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PHASE I SUMMARY AND PHASE II PLAN FOR COMPARING REGULATED WITH UNREGULATED STREAMFLOW IN THE YAKIMA RIVER AT UNION GAP, WASHINGTON

By C. H. Swift

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Multiply	By	To obtain
inches (in.)	2.540	centimeters (mm)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
acre-feet (acre-ft)	1233.	cubic meters (m^3)
cubic feet per second per square mile $(ft^3/s)/mi^2$	0.01093	cubic meter per second per square kilometer $(m^3/s)/km^2$

PHASE I SUMMARY AND PHASE II PLAN FOR COMPARING REGULATED WITH UNREGULATED STREAMFLOW IN THE YAKIMA RIVER AT UNION GAP, WASHINGTON

By C. H. Swift III

ABSTRACT

A first-phase, preliminary investigation of the effects of reservoir storage and canal diversion on the flow of the Yakima River at Union Gap was conducted to develop a work plan for a full investigation if a full investigation was warranted and feasible. Results of the preliminary investigation indicate that the effects are measurable and substantial--on the average causing a reduction of roughly one-quarter from the unregulated flow—thus confirming a contention of reduced flows and warranting a full investigation. Preliminary computations of the unregulated flow of the Yakima River at Parker (near Union Gap) for the 1978 water year using a U.S. Army Corps of Engineers SSARR (Streamflow Synthesis and Reservoir Regulation) model configured by the U.S. Bureau of Reclamation, indicate, however, that the flow figures computed by the model contain inaccuracies. Further investigation of the model indicates that the inaccuracies can be substantially reduced by using more of the available discharge data to improve the estimation of local inflows, thus providing a feasible mechanism for a full, detailed investigation.

INTRODUCTION

This is a planning document prepared to summarize a preliminary investigation and state a work plan for a full, detailed investigation. The preliminary investigation was necessary to determine whether a full investigation is warranted and feasible.

The preliminary investigation, which is called Phase I herein, was made in accord with a cooperative agreement between the Yakima Tribal Council and the U.S. Geological Survey (USGS). The Council contends that construction and operation of storage reservoirs and diversion canals upstream of their reservation have reduced the quantity of streamflow in the Yakima River below that allowed by treaty in support of agriculture, fisheries, and other uses. The treaty is that of June 9, 1855, when the tribal reservation was formed.

Purpose and Scope

The overall objective of the full investigation is to determine the extent to which streamflow in the Yakima River at Union Gap has been affected by storage and diversion upstream in the river basin. Union Gap is the point just downstream of Ahtanum Creek where the Yakima River first enters the Yakima Indian Reservation. The season of greatest interest is the irrigation period from April 15 to September 30, and the flows of greatest interest are the monthly mean and minimum discharges during that season.

The objectives of Phase I were to determine what information and data were available, and what analyses needed to be performed to achieve the overall objective. A fundamental finding needed to justify continuation of the investigation is that the effects of storage and diversion do exist in measurable quantities.

Project Area

The Yakima River basin upstream of Union Gap (fig. 1) has a great variation in surface-water runoff, topography, vegetation, and agricultural development. The average-annual runoff ranges from near zero on the sagebrush-covered plateaus, ridges, and coulees on the east side, to somewhat less than 1 cubic foot per second per square mile [$(ft^3/s)/mi^2$] in the central-valley irrigated farm and ranchlands, to more than 6 [$(ft^3/s)/mi^2$] in the high, forested Cascade Mountains to the northwest. Topography separates the basin into two parts; an upper subbasin contained by Umptanum Ridge south of Ellensburg and a lower subbasin contained by Ahtanum Ridge at Union Gap.

The development of reservoirs and canals has progressed in response to agricultural and urban growth, and is among the most complex of any in Washington. There are five major reservoirs, two minor reservoirs, and numerous small diversion dams that serve the 3,652 mi^2 drainage area upstream of Union Gap. At least three of the major reservoirs were constructed on the sites of natural lakes, and four of them have storage capacities ranging from about 50 to 100 percent of the average-annual runoff at those locations. The earliest reservoir was established in September 1905 behind a crib dam at Kachess Lake, and the most recent storage modification was the raising of the spillway elevation at Cle Elum Lake in February 1932.

There are more than 50 canals that divert water from the various streams, and at least 13 of the larger canals divert water at average-annual rates ranging from about 30 to 430 ft^3/s. The actual irrigation-season rates are about double the average-annual rates, and, usually, little or no flow occurs in the canals during the remainder of the year. Four of those major canals are in the upper subbasin, and all terminate there, one after traversing more than 40 miles. Most of the canals have wasteways that can return water directly to the rivers or to tributary creeks, and some of the larger, longer canals can waste and sometimes divert water at most crossings with creeks. The earliest recorded use of a canal was in 1880 in the vicinity of Ellensburg. Canal development was most pronounced from 1890 to 1910.

Acknowledgment

David E. LaFrance performed the analytic work necessary for this preliminary investigation and report, and his contribution is gratefully acknowledged.

SUMMARY OF PHASE I

Approach to Preliminary Investigation

The true measure of the effects of storage and diversion is the difference between the observed river discharges that are affected by storage and diversion, and the natural river discharges that would occur otherwise. However, no method is presently available for accurately determining what those natural discharges might otherwise have been. That is because storage and diversion not only can alter the distribution of streamflow in time and place in the river basin, but also can change the amount of evapotranspiration (ET) and ground-water interchange. However, the effects of these changes in ET and ground-water interchange should be very small when compared to the volume of flow, and estimates of natural streamflow can be obtained by simple arithmetic; adding to or subtracting from streamflow the amounts removed or added by changes in storage, by diversion, and by waste return. Discharges so estimated are called unregulated to distinguish them from natural discharge, and observed discharges affected by storage and diversion are called regulated.

The Yakima River basin is a complicated network of streams, reservoirs, and canals; and each inaccuracy in estimating flow in parts of the network can affect the accuracy of, and confidence in, the estimated flow from the basin. Because accuracy is a major concern in the overall objective, a digital-computer model of streamflow was chosen to analyze the entire system, including the errors of estimates. The purpose of such a model is to simulate, with hydrologic relationships and hydraulic parameters, the streamflow, storage, diversions, and returns that occur at selected locations in a river network. One model for the Yakima River basin has been configured and calibrated by the U.S. Bureau of Reclamation (USBR). That model is of U.S. Army Corps of Engineers design and is called SSARR, for Streamflow Synthesis and Reservoir Regulation.

Other factors also contributed to the decision to use a computer model for this study. Because the development and utilization of storage and diversion has been a dynamic process with regulatory structures beginning operation on different dates and at many locations, the effects of each major reservoir and canal are distinct and need to be analyzed separately. In addition, because precipitation and runoff vary naturally throughout the basin each year and from year to year, the magnitude of unregulated flow also varies with time and place, and all of the available discharge records for significant streams, reservoirs, and canals need to be included in the analysis.

There are also some factors that can limit the accuracy achievable with the computer model. The measurement of reservoir stage, and the conversion of stage to storage, and change in storage to outflow, are inherently less accurate than the direct measurement of reservoir discharge. The determination of unregulated flow must extend over all days of all years because the major reservoirs have the capacity to affect flow not only within years but also between years, although the quality of flow records may not be the same for all years available. The ungaged parts of the basin, called locals herein, comprise approximately 40 percent of the total basin area and, as a rough estimate, contribute about 20 percent to the total unregulated outflow from the basin at Union Gap. Not all of the gaged parts of the basin have similar periods of record, therefore, some records will need to be extended with estimates.

In addition to the stated objectives of Phase I, five questions were to be answered if possible:

1. Would another streamflow model be better than the SSARR model?
2. Could the accuracy of calculated unregulated flows be improved by using in SSARR or another model some data or analyses not presently used by USBR in SSARR?
3. Do reasonable changes in the hydraulic parameters used in SSARR cause variations in the computed unregulated flows that exceed the difference between the unregulated and the observed flows?
4. Are the differences between observed natural flows and computed regulated flows for 1896-1903 of the same magnitude as the differences between observed regulated flows and computed unregulated flows for 1904-1977?
5. How do the natural flows observed between 1896 and 1903 compare statistically with the regulated flows observed between 1904 and 1977?

The entire investigation was to be concluded if the answers to all of the first three questions were no. Questions 4 and 5 have become moot because the first diversions were made prior to the first collection of any surface-water data; in other words, there is no known record of natural flow in the Yakima River.

Results of Preliminary Investigation

Selection of a Digital Streamflow Model

At least three digital-computer models of streamflow have been developed for the Yakima River basin. In addition to the SSARR model used by the USBR, there are two models—a watershed model and a forest-runoff model—constructed by the University of Washington (Seattle) and Washington State University (Pullman).

Although unconfigured to the Yakima Basin, there are also numerous other streamflow models available from other institutions and agencies, including the USGS. Within each of these models the functional relationships may differ in accord with the designer's concept of how a streamflow system works and with the purpose of the design. Each model may also differ in the amount and type of input data required, in the detail of processing and output data, and in the accuracy of the results.

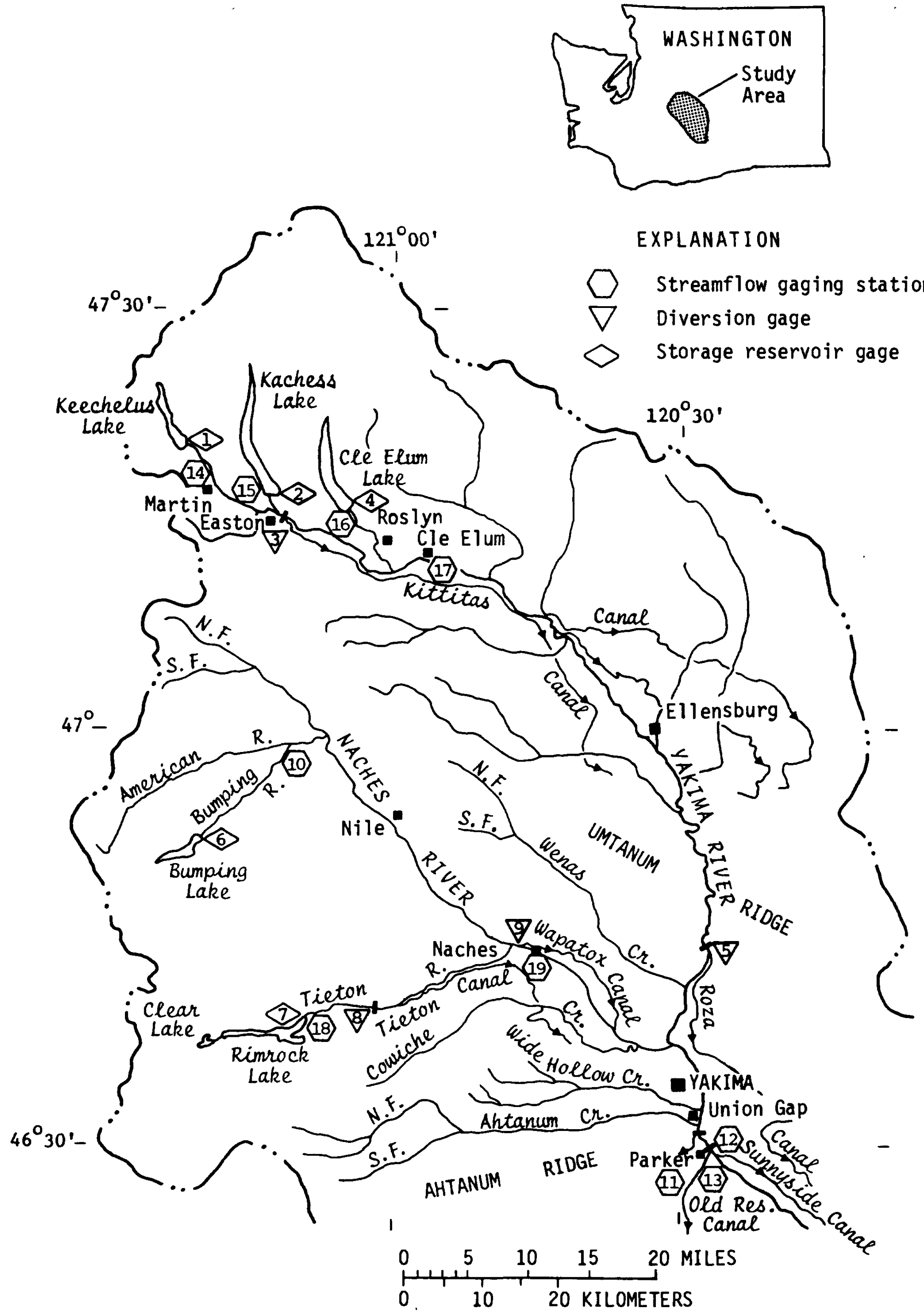
None offers any particular advantages over the SSARR model for the objectives of this investigation.

The SSARR model is an operations type, designed to synthesize and simulate streamflow under a wide variety of hydrologic and physical conditions, including all of those found in the Yakima River basin, and it has been applied successfully in many areas of the world. For those reasons and because the SSARR model has already been configured and calibrated for much of the Yakima River basin, it has been selected for continued application in this investigation.

Description of the Yakima SSARR Model

As configured to the Yakima River basin by the USBR, the SSARR model uses data from the 19 numbered stations shown in figure 1 and computes unregulated streamflow for the Yakima River near Parker, a site 3 miles downstream from Union Gap. For this preliminary investigation, the model was not applied to compute streamflow values specifically at Union Gap. Although there may be large differences between regulated streamflow at Union Gap and near Parker, unregulated streamflow should be very similar at those locations.

A schematic of the Yakima SSARR model is shown in figure 2. As water in streams advances from the northwest and west toward the southeast in figure 1, so does streamflow simulated by the model advance from the top-left and left toward the lower right in figure 2. The 19 symbols with names and identification numbers in figure 2 correspond to the 19 stations shown in figure 1. All five of the major reservoirs and six of the major canals are represented in the model. Each of the small circles in figure 2 represents a point where a flow summation takes place within the model. Unregulated streamflow is computed by the model at each of the five summation points immediately downstream from the five reservoirs, then routed downstream along lengths of channel reach, and finally combined with local inflows to three stations (13, 17, and 19) where unregulated streamflow again is computed. Local inflow is computed as the arithmetic sum of regulated flow at a downstream station (13, 17, or 19), minus the regulated flows at the stations immediately upstream, plus any flows diverted in upstream canals. The three locals in this model represent a very large part (84 percent) of the total-basin drainage area and a roughly estimated large part (about 55 percent) of the average-annual unregulated streamflow from the basin.



STATION IDENTIFICATION

1. Keechelus reservoir
2. Kachess reservoir
3. Kittitas diversion
4. Cle Elum reservoir
5. Roza diversion
6. Bumping reservoir
7. Rimrock reservoir
8. Tieton diversion
9. Wapatox diversion
10. Bumping River near Nile
11. Old Reservation canal
12. Sunnyside canal
13. Yakima River near Parker
14. Yakima River near Martin
15. Kachess River near Easton
16. Cle Elum River near Roslyn
17. Yakima River at Cle Elum
18. Tieton River at Tieton Dam
19. Naches River near Naches

FIGURE 1.--Data stations used by the U.S. Bureau of Reclamation for the Streamflow Synthesis and Reservoir Regulation model of streamflow in the Yakima River near Parker, Wash.

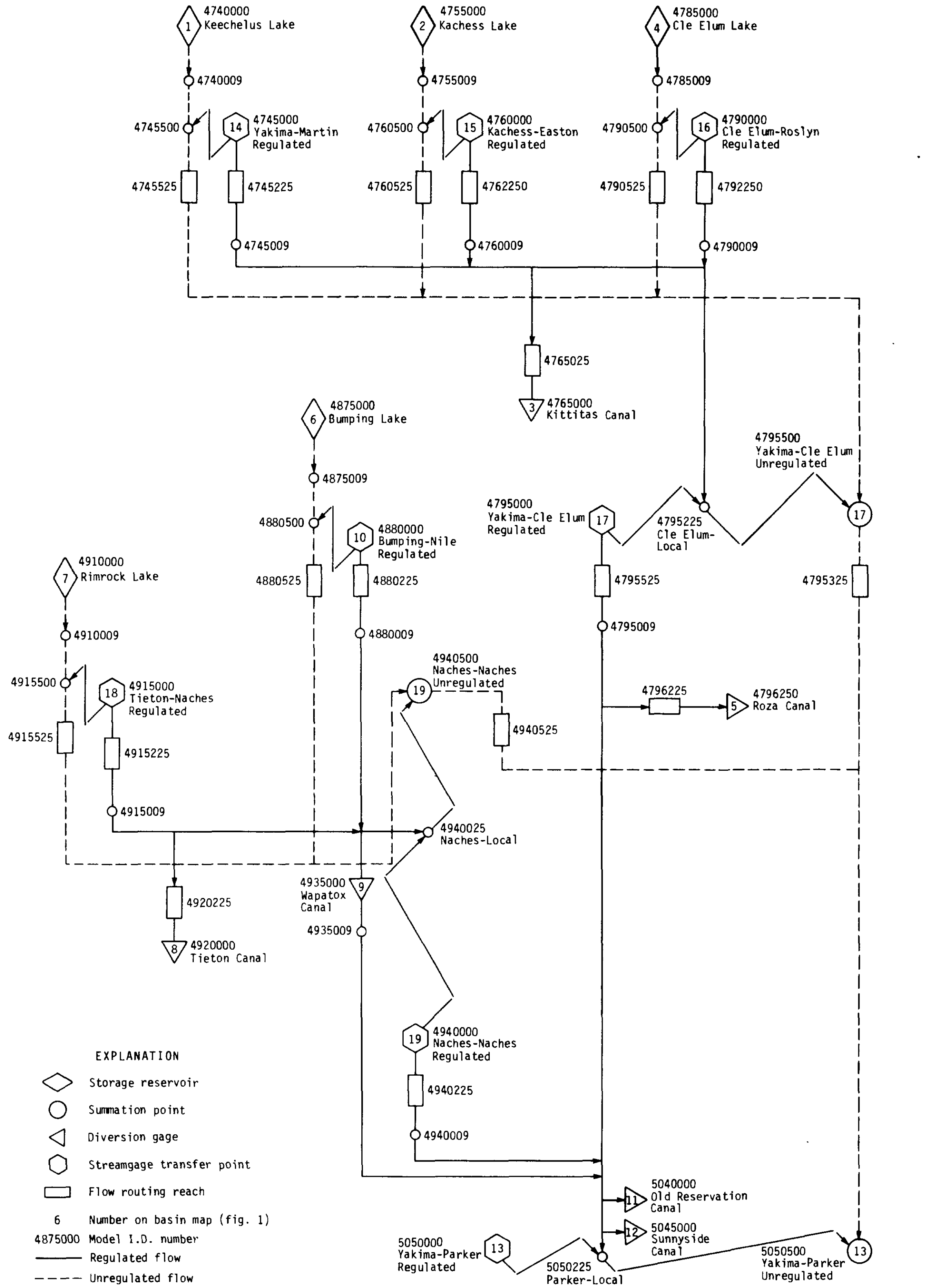


FIGURE 2.--Schematic of the SSARR model as configured by the U.S. Bureau of Reclamation for the Yakima River basin upstream of Parker, Wash.

The USBR used in their Yakima River SSARR model only those stations (19) that were useful and necessary to the objectives for which they constructed the model. There are numerous additional stations (at least 43 more) at which discharge records have been collected in the Yakima River basin. If all of those records were usable and had been used in the USBR's model, the locals in the model would represent a much smaller part (about 40 percent) of the total-basin drainage area and a much smaller part (about 20 percent) of the average-annual unregulated streamflow from the basin.

Evaluation of Flows Computed by the Yakima SSARR Model

Several model simulations of unregulated flow were completed for the Yakima River near Parker, but only for the 1978 water year (a 12-month period ending September 30). The 1978 observed regulated daily mean discharges are compared with one of the simulations of unregulated discharges for Parker in figure 3. The discharge scale is logarithmic, which compresses the differences among high discharges and expands the differences among low discharges, but the effects of storage and diversion are obvious and substantial. During the irrigation season (April 15-September 30), the graph of regulated streamflow varies as might be expected when day-to-day changes in diversion and storage are imposed on natural runoff. However, the graph of unregulated streamflow is uncharacteristically jagged during the irrigation season and similar in pattern of variation to the graph of regulated streamflow, suggesting that the unregulated discharges contain large inaccuracies.

There are at least several possible explanations for the irregular recession of unregulated streamflow from the usual winter and spring high flows to the normal summer low flows. Any or all of the accuracy-limiting factors described in the "Approach to Preliminary Investigation" could apply. In particular, the three locals in the Yakima SSARR model are suspect due to the method of computing their inflow contributions and the large percentage of total flow and drainage area that they represent. As a difference between upstream and downstream flows in the river with diversions in the reach added, local inflow contains all of the errors in the records of regulated flow at gaging stations on the river and the diversion canals. Examination of the 1978 daily mean discharges computed for the three locals in the model indicated that they were all large relative to the observed discharges of the Yakima River near Parker, at times even exceeding those observed discharges. The computed local discharges were also highly variable, at times even becoming negative, indicating unaccounted losses. Although data for other years were not examined, the accuracy of the model results can almost certainly be improved by accounting for more of the losses and gains and thus reducing the relative size of the locals.

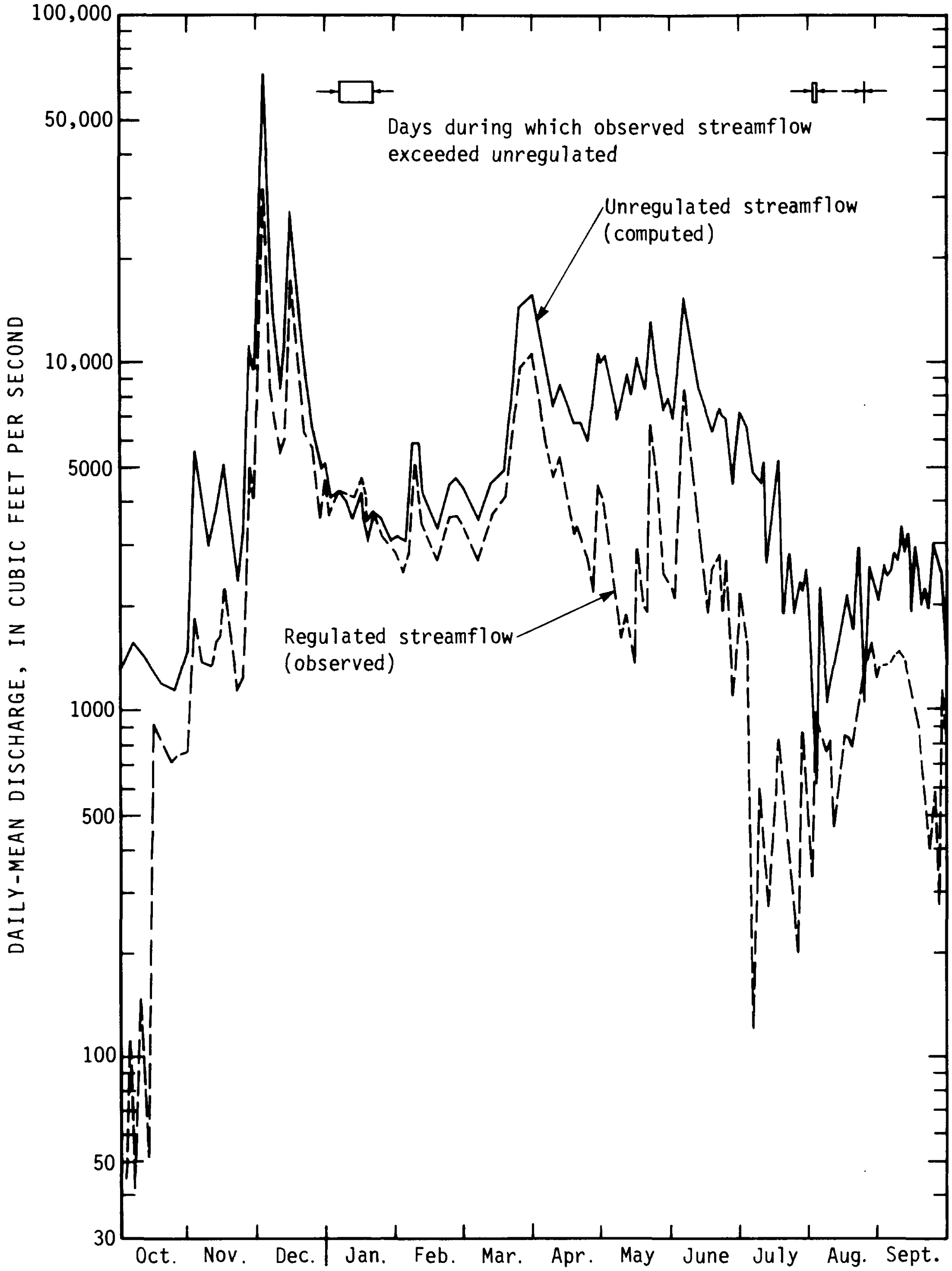


FIGURE 3.--Comparison between unregulated discharges computed by the SSARR model and observed regulated discharges for the 1978 water year, Yakima River near Parker, Wash.

Preliminary Sensitivity Analysis of the Model

Sensitivity analysis is the determination of the extent of changes in model output as selected input variables are changed by selected amounts. It is the part of the model-calibration process that establishes the accuracy and consistency of the model.

Six simulations were made with the Yakima SSARR model with 1978 water-year data to test the sensitivity of computed unregulated flow to large changes in three channel-routing factors. The channel-routing factors affect the amount of water moving along a length of channel and the time of arrival at a confluence of two streams or any other location.

The most widespread of the unregulated flows computed for 1978 by the model sensitivity tests are shown in figure 4. The two graphs indicate very little difference from one another or from the unregulated flows shown in figure 3. Incorrect channel-routing factors may help to explain some of the jaggedness of the unregulated-flow graph in figure 3, but certainly not all of the jaggedness.

No functional relationships other than channel routing were tested, but certain other relationships are now suspect. In particular, the change in storage-to-discharge relationships and the size of the local flow and diversion relationships could easily account for negative local values in the Yakima SSARR model and need to be tested.

In summary, the results of experimental simulations for 1978 with the SSARR model indicate large inaccuracies in the computed unregulated flows, and the inaccuracies are more likely due to errors in simulating flow from the large ungaged areas of the basin than to errors in the choice of channel-routing factors.

Statistical and Other Evaluations

Statistical tests were performed on three periods of record of storage-only adjusted annual-mean flows for the Yakima River at Union Gap. The three periods, 1898-1905, 1906-32, and 1933-77, were selected to represent no storage, development of storage, and fully developed storage, respectively, in the basin. For the tests a record of annual-mean flows from 1898-1977 was constructed for the Yakima River at Union Gap downstream of Ahtanum Creek by combining midterm records for the Yakima River near Parker (after adding the three major diversions between Parker and Union Gap) with early records for the Yakima River at Union Gap and recent records for the Yakima River above Ahtanum Creek (after adding Ahtanum Creek at Union Gap), and then adjusting the entire 1898-1977 record for the year-to-year change in storage of the five major reservoirs. Although only two major diversions are shown between the stations near Parker and above Ahtanum Creek in figures 1 and 2, records for the third major diversion, the New Reservation Canal, were actually combined by USBR with records for the Old Reservation Canal in the SSARR model.

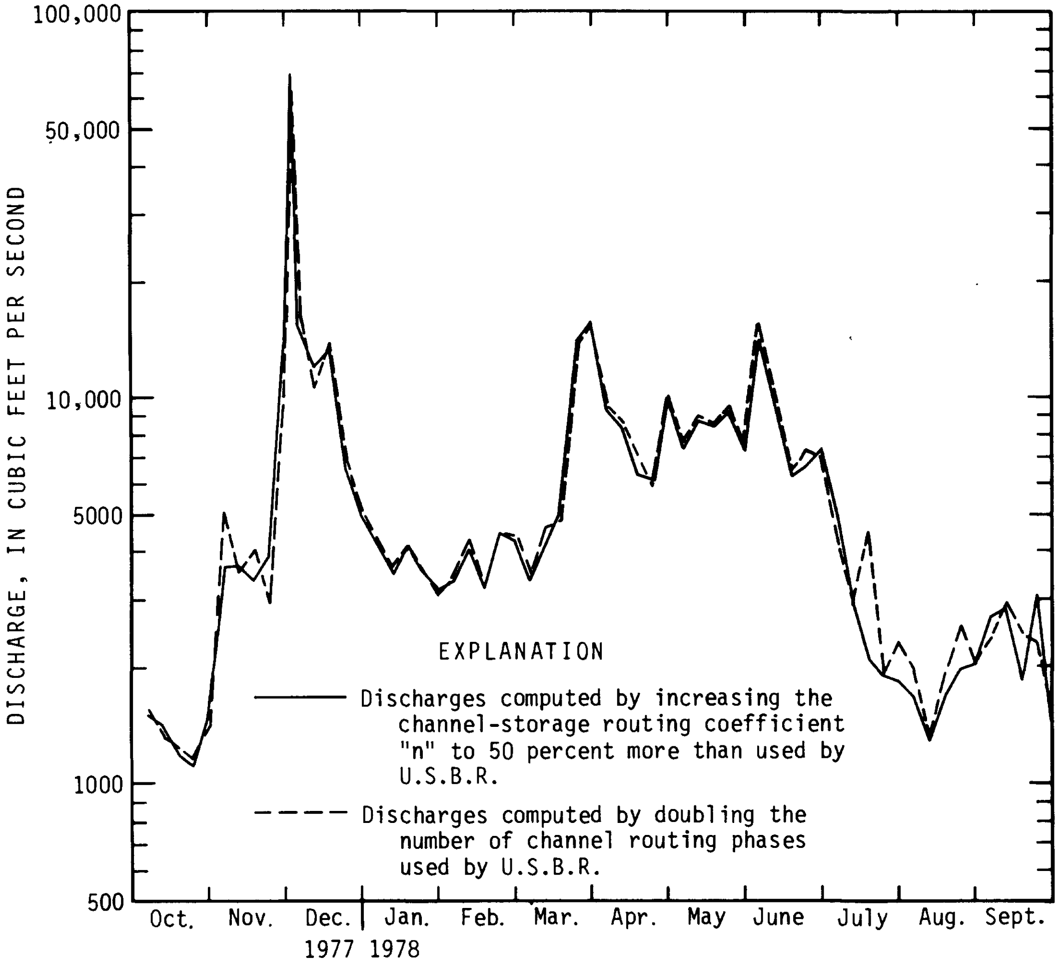


FIGURE 4.--Comparison of unregulated discharges computed by the SSARR model when selected channel-routing factors are changed, Yakima River near Parker, Wash.

The tests performed were covariance analyses (Dixon and Massey, 1957, p. 209-220), using the annual total precipitation at Ellensburg as the common variable. They were performed to determine whether any difference in annual-mean flows existed for the three periods due only to diversions; that is, after the effects of only storage and precipitation variation were removed. No difference at the 95-percent confidence level was detected among flows for the three periods. The lack of difference may be due to poor selection of periods or to reappearance of a large percentage of the diversion as return flow, but was more probably due to the fact that diversion had already been well developed in the basin by 1898.

A comparison was also made on the mean-monthly discharges over two periods, 1898-1905 and 1967-77, for the Yakima River at Union Gap. The record for the early period was obtained at Union Gap and for the later period was constructed by adding records for the Yakima River above Ahtanum Creek to records for Ahtanum Creek at Union Gap. No adjustments were made for changes in storage in the basin. This comparison is shown in figure 5 and suggests that storage has changed the shape of the annual hydrograph, increasing the summer flows and decreasing the winter and spring flows. The average-annual flows for the two periods were different, but were approximately equal when the storage-affected average-annual flow was adjusted for the difference in precipitation during the two periods.

The last evaluation of station records in the basin involved: (1) compiling a list of pertinent information concerning the records at important reservoir, canal, and stream-gaging stations in the basin (table 1); and (2) making an inventory of average annual discharges by subbasin (table 2).

The station records listed in table 1 include nearly all of the information known about storage and discharge in the upstream basin. Only 19 of the 62 station records shown in table 1 were used in the SSARR model. The dates given for initial operation are the dates when measurements or records were first collected and, for reservoirs and canals, do not necessarily represent the date of first construction and use. The flow capacities listed are those found in various sources of literature and, for stream-gaging stations, may or may not be adjusted for storage and diversion.

About 2,600 station years of combined storage and discharge records have been collected in the upstream basin, and about 1,400 of those station years are contained in USGS computer files. At most, the 19 stations used in the SSARR model represent about 1,200 of the station years of record collected (about 1,100 station years in computer files). Many of the additional available records, particularly those for canal diversions, are contained in USBR files. Although probably not all of the additional available records are needed to improve the accuracy of the SSARR model for the basin, there are plentiful data for improvement.

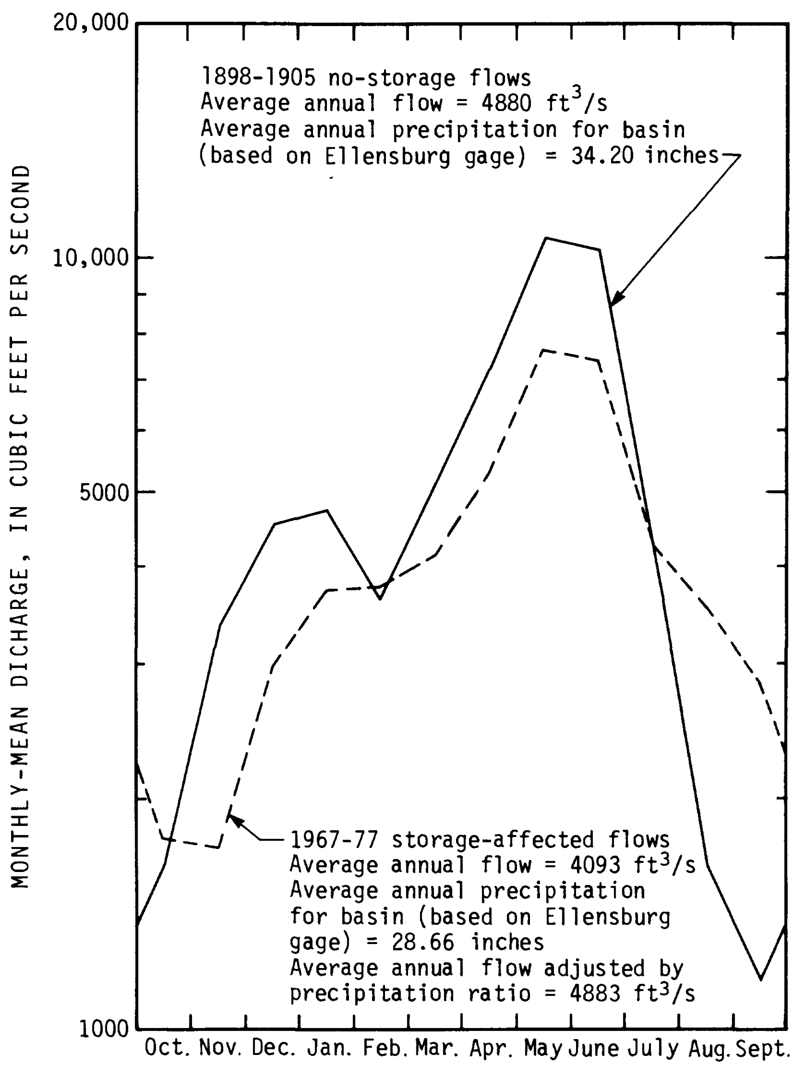


FIGURE 5.--Comparison between mean discharges during an 8-year diverted flow period and during an 11-year regulated and diverted-flow period, Yakima River at Union Gap, Wash.

PLAN FOR PHASE II

Phase II of the investigation represents the work needed to estimate unregulated streamflow and the effects of storage and diversion. For this phase, the SSARR model will be reconfigured to include some of the pertinent station records represented in table 1. The model will be calibrated on the basis of observed, regulated flows for some portion of the 1898-1978 period, and tested for sensitivity to obtain an estimate of its accuracy.

The following are the anticipated tasks.

1. Correct erroneous data that are currently in the data base.
2. Expand the data base with some of the additional pertinent station records available (table 1) but not presently used in the SSARR model.
3. Reconfigure the SSARR model into additional subbasins and associated local inflow areas with available station records.
4. Calibrate the model on a subset of the 1898-1978 station records of observed, regulated flows.
5. Perform verification and sensitivity tests to determine model accuracy.
6. Operate the model to obtain unregulated flows for Union Gap for as much of the 1898-1978 period as is possible.
7. Calculate and compare monthly mean flows and low flows from the regulated and unregulated records for the irrigation season.
8. Prepare an open-file report for the Yakima Tribal Council to transmit the data and information obtained in tasks 5, 6, and 7.

TABLE 1.--Pertinent information for reservoir, canal, and stream gages, Yakima River basin upstream from Parker, through September 30, 1977

Name	Number in fig. 1	Official station number	Drainage area (mi^2)	Record type (a)	Date initially operated (b)	Date present structure completed (b)	Present usable storage capacity (acre-ft)	Flow capacity (ft^3/s) (c)	Water years included in: Written record (no./yrs) (d)	Computer record (no./yrs) (d)
Keechelus Lk nr Martin	1	12474000	54.7	S	1-12-1906	8-19-1914	157,800	3,000M	71 (1901-77)	61 (1912-72)
Yakima R nr Martin	14	12474500	54.7	R	10-18-1903	--	--	338A	74 (1904-77)	73 (1905-77)
Cabin Cr nr Easton	--	12475000	29.3	R	5-12-1909	--	--	88A	6 (1910-15)	0
Kachess Lk nr Easton	2	12475500	63.6	S	9-20-1905	6-30-1911	239,000	5,000M	72 (1906-77)	61 (1912-72)
Kachess R nr Eastern	15	12476000	63.6	R	10-14-1903	--	--	294A	74 (1904-77)	73 (1905-77)
Kittitas Highline Canal at Easton	3	12476500	--	D	4 -b-1930	--	--	347A 1,320M	48 (1930-77)	48 (1930-77)
Yakima R at Easton	--	12477000	188	R	5-12-1904	--	--	610A	17 (1911-15, 1942-53)	0
Cle Elum Lk nr Roslyn	4	12478500	203	S	5 -b-1906	2-26-1932	436,900	5,000M	71 (1907-77)	61 (1912-72)
Cle Elum R nr Roslyn	16	12479000	203	R	10-10-1903	--	--	933A	74 (1904-77)	74 (1904-77)
Yakima R at Cle Elum	17	12479500	495	R	8-26-1906	--	--	2,040A	71 (1907-77)	17 (1961-77)
Teanaway R blw Forks, nr Cle Elum	--	12480000	172	R	6- b-1911	--	--	372A	5 (1968-72)	5 (1968-72)
Teanaway R nr Cle Elum	--	12480500	200	R	4- 2-1909	--	--	374A	10 (1910-11, 1913-14, 1947-52)	10 (1910-11, 1913-14, 1947-52)
Swauk Cr nr Cle Elum	--	12481000	90.7	R	4-30-1909	--	--	61A	5 (1910-14)	0
Cascade Canal near Ellensburg	--	12481500	--	D	b- b-1902	--	--	105A 150M	70 (1905, 1909-77)	0
Taneum Cr nr Thorp	--	12482000	74.3	R	4- b-1909	--	--	66A	1 (1910)	0
West Side Kittitas Canal nr Thorp	--	12482500	--	D	b- b-1905	--	--	70A	37 (1905, (1909-11, 1914, 1919-50)	0
Ellensburg Water Co. Canal nr Ellensburg	--	12483000	--	D	b- b-1885	--	--	100A	64 (1904, 1909-15, 1922-77)	0
Manastash Cr nr Ellensburg	--	12483500	74.5	R	4- 5-1909	--	--	60A	5 (1910-14)	0
Naneum Cr nr Ellensburg	--	12483800	69.5	R	3- b-1957	--	--	56A	19 (1958-71, 1973-77)	16 (1958-71, 1973-74)
Wilson Cr at Thrall	--	12484000	382	R/W	8- b-1911	--	--	(f)	0 (1911 partial)	0
Yakima R at Umtanum	--	12484500	1,594	R	8-25-1906	--	--	2,449A	Not all daily 71 (1907-77)	42 (1932-74)
Roza Canal nr Moxee City	5	(n)12479625 12485000	--	D	b- b-1941	--	--	366A 2,300M	37 (1941-77)	37 (1941-77)
Selah-Moxee Canal nr Selah	--	12485500	--	D	b- b-1904	--	--	33A 132M	67 (1905, 1909-15, 1919-77)	1 (1911)
Wenas Cr abv dam nr Naches	--	(e)	106	R	b- b-1942	--	--	(f)	3 (1942-44)	0
Wenas Cr Reservoir	--	(e)	114	S	b- b-1912	b- b-1912	1,050	(f)	66 (1912-77)	0
Wenas Cr blw dam nr Naches	--	(e)	114	R	b- b-1925	--	--	(f)	6 (1925-27, 1942-44)	0
Wenas Cr nr Selah	--	12486000	192	R	3-30-1909	--	--	10A	0 (1909 partial)	0
Taylor Canal nr Selah	--	12486500	--	D	b- b-1905	--	--	9A 55M	58 (1909-12, 1923-77)	2 (1910-11)
Yakima R at Selah Gap nr North Yakima	--	12487000	2,135	R	5-19-1897	--	--	(f)	0 (partials 1897,1904, 1911,1912)	0 (partials 1897,1904, 1911, 1912)
Bumping Lk nr Nile	6	12487500	69.3	S	4-27-1909	11- 3-1910	33,700	1,500M	68 (1910-77)	61 (1912-72)
Bumping R nr Nile	10	12488000	70.7	R	6-13-1906	--	--	296A	68 (1910-77)	68 (1913-77) (1910-74)
American R nr Nile	--	12488500	78.9	R	4-25-1909	--	--	246A	40 (1910-11, 1940-77)	35 (1940-74)
Naches R at Anderson Ranch nr Nile	--	12489000	394	R	4-24-1909	--	--	1,030A	5 (1910-14)	0 (1911 partial)
Naches R at Oak Flat nr Nile	--	12489500	641	R	6-25-1904	--	--	1,230A	13 (1905-17)	8 (1905-10, 1912,13)
Selah Valley Canal nr Naches	--	12490000	--	D	4- b-1904	--	--	63A 136M	62 (1910-14, 1921-77)	0

TABLE 1.--Pertinent information for reservoir, canal, and stream gages, Yakima River basin upstream from Parker, through September 30, 1977--Continued

Name	Number in fig. 1	Official station number	Drain-age area (mi^2)	Record type (a)	Date initially operated (b)	Date present structure completed (b)	Present usable storage capacity (acre-ft)	Flow capacity (ft^3/s) (c)	Water years included in: Written record (no./yrs) (d)	Computer record (no./yrs) (d)
Clear Cr Reservoir near Naches	--	(e)	61.4	S	b- b-1915	b- b-1915	5,300	500M	11 (1915-25)	0
Rimrock Lk at Tieton Dam nr Naches	6	12491000	187	S	4-27-1925	4-27-1925	198,000	2,750M	51 (1926-77)	47 (1926-72)
Tieton R at Tieton Dam nr Naches	18	12491500	187	R	8-28-1908	--	--	507A	58 (1909-12, 1919-20, 1926-77)	53 (1910-12, 1919, 20 1926-74)
Tieton Canal nr Naches	8	12492000	--	D	5- b-1910	--	--	126A 350M	68 (1910-77)	68 (1910-77)
Tieton R at (below) head-works of Tieton Canal nr Naches	--	12492500	239	R	3-29-1906	--	--	569A	Not all daily 71 (1907-77)	46 (1908-13, 1920,26) 1937-74)
Tieton R abv and blw Oak Cr nr Naches	--	12493000	296	R	4-24-1902	--	--	615A	11 (1903-13)	0
Wapatox Canal nr Naches	9	12493500	--	D	5-18-1904	--	--	429A 709M	63 (1913-14, 1917-77)	60 (1917-76)
Naches R blw Tieton R nr Naches	19	12494000	941	R	8- 4-1905	--	--	1,742A	Not all daily 69 (1909-77)	41 (1910-12, 1937-74)
Naches Canal Co. (Gleed) Canal nr Naches	--	12494500	--	D	5- b-1904	--	--	50A 92M	61 (1909-14, 1923-77)	0
Yakima Valley (Congdon) Canal nr Naches	--	12495000	--	D	5- 1-1904	--	--	47A 69M	65 (1904-05, 1911-14, 1919-77)	0
Naches-Cowiche Canal nr North Yakima	--	12495500	--	D	5- 4-1904	--	--	32A 50M	61 (1909-14, 1923-77)	0
Cowiche Cr nr North Yakima	--	(e)	120	R	b- b-1912	--	--	(f)	0 (Partial 1912-14)	0
North Yakima (Fruitvale) Power Canal nr North Yakima	--	12496000	--	D	5- 5-1904	--	--	100A 308M	63 (1904-05, 1910-15, 1923-77)	0
Old Union Canal nr North Yakima	--	12498000	--	D	5- 6-1904	--	--	45A 77M	63 (1904-05, 1910-15, 1923-77)	0
Naches R nr North Yakima	--	12499000	1,106	R	8- b-1896	--	--	1,712A	16 (1899-1914)	10 (1899-1901, 1904,1908-13)
Union Gap Canal at Union Gap	--	(e)	--	D	b- b-1909	--	--	17A 80M	69 (1909-77)	0
Wide Hollow Cr at Union Gap	--	(e)	64.8	R	b- b-1911	--	--	(f)	16 (1911-15, 1922-33)	0
Yakima R abv Ahtanum Cr at Union Gap	--	12500450	3,479	R	10- b-1966	--	--	4,001A	11 (1967-77)	7 (1967-70, 1972-74)
North Fork Ahtanum Cr near Tampico	--	12500500	68.9	R	8-26-1907	--	--	70A	53 (1910-15, 1931-77)	48 (1911-15, 1932-74)
South Fork Ahtanum Cr at Conrad Ranch nr Tampico	--	12501000	24.8	R	3-15-1915	--	--	20A	47 (1931-77)	43 (1932-74)
South Fork Ahtanum Cr nr Tampico	--	12501500	28.5	R	8-27-1907	--	--	24A	6 (1909-14)	6 (1909-14)
Ahtanum Cr at Union Gap	--	12502500	173	R	5-11-1904	--	--	83A	21 (1912-14, 1952, 1961-77)	18 (1912-14, 1952, 1961-74)
Yakima R at Union Gap	--	12503000	3,652	R	8-14-1893	--	--	4,522A	19 (1897-1914, 1964	13 (1899-1907, 1912-14,1964)
New Reservation Canal nr Parker	--	12503500	--	D	5- 9-1904	--	--	673A 2,260M	Monthly only 73 (1905-77)	26 (1911,19,22, 1936-58)
Old Reservation Canal nr Parker	11	12504000	--	D	6- 7-1904	--	--	43A 386M	Monthly only 71 (1907-77)	68 (1909, 1911-77)
Sunnyside Canal nr Parker	12	12504500	--	D	4-22-1904	--	--	591A 1,320M	Monthly only 73 (1905-77)	68 (1909, 1911-77)
Yakima R nr Parker	13	12505000	3,660	R	4-25-1908	--	--	2,522A	Not all daily 69 (1909-77)	69 (1909-77)

[a] Type: D, diversion from flow; S, storage of river flow; R, river flow; and W, wasteway to river flow.

[b] Exact day or month unknown; year is year that record first began.

[c] For reservoirs flow capacity is design maximum (M) listed for outlet works, excluding spillway; for canals flow capacity is design or recorded maximum (M) and approximate seasonal average (A); and for streams flow capacity is the average annual flow (A) from records or literatur

[d] Complete years ending September 30.

[e] Number not yet assigned, or chosen differently by USBR than by USGS.

[f] Undetermined.

The subbasin inventory shown in table 2 is only a very approximate accounting of the distribution of regulated, unregulated, and diverted mean-annual flows in the basin. However, the values are thought to be reasonable, totaling correctly for the subbasins and the entire basin. The values indicate that diversion losses, although different by subbasin, may amount to about one-quarter of the unregulated flow of the Yakima River at Union Gap; and may amount to about one-half of the unregulated flow of the Yakima River near Parker. In effect, this accounting portrays the most detailed configuration that can be achieved for the SSARR model, based on the records available for stations in the basin. If this configuration is applied to the SSARR model, the number of local inflow areas will be increased from 3 to 11; but the total local (ungaged) inflow area will be reduced from 84 to 39 percent of the total basin drainage area.

TABLE 2.--Approximate inventory of average annual water discharge in the Yakima River basin upstream of Parker[a]

River: Subbasin name: Subarea or gage name: River gage name	Drainage area (mi^2)	Stream runoff before diversion ($(ft^3/s)/mi^2$)	Stream discharge before diversion (ft^3/s)	Diversion (ft^3/s)	Stream discharge after diversion (ft^3/s)	Percent diverted
Yakima River Main Stem:						
Cle Elum subbasin:						
Yakima R - Martin	54.7	6.18	338	(0)	338	
Cabin Cr - Easton	29.3	3.00	88	(0)	88	
Kachess R - Easton	63.6	4.62	294	(0)	294	
Kittitas Canal - Easton	--	--	--	-347	-347	
Cle Elum R - Roslyn	203	4.60	933	(0)	933	
Cle Elum Local	(144)	(2.7)	(387)	(0)	(387)	
Yakima R - Cle Elum	495	4.12	2,040	(-347)	(1,693)	(17)
Ellensburg subbasin:						
Teanaway R - Cle Elum	200	1.87	374	(0)	374	
Swauk Cr - Cle Elum	90.7	.67	61	(0)	61	
Cascade Canal - Ellensburg	--	--	--	-105	-105	
Taneum Cr - Thorp	74.3	.89	66	(0)	66	
West Side Canal - Thorp	--	--	--	-70	-70	
Ellensburg Canal - Ellensburg	--	--	--	-100	-100	
Manastash Cr - Ellensburg	74.5	.81	60	(0)	60	
Wilson Cr - Thrall	382	(.8)	(306)	(-30)	(276)	
Ellensburg Local	(278)	(.7)	(194)	--	(194)	
Yakima R - Umptanum	1,594	(1.9)	(3,101)	(-652)	2,449	(21)
Selah subbasin:						
Roza Canal - Moxee City	--	--	--	-366	-366	
Selah - Moxee Canal - Selah	--	--	--	-33	-33	
Wenas Cr - Selah	192	(.4)	(77)	(-67)	10	(87)
Taylor Canal - Selah	--	--	--	-9	-9	
Selah Local	(394)	(.2)	(70)	(0)	(70)	
Yakima R - Selah Gap	2,135	(1.5)	(3,248)	(-1,127)	(2,121)	(35)
Fruitvale subbasin:						
Naches R - North Yakima	1,106	(1.6)	(1,816)	(-463)	[b](1,353)	(25)
Union Gap Canal - Union Gap	--	--	--	-17	-17	
Wide Hollow Cr - Union Gap	64.8	(.4)	(26)	(0)	(26)	
Fruitvale Local	(173)	(.3)	(52)	(+209)	(261)	
Yakima R abv Ahtanum Cr - Union Gap	3,479	(1.5)	(5,142)	(-1,398)	[b](3,744)	(27)
Union Gap subbasin:						
Ahtanum Cr - Union Gap	173	(.7)	(117)	(-34)	83	(29)
Yakima R - Union Gap	3,652	(1.4)	(5,259)	(-1,432)	[b](3,827)	(27)
Parker subbasin:						
New Reservation Canal - Parker	--	--	--	-673	-673	
Old Reservation Canal - Parker	--	--	--	-43	-43	
Sunnyside Canal - Parker	--	--	--	-591	-591	
Parker Local	(8)	(.2)	(2)	(0)	(2)	
Yakima R - Parker	3,660	(1.4)	(5,261)	(-2,739)	2,522	(52)

TABLE 2.--Approximate inventory of average annual water discharge in the Yakima River basin upstream of Parker[a]--Continued

River: Subbasin name: Subarea or gage name: River gage name	Drainage area (mi^2)	Stream runoff before diversion ($(ft^3/s)/mi^2$)	Stream discharge before diversion (ft^3/s)	Diversion (ft^3/s)	Stream discharge after diversion (ft^3/s)	Percent diverted
Naches River Main Stem:						
Nile subbasin:						
Bumping R - Nile	70.7	4.19	296	(0)	296	
American R - Nile	78.9	3.12	246	(0)	246	
Little Naches R	117	(2.8)	(328)	(0)	(328)	
Nile Local	(127)	(.6)	(76)	(0)	(76)	
Naches R - Anderson Ranch - Nile	394	(2.4)	b(946)	(0)	b(946)	(0)
Oak Flat subbasin:						
Rattlesnake Cr	134	(.9)	(121)	(0)	(121)	
Oak Flat Local	(113)	(.5)	(60)	(0)	(60)	
Naches R - Oak Flat - Nile	641	(1.8)	b(1,127)	(0)	b(1,127)	(0)
Naches subbasin:						
Selah Valley Canal - Naches	--	--	--	-63	-63	
Tieton R - Oak Cr - Naches	296	2.08	615	(-126)	(489)	(20)
Wapatox Canal - Naches	--	--	--	-429	-429	
Naches Local	(4)	(0)	(0)	(0)	(0)	
Naches R - Tieton R - Naches	941	1.85	1,742	(-618)	(1,124)	(35)
North Yakima subbasin:						
Wapatox Canal return	--	--	--	(+429)	(+429)	
Naches Co. Canal - Naches	--	--	--	-50	-50	
Yakima Valley Canal - Naches	--	--	--	-47	-47	
Naches-Cowiche Canal - North Yakima	--	--	--	-32	-32	
Cowiche Cr - North Yakima	120	(.5)	(60)	(0)	(60)	
North Yakima Canal - North Yakima	--	--	--	-100	-100	
Old Union Canal - North Yakima	--	--	--	-45	-45	
North Yakima Local	(45)	(.3)	(14)	(0)	(14)	
Naches R - North Yakima	1,106	(1.6)	(1,816)	(-463)	b(1,353)	(25)
Tieton River Main Stem:						
Rimrock subbasin:						
Tieton R - Tieton Dam - Naches	187	2.71	507	(0)	507	
Tieton Canal - Naches	--	--	--	-126	-126	
Rimrock Local	(52)	(1.2)	(62)	(0)	(62)	
Tieton R - Tieton Canal - Naches	239	2.38	569	(-126)	(443)	(22)
Oak Creek subbasin:						
Oak Cr Local	(57)	(.8)	(46)	(0)	(46)	
Tieton R - Oak Cr - Naches	296	2.08	615	(-126)	(489)	(20)
Ahtanum Creek Main Stem:						
Ahtanum subbasin:						
N.F. Ahtanum - Tampico	68.9	1.02	70	(0)	70	
S.F. Ahtanum - Tampico	28.5	.84	24	(0)	24	
Ahtanum Local	(76)	(.3)	(23)	(-34)	(-11)	
Ahtanum Cr - Union Gap	173	(.7)	(117)	(-34)	(83)	(29)

[a]Estimates are enclosed in parentheses; other numbers obtained from records.
[b]An estimated value that differs from the recorded value given in table 1.

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