

BULLETIN 353

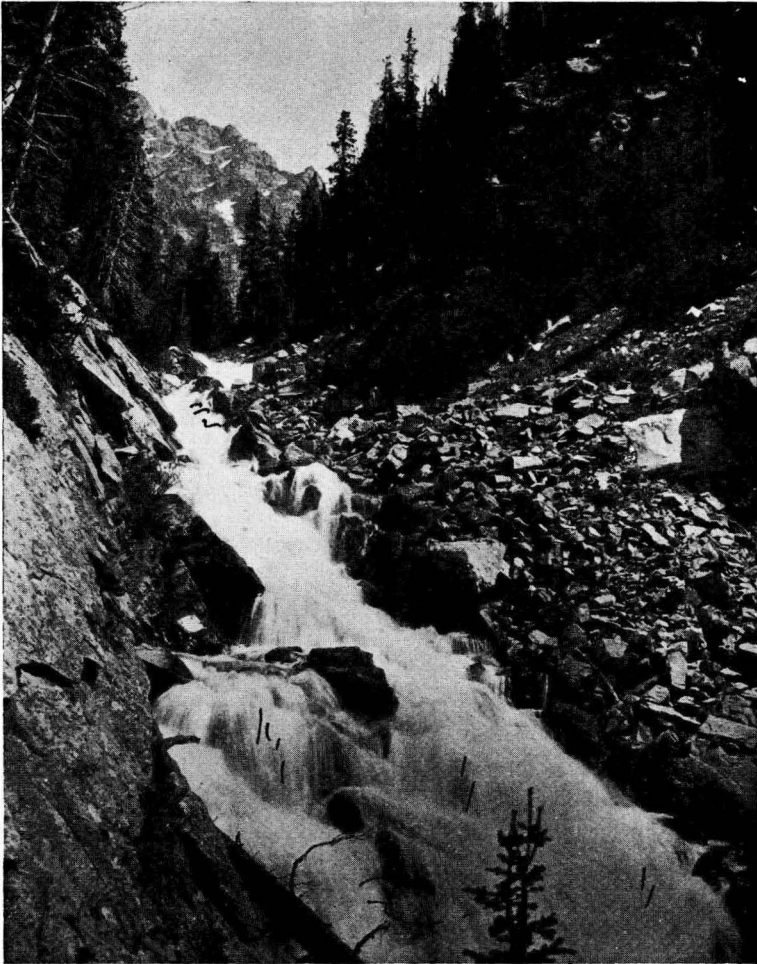
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Irrigation Development in Montana
Part I. Water Supply



MONTANA STATE COLLEGE
AGRICULTURAL EXPERIMENT STATION
BOZEMAN, MONTANA

SUMMARY

1. Montana has about 146,000 square miles of watershed which drain into the Missouri and the Columbia rivers and into the Hudson Bay.
2. An average of 36,000,000 acre feet of water flows out of Montana annually, of which about 70 per cent originates in the state. This is equivalent to a depth of 3.2 inches over all the land area of the state, and represents about 20 per cent of the mean annual precipitation.
3. 85.3 per cent of the state is drained by tributaries to the Missouri River, 14.6 per cent by the Columbia River, and .1 per cent flows to the Hudson Bay; but of the water which leaves the state, 43.8 per cent flows east through the Missouri, 54.9 per cent west through the Columbia, and 1.3 per cent through the St. Mary which empties into the Hudson Bay—a geographical distribution which is unfavorable for its most complete use for irrigation.
4. The seasonal variation in the distribution of runoff also prevents complete utilization of the stream flow for irrigation, except through storage, as only about 60 per cent of the runoff occurs during the crop growing season. If the irrigated area were limited to the number of acres for which a full supply was assured during July and August, then only about 40 per cent of the summer flow could be used, or only 24 per cent of the annual flow.
5. The variability of flow of streams from month to month and from year to year makes necessary long-time stream flow measurement upon which to base plans for economical irrigation development. Runoff records should be continuous through many years to be of most value.
6. Since the possibilities for irrigation development come from the tributaries rather than from the main streams, gaging stations should also be established on these tributaries.
7. A comprehensive survey should be made—not alone of all the water resources in Montana, but also of their availability to the land where they could be used. Then plans for the most permanent benefits could be worked out.
8. Conservation of water implies putting it to the best use for the most people. If power systems were developed in the higher reaches of the streams, the water could also be used for irrigation in the valley below and yet further down on the larger rivers again be used for power.
9. Wherever possible the uses of water for irrigation, for power, for recreation, and for domestic purposes should be coordinated so as to enhance the value of such development.
10. It is recognized that the benefits of irrigation are enjoyed by many people other than those who live on the land actually irrigated. Merchants, transportation companies, manufacturers, banks, professional people, tradesmen, and the general public who live in or adjacent to the irrigation development, enjoy the benefits in an equal degree to the people who till the soil. Irrigation development will proceed much faster when all those who benefit contribute their proportionate share of the costs of irrigation development.
11. Special legislation will be needed to permit the organization of improvement districts with power to apportion the costs of irrigation among all who benefit from it.

48015

Irrigation Development in Montana

Part I. Water Supply

By

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INTRODUCTION

In this bulletin an attempt is made to give a picture of one of Montana's most valuable natural resources, the water supply from her rivers and small streams. A brief description is given of the present and potential uses of this water supply together with a discussion of some of the problems involved in the development and use of this valuable resource—primarily from the standpoint of irrigation.

Irrigation has fully demonstrated its value to Montana's agriculture. Indeed, its value is appreciated to such an extent that there is danger of proceeding without due consideration being given to the hazards which attend irrigation development. Thorough investigation must be made of all the factors which contribute to the success of an irrigation project if success is to be achieved and failure averted. The making of complete surveys before undertaking construction cannot be too strongly urged.

Many agencies have contributed to the irrigation development of Montana. Their participation has resulted from a gradually growing and evolving water policy designed to meet conditions as they existed. It would seem advisable at this point to coordinate efforts of all agencies now engaged in water development under a single responsible department or bureau, and thus make possible still more efficient planning and carrying out of a definite and complete water development policy.

THE WATER SUPPLY

The past seven or eight years have clearly shown that the development of Montana's agricultural resources—indeed, the development of all her natural resources, depends upon the availability and conservation of her water supply. The best utilization of the range requires the systematic development of watering places within easy reach of the grazing cattle or sheep which should not be forced to travel more than one to two miles to

water. The development of water for irrigation in the range area will provide hay and grain to carry the stock through a drouth or a hard winter or finish them for market. Since the water supply is limited as compared to the land, the farmer's aim should be to make the available supply serve in every possible way to increase farm production.

SOURCES OF WATER FOR IRRIGATION

The streams of Montana, fed from the heavy snows and rains, represent the major part of the water supply. An area of 146,131 square miles, or 93,523,840 acres is drained by three major river systems, 1. the Mississippi-Missouri, 2, the Columbia and 3, the Hudson Bay. Drainage from the central and eastern parts of the state flows into the Gulf of Mexico through the Missouri and Mississippi rivers, from the western part through the Clark Fork of the Columbia River to the Pacific Ocean, and from a small area in the northwestern part of the state into the Hudson Bay.

These three major drainage systems may be divided naturally into six drainage basins as shown in table 1. This table also gives the total and the relative size of the areas drained, the amount of water discharged, and the number of acres irrigated in Montana.

From the total given in table 1 we note that about 85 per cent of the state drains eastward into the Gulf, 14.9 per cent westward into the Pacific, and .1 of 1 per cent northward into Hudson Bay. The eastward flowing streams are of most importance from the standpoint of irrigation since they supply the water for 80 per cent of the irrigated land of the state. The streams flowing west provide irrigation water for 16.9 per cent of the irrigated lands in the state, leaving about 3.1 per cent to be irrigated by water which is diverted from the St. Mary River across the Divide into the Missouri drainage basin. The streams flowing east from the mountains are also used largely for the production of hydro-electric power, 10 of the 11 existing plants being located on these streams.

Further development may change this picture somewhat, but east of the Divide water will always be relatively scarce and the need for its use much greater than to the west. It is, therefore, not improbable that if agricultural development continues,

the time will come when other trans-watershed diversions, similar to the present diversions from St. Mary's River, to irrigate lands in the Missouri drainage basin will be desirable. Unless this is done thousands of acres of land in the Marias basin will never be fully developed because the amount of water available

TABLE 1.—AREA OF DRAINAGE BASINS IN MONTANA

Name of basin	Area in Montana Sq. mi.	Pct. of area of the state	Mean annual runoff ^a Ac. ft.	Pct. Total runoff ^d	No. acres irrigated in Montana in 1929	Pct. of total irr. lands
Mississippi-Missouri						
1. Missouri and trib.....	86,824	58.5	5,317,200 ^b	14.8	838,474	52.7
2. Yellowstone and trib.	35,920	24.2	10,352,590 ^c	28.7	434,550	27.2
3. Little Missouri	3,440	2.3	87,620 ^c	.3	1,462	.1
Sub total	126,184	85.0	15,757,410	43.8	1,274,486	80.0
Columbia						
4. Clark's Fork	19,450	13.1	13,257,600 ^c	36.7	262,836	16.4
5. Kootenai	3,825	1.8	6,583,520 ^c	18.2	7,590	.5
Sub Total	23,275	14.9	19,841,120	54.9	270,426	16.9
Hudson Bay						
6. St. Mary	200	.1	476,330 ^d	1.3	50,000*	3.1
Grand total	149,659	100.0	36,074,860	100.0	1,594,912	100.0
Less areas						
outside of state*	-3,528					
Net area in Montana	146,131					

*Estimated.

^aDischarge where stream leaves Montana.

^b5-year average, 1928-1933.

^c10-year average 1923-1932.

^d10-year average, 1907-1917

*Drainage areas outside of state estimated at 3,528 square miles.

from the Teton and Marias rivers, even though controlled by storage, is inadequate to supply water for all the lands adaptable for irrigation in the valleys of these rivers. Trans-watershed diversions involve expensive construction which cannot be made until the demand for lands, through increase in population, makes this justifiable.

ANNUAL RUNOFF FROM MONTANA WATERSHEDS

The mean annual discharge from the several streams which flow out of the state is about 36,000,000 acre feet of water. (See table I.) Of this amount about 15,750,000 acre feet or 43.8 per cent flows toward the Atlantic Ocean, 19,841,000 acre feet or 54.9 per cent flows toward the Pacific, and about 441,600 feet or 1.3 per cent flows into the Hudson Bay.

Of the water flowing out of the state but 69.5 per cent originates within its borders. The remainder flows in from Wyo-

TABLE 2.—ANNUAL RUNOFF FROM MONTANA (1929-1933)*

River	Gaging station	Runoff—acre ft.			Runoff originating within state—acre ft.		
		Aver.	(1933) Max.	(1931) Min.	Aver.	Max.	Min.
Missouri	Williston, N. D. (Yellowstone deducted)	5,447,400	5,920,000	3,590,000	5,233,158	5,688,080	3,439,130
Milk River	Eastern Crossing	214,242	231,920	150,570	0	0	0
N. F. of Milk R.	Near Boundary	140,256	157,760	134,370	140,256	157,760	134,370
S. F. of Milk R.	Near Boundary	31,816	36,390	10,750	31,816	36,390	10,750
Yellowstone	Intake, Montana	8,316,000	8,280,000	6,030,000	4,133,570	4,061,000	2,712,000
Powder	Moorhead Montana	286,627	416,000	207,310	0	0	0
Tongue	Decker, Montana	313,800	423,000	181,000	0	0	0
Big Horn	Kane, Wyoming	1,792,000	1,780,000	1,440,000	0	0	0
Yellowstone	Corwin Spr.	1,790,000	1,600,000	1,490,000	0	0	0
Clarks Fk.	Heron, Montana	13,446,000	18,400,000	9,430,000	12,945,920	17,680,000	9,130,720
N. F. of Flathead	Trail Creek, Mont.	500,082	719,850	299,280	0	0	0
Kootenai	Leonla, Idaho	8,734,000	11,700,000	6,020,000	2,146,000	2,860,000	1,210,000
Kootenai	Rexford, Montana	6,588,000	8,840,000	4,810,000	0	0	0
Little Missouri	Medora, N. D.	385,040	958,650	79,870	316,830	794,340	76,390
Little Missouri	Alzada, Montana	68,214	164,310	3,480	0	0	0
St. Marys	Kimball, Alberta	441,600	528,000	296,000	441,600	528,000	296,000
					25,389,150	31,805,570	17,009,360

*Data from U. S. Geological Survey Water Supply Papers.

TABLE 3.—AVERAGE RUNOFF FROM SIX DRAINAGE BASINS IN MONTANA AT PRINCIPAL GAGING POINTS.*

Stream and gaging station	Thousands of acre feet (000 omitted)												
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
Missouri													
Three Forks	185.2	208.6	195.2	187.5	180.0	211.2	280.3	492.2	516.4	241.8	138.8	133.1	2970.3
Fort Benton	234.9	249.3	264.9	250.0	225.7	308.9	492.7	564.3	625.5	286.0	182.4	180.5	3865.1
Wolf Point	272.0	273.8	270.9	261.2	345.4	530.5	654.3	792.4	974.2	362.3	275.3	224.8	5237.1
Yellowstone													
Corwin Springs	92.6	72.6	59.1	47.6	42.1	54.4	89.2	368.7	548.8	316.7	158.4	92.6	1942.8
Livingston	121.0	90.6	78.5	63.2	61.3	74.4	99.6	348.2	664.2	347.7	177.5	118.1	2244.3
Billings	235.8	184.0	145.3	134.1	118.6	188.2	224.2	568.1	1140.0	519.9	245.9	185.1	4077.8
Miles City	408.7	333.0	244.8	237.7	275.0	372.9	407.4	1040.5	1992.6	851.7	425.5	318.7	6908.5
Intake	450.3	372.5	277.4	254.2	319.6	691.5	552.5	1118.3	2053.5	876.5	442.7	376.5	7785.5
Clark Fork of Columbia													
Above Missoula	79.0	84.5	81.8	91.2	85.8	104.4	276.6	391.2	367.2	108.3	63.2	60.0	1793.2
Below Missoula	129.9	126.4	112.6	120.3	131.6	189.7	444.4	749.9	757.1	212.9	84.2	98.4	3157.4
St. Regis	182.4	209.2	259.6	217.4	195.7	282.2	671.0	1038.2	994.1	286.4	137.3	132.2	4605.7
Plains	435.0	531.5	548.0	504.7	407.0	516.3	1181.0	2897.3	3363.5	1538.3	610.7	391.7	12925.0
Heron	483.8	578.7	674.0	606.5	487.3	663.5	1498.7	3286.5	3697.0	1710.0	694.4	441.3	14821.7
Kootenai													
Rexford	237.5	193.0	169.0	175.6	150.7	197.6	605.6	1597.0	2135.0	1077.8	505.5	318.0	7362.3
Libby	246.5	202.5	187.3	191.5	189.3	258.4	797.8	1639.4	2293.0	1139.2	527.2	322.8	7994.9
Leonia	273.8	240.5	220.3	290.5	242.4	346.2	1067.0	2202.0	2256.8	1205.6	558.4	344.9	9248.4
Little Missouri													
Alzada .....	.15	.06	.01	.01	4.79	20.74	15.80	9.10	10.31	1.40	.60	.60	663.57
Medora, N. D.	5.10	3.05	.88	.51	6.22	93.82	60.87	70.43	83.23	14.48	6.89	5.31	350.79
St. Mary													
Kimball, Alberta, Canada	26.00	21.50	12.90	11.40	10.80	15.30	38.40	108.50	130.1	54.40	25.90	21.10	359.21

*Data from U. S. Geological Survey Water Supply Papers.

ming through the Powder, Tongue, Big Horn, and Yellowstone rivers and from Canada through the Flathead, Kootenai, and small tributaries of the Milk river. Table 2 gives an average five-year record of the amount of water which originates in this state, and flows out through the various rivers of the state. It amounts to 25,389,125 acre feet annually.

This vast amount of water, which on the average originates in and leaves Montana each year, is sufficient if spread uniformly to cover the entire state to a depth of 3.2 inches. It represents the equivalent of about 20 per cent of the average annual precipitation received.

The actual distribution of this water over the state is, however, very uneven. The area west of the Divide receives much more precipitation than the part east of the Divide and thus has a much greater runoff. Indeed, it has been observed that under conditions of heavy rainfall, a larger percentage, as well as a larger amount of runoff occurs. Altitude also affects the amount of rainfall; thus, the high mountainous lands receive more rain and snow during the year than the rolling plains, and they also yield a higher percentage of runoff. This is true not alone of the main Rocky Mountain Divide but is likewise so for all the mountains of the state; viz, that they receive a higher precipitation on their western than on their eastern slopes.

The differences in altitude and location, therefore, which affect the precipitation received are reflected in the amount of water flowing out of the various drainage basins. Table 3 gives the runoff by months from the various drainage basins at a number of points along each stream and shows the contribution of the tributaries between the points of measurement. Figures 1 to 6 have been arranged to illustrate table 3. They show at a glance the proportionate amount of the water, originating in each section or division of the drainage basin, that flows out of the state.

OTHER SOURCES OF WATER

While the flowing streams are the most important sources of water for irrigation in Montana, there are several minor sources which supply water for about 27,272 acres (1)* or 1.7 per cent of the irrigated area. These other sources are as follows:

*Figures in parentheses apply to Reference List, page 47.

Flowing wells supply water for 821 acres; *pumped wells*, for 243 acres, making 1,164 acres or .07 per cent of the irrigated area.

Lakes supply 5,528 acres by pumping and 4,905 acres by gravity, making a total .65 per cent.

Springs supply 10,947 acres or 69 per cent, and stored storm water 4,828 acres or .30 per cent.

There are yet many other possibilities for development along these lines.

DESCRIPTION OF DRAINAGE BASINS

THE MISSOURI

The *Missouri River* is formed by the confluence of the Jefferson, the Madison, and the Gallatin rivers near Three Forks, in the southwestern part of the state. From here it flows in a

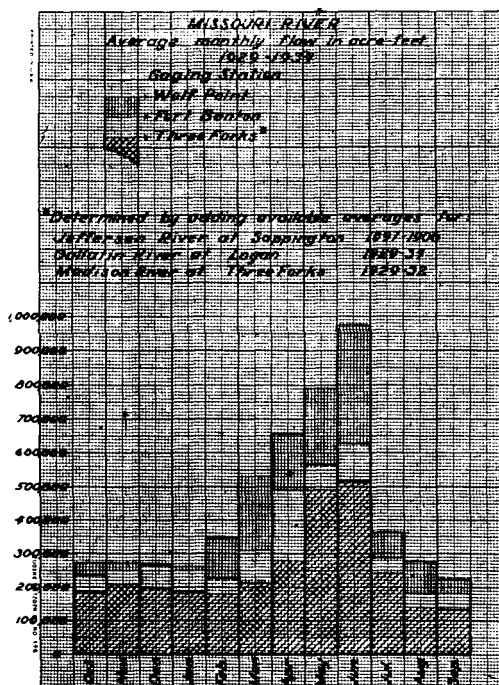


Figure 1. Missouri River—Average monthly flow in acre feet, 1929-1934.

northwest direction to Wolf Creek, thence northeast to Virgelle and then easterly to the crossing of the Dakota line at Mondak near Fairview about 700 miles from its source. The upper Mis-

souri basin from its source to a point near Great Falls lies in the north Rocky Mountains. The river flows for long stretches through rocky canyons where the surrounding country is rough and mountainous. About 30 miles above Great Falls the river emerges from the mountains and enters the Great Plains, the topography of which characterizes the rest of its course through the state.

The mean annual runoff from the Missouri for the six years, 1929-1934 inclusive, at Wolf Point — the first gaging station above the junction with the Yellowstone—was 5,338,600 acre feet or about 65 acre feet per square mile. For the same six-year period the average runoff above Ft. Benton was 3,951,200 acre feet or 160 acre feet per square mile. The average inflow between Ft. Benton and Wolf Point was 1,387,500 acre feet or 26 per cent of the flow at Wolf Point. A thirty-five year average at Ft. Benton gives an average runoff above that point of 6,360,000 acre feet or 258 acre feet per square mile. (Obviously the six-year average during 1929-1934 at Wolf Point was below the normal flow.) If there were no diversions for irrigation the average discharge of the Missouri at Wolf Point would be 9,777,000 acre feet or 118 acre feet per square mile.

Three Forks basin consists of the Jefferson, the Madison and the Gallatin rivers which are the headwaters of the Missouri River. Located in the extreme southwestern part of the state, this basin covers 13,880 square miles or 16 per cent of the area drained by the Missouri River in Montana. The Jefferson is the largest of the three and drains 9,520 square miles; the Madison drains 2,520 square miles, and the Gallatin 1,840 square miles. The combined mean annual runoff from the three streams is about 3,390,000 acre feet, which is over one-half the average annual runoff of the Missouri River at Ft. Benton. Of this the Jefferson contributes 1,660,000 acre feet or 420 acre feet per square mile; the Gallatin, 720,000 acre feet or 600 acre feet per square mile. In addition to the run-off measured at Three Forks, water from these three streams is diverted for the irrigation of 487,500 acres of land situated in their valleys.

The main ranges of the Rocky Mountains, rising to heights of 9,000 to 11,000 feet, occupy about half the basin. The other half is divided between plateaus, terraces, and high rolling land.

There are about 2,933,000 acres of land in farms in the Three Fork's basin of which 487,501 acres or 16.6 per cent are irrigated as follows: (1) 363,380 in the Jefferson and its tributaries; 30,368 in the Madison; and 93,753 in the Gallatin. The principal crops in the higher valleys are hay, grain, and pasture, while on the lower lands, seed and canning peas, beans, and potatoes are grown. In addition to the present irrigated area there were in 1929, about 55,500 additional acres of irrigable land under the ditch.

There are 2 hydro-electric plants in the basin, with a capacity of 12,000 kilowatts. Besides these the water which flows past Three Forks helps operate 7 other plants farther down the Missouri River.

Smith River (2), the first important tributary of the Missouri below Three Forks, rises near Ringling in Meagher County and flows northward joining the Missouri near Ulm, a few miles above Great Falls. It drains about 2,000 square miles and has a mean annual runoff at Truly, Meagher County, of 159,000 acre feet or 79.5 acre feet per square mile, all of which flows into the Missouri River.

The irrigated land in the Smith River basin is 25,460 acres (2) which is devoted to hay, grain, and pasture. There are two small reservoirs on this river but their combined capacity is only 700 acre feet, and their regulatory effect is therefore small.

There are no hydro-electric power plants along the Smith River but its waters after joining the Missouri help to produce power at several plants below Great Falls.

The Sun River (2), formed by the junction of the North and South Forks in the western part of Teton County, flows eastward to Great Falls where it joins the Missouri. It drains about 2,300 square miles of mountainous watershed. The average runoff at a point a few miles above its confluence with the Missouri is 395,000 acre feet annually or 398 acre feet per square mile. The maximum flow is nearly three times as much as the average, and the minimum is about half as much. In addition to the large volume of water discharged annually into the Missouri, water is supplied from the Sun River to irrigate 28,000 acres of land (1), the most of which is under the Sun River Project. The Sun River drains approximately the same watershed area as the Smith River, but the runoff per square mile is five times as

much as that of the Smith. There are no hydro-electric power plants on the Sun River.

The Marias River (4) and its principal tributary, *the Teton*, drain an area in north central Montana comprising wholly or in part, the counties of Glacier, Toole, Liberty, Hill, Pondera, Teton and Choteau. The Marias drains approximately 7,145 square miles and the Teton 2,015 square miles making a total of 9,160 square miles.

The Marias is formed by the junction of Cut Bank Creek and Birch Creek in the southeastern part of Glacier County and flows in an easterly direction about 80 miles to Brinkman, Hill County, thence south 33 miles to its confluence with the Teton. Seven miles further on it joins the Missouri northeast of Ft. Benton.

The western part of the Marias drainage basin is high rough land, often rising to elevations of 10,000 feet. Eastward the basin slopes off to a rolling plain, beginning at 5,000 feet and dropping down to 2,000 feet where the Marias joins the Missouri.

Runoff records on the Marias and Teton rivers are meager but, according to the estimates made by the Army Engineers, the average for the Marias at Brinkman is 688,900 acre feet annually. To this the Teton adds 55,700 acre feet, making a total of 743,900 acre feet or 81 acre feet per square mile. The runoff of the Marias watershed is about 96 acre feet per square mile, while the Teton discharges about 28 acre feet per square mile. This runoff is measured below all the diversions for irrigation and, therefore, does not represent the total flow from this watershed. There are approximately 102,300 acres of irrigated lands in the Marias-Teton basin.

Power development on the Marias is not important as only a small municipal plant of 70 horsepower at Cut Bank has been constructed. Three potential sites have been surveyed but were not considered feasible.

The Judith River (2) is the next most important tributary of the Missouri. It rises in the southern part of Judith Basin County, flows north through Judith Basin and Fergus counties and joins the Missouri at a point north of Winifred. It drains an area of 2,750 square miles or about the same as the Smith River or the Sun River.

Records of runoff available for the Judith River at Winifred cover only a short period. Records for 1930 and 1931, partly estimated, show an annual runoff of 338,000 and 199,000 acre feet respectively with a mean for the two years of 268,000 acre feet or 125 acre feet per square mile. For the same years the runoff at Utica, which is 99 miles above the mouth, ranged from 35,400 acre feet to 6,350 acre feet with a mean of 20,875 acre feet or 69 acre feet per square mile which was 55 per cent of the flow at Winifred during the same period. The mean of a twelve-year record at Utica shows a runoff of 44,900 acre feet or 148 acre feet per square mile, which indicates that the figures given for Winifred are probably too low to represent a true average.

There were 7,435 acres irrigated in the Judith River basin in 1929, a decrease of 51 per cent since 1919 when 15,173 acres were reported. No hydro-electric power plants are located on the Judith River, nor is it probable that the generation of electricity will ever be important on this stream.

The Musselshell River (5) rises in the Crazy Woman Mountains in the eastern part of Meagher County and flows east through Wheatland, Golden Valley, and Musselshell counties, then turns north, flowing between Musselshell and Rosebud counties and also between Petroleum and Garfield counties. It drains about 9,570 square miles, most of which is rolling plains country.

Runoff records of the Musselshell River are limited. At Mosby, 60 miles above the confluence with the Missouri, a record for two years (1930-1931) is given in the Missouri River report. The mean of the two years, both of which are partly estimated, is 47,000 acre feet or a little less than 6 acre feet per square mile as compared with 125 acre feet per square mile for the Marias basin during the same years. Mosby is below all diversion for irrigation, however, so the above reported runoff represents only a small part of the total runoff from the Musselshell basin. Allowing for diversions equal to the average for the state* and a 40 per cent return flow, the total runoff would be about 200,000 acre feet or 25 acre feet per square mile. It should, however, be remembered that the runoffs for the years 1930 and 1931 were probably far below the twelve-year average, as was shown to be the case with the Judith River.

There were 59,286 acres of irrigated land in the Musselshell

*Average diversion from 15th Census, 4.3 acre feet per acre.

basin in 1929 according to the 1930 U. S. Census. This area was an increase of 30 per cent over the 1919 report but was only 70 per cent of the total irrigable area of 84,738 acres which the Census has included in enterprises for which water was available in 1930. There are no hydro-electric plants on the Musselshell.

The Milk River (6) is an international stream. It is formed by the junction of the North and the South Fork in the southeastern part of Alberta, Canada, near the international boundary. It flows southwesterly through Alberta and Montana, joining the Missouri River near Nashua about 200 miles above Williston, North Dakota. It has a flat gradient ranging from 3 feet per mile in the upper portion of its course to about one foot per mile in the lower part. The Milk River drainage basin covers 23,800 square miles of which 15,521 square miles or 65 per cent is in the United States, and 8,279 square miles, or 35 per cent is in Canada.

The average annual runoff during 1915-1920 and 1929-1931 from the Milk River basin at Vandalia was 653,000 acre feet or 27.4 acre feet per square mile, which compares with 6 acre feet per square mile on the Musselshell and 125 acre feet per square mile on the Marias. On the basis of average diversion and return flow, the total annual runoff would be 882,000 acre feet or nearly 37 acre feet per square mile as compared with the corrected value of 25 acre feet per square mile for the Musselshell.

A total of 88,218 acres of land were irrigated from the Milk River in 1929, a decrease of nearly 19 per cent over the 1919 report. The 1930 census reports a total of 190,218 acres under the ditch for which water was available in 1930. There are no hydro-electric plants along the Milk River.

Other tributaries of the Missouri below the mouth of the Milk River include the Poplar, the Big Muddy and the Red Water. These are intermittent streams which flow only after heavy storms and during the spring runoff. They could be useful for irrigation if controlled by storage reservoirs.

THE YELLOWSTONE RIVER (7)

The Yellowstone basin is located in north central Wyoming, southeastern Montana and western North Dakota. It drains an area of 70,400 square miles of which 35,920 square miles or 51 per cent are in Montana, 33,740 square miles or 48 per cent are in Wyoming, and 740 square miles or one per cent are in North Dakota.

The main stem of the Yellowstone River originates in Yellowstone Lake in Yellowstone Park. It flows northeasterly, through Park, Sweet Grass, Stillwater, Yellowstone, Treasure, Rosebud, Custer, Prairie, Dawson, and Richland counties and joins the Missouri at Buford, North Dakota just across the Montana line.

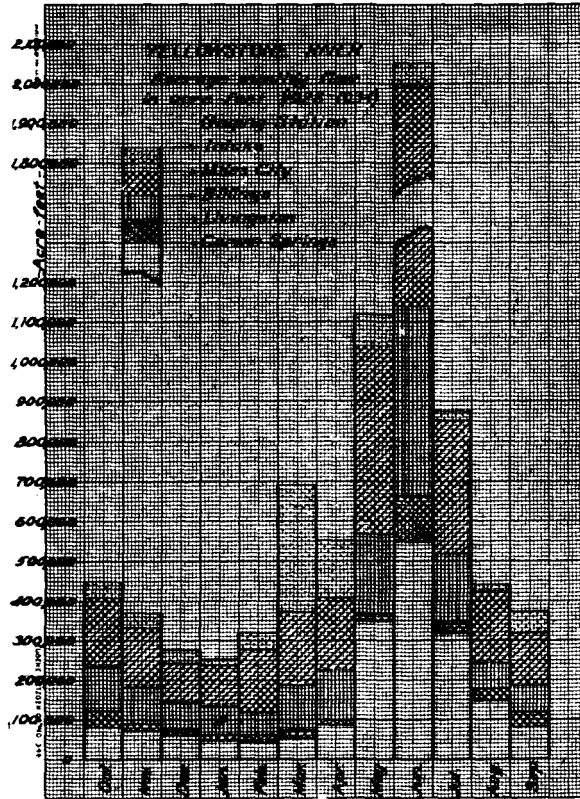


Figure 2. Yellowstone River—Average monthly flow in acre feet, 1928-1934.

The western and southern parts of the Yellowstone basin lie in rough, mountainous country, while the eastern and northern parts extend into the Great Plains section. The four principal tributaries all rise in Wyoming and flow north to their confluence with the Yellowstone. They are Clark's Fork, Big Horn, Tongue and Powder rivers.

The twenty-year average annual runoff at Intake, in excess of all diversions for irrigation, is 10,200,000 acre feet or 145

acre feet per square mile. This is almost twice as much as the runoff from the Missouri basin although the Yellowstone drainage basin above Intake is only 82 per cent as large as the Missouri above Ft. Benton. It might be assumed that the difference is due to larger diversions for irrigation in the Missouri basin, but such is not the case. In fact, diversions from the Yellowstone and its tributaries supply water for 1,447,821 acres as compared to the 839,936 acres supplied by the Missouri. If we allow for average diversions for and return from, irrigation, the total runoff would be 13,930,000 acre feet or 198 acre feet per square mile as compared with the corrected value of 118 acre feet per square mile for the Missouri above Wolf Point. It is evident, therefore, that conditions in the Yellowstone basin favor a coefficient of runoff nearly 1.7 times as great as occurs from the Missouri basin.

Thirty per cent of the total area irrigated by diversions from the Yellowstone and its tributaries (434,550 acres) lies in Montana. Irrigation represents the most important use of the Yellowstone at the present time, although there was a time when its principal usefulness was navigation. Boats ascended the river during high water as far as the mouth of the Big Horn and even up to Billings to transport buffalo hides back to Omaha and St. Louis, but at the present time navigation is not considered important. Indeed, the construction of a concrete diversion dam at Intake precludes the passage of boats beyond that point.

There are 9 existing hydro-electric power plants in the Yellowstone basin, of which 2 are in Montana—the Mystic Lake plant of the Montana Power Company on the west Rosebud, and the Gardiner plant on Gardiner River, owned by Gardiner Electric Light and Water Company. The Mystic Lake plant has a capacity of 12,500 kilowatts and the Gardiner plant, 105 kilowatts or a combined total of 12,605 kilowatts. The total installed capacity of all plants in the Yellowstone basin is 21,355 kilowatts or 30,973 horsepower. A large number of potential power sites have been investigated by reconnaissance surveys but have not been found feasible either because of a deficient water supply or because of the excessive costs involved.

The Clark's Fork (7) rises in the northwest corner of Wyoming and flows east and north, crossing the Montana State line at Chance, Wyoming, and flowing through Carbon and Stillwater

counties to its junction with the main stem of the Yellowstone near Laurel, Montana. According to the 1930 census 16,310 acres of land are irrigated by diversion from the stream and its tributaries in Montana. This is a little over 85 per cent of all the irrigated land in Clark's Fork basin. In addition to waters thus put to a useful purpose, it contributes on the average about 760,525 acre feet to the Yellowstone River at Laurel.

Four smaller tributaries which enter the Yellowstone River above Clark's Fork are the Shields River in Park County and Sweet Grass Creek in Sweet Grass County, which flow from the north; and Boulder River and the Stillwater, which enter from the south, the first in Sweet Grass County and the latter in Stillwater County. These streams supplied water for approximately 85,337 acres (7) in 1929, which was about the same amount as was irrigated by Clark's Fork in Montana. Sweet Grass Creek, however, does not provide a supply for the full irrigating season.

The Big Horn River (7) originates in Fremont County, Wyoming, and flows in a general northerly direction through Hot Springs and Big Horn counties, Wyoming, and crosses the Montana state line below Kane, Wyoming. Thence it flows north through Big Horn County to its confluence with the Yellowstone near Big Horn, Montana.

The Big Horn watershed is characterized by a rolling Great Plains topography. The streams are fed in the spring by the melting snow and in the summer by runoff from heavy rains. There is comparatively little snow piled up in the hills to maintain the flow during the summer months. Only Wind River receives an appreciable amount of its summer flow from glaciers and snow banks.

The five-year average (1929-1933 inclusive) discharge of the Big Horn River at Hardin, Montana, about 30 miles above the junction with the Yellowstone, was 2,774,000 acre feet or 134 acre feet per square mile. The amount of runoff per square mile varies greatly in different parts of the Big Horn drainage basin. For the section above Thermopolis, a long-time average record (1914-1933) shows an annual runoff of 183 acre feet per square mile. During the five-year period, 1929-1933, the average was 150 acre feet per square mile. Between Thermopolis and Kane the five-year average for the same period was 75 acre feet per square

mile, while the average between Kane and Hardin was 200 acre feet per square mile. The upper section includes the Shoshone River which is fed from the snow fields of the high mountains in the eastern part of Yellowstone Park.

The irrigable area in existing enterprises of the Big Horn basin totals 600,618 acres of which according to the 1930 census, only 43,319 acres or 7.2 per cent are in Montana. Judging by the large volume of water which the Big Horn pours into the Yellowstone each year, there are possibilities of expanding the use of this stream in Montana.

The Tongue River (7) rises in the Big Horn National Forest in Sheridan County, Wyoming, and flows in a northeasterly direction about 175 miles to its junction with the Yellowstone near Miles City, Montana. Most of the Tongue River watershed lies at a comparatively low elevation with the few tributaries fed from snow banks or springs to maintain its flow. Its water supply comes from the melting of fairly light snows during the spring months and from the torrential rains which occur during the summer. Because of these conditions it may vary from almost a raging flood in May and early June to practically no flow in August and September and may be dry all winter.

No records are available giving the total flow emptied into the Yellowstone River, but an eight-year record (1928-1935 inclusive) at Decker, Montana shows an average flow of 251,000 acre feet during the growing season from April 1 to September 30. This is over 155 acre feet per square mile, equivalent to an average depth of 2.9 inches over the drainage basin of 1,610 square miles above Decker, Montana.

Diversions from the Tongue River and its tributaries supply water for 159,980 acres of land of which 13,303 acres or 8.3 per cent are located in Montana. If water of the Tongue River were controlled by reservoirs capable of storing the flood water which is now carried away during May and June this water could be used in growing crops during July and August. Along its course there are thousands of acres of land level enough to irrigate. The nature of the flow, as well as the topography, does not favor hydro-electric power development.

Powder River (7) is formed by the junction of South Fork, Middle Fork and North Fork near the south central part of Johnson County, Wyoming and flows northwest and north about 310 miles

to its confluence with the Yellowstone River near Terry, Montana. The characteristics of the Powder River drainage basin are much the same as for the Tongue River. It, too, is fed by melting snow of early spring and by the heavy rains which sometimes occur in the form of cloudbursts and thunderstorms. This makes the flow uncertain and variable rather than steady and continuous, which would be the case if the supply were derived from large slowly melting snow fields of high watersheds similar to those of the western part of the state.

Records are not available for the flow of the Powder River into the Yellowstone, but measurements made during 1928-1935 inclusive, at Arvada, Wyoming, show a runoff of 171,825 acre feet from April 1 to September 30. This amounts to 28 acre feet per square mile for the 6,050 square miles of drainage basin above Arvada. This is a smaller unit runoff than occurs in the Tongue River basin, but it represents an area nearly four times as large as that of the Tongue with a larger percentage at the lower elevations. Annual records from 1919 to 1933—part of which are interpolations—show an average of 41.6 acre feet per square mile of drainage.

The Powder River and its tributaries supply water for 165,195 acres of irrigated land, of which 1,444 acres or less than one per cent, are located in Montana. There are thousands of acres of land bordering the Powder River in Montana, which could be irrigated if the flood waters were regulated and controlled so as to make them available when needed.

LITTLE MISSOURI

The Little Missouri River (8) rises in Crook County, Wyoming, and flows north and east through Carter County, Montana; Harding County, South Dakota; and Bowman, Slope, Golden Valley, Billings, and McKenzie counties in North Dakota, joining the Missouri near Elbowoods, North Dakota, about 560 miles from its source. It drains an area of 9,500 square miles, of which about 3,440 square miles or 36.2 per cent lie in Montana. The entire drainage basin is a rolling plain with no high mountains to hold the snow and delay its rapid melting. Little of the water soaks into the ground as generally the soil is heavy and absorbs water very slowly. Thus the proportion of runoff is large.

The flow varies from nothing to as much as 5,000 second feet

at Alzada and 33,700 second feet at Medora, North Dakota. This occurs in a series of peaks rather than a steady flow. There is generally a high peak in March or April from the melting snows, and a second peak, usually the highest, from the spring rains during the first part of June. Less pronounced peaks may occur for a day or two during each of the summer months with a prominent one following the equinoctial rains in September. Clearly such an erratic flow does not favor economical use for irrigation.

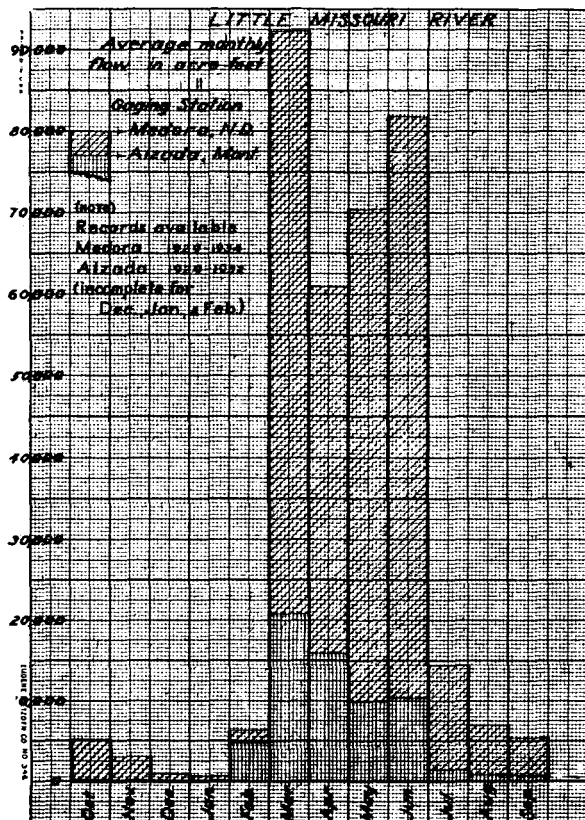


Figure 3. Little Missouri River—Average monthly flow in acre feet.

The mean annual runoff at Medora amounts to about 441,000 acre feet or 70 acre feet per square mile of drainage basin. The runoff from that part of the Little Missouri drainage basin located in Montana is slightly less than the average for the entire basin.

Records available for the growing season show a runoff of 72 acre feet per square mile above Alzada and 49 acre feet per square mile for the section between Alzada and Medora.

The Little Missouri has little value for irrigation by direct diversion because of its erratic flow. It is estimated that only about 2,102 acres are irrigated by its waters, of which 1,462 acres are in Montana and 640 acres in South Dakota. Future development along this stream is limited by the water supply, the complete control of which would be very expensive due to the large reservoir capacity needed to care for peak floods and provide a reserve supply for any extremely dry years.

In this drainage basin as on all streams in eastern Montana, *silt* is a factor to consider very seriously in connection with any storage development. Hundreds of tons of soil are washed annually from each square mile of the drainage basins in this part of the state. Such large volumes of silt would rapidly fill storage reservoirs.

Estimates based on observations at Glendive by the Army Engineers during 1929-1931, show that the Yellowstone River during a period of 789 days carried 832 tons of silt for each square mile of drainage area. This is equivalent to 385 tons per year from each square mile drained by the Yellowstone above Glendive, or more than one-half ton per acre. The silt content varies greatly with the season and from year to year. A 437 day period of observation between September 1919, and November 1930, showed an average load of 484 tons of silt per square mile, which is at the rate of 405 tons per year per square mile of drainage basin. About one-half of the silt load carried by the Yellowstone comes from the Big Horn River. It has been estimated that the silt discharge per square mile of drainage from the Big Horn is one and one-half times as great as that of the Yellowstone at Glendive. Data are not available for the Tongue and Powder rivers, but it is believed that their silt problem is equally serious.

Observations on the Little Missouri at Medora indicate that about 469 tons of silt per square mile of drainage area are being transported to the Missouri River. This amounts to 1,610,000 tons from the corner of Montana drained by this stream.

THE COLUMBIA DRAINAGE

Clark's Fork of the Columbia (9), the largest stream in western Montana, rises near Butte and flows north and north-

west for 136 miles to Missoula. Thence it flows west and north-west to St. Regis where it swings northeast 26 miles to its confluence with the Flathead River. From this point its course is north-west into Idaho. With its tributaries it drains about 22,000 square miles in Montana.

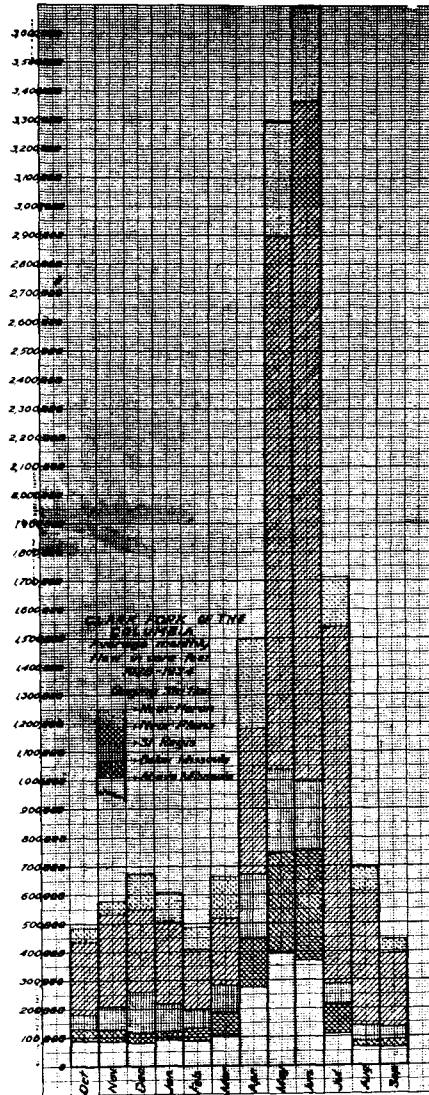


Figure 4. Clark's Fork of the Columbia—Average monthly flow in acre feet.

The Clark's Fork watershed is rough and mountainous and lies between main ranges of the Bitterroot and the Rocky Mountains which rise to elevations of 7,000 to 9,000 feet.

The watershed drains the western slope of the Continental Divide and has a high runoff. The precipitation is much greater than it is to the east of the Divide. Moreover, much of this comes as snow and accumulates at high elevations, melting gradually in the spring and early summer.

The average flow of Clark's Fork of the Columbia River at Heron, Montana, four miles above the Idaho boundary, is 23,000 second feet or 8,000,000 acre feet annually. The total drainage area above this point is 21,900 square miles which gives a runoff of 383 acre feet per square mile as compared with 145 acre feet per square mile for the Yellowstone and 65 acre feet per square mile for the Missouri on the east of the Continental Divide. When corrections are made for the diversions for irrigation and the return flow of the Clark's Fork of the Columbia, the average annual runoff is 8,676,000 acre feet or 396 acre feet per square mile.

Clark's Fork of the Columbia offers many possibilities for the development of both power and irrigation. A hydro-electric power plant with a total capacity of 35,000 kilowatts, located at Thompson Falls, is the only one on this stream at the present. Another plant is under construction on the Flathead River near Polson which, when completed, will have a capacity of 168,000 kilowatts. Numerous other power sites exist, awaiting only a sufficient demand for power to justify their development.

The Bitterroot River rises between the Bitterroot and the Sapphire mountains and flows north through the Bitterroot Valley to its junction with Clark's Fork seven miles west of Missoula. A three-year runoff record at Grantsdale for the years 1903, 1904, and 1905, gives an average of 901,139 acre feet passing this point, or 580 acre feet per square mile. During 1904 measurements made at Missoula showed 1,498,070 acre feet as compared with 1,068,545 acre feet at Grantsdale for the same year—an increase of 529,525 acre feet between the two points. This is equal to 310 acre feet per square mile for the tributary drainage between the points of measurement. There are 89,762 acres of irrigated land in the valleys which derive their water supply from the Bitterroot and its tributaries. This is 34 per cent of all the land irrigated from Clark's Fork of the Columbia in Montana.

The Blackfoot River rises in the Missoula National Forest and flows west through Powell and Missoula counties, joining Clark's Fork of the Columbia a few miles above Missoula. The records during 1904 and 1905 for the Blackfoot River at Bonner show a runoff amounting to 868,973 acre feet or 352 acre feet per square mile. Waters from the Blackfoot irrigate 32,435 acres of land or about 12.8 per cent of the area irrigated from Clark's Fork of the Columbia in Montana.

The Flathead River is formed by the junction of North Fork, which rises in British Columbia, and of the Middle Fork and South Fork, which rise in the Glacier Park Mountains. The junction takes place near Columbia Falls east of Kalispell; from here it flows generally south through Flathead and Lake counties to its confluence with Clark's Fork at Paradise. Its tributary streams are fed by melting snows at high elevations. Thus the flow is fairly high and uniform throughout the season except for a high peak flow which occurs during the latter part of May and early June, when the snow is leaving the valleys and foothills, and is augmented by the rainy season occurring during this same time.

The runoff from the Flathead River is larger than that of either the Bitterroot or the Blackfoot. A long record at Columbia Falls, covering a drainage area of 1,640 square miles, gives an average runoff amounting to 1,200,000 acre feet or 733 acre feet per square mile. At Polson, above which the drainage area is 7,010 square miles, the runoff has been increased by tributary drainage to 4,280,000 acre feet. This is equal to 610 acre feet per square mile for the entire area. As with the Bitterroot and Blackfoot rivers, the highest parts of the watershed contribute the greatest proportion of the water.

There are 50,787 acres of land irrigated from the Flathead River, or 19.4 per cent of the land irrigated from Clark's Fork of the Columbia in Montana. The three main tributaries; viz, the Bitterroot, the Blackfoot, and the Flathead, supply 66.2 per cent of the water used for irrigation along Clark's Fork, leaving 33.8 per cent to be supplied from the main stream and minor tributaries.

The Kootenai River flows through the heavily timbered mountains in the northwest corner of Montana and drains 3,825 square miles in this state. The valley of the Kootenai is narrow and

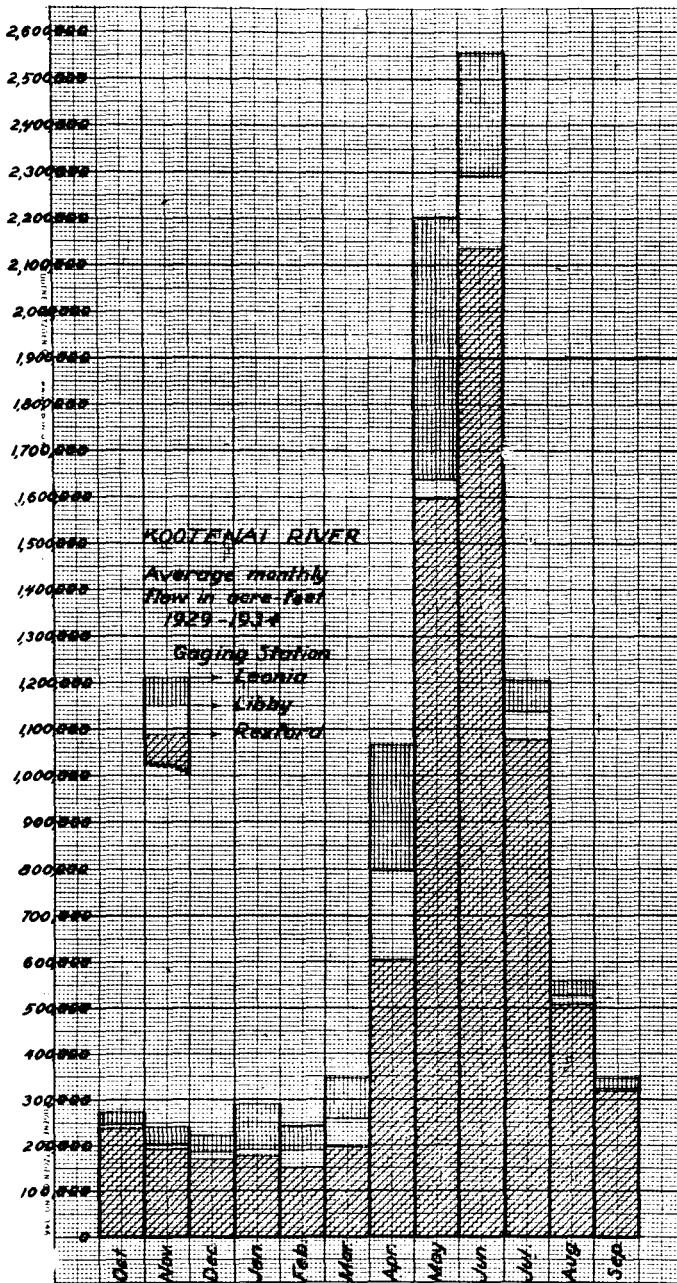


Figure 5. Kootenai River—Average monthly flow in acre feet.

is flanked by mountains which rise to elevations of 5,000 and 7,000 feet.

The annual runoff is high when compared with other streams in the state. At Rexford, soon after entering Montana, there is an annual discharge of nearly 7,000,000 acre feet or 831 acre feet per square mile of drainage area. At Libby the volume has been increased by 780,000 acre feet, making it 7,780,000 acre feet annually or 708 acre feet per square mile. The water of the Kootenai

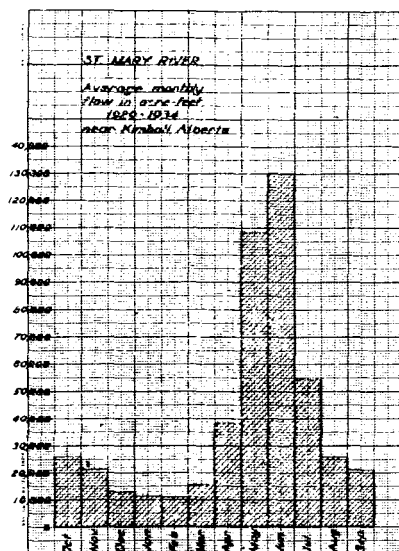


Figure 6. St. Mary's River—Average monthly flow in acre feet, 1924-1934.

is used probably less than that of any other Montana stream. Only 7,590 acres of land are now irrigated from its water and there are no hydro-electric power plants along its course.

HUDSON BAY DRAINAGE

The *St. Mary River* drains approximately 200 square miles of high mountainous country in the northern part of Montana, flowing northward through Canada into the Hudson Bay. This watershed, though small, yields a relatively large volume of water because of the heavy accumulation of snow on the high mountains. The mean flow at Kimball, Alberta, Canada, near where the river leaves Montana, is 441,600 acre feet. About 122,900 acre feet of this, or 27.6 per cent based on a fifteen-year average, is diverted

TABLE 4.—RUNOFF PER SQUARE MILE FROM MONTANA WATERSHEDS.

Name of stream	Gaging station	Tributary to	Area in sq. mi.	Runoff in ac. ft. per sq. mi.
Jefferson River	Three Forks	Missouri	9,520	172
Madison River	Three Forks	"	2,520	420
Gallatin River	Logan	"	1,840	375
Smith River	Truly	"	2,000	80
Sun River	Sun River	"	2,300	398
Marias River	Mouth	"	9,160	85
Judith River	Winifred	"	2,750	125
Musselshell River	Mosby	"	9,570	25
Milk River	Glasgow	"	8,279 in U. S.	27
Yellowstone River	Intake	"	68,000	198
Big Horn River	Hardin	Yellowstone	20,000	126
Tongue River	Decker, Wyo.	"	1,615	186*
Powder River	Arvada	"	6,080	46
Little Mo. River	Medora, N. D.	Missouri	10,000	44
Clark Fork River	Heron	Columbia	21,900	383
Bitterroot River	Missoula	Clark Fork	1,500	580
Blackfoot River	Bonner	" "	2,460	352
Flathead River	Columbia Falls	" "	1,365	733
Flathead River	Polson	" "	7,040	610

*For irrigation season.

near Babb through the St. Mary Canal into the Milk River for use in irrigating land in the Milk River Valley. The runoff from the St. Mary watershed averages over 2,208 acre feet per square mile, which is equal to an average depth of 41 inches. This is the highest runoff from any watershed in Montana. Diversion of water from a watershed with a surplus to another where the water supply is deficient is desirable where land suitable for irrigation is available. Table 4 gives a general summary of the area of these various watersheds and shows the variation in runoff per square mile for the different areas.

WATER AVAILABLE FOR USE

The statement that 36,000,000 acre feet of water flow out of Montana annually does not give a complete picture of the usable water supply. Indeed, such a statement may give an erroneous impression in regard to the abundance of the waters of the state and lead one to think that the 36,000,000 acre feet of water represents a surplus over and above the present needs, or that this vast amount of water is available for use and simply awaits the construction of diversion dams and canals to put it to use for irrigation or for the generation of power. To evaluate the water resources of the state, the time and the place that water is available is as important as the amount of supply. The geographical distribution of the waters of the state varies widely. This may be seen

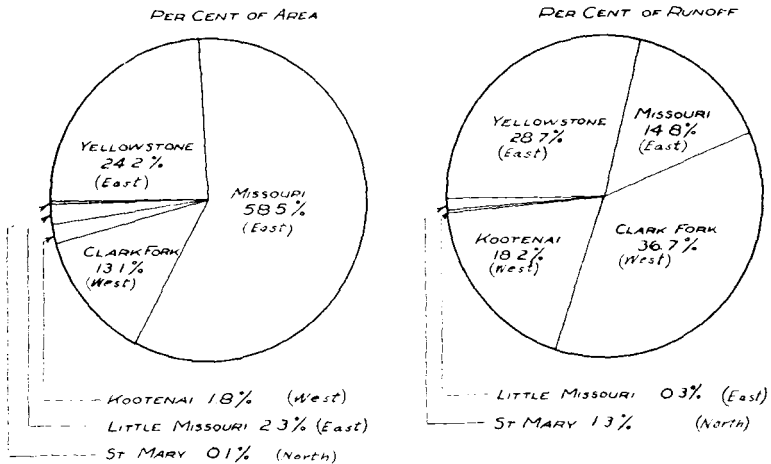
DRAINAGE BASINS AND RUNOFF IN MONTANA

Figure 7.

from figure 7 which shows graphically the amount of water drained from the principal watersheds of the state. It will be noted that the eastern drainage, which represents 85 per cent of the area of the state, yields only 43.8 per cent of the water; the western slope, which comprises 14.9 per cent of the state, yields 54.9 per cent of the total water; and the Hudson Bay drainage, which covers only .1 per cent of the state, yields 1.3 per cent of the water leaving the state annually.

SEASONAL FLUCTUATION IN STREAM FLOW

The seasonal fluctuation in stream flow varies even more than the regional, and from the standpoint of use, this is very important. Approximately 40 per cent of the runoff occurs between October 1 and April 1. Thus, about 14,400,000 acre feet (approximately 10,000,000 of which originates in Montana) flows out during the fall and winter months when it cannot be used for irrigation. This leaves only 21,600,000 acre feet (15,354,000 of which originates in Montana) to flow out during the growing season. See table 5.

It is fortunate that the season of maximum flow coincides with the growing season because this increases the possibility of its use. There is, however, a variability in the monthly runoff. The flow is fairly constant during fall and winter but in March

TABLE 5.—RUNOFF FROM MONTANA WATERSHEDS DURING IRRIGATION SEASON,*
APRIL 1—SEPTEMBER 30, 1929-33

River	Station	Total—acre feet			Water originating in Montana which leaves the state—acre feet		
		Aver.	Max. (1933)	Min. (1931)	Aver.	Max. (1933)	Min. (1931)
Missouri	Williston, N. D. (Yellowstone deducted)	2,642,800	3,411,000	1,266,000	2,503,800	3,256,300	1,145,400
Milk River	Eastern Crossing	185,590	213,100	140,640	0	0	0
N. F. of Milk	Near Boundary	131,310	150,860	99,190	0	0	0
S. F. of Milk	Near Boundary	28,280	33,526	7,263	0	0	0
Milk River	At Vandalia	163,806	227,000	5,594	100,896	116,108	0
Yellowstone	Intake, Montana	4,947,000	5,300,000	3,165,000	2,126,950	2,172,480	1,126,170
Powder	Moorhead, Montana	220,826	319,250	121,370	0	0	0
Tongue	Decker, Montana	230,480	305,020	123,960	0	0	0
Big Horn	Kane, Wyoming	1,070,100	1,275,000	851,800	0	0	0
Yellowstone	Corwin Springs	1,298,640	1,228,500	941,700	0	0	0
Clarks Fork	Heron, Montana	9,344,000	13,880,000	5,864,000	8,912,580	13,257,000	5,607,800
N. F. of Flathead	Trail Creek, Montana	431,420	623,100	256,200	0	0	0
Kootenai	Leonia, Idaho	6,268,600	8,706,000	4,138,000	1,215,800	1,956,000	737,000
Kootenai	Rexford, Montana	5,052,800	6,750,000	3,401,000	0	0	0
Little Missouri	Medora, N. D.	204,860	200,740	62,650	182,560	184,140	99,710
Little Missouri	Alzada, Montana	22,300	16,600 ^b	2,940	0	0	0
St. Marys	Kimball, Alberta	311,740	409,900	211,200	311,740	409,900	211,200
					15,354,326	21,351,928	8,887,280

*Data from Water Supply Papers, U. S. Geological Survey.

^bEstimated from flow at Medora, North Dakota.

there is usually an increase caused by the melting snow and the spring rains in the lowers valleys. This rise continues during April, May and June.

TABLE 6.—DISTRIBUTION OF RUNOFF DURING THE IRRIGATION SEASON PER CENT OF TOTAL FOR SEASON

A—Streams east of the Continental Divide						
Name of stream	April	May	June	July	August	September
Missouri	13.8	20.2	34.8	16.1	7.9	6.9
Yellowstone	9.7	19.6	38.6	16.7	8.3	7.0
Mean	11.7	19.9	36.7	16.4	8.1	6.9
B—Streams west of the Continental Divide						
Clarks Fork of the Columbia	10.0	27.6	35.3	16.5	6.5	4.1
Kootenai	9.1	25.9	36.0	16.3	7.6	5.2
Mean	9.5	26.7	35.6	16.4	7.1	4.6

Again during the summer months extreme variations occur. For example, 56.6 per cent of the total summer runoff east of the Continental Divide occurs during May and June, and west of the Divide 62.3 per cent of the total summer runoff occurs during these same two months. Neither the demand for irrigation nor for power can conform to this uneven distribution of supply.

The distribution of runoff during the six-months growing season is given in table 6. It shows that in general the monthly distribution is practically the same on both sides of the Divide

TABLE 7.—DISTRIBUTION OF THE DEMAND FOR IRRIGATION WATER IN PER CENT OF SEASONAL USE.

A—Projects east of the Continental Divide						
Name of stream	April	May	June	July	August	September
Valier	0	10.6	25.0	45.5	16.9	2.0
Sun River— Fort Shaw Division	0	13.2	28	34.2	21.4	3.2
Sun River— Greenfield Division	0	10.5	24.5	52.5	11	1.5
Lower Yellowstone .....	.1	14.2	14.4	30.4	29	11.9
Huntley .....	.1	15.1	17.8	33	25.5	8.5
Milk River	2.3	21.2	19.7	33.4	18.3	5.1
Mean .....	.413	14.13	21.56	38.16	20.35	5.36
B—Projects west of the Continental Divide						
Flathead Project						
Camas Division .....	.2	22.5	22.5	30.5	19.5	4.8
Jocko Division .....	.1	18.1	25.0	26.8	23.3	6.7
Mission Division .....	.0	19.2	22.9	34.7	18.6	4.6
Bitterroot Project	5.5	17.9	23.7	23.4	20.0	9.5
Ravalli Irrigation District	4.5	20.5	24.1	21.4	17.5	12.0
Mean	2.06	19.64	23.64	27.36	19.78	7.52

except for the month of May, when there is almost a 7 per cent greater proportion of the summer flow west of the Divide than to the east. In other words, the high water peak occurs about 10 to 15 days earlier on the west than it does on the east of the Divide. The relative demand for irrigation water for the several months of the growing season for projects both east and west of the Continental Divide is given in table 7. In general, the peak demand for irrigation also occurs a few days earlier on the west of the Divide than on the east. Where storage reservoirs have been built however, the peak use for the water occurs later in the season than when the natural flow of the stream is depended on.

For instance on the Valier Project, the Greefields division of the Sun River Project, and the Mission division of the Flathead Project, each of which has a reservoir to regulate the stream flow, the peak demand for July is much higher than is the July demand on those projects depending solely on the natural flow of the stream.

How the natural stream flow fits the demand for irrigation water is shown in table 8 and illustrated in figure 8. This table and this figure are based on the average monthly demand for

TABLE 8.—PER CENT OF NATURAL FLOW WHICH CAN BE DEVELOPED FOR IRRIGATION WITHOUT REGULATION THROUGH STORAGE*

Month	East of the Divide					
	Supply		Demand		Use	
	Per cent of seasonal use	No. of feet	Per cent of seasonal use	No. of feet	Based on supply available acre feet	Based on full supply acre feet
April	11.7	117	.5	5	5	2
May	20.0	200	14.2	142	142	58
June	36.7	367	21.4	214	214	87
July	16.5	165	37.6	376	165	152
August	8.2	82	20.2	202	82	82
September	6.9	69	6.1	61	61	25
Total	100.0	1000	100.0	1000	669	406
Month	West of the Divide					
	Per cent of seasonal use	No. of feet	Per cent of seasonal use	No. of feet	Based on supply available acre feet	Based on full supply acre feet
	Per cent of seasonal use	No. of feet	Per cent of seasonal use	No. of feet	Based on supply available acre feet	Based on full supply acre feet
April	9.5	95	1.7	17	17	7
May	26.7	267	19.5	195	195	71
June	35.6	356	23.5	235	235	86
July	16.4	164	27.2	272	164	99
August	7.2	72	19.7	197	71	71
September	4.6	46	7.9	79	46	29
Total	100.0	1000	99.5	995	728	363

*On the basis of 1000 acre feet of water available during the growing season as given in columns 2 and 3, the amount used is given in columns 6 and 7 according to demand distribution given in column 5.

water and on the assumption that 500 acres of land can be irrigated; and that 1,000 acre feet of water are available during the irrigation season.

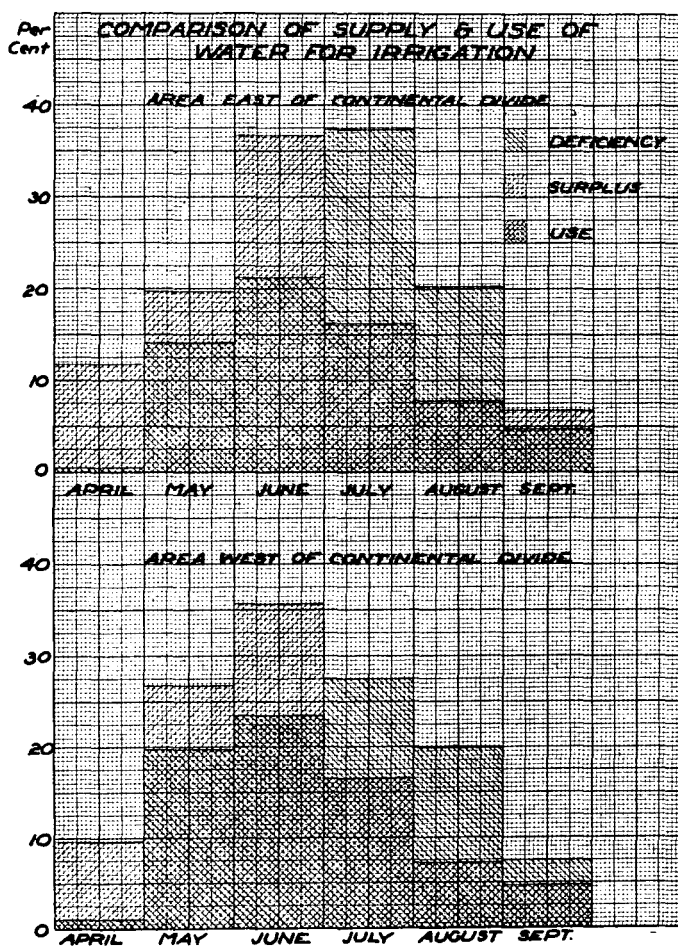


Figure 8.

With the problem before us two alternatives are possible: (1) put all the land in cultivation and irrigate all the land that the water supply makes possible during each month of the year, or (2) cultivate only the area of land which can be irrigated adequately during the critical months of the growing season.

With the first plan in use in the area to the east of the Divide,

5 acre feet of water would be used in April whereas 117 acre feet are available; only 142 acre feet would be needed in May although 200 acre feet are available; and 214 acre feet would be used in June although 367 acre feet would be available. In July, however, only 165 acre feet could be used (that being the total available supply), although 376 acre feet were needed, and so on through August and September with the available supply insufficient to meet the needs. The net result would be that during the latter part of the season the irrigated lands would suffer a water shortage of 331 acre feet while earlier in the season a like amount of water had been wasted. In other words only 67 per cent of the available supply could be used beneficially and 33 per cent of the water would serve no useful purpose, because of not being available when needed.

Water would be available only for early crops such as first cuttings of alfalfa, grain, hay, and perhaps certain other early ripening crops. In column 5, table 6, it is seen that August is the month of low water. Therefore, if only enough land were irrigated to give a full water supply during August, the amount used during other months would be reduced as shown in column 6, table 8 which gives a total use of 406 acre feet or only 40.6 per cent of the total available from the seasonal runoff. This analysis shows that only a small part of the water supply of the state can be used to best advantage for irrigation without regulation of flow through construction of storage reservoirs.

Only 60 per cent of the runoff occurs during the growing season and if only 40 per cent of this is available as needed from the natural flow, than only 24 per cent of the annual supply can be considered available for irrigation without regulation through storage. Physical limitations such as engineering problems and availability of tillable land contiguous to the water supply limit still further the extent to which the natural flow of a stream can be used for irrigation. There is also a large annual variation in the stream flow as well as monthly variations, and this makes it necessary to restrict still further the area for which a dependable full water supply is assured during low water years. Thus, of the 36,000,000 acre feet of water which flow out of the state, perhaps not over 5,000,000 or 6,000,000 acre feet are available for use without regulation of the flow.

Low water years, as well as low water months, are controlling

TABLE 9.—AREA IRRIGATED BY DRAINAGE BASIN, 1919 AND 1929 (1)

	Area irrigated			Area enterprises were capable of supplying with water, 1930	Irrigable area in enterprises, 1930
	1929	1919	Increase	1930	1930
	Acres	Acres	Per cent	Acres	Acres
Total	1,594,912	1,681,729	-5.2	2,276,000	2,622,423
Missouri River and					
Tributaries	1,324,486	1,389,763	-4.7	1,871,958	2,188,247
Missouri River direct	17,069	15,635	9.2	18,234	19,924
Jefferson River and					
tributaries	363,380	425,685	-14.6	403,325	476,421
Jefferson River					
direct	16,393	21,276	-23.0	18,940	19,882
Beaverhead River	131,354	145,673	-9.8	142,333	155,916
Big Hole River	146,736	184,655	-20.5	162,503	166,846
Ruby River	31,071	34,474	-9.9	33,526	36,901
Other tributaries	37,826	36,607	-4.5	46,023	96,876
Madison River	30,368	34,425	-11.8	37,004	46,339
Gallatin River	93,753	95,063	-1.4	114,408	120,321
Smith River	25,461	16,861	51.0	31,259	31,389
Sun River	28,070	31,785	-11.7	67,566	121,277
Teton River	46,974	44,945	4.5	66,799	67,699
Marias River	55,360	63,758	-13.2	99,924	101,814
Judith River	7,435	15,173	-51.0	13,075	14,603
Musselshell River	59,286	45,559	30.1	84,738	96,570
Milk River and					
tributaries	88,218	108,555	-18.7	190,218	216,998
Milk River direct	55,499	19,766	180.8	148,661	169,716
Snake River	60	910	-93.4	160	160
Other tributaries	32,659	87,879	-62.8	41,397	47,122
Yellowstone River and					
tributaries	434,550	440,354	-1.3	613,707	651,065
Yellowstone River					
direct	162,312	189,453	-14.3	236,401	242,693
Boulder River	11,309	—	—	12,479	12,981
Shields River	32,866	25,940	26.7	49,462	59,517
Stillwater River	22,162	23,926	-7.4	31,087	32,327
Clark Fork	86,310	68,839	25.4	100,548	102,285
Big Horn River	43,319	51,103	-15.2	77,447	87,171
Tongue River	13,303	11,170	19.1	18,497	18,604
Powder River	1,144	728	57.1	1,217	1,672
Other tributaries	61,825	69,195	-10.6	86,569	93,915
Little Missouri					
River	1,462	380	284.7	1,962	2,127
Other tributaries of					
Missouri River	73,100	51,585	41.7	129,739	221,700
Tributaries of					
Columbia River	270,426	291,966	-7.4	404,042	434,176
Clark Fork and					
tributaries	262,836	285,984	-8.1	394,610	423,846
Clark Fork direct	12,771	5,432	135.1	15,417	16,919
Big Blackfoot River	32,435	40,604	-29.1	43,572	45,246
Bitterroot River	89,762	112,622	-20.3	109,782	114,631
Flathead River	50,787	44,333	14.6	128,588	143,787
Other tributaries	77,081	82,993	-7.1	97,251	103,263
Kootenai River	7,590	5,982	26.9	9,432	10,330

A minus sign (-) denotes decrease. Per cent not shown when more than 1,000.

factors in planning the use of a stream for irrigation. Low water years are generally coincident with years of low rainfall. These are the times when water for irrigation is most badly needed. A water shortage at such a time has the same effect as a severe drouth. But if the 76 per cent of the yearly runoff which is lost during periods of non-use were stored in reservoirs and released as needed, irrigated lands would in most cases be adequately supplied.

WATER USED AT PRESENT TIME FOR IRRIGATION

The area irrigated from the various streams in the state is shown in table 9. Only the principal streams and tributaries are listed, the minor tributaries being included with the larger streams. The table shows the increase or decrease for each stream between the years 1919 and 1929. Comparison is also made between the area the enterprises were capable of supplying with water, and the irrigable^a area in the enterprises. It is significant to note that the area which the enterprises were capable of supplying is less than the irrigable area under the ditch and also that the area actually irrigated was still less. However, the comparison between the area enterprises were capable of supplying with water and the irrigated area, is likely to give an erroneous idea as to the adequacy of the supply, because the capability of supplying water is measured on the basis of length and capacity of ditches constructed and land which can be served from these ditches, and upon the so-called normal flow, rather than upon a dependable water supply. The so-called "normal flow" seldom, if ever, occurs and the nature of the term itself implies that below normal conditions occur half of the time. For example, in 1930 it was necessary because of water shortage to appoint a water commissioner on the Gallatin River on July 1, and on that date water was cut off from all water rights of later priority than 1889. This represents 53 per cent of the water

^aDefinitions for headings in table 9: Area irrigated, 1929, is the acreage to which water was applied in the season of 1929. It takes no account of sufficiency of the irrigation.

Irrigable area represents the extent of the plans of those controlling the enterprises.

Area enterprises were capable of supplying with water represents the area which the constructed works and control and "normally" available water supply could serve. (Fifteenth Census of the United States).

rights on the river, so it is evident that the irrigated lands depending upon the Gallatin River for water received only a partial supply during the season of 1930. This is true of many other streams in the state.

The lands classed as irrigated for tax purposes are distributed according to counties as shown in figure 9. On this map is shown the relative amount of tillable land in relation to the total. It also shows the importance which irrigation bears to agriculture in the various parts of the state. In the eastern counties the tillable land occupies a large part in proportion to the total area, while irrigation appears to be unimportant. Several counties have no land taxed as irrigated. In the west the situation is different, there being three counties, Ravalli, Granite, and Jefferson, where farming appears to be entirely dependent upon irrigation.

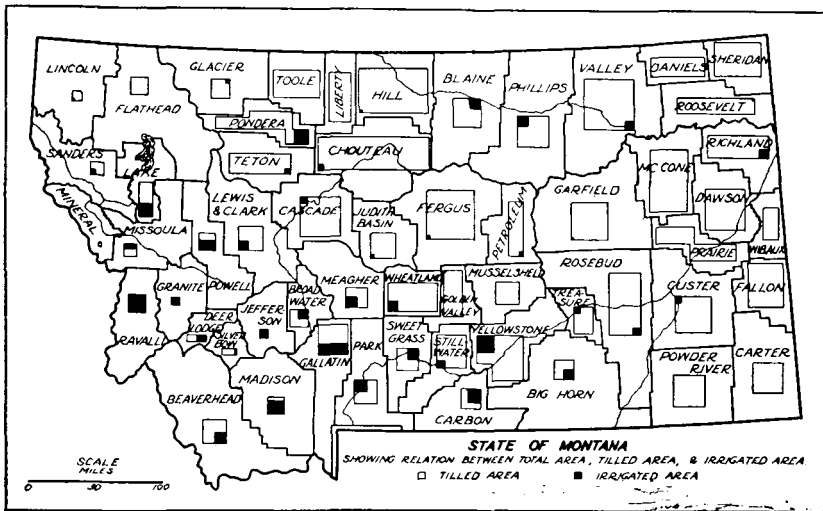


Figure 9.

WATER DIVERTED FOR IRRIGATION

The 1930 United States Census Report gives the irrigated area for Montana as 1,594,912 acres. It also states that 4.3 acre feet of water were diverted for each acre of land irrigated during 1929, based on data obtained from an irrigated area of 516,637 acres. On this basis the total irrigated area in the state required the

diversion of 6,850,000 acre feet of water. As shown in table 1, this is less than one-fifth as much as that which leaves the state annually and less than one-half as much as the amount which originates in and leaves the state during the growing season. It is evident, therefore that our water resources offer possibilities for considerable development

TABLE 10.—RELATION OF IRRIGATION WATER DIVERTED FROM SOURCE TO AMOUNT DELIVERED TO FARM

Item	Averages ^a		Measured ^b		Not measured ^c	
	1929	1919	1929	1919	1929	1919
Number of acres irrigated per sec. ft. diverted	57	35	62	42	52	29
Average amount diverted—acre feet per acre	4.3	5.5	3.2	4.2	5.2	7.2
Average amount delivered to farms—acre feet per acre	1.7	3.3	1.6	2.3	1.8	5.1
Conveyance and delivery loss—acre feet per acre	2.6	2.2	1.6	1.9	3.4	2.1
Conveyance and delivery loss—per cent	60.5	40	50	45	65.5	29

^aThese averages cover all irrigation canals in the state.

^bFigures under Measured apply to canals where measuring devices are used.

^cFigures not measured are estimates as no measuring devices were installed on these canals.

OPERATION AND DELIVERY LOSSES OF WATER

Much of the water diverted for irrigation is lost through seepage and evaporation before it reaches the farm. According to table 10 the average amount of water delivered per farm in 1929, was 1.7 acre feet per acre which is slightly less than 40 per cent of the amount diverted, indicating conveyance losses of about 60.5 per cent. When located under canals where the water delivered is measured, the land received about 50 per cent of the amount diverted, but lands located under ditches with no delivery measurement received only 34.5 per cent of the amount diverted. Such high conveyance losses indicate a waste of water. Conveyance and delivery losses are caused by (1) excessive seepage in porous sections of canals, (2) transpiration losses from weeds and willows, (3) overflowing because of ditches being choked with weeds and silt (4) leaky headgates, and (5) the practice in some areas of irrigating only during daylight, thus wasting the water for several hours of each day.

Conveyance losses could be very much reduced by proper care and treatment of canals and ditches. Lining with cement is

expensive, but a careful study might show that the value of the water saved would offset the cost of lining or improving the canal. The lining of the canal however, would prevent seepage losses, prevent water-logging of valuable land, and avoid possible drainage costs which would in a large measure also offset the cost of canal lining and canal improvement. Other types of treatment such as oil, and artificial silting have been successfully used and are generally less expensive than concrete. The figures given in table 10 show that considerable improvement in the ditches was accomplished during the ten-year period between 1919 and 1929, and the seepage losses from the canals much reduced.

WATER USED FOR POWER

The rivers and streams of Montana operate 11 hydro-electric power plants, having a total capacity of 296,000 kilowatts or 393,000 horsepower. In addition there are a number of small municipal and private plants with a capacity of about 3,000 kilowatts, making a total of 299,310 kilowatts, as shown in table 11.

Hydro-electric power depends on the two factors, viz, head and volume of water. With a combined head on all existing plants of around 1,720 feet, it is estimated that they are equipped to use between 2,300,000 and 2,500,000 acre feet of water annually.

The rate at which the water is available is equally as important in the production of power as it is for the irrigation of growing crops. It is impossible to convert a fluctuating stream flow

TABLE 11.—EXISTING POWER DEVELOPMENT ON STREAMS IN MONTANA

Name of stream		Location	Head	Capacity
			Feet	Kilowatts
Missouri	River	Canyon Ferry near Helena	38	7,500
"	"	Hauser Lake near Helena	66	18,000
"	"	Holter Lake near Wolf Creek	109	50,000
"	"	Black Eagle near Great Falls	52	19,500
"	"	Rainbow near Great Falls	116	35,600
"	"	Volta near Great Falls	153	60,000
"	"	Morony near Great Falls	86	45,000
Madison	River	Madison No. 1	—	2,000
"	"	Madison No. 2	122.5	10,000
Blaine Spring	Creek	Virginia City	—	450
Yellowstone	River	Mystic Lake, Alpine	1,050	12,500
"	"	Yellowstone Park (Govt. Plant)	310	360
Clarks Fork	of Columbia	Thompson Falls	50	35,000
Black	Foot	Mill Town	28.7	3,400
			2181.2	299,310

into a steady electric current, except by first regulating the flow of the stream. For this reason regulating reservoirs are build in connection with hydro-electric power plants wherever possible. in order that the entire available flow be used to the best advantage. The average output in kilowatts for the several plants is shown in figure 10. Note that the average output of the 9 largest plants is fairly uniform except for a slight depression during the summer months. The wide fluctuation between individual plants, caused principally by variations in stream flow, is ironed out by interlocking power lines and by the regulating effect of several reservoirs.

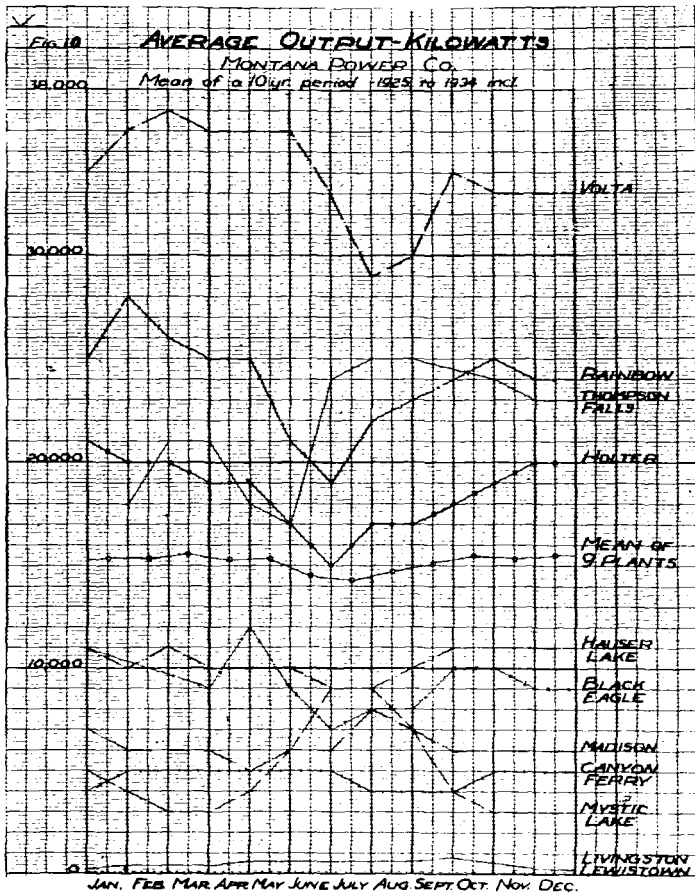


Figure 10.

The comparative value of using water for the generation of electricity or for irrigation depends upon the demand for power as compared with the agricultural development which is possible under irrigation. It is quite generally believed that about \$2.00 per acre or \$1.00 per acre foot represents the average price which farmers can afford to pay for irrigation water for general farm use. If the water is used on fertile, highly productive soil or to grow high value crops, more than this can be paid; but if water is used on gravelly, unproductive soil or where intensive cropping is not possible, the farmer cannot afford to pay so much. Any general statement that the use of water for irrigation should have preference over its use for power should take into consideration the differences in benefits at the point of use.

The value of a given volume of water for the generation of power is proportional to the head or distance through which it falls. Thus, a second foot of water with a fall of 10 feet should develop, theoretically, .846 kilowatts of electricity. Reduced to kilowatt hours, a second foot with a 10-foot fall should produce 20.3 kilowatt hours per day. In practice, however, it is not possible to obtain 100 per cent efficiency, the average being about 80 per cent of the theoretical.

A second foot should, therefore, develop about 16 kilowatt hours of electricity per day with a 10-foot fall or about 160 kilowatt hours per day with a 100-foot fall. A second foot is equal to 1.98 acre feet per day, and on this basis an acre foot of water will generate 8.1 kilowatt hours of electricity with a 10-foot fall or 81 kilowatt hours with a 100-foot fall. A practical example is given in the case of the section of the Missouri River below Three Forks where 7 hydro-electric power plants with a combined effective head of 616 feet are capable of developing 500 kilowatt hours from an acre foot of water.

A power plant is able to use the water 365 days of the year, while its use for irrigation covers only about half of the year. Moreover, the water is most valuable for power development where a high head is available. This condition prevails generally in or near the mountains where there is little or no need for irrigation, while the same water can often be diverted below the power plant and used for irrigation. Under these conditions water can be made to serve several useful purposes. It is important,

therefore, to so plan development that it will serve as many useful purposes as possible. A list of potential power developments is given in the Appendix.

MUNICIPAL USE OF WATER

Water diverted for municipal use in Montana, while very important from the standpoint of need is not so important from the standpoint of amount used because of the small population served.

The use of water for municipal purposes varies with the season as it does for irrigation. July and August are the months of greatest demand. The daily per capita use of water during these 2 months in 1934 for 12 Montana cities varied from 104 gallons at Glasgow to 737 gallons at Missoula. The month of least demand at Glasgow is January when the per capita use is about 40 gallons per day. In Missoula the month of least demand is March, when about 351 gallons per capita per day are used. (See table 12).

These wide variations between the per capita use of water in Montana towns are an index as to the availability of water and its relative cost. Naturally with an abundance of water available at low cost, the tendency is to use it freely, and such use need not always be construed as wasteful. The seemingly excessive use of water may be due to uses beyond ordinary needs, such as flushing the streets and gutters, or to the excessive irrigation of lawns and gardens. To the extent that wasteful use is avoided,

TABLE 12.—MONTHS OF GREATEST DEMAND AND OF LEAST DEMAND FOR CITY WATER IN MONTANA DURING 1934*

City	Greatest demand		Least demand	
	Month	Amt. used per cap. per day Gallons	Month	Amt. used per cap. per day Gallons
Billings	July	242	March	94
Bozeman	July	511	May	198
Butte	August	163	February	103
Choteau	August	383	February	119
Fort Benton	August	490	April	112
Forsyth	July	209	November	41
Glasgow	August	104	January	40
Hardin	July	240	August	77
Havre	July	173	December	61
Kalispell	August	215	January	71.5
Livingston	July	466	January	284
Missoula	July and Aug.	737	March	351

*Data supplied by mayors and city managers of cities listed.

irrigation of lawns and gardens should be encouraged.

From the farm standpoint the amount of water needed for the city supply will be better understood from the fact that a stream of one cubic foot per second will deliver 1.98 acre feet of water or 645,000 gallons in 24 hours. This would supply 645 gallons per capita per day to 1,000 people, which would be rather liberal. The same amount of water used for irrigation is enough to supply a 40 acre field.

RECREATIONAL USE OF WATER

As yet comparatively little work has been done in developing water resources for recreational use, but such value should not be overlooked. It is not possible to state definitely in terms of dollars and cents the recreational value of Montana's rivers, streams, lakes, and reservoirs, but information from the State Fish and Game Commission shows that for fishing alone it amounts to over one and one-half million dollars a year. A letter received from the State Fish and Game Warden states: "The number of fishing licenses sold annually is around 67,837, but as this also includes the bird licenses it is not possible to state accurately just how many of these are purchased for the purpose of fishing only.

"We have no information as to the amount of money spent by fishermen for equipment, travel expense, and hotel accommodations; but it has for some time been agreed that the average fisherman will spend between \$25.00 and \$50.00 per year, which we believe to be a most conservative estimate."

From the sportsman's viewpoint, the water supply is thus a valuable asset to the State, and its conservation and development is fully appreciated by those best qualified to speak on the subject.

UNDEVELOPED WATER RESOURCES IN MONTANA

The record shows that about 36,000,000 acre feet of water flow out of the state annually. Of this amount about 2,740,000 acre feet represent return flow from water diverted for irrigation, and about 2,000,000 acre feet, the amount which has been used to generate hydro-electric power. This leaves a net of 31,460,000 acre feet of water leaving the state without having served a useful purpose for irrigation or power. Some of it has of

course, been useful from the standpoint of the sportsman, but this is an incidental use and would not be seriously jeopardized by other forms of development.

To this measure of the gross undeveloped water resources of Montana, further corrections must be made to allow for unfavorable geographical distribution, and seasonal fluctuations in stream flow, but the latter need to be supported by data based on accurate surveys and measurements.

NEED FOR COMPREHENSIVE SURVEYS

Clearly there is a need that comprehensive surveys be made of all the drainage basins in the state, and there is need for the adoption at an early date of a definite program of extending present surveys to cover the entire state, which would greatly aid in planning for the permanent and successful development of these resources. In the past much time and effort has been wasted on projects which later were found unable to meet successfully the competition from more favorably situated areas. If complete surveys were made these failures could be prevented, and it would be possible to establish an order of preference so that always the most feasible projects could be undertaken regardless of local influences.

A comprehensive survey should give complete information on: (1) topography, (2) soil and vegetative cover, (3) present use, (4) population, (5) public utilities and (6) stream flow. The deficiency of data is greatest under numbers 1, 2, and 6, since the activities of federal and state agencies working in these technical fields have not kept pace with the need for the information. It would seem to be very much worth while that these agencies expand their activities so as to complete these much needed surveys as soon as possible.

IRRIGABLE LANDS IN MONTANA

Various estimates place the undeveloped irrigable lands in Montana at 2,000,000 to 2,500,000 acres. These estimates are unsupported by complete surveys.

Reconnaissance surveys covering 62 irrigation projects are reported in the 308 Army Engineers' reports. (References 2, 3, 4, 5, 6, 7, 8.) These reconnaissance surveys include a total area of 1,726,768 acres. If all these projects were built, the irrigated area

in Montana would be more than doubled. Thirty-eight of the 62 projects involve storage reservoirs, 18 are pumping projects and 6 are diversion and gravity systems. This preponderance of storage projects illustrates the trend of irrigation development due to the water shortage in the critical months of July and August. A summary of the army reports is given in table 1, Appendix.

Besides this long list of large projects there are thousands of possibilities of conserving water on individual farms throughout the state through the prevention of runoff or of diverting flood waters from intermittent streams. This type of irrigation, known as Flood Irrigation, was initiated by the Montana Extension Service over twenty-five years ago. Two bulletins and two circulars have been published by the Montana Experiment Station and Extension Service which describe Flood Irrigation. (See numbers 20, 21, 22, 23 in reference.)

In addition to the many irrigation possibilities which exist for the development of Montana's water resources, there are also numerous opportunities for the development of hydro-electric power plants. A list of 40 such possibilities is given in table 2, Appendix, based on investigations by the U. S. Army Engineers. Countless opportunities also exist for the construction of small reservoirs for recreational purposes, upon which relief labor could be used to advantage.

AGENCIES WORKING FOR IRRIGATION DEVELOPMENT IN MONTANA

The irrigation of 1,594,912 acres (1) of land in Montana has been accomplished through the activities of many agencies, and such lands may, therefore, be roughly classified by character of enterprise into groups as given in table 13.

PRIVATE AGENCIES

The first 2 under private agencies, representing nearly 82 per cent of the irrigated area, are made up of small, easily constructed enterprises. To construct them required only the individual or cooperative effort of farmers who would be directly benefitted. Generally the engineering difficulties to be overcome were few and simple, so that construction costs were comparatively low, and complicated financial organization was unnecessary.

The success of these individual and cooperative projects led

to the belief that irrigation development was a fruitful field for investment and speculation, and the result was further expansion under irrigation districts, Carey Act, and commercial companies amounting to 7.2 per cent of the present irrigated area. But the cost of building irrigation projects was rapidly rising due to the fact that more difficult projects were undertaken which involved technical engineering services, and expensive construction.

The increase in cost of irrigation development resulted in financial difficulties and economic failure on many of these projects. A complete discussion of these problems of organization and financing will be given in Part II of this bulletin series. (See also references 13-17 inclusive.)

TABLE 13.

Character of enterprise	No. of acres	Per cent of total
I. Private agencies		
a. Individual and partnership	885,274	55.5
b. Cooperative	418,862	26.2
c. Irrigation District	83,870	5.2
d. Carey act	10,000	.6
e. Commercial companies	22,375	1.4
II. Federal agencies		
a. U. S. Bureau of Indian Affairs	75,844	4.7
b. U. S. Bureau of Reclamation	98,327	6.2
III. State agencies	360	.2

FEDERAL AGENCIES

As the point was reached when investment in irrigation development was no longer attractive to private capital, it seemed advisable for the federal government to assume the responsibility for further construction of irrigation projects. The U. S. Reclamation Service was created by an act of 1902. (See references 11 and 12). This has since become the Bureau of Reclamation. Four large projects and one small one have been built by the Reclamation Bureau in Montana. A number of others have been surveyed. Similar work has been done on the Flathead Indian Reservation, the Ft. Belnap Indian Reservation, and the Crow Indian Reservation by the U. S. Bureau of Indian Affairs. (See references 11 and 12). These two federal agencies have been instrumental in reclaiming 174,171 acres or 10.9 per cent of all irrigated lands in Montana. Because of difficult construction and incidental high costs which will be characteristic of future irri-

gation development, federal agencies will no doubt have a larger share than heretofore.

THE STATE WATER CONSERVATION BOARD

The newest agency given the responsibility of developing the water resources of the state is the Water Conservation Board of Montana which was created by an act of the Twenty-third Legislative Assembly in 1933. (See Chapter 35: Laws of Montana). This was later amended by Chapters 95, 96, and 97 of the Twenty-fourth Legislative Assembly. Section 1 explains the purpose of the act as follows:

“Section 1. Water Conservation a state purpose. It is hereby declared that the public interest, welfare, convenience, and necessity require the construction of a system of works, in the manner hereinafter provided: for the conservation, development, storage, distribution, and utilization of water. The construction of said system of works is, and is hereby declared to be, a single object; and the construction, operation and maintenance of said system of works, as herein provided for is hereby declared to be in all respects for the welfare and benefit of the people of the State, for the improvement of their prosperity and living conditions, and the State Water Conservation Board hereinafter created shall be regarded as performing a governmental function in carrying out the provisions of the act.”

The creation of the State Water Board is a recognition, by the State Legislature, of the responsibility of the State to develop its natural resources for the benefit of its people. This new agency has been active during the past two years in developing Montana's water resources. A large number of projects have been surveyed and several are under construction. Fifty-five projects have been undertaken by the State Water Board through the Public Works Administration. The total estimated cost of these projects is \$15,543,500, and their completion will result in the storage of 719,336 acre feet of water at an average cost of \$21.50 per acre foot.

The Water Conservation Board working through the Works Progress Administration also proposes to develop a large number of smaller projects—principally the construction of stock water reservoirs, which will cost a total of \$4,003,790.

Through the Soil Conservation Service, two other projects are being built with W. P. A. funds, providing for the storage of 24,000 acre feet of water.

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18. Water Supply papers Missouri River Basin.
19. Water Supply papers North Pacific Slope—Part XII A.
20. Montana Extension Bulletin 59.
21. Montana Extension Circular 17.
22. Experiment Station Bulletin 301.
23. Montana Extension Circular 84.

TABLE 1.—POTENTIAL IRRIGABLE LANDS

**Jefferson, Madison and Gallatin Rivers
(House Document No. 193—Pages 27-39)**

Name of Project	Location	Description	No. of acres	Est. cost	Remarks
1. Madison River Project I	Near Three Forks and Crow Creek Valley	Large reservoir and 150 miles canal	148,000	\$14,413,000	Cost excessive
Project II	Cameron, Mont.	40 miles canal	30,000	—————	Gravelly soil
2. Eight Mile Bench	South of Ennis	20 miles canal	7,000	—————	Poor soil
3. Red Rock Project	Above Red Rock	Enlarge reservoir and 40 miles canal	8,000	—————	Limited to hay
4. Ruby River Project	Between Ruby and Beaverhead Rivers, N. E. of Dillon	Reservoir, 50 miles main canal and 55 miles lateral canal	—————	—————	—————
5. Whitetail	North of Whitehall	Complete storage and 28 miles canal	5,076	429,000	Irrigation district
6. East Bench Scheme 1	Beaverhead River and Grasshopper Creek	Grasshopper Reservoir and 28.5 miles canal	7,000	775,400	Fairly good soil
Scheme 2	Beaverhead River and Red Rock Lake	Red Rock Reservoir and 30 miles canal	8,000	707,000	"
Scheme 3	Beaverhead River, Grasshopper Creek and Red Rock Lake	Combination of Schemes 1 and 2	16,000	1,530,000	"
7. Valley View Scheme 1	Near Three Forks on Jefferson River	Pumping 137 ft. lift and 3 miles canal	1,300	66,400	Good soil
Scheme 2	"	Pumping 186 ft. lift and 6 miles canal	1,395	122,000	—————
8. South Bench	Bench south of Three Forks	Reservoir and 17 miles canal	8,000	876,000	Fairly good soil
9. Crow Creek Scheme 1	Crow Creek Valley near Radersburg	Big Hole reservoir and 75 miles canal	68,000	23,639,000	District organized 1919
Scheme 2	"	"	83,000	36,665,000	"
Scheme 3	"	" and Crow Creek reservoir	83,000	37,468,000	"

APPENDIX

TABLE 1.—POTENTIAL IRRIGABLE LANDS—(Continued)

Main Stem Missouri River and Tributaries
(House Document No. 238, Pages 148-149)

Name of Project	Location	Description	No. of acres	Est. cost	Remarks
10. Fort Peck Indian Project Extension	Poplar River, Big Muddy Creek and Missouri River	Direct diversion and storage	112,601	—————	Dependent on policies of Indian Service
11. Ulm Irrigation District	North of Great Falls	Pumping projects—43 to 123 ft. lifts	12,150	—————	Cost excessive
12. Silver Irrigation Project	North of Helena	Reservoirs, canals and laterals	7,750	—————	2 units
13. Galpin Bottom	North side of Missouri above mouth of Milk River	Pumping project—26 ft. lift. 13.2 miles canal	6,000	—————	—————
14. Woods Gulch Irrigation Project	East side of Woods Gulch, Meagher County	3 miles canal	800	—————	—————
15. Brockway Irrigation Project	East side Duck Creek and west side Red-water Creek	3 small reservoirs and canals	2,740	—————	2 units, limited water supply
16. Newland Creek Irrigation Project	Both sides of Newland Creek in Meagher County	Storage reservoir	1,000	—————	—————
17. Upper Missouri River Project	Between Lombard and Helena	Diversion dam on Missouri River, canals, pumping plant and storage on Big Hole River	85,000 to 105,000	—————	Plan for larger project. Both plans include No. 9
18. Toston Irrigation Project	Townsend bench near Toston	Diversion dam and canal on Missouri River, and pumping plant with 80 ft. lift or diversion from Sixteen Mile Creek	30,000	—————	Investigated by Bureau of Reclamation
19. Broadwater Irrigation District	East side of Missouri River near Toston	Diversion from Missouri River	10,000	—————	Included in No. 17

TABLE 1.—POTENTIAL IRRIGABLE LANDS—(Continued)

Name of Project	Location	Description	No. of acres	Est. cost	Remarks
20. Toston Irrigation District Project	"	Pumping project, 100 ft. lift	5,000	—————	Included in No. 17
21. Prickly Pear Irrigation District Project	Prickly Pear Creek	Plan indefinite	3,500	—————	Area approximate
22. Helena Irrigation Project	East side of Lake Helena	Pump project	16,000	—————	District dissolved
23. Shonkin Irrigation Project	South side of Missouri River near Great Falls	Storage on all small streams	200,000	—————	Area approximate, investigated by Reclamation Bureau
24. Smith River Irrigation Project	West side of Smith River above mouth	Storage	Indefinite	—————	Water supply limited
25. Dearborn Irrigation Project	Dearborn River in Lewis and Clark County	Old Carey Act Project	Indefinite	—————	Abandoned because of insufficient water supply
26. Brockway-Ash Creek Irrigation Project	Brockway	Storage on Ash Creek	206	—————	Included in No. 15
27. Missouri River Irrigation Project	Near North Dakota boundary	Pumping Project	Indefinite	—————	Enlargement and extension of No. 10
28. Sun River Extension	Cascade County	Enlargement and construction of new canals	50,697	—————	Investigated by Reclamation Bureau
29. Judith Basin	Both sides of Judith River	Storage for 42,800 acre ft. and 37 miles canals	25,000	2,175,500	"
30. Stanford	Skull and Meadow Creeks	12,000 acre feet storage reservoir	7,000	1,011,100	"

TABLE 1.—POTENTIAL IRRIGABLE LANDS—(Continued)

Marias River					
(House Document No. 191—Pages 17-23)					
Name of Project	Location	Description	No. of acres	Est. cost	Remarks
31. Cut Bank Irrigation District	Cut Bank Creek	Reservoir	14,500	1,163,982	Water supply principally from storage
32. Toole County Project	Cut Bank Creek, Two Medicine River, Badger Creek	Four reservoirs	200,000	18,000,000	"
33. Marias Project	Marias River	Two reservoirs	150,000	15,400,000	"
34. Blackfoot Indian Project	Blackfoot Indian Reservation	Diverston	107,500	7,326,088	Under construction
Milk River					
(House Document No. 88—Pages 123-127)					
35. Savoy-Coburg	Chinook Division of Milk River Project	Enlarge and extend Fort Belknap Canal	12,000	—————	Investigated by Reclamation Bureau
36. Downen Reservoir	20 miles N. W. of Chinook	Storage reservoir	3,000	\$100 per acre	Poor soil
37. Whitewater Creek	Near Saco	Small reservoir and 3 distribution systems	6,200	—————	Investigated by Reclamation Bureau
38. Beaver Creek	South of Milk River near Malta	Storage reservoirs	9,000	654,870	Poor soil
39. Rock Creek	North of Hinsdale	Reservoir and 3 canals, flood storage	1,900	626,000	Cost excessive
40. Nelson North Canal	Near Tampico	50 miles canal, including flumes and siphon	9,500	555,000	Possible extension to Milk River Proj.
41. Vandalia North Canal	North of Milk River from Vandalia to Nashua	St. Mary's storage and canals	10,000	—————	Unit of Milk River Project

TABLE 1.—POTENTIAL IRRIGABLE LANDS—(Continued)

Main Stem of Yellowstone River and Principal Tributaries
(House Document No. 256—Pages 53-55)

Name of Project	Location	Description	No. of acres	Est. cost	Remarks
42. Brackett Creek Scheme 1	West of Clyde Park	Storage reservoir and 34.5 miles canal.	9,791	1,189,100	Insufficient water supply.
Scheme 2	"	Storage reservoir and 19 miles canal.	5,550	568,100	
43. Glendive-Fallon Upper unit	North side of Yellowstone River between Glendive and Fallon	2 pumping plants, 43 and 75 ft. lifts, 16.5 miles canal	3,370	132,700	Water supply from Yellowstone River
Lower unit	"	Pumping plant, 100 ft. lift, 12 miles canal	5,600	272,600	"
44. Hysham	Near Hysham, south of Yellowstone River	Pumping plant 98 ft. lift, 18 miles canals	6,400	340,000	"
45. Sheffield	North of Yellowstone River near Miles City	Pumping, 2 lifts. First lift 20 ft. Second lift 35 ft. 21.8 miles canal	5,800	209,200	"
46. Highland Park Irrigation Dist.	South of Yellowstone River east of Forsythe	Pumping plant, 220 ft. lift, 20 miles canal	4,933	—————	"
47. Shirley-Blatchford	South of Yellowstone River between Shirley and Blatchford	Pumping plant, 42 ft. lift, 13.9 miles canal	4,160	171,000	"
48. Upper Yellowstone Irrigation Dist.	12 miles above Livingston	Direct diversion, 10 miles canal	3,680	—————	\$75,000 requested bond issue
49. Cedar Creek	North of Yellowstone River below Terry	2 pumping plants, 60 and 45 ft. lifts. 15.1 miles canals	3,440	171,400	Water supply from Yellowstone River
50. Kinsey	North side Yellowstone River near Kinsey	Pumping, 40 ft. lift. 10.2 miles canal	2,840	100,000	"
51. Graycliff Irrigation Dist.	South side Yellowstone River, near Graycliff	Direct flow from Boulder River. Extend old Bailey Ditch	2,000	70,000	\$35.00 per acre

TABLE 1.—POTENTIAL IRRIGABLE LANDS—(Continued)

Main Stem of Yellowstone River and Principal Tributaries
(House Document No. 256—Pages 53-55)

Name of Project	Location	Description	No. of acres	Est. cost	Remarks
52. Calypso	North side Yellowstone River west of Terry	Pumping, 52 ft. lift. 5.3 miles canal	1,700	64,200	Water supply from Yellowstone River
53. Orinoco	North side Yellowstone River below Forsythe	Pumping, 25 ft. lift. 5.3 miles canal	1,250	34,500	"
54. Hathaway	South side Yellowstone River near Hathaway	Pumping, 40 ft. lift. 4.6 miles canal	1,000	38,000	"
55. Terry	South side Yellowstone River near Terry	2 pumping plants, lift 90 ft.	940	—	"
56. Saugus	North side Yellowstone River near Saugus	Pumping plant, 35 ft. lift. 3 miles canal	720	22,600	"
57. Lower Yellowstone Project Improvement.	West side of Yellowstone River below Intake	Direct diversion from Yellowstone River at Intake	10,871	—	No Storage
58. Huntley Project Improvement	South side of Yellowstone River between Huntley and Bull Mountain	Direct diversion	—	—	—
59. Joliet and White Horse Irrigation District	North side of Rock Creek north of Joliet	1 Canal, 132 c. f. s. 1 canal, 150 c. f. s.	12,531	474,300	East Rosebud Reservoir 10,000 acre ft. capacity
60. Big Horn	Both sides of river south of Hardin	West canal 389 c. f. s. East canal 65 c. f. s.	50,100	12,569,500	Storage reservoirs 16,000 acre ft.
61. Crow Indian Project Extension	Crow Indian Reservation	Extension of existing canals	11,991	—	Possibly small storage
62. Powder River	Near Broadus and Powderville	—	—	—	—
Scheme No. 1	Broadus Canal	28 miles, 54 c. f. s.	12,650	1,125,000	Direct diversion
Scheme No. 2	Powderville Canal System Reservoir	49.2 miles, 127 c. f. s. Same as above 56,000 acre feet storage	62,090	4,040,000	Direct diversion and storage

TABLE 2.—POTENTIAL POWER DEVELOPMENTS ON STREAMS IN MONTANA

No.	Name of stream	Location	Normal head	Total reservoir capacity	Installed capacity	Prime power rating
				Acre ft.	Kw.	Kw.
1	Missouri River	Reconstruction of Canyon Ferry	95	895,000	54,000	18,700
2		Hardy, run of river Cascade Co.	64	72,500	22,500	9,350
3		Ulm, run of river Cascade Co.	25	237,800	10,500	4,800
4		Portage, run of river Cascade Co.	61	7,600	24,000	10,500
5		Carter, reservoir Choteau Co.	110	215,100	61,500	20,100
6		Fort Benton Reservoir, Choteau Co.	52	75,300	24,000	7,350
7		Iliad Reservoir, Fergus and Choteau Counties	176.6	3,037,000	220,000	72,000
8		Bearpaw, run of river Fergus and Blaine Counties	80	210,600	42,000	19,600
9		Garfield Reservoir Garfield and Phillips Counties	158.6	5,916,000	250,000	75,000
10		Leedy, run of river Garfield and Phillips Counties	27.1	75,000	15,600	6,950
11		Fort Peck Reservoir	91	3,461,000	130,000	43,000
12	Gallatin River	Lower Basin Reservoir	209		14,000	
13		Lower Basin run of river Plant 1	66.2		3,400	
14		Lower Basin run of river Plant 2	66.2		3,400	
16	Big Hole River	Glen Reservoir	190		23,000	
17	Madison No. 3	Madison No. 3	70		10,000	3,246
<p>The above data was obtained from House Document No. 238—Missouri River U. S. Army Engineer's Report</p>						
1	Cut Bank Creek	But Bank				1,710
2	Marias River	Brinkman				5,400
3	Teton River	Loma				800
<p>The above data was obtained from House Document No. 191—Marias River U. S. Army Engineer's Report</p>						
1	Yellowstone River	Yankee Jim Canyon	175	279,900	44,000	15,000
2		Lower Canyon	229	1,384,000	135,000	45,000
3		Yankee Jim Canyon and Lower Canyon	229	1,384,000	160,000	63,000
4	Boulder River	Natural Bridge	183	33,000	3,800	1,700
5	Big Horn River	Big Horn Canyon	368.5	830,000	180,000	61,000
<p>The above data was obtained from House Document No. 256—Yellowstone River U. S. Army Engineer's Report</p>						

TABLE 2.—POTENTIAL POWER DEVELOPMENTS ON STREAMS IN MONTANA—(Continued)

No.	Location	Normal head	Total reservoir capacity	Installed capacity	Prime power
			Acre ft.	Kw.	Kw.
1	Kootenai River Custer	89	501,000	48,000	18,900
2	Kootenai Falls	89			13,100
3	Flathead River Leonia	50			7,400
4	South Fork of Flathead Hungry Horse Creek	303	1,100,000		63,300
5	Flathead River Coram	90			11,900
6	Polson	185			89,500
7-10	Four sites below Polson	182			83,500
11	Clark Fork of the Columbia Fish Creek Site	108			8,800
12	Thompson Falls	50			30,200
13	Donlan Site	40			24,200
14	Rock Island Gorge	50			32,500
15	Cabinet Gorge	77			48,700

The above data was obtained from House Document No. 103 Vol. II.—Columbia River
U. S. Army Engineer's Report

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