields most of the sulfate in the ground water of the basalt.

Among other special types of ground water, the hot water at Union Hot Springs is a sodium chloride water (analysis 483) having 56 mg/l of sulfate, and the warm water at Bingham

Springs is a sodium chloride water (analysis 364) having little sulfate. Neither the carbon dioxide charged waters near Klickitat Springs (analyses 3 and 4) nor the partly connate high chloride waters rising into the basalt of western Oregon (analyses 444 and 488, Hart and Newcomb, 1965) contain much sulfate.

Chloride

The prevalent type of ground water contains only small amounts of chloride, the total range being from 1 to 50 mg/l. Most determinations fall between 5 and 30 mg/l, and the average is about 10 mg/l. Because of the lack of a source of chloride ions in the basalt, chloride is so uncommon that analyses with more than 30 mg/l indicate distinctive ground water. The largest group of analyses showing more than 30 mg/l chloride is on ground water at rather shallow depth beneath semiarid basins of eastern Washington where recharge water apparently picks up chloride from evaporite concentrations in the soils and overburden (analyses 42, 165, and 212). This special type of ground water, newly recharged in the Columbia Basin Irrigation Project, contains up to 147 mg/l (analyses 92, 120). The hot water at Union Hot Springs (analysis 483) has 129 mg/l of chloride. Waters having the highest chloride contents are the calcium sodium chloride waters rising into the basalt west of the Cascade Range. These waters may contain several hundred milligrams per liter of chloride (analyses 300–302 and 432), or, in extreme situations (analysis 326), the chloride content may approach that of the saline water in the underlying sedimentary rocks.

MINOR IONS OF MOSTLY ANION REACTION

In the prevalent ground water, the combined content of fluoride, nitrate, phosphate, and boron amounts to less than 5 mg/l, although in some areas the nitrate varies greatly and is more than a minor anion. Also, even though the quantity is small some of these ions can be of great importance to the health of plants and animals using the water.

Fluoride

The total range of fluoride is from 0 to 2 mg/l; an exceptionally great concentration is exemplified by one water sample (analysis 54) from well 12/29–28L1 north of Pasco which contained 4.7 mg/l in one of three analyses. The common range of fluoride, which doesn't vary geographically, is from 0.2 to about 0.8 mg/l. The higher part of the total range, from 0.7 to 2 mg/l, occurs in the sodium bicarbonate ground water that is in the synclinal basins of eastern Oregon and Washington. Analyses of the prevalent type of ground water from 58 sources show 1 mg/l or more fluoride; of these, 56 also show a predominance of sodium over calcium, in milligrams per liter. The two exceptions (analyses 135 and 466) have calcium exceeding sodium in ratios of only 24 : 22 and 26 : 22 mg/l. The basinal areas along the east-west The Dalles-Umatilla syncline in south-central Washington and north-central Oregon and the structural sag running south from near Ephrata to Wallula in central Washington (Newcomb, 1970) are the main localities of this sodium fluoride ground water.

Of the special types of ground water, the saline connate waters that rise into the basalt at places in western Oregon contain relatively small amounts of fluoride, as do the newly recharged ground waters of the Columbia Basin Irrigation Project. The warm and hot waters of springs and wells contain above-average amounts of fluoride, and the carbon dioxide charged water near Klickitat Springs in two analyses contain both average and above-average amounts of fluoride.

La Sala and Doty (1971) reported chemical analyses for water in the basalt and interbedded sedimentary layers at depths of 362–1,200 feet and for water in basalt aquifers at intervals from a depth of 1,200–4,283 feet in the Atomic Energy Commission's deep exploratory well ARH–DC–1, located in the Cold Creek syncline northwest of Pasco (in sec. 35, T. 13 N., R. 26 E.). A study of the 18 analyses listed by La Sala and Doty (p. 50) indicates that the waters are similar to the sodium-rich type of the prevalent ground water of the basalt except for the high fluoride concentrations reported for most of the water-bearing zones below a depth of 726 feet. These high fluoride concentrations range from 2.0 to 21 mg/l and are mostly in the 10- to 20-mg/l range in the water samples taken between 720 and 4,283 feet in depth. The well was drilled by air-rotary methods; water and detergents were added to the air stream. Supposedly any contaminants were cleared from the well before the samples were taken, and some of the samples were believed by La Sala and Doty (p. 51) to have been uncontaminated; consequently, there may be a possibility that such high-fluoride ground water occurs in the basalt at depths below 1,000 feet at some places. All evidence for such an occurrence is limited to the La Sala and Doty (1971) data.

Nitrate

Nitrate occurs within a common range of 0.2–6 mg/l, and most of the analyses show less than 2 mg/l. The total range runs from 0 to 99 mg/l. Almost all the sources showing more than 10 mg/l are from wells that are less than 400 feet deep, as shown in figure

4. Most of these waters having more than 10 mg/l of nitrate also have calcium predominating over sodium, as shown in figure 5.

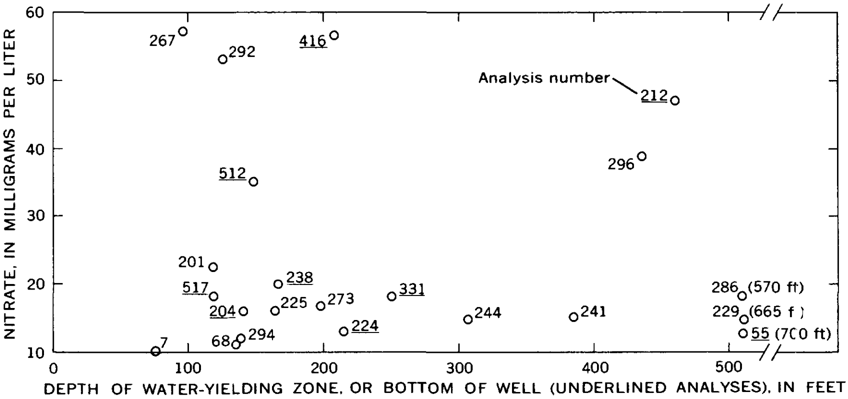

FIGURE 4. — The relation of depth of the water-yielding zone to the amount of nitrate, for analyses having 10 mg/l or more nitrate, in the prevalent type of ground water.

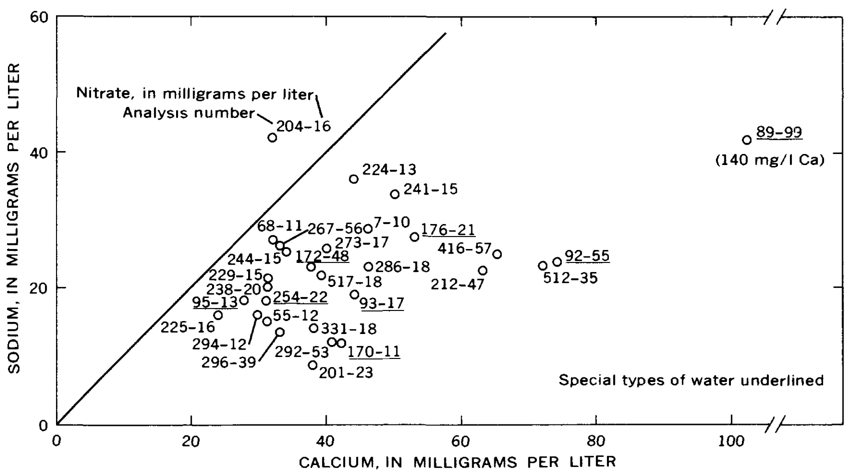

FIGURE 5. — The general predominance of calcium over sodium in the ground water having 10 mg/l or more of nitrate.

Many of the analyses having more than 20 mg/l nitrate are on the special type of ground water that is being artificially recharged by irrigation water (analyses such as 92 and 177). Three other special types of ground water — the carbon dioxide charged waters, the hot springs, and the high chloride waters west of the Cascade Range — do not show more than a few tenths of a milligram per liter of nitrates.

The source of the nitrate, where there is more than about 2 mg/l, seems to be leached evaporite minerals, nitrogen fertilizer chemicals, or soluble organic materials between the surface and the aquifers.

The U.S. Public Health Service (1962, p. 78) fixed a limit of 45 mg/l for nitrates in public water supplies and stated (p. 48) that nitrates in excess of 50 mg/l may give rise to infantile methemoglobinemia. Three private wells yield water that exceeds 50 mg/l; two of these wells (analyses 267 and 292) draw water from permeable zones within 100 feet of the surface and one (analysis 416) is cased to only 60 feet.

Phosphate

The content of phosphate ranges from 0 to 2.8 mg/l and has a common range between 0.02 to 0.30 mg/1 for the 138 determinations given in table 1. There is no evident correlation between geologic or geographic differences among the sample sources and the higher or lower amounts of phosphate.

Boron

Determinations of boron are given (table 1) for 111 samples, and the analyses show a range from 0 to 10 mg/l. Only 14 of those analyses show more than 0.20 mg/l. From the few analyses for boron, no geographic distribution is apparent. The concentrations exceeding 1 mg/l are in the special types of ground water. Boron content is higher than 1 mg/l in the calcium sodium chloride water (analysis 326) which rises into the basalt west of the Cascade Range and is almost 2 mg/l in the ground water associated with intercalated sedimentary rocks in the Baker area (analyses 492–493). By far the greatest concentration (10 mg/l) is in the warm water from Bingham Springs (analysis 364). Apparently, the presence of boron in concentrations ranging from a few hundredths to a few tenths of a milligram per liter is characteristic of the ground water in the basalt. The boron usually occurs in the small concentrations that are beneficial to plant growth when the water is used for irrigation. The amounts that might cause damage to crops irrigated with the ground water are present only in the above-mentioned special types of water.

OTHER CHARACTERISTICS OF THE QUALITY OF THE GROUND WATER

Dissolved Solids

The prevalent type of ground water has total dissolved solids showing extremes that range from 68 to 568 mg/l and a common range of about 150–400 mg/l. There is little evidence of a consistent variation of dissolved solids with depth, but there is some indication that the ground water occurring near natural recharge areas contains fewer total dissolved solids than does ground water in deep zones, remote from probable recharge areas. For example, the total dissolved solids in the Walla Walla Valley, close to recharge areas in the Blue Mountains (analyses 9–27), average 180 mg/l compared with 290 mg/l for wells in the flat-lying basalt north of Pasco (analyses 90–99).

As a rule, the special types of ground water carry more dissolved solids. The calcium sodium chloride water rising into the basalt of western Oregon has the greatest dissolved solids, 18,500 mg/l in analysis 326. One of the analyses of the carbon dioxide charged water (analysis 3) contains 950 mg/l dissolved solids. The warm and hot spring waters (analyses 364 and 483) are only moderately high in dissolved solids, 464 and 461 mg/l respectively; the smaller amounts of dissolved solids have resulted partly from the loss of bicarbonate that has accompanied the temperature rise in these spring waters.

Dissolved Gases

The principal readily discernible dissolved gas is hydrogen sulfide, which occurs in small amounts in most of the ground water from wells in the basalt. It seems to be present in greatest amounts in the water from newly drilled wells. The consensus is that the gas diminishes with time as the well is pumped, rather than that the users become accustomed to it and notice it less with time. At some wells, where the gas is sufficiently strong, the owners find it desirable to lay a discharge line to their reservoir so that the water can be aerated before entering the pressurized system. Pumping directly into water mains, especially one incorporating a pressure tank, is objectionable because bubbles of the accumulated hydrogen sulfide gas can, at times, move out with the water flowing to users. No relations have been detected between the amount of this hydrogen sulfide in the water and the depth, the location, or the pressure of confinement of the water in basalt wells.

Carbon dioxide occurs in small quantities and rises freely from the ground water in springs and wells at Klickitat Springs, and possibly at other places. Thirty-eight analyses in table 2 show carbon dioxide concentrations that range from 0.01 to 50 mg/l. A small amount of free carbon dioxide is apparently in balance with the bicarbonate and other ions in most of the ground water. At Klickitat Springs, carbon dioxide rises along a fault and occurs with the ground water, greatly exceeding the level of saturation. It rises through the ground water and lies in permeable parts of the basalt above the water table. For about 40 years the carbon dioxide at Klickitat Springs has been collected at springs and wells for the manufacture of dry ice.

The concentration of dissolved oxygen is very low in most of the ground water. A number of determinations, for which no recorded data are available, are known by the author to have found no oxygen in ground water of the basalt when it was correctly sampled before surface or pump-column aeration. Four of five analyses listed in table 2 show that dissolved oxygen ranged from 0.2 to 5.3 mg/l, but no descriptions of the techniques of sampling and analyzing these samples are available. The procedure followed in the analyses listed are known to have involved field sampling and later laboratory analysis; hence, some of the analyses may be assumed to have been made on water which had been aerated. Because most of the ground water is confined under pressure within aquifers that contain fresh, untarnished, and unoxidized iron pyrite and because of the reported determinations of no oxygen, it is assumed that the ground water of the basalt is largely devoid of dissolved oxygen. Oral reports of experimenters in water treatment and fish culture state that the water from basalt wells dissolves oxygen readily when aerated at the surface.

Hardness

The ground water ranges from soft to very hard, according to the scale used by the U.S. Geological Survey, which terms 0–60 mg/l soft, 61–120 moderately hard, 121–180 hard, and more than 180 very hard. The range of hardness in the analyses is 4–412 mg/l and an approximated common range is 50–250 mg/l. In most of the waters sampled, the calcium and magnesium, comprising essentially all the constituents that unite with soap to form insoluble compounds, are in balance with bicarbonate anions; thus, the hardness is largely of the temporary type, meaning it can be eliminated by boiling the water. The sulfate and chloride types of hardness, the types called permanent, are prominent in the prevalent type of ground water east of the Cascade Range only in a few widely separated places within basinal areas of southern Washington and northern Oregon.

There seems to be no consistent relation between the hardness of ground water and the depth of the aquifers within the basalt. The analyses show that the hardness of water varies somewhat from place to place and even from well to well within the same area and depth zone of the basalt. Of the analyses on four city wells of similar depth at Ritzville, one yields samples containing 280 and 304 mg/l hardness (analyses 211–212) and the other three have hardnesses of only 114, 114 and 119 mg/l. Most of the water supplies used by cities and towns fall in the range of moderately hard water, about 80–120 mg/l. Some of the softest water of the public supplies belongs to the towns and cities adjacent to areas of substantial natural recharge, such as the slopes of the Blue Mountains. The town of Elgin, northeast of La Grande, receives some of the softest water (analyses 323–324) which has only 20 mg/l of hardness. The sodium-rich ground waters of the synclinal basins contain some soft waters. Umatilla and Othello have some wells that yield particularly soft water.

The special types of ground water in the basalt include the very hard calcium sodium chloride water, the hard and very hard carbon dioxide charged ground water near Klickitat Springs, and soft sodium water in or near warm and hot springs of northeastern Oregon.

pH

The pH of the prevalent type of ground water ranges from 6.5 to 9.2 on the commonly used scale for which 7 is the neutral point at which neither acid nor alkaline conditions exist in the water. Most of the values fall between 7.2 and 8.4 and show that a slightly basic condition exists in the ground water of the basalt. The median point, 7.8, of the common range seems to be about the average pH condition. The sodium-rich water of The Dalles–Umatilla syncline (as shown by analyses 372–380) has a pH range of 8.2–8.5.

Of the special types of ground water, the carbon dioxide charged water near Klickitat Springs has the lowest pH, the two values being 6.4 and 6.6. The calcium sodium chloride water west of the Cascade Range shows low pH (6.2 in analysis 326), high pH (9.6 in analysis 444), and intermediate conditions (8.0 in analysis 453). The hot springs water (analysis 483), in which much of the bicarbonate has been converted to carbonate by the near-boiling temperatures, has the next to the highest pH (9.5) listed in the analyses. The somewhat similar warm sodium chloride waters near Bingham Springs (analyses 364–365), though low in bicarbonate, have lower pH values (8.6 and 8.5).

Sodium-Adsorption-Ratio

A ratio, called SAR (sodium-adsorption-ratio), has replaced older concepts because it more closely approximates the adsorption of sodium by an average soil when a water is used for irrigation. The ratio is given by the following equation when ion concentrations are expressed in milliequivalents per liter:

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

The total range of the SAR values for the prevalent ground water in the basalt (table 1) is from 0.2 to 19.6, and the common range is from 0.5 to 4.0. When the SAR and the specific conductance of a water are plotted on a diagram devised by the U.S. Salinity Laboratory Staff (1954, p. 80), as in figure 6, approximate salinity and sodium (alkali) hazards are obtained for irrigation use of water on a soil that is assumed to be average. The plotting of representative analyses (fig. 6) shows that the prevalent ground waters fall in classes C1–S1 and C2–S1, which represent low and medium salinity hazard and low alkali hazard. The only waters that show characteristics classed as hazardous to irrigation use are among the special types of ground water. One analysis of a special type of ground water, the calcium sodium chloride water in parts of western Oregon, is shown by the plotting (fig. 6) to be very high in both salinity and alkali hazards. In analyses of two other special types of ground water, those of areas artificially recharged with lost irrigation water and that from one hot spring fall in positions intermediate between the safe waters and the hazardous waters (fig. 6).

Specific Conductance

The analyses of table 1 give a total range of specific electrical conductivity from 107 to 694 micromhos and a common range of 200–500 for the prevalent type of ground water. In general, the low specific conductance expresses the low concentration of dissociated ions (all ions except the silica). The special type of ground water resulting from recent artificial recharge of the Columbia Basin Irrigation Project has specific conductance ranging from about 700 to as much as 1,820 (analysis 261), and the calcium sodium chloride waters have a conductance as high as 29,600 micromhos (analysis 326). When plotted against the SAR (as in fig. 6), the specific conductance, by expressing the amount of chemically active dissociated ions, helps to indicate the salinity and alkali hazards of the ground water used for irrigation.

Trace, or Minor, Constituents

The analyses for lithium, strontium, barium, chromium, copper, lead, nickel, titanium, vanadium, arsenic, and a few other minor elements in the ground water are given in table 2. Most of the values for the first nine ions listed above were taken from Adams (1957, 1960), and most of the arsenic analyses were by the Oregon Board of Health. Minor elements constitute less than a few milligrams per liter of the total dissolved solids found in the analyses.

Chromium determinations had a maximum of 0.03 mg/l, well below the limit of 0.05 mg/l recommended for domestic use in

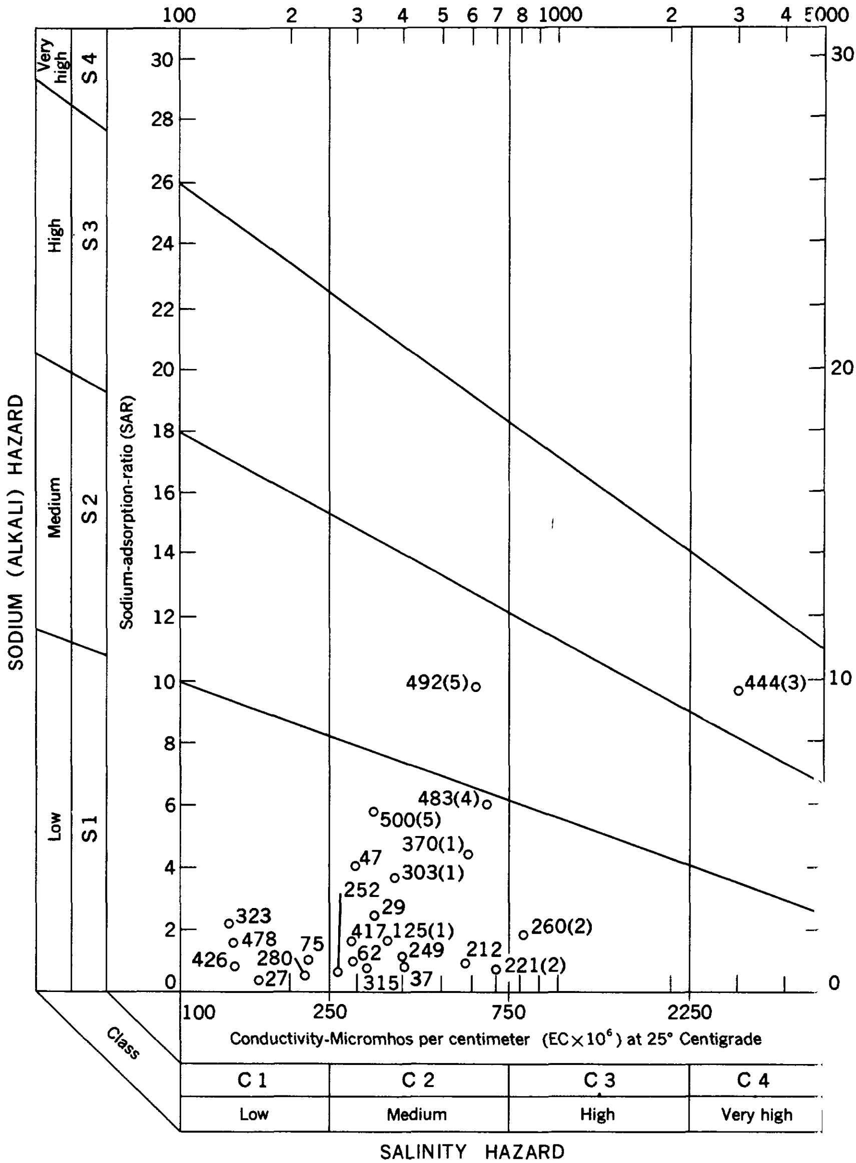

FIGURE 6. — Plot of SAR and specific conductance for 18 representative analyses of the prevalent ground water and six analyses of special types of ground water. Numbers in parentheses indicate (1) high sodium, prevalent ground water, (2) artificially recharged ground water, (3) calcium sodium chloride water west of the Cascade Range, (4) hot-spring water, and (5) ground water in an area where much sedimentary material is interbedded with the basalt.

the standards of the U.S. Public Health Service (1962). Lead was analyzed in four samples, the greatest of which amounted to 0.022 mg/l, also well below the recommended limit of 0.1 mg/l. Arsenic values in 15 analyses were less than 0.005 mg/l except one, which was listed as 0.005 mg/l; these values are one-tenth, and less, of the recommended limit of 0.05 mg/l.

Barium was in all the ground-water samples for which it was analyzed. In only one sample, from a well at Pomeroy where 2.23 mg/l was found, was the content reported to be more than 0.10 mg/l. A limit of 1 mg/l is recommended by the U.S. Public Health Service (1962, p. 28).

Strontium was present in small amounts in all 65 analyses for which determinations were listed; in only five of these analyses was it greater than 1 mg/l. These five analyses on water from five wells south and west of Portland gave values ranging from 1.2 to 28 mg/l. Two of these well waters are the calcium sodium chloride type that rise into the basalt in parts of that area.

Lithium content was determined for only three samples, all from Ephrata, and the three analyses range from 0.02 to 1.77 mg/l.

Radioactivity

The 27 analyses of table 3 include determinations of gross beta-gamma activity in micromicrocuries per liter (μμc/l), radium in micromicrocuries per liter, and uranium in micrograms per liter (μg/l). The analyses (samples 38, 43, 59, 61, and 63), made before 1952, determined the gross beta-gamma activity, radium, and uranium down to cutoff points that were, respectively, 100, 10, and 1,000 times larger than the cutoff points used as minimum measurable amounts after 1955.

The 21 analyses carried to the accuracy of the post-1952 measurements show maximum beta-gamma activity of 32 μuc/l, indicating that the greatest radioactivity of water samples was far below the gross beta-activity safety limit of 1,000 μμc/l for public water supplies, as set by the U.S. Public Health Service (1962, p. 9). Twenty-two post-1951 analyses show the maximum radium content to be 0.6 μμc/l and the maximum uranium content to be 10 μg/l. The radioactivity of the ground waters of the basalt is low, in keeping with the low range of radioactivity common to basaltic rocks.

PHYSICAL CHARACTERISTICS

COLOR

Of the 201 determinations of color listed in table 1, 95 give a 0 value, and the greatest is 20 on the scale for which 500 is the top, or mostly opaque, standard. The ground water of the basalt is customarily clear and devoid of coloring matters in solution. Sediment or suspended matter in the ground water taken from wells and springs is usually due to inadequate casing which admits material from overlying or interbedded sedimentary formations, from entrainment of materials deposited on the casing and pump, or from the precipitation of small amounts of dissolved materials like iron oxide; this type of cloudiness is lacking in the water from adequately constructed and operated wells.

TEMPERATURE

In general, the temperature of the ground water is a few degrees higher than the sum of mean annual temperature of its area and the temperature increase due to the earth's thermal gradient down to the aquifer in which the water occurs. There are many variations from this generalization; some of the ground water is much warmer, and some is cooler than would be expected from the "normal" thermal gradient which is considered to be an increase of 1°C, or 1.8°F, for each 100 feet of depth beyond the top 100 feet. Each of the Celsius (centigrade) values in table 1 can be converted to the more familiar Fahrenheit scale by multiplying by 1.8 and adding 32.

Just over half the analyses in table 1 include water temperatures. Supposedly, these temperatures were recorded at the time of sampling in all cases. However, interaquifer circulation in certain wells had preceded the sampling, so a few of the temperatures listed may not be correct for the ground water in the aquifers to which it is assigned. Some of the multiple analyses on single wells have temperatures that differ by several degrees. For example, analyses 20 and 21 (well 7/36–22N1 at Walla Walla) have a temperature difference of 2.9°C (5°F), whereas, analyses 133 and 134 (well 15/45–32N1 at Pullman) show a temperature difference of 6.1°C (11°F).

It has been the author's experience that nonrepresentative temperatures can be observed for ground water through one or both of two types of error involving improper techniques and inadequate samples. The proper technique requires a careful measurement of water temperature at the well and a large sample, preferably a sustained pump discharge. The useful sample is one large enough to represent conditions in the aquifer. Obtaining true samples from each aquifer of a multiaquifer well can be a formidable task. Apparent discrepancies in the records notwithstanding, the general nature of the temperatures of the ground water can be approximated from the data in table 1.

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The temperatures of the prevalent type of ground water range from 8.9°C (48°F) to 30°C (86°F). These extremes, respectively, are on water from a 213-foot well south of Davenport (analysis 273) and a 1,150-foot well near La Grande (analysis 443). The coolest item of this range is only a degree or so less than the mean annual temperature; this is common in the uppermost 100 feet of the earth. If the ground water comes from the lowest part of the well, 1°C (1.8°F) should be added to the mean annual temperature for the additional depth to 200 feet. However, the upper item of the temperature range, 30°C (86°F), is 11°C (19°F) above the 9.7°C (49.4°F) mean annual temperature at La Grande plus 10°C (18°F) for 1,000 feet of depth. This is the general situation for deeper ground waters—locally the temperature is higher than the depth alone would indicate it should be. Areas within which the deeper ground waters are warmer than normal earth temperatures have been noted at the southeast side of Walla Walla, at places in the Quincy Basin southwest of Ephrata, and at The Dalles (Newcomb, 1959, p. 16); also, they have been observed in the Grande Ronde Valley near La Grande (Hampton and Brown, 1964, p. 44) and in the Umatilla River basin (Hogenson, 1964, p. 54–56). Hogenson (1964, p. 55) concluded that the data on wells near Pilot Rock, 13 miles south of Pendleton, indicated a temperature increase of at least 2°F per 100 feet of depth below the first 100 feet of the basalt.

The ground water having higher-than-normal temperature near The Dalles occurs in structural compartments, each of which has rather distinct temperatures. The "Mill Creek artesian aquifer," which ranges in depth from 300 to 800 feet, has 27.8°C (82°F) water (analysis 303) and extends downvalley for several miles to a terminating fault barrier. The same water-bearing stratum northeast of that barrier contains water whose pressure level stood 600 feet lower; this lower pressure water has a temperature of 21–22°C (69–72°F), still nearly 8.3°C (15°F) above the normal thermal gradient for its 200- to 300-foot depth (Newcomb, 1969, p. 26).

The hot spring (analysis 483) and some of the warm waters analyses 3 and 364) occur near faults through which water or gas from greater depths may bring excess heat. Also, the ground water near known faults, some of which are geologically young, is commonly warmer than the normal thermal gradient would allow, leading one to believe that the pickup of heat from zones of mechanical rupture or the ascent of ground water from deeper and warmer zones are possible explanations of the excess heat. Because young volcanic rocks of Pleistocene and Holocene age occur in and adjacent to the Cascade Range and also in small areas scattered across northern Oregon, local areas of volcanic heat cannot be ruled out as sources of the elevated temperature of some of the warmer ground water. However, in the deeper ground waters, the widespread occurrence of a few degrees of temperature above that of the normal thermal gradient indicates that a higher-than-average thermal gradient exists in the basalt, as suggested by Hogenson (1964).

Within and adjacent to some of the areas of generally warmer deep water, there are aquifers whose water shows normal earth temperatures and some whose water is several degrees cooler than normal. Ground water that is a few degrees cooler than the normal temperature occurs in the basalt around the edges of some of the downwarped basins and is commonly attributed to the rapid descent and lateral movement of cooler water from the surface.

EFFECT OF TIME ON THE QUALITY OF THE GROUND WATER

AGE OF THE GROUND WATER

Only a short time, geologically speaking, is required for the ground water of the basalt to acquire the dissolved constituents found by the first well and spring users. As ground water is withdrawn from the aquifers, other water moves into the ground-water reservoir and ultimately reaches the exit points. This influx of new water causes changes in the chemical quality of the water withdrawn from some wells.

The ground water now being withdrawn from wells drilled in newly developed ground-water areas is a composite from many different, largely natural, recharge events. In areas of greater pumpage and of long-term ground-water withdrawal, some of the more permeable aquifers may contain ground water which is a mixture of the old water and that newly drawn into the aquifer. These composite waters have average ages that show they have been underground for various periods, ranging from a few years to several tens of thousands of years.

Water samples taken from three different depth zones of the basalt within The Dalles–Umatilla syncline in northern Oregon were dated with carbon-14 in the Geological Survey Isotope Laboratory as follows (Robison, 1970):

Owner	Well No.	Depth of zone, in feet	Laboratory No.	Age, in years
O. W. Cutsforth	1/26-1J1	30-70	W-2112	Modern
U.S. Government	4N/27-8R1	256-453	W-2090	6,700
O. J. Hellberg	3N/26-5M1	[1]200-950	W-2092	27,250

[1]Zone is uncased, but the main water is believed to enter from the lower part.

Carbon-13 determinations of these ages showed the original source of the carbon in the carbonate ions to be the atmosphere, not carbonate minerals of the rocks traversed by the water. The stratigraphic manner in which the ground water occurs in these three wells is illustrated in the geologic section (fig. 7).

A water sample from an aquifer in the depth zone 540–620 feet of the deep test ARHDC–1, located within the Cold Creek syncline in sec 35, T. 13 N., R. 26 E., on the Hanford Reservation of the Atomic Energy Commission, was dated in the Radiocarbon Dating Laboratory of the University of Texas in 1969 as 13,000 years before the present (La Sala and Doty, 1971, p. 53). From age determinations on 44 samples of ground water from wells in east-central Washington, Jan Šilar (1969) concluded that the ages of the ground water in the top few hundreds of feet of the basalt ranged from 0 to 16,275±1,465 years before the present. The ages of the bulk of the determinations were between 0 and 6,000 years. The depth of the aquifers sampled ranged from 21 to 607 feet, only one sample (from the 600-foot level) being from deeper than 300 feet. No significant correlations between age and depth or age and aquifer were derived from Šilar's publication.

Age dates were obtained by Crosby and Chatters (1965) on 33 samples of ground water taken from wells in the basalt at Pullman and Moscow, in addition to seven other wells in loess and a residual weathering zone of older rocks and sedimentary deposits. The carbon-14 ages of the ground water in the basalt ranged from 1,685 to ⩾ 32,000 years. An appraisal of their data indicates that age may increase downward, roughly correlating with depth, but there are many exceptions to this relation. It is possible that most of the exceptions to this inferred correlation of age to depth occur within two depth zones where the aquifers have received substantial additions of younger water which was drawn in as a result of the large pump withdrawals from those aquifers during the last 60–80 years. When the data on the samples taken from the two areas (Pullman and Moscow) are plotted separately, on graphs that show the age of the water versus the altitude of the aquifer, the exceptions to the general trend of increasing age with depth are shown to be explainable by the above hypothesis (figs. 8 and 9).

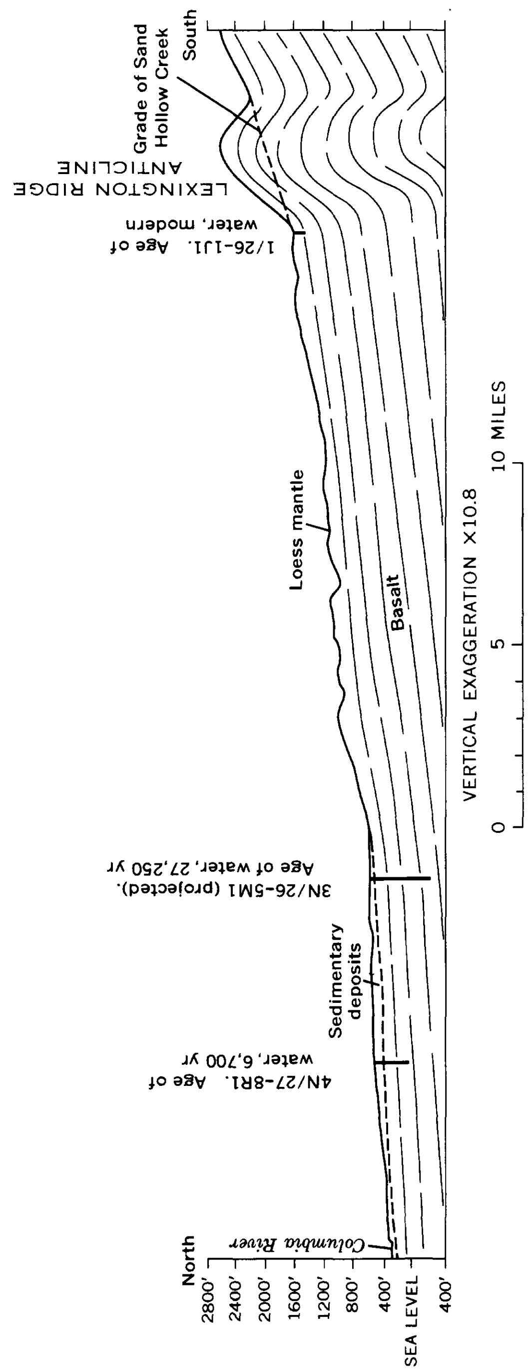

FIGURE 7.—Cross section, partly schematic, north-south in north-central Oregon, showing the wells for which carbon-14 ages have been obtained for water samples.

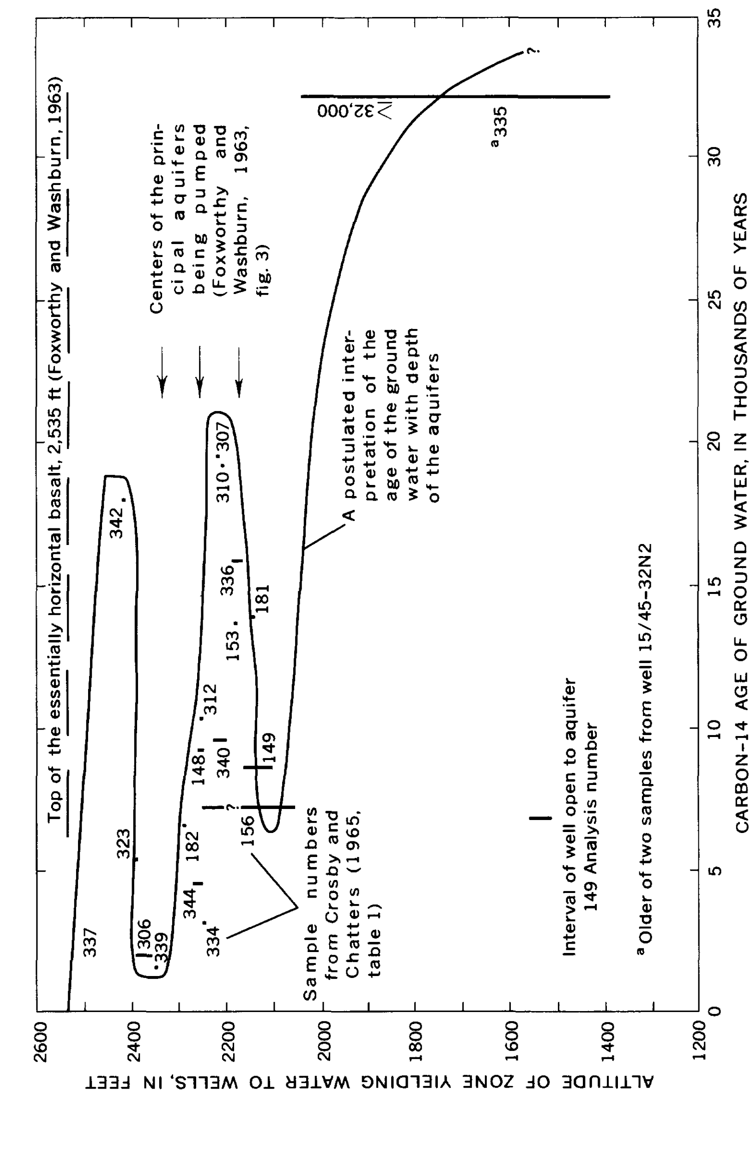

FIGURE 8.—Relation of altitude of the aquifer to the age of the ground water sampled from the basalt in the Pullman area, Washington.

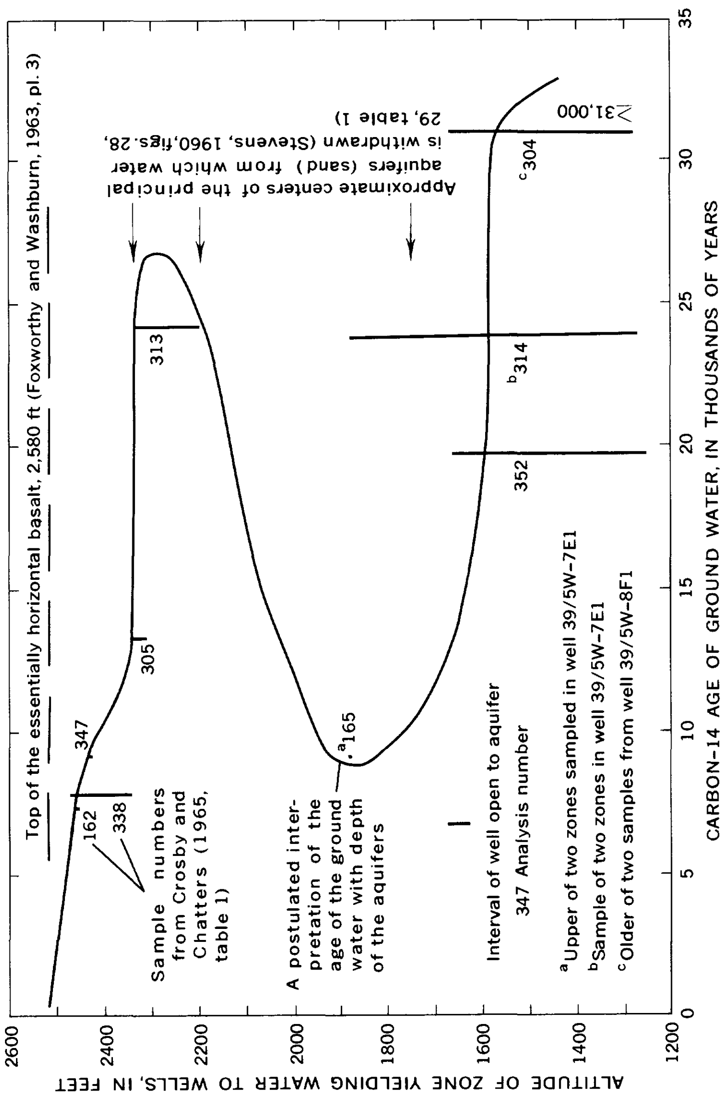

FIGURE 9.—Relation of altitude of the aquifer to the age of the ground water sampled from the basalt in the Moscow area, Idaho.

In addition to the age-depth relationships, some of the samples and age determinations of Crosby and Chatters (1965) may indicate other information about the ground water. Apparently, water was being withdrawn from more than one aquifer in certain wells when some of the water samples were taken. For example, an age of 6,150 years was obtained in 1964 and ⩾ 32,000 years in 1965 on water from well 15/45–32N2, the deep well of Pullman. This 954-foot well is cased to 399 feet, but its log contains no record of the type or tightness of the casing-to-rock seal and no record of the location of the water-bearing zone, or zones, below the casing. The differences in the two ages obtained on samples of water from this well could indicate that the water withdrawn comes from aquifers of different depths and may or may not be a mixture, depending on the extent and rate of presample pumping.

From the age data on hand and the knowledge of the recharge systems through which water has gained entry to the tabular aquifers in the basalt, it may be concluded that ground water of all ages, from modern times to many tens of thousands of years, is to be expected in the basalt. Patterns of the basic circulation routes of the ground water may be indicated when adequate data are at hand.

RELATION OF AGE TO QUALITY

A comparison of the ions in the three ground waters sampled by Robison for age determinations (analyses 437, 381, 361) indicates some general differences that correspond to greater age of the water deeper underground. These analyses show that the water at greater depth has a lower content of calcium (43–9 mg/l), magnesium (17–3 mg/l), and bicarbonate (226–176 mg/l), and, correspondingly, a greater content of sodium (24–57 mg/l inconsistently) and potassium (6–12 mg/l). There is an increase in the sulfate from 19 mg/l in the youngest water to 94 mg/l in the intermediate water, and then a decrease to 0.2 mg/l in the oldest ground water. The total dissolved solids in water of the three wells differ mainly in accordance with the amount of sulfate — the total of the other ions being roughly similar in the three waters. On the basis of these analyses, the differences in ion concentrations could be attributed to slight differences in the chemical history of the three ground waters rather than to chemical changes that occurred in one uniform type of water while it was gaining greater depth or age. However, the small amounts of calcium and magnesium in the older sodium-rich ground water indicate that some depletion of magnesium, and probably of calcium, occurs, either by base exchange or by chemical precipitation.

CHANGES IN QUALITY OF THE GROUND WATER AS RECORDED IN THE DATA

CHANGES INDICATED DURING ITS UNDERGROUND JOURNEY

A history describing the chemical acquisitions of the ground water in the basalt can be reconstructed because of the fact that water, on the surface, has low ion concentrations and, while passing through sedimentary materials and soils that lie on the basalt, it acquires additional ions. The analyses below indicate that the ground water obtained some additional ions early in its traverse of the basalt aquifers as well. The result of the three acquisitions — on the surface, within the overburden, and within the basalt — resulted in the dissolved-solids load typical of the average native ground waters of the basalt. Analyses representing these three epochs in the simulated history of ground water in the drier part of the basalt region follow. The data was selected and averaged from that given for the Walla Walla Valley (Newcomb, 1965), Umatilla River valley (Hogenson, 1964; Santos, 1965), Upper Grande Ronde River valley (Hampton and Brown, 1964), and the Palouse River valley (Foxworthy and Washburn, 1963). There is some evidence that a similar three-stage pickup of dissolved solids has also characterized the ground water in the basalt of the slightly more humid areas of the basalt region.

	Ions, in milligrams per liter						
	SiO_2	Ca	Mg	Na	K	HCO_3	Dissolved solids
Walla Walla Valley:							
Mill Creek (about two-thirds surface runoff)	28	6	2	2	2	33	61
Ground water in overburden (three wells)	42	36	10	19		197	251
In basalt (top 250 ft, two wells just west of Walla Walla)	61	35	14	16	6	182	256
Umatilla River valley:							
Umatilla River at Pendleton during high flow (Santos, 1965, p. 66)	30	7.5	1.2	3.4	1.6	33	70
Ground water in overburden (four wells)	48	30	11	26	3	190	232
In basalt (top 250 ft, four wells)	49	57	13	47	7	214	297
Upper Grande Ronde River valley:							
Grande Ronde River (mostly surface runoff)	31	5.0	1.6	3.1	1.5	31	59
Ground water in overburden (seven wells, less than 100 ft deep)	49	23	11	12	3	132	212
In basalt (four wells, 655–1,435 ft deep)	71	6	1	25	5	73	149
Palouse River valley near Pullman:							
Paradise Creek near Pullman	26	12	4	6	5	55	116
Ground water in granitic sand overburden, (one well, 83 ft deep)	46	42	15	18	2	192	272
In basalt (two wells, less than 100 ft deep)	64	22	15	25	3	203	225

Despite the evidence that some of the dissolved materials were obtained before the water entered the basalt, much of the ground water has had at least many hundreds or thousands of years residence, as described previously, and is in general chemical equilibrium with the basalt. One analysis of water from the sandy deposits overlying the basalt in the Upper Grande Ronde River valley (Hampton and Brown, 1964) and many analyses given by Walters and Grolier (1960) for the Columbia Basin Irrigation Project area show that some of the ground water in the overburden of basin areas has a greater content of dissolved solids than does the ground water in the basalt below. This larger load of dissolved solids in ground water of the overburden may indicate that one or several of the following three conditions were operative: (1) The ground water entered the basalt beneath adjacent slopes where less sedimentary cover exists, has little dissolved matter from the overburden and was long isolated from the drainage of the overlying materials, (2) some of the ground water in the basalt percolated through the overburden in more humid times when the overburden contained a lesser amount of soluble salts, or (3) removal of ions from solution has occurred in the basalt.

CHANGES IN QUALITY OF THE GROUND WATER WITH TIME

Among the analyses listed in table 1 are many that were made on samples from the same wells over the span of a decade; also, there are a few that were made on samples from the same wells over several decades. The longest period of time is covered by analyses 182–185 on samples taken from well 19/24–7J1 near Quincy (17 miles southwest of Ephrata) in 1916, 1950, 1960, and 1961.

The only changes that have occurred in the quality of the ground water within the period covered by the analyses are man made and consist of: (1) An increase in the concentrations of calcium, sodium and chloride at some pumped wells in water which rises into the basalt west of the Cascade Range, and (2) an increase in most of the principal ions in ground water near areas of artificial recharge from irrigation water in the Columbia Basin Irrigation Project area.

The increase in ionic concentrations in the calcium sodium chloride water is shown by analyses 453–456 on samples from two wells at Lake Oswego, southwest of Portland. Apparently the pumping of these wells induced the rise of a proportionately greater amount of saline ground water. The total thickness of the basalt of the Columbia River Group in that area is only 600–

800 feet, and heavily pumped wells drawing water from the lower part of that basalt section are vulnerable to this change in the quality of the water unless adequate means of natural recharge occur in that locality. Analyses 327 and 328 show that no such change has occurred in a well at North Plains, 20 miles northwest of Lake Oswego.

The general increase in most of the principal ions (particularly the sulfate, chloride, sodium, and calcium) in the ground water near areas of artificial recharge in the Columbia Basin Irrigation Project is shown by analyses 118–120, 175–177, 220 and 221, and 254–256. That this increase in dissolved solids is not widespread in the project area is shown by the unchanged quality of the ground water of the basalt in series of analyses on other wells, such as analyses 227–230 and 231–234 for wells at Larson Air Force Base.

Wells 14/30–8G1 and 14/30–20A1, in areas of recharge from lost irrigation water, had a decrease in both sulfate and nitrate between 1958 and 1962. This decrease is indicated by the amounts shown in table 1 for 1958 (368 and 99, 93 and 55, the sulfate and nitrate from each of the two wells, respectively) as compared to the amounts (168 and 48, 56 and 30) found in partial analyses for June 1962, not shown in table 1. A decline from the high sulfate and nitrate concentrations of 1958 may indicate that the main flush of salts had occurred and that subsequent concentrations of salts in the water of these wells would be lower.

Series of analyses over an expanse of several years show an increase of nitrates in the recharge-augmented ground water of some wells in the Columbia Basin Irrigation Project and of some of the wells at the Fairchild Air Force Base west of Spokane.

The water from most deep wells has remained rather constant in hardness during the long-term use, but a few changes of the hardness of water are shown in the data on table 1. Analyses 278–283 on water from one 410-foot well at Fairchild Air Force Base west of Spokane show a nearly constant hardness, ranging from 82 to 90 mg/l from 1947 to 1959, and a rise in hardness to 125 mg/l accompanying an increase in calcium and a decrease in sodium in 1960.

SUMMARY

The ground water native to the Columbia River basalt, as known from the more than 500 chemical analyses, has a moderate dissolved-solids content of about 275 mg/l. Calcium, sodium, bicarbonate, and silica are the principal constituents of the dissolved solids in the prevalent type of water.

The chemical nature of the ground water of the basalt is rather uniform throughout the 50,000 square miles of diverse topography, climate, and rock structure, but a few differences occur. Sodium-rich waters are characteristic of the synclinal basins east of the Cascade Range, sulfate is low or lacking west of the Cascade Range, and chloride is lowest near recharge areas in mountain terrain. Only nitrate, which is greatest in wells less than 400 feet deep, seems to have a depth-of-aquifer relation. The chemistry of the prevalent type of ground water agrees with the general characteristics of ground water in basalt terranes as stated by Hem (1959, p. 203–207).

The prevalent type of ground water contains, on an average, 55 mg/l silica, 0.2 mg/l iron, 19 mg/l calcium, 8 mg/l magnesium, 37 mg/l sodium, 7 mg/l potassium, 150 mg/l bicarbonate, 20 mg/l sulfate, 10 mg/l chloride, 0.5 mg/l fluoride, 1 mg/l nitrate, 0.15 mg/l phosphate, and 0.1 mg/l boron. It has moderate hardness and a pH of 7.8. Water from some wells has a slight odor of hydrogen sulfide. Except for silica, the content of most of the dissolved elements varies with the predominance of other elements; for example, fluoride is generally greatest and magnesium is least in sodium-rich waters.

Special types of the natural ground water include: (1) Calcium sodium chloride waters that rise from underlying sedimentary rocks west of the Cascade Range, (2) mineralized water at or near warm or hot springs, (3) mineralized water at or near one carbon dioxide charged locality, and (4) water within or near sedimentary rocks at the edges of the basalt where unusual concentrations of ions, especially chloride, occur. In addition to the native or natural types, one artificially altered type, a sodium calcium sulfate chloride bicarbonate water has resulted where irrigation water recharged the ground water after passage through soils and sedimentary deposits. These five special types of ground water contain the only water unsuitable for most ordinary uses; the calcium sodium chloride water in places reaches salinities that are undesirable for many common uses of water.

Carbon-14 dates of the ground waters range from 0 to equal to or greater than the 32,000-year limit of the dating process.

The temperature of the ground water is usually slightly higher than would be indicated by the normal thermal gradient, but exceptions to the rule, both warmer and cooler, occur. The warmest waters occur near the traces of faults, and several natural sources of the excess heat can be postulated.

The minor elements like lithium, strontium, the metals, vanadium, and arsenic occur in only trace amounts, and only one element (barium) in one analysis (table 2) surpasses the limits set in health standards. Radioactive elements are present in very small amounts.

The origin of the dissolved materials appears to lie primarily in the history of the water during its descent to the basalt and secondarily to the solution and exsolution of ions within the basalt.

According to standards set for most types of water use, the ground water is of excellent quality except for: (1) the generally high content of silica, forming scale on boilers, (2) the moderate hardness, (3) a small and variable iron content which, in places, needs removal for uses like laundering, (4) a slight hydrogen sulfide content which may need to be removed by aeration in some places and, (5) locally, at shallow depth, excess nitrate, which may be due to improper well construction and protection.

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TABLES 1–3

Serial number	Location number (S at end of number indicates spring)	Owner of well or spring (At time of sampling)	Depth of well (feet)	Depth of water-bearing zone(s) (feet)	Date water sample collected	Temperature (°C)	Milligrams per liter: Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Aluminum (Al)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
					WASHINGTON										
	T. 2 N., Ranges East														
1----	2/13-33R1----	S.P. & S. Ry.--	149	138-149	7-28-30	15.6	51	0.04	----	----	20	8.3	22	4.5	137
	T. 3 N., Ranges East														
2----	3/11-30F1----	Underwood Fruit	265(?)	------------	10-29-59	17.4	57	.10	----	----	16	6.1	11	3	107
	T. 4 N., Ranges East														
3----	4/13-24H4----	Gas-Ice Corp---	295	148-164	10-21-64	27.2	121	11.0	0.2	----	120	106	63	10	1060
4----	4/14-19C1----	-----do--------	±200	------------	---do---	22.8	89	2.8	.1	----	27	25	30	4.3	284
5----	4/16-20H1----	Klickitat County	200	40-58; 117-127	5-19-60	12.8	47	.16	----	----	21	14	13	2	145
6----	4/24-3B1-----	S.P. & S. Ry.--	398	------------	7-18-66	20.6	48	.98	----	----	8.8	.7	92	6.7	225
	T. 5 N., Ranges East														
7----	5/23-3A1-----	R. J. Peterson-	81	80-81	5- 5-61	16.1	55	.00	----	----	46	12	29	4.3	163
	T. 6 N., Ranges East														
8----	6/23-11Q1----	George Smith---	670	654-670	4-30-62	21.0	57	.02	----	----	12	4.1	55	11	195
9----	6/35-10P1----	Frank Berard---	1145	700-710; 900-910; 1135-1145	8- 1-58	24.4	72	.03	----	----	12	1.7	32	8.6	126
10----	6/35-12N1----	A. A. Durand---	590	565-590	11-19-46	22.8	66	-----	----	----	24	6.8	----	----	142
11----	6/36-9L(?)1--	Baker & Baker--	1155	986-1155	10-31-52	21.6	---	-----	----	----	8	8	5.1	2.3	71
12----	6/36-9P1-----	-----do--------	2061	------------	11-29-46	23.2	60	.09	----	----	16	9.8	7.8	3.4	108
	T. 7 N., Ranges East														
13----	7/35-23M1----	U.S. Government	515	464-515	11-21-46	20	55	.03	----	----	11	2.1	31	7.8	125
14----	7/35-33H1----	Walla Wall Coll.	710	------------	8- 4-54	24	---	.08	.01	0.07	15	5.6	17	3.9	116
15----	7/35-36F3----	College Place--	708	620-700	10-22-59	20.5	65	.04	----	----	20	5.5	21	5.2	136
16----	7/36-13F1----	Walla Walla	810	750-810	11-26-46	----	54	-----	----	----	17	8.2	---7.1----		96
17----	7/36-13F1----	-----do--------	----	------------	4-23-53	----	43	.10	----	----	16	7.5	---7.4----		98
18----	7/36-13F1----	-----do--------	----	------------	6-24-55	16	---	-----	----	----	12	8.6	6	.6	101
19----	7/36-13F1----	-----do--------	----	------------	10-27-59	----	50	.01	----	----	16	6.5	6.2	2.6	97
20----	7/36-22N1----	-----do--------	789	400-789	10- 9-53	16.1	55	.17	----	----	17	6.1	--29------		152
21----	7/36-22N1----	-----do--------	----	------------	6-24-55	19	---	.03	.01	.01	15	7.6	22	9	129
22----	7/36-22N1----	-----do--------	----	------------	10-27-59	----	61	.06	----	----	19	5.2	25	5.2	149
23----	7/36-28R1----	-----do--------	1090	------------	7-29-60	23.3	62	.06	----	----	16	5.3	29	5.5	148
24----	7/36-33A1----	H. E. Studebaker	762	546-762	---do---	16.7	46	.17	----	----	19	5.8	23	3.2	142
25----	7/36-35R1----	J. E. Levin----	222	------------	11-21-46	----	54	-----	----	----	28	9.4	--22------		142
26----	7/37-13J1----	R. E. Meiners--	525	------------	11-18-46	----	56	-----	----	----	22	11	---7.4----		106
27----	7/37-18F1----	Walla Walla----	1169	------------	1-28-57	----	56	.0	----	----	17	6.5	9.3	2.6	106
	T. 8 N., Ranges East														
28----	8/24-2H1-----	Prosser--------	599	530-599	10-30-59	17.2	50	.12	----	----	17	6.1	54	9.8	221
29----	8/24-2J2-----	-----do--------	502	Below 485	---do---	18.9	59	.05	----	----	14	5.1	43	12	187
30----	8/24-2Q1-----	-----do--------	744	720-744	5-11-61	15.6	46	.06	----	----	16	6.6	46	10	202
31----	8/45-26K1----	J. Holzmiller--	100	------------	5- 1-61	11.1	30	.18	----	----	18	11	10	2.7	130
	T. 9 N., Ranges East														
32----	9/23-22J1----	Grandview------	1632	------------	8- 5-55	----	---	.03	.01	.02	2.8	.2	86	9	128
33----	9/31-4N1-----	Ray Sperry-----	343	320-343	4-28-42	----	50	.04	----	----	21	12	61	15	158
34----	9/31-4N1-----	-----do--------	----	------------	10-17-60	15	50	.02	----	----	20	7.9	58	18	172
	T. 10 N., Ranges East														
35----	10/22-25F1---	Sunnyside------	1570	1202-1570	8- 4-55	----	---	.14	.01	.05	30	10.7	13.7	5.9	146
36----	10/22-25G1---	-----do--------	1162	708-1162	---do---	----	---	.01	----	.05	88	28.8	28	7.1	231
37----	10/26-11D1---	U.S. Government	420	338-420	3-24-59	----	51	.68	----	----	38	21	13	4.8	176
38----	10/28-17B1---	-----do--------	228	220-224	6-15-51	----	18	.05	----	----	9.2	3.8	25	4.8	74

TABLE 1.—*Chemical analyses of ground water in the basalt*

[Analyses by the U.S. Geological

Milligrams per liter--Con.

Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids: Calculated	Dissolved solids: Residue on evaporation at 180°C	Hardness: As $CaCO_3$	Hardness: Noncarbonate	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH	Color	Remarks
WASHINGTON															
----	18	4.0	----	0.00	----	----	---	195	84	---	1.0	----	---	---	WSP (Water Supply Paper) 659-B. Klickitat County.[1]
0	.7	4.8	0.2	.0	0.09	----	152	158	65	---	.6	145	7.9	0	Wash. WSB (Water Supply Bull.) 24.[2]
0	3.4	3.5	.4	.3	.03	0.11	950	964	734	0	----	1410	6.6	0	Well 10. Carbon dioxide source.
0	.0	3.2	1.1	.2	.02	.03	320	325	172	0	----	429	6.4	0	Well 2. Do.
0	3.8	6.2	.3	8.0	.10	----	186	181	110	---	.5	271	7.5	5	Wash. WSB 24.
0	.0	34	1.6	.1	----	----	303	306	25	0	8.0	460	8.0	0	Whitcomb Sta. well. Benton County.
0	46	27	.5	10	.13	----	310	333	165	---	1.0	464	7.9	0	Wash. WSB 24. Klickitat County.
0	2.2	9.8	1.0	.6	.10	----	249	---	47	0	3.5	344	8.1	0	
0	3.2	6.5	.7	.0	.00	----	199	186	37	0	2.3	226	8.2	---	Wash. WSB 21. Walla Walla County.
0	31	6.5	.6	.2	----	----	238	---	88	0	----	239	---	---	Do.
---	2	.7	----	----	----	----	---	144	51	---	.8	----	8.0	---	Wash. Inst. Tech. B-237, no. 12.[3]
---	5.7	3.8	.6	.4	----	----	161	---	88	0	.6	186	---	---	Wash. WSB 21.
---	3.8	3.6	.6	.1	----	----	177	---	36	0	2.2	214	---	---	Wash. WSB 21. Bonneville Power Admin. substation well.
---	3.8	1.6	----	----	----	.14	235	---	---	---	1.0	----	7.6	---	Farm well.
---	5.4	4.2	.5	.0	----	----	200	---	72	0	1.1	229	8.2	---	Wash. WSB 21. Well 3.
---	9.7	1.8	.2	.2	----	----	145	---	76	0	----	150	---	---	Wash. WSB 21. Well 1.
---	3.1	2.8	.2	.2	----	----	144	---	69	---	----	----	7.6	---	Wash. WSB 21. Anal. by Char'ton Lab.
---	2.4	3.9	----	----	----	----	---	136	66	---	----	----	7.3	---	WIT B-237, no. 140.
---	1.7	1.0	.2	.5	----	----	140	---	67	0	.3	163	7.7	---	Wash. WSB 21.
1.2	6.6	5.6	.7	.04	----	----	208	---	68	---	----	----	---	---	Wash. WSB 21. Well 4.
---	5.3	5.7	----	----	----	----	---	186	70	---	----	----	7.9	---	WIT B-237, no. 142.
---	5.3	2.5	.9	.2	----	----	196	---	69	0	1.3	257	8.1	---	Wash. WSB 21.
---	5.0	3.0	1.0	.1	----	----	200	---	62	0	1.6	245	8.2	---	Wash. WSB 21. Well 5.
---	2.8	2.5	.7	.1	----	----	173	---	71	0	1.2	230	8.2	---	Wash. WSB 21.
---	30	3.2	.6	3.4	----	----	221	---	108	0	----	231	---	---	Do.
---	19	3.2	.6	3.9	----	----	175	---	100	13	----	227	---	---	Do.
---	2.5	1.0	.2	.2	----	----	132	---	69	---	.5	169	8.0	---	Wash. WSB 21. Well 3.
0	.1	11	.9	.2	.08	----	258	248	68	---	3.2	388	7.5	0	Wash. WSB 24. Well 3. Benton Co.
0	4.8	6.5	.6	.2	.11	----	237	229	56	---	2.5	326	7.7	0	Wash. WSB 24. Well 2.
0	.6	9.5	.7	.1	.09	----	236	236	67	---	2.4	336	7.8	5	Wash. WSB 24. Well 4.
0	5.2	.8	.3	.3	.13	----	143	136	89	---	.5	210	8.1	5	Wash. WSB 24. Asotin County.
40	5.3	19.1	----	----	----	.20	---	325	8	---	4.2	----	9.2	---	WIT B-237, no. 237, Well 4. Yakima County.
8	86	9.5	.9	.1	----	----	341	336	102	---	2.6	480	---	---	Wash. WSB 8. Franklin County.
0	72	8.0	1.2	.3	.05	----	320	324	82	---	2.8	464	8.1	5	Wash. WSB 24.
3.6	19.2	7.1	----	----	----	----	---	303	119	---	----	----	7.8	---	WIT B-237, no. 233, Well 4. Yakima County.
0	89	33	----	----	----	----	---	493	284	---	----	----	7.6	---	WIT B-237, no. 230. Well 1.
0	43	7.5	.2	4.5	----	----	270	262	182	---	.4	397	7.7	5	Wash. WSB 24. Benton County.
16	2.1	10	1.0	.3	----	.06	119	130	39	---	1.8	206	9.2	---	WSP

of the Columbia River Group, Washington, Oregon, and Idaho

Survey, unless noted otherwise]

Serial number	Location number (S at end of number indicates spring)	Owner of well or spring (At time of sampling)	Depth of well (feet)	Depth of water-bearing zone(s) (feet)	Date water sample collected	Temperature (°C)	Milligrams per liter: Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Aluminum (Al)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
					WASHINGTON--Con.										
	T. 10 N., Ranges East--Continued														
39----	10/39-19R1---	Blue Mt. Can.	942	------------	6-24-55	17	---	0.16	0.00	0.09	21	15.2	18.7	2.3	152
40----	10/39-30H1---	Dayton--------	1250	[180-190, 749-762, 1223-1250]	6- 2-60	15.5	52	.02	----	----	27	10	8.8	2.2	148
41----	10/46-5Q1----	Wash. Water Power Co.----	1815	------------	10-28-59	23.3	65	.04	----	----	6.5	.2	42	9.9	113
	T. 11 N., Ranges East														
42----	11/21-22N1---	Dom. Watar Assoc	426	Below 378	4-30-62	16.1	43	.04	----	----	64	20	43	7.2	231
43----	11/27-20M1---	U.S. Government	321	293-321	6-15-51	----	46	.06	.00	----	36	9.9	17	10	162
44----	11/32-20A1---	Loren Loeber---	156	------------	3-13-58	15.0	37	.25	.02	----	51	18	31	2.5	241
45----	11/42-5D1----	Pomeroy--------	235	------------	6-23-55	----	---	.02	----	.01	29	14.2	9.9	4.3	171
46----	11/42-5D3----	-----do--------	347	------------	6-23-55	----	---	.004	----	.01	27	12.7	10.6	3.1	151
47----	11/46-30Q1---	Wash. Water Power Co.-----	1330	[860-890, 930-1070]	10-30-62	23.3	66	.01	----	.2	11	1.0	49	11	128
	T. 12 N., Ranges East														
48----	12/16-13D1---	Herke Bros.----	146	130-140	8-30-51	----	54	t.06	.00	----	16	9.7	10	1.8	116
49----	12/17-16D3---	Oral Brown-----	384	325-384	10-21-59	15.5	53	.05	----	----	13	5.3	17	3.2	113
50----	12/17-16R1---	Borton & Sons--	1078	1035-1073	4-18-52	17.2	38	t.27	.00	----	12	6.6	7.2	3.1	85
51----	12/28-12H1---	L. L. Bailie---	450	[at 350, 445-450]	4-27-42	----	52	.04	----	----	8.8	4.6	83	14	182
52----	12/28-12H1---	H. M. Cook	----	------------	10-17-60	18.9	53	t.88	----	----	7.5	1.9	84	16	192
53----	12/29-28F1---	U.S. Government	699	------------	1- -53	----	---	-----	----	----	9.4	4.6	46	6.3	116
54----	12/29-28F1---	-----do--------	----	------------	11- 2-56	----	---	.17	----	----	9	4.5	45	6.6	108
55----	12/29-28F1---	-----do--------	----	------------	12-27-56	----	---	-----	----	----	13	3.9	48	9.4	104
56----	12/30-5B1----	-----do--------	458	------------	3- 6-56	----	---	-----	----	----	31	21	15	3.9	156
57----	12/32-28B1---	Tom Thompson	792	------------	3-13-58	19.5	70	.03	.0	----	12	6.1	29	5.8	125
58----	12/42-31L1---	Pomeroy--------	997	------------	10-28-59	21.7	74	.04	----	----	16	2.3	10	5.5	90
	T. 13 N., Ranges East														
59----	13/24-25E1---	U.S. Government	777	652-777	11-30-51	23.9	65	.02	.00	----	19	12	27	8.5	189
60----	13/24-26G1---	-----do--------	697	696-697	12- 1-51	20.0	60	.06	.00	----	20	12	27	6.7	193
61----	13/24-36D1---	-----do--------	1092	936-1092	11-29-51	23.6	64	.03	.00	----	18	11	29	6.7	184
62----	13/25-1N2----	-----do--------	790	[764-769, 778-787]	9-21-53	23.0	39	.05	----	----	19	11	22	11	143
63----	13/25-30G1---	-----do--------	1110	860-1100	12- 1-51	27.0	62	.02	.00	----	17	9.4	30	9.9	181
64----	13/28-13N1---	-----do--------	1119	1111-1117	10- -54	----	---	-----	----	----	1.6	.2	78	17	177
65----	13/29-26B1---	-----do--------	175	------------	12-10-54	----	---	-----	----	----	35	22	24	5.5	135
66----	13/30-36C1---	-----do--------	340	Below 190	12-29-50	----	---	-----	----	----	25	14	17	7.4	169
67----	13/31-24R1---	C. McLean------	537	Below 477	3-13-58	11.1	42	1.2	.01	----	22	12	27	6.4	168
68----	13/32-1J1----	Connell Sand and Gravel Co-	220	[53-101, 211-215]	10-17-60	13.9	37	.06	----	----	32	10	27	4.6	184
69----	13/38-26E1---	Robert Ferrel	243	------------	8- 2-54	20.0	---	.06	.00	.02	23	9.6	8.5	3.1	122
70----	13/38-26E1---	-----do--------	---	217-236	1-27-61	20.0	67	.01	----	----	24	8.8	9.4	5.8	140
	T. 14 N., Ranges East														
71----	14/17-4N2----	Nachas (town)--	1000	[874-877, 880-912, 915-920]	12-27-51	14.5	44	.00	----	----	18	6.7	7.5	3.3	96
72----	14/19-28B1---	U.S. Government	600(?)	----------	4-20-51	20.6	56	.04	----	----	15	11	19	6.2	151
73----	14/19-28B1---	-----do--------	----	------------	9-29-53	20.6	59	.15	----	----	16	11	19	3.6	149
74----	14/19-28B1---	-----do--------	----	------------	10-25-56	19.4	49	.06	----	----	15	11	19	3.5	149
75----	14/19-28B1---	-----do--------	----	------------	9-14-60	20.0	52	.04	----	----	15	1[illegible]	19	3.7	147
76----	14/19-28G1---	-----do--------	548	------------	4-20-51	18.4	50	.05	----	----	35	19	32	7.2	246
77----	14/19-28G1---	-----do--------	----	------------	9-29-53	16.1	53	.20	----	----	36	1[illegible]	32	4.5	239
78----	14/19-28G1---	-----do--------	----	------------	10- 5-55	15.0	45	.08	----	----	34	17	30	4.4	222
79----	14/19-28H1---	-----do--------	590	------------	9-17-52	18.9	52	.11	----	----	17	10	22	4.5	154
80----	14/19-28H1---	-----do--------	----	------------	10- 5-55	17.2	49	.27	----	----	17	9.3	20	4.6	151
81----	14/25-1D1----	-----do--------	938	[895-900, 924-938]	8- 7-52	21.1	75	.22	----	----	12	4.5	47	19	157

TABLE 1. — *Chemical analyses of ground water in the basalt of the*

Milligrams per liter--Con.															
							Dissolved solids		Hardness						
Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Calculated	Residue on evaporation at 180°C	As $CaCO_3$	Noncarbonate	Sodium-adsorption ratio (SAR)	Specific conductance (micromhos at 25°C)	pH	Color	Remarks
							WASHINGTON--Con.								
6.0	1.9	5.3	----	-----	----	0.01	---	204	115	---	0.4	----	7.3	---	WIT B-237, no. 137.
0	2.2	2.5	0.3	2.1	0.30	----	180	180	110	---	----	247	7.6	5	Wash. WSB 24. Columbia County.
5	8.9	7.8	1.1	.1	.07	----	202	199	17	---	4.5	248	8.4	5	Wash. WSB 24. Well 2. Asotin Co.
0	70	53	.4	4.7	.04	----	419	-----	242	52	1.2	665	7.6	---	Yakima County.
----	40	6.1	.3	.1	----	.04	245	-----	130	0	.6	343	7.9	---	WSP . Benton County.
0	53	11	.2	.4	----	.04	331	331	200	---	.9	503	7.7	5	Wash. WSB 8. Franklin County.
----	16.8	6	----	----	----	.03	---	223	131	---	.4	----	7.3	---	WIT B-237, no. 136. Well 1. Garfield Co.
----	9.1	8.9	----	----	----	.02	---	209	119	---	----	----	7.3	---	WIT B-237, no. 135. Well 3. Garfield Co.
2	25	12	.9	.0	.02	----	241	-----	32	0	4.0	303	8.3	---	Well 5. Asotin County.
----	4.4	3.0	.2	1.6	----	----	158	-----	80	0	.5	194	7.7	---	WSP 1598. Yakima County.
0	.4	1.8	.5	.1	----	----	150	149	54	---	1.0	185	7.9	0	Wash. WSB 24.
----	4.4	1.2	.3	.2	----	----	115	-----	57	0	.4	136	7.9	---	WSP 1598.
7	59	9.5	1.0	.1	----	----	329	328	41	---	5.6	459	---	---	Wash. WSB 8.
0	57	9.5	1.2	.2	.05	----	325	321	26	---	7.1	456	8.2	10	Wash. WSB 24. Franklin County.
3	35	11	1.0	.4	----	----	---	230	42	---	3.1	282	8.0	---	Wash. WSB 8. Analysis by Bur. Recl.
0	40	12	4.7	1.2	----	----	---	236	41	---	3.0	310	7.4	---	Do.
0	50	11	1.5	----	----	----	---	234	48	---	3.0	343	7.7	---	Do.
0	30	21	.7	12	----	----	278	164	---	---	5.0	381	7.8	---	Do.
0	15	8.2	.9	.7	----	.28	---	215	55	---	1.7	256	8.0	---	Wash. WSB 8.
0	3.1	1.8	.4	.3	.04	----	157	154	50	---	.6	162	8.0	---	Wash. WSB 24. Well 4. Garfield Co.
----	1.8	5.8	.5	.1	----	.06	233	-----	97	0	1.2	291	7.8	---	Ford well. Benton County.
----	1.5	5.5	.5	.0	----	.07	228	-----	99	0	1.2	292	7.8	---	O'Brian well.
----	1.8	5.4	.6	.1	----	.07	227	-----	90	0	1.3	277	7.7	---	Enyeart well.
0	23	8.0	.4	.0	----	----	203	216	93	---	1.0	296	7.6	0	W8P
----	1.6	4.8	.6	.1	----	.05	225	-----	81	0	1.4	277	7.8	---	McGee well.
0	20	15	2.0	.2	----	----	---	336	5	---	----	388	8.6	---	Anal. Bur. Recl. Wash. WSB 8.Franklin Co.
----	71	----	---	-----	----	----	---	340	178	---	----	458	7.7	---	Do.
0	18	17	.0	1.4	----	.04	---	240	120	---	----	311	8.2	---	Do.
0	17	5.2	.5	3.8	----	.12	---	217	104	---	1.2	322	7.8	---	Wash. W8B 8.
0	14	8.0	.6	11	.31	----	236	239	122	---	1.4	355	7.8	0	Wash. WSB 24.
----	11	10.6	---	-----	----	.03	---	260	---	---	.4	----	7.5	---	WIT B-237, no. 271. Columbia Co.
0	2.8	2.0	.5	1.0	----	----	190	194	96	---	.4	227	7.6	0	Wash. WSB 24.
0	6.2	2.8	.2	1.8	.25	----	138	----	72	0	.4	179	7.9	---	Yakima County.
0	.7	4.1	.5	.0	----	----	187	179	83	---	.9	235	8.0	4	Wash. WSB 24. Well 5. Called "Pomona well."
0	.7	3.8	.5	.1	----	----	187	176	85	---	.9	244	7.8	4	Do.
0	.7	4.0	.4	.2	----	----	176	174	83	---	.9	234	7.8	0	Do.
0	.8	4.0	.6	.2	----	----	178	174	82	---	.9	220	7.9	0	Do.
0	23	9.2	.6	2.0	----	----	299	284	165	---	1.1	429	7.7	3	WSB 24. Called "Marie's well."
0	23	8.8	.6	3.8	----	----	297	293	164	---	1.1	441	7.5	8	Do.
0	21	8.2	.6	8.1	----	----	277	280	155	---	1.0	432	7.7	0	Do.
0	1.2	4.3	.5	.2	----	----	188	178	84	---	1.0	246	7.9	3	WSB 24. Called "Southeast well."
0	.2	4.5	.5	.2	----	----	179	175	81	---	1.0	247	7.7	0	Do.
0	25	9.7	.4	1.1	----	----	271	265	48	---	1.3	330	7.9	---	Wash WSB 24. Grant County.

Columbia River Group, Washington, Oregon, and Idaho — Continued

							Milligrams per liter								
Serial number	Location number (S at end of number indicates spring)	Owner of well or spring (At time of sampling)	Depth of well (feet)	Depth of water-bearing zone(s) (feet)	Date water sample collected	Temperature (°C)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Aluminum (Al)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
					WASHINGTON--Con.										
	T. 14 N., Ranges East--Continued														
82----	14/27-24C1---	U.S. Government	1396	1370-1396	3-23-59	----	64	0.07	----	----	7.0	0.8	80	26	216
83----	14/27-24C1---	do-------	----	------------	10-28-59	30.0	63	.00	----	----	7.0	.4	80	26	216
84----	14/29-9A1----	do-------	860	845-860	3-20-52	15.6	59	t.02	----	----	15	10	48	7.5	182
85----	14/29-9A1----	do-------	----	------------	9-29-55	20.5	55	.00	----	----	20	9.9	44	7.6	186
86----	14/29-9A1----	do-------	----	------------	6-28-60	----	56	.15	----	----	18	11	45	7.8	187
87----	14/29-9A1----	do-------	----	------------	10- 5-61	----	57	.04	----	----	20	10	45	8.1	186
88----	14/30-8G1----	do-------	371	[231-251, 271-291]	8- -52	----	---	-----	----	----	29	23	23	4.3	180
89----	14/30-8G1----	do-------	----	------------	3-13-58	13.4	40	.81	0.02	----	140	106	42	7.8	294
90----	14/30-10P1---	do-------	433	------------	7- -52	----	---	-----	----	----	26	19	30	5.1	162
91----	14/30-20A1---	do-------	717	293-298	1- -52	----	---	-----	----	----	20	9.4	62	11	223
92----	14/30-20A1---	do-------	----	------------	3-13-58	11.7	25	.51	.02	----	74	32	24	7.8	156
93----	14/30-27J1---	do-------	381	------------	11- -53	----	---	-----	----	----	44	37	19	5.9	168
94----	14/31-36B1---	Connell (city)	643	Below 258	6-30-55	----	---	.13	----	----	19	13	32	3.9	144
95----	14/31-36B2---	do-------	286	------------	4-28-42	15.5	45	.04	----	----	28	17	18	4.6	158
96----	14/31-36B2---	do-------	----	------------	6-30-55	----	---	-----	----	----	35	20	13	3.9	146
97----	14/31-36B2---	do-------	----	------------	3-13-58	15.5	38	.05	.0	----	30	15	11	2.5	151
98----	14/32-31D1---	do-------	505	------------	6-30-55	----	---	.02	----	----	23	12	19	5.8	145
99----	14/32-31D1---	do-------	----	------------	10-17-60	17.7	48	t.56	----	----	26	12	18	5.3	138
100----	14/45-5B2----	Wash. State Univ	237	Below 40	12- 2-38	----	65	t.24	----	----	22	16	22	4.2	203
101----	14/45-5B3----	do-------	223	195-220	3-28-55	----	---	.03	----	----	25	15	c28	----	216
102----	14/45-5B3----	do-------	----	------------	8-18-55	----	---	.43	.02	0.03	21	16.7	23	3.1	200
103----	14/45-5D1----	Pullman-------	164	147-164	8-16-46	----	58	.5	----	----	22	14	28	2.4	209
104----	14/45-5D1----	do-------	----	------------	6-22-55	20	---	.11	.02	.06	20	15.2	14	3.5	178
105----	14/45-5D3----	do-------	167	159-162	3-30-55	----	---	.19	----	----	24	13	c27	----	194
106----	14/45-5D3----	do-------	----	------------	6-22-55	21	---	.18	.02	.00	20	15	15.8	3.1	194
107----	14/45-5D3----	do-------	----	------------	11-17-59	----	69	.39	----	----	22	15	22	4.2	196
108----	14/45-5D4----	N.P. Ry. Co---	166	89-99	3-30-55	----	---	.02	----	----	22	14	c27	----	185
109----	14/45-5E1----	City Ice Co---	95	------------	---do---	----	---	.22	----	----	22	13	c28	----	198
110----	14/45-5G1----	Wash. State Univ.	213	------------	11- 4-52	----	55	----	----	----	19	10	----	----	199
111----	14/45-5G1----	do-------	----	------------	3-30-55	----	---	.21	----	----	21	15	c27	----	203
	T. 15 N., Ranges East														
112----	15/27-32E1---	U.S. Government	1140	982-1115	10-28-54	16.7	54	.29	----	----	21	8.8	26	12	146
113----	15/27-34L2---	do-------	636	604-614	1- 7-58	21.7	---	.07	----	----	13	6.0	40	18	152
114----	15/27-34L2---	do-------	----	------------	3-24-59	----	73	.02	----	----	14	6.1	35	19	150
115----	15/28-8E1----	C.M.St.P.&Pac.Ry	415	371-414	10-18-60	17.8	65	t.61	----	----	30	14	34	10	196
116----	15/28-15D1---	Saddle Mt. Water	865	------------	1- -52	----	---	----	----	----	20	15	33	9.4	291
117----	15/28-15D1---	do--------	----	------------	2- -52	----	---	----	----	----	19	13	56	11	198
118----	15/28-24L1---	U.S. Government	398	284-287	2- -52	----	---	----	----	----	29	22	24	4.7	193
119----	15/28-24L1---	do--------	----	------------	12- -53	----	---	----	----	----	32	19	30	4.7	173
120----	15/28-24L1---	do--------	----	------------	9-18-56	----	---	----	----	----	1.8	0	222	1.6	176
121----	15/28-35P1---	do--------	840	Below 400	8-24-56	----	---	----	----	----	24	15	25	5.9	169
122----	15/29-3D1----	Othello--------	693	[250-252, 347-363, 570-574, 613-693]	8- 2-55	----	----	.02	----	----	4.2	1.8	77	1.3	170
123----	15/29-4A1----	do--------	560	------------	4-27-42	20.0	52	.04	----	----	3.6	3.5	78	12	183
124----	15/29-4A1----	do--------	----	------------	8- 2-55	----	----	.02	----	----	2.8	1.2	69	13	162
125----	15/29-27R1---	S. Othello Water	550	------------	7- -52	----	----	----	----	----	19	12	40	5.9	170
126----	15/30-23A1---	G. Kleinbach---	415	------------	3-11-58	----	38	.40	.0	----	18	8.5	36	9.4	172
127----	15/30-36A1---	U.S. Government	492	------------	3-13-56	----	----	.04	----	----	20	16	25	3.1	175
128----	15/32-1J1----	George Pence---	353	------------	10-18-60	15.0	66	.07	----	----	10	2.1	51	8.8	160
129----	15/36-28N1---	Mrs. C. Hille--	144	Below 66	5- 1-62	----	47	.02	----	----	38	17	18	3.8	214
130----	15/37-22A1---	H. Milam-------	378	370-375	7-30-54	----	----	.06	.03	.02	34	19.8	22	5.1	250
131----	15/37-27H2---	McGregor Co----	226	------------	---do---	----	----	.07	.03	.04	33	18.5	20	5.1	225
132----	15/45-26K1---	Orval Boyd-----	302	------------	3-30-55	----	----	.67	----	----	24	9.4	c26	----	154
133----	15/45-32N1---	Pullman--------	231	170-176	---do---	13.9	----	.32	----	----	21	14	c22	----	184
134----	15/45-32N1---	do--------	----	------------	6-22-55	20	----	.02	.02	.00	20	15.7	17.5	3.5	184
135----	15/45-32N2---	do--------	954	Below 399	1959	----	60	.36	----	----	24	13	22	4.1	194

TABLE 1.—*Chemical analyses of ground water in the basalt of the*

Milligrams per liter--Con.															
							Dissolved solids		Hardness						
Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Calculated	Residue on evaporation at 180°C	As $CaCO_3$	Noncarbonate	Sodium-adsorption ratio (SAR)	Specific conductance (*micromhos at 25°C*)	pH	Color	Remarks
WASHINGTON--Con.															
0	28	12	1.2	0.1	----	----	325	316	20	---	8.3	415	8.1	5	Wash. WSB 24.
0	29	12	1.2	.5	----	----	325	322	19	---	8.3	457	8.0	5	Do.
0	26	13	1.0	.7	----	----	270	266	79	---	2.4	373	8.0	10	Wash. WSB 24. Franklin Co.
0	24	11	.9	.9	----	----	265	266	91	---	2.0	386	8.1	0	
0	24	11	1.1	.6	----	----	267	261	92	---	2.1	378	7.9	0	
0	25	12	1.1	.8	----	----	271	264	91	---	2.1	377	7.9	0	
0	47	27	.6	.4	----	----	---	-----	167	---	.8	449	8.0	---	Wash. WSB 8. Anal. Bur. Reclamation.
0	368	128	.3	99	----	0.08	1080	1180	460	---	.6	1570	7.9	---	Wash. WSB 8.
8	43	15	1.1	4.3	----	----	---	280	143	---	.9	396	8.5	---	Wash. WSB 8. Anal. Bur. Reclamation.
0	42	14	.5	.0	----	----	--	326	89	---	2.8	503	7.9	---	Do.
0	93	66	.4	55	----	.08	---	470	315	---	.6	735	7.7	---	*Inadvertent artificial recharge.*
0	100	42	.6	17	----	----	---	448	262	---	.5	587	7.5	---	Wash. WSB 8. Anal. Bur. Reclamation.
7.8	18	12	----	-----	----	.02	---	253	101	---	1.4	----	8.1	---	WIT B-237, no. 159. Well 2.
0	23	9.5	.4	13	----	----	---	242	140	---	.7	337	---	---	Wash. WSB 8. Well 1.
6.6	23	20	----	-----	----	.02	---	300	169	---	.4	----	7.5	---	WIT B-237, no. 158.
0	14	4.8	.4	14	----	.10	---	208	136	---	.4	308	8.0	---	Wash. WSB 8.
3.6	11	8.1	----	-----	----	.02	---	220	107	---	.8	----	7.8	---	WIT B-237, no. 160. Well 3.
0	22	10	.5	8.8	0.03	----	219	228	112	---	.7	311	7.9	10	Wash. WSB 24.
0	1.8	3.3	.2	.21	----	----	---	224	121	---	.9	----	---	---	WSP 1655. Well 2. Whitman Co.
---	2.9	4	----	-----	----	----	---	-----	124	---	----	323	7.8	---	WSP 1655. Powerhouse well 2.
0	6.2	4.3	----	-----	----	.02	---	218	119	---	1.0	----	7.6	---	WIT B-237, no. 245.
---	1.8	2.0	.4	-----	----	----	---	211	113	---	1.1	----	---	---	WSP 1655. City well 2. Idaho Health.
7.8	3.4	6.7	----	-----	----	.56	---	226	114	---	----	----	7.8	---	WIT B-237, no. 127.
4	3.7	4	----	-----	----	----	---	-----	113	---	----	304	8.4	---	WSP 1655.
---	1.4	6.8	----	-----	----	.01	---	223	110	---	.7	----	7.3	---	WIT B-237, no. 128.
---	3.1	4.2	.5	.2	.22	----	238	-----	118	---	.9	346	7.7	5	WSP 1655. Well 3.
---	12	5	----	-----	----	----	---	-----	112	---	----	305	8.2	---	WSP 1655.
---	2.1	3	----	-----	----	----	---	-----	108	---	----	299	8.2	---	Do.
0	----	3	----	-----	----	----	---	-----	88	---	----	----	7.5	---	Do.
---	2.9	3	----	-----	----	----	---	-----	114	---	----	305	8.3	---	Do.
0	25	5.8	.6	.1	----	----	226	231	89	---	1.4	298	7.9	5	Wash. WSB 24. Grant County.
0	26	8.2	.4	2.5	----	----	---	262	57	---	2.3	330	7.8	5	Do.
0	27	7.5	.5	2.7	----	----	259	249	60	---	2.0	327	7.6	0	Do.
0	41	10	.6	.7	.06	----	[illegible]	292	132	---	1.3	416	7.9	5	Wash. WSB 24. Adams County.
0	34	16	.5	.7	----	----	---	262	112	---	1.3	409	7.4	---	Wash. WSB 8. Anal. Bur. Reclamation.
7	40	16	.8	.9	----	----	---	318	101	---	2.4	442	8.1	---	Do.
---	47	13	.8	.7	----	----	---	292	163	---	.8	421	8.2	---	Do. *"Upper Saddle Gap Well."*
---	64	15	.6	4.7	----	----	---	290	158	---	1.0	431	7.7	---	Do.
0	236	68	.7	7.7	----	----	---	690	5	---	45.6	1100	8.0	---	Do. Sampled after art.rech.
---	32	11	.6	1.2	----	----	---	268	122	---	1.0	350	8.0	---	Wash. WSB 8. Anal. Bur. Reclamation.
6.0	23	16	----	----	----	.05	---	294	18	---	7.9	----	8.4	---	WIT B-237, no. 215. City Park well.
0	28	15	2.6	.1	----	----	---	287	23	---	7.0	397	---	---	Wash. WSB 8. City Hall well.
9.6	23	16	----	----	----	.05	---	281	12	---	8.7	----	8.5	---	WIT B-237, no. 216.
6	25	14	1	3.1	----	----	---	252	97	---	1.8	363	8.4	---	Wash. WSB 8. Anal. Bur. Reclamation.
0	22	8.2	.9	1.2	----	.34	---	226	80	---	1.8	339	8.1	---	Wash. WSB 8.
0	20	9.9	1	1.1	----	----	---	278	116	---	1.0	338	8.1	---	Wash. WSB 8. Anal. Bur. Reclamation.
0	10	9.0	1.6	.9	.04	----	239	238	34	---	2.1	297	8.2	0	Wash. WSB 21.
0	17	9.5	.4	.5	.13	----	256	-----	166	0	.6	392	7.2	---	
---	10.6	11.3	----	----	----	.03	---	475	---	---	.7	----	7.4	---	WIT B-237, no. 269. Whitman County.
---	7.7	10.7	----	----	----	.02	---	460	---	---	.7	----	7.5	---	WIT B-237, no. 268.
---	23	3	----	----	----	----	---	-----	99	---	----	287	8.3	---	WSP 1655.
6	.8	4	----	----	----	----	---	-----	110	---	----	291	8.5	---	WSP 1655. City well 2.
3	2.3	6.7	----	----	----	.01	---	206	112	---	.7	----	7.5	---	WIT B-237, no. 129.
0	.7	3.2	1.4	----	----	----	224	-----	114	---	.9	307	7.8	---	WSP 1655. City well 4. Wash. WSB 24 lists temperature as 14.5°C in 1958.

Columbia River Group, Washington, Oregon, and Idaho — Continued

Serial number	Location number (S at end of number indicates spring)	Owner of well or spring (At time of sampling)	Depth of well (feet)	Depth of water-bearing zone(s) (feet)	Date water sample collected	Temperature (°C)	Milligrams per liter: Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Aluminum (Al)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
					WASHINGTON--Con.										
	T. 16 N., Ranges East														
136----	16/24-1G1---	U.S. Government	800	709 727-748	1-24-60	23.3	51	0.26	----	----	40	24	45	10	252
137----	16/24-1G2---	-----do--------	915	725-730 884-887	11-17-59	23.3	57	.22	----	----	38	24	45	9.6	250
138----	16/24-1G2---	-----do--------	----	------------	12-12-59	24.4	50	.22	----	----	40	24	45	10	254
139----	16/25-6M1---	-----do--------	851	Below 700	11-21-49	----	---	-----	----	----	39	26	44	9	124
140----	16/28-8P1---	May------------	304	Below 170	3-11-58	----	36	.14	0.01	----	5.6	3.2	86	26	212
141----	16/29-34R1--	Othello--------	901	Below 407	5- 4-61	22.8	62	.00	----	----	3.0	.8	81	12	170
142----	16/30-18A1--	U.S. Government	392	345-392	6- -55	----	---	-----	----	----	12	10	67	11	197
143----	16/30-18A1--	-----do--------	----	------------	10-18-60	15.6	53	.04	----	----	15	19	32	1.7	144
144----	16/30-18A1--	-----do--------	----	------------	5- 4-61	16.1	53	.00	----	----	18	25	26	2.2	152
145----	16/30-35Q1--	-----do--------	----	------------	4-12-57	----	---	-----	----	----	17	17	44	3.9	171
146----	16/43-11G1--	Colfax---------	600	515-545	8-18-55	23.5	---	.10	.01	0.02	19	13.5	21	2.3	172
147----	16/43-11G1--	-----do--------	----	------------	6-20-58	22	---	.12	.02	.03	25	9	22	2.3	185
148----	16/43-14N2--	-----do--------	----	------------	---do---	----	---	.12	.02	.02	28	6	25	5.1	183
149----	16/43-14N2--	-----do--------	750	Below 280	11- -59	17.8	63	.09	----	----	21	11	24	3.5	173
	T. 17 N., Ranges East														
150----	17/25-11E1--	U.S. Government	285	233-285	10-18-60	16.7	51	.02	----	----	30	25	25	2.6	216
151----	17/25-23K1--	-----do--------	957	------------	7- -55	----	---	-----	----	----	36	16	74	8.2	203
152----	17/25-23K1--	-----do--------	----	------------	2- -56	----	---	.02	----	----	34	19	17	6.6	168
153----	17/25-23K1--	-----do--------	----	------------	3-18-57	----	---	.05	----	----	36	18	18	5.5	163
154----	17/26-28Q1--	O. Abramson----	404	------------	4-27-42	14.5	42	.44	----	----	32	18	43	13	182
155----	17/27-31D1--	U.S. Government	810	460-470 775-810	1951	----	---	-----	----	----	35	19	56	16	209
156----	17/28-12D1--	-----do--------	270	------------	4-25-51	----	---	-----	----	----	33	19	38	8.2	210
157----	17/30-10N1--	C.M.St.P.&Pac.Ry	499	------------	1944	----	55	.1	----	----	17	9	31	----	165
158----	17/30-33K1--	U.S. Government	1002	415-480 860-1000	10-28-59	22.2	78	.15	----	----	8	2.1	57	10	162
159----	17/30-33K2--	-----do--------	981	635-981	1-24-60	23.3	79	.45	----	----	8.5	1.9	57	9.9	161
160----	17/31-8R1---	-----do--------	155	------------	12- -53	----	---	-----	----	----	22	15	21	3.9	137
161----	17/31-8R1---	-----do--------	----	------------	10-19-60	13.9	39	.01	----	----	12	15	11	1.0	121
162----	17/31-8R1---	-----do--------	----	------------	5- 3-61	13.9	41	.01	----	----	16	17	13	1.3	148
163----	17/31-30C1--	C. W. Haugen---	337	------------	3-12-58	12.4	34	.11	.02	----	18	8	46	17	142
164----	17/32-6B1---	John Kulm------	424	------------	---do---	13.9	33	.08	.01	----	16	12	41	12	168
165----	17/33-12P1--	City of Lind---	286	------------	6-30-55	16	---	.47	.01	.02	30.8	30	26.9	5.9	173
166----	17/33-13D1--	-----do--------	382	------------	---do---	16	---	.05	.01	.01	22	11.4	20	3.5	136
167----	17/34-7N1---	-----do--------	405	------------	---do---	16	---	.07	----	.03	78	57	74.2	7.0	204
168----	17/44-32A1--	Colfax---------	----	------------	6-20-58	21	---	.4	.02	.02	36	2.4	19	2.3	180
	T. 18 N., Ranges East														
169----	18/23-36H1--	D. Davison-----	670	526-529	5- 8-50	----	---	-----	----	----	32	22	30	6.6	220
170----	18/23-36H1--	-----do--------	----	665-668	10-18-60	15.6	55	.01	----	----	42	25	14	2.4	170
171----	18/28-34R1--	U.S. Government	268	------------	7-29-47	----	---	-----	----	----	48	24	----41----		297
172----	18/28-36D1--	-----do--------	218	------------	2- -52	----	---	-----	----	----	38	24	23	4.7	206
173----	18/28-36D1--	-----do--------	----	------------	5-10-56	----	---	-----	----	----	38	24	24	3.9	181
174----	18/28-36D1--	-----do--------	----	------------	5-20-57	----	---	-----	----	----	41	27	25	4.3	181
175----	18/29-17P1--	-----do--------	342	------------	2- -52	----	---	-----	----	----	18	14	36	11	171
176----	18/29-17P1--	-----do--------	----	------------	10-19-60	15.0	58	t.29	----	----	53	34	28	3.5	180
177----	18/29-17P1--	-----do--------	----	------------	5- 3-61	15.6	59	t.05	----	----	63	36	29	3.6	160
178----	18/30-16R1--	-----do--------	185	------------	11- -53	----	---	-----	----	----	22	16	33	2.7	179
179----	18/31-23A1--	W. E. Franz----	355	310-355	3-12-58	----	30	.11	.0	----	13	7.2	55	5.0	177
180----	18/39-12K1--	G. D Ferris---	115	------------	7-29-54	----	---	.05	.00	.02	29	13	9.9	3.1	172
	T. 19 N., Ranges East														
181----	19/23-12A1--	U.S. Government	153	110-153	11- -53	----	---	-----	----	----	27	23	6.4	3.5	164
182----	19/24-7J1---	Howard Hyer----	502	at 172 Below 267	8-31-16	----	42	-----	----	----	34	22	----24----		235
183----	19/24-7J1---	-----do--------	----	------------	5- 1-50	----	44	.07	.0	----	27	18	32	5.9	221
184----	19/24-7J1---	-----do--------	----	------------	10-18-60	15.6	48	.46	----	----	31	25	11	2.7	176
185----	19/24-7J1---	-----do--------	----	------------	5- 4-61	12.8	---	-----	----	----	----	----	----	----	175

TABLE 1.—*Chemical analyses of ground water in the basalt of the*

Milligrams per liter--Con.															
							Dissolved solids		Hardness						
Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Calculated	Residue on evaporation at 180°C	As $CaCO_3$	Noncarbonate	Sodium-adsorption ratio (SAR)	Specific conductance (micromhos at 25°C)	pH	Color	Remarks
WASHINGTON--Con.															
0	69	19	0.6	0.1	----	----	383	384	197	---	1.4	566	7.9	5	Wash. WSB 24. Grant County.
0	68	19	.7	.1	----	----	385	380	192	---	1.4	575	7.7	5	Do.
0	70	18	.8	.2	----	----	383	366	199	---	1.4	581	7.9	5	Do.
0	72	7	.1	-----	----	----	---	378	204	---	1.6	575	7.9	---	Wash. WSB 8. Anal. Bur. Reclamation.
0	50	14	1.0	.5	----	0.10	---	330	27	---	3.1	508	8.1	---	Wash. WSB 8. Adams County.
6	27	14	2.8	.0	0.07	----	293	294	10	---	1.1	393	8.6	5	Wash. WSB 24. City well 3.
----	38	23	1	.1	----	----	---	332	71	---	3.5	467	7.6	---	Wash. WSB 8. Anal. Bur. Reclamation.
0	33	24	.8	2.8	.07	----	252	257	115	---	1.3	373	7.9	0	Wash. WSB 24.
0	44	22	.7	1.7	.06	----	268	271	146	---	.9	405	8.1	0	Do.
----	34	24	.8	6.2	----	----	---	274	112	---	1.8	426	7.6	---	Wash. WSB 8. Anal. Bur. Reclamation.
0	5.4	3.5	----	-----	----	.02	---	209	102	---	.9	----	7.7	---	WIT B-237,no.243.Clay St.well.Whitman Co.
----	3.8	4.6	----	-----	----	----	---	204	99	---	.9	280	7.4	---	WIT B-237A, no. 303.
----	7.7	9.3	----	-----	----	----	---	210	95	---	----	282	7.5	---	WIT B-237A, no. 304.Fairview St. well.
0	7.7	2.2	.5	.2	.05	----	218	217	98	---	1.0	285	7.9	0	Wash WSB 24 lists it as 14L1.
0	43	6.0	.8	.7	.06	----	290	284	117	---	.8	432	7.9	5	Wash. WSB 24. Grant County.
----	132	15	.9	-----	----	----	---	412	156	---	2.6	615	8.2	---	Wash. WSB 8. Anal. Bur. Reclamation.
----	56	13	.5	.8	----	---	---	316	163	---	.6	397	8.3	---	Do.
0	62	13	.5	3.7	----	----	---	302	164	---	.6	426	7.7	---	Do.
0	55	40	.5	.3	----	----	334	337	154	---	1.8	514	---	---	Do.
0	56	53	.5	0	----	----	---	394	165	---	1.9	601	8.2	---	Do.
0	43	25	.7	.1	----	----	---	314	160	---	1.3	483	7.9	---	Do.
----	11	10	----	-----	----	----	---	269	79	---	1.5	----	---	---	Wash. WSB 8. Analysis by owner.
4	15	7.2	1.2	.1	.06	----	263	264	29	---	4.6	321	8.4	5	Wash. WSB 24.
5	15	6.5	1.3	.1	----	----	264	270	29	---	4.6	317	8.4	10	Do.
----	29	9.2	.6	.5	----	----	---	228	117	---	.8	293	7.0	---	Wash WSB 8.Anal.Bur.Recl.Adams Co.
0	13	1.0	.3	.6	.10	----	153	146	90	---	.4	217	8.2	5	Wash. WSB 24.
0	14	2.2	.4	1.3	.08	----	179	180	111	---	.5	258	8.1	0	Do.
0	62	12	.6	.1	----	.15	268	269	78	---	2.3	410	8.0	---	Wash. WSB 8.
0	44	8.0	.5	.0	----	.14	250	247	88	---	1.9	385	8.0	5	Do.
----	53.9	38.6	----	-----	----	.02	---	367	219	---	---	334	7.5	---	WIT B-237, no. 162. City well 1.
----	18.2	18.5	----	-----	----	.02	---	233	102	---	---	----	7.6	---	WIT B-237, no. 161. City well 3.
----	9.6	204	----	-----	----	----	---	865	427	---	---	----	7.1	---	WIT B-237, no. 163. City well 4.
----	3.4	4.6	----	-----	----	----	196	-----	100	---	.8	265	7.4	---	WIT B-237A, no. 302. East Glenwood well. Whitman Co.
0	43	13	.6	.4	----	.0	---	314	170	---	1.0	438	---	---	Wash. WSB 8. Anal. Bur. Reclamation. Grant County.
0	35	33	.7	11	.04	----	302	314	260	---	.4	462	7.8	5	Wash. WSB 24.
14	14	14	----	11	----	----	---	-----	218	---	---	547	7.9	---	Wash. WSB 8.Anal.Bur.Reclamation.
0	33	16	.6	48	----	----	---	360	193	---	.7	508	8.3	---	Do.
----	35	13	----	53	----	----	---	-----	193	---	.7	491	7.6	---	Do.
----	35	17	----	81	----	----	---	-----	213	---	.7	508	7.9	---	Do.
0	29	18	.8	9.2	----	----	---	274	102	---	1.5	380	8.7	---	Do.
0	65	38	.6	71	.04	----	440	453	270	---	.7	637	7.9	5	Wash. WSB 24.
0	76	62	.5	93	.03	----	501	524	306	---	.7	745	7.9	0	Do. Shows effects art. recharge.
0	30	18	1.3	.2	----	----	---	288	121	---	1.3	376	7.5	---	Wash. WSB 8.Anal.Bur.Reclamation.
0	25	12	1.6	.3	----	.07	---	249	62	---	3.0	376	8.1	---	Wash. WSB 8. Adams County.
----	4.3	6	----	----	----	.02	---	333	---	---	---	----	7.7	---	WIT B-237, no. 266. Whitman Co.
0	30	16	.6	.2	----	---	---	280	162	---	2.2	362	8.0	---	Wash. WSB 8. Analysis by Bureau Reclamation. Grant County.
0	20	9.0	----	0	----	---	---	283	175	---	---	----	---	---	Well not cased to basalt.
----	27	6.8	.6	.1	----	.0	270	256	141	---	1.2	403	8.0	---	Wash. WSB 8.
0	29	17	.6	4.1	.06	---	256	262	180	---	3.6	394	8.1	5	
0	----	----	----	----	----	---	---	-----	186	---	---	406	8.0	---	

Columbia River Group, Washington, Oregon, and Idaho — Continued

Serial number	Location number (S at end of number indicates spring)	Owner of well or spring (at time of sampling)	Depth of well (feet)	Depth of water-bearing zone(s) (feet)	Date water sample collected	Temperature (°C)	Milligrams per liter: Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Aluminum (Al)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
					WASHINGTON--Con.										
	T. 19 N., Ranges East--Continued														
186----	19/24-19A1---	A. W. Bauer----	112	----------	5- 4-61	12.8	47	0.01	----	----	50	24	20	2.3	193
187----	19/24-28N1---	G. W. Murphy---	210	At 186	5- 1-50	----	55	.03	----	----	29	19	12	3.5	177
188----	19/26-1R1----	U.S. Government	459	Below 398	9-18-56	----	---	.0	----	----	18	4.3	33	2.7	111
189----	19/26-1R1----	-----do--------	----	----------	10-18-60	19.4	59	.06	----	----	33	12	32	5.2	208
190----	19/26-1R1----	-----do--------	----	----------	5- 3-61	17.8	---	-----	----	----	-----	-----	-----	----	211
191----	19/26-4Q1----	-----do--------	436	418-436	1-31-56	----	---	.01	----	----	25	6.5	53	2.0	179
192----	19/28-1C1----	Farm-in-a-day--	57	----------	7- -52	----	---	.01	0.01	0.01	-----	-----	7.6	2.7	101
193----	19/28-15Q1---	Moses Lake-----	909	----------	8- 2-55	----	---	.02	----	----	6	2	69	11	142
194----	19/28-15O1---	-----do--------	----	----------	11-29-55	18.3	68	.00	----	----	2.8	.2	79	11	154
195----	19/28-22B1---	-----do--------	544	84-100 284-295 433-450 501-539	8- 2-55	----	---	.02	.01	.01	5	2	70	13	159
196----	19/28-22B2---	-----do--------	763	Below 143	---do---	----	---	.02	----	----	25	14	39	9	199
197----	19/28-23D8---	-----do--------	956	Below 680	4-21-57	----	73	.1	----	----	4	.7	---70-----		171
198----	19/28-23D8---	-----do--------	----	----------	12- 4-59	----	60	.02	----	----	8	2.1	64	10	155
199----	19/28-23D8---	-----do--------	----	----------	5-16-60	20.6	---	-----	----	-----	-----	-----	56	----	157
200----	19/28-28K4---	-----do--------	1000	Below 752	8- 2-55	----	---	.02	.01	.04	7.6	4.6	86	15	187
201----	19/29-19B1---	V. Sieler------	157	at 85 at 152	4-25-42	----	29	.04	----	----	38	12	8.6	2.8	119
202----	19/29-22C1---	U.S. Government	352	----------	1- -52	----	---	-----	----	----	36	21	37	8.2	149
203----	19/29-34D2---	Ray Radach-----	285	----------	10-19-60	15.0	35	.98	----	----	11	4.5	24	2.7	106
204----	19/30-1E2----	C.M.St.P.&Pac.Ry	140	----------	4-29-50	----	53	.03	.0	----	32	20	43	6.4	183
205----	19/30-1E2----	-----do--------	----	----------	1944	----	41	-----	----	----	45	20	---44-----		227
206----	19/30-32N1---	U.S. Government	351	332-345	4- 4-51	----	---	-----	----	----	16	1.2	79	13	187
207----	19/31-26D1---	F. Kosanke-----	378	----------	3-12-58	11.7	48	.35	.01	----	40	7.3	30	5.9	152
208----	19/32-16M1---	E. V. Doss-----	101	50-52 60-98	10-19-60	11.7	40	.01	----	----	22	11	33	8.3	176
209----	19/35-14Q1---	Ritzville------	391	----------	7- 1-55	----	---	.08	----	.01	22	13.2	13.8	2.7	131
210----	19/35-14Q2---	-----do--------	508	----------	---do---	----	---	.02	.01	.01	23	14	23.4	7.9	149
211----	19/35-23C1---		460	----------	---do---	16	---	.04	----	.02	44	42	27	13.7	238
212----	19/35-23C1---	-----do--------	----	----------	10-22-59	----	43	.01	----	----	63	36	23	6.1	238
213----	19/35-23K1---	-----do--------	648	315-350 378-408	7- 1-55	----	---	.03	.01	.02	24	14.4	23.4	4.7	138
	T. 20 N., Ranges East														
214----	20/23-10N1---	U.S. Government	351	----------	9- -53	----	---	-----	----	----	32	19	27	3.9	182
215----	20/23-24H1---	Conrad Weber---	75	70-75	10-18-60	16.5	50	.00	----	----	24	20	27	3.0	158
216----	20/24-7R1----	Quincy---------	431	----------	8- 3-55	----	---	.01	----	----	32	10	25	4.3	153
217----	20/24-7R2----	-----do--------	376	----------	1-25-39	11.1	51	1.05	----	----	34	26	29	4.5	213
218----	20/24-9D1----	Cedargreen Corp	424	253 301-320 334-345	4-22-16	----	44	-----	----	----	32	12	---16-----		161
219----	20/24-9E2----	-----do--------	345	25-260 290-300 325-340	4-23-42	----	42	.04	----	----	37	15	19	3.9	156
220----	20/25-4M1----	U.S. Government	674	----------	10- 4-50	----	---	-----	----	----	21	12	38	9	164
221----	20/25-4M1----	-----do--------	----	----------	9-12-57	----	---	.05	----	----	50	23	24	2	140
222----	20/25-5P1----	W. L. Norton---	450	----------	8-22-16	----	56	-----	----	----	32	12	---12-----		151
223----	20/25-21A2---	U.S. Government	652	615-625	3- 3-48	----	---	-----	----	----	29	15	---23-----		193
224----	20/28-17Q1---	do.(Larson AFB)	212	----------	10-21-59	12.8	34	.63	----	----	44	17	36	9.2	265
225----	20/28-29E1---	-----do--------	165	160-165	6-20-56	13.9	60	.4	----	----	24	10	16	2.7	119
226----	20/28-29E1---	-----do--------	----	----------	10-21-59	13.9	58	.00	----	----	24	9.7	16	3.2	122
227----	20/28-32C1---	-----do--------	725	610-618 652-719	3-30-51	17.8	56	.01	----	----	26	16	17	5	164
228----	20/28-32C1---	-----do--------	----	----------	6- 3-52	----	56	.06	----	----	26	16	18	3.8	162
229----	20/28-32C1---	-----do--------	----	----------	6-20-56	13.9	53	.01	----	----	29	18	19	4.3	167
230----	20/28-32C1---	-----do--------	----	----------	10-21-59	13.9	45	.12	----	----	17	6.4	39	12	156
231----	20/28-32J1---	-----do--------	712	532-560 600-612	1943	----	54	.12	----	----	17	7	43	----	136
232----	20/28-32J1---	-----do--------	----	----------	3-30-51	----	49	.02	----	----	17	8.6	35	12	156
233----	20/28-32J1---	-----do--------	----	----------	8-24-55	----	44	.00	----	----	17	8.4	34	8.7	153
234----	20/28-32J1---	-----do--------	----	----------	10-21-59	----	43	.04	----	----	17	8.0	37	9.3	151
235----	20/28-33E1---	-----do--------	791	723-790	5-26-55	----	42	.07	.0	----	16	7.7	35	7.6	152

TABLE 1.— *Chemical analyses of ground water in the basalt of the*

Milligrams per liter--Con.							Dissolved solids		Hardness						
Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Calculated	Residue on evaporation at 180°C	As $CaCO_3$	Noncarbonate	Sodium-adsorption ratio (SAR)	Specific conductance (micromhos at 25°C)	pH	Color	Remarks
WASHINGTON--Con.															
0	54	35	0.6	7.0	0.06	----	335	347	223	---	0.6	531	7.9	0	Wash. WSB 24.
0	15	6.9	.4	9.7	----	----	238	234	150	---	.4	340	7.9	---	Wash. WSB 8.
0	42	7.8	.6	.2	----	----	---	212	63	---	1.8	314	8	---	Wash. WSB 8. Anal. Bur. Reclamation.
0	24	5.5	.5	2.6	.05	----	276	271	131	---	1.2	386	7.8	5	Wash. WSB 24.
0	----	-----	----	----	----	----	---	-----	132	---	----	394	7.9	---	Do.
0	24	16	1.9	.4	----	----	---	328	89	---	2.4	399	8.3	---	Wash. WSB 8. Anal. Bur. Reclamation.
---	13.5	1.8	----	----	----	0.005	---	112	80	---	----	----	7.9	---	WIT B-237, no. 56.
12.0	28	16	----	----	----	.06	---	294	25	---	6.2	----	8.6	---	WIT B-237, no. 213. Well 3.
10	24	16	1.6	.4	.0	----	289	278	8	---	12.4	380	8.7	0	Wash. WSB 24.
9.0	27	18	----	-----	----	.05	---	261	22	---	6.7	370	8.4	---	WIT B-237, no. 211. Well 1.
4.2	35	17	----	-----	----	.04	---	300	121	---	1.5	----	8.1	---	WIT B-237, no. 212. Well 2.
5	17	16	----	-----	----	----	---	265	13	---	----	----	8.2	---	Wash. WSB 8.Well 7.Anal.commer.lab.
4	19	17	2.5	.9	.00	----	264	261	29	---	5.2	363	8.3	0	Wash. WSB 24.
5	----	----	----	-----	----	----	---	-----	49	---	----	385	8.4	---	Do.
----	40	28	----	-----	----	.04	---	360	37	---	6.1	----	8.4	---	WIT B-237, no. 214. City well 4.
0	25	16	.2	23	----	----	---	235	144	---	.3	330	---	---	Wash. WSB 8.
0	82	46	.5	-----	----	----	---	368	176	---	1.2	572	7.5	---	Wash. WSB 8. Anal. Bur. Reclamation.
0	13	1.0	.4	.3	.07	----	145	144	46	---	1.5	198	8.1	10	Wash. WSB 24.
----	58	26	.5	16	----	.0	345	-----	162	---	1.5	508	7.8	---	
0	51	32	----	-----	----	----	---	394	195	---	----	----	---	---	Wash. WSB 8. Ruff well.Anal. by owner.
0	50	20	1.1	.0	----	----	---	350	45	---	5.1	463	8.1	---	Wash. WSB 8. Anal. Bur. Reclamation.
0	46	20	.5	2.2	----	.51	---	268	130	---	1.1	409	7.8	---	Wash. WSB 8. Adams County.
0	25	9	.7	.2	.07	----	236	223	100	---	1.4	350	8.0	0	Wash. WSB 24.
5.4	6.3	8.9	----	-----	----	.04	---	190	114	---	.6	----	7.8	---	WIT B-237, no. 166. City well 1.
1.2	16	20	----	-----	----	----	---	230	114	---	1.4	----	7.7	---	WIT B-237, no. 165. City well 2.
2.4	32	52	----	-----	----	----	---	457	280	---	.7	----	7.7	---	WIT B-237, no. 167. Owner's well 3.
0	42	56	.2	47	.00	----	433	455	304	---	.6	694	8.2	0	Wash. WSB 24.
----	16.3	19.9	----	-----	----	----	---	234	119	---	.9	----	7.3	---	WIT B-237, no. 164. Owner's well 4.
0	53	15	.4	.7	----	----	---	284	158	---	.9	427	7.8	---	Wash. WSB 8. Anal.Bur.Recl.Crant Co.
0	44	18	.7	2.2	.10	----	267	273	144	---	1.0	401	8.0	5	Wash.WSB 24. Area artif.recharge.
0	29	17	----	-----	----	----	---	248	121	---	1.0	408	7.8	---	WIT B-237,no. 218.City well 1.Art.rech.
0	68	5.5	.0	3.2	----	----	---	323	192	---	.9	----	---	---	Wash. WSB 8. Unused well.
0	18	9	----	.0	----	----	---	242	129	---	----	----	---	---	Do.
0	37	17	.4	8.4	----	----	---	272	154	---	.7	384	---	---	Do.
0	36	18	.7	.5	----	.02	---	318	102	---	1.6	367	7.9	---	Wash. WSB 8. Anal. Bur. Reclamation.
0	90	45	.6	3.7	----	----	---	448	219	---	.7	564	7.6	---	Do. In area artificial recharge.
0	18	8	----	1	----	----	---	227	129	---	----	----	---	---	Wash. WSB 8.
0	22	8.9	----	1.8	----	----	---	224	134	---	----	356	8	---	Wash. WSB 8. Anal.Bur.Reclamation.
0	28	6.8	.3	13	----	----	319	320	181	---	1.2	501	7.6	5	Wash. WSB 24. Well 7.
0	17	7.5	.4	16	----	----	213	210	101	---	.7	266	8.0	0	Wash. WSB 24. Well 6.
0	17	7.2	.3	13	----	----	208	210	100	---	.7	276	7.5	5	Do. Two intervening anal. similar.
0	21	6.1	.2	8.4	----	----	237	230	131	---	.6	319	8.0	4	Wash. WSB 24.Well 2. Five intervening analyses are similar.
0	25	7.9	.2	9.7	----	----	242	235	131	---	.7	328	8.1	---	Do.
0	26	9.5	.3	15	----	----	256	250	146	---	.7	365	8.1	0	Do.
0	25	9.2	.7	.1	----	----	231	228	69	---	2.0	330	8.2	5	Do.
----	24	13	----	-----	----	----	---	220	71	---	2.2	----	8.2	---	Wash.WSB 8. Well 1. Anal. Leucks Lab.
5	25	8.9	.6	.2	----	----	233	222	78	---	1.7	315	8.0	3	Wash. WSB 24.
0	24	9.0	.6	.8	----	----	222	228	77	---	1.7	317	8.1	0	Do.
0	27	11	.7	.2	----	----	227	228	75	---	1.9	317	8.1	0	Do. Five intervening anal. similar.
0	23	9	.5	.1	----	----	216	211	72	---	1.8	312	7.9	5	Wash. WSB 8. Well 3.

Columbia River Group, Washington, Oregon, and Idaho — Continued

Serial number	Location number (S at end of number indicates spring)	Owner of well or spring (at time of sampling)	Depth of well (feet)	Depth of water-bearing zone(s) (feet)	Date water sample collected	Temperature (°C)	Milligrams per liter: Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Aluminum (Al)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
					WASHINGTON--Con.										
	T. 20 N., Ranges East--Continued														
236----	20/28-33E1---	U.S. Government	----	-----------	11- 5-57	15.6	---	0.12	----	----	18	6.8	35	8.8	151
237----	20/28-33E1---	do.(Larson AFB)	----	-----------	10-21-59	15.6	42	.02	----	----	17	6.9	38	9.3	152
238----	20/29-11A1---	I. E. Cole-----	165	-----------	4-30-50	----	44	.1	.0	----	31	12	21	4.5	145
239----	20/29-28C1---	U.S. Government	416	385-406	1951	----	---	-----	----	----	13	6.7	59	13	167
240----	20/31-22N1---	Alvina Haas----	500	-----------	3-12-58	----	31	2.4	.01	----	18	12	51	14	208
241----	20/31-31B1---	J. Bischoff----	400	373-400	10-19-60	15.5	42	.05	----	----	50	20	34	9.6	146
242----	20/31-31B1---	-----do--------	----	-----------	5- 3-61	13.3	46	.00	----	----	38	14	37	10	151
243----	20/32-32B1---	U.S. Government	502	242-253, 334-355, 468-480	12- 1-59	17.8	55	.57	----	----	15	5.8	36	6.4	156
244----	20/43-10R1---	Rosalia--------	308	-----------	5- 1-62	11.1	46	.05	----	----	34	15	25	2.2	196
	T. 21 N., Ranges East														
245----	21/24-31L1---	I. Overen------	407	-----------	10-18-60	15.6	50	.08	----	----	36	8.7	17	3.5	140
246----	21/26-8M1----	Ephrata--------	1000	391-430, Below 430	7-22-55	----	---	.01	----	----	16	13	22	3	146
247----	21/26-8N1----	-----do--------	450	-----------	---do---	----	---	.01	----	.00	19	12	12	2	133
248----	21/26-14L1---	-----do--------	1025	756-1025	---do---	----	---	.004	.01	.01	14.4	12.7	12.7	1.8	150
249----	21/26-15E1---	Grant Co. PUD--	347	-----------	4-29-56	14.5	58	.04	.0	----	30	15	15	5.3	182
250----	21/26-16B3---	Ephrata--------	260	203-208, 241-242, 248-249	4-25-42	17.2	56	.04	----	----	24	12	15	3.9	150
251----	21/26-16B3---	-----do--------	----	-----------	7-22-55	----	---	.02	----	.02	17	14	14	5	147
252----	21/26-16B3---	-----do--------	----	-----------	10-19-60	15.1	55	.03	----	----	24	10	15	5	147
253----	21/26-21E1---	-----do--------	618	Below 275	7-22-55	----	---	.02	----	.02	17	12	12	4	129
254----	21/28-23D1---	U.S. Government	150	-----------	4-25-51	----	---	-----	----	----	31	19	18	5.1	133
255----	21/28-23D1---	-----do--------	----	-----------	10-19-60	14.5	37	.04	----	----	54	25	39	8.6	230
256----	21/28-23D1---	-----do--------	----	-----------	5- 3-61	14.5	40	.06	----	----	71	30	48	9.2	260
257----	21/30-3E1----	A. Zickler-----	451	176-203, 296-319, 438-451	10-19-60	15.6	46	.15	----	----	16	5.9	25	3.8	118
258----	21/38-23A2---	Sprague--------	208	-----------	7- 1-55	----	---	.12	.01	.08	18	12	11	3.1	118
	T. 22 N., Ranges East														
259----	22/25-13J2---	V. J. Barbre---	118	-----------	10-19-60	12.2	49	.04	----	----	14	6.9	8.4	2.0	87
260----	22/26-12B1---	J. A. Molet----	78	-----------	3- 6-56	----	---	-----	----	----	70	31	45	8.6	245
261----	22/26-12C2---	W. E. Hill-----	187	183-184	1-23-53	----	---	-----	----	----	55	28	323	20	566
262----	22/26-23M1---	Westmont Acres-	448	-----------	1952	----	---	-----	----	----	20	12	15	4.3	224
263----	22/26-24L1---	Soaplake-------	435	405-435	7-22-55	----	---	.13	----	----	15	15	20	4	156
264----	22/27-19N1---	-----do--------	466	430-460	---do---	----	---	.01	----	----	17	12	24	5	146
265----	22/27-23R1---	E. W. Short----	258	250-258	4-30-50	----	49	.02	.0	----	16	8.1	40	7.2	174
266----	22/33-27E1---	M. C. Weber----	305	-----------	5- 1-62	17.2	55	.25	----	----	13	4.2	52	6.7	178
267----	22/43-32L1---	W. Hendrexson--	115	80-115	5- 2-61	9.5	52	.03	----	----	33	8.7	26	.4	106
268----	22/45-19C1---	Fairfield(town)	359	285-287, 340-343, 353-359	10-31-62	11.1	54	.01	.3	----	24	6.4	12	1.5	116
	T. 23 N., Ranges East														
269----	23/28-36E1---	U.S. Government	187	175-187	4-25-51	----	---	-----	----	----	33	17	32	4.7	221
270----	23/29-14J1---	V. Stevens-----	664	108-512	8-10-54	----	---	.04	.00	.03	18	11.8	19.7	4	125
271----	23/29-23G1---	J. Rolls-------	550	-----------	---do---	----	---	.06	.01	.03	12.8	10.7	24	5.5	156
272----	23/29-34B1---	V. Stevens-----	1000	445-748	---do---	----	---	-----	----	----	16.6	8.4	24	4.3	128
273----	23/37-29F1---	H. Armstrong---	213	185-213	5- 2-61	8.9	38	.05	----	----	40	19	26	2.0	228
	T. 24 N., Ranges East														
274----	24/40-3N1----	Wash. (State)--	440	215-218, 400-440	12- 1-59	14.4	45	.20	----	----	23	9.7	18	1.7	149
275----	24/40-22L1---	U.S. Government	345	60-65, 335-345	11- 6-57	----	---	.12	----	----	29	11	15	2.8	148
276----	24/40-22L1---	-----do--------	----	-----------	9-23-59	----	45	.10	----	----	30	10	16	3.0	148
277----	24/40-22L1---	-----do--------	----	-----------	11- 8-60	----	43	.07	----	----	29	11	16	2.9	153

TABLE 1. — *Chemical analyses of ground water in the basalt of the*

Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids: Calculated	Dissolved solids: Residue on evaporation at 180°C	Hardness: As $CaCO_3$	Hardness: Noncarbonate	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH	Color	Remarks
Milligrams per liter--Con.															
WASHINGTON--Con.															
0	24	9	0.5	0.2	----	----	201	211	73	---	1.8	313	8.2	5	Wash. WSB 24.
0	25	9.5	.6	.2	----	----	224	218	71	---	2.0	314	8.2	5	Do. Two intervening anal. similar.
0	21	13	.3	20	.0	----	238	-----	127	---	.8	344	8	---	Wash. WSB 8.
---	35	22	1	----	----	----	---	282	60	---	3.3	401	7.9	---	Wash. WSB 8. Anal. Bur. Reclamation.
0	37	10	.5	.3	----	.14	---	274	94	---	2.3	438	7.9	---	Wash. WSB 8. Adams County.
0	80	48	.7	15	.02	----	371	390	207	---	1.2	602	7.8	0	Wash. WSB 24.
0	65	32	.6	5.9	.02	----	323	337	152	---	1.3	497	8.0	0	Do.
0	13	5.5	.9	.8	----	----	215	214	61	---	2.0	287	8.0	5	Do.
0	15	8.5	.5	15	.19	----	259	-----	150	0	.9	392	7.3	---	Whitman County.
0	36	8	.7	2.3	.18	----	231	240	126	---	.7	323	7.5	0	Wash. WSB 24. Grant County.
---	12	7	----	----	----	----	---	201	92	---	1.0	----	7.9	---	WIT B-237, no. 199. Well 3.
---	6	7	----	----	----	----	---	177	97	---	.5	----	7.6	---	WIT B-237, no. 200. Well 5.
8	11	6	----	----	----	----	---	221	87	---	.6	----	8.1	---	WIT B-237, no. 203. Well 6.
0	14	5.8	.3	4.1	----	.0	237	233	137	---	.7	334	7.4	---	Wash. WSB 8. Well 2.
0	11	4.3	.3	1.4	----	----	197	-----	109	---	.6	207	---	---	Do.
---	6	7	----	----	----	.0.	---	206	102	---	.6	----	7.6	---	WIT B-237, no. 201.
0	10	4.0	.4	2.1	.19	----	198	193	103	---	.7	263	7.5	5	Wash. WSB 24.
3.0	8	7	----	----	----	.01	---	195	94	---	.5	----	8.1	---	WIT B-237, no. 204. Well 4.
0	31	26	.5	22	----	----	---	282	155	---	.6	399	7.5	---	Wash. WSB 8. Anal. Bur. Reclamation.
0	87	27	.6	12	.18	----	404	407	238	---	1.1	630	7.9	5	Wash. WSB 24.
0	130	37	.4	11	.17	----	505	527	302	---	1.2	768	7.8	5	Do.
0	10	5.0	.3	6.3	.08	----	176	177	64	---	1.4	231	7.5	5	Do.
4	21.2	6.4	----	----	----	.02	---	208	95	---	.5	----	7.7	---	WIT B-237, no. 170. Lincoln County.
0	4.6	3.2	.4	1.9	.02	----	134	132	63	---	.5	158	7.4	5	Wash. WSB 24. Grant County.
0	137	45	.5	.6	----	----	---	568	302	---	1.1	792	7.5	---	Wash. WSB 8. Anal. Bur. Reclamation.
0	280	147	---	----	----	----	---	-----	252	---	8.9	1820	7.7	---	Do.
---	14	8.9	.9	9.9	----	----	---	212	99	---	.7	282	6.8	---	Do. Casing not set to basalt.
2.3	18	7	---	----	----	.03	---	251	102	---	.8	----	7.8	---	WIT B-237, no. 197. City well 3.
2.3	18	8	---	----	----	.009	---	236	92	---	1.0	----	7.9	---	WIT B-237, no. 198. City well 2.
0	17	6.1	.9	----	----	.0	230	-----	73	---	2.3	316	8.1	---	Wash. WSB 8.
0	11	7.5	1.0	.1	.05	----	---	239	50	0	3.2	320	8.2	---	Lincoln County.
0	24	13	.3	56	.36	----	266	285	118	---	1.0	359	7.3	5	Wash. WSB 24. Spokane County.
0	4.6	3.0	.5	9.3	.41	.00	173	-----	86	0	.6	220	7.2	---	
0	26	14	.5	1.2	----	----	---	286	152	---	1.1	427	7.4	---	Wash. WSB 8. Grant Co.Anal.Bur.Recl.
---	14	20	---	----	----	.02	---	305	93	---	.9	----	7.9	---	WIT B-237, no. 94.
---	8.7	7.5	---	----	----	.02	---	295	75	---	1.2	----	8.1	---	WIT B-237, no. 93.
---	14	9.6	---	----	----	----	---	295	75	---	1.2	----	7.9	---	WIT B-237, no. 95.
0	12	10	.3	17	.09	----	275	279	174	---	.8	429	7.9	5	Wash. WSB 24. Lincoln Co.Sand interbed.
0	11	3.0	.5	.0	.00	----	185	178	97	---	1.0	255	7.8	0	Wash. WSB 24. Spokane County.
0	20	5.5	.2	.4	----	----	191	197	118	---	.6	284	7.9	5	Wash. WSB 24.Spokane Co. Well 45-C.
2	21	5.5	.4	.0	----	----	206	204	117	---	.6	294	8.3	5	Do.
0	19	6.2	.3	.2	----	----	203	197	116	---	.6	291	8.0	5	Do. Two intervening anal. similar.

Columbia River Group, Washington, Oregon, and Idaho — Continued

Serial number	Location number (S at end of number indicates spring)	Owner of well or spring (at time of sampling)	Depth of well (feet)	Depth of water-bearing zone(s) (feet)	Date water sample collected	Temperature (°C)	Milligrams per liter: Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Aluminum (Al)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
					WASHINGTON--Con.										
	T. 24 N., Ranges East--Continued														
278----	24/41-3N1---	U.S. Government	410	-----------	2-26-47	----	51	0.02	----	----	21	9.2	----	----	130
279----	24/41-3N1---	(Fairchild AFB)	----	-----------	12- 6-50	----	50	.05	----	----	19	10	13	2.4	127
280----	24/41-3N1---	-----do--------	----	-----------	10- 6-54	----	48	.08	----	----	19	9.4	13	2.1	125
281----	24/41-3N1---	-----do--------	----	-----------	11- 6-57	----	---	.17	----	----	20	8.5	13	2.1	118
282----	24/41-3N1---	-----do--------	----	-----------	9-22-59	----	45	.29	----	----	20	7.7	12	1.7	109
283----	24/41-3N1---	-----do--------	----	-----------	10-10-61	----	18	.63	----	----	33	10	5.0	2.2	142
284----	24/41-11N1--	U.S. Government	274	204-209	11- 5-57	----	---	.08	----	----	14	4	5.3	1.3	62
285----	24/41-11N1---	-----do--------	----	225-274	11- 8-60	----	35	.06	----	----	13	4.3	5.9	1.1	60
	T. 25 N., Ranges East														
286----	25/22-21H1---	Waterville-----	600	440-448, 516-529, 577-600	10-29-59	12.8	43	t1.6	----	----	46	23	23	1.9	204
287----	25/37-21L2---	Davenport------	503	Below 300	5- 1-62	13.9	42	.07	----	----	17	8.7	25	8.0	128
288----	25/40-14R1---	U.S. Government	356	335-356	11- 6-57	----	---	.04	----	----	21	9.8	12	1.5	129
289----	25/40-14R1---	(Fairchild AFB)	---	-----------	9-23-59	----	43	.02	----	----	22	10	14	1.6	134
290----	25/41-1R1----	-----do--------	415	-----------	7-23-58	----	47	-----	----	----	28	13	11	2.2	165
291----	25/41-1R1----	-----do--------	----	-----------	11- 8-60	----	46	.15	----	----	26	14	14	2.0	168
292----	25/41-10G1---	-----do--------	150	95-110	11- 6-57	----	---	.03	----	----	41	14	12	2.3	144
293----	25/41-10G1---	-----do--------	----	115-150	11- 8-60	----	42	t.05	----	----	30	11	12	2.0	121
294----	25/41-34B1---	-----do--------	196	110-120, 150-160, 180-195	11- 5-57	----	---	.04	----	----	30	8.2	16	1.3	152
295----	25/41-34B1---	-----do--------	----		9-23-59	----	50	.00	----	----	31	8.2	18	1.6	154
296----	25/41-34C1---	-----do--------	433	-----------	10-30-56	19	45	.18	----	----	33	11	14	1.3	122
297----	25/41-34C1---	-----do--------	----	-----------	11- 8-60	18	40	t.62	----	----	36	9.8	15	1.4	121
	T. 26 N., Ranges East														
298----	26/31-32A1---	Almira---------	208	Below 60	11- 3-59	13.3	43	1.1	----	----	28	16	30	3.8	200
299----	26/33-18L1---	Wilbur---------	900	-----------	5- 1-62	14.4	41	.03	----	----	12	9.6	16	3.2	119
					OREGON										
	T. 1 N., Ranges East														
300----	1N/1-34N4----	Commonwealth---	508	370-508	1- 9-47	12.2	35	0.2	----	----	45	2	---174----		----
301----	1N/1-34N4----	-----do--------	----	-----------	3- 9-55	12.2	----	---	----	----	-----	-----	----	----	116
302----	1N/1-34P2----	Pacific Tel----	697	351-697	4- 3-51	----	43	.19	0.05	----	64	3.7	---189----		117
303----	1N/12-14R1---	J. Sandoz------	546	420-546	7-31-58	27.8	95	t.04	.00	0.0	16	4.6	62	11	234
304----	1N/13-3E1----	The Dalles-----	201	180-201	7-26-30	17.2	70	.02	----	----	18	8.2	44	6.2	196
305----	1N/13-3E1----	-----do--------	----	-----------	--------	----	----	.06	----	1.2	-----	-----	----	----	171
306----	1N/13-4F1----	-----do--------	304	242-280	10-27-60	16.7	62	.07	----	----	37	14	39	9.3	249
307----	1N/13-4P1----	-----do--------	570	292-296, 342-344, 464-466, 556-570	3-16-51	20.0	----	.09	----	.2	-----	-----	----	----	158
308----	1N/13-4P1----	-----do--------	---		6-25-54	----	80	0	0	----	17	12	----50----		160
309----	1N/13-4P1----	-----do--------	----	-----------	7-30-58	20.0	74	t.06	.00	0	17	6.8	44	8.0	190
310----	1N/13-4P1----	-----do--------	----	-----------	6-22-61	20.0	66	.04	----	----	26	10	44	8.8	194
311----	1N/13-8L1----	Viola Foster	365	354-365	7-31-58	----	86	.03	.00	.0	17	6.1	56	10	224
312----	1N/13-14M1---	Jack Martin----	196	180-196	7-30-58	16.8	74	t.00	.00	.0	27	13	15	5.0	173
313----	1N/13-23D1---	Cherry Hill Dist.	301	-----------	7-26-30	17.8	68	.01	----	----	15	8.9	11	3.0	109
314----	1N/13-32G2---	Milton Martin--	427	330-336	7-30-58	22.2	84	t.03	.0	1.0	15	2.9	41	7.2	167
315----	1N/17-9F1----	Wasco----------	449	267-284, 442-449	6- 1-54	----	71	t.05	.0	----	27	12	19	4.5	160
316----	1N/17-9F1----	-----do---------			6-28-60	17.2	61	.01	----	----	27	13	19	4.4	161
317----	1N/18-32D1---	E. E. Shull-----	157	Below 90	---do---	14.5	56	.05	----	----	22	12	23	4.7	154
318----	1N/25-13P1---	J. F. Barak-----	237	-----------	5-10-67	16.1	38	-----	----	----	17	5.6	34	5.9	126
319----	1N/26-10A1---	W. Doherty------	376	-----------	---do---	17.8	58	-----	----	----	71	38	54	12	252
320----	1N/27-24R1---	A. J. Vey-------	777	-----------	---do---	20.6	63	-----	----	----	8	1.6	48	4.5	128
321----	1N/28-28D1---	-----do---------	364	-----------	4-28-53	17.8	70	.2	----	----	15	5.7	40	5.2	163
322----	1N/31-30B1---	T. A. Cross-----	550	-----------	4-27-53	----	66	.1	----	----	36	12	22	4.4	154
323----	1N/39-22B1---	Elgin-----------	655	618-651	5-10-57	11.1	38	t 03	----	----	5.2	1.4	21	5.3	82
324----	1N/39-22B1---	-----do---------	----	-----------	3-17-67	----	44	.03	.06	<.02	6.2	2.3	17.3	5.9	c82

TABLE 1.—*Chemical analyses of ground water in the basalt of the*

Milligrams per liter--Con.															
							Dissolved solids		Hardness						
Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Calculated	Residue on evaporation at 180°C	As $CaCO_3$	Noncarbonate	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH	Color	Remarks
WASHINGTON--Con.															
0	11	2.8	0.2	0.1	----	----	---	163	90	---	----	220	---	---	Wash. WSB 24. Well 2.
0	11	2.2	.2	.3	----	----	171	164	88	---	0.6	215	7.7	2	Do.
0	11	2.6	.3	.4	----	----	168	164	86	---	.6	219	7.9	4	Do.
0	11	2.2	.3	.4	----	----	---	154	85	---	.6	214	7.6	5	Do.
0	12	2.2	.4	2.3	----	----	157	156	82	---	.6	208	7.8	0	Do.
0	14	3.5	.2	3.2	----	----	160	162	125	---	.2	262	7.8	5	Do. Thirteen intervening anal.similar.
0	5.8	1.0	.2	6.0	----	----	---	110	52	---	.3	129	7.5	5	Wash WSB 24. Well 37-C and L.
0	6.6	2.2	.2	6.2	----	----	105	107	50	---	.4	135	7.9	5	Do. Two intervening anal. similar.
0	35	26	.3	18	0.21	----	316	339	209	---	.7	499	7.7	0	Wash. WSB 24. Well 2. Douglas County.
0	15	8.0	.5	8.0	.23	----	196	-----	78	0	----	278	7.8	---	Lincoln County.
0	9.6	3	.3	.7	----	----	---	155	93	---	.5	229	7.8	5	Wash. WSB 24. Well 87-L.Spokane Co.
2	8.2	3.8	.6	.5	----	----	172	164	98	---	.6	235	8.3	0	Do. Two other analyses are similar.
0	6.4	2.5	.3	.0	----	----	191	188	124	---	.4	270	7.2	0	Wash. WSB 24. Well 87-C, no. 2.
0	11	6.2	.4	.3	----	----	203	193	124	---	.4	291	7.8	5	Do. Another analysis is similar.
0	22	3	.1	53	----	----	---	257	160	---	.4	373	7.9	5	Wash. WSB 24. Well 07-L.
0	17	4.2	.3	34	----	----	212	203	120	---	.5	291	7.8	5	Do. Two intervening anal. sim'lar.
0	4.5	5.0	.3	12	----	----	---	203	108	---	.7	283	7.8	5	Wash. WSB 24. Well 87-C, no. 2.
0	5.4	5.2	.8	13	----	----	209	205	111	---	.7	282	7.7	0	Do. Two other analyses are sim'lar.
0	13	7.8	.3	39	----	----	224	219	128	---	----	311	7.5	0	Wash. WSB 24.
0	15	9.5	.3	43	----	----	230	229	130	---	----	327	8.0	5	Do. Two intervening anal. similar.
0	24	11	.8	1.7	.00	----	258	247	134	---	1.1	391	7.8	0	Wash. WSB 24. Well 1. Lincoln Co.
0	5.8	2.8	.5	.3	.16	----	150	-----	70	0	.8	204	8.0	---	
OREGON															
----	13	308	----	-----	----	----	---	-- -	119	0	----	----	7.8	---	WSP-1619-O.Anal.Charlton Lab.Multnomah Co.
----	----	400	----	-----	----	----	---	-----	290	---	----	1510	7.1	---	Do. Used as supply and recharge well.
0	9.8	328	0.6	-----	----	----	697	-----	176	---	----	----	7.9	---	WSP-1619-O. Anal. Charlton Lab.
0	1.5	7.5	1.6	-----	0.00	----	314	296	59	0	3.5	378	7.9	0	Wasco County.
----	12	6.0	----	0.05	----	----	---	249	79	---	2.2	----	---	---	WSP-659-B. City Hall well.
----	29	-----	1.0	-----	----	----	---	-----	---	---	----	----	---	---	Anal. by Charlton Laboratories
----	28	10	.7	.5	----	----	328	-----	152	0	1.4	470	7.7	0	WSP-1594-E. Jordan Street well.
----	23	-----	.6	-----	----	----	---	-----	---	---	----	----	---	<.5	Marx well.
0	15	6.4	1.1	-----	.05	----	262	a195	77	---	----	----	7.6	2	Anal. Oregon Board of Health.
0	10	6.0	1.0	.0	.00	----	260	249	70	0	2.3	335	8	0	WSP-1594-E.
6	31	6.0	.9	.1	----	----	295	296	108	0	1.9	402	8.5	0	Do.
0	2.5	7.0	1.6	.0	.10	----	296	276	68	0	3.0	370	7.8	0	
0	6.6	6.5	.2	.0	.24	----	232	211	121	0	.6	300	7.5	0	
----	2.6	5.0	.71	-----	----	----	---	165	74	---	.5	----	---	---	WSP-659-B.
0	2.4	6.0	.9	.0	.00	----	241	228	49	0	2.5	279	8.5	0	
0	12	12	.5	1.7	----	0.05	239	229	117	0	.8	322	7.4	5	Sherman County.
0	12	12	.5	2.9	----	----	231	228	120	0	.8	314	7.7	0	
0	11	12	.7	.3	----	----	218	213	104	0	1.0	303	8.0	0	
0	24	14	.8	-----	----	----	201	181	66	0	1.6	292	7.9	---	USGS Hydrologic Atlas HA-387.Morrow Co.
0	120	91	.4	-----	----	----	568	561	334	127	1.2	891	7.9	---	HA-387.
----	.2	9	.9	-----	----	----	210	210	26	---	4.0	258	8.6	---	Do.
0	.6	15	.8	.4	----	.23	233	225	61	0	2.2	285	8.1	---	WSP-1620.
0	26	20	.4	9.9	----	.00	273	-----	139	13	.8	378	7.8	---	WSP-1620. Umatilla County.
0	3.5	.8	.4	.1	----	----	---	111	19	0	2.1	140	8.2	---	WSP-1597. Well 3. Union County.
----	3.5	.8	.42	.01	.16	----	---	130	21.2	--	1.5	107	8.4	1	Anal. Oregon Board of Health.

Columbia River Group, Washington, Oregon, and Idaho — Continued

Serial number	Location number (S at end of number indicates spring)	Owner of well or spring (at time of sampling)	Depth of well (feet)	Depth of water-bearing zone(s) (feet)	Date water sample collected	Temperature (°C)	Milligrams per liter: Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Aluminum (Al)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
					OREGON--Con.										
	T. 1 N., Ranges West														
325----	1N/1W-20H1---	C. E. Wismer--	480	396-480	5-17-51	13.9	52	t0.13	----	----	37	2.7	68	11	174
326----	1N/2W-24J1---	Somerset West-	550	480-515	10-24-62	----	31	-----	----	----	4290	83	2350	122	13
327----	1N/3W-1K2----	North Plains--	710	386-710	4- 3-51	15.0	49	.03	----	----	15	7.9	31	9.0	136
328----	1N/3W-1K2----	-----do-------	----	------------	10-24-67	----	50	.15	0.01	<0.02	11.5	5.2	35	5.5	c131
329----	1N/4W-23R1---	A. Goff-------	301	261-262	6-19-51	----	42	.12	----	----	8.4	4.1	7.7	1.8	62
	T. 2 N., Ranges East														
330----	2N/11-1M1----	Mosier--------	149	Below 72	7- 9-64	12.8	36	.91	.3	----	30	24	17	4.1	158
331----	2N/11-2J1----	-----do-------	250	Below 41	---do---	10.0	36	.67	.10	----	38	28	14	4.3	161
332----	2N/12-7E1----	Darel Evans---	620	------------	---do---	16.1	49	.19	.10	----	20	14	19	3.7	164
333----	2N/13-17R1---	Dalles Club---	300	------------	7-26-30	16.7	57	t1.97	----	----	48	31	15	3.8	194
334----	2N/13-32J3---	Chenowith Irrig.	268	------------	1-10-62	----	75	<.001	<.05	<.01	21	12.7	38	10	c187
335----	2N/14-31P1---	U.S. Government	700	------------	1954	15.6	56	.10	----	----	24	14	27	4.0	157
336----	2N/23-17R1---	H. Hynd-------	425	------------	5-11-67	21.1	68	-----	----	----	3.9	.7	73	8.8	164
337----	2N/25-28D1---	--------------	30	------------	6-16-58	27.2	115	t.00	.00	.1	1.6	.0	90	5.6	114
338----	2N/27-2J1----	C. Ammon------	835	777-799	5-10-67	22.2	71	-----	----	----	17	4.5	33	9.7	160
339----	2N/27-11H1---	J. S. Williams	525	330-525	4-28-53	16.1	66	.10	----	----	14	7.5	32	9.0	161
340----	2N/27-14M1---	McCarty-------	280	Below 90	6-17-58	14.4	72	t.01	.00	.0	25	12	30	7.2	198
341----	2N/27-26L1---	H. Proudfoot--	932	------------	5-10-67	22.8	69	-----	----	----	22	11	22	5.4	163
342----	2N/32-2N1----	Pendleton-----	700	Below 186	--1959--	15.6	59	.08	.00	.6	26	8.5	30	7	----
343----	2N/32-2R1----	-----do-------	774	159-774	1-17-49	10.6	40	.01	----	----	27	7.6	---31----		130
344----	2N/32-2R1----	-----do-------	----	------------	6-24-54	----	42	.37	.05	0	26	18	60	----	----
345----	2N/32-2R1----	-----do-------	----	------------	7-15-54	----	53	.01	.15	.27	8.7	1.2	--72.5---		----
346----	2N/32-2R1----	-----do-------	----	------------	--1959--	----	56	.04	.00	.71	9.3	2.2	64	9	----
347----	2N/32-9B1----	Oreg.State Hosp.	851	[350-361 680-691]	---do---	----	41	.04	.00	.71	32	11.1	24	5	----
348----	2N/32-10F1---	Pendleton-----	761	428-668	1-17-49	----	50	.20	----	.7	31	10.4	---24-----		149
349----	2N/32-10F1---	-----do-------	----	------------	6-13-52	----	49	t.03	.00	----	32	12	30	5.2	220
350----	2N/32-10F1---	-----do-------	----	------------	7-15-54	----	40	.10	.0	.51	37	12.6	---41.1---		----
351----	2N/32-10F1---	-----do-------	----	------------	--1959--	----	39	.04	.00	.6	38	13	33	5.3	162
352----	2N/32-10N1---	-----do-------	1008	[339-352 671-703]	--1954--	13.3	49	.01	0	.31	35	9.9	---46.2---		----
353----	2N/32-10N1---	-----do-------	----	------------	--1959--	----	47	.08	.00	.47	30	8	39	6.3	147
354----	2N/32-35H1---	John Crow-----	244	Below 70	3- 3-53	----	43	t.06	.00	----	9.2	2.8	70	9.9	136
355----	2N/33-14G1---	Pendleton-----	452	------------	12-19-66	15.5	44	.17	<.05	<.02	22	6.8	16	.5	c138
356----	2N/33-33N1---	Guy Mueller---	310	Below 119	6-18-58	15.6	68	t.00	.00	.0	20	8.8	23	4.8	154
	T. 3 N., Ranges East														
357----	3N/17-31N1---	Rufus---------	272	141-272	10- 1-62	----	50	<.001	<.05	<.01	41	25.1	15	3	c213
358----	3N/21-28D1---	Arlington-----	619	576-600	2-11-55	18.3	72	.03	0	----	7.2	.6	86	11	205
359----	3N/21-28D1---	-----do-------	----	------------	9-14-62	----	---	.0	.3	.	4.0	.3	107	9.7	c200
360----	3N/23-5E1----	Boeing Co.----	790	460-783	5- 9-67	----	61	-----	----	----	3.0	.6	106	15	209
361----	3N/26-5M1----	O. J. Hellberg	950	------------	5-11-67	23.3	78	-----	----	----	9.0	2.9	57	12	176
362----	3N/26-10N1---	E. Cramer-----	666	------------	---do---	23.3	79	-----	----	----	9.4	3.1	56	10	168
363----	3N/32-22C1---	George Mumm---	400	------------	3- 3-53	----	49	.11	.00	----	28	13	43	7.6	186
364----	3N/37-18H1s--	H. B. Gibbon--	----	------------	4- 1-54	34.5	68	t.20	----	----	14	3.5	133	7.6	46
365----	3N/37-22B1---	U.S. Government	97	89-97	7-27-61	10.0	66	.30	----	----	12	.7	95	9.4	49
	T. 4 N., Ranges East														
366----	4N/22-35C1---	U.P. Railway--	305	240-305	6-24-65	15.6	47	.53	----	----	17	7.1	78	10	205
367----	4N/24-22G1---	U.S. Government	100	------------	11-11-42	----	43	.05	----	----	36.8	21.4	---69.8---		244
368----	4N/24-22G1---	-----do-------	----	------------	5- 9-67	16.7	50	-----	----	----	30	20	64	4.5	258
369----	4N/25-7R1----	M. Cassidy----	85	Below 36	6-17-58	18.3	55	t.71	.00	.0	32	11	97	6.0	256
370----	4N/25-8F1----	Boardmen------	178	40-178	2- 1-65	----	49	.10	----	----	19	8.9	88	9.6	225
371----	4N/25-8J1----	-----do-------	350	[138-144 200-212]	10-30-64	18.9	53	.23	----	----	14	3.1	89	9.4	198
372----	4N/25-8J1----	-----do-------	585	539-585	1- 9-65	20.0	56	.07	----	----	3.5	.7	83	10	194
373----	4N/27-5B1----	U.S. Government	710	698-710	3-30-62	21.2	75	.04	.0	----	1.5	.4	74	11	170
374----	4N/27-5B1----	-----do-------	----	------------	4-22-63	----	74	.06	.0	----	1.5	.9	72	11	169
375----	4N/27-5B1----	-----do-------	----	------------	5-26-64	21.2	71	.11	.0	----	2.0	.3	72	11	176
376----	4N/27-5B1----	-----do-------	----	------------	8-16-65	----	70	.00	.0	----	1.2	.3	71	10	169

TABLE 1. — *Chemical analyses of ground water in the basalt of the*

Milligrams per liter--Con.															
							Dissolved solids		Hardness						
Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Calculated	Residue on evaporation at 180°C	As $CaCO_3$	Noncarbonate	Sodium-adsorption ratio (SAR)	Specific conductance (micromhos at 25°C)	pH	Color	Remarks
OREGON--Con.															
----	6.6	83	0.2	0.1	----	0.26	346	-----	104	0	2.9	541	7.6	---	WSP-1697. Washington County.
0	64	11600	----	-----	----	1.1	18500	-----	1100	1100	8.6	29600	6.2	---	Density 1.012;Bromide 17;Iodide 2.2 mg/l.
----	2.1	23	.2	.1	----	.3	204	-----	70	0	1.6	283	7.6	---	WSP-1697.
----	1.8	22.2	.4	<.01	0.22	----	----	203	56	----	2.1	272	8.0	1	Anal. Oregon Board of Health.
----	1.4	2.3	.1	.1	----	----	99	-----	38	0	.6	.99	7.4	---	WSP-1697.
0	74	3.5	.6	.2	.10	.00	269	274	172	42	.6	397	8.0	5	Well no. 1. Wasco County.
0	76	9.2	.2	18.0	.06	.04	304	319	209	77	.4	456	7.2	0	Well no. 2.
0	9.6	3.8	.4	.1	.17	.02	201	199	108	0	.8	281	7.9	0	
----	110	4.0	----	.20	----	----	----	-----	247	----	.4	-----	---	---	WSP-659-B.
----	47	6.6	1.0	.10	.063	----	----	295	105	----	1.6	310	8.1	1	Anal. Oregon Board of Health.
----	31	4.9	----	.04	----	----	----	-----	108	----	1.1	296	7.85	---	Bonneville Power Big Eddy well.
9	.2	20	1.9	-----	----	----	266	256	12	0	9.0	351	8.6	---	HA-387. Morrow County.
48	2.9	16	2.0	.0	.00	----	337	303	4	0	19.6	388	9.1	---	Drilled in rising column art.spring.
0	.2	10	.8	-----	----	----	225	201	60	0	1.8	275	8.1	---	HA-387. Umatilla County.
0	.8	9.5	.6	.20	----	.08	219	211	66	0	1.7	273	8.1	---	WSP-1620.
0	11	6.0	.4	.0	.05	----	261	224	112	0	1.2	343	7.6	0	
0	6.6	9.5	.6	-----	----	----	226	205	100	0	1.0	287	8.1	---	
----	13.1	11.4	.6	.5	2.8	----	235	216	101	----	1.3	-----	7.4	---	Stillman Park well.Anal.consult.engrs.
0	21	26	.3	-----	----	----	271	225	98	----	---	-----	7.7		WSP-1690. Byers St.well.Charl.anal.
----	20	33	.4	-----	----	----	300	-----	----	----	2.2	-----	8.2		
----	22.3	18.4	.7	.2	----	----	275	-----	95	----	---	-----	8.5	1	WSP-1690. Byers St.well.Charl. anal.
----	24.4	24.3	.6	.0	----	----	270	270	32	----	4.7	-----	8.6		Anal.1962 rept. of consult. engrs.
----	8.0	12.4	.3	.0	----	----	243	236	125	----	.9	-----	7.8	----	Do.
----	9.5	10.4	.2	-----	----	----	235	196	121	----	---	-----	7.5	----	Round-Up Park.Anal.Charlton Labs.
----	11	7.9	.2	2.9	----	.08	259	-----	129	0	1.1	385	7.8	----	WSP-1620.
----	15.7	17.6	.5	2.0	----	----	---	295	144	----	---	-----	7.6	----	Anal. Charlton Laboratories.
----	22.1	20	.3	.0	----	----	274	266	148	----	1.2	-----	7.5	----	Anal.1962 rept. of consult. engrs.
----	30.1	38.6	.3	.7	----	----	311	-----	128	----	---	-----	7.9	----	Twenty-first St.well.Anal.Charlton.
----	20.7	17.6	.4	.0	----	----	284	272	109	----	1.5	-----	7.8	----	Anal.1962 rept. of consult. engrs.
8.9	35	21	.7	.1	----	.01	272	-----	34	0	5.2	383	8.5	----	WSP-1620.
----	6.6	1.9	5	.0	.13	----	-----	202	84	----	.8	230	8.1	2	City well 7.Anal.Oreg.Boerd Health.
0	7.0	4.0	6	.0	.00	----	212	180	86	0	1.1	260	7.9	0	
----	13.2	13.1	.4	>1.0	.1	----	----	282	206	----	.5	340	7.8	2	First Rufus well. Anal. by Oregon Boerd of Health. Sherman County.
0	3.1	30	2.0	.1	----	----	313	308	20	0	8.3	415	7.9	7	Gilliam County.
----	.5	31.5	2.0	.0	.0	----	----	288	8.6	---	14.0	420	8.7	0	Anal. Oreg. Board of Health.
4	.4	53	2.0	-----	----	----	347	349	10	0	15.0	501	8.4	----	HA-387. Morrow County.
0	.2	20	1.5	-----	----	----	268	243	34	0	4.4	344	8.1	----	Do.
0	2.0	20	1.6	-----	----	----	264	253	36	0	4.0	329	8.0	----	Do.
----	31	23	.7	3.2	----	.05	290	-----	123	0	1.8	433	8.0	----	WSP-1620. Umatilla County.
9	.2	192	4.0	.2	----	10.0	464	491	50	0	8.1	765	8.6	----	WSP-1620. Bingham Springs.
9	5.4	130	2.7	.1	----	----	354	-----	33	----	7.2	536	8.5	----	Forest Service Guard Station.
4	24	35	.9	.0	----	----	325	320	72	0	4.0	490	8.4	0	Gilliam County.
----	42.1	29.9	.75	5.7	----	----	429	-----	180	----	---	-----	7.9	----	Anal. Charlton Lab. Morrow County.
0	50	26	.8	-----	----	----	372	367	158	0	---	-----	8.0	----	HA-387.
0	79	32	.8	.0	.00	----	439	401	125	0	3.8	656	7.7	0	Do.
0	55	34	1.2	.1	----	----	376	370	84	0	4.2	567	8.2	0	Old Boardman well.
3	52	24	1.2	.0	----	----	346	350	48	0	5.5	504	8.3	0	New well. Sample depth 350 feet.
4	1.8	28	1.8	.0	----	----	284	286	12	0	10.6	405	8.4	0	New well. Sampled after completion.
5	.0	17	1.4	.0	----	----	269	280	5	0	12.4	334	8.4	----	Umatilla Ordnance Depot well no. 6.
6	.2	17	1.3	.0	----	----	267	276	8	0	11.8	336	8.4	0	
3	.0	17	1.4	.0	----	----	265	269	6	0	----	339	8.4	0	
6	.4	16	1.4	.0	----	----	259	254	4	0	----	330	8.5	0	

Columbia River Group, Washington, Oregon, and Idaho — Continued

Serial number	Location number (S at end of number indicates spring)	Owner of well or spring (at time of sampling)	Depth of well (feet)	Depth of water-bearing zone(s) (feet)	Date water sample collected	Temperature (°C)	Milligrams per liter: Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Aluminum (Al)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
					OREGON--Con.										
	T 4 N., Ranges East--Continued														
377----	4N/27-5C1---	U.S. Government	682	672-680	3-30-62	----	76	0.36	0.0	----	2.0	0.1	73	11	168
378----	4N/27-5C1---	-----do--------	----	----------	4-22-63	----	75	.18	.0	----	2.0	.5	70	11	168
379----	4N/27-5C1---	-----do--------	----	----------	5-26-64	21.7	73	.11	.0	----	2.0	.3	71	12	168
380----	4N/27-5C1---	-----do--------	----	----------	10-31-67	----	73	.02	.01	----	1.8	.6	70	11	171
381----	4N/27-8R1---	-----do--------	453	433-441	3-30-62	----	62	.19	.0	----	23	12	74	6.4	192
382----	4N/27-8R1---	-----do--------	----	----------	4-22-63	20.6	62	.08	.1	----	22	13	76	7.2	189
383----	4N/27-8R1---	-----do--------	----	----------	5-26-64	----	62	.11	.1	----	18	8.5	84	9.4	186
384----	4N/27-8R1---	-----do--------	----	----------	8-16-65	20.6	59	.06	.0	----	15	7.8	86	9.8	186
385----	4N/27-18P1--	-----do--------	618	440-600	3-30-62	----	64	.06	.1	----	8.0	2.5	88	11	254
386----	4N/27-18P1--	-----do--------	----	----------	4-22-63	----	67	.03	.0	----	7.5	2.7	80	11	233
387----	4N/27-18P1--	-----do--------	----	----------	8-16-65	21.7	63	.02	.0	----	7.2	2.4	73	11	218
388----	4N/27-19C1--	-----do--------	600	Below 430	3-30-62	----	51	.12	.0	----	10	3.4	88	9.0	233
389----	4N/27-19C1--	-----do--------	----	----------	4-22-63	20.0	53	.04	.0	----	11	3.1	82	9.3	224
390----	4N/27-19C1--	-----do--------	----	----------	5-26-64	20.0	55	.06	.0	----	10	3.2	81	10	222
391----	4N/27-19C1--	-----do--------	----	----------	8-16-65	20.0	45	.22	.0	----	10	3.6	85	9.2	230
392----	4N/27-22K1--	-----do--------	360	Below 218	3-30-62	----	61	.08	.0	----	26	12	42	8.6	198
393----	4N/27-22K1--	-----do--------	----	----------	4-22-63	18.3	60	.32	.1	----	24	13	41	9.2	193
394----	4N/27-22K1--	-----do--------	----	----------	8-16-65	18.9	55	.00	.0	----	22	11	46	8.8	193
395----	4N/27-22K1--	-----do--------	----	----------	10-31-67	----	61	.04	.07	----	23	13	45	9.6	202
396----	4N/27-22P1--	-----do--------	327	302-315	4-26-41	----	---	.15	----	----	38	11	----	----	148
397----	4N/27-22P1--	-----do--------	----	----------	3-30-62	----	52	.01	.0	----	49	14	26	4.2	242
398----	4N/27-22P1--	-----do--------	----	----------	4-22-63	16.7	50	.01	.0	----	52	15	25	4.1	246
399----	4N/27-22P1--	-----do--------	----	----------	5-26-64	----	50	.02	.0	----	52	14	26	4.6	252
400----	4N/27-22P1--	-----do--------	----	----------	8-16-64	16.7	45	-----	----	----	54	15	28	4.0	265
401----	4N/28-10P1--	Hermiston------	500	----------	8- 3-50	----	---	-----	----	----	-----	-----	----	----	----
402----	4N/28-10P1--	-----do--------	----	----------	7-12-61	----	58	.03	.00	.8	23	8.9	50.5	15.5	c177
403----	4N/28-10P1--	-----do--------	----	----------	8-30-62	----	61.5	.04	.00	1.0	22.6	8.5	67.0	10.0	c177
404----	4N/28-10P1--	-----do--------	----	----------	6-29-64	----	53	.05	<.05	<.02	26.8	9.2	----	----	c197
405----	4N/28-11L1--	-----do--------	900	----------	7-12-61	----	63.5	.02	.00	.06	5.8	1.4	54	10.5	c133
406----	4N/28-11L1--	-----do--------	----	----------	8-30-62	----	65.5	.03	.00	1.0	4.4	1.0	71	10	c122
407----	4N/28-11N1--	-----do--------	962	----------	6-17-58	24.4	74	t.04	.00	.3	4.8	.0	72	11	148
408----	4N/28-11N1--	-----do--------	----	----------	7-12-61	----	68	.05	.00	.8	4.2	1.0	55	10.5	c124
409----	4N/28-11N1--	-----do--------	----	----------	8-30-62	----	63	.4	.00	1.0	6.3	2.3	72	10.5	c128
410----	4N/28-11N1--	-----do--------	----	----------	6-29-64	----	54	<.02	<.05	<.02	4.7	.4	90	16	c157
411----	4N/28-21R1--	C & B Livestock	407	352-401	5- 9-67	13.3	46	-----	----	----	45	12	18	4.1	202
412----	4N/28-22R1--	Pendleton Grain	170	[144-148 148-170]	---do---	14.5	47	-----	----	----	38	15	25	4.1	233
413----	4N/28-27J1--	U.P. Railway---	630	512-547	2-13-63	----	59	.15	.05	.05	9.3	5.1	43	9	c112
414----	4N/28-27J1--	-----do--------	----	----------	5-11-67	20.0	69	-----	----	----	12	4.1	43	8.4	160
415----	4N/31-9P1---	R. D. Bissinger	342	280-342	4-27-53	----	52	.01	----	----	18	9.1	41	8.7	173
416----	4N/33-29K1--	J. C. Hawkins--	211	----------	---do---	12.2	52	.0	----	----	65	30	25	2.6	236
417----	4N/35-19L2--	Athena---------	1200	----------	6-17-58	25.6	76	t.00	.00	.00	21	5.8	31	6.6	164
418----	4N/35-22Q1--	Weston---------	534	508-534	3- 2-67	----	65	.02	.06	<.02	29	12.9	15	3.9	c165
419----	4N/35-22Q2--	-----do--------	239	----------	---do---	12.2	56	.03	.05	<.02	28	12.6	12	3.9	c171
	T. 5 N., Ranges East														
420----	5N/28-17L1--	Umatilla-------	536	----------	5- 9-67	----	65	-----	----	----	2.6	.8	82	9.4	170
421----	5N/28-19A1--	-----do--------	785	755-785	---do---	24.4	67	-----	----	----	1.5	.4	86	12.0	163
422----	5N/32-31F1--	E. N. Brown----	98	----------	4-27-53	----	52	.0	----	----	2.8	2.2	106	11	224
423----	5N/35-2E1---	Milton-Freewater	952	----------	11- 6-60	----	45	.08	.1	<.02	17	9.9	6.1	3.4	c103
424----	5N/35-2H1---	-----do---------	502	----------	8- 1-58	12.8	56	t.06	.00	.1	14	4.9	6.5	3.2	81
425----	5N/35-5C1---	E. Key----------	777	572-592	8- 5-54	24.5	---	.13	.02	.03	17	10	18	4	146
426----	5N/35-12F1--	Milton-Freewater	651	----------	8- 1-58	16.1	52	t.06	.00	.1	14	4.4	8.0	2.8	80
427----	5N/35-12F2--	-----do---------	902	----------	11-18-46	----	---	.0	----	----	17	7.4	----33----		104
	T. 6 N., Ranges East														
428----	6N/33-23B1--	A. Harris-------	700	----------	1-10-55	----	---	.13	.04	.04	26	10	15	6	148
429----	6N/34-36K1--	E. Key----------	970	Below 748	8- 5-54	22.0	---	.21	.02	.02	19	10	18	3	146
430----	6N/34-36N1--	-----do---------	300	255-300	---do---	13.0	---	.06	.00	.05	34	18	25	3	183
431----	6N/34-36Q1--	-----do---------	402	Below 354	---do---	14.5	---	.03	.00	.02	52	17	37	5	226

TABLE 1.— *Chemical analyses of ground water in the basalt of the*

Milligrams per liter--Con.															
							Dissolved solids		Hardness						
Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Calculated	Residue on evaporation at 180°C	As $CaCO_3$	Noncarbonate	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH	Color	Remarks
OREGON--Con.															
6	0.4	17	1.4	0.4	----	----	271	264	6	0	13.7	343	8.5	5	Umatilla Ordnanca Depot. Well 7.
5	0	17	1.3	.0	----	----	265	276	7	0	13.3	333	8.5	0	
6	.2	17	1.4	.0	----	----	266	270	6	0	14.0	339	8.5	0	
4	.6	18	1.3	.1	----	----	264	270	7	---	13.1	336	8.4	---	
0	94	12	1.1	.0	----	----	380	392	109	0	2.6	539	8.0	---	Umatilla Ordnance Depot. Well 3.
0	103	13	1.1	.4	----	----	391	385	108	0	3.2	542	7.8	5	
0	90	18	1.4	.2	----	----	384	378	80	0	3.6	542	8.0	0	
0	84	19	1.5	.0	----	----	374	381	70	0	4.5	519	8.1	0	
0	5.8	12	1.3	.3	----	----	318	311	30	0	----	439	8.0	---	Umatilla Ordnance Depot. Well 5.
0	2.4	14	1.1	.0	----	----	300	311	30	---	6.4	401	7.9	0	
0	1.0	13	1.3	.0	----	----	279	286	28	0	6.0	368	8.1	0	
0	29	8.8	1.4	.2	----	----	316	331	39	0	6.1	458	8.2	---	Umatilla Ordnance Depot. Well 4.
3	29	9.2	1.4	.1	----	----	311	322	40	0	5.6	439	8.3	0	
0	25	10	1.4	.0	----	----	305	-----	80	---	5.7	429	8.1	0	
2	29	9.0	1.4	.1	----	----	308	312	40	0	5.8	449	8.3	0	
0	32	13	.7	.0	----	----	293	298	115	0	1.7	416	8.0	---	Umatilla Ordnance Depot. Well 2.
0	34	13	.5	.3	----	----	290	285	112	0	1.7	405	8.0	0	Umatilla County.
0	32	11	.8	.0	----	----	282	280	100	0	2.0	387	8.2	0	
0	32	13	1.6	.1	----	----	297	289	111	0	1.9	415	8.1	0	
----	11	11	----	-----	----	----	---	-----	140	---	----	----	7.7	---	WSP-1620.
0	14	12	.5	5.0	----	----	296	312	178	0	.9	449	7.8	---	Umatilla Ordnance Depot. Well 1.
0	16	13	.5	5.3	----	----	302	307	192	0	.8	449	7.8	0	
0	17	13	.4	6.1	----	----	307	304	188	0	----	469	7.8	0	
0	16	12	.4	6.1	----	----	311	316	194	0	----	457	8.2	0	
----	----	14	.9	-----	----	----	---	329	66	---	----	----	8.4	---	Anal. Oregon Board of Health.
----	61.7	11	.6	.00	----	----	---	354	95	---	2.3	----	8.1	---	Do.
----	59.7	12	.9	.0	----	----	---	260	92	---	3.0	----	8.2	---	Do.
----	69	11.9	1.0	.01	----	----	---	308	105	---	----	460	8.2	1	Do. Hermiston Wall 1.
----	17.7	20.1	.7	.00	----	----	---	272	20	---	5.2	----	8.4	---	Do. Hermiston Well 2.
----	13.2	18.5	1.6	.0	----	----	---	285	15	---	7.7	----	8.7	---	Do.
7	15	20	1.8	.0	0.12	----	279	237	12	0	13.0	352	8.4	0	Hermiston Well 3.
----	16	17.7	.7	.03	----	----	---	264	15	---	6.2	----	8.6	---	Anal.Oreg.Bd.Health.Hermiston Well 3.
----	25.1	19.5	1.6	.0	----	----	---	295	25.5	--	7.8	----	8.6	---	Do.
----	19.5	15.8	1.8	.05	----	----	---	239	13.5	--	10.5	350	8.3	1	Do.
0	14	12	.4	-----	----	----	250	270	162	0	.6	395	7.7	---	HA-387.
0	12	8	.4	-----	----	----	264	274	156	0	.9	416	7.9	---	Do.
----	2.0	17	1.2	.05	.08	----	---	155	44	---	2.8	280	8.1	2	Hinkle Sta.well.Anal.Oreg.Bd.Health.
0	.0	14	1.3	-----	----	----	231	205	47	0	2.7	289	8.2	---	
----	18	7.8	.6	6.3	----	0.02	247	-----	82	0	2.0	346	8.0	---	WSP-1620.
----	32	45	.4	57	----	.01	425	-----	---	---	.6	656	7.9	---	Do.
0	11	5.0	.7	.0	.00	----	238	227	76	0	1.6	288	7.9	0	
----	8.0	1.8	.46	.0	.03	----	---	235	125	---	.6	260	8.2	0	Anal.Oreg. Bd. Health. Well 1.
----	6.4	2.2	.46	.01	.07	----	---	220	121	---	.5	260	8.1	0	Anal. Oreg. Bd. Health. Well 2.
10	13	20	1.8	-----	----	----	289	298	10	0	12.5	390	8.6	---	City Well 1.
11	23	18	1.7	-----	----	----	301	298	5	0	16.1	399	8.7	---	Well 3 in WSP-1620. City Well 2.
----	42	23	.6	.3	----	.04	350	-----	16	0	11.5	510	8.3	---	
----	10.4	8.0	.28	.38	<.01	----	---	153	84	---	.3	194	8.0	3	Anal.Oreg. Bd. Health. Well 6.
0	2.3	4.0	.1	.0	.21	----	131	114	55	0	.4	145	7.6	0	Wash. WSB-21. Well 5.
----	5.8	10	----	-----	----	.06	280	-----	82	---	.9	----	8.1	---	WIT B-237, no. 85. Well 3.
0	1.8	5.0	.1	.0	.10	----	127	115	53	0	.5	148	7.6	0	Wash. WSB-21. Well 1.
----	9.9	5.8	.3	.2	----	.07	106	-----	73	0	----	180	---	---	Wash. WSB-21. Well 2.
----	15	9	----	-----	----	.09	217	-----	105	---	.7	----	7.0	---	WIT B-237, no. 125. Well 2.
----	5.2	11	----	-----	----	.07	280	-----	87	---	.8	----	8.1	---	WIT B-237, no. 86. Well 4.
----	14.4	32	----	-----	----	.03	415	-----	160	---	.8	----	6.8	---	WIT B-237, no. 88. Well 1.
----	10	60	----	-----	----	.05	560	-----	201	---	1.1	----	6.9	---	WIT B-237, no. 87. Well 2.

Columbia River Group, Washington, Oregon, and Idaho — Continued

Serial number	Location number (S at end of number indicates spring)	Owner of well or spring (at time of sampling)	Depth of well (feet)	Depth of water-bearing zone(s) (feet)	Date water sample collected	Temperature (°C)	Milligrams per liter: Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Aluminum (Al)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
					OREGON--Con.										
	T. 1 S., Ranges East														
432----	1/1-3E3---	Oregon Pub.Co.	930	898-925	1- 7-48	14.4	58	0.4	----	----	115	6	154	----	125
433----	1/1-32K1--	Alta Park-----	1100	990-1030	10- 5-61	----	59	.69	0.07	----	20	14	8.3	1.8	145
434----	1/4-10D1--	YMCA----------	310	309-310	9- 2-56	23.3	60	.06	----	----	5.2	.2	10	9.6	114
435----	1/24-6B1--	Ione----------	100	60-100	2-11-55	12.8	49	.04	----	----	60	23	49	5.2	336
436----	1/25-23L1-	Lexington-----	420	Below 88	6-16-58	15.6	66	.00	.00	0.0	34	17	28	6.2	186
437----	1/26-1J1--	O. W. Cutsforth	70	69-70	6-17-58	16.7	70	t.11	.00	.0	43	17	24	6.0	226
438----	1/26-1J1--	-----do--------	----	----------	5-10-67	16.1	65	-----	----	----	40	18	24	5.6	229
439----	1/32-9L1--	W. Chapman-----	491	440-480	4-23-53	18.9	71	.0	----	----	28	10	22	5.5	167
440----	1/32-9M1--	U.S. Gypsum Corp.	735	Below 200	6-18-58	18.4	70	t.03	.00	.0	42	15	22	4.8	208
441----	1/32-23J1-	Hilmer Horn----	794	705-794	12-22-54	20.0	70	.00	----	----	22	6.3	24	5.6	154
442----	1/38-24R1-	H. L. Wagner---	1150	665-1150	8- 9-50	28.9	88	.04	.00	----	3.6	.8	28	4.0	62
443----	1/38-24R1-	-----do--------	----	---------	5-22-64	30.0	---	-----	----	----	2.2	.2	26	5.5	48
	T. 1 S., Ranges West														
444----	1/1W-17A2-	St. Mary's Acad.	1507	1270-1505	11-19-53	22.8	45	.33	----	----	222	45	290	40	63
445----	1/1W-26E1-	Sawyers, Inc.--	162	Balow 14	9-22-52	----	47	.10	----	1.0	41.2	16.1	--- 15.9 --		192
446----	1/1W-27C1-	Robert Murphy--	314	288-303	3-17-52	12.8	---	-----	----	----	587	-----	-- 510 ----		---
447----	1/2W-24J3-	Aloha-Huber	720	250-720	1-22-63	----	61	.25	<.05	<.05	16.4	10.9	9	2	c114
448----	1/2W-31C1-	C. E. Asbahr---	715	266-715	5-15-51	----	50	.43	----	----	24	15	12	5.3	156
	T. 2 S., Ranges East														
449----	2/1-2N1---	Lake Oswego----	225	---------	11- 4-53	----	40	.9	----	----	30	11.2	--- 10.1 --		c182
450----	2/1-2N2---	-----do--------	450	---------	11- 4-53	----	40	.3	.0	----	30	8.8	--- 10.8 --		c178
451----	2/1-3L1---	-----do--------	980	957-980	---do---	----	30	.1	.0	----	10	2.2	--- 16.0 --		c137
452----	2/1-8H1---	-----do--------	188	166-188	---do---	----	30	.1	.0	----	21	14	--- 8.2 --		120
453----	2/1-8R1---	-----do--------	607	---------	8-21-44	----	53	1.2	.1	----	88.9	33.6	--- 26.1 --		---
454----	2/1-8R1---	-----do--------	----	---------	11- 6-45	----	55	t.52	.12	----	92	30	--- 76 ----		168
455----	2/1-9D1---	-----do--------	405	190-405	5-14-46	----	49	t.5	----	----	21	7.5	--- 17 ----		132
456----	2/1-9D1---	-----do--------	----	---------	2-10-61	----	---	.13	<.05	<.02	27.7	26.2	26	3.3	c167
457----	2/1-9J1---	-----do--------	502	[140-160 280-340]	11- 4-53	----	---	t.1	.0	----	17	6	---- 6.1 --		85
458----	2/1-15C1--	-----do--------	640	260-600	---do---	----	40	.1	.0	----	22	10	---- 8.8 --		c137
459----	2/1-24D1--	Robinwood Water	275	---------	---do---	15.6	40	.4	.0	----	34	9.8	--- 11.1 --		c163
460----	2/2-20F1--	Gladstone------	685	[200-210 675-685]	2-28-56	16.6	53	----	----	----	42	-----	----	----	116
461----	2/2-20F1--	-----do--------	----	---------	7-26-50	----	53	.07	.05	----	35.2	6.2	--- 87.1 --		122.2
462----	2/2-20F1--	-----do--------	----	---------	6-23-53	----	49	-----	----	----	37	12	--- 63 ----		114
463----	2/2-20K1--	-----do--------	250	---------	3-17-52	----	24	.13	.0	----	34.1	5.3	--- 82.3 --		116
464----	2/2-20K1--	-----do--------	----	---------	6- 9-53	----	49	.43	.05	----	54.3	14.7	--- 95.5 --		116
465----	2/27-31Q1-	Heppner--------	159	---------	4- 1-54	12.2	53	.01	----	----	18	8.8	6.1	1.4	105
466----	2/28-23E1s	W. W. Weaver	----	---------	---do---	14.5	55	.02	----	----	26	5.8	22	3.9	144
	T. 2 S., Ranges West														
467----	2/1W-10C1-	Tigard---------	453	192-453	4-21-58	12.2	72	t.03	.00	.0	21	8.8	8.5	2.8	124
468----	2/1W-32D1-	Sherwood-------	339	137-339	12-20-46	----	26	.1	----	----	8.9	2.6	--- 20.5 --		92
469----	2/1W-32F1-	-----do--------	275	130-275	4- 6-65	----	55	<.02	<.05	<.01	17	8.1	7.9	2	c107
470----	2/1W-32F2-	-----do--------	281	130-281	---do---	----	52	16.5	<.05	<.01	19	9.5	10	2	c122
	T. 3 S., Ranges East														
471----	3/21-19B2-	Condon---------	100	---------	4- 1-54	14.5	59	.00	----	----	29	5.7	16	3.2	126
472----	3/26-2A1--	Heppner--------	175	---------	8- 3-67	----	43	<.01	.01	<.02	38.1	16.1	23.3	4.9	c211
473----	3/27-2J1--	-----do--------	191	---------	5- 3-67	----	58	.04	.01	<.02	16.7	8.9	42.6	4.1	c170
474----	3/28-28M2-	-----do--------	352	194-213	6-16-58	16.7	59	t.00	.00	.0	17	4.9	18	4.2	111
475----	3/38-5M1--	U.P. Railway	1435	845-1435	1-21-55	25.0	72	-----	0	0	4.8	1.3	30	5	c77
476----	3/38-5M2--	-----do--------	1545	---------	---do---	26.8	84	-----	0	----	5.0	.3	27	5	---
477----	3/38-6H1--	La Grande------	1035	---------	10- 7-66	----	59	<.01	<.05	<.01	7.2	2.4	15.2	5.5	c117
478----	3/38-6H2--	-----do--------	1391	---------	5-10-57	27.2	71	t.03	----	----	10	.2	19	5	c84
479----	3/38-6H2--	-----do--------	----	---------	7-24-61	----	60	<.05	<.05	<.05	10	-----	22	6.5	c83
480----	3/38-6H2--	-----do--------	----	---------	2- 3-66	----	63	.02	<.01	<.01	9.2	.8	19.6	4.0	c76

TABLE 1.— *Chemical analyses of ground water in the basalt of the*

Milligrams per liter--Con.															
							Dissolved solids		Hardness						
Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Calculated	Residue on evaporation at 180°C	As $CaCO_3$	Noncarbonate	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH	Color	Remarks
OREGON--Con.															
12	7.1	356	----	-----	----	----	---	918	312	---	3.3	----	8.2	---	Anal. Charlton Lab. Multnomah Co.
----	.8	3.5	0.2	0.2	0.95	----	180	174	106	0	.4	236	7.2	---	WSP-1619-0.
5	1.2	92	3.2	.5	----	0.38	---	326	14	0	1.2	517	8.6		WSP-1793.
0	40	27	.3	2.9	----	----	422	425	244	0	1.4	662	7.0	---	Morrow County.
0	4.3	48	.4	.0	.00	----	295	290	155	2	1.0	447	7.7	0	
0	19	20	.4	.0	.00	----	310	308	177	0	.8	442	7.8	0	
----	15	22	.5	-----	----	----	303	-----	174	---	.8	437	7.9	---	HA-387.
----	13	8.5	.5	1.8	----	.01	243	-----	111	0	.9	310	7.8	---	WSP-1620. Umatilla County.
0	22	14	.4	4.1	.00	----	296	266	166	0	.8	418	7.7	0	Do.
----	7.9	5.0	.5	.3	----	.02	218	223	81	0	1.2	263	7.9	0	Do.
4.9	8.3	3.1	2.0	.2	----	.10	174	-----	12	---	3.5	148	8.0	---	WSP-1597. Union County.
12	5.3	2.5	----	0	----	.07	---	-----	6.5	--	1.4	143	8.8	---	Analyst unknown.
----	2.7	960	.1	.3	----	----	1640	-----	739	687	9.6	3140	8.2	---	WSP-1697. Washington County.
----	2.5	38.6	----	----	----	----	295	206	170	---	----	----	7.4	---	Do. Anal. Charlton Laboratories.
----	----	1840	----	----	----	----	---	3640	1480	---	----	----	---	---	Do.
----	1	11.8	.5	.07	.31	----	---	204	81	---	.4	240	8.1	2	Anal. Oregon Board of Health
----	1.6	15	.2	.1	----	.15	200	---	122	0	2.2	427	7.7	---	
----	13.2	22	.0	-----	----	----	---	212	128	---	----	----	7.3	3	Anal. Oregon Board of Health. Clackamas County.
----	21.1	101.0	.0	-----	----	----	---	240	134	---	----	----	7.4	4	Do.
----	9.8	25.5	.2	-----	----	----	---	162	29	---	----	----	8.3	4	Do.
----	15.3	16	.0	-----	----	----	---	196	109	---	----	----	6.9	2	WSP-1697.Anal.Oreg.Bd.Health.
24.0	8.9	238.0	.0	-----	----	----	---	752	360	---	----	----	8.0	---	Anal.Oreg.Bd.Health. Well 3.
----	.6	285	.9	-----	----	----	807	-----	353	216	----	----	7.4	---	WSP-1697. Anal. Charlton Labs.
----	.7	4.3	0	.2	----	----	175	-----	84	0	----	----	7.5	---	Do.
----	2.6	62.4	.2	.1	<.02	----	---	328	176	---	----	----	8.2	4	Anal. Oregon Board of Health
----	10.2	12	.02	-----	----	----	158	-----	67	---	----	----	6.8	2	WSP-1697. Oreg. Bd. Health.
0	29.2	16	.1	-----	----	----	---	192	83	---	----	----	6.9	2	Anal. Oregon Board of Health.
0	14.4	223	.1	-----	----	----	---	274	140	---	----	----	7.3	2	Do.
----	----	144	----	-----	----	----	452	-----	106	---	----	----	7.6	---	WSP-1793.
---	.3	149	.6	-----	----	----	480	-----	114	---	----	----	7.8	---	Do.
----	4.0	137	.4	-----	----	----	409	-----	144	---	----	----	7.8	---	Do.
----	.4	136.5	.4	-----	----	----	418	-----	107	---	----	----	7.7	---	WSP-1793. Well 2.
----	4.6	224.7	.4	-----	----	----	589	-----	195	---	----	----	7.7	---	Do.
0	3.8	2.8	.1	1.5	----	.05	148	138	81	0	1.0	180	7.9	7	Morrow County.
----	7.0	6.0	1.0	4.4	----	.05	202	202	89	0	.8	274	8.1	---	Flow estimated 35 gpm.
0	3.1	5	.0	.0	.29	----	182	183	89	0	.4	209	7.1	0	Tigard well 2. Washington County.
----	1.0	1.5	.1	.35	----	----	159	-----	34	0	----	----	7	---	Sherwood well 3.
----	<.5	3.5	.4	.06	.28	----	---	210	76	---	.4	175	6.5	1	Well 1.Anal.Oreg. Board Health.
----	.5	3.3	.4	.15	.06	----	---	276	87	---	.5	205	6.6	1	Well 2.Anal.Oreg. Board Health.
----	11	8.2	.5	3.6	----	.05	198	199	96	0	.7	260	7.8	---	Gilliam County.
----	25	13.0	.6	.03	.14	----	---	284	159	---	.9	370	7.8	3	Sheep corral well.Oreg.Bd.Health.
----	17.8	10.8	.9	.04	.31	----	---	243	78	---	2.3	320	8.1	1	Well 4.Oreg.Bd.Health.Morrow Co.
0	10	2.0	.5	1.5	.00	----	172	166	63	0	1.0	205	7.8	---	Well 1.
----	4.8	2.1	.5	-----	.04	----	---	166	15	---	----	----	7.9	3	WSP-1597.Oreg.Bd.Health.Union Co.
----	3.3	3.2	.5	-----	----	----	---	163	18	---	----	----	7.9	---	Do.
----	4.4	1.0	.5	.0	.05	----	---	-----	28	---	----	123	7.4	2.5	Well 1.Anal. Oreg.Bd.Health.
0	4.5	1.0	.5	.0	----	----	---	146	26	0	1.6	146	---	---	Well 2.Anal. Oreg. Bd. Health.
----	6.4	2.0	.5	.02	<.01	----	---	159	26	---	----	140	7.7	2	Do.
----	8.6	1.1	.6	<.01	<.01	----	---	150	26	---	1.7	135	8.3	2	Do.

Columbia River Group, Washington, Oregon, and Idaho — Continued

Serial number	Location number (S at end of number indicates spring)	Owner of well or spring (at time of sampling)	Depth of well (feet)	Depth of water-bearing zone(s) (feet)	Date water sample collected	Temperature (°C)	Milligrams per liter: Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Aluminum (Al)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
					OREGON--Con.										
	T. 3 S., Ranges West														
481----	3/1W-27R1--	C. E. Green----	1004	862-872 986-1004	6-18-63	12.5	41	2.3	0.1	----	92	11	147	16	62
	T. 4 S., Ranges East														
482----	4/20-10H1--	U.S. Government	1215	1150-1215	1-25-66	14.5	55	.09	.0	----	24	12	17	2.5	154
483----	4/39-5K1s--	A. J. Roth-----	----	---------	5-10-57	79.5	81	.00	----	----	3.6	.3	128	2.7	0
	T. 5 S., Ranges East														
484----	5/1-25G1--	R. Schnak------	350	325-340	7-26-62	15.6	43	1.1	----	----	30	7.5	33	4.0	130
	T. 5 S., Ranges West														
485----	5/4W-25G1-	Hilda Parvin---	280	200-280	6-15-63	12.8	41	t9.7	----	----	7.5	4.0	8.7	1.6	52
	T. 6 S., Ranges West														
486----	6/1W-10C1-	Mt. Angel------	631	601-629	5- 7-62	16.9	65	.03	----	----	28	1.9	20	3.5	106
487----	6/4W-1H1--	E. F. Curtis---	235	143-235	6-17-63	13.0	50	.07	----	----	4.5	1.7	5.6	2.0	36
	T. 7 S., Ranges West														
488----	7/1W-6R1--	O. Steffen-----	225	Below 120	7-20-62	13.3	54	.64	----	----	99	11	282	14	110
489----	7/1W-27N1-	K. Johnson-----	210	159-178	6- 7-62	14.5	26	.66	----	----	6.5	2.0	4.0	1.4	28
490----	7/3W-8R1--	F. W. Berms----	110	108-110	6-17-63	13.0	51	.03	----	----	6	2.2	8.8	2.6	49
	T. 8 S., Ranges West														
491----	8/1W-34L1-	Sublimity------	317	182-317	6- 5-62	13.3	41	1.1	----	----	10	4.4	14	1.6	80
	T. 9 S., Ranges East														
492----	9/40-15G1-	Sunny Slope Co-	740	700-740	6- -47	----	---	----	----	----	12	7.6	175	9.8	476
493----	9/40-16H1-	Baker Packing Co	600	---------	---do---	----	---	----	----	----	14	7.3	172	9.8	543
494----	9/40-18Q1-	P. V. Hill-----	575	---------	8-15-64	15.6	52	.16	.0	----	19	13	60	5.4	258
495----	9/40-28D1-	Calif-Pac Util.	578	Below 180	7- 7-53	----	52	.35	.1	1.1	26.4	17.7	-- 118.1 --		326
	T. 13 S., Ranges East														
496----	13/31-23K1	John Day-------	252	250-252	8-21-63	14.5	73	.3	.09	.8	18	7.1	65	4.1	252
497----	13/31-23M1	-----do--------	310	131-310	6- 3-54	13.4	74	t .41	.12	----	19	8.7	62	2.8	244
498----	13/31-23M1	-----do--------	----	---------	5-13-60	----	---	.2	.13	----	24	7.7	---	3.6	c238
499----	13/31-26G1	-----do--------	240	235-240	---do---	----	---	<.05	.04	----	21	-----	21	3.2	193
					IDAHO										
	Townships North, Ranges West and East														
500----	13N/3W-8cc3	Midvale--------	963	---------	5-24-62	----	---	-----	---	----	5.0	1.6	71	13.3	200
501----	13N/3W-8cc3	-----do--------	----	932-963	11- 1-62	27.2	84	0.02	---	0.1	9.5	.3	65	22	220
502----	13N/4W-13ba2	A. Fairchild---	1350	Below 471	---do---	26.9	69	.53	0.0	.3	3.5	.2	80	9.1	187
503----	14N/3W-3dd3	Cambridge------	925	910-925	---do---	21.6	68	.64	.0	.1	2.5	.1	67	6.6	148
504----	16N/1W-10db1	Boise-Cascade--	404	134-199 346-376	5-23-62	----	---	-----	----	----	14.2	7.4	21.6	4.7	85
505----	16N/1W-10db1	-----do--------	----	134-199 346-376	11- 2-62	----	61	.06	----	----	16	6.3	20	5.4	90
506----	16N/1W-14ba2	Council--------	381	Below 220	5-23-62	15.6	---	-----	----	----	10	4.4	12.4	3.9	83
507----	16N/1W-14ba2	-----do--------	----	Below 220	11- 2-62	15.6	62	.00	----	.1	10	4.3	14	4.8	88
508----	17N/1W-34ab1	John Gould-----	120	Below 60(?)	5-24-62	----	---	-----	----	----	17	7.8	8.7	2.7	109
509----	17N/1W-34ab1	-----do--------	----	Below 60(?)	11- 2-62	12.2	53	.39	.0	.1	20	6.4	8.2	2.3	108
510----	30N/2E-6bc1-	Fenn-----------	396	---------	10-12-62	----	50	-----	----	----	24	9.2	37	3.5	201

TABLE 1. — *Chemical analyses of ground water in the basalt of the*

Milligrams per liter--Con.															
							Dissolved solids		Hardness						
Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Calculated	Residue on evaporation at 180°C	As $CaCO_3$	Noncarbonate	Sodium-adsorption ratio (SAR)	Specific conductance (micromhos at 25°C)	pH	Color	Remarks
OREGON--Con.															
0	0.5	400	0.5	0.4	0.03	0.12	742	-----	276	224	3.8	1370	7.6	---	Clackamas County.
															Six previous analyses similar.
0	6.2	5.5	.6	4.5	----	----	203	202	110	0	.7	280	8.1	0	Condon Air Control. Gilliam Co.
31	56	129	1.6	.0	----	----	437	461	10	0	19.5	676	9.5	---	Union Hot Springs. Union County. Also contains 4 mg/l hydroxide.
0	5.2	50	.3	.0	.11	.11	238	-----	106	0	1.4	376	7.8	---	WSP-1997. Clackamas County.
0	9.6	2.0	.2	.6	1.0	----	102	-----	35	0	.6	110	7.5	---	Yamhill County.
0	3.0	24	.4	.0	.22	.02	198	-----	78	0	1.0	257	7.4	---	Marion County.
0	.0	2.0	.2	.9	.47	----	85	-----	18	0	.7	68	7.2	---	Yamhill County.
0	15	585	.7	1.6	.03	.89	1120	-----	292	202	7.2	2030	7.4	---	Marion County.
0	1.0	2.5	.0	9.0	.40	.00	67	-----	24	1	.3	74	6.8	---	
0	.2	2.5	.2	.7	.64	----	99	-----	24	0	.8	91	7.4	---	Polk County.
0	4.2	3.5	.4	.0	.45	.04	120	-----	43	0	----	143	7.8	---	Marion County.
0	12	14	---	----	----	1.9	---	-----	---	---	9.7	600	8.1	---	Anal.Bur.Reclamation. Baker Co.
0	.96	18	---	----	----	1.6	---	-----	---	---	9.3	650	7.9	---	Do.
0	19	5	.4	.6	.18	.3	302	312	102	0	2.6	443	7.7	0	
0	10.4	15.4	.2	.0	----	---	422	-----	138	---	----	----	---	---	Anal. Charlton Lab.
---	8.4	7.5	.4	.0	----	----	---	356	75	---	3.3	----	7.9	---	Well 3.Anal.Charlton. Grant Co.
0	7.1	4.8	.2	.2	----	----	299	297	83	0	2.9	394	7.6	8	Well 2.
---	8.1	5.4	.3	.17	.06	----	---	295	91	---	----	----	7.8	4	Anal. Oregon Board Health.
---	13.4	4.5	.2	1.0	.12	----	---	224	---	---	----	----	7.7	8	Well 1. Anal. Oregon Bd. Health.
IDAHO															
2.4	10.1	3.9	---	0.0	----	0.09	206	-----	19	---	5.7	333	8.4	---	WSP-1779-Q. Anal. Bur. Reclam.[4] Washington County.
0	10	3.0	0.6	.3	.06	0.15	303	-----	24	0	5.7	378	8.1	---	
12	14	3.8	.7	.4	.14	.18	286	-----	9	0	11.2	368	8.7	---	
10	15	3.5	.9	.0	.11	.21	248	-----	6	0	11.3	303	8.7	---	
.0	31.7	8.5	---	.0	----	.05	130	-----	66	---	1.2	225	7.5	---	WSP-1779-Q.Bur.Recl. Adams Co.
0	28	7.8	.2	.6	.29	----	190	-----	66	0	1.1	232	7.4	---	
.0	1.4	.0	.0	.0	----	.00	73	-----	43	---	.8	138	7.5	---	WSP-1779-Q.Bur.Recl. Town well 2.
0	3.0	.8	.1	.4	.24	----	143	-----	42	0	.9	148	7.6	---	May draw from interbedded layers.
.0	4.3	1.4	.0	.0	----	.00	96	-----	75	---	.4	176	7.3	---	WSP-1779-Q. Anal. Bur. Reclamation.
0	3.8	1.5	.1	2.5	.15	----	151	-----	76	0	.4	187	7.1	---	
0	11	1.8	.7	.1	.08	----	236	-----	98	0	1.6	333	7.8	---	Idaho County.

Columbia River Group, Washington, Oregon, and Idaho — Continued

Serial number	Location number (S at end of number indicates spring)	Owner of well or spring (at time of sampling)	Depth of well (feet)	Depth of water-bearing zone(s) (feet)	Date water sample collected	Temperature (°C)	Milligrams per liter: Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Aluminum (Al)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
					IDAHO--Con.										
	Townships North, Ranges West and East--Continued														
511----	31N/1E-8aa1--	Cottonwood---	604	Balow 300	10- 9-62	13.9	48	0.02	----	0.1	17	6.6	16	1.8	124
512----	32N/2E-3ad1--	A. Killmar---	150	Below 16	10-12-62	10.0	47	.12	----	.1	72	23	25	1.3	332
513----	34N/1W-33C1--	Craigmont----	612	------------	10- 9-62	17.2	49	.12	----	.1	28	11	29	2.3	200
514----	34N/3W-14ad1-	Ernest Peer--	240	233-240	---do---	9.5	41	.01	----	.1	22	9.6	19	2.4	158
515----	35N/4E-26aa1-	Ellis Snyder-	93	Below 45	10-12-62	----	36	.09	----	----	19	11	14	3.9	139
516----	36N/5W-32ad1-	Lewiston-----	350	Below 60	10-11-62	15.0	39	.02	----	----	24	14	50	8.5	148
517----	37N/5W-14ab1-	Genesee------	117	Below 20	---do---	10.0	47	.02	----	.1	39	11	22	2.7	178
518----	39N/5W-8ab2--	Moscow-------	373	354-372	5-22-46	12.2	---	6.5	----	----	30	11	-----	----	163
519----	39N/5W-8ab2--	-----do------	----	------------	1- 4-52	12.2	---	.95	----	----	33	12	-----	----	140
520----	39N/5W-8ab2--	-----do------	----	------------	3-29-55	----	---	.67	----	----	-----	-----	----	----	153
521----	39N/5W-8ab2--	-----do------	----	------------	9-29-55	----	55	.26	----	----	27	10	13	2.6	160
522----	44N/1W-15dd1s	G. Bailey and Santa Village	----	------------	10-10-62	----	38	.00	----	----	17	6.5	6.2	3.3	100
523----	45N/5W-29bb1-	Walter Olson-	227	226-227	---do---	----	50	.70	0.0	.1	22	11	13	2.7	150
524----	46N/4W-18aa1-	Plummer------	492	481-492	---do---	11.9	33	.12	----	.1	14	11	17	2.2	133
525----	47N/5W-23ab1-	Worley-------	508	------------	---do---	11.7	46	1.8	.0	.1	23	11	13	2.2	143

[1] County locetion reference applies continuously downward until a new county reference is given.

[2] Wash. WSB-24 means Water Supply Bulletin 24 of the Washington Department of Water Resources. See references cited.

[3] Wesh. I. T., B-237, or WIT B-237, means Bulletin 237 of the Washington Institute of Technology. See references cited.

[4] WSP-1779-Q means Water-Supply Paper 1779-Q of the U.S. Geological Survey. See references cited.

t Total iron.

c Calculated. In the bicarbonete column this indicates value celculated from the bicerbonete alkalinity reported on the analysis.

a Temperature of 105°C used for residue meesurement on all enalyses of Oregon Boerd of Heelth.

TABLE 1.— *Chemical analyses of ground water in the basalt of the*

Milligrams per liter--Con.							Dissolved solids		Hardness						
Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Calculated	Residue on evaporation at 180°C	As $CaCO_3$	Noncarbonate	Sodium-adsorption ratio (SAR)	Specific conductance (micromhos at 25°C)	pH	Color	Remarks
IDAHO--Con.															
0	3.8	1.0	0.6	0.7	0.11	----	157	-----	70	0	0.8	202	7.9	---	
0	12	8.8	.7	35	.18	----	389	-----	276	4	.7	598	7.6	---	
0	11	3.0	.6	.2	.07	----	233	-----	116	0	1.2	331	8.0	---	Lewis County.
0	5.4	1.2	.7	.2	.01	----	180	-----	94	0	.8	259	7.8	---	
0	12	1.8	.2	.1	.35	----	166	-----	94	0	.6	241	7.9	---	Clearwater County.
0	64	30	.5	.2	.07	----	303	-----	116	0	2.0	467	8.0	---	Potlatch Forests well.Nez Pe~ce Co.
0	11	14	.3	18	.40	----	254	-----	142	0	.8	377	7.4	---	Latah County.
----	17	1	.4	----	----	----	256	-----	120	---	----	----	6.6	---	First three anal. Idaho Dept.
----	22	4	.4	----	----	----	---	-----	132	---	----	----	6.9	---	Public Health. WSP-1460-H.
----	4	-----	---	----	----	----	---	-----	116	---	----	270	7.6	---	
----	11	2	.0	.2	----	----	200	-----	110	0	.5	266	7.2	---	WSP-1460-H. City well 5.
0	2.8	.5	.1	.4	.47	----	124	-----	69	0	.3	159	7.6	---	Renfro Spring. Benewah County.
0	6.6	1.8	.3	.2	.21	----	183	-----	100	0	.5	240	7.5	---	
0	7.0	1.5	.4	.1	.15	----	153	-----	78	0	.8	219	8.1	---	
0	7.2	7.0	.3	.2	.07	----	182	-----	103	---	.5	253	7.7	---	Kootenai County.

Columbia River Group, Washington, Oregon, and Idaho — Continued

Serial number (from Table 1)	Location number and date[1]	Dissolved oxygen	Free carbon dioxide (CO_2)	Lithium (Li)	Strontium (Sr)	Barium (Ba)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Nickel (Ni)	Titanium (Ti)	Vanadium (V)	Arsenic (AS)	Other
		Milligrams per liter												
						WASHINGTON								
21-----	7/36-22N1---- (6-24-55)	0.3	----	----	0.02	0.01	-----	-----	-----	-----	-----	-----	------	------
32-----	9/23-22J1---- (8-5-55)	0	----	----	.26	.10	0.03	0.01	-----	0.01	-----	-----	------	------
34-----	10/22-25F1--- (8-4-55)	1.4	0.01	----	.30	.09	-----	.01	-----	.01	0.006	0.01	------	------
35-----	10/22-25G1--- (8-4-55)	5.3	.1	----	.89	.07	-----	-----	-----	-----	-----	.01	------	------
39-----	10/39-19R1--- (6-24-55)	8.2	.2	----	.08	.06	.006	.02	-----	.10	.004	.01	------	------
45-----	11/42-5D1---- (6-23-55)	---	----	----	.13	2.23	.004	-----	-----	.01	-----	.02	------	------
46-----	11/42-5D3---- (6-23-55)	---	----	----	.11	.005	-----	-----	-----	-----	.004	.02	------	------
69-----	13/38-26E1--- (8-2-54)	---	----	----	.01	.03	.01	.03	0.01	-----	.002	.02	------	[2]0.01
94-----	14/31-36B1--- (6-30-55)	---	----	----	.11	.02	-----	.02	-----	-----	-----	.01	------	------
96-----	14/31-36B2--- (6-30-55)	---	----	----	.60	.005	-----	.02	-----	.01	-----	.01	------	------
98-----	14/32-31D1--- (6-30-55)	---	----	----	.11	.02	-----	.01	-----	-----	-----	.01	------	------
102----	14/45-5B3---- (8-18-55)	---	----	----	.11	.10	-----	.05	-----	.02	.004	-----	------	------
104----	14/45-5D1---- (6-22-55)	---	----	----	.09	.03	.003	-----	-----	.01	-----	-----	------	------
106----	14/45-5D3---- (6-22-55)	---	----	----	.09	.03	.003	-----	-----	.004	-----	-----	------	------
122----	15/29-3D1---- (8-22-55)	---	----	----	.01	.02	-----	-----	-----	-----	-----	-----	------	------
124----	15/29-4A1---- (8-2-55)	---	----	----	.004	-----	-----	.01	-----	-----	-----	-----	------	------
130----	15/37-22A1--- (7-30-54)	---	----	----	.22	.03	.005	.02	-----	-----	.003	.01	------	------
131----	15/37-27H2--- (7-30-54)	---	----	----	.16	.04	.004	.03	-----	-----	.003	.01	------	------
134----	15/45-32N1--- (6-22-55)	---	----	----	.08	.03	-----	-----	-----	.004	-----	-----	------	------
146----	16/43-11G1--- (8-18-55)	---	----	----	.08	.004	-----	-----	-----	.004	.004	-----	------	------
147----	16/43-11G1--- (6-20-58)	---	----	----	.12	.02	.002	.01	-----	.004	.004	-----	------	------
148----	16/43-14N2--- (6-20-58)	---	----	----	.11	.02	.002	.005	-----	.13	-----	-----	------	------
165----	17/33-12P1--- (6-30-55)	---	----	----	.54	.04	.005	.01	-----	-----	-----	.01	------	------
166----	17/33-13D1--- (6-30-55)	---	----	----	.16	.03	-----	.03	-----	.01	.005	.01	------	------
167----	17/34-7N1---- (6-30-55)	---	----	----	.61	.07	.01	.02	-----	.02	-----	.02	------	------
168----	17/44-32A1--- (6-20-58)	---	----	----	.12	.10	.004	.005	-----	.08	.004	-----	------	------
180----	18/39-12K1--- (7-29-54)	---	----	----	.16	.01	.01	.01	.01	-----	.002	.01	------	------
192----	19/28-1C1---- (7- -52)	---	----	----	.14	.02	-----	.01	.001	-----	.002	.004	------	------
193----	19/28-15Q1--- (8-2-55)	---	----	----	.03	.01	-----	-----	-----	-----	-----	-----	------	------
195----	19/28-22B1--- (8-2-55)	---	----	----	.01	.005	-----	-----	-----	-----	-----	-----	------	------
196----	19/28-22B2--- (8-2-55)	---	----	----	.21	.04	.01	.01	-----	-----	-----	.01	------	------
200----	19/28-28K4--- (8-2-55)	---	----	----	.03	.01	-----	-----	-----	-----	-----	-----	------	------
209----	19/35-14Q1--- (7-1-55)	---	----	----	.09	.01	-----	.01	-----	-----	-----	.02	------	------
210----	19/35-14Q2--- (7-1-55)	---	----	----	.09	.005	.003	.01	-----	-----	-----	-----	------	------

TABLE 2. — *Minor elements in the chemical analyses of ground water in the basalt of the Columbia River Group, Washington and Oregon*

Serial number (from Table 1	Location number and date[1]	Milligrams per liter: Dissolved oxygen	Free carbon dioxide (CO_2)	Lithium (Li)	Strontium (Sr)	Barium (Ba)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Nickel (Ni)	Titanium (Ti)	Vanadium (V)	Arsenic (As)	Other
							WASHINGTON--Continued							
211----	19/35-23C1-- (7-1-55)	---	----	----	0.37	0.04	-----	0.01	-----	-----	-----	0.01	------	------
213----	19/35-23K1-- (7-1-35)	---	----	----	.12	.01	-----	.02	-----	-----	-----	-----	------	------
216----	20/24-7R1--- (8-3-55)	---	----	----	.17	.01	-----	-----	-----	-----	-----	.02	------	------
246----	21/26-8M1--- (7-22-55)	---	----	0.08	----	----	-----	-----	-----	-----	-----	.01	------	------
247----	21/26-8N1--- (7-22-55)	---	----	.02	----	----	-----	-----	-----	-----	-----	.005	------	------
248----	21/26-14L1-- (7-22-55)	---	0.09	1.77	----	----	-----	-----	-----	-----	0.006	-----	------	------
250----	21/26-16B3-- (7-22-55)	---	----	----	.06	----	-----	.007	-----	0.01	-----	.01	------	------
253----	21/26-21E1-- (7-22-55)	---	----	----	.08	.004	-----	-----	-----	.005	-----	.01	------	------
258----	21/38-23A2-- (7-1-55)	---	----	----	.10	.02	.004	.004	-----	-----	.004	.01	------	------
263----	22/26-24L1-- (7-22-55)	---	----	----	.10	.07	-----	-----	-----	-----	-----	-----	------	------
264----	22/27-19N1-- (7-22-55)	---	----	----	.12	.005	-----	.005	-----	-----	-----	.01	------	------
270----	23/29-14J1-- (8-10-54)	---	----	----	.09	.03	-----	.005	-----	-----	-----	.02	------	------
271----	(23/29-23G1- (8-10-54)	---	----	----	.06	.04	.003	.005	-----	-----	-----	-----	------	------
							OREGON							
300----	1N/1-34N4--- (1-9-47)	---	3.0	----	----	----	-----	-----	-----	-----	-----	-----	------	------
302----	1N/1-34P2--- (4-3-51)	---	3.0	----	----	----	-----	-----	-----	-----	-----	-----	------	------
308----	1N/13-4P1--- (6-25-54)	---	8.4	----	----	----	-----	-----	-----	-----	-----	-----	------	------
324----	1N/39-22B1-- (3-17-67)	---	.5	----	----	----	-----	-----	-----	-----	-----	-----	------	------
326----	1N/2W-24J1-- (10-24-62)	---	----	----	----	----	-----	-----	-----	-----	-----	-----	0.0	[4]2.2 [5]17
328----	1N/3W-1K2--- (12-4-67)	---	2.2	----	----	----	-----	-----	-----	-----	-----	-----	<.005	------
334----	2N/13-32J3-- (1-10-62)	---	2.4	----	----	----	-----	-----	-----	-----	-----	-----	------	------
349----	2N/32-10F1-- (6/13-52)	---	.00	----	----	----	-----	-----	-----	-----	-----	-----	<.005	------
350----	2N/32-10F1-- (7-15-54)	---	9.0	----	----	----	-----	-----	-----	-----	-----	-----	------	------
352----	2N/32-10N1-- (7/15-54)	---	4.0	----	----	----	-----	-----	-----	-----	-----	-----	------	------
355----	2N/33-14G1-- (12-19-66)	---	1.7	----	----	----	-----	-----	-----	-----	-----	-----	------	------
358----	3N/21-28D1-- (9-14-62)	---	.1	----	----	----	-----	-----	-----	-----	-----	-----	------	------
367----	4N/24-22G1-- (11-11-42)	---	5.5	----	----	----	-----	-----	-----	-----	-----	-----	------	------
377----	4N/27-5C1--- (3-30-62)	---	.9	----	----	----	-----	-----	-----	-----	-----	-----	------	------
404----	4N/28-10P1-- (6-29-64)	---	2.1	----	----	----	-----	-----	-----	-----	-----	-----	<.005	------
410----	4N/28-11N1-- (6-29-64)	---	1.3	----	----	----	-----	-----	-----	-----	-----	-----	<.005	------
413----	4/28-27J1--- (2-13-63)	---	1.5	----	----	----	-----	-----	-----	-----	-----	-----	.005	------
417----	4N/35-19L2-- (6-17-58)	---	----	----	0.2	----	-----	-----	-----	-----	-----	-----	------	------
418----	4/35-22Q1--- (3-2-67)	---	1.7	----	----	----	-----	-----	-----	-----	-----	-----	<.005	------
419----	4N/35-22Q2-- (3-2-67)	---	2.2	----	----	----	-----	-----	-----	-----	-----	-----	<.005	------

TABLE 2. — *Minor elements in the chemical analyses of ground water in the basalt of the Columbia River Group, Washington and Oregon* — Continued

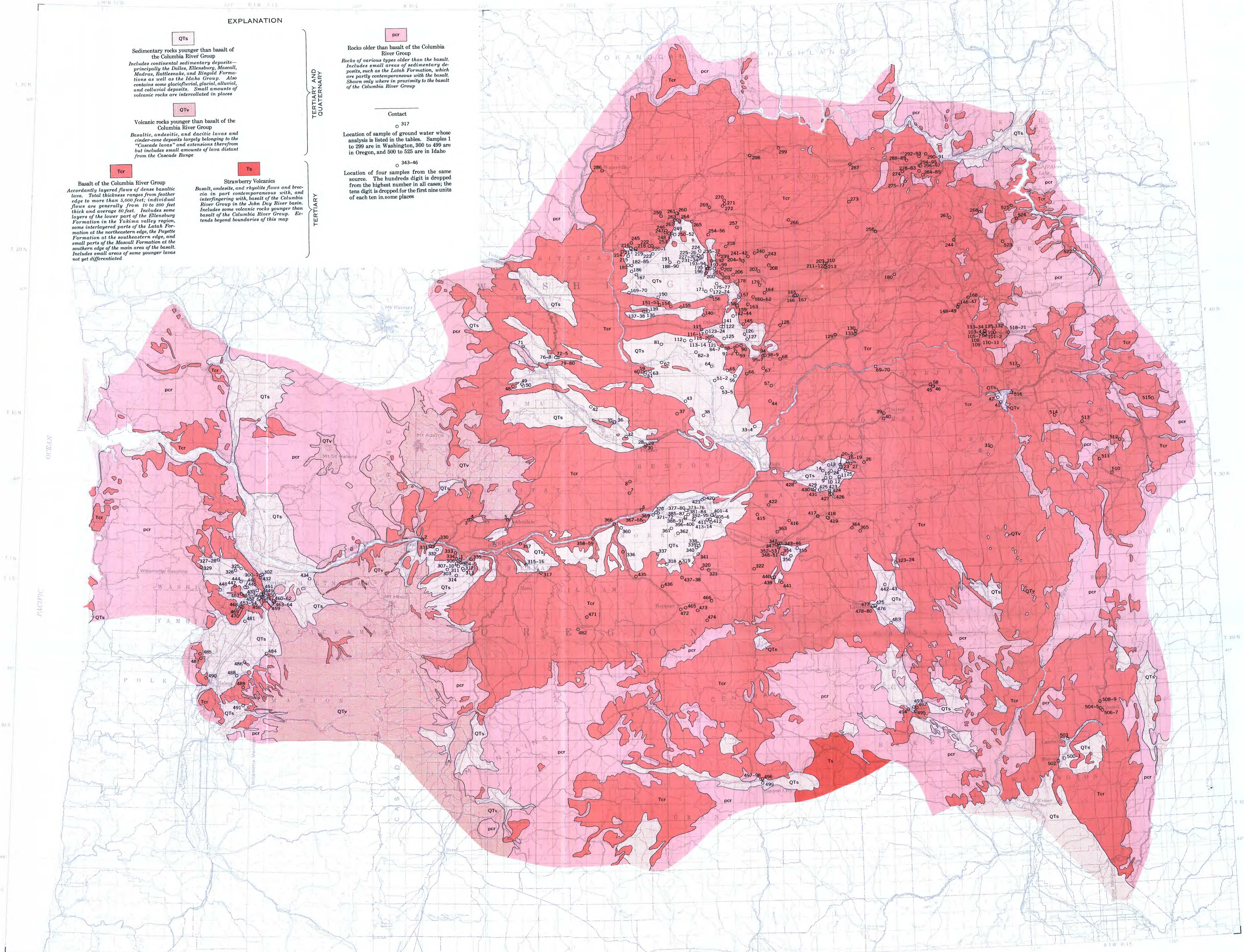
Serial number (from Table 1)	Location number and date[1]	Milligrams per liter												
		Dissolved oxygen	Free carbon dioxide (CO_2)	Lithium (Li)	Strontium (Sr)	Barium (Ba)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Nickel (Ni)	Titanium (Ti)	Vanadium (V)	Arsenic (As)	Other
						OREGON--Continued								
423----	5N/35-2E1-- (11-6-60)	---	1.7	----	----	-----	-----	-----	-----	-----	-----	-----	------	[3]0.05
424----	5N/35-2H1-- (8-1-58)	---	---	----	0.1	-----	-----	-----	-----	-----	-----	-----	------	------
425----	5N/35-5C1-- (8-5-54)	---	---	----	.06	0.03	0.003	0.03	-----	-----	0.002	-----	------	------
426----	5N/35-12F1- (8-1-58)	---	---	----	.1	-----	-----	-----	-----	-----	-----	-----	------	------
428----	6N/33-23B1- (1-10-55)	---	---	----	.13	.07	.002	.02	0.022	-----	.004	-----	------	------
429----	6N/34-36K1- (8-5-54)	---	---	----	.06	.02	.02	.02	-----	-----	.002	-----	------	------
430----	6N/34-36N1- (8-5-54)	---	---	----	.28	.06	.004	.03	-----	-----	.004	0 01	------	------
431----	6N/34-36Q1- (8-5-54)	---	---	----	.27	.05	.003	.03	-----	-----	.007	.01	------	------
436----	1/25-23L1-- (6-16-58)	---	---	----	.2	-----	-----	-----	-----	-----	-----	-----	------	------
447----	1/2W-24J3-- (1-22-63)	---	1.6	----	-----	-----	-----	-----	-----	-----	-----	-----	<0.005	------
448----	2/1-2N1---- (11-4-53)	---	---	----	15	-----	-----	-----	-----	-----	-----	-----	------	------
450----	2/1-2N2---- (11-4-51)	---	---	----	12	-----	-----	-----	-----	-----	-----	-----	------	------
451----	2/1-3L1---- (11-4-51)	---	---	----	1.2	-----	-----	-----	-----	-----	-----	-----	------	------
452----	2/1-8H1---- (11-4-53)	---	---	----	28	-----	-----	-----	-----	-----	-----	-----	------	------
456----	2/1-9D1---- (11-4-53)	---	---	----	17	-----	-----	-----	-----	-----	-----	-----	------	------
457----	2/1-9J1---- (11-4-53)	---	23	----	-----	-----	-----	-----	-----	-----	-----	-----	------	------
458----	2/1-15C1--- (11-4-53)	---	25	----	-----	-----	-----	-----	-----	-----	-----	-----	------	------
459----	2/1-24D1--- (11-4-53)	---	13	----	-----	-----	-----	-----	-----	-----	-----	-----	------	------
464----	2/2-20K1--- (6-9-53)	---	4	----	-----	-----	-----	-----	-----	-----	-----	-----	------	------
467----	2/1W-10C1-- (4-21-58)	---	----	----	<.1	-----	-----	-----	-----	-----	-----	-----	------	------
469----	2/1W-32F1-- (4-6-65)	---	50	----	-----	-----	-----	-----	-----	-----	-----	-----	<.005	------
470----	2/1W-32F2-- (4-6-65)	---	50	----	-----	-----	-----	-----	-----	-----	-----	-----	<.005	------
472----	3/26-2A1--- (8-3-67)	---	6.0	----	-----	-----	-----	-----	-----	-----	-----	-----	<.005	------
473----	3/27-2J1--- (5-3-67)	---	2.1	----	-----	-----	-----	-----	-----	-----	-----	-----	<.005	------
474----	3/28-28M2-- (5-16-58)	---	----	----	.1	-----	-----	-----	-----	-----	-----	-----	------	------
477----	3/38-6H1--- (10-7-66)	---	8	----	-----	-----	-----	-----	-----	-----	-----	-----	<.005	------
479----	3/38-6H2--- (7-24-61)	---	2.6	----	-----	-----	-----	-----	-----	-----	-----	-----	------	[3]<.05
480----	3/38-6H2--- (2-3-66)	---	.6	----	-----	-----	-----	-----	-----	-----	-----	-----	<.005	------
482----	4/20-10H1-- (5-3-67)	---	4.0	----	-----	-----	-----	-----	-----	-----	-----	-----	------	------
498----	13/31-23M1- (5-13-60)	---	4.5	----	-----	-----	-----	-----	-----	-----	-----	-----	------	------
499----	13/31-26G1- (5-13-60)	---	5.5	----	-----	-----	-----	-----	-- --	-----	-----	-----	------	------

[1] See table 1 for other data on water source and analyst.
[2] Silver (Ag).
[3] Alkyl benzyl sulfonate.
[4] Iodide.
[5] Bromide.

TABLE 2.—*Minor elements in the chemical analyses of ground water in the basalt of the Columbia River Group, Washington and Oregon*—Continued

Serial number (from Table 1)	Location number of well	Date sampled	Beta-gamma activity (micro-microcuries per liter)	Radium (Ra) (micro-microcuries per liter)	Uranium (U) (micrograms per liter)
			WASHINGTON		
9-------	6N/35-10P1	8- 1-58	14.1	0.3	0.1 ± 0.1
38------	10/28-17B1	6-15-51	------	<1	<100
43------	11/27-20M1	---do---	------	<1	---------
59------	13/24-25E1	12- 1-51	<100	<1	---------
61------	13/24-36D1	---do---	<100	<1	<100
63------	13/25-30G1	12- 1-51	<100	<1	<100
194-----	19/28-15Q1	11-29-55	<14	<.1	<.1
			OREGON		
303-----	1N/12-14R1	7-31-58	13	<0.1	<0.1
309-----	1N/13-4P1	7-30-58	<9	<.1	<.1
311-----	1N/13-8L1	7-31-58	<10	<.1	0.1 ± 0.1
312-----	1N/13-14M1	7-30-58	<7	<.1	.5 ± .1
314-----	1N/13-32G2	---do---	8.6	.1	<.1
337-----	2N/25-28D1	6-16-58	<13	<.1	<.1
340-----	2N/27-14M1	6-17-58	14	<.1	.3 ± .1
349-----	2N/32-10F1	6-13-52	<250	.14	<.4
356-----	2N/33-33N1	6-18-58	8.3	<.1	.1 ± .1
369-----	4N/25-7R1	6-17-58	<19	<.1	10 ± 1.0
407-----	4N/28-11N1	---do---	14	<.1	<.1
417-----	4N/35-19L2	---do---	<8	<.1	<.1
424-----	5N/35-2H1	8- 1-58	<5	<.1	.1 ± .1
426-----	5N/35-12F1	---do---	<5	<.1	<.1
436-----	1/25-23L1	6-16-58	<13	<.1	.1
437----	1/26-1J1	6-17-58	15	<.1	<.1
440----	1/32-9M1	6-18-58	32	<.1	2.0 ± 0.2
467----	2/1W-10C1	4-21-58	<8	<.1	.1 ± .1
474----	3/28-28M2	6-16-58	6.2	<.1	.4 ± .1
			IDAHO		
518----	39N/5W-8ab2	9-29-55	<10	0.6	<0.1

TABLE 3.—*Radioactivity and radioactive-chemical analyses of ground water in the basalt of the Columbia River Group, Washington, Oregon, and Idaho*



Base from U.S. Geological Survey 1:500,000.
State bases: Oregon, 1966; Washington, 1962;
Idaho, 1968

SCALE 1:1 000 000
25 0 25 50 MILES
25 0 25 50 KILOMETERS

Geology from Newcomb (1970), Wells and Peck (1961), and Huntting (1961)

MAP SHOWING LOCATION OF GROUND-WATER SAMPLING SITES IN THE BASALT OF THE COLUMBIA RIVER GROUP, WASHINGTON, OREGON, AND IDAHO