WATER RESOURCES ANALYSIS
AND INFORMATION SECTION

Office Report No. 43

AN INITIAL ANALYSIS OF THE FLOW OF THE MAIN STEM OF THE OKANOGAN RIVER IN WASHINGTON

by

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(For Use by the Water Resources Management Division)

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INTRODUCTION

The purpose of this report is to present the information available on the flow of the Okanogan River in Washington. The work presented here is an initial analysis and will be followed by a report on the frequency of flows in the river. The report presents information on which the latter report will be based.

THE BASIN

The Okanogan drainage basin covers an area of 8,400 square miles, with 6,000 square miles in south-central British Columbia and 2,400 square miles in north-central Washington. The Okanogan Basin can be divided into four sub-basins. These are (1) the Similkameen River, (2) the Okanagan above the confluence with the Similkameen, but below Okanogan Lake, and (4) the Okanagan below the confluence with the Similkameen. Information on each of these units are given in Table 1.

Okanagan Lake--a large lake with a control structure at the outlet--stabilizes the flow in the Okanagan above Oroville. The outlet control works are used to control the lake surface elevation for purposes of flood control, irrigation, navigation, and recreation. The permissible range in lake level is 4 feet, which gives a live storage of 336,800 acre-feet.

The Similkameen has a much less uniform measured flow than the Okanogan below the lake with 60 percent of the mean annual flow occurring in May and June. The mean annual flow (1929-58) was 2,286 cfs in the Similkameen near Nighthawk, Washington; 549 cfs in the Okanagan at Okanagan Falls, B.C.; and 2,894 cfs in the Okanogan at Tonasket, Washington. The distribution throughout the year of the flows in the Similkameen and Okanogan is shown on Figure 1.

The annual flow varies considerable about the mean. The range in annual flows is (in cfs):

TABLE 1. SUBBASINS IN THE OKANOGAN.

Name	Drainage Area (square miles)	Mean Annual Flow (cfs)	Flows in August (cfs) Mean	Flows in August (cfs) Low	Peak Flow in 1948 Flood
Similkameen	3,600	2,286	906	328	38,700
Okanogan Lake and Middle Okanagan	3,210	549	589	88	1,550
Lower Okanogan	1,590	2,894	1,329	406	40,900

Gage Stations: Similkameen---------- at Nighthawk, Washington
Okanogan Lake and Middle Okanagan - at Okanagan Falls, B.C.
Lower Okanogan---------- at Tonasket, Washington

Sources: CNP Study Vol. V, p. 231, 232
WSB No. 6 p. 510-516

Note: Measured flows.

	MINIMUM	MAXIMUM	MEAN
Similkameen at Nighthawk	1,150	3,413	2,286
Okanogan at Okanogan Falls	50	838	549
Okanogan at Tonasket	1,140	4,324	2,894

The flows in August and September are critical from the standpoint of irrigation use of the water. The maximum water use is in June through August, but the flows are lower in August than in July or June. Data on the mean, and lowest, August flows are shown on Table 1.

Flood Considerations

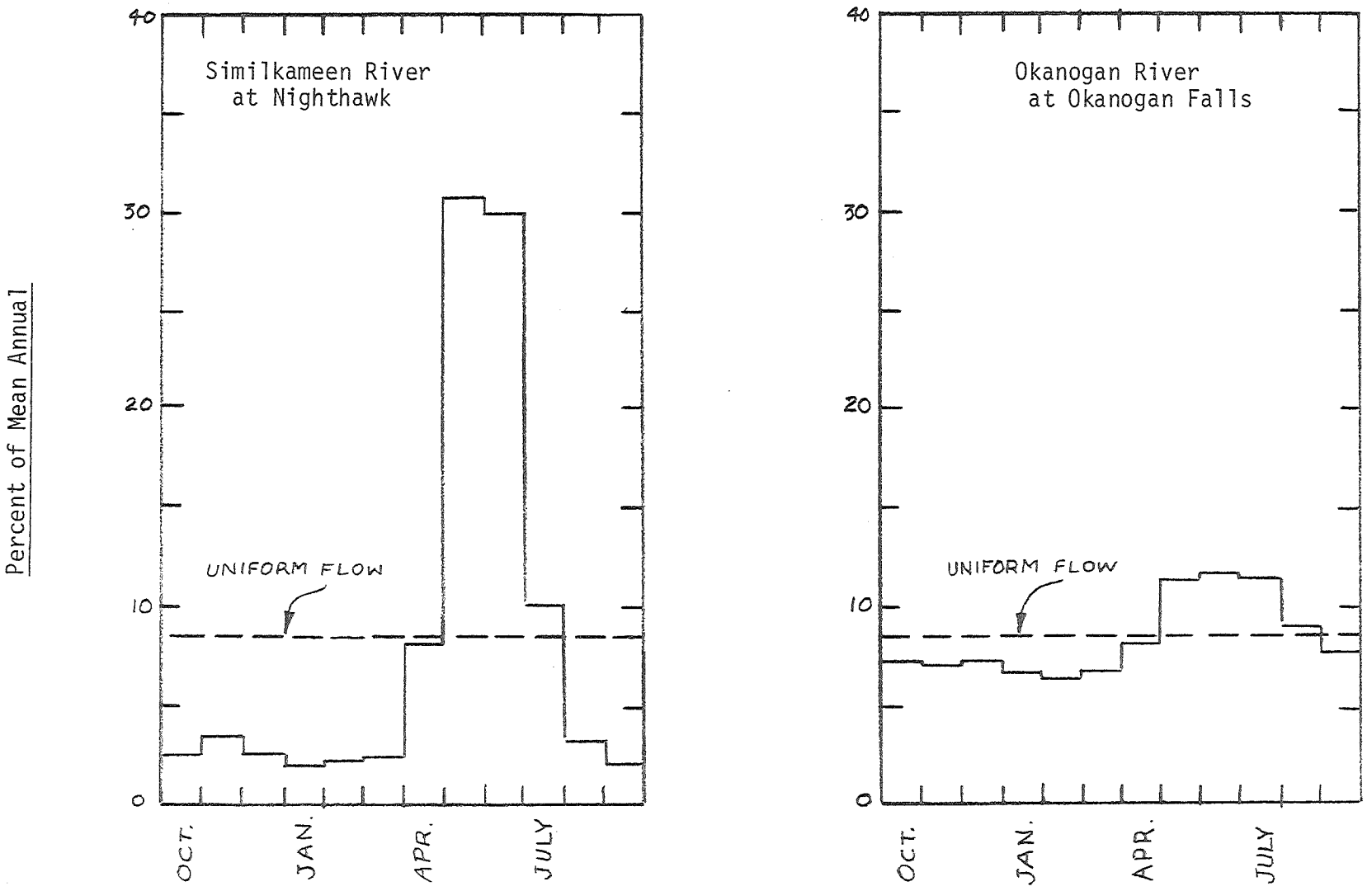
Floods on the Okanogan in Canada are controlled by flood control operation of the storage in Okanogan Lake; consequently, floods on the Okanogan in the United States are caused by snowmelt floods on the Similkameen. Data on flood flows during the 1948 flood are given on Table 1. The peak flow on the Similkameen during the 1972 flood was 46,500 cfs.

Flooding occurs at Palmer Lake when the flow of the Similkameen exceeds 4,000 second feet, causing water to flow into the lake. With about 20,000 cubic feet per second in the Similkameen, the lake is flooded 14 feet over its normal pool level. The 1948 flood of 38,700 second feet raised the water level to 20 feet and the 46,500 second feet on June 2, 1972, caused the water level to raised to about 22.5 feet above the normal elevation of 1,144.

The 24,000 second feet on May 22, 1972 caused flooding to pasture lands and inundated a part of one county road at the north end of the lake. The 46,500 second feet of June 2, 1972 caused a number of homes to be flooded and inundated portions of the road from Loomis to Nighthawk.

When flood flows in the Similkameen River approach 30,000 second feet, the flow of the Okanogan is reversed and water flows into Osoyoos Lake. The 1948 flood of 40,900 second feet caused the lake to rise from its normal level of about 911.0 to 916.74 m.s.l. (mean sea level). The 1972 flood of 45,200 second feet at Tonasket caused it to raise to only 916.98. Channel condi-

FIGURE 1. MONTHLY DISTRIBUTION OF FLOWS (MEASURED)



tions in the Okanogan below the mouth of the Similkameen were modified between 1948 and 1972, which accounts for comparability of water level in Osoyoos Lake with 4,300 second feet difference in discharge.

Because of steep gradients and occasional high discharges, Tonasket and Antoine Creeks deposit gravel and boulders in the Okanogan River, which reduces its cross sectional area. This partial blocking of the river, particularly by Antoine Creek, which enters below the mouth of the Similkameen, contributes to the Similkameen discharge reversing the flow of the Okanogan and raising the water level of Osoyoos Lake. The deposit has been removed but could form again with a flood in the creeks.

Although the overall stream gradient of the Okanogan River from Osoyoos Lake to Wells Reservoir is about 1.81 feet per mile, the gradient from the mouth of the Similkameen to Ellisford, about nine miles, is comparatively flat due to the meandering nature of the stream. This tends to impede the flood flows of the Similkameen, causing overflow in the area as well as the reversal of flows into Osoyoos Lake.

Flood protection dikes were constructed at Oroville, Riverside, Omak, and Okanogan after the 1948 flood. These dikes were built to accommodate floods like that of 1948, but they were severely damaged in the 1972 flood, causing a part of the total of $15 million damage to homes, businesses, utilities, and farms.

It has been determined that little or no flood damage occurs when the flow of the Okanogan River is at or below 17,000 second feet. In the 1972 flood, about 5,900 acres of agricultural land were flooded, including about 5,000 acres of pasture and field crops and about 900 acres of orchards. Some farm buildings and equipment were also damaged.

Water Use

The principal water use in the Okanogan Basin is for irrigation. About 100,600 acres are considered to be irrigated in the basin--30,100 in the United States and 70,500 in Canada. The distribution is:

Similkameen above Nighthawk:	10,500 acres in Canada 2,900 acres in United States
Okanogan above Oroville:	60,000 acres in Canada 2,700 acres in United States
Okanogan/Similkameen between Nighthawk/Oroville and Tonasket:	12,200 acres
Okanogan between Tonasket and Malott	10,700 acres
Below Malott	1,600 acres
T O T A L	100,600 acres

These data are the most often given for the Okanogan. A re-analysis of the available data is given in the following section.

Data for the major irrigation districts are given below:

DISTRICT	IRRIGATED AREA (acres)	STORAGE IN DISTRICT (ac-ft)	MAJOR SOURCE
Aeneas Lake	1,320	0	
Alta Vista	40	0	
Helensdale	200	--	Loup Loup Creek
Okanogan	5,040	23,500	Salmon Creek
Oroville-Tonasket	9,490	--	Similkameen
Whitestone	2,050	6,200	Toats Coulee Creek
T O T A L	18,140	29,700	

Information in a U. S. Bureau of Reclamation reconnaissance report indicates that in 1951, 16,000 acres were irrigated from tributary streams and 5,000 acres from the main stem of the Okanogan River below the Similkameen River (1,000 acres were irrigated from the Columbia River near Brewster--these have not been counted as Okanogan Basin acres). Of the 16,000 acres, about 7,500 are in the Oroville-Tonasket Irrigation District. The Soil Conservation Service reports that 29,400 acres were irrigated in 1967, 26,100 acres from surface water, and 5,400 acres, 3,300 acres from ground water. Of the 26,100 acres from surface water, 5,400 acres were from reservoirs. Of the 26,100 acres, about 8,000 acres are irrigated from the main stem of the Okanogan.

Using information in the CNP study, the estimated diversion per acres is 4.6 acre-feet per acre of which 2.5 acre-feet per acre is used consumptively. The remaining 2.1 acre-feet per acre is return flow. Using the information above and estimates of the irrigated average, the following is an estimate of the water diversions from the Similkameen and Okanogan Rivers:

	IRRIGATION YEAR	AUGUST
Oroville-Tonasket	43,600 acre-feet	180 cfs
Other divertors	37,000 acre-feet	150 cfs
T O T A L	72,000 acre-feet	330 cfs

In a hot, dry year, the water requirements would be higher and the duty of water could be the 5.5 acre-feet per acre which is typically used as a rough estimate. In that case, the diversions could be 400 cfs during August.

Municipal water use is about 20 cfs from wells near the Okanogan River, and 5 cfs from other sources. Industrial water use is not known, but a lumber company in Omak has a water right claim for 5,000 gallons per minute (1.12 cfs) from ground waters. If the use is the same per capita as in the area of the basin in British Columbia below Okanogan Lake, the use is 900 acre-feet per year (1.2 cfs). Direct diversion of domestic users from the Okanogan River is probably not more than 2 cfs. Hence, the diversion from the main stem Okanogan River for non-irrigation purposes is probably not more than 25 cfs with depletions of not more than 10 cfs.

Water Right Considerations

Some important water right considerations in the Okanogan Basin are the following:

1. Similkameen Decree

   This court decree of September 25, 1918 provides a first right to 250 second feet at the Enloe Dam for power production. This right is controlled by the Okanogan County Public Utility District. The second

right is controlled by the Oroville-Tonasket Irrigation District and provides for diversions as follows: April 1-15, 50 cfs, limited to 1,488 acre-feet; April 16-30, 107 cfs, limited to 3,184 acre-feet; May, 124 cfs, limited to 7,625 acre feet; June, 149 cfs, limited to 8,866 acre-feet; July, 186 cfs, limited to 11,437 acre-feet; August, 165 cfs, limited to 10,146 acre-feet; September, 128 cfs, limited to 7,617 acre-feet; and October 1-15, 50 cfs, limited to 1,448 acre-feet, or a total of 51,851 acre-feet.

The third adjudicated right on the Similkameen River is for 750 cfs. This right of the Okanogan County PUD was somewhat limited by the hydraulic capacity of the power plant, which was 667 second-feet.

The Oroville-Tonasket Irrigation District has a permit to store 10,500 acre-feet at Palmer Lake.

2. Similkameen River

The Oroville-Tonasket Irrigation District has a water right with a priority date of August 13, 1954 for 150 cfs from the Similkameen River.

3. Okanogan River

The Oroville-Tonasket Irrigation District also has a pumping right from the Okanogan River amounting to 32.25 cfs. In addition, there are appropriative rights by individuals and the Okanogan Irrigation District amounting to 111.94 second-feet.

The mill pond at Oroville has an appropriation of 126 acre-feet.

4. Withdrawals

The Bureau of Reclamation has withdrawn 70 cubic feet per second for the Okanogan Project. The Bureau also has filed a water right application for 6,000 acre-feet of storage in Palmer Lake for irrigation of the Oroville-Tonasket Project.

5. Boundary Waters Treaty of 1909

In 1909, the United States and Great Britain entered into a treaty relating to the boundary waters of the United States and Canada, and two questions on the boundary waters arose between the United States and Canada.

Article III of the treaty provides, among other things, that: "It is agreed that, in addition to the uses, obstructions, and diversions heretofore permitted or hereafter provided for by special agreement between the parties hereto, no further or other use or obstructions or diversions, whether temporary or permanent, of boundary waters on either side of the line, affecting the natural level or flow of boundary waters on the other side of the line, shall be made except by authority of the United States or the Dominion of Canada within their effective jurisdictions and with the approval, as hereinafter provided, of a joint commission, to be known as the International Joint Commission."

Any plans or programs in Washington, which affect Canada, must meet the requirements of this treaty.

In 1946, an International Osoyoos Lake Board of Control was established to supervise the operation of Zosel Dam on the Okanogan River near Oroville. Investigation in the Okanogan Basin has been done under the auspices of the Commission. The investigations resulted from a reference of the United States and Canada to the Commission on March 9, 1944. Quoting from Bloomfield and Fitzgerald (1958):

"The Commission set up an International Columbia River Engineering Board to make the necessary investigations required under the reference. A comprehensive study based on extensive surveys has been carried on and a report on various aspects of the development of the Columbia River and its various tributaries is under preparation. The Board has submitted to the Commission several interim reports on specific problems in the basin.

"An interim report on the Okanagan River was issued as the United States wanted a fish ladder to be constructed in a dam being built in Canada for flood control, so that the salmon would be able to swim up to Okanagan Lake. Canada answered that flood control was most urgent and should not be delayed. It was opposed to a fish ladder on the grounds that salmon would come into waters where they had never been before, and that these waters had been and would be

put to uses such that the protection of spawning grounds and appropriate water levels could not be ensured.

"The Commission recommended that the flood control works should be proceeded with as soon as possible; that Canada replace the spawning grounds destroyed by building these control works through improving the channel and providing artificial spawning beds below the dam, and that Canadian authorities keep in touch with the United States and confer with the latter before destruction of any spawning ground.

"Another interim report was issued on the Similkameen River problem. Canada wanted to divert water from that river for irrigation purposes and considered that it could do so without the permission of the Commission, but, as the reference was already in progress, Canada preferred to ask the advice of the Commission about the effect on the other side of the boundary in the case of a diversion.

"The report of the International Columbia River Engineering Board was to the effect that, if only flood waters and not the normal flow were diverted, there would be sufficient water for irrigation purposes and this would not cause any shortage of flow on the other side of the boundary. The Board recommended that such diversion should be permitted and the Commission concurred."

6. Colville Indian Reservation

The Winters Doctrine, as expressed by the United States Supreme Court, states that the right to use water from streams and rivers on, or adjacent to, Indian reservations was implicitly reserved by the United States along with the reservation of land by treaties creating Indian reservations.

Plans or programs for full utilization of the land and water resources of the Okanogan basin would have to make proper allowance for development within the Colville Indian Reservation.

Additional information on water rights in the Okanogan Basin is given in Office Report No. 28 by Greg Sorlie.

WATER BALANCE

The management and use of water is a modification of the water balance, hopefully for the benefit of man. This section presents the results of an analysis of the water balance of the Okanogan Basin.

Annual Water Balance

The results of an analysis of the water balance on an annual basis is presented in Table 2. The results for each subbasin are discussed below. The location of the subbasins is shown on Figure 2.

Okanogan Lake Basin

The drainage area of the Okanogan Lake Basin is 2,340 square miles. The dominate hydrologic feature of the basin is Okanogan Lake with a surface area of 84,200 acres. The annual evaporation from the lake is about 352,000 acre-feet and about 604,000 acre-feet of water would be discharged into the lake by tributary streams. The loss due to evaporation is 58 percent of the inflow.

A monthly water balance from the Okanogan Lake Basin is given in Table 3. The increase in basin storage in September and October is principally soil moisture storage while the increase in December, January, and February is due to a snow pack. Later, in April through June, the snow melts and is transferred into lake storage. The July and August decrease in basin storage is principally a loss of soil moisture.

The estimates of consumptive use and streamflows are for 1970 conditions of development. The lake outflows are Run "00" development by the British Columbia Water Resources Service. The estimates are for the period 1922 through 1970 calendar years.

The estimates of basin evapotranspiration are approximate although they are adequate for the purpose at hand. The estimates were made using the Blaney-Critical method to derive the annual distribution as a percent of the total. The change in annual storage was assumed to be zero and the

TABLE 2. ANNUAL WATER BALANCE FOR THE OKANOGAN BASIN

	Okanogan Lake Basin	Middle Okanogan Basin in British Columbia	Middle Okanogan Basin in Washington	Upper Similkameen in Washington	Similkameen Basin in British Columbia	Lower Similkameen Basin in Washington	Lower Okanogan Basin	Total Basin
Inflow								
Precipitation	2720	830	84	817	4585	436	1564	11037
Stream Flow	--	382*	442	--	484	1623	2198	--
Diversions	--	--	12	--	--	--	46	--
TOTAL	2720	1212	538	817	5069	2059	3808	11037
Outflow								
Evapotranspiration								
non-irrigated land	1933	707	75	333	3425	239	1314	8341
irrigated land	67	34	5	--	18	9	96	176
Major Lake Evaporation	372	28	7	--	--	6	12	320
Consumptive Use (non-irrigation)	12	1	0	--	3	--	2	18
Diversions	--	--	--	--	--	58	0	--
Stream Flow	336*	442	451	484	1623	1747	2384	2200
TOTAL	2720	1212	538	817	5069	2059	3808	11037
Area (square miles)	2340	785	85	333	2880	367	1735	8525

Flows in 1,000 acre-feet per year.

*Flow from Okanogan Lake Basin is for 1921-1970, flow into the Middle Okanogan Basin is for 1942-1970.

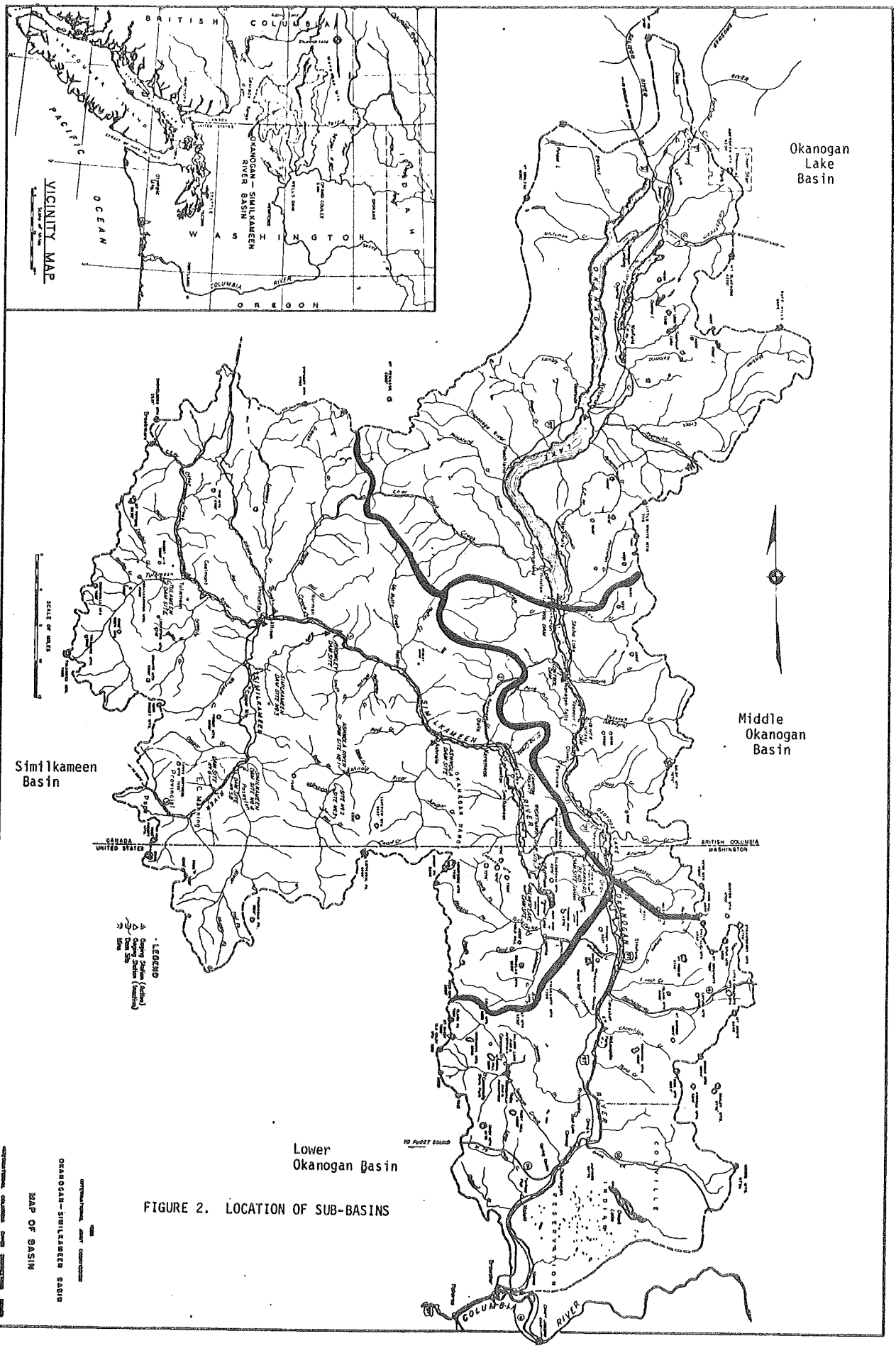


FIGURE 2. LOCATION OF SUB-BASINS

TABLE 3. MONTHLY WATER BALANCE FOR OKANOGAN LAKE BASIN

	MONTH												Annual
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	
INFLOW													
Precipitation	204	232	330	282	175	136	175	224	272	205	205	195	2635
OUTFLOW (to Okanogan Lake)													
Streamflow	25	13	11	9	12	26	67	197	132	51	31	30	604
Evapotranspiration, non-irrigated land	116	39	39	19	39	77	174	367	445	290	174	154	1933
irrigated land	2.4	0.6	0.4	0.3	0.4	1.7	4.9	8.5	14.1	14.1	14.1	5.6	67
Lake Evaporation	1.4	0.2	0	0	0	0.3	1.4	2.4	3.3	3.7	3.4	2.7	19
Consumptive Use (except irrigation)	0.7	0.4	0.5	0.5	0.3	0.5	0.6	1.3	1.9	2.1	2.3	0.8	12
T O T A L	146	53	51	29	52	106	248	576	596	361	225	193	2635
CHANGE IN BASIN STORAGE	+58	+179	+279	+253	+123	+30	-73	-352	-325	-156	-20	-02	0
OKANOGAN LAKE													
Inflow: Precipitation	7	8	10	9	6	5	6	7	9	6	6	6	85
Streamflow	25	13	11	9	12	26	67	197	132	51	31	30	604
TOTAL	32	21	21	18	18	31	73	204	141	57	37	36	689
Outflow: Evaporation	29	16	12	10	9	15	28	39	49	54	51	41	353
Streamflow	26	25	26	26	34	11	38	37	38	29	26	20	336
TOTAL	55	41	38	36	43	26	66	76	87	83	77	61	689
CHANGE IN LAKE STORAGE	-23	-20	-17	-18	-25	+ 5	+ 7	+128	+54	-26	-40	-25	0

(in kilo acre-feet)

monthly coefficient used to distribute the annual basin evapotranspiration. The water storage in the basin over a year is shown in Figure 3. Most of the storage is in soil moisture.

A control structure has been constructed at the outlet of Okanogan Lake for the purposes of regulating the lake level for recreation and aesthetics, and the flow from the lake for purposes of irrigation, flood control, and salmon fisheries. The present outlet works were constructed in the period 1950 to 1958 replacing older works.

Approximately 86 percent of the runoff of the Okanogan Basin above Oroville, Washington, occurs upstream of the Okanogan Lake outlet at Pentiction. The reservoir has a capacity equal to about 72 percent of the average annual discharge from the lake (capacity of 243 kilo acre-feet versus 336 kilo acre-feet discharge). Under natural conditions there would probably be no discharge from Okanogan Lake into the Middle Okanogan in some periods because evaporation probably lowered the lake level to an elevation below the natural sill level of the outlet. Because Okanogan Lake controls much of the flow in the Okanogan River below Okanogan Lake, the observations of the control structure at the lake outlet is the principal factor which controls the amount of water entering Washington from the Okanogan River in British Columbia. Measured monthly flows from Okanogan Lake and flows with two operating conditions and one possible future state of development are given in Table 4. The importance of operating criteria versus depletions is shown by flows in August--the alternative operation criteria results in a difference of about 11,000 acre-feet, while an increase in depletions result in a 900 acre-feet reduction in flows.

The change in irrigated land in the Okanogan Lake Basin is shown in Figure 4. Projections for 2020 range from 41,000 to 56,000 acres. The depletions resulting from irrigation use in the Okanogan Lake Basin are not independent of the total supply. The reduction in consumptive use caused by a supply shortage is given in Figure 5; the figure was taken from British Columbia, Canada, Okanogan Study report.

FIGURE 3. WATER STORAGE IN THE OKANOGAN LAKE BASIN

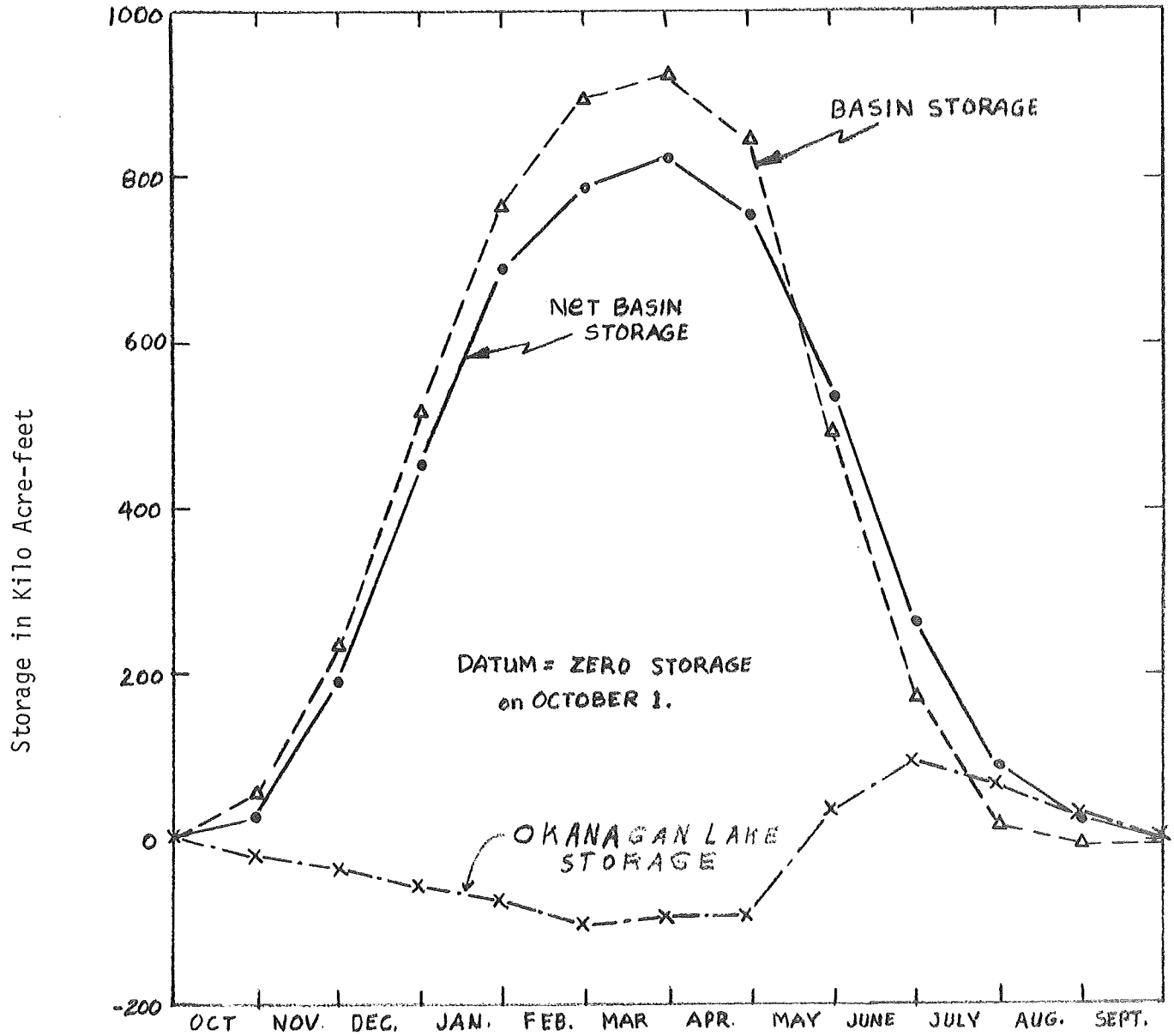
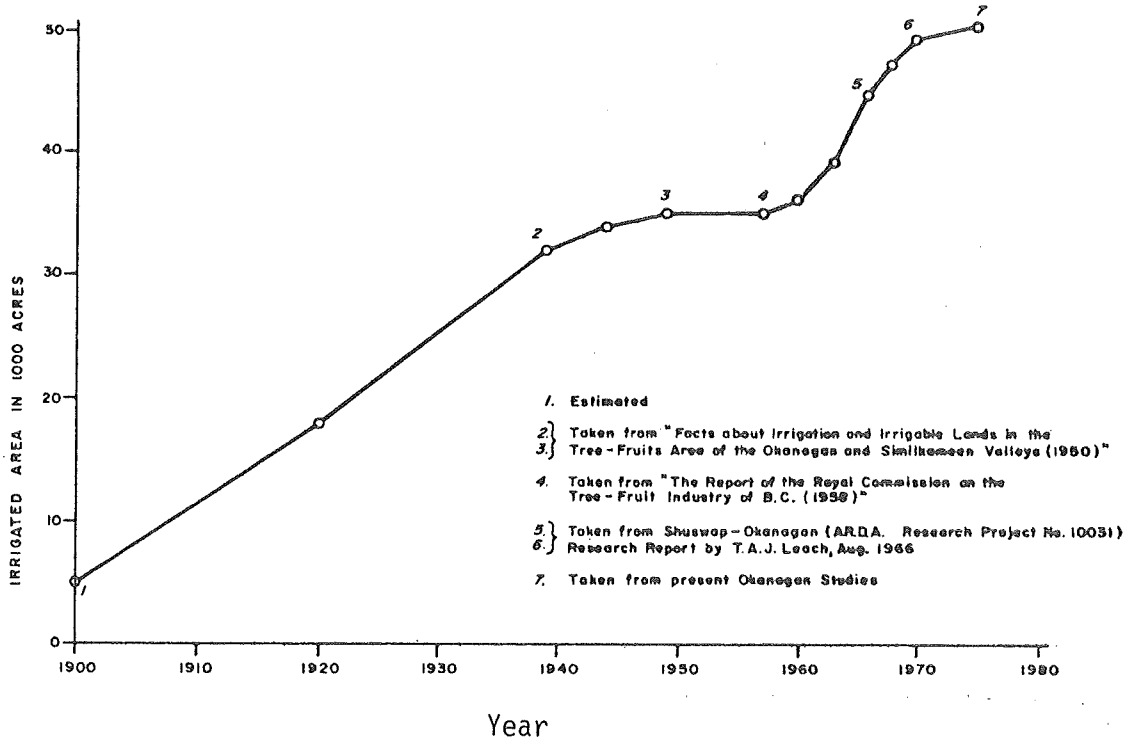


TABLE 4. DISCHARGE FROM OKANOGAN LAKE UNDER VARIOUS CONDITIONS.

M O N T H	Measured	1970 Conditions		2020 Conditions
		Run "0"	Run "3"	Run "0"
		(kilo acre-feet)		
January	24.5	26.1	46.5	23.5
February	22.2	33.9	36.0	32.0
March	27.8	11.2	12.6	11.8
April	28.5	38.0	31.9	37.6
May	35.6	36.7	29.6	36.0
June	39.8	37.6	37.3	37.5
July	38.0	29.0	20.6	27.6
August	33.4	26.5	15.3	25.6
September	29.3	19.5	8.4	19.9
October	26.8	25.7	7.3	23.4
November	24.8	24.9	44.1	22.5
December	25.3	25.8	44.3	23.3
Annual	356	335	334	321

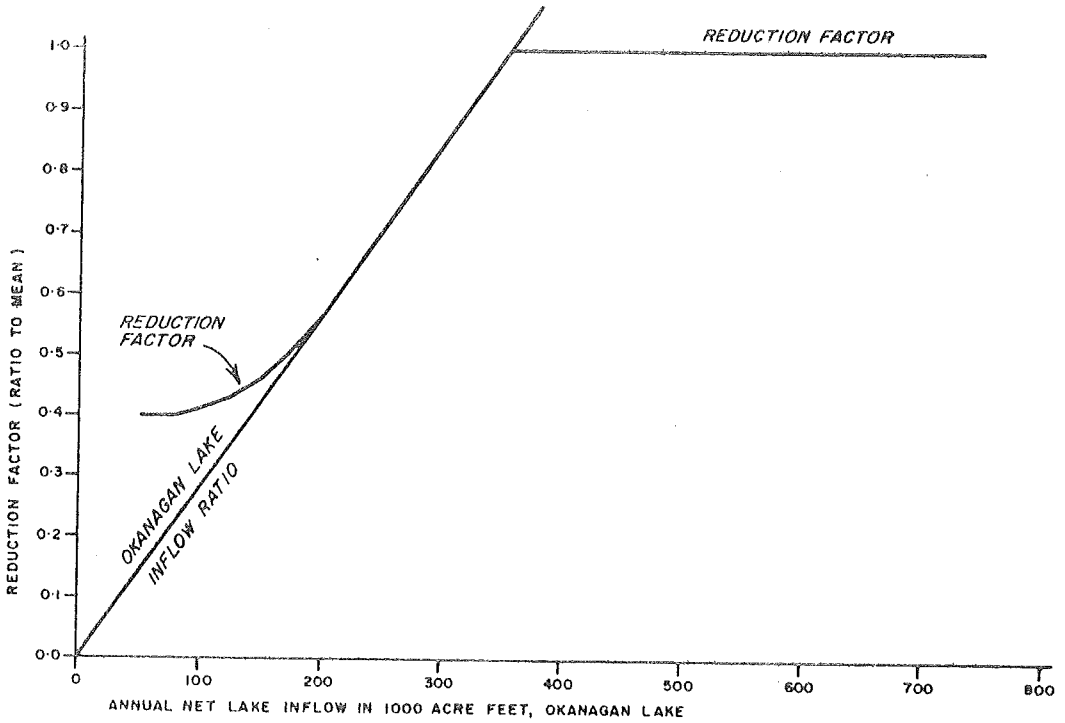
Period 1922-1970

FIGURE 4. IRRIGATED AREA IN THE OKANOGAN LAKE BASIN



(from Canada - B.C. Okanagan Study Report)

FIGURE 5. REDUCTION FACTOR FOR COMPUTATION OF OKANOGAN LAKE CONSUMPTIVE USE (IRRIGATION)



(from Canada - B.C. Okanagan Study Report)

Middle Okanagan Subbasin

The middle Okanagan subbasin is the portion of the basin above the Similkameen River but below Okanagan Lake. The area of the subbasin is 870 square miles of which 785 are in British Columbia and 85 in Washington. The subbasin has an annual rainfall of about 20 inches but the potential evapotranspiration is about 42 inches. Much of the land irrigated in British Columbia is irrigated by diversions from the Okanagan River. About 14,000 acres are irrigated in British Columbia. In Washington, approximately 2,355 acres in the subbasin are irrigated using water from the Similkameen (1,975 acres), from Osoyoos Lake (300 acres), and from Tonasket Creek (80 acres). The total irrigated land is about 16,400 acres.

The monthly water balance for the basin is given in Table 5. The flows are for the period 1943-1970. The change in flow of the main stem Okanagan is shown in Figure 6. The natural inflows to the river and the change in flow is presented in Table 6. The net change is the net impact of runoff, consumptive use, evaporation from the channel and lakes, stream bank use and errors in the measurements.

The diversion from the Similkameen was estimated to be 12,300 acre-feet per year using the following unit estimates:

Land in Middle Okanagan
irrigated using Similkameen water---------- 1,975 acres

Consumptive use---------- 2.40 acre-feet per acre

Diversion (39 percent overall efficiency)--- 6.22 acre-feet per acre

These estimates of consumptive use and diversion are from September 1974 feasibility report of the U. S. Bureau of Reclamation on the Oroville-Tonasket extension. The monthly distribution of consumptive use, diversion and return flow in the Oroville-Tonasket Irrigation District is given in Table 7.

TABLE 5. MONTHLY WATER BALANCE FOR MIDDLE OKANOGAN BASIN.

	MONTH												Annual
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	
INFLOW													
Precipitation	70	94	96	94	67	58	68	81	112	62	60	52	914
Streamflow	30	29	30	31	43	14	44	45	43	27	26	20	382
Diversions	0.5	0	0	0	0	0	0.5	1.8	2.2	2.6	2.6	2	12
T O T A L	100	123	126	125	110	72	112	128	157	92	89	74	1308
OUTFLOW													
Evapotranspiration, non-irrigated land	47	16	16	8	16	31	70	149	180	117	70	62	782
irrigated land	0.8	0.2	0.1	0.1	0.1	0.6	1.7	5.4	9.0	9.0	9.0	3.6	39
Major Lake Evaporation	2.8	1.2	0.2	0.1	0.7	1.5	2.8	4.0	5.2	5.9	5.7	4.4	35
Consumptive Use (except irrigation)	0.02	0.03	0.05	0.03	0.03	0.06	0.06	0.13	0.15	0.16	0.14	0.08	1
Streamflow	36	36	36	38	48	18	54	70	60	22	16	17	451
T O T A L	86	53	52	46	65	51	128	229	254	154	101	88	1308
CHANGE IN BASIN STORAGE	+14	+70	+74	+79	+45	+21	-15	-101	-97	-62	-12	-15	0

(in kilo acre-feet)

FIGURE 6. CHANGE IN THE FLOW OF THE OKANOGAN RIVER BETWEEN PENTICTION AND OROVILLE - 1970 condition.

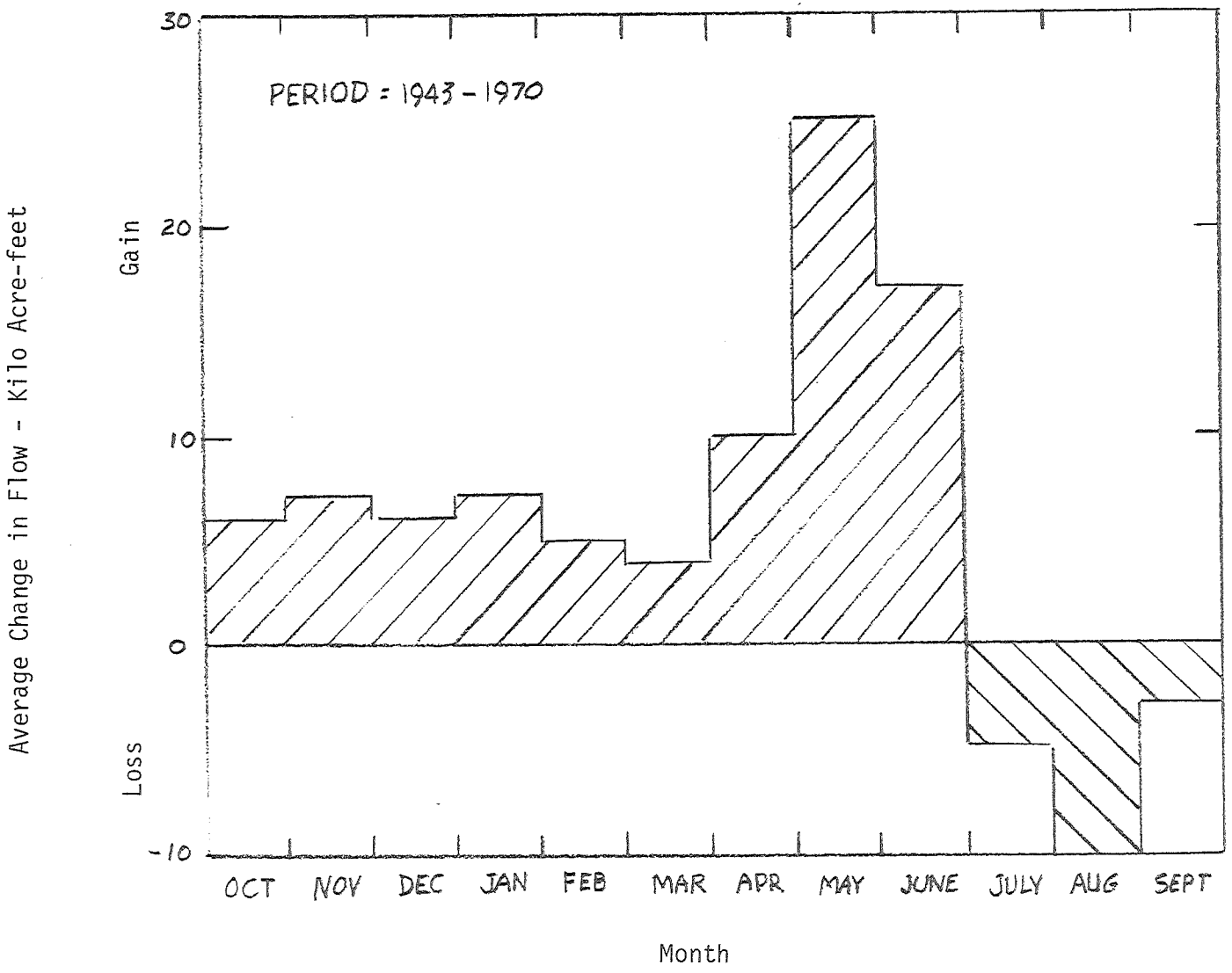


TABLE 6. CHANGE IN FLOW OF THE OKANOGAN RIVER BETWEEN PENTICTION AND OROVILLE.

M O N T H	Natural Runoff	Change in Flow of Okanogan River	Net Change
October	3	6	3
November	2	7	5
December	1	6	5
January	1	7	6
February	1	5	4
March	4	4	0
April	13	10	-3
May	42	25	-17
June	29	17	-12
July	9	-5	-14
August	5	-10	-15
September	3	-3	-6
Annual	112	69	-43

(in kilo acre-feet)

TABLE 7. UNIT WATER USE IN THE OROVILLE-TONASKET IRRIGATION DISTRICT.

M O N T H	Consumptive Use		Diversion	Return Flow	Net Depletion
	Farm Use	Phreatophyte			
October	0.07	0.01	0.25	0.30	0.05
November	0	0	0	0.17	-0.17
December	0	0	0	0.17	-0.17
January	0	0	0	0.14	-0.14
February	0	0	0	0.14	-0.14
March	0	0	0	0.10	-0.10
April	0.06	0.01	0.25	0.14	0.11
May	0.30	0.05	0.93	0.37	0.56
June	0.49	0.09	1.12	0.47	0.65
July	0.67	0.12	1.33	0.52	0.81
August	0.54	0.09	1.31	0.47	0.84
September	0.27	0.05	1.03	0.41	0.62
Total	2.40	0.42	6.22	3.40	2.82

(in acre-feet per acre)

The average annual depletions from the Middle Okanagan River are given in Table 8. The depletions in Washington are all negative because of the diversion of water from the Similkameen into the basin.

Similkameen Subbasin

The Similkameen subbasin has a drainage area of 3,580 square miles--700 in Washington with the remainder in British Columbia. The subbasin has an annual rainfall of about 30 inches. A monthly water balance for the Similkameen is given in Table 9.

Water is used within the basin to irrigate about 6,200 acres in British Columbia and 2,400 acres in Washington for a total of 8,600 acres. The annual unit depletion is estimated to be 2.8 acre-feet per acre in Washington and 2.25 acre-feet per acre in British Columbia. Using these rates, the annual depletions are:

British Columbia------	14,000 acre-feet
Washington----------	6,700 acre-feet
TOTAL----------	20,700 acre-feet

Water is also diverted from the Similkameen subbasin into the Lower Okanogan and Middle Okanagan Basin. An average annual diversion of 48,500 acre-feet is made near the mouth to irrigate land in the Oroville-Tonasket Irrigation District. A diversion of about 10,000 acre-feet annually is made from Toats Coulee Creek to irrigate land of the Whitestone Reclamation District. Information on the depletions from the Similkameen is given in Table 10. The diversions to the Lower Okanogan and Middle Okanagan are given in Table 11.

The diversions in the past have not been the same as in the present. Information on the diversions in 1926-29, pre-1960 and the present for the Oroville-Tonasket Canal are given in Table 12. The change in 1968 occurred as a result of construction of pumping plants downstream of the Similkameen which are used to irrigate some of the Oroville-Tonasket lands. The impact on the total depletions from the Similkameen Basin are given in Table 13.

TABLE 8. AVERAGE ANNUAL DEPLETIONS FROM THE MIDDLE OKANAGAN RIVER. (1970 conditions)

MONTH	British Columbia (kilo acre-feet)	Washington (kilo acre-feet)	TOTAL kilo acre-feet	cfs
October	-2790	-610	-3400	-55
November	-1540	-400	-1940	-33
December	-1520	-400	-1920	-31
January	-1220	-330	-1550	-25
February	-1230	-330	-1560	-28
March	- 800	-240	-1040	-17
April	-1200	-240	-1440	-24
May	6100	-520	5580	91
June	11460	-680	10780	181
July	11170	-710	10460	170
August	11450	-600	10850	177
September	2600	-570	2030	34
Annual	32480	-5630	26850	37

TABLE 9. MONTHLY WATER BALANCE FOR THE SIMILKAMEEN BASIN.

	MONTH												Annual
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	
INFLOW													
Precipitation	467.0	700.6	817.3	758.9	583.8	350.3	350.3	408.7	467.7	350.3	291.9	291.9	5838
OUTFLOW													
Evapotranspiration, non-irrigated land	239.8	79.9	79.9	40.0	79.9	159.9	359.7	759.4	919.3	599.6	359.7	319.8	3997
irrigated land	1.4	0.3	0.2	0.2	0.2	1.1	3.2	5.1	3.2	4.9	4.5	2.8	27
Diversion, to Middle Okanogan	0.5	0	0	0	0	0	0.5	1.8	2.2	2.6	2.6	2.0	12
to Lower Okanogan	1.9	0.1	0	0	0	0.1	2.2	8.0	9.1	9.8	8.5	6.6	46
Consumptive Use (except irrigation)	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.4	0.2	3
Lake Evaporation	0.5	0.2	0	0	0.1	0.3	0.5	0.7	0.9	1.0	1.0	0.8	6
Streamflow	47.2	57.6	51.7	40.8	50.2	40.3	97.5	513.6	576.4	189.2	51.0	31.8	1747
TOTAL	291.4	138.2	131.9	81.1	130.5	201.9	463.8	1288.5	1511.5	807.5	427.7	364.0	5838
CHANGE IN BASIN STORAGE	176	562	685	678	453	148	-113	-880	-1044	-457	-136	-72	0

TABLE 10. DEPLETIONS FROM THE SIMILKAMEEN BASIN.

MONTH	IRRIGATION			Domestic, Municipal, and Industrial Depletion	Total Above Nighthawk	Oroville-Tonasket Canal	Total for Basin	Above Nighthawk	Total
	Whitestone Canal	In British Columbia	In Washington						
October	0.4	-1.2	-0.4	0.1	-1.1	2.0	0.9	-18	15
November	0.1	-0.7	-0.3	0.1	-0.8	0	-0.8	-13	-13
December	0	-0.7	-0.3	0.1	-0.9	0	-0.9	-15	-15
January	0	-0.6	-0.3	0.1	-0.8	0	-0.8	-13	-13
February	0	-0.5	-0.3	0.1	-0.7	0	-0.7	-13	-13
March	0.1	-0.4	0	0.2	-0.1	0	-0.1	- 2	- 2
April	0.7	-0.5	1.4	0.2	1.8	2.0	3.8	30	64
May	2.6	2.6	2.1	0.3	7.6	7.2	14.8	124	241
June	2.6	5.0	1.0	0.4	9.0	8.7	17.7	152	298
July	2.0	4.9	2.0	0.4	9.3	10.4	19.7	152	332
August	0.9	5.0	1.8	0.4	8.1	10.2	18.3	132	298
September	0.6	1.1	0	0.2	1.9	8.0	9.9	31	167
Annual	10.0	14.0	6.7	2.6	33.3	48.5	81.8	46	113

(in 1,000 acre-feet)

TABLE 11. DIVERSIONS FROM THE SIMILKAMEEN SUBBASIN TO THE MIDDLE OKANOGAN AND LOWER OKANOGAN SUBBASINS.

M O N T H	Whitestone Reclamation Diversion	Oroville-Tonasket Diversion		Total to Lower Okanogan	Total Diversion
		To Lower Okanogan	To Middle Okanogan		
October	0.4	1.5	0.5	1.9	2.4
November	0.1	0	0	0.1	0.1
December	0	0	0	0	0
January	0	0	0	0	0
February	0	0	0	0	0
March	0.1	0	0	0.1	0.1
April	0.7	1.5	0.5	2.2	2.7
May	2.6	5.4	1.8	8.0	9.8
June	2.6	6.5	2.2	9.1	11.3
July	2.0	7.8	2.6	9.8	12.4
August	0.9	7.6	2.6	8.5	11.1
September	0.6	6.0	2.0	6.6	8.6
Annual	10.0	36.3	12.2	46.3	58.5

(in kilo acre-feet)

TABLE 12. MONTHLY DIVERSIONS BY OROVILLE-TONASKET CANAL FROM SIMILKAMEEN.

M O N T H	1926-29	USBR Unit Requirements	
		Pre-1968*	Present
October	0	2.3	2.0
November	0	0	0
December	0	0	0
January	0	0	0
February	0	0	0
March	0	0	0
April	3.0	2.3	2.0
May	7.8	8.4	7.2
June	8.3	10.1	8.7
July	9.4	12.0	10.4
August	9.3	11.8	10.2
September	6.3	9.3	8.0
Annual	44.1	56.2	48.5

* 9020 acres from Similkameen.

The Similkameen subbasin is not as significantly influenced by diversions as the other subbasins; hence, the measured data does give a reasonable idea of the variation in total discharge from the Okanogan Basin. In order to obtain some idea of the variation with time period, various time periods were analyzed and the results presented in Table 14. These data indicate that the period 1943-1970 does at least give a half-way decent estimate of the water supply available.

Lower Okanogan Subbasin

The Lower Okanogan Subbasin has a drainage area of 1,735 square miles. Under natural conditions, about 200,000 acre-feet (2.2 inches) of water would run-off into the main stem Okanogan River. The basin precipitation is about 17 inches. Consequently, about 13 percent of the rainfall runs off. At present, about 140,000 acre-feet (1.5 inches) of water runs off into the main stem of the Okanogan River--this includes the return flows from irrigation diversions into the Lower Okanogan from the Similkameen subbasin.

There are about 26,500 acres of land irrigated in the subbasin. The majority of these are in four districts as shown below:

DISTRICT	IRRIGATED LAND (acres)	ESTIMATED ANNUAL WATER USE (1,000 acre-feet)
Oroville-Tonasket (in subbasin)	8,025	49.9
Okanogan	5,315	22.3
Whitestone	2,050	12.4
Aeneas Lake	810	4.3
TOTAL IN FOUR DISTRICTS	16,200	88.9

These four districts make up about 61 percent of the land irrigated in the subbasin. The information in the table above is not the same as the table

TABLE 13. TOTAL DEPLETIONS FROM SIMILKAMEEN BASIN.

MONTH	1930's		PRE-1968		PRESENT	
	1000 ac-ft	cfs	1000 ac-ft	cfs	1000 ac-ft	cfs
October	-1.1	-18	1.2	20	0.9	15
November	-0.8	-13	-0.8	-13	-0.8	-13
December	-0.9	-15	-0.9	-15	-0.9	-15
January	-0.8	-13	-0.8	-13	-0.8	-13
February	-0.7	-13	-0.7	-13	-0.7	-13
March	-0.2	- 3	-0.1	- 2	-0.1	- 2
April	4.7	79	4.1	69	3.8	64
May	15.3	249	16.0	261	14.8	241
June	17.4	293	19.1	322	17.7	298
July	18.6	303	21.3	347	19.7	332
August	17.3	282	19.9	324	18.3	298
September	8.1	136	11.2	189	9.9	167
Annual	76.9	106	89.5	123	81.8	113

TABLE 14. AVERAGE MONTHLY FLOWS FOR SIMILKAMEEN NEAR NIGHTHAWK.

MONTH	PERIOD OF RECORD					
	1912 to 1975 (64 yrs)	1943 to 1970 (28 yrs)	1929 to 1970 (42 yrs)	1912 to 1928 (17 yrs)	1959 to 1974 (16 yrs)	1929 to 1945 (17 yrs)
October	741	802	758	753	780	639
November	850	970	912	713	865	813
December	727	843	766	653	761	660
January	610	663	614	636	689	512
February	648	895	670	604	768	598
March	667	654	680	608	764	677
April	1892	1668	2059	1691	1555	2510
May	7993	8466	7984	7665	7674	7118
June	9050	9838	8504	8085	11278	6972
July	3004	3248	2777	2874	3463	2240
August	898	996	866	874	933	685
September	601	668	601	609	614	477
Annual (kilo acre-feet)	1668	1793	1641	1556	1818	1441

(U.S.G.S. Gage 12-4425); data for the Similkameen near Oroville (corrected for diversions by the Oroville-Tonasket Canal) was used for the period 1912 to 1928.

presented previously because some of the lands irrigated by a district's supply are not within the district.

Additional information on water use within the subbasin is given in a following section.

The monthly water balance for the basin is given in Table 15. The streamflow into the subbasin is the sum of the Similkameen and the Okanogan at the mouth of the Similkameen. Diversions into the subbasin are through the Oroville-Tonasket Canal and the Whitestone Coulee Canal. The major lakes in the subbasin are:

Omak Lake (saline)	3,244 acres
Conconully Reservoir	450 acres
Spectacle Lake (reservoir)	315 acres
Salmon Lake (reservoir)	313 acres
Whitestone Lake (reservoir)	170 acres
Bonaparte Lake (reservoir)	159 acres
Aeneas Lake	61 acres
Duck Lake	29 acres
Farmers Dam Reservoir	20 acres
TOTAL	4,711 acres

The main stem of the Okanogan River has an annual net loss of water between the flow measurement stations near Nighthawk on the Similkameen and Oroville on the Okanogan which measure the flow into the Lower Okanogan, and the measurement station near Tonasket on the Okanogan midway through the Okanogan. Between Tonasket and Malott, the Okanogan gains water. These data are given in Table 16. Correcting for depletions, the reach above Tonasket would only loose water in April, May, and June. These data suggest there is a significant bank storage of water in the runoff season, that phreatophyte may be important in the reach, and that some water may be underflowing (i.e., ground water flow) the measurement station at Tonasket.

WATER USE IN THE LOWER OKANOGAN

The Lower Okanogan is divided into two divisions--the portion of the subbasin above the USGS gage at Tonasket and the portion below. These are shown in

TABLE 15. MONTHLY WATER BALANCE FOR THE LOWER OKANOGAN SUBBASIN.

	M O N T H												Annual
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	
INFLOW													
Precipitation	125	188	188	172	172	141	125	109	172	47	62	63	1564
Streamflow	83	94	88	79	98	58	152	583	636	211	67	49	2198
Diversions	2	0	0	0	0	0	2	8	9	10	8	7	46
T O T A L	210	282	276	251	270	199	279	700	817	268	137	119	3808
OUTFLOW													
Evapotranspiration, non-irrigated land	79	26	13	13	13	52	118	250	315	210	118	105	1314
irrigated land	4	1	0	0	1	3	8	15	16	19	17	11	96
Consumptive Use (except irrigation)	0.04	0.06	0.1	0.06	0.06	0.12	0.12	0.26	0.30	0.32	0.28	0.16	2
Lake Evaporation	1	0	0	0	0	1	1	1	2	2	2	2	12
Streamflow	91	102	96	87	99	72	160	580	689	249	93	67	2384
T O T A L	175	129	109	100	113	128	287	846	1022	480	230	185	3808
CHANGE IN BASIN STORAGE	35	153	167	151	157	71	- 8	-146	-205	-212	-93	-66	0

TABLE 16. CHANGE IN FLOW OF THE MAIN STEM OKANOGAN RIVER IN THE LOWER OKANOGAN SUBBASIN (1961-70).

M O N T H	Oroville/Nighthawk to Tonasket (cfs)	Tonasket to Malott (cfs)	Total (cfs)
October	30	69	99
November	52	123	175
December	49	93	142
January	50	105	155
February	94	146	240
March	71	110	181
April	-102	70	- 32
May	-597	- 3	-600
June	-356	380	24
July	- 80	109	29
August	-107	39	- 68
September	- 65	41	- 24
Annual (1000 ac-ft)	- 58.6	76.7	18.1
Incremental Area (square miles)	520	820	1340

TABLE 17. DEPLETIONS FROM WHITESTONE CREEK

MONTH	"Natural" Flow (cfs)	1959-65		1975 Conditions	
		Measured	Depletion	Measured	Depletion
October	0.7	2.2	-1.5	3.2	-2.5
November	0.7	1.4	-0.7	2.0	-1.3
December	0.7	3.1	-2.4	4.5	-3.8
January	1.1	3.4	-2.3	4.9	-3.8
February	1.8	3.1	-1.3	4.5	-2.7
March	3.0	2.4	0.6	3.5	-0.5
April	5.6	1.3	4.3	1.9	3.7
May	16.6	2.7	13.9	3.9	12.7
June	9.2	3.3	5.9	4.8	4.4
July	2.6	3.8	-1.2	5.5	-2.9
August	1.5	4.0	-3.5	5.1	-3.6
September	0.7	4.3	-3.6	6.2	-5.5
Annual	3.7	2.9	0.8	4.2	-0.5

Land Irrigated: 1965, 1830 acres; 1975, 2660 acres.

Figure 7. There are approximately 13,400 acres in the northern Lower Okanogan and 13,100 acres in the southern portion. Each of these are discussed below.

Northern Lower Okanogan Subbasin

There are three major irrigation units in the northern portion of the Lower Okanogan. These are the Oroville-Tonasket Irrigation District, Whitestone Irrigation District, and the Aeneas Lake District. The three account for 10,665 of the 13,400 acres in the area. The other 2,735 acres are located along tributary streams as well as the Okanogan River.

The Whitestone District diverts water from Toats Coulee Creek in the Similkameen subbasin. The diversion into the Whitestone Creek watershed as well as the flow from the watershed are shown in Figure 8.

Some of the water in the Toats Coulee Creek watershed leaves as ground water irrigation return flows. The impact of irrigation on the flows of Whitestone Creek is given in Table 17. Development is presently nearing completion for an increase of the irrigated land from 1,830 acres to 2,660 acres.

The water surface level of Aeneas Lake declined sharply between 1964 and 1970 as is shown in Figure 9. Beginning in June 1970, between 6 and 10 cfs has been pumped from the Okanogan River in order to maintain the level of the lake and adjacent ground water.

There are presently 810 acres irrigated in the Aeneas Irrigation District. These will increase to 1,324 in the near future as a result of development presently underway.

The Oroville-Tonasket Irrigation District diverts water from the Similkameen River and pumps some water from the Okanogan below the Similkameen. The U. S. Bureau of Reclamation has proposed a rehabilitation of the district which would improve the water use efficiency. Some new lands would be irrigated.

Data on the depletions from the Okanogan River below the USGS gage near Nighthawk on the Similkameen and the gage near Oroville on the Okanogan

FIGURE 7. LOWER OKANOGAN SUB-BASIN

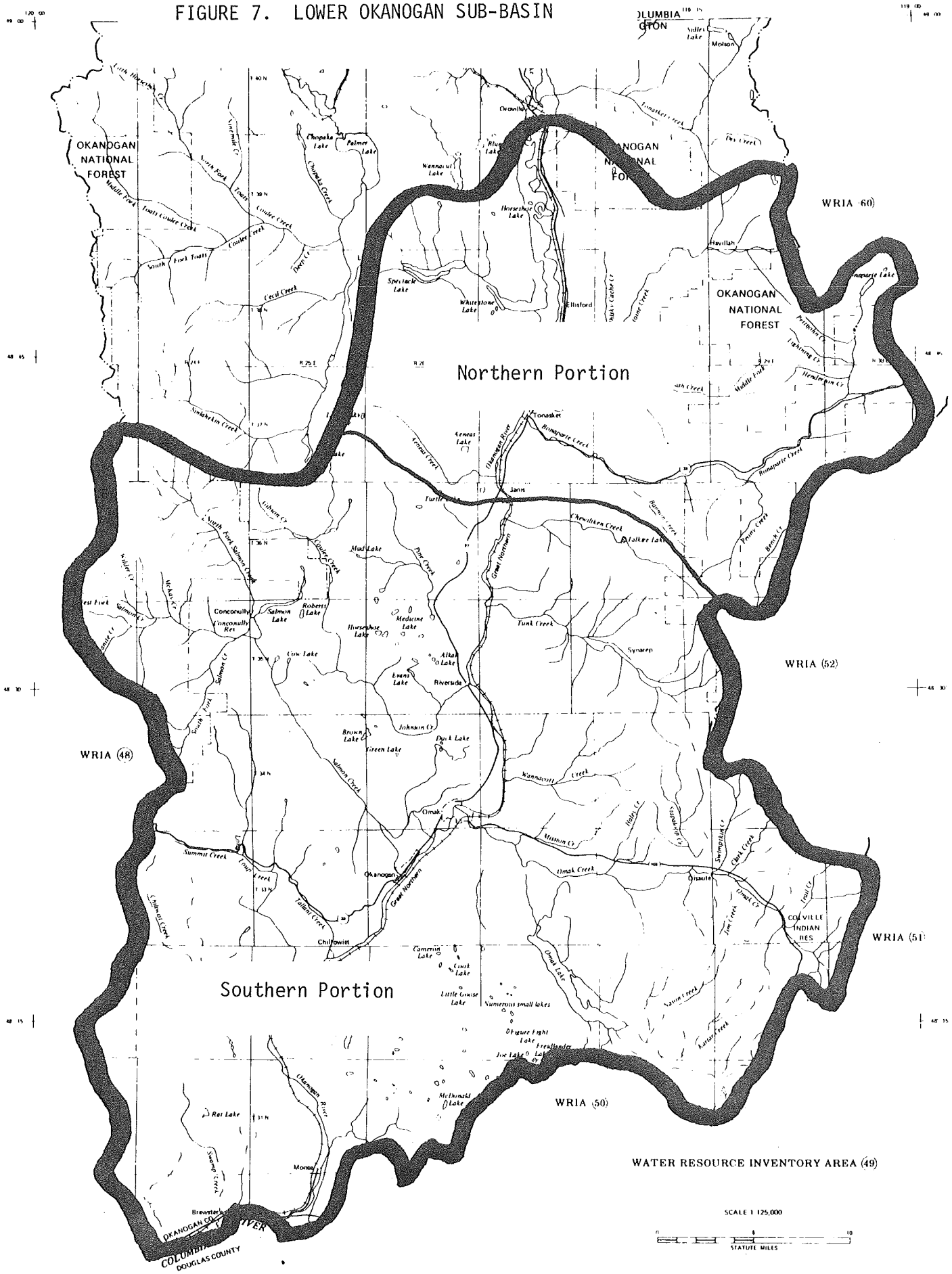


FIGURE 8. DISCHARGE TO AND FROM WHITE STONE CREEK

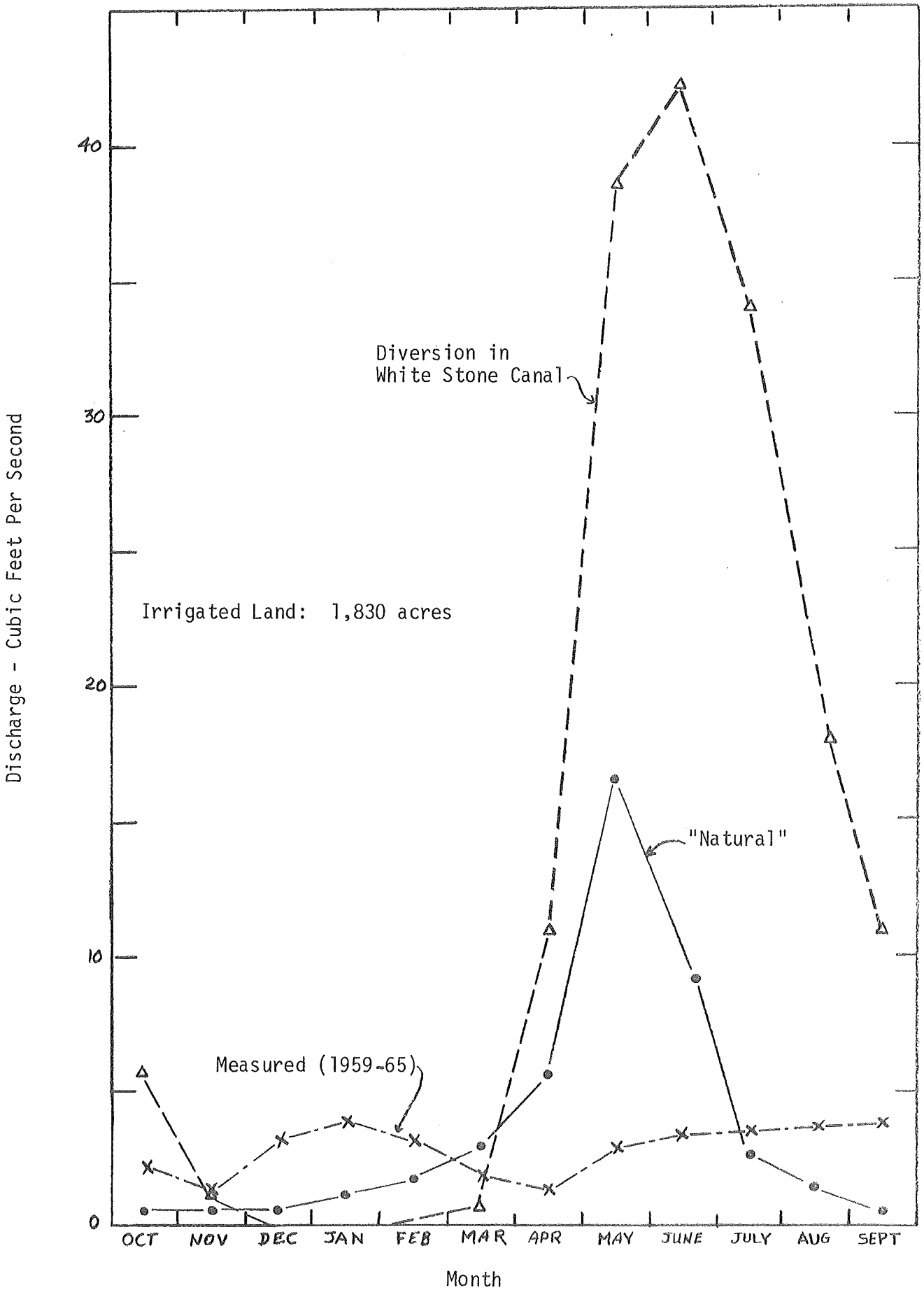
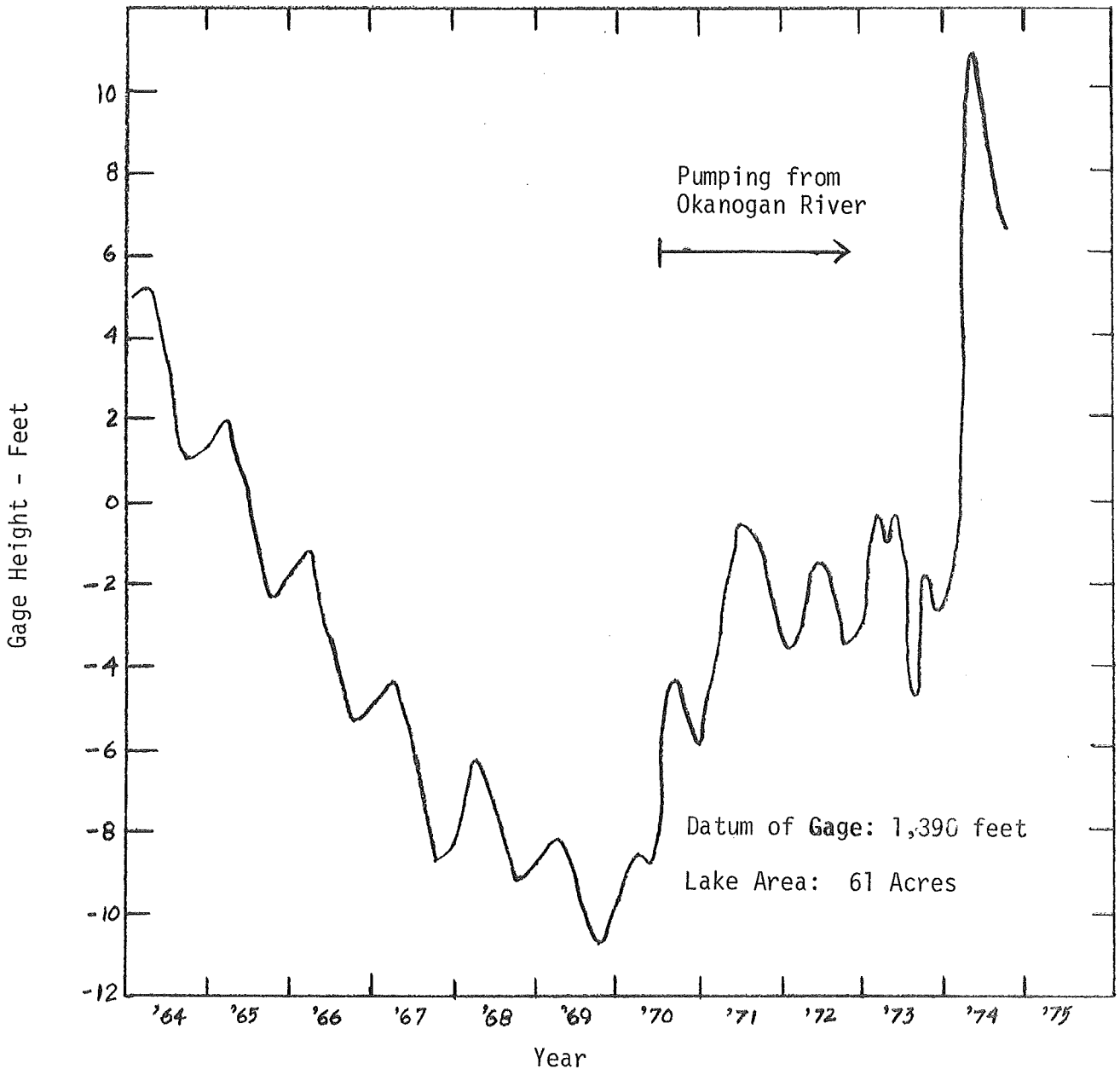


FIGURE 9. ELEVATION OF THE SURFACE OF AENEAS LAKE (1964-1974)



but above the Tonasket gage are given in Table 18. The present depletion from the Lower Okanogan is estimated to be 62 cfs annually. With the developments presently underway or proposed, the depletions would be 55 cfs.

The total depletion in the Okanogan Basin upstream of Tonasket gage, exclusive of development in the Canadian Okanagan, is given in Table 19. The annual depletion is 100 cfs. With the developments underway or proposed, the annual depletions would be 106 cfs. The future conditions are given in Table 20.

Southern Lower Okanogan Subbasin

There are presently 13,100 acres irrigated in the southern portion. Of these, 5,315 are irrigated in the Okanogan Irrigation District. The remainder are irrigated from ground water and tributary streams, except for maybe 2,000 acres irrigated from the Okanogan main stem. In addition to the 13,100 acres, there are 3,000 acres in the Brewster area irrigated from the Columbia River.

In 1973, the sources of water for the Okanogan Irrigation District was:

Salmon Creek----------	16,217 acre-feet
Duck Lake----------	1,276 acre-feet
Okanogan River----------	418 acre-feet
TOTAL	17,911 acre-feet

In addition, 461 acre-feet was pumped from the Okanogan River into Duck Lake and an unknown amount diverted from Johnson Creek into the lake. The depletions from the Okanogan River occur in May and June as a result of storage in Conconully and Salmon Reservoirs. The return flows may exceed the natural flow of Salmon Creek in August and September. No data is available to support this possibility.

TABLE 18. DEPLETIONS FROM THE OKANOGAN ABOVE TONASKET AND BELOW NIGHTHAWK ON SIMILKAMEEN AND OROVILLE ON OKANOGAN.

MONTH	1970 CONDITIONS (cfs)					FUTURE CONDITIONS (cfs)				
	Oroville-Tonasket (1)	Whitestone Coulee (2)	Aeneas Lake	Other	Total	Oroville-Tonasket (1)	Whitestone Coulee (2)	Aeneas Lake	Other	Total
October	2	- 6	5	0	1	5	- 7	7	0	5
November	- 24	- 3	6	- 3	-24	-10	- 4	7	- 3	- 10
December	- 24	- 3	5	- 3	-25	-10	- 4	6	- 3	- 11
January	- 18	- 2	5	- 2	-17	- 7	- 4	6	- 2	- 7
February	- 18	- 1	5	- 2	-15	- 6	- 3	6	- 2	- 5
March	- 13	1	6	- 2	- 8	- 5	0	7	- 2	0
April	24	3	7	2	36	10	2	9	2	23
May	103	10	9	16	138	65	7	10	16	98
June	125	0	7	29	161	114	- 3	8	29	148
July	150	- 7	5	42	190	163	-11	5	42	199
August	152	- 9	5	32	180	129	-11	6	32	156
September	114	- 8	4	13	123	57	-11	5	13	64
Annual	48	- 2	6	10	62	42	- 4	7	10	55
Irrigated Area (acres)	8025	1830	810	2735	13400	8495	2660	1325	2735	15215

(1) Diversions are for irrigation of an additional 1,975 acres with return flows to Osoyoos Lake.

(2) Diversion through Whitestone Canal charged against Similkameen above Nighthawk gage.

TABLE 19. TOTAL DEPLETIONS IN WASHINGTON FROM THE OKANOGAN ABOVE TONASKET AND FROM SIMILKAMEEN IN BRITISH COLUMBIA - 1970 CONDITIONS.

MONTH	Middle Okanogan In Washington (cfs)	SIMILKAMEEN		Lower Okanogan Above Tonasket (cfs)	TOTAL
		British Columbia (cfs)	Washington (cfs)		
October	-10	-18	0	1	-27
November	- 7	-10	- 3	-24	-44
December	- 6	-10	- 5	-25	-46
January	- 6	- 8	- 5	-17	-36
February	- 5	- 7	- 5	-15	-31
March	- 4	- 3	2	- 8	-16
April	- 4	- 5	37	36	64
May	- 8	47	77	138	254
June	-11	91	61	161	302
July	-12	86	66	190	330
August	-10	73	59	180	302
September	-10	21	10	123	144
Annual	- 8	23	23	62	100

TABLE 20. TOTAL DEPLETIONS IN WASHINGTON FROM THE OKANOGAN ABOVE TONASKET AND FROM SIMILKAMEEN IN BRITISH COLUMBIA - FUTURE CONDITIONS.

MONTH	Middle Okanogan In Washington (cfs)	SIMILKAMEEN		Lower Okanogan Above Tonasket (cfs)	TOTAL
		British Columbia (cfs)	Washington (cfs)		
October	- 4	-18	0	5	-17
November	- 3	-10	- 3	-10	-25
December	- 3	-10	- 5	-11	-29
January	- 3	- 8	- 5	- 7	-23
February	- 3	- 7	- 5	- 5	-19
March	- 2	- 3	7	0	- 1
April	- 1	- 5	43	23	60
May	- 2	47	108	98	251
June	- 2	91	90	148	327
July	- 2	86	66	199	349
August	- 1	73	59	156	287
September	- 1	21	10	64	94
Annual	- 2	23	30	55	106

The U. S. Bureau of Reclamation has proposed to rehabilitate the Okanogan Irrigation District facilities and to increase the irrigated land from 5,315 acres to 8,200 acres as an alternative to rehabilitation only. The impact on the flow of the Okanogan River, the increase in lands, and the diversion are shown in Table 21. The maximum net change is a 71 cfs depletion in August.

TABLE 21. CHANGE IN FLOW OF OKANOGAN RIVER BETWEEN MALOTT AND TONASKET (1961-70).

MONTH	PRESENT (cfs)	FUTURE (cfs)	CHANGE
October	69	78	9
November	123	128	5
December	93	98	5
January	105	109	4
February	146	150	4
March	110	113	3
April	70	74	4
May	- 3	- 20	- 17
June	380	354	- 26
July	109	52	- 57
August	39	- 32	- 71
September	41	- 20	- 61
Annual (1000 ac-ft)	76.7	65.7	12.0

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