DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 363

QUALITY OF THE SURFACE WATERS OF OREGON

BY

WALTON VAN WINKLE

Prepared in cooperation with
THE STATE OF OREGON
John H. Lewis State Engineer

WASHINGTON
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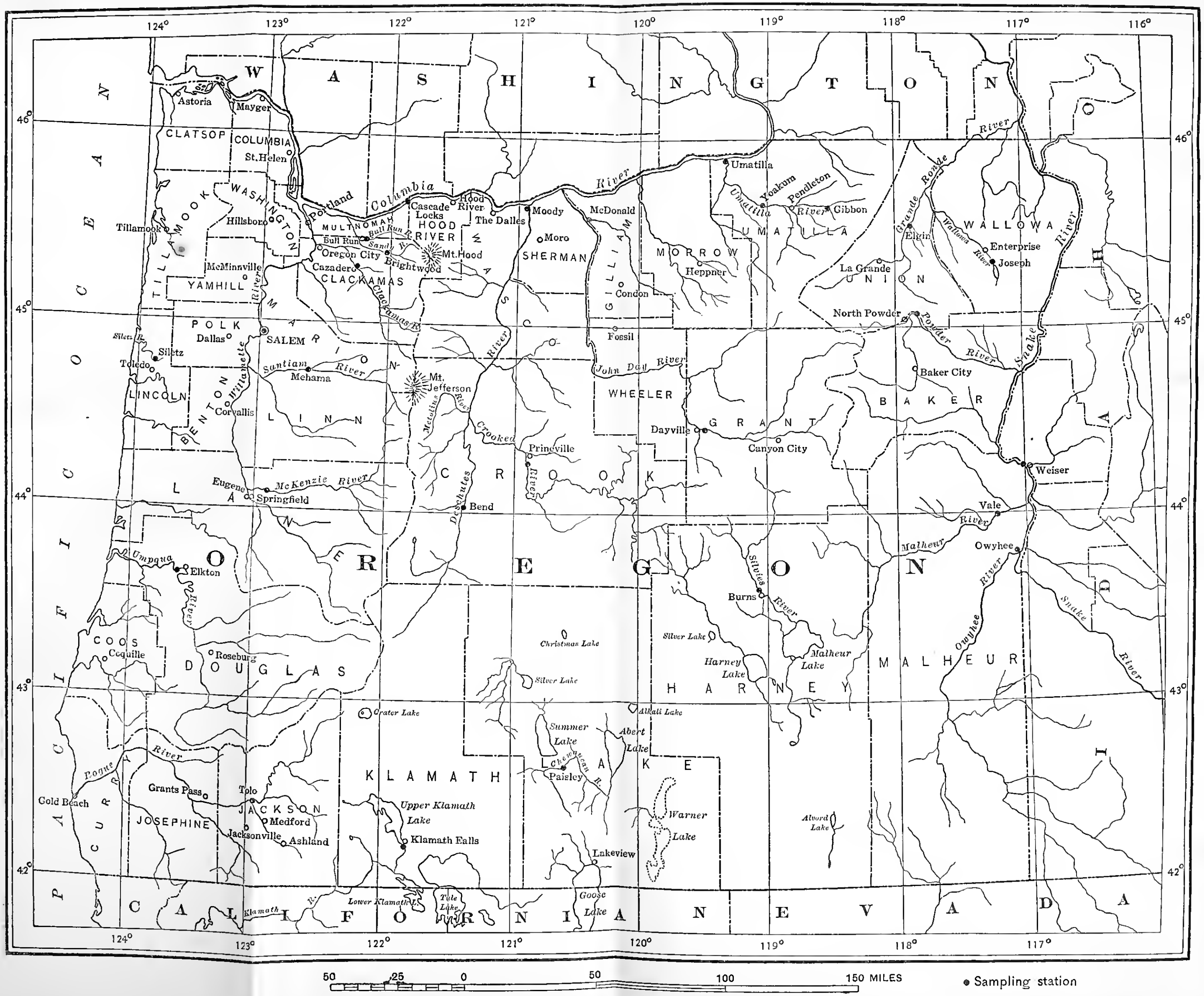

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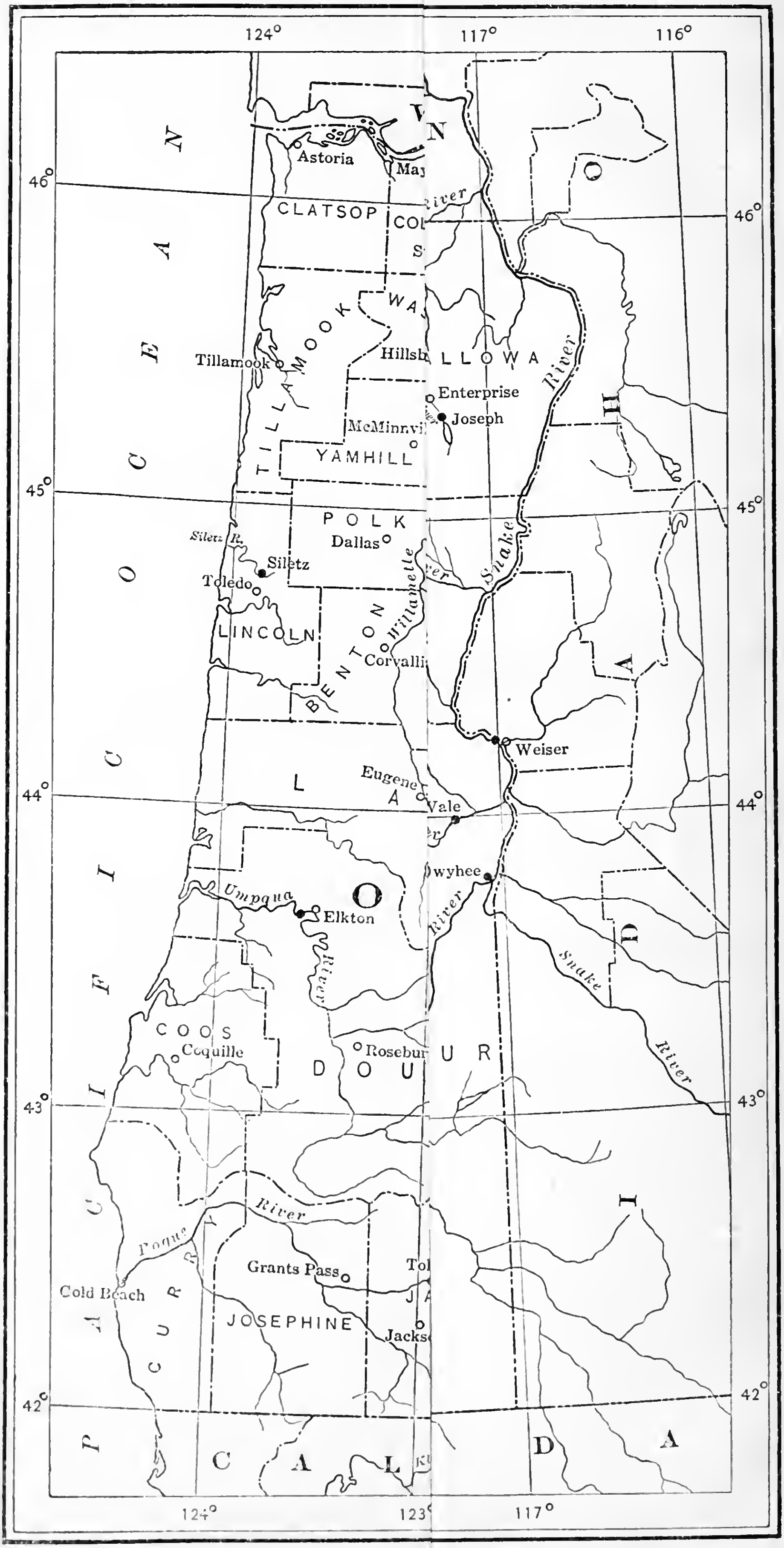

Sampling station

QUALITY OF THE SURFACE WATERS OF OREGON.

By WALTON VAN WINKLE.

OUTLINE OF INVESTIGATION.

On July 1, 1911, the Director of the United States Geological Survey made a contract with the State engineer of Oregon for the purpose of maintaining "in the State of Oregon a cooperative survey to determine the chemical composition of the waters of said State during a period of 14 months from the date" thereof. The further provision that the work should be carried on by a member of the United States Geological Survey led to the assignment of the author, an assistant chemist in the Survey, to the investigation.

In August, 1911, 23 sampling stations were established, all but two of which (Willamette River at Salem and Columbia River at Cascade Locks) were at places occupied by the Survey as stream-gaging stations. The location of the stations is shown by the following list and indicated by symbol on the map (Pl. I):

Rogue River near Tolo; below power plant at Gold Ray.
Umpqua River near Elkton; at ferry.
Siletz River at Siletz; one-half mile above bridge.
Owyhee River at Owyhee; 3 miles above mouth.
Powder River near North Powder; 7 miles east of North Powder.
Grande Ronde River at Elgin; at bridge on county road.
Wallowa River at Minam.
Snake River at Weiser, Idaho; at power house.
Umatilla River near Gibbon; 1 mile below town.
Umatilla River near Umatilla; 1½ miles above town.
John Day River near Dayville; at MacRae's ranch.
John Day River at McDonald; at ferry.
Crooked River near Prineville; at Stearns's ranch.
Deschutes River at Bend; at pumping plant.
Deschutes River near Moody; 1½ miles above mouth.
Bull Run River near Bull Run; just above Portland waterworks intake.
Sandy River at Brightwood; above and below Salmon River.
McKenzie River near Springfield; at Hendricks Ferry.
Santiam River at Mehama.
Clackamas River near Cazadero; at power house.
Willamette River at Salem; at county bridge.
Columbia River at Cascade Locks; just below the locks.
Chewaucan River near Paisley; one-fourth mile above town.

At each of these places samples of water were collected daily from the stream and forwarded to the laboratory at Willamette University, Salem, where all analyses were made. Collection of samples was begun in August, 1911, and was continued without interruption until August 15, 1912, with some minor exceptions, as follows: In August, 1911, the station at Gibbon was moved to Yoakum, 1½ miles east of the railway station, and that at Minam was moved to the gaging station at Joseph, below the outlet of Wallowa Lake. In October, 1911, a station was established on Silvies River, 4 miles from Burns. The station on Santiam River at Mehama was discontinued December 18, 1911.

All stations were visited at least once either by the author or by an engineer from the district office of the Geological Survey at Portland, and in August, 1912, the author made a rapid inspection trip through central and south-central Oregon, in course of which he collected samples from the following sources:

Crooked River near Paulina; at wagon bridge, 5 miles from Paulina.
Donner und Blitzen Canal near Narrows; at lowest wagon bridge.
Donner und Blitzen River at P Ranch; at bridge near ranch house.
Pelican Bay, Klamath Lake; spring in middle of arm of bay at Harriman Lodge.
Wood River above Fort Klamath; at wagon bridge on Crater Lake road.

Samples of water from the following lakes were also collected by interested parties and were analyzed in connection with the investigation.

Abert Lake.
Bluejoint Lake.
Crater Lake.
Crump Lake.
Flagstaff Lake.
Goose Lake.
Harney Lake.
Hart Lake.
Malheur Lake.
Pelican Lake.
Silver Lake (Harney County).
Silver Lake (Lake County).
Summer Lake.

The analyses were made by the author, assisted by N. M. Finkbiner and, during July, August, and September, 1912, by Florian Von Eschen, of Willamette University.

PREVIOUS WORK.

No systematic study of the quality of surface waters of Oregon has heretofore been made. A few analyses of lake waters have been published. Analyses of water from Columbia and Willamette rivers were reported by Bradley[1] in 1910, and a partial analysis of the water of Bull Run River was published by the water board of the city of Portland in its pamphlet relating to rates and regulations. Analyses of the water of Powder River near Baker City and near North Powder have been published in the Field Operations of the Bureau of Soils, 1903, 5th report, page 1162, Department of Agriculture. An analysis of the water of Lost River is given in the Annual Report of Irri-

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[1] Bradley, C. E., The water of the Columbia and Willamette rivers: Jour. Indus. and Eng. Chemistry, vol. 2, pp. 293-294, 1910.

gation and Drainage Investigations, Department of Agriculture, 1904, page 264, and several analyses made for the United States Reclamation Service, including one careful study of Link River, covering a period of about a year and a half, are reported by the United States Geological Survey in Water-Supply Paper 274, pages 53–55, 1911. An analysis of the water of Crater Lake, with analyses of Rogue and Wood rivers for comparison, was published in the Journal of Industrial and Engineering Chemistry for March, 1913, pages 198–199. No other analyses of Oregon river waters are known to have been printed.

VALUE OF INFORMATION REGARDING THE QUALITY OF SURFACE WATERS.

Water for drinking must be free from poisonous substances and disease-producing organisms and must not contain an excessive amount of any dissolved material; it must be clear, odorless, colorless, and of agreeable taste, and should also be soft and fairly free from iron. Laundry water should not be hard enough to cause waste of soap and should not contain substances that will spot or stain fabrics. Water for steam generation should not form excessive deposits of scale nor produce corrosion. Water for general industrial use should not contain substances that will injure the finished product or cause waste of raw materials. To ascertain the value of a water for any particular use, therefore, it is necessary to determine the nature and amount of the materials it holds in suspension and solution.

Knowledge of the mineral character of a surface water is sufficient for most practical purposes only when it is complete as to amounts and variations in amount of the mineral constituents under different conditions of run-off. Analyses of "spot samples" are as a rule misleading, especially those of waters from regions of slight rainfall or of marked seasonal variations in precipitation; but long-period samples, systematically studied, yield results of general as well as local value and elucidate many problems of physiography, chemical denudation, and geochemistry.

ACKNOWLEDGMENTS.

It is impossible to make full and specific acknowledgment of all assistance received in the preparation of this report, but appreciation of the helpful services of the many chemists, engineers, and others who have assisted the writer is hereby expressed. Particular thanks are due to the following persons: To Mr. John H. Lewis, State engineer of Oregon, whose cooperation made the work possible and who obtained laboratory and office space in which the work was performed; to Mr. F. F. Henshaw, who collected data regarding stream discharge and the Quaternary history of the Great Basin region; to Mr. R. B. Dole, who had immediate supervision of the investigation and whose advice, suggestion, and criticism were most helpful; to President Fletcher Homan and the faculty of Willamette University, who provided laboratory space; and to Prof. Withycombe and the staff of the Oregon Agricultural Experiment Station, who furnished many records hitherto unpublished.

The serial samples at Bull Run, Cazadero, Tolo, and Cascade Locks were collected through the kindness, respectively, of the Portland city water department, the Portland Railway Light & Power Co., the Rogue River Electric Co., and the United States Engineer Corps.

The writer has drawn freely on the geologic and other reports of the United States Geological Survey for information regarding the geology of the State and on publications of the United States Weather Bureau for information regarding climate and precipitation. Descriptions of rocks exposed in the basin of upper Wallowa River were furnished by Mr. Arthur Rudd, of Joseph, Oreg., and Mr. Charles Finkelnburg, of Baker, Oreg.

NATURAL FEATURES OF OREGON.

TOPOGRAPHY.

A line of mountains—the Cascade Range—extending north and south across the State, divides Oregon into a western humid region and an eastern arid region. The range merges into the Klamath Mountains on the south, and extends northward, broken only by the narrow pass of Columbia River at The Dalles, across the State of Washington into British Columbia. Its general elevation in Oregon is less than 6,000 feet above sea level, though isolated peaks exceed 10,000 feet in altitude. Mount Hood, a volcanic peak near the northern extremity of the range in Oregon, is the highest mountain in the State and reaches an elevation of 11,225 feet.[1] The range is of volcanic origin, and its slopes, especially on the west, are deeply eroded. Numerous streams, many of them excellent for power development, rise on its western slopes and most of them join Willamette, Umpqua, or Rogue River. The eastern slopes give rise to few streams. Deschutes River, parallel to the range and discharging into the Columbia above Celilo, is the largest.

Between the Cascade Mountains and the Pacific Ocean is the Coast Range. This range was formed by uplift and distortion of the coastal plain and has been deeply dissected by erosion. It receives copious rainfall, and its valleys are traversed by many short but torrential streams.

South of the Coast and Cascade ranges and merging into them is the Siskiyou Ridge of the Klamath Mountains, which has also been deeply dissected by erosion. The most important valleys in this ridge are occupied by Rogue, Coquille, and Illinois rivers. In the

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[1] Map of Mount Hood quadrangle, U. S. Geol. Survey, 1913.

northeastern part of the State are the Blue Mountains and the Wallowa Mountains, in which the general elevation is 8,000 feet and isolated peaks rise to greater height. The most important streams flowing from these mountains are Umatilla, Grande Ronde, Powder, and Silvies rivers. Many of the valleys are comparatively smooth, but because of the great dissection to which the mountains have been subjected the topography is commonly rough and broken.

The central and southern parts of the State consist of a high arid plateau over which are scattered many volcanic craters and which is so broken by cliffs and valleys that its appearance is in many places mountainous. Many of the valleys in this region contain large shallow lakes, some of which are permanent and others merely playas.

The topography of the region thus includes types ranging from the chaotically wild gorges of the Snake River basin to the level sagebrush plains of the Umatilla or the rolling prairies of Willamette Valley. Dense forests clothe the region west of the Cascades and are scattered over the better-watered highlands of the interior, but the arid plains are generally treeless.

HYDROGRAPHY.

RIVERS.

The principal rivers of Oregon discharge into the Pacific, either indirectly through the Columbia, as do Malheur, Owyhee, Powder, Grande Ronde, Umatilla, John Day, Deschutes, and Willamette rivers, or directly, as do Siletz, Umpqua, Coquille, Rogue, Illinois, and Klamath rivers.

Most of the streams of central, south-central, and southeastern Oregon, however, discharge into the landlocked lakes of the Great Basin. Few of the rivers of this region are perennial, and the large shallow lakes that occupy the chief depressions are permanent only when evaporation is balanced or exceeded by inflow. Where surface flow is deficient intermittent lakes or playas are formed. The chief streams of the Great Basin region are Chewaucan, Ana, Donner und Blitzen, and Silvies rivers; the important lakes are Warner, Harney, Malheur, Abert, Summer, and Silver lakes.

Goose Lake, in south-central Oregon and northern California, occupies a valley in all essential respects similar to the valleys of the Great Basin lakes, and has at present no surface outlet, but as it has, within historic times, overflowed southward into Pit River, a tributary of the Sacramento, it is considered part of the San Francisco Bay drainage basin.

LAKES.

About 1.13 per cent of the surface of Oregon is occupied by lakes, most of which are situated in the Great Basin region or in the Cascade Mountains. Owing partly to absence of detailed surveys but chiefly to the marked variations in size which many of the lakes undergo, precise information as to their areas is meager, but that which is available appears in the following table:

Principal lakes of Oregon.

Lake.	County.	Drainage area.	Water surface.
Abert	Lake	Great Basin	60 square miles.[a]
Alkali	do	do	Variable.
Alvord	Harney	do	Do.
Anderson	Lake	do	Do.
Aneroid	Wallowa	Wallowa River	
Aspen	Klamath	Klamath River	6.1 square miles.
Boca	Harney	Donner und Blitzen River	Overflow only.
Blur	Crook	Deschutes River	0.09 square mile.
Bluejoint	Lake	Great Basin	Variable.
Buck	Klamath	Klamath River	Swamp land only.
Bull Run	Clackamas	Sandy River	0.58 square mile.[b]
Christmas	Lake	Great Basin	Variable.
Clear	Lane	McKenzie River	0.40 square mile.[b]
Do	Wasco	Deschutes River	0.48 square mile.[b]
Cow Creek Lakes	Malheur	Owyhee River	Indefinite.
Crater	Klamath	Crater Lake	21.30 square miles.[c]
Crescent	do	Deschutes River	0.59 square mile.[d]
Crump	Lake	Great Basin	Variable.
Davis	Klamath	Deschutes River	4.25 square miles.[b]
Deer	do	do	0.96 square mile.[b]
Diamond	Douglas	Umpqua River	
Dog	Lake	Great Basin	0.75 square mile.[b]
East	Crook	Deschutes River	
Flagstaff	Lake	Great Basin	Variable.
Fish	Klamath	do	0.75 square mile.[b]
Do	Jackson	Rogue River	
Fourmile	Klamath	Klamath River	0.80 square mile.[b]
Goose	Lake	Great Basin	190 square miles, mostly in California.[d]
Guano	do	do	Playa.
Harney	Harney	do	54 square miles.[d]
Hart	Lake	do	Variable.
Juniper	Harney	do	
Do	Lake	do	
Klamath, Upper	Klamath	Klamath River	76.6 square miles.[b]
Klamath, Lower	do	do	133 square miles.[b] [e]
Klamath Marsh	do	do	69.8 square miles.[b]
Lake of the Woods	do	do	1.9 square miles.[b]
Loon	Douglas	Umpqua River	0.45 square mile.[b]
Long	Klamath	Klamath River	2 square miles.[b]
Lost	Clackamas	Sandy River	0.7 square mile.[b]
Malheur	Harney	Great Basin	73 square miles.[d]
Marion	Linn	Santiam River	0.56 square mile.[b]
Mugwump	Lake	Great Basin	Variable.
Odell	Klamath	Deschutes River	5.93 square miles.[b]
Olive	Grant	John Day River	0.15 square mile.[e]
Pauline	Crook	Deschutes River	
Pelican	Lake	Great Basin	Variable.
Round	Klamath	Klamath River	
Silver	Lake	Great Basin	15 square miles.[a]
Do	Harney	do	7 square miles.[d]
Squaw	Jackson	Rogue River	
Sutters	Crook	Deschutes River	0.43 square mile.[b]
Summer	Lake	Great Basin	70 square miles.[a]
Summit	Klamath	Deschutes River	1.36 square miles.[b]
Swan	do	Great Basin	Variable.
Thorn	Lake	do	Do.
Trout	Crook	Deschutes River	1.46 square miles.[b]
Tule	Klamath	Klamath River	Mostly in California.
Tumtum	Harney	Great Basin	Variable.
Waldo	Lane	Willamette River	8.9 square miles.[d]
Wallowa	Wallowa	Grande Ronde River	2.3 square miles.[e]
Warner (comprises Anderson, Bluejoint, Crump, Flagstaff, Hart, Mugwump, and Pelican lakes).	Lake	Great Basin	Variable.

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[a] Waring, G. A., Geology and water resources of a portion of south-central Oregon: U. S. Geol. Survey Water-Supply Paper 220, p. 11, 1908.

[b] Planimeter measurements by Walton Van Winkle on best available maps.

[c] Diller, J. S., Crater Lake National Park, Oregon, p. 28, U. S. Dept. Int., 1912.

[d] U. S. Reclamation Service, unpublished reports.

[e] Office records, U. S. Geol. Survey.

The larger lakes, except Crater Lake, are situated in the central Oregon plateau region, and are subject to wide fluctuations in area. Many of them, such as the Warner Lakes and Goose Lake, are slowly diminishing as a result of deficient inflow; several, among them Malheur, Harney, Silver (Harney County), Goose, and the Warner lakes, will eventually disappear, owing to the use of the tributary waters for irrigation.

SWAMPS.

The marshes that in places border Columbia and Willamette rivers are unimportant, but the long flat valleys of the Great Basin contain rich, fertile, swamp lands, susceptible of great development when drained. Much of Harney Valley may be classed as reclaimable swamp land, Blitzen Valley alone containing nearly 100,000 acres of marsh, most of which is now being drained. Chewaucan Marsh, below Paisley, contains more than 25,000 acres of land that has been drained and utilized for wild hay. Other important swamps are the Klamath marshes and the overflow lands of Warner Valley. Reclamation of these lands is either now under way or is contemplated.

FLOODS.

The rivers reach a high stage during winter, most often in January, and some rivers reach a second flood stage late in spring or early in summer. The winter flood is the normal result of increased precipitation in winter; the summer floods are caused by the melting of snow on the mountain slopes. Columbia River is exceptional in that its period of maximum discharge is in June, its winter discharge being relatively slight. The floods of the larger rivers are at times serious. A rise of more than 30 feet above low water has been recorded on the Willamette, and the Columbia sometimes reaches 60 feet above extreme low stage.

GEOLOGY.

ROCKS.

Comparatively little detailed information has been collected concerning the geology of Oregon as a whole, but the following general features have been ascertained, the result largely of investigations by Arnold and Hannibal, Condon, Diller, Lindgren, Merriam, Russell, Waring, and others.

The oldest geologic formations recognized in Oregon are exposed in the Blue and Wallowa mountains in the northeastern part of the State and in the Klamath Mountains of southern Oregon and northern California. The Blue and Wallowa mountains consist of sedimentary and igneous rocks, which have been referred to the Carboniferous, Jurassic, and Triassic periods. These rocks have been invaded by considerably younger plutonic masses and are overlapped on the flanks of the mountains by the Columbia River basalt and other volcanic and sedimentary formations of the John Day Basin and

Snake River plains. In the Klamath Mountains Paleozoic and Mesozoic (Jurassic and Lower Cretaceous) strata are exposed. The older rocks in the three mountain ranges mentioned occupy superficially a relatively small part of the State.

The Coast Range is composed chiefly of folded and faulted sediments of Tertiary age, overlain on both sides by Pleistocene and Recent deposits. The range contains also some volcanic, but no metamorphic, rocks, so far as known.

The Cascade Range consists chiefly of Tertiary volcanic rocks and contains several recent volcanoes. The lavas of the range overlie the older sediments of the western foothills. The prevailing rocks are basalts, rhyolites, and andesites. The range is bordered on the east by the Columbia River basalt, which, with other Tertiary rocks, chiefly of volcanic or lacustrine origin, covers all of eastern Oregon with the exception of the Blue Mountains and portions of the valleys of Snake and John Day rivers.

The Columbia River basalt has nowhere been traced to its source. It is considered to have issued from extensive fissures now hidden by the flow itself. The extent of the basalt-covered area has not been exactly determined, but Russell[1] considered previous estimates of 250,000 square miles to be decidedly conservative. The flows extend over southeastern Washington, eastern Oregon, northeastern California, northern Nevada, and parts of southern and western Idaho, to depths up to several thousand feet. The lower canyon of Deschutes River exposes in places 24 distinct superposed flows, and where the Columbia has cut its way through the gap at The Dalles sections of basaltic cliffs more than 3,000 feet thick are visible and the bottom of the flows is not exposed. The Steens Mountain fault exposes more than 5,000 feet of lava and an additional unknown thickness is hidden by the sediments of Alvord Valley. The rocks near Steens have not been studied in detail and possibly do not all belong to the Columbia River basalt, which consists essentially of a series of basaltic flows interstratified with beds of tuff and lapilli. A large territory east of the Cascade Mountains is covered with a deposit of pumiceous sand, and is for this reason called the Great Sandy Desert. The Columbia River basalt and associated volcanic and lacustrine formations were erupted or laid down during a long period of volcanism which began in early Tertiary time and continued more or less interruptedly into the Quaternary.

Quaternary lacustrine and fluviatile deposits overlie large areas of the basalts in central and southern Oregon. These deposits are of slight thickness but are important on account of the fertility of the soil derived from them and because of the possible occurrence in them of workable saline deposits.

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[1] Russell, I. C., Geology and water resources of central Oregon: U. S. Geol. Survey Bull. 252, p. 79, 1905.

SOILS.

Soil is residue from rock decay, altered and added to as a result of vegetable life. The soil may occupy the place of the rock from which it is derived, or it may have been brought from a distance by wind, water, or gravity. The character of the soil, then, is largely, but not necessarily entirely, determined by the composition of the neighboring rocks. Basaltic rocks, such as comprise the greater part of the Columbia River basalt, produce soils rich in lime but poor in phosphorus. The basaltic soils are light and easily worked, rich in iron, and therefore of reddish color. They are very productive, although their potash content is in many places low. Sedimentary rocks produce soils of great variety. Limestones form clayey soils of great productiveness; sandstones form light soils which are rich in arid regions but which are poor in regions of great humidity, owing to the leaching out of soluble plant food. In general, argillaceous sandstones produce rich loamy soils. Slates, shales, and allied rocks produce heavy clayey soils, and natural clays undergo little change.

In the following paragraphs Bradley[1] presents an excellent summary of conditions in Oregon affecting soils:

> The soils grade from the rich black loams of the coastal plains and lower river courses of western Oregon to the extremely sandy soils of the eastern and the coarse granite soils of the southern portion of the State, with many intermediate types. Volcanic rocks predominate in the northwest and Oregon soils are largely derived from weathered basalt, diabase, and diorite, particularly in the eastern and western part of the State. In southern Oregon granites, limestones, and other metamorphic rock exist also and have therefore determined in part the mineral character of the soils of this section. Where the weathering process has taken place under humid conditions, as in western Oregon, clay loams, rich in humus, have been formed, while under the climatic influences of the arid or semiarid conditions of that portion of the State east of the Cascade Range a sandy soil has resulted.
>
> The general soil types of the State may be distinguished as follows:
>
> Western Oregon:
> - Willamette Valley clay loams.
> - Red hill soil of foothills.
> - Beaverdam or muck soils.
> - Sandy loams of river bottoms.
> - Black loams of coastal plains.
>
> Eastern Oregon:
> - Clay loams of valleys.
> - Sandy.
> - Silt loams.
> - Volcanic ash.
>
> Southern Oregon:
> - Clay or adobe soils.
> - Clay loams.
> - Granitic.

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[1] Bradley, C. E., The soils of Oregon: Oregon Agr. Coll. Exper. Sta. Bull. 112, p. 4, 1912.

CLIMATE.[1]

Mean temperature in Oregon differs with elevation and with distance inland. In Columbia River valley and west of the Cascades at points below 2,000 feet above sea level it is approximately 52° F.; east of the Cascade Range and south of the Columbia it ranges from 43° to 51°. A universal characteristic is the uniformly low temperature of the summer nights. In the coastal strip the greatest annual range in temperature is from 10° to 97°, with an average of 217 days between frosts. In the valley strip between the Coast and Cascade ranges the range is greater; maximum recorded temperatures for Portland and Ashland have been 102° and 108° F., respectively; minimum temperatures for those places have been −2° and −4° F. The average time between last and first frosts ranges from 213 days at Portland to 179 days at Ashland. In the higher sections of this district the extremes of temperature both daily and yearly are more marked, and at Lakeview, elevation 5,060 feet above sea level, frosts have occurred every month in the year. The higher elevations of the Cascades and the Blue Mountains are subject to lower temperatures than those mentioned.

Rainfall ranges from less than 8 inches in the southeastern part of the State to more than 138 inches in the northwestern coastal strip, and averages from 75 to 138 inches along the coast, from 20 to 45 inches in the valley region west of the Cascade Range, from 50 to 100 inches in the Cascades, from 8 to 22 inches on the central high plateau, from 10 to 15 inches in the Columbia Valley east of the Cascades, and from 12 to 25 inches in the foothills and valleys of the Blue Mountains. Maximum precipitation occurs in winter, and the summers are dry. East of the Cascades there is a secondary maximum precipitation in May and June.

ECONOMIC FEATURES.

POPULATION.

Oregon is one of the most sparsely settled States. The census of 1910 showed that it contained 7 inhabitants to the square mile. The total population in 1910 was 672,765, an increase of 62.7 per cent over that shown by the census of 1900. About three-fourths of the inhabitants reside in the counties west of the Cascades and almost one-third in the city of Portland. Seven cities have more than 5,000 inhabitants each, all but one, Baker City, being in the western third of the State. Much of the high plateau region will probably be given over almost exclusively to cattle and sheep raising, the region being better suited for range than for other purposes, but the valley lands, the basins of Deschutes and Crooked rivers, and the Columbia River valley are well adapted to agriculture and will support a population much denser than the present.

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[1] Abstracted from Climatology of the United States: U. S. Dept. Agr. Weather Bur. Bull. Q, pp. 948-969, 1906.

AGRICULTURE.

The climatic differences between eastern and western Oregon have resulted in important differences in agricultural development. The high plateau region of the eastern part of the State is the seat of the live-stock industry, but in the valley regions and mesa lands along the Columbia and its tributaries wheat, barley, alfalfa, and kindred crops are raised. Dry farming is practiced successfully in some places, but irrigation is rapidly supplanting it. The census of 1910 reported 11,685,110 acres of farm land, of which 686,129 acres were irrigated, and the amount included in all irrigation projects begun or completed was 2,527,208 acres. The United States Reclamation Service is constructing projects in Klamath and Umatilla valleys to serve 185,000 acres. Several Carey Act projects are also under construction, but the largest acreage has been irrigated by private or partnership enterprises.

Though summers in western Oregon are dry, that region is plentifully supplied with rain in winter and irrigation has not been practiced extensively. Willamette Valley is the chief agricultural center, but several smaller sections produce excellent crops. The products include oats, potatoes, hops, prunes, apples, berries, and dairy products. The hop industry is especially important, the crop for 1910 being valued at little less than $2,000,000.[1] Prune growing is attaining prominence and is one of the most important industries of the valley. Hood River valley is famous for its apples and strawberries.

LUMBERING AND MANUFACTURING.

Lumbering is the principal industry of Oregon. The State ranked ninth as to amount of raw lumber cut in 1909. The value of lumber products for that year was $30,200,000, or 32.5 per cent of that for all industrial products of the State. The principal woods cut are Douglas fir and pine, and the centers of the industry are in Multnomah, Coos, and Lane counties. Most of the lumber is used as such, either raw or finished, but a small amount is converted into pulp, paper, and wood distillates.

Other important industries in the State are flour milling, slaughtering and meat packing, printing and publishing, manufacture of dairy products, tanning, and manufacture of woolen goods. The manufacture of metal goods is small.

Sawdust from the lumber mills, soda and sulphite wastes from the paper mills, waste liquors from the tanneries, scouring and dye liquors from the woolen mills affect the quality of the surface waters, and the disposal of these wastes should be regulated by proper protective legislation.

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[1] Hoff, O. P., Bureau of Labor Statistics, State of Oregon, Fourth Biennial Rept., p. 61, 1911.

CONSTITUENTS OF NATURAL WATERS.

Even rain, the purest natural water, contains appreciable amounts of organic and inorganic material in solution and in suspension. Rain falling near the seacoast contains more or less dissolved salt that has been derived from the ocean with the water vapor—a fact that has been utilized in the study of the pollution of waters near coasts by determining the quantity of chlorine carried by normal unpolluted waters.[1] Charts indicating the amount of chlorine brought down in rain can be prepared by plotting the results of such determinations and connecting points at which equal amounts are found, thus establishing lines of equal chlorine (isochlors). Abnormalities resulting from human pollution can be discovered by comparing analyses of other waters with the data in these charts. But isochlors are useful only near the coast in humid regions that do not contain chloride-bearing rocks, and they are of extremely doubtful value in regions where rainfall is subject to great seasonal variations. Streams flowing through arid regions contain relatively large amounts of chloride left after incomplete leaching of the sedimentary rocks, and though the amount of native chlorine may be small where the rocks are mostly volcanic or plutonic, unpolluted waters in that region may be high in chlorine because of the concentration of "cyclic" or wind-borne chlorine by evaporation.

Carbon dioxide and oxygen, the chief gases dissolved in rain water, are powerful agents of solution and oxidation, and the water containing them, having reached the earth, begins at once to acquire a further charge of dissolved matter. The carbon dioxide already present is augmented by that produced by the decay of vegetable matter on the surface of the ground and in the soil. Silica and the rock silicates are practically insoluble in pure water, but hydrated silicates are easily decomposed in weak solutions of carbonic acid, and "quartz is attacked and dissolved by prolonged digestion in even dilute alkaline carbonate solutions." [2] Silicate rocks are thus broken down by the action of water bearing carbon dioxide, and silica and alkalies are dissolved. The dissolved carbonic acid also attacks limestone with which it comes into contact, for calcium carbonate, though it is only slightly soluble in pure water, goes readily into solution in the presence of carbonic acid, probably as calcium bicarbonate.

Direct solution, hydrolysis, and double decomposition all aid in bringing other materials into solution. Many secondary rocks, such as gypsum, enter directly into solution, and limestone may be dissolved by interaction with alkali sulphates.

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[1] Jackson, D. D., The normal distribution of chlorine in the natural waters of New York and New England: U. S. Geol. Survey Water-Supply Paper 144, p. 10, 1905.

[2] Lunge and Millberg, Zeitschr. angew. Chemie, pp. 390 and 425, 1897. Cited by Chase Palmer, in The geochemical interpretation of water analyses: U. S. Geol. Survey Bull. 479, p. 23, 1911.

All elements are soluble in water to some extent, but relatively few are found in appreciable amounts in natural waters. The important materials usually found are silica, iron, alumina, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulphate, chloride, nitrate, and organic matter.

WATER FOR DOMESTIC USE.

Drinking water must be free from suspended or dissolved matter that may endanger health or render the water unpalatable. Even a small quantity of iron gives a disagreeable taste to water and injures the quality of tea and coffee by combining with the steep liquors of the beverages to produce inks. The presence of sodium chloride in water in amounts greater than 400 parts per million can be detected by taste by most persons, and water containing more than 1,000 parts per million would be palatable to few. Water containing large amounts of sulphate tends to produce unpleasant laxative effects.

The esthetic quality of water used for drinking is also important, and for this reason it should be clear, colorless, and odorless. Suspended matter not only renders water unattractive in appearance but clogs pipes and valves, reduces the capacity of reservoirs, stains clothes, and produces sludge in boilers. For domestic uses other than cooking and drinking water should be soft, as hard water increases the consumption of soap by reaction of the alkaline earths in the water with the soap to form insoluble compounds. Hard water and water containing iron also spot and "rust" clothing washed in it.

WATER FOR BOILERS.

Water used for generating steam should be examined for the purpose of forecasting and preventing corrosion, which shortens the life of a boiler, and the deposition of scale, which lowers the economy of heat transference. Foaming in the boiler, a serious trouble in some places, does not occur in using most surface waters of the Pacific Northwest.

CORROSION.

The corrosion or slow solution of a boiler manifests itself as pitting or grooving of the steel. As no metal is absolutely insoluble in water, a small—perhaps inappreciable—amount will be dissolved even under ideal conditions. Severe corrosion is caused by the action of acids or, if the metal of the boiler is nonhomogeneous, by the electrical action due to the presence of salt solutions. Severe corrosion due to the presence of organic matter or dissolved gases capable of producing acids or to the depolarizing effect of dissolved oxygen may occur with waters of low mineral content. The substances that cause corrosion are: (1) Dissolved carbon dioxide, hydrogen sulphide, and similar gases; (2) dissolved oxygen; (3) organic substances—particularly organic oils—that produce organic acids by decomposition; (4) dissolved mineral acids; (5) dissolved salts having acid reaction and dissolved salts that free acid when they are decomposed by heat, such as calcium nitrate, aluminum sulphate, copper sulphate, magnesium chloride, and, more rarely, calcium chloride and magnesium sulphate; and (6) dissolved alkali or other salts that undergo hydrolysis.

The means that may be adopted to prevent corrosion include allowing a thin film of scale to be deposited in the boiler, increasing the alkalinity of the water (particularly by means of soda ash), preheating the water to remove dissolved gases, generating an electric current to keep the iron of the boiler electro-positive, and making the boiler shell of absolutely pure, homogeneous metal. Any of these means may be effective under proper conditions, but the means to be employed should be adopted only after study of the causes and the resultant economy. Thus far, however, it has been impracticable to make boilers of pure, homogeneous metal.

Stabler's formula[1] is useful for ascertaining the approximate tendency of the dissolved solids in a water to produce corrosion, but it can not be depended upon absolutely in estimating the corrosive tendency of soft, highly colored waters like many of those found in Oregon, as corrosion with them is less likely to be caused by acids freed by reactions of dissolved mineral solids than by dissolved gases or by acids produced by decomposition of organic matter. The corrosion factor computed by his formula for such waters is misleading unless it can be understood that it refers only to preheated water and that sufficient soda ash may have to be introduced to counteract the effect of organic acids.

FORMATION OF SCALE.

Formation of scale is the deposition of material within the boiler either by sedimentation of suspended matter or by precipitation of dissolved matter. The texture of the scale may range from soft muck or sludge to hard, crystalline, closely adhering incrustations. Any material that is neither corrosive nor volatile will, when present in sufficient quantity, form scale, but as the more soluble substances, such as salts of the alkalies, do not become sufficiently concentrated to be deposited, scale usually comprises only compounds of the alkaline earths, suspended matter, and colloidal matter.

The scaling matter in the surface waters of Oregon is composed largely of silica, clay, and organic matter, which are deposited as more or less adherent crust. The colloidal material includes silica,

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[1] Stabler, Herman, Some stream waters of the western United States: U. S. Geol. Survey Water-Supply Paper 274, p. 173, 1911.

iron, aluminum, and organic matter. Silicon may be present as a silicate radicle in some waters, but it is usually considered to be entirely colloidal silica (SiO_2). Deposits of silica from most waters are relatively insignificant, but where it forms a large proportion of the scale-forming material, as in the waters of Oregon, it produces a hard, strongly adherent incrustation that is troublesome and dangerous and is removable only with great difficulty. Iron and aluminum are deposited mostly as hydrates which are converted by heat into oxides, although they may be precipitated as basic salts. The amount of these bases is usually too small to be important, but where aluminum sulphate is used as a coagulant in water purification, an excess of the reagent hydrolyzing in the boiler may cause precipitation of the hydrate and formation of sulphuric acid, which is strongly corrosive. Organic matter, especially that of an oily nature, is troublesome, as it either hydrolyzes and corrodes the metal of the boiler or is deposited as a hard varnish-like coating that renders the boiler walls liable to become overheated.

The chief scale-forming ingredient of most boiler waters is calcium, which is deposited as the carbonate or the sulphate. The amount of it that can be present without causing serious trouble depends largely on the relative abundance of the acid radicles; a given amount of calcium is less objectionable in a carbonate than in a sulphate water, because preheating a calcium carbonate water precipitates most of the calcium as soft, easily removable sludge, but preheating a calcium-sulphate water removes little scale-forming matter and leaves the water more likely to yield a hard, resistant incrustant. Magnesium is in some respects analogous to calcium in its action in a boiler, except that it usually is deposited as the oxide and thus sets free mineral acids that may under some conditions of reaction corrode the boiler.

Alkali salts form no permanent precipitate, but as the addition of soda ash or other alkali in water softening increases the amount of alkalies in the softened water and therefore its tendency to foam, it is well to ascertain beforehand whether chemical treatment is likely to obviate one objectionable feature by introducing another.

Bicarbonate is converted by heat into carbonate, part or all of which may be precipitated with the alkaline earths. Many natural waters contain enough bicarbonate to precipitate thus the greater part of the alkaline earths, the addition of softening reagents being then unnecessary. The carbonate scale from such water is soft sludge that is easily removable from the heating system by blowing off or similar means. Carbonate scale is the least harmful to boilers and the object of chemical treatment is to remove as much as possible of the incrustants as carbonates.

Sulphate forms hard, compact scale with the alkaline earths. As it is very expensive to remove the sulphate radicle from waters, it is customary to add sufficient carbonate alkali to precipitate the alkaline earths, the sulphate being left in equilibrium with the alkalies. The quantities of nitrate and chloride in most surface waters of Oregon are not great enough to make them important in boiler-room practice, though they may cause corrosion under some conditions in highly concentrated waters.

FOAMING.

Foaming in boilers is the formation of bubbles in the steam space above the surface of the water. If foaming proceeds to such extent that water is forced from the boiler with the steam, "priming" is said to occur. The causes of foaming and priming are somewhat obscure, but they are probably connected with the presence of the hydroxyl radicle, as foaming apparently takes place when a solution containing a weak acid in balance with a strong base is heated. As the amount of alkali in a water is an index of its hydroxyl-producing power, it is customary to measure the foaming propensity by the content of alkali bases. Suspended matter, not only that nominally in the feed water but also that composed of precipitated sludge and scale, may, however, cause foaming, and it is well recognized that the design of the boiler and the manner of its operation have much to do with accelerating or lessening foaming and priming.

WATER FOR USE IN FACTORIES.

INDUSTRIES CHIEFLY AFFECTED.

The factories of Oregon in which quality of water has direct bearing on economy of operation or quality of output or both comprise breweries, tanneries, dye works, ice plants, laundries, meat-packing houses, paper and pulp mills, and wool-scouring works, of which the largest are the paper mills, breweries, woolen mills, and laundries. A brief discussion of the use of water and the harmful effects of certain constituents in each of these industries is presented in the following paragraphs. The reader is referred to any of the standard works on industrial chemistry or on the use of water in special industries for more complete discussions of the operations and reactions that are involved.

BREWERIES.

The water used for brewing must be of great bacterial purity and must contain suitable mineral matter in solution, for it is not only a solvent and a reaction medium throughout the whole process but it also forms a part of the finished product. Decomposable organic substances or bacteria are specially harmful, as they mold the barley, lessen the activity of the yeast, and destroy the keeping qualities of the beer by producing offensive putrefaction products.[1] Iron forms dark-colored precipitates with the diastase, thus disturbing the conversion of the barley. As it also forms inks with the tannin of the hops, beer made with water containing much iron acquires a dark color, a disagreeable odor, and an unpleasant taste.

Calcium-sulphate water is desirable for making light-colored beer free from resinous taste, because the sulphate reacting with the soft resins ("bitter principle") dissolved from the hops produces insoluble resins and thus removes them from the beer. Water high in alkaline carbonates makes a dark beer, on the other hand, as carbonate promotes the solution of these resins. Light beer is said to have a hop flavor and dark beer a malt flavor, but there is more hop extract in dark than in light beers, the difference in flavor really being due to the greater amount of resins in the dark beer and to the less amount of both hop resins and malt in the light beer because of their slighter solubility in sulphate water. Waters moderately high in chloride aid the fermentation, but those too high in chloride retard development of the yeast and consequently retard fermentation.

PAPER MILLS.

Water is used in immense quantities in the manufacture of paper, many mills requiring almost 400,000 gallons of water per ton of product. It serves as a solvent and a carrier for chemicals, as in the digesters and cookers, it conveys the pulp through the various machines, it is used in the boilers and heaters, and finally it is the medium in which the wastes are removed. The water supply is usually treated to remove suspended and organic matter, particularly living organisms. Much suspended matter may cause irregularities in texture and appearance of the finer grades of paper, and organic matter may promote algal growths that streak and spot the paper and choke screens and pipes. Organic matter also wastes bleach and bisulphite liquors. Iron is especially undesirable in the water, as it is deposited from alkaline solutions and spots or streaks the paper. Cross and Bevan[2] state that very soft water is undesirable for loading papers with any form of calcium sulphate because of the solubility and consequent waste of these materials in such waters. Dole[3] mentions the probable undesirability of strong chloride waters for the same reason. The presence of alkali chlorides is, however, helpful in separating the thick sludge in preparing size. Very hard water is objectionable in the chemical processes and in making the

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[1] Palmer, Chase, Quality of the waters [of the Blue Grass region of Kentucky]: U. S. Geol. Survey Water-Supply Paper 233, p. 195, 1909.

[2] Cross, C. F., and Bevan, E. J., A textbook of paper-making, New York, p. 294, 1900. Cited by Dole, R. B., The chemical character of the waters [of north-central Indiana]: U. S. Geol. Survey Water-Supply Paper 254, p. 247, 1910.

[3] Idem.

large amounts of steam that are required in most mills. Hard water deposits calcium carbonate on the screens used to separate the pulp from the liquors; it also interferes with sizing by precipitating the resins of the size, and with tinting by wasting the dyes or changing their reactions.

WOOL-SCOURING, BLEACHING, AND DYEING WORKS.

Water in which wool is scoured should be soft, as hard water forms with the wool-grease insoluble soaps that cling to the fiber and interfere with subsequent processes, thus causing the wool to be of inferior grade, hard "feel," poor luster, and uneven color. No Oregon wool is now bleached, as the natural cream-colored stock is more salable.

Though hard water is required in some processes soft water is generally essential in economical and successful dyeing of wool. This textile combines with dyes much more readily than does cotton or linen because of the nitrogen in the wool, and dyeing it is therefore somewhat simpler. The dyes may be of acid, basic, or mordant type. As the reactions involved are delicate and easily disturbed and as large quantities of water are used it is very important to avoid irregularities in its quality that may cause variations in the color of the finished product. In some processes the dye may be precipitated on the fiber by reaction with alkaline earths and thus produce irregular spots. Iron is especially objectionable because it may alter the colors in white and madder dyeing. Much chloride is also objectionable as it may react with the dyes.

LAUNDRIES.

The calcium and magnesium in hard water cause waste of soap by forming insoluble compounds with the fatty acids and thus destroying their cleansing value. The insoluble compounds thus deposited on the fabrics, being later partly decomposed by heat, produce spots and rust on the cloth. Iron in water is also objectionable because it gives rise to rust spots. Suspended matter deposited on the cloth gives it a soiled appearance.

Whipple,[1] after having determined the soap-consuming power of waters of different hardness with nine different kinds of soap, concludes that for each part per million increase in hardness 200 pounds of soap is wasted for each million gallons of water used for cleansing. At 5 cents a pound this represents a loss of $10 per million gallons. It is therefore apparent that the expense of pretreating many waters for laundry use will be more than justified by the saving in cost of soap.

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[1] Whipple, G. C., The value of pure water, pp. 24-28, New York, 1907.

TANNERIES.

Hides to be tanned are usually unhaired by immersion in solutions of quicklime. If very hard water is used in that process the calcium carbonate that is deposited on the skins causes spots in the leather by preventing thorough action of the tannin. The tannin of the tan bark also is not thoroughly extracted and may be precipitated by hard water. Large quantities of chlorides prevent "plumping" in the tanning process and make the leather thin and flabby.[1]

SLAUGHTERHOUSES.

Meat-packing industries use large quantities of water in washing and preparing the various by-products, and it is necessary that this water be free from organisms that might grow in and cause decay of the finished goods. Soft water also is preferable, as much water is employed for heating.

PURIFICATION OF WATER.[2]

SLOW SAND FILTRATION.

Slow sand filters have been used for nearly a century and are constructed in essentially the same manner now as when first built. A series of perforated tiles or pipes connected with a discharge pipe is laid on the bottom of a large impervious basin, now usually constructed of concrete. Layers of gravel, graded in size from 25 to about 3 millimeters in diameter, are placed over this network to a depth of about 1 foot, and over the gravel is placed a layer of fine sand 2 to 5 feet thick. Regulating chambers, pumps, and sand-cleaning devices are secondary mechanical features of the plant. The filters are roofed where danger from freezing is serious, but where the climate is mild they may be left open in order to lessen the cost of construction. The filters are divided into beds usually less than an acre in extent, so that units can be withdrawn from service for cleaning without interrupting the operation of the system.

During filtration the water sinks through the sand, in which its suspended mud and bacteria are retained, and flows through the discharge pipe into the clear-water basin or the distribution system. The rate of filtration, ranging from 2,000,000 to 4,000,000 gallons per acre per day, depends on the physical condition of the filter, the thickness of the bed, the average size of the sand particles, and the turbidity and temperature of the water. When the loss of head in the filter, as it is gradually clogged with slime and detritus, becomes

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[1] Rogers, A., Leather: Rogers and Aubert's Industrial chemistry, p. 798, New York, 1912.

[2] For details of the construction, operation, and efficiency of filters, disinfection, and general treatment of water, see Johnson, G. A., The purification of public water supplies: U. S. Geol. Survey Water-Supply Paper 315, 1913.

great enough to cause too slow filtration, about half an inch of sand is removed from the top of the bed and filtration is resumed. The sand thus removed is washed and replaced before successive removals have rendered the bed too thin to be efficient. The time between cleanings is materially shortened when very turbid waters are filtered, so the slow sand process is adaptable only to relatively clear waters or to those that have previously been partly clarified by sedimentation.

By slow sand filtration the suspended matter, including the bacteria, is removed, color is only slightly reduced, hardness is not altered, and a small portion of the organic matter is destroyed. The efficiency of the filtration depends only partly on the straining effect of the sand particles, for it is greater in a filter that has been in service for a short time than in a clean one, possibly because of the absorption of certain materials on the surface of the sand by the coating of gelatinous muck and possibly because of colloidal agglutination and mechanical straining of the water through the gelatinous coating. Bacteriologic action in the deeper layers of the bed partly oxidizes the organic matter in the water and prevents further growth of organisms by destroying the available bacterial food.

The raw water is usually passed first through strainers or "roughing filters" or is detained in a sedimentation basin in order to remove excessive quantities of suspended matter. Water containing large amounts of iron is troublesome because of its tendency to assist growth of Crenothrix, an iron-secreting alga, in the underdrains and the discharge pipe. Water containing much iron may be aerated before filtration by being sprayed in fountain-like jets over the raw-water basin, thereby oxidizing and precipitating the iron. At several places, especially in Europe, preliminary sterilization by ozone, ultra-violet rays, or other means is practiced. A very high degree of purity is thus attained, but these methods are applicable only to clear waters.

RAPID SAND FILTRATION.

A rapid sand filter contains two essential parts—the coagulation basin and the filter chamber. The coagulation basin, generally an oblong tank, is of such size and construction that the water entering it reaches the outlet into the filter chamber in two to four hours, time for sedimentation as well as coagulation being thus allowed. The filter chamber consists of a tank, circular in the early forms but rectangular in the larger modern types, fitted with a perforated bottom, the openings of which are small enough to prevent passage of sand grains but large enough to allow ready outflow of the filtered water. On the bottom is a bed of carefully graded sand, 30 or 40 inches deep and somewhat coarser than that used in slow sand filters. After the water, mixed with the dissolved coagulant, has stood for a proper period in the coagulation basin it flows into the upper part of the filter chamber and passes rapidly through the bed of sand into the drainpipes, through which it is conducted to the clear-water basin for distribution. The rate of filtration is 80,000,000 to 190,000,000 gallons per acre per day, the usual rate being about 125,000,000 gallons.

Though several other coagulants are used the most common one is aluminum sulphate. When this substance is introduced in solution into the raw water it is immediately hydrolyzed to form aluminum hydrate and sulphuric acid. The sulphuric acid reacts with part of the carbonate, bicarbonate, and hydrate, setting free carbon dioxide and converting temporary into permanent hardness. While the aluminum hydrate precipitated in the alkaline solution as a gelatinous mass is forming and congealing it enmeshes the suspended matter, including the bacteria, and absorbs the coloring matter. If the natural alkalinity of the raw water is not great enough to react with all the aluminum sulphate some of the coagulant remains in solution, the efficiency of coagulation is reduced, and the effluent is acid in reaction and consequently corrosive. This trouble is obviated by adding with the aluminum sulphate proper proportions of milk of lime or of a solution of soda ash. The coagulant remaining in the water after the imperfect sedimentation in the coagulation chamber forms on the sand in the filter a slime that makes filtration more thorough. As rapid accumulation of this slime causes excessive loss of head the filter must be frequently cleaned—usually two to four times a day. This is done by passing water upward through the sand and at the same time forcing compressed air through the perforations to break up agglomerations of sand and dirt. The sand is thus thoroughly mixed at each washing, so that it can not segregate into pockets. The dirty water flows away over the top of the filter. Agitation of the sand during washing is effected in some of the older filters by means of revolving rakes with prongs extending downward into the sand.

Rapid sand filtration affects the chemical composition of the water to a much greater extent than slow sand filtration. Color is greatly reduced, some iron is precipitated, carbonate, bicarbonate, and hydrate are replaced to some extent by sulphate, and the total mineral content may be slightly increased. If large amounts of lime are added to assist coagulation the hardness and total mineral content are decreased; otherwise the temporary hardness is decreased and the permanent hardness proportionately increased. With filters of this type highly turbid waters can be treated, smaller basins are required than for slow sand filters, and highly colored waters can be partly decolorized. As rapid sand filters are used chiefly for purifying river waters, whose quality is subject to frequent and important fluctuations, their economical operation requires constant and intelligent supervision.

STERILIZATION.

Some methods by which sterilization of water for domestic consumption has been attempted rely on direct destruction of the bacteria, and others on their indirect destruction by oxidation and consequent removal of their food material, but combinations of the two methods have generally proved most effective.

Calcium hypochlorite has recently been used with excellent success to sterilize contaminated water supplies, especially in emergencies, and several hundred cities in the United States are now applying such treatment, mostly in conjunction with other methods of purification. The action of hypochlorite depends on the fact that its solution in contact with the water decomposes to form, first, hypochlorous acid, and, second, nascent oxygen. The immediate and chief effect is oxidation, although slower, less thoroughly understood reactions[1] complete the destruction of the organisms in the water. The successful use of this substance and the ease with which its application can be controlled place it in first rank among disinfectants of water. If the sodium salt is used the water is softened, but if the calcium salt is used the hardness may be slightly increased; the effect of such change is, however, practically negligible, as the hypochlorite is applied in so small quantity.[2] The early use of hypochlorite was attended by numerous complaints, because lack of definite knowledge regarding the proper quantity of reagent resulted in overdosing and thus imparting to the waters a strong medicinal taste or even an odor. Increased knowledge of the process proved that very small amounts of reagent are generally adequate to insure disinfection and that no odors or tastes result when the hypochlorite is properly applied.

Copper sulphate[3] has been used more often for the purpose of destroying algal growths than for destroying dangerous bacteria. Use of it may, however, leave undesirable and even harmful quantities of copper in solution, and alkaline salts in the water may cause waste of the chemical by precipitating the copper at the moment of application. The usual method of application—towing a sack of the solid reagent around the reservoir—is also crude and expensive. Copper sulphate has nevertheless proved to be a valuable algacide and its use has been decidedly beneficial to some waters.

Ozone is theoretically an ideal reagent for disinfection, as the only products of its complete reaction with organic matter are carbon dioxide and water. Considerable progress has recently been made in the use of this reagent, and sterilization by ozone is a valuable adjunct to filtration in Paris, St. Petersburg, and several other European

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[1] Rideal, Samuel, Water disinfection by chemical methods: Eng. News, vol. 68, p. 702, 1912.

[2] Johnson, G. A., The purification of public water supplies: U. S. Geol. Survey Water-Supply Paper 315, p. 67, 1913.

[3] Moore, G. T., and others, A symposium on the use of copper sulphate and metallic copper for the removal of organisms and bacteria from drinking water: New England Waterworks Assoc. Jour., vol. 19, pp. 474-582, 1905.

cities. The chief drawbacks have been the expense of manufacturing the ozone and the mechanical difficulties of effecting application without wasting the reagent.

Ultra-violet rays have been successfully used in Europe to sterilize water, but the process is still in an experimental stage in the United States.

SOFTENING.

Water is softened for the purpose of removing suspended matter, iron, aluminum, calcium, magnesium, and sometimes sulphate, particularly before its use in boilers. Preheating alone removes enough of the objectionable materials from some waters, but further treatment of others may be required.

Many methods alleged to obviate boiler troubles consist in introducing into the boiler with the feed water some "boiler compound" and subsequently removing the deposits produced by it. Many boiler compounds contain, in addition to considerable inert material, tannin or derivatives of tannic acid that cause corrosion of the boiler. Those that contain acetic or other acids are harmful for the same reason. Others contain organic material, such as glycerine, wood extract, or molasses, whose effects are solvent, as that of glycerine, or mechanical, as that of molasses. Starchy materials have also been employed. All such compounds are harmful because they induce instead of prevent corrosion and scale production or thicken and foul the water in the boiler. In general the introduction of reagents into the boiler is advisable only to correct minor troubles, and where such practice is necessary, because of inability to treat the supply before it enters the boiler, one or more of the inexpensive chemicals whose action and efficacy have been thoroughly established should be used.

Several really efficient reagents are available for softening and removing scale-forming ingredients from water before it enters the boiler, the most widely used of which are lime, as caustic lime ($Ca(OH)_2$), and soda, as soda ash (Na_2CO_3), or more rarely as caustic soda ($NaOH$). Barium carbonate ($BaCO_3$) is very efficient chemically for softening some bad waters, especially those high in sulphate, but it and other salts of barium are little used because of their cost. "Permutite," an artificial zeolite whose formula approaches $2SiO_2.Al_2O_3.Na_2O+6H_2O$, and the iron-alum reagents have also been used with reputed success.

The softening effect of lime is due to the formation of insoluble hydrates by reaction with certain basic radicles and the formation of calcium carbonate by reaction with the free carbon dioxide and part of the bicarbonate in the water. Caustic soda, which is sometimes used instead of caustic lime, besides being more expensive, has the decided disadvantage of increasing the total dissolved alkalies and consequently the danger of foaming and priming. It has no real advantage over a combination of lime and soda ash. Soda ash is used with lime in treating some waters from which the calcium and magnesium are not completely precipitated by lime alone.

The amount and nature of the reagents for softening water depend on the chemical composition of the water and on the method of treatment. Lime need not be added in treatment in open heaters as the bicarbonate radicle is decomposed by heat into free carbon dioxide, which escapes as a gas, and the carbonate radicle, which precipitates all or part of the alkaline earths. Some waters contain sufficient carbonate to react thus with all the calcium and magnesium and therefore need only be heated to purify themselves. Waters deficient in carbonate may be treated with soda ash before being heated.

Some waters are so highly charged with incrusting materials that they can not be used profitably even after softening because the foaming ingredients are so greatly increased; others are so slightly mineralized that sufficient scale to interfere noticeably with steaming is not deposited except after long periods of service. Dole,[1] citing the findings of the committee on water service of the American Railway Engineering and Maintenance of Way Association, states that it is not advisable to soften waters containing more than 850 parts per million of nonincrusting material and much incrusting sulphates, but that it is generally economical in locomotive practice to treat waters containing 250 to 850 parts per million of incrustants and those containing less than the lower amount if a large proportion of the incrustants is sulphates. An approximate classification reproduced from Dole's paper is as follows:

Approximate classification of waters for boiler use according to proportion of incrusting and corroding constituents.

Parts per million.		Classification.
More than—	Not more than—	
	90	Good.
90	200	Fair.
200	430	Poor.
430	680	Bad.
680		Very bad.

METHODS OF ANALYSIS.

RIVER WATER.

The methods of analysis used in studying the river waters of Oregon are, with the minor exceptions noted in the following paragraphs, those described by Dole.[2]

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[1] Dole, R. B., The chemical character of the waters [of north-central Indiana]: U. S. Geol. Survey Water-Supply Paper 254, p. 244, 1910.

[2] Dole, R. B., The quality of surface waters in the United States, Pt. I: Analyses of waters east of the 100th meridian: U. S. Geol. Survey Water-Supply Paper 236, pp. 9–26, 1909.

Only 100 to 250 instead of 500 cubic centimeters of very turbid waters having high coefficients of fineness was taken for the determination of total suspended matter, which was made as usual in all other respects.

Some of the waters that could not be completely clarified by being passed through a Gooch crucible were treated as follows: After the portion for the determination of suspended matter had been measured out, the remainder of the sample was allowed to settle for about one day, and the sample for total-solids determination was then measured out. This portion, after having been passed through a paper-pulp filter, was evaporated to dryness in the usual manner. For the filter ordinary filter paper of medium quality (S. & S. No. 597) was thoroughly macerated in a beaker with strong hydrochloric acid and then washed to remove the acid, the pulp remaining as a fine suspension in the water. A perforated porcelain disk was laid inside and over the stem of an ordinary Gooch filter tube about 1½ inches in diameter, and suction was applied. The suspended pulp was then slowly poured into the funnel until a mat about one-sixteenth inch thick was formed. This was tamped down thoroughly, another layer added and tamped down, and a further small amount of pulp added. The last layer, which was not tamped down, served to aid agglomeration of finely suspended material. The filter made in this manner was washed thoroughly and was then ready for use. As many as twenty samples could be passed through the same filter before it became fouled or choked, and the filtered liquid was clear and bright. The advantages of this method are that no chemical reactions occur and color is not perceptibly altered, and it was adopted after filtration through alundum crucibles and Nordmeyer-Berkefeld filters had been found unsatisfactory.

One additional treatment with barium hydrate followed by treatment with ammonia and ammonium carbonate was employed in the determination of alkalies, in order to insure the complete removal of impurities. The final evaporation and weighing of the alkali chlorides were made in a platinum dish.

The average sodium-potassium ratio in the water of each river was determined at the close of the investigation on the united solutions of the alkali chlorides obtained during the progress of the work. The united solutions of the chlorides were repurified and were evaporated nearly to dryness in a porcelain dish after addition of a measured amount of platinic chloride. The residue was allowed to solidify on cooling and was then treated with 80 per cent alcohol, and the potassium-platinic chloride was caught on a filter paper. The precipitate was dried to remove traces of alcohol and dissolved in hot water, and this solution was treated in the same porcelain dish with a drop of chlorplatinic acid and was again evaporated nearly to dryness and digested with 80 per cent alcohol. The precipitate was filtered out and washed with a little alcohol, and was then thoroughly dried at 100° C. The potassium-platinic chloride was then dissolved in hot water and this solution was evaporated to dryness in a clean platinum dish. After having been thoroughly dried at 135° C. and cooled, the dish and residue were weighed. The residue was again dissolved and the solution was passed through a filter paper, which was washed and then ignited in the platinum dish. The dish was cooled and weighed, the difference representing K_2PtCl_6. All determinations were made in duplicate. The method is long but gives accurate results.

Fiftieth-normal sulphuric acid, standardized by titration against an alkali and by precipitation with barium chloride, was substituted for the solution of potassium acid sulphate advised by Dole for titrating carbonate, as there is no apparent advantage in the use of the acid salt.

HIGHLY MINERALIZED WATERS.

As many of the lake waters of Oregon are highly concentrated and contain determinable amounts of unusual constituents, analysis of them by the customary methods is not practicable, and the following procedure was adopted:

Specific gravity.—Determinations of specific gravity were made with a Sprengel picnometer with thermometer attached. The determinations were made in duplicate, usually at 20° C., and the results are reported to four decimal places.

Total dissolved solids.—A weighed amount of the liquid was evaporated to dryness in a tared platinum dish, and the residue was heated for an hour in an air oven at 180° C. and weighed, after which the residue was carefully ignited to constant weight. Amounts of liquid were chosen that would give less than 5 grams of total ignited solids. Both the weight of the residue dried at 180° C. and the weight after ignition were recorded.

Silica, iron, alumina, calcium, and magnesium.—Silica, iron, and alumina were estimated on the portion used for the determination of total dissolved solids, Dole's procedure[1] being followed. Calcium was determined in the usual manner by titration with permanganate solution, and magnesium was determined gravimetrically as the pyrophosphate unless the amount was small, when it was titrated with a standard solution of uranium nitrate.

Sulphate and alkalies.—A weighed amount of the sample was acidified with hydrochloric acid and the sulphate was precipitated

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[1] Dole, R. B., The quality of surface waters in the United States, Pt. I: Analyses of waters east of the 100th meridian: U. S. Geol. Survey Water-Supply Paper 236, pp. 9-26, 1909.

and weighed as barium sulphate in the usual manner. The filtrate was used to determine alkalies, decrepitation of the chlorides after evaporation being prevented by precipitation of the concentrated brine with strong hydrochloric acid. Potassium was separated in each analysis as previously described. (See p. 31.)

Carbonate and bicarbonate.—Because of the possible presence of borate in many of the highly mineralized samples, titration in the presence of phenolphthalein and methyl orange would not give reliable values for carbonate and bicarbonate, and the amounts of these radicles were, therefore, gravimetrically determined. The apparatus consisted of a half-liter round-bottom flask, supported over a Fletcher burner, and fitted with a separatory funnel and a reflux condenser tilted at an angle of about 60° with horizontal. A train of bulbs and tubes was placed as follows: Calcium-chloride bulb, U-tube filled with glass beads and anhydrous copper sulphate, two calcium-chloride bulbs in series, potash bulbs with a calcium-chloride guard tube, calcium-chloride bulb, stopcock, and tube attached to a Richards suction pump. The potash bulbs were of Geissler's type, the guard tube being behind the bulbs of the potash set, and the safe capacity of the apparatus when filled was about 1 gram of carbon dioxide. A flask containing caustic potash was attached to the separatory funnel so that air free from carbon dioxide could be drawn into the reaction flask. All joints except the two by which the potash set was connected with the train were cork made air-tight by repeated coatings of shellac. The potash set was attached by means of rubber tubing, the glass ends being butted close together so that as little rubber as possible might be exposed. The apparatus with the potash set removed was saturated with carbon dioxide, and a current of air free from carbon dioxide was passed through the train to remove all excess of carbon dioxide. The potash set, after being weighed, was placed in the train and a weighed sample of the water to be tested was introduced into the flask through the separatory funnel. A measured amount of 1 to 4 hydrochloric acid was then cautiously introduced into the flask, the tube leading into the potash set was attached, a slow suction was started, and the reaction flask was slowly heated to incipient boiling. It was kept at this point for 15 minutes, then the source of heat was removed and the apparatus was allowed to stand for half an hour, a slow current of air being drawn through it. The suction was then removed, and the potash set was placed in the balance case and weighed as soon as possible. The increase in weight was computed as carbon dioxide set free from the sample. Determinations were made on a sample of the water and on a dried and ignited residue obtained by evaporating a sample. The difference between these two weights represents dissolved carbon dioxide and the carbon dioxide set free by the decomposition of bicarbonate on evaporation and heating, but as separate determinations of dissolved carbon dioxide were not made the entire difference has been referred to bicarbonate. The error is probably trivial, for if there had been an appreciable amount of dissolved carbon dioxide it would have reacted with the normal carbonate in the water to produce bicarbonate. As normal carbonate was present it was assumed that dissolved carbon dioxide was absent.

Chloride.—A weighed sample was acidified with nitric acid and chloride was precipitated with silver nitrate. It was considered unnecessary to boil the solution, and the precipitate, after being filtered out in a tared Gooch crucible fitted with an asbestos mat, was heated in an air oven at 130° C. to constant weight. Chloride was computed from this weight of silver chloride.

Nitrate.—Determination of nitrate was made by the phenol-disulphonic acid method after removal of chloride by means of silver sulphate.

Phosphate.—Phosphate was determined according to the colorimetric method proposed by Woodman and outlined by Mason.[1] Fifty grams of the water was evaporated to dryness after the addition of 3 cubic centimeters of nitric acid. The residue was heated two hours in a water oven, then extracted with cold water, filtered, and diluted to 50 cubic centimeters in a comparison tube. Four cubic centimeters of a solution containing 50 grams per liter of ammonium molybdate was added and the well-mixed liquid was then compared with standard phosphate solutions which had been treated in the same manner.

INTERPRETATION OF THE RESULTS OF ANALYSIS.

INDUSTRIAL INTERPRETATION.

Formulas for the industrial interpretation of water analyses have been developed by Stabler,[2] to whose articles the reader is referred for a full discussion of them.

The formulas are as follows:

$A = 11 + 1.79\ Fe + 5.54\ Al + 2.5\ Ca + 4.11\ Mg + 49.6\ H.$

$B = H + 0.0361\ Fe + 0.1116\ Al + 0.0828\ Mg - 0.0336\ CO_3 - 0.0165\ HCO_3.$

$C = 0.00833\ Sm + 0.00833\ Cm + 0.0107\ Fe + 0.0157\ Al + 0.0138\ Mg + 0.0246\ Ca.$

$D = 0.00833\ SiO_2 + 0.0138\ Mg + (0.016\ Cl + 0.0118\ SO_4 - 0.0246\ Na - 0.0145\ K).$

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[1] Mason, W. P., Examination of water, 4th ed., p. 102, New York, 1910.

[2] Stabler, Herman, The mineral analysis of water for industrial purposes and its interpretation by the engineer: Eng. News, vol. 60, pp. 355–357, 1908. Also Some stream waters of the western United States with chapter on industrial application of water analyses: U. S. Geol. Survey Water-Supply Paper 274, pp. 165–181, 1911.

$E = 0.00931\ Fe + 0.0288\ Al + 0.0214\ Mg + 0.258\ H + 0.00434\ HCO_3 + 0.0118\ CO_2$.

$F = 0.0167\ Fe + 0.0515\ Al + 0.0232\ Ca + 0.0382\ Mg + 0.462\ H - 0.0155\ CO_3 - 0.00763\ HCO_3$.

$k = \frac{2040}{Cl}$ when $Na - 0.65\ Cl$ is zero or negative.

$k = \frac{6620}{Na + 2.6\ Cl}$ when $Na - 0.65\ Cl$ is positive but not greater than $0.48\ SO_4$.

$k = \frac{662}{Na - 0.32Cl - 0.43SO_4}$ when $Na - 0.65Cl - 0.48SO_4$ is positive.

In these formulas A represents the cost in cents of soap at 5 cents a pound required to soften 1,000 gallons of the water. B represents the corrosion coefficient or the relative tendency to produce corrosion in a boiler. Stabler states that if B is positive the water is certainly corrosive; if $B + 0.0503\ Ca$ is negative no corrosion because of the mineral constituents will occur; and if B is negative but $B + 0.0503\ Ca$ is positive corrosion may or may not occur, the probability of corrosion varying directly with the value $(B + 0.0503\ Ca)$. C represents the number of pounds of scale that may be formed in a boiler per 1,000 gallons of feed water. D represents, similarly, the number of pounds of hard scale, whence the relative hardness of the scale is $\frac{D}{C}$. E represents the number of pounds of 90 per cent lime and F the number of pounds of 95 per cent soda ash required to soften 1,000 gallons of water. The alkali coefficient, k, is an index of the value of the water for irrigation; it represents the depth in inches of water which on evaporation would yield sufficient alkali to render a 4-foot depth of soil injurious to the most sensitive crops.

The symbols, Fe, Al, Ca, Mg, H, CO_3, HCO_3, Na, K, Cl, SO_4, SiO_2, CO_2, Sm, and Cm represent, respectively, the amounts in parts per million of iron, aluminum, calcium, magnesium, acidity (calculated as hydrogen), carbonate, bicarbonate, sodium, potassium, chlorine, sulphate, silica, free carbon dioxide, suspended matter, and colloidal matter (silica, ferric oxide, and alumina) found by analysis of the water.

The number of pounds of ordinary soap (G) necessary to soften 1,000 gallons of the water is obtained by dividing A by 5, whence,

$$G = 2.2 + 0.4\ Fe + 1.1\ Al + 0.5\ Ca + 0.8\ Mg + 9.9\ H.$$

This formula may be reduced for practical application to most waters of Oregon to

$$G = 2.2 + 0.5\ Ca + 0.8\ Mg.$$

The cost of softening the water with an average soap can then be obtained by multiplying the price per pound of soap by G. In like manner the cost of softening the water by lime and soda ash can be obtained by multiplying the price per pound of the respective reagents by E and F.

Stabler classifies irrigation waters in conformity with ordinary irrigation practice in the United States as follows:

Classification of irrigation waters.

Alkali coefficient (k).	Class.	Remarks.
More than 18	Good	Have been used successfully for many years without special care to prevent accumulation of alkali.
18 to 6	Fair	Special care to prevent gradual accumulation of alkali has generally been found necessary except on loose soils with free drainage.
5.9 to 1.2	Poor	Care in selection of soils has been found to be imperative and artificial drainage has frequently been found necessary.
Less than 1.2	Bad	Practically valueless for irrigation.

Whether injury would actually result from the application of a given water to any particular piece of land, however, depends on methods of irrigating, the crops grown, the character of the soil, conditions of drainage, and the quantity and distribution of rainfall, and it should be clearly understood that the alkali coefficient in no way takes account of such conditions.

GEOCHEMICAL INTERPRETATION.

The geochemical interpretation of water analysis depends on the geologic significance of the materials entering into solution. The primary rock formations yield waters containing a high percentage of alkalies, but sedimentary and metamorphic rocks yield waters containing greater proportions of the alkaline earths. Primary formations are usually siliceous, and neither chloride nor sulphate is prominent in them. Many secondary formations are rich in salts of these strong acid radicles, though they also contain much carbonate. Solutions of the alkaline substances from silicate rocks are high in carbonate. When a surface water collects in a basin to form a landlocked lake dissolved matter is gradually concentrated and salts are precipitated in accordance with their respective solubilities. A great proportion of the alkaline earths is usually removed from the solution during early stages of concentration; magnesium chloride, however, is one of the last materials to be deposited from a chloride water. Lake waters from volcanic regions produce carbonate waters on concentration, those from sedimentary regions may produce sulphate waters, and the final stage of continued concentration and deposition of salts produces the chloride waters, or true brines.

Palmer[1] has developed a system of geochemical classification of natural waters based on the above facts, and his paper on this subject is an important contribution to the science. His classification

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[1] Palmer, Chase, The geochemical interpretation of water analyses: U. S. Geol. Survey Bull. 479, 1911.

depends primarily on the relation between the radicles in water and the types of rock from which they are dissolved, and, secondarily, on the concentration of the waters. The radicles determined by analysis are grouped as (1) alkalies (sodium and potassium), (2) alkaline earths (calcium and magnesium), and (3) hydrogen (free acids).

The weak acid radicles (chiefly carbonate and bicarbonate) together are considered to measure the property of "alkalinity," and the strong acid radicles (chiefly chloride, nitrate, and sulphate) to measure the property of "salinity." As the alkalies are characteristic of the older or primary formations alkalinity or salinity due to their salts is called primary alkalinity or primary salinity. As alkaline earths are characteristic of secondary rocks alkalinity or salinity due to them is called secondary alkalinity or secondary salinity. Salinity due to free acids is called tertiary salinity.

In applying his classification Palmer has used the reaction coefficients of the radicles, as calculated by Stabler,[1] which are the quotients obtained by dividing the valences of the radicles by their respective molecular weights. The reaction coefficients of the radicles commonly reported in water analyses are shown in the following table:

Reaction coefficients of common radicles.

Positive radicles.	Reaction coefficients.	Negative radicles.	Reaction coefficients.
Ferrous iron (Fe)	0.0358	Carbonate (CO_3)	0.0333
Aluminum (Al)	.1107	Bicarbonate (HCO_3)	.0164
Calcium (Ca)	.0499	Sulphate (SO_4)	.0208
Magnesium (Mg)	.0822	Chlorine (Cl)	.0282
Sodium (Na)	.0435	Nitrate (NO_3)	.0161
Potassium (K)	.0256		
Hydrogen (H)	.992		

If the amount of a radicle obtained by analysis is multiplied by its reaction coefficient the product is the reacting value of the radicle. The quotients obtained by dividing the reacting value of each radicle by the sum of all the reacting values represent the percentage reacting values, from which Palmer's classification is made. He divides waters into five classes according to the relative numerical values of the various groups of percentage reacting values. If a, b, and d represent, respectively, the percentage reacting values of the alkalies, alkaline earths, and strong acids, any one of five numerical conditions may exist; d may be less than a; equal to a; greater than a and less than $a+b$; equal to $a+b$; or greater than $a+b$. He computes the properties of reaction of each class according to the formulas following.

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[1] Stabler, Herman, Some stream waters of the western United States, with a chapter on The industrial application of water analyses: U. S. Geol. Survey Water-Supply Paper 274, p. 167, 1911.

Formulas for properties of reaction.

CLASS I.

d less than a.

$2d$............Primary salinity.
$2\ (a-d)$.......Primary alkalinity.
$2b$............Secondary alkalinity.

CLASS II.

d equal to a.

$2a$ or $2d$........Primary salinity.
$2b$............Secondary alkalinity.

CLASS III.

d greater than a; d less than $a+b$.

$2a$............Primary salinity.
$2\ (d-a)$.......Secondary salinity.
$2\ (a+b-d)$....Secondary alkalinity.

CLASS IV.

d equal to $a+b$.

$2a$............Primary salinity.
$2b$............Secondary salinity.

CLASS V.

d greater than $a+b$.

$2a$............Primary salinity.
$2b$............Secondary salinity.
$2\ (d-a-b)$....Tertiary salinity (acidity).

Palmer found that surface waters belong chiefly to the first three classes and that sea water and brines form the greater number in Class IV.

SAN FRANCISCO BAY DRAINAGE BASIN.

GOOSE LAKE.

GENERAL FEATURES.

Goose Lake occupies a long, wide valley in south-central Oregon and northeastern California. Its valley is bordered on the east by Warner Mountains, which merge into gentler slopes on the north and west.

The water surface of Goose Lake was formerly slightly higher than at present and the lake discharged directly into the North Fork of Pit River. Such discharge is said to have occurred for a short time in 1869 and again in 1881. It is possible that considerable seepage water passes from it into Pit River. The annual precipitation at Lakeview, at the north end of the lake, is 17 inches. In Warner Mountains it probably reaches 25 inches, and on the low divide between Goose Lake and Lost River it is intermediate in amount. Practically no rain falls in the summer months. Timber grows on the high lands, but the interior valley is practically treeless. The valley lands are fertile and capable of producing abundant crops where sufficient moisture exists. Dry farming has been practiced in the valley with considerable success, but irrigation produces greater and more certain crops. Several irrigation projects have been constructed or are contemplated, some to use water from surface streams and some to be supplied from the lake itself.

CHARACTER OF THE WATER.

A sample of the water of Goose Lake was collected May 12, 1912, by J. T. Hansen, on the west side of the lake, about 60 feet from shore, near the Oregon-California boundary. The depth of the water at the sampling point was 3 feet, and the sample was collected 1 foot below the surface; the lake was rough and turbid at the time.

The remarkable content of phosphate suggests that the soils of the region are well supplied with available phosphorus, but it may be caused by the wild fowl which abound in this region. The principal material in solution is bicarbonate of soda, which is almost 75 per cent of the total dissolved matter. The ratio of potassium to sodium (1 to 10) is low, and the calcium-magnesium ratio (9 to 1) is high. The water is poor, and its use for irrigation should be restricted to carefully selected soils, in which artificial drainage should probably be introduced.

Mineral analysis of the water of Goose Lake.

[Analyst, Walton Van Winkle.]

	Parts per million.	Percentage of anhydrous residue.
Silica (SiO_2)	50	4.9
Iron (Fe)	.02	.0
Calcium (Ca)	18	1.8
Magnesium (Mg)	2.0	.2
Sodium (Na)	350	34.5
Potassium (K)	34	3.3
Carbonate radicle (CO_3)	98	40.7
Bicarbonate radicle (HCO_3)	638	....
Sulphate radicle (SO_4)	45	4.4
Chlorine (Cl)	100	9.9
Nitrate radicle (NO_3)	1.5	.2
Phosphate radicle (PO_4)	1.1	.1
Total dissolved solids	1,063	....

NORTH PACIFIC COAST DRAINAGE BASINS.

KLAMATH RIVER.

GENERAL FEATURES.

Klamath River rises in Upper Klamath Lake in southern Oregon and winds southwestward across northern California to the Pacific Ocean. The upper part of its basin is in the central Oregon plateau and the lower part is in Klamath Mountains. Upper Klamath Lake is fed by Anna River, which rises in springs near Crater Lake, Wood River, which joins Anna River near the Upper Klamath Marsh, and Williamson River, with its tributary Sprague River, which rises in the mountains of the Fremont National Forest. The outflow of the lake passes through Link River into Lake Ewauna, and thence outward as Klamath River. The river is connected with Lower Klamath Lake by a strait, the direction of flow through which depends on the relative stages of river and lake. Large swamps border the lakes. Irrigation is necessary for proper agricultural development in the valley, as precipitation is deficient, being only 12 inches at Klamath Falls. In the mountainous regions, however, the precipitation is copious. Most of the moisture falls as snow in winter, and the summers are arid.

Many large springs issue from the valley floor. One throws a 4-inch jet of cold water several inches above the surface of an arm of Pelican Bay in front of Harriman Lodge, where the lake is about 2½ feet deep. (See Pl. II, *A*.) Another larger spring discharges from the ground at old Fort Klamath. Some of the springs are hot, indicating very deep origin, but most of them are cold and only slightly mineralized, are of surface origin, and are produced by waters that seep through the porous lavas from the high Cascades or Winter Ridge and gather into well-defined underground streams to reappear above the surface in the valleys.

The elevation of the surface of Upper Klamath Lake was 4,140 feet in 1906, and that of the outlet of Link River, into which it empties, 4,080 feet. The drainage area above Keno, Oreg., which includes the basin of Lower Klamath Lake, is 3,150 square miles.

Klamath Falls, the only important settlement, is a town of 2,800 population on Link River and is the headquarters for the Klamath project of the United States Reclamation Service.

CHARACTER OF THE WATER.

Analyses of the water of Link River near Klamath Falls, made during 1905 and 1906 for the United States Reclamation Service, under the direction of W. H. Heileman, though already reported,[a] are included herewith for completeness.

Partial analyses of water from Link River at county bridge near Klamath Falls, 1905–6.

[Parts per million except as otherwise designated.]

Dates.	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium ($Na+\frac{3}{4}K$)	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Nitrate radicle (NO_3).	Suspended matter.	Dissolved solids.	Mean discharge (second-feet).
June 15, 16, 17	......	......	......	0	80	......	29	......	32	214	1,970
June 19–24	......	......	......	9.2	66	......	8	......	48	88	1,850
June 20 [b]	......	......	......	......	......	......	......	......	28	102	......
June 20 [c]	......	......	......	......	......	......	......	......	0	116	......
June 20 [d]	......	......	......	......	......	......	......	......	0	134	......
Dec. 25, 26, 27, 28	......	......	......	0	69	......	11	......	34	116	1,620
Jan. 11	......	......	......	0	77	......	6	0.09	......	123	1,800
Feb. 7	......	......	......	0	54	......	3	.22	30	114	1,920
Feb. 21	......	......	......	0	64	......	5	.22	42	94	2,040
Mar. 5	......	......	......	0	64	......	5	.22	16	124	2,040
Mar. 16	......	......	......	0	64	......	5	.22	36	160	2,310
Apr. 2	......	......	......	0	51	......	5	.13	30	98	2,740
Apr. 18	......	......	......	0	54	......	10	.09	46	82	3,770
July 2	12	6	19	0	65	12	5	.04	33	101	2,980
July 16	......	......	19	0	65	10	7	.04	42	110	2,520
Aug. 1	14	6	22	0	......	13	7	.04	30	128	1,800
Aug. 15	12	6	19	0	65	10	5	.04	23	107	1,440
Sept. 15	12	6	19	0	65	9	7	.04	31	103	1,150
Oct. 16	11	6	25	0	72	8	24	.04	......	96	1,180
Nov. 12	13	5	16	0	72	9	20	.04	......	96	1,390

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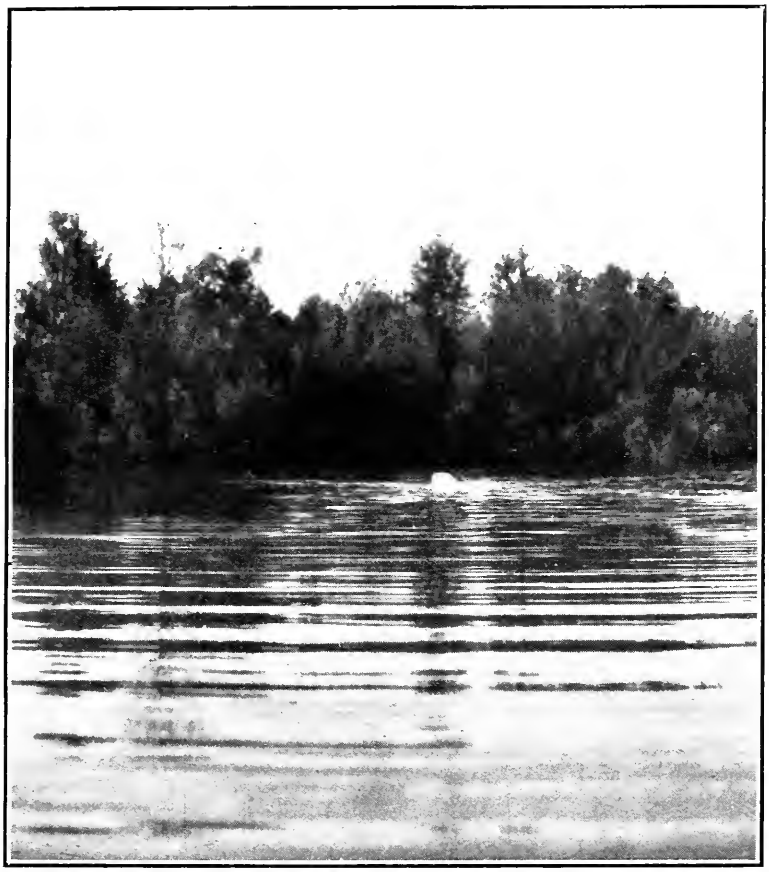
[a] Stabler, Herman, Some stream waters of the western United States: U. S. Geol. Survey Water-Supply Paper 274, p. 54, 1911.

[b] 90 feet from initial point for gaging.

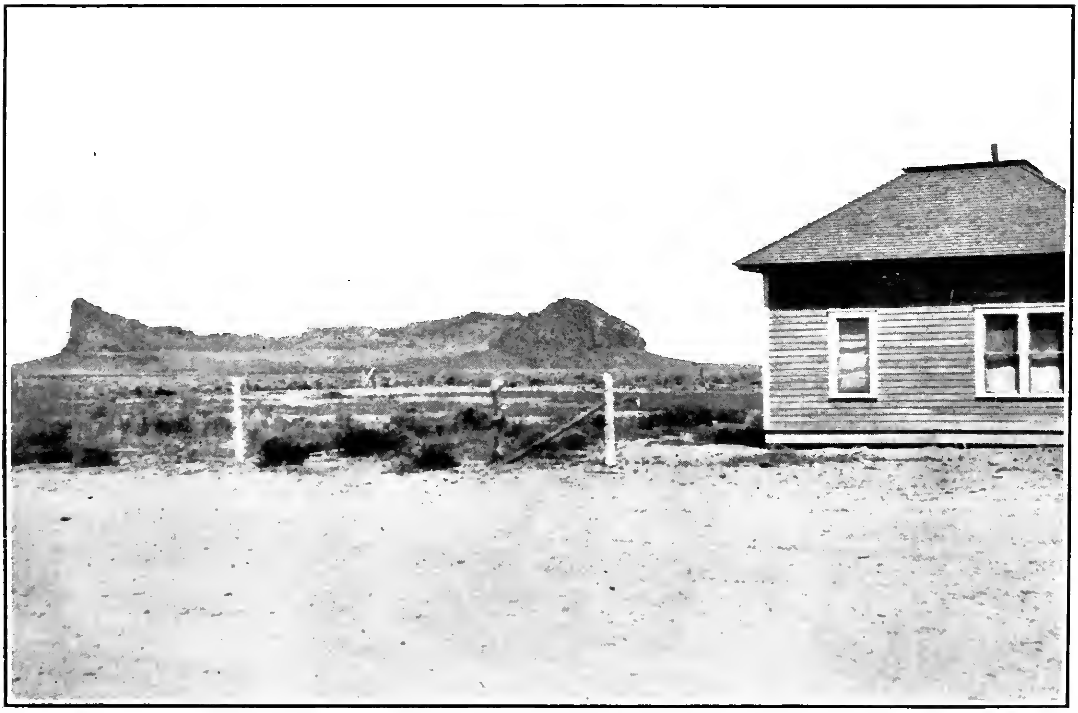
[c] 160 feet from initial point for gaging.

[d] 230 feet from initial point for gaging.



A. LARGE SPRING IN PELICAN BAY, UPPER KLAMATH LAKE.

(See p. 40.)



B. WATER-GOUGED SECTIONS AND BEACH SHOWN ON PROFILE OF ROCK NEAR FORT ROCK.

(See p. 116.)

The analyses indicate that there is little change in mineral content of the water throughout the year. The analysis for June 15, 16, and 17, 1905, appears abnormal, and the sample was probably faulty. The average mineral content is 107 parts per million, and the water is sodic carbonate. It is a good boiler water and is well suited for application to land of any type. Results of analyses of water from the spring in Pelican Bay and from Wood River, tabulated below, indicate no unusual features. The spring water is similar to the surface waters of the region. The water of Wood River is of the type usual for the region of the Columbia River basalt. Statements of analyses of the water of Lost River and of Lower Klamath Lake are also given. Lost River empties into Tule Lake, which is believed to discharge underground into Pit River. The basin of the lake is separated from Klamath basin by a very low divide and lies in the same big depression.

Mineral analyses of water in Klamath Basin.

	Parts per million.						Percentage of anhydrous residue.					
	1	2	3	4	5	6	1	2	3	4	5	6
Silica (SiO_2)	37	25	......	......	......	23	49.9	38.2	......	......	......	11.0
Iron (Fe)	.2	.15	......	......	......	[a]5.2	.3	.2	......	......	......	2.5
Calcium (Ca)	5.7	7.4	19	31	21	21	7.7	11.3	6.6	7.3	6.0	10.0
Magnesium (Mg)	2.0	2.7	14	16	20	27	2.7	4.1	4.9	3.7	5.7	12.9
Sodium (Na)	7.2	4.7	56	85	71	6.1	9.7	7.2	19.6	19.8	20.2	2.8
Potassium (K)			31	49	32	1.7			10.9	11.4	9.1	.8
Carbonate radicle (CO_3)	.0	.0	16	20	18	[b].0	18.6	33.1	44.4	43.9	46.4	55.0
Bicarbonate radicle (HCO_3)	28	44	225	341	295	233	......	......	......	......	......	......
Sulphate radicle (SO_4)	7.6	3.6	14	13	16	7.4	10.3	5.5	4.9	3.2	4.6	3.5
Chlorine (Cl)	.5	.25	25	46	28	3.2	.7	.4	8.7	10.7	8.0	1.5
Nitrate radicle (NO_3)	.06	Tr.	......	......	......	......	.1	.0	......	......	......	......
Total dissolved solids	81	69	289	428	351	220	......	......	......	......	......	......

[a] $Fe_2O_3+Al_2O_3$. [b] Combined CO_3 reported by analyst recomputed to HCO_3 by writer.

1. Wood River at bridge near Fort Klamath; collected Aug. 26, 1912, and analyzed by Walton Van Winkle.
2. Spring in Pelican Bay, Upper Klamath Lake; collected Aug. 25, 1912, and analyzed by Walton Van Winkle.
3. Lower Klamath Lake, T. 41 S., R. 9 E.
4. Lower Klamath Lake, three-eighths of a mile west of center of sec. 35, T. 48 N., R. 2 E.
5. Lower Klamath Lake, one-fourth of a mile east of center of sec. 17, T. 47 N., R. 3 E.

(Analyses 3, 4, and 5 by A. T. Sweet and S. G. McBeth; U.S. Dept. Agr. Field Oper. Bur. Soils, p. 1412, 1908.)

6. Lost River. Analysis by A. L. Kniseley, U. S. Dept. Agr. Ann. Rept. Irr. and Drainage Invest., p. 264, 1904.

The water of Lost River differs from most waters of central Oregon in that it contains relatively large amounts of the alkaline earths, possibly derived from the deposit of "chalk" that lies close to the surface over most of the basin. This chalk is reported to be a mixture of calcium carbonate, siliceous volcanic ash, and diatomaceous earth containing considerable soluble alkaline material.[1] In view of the latter part of this statement it is remarkable that the soluble alkalies are not present in the water in greater quantity. Some of

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[1] Sweet, A. T., and McBeth, S. G., Soil survey of the Klamath project, Oreg.: U. S. Dept. Agr. Bur. Soils Field Oper. 1908, p. 1385.

the characteristics of water flowing from igneous rocks are, however, retained by the water, for the reacting value of the alkalies is in excess of that of the strong acid radicles.

The water of Lower Klamath Lake is much more strongly concentrated than that of its influent, Link River. The concentration of the lake water differs greatly at different places, as a result of evaporation and local causes. As the direction of flow through the long strait connecting Lower Klamath Lake with Klamath River depends on the relative elevations of river and lake surfaces, the water of the lake is always more greatly concentrated than the water of Klamath River, and the mineral content is probably greater at the south than at the north end.

The water is of fair quality for irrigation, but land to which it is applied should be well drained to prevent accumulation of alkali.

CRATER LAKE.

GENERAL FEATURES.[1]

Crater Lake lies in a geologically recent caldera occupying the site of a once lofty volcanic peak, which has been named Mount Mazama, in the midst of the Cascade Range, about 55 miles northeast of Medford. The rim of the caldera is 7,000 to 8,000 feet and the lake surface was 6,175 feet above sea level in 1908. The inner slope of the rim bears in some places a sparse growth of pine, but in many others its walls, here and there fringed by steep talus slopes, drop sheer to the water's edge. The surficial area of the lake is approximately 21 square miles, and its drainage basin is only about 6 square miles larger. The greatest depth of water is 1,996 feet, and a cinder cone projects more than 760 feet above the surface at the western extremity of the lake to form Wizard Island. Precipitation is more than 70 inches a year, being possibly as great as 100 inches, and occurs chiefly as snow in winter. Evaporation is less than 55 inches, and this, with loss by percolation, almost completely balances the inflow, there being no surface outlet to the lake. Some of the water may find its way by percolation into Rogue River, but more of it probably goes southeastward, appearing as springs in the drainage basin of Klamath River.

CHARACTER OF THE WATER.

As the loss by percolation is less than half the loss by evaporation, analyses of the water of the lake might be expected to give chemical evidence of concentration. That the analysis really shows concentration almost identical with that of other surface waters of the region is explained, however, by the fact that no sedimentary materials are exposed, the andesites, dacites, and basalts forming the basin of the lake being nearly insoluble in cold water and consequently incapable

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[1] Abstracted from Diller, J. S., Crater Lake National Park, Oreg., U. S. Dept. Int., 1912.

of rapidly increasing its content of mineral matter. The concentration of chloride, great compared with that of other materials, indicates the concentrated character of the water. As the published analyses of rocks indicate that almost no chloride exists in the formations of the lake basin the high percentage of that radicle in the water may be due almost entirely to accumulated "cyclic" chlorine precipitated with the rain and snow. The unexpectedly high percentage of sulphate is possibly caused by solution of sulphur that remained in the bottom of the caldera in a more or less oxidized condition at the cessation of active volcanism. The slight excess of the reacting value of the strong acid radicles over that of the alkalies strengthens the assumption that the sulphate may have come from oxidation of sulphur or sulphides. Possibly the first waters in the caldera were acid and have become neutralized by reaction with the rock material. Otherwise the excess of strong acids over alkalies is a remarkable circumstance, as the water can have come into contact only with volcanic rock material and hence should contain greater proportion of alkalies.

Mineral analysis of water of Crater Lake.

[Analysis by N. M. Finkbiner.]

	Milligrams per liter.	Percentage of anhydrous residue.
Silica (SiO_2)	18	22.4
Iron (Fe)	.02	.0
Calcium (Ca)	7.1	8.9
Magnesium (Mg)	2.8	3.5
Sodium (Na)	11	13.7
Potassium (K)	2.2	2.7
Carbonate radicle (CO_3)	.0	20.9
Bicarbonate radicle (HCO_3)	34	(a)
Sulphate radicle (SO_4)	11	13.7
Chlorine (Cl)	11	13.7
Nitrate radicle (NO_3)	.38	.5
Phosphate radicle (PO_4)	.01	.0
Total dissolved solids	80	....

[a] HCO_3 computed to CO_3.

NOTE.—Collected Aug. 27, 1912, by M. Mecklem about a mile from shore at a depth of 6 feet.

ROGUE RIVER.

GENERAL FEATURES.

Rogue River is formed by three principal forks that flow from the Cascade Mountains and unite near Prospect, Jackson County, Oreg. North Fork, the main stream, has its origin in springs on the sides of Mount Mazama and the peaks west of it. Much of the spring water is probably seepage from Crater Lake, the porous lava of the caldera walls being well suited for the formation of seepage channels. All the springs can not so originate, however, as several (Lightning Spring, elevation 6,750 feet, for example) lie considerably higher than the lake itself. Middle Fork and Lower Fork rise among the Cascade

Mountains south of Crater Lake and unite before joining the North Fork below Prospect. The general elevation at the headwaters of Rogue River is about 6,000 feet, though isolated peaks reach 9,000 feet or more. Mount McLaughlin, on the divide between the Klamath and the Rogue basins, attains an altitude of 9,760 feet.

Below the junction of the forks the river takes an extremely tortuous though generally westerly course through the northern spurs of Klamath Mountains, discharging into the Pacific Ocean at Gold Beach. The total drainage area is 5,080 square miles. The river hugs the southern base of Rogue River Mountains throughout its lower course and receives most of its tributaries from the south.

The drainage basin is rough and mountainous and the upper stream affords many important power sites. A heavy growth of timber covers the headwater region, and extensive but less dense forests clothe much of the lower basin.

Rainfall is abundant at the source and near the mouth but is deficient in the middle valleys. At Gold Beach the average annual precipitation is 86 inches; at the headwaters it is 70 to 100 inches or more; and at Ashland and Grants Pass, in the middle valley, it is 27 and 33 inches, most of which occurs in winter. This middle valley is fertile and produces excellent crops when irrigated. It is especially suitable for fruit growing, the principal fruits of the valley being apples and pears.

Grants Pass, Medford, and Ashland are the chief cities of the drainage basin, Grants Pass alone being directly on Rogue River.

The headwaters of the river expose dacites, andesites, and basalts, probably overlying the early Tertiary sediments that outcrop in the valley. The middle course is over Cretaceous and earlier sediments. Exposures of serpentines, limestones, schists, etc., indicate that widespread metamorphosis has occurred. The lower course is largely through pre-Cretaceous schists and Eocene sandstones.

CHARACTER OF THE WATER.

Samples of water from Rogue River were collected by F. H. Farrar at the highway bridge 250 feet below the dam of the power house at Gold Ray, 1½ miles below Tolo. A gaging station is maintained at the same place, above which the drainage basin comprises 2,020 square miles.

The total mineral content of the water does not vary greatly, but the proportions of the individual constituents vary considerably, sulphate, chlorine, and calcium being particularly erratic. The water is soft and is excellent for use in boilers, requiring no reagents to be used with it to prevent either scale formation or corrosion. The chief scale-forming material is silica, but this will be prevented from forming a resistant incrustation by the carbonate scale and suspended matter that will be deposited with it.

Mineral analyses of water from Rogue River near Tolo, 1911–12.

[Parts per million except as otherwise designated.]

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
Sept. 10–19	3	3.4	1.13	......	31	0.02	7.5	4.0	6.6	0.0	42	5.3	0.48	2.3	78	0.90	1,250	11.5	263
Sept. 20–29	3	2.6	.87	0	30	.08	8.6	3.6	6.9	.0	43	6.6	.12	2.5	76	.85	1,215	8.0	249
Sept. 30–Oct. 9	4	4.6	1.15	Tr.	24	Tr.	5.8	5.1	11	.0	44	8.7	.36	1.9	77	.80	1,180	14.6	245
Oct. 10–19	1	3.2	3.20	Tr.	26	.03	7.2	3.4	7.5	.0	44	5.4	.44	1.8	75	.80	1,180	10.2	239
Oct. 20–29	1	....	....	1	32	.17	7.4	3.4	6.6	.0	48	5.9	.50	2.5	86	.77	1,162	....	269
Oct. 30–Nov. 8	3	2.4	.80	0	25	.05	9.0	2.7	7.9	.0	44	7.4	.40	1.8	80	.73	1,141	7.8	246
Nov. 9–18	1	6.0	6.00	16	22	.09	9.6	2.0	5.7	.0	36	6.0	.40	2.3	73	2.32	3,071	49.7	611
Nov. 19–28	Tr.	1.8	....	4	21	.07	9.9	1.5	7.9	.0	37	4.9	.40	1.5	70	1.77	2,144	10.4	405
Nov. 29–Dec. 8	Tr.	1.2	....	1	26	.02	7.4	2.2	7.6	.0	44	5.3	Tr.	1.9	75	1.42	1,722	5.6	348
Dec. 9–18	1	.8	.89	2	27	.05	6.7	2.3	6.2	.0	41	3.1	.42	2.4	70	1.36	1,660	3.6	313
Dec. 19–28	Tr.	4.8	....	3	24	.15	7.8	2.3	6.9	.0	41	6.7	.14	1.6	73	1.28	1,588	20.6	310
Dec. 29–Jan. 7	2	1.4	.70	1	26	.08	7.0	1.2	7.9	.0	41	3.1	Tr.	2.3	73	1.52	1,987	7.5	392
Jan. 8–17	40	53	1.32	23	21	.25	5.2	1.2	6.6	.0	34	2.1	.30	.40	80	5.29	9,493	1,360	2,050
Jan. 18–27	10	8.8	.88	18	21	.12	6.4	1.0	6.9	.0	33	3.6	.20	.85	66	4.40	7,462	177	1.322
Jan. 28–Feb. 6	7	6.6	.95	16	19	.01	7.8	1.6	7.6	.0	38	2.5	.08	1.3	65	3.35	4,739	84	830
Feb. 7–16	9	4.8	.53	12	23	.12	5.7	1.8	4.3	.0	34	3.2	.06	.75	61	3.7	5,525	72	910
Feb. 17–26	35	23	.66	......	21	.01	6.0	1.6	6.9	.0	34	1.8	.30	1.0	61	6.4	14,134	877	2,328
Feb. 27–Mar. 7	3	3.2	1.07	3	23	.11	6.1	.7	6.8	.0	38	1.2	.15	1.0	69	3.0	4,085	35	763
Mar. 8–17	15	9.8	.66	4	22	.08	5.8	.6	6.3	.0	40	1.6	.15	1.0	70	3.2	4,529	120	856
Mar. 18–27	10	10	1.00	16	21	.15	8.4	.9	6.9	.0	40	2.0	.24	1.5	76	2.9	3,926	106	806
Mar. 28–Apr. 6	2	6	3.00	4	19	.04	7.2	.6	7.9	[a]4.3	29	3.1	.21	1.3	68	2.5	3,254	53	597
Apr. 7–16	30	29	.97	25	21	.08	6.4	1.0	7.2	.0	35	3.8	.20	1.3	69	3.2	4,388	343	818
Apr. 17–26	10	7	.70	16	21	.22	7.6	.8	8.2	.0	40	1.8	.12	1.3	74	2.7	3,584	68	716
Apr. 27–May 6	20	19	.95	21	22	.09	7.6	.9	9.8	.0	42	8.6	.24	1.3	79	4.1	6,459	331	1,377
May 7–16	5	23	4.60	16	19	.04	9.0	.9	7.9	.0	38	6.6	.20	.75	66	3.9	5,849	379	1,041
May 17–26	5	15	3.00	10	20	.01	5.4	1.0	6.6	.0	32	1.6	.28	1.0	59	3.5	5,036	203	803
May 27–June 5	10	15	1.50	8	17	.02	7.0	.9	7.4	.0	33	5.8	.34	.75	64	3.7	5,362	217	924
June 6–15	13	21	1.62	8	14	.04	5.6	1.0	5.7	.0	29	3.1	.30	.40	54	3.4	4,782	271	698
June 16–25	5	8.8	1.76	5	25	.06	6.6	.8	7.2	.0	32	3.0	.56	1.0	65	2.7	3,559	85	624
June 26–July 5	3	9.8	3.26	4	30	.04	8.6	1.2	4.4	.0	33	3.1	.30	.75	71	2.2	2,762	73	530
July 6–15	5	2.6	.52	5	33	.05	7.8	1.6	5.7	.0	38	2.1	.40	1.4	76	1.8	2,212	15.5	454
July 16–25	350	156	.45	119	33	.04	7.8	.5	6.9	.0	42	2.8	.46	1.2	80	1.7	2,059	867	444
July 26–Aug. 4	8	21	2.12	4	28	Tr.	5.7	2.4	7.1	.0	38	4.4	.12	2.0	73	1.5	1,810	103	356
Aug. 5–14	12	22	1.87	2	26	.01	5.7	2.6	7.2	.0	40	3.8	.10	1.5	71	1.35	1,650	98	316
Mean	18	15	1.60	12	24	.07	7.2	1.7	[b]6.1 [b]1.3	.0	38	4.1	.26	1.4	72	....	....	[c]65,350	[c]251,800
Percentage of anhydrous residue	....	....	....	......	36.8	[d] .2	11.0	2.6	[b]9.4 [b]2.0	29.2	....	6.3	.4	2.1	....	....	....	....	....

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[a] Abnormal; computed to HCO_3 in average.

[b] Sodium and potassium, determined on combined alkali residues.

[c] Total annual denudation.

[d] Fe_2O_3.

UMPQUA RIVER.

GENERAL FEATURES.

Umpqua River is formed by the junction of two principal forks flowing from the Cascade Mountains in the extreme eastern part of Douglas County, Oreg. North Fork rises in Diamond Lake, at an elevation of 5,300 feet above sea level, and flows generally westward; South Fork rises on the slopes of Abbot Butte and Old Bailey, flows southwestward nearly to the town of Riddles, and then, winding northward, joins North Fork north of Roseburg. The main river proceeds in a northerly direction to the town of Elkton and then flows westward in a sinuous course to Winchester Bay. The drainage area comprises 4,000 square miles, of which about 80 per cent is densely forested. The valleys are narrow and the agricultural land is restricted to narrow strips near the streams. The general elevation of the headwater region is about 6,000 feet, but some peaks rise to 8,000 or 9,000 feet above sea level. The gradient of the upper stream is high, and wonderful possibilities for power development exist. Precipitation in the headwater region is 100 inches or more, occurring largely as snow in the winter months. About 30 inches of rain falls annually at Roseburg, the principal city of the basin, and probably as much as 60 inches near the mouth of the river. The seasonal distribution is poor, practically no rain falling in the valleys in July and August. Irrigation is necessary for the best agricultural results in the valley, but little has yet been practiced.

The river rises in the lavas of the Cascade Range and flows in its middle and lower course through sediments, most of which have been referred to the Eocene epoch. Basalts, rhyolites, and andesites compose the greater part of the lava formations, which are bordered by metamorphic rocks, such as metagabbros and serpentines, which in turn give place to the Eocene sandstones, shales, and limestones of the middle and lower river.

CHARACTER OF THE WATER.

The chemical composition of the water of Umpqua River is of interest as indicating the character of waters flowing through a densely forested region receiving a heavy rainfall and draining Eocene sandstones and later lavas or altered lavas.

Samples of water were collected daily from the river at Smiths Ferry, 4 miles below Elkton. A gaging station is maintained by the Geological Survey at this point, above which the drainage basin comprises 3,680 square miles. Analyses of 10-day composite samples were made from August 1 to December 8, 1911, and monthly composites were analyzed thereafter.

Mineral analyses of water from Umpqua River near Elkton, 1911–12.

[Parts per million except as otherwise designated.]

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
Aug. 1-10	1	2.4	2.40	4	30	0.06	7.0	1.6	12	0.0	43	7.2	0.48	3.2	86	0.37	1,123	7.3	261
Aug. 11-20	4	2.8	.70	......	21	.08	10	3.3	....	.0	35	7.0	......	......	68	.28	1,047	7.9	192
Aug. 21-30	1	.0	....	Tr.	22	.05	8.9	2.8	9.1	.0	32	7.6	1.1	3.1	70	.20	980	0	185
Aug. 31-Sept. 9	3	3.0	1.00	......	20	.05	8.3	3.5	7.6	.0	35	4.3	.28	3.3	65	.51	1,273	10.4	223
Sept. 10-19	3	1.6	.53	4	20	.08	9.4	2.8	5.0	.0	38	4.9	.44	5.3	67	.56	1,303	5.6	236
Sept. 20-29	2	4.4	2.20	4	20	.05	9.2	3.6	6.6	.0	42	7.2	.40	4.3	71	.64	1,397	16.6	268
Sept. 30-Oct. 9	1	4.4	4.40	2	20	Tr.	7.3	3.6	7.9	.0	41	5.9	.24	4.8	74	.78	1,525	18.1	305
Oct. 10-19	1	2.4	2.40	4	18	.04	11	2.8	6.1	.0	39	9.0	.41	4.1	73	.86	1,613	10.5	317
Oct. 20-29	2	3.2	1.60	0	18	.02	7.5	2.6	6.8	.0	40	7.8	.68	4.7	71	.41	1,160	10.0	223
Oct. 30-Nov. 8	Tr.	2.4	....	0	18	.03	10	2.2	6.6	.0	39	8.5	.32	4.0	71	.52	1,311	8.5	251
Nov. 9-18	15	45.2	3.01	40	18	.23	11	2.8	6.1	.0	39	6.7	.54	3.3	75	6.4	12,798	1,560	2,585
Nov. 19-28	5	2.8	.56	18	14	.15	7.8	2.0	6.1	.0	31	5.6	.38	2.5	59	4.7	8,392	63.5	1,336
Nov. 29-Dec. 8	5	3.6	.72	4	14	.04	8.4	1.0	6.9	.0	31	3.5	.28	3.3	57	2.7	4,133	40	637
Dec. 9-31	20	16	.80	47	16	.30	8.4	1.4	6.4	.0	35	5.3	.18	3.8	64	3.4	5,681	245	983
Jan. 1-31	60	75	1.25	44	16	.25	6.3	1.3	4.9	.0	29	5.0	.24	2.3	59	9.6	22,614	4,575	3,595
Feb. 1-29	15	17	1.13	17	16	.09	8.7	1.4	4.9	.0	33	3.0	.33	2.3	70	8.3	18,478	847	3,501
Mar. 1-31	10	13	1.30	16	17	.12	7.3	1.7	6.1	[a] Tr.	35	3.9	.12	2.8	66	5.6	10,518	369	1,870
Apr. 1-30	10	17	1.70	10	25	.05	9.0	1.9	7.1	[a] 4.8	28	4.8	.30	2.8	76	3.7	5,928	272	1,216
May 1-31	10	8.9	.89	12	23	.15	6.3	2.0	4.4	.0	32	2.9	.22	2.3	62	5.9	11,752	282	1,963
June 1-30	8	13	1.62	8	14	.01	5.9	2.0	6.5	[a] 7.4	19	8.2	.34	1.8	58	4.0	6,661	234	1,041
July 1-31	4	6.0	1.50	8	18	.01	6.7	2.3	7.3	.0	40	4.0	.40	4.0	63	1.6	2,495	40	425
Aug. 1-15	4	6.0	1.50	5	17	.15	8.0	3.6	8.5	.0	39	4.3	.06	2.8	67	.75	1,487	24	269
Mean	12	15	1.25	14	18	.10	7.9	2.2	[b] 5.7 [b] 1.6	.0	36	5.2	.30	3.0	67	....	....	[c] 217,400	[c] 488,500
Percentage of anhydrous residue	....	....	....	......	29.0	[d] .2	12.7	3.6	[b] 9.2 [b] 2.6	29.0	....	8.4	.5	4.8	....	....	....	....	....

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[a] Abnormal; computed to HCO_3 in average.

[b] Sodium and potassium, determined on the combined alkali residues.

[c] Total annual denudation.

[d] Fe_2O_3.

The water changes in quality very little from season to season, for the forests prevent rapid and excessive erosion following heavy rains and keep the run-off distributed to some extent. There is thus no great accumulation of transportable disintegration products of rock material during dry periods, but leaching occurs more or less continuously. The character of the water is shown in the table on the preceding page.

The water is silicic and calcic carbonate and is harder than that of Rogue River, but it can be used in boilers without prior treatment. Sedimentation of the water to remove turbidity before introduction into the boiler will reduce the amount of scale-forming matter almost one-half but will probably result in the deposition of a harder silicate scale. The water is nonfoaming and noncorrosive and is excellent for irrigation and for most industrial uses. Its content of organic matter is rather high because of the introduction of decomposition products from the forests of the basin. The content of chlorine is probably nearly normal for the region. Considerable chlorine from the ocean is introduced by rain, and more may be introduced by spring waters. Human or animal pollution is slight, however, and little chlorine can be considered to come from that source.

SILETZ RIVER.

GENERAL FEATURES.

Siletz River is typical of the streams originating among the sedimentary rocks of the Coast Range. It rises in the western part of Polk County, at an elevation of about 3,000 feet above sea level, and flows southwestward to the broad valley near Siletz, then turns northward and follows a general northwesterly course to the Pacific. Its length is approximately 50 miles and its drainage area 320 square miles.

The topography is rugged. Rainfall over the basin is copious, being 75 to 80 inches at the mouth and probably 150 inches or more at the headwaters. A dense growth of timber covering most of the drainage basin serves to retard surface erosion and to lessen the force of the floods. The gradient of the stream is steep, and fluctuations in stage are sudden and large, rises of a foot an hour for twelve or more hours being not uncommon. The river at flood stage discharges about 1,000 times the minimum run-off, and the increase in volume in 24 hours is often more than 100 times the initial discharge.

Eocene formations are exposed in the upper valley and later Tertiary along the lower course of the river. Shales and soft sandstones are most generally exposed, the rocks of the upper valley being usually better cemented than the more recent sediments of the lower valley, which in places are only partly consolidated sands and ooze.

Exposures of volcanic rock have been found in the headwater region, but the extent of these is unknown.[1]

CHARACTER OF THE WATER.

Samples of water were collected daily by John Kennta at the gaging station one-half mile above the new steel bridge near the Siletz-Toledo stage road. The area of the basin above this point is 220 square miles.

The water differs somewhat in character from that of either Rogue or Umpqua rivers, though it does not show clearly its origin among secondary formations. The content of alkaline earths is scarcely sufficient to combine with the strong acids—inconclusive evidence as to the character of the formations in the upper basin. The water is siliceous and carbonate in type, and alkalies are only slightly in excess of alkaline earths. The content of suspended matter is remarkably small, considering the character of the discharge and the softness of the rocks near Siletz. The formations above Siletz are possibly older and more firmly cemented than those observed farther downstream by the writer, and this is made more probable by the fact that the region near Black Rock, just east of the divide, exposes much harder shales and sandstones than those of the middle Siletz Valley. Dense forest growths aid in preventing the washing of soil and rock powder into the streams, and the waters are turbid only after excessively heavy rains. Chlorine averaged 1.2 parts per million more than in the water of Umpqua River at Elkton, the difference probably representing the normal difference in cyclic chlorine. Sulphate and calcium are important constituents of the water. It seems possible that the presence of dense forests, the continual washing away of soluble rock material, and the decaying organic matter in regions of large rainfall, such as the coastal slope of Oregon, tend to increase the alkalinity and to destroy the geochemical value of the analysis.

The water is excellent for all industrial uses. It is nonscaling but may under some conditions become corrosive. If it were used for a municipal supply its content of free carbonic acid would probably lead to corrosion of iron mains and service pipes and to the frequent delivery of "red water" from household boilers. The water is suitable in quality for use in paper mills, but the discharge of the stream is too "flashy" and its minimum flow too small to make its use desirable.

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[1] Personal communication from J. B. Winstanley, Portland, Oreg.

Mineral analyses of water from Siletz River near Siletz, 1911–12.

[Parts per million except as otherwise designated.]

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
Aug. 11–20	2	0.8	0.40	1	15	0.01	6.1	1.6	6.8	0.0	24	5.7	....	3.8	49	0.83	125	0.3	17
Aug. 21–30	1	1.6	1.60	......	12	.03	5.5	1.8	5.6	.0	22	5.3	0.40	3.5	46	.85	130	.6	16
Aug. 31–Sept. 9	2	2.7	1.35	......	13	.04	6.2	2.0	5.8	.0	22	2.9	.60	2.8	46	.85	128	.9	16
Sept. 10–19	3	4.0	1.33	......	8.0	.12	4.7	1.3	6.0	.0	20	6.0	.28	3.6	42	1.22	331	3.6	38
Sept. 20–29	2	....	....	......	8.8	.10	4.3	1.4	5.2	.0	20	4.2	.20	3.5	41	1.14	286	....	32
Sept. 30–Oct. 9	2	2.5	1.25	6	10	.02	4.9	.8	5.9	.0	23	5.0	.40	3.4	43	.93	159	1.1	19
Oct. 10–19	3	3.1	1.03	10	13	.02	8.1	3.2	12	0	50	6.6	.42	5.5	65	1.13	264	2.2	46
Oct. 20–29	1	1.4	1.40	12	12	.05	4.7	1.3	5.4	.0	23	4.4	.32	5.3	47	1.10	240	.9	30
Oct. 30–Nov. 8	1	4.6	4.60	2	9.7	.02	5.5	1.4	5.3	.0	18	7.6	.76	4.0	45	1.50	666	8.3	81
Nov. 9–18	5	18	3.60	8	8.4	.05	3.7	1.1	3.9	.0	13	5.8	.88	4.2	35	6.4	7,056	343	667
Nov. 19–28	3	7.0	2.33	5	9.1	.02	5.7	1.1	5.1	.0	15	9.7	2.0	4.5	46	3.3	2,657	50	330
Nov. 29–Dec. 8	1	4.1	4.10	1	9.6	.02	4.4	1.3	5.1	.0	13	6.5	1.8	4.3	45	....	[a] 1,200	13	149
Dec. 9–18	1	1.2	1.20	1	9.1	Tr.	4.5	1.0	5.8	.0	13	4.4	2.0	4.3	40	....	[a] 1,400	5	170
Dec. 19–28	1	5.3	5.30	1	9.2	.02	5.9	.8	6.4	.0	12	4.8	1.9	5.3	43	....	[a] 3,000	43	348
Dec. 29–Jan. 7	20	25	1.25	......	8.8	.06	3.6	.8	6.3	.0	13	6.3	1.8	4.5	46	....	[a] 4,500	304	559
Jan. 8–17	15	32	2.13	5	7.0	.08	2.8	.1	4.4	.0	11	2.4	.42	3.3	32	8.4	9,968	851	860
Jan. 18–27	2	11	5.50	Tr.	13	.03	3.9	.4	4.8	.0	12	4.9	.52	3.0	34	4.0	3,679	109	338
Jan. 28–Feb. 6	5	20	4.00	1	9.5	.09	4.6	.8	5.6	.0	12	3.1	2.1	4.0	41	4.7	4,594	248	506
Feb. 7–16	7	15	2.14	1	8.2	.06	3.7	1.0	5.0	.0	12	4.1	1.9	4.3	36	4.9	4,957	201	482
Feb. 17–26	Tr.	....	....	1	9.2	.01	5.6	1.2	5.2	.0	12	5.7	4.2	5.0	42	4.1	3,749	Tr.	364
Feb. 27–Mar. 7	3	4.1	1.37	Tr.	6.5	.02	3.5	.4	5.5	[b] 1.2	8.5	2.4	5.4	5.8	40	2.3	1,426	15.8	154
Mar. 8–17	1	3.1	3.10	Tr.	8.8	.03	3.3	.4	5.4	.0	9.5	2.4	6.0	5.0	42	2.1	1,129	9.5	128
Mar. 18–27	Tr.	....	....	2	9.0	.02	3.7	.4	8.5	.0	9.3	2.9	5.3	5.0	43	2.4	1,572	Tr.	183
Mar. 28–Apr. 6	3	7.2	2.40	1	7.5	.02	3.7	.6	5.2	.0	11	5.3	4.2	4.8	46	1.8	867	16.8	108
Apr. 7–16	Tr.	Tr.	....	1	8.3	.01	3.3	1.3	4.7	.0	14	3.9	.45	3.5	36	1.6	549	Tr.	53
Apr. 17–26	Tr.	Tr.	....	Tr.	8.0	.01	3.4	.2	5.5	.0	13	2.8	.60	4.0	38	1.4	445	Tr.	46
Apr. 27–May 6	1	10	10.00	2	6.6	.02	4.5	.3	6.5	.0	13	3.5	4.0	4.8	36	[a] 1.5	[a] 625	16.9	61
May 7–16	Tr.	Tr.	....	0	9.0	.02	3.9	.3	6.8	.0	15	3.6	.52	3.5	36	[a] 1.6	[a] 525	Tr.	51
May 17–26	Tr.	Tr.	....	0	7.6	.02	5.0	.5	6.0	.0	17	3.9	2.0	4.5	38	[a] 1.5	[a] 625	Tr.	64
May 27–June 5	Tr.	Tr.	....	Tr.	6.2	.08	4.5	.1	6.0	.0	17	3.3	.60	4.0	43	[a] 1.2	[a] 300	Tr.	35
June 6–15	Tr.	Tr.	....	8	11	.04	4.8	.6	6.0	.0	16	3.3	2.8	4.8	41	[a] 1.2	[a] 300	Tr.	33
June 16–25	Tr.	Tr.	....	3	9.9	.04	4.2	.7	4.8	.0	17	4.6	.92	4.0	40	[a] 1.4	[a] 425	Tr.	46
June 26–July 5	2	4	2.00	3	9.2	Tr.	3.8	.6	8.2	.0	18	2.1	1.1	4.8	42	[a] 1.2	[a] 300	3.2	34
July 6–15	3	6.8	2.27	5	11	.00	3.6	.8	7.9	.0	19	4.1	.90	4.0	45	[a] 1.2	[a] 300	5.5	36
July 16–25	Tr.	Tr.	....	4	7.6	Tr.	3.8	.8	6.0	.0	19	4.4	.34	3.5	40	[a] 1.6	[a] 525	Tr.	57
July 26–Aug. 4	4	5.6	1.40	1	9.0	Tr.	4.2	1.3	6.3	.0	20	5.6	.12	4.5	42	[a] 1.5	[a] 625	9.4	77
Aug. 5–14	5	6.6	1.34	6	8.4	.01	3.5	1.1	7.1	.0	20	6.3	.66	4.3	40	[a] 1.5	[a] 625	11.1	67
Mean	3	5.6	2.6	3	9.4	.03	4.5	.9	[c]5.5 [c].7	.0	17	4.6	1.6	4.2	42	....	....	[d] 22,400	[d] 62,100
Percentage of anhydrous residue	......	....	....	......	23.6	[e].1	11.3	2.3	[c]13.8 [c]1.8	21.1	....	11.5	4.0	10.5	....	....	....	....	....

[a] Estimated. [b] Abnormal; computed to HCO_3 for average. [c] Sodium and potassium, determined on combined alkali residues. [d] Total annual denudation. [e] Fe_2O_3.

COLUMBIA RIVER DRAINAGE BASIN.

GENERAL FEATURES.

The drainage basin of Columbia River comprises about 259,000 square miles in northwestern United States and southwestern Canada. Its eastern border is the crest of the Rocky Mountains, its northwestern limit is among the peaks of the Cascades, and its lower stretch receives drainage from the Coast Range. The basin is divided among several States and British Columbia, as follows:[1]

	Square miles.
Oregon	55,370
Washington	48,000
Idaho	81,380
Montana	25,000
Nevada	5,280
Wyoming	5,270
British Columbia	38,700

Columbia River, the trunk stream of the system, rises in Columbia Lake, in the eastern part of the Kootenai district in British Columbia, flows northwestward to the fifty-second parallel, then, turning abruptly southward, it nearly retraces its former course, passing through a series of narrow lakes until it crosses into Washington near the Idaho line. After a slight westerly deflection it resumes its progress southward to the Oregon-Washington line, where it swings west, and finally discharges through an estuary into the Pacific Ocean. The navigable stretches on the main stream aggregate 760 miles and on the entire system 2,136 miles.

The important tributaries of the Columbia are:

Entering from north and west.	Entering from south and east.
Kettle River.	Kootenai River.
Sanpoil River.	Clark Fork.
Okanogan River.[2]	Colville River.
Methow River.	Spokane River.
Chelan River.	Snake River.[3]
Entiat River.	Walla Walla River.
Wenatchee River.[2]	Umatilla River.[3]
Yakima River.[2]	Willow Creek.
Klickitat River.[2]	John Day River.[3]
White Salmon River.	Deschutes River.[3]
Lewis River.	Hood River.
Kalama River.	Willamette River.[3]
Cowlitz River.	Clatskanie River.

The drainage basin of this system includes all topographic features, from the bold peaks of the Cascade Range and the west slopes of

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[1] U. S. Geol. Survey Water-Supply Paper 272, p. 64, 1911.

[2] For analyses see Van Winkle, Walton, The quality of the surface waters of Washington: U. S. Geol. Survey Water-Supply Paper 339, 1914.

[3] Studied in connection with this investigation.

the Rocky Mountains to the flat sandy plains of the "Big Bend Country" in Washington. Much of the area is forested, and although extensive lumbering has been carried on the percentage of forest lands has been only slightly decreased.

Precipitation is unevenly distributed. Summer rainfall is small in most of the region. In some places, as along the coastal strip and at the summits of the Cascade Range, the average annual precipitation is 100 inches or more, but it decreases rapidly eastward from the mountains, and in the arid lands of eastern Oregon and the low valley of central Washington it is 9 inches or less. The climate of the coastal belt is mild, the summers being cool and the winters warm. In the valleys between the Coast and Cascade ranges the climate is still mild but less even. In the Oregon Plateau and much of the interior region high summer and low winter temperatures prevail, and on the elevated headwater regions the climate is extremely rigorous.

The only generally important industries of the region are lumbering and agriculture. Some mining is carried on in the headwater regions, especially in the Rocky Mountains.

The headwaters of the tributaries rising in the Rocky Mountains expose ancient strata, largely metamorphic and ranging from Proterozoic quartzites to Jurassic and Triassic or even younger sediments. Post-Cambrian intrusives cover large areas in Idaho and southern British Columbia, but the greater part of the basin, including most of the valleys of Snake and Columbia rivers in the United States, is covered by the thick Columbia River basalt, of Tertiary age. The soil of the basin is generally rich and fertile but in the plateau region is usually lacking in humus. The soil of the coastal strip is heavier and has been reported to be sour in places. The soil covering the basaltic plateau is "volcanic ash," or pumiceous sand and disintegrated basalts, and is rich in lime but poor in phosphorus and lacking in humus.

SNAKE RIVER.

GENERAL FEATURES.

Snake River heads near the Continental Divide in Yellowstone National Park, western Wyoming and northeastern Idaho. It flows in a great southward-hanging loop across Idaho, then northward through a steep canyon to its junction with the Clearwater at Lewiston, Idaho. It there turns sharply and flows southwestward to its confluence with the Columbia below Pasco, Wash. Its drainage area comprises 109,000 square miles and includes regions differing greatly in topography, structure, and climate. The headwater region is rough and mountainous, and the canyon between Idaho and Oregon traverses a remarkably broken and distorted country.

The river crosses the Columbia River basalt throughout its lower course and is there confined within a steep-walled canyon about 2,000 feet deep. According to Russell,[1] solid rock is exposed only in the canyon walls, which in many places rise nearly vertically from the talus slopes at their base. The soil is fine and deep and is practically free from pebbles, and where only a sparse desert growth exists it is easily swept up by the winds into great dunes. The depth and richness of the soil, however, render it eminently suitable for agriculture, and though the plateau has a forbidding desert-like aspect, it is capable of producing abundant crops when properly watered.

Precipitation is heavy in the mountain portion and is mostly snow, but in the lower valleys it amounts to only 8 to 10 inches a year. The temperature of the central valleys ranges from about 100° or higher in summer to considerably below zero in winter.

Power plants are in operation at American Falls, Shoshone Falls, and at the Minidoka dam on Snake River and on Payette and Boise rivers, tributaries of the Snake. There are many other sites along Snake River where large amounts of power might be developed.

CHARACTER OF THE WATER.

Samples of water from Snake River were collected for this investigation by A. J. Reeves, gage reader, at the gaging station maintained by the United States Geological Survey at the power house about 200 yards below the wagon bridge at Weiser, Idaho, and 1 mile below the mouth of Weiser River. The drainage area above this point comprises 74,900 square miles.[2]

The water is hard and will deposit a little soft scale in boilers—slightly less than 2 pounds per 1,000 gallons of water. It can be softened with excellent results by adding lime in the proportion of about three-quarters of a pound per 1,000 gallons of water or by preheating in open heaters. With proper attention the water will not foam in boilers.

The water is excellent for irrigation, for which it is extensively used. If it is applied to lands containing small amounts of "black alkali," they will lose some of that undesirable constituent and will receive white alkali and lime by the same reaction that occurs when land plaster is used.

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[1] Russell, I. C., A reconnaissance in southeastern Washington: U. S. Geol. Survey Water-Supply Paper 4, p. 15, 1897.

[2] Estimated by U. S. Weather Bureau.

Mineral analyses of water from Snake River near Weiser, Idaho, 1911–12.

[Parts per million except as otherwise designated.]

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO₂).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO₃).	Bicarbonate radicle (HCO₃).	Sulphate radicle (SO₄).	Nitrate radicle (NO₃).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
Aug. 11-20	6	8.6	1.43	1	34	0.08	33	14	31	0.0	142	43	1.2	20	247	5.1	6,830	159	4,555
Aug. 21-30	9	13	1.42	2	29	.02	37	15	30	.0	149	48	1.4	22	253	5.0	6,620	232	4,520
Aug. 31-Sept. 9	18	13	.72	......	31	.08	35	15	29	Tr.	153	45	1.05	22	253	4.9	6,164	216	4,205
Sept. 10-19	12	......	......	......	28	.10	38	15	30	Tr.	150	49	......	23	254	5.0	6,620	......	4,535
Sept. 20-29	5	16	3.20	0	31	.04	36	14	33	.0	150	46	.80	23	258	5.2	7,510	324	5,245
Sept. 30-Oct. 9	10	15	1.50	4	31	Tr.	35	15	30	Tr.	156	47	.80	23	259	5.5	8,686	351	6,070
Oct. 10-19	20	115	5.75	4	26	.01	37	13	31	Tr.	154	47	.82	23	256	6.7	14,968	4,640	10,340
Oct. 20-29	30	25	.83	4	28	.01	38	13	27	.0	155	45	.44	21	253	6.7	15,050	1,032	10,400
Oct. 30-Nov. 8	8	13	1.63	Tr.	26	.01	38	13	25	.0	155	44	.70	21	257	6.4	13,310	467	9,230
Nov. 9-18	25	19	.76	......	18	.01	40	12	30	Tr.	160	43	......	21	258	6.8	15,370	787	11,150
Nov. 19-28	7	7.4	1.06	5	21	.04	37	12	27	Tr.	156	44	.80	21	253	6.5	14,160	283	9,665
Nov. 29-Dec. 8	10	7.4	.74	2	22	.02	35	12	27	.0	156	39	.60	24	241	6.1	11,950	238	7,765
Dec. 9-18	3	3.0	1.00	1	29	.11	41	11	30	2.4	155	44	.54	22	256	6.6	14,300	116	9,878
Dec. 19-28	5	11	2.20	1	28	.02	42	12	28	Tr.	163	42	.50	22	260	6.6	14,210	422	9,970
Dec. 29-Jan. 7	5	3.2	.64	1	29	.01	42	12	28	.0	159	43	.60	21	259	6.2	12,000	104	8,380
Jan. 8-17	10	6.6	.66	Tr.	29	.02	39	11	27	.0	154	43	1.1	20	250	6.8	15,540	277	10,480
Jan. 18-27	80	108	1.35	17	27	.01	38	8.6	27	.0	154	40	.76	21	242	7.2	17,600	5,126	11,500
Jan. 28-Feb. 6	80	57	.72	Tr.	29	Tr.	36	4.8	30	.0	146	38	.60	20	238	7.1	17,260	2,655	11,085
Feb. 7-16	100	126	1.26	4	26	.01	31	12	29	.0	138	37	.40	19	263	7.5	19,600	6,665	13,910
Feb. 17-26	120	143	1.19	9	34	.06	29	5.2	26	.0	125	33	.63	17	212	7.8	21,320	8,220	12,200
Feb. 27-Mar. 7	20	35	1.75	9	32	.05	31	9.0	27	4.6	136	36	.72	20	245	6.9	15,840	1,495	10,465
Mar. 8-17	90	91	1.01	10	24	.05	34	6.4	30	4.3	129	39	.66	18	223	7.3	18,080	4,435	10,875
Mar. 18-27	60	51	.85	7	23	.02	32	7.6	28	9.6	114	37	.30	18	217	7.2	17,840	2,455	10,447
Mar. 28-Apr. 6	110	212	2.12	24	28	.04	26	7.2	21	14	101	25	.21	12	175	8.6	26,100	14,930	12,315
Apr. 7-16	155	224	1.45	26	20	.05	21	3.2	15	Tr.	83	21	.30	9.0	138	9.9	35,450	21,450	13,202
Apr. 17-26	225	272	1.21	28	22	.09	25	6.4	19	.0	96	24	.27	11	161	9.4	31,660	23,250	13,770
Apr. 27-May 6	100	246	2.46	45	18	.12	20	5.4	17	11	63	19	1.4	8.5	132	10.4	39,240	24,120	13,970
May 7-16	85	157	1.84	18	19	.03	22	7.4	17	9.6	73	21	Tr.	10	143	10.6	40,790	16,010	15,735
May 17-26	70	180	2.57	13	22	.06	28	7.6	16	Tr.	94	23	Tr.	9.8	154	12.3	54,760	26,590	22,760
May 27-June 5	90	126	1.40	......	20	.05	26	7.3	15	.0	94	17	.13	7.0	144	12.6	57,810	19,630	22,470
June 6-15	110	266	2.60	24	20	.08	25	3.8	9.8	.0	93	17	.24	7.5	152	13.7	67,360	48,300	27,640
June 16-25	80	144	1.80	16	16	.02	25	5.0	8.8	17	72	17	.36	6.9	134	12.7	58,450	22,690	21,135
June 26-July 5	50	62	1.24	16	18	.01	31	6.2	13	Tr.	117	24	.28	10	174	10.4	38,900	6,026	18,270
July 6-15	85	94	1.10	8	26	.02	30	6.0	22	.0	123	27	.66	11	186	8.5	25,810	6,540	12,950
July 16-25	100	105	1.05	13	33	.01	32	8.2	27	.0	131	38	.48	15	226	6.7	14,660	4,154	8,930
July 26-Aug. 4	280	290	1.05	7	42	Tr.	26	10	28	2.6	135	25	.16	19	238	6.0	11,260	8,810	7,225
Aug. 5-14	600	484	.81	......	39	Tr.	34	10	30	Tr.	139	39	1.2	22	268	6.3	12,907	16,875	9,340
Mean	80	104	1.51	10	26	.04	33	9.6	[a]22 [a]3.5	2.0	130	35	.6	17	220	......	......	[b]3,042,000	[b]4,208,000
Percentage of anhydrous residue	......	......	......	......	12.2	.0	15.5	4.5	[a]10.3 [a]1.7	31.0	......	16.5	.3	8.0	......	......	......	......	......

[a] Sodium and potassium, determined on combined alkali residues.

[b] Total annual denudation.

OWYHEE RIVER.

GENERAL FEATURES.

Owyhee River rises on the east slopes of the Tuscarora Mountains in Elko County, Nev., flows northward into southwestern Idaho, then northwestward into Oregon, where it turns abruptly to the northeast, and finally joins the Snake near Nyssa. The basin comprises an area of 11,100 square miles, which is 4,500 feet in general elevation, and except at the headwaters forests are lacking. Precipitation averages 6 to 9 inches, the larger part occurring as snowfall. Most of the low-water flow of the river is used for irrigation.

The headwaters of the river lie among Quaternary deposits, but the greater part of the upper and middle river traverses the Columbia River basalt. The lower river flows through a wide valley overlain by late Tertiary lake and river deposits, probably of the Payette formation.

The stream affords a striking example of a large river draining an extremely arid area in which the predominating formations are volcanic rocks of Tertiary age.

CHARACTER OF THE WATER.

Samples of water were collected by Gilder Watson from Owyhee River at the county bridge, half a mile from Owyhee post office and 3 miles above the mouth of the stream. A gaging station is maintained at the same point, above which the drainage basin comprises 11,100 square miles. Six miles above the gaging station a large ditch removes more than 200 second-feet of water from the river during irrigation seasons. The entire low-water flow is used for irrigation and the flow at the sampling station at such times is only seepage water. The river is sometimes frozen over. The character of the water is not affected noticeably by these conditions.

The concentration of dissolved material in Owyhee River varies greatly. In August, 1911, a maximum mineralization of 472 parts per million occurred, and in April, 1912, a minimum of 88 parts per million.

The water has a large amount of temporary and some permanent hardness. It is noncorrosive but might cause foaming in boilers if improperly used. It is excellent for irrigation.

Waters draining volcanic formations are not so well suited for irrigation as are waters flowing from sediments, as they contain relatively large amounts of alkaline carbonates and hence, if sufficiently concentrated, tend to increase the "black alkali" content of the soil. The waters of eastern Oregon are generally not sufficiently mineralized to cause trouble in this manner, but wherever irrigation is practiced in the State care should be taken to insure adequate drainage, as both water and soil yield black alkali, which becomes concentrated in spots if the drainage is poor.

Mineral analyses of water from Owyhee River near Owyhee, 1911–12.

[Parts per million except as otherwise designated.]

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
Aug. 11–20	40	32	0.81	2	38	0.08	58	20	76	a Tr.	262	95	2.0	32	445	2.03	4.4	0.38	5.3
Aug. 21–30	30	28	.93	16	40	.01	58	19	79	a Tr.	289	97	1.3	32	472	2.05	5.0	.38	6.4
Aug. 31–Sept. 9	50	28	.56	8	40	.01	55	14	69	0.0	290	96	.60	34	472	2.05	5.0	.38	6.4
Sept. 10–19	50	42	1.84	20	36	.11	47	17	78	.0	258	87	.64	33	438	2.09	7.0	.79	8.3
Sept. 20–29	30	21	.70	5	35	.11	52	18	78	a Tr.	266	90	.88	33	451	2.15	10.0	.57	12.2
Sept. 30–Oct. 9	25	19	.76	6	31	.10	37	12	61	.0	204	65	.72	24	334	2.24	21.4	1.1	19.4
Oct. 10–19	60	79	1.32	40	35	.12	29	11	61	.0	186	51	1.0	21	334	2.43	59	11.9	53
Oct. 20–29	65	25	.39	27	35	.11	24	6.4	52	.0	158	39	.60	16	264	2.38	46	3.1	33
Oct. 30–Nov. 8	25	20	.80	20	38	.22	26	6.2	51	.0	160	43	.56	16	275	2.35	38	1.9	28
Nov. 9–18	35	4.8	.14	......	33	.42	26	6.4	49	.0	148	43	.54	15	261	2.42	56	.7	39
Nov. 19–28	20	10	.50	8	33	.22	21	4.8	49	.0	146	34	.36	16	243	2.54	95	2.6	62
Nov. 29–Dec. 8	11	19	1.73	9	28	.05	22	5.2	45	.0	139	36	.58	15	230	2.57	105	5.4	65
Dec. 9–18	5	.0	....	4	36	.10	21	5.0	46	.0	134	34	.26	12	224	2.67	147	.0	89
Dec. 19–28	20	15	.75	8	35	.11	22	4.2	47	.0	142	33	.40	15	237	2.80	206	8.3	131
Dec. 29–Jan. 7	20	29	1.45	4	34	.12	24	6.4	51	.0	155	46	.44	16	260	3.20	210	16.5	147
Jan. 8–17	140	107	.77	16	33	.01	23	4.8	47	.0	144	32	.66	13	231	3.8	410	118	255
Jan. 18–27	400	378	.97	18	24	.01	22	4.6	38	.0	122	26	.56	12	197	4.0	695	710	370
Jan. 28–Feb. 6	100	72	.72	26	29	.02	18	3.8	32	.0	109	23	.40	9.0	172	3.6	611	119	283
Feb. 7–16	100	84	.84	32	27	.02	16	4.0	29	.0	104	24	.52	8.5	164	3.9	932	211	412
Feb. 17–26	175	190	1.08	30	22	.11	12	3.1	19	.0	68	12	1.1	5.3	120	4.8	1,928	988	625
Feb. 27–Mar. 7	75	44	.59	......	25	.08	16	1.0	20	.0	76	14	1.5	2.0	123	3.6	742	88	245
Mar. 8–17	170	144	1.0	40	14	.05	15	2.0	20	a 14	53	13	.12	4.2	121	4.4	1,478	574	483
Mar. 18–27	100	65	.65	20	31	.35	16	4.0	21	a Tr.	88	17	.66	6.0	152	3.9	949	167	389
Mar. 28–Apr. 6	125	269	2.15	20	24	.45	12	2.8	13	.0	54	13	1.2	2.8	104	6.4	4,188	3,020	1,175
Apr. 7–16	100	176	1.76	32	21	.23	10	2.8	9.1	.0	43	12	.22	2.0	88	7.3	6,466	3,070	1,533
Apr. 17–26	340	361	1.06	......	27	.35	11	2.9	14	.0	59	12	.36	3.0	110	7.4	7,120	6,935	2,110
Apr. 27–May 6	120	217	1.81	79	22	.07	14	2.0	12	a 26	1.2	7.2	.44	2.5	98	7.8	7,892	4,620	2,080
May 7–16	90	96	1.07	60	27	.06	18	1.8	12	.0	67	11	.36	2.8	117	7.3	6,387	1,657	2,015
May 17–26	90	99	1.10	50	27	.10	18	2.4	12	.0	74	8.7	....	3.0	125	7.2	6,152	1,643	2,073
May 27–June 5	60	104	1.73	28	70	.15	22	2.8	19	.0	110	10	.32	5.5	210	6.3	4,202	1,179	2,380
June 6–15	750	1,765	2.35	40	21	.01	23	2.9	16	.0	98	13	.42	3.5	142	5.6	2,959	14,099	1,135
June 16–25	40	78	1.95	20	18	.10	22	4.1	20	.0	104	11	.30	5.5	139	4.7	1,792	377	670
June 26–July 5	30	38	1.27	12	32	.08	28	5.9	25	.0	128	18	.30	8.8	198	3.6	754	77	403
July 6–15	25	22	.88	20	30	.10	23	3.8	24	.0	128	18	1.0	8.0	181	3.1	396	26	193
July 16–25	1,200	650	.54	23	38	.08	28	6.8	42	a Tr.	156	38	1.2	12	249	2.8	243	426	164
July 26–Aug. 4	675	310	.46	0	31	.02	29	7.2	42	a 4.8	156	35	.36	14	250	2.4	62	52	42
Aug. 5–14	800	459	.57	26	39	.20	28	7.4	50	.0	170	40	.20	14	276	2.5	89	110	66
Mean	167	165	.98	22	31	.12	26	6.4	b35 b4.6	.0	139	35	.64	13	230	....	....	c397,800	c195,400
Percentage of anhydrous residue	......	....	....	......	14.1	d.1	11.8	2.9	b15.9 b2.1	31.0	....	15.9	.3	5.9	....	....	....	....	....

a Abnormal, computed to HCO_3 in average.
b Sodium and potassium, determined on the combined alkali residues.
c Total annual denudation.
d Fe_2O_3.

MALHEUR RIVER.

GENERAL FEATURES.

Malheur River rises in the eastern part of Harney County, flows northward until it is joined by Middle and North forks, then northeastward, discharging into Snake River at Ontario. The total drainage area is 4,150 square miles. The headwaters reach an elevation of more than 5,000 feet, and the mouth of the river is about 2,000 feet above sea level. Timber grows sparsely in the headwater region, but the valley proper is in general a sagebrush desert. Precipitation ranges from 16 inches in the upper reaches to 10 inches at Vale, near the mouth of the river.

Malheur River was formerly the outlet for Malheur Lake, but the aridity of the region has increased, the old channel has been closed by lava flows, and the lake now occupies one of the minor depressions of the Great Basin.

Basaltic or rhyolitic rocks exposed along the upper reaches of the Malheur give place in the lower valley to sediments of late Tertiary age. It is entirely possible that the lake beds of the Payette formation extend far into Malheur Valley, but no detailed geologic studies have been made, and such assumption is without definite supporting evidence.

CHARACTER OF THE WATER.

Samples of water were collected by the United States Reclamation Service from March 26 to December 4, 1905, from Malheur River at the gaging station maintained by the United States Geological Survey at a highway bridge near Vale, and were analyzed at Berkeley, Cal., under the direction of Thomas H. Means. The drainage area above Vale comprises 4,860 square miles. The following tables[1] show the results of these analyses:

Relative amount of substances in solution in water from Malheur River near Vale, 1905.

Limiting dates of composite.	Number of daily samples.	Dissolved solids (parts per million).	Radicles in percentage of dissolved solids.							
			Calcium (Ca).	Magnesium (Mg).	Sodium and potassium ($Na+\frac{3}{4}K$).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Nitrate radicle (NO_3).
Mar. 26–Apr. 21	22	182	8.8	4.2	14	0.00	59	12	4.6	0.05
Apr. 23–May 20	18	210	11	4.3	14	.00	70	16	6.2	.04
May 21–June 17	20	254	10	4.3	16	.00	68	17	8.3	.05
June 18–July 15	26	342	11	5.0	18	2.3	61	19	7.6	.01
July 16–Aug. 12	27	424	......	4.7	17	.00	63	19	8.0	.03
Aug. 13–Sept. 21	26	514	13	4.1	18	.00	......	16	12	.01
Sept. 22–Nov. 9	28	322	13	4.7	16	.00	62	21	8.7	.01
Nov. 10–Dec. 4	17	283	11	4.2	16	.00	56	19	8.1	.03
Mean	......	316	11	4.4	16	.29	63	17	7.9	.03
Average composition (parts per million)	......	316	35	14	51	.0	200	54	25	.09

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[1] Stabler, Herman, Some stream waters of the western United States: U. S. Geol. Survey Water-Supply Paper 274, p. 57, 1911.

Partial analyses of water from Malheur River near Vale, 1905.

[Parts per million except as otherwise designated.]

Dates.	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Chlorine (Cl).	Suspended matter.	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Solids (tons per day).	
								Suspended matter.	Dissolved solids.
Mar. 26, 27, 28, 29, 30, 31	4	99	13	105	195	6.1	1,230	349	647
Apr. 2, 3, 4, 5, 6, 7	0	99	8	220	162	6.1	1,250	742	546
Apr. 9, 10, 11, 12, 13, 14	0	90	6	96	166	6.0	1,090	282	488
Apr. 17, 18, 20, 21	0	94	10	36	162	5.5	708	69	310
Apr. 23, 24, 25, 29	0	106	9	50	200	5.3	600	81	324
Apr. 26	0	131	32	70	240	5.3	575	109	373
Apr. 30, May 1, 2, 3, 5	0	112	11	34	184	5.1	436	40	217
May 11, 12, 13	6	132	10	78	220	4.5	206	43	117
May 14, 15, 16, 18, 19, 20	0	165	16	26	278	4.3	154	11	115
May 17	0	181	18	30	288	4.3	153	12	118
May 21, 22, 23	6	180	29	6	344	4.2	126	2	117
May 31, June 1, 2, 3	0	169	14	840	252	4.5	250	567	170
June 4, 5, 6, 7, 8, 9, 10	9	149	16	1,670	256	4.8	370	1,670	255
June 11, 12, 13, 15, 16, 17	0	165	14	412	264	4.8	310	345	221
June 18, 19, 20, 21, 22, 23	0	189	29	306	312	4.4	170	141	143
June 25, 26, 27, 28, 29, 30, July 1	0	207	29	52	366	4.2	122	17	120
July 2, 3, 4, 5, 6, 8, 9	0	170	21	30	290	3.9	75	6	78
July 10, 11, 12, 13, 14, 15	9	244	32	72	390	3.6	24	5	25
July 16, 17, 18, 19, 20, 21, 22	7	240	37	90	400	3.7	31	8	33
July 23, 24, 25, 26, 27, 28, 29	9	242	36	24	498	3.6	21	1	28
July 30, 31, Aug. 2, 3, 4, 5	12	229	37	54	436	3.6	19	3	22
Aug. 6, 7, 8, 9, 10, 11, 12	0	279	40	62	442	3.6	16	3	19
Aug. 13, 14, 15, 16, 17, 18, 19	0	292	44	24	462	3.6	12	1	15
Aug. 20, 21, 22, 23, 30, 31, Sept. 1	0	290	40	18	486	3.6	16	1	21
Sept. 3, 6, 7, 8, 9	43	186	42	68	486	3.6	19	3	25
Sept. 10, 11, 17, 18, 19, 20, 21	0	236	35	36	406	3.7	35	3	38
Sept. 22, 23, 24, 25, 26, 27, Oct. 7	15	195	29	48	398	3.8	49	6	53
Oct. 8, 9, 10, 11, 12, 13, 14	0	196	27	18	368	3.9	57	3	57
Oct. 15, 16, 17, 18, 19, 20, 21	0	186	23	20	340	4.0	85	5	78
Oct. 22, 23, 24, Nov. 6, 7, 8, 9	0	178	20	44	318	4.1	105	12	90
Nov. 10, 11, 12, 13, 14, 15, 16	0	166	17	70	254	4.2	115	22	79
Nov. 17, 18, 19, 20,	0	165	21	106	336	4.2	127	36	115
Nov. 26, 27, 30, Dec. 1, 3, 4	0	155	22	10	340	4.3	150	4	138

The water varies greatly in total mineralization and carries much suspended matter. During the period covered by the investigation suspended matter ranged from 6 to 1,670 parts per million. Increases in run-off are generally accompanied by increases in suspended matter and followed by decreases in total mineralization; the data indicate that the relation between discharge and suspended matter is definite, but they are insufficient to determine any mathematical relation. The water is sodic carbonate in type and is hard but can be softened by heating. It is excellent for irrigation.

POWDER RIVER.

GENERAL FEATURES.

Powder River rises in the Blue Mountains, in the western part of Baker County, flows eastward and northward through Baker City to North Powder, then turns toward the southeast and finally discharges into Snake River in the east-central part of Baker County.

Its total drainage area is 1,660 square miles, of which only the headwater regions are forested. The middle and lower valleys are semiarid, and irrigation is necessary for their proper agricultural development. The general elevation of the headwater region is 6,000 feet; the average elevation of the valley is 3,300 feet. Precipitation ranges from 30 inches on the mountains to 15 inches at Baker City and less in the lower valleys. The topography in the upper reaches of the river is rough and broken, but the lower valleys are broad and flat.

Powder River rises among Paleozoic argillites, limestones, and lavas of the Blue Mountains, and flows through later Tertiary lake beds, lavas, and late river deposits in its middle and lower course. North Powder River, its chief tributary, rises among intrusive rocks—granites, granodiorites, gabbros, diabases, and serpentines—and flows through similar igneous and metamorphic rocks to its junction with the Powder.

CHARACTER OF THE WATER.

Samples of water from Powder River were collected by M. B. Fisk, at the gaging station of the United States Geological Survey at Thief Valley, 7 miles east of North Powder. The drainage basin above this point comprises 826 square miles. The water is hard and will produce a little medium or hard scale in boilers. It can be softened by the use of lime or by being heated. It is well suited for irrigation, and this is the chief use to which it will be put in the immediate future.

The following table shows the character of the water of Powder River above the mouth of the North Powder and below Baker City, as determined by the Bureau of Soils of the Department of Agriculture:

Analyses of the water of Powder River.[a]

	Parts per million.		Percentage of anhydrous residue.	
	1	2	1	2
Calcium (Ca)	25	7	1.7	3.5
Magnesium (Mg)	22	11	1.5	5.4
Sodium (Na)	416	54	28.1	26.6
Potassium (K)	14	8	1.0	3.9
Carbonate radicle (CO_3)	11	14	.7	6.9
Bicarbonate radicle (HCO_3)	72	166	2.4	40.4
Sulphate radicle (SO_4)	952	17	64.2	8.4
Chlorine (Cl)	5	10	.3	4.9
Total dissolved solids	1,517	287	....	....

[a] Analyses by A. L. Knisely, U. S. Dept. Agr. Bur. Soils Fifth Rept. Field Oper., p. 1162, 1903.

1. Powder River, 1 mile north of Baker City.
2. Powder River above North Powder; center of sec. 25, T. 6 S., R. 39 E.

Mineral analyses of water from Powder River near North Powder, 1911–12.

[Parts per million except as otherwise designated.]

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
Aug. 11-20	3	5.2	1.73	27	32	0.06	20	8.8	48	0.0	157	36	1.70	12	231	0.71	3.4	0.05	2.1
Aug. 21-30	10	5.0	.50	6	25	.05	21	8.8	39	.0	151	30	1.50	11	213	.69	3.1	.04	1.8
Aug. 31-Sept. 9	5	7.0	1.40	......	26	.11	22	8.9	39	.0	160	27	.56	9.8	216	.67	2.8	.05	1.6
Sept. 10-19	5	4.6	.92	8	25	.05	24	9.2	36	[a] Tr.	162	35	.16	13	231	.79	5.2	.06	3.2
Sept. 20-29	1	5.6	5.60	......	21	.04	27	9.0	42	.0	160	36	.40	12	230	.89	7.7	.12	4.8
Sept. 30-Oct. 9	2	4.2	2.10	10	23	Tr.	29	9.8	43	.0	177	40	.32	13	247	1.00	11.3	.13	7.5
Oct. 10-19	4	7.2	1.80	16	27	.05	30	10	39	.0	166	36	.50	11	234	1.14	16.5	.32	10.4
Oct. 20-29	5	6.4	1.28	8	26	.22	28	9.6	37	.0	155	32	.44	9.5	222	1.17	18	.31	10.8
Oct. 30-Nov. 8	1	2.6	2.6	8	25	.02	25	6.2	29	.0	140	25	.50	7.2	196	1.4	31	.22	16.4
Nov. 9-18	80	240	3.0	......	25	.11	27	6.4	45	.0	166	38	.80	11	249	1.8	80	52	54
Nov. 19-28	30	13	.43	......	26	.02	23	5.8	32	.0	137	28	.88	6.8	197	1.6	45	1.6	24
Nov. 29-Dec. 8	3	4	1.33	8	22	.02	24	5.2	24	.0	126	18	.50	5.8	173	1.7	[b] 35	.4	16
Dec. 9-18	1	4.6	4.60	6	27	.02	22	5.2	27	.0	132	18	.20	5.8	178	1.6	[b] 30	.4	14
Dec. 19-28	1	.0	....	7	26	.10	22	5.2	27	.0	131	22	.22	6.2	177	1.8	[b] 30	.0	14
Dec. 29-Jan. 7	1	1.2	1.20	5	23	.01	25	5.2	24	.0	132	18	.40	6.0	171	1.9	[b] 45	.15	21
Jan. 8-17	3	1.2	.40	6	22	.06	22	4.4	24	.0	118	15	.48	5.8	154	2.4	[b] 50	.15	21
Jan 18-27	2	4.0	2.00	7	24	.10	23	3.8	28	.0	137	19	.40	1.0	176	2.3	[b] 50	.5	24
Jan. 28-Feb. 6	90	158	1.76	20	21	.05	21	3.2	29	.0	137	17	.44	5.8	214	2.1	[b] 50	21.5	29
Feb. 7-16	210	258	1.26	25	27	.06	20	6.3	38	.0	148	27	1.00	6.8	205	2.8	212	153	117
Feb. 17-26	55	59	1.08	......	33	.07	26	6.6	41	.0	178	33	.96	6.8	244	2.9	352	56	232
Feb. 27-Mar. 7	50	62	1.24	20	28	.08	26	7.8	33	.0	151	31	1.30	6.3	220	2.3	192	32	114
Mar. 8-17	90	104	1.16	18	31	.12	30	7.4	42	.0	177	28	.99	7.3	296	2.7	281	79	164
Mar. 18-27	100	133	1.33	40	30	.10	23	7.8	32	.0	139	23	1.5	4.8	190	2.9	354	127	182
Mar. 28-Apr. 6	80	31	.39	30	25	.11	18	4.8	21	[a] 7.2	92	19	.42	2.8	150	3.5	634	53	256
Apr. 7-16	100	157	1.57	42	31	.12	19	5.4	18	.0	92	15	.75	2.0	146	4.3	779	330	307
Apr. 17-26	30	87	2.90	18	22	.16	20	5.8	15	[a] 9.6	84	16	.34	2.0	144	3.5	520	122	202
Apr. 27-May 6	20	32	1.60	22	29	.25	19	5.3	15	[a] 4.8	95	14	.40	3.9	147	3.4	487	42	193
May 7-16	35	55	1.57	40	33	.26	17	4.9	15	.0	90	16	.44	1.3	141	3.4	477	71	181
May 17-26	80	277	3.46	52	32	.04	18	5.5	22	.0	109	11	.60	3.3	160	5.0	1,001	748	432
May 27-June 5	10	23	2.30	53	22	.03	18	5.6	18	.0	93	15	.30	2.8	142	6.0	1,344	83	511
June 6-15	15	18	1.20	39	23	.07	16	5.5	17	.0	94	12	.40	2.3	143	6.7	1,587	77	612
June 16-25	11	20	1.82	32	23	.06	16	4.6	14	[a] Tr.	83	9.7	.22	2.5	128	5.6	1,225	66	423
June 26-July 5	10	16	1.60	39	24	.05	18	5.5	19	.0	104	14	.10	4.6	151	....	[b] 1,023	44	417
July 6-15	15	14	.93	16	19	.04	19	6.1	27	.0	126	19	.32	6.0	160	....	[b] 821	31	355
July 16-25	25	12	.48	16	20	.03	24	6.4	39	[a] 10	132	30	.30	7.5	206	....	[b] 619	20	344
July 26-Aug. 4	50	114	2.28	32	32	.04	26	6.9	43	[a] Tr.	179	26	.20	7.3	243	....	[b] 417	13	274
Aug. 5-14	80	270	3.38	16	30	.02	28	7.8	30	.0	158	23	.40	7.8	220	....	[b] 215	16	128
Mean	35	60	1.74	22	26	.08	23	6.5	[c] 27 [c] 4.1	.0	136	24	.58	6.5	193	....	....	[d] 22,100	[d] 56,400
Percentage of anhydrous residue	......	....	....	......	14.1	[e] .1	12.4	3.5	[c] 14.6 [c] 2.2	36.3	....	13.0	.3	3.5	....	....	....	....	....

[a] Abnormal; computed to HCO_3 for average. [b] Estimated. [c] Sodium and potassium, determined on combined alkali residues. [d] Total annual denudation. [e] Fe_2O_3.

The analyses on page 59 represent water suitable for irrigation. The reported differences in total mineral content and in the relative proportions of the different materials in solution are surprising, as there is little surface inflow between the two points of collection and the soil map indicates no unusual condition in the region. The change from secondary salinity to primary alkalinity between Baker City and North Powder, shown by the analyses, would not be expected, as the river traverses late Tertiary sediments almost entirely throughout this distance. As both samples were received[1] at the laboratory at or about the same time it is improbable that the analyses represent the water at radically different stages. In the absence of other information it may be assumed that the sample of higher content, which is labeled in some of the records of the Bureau of Soils "irrigation water," was really seepage water.

GRANDE RONDE RIVER.

GENERAL FEATURES.

Grande Ronde River rises in the Blue Mountains in the southern part of Union County, Oreg., flows northeastward and joins Snake River near Zindel, Wash. A large part of its drainage area of 3,950 square miles is forested.

The country drained is rugged, and the mountains of the headwater regions are among the highest in the State. From Blue and Wallowa mountains, which lie at an average elevation of 8,000 feet above sea level, the tributary valleys converge to the central Grande Ronde Valley 2,700 feet above sea level. This valley is fertile and produces large amounts of wheat. The principal tributary streams are Joseph Creek, Wallowa River, and Catherine Creek. The river flows for most of its course in a canyon, which at its mouth is about 1,000 feet deep.

Precipitation ranges from about 35 inches in the headwater region to 19 inches at La Grande. The greater part occurs as snowfall, and irrigation is necessary to produce crops other than drought-resistant grains.

The headwaters of the river are in the post-Cambrian intrusives of the Blue Mountains and in Columbia River basalt, and the lower course is entirely through lava rocks.

CHARACTER OF THE WATER.

Samples of water were collected from Grande Ronde River at the lower end of Grande Ronde Valley by John Graham, reader of the Survey gage, at the county highway bridge on the road from Elgin to Wallowa, within the city limits of Elgin, above the mouth of Clark Creek and below the mouth of Indian Creek. The drainage basin above this point comprises 1,350 square miles.

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[1] Personal communication from the Bureau of Soils.

Mineral analyses of water from Grande Ronde River at Elgin, 1911–12.

[Parts per million except as otherwise designated.]

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
Aug. 11–20	10	11	1.10	16	41	0.25	13	3.7	11	0.0	66	4.1	1.6	1.5	114	1.2	24	0.71	7.4
Aug. 21–30	19	23	1.21	16	39	.42	14	4.7	6.8	.0	66	5.6	.52	.50	114	1.1	19	1.18	5.8
Aug. 31–Sept. 9	20	18	.90		35	.20	13	4.4	8.2	.0	64	7.6	1.60	.75	110	1.2	24	1.17	7.1
Sept. 10–19	20	16	.80		32	.12	15	7.0	11	.0	93	4.8	.88	2.0	125	1.3	33	1.42	11.1
Sept. 20–29	20	22	1.05	16	39	.25	15	3.2	14	.0	92	10	.52	3.0	135	1.4	35	2.08	12.6
Sept. 30–Oct. 9	10	13	1.30	9	31	.05	12	5.2	13	.0	76	5.6	.48	2.3	106	1.5	48	1.68	14
Oct. 10–19	10	8.2	.82		38	.10	11	4.4	11	.0	67	5.4	1.0	2.0	97	1.6	72	1.59	19
Oct. 20–29	3	4.0	1.33	7	31	.11	13	3.8	13	.0	71	5.9	.48	2.3	108	1.6	63	.68	18
Oct. 30–Nov. 8																		a 1.60	a 22
Nov. 9–18	5	10	2.00	8	29	.08	12	2.6	12	.0	68	3.8	.40	1.5	100	1.7	97	2.62	26
Nov. 19–28	10	8.8	.88	28	32	.22	11	3.4	12	.0	64	3.8	.60	2.0	104	1.8	115	2.73	32
Nov. 29–Dec. 8	4	7.6	1.90	12	25	.24	16	3.2	11	.0	67	14	.36	1.6	109	1.7	99	2.03	29
Dec. 9–18	3	4.6	1.53	8	26	.20	12	3.5	9.0	.0	60	8.1	Tr.	1.9	94	1.7	96	1.19	24
Dec. 19–28	4	3.2	.80	7	32	.15	11	2.8	11	.0	59	4.6	1.4	5.3	106	1.7	90	.78	26
Dec. 29–Jan. 7	7	6.0	.86		28	.15	9.7	3.0	12	.0	56	6.6		3.0	104	1.8	73	1.18	21
Jan. 8–17	20	32	1.60	66	25	.15	9.0	1.4	8.2	.0	43	5.8	1.3	.85	85	2.6	549	47.26	126
Jan. 18–27	60	73	1.22	60	20	.35	8.8	2.0	8.8	.0	39	5.4	2.4	1.8	78	3.2	980	193	230
Jan. 28–Feb. 6	22	32	1.45	59	33	.16	8.6	3.8	6.3	.0	46	3.6	1.8	1.8	105	3.1	866	75	245
Feb. 7–16	60	82	1.37		29	.14	7.8	3.0	5.2	.0	40	3.1	1.2	1.8	84	3.8	1,716	380	389
Feb. 17–26	50	51	1.02		34	.35	7.3	.80	9.5	.0	45	6.3	2.2	.25	100	4.1	2,236	307	604
Feb. 27–Mar. 7	20	12	.60	24	23	.70	10	1.4	14	b 4.1	45	5.6	.30	1.8	110	3.0	636	20.6	189
Mar. 8–17	40	24	.60	30	29	.38	10	4.0	11	.0	56	7.1	.75	2.5	110	3.1	822	53	242
Mar. 18–27	45	38	.84	40	33	.58	9.4	1.6	10	.0	47	4.4	.54	1.5	107	3.2	981	100	281
Mar. 28–Apr. 6	55	76	1.39	18	30	.60	7.6	1.2	9.0	.0	38	4.3	.45	.50	95	4.9	3,545	727	957
Apr. 7–16	75	71	.95	12	25	.60	6.4	.80	7.9	.0	34	2.5	.90	.25	88	6.4	6,088	1,165	1,446
Apr. 17–26	30	35	1.17	41	31	.55	6.2		11	.0	38	2.6	.18	.50	96	5.1	3,856	364	998
Apr. 27–May 6	35	34	.97	42	26	.55	6.4		8.5	.0	35	2.6	.27	.25	93	6.0	5,430	498	1,363
May 7–16	25	29	1.16	48	22	.25	6.2	.96	7.9	.0	33	4.6	.42	.40	78	6.5	6,430	503	1,353
May 17–26	15	30	2.00	40	26	.20	6.6	.56	4.7	.0	30	3.1	.32	.45	76	6.3	6,070	491	1,245
May 27–June 5																6.3	5,890	a 399	a 1,070
June 6–15																5.4	4,288	a 307	a 894
June 16–25	15	25	1.67	37	27	.18	7.8	.20	6.0	.0	40	3.5	.36	1.1	84	4.7	3,171	214	718
June 26–July 5	10	30	3.00	40	26	.28	8.2	.20	7.2	.0	44	3.5	.30	.85	81	3.7	1,512	122	331
July 6–15	50	32	.64	10	24	.01	8.4	3.0	6.3	.0	48	4.0	.22	1.5	77	2.6	4,874	421	1,013
July 16–25	50	32	.64	10	25	.01	10	3.4	7.2	b 11	30	8.9	.40	1.5	88	2.2	2,656	229	631
July 26–Aug. 4	40	30	.75	12	32	.01	12	4.2	5.4	.0	58	5.9	.24	1.8	103	2.0	1,853	150	515
Aug. 5–14	40	22	.55	24	30	.01	12	4.0	7.7	.0	64	4.1	.34	2.0	101	2.0	1,846	110	503
Mean	27	2	1.18	26	30	.25	10	2.8	c7.8 c2.0	.0	54	5.3	.75	1.6	99			d68,000	d154,100
Percentage of anhydrous residue					34.2	e.4	11.4	3.2	c8.9 c2.3	30.8		6.1	.9	1.8					

a Estimated. b Abnormal; computed to HCO_3 in average. c Sodium and potassium, determined on combined alkali residues. d Total annual denudation. e Fe_2O_3.

The water is used in Grande Ronde Valley chiefly for irrigation, for which it is well suited. It is characterized by temporary hardness only, and the amount of scale deposited by it in boilers will be small. It is nonfoaming and noncorrosive and can be softened by being heated or by the use of small quantities of lime.

Seasonal fluctuations in quality are not great, although the river has a large seasonal variation in discharge. The high turbidity may be partly due to local conditions, as there is much corrosion of the banks at the sampling station during high water. High water is usually accompanied by a high coefficient of fineness and low water by a low coefficient. The cause for the high color of the water is not entirely apparent. The water is siliceous and calcic carbonate and is characterized by primary alkalinity resulting from the igneous character of the rocks of the basin.

WALLOWA RIVER.

General features.—Wallowa River, the principal tributary of Grande Ronde River, rises in Wallowa Lake in the Wallowa Mountains, flows in general northwest, and joins the Grande Ronde near Elgin, Oreg. Its basin comprises 870 square miles of country, much of which is forested. The altitude of Wallowa Lake is approximately 4,340 feet, and the general elevation of the headwaters is 8,000 feet above sea level.

The little that is known of the geology of this region indicates the prevalence of Tertiary and later effusive rocks.

Character of the water.—Samples of water were collected daily from Wallowa River near Elgin from August 1 to 13, 1911, and near Joseph from August 18, 1911, to August 15, 1912. Those collected near Elgin were taken by A. M. Boswell, gage reader, at the United States Geological Survey gaging station in Wallowa Canyon, at Minam post office, just below the mouth of Minam River and 12 miles from Elgin, but the results of the analysis have not been included in this report. The samples collected near Joseph were taken by John Martin, gage reader, at the United States Geological Survey gaging station, about 300 feet below the controlling dam at the outlet of Wallowa Lake and about 1½ miles above Joseph. As the storage afforded by the lake greatly reduces the seasonal variation in the quality of the water, monthly composites were analyzed.

Mineral analyses of water from Wallowa River near Joseph, 1911–12.

[Parts per million except as otherwise designated.]

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium. (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
Aug. 18-31	1	1.2	1.20	1	14	0.01	16	1.3	0.8	0.0	45	7.9	Tr.	0.25	68	2.35	148	0.48	27
Sept. 1-30	1	2.0	2.00		4.1	.11	15	1.3	3.8	.0	53	8.7	0.32	.50	72	2.14	90	.49	17
Oct. 1-31	3	1.1	.37	0	12	Tr.	14	.90	4.5	.0	48	7.1	.42	.60	64	2.09	78	.23	13
Nov. 1-30	1	.3	.30	0	8.6	Tr.	15	.88	3.5	.0	44	7.6	.46	.65	60	2.02	63	.05	10
Dec. 1-31	2	.0		1	7.7	.01	16	1.2	4.6	.0	50	8.7	.12	.20	65	2.0	65	.00	11
Jan. 1-31	1	.6	.60	Tr.	18	.10	16	.70	4.2	.0	46	7.2	.16	.65	62	2.0	57	.09	9.5
Feb. 1-29	Tr.			1	9.6	Tr.	17	.70	3.5	.0	49	8.4	.30	.75	66	2.0	60	Tr.	10.7
Mar. 1-31	Tr.			Tr.	7.3	.01	14	.50	5.5	.0	46	9.5	.12	.25	63	1.9	51	Tr.	8.7
Apr. 1-30	Tr.			3	9.6	.03	15	.04	4.3	[a] Tr.	46	7.2	.22	.50	63	2.1	70	Tr.	12
May 1-31	Tr.			5	8.9	Tr.	16	.04	4.9	.0	48	9.8	.20	.50	66	2.4	180	Tr.	32
June 1-30	Tr.			2	9.0	Tr.	14	.06	6.3	[a] 6.7	31	11	.06	.75	63	3.2	549	Tr.	93
July 1-31	Tr.			Tr.	11	Tr.	14	.10	6.8	.0	46	9.4	.10	.75	63	2.9	385	Tr.	65
Aug. 1-15	Tr.				11	Tr.	13	.10	6.1	.0	44	7.4	.20	1.0	62	2.8	316	Tr.	53
Mean	1			1	10	.02	15	.6	[b]3.8 [b]1.0	.0	47	8.5	.21	.55	64			[c] 33.5	[c]9,790
Percentage of anhydrous residue					15.9	[d].1	23.9	1.0	[b]6.1 [b]1.6	36.7		13.5	.3	.9					

[a] Abnormal; computed to HCO_3 for average.

[b] Sodium and potassium, determined on combined alkali residues.

[c] Total annual denudation.

[d] Fe_2O_3.

The analytical data are of considerable scientific interest, as they indicate that the prevailing opinion regarding the rocks of this region is erroneous, the water not being such as would come from volcanic formations. The water is characterized by secondary salinity, the proportion of calcium being exceptional for a surface water of the Northwest. The ratio of magnesium to calcium is lower than that of any other surface water in the United States whose mineral composition is known to the author and is a ratio that might be found in water draining limestones fairly free from magnesium. In this respect it resembles ground water from Tertiary calcareous formations in Georgia. Sulphate is present in greater quantity than would be expected in drainage from limestone, unless considerable gypsum also were present, and the amount of alkalies in excess of that which can combine with chlorine indicates that the basin contains some secondary rocks.

The water is in many respects similar to that of Thames River at Kew, England, as analyzed by Graham, Miller, and Hofmann.[1] This is remarkable, as the Thames rises in Cretaceous oolitic formations and traverses only Cretaceous and Tertiary and possibly some Jurassic sediments. Its water differs from that of Wallowa River in having a greater preponderance of strong acid radicle over the alkalies, indicating that the formations are more wholly secondary than those in the Wallowa basin. The formations at the headwaters of Wallowa River contain considerable chloride; the water of Thames River derives its alkalies from the country rock, as the small amount of chlorine in it proves that neither cyclic sodium nor solution of common salt from the rocks produces the alkali. The decomposition of silicate rocks probably sets free much of the alkali.

The composition of the water of Wallowa River indicates that in the small part of the basin above Joseph (47 square miles) calcareous sediments are exposed in large amount, and that possibly good deposits of limestone may occur there. The meager information at hand when this investigation was begun indicated that only Tertiary lavas and other volcanic rocks, and no Paleozoic, Triassic, or Jurassic rocks were exposed in the upper basin. The pronounced calcareous nature of the water, however, showed the error of these assumptions, and inquiries sent to mining engineers and others brought forth the following information:[2] A fault extending northwest and southeast, with a throw of 1,000 to 1,500 feet, crosses the Wallowa in the SE. ¼ sec. 29, T. 3 S., R. 45 E. This meets another fault in the southern edge of the SW. ¼ sec. 34, T. 3 S., R. 45 E., which extends southward to Imnaha

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[1] Clarke, F. W., The data of geochemistry: U. S. Geol. Survey Bull. 491, p. 85, 1911.

[2] Personal communication from A. H. Rudd, county surveyor, Joseph, Oreg.; confirmed by personal communication from O. C. Finkelnburg, Baker, Oreg., and by hasty field inspection by Prof. F. Von Eschen in the summer of 1913.

River. A third fault, also extending north and south, meets the one first mentioned in the SW. ¼ sec. 31, T. 1 S., R. 43 E. The area included within these faults contains sedimentary rocks which rest on diorite. Limestone occurs in patches and in places shows a thickness of 500 feet or more. Other minor exposures of calcareous rocks have been found in Wallowa County but not in Wallowa River basin. In places the streams have cut entirely through the limestone, which almost everywhere crowns the ridges.

The analyses indicate that the water is good for domestic use, is nonfoaming and noncorrosive, and will deposit a small amount of soft scale in boilers. Preheating or the addition of a little lime will greatly soften the water. It is very well suited for irrigation and will tend to correct any trouble from black alkali. Land irrigated with it should improve in quality if proper rotation and fertilization is practiced. The quality of the water undergoes little seasonal variation.

UMATILLA RIVER.

GENERAL FEATURES.

Umatilla River rises in the Blue Mountains, in the northeastern corner of Umatilla County, flows generally westward, and discharges into the Columbia at the town of Umatilla. It receives several tributaries above Pendleton, the largest being Wild Horse Creek. Below Pendleton its only important affluent is Butter Creek.

The headwater regions are well forested, but the valley lands are largely treeless prairies. The valley lands are used chiefly for wheat raising, but a 20,000-acre irrigation project completed by the United States Reclamation Service at Hermiston will permit other products to be grown. Rainfall ranges from 30 inches in the Blue Mountains to 9 inches at the mouth.

The drainage basin is completely overlain with the Columbia River basalt, and the rocks of the lower valley are mostly hidden by the sandy products of their decay.

CHARACTER OF THE WATER.

Samples of water were collected daily from Umatilla River at Gibbon during August, 1911; at Yoakum, from August 31, 1911, to August 14, 1912; and at Umatilla from August 1, 1911, to August 14, 1912. The samples at Gibbon were collected by Walter Swart, gage reader, at the gaging station 1 mile below Gibbon, about 1½ miles below the mouth of Meacham Creek, and 2 miles above the mouth of Squaw Creek. As the river at this point is subject to high floods, which greatly shift the channel, sampling was discontinued at the end of one month, and collections were thereafter made at Yoakum by John Doherty and the Bond Ranch Co.'s local representative, the water being taken from the river at the Yoakum highway bridge, 1½ miles east of Yoakum station of the Oregon Railroad & Navigation Co., and 18 miles below Pendleton. A few ditches withdraw water above Yoakum, but practically no return water enters the stream above the gaging station, the basin above which comprises 1,200 square miles. The collections at Umatilla were made by C. A. Holder, gage reader, at the gaging station about 1½ miles above Umatilla, about one-half mile below the diversion dam of the Oregon Land & Water Co.'s canal, and one-fourth mile above the headgate of the Brownell ditch. The drainage basin above this point comprises 2,130 square miles. The entire summer flow of the river is diverted between Yoakum and Umatilla and the summer flow at the latter place represents only return water from irrigation. Several stretches between Echo and the mouth of the river are dry in summer.

As little tributary water reaches the river between Yoakum and Umatilla, a comparison of the composition of the water at the two places gives valuable information regarding the effect of irrigation on the quality of the water. The water at Umatilla is not greatly dissimilar from that at Yoakum during winter. In summer, however, difference in quality is marked. Comparison of the figures representing the percentage composition of the waters minus the silica content shows that though there is little difference in the relative quantity of the basic radicles there is a decided difference in the content of acid radicles. While the water is passing from Yoakum to Umatilla its relative content of carbonate is decreased and its relative content of sulphate is increased. This change seems to indicate a measurable increase in the alkali content of the soils due to the use of the water for irrigation. Yet as the discharge of the river at Umatilla is only slightly less than at Yoakum but the mineral content of its water at Umatilla is almost double that at Yoakum, the alkali content of the soil is actually decreased by irrigation.

It is true of this river, as it is of San Gabriel River, and to a less degree of Santa Ana River, in California,[1] that the greatest effect of irrigation, indicated by the composition of the drainage water, is an increase in total mineral content, changes in character of the water being insignificant compared with the increase in concentration

The water of the Umatilla at Yoakum is well suited for industrial use. Its hardness is not great and is temporary in character. It is nonfoaming and noncorrosive and is excellent for irrigation. At Umatilla the water is twice as concentrated and is not so well suited for use in boilers. Lime is an excellent corrective for either water.

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[1] Van Winkle, Walton, and Eaton, F. M., The quality of California surface waters: U. S. Geol. Survey Water-Supply Paper 237, pp. 98–107, 1910.

Mineral analyses of water from Umatilla River.

[Parts per million except as otherwise designated.]

Near Gibbon.

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
1911.																			
Aug. 1-10	1	4.2	4.20	3	41	0.04	10	1.0	13	0.0	48	7.2	Tr.	4.0	108	0.10	50	0.57	14.6
Aug. 11-20	2	2.4	1.20	2	41	.02	7.4	3.0	12	.0	41	4.1	0.56	4.0	90	.06	44	.29	10.7
Aug. 21-30	5	1.6	.32	......	40	.10	9.2	2.9	10	.0	45	6.7	.52	4.1	100	.05	42	.18	11.3
Mean	3	2.7	1.0	2	41	.05	8.9	2.3	12	.0	45	6.0	.36	4.0	99	......	......	......	......
Percentage of anhydrous residue	......	......	......	......	42.4	[a].1	9.2	2.4	12.4	22.8	......	6.2	.4	4.1	......	......	......	......	......

Near Yoakum.

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
1911-12.																			
Aug. 31-Sept. 9	5	10	2.00	16	40	0.08	25	6.4	18	0.0	104	11	1.1	7.8	161	3.1	36	1.0	16
Sept. 10-19	5	5.2	1.04	2	38	.04	15	5.6	16	.0	82	12	.52	6.8	134	3.3	61	.9	22
Sept. 20-29	2	7.8	3.90	......	32	.12	15	5.0	13	.0	71	7.6	.40	6.0	116	3.2	53	1.1	17
Sept. 30-Oct. 9	12	10	.83	4	30	.02	12	4.8	9.9	.0	63	9.5	.52	5.3	103	3.3	56	1.5	16
Oct. 10-19	10	11	1.10	5	31	.01	11	4.8	12	.0	65	7.9	.52	5.0	101	3.4	71	2.1	19
Oct. 20-29	3	5.8	1.93	8	30	.10	18	4.8	17	.0	100	14	.90	8.1	161	3.4	81	1.3	35
Oct. 30-Nov. 8	2	7.8	3.90	......	32	Tr.	21	6.7	21	.0	110	15	.76	9.3	166	3.4	75	1.6	34
Nov. 9-18	1	7.2	7.20	5	32	.01	10	3.4	12	.0	59	7.0	.60	4.2	101	3.7	128	2.5	35
Nov. 19-28	5	8.4	1.68	8	16	Tr.	5.9	2.3	7.6	.0	45	2.8	.60	3.5	92	4.1	267	6.1	66
Nov. 29-Dec. 8	5	2.4	.48	Tr.	31	.02	10	2.5	11	.0	54	6.9	.40	4.0	98	3.8	162	1.1	43
Dec. 9-18	1	4.0	4.00	......	28	.03	9.8	2.0	9.9	.0	54	5.9	Tr.	3.5	87	3.8	165	1.8	39
Dec. 19-28	5	1.4	.28	1	27	.05	8.8	2.6	11	.0	50	6.1	.36	3.3	93	4.0	208	.8	52
Dec. 29-Jan. 7	7	3.6	.52	......	28	.01	11	2.8	9.3	.0	50	7.6	.20	2.5	90	3.9	197	1.9	48
Jan. 8-17	40	60	1.50	......	30	.12	8.6	2.8	9.5	.0	44	3.8	.40	2.3	95	5.6	1,644	266	422
Jan. 18-27	30	42	1.40	25	23	.10	8.5	2.2	8.8	.0	39	4.0	.52	2.3	85	6.1	1,600	168	317
Jan. 28-Feb. 6	10	21	2.10	25	28	.05	6.2	3.6	6.6	.0	36	4.4	1.5	1.8	81	6.4	1,782	101	389
Feb. 7-16	15	41	2.73	20	28	.03	6.4	3.6	6.3	.0	40	5.4	.90	1.8	85	6.4	1,912	211	516
Feb. 17-26	50	58	1.16	......	29	.01	6.6	.4	8.4	.0	35	4.4	.36	.50	81	6.8	2,240	350	490
Feb. 27-Mar. 7	7	10	1.43	17	33	.25	7.4	1.2	8.7	.0	46	7.1	.51	.50	93	5.3	872	23.5	219
Mar. 8-17	3	4.0	1.33	16	27	.16	9.0	2.8	9.5	.0	42	5.9	.69	1.5	92	5.6	1,045	11.3	259
Mar. 18-27	10	7.4	.74	10	27	.21	8.4	1.8	7.7	.0	42	5.1	.78	1.0	91	5.7	1,168	23.3	288

Mar. 28–Apr. 6	35	25	.71	30	25	.28	6.6	1.8	8.6	.0	37	4.1	1.0	.50	85	7.2	2,669	180	612
Apr. 7–16	40	63	1.57	......	26	.19	6.0	2.0	8.5	.0	35	4.3	.69	1.8	82	7.9	3,729	634	825
Apr. 17–26	20	40	2,00	39	26	.02	5.4	.6	10	.0	35	5.3	.60	.95	78	7.0	2,438	263	513
Apr. 27–May 6	60	84	1.40	44	34	.01	6.8	.3	7.9	.0	35	3.0	.54	.85	82	8.1	3,964	900	878
May 7–16	35	47	1.34	22	16	.24	5.2	1.2	7.7	.0	31	3.0	.45	.25	72	7.8	3,457	438	672
May 17–26	30	37	1.23	20	21	.20	5.6	1.4	7.4	.0	33	3.0	.27	.75	76	6.6	1,935	193	393
May 27–June 5	60	52	.87	21	33	.03	8.0	2.0	6.2	.0	42	2.8	.40	.25	83	6.6	1,955	274	438
June 6–15	80	58	.73	13	29	.11	9.6	1.4	7.6	.0	48	3.8	.32	.90	90	5.3	852	133	207
June 16–25	50	38	.76	20	31	.02	10	2.6	11	.0	53	10	.32	.80	105	4.7	530	54	152
June 26–July 5	30	11	.37	16	36	.02	10	2.8	9.8	.0	57	4.6	.60	2.0	102	3.9	197	5.8	54.2
July 6–15	15	16	1.07	9	30	.01	12	1.8	9.8	*b* 4.3	53	2.5	.40	1.3	99	3.6	116	5.0	31.0
July 16–25	90	86	.96	20	29	.01	12	4.0	13	*b* 6.2	63	4.1	.22	3.5	104	3.6	115	26.7	32.3
July 26–Aug. 4	200	86	.43	......	29	.01	14	5.2	15	*b* 3.1	77	7.6	.24	3.8	124	3.3	65	15.1	21.7
Aug. 5–14	60	45	.75	21	33	.25	15	6.0	14	.0	86	7.2	.18	3.9	126	3.4	81	9.9	27.6
Mean	30	29	1.6	16	29	.08	10	3.0	*c*9.7 *c*1.7	.0	55	6.2	.54	2.9	100	....	....	*d* 44,900	*d* 85,500
Percentage of anhydrous residue	....	....	....	......	32.2	*a*.1	11.1	3.3	*c*10.8 *c*1.9	29.9	....	6.9	.6	3.2	....	....	....	....	....

Near Umatilla.

1911–12.																			
Aug. 11–20	4	5.2	1.30	4	39	0.04	33	11	45	*b* 2.4	170	41	1.8	15	266	2.5	90	1.3	65
Aug. 21–30	10	9.0	.90	......	42	.02	30	9.8	43	.0	163	43	2.0	17	273	2.5	90	2.2	66
Aug. 31–Sept. 9	4	8.0	2.00	......	40	.02	36	14	42	.0	189	42	......	......	294	2.5	97	2.1	77
Sept. 10–19	5	6.4	1.28	......	36	.01	35	14	43	.0	195	35	1.7	16	281	2.5	102	1.8	77
Sept. 20–29	1	4.4	4.40	8	43	.07	34	12	36	.0	174	33	1.4	15	267	2.5	83	1.0	60
Sept. 30–Oct. 9	2	5.2	2.60	3	39	Tr.	33	12	35	.0	176	36	1.1	15	260	2.5	82	1.2	57
																2.5	92	*e* 1.4	*e* 60
Oct. 20–29	1	6.4	6.40	6	35	.01	32	11	33	.0	164	32	1.2	14	243	2.5	95	1.6	62
Oct. 30–Nov. 8	Tr.	5.2	....	......	32	.03	42	9.6	33	*b* Tr.	168	70	1.6	14	261	2.5	95	1.3	67
Nov. 9–18	Tr.	5.0	....	Tr.	33	.02	34	7.2	27	.0	165	30	1.6	13	240	2.6	131	1.8	85
Nov. 19–28	3	10	3.33	......	39	.01	30	7.5	31	*b* 1.2	149	26	1.0	11	225	2.7	173	4.7	105
Nov. 29–Dec. 8	8	8.6	1.08	0	32	.02	29	7.8	27	.0	145	27	1.2	12	218	2.6	115	2.7	68
Dec. 9–18	1	12	*f* 12.00	4	36	.01	31	10	30	.0	154	29	.70	12	229	2.6	111	3.6	69
Dec. 19–28	3	5.2	1.73	4	37	.02	30	8.4	31	.0	161	27	.90	13	231	2.5	90	1.3	56
Dec. 29–Jan. 7	10	13	1.30	3	35	.01	32	7.2	27	.0	142	27	1.1	13	217	2.6	112	3.9	66
Jan. 8–17	90	116	1.29	18	32	.02	17	1.6	21	.0	72	11	12	9.5	138	3.6	1,255	393	468
Jan. 18–27	40	55	1.38	18	30	.18	12	2.9	13	.0	54	8.9	.60	2.5	101	4.0	1,450	215	395
Jan. 28–Feb. 6	10	30	3.00	21	33	.10	8.6	1.0	10	.0	48	5.8	.63	.75	98	4.1	1,597	129	422
Feb. 7–16	30	62	2.07	12	32	.09	8.6	3.6	10	.0	51	6.7	.60	1.0	99	4.1	1,637	274	437
Feb. 8–26	60	77	1.29	31	28	.06	7.2	2.4	9.0	.0	43	8.4	.54	1.5	88	4.4	2,021	420	476
Feb. 27–Mar. 7	10	11	1.10	......	39	.15	15	1.4	15	.0	67	11	.60	1.5	123	3.3	594	18	197
Mar. 8–17	10	15	1.50	6	33	.20	11	2.7	14	.0	62	10	.69	3.0	117	3.5	737	30	231
Mar. 18–27	15	23	1.53	8	34	.15	12	2.2	12	.0	57	8.6	.30	3.5	110	3.5	786	49	232
Mar. 28–Apr. 6	20	68	3.40	16	26	.24	7.6	1.4	8.7	.0	38	6.6	.45	1.8	87	4.5	2,195	403	514
Apr. 7–16	90	64	.71	32	29	.15	7.2	1.6	9.6	.0	46	7.6	.51	2.3	86	5.2	3,344	535	776

a Fe_2O_3.
b Abnormal; computed to HCO_3 for average.
c Sodium and potassium, determined on combined alkali residues.
d Total annual denudation.
e Estimated.
f Omitted from average.

Mineral analyses of water from Umatilla River—Continued.

Near Umatilla—Continued.

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
Apr. 17-26	20	59	2.45	8	29	0.01	8.6	1.5	9.8	0.0	46	6.3	0.56	3.3	95	4.4	2,023	322	520
Apr. 27-May 6	80	113	1.41	16	23	.16	9.4	2.6	7.7	[a] 7.7	30	2.8	.22	2.1	89	5.1	3,261	995	784
May 7-16	40	66	1.65	12	35	.14	12	2.6	13	.0	59	4.9	.30	3.4	116	5.2	3,264	581	1,024
May 17-26	20	16	.80	......	30	.09	11	3.4	12	.0	50	4.9	....	3.4	101	4.3	1,871	81	510
May 27-June 5	30	15	.50	......	35	.09	11	3.6	16	.0	58	6.3	....	2.5	114	4.3	1,882	76	579
June 6-15	95	173	1.82	13	38	.06	18	2.0	19	.0	84	10	.30	7.8	143	3.4	700	327	270
June 16-25	35	70	2.00	16	32	.04	24	5.8	28	.0	116	20	.32	11	188	3.0	418	79	212
June 26-July 5	5	19	3.80	10	29	.06	27	10	44	.0	163	38	.40	18	250	2.6	130	6.7	88
July 6-15	7	22	3.14	12	36	.04	32	9.0	44	.0	167	38	.60	18	268	2.6	119	7.1	86
July 16-25	1,800	772	.43	61	43	.03	33	9.6	44	[a] 8.4	153	34	.60	17	273	2.7	159	331	117
July 26-Aug. 4	290	184	.63	5	41	.10	35	12	39	[a] Tr.	181	38	1.2	18	287	2.6	122	61	94
Aug. 5-14	5	10	2.00	10	34	.08	34	13	38	[a] Tr.	182	39	.36	17	274	2.6	117	3.2	87
Mean	79	59	1.9	13	34	.07	23	6.6	[b] 22 [b] 4.8	.0	116	23	1.2	9.4	188	....	....	[c] 53,000	[c] 94,300
Percentage of anhydrous residue	....	....	....	......	18.8	[d] .1	12.7	3.6	[b] 12.1 [b] 2.6	31.5	....	12.7	.7	5.2	....	....	....	....	....

[a] Abnormal; computed to HCO_3 for average.

[b] Sodium and potassium, determined on combined alkali residues.

[c] Total annual denudation.

[d] Fe_2O_3.

JOHN DAY RIVER.

GENERAL FEATURES.

John Day River rises in the Blue Mountains along the eastern border of Grant County, at an elevation about 16,000 feet above sea level, flows westward to the west edge of Wheeler County, then turns northward and joins the Columbia 28 miles above The Dalles. Its headwaters cover a large area and are divided into North Fork, Middle Fork, Upper John Day River, and South Fork. The total area drained is 7,800 square miles, and only the upper region is forested. The average rainfall is 24 inches at the headwaters and 10 inches at the mouth. The valley lands and uplands require irrigation for the production of crops, and though several projects are contemplated along the stream little irrigation has yet been practiced.

The river heads in the post-Cambrian intrusives and metamorphic Paleozoic rocks of the Blue Mountains and traverses a basin in which the overlying rock is chiefly Columbia River basalt. The river and its tributaries have cut through the lava sheet in most places, and the rocks exposed in the canyon and valley walls are largely the stratified deposits of the John Day formation of Tertiary (Oligocene) age. This formation is usually referred to as a lake deposit, but, as pointed out by Merriam,[1] it is composed largely of tuffs, ashes, and rhyolite flows, with relatively small amounts of sands and gravels. The fossils obtained seem not to indicate a lacustrine origin for the tuffs, ashes, etc., and only in the upper sediments have aquatic fossils other than rodents been obtained. Probably the predominant deposits are partly lacustrine and partly eolian.

CHARACTER OF THE WATER.

Analyses of the water of John Day River near Dayville and at McDonald were made during the period covered by the investigations. Samples were collected daily by K. F. MacRae, gage reader, at the gaging station located at a private wagon bridge on MacRae's ranch, 3 miles above Dayville and 3 miles above the mouth of the South Fork of John Day River. The drainage basin above these points measures 1,000 square miles. The samples were united in monthly composites before analysis. The samples at McDonald were collected by William Murray and Wm. G. McDonald at McDonald ferry and post office, 16 miles above the mouth of the river and half a mile below the mouth of Rock Creek. The drainage basin above this point comprises 7,800 square miles.

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[1] Merriam, J. C., A contribution to the geology of the John Day Basin: Univ. California Dept. Geology Bull., vol. 2, pp. 299-302, 1901.

Mineral analyses of water from John Day River.

[Parts per million except as otherwise designated.]

Near Dayville.

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO₂).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO₃).	Bicarbonate radicle (HCO₃).	Sulphate radicle (SO₄).	Nitrate radicle (NO₃).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
1911-12.																			
Aug. 1-31	4	3.8	0.95	4	38	0.05	40	17	31	0.0	229	17	1.8	3.5	250	-0.36	19	19	13
Sept. 1-30	100	135	1.35	16	40	.14	30	18	26	.0	220	14	.84	3.0	235	-.17	50	19	31.7
Oct. 1-31	60	70	1.16	8	38	.04	22	13	17	.0	156	12	....	1.8	182	+.03	62	12	30.5
Nov. 1-30	70	86	1.23	8	32	.02	19	9.4	15	.0	142	7.9	.48	2.3	163	....	*a* 90	20.9	39.4
Dec. 1-31	20	17	.85	4	33	.05	19	10	16	.0	137	7.6	.20	2.3	155	....	*a* 90	4.1	37.7
Jan. 1-31	240	326	1.36	52	24	.01	21	6.6	15	.0	125	8.7	1.4	1.8	148	1.44	398	351	159
Feb. 1-29	100	218	2.18	42	35	.15	19	10	13	.0	121	8.7	1.6	.75	145	2.5	683	402	267
Mar. 1-31	80	142	1.78	9	34	.03	19	9.4	8.2	*b* Tr.	121	6.3	.56	6.0	144	2.03	517	198	201
Apr. 1-30	200	385	1.92	24	25	.05	18	7.6	8.0	*b* 8.6	84	3.8	.24	1.3	121	3.75	1,184	1,260	387
May 1-31	300	554	1.84	9	32	.05	18	8.8	6.6	.0	100	6.1	.80	.25	130	4.8	1,824	2,730	639
June 1-30	300	532	1.77	64	30	.09	16	5.3	8.5	*b* Tr.	93	4.0	.52	.25	121	3.4	1,067	1,533	349
July 1-31	120	120	1.00	10	39	.05	24	15	14	.0	163	9.9	.50	3.0	191	.95	242	78	125
Aug. 1-15	500	539	1.08	12	33	.10	22	14	14	.0	155	10	.22	2.3	169	.84	214	311	98
Mean	160	241	1.42	20	33	.06	22	11	*c*13 *c*2.1	.0	143	8.9	.76	2.2	166	....	....	*d*198,000	*d* 68,000
Percentage of anhydrous residue	....	....	....	......	20.2	*e*.1	13.5	6.7	*c* 8.0 *c* 1.3	42.9	....	5.5	.5	1.3	....	....	....	....	....

At McDonald.

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO₂).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO₃).	Bicarbonate radicle (HCO₃).	Sulphate radicle (SO₄).	Nitrate radicle (NO₃).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
1911-12.																			
Aug. 11-20	4	4.6	1.15	4	31	0.08	24	14	14	0.0	134	12	1.4	2.8	153	1.14	101	1.3	42
Aug. 21-30	10	3.6	.36	4	20	.01	22	11	14	.0	135	14	.92	2.7	153	1.10	87	.8	36
Aug. 31-Sept. 9	4	11	2.80	......	19	.05	27	12	20	.0	144	12	....	2.8	162	1.22	133	3.9	58
Sept. 10-19	1,400	858	.61	......	25	.14	30	11	35	.0	176	37	4.4	6.0	239	1.47	238	551	154
Sept. 20-29	500	295	.59	24	27	.25	31	11	25	.0	167	20	2.0	4.8	210	1.38	191	152	108
Sept. 30-Oct. 9	430	285	.66	16	30	.22	26	13	25	.0	170	21	1.9	3.8	204	1.60	314	241	173
Oct. 10-19	220	163	.74	19	28	.10	29	12	21	.0	161	15	1.6	3.3	187	1.64	336	148	170
Oct. 20-29	90	60	.66	27	24	.04	25	10	17	.0	140	13	1.2	3.0	170	1.64	336	54	154
Oct. 30-Nov. 8	50	40	.80	16	27	.02	22	10	18	.0	145	12	.90	3.5	167	1.60	310	33	140
Nov. 9-18	80	56	.70	8	27	.22	26	10	17	.0	138	20	1.4	3.3	170	1.77	427	65	196
Nov. 19-28	380	245	.64	65	25	.03	21	0.7	14	.0	113	11	.82	2.6	146	1.99	609	402	240

Nov. 29–Dec. 8	85	56	.66	......	28	.20	23	8.4	15	.0	126	14	.90	3.1	162	1.78	433	65	189
Dec. 9–18	65	11	.17	9	27	.03	23	5.8	16	.0	127	14	.26	2.5	151	1.80	447	13	182
Dec. 19–28	20	38	1.90	8	30	.04	23	8.4	17	.0	129	14	.26	2.7	153	1.78	431	44	178
Dec. 29–Jan. 7	75	51	.68	20	27	.05	24	9.4	18	.0	147	15	.56	2.8	170	1.91	539	74	247
Jan. 8–17	900	407	.45	48	20	.01	21	7.2	19	.0	124	13	......	3.3	153	3.4	2,852	3,130	1,178
Jan. 18–27	700	423	.60	80	22	.02	20	5.6	14	.0	106	11	3.8	2.1	136	3.9	3,494	3,985	1,280
Jan. 28–Feb. 6	225	164	.73	......	29	.03	19	4.4	12	.0	99	7.7	1.7	......	127	4.0	3,586	1,587	1,132
Feb. 7–16	300	268	.89	41	29	.02	16	4.8	11	.0	94	5.6	.80	1.8	122	4.4	4,336	3,135	1,427
Feb. 17–26	200	144	.72	60	34	.18	17	6.0	11	.0	99	6.6	1.4	.5	130	4.6	4,898	1,903	1,719
Feb. 27–Mar. 7	95	89	.94	60	30	.05	19	7.6	13	.0	118	8.1	2.0	2.3	149	3.3	2,264	544	911
Mar. 8–17	100	92	.92	36	32	.03	21	8.0	13	.0	123	8.2	1.3	.5	144	3.4	2,332	578	906
Mar. 18–27	100	170	1.70	25	29	.05	22	8.2	13	.0	116	9.4	.27	2.0	145	3.4	2,397	1,100	939
Mar. 28–Apr. 6	250	266	1.06	41	24	.05	15	5.6	9.8	.0	77	8.7	1.1	2.0	112	5.7	7,630	5,470	2,306
Apr. 7–16	110	129	1.17	30	20	.08	13	4.9	8.8	.0	63	8.4	1.7	1.5	99	6.7	10,512	3,660	2,810
Apr. 17–26	100	96	.96	26	24	.07	16	5.9	9.5	.0	81	7.7	.30	1.5	113	5.7	7,587	1,967	2,315
Apr. 27–May 6	170	212	1.25	14	27	.09	16	5.8	6.1	.0	78	5.9	.32	2.5	116	6.5	10,057	5,720	3,133
May 7–16	210	292	1.39	......	22	.08	16	5.2	13	.0	65	4.0	......	1.5	100	7.3	12,564	9,890	3,389
May 17–26	175	280	1.60	27	18	.06	17	5.2	10	.0	57	3.0	.13	.50	100	6.9	11,201	8,465	3,027
May 27–June 5	240	532	2.22	44	21	Tr.	11	3.0	15	.0	66	13	.54	3.0	93	6.7	10,5721	5,170	2,652
June 6–15	800	149	.19	27	24	.01	13	3.6	6.5	.0	65	8.2	.60	.50	98	5.8	7,810	3,135	2,066
June 16–25	175	312	1.78	25	23	.03	14	4.8	5.7	.0	68	10	.30	3.8	101	4.7	5,056	4,260	1,378
June 26–July 5	90	88	.98	16	23	.04	13	2.8	15	*b* 8.2	61	9.7	.40	1.1	109	3.7	2,838	674	835
July 6–15	35	24	.69	8	22	.01	20	5.6	18	*b* 3.6	104	12	.30	3.3	129	2.9	1,593	103	554
July 16–25	390	148	3.8	13	30	.02	22	7.2	19	.0	123	11	.40	3.1	151	2.2	777	310	317
July 26–Aug. 4	90	88	.98	8	20	.01	15	8.6	19	*b* 12	84	11	.16	5.5	126	1.9	564	134	192
Aug. 5–14	200	125	.62	16	32	.02	23	9.6	18	*b* 6.7	121	13	.20	4.0	163	2.0	660	223	291
Mean	245	180	1.05	27	26	.07	20	7.6	*c* 13 *c* 2.4	.0	114	12	1.1	2.7	144	....	....	*d*759,500	*d*365,000
Percentage of anhydrous residue	....	....	....	......	18.5	*e* .1	14.2	5.4	*c* 9.2 *c* 1.7	39.7	....	8.5	.8	1.9	....	....	....	....	....

a Estimated. *b* Abnormal; computed to HCO_3 for average. *c* Sodium and potassium, determined on combined alkali residues. *d* Total annual denudation. *e* Fe_2O_3.

The water at the mouth is similar in character to that at Dayville. There is a small increase downstream in total mineral content and in proportion of sulphate, but the other differences are insignificant. The water is characterized by primary alkalinity and is siliceous and calcic carbonate in type. It does not show evidence of its contact with sedimentary material, but as the sediments of the basin are only partly lacustrine and as the lake deposits were derived largely from igneous rock, the soluble material in them would be similar in nature to the primary rocks of the region. The water is well suited for irrigation.

DESCHUTES RIVER.

GENERAL FEATURES.

Deschutes River rises in large lakes near the summits of the Cascade Range in Klamath and Crook counties. Its two main branches, East Fork and West Fork, unite near the town of Lava, whence their combined waters flow in general northward, joining the Columbia 15 miles above The Dalles. Crooked, Metolius, Warm Springs, and White rivers are the principal tributaries, and all except Crooked River drain eastern slopes of the Cascades. The general elevation of the headwater region in the Cascade Mountains is 5,000 to 6,000 feet above sea level, and that of the upper portions of Crooked River basin slightly exceeds 4,000 feet. The basin comprises about 9,180 square miles, of which about 2,920 square miles is in Crooked River basin. The headwater regions of the Deschutes and its principal tributaries are forested; the rest of the basin is timberless. Annual precipitation ranges from 100 inches on the summits of the Cascades to 15 inches at Bend, 20 inches in the upper part of Crooked River basin, 9 inches at Prineville, and 11 inches at Warm Springs. The range in temperature is great, but there is sufficient time between last and first frosts to make the region suitable for agriculture. The streams do not as a rule freeze hard in winter, owing to the large proportion of water that enters from springs.

The drainage basin lies entirely within the borders of the Columbia River basalt, which consists of layers of porous lavas interstratified with tuffs and pumiceous sand, and therefore favors seepage and the formation of springs. In fact, direct surface run-off is slight, and, owing to the conserving effect of the percolation, the discharge of middle and lower Deschutes River is remarkably constant.

The upper river flows over the top of the lava, but a short distance below Bend it enters a canyon which, in its lower course, it has excavated to a depth of over 800 feet. The tributary streams have also cut steep-walled canyons, but the plateau has in general the appearance of a gently rolling prairie.

The slight rainfall and the great amount of seepage make the uplands and valleys desert-like in appearance. The soil is fertile, however, and with proper irrigation large tracts can be brought under cultivation. The upper and middle Deschutes Valley is the site of the most important irrigation development of the State. Deschutes River is also remarkable for its many large rapids and falls, which, with its uniform discharge, afford great opportunities for power development.

CHARACTER OF THE WATER.

Sampling stations were maintained on Deschutes River at Bend and at Moody. At the former place Mr. C. A. Stanburrough, engineer of the city pumping plant, furnished daily samples of the river water, which were combined into monthly composites for analysis. The area of the drainage basin above Bend is 1,530 square miles. At Moody, Mr. S. N. Arnold, engineer for a local irrigation project, engaged collectors, who took daily samples from the river at the gaging station of the United States Geological Survey, 1½ miles above the mouth of the river. The basin above this point comprises about 9,180 square miles. These samples were combined in sets of 10 for analysis. The results of the analyses of water from these two stations are shown in the preceding tables.

The water of the Deschutes at Bend is excellent for boiler and laundry use and requires no softening. The water is also well suited for irrigation, and the fertility of the soil of the basin lands and their excellent natural drainage make irrigation projects in this region particularly attractive. There is little pollution of Deschutes River above Bend, and any sewage discharged into the stream becomes very diluted, but the water at Bend is not safe for drinking unless it is first purified. Slow sand filters, covered to prevent freezing, can be used, and sand of suitable quality for them may be obtainable from the pumiceous deposits of the locality.

The water of the river at Moody is more turbid than that at Bend. As rainstorms were frequent during the period of investigation the recorded turbidity of the water is probably higher than the normal, which might be determined by further study. The turbidity indicates with considerable regularity the conditions of precipitation in the drainage basin. A thaw accompanied by rain in the middle of January, 1912, is indicated by a sudden great rise in turbidity. Slight precipitation the later part of February checked the slow decrease in turbidity but was not sufficient to cause noticeable increase of it. In April the effect of another severe rainstorm was registered by a sudden change in turbidity. Little precipitation occurred after that until the later part of July, when there was a storm which apparently caused a marked increase in the turbidity of the water though it had no appreciable effect on the stream flow.

Mineral analyses of water from Deschutes River.

[Parts per million except as otherwise designated.]

At Bend.

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
1911-12.																			
Aug. 1-31	3	2.2	0.73	1	29	0.06	6.2	3.4	8.7	0.0	39	2.5	0.32	1.3	75	1.1	918	5.5	186
Sept. 1-30	1	2.1	2.10	1	27	.05	5.6	2.8	6.5	.0	33	5.4	.24	1.0	66	1.2	1,050	6.0	187
Oct. 1-31	2	3.0	1.50	0	21	.01	6.0	2.3	7.9	.0	37	4.9	.40	1.4	67	1.3	1,130	9.0	205
Nov. 1-30	2	2.4	1.20	2	24	.01	4.2	1.2	8.8	.0	34	2.5	.36	1.3	65	1.5	1,310	8.5	230
Dec. 1-31	2	0.9	.45	1	26	.09	5.9	1.4	8.1	.0	38	1.7	.10	.90	64	1.5	1,260	3.6	218
Jan. 1-31	1	1.0	1.00	2	18	.06	4.4	1.4	7.6	.0	33	3.3	.12	1.2	64	1.2	1,380	3.7	238
Feb. 1-29	Tr.	....	....	6	25	.05	5.2	1.8	7.1	.0	35	3.2	.27	1.3	63	1.5	1,510	Tr.	258
Mar. 1-31	Tr.	....	....	2	24	.02	3.9	1.2	7.4	.0	32	3.7	.09	1.0	64	1.2	1,360	Tr.	235
Apr. 1-30	3	5.3	1.77	1	23	.07	3.8	1.1	8.4	.0	32	4.2	.20	1.2	64	1.3	1,430	20.5	247
May 1-31	Tr.	....	....	8	24	.02	5.0	.7	8.2	[a]2.4	24	4.6	.25	1.0	64	1.5	1,580	Tr.	273
June 1-30	3	5.4	1.80	14	30	.02	5.1	.6	6.9	[a]1.4	33	2.5	.24	.40	72	1.6	1,690	24.7	328
July 1-31	Tr.	....	....	4	22	Tr.	3.6	1.5	7.4	[a]Tr.	33	2.5	.10	1.5	58	1.2	1,310	Tr.	205
Aug. 1-15	5	10	2.00	1	21	.10	7.2	....	12	.0	34	6.6	.10	1.5	76	1.1	1,194	37.2	245
Mean	2	2.5	.96	3	24	.04	5.1	1.6	[b]6.7 [b]1.6	.0	34	3.6	.22	1.2	66	....	....	[c]2,850	[c]85,600
Percentage of anhydrous residue	....	....	....	......	39.3	[d].1	8.3	2.6	[b]11.0 [b]2.6	27.8	....	5.9	.4	2.0	....	....	....	....	....

At Moody.

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
1911-12.																			
Aug. 21-30	25	41	1.64	......	36	0.01	14	4.0	12	0.0	60	8.4	0.24	1.8	100	2.2	4,898	542	1,322
Aug. 31-Sept. 9	60	93	1.55	......	37	.10	9.3	3.6	12	.0	55	6.9	.40	1.0	92	2.2	4,924	1,236	1,223
Sept. 10-19	5	37	7.40	......	33	.05	9.4	4.0	12	.0	55	6.6	.44	2.0	92	2.2	4,950	495	1,228
Sept. 20-29	3	12	4.00	4	27	Tr.	6.9	4.2	6.9	.0	56	6.4	.64	2.3	88	2.2	4,898	161	1,044
Sept. 30-Oct. 9	6	15	2.50	0	27	.02	6.8	4.0	12	.0	55	4.8	.74	1.8	85	2.3	5,080	206	1,166
Oct. 10-19	1	7	7.00	0	30	.01	7.1	4.6	13	.0	58	4.6	.54	2.1	91	2.3	5,080	96	1,249
Oct. 20-29	4	5.6	1.40	0	28	.01	10	3.6	6.8	.0	59	3.3	.40	1.9	88	2.2	4,846	73	1,151
Oct. 30-Nov. 8	4	4.4	1.10	1	23	Tr.	7.0	2.8	12	.0	57	2.3	.30	1.8	88	2.2	4,872	58	1,158
Nov. 9-18	10	28	2.80	2	24	.07	6.2	2.6	12	.0	54	4.6	.50	2.0	90	2.5	5,552	420	1,349
Nov. 19-28	20	30	1.50	2	25	.01	6.6	3.0	11	.0	53	5.6	.60	2.0	87	2.5	5,782	469	1,359
Nov. 29-Dec. 8	Tr.	7.8	....	1	28	.08	7.6	3.1	10	.0	57	5.8	Tr.	1.3	87	2.5	5,540	117	1,286

Dec. 9-18	1	7.6	7.60	4	26	.01	7.8	3.6	13	.0	55	6.6	.30	1.8	90	2.4	5,280	108	1,283
Dec. 19-28	1	5.6	5.60	2	29	.06	7.4	3.2	12	.0	56	6.7	.36	2.3	89	2.4	5,250	79	1,261
Dec. 29-Jan. 7	1	8.0	8.00	1	31	.04	6.7	3.0	12	.0	56	3.8	.30	2.0	86	2.2	4,732	102	1,100
Jan. 8-17	45	27	.60	44	24	.06	6.8	2.6	11	.0	50	2.0	1.1	1.9	78	3.4	9,494	691	1,996
Jan. 18-27	280	146	.52	61	31	.02	11	5.4	9.5	.0	69	5.9	1.5	3.0	105	3.2	8,034	3,166	2,278
Jan. 28-Feb. 6	60	105	1.75	20	26	.02	8.1	4.8	8.7	.0	55	3.6	.90	2.3	87	3.3	8,704	2,289	2,040
Feb. 7-16	80	101	1.26	32	29	.01	9.4	4.5	9.6	.0	60	2.0	1.3	3.3	92	3.5	9,400	2,565	2,332
Feb. 17-26	60	110	1.83	39	29	.01	9.8	2.6	12	.0	56	5.3	1.3	2.5	96	3.9	11,568	3,438	2,999
Feb. 27-Mar. 7	8	26	3.25	5	31	.12	11	.6	11	.0	57	5.1	.39	2.3	95	3.0	7,576	532	1,943
Mar. 8-17	15	12	.80	7	33	.15	8.2	.6	15	.0	56	6.4	.28	1.8	98	2.8	6,862	222	1,816
Mar. 18-27	5	16	3.20	4	32	.05	8.2	1.0	14	.0	54	5.8	.64	1.3	95	2.8	6,608	219	1,693
Mar. 28-Apr. 6	40	72	1.80	9	30	.04	8.5	.6	15	.0	61	7.6	1.0	1.3	96	3.2	8,194	1,592	2,121
Apr. 7-16	80	145	1.81	16	28	.03	8.4	.4	14	.0	57	5.6	.84	2.0	92	3.8	10,916	4,271	2,710
Apr. 17-26	15	29	1.93	......	28	.14	9.2	.8	12	.0	59	2.8	.16	1.5	97	3.4	8,852	694	2,319
Apr. 27-May 6	80	101	1.26	21	23	.04	9.6	1.2	14	[a]11	45	5.1	.10	1.8	96	3.4	9,046	2,123	2,344
May 7-16	45	87	1.94	20	30	.16	10	2.6	7.6	.0	59	4.9	2.9	2.3	117	3.6	9,800	2,301	3,097
May 17-26	15	45	3.00	14	26	.10	8.0	1.8	12	.0	53	4.4	1.6	1.8	92	3.6	9,910	1,204	2,461
May 27-June 5	15	41	2.73	10	14	.02	8.8	.8	11	.0	56	6.1	.34	2.3	79	3.6	9,948	1,101	2,121
June 6-15	30	66	2.20	10	26	.04	8.6	1.9	11	.0	51	4.6	.30	2.3	93	3.3	8,566	1,526	2,151
June 16-25	20	43	2.15	8	22	.10	8.6	1.4	10	.0	52	4.8	.58	2.1	91	3.0	7,500	870	1,842
June 26-July 5	5	6	1.20	10	27	.02	7.2	1.4	10	.0	49	4.8	1.10	2.4	85	2.6	6,086	99	1,397
July 6-15	Tr.	....	....	13	31	.01	7.4	1.7	14	.0	61	4.3	.36	2.5	96	2.6	5,982	....	1,551
July 16-25	50	91	1.82	6	34	.20	7.8	4.2	13	.0	54	3.6	.16	2.9	93	2.6	5,856	1,436	1,494
Mean	32	48	2.72	12	28	.05	8.5	2.7	[b]11 [b]2.0	.0	57	5.0	.66	2.1	92	....	....	[c]370,400	[c]642,900
Percentage of anhydrous residue	....	....	....	......	31.8	[d].1	9.6	3.1	[b]12.5 [b]2.3	31.8	....	5.7	.7	2.4	....	....	....	....	....

[a] Abnormal; computed to HCO_3 in average.

[b] Sodium and potassium, determined on combined alkali residues.

[c] Total annual denudation.

[d] Fe_2O_3.

Much of the suspended matter in the water of the Deschutes at Moody comes from surface wash from Crooked River basin and glaciers in White River basin. The data indicate that much of the effect of the turbidity of White River is masked by the dilution of its water when it is mixed with that of the Deschutes. Crooked River exerts a stronger influence on the water of the Deschutes during spring, when its discharge and its turbidity are high. The effect of this tributary is shown in the analyses of the water at Moody in the continual presence of suspended matter and also, to less extent, in the character of the dissolved constituents.

The water of Deschutes River at Moody is more highly mineralized than that at Bend, the total amount of dissolved matter being 15 to 30 parts per million greater and the proportions of carbonate and calcium somewhat greater. Though these increases can not be directly traced to Crooked River, they are probably due in large part to its influence. The volume of Crooked River below Prineville is augmented by the flow from Opal Springs, which discharge about 150 second-feet. The character of the water of these springs is unknown. The rivers entering the Deschutes below the mouth of Crooked River are probably less highly mineralized and dilute the waters of that river. Were it not for this dilution the water at Moody would probably have an average mineral content between 108 and 110 parts per million.

The water of Deschutes River is siliceous and sodic carbonate. At Bend it is typical of water in a semiarid area flowing from basaltic rocks overlain with pumiceous sand. The water at Moody is somewhat more mixed in type but maintains the general character of a water from lava formations.

CROOKED RIVER.

GENERAL FEATURES.

Crooked River has its source in a number of warm springs near the outlet of a broad valley in the southeastern corner of Crook County. It flows northward for about 20 miles, then, joined by Beaver Creek, it follows a sinuous course westward and empties into the Deschutes below the mouth of Opal Canyon. Its total length is about 125 miles. Its drainage boundaries are well defined except on the southeast, where the uplands merge gradually into the arid undrained region of the Great Sandy Desert of Oregon. The principal tributaries are Bear, Beaver, and Ochocho creeks.

Throughout much of its course the river flows through a narrow valley or canyon. Below Prineville this canyon has been cut to a total depth of about 800 feet. The plateau in which the valley is sunk is a basaltic table-land sloping gradually on the north to the Blue Mountains and on the south to the Pauline Ridge. Several dam sites and natural reservoir sites on the stream can be utilized to conserve flood waters for irrigation.

The principal rocks of the valley are basaltic lavas, tuffs, and unconsolidated sediments of volcanic origin. Tertiary sediments, probably of the John Day formation, are exposed along the tributary Camp Creek. Much of the soil of the basin is composed of the disintegrated lava rocks. It does not show strong alkalinity except in the southern and southeastern parts, where the vegetation indicates the presence of carbonate of soda.

About 20 per cent of the drainage basin is forested. The valley proper contains little timber of value; in the mountain regions, however, are extensive pine forests, almost all of which are included in National forests.

The average annual precipitation at Prineville is 9 inches. It is much greater in the mountain regions and is well distributed throughout the year, but over a large part of the basin the average is probably not more than 6 or 7 inches. Owing to natural decrease of summer flow and also to withdrawals for irrigation, Crooked River and several of its tributaries are dry during much of the summer.

Cattle raising and grain culture are the chief occupations in the valley. Prineville, a town of about 1,000 population, situated about 43 miles from the mouth of the river at the junction of Ochocho Creek, besides being the county seat, is an important trading and agricultural center.

CHARACTER OF THE WATER.

Samples of water for this investigation were collected daily by S. S. Stearns from Crooked River at the gaging station on Stearns's ranch, 5½ miles southeast of Prineville. The drainage basin above this point comprises 1,990 square miles. During 1911 analyses were made of composite samples, each representing one month's collections, but in 1912 analyses of 10-day composite samples were made. One-half of the total discharge of the stream during the period of the investigation occurred in the 50 days from March 28 to May 16, 1912. The flow during August, 1911, was almost nothing. Two periods of sudden increase in discharge occurred, one during a thaw early in January, 1912, and the other following rains in May, 1912, after which the discharge very rapidly decreased. The use of the water of the river for irrigation partly accounts for its very irregular discharge.

The total mineralization of the water varies greatly, ranging from about 100 to almost 400 parts per million. The water is used principally for irrigation, for which it is well suited, but is rather hard for laundry or boiler use. The upper part of the basin contains much material of strongly alkaline nature. As rainfall is deficient rock decay is progressing more rapidly than soil leaching, and consequently the lands of the "high desert" region probably are deteriorating in quality. Much of the dissolved matter in the water of Crooked River is derived from the salts of this region.

Mineral analyses of water from Crooked River near Prineville, 1911–12.

[Parts per million except as otherwise designated.]

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
Aug. 1–31	4	11	2.75	4	35	0.05	29	16	73	9.6	287	29	0.56	18	358	0.26	9.3	0.27	9.0
Sept. 1–30	30	20	.67	20	28	.30	29	17	65	7.2	261	25	.56	18	324	.40	18.1	.98	15.7
Oct. 1–31	20	27	1.35	30	33	.05	31	16	63	Tr.	280	23	.74	20	331	.72	50.8	3.72	46
Nov. 1–30	30	15	.50	6	36	.15	29	12	52	.0	243	20	.40	15	297	.82	66.7	2.70	53
Dec. 1–8	18	8	.44	9	36	.11	28	13	48	.0	234	19	.20	14	279	.79	62	1.35	50
Dec. 9–18	10	26	2.60	7	41	.11	30	13	47	.0	222	16	.18	13	268	1.04	116	8.14	84
Dec. 19–28	25	17	.68	5	45	.12	31	12	48	.0	240	17	.30	14	287	.76	58	2.66	45
Dec. 29–Jan. 7	3	8.4	2.80	4	48	.04	32	13	49	1.2	235	20	.20	14	288	.89	80	1.82	62
Jan. 8–17	200	126	.63	......	38	.05	27	10	37	.0	193	15	......	23	228	1.47	244	83.0	150
Jan. 18–27	550	597	1.08	58	18	.01	23	7.1	26	.0	131	8.2	.60	6.0	172	2.14	514	829	239
Jan. 28–Feb. 6	100	65	.65	32	32	.03	22	10	34	.0	159	16	.40	9.8	202	2.17	475	101	259
Feb. 7–16	463	519	1.13	30	28	.5	20	7.6	27	.0	133	9.2	.44	5.8	169	2.94	819	1,148	374
Feb. 17–26	190	192	1.0	27	29	Tr.	16	4.8	23	4.8	110	12	.12	5.3	158	2.97	787	408	336
Feb. 27–Mar. 7	90	45	.50	15	36	Tr.	22	9.1	26	.0	160	13	.27	7.0	198	1.88	750	92	401
Mar. 8–17	100	60	.60	......	34	.13	21	7.8	27	.0	150	11	.15	5.8	182	1.91	285	46.2	140
Mar. 18–27	100	112	1.12	24	35	.04	22	7.4	27	.0	149	9.2	.20	5.5	179	1.95	305	92.3	147
Mar. 28–Apr. 6	330	477	1.44	40	31	.15	16	5.4	14	.0	92	6.7	.40	1.0	122	3.94	1,236	1,594	407
Apr. 7–16	172	290	1.68	28	28	.02	13	3.6	8.5	.0	73	4.3	.24	.75	103	4.57	1,612	1,264	448
Apr. 17–26	190	202	1.06	42	31	.12	17	5.3	15	.0	100	8.7	.32	1.5	130	3.87	1,184	646	415
Apr. 27–May 6	125	299	2.39	21	30	.10	20	4.8	14	.0	93	4.9	.32	.85	124	4.53	1,578	1,274	528
May 7–16	130	276	2.12	24	29	.02	13	3.2	10	.0	73	6.6	.62	1.0	107	4.71	1,686	1,256	487
May 17–26	50	61	1.24	21	31	.15	18	4.7	14	Tr.	92	11	.29	1.1	127	3.33	893	147	306
May 27–June 5	35	59	1.69	14	39	.04	22	6.8	17	.0	127	8.7	.36	3.0	170	2.99	730	116	335
June 6–15	600	530	.88	29	40	.01	28	7.6	25	.0	169	15	.34	4.3	218	1.95	297	425	175
June 16–25	40	44	1.10	16	42	Tr.	27	12	31	14	177	19	.28	6.5	241	1.28	124	14.7	81
June 26–July 5	15	22	1.47	16	30	.05	34	14	44	12	221	24	.50	10	282	.90	51	3.06	39
July 6–15	6	6.4	1.07	16	36	.08	34	14	57	4.3	257	22	.80	12	308	.89	45	.78	37
July 16–25	120	......	......	10	30	.04	26	13	49	Tr.	240	26	.74	12	287	.66	20	......	15
Aug. 5–14	150	118	.79	18	36	.18	35	15.	62	Tr.	282	21	.24	15	338	.61	16	5.1	15
Mean	110	122	1.26	20	34	.09	26	11	[a] 38 [a] 5.2	1.1	199	17	.42	11	246	......	......	[b] 96,600	[b] 58,400
Percentage of anhydrous residue	......	......	......	......	14.1	[c] .1	10.7	4.5	[a] 15.7 [a] 2.2	41.0	......	7.0	.2	4.5	......	......	......	......	......

[a] Sodium and potassium, determined on combined alkali residues.

[b] Total annual denudation.

[c] Fe_2O_3.

The following analysis of a sample of water from Crooked River below Paulina indicates that the water there is similar in character to that at Prineville:

Mineral analysis of water from Crooked River at bridge near Paulina.

	Parts per million.	Percentage of anhydrous residue.
Silica (SiO_2)	45	19.5
Iron (Fe)	.03	
Calcium (Ca)	32	13.8
Magnesium (Mg)	11	4.7
Sodium and potassium (Na+K)	28	12.1
Carbonate radicle (CO_3)	.0	.0
Bicarbonate radicle (HCO_3)	193	41.1
Sulphate radicle (SO_4)	16	6.9
Chlorine (Cl)	4.5	1.9
Nitrate radicle (NO_3)	.1	
Total dissolved solids	219	
Turbidity	10	
Suspended matter	8.4	

Sample collected Aug. 18, 1912. Analysis by Walton Van Winkle.

WHITE RIVER.

White River has its origin in glaciers on the sides of Mount Hood, flows at first southward, then veers gradually to the east, and finally flows northeastward into Deschutes River below Tygh Valley. The water is used for irrigation and also for power development, and the chief interest centers in the effect of the glacial silt on lands and on water wheels, but as little sediment was held in suspension at the time the sample was collected, the effects of the sediment are not determinable.

The water is calcic and sodic carbonate in type and is in this respect of somewhat unusual character for a water flowing from lavas.

Mineral analysis of water from White River at Tygh Valley dam site.

	Parts per million.	Percentage of anhydrous residue.
Silica (SiO_2)	18	34
Iron (Fe)	.1	.2
Calcium (Ca)	5.8	10.9
Magnesium (Mg)	1.8	3.4
Sodium and potassium (Na+K)	5.4	10.2
Carbonate radicle (CO_3)	.0	.0
Bicarbonate radicle (HCO_3)	31	28.3
Sulphate radicle (SO_4)	5.9	11.1
Chlorine (Cl)	1.0	1.9
Nitrate radicle (NO_3)	Tr.	.0
Total dissolved solids	60	
Color	4	
Suspended matter	34	
Turbidity	19	

Sample collected December, 1911, by Pacific Power & Light Co. Analysis by Walton Van Winkle.

SANDY RIVER.

GENERAL FEATURES.

Sandy River, like White River, has its source in glaciers on the slopes of Mount Hood, but its course is in general northwestward, and it discharges into the Columbia at Troutdale, Oreg. It includes as a tributary Bull Run River, which is of great local importance, as it forms the water supply of the city of Portland. Other tributaries are Salmon River, Little Sandy River, and Zigzag, Camp, and Still creeks. Elevations in the basin range from nearly sea level at the mouth of the Sandy to 11,225 feet at the summit of Mount Hood.

The mean annual precipitation ranges from more than 40 inches near the mouth of the river to 100 inches or more at the higher altitudes. Much of the total precipitation is in the form of snow, but in the foothills there is copious rainfall throughout the winter months. A large part of the basin is forested, and most of the forests are in the Oregon National Forest or the Bull Run Forest Reserve.

CHARACTER OF THE WATER.

Samples of water for this investigation were collected daily from Sandy River by J. T. McIntyre, gage reader, from August 1 to November 28, 1911, and by Glenn McIntyre, gage reader, from December 11, 1911, to August 14, 1912. J. T. McIntyre collected samples from the river at the gaging station at a highway bridge 1 mile below the mouth of Salmon River and 1 mile below Brightwood; and Glenn McIntyre collected samples from the river at the gaging station a short distance above the mouth of the Salmon. Sandy River is a glacial stream and carries large amounts of silt at certain seasons, but the water of Salmon River is at all times clear. It was hoped that the change of station would aid in studying the effects of glacial movement on the quality of the water, but the differences in the results are not so apparent as had been expected.

The analyses show clearly the results of glacial action at the headwaters. Turbidity is slight in winter and spring but great in summer and early autumn. The coefficient of fineness averaged 3.63 and at times reached 12. Samples collected in large wide-mouthed containers would probably have shown even higher coefficients. The coefficient indicates that the water carries coarse sand in suspension, but this is only part of the truth; the suspended matter ranges in size from coarse sand to the finest flour, and although the sand grains settle rapidly in quiescent water the flour remains in suspension for days. The usual period of silt transportation is from late June until late September, but it varies according to climatic conditions at the headwaters.

Mineral analyses of water from Sandy River near Brightwood.

[Parts per million except as otherwise designated.]

Below mouth of Salmon River.

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
1911.																			
Aug. 11-20	85	136	1.60	8	22	0.10	5.1	2.1	6.0	0.0	25	12	Tr.	2.3	62	3.19	362	133	60
Aug. 21-30	90	181	2.01	......	23	.10	4.7	2.7	6.8	.0	23	13	Tr.	2.0	67	3.07	322	150	56
Aug. 31-Sept. 9	140	534	3.81	16	17	.11	8.4	3.1	6.9	.0	23	9.4	......	1.8	65	3.49	402	57.9	71
Sept. 10-19	35	79	2.26	4	21	.12	8.6	2.3	6.9	.0	23	12	0.12	2.8	62	3.83	504	107	84
Sept. 20-29	1	12	12.00	......	20	.13	5.8	2.0	5.4	.0	27	8.6	Tr.	2.5	64	3.67	389	13	67
Sept. 30-Oct. 9	5	48	9.60	3	18	.04	5.2	3.5	5.8	.0	24	8.6	.48	2.0	57	4.61	720	93	111
Oct. 10-19	3	8.4	2.80	6	20	.04	5.0	2.8	6.5	.0	24	9.5	.22	1.8	61	4.21	502	11	83
Oct. 20-29	4	5.8	1.45	4	20	.06	6.0	2.8	8.2	.0	28	10	.54	2.3	66	3.60	376	5.9	67
Oct. 30-Nov. 8	15	......	......	1	19	.10	5.9	1.7	5.0	.0	23	8.0	.50	2.0	60	3.90	660	......	107
Nov. 9-18	5	60	12.00	......	12	.05	3.1	1.2	2.8	.0	13	5.3	.48	1.0	38	5.30	1,720	279	176
Nov. 19-28	10	36	3.60	......	12	.01	5.8	.6	3.9	.0	12	3.5	......	.5	37	4.98	1,816	176	181

Above mouth of Salmon River.

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
1911-12.																			
Dec. 11-18	1	0.0	......	5	16	0.12	3.8	......	5.4	0.0	17	5.4	0.12	1.3	45	2.37	816	0.0	99
Dec. 19-28	1	2.2	2.20	4	15	.13	5.6	0.7	6.6	.0	18	5.8	Tr.	.75	49	2.18	680	4.0	90
Dec. 29-Jan. 7	3	.6	.20	2	17	.02	4.6	.3	4.9	.0	17	8.0	.40	1.0	53	1.74	439	.7	63
Jan. 8-17	5	29	5.80	4	14	.08	3.4	.1	3.7	.0	16	5.6	.20	1.4	37	3.50	2,234	175	222
Jan. 18-27	1	4	4.00	5	13	.04	3.8	.2	3.7	.0	17	7.2	.16	1.3	40	2.91	1,363	14.7	147
Jan. 28-Feb. 6	2	5.7	2.85	1	13	.17	3.2	.2	3.8	.0	13	4.4	.08	.95	37	3.10	1,465	22.5	147
Feb. 7-16	3	5.9	1.97	4	11	.05	3.2	.6	3.3	.0	13	4.3	.12	1.50	33	3.37	1,739	27.7	155
Feb. 17-26	Tr.	1.7	......	12	13	.05	4.7	1.1	3.6	.0	15	5.7	.15	1.50	38	3.17	1,672	7.7	172
Feb. 27-Mar. 7	Tr.	Tr.	......	1	17	.05	5.1	1.2	5.1	.0	18	6.1	.21	1.8	47	2.05	747	Tr.	95
Mar. 8-17	2	1.0	.50	Tr.	18	.06	3.9	.8	4.2	.0	18	6.9	.30	1.8	52	1.69	545	1.5	77
Mar. 18-27	Tr.	Tr.	......	Tr.	15	.05	3.9	.6	4.9	.0	18	4.8	.30	1.7	46	1.77	587	Tr.	73
Mar. 28-Apr. 6	1	2.2	2.20	Tr.	13	.05	3.3	.5	3.7	.0	16	5.4	.18	1.6	44	2.10	775	4.6	92
Apr. 7-16	Tr.	Tr.	......	Tr.	11	.05	3.1	.7	3.8	[a]1.7	11	5.5	.12	1.4	40	2.29	897	Tr.	97
Apr. 17-26	Tr.	Tr.	......	1	14	.05	3.9	.7	5.0	.0	18	6.3	.27	1.5	50	2.01	721	Tr.	98
Apr. 27-May 6	Tr.	Tr.	......	7	15	.02	3.8	1.0	3.9	.0	16	3.8	.16	1.5	39	2.43	986	Tr.	104

[a] Abnormal; computed to HCO_3 in average.

Mineral analyses of water from Sandy River near Brightwood—Continued.

Above mouth of Salmon River—Continued.

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
May 7-16	Tr.	Tr.	....	8	13	0.03	3.2	0.8	4.1	0.0	13	6.4	0.28	1.5	38	2.86	1,318	Tr.	135
May 17-26	Tr.	Tr.	....	8	14	.04	3.1	.6	3.5	.0	13	5.4	.34	1.8	40	2.56	1,077	Tr.	116
May 27-June 5	4	....	....	10	14	.04	4.0	.8	5.9	.0	15	3.5	.25	1.5	40	2.55	1,076	Tr.	116
June 6-15	3	14	4.66	6	13	.04	4.1	.8	4.0	.0	16	5.3	.26	1.5	44	2.23	856	32	101
June 16-25	25	41	1.64	8	14	.06	3.9	1.4	5.5	.0	18	9.5	.18	1.6	47	2.15	805	82	101
June 26-July 5	18	42	2.33	5	18	.05	4.2	1.5	5.0	.0	19	5.8	.20	3.3	49	1.90	658	75	87
July 6-15	6	12	2.00	8	17	.03	4.5	1.4	4.1	.0	18	8.3	.26	2.4	53	1.74	570	18	82
July 16-25	8	46	5.75	9	21	.06	4.7	1.4	3.5	.0	19	7.0	.44	3.1	57	1.59	497	62	71
July 26-Aug. 4	23	51	2.22	6	17	.15	5.7	1.5	3.8	.0	20	8.4	.20	1.3	58	1.43	425	54	67
Aug. 5-14	25	35	1.4	8	19	.25	5.7	1.7	5.4	.0	20	13	.16	2.0	61	1.30	372	35	61
Mean	15	39	3.63	5	16	.07	4.6	1.3	[a]4.2 [a].8	.0	18	7.2	.23	1.7	49	....	....	....	....
Percentage of anhydrous residue	....	....	....	....	35.5	[b].2	10.2	2.9	[a]9.3 [a]1.8	19.8	....	16.0	.5	3.8	....	....	....	....	....

[a] Sodium and potassium, determined on combined alkali residues.

[b] Fe_2O_3.

The water is siliceous and calcic carbonate and sulphate in type, is characterized by little primary alkalinity, and contains an unusual amount of sulphate for a water flowing from lava rocks. Possibly the recent lavas of Mount Hood contain more sulphur than those of the Cascade Range or the Columbia River basalt. The water is soft and not greatly mineralized but might cause corrosion in boilers under some conditions. Sedimentation basins would have to be installed if Sandy River were used for power development, and it is probable that the glacial débris would materially shorten the life of turbines. The water of Sandy River is not so well suited for a municipal supply as that of either of its tributaries, Bull Run and Salmon rivers.

BULL RUN RIVER.

GENERAL FEATURES.

Bull Run River flows from a small lake formed by a morainal dam lying across an upland valley near Mount Hood. The lake discharges through its surface outlet only at high stages, the usual outflow being by seepage through the bowlders of the moraine. The outflowing stream flows northwestward a few miles, then southwestward to its junction with Sandy River. A long, low rise separates this basin from the Mount Hood glaciers, and no glacial water reaches the river. The basin comprises 168 square miles, of which the greater part is heavily forested.

The mean annual precipitation at Bull Run post office, which is 647 feet above sea level and above which there are 96 square miles of the drainage basin, is 76 inches. Much of this falls as snow in winter, but storage in the lake tends to equalize the run-off somewhat and to increase the volume of the low-water flow.

The annual run-off from the drainage basin probably averages more than 100 inches in depth over the area.

The quality of the water of this river is important because the city of Portland diverts water from it near the town of Bull Run through two lines of pipe for a municipal supply. The entire drainage basin above the intake of the pipe lines is included in the Bull Run Forest Reserve, and trespass is prevented by efficient policing. Because of the remoteness of upper Bull Run basin and the ideal sanitary conditions and effective patrol in it, Portland's water supply may be considered primarily pure and above criticism.

CHARACTER OF THE WATER.

Samples of water for analysis were collected daily during the period covered by the investigations through the courtesy of the water board of Portland. The water is always clear, largely because of lake storage and underground flow. It is very slightly mineralized and is not subject to great changes in mineral content, as shown by the following analyses:

Mineral analyses of water from Bull Run River near Bull Run, 1911–12.

[Parts per million except as otherwise designated.]

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
Aug. 1-10	2	1.4	0.70		15	0.02	6.1	1.7				4.1		0.40	45	2.9	134	0.5	16
Aug. 11-20	1	.1	.10	1	13	.05	4.7	1.7	6.4	0.0	20	4.6	Tr.	1.3	41	2.8	122	.03	13
Aug. 21-30	Tr.	.1			15	.02	3.7	1.6	3.9	.0	20	3.9	Tr.	.75	40	2.7	97	.03	11
Aug. 31-Sept. 9	1	2.7	2.70		14	.10	4.4	1.6	4.2	.0	19	3.5	Tr.	.75	40	3.0	184	1.34	20
Sept. 10-19	3	.6	.20		9.8	.10	3.5	1.0	3.3	.0	16	4.8	0.04	1.30	33	3.6	377	.6	34
Sept. 20-29	Tr.	.5			12	.05	3.2	1.3	3.0	.0	16	3.1	.20	1.30	38	3.2	211	.3	22
Sept. 30-Oct. 9	Tr.	1.1		8	7.7	.01	2.9	.76	2.7	.0	11	2.6	.40	1.30	27	3.7	423	1.3	31
Oct. 10-19	Tr.	.0		6	10	Tr.	2.9	.80	3.5	.0	13	3.4	.38	1.30	29	3.7	402	.0	31
Oct. 20-29	Tr.	.0		4	12	.03	2.8	1.0	2.4	.0	12	2.5	1.1	1.4	32	3.1	198	.0	17
Oct. 30-Nov. 8	2	1.0	.50	4	9.4	Tr.	3.0	.70	4.3	.0	13	3.6	.42	1.30	32	4.0	867	2.3	75
Nov. 9-18	3	5.4	1.80	10	8.5	.02	2.1	.42	2.3	.0	9.0	3.5	.94	1.0	26	5.9	2,417	35.2	169
Nov. 19-28	1	.0		8	11	.02	2.5	.60	2.0	.0	11	4.3	.40	.65	29	5.1	1,450	.0	144
Nov. 29-Dec. 8	Tr.			0	8.4	.01	2.3	.34	3.1	.0	11	2.0	.34	.85	25	4.1	616	.0	41
Dec. 9-18	Tr.	.0		4	7.6	.01	2.2	.20	2.4	.0	8.8	4.0	.20	1.0	24	5.1	1,137	.0	77
Dec. 19-28	Tr.	.0		2	5.9	Tr.	2.3	.16	2.6	.0	8.5	3.1	.10	.85	22	4.5	845	.0	50
Dec. 29-Jan. 7	Tr.			1	8.7	.01	2.2	.20	3.7	.0	12	2.6	.32	1.8	27	3.8	422	.0	31
Jan. 8-17	Tr.			Tr.	6.2	.01	2.0	.10	3.5	.0	9.8	3.9	.08	1.3	24		3,743	.0	243
Jan. 18-27	Tr.			Tr.	6.3	.06	1.7	.04	2.9	.0	9.8	1.7	.08	.75	21	4.8	1,183	.0	67
Jan. 28-Feb. 6	Tr.			1	5.9	.13	1.7	.04	2.3	.0	8.5	2.7	.16	.50	22	5.3	1,848	.0	110
Feb. 7-16	Tr.			2	6.4	.02	2.1	.08	2.7	.0	8.1	1.1	.08	2.0	22	5.8	2,212	.0	131
Feb. 17-26	Tr.			7	4.1	.01	1.9	.20	3.3	.0	8.5	2.1	.15	.25	23	5.3	1,799	.0	112
Feb. 27-Mar. 7	Tr.			1	5.8	.01	2.2	.16	3.0	.0	10	3.3	.09	1.0	25	3.7	479	.0	32
Mar. 8-17	Tr.			1	7.6	.01	2.1	.16	3.9	.0	11	3.8	.06	1.3	27	3.4	335	.0	24
Mar. 18-27	Tr.			1	5.1	Tr.	2.1	.14	4.3	.0	11	3.4	.09	1.7	28	3.6	439	.0	33
Mar. 28-Apr. 6	1	5.4	5.40	0	8.0	.01	2.9	.40	6.3	.0	13	2.3	.90	3.5	33	3.9	560	8.2	50
Apr. 7-16	1	5.0	5.00	0	6.6	.01	2.7	.12	3.8	.0	11	2.1	.26	1.8	25	3.9	563	7.6	38
Apr. 17-26	Tr.			10	5.2	.01	2.8	.40	3.8	.0	11	1.9	.20	1.0	22	3.8	502	.0	30
Apr. 27-May 6	Tr.			12	5.8	Tr.	2.4	.10	4.1	.0	10	1.8	.60	2.0	23	4.4	906	.0	56
May 7-16	Tr.			2	5.6	.01	2.5	.10	5.0	.0	11	2.5	.26	2.5	26	4.4	900	.0	63
May 17-26	Tr.			2	16	.06	2.7	.16	3.0	.0	11	5.6	.42	.75	39	4.0	613	.0	65
May 27-June 5	Tr.			4	7.7	.02	2.6	.10	2.6	.0	11	2.3	.28	1.3	27	3.9	884	.0	64
June 6-15	Tr.			5	8.3	.02	2.7	.18	5.3	.0	14	2.1	.72	3.5	31	3.6	434	.0	36
June 16-25	1	1.5	1.50	6	8.6	Tr.	2.5	.70	3.2	.0	12	5.8	.60	1.8	34	3.8	501	2.0	46
June 26-July 5	5			4	12	.06	2.7	.60	1.8	.0	16	1.6	.28	.25	33	3.6	408		36
July 6-15	6			4	12	.11	3.8	.40	3.2	.0	18	3.8	.68	1.8	42	3.2	273		31
July 16-25	7			4	13	.09	2.9	.96	3.6	.0	20	2.8	Tr.	1.3	40	2.9	178		19
Mean	Tr.			3	9.0	.03	2.7	.53	[a]3.1|[a].5	.0	12	3.1	.31	1.3	30			[b]650	[b]21,000
Percentage of anhydrous residue					34.0	[c].1	10.2	2.0	[a]11.7|[a]1.9	22.3		11.7	1.2	4.9					

[a] Sodium and potassium, determined on combined alkali residues.

[b] Total annual denudation.

[c] Fe_2O_3.

The water typically represents surface water flowing over igneous rocks in a heavily forested region of large rainfall. It is characterized by primary alkalinity as a result of its origin among volcanic rocks, and it is alkaline carbonate in type—that is, alkalies are present in excess of alkaline earths—and carbonate comprises more than 72 per cent of the acidic radicles. It is soft and nonscaling. One of the largest laundries in Portland finds it cheaper to buy Bull Run water from the city than to use Willamette River water, which may be obtained without cost, the saving in cost of soap more than counterbalancing the cost of the water. The water will not corrode boilers or pipes as a result of its mineral content, but it may, unless first heated in an open heater, cause corrosion and rusting because of its content of dissolved carbon dioxide and oxygen. Any natural water of great mineral purity is likely to do the same, however, and it is by no means a peculiarity of Bull Run water. The water is very slightly colored and its appearance is exceptionally attractive. The pride of the city in its water supply appears to be amply justified by the facts.

WILLAMETTE RIVER.

GENERAL FEATURES.

Willamette River is formed by three main branches: Middle Fork, which drains the larger area and is therefore considered the continuation of the main stream, rises in a number of lakes in the Cascade Range near Diamond and Maiden peaks, and flows northwest, receiving above Eugene the Coast Fork and below Springfield (near Eugene) McKenzie River. The Coast Fork rises in the Coast and Calapooya ranges and flows north to the junction. The McKenzie rises in the Cascade Mountains on the slopes of Mount Washington and the Three Sisters peaks and flows westward. Below the mouth of the McKenzie the Willamette flows northward through a broad valley to the Columbia, which it enters near Portland.

The basin is roughly rectangular in shape, about 140 miles long, 85 miles in average width, and comprises 11,150 square miles. The nearly level valley floor merges insensibly into rolling uplands which are flanked by steep and rugged mountains. The topographic features indicate that the valley was probably at one time an arm of the ocean and has been raised by uplift to form a river valley. The lower Columbia presents a "drowned" aspect, indicating subsidence, hence it is probable that at least the lower part of the Willamette Valley has been first elevated and then somewhat lowered.

The mountains bordering the basin on the east are volcanic, and the lavas along their western front overlie the Tertiary sediments of the lower hills. The valley proper is covered with Pleistocene and

Recent sediments and river gravels. The Coast Range, which forms the western border, is formed by folds of the Tertiary sediments. The soil of the valley is good, though in many places heavy. Extensive forests cover the higher parts of the basin, much of them in national forest reserves.

Rainfall is abundant on the uplands but moderate in the valley itself. On the Coast Range it is as much as 150 inches and it is nearly 100 inches on the Cascade Range, but in the valley it ranges from 50 inches at the mouth of the river to 40 inches or less at the headwaters. The Calapooya Mountains, which form the southern boundary of the valley, receive 55 to 60 inches of rain annually. Except in the mountains the greater part of the precipitation occurs from September to May. Irrigation must therefore be practiced in the valley to insure the best crop production, but little has been done in this respect up to the present time.

The Willamette receives numerous tributaries. The most important streams joining it from the Coast Range are Longtom, Marys, Luckiamute, Yamhill, and Tualatin rivers; the important tributaries rising in the Cascades are Santiam, Molalla, and Clackamas rivers. Power sites are abundant on the Cascade rivers and along the Willamette itself.

CHARACTER OF THE WATER.

Samples of water were collected daily from Willamette River below the intercounty bridge at Salem by Herbert Savage, from August 10 to December 31, 1910, and at the bridge by A. B. Seely, from August 1, 1911, to August 14, 1912. The drainage basin above Salem comprises 7,520 square miles. The character of the water is shown by the table on pages 89 and 90.

The water is soft and well adapted for use in boilers, for it is noncorrosive and causes the formation of only a little siliceous scale, which experience at steam plants at Salem indicates is not troublesome. The character of the water is determined chiefly by the lava formations at the headwater regions. The water is calcic carbonate, and its slight hardness is chiefly temporary. The samples collected in 1910 contained a greater proportion of alkalies and chloride than those collected in 1911–12, a difference probably due to the fact that, contrary to instructions, the samples in 1910 were collected below the outlet of one of the city sewers and were therefore contaminated to some extent by sewage. The samples collected in 1911–12 were taken from midstream above local sources of contamination, and they were collected early in the morning before heavy traffic across the bridge commenced.

Mineral analyses of water from Willamette River at Salem.

[Parts per million except as otherwise designated.]

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
1910.																		
Aug. 10-19	2	4.7	2.35	......	13	0.01	5.9	2.3	8.3	0.0	37	4.3	0.00	4.8	63	......	......	......
Aug. 20-29	3	8.8	2.93	......	8.9	.02	6.2	2.4	8.8	.0	37	4.0	1.20	5.3	53	......	......	......
Aug. 30-Sept. 8	18	26	1.44	......	12	.02	6.9	2.3	6.2	.0	36	3.0	.30	3.2	54	......	......	......
Sept. 9-18	15	13	.87	......	17	.02	5.6	2.1	6.5	.0	38	2.4	.90	2.8	58	......	......	......
Sept. 19-28	4	4.1	1.02	......	17	.02	6.3	1.9	6.3	.0	31	7.8	.30	4.4	62	......	......	......
Sept. 29-Oct. 8	4	2.6	.65	......	18	.02	7.2	2.0	5.4	.0	32	9.3	.45	3.1	62	......	......	......
Oct. 9-18	8	3.6	.45	......	16	.02	5.7	2.1	6.2	.0	33	5.6	.20	4.0	58	......	......	......
Oct. 19-28	6	3.7	.62	......	16	.01	5.8	2.1	8.4	.0	32	6.8	6.5	6.3	64	......	......	......
Oct. 29-Nov. 7	2	2.0	1.00	......	18	.02	6.6	1.8	7.2	.0	36	4.8	3.5	4.8	64	......	......	......
Nov. 8-17	13	19	1.46	......	4.1	.01	5.6	2.0	6.0	.0	25	9.8	4.0	3.8	57	......	......	......
Nov. 18-27	20	36	1.80	......	16	.23	6.9	1.9	5.2	.0	28	4.6	3.6	3.5	59	......	......	......
Nov. 28-Dec. 7	45	35	.78	......	18	.50	6.3	2.3	6.1	.0	33	8.2	.75	3.2	71	......	......	......
Dec. 8-17	10	17	1.70	......	19	.14	7.8	2.6	6.1	.0	38	7.0	2.00	3.5	72	......	......	......
Dec. 18-27	10	6.2	.62	......	16	.07	6.9	2.4	5.1	.0	33	4.1	Tr.	4.5	63	......	......	......
Dec. 28-31	1	.8	.80	......	10	Tr.	7.2	2.2	4.9	.0	31	3.3	.80	2.4	51	......	......	......
Mean	11	12	1.23	......	15	.07	6.5	2.2	6.4	.0	33	5.7	1.6	4.0	61	......	......	......
Percentage of anhydrous residue	......	......	......	......	26.1	[a].2	11.3	3.8	11.1	27.8	......	9.9	2.8	7.0	......	......	......	......
1911-12.																		
Aug. 11-20	3	1.9	.63	1	18	.03	6.5	1.9	7.9	.0	33	4.0	1.1	3.0	58	4,350	22.3	681
Aug. 21-30	3	2.4	.80	......	17	.08	7.3	2.5	6.5	.0	34	6.5	1.5	3.3	60	3,580	23.2	580
Aug. 31-Sept. 9	3	10	3.33	5	16	.02	6.2	2.8	5.5	.0	33	4.9	.16	1.3	56	5,550	150	840
Sept. 10-19	4	8.0	2.00	......	....	.10	6.7	2.3	5.4	.0	37	5.6	.12	1.8	64	6,338	136	1,090
Sept. 20-29	3	7.6	2.53	......	18	.11	6.2	2.4	4.4	.0	35	6.3	Tr.	2.0	60	5,863	120	950
Sept. 30-Oct. 9	5	7.9	1.58	5	38	.04	4.7	2.2	6.4	.0	31	7.1	.32	2.3	83	7,626	162	1,705
Oct. 10-19	2	4.8	2.40	4	17	.04	5.9	1.8	5.5	.0	33	5.3	.32	2.3	55	6,932	90	1,029
Oct. 20-29	4	3.3	.82	5	19	.02	6.4	1.8	5.7	.0	31	4.8	.40	2.5	56	5,286	47	799
Oct. 30-Nov. 8	2	4.0	2.00	0	16	.01	5.9	2.0	5.1	.0	32	5.1	.40	2.1	56	5,704	62	864
Nov. 9-18	30	68	2.27	22	15	.28	4.5	1.5	3.6	.0	19	5.7	.56	1.4	48	42,330	7,760	5,480
Nov. 19-28	7	16	2.28	16	14	.11	4.1	1.4	3.2	.0	18	4.9	.48	1.7	46	34,420	1,489	4,280
Nov. 29-Dec. 8	6	6.6	1.10	12	15	.12	5.1	1.6	3.6	.0	21	5.3	.32	1.5	50	15,420	275	2,080
Dec. 9-18	10	5.7	.57	16	15	.14	5.0	1.5	4.3	.0	24	4.0	.26	2.0	47	16,670	256	2,115
Dec. 19-28	5	14	2.80	30	17	.13	5.5	1.1	5.3	.0	23	2.8	.20	1.3	53	23,500	889	3,362
Dec. 29-Jan. 7	35	21	.60	18	16	.30	4.5	1.2	4.6	.0	24	1.7	.34	2.3	51	29,830	1,692	4,110

[a] Fe_2O_3.

Mineral analyses of water from Willamette River at Salem—Continued.

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
1912.																		
Jan. 8-17	50	88	1.76	56	9.8	0.23	3.8	0.8	3.9	0.0	18	3.1	0.20	1.6	48	122,060	29,000	15,820
Jan. 18-27	15	33	2.20	52	16	.16	4.7	1.1	4.1	.0	24	2.0	.04	1.8	56	54,630	4,865	8,260
Jan. 28-Feb. 6	12	22	1.83	36	14	.50	4.4	1.1	4.1	.0	21	3.0	.08	1.8	44	52,300	3,100	6,200
Feb. 7-16	12	21	1.75	28	12	.05	3.9	1.4	3.7	.0	22	4.0	.28	1.5	50	47,380	2,680	6,380
Feb. 17-26	30	54	1.80	40	14	.09	3.7	1.0	3.6	.0	21	2.4	.12	1.5	41	73,190	10,650	8,100
Feb. 27-Mar. 7	5	14	2.80	7	17	.25	4.1	.9	4.7	.0	23	2.1	.30	.50	51	33,630	895	3,260
Mar. 8-17	5	23	4.60	9	16	.12	5.5	1.5	2.7	[a]3.6	20	2.8	.30	1.5	49	23,310	1,450	3,080
Mar. 18-27	5	15	3.00	7	14	.17	5.1	1.6	2.9	.0	24	1.6	.30	1.8	45	26,590	1,080	3,230
Mar. 28-Apr. 6	3	9.4	3.14	2	14	.05	5.0	1.6	3.4	[a]6.7	13	2.6	.50	1.8	45	18,670	756	2,260
Apr. 7-16	5	10	2.00	4	15	.02	4.8	1.5	3.3	.0	24	1.6	.37	1.5	44	18,090	487	2,140
Apr. 17-26	2	11	5.50	3	12	.01	5.3	1.6	2.3	.0	27	1.7	.25	1.8	45	15,610	465	1,890
Apr. 27-May 6	10	22	2.20	8	12	.11	4.8	1.2	2.0	.0	23	2.0	.35	1.5	46	28,530	1,694	3,540
May 7-16	2	14	7.00	6	11	.02	4.6	1.2	3.2	[a]3.6	17	1.7	.37	1.5	44	25,690	973	3,060
May 17-26	1	6.8	6.80	1	12	.01	4.4	1.2	2.5	.0	22	1.3	.36	1.3	41	19,250	354	2,138
May 27-June 5	3	15	5.00	4	11	.04	4.6	.2	5.2	.0	20	3.4	.36	1.0	44	26,520	1,070	3,150
June 6-15	1	13	13.00	5	16	.02	4.0	.5	4.5	.0	21	3.4	.36	1.4	45	18,790	660	2,280
June 16-25	2	14	7.00	9	13	.03	4.9	.8	4.4	.0	21	4.4	.30	1.4	46	20,840	790	2,600
June 26-July 5	3	10	3.33	4	16	.02	5.0	.3	5.7	.0	24	4.8	.56	1.3	48	15,510	420	2,050
July 6-15	3	4.8	1.60	......	16	.02	8.0	.1	6.3	.0	31	5.3	.30	4.5	55	11,286	146	1,670
July 16-25	Tr.	....	....	4	16	.02	5.7	1.2	4.6	.0	29	3.3	.28	4.5	52	8,526	0	1,195
July 26-Aug. 4	Tr.	....	....	5	14	.08	7.2	1.9	4.9	.0	32	5.8	.40	2.0	53	7,184	0	1,025
Aug. 5-14	Tr.	....	....	4	14	.06	6.5	1.9	4.2	.0	32	2.4	.30	2.3	51	6,142	0	845
Mean	8	16	3.00	13	15	.10	5.3	1.4	[b]3.8 [b].8	.0	26	3.7	.36	1.9	51	....	[c]737,000	[c]1,126,000
Percentage of anhydrous residue	......	....	....	......	33.0	[d].3	11.7	3.1	[b]8.4 [b]1.8	28.6	....	8.1	.8	4.2	....	....	....	....

[a] Abnormal; computed to HCO_3 for average.

[b] Sodium and potassium, determined on combined alkali residues.

[c] Total annual denudation.

[d] Fe_2O_3.

Willamette River is the source of water supply for many towns along its banks, chief among which are Salem, Eugene, and Albany. As the water is badly contaminated, it must be purified before being forced into the mains. At Eugene, Albany, and Oregon City rapid sand filtration is practiced, and at Salem reliance is placed on the uncertain filtering action of the river sands and hypochlorite treatment at the pumps. The present (1914) supplies of these towns are considered unsatisfactory, and plans have been proposed at different times to furnish mountain water to all the cities in Willamette Valley, but no definite action in this direction has yet been taken.

McKENZIE RIVER.

GENERAL FEATURES.

McKenzie River, the north fork of the Willamette, rises in Clear Lake, at the foot of the Three Sisters in Lane County, Oreg., at an elevation of over 3,250 feet above sea level. It flows generally westward to its junction with Willamette River near Springfield. Its basin is heavily forested, precipitation is copious, and the run-off represents a depth of more than 70 inches of water over the drainage area. Power sites along the river are numerous.

CHARACTER OF THE WATER.

Samples of water for this investigation were collected by Mrs. N. M. Hendricks and Samuel Hasbrouck at the gaging station on the highway bridge at Hendricks Ferry, 11 miles east of Springfield, 3 miles below Waterville, 4 miles above Thurston, and 3 miles above the mouth of Camp Creek. The drainage basin above the sampling point comprises 960 square miles.

The water is of good quality throughout the year and is soft and nearly free from color and suspended matter. It is well suited for use in boilers, causing deposits of only small amounts of soft scale. Alkalies and alkaline earths are present in approximately equal amounts, but on account of difference in reacting values the water must be classed as siliceous and calcic carbonate. Above possible sources of pollution the water would make a very satisfactory municipal supply.

Mineral analyses of water from McKenzie River near Springfield, 1911–12.

[Parts per million except as otherwise designated.]

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
Aug. 11-20	5	2.8	0.56	1	22	0.06	6.0	2.0	8.0	0.0	28	8.7	0.28	1.2	59	1.21	1,690	12.8	269
Aug. 21-30	2	1.6	.80		23	.02	6.8	2.3	6.9	.0	32	4.8	Tr.	1.8	64	1.11	1,592	6.9	275
Aug. 31-Sept. 9	4	5.8	1.45		22	.10	6.6	2.5	6.0	.0	32	4.2	Tr.	1.5	60	1.53	2,079	32.5	336
Sept. 10-19	2	3.2	1.60		22	.07	9.6	1.0	7.2	.0	30	7.7	.12	2.3	56	1.38	1,873	16.2	283
Sept. 20-29	2	7.1	6.55	6	19	.03	5.2	2.3	5.9	.0	35	6.7	Tr.	2.3	60	1.59	2,121	40.6	344
Sept. 30-Oct. 9	3	5.4	1.80	5	20	.02	5.1	2.1	6.1	.0	33	2.6	Tr.	1.8	55	1.57	2,095	35.0	311
Oct. 10-19	1	1.5	1.50	2	18	Tr.	5.5	1.5	5.7	.0	29	3.8	.40	1.8	53	1.42	1,920	7.8	274
Oct. 20-29	1	.0		2	21	.02	4.3	1.3	5.8	.0	31	4.9	.40	1.5	59	1.21	1,691	Tr.	256
Oct. 30-Nov. 8	Tr.	3.0		2	20	.05	4.1	2.4	5.1	.0	29	5.2	.40	1.8	55	1.71	2,468	20.0	366
Nov. 9-18	1	11	11.00	2	16	.07	3.7	1.3	3.8	.0	20	2.9	.46	1.1	43	4.60	8,552	254	992
Nov. 19-28	4			3	16	.20	5.6	.6	4.4	.0	21	4.3	.20	1.0	46	3.66	5,505		684
Nov. 29-Dec. 8	1	.6	.60	3	17	.05	4.1	1.2	4.4	.0	23	4.3	Tr.	1.3	47	2.67	3,586	5.8	490
Dec. 9-18	1	.6	.60	1	17	.40	5.9	1.2	4.6	.0	23	3.3	Tr.	.85	48	2.76	3,783	6.1	491
Dec. 19-28	Tr.	1.3		1	15	.05	5.0	1.2	4.7	.0	23	4.6	.08	.75	46	3.05	4,207	14.7	522
Dec. 29-Jan. 7	4	5.8	1.45	4	16	.06	3.9	1.2	4.7	.0	23	4.3	.10	1.0	46	3.04	4,728	74	587
Jan. 8-17	5	40	8.00	9	12	.09	2.9	.9	3.9	.0	18	3.3	.20	.75	40	6.64	15,204	1,641	1,641
Jan. 18-27	1	3.1	3.10	Tr.	14	Tr.	3.9	.7	4.4	.0	20	4.1	.28	1.0	39	4.53	7,767	64.9	816
Jan. 28-Feb. 6	Tr.			2	14	.17	3.5	.4	3.7	.0	20	2.8	.12	.75	40	4.18	6,866	Tr.	742
Feb. 7-16	3	4.6	1.53	4	13	.11	3.4	.8	3.4	.0	20	3.7	.16	1.3	39	4.54	7,966	99	816
Feb. 17-26	1	5.0	5.00	5	14	.06	4.6	1.0	3.6	.0	21	2.1	.21	1.5	39	5.36	10,547	142	1,110
Feb. 27-Mar. 7	1	2.3	2.30	Tr.	16	.06	3.2	1.6	4.2	.0	21	2.6	.15	.50	45	3.55	5,422	33.6	657
Mar. 8-17	1	2.6	2.60	Tr.	17	.04	3.4	.8	3.9	.0	24	2.6	.24	.75	46	2.96	4,283	30.1	532
Mar. 18-27	Tr.			Tr.	15	.02	3.5	.7	4.7	.0	21	1.9	.18	3.8	44	2.77	3,925	Tr.	466
Mar. 28-Apr. 6	1	3.9	3.90	Tr.	15	.02	3.7	.5	4.4	.0	20	3.5	.09	1.3	45	2.52	3,537	37.2	429
Apr. 7-16	1	.7	.70	Tr.	12	.02	3.5	.6	4.2	.0	18	2.3	.15	.25	43	2.76	3,933	7.4	456
Apr. 17-26	Tr.			Tr.	15	.01	3.8	.7	4.3	.0	22	3.3	.12	1.0	47	2.41	3,376	Tr.	428
Apr. 27-May 6	Tr.			1	14	.03	4.4	.2	4.6	[a] 1.9	16	1.6	.20	1.2	42	3.50	5,387	Tr.	610
May 7-16	1	3.4	3.40	Tr.	17	.01	3.3	.2	5.5	.0	20	3.2	.22	1.0	46	3.71	5,735	52.6	711
May 17-26	Tr.			0	13	.02	3.1	.1	6.3	.0	19	4.1	.26	1.0	41	3.28	4,827	Tr.	534
May 27-June 5	Tr.			Tr.	13	.02	3.3	.3	4.9	.0	19	2.8	.30	1.0	43	4.02	6,500	Tr.	755
June 6-15	1	.6	.60	4	15	.02	3.8	.5	3.5	.0	20	1.3	.32	1.0	43	3.46	5,228	8.5	606
June 16-25	Tr.			5	16	.04	4.1	1.0	4.6	.0	23	3.8	.20	1.3	45	3.09	4,442	Tr.	539
June 26-July 5	Tr.			4	17	Tr.	3.3	1.2	5.4	.0	24	1.4	.20	1.3	49	2.68	3,773	Tr.	499
July 6-15															[b] 51	2.07	2,925	[b] Tr.	[b] 403
July 16-25	Tr.			4	20	.01	3.4	1.3	5.6	.0	28	3.6	.28	1.3	53	1.74	2,525	Tr.	362
July 26-Aug. 4	Tr.			1	19	.08	5.1	1.4	5.2	[a] 2.6	22	3.8	.12	2.0	53	1.54	2,306	Tr.	330
Aug. 5-14	Tr.			1	19	.04	5.1	1.0	6.9	.0	28	5.8	.16	2.0	54	1.35	2,110	Tr.	308
Mean	Tr.			2	17	.06	4.4	1.1	[c]4.1 [c]1.2	.0	24	3.8	.18	1.3	50			[d]26,800	[d]199,600
Percentage of anhydrous residue					37.6	[e] .2	9.7	2.4	[c]9.1 [c]2.7	26.6		8.4	.4	2.9					

[a] Abnormal; computed to HCO_3 in average. [b] Estimated. [c] Sodium and potassium, determined on combined alkali residues. [d] Total annual denudation. [e] Fe_2O_3.

SANTIAM RIVER.

GENERAL FEATURES.

Santiam River rises at the foot of Mount Jefferson and Three Fingered Jack, in the Cascade Range, and flows westward, discharging into Willamette River below Albany. Its upper course is through narrow defiles in the mountains, and its grade is steep, but when it emerges from the foothills it meanders over the plain in a shallow valley. Many power sites exist along the river, and the waters are available for use for power, for irrigation, and possibly for municipal supply.

CHARACTER OF THE WATER.

Samples of water were collected from Santiam River at the Survey gaging station at Mehama, from August 1 to December 18, 1911, by J. W. Irvine, gage reader. The drainage basin above this point comprises 740 square miles. (See p. 94 for analyses.)

The water carries little dissolved mineral matter and is similar in every respect to the waters of Clackamas River and McKenzie River, both of which, as well as the Santiam, head close together on the slopes of the Cascades. Because of this similarity in character the station at Mehama was discontinued December 18, 1911.

BREITENBUSH HOT SPRINGS.

One of the chief tributaries of Santiam River is Breitenbush River, which rises in the Cascades between Olallie Butte and Mount Jefferson and flows southwestward to its junction with the Santiam near Detroit. Breitenbush Hot Springs are situated near this river about 12 miles above Detroit. Their exact elevation is unknown, but it is probably somewhat more than 2,000 feet above sea level.

The valley of the Breitenbush is narrow and the rocks exposed are lavas. Faults at the springs were not observed during field studies but possibly the waters issue from a fault. More than 60 hot springs in three general groups lie along both sides of the stream for almost a third of a mile. A few cold springs, entirely different in character, lie within the limits of the groups, but as they are normal for the region they are unimportant. All the hot springs have nearly the same temperature, and the manner of their grouping suggests a common origin. Curative properties have been ascribed to the various springs, and a crude health resort has been constructed. Many patients take the waters each year, and if the place were more readily accessible it would undoubtedly enjoy a large patronage.

Mineral analyses of water from Santiam River at Mehama, 1911.

[Parts per million except as otherwise designated.]

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
Aug. 1-10	1	1.4	1.40	2	21	0.10	5.7	0.8	7.6	0.0	28	4.3	0.48	1.5	55	2.4	830	3.1	123
Aug. 11-20	3	2.2	.73	2	23	.07	6.0	2.0	5.5	.0	24	5.6	.32	.75	54	2.3	749	4.4	109
Aug. 21-30	3	2.7	.90	......	21	.02	5.3	1.7	4.7	.0	26	4.4	Tr.	1.0	54	2.2	676	4.9	99
Aug. 31-Sept. 9	3	2.2	.73	......	21	.05	6.7	.8	5.8	.0	26	5.6	....	.80	49	2.4	899	5.3	119
Sept. 10-19	2	.0	....	......	....	.01	7.2	1.0	5.3	.0	29	5.4	.28	1.8	59	2.7	1,136	0	181
Sept. 20-29	1	3.8	3.80	Tr.	23	.08	7.5	2.4	5.2	.0	31	5.9	Tr.	1.3	62	2.5	895	9.2	150
Sept. 30-Oct. 9	1	2.5	2.50	6	16	.02	6.3	1.6	5.1	.0	31	6.1	Tr.	1.0	52	2.8	1,213	8.2	170
Oct. 10-19	Tr.	1.9	....	2	15	.02	4.6	1.0	4.5	.0	22	3.0	.26	1.5	43	2.7	1,112	5.7	129
Oct. 20-29	1	1.2	1.20	3	21	.02	4.3	1.2	5.0	.0	26	2.1	.34	1.8	52	2.4	812	2.6	114
Oct. 30-Nov. 8	5	4.3	.86	Tr.	16	.05	5.6	1.3	3.6	.0	22	3.0	.36	.90	46	3.4	2,504	29	311
Nov. 9-18	1	8.7	8.70	1	8.9	.03	3.4	.8	2.4	.0	10	2.3	.42	.65	28	5.9	8,346	196	630
Nov. 19-28	2	1.2	.60	2	8.2	.02	3.4	.9	2.4	.0	15	4.4	.40	.15	33	4.9	5,074	16.4	452
Nov. 29-Dec. 8	2	.7	.35	3	11	.02	3.4	1.2	3.0	.0	17	5.1	.36	.40	37	3.8	2,572	4.9	257
Dec. 9-18	3	1.0	.33	1	10	.02	3.3	.9	3.5	.0	17	5.3	Tr.	.85	33	4.3	3,414	9.2	304
Mean	2	2.4	1.84	2	17	.04	5.2	1.3	[a]3.7 [a]1.1	.0	23	4.5	.25	1.0	47	....	....	....	....
Percentage of anhydrous residue	....	....	....	......	37.7	[b].1	11.5	2.9	[a]8.2 [a]2.4	24.4	....	10.0	.6	2.2	....	....	....	....	....

[a] Sodium and potassium, determined on combined alkali residues.

[b] Fe_2O_3.

In September, 1912, field determinations of the temperature and alkalinity of 23 of the springs were made. Samples of water collected September 27, 1912, from 9 of these hot springs, from 1 cold spring, and from Breitenbush Creek above and below the springs were analyzed conjointly by the writer, N. M. Finkbiner, and S. C. Dinsmore, State chemist of Nevada. The accompanying table gives results of both field and laboratory tests of these samples; the other 14 springs, field tests of which were made but are not reported, furnish water of similar character.

The figures show that the several hot springs are merely separate outflows from a common source. The water is sodic chloride in character, but it contains small amounts of silica, calcium, bicarbonate, and sulphate. Minimum medicinal doses of both sulphate and carbonate might be obtained by drinking about 4 kilograms (about 1 gallon) of the water,[1] but the disagreeable and even nauseating taste of the chloride would make the drinking of that amount in one day a Herculean feat. Any curative properties attributable to the mineral content are certainly psychologic rather than physiologic.

Mineral analyses of the waters at Breitenbush Hot Springs.

[Parts per million except as otherwise designated.]

	1	2	3	4	5	6	7	8	9	10	11	12
Silica (SiO_2)	141	134	142	138	144	141	151	147	142	142	24	24
Iron (Fe)	.85	.10	.17	.20	.10	.10	.80	.10	.05	.27	.70	.01
Calcium (Ca)	99	93	89	90	86	95	93	97	96	93	5.2	4.4
Magnesium (Mg)	1.7	1.5	1.2	1.5	1.5	1.5	1.0	.8	......	1.4	2.4	1.1
Sodium (Na)	735	......	......	......	733	......	......	......	......	734	8.7	6.9
Potassium (K)	41	......	......	......	41	......	......	......	......	41		
Carbonate radicle (CO_3)	.0	.0	.0	.0	.0	.0	.0	.0	......	.0	.0	.0
Bicarbonate radicle (HCO_3)	154	116	128	127	128	141	128	146	......	133	27	24
Sulphate radicle (SO_4)	143	137	138	137	137	135	139	137	133	137	1.2	2.3
Chlorine (Cl)	1,138	1,128	1,135	1,120	1,133	1,115	1,143	1,145	1,120	1,131	2.3	2.0
Nitrate radicle (NO_3)	Tr.	......	......	......	Tr.	......	......	......	......	Tr.	.26	Tr.
Total dissolved solids at 180° C	2,470	2,380	2,408	2,379	2,423	2,384	2,433	2,434	2,396	2,412	67	54
Temperature (°C.)	67	59	73	73.5	73	69	69	83	66	70	13	......

1. Spring flowing from crevice in rock near right bank of creek, at northeast end of group. Flow about "size of wrist."
2. "Arsenic" spring near left bank of creek, about 600 feet southwest of 1. Flow one-half that of 1.
3. Spring 43 feet from 2 and N. 84° E. of 1. Flow same as that of 1.
4. Spring 58 feet N. 87° E. of 2. Flow same as that of 1.
5. Spring 150 feet from 2 and due west. Flow one-fourth size of wrist.
6. Spring 175 feet about N. 95° W. of 4.
7. Spring 150 feet N. 64° W. of 6.
8. Spring at southwest end of group.
9. Spring in main bathhouse; difficult of access.
10. Average of analyses 1 to 9, inclusive.
11. Cold "Iron" spring on right bank of creek, 250 feet above mouth of Mansfield Creek.
12. Composite sample from Breitenbush River.

CLACKAMAS RIVER.

GENERAL FEATURES.

Clackamas River rises at the foot of Olallie Butte in the Cascade Mountains, in the eastern edge of Clackamas County, and flows northwestward to its junction with the Willamette below Oregon City. It affords numerous power sites, two of which are now used to furnish power for the Portland Railway, Light & Power Co. Its use will probably be confined chiefly to power development.

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[1] Dole, R. B., The concentration of mineral water in relation to therapeutic activity: U. S. Geol. Survey Mineral Resources, 1911, pp. 1175-1192, 1912.

Mineral analyses of water from Clackamas River at Cazadero, 1911–12.

[Parts per million except as otherwise designated.]

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
Aug. 11-20	2	0.0	....	1	24	0.02	7.3	2.1	7.6	0.0	38	4.0	Tr.	2.2	64	26	870	0.0	150
Aug. 21-30	2	1.2	0.60	1	19	.06	8.2	2.0	6.9	.0	38	4.9	Tr.	2.8	62	26	845	2.7	141
Aug. 31-Sept. 9	1	2.8	2.80	......	31	.06	7.2	2.2	5.4	.0	32	6.3	.20	2.2	75	26	1,023	7.7	207
Sept. 10-19	1	2.1	2.10	7	19	.02	6.4	2.4	5.6	.0	34	4.9	.20	2.5	58	26	1,130	6.4	177
Sept. 20-29	1	2.0	2.00	5	19	.05	6.0	2.7	6.8	.0	35	6.7	Tr.	2.8	63	26	950	5.1	162
Sept. 30-Oct. 9	3	4.5	1.50	6	20	.06	5.8	1.8	5.1	.0	34	5.4	1.5	2.4	61	26	1,113	1.4	183
Oct. 10-19	1	1.6	1.60	2	20	.01	5.9	2.2	6.5	.0	35	5.4	.48	2.5	60	26	1,006	4.3	162
Oct. 20-29	2	2.0	1.00	4	20	.02	6.4	1.8	5.7	.0	35	5.5	.28	2.7	61	26	855	4.6	141
Oct. 30-Nov. 8	Tr.	4.5	....	2	16	.01	5.7	1.9	4.8	.0	31	3.9	.38	2.6	57	27	1,468	17.8	226
Nov. 9-18	1	3.5	3.50	12	16	.06	4.3	1.3	3.2	.0	21	1.8	.46	1.5	43	29	4,188	39.6	487
Nov. 19-28	Tr.	.0	....	Tr.	16	.07	4.1	1.4	3.5	.0	22	5.6	.48	1.3	46	28	3,155	.0	392
Nov. 29-Dec. 8	1	.0	....	2	14	.02	4.9	1.4	4.6	.0	23	4.4	Tr.	1.3	46	27	1,925	.0	239
Dec. 9-18	1	1.0	1.00	4	15	.05	4.9	1.4	4.9	.0	22	3.8	Tr.	1.1	45	28	2,444	6.6	297
Dec. 19-28	1	1.4	1.40	5	16	.06	5.7	.6	5.0	.0	26	5.2	.08	1.3	49	28	2,480	9.4	328
Dec. 29-Jan. 7	6	5.5	.92	12	16	.14	5.7	.9	4.9	.0	24	2.6	Tr.	1.5	49	27	2,064	30.6	273
Jan. 8-Jan. 17	15	27	1.80	18	13	.12	3.9	1.2	3.8	.0	24	1.6	.08	.75	44	31	8,260	602	982
Jan. 18-27	3	7.0	2.33	5	15	.06	4.3	.7	4.2	.0	20	2.5	.08	1.0	40	30	5,159	97.6	557
Jan. 28-Feb. 6	3	4.2	1.40	3	14	.06	3.9	.7	4.0	.0	21	1.6	.04	.75	39	30	5,333	60.4	561
Feb. 7-16	8	7.7	.95	4	13	.07	3.8	1.0	2.4	.0	18	4.0	.12	1.5	39	31	6,615	137	696
Feb. 17-26	Tr.	....	....	4	13	.03	5.2	.9	4.3	.0	21	3.3	.30	1.0	41	30	5,815	Tr.	643
Feb. 27-Mar. 7	Tr.	....	....	1	16	.04	4.2	1.6	4.3	.0	24	3.2	.15	1.0	47	28	2,660	Tr.	338
Mar. 8-17	2	2.5	1.25	2	19	.05	4.8	1.4	3.9	.0	28	6.1	.15	.50	54	27	1,938	13.1	283
Mar. 18-27	Tr.	....	....	Tr.	15	.05	5.1	.9	6.0	.0	27	2.5	.14	1.0	52	27	2,020	Tr.	284
Mar. 28-Apr. 6	1	3.8	3.80	1	15	.06	4.8	.9	5.3	Tr.	24	3.0	.12	1.3	48	28	2,379	24.4	308
Apr. 7-16	Tr.	....	....	Tr.	18	.03	4.3	1.0	5.5	.0	22	3.0	.30	2.0	51	28	2,783	Tr.	384
Apr. 17-26	1	1.9	1.90	1	14	.05	4.7	.9	6.0	.0	21	3.1	.14	2.3	49	28	2,309	11.9	307
Apr. 27-May 6	1	2.8	2.80	Tr.	14	.01	4.2	.8	4.4	.0	22	1.2	.24	1.3	43	28	3,162	23.9	367
May 7-16	1	4.3	4.30	8	14	.01	4.1	.7	3.5	.0	18	3.0	.26	1.0	40	29	4,379	50.8	473
May 17-26	Tr.	....	....	5	15	.01	4.1	.5	3.7	.0	18	3.5	.26	1.3	39	29	3,816	Tr.	402
May 27-June 5	Tr.	....	....	5	15	.06	4.8	.8	4.7	.0	18	4.3	.24	1.0	40	29	3,965	Tr.	428
June 6-15	Tr.	....	....	4	14	.02	4.4	1.0	4.3	.0	21	4.7	.40	1.5	41	28	2,944	Tr.	326
June 16-25	1	2.2	2.20	5	15	.01	4.3	1.2	4.7	.0	23	3.4	.34	1.9	44	28	2,558	15.2	304
June 26-July 5	1	.50	.50	4	18	.01	5.0	1.3	5.7	.0	26	2.1	.24	1.7	47	27	1,849	2.5	235
July 6-15	3	4.2	1.40	......	16	Tr.	5.9	1.6	2.4	.0	25	3.9	.30	2.4	54	27	1,493	16.9	218
July 16-25	Tr.	....	....	5	18	.01	6.3	1.6	4.1	.0	31	4.9	.28	2.3	58	26	1,272	Tr.	199
July 26-Aug. 4	Tr.	....	....	Tr.	17	.04	6.9	1.9	5.2	.0	33	4.9	.10	2.8	55	26	1,136	Tr.	169
Aug. 5-14	Tr.	....	....	2	18	.07	7.3	1.8	5.0	.0	33	4.0	.24	3.0	58	26	1,042	Tr.	163
Mean	2	2.7	1.87	4	17	.05	5.3	1.4	[a]4.2 [a].8	.0	26	3.9	.23	1.7	50	....	....	[b]11,750	[b]120,300
Percentage of anhydrous residue	......	....	....	......	35.7	[c].2	11.1	2.9	[a]8.8 [a]1.7	27.3	....	8.2	.5	3.6	....	....	....	....	....

[a] Sodium and potassium, determined on combined alkali residues.

[b] Total annual denudation.

[c] Fe_2O_3.

CHARACTER OF THE WATER.

Samples of water for this investigation were collected from Clackamas River through the courtesy of the Portland Railway, Light & Power Co., at its power house at Cazadero. (See analyses, p. 96.)

The run-off of Clackamas River above Cazadero is large, averaging considerably more than 60 inches in depth over the drainage area, which comprises 685 square miles. The average amount of dissolved solids is 50 parts per million, the chief constituents being silica, calcium, and bicarbonate. The water is well suited for use in boilers and for most industrial processes.

COLUMBIA RIVER AT CASCADE LOCKS.

GENERAL FEATURES.

At Cascade Locks, on the Oregon side of Columbia River, 20 miles below The Dalles, the river flows in a deep, narrow gorge cut through the basalts of the Cascade Mountains and over a basalt ledge in a series of rapids known as the Cascades. This gorge is a continuation of that which the river enters at The Dalles and is now worn nearly to base level, the surface of the river at The Dalles at low water being only 45 feet above mean sea level.

The lowest place on Columbia River unaffected by tides is at Cascade Locks, and consequently this is the lowest place where representative samples of water and trustworthy discharge measurements can be obtained, though the current of the river, even near the mouth, is strong enough to prevent the water from becoming saline.

Columbia River receives between Pasco and Cascade Locks the following tributaries, which contribute more than 35 per cent of the total discharge at Cascade Locks: From the west and north, Klickitat River,[1] and White Salmon River; from the east and south, Snake River,[1] Walla Walla River, Umatilla River,[2] Willow Creek, John Day River,[2] Deschutes River,[2] and Hood River.

CHARACTER OF THE WATER.

Samples of water were collected daily from the Columbia in the swift flowing water just above the rapids at Cascade Locks from March 13 to December 31, 1910, and from August 1, 1911, to August 14, 1912, by Val W. Tomkins, inspector at Cascade Locks, through the courtesy of the district engineer of the Engineer Corps, United States Army. The collections were made without interruption in 1910, but could not be made from January 4 to 17, 1912, because

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[1] Studied in connection with a chemical survey of the surface waters of Washington in 1910 and 1911. See Van Winkle, Walton, The quality of the surface waters of Washington: U. S. Geol. Survey Water-Supply Paper 339, 1914.

[2] Studied in connection with the present investigation.

there was no reasonably safe place at which a container could be lowered through the ice to flowing water. The estimates of discharge included in the table of analyses have been computed from those obtained at the gaging station at The Dalles by correcting them for the difference in drainage area. The basin of Columbia River above The Dalles covers 236,800 square miles and above Cascade Locks only 2,600 square miles more.

Columbia River at Cascade Locks is more highly mineralized than at Pasco.[1] The changes in character involve increases in percentages of silica, alkalies, and chloride, and decreases in percentages of alkaline earths and bicarbonate. Most of these changes can be attributed to the influence of Snake River, as the effect of such streams as Umatilla and John Day rivers, which are much more highly mineralized than Columbia River, is unnoticeable on account of their relatively small discharge. The increase in silica content between Pasco and Cascade Locks is probably due to the introduction of larger amounts of this substance by the highly siliceous waters of the tributaries entering between those places.

The water of Columbia River at Cascade Locks is suitable for most industrial uses, as it is low in mineral content and is characterized by temporary hardness and by low permanent hardness. The scale-forming ingredients of the water might be decreased somewhat by preheating or by adding small amounts of lime, but such treatment is unnecessary because the scale that would be deposited is small in amount, soft, and easily removable from boilers. The water might cause corrosion, but trouble from that cause would be slight. The water is excellent for irrigation, for which a large amount will probably be used along the river above The Dalles on the stretches of arid but fertile land, which can be made very productive if it is supplied with water. It will be possible to pump the water onto this land by developing cheap summer power at such places as Celilo on the Columbia, or along the Deschutes.

The average salinity of the water for the period of examination was 89 parts per million. The denudation at Cascade Locks is markedly less than that at Pasco, as might be expected. At Pasco 111 tons per square mile per year are carried out in solution, whereas at Cascade Locks only 70 to 90 tons per square mile are dissolved. Snake River, with a drainage area greater than that of the Columbia at Pasco, carries in solution but 62.6 tons per square mile, and this river entering below Pasco decreases the figure for the Columbia, and the waters that enter from the insoluble lavas and basalts of the lower Columbia basin decrease the figure still further.

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[1] For analyses of the water of Columbia River at Pasco see Van Winkle, Walton, The quality of the surface waters of Washington: U. S. Geol. Survey Water-Supply Paper 339, 1914.

Mineral analyses of water from Columbia River at Cascade Locks.

[Parts per million except as otherwise designated.]

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
1910-11.																		
Feb. 1-10																100,300	[a] 25,000	[a] 60,500
Feb. 11-20																93,300	[a] 50,000	[a] 70,300
Feb. 21-Mar. 2																113,800	[a] 75,000	[a] 80,100
Mar. 3-12																287,700	[a] 100,000	[a] 89,900
Mar. 13-22	70	175	2.50		27	0.25	17	4.2	5.3	[b] 18	32	12	0.12	2.4	108	274,700	129,500	80,200
Mar. 23-Apr. 1	100	184	1.84		23	.18	14	4.3	9.7	.0	55	16	.22	1.8	103	373,200	185,500	103,900
Apr. 2-11	60	75	1.25		19	.09	14	3.9	7.9	.0	59	15	.65	2.0	93	279,200	56,600	70,100
Apr. 12-21	60	74	1.23		17	.05	9.4	4.1	8.7	.0	57	6.6	.45	1.5	85	348,700	69,800	80,000
Apr. 22-May 1	50	77	1.54		14	.05	12	3.1	8.2	.0	48	13	.32	2.0	80	477,900	99,400	103,100
May 2-11	30	81	2.70		10	.04	14	1.9	6.5	.0	60	9.9	.27	1.2	77	521,700	114,000	108,000
May 12-21	30	76	2.53		14	.04	15	2.4	7.9	.0	57	10	.60	.8	62	613,300	125,800	135,800
May 22-31	20	28	1.40		12	.04	15	4.7	6.6	.0	57	9.9	.20	1.0	80	559,500	42,300	120,900
June 1-10	15	36	2.40		14	.05	16	4.8	6.0	.0	60	11	.50	.8	84	523,800	50,800	118,500
June 11-20	9	13	1.44		14	.01	14	4.4	6.0	.0	66	9.4	.00	.6	82	445,100	15,600	98,500
June 21-30	5	8.4	1.68		4.3	.01	16	4.2	4.1	[b] 17	32	11	.20	1.3	71	372,600	8,460	71,300
July 1-10	13	17	1,31		9.4	.02	17	5.6	6.1	.0	70	8.7	.20	.8	81	302,200	13,900	66,100
July 11-20	10	11	1.10		8.8	.01	17	5.2	5.7	.0	70	12	.20	1.0	99	238,100	7,080	63,600
July 21-30	18	21	1.17		11	.02	16	4.5	4.7	.0	70	9.7	.25	1.3	83	216,000	12,200	48,400
July 31-Aug. 9	10	20	2.00		8.8	.02	18	4.4	5.2	.0	68	13	.20	2.5	88	191,800	10,400	45,500
Aug. 10-19	5	11	2.20		7.8	.01	18	4.9	6.6	.0	71	11	.20	1.3	82	161,500	4,800	35,700
Aug. 20-29	20	111	5.55		9.2	.01	17	4.3	5.0	.0	71	9.1	.20	2.3	85	140,700	42,200	32,300
Aug. 30-Sept. 8	28	48	1.71		6.2	Tr.	19	4.0	5.0	.0	73	8.2	1.10	1.4	83	113,800	4,750	25,500
Sept. 9-18	8	20	2.50		12	.13	19	3.4	7.1	.0	73	12	.40	2.3	94	92,850	5,020	23,600
Sept. 19-28	5	4.8	.96		13	.03	19	4.2	11	.0	78	17	1.8	3.0	106	85,430	1,110	24,400
Sept. 29-Oct. 8	21	80	3.81		11	.12	19	4.6	11	.0	79	18	1.0	3.5	104	89,390	19,300	25,100
Oct. 9-18	12	31	2.58		8.8	.01	18	4.3	10	.0	70	14	.00	4.3	92	102,000	8,540	25,300
Oct. 19-28	22	38	1.73		10	.04	17	5.2	7.6	.0	68	14	.98	4.0	94	109,700	11,300	27,600
Oct. 29-Nov. 7	15	50	3.33		10	.01	18	4.8	7.6	.0	76	19	.60	2.0	94	110,900	15,000	28,100
Nov. 8-17	12	34	2.83		12	Tr.	17	4.4	7.7	.0	71	20	.45	2.2	97	121,700	11,200	31,800
Nov. 18-27	30	59	1.97		14	Tr.	16	4.7	8.0	.0	70	15	.65	2.0	94	132,500	21,100	33,600
Nov. 28-Dec. 7	12	25	2.08		11	Tr.	16	4.0	7.2	.0	67	13	.30	2.0	90	134,700	9,100	32,700
Dec. 8-17	20	43	2.15		17	.01	16	3.9	5.7	.0	68	9.4	.20	3.0	97	124,800	14,500	32,600
Dec. 18-27	40	53	1.32		17	Tr.	19	4.0	7.7	.0	72	19	.64	3.0	102	97,670	14,000	26,900
Dec. 28-31	25	46	1.84		14	Tr.	17	4.8	6.8	.0	76	14	Tr.	3.0	80	98,930	12,300	21,300

[a] Estimated.

[b] Abnormal; computed to HCO_3 in average.

Mineral analyses of water from Columbia River at Cascade Locks—Continued.

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO$_2$).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO$_3$).	Bicarbonate radicle (HCO$_3$).	Sulphate radicle (SO$_4$).	Nitrate radicle (NO$_3$).	Chlorine (Cl).	Dissolved solids.	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
1911.																		
Jan. 1-10																	a 10,000	a 31,000
Jan. 11-20																	a 8,000	a 40,900
Jan. 20-30																	a 6,000	a 50,700
Mean	26	52	2.09		13	0.04	16	4.2	7.1	0.0	67	13	0.43	2.0	89		b14,095,600	b21,638,000
Percentage of anhydrous residue					14.6	c .1	18.0	4.7	8.0	37.2		14.6	.5	2.3				
1911-12.																		
Aug. 11-20	12	19	1.60	2	23	.06	19	4.5	9.3	.0	76	10	1.4	1.0	103	187,419	9,614	52,120
Aug. 21-30	5	11	2.20	1	9.4	.03	18	3.3	9.5	.0	73	13	.56	1.7	88	147,235	4,380	35,050
Aug. 31-Sept. 9	12	18	1.50		10	1.10	20	5.0	6.0	.0	70	13	.56	1.8	91	129,529	6,300	30,780
Sept. 10-19	10	29	2.90		10	.01	17	5.8	6.3	.0	71	9.5	.36	2.0	89	125,161	9,820	30,100
Sept. 20-29	5	32	6.40		10	.05	20	4.9	8.2	.0	74	15	.44	2.3	95	108,720	9,380	27,800
Sept. 30-Oct. 9	5	11	2.20	Tr.	12	Tr.	20	6.4	9.5	.0	79	17	.52	3.0	113	93,170	2,760	28,400
Oct. 10-19	12	34	2.83	Tr.	16	.01	16	5.0	9.6	.0	67	13	.44	2.8	87	85,571	7,850	20,100
Oct. 20-29	10	38	3.80	2	14	Tr.	21	5.6	11	.0	88	7.3	.56	5.0	114	81,808	8,400	25,200
Oct. 30-Nov. 8	25	39	1.56	0	9.2	.02	21	6.4	7.9	.0	84	13	.60	4.8	115	74,710	7,860	23,200
Nov. 9-18	40	120	3.00	0	13	Tr.	19	5.3	11	.0	81	15	.66	4.4	111	78,765	25,500	23,600
Nov. 19-28	20	40	2.00	0	14	.02	19	5.0	10	.0	77	14	1.2	4.9	108	86,640	9,360	25,200
Nov. 29-Dec. 8	10	6.4	.64	2	13	Tr.	19	6.7	8.4	.0	71	17	.78	4.0	109	75,587	13,100	22,300
Dec. 9-18	4	d 57	e 14.25	3	15	.01	18	4.6	10	.0	79	13	.60	4.0	107	71,902	11,050	20,750
Dec. 19-28	4	28	7.00	2	16	.02	19	4.4	11	.0	84	16	.32	4.3	116	70,255	5,300	21,900
Dec. 29-Jan. 3	5	11	2.20	1	15	.03	22	4.4	12	.0	82	16	.14	5.2	119	60,603	1,800	19,450
Jan. 4-17																72,633	f 1,950	f 21,500
Jan. 18-27	80	78	.98	17	18	.06	17	4.4	10	.0	71	11	.56	4.0	102	93,329	1,960	25,610
Jan. 28-Feb. 6	100	155	1.55	25	19	.11	14	3.6	11	.0	61	9.4	.52	3.3	129	196,789	82,500	68,600
Feb. 7-16	45	64	1.42	16	20	.01	15	6.2	6.1	.0	64	10	.48	3.8	99	110,293	19,050	29,620
Feb. 17-26	60	58	.97	60	21	Tr.	13	4.0	9.8	.0	60	9.1	.69	3.8	104	133,810	20,900	37,550
Feb. 27-Mar. 7	30	66	2.20	15	20	.06	15	3.6	11	.0	70	13	.90	3.5	107	91,251	16,250	26,300
Mar. 8-17	20	38	1.90	7	20	.03	18	3.9	13	.0	79	14	.45	4.5	117	78,761	8,060	24,800
Mar. 18-27	20	22	1.10	8	19	.05	19	4.0	12	g 2.4	74	11	.30	9.8	115	80,570	4,790	25,000
Mar. 28-Apr. 6	50	52	1.04	25	22	.35	17	3.8	11	Tr.	74	11	.94	5.0	116	118,150	16,600	37,100
Apr. 7-16	80	65	.81	40	18	.18	14	2.6	8.5	g 7.2	44	8.2	.30	3.0	90	190,495	33,400	46,200
Apr. 17-26	40	41	1.02	16	15	.16	14	2.4	8.2	.0	57	8.9	.24	2.3	89	200,755	22,200	48,100
Apr. 27-May 6	45	44	.98	20	15	.12	14	2.4	6.3	.0	51	5.4	.27	2.3	80	246,561	29,300	53,300
May 7-16	50	34	.68	9	9.2	.10	16	3.0	9.1	g 6.5	42	11	.24	2.4	79	324,073	29,800	69,200
May 17-26	25	31	1.24	10	12	.12	15	2.4	6.9	.0	50	8.6	.26	1.9	75	517,870	43,400	104,900
May 27-June 5	20	22	1.10	9	14	.07	15	2.5	7.9	.0	53	9.9	.27	2.0	76	610,266	36,200	125,000
June 6-15	15	32	2.11	12	10	.10	14	1.8	4.7	.0	50	7.6	.28	1.0	68	624,854	53,900	114,000

June 16-25	20	25	1.25	8	11	.13	17	1.3	4.4	Tr.	57	8.6	.32	1.4	74	573,314	38,600	114,200
June 26-July 5	11	20	1.82	5	7.8	.05	17	2.8	6.5	[g]2.9	54	7.9	.30	1.2	72	519,810	28,000	103,500
July 6-15	10	26	2.60	5	8.0	.06	18	2.3	6.9	.0	65	12	.20	1.6	83	374,009	26,200	83,800
July 16-25	10	20	2.00	5	13	.05	19	2.2	6.3	.0	65	9.4	.28	1.6	82	275,672	14,300	58,600
July 26-Aug. 4	25	29	1.16	15	4.8	.03	18	2.0	6.9	.0	65	10	.24	2.5	80	223,503	17,500	48,200
Aug. 5-14	50	57	1.14	13	7.2	.04	19	2.6	13	.0	72	17	.16	2.3	93	196,649	30,300	49,400
Mean	27	40	1.97	11	14	.06	17	3.9	[h]7.5 [h]1.8	.0	69	12	.48	3.2	97		[b]7,000,000	[b]17,000,000
Percentage of anhydrous residue					14.9	[c].1	18.1	4.1	[h]8.0 [h]1.9	36.2		12.8	.5	3.4				

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[a] Estimated.
[b] Total annual denudation.
[c] Fe_2O_3.
[d] Sand blown from shores.
[e] Omitted from average.
[f] Estimated. In computing annual denudation it was assumed that 1,800 tons per day was carried for the 10 days Dec. 29 to Jan. 7, and 1,950 tons for the 10 days Jan. 8 to 17.
[g] Abnormal; computed to HCO_3 in average.
[h] Sodium and potassium, determined on combined alkali residues.

The water of the lower Columbia River is mixed drainage from a very large area, the upper section of which contains large bodies of Paleozoic and older sediments, now more or less metamorphosed, and the lower section chiefly basalt and other effusive rocks. The water of Columbia River at Northport exhibits secondary salinity. The water of the river at Pasco may be classed midway between a secondary saline and a primary alkaline water. Columbia River at Cascade Locks is also in the border class but is more nearly secondary saline. The average of all the analyses shows it to have a slight excess of strong acids over alkalies. The effect of the addition of the primary alkaline waters of Washington and Oregon on the water of Columbia River above the Cascades is, then, to destroy its secondary salinity but not to give it pronounced primary alkalinity.

Mineral analysis of the water of Columbia River at Mayger.

	Parts per million.	Percentage of anhydrous residue.
Silica (SiO_2)	2.4	4.6
Ferric oxide and alumina ($Fe_2O_3+Al_2O_3$)	2.2	4.2
Calcium (Ca)	8.7	16.8
Magnesium (Mg)	2.5	4.8
Sodium (Na)	4.0	7.7
Potassium (K)	4.1	7.9
Carbonate radicle (CO_3)	.0	31.8
Bicarbonate radicle (HCO_3)[a]	33	....
Sulphate radicle (SO_4)	5.5	10.6
Chlorine (Cl)	5.5	10.6
Phosphate radicle (PO_4)	.08	.2
Ammonium radicle (NH_4)	.42	.8
Total dissolved solids at 180° C	52	....

[a] Bicarbonate computed from reported carbonate.

Sample collected August, 1909; analysis by B. Pilkington, reported in Oregon Agr. Coll. Exper. Sta. Bull. 112, p. 45, 1912.

The values of sodium and potassium in the accompanying analysis of the water of Columbia River at Mayger, about 30 miles above the mouth, are evidently erroneous, as the excess of potassium over sodium is entirely abnormal for river waters in North America. The average potassium content of 7 composite samples from the same source, each of which represents one month's water, is reported in a private communication from the director of the Oregon Agricultural College experiment station as 0.97 part per million, which is in accord with the writer's determinations on water from Cascade Locks. If sodium is corrected to 6.5 and potassium to 1.6 parts per million, the analysis indicates that the water of Columbia River at Mayger is characterized by primary alkalinity. This is chiefly the result of the addition to it of the primary alkaline waters of Willamette and Lewis rivers, which drain regions of volcanic rock.

THE GREAT BASIN.

OUTLINE OF GEOLOGIC HISTORY.

The Great Basin, a roughly triangular area covering parts of the States of Utah, Nevada, California, Oregon, Idaho, and Wyoming, comprises many small independent drainage basins, all of which can be grouped into a few greater provinces. The reports on the Quaternary history of two of these provinces, by Gilbert[1] and Russell,[2] form most important contributions to our knowledge of that period. These writers conclude that the Great Basin was well outlined at the beginning of the Quaternary period. Orogenic movements had produced the dominating crustal structure, consisting primarily of huge uptilted fault blocks bounded on one or more sides by bold escarpments. These structural forms had been subdued by erosion and the valley bottoms filled in by river and lake alluvium. The Tertiary period is believed to have been characterized by intervals of greater humidity and the formation of extensive lakes. Whether these lakes discharged into the ocean is uncertain, though presumably they did. The Tertiary humid period was followed by a long period of greater aridity, in which erosion continued its leveling process on the hills of the Basin. During this time widespread topographic changes occurred, caused by continuing crustal displacements, uplift, subsidence, faulting, and similar movements. Then succeeded another more humid period, this being the first Quaternary period of greater humidity. Lakes that were then formed gradually encroached on the land of the Basin to form extensive inland seas, the largest of which were Bonneville in Utah and Lahontan in Nevada. This humid period was long but not sufficiently marked to cause these two lakes to find an outlet into the ocean. The lake levels fluctuated greatly because of variations of rainfall, and their oscillations are recorded in the form of partly buried or obliterated shore terraces and beaches. The humid period was succeeded by a more arid one in which stream erosion became effective in the sediments uncovered by receding lake waters. This relatively short period was succeeded by a short but strongly pronounced humid period, in which the basins again filled, and at least one lake—Bonneville—overflowed into rivers reaching the ocean. The beaches formed in this period were fewer but more strongly molded than those previously formed. In Lake Bonneville Gilbert found two chief beaches, formed by overflow of the lake water through a high pass, followed by the erosion of the outlet to a greater depth, at which resistant rock was exposed. Russell found no evidence of overflow in Lake Lahontan during the

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[1] Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, 1890.

[2] Russell, I. C., Geological history of Lake Lahontan: U. S. Geol. Survey Mon. 10, 1885.

same period, and concluded that this lake attained a condition of balance between inflow and evaporation before it reached an outlet pass.

After the precipitation of this humid period had reached its maximum it rapidly diminished and a period of probable maximum aridity followed. The lakes shrank to relatively small size or entirely disappeared, and deserts took their place. Then finally came the present period of lessened aridity, in which the few mountain streams that do not lose themselves in the sands of the valley floors serve barely to sustain the lakes and pools in the lowest depressions.

HARNEY BASIN.

GENERAL FEATURES.

Malheur, Harney, and Silver lakes occupy parts of a large basin in the central part of Harney County. The floor of the valley lies in general 4,100 feet above sea level, and the ranges bordering it attain altitudes of 5,000 to 7,000 feet. Little of the basin or its rim is forested, only the northern part lying within the woodlands of the Blue Mountains. The principal streams are Silvies River, which flows from the southern margin of the Blue Mountains southeastward to Malheur Lake; Silver Creek, which rises in the high plateau on the borders of the Malheur National Forest and flows generally southeastward, passing through Silver Lake into Harney Lake; and Donner und Blitzen River, which rises on the west slopes of Steens Mountain and flows northward through a long swamp-filled valley into Malheur Lake.

The upper parts of the basin expose basalts, rhyolites, and tuffs almost exclusively, and the valley floor is everywhere composed of alluvium, chiefly of lacustrine origin. According to Waring,[1] the valley sediments are not more than 300 feet thick, except perhaps in a few places. The alluvium is underlain by lavas and tuffs of indeterminate extent, which afford excellent storage reservoirs for underground water. Deep wells sunk in the valley have proved the existence of artesian water, which can, if necessary, be used to augment the present surface supply for irrigation or for other purposes.

In early Quaternary time the valley was occupied by a broad shallow sheet of fresh water receiving inflow from Warner Lakes,[2] the Steens Mountain uplands, and the then well-watered slopes of the Blue Mountains, and possibly also from the Chewaucan, Alkali, and Christmas basins, whose ancient outlets have yet to be discovered. It had an outlet into Malheur River through a gap about 20 feet above the present valley floor. The appearance of this pass indicates that

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[1] Waring, G. A., Geology and water resources of the Harney Basin, Oreg.: U. S. Geol. Survey Water-Supply Paper 231, p. 23, 1909.

[2] See description of Warner Lake outlet, p. 110.

the amount of discharge from the valley was large, for erosion has been extensive and the gap is wide. Another pass into the drainage basin of the Malheur lies north of and somewhat higher than the gap just mentioned. This basin presents numerous proofs of its origin as a river valley, and it is probable, as Russell pointed out,[1] that the region has been tilted and faulted subsequent to the development of the valley so that its original elevation has been lost.

The average annual precipitation throughout the basin ranges from about 18 to 20 inches on the divides to 10 inches in the valley, and irrigation must be practiced to produce other than the most drought-resisting crops. The valley lands comprise almost 700,000 acres of rich alluvial soil lying in a broad, flat plain around the lakes, with arms extending well up into the stream valleys. Much of the land is swampy and can not be used for intensive agriculture until drained. The swamps are now utilized for the production of wild hay.

Plans have been made for the irrigation of other districts in Harney Basin and development will probably be rapid.

Estimates made by F. F. Henshaw indicate there should be relatively little return or waste water entering Malheur Lake when the surface water of the valley has been fully utilized for irrigation. This lake can therefore be drained into Harney Lake through a canal, and its bed can be cultivated. Harney Lake will then also receive a greatly diminished inflow and will gradually dwindle in size, possibly until it becomes a playa.

CHARACTER OF THE WATER.

Silver Lake is a large shallow body of water in the western part of Harney Basin just north of Iron Mountain. Its size varies greatly according to the season, as it receives little inflow except during high stages of Silver Creek. A sample of water was collected from the lake on March 11, 1912, when the water level was extremely low. The water was strongly alkaline and was unfit for irrigation or other uses. During high stages the water will doubtless be more dilute and of better quality, but it should never be used for irrigation if other less alkaline supplies are available. If the water is applied to the land, land plaster should be used to counteract the harmful effects of the black alkali in the water. Irrigation development now contemplated for the upper Silver Valley will decrease the inflow of this lake greatly, possibly rendering it a playa.

Malheur Lake is a shallow body of water about 73 square miles in area at medium stage but varying within wide limits during wet and dry seasons. It receives the drainage of Harney and Blitzen valleys and is connected by a channel or strait called The Narrows with Harney Lake, into which it flows. Its surface evaporation is great, but owing

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[1] Russell, I. C., Preliminary report on the geology and water resources of central Oregon: U. S. Geol. Survey Bull. 252, p. 39, 1905.

to its discharge into Harney Lake it never becomes strongly alkaline, though it is more strongly impregnated with salts than its influent waters. Analysis of a sample collected March 8, 1912, from the northern part of the lake showed the water to be of alkaline-carbonate type but less harmful for irrigation than the water of Silver Lake. It could be used for irrigation if great care were exercised to prevent accumulation of alkali. Land plaster would also be beneficial on lands irrigated with this water.

Harney Lake occupies the lowest part of the basin and its water is highly concentrated. Its level fluctuates markedly, and as no records of stage have been kept and its average depth is unknown it is impossible to estimate the quantity of material it holds in solution. A sample of water of the lake was collected August 5, 1902, when the lake was either at high stage or diminishing somewhat in volume, and another was collected March 10, 1912, when the lake was at the lowest level it has been known to reach. The water is similar in composition to that of Owens Lake in California, but its concentration is only from one-twentieth to one-tenth that of Owens Lake. It contains much dissolved organic matter, which would be troublesome in commercial operations for the recovery of salts. The amount of sulphate in the water is greater than that in either Abert or Summer Lake (p. 119), and the amount of chloride is greater than that in Summer Lake. It is therefore inferior to these lakes as a source of natural soda. Until the water reaches greater concentration in the late spring and summer, it will not be at all profitable to attempt the recovery of salts from it.

Mineral analyses of lake waters of the Harney Basin.

	Parts per million.				Percentage of anhydrous residue.			
	1	2	3	4	1	2	3	4
Silica (SiO_2)	29	31	14	85	0.3	0.1	2.9	3.0
Iron (Fe)	.0	.1	.01	.21	.0	.0	......	.0
Aluminum (Al)	.0	12	Tr.	5.5	.0	.1	......	.2
Calcium (Ca)	.0	7.7	27	10	.0	.0	5.6	.4
Magnesium (Mg)	7	.9	20	.8	.1	.0	4.1	.0
Sodium (Na)	3,749	8,825	117	1,041	35.8	39.4	24.2	36.7
Potassium (K)	200	335	27	94	1.9	1.5	5.6	3.3
Carbonate radicle (CO_3)	2,710	1,594	.0	308	25.9	7.1	41.6	10.9
Bicarbonate radicle (HCO_3)	......	5,755	439	1,404	......	[a]12.7	......	[a] 24.4
Sulphate radicle (SO_4)	804	1,929	37	138	7.6	8.6	7.7	4.9
Chlorine (Cl)	2,881	6,804	22	456	27.5	30.4	4.5	16.1
Nitrate radicle (NO_3)	......	2.8	2.4	3.0	......	......	.5	.1
Phosphate radicle (PO_4)	......	10	1.6	1.2	......	.1	.3	.0
Tetraborate radicle (B_4O_7)	97	Present.	.0	Present.	.9	......	......	......
Total solids	10,477	23.687	524	2,930	......	......	......	......
Specific gravity	......	1.0209	......	......	......	......	......	......

[a] Computed as carbonate (CO_3).

1. Harney Lake; collected Aug. 5, 1902; analysis by George Steiger, pub. by Clarke, F. W., The data of geochemistry: U. S. Geol. Survey Bull. 491, p. 151, 1911.
2. Harney Lake; collected Mar. 10, 1912, by R. D. Cooper; analysis by Walton Van Winkle.
3. Malheur Lake; collected Mar. 8, 1912, by R. D. Cooper; analysis by Walton Van Winkle.
4. Silver Lake; collected Mar. 11. 1912, by R. D. Cooper; analysis by Walton Van Winkle.

DONNER UND BLITZEN RIVER.

GENERAL FEATURES.

Donner und Blitzen River rises on the western slopes of Steens Mountains and flows northward through a long, narrow swamp, finally discharging into Malheur Lake. The Steens Mountain ridge is more than 60 miles long, rises 9,000 to 10,000 feet above sea level and is practically devoid of timber. Precipitation upon it is almost wholly in the form of snow, which collects in great drifts in the canyons, and by its slow melting produces a well-sustained stream flow.

CHARACTER OF THE WATER.

A sample of water was collected August 19 from the drainage canal cut through Blitzen Marsh and one, August 20, 1912, from the river opposite the P ranch. The following table gives the results of analysis of these samples:

Mineral analyses of the water of Donner und Blitzen River.

	Parts per million.		Percentage of anhydrous residue.	
	1	2	1	2
Silica (SiO_2)	29	32	37.2	30.2
Iron (Fe)	.12	.17	.2	.2
Calcium (Ca)	8.2	13	10.5	12.3
Magnesium (Mg)	4.0	6.8	5.1	6.4
Sodium and potassium (Na+K)	8.5	10	10.9	9.4
Carbonate radicle (CO_3)	.0	.0	32.1	38.7
Bicarbonate radicle (HCO_3)	51	84	....	....
Sulphate radicle (SO_4)	2.3	2.6	3.0	2.4
Chlorine (Cl)	.75	.25	1.0	.2
Nitrate radicle (NO_3)	Trace.	.26	.0	.2
Total dissolved solids	93	106	....	....

1. Donner und Blitzen River at P ranch, Aug. 20, 1912.
2. Drainage canal in Blitzen Valley at lowest bridge, Aug. 19, 1912.

The water is of excellent quality, having the composition common to all waters of the Columbia River basalt region. The chief feature of interest is the small concentration of the drainage waters from the swamp. The organic matter in solution in the swamp water, as is to be expected, is noticeable, but it can not amount to more than 5 or 6 parts per million.

SILVIES RIVER.

GENERAL FEATURES.

Silvies River rises on the slopes of the southern spurs of the Blue Mountains and flows southeastward, discharging into the swamp bordering Malheur Lake. It drains a well timbered area, but its character is nevertheless "flashy." Its summer discharge is almost nothing, but its early spring flow frequently averages over 1,500 second-feet.

Mineral analyses of water from Silvies River near Burns, 1911–12.

[Parts per million except as otherwise designated.]

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
Oct. 12–19	12	....	....	27	32	0.20	12	4.2	16	0.0	91	7.6	0.50	1.3	130	16.5	....	5.8
Oct. 20–29	25	26	1.04	24	38	.22	22	5.8	21	.0	124	11	1.9	4.3	175	20.1	1.4	9.5
Oct. 30–Nov. 8	12	8.6	.72	11	34	.18	18	5.5	16	.0	104	8.0	.66	1.8	145	20.7	.5	8.1
Nov. 9–18	10	12	1.20	14	34	.15	19	5.6	14	.0	103	13	.40	2.0	146	26.7	.9	10.5
Nov. 19–28																29.9	1.0	11.7
Nov. 29–Dec. 8	10	5.6	.56	16	32	.15	24	7.4	19	.0	135	10	.66	3.3	175	22.1	.3	10.3
Dec. 9–18	10	14	1.40	......	40	.14	22	....	18	.0	125	7.7	....	1.5	164	19.3	.7	8.5
Mar. 8–17	35	17	.49	......	34	.16	18	....	12	.0	98	5.6	.18	1.5	138	68.2	3.1	25.4
Mar. 18–27	30	24	.80	7	33	.03	32	6.8	20	Tr.	123	17	5.0	17.0	208	101.4	6.6	57
Mar. 28–Apr. 6	85	64	.75	21	26	.04	19	2.8	14	3.6	81	7.2	1.0	4.5	134	341.2	59	123
Apr. 7–16	80	77	.96	18	28	.06	20	2.8	13	Tr.	93	10	.72	2.0	138	874.4	181	325
Apr. 17–26	30	21	.70	32	31	.05	25	4.4	15	2.9	106	9.7	.86	1.3	158	694.1	39	296
Apr. 27–May 6	30	47	1.57	20	24	.03	23	4.0	15	.0	112	10	.24	3.0	153	1,123.5	142	465
May 7–16	25	23	.92	28	37	.12	25	4.7	17	13	87	14	.38	4.1	166	1,434	89	644
May 17–26	7	12	1.72	7	47	.04	20	3.6	19	.0	114	12	1.8	4.8	188	1,187	38	602
May 27–June 5	8	4.6	.57	4	49	.03	18	4.4	21	.0	114	9.9	3.0	5.3	185	974.1	12	450
June 6–15	1	7.6	7.60	8	56	.05	20	6.0	27	.0	126	14	2.2	6.8	212	564.9	12	323
June 16–25	4	9.0	2.25	6	58	.03	20	5.8	27	.0	128	15	2.0	7.5	215	329.5	8.1	192
June 26–July 6	5	8.0	1.60	6	58	.04	20	6.2	28	.0	127	15	2.6	7.5	213	127.8	2.8	73.5
July 7–16	7	16	2.29	......	69	.03	22	4.2	27	.0	131	15	1.4	3.3	200	55.1	2.4	30
July 17–26	Tr.	Tr.	....	5	55	.02	20	6.6	27	1.9	126	16	2.5	7.3	213	27.2	Tr.	15.7
July 27–Aug. 4	Tr.	Tr.	....	6	43	.05	22	5.6	27	6.2	115	18	1.9	8.0	202	20	Tr.	10.9
Aug. 5–14	Tr.	Tr.	....	5	60	.04	20	5.6	28	.0	130	17	2.6	7.3	207	15	Tr.	8.4
Mean	19	18	1.49	14	41	.09	21	5.1	[a]17 [a]4.0	1.2	113	12	1.5	4.7	174	....	....	....
Percentage of anhydrous residue	....	....	....	......	25.1	[b].1	12.9	3.1	[a]10.4 [a]2.4	34.9	....	7.3	.9	2.9	....	....	....	....

[a] Sodium and potassium, determined on combined alkali residues.

[b] Fe_2O_3.

CHARACTER OF THE WATER.

Daily samples of water were collected from Silvies River near Burns, but with considerable irregularity, during the period covered by this investigation. Through the help of Mr. C. B. McConnell, of the Silver Valley Irrigation Co., collection was begun by Thomas Jourdan October 12, and was continued without interruption until December 14, 1911. On March 9, 1912, collection was resumed by Alfred Taylor, who was shortly afterward succeeded by Charles Caulfield, who continued the collections until August 15, 1912. The drainage basin above the sampling point, which is 4 miles from Burns, comprises 865 square miles.

WARNER LAKE BASIN.

GENERAL FEATURES.

Warner Lake basin occupies 2,100 square miles in eastern Lake County and southwestern Harney County. Its eastern part includes a narrow valley 360 square miles in extent but only 6 or 8 miles wide at the northern end, which is flanked by escarpments of the Basin Range type and contains a series of shallow pools—remnants of what was once Warner Lake. No perennial streams feed the lakes from the north or east, but Twentymile Creek enters from the south and Deep and Honey creeks from the west. These streams rise in forested plateaus, but there is little timber land in the rest of the drainage basin.

From records of precipitation in near-by valleys and from statements of engineers familiar with the region it is estimated that the average annual rainfall is not more than 9 or 10 inches at the north end of the valley, about 12 inches at the south end, and 25 inches or more in the mountainous portions of the basin. The valley floor is 4,455 to 4,480 feet[1] above sea level, the general elevation of the divides being more than 6,500 feet and that of Warner Mountains on the eastern rim 7,500 feet. The scarp on the east side of the valley, a cliff of remarkable grandeur, averages more than 2,000 feet in height. The scarp on the west side is lower and less steep and is so deeply dissected in its northern part by the valleys of Honey and Deep creeks as largely to have lost its original character, though in its southern part it is bold. The divide north of the valley is low and its slopes are gentle. The scarps rise from the valley to a rough broken plateau forming the uplands of the basin. This plateau has been cut by erosion into valleys and gulches. The valley bottom presents a remarkable contrast to the rocky highlands. It is almost level, with a slight downward slope to the north. The greater part of the plain is covered with lakes or marshes, those at the south end

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[1] Unpublished surveys of Oregon-Washington Railroad & Navigation Co.

being fringed with tules and other aquatic plants and those at the north being barren and desolate.

The lakes now lying in Warner Valley are, from south to north, Pelican, Crump, Hart, Anderson, Mugwump, Flagstaff, and Bluejoint, which occupy indefinite areas, flooding their low banks in the wet season and becoming brackish sinks in the dry season. A proposed irrigation project for this valley contemplates the control of the waters entering these lakes and possibly the drainage of some of them. What effect irrigation will have on the total water supply of the lakes is yet unknown.

OUTLET OF QUATERNARY LAKE WARNER.

Shore lines of a large, deep lake that occupied the valley within Quaternary time are discernible at several places along the cliffs, and one strongly defined beach, 200,[1] 225,[2] or 268[3] feet above the present water surface can be traced for miles. The strong definition of this beach is evidence that the lake was stationary at one level for a long time. It is apparently the current belief that the Quaternary Warner Lake had no outlet, for Russell,[4] after a reconnaissance of the Great Basin in southern Oregon, stated that only the lakes occupying the Harney, Goose, and Klamath basins in Oregon and the Madeline Plains in California had outlets, and his statement apparently was accepted by Waring.[5] Free [6] also has concluded that the Warner Basin has always been entirely inclosed. The writer's investigations have, however, led him to believe that the lake had an outlet.

The rim of its basin north of Warner Lake is relatively low,[7] a gentle slope rising northward and attaining a maximum elevation of about 190 feet above the present level of Bluejoint Lake, about 12 miles north of the lake. The top of the divide there appears to have been formed by deposits from a stream that flowed in a canyon opening from the west. Just north of the divide Mule Spring discharges into a rivulet which flows northward in a wide, shallow valley 25 feet lower than the divide and finally sinks into the desert. Approximately a mile beyond Mule Spring is another divide, perhaps 25 feet higher than the more southerly one, and also formed apparently by

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[1] Elevation from level carried from Bluejoint Lake to beach by J. T. Whistler, Portland.

[2] Russell, I. C., A geological reconnaissance in southern Oregon: U. S. Geol. Survey Fourth Ann. Rept., p. 459, 1883.

[3] Elevation carried by leveling from datum of Crump Lake gage to beach by J. E. Stewart, of the U. S. Geological Survey.

[4] Russell, I. C., op. cit., p. 458.

[5] Waring, G. A., Geology and water resources of the Harney Basin region, Oreg.: U. S. Geol. Survey Water-Supply Paper 231, 1909.

[6] Free, E. E., The topographic features of the desert basins of the United States with reference to the possible occurrence of potash: U. S. Dept. Agr. Bull. 54, pp. 26, 60, 1914.

[7] Description and elevations based on notes by Garfield Stubblefield, civil engineer, Portland, and on unpublished surveys by the Oregon Eastern Railway.

alluvial deposits.[1] A basin north of this second divide, probably a continuation of the valley of the Mule Spring creek, also terminates on the north in a divide with another basin beyond. Thus there are three basins separated by low divides. The floors of the basins are less than 4,700 feet above sea level and slope northward. Beyond the northernmost divide a canyon, which winds away to the northwest, opens into Big Stick Canyon, which, in turn, circles around Iron Mountain and enters Harney Basin from the west. The elevations of the different basins decrease from south to north, and the low divides were apparently formed by deposits washed in from side canyons. The elevation of the pass with the detritus removed would be very nearly the elevation of the ancient beaches.[2]

Elevations from Big Stick Canyon to Bluejoint Lake.

Distance.	Elevation above sea level.	Remarks.
Miles.	*Feet.*	
0	4,231.83	
3	4,255	
7.5	4,595	Maximum ground bed.
	....	Flat; rising easily.
13.7	4,717	Summit ground.
23.6	4,785	Do.
26.0	4,683	Trough of ground.
28.2	4,791	Summit ground.
	....	Broad flat.
32.0	4,626	Bottom ground.
33.1	4,650	Summit ground.
46.0	4,458	High water Warner Lake; north end of Bluejoint Lake.

The preceding table gives an abstract of the maximum and minimum elevations obtained by the Oregon-Washington Railroad & Navigation Co. during its survey from Big Stick Canyon to Bluejoint Lake, the distances being measured from the junction of the main line and the Warner Lake branch in Big Stick Canyon. The survey line is partly within the canyon and partly above the rock rim and it crosses three summits that are higher than the level of the old beach line of Warner Lake. If these low divides have been formed by alluvial material brought into the main canyon by side streams, the rock flow of the canyon may be at a lower elevation than the beach and the canyon may thus have afforded an outlet by which Warner Lake drained northward into Malheur River and thence into the Snake.

The probability of the existence of an outlet to the Quaternary lake can also be roughly determined by considering the relation of

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[1] The railroad surveys of the Oregon Eastern Railway do not follow the canyon closely at all places, and the elevations as shown by the railroad surveys are somewhat greater than those mentioned.

[2] Since the above statements were written J. E. Stewart has discovered a basaltic dike that lies across the outlet canyon and extends about 80 feet above the level of the ancient beach. The surface of the dike is water worn, and it presents a problem to be solved before the existence of the ancient outlet can be determined.

its water surface to the area of its drainage basin. If a lake has no outlet its water level will rise until evaporation from the surface counterbalances the additions by rainfall and inflow. At that stage there will be for a given set of conditions a definite ratio between the area of the lake surface and that of the tributary basin, which will be the same for all basins exposed to similar conditions. Russell placed the ratio of the surface of Lake Lahontan to its total drainage area at approximately 1 to 5.[1] No topographic maps have been made which will furnish exact information regarding the extent of Quaternary Warner Lake and its basin, but the best available maps indicate that the ratio of its water surface to its drainage area was about 1 to 5. If this ratio is correct and if Warner Lake had no outlet the early Quaternary precipitation in Warner Basin must have been almost exactly equal to that in Lahontan Basin. But as the precipitation in Warner Basin is now one-third greater than in Lahontan Basin and as no known physiographic changes since early Quaternary time would have made a great alteration in relative precipitation, it is probable that precipitation then was greater in Warner Basin than in Lahontan Basin. On this assumption, Warner Lake must either have had an outlet or must have filled its basin to a level several hundred feet higher than the highest beach—an obvious improbability.

Briefly, the available physical evidence points to the possibility that the ancient Warner Lake discharged northward; confirmation of this evidence might be obtained by determining whether the low divides of the basin are composed of alluvial material or bedrock and also whether the surface has been locally distorted since early Quaternary time.

SALT DEPOSITS IN THE BASIN.

If Warner Lake overflowed in early Quaternary time its water was then fresh, and consequently salt deposits that may now occupy the former lake bed have been formed by concentration only of the material that has been washed into the lake bottom since the lake ceased to have an outlet. The small size of the former lake and the presumably low concentration of its water make it entirely unlikely that saline deposits of great thickness or extent now underlie the surface, and this relatively small amount of saline material is probably mixed with much greater quantities of clay and silt. Several wells that have been sunk in the valley are said to have penetrated strata of strongly alkaline and probably borated salts mingled with silt and sand, a condition that renders unlikely the existence of extensive valuable saline deposits. Rock salt of low grade has been obtained for years by solar evaporation of brines obtained presumably from the strata just below the surface at the north end of the valley, but this

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[1] Russell, I. C., The geological history of Lake Lahontan: U. S. Geol. Survey Mon. 11, p. 260, 1885.

deposit is probably local and the product is economically unimportant, being used chiefly for salting stock. The salt is somewhat carbonated but contains only a small amount of sulphate.

CHARACTER OF THE WATER.

Samples of water were collected September 5, 6, and 7, 1912, from Pelican, Crump, Hart, Flagstaff, and Bluejoint lakes through the kindness of Mr. John Dubuis, of Portland.

Mineral analyses of lake waters in Warner Lake basin.

	Parts per million.					Percentage of anhydrous residue.				
	1	2	3	4	5	1	2	3	4	5
Silica (SiO_2)	24	3.0	19	28	20	1.2	2.9	8.0	6.6	0.6
Iron (Fe)	.3	.2	.56	.6	.5	.0	.2	.2	.1	.0
Calcium (Ca)	45	13	22	19	21	2.3	12.5	9.3	4.5	.6
Magnesium (Mg)	52	5.6	9.8	19	23	2.6	5.4	4.1	4.5	.6
Sodium (Na)	580	21	55	102	1,372	29.3	20.1	23.2	24.1	37.7
Potassium (K)	71			15	82	3.6			3.5	2.3
Carbonate radicle (CO_3)	167	.0	.0	60	511	8.4	.0	.0	14.2	14.0
Bicarbonate radicle (HCO_3)	904	95	211	238	1,823	[a]22.4	[a]45.1	[a]43.9	[a]27.6	[a]24.7
Sulphate radicle (SO_4)	438	8.6	16	24	206	22.1	8.2	6.8	5.7	5.6
Chlorine (Cl)	158	4.2	9	37	504	8.0	4.0	3.8	8.8	13.8
Nitrate radicle (NO_3)	1.0	1.7	.8	1.0	.84	.0	1.6	.3	.2	.0
Phosphate radicle (PO_4)	1.4	Tr.	.82	.82	2.0	.1	.0	.4	.2	.1
Tetraborate radicle (B_4O_7)	Present.	.0	.0	Present.	Present.	......	.0	.0	......	......
Total dissolved solids at 180° C	2,135	135	267	461	3,951	......	......	......	......	......
Total solids after ignition	1,946	95	217	386	3,756	......	......	......	......	......

[a] Computed as carbonate (CO_3).

1. Pelican Lake; collected Sept. 7, 1912, by Dallas Dodd, from a shallow arm south of middle of west end of lake, 100 feet from main lake; many cattle standing in arm.
2. Crump Lake; collected Sept. 7, 1912, by Dallas Dodd, where road comes near the lake; no wind; water clear.
3. Hart Lake; collected Sept. 5, 1912, by Dallas Dodd, about 1 mile north of mouth of Honey Creek windy; water turbid.
4. Flagstaff Lake; collected Sept. 6, 1912, by Dallas Dodd, at Cliff House, near pump station No. 1, 20 feet east of township line.
5. Bluejoint Lake; collected Sept. 6, 1912, by Dallas Dodd, 30 feet from shore near intersection of fence due south of Laird's Ranch; heavy wind and rain.

The waters are of surprisingly slight concentration, especially that of Bluejoint Lake, which is the last lake in the series and is fed only by overflow from Flagstaff Lake and by temporary streams from the arid north rim of the basin. The waters are sodic bicarbonate and carbonate, as would be expected in this region, and present few unusual features of composition.

The remarkably high concentration of the water of Pelican Lake is partly accounted for by the explanation of the collector, that the sample was collected from an open arm in which cattle were wading. Pelican Lake is connected with Crump Lake only through a stagnant swamp, and as Crump Lake is directly fed by Deep Creek the decidedly lower concentration of dissolved material in its water seems reasonable. The proportionately high sulphate in Pelican Lake may be due to hot springs, which are reported to occur in the lake.

The analysis is of somewhat doubtful value, but it indicates that the water is poor in quality and should not be used for irrigation unless rapid and thorough drainage is provided. The water is not suitable for use on the heavy soils of the valley.

The waters of Crump and Hart lakes are excellently suited for use on the lands of the valley. They hold much organic matter in solution, which is to be expected, but they are not strongly mineralized and will not noticeably increase soil alkalinity.

Flagstaff Lake contains water that could be used on loose soils without any special precautions to prevent accumulation of alkali. As the soils of Warner Valley are, however, generally heavy, they should be carefully drained if this water in the condition shown by the analysis is used. This conclusion is possibly too harsh, as the analysis represents the water at low stage, when it is most strongly concentrated. The season for withdrawing water for irrigation in this valley will be from the last part of May until about the first of September. The water withdrawn during the early part of the irrigation season will be much more dilute and therefore better suited for use. If the lake were pumped nearly dry and the purer water of Hart and Crump lakes allowed to enter it, the resulting composite water would be better suited for irrigation. Withdrawal of water in early summer will greatly lower the level of the lake, and the irrigation company, in fact, plans to drain the lake completely at first in order that the basin may be freshened and the water of the lake thereafter be better fitted for irrigation. Bluejoint Lake, also, will probably be periodically desiccated for like reasons. It seems, therefore, possible to utilize the waters of Crump, Hart, and Flagstaff lakes as planned without danger of hurting the irrigated lands, provided, however, that the water table can be kept low enough to prevent serious rise of alkali.

The water of Bluejoint Lake is entirely unsuited for irrigation, as it would choke the soil with alkali. Use of it is not contemplated and diversion of water that now enters the lake from the south will probably allow the lake to dry up during dry seasons; when the lake basin then becomes refilled the water in it should be better than it is now on account of the previous dissipation or burial of the salts now in solution.

ALKALI LAKE BASIN.

Alkali Lake occupies a broad shallow basin lying north and northeast of Abert Lake. The bottom of the basin is a valley about 20 miles long and 5 miles wide, divided into a north and a south section by a spur of hills that project into it from the west. The south ection contains Alkali Lake and the north one a still more ephemeral body of water known as Little Alkali Lake. The water of these playas is highly concentrated, the dissolved matter averaging more than 10 per cent by weight of the total brine. No analyses were made of the waters, but they probably are carbonate brines, containing only small amounts of sulphate or chloride, as large "potholes" in the valley contain almost pure sodium carbonate. These potholes have been worked for their soda at different times and have been found to refill slowly with nearly pure crystalline soda after having been mined. The workings are now controlled by the American Soda Products Co.

The geologic history of this valley is not well known. It is possible that in early Quaternary time it contained a shallow lake without outlet, but more definite knowledge of the topography of its northern portion may show that there was drainage northward into the river whose traces remain in Big Stick Canyon. The lake may, on the other hand, have had a more or less continuous outflow into Chewaucan Basin, or the waters of the latter may have flowed into Alkali Lake basin. The nature of the deposits in the basin indicate that there was an outlet to Alkali Lake, though the discharge was so slight that the waters became sufficiently concentrated to precipitate the less soluble alkali carbonates but not the more soluble chlorides.

Though early reports indicated the presence of large deposits of borates in this valley, later investigations, reported verbally to the writer by Mr. E. E. Smith, of the American Soda Products Co., have shown the presence of only traces in the surface deposits.

CHRISTMAS LAKE BASIN.

GENERAL FEATURES.

Silver Lake occupies the extreme southern corner of an irregular valley lying north of Summer Lake, at an elevation of about 4,700 feet. Though the basin is large, including the drainage areas of Fossil, Christmas, and Thorn lakes, only a small part of it is now tributary to Silver Lake. Silver Creek, southwest of Silver Lake, is the only important stream in the region. It rises in the mountains back of Winter Ridge, flows northward into Pauline Marsh, then turns to the southeast and empties into Silver Lake, after being augmented by the waters of Bear and Bridge creeks. Its headwaters lie in the woodlands of the Fremont National Forest, the only forested part of the whole basin.

Silver Lake is about 15 square miles in extent at normal stage but is subject to marked fluctuations. It has dried up several times and it has also overflowed, flooding Thorn Lake and the near-by desert. The frequent desiccations to which it has been subject have had a pronounced effect on the composition of its water. It is not strongly concentrated, as is common with the water of lakes in the Great Basin, but, as shown by the accompanying analysis, is fresh. The most satisfactory explanation of this phenomenon is that when the lake dries up its deposited mineral salts are blown over the desert and so dissipated, or are covered with an impermeable coating of silt and sand. When the lake is renewed there are no surface salts to be redissolved and consequently the water is fresh. The amount of freshening the water of Silver Lake undergoes by dilution and flooding into Thorn Lake is probably insignificant compared with that effected by frequent desiccations. Some of the irrigated lands bordering Silver Lake produce good crops. Pauline Marsh is used for cropping wild hay, but it is capable of more intensive development. Much of the valley around the lake can be profitably irrigated.

About 20 miles northeast of Silver Lake is a small perennial body of water known as Christmas Lake, which is fed by an intermittent spring at its south end and possibly also by subsurface inflow from other springs. A shallow well near its west shore yields uniformly cool water containing about 400 parts per million [1] of mineral matter, although other wells in the vicinity are much more highly charged. The well and the springs evidently yield water from the lava formations of better watered uplands some distance away.

A small lake called Fossil Lake, still farther from Silver Lake, is also spring fed, the waters entering it being sweet and not excessively hard. Beach marks indicate that the basin in which Silver Lake lies contained an immense Quaternary lake that must have long remained at a constant level, for its prominent shore line is in places cut into solid rock, as at Fort Rock, near Fremont. (See Pl. II, *B*, p. 40.) The lake probably had an outlet, but the location of this outlet has not yet been discovered. A hasty examination of the part of the shore line visible from the road between Bend and Paisley revealed no traces of the outlet. No evidence of a connection between Christmas Lake Basin and Chewaucan Basin was found at the north end of Summer Lake. The sources of Big Stick Canyon, old Crooked River, and old Deschutes River, which have not been studied, may hold valuable evidence on this interesting problem.

CHARACTER OF THE WATER.

The following analyses indicate the character of the surface, spring, and normal subsurface waters of the region:

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[1] Waring, G. A., Geology and water resources of a portion of south-central Oregon: U. S. Geol. Survey Water-Supply Paper 220, p. 66, 1908.

Mineral analyses of waters in Christmas Lake basin.

	Parts per million.					Percentage of anhydrous residue.				
	1	2	3	4	5	1	2	3	4	5
Silica (SiO_2)	57	......	......	......	......	15.0	......	......	......	......
Iron (Fe)	.3	......	......	......	......	.1	......	......	......	......
Calcium (Ca)	42	22	56	82	13	11.4	7.5	2.5	1.9	21.0
Magnesium (Mg)	25	17	48	82	5.1	6.6	5.8	2.2	1.9	8.3
Sodium and potassium (Na+K)	62	84	700	1,285	14	16.4	28.7	31.5	30.0	22.6
Carbonate radicle (CO_3)	23	.0	.0	.0	.0	47.2	42.7	17.4	5.1	35.5
Bicarbonate radicle (HCO_3)	319	253	788	441	44	......	......	......	......	......
Sulphate radicle (SO_4)	9.2	25	880	2,040	1.7	2.4	8.5	39.5	47.7	2.7
Chlorine (Cl)	3.3	20	153	574	6.1	.9	6.8	6.9	13.4	9.9
Nitrate radicle (NO_3)	.24	.0	Trace.	Trace.	.0	.1	.0	Tr.	Tr.	.0
Total dissolved solids at 180° C.	394	368	2,350	4,328	100	......	......	......	......	......
Color	25	......	......	......	......	......	......	......	......	......

1. Silver Lake; sample collected February, 1912, by W. O. Harmon; Walton Van Winkle, analyst.
2. Well of J. Wilson, near Fossil Lake.
3. Well of J. C. Green, near Fossil Lake.
4. Well of John Ross, Christmas Lake Valley.
5. Stream at A. Eglis's, Wagontire Mountain.

Analyses 2, 3, 4, 5 by W. H. Heilman; reported by Waring, G. A., Geology and water resources of a portion of south-central Oregon: U. S. Geol. Survey Water-Supply Paper 220, p. 72, 1908.

CHEWAUCAN BASIN.

GENERAL FEATURES.

The Chewaucan Basin is a large, roughly triangular area in central Lake County, containing the U-shaped valley of Summer and Abert lakes, Summer Lake occupying the upper end of the left arm and Abert Lake filling most of the smaller right arm. Between the two lakes is Chewaucan River and Marsh, draining the mountains to the west and separated from Summer Lake by a divide less than 200 feet above the lake level. The elevation of the lake surfaces is about 4,400 feet above sea level, and that of the rim of the divide is 6,500 feet on the south and west and slightly over 5,000 feet on the north. The principal perennial streams of the basin are Ana River, rising from springs and flowing into Summer Lake, and Chewaucan River, Coyote Creek, and Crooked Creek, flowing from the highlands on the west and south to Abert Lake. The basin is timberless except at the western edge, and except in the valley bottoms can not easily be made productive. A project is being developed under the Carey Act to irrigate slightly more than 12,000 acres in Summer Lake Valley with the waters of Chewaucan River.

The formations of the basin consist of basalts and tuffs or the disintegration and erosion products of these, and the soil of the valley floor is fertile except where the strongly alkaline waters from the lakes overflow it. The lakes occupy portions of the site of a large Quaternary lake. The analyses on page 106 indicate that the lakes are comparable in age, as landlocked seas, with Harney Lake. Russell[1] concluded from evidence then in hand that the valleys of

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[1] Russell, I. C., A geological reconnaissance in southern Oregon: U. S. Geol. Survey Fourth Ann. Rept., p. 459, 1884.

Summer and Abert lakes and Chewaucan River were once filled with water to a height of 300 or 350 feet above the present lake levels and considered that the present lakes are remains of this ancient lake. The highest beaches are visible in places at about this elevation and do not indicate any perceptible distortion or tilting. It is more probable that there was at some time a period of complete desiccation, and that the greater part of the solid matter deposited from the former lake by concentration and evaporation now lies beneath the valley floor. This material may lie in beds, but it may be so mixed with the valley silts that it can not be profitably extracted.

The evidence is conclusive that no connection has existed between Christmas Lake Basin and Chewaucan Basin within Quaternary time. Chewaucan Basin is separated from Alkali Lake Basin on the northeast by a low ridge, and an outlet from one basin into the other may have existed in earlier Quaternary time. Whether Alkali Lake Basin drained into Big Stick Canyon on the north is important. If Alkali Lake discharged into Chewaucan Basin, there is a strong possibility that valuable saline deposits lie beneath the floor of this basin; if it discharged into Big Stick Canyon, the question of the existence of an outlet to Chewaucan Basin assumes considerable importance in any search for valuable saline deposits. The salt deposits or incrustations in Alkali Lake Basin are chiefly soda and gypsum, with small amounts of common salt—evidence that that basin had an outlet and that, though the water in it became sufficiently concentrated to deposit the less soluble salts, it did not deposit the more soluble material. Free[1] considers the Chewaucan Basin less likely to contain deposits of potash than Warner Basin. The writer believes, however, that there is greater probability of the existence of workable deposits in the Chewaucan Basin and that this probability warrants a careful examination of the local features in order to determine the existence of an ancient outlet of the basin.

Abert Lake is a shallow body of water, 60 miles in extent, lying in the eastern part of Chewaucan Basin. Its average depth has never been accurately determined but is probably about 5 feet. It is fed by Chewaucan River and its tributaries and by a few minor streams and possibly by subsurface springs. A project that is now being developed to recover salt, soda, and borax from the waters by evaporation contemplates the damming of the north end of the lake and the evaporation of the concentrated waters held in the basin thus formed.

Summer Lake covers an area of about 70 square miles in the western part of Chewaucan Basin. It is fed chiefly by Ana River, which rises in large springs in the north end of the valley, flows in a mean-

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[1] Free, E. E., The topographic features of the desert basins of the United States with reference to the possible occurrence of potash: U. S. Dept. Agr. Bull. 54, pp. 161-162, 1914.

dering course 7 miles, and discharges about 145 second-feet of water into the lake. Other springs contribute unmeasured amounts of water, and temporary streams add somewhat to the winter inflow. The west shore of the lake, lying under the shelter of the Winter Ridge rim rock, is well protected from frosts and produces large yields of fruits and berries. Large tracts of land in the valley can be made productive through irrigation, and steps are now being taken to reclaim some of these. The recovery of the salts in solution in the lake also promises to be an important local industry.

CHARACTER OF THE WATER.

Many analyses of the waters of Summer and Abert lakes have been made at various times and some experimental work has been done in connection with plans for soda recovery, but though Chatard called attention to the Oregon lakes[1] by an analysis published as early as 1890, no systematic attempt at their utilization has been made until quite recently. Stillwell & Gladding, of New York, made analyses of the waters of Summer and Abert lakes in 1901 for a private investigator, and in 1902 Mr. E. T. Dumble, chemist for the Southern Pacific Co., also made analyses. In 1910–11 Mr. F. Von Eschen, and in 1913 Messrs. Edward and Lazell, of Portland, made studies of the waters and their utilization, but the results of these studies have not been published. Analyses of the waters of Abert and Summer lakes were made by the writer in February, 1912, the results being tabulated herein with those of Chatard, Stillwell & Gladding, and Dumble. Analyses of the water of Ana River and the springs at its source by the United States Reclamation Service are included in the table.

Mineral analyses of waters of Chewaucan Basin.

	Milligrams per kilogram.					Percentage of total solids.				
	1	2	3	4	5	1	2	3	4	5
Silica (SiO_2)	225	165	300	96	268	0.59	0.21	0.44	0.31	0.73
Iron (Fe)	....	....	....	.12	....	......	......	......	.00	......
Aluminum (Al)	....	....	....	34	....	......	......	......	.11	......
Calcium (Ca)	....	....	....	Tr.	....	......	......	......	.00	......
Magnesium (Mg)	....	....	....	.60	....	......	......	......	.00	......
Sodium (Na)	14,246	30,032	26,570	11,470	14,529	37.51	38.01	39.48	37.24	39.75
Potassium (K)	522	1,233	1,043	502	727	1.37	1.56	1.55	1.63	1.98
Carbonate radicle (CO_3)	5,852	13,363	[a]15,742	4,920	[a]13,294	15.40	16.91	[a]23.39	15.98	[a]36.38
Bicarbonate radicle (HCO_3)	3,403	5,292		2,500		[b]8.96	[b]6.69		[b]8.12	
Sulphate radicle (SO_4)	685	1,444	1,281	565	1,452	1.80	1.83	1.92	1.83	3.97
Chlorine (Cl)	13,055	27,483	22,359	10,711	6,280	34.37	34.79	33.22	34.78	17.19
Nitrate radicle (NO_3)	....	....	....	1.0	....	......	......	......	.00	......
Total solids	37,988	79,012	67,295	30,799	36,550	......	......	......	......	......
Specific gravity	1.03117 (at 19.8° C.).	1.064 (temp. not given).	1.0515 (at 15.5° C.).	1.0255 (at 15.0° C.).	1.0319 (at 15.5° C.).	......	......	......	......	......

[a] Total combined carbonate expressed as CO_3. [b] Not computed to carbonate.

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[1] Chatard, T. M., Natural soda, its occurrence and utilization: U. S. Geol. Survey Bull. 60, p. 51, 1890.

Mineral analyses of waters of Chewaucan Basin—Continued.

	Milligrams per kilogram.					Percentage of total solids.				
	6	7	8	9	10	6	7	8	9	[a]10
Silica (SiO_2)	288	104	......	......	37	0.87	0.58	......	......	23.9
Iron (Fe)	......	.25	......	......	.01	......	.00	......	......	.0
Aluminum (Al)	......	24	......	......	......	......	.13	......	......	......
Calcium (Ca)	......	Tr.	12	10	4.9	......	.00	5.4	4.7	3.2
Magnesium (Mg)	......	.40	6	5	4.4	......	.00	2.7	2.3	2.8
Sodium (Na)	12,105	6,567	55	58	39	36.74	36.36	25.0	27.1	25.2
Potassium (K)	560	265				1.70	1.47			
Carbonate radicle (CO_3)	8,302	4,514	.0	14	8.6	25.20	24.99	.0	6.5	5.6
Bicarbonate radicle (HCO_3)	4,902	2,851	116	89	86	[b]14.88	[b]15.78	[c]26.0	[c]20.5	[c]26.9
Sulphate radicle (SO_4)	1,233	694	12	37	8.1	3.74	3.85	5.4	17.3	5.2
Chlorine (Cl)	5,559	3,038	39	19	11	16.87	16.82	17.7	8.9	7.1
Nitrate radicle (NO_3)	......	3.6	.0	.0	.20	......	.02	.0	.0	.1
Total solids	32,949	18,061	220	214	158	......	......	......	......	......
Specific gravity	1.0354 (temp. not given).	1.0162 (at 15.° C.).	......	......	......	......	......	......	......	......

[a] Percentage of anhydrous residue. [b] Not computed to carbonate. [c] Computed to carbonate (CO_3).

1. Abert Lake; analysis by T. M. Chatard; sample collected September, 1887, by H. T. Biddle, at middle of west side of lake. U. S. Geol. Survey Bull. 60, p. 55, 1890.
2. Abert Lake; analysis by E. T. Dumble for Southern Pacific Co., 1902.
3. Abert Lake; analysis by Stillwell & Gladding, Oct. 14, 1901.
4. Abert Lake; analysis by Walton Van Winkle; sample collected by W. O. Harmon, February, 1912, from south end of lake.
5. Summer Lake; analysis by Stillwell & Gladding, Oct. 2, 1901.
6. Summer Lake; analysis by E. T. Dumble for Southern Pacific Co., 1902.
7. Summer Lake; analysis by Walton Van Winkle; sample collected by W. O. Harmon, February, 1912.
8. Ana River springs; analysis by W. H. Heileman, December, 1906; U. S. Geol. Survey Water-Supply Paper 274, p. 145, 1911.
9. Ana River; analysis by W. H. Heileman, July 28, 1905; U. S. Geol. Survey Water-Supply Paper 274, p. 143, 1911.
10. Ana River; analysis by Walton Van Winkle, February, 1912.

All available analyses of the water of Abert Lake, except an early and apparently erroneous one by Taylor, agree in percentage composition of dissolved material but show a wide range in concentration, which varies markedly with the season, being at least twice as great in the autumn as late in winter or in the spring. The annual evaporation has been estimated at 5.17 feet[1] for Abert Lake, and the relative concentration of the water at different seasons, shown by the analyses, indicates that this is also a maximum figure for the average depth of the lake. From these figures the total content of carbonate and bicarbonate of soda may be roughly estimated as 6,000,000 tons, of which 4,300,000 is monocarbonate and 1,700,000 bicarbonate of soda. In the United States Census of 1900 the content of these salts is estimated at 5,000,000 tons. The analyses indicate that soda of good grade can be recovered from the water if proper methods are employed. The chemical problem is simple, but the problems of economy in production and transportation are of such magnitude that it is improbable that recovery of soda will prove commercially profitable. Lunge[2] states that though Abert Lake would be excellent for the manufacture of soda if it were more easily accessible, it

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[1] Waring, G. A., Geology and water resources of a portion of south-central Oregon: U. S. Geol. Survey Water-Supply Paper 220, p. 40, 1908.

[2] Lunge, George, The manufacture of sulphuric acid and alkali, 3d edition, vol. 2, pt. 1, p. 69, 1909, English trans.

is at present too far from a railroad. His criticism applies also to Summer Lake, though he reported no information with regard to that lake. His statements are based on Chatard's analysis of Abert Lake, which does not represent the water at the beginning of an evaporation season, and therefore he probably considered the average concentration of the lake waters to be greater than it really is.

Though the proportion of soda in the water of Summer Lake is much greater than in that of Abert Lake, there is also much greater proportion of the troublesome sulphate. But even this is small in comparison with that found in other waters already employed for the manufacture of natural soda; the salts in the water of Owens Lake in California, for example, contain 14.7 per cent of sulphate. The percentage of bicarbonate in Summer Lake is higher than in Abert Lake, and consequently greater yield of "summer soda," or trona ($Na_2CO_3.NaHCO_3.2H_2O$) should be obtained. Recovery will possibly be simpler and less expensive here than at Abert Lake, but here also profitable recovery is problematic. If the annual evaporation is estimated to be 3.94 feet,[1] the lake contains almost 6,000,000 tons of soda, 4,000,000 tons of which is the monocarbonate and 2,000,000 tons the bicarbonate. The figure for evaporation may be too low because of the great quantity of spring water entering the lake, and local conditions at the points of collection may have rendered nonrepresentative the differences between concentrations shown by the analyses. There is also no means of knowing that the analyses represent normal extremes; consequently the figures representing the probable content of soda are only rough approximations. At Summer Lake, as well as at Abert Lake, careful experimentation must precede efficient commercial extraction, and the method finally adopted must be such that the product can compete in open market with Leblanc, Solvay, and electrolytic soda.

It is said locally that large springs discharge into both these lakes below the water line in addition to the surface flow and rainfall. A portion of the water of Summer Lake may come from such sources, but the analyses show that these springs discharge not the soda water they have been said to yield but water of very slight mineral content similar to the surface waters and other springs of the vicinity.

Ana River, the important feeder of Summer Lake, originates in the Ana springs, and its flow is augmented by inflow from other springs and by seepage. According to analysis 8 (p. 120) the springs at the headwaters contain 220 parts per million of dissolved solids, and according to analysis 10 the river water below the springs contained in winter only 158 parts per million of dissolved solids. Alkali carbonates and chlorides predominate in both waters, though alkaline earths are present.

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[1] Waring, G. A., Geology and water resources of a portion of south-central Oregon: U. S. Geol. Survey Water-Supply Paper 220, p. 40, 1908.

Mineral analyses of water from Chewaucan River near Paisley, 1911–12.

[Parts per million except as otherwise designated.]

Date.	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Dissolved solids.	Mean gage height (feet).	Mean discharge (second-feet).	Suspended matter (tons per day).	Dissolved matter (tons per day).
Aug. 11–20	6	7.0	1.17	8	46	0.12	8.5	2.9	5.7	0.0	50	3.1	0.48	0.25	98	3.9	35	0.66	9.3
Aug. 21–30	3	5.8	1.93	4	34	.10	7.6	2.9	6.3	.0	43	3.8	.32	.60	81	3.9	35	.55	7.6
Aug. 31–Sept. 9	5	7.8	1.56	......	15	.10	8.0	2.6	9.0	.0	44	5.6	.36	.75	87	3.9	39	.82	9.2
Sept. 10–19	3	.8	.27	......	33	.04	7.0	2.8	6.7	.0	43	5.3	.52	.50	81	4.0	40	.09	8.8
Sept. 20–29	3	8.0	2.67	7	31	.11	9.7	3.2	7.2	.0	46	4.9	.20	.25	81	4.0	41	.89	9.0
Sept. 30–Oct. 9	1	......	......	8	34	.11	7.2	3.2	9.8	.0	48	5.8	.30	.10	88	4.0	44	......	10.5
Oct. 10–19	4	8.4	2.10	10	30	.04	7.3	3.2	8.3	.0	49	3.5	.60	.15	81	4.0	43	......	9.4
Oct. 20–29	Tr.	6.2	......	4	30	.01	7.8	2.4	10	.0	50	3.5	.40	.50	85	4.0	42	.97	9.6
Oct. 30–Nov. 8	5	2.4	.48	......	28	.02	12	.8	11	.0	49	4.3	......	.30	82	4.0	44	.70	9.7
Nov. 9–18	20	14	.70	16	29	.15	7.6	2.1	8.2	.0	46	5.1	.34	.25	81	4.0	59	.28	12.9
Nov. 19–28	25	30	1.20	16	28	.12	12	.8	9.5	.0	48	4.3	.34	.25	86	4.0	62	2.23	14.4
Nov. 29–Dec. 8	20	50	2.50	9	32	.23	8.5	2.6	8.2	.0	46	6.6	.20	.25	86	3.9	55	5.00	12.8
Dec. 9–18	2	7.8	3.90	8	31	.11	9.1	1.4	7.6	.0	45	6.1	.06	.30	85	4.0	49	7.40	11.2
Dec. 19–28	6	2.8	.47	......	30	.10	8.8	1.6	12.	.0	51	7.6	Tr.	.35	93	4.6	40	1.06	10.1
Dec. 29–Jan. 7	4	12	3.00	7	30	.52	9.0	1.0	14	.0	46	5.3	.32	.45	85	4.4	57	.30	13.1
Jan. 8–17	10	17	1.70	......	30	.03	8.0	.5	11	.0	48	2.6	.27	1.8	103	4.5	65	1.85	18.1
Jan. 18–27	20	25	1.25	......	24	.62	9.0	.5	9.8	.0	45	2.1	......	......	83	4.2	86	2.98	19.3
Jan. 28–Feb. 6	15	11	.73	......	34	.10	8.3	.4	11	.0	43	4.1	.33	1.3	106	4.0	66	5.80	19
Feb. 7–16	80	90	1.13	......	28	.22	7.6	1.2	12	.0	45	7.2	.24	1.3	91	4.2	92	1.96	23
Feb. 17–26	145	181	1.25	30	35	.36	5.1	2.5	8.2	.0	45	4.3	.33	.25	92	4.2	105	22.4	26
Feb. 27–Mar. 7	30	31	1.03	40	29	.22	9.8	.4	8.7	.0	43	5.6	.27	.25	90	4.0	62	51	15
Mar. 8–17	30	24	.80	16	31	.15	7.0	2.8	8.0	[a]Tr.	48	2.8	.18	.25	88	3.9	59	5.2	14
Mar. 18–27	90	92	1.02	12	30	.10	8.2	2.7	8.8	.0	49	2.0	.36	.25	92	4.0	71	3.8	18
Mar. 28–Apr. 6	80	40	.50	14	27	.35	6.8	2.6	7.7	.0	45	2.1	.48	.25	89	4.4	125	17.6	30
Apr. 7–16	90	150	1.67	18	27	.50	6.6	2.3	7.2	.0	40	1.3	.36	.50	83	4.9	227	13.5	51
Apr. 17–26	30	36	1.20	30	25	.30	7.3	2.2	8.5	[a] 4.0	36	1.3	.30	.25	84	[b] 3.1	133	92	30
Apr. 27–May 6	85	140	1.65	61	28	.55	6.4	2.0	8.5	.0	42	4.6	.45	.45	88	2.8	223	12.9	53
May 7–16	110	288	2.62	61	21	.48	6.5	1.9	6.6	.0	37	4.3	.48	.40	71	2.2	492	84	94
May 17–26	70	98	1.40	45	22	.35	5.9	.5	6.9	.0	32	4.3	.40	.45	71	1.9	630	383	121
May 27–June 5	35	90	2.57	24	22	.15	6.0	1.0	7.6	.0	35	3.8	.34	1.0	72	1.6	784	167	163
June 6–15	20	57	2.85	13	17	.15	4.6	1.5	6.9	[a] Tr.	28	6.7	.30	.40	64	1.9	613	190	106
June 16–25	10	4.8	.48	20	34	.38	6.2	1.5	10	.0	37	5.4	.36	.50	90	2.7	263	94	64
June 26–July 5	10	7.6	.76	16	15	.06	5.2	1.2	11	.0	35	8.6	.20	.75	66	3.0	156	3.4	28
July 6–15	8	7.6	.95	13	35	.04	5.6	1.0	10	.0	39	7.4	.26	.50	78	3.2	85	3.2	18
July 16–25	50	28	.56	24	25	.04	6.2	1.0	11	[a] 5.3	30	4.6	.20	.50	73	3.1	72	1.7	14
July 26–Aug. 4	50	92	1.84	8	32	.20	7.6	3.4	5.4	.0	46	3.8	.42	1.1	87	3.3	74	5.4	17
Aug. 5–14	5	9.2	1.84	4	31	.18	7.4	3.2	4.7	[a] Tr.	42	3.8	.90	.75	88	3.4	60	18.4	14
Mean	32	47	1.44	19	29	.20	7.6	1.9	[c]6.8 [c]2.5	.0	44	4.5	.34	.5	85	......	......	[d]12,200	[d]10,980
Percentage of anhydrous residue	......	......	......	......	38.4	[e].4	10.1	2.5	[c]9.0 [c]3.3	29.2	......	6.0	.4	.7	......	......	......	......	......

[a] Abnormal; computed to HCO_3 in average. [b] Gage changed Apr. 15, 1912. [c] Sodium and potassium, determined on combined alkali residues. [d] Total annual denudation. [e] Fe_2O_3.

The water of Chewaucan River, the chief feeder of Abert Lake, contains even less mineral matter than that of Ana River, averaging 85 parts per million. Analyses of other springs and streams in this part of Lake County indicate that the above figures are entirely normal. Consequently the evidence afforded by the composition of the lake waters and the surface and subsurface waters of the region indicates that any springs that may exist under the lake beds are fresh and not soda springs, and that the lakes are merely concentrates formed by evaporation of the present influent waters and are of comparatively recent origin. A conservative estimate of the age of Summer and Abert lakes, based on their concentration and area, the composition of influent waters, and the rate of evaporation heretofore assumed, is 4,000 years. It is quite possible that the lakes are recent pools and that the salt and soda deposits of early Quaternary Chewaucan Lake lie buried beneath them.

GENERAL CHARACTERISTICS OF THE SURFACE WATERS.

CONDITIONS INFLUENCING QUALITY.

The chemical composition of a surface water is influenced by the nature of the rocks, the composition and texture of the soils, the distance from the ocean, the amount and distribution of precipitation, and many other conditions of the drainage basin. Only two of these influencing conditions, however, determine the general character of most of the river waters of Oregon—the precipitation and the nature of the rocks.

The amount and distribution of precipitation chiefly control the quantitative relation between the water and the mineral matter it holds in solution; the greater and more uniform the precipitation the less and the more uniform will be the mineral content, and conversely, the less and more irregular the precipitation the greater and more fluctuating will be the mineral content of the waters.

The nature of the rocks in the drainage basin determines the relative proportions of the various mineral substances in solution. Igneous rocks, such as granite, diorite, diabase, porphyrite, rhyolite, andesite, and basalt, contain large amounts (40 to 75 per cent) of silica, and all but pyroxenite, augitite, leucite, and nepheline contain feldspar as an essential constituent.[1] Disintegration and decomposition of these rocks by atmospheric and aqueous agencies produce as soluble products silica and alkalies (sodium and potassium) with some alkaline earths (calcium and magnesium). The basic materials are brought into solution chiefly as carbonates, and waters flowing over or through such rocks contain carbonate in excess of the amount

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[1] Merrill, G. P., Rocks, rock weathering, and soils, pp. 61-98, New York, 1906.

necessary to combine with the alkaline earths. Such waters are classed by Palmer (see p. 36) as primary alkaline waters. Rocks formed in water, including sedimentary rocks, contain relatively large amounts of salts of strong acids (sulphates and chlorides) and therefore yield solutions in which the amount of strong acids exceeds that necessary to combine with the alkalies. Waters flowing over or through such rocks may be called secondary saline waters. An exception to this rule is to be noted. Volcanic tuffs and allied rocks are laid down practically undecomposed and are classed as igneous rocks because of the nature of their decomposition products. Other characteristics, such as the acidity or basicity or the nature of the preponderant radicles of the rocks, also affect the character of a water; a water flowing from dolomite, for example, has a smaller calcium-magnesium ratio than one flowing from limestone.

A water analysis thus affords evidence regarding the nature of the predominant rock formations of the drainage basin from which the water has flowed. The evidence as to the general character of the rocks is fairly exact, but the evidence as to the specific nature of the rock, whether basalt or rhyolite, limestone or marl, is conclusive only where a rock of pronounced chemical type is almost universally and exclusively exposed throughout the drainage basin. The limestone of Wallowa River basin illustrates a rock whose nature may be predicted from the composition of the regional water.

Distance from the ocean chiefly affects the chlorine content, and its effects are noticeable only in waters of humid regions. The coastal waters of the Northwest give marked evidence of the effects of "cyclic salt," but the waters of the inland arid regions contain sufficient chlorine completely to mask the effects of wind-borne salt from the ocean.

AVERAGE CHEMICAL COMPOSITION.

The following table gives the average chemical composition, in parts per million and in percentage composition of the anhydrous residues, of river waters that were regularly examined during this investigation. Many single analyses of surface waters that have been given in preceding sections are not included in the table. (See also fig. 1.)

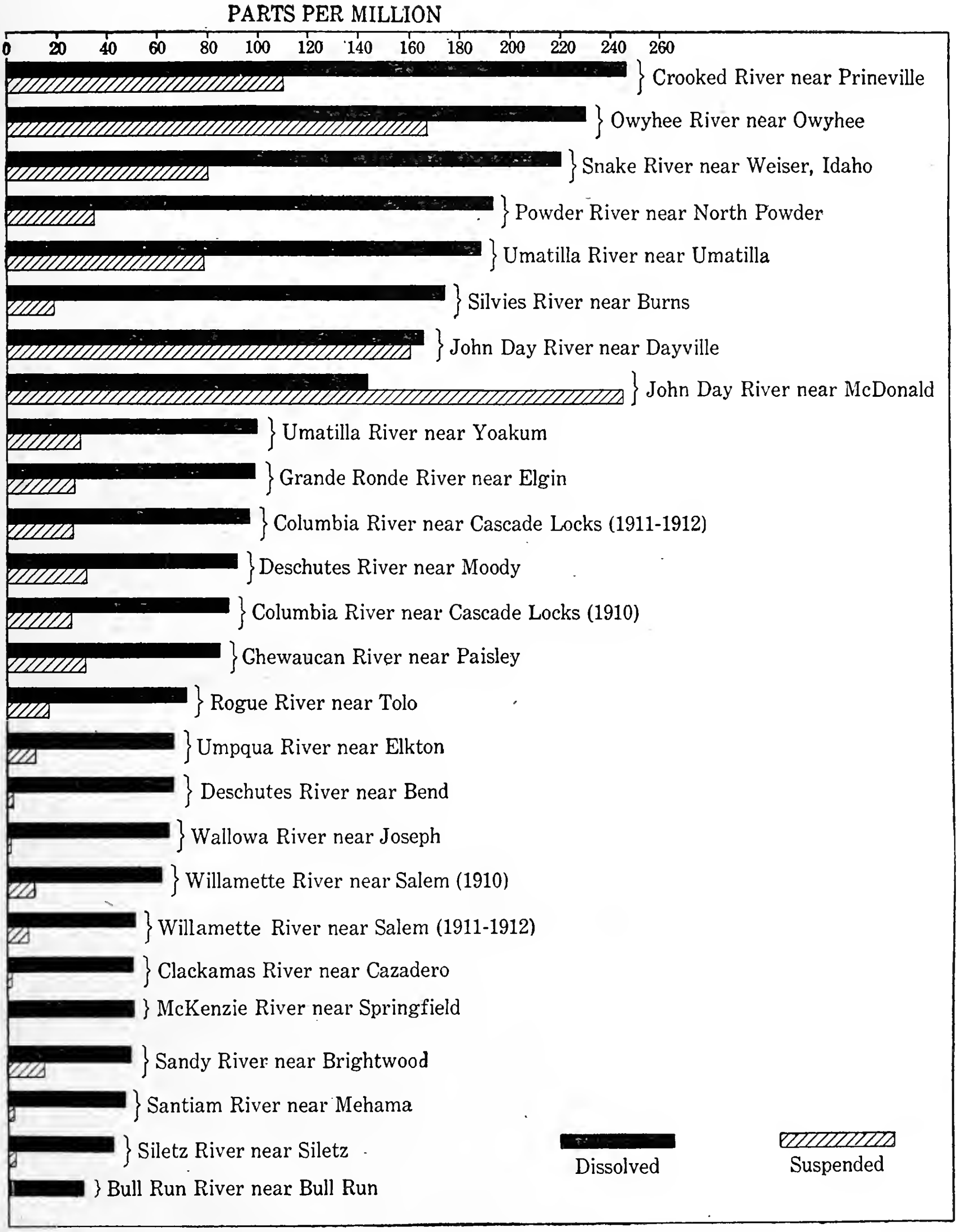

FIGURE 1.—Diagram showing relative content of suspended and dissolved matter in Oregon river waters.

Average chemical composition of the water of Oregon rivers.

Source of sample (river).	Mineral content (parts per million).																Percentage of anhydrous residue.									
	Turbidity.	Suspended matter.	Coefficient of fineness.	Color.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3.)	Chlorine (Cl).	Total dissolved solids.	Silica (SiO_2).	Oxide of iron (Fe_2O_3).	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).
Bull Run, Bull Run	Tr.	......	.....	3	9.0	0.03	2.7	0.53	3.1	0.5	0.0	12	3.1	0.31	1.3	30	34.0	0.1	10.2	2.0	11.7	1.9	22.3	11.7	1.2	4.9
Chewaucan, Paisley	32	47	1.44	19	29	.20	7.6	1.9	6.8	2.5	.0	44	4.5	.34	.5	85	38.4	.4	10.1	2.5	9.0	3.3	29.2	6.0	.4	.7
Clackamas, Cazadero	2	2.7	1.87	4	17	.05	5.3	1.4	4.2	.8	.0	26	3.9	.23	1.7	50	35.7	.2	11.1	2.9	8.8	1.7	27.3	8.2	.5	3.6
Columbia, Cascade Locks:																										
1910	26	52	2.09	....	13	.04	16	4.2	7.1		.0	67	13	.43	2.0	89	14.6	.1	18.0	4.7	8.0		37.2	14.6	.5	2.3
1911-12	27	40	1.97	11	14	.06	17	3.9	7.5	1.8	.0	69	12	.48	3.2	97	14.9	.1	18.1	4.1	8.0	1.9	36.2	12.8	.5	3.4
Crooked, Prineville	110	122	1.26	20	34	.09	26	11	38	5.2	1.1	199	17	.42	11	246	14.1	.1	10.7	4.5	15.7	2.2	41.0	7.0	.2	4.5
Deschutes:																										
Bend	2	2.5	.96	3	24	.04	5.1	1.6	6.7	1.6	.0	34	3.6	.22	1.2	66	39.3	.1	8.3	2.6	11.0	2.6	27.8	5.9	.4	2.0
Moody	32	48	2.72	12	28	.05	8.5	2.7	11	2.0	.0	57	5.0	.66	2.1	92	31.8	.1	9.6	3.1	12.5	2.3	31.8	5.7	.7	2.4
Grande Ronde, Elgin	27	28	1.18	26	30	.25	10	2.8	7.8	2.0	.0	54	5.3	.75	1.6	99	34.2	.4	11.4	3.2	8.9	2.3	30.8	6.1	.9	1.8
John Day:																										
Dayville	160	241	1.42	20	33	.06	22	11	13	2.1	.0	143	8.9	.76	2.2	166	20.2	.1	13.5	6.7	8.0	1.3	42.9	5.5	.5	1.3
McDonald	245	180	1.05	27	26	.07	20	7.6	13	2.4	.0	114	12	1.1	2.7	144	18.5	.1	14.2	5.4	9.2	1.7	39.7	8.5	.8	1.9
McKenzie, Springfield	Tr.	......	.....	2	17	.06	4.4	1.1	4.1	1.2	.0	24	3.8	.18	1.3	50	37.6	.2	9.7	2.4	9.1	2.7	26.6	8.4	.4	2.9
Owyhee, Owyhee	167	165	.98	22	31	.12	26	6.4	35	4.6	.0	139	35	.64	13	230	14.1	.1	11.8	2.9	15.9	2.1	31.0	15.9	.3	5.9
Powder, North Powder	35	60	1.74	22	26	.08	23	6.5	27	4.1	.0	136	24	.58	6.5	193	14.1	.1	12.4	3.5	14.6	2.2	36.3	13.0	.3	3.5
Rogue, Tolo	18	15	1.60	12	24	.07	7.2	1.7	6.1	1.3	.0	38	4.1	.26	1.4	72	36.8	.2	11.0	2.6	9.4	2.0	29.2	6.3	.4	2.1
Sandy, Brightwood	15	39	3.63	5	16	.07	4.6	1.3	4.2	.8	.0	18	7.2	.23	1.7	49	35.5	.2	10.2	2.9	9.3	1.8	19.8	16.0	.5	3.8
Santiam, Mehama	2	2.4	1.84	2	17	.04	5.2	1.3	3.7	1.1	.0	23	4.5	.25	1.0	47	37.7	.1	11.5	2.9	8.2	2.4	21.4	10.0	.6	2.2
Siletz, Siletz	3	5.6	2.6	3	9.4	.03	4.5	.9	5.5	.7	.0	17	4.6	1.6	4.2	42	23.6	.1	11.3	2.3	13.8	1.8	21.1	11.5	4.0	10.5
Silvies, Burns	19	18	1.49	14	41	.09	21	5.1	17	4.0	1.2	113	12	1.5	4.7	174	25.1	.1	12.9	3.1	10.4	2.4	34.9	7.3	.9	2.9
Snake, Weiser, Idaho	80	104	1.51	10	26	.04	33	9.6	22	3.5	2.0	130	35	.6	17	220	12.2	.0	15.5	4.5	10.3	1.7	31.0	16.5	.3	8.0
Umatilla:																										
Yoakum	30	29	1.6	16	29	.08	10	3.0	9.7	1.7	.0	55	6.2	.54	2.9	100	32.2	.1	11.1	3.3	10.8	1.9	29.9	6.9	.6	3.2
Umatilla	79	59	1.9	13	34	.07	23	6.6	22	4.8	.0	116	23	1.2	9.4	188	18.8	.1	12.7	3.6	12.1	2.6	31.5	12.7	.7	5.2
Umpqua, Elkton	12	15	1.25	14	18	.10	7.9	2.2	5.7	1.6	.0	36	5.2	.30	3.0	67	29.0	.2	12.7	3.6	9.2	2.6	29.0	8.4	.5	4.8
Wallowa, Joseph	1	......	.....	1	10	.02	15	.6	3.8	1.0	.0	47	8.5	.21	.55	64	15.9	.1	23.9	1.0	6.1	1.6	36.7	13.5	.3	.9
Willamette, Salem:																										
1910	11	12	1.23	....	15	.07	6.5	2.2	6.4		.0	33	5.7	1.6	4.0	61	26.1	.2	11.3	3.8	11.1		27.8	9.9	2.8	7.0
1911-12	8	16	3.00	13	15	.10	5.3	1.4	3.8	.8	.0	26	3.7	.36	1.9	51	33.0	.3	11.7	3.1	8.4	1.8	28.6	8.1	.8	4.2

GEOCHEMICAL CHARACTER.

The following table gives the geochemical classification of the water of Oregon rivers in accordance with the scheme outlined by Palmer. (See p. 36.) The data have been arranged in descending order of primary alkalinity. In computing these reactions the small numerical differences caused mostly by error of analysis have been eliminated by assigning them to bicarbonate. The information regarding the lithologic character of the drainage basins is necessarily generalized, more details having been previously given in the discussions of the quality of the various waters.

Geochemical classification of river waters of Oregon.

Source of sample (river).	Primary alkalinity.	Secondary alkalinity.	Primary salinity.	Secondary salinity.	Class.	Lithologic character of basin.
Powder, above North Powder	50.4	32.9	16.7	None.	I	Igneous and metamorphic rocks.
Deschutes, Bend	30.7	53.7	15.6	None.	I	Basalts, tuffs, pumiceous sand, etc.
Deschutes, Moody	30.3	54.9	14.8	None.	I	Do.
Crooked, Prineville	28.0	55.2	16.8	None.	I	Tertiary basalts, tuffs, etc.
Chewaucan, Paisley	27.6	59.8	12.6	None.	I	Basalts and other effusives.
Donner und Blitzen, P ranch	27.2	66.6	6.2	None.	I	Basalts and more siliceous effusives.
Umatilla, Gibbon	21.8	56.5	21.7	None.	I	Basalts and other effusives.
Rogue, Tolo	21.2	62.6	16.2	None.	I	Effusives and metamorphics.
Crooked, Paulina	20.4	67.2	12.4	None.	I	Basalts and other effusives.
Umatilla, Yoakum	20.3	61.6	18.1	None.	I	Do.
Grande Ronde, Elgin	20.0	65.0	15.0	None.	I	Do.
Powder, North Powder	19.8	56.8	23.4	None.	I	Igneous and metamorphic rocks.
Link, Klamath Falls	19.3	54.5	26.2	None.	I	Basalts and other effusives and eruptives.
Silvies, Burns	18.9	63.5	17.6	None.	I	Basalts and other effusives.
McKenzie, Springfield	17.4	59.8	22.8	None.	I	Basalts and Tertiary sediments.
Owyhee, Owyhee	15.5	52.6	31.9	None.	I	Basalts and lake sediments.
John Day, Dayville	13.7	76.4	9.9	None.	I	Basalts and other effusives.
Bull Run, Bull Run	12.7	54.7	32.6	None.	I	Effusives and morainal deposits.
John Day, McDonald	12.6	72.1	15.3	None.	I	Basalts, lake sediments, etc.
Clackamas, Cazadero	12.1	65.1	22.8	None.	I	Basalts and other effusives.
Santiam, Mehama	11.4	66.0	22.6	None.	I	Do.
Umatilla, Umatilla	11.4	61.0	27.6	None.	I	Do.
Umpqua, Elkton	10.6	66.5	22.9	None.	I	Basalts and other effusives; metamorphics.
Willamette, Salem (1911–12)	8.8	67.1	24.1	None.	I	Effusives; Tertiary sediments.
Malheur, Vale	7.6	56.7	35.7	None.	I	Basalts and lake sediments.
Columbia, Mayger	5.6	66.4	28.0	None.	I	Metamorphics, effusives, sediments, etc.
Siletz, Siletz	3.1	53.7	43.2	None.	I	Sediments, some effusives, etc.
Willamette, Salem (1910)	1.9	65.0	33.1	None.	I	Effusives, Tertiary sediments.
Columbia, Cascade Locks (1911–12).	1.6	75.8	22.6	None.	I	Metamorphics, effusives, sediments, etc.
Sandy, Brightwood	.4	62.3	37.3	None.	I	Basalts and other effusives; glacial débris.
Wallowa, Joseph	None.	80.2	19.3	0.5	III	Sediments, metamorphics, effusives.
Columbia, Cascade Locks (1910)	None.	76.5	20.0	3.5	III	Metamorphics, effusives, sediments, etc.
Snake, Weiser, Idaho	None.	65.1	30.0	4.9	III	Sediments at headwaters, intrusives, effusives, lake deposits.
Powder, north of Baker City	None.	7.3	85.8	6.9	III	Igneous and metamorphic rocks.

In Oregon volcanic rocks preponderate in areal extent and most of the surface waters are characterized by primary alkalinity. The headwaters of the Columbia, the Snake, and the Wallowa are among old sedimentary rocks, and the waters of these rivers exhibit slight secondary salinity.

Primary alkalinity is greatest in the water of rivers that traverse the Columbia River basalt, is small in the waters of the north coastal and the valley strips, and is lacking in the waters from the older sedimentary formations.

The analysis of the water of Powder River above North Powder is of doubtful value, and it is questionable whether seepage from irrigated land between Baker and the point of collection would alter the composition of the water to the extent shown by the reported analyses. The valley contains none except igneous rocks, and there is no good reason for expecting that change like that indicated would occur.

The water of Snake River at Weiser is characterized by secondary salinity because of drainage from old sediments in the upper basin of the river. Where the stream joins the Columbia, at Burbank, Wash., the secondary saline character of its water is less pronounced,[1] however, on account of the influence of the lava formations in its middle and lower valleys.

DENUDATION.

The amount of dissolved material in a river water and the rate of discharge of the river measure the rate of chemical erosion by that river. The amount of suspended material, however, is not truly proportional to the rate of mechanical corrasion, as corrasion is also caused by rock fragments that are too heavy to be carried in suspension but are light enough to be rolled downstream along the bed of the river. Such material forms an appreciable part of the total material transported, and it exerts a real but unmeasured corrasive effect on the stream bed. It was not possible to determine the amount of such material in the streams studied, and consequently the suspended matter is necessarily considered to represent the total amount of corrasive transported material. Values representing the amount of mechanical and chemical denudation of the drainage basin thus obtained, though they are not exact, are probably not far from the correct values and are comparable with similarly derived estimates.

In computing the following table it has been assumed that denudation removes uniformly over the whole drainage basin material having the uniform specific gravity of 2.64. The latter value is very nearly the average density of the rock mass. The assumption that denudation is uniform over the entire basin is conventional, as the erosive action is, of course, confined largely to the main channel and the smaller influent channels of the stream itself, and the rate of denudation is therefore variable throughout the basin. The results are valuable because they indicate differences in rate of erosion and

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[1] Van Winkle, Walton, The quality of the surface waters of Washington: U. S. Geol. Survey Water-Supply Paper 339, p. 101, 1914.

give much information concerning the time during which the streams have been eroding their channels. Because of the probability that there were larger amounts of atmospheric carbon dioxide in former ages, that tremendous changes in rainfall have occurred at different times in the earth's history, and that many other conditions influence the rate of denudation in relation to time, no attempt is made to discuss this problem.

The tons per day of dissolved and suspended matter carried past each sampling station has been computed for each 10-day period represented by the composite samples of waters, and these figures have been recorded in the tables of analyses. The average annual loads of suspended and dissolved matter of each stream have been computed by multiplying the averages of the 10-day estimates by 365, and the denudation in tons per square mile per annum has been computed by dividing those figures by the areas of the respective basins. The insignificant numerical differences between the estimates of denudation based on the analyses of the water of Columbia River at Cascade Locks in 1910 and those previously published[1] are caused by difference in the manner of estimating denudation during the periods not covered by analyses.

Denudation by rivers in Oregon.

Drainage basin.	Area in square miles.[a]	Material removed from drainage basin.						Years required to remove 1 inch.		
		Tons per annum.		Tons per square mile per annum.		Millionths of an inch of rock material per annum.				
		Dissolved.	Suspended.	Dissolved.	Suspended.	Dissolved.	Suspended.	Dissolved.	Suspended.	Total.
Bull Run, Bull Run	96	21,000	650	219	6.8	1,100	35	880	28,000	850
Chewaucan, Paisley	272	10,980	12,200	40	45	210	230	4,800	4,300	2,300
Clackamas, Cazadero	685	120,300	11,750	176	17	920	89	1,100	11,000	1,000
Columbia, Cascade Locks:										
1910	239,600	21,638,000	14,095,600	90.3	58.8	470	310	2,100	3,300	1,300
1911–12	239,600	17,000,000	7,000,000	71.0	29.2	370	150	2,700	6,600	1,900
Crooked, Prineville	1,990	58,400	96,600	29	49	150	250	6,500	4,000	2,500
Deschutes:										
Bend	1,530	85,600	2,850	56	1.9	290	10	3,400	99,000	3,300
Moody	9,180	642,900	370,400	70	40	360	210	2,700	4,800	1,700
Grande Ronde, Elgin	1,350	154,100	68,000	114	50	600	260	1,700	3,800	1,200
John Day:										
Dayville	1,000	68,000	198,000	68	198	360	1,000	2,800	970	730
McDonald	7,800	365,000	759,500	47	97	240	510	4,100	2,000	1,300
McKenzie, Springfield	960	199,600	26,800	208	28	1,100	150	920	6,800	810
Owyhee, Owyhee	11,100	195,400	397,800	18	36	92	190	11,000	5,400	3,600
Powder, North Powder	826	56,400	22,100	68	27	360	140	2,800	7,200	2,000
Rogue, Tolo	2,020	251,800	65,350	125	32	650	170	1,500	6,000	1,200
Siletz, Siletz	220	62,100	22,400	282	102	1,500	530	680	1,900	500
Snake, Weiser, Idaho	74,900	4,208,000	3,042,000	56	41	290	210	3,400	4,700	2,000
Umatilla:										
Yoakum	1,200	85,500	44,900	71	37	370	200	2,700	5,100	1,800
Umatilla	2,130	94,300	53,000	44	25	230	130	4,300	7,700	2,800
Umpqua, Elkton	3,680	488,500	217,400	133	59	690	330	1,400	3,000	970
Wallowa, Joseph	47	9,790	33.5	208	.7	1,100	3.7	920	270,000	920
Willamette, Salem (1911–12)	7,520	1,126,000	737,000	150	98	780	510	1,300	2,000	770

[a] Computed from best available maps, many of which are, however, incomplete.

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[1] Van Winkle, Walton, The quality of the surface waters of Washington: U. S. Geol. Survey Water-Supply Paper 339, p. 98, 1914.

INDUSTRIAL VALUE.

The following table shows the average industrial value of the river waters that were studied in connection with this investigation. The figures in the table have been computed from those showing the average composition of the waters (p. 126) by means of the formulas given on pages 34 to 36. The amounts of reagents required to soften the waters are for the most part theoretical, as most of the waters contain so little scale-forming matter that they do not need treatment. The statements regarding the corrosive tendencies of the waters are based only on determinations of the solid constituents, and consequently allowance should be made for corrosion that might be caused by dissolved gases. For the same reason allowance should be made for free carbon dioxide, which could not be determined, in adjusting lime treatment.

Average industrial value of Oregon river waters.

River.	Near—	Soap consumed (pounds per 1,000 gallons).	Softening reagents required (pounds per 1,000 gallons).		Corrosive power.[c]	Scale-forming constituents (pounds per 1,000 gallons).	Hardness of scale.	Color (parts per million).
			Lime.[a]	Soda ash.[b]				
Bull Run	Bull Run	20.0	[d] 0.06	0.00	N.C.	0.15	Hard	3
Chewaucan	Paisley	38.1	[d] .23	.00	N.C.	.47	do	19
Clackamas	Cazadero	30.9	[d] .14	.00	(?)	.29	Medium.	4
Columbia	Cascade Locks	69.0	[d] .37	[d] .02	(?)	.57	do	11
Crooked	Prineville	121.4	1.11	.00	N.C.	1.08	do	20
Deschutes	Bend	30.4	[d] .18	.00	N.C.	.35	Hard	3
Do	Moody	43.0	[d] .30	.00	N.C.	.47	do	12
Grande Ronde	Elgin	48.0	[d] .29	.00	N.C.	.54	do	26
John Day	Dayville	111.3	.85	.00	N.C.	.97	Medium.	20
Do	McDonald	92.4	.65	.00	N.C.	.83	Hard	27
McKenzie	Springfield	26.6	[d] .12	[d] .04	N.C.	.24	do	2
Owyhee	Owyhee	100	.73	.00	N.C.	.94	Medium.	22
Powder	North Powder	95.3	.72	.00	N.C.	.35	Hard	22
Rogue	Tolo	36.1	[d] .20	.00	N.C.	.39	(?)	12
Sandy	Brightwood	28.0	[d] 10	[d] .04	(?)	.29	Hard	5
Santiam	Mehama	29.4	[d] .13	.00	N.C.	.31	do	2
Siletz	Siletz	26.3	[d] .10	[d] .01	(?)	.20	Medium.	3
Silvies	Burns	84.6	.60	.00				14
Snake	Weiser, Idaho	133	.78	.10	N.C.	1.93	Soft	10
Umatilla	Umatilla	95.8	.64	.00	N.C.	1.04	Medium.	13
Do	Yoakum	48.5	[d] .31	.00	N.C.	.53	Hard	16
Umpqua	Elkton	40.0	[d] .20	.00	N.C.	.50	Medium.	14
Wallowa	Joseph	51.0	[d] .22	[d] .02	N.C.	.46	Soft	1
Willamette	Salem	27.5	[d] .14	.00	N.C.	.28	Hard	13

[a] 90 per cent CaO.

[b] 95 per cent Na_2CO_3.

[c] N. C., noncorrosive; ?, doubtful whether mineral constituents would cause corrosion.

[d] Figure only of theoretical value; water does not require treatment.

The river waters of Oregon are in general exceptionally soft and free from harmful mineral constituents, being comparable in these respects with the best surface waters of New England, northern New York, and northern Wisconsin, enormous quantities of which are used in all kinds of manufacturing. Few of them are so highly colored as many waters used in the East without trouble in paper mills, bleacheries, and dye works. The river waters of western Oregon are soft, do not require treatment for use in boilers, and would not cause corrosion under most conditions of use. Those of eastern Oregon are not uniform in character; the waters of Chewaucan, Deschutes, Grande Ronde, and Wallowa rivers are soft, but those of Crooked, John Day, Owyhee, Powder, Silvies, Snake, and Umatilla rivers are hard and need softening for best results in boiler practice.

The slight mineralization and the small amount of incrustants in waters flowing through the arid portions of the State are surprising. In these respects they differ greatly from the desert waters of California. The insoluble character of the Columbia River basalt, compared with the relatively soluble character of the rocks of the Diablo, Gabilan, Santa Ynez, and other mountains of California, is doubtless the chief cause of this difference, in addition to which the colder waters of the Oregon plateau do not dissolve rock material so rapidly as the warmer waters of California.

VALUE FOR IRRIGATION.

All the river waters of the State that were examined are excellent for irrigation and could be used almost indefinitely without causing injurious accumulation of alkali because of the dissolved matter in them.

The following table shows the relative suitability of the lake waters for irrigation. Most of these lakes are in regions where water for irrigation is highly prized, but one, Crater Lake, has been included merely to indicate the difference in irrigation value between the lake waters of the arid region and a water similar to those flowing in Oregon rivers. Crump Lake, of the Warner chain, is the only one containing good water for irrigation, though Hart Lake contains water only slightly poorer. The waters of Silver Lake (in Lake County), Lower Klamath Lake, and Flagstaff Lake are of fairly good quality; those of Goose Lake, Malheur Lake, and Pelican Lake are poor; and those of Abert, Bluejoint, Harney, Silver (in Harney County), and Summer lakes are unfit for irrigation. All. the lake waters are characterized by the presence of black alkali or sodium carbonate.

Value of some lake waters of Oregon for irrigation.

Lake.	Basin.	County.	Alkali coefficient.	Type of alkali.	Classification.
			Inches.		
Abert	Chewaucan	Lake	0.08	Carbonate	Bad.
Bluejoint	Warner	do	.55	do	Do.
Crater	Crater Lake	Crater Lake National Park.	130	do	Good.
Crump	Warner	Lake	41	do	Do.
Flagstaff	do	do	7	do	Fair.
Goose	San Francisco Bay	do	2	do	Poor.
Harney	Harney	Harney	.25	do	Bad.
Hart	Warner	Lake	15	do	Fair.
Lower Klamath	Klamath River	Klamath, T. 41 S., R. 9 E.	9	do	Do.
Do	do	Siskiyou (Cal.), T. 48 N., R. 2 E.	6	do	Do.
Do	do	Siskiyou (Cal.), T. 47 N., R. 3 E.	8	do	Do.
Malheur	Harney	Harney	5.5	do	Poor.
Pelican	Warner	Lake	1.6	do	Do.
Silver	Harney	Harney	.71	do	Bad.
Do	Silver Lake	Lake	12	do	Fair.
Summer	Chewaucan	do	.12	do	Bad.

SUMMARY.

The river waters of Oregon are low in mineral content and are very good for general industrial use and for irrigation. With one or two exceptions they carry small amounts of suspended matter that can be readily removed. The waters of John Day and Sandy rivers, however, are characterized by very finely comminuted suspended matter, the removal of which would be difficult and would probably necessitate filtration through rapid filters. Slow sand filtration can be used with many of the river waters, but coagulation and rapid filtration is better suited to some of them.

Erosion progresses most rapidly in the upper basin of John Day River, where it is chiefly by corrasion, somewhat less rapidly in the Coast Range, still less in the Cascades, and most slowly in the central part of the State.

The lakes of central Oregon are large and the waters of some of them are economically important. Detailed studies should be made of the deposits and brines in order to ascertain the location, nature, extent, and commercial value of the residues.

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