BUREAU OF RECLAMATION

Technical Memorandum

Modified Flows 2020, Deschutes River Basin

Columbia Pacific Northwest Region

U.S. Department of the Interior

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Mission Statements

The Department of the Interior conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Acronyms and Abbreviations

Acronym or Abbreviation	Definition
AF	Acre-feet
AID	Arnold Irrigation District
ARNO	Arnold Canal
BENO	Deschutes River at Benham Falls
BPA	Bonneville Power Administration
CENO	Central Oregon Canal
cfs	Cubic feet per second
COID	Central Oregon Irrigation District
Corps	Corps of Engineers
CRAO	Deschutes River below Crane Prairie Reservoir
CREO	Crescent Creek below Crescent Lake
CROO	Crooked River Outflow
CULO	Culver gage
DEBO	Deschutes River at Bend
DRC	Deschutes River Conservancy
LAPO	Little Deschutes River near La Pine
LPID	Lone Pine Irrigation District
MADRAS	Deschutes gage at Madras
Metolius	Metolius gage
NCAO	North Canal
NUID	North Unit Irrigation District
OCHO	Ochoco outflow
OSF	Oregon spotted frog
OWRD	Oregon Department of Water Resources
PRVO	Prineville outflow
Reclamation	Bureau of Reclamation
SID	Swalley Irrigation District
TID	Tumalo Irrigation District
TSID	Three Sisters Irrigation District

Acronym or Abbreviation	Definition
TUMO	Tumalo Creek below Tumalo Feed Canal
Walker	Walker Irrigation District
WICO	Deschutes River below Wickiup Reservoir
WHYCHUS	Whychus Creek

1. Introduction

Modified Flows, as computed by the Bureau of Reclamation (Reclamation), are the historical unregulated streamflows from 1928 through 2018 adjusted to reflect what would have occurred with 2020 level reservoir regulation and 2020 level demands. Reclamation produces these flows for the Deschutes, Upper Snake, and Yakima river systems and provides the data to Bonneville Power Administration (BPA) for use in Columbia River System models.

The Modified Flows produced by Reclamation are different from the Modified Flows produced by the U.S. Army Corps of Engineers (Corps) and BPA for other parts of the Columbia System. For inputs other than from the Deschutes, Upper Snake, and Yakima, the Corps and BPA use streamflows that would have been observed if current irrigation depletions (as of year 2018) existed in the past and if the effects of river regulation were removed; for these locations, these flows are also termed Modified Flows. Stated another way, Modified Flows from the Corps and BPA differ from those produced by Reclamation in that the Corps/BPA Modified Flows are unregulated and Reclamation's are regulated. However, both flow datasets are adjusted for the influence of irrigation.

Modified Flows quantified in the Pacific Northwest by the Corps, BPA, and Reclamation are used together as baseline streamflows for analysis of future conditions, such as changes to the Federal Columbia River Power system due to operational or climatic changes.

This report describes the data, models, and processes that were used to develop the 2020 level Modified Streamflows for the Deschutes River. Figure 1 shows a map of the basin and the included tributaries.

1.1. Reclamation Modified Flows Process

Modified Flows in the Deschutes, Upper Snake, and Yakima river basins are generated using the generalized process outlined below.

1. Unregulated reach gains/losses in the basin are developed using measured historical data. Unregulated flows at gaged locations are developed using these reach gains/losses.
2. A demand pattern for each diversion location is developed to represent current level conditions.
3. The regulation model is updated to include current level reservoir operations.
4. The unregulated reach gains/losses are input into the model along with the current level demand pattern. The output is the Modified Flows dataset.

The details of this process for the Deschutes basin are described in this document.

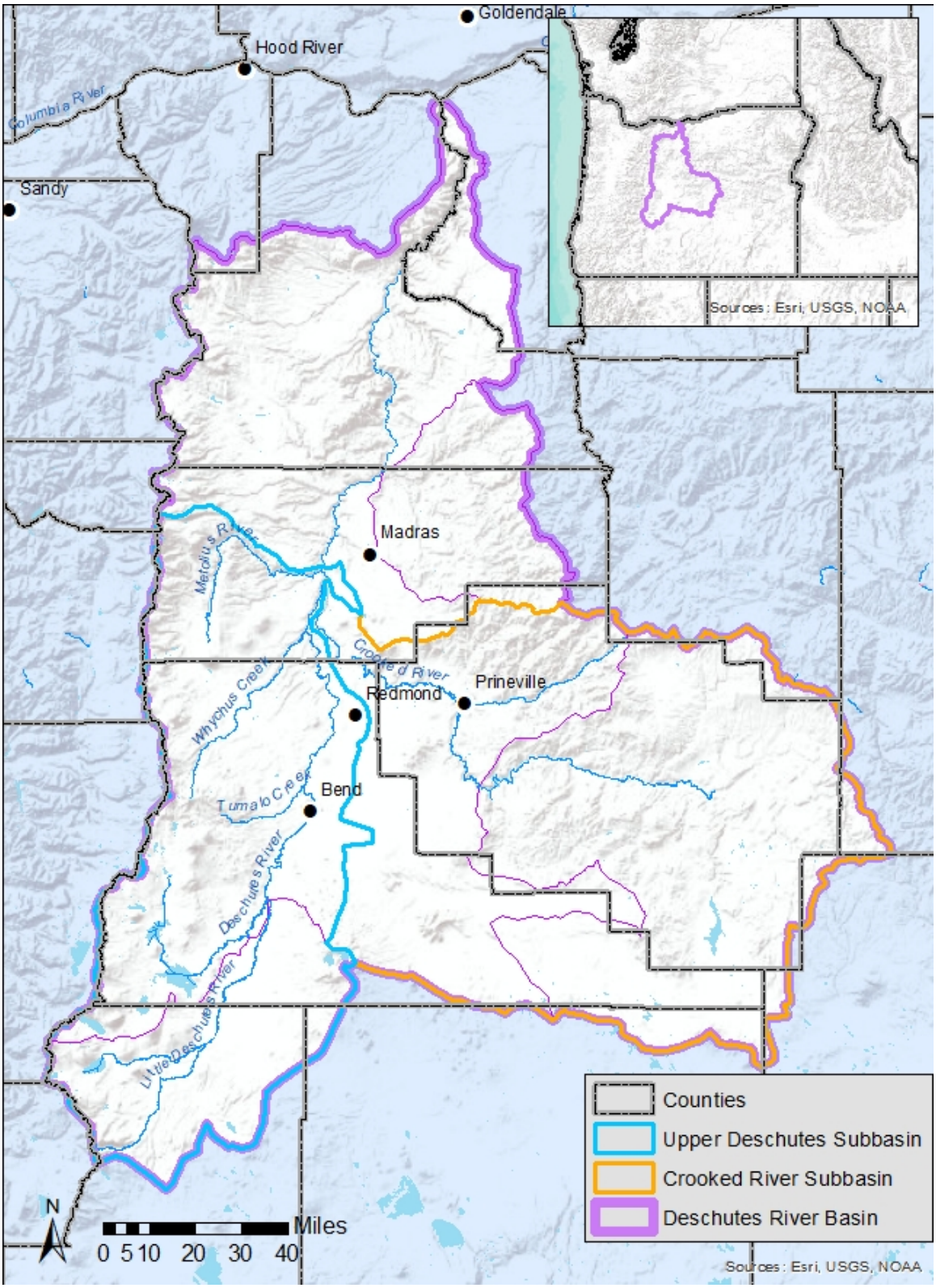

Figure 1. Deschutes River and Crooked River basins

2. Unregulated Flow Dataset Development

Unregulated flows are the basis for any water resources modeling study because they describe the flow in the system without any influence from regulation activities such as reservoir operation, diversion from the river, or return flow from irrigation activities. The intent of developing unregulated flows is to estimate the natural inflows to the system using measured data from the regulated system.

2.1. Unregulated Flows Methodology

Unregulated flows were calculated by first calculating reach gains and losses based on mass balance equations that assume that water can neither be created or destroyed. Equation 1 is the generalized equation that is used to calculate gains/losses to a river reach that contains a reservoir, where g/l is calculated gains and losses, o is measured outflow, i is measured inflow, d is measured diversion, r is calculated return flows, e is reservoir evaporation, s is reservoir seepage, p is groundwater pumping, and Δs is the change in reservoir storage.

$$g/l = o - i + d - r + e + s + p + \Delta s \qquad \text{Equation 1}$$

Equation 2 is the generalized equation that is used to calculate gains/losses to a river reach without a reservoir.

$$g/l = o - i + d - r + p \qquad \text{Equation 2}$$

A detailed methodology for determining unregulated reach gains and losses can be found in a separate Reclamation report (Reclamation 2017c); the equations used to calculate the unregulated gains and losses for this study are presented in Appendix A.

For the Deschutes River, a daily MODSIM model was used to calculate the gains, losses, and unregulated flows. The MODSIM model uses the equations described above with measured regulated flow data.

This study included an additional step where reach gains and losses were quality controlled before being summed in to unregulated flows. This was done by examining the gains and losses for outliers caused by missing data or gage measurement errors; such errors could have be caused by many factors, including high flows and wind. Negative outliers were often followed by positive outliers within a couple of days when the gage corrected itself and vice versa. These paired negative-positive outliers (>200 cubic feet per second (cfs)) were smoothed out while still conserving the amount of water flowing through each gage.

2.2. Unregulated Flows in the Deschutes

Unregulated flows in the Deschutes basin have been calculated at both a monthly and a daily timestep for the period of October 1928 through September 2018. Figure 2 and Figure 3 show the time series of the daily unregulated flows for the gage locations in the Deschutes basin (blue dashed) from October 2008 through September 2018. Monthly average flows were calculated from the daily time series and the plots show how much the variability was smoothed by the averaging process. The day-to-day variability is larger than the monthly average variability, which can partly be attributed to daily weather events. This can be especially true on reaches with reservoirs where wind and wave activity from boats on the reservoirs can cause changes to the daily measured forebay elevations; small changes in forebay elevation can translate into large variation in storage[1].

[1] Reservoir storage is computed from measured forebay elevations.

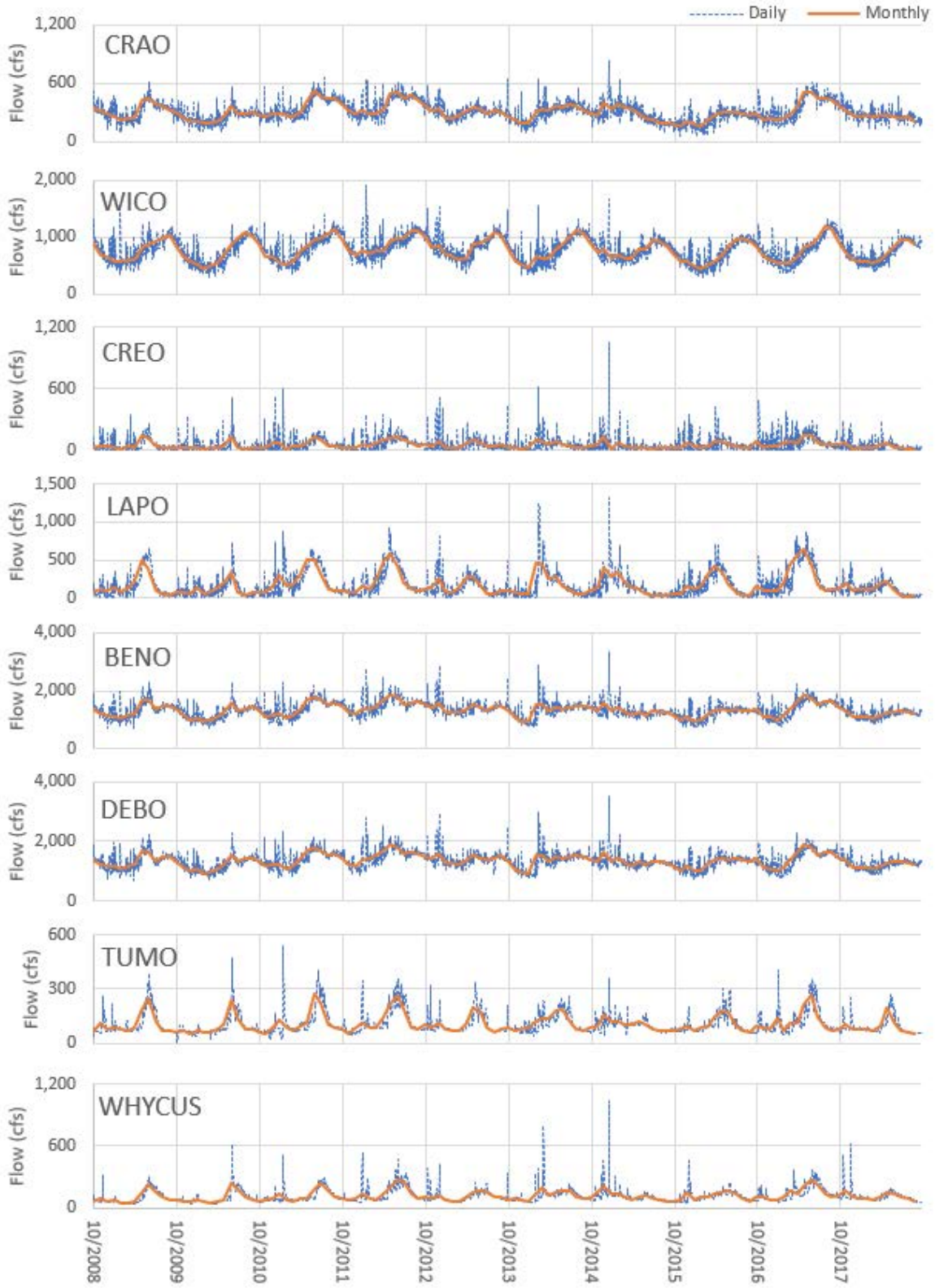

Figure 2. Unregulated flows for the different gages in the Deschutes on a daily (blue) and a monthly (orange) time step; first of two groupings of gages

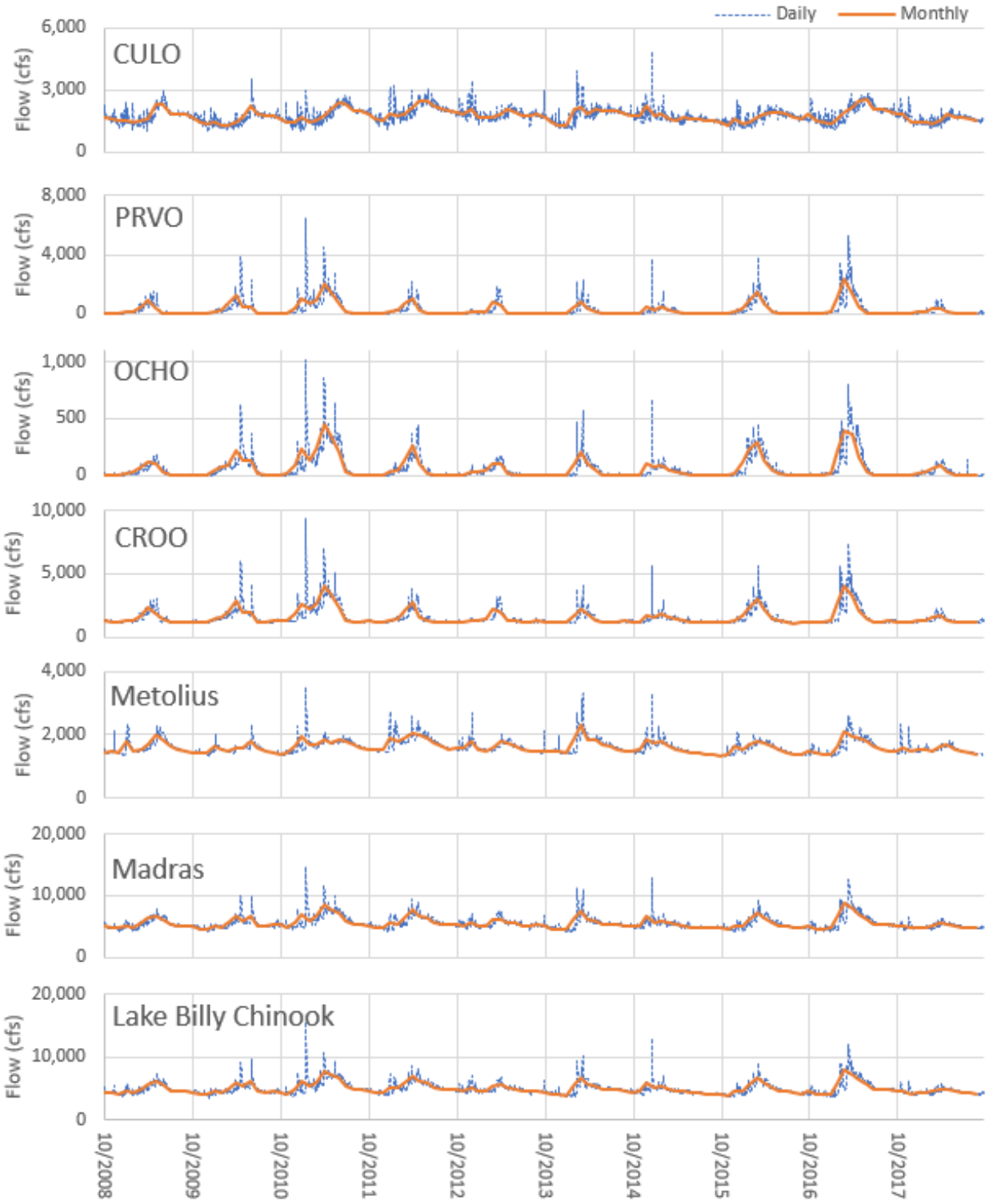

Figure 3. Unregulated flows for the different gages in the Deschutes on a daily (blue) and a monthly (orange) time step; second of two groupings of gages

Compared to unregulated flows for Lake Billy Chinook, inflows from the 2010 Modified Flows data set, the 2020 regulated flows were slightly higher on average. The differences in annual volume and peaks for 1996-2005[2] (the last ten years of overlap in the two datasets) are presented in Table 1. The annual (October through September) volumes for the 2020 dataset are three percent higher than the 2010 dataset on average. The annual monthly average maximums for 2020 are one percent lower than the 2010 dataset average. The annual monthly average minimums are three percent higher than the 2010 dataset.

Table 1. Comparison of the flows into Lake Billy Chinook for the 2020 Unregulated Flows dataset to the 2010 Unregulated Flows dataset for years 1996-2005 (the last 10 years of overlap). All volumes are in acre-feet.

Year	Annual Volume		Annual Maximum		Annual Minimum	
	2020	2010	2020	2010	2020	2010
1996	4,559,707	3,979,621	532,235	512,776	285,336	239,767
1997	4,004,512	4,468,582	451,180	506,615	277,049	287,729
1998	4,234,111	3,874,745	429,506	432,758	280,708	260,338
1999	3,957,890	4,125,262	433,548	444,069	287,526	265,101
2000	3,132,814	3,755,353	287,280	438,415	227,849	249,354
2001	3,223,259	2,995,159	336,650	286,479	222,187	225,720
2002	3,111,100	3,111,654	289,395	349,031	227,638	219,436
2003	3,417,102	3,013,184	380,189	294,977	228,454	214,697
2004	3,038,866	3,285,127	330,598	391,024	208,431	213,987
2005	3,881,893	2,930,135	472,370	340,855	234,235	209,174
Averages	3,656,125	3,553,882	394,295	399,700	247,941	238,530
% Difference vs. 2010	3%	--	-1%	--	4%	--

3. Modified Flow Dataset Development

Modified Flows are flows that represent 2020 level reservoir operations and irrigation demand levels throughout the period of record, from 1929 through 2018. The Deschutes RiverWare model was used to develop the Modified Flows dataset from 1929 through 2018. Operations in the Deschutes River basin have undergone a number of changes since 2010 due to legislation regarding the storage accounts in Prineville Reservoir and ongoing Endangered Species Act (ESA) negotiations. The operations described in this report and used in the 2020 level Modified Flows development reflect

[2] Though the 2010 Modified Flows study went through 2008, the model only simulated data through 2005. Data estimated by Portland General Electric for the inflows to Lake Billy Chinook were used for 2006-2008. Therefore, the model comparisons are from 1995 to 2005.

the most current information about operations. These conditions may continue to change as negotiations proceed and related operations are implemented.

3.1. Reference RiverWare Model

The water resources modeling for the 2020 Modified Flows study was conducted using a daily timestep RiverWare model of the Deschutes basin above the Deschutes River at Madras gage. A short summary of the model is presented in this section. A complete description of the model development is described in depth in a separate document (Reclamation 2017a).

The RiverWare model represents the Upper Deschutes River, Crescent Creek, the Little Deschutes River, Tumalo Creek, Whychus Creek, the Crooked River, and Ochoco Creek (Figure 1).

RiverWare is a general rules-based modeling platform that requires definition of the physical layout of a river system and logic to define operation of the system. The model is constructed using RiverWare objects that define reservoirs, diversions, river reaches, control points (which monitor in-stream flow locations), and river gages. Figure 4 and Figure 5 diagram the layout of the RiverWare model for the Upper Deschutes and the Crooked River subbasins, respectively. The red circles indicate water users (representing diversions) and are labeled with the irrigation district or other water user acronym that they serve. The orange boxes indicate stream gages and are named with their four-letter acronym from the Hydromet program (https://www.usbr.gov/pn/hydromet/), with the exception of the Highway 126 gage on the Crooked River. The green triangles represent locations where gains and losses are input into the model. The blue diamonds represent control points. The model itself includes significantly more detail than these schematics, but the figures illustrate the most relevant features of the model.

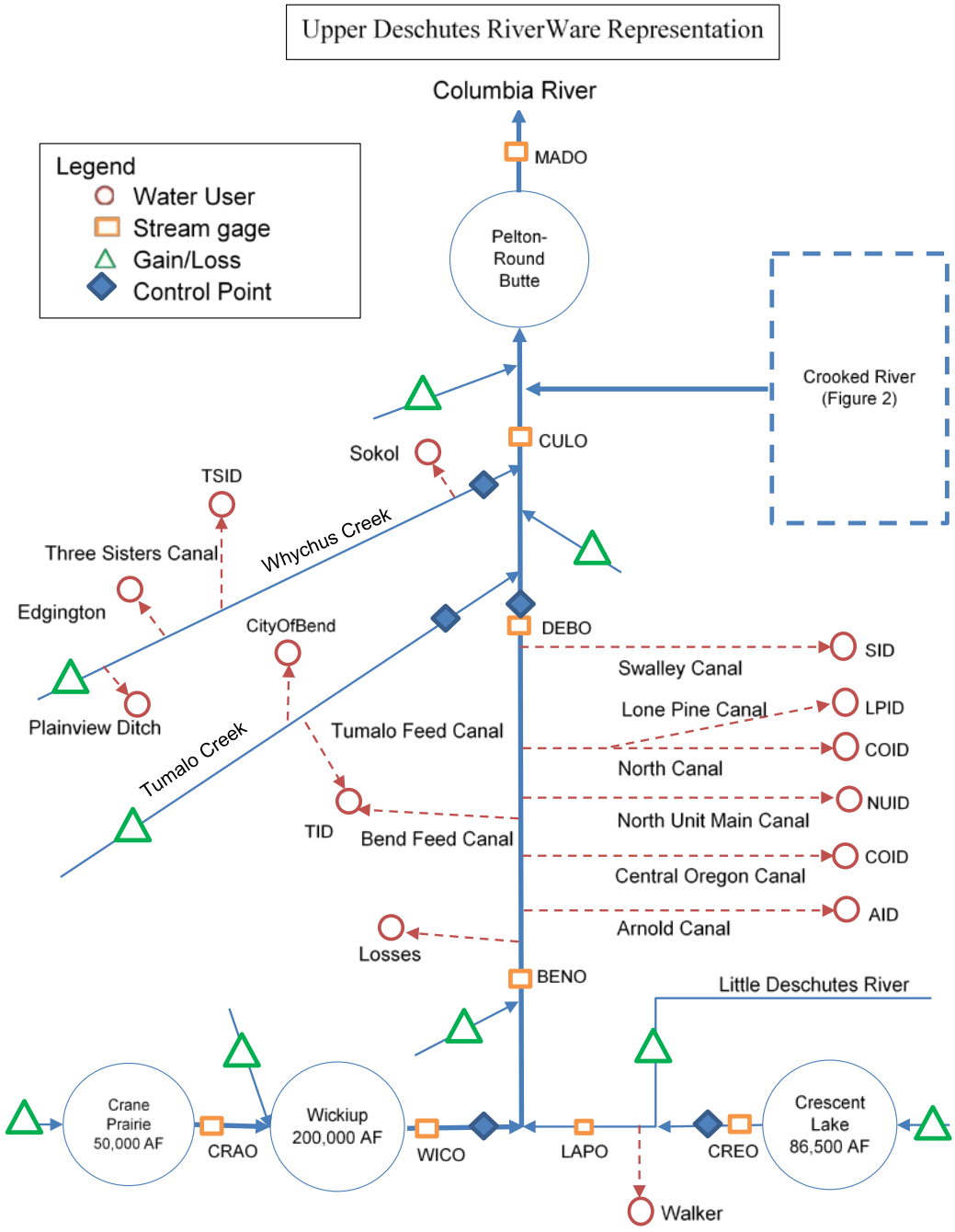

Figure 4. Schematic of RiverWare representation of the Upper Deschutes River

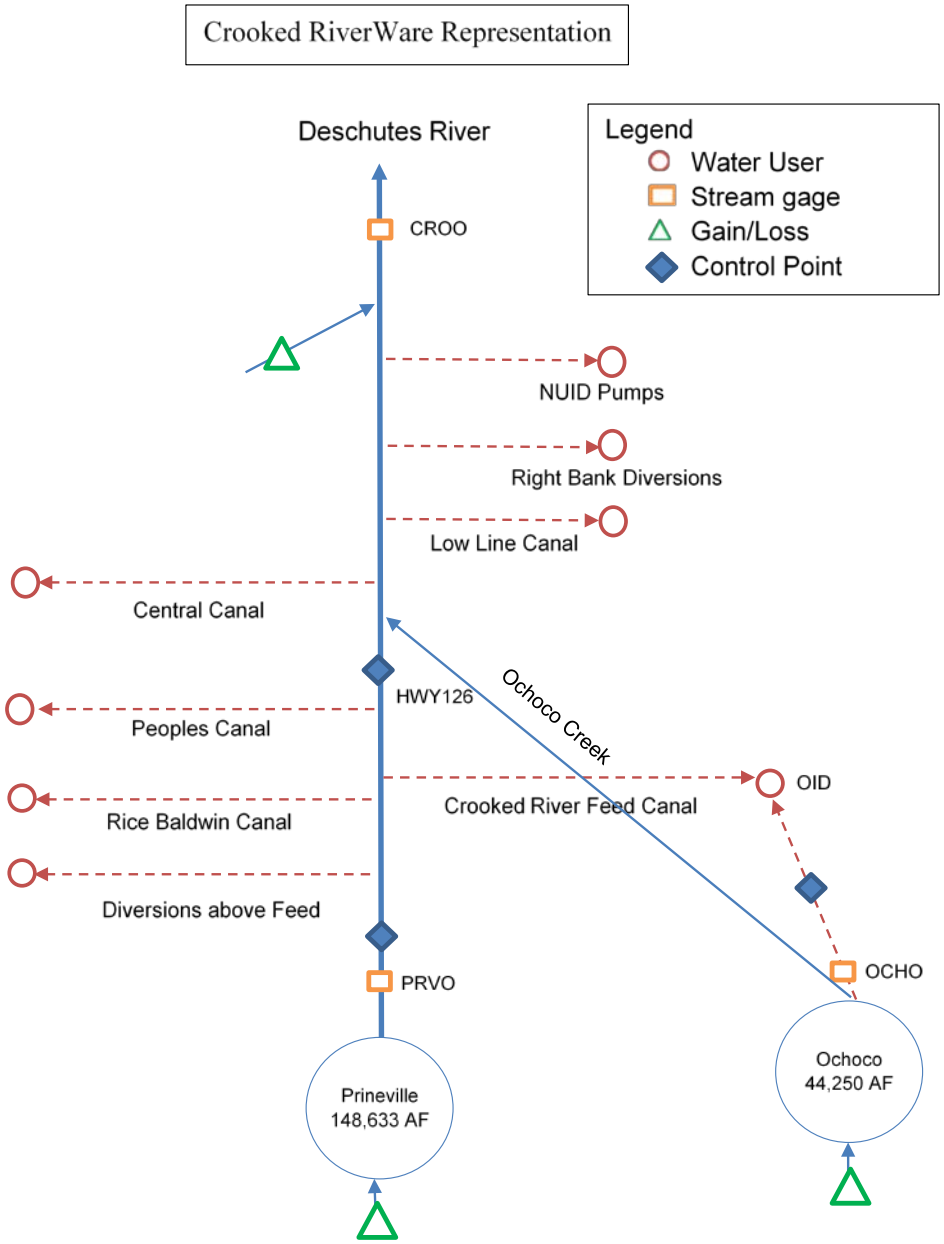

Figure 5. Schematic of RiverWare representation of the Crooked River

Operating rule logic was first developed to simulate historical operations from 1984 through 2009, the years in which measured data could be compared to model output to ensure proper operation. The model used water rights, diversion patterns, and inflow hydrology representative of the time period. Detailed information about the inputs and calibration quality is provided in a separate report describing model development (Reclamation 2017a). The operating logic was then updated to incorporate recent changes in the basin, including the Oregon Spotted Frog Biological Assessment

(Reclamation 2017b) and the Crooked River Collaborative Water Security and Jobs Act of 2014. The details of those operations are described in Sections 3.3 and 3.4 of this document.

It is important to recognize that there are many assumptions and simplifications that are required when developing a model. The data and operating logic attempt to simulate realistic conditions and water management as closely as possible, but it is likely there will be some operations that are handled differently in real time. The operations described in this report are relatively new and are still undergoing changes as real-time experience informs the operations.

3.2. Irrigation Demand Pattern

The Modified Flows study is designed to represent the response of a system using the current operational rules and demand levels. Demands were changed from the historical daily time series that varies from year to year to categorized dry, average, and wet year patterns that represent average irrigation diversions calculated from measured data for recent years (2009 to 2018). Though the model is run at a daily timestep, demands change weekly to be more representative of real-world operations.

For the Upper Deschutes, dry and wet years were categorized as the 35th and 65th percentile annual runoff for the entire record (1928 through 2018) and the 25th and 75th percentiles were used for the Crooked River. The Upper Deschutes used a slightly different set of percentiles to ensure that at least one year in the last ten could be used as a dry year pattern. Table 2 shows the years used to create the wet, average, and dry demand patterns using diversion data from recent years (2009 to 2018) as they were categorized using the entire runoff period (1928 through 2018). Table 3 shows the total average annual volume for each dry, average, and wet year pattern for each district. Figure 6 shows the weekly diversion pattern that is repeated every wet, average, and dry year for the model simulation period for the ten irrigation districts.

Table 2. Years used to create wet, average, and dry patterns for the different basins

Basin	Wet Years	Average Years	Dry Years
Upper Deschutes	2012, 2013, 2017	2009, 2010, 2011, 2014, 2015, 2018	2016
Crooked River	2011, 2017	2009, 2010, 2012, 2014, 2016	2013, 2015, 2018

Table 3. Total annual demand for the dry, average, and wet year patterns used in modeling

District	Water User	Total Annual Demand (acre-feet)		
		Wet	Average	Dry
Arnold Irrigation District (AID)	Arnold Canal (ARNO)	32,517	32,408	32,708
Central Oregon Irrigation District (COID)	Central Oregon Canal (CENO)	161,192	158,768	155,592
Central Oregon Irrigation District (COID)	North Canal (NCAO)	147,720	147,175	147,747
Lone Pine Irrigation District (LPID)	LPID	12,194	12,016	11,783
North Unit Irrigation District (NUID)[3]	NUID	190,216	181,221	171,298
Ochoco Irrigation District (OID)	OID	78,743	77,083	77,247
Swalley Irrigation District (SID)	SID	24,847	25,144	26,716
Tumalo Irrigation District (TID)	TID	55,187	52,443	51,024
Three Sisters Irrigation District (TSID)	TSID	31,347	27,913	31,722
Walker Irrigation District (Walker)	Walker	8,170	7,595	5,799

[3] This volume is only for the demand on the Deschutes River. NUID also diverts water from the Crooked River that totals about 20,000 acre-feet per year.

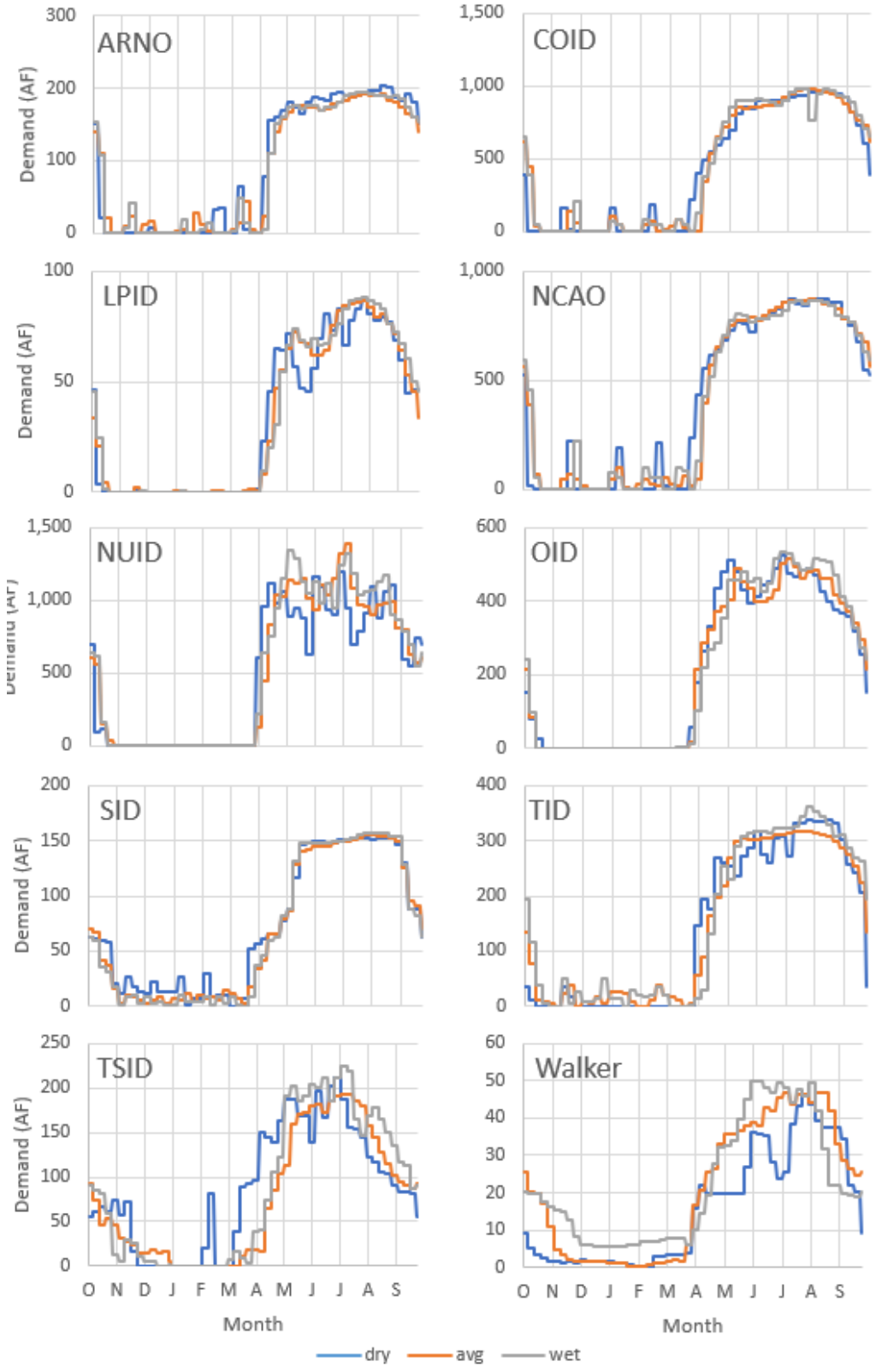

Figure 6. Annual irrigation demand diversion patterns for the ten irrigation districts; these patterns are repeated for every dry, average, and wet year in the model simulations

When water is applied to irrigated lands, excess water can seep below the root zone and travel, via the aquifer, back to the river. The time it takes for that water to return to the river is described by a time-dependent function known as a groundwater response function. Response functions are also used to describe the lagged effect on the river due to pumping water from the aquifer. The response functions for the Deschutes model were calculated using a groundwater model of the basin (Gannett and Lite 2004). In addition, the groundwater model describes where the water returns to the system and these locations are incorporated into the RiverWare model.

For the Modified Flows analysis, the model was corrected for groundwater responses based on 2020 level demands. In the Deschutes basin, it can take up to 50 years for the system to equilibrate with respect to groundwater responses based on simulated response functions. Thus, it was necessary to calculate equilibrium groundwater response hydrographs and input them directly into the Modified Flows RiverWare model. In other words, the equilibrium groundwater return flows were calculated separately and "hardwired" into the model.

3.3. Upper Deschutes River Operation

Baseline operating rules for the Upper Deschutes River reflect the operating criteria in the Oregon Spotted Frog Biological Assessment (Reclamation 2017b). Generally, the operation is intended to minimize elevation changes in Crane Prairie Reservoir and set a minimum outflow from Wickiup Reservoir. In addition, winter outflows from Crane Prairie Reservoir, Wickiup Reservoir, and Crescent Lake were all larger than historical releases to enhance habitat conditions in the downgradient stream network.

3.3.1. Crane Prairie Reservoir

Crane Prairie Reservoir is operated to minimize elevation changes throughout the year to maximize habitat for the Oregon spotted frog (OSF). The reservoir is operated between 35,000 acre-feet and 50,000 acre-feet. In the model, this is accomplished by including a storage account that is dedicated to the OSF with a senior priority date (August 30, 1899; 1 day earlier than the most senior water right on the system, held by Swalley Irrigation District), which ensures that the highest priority in the model is to maintain 35,000 acre-feet of storage in Crane Prairie Reservoir. Three other storage accounts represent 5,000 acre-feet of storage each for Arnold Irrigation District (AID), Central Oregon Irrigation District (COID), and Lone Pine Irrigation District (LPID).

Because of the senior priority date of the OSF account (35,000 acre-feet), it is kept full unless evaporation or seepage reduce its volume and it cannot be made up with inflows. The 15,000 acre-foot operating range is used to meet seasonal OSF habitat and irrigation needs according to the schedule summarized below.

- January 1 to March 15: Crane Prairie Reservoir begins to store water, if available, until the reservoir reaches 45,000 acre-feet.

- March 16 to May 1: Crane Prairie Reservoir passes inflow to hold the storage volume achieved on March 15. Ideally, this volume would be 45,000 acre-feet.
- May 2 to May 15: Crane Prairie Reservoir stores water up to 1.1 feet above the elevation achieved on March 15. Ideally, this volume would be 50,000 acre-feet.
- May 16 to July 15: Crane Prairie Reservoir passes inflow to hold the storage volume achieved on May 15.
- July 15 to October 1: Crane Prairie Reservoir releases water in the irrigation district accounts to reduce the reservoir back down to 35,000 acre-feet.
- October 2 to December 30: Crane Prairie Reservoir passes inflow to maintain 35,000 acre-feet.

Outflows from Crane Prairie Reservoir are generally managed to release a maximum of 400 cfs throughout the year. The minimum release varies depending on the time of the year, with 100 cfs released from December 1 through August 30 and 75 cfs released the remainder of the year. These flow criteria are considered less important than reaching and maintaining the elevations in Crane Prairie Reservoir. Therefore, there are times when the minimum outflow is allowed to decrease down to a minimum of 30 cfs in support of the higher priority criteria. Outflows are allowed to increase above 400 cfs when there is an elevation restriction and inflows exceed 400 cfs minus seepage.

Although the location and timing of returns from Crane Prairie Reservoir seepage are not fully understood, it is generally believed that seepage losses return to the stream network upstream of Wickiup Reservoir. This is based on physical observations and geological knowledge of the area, including: (1) the proximity of a major groundwater discharge area (approximately 300 cfs to Sheep Springs); (2) the change in the underlying geology to low-permeability sedimentary deposits of the La Pine sub-basin; (3) the location of a fault at Sheep Springs (a likely impediment to groundwater flow); and (4) the groundwater head gradient. All of these factors point to Wickiup Reservoir (Sheep Springs) being the location of returns from Crane Prairie Reservoir seepage (LaMarche 2018).

For the calibration/historical model, it was assumed that any returns from Crane Prairie Reservoir seepage would be captured in the gains between Crane Prairie Reservoir and Wickiup Reservoir. However, since the seepage is dependent on elevation, it is expected that seepage from the current operation would be different than historical. Accordingly, the change in potential seepage was calculated by taking the historical seepage calculation and subtracting it from a new seepage calculation using the new reservoir elevations. Based on conversations with Oregon Department of Water Resources, a 3-month lag time was assumed to route the change in seepage back to the reach above Wickiup Reservoir. This addition to the model was done with equations that use the current Crane Prairie Reservoir elevation as input, so any new changes to Crane Prairie Reservoir elevation would adjust the seepage return.

3.3.2. Wickiup Reservoir

Outflows from Wickiup Reservoir are managed to maintain a minimum between September 16 and March 30, based on the storage contents in Wickiup Reservoir on November 1 of the previous year,

using a variable outflow equation. The minimum outflow for the upcoming year is chosen on November 1 using a linear interpolation between 10,000 and 100,000 acre-feet to choose a minimum outflow between 100 and 500 cfs for the non-irrigation season. Higher flows are chosen for higher November 1 storage contents.

$$\text{Minimum Outflow in acre} - \text{feet (AF)} = 100\ cfs + (Wickiup\ Storage\ on\ November\ 1 - 10{,}000\ AF) * \frac{500\ cfs - 100\ cfs}{100{,}000\ AF - 10{,}000 AF}$$

Between March 30 and September 15, a minimum outflow of 600 cfs is used, if possible. Once irrigation releases begin, outflows from Wickiup Reservoir often exceed 600 cfs to meet downstream irrigation demand. If required releases exceed 600 cfs prior to April 30, the outflows are required to be at or above the previous day's outflows. Maximum non-irrigation season outflows are kept below 800 cfs until April 15 unless the reservoir needs to make flood releases.

3.3.3. Crescent Lake

As long as there is enough inflow and stored water, outflows from Crescent Lake are managed to maintain a minimum flow of 30 cfs from March 15 through November 30 and 20 cfs from December 1 through March 14. If the reservoir storage drops below 7,000 acre-feet, outflows are reduced to 6 cfs.

3.4. Crooked River Operation

Operating rules on the Crooked River, particularly at Prineville Reservoir, reflect changes that were made in the Crooked River Collaborative Water Security and Jobs Act of 2014 (also called Crooked River Legislation). Changes are still being made to the operations as real-time implications are observed and discussed. As additional experience is gained, the model logic will continue to be refined; for the purpose of this study, the logic is as described below.

Prineville Reservoir has seven storage accounts that fill in priority by the dates shown Table 4. All of the accounts except for the uncontracted account fill in proportion to their space with equal priority. The uncontracted space fills last and is used to augment flows seasonally for fishery purposes as coordinated by U.S. Fish and Wildlife Service and Reclamation.

Table 4. Prineville Reservoir storage rights from Crooked River Legislation

Model Water Right Name	Priority Date	Maximum Storage Volume (acre-feet)
CityOfPrineville	4/8/1914	5,100
LowLine	4/8/1914	330
Ochoco	4/8/1914	60,640
Others	4/8/1914	6,527
Peoples	4/8/1914	3,497
RentalNUID	4/8/1914	10,000
Uncontracted	4/9/1914	65,520
Total	--	151,614

Releases from the uncontracted account are calculated for the irrigation season (April 1 to October 15) and the non-irrigation season (October 16 to March 30) using the storage in the account on April 1. To calculate for the irrigation season, the model first reserves a volume of water for the non-irrigation season equal to 50 cfs released each day from October 16 to March 30 or the volume of water in the uncontracted account on April 1, whichever is greater (Minimum Winter Release Volume [MWRV]). The remaining volume is then divided equally among the 365 days and that value is released each day (irrigation season release).

$$\text{MWRV} = \text{Max}\begin{Bmatrix} V * 50\ \text{cfs} * 1.98\ \text{AF/d/cfs} \\ \text{UV} \end{Bmatrix} \text{ where}$$

MWRV = Minimum Winter Release Volume

V = Number of days between April 1 next year and October 15 current year

UV = Storage in the uncontracted Account on April 1

$$\text{Irrigation Season Release} = \text{Max}\begin{Bmatrix} (\text{UV} - \text{MWRV})/(365\ \text{d} * \frac{1.98\frac{\text{AF}}{\text{d}}}{\text{cfs}}) \\ 0\ \text{cfs} \end{Bmatrix}$$

For the non-irrigation season, the irrigation season release flow rate is added to the minimum winter release flow rate and is released from the uncontracted account.

Non-Irrigation Season Release = Irrigation Season Release + MWRV

Table 5 shows example irrigation season and non-irrigation season releases from the uncontracted account given April 1 storage volumes in the uncontracted account. These releases are added to irrigation season storage releases, runoff season flood releases, and other minimum flow requirements described below.

Table 5. Calculated irrigation and non-irrigation season releases based on April 1 uncontracted volume in Prineville Reservoir.

Total Storage Prineville Reservoir (acre-feet)	Uncontracted Volume April 1 (acre-feet)	Irrigation Season Release (cfs)	Non-irrigation Season Release (cfs)
148,633	62,520	63.3	113.4
118,000	36,987	21	71.1
88,000	6,987	0	5.7
78,000	0	0	0

Other minimum releases include a minimum of 10 cfs release maintained from Bowman Dam and a 7 cfs release from the City of Prineville mitigation account. If releases from Bowman Dam are less than 10 cfs, these releases are executed in the model using the logic presented below.

1. The first 7 cfs will be released from the City of Prineville mitigation account, if available. If the City of Prineville mitigation account did not fill, the release will be the amount of storage in the account on April 1 divided by 365 days.
2. The remainder will be made up with water from the uncontracted/fish and wildlife account.
3. If the uncontracted/fish and wildlife account is empty, the remainder will be made up with live flow.
4. If there is insufficient live flow, the remainder will be made up with stored water from the first fill accounts in proportion to their storage.

3.5. Special Diversion Operations

TID, OID, and NUID divert water from multiple streams to satisfy demand for their districts. All three of these diversions require unique model constructs and rules to ensure the correct amount of water is diverted from the appropriate tributary.

TID diverts water from Tumalo Creek and supplements with water from Crescent Lake via the Upper Deschutes. It also has a live flow of 9.5 cfs directly from the Deschutes. TID first tries to satisfy its demand using natural flow rights, the majority of which are on Tumalo Creek. If there is still shortage, TID will request stored water from Crescent Lake via the Upper Deschutes.

OID diverts from both the Crooked River and Ochoco Creek and first tries to satisfy the historical demand from each tributary, Crooked River and Ochoco Creek, using both natural flow and stored water rights. If there is still a shortage, OID will divert additional water from Prineville Reservoir.

NUID diverts water from both the Upper Deschutes River and the Crooked River. On the Upper Deschutes, NUID can divert water under its 1913 live flow water right and can request stored water

from Wickiup Reservoir. On the Crooked River, it can divert under its 1955 live flow right and request rental water from Prineville Reservoir [4].

When the model is running, it will first try to satisfy the total demand for the district using historical diversion rates for each tributary. If there are still shortages, additional water will be diverted from the Crooked River to satisfy the demand limited by the pump capacity, amount of water in the rental account on Prineville Reservoir, and the requirement to leave water instream per an agreement between Deschutes River Conservancy (DRC) and NUID, called the DRC agreement (OWRD 2013). This agreement, signed in 2013, requires that NUID allow flow to bypass its pumps. The amount of flow varies depending on water year conditions and month (Table 6). A dry year is defined if the storage in Prineville Reservoir is less than 135,000 acre-feet after March 30, or if the outflow from the reservoir is less than 75 cfs for the previous 30 days.

Table 6. Deschutes River Conservancy bypass flows for Dry and Non-Dry years

Month	Dry Year (cfs)	Non-Dry Year (cfs)
Jan	0	0
Feb	0	0
Mar	0	0
Apr	120.617	181.417
May	43.798	95.598
Jun	54.381	86.081
Jul	51.451	61.451
Aug	56.846	68.146
Sep	57.599	114.219
Oct	121.874	151.574
Nov	0	0
Dec	0	0

3.6. 2020 Modified Flows in the Upper Deschutes

The 2020 Modified flows in the Deschutes basin have been calculated at both a monthly and daily timestep. Figure 7 shows the time series of the daily regulated flows at the MADRAS gage (blue dashed line). Monthly average flows were calculated from the daily time series and are also shown on the figure (orange solid line). Figure 7 shows how much the variability was smoothed by the averaging process.

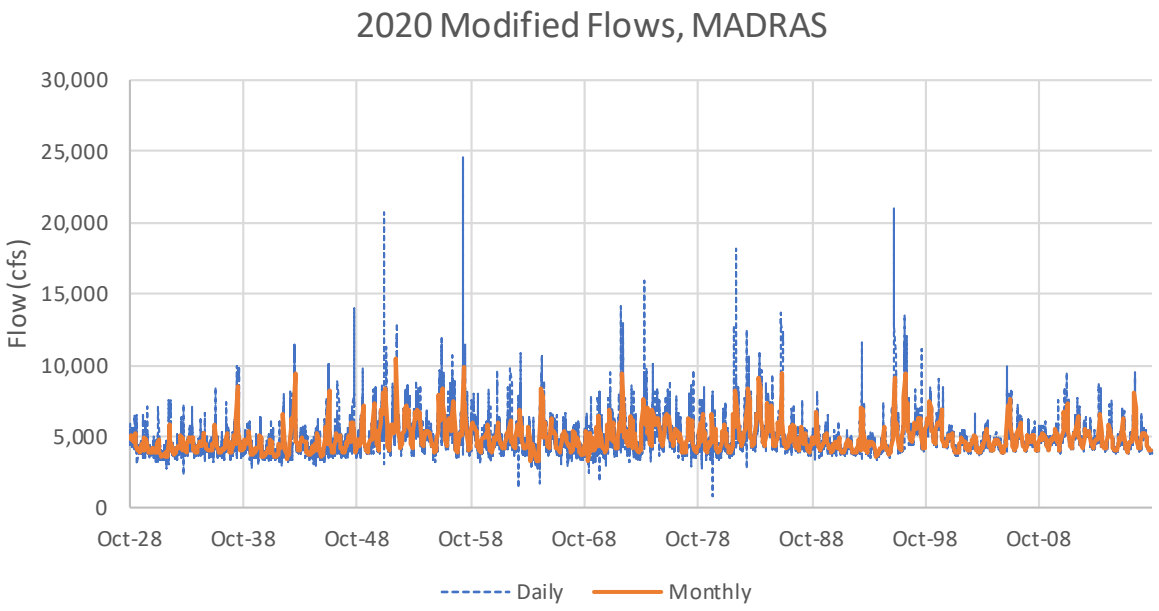

Figure 7. 2020 Modified Flows data set for the MADRAS gage for water years 1929 to 2018

4. Discussion

The Modified Flows that were calculated in the 2020 level of development update are different than the 2010 Level Modified Streamflows data set (BPA 2011). This is largely due to using an updated daily timestep RiverWare model instead of a monthly timestep MODSIM model. It is also due to changes in operations that are currently being implemented in the basin as described in sections 3.3 and 3.4. In addition, the 2010 modified flows were reported as the inflows to Lake Billy Chinook, which has no gage.

Total annual demand has decreased slightly from the 1980s. Figure 8 shows the total annual demand for the Deschutes broken down by individual irrigation district. Reasons for the decrease in total demand could be attributed to advancements in irrigation techniques and increased efficiency in canal systems. Decreased demand and more efficient systems also decrease groundwater return flows.

Average annual demand for the watershed did not change significantly between the most recent 10-year period (2009 to 2018) and the previous 10-year period (1999 to 2008). Most of the irrigation districts over the most recent period changed within +/- 5 percent, with the exception of SID, TSID, and NUID. SID and TSID decreased demand by 20 percent and 23 percent, respectively, due to large scale conservation projects, whereas NUID increased average demand by 8 percent.

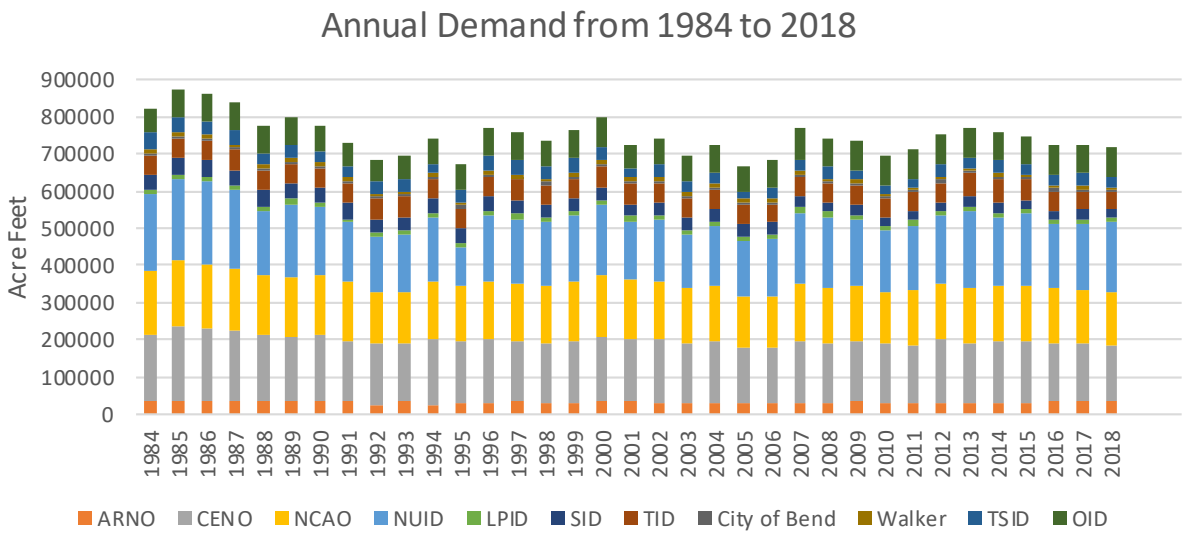

Figure 8. Total annual demand for the irrigation districts from 1984 to 2018

Because there is no gage of inflows into Lake Billy Chinook, historical data from the gage downstream of the reservoir, Deschutes River at Madras (MADRAS), were compared to modeled data for that location. Table 7 shows the comparison of the modeled MADRAS data to historical data for 2009 through 2018. The annual volumes for the modeled dataset are 4 percent larger than

the actual flows on average. The annual maximum modeled inflows are 5 percent larger than the actual flows and the annual minimum actual inflows are 2 percent larger.

Table 7: Comparison of the modeled MADRAS dataset to actual MADRAS flows for years 2009 to 2018. All volumes are in acre-feet.

Year	Annual Volume		Annual Maximum		Annual Minimum	
	Modeled	Actual	Modeled	Actual	Modeled	Actual
2009	3,423,496	3,268,391	317,689	303,952	242,679	237,068
2010	3,418,337	3,320,558	327,513	321,882	248,423	249,723
2011	3,967,525	3,828,314	434,010	413,996	248,323	243,514
2012	3,656,902	3,580,376	382,631	369,129	247,139	242,820
2013	3,504,861	3,368,856	340,988	333,982	253,883	246,589
2014	3,511,199	3,293,443	399,334	364,726	247,809	241,868
2015	3,388,318	3,280,550	354,970	351,437	238,901	233,597
2016	3,394,876	3,263,532	386,198	368,633	232,552	230,146
2017	3,718,624	3,596,502	497,172	454,916	247,719	243,098
2018	3,345,997	3,158,724	319,872	302,642	236,232	232,942
Average	3,533,014	3,395,925	376,038	358,530	244,366	240,136
% Difference, Modeled vs. Actual	4%		5%		2%	

The comparison of the daily modeled data set to the actual inflows is shown for the most recent 10-year period, water years 2009 through 2018, in Figure 9. The MADRAS data accurately represent the 2009 through 2018 water years with r-squared values of 0.94 for the monthly data and 0.82 for the daily data. A difference between modeled and actual data can be seen in the winter flows where the modeled data typically have higher winter flows. This is attributed to a change in operations at Wickiup Reservoir where winter flows are increased to a minimum 100 cfs from 20 cfs. This change in operations has only been implemented in recent years as storage in Wickiup allowed, so the data in some years show lower winter flows than those that were modeled. The differences in these datasets are considered negligible, and the modeled output is considered to be representative of the Modified Flows dataset as defined.

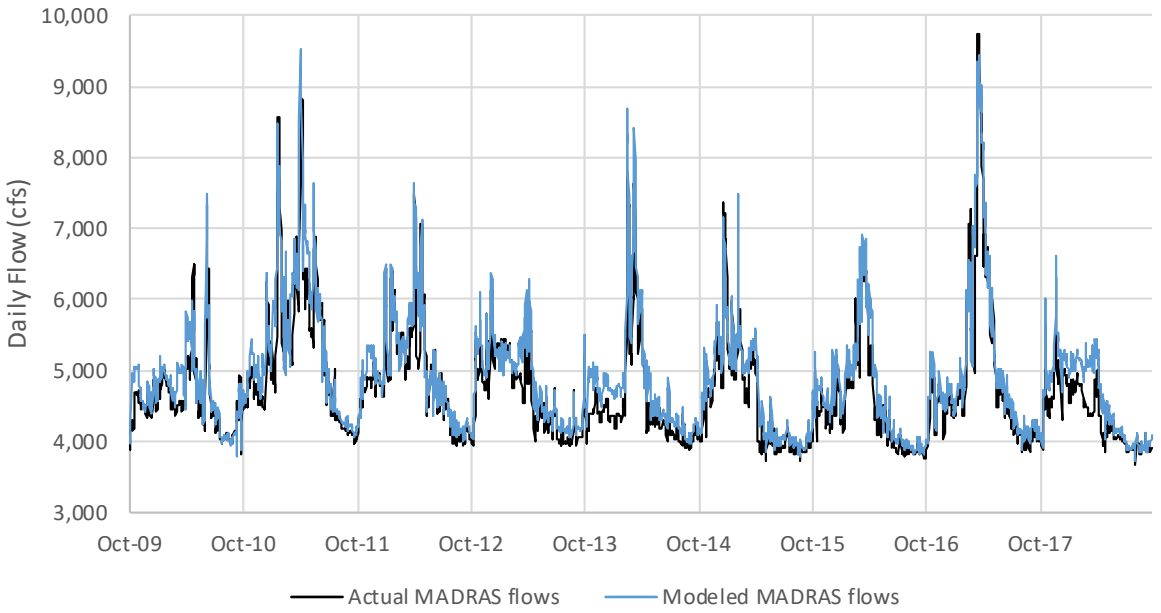

Figure 9. Modeled MADRAS daily data set compared with the actual MADRAS flows for water years 2009 to 2018

The differences in annual volumes and peaks for 1999 through 2008 (the last ten years of overlap in the two datasets) are presented in Table 8. The annual volumes for the 2020 dataset are six percent smaller than the 2010 dataset on average. The annual maximums for 2020 are eight percent smaller than the 2010 dataset average and the annual minimums are eight percent smaller.

Table 8: Comparison of the 2020 Lake Billy Chinook inflows to the 2010 Modified Flows dataset for years 1999 to 2008 (the last 10 years of overlap). All volumes are in acre-feet.

Year	Annual Volume (acre-feet)		Annual Maximum (acre-feet)		Annual Minimum (acre-feet)	
	2020	2010	2020	2010	2020	2010
1999	3,633,182	3,972,613	398,533	443,285	231,902	246,807
2000	3,527,020	3,576,309	372,064	417,816	222,128	233,652
2001	2,880,568	2,993,637	281,662	289,650	197,742	217,101
2002	2,774,028	2,923,454	254,394	283,806	202,827	217,565
2003	2,729,746	2,941,110	265,106	275,051	197,884	216,612
2004	2,923,757	3,033,946	307,075	329,383	207,921	220,600
2005	2,681,777	2,882,553	253,717	265,865	197,614	209,898
2006	3,346,378	3,576,127	407,208	444,986	210,213	228,853
2007	3,045,876	3,297,313	319,951	335,907	209,963	234,625

Year	Annual Volume (acre-feet)		Annual Maximum (acre-feet)		Annual Minimum (acre-feet)	
	2020	2010	2020	2010	2020	2010
2008	3,013,153	3,273,951	287,240	309,651	213,298	236,053
Averages	3,055,548	3,247,101	314,695	339,540	209,149	226,177
% Difference vs. 2010	-6%	--	-8%	--	-8%	--

The comparison of the monthly 2020 Modified Flows data set to the 2010 Modified Flows data set is shown in Figure 10. The 2010 data set extends through 2008.

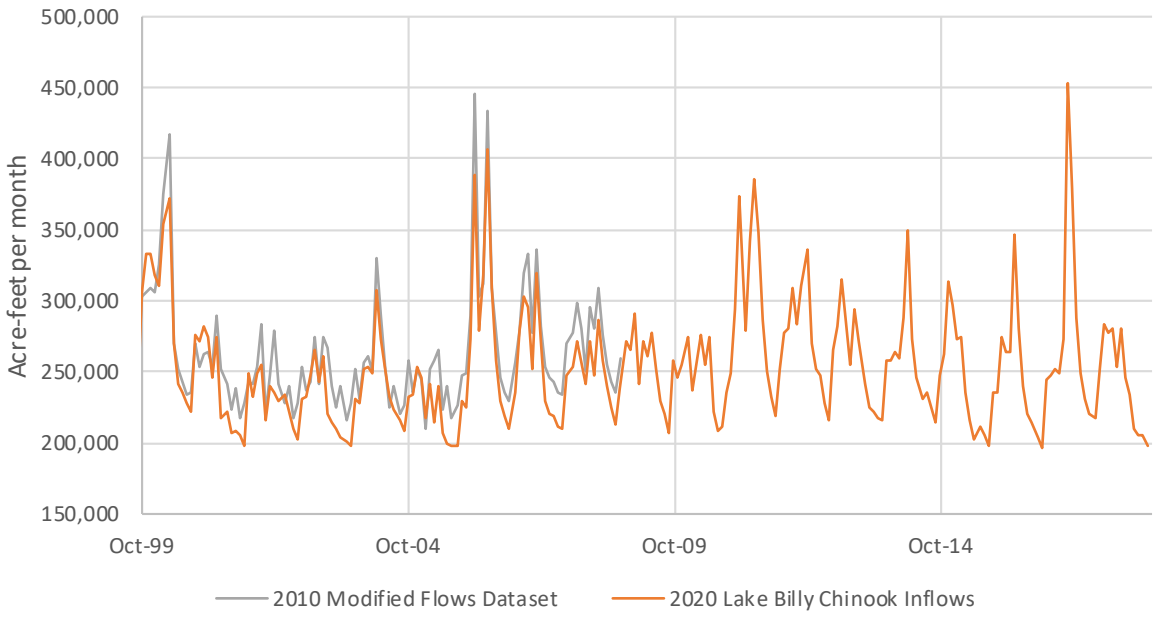

Figure 10. 2020 Lake Billy Chinook inflows monthly data set compared with the 2010 Modified Flows data set for water years 1999 to 2018

5. Summary

The 2020 level Modified Flows for the Deschutes River Basin represent operations as they are defined in 2020, along with current level diversions and return flows representative of 2008 through 2018. Operations in this basin have recently been updated and are currently being defined due to recent legislation and ESA requirements. In addition, the model used to develop the 2020 Level Modified Flows is a daily RiverWare model as compared to a monthly MODSIM model. These changes in operations along with model improvements are reflected in both the comparison to the 2010 level Modified Flows and in the comparison to recent measured flows.

6. Literature Cited

Parenthetical Reference	Bibliographic Citation
BPA 2011	Bonneville Power Administration (BPA). 2011. *2010 Level Modified Streamflow*. Cooperating agencies: U.S. Army Corps of Engineers and Bureau of Reclamation. DOE/BIP-4352. August 2011.
Gannett and Lite 2004	Gannett, M. and K. Lite Jr. 2004. "Simulation of Regional Ground-Water Flow in the Upper Deschutes Basin, Oregon." Water-Resources Investigations Report 2003-4195. Oregon Water Science Center, U.S. Geological Survey. 95 pp.
LaMarche 2018	LaMarche, J. 2018. Personal communication. Conversations and emails between Jonathan LaMarche and Jennifer Johnson regarding the seepage processes between Crane Prairie and Wickiup Reservoirs. August 2018.
OWRD 2013	Oregon Water Resources Department (OWRD). 2013. *Agreement Between North Unit Irrigation District and Deschutes River Conservancy Regarding Minimum Stream Flows in the Crooked River*. Attachment 3 to Conserved Water Application CW-75. April 12, 2012. Signed September 18, 2013.
Reclamation 2017a	Bureau of Reclamation. 2017. *Development of a Daily Water Management Model of the Deschutes River, Oregon, using RiverWare*. March 2017.
Reclamation 2017b	Bureau of Reclamation. 2017. *Hydrologic Evaluation of Baseline and Proposed Management of the Deschutes Project for Oregon Spotted Frog (OSF Proposal)*. January 2017.
Reclamation 2017c	Bureau of Reclamation. 2017. *Unregulated Flows in the Upper Deschutes Basin, Oregon*. October 2017.

Appendix A: Unregulated Flow Equations

Table A-1. Locations of unregulated flow calculations including the Oregon Department of Water Resources (OWRD) gage numbers and equation to convert gain/loss into unregulated flows

Site Name	OWRD Gage Number	Reclamation Gage Name	Flow Calculation
Deschutes River below Crane Prairie Reservoir	14054000	CRAO	$CRAO_{unreg} = CRAO_{gain/loss}$
Deschutes River below Wickiup Reservoir	14056500	WICO	$WICO_{unreg} = CRAO_{gain/loss} + WICO_{gain/loss}$
Crescent Creek below Crescent Lake	14060000	CREO	$CREO_{unreg} = CREO_{gain/loss}$
Little Deschutes River near La Pine	14063000	LAPO	$LAPO_{unreg} = CREO_{gain/loss} + LAPO_{gain/loss}$
Deschutes River at Benham Falls	14064500	BENO	$BENO_{unreg} = CREO_{gain/loss} + LAPO_{gain/loss} + CRAO_{gain/loss} + WICO_{gain/loss}$
Deschutes River at Bend	14070500	DEBO	$DEBO_{unreg} = CREO_{gain/loss} + LAPO_{gain/loss} + CRAO_{gain/loss} + WICO_{gain/loss} + BENO_{gain/loss}$
Tumalo Creek below Tumalo Feed Canal	14073520	TUMO	$TUMO_{unreg} = TUMO_{gain/loss}$
Whychus Creek	14075000	WHYCHUS	$WHYCHUS_{unreg} = WHYCHUS_{gain/loss}$
Culver gage	14076500	CULO	$CULO_{unreg} = CREO_{gain/loss} + LAPO_{gain/loss} + CRAO_{gain/loss} + WICO_{gain/loss} + BENO_{gain/loss} + DEBO_{gain/loss} + TUMO_{gain/loss} + WHYCHUS_{gain/loss} + CULO_{gain/loss}$
Prineville outflow	14080500	PRVO	$PRVO_{unreg} = PRVO_{gain/loss}$
Ochoco outflow	14085300	OCHO	$OCHO_{unreg} = OCHO_{gain/loss}$
Crooked River	14087400	CROO	$CROO_{unreg} = PRVO_{gain/loss} + OCHO_{gain/loss} + CROO_{gain/loss}$
Metolius gage	14091500	Metolius	$Metolius_{unreg} = Metolius_{gain/loss}$
Deschutes gage at	14092500	Madras	$Madras_{unreg} = CREO_{gain/loss} + LAPO_{gain/loss} + CRAO_{gain/loss} + WICO_{gain/loss} + BENO_{gain/loss} +$

Site Name	OWRD Gage Number	Reclamation Gage Name	Flow Calculation
Madras			$DEBO_{gain/loss} + TUMO_{gain/loss} + WHYCHUS_{gain/loss} + CULO_{gain/loss} + PRVO_{gain/loss} + OCHO_{gain/loss} + CROO_{gain/loss} + Metolius_{gain/loss} + Madras_{gain/loss}$
Inflows to Lake Billy Chinook	None	Billy Chinook	$BillyChinook_{unreg} = Madras_{unreg} - Madras_{gain/loss}$

Appendix B: Unregulated Flows Data

Table B-1. Unregulated flows at MADRAS gage for water years 1929 to 2018 (acre-feet per month)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1929	322,015	264,363	265,796	262,427	236,964	303,421	330,497	319,365	302,970	278,088	270,076	259,055
1930	258,817	238,675	282,361	255,196	289,320	291,173	316,364	287,938	272,027	267,506	265,895	251,087
1931	255,190	235,241	237,383	239,627	219,742	270,740	332,841	280,449	255,901	241,890	239,664	231,338
1932	235,372	218,407	228,356	236,024	228,987	374,822	397,785	367,738	303,356	275,573	266,786	250,474
1933	253,542	252,313	251,156	258,153	226,462	276,766	373,715	346,697	386,068	319,666	291,763	278,275
1934	269,818	249,171	290,047	304,528	260,984	299,861	328,140	293,202	289,004	281,187	277,823	257,972
1935	268,809	256,621	275,542	270,119	249,804	288,516	393,078	353,331	324,451	298,914	282,380	269,576
1936	262,070	239,966	247,319	275,942	260,135	330,402	436,529	368,826	318,768	288,018	282,134	268,046
1937	259,168	233,736	249,201	246,120	232,193	296,436	414,553	359,130	346,206	289,174	269,990	261,834
1938	264,628	263,524	315,940	306,336	288,992	420,508	550,023	436,230	353,501	304,995	291,751	276,996
1939	280,363	268,760	275,413	265,181	242,651	336,219	354,275	306,010	284,023	270,771	263,165	253,866
1940	251,463	227,119	247,577	250,738	267,164	374,717	384,694	296,651	258,228	251,236	251,353	238,163
1941	243,470	227,494	243,753	246,735	229,439	315,897	320,155	288,418	261,495	241,146	244,392	230,647
1942	232,525	234,021	279,693	255,583	265,066	308,592	416,148	322,323	286,927	252,718	236,276	230,082
1943	233,902	264,405	368,126	395,722	349,723	434,914	578,133	410,786	370,442	344,514	308,568	292,378
1944	302,726	288,135	283,081	279,268	263,748	306,723	338,447	290,466	287,784	267,204	255,866	245,619
1945	250,424	238,895	230,139	259,236	274,813	272,529	368,996	378,904	301,928	255,294	253,019	241,566
1946	248,229	242,221	320,404	351,105	267,676	405,418	464,895	402,202	347,003	318,474	294,370	286,576
1947	293,405	288,355	326,319	288,098	288,659	333,132	352,103	321,849	323,517	292,120	284,175	271,152
1948	296,024	264,791	268,656	312,909	271,898	290,484	398,570	427,222	440,486	332,112	316,463	292,187
1949	300,500	280,126	291,025	256,284	298,195	387,710	452,839	427,659	346,819	324,167	318,910	293,354
1950	301,663	276,407	277,756	280,523	284,660	382,163	463,020	403,592	439,748	359,413	324,057	314,775
1951	346,943	355,626	411,315	375,203	460,843	440,258	526,459	475,404	375,536	358,828	350,589	327,016
1952	351,966	324,261	337,105	309,705	335,230	401,508	606,618	467,288	415,797	383,688	352,077	326,516
1953	325,366	291,283	302,898	404,324	405,644	376,826	456,011	452,402	429,358	374,643	358,318	330,628
1954	336,520	335,043	383,867	366,047	372,355	410,817	454,095	414,531	402,557	368,980	361,122	335,227
1955	333,065	288,165	297,242	286,690	258,974	305,948	366,628	380,140	364,171	332,708	325,496	305,802
1956	309,355	307,076	451,166	476,376	359,947	453,441	534,468	568,769	463,377	398,673	374,920	358,809
1957	354,813	314,764	360,790	299,707	328,274	481,160	487,400	446,019	350,324	332,942	325,723	322,380
1958	332,936	284,464	287,250	351,382	499,092	397,234	490,107	471,826	430,703	363,889	346,223	328,557
1959	331,202	323,148	339,417	344,784	300,405	335,088	379,588	344,225	321,381	314,188	312,540	310,616
1960	315,811	280,762	278,697	277,061	270,478	355,447	407,050	351,671	375,804	287,084	313,647	290,926
1961	291,283	292,669	288,639	277,079	332,900	344,760	346,914	344,489	353,781	334,584	337,430	319,030
1962	311,464	289,176	305,260	311,261	302,688	346,063	441,188	377,435	345,099	350,288	354,383	321,672
1963	340,185	309,224	358,293	294,186	393,459	324,991	365,908	394,320	337,013	341,009	346,488	321,702

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1964	305,426	290,200	283,831	214,927	179,657	235,833	309,372	312,054	324,314	287,705	279,767	262,810
1965	253,720	236,931	446,462	536,967	467,630	316,205	432,191	416,578	383,783	373,506	375,510	338,316
1966	316,328	289,611	318,701	303,138	274,263	302,228	354,251	348,216	338,334	335,457	317,742	303,725
1967	296,817	274,092	306,004	296,215	293,679	296,694	321,464	368,925	353,466	320,589	311,741	298,334
1968	308,414	270,819	313,966	266,817	247,555	297,721	291,432	291,732	289,528	293,663	294,358	270,224
1969	266,903	278,555	325,772	302,886	185,836	263,386	413,548	356,314	377,887	318,965	320,706	306,570
1970	304,577	277,216	258,436	389,204	360,841	317,281	352,627	331,042	338,417	325,022	314,329	310,705
1971	292,212	309,956	327,359	430,081	323,814	312,601	411,757	403,783	399,100	378,265	356,314	330,402
1972	338,998	299,030	315,196	419,222	321,545	625,479	424,782	405,732	425,693	399,411	380,349	355,644
1973	372,872	308,968	321,050	365,309	216,537	303,581	336,846	339,607	317,513	321,898	318,578	302,726
1974	299,523	345,599	408,339	458,151	335,910	389,044	480,455	438,886	450,822	427,634	386,111	349,354
1975	444,494	308,319	330,249	343,253	322,554	404,139	435,231	466,593	416,440	397,044	363,618	333,460
1976	343,100	316,489	362,444	383,080	340,234	379,802	450,048	414,568	376,333	378,031	397,050	333,234
1977	338,334	293,080	294,524	313,007	235,892	302,905	314,710	297,008	284,952	284,384	295,704	279,025
1978	279,262	292,782	421,688	406,833	337,182	371,735	409,686	347,484	303,499	305,653	303,698	300,351
1979	284,274	262,804	311,150	355,914	282,155	434,650	365,527	396,478	296,490	299,117	299,461	283,559
1980	303,446	266,208	283,696	385,877	303,409	363,286	373,995	317,896	305,981	300,654	287,520	280,257
1981	273,193	275,645	339,269	304,141	338,004	336,779	347,741	320,478	306,885	286,629	286,364	273,919
1982	286,094	270,284	430,303	353,098	482,720	455,851	432,643	427,573	400,915	379,937	346,359	332,704
1983	328,810	290,557	331,571	354,715	405,511	554,393	503,460	493,002	414,030	386,449	358,429	344,117
1984	323,417	334,269	402,486	372,126	389,361	583,201	581,319	498,373	431,562	384,049	360,756	360,644
1985	336,547	394,644	344,392	331,483	300,755	415,856	480,530	361,663	374,731	341,424	341,021	339,150
1986	329,617	333,855	298,509	314,013	482,798	607,837	416,085	371,162	359,942	335,422	335,889	328,557
1987	319,927	302,530	324,041	270,711	303,740	393,668	377,873	340,162	308,902	333,935	310,249	291,136
1988	304,191	267,651	338,706	281,242	265,940	333,990	341,229	318,248	315,943	306,951	290,478	282,630
1989	290,416	301,899	266,419	301,307	271,273	434,907	465,879	384,628	320,167	311,292	319,471	316,433
1990	294,503	267,844	270,700	295,164	278,137	293,353	306,268	321,754	308,294	297,474	297,770	293,058
1991	279,016	264,046	276,305	255,067	250,417	304,885	291,265	309,317	290,059	297,618	280,362	268,594
1992	279,048	273,216	297,519	265,545	260,176	292,728	302,599	282,167	270,397	286,695	286,149	273,084
1993	266,608	255,145	284,064	262,145	226,182	561,031	488,177	439,738	358,832	308,536	307,177	290,511
1994	303,797	261,494	253,265	267,960	243,470	280,228	311,655	287,025	271,983	265,237	271,043	259,935
1995	254,461	248,304	248,652	290,338	363,260	371,801	317,545	324,759	304,512	303,790	282,196	272,860
1996	280,055	291,814	390,327	376,110	573,393	419,862	409,773	420,419	337,241	330,606	322,297	308,466
1997	317,284	334,778	500,096	586,826	430,496	488,975	457,414	426,540	406,671	385,811	367,092	357,523
1998	363,058	331,977	317,614	352,283	314,257	437,216	401,034	484,659	408,213	339,452	324,954	305,945
1999	318,117	322,080	352,077	383,652	347,809	488,356	464,167	449,838	428,587	397,349	385,725	342,522
2000	346,353	334,352	340,710	342,570	347,550	436,998	466,315	377,271	354,313	340,664	328,954	321,142
2001	322,046	293,197	294,682	282,346	261,940	318,503	309,001	316,410	282,364	286,611	283,490	275,317
2002	276,032	268,867	286,648	322,581	262,348	316,220	371,566	320,125	329,674	307,970	299,232	287,784

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
2003	284,611	256,204	280,994	300,985	292,853	333,130	330,340	314,870	296,836	289,386	285,119	279,776
2004	281,326	252,978	295,353	305,202	309,356	416,530	365,431	364,801	330,635	307,694	305,980	293,967
2005	291,411	260,698	288,823	268,240	239,602	318,181	328,584	368,281	290,603	280,686	282,215	276,354
2006	280,638	268,668	317,693	471,817	334,559	390,835	518,748	461,056	390,573	326,376	309,259	299,184
2007	295,490	305,388	345,117	333,881	302,366	404,415	365,231	341,375	317,809	309,378	302,718	305,245
2008	328,960	291,589	300,266	282,241	270,192	345,218	366,004	432,251	381,247	337,093	319,306	306,175
2009	304,489	283,535	292,865	303,671	263,114	339,566	372,308	408,405	368,502	320,034	315,828	301,251
2010	307,570	273,489	278,048	305,957	267,757	336,691	400,300	354,267	397,391	316,839	307,683	317,787
2011	329,827	290,197	336,797	419,105	325,321	409,731	502,022	478,847	422,628	367,420	332,241	314,786
2012	316,026	291,341	295,831	345,434	313,292	395,964	458,575	409,600	372,960	350,773	332,503	313,647
2013	329,150	304,673	345,208	312,425	280,523	371,740	371,666	351,160	326,949	313,792	314,897	312,645
2014	308,580	273,123	275,310	271,240	360,891	458,029	362,918	354,221	322,747	329,040	322,589	307,045
2015	306,799	305,636	401,120	347,659	328,223	338,145	311,284	312,023	286,927	301,705	292,996	285,204
2016	295,163	268,734	308,019	316,226	349,803	443,369	385,577	345,166	307,046	306,048	294,355	282,252
2017	313,886	269,384	281,221	287,636	370,576	541,496	468,035	428,164	369,919	332,567	326,500	314,048
2018	310,006	298,587	296,972	294,789	268,838	313,167	339,337	328,794	302,897	300,613	295,258	284,967

Table B-2. Unregulated flows at MADRAS gage for water years 1929 to 2018 (cfs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1929	5,237	4,443	4,323	4,268	4,267	4,935	5,554	5,194	5,092	4,523	4,392	4,354
1930	4,209	4,011	4,592	4,150	5,209	4,735	5,317	4,683	4,572	4,351	4,324	4,220
1931	4,150	3,953	3,861	3,897	3,957	4,403	5,594	4,561	4,301	3,934	3,898	3,888
1932	3,828	3,670	3,714	3,839	3,981	6,096	6,685	5,981	5,098	4,482	4,339	4,209
1933	4,123	4,240	4,085	4,198	4,078	4,501	6,280	5,638	6,488	5,199	4,745	4,677
1934	4,388	4,187	4,717	4,953	4,699	4,877	5,515	4,768	4,857	4,573	4,518	4,335
1935	4,372	4,313	4,481	4,393	4,498	4,692	6,606	5,746	5,453	4,861	4,592	4,530
1936	4,262	4,033	4,022	4,488	4,522	5,373	7,336	5,998	5,357	4,684	4,588	4,505
1937	4,215	3,928	4,053	4,003	4,181	4,821	6,967	5,841	5,818	4,703	4,391	4,400
1938	4,304	4,429	5,138	4,982	5,204	6,839	9,243	7,095	5,941	4,960	4,745	4,655
1939	4,560	4,517	4,479	4,313	4,369	5,468	5,954	4,977	4,773	4,404	4,280	4,266
1940	4,090	3,817	4,026	4,078	4,645	6,094	6,465	4,825	4,340	4,086	4,088	4,002
1941	3,960	3,823	3,964	4,013	4,131	5,138	5,380	4,691	4,395	3,922	3,975	3,876
1942	3,782	3,933	4,549	4,157	4,773	5,019	6,994	5,242	4,822	4,110	3,843	3,867
1943	3,804	4,443	5,987	6,436	6,297	7,073	9,716	6,681	6,225	5,603	5,018	4,914
1944	4,923	4,842	4,604	4,542	4,585	4,988	5,688	4,724	4,836	4,346	4,161	4,128
1945	4,073	4,015	3,743	4,216	4,948	4,432	6,201	6,162	5,074	4,152	4,115	4,060
1946	4,037	4,071	5,211	5,710	4,820	6,593	7,813	6,541	5,832	5,179	4,787	4,816
1947	4,772	4,846	5,307	4,685	5,198	5,418	5,917	5,234	5,437	4,751	4,622	4,557
1948	4,814	4,450	4,369	5,089	4,727	4,724	6,698	6,948	7,403	5,401	5,147	4,910

1949	4,887	4,708	4,733	4,168	5,369	6,305	7,610	6,955	5,828	5,272	5,187	4,930
1950	4,906	4,645	4,517	4,562	5,126	6,215	7,781	6,564	7,390	5,845	5,270	5,290
1951	5,642	5,976	6,689	6,102	8,298	7,160	8,847	7,732	6,311	5,836	5,702	5,496
1952	5,724	5,449	5,482	5,037	5,828	6,530	10,195	7,600	6,988	6,240	5,726	5,487
1953	5,292	4,895	4,926	6,576	7,304	6,128	7,664	7,358	7,216	6,093	5,827	5,556
1954	5,473	5,631	6,243	5,953	6,705	6,681	7,631	6,742	6,765	6,001	5,873	5,634
1955	5,417	4,843	4,834	4,663	4,663	4,976	6,161	6,182	6,120	5,411	5,294	5,139
1956	5,031	5,161	7,338	7,748	6,258	7,375	8,982	9,250	7,787	6,484	6,097	6,030
1957	5,770	5,290	5,868	4,874	5,911	7,825	8,191	7,254	5,887	5,415	5,297	5,418
1958	5,415	4,781	4,672	5,715	8,987	6,460	8,237	7,674	7,238	5,918	5,631	5,522
1959	5,386	5,431	5,520	5,607	5,409	5,450	6,379	5,598	5,401	5,110	5,083	5,220
1960	5,136	4,718	4,533	4,506	4,702	5,781	6,841	5,719	6,316	4,669	5,101	4,889
1961	4,737	4,918	4,694	4,506	5,994	5,607	5,830	5,603	5,945	5,441	5,488	5,361
1962	5,065	4,860	4,965	5,062	5,450	5,628	7,414	6,138	5,800	5,697	5,763	5,406
1963	5,533	5,197	5,827	4,784	7,085	5,285	6,149	6,413	5,664	5,546	5,635	5,406
1964	4,967	4,877	4,616	3,495	3,123	3,835	5,199	5,075	5,450	4,679	4,550	4,417
1965	4,126	3,982	7,261	8,733	8,420	5,143	7,263	6,775	6,450	6,074	6,107	5,686
1966	5,145	4,867	5,183	4,930	4,938	4,915	5,953	5,663	5,686	5,456	5,168	5,104
1967	4,827	4,606	4,977	4,817	5,288	4,825	5,402	6,000	5,940	5,214	5,070	5,014
1968	5,016	4,551	5,106	4,339	4,304	4,842	4,898	4,745	4,866	4,776	4,787	4,541
1969	4,341	4,681	5,298	4,926	3,346	4,284	6,950	5,795	6,351	5,187	5,216	5,152
1970	4,953	4,659	4,203	6,330	6,497	5,160	5,926	5,384	5,687	5,286	5,112	5,222
1971	4,752	5,209	5,324	6,995	5,831	5,084	6,920	6,567	6,707	6,152	5,795	5,553
1972	5,513	5,025	5,126	6,818	5,590	10,172	7,139	6,599	7,154	6,496	6,186	5,977
1973	6,064	5,192	5,221	5,941	3,899	4,937	5,661	5,523	5,336	5,235	5,181	5,087
1974	4,871	5,808	6,641	7,451	6,048	6,327	8,074	7,138	7,576	6,955	6,279	5,871
1975	7,229	5,181	5,371	5,582	5,808	6,573	7,314	7,588	6,999	6,457	5,914	5,604
1976	5,580	5,319	5,895	6,230	5,915	6,177	7,563	6,742	6,324	6,148	6,457	5,600
1977	5,502	4,925	4,790	5,091	4,247	4,926	5,289	4,830	4,789	4,625	4,809	4,689
1978	4,542	4,920	6,858	6,617	6,071	6,046	6,885	5,651	5,100	4,971	4,939	5,048
1979	4,623	4,417	5,060	5,788	5,080	7,069	6,143	6,448	4,983	4,865	4,870	4,765
1980	4,935	4,474	4,614	6,276	5,275	5,908	6,285	5,170	5,142	4,890	4,676	4,710
1981	4,443	4,632	5,518	4,946	6,086	5,477	5,844	5,212	5,157	4,662	4,657	4,603
1982	4,653	4,542	6,998	5,743	8,692	7,414	7,271	6,954	6,738	6,179	5,633	5,591
1983	5,348	4,883	5,392	5,769	7,302	9,016	8,461	8,018	6,958	6,285	5,829	5,783
1984	5,260	5,618	6,546	6,052	6,769	9,485	9,769	8,105	7,253	6,246	5,867	6,061
1985	5,473	6,632	5,601	5,391	5,415	6,763	8,076	5,882	6,298	5,553	5,546	5,700
1986	5,361	5,611	4,855	5,107	8,693	9,886	6,993	6,036	6,049	5,455	5,463	5,522
1987	5,203	5,084	5,270	4,403	5,469	6,402	6,350	5,532	5,191	5,431	5,046	4,893

1988	4,947	4,498	5,509	4,574	4,623	5,432	5,735	5,176	5,310	4,992	4,724	4,750
1989	4,723	5,074	4,333	4,900	4,885	7,073	7,829	6,255	5,381	5,063	5,196	5,318
1990	4,790	4,501	4,403	4,800	5,008	4,771	5,147	5,233	5,181	4,838	4,843	4,925
1991	4,538	4,437	4,494	4,148	4,509	4,958	4,895	5,031	4,875	4,840	4,560	4,514
1992	4,538	4,592	4,839	4,319	4,523	4,761	5,085	4,589	4,544	4,663	4,654	4,589
1993	4,336	4,288	4,620	4,263	4,073	9,124	8,204	7,152	6,030	5,018	4,996	4,882
1994	4,941	4,395	4,119	4,358	4,384	4,557	5,238	4,668	4,571	4,314	4,408	4,368
1995	4,138	4,173	4,044	4,722	6,541	6,047	5,337	5,282	5,118	4,941	4,589	4,586
1996	4,555	4,904	6,348	6,117	9,968	6,828	6,886	6,837	5,668	5,377	5,242	5,184
1997	5,160	5,626	8,133	9,544	7,751	7,952	7,687	6,937	6,834	6,275	5,970	6,008
1998	5,905	5,579	5,165	5,729	5,658	7,111	6,740	7,882	6,860	5,521	5,285	5,142
1999	5,174	5,413	5,726	6,240	6,263	7,942	7,801	7,316	7,203	6,462	6,273	5,756
2000	5,633	5,619	5,541	5,571	6,042	7,107	7,837	6,136	5,954	5,540	5,350	5,397
2001	5,238	4,927	4,793	4,592	4,716	5,180	5,193	5,146	4,745	4,661	4,611	4,627
2002	4,489	4,518	4,662	5,246	4,724	5,143	6,244	5,206	5,540	5,009	4,867	4,836
2003	4,629	4,306	4,570	4,895	5,273	5,418	5,552	5,121	4,989	4,706	4,637	4,702
2004	4,575	4,251	4,803	4,964	5,378	6,774	6,141	5,933	5,557	5,004	4,976	4,940
2005	4,739	4,381	4,697	4,363	4,314	5,175	5,522	5,990	4,884	4,565	4,590	4,644
2006	4,564	4,515	5,167	7,673	6,024	6,356	8,718	7,498	6,564	5,308	5,030	5,028
2007	4,806	5,132	5,613	5,430	5,444	6,577	6,138	5,552	5,341	5,032	4,923	5,130
2008	5,350	4,900	4,883	4,590	4,697	5,614	6,151	7,030	6,407	5,482	5,193	5,145
2009	4,952	4,765	4,763	4,939	4,738	5,523	6,257	6,642	6,193	5,205	5,136	5,063
2010	5,002	4,596	4,522	4,976	4,821	5,476	6,727	5,762	6,678	5,153	5,004	5,341
2011	5,364	4,877	5,477	6,816	5,858	6,664	8,437	7,788	7,103	5,976	5,403	5,290
2012	5,140	4,896	4,811	5,618	5,447	6,440	7,707	6,662	6,268	5,705	5,408	5,271
2013	5,353	5,120	5,614	5,081	5,051	6,046	6,246	5,711	5,495	5,103	5,121	5,254
2014	5,019	4,590	4,477	4,411	6,498	7,449	6,099	5,761	5,424	5,351	5,246	5,160
2015	4,990	5,136	6,524	5,654	5,910	5,499	5,231	5,075	4,822	4,907	4,765	4,793
2016	4,800	4,516	5,009	5,143	6,081	7,211	6,480	5,614	5,160	4,977	4,787	4,743
2017	5,105	4,527	4,574	4,678	6,673	8,807	7,866	6,963	6,217	5,409	5,310	5,278
2018	5,042	5,018	4,830	4,794	4,841	5,093	5,703	5,347	5,090	4,889	4,802	4,789

Table B-3. Unregulated flows into Lake Billy Chinook for water years 1929to 2018 (acre-feet per month)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1929	265,975	264,375	253,622	260,982	240,252	275,278	275,133	303,876	307,010	245,407	243,716	244,226
1930	241,053	233,795	257,489	253,314	266,582	260,361	271,474	272,474	268,368	247,313	243,956	234,545
1931	235,698	231,564	223,720	241,121	225,701	245,198	284,220	276,747	254,640	226,136	221,641	216,943
1932	224,482	218,258	216,224	240,992	219,755	350,792	348,681	342,362	281,792	259,629	251,088	238,514
1933	242,615	249,927	242,000	241,238	219,658	260,256	319,839	353,153	388,306	300,968	272,935	260,400
1934	258,356	249,052	283,677	294,966	255,180	277,073	298,995	279,791	275,330	253,560	251,451	235,021

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1935	243,685	243,167	252,164	249,453	246,122	259,408	324,415	326,756	295,454	272,984	258,473	247,731
1936	242,812	236,848	232,064	260,625	241,504	309,287	353,478	345,203	291,217	265,624	259,463	246,761
1937	243,900	230,933	234,812	254,378	221,597	271,484	363,100	339,761	324,772	262,617	248,457	240,942
1938	246,095	245,589	279,883	292,261	283,960	395,223	369,556	397,154	338,643	280,086	265,772	254,800
1939	262,039	258,139	256,960	246,637	233,165	303,655	280,114	277,227	282,149	249,188	241,213	234,450
1940	233,453	218,413	234,941	233,853	249,942	323,122	341,184	287,047	259,144	232,968	232,131	226,440
1941	220,492	220,502	235,390	238,575	240,368	258,485	249,832	260,416	237,461	220,233	222,656	213,444
1942	219,440	236,764	257,059	252,638	278,090	371,009	291,932	280,818	252,926	227,655	213,918	209,112
1943	222,084	277,811	347,576	352,895	393,731	455,882	375,857	344,889	333,948	308,568	283,388	271,593
1944	279,939	276,823	264,726	266,860	273,072	291,007	261,465	263,558	262,881	242,640	232,353	227,684
1945	230,490	232,885	231,639	267,500	257,219	322,052	302,030	317,945	266,219	234,837	232,181	226,446
1946	234,708	270,742	295,809	298,717	330,984	418,091	288,367	333,046	306,010	279,158	266,626	261,524
1947	272,652	276,258	288,486	284,101	290,564	294,862	267,427	292,077	286,957	261,123	255,054	245,607
1948	260,828	246,416	265,796	284,968	249,983	334,448	351,800	351,591	327,498	290,982	283,007	267,856
1949	266,380	257,044	261,541	275,721	310,496	370,136	315,490	348,486	304,904	289,648	284,655	265,220
1950	271,982	256,080	252,914	278,266	293,368	418,066	348,973	360,212	375,191	318,646	294,216	290,634
1951	313,641	358,803	358,066	402,903	399,113	434,957	378,981	376,402	333,912	324,253	324,290	308,075
1952	318,037	306,469	302,013	305,887	369,656	500,264	377,482	394,744	373,061	344,059	313,425	293,306
1953	291,289	272,866	317,883	390,390	381,052	420,354	354,650	382,354	351,437	329,062	318,105	296,859
1954	301,841	328,372	335,924	355,022	347,840	372,325	331,264	366,840	352,883	327,211	318,652	300,542
1955	291,861	260,935	264,819	256,807	244,351	295,348	325,528	305,672	323,279	286,481	285,368	268,403
1956	272,954	333,079	419,850	387,839	420,850	413,793	413,578	432,805	398,112	347,594	326,787	315,888
1957	305,247	294,359	323,104	307,258	345,974	424,898	361,053	369,392	315,936	298,680	290,705	294,859
1958	291,044	272,229	309,884	446,689	370,266	425,869	378,797	381,296	366,688	314,409	300,673	286,528
1959	285,055	292,431	312,817	302,769	277,024	304,903	292,913	294,825	280,983	271,835	270,635	271,860
1960	269,627	248,368	243,753	245,794	289,638	333,655	304,892	303,212	337,096	247,737	274,048	260,376
1961	257,877	263,839	251,125	242,160	290,530	290,687	277,757	305,954	320,857	297,223	296,897	282,405
1962	270,346	251,926	256,327	263,435	253,559	286,961	360,095	329,351	302,006	301,564	304,251	275,574
1963	289,396	271,837	315,196	247,344	346,752	272,431	285,594	343,315	288,635	291,345	298,090	278,852
1964	261,271	250,046	239,830	245,149	231,248	244,079	275,788	288,670	323,880	300,316	288,074	272,212
1965	260,441	247,642	520,500	499,840	414,413	310,917	378,458	388,835	349,372	338,113	337,000	309,331
1966	303,120	271,997	290,047	271,914	225,057	288,793	322,327	325,077	310,134	307,061	292,070	276,442
1967	268,840	257,627	284,434	277,252	261,567	250,363	268,623	353,270	328,063	291,658	284,329	272,235
1968	283,155	253,848	248,807	260,189	268,925	269,418	240,805	271,804	267,796	266,897	269,443	245,744
1969	242,492	262,096	249,736	276,864	227,800	270,519	355,138	345,750	359,529	303,071	299,246	284,386
1970	282,595	239,799	246,956	365,242	322,231	293,718	284,047	306,434	309,039	292,243	276,126	274,645
1971	271,213	279,233	275,444	392,764	308,191	313,186	354,662	388,497	370,341	352,274	330,021	304,701
1972	298,594	277,519	296,787	330,784	322,483	598,627	384,016	392,930	398,737	372,128	351,007	328,503
1973	327,174	285,017	308,937	306,299	255,603	272,646	273,747	302,683	281,227	283,622	279,268	265,892
1974	260,041	310,045	377,146	418,718	294,124	364,584	418,487	410,362	412,887	387,445	347,090	316,983

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1975	405,326	278,781	299,129	308,758	288,842	350,749	381,564	433,027	377,690	359,597	320,896	296,424
1976	305,087	288,278	329,634	344,409	303,213	337,596	398,838	378,880	333,906	336,108	352,637	295,877
1977	290,472	265,232	262,365	253,253	222,124	241,490	242,394	267,057	243,661	239,535	247,805	238,728
1978	238,895	253,229	371,759	332,388	299,261	377,091	346,700	311,193	266,999	263,521	261,129	263,066
1979	240,924	229,112	241,957	245,210	310,913	392,918	329,836	360,692	252,706	250,270	252,109	242,453
1980	247,565	235,789	257,901	321,314	299,227	316,481	302,131	285,202	261,263	252,355	238,502	231,950
1981	233,158	238,579	297,211	264,813	289,936	294,376	279,787	271,490	258,484	237,733	236,860	229,457
1982	237,137	228,577	366,059	305,764	436,307	394,479	378,142	382,305	359,690	333,335	302,105	286,534
1983	278,979	252,581	281,390	311,033	355,726	503,695	432,697	452,125	365,224	341,347	314,520	292,925
1984	294,878	292,961	331,581	340,056	353,753	533,703	525,107	464,649	391,957	340,471	321,618	312,546
1985	314,173	367,769	314,632	285,073	267,554	351,416	443,437	328,793	329,941	295,790	295,930	291,121
1986	283,284	258,582	253,111	283,514	412,116	514,875	351,676	332,941	310,525	291,599	286,885	286,263
1987	276,227	260,758	256,142	259,221	264,629	349,129	321,423	304,453	266,454	289,695	272,044	256,415
1988	253,379	234,652	254,864	252,966	243,820	270,733	278,444	273,929	274,792	263,715	248,624	240,298
1989	244,105	253,688	243,162	244,521	233,719	411,195	401,522	345,003	285,355	272,516	278,514	265,186
1990	262,681	236,929	235,848	252,813	216,661	261,838	268,494	282,407	271,592	260,642	256,330	242,587
1991	247,895	233,755	226,356	237,400	222,535	245,792	247,242	276,913	260,114	262,798	245,927	232,836
1992	237,885	243,700	253,894	230,424	234,011	242,762	252,264	247,197	234,958	248,522	246,825	233,611
1993	225,813	221,416	224,138	223,107	201,649	499,142	443,809	413,761	327,732	278,534	275,247	257,944
1994	264,152	226,622	237,065	236,094	205,753	244,518	253,816	253,828	236,883	237,716	230,664	224,025
1995	221,942	217,774	220,356	258,326	323,632	319,815	271,998	296,888	272,586	271,659	249,107	239,681
1996	244,797	261,945	347,169	337,986	508,859	382,630	373,214	394,864	315,685	303,874	293,200	282,356
1997	285,336	308,009	449,808	532,235	399,360	435,188	411,254	393,958	364,355	342,543	322,798	314,862
1998	324,656	299,339	289,114	322,833	294,944	399,136	366,756	451,180	374,248	310,861	294,395	277,049
1999	280,708	290,439	315,850	339,188	304,309	424,786	419,583	429,506	400,945	365,372	353,860	309,565
2000	310,934	309,836	309,935	306,833	317,953	388,510	433,548	358,580	327,422	311,222	295,592	287,526
2001	287,280	259,102	261,531	251,761	227,849	275,791	271,198	286,315	255,718	257,688	253,719	244,862
2002	246,994	238,645	254,024	274,921	222,187	268,792	336,650	291,405	296,648	275,735	263,759	253,499
2003	247,467	227,638	238,562	271,899	256,800	289,395	283,123	281,603	263,062	255,657	250,690	245,202
2004	241,377	228,454	250,102	259,496	278,082	380,189	329,754	336,195	302,517	277,606	273,595	259,734
2005	252,071	228,393	249,865	236,055	208,431	267,902	280,522	330,598	255,472	244,814	244,098	240,645
2006	240,896	234,235	280,879	417,116	291,972	340,299	472,370	415,653	351,295	289,289	278,315	269,574
2007	262,700	276,656	307,594	293,832	270,448	357,077	319,265	302,261	282,048	275,667	267,963	261,844
2008	269,295	257,083	270,543	257,244	247,090	307,629	327,502	406,841	357,475	313,079	293,944	278,676
2009	271,958	259,255	256,941	281,784	236,433	293,498	332,743	376,396	333,289	285,965	282,092	265,673
2010	269,089	244,968	245,859	275,691	243,218	290,609	349,466	323,725	359,672	279,793	267,595	269,776
2011	263,149	246,353	303,451	381,963	292,873	358,571	453,865	444,710	391,610	335,960	300,086	285,280
2012	283,106	258,938	266,804	310,604	288,694	358,863	411,806	375,554	342,899	320,029	301,560	282,092
2013	292,179	278,913	319,092	278,322	252,683	332,860	334,881	315,589	290,388	275,806	273,828	274,261
2014	270,782	246,823	244,100	240,637	312,753	408,399	327,521	323,782	293,349	300,539	292,743	273,246

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
2015	271,800	269,682	359,447	314,745	304,220	294,252	266,043	274,223	251,052	262,112	255,043	244,601
2016	244,911	232,516	283,002	286,342	319,884	403,326	345,138	312,148	278,498	273,052	257,290	246,095
2017	274,742	245,247	247,525	246,442	331,431	496,971	432,921	399,458	339,259	299,413	292,916	284,304
2018	280,750	275,357	254,607	262,524	239,653	276,000	294,286	296,592	266,865	263,969	257,806	247,026

Table B-4. Unregulated flows into Lake Billy Chinook for water years 1929 to 2018 (cfs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1929	4,326	4,443	4,125	4,244	4,326	4,477	4,624	4,942	5,159	3,991	3,964	4,104
1930	3,920	3,929	4,188	4,120	4,800	4,234	4,562	4,431	4,510	4,022	3,968	3,942
1931	3,833	3,892	3,638	3,921	4,064	3,988	4,776	4,501	4,279	3,678	3,605	3,646
1932	3,651	3,668	3,517	3,919	3,820	5,705	5,860	5,568	4,736	4,222	4,084	4,008
1933	3,946	4,200	3,936	3,923	3,955	4,233	5,375	5,743	6,526	4,895	4,439	4,376
1934	4,202	4,185	4,614	4,797	4,595	4,506	5,025	4,550	4,627	4,124	4,089	3,950
1935	3,963	4,087	4,101	4,057	4,432	4,219	5,452	5,314	4,965	4,440	4,204	4,163
1936	3,949	3,980	3,774	4,239	4,199	5,030	5,940	5,614	4,894	4,320	4,220	4,147
1937	3,967	3,881	3,819	4,137	3,990	4,415	6,102	5,526	5,458	4,271	4,041	4,049
1938	4,002	4,127	4,552	4,753	5,113	6,428	6,211	6,459	5,691	4,555	4,322	4,282
1939	4,262	4,338	4,179	4,011	4,198	4,938	4,707	4,509	4,742	4,053	3,923	3,940
1940	3,797	3,671	3,821	3,803	4,345	5,255	5,734	4,668	4,355	3,789	3,775	3,805
1941	3,586	3,706	3,828	3,880	4,328	4,204	4,199	4,235	3,991	3,582	3,621	3,587
1942	3,569	3,979	4,181	4,109	5,007	6,034	4,906	4,567	4,251	3,702	3,479	3,514
1943	3,612	4,669	5,653	5,739	7,090	7,414	6,316	5,609	5,612	5,018	4,609	4,564
1944	4,553	4,652	4,305	4,340	4,747	4,733	4,394	4,286	4,418	3,946	3,779	3,826
1945	3,749	3,914	3,767	4,350	4,631	5,238	5,076	5,171	4,474	3,819	3,776	3,806
1946	3,817	4,550	4,811	4,858	5,960	6,800	4,846	5,416	5,143	4,540	4,336	4,395
1947	4,434	4,643	4,692	4,620	5,232	4,795	4,494	4,750	4,822	4,247	4,148	4,128
1948	4,242	4,141	4,323	4,635	4,346	5,439	5,912	5,718	5,504	4,732	4,603	4,501
1949	4,332	4,320	4,254	4,484	5,591	6,020	5,302	5,668	5,124	4,711	4,629	4,457
1950	4,423	4,304	4,113	4,526	5,282	6,799	5,865	5,858	6,305	5,182	4,785	4,884
1951	5,101	6,030	5,823	6,553	7,186	7,074	6,369	6,122	5,612	5,273	5,274	5,177
1952	5,172	5,150	4,912	4,975	6,426	8,136	6,344	6,420	6,269	5,596	5,097	4,929
1953	4,737	4,586	5,170	6,349	6,861	6,836	5,960	6,218	5,906	5,352	5,173	4,989
1954	4,909	5,518	5,463	5,774	6,263	6,055	5,567	5,966	5,930	5,322	5,182	5,051
1955	4,747	4,385	4,307	4,177	4,400	4,803	5,471	4,971	5,433	4,659	4,641	4,511
1956	4,439	5,598	6,828	6,308	7,317	6,730	6,950	7,039	6,691	5,653	5,315	5,309
1957	4,964	4,947	5,255	4,997	6,230	6,910	6,068	6,008	5,309	4,858	4,728	4,955
1958	4,733	4,575	5,040	7,265	6,667	6,926	6,366	6,201	6,162	5,113	4,890	4,815
1959	4,636	4,914	5,087	4,924	4,988	4,959	4,923	4,795	4,722	4,421	4,401	4,569
1960	4,385	4,174	3,964	3,997	5,035	5,426	5,124	4,931	5,665	4,029	4,457	4,376
1961	4,194	4,434	4,084	3,938	5,231	4,728	4,668	4,976	5,392	4,834	4,829	4,746

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1962	4,397	4,234	4,169	4,284	4,566	4,667	6,052	5,356	5,075	4,904	4,948	4,631
1963	4,707	4,568	5,126	4,023	6,244	4,431	4,800	5,583	4,851	4,738	4,848	4,686
1964	4,249	4,202	3,900	3,987	4,020	3,970	4,635	4,695	5,443	4,884	4,685	4,575
1965	4,236	4,162	8,465	8,129	7,462	5,057	6,360	6,324	5,871	5,499	5,481	5,198
1966	4,930	4,571	4,717	4,422	4,052	4,697	5,417	5,287	5,212	4,994	4,750	4,646
1967	4,372	4,330	4,626	4,509	4,710	4,072	4,514	5,745	5,513	4,743	4,624	4,575
1968	4,605	4,266	4,046	4,232	4,675	4,382	4,047	4,420	4,500	4,341	4,382	4,130
1969	3,944	4,405	4,062	4,503	4,102	4,400	5,968	5,623	6,042	4,929	4,867	4,779
1970	4,596	4,030	4,016	5,940	5,802	4,777	4,774	4,984	5,194	4,753	4,491	4,616
1971	4,411	4,693	4,480	6,388	5,549	5,093	5,960	6,318	6,224	5,729	5,367	5,121
1972	4,856	4,664	4,827	5,380	5,606	9,736	6,454	6,390	6,701	6,052	5,709	5,521
1973	5,321	4,790	5,024	4,981	4,602	4,434	4,600	4,923	4,726	4,613	4,542	4,468
1974	4,229	5,210	6,134	6,810	5,296	5,929	7,033	6,674	6,939	6,301	5,645	5,327
1975	6,592	4,685	4,865	5,021	5,201	5,704	6,412	7,043	6,347	5,848	5,219	4,982
1976	4,962	4,845	5,361	5,601	5,271	5,490	6,703	6,162	5,611	5,466	5,735	4,972
1977	4,724	4,457	4,267	4,119	4,000	3,927	4,074	4,343	4,095	3,896	4,030	4,012
1978	3,885	4,256	6,046	5,406	5,388	6,133	5,826	5,061	4,487	4,286	4,247	4,421
1979	3,918	3,850	3,935	3,988	5,598	6,390	5,543	5,866	4,247	4,070	4,100	4,075
1980	4,026	3,963	4,194	5,226	5,202	5,147	5,077	4,638	4,391	4,104	3,879	3,898
1981	3,792	4,009	4,834	4,307	5,221	4,788	4,702	4,415	4,344	3,866	3,852	3,856
1982	3,857	3,841	5,953	4,973	7,856	6,416	6,355	6,218	6,045	5,421	4,913	4,815
1983	4,537	4,245	4,576	5,058	6,405	8,192	7,272	7,353	6,138	5,551	5,115	4,923
1984	4,796	4,923	5,393	5,530	6,150	8,680	8,825	7,557	6,587	5,537	5,231	5,253
1985	5,110	6,181	5,117	4,636	4,818	5,715	7,452	5,347	5,545	4,811	4,813	4,892
1986	4,607	4,346	4,116	4,611	7,421	8,374	5,910	5,415	5,219	4,742	4,666	4,811
1987	4,492	4,382	4,166	4,216	4,765	5,678	5,402	4,951	4,478	4,711	4,424	4,309
1988	4,121	3,943	4,145	4,114	4,239	4,403	4,679	4,455	4,618	4,289	4,043	4,038
1989	3,970	4,263	3,955	3,977	4,208	6,687	6,748	5,611	4,796	4,432	4,530	4,457
1990	4,272	3,982	3,836	4,112	3,901	4,258	4,512	4,593	4,564	4,239	4,169	4,077
1991	4,032	3,928	3,681	3,861	4,007	3,997	4,155	4,504	4,371	4,274	4,000	3,913
1992	3,869	4,096	4,129	3,747	4,068	3,948	4,239	4,020	3,949	4,042	4,014	3,926
1993	3,672	3,721	3,645	3,628	3,631	8,118	7,458	6,729	5,508	4,530	4,476	4,335
1994	4,296	3,809	3,855	3,840	3,705	3,977	4,266	4,128	3,981	3,866	3,751	3,765
1995	3,610	3,660	3,584	4,201	5,827	5,201	4,571	4,828	4,581	4,418	4,051	4,028
1996	3,981	4,402	5,646	5,497	8,847	6,223	6,272	6,422	5,305	4,942	4,768	4,745
1997	4,641	5,176	7,315	8,656	7,191	7,078	6,911	6,407	6,123	5,571	5,250	5,291
1998	5,280	5,031	4,702	5,250	5,311	6,491	6,164	7,338	6,289	5,056	4,788	4,656
1999	4,565	4,881	5,137	5,516	5,479	6,908	7,051	6,985	6,738	5,942	5,755	5,202
2000	5,057	5,207	5,041	4,990	5,528	6,319	7,286	5,832	5,503	5,062	4,807	4,832
2001	4,672	4,354	4,253	4,094	4,103	4,485	4,558	4,656	4,297	4,191	4,126	4,115

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
2002	4,017	4,011	4,131	4,471	4,001	4,371	5,658	4,739	4,985	4,484	4,290	4,260
2003	4,025	3,826	3,880	4,422	4,624	4,707	4,758	4,580	4,421	4,158	4,077	4,121
2004	3,926	3,839	4,068	4,220	4,834	6,183	5,542	5,468	5,084	4,515	4,450	4,365
2005	4,100	3,838	4,064	3,839	3,753	4,357	4,714	5,377	4,293	3,982	3,970	4,044
2006	3,918	3,936	4,568	6,784	5,257	5,534	7,938	6,760	5,904	4,705	4,526	4,530
2007	4,272	4,649	5,003	4,779	4,870	5,807	5,365	4,916	4,740	4,483	4,358	4,400
2008	4,380	4,320	4,400	4,184	4,296	5,003	5,504	6,617	6,008	5,092	4,781	4,683
2009	4,423	4,357	4,179	4,583	4,257	4,773	5,592	6,122	5,601	4,651	4,588	4,465
2010	4,376	4,117	3,999	4,484	4,379	4,726	5,873	5,265	6,044	4,550	4,352	4,534
2011	4,280	4,140	4,935	6,212	5,273	5,832	7,627	7,233	6,581	5,464	4,880	4,794
2012	4,604	4,352	4,339	5,051	5,019	5,836	6,921	6,108	5,763	5,205	4,904	4,741
2013	4,752	4,687	5,190	4,526	4,550	5,413	5,628	5,133	4,880	4,486	4,453	4,609
2014	4,404	4,148	3,970	3,914	5,631	6,642	5,504	5,266	4,930	4,888	4,761	4,592
2015	4,420	4,532	5,846	5,119	5,478	4,786	4,471	4,460	4,219	4,263	4,148	4,111
2016	3,983	3,908	4,603	4,657	5,561	6,559	5,800	5,077	4,680	4,441	4,184	4,136
2017	4,468	4,122	4,026	4,008	5,968	8,082	7,275	6,497	5,701	4,869	4,764	4,778
2018	4,566	4,628	4,141	4,270	4,315	4,489	4,946	4,824	4,485	4,293	4,193	4,151

Appendix C: Modified Flows Data

Table C-1. Modified flows at MADRAS gage for water years 1929 to 2018 (acre-feet per month)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1929	305,544	302,206	295,821	290,440	257,713	323,507	307,857	266,355	240,474	252,630	243,632	231,975
1930	274,565	242,626	289,521	248,974	274,568	292,941	284,818	251,351	233,194	241,440	237,197	228,864
1931	252,023	237,431	250,462	234,610	210,959	270,208	285,278	237,479	222,024	224,594	223,972	217,391
1932	230,248	216,375	233,672	223,267	221,818	303,941	347,770	293,615	258,999	242,956	230,600	221,561
1933	238,109	250,651	257,555	263,331	228,179	269,409	304,678	250,107	289,173	263,432	242,951	231,374
1934	249,378	268,248	292,757	302,315	256,486	300,626	290,534	247,109	239,759	247,700	240,732	233,722
1935	266,295	261,042	287,933	281,124	240,274	282,125	313,114	278,531	269,357	255,919	243,072	235,205
1936	249,492	237,408	251,510	270,182	251,904	285,714	348,889	276,244	259,572	243,850	238,345	230,179
1937	247,353	235,116	260,183	244,291	233,871	280,652	309,977	288,286	278,489	252,943	233,377	227,321
1938	249,442	265,735	312,788	300,653	250,739	386,001	507,775	331,973	268,358	250,173	245,536	235,921
1939	259,162	280,828	290,254	275,706	248,745	309,080	315,080	255,516	225,012	236,334	228,158	221,781
1940	258,791	227,389	252,480	254,181	248,203	314,535	290,511	241,559	213,477	225,078	219,897	218,864
1941	240,248	234,233	251,821	247,609	217,729	292,775	274,818	239,211	222,813	220,425	217,202	219,159
1942	232,276	228,028	275,346	254,508	235,045	272,583	389,284	266,159	236,381	226,004	213,928	214,484
1943	228,665	251,604	350,225	386,012	326,873	392,007	563,441	308,910	274,539	272,925	247,691	238,488
1944	274,551	290,794	288,766	282,268	267,958	286,419	277,349	238,462	231,980	230,981	224,341	219,656
1945	261,159	227,167	236,272	244,312	246,464	248,177	310,418	293,694	246,339	220,505	219,253	212,140
1946	230,148	239,169	304,893	348,148	244,082	371,235	488,009	295,130	265,391	258,049	237,426	230,008
1947	264,969	286,161	324,335	288,582	268,090	298,838	300,397	255,833	251,004	239,734	237,004	226,915
1948	288,146	255,931	263,771	307,132	264,705	284,529	356,505	370,765	355,248	258,733	240,963	231,914
1949	268,363	282,735	290,940	267,118	284,616	377,358	430,372	323,077	270,469	255,924	246,701	234,367
1950	269,089	280,584	294,694	289,304	281,663	346,872	431,026	301,982	321,372	275,326	252,673	240,898
1951	307,463	355,942	418,284	399,794	444,387	412,130	501,206	359,360	291,430	267,373	250,974	257,760
1952	347,066	345,011	357,225	324,989	337,001	385,665	625,619	349,427	316,123	282,598	256,477	268,108
1953	324,511	320,899	329,975	423,403	393,568	376,266	410,811	347,557	322,504	278,973	256,484	253,554
1954	333,827	368,239	412,460	382,648	383,020	389,679	399,397	308,486	301,857	277,219	263,241	271,814
1955	330,744	313,736	323,335	325,483	289,843	314,997	304,692	261,260	268,143	260,900	238,370	239,837
1956	288,978	320,695	449,440	483,208	351,784	454,275	496,737	450,328	360,808	290,312	269,824	288,854
1957	349,631	352,889	388,610	328,407	330,089	463,031	433,631	334,077	265,398	242,502	240,602	235,345
1958	323,322	310,593	309,056	368,136	546,731	396,121	442,978	356,639	328,248	267,765	248,556	246,086
1959	328,589	354,118	364,420	360,038	315,252	340,359	321,306	263,039	244,760	243,999	239,409	244,174
1960	297,246	296,181	303,074	299,692	287,690	329,840	343,888	268,488	261,433	248,205	246,835	233,169
1961	277,433	288,135	297,379	291,009	331,300	353,342	323,098	272,607	273,467	258,383	254,882	248,700
1962	276,775	290,694	315,855	316,174	297,995	335,053	367,808	287,772	264,405	263,318	264,553	249,089
1963	304,644	335,379	360,738	313,680	377,228	328,743	335,254	292,625	251,384	257,547	252,926	252,080
1964	279,440	337,301	295,408	223,114	185,102	243,081	267,957	233,278	227,018	202,993	199,568	192,980
1965	229,005	236,756	421,840	514,027	428,610	304,620	356,451	310,118	280,441	266,282	267,398	248,788

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1966	291,104	370,196	343,608	320,549	296,053	309,290	298,315	255,356	249,524	257,667	240,552	238,951
1967	291,626	304,888	326,133	308,456	287,792	314,444	277,805	261,628	264,796	250,303	241,054	235,417
1968	291,658	320,477	321,222	270,167	245,815	302,126	262,664	235,971	229,704	232,716	234,286	225,125
1969	256,099	270,914	329,402	285,916	178,496	245,292	310,800	261,667	291,149	245,665	243,517	242,599
1970	263,059	333,326	264,703	395,386	330,861	304,895	309,223	257,631	255,758	242,500	238,768	244,928
1971	259,117	341,868	325,486	417,513	300,312	290,141	358,850	288,009	285,879	277,515	259,273	247,874
1972	305,898	359,235	326,929	423,374	306,804	579,776	366,571	303,746	322,065	282,398	267,956	264,854
1973	360,521	384,211	343,527	378,241	231,257	318,015	299,364	250,467	235,101	240,427	242,750	237,125
1974	285,061	348,035	427,415	470,115	337,545	356,877	421,126	323,081	318,611	301,285	273,289	253,747
1975	418,876	382,648	354,101	359,805	319,440	381,801	376,063	371,542	314,336	294,081	272,910	254,817
1976	329,548	348,449	383,992	403,552	343,152	357,367	385,178	312,105	282,539	283,236	292,612	254,163
1977	330,735	330,722	322,129	331,423	253,552	321,440	278,586	236,166	231,622	235,875	242,944	231,547
1978	285,432	286,221	382,451	378,951	313,444	334,471	362,994	282,667	239,177	245,847	239,040	244,212
1979	268,466	264,762	318,884	367,071	257,829	406,954	329,070	316,508	235,508	234,528	237,604	239,097
1980	286,314	258,057	280,267	404,578	269,580	335,561	331,454	254,392	243,840	235,546	235,224	235,332
1981	258,605	270,912	330,188	306,573	319,675	303,753	307,325	265,316	252,729	234,841	234,586	230,656
1982	268,382	267,966	401,857	352,336	454,336	422,118	398,976	323,443	286,196	286,382	263,384	260,328
1983	297,538	313,250	339,054	371,852	414,111	512,144	439,705	381,464	295,723	288,461	269,639	268,491
1984	300,768	358,872	407,324	391,569	403,722	561,766	494,501	382,002	323,360	283,016	267,211	271,451
1985	319,601	436,147	362,633	350,466	300,532	386,667	422,210	265,385	280,589	270,497	264,454	264,386
1986	304,035	352,488	322,296	331,664	446,735	575,297	363,764	272,384	273,739	260,382	260,753	255,622
1987	299,923	314,749	344,759	285,812	298,301	355,446	338,649	265,355	249,759	264,486	251,850	239,388
1988	304,649	271,812	345,714	287,797	261,122	317,932	277,656	256,856	253,543	246,488	237,674	236,262
1989	281,785	293,170	271,499	303,671	253,229	362,452	402,834	294,015	253,232	251,365	253,843	257,633
1990	273,710	276,249	291,299	307,277	290,607	287,572	255,558	256,763	246,740	242,312	246,272	246,188
1991	271,345	260,924	284,658	259,903	249,121	298,688	249,194	241,056	232,002	241,892	233,973	227,988
1992	260,934	261,358	289,932	267,585	247,414	279,265	262,931	244,387	231,333	236,595	236,973	229,805
1993	255,427	253,220	288,620	263,745	225,862	434,590	409,136	330,599	274,030	248,456	245,429	234,356
1994	280,818	272,354	262,402	279,013	253,527	277,162	261,457	238,573	229,534	220,116	229,086	219,137
1995	251,684	245,362	256,507	271,844	313,780	315,490	271,641	255,319	242,356	245,055	232,600	226,894
1996	256,771	283,483	354,442	353,913	520,323	373,080	347,502	315,023	250,580	255,396	252,570	241,147
1997	296,259	337,103	479,615	579,552	413,982	446,697	393,593	329,088	309,570	291,564	284,144	277,213
1998	344,655	353,596	343,050	354,289	312,831	383,487	348,698	382,025	310,514	262,890	257,742	246,171
1999	299,057	326,120	356,096	385,857	334,786	462,103	413,951	329,268	322,397	298,537	286,320	264,859
2000	341,575	358,332	364,356	353,509	340,465	403,284	404,830	288,910	268,633	265,487	261,197	255,744
2001	310,577	305,277	314,813	305,554	279,441	316,797	255,411	251,526	233,181	236,980	235,908	228,197
2002	277,829	263,090	281,787	302,054	255,736	288,011	270,267	258,466	266,914	253,455	245,093	237,112
2003	268,410	261,773	289,541	294,192	279,686	304,941	268,122	248,157	243,778	237,874	234,817	232,458
2004	270,289	251,866	297,260	299,693	280,066	343,416	308,793	280,958	260,585	252,894	247,931	242,154
2005	272,101	265,796	292,675	278,734	249,019	291,950	262,229	277,825	242,216	234,639	236,080	233,323

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
2006	269,416	259,984	310,282	442,872	321,093	368,131	453,587	354,541	296,873	267,149	250,141	239,823
2007	267,523	307,539	340,724	335,122	283,783	367,289	318,039	269,195	255,992	252,080	246,282	253,364
2008	307,358	287,659	301,264	281,714	264,573	308,902	286,032	312,650	282,409	264,287	249,648	240,796
2009	271,742	295,240	301,005	312,882	268,196	317,689	300,924	309,307	286,793	263,499	253,539	242,679
2010	296,979	274,206	287,123	304,941	261,885	302,140	327,513	285,732	312,058	258,417	248,423	258,920
2011	301,644	292,249	328,094	411,314	311,538	392,912	434,010	382,551	317,745	282,681	264,462	248,323
2012	285,361	310,028	309,014	344,266	307,467	347,902	382,631	304,089	281,827	277,749	259,429	247,139
2013	302,086	308,001	340,988	319,489	283,171	332,913	307,570	276,759	261,780	259,780	258,443	253,883
2014	295,618	283,937	295,364	290,121	335,834	399,334	308,140	276,059	260,602	263,659	254,721	247,809
2015	281,771	298,656	354,970	330,070	296,908	318,546	281,264	254,250	238,988	250,908	243,085	238,901
2016	286,183	271,184	300,015	294,422	294,319	386,198	321,228	272,350	248,456	247,485	240,484	232,552
2017	284,254	271,224	285,865	289,641	312,513	497,172	414,947	317,349	279,594	264,634	253,712	247,719
2018	280,521	307,013	319,872	313,214	282,461	318,445	290,856	266,078	246,327	242,427	242,550	236,232

Table C-2. Modified flows at MADRAS gage for water years 1929 to 2018 (cfs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1929	4,969	5,079	4,811	4,724	4,640	5,261	5,174	4,332	4,041	4,109	3,962	3,898
1930	4,465	4,077	4,709	4,049	4,944	4,764	4,787	4,088	3,919	3,927	3,858	3,846
1931	4,099	3,990	4,073	3,816	3,799	4,395	4,794	3,862	3,731	3,653	3,643	3,653
1932	3,745	3,636	3,800	3,631	3,856	4,943	5,844	4,775	4,353	3,951	3,750	3,723
1933	3,872	4,212	4,189	4,283	4,109	4,382	5,120	4,068	4,860	4,284	3,951	3,888
1934	4,056	4,508	4,761	4,917	4,618	4,889	4,883	4,019	4,029	4,028	3,915	3,928
1935	4,331	4,387	4,683	4,572	4,326	4,588	5,262	4,530	4,527	4,162	3,953	3,953
1936	4,058	3,990	4,090	4,394	4,379	4,647	5,863	4,493	4,362	3,966	3,876	3,868
1937	4,023	3,951	4,231	3,973	4,211	4,564	5,209	4,689	4,680	4,114	3,796	3,820
1938	4,057	4,466	5,087	4,890	4,515	6,278	8,533	5,399	4,510	4,069	3,993	3,965
1939	4,215	4,719	4,721	4,484	4,479	5,027	5,295	4,156	3,781	3,844	3,711	3,727
1940	4,209	3,821	4,106	4,134	4,315	5,115	4,882	3,929	3,588	3,661	3,576	3,678
1941	3,907	3,936	4,095	4,027	3,920	4,762	4,618	3,890	3,745	3,585	3,532	3,683
1942	3,778	3,832	4,478	4,139	4,232	4,433	6,542	4,329	3,973	3,676	3,479	3,605
1943	3,719	4,228	5,696	6,278	5,886	6,375	9,469	5,024	4,614	4,439	4,028	4,008
1944	4,465	4,887	4,696	4,591	4,658	4,658	4,661	3,878	3,899	3,757	3,649	3,691
1945	4,247	3,818	3,843	3,973	4,438	4,036	5,217	4,776	4,140	3,586	3,566	3,565
1946	3,743	4,019	4,959	5,662	4,395	6,038	8,201	4,800	4,460	4,197	3,861	3,865
1947	4,309	4,809	5,275	4,693	4,827	4,860	5,048	4,161	4,218	3,899	3,855	3,813
1948	4,686	4,301	4,290	4,995	4,602	4,627	5,991	6,030	5,970	4,208	3,919	3,897
1949	4,365	4,752	4,732	4,344	5,125	6,137	7,233	5,254	4,545	4,162	4,012	3,939
1950	4,376	4,715	4,793	4,705	5,072	5,641	7,244	4,911	5,401	4,478	4,109	4,048
1951	5,000	5,982	6,803	6,502	8,002	6,703	8,423	5,844	4,898	4,348	4,082	4,332
1952	5,644	5,798	5,810	5,285	5,859	6,272	10,514	5,683	5,313	4,596	4,171	4,506

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1953	5,278	5,393	5,367	6,886	7,087	6,119	6,904	5,652	5,420	4,537	4,171	4,261
1954	5,429	6,188	6,708	6,223	6,897	6,338	6,712	5,017	5,073	4,509	4,281	4,568
1955	5,379	5,273	5,259	5,293	5,219	5,123	5,121	4,249	4,506	4,243	3,877	4,031
1956	4,700	5,389	7,309	7,859	6,116	7,388	8,348	7,324	6,064	4,721	4,388	4,854
1957	5,686	5,931	6,320	5,341	5,944	7,530	7,287	5,433	4,460	3,944	3,913	3,955
1958	5,258	5,220	5,026	5,987	9,844	6,442	7,444	5,800	5,516	4,355	4,042	4,136
1959	5,344	5,951	5,927	5,855	5,676	5,535	5,400	4,278	4,113	3,968	3,894	4,103
1960	4,834	4,977	4,929	4,874	5,002	5,364	5,779	4,367	4,394	4,037	4,014	3,919
1961	4,512	4,842	4,836	4,733	5,965	5,747	5,430	4,434	4,596	4,202	4,145	4,180
1962	4,501	4,885	5,137	5,142	5,366	5,449	6,181	4,680	4,443	4,282	4,303	4,186
1963	4,955	5,636	5,867	5,102	6,792	5,346	5,634	4,759	4,225	4,189	4,113	4,236
1964	4,545	5,669	4,804	3,629	3,218	3,953	4,503	3,794	3,815	3,301	3,246	3,243
1965	3,724	3,979	6,861	8,360	7,718	4,954	5,990	5,044	4,713	4,331	4,349	4,181
1966	4,734	6,221	5,588	5,213	5,331	5,030	5,013	4,153	4,193	4,191	3,912	4,016
1967	4,743	5,124	5,304	5,017	5,182	5,114	4,669	4,255	4,450	4,071	3,920	3,956
1968	4,743	5,386	5,224	4,394	4,274	4,914	4,414	3,838	3,860	3,785	3,810	3,783
1969	4,165	4,553	5,357	4,650	3,214	3,989	5,223	4,256	4,893	3,995	3,960	4,077
1970	4,278	5,602	4,305	6,430	5,957	4,959	5,197	4,190	4,298	3,944	3,883	4,116
1971	4,214	5,745	5,294	6,790	5,407	4,719	6,031	4,684	4,804	4,513	4,217	4,166
1972	4,975	6,037	5,317	6,886	5,334	9,429	6,160	4,940	5,412	4,593	4,358	4,451
1973	5,863	6,457	5,587	6,152	4,164	5,172	5,031	4,073	3,951	3,910	3,948	3,985
1974	4,636	5,849	6,951	7,646	6,078	5,804	7,077	5,254	5,354	4,900	4,445	4,264
1975	6,812	6,431	5,759	5,852	5,752	6,209	6,320	6,043	5,283	4,783	4,438	4,282
1976	5,360	5,856	6,245	6,563	5,966	5,812	6,473	5,076	4,748	4,606	4,759	4,271
1977	5,379	5,558	5,239	5,390	4,565	5,228	4,682	3,841	3,893	3,836	3,951	3,891
1978	4,642	4,810	6,220	6,163	5,644	5,440	6,100	4,597	4,020	3,998	3,888	4,104
1979	4,366	4,449	5,186	5,970	4,642	6,618	5,530	5,148	3,958	3,814	3,864	4,018
1980	4,656	4,337	4,558	6,580	4,687	5,457	5,570	4,137	4,098	3,831	3,826	3,955
1981	4,206	4,553	5,370	4,986	5,756	4,940	5,165	4,315	4,247	3,819	3,815	3,876
1982	4,365	4,503	6,536	5,730	8,181	6,865	6,705	5,260	4,810	4,658	4,284	4,375
1983	4,839	5,264	5,514	6,048	7,456	8,329	7,389	6,204	4,970	4,691	4,385	4,512
1984	4,892	6,031	6,624	6,368	7,019	9,136	8,310	6,213	5,434	4,603	4,346	4,562
1985	5,198	7,330	5,898	5,700	5,411	6,289	7,095	4,316	4,715	4,399	4,301	4,443
1986	4,945	5,924	5,242	5,394	8,044	9,356	6,113	4,430	4,600	4,235	4,241	4,296
1987	4,878	5,290	5,607	4,648	5,371	5,781	5,691	4,316	4,197	4,301	4,096	4,023
1988	4,955	4,568	5,623	4,681	4,540	5,171	4,666	4,177	4,261	4,009	3,865	3,971
1989	4,583	4,927	4,416	4,939	4,560	5,895	6,770	4,782	4,256	4,088	4,128	4,330
1990	4,451	4,643	4,738	4,997	5,233	4,677	4,295	4,176	4,147	3,941	4,005	4,137
1991	4,413	4,385	4,630	4,227	4,486	4,858	4,188	3,920	3,899	3,934	3,805	3,831
1992	4,244	4,392	4,715	4,352	4,301	4,542	4,419	3,975	3,888	3,848	3,854	3,862

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1993	4,154	4,256	4,694	4,289	4,067	7,068	6,876	5,377	4,605	4,041	3,992	3,938
1994	4,567	4,577	4,268	4,538	4,565	4,508	4,394	3,880	3,857	3,580	3,726	3,683
1995	4,093	4,123	4,172	4,421	5,650	5,131	4,565	4,152	4,073	3,985	3,783	3,813
1996	4,176	4,764	5,764	5,756	9,046	6,068	5,840	5,123	4,211	4,154	4,108	4,053
1997	4,818	5,665	7,800	9,426	7,454	7,265	6,615	5,352	5,203	4,742	4,621	4,659
1998	5,605	5,942	5,579	5,762	5,633	6,237	5,860	6,213	5,218	4,276	4,192	4,137
1999	4,864	5,481	5,791	6,275	6,028	7,515	6,957	5,355	5,418	4,855	4,657	4,451
2000	5,555	6,022	5,926	5,749	5,919	6,559	6,803	4,699	4,515	4,318	4,248	4,298
2001	5,051	5,130	5,120	4,969	5,032	5,152	4,292	4,091	3,919	3,854	3,837	3,835
2002	4,518	4,421	4,583	4,912	4,605	4,684	4,542	4,204	4,486	4,122	3,986	3,985
2003	4,365	4,399	4,709	4,785	5,036	4,959	4,506	4,036	4,097	3,869	3,819	3,907
2004	4,396	4,233	4,834	4,874	4,869	5,585	5,189	4,569	4,379	4,113	4,032	4,070
2005	4,425	4,467	4,760	4,533	4,484	4,748	4,407	4,518	4,071	3,816	3,839	3,921
2006	4,382	4,369	5,046	7,203	5,782	5,987	7,623	5,766	4,989	4,345	4,068	4,030
2007	4,351	5,168	5,541	5,450	5,110	5,973	5,345	4,378	4,302	4,100	4,005	4,258
2008	4,999	4,834	4,900	4,582	4,600	5,024	4,807	5,085	4,746	4,298	4,060	4,047
2009	4,419	4,962	4,895	5,089	4,829	5,167	5,057	5,030	4,820	4,285	4,123	4,078
2010	4,830	4,608	4,670	4,959	4,715	4,914	5,504	4,647	5,244	4,203	4,040	4,351
2011	4,906	4,911	5,336	6,689	5,610	6,390	7,294	6,222	5,340	4,597	4,301	4,173
2012	4,641	5,210	5,026	5,599	5,345	5,658	6,430	4,946	4,736	4,517	4,219	4,153
2013	4,913	5,176	5,546	5,196	5,099	5,414	5,169	4,501	4,399	4,225	4,203	4,267
2014	4,808	4,772	4,804	4,718	6,047	6,495	5,178	4,490	4,380	4,288	4,143	4,165
2015	4,583	5,019	5,773	5,368	5,346	5,181	4,727	4,135	4,016	4,081	3,953	4,015
2016	4,654	4,557	4,879	4,788	5,117	6,281	5,398	4,429	4,175	4,025	3,911	3,908
2017	4,623	4,558	4,649	4,711	5,627	8,086	6,973	5,161	4,699	4,304	4,126	4,163
2018	4,562	5,160	5,202	5,094	5,086	5,179	4,888	4,327	4,140	3,943	3,945	3,970

Table C-3. Modified flows into Lake Billy Chinook for water years 1929 to 2018 (acre-feet per month)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1929	249,503	302,218	283,646	288,995	261,001	295,364	252,494	250,866	244,514	219,949	217,272	217,146
1930	256,801	237,747	264,649	247,092	251,831	262,129	239,927	235,886	229,535	221,247	215,258	212,321
1931	232,531	233,753	236,800	236,104	216,918	244,666	236,656	233,777	220,763	208,840	205,950	202,997
1932	219,358	216,226	221,541	228,235	212,586	279,912	298,667	268,238	237,435	227,012	214,902	209,601
1933	227,183	248,265	248,400	246,415	221,376	252,900	250,802	256,564	291,411	244,733	224,123	213,498
1934	237,917	268,129	286,387	292,754	250,682	277,838	261,388	233,699	226,085	220,073	214,359	210,771
1935	241,171	247,588	264,555	260,458	236,592	253,016	244,451	251,956	240,360	229,989	219,166	213,361
1936	230,234	234,290	236,254	254,865	233,273	264,599	265,838	252,621	232,022	221,456	215,674	208,894
1937	232,085	232,313	245,794	252,549	223,275	255,700	258,523	268,918	257,055	226,386	211,844	206,429
1938	230,910	247,800	276,732	286,578	245,707	360,717	327,309	292,897	253,500	225,264	219,557	213,726
1939	240,838	270,206	271,802	257,161	239,259	276,515	240,919	226,734	223,137	214,751	206,206	202,364

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1940	240,781	218,683	239,844	237,296	230,981	262,940	247,001	231,954	214,393	206,810	200,676	207,142
1941	217,270	227,241	243,459	239,449	228,659	235,363	204,495	211,209	198,779	199,512	195,466	201,956
1942	219,191	230,771	252,712	251,563	248,068	335,000	265,067	224,654	202,380	200,941	191,571	193,514
1943	216,847	265,011	329,676	343,186	370,881	412,975	361,166	243,013	238,045	236,979	222,512	217,703
1944	251,764	279,482	270,412	269,860	277,282	270,703	200,368	211,555	207,077	206,416	200,828	201,722
1945	241,224	221,157	237,773	252,576	228,870	297,700	243,451	232,735	210,630	200,048	198,415	197,020
1946	216,627	267,690	280,297	295,760	307,390	383,907	311,482	225,974	224,398	218,733	209,682	204,956
1947	244,216	274,064	286,501	284,586	269,995	260,567	215,722	226,060	214,444	208,738	207,884	201,370
1948	252,950	237,556	260,912	279,191	242,789	328,493	309,735	295,134	242,260	217,603	207,507	207,582
1949	234,243	259,653	261,457	286,555	296,918	359,785	293,022	243,904	228,554	221,404	212,446	206,234
1950	239,408	260,257	269,853	287,048	290,371	382,775	316,978	258,602	256,815	234,559	222,832	216,757
1951	274,161	359,119	365,035	427,495	382,656	406,829	353,728	260,357	249,806	232,798	224,676	238,819
1952	313,136	327,219	322,134	321,171	371,428	484,422	396,484	276,883	273,386	242,969	217,825	234,898
1953	290,434	302,483	344,960	409,470	368,976	419,794	309,450	277,509	244,583	233,392	216,271	219,785
1954	299,148	361,569	364,518	371,624	358,505	351,188	276,567	260,796	252,182	235,450	220,771	237,128
1955	289,541	286,506	290,912	295,599	275,220	304,396	263,592	186,791	227,251	214,673	198,242	202,439
1956	252,577	346,699	418,123	394,671	412,688	414,627	375,847	314,365	295,543	239,234	221,691	245,933
1957	300,065	332,485	350,923	335,957	347,789	406,769	307,284	257,450	231,010	208,241	205,584	207,824
1958	281,429	298,359	331,690	463,443	417,905	424,757	331,668	266,109	264,232	218,285	203,005	204,058
1959	282,442	323,401	337,820	318,023	291,871	310,174	234,631	213,639	204,362	201,646	197,505	205,418
1960	251,062	263,786	268,130	268,425	306,851	308,049	241,730	220,029	222,725	208,858	207,236	202,619
1961	244,027	259,305	259,865	256,090	288,930	299,269	253,942	234,072	240,542	221,022	214,349	212,075
1962	235,658	253,444	266,922	268,349	248,866	275,951	286,715	239,688	221,312	214,595	214,421	202,990
1963	253,855	297,992	317,641	266,838	330,521	276,183	254,940	241,621	203,006	207,883	204,528	209,230
1964	235,285	297,147	251,407	253,336	236,693	251,327	234,372	209,894	226,583	215,605	207,875	202,382
1965	235,725	247,467	495,878	476,900	375,393	299,332	302,718	282,374	246,029	230,889	228,888	219,803
1966	277,896	352,583	314,955	289,325	246,847	295,855	266,391	232,217	221,325	229,272	214,881	211,668
1967	263,648	288,423	304,563	289,493	255,680	268,112	224,964	245,973	239,393	221,372	213,643	209,319
1968	266,398	303,506	256,063	263,539	267,184	273,823	212,037	216,042	207,972	205,950	209,371	200,645
1969	231,688	254,455	253,365	259,894	220,461	252,425	252,390	251,104	272,792	229,770	222,057	220,416
1970	241,077	295,909	253,223	371,424	292,251	281,333	240,644	233,023	226,381	209,721	200,565	208,868
1971	238,118	311,145	273,571	380,195	284,689	290,725	301,755	272,723	257,120	251,524	232,981	222,174
1972	265,494	337,724	308,519	334,935	307,742	552,924	325,804	290,945	295,109	255,116	238,614	237,714
1973	314,823	360,260	331,414	319,231	270,323	287,080	236,265	213,543	198,814	202,150	203,441	200,291
1974	245,579	312,480	396,222	430,682	295,758	332,417	359,157	294,557	280,676	261,096	234,268	221,376
1975	379,707	353,109	322,982	325,310	285,728	328,411	322,396	337,976	275,586	256,634	230,188	217,781
1976	291,536	320,237	351,181	364,882	306,131	315,161	333,968	276,417	240,112	241,313	248,199	216,805
1977	282,872	302,874	289,971	271,668	239,784	260,025	206,270	206,215	190,331	191,025	195,044	191,250
1978	245,065	246,668	332,522	304,507	275,523	339,826	300,008	246,376	202,677	203,715	196,472	206,926
1979	225,116	231,070	249,691	256,368	286,587	365,221	293,379	280,722	191,725	185,681	190,251	197,991

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1980	230,434	227,638	254,472	340,015	265,398	288,756	259,590	221,698	199,122	187,247	186,206	187,026
1981	218,570	233,846	288,130	267,245	271,606	261,350	239,370	216,328	204,328	185,945	185,082	186,194
1982	219,425	226,259	337,614	305,002	407,923	360,746	344,476	278,175	244,971	239,780	219,130	214,158
1983	247,708	275,274	288,874	328,171	364,326	461,447	368,942	340,587	246,917	243,359	225,730	217,299
1984	272,229	317,563	336,419	359,499	368,114	512,268	438,289	348,278	283,755	239,437	228,074	223,352
1985	297,227	409,272	332,873	304,055	267,331	322,227	385,116	232,515	235,799	224,863	219,363	216,358
1986	257,703	277,215	276,898	301,166	376,053	482,335	299,355	234,163	224,322	216,559	211,750	213,328
1987	256,223	272,977	276,860	274,321	259,190	310,907	282,199	229,645	207,311	220,247	213,645	204,666
1988	253,837	238,813	261,872	259,521	239,002	254,675	214,872	212,537	212,392	203,252	195,820	193,930
1989	235,474	244,960	248,242	246,885	215,675	338,741	338,478	254,390	218,420	212,589	212,886	206,386
1990	241,888	245,335	256,447	264,926	229,130	256,057	217,784	217,417	210,038	205,480	204,832	195,717
1991	240,224	230,633	234,709	242,236	221,239	239,595	205,172	208,653	202,057	207,072	199,539	192,229
1992	219,772	231,843	246,307	232,464	221,250	229,299	212,596	209,417	195,894	198,423	197,649	190,332
1993	214,632	219,491	228,693	224,707	201,329	372,702	364,768	304,623	242,930	218,454	213,498	201,789
1994	241,172	237,482	246,202	247,148	215,810	241,453	203,618	205,376	194,434	192,595	188,708	183,228
1995	219,165	214,833	228,211	239,832	274,152	263,505	226,094	227,448	210,429	212,923	199,512	193,715
1996	221,513	253,614	311,284	315,790	455,789	335,848	310,943	289,468	229,023	228,664	223,473	215,037
1997	264,312	310,333	429,327	524,960	382,846	392,910	347,433	296,507	267,254	248,295	239,850	234,552
1998	306,253	320,958	314,551	324,839	293,519	345,408	314,420	348,547	276,550	234,299	227,183	217,276
1999	261,647	294,479	319,870	341,393	291,285	398,533	369,367	308,937	294,755	266,559	254,455	231,902
2000	306,156	333,815	333,581	317,772	310,867	354,796	372,064	270,219	241,742	236,044	227,834	222,128
2001	275,811	271,182	281,662	274,968	245,351	274,085	217,608	221,431	206,536	208,056	206,136	197,742
2002	248,791	232,869	249,162	254,394	215,575	240,583	235,351	229,746	233,888	221,220	209,620	202,827
2003	231,266	233,207	247,109	265,106	243,633	261,207	220,905	214,890	210,005	204,146	200,388	197,884
2004	230,341	227,342	252,010	253,987	248,792	307,075	273,116	252,352	232,466	222,807	215,547	207,921
2005	232,762	233,491	253,717	246,549	217,848	241,671	214,168	240,142	207,086	198,766	197,964	197,614
2006	229,675	225,551	273,468	388,170	278,506	317,595	407,208	309,138	257,595	230,062	219,197	210,213
2007	234,733	278,808	303,201	295,072	251,866	319,951	272,073	230,081	220,232	218,369	211,527	209,963
2008	247,693	253,153	271,541	256,718	241,471	271,313	247,531	287,240	258,636	240,273	224,285	213,298
2009	239,211	270,960	265,081	290,995	241,515	271,622	261,359	277,298	251,581	229,430	219,803	207,101
2010	258,498	245,685	254,934	274,675	237,346	256,058	276,678	255,190	274,339	221,372	208,335	210,909
2011	234,967	248,405	294,748	374,172	279,090	341,751	385,853	348,414	286,727	251,221	232,307	218,817
2012	252,442	277,625	279,987	309,436	282,869	310,801	335,862	270,043	251,767	247,005	228,486	215,584
2013	265,115	282,242	314,872	285,386	255,331	294,033	270,785	241,188	225,218	221,794	217,373	215,499
2014	257,820	257,637	264,153	259,518	287,696	349,705	272,743	245,621	231,203	235,157	224,875	214,010
2015	246,773	262,702	313,298	297,156	272,905	274,653	236,023	216,449	203,113	211,315	205,132	198,298
2016	235,931	234,966	274,998	264,539	264,401	346,154	280,789	239,331	219,908	214,489	203,419	196,394
2017	245,110	247,087	252,169	248,447	273,368	452,647	379,833	288,643	248,934	231,480	220,127	217,976
2018	251,265	283,783	277,507	280,949	253,276	281,278	245,806	233,876	210,295	205,783	205,098	198,291

Table C-4. Modified flows into Lake Billy Chinook for water years 1929 to 2018 (cfs)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1929	4,058	5,079	4,613	4,700	4,700	4,804	4,243	4,080	4,109	3,577	3,534	3,649
1930	4,176	3,995	4,304	4,019	4,534	4,263	4,032	3,836	3,857	3,598	3,501	3,568
1931	3,782	3,928	3,851	3,840	3,906	3,979	3,977	3,802	3,710	3,396	3,349	3,411
1932	3,568	3,634	3,603	3,712	3,696	4,552	5,019	4,362	3,990	3,692	3,495	3,522
1933	3,695	4,172	4,040	4,008	3,986	4,113	4,215	4,173	4,897	3,980	3,645	3,588
1934	3,869	4,506	4,658	4,761	4,514	4,519	4,393	3,801	3,799	3,579	3,486	3,542
1935	3,922	4,161	4,303	4,236	4,260	4,115	4,108	4,098	4,039	3,740	3,564	3,586
1936	3,744	3,937	3,842	4,145	4,055	4,303	4,468	4,108	3,899	3,602	3,508	3,511
1937	3,775	3,904	3,997	4,107	4,020	4,159	4,345	4,374	4,320	3,682	3,445	3,469
1938	3,755	4,164	4,501	4,661	4,424	5,867	5,501	4,764	4,260	3,664	3,571	3,592
1939	3,917	4,541	4,420	4,182	4,308	4,497	4,049	3,687	3,750	3,493	3,354	3,401
1940	3,916	3,675	3,901	3,859	4,016	4,276	4,151	3,772	3,603	3,363	3,264	3,481
1941	3,534	3,819	3,959	3,894	4,117	3,828	3,437	3,435	3,341	3,245	3,179	3,394
1942	3,565	3,878	4,110	4,091	4,467	5,448	4,455	3,654	3,401	3,268	3,116	3,252
1943	3,527	4,454	5,362	5,581	6,678	6,716	6,070	3,952	4,000	3,854	3,619	3,659
1944	4,095	4,697	4,398	4,389	4,821	4,403	3,367	3,441	3,480	3,357	3,266	3,390
1945	3,923	3,717	3,867	4,108	4,121	4,842	4,091	3,785	3,540	3,253	3,227	3,311
1946	3,523	4,499	4,559	4,810	5,535	6,244	5,235	3,675	3,771	3,557	3,410	3,444
1947	3,972	4,606	4,659	4,628	4,862	4,238	3,625	3,677	3,604	3,395	3,381	3,384
1948	4,114	3,992	4,243	4,541	4,221	5,342	5,205	4,800	4,071	3,539	3,375	3,489
1949	3,810	4,364	4,252	4,660	5,346	5,851	4,924	3,967	3,841	3,601	3,455	3,466
1950	3,894	4,374	4,389	4,668	5,228	6,225	5,327	4,206	4,316	3,815	3,624	3,643
1951	4,459	6,035	5,937	6,953	6,890	6,616	5,945	4,234	4,198	3,786	3,654	4,013
1952	5,093	5,499	5,239	5,223	6,457	7,878	6,663	4,503	4,594	3,952	3,543	3,948
1953	4,723	5,083	5,610	6,659	6,644	6,827	5,200	4,513	4,110	3,796	3,517	3,694
1954	4,865	6,076	5,928	6,044	6,455	5,712	4,648	4,241	4,238	3,829	3,590	3,985
1955	4,709	4,815	4,731	4,807	4,956	4,951	4,430	3,038	3,819	3,491	3,224	3,402
1956	4,108	5,826	6,800	6,419	7,175	6,743	6,316	5,113	4,967	3,891	3,605	4,133
1957	4,880	5,588	5,707	5,464	6,262	6,615	5,164	4,187	3,882	3,387	3,344	3,493
1958	4,577	5,014	5,394	7,537	7,525	6,908	5,574	4,328	4,441	3,550	3,302	3,429
1959	4,593	5,435	5,494	5,172	5,255	5,044	3,943	3,475	3,434	3,279	3,212	3,452
1960	4,083	4,433	4,361	4,366	5,335	5,010	4,062	3,578	3,743	3,397	3,370	3,405
1961	3,969	4,358	4,226	4,165	5,202	4,867	4,268	3,807	4,042	3,595	3,486	3,564
1962	3,833	4,259	4,341	4,364	4,481	4,488	4,818	3,898	3,719	3,490	3,487	3,411
1963	4,129	5,008	5,166	4,340	5,951	4,492	4,284	3,930	3,412	3,381	3,326	3,516
1964	3,827	4,994	4,089	4,120	4,115	4,087	3,939	3,414	3,808	3,506	3,381	3,401
1965	3,834	4,159	8,065	7,756	6,759	4,868	5,087	4,592	4,135	3,755	3,723	3,694
1966	4,520	5,925	5,122	4,705	4,445	4,812	4,477	3,777	3,719	3,729	3,495	3,557
1967	4,288	4,847	4,953	4,708	4,604	4,360	3,781	4,000	4,023	3,600	3,475	3,518

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1968	4,333	5,101	4,164	4,286	4,645	4,453	3,563	3,514	3,495	3,349	3,405	3,372
1969	3,768	4,276	4,121	4,227	3,970	4,105	4,242	4,084	4,584	3,737	3,611	3,704
1970	3,921	4,973	4,118	6,041	5,262	4,575	4,044	3,790	3,804	3,411	3,262	3,510
1971	3,873	5,229	4,449	6,183	5,126	4,728	5,071	4,435	4,321	4,091	3,789	3,734
1972	4,318	5,676	5,018	5,447	5,350	8,992	5,475	4,732	4,959	4,149	3,881	3,995
1973	5,120	6,054	5,390	5,192	4,867	4,669	3,971	3,473	3,341	3,288	3,309	3,366
1974	3,994	5,251	6,444	7,004	5,325	5,406	6,036	4,791	4,717	4,246	3,810	3,720
1975	6,175	5,934	5,253	5,291	5,145	5,341	5,418	5,497	4,631	4,174	3,744	3,660
1976	4,741	5,382	5,711	5,934	5,322	5,126	5,613	4,495	4,035	3,925	4,037	3,644
1977	4,600	5,090	4,716	4,418	4,318	4,229	3,466	3,354	3,199	3,107	3,172	3,214
1978	3,986	4,145	5,408	4,952	4,961	5,527	5,042	4,007	3,406	3,313	3,195	3,478
1979	3,661	3,883	4,061	4,169	5,160	5,940	4,930	4,566	3,222	3,020	3,094	3,327
1980	3,748	3,826	4,139	5,530	4,614	4,696	4,363	3,606	3,346	3,045	3,028	3,143
1981	3,555	3,930	4,686	4,346	4,891	4,250	4,023	3,518	3,434	3,024	3,010	3,129
1982	3,569	3,802	5,491	4,960	7,345	5,867	5,789	4,524	4,117	3,900	3,564	3,599
1983	4,029	4,626	4,698	5,337	6,560	7,505	6,200	5,539	4,150	3,958	3,671	3,652
1984	4,427	5,337	5,471	5,847	6,400	8,331	7,366	5,664	4,769	3,894	3,709	3,754
1985	4,834	6,878	5,414	4,945	4,814	5,241	6,472	3,781	3,963	3,657	3,568	3,636
1986	4,191	4,659	4,503	4,898	6,771	7,844	5,031	3,808	3,770	3,522	3,444	3,585
1987	4,167	4,588	4,503	4,461	4,667	5,056	4,743	3,735	3,484	3,582	3,475	3,440
1988	4,128	4,013	4,259	4,221	4,155	4,142	3,611	3,457	3,569	3,306	3,185	3,259
1989	3,830	4,117	4,037	4,015	3,883	5,509	5,688	4,137	3,671	3,457	3,462	3,468
1990	3,934	4,123	4,171	4,309	4,126	4,164	3,660	3,536	3,530	3,342	3,331	3,289
1991	3,907	3,876	3,817	3,940	3,984	3,897	3,448	3,393	3,396	3,368	3,245	3,231
1992	3,574	3,896	4,006	3,781	3,846	3,729	3,573	3,406	3,292	3,227	3,214	3,199
1993	3,491	3,689	3,719	3,655	3,625	6,061	6,130	4,954	4,083	3,553	3,472	3,391
1994	3,922	3,991	4,004	4,019	3,886	3,927	3,422	3,340	3,268	3,132	3,069	3,079
1995	3,564	3,610	3,712	3,901	4,936	4,285	3,800	3,699	3,536	3,463	3,245	3,255
1996	3,603	4,262	5,063	5,136	7,924	5,462	5,226	4,708	3,849	3,719	3,634	3,614
1997	4,299	5,215	6,982	8,538	6,894	6,390	5,839	4,822	4,491	4,038	3,901	3,942
1998	4,981	5,394	5,116	5,283	5,285	5,618	5,284	5,669	4,648	3,811	3,695	3,651
1999	4,255	4,949	5,202	5,552	5,245	6,482	6,207	5,024	4,954	4,335	4,138	3,897
2000	4,979	5,610	5,425	5,168	5,404	5,770	6,253	4,395	4,063	3,839	3,705	3,733
2001	4,486	4,557	4,581	4,472	4,418	4,458	3,657	3,601	3,471	3,384	3,352	3,323
2002	4,046	3,913	4,052	4,137	3,882	3,913	3,955	3,736	3,931	3,598	3,409	3,409
2003	3,761	3,919	4,019	4,312	4,387	4,248	3,712	3,495	3,529	3,320	3,259	3,326
2004	3,746	3,821	4,099	4,131	4,325	4,994	4,590	4,104	3,907	3,624	3,506	3,494
2005	3,786	3,924	4,126	4,010	3,923	3,930	3,599	3,906	3,480	3,233	3,220	3,321
2006	3,735	3,791	4,448	6,313	5,015	5,165	6,843	5,028	4,329	3,742	3,565	3,533
2007	3,818	4,686	4,931	4,799	4,535	5,204	4,572	3,742	3,701	3,551	3,440	3,529

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
2008	4,028	4,254	4,416	4,175	4,198	4,412	4,160	4,672	4,347	3,908	3,648	3,585
2009	3,890	4,554	4,311	4,733	4,349	4,418	4,392	4,510	4,228	3,731	3,575	3,480
2010	4,204	4,129	4,146	4,467	4,274	4,164	4,650	4,150	4,610	3,600	3,388	3,544
2011	3,821	4,175	4,794	6,085	5,025	5,558	6,484	5,666	4,819	4,086	3,778	3,677
2012	4,106	4,666	4,554	5,033	4,918	5,055	5,644	4,392	4,231	4,017	3,716	3,623
2013	4,312	4,743	5,121	4,641	4,597	4,782	4,551	3,923	3,785	3,607	3,535	3,622
2014	4,193	4,330	4,296	4,221	5,180	5,687	4,584	3,995	3,886	3,824	3,657	3,597
2015	4,013	4,415	5,095	4,833	4,914	4,467	3,966	3,520	3,413	3,437	3,336	3,333
2016	3,837	3,949	4,472	4,302	4,597	5,630	4,719	3,892	3,696	3,488	3,308	3,301
2017	3,986	4,152	4,101	4,041	4,922	7,362	6,383	4,694	4,183	3,765	3,580	3,663
2018	4,086	4,769	4,513	4,569	4,560	4,575	4,131	3,804	3,534	3,347	3,336	3,332