Irrigation and Streamflow Depletion in Columbia River Basin above The Dalles, Oregon

By W. D. SIMONS

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1220

An evaluation of the consumptive use of water based on the amount of irrigation

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1953

UNITED STATES DEPARTMENT OF THE INTERIOR

Douglas McKay, *Secretary*

GEOLOGICAL SURVEY

W. E. Wrather, *Director*

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 50 cents (paper cover)

CONTENTS

	Page
Abstract	1
Introduction	2
Purpose and scope	2
Acknowledgments	3
Irrigation in the basin	3
Historical summary	3
Legislation	6
Records and sources for data	8
Stream depletion due to irrigation	10
Consumptive use by crops	11
Methods of measurement	12
Experiments with soil tanks	12
Lysimeter experiments	13
Experiments with field plots	13
Determinations of soil moisture	14
Fluctuations of the water table	14
Studies of inflow and outflow	15
Estimates of average consumptive use	15
Irrigated areas and estimated streamflow depletion	18
Columbia River above the international boundary	23
Kootenai River basin	23
Pend Oreille River basin	25
Clark Fork above Missoula, Mont	26
Clark Fork below Missoula, Mont	27
Clark Fork at St. Regis, Mont	29
Flathead River	31
Pend Oreille River below Z Canyon near Metaline Falls, Wash	32
Columbia River at international boundary	35
Columbia River, international boundary to Grand Coulee Dam	36
Kettle River	36
Colville River	37
Spokane River	38
Columbia River at Grand Coulee Dam, Wash	39
Columbia River, Grand Coulee Dam to Snake River	40
Okanogan River	40
Methow River	42
Chelan River	45
Entiat River	46
Wenatchee River	47
Columbia River at Trinidad	49
Crab Creek	50
Yakima River	52
Columbia River, between Yakima River and Snake River	57
Snake River basin	58
Snake River above Heise	58
Snake River, Heise to King Hill	60
Henrys Fork	61
Portneuf River	63
Minor tributaries, Neeley to King Hill	64
Mud Lake area	66
Little Lost River	66
Big Lost River	67
Big Wood River	67

Page

Irrigated areas and estimated streamflow depletion—Continued
Snake River basin—Continued
Snake River, Heise to King Hill—Continued
Snake River at King Hill, Idaho.......... 69
Snake River, King Hill to mouth.......... 70
Bruneau River.......... 70
Snake River, King Hill to Murphy.......... 72
Owyhee River.......... 73
Boise River.......... 78
Malheur River.......... 81
Payette River.......... 84
Weiser River.......... 88
Snake River, Murphy to Weiser.......... 90
Burnt River.......... 91
Powder River.......... 93
Snake River, Weiser to Oxbow.......... 95
Pine Creek.......... 96
Imnaha River.......... 97
Salmon River.......... 99
Grande Ronde River.......... 102
Clearwater River.......... 104
Snake River, Oxbow to Clarkston.......... 106
Columbia River, Snake River to The Dalles.......... 108
Walla Walla River.......... 108
Umatilla River.......... 110
Willow Creek.......... 112
John Day River.......... 113
Deschutes River.......... 116
Columbia River near The Dalles, Oreg.......... 121
References cited.......... 123
Index.......... 125

ILLUSTRATIONS

Page.

Plate 1. Map showing drainage basin of Columbia River above The Dalles, Oreg.......... In pocket
Figure 1. Graph showing irrigated area, above selected points in the Columbia River basin.......... 6

TABLES

Table 1. Net consumptive use, by subdivisions, of the Columbia River basin.... 22

IRRIGATION AND STREAMFLOW DEPLETION IN COLUMBIA RIVER BASIN ABOVE THE DALLES, OREGON

By W. D. Simons

ABSTRACT

The Columbia River is the largest stream in western United States. Above The Dalles, Oregon, it drains an area of 237,000 square miles, of which 39,000 square miles is in Canada. This area is largely mountainous and lies between the Rocky Mountains and and the Cascade Range. The Kootenai, Pend Oreille, and Snake Rivers are the principal tributaries. Precipitation varies from 7 inches near Kennewick, Wash. to over 100 inches in some of the mountainous regions. Most of the runoff occurs in the spring and summer months as a result of melting snow. Precipitation is generally light during the summer months, and irrigation is necessary for sustained crop production.

Historical data indicate that irrigation in the Columbia River basin began prior to 1840 at the site of missions established near Walla Walla, Wash. and Lewiston, Idaho. During the next half century the increase in irrigated area was slow and by 1890 included only 506,000 acres. The period 1890 to 1910 was marked by phenomenal increase to a total of 2,276,000 acres in 1910. Since that time there has been more gradual addition to a total of 4,004,500 acres of irrigated land in 1946 in the Columbia River basin above The Dalles, Oreg. Of this total 918,000 acres were located in the Columbia Basin above the mouth of the Snake River; 2,830,000 acres in the Snake River basin, and the balance, 256,000 acres below the mouth of the Snake River.

Values of net consumptive use were determined or estimated for various tributary basins of the Columbia River basin and compared to available experimental data. These values were then used to compute the average depletion which could be directly attributed to irrigation. The yield of a drainage basin was considered to be the sum of the observed runoff and the estimated depletion. For purposes of comparison, the depletion was expressed both in terms of acre-feet and as a percentage of the yield of the basin. This percentage depletion varied from less than 1 percent for many tributary basins to 53 percent for the portion of the Snake River basin between Heise and King Hill, Idaho. For the Columbia River near The Dalles, Oreg., the average depletion during the period 1921 through 1945, amounted to 4.7 percent of the yield and the depletion represented by the 1946 stage of irrigation development amounted to 5.3 percent of the long-term yield.

INTRODUCTION

PURPOSE AND SCOPE

Safe and economical design of a water-use project requires adequate knowledge of the available water supply. The hydrologic data necessary to determine the probable future water supply must be collected over a period of many years in order to adequately evaluate the effects of the vagaries of the weather and to determine the dependable yield during drought period. If during the period of investigation changes have occurred in the use of water, the effects of these changes must be considered in analyzing the data to determine probable future supply. Records of runoff covering a period of many years should be adjusted to a comparable level of water-supply development and water use.

Irrigation is one use of water that has been continually changing. The object of this report is to trace the enlargement in irrigated area in the various subdivisions and to evaluate the net depletion in streamflow resulting from increased irrigation. Thus it presents some data necessary for the proper interpretation of runoff records used in water-supply studies.

Data on irrigated area presented herein was gathered from many sources. Information from any one source was never complete and was in many instances in conflict with information from another source. Thus it became necessary to resolve these differences and to estimate the missing periods. However, it is believed that the inaccuracies from these sources are, on the whole, relatively minor and that the data on irrigated area are sufficiently accurate for use in this study.

The adequacy of the water supply for specific areas is seldom known for a particular year. Likewise in the determination of net consumptive use, records are inadequate for estimating rates for individual years but are believed to be reliable when taken as an average over a period of years. Consumptive use will be greater during dry, hot summers, and a greater part of the water must be supplied by irrigation during these years. In a general study such as this, available data did not warrant an attempt to determine the net depletion, except on the basis of average annual rates for each part of the basin.

In the absence of reliable data on the ground-water conditions underlying these irrigated areas, assumptions had to be made as to locations where return flow would be recaptured by gaged streams. No allowance was made for water temporarily or permanently detained in ground-water storage.

Only the United States portion of the basin has been considered in this report. Irrigation in Canada is relatively unimportant, except in the Okanogan River basin. Reference to irrigation in Canada is made in the discussions of individual tributary basins.

It is noteworthy that for most tributary basins the net depletion is a minor fraction of the yield of that basin, but this is no warranty that much greater supplies can be developed easily and cheaply. Indeed, the current use of water may be equal to or greater than the supply during the low-water season, even though the depletion is so small a fraction of the annual yield.

ACKNOWLEDGMENTS

The records of irrigated area included in this report were collected from many sources through the generous cooperation and assistance of many Federal, State, and local agencies, watermasters, county agents, lawyers, and private citizens. Reports of the Bureau of the Census and the Bureau of Reclamation were used extensively. The collection of detailed data on irrigation was performed by the following Geological Survey engineers: C. D. Bue for Montana, Lynn Crandall for upper Snake River, R. W. Revell for the remainder of Idaho, A. P. Lyman for Oregon, and G. L. Bodhaine for Washington. This report was prepared under the direct supervision of C. C. McDonald, staff engineer, Technical Coordination Branch, Tacoma, Wash. and under the administrative direction of R. W. Davenport, chief, Technical Coordination Branch, Washington, D. C.

IRRIGATION IN THE BASIN

HISTORICAL SUMMARY

The development of irrigation in the Columbia River basin has been intimately associated with the settlement and industrial development of the Northwest. Most of the basin suitable for crop production is semiarid, and irrigation is required during the growing season. Irrigation agriculture was practiced by the early settlers to meet the local needs for vegetable and grain crops. Transportation was slow and difficult, requiring each settlement to be practically self-sustaining. As settlement of the Northwest progressed, markets for farm products expanded continually, and irrigation agriculture became an increasing factor in the region's economy.

The early settlers found ample opportunity to divert water from tributary streams to adjacent rich bottom or bench lands with little work and expense. These lands were well adapted to irrigation; they were level or gently rolling, had good natural drainage and were covered with grasses and sagebrush, which made preparation of the land for cultivation possible at low cost.

Probably the earliest irrigation in the Columbia River basin was carried on by the missionaires who settled in the basins of Walla Walla River and Clearwater River. In the fall of 1836 missions were located near Walla Walla, Wash. by Dr. Whitman and near Lewiston, Idaho by Dr. Spalding. The following year crops were grown at these missions, using water from Doan and Lapwai Creeks.

In the upper Columbia River basin, the earliest known irrigation was at St. Mary's Mission, on the Bitterroot River, about thirty miles south of Missoula, Mont. In about 1846 or 1847 the mission is reported (Bancroft, H. H., 1890, p. 604) to have produced wheat, potatoes, and other vegetables by irrigation from two small creeks running through its farm. In 1854 Father DeSmet founded St. Ignatius' Mission about 32 miles north of Missoula in the Flathead River basin, and irrigation probably was started during the following year.

There is an unauthenticated report of irrigation in the Yakima River basin, Washington antedating the Treaty of 1855 (House Doc. 103, vol. 2, 1934, p. 879). However it is probable that the first development came in 1867 when the Nelson Ditch was constructed to divert water from the Naches River. (Parker and Storey, 1917, p. 28.) This was 2 years after Yakima County was created in the Territory of Washington and about 6 years after the first pioneers had settled in this valley.

In other parts of the Columbia River basin settlers were beginning to irrigate in order to meet the greatly increased demand for food crops created by the influx of settlers accompanying the booming mining and cattle raising activities during the period 1860 to 1880. During this period the railroads also were pushing westward, bringing additional settlers and expanding the markets for farm products.

In 1870 there were only 129,877 people in Washington, Oregon, and Idaho, and approximately 48,000 acres of land were being irrigated in the Columbia River basin above The Dalles, Oreg. The most rapid increase in population during the period 1870 to 1880 occurred west of the Cascade Range. By 1880 the population was 300,949, the greatest increase having occurred in the Willamette Valley in Oregon.

The decade from 1880 to 1890 was one of intensive development in the Northwest. Transcontinental rail connections between the Great Lakes region and the ocean ports of the Pacific Northwest were completed in 1883, opening vast new markets for the products of the lands, mines, and forests of the Northwest. Large irrigation projects were undertaken in the Snake and Yakima River valleys, and the population of Washington, Oregon, and Idaho increased 170 percent.

The rate of population increase during the period 1890 to 1900 was much below that of previous decades, reflecting the influence of the panic of 1893, but the total numerical increase of 329,927 was about twice that of the preceding decade. The irrigated area in the Columbia River basin above The Dalles, Oreg., meanwhile was expanding rapidly. From a total of 48,000 acres in 1870, it has increased to 153,000 acres in 1880 and 506,000 acres in 1890. (See page 122.) During the period 1884 to 1896 construction was commenced on practically all the canals that presently serve the lands above American Falls on the upper Snake River.

During the next two decades, 1890 to 1910, the expansion of irrigated area was phenomenal, reaching a total of 2,276,000 acres in 1910. Irrigation agriculture was firmly established as an important part of the economy of the basin east of the Cascade Range. Export markets became available and the agricultural economy was no longer geared to local needs. Aided by the above-normal rainfall during this period, dry farming, chiefly the raising of wheat, developed rapidly. Favorable Federal and State legislation and the participation of the Federal Government in water resource development (see p. 6) provided impetus to irrigation development, making possible the creation of irrigation districts.

Subsequent to 1920, the increase in irrigated lands has been gradual though in some of the smaller basins the increase amounts to a substantial part of the total irrigated area in these basins. The gradual change from the wet period of 1890-1910 to the dry period, which reached its most critical stage during the period 1929 to 1934 in most parts of the basin, had a substantial effect on irrigation developments. Many irrigation districts found that their storage reserves were inadequate to cope with such conditions and supplemental water supplies or additional storage capacity was needed. Additional irrigation projects were more expensive to develop, water supplies were less accessible than those for earlier projects, and pumping was often required. These factors tended to restrict irrigation expansion, especially during the years of the business depression. Recent irrigation activities generally have been limited to extensions of earlier projects, to providing supplemental water supplies, or to a combination with power projects that provide low-cost power for pumping. The great Columbia Basin Project in central Washington, now in process of construction, is an example of the latter type of development. Power for the pumping of stored irrigation water for more than a million acres of land will be provided by Grand Coulee Dam.

In 1946 the irrigated area in the Columbia River basin above The Dalles, Oreg. totaled 4,004,500 acres. Of this total 918,300 acres were located above the mouth of the Snake River, 2,829,700 acres within the Snake River basin, and the balance of 256,500 acres below the mouth of the Snake River. The rate of expansion of irrigation is shown graphically by figure 1. From the modest beginnings made by the missionaries over a hundred years ago, irrigation has become the dominating factor in the agricultural economy of the Columbia River basin.

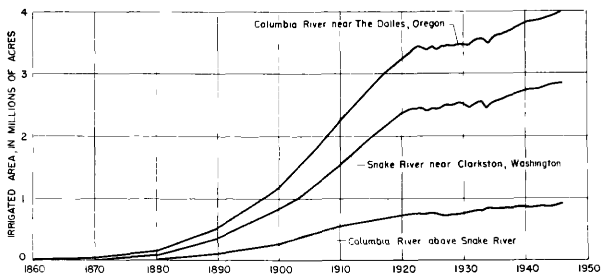

Figure 1.-Graph showing irrigated area, above selected points in the Columbia River basin.

LEGISLATION

The Federal and State laws relating to water rights and control of the public lands have had great influence upon the development of irrigation in the arid West. Some of this legislation was a matter of necessity in settling disputes arising from conflicting uses of water; some was designed specifically to stimulate irrigation.

The English common law recognizes the riparian doctrine. This doctrine vests in the owner of the land adjacent to a stream, the right to have the stream flow past his land in perpetuity, undiminished in quantity and unimpaired in quality. The riparian rule originated in England in a humid climate and was adapted to conditions and common uses in that country and in the eastern United States, but it proved to be inappropriate for conditions requiring the use of water for irrigation. The riparian doctrine gave rise to many disputes in the early days of development of the West.

The doctrine of appropriation recognizes the principle that the first to put the water to beneficial use has a right to the water superior to all later appropriations. This doctrine was essentially developed among the gold miners of California, and it became law through the sanction of the local courts. Most of the land in the arid and semiarid region was originally public land, and under the riparian doctrine the ownership of the streams was an accompaniment of the ownership of the land. In the Act of 1886, the Federal Government recognized the water rights existing under local customs, laws, and decisions of courts and the right to construct ditches across public lands. The necessity of diverting water from the streams to irrigate lands distant from the streams was recognized and specifically provided for in the Desert Land Act of March 3, 1877, which required irrigation as a condition of land ownership. This law required a dedication of the water by its owner to the uses of irrigation, except where expressly forbidden in the case of navigable streams. These policies were later incorporated in the Reclamation Act in 1902 and are still in effect.

Until comparatively recent years, the title to irrigation water in some localities was in a chaotic state, but the acceptance of the doctrine of appropriation by substantially all the arid states and the early recognition by the Federal Government of State authority over nonnavigable waters have tended to eliminate most of the difficulties. In 1939 the Idaho Supreme Court stated: "The right of riparian ownership has been abrogated in Idaho." (National Resources Planning Board, 1943, p. 101.) In the years between 1921 and 1925, court decisions in Montana left no doubt that the appropriation doctrine prevails in the State. Montana is the only State in the Columbia River basin that has not provided by statute for centralized control over the appropriation and administration of water. Although the Oregon Water Code of 1909 recognized riparian rights to some degree, the effect of court decisions and later statutes is to make the riparian doctrine little more than legal fiction in Oregon. (National Resources Planning Board, 1943, p. 107.) The Common Law doctrine of riparian rights is in force in Washington but "has been stripped of some of its rigors" particularly during the past 20 to 25 years, (National Resources Planning Board, 1943, p. 110) so that today it is of minor importance in the irrigation economy of the State.

The Carey Act of 1894 was designed to stimulate irrigation development in the arid states containing public lands by providing for the transfer of not more than 1,000,000 acres of arid public land to each State for development. Title to the land was acquired by individuals through State sponsorship with the requirement that the land be irrigated within 10 years after passage of the Act. This Act did much to stimulate development of irrigation especially in the Snake River basin in Idaho and Oregon.

State authorization of irrigation districts in Washington, Oregon, and Idaho during the period 1890-95 contributed to the great increase of irrigation during this period.

The Reclamation Act of 1902 created the present Bureau of Reclamation and its Reclamation Fund and marked the beginning of Federal sponsorship of irrigation projects. By means of the Reclamation Fund the Federal Government may finance the construction of an irrigation project, and the costs are repaid by the land owners over a period of years. The Yakima Project, Washington and the Minidoka Project, Idaho were among the first undertaken by the Federal Government under the Reclamation Act. In 1948 the Tieton Irrigation District, Yakima Project, became the first Bureau project to liquidate its construction obligations (U. S. Bureau of Reclamation, 1948, p. 465).

RECORDS AND SOURCES FOR DATA

In general, "irrigated area" as used in this report is the gross farm area upon which water is artificially applied for the production of crops with no reduction for access roads, canals, or farm buildings. Native meadows and pasture lands are included if water is artificially applied during the year. This definitior is similar to the definition of irrigated land used by the Bureau of the Census:

Land should be classed as irrigated which has water supplied to it for agricultural purposes by artificial means or by seepage from canals, reservoirs, or irrigated lands, but land which has natural ground water sufficiently near the surface to support plant life should not be classed as irrigated. Land which is flooded during high-water periods should be classed as irrigated if water is caused to flow over it by dams, canals, or other works, but should not be classed as irrigated if the overflow is due to natural causes alone.

Available data on irrigated areas are not entirely consistent with respect to the inclusion of land utilized for miscellaneous farm purposes other than the growing of irrigated crops. This report, however, uses the gross farm area on the premise that it would more accurately represent total consumptive use. This definition of irrigated area does not distinguish between lands having an adequate or inadequate supply of water.

Records are not sufficiently accurate or complete to reflect yearly fluctuations in the irrigated area in all tributary basins, and in many it has been necessary to estimate the acreage for years when the irrigated area could not be determined directly.

Determinations of irrigated area were based upon data from as many independent sources as possible. The following sources have been used: Census Reports, recorded water rights and court adjudications, Bureau of Reclamation reports, water-supply papers of the Geological Survey, County tax rolls, watermaster reports, records of irrigation companies and districts, State Engineers' reports, publications of pioneer activities, Soil Conservation Service reports, and field reconnaissance.

A census of irrigation is available for 1889, 1899, 1902, 1909, 1919, 1929, 1934, and 1939. Tabulations of irrigated areas by counties were of limited usefulness. During early years many county boundaries were changed so that much of the data for early years are not comparable with that for recent years except on a state-wide basis. Further, county lines do not coincide with topographic drainage divides so that for the purpose of this report, data by counties were useful only in a general way. Tabulations of irrigated area by drainage basins were made in 1902, 1919, 1929, and 1939. These proved very useful in checking data from other sources although the drainage basin subdivisions used by the Bureau of the Census were seldom coincident with those of the stream-gaging stations.

The records concerning water rights and court adjudications were fruitful sources of data. Although many conflicts arose, commonly these records afforded the only information available for small or isolated areas and for early years. Data obtained from this source were used extensively to distribute the Census tabulations by tributary basins, especially in Idaho and Oregon. Usually they indicate the maximum amount of irrigated lands and have been so used for some areas.

The yearly and special reports of the Bureau of Reclamation contain complete records for projects constructed by that bureau; they afford data on the area actually supplied with water, and on the net area in cultivation. Investigational reports on areas where projects were considered gave information relative to the stage of development existing at the time.

Water-supply papers of the Geological Survey also supplied data that could be used to spot check the tabulations of irrigated areas. These were primarily the reports on water utilization for specific areas, for example; Water utilization in the Snake River basin, Water-Supply Paper 657, and Water power of the Cascades, Yakima River basin, Water-Supply Paper 369.

The tax records of many counties contain data on irrigated areas, owing to their higher appraisal value for tax purposes. However, for some parts of the basin information from this source was not entirely reliable and was used only in the absence of more accurate data. Montana, in compliance with an act passed by the legislature about 1919 requiring the classification of land in the State, made field surveys of all irrigated lands for tax purposes. From these land classification surveys the County totals were broken down by tributary basins. Although these breakdowns apply only to the year in which the surveys were made, they provided a guide for distributing county totals for other years. Since about 1920, the Montana State Board of Equalization has published tabulations of irrigated area by counties in its biennial reports.

Reports of local watermasters, where available, were used in connection with material from other sources. In the Boise River valley and Snake River Plains such reports were used extensively.

The records kept by irrigation companies were utilized where available. In Washington each irrigation district formed under State law is required to submit a report annually to the Department of Conservation and Development, listing among other things the area irrigated during that year. These records were compiled and used extensively.

Various reports of the State agencies for Montana, Idaho, Oregon, and Washington were scanned for information. However, in most of these reports the information relating to irrigated area was not in sufficient detail to be useful for the purpose of this report. Field reconnaissance of many areas was necessary in order to complete the tabulations and to reconcile conflicting data from several sources. Farmers, lawyers, judges, bankers, pioneers, and other qualified persons were interviewed to obtain supplementary data. Conflicts between data from various sources have been resolved so far as possible, and any residual discrepancies are discussed under the appropriate area.

STREAM DEPLETION DUE TO IRRIGATION

The use of water to irrigate land and produce crops unavoidably reduces the amount of water available for other purposes. Usually the total amount of water diverted is considerably greater than the net loss to the basin, which is the amount dissipated through transpiration by crops and through evaporation from the land surfaces that have been artificially wetted. Most of the remaining undissipated water returns ultimately to the streams, largely by underground percolation at a time and rate unlike natural runoff. This return flow usually contains a higher concentration of dissolved minerals than does native river water, owing in part to its prolonged contact with the earth material through which it percolates and partly because it tends to accumulate the dissolved matter that is dissipated by plant growth. Thus, the use of water for irrigation diminishes streamflow by increasing evapotranspiration, changes the regimen of the stream by altering runoff conditions, and commonly increases the mineral content of the water.

Under natural conditions a portion of the available precipitation becomes soil water and meets the demand of evaporation and transpiration. The amount so consumed depends upon the amount and seasonal distribution of the precipitation, the concurrent temperatures, characteristics of the soil, and the types and amount of vegetation. Under irrigation, both the available soil water and the opportunity for evaporation and transpiration are greatly increased. More water is dissipated by transpiration of the irrigated vegetation, by evaporation from the artificially wetted soil, and by evaporation from artificial water surfaces such as reservoirs, canals, and waste-water swamps. The moisture available under natural conditions influences the extent and nature of the native vegetal cover. In the Columbia Basin, most of the land currently being irrigated was originally arid or semiarid, and little moisture was available to support native vegetation. Consequently the consumptive use by the native vegetation was relatively small. These same factors tend to make the net consumptive use by irrigated crops relatively large.

When irrigation is first begun in a new area, all potential return flow does not get back into the streams. Commonly part of this potential flow goes into building up ground-water storage in the area. An unstable condition is established that may require years to stabilize. Thus the amount and the seasonal distribution of the return flow depends not only upon the distance and the rate of percolation back to the stream but also upon the volume of water retained in ground-water storage. Streamflow characteristics may be further modified by storage in surface reservoirs and by evaporation from reservoirs and canals.

Large blocks of irrigated land, such as on the Snake River Plains, may exert some influence upon the climate of the region. However, this effect is believed to be relatively small and highly localized and has not been considered further in this report.

CONSUMPTIVE USE BY CROPS

The term "consumptive use" has been generally accepted as synonymous with evapotranspiration, and represents the quantity of water absorbed and transpired in building plant tissue, together with that evaporated from the adjacent land surface. Investigators have found difficulty in separately measuring the water absorbed by plants and that evaporated from the land. Accordingly, these two components have been combined as "evapotranspiration." As the term applies to irrigated lands, consumptive use may be defined as the quantity of water in acre-feet per acre per year absorbed by the crop and transpired or used directly in building plant tissue, together with that evaporated directly from the crop-producing land. Definitions applicable to large irrigated areas or basins including bare ground and natural vegetation, includes water evaporated from snow and that intercepted and evaporated from vegetation. This report is concerned primarily with the consumptive use by crops, of the water applied to the land through irrigation. This quantity which has been called net consumptive use, is determined by deducting the estimated contribution by rainfall toward the production of irrigated crops from the annual consumptive use.

The net consumptive use so determined is considered to represent the depletion of streamflow as a result of irrigation, disregarding evaporation from reservoirs and canals. Total depletion in a basin may be defined as the difference between precipitation and runoff, with appropriate allowance for changes in storage. No attempt is made in this report to estimate natural or total depletion, but only the depletion directly attributable to irrigation.

As used in this report, return flow is that portion of the irrigation water which returns at any time or place to a surface stream.

METHODS OF MEASUREMENT

Many methods of determining consumptive use have been used in hydrologic investigations: direct measurement on soil tanks, lysimeters, or field plots, determination and interpretation of fluctuations in soil moisture, evaluation of water table fluctuations, and inflow-outflow inventories on farms, irrigation projects, or valleys.

EXPERIMENTS WITH SOIL TANKS

Experiments with soil tanks have been used by many investigators because the construction of these tanks is simple and the investment required is small. An unsealed tank is filled with undisturbed soil native to the area and set flush with the surrounding land surface. Evapotranspiration is determined by applying water only in such quantities as to satisfy the evapotranspirational demands. Thus the amount of water applied, including precipitation, is the consumptive use. The success of this type of experiment is limited by the ability of the experimenter to reproduce natural conditions. The tanks may be of any size or depth necessary to permit normal root development. The plant density should be representative of the area and the foliage of the plants should not extend beyond the walls of the tank.

In 1930 the Duty of Water Committee of the American Society of Civil Engineers (Harding, 1930, pp. 1349-1377) called attention to the difficulties of reproducing natural conditions with tank experiments and indicated that the results may be of questionable value. However, many recent experiments have been made using this method successfully.

In the upper Rio Grande Valley this method was used by Bureau of Agricultural Engineering, Department of Agriculture (Blaney and others, 1938, pp. 89-92) in connection with the integration method of determining streamflow depletion. In Idaho, Lynn Crandall used this method successfully in measuring net consumptive use[1].

LYSIMETER EXPERIMENTS

The lysimeter method is similar to the soil-tank method. A lysimeter is essentially a tank in which natural soil conditions are retained or reproduced as nearly as possible, except that the bottom is enclosed and provision is made for measuring the water that may percolate below the root zone. Consumptive use is determined by weighing the entire lysimeter and contents on a suitable scale. The soil moisture may be brought up to field capacity at the beginning and the end of the experiment; the observed losses represent the consumptive use.

Soil tanks or lysimeters, equipped with Mariotte supply tanks to maintain a water table at a specified depth, have also been quite successful in measuring the water consumed by plants. The tank or lysimeter method has probably been more extensively used than any other method for determining the transpiration of individual plants or groups of plants, and for determining rates of infiltration, percolation, and related phenomena.

In the Columbia River basin, lysimeters were used by Bark (1916) to determine consumptive use for conditions in Idaho.

EXPERIMENTS WITH FIELD PLOTS

Field plots have been used extensively to determine consumptive use by crops growing under normal field conditions in undisturbed soil. The method is essentially identical to that used for soil tanks, in which moisture is applied in controlled amounts sufficient only to maintain soil moisture adequate for crop production. For successful operation, this method requires a deep water table to prevent the transfer of water from the water table to the root zone by capillary action.

[1] Crandall, Lynn, Report of use of water on Twin Falls North Side Project, unpublished, 1918.

279538 O - 53 - 2

Field-plot experiments have been performed by numerous investigators, among them being Fortier and Young (1930) who made studies of monthly and seasonal net consumptive use in the Columbia River basin. Powers (1914; 1917) used this method in studies of soil moisture and requirements for irrigation in Oregon. Field plots were also used by Hemphill (1922) in Colorado, Widstoe (1912) in Utah, and Snelson (1922) in Alberta, Canada.

DETERMINATIONS OF SOIL MOISTURE

The soil-moisture method has been used in connection with field-plot experiments and relies upon sampling the soil to trace the movement and dissipation of water applied to the soil. Samples are taken with a soil tube at various depths from the land surface to well below the root zone of the vegetal cover. This method provides a means of evaluating the amount of deep seepage, which is the variable element in the field plot method, as well as the determination of the optimum soil moisture for a given cover crop. As in the field plot experiments, this method also requires a deep water table to prevent transfer of water from the water table to the root zone by capillary action. Blaney (1930) is credited with developing this method in California, and it has been used primarily by Blaney and his associates.

FLUCTUATIONS OF THE WATER TABLE

Where the water table is near the surface, so that the capillary fringe is within reach of the plant roots, the recorded fluctuations of the water table may be evaluated in terms of evapotranspiration losses. For successful application of this procedure, relatively flat areas are required and ground water flow must be at a minimum. Adjustments of the results for precipitation and irrigation are possible if the quantities of water applied are carefully measured. In areas of moderate to slight movement of ground water, daily consumptive use may be determined from the records of diurnal fluctuations of the water table.

The specific yield of the aquifer must be determined, and continuous records of the fluctuations of the water table must be obtained by installing test wells equipped with water-level recorders at representative locations in the area. The daily ground water replenishment to the area is based on the rise in ground water from midnight to 4 a.m. when evapotranspiration losses are assumed to be zero. The daily consumptive use is determined by adjusting the daily ground water replenishment by the amount of water represented by the rise or fall in the water table during the 24-hour period. This method was developed by W. N. White (1932, pp. 87, 88) in his studies of the ground water in Escalante Valley, Utah.

STUDIES OF INFLOW AND OUTFLOW

Consumptive use may be determined for irrigated farms or projects from inflow and outflow data. The inflow to the area is measured as precipitation, streamflow, canal diversions, and ground-water seepage. The outflow includes waste from the irrigation system, streamflow below the project, drainage or other return flow, and outflow of ground water. Changes in ground-water storage, soil moisture, and losses by deep seepage must be determined or must be kept to a minimum. These factors are sometimes difficult to determine and may invalidate the experiment unless adequately evaluated.

Many investigations have been made by the inflow-outflow method, several of them in the Columbia River basin. Lynn Crandall[2] used this method in analyzing the water requirements of the North Side Twin Falls area. Similar studies were made by Lewis[3] in the same general area. During 1916 and 1917 Steward and Paul[4] used the inflow-outflow method in the course of drainage investigations in the lower valley of the Boise River. Recently the Bureau of Reclamation made a similar study in the lower Yakima River basin.

Under certain conditions an entire valley may be included in evapotranspiration studies. The primary requirement is that such a valley be underlain with impervious bedrock so that a minimum amount of water escapes through deep percolation. All the inflow, outflow, and storage factors must be measured, including allowances for evaporation from water surfaces and wet lands and consumptive use by natural vegetation.

This type of study has been made by many investigators, including Lee (1912) in the Owens Valley, Ullrich[5] in the Sevier River basin, Hemphill (1922) in the Cache La Poudre Valley, and Parshall (1930, p. 961) in the South Platte River basin.

ESTIMATES OF AVERAGE CONSUMPTIVE USE

For maximum usefulness evapotranspiration data should be correlated with the basic causative factors, so that the data obtained at one location are applicable at another locality on a sound basis.

[2] Crandall, Lynn, 1918, Report of use of water on Twin Falls North Side Project, unpublished.
[3] Lewis, M. R., 1919, Experiments on the proper time and amount of study of irrigation, Twin Falls Expert. Sta., 1914, 1915, and 1916, U. S. Dept. of Agriculture cooperating with Twin Falls County Commissioners, Twin Falls Canal Co., and Twin Falls Commercial Club.
[4] Steward, W. G., and Paul, D. J., 1919, Report on drainage investigations of Pioneer and Nampa-Meridian Districts in Boise Valley for the years 1916 and 1917, U. S. Bur. of Reclamation, unpublished.
[5] Ullrich, C. J., Testimony at hearing of the Colorado River Comm. Salt Lake City, Utah, March 27, 28, 1922.

Of the studies to correlate evapotranspiration with known meteorologic conditions, the works of Lowry and Johnson (1942, p. 1243) and Blaney and Criddle[6] are possibly the two best known examples. Both provide a means of estimating the probable consumptive use by irrigated crops.

Lowry and Johnson analyzed data on consumptive use from irrigated valleys and humid watersheds, representing a wide range in climate, latitude, elevation, and type of crops. They found a straightline relation between annual consumptive use and heat supply, expressed in terms of accumulated daily maximum temperatures above 32 F. during the growing season. So far as possible data excluded deep percolation losses. As defined for the effective-heat method, consumptive use is the quantity of water per year absorbed by the crop and transpired or used directly in building plant tissue, over the "equivalent valley area". The equivalent valley area in each case comprises the entire area or valley (except for areas using no streamflow), reduced to an area consuming water at a rate equivalent to that by the cropped area. The unit values of consumptive use derived by the effective-heat method represent estimated average annual consumptive use per acre of cropped land.

An adequate water supply is assumed in using this method and a mixture of the crops commonly grown on irrigation projects. The relationship was based upon studies made of twenty irrigated and natural valleys or areas where records of inflow and outflow were readily available or could be closely estimated. Records for individual areas ranged from 1 to 18 years in length. The records of years of inadequate water supply were adjusted to make them comparable with those for years having a normal water supply. The mean values of consumptive use and effective heat for each individual area were used to determine the relationship. The values for individual years were found to scatter through wide limits, but the average values for consumptive use and heat supply plot on a fairly well defined curve. The use of the average values in the correlation removes the apparent inconsistencies of some individual years and tends to exaggerate the degree of correlation obtained. The results derived from the use of this relationship are general and are applicable only under average conditions of water supply, crop distribution, and irrigation practices.

To determine the net consumptive use that is supplied by irrigation water the "effective precipitation" must be deducted from the annual consumptive use. Effective precipitation is that portion of the precipitation which is estimated to be used by the grow-

[6] Blaney, Harry F., and Criddle, W. D., A method of estimating water requirements in irrigated areas from climatological data: Div. of Irrigation, Soil Conserv. Service, U. S. Dept. of Agr., revised Dec. 1947. (mimeographed)

ing crops and depends upon the amount and intensity of the precipitation, type of soil, and rate at which soil water can be used by the plants.

Blaney and Criddle took a different approach to the determination of consumptive use. Their method is a modification of methods used in the investigations in the upper Rio Grande (Blaney and others, 1938, pp. 293-423) and Pecos River (Blaney and others, 1942, pp. 172-230). The authors demonstrated that consumptive use for each type of crop varies with the mean temperature and the number of daylight hours. A consumptive use factor is obtained by multiplying the mean temperature for the month by the percent of the total annual daylight hours that occur during the month. Consumptive use is assumed to vary directly as this factor. Using the notations shown below, this relationship can be expressed mathematically as follows: $U=KF$ where $F=\Sigma f$ and $f=tp$

U = consumptive use in inches, for a given period of time.
F = sum of monthly consumptive use factors.
K = an empirical coefficient, computed from known data for each type of crop.
f = monthly consumptive use factor.
t = mean monthly temperature in degrees Fahrenheit.
p = monthly percent of total daylight hours during the year.

Consumptive use data for a particular crop from one area are applicable to other areas by means of the above formula according to Blaney and Criddle if the following assumptions are made:

The fertility and producing power of the soils are similar.
Sufficient water is applied and at proper time to maintain good growing conditions.
The length of growing season, to a large extent, determines the production and annual consumptive use of water for continuous growing crops such as alfalfa and pasture.
Consumptive use of water varies directly with the consumptive use factor.
The effects of insects and diseases on the crops are similar from year to year.

The coefficients used in this formula are based primarily upon studies made by tank and field-plot methods in many parts of the West. A list of the K values and lengths of growing season for use in this formula follows:

Tentative values of the consumptive-use coefficient (K)
[After Blaney and Criddle]

Crop	Length of growing season or period	Consumptive use coefficient (K)
Alfalfa	Between frosts	0.85
Beans	3 months	.65
Corn	4 months	.75
Cotton	7 months	.62
Citrus orchard	7 months	.55
Deciduous orchard	Between frosts	.65
Pasture	Between frosts	.75
Potatoes	3 months	.70
Small grains	3 months	.75
Sorghum	5 months	.70
Sugar beets	5½ months	.70

A comparison has been made between the methods of Lowry and Johnson and those of Blaney and Criddle for estimating consumptive use and an actual determination by the inflow-outflow method in the lower Yakima Valley in Washington. The inflow-outflow studies and the computations of Lowry and Johnson were made by the U. S. Bureau of Reclamation in connection with the determination of water requirements for the proposed Kennewick division, an extension of the Yakima Project. The Blaney-Criddle method was applied by the writer to base data extracted from the report by the Bureau of Reclamation. Net consumptive use values were computed for both indirect methods. The net consumptive use as determined by the inflow-outflow studies covering the period 1936-45 was 1.94 acre-feet per acre. The Lowry-Johnson method gave a value of 2.04 acre-feet per acre, and the Blaney-Criddle method gave 1.97 acre-feet per acre.

The values derived by these two indirect methods agree very closely with the measured values. It is therefore believed that either method, properly used, will yield reliable estimates of net consumptive use for areas where direct measurements are not available.

IRRIGATED AREAS AND ESTIMATED STREAMFLOW DEPLETION

The tables on the following pages include data on irrigated acreage, annual discharge in acre-feet, and estimated streamflow depletion in acre-feet per year, for many tributary basins of the Columbia River basin above The Dalles, Oreg. The Canadian portion of the basin is not included in these tabulations, but the available information regarding irrigation in Canada is included with the discussion of appropriate subdivisions.

The drainage area above The Dalles, Oreg., was subdivided on basis of available data on irrigation and streamflow as well as hydrologic factors. In general these subdivisions were made to conform with the locations of key gaging stations or to span all of the basin of a tributary stream. Areas were kept as small as possible, consistent with available data, in order to provide detailed information on irrigation and depletion in tributary streams. It was not always possible, however, to determine the irrigated acreage within a small basin or restricted area. Records of irrigation often were available only by counties or by basins of large tributary streams.

The following list shows the tributary basins, subdivisions, or gaging stations, for which data on irrigated area, or irrigated area, and estimated streamflow depletion, are given. The numbers correspond to locations shown on plate 1.

List of tributary basins, subdivisions, or gaging stations for which data are given

1. Kootenai River at Bonners Ferry, Idaho.
2. Clark Fork above Missoula, Mont.
3. Bitterroot River basin.
4. Clark Fork below Missoula, Mont.
5. Clark Fork at St. Regis, Mont.
6. Flathead River basin above Flathead Lake, Mont.
7. Flathead River at mouth.
8. Clark Fork near Plains, Mont.
9. Priest River basin.
10. Pend Oreille River at Priest River, Idaho.
11. Pend Oreille River below Z Canyon near Metaline Falls, Wash.
12. Columbia River at international boundary.
13. Kettle River near Laurier, Wash.
14. Kettle River at mouth.
15. Colville River basin.
16. Spokane River at Post Falls, Idaho.
17. Spokane River at Spokane, Wash.
18. Spokane River at mouth.
19. Columbia River at Grand Coulee Dam, Wash.
20. Similkameen River near Nighthawk, Wash.
21. Okanogan River near Tonasket, Wash.
22. Okanogan River at mouth.
23. Methow River at Twisp, Wash.
24. Methow River at Pateros, Wash.
25. Chelan River basin.
26. Entiat River at Entiat, Wash.
27. Wenatchee River at Peshastin, Wash.
28. Wenatchee River at mouth.
29. Columbia River at Trinidad, Wash.
30. Crab Creek basin.
31. Yakima River at Umtanum, Wash.
32. Yakima River near Parker, Wash.
33. Yakima River at Kiona, Wash.
34. Yakima River basin.
35. Columbia River basin above mouth of Snake River.
36. Snake River basin in Wyoming.
37. Snake River near Heise, Idaho.
38. Henrys Fork near Ashton, Idaho.
39. Falls River near Squirrel, Idaho.
40. Teton River above St. Anthony, Idaho.
41. Snake River near Blackfoot, Idaho.
42. Portneuf River basin.
43. Snake River at Neeley, Idaho.
44. Snake River at Milner, Idaho.
45. Mud Lake basin.
46. Little Lost River basin.
47. Big Lost River above Mackay Reservoir, Idaho.
48. Big Lost River basin.
49. Big Wood River basin.
50. Snake River at King Hill, Idaho.
51. Bruneau River near Hot Spring, Idaho.
52. Bruneau River basin.
53. Snake River near Murphy, Idaho.
54. Owyhee River basin in Nevada.
55. Jordan Creek above Jordan Valley, Oreg.
56. Owyhee River above Owyhee Reservoir, Oreg.
57. Owyhee River at mouth.
58. South Fork Boise River near Featherville, Idaho.
59. South Fork Boise River at Anderson Ranch Dam, Idaho.
60. Boise River at Dowling ranch near Arrowrock, Idaho.
61. Moore Creek near Arrowrock, Idaho.
62. Boise River basin.
63. Malheur River below Warm Springs Reservoir, Oreg.
64. Malheur River basin.
65. South Fork Payette River near Banks, Idaho.
66. Lake Fork of Payette River below Lake Irrigation District canal, near McCall, Idaho.

List of tributary basins, subdivisions, or gaging stations for which data are given—Continued

67. North Fork Payette River at Cascade, Idaho.
68. North Fork Payette River near Banks, Idaho.
69. Payette River near Horseshoe Bend, Idaho.
70. Payette River at mouth.
71. Weiser River at Starkey, Idaho.
72. Weiser River near Council, Idaho.
73. Weiser River near Cambridge, Idaho.
74. Little Weiser River near Indian Valley, Idaho.
75. Weiser River above Crane Creek near Weiser, Idaho.
76. Weiser River at mouth.
77. Snake River at Weiser, Idaho.
78. Burnt River near Hereford, Oreg.
79. Burnt River at mouth.
80. Powder River near Robinette, Oreg.
81. Snake River at Oxbow, Oreg.
82. Pine Creek basin.
83. Imnaha River at Imnaha, Oreg.
84. Salmon River near Obsidian, Idaho.
85. Valley Creek at Stanley, Idaho.
86. Salmon River below Yankee Fork near Clayton, Idaho.
87. Salmon River near Challis, Idaho.
88. Pahsimeroi River near May, Idaho.
89. North Fork Salmon River at North Fork, Idaho.
90. Salmon River near French Creek, Idaho.
91. Little Salmon River basin.
92. Salmon River at White Bird, Idaho.
93. Wallowa River basin.
94. Grande Ronde River at Rondowa, Oreg.
95. Clearwater River at Kamiah, Idaho.
96. Clearwater River at mouth.
97. Snake River near Clarkston, Wash.
98. Columbia River basin below the Snake River, Wash.
99. Walla Walla River basin.
100. McKay Creek basin.
101. Birch Creek basin.
102. Butter Creek basin.
103. Umatilla River near Umatilla, Oreg.
104. Willow Creek basin.
105. North Fork John Day River at Monument, Oreg.
106. John Day River at McDonald ferry, Oregon.
107. Crooked River near Post, Oreg.
108. Crooked River above Hoffman Dam near Prineville, Oreg.
109. Crooked River near Culver, Oreg.
110. Deschutes River near Madras, Oreg.
111. White River below Tygh Valley, Oreg.
112. Deschutes River at Moody, near Biggs, Oreg.
113. Columbia River near The Dalles, Oreg.

Records of the irrigated area for these tributary basins were then accumulated at downstream points. Thus, where tabulations are given for more than one location on a stream the tabulations for the downstream station include those for the upstream station. The irrigated area between any two stations on the same stream may be determined by subtraction. The data was subjected to a minimum of "rounding off" and often on main stem stations, carried to more significant figures than the overall accuracy may seem to warrant. However this procedure was followed in order to minimize the possible errors in accumulations. Some estimates were necessary, especially for earlier years to formulate the tabulations by subdivisions given in this report.

Gaging stations are not always in desirable locations with respect to irrigated areas and return flow. The gaging stations chosen are those where depletion estimates would be significant. An ideal location for this purpose would be below all points of diversion, and below points where return flow and wasteways reenter the stream. In general, gaging stations that substantially meet these qualifications were selected, and any material deviation is noted. Gaging stations located within an irrigated area, with unmeasured canal flow bypassing those stations and with a complicated or unknown pattern of wasteways and return flow, have of necessity been omitted.

Computations that would be applicable to 23 areas for annual and/or net consumptive use by the Lowry-Johnson method were made available by the U. S. Bureau of Reclamation. These localities were well distributed throughout the drainage basin of the Columbia River above The Dalles, Oreg., and the estimates of net consumptive use for the remaining areas were based upon these computed values. The values of net consumptive use in the following table were compared with available experimental data and were spot checked by the Blaney-Criddle method with consistent results.

Commonly the total consumptive use is computed by applying the factor for net consumptive use to the net cropped area and allowing an additional 10 to 15 percent to cover other miscellaneous losses, including deep seepage. However, the net cropped area was not always known, and in this report the net consumptive use was applied to the gross farm area. Since the difference between the gross farm area and the net cropped area usually amounts to 10 to 15 percent, no further allowance was made for the usual miscellaneous losses.

Net consumptive use, by subdivisions of the Columbia River basin

Locality	Net consumptive use (acre-feet per acre)	Remarks
Kootenai River basin	1.25	Estimated.
Clark Fork basin above Missoula, Mont	1.0	Estimated.
Bitterroot River basin	1.4	Lowry-Johnson method.
Clark Fork, Missoula to Plains, Mont	1.4	Lowry-Johnson method.
Flathead River basin	1.2	Lowry-Johnson method.
Clark Fork, Plains, Mont. to mouth	1.25	Estimated.
Columbia River, international boundary to Grand Coulee Dam, Wash.	1.35	Estimated
Kettle River basin	1.25	Estimated.
Colville River basin	1.5	Estimated.
Spokane River basin	1.35	Lowry-Johnson method.
Columbia River, Grand Coulee Dam to Trinidad, Wash.	2.00	Lowry-Johnson method.
Okanogan River basin	1.50	Estimated.
Methow River basin	1.75	Estimated.
Chelan River basin	1.75	Estimated.
Entiat River basin	1.75	Estimated.
Wenatchee River basin	2.0	Lowry-Johnson method.
Columbia River, Trinidad to Pasco, Wash	2.0	Estimated.
Crab Creek basin	1.75	Estimated.
Yakima River basin	2.0	Lowry-Johnson method.
Snake River basin above Heise, Idaho	.8	Lowry-Johnson method.
Henrys Fork basin	1.0-1.4	Estimated.
Teton River above St. Anthony, Idaho	1.1	Lowry-Johnson method.
Snake River, Heise to Milner, Idaho	1.8	Lowry-Johnson method.
Portneuf River basin	1.6	Estimated.
Mud Lake basin	1.6	Lowry-Johnson method.
Little Lost River basin	1.3	Estimated.
Big Lost River basin	1.3	Estimated.
Big Wood River basin	1.7	Estimated.
Snake River, Milner to King Hill, Idaho	1.7	Estimated.
Bruneau River basin	1.8	Estimated.
Snake River, King Hill to Weiser, Idaho	2.0	Lowry-Johnson method.
Owyhee River above Owyhee Reservoir, Oreg.	1.0-1.4	Lowry-Johnson method and estimated.
Owyhee River below Owyhee Reservoir, Oreg.	1.9	Estimated.
Boise River above Boise diversion	1.0	Estimated.
Boise River below Boise diversion	2.2	Inflow-outflow studies.
Malheur River basin	1.0-1.9	Estimated and Lowry-Johnson method.
Payette River above Horse Shoe Bend, Idaho	1.0	Estimated.
Payette River below Horse Shoe Bend, Idaho	2.2	Estimated.
Weiser River basin	1.5-2.0	Lowry-Johnson method.
Snake River, Weiser, Idaho to Clarkston, Wash.	1.4	Estimated.
Burnt River basin	1.4	Estimated.
Powder River Basin	1.5	Lowry-Johnson method.
Pine Creek basin	1.4	Estimated.
Imnaha River basin	1.2	Estimated.
Salmon River basin	1.6	Lowry-Johnson method.
Grande Ronde River basin	1.2	Lowry-Johnson method.
Clearwater River basin	1.5	Lowry-Johnson method.
Snake River, Clarkston to mouth	1.5	Estimated.
Columbia River, Pasco, Wash., to The Dalles, Oreg.	2.0	Lowry-Johnson method.
Walla Walla River basin	1.9	Lowry-Johnson method.
Umatilla River basin	1.5-2.0	Lowry-Johnson method.
Willow Creek basin	1.7	Estimated.
John Day River basin	1.7	Estimated.
Crooked River basin	1.7	Lowry-Johnson method.
Deschutes River basin	1.7	Estimated.

The estimated depletion given in the following tables represents average conditions for the respective subdivisions and assumes an average water supply. The actual depletion in individual years may be expected to deviate from these values, although in many localities the deviations may be small because of the compensating factors. For example, during years having temperature above normal, the consumptive use might be expected to be greater than average, but commonly during such years less water is available for irrigation. Some areas often have an inadequate water supply, and the cropped area tends to become adjusted to the available supply. The types of crops undoubtedly influence the consumptive use, but to some extent the types of crops are adjusted to the climate, soil conditions, and the available water supply. These factors tend to promote both regional and year to year diversification in the types of crops grown. Data on irrigation by crop types is very meagre for earlier years, and no attempt has been made to adjust for this factor. Considering all these variables, however, it is believed that the estimated depletions given in following tables are reasonably dependable in terms of average depletion over a period of years.

The estimated depletion, expressed as a percentage of the yield of the watershed, has been computed for many locations in the basin. In this respect the yield was assumed to be the sum of the measured runoff and the estimated depletion. These values were accumulated over a period of years, so as to be representative of average conditions. Where records were available, the 25-year period (1921-45) has been used. In places where the irrigated area has been expanding rapidly, the estimated percentage of depletion for 1946, in terms of the long-term yield has also been computed. It should be reiterated that all of the computations herein are on annual basis and do not take into account the seasonal distribution of water supply or consumptive use.

COLUMBIA RIVER ABOVE THE INTERNATIONAL BOUNDARY

KOOTENAI RIVER BASIN

The Kootenai River (Kootenay in Canada) is primarily a Canadian stream, with 14,500 square miles of the total of 19,300 square miles drainage area lying in southeastern British Columbia. In terms of total drainage area, the Kootenai River is the third largest of the Columbia River tributaries. It is exceeded only by the Snake River and Pend Oreille River.

The United States portion of the basin, lying in northwestern Montana and northern Idaho, is roughly triangular in shape and is largely mountainous. The Galton Range and Salish Mountains form the eastern boundary, the Purcell Mountains roughly bisects the basin from north to south, and the Selkirk and Cabinet Mountains form the western boundary. The land devoted to agriculture lies principally in the flood plain of the main stem of the Kootenai River between Bonners Ferry, Idaho, and the international boundary, and an area along the Tobacco River in Montana. About 50, 000 acres in the flood plain north of Bonners Ferry are partially protected by dikes and does not require irrigation because of the high ground-water table underlying the farmed area.

The Glen Lake Irrigation District is the only sizeable irrigation project in the Kootenai River basin within the boundaries of the United States. It was developed about 1916, and includes about 2,050 acres along the Tobacco River. The remainder of the irrigated land consists of relatively small tracts along Fisher River, in the upper reaches, and near Libby, all in Montana.

Irrigation in the Kootenay River basin in Canada is done on many scattered tracts, which in 1949 totaled 19,700 acres (International Columbia River Engineering Board, 1950, Interim Report on Kootenay River 1933 in the files of the International Joint Commission, Washington and Ottawa).

The following table shows the total irrigated area for the portion of the basin in the United States for the selected years. These data are based on census reports for the years 1890, 1900, 1902, 1919, 1929, and 1939, supplemented by local inquiries. The census report for 1890 shows no irrigation in the basin. For the year 1920, the Montana State Board of Equalization reported a total of 4,780 acres irrigated. Census reports for 1919 show 5,920 acres irrigated. The difference between the two areas probably results from the methods of classification of "irrigated" land.

The net consumptive use was estimated to be 1. 25 acre-feet per acre for all irrigated land in this basin. The return flow was estimated to reach the main river south of the international boundary. The average depletion in this basin is insignificant when compared to the flow of the river at Bonners Ferry, Idaho, and has remained essentially constant during the past 20 years. Expressed as a percentage during the period 1929-46, it has amounted to only about 0. 1 percent of the yield of this basin.

Irrigated area in the United States, annual runoff, and estimated depletion for Kootenai River at Bonners Ferry, Idaho

Year	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1900	2,000	....	2,500
1905	3,200	....	4,000
1910	4,200	....	5,250
1915	5,200	....	6,500
1920	6,100	....	7,620
1921	6,300	....	7,870
1922	6,450	....	8,060
1923	6,600	....	8,250
1924	6,750	....	8,440
1925	6,950	....	8,680
1926	7,100	....	8,880
1927	7,250	....	9,060
1928	7,400	....	9,250
1929	7,600	8,090,000	9,500
1930	7,580	8,470,000	9,480
1931	7,560	6,360,000	9,450
1932	7,540	11,100,000	9,420
1933	7,520	12,800,000	9,400
1934	7,500	14,440,000	9,380
1935	7,480	11,000,000	9,350
1936	7,460	8,082,000	9,320
1937	7,440	7,499,000	9,300
1938	7,420	11,590,000	9,280
1939	7,390	8,367,000	9,240
1940	7,400	7,771,000	9,250
1941	7,400	6,508,000	9,250
1942	7,400	12,190,000	9,250
1943	7,400	11,910,000	9,250
1944	7,400	5,599,000	9,250
1945	7,400	7,729,000	9,250
1946	7,400	11,970,000	9,250

PEND OREILLE RIVER BASIN

The Pend Oreille River basin is largely in western Montana, but it includes a part of the Idaho panhandle, most of Pend Oreille County in northeastern Washington, and two areas totalling 1,203 square miles in British Columbia. The Flathead River, tributary of the Clark Fork, originates in the eastern area in British Columbia. The western area in Canada is contiguous with the northeast corner of Washington and consists mostly of the drainage area of Salmo River, which joins the Pend Oreille about 14 miles above its mouth. The total drainage area of the Pend Oreille basin is 25,960 square miles, of which 24,757 square miles are in the United States, making it the second largest tributary of the Columbia in terms of drainage area.

The drainage basin is an area of conifer forests, lying on the western slope of the Rocky Mountains. Its perimeter is defined by the divides of various mountain ranges, and numerous other ranges are included within its boundaries. On the east, southeast and south, the Continental Divide forms the boundary. On the west, the Bitterroot Range marks both the basin boundary and the Idaho-Montana State line for a distance of 200 miles. Farther west, the boundary is formed by lesser ranges. To the north, the divide between the Kootenai and the Clark Fork is formed by the Selkirk, Cabinet and Salish Mountains.

Along most of the major tributaries and many of the minor tributaries and intermontane valleys and prairies suitable to agriculture. The floors of these valleys range from 2,000 to 4,000 feet above sea level and are suitable for hay, grain, and certain fruit crops. The greater part of the irrigated areas are in basins of Flathead, Bitterroot and Blackfoot Rivers, where some of the earliest irrigation in the Northwest was done.

CLARK FORK ABOVE MISSOULA, MONT.

Most of the irrigated land above this station lies in scattered tracts along the main Clark Fork and its principal tributaries. The majority of these lands were irrigated prior to 1910 by individuals to provide forage crops for stock ranches.

Approximately half of the irrigated land shown in the following table is in the Blackfoot River basin, with the largest concentration near Nevada Creek reservoir, which was completed in 1938. Of the remaining half of the irrigated area, the largest concentration is along Flint Creek. In 1938 a reservoir on the East Fork of Rock Creek was built to store additional water for lands in this part of the basin.

The return flow from all irrigated land was assumed to have reentered the main stem of the Clark Fork above this gaging station.

The net consumptive use was estimated to be 1.0 acre-foot per acre per year. The percentage of streamflow depletion based upon the 17-year period, 1930 through 1946, amounted to 6.7 percent of the yield of the watershed and has remained essentially constant during the period of gaging-station record at this point.

Irrigated area, annual runoff, and estimated depletion for Clark Fork above Missoula, Mont.

Year	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1870	6,000	...	6,000
1880	20,000	...	20,000
1890	53,000	...	53,000
1900	102,000	...	102,000
1905	117,000	...	117,000
1910	119,500	...	119,500
1915	125,000	...	125,000
1920	130,425	...	130,425
1921	130,415	...	130,415
1922	130,998	...	130,998
1923	130,432	...	130,432
1924	130,164	...	130,164
1925	125,822	...	125,822
1926	125,271	...	125,271
1927	124,930	...	124,930
1928	124,690	...	124,690
1929	125,724	...	125,724
1930	124,683	1,640,000	124,683
1931	123,064	1,039,000	123,064
1932	128,205	1,602,000	128,205
1933	124,745	2,087,000	124,745
1934	128,008	2,425,000	128,008
1935	127,107	1,410,000	127,107
1936	119,987	1,622,000	119,987
1937	127,698	1,035,000	127,698
1938	120,458	2,006,000	120,458
1939	118,576	1,592,000	118,576
1940	119,272	1,223,000	119,272
1941	118,992	973,200	118,992
1942	119,327	1,932,000	119,327
1943	119,743	2,990,000	119,743
1944	119,287	1,475,000	119,287
1945	118,720	1,600,000	118,720
1946	119,720	1,728,000	119,720

CLARK FORK BELOW MISSOULA, MONT.

The Bitterroot River basin has at present about 113,800 acres under irrigation, although the water supply during dry years is inadequate. Very little information is available regarding irrigation prior to 1890, although a note in the 1889 census states that the Bitterroot Valley was at that time extensively irrigated along the river. Most of the water used for irrigation is supplied by small irrigation companies and districts. The largest organization is the Bitterroot River Irrigation District, which controls approximately 19,000 acres. The return flow from these lands is believed to enter the Bitterroot River above its mouth. The irrigated area and estimated annual depletion are shown in the following table. The net consumptive use of 1.4 acre-feet per acre used to compute the estimated depletion was based upon computations by the Lowry-Johnson method. Assuming the difference between the gaging stations on Clark Fork above and below Missoula to be the yield of the Bitterroot River basin, the percentage depletion was estimated to be 9.6 percent.

Between the gaging stations on Clark Fork above and below Missoula are three principal diversions from the Clark Fork main stem: Flynn Ditch, Grass Valley Ditch, and Orchard Homes District canal. Flynn Ditch was built about 1906 to provide supplemental water to land which formerly received only flood water from Granite Creek. This ditch diverts water from the north bank of the Clark Fork at the west edge of Missoula, and serves 1,900 acres. The Grass Valley Ditch diverts water from the Clark Fork above the mouth of the Bitterroot River. Diversion first began in 1903, and at present about 3,000 acres are served. The Orchard Homes District serves two tracts: Tract 1, started about 1878 now serves 3,200 acres, the majority of which was developed prior to 1920. Tract 2 includes about 550 acres and was started in 1896. The irrigated area and estimated depletion for the basin above the gaging station on Clark Fork below Missoula, Mont., are shown in the table below. The percentage depletior for this station is 8.4 percent of the yield of the watershed for period 1930 through 1946.

Irrigated area and estimated depletion for Bitterroot River basin

Year	Irrigated area (acres)	Estimated depletion (acre-feet)
1870	2,000	2,800
1880	5,000	7,000
1890	17,000	23,800
1900	72,700	101,800
1905	101,000	141,400
1910	103,000	144,200
1915	105,000	147,000
1920	107,522	150,500
1921	107,522	150,500
1922	117,957	165,100
1923	115,577	161,800
1924	114,028	159,600
1925	110,983	155,400
1926	108,868	152,400
1927	107,725	150,800
1928	107,944	151,100
1929	107,951	151,100
1930	105,849	148,200
1931	104,957	146,900
1932	103,794	145,300
1933	103,009	144,200
1934	105,628	147,900
1935	105,534	147,700
1936	104,290	146,000
1937	104,577	146,400
1938	104,126	145,800
1939	106,420	149,000
1940	103,380	144,700
1941	103,062	144,300
1942	102,740	143,800
1943	102,412	143,400
1944	103,222	144,500
1945	103,445	144,800
1946	105,620	147,900

Irrigated area, annual runoff, and estimated depletion for Clark Fork below Missoula, Mont.

Year	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1860	1,000	....	1,400
1870	8,000	....	8,800
1880	25,000	....	27,000
1890	70,000	....	76,800
1900	175,000	....	204,000
1905	219,000	....	259,800
1910	223,500	....	265,100
1915	234,600	....	278,400
1920	245,585	....	288,500
1921	246,075	....	289,000
1922	257,093	....	307,500
1923	254,147	....	303,600
1924	252,330	....	301,200
1925	244,943	....	292,600
1926	242,777	....	289,100
1927	241,293	....	287,100
1928	241,272	....	287,200
1929	242,813	....	289,600
1930	239,900	3,050,000	288,800
1931	237,389	1,980,000	283,100
1932	241,367	3,080,000	286,600
1933	237,122	3,740,000	282,000
1934	243,004	4,253,000	289,000
1935	242,009	2,671,000	287,900
1936	233,645	3,105,000	279,100
1937	241,643	1,869,000	287,200
1938	233,952	3,619,000	279,400
1939	234,364	3,022,000	280,700
1940	232,020	2,227,000	277,100
1941	231,422	1,881,000	276,400
1942	231,425	3,634,000	276,200
1943	231,523	5,544,000	276,200
1944	231,877	2,570,000	276,900
1945	231,533	2,803,000	276,600
1946	234,708	3,235,000	280,700

CLARK FORK AT ST. REGIS, MONT.

The majority of irrigated lands between Missoula and the gaging station on the Clark Fork at St. Regis, Mont., are scattered in small tracts along tributaries of the main river. The Frenchtown project is the largest irrigation enterprise within this reach. This project extends from Frenchtown to Huson, Mont. and includes about 2,200 acres, all on the north side of the river. The return flow from all irrigated land in this subdivision is assumed to reach the Clark Fork above the gaging station. The irrigated area above this gaging station, and the estimated depletion are given in the following table. Based upon the records for the period 1921 through 1945 and a net consumptive use for this subdivision of 1.4 acre-feet per acre, the percentage depletion of the yield of the watershed was estimated to be 3.3 percent.

279538 O - 53 - 3

Irrigated area, annual runoff, and estimated depletion for Clark Fork at St. Regis, Mont.

Year	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1860	1,000	....	1,400
1870	8,000	....	8,800
1880	25,000	....	27,000
1890	74,000	....	76,800
1900	180,000	....	211,200
1905	232,000	....	278,000
1910	243,100	....	292,400
1911	....	5,630,000	....
1912	....	6,550,000	....
1913	....	7,760,000	....
1914	....	5,230,000	....
1915	248,000	4,220,000	296,600
1916	....	8,460,000	....
1917	....	8,090,000	....
1918	....	7,840,000	....
1919	....	3,930,000	....
1920	252,661	5,140,000	298,400
1921	253,155	6,270,000	298,900
1922	264,287	5,840,000	317,600
1923	261,392	5,260,000	313,700
1924	259,595	*3,524,000	311,400
1925	252,136	*5,811,000	302,700
1926	249,995	*2,932,000	299,200
1927	248,519	*6,414,000	297,200
1928	248,448	*7,250,000	297,200
1929	249,980	*3,721,000	299,600
1930	247,094	3,930,000	298,900
1931	244,577	2,590,000	293,200
1932	248,580	4,330,000	296,700
1933	244,363	5,400,000	293,100
1934	250,160	6,780,000	299,000
1935	249,163	3,988,000	297,000
1936	240,734	4,139,000	289,000
1937	250,918	2,647,000	300,200
1938	243,229	4,856,000	292,400
1939	243,625	3,886,000	293,700
1940	241,254	3,027,000	290,000
1941	240,738	2,476,000	289,400
1942	240,751	4,697,000	289,200
1943	240,838	7,307,000	289,200
1944	241,181	3,246,000	289,900
1945	240,971	3,767,000	289,800
1946	243,979	4,282,000	293,700

* Estimated, or partly estimated in unpublished report.

FLATHEAD RIVER

In the Flathead River basin, irrigation above Flathead Lake has been developed principally by private enterprise, the largest project being the Ashley Irrigation District. The remainder of the irrigated area lies in small tracts along Swan River, Whitefish River, and Stillwater River. A relatively small amount of land has been developed within the proposed Kalispell Project of the U. S. Bureau of Reclamation by private enterprise.

Below Flathead Lake, the largest development has been the Flathead Project, initiated by the U. S. Bureau of Reclamation in 1907 and delegated to the Bureau of Indian Affairs in 1924 for completion and operation. All the land lies within the early boundaries of the Flathead Indian Reservation and the project is designed for the ultimate irrigation of 138,000 acres in three divisions: Camas, Jocko, and Mission Valley. The project area of Camas division consists of about 13,000 acres primarily in the Little Bitterroot River basin, which is served by gravity diversion from the main stream and tributaries. This water supply has been augmented by two small diversions from the Thompson River basin. Diversion from Alder Creek began about 1933 and from McGinnis Creek in 1941. The Jocko division includes about 13,400 acres and is served by gravity diversion from Jocko River and Finley Creek. A diversion from Placid Creek, an indirect tributary of the Blackfoot River, enters the Middle Fork of the Jocko River but is generally used for irrigation in the Mission Valley division. The major sources of water supply for the Mission Valley division are the minor tributaries of the Flathead River arising in the Mission Range and water pumped directly from the Flathead River near the lake outlet. About 113,700 acres may eventually be irrigated in this division. There is about 148,000 acre-feet of storage in all three divisions, and to a large extent all of the divisions are interconnected. The return flow from all these lands is assumed to enter the Flathead River above its mouth. The net consumptive use for all lands in the entire basin was estimated to be 1.2 acre-feet per acre and was based upon computations by the Lowry-Johnson method. The irrigated area and estimated depletion for the Flathead River basin, disregarding the minor effects of importation of water from adjacent basins, are shown in the following table.

Irrigated area and estimated depletion for Flathead River basin, Montana

Year	Flathead River above Flathead Lake	Flathead River at mouth	
	Irrigated area (acres)	Irrigated area (acres)	Estimated depletion (acre-feet)
1900	1,000	6,070	7,280
1905	2,000	11,500	13,800
1910	3,100	14,500	17,400
1915	3,300	19,700	23,640
1920	3,501	38,367	46,040
1921	3,501	36,016	43,220
1922	3,501	35,888	43,070
1923	3,501	24,026	28,830
1924	3,501	35,371	42,440
1925	3,501	38,018	45,620
1926	3,401	39,378	47,250
1927	3,401	31,568	37,880
1928	3,301	39,831	47,260
1929	3,301	45,331	54,400
1930	3,201	48,831	58,600
1931	3,201	57,631	69,160
1932	3,161	62,891	75,470
1933	3,399	64,429	77,310
1934	3,301	65,531	78,640
1935	3,301	72,331	86,800
1936	3,301	73,331	88,000
1937	3,230	77,760	93,310
1938	3,278	81,308	97,570
1939	2,240	80,570	96,680
1940	2,562	81,892	98,270
1941	2,001	80,931	97,120
1942	2,008	76,438	91,720
1943	2,721	83,151	99,780
1944	2,713	85,343	102,410
1945	2,701	88,431	106,120
1946	2,701	90,731	108,880

PEND OREILLE RIVER BELOW Z CANYON NEAR METALINE FALLS, WASH.

Irrigation below the mouth of Flathead River lies in scattered small tracts along the Clark Fork and Pend Oreille Rivers. An irrigation district near Usk, Wash. utilizes water from Calispell Creek to irrigate about 1,500 acres. The net consumptive use for this subdivision of the basin was estimated to be 1.25 acre-feet per acre. All return flow was assumed to have reentered the main river above the indicated gages. The irrigated area, runoff, and estimated depletion at the gaging station on Clark Fork near Plains, Mont. are shown in the following table. For the period 1921 through 1945 the percent depletion was estimated to be 2.7 percent. The irrigated area for Priest River and Pend Oreille River at Priest River, Idaho is shown in the table on page 34. The total irrigated area, runoff, and estimated depletion, in the basin above the gaging station on Pend Oreille River below Z Canyon near Metaline Falls, Wash., is shown in the table on page 35.

Irrigated area, annual runoff, and estimated depletion for Clark Fork near Plains, Mont.

Year	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1860	1,000	....	1,400
1870	8,000	....	8,800
1880	25,000	....	27,000
1890	74,000	....	76,800
1900	186,700	....	218,500
1905	243,700	....	291,800
1910	257,800	....	309,800
1913	....	17,400,000	....
1914	....	12,500,000	....
1915	270,500	11,400,000	320,300
1916	....	*20,271,000	....
1917	....	*17,601,000	....
1918	....	17,400,000	....
1919	....	10,900,000	....
1920	291,061	*12,552,000	344,500
1921	289,204	16,500,000	342,200
1922	300,208	14,100,000	360,700
1923	285,451	14,100,000	342,600
1924	294,999	11,600,000	353,900
1925	290,187	*17,617,000	348,400
1926	289,406	9,150,000	346,500
1927	280,120	19,300,000	335,100
1928	288,312	21,300,000	344,500
1929	295,344	11,000,000	354,000
1930	295,958	10,100,000	357,500
1931	302,241	8,250,000	362,400
1932	311,504	13,700,000	372,200
1933	308,825	16,000,000	370,400
1934	315,724	18,430,000	377,700
1935	321,527	12,660,000	383,800
1936	314,098	11,670,000	377,000
1937	328,711	8,784,000	393,600
1938	324,570	12,250,000	390,000
1939	324,228	11,460,000	390,300
1940	323,179	8,213,000	388,300
1941	321,702	6,404,000	386,600
1942	317,222	12,740,000	381,000
1943	324,022	17,710,000	389,000
1944	326,557	7,862,000	392,400
1945	329,435	10,330,000	396,000
1946	334,743	13,480,000	402,600

* Estimated, or partly estimated in unpublished report.

Irrigated area in acres for indicated years

Year	Priest River basin	Pend Oreille River at Priest River, Idaho
1860	....	1,000
1870	....	8,000
1880	....	25,000
1890	....	74,000
1900	....	186,100
1905	....	245,400
1910	....	260,900
1915	....	273,000
1920	63	293,749
1921	63	291,894
1922	63	302,925
1923	63	288,170
1924	63	297,721
1925	63	292,912
1926	63	292,150
1927	73	282,892
1928	73	291,106
1929	73	298,141
1930	73	298,758
1931	73	305,044
1932	73	314,309
1933	73	311,632
1934	73	318,534
1935	73	324,360
1936	73	316,934
1937	73	331,549
1938	73	327,410
1939	73	327,071
1940	73	326,025
1941	73	324,531
1942	73	320,083
1943	73	326,885
1944	73	329,423
1945	73	332,304
1946	73	337,650

Irrigated area, annual runoff, and estimated depletion for Pend Oreille River below Z Canyon near Metaline Falls, Wash.

Year	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1860	1,000	....	1,400
1870	8,000	....	8,800
1880	25,000	....	27,000
1890	74,000	....	76,800
1900	186,213	....	218,600
1905	245,416	....	293,900
1910	260,932	....	316,700
1913	....	24,800,000	....
1914	....	17,600,000	....
1915	273,092	15,400,000	335,400
1916	....	27,900,000	....
1917	....	23,300,000	....
1918	....	21,800,000	....
1919	....	15,800,000	....
1920	294,109	15,700,000	348,300
1921	292,314	22,400,000	346,100
1922	303,405	17,800,000	364,700
1923	288,710	18,100,000	346,700
1924	297,721	14,500,000	357,300
1925	293,672	23,200,000	352,800
1926	292,870	11,700,000	350,800
1927	283,672	25,300,000	339,500
1928	291,946	27,600,000	349,000
1929	299,041	13,900,000	358,600
1930	299,733	12,600,000	362,100
1931	306,094	11,100,000	367,200
1932	315,434	19,500,000	377,100
1933	312,832	22,400,000	375,400
1934	319,709	26,170,000	382,700
1935	325,710	18,270,000	389,000
1936	317,469	15,560,000	381,200
1937	333,049	12,130,000	399,100
1938	328,985	18,410,000	395,500
1939	328,721	15,250,000	395,600
1940	327,675	12,270,000	393,900
1941	326,181	9,951,000	391,200
1942	321,733	18,170,000	386,600
1943	328,535	23,760,000	394,600
1944	331,173	10,480,000	398,200
1945	333,954	14,680,000	401,600
1946	339,300	19,670,000	408,300

COLUMBIA RIVER AT INTERNATIONAL BOUNDARY

The following table shows the irrigated area, runoff, and estimated depletion for the basin above the gaging station on Columbia River at the international boundary. This is essentially a summation of the Kootenai and Pend Oreille River basins. No allowance has been made for the irrigated area in Canada, which on basis of published reports is assumed to be less than 25,000 acres. The average net depletion based upon the period 1939 through 1946 was estimated at 0.7 percent of the yield of the watershed above this point.

Irrigated area, annual runoff, and estimated depletion for Columbia River at the international boundary

Year	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1860	1,000	....	1,400
1870	8,000	....	8,800
1880	25,000	....	27,000
1890	74,000	....	76,800
1900	188,213	....	221,100
1905	248,616	....	297,400
1910	265,132	....	321,900
1915	278,242	....	341,900
1920	300,209	....	355,900
1921	298,614	....	354,000
1922	309,855	....	372,800
1923	295,310	....	354,900
1924	305,071	....	365,700
1925	300,522	....	361,500
1926	299,970	....	359,700
1927	290,922	....	348,600
1928	299,346	....	358,200
1929	306,641	....	367,100
1930	307,313	....	371,600
1931	313,654	....	376,600
1932	322,974	....	386,500
1933	320,352	....	384,800
1934	327,309	....	392,100
1935	333,190	....	398,400
1936	325,819	....	389,500
1937	340,489	....	408,400
1938	336,405	....	406,800
1939	336,121	60,920,000	404,800
1940	335,075	59,580,000	402,100
1941	333,581	52,590,000	400,400
1942	329,133	69,180,000	397,800
1943	335,935	70,420,000	403,800
1944	338,473	46,190,000	407,400
1945	341,354	56,600,000	410,800
1946	346,700	74,760,000	417,500

COLUMBIA RIVER, INTERNATIONAL BOUNDARY TO GRAND COULEE DAM

KETTLE RIVER

There is little irrigation in the United States portion of the Kettle River basin. At present, about 880 acres are under irrigation, mostly in the upper reaches above Laurier, Wash. The 1940 Canada Yearbook lists 2,090 acres under irrigation in the Canadian portion of the basin. The following table shows the irrigated area in the Kettle River basin in the United States, as determined primarily from census figures. The net consumptive use for this subdivision was estimated to be 1.25 acre-feet per acre.

Irrigated area, in acres, in Kettle River basin in the United States

Year	Kettle River near Laurier, Wash.	Kettle River at mouth
1890	100	125
1900	280	345
1905	230	280
1910	210	250
1915	300	365
1920	390	475
1921	415	505
1922	435	530
1923	460	560
1924	480	585
1925	505	615
1926	525	640
1927	550	670
1928	570	695
1929	590	720
1930	600	735
1931	615	750
1932	625	765
1933	640	780
1934	650	795
1935	665	810
1936	675	825
1937	690	840
1938	705	860
1939	720	880
1940	720	880
1941	720	880
1942	720	880
1943	720	880
1944	720	880
1945	720	880
1946	720	880

COLVILLE RIVER

Little irrigating has been done in the Colville River basin, and only a small percentage of all the land within the basin is classed as irrigable. The water requirements for this area are largely satisifed under natural conditions, such as precipitation and flooding without adequate drainage. At present all irrigation is done by individuals, but at one time two irrigation districts diverted water from Colville River below the hydroelectric plant at Kettle Falls to irrigate lands along the Columbia River.

The Fruitland Irrigation Co. started about 1908 with 1,200 acres (downstream from Kettle Falls), but the acreage diminished to 500 in 1925. This latter acreage was irrigated until about 1937 when the district was dissolved because it was within the reservoir area of Grand Coulee Dam. The Columbia Irrigation District (Plantation Irrigation Co.), during 1910 and 1911 irrigated about 1,000 acres of land just upstream from Colville River.

Return flow from presently irrigated land is believed to reenter the Colville River above the gaging station at Kettle Falls, although from 1908 to 1937 the return flow from Fruitland Irrigation Co. was direct to the Columbia River downstream from the mouth of the Colville River. The irrigated area shown in the following table was determined from water rights, census reports, and local inquiry. The net consumptive use for this tributary basin was estimated to be 1.5 acre-feet per acre.

SPOKANE RIVER

Irrigation in the Spokane River basin started during the latter part of the nineteenth century but developed slowly until about 1905. From 1905-15 expansion was rapid, primarily just east of Spokane. The region was organized into small irrigation districts and companies, a total of 30 having been active at various times. The three largest were the Spokane Valley, Vera, and Otis Orchards irrigation districts. These districts serve approximately 4,360, 2,300, and 2,700 acres respectively. About one-third of the districts derived their water from wells; the remainder use water from lakes and from the Spokane River, mostly by pumping. The irrigated area for this basin was computed primarily from reports of the Idaho State Engineer and records of the Spokane County Treasurer, supplemented by information obtained from officials of the privately operated irrigation districts and companies, and from Fred J. Cunningham, Spokane attorney. The course and seasonal distribution of the return flow from the irrigated acreages in this basin is not well defined owing to the presence of extensive beds of highly permeable material. The Geological Survey has been investigating ground-water movement through portions of this basin and a preliminary report was issued as Water-Supply Paper 889-B. Because return-flow conditions are unknown, no attempt has been made in this report to estimate depletion at any of the gaging stations in this basin. However, for purposes of computing depletion at sites downstream on the Columbia River, a net consumptive use of 1.35 acre-feet per acre was used. This was estimated on the basis of computations by Lowry-Johnson method. Irrigated area above selected locations in the Spokane River basin are shown in the following table.

Irrigated area, in acres, for indicated year

Year	Colville River basin	Spokane River at Post Falls, Idaho	Spokane River at Spokane, Wash.	Spokane River at mouth
1890	360	....	....	....
1900	1,400	....	....	500
1905	1,900	....	1,120	2,005
1910	5,400	272	10,864	13,120
1915	4,560	272	15,824	22,840
1920	4,630	272	18,474	26,240
1921	4,270	272	18,594	26,470
1922	3,910	212	18,874	26,850
1923	3,550	212	24,255	31,800
1924	3,180	212	24,294	28,680
1925	2,820	212	23,026	25,250
1926	2,760	212	23,169	24,990
1927	2,700	212	23,119	24,930
1928	2,640	212	22,749	24,560
1929	2,580	212	22,421	24,230
1930	2,740	212	22,369	24,190
1931	2,890	212	22,539	24,370
1932	3,040	212	22,679	24,520
1933	3,200	212	22,796	24,650
1934	3,360	212	22,373	24,230
1935	3,510	212	22,659	24,530
1936	3,660	212	22,532	24,410
1937	3,820	212	22,566	24,460
1938	3,480	212	22,586	24,490
1939	3,630	212	22,713	24,620
1940	3,630	212	22,303	24,210
1941	3,630	212	22,316	24,230
1942	3,630	212	22,308	24,220
1943	3,690	212	22,110	24,020
1944	3,980	212	21,347	23,260
1945	4,080	212	21,339	23,250
1946	4,080	1,492	22,646	24,560

COLUMBIA RIVER AT GRAND COULEE DAM, WASH.

Outside the major subdivisions already described, a small amount of land is irrigated with water diverted from minor tributaries of the Columbia River and water pumped directly from the river. Very little specific information is available regarding these tracts, and most of the data have been derived from census reports supplemented by information from residents and from the files of the Nespelem Indian Agency. This agency operates two small irrigation projects on Hall and Stranger Creeks. The return flow from the lands irrigated in this portion of the basin enters the Columbia River main stem above Grand Coulee. The net consumptive use for lands in this portion of the basin was estimated to be 1.35 acre-feet per acre. The percentage depletion of the yield of the basin above Grand Coulee Dam for the period 1921 through 1945 was estimated to be 0.6 percent. The following table shows irrigated area, annual runoff, and estimated depletion for the basin above Grand Coulee Dam, Wash. Pumping from Franklin D. Roosevelt Lake for irrigation of lands in the Columbia Basin project is expected to begin in 1951.

Irrigated area, annual runoff, and estimated depletion for Columbia River at Grand Coulee Dam, Wash.

Year	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1860	1,000	....	1,400
1870	10,000	....	11,500
1880	26,000	....	28,400
1890	75,210	....	78,500
1900	191,813	....	226,100
1905	254,526	....	305,600
1910	288,442	....	354,200
1914	....	81,400,000	....
1915	310,682	70,100,000	386,340
1916	....	98,000,000	....
1917	....	82,800,000	....
1918	....	85,700,000	....
1919	....	78,800,000	....
1920	336,354	71,800,000	405,300
1921	333,244	91,700,000	401,300
1922	344,615	74,900,000	420,200
1923	334,775	79,000,000	408,600
1924	339,056	62,600,000	409,300
1925	332,732	91,000,000	405,400
1926	331,570	53,200,000	402,700
1927	322,122	91,400,000	391,100
1928	329,646	103,000,000	399,400
1929	335,781	58,700,000	406,800
1930	336,723	61,400,000	411,600
1931	343,544	58,500,000	417,300
1932	353,354	82,800,000	427,900
1933	351,132	91,400,000	426,400
1934	357,979	101,400,000	433,900
1935	364,460	81,440,000	441,100
1936	357,269	70,830,000	432,400
1937	372,299	57,500,000	451,800
1938	368,555	81,960,000	450,600
1939	368,701	69,280,000	449,200
1940	367,245	*67,800,000	446,000
1941	365,771	*59,290,000	443,800
1942	361,313	*79,540,000	441,700
1943	367,975	*80,810,000	447,500
1944	370,043	*50,950,000	450,500
1945	373,014	*65,040,000	454,100
1946	379,670	86,090,000	462,500

* Adjusted for change in contents in Franklin D. Roosevelt Lake.

COLUMBIA RIVER, GRAND COULEE DAM TO SNAKE RIVER

OKANOGAN RIVER

The land currently irrigated in the United States portion of the Okanogan River basin totals about 22,000 acres, a large part lying in narrow, discontinuous strips along the main river channel.

Three irrigation districts provide water by gravity to approximately half the irrigated area. The Whitestone Project, near Loomis, Wash., which includes about 2,000 acres, is an off-stream development and obtains water from Toats Coulee Creek.

Blue, Spectacle, and Whitestone Lakes provide storage for this project. Originally it was planned to develop over 10,000 acres of irrigated land but due to insufficient water the project shrank to its present size. The Okanogan Project of the Bureau of Reclamation includes about 3,800 acres of land between Johnson Creek and Salmon Creek. Water is diverted from Salmon Creek, and storage is provided by Conconully Lake. At one time, about 8,000 acres were irrigated, but owing to an inadequate water supply, the area has been reduced to its present size. The largest irrigation project in the basin is the Oroville-Tonasket Irrigation District, which diverts water from the Similkameen River between Nighthawk and Oroville, Wash. The irrigated land lies on both sides of Okanogan River from the international boundary to and just south of Tonasket, Washington, and includes about 7,000 acres. Many small private and company-owned pumping plants supply water to the bench lands along the Okanogan River.

Irrigation in the Similkameen River basin is located around Palmer Lake and the Sinlahekin Valley. The Canada Yearbook for 1940 shows 34,848 acres of irrigated land in the Canadian portion of the Okanogan River basin. Most of this land is irrigated by direct diversion from the Okanogan River. Water stored in Okanagan Lake is used to supplement the late summer streamflows for the irrigated area near Oliver, British Columbia.

The following table shows the irrigated area in the United States portion of the Okanogan River basin. These data were obtained from irrigation district reports, census reports, records of watermasters, and from pioneer residents. All return flow is believed to enter the Okanogan River above its mouth except that from about 500 acres of the Monse Indian project, which enters the Columbia River directly. The average net consumptive use for all lands in this subdivision was estimated to be 1.5 acre-feet per acre.

Irrigated area, in acres, for Okanogan River basin in the United States

Year	Similkameen River near Nighthawk, Wash.	Okanogan River near Tonasket, Wash.	Okanogan River at mouth
1860	....	20	20
1870	....	20	20
1880	205	225	225
1890	470	490	960
1900	1,480	1,560	2,100
1905	1,500	1,670	2,230
1910	1,580	1,760	7,940
1915	1,580	2,760	12,500
1920	2,580	10,800	18,850
1921	2,780	11,000	19,300
1922	2,880	11,100	19,300
1923	2,980	11,200	19,100
1924	3,020	11,200	19,700
1925	3,100	11,100	19,800
1926	3,100	11,100	20,000
1927	3,060	11,000	19,400
1928	2,980	10,900	19,400
1929	2,940	11,000	19,800
1930	2,940	10,900	19,700
1931	2,940	10,800	19,600
1932	3,000	10,800	19,300
1933	3,000	10,700	19,300
1934	3,040	10,700	19,300
1935	3,040	10,700	19,400
1936	3,040	10,700	19,200
1937	3,200	10,900	19,300
1938	3,160	10,800	19,600
1939	3,120	10,700	19,100
1940	3,180	10,700	19,300
1941	3,050	10,600	19,100
1942	3,010	10,600	19,400
1943	2,970	10,600	19,800
1944	2,970	10,600	20,200
1945	2,930	10,700	20,500
1946	2,930	10,700	22,100

METHOW RIVER

The earlier inhabitants of the Methow Valley were primarily interested in mining and in raising livestock. Some ditches were first constructed in connection with mining, and after the turn of the century they were converted to agricultural purposes. Most of the irrigated lands lie along the river in small tracts, and water is supplied by small ditches maintained under individual or partner ownership. The majority of the expansion took place between 1905 and 1910.

The China Ditch, near Pateros, was the first known diversion in the Methow Valley. It was originally used for placer mining, but irrigation probably started about 1900. There was little expansion in this area until a district was organized in 1922. Since that time water has been supplied to about 330 acres, along the

Columbia River downstream from Methow River. The Pateros Ditch was built in 1903, and in 1904 delivered water to 300 acres, which later was reduced to about 250 acres. The district was formed in 1916 to include land lying along the north side of Methow River and the Columbia River upstream from the confluence of these streams.

The Methow Canal Co. diverted water from Twisp and Methow Rivers to irrigate land along the lower 4 miles of Twisp River and the 10 miles immediately downstream from the confluence of that stream with the Methow River. The first irrigation water was delivered in 1909. In 1919 the Methow Canal Co. became the Methow Valley Irrigation District, which presently irrigates about 1,900 acres.

The Wolf Creek Irrigation District was formed in 1922 to irrigate land in the vicinity of Winthrop. Water is diverted from Wolf Creek and stored in Patterson Lake for about 650 acres.

The discharge records of the gaging station on Methow River at Twisp do not represent the yield of the basin at that point. Two canals of the Methow Valley Irrigation District and Risley ditch divert water around the station. The gaging station on Methow River at Pateros, is essentially at the mouth of the stream, and except as has been indicated all return flow is believed to enter the stream above this point.

The irrigated area in this basin, shown in the following table, is based primarily on records of existing irrigation districts, adjudicated water rights, and census reports. The distribution of private irrigated lands above and below Twisp was based on a survey made by the Washington State Department of Conservation and Development in 1924. Field investigations by the Geological Survey in 1915 and 1947 were also used. The net consumptive use for this basin was estimated to be 1.75 acre-feet per acre.

Irrigated area, annual runoff, and estimated depletion for Methow River basin

Year	Methow River at Twisp, Wash.	Methow River at Pateros, Wash.		
	Irrigated area (acres)	Irrigated area (acres)	Annual runoff (acre-feet)	Estimated depletion (acre-feet)
1890	30	650		1,140
1900	50	1,550		2,710
1904			1,650,000	
1905	1,800	3,900	1,360,000	6,820
1906			1,100,000	
1907			1,380,000	
1908			1,210,000	
1909			1,110,000	
1910	5,900	11,800	1,720,000	20,650
1911			1,170,000	
1912			946,000	
1913			1,130,000	
1914			1,220,000	
1915	7,450	10,400	870,000	18,200
1916			1,730,000	
1917			1,050,000	
1918			987,000	
1919			1,140,000	
1920	6,990	12,580	633,000	22,020
1921	6,900	12,500		21,880
1922	6,810	12,410		21,720
1923	6,720	12,330		21,580
1924	6,630	12,250		21,440
1925	6,510	12,150		21,260
1926	6,390	12,050		21,090
1927	6,270	11,950		20,910
1928	6,140	11,850		20,740
1929	6,010	11,760		20,580
1930	6,210	11,980		20,960
1931	6,380	12,100		21,180
1932	6,530	12,240		21,420
1933	6,620	12,350		21,610
1934	6,770	12,490		21,860
1935	6,920	12,650		22,410
1936	6,990	12,400		21,700
1937	7,140	12,560		21,980
1938	7,290	12,720		22,260
1939	7,440	12,880		22,540
1940	7,430	12,870		22,520
1941	7,430	12,870		22,520
1942	7,420	12,840		22,470
1943	7,410	12,830		22,450
1944	7,400	12,800		22,400
1945	7,400	12,800		22,400
1946	7,410	12,830		22,450

CHELAN RIVER

Owing to the rugged terrain surrounding Lake Chelan and to the use of the lake to store water for generating hydroelectric power the amount of irrigation within the Chelan River basin is relatively small. Most of the irrigated lands are in organized districts. The earliest irrigation was on the south side of Lake Chelan near Manson; water was diverted from First Creek, and about 100 acres have been under irrigation since 1907. This area was organized in 1922 as the First Creek Irrigation District.

The Chelan Falls Irrigation District started the following year on 300 acres on the west bank of the Columbia River with water diverted from Lake Chelan.

The Lake Chelan Reclamation District, on the north side of Lake Chelan near Manson, constitute the largest block of irrigated land in the basin. The district was started with about 400 acres in 1909. The increase was gradual up to about 2,000 acres in 1926, then 1,000 acres were added in 1927 to make a total of 3,000 acres. At the present time about 3,600 acres are irrigated from the waters of seven mountain streams, storage being provided by several small lakes.

The Isenhart Irrigation District was started in 1931 and irrigates 250 acres just northeast of Lake Chelan. Water is pumped from the lake.

The irrigated acreages shown in the following table have been estimated on the basis of records of the irrigation districts and by field investigations, which included the collection of information from pioneers of the area. Officials of the Washington Water Power Co. supplied information concerning the amount of land served since the development of their hydroelectric plant at Chelan Falls. The net consumptive use for this basin was estimated to be 1.75 acre-feet per year.

279538 O - 53 - 4

Irrigated area, and estimated depletion for Chelan River basin, including land irrigated with Chelan River water

Year	Irrigated area (acres)	Estimated depletion (acre-feet)
1910	1,610	2,820
1915	2,500	4,380
1920	3,360	5,880
1921	3,500	6,120
1922	3,650	6,390
1923	3,790	6,630
1924	3,930	6,880
1925	4,080	7,140
1926	4,220	7,380
1927	5,260	9,200
1928	5,330	9,330
1929	5,380	9,420
1930	5,430	9,500
1931	5,730	10,030
1932	5,760	10,080
1933	5,800	10,150
1934	5,840	10,220
1935	5,870	10,270
1936	5,920	10,360
1937	5,960	10,430
1938	6,020	10,540
1939	6,060	10,600
1940	6,110	10,690
1941	6,140	10,740
1942	6,160	10,780
1943	6,190	10,830
1944	6,220	10,880
1945	6,250	10,940
1946	6,280	10,990

ENTIAT RIVER

Owing to its mountainous nature there has been relatively little irrigation development in the Entiat River basin. Most of the land is irrigated from privately owned ditches and lies along the lower reaches of the river above the gaging station at Entiat, which is essentially at the mouth of the river. The exception is the Entiat Irrigation District, formed in 1920, where water is diverted from the river above the gaging station at Entiat to irrigate about 600 acres lying below the gaging station along the west bank of the Columbia River. Past records of this diversion are not available, and the canal flow is not included in the gaging-station record.

The following table shows data for the Entiat River. The return flow from all lands except the Entiat Irrigation District is assumed to reach the river above its confluence with the Columbia River. The net consumptive use for this basin was estimated to be 1.75 acre-feet per acre.

Irrigated area, annual runoff, and estimated depletion, for Entiat River at Entiat, Wash.

Year	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1900	360	...	630
1905	3,190	...	5,580
1910	3,400	...	5,950
1911	...	345,000	...
1912	...	336,000	...
1913	...	417,000	...
1914	...	376,000	...
1915	2,650	249,000	4,640
1916	...	589,000	...
1917	...	371,000	...
1918	...	358,000	...
1919	...	379,000	...
1920	2,030	204,000	3,550
1921	2,020	492,000	3,540
1922	2,010	317,000	3,520
1923	2,000	349,000	3,500
1924	1,980	261,000	3,460
1925	1,970	364,000	3,450
1926	1,950	...	3,410
1927	1,940	...	3,400
1928	1,930	...	3,380
1929	1,910	...	3,340
1930	1,980	...	3,460
1931	2,040	...	3,570
1932	2,100	...	3,680
1933	2,170	...	3,800
1934	2,240	...	3,920
1935	2,300	...	4,020
1936	2,370	...	4,150
1937	2,430	...	4,250
1938	2,500	...	4,380
1939	2,560	...	4,480
1940	2,560	...	4,480
1941	2,560	...	4,480
1942	2,560	...	4,480
1943	2,560	...	4,480
1944	2,560	...	4,480
1945	2,560	...	4,480
1946	2,560	...	4,480

WENATCHEE RIVER

Irrigation has been practiced in the Wenatchee River valley of Washington from the time of the earliest white settlers, beginning on a small scale with the construction of Miller Ditch about 1870, to divert water from Squillchuck Creek. During the next few years several other small ditches were constructed on tributary streams, but no large ditches were built until 1891, when work was started on the Gunn Ditch, which diverts water from Wenatchee River about 1 mile above Monitor. By 1898, this ditch had been extended as far as Wenatchee and served about 1,000 acres including some lands along the Columbia River above and below the mouth of the Wenatchee River.

The Peshastin Ditch was built about 1898 to irrigate about 1,900 acres of land near the mouth of the Peshastin Creek and on the south side of Wenatchee River between Dryden and Cashmere. The Peshastin Irrigation District took over the operation of this canal in 1917, and now serves about 3,600 acres.

The largest project in the basin is the Wenatchee Reclamation District which was formed in 1915. Hiline Canal, the principal canal of this district, was constructed during the period 1902 to 1907. Water is diverted above Dryden, and carried down the north bank of the river to a point near the mouth of the Wenatchee River; there the canal divides, one branch extending a short distance up the west bank of the Columbia and the other extending downstream along the Columbia into Douglas County. About 11,500 acres are served by this canal.

The Jones-Shotwell ditch, completed in 1903, has its intake 1 mile above Cashmere, and serves about 700 acres along the east side of Wenatchee River. The Icicle Irrigation District was formed in 1917, although water had been delivered by the Icicle Canal Co. since 1910. With about 1,000 acres in the beginning, the company now serves about 3,000 acres on both sides of Wenatchee River near Leavenworth, and downstream as far as Mission Creek.

There has been comparatively little new development in irrigation since about 1915 except for the Wenatchee-Chiwawa Irrigation District, which was formed in 1923, and now irrigates about 1,400 acres near Plain.

The following table shows the data on Wenatchee River basin. The irrigated areas were determined from reports of irrigation districts, supplemented by information from local pioneer residents, county tax records, and census reports. The return flow from the irrigated lands in this subdivision is partly direct to the Wenatchee River and part directly to the Columbia, above the dam at Rock Island. The net consumptive use as computed by Lowry-Johnson method is 2.0 acre-feet per acre.

Irrigated area and estimated depletion for Wenatchee River basin

Year	Wenatchee River at Peshastin, Wash.	Wenatchee River at mouth	
	Irrigated area (acres)	Irrigated area (acres)	Estimated depletion (acre-feet)
1900	....	3,100	6,200
1905	650	12,850	25,700
1910	760	19,210	38,420
1915	1,430	23,470	46,940
1920	1,740	23,180	46,360
1921	1,770	23,150	46,300
1922	1,820	23,180	46,360
1923	3,160	24,520	49,030
1924	3,190	24,530	49,060
1925	3,230	24,550	49,100
1926	3,280	24,560	49,120
1927	3,320	24,590	49,180
1928	3,360	24,630	49,260
1929	3,350	24,600	49,200
1930	3,350	24,650	49,300
1931	3,310	24,700	49,400
1932	3,260	24,700	49,400
1933	3,220	24,740	49,480
1934	3,170	24,760	49,520
1935	3,130	24,790	49,580
1936	3,060	24,780	49,560
1937	3,120	24,910	49,820
1938	3,120	24,980	49,960
1939	3,180	25,020	50,040
1940	3,200	25,190	50,380
1941	3,230	25,300	50,600
1942	3,250	25,370	50,740
1943	3,290	25,490	50,980
1944	3,280	25,500	51,000
1945	3,260	25,490	50,980
1946	3,240	25,470	50,940

COLUMBIA RIVER AT TRINIDAD, WASH.

In addition to the major tributary basins between Grand Coulee Dam and the gaging station on Columbia River at Trinidad, already discussed, there is additional irrigation along the main stem of the Columbia River, utilizing water from minor tributaries or pumping directly from the Columbia River. These tracts vary in size from a few hundred acres to about 1,500 acres and are fairly well distributed along the narrow river valley below the Okanogan River. The return flow from all of these lands enters the Columbia River above the gaging station at Trinidad. The net consumptive use for this portion of the basin was estimated to be 2.0 acre-feet per acre, the same as for the Wenatchee River basin.

The following table shows data for the United States portion of the Columbia River basin above the gaging station at Trinidad, Wash. The percentage depletion, based upon the period 1921 through 1945 was computed to be 0.7 percent and has shown only a slight increase during this period.

Irrigated area, annual runoff, and estimated depletion for Columbia River at Trinidad, Wash.

Year	Irrigated area (acres)	Runoff (acre-feet)*	Estimated depletion (acre-feet)
1860	1,020	....	1,430
1870	10,000	....	11,530
1880	28,000	....	28,740
1890	76,820	....	81,080
1900	201,183	....	243,300
1905	279,436	....	352,500
1910	338,692	....	447,400
1914	....	91,600,000	....
1915	372,072	76,900,000	498,800
1916	....	112,000,000	....
1917	....	91,900,000	....
1918	....	96,200,000	....
1919	....	88,800,000	....
1920	404,864	77,600,000	529,200
1921	403,324	103,000,000	526,900
1922	414,855	82,600,000	545,900
1923	406,495	87,200,000	536,800
1924	411,416	68,600,000	538,400
1925	405,232	99,400,000	534,800
1926	404,180	58,100,000	532,400
1927	394,952	99,700,000	521,300
1928	402,546	113,000,000	529,700
1929	408,751	64,000,000	537,100
1930	410,483	66,400,000	543,500
1931	417,314	62,200,000	549,300
1932	426,624	87,800,000	559,100
1933	424,362	98,800,000	557,500
1934	431,319	110,800,000	564,200
1935	438,140	88,520,000	573,300
1936	430,239	74,620,000	563,000
1937	445,519	61,820,000	582,800
1938	442,215	86,940,000	582,200
1939	442,201	72,450,000	580,500
1940	441,165	71,480,000	578,200
1941	440,031	63,210,000	576,800
1942	436,503	84,840,000	576,400
1943	444,075	90,220,000	583,800
1944	447,053	56,660,000	588,200
1945	450,694	71,570,000	593,100
1946	459,300	93,580,000	604,600

* Adjusted for storage in Franklin D. Roosevelt Lake since October 1939.

CRAB CREEK

Crab Creek drains a semiarid area having very low runoff. The stream is discontinuous or intermittent except in certain reaches. The lower portion of the basin encompasses much of the area included in the Columbia Basin Project to be irrigated by pumping from Franklin D. Roosevelt Lake. At present extensive areas in the basin are cultivated by dry-farming methods and produce grain crops.

Irrigation in the basin has been limited to small scattered tracts, Moses Lake Irrigation District being the only organized enterprise. This district stores water in Moses Lake and member farmers pump directly from the lake. Other lands are irrigated by water from small tributary streams or springs. The irrigated areas shown in the following table have been compiled from data furnished by pioneers and other local residents, supplemented by census reports.

Movement of ground water in the area is not well known, but it is believed that a considerable amount escapes directly to the Columbia River. The depletion of Crab Creek by irrigation is therefore not estimated in connection with any of the gaging stations within the basin. The net consumptive use for lands in this basin was estimated to be 1.75 acre-feet per acre.

Irrigated area, in acres, at indicated years for Crab Creek basin

Year	Irrigated area (acres)
1890	330
1900	1,670
1905	2,180
1910	3,090
1915	6,110
1920	6,560
1921	6,500
1922	6,440
1923	6,380
1924	6,320
1925	6,260
1926	6,000
1927	5,940
1928	5,880
1929	5,740
1930	5,680
1931	5,620
1932	5,550
1933	5,490
1934	5,430
1935	5,370
1936	5,610
1937	5,850
1938	6,090
1939	6,340
1940	6,640
1941	6,940
1942	7,240
1943	7,430
1944	9,130
1945	12,130
1946	13,430

YAKIMA RIVER

Irrigation agriculture has played a dominant role in the development of the Yakima Valley of central Washington, the largest irrigated area in the Columbia River basin above the Snake River. The earliest irrigation was reputedly started prior to 1860 by Indians, who had been taught the advantage of irrigation by missionaries a few years earlier. There were very few white settlers in the valley before this time. The first authentic report of irrigation by white men was of the diversion of water from the Naches River through a small ditch constructed by George Nelson in 1867. Through the formation of a small stock company, this ditch was later enlarged to the present Union Canal. The Lauber and Schanno ditch was constructed in 1873 and was extended in 1875 as far as Yakima.

The earliest of the large-scale undertakings was made by the Northern Pacific Railway, which had its western terminus at Yakima for 2 years. In 1890 the company began construction of the Sunnyside Project to irrigate some 40,000 acres. In 1905 the U. S. Bureau of Reclamation purchased all rights from the Northern Pacific Railway and has extended this district to 105,000 acres, of which about 83,000 acres are currently irrigated. This was one of the first projects constructed under the Reclamation Act.

The failure of several private and stock companies during the 1890's made the financing of storage projects difficult, thus limiting development to land easily accessible to natural river flow. There were 55 principal canals between Cle Elum and the mouth of the Yakima River, including those on the Naches River, plus innumerable small canals on the minor tributaries. This basin has been the focus of intensive development by governmental agencies, until at the present time the projects operated by the Bureau of Reclamation and the Yakima Indian Reservation comprise about 80 percent of all irrigated lands in this basin.

Because of the complex pattern of the irrigation works, no attempt will be made to analyze in detail the projects which have been developed. The Yakima Project, of the Bureau of Reclamation is comprised of five operating divisions: Sunnyside, Tieton, Kittitas, Roza, and Kennewick divisions. Of these the Sunnyside and Kittitas are the largest. Water is stored in six upstream reservoirs operated by the Bureau of Reclamation to provide irrigation water during low-water seasons. The Wapato Indian Project consists of land which lies mostly on the Indian reservation and which is served by minor tributaries and by the Yakima River.

The values for irrigated acreage shown in this report have been compiled from the records of the Yakima Project, Wapato Indian Project, and irrigation districts which receive water from these agencies. Records available through the Yakima office of the Bureau of Reclamation were supplemented by data collected by the Geological Survey. These records do not compare closely with census figures for the earlier years, probably owing to differences in classification of irrigated land. This was particularly true in the Kittitas Valley where the census figure indicated 30,000 acres irrigated in the earlier years, though Water-Supply Paper 369 indicates that the irrigated lands in this basin received only about one-third of their water requirement. In this report it is assumed that 10,000 acres have been adequately irrigated during the early stage of development. In recent years the irrigated acreage has been based on the records of irrigation districts and irrigation companies, which agree substantially with census figures.

The irrigated area above the gaging station on Yakima River near Umtanum, consists mainly of lands in the Kittitas Valley near Ellensburg. These lands receive their water supply principally from the Kittitas Reclamation District and the Cascade Canal Co. supplemented by small district and private irrigation systems. There is a small amount of irrigated land located near Cle Elum adjacent to both the Yakima and Teanaway Rivers. The diversion and return flow from all these lands is assumed to reach the Yakima River above the gaging station near Umtanum.

The irrigated lands above the gaging station on Yakima River at Parker, are those in the main Yakima Valley and the lower portion of the Naches River valley. They are served primarily by works constructed by the Bureau of Reclamation, the Tieton division being the largest single supplier of water in this area. Many small irrigation districts also serve this area. The return flow from all these lands is assumed to reach the Yakima River at or above Union Gap. The discharge measured at the gaging station near Union Gap includes the flow of canals diverting at this point.

The irrigated lands below the gaging station on Yakima River near Parker, and above the gaging station at Kiona constitute the largest such tract in the Yakima Valley. South of the river are the lands of the Wapato Indian Project and others to which water is supplied by the Indian Service. The Sunnyside division and the newly created Roza division form the majority of the remaining irrigated area in this portion of the basin. The return flow for all these lands is assumed to reach the Yakima River above the gaging station at Kiona.

In addition, a small amount of land is irrigated along the lower reaches of the Yakima River and along the Columbia River near its confluence with the Yakima. These are comprised mainly of the Kennewick division and the Columbia Irrigation District. The return flow from these particular lands is assumed to reach the Columbia River above the mouth of the Snake.

The average net consumptive use for this basin has been estimated to be 2.0 acre-feet per acre and was based upon computations by Lowry-Johnson method, Blaney-Criddle method and results of inflow-outflow studies for a portion of the basin. The depletion shown in the following table represents an average depletion of 11.6 percent of the yield of the watershed above Parker. This is for the period 1921 through 1945. A gradual growth has taken place during this period and in 1946 the depletion represents about 13.6 percent of the long-term yield. Considering the 13-year period 1934 through 1946, the percentage depletion above Kiona has averaged 27.2 percent and in 1946 it represents 28.9 percent of the long-term yield.

Irrigated area, annual runoff, and estimated depletion for Yakima River basin

Year	Yakima River at Umtanum, Wash.	Yakima River near Parker, Wash.			Yakima River at Kiona, Wash.	Yakima River basin	
	Irrigated area (acres)	Irrigated area (acres)	Annual runoff (acre-feet)	Estimated depletion (acre-feet)	Irrigated area (acres)	Irrigated area (acres)	Estimated depletion (acre-feet)
1860		500		1,000	1,000	1,000	2,000
1870		1,000		2,000	1,600	1,600	3,200
1880	2,100	3,600		7,200	4,200	4,200	8,400
1890	7,800	20,800		41,600	26,750	26,750	53,500
1897			4,040,000				
1898			3,730,000				
1899			3,760,000				
1900	27,800	49,300	3,570,000	98,600	67,450	67,450	134,900
1901			3,930,000				
1902			3,550,000				
1903			4,180,000				
1904			4,480,000				
1905	42,890	81,890	2,610,000	163,780	131,190	136,430	272,860
1906			2,720,000				
1907			4,320,000				
1908			3,240,000				
1909			2,540,000				
1910	49,860	103,760	4,580,000	207,520	184,290	197,280	394,560
1911			2,950,000				
1912			3,190,000				
1913			3,730,000				
1914			3,180,000				
1915	51,120	129,620	2,050,000	259,240	236,860	253,220	506,440
1916			5,210,000				
1917			3,310,000				
1918			4,020,000				
1919			3,360,000				
1920	54,320	141,120	1,860,000	282,240	305,370	322,490	644,980

Irrigated area, annual runoff, and estimated depletion for Yakima River basin—Continued

Year	Yakima River at Umtanum, Wash.	Yakima River near Parker, Wash.			Yakima River at Kiona, Wash.	Yakima River basin	
	Irrigated area (acres)	Irrigated area (acres)	Annual runoff (acre-feet)	Estimated depletion (acre-feet)	Irrigated area (acres)	Irrigated area (acres)	Estimated depletion (acre-feet)
1921	54,660	142,060	4,110,000	284,120	308,600	325,880	651,760
1922	55,000	142,700	2,630,000	285,400	314,800	332,290	664,580
1923	55,340	142,690	2,940,000	285,380	316,100	332,690	665,380
1924	55,680	142,750	2,420,000	285,500	315,190	331,590	663,180
1925	56,010	143,860	2,940,000	287,720	319,110	334,980	669,960
1926	54,500	142,800	1,630,000	285,600	322,150	338,240	676,480
1927	52,500	139,700	3,070,000	279,400	319,480	337,460	674,920
1928	50,500	138,000	3,370,000	276,000	315,020	333,070	666,140
1929	48,610	137,110	1,680,000	274,220	312,710	329,200	658,400
1930	59,810	148,310	1,570,000	296,620	328,080	345,230	690,460
1931	81,330	168,730	1,570,000	337,460	349,670	366,800	733,600
1932	89,590	178,290	3,060,000	356,580	353,260	368,690	737,380
1933	94,380	183,720	3,700,000	367,440	359,800	374,580	748,760
1934	102,170	191,070	4,554,000	382,140	376,010	391,050	782,100
1935	106,880	195,780	3,437,000	391,560	383,170	397,960	795,920
1936	104,430	193,480	2,692,000	386,960	376,090	391,240	782,480
1937	106,000	195,650	2,308,000	391,300	386,000	403,440	806,880
1938	108,010	197,330	3,142,000	394,660	390,170	408,250	816,500
1939	108,120	198,250	2,008,000	396,500	391,350	409,150	818,300
1940	110,100	200,280	1,844,000	400,560	395,140	412,700	825,400
1941	110,780	200,520	1,398,000	401,040	396,720	414,340	828,680
1942	111,100	202,630	1,913,000	405,260	403,420	421,860	843,720
1943	108,450	201,220	3,296,000	402,440	406,410	421,410	842,820
1944	104,460	196,790	1,306,000	393,580	404,810	419,570	839,140
1945	104,640	198,120	2,013,000	396,240	413,920	428,580	857,160
1946	104,640	198,510	3,141,000	397,020	424,430	439,300	878,600

COLUMBIA RIVER, BETWEEN YAKIMA RIVER AND SNAKE RIVER

There is a small amount of irrigation along the Columbia River between the Yakima and Snake River, of which the Franklin County Irrigation District serves the largest part. The remainder consists of small isolated tracts. The water supply is obtained by pumping from the Columbia River. The return flow from these lands is assumed to reach the Columbia River above the mouth of the Snake.

The irrigated area and estimated depletion for that portion of the Columbia River above the Snake River is summarized in the following table.

Irrigated area and estimated depletion for the Columbia River above mouth of Snake River

Year	Irrigated area (acres)	Estimated depletion (acre-feet)
1860	2,020	3,430
1870	12,000	14,730
1880	32,000	37,140
1890	103,900	125,200
1900	270,303	381,120
1905	418,636	630,300
1910	541,692	852,600
1915	634,902	1,022,900
1920	738,134	1,194,100
1921	739,914	1,198,500
1922	757,795	1,230,100
1923	749,775	1,221,800
1924	754,646	1,223,300
1925	751,592	1,225,900
1926	753,740	1,230,000
1927	743,692	1,217,300
1928	746,846	1,216,800
1929	749,051	1,216,300
1930	766,813	1,254,700
1931	795,214	1,303,700
1932	806,404	1,317,300
1933	810,102	1,327,600
1934	833,509	1,367,200
1935	847,240	1,390,200
1936	832,949	1,367,000
1937	860,779	1,411,900
1938	862,635	1,421,500
1939	863,761	1,422,000
1940	866,595	1,427,400
1941	867,451	1,429,500
1942	871,673	1,444,900
1943	878,985	1,451,800
1944	881,803	1,455,400
1945	897,524	1,483,700
1946	918,340	1,519,300

SNAKE RIVER BASIN

The Snake River is a major tributary of the Columbia River and has a drainage area of 109,000 square miles. Rising in Yellowstone National Park in western Wyoming, it traverses southern Idaho westward in a broad arc and then flows almost due north to form a part of the boundaries between Idaho, Oregon, and Washington. Near Lewiston, Idaho it turns west to join the Columbia River near Pasco, Wash. The Snake River drains the southeastern part of the Columbia River basin including portions of the following States: Wyoming, Idaho, Utah, Nevada, Oregon, and Washington.

Mountain ranges and high plateaus enclose the Snake River basin. On the east are the Rockies, on the north are the Centennial Mountains and Beaverhead Range, to the west are the Blue Mountains and the high plateau of eastern Oregon, and to the south the barren mountains and plateaus of northern Nevada and Utah.

Within the Snake River basin lies one of the largest and most highly developed irrigated areas in the United States. The early settlers soon found the advantages of irrigation for crop production. The earlier irrigation projects were established by individuals who diverted the waters of small tributaries directly upon the land. As these smaller tributaries became fully utilized, large groups and companies were formed to draw upon the waters of the Snake River and its larger tributaries. Additional impetus was furnished by Federal legislation. These factors, combined with favorable natural conditions account for the remarkable growth which took place between 1890 and 1910. Recent development has been more gradual and generally limited to extension and intensified use of early projects, to provision of more storage facilities, or to evolution into multipurpose projects. From the early beginnings of nearly a century ago the irrigated area has grown until at present there are about 2,400,000 acres irrigated above Weiser, Idaho. In the pages that follow, each subdivision is treated in more detail.

SNAKE RIVER ABOVE HEISE

The drainage area above the gaging station on Snake River near Heise, Idaho, is about 5,700 square miles of which about 80 percent is in northwest Wyoming and the remainder is in east-central Idaho. The area is generally mountainous and its perimeter includes portions of the Continental Divide and of the Teton, Gros Ventre, Salt River and Caribou Ranges.

Snake River heads in Yellowstone National Park, thence flows southward about 65 miles before turning westward through the so-called Grand Canyon to the Wyoming-Idaho State line, and there veers generally northwest to and beyond Heise.

In Wyoming the main tributaries above Jackson Lake are the Lewis and Heart Rivers, which are fed primarily by geysers; those below this lake are the Buffalo Fork, Gros Ventre, Hoback, and Salt Rivers.

The drainage area is generally mountainous, with only a small portion suitable for agriculture and only a small fraction of this arable land is irrigated. Hay and forage crops predominate and are fed for the most part to livestock locally.

Irrigation in this area was developed primarily by private and cooperative enterprises, which had reached most of their growth before 1910. The principal diversions are from the Gros Ventre, Hoback, and Salt Rivers; minor amounts are diverted from the Snake River. There are three active storage reservoirs in the area with an aggregate capacity of 852,000 acre-feet, but very little of the stored water is used within the tributary basin. All return flow from the irrigated area in this tributary basin is assumed to have returned to the Snake River above the gaging station at Heise. The net consumptive use was estimated to be 0.8 acre-feet per acre and was based upon computations by the Lowry-Johnson method. The irrigated area, estimated annual depletion and annual runoff for the gaging station at Heise are shown in the following table. The estimated depletion, expressed as a percentage of the yield of the watershed is 1.7 percent for the period 1921 through 1945.

Irrigated area, annual runoff, and estimated depletion for Snake River above Heise, Idaho

Year	Snake River in Wyoming	Snake River near Heise, Idaho		
	Irrigated area (acres)	Irrigated area (acres)	Annual runoff (acre-feet)	Estimated depletion (acre-feet)
1890	7,450	7,990	....	6,390
1900	34,500	40,300	....	32,240
1905	55,000	64,000	....	51,200
1910	72,000	82,700	....	66,160
1911	....	....	5,758,000	....
1912	....	....	5,949,000	....
1913	....	....	6,442,000	....
1914	....	....	5,809,000	....
1915	77,000	88,500	3,940,000	70,800
1916	....	....	5,761,000	....
1917	....	....	6,448,000	....
1918	....	....	6,620,000	....
1919	....	....	3,869,000	....
1920	81,500	94,800	5,082,000	75,840
1921	82,000	95,300	5,690,000	76,240
1922	83,000	96,400	5,129,000	77,120
1923	83,500	96,900	5,144,000	77,520
1924	84,000	96,000	3,766,000	76,800
1925	84,500	98,100	5,530,000	78,480
1926	85,000	97,700	4,296,000	78,160
1927	85,000	98,700	5,782,000	78,960
1928	85,500	99,200	6,195,000	79,360
1929	85,700	99,400	4,506,000	79,520
1930	86,000	99,700	4,419,000	79,760
1931	86,500	99,000	3,231,000	79,200
1932	86,800	100,600	4,325,000	80,480
1933	87,000	100,800	4,323,000	80,640
1934	87,500	99,500	2,980,000	79,600
1935	88,000	101,800	4,004,000	81,440
1936	88,400	102,600	5,103,000	82,080
1937	88,800	103,300	3,941,000	82,640
1938	89,200	103,900	4,994,000	83,120
1939	89,500	104,600	4,406,000	83,680
1940	89,700	105,000	3,566,000	84,000
1941	89,900	105,400	3,635,000	84,320
1942	90,000	105,700	4,219,000	84,560
1943	90,100	106,000	6,183,000	84,800
1944	90,200	106,100	4,321,000	84,880
1945	90,300	106,200	4,423,000	84,960
1946	90,300	106,200	5,466,000	84,960

SNAKE RIVER, HEISE TO KING HILL

Along the main stem of Snake River from Heise to King Hill, lies one of the most intricate and highly developed irrigation systems in the United States. Most of the irrigated lands in this reach are in two compact bodies along either bank of the river.

In the upper reach--that is, from Heise downstream to American Falls irrigation was financed by private capital, excepting on the Fort Hall Indian Reservation lands. Canal companies, irrigation districts and water-user associations were organized to expand the irrigated area. Some of the earliest water rights in the upper Snake River basin exist here. Development was very rapid from 1890 to 1910, with only a moderate subsequent expansion. Numerous canals serve this area; some of the larger ones are: Anderson, Eagle Rock, Harrison, Burgess, Butte, and Market Lake, Idaho, Snake River Valley, Great Western and Porter, Blackfoot, Peoples and Aberdeen-Springfield canals. Waters from Willow Creek and Blackfoot River are used interchangeably with water from Snake River in serving some of the lands. The Fort Hall irrigation system was developed for use by the Indian Service for lands under their jurisdiction.

In contrast to this area above American Falls, the lower area--from Lake Walcot to Bliss--largely was developed subsequent to 1900 as projects under the Carey Act and Bureau of Reclamation.

The South Side Twin Falls project is one of the largest and most successful of the Carey Act enterprises. It surrounds the towns of Twin Falls and Buhl south of the Snake River. Water for this area is diverted at Milner Dam, which has been in operation since 1905.

The North Side Twin Falls project is another very successful Carey Act enterprise. This is located north of the Snake River near Jerome and Bliss, opposite the South Side Twin Falls area. Water was first delivered during 1908 but the project was not substantially completed until 1916.

The Minidoka project, next downstream, was developed by the Bureau of Reclamation and includes three divisions – North Side Minidoka, South Side Minidoka, and Gooding. Part of this area has been turned over by the Bureau of Reclamation to irrigation districts. The development started as early as 1907 for the North and South Side divisions. The Gooding division was started in 1927, and delivered its first water to the lower Wood River area in 1931, thereby supplementing the water supply of that basin.

The net consumptive use for this entire area between Heise and King Hill has been estimated to be 1.8 acre-feet per acre, based upon studies by the Bureau of Reclamation and others for several component projects. The return flow from all this area is assumed to be recaptured by the Snake River above the gaging station at King Hill, but in considerable part within a relatively short reach just upstream from that station.

HENRYS FORK

The Henrys Fork basin drains about 3,010 square miles of eastern Idaho and northwestern Wyoming. The Centennial Mountains,

279538 O - 53 - 5

Teton and Snake River Ranges form the northern, eastern and southern boundaries.

Most of the irrigated lands are in the lower valley, chiefly between Ashton and Rexburg, although there are some irrigated meadows in the mountain valleys. The land in the lower valley was favorably situated and was among the first areas to be extensively developed in the upper Snake River basin. There are 36 canals diverting water from the Henrys Fork below Ashton and from the lower reaches of its larger tributaries. Of these the St. Anthony Union, Egin, Marysville, and Falls River Canals are the largest and on the average serve more than 8,000 acres each. The table on page 63 shows the estimated distribution of the irrigated lands in this basin.

Owing to the porous nature of the soil, large quantities of water are applied. In some areas it is common practice to apply sufficient quantities to raise the water table to the root zone of the crops. However, the net consumptive use has been estimated 1.0 and 1.4 acre-feet per acre for the upper and lower portions of the basin respectively. In this report it is predicated that the proportionately large return flow from the irrigated area in the Henrys Fork basin is recaptured by the source streams only in small part, and in large part moves by way of the very large groundwater body which underlies the eastern and central parts of the Snake River Plain and which discharges principally in the many large springs in and near the Hagerman Valley upstream from King Hill. Accordingly, this report does not estimate depletion for the Henrys Fork and other subdivisions of the Snake River basin between Heise and King Hill. Depletion for all the area above King Hill is estimated in the table on page 70.

Irrigated area, in acres, at indicated years for Henrys Fork basin

Year	Henrys Fork near Aston, Idaho	Fall River near Squirrel, Idaho	Teton River above St. Anthony, Idaho
	Irrigated area (acres)	Irrigated area (acres)	Irrigated area (acres)
1890	960	....	920
1900	8,800	....	20,700
1905	14,200	4,300	30,300
1910	17,100	6,500	34,300
1915	17,800	8,000	36,100
1920	18,100	10,000	37,100
1921	18,200	10,000	37,300
1922	18,300	10,200	37,400
1923	18,400	10,500	37,500
1924	17,200	8,500	32,200
1925	18,500	10,500	37,700
1926	18,000	9,000	34,200
1927	18,600	10,500	37,900
1928	18,600	10,700	38,000
1929	18,600	11,000	38,100
1930	18,600	11,000	38,200
1931	16,500	6,400	33,200
1932	18,600	10,000	36,300
1933	18,600	10,500	38,300
1934	16,000	8,000	31,300
1935	18,200	10,000	37,300
1936	18,600	10,000	38,300
1937	18,600	12,200	38,300
1938	18,600	12,200	38,300
1939	17,500	13,200	38,300
1940	17,500	13,800	38,300
1941	17,500	13,800	38,300
1942	17,500	13,800	38,400
1943	17,500	14,000	38,400
1944	17,500	15,000	38,400
1945	17,500	15,500	38,400
1946	17,500	16,000	38,400

PORTNEUF RIVER

The Portneuf River drains about 1,700 square miles south and southeast of Pocatello, Idaho. The stream heads on the Fort Hall Indian Reservation and flows south to the divide between the Snake and Bear Rivers; and then north to join the Snake River near Pocatello.

The 33,700 irrigated acres in this basin are in two main areas--one just downstream from Portneuf Reservoir and the other near McCammon. These areas are under private management and are served by small ditches diverting water from tributary creeks and the main river. Hay and grains are the principal crops grown.

The growth of irrigated area within this tributary basin is shown in the following table. The net consumptive use for the Portneuf River basin has been estimated at 1.6 acre-feet per acre. The return flow is believed to be through porous underbeds which drain towards the Snake River, and to sustain part of the discharge of the Portneuf springs. These springs are about 4 miles downstream from Pocatello.

MINOR TRIBUTARIES, NEELEY TO KING HILL

The minor tributaries joining the Snake River from the south, downstream from the Portneuf River, head in the barren plateaus which form the divide between the drainage basins of the Snake River and the Great Salt Lake. These tributaries are Raft River, Goose, Rock, and Salmon Falls Creeks. Most of the area irrigated by the water of these creeks lies along the south rim of the plain near Minidoka and South Side Twin Falls Projects. However there are scattered tracts along these creeks and near Rockland and Albion, Oakley and Kenyon, and Hollister and Amsterdam. Approximately 4,700 acres are in Utah and 11,500 acres in Nevada.

Net consumptive use for the lands irrigated by the tributaries has been estimated at 1.6 acre-feet per acre. Return flow has been assumed to be captured by the Snake River before it reaches King Hill.

Irrigated areas, in acres, in Snake River and tributary basins above King Hill, Idaho

Year	Snake River near Blackfoot, Idaho	Portneuf River basin	Snake River at Neeley, Idaho	Tributaries, Neeley to Milner	Snake River at Milner, Idaho	Tributaries, Milner to King Hill
1870	10	270	280	....	280	....
1880	1,040	1,350	2,390	3,700	6,090	1,480
1890	56,450	5,040	62,190	20,000	82,190	8,180
1900	286,800	12,100	303,400	36,000	339,400	15,850
1905	410,100	17,300	434,350	30,000	464,450	17,920
1910	514,400	23,300	546,440	41,000	742,140	24,340
1915	578,400	25,700	614,000	40,000	968,600	55,000
1920	620,700	31,900	662,770	48,000	1,129,570	70,150
1921	626,700	32,500	669,420	48,500	1,153,120	72,200
1922	630,500	32,700	673,470	49,000	1,158,770	73,700
1923	632,700	32,800	675,830	49,500	1,162,530	71,900
1924	618,400	32,900	661,600	40,000	1,133,000	66,500
1925	637,700	33,000	681,000	50,000	1,166,500	71,100
1926	629,500	33,100	668,900	42,000	1,147,200	52,800
1927	645,800	33,200	685,300	50,000	1,172,700	69,300
1928	647,900	33,200	687,400	50,000	1,177,000	65,400
1929	651,500	33,200	691,000	50,000	1,182,600	68,100
1930	652,900	33,200	692,400	50,000	1,185,000	60,300
1931	630,600	28,700	665,600	40,000	1,181,500	51,000
1932	651,000	33,700	691,000	50,000	1,215,000	69,100
1933	654,600	33,700	694,100	50,000	1,224,900	60,100
1934	629,800	26,700	662,900	30,000	1,183,400	36,200
1935	655,000	31,700	693,200	46,000	1,231,700	59,000
1936	659,700	33,700	700,000	50,000	1,246,400	63,100
1937	664,000	33,700	704,500	50,000	1,258,100	61,200
1938	665,700	33,700	706,400	50,000	1,265,800	61,200
1939	668,700	33,700	709,900	50,000	1,273,900	61,200
1940	671,100	33,700	712,300	50,000	1,278,100	58,200
1941	673,600	33,700	714,800	50,000	1,285,700	58,000
1942	676,300	33,700	717,500	50,000	1,297,000	63,800
1943	679,200	33,700	720,400	50,000	1,315,900	68,200
1944	683,900	33,700	725,100	50,000	1,320,600	68,200
1945	686,600	33,700	727,800	50,000	1,322,800	67,800
1946	689,180	33,700	730,380	50,500	1,328,680	71,000

MUD LAKE AREA

The Mud Lake area lies at the foot of the Beaverhead Range and Centennial Mountains of eastern Idaho and is adjacent to the Henrys Fork basin. It includes the basins of Camas, Beaver, Medicine Lodge, and Birch Creeks, and the adjacent lakes.

The irrigated land of this area is in the intermountain valleys along the several creeks just cited and around the south side of Mud Lake. Irrigation along the creeks previously mentioned began about 1870 in connection with stock ranches but it was not until 1908 that development using water from Mud Lake was started. At one time developments in this area were projected to include about 150,000 acres of which approximately 30,000 acres were to be in Carey Act projects. However at present time only about 47,000 are being irrigated. (See table on p. 69.) The water supply for these lands is largely pumped from Mud Lake and from adjacent lakes and sloughs and from shallow wells.

The net consumptive use on these lands has been estimated at 1.6 acre-feet per acre. Return flow is believed to be tributary to the ground-water body which sustains the Thousand Springs and other ground-water discharge in and near Hagerman Valley, far to the west.

LITTLE LOST RIVER

The Little Lost River basin is an intermontane valley between the Lemhi and Lost River Range and is just west of Birch Creek. The river flows southward from these mountains and sinks into the north margin of the permeable Snake River Plain.

Settlement of the valley began about 1880; irrigation was introduced gradually until slightly over 11,000 acres were being irrigated by about 1910. Very little change in irrigated area has taken place subsequently except during extremely dry years when the available water has been insufficient for all lands. The irrigated area shown in the table on page 69 is mainly devoted to hay and forage crops and depends almost wholly upon the natural flow of the streams because there is no satisfactory storage of surplus water.

Net consumptive use for the lands of the Little Lost River basin has been estimated at 1.3 acre-feet per acre. Return flow has been assumed to be captured by the Snake River near Hagerman, far to the west.

BIG LOST RIVER

The Big Lost River drains about 2,000 square miles of central Idaho, between the Salmon and Snake Rivers. It heads in the Lost River Range and Sawtooth Mountains and flows southward to the margin of the Snake River Plain. Then it swings to the east and northeast and gradually "sinks" into the gravel-lined channel through which it flows.

As in adjacent basins, the agricultural lands are in the valleys near the mountains and are devoted largely to hay and other forage crops. Settlement began quite early, and by 1911 approximately 40,000 acres were being irrigated (see table on p. 69). Mackay Dam was constructed in 1916 and the reservoir now affords about 38,000 acre-feet of storage space. It was contemplated that this reservoir would be raised to a higher elevation but excessive leakage prevented this. By 1923 the irrigated area had increased to 50,000 acres, but during ensuing years of low runoff some lands could not be supplied with water.

The storage unit and water rights of the Utah Construction Co. were purchased by the Big Lost River Irrigation District prior to 1937. Thereafter the water previously applied to lands of the Carey Act project was used to supplement supplies available for the irrigation district lands. Currently about 42,000 acres, between Mackay Reservoir and Arco, are being irrigated.

Net consumptive use has been estimated to be 1.3 acre-feet per acre. Return flow is assumed, like that of the Mud Lake area and the Little Lost River, to be captured by the Snake River just above King Hill.

BIG WOOD RIVER

The Big Wood River heads in the southern slopes of the Sawtooth Mountains of central Idaho and flows generally south and west to its confluence with the Snake River near Hagerman. Below Henrys Fork, it is the first major tributary to join the Snake River from the north. Its basin is timbered in the upper reaches, but in the lower reaches sage and cactus are the native vegetation.

The agricultural lands are in the upper valleys of the Big Wood River and on the Snake River Plain. Hay and forage crops are dominate, although some diversified farming is practiced in the lower reaches.

Most of the irrigation projects in the Big Wood River basin were under the Carey Act but as such did not have the early rapid growth which characterized the areas further upstream. The water supply was plentiful in early years and overexpansion took place. This reached a climax about 1920-21, when approximately 117,000 acres were irrigated (see table on p. 69). The succession of dry years that followed 1921 showed the necessity of abandoning part of the acreage or developing a new source of water. To alleviate this condition, the Bureau of Reclamation in 1931 constructed the Milner-Gooding Canal, which diverts water from the Snake River at Milner, 75 miles to the southeast. This canal currently supplies water to 49,000 acres, of which 32,000 acres formerly were supplied from the Big Wood River.

The main irrigated areas extend from Ketchum to and below Bellevue, and center around Carey, Shoshone, Gooding, and Richfield. There is also some irrigated lands above Magic Reservoir in the Camas Creek basin and in the Fish Creek basin. This scattering of irrigated areas is due in part to excessively permeable soils which cover some portions of the sub-basin, and which cause excessive losses to ground water.

Net consumptive use for the lands of the Big Wood River basin has been estimated at 1.7 acre-feet per acre. Return flow has been assumed to reach the Snake River above King Hill, possibly via Malad Springs in whole or in part.

Irrigated area in acres for indicated years

Year	Mud Lake basin	Little Lost River basin	Big Lost River above Mackay Reservoir, Idaho	Big Lost River basin	Big Wood River basin*
1880	10	50	130	130	....
1890	2,300	1,540	1,790	1,790	14,810
1900	9,200	4,920	5,100	20,500	40,200
1905	12,200	6,100	5,500	25,500	52,800
1910	13,300	7,900	8,300	38,300	71,400
1915	15,000	9,000	8,500	37,500	90,400
1920	26,200	11,400	8,000	42,000	115,100
1921	27,400	11,600	9,000	48,200	117,000
1922	27,700	11,800	10,000	49,700	111,300
1923	28,900	11,900	10,000	50,200	113,200
1924	24,900	9,200	8,500	43,800	103,400
1925	27,600	11,900	9,500	48,500	111,900
1926	24,800	9,400	8,700	44,000	108,700
1927	29,300	11,900	9,500	46,500	113,300
1928	29,900	11,900	9,500	47,300	110,800
1929	29,300	11,900	9,500	47,300	106,000
1930	29,600	11,900	9,200	47,100	101,300
1931	24,000	8,500	8,000	39,000	74,500
1932	28,000	11,900	8,500	43,500	79,200
1933	30,000	11,900	8,700	45,500	82,200
1934	25,000	8,000	7,000	33,000	73,800
1935	31,000	11,000	8,000	45,800	77,700
1936	34,000	11,900	9,000	43,000	81,900
1937	37,700	11,900	9,000	42,000	83,700
1938	39,200	11,900	9,000	42,000	82,900
1939	40,700	11,900	9,000	42,000	82,800
1940	41,500	11,900	9,000	42,000	83,100
1941	42,000	11,900	9,000	42,000	83,100
1942	42,500	11,900	9,000	42,000	82,100
1943	42,700	11,900	9,000	42,000	85,100
1944	43,000	11,900	9,000	42,000	88,100
1945	43,200	11,900	9,000	42,000	88,600
1946	43,200	11,900	9,000	42,000	88,800

* Beginning in 1931, a portion of lands formerly irrigated from Big Wood River was irrigated thereafter from Snake River through the Milner-Gooding Canal.

SNAKE RIVER AT KING HILL, IDAHO

This is the first gaging station on the Snake River downstream from Heise for which an estimate depletion and yield would not be complicated by unmeasured flow bypassing the gaging station. The irrigated area shown in the following table is an accumulation of all irrigated area above this point. Likewise the estimated depletion is the summation of the depletion in each of the sub-basins above here. The estimated average depletion, during the period 1921 through 1945 represents 25.4 percent of the yield of the basin. Owing to the increase in irrigated area, the estimated depletion has gradually been increasing, and by 1946 it represented 27.7 percent of the long-term yield. The depletion due to irrigation between Heise and King Hill during the same period of time, represents 48.7 percent of the estimated yield of this subdivision. The estimated depletion for 1947 represents 53 percent of the long term yield of this subdivision.

Irrigated area, annual runoff, and estimated depletion for Snake River at King Hill, Idaho

Year	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1870	280	....	450
1880	7,760	....	13,000
1890	117,710	....	176,000
1900	432,140	....	660,000
1905	581,100	....	878,000
1910	899,740	9,370,000	1,403,000
1911	....	8,940,000	....
1912	....	9,840,000	....
1913	....	10,400,000	....
1914	....	9,690,000	....
1915	1,177,500	7,420,000	1,886,000
1916	....	8,990,000	....
1917	....	11,000,000	....
1918	....	9,610,000	....
1919	....	7,770,000	....
1920	1,397,320	7,100,000	2,258,000
1921	1,432,420	9,470,000	2,280,000
1922	1,435,870	8,650,000	2,320,000
1923	1,441,530	7,970,000	2,329,000
1924	1,382,800	6,850,000	2,242,000
1925	1,440,400	8,260,000	2,326,000
1926	1,389,000	7,240,000	2,248,000
1927	1,445,900	7,120,000	2,336,000
1928	1,445,200	9,440,000	2,334,000
1929	1,448,100	7,540,000	2,339,000
1930	1,438,100	6,690,000	2,322,000
1931	1,380,500	5,880,000	2,246,000
1932	1,449,600	5,660,000	2,348,000
1933	1,457,500	5,820,000	2,360,000
1934	1,361,200	5,411,000	2,219,000
1935	1,458,400	5,070,000	2,363,000
1936	1,483,200	6,209,000	2,403,000
1937	1,497,500	5,874,000	2,354,000
1938	1,505,900	7,233,000	2,440,000
1939	1,515,400	6,663,000	2,456,000
1940	1,517,500	5,687,000	2,459,000
1941	1,525,400	5,646,000	2,473,000
1942	1,542,100	6,434,000	2,502,000
1943	1,568,700	9,002,000	2,548,000
1944	1,576,700	7,592,000	2,561,000
1945	1,579,200	6,963,000	2,565,000
1946	1,588,480	8,684,000	2,581,000

SNAKE RIVER, KING HILL TO MOUTH

BRUNEAU RIVER

The Bruneau River heads in the Copper Mountains of northern Nevada and drains about 3,200 square miles in that state and in southern Idaho. The terrain is moderately rugged and there is little agricultural enterprise other than stock raising. The small irrigated area in this basin, 39,000 acres is in scattered tracts along the main river and tributaries. (See the following table.) Except for that adjacent to the Snake River most of the irrigated area is hay and forage crops.

The Grandview Irrigation District currently irrigates 5,400 acres and is the largest single block of irrigated land in the basin. This tract is south of the Snake River downstream from the confluence of the Bruneau River; it uses water from both rivers. The net consumptive use has been estimated to be 1.8 acre-feet per acre. Return flow has been assumed to be recaptured by the Snake River above the gaging station near Murphy.

Irrigated area and estimated depletion for Bruneau River basin

Year	Bruneau River near Hot Spring, Idaho	Bruneau River basin	
	Irrigated area (acres)	Irrigated area (acres)	Estimated depletion (acre-feet)
1870	....	18	30
1880	....	460	830
1890	2,600	4,590	8,260
1900	4,700	8,660	15,590
1905	4,900	10,870	19,570
1910	5,220	14,430	25,970
1915	5,870	19,410	39,940
1920	6,100	19,810	35,660
1921	6,290	20,000	36,000
1922	6,470	20,690	37,240
1923	6,650	20,380	36,680
1924	6,830	20,580	37,040
1925	7,020	20,780	37,400
1926	7,200	19,970	35,950
1927	7,380	20,610	37,100
1928	7,560	20,810	37,460
1929	7,740	20,460	36,830
1930	7,820	21,040	37,870
1931	7,890	21,130	38,030
1932	7,960	21,220	38,200
1933	8,040	21,280	38,300
1934	8,110	21,360	38,450
1935	8,180	21,440	38,590
1936	8,260	21,530	38,750
1937	8,330	21,700	39,060
1938	8,410	21,790	39,220
1939	8,480	21,860	39,350
1940	8,480	21,860	39,350
1941	8,480	21,860	39,350
1942	8,480	21,860	39,350
1943	8,480	21,860	39,350
1944	8,480	21,860	39,350
1945	8,480	21,860	39,350
1946	8,480	21,860	39,350

SNAKE RIVER, KING HILL TO MURPHY

In addition to the area irrigated from Bruneau River there are about 17,000 irrigated acres within this subdivision. The miscellaneous creeks furnish most of the water for these lands. The area near Mountain Home is an exception. It receives part of its water supply from the South Fork Boise River drainage via a canal from Little Camas Reservoir to Long Tom Reservoir. This area was developed by private enterprise starting about 1895, was consolidated in 1925 to the Mountain Home Irrigation District, and includes about 5,000 acres. However, only about 4,400 acres are currently being irrigated. These lands and the resulting streamflow depletions are included in this subdivision rather than under the Boise River basin. With the intermingling of water from two sources it becomes very difficult to segregate the acreage on the basis of the source of the irrigation water. Consequently in most cases the irrigated area and the estimated depletion of streamflow have been tabulated according to the geographic location, with cross-references to properly identify the areas involved.

The net consumptive use for all irrigated land in this subdivision was taken at 2.0 acre-feet per acre. Return flow from this area is assumed to be captured by the Snake River above the gaging station near Murphy.

The average streamflow depletion above the gaging station (see the following table) during the period 1921 through 1945 represents 25.5 percent of the yield of the basin. The irrigated area has been increasing slightly during the period and the estimated depletion for 1946 amounts to 27 percent of the long-term yield. In the subdivision between King Hill and Murphy the average depletion for the period 1921 through 1945 represents 18.2 percent of the yield of this subdivision, and it has remained essentially constant during the base period.

Irrigated area, annual runoff, and estimated depletion for Snake River near Murphy, Idaho

Year	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1870	1,000	....	1,890
1880	12,280	....	21,930
1890	129,470	....	198,600
1900	451,400	....	696,790
1905	602,800	....	919,220
1910	926,520	....	1,453,700
1914	....	10,400,000	....
1915	1,216,100	7,630,000	1,959,400
1916	....	9,340,000	....
1917	....	11,400,000	....
1918	....	9,900,000	....
1919	....	7,950,000	....
1920	1,439,700	7,360,000	2,338,900
1921	1,475,100	9,970,000	2,361,400
1922	1,478,900	9,020,000	2,401,800
1923	1,483,900	8,250,000	2,409,700
1924	1,425,300	7,090,000	2,322,900
1925	1,481,900	8,630,000	2,404,850
1926	1,429,100	7,480,000	2,324,200
1927	1,486,300	7,430,000	2,412,600
1928	1,485,800	9,760,000	2,411,000
1929	1,488,300	7,790,000	2,415,400
1930	1,478,400	6,940,000	2,398,500
1931	1,420,700	6,110,000	2,322,110
1932	1,490,200	6,120,000	2,424,900
1933	1,497,600	6,020,000	2,436,000
1934	1,401,000	5,523,000	2,294,300
1935	1,497,700	5,337,000	2,437,200
1936	1,522,200	6,682,000	2,476,700
1937	1,536,900	6,105,000	2,428,400
1938	1,545,900	7,690,000	2,515,600
1939	1,555,500	6,979,000	2,531,700
1940	1,557,600	5,988,000	2,534,700
1941	1,565,400	5,910,000	2,548,700
1942	1,581,700	6,870,000	2,576,800
1943	1,608,400	9,788,000	2,623,100
1944	1,615,800	8,051,000	2,634,800
1945	1,618,200	7,452,000	2,638,700
1946	1,627,400	9,043,000	2,654,600

OWYHEE RIVER

The Owyhee River is the principal tributary of the Snake River from the south, and drains about 12,000 square miles. It heads in the mountains of northern Nevada and flows generally northwest and north across southwestern Idaho and southeastern Oregon to its confluence with the Snake River just upstream from the Boise River. The drainage area is primarily rough to rolling terrain, and has a native cover almost exclusively of sagebrush.

The irrigated lands are located in three general areas -- the Western Shoshone Indian Reservation in Nevada, the valley of Jordan Creek in Idaho and Oregon, and the Owyhee Project in Oregon. Other irrigated areas are scattered throughout the basin.

Above Owyhee Reservoir stock raising is the principal agricultural enterprise and most of the irrigated land is in hay or forage crops. In contrast, the area below Owyhee Dam is primarily devoted to row and specialty crops.

In large part the irrigated lands in the upper basin are within the Shoshone Indian Reservation; these have been irrigated gradually by the Bureau of Indian Affairs. Wild Horse Reservoir in Nevada, on the South Fork Owyhee River, was completed in 1937 and furnishes water for about 9,200 acres of land in the Western Shoshone Indian Reservation. This reservoir has an active capacity of 32,000 acre-feet. Other irrigated tracts in this portion of the basin are scattered along the South Fork and East Fork of the Owyhee River.

The Jordan Valley Irrigation District was formed in 1926 by consolidating some of the old water rights of that valley in Oregon. Antelope Reservoir, an off-stream storage development, supplies water for the 8,000 acres in this district. In addition, about 18,000 acres of irrigated land within the Jordan Creek basin is irrigated from natural streamflow.

The largest and most productive block of irrigated land is located below Owyhee Dam and comprises about 105,000 acres in eight operating divisions. Of this about 32,000 to 33,000 acres are estimated to be within the natural drainage basin of the Malheur River. Earlier projects irrigated by the Owyhee Canal, Gem Irrigation District, Shoestring Ditch, Kingman Colony Irrigation Co. and the Riverview Irrigation System have been integrated into the Owyhee Project or are being supplied with supplemental water by it. Of these only the Owyhee Canal originally diverted water from Owyhee River; the others pumped their water from the Snake River. The Gem Irrigation District is designed to utilize water from either the Snake or the Owyhee Rivers, and since 1937 has drawn from both those sources. In this district the water from Owyhee Reservoir has been used to irrigate new lands while that pumped from the Snake River has served the old lands.

The irrigated areas shown in the following table are based upon adjudicated rights, Water-Supply Paper 657, and reports and records of Bureau of Census, Bureau of Reclamation, irrigation districts, and irrigation companies. Data from these several sources were adjusted to common values, which are believed to be reasonably dependable.

Net consumptive use values of 1.2 and 1.9 acre-feet per acre were used for lands above and below Owyhee Reservoir, respectively. Return flow from all lands in Nevada was assumed to reach the East Fork or South Fork within that State; that from lands in Jordan Creek valley and above Owyhee Reservoir, to be recaptured above the gaging stations in those two subdivisions. Return flow from the lands served by the Owyhee project was assumed to be captured by the Snake River above the gaging station at Weiser. The average streamflow depletion for the portion of the sub-basin above Owyhee Reservoir during the period 1931 through 1946 amounts to 13 percent of the yield of the basin. The irrigated area below Owyhee Reservoir has been expanding rapidly during the period and consequently the average depletion over the period would have little meaning. The average depletion for 1945-46 for the entire basin amounts to 27 percent of the long-term yield of the gaging station above Owyhee Reservoir.

Irrigated area, annual runoff, and estimated depletion in Owyhee River basin

Year	Owyhee River in Nevada	Jordan Creek, Oreg.	Owyhee River above Owyhee Reservoir, Oreg.			Owyhee River at mouth	
	Irrigated area (acres)	Irrigated area (acres)	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)	Irrigated area (acres)	Estimated depletion (acre-feet)
1870	...	...	889	...	1,070	889	1,070
1880	400	...	5,058	...	6,070	5,058	6,070
1890	4,100	...	15,164	...	18,200	16,124	20,000
1900	7,900	160	22,069	...	26,480	27,119	36,100
1905	14,200	500	32,193	...	38,630	39,193	51,930
1910	23,600	850	44,802	...	53,760	53,802	70,900
1915	33,000	1,210	58,400	...	70,080	69,399	91,000
1920	39,800	1,540	71,306	...	85,570	84,806	111,200
1921	39,100	1,600	71,204	...	85,440	84,704	111,100
1922	38,400	1,650	71,052	...	85,260	84,552	110,900
1923	37,800	1,710	71,409	...	85,690	84,909	111,300
1924	37,100	1,760	71,165	...	85,400	84,665	111,000
1925	36,400	1,820	70,821	...	84,980	84,321	110,600
1926	35,700	1,860	70,322	...	84,400	83,822	110,000
1927	35,000	1,900	69,708	...	83,650	83,208	109,300
1928	34,300	1,930	69,163	...	83,000	82,663	108,600
1929	33,640	1,970	68,589	...	82,310	82,090	108,000
1930	35,900	2,010	71,008	...	85,210	84,508	110,860
1931	38,100	2,020	73,266	153,000	87,920	86,766	113,600
1932	40,300	2,030	75,512	827,150	91,090	89,012	116,700
1933	42,500	2,050	77,856	379,000	93,430	91,356	119,100
1934	44,800	2,060	80,262	167,000	96,310	93,762	122,000
1935	47,000	2,070	82,502	793,000	99,000	101,177	134,500

1936	47,200	2,080	82,886	912,400	99,460	104,879	141,200
1937	47,400	2,090	83,116	471,200	99,740	124,414	178,200
1938	47,600	2,100	83,336	939,600	100,000	147,375	221,700
1939	47,700	2,100	83,649	566,300	100,380	157,218	240,200
1940	47,800	2,100	83,995	430,200	100,800	164,752	254,300
1941	47,900	2,100	84,101	605,100	100,900	168,121	260,500
1942	48,000	2,100	84,232	871,600	101,100	171,389	266,700
1943	48,100	2,100	84,332	1,107,000	101,200	173,601	270,800
1944	48,200	2,100	84,657	415,500	101,600	175,283	273,800
1945	48,300	2,100	84,846	926,300	101,800	176,382	275,700
1946	48,400	2,100	85,181	858,300	102,200	176,147	275,000

BOISE RIVER

The Boise River rises in the Sawtooth Mountains of central Idaho and flows generally westward to its confluence with the Snake River near Parma. It drains about 4,100 square miles of which only about 30 percent are below an altitude of 5,000 feet. Its mountainous area is generally forest covered and fairly rugged. The lower valley contains a highly developed block of irrigated land extending from Boise west and southwest to the Snake River.

Some of the earliest water rights in the Snake River basin are in the Boise valley. According to the "Steward Decree" these extend back to 1864. Early development was by private enterprise, but recent development has been primarily sponsored by the Bureau of Reclamation, which started work in this basin in 1905 and up to the present has continued to assist in irrigation development. The Arrowrock division of the Boise Project furnishes full or supplemental water supplies for most of the irrigated lands in the basin. (See tables on pp. 80 and 81.)

The acreage irrigated in the headwater and tributary basins of the Boise River was computed from data in court decrees, State water licenses, and census reports. The Boise River watermaster has very complete reports for the main valley for each year, beginning about 1915; extensive use was made of these reports and of reports by the U. S. Bureau of Reclamation. Accurate figures were available from surveys relating to litigation in 1903 and the census of 1902. Reliable data for several of the larger irrigation ditches for 1911 and 1912 were obtained from reports of the State Engineer. Reports of the U. S. Bureau of Reclamation list acreages for others for each year back to 1906. The relation between actual irrigated area and decreed water rights for the ditches with accurate records, was applied to the rest of the more than 50 ditches, estimates of irrigated area were made that are believed to be reliable for the years since about 1902.

The amount of land irrigated prior to 1902 is subject to considerable doubt. All water rights are known from State records, and the earliest dates from 1865. At first it was possible to establish a water right as soon as one-eighth of the land was in cultivation. Many ditch companies were slow to cultivate all the land for which they had water rights. Thus it was impossible to derive reliable estimates of irrigated area from data on water-right decrees. Reports of the State Engineer gave estimates of irrigated acreage for 1896 and 1900. Acreages for all intervening periods were obtained by interpolation. In the lower valley the system of canals, lateral and drains is so complex that only the total acreage has any significance.

Considerable information on the principal Boise River canals is given in Water-Supply Paper 657, and on all canals in the annual reports of the watermaster for the Boise River. The tabulated figures for the Boise River include a small acreage in Oregon lying east of the Snake River opposite Adrian, Oreg., and irrigated from the Boise River.

Water is diverted from the South Fork Boise River for irrigation of land near Mountain Home, which was previously described. This irrigated area and the resulting depletion was not included in the totals for Boise River.

Diversified crops are generally grown throughout the basin at present, although in early days most of the irrigated land was devoted to grain and forage and hay crops. Considerable land in the lower areas are waterlogged and drainage has become a major problem locally.

The net consumptive use was taken as 1.0 and 2.2 acre-feet per acre for the upper and lower portions of the Boise River basin respectively. The value for the lower basin was based upon the inflow-outflow studies by Steward and Paul on the Pioneer and Nampa-Meridian Irrigation Districts in 1917. The return flow is recaptured by the Boise and Snake Rivers and is included in the flow passing the gaging station on Snake River at Weiser. In some parts of the lower valley the return flow from upstream areas is reused during the late summer. The average depletion in the upper basin is negligible. The average depletion for entire basin for the period 1921 through 1945 represents 28.6 percent of the yield of the Boise River basin above Dowling Ranch plus Moore Creek. The depletion has been increasing slightly during recent years and for 1946 it was 29.3 percent of the long-term yield.

Irrigated area, annual runoff and estimated depletion in the upper Boise River basin

Year	South Fork Boise River near Featherville, Idaho	South Fork Boise River at Anderson Ranch Dam, Idaho	Boise River at Dowling Ranch near Arrowrock, Idaho		
	Irrigated area (acres)	Irrigated area (acres)	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1890	...	170	170	...	170
1900	110	650	960	...	960
1905	160	630	1,760	...	1,760
1910	170	650	2,520	...	2,520
1912	...	...	...	2,080,000	...
1913	...	...	...	1,790,000	...
1914	...	...	...	1,890,000	...
1915	250	810	3,100	1,040,000	3,100
1916	...	...	...	2,190,000	...
1917	...	...	...	2,070,000	...
1918	...	...	...	1,740,000	...
1919	...	...	...	1,470,000	...
1920	490	1,320	3,710	1,360,000	3,710
1921	550	1,440	3,790	2,500,000	3,790
1922	600	1,540	3,860	2,070,000	3,860
1923	650	1,640	3,930	1,560,000	3,930
1924	700	1,740	4,000	827,000	4,000
1925	740	1,840	4,070	2,040,000	4,070
1926	750	1,840	4,040	999,000	4,040
1927	750	1,840	4,020	2,270,000	4,020
1928	750	1,850	3,990	2,120,000	3,990
1929	750	1,850	3,960	1,190,000	3,960
1930	750	1,850	3,930	1,200,000	3,930
1931	750	1,850	3,930	861,000	3,930
1932	750	1,850	3,930	1,700,000	3,930
1933	750	1,850	3,930	1,430,000	3,930
1934	750	1,850	3,930	962,500	3,930
1935	750	1,850	3,930	1,408,000	3,930
1936	750	1,850	3,930	1,737,000	3,930
1937	750	1,850	3,930	1,015,000	3,930
1938	750	1,850	3,930	2,254,000	3,930
1939	750	1,850	3,930	1,226,000	3,930
1940	750	1,850	3,930	1,386,000	3,930
1941	750	1,850	3,930	1,261,000	3,930
1942	750	1,850	3,930	1,499,000	3,930
1943	750	1,850	3,930	3,006,000	3,930
1944	750	1,850	3,930	1,198,000	3,930
1945	750	1,850	3,930	1,449,000	3,930
1946	750	1,850	3,930	2,025,000	3,930

Irrigated area and estimated depletion in the Boise River basin

Year	Moore Creek near Arrowrock, Idaho	Boise River basin	
	Irrigated area (acres)	Irrigated area (acres)	Estimated depletion (acre-feet)
1870	....	6,000	13,200
1880	....	16,000	35,200
1890	....	26,000	57,200
1900	40	56,000	122,000
1905	150	122,590	267,320
1910	290	173,435	378,180
1915	510	255,384	557,510
1920	680	295,776	645,440
1921	690	295,979	645,780
1922	700	295,143	643,840
1923	700	295,314	644,130
1924	710	305,142	665,660
1925	720	304,934	665,110
1926	720	319,870	698,000
1927	730	329,808	719,880
1928	740	330,774	722,030
1929	750	334,684	730,650
1930	750	337,122	736,050
1931	760	337,494	736,860
1932	770	329,472	719,200
1933	780	337,380	736,580
1934	790	329,232	718,650
1935	800	328,127	716,200
1936	800	329,265	718,710
1937	810	332,199	725,150
1938	820	331,154	722,840
1939	830	331,497	723,580
1940	840	337,166	736,040
1941	850	334,088	729,260
1942	860	333,615	728,210
1943	870	331,122	722,710
1944	890	335,610	732,560
1945	900	335,081	731,380
1946	910	334,329	729,720

MALHEUR RIVER

The Malheur River rises in Strawberry Mountain of eastern Oregon and flows eastward to its confluence with the Snake River near Ontario, Oreg. It has a drainage area of about 4,700 square miles, of which the higher parts are sparsely covered by coniferous trees, and the lower parts originally were covered by desert vegetation.

The Malheur River valley was known to the early explorers and fur traders and is reputed to have been named by Peter Skene Ogden, a Hudson's Bay Co. trader. Early settlers who were headed for the Oregon coast, sometimes traversed it via Bend to Salem and Portland. It was natural that some of the earliest pioneers settled in this broad valley and took up farming, raising stock and

279538 O - 53 - 7

forage crops, which were the most profitable ventures of the day. With increase in population specialty crops and orchards have become the important products of the region.

Most of the early irrigation projects were financed by private interests and some of the early canals have rights dating back to 1881-1885. These canals include the McLaughlin, Nevada, Linebarger, Gellerman and Froman, Farmer, J. H., Canyon and Sand Hollow, Mill, Vines, and Brosman. The possibilities of expanding irrigation in this valley have been investigated on several occasions by Federal and State agencies, most intensively in 1903-1905, 1914 and 1927. During the early investigations an association of water users was formed by some of the irrigators in the valley but satisfactory arrangements could not be reached between this association and the Reclamation Service.

Following the investigations of 1914, the Warmsprings Irrigation District was formed, by consolidating some of the existing irrigation units. This district constructed the Warm Springs Reservoir in 1919 to a capacity of 170,000 acre-feet. In 1930 the capacity was increased to 190,000 acre-feet and half of this was sold to the Bureau of Reclamation to serve the Vale project. In return the Bureau of Reclamation constructed a series of drain ditches throughout the lands of the Warmsprings Irrigation District to reclaim some lands which had been abandoned because of waterlogging. Later, in 1935, the Bureau built the Agency Valley Reservoir on the North Fork Malheur River for use of the Vale project. The Vale project is currently serving about 31,000 acres and the Warmsprings Irrigation District about 18,000 acres.

The Willow Creek No. 3 dam was constructed in 1910-11 by the Willow River Land and Irrigation Co. as a part of the Brogan project. The promoters expected to irrigate a large area around and below the town of Brogan in the lower valley of Willow Creek, and the reservoir was constructed with a capacity of 50,800 acre-feet as the major storage supply for the project lands. Discharge records for Willow Creek were not available at the time, except for a part of the flood of 1910. This record was extremely misleading as it covered a period during one of the greatest floods in the stream's history. The reservoir has never filled. An irrigation distribution system was constructed to serve about 25,000 acres, a large part of the land was sold to prospective settlers, and scattered tracts were irrigated. However after much litigation the project was reduced to about 3,000 acres, for which the water supply is still inadequate.

The remainder of the irrigated area shown in the following table is scattered throughout the basin, primarily in connection with ranches on the upper tributaries.

The net consumptive use for this basin has been estimated to be 1.0 acre-foot per acre for the South Fork and main stem, 1.6 acre-feet per acre for the North Fork and the middle reaches of Willow Creek, and 1.9 acre-feet per acre for the lower basin including Bully Creek. The return flow from the lands irrigated above Drewsey all returns to the main stem above the gaging station near that place; there is no irrigation and no additional return flow between this point and the Warmsprings Reservoir.

There is no gaging station in the lower valley that can be used for a depletion evaluation, inasmuch as all stations are complicated by ungaged flow bypassing them.

In addition to the lands irrigated from the Malheur River and tributaries, a large block of land is supplied from the Owyhee River. The return flow from this and from all lands in the lower valley is assumed to be captured by the Snake River above the gaging station at Weiser, Idaho.

Irrigated area and estimated depletion for Malheur River basin

Year	Malheur River below Warm Springs Reservoir, Oreg.	Malheur River basin	
	Irrigated area (acres)	Irrigated area (acres)	Estimated depletion (acre-feet)
1870	....	196	300
1880	46	2,019	3,300
1890	3,573	28,099	46,500
1900	7,191	35,521	56,600
1905	8,156	40,687	64,000
1910	8,905	45,055	70,900
1915	10,205	48,532	75,700
1920	12,137	52,016	80,200
1921	12,153	53,312	82,600
1922	12,283	53,799	83,400
1923	12,284	56,079	87,800
1924	12,284	56,208	88,000
1925	12,284	57,599	90,600
1926	12,284	59,339	93,900
1927	12,284	63,106	100,100
1928	12,284	63,134	100,200
1929	12,363	63,217	100,300
1930	12,456	64,624	102,800
1931	12,501	65,261	103,900
1932	12,501	67,440	108,000
1933	12,501	67,613	108,300
1934	12,501	68,842	110,600
1935	12,501	70,210	113,200
1936	12,561	72,955	118,400
1937	12,561	77,102	126,300
1938	12,561	80,622	133,000
1939	12,561	82,085	135,800
1940	12,561	83,557	138,600
1941	12,561	83,910	139,220
1942	12,561	86,522	144,200
1943	12,561	88,195	147,400
1944	12,583	88,652	148,200
1945	12,583	89,090	149,000
1946	12,743	89,716	150,100

PAYETTE RIVER

The Payette River drains about 3,300 square miles, including some of the high mountainous terrain of central Idaho. Its confluence with the Snake River is near Ontario, Oreg. The upper basin, above Black Canyon Dam, is mountainous and in large part timbered. Most agricultural lands are in the lower basin on the valley floor from Black Canyon Dam westward to the Snake River.

For the upper basin, irrigated acreages were computed from water-right decrees, reports of irrigation districts, and the census reports. In the lower basin most of the irrigation enterprises are cooperative ditch companies, and water is distributed on the basis of shares rather than acreage, thus reliable data was scarce.

Accurate records are available for the Emmett Irrigation District and Black Canyon unit No. 2, both of which divert water at Black Canyon Dam, but for the lands further downstream it was necessary to interpolate on basis of the meager data available. For 1900 the acreage was obtained from the report of the State Engineer, for 1902 from the census report, for 1938 from a report by the Bureau of Reclamation, and for 1939 from the census report. The Geological Survey report "Storage and Power Possibilities, Payette River basin, Idaho" by W. G. Hoyt, dated January, 1927, and later incorporated in Water-Supply Paper No. 657, stated that the irrigated area below Black Canyon Dam was between 80,000 and 85,000 acres. Since most of the field work for that report was done during 1925, it was assumed that the figures applied to that year and 82,000 acres was adopted for this study. The census figure for 1919 appeared to be rather large, so it was assumed that the ratio between actual irrigation and that reported was the same as for the Boise River. This gave a figure consistent with known information.

From George Knowles, engineer and ex-officio watermaster, it was learned that the increase in acreage was gradual between 1902 and 1919, but that later a large amount of land was abandoned because of waterlogging. He reported that construction of drain ditches was started in 1929 and that since about 1940 some 10,000 acres had been returned to irrigation. The above information, the Bureau of Reclamation report of 1938, and the 1939 irrigation census were sufficient to establish accurately the irrigated acreage after 1938. For the intervening years back to 1902 the acreage was interpolated between the few computed values. The second annual report of the U. S. Reclamation Service (1902-03) stated that practically all development had been made during the preceding 10 years. On this basis, the irrigated acreage prior to 1900 was computed back to the beginning in 1865. (See tables on pp. 86, 87.) Over 800,000 acre-feet of storage capacity has been developed in four major reservoirs in the upper basin. These are the Payette Lake, Little Payette Lake, Deadwood, and Cascade Reservoirs. It is ironic that in this, one of the most intensely irrigated areas in the State, records of irrigated acreage should be so fragmentary. Because of the abundance of water, the water rights have never been adjudicated and many users have not bothered to register their water rights.

The net consumptive use for lands in this basin have been estimated at 1.0 acre-feet per acre for those above Black Canyon Dam and at 2.2 acre-feet per acre for all lands below that dam. The return flow is assumed to be recaptured by Payette and Snake Rivers, and all of it passes the gaging station on Snake River at Weiser. The average depletion for the upper basin during the period 1921 through 1945 amounts to 2.1 percent of the yield of the basin as measured at the gaging station near Horseshoe Bend. The streamflow depletion above here has remained essentially constant during the period. The average depletion for the entire basin for the same period, amounts to 10.2 percent of the yield of the basin at the gaging station near Horseshoe Bend. Because additional lands are being irrigated, the depletion has been increasing during recent years and in 1946 amounted to 13.2 percent of the long-term yield.

Irrigated area in upper Payette River basin

Year	South Fork Payette River near Banks, Idaho	Lake Fork below Lake Irrigation District canal, near McCall, Idaho	North Fork Payette R. at Cascade, Idaho	North Fork Payette River near Banks, Idaho*
1890	1,880	....	....	390
1900	2,770	....	3,000	3,700
1905	2,770	....	5,000	6,100
1910	2,770	....	7,600	9,300
1915	2,780	....	10,400	12,700
1920	2,820	....	14,000	17,200
1921	2,830	....	16,200	19,900
1922	2,840	....	18,100	22,200
1923	2,850	....	23,600	28,900
1924	2,870	....	25,900	31,800
1925	2,880	3,000	32,500	39,800
1926	2,880	5,000	35,000	43,000
1927	2,890	5,000	35,300	43,300
1928	2,900	5,500	36,500	44,700
1929	2,900	6,000	38,100	46,700
1930	2,910	6,000	38,100	46,700
1931	2,910	6,000	35,900	44,000
1932	2,910	6,000	35,900	44,000
1933	2,910	6,000	36,600	44,900
1934	2,910	6,000	36,800	45,100
1935	2,910	6,000	37,000	45,400
1936	2,910	6,000	36,000	44,000
1937	2,910	6,000	36,000	44,000
1938	2,910	6,000	36,800	45,100
1939	2,910	6,000	36,820	45,140
1940	2,910	6,000	36,800	45,100
1941	2,910	6,000	36,800	45,100
1942	2,910	6,000	36,800	45,100
1943	2,910	6,000	36,800	45,100
1944	2,910	6,000	37,200	45,700
1945	2,910	6,000	37,200	45,700
1946	2,910	6,000	37,400	45,900

* This figure also represents irrigation above gage on North Fork Payette River near Smiths Ferry, Idaho, (discontinued) and total for North Fork Payette River.

Irrigated area, annual runoff, and estimated depletion for the Payette River basin

Year	Payette River near Horseshoe Bend, Idaho			Payette River at mouth	
	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)	Irrigated area (acres)	Estimated depletion (acre-feet)
1870	40	....	40	1,650	3,090
1880	860	....	860	5,890	9,730
1890	3,140	....	3,140	15,050	25,850
1900	7,380	....	7,380	39,350	72,950
1905	9,830	....	9,830	56,980	107,980
1908	....	2,170,000	....	....	....
1909	....	3,050,000	....	....	....
1910	13,160	3,160,000	13,160	73,180	139,180
1911	....	2,860,000	....	....	....
1912	....	2,540,000	....	....	....
1913	....	2,510,000	....	....	....
1914	....	2,250,000	....	....	....
1915	16,650	1,560,000	16,650	92,010	176,370
1920	21,190	1,840,000	21,190	109,950	210,390
1921	23,900	3,250,000	23,900	113,760	215,520
1922	26,200	2,390,000	26,200	115,270	216,070
1923	32,920	2,110,000	32,920	121,680	222,120
1924	35,840	1,110,000	35,840	123,700	227,240
1925	43,850	2,450,000	43,850	130,910	229,310
1926	47,050	1,290,000	47,050	131,620	227,020
1927	47,360	3,140,000	47,360	130,420	224,020
1928	48,770	2,880,000	48,770	130,330	222,130
1929	50,780	1,440,000	50,780	130,840	220,840
1930	50,780	1,560,000	50,780	129,840	218,640
1931	48,080	1,060,000	48,080	127,160	215,980
1932	48,080	2,290,000	48,080	127,000	215,630
1933	48,980	1,960,000	48,980	128,350	217,520
1934	49,180	1,635,000	49,180	129,050	218,820
1935	49,479	1,654,000	49,479	130,760	222,220
1936	48,090	2,103,000	48,090	129,360	220,800
1937	48,110	1,364,000	48,110	129,690	221,490
1938	49,228	2,859,000	49,228	131,320	223,720
1939	49,280	1,608,000	49,280	133,700	228,880
1940	49,260	2,192,000	49,260	139,190	240,970
1941	49,280	1,938,000	49,280	143,150	249,650
1942	49,300	2,283,000	49,300	148,470	261,320
1943	49,320	3,478,000	49,320	156,040	277,950
1944	49,930	1,465,000	49,930	161,280	288,720
1945	49,950	1,958,000	49,950	164,710	296,140
1946	50,150	2,644,000	50,150	167,610	302,370

WEISER RIVER

The Weiser River is the last downstream tributary entering the right bank of the Snake River before that stream flows through another canyon section. Thus the Weiser River subdivision is the downstream or northernmost segment of the intensively irrigated area in the Snake River basin. It drains about 1,600 square miles. The mountainous part of the basin is generally forested. The valleys and adjacent bench land constitute that portion of the basin which is devoted to agriculture. The irrigated tracts are small, scattered throughout the basin, and were developed by private capital. Very little storage capacity is available in the basin, and many of the projects would benefit from supplemental water late in the growing season. The irrigated lands are concentrated generally in three main areas -- an upper area near Council, near Mesa, and on Hornet Creek; a middle area near Cambridge and Midvale; and a lower area including adjacent benches along the Snake River near Weiser.

In general, the values of irrigated acreage for this subdivision basin were based upon water-right adjudications, reports of irrigation districts, Idaho State Engineer, Bureau of Reclamation, and Bureau of the Census; also on Water-Supply Paper 657. A Bureau of Reclamation report gave substantially higher figures than the 1939 Census and were given more weight in the determination of values for this report. (See tables on pp. 89, 90.)

In this report, the estimated net consumptive use within the Weiser River basin was 1.5 acre-feet per acre for the area above the gaging station on Weiser River above Crane Creek, and 2.0 acre-feet per acre for the area below Crane Creek. The return flow from the area above the gaging station, Weiser River above Crane Creek, was assumed to have been recaptured by the river above that station. That from the area below Crane Creek was assumed, for convenience, to have been intercepted by the Snake River above the gaging station at Weiser. This may not be strictly true because some of the return flow from the irrigated bench lands near Weiser may reach the Snake River below the gage. However its effect on the Snake River flow would be relatively minor. The average streamflow depletion during the period 1922 through 1946 amounts to 5 percent of the yield of the basin above the gaging station Weiser River near Crane Creek. It has remained comparatively constant during the period.

Irrigated area in upper Weiser River basin, Idaho

[Note: No irrigation above gages on Weiser River st Tamarack, Idaho, and Lost Creek near Tamarack, Idaho]

Year	Weiser River at Starkey, Idaho	Weiser River near Council, Idaho	Weiser River near Cambridge, Idaho	Little Weiser River near Indian Valley, Idaho
1880	....	18	18	....
1890	7	1,370	1,570	48
1900	72	3,240	3,610	80
1905	72	4,670	5,170	80
1910	72	6,410	7,100	80
1915	72	7,050	8,080	80
1920	72	7,050	8,400	80
1921	72	7,050	8,460	80
1922	72	7,050	8,510	80
1923	72	7,050	8,570	80
1924	72	7,050	8,630	80
1925	72	7,050	8,690	80
1926	72	7,050	8,750	80
1927	72	7,050	8,810	80
1928	72	7,050	8,870	80
1929	72	7,050	8,920	80
1930	72	7,050	8,980	80
1931	72	7,050	9,040	80
1932	72	7,050	9,100	80
1933	72	7,050	9,160	80
1934	72	7,050	9,220	80
1935	72	7,050	9,220	80
1936	72	7,050	9,220	80
1937	72	7,050	9,220	80
1938	72	7,050	9,220	80
1939	72	7,050	9,220	80
1940	72	7,050	9,220	80
1941	72	7,050	9,220	80
1942	72	7,050	9,220	80
1943	72	7,050	9,220	80
1944	72	7,050	9,220	80
1945	72	7,050	9,220	80
1946	72	7,050	9,220	80

Irrigated area, annual runoff, and estimated depletion for Weiser River basin

Year	Weiser River above Crane Creek near Weiser, Idaho			Weiser River at mouth*	
	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)	Irrigated area (acres)	Estimated depletion (acre-feet)
1870	....	....	....	32	60
1880	480	....	720	1,340	2,440
1890	7,900	....	11,850	12,820	21,690
1900	15,000	....	22,500	23,350	39,200
1905	16,980	....	25,470	27,500	46,510
1910	19,910	....	29,860	34,240	58,520
1915	20,950	....	31,420	37,950	65,420
1920	21,280	....	31,920	41,820	73,000
1921	21,340	....	32,010	40,670	70,670
1922	21,400	794,000	32,100	39,840	68,980
1923	21,460	682,000	32,190	38,900	67,070
1924	21,520	224,000	32,280	38,410	66,060
1925	21,580	790,000	32,370	37,740	64,690
1926	21,630	372,000	32,440	37,100	63,380
1927	21,690	1,060,000	32,540	37,100	63,360
1928	21,750	772,000	32,620	37,570	64,260
1929	21,810	368,000	32,720	38,530	66,160
1930	21,870	284,000	32,800	38,600	66,260
1931	21,930	277,000	32,900	38,650	66,340
1932	21,990	750,000	32,980	38,420	65,840
1933	22,040	566,000	33,060	38,830	66,640
1934	22,100	358,600	33,150	39,250	67,450
1935	22,100	471,600	33,150	39,250	67,450
1936	22,100	585,600	33,150	39,260	67,470
1937	22,100	362,400	33,150	39,260	67,470
1938	22,100	1,097,000	33,150	39,730	68,410
1939	22,100	431,400	33,150	40,180	69,310
1940	22,100	777,100	33,150	40,620	70,190
1941	22,100	727,800	33,150	40,620	70,190
1942	22,100	764,400	33,150	40,620	70,190
1943	22,100	1,005,000	33,150	40,620	70,190
1944	22,100	363,400	33,150	40,620	70,190
1945	22,100	683,000	33,150	40,620	70,190
1946	22,100	838,900	33,150	40,620	70,190

* Irrigation is negligible above station on Crane Creek near Midvale, Idaho.

SNAKE RIVER, MURPHY TO WEISER

In addition to the subdivisions already discussed there are minor tracts of irrigated land supplied with water by small tributaries and by pumping directly from the Snake River.

Data on irrigated area and streamflow depletion for the entire Snake River basin above Weiser, Idaho, are given in the following table. The average streamflow depletion for the period 1921 through 1945 amounts to 24.2 percent of the yield of the basin above this point. In 1946 the estimated depletion had increased to 26.8 percent of the long-term yield. For the subdivision between Murphy and Weiser the average depletion over the base period amounted to 22.7 percent of the yield of this subdivision. In 1946 this had increased to 26.8 percent of the long-term yield.

Irrigated area, annual runoff and estimated depletion for Snake River at Weiser, Idaho

Year	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1870	10,287	....	20,650
1880	43,511	....	80,520
1890	229,383	....	373,480
1900	635,169	....	1,028,500
1905	892,335	....	1,462,130
1910	1,312,724	....	2,184,060
1911	....	15,900,000	....
1912	....	16,800,000	....
1913	....	16,200,000	....
1914	....	16,200,000	....
1915	1,732,750	10,400,000	2,951,250
1916	....	17,100,000	....
1917	....	18,000,000	....
1918	....	14,600,000	....
1919	....	12,200,000	....
1920	2,044,168	10,700,000	3,497,780
1921	2,085,125	18,300,000	3,528,570
1922	2,090,104	15,500,000	3,568,390
1923	2,102,382	12,800,000	3,583,620
1924	2,054,345	8,990,000	3,521,410
1925	2,118,004	14,300,000	3,604,760
1926	2,079,451	10,200,000	3,544,200
1927	2,148,542	15,000,000	3,665,060
1928	2,147,871	16,400,000	3,662,120
1929	2,155,761	10,800,000	3,676,200
1930	2,151,494	9,500,000	3,668,530
1931	2,094,431	7,880,000	3,594,210
1932	2,160,994	11,300,000	3,687,690
1933	2,180,619	9,840,000	3,721,630
1934	2,080,736	7,880,000	3,569,520
1935	2,185,874	8,136,000	3,726,670
1936	2,217,189	11,320,000	3,780,350
1937	2,259,635	8,708,000	3,785,600
1938	2,296,171	14,790,000	3,923,860
1939	2,320,250	10,220,000	3,968,060
1940	2,342,955	10,520,000	4,013,390
1941	2,355,359	10,240,000	4,036,110
1942	2,382,386	12,110,000	4,086,010
1943	2,418,048	19,150,000	4,150,740
1944	2,437,315	10,970,000	4,186,860
1945	2,444,153	12,020,000	4,199,700
1946	2,455,892	15,410,000	4,220,570

BURNT RIVER

The Burnt River rises in the Blue Mountains of eastern Oregon and drains about 1,100 square miles as it flows eastward to its confluence with the Snake River near Huntington. The upper reaches of the basin are covered with timber and the lower reaches are characterized by rolling hills covered with sagebrush and grass. The bottom lands, which are devoted to agriculture, occur in three general areas: near Unity, Bridgeport, and Durkee.

The irrigated area in the Burnt River basin is largely in small scattered tracts along the main stem; however some is along the tributary streams. (See the following table.) The main irrigation tracts are the Durkee Irrigation District and the Burnt River Irrigation District, both of which are below Unity Reservoir. The Burnt River also furnishes a small amount of water for lands within the Malheur River basin, via Eldorado Ditch.

Owing to water shortages that had shown up during years of low flow the Bureau of Reclamation, in 1937, constructed the Unity Reservoir just below the North and South Forks to supply supplemental water for lands already under irrigation. This reservoir has a usable capacity of 25,220 acre-feet.

The net consumptive use for lands within the basin has been estimated at 1.4 acre-feet per acre. The return flow from the lands above Unity Reservoir is assumed to be recaptured by the main stem above the gaging station near Hereford. The return flow from lands below Unity Reservoir probably is recaptured by the Burnt River before it joins the Snake River, on which the next gaging station downstream is at Oxbow, Oreg., nearly 50 miles downstream. Based upon records for the period 1930 through 1946, the average depletion amounts to 19 percent of the yield above the gaging station near Hereford.

Irrigated area, annual runoff, and estimated depletion for Burnt River basin

Year	Burnt River near Hereford, Oreg.			Burnt River at mouth	
	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)	Irrigated area (acres)	Estimated depletion (acre-feet)
1870	79	....	110	1,050	1,470
1880	501	....	700	4,420	6,190
1890	3,549	....	4,970	14,200	19,880
1900	5,256	....	7,360	18,400	25,760
1905	5,699	....	7,980	20,000	28,000
1910	6,499	....	9,100	22,000	30,800
1915	6,848	....	9,590	24,000	33,600
1920	7,706	....	10,790	25,500	35,700
1921	7,978	....	11,170	25,800	36,120
1922	8,270	....	11,580	26,300	36,820
1923	8,550	....	11,970	26,900	37,660
1924	8,639	....	12,090	27,100	37,940
1925	8,639	....	12,090	27,200	38,080
1926	8,639	....	12,090	27,200	38,080
1927	8,639	....	12,090	27,400	38,360
1928	8,639	....	12,090	27,700	38,780
1929	8,639	....	12,090	27,900	39,060
1930	8,639	30,700	12,090	28,100	39,340
1931	8,639	32,400	12,090	28,100	39,340
1932	8,639	66,900	12,090	28,300	39,620
1933	8,659	57,100	12,120	28,400	39,760
1934	8,659	22,460	12,120	28,400	39,760
1935	8,659	34,270	12,120	28,500	39,900
1936	8,659	47,840	12,120	28,500	39,900
1937	8,659	30,770	12,120	28,500	39,900
1938	8,659	68,160	12,120	28,600	40,040
1939	8,659	39,980	12,120	28,600	40,040
1940	8,659	42,160	12,120	28,700	40,180
1941	8,659	52,090	12,120	29,000	40,600
1942	8,659	82,040	12,120	29,200	40,880
1943	8,659	107,100	12,120	29,400	41,160
1944	8,659	34,040	12,120	29,700	41,580
1945	8,659	46,450	12,120	29.700	41,580
1946	8,659	80,450	12,120	29,800	41,720

POWDER RIVER

The Powder River heads in the Blue Mountains of eastern Oregon and flows eastward to a confluence with the Snake River near Robinette, Oreg., at the head of the Grand Canyon of the Snake River. The headwater area is generally mountainous, draining parts of the forested Elkhorn, Blue, and Wallowa Mountains. The lowland is roughly divided into a series of bowl-shaped valleys connected by successive short canyons. The principal lowland is around Baker and Haines; it contains about three-fourths of the irrigated land in all the drainage basin.

The Powder River basin was settled comparatively early and some of its water rights date back to 1863. Most of the irrigation works have been small and privately-financed ventures. Some lands are largely irrigated from subsurface sources. Hay, forage crops, and livestock are the principal agricultural products.

The Thief Valley Reservoir was constructed in 1932 by the Bureau of Reclamation to furnish supplemental water supply to the lands near Keating.

In the Big Creek subdivision there are approximately 3,300 acres that are supplied by water from Catherine Creek, a tributary to the Grande Ronde River.

The areas shown in the following table are based upon adjudicated water rights, and are substantiated by a statement by Mr. Maxwell, the watermaster for Baker County, that the areas are within 5 percent of the actual irrigated area. There are some late-season water shortages during years of low runoff and some lands received inadequate amounts of water in all years.

The net consumptive use for the lands in this basin has been estimated at 1.5 acre-feet per acre. For the purposes of this report, it is assumed that all return flow occurs above the gaging station on Powder River near Robinette.

Based upon the period, 1929 through 1946, the average depletion represents 33 percent of the yield of the basin above Robinette and it has remained essentially constant during this period.

Irrigated area, annual runoff, and estimated depletion for Powder River near Robinette, Oreg.

Year	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1870	8,762	...	13,140
1880	21,564	...	32,350
1890	43,952	...	65,930
1900	65,625	...	98,440
1905	72,239	...	108,400
1910	79,853	...	119,800
1915	87,326	...	131,000
1920	95,022	...	142,500
1921	95,791	...	143,700
1922	96,366	...	144,500
1923	97,397	...	146,100
1924	98,062	...	147,100
1925	98,433	...	147,600
1926	99,006	...	148,500
1927	99,545	...	149,300
1928	100,153	...	150,200
1929	100,763	265,000	151,100
1930	100,903	156,000	151,400
1931	101,661	172,000	152,500
1932	101,871	433,000	152,800
1933	102,220	398,000	153,300
1934	102,485	178,900	153,700
1935	103,034	209,900	154,600
1936	103,420	274,200	155,100
1937	103,548	192,900	155,300
1938	103,785	512,700	155,700
1939	103,929	273,800	155,900
1940	104,655	341,400	157,000
1941	104,809	514,700	157,200
1942	104,898	567,300	157,300
1943	104,969	583,100	157,500
1944	104,999	221,300	157,500
1945	105,164	364,400	157,700
1946	105,622	527,900	158,400

SNAKE RIVER, WEISER TO OXBOW

Other than in the Burnt and Powder River basins previously discussed, there are only minor amounts of irrigated land in this subdivision. The Snake River at Oxbow, Oreg., is below all the large, intensively irrigated areas and the return flow from all irrigated lands above this point has been recaptured by the main-stem river. The average streamflow depletion for the period, 1924 through 1946, represents 25 percent of the yield of the basin above the gaging station at Oxbow. The depletion, as shown in the following table, was increasing during the period of record and in 1946, amounted to 27.5 percent of the long-term yield.

Irrigated area, annual runoff and estimated depletion for Snake River at Oxbow, Oreg.

Year	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1870	20,099	....	35,260
1880	69,534	....	119,110
1890	287,815	....	459,690
1900	719,964	....	1,153,780
1905	985,554	....	1,599,900
1910	1,415,997	....	2,336,650
1915	1,846,336	....	3,119,010
1920	2,167,260	....	3,679,580
1921	2,209,306	....	3,712,020
1922	2,215,390	....	3,753,380
1923	2,229,319	....	3,771,080
1924	2,182,177	9,420,000	3,710,190
1925	2,246,327	15,000,000	3,794,210
1926	2,208,357	10,300,000	3,744,560
1927	2,278,187	15,500,000	3,856,500
1928	2,278,424	17,200,000	3,854,880
1929	2,287,124	11,400,000	3,870,140
1930	2,283,197	9,790,000	3,863,050
1931	2,226,892	8,080,000	3,789,830
1932	2,293,865	11,900,000	3,883,890
1933	2,313,939	10,500,000	3,918,470
1934	2,214,321	8,197,000	3,766,760
1935	2,320,108	8,512,000	3,924,950
1936	2,351,809	11,750,000	3,979,130
1937	2,394,383	9,058,000	3,984,580
1938	2,431,256	15,510,000	4,123,380
1939	2,455,477	10,670,000	4,167,780
1940	2,479,010	10,980,000	4,214,350
1941	2,491,898	11,010,000	4,237,730
1942	2,519,244	13,160,000	4,288,050
1943	2,555,207	19,750,000	4,353,310
1944	2,574,834	11,270,000	4,389,890
1945	2,581,877	12,420,000	4,402,980
1946	2,594,204	15,950,000	4,424,740

PINE CREEK

Pine Creek drains about 280 square miles on the east slope of Wallowa Mountains in eastern Oregon, between the Powder and Imnaha drainage basins. The upper part of the basin is rugged and mountainous but the lower part includes a fairly broad valley.

The irrigated lands (see the following table) have been developed by private enterprise. There are numerous small lakes and reservoirs which are used for storage of irrigation water. Net consumptive use for this basin has been estimated at 1.4 acre-feet per acre. Return flow from these lands has been assumed to reach the Snake River downstream from the gaging station at Oxbow.

Irrigated area for Pine Creek basin

Year	Irrigated area (acres)
1870	75
1880	2,130
1890	8,510
1900	12,600
1905	13,000
1910	14,100
1915	16,353
1920	16,700
1921	16,700
1922	16,700
1923	16,700
1924	16,700
1925	16,900
1926	17,000
1927	17,200
1928	17,600
1929	17,700
1930	17,900
1931	18,300
1932	18,300
1933	18,300
1934	18,300
1935	18,300
1936	18,600
1937	18,700
1938	18,700
1939	18,700
1940	18,700
1941	18,700
1942	18,700
1943	18,700
1944	18,800
1945	19,100
1946	19,100

IMNAHA RIVER

The Imnaha River rises on the northern slope of the Wallowa Mountains in eastern Oregon and flows northeastward to its confluence with the Snake River, a short distance upstream from the mouth of the Salmon River. The drainage area is approximately 900 square miles. The headwater area is rugged and mountainous, and to a large extent is forested. The lower portions of the basin are rolling hills covered with sagebrush and grass. There is very little agricultural land even in the narrow valley bottoms. Forage crops and stock are the chief products.

The irrigated lands are restricted to small tracts scattered throughout the basin. They have been developed by private enterprise and are not consolidated. The Wallowa Improvement District No. 1, in the Grande Ronde River basin, diverts water from Sheep Creek a tributary of the Imnaha River. The lands using this water have not been included in the following table but are included in the table on page 104.

It has been assumed, for the purpose of this report, that all acreage listed in the table below is above the gaging station on the Imnaha River at Imnaha and all return flow is recaptured by the stream above this point. This may not be strictly true, but in view of relatively small amounts involved it is believed that no appreciable error will result from this assumption. The net consumptive use for the acreages listed in the following table has been estimated at 1.2 acre-feet per acre. The average streamflow depletion over the period 1929 through 1946 amounts to 1.5 percent of the yield of the drainage basin and it has been practically constant during the period of record.

Irrigated area, annual runoff and estimated depletion for Imnaha River at Imnaha, Oreg.

Year	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1880	521	....	620
1890	1,480	....	1,780
1900	2,173	....	2,610
1905	2,370	....	2,840
1910	2,556	....	3,070
1915	2,727	....	3,270
1920	3,323	....	3,990
1921	3,639	....	4,370
1922	3,647	....	4,380
1923	3,683	....	4,420
1924	3,707	....	4,450
1925	3,718	....	4,460
1926	3,718	....	4,460
1927	3,718	....	4,460
1928	3,722	....	4,470
1929	3,821	282,000	4,580
1930	3,837	220,000	4,600
1931	3,852	179,000	4,620
1932	3,852	370,000	4,620
1933	3,852	360,000	4,620
1934	3,913	233,000	4,700
1935	3,913	266,800	4,700
1936	3,914	226,600	4,700
1937	3,914	219,200	4,700
1938	3,914	546,100	4,700
1939	3,914	236,900	4,700
1940	3,914	290,600	4,700
1941	3,972	397,000	4,770
1942	3,972	496,600	4,770
1943	3,972	448,700	4,770
1944	3,972	241,600	4,770
1945	4,181	351,400	5,020
1946	4,200	394,600	5,040

SALMON RIVER

The Salmon River heads in the Sawtooth Mountains of central Idaho and flows generally north and west to join the Snake River near the lower end of its spectacular Grand Canyon. The drainage area of about 14,000 square miles, makes the Salmon River the largest of the Snake River tributaries from the standpoint of land drained. Rough, rugged terrain characterizes this tributary basin. There is only a small amount of farm land and not much of that can be irrigated.

Irrigation was started in the Salmon River basin about 1860 in Lemhi County, near Salmon City. There was a steady increase in acreage under irrigation from 1880 to about 1920, after which time expansion has gradually tapered off. The irrigation has mostly been by individuals, irrigation districts, or companies, backed by private capitol and has largely centered in four general areas; near Challis, in the Pahsimeroi Valley, in the Lemhi Valley and along the Little Salmon River near New Meadows. The Challis Irrigation District is a major organization in this area and it irrigates several thousand acres near Challis. Another large organization is the Keating Carey Land Co. which irrigates several thousand acres in the Lemhi Valley. Most of the other land in this tributary basin is irrigated from individually- or cooperatively-owned canals. The amount of irrigated area listed in the three tables following were computed primarily from data on water rights and reports by the State Engineer, Bureau of Reclamation, and Geological Survey.

Very little surface storage has been provided in this basin because the soil in the upper basin is, in general, highly permeable. The permeability factor has limited the amount of land that can be irrigated by a single canal.

A net consumptive use of 1.6 acre-feet per acre has been used for all lands in the Salmon River basin. It is assumed that neither the diversion nor the return flow bypasses any of the several gaging stations listed in the cited tables. The average streamflow depletion in this basin is relatively minor in comparison to its yield. For the area above the gaging station on Salmon River below Yankee Fork near Clayton, it amounts to only 1 percent of long-term yield based on the period 1922 through 1946. Downstream at the gaging station near Challis it amounts to 1.5 percent of the long-term yield based upon the period 1929 through 1946. The average depletion for the period 1921 through 1945 for the basin above the gaging station at White Bird amounts to 2 percent of the yield of the basin above this point.

Irrigated area, annual runoff and estimated depletion for upper Salmon River basin

Year	Salmon River near Obsidian, Idaho	Valley Creek at Stanley, Idaho	Salmon River below Yankee Fork near Clayton, Idaho		
	Irrigated area (acres)	Irrigated area (acres)	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1905	...	90	90	...	140
1910	...	240	440	...	700
1915	30	340	940	...	1,500
1920	510	440	2,500	...	4,000
1921	640	450	2,790	...	4,460
1922	770	470	2,990	...	4,780
1923	860	480	3,140	696,000	5,020
1924	960	490	3,280	437,000	5,250
1925	960	490	3,320	...	5,310
1926	960	500	3,360	444,000	5,380
1927	960	500	3,360	848,000	5,380
1928	960	500	3,360	852,000	5,380
1929	960	500	3,360	498,000	5,380
1930	960	500	3,360	566,000	5,380
1931	960	500	3,360	415,000	5,380
1932	960	500	3,360	675,000	5,380
1933	960	500	3,360	624,000	5,380
1934	1,100	500	3,500	532,300	5,600
1935	1,200	500	3,700	576,500	5,920
1936	1,300	500	3,900	699,900	6,240
1937	1,400	500	4,200	428,800	6,720
1938	1,550	500	4,550	818,200	7,280
1939	1,600	500	4,800	493,900	7,680
1940	1,600	510	5,110	584,700	8,180
1941	1,700	520	5,420	553,300	8,670
1942	1,700	540	5,740	713,700	9,180
1943	1,700	550	5,950	1,139,000	9,520
1944	1,700	560	5,960	610,600	9,540
1945	1,700	570	5,970	571,300	9,550
1946	1,700	590	5,990	753,900	9,580

Irrigated area, annual runoff and estimated depletion for central Salmon River basin

Year	Salmon River near Challis, Idaho			Pahsimeroi River near May, Idaho	North Fork Salmon River at North Fork, Idaho
	Irrigated area (acres)	Annual runoff (acre-feet)	Estimated depletion (acre-feet)	Irrigated area (acres)	Irrigated area (acres)
1880	200	....	300	....	....
1890	3,270	....	5,230	4,290	....
1900	3,500	....	5,600	11,470	290
1905	3,590	....	5,740	12,490	637
1910	4,040	....	6,460	12,490	770
1915	4,930	....	7,890	12,490	820
1920	6,800	....	10,900	12,490	820
1921	7,090	....	11,300	12,490	820
1922	7,290	....	11,700	12,490	820
1923	7,440	....	11,900	12,490	820
1924	7,580	....	12,100	12,490	820
1925	7,620	....	12,200	12,490	820
1926	7,660	....	12,300	12,490	820
1927	7,660	....	12,300	12,490	820
1928	7,660	....	12,300	12,490	820
1929	7,660	768,000	12,300	12,490	820
1930	7,660	878,000	12,300	12,490	820
1931	7,660	619,000	12,300	12,490	820
1932	7,660	1,010,000	12,300	12,490	820
1933	7,660	910,000	12,300	12,490	820
1934	7,800	735,400	12,500	12,490	820
1935	8,000	854,800	12,800	12,490	820
1936	8,200	1,015,000	13,100	12,490	820
1937	8,500	636,900	13,600	12,490	830
1938	8,850	1,218,000	14,200	12,490	830
1939	9,100	738,800	14,600	12,490	830
1940	9,410	854,800	15,100	12,490	840
1941	9,720	835,200	15,600	12,490	840
1942	10,040	1,100,000	16,100	12,490	840
1943	10,250	1,667,000	16,400	12,490	840
1944	10,260	967,800	16,400	12,490	840
1945	10,270	846,200	16,400	12,490	840
1946	10,290	1,092,000	16,500	12,490	840

Irrigated area, annual runoff, and estimated depletion for Salmon River basin

Year	Salmon River near French Creek, Idaho	Little Salmon River basin	Salmon River at White Bird, Idaho		
	Irrigated area (acres)	Irrigated area (acres)	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1870	530	....	530	....	850
1880	5,940	35	5,970	....	9,550
1890	24,810	990	26,000	....	41,600
1900	41,140	3,670	45,510	....	72,800
1905	48,420	4,970	54,750	....	87,600
1910	54,600	6,550	63,240	....	101,200
1911	....	....	....	9,480,000	....
1912	....	....	....	9,260,000	....
1913	....	....	....	9,570,000	....
1914	....	....	....	7,330,000	....
1915	67,380	8,230	78,060	5,690,000	124,900
1916	....	....	....	10,600,000	....
1917	....	....	....	9,320,000	....
......	....	....	....	....	....
1920	80,470	9,900	92,960	6,970,000	148,700
1921	81,700	10,320	94,640	10,800,000	151,400
1922	82,630	10,740	95,990	8,040,000	153,600
1923	83,330	11,160	97,110	7,130,000	155,400
1924	84,080	11,580	98,280	5,030,000	157,200
1925	84,634	12,000	99,250	8,190,000	158,800
1926	84,977	12,280	99,880	4,960,000	159,800
1927	85,301	12,560	100,480	9,110,000	160,800
1928	85,410	12,840	100,880	9,330,000	161,400
1929	85,570	13,120	101,330	5,890,000	162,100
1930	85,740	13,400	101,820	6,190,000	162,900
1931	85,790	13,420	101,930	4,200,000	163,100
1932	85,920	13,440	102,120	7,940,000	163,400
1933	85,930	13,460	102,200	7,410,000	163,500
1934	86,090	13,480	102,440	5,536,000	163,900
1935	86,300	13,500	102,730	5,827,000	164,400
1936	86,520	13,510	103,000	7,106,000	164,800
1937	86,940	13,510	103,480	4,687,000	165,600
1938	87,300	13,520	103,900	8,907,000	166,200
1939	87,570	13,530	104,200	5,857,000	166,700
1940	87,910	13,530	104,560	6,460,000	167,300
1941	88,240	13,530	104,920	6,444,000	167,900
1942	88,580	13,540	105,270	8,786,000	168,400
1943	88,810	13,540	105,520	11,480,000	168,800
1944	88,850	13,550	105,580	6,107,000	168,900
1945	88,880	13,550	105,620	6,576,000	169,000
1946	88,920	13,600	105,720	7,596,000	169,200

GRANDE RONDE RIVER

The Grande Ronde River drains 4,070 square miles, of which most is in northeastern Oregon and only a very small part, near the mouth of the stream, is in southeastern Washington. The stream rises on the eastern slope of the Blue Mountains and flows generally northeastward to its confluence with the Snake River. The upper and lower parts of the basin are mountainous; the agricultural land lies near the center of the basin in the valleys of the Grande Ronde and the Wallowa Rivers.

These two valley areas were irrigated by private enterprise. Some of the adjudicated rights date back into the decade of 1860-70. By 1900 about half of the lands currently irrigated had been developed. In the valley of the Grande Ronde the irrigated land is between Union, Cove, La Grande and Elgin. Poor drainage and a consequent high water table are local problems in this basin. In this report the irrigated acreage (table p. 104) was derived after a field reconnaissance and a study of the water rights by the county agent, the watermaster for Union County, and representatives of the Survey. One of the difficulties in reaching an accurate determination of irrigated area in this valley has been the combination of relatively high precipitation and a high water table. Under these circumstances the amount of land actually irrigated in any year depends to a large extent upon variations in precipitation. Nevertheless water is used consumptively regardless of its source, and so all lands with an active water right have been classified as irrigated. Water is diverted from Catherine Creek, a tributary of the Grande Ronde, for use in the Powder River basin. The land using this water has been included in the table on page 95.

Irrigation in the Wallowa River valley has paralleled, to a large degree, that on the Grande Ronde River valley except that there has been very little increase in acreage of land irrigated during the past 30 years. The irrigated land, some 54,000 acres, as shown in the following table, lies between Wallowa Lake and Wallowa.

Since 1906 the Wallowa Improvement District No. 1 has received a portion of its water supply by diversion from Sheep Creek, a tributary of the Imnaha River. The lands using this water have been included in the following table. About 41,000 acre-feet storage capacity is available in Wallowa Lake.

In addition to these two valleys, a few hundred acres of land are irrigated with water from Joseph Creek. These have been included in the following table for purposes of estimating depletion for the subdivision. A net consumptive use of 1.2 acre-feet per acre was used for the irrigated land in the entire subdivision. For purposes of this report, it was assumed that all diversion and return flow occurs above the gaging station on Grande Ronde River at Rondowa. The average depletion for period 1927 through 1946 amounts to 7.4 percent of the yield of the basin above the gaging station at Rondowa and has changed very slightly over the period of record.

Irrigated area, annual runoff, and estimated depletion for Grande Ronde River basin

Year	Wallowa River basin	Grande Ronde River at Rondowa, Oreg.		
	Irrigated area (acres)	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1870	....	7,260	....	8,710
1880	1,041	14,988	....	18,000
1890	10,402	28,495	....	34,200
1900	30,529	51,316	....	61,600
1905	40,415	65,481	....	78,600
1910	42,831	70,855	....	85,000
1915	44,211	77,066	....	92,500
1920	51,173	84,701	....	101,600
1921	51,376	85,160	....	102,200
1922	51,709	85,720	....	102,900
1923	51,830	86,136	....	103,400
1924	51,987	86,517	....	103,800
1925	52,207	86,993	....	104,400
1926	52,570	87,682	....	105,200
1927	52,698	88,049	1,650,000	105,700
1928	52,871	88,373	2,050,000	106,000
1929	53,035	88,682	1,130,000	106,400
1930	53,389	89,213	977,000	107,100
1931	53,480	89,347	876,000	107,200
1932	53,578	89,501	1,850,000	107,400
1933	53,619	89,697	1,640,000	107,600
1934	53,686	89,816	1,069,000	107,800
1935	53,935	90,168	1,092,000	108,200
1936	54,011	90,950	1,356,000	109,100
1937	54,203	91,762	999,200	110,100
1938	54,318	92,596	1,418,000	111,100
1939	54,378	92,936	1,186,000	111,500
1940	54,501	93,495	1,121,000	112,200
1941	54,606	93,642	1,214,000	112,400
1942	54,669	93,705	1,682,000	112,400
1943	54,727	93,763	2,138,000	112,500
1944	54,769	93,805	925,200	112,600
1945	54,769	94,105	1,323,000	112,900
1946	54,846	94,449	1,800,000	113,300

CLEARWATER RIVER

The Clearwater River rises on the western slope of the Bitterroot Mountains and flows generally west to its confluence with the Snake River at Lewiston, Idaho. Most of the basin is covered with timber and only a very small part of the agricultural land is irrigated. (See the following table.)

There are approximately 3,700 acres of irrigated land within this basin, of which 2,900 acres are within the Lewiston Orchard Irrigation District. The remainder is scattered, principally between Kamiah, Idaho and Clarkston, Wash.

The Lewiston Orchard Irrigation District is located on the bench just east of Lewiston, Idaho. This project was started in 1906 by private capital. However, the Bureau of Reclamation undertook to rehabilitate the system for distribution of water in 1947. The project area is highly subdivided, with the average individual tract being 5 acres. Water supply, which is received from several creeks just east of the project, is delivered in pressure conduits.

The net consumptive use was estimated at 1.5 acre-feet per acre, based upon computations by Lowry-Johnson method. Return flow from these lands is captured by the Snake River above the gaging station near Clarkston.

Irrigated area, and estimated depletion for Clearwater River basin

Year	Clearwater River at Kamiah, Idaho	Clearwater River at mouth	
	Irrigated area (acres)	Irrigated area (acres)	Estimated depletion (acre-feet)
1890	....	550	820
1900	....	1,750	2,620
1905	....	1,860	2,790
1910	19	3,960	5,940
1915	36	3,860	5,790
1920	56	3,860	5,790
1921	60	3,870	5,800
1922	75	3,810	5,720
1923	90	3,760	5,640
1924	100	3,690	5,540
1925	120	3,630	5,440
1926	140	3,570	5,360
1927	150	3,480	5,220
1928	160	3,430	5,140
1929	180	3,410	5,120
1930	200	3,350	5,020
1931	210	3,370	5,060
1932	220	3,380	5,070
1933	240	3,400	5,100
1934	260	3,410	5,120
1935	280	3,450	5,180
1936	300	3,490	5,180
1937	310	3,500	5,250
1938	330	3,550	5,320
1939	340	3,560	5,340
1940	360	3,460	5,190
1941	370	3,470	5,200
1942	380	3,480	5,220
1943	390	3,500	5,250
1944	400	3,510	5,260
1945	410	3,520	5,280
1946	420	3,630	5,440

SNAKE RIVER, OXBOW TO CLARKSTON

There are only minor areas of irrigation between the gaging stations on the Snake River at Oxbow and near Clarkston, other than in the subdivision already discussed. The station near Clarkston is the furthest downstream station on the main stem of the Snake River for which discharge records are available and as such, affords an opportunity to evaluate the aggregate streamflow depletion that can be directly attributed to the irrigation in the Snake River basin. The average depletion during the period 1929 through 1946, amounts to 12.7 percent of the yield of the basin above the gaging station near Clarkston. During this period, the irrigated area has been increasing, and the depletion for 1946 represents 13.7 percent of the long-term yield, 19 percent of the yield during 1931, or 8.8 percent of the yield during 1943. These values indicate the percentage of the yield of the basin, during an average, a low, and a high water year respectively, which is used consumptively by the 1946 stage of irrigation development in the Snake River basin. The irrigated area and estimated depletion above the gaging station Snake River near Clarkston is shown in the following table, and for the Columbia River below the Snake River in the table on page 108.

Irrigated area, annual runoff, and estimated depletion for Snake River near Clarkston, Wash.

Year	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1870	27,964	....	44,920
1880	93,143	....	150,260
1890	352,750	....	550,650
1900	833,254	....	1,313,530
1905	1,123,630	....	1,793,600
1910	1,573,341	....	2,556,200
1915	2,027,583	....	3,373,320
1916	....	46,500,000	....
1917	....	46,300,000	....
1918	....	42,600,000	....
1919	....	28,900,000	....
1920	2,372,260	30,800,000	3,968,310
1921	2,416,834	49,800,000	4,004,540
1922	2,424,859	39,400,000	4,048,840
1923	2,440,359	....	4,068,880
1924	2,394,828	....	4,010,240
1925	2,460,645	....	4,096,760
1926	2,424,107	....	4,049,040
1927	2,495,121	....	4,162,750
1928	2,496,492	....	4,162,550
1929	2,506,227	27,000,000	4,179,340
1930	2,503,463	25,000,000	4,173,950
1931	2,447,814	20,600,000	4,101,550
1932	2,515,129	34,800,000	4,196,100
1933	2,535,473	32,700,000	4,230,960
1934	2,436,248	29,400,000	4,079,900
1935	2,542,671	25,020,000	4,239,000
1936	2,575,719	31,460,000	4,294,850
1937	2,619,679	22,310,000	4,302,330
1938	2,657,810	37,540,000	4,442,740
1939	2,682,664	27,320,000	4,488,020
1940	2,707,010	28,810,000	4,535,740
1941	2,720,486	26,290,000	4,560,020
1942	2,748,265	34,490,000	4,610,870
1943	2,784,576	49,030,000	4,676,670
1944	2,804,425	25,500,000	4,713,570
1945	2,812,346	30,800,000	4,727,760
1946	2,825,256	37,860,000	4,750,310

Irrigated area and estimated depletion for the Columbia River below Snake River

Year	Irrigated area (acres)	Estimated depletion (acre-feet)
1860	2,020	2,300
1870	39,964	59,650
1880	125,143	187,400
1890	457,710	687,440
1900	1,105,557	1,697,650
1905	1,545,186	2,428,280
1910	2,120,073	3,416,360
1915	2,669,905	4,407,350
1920	3,119,274	5,175,730
1921	3,165,788	5,216,600
1922	3,191,684	5,292,480
1923	3,199,184	5,304,260
1924	3,155,214	5,242,150
1925	3,217,787	5,330,980
1926	3,183,197	5,287,060
1927	3,243,963	5,387,770
1928	3,248,298	5,386,790
1929	3,260,008	5,402,740
1930	3,274,716	5,435,310
1931	3,247,198	5,411,510
1932	3,325,323	5,519,080
1933	3,349,275	5,564,110
1934	3,273,397	5,452,560
1935	3,393,571	5,634,690
1936	3,412,248	5,667,220
1937	3,483,958	5,719,480
1938	3,524,225	5,869,910
1939	3,550,475	5,916,100
1940	3,577,995	5,969,720
1941	3,592,327	5,996,100
1942	3,624,328	6,062,350
1943	3,667,951	6,135,050
1944	3,690,618	6,175,550
1945	3,714,320	6,218,140
1946	3,748,046	6,276,290

COLUMBIA RIVER, SNAKE RIVER TO THE DALLES

WALLA WALLA RIVER

The Walla Walla River in southern Washington and northern Oregon, is the first tributary to the Columbia River downstream from the Snake River. It drains 1,760 square miles. The river heads in the northern tip of the Blue Mountains and flows generally westward to its confluence with the Columbia River near Wallula, Wash.

Owing to its advantageous location and terrain, the Walla Walla River valley was traversed by the earliest explorers and settlers, and consequently was settled earlier than most other parts of the Oregon Territory. Marcus Whitman established a mission in this valley in 1836. He diverted water from Doan Creek to irrigate garden crops at the mission and soon interested the Indians in doing likewise.

Irrigation in this basin has been financed by private capital, through small irrigation districts or companies and individual enterprise. The irrigated land is concentrated largely between Walla Walla, Wash. and Freewater, Oreg. and at present totals about 37,000 acres. Of this amount about 22,000 acres are in Washington and 15,000 acres are in Oregon. While most of the area shown in the following table is supplied by direct diversion from small tributaries and branches of the main stream, there is an increasing use of wells and springs for supplemental supply. The average values in the cited table were compiled primarily from adjudicated rights and records of the irrigation districts and companies, supplemented by local inquiry. Mr. W. C. Mason, assistant watermaster for Umatilla County, Oreg., was helpful in supplying data for the Oregon portion of the valley.

The net consumptive use in the Walla Walla valley was estimated at 1.9 acre-feet per acre, based upon computations by the Lowry-Johnson method. Return flow from the irrigated lands was assumed to be complete only at the mouth of the river.

Irrigated area and estimated depletion for Walla Walla River basin

Year	Irrigated area (acres)	Estimated depletion (acre-feet)
1870	1,280	2,430
1880	2,950	5,600
1890	7,170	13,600
1900	12,100	22,990
1905	16,070	30,530
1910	22,370	42,500
1915	29,620	56,280
1920	33,300	63,270
1921	32,960	62,620
1922	32,790	62,300
1923	32,630	62,000
1924	32,510	61,770
1925	32,240	61,260
1926	31,970	60,740
1927	32,130	61,050
1928	31,790	60,400
1929	31,450	59,760
1930	31,850	60,520
1931	32,320	61,410
1932	32,710	61,150
1933	33,190	63,060
1934	33,600	63,840
1935	34,000	64,600
1936	34,350	65,260
1937	34,750	66,020
1938	35,090	66,670
1939	35,500	67,450
1940	35,520	67,490
1941	35,550	67,540
1942	35,690	67,810
1943	35,790	68,000
1944	35,820	68,060
1945	36,470	69,290
1946	36,680	69,690

UMATILLA RIVER

The Umatilla River heads in the Blue Mountains of northeastern Oregon and flows generally westward to its confluence with the Columbia River at Umatilla, Oreg. It drains 2,290 square miles. The upper reaches of this basin are heavily forested, but the middle part is largely rolling plains devoted to dry farming. The irrigated area is located primarily on the lower plains near the mouth of the river.

Irrigation in the Umatilla River basin started about 1860, expanded slowly until shortly after 1900 and at present is about 45,000 acres. In 1905 the Bureau of Reclamation started work on its Umatilla project which comprises two operating divisions -- namely, the East or Hermiston and the West Extension divisions. The project includes 13,000 acres near Umatilla. Storage of flood waters is provided in two reservoirs, Cold Springs and McKay Creek Reservoirs. The Cold Springs Reservoir was built in 1907, with a capacity of 50,000 acre-feet. It is supplied with water from the Umatilla River by means of a feeder canal which diverts water near Echo. The McKay Creek Reservoir was built during 1923-26 on McKay Creek near Pendleton, and has a capacity of 73,660 acre-feet. Besides furnishing water to the Hermiston and West Extension divisions, these reservoirs supply some water to the private irrigation districts below Pendleton.

Nine irrigation districts have been developed by private capital, the Stanfield Irrigation district and the Westland Irrigation District being the two largest. There are also small irrigation developments on Birch and Butter Creeks. There is a small amount of water diverted from upper reaches of the John Day River into Butter Creek. The following table shows the distribution of the irrigated area within the basin. The values shown in this table were compiled largely from records of the Oregon State Engineer and the Bureau of Reclamation: according to Mr. M. B. Bennett, watermaster of Umatilla County, these should be very close to the actual irrigated acreage.

A net consumptive use of 2.0 acre-feet per acre was used for all lands in this basin. Return flow from these lands was estimated to reach the Umatilla River above its confluence with the Columbia. This may be slightly in error because of the irrigated bench lands lying along the Columbia River, but for purpose of this report this small bypass has been disregarded. The average net streamflow depletion for the period 1921 through 1945 amounted to 23.2 percent of the yield of this basin. It has remained essentially constant during this 25-year period.

Irrigated area, annual runoff and estimated depletion for Umatilla River basin

Year	McKay Creek basin	Birch Creek basin	Butter Creek basin	Umatilla River near Umatilla, Oreg.		
	Irrigated area (acres)	Irrigated area (acres)	Irrigated area (acres)	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1860	...	...	...	23	...	50
1870	...	36	1,111	1,226	...	2,450
1880	30	691	2,084	3,785	...	7,570
1890	60	1,365	2,901	5,669	...	11,340
1900	834	2,039	5,150	12,990	...	25,980
1904	...	...	...	...	805,400	...
1905	1,777	2,525	5,475	18,794	208,000	37,590
1906	...	...	...	...	435,000	...
1907	...	...	...	...	619,000	...
1908	...	...	...	...	299,000	...
1909	...	...	...	...	242,000	...
1910	1,399	3,007	5,475	25,712	477,000	51,420
1911	...	...	...	...	204,000	...
1912	...	...	...	...	620,000	...
1913	...	...	...	...	631,000	...
1914	...	...	...	...	327,000	...
1915	1,627	3,612	5,475	36,491	169,000	72,980
1916	...	...	...	...	667,000	...
1917	...	...	...	...	770,000	...
1918	...	...	...	...	456,000	...
1919	...	...	...	...	265,000	...
1920	1,686	3,707	5,618	43,096	445,000	86,190
1921	1,686	3,717	5,618	43,132	578,000	86,260
1922	1,686	3,722	5,618	43,189	475,000	86,380
1923	1,710	3,722	5,618	43,244	251,000	86,490
1924	1,819	3,750	5,618	43,416	249,000	86,830
1925	1,937	3,771	5,618	43,555	308,000	87,110
1926	2,072	3,771	5,663	43,735	174,000	84,470
1927	2,193	3,771	5,663	43,858	338,000	87,720
1928	2,193	3,869	5,663	43,956	613,000	87,910
1929	2,193	3,869	5,663	44,018	212,000	88,040
1930	2,193	3,869	5,663	44,018	160,000	88,040
1931	2,193	3,869	5,663	44,018	197,000	88,040
1932	2,193	3,869	5,663	44,078	472,000	88,160
1933	2,193	3,869	5,663	44,078	332,000	88,160
1934	2,193	3,869	5,663	44,078	183,300	88,160
1935	2,193	3,907	5,663	44,150	149,200	88,300
1936	2,203	3,945	5,663	44,241	234,800	88,481
1937	2,203	4,065	5,663	44,601	170,700	89,200
1938	2,203	4,065	5,663	44,721	226,700	89,440
1939	2,203	4,070	5,663	44,726	203,100	89,450
1940	2,229	4,070	5,663	44,786	223,900	89,570
1941	2,229	4,091	5,663	44,807	123,600	89,610
1942	2,229	4,091	5,663	44,807	386,300	89,610
1943	2,229	4,091	5,663	44,807	558,600	89,610
1944	2,229	4,091	5,663	44,807	172,600	89,610
1945	2,229	4,091	5,784	45,048	303,700	90,100
1946	2,229	4,091	5,784	45,134	385,100	90,270

WILLOW CREEK

Willow Creek drains approximately 900 square miles of land lying between the John Day and the Umatilla watersheds in north-central Oregon. The irrigation projects have been minor and have changed little since about 1910. Most of the lands are scattered along both the main stem and tributaries and have been developed by private enterprise. During the autumn there is insufficient water to supply all water rights in full. In the "Review Report of Columbia River and Tributaries," Appendix, K, "Minor Tributaries below the Yakima River," by the Corps of Engineers, Department of the Army, October 1, 1948, the following statement is made: "Owners of most of these lands have established rights to the waters of the streams for irrigation, but the water supply is so undependable that only about 60 percent of these lands are irrigated. In the valley below Heppner a total of 69 separate diversion rights for the irrigation of 3,760 acres has been established." The steep gradient of the river makes it easy to construct and operate small canals suitable for supplying individual farms. There is no storage reservoir within the basin. A small amount of water is diverted into the upper reaches of Willow Creek from the John Day River basin to the south.

There is no gaging station within the Willow Creek basin so that the total irrigated acreage shown in the following table is not subdivided. A net consumptive use of 1.7 acre-feet per acre was estimated for the irrigated lands. Return flow is assumed to be recaptured above the mouth of the creek.

Irrigated area and estimated depletion for Willow Creek basir

Year	Irrigated area (acres)	Estimated depletion (acre-feet)
1870	146	250
1880	1,137	1,930
1890	2,127	3,610
1900	4,499	7,650
1905	5,679	9,650
1910	6,253	10,630
1915	6,458	10,980
1920	6,491	11,030
1921	6,505	11,060
1922	6,519	11,080
1923	6,573	11,170
1924	6,615	11,250
1925	6,630	11,270
1926	6,662	11,320
1927	6,667	11,330
1928	6,687	11,370
1929	6,687	11,370
1930	6,719	11,420
1931	6,719	11,420
1932	6,719	11,420
1933	6,719	11,420
1934	6,850	11,640
1935	6,870	11,680
1936	6,887	11,710
1937	6,887	11,710
1938	6,887	11,710
1939	6,887	11,710
1940	6,887	11,710
1941	6,887	11,710
1942	6,887	11,710
1943	6,887	11,710
1944	6,887	11,710
1945	6,887	11,710
1946	6,887	11,710

JOHN DAY RIVER

The earliest settlers in the John Day River basin were cattlemen who came to the valley near Prairie City about 1860. Soon after, the area had a short-lived gold rush following a discovery of gold near Canyon City. Settlement of the basin has been slow owing to lack of adequate transportation facilities. Irrigation, which has increased with the growth of the livestock industry, is used primarily to grow forage crops for local consumption and has been developed mostly by private enterprise. The earlier projects were centered around Prairie City and are reported to have begun shortly after 1860. Most of the irrigation is done or the upper reaches of the river, where the agricultural land lies close enough to the stream to permit simple diversion works. The lower reaches of the river flow mostly through canyons, and there the land, in general, is unsuitable for farming.

279538 O - 53 - 9

There are no large reservoirs within the basin and most of the lands served by existing irrigation ditches would benefit from supplemental stored water. Two small diversions carry water from the John Day River basin at present -- one into Willow Creek and the other into Butter Creek, a tributary of the Umatilla River, However, comparatively small amounts of water are carried. The Teel project included plans for an interbasin diversion of water from Camas Creek into Butter Creek by means of a long canal and tunnel with a capacity of 350 second-feet; however, this project was closed down because of financial difficulties and has never been completed.

The irrigated acreages which are shown in the following table are based primarily upon the records of Oregon State Engineer, which agree fairly well with the reports published by the Bureau of the Census of 1939. It is believed that these two records represent the amount of land which ordinarily is irrigated during the years of sufficient water supply. Tabulation of irrigated area have been subdivided to show the area above the gaging stations, North Fork John Day River near Monument and John Day River at McDonald Ferry. Return flow from the lands above these two gaging stations is assumed to reach the main stem of the river above the respective stations. In this basin, net consumptive use of 1.7 acre-feet per acre was estimated for the irrigated lands. The average streamflow depletion for the period 1921 through 1945 amounts to 6.0 percent of the yield of this basin above McDonald Ferry. It has increased only slightly during this period, and in 1946 the net depletion represents 6.3 percent of the long-term yield of this basin.

Irrigated area, annual runoff, and estimated depletion for John Day River basin

Year	North Fork John Day River at Monument, Oreg.	John Day River at McDonald Ferry, Oreg.		
	Irrigated area (acres)	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1860	....	85	....	140
1870	74	3,891	....	6,610
1880	406	11,613	....	19,740
1890	1,751	23,018	....	39,130
1900	2,162	28,261	....	48,040
1905	2,310	32,005	....	54,410
1906	....	....	1,430,000	....
1907	....	....	2,100,000	....
1908	....	....	981,800	....
1909	....	....	992,000	....
1910	2,804	38,148	1,500,000	64,850
1911	....	....	961,000	....
1912	....	....	2,410,000	....
1913	....	....	1,770,000	....
1914	....	....	1,520,000	....
1915	3,168	42,087	729,000	71,550
1916	....	....	2,380,000	....
1917	....	....	2,250,000	....
1918	....	....	1,370,000	....
1919	....	....	1,280,000	....
1920	3,615	44,415	1,520,000	75,510
1921	3,642	44,500	2,610,000	75,650
1922	3,652	44,731	2,170,000	76,040
1923	3,692	44,971	1,420,000	76,450
1924	3,702	45,254	803,000	76,930
1925	3,714	45,300	1,510,000	77,010
1926	3,726	45,511	769,000	77,370
1927	4,002	46,615	1,620,000	79,250
1928	4,177	47,149	1,930,000	80,150
1929	4,248	47,370	974,000	80,530
1930	4,272	47,598	531,000	80,920
1931	4,308	47,657	579,000	81,020
1932	4,308	47,710	1,650,000	81,110
1933	4,321	47,768	1,160,000	81,210
1934	4,338	47,835	461,500	81,320
1935	4,346	47,993	665,300	81,590
1936	4,351	48,092	876,600	81,760
1937	4,378	48,183	1,057,000	81,910
1938	4,378	48,723	1,615,000	82,830
1939	4,530	49,026	943,200	83,340
1940	4,574	49,220	1,026,000	83,670
1941	4,624	49,378	1,157,000	83,940
1942	4,626	49,411	2,041,000	84,000
1943	4,642	49,443	2,443,000	84,050
1944	4,699	49,626	623,300	84,360
1945	4,739	49,742	1,220,000	84,560
1946	4,894	50,307	1,559,000	85,520

DESCHUTES RIVER

Irrigation in Deschutes River basin has increased gradually since about 1880 with the largest spurts from 1890 to 1910 and after 1945. This basin has extensive irrigable land, but because the soil commonly is very permeable, a large part of it has been without an adequate water supply. The earliest irrigation ventures were started as Carey Act projects, the largest of which are the Crook County Improvement District, the Arnold Irrigation Co., the Central Oregon Irrigation District and the Swalley Irrigation Co. All are in the upper valley near Bend, Oreg.

The Crooked River is the largest tributary of the Deschutes and its irrigated area is about 38,000 acres out of a total of 145,000 irrigated acres in all the Deschutes River basin. Most of the irrigation in the valley of Crooked River is in the headwater area above Ochoco Creek. The only large irrigation project in the valley, the Ochoco Irrigation Co. was developed by private capital in 1921. It started with an irrigable area of 22,000 acres but later this was reduced to 8,500 acres because of water shortages. (See table on page 118.)

Smaller tributaries along the lower Deschutes River, namely Squaw and Tumalo Creeks, have scattered tracts of irrigated land but their total irrigated area is small in comparison with that of the main valley. In recent years a small amount of land has been irrigated in the White River basin by three small ditch companies. There is very little chance for irrigation in the Metolius River basin.

The irrigated acreages listed in the tables on pp. 119, 120 have been based on adjudicated water rights and the records of the irrigation districts within the Deschutes River basin. They were derived independently of, but agree very closely with the values given in reports by the Geological Survey (Henshaw, Lewis, and McCaustland, 1914), and the Federal Power Commission (Henry, Cavanaugh and Henshaw, 1922).

This basin is so subdivided topographically as to define quite closely the points at which most of the return flow from the irrigated areas might be expected to be recaptured by the Deschutes River. Along the main stem, the return flow from all the irrigated area above the gaging station near Madras (see table on p. 119) is assumed to be recaptured above that station; return flow from the Crooked River basin, all above the gaging station near the mouth of that tributary near Culver, and from the areas along the other tributaries, all above the mouth of the main stem and and above the gaging station at Moody near Biggs. (See table on p. 120). A net consumptive use of 1.7 acre-feet per acre has been used in estimating streamflow depletion.

The north unit of the Deschutes project is currently irrigating land located north of the Crooked River along the east bank of the Deschutes River. The first large scale irrigation by this unit started in 1946 and has been expanding since that time. The return flow from this area is assumed to be down Willow and Mud Spring Creeks to the Deschutes River. Probably about half this area drains to the main stem above the station at Madras and the remainder above the station near Biggs.

In the Deschutes River basin streamflow depletion is not a very important factor. During the period 1921 through 1945, the average depletion above the gaging station Crooked River near Culver, has amounted to only 5.2 percent of the yield of the basin. There has been only a slight increase during the base period, and in 1946, it amounted to 5.7 percent of the long-term yield. The average depletion during the period 1924 through 1946, has amounted to 3.8 percent of the yield of the basin above the gaging station near Madras. During 1945 and 1946, a large increase in irrigated area took place, and for 1946, the depletion amounted to 5.7 percent of the long-term yield. The average depletion above the station at Moody during the period 1921 through 1945, amounted to 3.6 percent. For 1946, the depletion amounted to 5.1 percent of the long-term yield.

Irrigated area, annual runoff and estimated depletion for Crooked River basin

Year	Crooked River near Post, Oreg.	Crooked River above Hoffman Dam near Prineville, Oreg.	Crooked River near Culver, Oreg.		
	Irrigated area (acres)	Irrigated area (acres)	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1870	530	660	1,190	....	2,020
1880	2,340	2,940	5,309	....	9,030
1890	5,900	7,500	13,556	....	23,040
1900	9,300	11,600	21,124	....	35,910
1905	10,800	13,500	24,414	....	41,500
1910	11,800	14,600	26,746	....	45,470
1915	12,500	15,800	28,217	....	47,970
1918	....	....	....	958,000	....
1919	....	....	....	1,000,000	....
1920	13,820	17,200	31,457	920,000	53,480
1921	13,900	17,300	31,683	1,170,000	53,860
1922	14,000	17,400	31,752	1,041,000	53,980
1923	14,100	17,600	32,122	999,000	54,610
1924	14,200	17,700	32,177	902,000	54,700
1925	14,250	17,800	32,217	1,076,000	54,770
1926	14,300	17,800	32,231	928,000	54,790
1927	14,300	17,900	32,483	1,110,000	55,220
1928	14,300	18,000	32,564	1,076,000	55,360
1929	14,400	18,000	32,594	914,000	55,410
1930	14,400	18,100	32,787	923,000	55,740
1931	14,500	18,200	32,837	894,000	55,820
1932	14,500	18,300	32,995	1,088,000	56,090
1933	14,500	18,400	33,095	995,000	56,260
1934	14,600	18,500	33,213	894,700	56,460
1935	15,050	18,900	34,133	978,700	58,030
1936	15,000	18,900	34,168	1,065,000	58,090
1937	15,000	19,000	34,168	1,023,000	58,090
1938	15,500	19,500	34,203	1,286,000	58,150
1939	15,800	19,800	35,800	977,600	60,860
1940	15,900	19,900	36,073	1,087,000	61,320
1941	15,900	20,000	36,126	1,069,000	61,410
1942	16,000	20,000	36,126	1,183,000	61,410
1943	16,000	20,100	36,196	1,460,000	61,530
1944	16,100	20,200	36,651	995,800	62,310
1945	16,100	20,300	36,688	1,143,000	62,370
1946	16,200	20,400	37,430	1,360,000	63,630

Irrigated area, annual runoff and estimated depletion for Deschutes River near Madras, Oreg.

Year	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1860	28	....	50
1870	1,254	....	2,130
1880	6,015	....	10,230
1890	18,748	....	31,870
1900	40,371	....	68,630
1905	48,156	....	81,870
1910	53,952	....	91,720
1915	65,562	....	111,500
1920	69,647	....	118,400
1921	69,873	....	118,800
1922	69,962	....	118,900
1923	70,736	....	120,300
1924	70,927	2,980,000	120,600
1925	70,973	3,370,000	120,700
1926	71,185	2,920,000	121,000
1927	71,444	3,340,000	121,500
1928	71,525	3,400,000	121,600
1929	71,605	2,900,000	121,700
1930	71,828	2,800,000	122,100
1931	71,913	2,600,000	122,300
1932	72,071	2,840,000	122,500
1933	72,171	2,910,000	122,700
1934	72,289	2,824,000	122,900
1935	73,215	2,988,000	124,500
1936	73,326	3,744,000	124,700
1937	73,326	2,938,000	124,700
1938	73,361	3,461,000	124,700
1939	74,966	2,907,000	127,400
1940	75,361	2,829,000	128,100
1941	75,426	2,690,000	128,200
1942	75,439	2,866,000	128,200
1943	75,569	3,703,000	128,500
1944	76,304	2,942,000	129,700
1945	78,928	2,811,000	134,200
1946	105,752	3,262,000	179,800

Irrigated area, annual runoff, and estimated depletion for Deschutes River basin

Year	White River below Tygh Valley, Oreg.	Deschutes River at Moody, near Biggs, Oreg.		
	Irrigated area (acres)	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1860	....	28	....	50
1870	734	2,072	....	3,520
1880	1,762	8,415	....	14,300
1890	1,927	22,679	....	38,550
1900	2,203	46,197	....	78,530
1905	2,870	54,815	....	93,190
1910	3,370	61,140	5,690,000	103,900
1911	....	....	4,420,000	....
1912	....	....	5,100,000	....
1913	....	....	4,840,000	....
1914	....	....	4,410,000	....
1915	4,332	73,907	3,600,000	125,600
1916	....	....	5,160,000	....
1917	....	....	4,510,000	....
1918	....	....	4,200,000	....
1919	....	....	3,950,000	....
1920	4,647	78,746	3,820,000	133,900
1921	4,687	79,012	4,800,000	134,300
1922	4,743	79,157	4,730,000	134,600
1923	5,041	80,229	4,410,000	136,400
1924	5,151	80,530	3,560,000	136,900
1925	5,270	80,772	4,270,000	137,300
1926	5,295	80,959	3,410,000	137,600
1927	5,430	81,353	4,340,000	138,300
1928	5,455	81,459	4,290,000	138,500
1929	6,550	82,634	3,450,000	140,500
1930	6,560	82,867	3,240,000	140,900
1931	6,575	82,967	3,030,000	141,000
1932	6,724	83,274	3,520,000	141,600
1933	6,724	83,374	3,600,000	141,700
1934	6,769	83,537	3,466,000	142,000
1935	6,769	84,463	3,590,000	143,600
1936	6,769	84,574	3,744,000	143,800
1937	6,769	84,574	3,550,000	143,800
1938	6,769	84,609	4,507,000	143,800
1939	6,769	86,214	3,406,000	146,600
1940	6,909	86,749	3,392,000	147,500
1941	6,909	86,814	3,111,000	147,600
1942	6,909	86,827	3,496,000	147,600
1943	7,109	87,157	5,113,000	148,200
1944	7,109	87,892	3,409,000	149,400
1945	7,124	90,531	3,363,000	153,900
1946	7,223	117,454	4,150,000	199,700

COLUMBIA RIVER NEAR THE DALLES, OREG.

The gaging station on the Columbia River near The Dalles, Oreg. is the last one where the yield of the Columbia River basin may be measured directly. This affords an opportunity to evaluate the aggregate effects of all upstream irrigation on the yield of the basin as shown in the following table. The average streamflow depletion amounted to 4.7 percent of the yield during the period 1921 through 1945. There has been a slight increase in irrigated area during the base period and the depletion for 1946 represents 5.3 percent of the yield during that period; 7.4 percent of the yield for 1926; and 3.8 percent of the yield for 1928. These values indicate the magnitude of the depletion, which is represented by the 1946-stage of irrigation development, in comparison to the average, minimum and maximum yields during the base period.

Thus it can be seen, that from an overall viewpoint, the streamflow depletion that can be attributed to irrigation is not a major part of the yield of the basin. In fact it is relatively small in comparison to the fluctuations caused by the vagaries in climatic conditions.

Irrigated area, annual runoff and estimated depletion for the Columbia River near The Dalles, Oreg.

Year	Irrigated area (acres)	Runoff (acre-feet)	Estimated depletion (acre-feet)
1860	2,156	...	2,590
1870	48,580	...	74,910
1880	153,042	192,000,000	236,540
1890	518,373	143,000,000	793,670
1900	1,209 [illegible]04	163,000,000	1,880,840
1901	...	158,000,000	...
1902	...	143,000,000	...
1903	...	153,000,000	...
1904	...	176,000,000	...
1905	1,672,550	102,000,000	2,653,650
1906	...	114,000,000	...
1907	...	166,000,000	...
1908	...	143,000,000	...
1909	...	139,000,000	...
1910	2,272,696	154,000,000	3,689,660
1911	...	136,000,000	...
1912	...	134,000,000	...
1913	...	155,000,000	...
1914	...	135,000,000	...
1915	2,858,468	107,000,000	4,744,740
1916	...	173,000,000	...
1917	...	152,000,000	...
1918	...	148,000,000	...
1919	...	125,000,000	...
1920	3,325,324	115,000,000	5,545,630
1921	3,371,897	167,000,000	5,586,490
1922	3,398,070	133,000,000	5,662,880
1923	3,406,831	130,000,000	5,676,770
1924	3,363,539	99,300,000	5,615,830
1925	3,426,234	146,000,000	5,704,930
1926	3,392,034	85,500,000	5,661,560
1927	3,454,596	149,000,000	5,765,420
1928	3,459,339	168,000,000	5,765,120
1929	3,472,167	96,100,000	5,782,940
1930	3,487,948	95,200,000	5,817,110
1931	3,461,879	88,400,000	5,794,400
1932	3,539,814	135,000,000	5,902,520
1933	3,564,404	143,000,000	5,949,660
1934	3,489,297	135,100,000	5,839,520
1935	3,611,047	123,200,000	6,024,460
1936	3,616,892	115,400,000	6,058,230
1937	3,689,453	93,190,000	6,112,120
1938	3,730,755	137,700,000	6,264,360
1939	3,769,328	108,400,000	6,314,650
1940	3,801,157	107,800,000	6,369,660
1941	3,835,763	94,130,000	6,396,500
1942	3,846,960	129,300,000	6,463,080
1943	3,892,035	150,100,000	6,536,620
1944	3,915,650	86,830,000	6,578,690
1945	3,943,018	109,200,000	6,627,700
1946	4,004,508	142,000,000	6,733,180

REFERENCES CITED

Bancroft, H. H., 1890, History of Washington, Idaho, and Montana, San Francisco, Calif., History Co.

Bark, D., 1916, Experiments on economical use of irrigation water in Idaho: U. S. Dept. Agr., Bull. 339.

Blaney, H. F., 1930, Rainfall penetration and consumptive use of water in Santa Anna River valley and coastal plain; California Dept. of Public Works, Div. of Water Resources Bull. 33, pt. 1, chap. 2.

Blaney, H. F., Ewing, P. A., Israelsen, O. W., Rohwer, Carl, and Scobey, F. C., Feb. 1938, Water utilization, Upper Rio Grande basin; National Resources Committee, pt. 6, pp. 293-423.

Blaney, H. F., and others, 1942, Consumptive water use and requirements, report of the participating agencies, Pecos River Joint Investigations: National Resources Planning Board, pp. 170-230.

Congressional Documents, 1934, 73d Cong., 1st Sess., H. Doc. 103, vol. 2, p. 879.

Fortier, Samuel, and Young, A. A., 1930, Irrigation requirements of the arid and semiarid lands of the Columbia River basin; U. S. Dept. Agr. Tech. Bull. 200.

Harding, S. T., 1930, Consumptive use of water in irrigation, Progress report of the Duty of Water Committee of the Irrigation Division: Am. Soc. Civ. Eng. Trans., vol 94, pp. 1349-1377.

Hemphill, R. G., 1922, Irrigation in northern Colorado: U. S. Dept. Agr. Bull. 1026.

Henshaw, F. F., Lewis, J. H., McCaustland, E. J., 1914, Deschutes River, Oregon, and its utilization, U. S. Geol. Survey Water-Supply Paper 344.

Henny, D. C., Cavanaugh, J. B., and Henshaw, F. F., 1922, Report to the Federal Power Commission on uses of Deschutes River, Oregon.

Lee, C. H., 1912, An intensive study of the water resources of a part of Owens Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 294.

Lowry, R. L., Jr., and Johnson, A. F., 1942, Consumptive use of water for agriculture: Am. Soc. Civ. Eng. Trans., vol. 107, pp. 1243-1266.

National Resources Planning Board, June 1943, State water law in the development of the West, Report to the Water Resources Committee by its subcommittee on state water law.

Parker, G. L., and Storey, F. B., 1915, Water powers of the Cascade Range; Part 3, Yakima River basin: U. S. Geol. Survey Water-Supply Paper 369.

Parshall, R. L., 1930, Experiments to determine rate of evaporation from saturated soils and river-bed sands: Am. Soc. Civ. Eng. Trans., vol. 94, pp. 961-972.

Powers, W. L., 1914, Irrigation and soil-moisture investigations in western Oregon: Oregon Agr. Coll. Exp. Sta. Bull. 122.

——— 1917, The economical use of irrigation water: Oregon Agr. Coll. Exp. Sta. Bull. 140.

Snelson, W. H., 1922, Irrigation practice and water requirements for crops in Alberta: Canada Dept. of Interior, Irrigation Series, Bull. 6.

U. S. Bureau of Reclamation, Dec. 1948, Reclamation Project Data.

White, W. N., 1932, A method of estimating ground-water supplies based on discharge by plants and evaporation from soil: U. S. Geol. Survey Water-Supply Paper 659-A, pp. 1-106.

Widtsoe, J. A., and Merrill, L. A., 1912, The yields of crops with different quantities of water: Utah Agr. Exp. Sta. Bull. 117.

INDEX

	Page
Appropriation doctrine	7
Big Lost River	67
Big Wood River	67-69
Boise River	78-81
Bruneau River	70-71
Burnt River	91-93
Carey Act of 1894	7
Chelan River	45-46
Clark Fork, above Missoula, Mont	26-27
at St. Regis, Mont	29-30
below Missoula, Mont	27-28
Clarkston to Oxbow, Snake River	106-120
Clearwater River	104-105
Columbia River, at Trinidad, Wash	49-50
at Grand Coulee Dam, Wash	39-40
at the international boundary	35-36
between Yakima River and Snake River	57
near The Dalles	121-122
Colville River	37-38
Consumptive use, coefficient	17
definition of	11-12
estimates of average	15-18
formulas for	17
comparison of	18
net (table)	22
Crab Creek	50-51
Deschutes River	116-120
Earliest irrigation	4
Entiat River	46-47
Evaporation	11
Evapotranspiration	10, 11
Field plots	13-14
Flathead River, above Flathead Lake	31
below Flathead Lake	31-32
Formula for average consumptive use	17
Gaging stations, list of	19-20
Grand Coulee Dam, Columbia River at	39-40
to Snake River, Columbia River	40-56
Grand Ronde River	102-104
Heise, Snake River above	58-60
Heise to King Hill	62-66
Henrys Fork	60-62
History of irrigation in the basin, earliest irrigation	4
rate of expansion	6
transportation	5

	Page
Imnaha River	97-98
International boundary, Columbia River at	35-36
International boundary to Grand Coulee Dam, Columbia River	36-40
John Day River	113-115
Kettle River	36-37
King Hill, Snake River at	69-71
King Hill, Heise to, Snake River	62-66
King Hill to Murphy, Snake River	72-90
King Hill to Neeley, Minor tributaries	64-66
Kootenai River basin	23-25
Legislation, appropriation doctrine	7
Carey Act of 1894	7
Reclamation Act of 1902	8
riparian doctrine	6
Little Lost River	66
Lysimeter	13
Malheur River	81-84
Measurements of water consumption, methods, field plots	13-14
inflow and outflow, studies of	15, 18
lysimeter	13
soil-moisture method	14
soil tanks	12-13
water table, fluctuations of	14
Methow River	42-44
Minor tributaries, Neeley to King Hill	64-66
Missoula, Mont., Clark Fork above	26-27
Clark Fork below	27-28
Mud Lake area	66
Murphy, King Hill to, Snake River	72-90
Murphy to Weiser, Snake River	90-95
Neeley to King Hill, minor tributaries	64-66
Okanogan River	40-42
Owyhee River	73-77
Oxbow to Clarkston, Snake River	106-120
Oxbow, Weiser to, Snake River	95-105
Payette River	84-87
Pend Oreille River basin	25-36
Pend Oreille River below Z Canyon near Metaline Falls, Wash	32-35
Pine Creek	96-97
Portneuf River	63-64

	Page
Powder River	93-95
Reclamation Act of 1902	8
Return flow, mineral content of	10
Riparian doctrine	6
St. Regis, Mont., Clark Fork at	29-30
Salmon River	99-102
Snake River	58-120
above Heise	58-60
at King Hill	69-71
Grand Coulee to, Columbia River	40-56
Heise to King Hill	62-66
King Hill to Murphy	72-90
Murphy to Weiser	90-95
Oxbow to Clarkston	106-120
Weiser to Oxbow	95-105
Snake River and Yakima River, Columbia River between	57
Soil-moisture method of water consumption measurement	14
Soil tanks, experiments with for water consumption measurement	12-13
Sources of data on irrigation	8-10
Spokane River	38-39
The Dalles, Columbia River near	121-122
Transpiration	11
Tributaries, minor, Neeley to King Hill	64-66
Tributary basins, list of	19-20
Trinidad, Columbia River at	49-50
Umatilla River	110-111
Walla Walla River	108-109
Water table, fluctuations of	14
Weiser River	88-90
Weiser to Murphy, Snake River	90-95
Weiser to Oxbow, Snake River	95-105
Wenatchee River	47-49
Willow Creek	112-113
Yakima River	52-56
Yakima River and Snake River, Columbia River between	57
Z Canyon, Pend Oreille River below	32-35

U. S. GOVERNMENT PRINTING OFFICE: O—1953

MAP SHOWING DRAINAGE BASIN OF COLUMBIA RIVER ABOVE THE DALLES, OREGON

279538 O - 53 (In pocket)