Attachments

Attachment A—Calculation of Natural Marsh and Cropland Evapotranspiration

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Attachment A—Calculation of Natural Marsh and Cropland Evapotranspiration

Terms

1. Consumptive use (CU) or evapotranspiration (ET): The amount of water consumed within a given area by plant transpiration, building of plant tissue, and evaporation from plant surfaces and adjacent soil, water, and snow surfaces. The terms include effective precipitation, as defined below. Consumptive use and ET are expressed either in depth or volume per unit of time.

2. Effective precipitation (EP): Precipitation occurring during the growing period of a crop or plant that becomes available to help meet consumptive use water requirements. It does not include surface runoff or deep percolation below the root zone. (Although this definition precludes that EP occurs during the non-growing season, winter EP is included in the lake marsh net ET calculations as described in this attachment.)

3. Net consumptive use or net evapotranspiration: The quantity of water, exclusive of effective precipitation, that is consumptively used by plants or evaporated from associated soil, water, and snow surfaces. It does not include water requirements for soil leaching, frost protection, or wind erosion protection. Net consumptive use may be numerically determined by subtracting effective precipitation from consumptive use.

4. Potential consumptive use or potential evapotranspiration: A typically calculated value which estimates a maximum consumptive use rate, under ideal growing conditions, for a given plant type and a specific set of climatic conditions. Actual consumptive use should be equal to or less than this value, depending primarily on soil moisture and nutrient conditions.

Background

A key part of the Upper Klamath River Basin water budget is the determination of water used by local vegetation through evapotranspiration. Estimates of net ET were necessary for several components in the water budget to determine natural streamflow in the Klamath River at Keno. The estimated net consumptive use of water by vegetation within the predevelopment marshes around Upper Klamath

Lake (UKL) were calculated. Likewise, net consumptive use by predevelopment riparian and marsh vegetation along river and creek corridors was estimated. Crop net ET estimates were calculated to naturalize streamflow records since historic diversion records are not available.

Marsh ET at UKL was input into the water balance equation where

inflows – predevelopment net evaporation and net ET = outflows

Marsh and irrigated crop net ET estimates were used to naturalize streamflow records of rivers and creeks that flow into UKL where

gauged streamflow + irrigated crop net ET – predevelopment marsh net ET = natural flow

The main factors influencing ET are climate, plant characteristics, and environmental conditions. Climate factors are precipitation, air temperature, air humidity, solar radiation, and wind speed. The plant characteristics that affect ET are leaf area, albedo (surface reflectance), rooting characteristics, and ground cover. The stage of plant growth is also a factor in the ET rate. The main environmental factors influencing ET are soil moisture, soil fertility, soil permeability, pests, and diseases. The following discussion describes the methods used to estimate net evapotranspiration or consumptive use.

Method Selection

Several methods may be used to directly measure the consumptive water usage by plants. These include the use of tank lysimeters, measuring water balance, measuring energy balance, and by determining mass transfer. Because these measurement-intensive methods are time consuming and costly, an estimated value is usually computed by using empirical methods that are based on measured data.

Several classifications of empirical ET calculation methods exist. The methods are based on solar radiation, air temperature, pan evaporation, or a combination of these. The method chosen for use in this study is the SCS Modified Blaney-Criddle method (Jensen et al., 1990), which is based on average monthly air temperature. This method was chosen because it accommodates a monthly time step, and more importantly, because of the minimal climate data needed.

Regardless of the method used, it is significant to note that calculated values are potential ET and represent an estimation of the maximum rate expected under ideal growing conditions. With irrigated agricultural crops, where plant stress due to low soil moisture conditions should not occur, potential ET and actual ET should be nearly equal. Under natural conditions, however, actual ET may be significantly less than potential ET when soil moisture is depleted. This consideration is discussed later as it pertains to marsh ET estimates.

The Modified Blaney-Criddle equation's variables are mean monthly temperature and percentage time of daylight. Other empirical methods, consisting of certain pan evaporation, radiation and combination methods are typically more accurate in estimating ET (Jensen et al., 1990), but the limited climatic data available for the study did not allow for using these ET estimation methods. The apparently significant weaknesses of the Modified Blaney-Criddle method relative to the study area are its limitations in accounting for high altitude and low humidity. These were addressed by adjusting the calculated values as discussed later in this attachment.

The ET computer model used for this study, and used extensively by the Bureau of Reclamation for monthly planning studies is XCONSVB (XCONSVB 1996). This program was developed in the late 1970s using FORTRAN computer software language, and it utilizes the SCS Modified Blaney-Criddle ET equation and both the Reclamation and SCS effective precipitation equations. Later updates included converting the FORTRAN code module to run with Visual Basic language. The input and output files are text format files, which may be viewed with a word processor.

Data

Weather data was obtained from the National Weather Service via the internet at the Western Region Climate Center (http://www.wrcc.dri.edu/climsum.html) and through various CD databases produced by HydroSphere (2002). Although the temperature and precipitation data available for 1948 to 2002 were incomplete for most of the stations used within the study area, sufficient overlapping data were available to statistically complete all data gaps with reasonable confidence. In most cases, only a small percentage of the weather record had to be reconstructed. The following climate stations were used to compile the needed average temperature and monthly precipitation data for this study: Rocky Point 3S, Fort Klamath 7SW, Chiloquin 7NW, Chiloquin 1E, Klamath Falls 2SSW, Merrill 2N, Sprague River 2 SE, and Round Grove.

Several sources of data were used in this study to determine land use and total acreage of plant and crop types. Geographic information system (GIS) coverages of irrigated crops, composed by the Oregon Water Resources Department (OWRD) for use in water rights and hydrology studies, were provided for the Upper Klamath Basin tributaries (J. La Marche, electronic communication, 2003). Crop patterns were estimated based on recent studies by NRCS (2004) and a report by the Oregon Klamath River Commission (1954). Modern aerial photography and historic maps were evaluated in estimating predevelopment marsh areas in certain river and creek corridors, and historic maps were evaluated in estimating predevelopment lake marshland areas.

Only limited anecdotal information was located during this study on the types and quantities of wetland plants which existed within the predevelopment marshes. Since no basis for quantification of specific plant types was identified, assumptions were made to define wetland plant type categories. It is assumed the predevelopment marsh plant communities were composed of predominantly emergent wetland plant types with either moderate or high consumptive use characteristics. The high water demand plants are associated with areas assumed to be inundated during the entire growing season, and the moderate demand plants in intermittently inundated areas. It appears the only floating wetland plant with lower consumptive use characteristics which may have existed in significant quantities (5-10 percent coverage) is the wocus plant, which is a type of water lilly. It is assumed compensation for this plant type with a third plant category would not change the overall marsh consumptive use values appreciably. Also, given the absence of relevant data, extensive areas of open water that may have existed within the marsh perimeters are not specifically addressed.

Based on the above, only two marsh plant types were used in the ET estimates. The XCONSVB tules and cattail wetland plant category is the high demand permanently inundated type, and the salt grass category is the moderate demand intermittently inundated type.

The growing seasons for all vegetation and agricultural crops were calculated by XCONSVB based on mean monthly temperature data. Beginning and ending growing season temperature triggers were included in the XCONSVB input, and in the case of spring grain, over-riding default growing season dates were input.

Crop coefficients in the XCONSVB program were developed from the SCS Technical Release 21 (SCS 1970) for all identified crops. The marsh plant coefficients were developed from a *Salinity Investigation of the Price-San Rafael Rivers Unit* located in Utah performed by CH2M Hill (1983) for Reclamation.

Procedure

The following is a general step-by-step overview of the consumptive use estimation procedure used. Details on these steps are provided later in this attachment.

Step 1. Existing crop types and areas were estimated and predevelopment marsh types and areas were also estimated.

Step 2. The climate station data (temperature and precipitation) were completed, as necessary, and compiled for each of the lake subdivisions and rivers and creeks.

Step 3. The growing or irrigation season for each plant or crop was defined.

Step 4. XCONSVB input files were prepared using the above data.

Step 5. XCONSVB runs were made and output files were generated containing monthly ET, EP, and net ET.

Step 6. The XCONSVB output was compared to other study results, and certain adjustments were made to the marsh ET and crop net ET values.

Step 7. The adjusted monthly net ET values were multiplied by the appropriate areas to calculate total consumptive use in acre-feet. (The area values which were multiplied by the net ET rates in this step, in most cases, were not static for the study period and were adjusted as a function of agricultural development or water limiting marsh ET effects.)

The growing or irrigation seasons for the agricultural crops and marsh plant types used in the consumptive use analysis are as follows:

Alfalfa: The irrigation season for this perennial crop is defined by threshold temperatures; i.e., growth begins when the mean daily air temperature reaches 47 °F in the spring, and it ends the day after the mean daily air temperature of 45 °F or below occurs in the fall. On the basis of this criterion, the irrigation season is approximately April 15 - May 1 through October 15 - 30.

Pasture: The irrigation season for this perennial crop is defined by threshold temperatures of 40 °F in the spring and 45 °F in the fall. On the basis of these criteria, the irrigation season is approximately April 1 through October 15.

Spring Grain: Includes annual crops, such as barley, oats, spring wheat, and other small grains that normally mature in 130 days or less. The irrigation season is defined by threshold temperatures of 50 °F in both the spring and the fall, with a default period defined as May 10 through September 15.

Salt Grass: The growing season for this perennial marsh vegetation type is defined by threshold temperatures of 40 °F in the spring and 45 °F in the fall. On the basis of these criteria, the irrigation season is approximately April 1 through October 15.

Willow Trees: The growing season for this perennial riparian marsh vegetation type is defined by threshold temperatures of 42 °F in the spring and 42 °F in the fall. The typical average growing season for this plant is from April 10 through October 25.

Tules and Cattails: The growing season for this perennial marsh plant mix is defined by threshold temperatures of 40 °F in the spring and 45 °F in the fall. The typical average growing season for this plant mix is from April 1 through October 15.

Consumptive Use or Evapotranspiration Computed Using the SCS Modified Blaney-Criddle Method

The U.S. Department of Agriculture's Soil Conservation Service, now the Natural Resources Conservation Service (NRCS), Modified Blaney-Criddle method was introduced in 1967 and later revised and published in 1970 (SCS, 1970). The method uses mean monthly air temperatures (*T*) expressed in degrees Fahrenheit, monthly percentage of annual daylight hours (*P*) based on the latitude of the area under study, monthly consumptive use coefficients (*k*), and length of growing season to estimate the total potential consumptive use of water during the growing season for a crop that is well-watered and free of disease. The potential consumptive use in inches for each month is expressed as:

$$CU = ET = [(T)(P)/100](k)$$

Where $k = (kt)(kc)$ and $kt = 0.0173T-0.314$

The distinctive feature of the SCS "Modified" Blaney-Criddle method is the procedure used to arrive at the final value of the consumptive use coefficient (k). The climatic coefficient (kt), which is expressed as a function of the mean monthly temperature was not a component of the original Blaney-Criddle equation. Multiplying the crop coefficient (kc) by kt yields the final value of the consumptive use coefficient (*k*) for a specific crop and month. In a month in which the growing season begins or ends, the consumptive use coefficient is multiplied by the ratio of the number of days in the month the crop is "growing" to the total number of days in that month. The kc values used for each of the crops and plants modeled are summarized in Table A-1, and the associated coefficient curves are shown in Figure A-1.

Table A-1. Summary of XCONSVB crop coefficients (kc)

Crop	April	May	June	July	Aug	Sept	Oct
Alfalfa	0.96	1.07	1.13	1.12	1.08	1.01	0.93
Pasture	0.84	0.89	0.92	0.93	0.91	0.88	0.82
Spring Grain	0.77	0.99	1.20	1.31	1.23	0.96	0.60
Salt Grass	0.61	0.94	1.20	1.19	1.10	1.02	0.89
Willow Trees	0.65	0.73	0.80	0.88	0.95	1.04	1.13
Tules & Cattails	1.13	1.48	1.52	1.49	1.39	1.20	0.60

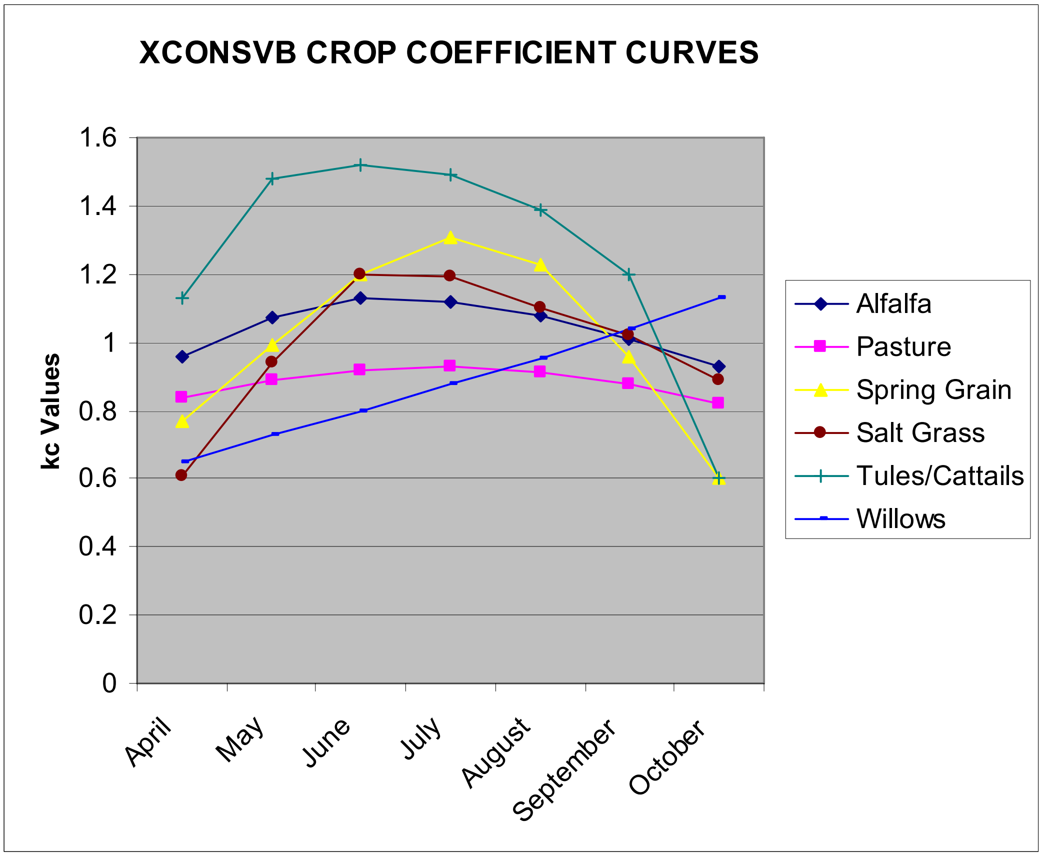

Figure A-1. XCONSVB Crop Coefficient Curves.

Effective Precipitation

As defined at the beginning of this attachment, effective precipitation is the portion of total precipitation that is used by vegetation and evaporated from surrounding surfaces. It is a function of the amount of moisture in the soil when precipitation occurs. Once any soil moisture deficit is replenished, excess precipitation either runs off and/or causes deep percolation below the root zone, and the amount that replenishes the deficit is EP.

The SCS effective precipitation equation is used within XCONSVB to estimate EP in the agricultural crop net ET calculations. Using soil-moisture balance data derived from an analysis of 50 years of precipitation records at 22 Weather Bureau stations in the United States, the SCS developed this equation to estimate effective precipitation as a function of plant consumptive use, soil moisture depletion depth, and rainfall.

$$EP = (0.70917Rt^{0.82416} - 0.11556)(10\ 0.0242^{cu})(f)$$

where Rt is the precipitation in inches; CU is the monthly consumptive use in inches; and f is given as:

$$f = 0.531747 + 0.295164D - 0.057697D^2 + 0.003804D^3$$

where *D* is the normal soil profile depth of depletion. The SCS effective precipitation cannot exceed the average monthly rainfall or average monthly consumptive use. The monthly consumptive irrigation requirement for each crop in the cropping pattern is computed by subtracting the effective precipitation from the consumptive use.

In a marsh environment with saturated soils and/or water inundated surfaces, EP is actually near zero because almost all precipitation runs off. And this is how EP is treated in the net ET calculations (EP=0) for the marsh areas in the river and creek corridors, where all runoff is accounted for in the stream gage component of the water budget model. However, for the purposes of this study, EP is considered to be a significant portion of total precipitation in the lake marsh net ET calculations, as discussed below.

Since lake marsh runoff is not included in the stream gage component and it contributes to the lake storage levels in the water budget model, precipitation falling on the lake marshes must be accounted for. This is done in the net ET calculations. Lake marsh effective precipitation during May through October is considered to be 100 percent of total precipitation. It is assumed the marshes remain frozen during winter months, and a portion of winter precipitation is not accounted for in the net ET calculations until each spring (March and April). Also, it is assumed a portion of this frozen precipitation is lost to sublimation and/or evaporation. Hence, EP for November through February is calculated by subtracting the estimated evaporation (Attachment B) from total precipitation, and then multiplying the remainder by 50 percent to simulate the amount of precipitation that melts from the bottom of the marsh ice surface. The month of March EP is calculated by adding 50 percent of the remaining net precipitation from November through February to March total precipitation, minus March evaporation. April EP is calculated by adding 50 percent of the remaining net precipitation from November through February to April total precipitation. (April evaporation is included in the XCONSVB ET calculations.)

Again, monthly net consumptive use for each crop and marshland plant type is computed by subtracting the effective precipitation from the potential consumptive use. Given the method discussed above, net ET values for the lake marsh areas are calculated to be negative for most winter and spring months (November – April).

Results

The XCONSVB output includes monthly, annual, and average potential consumptive use, effective precipitation, and net potential consumptive use for the period analyzed. The Klamath output ET and net ET values were compared to appropriate values from other studies, and certain adjustments were made to the output, as discussed below. The adjusted monthly net potential ET was then multiplied by the respective acreage of each land type and converted to acre-feet values. These values were then input into the water budget model, where certain monthly total net ET values (during dry periods) are adjusted again to account for water limiting effects.

Discussion

The XCONSVB output was compared to other Klamath area ET study results, and certain output was adjusted based on the comparison. The agricultural crop XCONSVB output was compared to the Oregon Crop Water Use and Irrigation Requirements guidebook (Cuenca et al., 1992). The marsh vegetation XCONSVB output was compared to study findings by Bidlake (1997 and 2000) and Bidlake and Payne (1998) and to study findings by the Irrigation Training and Research Center (ITRC) at the California Polytechnic University (2003 Draft).

The Oregon Crop Water Use and Irrigation guidebook includes net ET values for economically significant crops in 27 Oregon regions. The Klamath Region coincides with the study area, and for this region, values were published for alfalfa, pasture, spring grain, and potatoes. The published values were calculated using the United Nation's Food and Agricultural Organization Paper No. 24 (FAO-24) modified Blaney-Criddle method. This method includes parameters that account for humidity, wind, and altitude conditions that are not included in XCONSVB's Modified Blaney-Criddle equation.

Cuenca (Personal Comm., October 2004) reports the climate station data used for the Klamath Region ET calculations were from the Klamath Falls 2SSW station. Given this, a comparison was made between the XCONSVB output for the Klamath Falls 2SSW station and the guidebook's Klamath Region values. Of the guidebook crops mentioned above, the Klamath Falls 2SSW XCONSVB output included alfalfa and pasture. The net ET values compared are summarized in Table A-2 below. The monthly XCONSVB values shown are averages for the period 1948 to 2001.

Table A-2. Comparison of XCONSVB and Cuenca net ET values (inches)

Crop	April	May	June	July	Aug	Sept	Oct	Total
Pasture Cuenca	1.73	3.31	4.49	6.77	5.39	3.66	0.63	25.98
Pasture XCONSVB	1.16	2.30	3.65	5.50	4.64	2.86	1.03	21.40
Alfalfa Cuenca	0	1.77	4.25	6.34	4.92	0	0	17.28
Alfalfa XCONSVB	0.37	2.64	4.60	6.66	5.50	3.30	1.22	24.30

Based on the comparison, the XCONSVB output for pasture was adjusted to fit the Cuenca values. Specifically, monthly adjustment factors were developed and applied to all XCONSVB pasture output. The adjustment factors were calculated using the XCONSVB monthly average values and the Cuenca values shown in Table A-2. The XCONSVB output for alfalfa was not adjusted because the monthly values compare relatively well, and the total growing season discrepancy is due to the shorter growing season used by Cuenca. Also, only 420 acres of alfalfa are included in the Klamath analysis. The 1948 to 2001 average monthly net ET values for all crops and climate station data used are summarized in Table A-3 below.

Table A-3. Summary of 1948-2001 adjusted average monthly net crop ET values used (inches)

Crop and Climate Station	April	May	June	July	Aug	Sept	Oct	Total
Pasture Sprague River 2SE	0.86	2.65	4.01	5.34	4.24	2.30	0.18	19.64
Pasture Round Grove	0.72	1.74	3.01	5.14	4.23	2.62	0.34	17.82
Pasture Chiloquin 1E	0.31	2.24	3.39	5.27	4.03	2.59	0.30	14.79
Alfalfa Chiloquin 1E	0.01	1.09	3.48	4.67	1.96	0.11	0	11.32
Spring Grain Chiloquin 1E	0	0.45	2.98	5.61	0.89	0	0	9.92

The Bidlake and Payne marsh ET studies were performed at sites in the Klamath Forest (Klamath Marsh) and Upper Klamath and Lower Klamath National Wildlife Refuges in south-central Oregon and northern California. The studies were performed in 1996 and 1997 for the U.S. Fish and Wildlife Service, and involved energy balance techniques to develop and calibrate various ET computer models. Specifically, models using the Penman Monteith and Priestley-Taylor equations were calibrated with several days of eddy correlation analysis (energy balance) results from field measurements.

Bidlake and Payne's Upper and Lower Klamath Lake study sites were both in bulrush and cattail open water marshes. Based on this, the XCONSVB tules and cattails marsh plant type output was compared to the Bidlake and Payne values. The Upper Klamath Lake site comparison was made using the 1997 XCONSVB run with Rocky Point 3S climate station data, and the Lower Klamath Lake comparison was made using the 1996 Merrill 2N climate station data. The ET values compared are summarized in Table A-4.

Table A-4. Comparison of XCONSVB and Bidlake and Payne ET (inches)

	May	June	July	Aug	Sept	Oct	Total
1997 XCONSVB Rocky Point 3S	5.23	5.78	7.58	6.71	3.27	0.53	29.10
1997 Bidlake & Payne UKL	5.74	5.43	6.10	5.37	3.07	1.34	27.05
1996 XCONSVB Merrill 2N	4.08	5.91	8.40	6.64	3.01	0.67	28.71
1996 Bidlake & Payne LKL	3.30	5.00	7.20	6.10	3.90	2.20	27.70

Two sets of marsh ET adjustment factors were developed based on the above data, and were applied to all XCONSVB tules and cattails output ET values for 1948 to 2001. One set of factors is based on the UKL comparison and the other set is based on the LKL comparison. The UKL factors were applied to the output for the Rocky Point 3S, Fort Klamath 7SW, Chiloquin 1E, and Chiloquin 7NW climate station runs used for the UKL water budget; and the Round Grove and Sprague River 2SE climate station runs used for the Williams River streamflow naturalization. The LKL factors were applied to the output for the Klamath Falls 2SSW run used for the UKL water budgets.

The salt grass marsh plant type XCONSVB output average annual net ET values are 12 to 15 percent lower than the tules and cattails output, and the willows marsh type output is about 30 percent lower than the tules and cattails output. Because no data exist to compare these output to, and because the significantly lower values appear reasonable, the salt grass and willows output was not adjusted. Also, the areas associated with these marsh plant types are significantly smaller than that of the tules and cattails category. The 1948 to 2001 average monthly net ET values for all marsh vegetation types and climate station data used are summarized in Table A-5. (Again, the negative winter and spring month values reflect the lake marsh effective precipitation in excess of ET.)

Table A-5. Summary of 1948-2001 adjusted average monthly marsh plant type net ET values (inches)

Marsh Plant Type & Climate Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Salt Grass Round Grove	0.00	0.00	0.06	0.78	2.59	4.47	5.80	4.86	2.96	1.03	0.00	0.00	22.49
Salt Grass Sprague River 2SE	0.00	0.00	0.00	0.34	2.60	4.77	6.02	4.90	2.92	0.88	0.00	0.00	22.43
Salt Grass Klamath Falls 2SSW	-0.68	-0.10	-0.13	-0.60	2.34	4.95	6.88	5.32	3.11	0.57	-0.45	-0.88	20.33
Salt Grass Chiloquin 7NW	-1.20	-0.66	-1.82	-2.37	1.35	3.77	5.14	4.22	2.49	-0.64	-0.81	-1.47	8.00
Salt Grass Rocky Point 3S	-1.54	-0.67	-2.71	-2.63	1.55	3.58	5.56	4.59	1.96	-0.75	-1.24	-1.43	6.27
Salt Grass Fort Klamath 7SW	-1.92	-1.24	-4.73	-4.29	1.49	3.39	5.27	3.76	2.01	-1.60	-1.79	-1.70	-1.37
Tules & Cattails Round Grove	0.00	0.00	0.08	1.49	4.19	5.15	5.83	4.97	3.06	1.51	0.00	0.00	26.20
Tules & Cattails Sprague River 2SE	0.00	0.00	0.13	1.75	4.43	5.49	6.05	5.01	3.02	1.34	0.00	0.00	27.10
Tules & Cattails Merrill 2N	-0.23	0.13	1.08	0.97	2.52	4.26	6.16	5.42	3.85	1.26	-0.12	-0.43	24.86
Tules & Cattails Klamath Falls 2SSW	-0.68	-0.10	-0.13	0.60	2.99	5.19	7.45	6.34	4.70	1.66	-0.45	-0.88	26.68
Tules & Cattails Chiloquin 1E	-1.04	-0.32	-1.20	-0.96	3.26	4.37	5.41	4.15	2.25	0.05	-0.80	-1.10	14.07
Tules & Cattails Chiloquin 7NW	-1.20	-0.66	-1.82	-1.54	2.99	4.45	5.17	4.33	2.59	-0.14	-0.81	-1.47	11.88
Tules & Cattails Rocky Point 3S	-1.54	-0.67	-2.71	-1.72	3.27	4.31	5.59	4.69	2.06	-0.26	-1.24	-1.43	10.37
Tules & Cattails Fort Klamath 7SW	-1.92	-1.24	-4.73	-3.64	3.11	4.06	5.30	3.86	2.10	-1.16	-1.79	-1.70	2.23
Willows Chiloquin 7NW	0.00	0.00	0.01	0.55	2.03	2.93	4.31	4.42	3.19	0.56	0.00	0.00	18.01

ITRC performed a study at Lower Klamath Lake using daily reference ET values calculated with weather data from Reclamation's Klamath Falls Agrimet station during 1999 to 2001 (Burt and Feeman, 2003). The standardized Penman-Monteith version and the dual crop coefficients used were from *FAO Paper No. 56* (Allen et al*.,* 1998*)*. Burt and Freeman (2003) report annual ET for Lower Klamath Lake wetlands was estimated to be approximately 2.7 feet in 1999 and 2000, and 2.43 feet in 2001. The adjusted annual XCONSVB net ET values for the Klamath Falls 2SSW climate station are 2.29 feet for 1999, 2.24 feet for 2000, and 2.61 feet for 2001. These values compare relatively well, and the adjusted XCONSVB values are consistently below the ITRC estimates by 7 to 17 percent.

River and Lake Basin Computations and Analysis

As mentioned previously, estimates of ET were necessary for several components in the water budget for the Upper Klamath River Basin. These data were needed for naturalizing streamflow and for estimating natural losses associated with riparian and lake marshes in the basin.

Williamson River

Net crop consumptive use was developed as an estimate of the effects of agricultural depletions on the Williamson River. Estimates of net crop consumptive use were generated for the irrigated areas along the Sprague River and adjacent to UKL. Agricultural developments in the Sprague River Valley also reclaimed natural marshlands for use by agriculture. These natural marshes are called affected marshlands herein, and these areas would have generated additional streamflow losses if these areas had remained in natural conditions. These losses to streamflow were estimated by developing net marsh consumptive use. The development of net consumptive uses for crops and marshes are separated below into two sections, irrigation in the Sprague River Valley and for the Modoc Canal diversion.

Sprague River Valley Irrigation

Irrigation in the Sprague River Valley has affected streamflow in the Williamson River. Net consumptive use estimates were generated for the irrigated crops and affected marsh areas to naturalize streamflow in the Williamson River. Net consumptive use was generated using the XCONSVB model, and these values were multiplied by estimated acreages of predevelopment marshland and agricultural lands.

The extent and location of predevelopment marshes were assessed through interpretation of modern aerial photographs and by indications shown on 15-minute quadrangles dated between 1955 and 1957. The 2001 Sprague River corridor ortho-rectified color aerial photography that was used was provided to Reclamation's Klamath Basin Area Office by the Fish and Wildlife Service. These images were received as a single file (sprague2001_83.sid), which did not include metadata. The extent of existing irrigated lands was based on GIS information provided by OWRD (J. La Marche, electronic communication, 2003); and the historic development of these lands was estimated based on information contained in reports by the Oregon State Water Resources (OSWR, June 1971) and Oregon Klamath River Commission (OKRC, December 1954). Both the irrigated areas and natural marshes were transposed onto rescaled 15-minute quadrangles of the area dated between 1955 and 1957. The intersection of natural marshland and irrigated areas enabled determination of the extent of affected natural marsh. The overlapping areas of affected marshlands and agricultural lands were planimetered, and the resulting acreage was assumed to be the maximum affected marsh area after full agricultural development. It was assumed agricultural development occurred uniformly in the upper and lower portions of the basin; increasing from 13,000 to 52,789 acres during 1948 to 1985, and that marsh areas were the first to be developed. Hence, the agricultural area values that were multiplied by the associated net ET rates increased each year from 1948 to1985, and were static for the remainder of the study period. The affected marsh areas increased during 1948 to 1974, as a function of the assumed agricultural development rate.

The Sprague River Valley was divided into upper and lower reaches for ET calculation purposes. The upper reach of the Sprague River includes all irrigated areas upstream of Beatty. The lower reach includes irrigated lands from the lower portion of the Sycan River, a tributary to the Sprague River, down to the mouth of the Sprague River. The upper basin contained estimated maximums of 17,132 acres of agricultural lands and 8,224 acres of affected marshlands. The lower basin was comprised of estimated maximums of 35,657 acres of agricultural lands and 8,816 acres of affected marshlands. The respective climatic stations used in the upper and lower basin ET computations were the Round Grove and Sprague River 2SE stations.

Based on an NRCS study (2004) report, all irrigated cropland in the Sprague River Basin was modeled as pasture. Based on field investigations, marsh lands in the Sprague River Basin were modeled as 20 percent tules and cattails and 80 percent salt grass marsh.

The Sprague River annual natural flow estimates were calculated by adding the crop consumptive use to, and subtracting the marsh consumptive use from the stream flow gage values for both basins. Irrigation losses (runoff and deep percolation) were not calculated because they are reflected in the stream flow gage values, since the gage is located below the irrigated lands. The total monthly crop and marsh net ET values for the Sprague River Basin are Summarized in Tables A-6 and A-7, respectively.

Table A-6. Net agricultural consumptive water use for crop lands in the Sprague River Basin. Total monthly values in acre-feet.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	210.9	0.0	0.0	0.0	0.0	0.0	700.3	2489.9	4277.4	6176.1	5015.8	4501.1	23371
1950	302.4	0.0	0.0	0.0	0.0	0.0	0.0	1909.5	3241.2	6897.6	6569.2	827.0	19747
1951	146.9	0.0	0.0	0.0	0.0	0.0	518.3	2956.6	5697.7	7015.4	5264.0	2711.4	24310
1952	14.5	0.0	0.0	0.0	0.0	0.0	1040.8	1973.5	3178.6	7214.2	4989.5	4200.1	22611
1953	874.9	0.0	0.0	0.0	0.0	0.0	0.0	2046.4	3243.1	6683.0	4932.8	3888.2	21668
1954	98.7	0.0	0.0	0.0	0.0	0.0	1506.8	3069.1	3664.9	6973.1	4778.3	3258.4	23349
1955	145.6	0.0	0.0	0.0	0.0	0.0	0.0	2568.7	5421.1	6119.0	6063.4	3030.6	23348
1956	204.1	0.0	0.0	0.0	0.0	0.0	633.4	2324.6	3200.0	7047.4	5388.5	2516.7	21315
1957	320.3	0.0	0.0	0.0	0.0	0.0	675.6	3370.0	6919.7	7837.3	4472.1	2211.2	25806
1958	0.0	0.0	0.0	0.0	0.0	0.0	419.2	2198.4	4094.2	7250.5	6676.2	3380.5	24019
1959	932.9	0.0	0.0	0.0	0.0	0.0	0.0	1694.5	5655.2	7436.4	4908.7	2828.0	23456
1960	695.3	0.0	0.0	0.0	0.0	0.0	0.0	2360.1	6121.4	8761.3	5658.4	4183.0	27779
1961	128.6	0.0	0.0	0.0	0.0	0.0	0.0	2148.6	7017.8	7769.2	6546.7	2317.6	25928
1962	61.2	0.0	0.0	0.0	0.0	0.0	0.0	1784.1	5660.5	6649.7	5216.0	1481.4	20853
1963	186.0	0.0	0.0	0.0	0.0	0.0	0.0	3927.6	4596.8	5757.6	6333.4	4457.3	25259
1964	120.4	0.0	0.0	0.0	0.0	0.0	0.0	1061.4	3562.5	8388.8	6416.9	4082.0	23632
1965	391.7	0.0	0.0	0.0	0.0	0.0	2212.8	2411.2	5131.2	5845.1	5896.2	4069.5	25958
1966	423.6	0.0	0.0	0.0	0.0	0.0	1486.5	4804.8	3984.2	5800.4	6817.9	4824.7	28142
1967	318.4	0.0	0.0	0.0	0.0	0.0	0.0	3580.6	6779.3	10305.8	9315.0	4651.2	34950
1968	692.3	0.0	0.0	0.0	0.0	0.0	0.0	3947.0	6767.8	8667.6	5719.2	3225.4	29019
1969	135.7	0.0	0.0	0.0	0.0	0.0	1180.0	3893.9	6731.1	10058.0	7843.5	4277.8	34120
1970	173.5	0.0	0.0	0.0	0.0	0.0	0.0	5045.9	8304.5	11367.9	9004.7	2621.8	36518
1971	36.3	0.0	0.0	0.0	0.0	0.0	75.2	3174.3	6239.5	10944.2	9211.4	3407.4	33088
1972	47.0	0.0	0.0	0.0	0.0	0.0	0.0	5643.0	9127.7	11723.9	9324.0	3057.3	38923
1973	341.9	0.0	0.0	0.0	0.0	0.0	1437.3	7715.9	9711.9	12048.0	9077.6	3259.0	43592
1974	100.2	0.0	0.0	0.0	0.0	0.0	0.0	5164.6	11077.0	10829.4	10606.8	7699.9	45478
1975	671.0	0.0	0.0	0.0	0.0	0.0	0.0	5042.5	6927.1	12294.1	9403.8	5344.9	39683
1976	290.6	0.0	0.0	0.0	0.0	0.0	293.5	8511.9	7137.4	9535.8	7151.3	8703.1	41624
1977	1366.4	0.0	0.0	0.0	0.0	0.0	0.0	2334.1	11681.4	15081.1	10477.5	5302.0	46243
1978	429.4	0.0	0.0	0.0	0.0	0.0	0.0	4401.4	10192.9	15147.3	11803.9	6759.8	48735
1979	1576.8	0.0	0.0	0.0	0.0	0.0	975.3	8522.5	12610.5	13702.5	12542.6	5336.4	55267
1980	222.4	0.0	0.0	0.0	0.0	0.0	2761.6	6007.1	8313.6	18691.3	13251.0	7937.9	57185
1981	1025.9	0.0	0.0	0.0	0.0	0.0	1394.2	9056.3	13628.9	18472.8	17563.3	7815.7	68957
1982	47.3	0.0	0.0	0.0	0.0	0.0	0.0	7320.1	13106.9	18345.8	15801.4	6396.9	61018
1983	75.2	0.0	0.0	0.0	0.0	0.0	306.8	11845.3	12166.8	16063.9	17336.9	9088.0	66883
1984	463.9	0.0	0.0	0.0	0.0	0.0	0.0	9703.5	13877.0	20568.0	17965.3	8102.5	70680
1985	0.0	0.0	0.0	0.0	0.0	0.0	4869.8	12611.3	17059.0	27258.1	14987.7	7177.8	83964
1986	544.8	0.0	0.0	0.0	0.0	0.0	112.5	12374.1	23752.5	23555.9	20978.0	6330.0	87648
1987	1549.6	0.0	0.0	0.0	0.0	0.0	8837.2	12952.7	16297.3	20057.4	21668.4	16056.7	97419
1988	3862.2	0.0	0.0	0.0	0.0	0.0	2458.6	8127.3	18164.5	28310.7	21489.2	14431.0	96843
1989	1504.8	0.0	0.0	0.0	0.0	0.0	7503.9	12180.4	20038.8	22912.7	14159.0	5990.5	84290
1990	1087.2	0.0	0.0	0.0	0.0	0.0	2265.3	8158.3	15531.1	24154.0	18098.6	13124.9	82419
1991	1948.2	0.0	0.0	0.0	0.0	0.0	0.0	7350.8	13017.1	27717.0	22845.9	16287.2	89166
1992	1982.4	0.0	0.0	0.0	0.0	0.0	7202.8	16033.0	17397.2	25421.1	23769.7	8331.8	100138
1993	1323.1	0.0	0.0	0.0	0.0	0.0	0.0	9135.6	14141.5	16901.9	16986.4	11613.9	70102
1994	1771.4	0.0	0.0	0.0	0.0	0.0	3529.6	12762.0	14111.4	26577.7	20152.1	15012.4	93916
1995	575.3	0.0	0.0	0.0	0.0	0.0	2048.8	9011.6	12712.3	21379.8	18342.8	14696.7	78767
1996	1624.7	185.6	0.0	0.0	0.0	0.0	0.0	5677.2	16805.5	27319.2	18519.6	9179.7	79312
1997	371.8	0.0	0.0	0.0	0.0	0.0	838.5	13138.2	12144.5	19492.6	18035.0	9233.0	73254
1998	230.9	0.0	0.0	0.0	0.0	0.0	0.0	2974.4	13045.9	25855.6	20533.5	13520.0	76160
1999	646.2	0.0	0.0	0.0	0.0	0.0	0.0	8391.5	16667.3	18696.6	20171.0	11198.7	75771
2000	2148.9	0.0	0.0	0.0	0.0	0.0	7287.4	14756.2	20441.2	25714.1	21004.8	9145.4	100498

Table A-7. ET losses from affected marshlands in the Sprague River Basin.
Total monthly losses in acre-feet

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	1083.0	0.0	0.0	0.0	0.0	0.0	1602.4	4041.3	5314.8	6577.0	5128.1	4319.2	28066
1950	898.0	0.0	0.0	0.0	0.0	0.0	494.4	2912.4	4406.7	7016.5	6701.9	2840.3	25270
1951	1311.5	0.0	0.0	0.0	0.0	0.0	1252.8	3354.2	5997.1	6691.5	5259.7	3462.8	27330
1952	680.9	0.0	0.0	0.0	0.0	0.0	1171.7	3471.7	4635.4	7002.8	5311.0	3727.2	26001
1953	1827.4	0.0	0.0	0.0	0.0	0.0	307.8	2954.7	3993.1	6627.7	5097.7	3906.6	24715
1954	1415.6	0.0	0.0	0.0	0.0	0.0	1216.2	3991.1	4501.6	6500.8	4533.3	2824.0	24983
1955	540.9	0.0	0.0	0.0	0.0	0.0	103.5	2946.7	5615.6	5723.6	5990.5	3268.4	24189
1956	1337.9	0.0	0.0	0.0	0.0	0.0	1139.0	3755.9	4738.3	7020.7	4965.5	3253.4	26211
1957	1130.1	0.0	0.0	0.0	0.0	0.0	1524.0	3476.9	7305.6	7118.8	5583.6	3907.6	30047
1958	893.4	0.0	0.0	0.0	0.0	0.0	716.7	4486.2	5612.1	7224.4	6403.2	3108.0	28444
1959	1908.9	0.0	0.0	0.0	0.0	0.0	965.1	2230.6	5781.2	7925.2	5561.2	2991.7	27364
1960	1264.9	0.0	0.0	0.0	0.0	0.0	796.9	2838.7	5906.7	7818.7	5069.7	3698.9	27395
1961	1103.6	0.0	0.0	0.0	0.0	0.0	705.0	2885.7	7037.0	7378.7	6734.3	2921.8	28766
1962	1108.8	0.0	0.0	0.0	0.0	0.0	1023.6	2367.9	5368.1	6477.6	5236.6	3921.0	25504
1963	1372.6	0.0	0.0	0.0	0.0	0.0	280.3	3976.8	4828.0	5952.6	5350.5	4249.8	26011
1964	1576.9	0.0	0.0	0.0	0.0	0.0	276.6	2506.2	5160.7	7112.9	5399.6	3059.7	25093
1965	1664.7	0.0	0.0	0.0	0.0	0.0	1596.8	3284.4	5649.6	6964.7	5501.9	3002.0	27664
1966	1904.8	0.0	0.0	0.0	0.0	0.0	1356.2	4261.3	5123.4	6454.0	6142.6	3881.6	29124
1967	768.2	0.0	0.0	0.0	0.0	0.0	114.3	3787.5	6171.3	8170.7	7292.3	4471.6	30776
1968	1602.5	0.0	0.0	0.0	0.0	0.0	464.1	3778.7	6364.0	8497.0	5541.5	3610.8	29859
1969	1396.7	0.0	0.0	0.0	0.0	0.0	1125.6	4857.4	6831.7	7615.3	6209.1	4028.5	32064
1970	613.4	0.0	0.0	0.0	0.0	0.0	234.2	4092.2	7378.6	8463.4	6632.5	3167.4	30582
1971	797.7	0.0	0.0	0.0	0.0	0.0	635.4	3923.1	5790.7	8261.5	7488.2	3178.6	30075
1972	304.5	0.0	0.0	0.0	0.0	0.0	549.7	4308.7	7215.1	8578.0	7216.9	3414.2	31587
1973	1105.5	0.0	0.0	0.0	0.0	0.0	1205.0	5310.5	7326.1	8434.7	6927.5	4152.0	34461
1974	1172.5	0.0	0.0	0.0	0.0	0.0	656.2	3547.0	8106.3	7733.4	7105.6	4643.9	32965
1975	1301.3	0.0	0.0	0.0	0.0	0.0	154.3	3905.6	5952.0	8587.1	6213.8	4742.4	30856
1976	1049.7	0.0	0.0	0.0	0.0	0.0	702.8	4538.1	5972.9	8755.3	5821.1	4660.9	31501
1977	1875.3	0.0	0.0	0.0	0.0	0.0	1288.6	2688.7	8641.5	8815.4	7985.6	4060.0	35355
1978	1710.1	0.0	0.0	0.0	0.0	0.0	1047.5	3471.6	7105.4	8511.4	7036.4	3639.3	32522
1979	1947.9	0.0	0.0	0.0	0.0	0.0	1314.6	4758.6	6931.8	8770.9	6743.1	4937.6	35405
1980	2256.2	0.0	0.0	0.0	0.0	0.0	1629.8	4127.2	5754.7	8778.0	6369.7	4503.5	33419
1981	2134.1	0.0	0.0	0.0	0.0	0.0	1457.5	4055.7	6830.2	8134.7	7816.5	4386.5	34815
1982	1164.6	0.0	0.0	0.0	0.0	0.0	370.9	4246.1	6962.2	7802.4	6964.5	3748.2	31259
1983	1073.8	0.0	0.0	0.0	0.0	0.0	576.6	4578.2	6266.3	6968.6	7274.8	4071.2	30810
1984	1941.7	0.0	0.0	0.0	0.0	0.0	608.7	4513.5	6115.6	9442.8	7143.1	3738.7	33504
1985	522.6	0.0	0.0	0.0	0.0	0.0	1704.6	4248.7	7612.5	9528.4	6647.9	3127.0	33392
1986	873.4	0.0	0.0	0.0	0.0	0.0	1096.0	4232.5	8644.4	7710.3	8485.9	3180.1	34223
1987	1546.1	0.0	0.0	0.0	0.0	0.0	2340.7	4998.7	8081.5	7245.7	7160.2	4667.1	36040
1988	2669.9	0.0	0.0	0.0	0.0	0.0	1823.5	3916.9	7036.9	9337.9	7136.8	4193.9	36116
1989	2743.5	0.0	0.0	0.0	0.0	0.0	2130.0	4243.6	7325.9	8135.7	6506.0	4123.1	35208
1990	1144.9	0.0	0.0	0.0	0.0	0.0	2380.7	3690.3	6025.5	9315.4	7236.0	4714.0	34507
1991	1533.1	0.0	0.0	0.0	0.0	0.0	667.9	3452.9	6002.3	9482.7	7695.4	5154.5	33989
1992	2071.5	0.0	0.0	0.0	0.0	0.0	1990.2	6232.5	7911.0	8651.3	7896.2	4227.6	38980
1993	1921.5	0.0	0.0	0.0	0.0	0.0	850.0	4748.3	5925.4	6323.0	6299.0	4141.7	30209
1994	1686.5	0.0	0.0	0.0	0.0	0.0	1672.1	4789.4	6638.4	9550.3	6663.4	4429.5	35430
1995	885.3	0.0	0.0	0.0	0.0	0.0	1065.3	4259.5	6204.1	7695.8	6148.0	4422.5	30680
1996	1371.3	126.1	0.0	0.0	0.0	0.0	943.7	3421.2	6639.5	9279.0	7164.3	3725.6	32671
1997	1194.5	0.0	0.0	0.0	0.0	0.0	852.5	5225.3	6189.3	7900.6	7135.6	4199.0	32697
1998	1012.1	0.0	0.0	0.0	0.0	0.0	543.6	2882.9	6257.0	9227.2	7488.4	4786.1	32197
1999	955.7	0.0	0.0	0.0	0.0	0.0	512.9	3348.0	6284.5	7171.2	6953.3	4075.9	29301
2000	1932.4	0.0	0.0	0.0	0.0	0.0	2085.1	4579.6	7862.3	8448.9	7721.3	4190.8	36820

Modoc Canal Irrigation

The Sprague River supplies a small diversion on the lower reaches of the river that services approximately 4,200 acres of agricultural crops within the Modoc Irrigation District. Diversions from the Modoc Canal were estimated by generating net crop consumptive use for this 4,200 acre area and estimating associated irrigation losses. The primary crops grown in this area include alfalfa (10 percent), grain (10 percent), and pasture (80 percent). These crop percentages were reported by the California Polytechnic State Universities' Irrigation Training and Research Center (Beau Freeman July 2005 e-mail correspondence).

Crop consumptive use was calculated with XCONSVB for each crop type using meteorological records from the Chiloquin 1E climate station. Records from the Chiloquin station were not complete for the period of record between water years 1949 and 2000, so missing records for average monthly temperature and precipitation were reconstructed using correlations with the Klamath Falls 2SSW climate station data. Total estimated crop consumptive use was calculated by multiplying the total number of crop acres (4,200) by the weighted average crop mix net ET. The weighted crop mix net ET was calculated based on the above assumed crop percentages.

The Williamson River annual natural flow estimates were calculated by adding the crop consumptive use and the irrigation losses associated with the consumptive use to the stream flow gage values. Irrigation losses (runoff and deep percolation) were included because they are not reflected in the stream flow gage values, since the gage is located above the irrigated lands. The predevelopment marsh consumptive use associated with the Modoc area is included in the Upper Klamath Lake calculations discussed below. The total monthly crop net ET values for the Modoc Irrigation District are summarized in Table A-8.

Table A-8. Net agricultural consumptive water use for crop lands within the Modoc Irrigation District — Total monthly values in acre-feet

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	160.6	0.0	0.0	0.0	0.0	0.0	267.0	738.1	1508.7	1838.0	1237.3	853.0	6603
1950	111.0	0.0	0.0	0.0	0.0	0.0	79.3	1058.3	959.2	2207.0	1557.3	734.7	6707
1951	0.0	0.0	0.0	0.0	0.0	0.0	108.5	691.5	1532.9	2100.6	1576.7	1091.5	7102
1952	0.0	0.0	0.0	0.0	0.0	0.0	442.2	860.9	696.4	2589.8	1904.1	1421.7	7915
1953	251.1	0.0	0.0	0.0	0.0	0.0	0.0	24.2	841.1	2080.3	916.9	1104.2	5218
1954	78.6	0.0	0.0	0.0	0.0	0.0	287.9	1154.7	934.3	2016.5	922.0	605.7	6000
1955	47.8	0.0	0.0	0.0	0.0	0.0	0.0	703.6	1482.6	1559.9	1476.5	573.4	5844
1956	76.9	0.0	0.0	0.0	0.0	0.0	279.5	590.3	840.0	1515.9	1131.5	577.0	5011
1957	0.0	0.0	0.0	0.0	0.0	0.0	66.8	703.6	1499.1	1560.9	1074.9	344.1	5249
1958	37.6	0.0	0.0	0.0	0.0	0.0	83.4	891.3	622.5	1629.1	1484.8	695.3	5444
1959	114.4	0.0	0.0	0.0	0.0	0.0	0.0	380.9	1366.3	1988.7	900.3	659.5	5410
1960	46.1	0.0	0.0	0.0	0.0	0.0	0.0	216.3	1494.4	1929.1	1187.0	953.3	5826
1961	111.0	0.0	0.0	0.0	0.0	0.0	0.0	326.6	1345.8	1944.8	1525.4	440.8	5694
1962	3.4	0.0	0.0	0.0	0.0	0.0	0.0	275.6	1284.3	1624.4	942.2	799.2	4929
1963	0.0	0.0	0.0	0.0	0.0	0.0	0.0	890.8	1142.9	1431.4	1277.4	774.1	5517
1964	80.3	0.0	0.0	0.0	0.0	0.0	0.0	364.1	741.7	1737.4	1137.9	652.3	4714
1965	145.2	0.0	0.0	0.0	0.0	0.0	0.0	553.4	1146.1	1492.2	895.1	713.2	4945
1966	201.5	0.0	0.0	0.0	0.0	0.0	171.1	1135.8	1197.1	1548.2	1223.4	870.9	6348
1967	87.1	0.0	0.0	0.0	0.0	0.0	0.0	655.4	515.7	1911.7	1660.6	1043.9	5874
1968	49.5	0.0	0.0	0.0	0.0	0.0	0.0	284.2	1298.8	1940.4	691.7	956.9	5222
1969	66.6	0.0	0.0	0.0	0.0	0.0	79.3	1179.4	793.5	1787.2	1111.6	899.6	5917
1970	10.2	0.0	0.0	0.0	0.0	0.0	0.0	771.2	1215.5	1954.5	1372.5	695.3	6019
1971	0.0	0.0	0.0	0.0	0.0	0.0	0.0	258.0	833.1	1865.7	1517.8	430.1	4905
1972	18.8	0.0	0.0	0.0	0.0	0.0	0.0	812.4	1446.9	1928.2	1566.2	573.4	6346
1973	23.9	0.0	0.0	0.0	0.0	0.0	154.4	1156.8	1482.5	1955.9	1259.1	681.0	6713
1974	1.7	0.0	0.0	0.0	0.0	0.0	0.0	676.1	1477.8	1697.8	1476.1	921.1	6251
1975	116.1	0.0	0.0	0.0	0.0	0.0	0.0	672.9	1024.3	1554.4	1047.9	982.0	5398
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	756.6	977.4	1782.8	279.3	863.7	4660
1977	203.3	0.0	0.0	0.0	0.0	0.0	0.0	140.4	1342.8	1846.0	1621.4	175.6	5329
1978	68.3	0.0	0.0	0.0	0.0	0.0	0.0	302.2	1131.4	1769.0	1172.7	387.1	4831
1979	165.7	0.0	0.0	0.0	0.0	0.0	12.5	676.6	1370.5	1636.1	830.9	974.8	5667
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	710.5	916.4	1931.4	1156.5	827.9	5543
1981	111.0	0.0	0.0	0.0	0.0	0.0	12.5	644.9	1344.1	1902.9	1535.0	792.1	6343
1982	22.2	0.0	0.0	0.0	0.0	0.0	0.0	818.7	976.5	1509.1	1083.6	612.9	5023
1983	20.5	0.0	0.0	0.0	0.0	0.0	0.0	1014.2	1177.8	1438.3	1262.2	813.6	5727
1984	97.4	0.0	0.0	0.0	0.0	0.0	0.0	773.9	1085.9	2099.3	980.8	713.2	5751
1985	0.0	0.0	0.0	0.0	0.0	0.0	363.0	847.1	1415.5	2093.4	1252.9	175.6	6148
1986	0.0	0.0	0.0	0.0	0.0	0.0	87.6	908.1	1471.8	1684.6	1647.8	222.2	6022
1987	97.4	0.0	0.0	0.0	0.0	0.0	467.3	1003.1	1513.3	1078.5	1324.1	960.5	6444
1988	269.9	0.0	0.0	0.0	0.0	0.0	87.6	545.1	1134.3	2239.6	1236.9	845.8	6359
1989	280.1	0.0	0.0	0.0	0.0	0.0	262.8	714.6	1471.4	2156.6	1112.4	476.7	6475
1990	39.3	0.0	0.0	0.0	0.0	0.0	358.8	219.3	1329.5	1825.1	1030.3	741.9	5544
1991	114.4	0.0	0.0	0.0	0.0	0.0	0.0	387.9	1131.4	2161.5	1591.3	1123.1	6510
1992	186.2	0.0	0.0	0.0	0.0	0.0	424.3	1531.8	1358.9	2029.1	1456.1	813.6	7800
1993	71.7	0.0	0.0	0.0	0.0	0.0	41.7	462.9	868.7	1391.7	932.0	741.9	4511
1994	119.6	0.0	0.0	0.0	0.0	0.0	216.9	893.0	1363.0	2426.8	1164.3	881.7	7065
1995	80.3	0.0	0.0	0.0	0.0	0.0	45.9	958.4	850.8	1819.7	983.2	845.8	5584
1996	165.7	0.0	0.0	0.0	0.0	0.0	12.5	402.3	1055.5	2346.8	1210.6	491.0	5684
1997	61.5	0.0	0.0	0.0	0.0	0.0	121.0	1106.5	1096.7	1803.9	1085.4	491.0	5766
1998	32.5	0.0	0.0	0.0	0.0	0.0	0.0	100.8	1128.3	2264.1	1354.8	752.6	5633
1999	80.3	0.0	0.0	0.0	0.0	0.0	0.0	557.2	1413.1	1704.6	838.0	824.3	5418
2000	198.1	0.0	0.0	0.0	0.0	0.0	87.6	898.8	1598.6	1600.4	1661.5	573.4	6618

Upper Klamath Lake ET

The development of an UKL water budget required the inflows and outflows to the natural system, including the natural losses resulting from lake and riparian marsh ET. The water budget approach used for UKL is unique from other approaches, because most water budgets typically attempt to reverse the effects of development (diversions, canals, dams, etc) on streamflow or lake level data. Instead, this assessment attempted to estimate and model only the natural inputs and outputs to UKL, which would have occurred under predevelopment conditions. This approach was considered necessary for UKL, since very few historical data exist on diversions and the effects of agricultural development in the area immediately surrounding the lake. Therefore, only the ET consumed by natural marshland and riparian areas were required for input to the water budget of UKL.

The natural losses to ET were estimated using results from the XCONSVB model. Monthly net ET losses were developed in XCONSVB based on temperature and precipitation histories at five climatic stations. Three of these records included several gaps in the period of record, and a complete record was necessary for each station as input to XCONSVB. The remaining two meteorological stations had complete periods of record between October 1948 and September 2000. These complete records were utilized to reconstruct missing monthly average temperature and total precipitation values in the shorter records through correlation analyses. The stations that needed reconstruction of missing data were Chiloquin 7NW, Fort Klamath 7SW, and Rocky Point 3S. The stations with complete histories were Chiloquin 1E and Klamath Falls 2SSW.

The predevelopment conditions of UKL were evaluated using historical maps. Such maps were used to determine the extent of natural marshlands in the Wood River Valley and adjacent to UKL. Before 1890, plane-table surveys covering Upper Klamath Lake were generated by the U.S. Geological Survey. An updated compilation of these quadrangles was published in April 1905 by the U.S. Reclamation Service (USRS) at 1:250,000 scale. This 1905 compilation map is entitled "Klamath Project, California – Oregon, Map No. 6092." Also, a topographical map from a 1920 USRS study (La Rue, 1922) which was based on a 1916 survey was analyzed. Digital (scanned) versions of these maps were printed to evaluate the lake and marsh areas. The areal extent of marshland on these maps was considered to represent predevelopment marsh area. Marsh areas depicted on the maps were planimetered to estimate the areal extent of natural marshlands.

Three different types of natural marsh were assumed to surround UKL during predevelopment conditions. These classifications include permanently flooded lake marsh, intermittently flooded lake marsh, and riparian marsh.

The permanently flooded lake marsh type consists of high water demand vegetation in areas completely submerged year round, such as bulrush, sedges, cattails, and tules. This marsh is considered to exist below the elevation 4140 feet, which represents "the shoreline [of UKL] prior to drainage (USGS, 1999, p.13)." The wetland classification of this area is considered to be SYSTEM Palustrine, CLASS Emergent Wetland, SUBCLASS Persistent, WATER REGIME Permanently Flooded (Cowardin, 1979). In total, approximately 55,517 acres of permanently flooded lake marsh surrounded UKL under predevelopment conditions. In this assessment, net ET from permanently flooded lake marsh was estimated using tules and cattails as the crop type category in XCONSVB. To estimate the total net ET consumed by permanently flooded marshes, the adjusted XCONXVB results from each record were multiplied against a portion of the total marsh acreage. The total marsh acreage was divided and assigned to each climate station based on proximity of the station to the marsh. A simplified Thiessen method was used to divide the total marsh area into the respective acreages for each climate station, as presented in Table A-9 below.

Table A-9. Upper Klamath Lake permanently flooded marsh acreages by climate station

Climate Station	Permanently Flooded Lake Marsh (acres)
Chiloquin 1E	10,826
Chiloquin 7NW	3,071
Fort Klamath 7SW	10,171
Klamath Falls 2SSW	11,412
Rocky Point 3S	20,036
Total	55,517

Marshland areas above 4,140 feet that are still affected by the lake hydrology were considered intermittently flooded lake marsh. The intermittently flooded lake marsh represents moderate water demand vegetation that is submerged only during part of the growing season, and includes small rushes and salt grass. The wetland classification of this area is considered to be SYSTEM Palustrine, CLASS Emergent Wetland, SUBCLASS Persistent, WATER REGIME Intermittently Flooded (Cowardin, 1979). These marshland areas measured approximately 9,625 acres and were located mainly north of UKL. In this assessment, ET from intermittently flooded lake marsh was estimated using northern climate salt grass at water table depth of 0-12 inches as the crop type category in XCONSVB. As described previously, total ET consumed by marshes was developed by multiplying the adjusted XCONSVB results against sections of marsh area. A simplified Thiessen method was used to divide the total marsh area into the respective acreages for each climate station, as presented in Table A-10.

Table A-10. Upper Klamath Lake intermittently flooded marsh acreages by climate station

Climate Station	Intermittently Flooded Lake Marsh (acres)
Chiloquin 7NW	1,350
Fort Klamath 7SW	7,616
Klamath Falls 2SSW	192
Rocky Point 3S	467
Total	9,625

The total amount of water consumed by natural marshland surrounding UKL was estimated by aggregating the results from each respective marsh type.

Marsh areas also existed along the river corridors of Sevenmile Creek, Wood River, Fort Creek, and Crooked Creek. These marshes are called riparian marsh herein, which represent areas with a mix of tules and cattails, as well as willow trees. The wetland classification of this area is considered to be SYSTEM Palustrine, CLASS Scrub-Shrub Wetland, SUBCLASS Broad-leaved Deciduous, WATER REGIME Intermittently Flooded (Cowardin, 1979). For this exercise, net ET from riparian marshes were estimated in XCONSVB using a crop type of tules and cattails along Sevenmile Creek and a mix of 80 percent tules and cattails and 20 percent willows along Wood River and Crooked Creek. The areas indicated as riparian marsh were estimated based on interpretive assessments of modern aerial photography. The natural riparian marsh areas along each of these rivers and the respective climate station data used in XCONSVB are presented in Table A-11 below.

Table A-11. Upper Klamath Lake riparian marsh acreages by stream and climate station

Stream Name	Climate Station	Riparian Marsh (acres)
Wood River/ Fort Creek	Chiloquin 7NW	536
Crooked Creek	Chiloquin 7NW	314
Sevenmile Creek	Fort Klamath 7SW	109

Marsh Inundation and Water Limiting Effects on ET

Accommodation for marsh inundation has been included in the model to simulate the water limiting effects on ET. As the water-surface elevation changes in Upper Klamath Lake, the inundation area of marshland adjacent to the lake may change. It is assumed the marsh areas at UKL would begin to dry-up at varying rates as ground water within the marsh drops below a certain level. To simulate this, the net ET values for the various permanently inundated marsh areas were reduced by factors based on reduced groundwater levels estimated in a water budget for each marsh or group of marshes being evaluated. These relationships between lake level and water recovered to groundwater levels are based on the apparent marsh-open water interface conditions. This process is discussed further in Attachment F.

The fully adjusted net marsh ET values associated with UKL are summarized in Tables A-12 and A-13.

Table A-12. ET losses from marshes surrounding Upper Klamath Lake—
Total monthly losses in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	3533.9	29323.1	-7422.1	619.6	-2557.3	-4254.7	1074.6	11873.9	21330.9	26556.2	2738.4	14459.7	97276
1950	9217.0	9958.5	6940.5	-7873.1	-40.4	-12405.5	-1666.9	16341.8	17910.2	29655.6	-2166.7	11926.7	77798
1951	1160.9	13206.6	-6441.6	-5707.1	-2947.8	-4508.4	-2235.9	13234.1	25088.1	29006.9	2763.7	15228.2	77848
1952	3695.8	12296.1	-9181.4	-4182.8	-3925.8	-9736.5	-1408.0	15299.7	12579.9	31349.4	24928.9	4691.4	76407
1953	11562.0	6533.3	-7797.9	-10318.8	-1511.9	-10667.8	-8126.1	3069.0	14914.6	28082.2	17461.9	10262.1	53463
1954	8264.5	9073.1	-6007.0	-9109.9	26.9	-9673.9	-5815.5	18773.4	14460.6	27030.8	15778.0	9729.8	72531
1955	9861.6	2931.9	-4635.6	-2072.7	890.4	-584.0	-8642.8	15686.4	21192.8	18348.8	2855.5	9189.0	65021
1956	6185.5	7163.6	-9861.7	-7580.2	-5030.7	-13314.2	-9142.5	12515.8	16624.3	23874.0	21269.8	6897.0	49601
1957	4226.9	822.8	-6442.0	-5639.0	-4115.4	-22658.8	-1843.2	11080.4	23825.1	24407.6	11745.4	6716.6	42126
1958	7511.1	-3349.7	-5994.6	-9491.9	-9558.7	-11095.5	-12917.5	15949.3	8898.2	21315.0	23846.1	7192.7	32305
1959	8186.6	373.8	-2254.5	-4116.1	-625.1	-1226.6	3870.6	10893.2	20402.1	17442.8	3367.3	10606.4	66921
1960	5594.0	10642.8	4383.8	-3810.9	-6014.0	-13473.0	-570.7	6594.0	25278.8	24602.3	4298.7	12494.4	70020
1961	7078.9	7822.0	10894.9	-1153.9	-4470.1	-10834.4	-3216.4	8746.4	22066.3	15703.4	1369.0	9923.6	63930
1962	4122.4	6649.4	-2537.0	-2289.9	-2302.2	-9110.5	-1787.1	10328.1	21575.0	21502.5	1536.3	11832.9	59520
1963	776.9	21038.9	-3465.9	-1900.0	-3817.5	-2446.9	-14389.8	15289.1	15823.5	20899.7	10710.9	6558.3	65077
1964	7369.2	5832.8	9919.7	-6148.1	1791.7	-3567.0	-2061.8	12429.6	13313.1	25301.6	-4502.7	10685.1	70363
1965	5447.8	4103.7	9148.5	-5997.7	508.2	-3450.3	-9590.6	14043.2	17939.4	23622.5	8975.1	9767.2	74517
1966	6423.5	4841.6	-2873.4	-4196.1	978.9	-4789.9	925.5	18576.0	17420.1	11150.3	3298.0	9133.8	60888
1967	6614.6	5644.5	7950.5	-7788.5	37.5	-13105.1	-18517.1	12445.4	16221.5	28565.6	25472.7	4948.9	68491
1968	11388.2	11870.8	6197.0	6577.0	-3567.2	181.1	2201.7	9136.8	12480.9	1031.9	5406.1	10910.3	73815
1969	3553.3	7676.0	8510.9	-7262.1	-1160.5	-5322.4	-7119.4	17005.9	15462.1	26414.6	9302.4	5738.6	72799
1970	6307.7	10462.4	3082.0	-6819.0	1486.6	-9302.2	-8218.9	15554.3	21735.0	2578.9	6761.5	6306.7	49935
1971	3854.2	7256.3	-2080.0	-6225.5	-703.8	-23099.0	-10548.9	4755.2	16138.5	26792.2	25194.6	1827.3	43161
1972	10302.4	4879.9	-2456.4	-9589.3	-2079.8	-25487.9	-13869.0	16107.8	22917.8	28184.2	14058.3	8523.8	51492
1973	8968.6	8281.4	-5711.0	-3939.5	-154.2	-3072.5	711.0	18835.7	23995.9	1053.6	11059.5	7843.0	67872
1974	5947.2	9968.4	-5285.4	-5728.2	-1954.6	-20830.3	-13999.9	15927.2	25691.8	24145.2	22855.4	5501.2	62238
1975	10395.0	8759.6	7075.4	-2911.2	-6878.2	-15239.8	-7716.1	15579.0	16724.7	24263.7	18811.5	4403.7	73267
1976	4662.9	2732.1	-4541.3	-2959.9	-4029.8	-4519.7	-4199.6	16373.8	17789.2	26482.1	-510.0	18133.7	65413
1977	5008.7	9493.3	2758.5	-511.6	133.1	4230.8	7842.7	3442.4	16698.2	2561.1	8489.4	4310.8	64457
1978	9386.9	1859.8	8671.2	-3381.9	-2137.8	-19041.5	-13570.1	12571.4	20000.4	25494.7	2417.2	10003.9	52274
1979	9323.8	4969.1	6867.1	3433.4	-1014.2	-190.7	-4111.0	11712.7	18397.5	-990.6	6035.2	9339.0	63771
1980	847.1	9364.2	7025.2	-7398.2	-3423.5	-6397.1	-6620.7	13078.9	15879.2	22962.1	4550.8	10699.7	60568
1981	7100.2	6772.6	6179.0	7184.0	-1638.9	-5813.5	-918.4	9896.3	17256.6	577.2	9574.6	6699.7	62869
1982	5689.7	10011.6	12099.5	-3436.4	-5562.8	-17193.2	-17489.3	16377.0	16528.0	22872.1	14991.1	1899.9	56787
1983	4292.5	4455.1	-4706.9	-3776.5	-7319.5	-16583.3	-8482.7	16072.4	19659.0	20434.5	18513.6	7770.1	50328
1984	3621.4	-1758.9	-10591.2	1002.3	-2854.0	-9258.6	-10318.0	14479.1	17947.8	29679.7	18965.4	7268.8	58184
1985	4619.7	-4538.7	-2200.6	472.0	-2045.0	-4078.6	2323.9	15487.0	22889.9	28530.8	4165.8	10071.7	75698
1986	7904.3	-908.2	-1786.8	-5621.7	-9380.7	-10655.7	-3636.3	14482.6	25191.3	23751.4	4565.7	7992.7	51899
1987	7421.7	5213.8	300.8	-5078.6	162.8	-5852.2	6342.9	18309.7	21734.6	1933.1	13611.7	5793.5	69894
1988	10250.5	5943.6	8425.2	-5091.1	1849.5	-564.4	-2910.0	11175.0	13775.3	7252.0	7518.5	7445.5	65070
1989	8699.1	4246.5	13200.8	-4314.9	230.0	-14481.4	-5325.8	12423.5	24699.2	27003.2	3021.0	9713.0	79114
1990	6095.0	7067.8	5832.5	252.9	-1541.0	-4660.8	-23.5	4811.8	17789.9	3138.8	9042.5	8084.0	55890
1991	6556.6	6110.5	5473.7	2106.4	2128.4	-10071.9	-2330.5	6395.4	11576.7	1168.0	9285.9	6668.4	45068
1992	7230.7	5606.9	7706.8	2850.4	1315.1	-782.9	-2269.8	6346.6	2267.4	6557.8	9245.3	7337.1	53411
1993	5305.3	7082.5	7494.3	2902.0	-2100.0	-17186.6	-11994.9	10218.1	15015.5	20491.9	8743.7	4357.6	50329
1994	4927.3	6070.4	3432.6	4160.5	-2598.9	2479.4	508.7	9759.0	3106.6	4635.5	7871.7	6675.2	51028
1995	8241.1	4111.9	10161.2	-982.5	1626.5	-19979.1	-12353.0	15068.7	14397.3	25478.0	-3629.5	9006.7	51147
1996	5110.6	6141.2	4896.2	15296.7	-4765.7	-10255.2	-12508.6	7636.7	18907.1	32752.7	-137.8	14023.9	77098
1997	6312.2	6235.9	-3335.6	-8926.9	836.6	-8867.8	-12551.1	19778.9	18179.7	24756.4	3052.5	11386.2	56857
1998	5211.8	5555.4	-1684.7	-8905.4	-2566.8	-13652.3	-4563.1	-2244.4	20279.4	31770.6	25726.3	5119.5	60046
1999	12339.8	5304.4	19103.2	-7759.2	-3187.1	-5436.9	-5858.5	14221.2	23195.1	24909.1	16655.1	8090.0	101576
2000	5866.1	6703.5	386.4	-10422.2	-5263.1	-8079.2	-9622.8	16345.1	26146.8	23474.8	6464.3	11055.2	63055

Table A-13. Total monthly ET losses from riparian marshes north of Upper Klamath Lake in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	150.9	0.0	0.0	0.0	0.0	8.5	168.7	348.5	405.9	415.3	381.4	277.9	2157
1950	116.1	0.0	0.0	0.0	0.0	0.0	133.2	338.1	380.8	476.7	430.0	217.7	2093
1951	79.1	0.0	0.0	0.0	0.0	0.0	159.4	312.6	402.4	462.2	423.6	310.3	2150
1952	95.6	0.0	0.0	0.0	0.0	0.0	182.2	345.3	371.8	540.8	497.3	398.7	2432
1953	157.4	0.0	0.0	0.0	0.0	0.0	129.6	247.3	312.6	448.0	371.9	320.4	1987
1954	116.5	0.0	0.0	0.0	0.0	0.0	180.8	355.3	328.5	441.4	338.5	212.5	1974
1955	67.4	0.0	0.0	0.0	0.0	0.0	39.2	280.1	391.3	383.5	406.5	245.7	1814
1956	117.9	0.0	0.0	0.0	0.0	4.5	173.6	357.8	342.2	427.1	356.1	237.6	2017
1957	65.8	0.0	0.0	0.0	0.0	10.8	146.1	325.8	393.8	386.4	342.9	273.4	1945
1958	85.0	0.0	0.0	0.0	0.0	0.0	108.7	372.0	387.4	440.2	420.4	224.5	2038
1959	125.2	0.0	0.0	0.0	0.0	19.7	172.6	253.0	369.7	437.6	359.0	209.2	1946
1960	85.8	0.0	0.0	0.0	0.0	32.3	124.5	245.3	403.3	471.8	355.7	276.9	1996
1961	116.1	0.0	0.0	0.0	0.0	0.0	124.1	266.8	446.4	428.6	423.5	213.7	2019
1962	81.0	0.0	0.0	0.0	0.0	0.0	163.6	250.2	345.9	394.6	362.1	281.5	1879
1963	114.5	0.0	0.0	0.0	0.0	0.0	42.4	339.4	333.0	350.4	364.4	286.6	1831
1964	101.7	0.0	0.0	0.0	0.0	0.0	50.6	257.7	325.1	409.4	348.3	202.0	1695
1965	129.2	0.0	0.0	0.0	0.0	0.0	155.7	273.0	357.4	400.2	371.4	206.6	1894
1966	142.8	0.0	0.0	0.0	0.0	0.0	145.6	371.6	336.1	378.5	402.1	258.9	2036
1967	90.2	0.0	0.0	0.0	0.0	0.0	18.4	308.2	358.1	425.5	441.8	298.0	1940
1968	88.4	0.0	0.0	0.0	0.0	0.0	77.5	280.2	354.7	435.8	328.4	277.3	1842
1969	92.0	0.0	0.0	0.0	0.0	0.0	103.4	358.9	385.9	417.1	350.9	266.9	1975
1970	55.0	0.0	0.0	0.0	0.0	0.0	28.1	311.0	428.2	434.1	394.2	200.8	1851
1971	55.4	0.0	0.0	0.0	0.0	0.0	61.8	278.7	316.1	434.1	427.1	205.8	1779
1972	42.8	0.0	0.0	0.0	0.0	0.0	61.6	329.1	417.0	430.2	431.8	185.2	1898
1973	76.6	0.0	0.0	0.0	0.0	0.0	127.2	376.9	393.2	446.5	376.8	254.3	2052
1974	95.8	0.0	0.0	0.0	0.0	0.0	67.0	273.0	435.9	417.3	405.5	267.8	1962
1975	107.1	0.0	0.0	0.0	0.0	0.0	13.7	285.5	344.5	417.1	351.0	285.3	1804
1976	86.6	0.0	0.0	0.0	0.0	0.0	48.8	292.8	298.3	417.3	340.5	281.8	1766
1977	135.3	0.0	0.0	0.0	0.0	0.0	127.9	229.2	459.5	417.1	434.8	179.3	1983
1978	86.1	0.0	0.0	0.0	0.0	0.0	61.3	241.1	370.4	427.3	391.2	200.7	1778
1979	115.5	0.0	0.0	0.0	0.0	0.0	116.5	333.1	358.1	401.5	351.0	281.7	1957
1980	97.6	0.0	0.0	0.0	0.0	0.0	145.2	286.3	311.3	432.2	325.7	234.6	1833
1981	115.0	0.0	0.0	0.0	0.0	12.5	145.0	295.0	365.3	385.2	389.4	241.2	1949
1982	65.1	0.0	0.0	0.0	0.0	0.0	49.3	291.2	385.9	393.5	353.6	200.0	1739
1983	67.4	0.0	0.0	0.0	0.0	0.0	81.6	321.3	327.6	336.1	358.2	214.7	1707
1984	102.4	0.0	0.0	0.0	0.0	0.0	108.2	314.3	334.5	451.8	372.3	216.8	1900
1985	29.9	0.0	0.0	0.0	0.0	0.0	175.9	303.1	405.9	502.6	340.3	181.4	1939
1986	47.5	0.0	0.0	0.0	0.0	52.0	139.9	307.8	459.2	374.0	430.2	185.2	1996
1987	109.8	0.0	0.0	0.0	0.0	25.0	201.9	382.4	459.2	388.5	403.6	277.3	2248
1988	169.0	0.0	0.0	0.0	0.0	18.0	175.3	289.9	398.9	478.5	394.4	250.1	2174
1989	172.1	0.0	0.0	0.0	0.0	12.1	186.7	289.9	434.2	425.3	346.3	242.2	2109
1990	90.9	0.0	0.0	0.0	0.0	25.9	209.9	281.6	375.5	486.1	391.2	280.4	2141
1991	88.8	0.0	0.0	0.0	0.0	0.0	76.1	255.6	341.0	493.2	408.7	298.0	1961
1992	145.0	0.0	0.0	0.0	1.1	57.7	186.7	450.7	460.7	442.8	415.2	242.2	2402
1993	124.5	0.0	0.0	0.0	0.0	0.0	116.5	358.7	341.0	337.3	364.6	259.8	1902
1994	125.0	0.0	0.0	0.0	0.0	40.1	173.2	360.9	393.4	509.9	389.2	265.7	2257
1995	73.9	0.0	0.0	0.0	0.0	0.0	94.8	323.0	377.2	429.0	337.4	264.6	1900
1996	95.8	0.0	0.0	0.0	0.0	10.8	145.0	295.0	400.3	509.9	406.8	222.1	2086
1997	94.5	0.0	0.0	0.0	0.0	19.8	128.4	396.9	379.0	425.3	399.0	243.4	2086
1998	88.4	0.0	0.0	0.0	0.0	4.5	141.1	253.1	391.6	515.5	430.0	280.2	2104
1999	86.6	0.0	0.0	0.0	0.0	0.0	86.3	275.9	378.9	420.3	385.9	250.8	1885
2000	126.5	0.0	0.0	0.0	0.0	13.8	177.6	324.6	451.3	437.8	400.3	228.8	2161

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Attachment B—Estimation of Natural Inflow to Upper Klamath Lake from Streams

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Attachment B—Estimation of Natural Inflow to Upper Klamath Lake from Streams

The water budget of Upper Klamath Lake (UKL) required input streamflow data with a complete period of record between October 1948 and September 2000. Natural inflow to UKL was estimated by developing synthetic records for each tributary between October 1948 and September 2000 (water years 1949-2000). Several methods were employed to estimate natural streamflow. The method employed depended on the availability of measured streamflow data, the location of diversions, basin characteristics, and dominant flow regime (surface water or groundwater). In order to choose a methodology, available streamflow data was initially compiled, which provided the basis for all record development.

Data Sources

Streamflow measurements used in this investigation are available from the United States Geological Survey (USGS), the United States Department of Agriculture—Forest Service (FS), and the State of Oregon Water Resources Department (OWRD). Most USGS data are readily available in CD-form from Hydrosphere, but miscellaneous and peak streamflow measurements are mainly found in the Water Resources Data Publications for Oregon, including summary and individual water year volumes. The FS has made several years of daily gaged record available on the OWRD website. Additionally, more recent years of daily gaged data and numerous miscellaneous streamflow measurements were obtained by contacting the Winema National Forest—Supervisor's Office in Klamath Falls, Oregon. Miscellaneous streamflow measurements collected by OWRD can be downloaded from their website. These measurement sites are indicated on three figures located at the end of this attachment.

Temperature and precipitation were integral for estimating streamflow in unique watersheds, such as Annie Creek and Denny Creek. Such climate data are available from the Oregon Climate Service or the National Oceanic and Atmospheric Administration. Incomplete data records were extended using the same techniques employed for streamflow record extension, as described by Reid, Carroon, and Pyper (1968) for the state of Utah. Watersheds were delineated using a Geographic Information System (GIS) and electronic topographic maps (Digital Raster Graphics) available on the USGS EarthExplorer website. Other GIS information was collected from the FS and the state of Oregon, which provided several basic GIS information layers.

Methodology Determination

The applicable method used to develop streamflow inputs to UKL was determined through an analytical process. This process was applied to the available data for each UKL tributary. To begin this analysis of available data, all available gaged data, including any miscellaneous, instantaneous streamflow measurements, were gathered and compiled. Daily streamflow data, or daily discharge values, were aggregated to determine monthly total volumetric streamflow in the units of acre-feet. The process for choosing a methodology was applied to these monthly total streamflow values.

The methodology determination process consisted of applying four questions to the available data for each tributary. These four questions provide the basic separation points in the methodologies employed herein:

Question 1: Do the available records provide a complete period of record between October 1948 and September 2000 (water years 1949-2000)?

Question 2: Are the available data natural; i.e., do they represent streamflow under predevelopment conditions?

Question 3: Are there additional groundwater accruals to the stream below the gage location and before the stream releases into UKL?

Question 4: Do the available records exhibit similarities to nearby natural streams, in terms of streamflow response, basin characteristics, or dominant flow regime (winter-precipitation or snowmelt runoff)?

NOTE: These questions do not represent all questions that were applied against the available data, nor do they represent all questions required to estimate natural streamflow. For example, when streamflow records do not represent natural conditions, the next logical questions would be:

1. What human activities have affected streamflow?
2. Have any of these activities been recorded (do diversion records exist)?

These additional questions did not create additional separations in the decision-making process, and thus are not covered separately in this discussion.

Figure B-1 below illustrates the decision-making process. The flowchart ends by listing each UKL tributary next to the method employed. A detailed description of each question and the analysis undertaken to answer each question is described after the flowchart.

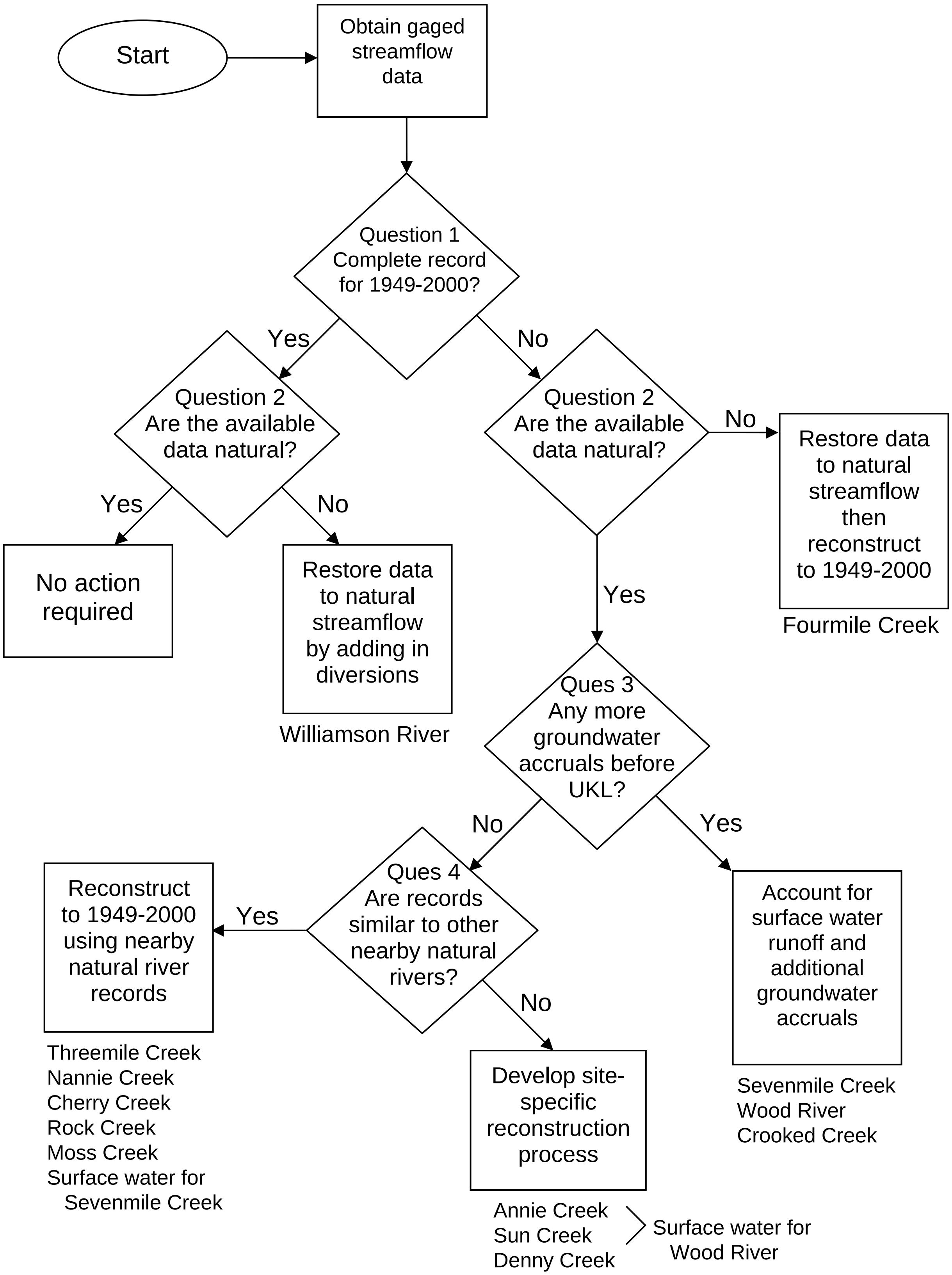

Figure B-1. Flowchart of natural streamflow methods for inflow to UKL.

Question 1: Do the available records provide a complete period of record between October 1948 and September 2000 (water years 1949-2000)?

Streamflow records existed for every UKL tributary. However, only one tributary, the Williamson River, has a complete period of record between 1949 and 2000. All other tributaries have varying degrees of streamflow records; Annie Creek, Sevenmile Creek, and Cherry Creek have extensive daily gage records, while other tributaries have only a few years. In some cases, miscellaneous, instantaneous streamflow measurements were available in addition to or instead of continuous daily records. To build a larger data set, monthly total flow estimates were made from these instantaneous streamflow measurements through a hydrograph-matching process.

Monthly total flows were estimated by relating instantaneous flow measurements to at least two other concurrent daily gaged records. When sufficient concurrent measurements were available between a nearby gage and the desired watershed (i.e., at least one measurement per month for several months), monthly total flows for the otherwise ungaged watershed were estimated by rescaling the daily gaged records from nearby watersheds to create a daily record for the ungaged watershed. This rescaling (termed hydrograph-matching) was typically done with at least two nearby gages. The rescaled estimates were compared and reviewed for consistency. When estimates for the same month were consistent or showed very little difference, then results from either effort were considered adequate and used for further analysis. When results differed greatly, then values estimated beyond the original range of data were refined using professional judgment. Usually, the lower of the refined estimates were considered more conservative and were used in further analysis. In general, most rescaled estimates for the same period of record produced very similar results. Only daily discharge estimates that were generated from concurrent instantaneous flow measurements recorded in months before, during, and after the pertinent month were considered to be accurate and were used in further analyses.

Question 2: Are the available data natural; i.e., do they represent streamflow under predevelopment conditions?

To determine how natural the available data are, the presence of any upstream diversions into or out of the stream were determined and quantified. The presence of diversions was researched by reviewing documentation provided by the USGS with their gaged data or through the OWRD water rights on-line database.

Despite the narrow scope of the study of only accounting for the effects of agriculture, the efforts in the Wood River Valley investigated any major land characteristic changes, such as those resulting from timber harvesting. Land management activities in the headwaters of the Wood River Valley are administered within Crater Lake National Park and the Winema National Forest.

Land management practices were reviewed by researching land management policies and FS documents. National Park Service policies were assumed to prohibit timber harvesting practices in Crater Lake National Park. The park is located on the north end of the valley and protects the headwaters of Annie Creek and Sun Creek from timber harvesting activities. Also, the Sky Lakes and Mountain Lakes Wilderness Areas of the Winema National Forest prohibit timber removal practices in the headwaters of creeks on the east flank of the Cascades (Sevenmile, Threemile, Nannie, Cherry, Rock, Fourmile, and Moss Creeks). Even though the floor of the Wood River Valley has been altered significantly within the last 100 years, most of the contributing headwaters remain in a relatively natural condition (USDA, 1994; USDA, 1995, USDA, 1996).

Most gaged data were considered natural or "unregulated," since no upstream diversions have been recorded. The available streamflow measurements for the Williamson River do not represent natural conditions due to several upstream agricultural diversions. Although gaged streamflow data existed for every UKL tributary in the Wood River Valley, not all of this data represented natural streamflow conditions. For example, several streamflow measurements were available for Wood River, but upstream diversions from the river were not regularly measured except for a few years (Marshall Gannett, hydrologist, USGS, pers. comm.). This short period of record allowed for the determination of natural streamflow in the Wood River. It was found that some natural streamflow data was available for every Wood River Valley stream, with one exception. In the case of Fourmile Creek, streamflow records did not represent natural conditions due to the existence of Fourmile Dam. For the development of all other Wood River Valley tributaries, only natural streamflow measurements were used herein.

Question 3: Are there additional groundwater accruals to the stream below the gage location and before the stream releases into UKL?

Several streams in the Wood River Valley have significant groundwater accruals before releasing streamflow into UKL. These groundwater accruals result from springs along the valley floor that contribute additional streamflow to Sevenmile Creek, Wood River (including Fort Creek), and Crooked Creek. The process for accounting for groundwater accruals proved to be complicated due to very limited data that represents natural conditions.

Question 4: Do the available records exhibit similarities to nearby natural streams, in terms of streamflow response, basin characteristics, or dominant flow regime (winter-precipitation or snowmelt runoff)?

As mentioned previously, the water budget of UKL required streamflow data with a complete period of record between October 1948 and September 2000. Similarities between watersheds are necessary to fill in gaps in the period of record. The shapes of streamflow hydrographs were compared to determine the similarity to streamflow in other watersheds. In particular, these comparisons were generated against streams with longer periods of records, especially if the two periods of record overlapped. Reconstruction of missing streamflow records was only completed between similar watersheds that included several overlapping monthly totals.

The most obvious differences in streamflow hydrographs were identified between streams dominated by groundwater accruals, winter-precipitation, or spring snowmelt runoff. Most Wood River Valley streams exhibited similarities with other nearby gaged rivers. Once the available Fourmile Creek data were restored to represent natural conditions, the Fourmile Creek streamflow data also exhibited similarities to nearby natural gages.

Three streams in the Wood River Valley did not exhibit similarities to other streamflow gages. These exceptional streams are Denny Creek, Annie Creek, and Sun Creek. The streamflow hydrograph of Denny Creek exhibited streamflow that is dominated by winter precipitation; i.e., streamflow peaks occurred in the winter rather than during spring snowmelt-runoff. All nearby gages with a long period of record were dominated by spring-snowmelt runoff. The streamflow hydrograph for Annie Creek was also quite different from the nearby gages in that streamflow peaking was not consistent with other streamflow gages. This difference is considered to be the result of different geology throughout the Annie Creek drainage. Sun Creek, which had very little available data, is located adjacent to Annie Creek and has similar geologic characteristics. The streamflow of Sun Creek was considered to be similar to Annie Creek after a comparison of several concurrent streamflow measurements.

NOTE: Initially, estimation of streamflow in watersheds with short period of records was attempted using basin characteristics. Gaged streamflow information was transferred between all adjacent gaged watersheds using basin characteristics to ascertain the best gage transference methodology and equation. Characteristics reviewed included watershed area, weighted-average annual precipitation from 1961-1990, and effective precipitation (average annual precipitation / drainage area). These attempts to recreate known gaged streamflow using basin characteristics were unsuccessful due to the inability to recreate sufficient variability within the available time. Instead, the estimation of streamflow for most Wood River Valley streams relied on actual gaged streamflow measurements despite some minimal periods of record.

Restoring Affected Streamflow Data to Natural Data

The water budget of UKL utilized a natural approach, which attempted to simulate the natural inflows and outflows that occurred in UKL during predevelopment conditions. As such, streamflow releases to UKL for the water budget needed to represent natural conditions. Two UKL tributaries had streamflow data available that did not represent natural conditions, the Williamson River and Fourmile Creek. To develop natural input to the water budget of UKL, the available data for these streams needed to be restored to represent natural conditions.

The method for restoring streamflow data depends on why the data are not considered natural. The available streamflow measurements for the Williamson River do not represent natural conditions due to several upstream agricultural diversions. These agricultural diversions were estimated and added to gaged streamflow to represent natural conditions in the Williamson River. A more detailed description of this method is discussed below.

Streamflow records for Fourmile Creek did not represent natural conditions due to the existence of Fourmile Dam and the export of water from Fourmile Lake out of the UKL basin. The existence of Fourmile Dam has affected the timing of streamflow in Fourmile Creek. More importantly, the diversion of water from Fourmile Lake through Cascade Canal has resulted in minimal or no releases to Fourmile Creek from the contributing area above Fourmile Dam. To naturalize streamflow in Fourmile Creek, the amount of water exported out of the Klamath River Basin through Cascade Canal was estimated and added to gaged measurements in Fourmile Creek. A more detailed description of this process is discussed in the section entitled "Combination Methods."

Williamson River—at Outlet

The Williamson River is the largest contributor of streamflow to UKL. The entire Williamson River drainage at the outlet to UKL measures about 3,048 square-miles in area. The Sprague River is the largest tributary to the Williamson River and contributes 1,610 square-miles to the Williamson River drainage.

Daily streamflow records of the Williamson River have been recorded by the USGS since 1917. The USGS streamflow data used herein were recorded at gage # 11502500, Williamson River below Sprague River near Chiloquin, Oregon, which is currently in operation. This gage is downstream of the Sprague River outlet near the town of Chiloquin. Since natural streamflow inputs to UKL were required for the water budget, the restoration of streamflow only required an assessment of factors that would have significantly altered natural streamflow at this gage location.

The USGS annual periodical "Water Resources Data for Oregon" was reviewed to assess whether the Williamson River gage has been affected by agriculture. Between 1949 and 2000, the "REMARKS" header for this gage contained the description "Some regulation by diversion dams and logpond operations on Sprague River. Diversions for irrigation upstream from station." This description indicated that the recorded streamflow at this gage does not represent natural conditions and that agriculture diversions have historically depleted streamflow. Additionally, the natural extent of Klamath Marsh has changed from pre-development conditions, especially within its lower segment.

The extent and location of upstream diversions was necessary to restore gaged streamflow to represent natural conditions. Natural streamflow can be estimated by adding such depletions to gaged streamflow. Unfortunately, monthly total irrigation diversions have not historically been compiled for the Sprague and Williamson River watersheds. As a result, information regarding upstream irrigation practices was gathered from OWRD and Reclamation's Klamath Basin Area Office. Current irrigation practices were also examined by a field reconnaissance survey in August of 2002.

Agricultural development has occurred along the streamcourse of the Sprague and Williamson Rivers. Much of the marshland and valley-bottom wetland in the upper Sprague River, near the towns of Beatty and Sprague River, has been reclaimed for agriculture and is irrigated through flood irrigation practices. The primary crops irrigated in this area include pasture grass and hay. Water is also diverted from the Sprague just above its confluence with the Williamson River for irrigating land on the Williamson delta adjacent to UKL. This diversion transports water through the Modoc Canal. Although some of the wetlands of Klamath Marsh have been drained and reclaimed, large areas of pastureland are located above Klamath Marsh. However, pastureland development in this area has not caused significant changes to the natural flow character of the Williamson below Klamath Marsh, so these areas were not included in this assessment.

Irrigation return flows and any potential delays in these returns were evaluated for effects on streamflow. Irrigation return flows in the Sprague River Valley occur due to field runoff resulting from flood irrigation practices. Diverted water is mostly applied to land adjacent to the river. As such, these return flows are not delayed significantly in returning to the stream after application to the land. The Sprague River does not have an underlying transmissive valley fill alluvial aquifer, so any percolation losses were assumed to not return to the river. Any irrigation return flows from field runoff are included in gaged streamflow data and are not considered to incorporate any delays, since delays typically result from groundwater drainage to the stream. Therefore, the net impact to the gage is from the water used by the irrigated crops (net crop consumptive use), because net crop consumptive use represents the amount of water not appearing at the gage. Net crop consumptive use may be defined as potential evapotranspiration less effective precipitation. Because not all precipitation is sufficient to offset potential evapotranspiration, only the part that is effective in doing so is considered.

Net crop consumptive use was developed for the irrigated areas along the Sprague River and adjacent to UKL as an estimate of the effects of agriculture depletions on the Williamson River. A detailed description of these estimated depletions are found in attachment A.

Under predevelopment conditions, riparian systems were assumed to exist along the Sprague River. Parts of the current irrigated areas would have been marsh. These areas are termed affected natural marshlands, which represent only the natural marshes that have been reclaimed for agriculture. Other natural marshes still exist adjacent to irrigated areas on the Sprague River. Natural streamflow would have been depleted by evapotranspiration (ET) in these marsh areas. The losses due to natural marsh ET were estimated to provide a more accurate representation of natural streamflow. These losses were estimated by developing consumptive use requirements for the affected marshlands. The existing marshes were not included in this assessment, since any streamflow losses due to ET from these marshes are already accounted for in gaged records. A detailed description of affected marsh net evapotranspiration estimates are found in attachment A.

Within the Sprague and Williamson watersheds, and especially that of the Sprague, numerous wells pump from the confined regional aquifer. Assessment of the effect of this pumping on streamflow was not assessed.

The water budget for natural streamflow at the Williamson River gage is:

> natural flow = gaged flow + crop net consumptive use – affected natural marshland net evapotranspiration

Table B-1 provides the natural streamflow estimate generated for the Williamson River at the USGS gage No. 11502500.

NOTE: The Williamson River gage is not located immediately upstream of UKL. Rather, the Williamson River continues another 3.2 miles before becoming directly hydraulically connected with UKL on an alluvial fan, about 7 river miles upstream of the lake. In this stretch of river, some gains and losses of flow are likely to occur, including gains from groundwater, losses to deep percolation, or gains from additional drainage area runoff. The extents of such changes are unable to be determined without a more site-specific analysis, but some estimates can be generated. For example, the increase of drainage area from 3001.4 square-miles at the gage location to 3010.8 square-miles at the downstream hydrologic connection point is only 0.3 percent. Such a small increase would not noticeably affect streamflow. More refined estimates of these factors could be determined with more site specific analyses, but the necessary data does not exist at this time.

Table B-1. Williamson River synthetic natural streamflow record—Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	34624.9	36173.0	37601.0	34620.0	38859.0	79897.0	93669.5	87128.4	47592.8	34510.5	33512.1	34110.4	592299
1950	35515.5	37669.0	37611.0	41691.0	48433.0	92610.0	105083.1	96811.0	61056.4	36574.5	33770.2	29818.1	656643
1951	37189.8	45644.0	91773.0	61203.0	101853.0	104530.0	170242.7	134689.5	56847.0	38115.3	35797.1	34495.5	912380
1952	40145.8	41838.0	58077.0	52753.0	67733.0	85076.0	327523.9	243994.2	111899.4	69180.1	47395.0	43533.5	1189149
1953	43063.6	46811.0	48530.0	109212.0	134481.0	118653.0	144594.2	189662.6	159381.8	71603.7	46983.3	47115.9	1160092
1954	52225.1	72479.0	94434.0	71797.0	86937.0	161913.0	246804.9	170663.1	85339.5	59355.3	45893.5	47559.9	1195401
1955	53408.6	59650.0	60937.0	54858.0	51490.0	72921.0	104780.0	87302.8	52945.8	40854.6	36523.6	36922.4	712594
1956	43853.1	55972.0	139619.0	186687.0	97430.0	152293.0	321671.4	268958.4	144291.6	75567.7	57358.6	50034.1	1593736
1957	64366.8	76385.0	80705.0	63597.0	78822.0	194423.0	142520.2	147806.9	78885.7	48433.4	38790.7	40793.3	1055529
1958	69943.2	75492.0	82811.0	82117.0	213583.0	200889.0	201768.1	208454.4	119437.5	82300.1	60837.9	53715.1	1451348
1959	60063.7	68014.0	72854.0	81185.0	75313.0	86401.0	81471.1	68593.5	48490.4	39971.6	36275.7	39722.3	758355
1960	50067.0	52418.0	53326.0	50105.0	72777.0	96041.0	91967.8	75138.1	54451.1	40192.4	36853.2	36658.0	709995
1961	39206.9	45785.0	62716.0	54241.0	82038.0	81443.0	75170.2	64529.2	55278.0	36753.3	35435.7	33823.7	666420
1962	38652.2	44577.0	58180.0	52448.0	66007.0	72310.0	134596.0	83341.8	49282.2	35136.1	33561.1	29886.2	697978
1963	75011.6	60213.0	97588.0	57355.0	112127.0	79737.0	136331.6	136846.9	66637.9	45736.0	38237.6	35477.9	941299
1964	36780.8	49570.0	51926.0	49988.0	43189.0	59301.0	127123.1	87709.3	65545.9	42798.9	37514.9	34936.4	686383
1965	35008.0	38974.0	226428.0	189047.0	174707.0	110818.0	110207.5	124886.3	66382.1	45662.0	40936.5	39419.7	1202476
1966	40101.5	51500.0	53900.0	48933.0	45414.0	90102.0	135713.2	70414.1	43265.4	35654.2	32895.5	34933.0	682826
1967	35153.2	43865.0	70523.0	54203.0	68570.0	98223.0	113848.7	185005.2	110572.5	46189.3	35676.5	32815.2	894645
1968	38621.2	40208.0	42346.0	43161.0	81667.0	87274.0	57060.2	44218.5	35518.0	30037.6	32934.6	30969.5	564016
1969	34779.2	40555.0	50575.0	52265.0	52737.0	78596.0	228174.5	148804.9	66326.1	42349.4	33591.1	33155.8	861909
1970	39103.0	38825.0	58880.0	152503.0	123255.0	116431.0	81601.5	86512.3	57871.1	42066.8	34590.2	33186.4	864825
1971	38924.0	48768.0	68907.0	92354.0	91023.0	122402.0	196016.0	193947.3	113440.1	61317.3	42561.1	37888.5	1107548
1972	43867.5	50615.0	58767.0	70511.0	83823.0	261723.0	135689.5	121372.1	67496.7	47110.6	40654.6	37986.8	1019617
1973	44754.7	53793.0	61707.0	72303.0	61231.0	79737.0	69030.3	68207.9	40831.5	35596.5	32635.0	30971.3	650798
1974	36871.8	80052.0	108775.0	142463.0	86560.0	147553.0	211347.8	154959.2	87668.5	52962.9	43078.7	39317.2	1191609
1975	40922.2	51057.0	61207.0	55284.0	59162.0	115817.0	125690.6	179771.7	101338.4	58687.8	44773.6	39140.9	932852
1976	47076.0	59874.0	70256.0	68877.0	59975.0	92114.0	97477.2	90430.3	48929.9	38875.1	43750.4	43673.0	761308
1977	44509.5	49740.0	48917.0	40455.0	40807.0	60517.0	50698.8	49852.3	47826.2	41785.4	36613.3	36240.4	547962
1978	38165.5	46184.0	83605.0	115519.0	86044.0	120597.0	138451.7	109336.7	57667.6	46332.2	37321.5	38340.3	917564
1979	34887.2	35171.0	41281.0	45456.0	44307.0	76402.0	62427.2	77989.4	42241.0	34703.4	35266.1	30911.1	561042
1980	33028.4	40588.0	52844.0	95242.0	84081.0	85588.0	82683.9	95446.9	49447.8	48724.1	37342.4	35057.9	740074
1981	34594.6	38533.0	48582.0	53501.0	60608.0	65505.0	64473.4	57018.9	39617.1	38652.6	36223.4	31117.6	568427
1982	36547.2	54001.0	113758.0	69502.0	194968.0	177503.0	172168.9	175839.6	87729.1	63841.1	43498.8	36448.7	1225806
1983	38466.8	47299.0	62573.0	73689.0	108240.0	197537.0	191629.6	193500.6	152995.7	77025.7	58799.9	47376.9	1249133
1984	46291.1	63629.0	100365.0	82238.0	81462.0	181550.0	181868.8	181492.5	115523.5	67815.3	52437.4	47218.9	1201891
1985	51106.4	78332.0	70920.0	59916.0	54762.0	91876.0	180593.9	99013.1	69450.4	56396.7	44649.6	48206.4	905223
1986	50827.7	54255.0	54846.0	74028.0	157371.0	226952.0	134550.3	101964.1	79527.2	61126.8	50969.0	43889.9	1090307
1987	49973.2	54473.0	58930.0	55810.0	61631.0	93701.0	81855.8	67735.7	50496.0	51936.9	48328.9	44640.2	719512
1988	39092.2	43944.0	60550.0	56351.0	63163.0	75294.0	60965.5	55094.8	54697.6	49967.6	41756.4	37763.7	638640
1989	30813.1	40682.0	49504.0	44210.0	42013.0	172465.0	178684.3	118218.5	66715.4	49360.7	39027.5	35334.3	867028
1990	37865.9	39775.0	40642.0	55032.0	41657.0	75393.0	61510.6	42807.6	46175.2	43893.8	39345.5	37405.7	561503
1991	34993.2	35322.0	33952.0	36183.0	35467.0	50099.0	47168.3	53666.7	42025.1	49533.7	42051.8	38157.7	498619
1992	31386.1	33692.0	34900.0	34672.0	33672.0	38034.0	40601.9	36603.8	32708.3	42927.5	38194.2	29388.4	426780
1993	29707.9	33067.0	33527.0	34795.0	35378.0	181038.0	165670.1	134853.0	89744.5	45218.9	42450.2	38559.2	864009
1994	36211.8	34477.0	37623.0	36877.0	32730.0	47598.0	45107.1	43217.5	33434.6	40619.0	34476.4	35192.6	457564
1995	29962.8	31559.0	34190.0	53499.0	74330.0	122543.0	121594.5	126809.5	77013.7	54301.1	41542.1	38772.8	806118
1996	35205.2	35552.5	58841.0	74463.0	192368.0	146521.0	122351.7	129137.2	67877.6	53647.1	40779.4	38048.2	994792
1997	36132.5	42118.0	79078.0	250060.0	126032.0	111453.0	115594.6	102332.2	52261.7	46450.3	42571.5	38804.1	1042888
1998	35979.9	40692.0	45119.0	83208.0	92332.0	135037.0	132311.2	181682.7	128075.3	70146.0	48075.2	43492.7	1036151
1999	38416.3	56423.0	81203.0	74163.0	61151.0	140630.0	188978.5	182239.5	118575.3	60991.4	53108.4	47809.4	1103689
2000	46378.4	52430.0	58608.0	69087.0	83644.0	111096.0	134941.7	110492.2	65090.0	55045.8	45797.0	39961.2	872571

Reconstruction Method using other Natural Rivers

A complete period of record between October 1948 and September 2000 for the UKL water budget was reconstructed as necessary for an extended, synthetic period of record for UKL tributaries. Gaps in the required period of record were estimated using correlation analyses with other streamflow gages. Correlations were generated against nearby natural gages with longer periods of record in the Wood River Valley, Rogue River basin, or the Deschutes River basin. A variety of linear and curvilinear correlations were used to develop each synthetic time series. To adequately capture variability in streamflow throughout the year, correlations were developed for specific flow regimes (low-flow or high-flow) within individual months, each season, or for all months, depending on the number of available concurrent values.

The reconstruction process includes the following steps:

1. Relate monthly total discharges to those from nearby, similar gages with large period of record.
2. Create a synthetic natural time series based on monthly total flow correlation equations.

A correlation between streamflow data from one UKL tributary and another gage with a more extensive period of record was the most common procedure used. Monthly total discharge values from a nearby, similar gage record were correlated to those from each desired watershed. Correlations were developed for specific flow regimes (low-flow or high-flow) within individual months, each season, or for all months, depending on the number of available concurrent values. The least-squares method defined by Pollard (1977) was used to determine the accepted best-fit line. However, the least-squares line does not always capture sufficient variability. The amount of explained variability captured by a line is determined by calculating R^2 (Lapin, 1983) as modified for the line of minimum absolute deviation (MAD) or a generally similar fitted line (Zebrowski, 1979; Troutman and Williams, 1987; Williams 1983). The use of these modified lines ensured sufficient variability was recovered. Again, correlation equations were used to develop synthetic time series from October 1948 to September 2000. The following Wood River tributaries were quantified using the standard process described above:

Stream Name:	Tributary to:
Threemile Creek	Crane Creek
Nannie Creek	Cherry Creek
Cherry Creek	Fourmile Creek
Rock Creek	Crystal Creek
Moss Creek	UKL

The time series for each watershed was developed uniquely and is explained in more detail below. Any deviations from the standard process are described, along with a qualitative discussion of each synthetic time series.

Threemile Creek—at Outlet

The Threemile Creek watershed is located just south of the Sevenmile drainage and totals 9.7 square miles in area. Threemile Creek flows perennially into Crane Creek on the valley floor, and streamflow is dominated by spring snowmelt runoff. The geology of the watershed is similar to Sevenmile, with cinder cones defining the northern and southern ridge tops and abundant loose unconsolidated volcanics. High infiltration rates in these soils limit streamflow yield. The southern ridge tops probably provide groundwater recharge for springs on the valley bottom, such as Mares Egg Spring.

The Threemile Creek watershed is partially protected by the Sky Lake Wilderness of the Winema National Forest. About 50 percent of the Threemile watershed lies within the wilderness area, while the remaining portion is nonwilderness. Despite some timber harvest and road construction in the watershed, there appears to be no effect from these activities on timing of peak flows. Although Threemile Creek was only intermittent previously, due to water going subsurface into the alluvial fan upstream of the confluence with Crane Creek, the current perennial flow has been attributed to natural channel downgrading that occurred during the 1964 flood. During this storm, the channel bottom was lowered by about 10 feet, thereby bringing the stream closer to the water table (USDA, 1995). Therefore, the magnitude and timing of flows observed by gaged streamflow measurements are considered to be natural.

The USGS collected instantaneous and streamflow measurements about once a month between September 1964 and October 1967 at a location above the alluvial fan. The USGS published monthly total flow estimates from these data (Hubbard, 1970). Annual peak flow measurements from water years 1965 through 1974 allowed for reconstruction of monthly totals between 1964 and 1967. Reconstruction of monthly total flow was completed by rescaling the Varney Creek and South Fork Rogue River (S.F. Rogue + S.F. Power Canal near Prospect) gages. The estimates generated from each gage varied slightly, particularly in the late summer and early autumn, mainly because Varney Creek exhibited a lack of surficial baseflow, unlike Threemile Creek and South Fork Rogue River. Otherwise, the reconstructed values were similar to those developed previously.

The FS also collected miscellaneous flow measurements between December 1991 and May 1997. Monthly total estimates were generated for several months from the Rogue River above Prospect and Cherry Creek gages. All estimates were used to develop correlations between the extended synthetic time series for Cherry Creek (see Cherry Creek). Specific month correlation equations provided additional calibration for March through July, while a generic equation encompassing all estimates was applied to the other months. The final synthetic time series yielded very similar results to expected values.

On July 29, 1992, the USGS measured instantaneous streamflow at two locations. One measurement was taken at the old USGS gage location on the alluvial fan and the other measurement was taken upstream in a V-notch valley. The upstream value of 0.83 cfs is almost four times higher than the 0.21 cfs measured on the alluvial fan. The majority of available streamflow measurements were taken on the alluvial fan, and the synthetic time series developed from these data are representative of surface flow (Table B-2). The water that became subsurface at the alluvial fan is most likely captured and released through evapotranspiration by the wetlands 2/3 mile downstream.

Table B-2. Threemile Creek synthetic natural streamflow record—Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	59.3	84.0	131.7	41.5	74.2	161.0	883.6	2079.2	533.8	63.0	55.2	42.0	4209
1950	62.8	84.9	68.8	145.3	151.1	300.6	515.1	1410.3	1237.1	144.7	75.4	54.5	4251
1951	236.1	563.1	819.1	307.2	499.2	178.7	904.2	1028.3	418.3	114.8	88.4	67.3	5225
1952	154.3	277.7	469.4	113.0	251.3	170.5	1077.5	2509.7	1505.6	236.2	118.4	85.8	6969
1953	88.4	82.9	91.6	613.1	499.4	162.6	356.2	1209.7	1911.2	279.7	123.5	80.3	5499
1954	100.2	482.3	675.3	221.4	406.9	260.7	944.1	1104.8	658.9	145.3	106.3	81.7	5188
1955	93.0	101.0	93.2	69.8	59.6	124.2	164.7	1084.5	965.3	76.3	51.9	41.1	2925
1956	64.0	217.5	1002.9	659.0	135.0	150.6	793.5	1834.0	1203.1	184.3	115.1	82.5	6442
1957	138.3	224.5	692.9	94.7	367.8	531.8	428.1	817.5	320.5	78.4	75.0	58.7	3828
1958	101.2	200.4	375.5	321.2	713.4	183.5	412.7	1533.4	939.9	149.5	100.2	77.3	5108
1959	89.1	243.3	167.9	357.1	150.4	187.9	414.5	512.5	253.6	56.6	55.5	50.6	2539
1960	75.1	61.7	46.9	39.7	155.6	340.6	590.8	1026.5	626.2	55.5	48.7	36.2	3104
1961	48.6	168.5	195.9	85.3	483.4	249.8	471.7	957.2	664.5	64.8	57.0	44.8	3492
1962	78.5	264.2	283.5	151.0	142.5	131.7	678.9	710.7	400.4	63.4	60.8	43.6	3009
1963	142.0	244.1	458.4	76.8	463.0	158.2	278.5	914.3	237.6	57.4	53.5	43.5	3127
1964	59.3	349.3	206.8	170.8	131.3	133.3	326.9	977.0	1156.4	125.7	66.4	48.1	3751
1965	37.3	186.6	5811.7	630.8	490.0	202.4	693.2	804.0	471.6	106.3	102.6	79.8	9616
1966	89.1	131.0	122.4	172.6	96.2	252.9	821.9	1235.0	207.5	119.4	104.5	92.2	3445
1967	88.3	104.4	162.6	292.7	181.6	169.5	141.8	1088.1	722.1	87.7	55.8	36.7	3131
1968	59.8	50.3	52.0	78.6	445.7	182.4	144.3	240.6	125.6	41.0	35.6	24.4	1480
1969	40.4	256.7	210.2	183.6	68.0	136.1	517.1	1532.7	518.8	67.9	50.7	38.0	3620
1970	60.8	58.1	209.7	806.4	200.7	193.5	144.9	647.8	296.1	54.2	51.8	41.7	2766
1971	61.0	404.0	213.1	562.4	251.8	248.3	437.9	2419.5	1455.5	223.4	116.1	93.3	6486
1972	113.2	285.0	339.8	460.5	413.6	1304.8	605.7	1520.1	1077.1	173.7	122.9	95.0	6511
1973	111.0	136.9	239.4	213.8	104.7	148.1	200.5	406.8	145.7	43.5	38.9	41.0	1830
1974	63.6	582.5	738.9	751.3	157.7	426.6	677.8	1412.2	1901.6	226.1	127.2	91.1	7157
1975	109.7	116.5	184.0	205.5	214.5	252.6	194.2	1778.5	1795.1	212.6	106.4	74.9	5245
1976	123.9	254.0	658.9	334.5	183.4	168.8	285.8	1272.5	575.9	140.4	131.5	78.3	4208
1977	87.2	78.8	53.3	34.1	29.0	93.5	142.5	266.7	134.3	40.3	26.6	28.9	1015
1978	38.3	360.5	854.3	275.3	206.7	177.3	160.7	332.2	196.6	49.0	43.5	44.5	2739
1979	40.4	57.4	109.8	156.5	130.3	262.1	229.9	816.0	165.9	43.2	32.6	20.3	2064
1980	71.2	156.6	216.2	513.4	183.1	171.0	282.5	360.5	171.0	45.2	35.0	28.1	2234
1981	39.8	89.8	324.5	78.6	226.0	130.9	146.3	223.4	210.9	42.7	26.8	21.8	1562
1982	47.4	281.3	1083.1	169.4	590.7	245.2	399.4	1321.2	873.4	163.0	88.0	67.9	5330
1983	105.0	143.4	621.3	311.0	465.1	435.8	398.5	1369.1	907.4	205.0	114.4	76.3	5152
1984	88.1	317.9	639.7	373.1	388.1	439.5	472.9	1353.5	1467.7	212.1	123.0	90.3	5966
1985	138.9	511.4	213.1	120.8	115.2	157.7	850.0	790.0	498.7	65.8	58.6	54.0	3574
1986	97.9	111.7	167.4	297.7	664.0	525.3	204.2	572.6	305.2	52.1	53.4	74.3	3126
1987	123.0	223.3	129.4	133.3	250.8	200.4	320.9	350.4	122.5	55.3	36.0	25.6	1971
1988	29.9	36.4	84.2	124.5	128.3	167.8	166.8	322.9	284.6	42.9	26.1	18.3	1433
1989	21.6	112.8	89.2	79.1	77.0	488.1	1082.2	959.9	466.0	65.6	57.0	40.0	3539
1990	56.6	63.1	89.1	132.1	64.0	227.4	363.4	304.7	249.1	44.8	37.3	25.4	1657
1991	36.6	67.8	58.5	165.8	161.4	207.2	211.3	540.7	250.9	46.5	30.8	18.6	1796
1992	49.4	96.4	144.5	61.0	91.4	156.9	379.6	144.2	60.4	42.1	16.0	11.7	1254
1993	24.5	199.7	103.0	42.7	56.1	616.5	684.8	1752.2	777.5	173.6	78.9	49.1	4559
1994	61.7	68.1	107.2	69.5	50.8	172.2	266.0	411.2	79.0	40.3	17.7	24.0	1368
1995	46.7	58.2	70.1	192.0	716.7	403.6	394.5	1159.0	693.6	148.5	87.0	60.4	4030
1996	55.9	238.6	1547.8	657.0	653.4	606.9	1016.2	1324.5	510.6	155.1	105.7	72.5	6944
1997	104.7	672.7	678.7	665.4	345.5	309.4	944.4	1166.4	268.0	69.1	72.5	69.7	5367
1998	130.1	149.9	115.3	572.2	215.0	419.4	352.1	771.1	597.6	75.1	61.3	43.0	3502
1999	76.4	201.8	285.6	422.8	171.9	184.6	341.5	1386.8	1505.5	244.4	112.0	73.1	5006
2000	82.5	105.8	138.9	167.6	172.7	246.0	984.7	795.0	237.4	50.7	46.9	39.4	3068

Nannie Creek—at Outlet

Nannie Creek is only 3.5 square miles in area and lies on the west side of the Wood River Valley, just south of Threemile Creek. Only 9 percent of the drainage has been clearcut over the past 25 years. The most significant change to hydrologic processes in the watershed has resulted from alteration of the fire regime. Fire suppression in the Nannie Creek drainage has increased the amount of area with 70-100 percent canopy closure from 2 to 27 percent since 1940. This increase in canopy cover may affect snowmelt runoff, but these effects have yet to be quantified (USDA, 1994).

Since only limited information was available regarding effects to streamflow, a synthetic natural time series was made assuming USGS gaged streamflow measurements were not significantly altered from natural conditions. Instantaneous streamflow measurements were collected by the USGS between August 1964 and October 1967. Monthly total flow estimates were generated by rescaling daily gaged records from Varney Creek, which had similar peaks and baseflow regime as Nannie Creek, and South Fork Rogue River (S.F. Rogue + S.F. Power Canal near Prospect). The FS also estimated baseflow and peak measurements in 1993 (USDA, 1994), but the monthly total estimates developed from these data were not considered accurate enough for use in correlation equation development. These estimates were used only to verify calculated values.

Very few monthly total streamflow estimates could be generated. The monthly flow estimates usable in completing a correlation analysis were restricted to values above zero, since several months had no flow, so only 10 data points (monthly totals) were available for the analyses. Only one general equation was developed to make synthetic time series for Nannie Creek. This equation relates concurrent monthly totals against Cherry Creek data to create a synthetic time series from October 1947 to September 2001.

The quality of the Nannie Creek synthetic time series is obviously lower than other Klamath Lake basin watersheds. The reasons for a lower quality record are:

1. A continuous daily gage record was not available.
2. Very few monthly total flows could be estimated.
3. The estimates made were only for 1964-1967, rather than more than one time period.
4. Month-specific equations could not be determined due to lack of data.

Despite the inability to calibrate these numbers with more accuracy, the monthly total estimates used in correlation exhibit sufficient variability to represent the natural streamflow of Nannie Creek. During the period of record of gaged data, between 1964 and 1967, a complete range of streamflow measurements were observed in Nannie Creek. In December and January 1964, a significant flood event occurred and is apparent in the December 1964 Nannie Creek streamflow measurements. For low flows, Nannie Creek was observed to be dry in September of 1966 and 1967. Intermediately, eight other monthly flow estimates defined the typical flow regime of Nannie Creek. Though the synthetic time series for Nannie Creek (Table B-3) is not based on numerous data points, a representative time series was generated by capturing sufficient variability from the available data.

Table B-3. Nannie Creek synthetic natural streamflow record —Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	0.0	0.0	0.0	0.0	0.0	0.0	69.6	1744.1	45.3	0.0	0.0	0.0	1859
1950	0.0	0.0	0.0	0.0	0.0	10.8	32.7	860.4	194.3	0.8	0.0	0.0	1099
1951	3.5	34.0	117.2	7.9	26.0	0.8	72.3	151.7	27.9	0.0	0.0	0.0	441
1952	0.0	5.9	22.6	0.0	4.3	0.3	99.3	1957.9	864.6	5.7	0.0	0.0	2961
1953	0.0	0.0	0.0	41.0	26.0	0.0	20.1	200.7	1523.0	8.6	0.0	0.0	1819
1954	0.0	24.1	50.5	2.7	16.2	6.9	77.9	171.6	67.1	0.8	0.0	0.0	418
1955	0.0	0.0	0.0	0.0	0.0	0.0	2.9	166.2	130.0	0.0	0.0	0.0	299
1956	0.0	2.5	156.2	48.0	0.0	0.0	58.4	1622.3	185.9	2.7	0.0	0.0	2076
1957	0.0	2.9	53.4	0.0	12.6	43.0	25.9	103.3	15.5	0.0	0.0	0.0	257
1958	0.0	1.7	13.3	8.9	56.8	1.0	24.7	1120.8	124.4	1.0	0.0	0.0	1353
1959	0.0	3.9	0.4	11.7	0.0	1.3	24.8	44.8	8.5	0.0	0.0	0.0	95
1960	0.0	0.0	0.0	0.0	0.0	15.3	38.5	151.3	61.2	0.0	0.0	0.0	266
1961	0.0	0.5	1.5	0.0	24.2	5.9	29.3	134.4	68.2	0.0	0.0	0.0	264
1962	0.0	5.1	6.3	0.0	0.0	0.0	46.2	76.8	25.4	0.0	0.0	0.0	160
1963	0.0	3.9	21.4	0.0	21.9	0.0	13.6	124.4	7.1	0.0	0.0	0.0	192
1964	0.0	11.1	2.0	0.5	0.0	0.0	17.7	139.1	174.5	0.0	0.0	0.0	345
1965	0.0	0.0	3597.5	82.9	24.9	2.2	38.2	92.7	35.6	0.0	0.0	0.0	3874
1966	0.0	0.0	0.0	0.6	0.0	46.1	61.8	72.9	4.0	0.0	0.0	0.0	185
1967	0.0	0.0	0.2	3.2	0.3	0.3	0.0	179.0	132.4	2.4	0.0	0.0	318
1968	0.0	0.0	0.0	0.0	20.1	1.0	0.0	8.7	0.0	0.0	0.0	0.0	30
1969	0.0	4.6	2.2	1.0	0.0	0.0	32.9	1119.2	42.9	0.0	0.0	0.0	1203
1970	0.0	0.0	2.2	73.7	1.7	1.6	0.1	66.3	12.8	0.0	0.0	0.0	158
1971	0.0	15.9	2.3	33.9	4.3	5.7	26.7	1913.1	778.6	4.9	0.0	0.0	2785
1972	0.0	6.4	10.3	21.6	16.8	215.2	39.7	1092.5	155.6	2.2	0.0	0.0	1560
1973	0.0	0.0	3.7	2.3	0.0	0.0	6.6	29.3	0.6	0.0	0.0	0.0	43
1974	0.0	36.7	61.3	63.5	0.1	26.6	46.1	864.5	1791.2	5.1	0.0	0.0	2895
1975	0.0	0.0	1.0	2.0	2.4	6.1	6.0	1594.7	1642.2	4.3	0.0	0.0	3259
1976	0.0	4.5	47.9	9.9	1.0	0.2	14.2	219.3	52.4	0.6	0.0	0.0	350
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.5	0.1	0.0	0.0	0.0	12
1978	0.0	12.0	124.2	5.7	2.0	0.7	2.4	19.4	3.8	0.0	0.0	0.0	170
1979	0.0	0.0	0.0	0.0	0.0	7.0	9.3	103.0	1.7	0.0	0.0	0.0	121
1980	0.0	0.0	2.5	27.7	1.0	0.3	14.0	23.1	2.1	0.0	0.0	0.0	71
1981	0.0	0.0	9.1	0.0	2.9	0.0	0.4	6.9	4.9	0.0	0.0	0.0	24
1982	0.0	6.1	175.0	0.5	37.8	5.5	23.6	234.2	110.0	1.6	0.0	0.0	594
1983	0.0	0.0	42.2	8.2	22.1	27.9	23.5	773.3	117.3	3.9	0.0	0.0	1018
1984	0.0	8.7	84.4	13.1	14.4	28.5	29.4	244.4	799.5	4.3	0.0	0.0	1227
1985	0.0	27.5	2.3	0.0	0.0	0.0	65.2	97.6	39.7	0.0	0.0	0.0	232
1986	0.0	0.0	0.4	7.2	48.7	41.9	6.9	54.2	13.8	0.0	0.0	0.0	173
1987	0.0	2.8	0.0	0.0	4.3	2.1	17.2	21.7	0.0	0.0	0.0	0.0	48
1988	0.0	0.0	0.0	0.0	0.0	0.2	3.1	18.2	11.6	0.0	0.0	0.0	33
1989	0.0	0.0	0.0	0.0	0.0	35.9	100.2	135.0	34.7	0.0	0.0	0.0	306
1990	0.0	0.0	0.0	0.0	0.0	4.0	20.7	16.0	8.1	0.0	0.0	0.0	49
1991	0.0	0.0	0.0	0.4	0.2	2.5	7.6	49.2	8.3	0.0	0.0	0.0	68
1992	0.0	0.0	0.1	0.0	0.0	0.0	0.6	0.4	0.0	0.0	0.0	0.0	1
1993	0.0	1.6	0.0	0.0	0.0	57.8	45.6	1583.4	90.0	2.1	0.0	0.0	1781
1994	0.0	0.0	0.0	0.0	0.0	0.4	12.5	30.0	0.0	0.0	0.0	0.0	43
1995	0.0	0.0	0.0	1.4	57.4	23.4	23.2	186.4	73.6	0.9	0.0	0.0	366
1996	0.0	3.6	852.2	32.8	31.3	27.1	89.0	217.0	27.3	0.0	0.0	0.0	1280
1997	0.0	50.1	51.1	49.0	10.8	11.7	78.0	188.4	9.9	0.0	0.0	0.0	449
1998	0.0	0.0	0.0	35.3	2.4	25.6	19.8	87.0	56.1	0.0	0.0	0.0	226
1999	0.0	1.8	6.4	17.7	0.6	1.1	18.9	810.7	864.4	6.3	0.0	0.0	1728
2000	0.0	0.0	0.0	0.4	0.6	5.6	84.0	98.6	7.1	0.0	0.0	0.0	196

Cherry Creek—at Outlet

The Cherry Creek drainage is 16 square miles in area and lies on the west side of the Wood River Valley, just south of Nannie Creek. The watershed aspect is east-west, and the flow direction is to the west. The original stream split into three main channels atop an alluvial fan below the watershed outlet, which either flowed into Fourmile Creek or directly into downstream wetland areas. Flow is now diverted for irrigation purposes near the watershed outlet or is channelized into Fourmile Canal. More than half of the watershed is protected by the Sky Lakes Wilderness and has been relatively unaltered by land management activities. The remaining area has experienced minimal harvest activity during the last 25 years, and only 1 percent of the entire watershed has been affected by clearcuts (USDA, 1994).

The FS has maintained a daily recording gage on Cherry Creek since October 1992. Unlike other Wood River Valley tributaries, the available gaged data for Cherry Creek were taken in an excellent location, within a constricted valley above the watershed outlet. These data are considered to be highly reliable natural streamflow measurements due to their prime measurement location and the lack of significant upstream land management activities (USDA, 1994).

Instantaneous streamflow measurements were made by the USGS between 1964 and October 1967. Monthly total estimates were generated from these data by rescaling the Varney Creek and South Fork Rogue River (S.F. Rogue + S.F. Power Canal near Prospect) gaged records. The estimates generated from each gage varied slightly, particularly in the late summer and early autumn, mainly because Varney Creek exhibited a lack of surficial baseflow, unlike Cherry Creek and South Fork Rogue River.

The FS also collected streamflow measurements between December 1991 and July 1992. Total monthly flow estimates were made by rescaling the Rogue River above Prospect daily gaged record. This was the only record rescaled because it was the only natural daily flow recorded during that time period near the Wood River Valley. These monthly total flow estimates were combined with the 1960s estimates and gaged records to develop the synthetic time series.

Gaged and estimated monthly totals were used to create a complete synthetic time series for Cherry Creek (Table B-4) between October 1947 and September 2001. The derivation procedure used the same generalized correlation procedure modified for the line of minimum absolute deviation to estimate values between October 1947 and September 1992. This correlation analysis was completed against the Rogue River above Prospect gage on a month-by-month basis. Relatively good correlations were found. Despite having several low r^2 values in the summer months of July and August, trends exhibited in the gaged data are quite prevalent and are reproduced in the synthetic data.

Cherry Creek has geologic features typical of the eastern slopes of the Cascades. The headwaters begin with steep rock escarpments and talus slopes that drain into the Cascade summit, characterized by broad, flat plateaus with abundant kettle lakes and wet meadows. Steep, heavily forested slopes of the lower watershed descend to the lacustrine environment of the UKL Basin (USDA, 1994). The same land-forming processes occurred all along the east side of the Cascade Range; therefore all western Wood River Valley streams are characterized by basaltic lava material overlain by pumice ash deposits. As a result, the complete synthetic time series for Cherry Creek was used to generate synthetic time series for these other watersheds under the following premises:

1. Similar geology and sedimentation leads to similar permeability and water-bearing capacity.

2. Streams on the east side receive less rainfall than the watersheds to the west, where the majority of gaged streamflow data are available, so deriving a quality synthetic record from Cherry Creek is more accurately relatable to other Wood River Valley tributaries than using data from over the ridge.

3. The gaged data available for Cherry Creek are considered highly representative of all the water produced by the Cherry Creek drainage, since the gage location was placed in a constricted, V-notch valley.

4. The synthetic time series for Cherry Creek was used in generating time series for Threemile Creek, Nannie Creek, Rock Creek, and Moss Creek.

Instantaneous streamflow measurements were made by the USGS between 1964 and October 1967. These data are available from the OWRD website, but cross-checking with the original data published by the USGS revealed several errors in the OWRD data. These errors were corrected, and updates related to the other watersheds were made based on the corrected Cherry Creek data.

Table B-4. Cherry Creek synthetic natural streamflow record—Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	596.2	686.2	858.7	531.3	650.6	926.3	3166.5	6977.8	2667.3	749.7	581.3	533.1	18925
1950	609.1	689.5	630.7	908.0	928.7	1623.4	2354.4	5637.1	4920.8	1021.3	654.7	578.8	20557
1951	1233.8	2390.0	3943.3	1487.1	2165.3	1020.3	3217.6	4411.4	2219.5	893.8	701.9	625.3	24309
1952	940.1	1382.3	2060.5	791.0	1287.9	977.1	3674.0	7302.2	5643.5	1373.1	810.7	692.7	26935
1953	702.0	682.2	713.5	2565.4	2166.1	934.8	1979.1	4993.4	6642.4	1524.4	829.1	672.8	24405
1954	744.8	2106.1	2783.4	1181.1	1840.3	1433.9	3318.4	4657.1	3120.5	1023.9	766.8	677.6	23654
1955	718.9	747.7	719.6	634.5	597.4	724.5	1191.4	4591.8	4124.3	814.7	569.4	530.0	15964
1956	613.5	1167.2	4468.3	2726.4	870.8	869.9	2949.1	6793.0	4825.2	1180.3	798.8	680.6	27943
1957	882.5	1192.3	2845.0	724.9	1702.1	2611.8	2161.6	3735.3	1813.6	823.9	653.5	593.9	19740
1958	748.6	1105.9	1729.2	1536.9	2917.0	1045.4	2124.6	6032.1	4045.8	1041.5	744.8	661.9	23734
1959	704.5	1259.6	989.2	1664.0	926.1	1068.7	2129.0	2655.1	1518.7	712.2	582.4	564.5	14774
1960	653.6	604.9	550.9	524.7	945.1	1807.4	2504.2	4405.7	3004.7	704.8	557.7	512.1	16776
1961	557.4	991.3	1089.9	690.8	2109.7	1380.8	2261.3	4183.6	3139.8	759.5	587.9	543.4	18295
1962	666.0	1334.1	1402.9	928.3	897.7	766.0	2686.5	3297.4	2147.3	752.1	601.7	539.2	16019
1963	895.8	1262.4	2021.7	660.0	2038.0	911.3	1742.4	4045.8	1446.2	717.0	575.3	538.5	16854
1964	596.4	1636.3	1128.8	999.6	857.2	774.9	1895.7	4247.1	4692.1	941.3	622.0	555.4	18947
1965	516.1	735.8	9789.8	3405.2	2133.3	1143.4	2495.6	3569.0	2430.1	856.7	789.9	694.7	28560
1966	628.1	719.7	762.6	1006.2	616.1	1395.9	3016.7	3228.6	1268.4	660.7	528.9	518.4	14350
1967	488.7	741.0	970.2	1435.5	1038.5	971.8	868.9	4603.5	3338.6	861.3	583.5	513.9	16415
1968	598.0	563.5	569.8	666.4	1977.1	1039.8	945.0	1527.0	905.9	552.7	509.7	469.0	10324
1969	527.3	1307.2	1141.1	1045.8	627.8	790.6	2358.5	6029.8	2610.8	775.8	565.1	518.7	18299
1970	601.6	591.8	1139.4	3242.9	1106.9	1097.7	958.2	3104.5	1708.0	695.9	569.0	532.1	15348
1971	602.3	1829.9	1151.5	2387.5	1289.7	1373.3	2184.8	7234.2	5512.9	1326.8	802.5	719.8	26415
1972	792.0	1408.0	1602.7	2029.1	1863.8	5150.8	2532.3	5989.2	4461.0	1138.9	826.9	726.0	28521
1973	783.8	877.4	1245.6	1153.8	761.0	856.5	1419.9	2262.2	1007.1	596.5	522.0	529.5	12015
1974	612.0	2458.1	3006.3	3049.6	952.5	2182.8	2684.0	5643.3	7049.3	1336.8	842.4	712.0	30529
1975	779.2	804.0	1047.0	1124.1	1156.5	1394.7	1386.3	6751.2	6823.2	1287.3	767.2	652.9	23974
1976	830.6	1297.7	2726.1	1583.9	1044.8	967.7	1767.0	5194.9	2823.2	1003.7	858.0	665.4	20763
1977	697.8	667.3	574.4	504.3	485.6	548.4	894.4	1655.4	950.0	534.4	477.1	485.5	8475
1978	519.7	1676.3	4043.7	1373.6	1128.5	1013.0	1156.5	1954.6	1254.7	655.5	538.8	542.3	15857
1979	527.5	589.3	779.6	948.1	853.7	1440.6	1557.8	3730.6	1106.7	592.8	499.0	454.0	13080
1980	639.6	948.5	1162.6	2215.5	1043.7	979.6	1756.0	2075.0	1131.9	617.9	507.6	482.3	13560
1981	525.3	707.1	1548.6	666.4	1197.7	761.9	984.1	1438.6	1322.3	585.2	477.7	459.4	10674
1982	553.0	1395.0	4697.5	994.7	2486.7	1358.3	2091.9	5351.1	3836.8	1096.3	700.4	627.7	25189
1983	762.1	900.8	2594.1	1500.7	2045.6	2221.4	2089.7	5505.0	3944.2	1258.8	796.3	658.1	24277
1984	700.9	1525.2	3430.7	1720.9	1773.7	2237.1	2264.1	5454.9	5544.7	1285.3	827.5	708.8	27474
1985	884.7	2208.4	1151.5	819.5	799.1	908.7	3084.3	3647.0	2534.4	765.0	593.6	577.1	17973
1986	736.4	786.3	987.5	1453.4	2743.7	2586.2	1438.9	2861.0	1747.6	681.0	574.8	650.8	17248
1987	827.2	1187.8	850.3	864.7	1286.3	1133.3	1878.1	2032.3	890.3	703.1	511.4	473.2	12638
1988	489.0	512.9	686.8	832.6	846.5	962.7	1207.9	1913.7	1657.3	588.6	475.1	446.7	10620
1989	458.6	790.3	705.0	668.3	660.5	2437.3	3687.1	4192.0	2408.1	763.7	587.8	526.0	17885
1990	586.6	610.1	704.7	860.3	613.2	1270.1	1998.6	1832.5	1498.7	614.0	516.2	472.5	11578
1991	513.4	627.3	593.2	981.8	965.9	1168.2	1473.9	2753.1	1506.5	631.9	492.2	447.5	12155
1992	476.1	728.3	956.6	698.0	901.7	606.8	1005.5	982.5	562.2	575.7	438.0	422.2	8354
1993	469.1	1094.9	755.1	535.7	584.5	2937.4	2673.8	6734.0	3524.7	1138.5	763.6	589.7	21801
1994	715.1	707.2	770.3	633.4	565.3	985.8	1698.6	2279.8	743.3	533.9	471.7	441.7	10546
1995	497.3	513.9	635.7	1075.7	2928.4	2084.8	2079.6	4831.0	3241.0	1037.2	608.2	562.6	20095
1996	584.0	1242.8	5624.7	2357.9	2315.2	2197.1	3506.8	5170.5	2202.3	946.1	702.7	644.3	27494
1997	761.2	2774.2	2795.3	2748.8	1622.9	1664.5	3319.3	4854.6	1583.7	781.5	644.4	634.0	24184
1998	852.9	924.3	799.4	2421.9	1158.4	2152.1	1967.6	3475.1	2901.9	809.3	603.6	536.7	18603
1999	658.3	1110.8	1410.3	1896.2	1003.7	1051.3	1937.9	5561.7	5643.1	1402.3	787.4	646.6	23110
2000	680.5	765.0	884.9	988.2	1006.3	1362.3	3423.4	3663.2	1445.2	669.7	550.9	523.7	15963

Rock Creek—at UKL

The Rock Creek drainage is 16.5 square miles in area and lies on the west side of the Wood River Valley, just south of Cherry Creek. About 33 percent of the watershed is within the Sky Lakes Wilderness, and only 3.6 percent of the watershed has been clearcut. There are no diversions into or out of Rock Creek. The streamflow measured at the outlet is relatively unaffected by land management practices or diversions (USDA, 1994).

The USGS, FS, and OWRD have collected numerous miscellaneous flow measurements on Rock Creek. Similar to other watersheds, the USGS collected instantaneous streamflow measurements between December 1964 and October 1967. These data were previously used to develop monthly total estimates (Hubbard, 1970), but several months were redeveloped by rescaling Varney Creek and South Fork Rogue River daily gages. In the 1990s, OWRD measured streamflow between December 1991 and May 1993, and the FS measured streamflow between December 1991 and May 1997. These measurements were combined to make monthly total streamflow estimates for several months between 1992 and 1997.

The measurement location of the FS (1990s) data is upstream from the USGS (1960s) site. This downstream site is located on an alluvial fan where Rock Creek meets the Klamath Lake Basin. The USGS measurements are most likely to underestimate the yield of the Rock Creek drainage due to the location of the gage measurements and the likelihood some water had gone subsurface at the top of the alluvial fan. Unfortunately, there are no concurrent measurements between these two sites, so further field work would be necessary to adjust the 1960s data to a more natural condition. Consequently, the 1990s estimates were relied on more heavily in the development of natural streamflow correlation equations.

Correlation equations were developed to create a Rock Creek synthetic time series (Table B-5) from October 1947 to September 2001. A general correlation based upon the synthetic natural time series for Cherry Creek was used for most months, but month-specific equations were developed for May through September. Despite being similar to Cherry Creek in size and average precipitation, the Rock Creek drainage produces far less streamflow. The reason for the lower flow levels may be based on slightly different geology and water retention capabilities of the watershed (USDA, 1994).

Table B-5. Rock Creek synthetic natural streamflow record—Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	0.0	0.0	29.3	0.0	0.0	55.2	1054.4	3147.8	751.5	16.7	0.0	0.0	5055
1950	0.0	0.0	0.0	47.5	56.2	349.1	623.8	2032.4	2001.0	157.0	10.2	7.8	5285
1951	246.3	640.0	1430.6	309.7	542.5	101.8	1085.9	1478.2	529.7	73.5	38.2	23.0	6499
1952	61.3	281.9	500.5	9.8	258.8	78.8	1312.2	3417.7	2377.3	338.1	102.7	45.1	8784
1953	0.0	0.0	0.0	723.0	542.9	58.9	469.4	1655.6	2897.6	389.1	113.6	38.6	6889
1954	0.0	518.5	834.9	234.7	419.5	295.3	1149.6	1554.7	1012.8	159.0	76.7	40.1	6296
1955	0.0	0.7	0.0	0.0	0.0	0.0	236.9	1534.6	1586.1	37.3	0.0	0.0	3396
1956	0.0	231.8	1669.6	804.7	33.5	33.1	926.2	2994.1	1951.2	273.0	95.7	41.1	9054
1957	37.7	237.1	868.2	0.0	373.5	746.0	541.0	1255.1	359.8	40.9	9.5	12.7	4482
1958	0.8	155.0	382.2	323.6	908.1	116.3	526.0	2361.0	1545.3	173.1	63.7	35.0	6590
1959	0.0	252.2	85.0	361.5	55.1	130.6	527.7	860.7	254.9	8.4	0.0	3.1	2539
1960	0.0	0.0	0.0	0.0	63.5	408.2	693.3	1476.4	942.5	7.1	0.0	0.0	3591
1961	0.0	86.1	144.3	0.0	520.0	281.5	582.9	1405.1	1024.7	19.3	0.0	0.0	4064
1962	0.0	269.9	287.2	56.0	43.4	4.2	784.0	1100.8	497.3	17.3	0.0	0.0	3060
1963	42.7	252.8	485.5	0.0	491.8	48.9	386.5	1359.8	231.5	9.3	0.0	0.0	3309
1964	0.0	353.0	171.0	90.5	28.8	6.1	438.9	1425.6	1881.8	100.9	0.0	0.0	4497
1965	0.0	0.0	4714.9	1206.0	529.5	226.8	362.8	1197.4	629.5	55.0	90.4	45.7	9058
1966	0.0	0.0	3.5	94.0	0.0	139.7	283.9	288.2	178.2	0.0	0.0	0.0	988
1967	0.0	0.0	75.4	295.7	112.3	76.2	32.8	860.9	1218.3	57.2	0.0	0.0	2729
1968	0.0	0.0	0.0	0.0	468.7	113.0	63.5	399.0	87.1	0.0	0.0	0.0	1131
1969	0.0	263.3	226.3	116.6	0.0	9.7	625.7	2359.1	721.5	24.0	0.0	0.0	4346
1970	0.0	0.0	226.0	1101.7	155.7	149.5	69.6	1030.5	320.4	5.7	0.0	0.0	3059
1971	0.0	415.9	228.5	638.8	259.2	279.6	550.6	3361.2	2309.3	322.4	97.9	54.0	8517
1972	10.0	288.5	342.9	488.4	427.6	1996.9	706.9	2325.3	1761.5	261.7	112.3	56.0	8778
1973	8.1	35.8	249.0	228.9	3.2	28.6	291.6	705.7	110.2	0.0	0.0	0.0	1661
1974	0.0	671.5	959.0	984.3	66.9	549.7	782.7	2037.5	3109.5	325.8	121.5	51.4	9660
1975	7.0	13.0	117.3	167.7	229.5	285.1	282.9	2959.3	2991.7	309.1	76.9	32.0	7472
1976	20.4	261.1	804.6	337.3	116.0	74.2	394.6	1664.5	837.2	143.6	130.8	36.1	4820
1977	0.0	0.0	0.0	0.0	0.0	0.0	42.2	454.1	96.9	0.0	0.0	0.0	593
1978	0.0	365.4	1475.5	279.7	170.8	97.7	229.5	580.0	174.3	0.0	0.0	0.0	3373
1979	0.0	0.0	7.1	64.9	27.6	297.1	329.6	1253.5	134.7	0.0	0.0	0.0	2115
1980	0.0	65.1	230.8	563.4	115.3	80.1	391.0	629.7	141.1	0.0	0.0	0.0	2217
1981	0.0	0.0	327.0	0.0	238.3	3.4	82.4	360.7	193.8	0.0	0.0	0.0	1206
1982	0.0	285.1	1777.5	87.9	685.0	275.8	512.9	1794.4	1436.4	220.7	37.3	23.8	7137
1983	3.4	44.7	737.2	313.4	494.7	565.9	512.0	1922.5	1492.3	299.5	94.2	33.7	6514
1984	0.0	320.3	1222.9	379.6	396.8	572.6	584.1	1880.8	2325.9	308.4	112.7	50.4	8155
1985	38.5	560.4	228.5	17.2	11.8	47.8	1004.8	1224.6	681.9	20.8	0.0	7.2	3844
1986	0.0	8.7	84.1	300.5	813.8	733.3	296.6	939.5	334.9	3.6	0.0	31.4	3546
1987	19.4	236.2	26.5	31.3	258.4	174.2	432.7	612.1	83.7	6.8	0.0	0.0	1881
1988	0.0	0.0	0.0	21.0	25.3	71.8	240.5	563.0	302.2	0.0	0.0	0.0	1224
1989	0.0	9.6	0.0	0.0	0.0	661.8	1317.9	1407.8	618.7	20.4	0.0	0.0	4036
1990	0.0	0.0	0.0	29.8	0.0	254.6	476.8	529.1	248.4	0.0	0.0	0.0	1539
1991	0.0	0.0	0.0	81.2	73.3	232.0	306.0	898.4	250.9	0.0	0.0	0.0	1842
1992	0.0	0.0	68.9	0.0	45.0	0.0	93.6	158.0	22.6	0.0	0.0	0.0	388
1993	0.0	147.6	2.0	0.0	0.0	919.6	1049.4	2945.0	1277.0	261.3	74.8	11.3	6688
1994	0.0	0.0	5.1	0.0	9.0	83.3	372.4	712.8	53.9	0.0	0.0	0.0	1237
1995	0.0	0.0	0.0	135.1	914.5	510.1	508.0	1607.4	1088.5	169.6	0.0	2.5	4936
1996	0.0	248.3	2235.1	625.4	606.4	555.7	895.2	1644.2	618.0	104.0	38.7	29.2	7600
1997	3.2	830.0	841.2	816.5	348.9	361.7	1150.2	1614.5	276.7	25.8	4.1	25.9	6299
1998	27.4	54.3	11.9	654.6	229.9	537.1	465.1	1164.4	882.1	35.3	0.0	0.0	4062
1999	0.0	158.4	289.1	439.1	92.7	119.9	454.2	1969.6	2377.1	347.9	88.9	30.0	6367
2000	0.0	4.0	38.6	84.5	94.1	276.8	1218.1	1230.2	231.2	2.3	0.0	0.0	3180

Moss Creek—at UKL

The Moss Creek watershed is 8.3 square miles in area and drains into Ball Bay of UKL. About 77 percent of this watershed area is protected by the Mountain Lake Wilderness area of the Winema National Forest, and an additional 12 percent is within National Forest boundaries. The remaining 11 percent is most likely privately owned. In comparison to other neighboring watersheds, land management activities and road development in this watershed probably have not significantly affected streamflow, since areas with far less wilderness have been attributed with relatively no effects.

The USGS measured streamflow in Moss Creek occasionally between December 1964 and October 1967, but did not denote whether diversions occurred upstream of this site. There is only one water right in the Moss Creek watershed, and the water right certificate was established for irrigation purposes allowing a maximum of 1.5 cfs to be diverted. The gage record shows Moss Creek going dry in the summer and early fall. This water right probably was not used during these months. Any diversions during snowmelt runoff months would have minimal effect on total monthly flow. Since the majority of the Moss Creek drainage has been unaltered by diversions or land management activities, the few gaged streamflow measurements available are considered natural.

The USGS gaged streamflow measurements between December 1964 and October 1967 were used to develop total monthly streamflow estimates by rescaling Varney Creek and South Fork Rogue River (S.F. Rogue + S.F. Power Canal near Prospect) gaged records. The USGS has developed monthly total flow estimates between October 1964 and September 1967 (Hubbard, 1970). For the other watersheds where estimates had already been developed by the USGS (Rock Creek and Fourmile Creek), the redevelopment completed showed very similar results in the majority of months.

One general equation that accounts for low and high flows was developed and used to generate the synthetic time series for Moss Creek. Sufficient data were not available to create month-specific equations. A season-specific equation was attempted to account for spring runoff, but no further calibration was found from this equation.

The inadequacies of this time series are analogous to those of Nannie Creek. Despite the inability to calibrate these numbers with more accuracy, the monthly total estimates used for correlations exhibit sufficient variability to represent natural streamflow in Moss Creek. The occurrence of a significant flood event and observations of Moss Creek being dry represent the full extent of streamflow variation expected in a 50-year period. Thus, even though the synthetic time series for Moss Creek was not based on numerous data points, a representative time series (Table B-6) was generated by capturing sufficient variability.

Table B-6. Moss Creek synthetic natural streamflow record—Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	0.0	0.0	13.2	0.0	0.0	18.8	447.3	958.1	249.5	4.4	0.0	0.0	1691
1950	0.0	0.0	0.0	17.3	19.0	81.9	158.5	838.8	775.0	26.8	0.0	0.0	1917
1951	45.4	162.5	688.0	68.8	137.6	26.7	470.8	729.7	143.5	16.1	0.6	0.0	2490
1952	19.9	59.0	126.4	7.7	50.3	23.1	664.1	987.0	839.3	58.1	9.3	0.0	2844
1953	0.6	0.0	1.5	216.2	137.7	19.5	117.8	781.5	928.2	72.3	10.8	0.0	2286
1954	4.0	131.3	290.4	40.7	103.5	63.8	518.9	751.6	426.7	27.0	5.7	0.0	2364
1955	1.9	4.2	2.0	0.0	0.0	2.3	41.6	745.7	704.1	9.6	0.0	0.0	1511
1956	0.0	39.5	734.7	269.9	14.2	14.1	354.1	941.6	766.5	40.7	8.3	0.0	3184
1957	15.2	41.7	313.4	2.4	89.6	231.1	137.2	669.5	100.8	10.3	0.0	0.0	1611
1958	4.3	34.1	92.3	73.5	341.3	28.9	133.2	873.9	697.1	28.5	4.0	0.0	2311
1959	0.8	47.7	24.1	85.8	18.8	30.9	133.7	245.4	71.8	1.4	0.0	0.0	660
1960	0.0	0.0	0.0	0.0	20.4	100.1	197.3	729.2	376.9	0.8	0.0	0.0	1425
1961	0.0	24.3	32.7	0.0	131.6	58.8	148.1	709.4	435.3	5.1	0.0	0.0	1545
1962	0.0	54.5	60.9	19.0	16.4	5.7	256.1	508.6	135.7	4.5	0.0	0.0	1061
1963	16.3	48.0	122.3	0.0	124.0	17.5	93.6	697.1	64.9	1.7	0.0	0.0	1185
1964	0.0	83.1	36.1	25.0	13.1	6.4	109.2	715.1	754.7	20.0	0.0	0.0	1763
1965	0.0	3.2	1208.4	371.3	164.0	80.5	174.5	654.7	393.8	13.0	0.0	0.0	3063
1966	0.0	2.0	14.0	25.5	0.0	84.0	77.0	89.0	48.5	0.0	0.0	0.0	340
1967	0.0	3.7	22.5	63.9	28.3	22.6	41.9	328.0	577.1	29.0	0.0	0.0	1117
1968	0.0	0.0	0.0	0.0	117.6	28.4	20.4	72.6	17.1	0.0	0.0	0.0	256
1969	0.0	52.1	37.2	28.9	0.0	7.6	158.9	873.7	230.7	6.4	0.0	0.0	1396
1970	0.0	0.0	37.0	482.6	34.2	33.4	21.5	419.6	90.2	0.1	0.0	0.0	1119
1971	0.0	102.4	38.1	162.2	50.5	58.1	139.7	980.9	827.7	53.8	8.6	2.0	2424
1972	7.8	61.3	79.9	123.1	105.9	795.5	205.9	870.1	734.1	37.0	10.6	2.5	3034
1973	7.1	14.7	46.5	38.3	5.3	13.0	62.5	148.2	25.6	0.0	0.0	0.0	361
1974	0.0	170.2	377.6	395.8	21.0	139.5	255.2	839.3	964.5	54.8	11.9	1.3	3231
1975	6.7	8.7	29.0	35.7	38.5	60.1	59.3	937.9	944.3	50.2	5.8	0.0	2176
1976	10.9	51.2	269.8	78.0	28.8	22.3	96.1	799.4	305.1	25.3	13.1	0.0	1700
1977	0.2	0.0	0.0	0.0	0.0	0.0	16.1	85.0	20.8	0.0	0.0	0.0	122
1978	0.0	87.1	697.0	58.2	36.1	26.1	38.5	115.3	47.3	0.0	0.0	0.0	1106
1979	0.0	0.0	6.8	20.6	12.8	64.4	75.5	669.1	34.2	0.0	0.0	0.0	883
1980	0.0	20.6	39.1	143.1	28.7	23.3	95.0	127.9	36.4	0.0	0.0	0.0	514
1981	0.0	1.0	74.6	0.0	42.2	5.3	23.7	64.2	53.4	0.0	0.0	0.0	264
1982	0.0	60.1	755.1	24.5	173.5	56.7	129.7	813.3	678.5	33.3	0.4	0.0	2725
1983	5.3	16.7	225.3	70.1	124.8	143.7	129.5	827.0	688.1	47.7	8.1	0.0	2286
1984	0.5	72.4	642.4	91.5	96.8	145.5	148.4	822.6	830.5	50.1	10.6	1.1	2912
1985	15.3	142.3	38.1	10.0	8.3	17.3	410.8	661.7	206.5	5.6	0.0	0.0	1516
1986	3.3	7.3	23.9	65.6	276.1	222.8	64.2	319.5	94.1	0.0	0.0	0.0	1077
1987	10.6	41.3	12.5	13.7	50.2	36.5	107.3	123.4	15.8	0.6	0.0	0.0	412
1988	0.0	0.0	0.0	11.1	12.2	21.8	43.1	111.0	85.2	0.0	0.0	0.0	284
1989	0.0	7.6	0.8	0.0	0.0	167.8	665.2	710.2	164.5	5.5	0.0	0.0	1722
1990	0.0	0.0	0.8	13.3	0.0	48.7	119.9	102.7	69.9	0.0	0.0	0.0	355
1991	0.0	0.0	0.0	23.5	22.1	39.6	67.5	279.4	70.6	0.0	0.0	0.0	503
1992	0.0	2.6	21.3	0.2	16.7	0.0	25.5	23.5	0.0	0.0	0.0	0.0	90
1993	0.0	33.2	4.8	0.0	0.0	349.4	251.7	936.4	650.8	37.0	5.5	0.0	2269
1994	1.6	1.0	6.0	0.0	0.0	23.8	89.3	150.2	3.8	0.0	0.0	0.0	276
1995	0.0	0.0	0.0	31.5	345.8	129.0	128.4	767.0	481.7	28.2	0.0	0.0	1912
1996	0.0	46.2	837.7	158.9	154.1	141.1	649.2	797.2	141.7	20.4	0.6	0.0	2947
1997	5.3	287.0	294.8	277.9	81.8	85.9	519.3	769.1	78.0	6.9	0.0	0.0	2406
1998	12.7	18.6	8.4	166.1	38.7	136.2	116.6	646.4	335.3	9.2	0.0	0.0	1488
1999	0.0	34.5	61.6	109.2	25.3	29.4	113.5	832.1	839.3	60.8	7.4	0.0	2113
2000	0.0	5.6	15.3	24.0	25.5	57.1	641.8	663.1	64.8	0.0	0.0	0.0	1497

Site-Specific Reconstruction Processes

Some watersheds in the Wood River Valley basin have unique geology or the dominant flow regime is driven by winter rain instead of snow runoff. The standard methodology for developing a natural time series is inadequate for such watersheds. The presence of diversions or a dam also required additional work beyond the standard methodology. Each of these situations necessitated the need for site-specific methodologies.

Estimated runoff in watersheds that had unique geology; i.e., Annie and Sun Creeks, were developed using streamflow along with precipitation data. Denny Creek was developed in a similar fashion since the flow regime is dominated by winter precipitation rather than snowmelt runoff, unlike most Wood River Valley basins. Some streams are highly dependent on spring flow instead of being dominated by surface water runoff. Groundwater contributions to Wood River, Crooked Creek, and Fort Creek were developed through comparisons to Fall River in the Deschutes River basin, which is also dominated by spring flow releases. Finally, the Fourmile Creek natural time series was developed by removing the estimated effects of Fourmile Dam on the available streamflow measurements before proceeding with a more standard process as previously described. A detailed description of each uniquely addressed watershed follows.

Annie Creek—at Gage South of Crater Lake National Park / Winema National Forest Boundary

The geology of the Cascade Range varies within the Wood River Valley. Between 4,000 and 7,000 years ago, collapse of Mount Mazama formed the current day caldera of Crater Lake. The pre-collapse elevation of Mount Mazama was likely more than 12,000 feet above sea level. The steep slopes of Crater Lake show abundant evidence of large glaciers, particularly on the south side. The south valleys are U-shaped and have the smooth parallel sides characteristic of glacial channels. During the final eruptions of Mount Mazama, glowing pumice and scoria lava flowed down the south side into the Annie Creek and Sun Creek drainages (Frank et al, 1969; Williams, 1956). Because the geology of these watersheds is uniquely different compared to the other Wood River Valley drainages, the standard process for quantifying natural streamflows was inadequate.

The Annie Creek drainage is 28.5 square miles in area and drains south, with headwaters located on the south side of Crater Lake. The streamflow hydrograph for Annie Creek is characterized by spring-fed flow in the autumn and winter and snowmelt runoff driven spring and summer time flows. The spring flow dominating this watershed may even have originated in Crater Lake. The extended period of record for Annie Spring, near the Crater Lake National Park Headquarters, was invaluable in developing a synthetic time series for Annie Creek.

The USGS has collected streamflow gaged records at Annie Spring since June 1977. Similarly, the FS has maintained a gage at the National Park/National Forest boundary since October 1993. Some water is diverted above this gage for residential uses, and these diversions are quantified and available in the USGS Water Resources Data Publications for Oregon. From the available gaged data, a natural synthetic time series was initiated for Annie Creek by performing month-specific linear correlation analyses that had been modified for the line of minimum absolute deviation or a generally similar fitted line.

These month-specific correlations were created between Annie Creek data and the naturalized Annie Spring data. The Annie Creek data were not naturalized, per se, before correlating with Annie Spring, but the upstream diversions were expected to have inconsequential effect on the Annie Creek gage, which represents flow resulting from a large drainage area. There are no other diversions above the Annie Creek gage location, as the intermediary land is part of Crater Lake National Park. The relationships developed for most months exhibited R^2 values around 0.90, with March and November exhibiting R^2 values around 0.60. This correlation analysis extended the Annie Creek record back to June 1977, but estimates needed to be made back to 1947.

Several techniques were attempted to develop the earlier years. Relationships between Annie Spring and Annie Creek data with other nearby gages unfortunately exhibited no correlation. Near the crest of Crater Lake within the Annie Creek drainage, the U.S. Department of the Interior National Park Service (NPS) has collected extensive temperature and precipitation data at the Crater Lake National Park Headquarters. The Crater Lake temperature and precipitation gage data extends beyond 1946 and were used to develop the early years of the synthetic time series for Annie Creek. Correlations were completed against Annie Creek monthly streamflow totals. Even though the Annie Creek record was extended back to 1977, the 1977-1992 streamflow estimates were not considered sufficiently accurate to be used in correlations against weather data. Annie Creek gaged streamflow data were obtained for water year 2002 and were included in the remaining correlation analyses. Therefore, 10 years of gaged streamflow data were available for developing the initial years of the time series.

Crater Lake temperature data showed definite trends as to which month the peak spring runoff had occurred. The peak runoff month for 1948-1976 was determined by employing a monthly average temperature rule. This rule generally defined the month with the largest spring runoff as being the second spring month with average temperature above 33 ºF, with a few exceptions. This rule provided the backbone for estimating the early years, when coupled with the ability to estimate total discharge in the peak month.

The available weather data were used to develop peak monthly total flow for 1948-1976. A good relationship (R^2 value of 0.98) was found between lagged total winter precipitation and total streamflow in the peak runoff month. Total winter precipitation was defined as total precipitation between the months when average temperature fell below 33 ºF through the peak runoff month. The winter precipitation totals were lagged over 5 years, since the flow in Annie Creek is not directly related to only the previous winter. The accumulation of snow and rain in Crater Lake recharges groundwater aquifers, which provide streamflow to Annie Creek. The movement of subsurface water can be quite slow, depending on the regional geology, and can affect groundwater discharge to the surface for several years. The lagging of winter precipitation totals mimics the combination of direct snowmelt runoff from that winter's total precipitation plus the reappearance of groundwater in Annie Creek.

The baseflow months of Annie Creek are very distinctive. Streamflow in the late summer and early autumn months declined at a similar rate every year. Since incidental streamflow measurements in August, September, and early October were available for 1949 through 1973, the baseflow level could be estimated for each year.

With the peak runoff and baseflow estimates, the intermediate months could be estimated. Month-to-month correlations were developed where the flow in one month could define the total flow in the following month when combined with precipitation data. Equations were developed to generally define the following month, where relationships between gaged flows and precipitation qualified whether a month-to-month discharge equation or a precipitation driven equation is used to estimate monthly total flow. Precipitation driven equations were used mostly in the autumn months, before the average monthly temperature fell below 33 ºF, and were not employed in sub-freezing months. Of course, rain-on-snow events occur in the region and needed to be addressed.

A significant flood event occurred December 24, 1996, to January 3, 1997, during which the FS maintained a daily recording stream gage. Assuming the gage did not malfunction, which does not seem likely from the peaking evident in gaged daily streamflow data, then apparently Annie Creek does not experience as severe floods as observed elsewhere. Large increases in monthly total flow that were observed by nearby gages were not seen in the Annie Creek gage. The Rogue River above Prospect monthly total flow increased 189 percent from November to December in 1996. Similarly, the Sevenmile Creek near Fort Klamath total monthly flow increase by 129 percent. The total monthly flow in Annie Creek fell by about 1 percent between November and December 1996. Flows in Annie Creek generated by this winter storm were within normal winter streamflow variation and did not exceed typical peaks of spring runoff flows. Despite the similarly shaped daily streamflow hydrographs, the effect of this rain-on-snow event on Annie Creek monthly total streamflow was minimal compared to other nearby watersheds.

The winter storm of December 29, 1995, to January 1, 1996, was also captured by Annie Creek streamflow records. Monthly total streamflow increased from November to December in the Rogue River above prospect and Sevenmile Creek near Fort Klamath gaged records by 317 percent and 318 percent, respectively. Annie Creek experienced a 165 percent increase in monthly total flow. The effects of this storm on Annie Creek are more prevalent than those from the December 1996 event, but estimating these effects without streamflow measurements would be highly data intensive and not necessarily accurate. Antecedent snow pack conditions would need to be known, along with the precipitation type (rain or snow) and snow-line elevation of each storm to attempt incorporating the dramatic effects of winter storms. Therefore, the effects of rain-on-snow events were not incorporated into the monthly synthetic time series, with one exception.

The effects of the December 1964 storm were included in the Annie Creek synthetic record. Monthly total estimates were developed for this storm by comparing the effects of the December 1995 storm on the Rogue River above Prospect gaged record and the Annie Creek record. This particular storm was estimated and included because of the large effect this storm had on streamflow across the Wood River Valley. Inclusion of these estimates was an attempt to further calibrate the synthetic time series for Annie Creek.

Additional instantaneous streamflow measurements were available to estimate streamflow between May 1991 and September 1992. Work related to a report on water quality of Wood River subbasins (Hathaway et al, 1993; Hathaway, 2003) provided streamflow measurements in Annie and Sun Creek. The USGS also collected several instantaneous flow measurements at the same Annie Creek location during that time period. When these measurements were combined, streamflow had been measured at least once a month between May and October 1991 and between March and November 1992. The estimates found using these miscellaneous flow measurements were highly similar to those found using the correlations against Annie Spring. The monthly total estimates generated from miscellaneous flow measurements were considered more accurate than the Annie Spring generated estimates and thus were used in the final synthetic file.

Development of the natural synthetic time series for Annie Creek took extensive time to gather available data and complete correlation analyses. Also, all data used in this development were measured within the Annie Creek basin. In the end, the natural synthetic record for Annie Creek (Table B-7) is believed to be sufficiently representative, despite the inability to predict the effects of rain-on-snow events. This synthetic record provided the basis for the Sun Creek watershed, located immediately to the east, and was used with ample confidence in its reliability.

Table B-7. Annie Creek synthetic natural streamflow record —Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	3101.2	2596.3	2694.3	2319.3	2117.5	2824.8	3008.8	6875.9	7538.4	5243.5	4165.0	3101.7	45587
1950	3192.2	2605.0	2423.1	2545.9	2254.4	2938.4	3153.7	7098.8	7604.2	7301.2	4923.7	3709.1	49750
1951	3815.6	5986.8	4728.5	3265.9	2689.3	3299.3	3614.0	6079.9	6691.1	6413.6	5378.4	4064.4	56027
1952	5539.0	4033.7	3575.5	2371.4	2149.0	2851.0	3042.1	6388.9	8479.8	10871.6	4496.1	4065.8	57864
1953	3850.9	2585.5	2531.4	4572.6	3478.5	3954.2	4449.3	6563.7	11551.3	8780.0	5408.1	4082.2	61808
1954	4154.9	5436.5	4018.2	2895.0	2465.3	3113.4	3376.9	6284.1	8370.1	7327.6	6665.9	4570.1	58678
1955	3778.6	2752.6	2538.8	2554.1	2259.4	2942.5	2879.0	6229.8	10212.4	5207.6	4000.9	3065.4	48421
1956	2963.8	3616.8	5050.0	4767.8	3596.4	3320.4	3640.9	8591.1	11498.5	8915.1	5485.8	4599.1	66046
1957	5130.6	3665.5	4208.2	4165.2	3232.5	3750.0	4188.9	5517.8	5832.4	5299.5	4911.9	3757.5	53660
1958	4181.3	3498.1	3372.3	3326.1	2725.7	2710.6	2863.1	7427.1	10068.3	7506.5	5781.9	4418.3	57879
1959	4320.1	3795.8	2821.3	3480.2	2818.7	3406.7	3751.0	4620.0	5130.6	4220.9	4151.9	3452.0	45969
1960	2833.5	2365.3	2301.9	2378.9	2153.5	2854.7	3046.9	6075.1	8157.6	7536.9	3861.3	2850.4	46416
1961	2943.5	3275.9	2910.7	2202.3	2046.9	2766.2	2934.0	5890.6	8405.5	4673.7	4214.8	3264.8	45529
1962	3595.6	3940.2	3154.6	2574.3	2271.6	2952.6	3171.8	5153.9	6545.7	4602.7	4032.5	3223.2	45219
1963	5224.8	3801.4	3551.8	3042.2	2554.2	3187.2	3123.7	5776.0	4958.9	4267.0	4069.9	3130.0	46687
1964	3102.3	4526.0	2943.5	2670.2	2329.5	3000.7	3233.1	5943.3	5228.7	6489.4	4587.7	3506.8	47561
1965	2855.2	2807.3	7165.5	4979.2	5490.7	5962.9	7027.0	5210.5	6435.5	5632.3	5246.3	3830.9	62643
1966	3494.3	2804.2	2485.0	2543.2	2252.8	2937.1	3152.0	5573.3	6466.7	3966.9	3548.6	3207.3	42431
1967	2770.8	3733.3	3238.0	2688.9	2340.8	3010.1	2946.6	6625.0	7888.9	4325.4	3562.3	3260.9	46391
1968	3113.5	2233.3	2332.6	2400.9	2166.8	2865.7	3061.0	3320.6	3302.6	3754.9	3099.5	2277.9	33929
1969	2613.2	3888.2	2953.7	2729.5	2365.3	3030.4	3271.1	7425.2	7434.8	4829.5	3949.8	3493.9	47985
1970	3139.4	2324.8	2952.3	5393.8	3974.5	4365.8	4302.3	4993.5	6470.3	4065.4	3996.1	3191.5	49170
1971	3144.6	4901.4	2962.2	4357.0	3348.3	3846.1	3782.6	4985.9	8760.7	10402.2	6341.7	3990.3	60823
1972	4489.5	4083.6	3291.4	3922.7	3086.0	3628.5	3565.0	7391.4	10830.3	8495.3	6066.5	5038.0	63888
1973	4431.4	3046.6	3037.4	2861.9	2445.3	3096.8	3355.7	4293.4	3656.7	3115.0	3150.0	2825.5	39316
1974	3212.7	6118.9	4154.7	5159.5	3833.0	4248.3	4184.8	7104.0	12738.8	10502.9	7504.1	4902.4	73664
1975	4398.3	2885.4	2873.4	2825.9	2423.5	3078.7	3015.2	6878.7	9129.9	10000.7	4908.4	4331.3	56750
1976	4762.9	3869.7	3983.1	3383.2	2760.1	3358.1	3294.6	6731.2	7824.6	7123.3	4097.8	4452.5	55641
1977	3210.0	2883.5	2725.5	2701.2	2348.2	3016.3	3253.0	2668.7	3060.4	2343.1	2258.0	2077.6	32546
1978	1862.0	1733.4	6135.9	4127.3	3000.8	3279.3	4196.0	5455.3	7904.7	6372.0	4282.8	3617.0	51966
1979	3058.4	2807.7	2830.4	2961.2	2475.8	2965.7	3014.4	5941.8	6517.1	4482.2	3442.6	3083.2	43581
1980	2847.0	3031.0	3251.4	3347.6	2822.1	3134.4	3299.8	6663.7	5968.1	5292.3	4193.5	3446.5	47297
1981	3178.2	2935.3	3141.4	3542.5	2931.0	3573.4	3688.1	5204.2	4641.5	3867.8	3009.7	2846.0	42559
1982	2807.1	2879.4	4629.1	3794.8	3273.1	3984.3	3613.4	6004.6	10985.0	9595.0	5912.3	4224.8	61703
1983	3976.3	3953.7	3935.4	3347.6	2735.5	3118.1	3110.0	4827.5	10207.3	9618.2	7083.5	4921.7	60835
1984	4874.1	4777.9	4629.1	3943.8	3608.3	3768.1	4016.8	5471.0	9414.4	11844.2	6243.3	4654.8	67246
1985	4714.5	4804.5	4318.1	3450.8	2840.2	3303.1	4166.2	5832.0	8438.5	5792.3	4219.1	3735.6	55615
1986	3816.6	3581.4	3100.7	3106.8	2628.0	4222.3	4644.2	5643.6	12281.2	5722.8	3900.9	3409.4	56058
1987	3497.4	3554.8	3457.1	3137.8	2520.5	2970.0	3488.0	8233.1	5480.1	3728.7	2997.0	2619.2	45684
1988	2563.6	2347.7	2421.5	2713.6	2207.7	2839.1	3416.3	4702.0	5678.4	4482.2	3302.5	2831.2	39506
1989	2661.4	2446.0	2194.2	2609.2	2030.3	2601.2	3822.6	7134.6	8362.2	6545.9	4524.7	3646.6	48579
1990	4016.2	4458.9	4126.8	3301.8	2521.9	2779.7	3613.4	6334.2	5327.6	3867.8	2997.0	2601.4	45947
1991	2491.8	2281.2	2043.6	2547.3	2008.0	2643.4	2506.6	4309.8	4127.2	3500.6	2777.0	2406.4	33643
1992	2541.7	2270.6	2529.1	2782.4	2225.8	2659.6	2912.1	3996.0	2838.3	2802.4	2532.5	2181.5	32272
1993	2118.5	2169.0	1759.8	2458.1	1957.2	2879.0	2935.2	6426.7	8413.6	6687.3	4414.4	3500.0	45719
1994	3356.5	2913.9	2798.3	2421.3	1990.4	2658.8	2969.6	4174.5	3019.8	2512.9	2253.1	2169.4	33239
1995	2338.5	2138.2	2134.2	2310.8	2025.2	2868.1	2933.6	5089.7	7089.0	6718.1	4032.5	3223.2	42901
1996	2891.9	2874.1	4752.5	4661.2	4613.6	4012.6	4728.7	7446.1	8590.5	6069.5	4776.3	4121.7	59539
1997	4186.6	5168.1	5154.8	5780.5	4050.2	4398.5	4985.1	9187.6	9437.2	6393.5	5053.5	4211.3	68007
1998	4322.0	3891.6	3732.9	3707.2	2963.3	3669.5	3903.5	6351.2	9699.3	8717.5	5319.7	4470.8	60749
1999	4026.5	3982.9	3691.3	3570.3	3024.8	3005.0	3205.3	5389.2	10107.9	10284.4	6305.5	4556.1	61149
2000	4422.7	4066.6	3856.4	3672.3	3200.0	3287.4	4491.3	6293.7	7682.9	5127.3	4084.9	3598.4	53784

Sun Creek—at Crater Lake National Park/ Sun Pass State Forest Boundary

All land upstream of the gage location on Sun Creek is protected wilderness within Crater Lake National Park. There are no diversions from the stream within the park, and the contributing drainage area for the gage is 11.1 square miles. The same glacial and volcanic processes that formed the geology of Annie Creek occurred in Sun Creek. Due to the similar geology, the streamflow hydrograph that occurs in Sun Creek is likely to be more similar to Annie Creek than any other stream. Hence, the Annie Creek synthetic time series provided the basis for the estimated natural streamflow of Sun Creek (Table B-8).

Very little streamflow information is available for Sun Creek. Hathaway and Todd (1993) collected several years of miscellaneous streamflow measurements on Annie Creek and Sun Creek. From the concurrent measurements at the most upstream and natural sites, the flow in Sun Creek was estimated to be about 25 percent of the magnitude of Annie Creek flow. Total monthly streamflow estimates were generated for May -October 1991 and March - November 1992. In most cases, these estimates were used in place of the estimates generated by rescaling the synthetic time series for Annie Creek, since these estimates were considered more accurate due to their basis of actual gaged Sun Creek data.

Table B-8. Sun Creek synthetic natural streamflow record—Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	780.6	653.6	678.2	583.8	533.0	711.1	757.4	1730.8	1897.6	1319.9	1048.4	780.8	11475
1950	803.6	655.7	610.0	640.9	567.5	739.7	793.9	1786.9	1914.2	1837.9	1239.4	933.7	12523
1951	960.5	1507.0	1190.3	822.1	677.0	830.5	909.7	1530.5	1684.3	1614.5	1353.9	1023.1	14103
1952	1394.3	1015.4	900.0	596.9	541.0	717.7	765.8	1608.2	2134.6	2736.6	1131.8	1023.5	14566
1953	969.4	650.8	637.2	1151.0	875.6	995.4	1120.0	1652.2	2907.7	2210.1	1361.3	1027.6	15558
1954	1045.9	1368.5	1011.5	728.7	620.6	783.7	850.0	1581.9	2107.0	1844.5	1678.0	1150.4	14771
1955	951.2	692.9	639.1	642.9	568.7	740.7	724.7	1568.2	2570.7	1310.9	1007.1	771.6	12189
1956	746.1	910.4	1271.2	1200.2	905.3	835.8	916.5	2162.6	2894.4	2244.1	1380.9	1157.7	16625
1957	1291.5	922.7	1059.3	1048.5	813.7	944.0	1054.4	1389.0	1468.2	1334.0	1236.4	945.9	13508
1958	1052.5	880.6	848.9	837.3	686.1	682.3	720.7	1869.6	2534.4	1889.6	1455.4	1112.2	14570
1959	1087.5	955.5	710.2	876.0	709.5	857.5	944.2	1163.0	1291.5	1062.5	1045.1	869.0	11572
1960	713.3	595.4	579.4	598.8	542.1	718.6	767.0	1529.2	2053.5	1897.2	972.0	717.5	11684
1961	741.0	824.6	732.7	554.4	515.2	696.3	738.6	1482.8	2115.9	1176.5	1061.0	821.8	11461
1962	905.1	991.8	794.1	648.0	571.8	743.3	798.4	1297.4	1647.7	1158.6	1015.1	811.4	11383
1963	1315.2	956.9	894.1	765.8	643.0	802.3	786.3	1454.0	1248.3	1074.1	1024.5	787.9	11752
1964	780.9	1139.3	740.9	672.2	586.4	755.4	813.9	1496.1	1316.2	1633.5	1154.8	882.8	11972
1965	718.7	706.7	1803.7	1253.4	1382.1	1501.0	1768.9	1311.6	1620.0	1417.8	1320.6	964.3	15769
1966	879.6	705.9	625.5	640.2	567.1	739.3	793.4	1402.9	1627.8	998.6	893.3	807.4	10681
1967	697.5	939.8	815.1	676.9	589.2	757.7	741.7	1667.7	1985.8	1088.8	896.7	820.8	11678
1968	783.7	562.2	587.2	604.4	545.4	721.4	770.5	835.9	831.3	945.2	780.2	573.4	8541
1969	657.8	978.8	743.5	687.1	595.4	762.8	823.4	1869.1	1871.5	1215.7	994.3	879.5	12079
1970	790.3	585.2	743.2	1357.7	1000.5	1099.0	1083.0	1257.0	1628.7	1023.4	1005.9	803.4	12377
1971	791.6	1233.8	745.7	1096.8	842.9	968.2	952.2	1255.1	2205.3	2618.5	1596.3	1004.5	15311
1972	1130.1	1027.9	828.5	987.4	776.8	913.4	897.4	1860.6	2726.2	2138.5	1527.1	1268.2	16082
1973	1115.5	766.9	764.6	720.4	615.5	779.5	844.7	1080.8	920.5	784.1	792.9	711.2	9897
1974	808.7	1540.3	1045.8	1298.8	964.9	1069.4	1053.4	1788.2	3206.7	2643.8	1889.0	1234.1	18543
1975	1107.2	726.3	723.3	711.3	610.1	775.0	759.0	1731.5	2298.2	2517.4	1235.6	1090.3	14285
1976	1198.9	974.1	1002.6	851.6	694.8	845.3	829.3	1694.4	1969.6	1793.1	1031.5	1120.8	14006
1977	808.0	725.8	686.1	680.0	591.1	759.3	818.9	671.8	770.4	589.8	568.4	523.0	8192
1978	468.7	436.3	1544.6	1038.9	755.4	825.5	1056.2	1373.2	1989.8	1604.0	1078.1	910.5	13081
1979	769.9	706.8	712.5	745.4	623.2	746.5	758.8	1495.7	1640.5	1128.3	866.6	776.1	10970
1980	716.7	763.0	818.5	842.7	710.4	789.0	830.6	1677.4	1502.3	1332.2	1055.6	867.6	11906
1981	800.0	738.9	790.8	891.7	737.8	899.5	928.4	1310.0	1168.4	973.6	757.6	716.4	10713
1982	706.6	724.8	1165.3	955.2	823.9	1002.9	909.6	1511.5	2765.2	2415.3	1488.3	1063.5	15532
1983	1000.9	995.2	990.6	842.7	688.6	784.9	782.9	1215.2	2569.4	2421.1	1783.1	1238.9	15314
1984	1226.9	1202.7	1165.3	992.7	908.3	948.5	1011.1	1377.2	2369.8	2981.5	1571.6	1171.7	16927
1985	1186.8	1209.4	1087.0	868.6	714.9	831.5	1048.7	1468.1	2124.2	1458.1	1062.0	940.3	14000
1986	960.7	901.5	780.5	782.1	661.5	1062.9	1169.1	1420.6	3091.5	1440.6	982.0	858.2	14111
1987	880.4	894.8	870.2	789.9	634.5	747.6	878.0	2072.5	1379.5	938.6	754.4	659.3	11500
1988	645.3	591.0	609.5	683.1	555.7	714.7	860.0	1183.6	1429.4	1128.3	831.3	712.7	9945
1989	669.9	615.7	552.3	656.8	511.1	654.8	962.2	1796.0	2105.0	1647.8	1139.0	917.9	12228
1990	1011.0	1122.4	1038.8	831.1	634.8	699.7	909.6	1594.5	1341.1	973.6	754.4	654.8	11566
1991	627.2	574.2	514.4	641.2	505.5	665.4	631.0	1276.7	1061.7	776.2	800.0	706.4	8780
1992	632.8	571.6	636.6	700.4	560.3	669.5	733.0	1100.5	714.5	737.5	694.8	621.3	8373
1993	531.5	554.8	443.0	618.8	492.7	724.7	738.9	1617.8	2117.9	1683.4	1111.2	881.0	11516
1994	844.9	733.5	704.4	609.5	501.0	669.3	747.5	1050.8	760.2	632.6	567.2	546.1	8367
1995	588.7	538.2	537.2	581.7	509.8	722.0	738.5	1281.2	1784.5	1691.1	1015.1	811.4	10799
1996	728.0	723.5	1196.3	1173.3	1161.4	1010.1	1190.3	1874.4	2162.4	1527.8	1202.3	1037.5	14987
1997	1053.9	1300.9	1297.6	1455.1	1019.5	1107.2	1254.9	2312.7	2375.6	1609.4	1272.1	1060.1	17119
1998	1088.0	979.6	939.7	933.2	745.9	923.7	982.6	1598.7	2441.5	2194.4	1339.1	1125.4	15292
1999	1013.6	1002.6	929.2	898.7	761.4	756.4	806.9	1356.6	2544.4	2588.8	1587.2	1146.9	15393
2000	1113.3	1023.7	970.7	924.4	805.5	827.5	1130.6	1584.3	1934.0	1290.7	1028.3	905.8	13539

Denny Creek—at UKL

Denny Creek is located near the south end of UKL and flows into Ball Bay. The watershed drains approximately 51 square miles and contains Aspen Lake. Only 17 percent of this watershed is within FS land, with the majority within the Mountain Lakes Wilderness area. The remaining watershed area seems to be privately owned. Despite similarities in geology between Denny Creek and adjacent watersheds, Denny Creek differs from most Wood River Valley watersheds in that the flow regime is not dominated by snowmelt runoff.

The streamflow hydrograph for Denny Creek is driven by the release of water from springs and winter precipitation, as seen in the peaking during winter months. Less snow accumulates in the headwaters of Denny Creek due to lower elevations. Because of this different flow regime, generating the synthetic natural time series for Denny Creek from a streamflow gage that was driven by snowmelt runoff was considered inappropriate. Streamflow gages for the area were analyzed for their dependence on winter precipitation, but no available gages were similar to Denny Creek. For lack of better data, the precipitation gage at Rocky Point was analyzed for relationships to streamflow in Denny Creek.

Instantaneous flow measurements were collected on Denny Creek by the USGS between September 1964 and October 1967. The USGS did not document whether any diversions occurred upstream of these measurements, so no diversions were assumed to have occurred. The Oregon Water Resources Department website shows one point of diversion upstream of the gage site, but the water right certificate connected to the point did not discuss or allow a diversion out of Denny Creek. This point of diversion was considered an error.

The USGS developed monthly total estimates for this time period (Hubbard, 1970), but these values were compared to redeveloped values to ensure accuracy. Redevelopment of monthly total streamflow estimates was completed using Varney Creek and Red Blanket Creek gaged data, and the results differed greatly from the USGS estimates, especially in low flow or baseflow months. The USGS estimates were considerably larger for these months. The redeveloped estimates were used in developing correlations to monthly precipitation data.

Precipitation is not considered to directly affect the flow in each month. The transit time over 58 square miles to the Denny Creek gage can be considerable, and groundwater recharge and resurfacing does not occur immediately. To represent these flow-affecting processes, precipitation totals were lagged over several months, with different percentages applied to each month, to find the effective precipitation value for each month. Ultimately, the best correlation to streamflow was found by lagging precipitation data 6 months, with 30 percent reaching the gage concurrently and the remaining 70 percent being lagged over the next 6 months. This effective percentage decreases each month, so the effective precipitation for each month is related to the precipitation from the previous 6 months. For example, the effective precipitation value for June is

30 percent of June's total precipitation, 21 percent of the May's precipitation, 15 percent of April's precipitation, and so on.

Correlations to streamflow were found between monthly effective precipitation values and monthly total streamflow estimates found between 1964 and 1967. Least-squares equations were found for effective precipitation values above and below 2.5 inches. The majority of effective precipitation values were below 2.5 inches, which was captured by a curvilinear relationship that recovered 86 percent of variability (R^2 value of 0.86).

The synthetic time series developed for Denny Creek (Table B-9) is unique in that it depends solely on relationships between effective precipitation and streamflow between 1964 and 1967. The final time series sufficiently represents the streamflow in Denny Creek, since low-flow and extremely high flows were available in the gaged streamflow data, but this time series is not necessarily exact.

Table B-9. Denny Creek synthetic natural streamflow record—Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	211.6	322.1	854.2	425.6	417.5	320.9	230.6	242.7	189.4	121.6	90.9	87.3	3514
1950	89.2	140.4	232.5	856.2	516.5	1469.6	422.8	305.1	268.3	171.9	112.5	95.1	4680
1951	349.2	395.4	1323.0	1786.6	1461.1	533.3	321.6	248.3	169.6	115.3	84.5	86.7	6875
1952	264.0	376.7	1596.8	1525.5	1498.5	1092.8	368.2	278.9	318.2	190.8	127.4	197.3	7835
1953	144.8	171.6	367.7	1484.7	998.7	689.0	348.5	335.2	276.4	170.1	137.6	135.4	5260
1954	169.7	390.0	670.8	1941.5	810.4	621.9	364.8	259.1	247.4	158.0	123.8	103.4	5861
1955	96.6	151.6	232.3	270.1	249.8	235.1	279.9	207.2	185.3	143.9	102.1	112.3	2266
1956	159.1	880.9	4429.2	7684.2	5445.1	1758.7	416.5	356.7	288.2	218.9	131.9	149.6	21919
1957	304.6	254.9	409.6	909.6	996.8	3888.3	1092.0	551.2	297.1	190.8	132.9	381.7	9410
1958	340.6	1068.8	2313.4	4324.5	6137.2	2615.3	853.7	392.8	784.4	352.4	208.2	172.8	19564
1959	178.1	187.7	243.9	320.0	321.3	273.2	207.2	176.7	167.1	116.1	94.4	126.7	2412
1960	146.6	119.4	157.4	244.1	377.2	1465.0	664.5	375.9	253.7	203.9	165.3	130.0	4303
1961	123.6	339.6	312.3	319.6	409.4	568.4	336.5	298.0	217.5	147.7	110.8	136.9	3320
1962	241.8	390.9	399.1	403.3	385.1	362.1	291.0	240.3	164.0	114.0	106.5	115.4	3214
1963	733.0	577.7	391.9	369.3	421.0	328.2	337.0	246.3	257.9	179.2	146.3	104.5	4092
1964	123.8	272.0	278.0	653.5	371.6	295.1	221.4	195.3	233.6	161.0	112.2	93.5	3011
1965	107.2	282.4	9280.4	5895.6	3292.4	1767.0	882.8	281.3	53.5	97.5	142.4	147.2	22230
1966	142.1	412.2	315.7	481.3	355.5	507.7	365.7	152.8	115.7	67.5	69.3	58.4	3044
1967	98.9	259.4	331.6	272.8	286.4	353.3	322.1	233.8	127.7	126.7	149.6	145.6	2708
1968	120.2	105.6	158.1	169.7	268.2	232.9	165.9	172.2	137.3	99.3	132.9	99.9	1862
1969	121.1	333.9	961.6	4314.5	2440.7	681.0	349.7	295.9	302.1	184.9	112.0	87.7	10185
1970	156.6	150.6	352.3	2715.7	838.8	642.4	356.2	262.6	229.9	143.2	89.0	74.9	6012
1971	171.0	1966.5	2307.2	3622.3	2273.6	4022.9	1654.9	1186.7	371.7	254.8	160.1	189.3	18181
1972	168.9	386.1	956.0	2446.2	1755.3	3551.1	1851.9	519.2	304.4	198.3	132.8	118.6	12389
1973	144.7	212.3	327.6	404.4	367.4	329.9	243.0	200.6	137.5	99.8	76.7	95.5	2639
1974	210.8	1053.6	2154.6	3191.9	1949.1	2669.6	1178.0	336.3	216.0	161.8	113.8	84.1	13320
1975	70.9	96.7	228.4	274.7	552.3	1139.9	400.1	299.8	288.7	204.5	163.8	139.0	3859
1976	340.8	310.3	406.8	426.6	644.6	358.4	292.4	205.1	163.8	116.2	133.6	105.5	3504
1977	94.1	91.8	83.7	122.1	158.6	146.3	120.9	172.0	224.9	163.8	147.1	294.8	1820
1978	226.6	416.1	1605.4	1252.4	1036.3	2550.4	1014.7	369.2	274.4	190.3	150.4	137.0	9223
1979	90.3	105.4	160.2	309.7	337.4	301.7	281.6	273.0	206.4	140.2	120.9	102.8	2430
1980	265.5	1384.4	803.3	1617.6	1517.4	600.9	374.4	282.9	223.7	155.9	103.5	113.2	7443
1981	121.6	171.9	261.4	293.1	351.4	350.6	265.4	240.7	178.2	125.8	91.4	93.9	2545
1982	147.1	1344.2	5674.0	3398.5	3165.0	2847.3	1495.9	402.3	348.7	223.4	157.1	134.3	19338
1983	181.0	284.4	753.4	668.1	1140.8	2748.5	875.5	364.5	258.7	178.1	158.7	144.0	7756
1984	147.1	784.0	2912.9	1329.5	1087.6	777.1	408.6	302.6	231.3	156.1	117.7	118.0	8373
1985	211.8	1271.8	753.0	404.7	405.5	366.1	280.1	211.9	171.0	145.8	117.9	285.8	4625
1986	263.8	348.2	309.2	411.7	1163.4	1037.7	386.7	306.2	247.2	173.9	117.7	286.1	5052
1987	231.5	248.3	232.3	321.3	286.9	370.9	240.6	194.3	172.1	185.8	130.1	96.5	2711
1988	83.0	127.5	302.0	543.4	339.8	273.7	244.3	231.8	226.7	148.7	99.8	85.2	2706
1989	78.7	679.0	554.2	756.3	392.6	1838.0	765.5	380.2	236.2	161.3	121.6	202.2	6166
1990	207.2	217.7	169.5	370.2	333.4	352.5	278.6	292.7	214.0	192.3	153.1	124.2	2905
1991	116.2	142.7	159.2	242.8	247.5	393.3	340.4	319.5	234.3	170.0	128.7	94.8	2589
1992	101.2	204.8	226.0	261.8	273.4	221.0	260.6	198.5	199.9	146.2	104.3	120.7	2318
1993	196.4	304.7	671.7	1765.3	1363.1	2103.4	1452.9	810.3	428.8	261.2	177.7	138.6	9674
1994	139.4	138.0	205.8	234.9	253.0	194.5	171.3	223.4	190.1	133.8	96.8	98.3	2079
1995	96.1	423.5	379.6	1740.2	884.3	2894.9	1528.1	536.1	409.8	264.8	162.5	114.7	9435
1996	85.7	118.2	555.6	3404.3	4597.0	2440.2	1507.9	855.7	569.8	266.2	156.4	142.7	14700
1997	179.6	270.2	1878.7	3211.2	1800.7	716.7	408.6	308.9	265.7	178.1	132.0	136.6	9487
1998	190.6	394.9	352.3	1978.4	2175.8	2495.3	809.3	1494.3	423.1	271.2	161.4	136.2	10883
1999	103.5	2977.4	2831.8	3833.1	2452.2	1071.5	393.2	284.2	167.8	116.5	107.5	79.7	14418
2000	95.4	156.8	209.5	1241.4	1664.6	921.9	390.0	288.1	201.7	150.0	93.4	92.8	5506

Groundwater Accruals

Groundwater provides additional streamflow to several rivers upstream of UKL, namely Sevenmile Creek, Wood River, and Crooked Creek. For these streams, the development of natural streamflow estimates required the consideration of three primary elements. First, any surface water runoff was estimated. Second, the groundwater accrual to stream was determined. Third, streamflow losses resulting from the attendant natural riparian marsh system were estimated. Each of these pieces was accounted for to accurately reflect inflow to UKL from these streams. The natural streamflow development process for Wood River and Crooked Creek are discussed below, and Sevenmile Creek is discussed in the following “Combination Methods” section.

Groundwater accruals to the Wood River and Crooked Creek result from springs and seeps that discharge from the regional aquifer. Recent published information (Gannett, et al., 2003) and provided data (Marshall Gannett, hydrologist, USGS, pers. comm.) indicate recharge to the regional aquifer is related to longer-term variability in climatic conditions. The discharge of the Fall River, a tributary to the Deschutes River which is just north of the study area, is dominated by groundwater from the regional aquifer that discharges to the stream. The Fall River has been shown to provide an excellent basis for the comparison of discharge measurements from groundwater springs for the evaluation of the climatically variable discharge that is evident within the regional aquifer system (Gannett, et al., 2003).

As a result of these findings, comparisons of gaged spring flows to the discharge of Fall River were used to estimate groundwater accruals to UKL tributaries. Comparisons were completed to estimate the discharge of Wood River Springs and groundwater accruals to Wood River, Fort Creek, and Crooked Creek. Due to a lack of data on Fort Creek and Crooked Creek, relationships between groundwater accruals to the Wood River and those of Fort Creek and Crooked Creek were used to estimate groundwater accruals to Fort Creek and Crooked Creek. By this means, a reasonable estimate of monthly groundwater discharges was developed for these streams for the 1949 to 2000 period of interest.

Characterization of groundwater inflows to the Wood River was initially accomplished by evaluating miscellaneous flow measurements completed by USGS from 1904 to about 1960. Because flow of the Wood River is extensively diverted for flood irrigation of pasturelands, the assessment of these measurements was limited to the headwaters region of the Wood River. Deep percolation losses from irrigation would drain back to the stream and thereby not provide accurate information for estimating the natural groundwater inflow to the stream. Miscellaneous flow measurements in the headwaters region, however, were not always consistently made in the same location. Therefore, reasonable estimates could only be derived by examination and grouping of the flow measurements on a monthly basis.

Three locations were used to evaluate these flow measurements. These locations were (1) the stream gage at Fort Klamath, (2) a measurement site location at Dixon Road, and (3) various sites located near the headwaters springs for the Wood River. Several of the measurements noted for location 3 were very close to the same measuring site as location 2. Flows at the Fort Klamath gage were used to help estimate natural flows for Wood River Springs.

Miscellaneous flow measurements were also evaluated for Fort Creek, a stream that is also dominated by groundwater accruals from springs. These miscellaneous measurements were made by USGS over the same general time period as those for the Wood River. These miscellaneous flow measurements allowed a characterization of spring inflows accruing to Fort Creek that could be compared to flow of the Wood River at the Fort Klamath gage. Hence, the same general characterization could also be developed for monthly flows for Fort Creek.

The miscellaneous flow measurements for the Wood River near Wood River Springs, and those for Fort Creek, were each evaluated by grouping monthly flows and looking for similarities and unexplained differences. Measured upstream diversions were added to measured streamflow to provide the total flow. These monthly groupings covering the period of miscellaneous measurements allowed development of estimates for groundwater accruals to the Wood River and Fort Creek and estimated monthly flows for these streams. Similar miscellaneous flow measurements by the USGS over the same time period were also available for Crooked Creek. The same process of monthly grouping was also used to develop estimated monthly flows in Crooked Creek. Relationships were then developed for Crooked Creek and Fort Creek flows in relation to those at Wood River Springs.

One significant drawback to using this approach is that the lack of long-term trends in climatic variability in the estimated monthly flows. To address this shortcoming, measured flows of the Wood River at Dixon Road, over the period September 1979 to September 1989, were correlated with monthly average flows over the same time period for the Fall River. This correlation was used to develop a longer term time series for the Wood River at Dixon Road which could then be used as inflow to develop a water budget for the Wood River. Because the flow relationships in Fort Creek and Crooked Creek were known in comparison with estimated monthly flows for the Wood River (as mentioned above), a similar correlation to the flows for Fall River was inferred for Fort Creek and Crooked Creek. The general relationship for the flow of Fort Creek and of Crooked Creek to that of the Wood River at Dixon Road is 36.6 percent and 39.9 percent, respectively. This process has been indicated by Gannett (2003, and personal communication) to address incorporation of climatic variability in the developed time series. The relationships used in the correlation process are shown in Figure B-2.

The relationship of Spring Creek to Fall River, for the same 1979 to 1989 time period, was used to indicate the validity of the developed flows for Fort Creek and Crooked Creek. Spring Creek is near the springs discharging into Fort Creek and Crooked Creek. Because the groundwater discharge into Spring Creek is evidently supported by a baseflow of 225 cfs, subtraction of this baseflow from the Spring Creek flow values gives a relationship very close to that derived for Fort and Crooked Creeks.

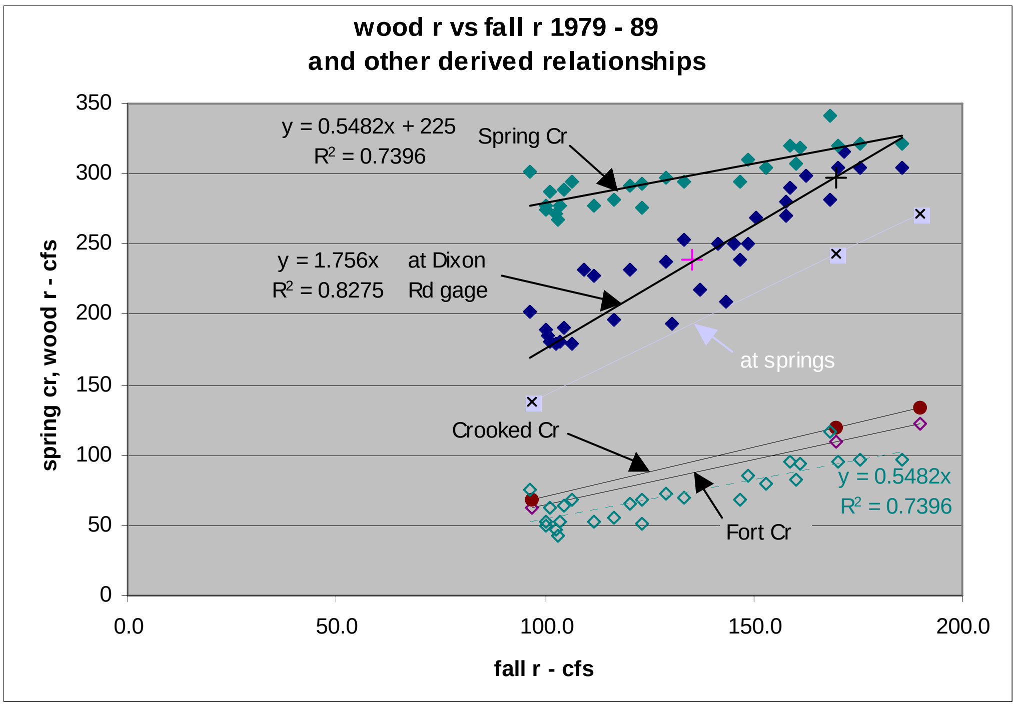

Figure B-2. Wood River vs Fall River 1979 to 1989 and other derived relationships.

A detailed description of each streamflow record development process is described below.

Wood River at Upper Klamath Lake

Streamflow in the Wood River is the result of surface water runoff, groundwater releases, and losses to riparian marshes. Outflow of Wood River into UKL is expressed by the equation:

> Wood River @ UKL = Wood River @ Dixon Rd. + Annie Creek below Sun Creek + Fort Creek outflow – riparian marsh ET along Fort Creek and Wood River

The drainage area above Annie Creek and Sun Creek form the headwaters of Wood River. The time series generated for Annie and Sun Creeks were used as inflow to the Wood River to account for surface water runoff and other upstream spring flows. Groundwater contributions result from Wood River Springs, at the head of Wood River on the valley floor, from additional springs along Wood River, and from groundwater-dominated Fort Creek, a tributary to the Wood River. Also, some streamflow is consumed by the ET of natural riparian vegetation along the stream corridor.

Streamflow measurements were compiled for several locations on the Wood River and Fort Creek between 1904 and 1989. Although some later measurements were used, records before the early 1970s were assumed to represent streamflow that was least affected by development. These data were sorted by month of occurrence and measurements that had been affected by diversions and other upstream uses were either naturalized based on available diversion information or removed from further analyses. The locations for the gage records, and each of the miscellaneous measurement sites, were location-checked and plotted at their respective locations on the Fort Klamath 7.5-min 1:24,000 scale quadrangle.

A large number of instantaneous streamflow measurements were collected by the USGS at Dixon Road between 1900 and 1999. Measurements of most importance were those collected during the winter season when the effects of agricultural development are minimal. Comparisons of data illustrated that between 1979 and 1989, the Wood River discharge correlated very well with concurrent discharge measurements of Fall River. From this, a monthly natural discharge history of Wood River at Dixon Road between 1949 and 2000 was determined. The average total natural flow of the Wood River at Dixon Road is about 300 cubic feet per second (cfs).

The evaluation of Fort Creek was similar to that of the Wood River. Miscellaneous flow measurements for Fort Creek were compiled, sorted by month of occurrence, and evaluated for any effects of diversions and other upstream uses. Measurements that were considered unaffected by upstream uses were used in further analyses.

Streamflow in Fort Creek is dominated by groundwater. Comparisons of unaffected miscellaneous streamflow measurements on Fort Creek and for Wood River at Dixon Road exhibited a strong relationship between resultant streamflow. This relationship is not surprising, since Wood River at Dixon Road is dominated by groundwater releases at Wood River Springs. Fort Creek was found to produce approximately 36.6 percent of the flow measured in the Wood River at Dixon Road. This relationship was used to develop a monthly period of record for Fort Creek streamflow between 1949 and 2000 from the estimated streamflow of Wood River at Dixon Road. The derived estimate indicated the natural spring flow of Fort Creek was about 89 cfs.

Evaluation of the stream-associated riparian system was based on a detailed photo-interpretive assessment of color-infrared ortho-photography that had been flown in July 2002 and assembled by Reclamation (drawing #12-208-1000). This imagery covered approximately the eastern third of the Wood River Valley. From this imagery, and 9 inch by 9 inch prints of the acquired color infrared photography (flight #BR-KLA-14), the trace of the previously existing, stream-associated, natural riparian area was delineated. Because the color infrared photography was provided as approximately 1:31,000 scale prints, and as an ortho-photo image mosaic scaled at 1:40,000 and at 1:10,000, these delineated areas were collectively posted on 7.5 minute quadrangle overlays that had been scale reduced to 1:40,000. These overlays were then reduced to 1:63,360 and planimetered to determine the land-surface area of the riparian marshland affecting natural flow of the Wood River and Crooked Creek. These riparian marshland areas did not include lake wetland marsh areas around UKL.

Annie Creek and Sun Creek inflows were added to estimated natural streamflow of Wood River at Dixon Road. Fort Creek streamflow was then added and losses determined for the associated riparian areas were subtracted from this estimated Wood River natural streamflow to provide an estimate of inflow to UKL from the Wood River (Table B-10). For the period of interest, 1949 to 2000, this inflow to UKL was estimated to average about 440 cfs.

Table B-10. Wood River synthetic natural streamflow record—Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	26551.1	25991.4	26519.7	25253.5	24479.4	25075.2	27898.4	33826.3	34250.2	31768.1	30751.0	29680.4	342045
1950	30054.4	29377.2	28063.1	27449.2	26244.1	26839.8	27978.4	34626.8	35303.1	34720.9	29238.5	28630.3	358526
1951	28807.1	31626.9	30978.5	30001.9	29395.8	31245.9	35623.1	41404.6	42083.0	40417.4	38324.7	35260.0	415169
1952	36874.5	33831.1	33141.5	30692.5	29660.8	30192.2	32227.5	40922.4	40831.6	44376.5	35800.5	34537.6	423089
1953	33689.1	30743.3	30733.5	32912.5	30789.5	31341.7	32193.2	37679.5	43677.6	40512.2	36174.6	35036.1	415483
1954	33229.6	34761.8	32739.8	30536.9	29941.1	31853.3	35775.4	39328.3	41548.9	38983.5	38328.8	34980.7	422008
1955	32787.5	30460.1	28903.3	28444.4	27698.9	28597.5	28561.5	32553.9	36468.2	30245.7	28459.7	25202.7	358383
1956	25408.6	26443.4	27716.4	27696.2	26620.7	25565.3	31470.8	42390.5	46233.3	41825.6	36402.3	34423.1	392196
1957	35088.5	32747.3	32311.2	31938.7	31118.8	32070.9	34141.3	36341.0	35894.8	34778.6	33873.2	31428.5	401733
1958	29554.7	28655.8	28049.3	27846.6	27703.3	28350.7	29439.6	36862.9	40922.9	36687.1	34035.4	31126.0	379234
1959	30713.4	29173.3	27692.6	28271.3	27935.6	28526.9	28784.2	31277.1	30844.5	28865.5	27533.5	25498.4	345116
1960	25390.3	24326.2	24029.5	23575.5	22974.6	23867.0	24484.2	28116.2	30115.1	28990.4	24185.7	22297.3	302352
1961	22370.4	22815.5	21764.4	20790.6	21117.5	22626.4	23966.3	28232.8	31396.0	26984.5	26308.5	24655.6	293029
1962	24591.8	24791.5	23938.4	23400.1	22847.2	23888.2	25582.1	28237.5	30168.3	27576.4	26283.1	25429.2	306734
1963	27558.6	25081.3	24899.2	24072.8	23910.9	25253.8	26014.4	30015.9	30064.6	29806.8	29082.0	27210.0	322970
1964	26596.0	28132.2	25412.2	24780.3	23803.3	24296.1	25673.3	29167.9	27606.9	27751.3	25645.6	23857.8	312723
1965	22288.8	22359.2	28438.5	27222.2	29847.0	32495.0	37158.7	36608.0	38170.7	36382.9	34712.0	31752.1	377435
1966	30157.5	28511.3	28357.9	29126.0	28733.5	29908.8	31076.0	33557.1	33285.0	29416.6	28183.1	27046.0	357359
1967	25616.0	26154.8	24897.3	23398.7	22919.5	24018.1	24648.3	29514.4	30763.7	25071.0	23579.7	22724.3	303306
1968	22351.5	20974.3	21098.6	20764.0	20514.4	20882.5	21228.4	21538.9	21559.9	22430.3	21015.9	19277.4	253636
1969	19335.1	20801.1	19457.3	19118.6	18604.8	19350.6	20332.6	25939.2	26356.8	23138.3	21790.7	21133.1	255358
1970	20834.0	20002.4	20918.5	24047.6	22183.8	23253.1	23622.6	25009.5	27307.4	24528.2	24064.8	22376.8	278149
1971	21955.8	24184.4	21611.7	23401.4	22587.5	24123.3	27317.3	30735.8	34795.6	36025.2	30173.7	26389.7	323301
1972	27318.8	27259.7	26296.7	26913.3	25909.3	28949.5	30781.9	35789.8	40341.5	37577.5	34449.8	33249.0	374837
1973	32026.0	29539.0	29064.0	28438.7	28119.9	29428.0	29592.8	30578.5	29346.9	28089.3	27394.4	26249.4	347867
1974	26096.8	29286.4	26276.8	27143.7	24845.6	24974.5	27357.4	34314.7	41239.1	38265.9	33656.8	29458.0	362916
1975	28971.8	27541.1	26743.9	26409.2	26919.3	28507.3	29296.9	36451.5	39414.9	39983.7	32739.0	31495.1	374474
1976	31340.2	29961.2	29625.1	28961.0	28658.8	29784.1	30660.6	35093.7	36592.9	35686.0	31434.4	31226.7	379025
1977	29019.3	27900.8	27036.7	26716.6	25767.6	26560.7	26118.4	25213.0	25167.4	23632.1	23004.1	21865.7	308002
1978	21653.7	20652.6	26005.1	22853.1	21631.0	22283.9	23924.1	25689.0	29190.2	26778.7	23583.7	22272.1	286517
1979	21138.2	20505.6	20563.1	20161.9	19322.5	20428.3	20692.0	24502.0	25048.4	22602.1	21691.6	20763.7	257420
1980	19946.5	19974.1	20467.4	20732.6	19162.2	18423.4	19267.7	23146.3	21420.8	22095.6	21082.0	18987.9	244706
1981	18463.7	18333.4	18475.5	19006.7	18357.0	19335.1	19594.6	22043.2	21237.3	20283.1	19136.3	18554.8	232821
1982	18303.3	18263.4	20729.2	20046.8	19741.3	22876.8	23426.4	28303.2	35552.5	33522.5	28781.5	26581.8	296129
1983	26270.7	26141.0	25828.4	25150.4	24659.2	27035.8	28763.8	31551.4	38229.0	37491.5	33724.1	30467.2	355312
1984	29871.6	29548.4	29159.3	27808.8	27591.6	29095.3	31550.3	33762.1	38699.2	41654.4	34410.3	31726.3	384878
1985	31511.4	31464.7	30102.6	28263.5	26890.6	27006.7	28391.5	30332.2	33421.7	29905.9	27805.9	26809.5	351906
1986	26403.9	25559.0	24493.7	24240.6	23728.1	26795.9	28830.5	30081.8	38088.0	29587.1	26726.7	25705.8	330241
1987	25236.5	24931.8	24215.7	23366.8	22492.6	23258.1	24153.0	30180.7	26661.6	24294.9	22958.8	21993.3	293744
1988	21445.7	20654.0	20500.1	20416.8	19479.2	20139.5	20905.5	22326.9	23317.7	21472.3	19691.2	18898.4	249247
1989	18178.8	18039.5	17246.2	17780.3	16896.1	17871.7	20472.7	24590.4	26648.8	24592.1	21916.6	20411.7	244645
1990	20903.4	21790.8	21143.3	19965.6	18858.7	18848.4	19732.8	23211.7	22168.7	20341.0	19221.8	18494.8	244681
1991	17589.8	17022.0	16203.1	16210.9	15521.2	16302.2	15682.0	17606.4	17957.2	17520.3	16324.6	15542.0	199482
1992	15885.2	15705.1	16130.1	16592.2	15851.8	16539.8	17667.0	19371.7	17386.4	17066.2	16091.0	15072.1	199359
1993	14935.3	15215.8	14674.5	15447.4	14356.7	15916.4	18608.5	24109.6	26249.6	23856.5	21010.8	19706.7	224088
1994	19454.6	18886.0	19031.0	18631.4	18135.4	19030.1	19549.6	20696.1	18844.8	18007.4	17508.3	16867.6	224642
1995	16585.8	15962.9	15364.5	15279.5	14867.3	16566.0	16934.5	19700.6	22234.3	21739.4	18235.7	17078.0	210549
1996	16671.3	16982.2	19840.8	20074.2	21709.3	23564.1	27212.7	31628.8	32627.1	30195.0	30314.0	28190.9	299010
1997	27461.0	28863.7	28948.4	30586.4	29014.0	30405.9	32791.6	38951.2	39466.5	34888.1	31704.0	29563.2	382644
1998	28731.3	27468.3	26690.2	26513.2	25292.2	25886.6	26469.3	29388.9	33725.6	32351.5	27663.0	26310.4	336490
1999	25174.8	25120.2	24175.7	23734.5	22906.7	23606.2	25739.9	31516.0	37278.9	37355.1	31504.4	28010.5	336123
2000	27119.3	26528.6	25830.9	25310.7	24574.5	25408.2	28943.3	30765.4	31925.3	28580.8	26986.1	26232.1	328205

Crooked Creek

The evaluation of Crooked Creek followed the same general approach taken for the Wood River. Crooked Creek is a tributary of the Wood River, yet there is evidence this was not always so. Although the Wood River has a well-established channel along the eastern margin of the wetland marsh at the northern end of Agency Lake, an extension of UKL, there apparently were times when the Wood River was lost in the wetland area, and Crooked Creek was not directly tributary to the Wood River. For predevelopment conditions considered herein, Crooked Creek may have entered the Wood River along the eastern margin of the wetland marsh area just above the mouth of the Wood River at Agency Lake. The present-day channel of Wood River has been channelized and straightened generally along the pre-existing alignment the stream had under natural conditions.

Above its confluence with the Wood River, Crooked Creek flows in a tightly meandering channel along the eastern margin of the valley floor. Because there is virtually no contributing watershed area, flow in Crooked Creek is limited to inflow from several springs and groundwater seepage that arises along east bounding wall of the Wood River Valley. The accumulation of this flow is initiated about 1.7 miles southeast of Fort Klamath. These springs increasingly add to the flow of Crooked Creek. Records indicate various names for some of these springs, of which one or two were given inconsistent reference. However, for most miscellaneous flow measurements that are published for Crooked Creek, the indicated locations were sufficiently distinct that a representative assessment could be accomplished and the locations of named springs determined along the stream.

Miscellaneous flow measurements from 1900 to 1960 were considered. Although diversions occur from Crooked Creek, notes in many of the records indicated if the measurements were made above, or below, these diversions, and frequently noted the quantity then being diverted. The inclusive body of these measurements was compiled, sorted by month, and assessed for trends due to development. Measurements that could be naturalized by adding in diversion information or represented natural conditions were used for further analysis. Natural measurements were compared to streamflow measurements of the Wood River at Dixon Road. This comparison illustrated that Crooked Creek streamflow measured approximately 39.9 percent of streamflow in the Wood River. An extended synthetic natural streamflow record was developed between 1949 and 2000 from this relationship. The natural groundwater influx into Crooked Creek was estimated to be about 95 cfs, but may have been as high as 103 cfs.

Crooked Creek also had an associated riparian marshland under natural conditions that does not coincide with the extent of marsh seen today. This natural riparian area would have caused additional losses of streamflow under natural conditions. The extent of the natural riparian marsh was evaluated as described previously for the Wood River and Fort Creek. This riparian marsh may cause an approximate

2 cfs loss to the flow of Crooked Creek during the summer before inflow to UKL. For the period of interest, 1949 to 2000 (Table B-11), average natural flow of Crooked Creek, including this natural loss, was about 102 cfs. The losses to riparian marsh were subtracted from the groundwater influx to Crooked Creek described previously to estimate the outflow of Crooked Creek under natural conditions.

Table B-11. Crooked Creek synthetic natural streamflow record—Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	6632.7	6653.9	6772.6	6539.5	6386.9	6302.1	7060.8	7378.6	7259.9	7374.4	7471.9	7548.1	83381
1950	7624.4	7641.4	7323.5	7098.9	6853.1	6776.8	7031.1	7531.2	7543.9	7484.6	6751.4	7018.4	86679
1951	7031.1	7060.8	7332.0	7582.0	7615.9	7933.8	9099.3	9887.6	9862.2	9476.5	9243.4	8828.1	100953
1952	8760.2	8421.2	8387.3	8111.8	7891.4	7789.7	8315.2	9633.3	8840.8	9001.8	8828.1	8616.2	102597
1953	8446.6	8048.2	8065.2	7955.0	7734.6	7721.9	7789.7	8620.4	8548.3	8637.3	8603.4	8756.0	98927
1954	8200.8	8179.6	8107.6	7874.5	7857.5	8179.6	9230.7	9205.3	9090.8	8722.1	8773.0	8561.1	101983
1955	8209.3	7904.1	7526.9	7387.1	7276.9	7289.6	7302.3	7243.0	6929.4	6942.1	6861.6	6251.3	87124
1956	6348.7	6412.3	6259.7	6357.2	6471.6	6264.0	7874.5	9256.1	9315.4	8972.2	8641.6	8387.3	90561
1957	8387.3	8239.0	7912.6	7819.4	7921.1	8010.1	8455.1	8611.9	8366.1	8234.7	8111.8	7819.4	97888
1958	7115.8	7103.1	6971.8	6929.4	7107.4	7302.3	7565.1	8065.2	8285.6	7984.7	7840.6	7488.8	89760
1959	7404.0	7145.5	7069.2	6997.2	7141.3	7098.9	7048.0	7459.1	7145.5	6899.7	6535.2	6196.2	84140
1960	6391.1	6251.3	6187.7	6026.6	5933.4	5937.6	6047.8	6001.2	5823.2	5721.5	5662.2	5479.9	71464
1961	5467.2	5475.7	5301.9	5276.5	5429.1	5607.1	5937.6	6102.9	6107.2	6183.5	6153.8	6018.2	69061
1962	5878.3	5810.5	5848.6	5903.7	5852.9	5908.0	6323.3	6374.2	6429.3	6382.6	6213.1	6259.7	73184
1963	6149.5	5946.1	5984.3	5929.2	6060.5	6221.6	6467.4	6666.6	6980.2	7158.2	7018.4	6814.9	77397
1964	6645.4	6573.4	6357.2	6272.5	6111.4	6009.7	6327.6	6357.2	6162.3	5742.7	5823.2	5696.1	74079
1965	5475.7	5513.8	5696.1	6141.1	6721.7	7323.5	8298.3	8802.6	8811.1	8582.2	8234.7	7887.2	87488
1966	7543.9	7315.0	7387.1	7590.5	7582.0	7675.3	7938.0	7777.0	7370.1	7154.0	6946.3	6738.7	89018
1967	6480.1	6285.2	6098.7	5861.4	5848.6	5924.9	6132.6	6208.9	6111.4	5751.2	5594.4	5454.5	71752
1968	5399.4	5318.9	5318.9	5196.0	5208.7	5060.3	5090.0	5085.8	5098.5	5187.5	5013.7	4806.1	61784
1969	4700.1	4662.0	4611.1	4594.2	4577.2	4551.8	4751.0	4869.6	4988.3	5001.0	4929.0	4903.5	57139
1970	4945.9	5001.0	5039.2	5060.3	5034.9	5204.4	5335.8	5488.4	5619.8	5687.6	5577.4	5378.2	63373
1971	5272.3	5280.7	5238.3	5251.1	5382.4	5649.4	6607.3	7166.7	6971.8	6730.2	6505.6	6259.7	72315
1972	6348.7	6480.1	6488.6	6437.7	6450.5	7141.3	7700.7	7764.3	7836.3	7883.0	7857.5	7883.0	86272
1973	7747.3	7526.9	7391.3	7272.7	7332.0	7476.1	7429.5	7374.4	7247.2	7077.7	6861.6	6645.4	87382
1974	6458.9	6327.6	6166.5	6052.1	5865.6	5751.2	6471.6	7437.9	7399.8	7348.9	7098.9	6823.4	79202
1975	6865.8	7001.4	6772.6	6692.0	6988.7	7213.3	7467.6	8145.7	8188.1	8035.5	7781.2	7628.7	88781
1976	7425.2	7348.9	7209.1	7234.5	7374.4	7484.6	7764.3	7802.4	7840.6	7832.1	7696.5	7505.8	90518
1977	7315.0	7107.4	6912.4	6827.7	6679.3	6666.6	6450.5	6399.6	6242.8	6056.3	5903.7	5636.7	78198
1978	5653.7	5407.9	5361.3	5174.8	5229.9	5318.9	5463.0	5518.1	5645.2	5501.1	5331.6	5191.7	64797
1979	5064.6	4971.3	4979.8	4814.5	4746.7	4890.8	4950.2	4992.5	4941.7	4971.3	5085.8	4945.9	59355
1980	4793.3	4734.0	4797.6	4840.0	4573.0	4242.4	4428.9	4331.4	4081.3	4526.3	4632.3	4293.2	54274
1981	4238.1	4289.0	4255.1	4263.6	4297.5	4348.3	4382.2	4543.3	4513.6	4517.9	4496.7	4386.5	52532
1982	4327.1	4289.0	4369.5	4475.5	4577.2	5234.1	5530.8	6081.7	6378.4	6293.6	6255.5	6230.1	64043
1983	6230.1	6200.4	6115.6	6132.6	6213.1	6768.3	7276.9	7463.4	7446.4	7446.4	7272.7	7111.6	81678
1984	6954.8	6895.5	6836.1	6692.0	6751.4	7132.8	7760.0	7874.5	7874.5	7849.0	7781.2	7577.8	87980
1985	7493.0	7446.4	7226.0	7005.7	6827.7	6692.0	6781.0	6738.7	6687.8	6628.5	6590.3	6475.9	82593
1986	6327.6	6166.5	6030.9	5954.6	5980.0	6293.6	6734.4	6734.4	6645.4	6560.7	6391.1	6272.5	76092
1987	6102.9	5992.7	5819.0	5687.6	5657.9	5717.3	5789.3	5814.7	5793.5	5742.7	5619.8	5475.7	69213
1988	5335.8	5183.3	5111.2	4979.8	4890.8	4852.7	4865.4	4810.3	4742.5	4640.8	4551.8	4492.4	58457
1989	4344.1	4382.2	4242.4	4246.6	4200.0	4276.3	4589.9	4581.4	4734.0	4797.6	4755.2	4636.5	53786
1990	4645.0	4742.5	4674.7	4632.3	4594.2	4496.7	4450.1	4471.2	4534.8	4534.8	4526.3	4458.5	54761
1991	4233.9	4144.9	3992.3	3810.1	3805.9	3801.6	3670.2	3572.8	3742.3	3844.0	3759.2	3666.0	46043
1992	3716.9	3763.5	3793.1	3835.5	3822.8	3865.2	4102.5	4204.2	4047.4	3966.9	3780.4	3610.9	46509
1993	3593.9	3657.5	3649.0	3619.4	3483.8	3602.4	4369.5	4700.1	4598.4	4530.6	4530.6	4484.0	48819
1994	4462.8	4458.5	4543.3	4564.5	4577.2	4594.2	4632.3	4526.3	4407.7	4348.3	4297.5	4140.7	53553
1995	3996.3	3887.4	3713.8	3624.2	3608.2	3796.5	3880.3	3899.8	3908.8	3899.8	3858.5	3816.2	45890
1996	3818.6	3916.0	4064.4	4166.1	4662.0	5424.8	6230.1	6526.7	6399.6	6611.5	7120.1	6738.7	65679
1997	6501.3	6552.2	6581.8	6831.9	7005.7	7285.4	7768.5	8031.3	8090.6	7866.0	7425.2	7107.4	87047
1998	6823.4	6611.5	6442.0	6399.6	6314.8	6230.1	6314.8	6272.5	6314.8	6272.5	6145.3	6060.5	76202
1999	5891.0	5891.0	5721.5	5636.7	5594.4	5806.3	6357.2	7247.2	7204.8	7162.5	6908.2	6526.7	75948
2000	6314.8	6272.5	6145.3	6060.5	6018.2	6230.1	6823.4	6696.3	6526.7	6484.4	6399.6	6357.2	76329

Combination Methods

Two UKL tributaries had streamflow data that required application of two previously discussed methods to estimate natural streamflow. In order to develop a complete period of record of natural streamflow for Fourmile Creek, the available data first needed to be restored to natural condition. For Sevenmile Creek, surface water contributions needed to be assessed first, by reconstructing the available natural streamflow data to a complete period of record, then groundwater accruals were incorporated.

Fourmile Creek—at UKL

Fourmile Creek is located on the east side of the Wood River Valley, immediately south of Rock Creek. The entire Fourmile Creek watershed drains approximately 105 square miles, and flows directly into the marshlands near Pelican Bay of UKL. There are three major subwatersheds known as Fourmile Creek, Fourmile Creek above Seldom Creek, and Lost Creek. The Seldom Creek subwatershed contains Lake of the Woods and only releases water into Fourmile Creek intermittently. Of the entire watershed area, 32 percent is contained within wilderness areas of the Winema and Rogue River National Forests and has remained in a relatively unaltered state, 2 percent is private land, and the remaining 66 percent is non-wilderness National Forest land.

The water and land of Fourmile Creek watershed has been actively managed during the last century. Timber harvesting in the drainage began around 1900. The south and southwest slopes of Pelican Butte, Fourmile Flat area, and the lower Lost Creek drainage were harvested in the early 1900s, and harvest activities were greatest in the 1960s, when partial timber removal occurred on at least 7.5 square miles. Timber harvesting has continued since then, but to a lesser extent. Since canopy closure has not been significantly reduced in the Fourmile Creek watershed, it is considered unlikely that timber harvesting has had a measurable effect on streamflow (USDA, 1996).

On the other hand, a definite change in streamflow variability has occurred due to the presence of Fourmile Dam. Fourmile Creek above Seldom Creek contains Fourmile Lake, which is actively managed by operation of Fourmile Dam. Not only is water held back by the dam, water is diverted out of Fourmile Lake by Cascade Canal, which transports the water out of the Fourmile and Klamath Basins. Water from Cascade Canal is carried west over the Cascade Range into Rogue River basin and is discharged into North Fork Little Butte Creek upstream from Fish Lake.

Originally, Cascade Canal was composed of earth and rock. Upgrades were made in 1915 to build the concrete structure still in use today. Upon completion of

Fourmile Dam in October 1922, the capacity of the natural lake was increased, and the flow regime in Fourmile Creek stabilized to present conditions.

Within the last few years, no active releases to Fourmile Creek have been made. An assumption is that the water from Fourmile Lake was only directly connected with Fourmile Creek if the spillway was crested. In the past, flash boards have been used on Fourmile Dam to increase the capacity. Therefore, only very large flood waters were assumed to contribute directly to flow in Fourmile Creek.

Streamflow in Fourmile Creek may still have been replenished by water retained behind Fourmile Dam. The Fourmile Lake/Dam system is anticipated to recharge surficial aquifers that contribute to flow downstream in Fourmile Creek. This seepage could not be quantified from available stream gage records, and thus was considered to be minimal for lack of better data.

The Fourmile Dam and Cascade Canal regulations have affected the timing, duration, and quantity of streamflow in Fourmile Creek by disconnecting a large headwater area. To estimate the natural streamflow of the Fourmile Creek watershed, the total flow captured and diverted from this headwater area needed to be quantified and added to the streamflow generated by the remaining connected area. Using reservoir content and Cascade Canal diversion data, the inflow to Fourmile Lake was estimated. These data were then added to the available gaged records to create natural monthly streamflow totals.

The streamflow records for Fourmile Creek are available from the USGS and FS. Monthly total streamflow estimates were made from the FS data, which constituted miscellaneous instantaneous streamflow measurements in the spring and summers between April 1992 and May 1997. The FS gage site is located in a narrow valley 3/4 mile above the Seldom Creek confluence, and this site includes all water produced by the upstream watershed less the area above Fourmile Lake. Alternatively, the USGS maintained a daily recording streamflow gage on Fourmile Creek near Rocky Point (below Varney Creek) between October 1964 and September 1967. The measurement location of the USGS gage is situated in an alluvial valley bottom, most likely with lacustrine deposits. Some water produced by the Fourmile Creek watershed has likely already gone subsurface at this location. Neither gage location is perfect for use in developing a larger synthetic time series, but the available gage data still proved to be highly beneficial.

The FS data accurately depict the water produced above Seldom Creek minus the Fourmile Lake watershed. Without any gage information for Seldom Creek, assumptions must be made about the additional water generated by this area. Since Seldom Creek is noted to only provide flow to Fourmile Creek intermittently, which are typically very large flows, Seldom Creek was assumed to not directly connect to Fourmile Creek for the months estimated in the 1990s. Since the majority of water in Fourmile Creek originates from springs in the upper headwater areas, the lower portion of the watershed is considered to produce minimal flow in comparison to the upper. The monthly total estimates generated from the FS measurements were considered to be representative of what is produced by Fourmile Creek without the Fourmile Lake and Varney Creek watersheds.

During the 1960s, the USGS collected daily streamflow measurements on Varney Creek and Fourmile Creek. These gages are both recorded during the same time period in the mid 1960s, between October 1964 and September 1967. These gages clearly illustrate how much water seeps subsurface on the alluvial valley floor. The flow in Varney Creek was measured just upstream of the confluence with Fourmile Creek. For several months, Varney Creek flow measured between 20 and100 acre-feet, while the Fourmile Creek gage recorded no flow at all. By comparing the two records, losses in Varney Creek along the valley floor were estimated. In July 1965, the Varney Creek gage measured 113 acre-feet in total flow, and the Fourmile Creek gage measured only 1 acre-foot. Assuming Fourmile Creek above Varney Creek was otherwise dry that month, the losses in Varney Creek were estimated to be around 100 acre-feet per month. This information aided in generating natural flow estimates for the 1990s.

Monthly streamflow totals were naturalized by adding water excluded from gaged records to the gaged records. In the 1990s, the Varney Creek monthly total streamflow was estimated from FS miscellaneous streamflow measurements. These totals, minus the estimated Varney Creek losses, were added to the Fourmile Creek monthly flow estimates. The remaining piece needed to naturalize streamflow was the water produced by the Fourmile Lake watershed.

The inflow to Fourmile Lake was estimated as monthly change in reservoir storage plus outflow. Since outflow to Fourmile Creek has not occurred over the last few years, and no documented outflows have been recorded, the only outflows included are those diverted into Cascade Canal. Diversion records for Cascade Canal out of Fourmile Lake are available from Reclamation back to June 1992. Prior to that 1992, the USGS maintained records for Cascade Canal near Fourmile Lake intermittently since 1923. These diversions were added to change in reservoir storage, which were generated from end-of-month (EOM) reservoir contents. Reservoir EOM data have been collected intermittently for Fourmile Lake since 1923. A continuous record begins in September 1991 and is available through 2003. After adding diversions to change in storage, several resultant "inflow" values in the winter and early spring were still negative. These values are likely the result of losses to groundwater and evaporation.

To accurately naturalize gaged streamflow, negative numbers found by adding Cascade Canal diversions to the change in reservoir storage were replaced by zero values. When otherwise naturalizing streamflow after a dam is present, the evaporation losses would be estimated and added to the diversions and change in storage. Evaporation losses off Fourmile Lake were estimated to average

320 acre-feet per month, as long as evaporation rates are similar to those for UKL. These evaporation losses were not used to naturalize lake inflows, because Fourmile Lake is a natural lake. Documentation of the lake's surface area prior to dam construction could not be found, so the post-dam evaporation losses were assumed to be similar to natural values. In the end, natural lake inflows were considered relatively equal to the change in Fourmile Lake storage plus diversions.

Natural flows were developed for Fourmile Creek during two time periods. To naturalize gaged data for Fourmile Creek, the estimated inflow to Fourmile Lake was added to monthly streamflow totals between October 1964 and September 1967 and estimated monthly totals between April 1992 and July 1996. Varney Creek flows were already reflected in the 1964-67 Fourmile gaged data, but the 1992-96 estimates did not reflect this additional water. Miscellaneous flow measurements on Varney Creek were collected by the FS between April 1992 and July 1996, which enabled the development of monthly total estimates for Varney Creek. These estimates were generated by rescaling South Fork Rogue River (S.F. Rogue + S.F. Power Canal near Prospect) and Rogue River above Prospect gages based on concurrent measurements. The Varney Creek monthly flow estimates were decreased to reflect channel losses, which were estimated from the 1964-67 data, and then added to the 1992-1996 flows for Fourmile Creek. In total, natural monthly streamflow estimates for both the 1964-67 and 1992-96 time periods reflected the Varney Creek drainage, the Fourmile Lake headwaters, and the water produced by the in-between area.

The natural flow estimates from the 1990s still differ slightly from the 1960s data. The gage location of the 1960s Fourmile Creek data suggests some water was probably lost to groundwater prior to being gaged near Rocky Point. Conversely, the gage location of the 1990s data reflects the water produced by the watershed more accurately for that time period. The flow of groundwater through the alluvial valley bottom is likely to accrue towards UKL even though some water may go subsurface upstream from the USGS gage location. To answer the ultimate question regarding how much water from Fourmile Creek would have provided inflow to the lake under natural conditions, the 1960s data were acknowledged to slightly underestimate the natural inflow to the lake from Fourmile Creek. The 1990s data were accepted as being more representative.

The monthly total natural flow estimates were then used to develop correlations with South Fork of the Rogue River. The Rogue River above Prospect was considered for correlation as well, but the South Fork Rogue River proved to reproduce expected values more accurately. This discovery is not surprising, since South Fork Rogue River lies closer to Fourmile Creek, immediately to the northwest with a common watershed boundary, and has similar geology and topography.

Correlation were developed using monthly natural streamflow totals. A general equation incorporating all available data was generated to represent most months, while some spring and summer months were further calibrated with season or month-specific equations. The flood event of December 1964 to January 1965 and several subsequent runoff months were not included in these correlations, since the gaged streamflow values for Fourmile Creek during and after that event seem uncharacteristic for watersheds in the area. The cause for this departure can be attributed to either partial spill releases from Fourmile Lake, the reconnection of Seldom Creek during an extremely high flow event, or both.

The Fourmile Creek synthetic time series should be considered a rough estimate. Despite efforts to naturalize inflow to Fourmile Lake, the error incorporated in these data could not be determined. The derived natural flows for Fourmile Creek (Table B-12) may be considered representative, since they reflect actual stream variability including zero values and significantly high flows. Although the extremely large flow events may not be represented with as much accuracy, the typical flows are effectively captured since the correlation equations used were based on typical flow regimes in two separate time periods.

Table B-12. Fourmile Creek synthetic natural streamflow record—Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	16.1	20.3	53.0	21.9	47.9	442.4	5534.0	10093.6	2645.5	62.7	35.4	15.8	18989
1950	28.0	18.4	21.1	399.9	156.2	2715.9	4370.8	8601.8	5661.5	796.3	46.4	28.6	22845
1951	168.2	1635.7	8894.8	3469.9	6374.6	1173.6	6215.2	4907.6	1288.5	83.0	51.5	29.6	34292
1952	179.3	560.1	1867.7	646.2	1905.3	943.2	8592.6	11628.6	7533.7	2207.5	347.8	81.3	36493
1953	44.2	27.8	32.9	4167.3	6521.7	697.3	2128.6	5740.1	7949.6	2223.1	255.1	51.0	29839
1954	49.6	2713.1	4139.0	2161.0	3162.3	2488.6	4786.7	4214.6	2770.1	161.0	62.1	41.5	26750
1955	31.2	24.0	27.4	31.7	11.8	37.6	721.9	4784.6	5829.9	89.9	33.1	17.2	11640
1956	22.2	67.0	6620.0	7632.5	1701.2	492.3	4104.6	10058.5	5592.3	1416.0	152.0	49.1	37908
1957	157.7	339.1	5918.0	369.3	933.3	8393.3	4236.8	4226.4	1430.7	63.4	44.9	26.8	26140
1958	35.2	180.1	926.2	2842.1	7496.7	1920.2	1450.9	4771.4	3076.4	1105.8	110.9	47.9	23964
1959	38.0	498.8	341.1	461.7	217.2	377.0	1574.3	1427.7	268.6	29.4	15.8	6.6	5256
1960	7.5	0.0	0.0	4.9	83.8	1754.5	3378.6	4613.3	3326.3	53.0	35.8	12.3	13270
1961	5.9	40.3	120.7	41.2	929.0	1411.7	2141.5	3111.0	2893.8	57.2	32.9	8.4	10794
1962	17.8	225.1	707.5	334.0	146.1	158.7	3969.3	4003.3	2798.4	77.6	41.8	16.4	12496
1963	345.8	383.8	3138.6	158.9	3125.6	687.7	1799.7	4980.8	1094.3	59.8	31.9	17.5	15824
1964	16.7	439.7	156.4	339.8	242.8	179.8	2064.6	5801.4	8036.4	1208.7	74.2	32.5	18593
1965	18.6	73.0	10375.0	9591.0	5593.0	2051.5	3044.7	5790.0	1805.8	97.6	54.6	33.1	38528
1966	27.7	28.3	27.1	177.5	23.9	286.2	6429.5	2698.9	262.4	38.0	19.1	0.0	10019
1967	3.7	52.2	376.7	704.6	795.1	580.7	561.6	4655.0	4452.3	85.9	44.3	17.3	12329
1968	12.2	0.0	0.0	5.9	643.0	294.6	391.8	435.1	72.8	0.0	0.0	0.0	1855
1969	0.0	186.8	119.6	390.4	52.6	52.4	2846.7	11069.4	5845.3	881.0	49.7	22.0	21516
1970	20.9	10.7	137.5	6785.7	1981.9	1952.2	739.7	2144.9	932.3	40.0	19.6	5.9	14771
1971	6.1	1189.7	452.9	7141.1	1930.8	2991.1	3776.0	11107.7	8125.7	2167.4	284.2	76.3	39249
1972	46.4	209.5	1612.5	5640.1	3124.7	3800.0	4867.0	8812.3	7490.4	1873.2	346.5	77.5	37900
1973	49.4	52.0	483.7	702.9	129.2	573.6	1203.9	2219.4	231.6	28.4	21.4	15.1	5711
1974	20.1	3590.6	4904.6	6151.8	922.0	3930.2	5137.7	7264.6	7973.1	1269.7	141.9	39.9	41346
1975	32.3	27.8	170.5	321.4	683.5	3094.6	1236.8	8696.1	8763.3	1463.3	144.9	45.3	24680
1976	54.9	266.0	2898.3	3061.1	802.0	742.7	1422.6	6973.4	2884.0	149.2	283.4	44.0	19582
1977	35.8	20.6	12.5	8.1	0.0	13.7	385.8	949.2	461.0	19.9	0.0	2.7	1909
1978	0.0	423.9	5680.4	1862.2	1077.3	972.4	1019.5	1168.8	435.0	59.4	24.6	16.3	12740
1979	0.0	6.7	68.8	288.2	85.1	1034.1	1360.2	4977.6	591.4	31.5	13.5	0.0	8457
1980	10.4	98.9	355.2	3517.7	406.2	569.9	1474.6	1574.3	593.2	41.1	15.0	0.0	8657
1981	0.0	9.9	226.9	41.1	169.0	240.3	805.2	1009.4	826.6	30.8	5.2	0.0	3364
1982	0.0	156.4	8753.3	2098.3	6745.3	3689.9	1939.0	6027.9	3342.5	607.1	46.7	35.0	33441
1983	38.6	33.0	1868.7	874.9	3108.0	4390.0	3015.3	5889.0	4547.4	1347.9	162.8	47.7	25323
1984	33.2	520.7	6049.4	2835.6	2970.1	6055.2	2895.0	7711.4	7236.6	1710.5	238.2	46.6	38303
1985	71.9	2044.0	336.5	240.2	171.7	396.4	5255.9	3548.9	2469.3	66.9	38.6	26.9	14667
1986	39.0	35.1	139.5	1885.0	6463.5	7411.6	1263.2	2263.2	1384.0	46.4	33.6	43.7	21008
1987	53.8	183.5	51.4	310.3	1203.2	1241.9	2043.0	1251.5	210.2	51.3	15.1	0.0	6615
1988	0.0	0.0	16.2	259.9	239.0	547.3	905.1	1135.6	1251.8	29.2	2.8	0.0	4387
1989	0.0	35.7	20.4	55.6	50.4	6855.5	7469.0	4626.8	2301.6	66.5	37.1	13.9	21533
1990	14.4	7.4	20.4	303.2	38.1	1964.5	2291.3	1060.4	1014.4	33.5	16.6	0.0	6764
1991	0.0	10.5	0.0	503.0	428.2	1428.6	1320.3	2111.5	1026.3	36.6	8.8	0.0	6874
1992	0.0	26.8	109.7	28.6	84.8	10.4	2554.3	341.1	81.2	17.0	0.0	0.0	3254
1993	23.0	21.3	22.0	40.7	45.3	9979.3	5794.9	9223.6	4296.7	296.4	68.2	27.5	29839
1994	20.5	5.5	4.7	134.9	24.3	462.3	1188.9	855.9	222.8	32.6	10.2	0.0	2963
1995	0.0	0.0	16.8	1412.4	4202.1	4309.9	2497.3	3805.8	2373.2	630.4	47.4	21.0	19316
1996	19.6	68.5	8716.8	4249.0	6631.6	3913.7	6220.3	7964.6	2414.7	125.5	68.3	39.7	40432
1997	44.7	2327.8	11015.2	8798.7	3530.2	3968.3	4216.7	5218.9	2863.9	1285.7	297.5	61.0	43629
1998	65.0	166.6	228.0	5712.1	1399.2	5775.8	2398.1	4932.5	4059.8	1026.6	104.0	36.3	25904
1999	25.4	407.1	2460.3	3120.4	1672.7	4318.4	3112.8	8669.4	6922.3	1261.0	54.8	37.4	32062
2000	36.6	132.2	647.4	1731.9	3218.2	3996.6	4720.1	4337.0	1969.7	100.2	49.8	28.3	20968

Sevenmile Creek—Below Short Creek and Above Mares Egg Spring

Sevenmile Creek begins in the east Cascades south of Crater Lake, in the northwestern area of the Wood River Valley. The entire drainage area, including Short Creek is approximately 50 square miles. The two major subwatersheds are Dry Creek, which is 13.3 square miles in area and is located on the north side, and Sevenmile Creek, which is 12.1 square miles in area and lies immediately to the south. About 58 percent of the Sevenmile Creek subbasin is protected by the Sky Lake Wilderness areas, and 62 percent of the Dry Creek subbasin is also wilderness. Only about 5 percent of entire drainage area is private land. Despite timber harvesting and road construction activities on FS land, the magnitudes and peaking of streamflow in Sevenmile Creek above irrigation diversions are likely to not have been significantly affected from natural conditions (USDA, 1995). Therefore, gaged streamflow measurements taken above irrigation diversions are considered natural.

The headwater area of Sevenmile Creek begins along the east side of Cascade Ridge where an abundance of glacial till and loose unconsolidated volcanic material is located. The watershed is dominated by pumice soils, especially in the Dry Creek drainage, which has a high infiltration rate. Therefore, the fact that Sevenmile Creek has lower peak flows per drainage area than other western Wood River Valley streams is not surprising.

The high elevation peaks of Sevenmile Creek, particularly Klamath Point and Pelican Butte, are composite volcanoes composed of ashes and blocky basalt flows. These areas have very little drainage network, which implies groundwater recharge occurs here. Springs can be found at the valley bottom along the edge of wetlands, which are most likely fed by groundwater recharge occurring in the Sevenmile drainage (USDA, 1995). The natural, synthetic time series developed for Sevenmile Creek attempts to account for surficial streamflow and water released by these springs at the bridge below Short Creek.

The FS has maintained a daily recording streamflow gage on Sevenmile Creek below Dry Creek since October 1992. These values were measured above irrigation diversions, but these data are likely lower than the actual amount of water produced by the Sevenmile/Dry Creek watersheds, since the observation site is located on an alluvial fan. Consequently, a portion of flow has probably gone subsurface upstream at the top of the alluvial fan. Some of this flow likely returns to Sevenmile Creek on the valley floor, while some may be lost to the regional groundwater aquifer.

Additional groundwater accruals occur downstream of this gage location. Several miscellaneous flow measurements were collected by the USGS in 1992-1993. Measurements were taken above Dry Creek, as well as downstream below Short Creek and several unnamed springs. These measurements are concurrent with the FS record, so relationships were developed between the FS gage and measurements taken below Short Creek to develop monthly total streamflow estimates for Sevenmile Creek below Short Creek from October 1992 to September 2001. February 1999 was not estimated since the FS gage was not continuous during this time period.

In general, Short Creek and the unnamed springs provided at least an additional 30 cfs to Sevenmile Creek. Only two streamflow measurements were collected when upstream diversions were not in use and were concurrent with the period of record of the FS gage. These autumn measurements were used to estimate baseflow contributions from the unnamed springs and Short Creek. Larger increases between the two gage sites were seen during spring runoff, which varied by at least 81 cfs, but unmeasured diversions between the two locations make it impossible to back-calculate the natural amount of water available with sufficient confidence. Part of the flow measured below Short Creek may also be accounting for water from the Sevenmile and Dry Creek watersheds that went subsurface and is not accounted at the FS gage. The synthetic time series developed for Sevenmile Creek below Short Creek, therefore, accounts for the water produced by the unnamed springs, all the water observed in the FS gage below Dry Creek, some of the water that went subsurface upstream of the FS gage, and some water related to spring runoff in the intermediate area below the FS gage.

The monthly total flow estimates below Short Creek were used to create a complete synthetic time series for Sevenmile Creek between October 1947 and September 2001. This correlation analysis was completed against the Rogue River above Prospect gage on a month-by-month basis. Good correlations were found between the Sevenmile estimates and the Rogue River above Prospect gage, and sufficient variability was apparent in each month. The combination of the original monthly total streamflow estimates and those derived from the line of minimum absolute deviation for each month composes the synthetic time series for Sevenmile Creek below Short Creek, with one exception.

Several instantaneous streamflow measurements were collected below Short Creek by USGS between August 1949 and October 1962. Of these values, most can be considered natural, because the upstream irrigation canal was noted as being “dry.” For the other measurements where the diversion canal was not dry, a flow measurement was collected for the diversion canal. By adding together these streamflow and diversion flow measurements, these streamflow measurements were naturalized. All of these natural values were used to rescale the Rogue River above Prospect and Red Blanket Creek daily gage records to estimate monthly total flows for several autumn months between 1950 and 1962. The monthly totals found by rescaling the two gaged records yielded very similar results, generally within 10 percent of each other. Even though only two of these measurements were noted as “baseflow” by USGS, these estimates will be referenced to as baseflow estimates since they were only for early autumn months.

These baseflow month estimates were considered accurate for natural flow in Sevenmile Creek below Short Creek. The baseflow recession rate at the FS gage most likely has more variability than the baseflow rate below Short Creek. The gage below Short Creek is more dependent on spring-fed flows than the FS gage, and the FS gage may be underestimating baseflow due to the alluvial fan location. Since greater variability is considered to more accurately represent natural streamflows, these less variable monthly total flow estimates were omitted in the least-squares line development. These values were considered accurate, though, as they directly resulted from gaged information. Therefore, they were used in the final synthetic time series in place of values derived using the MAD line to provide additional calibration to the Sevenmile Creek synthetic time series (Table B-13).

Table B-13. Sevenmile Creek synthetic natural streamflow record—Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	4455.0	4232.7	4195.7	3488.6	3978.3	4163.2	6906.2	8203.8	6137.9	4657.4	4387.6	4266.7	59073
1950	4489.6	4238.1	3792.0	4205.5	4304.5	5114.7	5772.8	7737.2	7518.8	5232.5	4646.8	3703.5	60756
1951	6102.5	6379.8	7223.6	4968.7	5387.5	4316.7	6977.4	7310.6	5854.9	4963.2	3827.1	3488.8	66801
1952	5344.4	5142.9	5507.4	4020.5	4629.3	4247.5	7614.4	8316.7	7961.7	5976.1	3579.4	3175.4	65516
1953	2971.1	2713.7	3073.3	6353.8	5388.2	4177.5	5249.1	7513.1	8573.8	6295.9	5192.2	4777.5	62279
1954	4840.6	6031.3	6166.3	4575.5	5106.6	4889.8	7118.1	7396.1	6415.6	5238.0	4998.8	4903.5	67680
1955	4642.6	4331.6	3964.3	3728.7	3900.2	3783.8	4083.3	7373.4	7030.7	4796.1	4341.7	4251.0	56227
1956	4547.1	4878.9	7702.1	6560.7	4244.5	4064.9	6602.8	8139.5	7460.2	5568.6	5098.0	4916.1	69783
1957	5195.8	4909.8	6222.4	3904.9	4987.2	6188.8	5503.8	7075.3	5568.2	4815.5	4642.9	4551.1	63566
1958	4850.2	4803.7	5204.9	5032.5	6037.2	4355.8	5452.2	7874.7	6982.6	5275.3	4930.5	4837.7	65637
1959	5310.3	4992.3	4384.8	5195.8	4301.9	4391.5	5458.2	6699.3	5333.9	4572.9	4391.6	4418.6	59451
1960	4977.0	4086.4	3611.6	3471.1	4321.0	5318.0	5981.8	7308.6	6344.6	4555.7	4295.6	4157.8	58429
1961	4440.9	4663.0	4517.8	3841.3	5339.4	4823.1	5642.9	7231.3	6427.4	4678.8	4412.4	4412.0	60430
1962	4637.0	5083.7	4880.8	4235.6	4272.7	3869.0	6236.3	6922.9	5806.4	4662.6	4463.1	4297.4	59368
1963	3962.4	4995.8	5472.0	3781.1	5277.5	4137.5	4918.7	7183.4	5271.9	4584.0	4364.5	4293.8	58243
1964	4455.4	5454.7	4566.7	4337.3	4229.9	3886.5	5132.7	7253.4	7378.7	5063.5	4535.7	4375.9	60670
1965	4356.7	4366.3	10850.9	6784.8	4830.0	4444.6	5822.8	6946.6	5769.5	4885.0	4753.5	4540.0	68351
1966	4600.1	4364.3	3884.1	4202.6	3863.8	4693.0	7659.0	7098.5	5172.1	4510.4	4192.2	4100.2	58340
1967	4321.2	4952.7	5005.0	4357.1	4299.3	4081.5	3523.2	7538.8	6254.9	4597.9	4196.7	4026.1	57154
1968	4459.7	4002.8	3657.3	3793.8	5224.9	4347.1	3620.8	6302.9	4723.4	4151.1	4090.9	3909.5	52284
1969	4251.8	5050.8	4581.8	4400.1	3945.7	3917.4	5778.5	7873.9	6103.2	4713.9	4324.8	4193.0	59135
1970	4469.6	4060.7	4579.7	7224.1	4472.5	4435.1	3647.8	6855.7	5487.3	4534.9	4340.1	4261.9	58369
1971	4471.6	5692.4	4594.5	6125.2	4630.8	4813.6	5536.1	8293.0	7881.6	5878.4	5109.6	5080.7	68108
1972	4962.4	5174.5	5084.4	5664.8	5126.9	8937.3	6021.1	7859.7	7237.1	5481.2	5185.4	5106.4	71841
1973	4941.3	4517.8	4706.3	4540.5	4120.8	4040.9	4454.4	6562.6	4841.7	4280.1	4145.9	4248.6	55401
1974	4497.2	6463.4	6369.5	6975.8	4328.4	5724.4	6232.9	7739.4	8823.2	5899.3	5233.6	5047.6	73335
1975	4929.2	4415.8	4462.3	4502.3	4515.7	4840.7	4402.5	8125.0	8684.6	5794.7	5000.1	4799.9	64473
1976	5061.9	5039.1	6114.1	5093.0	4416.4	4232.1	4953.0	7583.3	6233.4	5195.5	5281.9	4852.5	64056
1977	4719.2	4200.3	3668.1	3415.2	3702.6	3354.4	3514.5	6350.6	4776.2	4093.3	3933.6	4008.9	49737
1978	4227.2	5503.7	7315.0	4822.8	4491.4	4305.2	4022.4	6455.5	5097.5	4436.4	4218.0	4312.4	59208
1979	4252.5	4055.7	4068.8	4264.4	4226.1	4897.9	4659.2	7073.6	4949.5	4269.6	4041.0	3812.3	54571
1980	4569.0	4610.0	4608.0	5904.3	4415.5	4251.5	4937.7	6497.4	4975.7	4338.8	4081.1	3990.0	57179
1981	4245.2	4267.3	5031.0	3793.8	4551.3	3860.6	3699.8	6268.5	5161.0	4248.0	3936.5	3848.0	52911
1982	4331.6	5158.5	7911.0	4330.4	5665.2	4794.4	5406.5	7637.7	6854.5	5391.0	4792.5	4694.2	66968
1983	4885.1	4548.9	5993.7	4986.0	5284.1	5766.2	5403.4	7691.2	6920.4	5734.6	5090.4	4821.6	67126
1984	4727.2	5318.3	6756.3	5268.9	5049.0	5783.1	5646.9	7673.8	7901.1	5790.5	5187.5	5034.4	70137
1985	5201.5	6156.9	4594.6	4067.6	4165.3	4133.1	6791.4	7044.5	6056.4	4690.6	4433.5	4476.2	61812
1986	4818.9	4389.9	4382.4	4925.3	5887.4	6161.1	4483.4	6771.0	5518.0	4499.2	4362.4	4791.2	60990
1987	5053.0	4904.2	4182.6	4139.6	4627.9	4487.5	5108.1	6482.6	4704.1	4551.9	4098.4	3935.5	56275
1988	4121.0	3888.3	3903.6	4088.8	4218.4	4223.9	4111.6	6441.3	5447.3	4257.9	3923.0	3762.7	52388
1989	4003.9	4395.8	3937.6	3797.5	3992.0	5999.9	7632.6	7234.2	5977.5	4687.8	4412.0	4230.6	60301
1990	4428.5	4096.3	3937.1	4132.7	3924.2	4678.7	5276.3	6413.0	5317.0	4328.4	4120.0	3930.9	54583
1991	4206.2	4128.7	3711.1	4312.4	4341.5	4537.8	4536.1	6733.4	5323.6	4375.8	4008.6	3768.5	53984
1992	4073.2	4301.3	4339.5	3544.6	4078.5	3512.5	3742.2	5991.6	4324.9	3973.6	3715.3	3580.6	49178
1993	3962.4	3892.6	4111.5	4054.6	3623.3	4698.5	4590.4	7407.5	6725.4	5045.1	4412.0	4272.1	56795
1994	4412.2	4212.7	4509.0	4542.3	3999.6	4817.7	5183.8	5829.9	4455.7	4340.0	4205.7	4147.7	54656
1995	4277.6	4314.9	4438.9	4625.6	5028.6	5495.5	5652.1	7413.5	6538.5	4784.6	4457.0	4411.7	61439
1996	4425.0	4826.2	8945.1	6603.3	6055.3	5908.1	6656.0	7823.2	6148.0	5115.3	4797.8	5013.9	72317
1997	5005.1	6485.4	7815.3	7610.5	5300.1	5799.1	6724.7	7725.9	5929.5	5308.1	5166.7	5051.8	73922
1998	5011.4	4745.7	4703.3	5499.5	5086.5	6019.4	6485.2	7646.4	6874.1	5490.4	5000.0	4397.3	66959
1999	4571.9	4551.7	3589.8	4226.8	4737.7	4743.2	5510.1	7505.5	7521.4	5591.9	4651.9	4494.4	61696
2000	4879.2	5102.7	5031.2	5036.0	4958.5	5703.2	7214.6	7413.4	6026.5	4959.2	4756.6	4537.8	65619

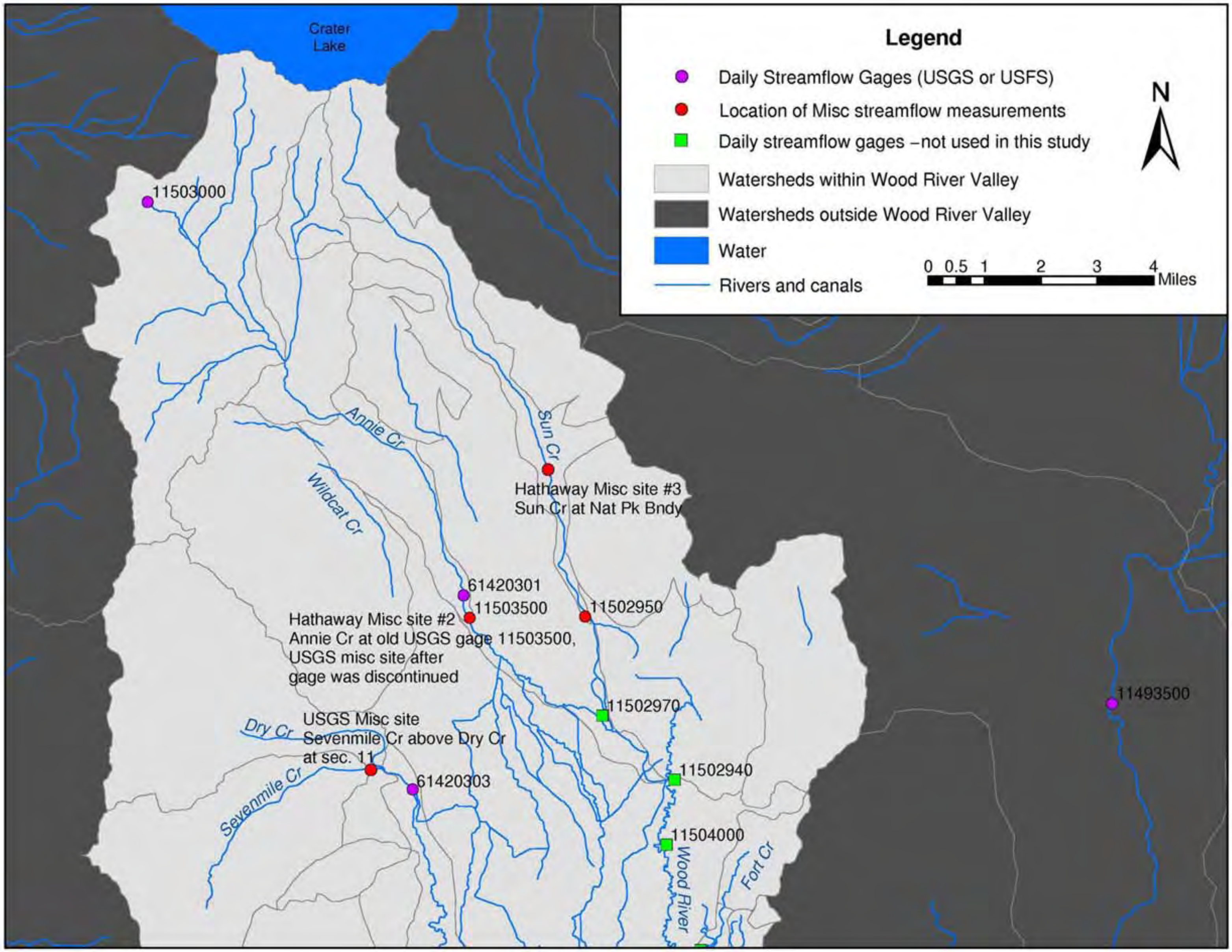

Figure B-3. Streamflow measurement locations for Northern Wood River Valley.

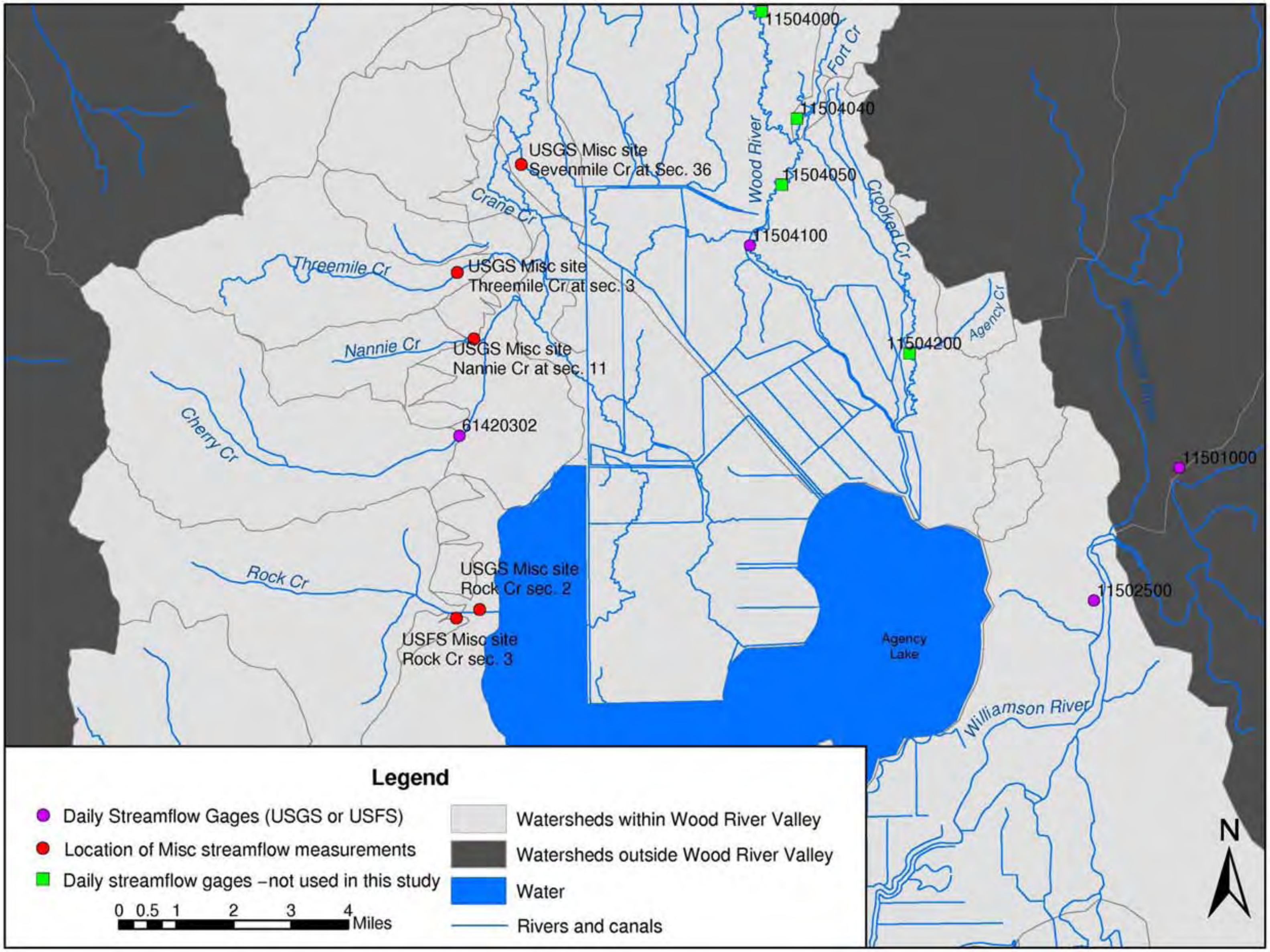

Figure B-4. Streamflow measurement locations for Middle Wood River Valley.

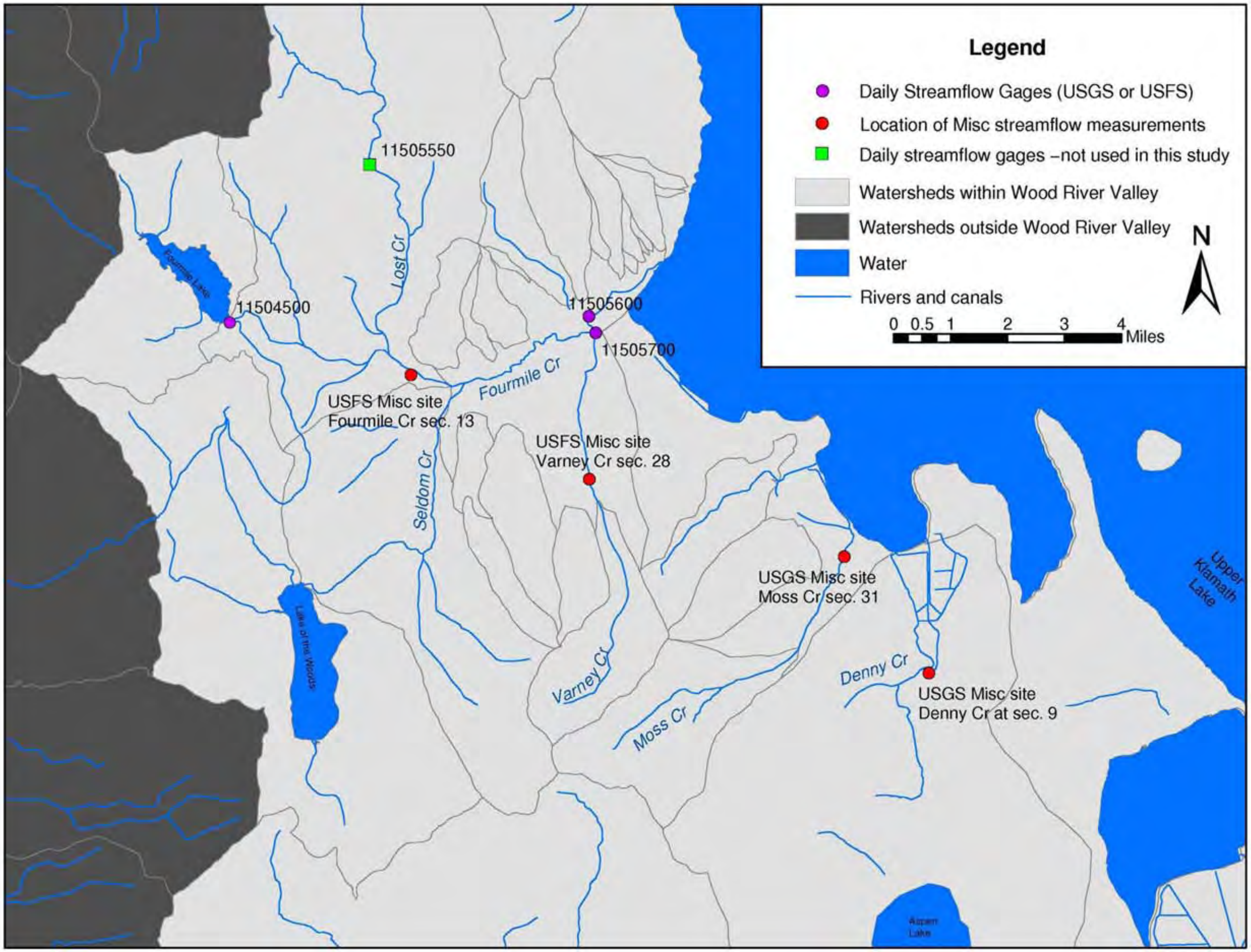

Figure B-5. Streamflow measurement locations in Southern Wood River Valley.

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Attachment C—Time Series Synthesis and other Statistical Methods

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Attachment C—Time Series Synthesis and other Statistical Methods

Time Series Synthesis

The restoration of gaged monthly flow histories to longer-term natural flow histories and the determination of inflows from ungaged watersheds are based on available recorded information. For the study area, gaging station and meteorological records were examined for completeness. Nearby stations from outside the Klamath Basin were also used in the assessment. A time-series history for each record is developed, based on a reconstruction for the period of interest. Also, the reconstruction must be consistent with conditions existing near the station of record being reconstructed.

These considerations are important for both climate and streamflow records. Net ET estimates for irrigated crops and natural marshlands require monthly precipitation and average temperature for the period of interest. Natural flow is adjusted by these consumptive uses. Further, many of the stream reaches treated in the water budget require a complete history of flow for the period of interest.

Initially, all stream-gaging records are reconciled as natural flow records where measured flow at the gage is unaltered by upstream diversions, reservoir storage, or other uses and longer-term temporal changes in watershed conditions that may adversely affect natural streamflow. Records having demonstrated effects from upstream uses were adjusted to remove the alterations to the gaged flow caused by such uses. In many cases, upstream uses are inconsequential to restoration and the gaged flow may be considered equivalent to natural flow. Records possessing natural variations are generally easy to compare and cross-correlate. When such records may be of insufficient length to otherwise provide meaningful results, they are statistically restored to a longer period of record. Such records can be useful in evaluating the impact of watershed alterations.

Meteorological records have different requirements. A complete time series for a station at one location is reconciled for that location. Because a particular data record may be for a station that has been relocated, usually to a location less than 3 miles away, historic records are examined to determine if the new record is continuous with the older record or if there is a break due to slightly different climatic conditions existing at the new location. Useable records show no breaks. Records that do not meet these criteria are reconstructed using correlation techniques.

In the correlation process, there are two types of records. Primary records are time-series histories considered independent and form the basis of the correlation. Time-series histories of insufficient length or having missing values, are secondary records to be restored. The common base-period for the reconstruction must be of sufficient length so that meaningful results are derived from the records. For a collection of shorter-term records used in the correlation process, the length of this common base-period is usually defined as the date of the earliest record starting the period in question, and the ending date of the latest record terminating the period in question. Either a least-squares correlation procedure or a linear minimum absolute deviation procedure is used to derive the values for the secondary record.

For this analysis to be successful, three criteria are generally satisfied. First, the primary record used to restore missing values should have unaltered seasonal characteristics or monthly variations similar to the secondary record being restored. Unaltered seasonal characteristics, as indicated previously, are indicative of the regional climatic factors. Second, concurrence of these records should demonstrate meaningful results in the correlation. If concurrence is insufficient, correlation results can become deceptive or difficult to interpret. Third, the primary records should come from stations in the geographic vicinity of the secondary records being restored. This maintains regional consistency regarding climatic factors that affect precipitation and drive streamflow.

Completion of the reconstruction process is relatively straightforward. A pool of available primary records is statistically compared in the correlation with the secondary record being reconstructed, and the explained variation being recovered is noted in a matrix for each month with each primary record. This explained variation is used as a guide, but not as a rule, in selecting the best monthly correlations that will be assembled into the final record. Because this analysis was carried out on a calendar month basis, the best correlation for each given month may be chosen from the cadre of correlation results that were available from the pool of useable records.

In addition, special considerations are examined in completing the correlation analysis. For example, non-negative values are derived from a line forced through the origin. In general, a line of minimum absolute deviation (Zebrowski, 1979) is used where loss of information in the least-squares correlation is noted to significantly degrade recovered variability. In particular, depending on the evidence of curvature noted in the scatter plot, any one of several line-fitting procedures may be used based on the successful recovery of variability estimated to exist within the record being reconstructed. As such, this recovered variability is unexplained. For the generalized procedure, the line of minimum absolute deviation was found to give results equivalent to the least-squares procedure when the explained variation was greater than about 70 percent. Application of this method provides recovery of records with explained variability less than 70 percent, as well. The procedures used for this study were essentially the same as those demonstrated graphically by Ried, Carroon, and Pyper (1969) and described in Pollard (1977) and Lapin (1983), in addition to Zebrowski (1979). Special methods used in the reconstruction of Cascade east-slope flows are described elsewhere in this report.

Sources of Records being Used

Stream gaging-station records are available from the water-supply papers published by the USGS, or are accessible from comprehensive databases maintained by the USGS, the Oregon Water Resources Department, or on compact disks as published by Hydrosphere. Streamflow records of principal interest included the gaged record for the Rogue River above Prospect and for South Umpqua River at Tiller, both considered as basis stations. In addition, the gaged record for Sprague River near Chiloquin and for Williamson River below Sprague River near Chiloquin, were primary records that were complete for the period of interest but had alterations to flow due to diversions upstream. Other needed records were supplied by the Forest Service for streams along the eastern flank of the Cascades.

Comprehensive databases providing precipitation records are available from the National Oceanographic and Atmospheric Administration and from compact disc records of U. S. Weather Bureau weather-data summaries published by Hydrosphere. In addition, long-term records were available from the Hydroclimatic Data Network. The meteorological records of principal interest essentially included Klamath Falls, Chiloquin, Sprague River, and Round Grove. The Klamath Falls precipitation record comprises a sequence documenting a continuous and nearly complete history from about 1906 to 2001. These records (except Chiloquin) were carefully examined and missing monthly values were researched and recovered from Weather Bureau monthly summaries showing values for missing entries that had been previously estimated and published. Remaining missing values in these precipitation records were then statistically reconstructed, if required, by correlation with the record of one, or more, nearby precipitation stations. Precipitation records for Prospect and Crater Lake were also of principal interest and considered as basis stations.

Basis Stations for Comparing Restored Natural Flow

To establish regional consistency in climatic factors, an assessment of trend evidenced for precipitation at Prospect, and at Crater Lake, was completed. Precipitation histories for each of these stations were examined and several missing monthly values reconstructed so that a complete precipitation history was available for each station. The comparisons are for normalized values of annual precipitation. Similar comparisons were also completed for each month, and these were checked to determine the reasonable nature of the results. Both records are stable as they are each from data collection platforms maintained at fixed locations. Results of the annual analysis for these time series are shown below. Of note is the indication that annual total precipitation shows a slightly greater declining trend on the east side of the Cascades compared to that seen on the west side of the Cascades (Figure C-1). The double-mass curve (Figure C-2) shows the mass accumulations have no deviations, as expected for stable records.

Trend assessments were also completed to establish the reasonable nature of the record for the basis station used to evaluate reconstructed natural flows. This station is gage 14328000, Rogue River above Prospect, which was compared against the natural flow record of gage 14308000, South Umpqua River at Tiller (Figure C-3). This second gage is in an independent west-side watershed north of the Rogue watershed. Of note is the nearly exact concordance in trend evidenced for the annual flow time series of these two stations. The straight-line double-mass curve indicates these are stable, unaffected, natural-flow records (Figure C-4).

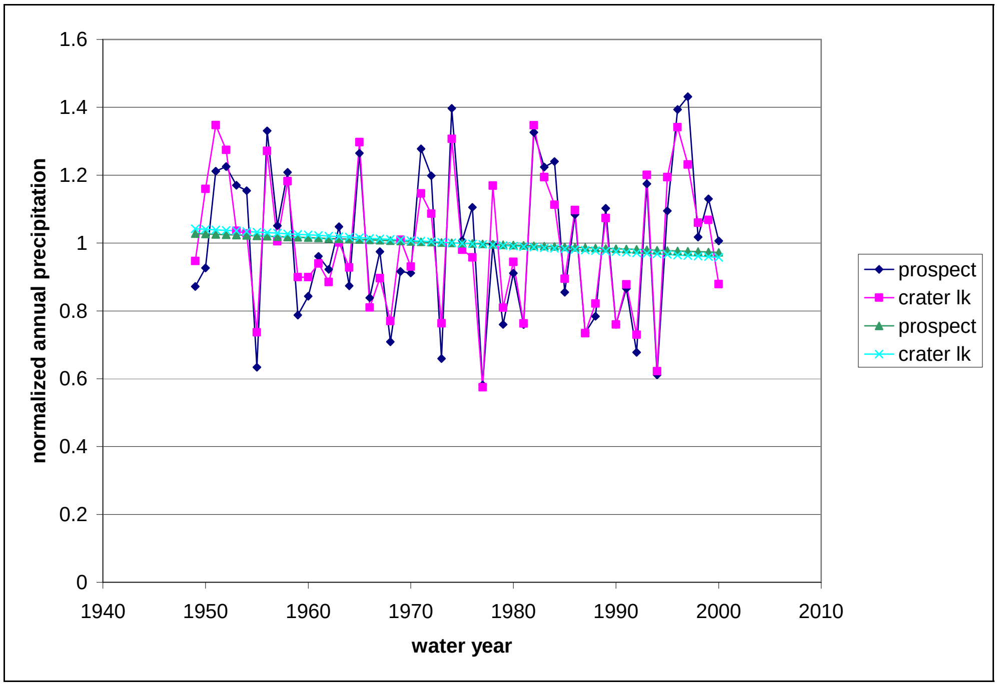

Figure C-1. Trend assessment for annual time series of precipitation at Crater Lake National Park and Prospect, Oregon, normalized annual precipitation, 1949-2000.

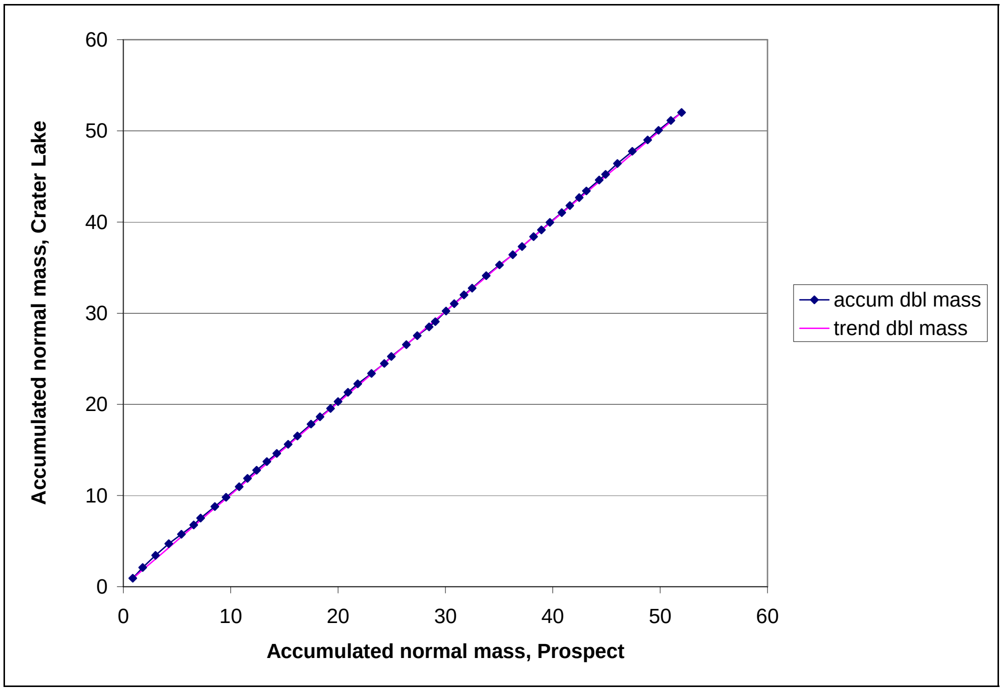

Figure C-2. Double mass curve, Crater Lake National Park vs. Prospect, Oregon, accumulated normal mass for annual precipitation, 1949-2000.

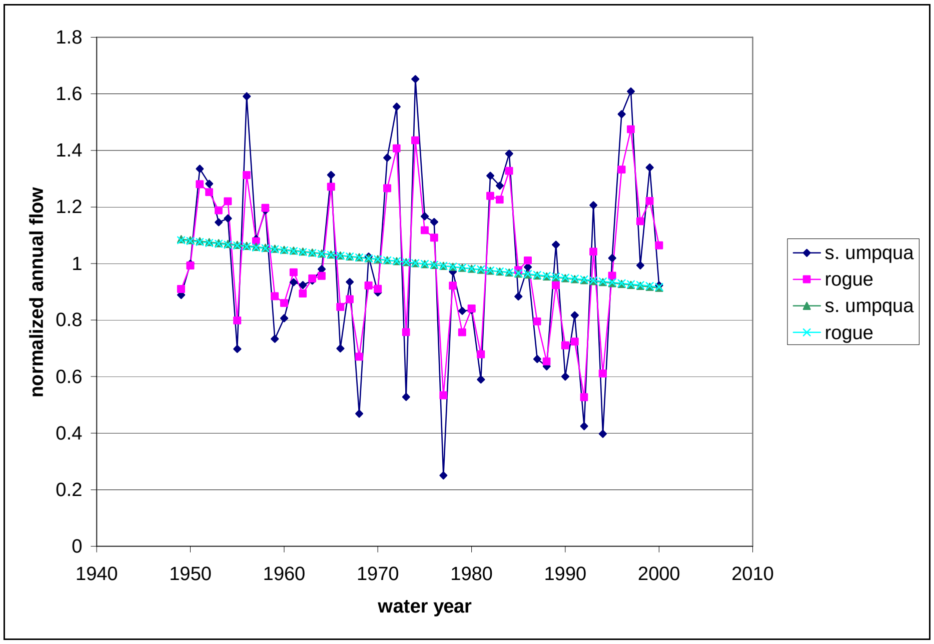

Figure C-3. Trend assessment for annual time series of streamflow, Rogue River above Prospect and South Umpqua River at Tiller, Oregon, normalized annual inflow, 1949-2000.

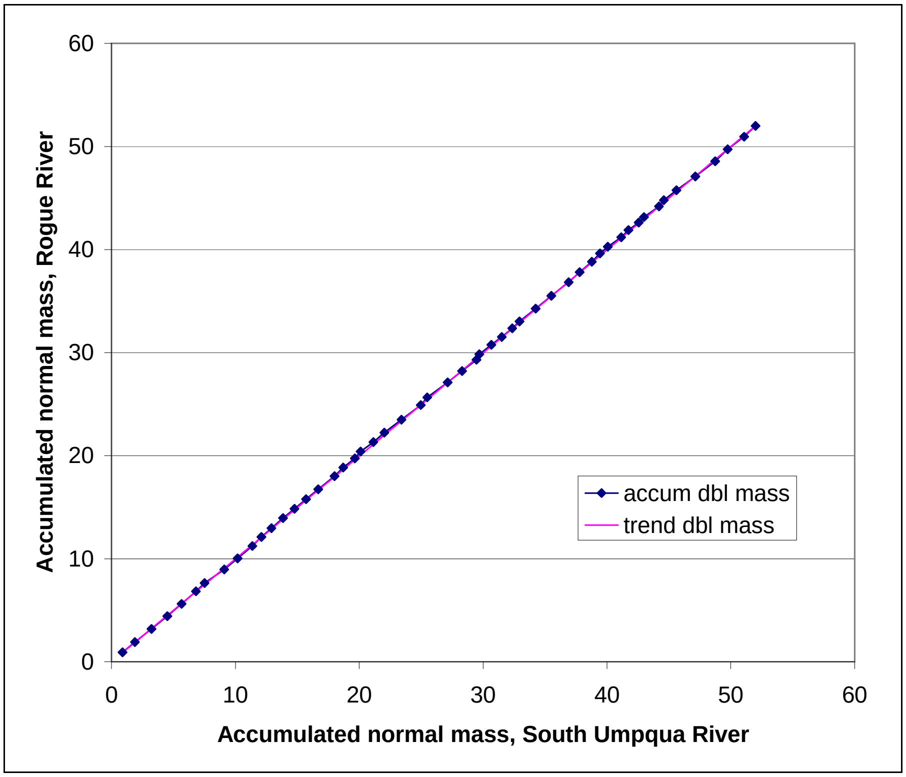

Figure C-4. Double mass curve, Rogue River vs South Umpqua River, accumulated normal mass for annual streamflow, 1949-2000.

The results in comparison of the natural flow record of the Rogue River with that of the South Umpqua River show the gage for the Rogue provides a reasonable record of natural flow to use as a basis in challenging the veracity of other records for restored natural flow at nearby locations. The consistency in trends noted for these records also indicates climatic dominance is consistent within the region. The independently observed consistency in trends noted for the two longer-term precipitation records that were examined, Prospect and Crater Lake, indicates a divergence in trend that, over the period of interest, indicates trend has decreased somewhat more rapidly on the east side of the Cascades than on the west. This same indication could be expected for restored natural flow in the upper Klamath Basin when compared with the natural flow record of the Rogue River.

Sprague and Williamson Rivers

The assessment of natural flow for the Sprague and Williamson Rivers was unable to account for changes in watershed condition other than an accommodation of irrigation uses and reclamation of marshlands that would affect flow of the stream. An assumption in this evaluation has been that over the period of interest, there have been no marked changes in area for either irrigation or reclaimed marshland. Although essentially false, implementation of the assumption is conservative in the adjustment of the gaged flows throughout the 52 year period of interest, and does not, thereby, tend to underestimate natural flow of these streams. The assumption implies that irrigated areas have been stable, more or less, even though no detailed information was available regarding the locations, timing of changes, and extent of increases in these areas. The resulting analysis provides a time series for the natural flow of the Sprague and Williamson Rivers. Evidently, adding irrigation depletions to gaged flow and subtracting natural losses for reclaimed marshland are comparable in this case.

An examination of the normalized time series (Figure C-5) and double-mass curves (Figure C-6) for the Sprague, and Williamson below the Sprague, illustrate the nature of the derived results. In Figure C-5, the trend for the Sprague when compared to Rogue River is that streamflow is declining faster over time on the east side of the Cascades than on the west side of the Cascades. This is similar to the trend shown for two precipitation stations in Figure C-1.

An examination of the results for natural flow of the Williamson below its confluence with the Sprague indicates that including the Williamson watershed above the Sprague in the determination of natural inflow to Upper Klamath Lake is also reasonable. The double-mass curve (Figure C-6) indicates the reconstruction appears very good and shows no distinct deviations or abrupt changes in trend that would be characteristic of development and other changes within the watershed above the Sprague. Trends for each time series and double mass provide results that are consistent with those derived for the Sprague.

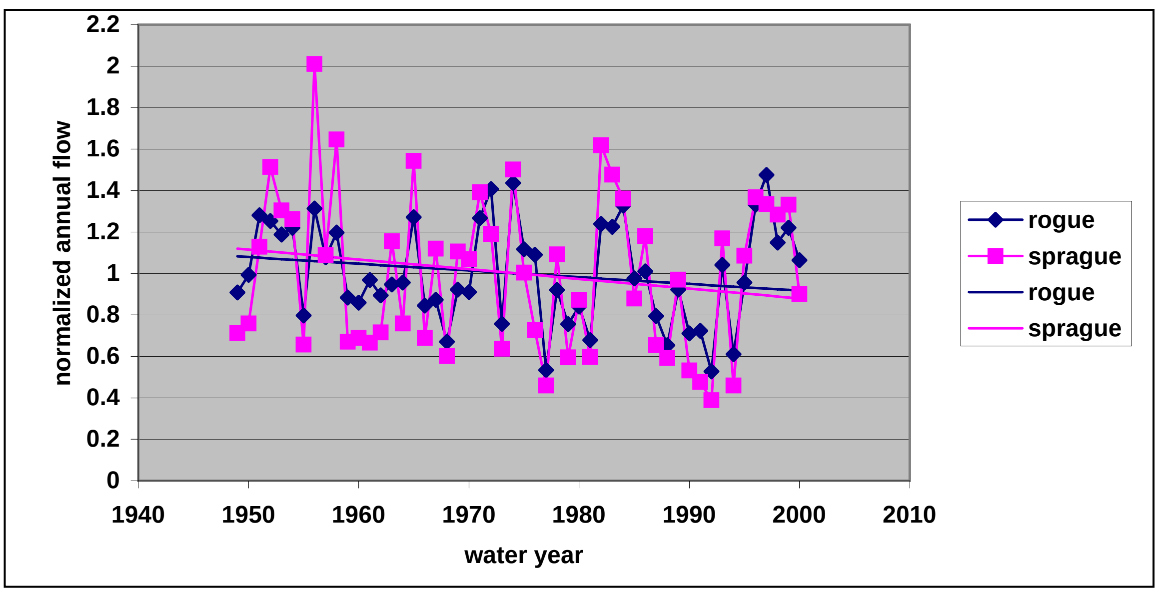

Figure C-5. Trend assessment for annual time series of streamflow for the Sprague River below Chiloquin and Rogue River above Prospect, Oregon.

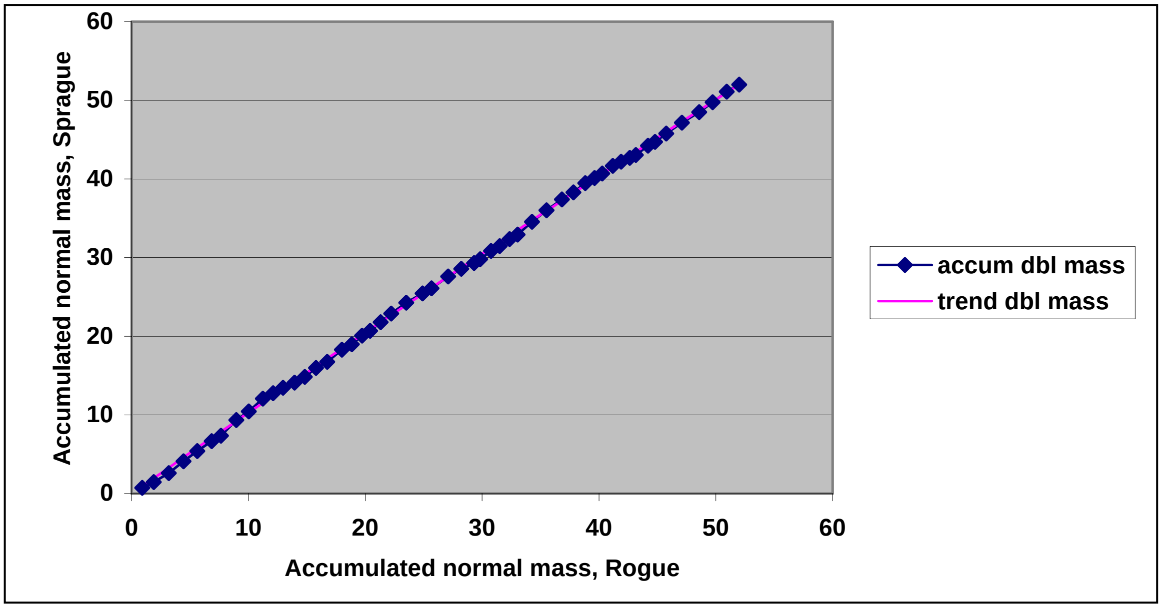

Figure C-6. Double mass curve, Sprague River vs. Rogue River, accumulated normal mass for annual natural streamflow, 1949-2000.

Cherry Creek

Flow histories for several watersheds along the east flank of the Cascades have been estimated by transference of reconstructed gaged flows from nearby watersheds. Of special interest is the examination of reconstructed flow histories that form the basis of the transference, especially where the reconstructed flow histories did not need to be restored to natural flow. A typical reconstructed record from a type-watershed used in the transference is that of Cherry Creek. Records available for Cherry Creek are somewhat sparse yet sufficient for statistical reconstruction of a natural flow history covering the period of interest. Reconstruction of the record for Cherry Creek was based on monthly flows estimated from incidental flow measurements, or on a gaged flow record for years when that record was available. The correlation analysis in the reconstruction of the full time series used a special adaptation of the procedure for fitting the line of minimum absolute deviation, where the line of correlation was curved to accommodate the base-flow deviation observed, or suspected, in the scatter plot. The gaged history for the Rogue above Prospect was the principal station used in the reconstruction. Validation of the methods used, and the results obtained, was provided by the comparison of the reconstructed record with that of the Rogue River. The record for the Rogue is also the basis station for this comparison. Because these stations are in watersheds on adjacent slopes of the Cascades, flow observed in these streams is influenced by dominant regional climatic conditions. Hence, the adequacy in the reconstruction will be reflected in the degree to which the record for the Rogue appears as a surrogate in the reconstructed record for Cherry Creek.

The time series for normalized annual flow (Figure C-7) and resulting double-mass curve (Figure C-8) shows the recovery of information for the reconstructed Cherry Creek time series. For the normalized annual flows, the decline in trend exhibited by the Cherry Creek annual flow time series agrees well with that observed in comparing precipitation histories for Prospect and Crater Lake (Figure C-1). The double-mass curve shows the characteristic agreement that would be expected for comparison of two natural flow gages in essentially adjacent watersheds in stable natural conditions. The curve has no expressed deviations that would be indicative of changes in watershed conditions. An artifact visible in the double-mass curve is the slight curvature associated with the difference in rate of decline indicated by the trend demonstrated in the normalized annual time series. Recovery of information for Cherry Creek shows trend consistency with that evidenced east of the Cascades.

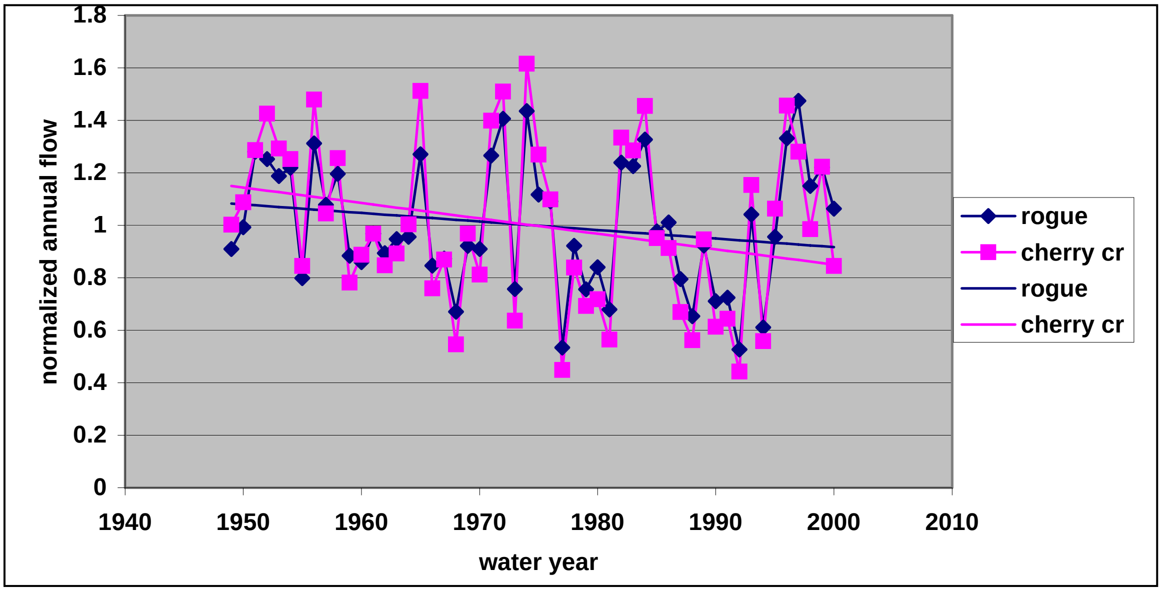

Figure C-7. Trend assessment for reconstructed annual time series, Cherry Creek vs. Rogue River above Prospect, Oregon, normalized annual natural flow, 1949-2000.

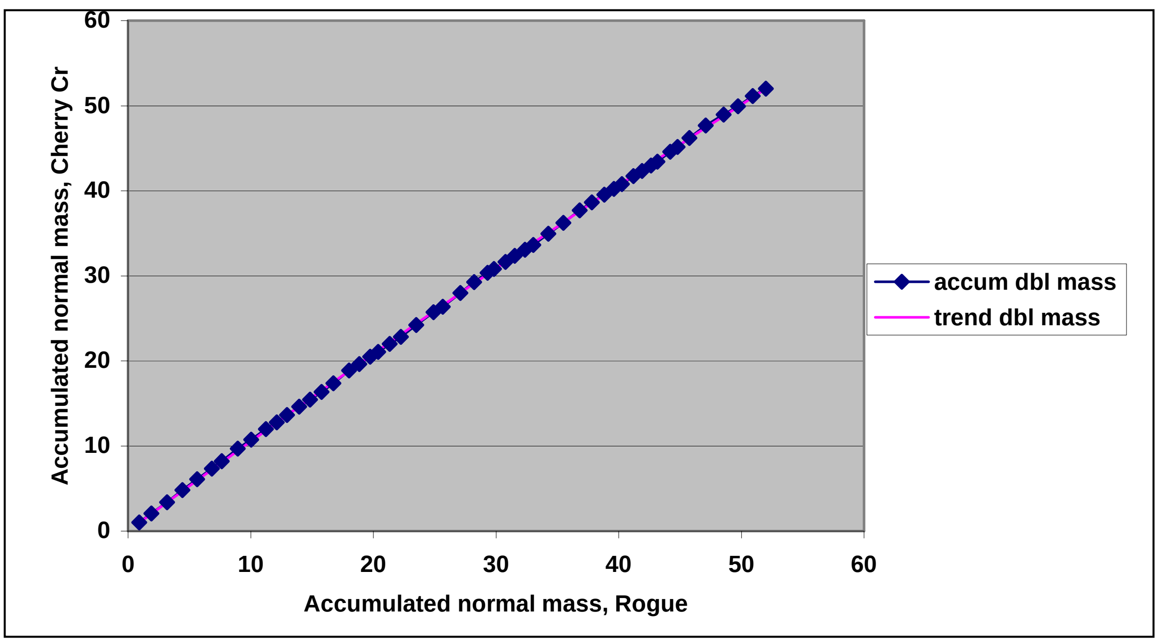

Figure C-8. Double mass, Cherry Creek vs. Rogue River, accumulated normalized annual natural flow, 1949-2000.

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Attachment D—Calculation of Open-Water Surface Evaporation

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Attachment D—Calculation of Open-Water Surface Evaporation

No water balance calculation is complete without estimates or measurements of evaporative losses from the system in question. Unfortunately, there are few reservoir systems for which long-term evaporation measurements are available (Linsley, et al. 1982), particularly when considering pre-development conditions. Given these constraints, an empirical or energy balance method of estimating evapotranspiration in the Klamath system had to be developed.

Energy Balance Method

The Penman Equation, or one of its many derivatives, is one of the most widely used and accepted methods for calculating potential evaporative losses from a free water surface. Penman is also considered by many to be the recommended method when appropriate data are available (FutureWater, 2003, Snyder, 2000). Estimations of potential evaporation are calculated by considering the requirements to balance the energy budget at the water surface (Penmanetc, 2003).

The Penman Equation requires a large amount of measured data, including net radiation exchange at the water surface, energy advected to the water body, minimum and maximum temperature, relative humidity, and wind speed (Penmanetc, 2003). Needless to say, the required data for proper calculation of Penman evaporation is not readily available in the Klamath Basin, nor is it available for the period of record of this study.

Reclamation recently began collecting the necessary data to calculate a Penman equation derivative, the Kimberly-Penman formulation, through the AgriMet station in Klamath Falls. These data are available for the period of March 31, 1999, through the present (AgriMet, 2003).

Empirical Method

The Hargreaves Equation is an empirical formula derived to estimate potential evaporation based solely on air temperature and a knowledge of the latitude of the site (Penmanetc, 2003, Snyder, 2000). Even though the Hargreaves Equation was originally developed to estimate evaporation from agricultural systems, reasonable estimates of potential evaporative losses can be obtained by considering monthly totals (Penmanetc, 2003).

The Hargreaves Equation takes the form:

$$E = 0.0023 S_0 (T + 17.8)\sqrt{\delta}$$

Where:

E = Potential evaporation (mm/day)
T = Temperature (°C)
$*_T$ = The difference between mean monthly maximum and minimum temperatures (°C)
S_0 = Extraterrestrial radiation given by:

$$S_0 = 15.392 d_r (\omega_s \sin\phi \sin\beta + \cos\phi \cos\beta \sin\omega_s)$$

Where:

N = Site latitude
T_s = Sunset hour angle (radians) given by:

$$\omega_s = \arccos(-\tan\phi \tan\beta)$$

β = Solar declination on julian day **J** given by:

$$\beta = 0.4093 \sin\left(\frac{2\pi}{365} J - 1.405\right)$$

d_r = Relative distance from the earth to the sun for julian day J given by:

$$d_r = 1 + 0.033 \cos\left(\frac{2\pi}{365} J\right)$$

Procedure Used to Calculate Potential Evaporation

The first attempt to determine potential evaporation was a correlation of existing Kimberly-Penman evaporation from the AgriMet station to readily available maximum, minimum, and average air temperature readings for the same period. This exercise resulted in only marginal success with R^2 values ranging from 0.61 to 0.79.

Because of the lack of appropriate data necessary to calculate evaporation using any of the Penman Equation derivatives, and the references obtained indicating that the Hargreaves Equation is capable of producing reasonable results

(Penmanetc, 2003, Hargreaves,' 2003, FutureWater, 2003), the Hargreaves Equation was chosen for this study.

The temperature and station location data used to calculate the Hargreaves potential evaporation came from the 2002 Hydrodata CD. Evaporation for six stations—Klamath Falls, Chemult, Chiloquin, Merrill, Sprague River, and Tule Lake—was calculated. Two stations were used to get a complete period of record for the Klamath Falls area, with the primary data coming from the 2SSW station. Missing data was supplemented from the AgriMet station when available.

The daily Hargreaves evaporation estimates were compared with the Kimberly-Penman evaporation data obtained for the Reclamation AgriMet station for the period March 31, 1999, through December 1, 2001. The Hargreaves Equation generally gave a lower estimate of open water evaporation. Figure D-1 shows Hargreaves estimated evaporation compared against Kimberly-Penman calculations. Attempts to adjust the Hargreaves calculated numbers to more closely match Kimberly-Penman evaporation estimates were made with good results ($R^2 = 0.92$). The fourth-order equation derived to adjust the Hargreaves equation takes the form:

$$AH = -117.79984x^4 + 58.283199x^3 - 8.42755502x^2 + 1.7850829x - 0.011896042$$

Where: AH = Adjusted Hargreaves evaporation estimates
x = Unadjusted Hargreaves evaporation estimates

Figure D-2 shows the comparison of adjusted Hargreaves and Kimberly-Penman evaporation. Pan evaporation measurements were also available for very limited periods of record. The adjusted Hargreaves evaporation estimates were compared against these pan data with good correlation. The open-water surface evaporation data used in the model are the adjusted Hargreaves numbers reduced by 15.7 percent (0.75/0.89) to more closely match evaporation estimates based on pan measurements, and tied estimated evaporation to physical measurements. In this adjustment, 0.89 restores the relationship to a 1 to 1 correspondence, and 0.75 is the pan coefficient.

Net open-water surface evaporation was required for the water budget of natural streamflow in the Klamath River at Keno to account for the effects of evaporation and precipitation on UKL. Estimated total monthly evaporation (in inches) was added to total monthly precipitation from available climate stations to develop total net open-water surface evaporation on each lake. Precipitation from the Klamath Falls and Chiloquin climate stations were used to estimate net open-water surface evaporation off UKL. A simplified Thiessen method was used to distribute relative station influence. On UKL, 67 percent (approximately 44,873 acres) of open-water surface area was attributed to the Chiloquin station, and 33 percent (approximately 22,102 acres) to the Klamath Falls station for UKL. Monthly net open water surface evaporation for UKL for the study period is shown in Tables D-1.

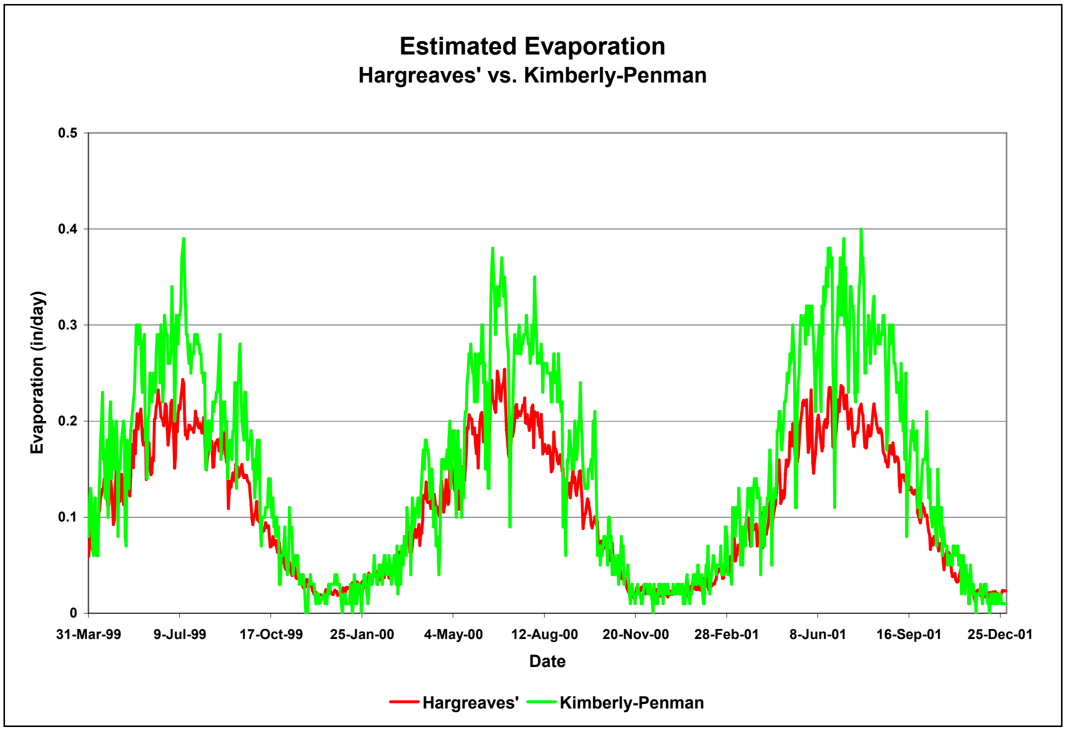

Figure D-1. Unadjusted Hargreaves vs Kimberly-Penman evaporation estimates

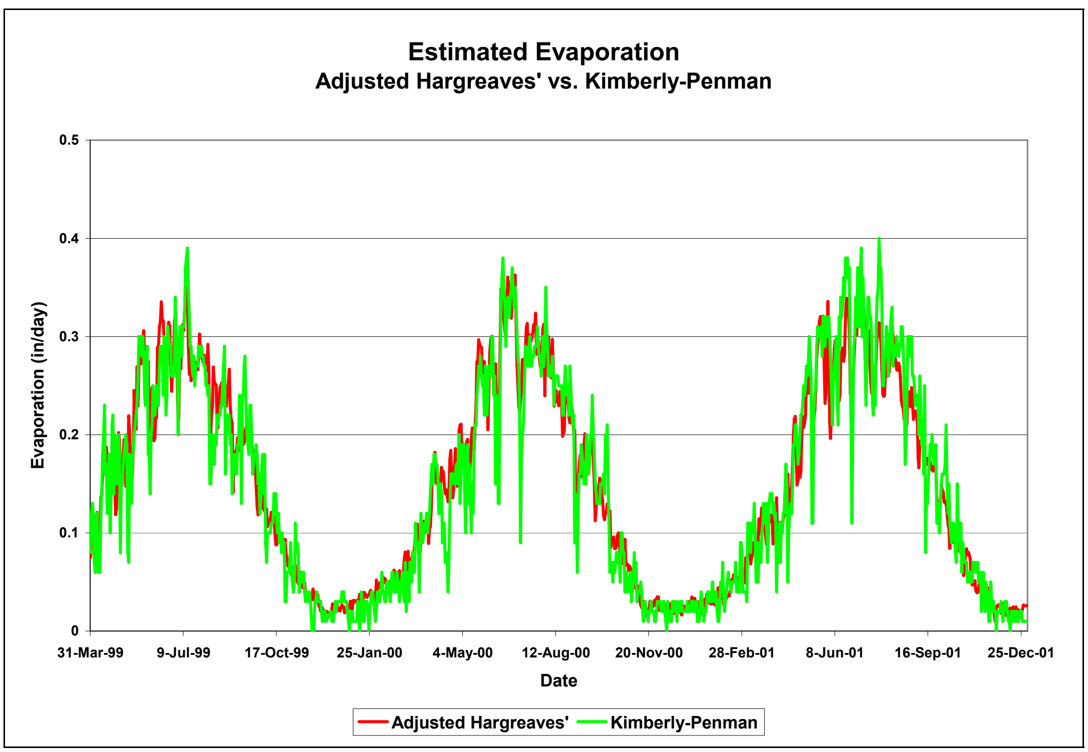

Figure D-2. Adjusted Hargreaves vs Kimberly-Penman evaporation estimates

**Table D-1. Net open-water surface evaporation for Upper Klamath Lake—
Total monthly losses in acre-feet**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	9190.5	-5285.0	-14983.5	-1846.8	-3636.3	7056.8	19308.0	24558.6	37949.3	41685.0	33617.7	22787.6	170402
1950	11191.9	500.6	-1897.2	-22255.0	1864.0	-796.0	14796.0	30796.9	30286.6	44666.3	36041.8	22612.0	167808
1951	-9729.8	178.9	-17764.6	-10290.3	-4680.1	6923.3	15015.0	25914.0	39814.7	43564.4	36503.3	25378.3	150827
1952	-1830.8	-6184.3	-25566.5	-7433.5	-6914.6	3971.0	20378.2	27940.7	24512.2	46361.6	38292.6	24205.9	137732
1953	14493.1	-37.7	-19105.8	-18629.1	-2291.4	6367.7	15510.7	12545.8	29356.4	43537.0	27969.7	25223.4	134940
1954	6638.8	-18941.8	-6886.8	-17496.7	3321.0	3441.3	15638.7	32351.6	29282.9	43124.7	28678.4	19979.9	139132
1955	11186.2	381.8	-7282.7	-2906.6	2411.9	6403.3	10175.6	29754.5	37287.8	37592.2	36200.0	19081.7	180286
1956	7934.3	-18015.9	-30157.1	-23282.2	-8177.4	7561.8	17428.8	22753.7	28759.3	36738.5	32628.9	18026.2	92199
1957	-3034.5	3322.9	-6253.5	-11807.0	-6138.9	-10735.3	15077.9	23982.8	38934.7	39387.6	32671.6	9884.1	125292
1958	4073.7	-7586.0	-17136.0	-16830.8	-15868.1	5158.7	14671.0	27614.1	21602.2	36983.4	34945.1	20488.0	108115
1959	10400.6	-1104.0	-2342.7	-5853.2	113.4	7644.1	18923.7	25076.3	36186.8	43140.4	27140.8	19641.6	178968
1960	9117.5	4994.2	-463.3	-5004.0	-9811.3	-2300.5	16337.2	19698.8	39757.3	41480.6	32655.7	23696.6	170159
1961	9970.8	-15503.6	-7282.4	-59.7	-6928.3	1765.8	17624.2	20222.6	36562.5	42508.2	34897.0	16239.9	150017
1962	1915.0	-12536.2	-12558.5	-4749.6	-1463.7	3016.6	18055.8	22284.7	36999.4	39959.9	29025.3	21577.5	141526
1963	-13110.5	-1671.1	-7323.9	-1846.7	-2833.5	7426.4	4015.1	29010.6	31954.3	37002.3	31621.5	22046.9	136291
1964	8446.0	-8427.0	-2752.6	-17465.8	3363.6	4200.5	16484.4	25705.3	26949.1	40228.1	32437.0	20438.8	149607
1965	11633.0	-11970.9	-58945.2	-12212.1	4427.1	11827.7	11034.5	26986.2	32943.6	38494.3	24741.9	22049.8	101010
1966	13212.6	-9099.4	-5054.1	-6710.9	3422.5	5159.2	17245.6	31612.1	33341.7	37396.7	30603.7	23240.8	174371
1967	11481.0	-10240.8	-13481.1	-15150.0	3327.2	638.7	3454.7	26317.6	24544.9	42565.2	37767.7	25383.9	136609
1968	7172.3	2986.2	-5900.4	-3093.9	-5326.7	8186.7	17621.5	21364.2	36253.6	43027.8	23406.7	23939.3	169637
1969	8410.0	-10959.3	-7189.9	-22766.9	-3082.5	7543.3	15936.2	31632.7	27351.9	41305.5	33518.7	23337.1	145037
1970	1742.3	3392.8	-22069.1	-29524.9	3783.8	2841.3	14071.8	28924.4	34738.3	42727.5	35373.7	21923.3	137925
1971	1216.6	-15825.1	-7563.5	-8909.5	363.4	-6928.1	14626.3	16449.6	29851.0	41474.5	36117.4	16187.1	117060
1972	9759.2	-9513.6	-8376.1	-18975.0	-2508.3	-7411.0	11914.7	28731.2	37471.5	42758.3	36663.1	19494.5	140009
1973	5643.8	-97.0	-8912.7	-5668.6	1517.1	4770.2	17443.5	31721.0	38569.8	42236.0	34344.2	20119.9	181687
1974	1151.1	-21435.3	-11672.6	-9594.1	-1962.8	-4460.4	9456.0	28917.9	38987.4	38603.5	35196.0	25227.2	128414
1975	11246.7	2076.9	-7907.2	-4408.6	-12809.8	-5313.3	12122.2	29781.3	31725.5	37514.6	31286.7	25001.4	150316
1976	545.1	-1657.5	-6158.6	-3429.3	-5974.8	5092.8	16215.8	30353.6	32698.0	40930.7	13794.8	22784.0	145195
1977	13016.6	5268.6	2184.7	-423.1	2649.5	7051.8	19201.5	14420.2	34851.2	41112.2	36662.9	10471.6	186467
1978	11207.6	-15709.4	-17041.7	-3652.6	-1568.2	2213.2	9751.3	25285.1	33914.7	40398.7	30976.5	16285.8	132061
1979	14592.7	1476.3	-1650.1	-11942.2	-2381.0	8230.1	11463.1	24703.5	37268.6	40880.6	27472.7	24587.3	174702
1980	-2032.5	-24012.4	-1273.3	-12161.0	-4860.1	6477.0	15455.5	26616.3	30461.0	42139.3	33610.9	21172.9	131594
1981	10699.3	-1138.9	-7755.0	-920.9	-4631.2	4969.9	14136.3	25487.0	36306.3	40444.0	36977.6	22564.9	177139
1982	5374.7	-22883.6	-31706.1	-4130.0	-9502.9	-45.3	12168.7	28576.3	29677.2	37606.2	31842.0	19243.5	96221
1983	5358.7	-6528.7	-16273.0	-3134.2	-9398.1	-4422.6	9979.7	30277.1	33628.2	35770.2	31733.3	21699.7	128690
1984	9017.3	-19279.8	-32342.1	1199.1	-3691.2	4538.9	14013.4	28523.1	31880.3	41619.0	27866.1	21594.7	124939
1985	1219.2	-19774.3	-6019.7	683.9	-2848.0	3896.5	19591.4	28183.1	35678.7	41069.5	33939.4	10143.9	145763
1986	7802.3	-6908.8	-2184.9	-7550.1	-15386.8	4237.7	18107.1	27877.7	37399.1	39109.2	38434.3	11529.7	152467
1987	10653.7	-327.3	-558.9	-6682.4	3257.7	1505.5	20218.5	30520.8	38095.1	29843.2	36632.2	25664.2	188822
1988	14665.1	200.7	-21527.4	-12512.3	5554.0	8415.6	15517.3	23733.7	32830.9	43911.7	36424.4	24207.3	171421
1989	15030.4	-23263.5	-4875.1	-8169.4	1245.2	-6245.6	14778.4	25757.5	38760.8	38925.3	32275.3	15723.0	139942
1990	6886.8	188.8	649.1	-14465.5	-7.9	4165.6	17084.3	17576.9	36340.0	38080.7	27039.0	21905.2	155443
1991	11042.0	683.5	-3076.6	-4220.7	3107.9	-1898.6	12188.7	23360.4	34209.6	43393.8	35866.6	26513.0	181170
1992	11638.5	-4974.9	-3417.4	-1151.4	3472.7	10582.8	16243.5	35107.0	35212.2	41761.3	37605.6	22456.6	204537
1993	5137.4	-6676.0	-20626.6	-16870.0	-5875.0	-1181.9	10255.5	20461.7	28238.8	37361.1	31079.8	23683.6	104988
1994	10288.5	1551.4	-5139.0	-82.0	985.7	10553.9	17895.2	25366.5	35947.1	45309.0	36174.7	24251.9	203103
1995	11588.3	-20628.0	-3044.6	-19069.7	3407.8	-6246.9	8867.4	28535.9	27444.2	41474.9	34460.1	25440.9	132230
1996	12882.4	1689.3	-27143.9	-26744.5	-13558.4	5249.7	13447.3	20479.0	30782.5	44517.1	35591.9	19626.8	116819
1997	7004.8	-4612.5	-24834.5	-16129.6	145.8	8085.1	12033.4	30123.4	32558.0	39103.6	33086.6	19149.2	135713
1998	5557.5	-11172.8	-1611.0	-22518.7	-7484.9	-397.2	14712.1	10349.7	34106.7	45012.4	38084.9	22885.0	127524
1999	12372.4	-33853.4	-5344.6	-14571.0	-6031.2	4853.8	14697.5	26918.9	36207.8	40756.9	25483.5	24462.7	125953
2000	10939.7	-967.4	-1196.4	-26003.8	-7286.8	5028.4	10803.7	28563.4	39814.0	39768.1	36061.6	18293.3	153818

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Attachment E—Groundwater Balance for Upper Klamath Lake

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Attachment E—Groundwater Balance for Upper Klamath Lake

The groundwater inflow to Upper Klamath Lake is a significant unmeasured component in the water budget for the lake. Determination of this inflow requires measuring or estimating all appreciable sources of inflow and outflow from the lake. Among these sources of inflow and outflow are precipitation to, and evaporation from, the lake surface, evapotranspiration from marshlands associated with the lake, and inflow from streams and other sources.

For water years 1965 through 1967, Hubbard (1970) evaluated these inflow and outflow components. The groundwater accrual to the lake was determined as a residual in his water budget. In determining the water budget for the lake, Hubbard had used an out-of-date area-capacity table for the reservoir. Further, the area table for inundated marsh incorrectly referenced USGS elevations to Reclamation datum. For this study, Hubbard's water budget was re-evaluated using the appropriate area-capacity table for the time of his study and a corrected table for marsh inundated area versus elevation referenced to Reclamation elevation datum. Hubbard's results would have been similar if he had used the area-capacity table used in the natural flow study.

Hubbard's water budget measured outflow from Upper Klamath Lake, as defined by the flow at the gage on Link River (plus the A Canal), as the result of all other inflow and outflow components to the lake. Measured inflow used by Hubbard included gaged inflow from the Williamson and Wood Rivers, generally unmeasured inflow estimated from temporary gage readings or field measurements of flow from several streams tributary to the lake, including Denny Creek, Fourmile Creek, Rock Creek, and Sevenmile Creek, as well as measured flow from several canals and drains, including the Sevenmile Canal, Central Canal, and Modoc Point Canal drain. Inflow from precipitation was estimated from precipitation measured adjacent to the lake. Similarly, evaporation was estimated from pan evaporation measured at the lake. Precipitation and evaporation were applied to the estimated constant open-water surface area of the lake. Using the estimated areal extent of inundated marshlands, associated transpiration of water from these marshlands was estimated using the Blaney-Criddle procedure. Hubbard considered the sum of marshland losses and evaporation from the open-water surface of the lake to be evapotranspiration from the lake. Other measured outflow accounted for in the water budget included irrigation pumpage from the lake.

The monthly summation of all of the elements in the water budget may be stated by the general form of the hydrologic equation; namely,

$$i = o + \Delta s$$

where

i = inflow to Upper Klamath Lake
o = outflow from Upper Klamath Lake

and

Δs = change in storage of Upper Klamath Lake.

Because the equation does not balance using all of the measured or estimated components, the additional water required to balance the equation was determined by Hubbard to be due to unmeasured groundwater accruing to the lake. He characterized this required additional inflow as the unmeasured inflow from springs and seeps that are below the water surface of the lake. This additional water required to balance the equation is termed the derived groundwater inflow. Because this quantity is extracted as a residual in balancing the equation, the derived quantity accumulates all of the other consequent errors associated with the measurement of inflow, measurement and estimation of precipitation and evaporation accruals to the lake, and gaging storage within the lake. Additional errors are attributable to the application of the Blaney-Criddle method and the estimation of evaporation from the open-water surface of the lake in the determination of total evapotranspiration from the lake.

Evaluation of Hubbard's Water Budget for Upper Klamath Lake

Several background sources of supporting information were used in evaluating the water budget Hubbard developed for Upper Klamath Lake, including the capacity table used by the Hubbard water budget, the marshland inundation table in his water budget, and the evaporation data. For the water budget as published, the following were noted:

1. At the time of Hubbard's study, USGS was using an out-dated capacity table that had been developed in 1923 for Upper Klamath Lake. The best available data at the time of Hubbard's study had been developed from a bathymetric survey of Upper Klamath Lake that Reclamation completed in 1953. The Reclamation table incorporated inundated areas determined from preliminary editions of the new USGS 15' topographic surveys of the area, on file Reclamation plane-table surveys, and extensive aerial photography of the lake and associated irrigated areas on file in the Klamath Basin Area Office. Reclamation also republished the 1953 table in 1974. For the natural flow study, Upper Klamath Lake storage and surface area elements in Hubbard's water budget were adjusted with a digital version of the 1953 table.

2. The marshland inundation table used by Hubbard referenced Reclamation data for areas below the water surface of the lake, but evidently

determined inundated areas above the water surface from published USGS topographic surveys that were used in 1953 by Reclamation in preliminary form. Therefore, water surface areas in this table are referenced to Reclamation elevation datum for areas below the water surface of the lake, but referenced the USGS elevation datum for elevations of inundated areas that were above the near-average water surface of the lake. Consequently, the area of inundation was posted to elevations that, in effect, referenced a blended datum. For the natural flow study, the elevation data for Hubbard's inundated marsh area table were determined by matching total water surface areas given Hubbard's table with those in the 1953 Reclamation table and cross referencing the elevations to the datum. The inundated marsh area table was validated by subtracting the inundated marsh area from the corresponding total water surface area given in a specially extended version of the Reclamation 1953 area table. The remainder in the subtraction, 66,500 acres, is the open-water surface area that was used by Hubbard.

3. For the natural flow study, land-pan evaporation data were from the Klamath Falls Agricultural Station at Kingsley Field. This source was validated. Floating-pan data were collected by Pacific Power and Light (PP&L) from the floating pan near the outlet of Upper Klamath Lake. Floating-pan data could not be verified, or validated, using similar data records on file in the Klamath Basin Area Office.

Evaluation and Implementation of Calculated Results

Evaluating Hubbard's water budget for Upper Klamath Lake begins with a replacement of his capacity table and re-computation of Δs in storage. These revisions affect the sequential computation process and the results in Hubbard's water budget. For the period of Hubbard's study from October 1965 to September 1967, the revisions indicate an average groundwater accrual of approximately 19,500 acre-feet per month. For the natural flow study, implementation of this accrual to the natural lake was accomplished in a manner similar to that used for groundwater accruals noted for other climate-signal adjusted groundwater accruals to streamflows into Upper Klamath Lake. These groundwater accruals were adjusted based on the inferred relationship to flows of the Fall River. Unmeasured and model-estimated groundwater discharges to Upper Klamath Lake are inferred to be sourced from the regional aquifer and responsive to the inferred climatically variable discharge that is exhibited by the regional aquifer (see Gannett, et al., 2003). Adjustment of the groundwater discharges to Upper Klamath Lake was indexed to the Fall River discharge based on the average Fall River discharge for the 1965 to 1967 time period, the time period of Hubbard's study. Monthly flow values for the Fall River were first compared to the indexing average for the Fall River to produce an indexed time series for calculation of adjustments to groundwater accruals to Upper Klamath Lake (see Figure E-1.) This average discharge thereby provides a consistent reference to the Fall River indexing value and the indications given by climatic variability.

Table E-1 provides the groundwater inflow summary for Upper Klamath Lake.

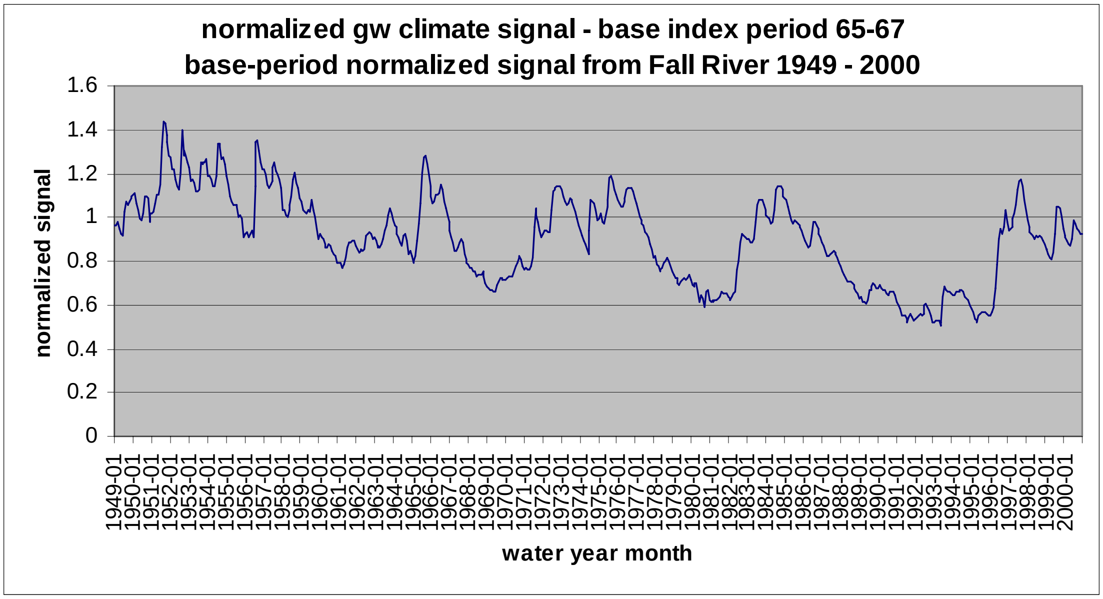

Figure E-1. Normalized groundwater climate signal; base index period 1965 to 1967. Base period normalized signal from Fall River 1949 to 2000.

Table E-1. Groundwater Inflow to Upper Klamath Lake—
Total Monthly Inflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	19245.4	19291.0	19651.2	18974.8	18486.5	18286.2	20470.6	21409.7	21048.1	21397.4	21680.3	21883.6	241825
1950	22123.0	22153.9	21249.9	20598.1	19835.8	19663.5	20384.6	21852.4	21871.3	21717.2	19589.7	20347.7	251387
1951	20401.3	20470.6	21274.5	22000.0	22043.9	23020.7	26380.8	28689.8	28592.5	27496.9	26820.6	25594.4	292786
1952	25418.7	24414.8	24336.5	23537.2	22860.1	22602.6	24107.6	27951.9	25631.2	26119.6	25615.4	24980.0	297576
1953	24508.7	23333.5	23401.9	23082.2	22387.4	22405.8	22584.0	25012.9	24783.4	25062.0	24963.7	25385.5	286911
1954	23795.4	23714.4	23524.9	22848.5	22743.1	23733.9	26761.7	26709.9	26356.2	25308.0	25455.6	24820.3	295772
1955	23820.0	22915.8	21840.1	21434.3	21062.6	21151.5	21171.0	21016.2	20089.7	20143.1	19909.4	18123.7	252677
1956	18421.5	18590.6	18163.2	18446.1	18747.2	18175.5	22829.7	26857.5	27007.4	26033.5	25074.3	24316.5	262663
1957	24336.5	23886.5	22959.2	22688.7	22927.2	23242.0	24513.1	24988.3	24255.1	23893.8	23537.2	22670.0	283897
1958	20647.3	20593.5	20229.2	20106.2	20571.9	21188.4	21932.8	23401.9	24021.6	23168.2	22750.1	21711.6	260323
1959	21483.5	20716.3	20512.0	20303.0	20670.0	20598.1	20433.7	21643.4	20716.3	20020.1	18962.5	17964.0	244023
1960	18544.4	18123.7	17954.2	17486.9	17188.0	17228.6	17533.9	17413.1	16882.7	16601.5	16429.3	15887.4	207274
1961	15863.6	15875.2	15384.0	15310.2	15714.1	16269.4	17214.5	17708.2	17706.0	17941.9	17855.8	17447.9	200291
1962	17056.5	16845.8	16970.4	17130.2	16940.8	17142.5	18332.6	18495.2	18639.8	18519.8	18027.9	18148.3	212250
1963	17843.5	17239.0	17363.9	17204.0	17541.9	18052.5	18750.4	19343.8	20237.1	20770.3	20364.4	19757.9	224469
1964	19282.3	19057.6	18446.1	18200.1	17703.7	17437.7	18344.9	18446.1	17865.7	16662.9	16896.6	16514.1	214858
1965	15888.2	15985.7	16527.7	17818.9	19455.6	21249.9	24058.5	25541.6	25545.2	24902.2	23893.8	22866.6	253734
1966	21889.3	21207.8	21434.3	22024.6	21945.8	22270.5	23014.1	22565.7	21367.6	20758.0	20155.4	19536.8	258170
1967	18802.7	18222.0	17695.9	17007.3	16928.6	17191.7	17779.7	18015.7	17718.2	16687.5	16232.5	15813.7	208096
1968	15666.9	15420.5	15433.2	15076.6	15088.6	14683.1	14757.0	14756.8	14781.6	15052.0	14547.8	13933.8	179198
1969	13637.8	13516.0	13379.5	13330.4	13248.4	13207.4	13774.0	14129.7	14462.1	14510.9	14301.8	14216.4	165714
1970	14351.0	14499.0	14621.6	14683.1	14573.3	15101.2	15469.7	15925.1	16292.9	16503.1	16183.3	15592.5	183796
1971	15297.9	15309.9	15199.6	15236.4	15579.2	16392.4	19155.9	20794.9	20212.6	19528.2	18876.5	18148.3	209732
1972	18421.5	18787.2	18827.3	18679.7	18685.9	20721.1	22326.0	22528.8	22719.2	22873.1	22799.3	22854.3	250223
1973	22479.6	21822.2	21446.6	21102.3	21222.0	21692.6	21539.6	21397.4	21011.2	20536.6	19909.4	19266.4	253426
1974	18741.2	18344.9	17892.7	17560.6	16977.6	16687.5	18762.7	21581.9	21453.6	21323.6	20598.1	19782.5	229707
1975	19921.7	20298.6	19651.2	19417.6	20228.4	20930.1	21650.2	23635.6	23739.0	23315.8	22578.0	22117.1	257483
1976	21545.0	21306.1	20917.8	20991.6	21362.3	21717.2	22510.3	22639.5	22731.5	22725.5	22332.0	21760.8	262540
1977	21225.3	20605.8	20057.0	19811.1	19332.9	19343.8	18701.2	18569.0	18099.2	17572.9	17130.2	16342.1	226790
1978	16404.7	15678.6	15556.2	15015.1	15137.6	15433.2	15838.3	16011.2	16366.6	15962.0	15470.1	15051.9	187925
1979	14695.4	14413.0	14449.4	13969.8	13739.1	14191.2	14351.5	14486.3	14327.0	14424.8	14756.8	14339.2	172144
1980	13908.3	13724.9	13920.6	14043.6	13247.1	12309.7	12840.2	12567.9	11832.6	13133.6	13441.0	12447.0	157417
1981	12297.4	12434.7	12346.6	12371.2	12438.8	12617.1	12705.0	13182.8	13085.9	13109.0	13047.5	12717.3	152353
1982	12555.6	12434.7	12678.6	12986.0	13248.4	15187.3	16034.9	17646.7	18492.3	18261.6	18150.9	18062.3	185739
1983	18077.1	17976.3	17745.1	17794.3	17983.5	19638.9	21097.2	21655.7	21588.7	21606.5	21102.3	20618.0	236884
1984	20180.0	19991.4	19835.7	19417.6	19557.5	20696.5	22498.0	22848.5	22829.7	22774.7	22578.0	21969.6	255177
1985	21741.8	21588.7	20967.0	20327.6	19762.2	19417.6	19659.6	19552.8	19389.3	19233.1	19122.4	18775.0	239537
1986	18360.0	17878.0	17499.2	17277.8	17308.8	18261.6	19524.5	19540.5	19266.4	19036.3	18544.4	18185.2	220683
1987	17708.2	17374.2	16884.3	16503.1	16376.5	16589.2	16784.4	16872.0	16796.7	16662.9	16306.3	15875.2	200733
1988	15482.4	15027.3	14830.6	14449.4	14167.9	14080.5	14105.8	13957.5	13749.5	13465.6	13207.4	13024.5	169548
1989	12604.8	12705.0	12309.7	12322.0	12156.7	12408.0	13307.1	13293.5	13724.9	13920.6	13797.7	13442.3	155992
1990	13477.9	13749.5	13564.0	13441.0	13297.5	13047.5	12901.6	12973.7	13147.4	13158.2	13133.6	12926.2	158818
1991	12285.1	12017.0	11584.1	11055.3	11015.8	11030.7	10640.8	10366.7	10849.7	11153.7	10907.8	10628.5	133535
1992	10784.8	10911.1	11006.1	11129.1	11074.0	11215.2	11894.1	12199.0	11734.3	11510.3	10969.3	10468.8	134896
1993	10428.2	10603.9	10588.0	10502.0	10083.5	10452.8	12668.2	13637.8	13331.7	13145.9	13145.9	12999.9	141588
1994	12949.1	12926.2	13182.8	13244.3	13248.4	13330.4	13430.0	13133.6	12778.8	12617.1	12469.5	12004.7	155315
1995	11595.6	11270.5	10775.9	10516.0	10443.8	11015.8	11249.8	11315.7	11332.4	11315.7	11195.7	11064.0	133091
1996	11079.9	11353.4	11793.2	12088.3	13504.9	15740.6	18062.3	18938.0	18553.8	19183.9	20659.6	19536.8	190495
1997	18864.2	18996.1	19097.8	19823.4	20277.5	21139.2	22522.6	23303.5	23456.4	22823.9	21545.0	20605.8	252455
1998	19798.8	19168.1	18692.0	18569.0	18277.9	18077.1	18308.0	18200.1	18308.0	18200.1	17831.2	17570.8	221001
1999	17093.3	17079.3	16601.5	16355.5	16192.5	16847.4	18430.9	21028.5	20888.4	20782.6	20044.7	18922.4	220267
2000	18323.1	18185.2	17831.2	17585.2	17433.6	18077.1	19782.5	19429.8	18922.4	18815.0	18569.0	18430.9	221385

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Attachment F—Relevant Hydraulic Characteristics of the Natural Upper Klamath Lake and Lower Klamath Lake

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Attachment F—Relevant Hydraulic Characteristics of the Natural Upper Klamath Lake and Lower Klamath Lake

Upper Klamath Lake

Area and Capacity

Capacity of the natural lake to store water is determined by the integration of changes in area with changes in depth. The change in area is easily determined as a function of depth where depth has been determined as the gage height for the corresponding water-surface elevation of the lake. At the minimum elevation for discharge from the natural lake, 4137.8 feet, the open-water surface area of the lake has evacuated the area of wetland marsh that is attendant to the lake. As the depth of the lake increases above this elevation to the estimated natural shore of the lake at 4140 feet, the inundation surface area of the storage prism also increases to the area indicated by the sum of the areas for the open-water surface and area of inundated marsh. At 4140 feet the open water surface and inundated area is at its stable water-surface elevation. The additional area inundated at the maximum observed water-surface elevation of the natural lake may also be integrated into the storage prism, thereby allowing an estimate of the maximum natural capacity of the lake to store water.

Study by La Rue

Before 1916, the capacity of the natural lake had been estimated based upon information available from early plane-table surveys completed by the USGS. However, in an unpublished study completed in 1922 by E. C. La Rue of the USGS, a summary area-capacity table for the natural Upper Klamath Lake is presented following page 90 of his report. Illustrations in the appendices of the 1922 study provide visual details regarding marshland areas that had been diked and removed from the interactive storage area of the lake. There were, however, no other data presented by La Rue regarding the information that he used in developing the table.

A search for additional historical information found an original 1:24,000 scale plane-table survey of Upper Klamath Lake that USRS completed in 1916. This historical information, which was provided by the Klamath Basin Area Office, indicates the primary source of data that La Rue had used in his assessment of Upper Klamath Lake was the 1916 USRS survey. The U.S. Reclamation Service had completed and used this somewhat detailed 1:24, 000 scale plane-table survey of the lake for volumetric evaluation of storage and potential development of additional storage within the lake. Among additional information provided were three plane-table survey boards that were used in compiling the completed sheet for the 1916 survey. These boards show the condition of the land surface for reclaimed marsh areas bordering the shoreline perimeter of Upper Klamath Lake, exclusive of Agency Lake. With the completed 1916 lake survey, there was also provided an original compilation map of Upper Klamath Lake with notations by La Rue regarding when dikes had been completed around specific marshes. Details on this map by La Rue appear to have been taken directly from the 1916 survey by the USRS. The original by La Rue is substantially the same as the 1916 USRS survey and is evidently the base that he used for the map of Upper Klamath Lake shown in the appendix of his 1922 report.

Missing from the La Rue's compilation map are indications of areas for marshes that had been removed from interactive storage. Some details are provided in USGS Water Supply Paper 881 (WSP 881) regarding the areas of marsh that La Rue had estimated were removed within specific elevation bands around the perimeter of the lake. However, no trace has yet been possible to reconcile the indications given in WSP 881 with the area-capacity table La Rue provided.

A detailed evaluation of the USRS 1916 survey provides an assessment of the natural lake that is very close to that given by La Rue. Information developed from the plane-table survey boards also gives additional detail regarding the condition of reclaimed marsh. Missing from the assessment are details regarding areas of reclaimed lake floor, the extent of shoreline fringe marshes, or indications of areas of floating Wocus mats that occupied the surface of the lake. However, information developed from the 1916 survey is similar to information that had originally been developed for the natural flow study. Therefore, information for the natural lake developed from the 1916 survey was used directly in the natural flow study. Table F-1 provides the developed natural lake area and capacity taken from the 1916 survey. Figure F-1, which follows, shows the map developed by La Rue for his 1922 report.

Table F-1. Area and capacity information developed from the 1:24,000 scale plane-table survey completed by the USRS in 1916 for Upper Klamath Lake.

Capacity 1885 predevelopment lake						
Delta h	Cylinder	Prism	Total storage	Norm storage	USRS - elevation	Gage height ab 4136.13
				0	4137.8	1.67
0.2	12471.12	85.14	12556.26	0.018537	4138	1.87
1	63207	451	76214.26	0.1125163	4139	2.87
1	64109	5670.5	145993.8	0.2155328	4140	3.87
1	75450	8316.526	229760.3	0.3391986	4141	4.87
1	92083.05	7607.529	329450.9	0.4863733	4142	5.87
1	107298.1	4290.985	441040	0.651114	4143	6.87
1	115880.1	1112.779	558032.8	0.8238323	4144	7.87
1	118105.6	1223.682	677362.1	1	4145	8.87

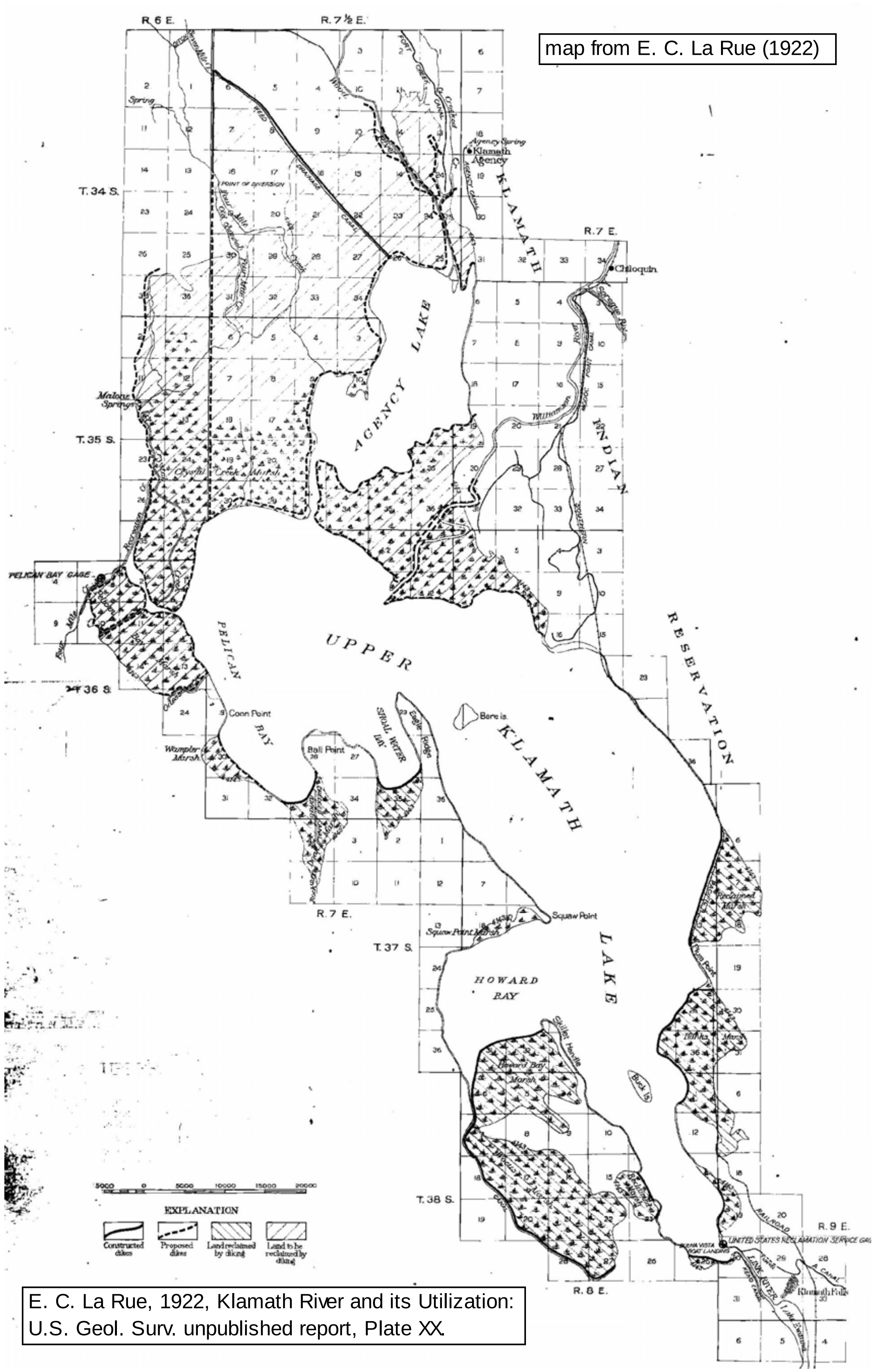

Figure F-1. La Rue's 1922 map of Upper Klamath Lake.

The Natural Lake

Derived changes in inundated area and capacity may each be expressed as a function of gage height above the established zero datum for the gage. The water-budget of the lake uses gage height as an inverse function of storage. For Upper Klamath Lake, the elevation of the zero datum for the gage was established as 4136.13 feet above USRS datum at installation of the gage, and the required factors for gage height and storage are related to this elevation. Gage height of the water surface was derived from storage by calculating gage height as a function of normalized capacity. Use of this curve would also provide information about the simulated elevation of the water surface of the natural lake. The resulting graph for this function is shown in Figure F-2.

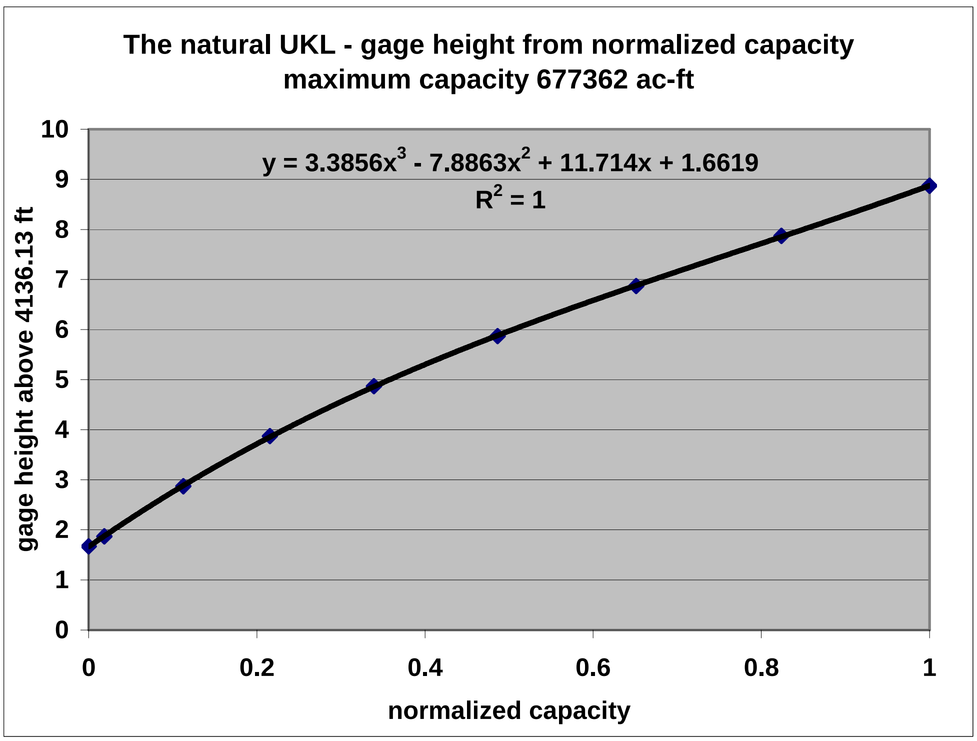

Figure F-2. Upper Klamath gage height from normalized capacity.

Elevation and Discharge

The discharge, or outfall, from the natural lake is dependent on the water-surface elevation of storage in the lake. Therefore, discharge from the natural lake may be directly related to gage height of the water surface. Given storage as a known factor in the water budget for the lake, the gage height and hence, discharge from the lake, may be calculated directly. To calculate the discharge, a discharge-rating curve must be derived for the natural lake based upon recorded monthly total discharge from the lake and the concurrently observed monthly average water-surface elevation. For the pre-dam period before the Link River crib dam was constructed, outfall from the lake was uncontrolled and dependent on the elevation of the water surface in the lake.

Development of the rating curve was accomplished by noting the recorded monthly total discharge of the Link River, which included diversions to the A canal, the Keno/West Side Power Canal, and flow past the Link River gage. The monthly average water-surface elevation of the lake was determined from records of the daily observed or daily recorded values at the gage above the outlet to the lake. Some of these data also included recorded water-surface elevations at the Pelican Bay gage.

Problems with the Friez automatic recording gage near the outlet on Klamath Lake, however, had to be given special consideration in developing the rating curve. After initial installation of the Friez gage, the mechanism was not operating smoothly in response to changes in the water-surface elevation of the lake, and this posed problems in maintaining accurate records. This difficulty, which caused a series of ongoing maintenance problems with the gage, was evidently related to the Friez automatic register and the integrated pulley assembly for the recorder. The cause and record-artifacts of this difficulty are conceptually well understood. Further, up-valley winds were noted to decrease the outfall while maintaining the water-surface elevation of the lake. These two factors, problems with the recorder and winds on the lake, are commingled in the records for elevation of the water surface.

Separating the difficulties evident with the Friez recorder was facilitated by the absence of daily values in the record. For these missing days, generally every few days or at least once weekly, a gage-height reading was noted for the water-surface elevation of the lake. Computer processing of these data allowed reasonable estimates of the average water-surface elevation for each month that was considered in the record. Deviations from a regularly smooth trace for discharge plotted against gage height were evident by smearing of the scatter of plotted points away from a limiting envelope along the left side of the scatter plot. Therefore, in developing the rating curve for outfall from the lake, the limiting envelope at the left side of the data scatter (Figure F-3, F-4) was used as the definition of the rating curve. The lowest value on this curve was derived from the daily total flow on July 18, 1918, and several days preceding, when the lowest historic daily water-surface elevation was recorded for Upper Klamath Lake. Although up-valley winds occurring on this date caused flow from the lake to cease for a period of several hours on July 18, for the day and approximately six days prior, an average daily discharge was noted.

Closure of the curve to zero discharge was estimated by extending the curve along the limiting envelope of the outlet recording gage data. The rating curve for simulated water-surface elevations less than 3.7 feet gage was used to calculate discharge from the lake when the simulated gage height was indicated to be less than 3.7 feet. This rating curve was intended to preclude underestimation of the outfall and maintain determination of reasonable results. The data plot and curves derived are illustrated in Figures F-3, F-4, and F-5.

Estimated data establishing the curve along the limiting envelope were used directly for the generalized rating curve. Monthly average readings for gage height of the water surface at the outlet-recording gage and concurrent monthly discharge for the restored Link River gage are shown in the graph. Pelican Bay data, which covers only about one year, were not used for any substantial information regarding the rating curve. Of note regarding the Friez recording gage defined rating curve is the flexure tending to bend the curve slightly downward above 6.0 feet gage. This flexure indicates that at the higher discharges above 6.0 feet gage the outlet channel is increasingly regulating the uncontrolled outfall from the lake.

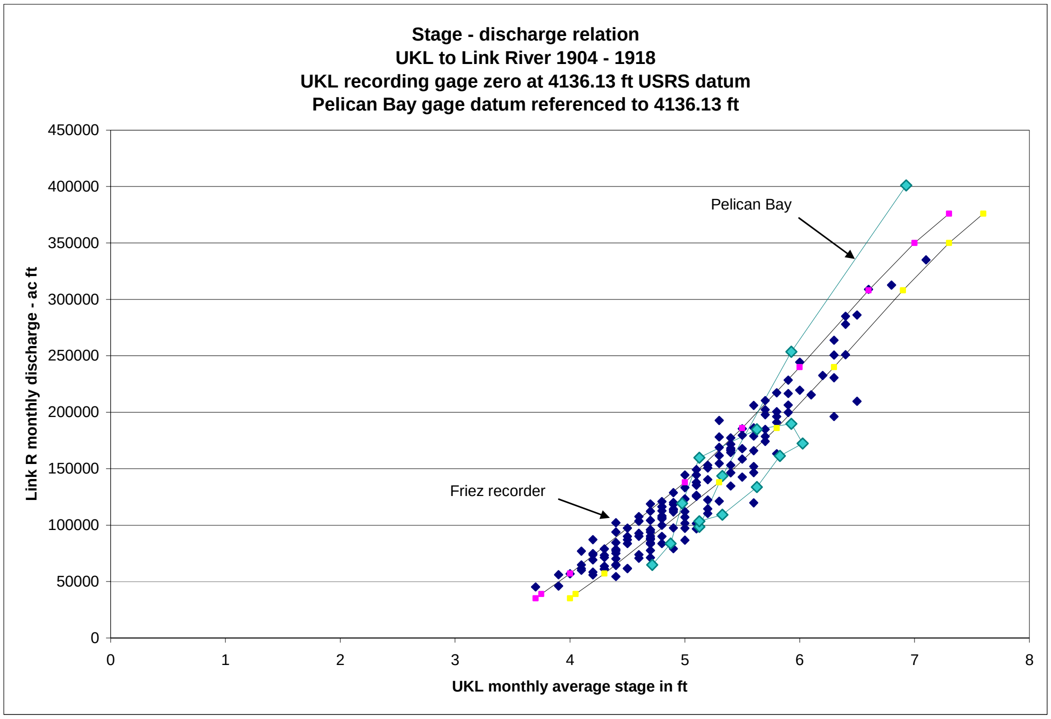

Figure F-3. Stage-discharge relation. Upper Klamath Lake to Link River between 1904 and 1918.

For use in the simulation, the rating curve was extended to 9.05 feet gage to accommodate the maximum-recorded water-surface elevation of the lake, which occurred in mid-April, 1904. Also, extension of the curve for an alternate rating curve below 3.7 feet gage, was forced to closure for zero flow at a stage of 2.0 feet gage (Figure F-5). Table F-2 shows the 1949 to 2000 estimated natural lake discharge, monthly, for UKL at Link River.

Table F-2. Natural Lake Discharge of Upper Klamath Lake at Link River— Total monthly discharge in acre-feet

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	79830.9	78120.8	85651.6	94050.8	95282.9	108847.5	129262.9	140698.9	116614.1	72610.5	52321.8	55802.3	1109095
1950	68102.9	80386.6	91688.5	108732.8	115871.8	130320.4	154107.7	151921.2	130743.9	88263.0	53804.4	49234.0	1223177
1951	72022.6	99844.6	137606.4	162611.1	165923.7	174322.0	197292.3	213305.3	163985.1	100201.9	68935.8	63170.2	1619221
1952	84780.2	112741.6	136078.2	147252.0	143954.5	150969.3	230983.6	313639.5	269292.8	177599.8	107880.3	82793.0	1957965
1953	83492.3	95152.8	117740.4	160011.6	198475.5	201944.0	201206.2	225769.0	238322.8	182066.0	117042.6	92393.4	1913617
1954	96072.8	128661.0	164336.7	174492.8	167335.9	187872.7	250793.2	263646.0	204854.0	136751.9	96532.5	88622.8	1959972
1955	95242.8	109878.7	124286.3	127767.5	119894.7	119458.5	138138.1	142626.7	114791.6	80050.2	54863.7	52370.4	1279369
1956	67784.9	96760.4	162835.0	239981.0	237032.2	210265.1	270082.9	333820.4	294633.7	201603.1	129422.2	102142.0	2346363
1957	116791.1	138824.2	152463.9	158764.8	156328.0	208036.0	244050.2	219092.8	171582.0	109177.9	75531.2	76542.2	1827184
1958	101598.2	128972.0	151718.2	167746.3	219901.8	270414.1	271348.9	266434.6	235214.8	172591.3	116293.6	93071.7	2195305
1959	97129.0	114343.2	129822.3	141490.4	144868.1	141760.8	136583.0	122568.4	95548.9	61658.9	48886.9	56939.3	1291599
1960	71872.2	85689.4	95430.7	103593.4	117548.2	141905.0	149746.4	136223.0	104539.1	63935.6	44042.2	45907.8	1160433
1961	57583.7	77958.6	101512.6	108078.3	118310.0	135856.7	133109.1	119419.8	96475.3	62317.5	43228.7	48801.4	1102652
1962	66007.1	88470.0	111039.3	117930.4	116884.3	122549.0	144889.0	149543.0	109506.6	66460.3	47681.1	49088.0	1190048
1963	81498.6	115290.4	133544.2	138576.3	143590.0	151058.9	162899.8	179338.5	143898.5	94234.1	65991.6	57692.6	1467613
1964	65499.4	89751.8	108449.2	116832.3	112625.8	105576.5	129465.9	142300.9	122680.4	86297.0	54771.5	49277.7	1183529
1965	56557.7	73204.4	178184.1	291643.7	274662.5	231215.0	199873.6	188638.6	154088.8	105120.5	80588.5	75650.8	1909428
1966	77095.5	96630.1	117190.6	122285.6	117325.5	126073.3	159913.6	152057.2	104987.9	69646.8	51404.6	52818.4	1247429
1967	62937.3	79539.1	109812.2	129204.8	125740.2	135494.9	160566.6	187103.2	182268.8	117241.5	58515.4	40889.7	1389314
1968	52465.7	70356.0	80946.2	89059.7	107270.3	124685.3	111536.8	86913.3	59730.2	33934.7	32211.0	40508.8	889618
1969	47170.8	65703.9	84655.0	103709.3	111610.7	110358.6	163956.3	204403.9	155814.7	90248.7	49616.9	40184.1	1227433
1970	54211.6	71014.8	92624.0	158786.5	196431.5	180403.6	160480.5	130288.0	97682.6	60970.4	40815.1	42769.2	1286478
1971	58674.1	85210.3	111041.0	137674.2	151656.0	169017.2	212396.4	245828.7	223306.2	149347.0	87689.9	68360.7	1700202
1972	76874.1	98140.2	120139.1	141235.8	154382.3	224572.3	272844.7	221151.7	165278.6	107583.8	71914.1	67026.9	1721144
1973	83656.9	103664.0	121546.8	136436.2	135172.8	133511.5	131093.4	112690.4	81664.4	51405.3	43367.2	50291.7	1184501
1974	64521.1	103320.5	154621.0	193520.4	189618.4	190612.5	236420.2	240147.2	188806.0	127494.8	83223.9	65229.6	1837536
1975	69709.8	87403.6	109337.4	121671.7	128149.0	157397.1	183564.8	201530.9	196841.9	143801.6	96233.0	75461.2	1571102
1976	87291.2	112991.0	131526.2	142840.4	140726.6	144318.6	152230.0	146908.0	119762.7	81761.9	72672.2	77951.4	1410980
1977	78691.2	89068.9	98463.1	100370.0	97814.2	99140.5	94573.7	88682.2	76119.1	51996.7	41752.8	49640.1	966312
1978	61546.7	78842.5	120244.0	158033.2	157484.3	161612.4	181405.3	168603.4	120509.1	73367.8	48933.3	49756.7	1380339
1979	58035.3	63444.5	73699.0	89392.6	96547.4	101476.7	106963.8	104877.4	81611.7	47116.0	39264.2	43547.7	905976
1980	53047.2	76913.3	94676.1	120792.5	142229.4	135440.4	127251.6	117949.6	90924.1	55521.3	38954.9	40303.2	1094003
1981	48513.3	59808.8	76027.3	89168.3	98102.7	104850.7	102245.1	89079.6	63709.5	39401.7	31689.0	34392.9	836989
1982	45598.0	73552.7	134180.9	161364.5	183734.5	233731.5	239717.8	227008.0	184492.8	125235.2	82491.9	65943.7	1757051
1983	74064.7	93774.3	118633.4	135188.4	152992.5	207781.9	251459.5	247661.3	222137.3	168495.9	115243.0	90544.7	1877977
1984	88183.7	112834.2	162961.7	177430.0	159747.0	189908.4	233432.0	237801.4	209354.7	150133.7	102936.6	87327.6	1912051
1985	98186.8	134529.9	153782.7	140068.7	126696.1	132160.1	170498.7	176815.7	130198.2	87552.8	62392.5	68944.8	1481827
1986	88656.1	103256.6	111883.8	122987.5	170535.1	240347.2	242477.5	186362.0	136386.8	95775.4	66280.5	66047.7	1630996
1987	81758.6	94166.7	105636.8	112304.1	114010.7	125157.4	129405.5	108208.5	78465.6	61507.3	53789.7	50252.1	1114663
1988	55874.8	65716.4	88798.3	110482.2	110499.1	107759.6	105039.2	90664.5	73182.2	51885.0	38667.7	39829.8	938399
1989	43101.8	61075.0	82411.1	89173.8	87957.6	134419.4	204743.4	192246.7	132474.9	77352.7	49765.2	47962.9	1202684
1990	60028.6	72212.4	79051.9	94013.5	100231.1	102041.9	104962.3	89683.4	66522.5	44692.2	39806.3	44321.6	897567
1991	48284.8	55663.7	62981.2	69792.9	72675.1	80802.7	85860.7	76728.0	58787.5	38894.9	32041.6	32909.9	715423
1992	37409.2	49456.2	61702.7	65820.3	66166.1	64506.1	64274.2	51820.3	35057.0	30425.2	27627.7	26430.5	580695
1993	34337.5	50929.3	66929.8	80905.2	84277.7	134022.9	203063.6	200102.2	162353.9	103371.4	61496.4	48340.7	1230131
1994	52355.0	62929.1	73225.6	79769.3	78429.7	76844.0	75150.4	67264.2	48003.1	32662.5	28437.9	30486.5	705557
1995	37841.9	54763.3	67946.7	82656.7	103456.8	136743.5	167592.7	158727.8	128592.6	83729.5	49298.0	39111.3	1110461
1996	44353.1	55422.7	88744.9	133837.7	188710.6	224111.5	210167.3	196002.2	155948.3	95466.8	61239.3	57867.3	1511872
1997	70216.2	90639.1	132688.4	225312.1	259646.5	214579.1	198809.9	179934.2	136316.9	92778.8	68745.7	65189.4	1734857
1998	75986.9	94504.2	105584.2	131295.3	159731.9	179838.1	194272.6	208815.5	201184.0	136131.7	80053.2	61544.7	1628942
1999	65805.5	96368.7	132455.2	146198.4	143183.1	156029.3	199091.2	223061.0	200352.3	140555.7	96461.3	79167.3	1678729
2000	77545.0	92521.2	107952.9	130090.2	150305.8	160995.6	181592.7	176596.1	128213.7	83217.7	60058.9	57665.9	1406756

Calculation of Water-Surface Elevation

The water-surface elevation of the lake for any month may be determined from the water-surface elevation given in the previous month, the net inflow to the lake, and the change in storage for the lake. A third-order Runge-Kutta procedure (Chow, et. al, 1988) is used to determine the required change in elevation of the water surface necessary to balance the calculated outfall with the net inflow and resulting change in storage. To begin the process, each month in succession, as well as the net inflow for that month, is broken into thirds. The change in water-surface elevation and the outfall are then determined for each of the first, second, and third parts based on the noted change in inundated area required to account for the change in water-surface elevation due to the change in storage, for each part. For the ending monthly result, the process determines the total change in elevation of the water surface required to balance the interaction between the net inflow, outfall, and resulting change in storage. The process essentially determines a procedure for routing the net inflow through the lake.

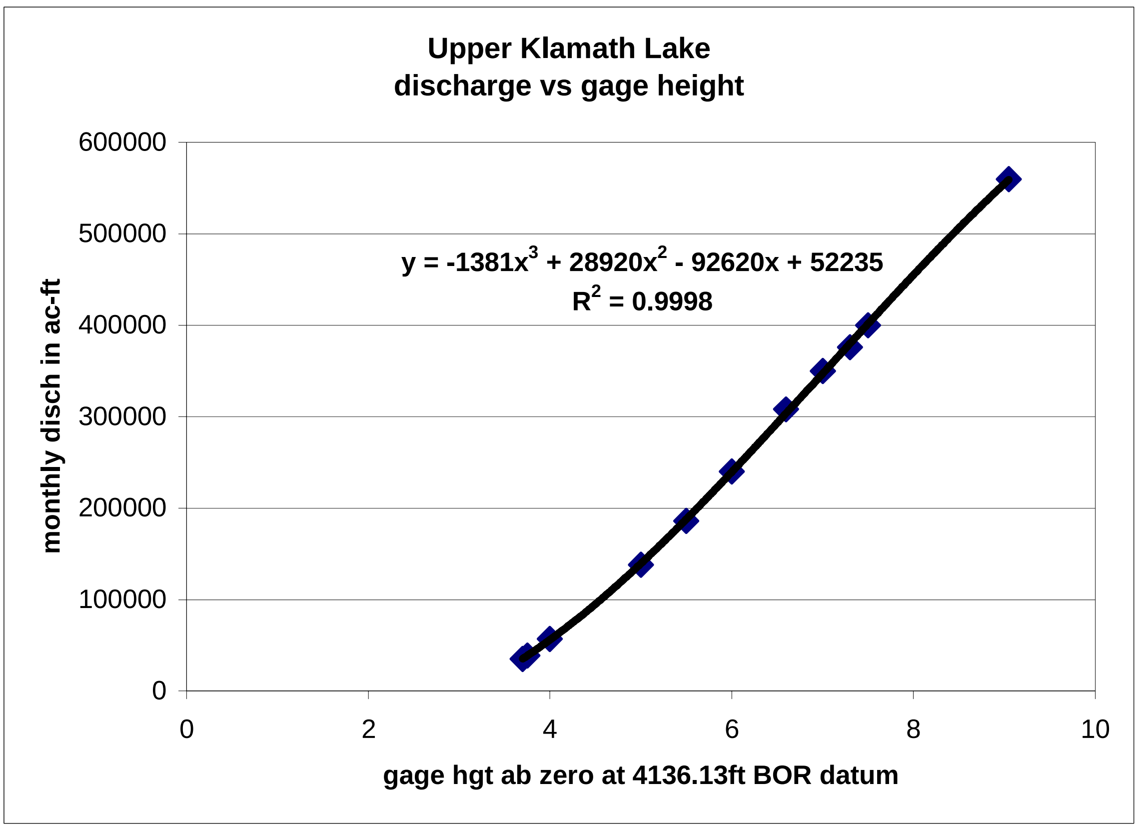

Figure F-4. Upper Klamath Lake discharge vs. gage height.

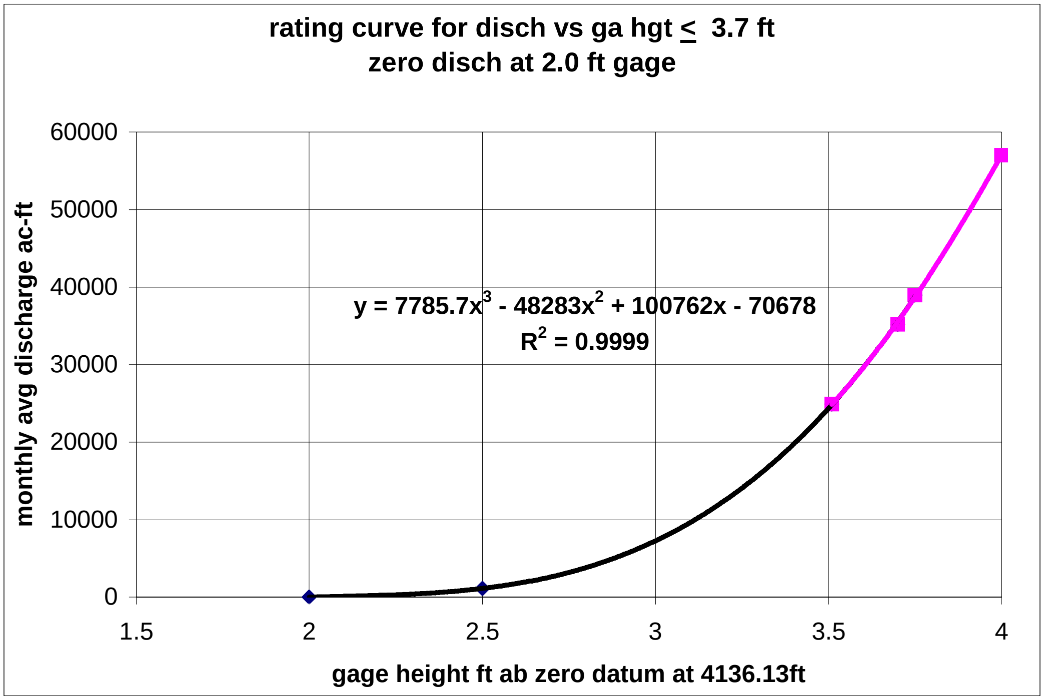

Figure F-5. Rating curve for discharge vs gage height less than 3.7 feet.

Calibration: Outfall from Upper Klamath Lake for Water Years 1907 to 1909

Calibration of the calculation sequence to determine the simulated outfall from Upper Klamath Lake required an extensive re-evaluation of existing data for the lake. To complete the evaluation process, a new area-capacity table had to be developed based on the existing condition of the lake during the 1907 to 1909 time of interest for the calibration. An evaluation of the existing 1:24,000 scale plane-table survey of Upper Klamath Lake was used to develop the new area-capacity table to be used in the calibration. The survey was completed in 1916. Historical information from an unpublished report by E. C. La Rue (1922) and from land-surface conditions indicated on three plane-table survey boards of Upper Klamath Lake was used to determine the condition of the lake during this 2 or 3 year time of interest.

Although planimetric errors exist in the 1916 plane-table survey, the total difference in land-surface area is probably not more than about 3,000 acres less than would be determined using present-day planimetric mapping procedures. The primary difference noted was in the area of the open-water surface which was noted as 64,855 acres at elevation 4140 feet for the 1916 survey, and about 66,500 acres as noted in the study by Hubbard (1970). The 1916 survey, however, was of sufficient detail that, for the time of interest, information could be developed regarding the area and capacity of the lake generally in single-foot elevation bands from elevations 4138 to about 4145 feet. All elevations were noted as established in feet above mean sea level referenced to the Reclamation Service datum.

Other critically evaluated data included stream and lake gaging records for the 1904 to 1910 time period. Missing values were estimated as closely as feasible. This gaging record allowed the net inflow to Upper Klamath Lake to be determined. The net inflow was calculated as the monthly total outfall less the previous end-of-month to current end-of-month noted change in storage. The monthly total outfall includes the total monthly flow measured at the Link River gage plus the estimated monthly diversion into the Keno Power Canal and the measured total monthly diversion at the A-canal heading. The changes in storage were determined from the end-of-month gaged lake elevation recorded at the Buena Vista gage and the successive end-of-month differences in storage that were determined using the revised area-capacity table.

Because a discharge-rating curve was needed for calculating the modeled outfall from Upper Klamath Lake, the rating curve used was the same as that developed above where the total monthly outfall was taken as a function of the average monthly gage height noted for the water surface of the lake. Data for the total monthly outfall and average gage height over the period September 1905 to December 1918 were used in the rating curve evaluation. These data are sufficient for comparison prior to placement of the crib dam in 1919 to regulate the storage and discharge of Upper Klamath Lake. Conditions existing for Upper Klamath Lake during this time were sufficiently stable that these data could be used because marsh reclamation had little effect upon the hydraulic performance of the lake at its outfall.

To initiate the calibration process, a comparison was needed to establish that the average monthly gage height was equivalent to the recorded end-of-month gage height noted for the lake. The comparison (figure 6) was completed for data from September 1906 to September 1909. The comparison shows equivalence with a positive departure from 1:1 correspondence of about 0.9 percent for average monthly gage height.

Once this equivalence is established, calculation of the outfall from Upper Klamath Lake may be undertaken using these and other developed data. The structure of the calculation sequence used in the calibration check is identical to the calculation sequence used in the natural flow model. Essentially, in the natural flow model, the net inflow to the natural lake is determined and used as the realized inflow into the lake in calculating the discharge, or outfall, from the lake. The outfall is calculated from the rating curve by using the Runge-Kutta routing scheme to determine the resulting stage of the lake that would be consequent to the net inflow. The same process may be used in the calibration check because the 1906 to 1909 net inflow has already been determined and may

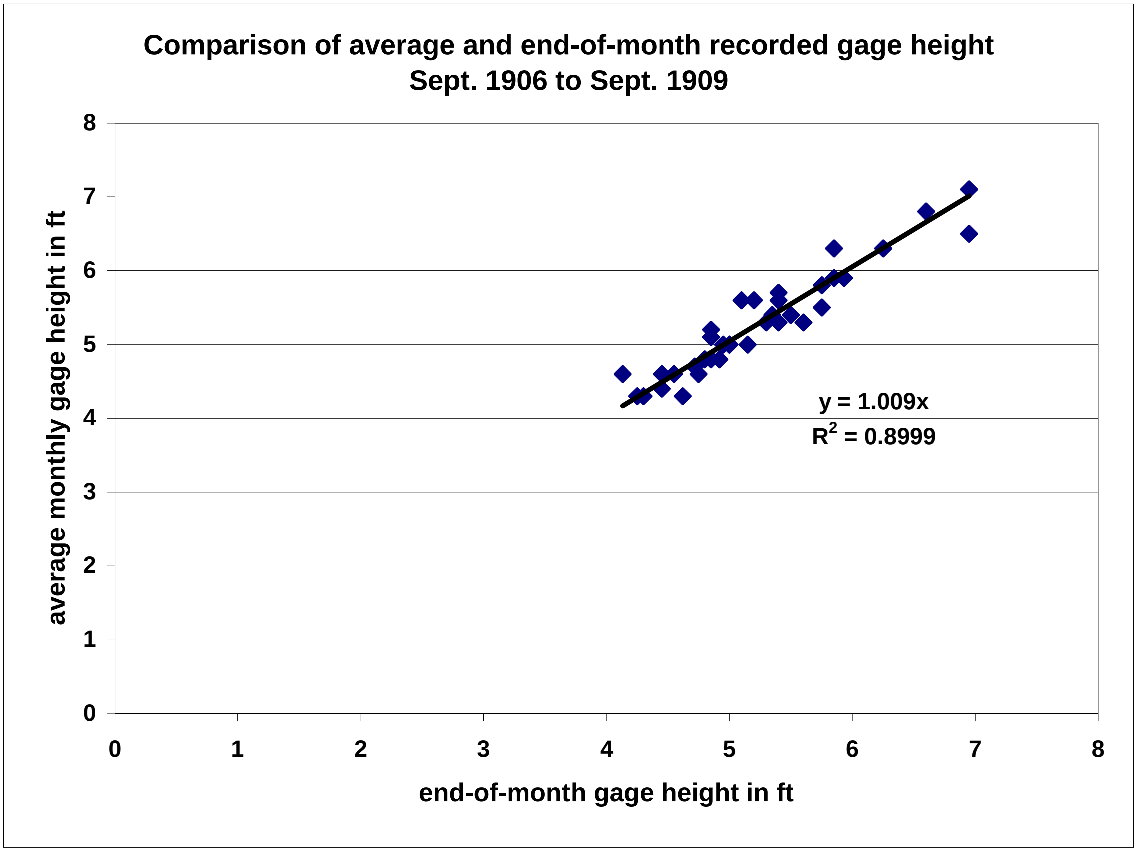

Figure F-6. Comparison of recorded gage height, September 1906 to 1909.

be used in the calculation process. Whether for the natural lake, or for the lake in its 1909 condition, the net inflow is the consequent residual of all the processes within the lake that deplete accruals from stream inflow to the lake.

Results show that the Runge-Kutta method yields excellent results. As shown in Figure F-7, the computed outfall agrees well with the gaged outfall. The routing scheme using the Runge-Kutta method evidently explains about 95 percent of the variability evident within the discharge from Upper Klamath Lake during the calibration period. Similarly, as shown in Figure F-8, the computed lake elevations are also found to be in agreement with actual end-of-month measured lake elevations. The Runge-Kutta approach when used in the simulated routing scheme, explains slightly more than 90 percent of the variability observed in lake elevation.

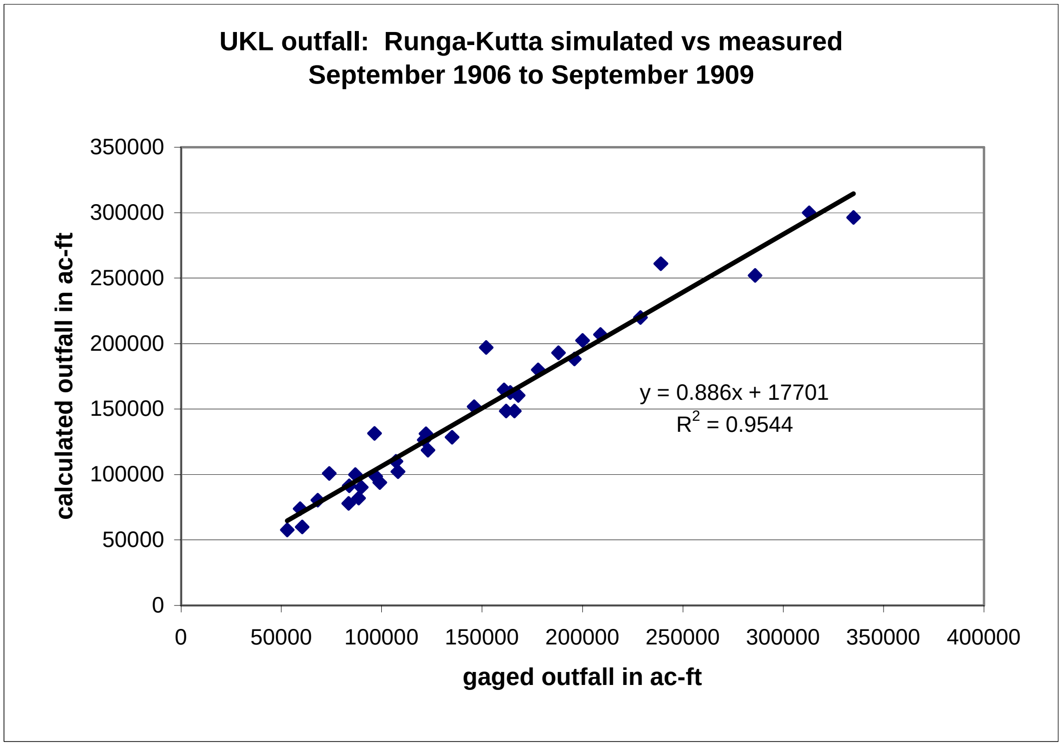

Figure F-7. Computed discharge calibration for Upper Klamath Lake outfall.

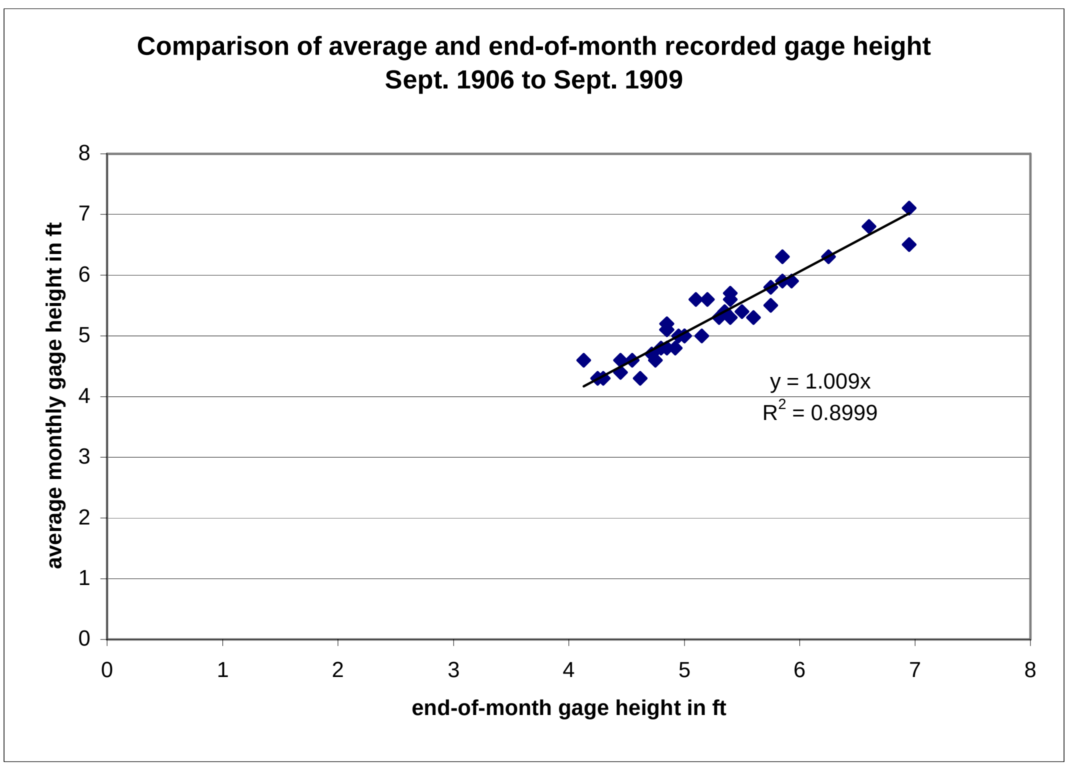

Figure F-8. Computed elevation calibration for Upper Klamath Lake stage.

Marsh Water Limiting Functions

Late summer observations given by Hall (1908) for marsh in Lower Klamath Lake show a static water-surface elevation within the marsh that is about 2.5 feet below the water-surface elevation of the lake. This static water-surface elevation indicates the limiting condition for water use by marshes that border the lake. An assumption in implementing this limiting condition in a water budget for the marsh areas is that variation in water use by the marsh is linear with depth of the groundwater surface below the ground-surface elevation of the marsh. Even though the size of the marsh areas being described by Hall (1908) are of extraordinary size compared to some of the marshes in Upper Klamath Lake, the conditions Hall indicated may be taken as limiting conditions under ideal conditions at Upper Klamath Lake. Therefore, water use by the marsh is at the potential full net ET when the elevation of the groundwater surface is at, or above, the ground-surface elevation of the marsh. When the groundwater-surface elevation reaches 2.5 feet below the ground-surface elevation of the marsh, water use by the marsh is assumed to be nil.

Implementation of a scheme for water limiting by marshes for Upper Klamath Lake uses this linear relationship. The water use scheme is implemented with a water-budget for each marsh, or marsh series, which is tied to the particular meteorological station for which marsh ET has been calculated. Water limiting must, therefore, address inundated areas of marsh and depth of the groundwater surface below the ground-surface elevation of the marsh. To do this, the linear relationship was evaluated for depth of groundwater below a specific ground-surface elevation related to the individual marshes being evaluated. Ground-surface elevation varies across the extent of some marshes from the elevation of the shoreline interface with the open water area, or elevation 4140 feet, upward for 1 or 2 feet to 4142 feet. Areas above elevation 4142 feet were not considered as inundated marsh for the water-limiting scheme because these areas and marsh are only intermittently inundated. Therefore, water use limiting was calculated for individual marshes depending on their state of inundation, and changes in ground-surface elevation above 4140 feet in either 1 or 2 foot elevation bands. Some marshes, such as Hank's Marsh, are nearly fully inundated at 4140 feet and only have a narrow surrounding perimeter that becomes inundated from 4140 to 4142 feet. However, not all marshes are like Hank's Marsh. Pelican Bay Marsh, for instance, becomes progressively inundated from 4140 to 4141 feet and has a narrow surrounding perimeter that becomes inundated from 4141 to 4142 feet. Doak Marsh (also known as Ball Bay West) becomes broadly inundated only above 4141 feet. The general nature of the water-limiting functions must, therefore, accommodate addressing these various individual conditions.

Linear, parabolic, and extinction function variations in the type of limitation function were examined. Of these, only the linear-function type was used. The water-limiting functions used for various inundation conditions are illustrated in Figure F-9. Water-use limitation functions used in this study were *linear* for marsh areas inundated at 4140 feet, *band at 1'* for marsh areas inundated in 1-

foot elevation bands below 4141 or 4142 feet, or *band at 2'* for some marsh areas inundated below 4142 feet. Both the 1-foot and 2-foot elevation-band functions were developed from the linear function. Total potential net evapotranspiration computed for the marsh is simply scaled by the indicated water use available for the marsh given by the water-use limitation function. The water use that is available is determined by the depth to groundwater below the specific upper limit elevation (i.e., 4141 feet) of the land surface of the marsh that is being evaluated.

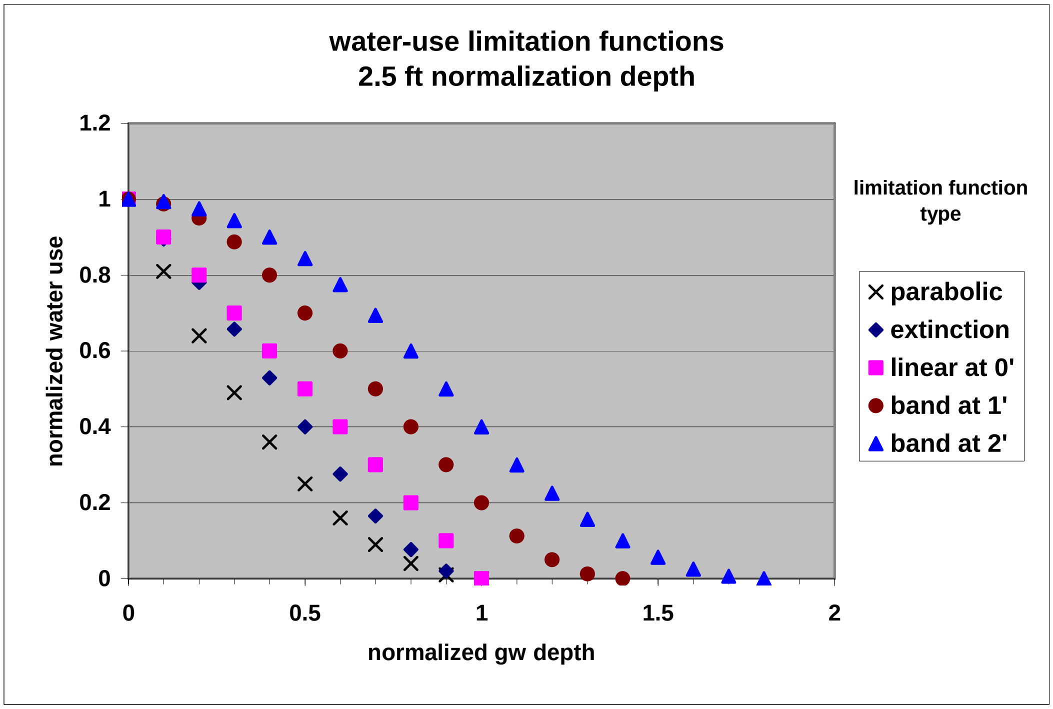

Figure F-9. Water-use limitation functions normalized at 2.5 feet.

Water-Use Limitation: Hydraulic Interaction of the Permanently Inundated Marsh and Lake

Water use by individual permanently inundated marshes is referenced to the net evapotranspiration calculated for the nearest respective meteorological station. This calculated evapotranspiration includes winter precipitation that accumulates as snow on the surface of the marsh and is released as snowmelt in the spring. Each marsh, therefore, has representative gains and losses related to net evapotranspiration. The interactive gains and losses seen by the lake are determined through a water budget for each marsh, or series of marshes, tied to each relevant meteorological station.

Calculation of the interactive sequence begins by computing the depth of the groundwater surface below the ground-surface elevation of the marsh. The depth to groundwater results from water gained or lost through net evapotranspiration and the seepage interaction with the lake. If the groundwater-surface elevation is below the inundation elevation of the marsh, seepage is assumed between the lake and the marsh in response to the head difference between the water-surface elevation of the lake and the groundwater-surface elevation of the marsh. With this occurrence, the loss that accrues to the lake is the seepage that is gained by the marsh. However, if the elevation of the water surface in the marsh is above the inundation elevation of the marsh, the gain or loss that accrues to the lake is consequent to the net evapotranspiration of the marsh. A noted consequence of this interaction sequence is that the timing of some of the summer losses accruing to the lake may be shifted to somewhat later than the time of highest evapotranspiration during the middle of the summer.

During the fall, the water-surface elevation of the lake generally rises to above the inundation elevation of the marsh and thereby floods the marsh. As the fall progresses into the winter, the accumulation of snow on the marsh provides water that will be released during the snowmelt period in the spring. As evapotranspiration increases into the summer and is supported by groundwater from within the marsh, the elevation of the groundwater surface drops below the inundation elevation of the marsh. Consequently, only a portion of the loss incurred by evapotranspiration during this period is replaced by seepage from the lake. Concurrently, though, the depression of the groundwater elevation increases the depth to groundwater in the marsh and causes a reduction in evapotranspiration from the marsh.

A cursory assessment of the water-limiting scheme shows that there may be significant reductions in marsh evapotranspiration from water limitation. These reductions change the mass balance in the interaction of the lake with the marsh and effectively shift the water balance into the lake. This water then becomes a part of the general water budget for the lake.

Lower Klamath Lake and Keno Outfall

LKL is a unique water body in the vicinity of Klamath Falls, Oregon. This lake historically consisted of a large open water area surrounded by huge tracts of wetlands/wet meadow plants. Water supplied to the lake was primarily from the Klamath River with small, unmeasured tributaries around the edges, and both measured and unmeasured groundwater/springs inflows. The open water area of the lake was primarily in the south of the lake/marsh complex with a lake-bottom elevation of 4070 feet at its deepest point. Water from the river entered and exited the lake through a single channel, called the Klamath Strait, and at or during higher water events, additionally infiltrated through a long complex of wetlands all along the interface between the river and lake.

Several attempts were made to model this complex system using a digital representation in Excel® of the lake/river physical interaction. Because of the complexity of the hydraulics, and the need for detailed data, this modeling is not possible at this time. A correlation approach was used to estimate Keno flows at the outfall of the LKL system. Measured data for the period of October 1904 through September 1918 for the Link River and Keno gages were used. This period represents the time when river flow data were available and the river system was in a pre-development condition. Naturally, the claim of pre-development is not absolute, but as close an approximation as possible is achieved. Prior to 1904, no data was collected, and after 1918, the Upper Klamath Lake outfall was greatly affected by the dam.

History of the Gages

The Link River gage was established in May 1904, as a vertical staff mounted on the county bridge 1¼ miles below the outlet of Upper Klamath Lake at the head of Lake Ewauna. It was quickly noted that during times of high winds blowing in the upstream direction, the flow measurements became very unreliable. During these events, water in Lake Ewauna would begin to backup under the bridge causing an inaccurate stage measurement. At the same time, the wind would hold a gradient on Upper Klamath Lake, causing a reduced flow over the controlling reef. Thus, flow from the lake into Link River would be reduced, even stopped at times, but the gage at the county bridge would be recording higher stages, translating into higher flows. On March 7, 1907, an anemometer and ships' taffrail were installed at the gage site to help measure the wind effects. It was believed that the person measuring flows at the gage would be able to adjust the readings based on the velocity and direction of the wind using the anemometer, as well as to determine the direction of flow by noting the position of the taffrail in the water. While it is generally believed that the accuracy of the data reported after the installation of the anemometer and taffrail was improved, the Water Supply Papers of the time report that the data is questionable. In April 1908, the staff gage was replaced by a chain gage.

In June 1908, a Friez recorder was installed on the right-hand bank of the river in the rapids closer to the outlet of Upper Klamath Lake. With the installation of the Friez gage, the data obtained are more reliable. Unfortunately, with the Friez record on the right bank, it was subject to log jam backwater effects and damage from log impacts. Because of this, the daily discharge records from the Friez recorder from 1908 through the end of 1912 are supplemented with bridge data with all associated inaccuracies. Further study of the descriptive record indicates that as the users made adjustments and repairs, they failed to keep the gage at the reported datum. As a result, data published for late 1909 and 1910 have uncertain accuracy, and though gage height data are reported, no discharges could be computed for 1911. In September 1912, the Friez recorder was moved to the left-hand bank with subsequent data of high quality and reliability.

Data for the Keno gage is available for the period October 1904 through December 1913. The Keno gage was then again used to measure flows after October 1927. During the intervening period, flows were measured at the

Spencer Bridge a couple miles downstream of the Keno gage. The Water Supply Papers indicate that the only difference between data obtained from the Keno and the Spencer Bridge gages is the small inflow of Spencer Creek. Data for both gages is available for October, November, and December 1913. Using the overlapping period of record, an estimate of Spencer Creek flows was calculated and used to adjust the Spencer Bridge data.

Figure F-10 shows the average monthly flows recorded during the full 1904-1918 period of record for both the Link River and Keno gages (1913-1918 Keno data estimated from Spencer Bridge and adjusted as noted above).

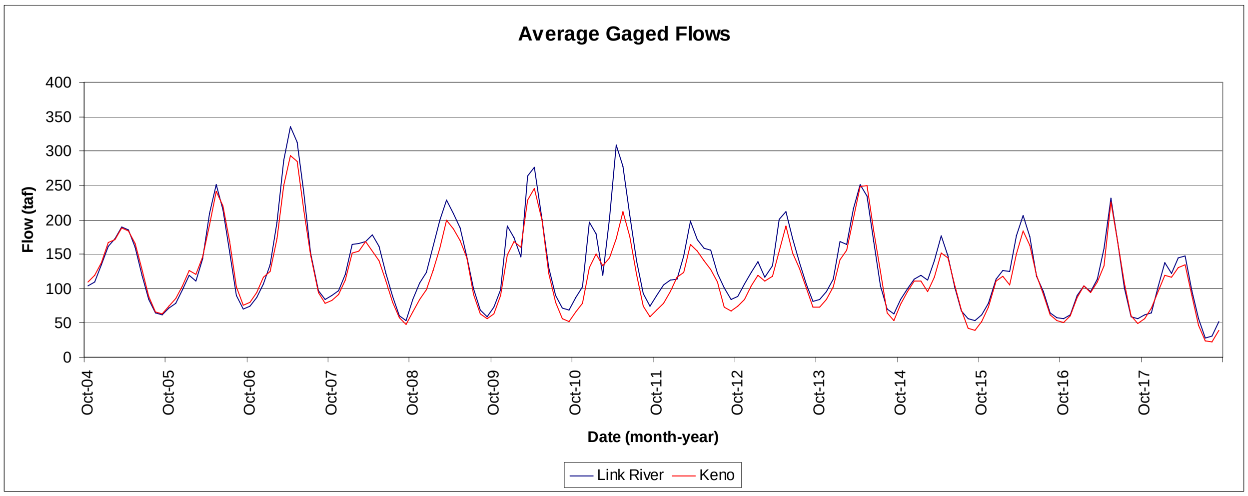

Figure F-10. Average flow recorded at the Link River and Keno gages

The shape of the Link River hydrograph during late 1909 through 1911 is of special interest. As discussed above, this is the time period when the gage had been moved into the rapids just below the outfall of Upper Klamath Lake and was subject to log jams, log impacts, and a shifting, undocumented datum. The Water Supply Papers specifically indicate the data from this time period as, "… subject to considerable uncertainty." Based on the uncertainty of the data, it was decided to remove this period (October 1909 through December 1911) from the correlation analysis.

To maintain as much integrity in the correlation as possible through the entire range of potential flows in the system, two correlation curves were generated—one for the low flow period July through October, the second for the higher flow period November through June. Additionally, prior to the correlation analysis, the data was normalized to force all error in the analysis into the equation coefficients. For both periods, a 3rd order polynomial was found to be the best curve fit. Figures F-11 and F-12 show the correlation curves for the low and high flow periods, respectively. In addition, the polynomial equations with all coefficients are listed.

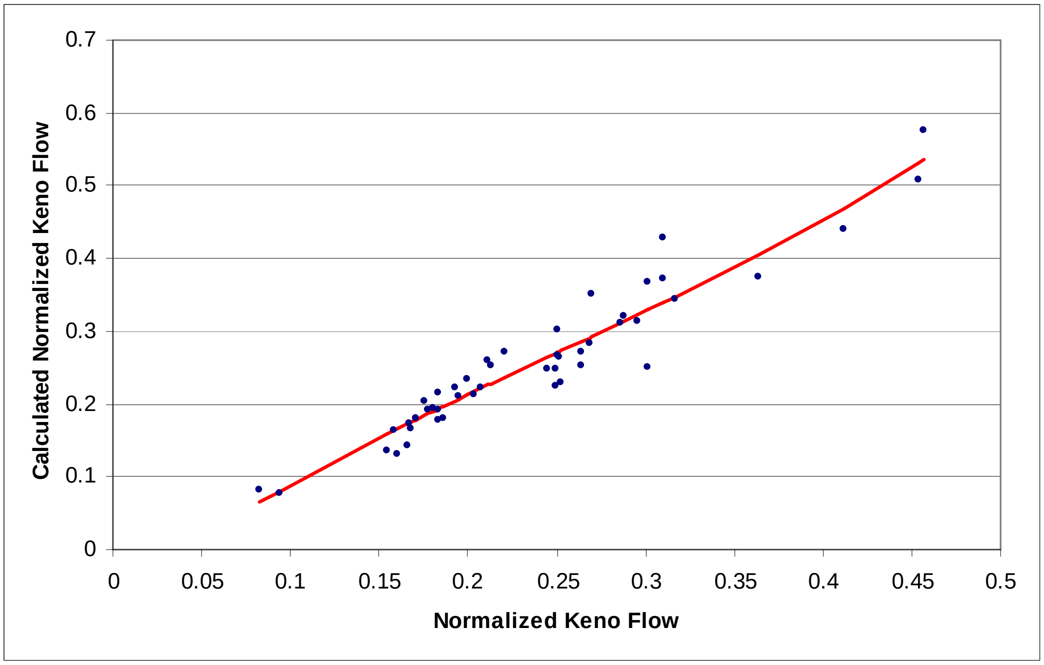

Figure F-11. Correlation curve for July through October.

$$Keno = -0.066 + 1.762(Link) - 2.513(Link)^2 + 3.370(Link)^3$$

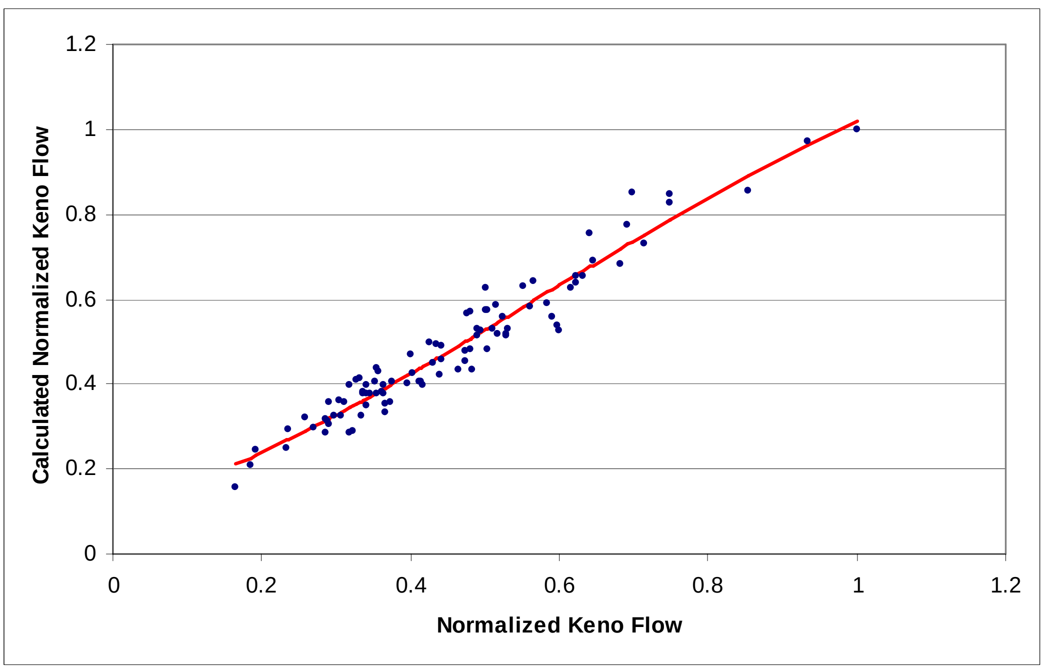

Figure F-12. Correlation curve for November through June.

$$Keno = 0.102 + 0.522(Link) + 0.920(Link)^2 - 0.525(Link)^3$$

Figure F-13 displays the raw data with the simulated Keno flow superimposed. The correlation coefficient for the entire period of record is 0.958.

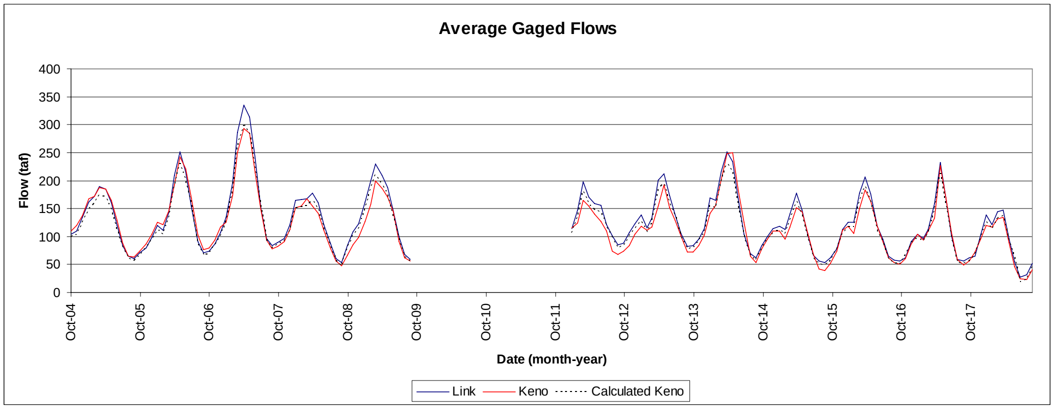

Figure F-13. Raw Link River and Keno flow data with estimated Keno flow.

Interestingly, the correlation estimate of Keno flow based on Link River flows is under-estimated during the early part of the record, 1904 through 1906. After this time, however, the correlation over-estimates Keno gage flow 2 to1. During the entire period of the analysis, the magnitude of over and under flow estimation is balanced with maximum over-estimation at 34 taf and maximum under-estimation at 31 taf. The overall average difference between measured and estimated Keno flows is 0 taf.

Table F-3. Klamath River Natural Streamflow at Keno Gage—Total monthly streamflow in acre-feet

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	75273.1	78106.9	83885.8	90511.3	91498.3	102602.3	120034.0	130109.0	109140.5	68060.0	47130.9	50827.5	1047180
1950	63516.4	79828.9	88629.5	102506.7	108510.3	120957.3	142143.9	140167.3	121327.5	83664.9	48712.3	43802.2	1143767
1951	67469.8	95185.0	127365.5	149874.8	152903.2	160614.7	181852.6	196663.3	151129.8	95664.2	64359.2	58487.9	1501570
1952	80197.4	105865.1	126014.9	135963.9	133010.9	139308.4	212881.3	282911.4	246915.6	194555.1	103565.4	78220.6	1839410
1953	78916.2	91393.9	110098.7	147504.5	182948.6	186160.6	185477.5	208119.5	219542.4	202278.1	113298.5	87789.9	1813528
1954	91484.8	119509.4	151451.3	160772.0	154196.7	173129.1	230726.3	242032.4	188854.0	135906.6	91948.2	84023.4	1824034
1955	90649.3	103463.3	115714.2	118731.6	111938.1	111564.9	127836.3	131825.7	107595.3	75491.5	49836.0	47182.9	1191829
1956	63194.1	92687.0	150079.2	221040.0	218374.9	193856.8	247594.3	297535.6	268057.0	239897.0	127181.1	97643.0	2217140
1957	113026.0	128444.3	140657.4	146369.7	144155.9	191797.0	224702.0	201994.2	158094.1	104921.2	70985.0	71994.9	1697142
1958	97087.2	119780.4	139984.0	154572.9	202738.0	247878.5	248679.5	244450.8	216727.9	186246.4	112487.7	88469.4	2059103
1959	92550.2	107216.1	120522.2	130813.2	133827.7	131054.0	126460.6	114232.9	91711.9	56932.7	43424.8	52023.4	1200770
1960	67318.6	83915.2	91617.0	98251.4	109935.0	131182.4	138206.4	126142.7	99030.1	59272.7	38087.3	40158.9	1083118
1961	52698.7	77984.2	96545.4	101961.6	110584.1	125819.4	123400.5	111531.8	92457.2	57611.4	37177.3	43331.8	1031103
1962	61388.1	86088.5	104434.9	110260.5	109370.1	114216.2	133846.4	138023.3	103152.3	61849.2	42108.9	43643.5	1108382
1963	76932.9	108017.6	123782.8	128224.6	132685.3	139389.2	150138.4	165239.6	132960.9	89635.4	61372.3	52812.7	1361192
1964	60870.8	87097.3	102270.4	109326.0	105767.7	99886.5	120211.2	131535.2	114329.3	81706.7	49738.4	43849.6	1106589
1965	51622.7	74421.8	164174.4	265635.9	251505.8	213092.1	184243.5	173838.0	142126.8	100702.9	76027.3	71104.6	1768496
1966	72547.0	92581.9	109630.6	113989.6	109745.4	117260.5	147415.2	140290.1	99400.3	65077.4	46147.2	47661.8	1161747
1967	58248.8	79183.0	103407.7	119983.4	116971.9	125500.2	148010.1	172417.0	167946.1	113514.4	53672.3	34537.4	1293392
1968	47284.8	72319.8	80256.4	86552.1	101289.9	116058.9	104852.3	84869.2	64703.3	26463.6	24406.6	34104.1	843161
1969	41549.6	68940.7	83112.0	98346.8	104914.3	103864.7	151103.5	188437.5	143690.4	85645.6	44217.6	33733.9	1147557
1970	49144.9	72803.8	89373.0	146389.5	181055.3	166223.0	147931.6	120929.0	93431.5	56221.6	34452.7	36661.6	1194617
1971	53837.8	83542.8	104436.4	127425.6	139927.9	155738.5	195824.7	226296.5	205863.4	151992.0	83093.8	63777.4	1591757
1972	72326.2	93801.7	112147.3	130586.6	142392.4	207023.8	249957.9	203886.3	152312.7	103256.5	67360.7	62425.1	1597477
1973	79079.9	98309.5	113354.5	126331.0	125216.2	123754.1	121633.3	105822.0	80806.4	46148.0	37332.6	44947.8	1102735
1974	59871.9	98027.2	142608.6	178358.8	174745.1	175665.6	217820.7	221189.9	173993.0	124954.0	78649.2	60595.6	1706479
1975	65141.0	85252.6	103011.1	113461.8	119063.6	145126.5	169144.0	185778.1	181435.4	144725.0	91646.3	70915.0	1474700
1976	82696.6	106075.2	122012.2	132016.2	130133.6	133336.3	140446.1	135655.3	111825.1	77194.9	68122.1	73400.7	1312914
1977	74137.9	86559.3	94063.3	95612.8	93537.9	94612.7	90929.7	86255.2	76597.9	46782.7	35515.7	44242.7	918848
1978	56816.9	78653.8	112237.1	145704.5	145205.8	148963.4	167148.2	155358.9	112464.2	68819.7	43475.2	44369.1	1279217
1979	53171.1	67324.4	74789.3	86814.2	92515.2	96516.1	101035.5	99309.1	80766.0	41489.5	32681.4	37534.8	863946
1980	47906.0	77195.2	91011.7	112707.2	131471.4	125452.1	118283.2	110276.9	88023.5	50531.1	32326.1	33869.8	1019054
1981	43017.9	64758.3	76529.0	86637.5	93771.3	99287.0	97144.9	86567.7	67513.1	32839.1	23779.0	27006.5	798851
1982	39816.4	74680.5	124342.7	148737.4	169300.8	215381.3	220802.5	209252.9	170002.0	122376.0	77921.1	61323.5	1633937
1983	69517.9	90290.3	110860.1	125230.0	141135.2	191562.0	231318.3	227935.4	204791.2	179715.7	111355.4	85941.3	1769653
1984	83585.8	105943.1	150194.9	163478.7	147263.6	175013.7	215109.1	219070.9	193015.7	153048.2	98456.6	82732.9	1786913
1985	93619.6	124649.9	141849.7	129548.8	117800.7	122567.7	157098.6	162912.4	120850.6	82957.2	57688.5	64368.3	1375912
1986	84056.6	97974.6	105143.7	114593.8	157132.1	221370.3	223288.9	171731.0	126287.4	91185.3	61666.4	61429.5	1515860
1987	77191.6	90604.0	99936.4	105497.0	106935.2	116467.3	120158.5	102069.9	78368.0	56776.2	48696.8	44905.0	1047606
1988	50904.0	68949.7	86346.4	103968.2	103982.3	101696.5	99442.6	87818.1	74405.4	46662.9	31995.7	33329.2	889501
1989	37035.1	65647.0	81379.7	86641.8	85686.5	124552.7	188751.6	177179.0	122843.8	72803.7	44378.3	42417.2	1129316
1990	55246.3	73686.9	78812.7	90481.5	95499.6	96978.4	99379.1	87043.3	69530.4	38811.5	33302.3	38399.0	857171
1991	42768.8	61886.5	66994.9	71907.2	74029.4	80146.7	84048.5	77055.7	64045.3	32257.2	24203.1	25243.5	704587
1992	30540.7	57696.8	66089.6	69024.5	69273.4	68081.8	67916.0	59276.5	48520.6	22250.1	18818.2	17328.9	594817
1993	26941.0	58678.8	69824.6	80225.1	82819.8	124203.7	187197.1	184455.2	149640.0	98902.6	56765.0	42829.8	1162483
1994	47166.5	66958.0	74437.6	79358.3	78340.8	77143.0	75871.9	70066.5	56735.9	24947.7	19819.1	22324.6	693170
1995	31042.3	61270.5	70561.3	81568.6	98139.2	126602.4	154432.1	146336.1	119449.8	79152.1	43871.6	32505.8	1044932
1996	38434.0	61721.3	86304.5	124040.8	173904.7	206601.6	193766.5	180657.6	143811.5	90874.6	56499.6	52995.5	1409612
1997	65651.8	87798.1	123031.2	207701.3	238541.2	197838.1	183258.3	165789.6	126225.7	88175.9	64166.9	60554.6	1608733
1998	71440.3	90874.1	99892.9	121810.0	147249.8	165700.8	179055.5	192517.5	185456.9	135151.6	75494.5	56814.9	1521459
1999	61182.7	92371.3	122826.5	135018.9	132322.0	143884.9	183518.9	205638.6	184686.8	140609.1	91876.5	74612.3	1568549
2000	72995.4	89291.2	101857.2	120756.1	138710.3	148401.1	167321.4	162709.9	119119.9	78643.0	55277.8	52784.8	1307868

Table F-4. Klamath River Natural Streamflow at Keno Gage—Average monthly streamflow in cfs

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Ann Avg
1949	1224.2	1312.6	1364.3	1472.0	1647.5	1668.6	2017.2	2116.0	1834.1	1106.9	766.5	854.2	1449
1950	1033.0	1341.5	1441.4	1667.1	1953.8	1967.2	2388.8	2279.6	2038.9	1360.7	792.2	736.1	1583
1951	1097.3	1599.6	2071.4	2437.4	2753.1	2612.1	3056.1	3198.4	2539.8	1555.8	1046.7	982.9	2079
1952	1304.3	1779.1	2049.4	2211.2	2395.0	2265.6	3577.5	4601.0	4149.5	3164.1	1684.3	1314.5	2541
1953	1283.4	1535.9	1790.6	2398.9	3294.1	3027.6	3117.0	3384.7	3689.5	3289.7	1842.6	1475.3	2511
1954	1487.8	2008.4	2463.1	2614.7	2776.4	2815.6	3877.4	3936.2	3173.8	2210.3	1495.4	1412.0	2523
1955	1474.2	1738.7	1881.9	1931.0	2015.5	1814.4	2148.3	2143.9	1808.2	1227.7	810.5	792.9	1649
1956	1027.7	1557.6	2440.8	3594.8	3932.0	3152.7	4160.9	4838.9	4504.8	3901.5	2068.4	1640.9	3068
1957	1838.2	2158.5	2287.5	2380.4	2595.6	3119.2	3776.2	3285.1	2656.8	1706.4	1154.4	1209.9	2347
1958	1578.9	2012.9	2276.6	2513.9	3650.4	4031.3	4179.1	3975.6	3642.2	3029.0	1829.4	1486.8	2851
1959	1505.2	1801.8	1960.1	2127.4	2409.7	2131.4	2125.2	1857.8	1541.2	925.9	706.2	874.3	1664
1960	1094.8	1410.2	1490.0	1597.9	1979.5	2133.4	2322.6	2051.5	1664.2	964.0	619.4	674.9	1500
1961	857.1	1310.5	1570.1	1658.2	1991.1	2046.2	2073.8	1813.9	1553.8	936.9	604.6	728.2	1429
1962	998.4	1446.7	1698.4	1793.2	1969.3	1857.5	2249.3	2244.7	1733.5	1005.9	684.8	733.4	1535
1963	1251.2	1815.3	2013.1	2085.3	2389.1	2266.9	2523.1	2687.3	2234.4	1457.8	998.1	887.5	1884
1964	990.0	1463.7	1663.2	1778.0	1904.4	1624.5	2020.2	2139.2	1921.3	1328.8	808.9	736.9	1532
1965	839.5	1250.7	2670.0	4320.1	4528.5	3465.6	3096.3	2827.2	2388.5	1637.8	1236.4	1194.9	2455
1966	1179.8	1555.9	1782.9	1853.8	1976.0	1907.0	2477.4	2281.6	1670.5	1058.4	750.5	801.0	1608
1967	947.3	1330.7	1681.7	1951.3	2106.2	2041.0	2487.4	2804.1	2822.4	1846.1	872.9	580.4	1789
1968	769.0	1215.4	1305.2	1407.6	1823.8	1887.5	1762.1	1380.2	1087.4	430.4	396.9	573.1	1170
1969	675.7	1158.6	1351.7	1599.4	1889.1	1689.2	2539.3	3064.6	2414.8	1392.9	719.1	566.9	1588
1970	799.3	1223.5	1453.5	2380.8	3260.0	2703.3	2486.0	1966.7	1570.1	914.3	560.3	616.1	1661
1971	875.6	1404.0	1698.5	2072.3	2519.5	2532.8	3290.9	3680.3	3459.6	2471.9	1351.4	1071.8	2202
1972	1176.3	1576.4	1823.9	2123.8	2563.9	3366.9	4200.6	3315.8	2559.7	1679.3	1095.5	1049.1	2211
1973	1286.1	1652.1	1843.5	2054.5	2254.6	2012.6	2044.1	1721.0	1358.0	750.5	607.1	755.4	1528
1974	973.7	1647.4	2319.3	2900.7	3146.4	2856.9	3660.5	3597.3	2924.0	2032.2	1279.1	1018.3	2363
1975	1059.4	1432.7	1675.3	1845.3	2143.8	2360.2	2842.5	3021.3	3049.1	2353.7	1490.5	1191.7	2039
1976	1344.9	1782.6	1984.3	2147.0	2343.1	2168.5	2360.2	2206.2	1879.3	1255.4	1107.9	1233.5	1818
1977	1205.7	1454.7	1529.8	1555.0	1684.2	1538.7	1528.1	1402.8	1287.3	760.8	577.6	743.5	1272
1978	924.0	1321.8	1825.3	2369.6	2614.5	2422.6	2809.0	2526.6	1890.0	1119.2	707.0	745.6	1773
1979	864.7	1131.4	1216.3	1411.9	1665.8	1569.7	1697.9	1615.1	1357.3	674.8	531.5	630.8	1197
1980	779.1	1297.3	1480.1	1833.0	2367.2	2040.3	1987.8	1793.5	1479.3	821.8	525.7	569.2	1415
1981	699.6	1088.3	1244.6	1409.0	1688.4	1614.7	1632.5	1407.9	1134.6	534.1	386.7	453.9	1108
1982	647.5	1255.0	2022.2	2418.9	3048.4	3502.8	3710.7	3403.1	2856.9	1990.2	1267.2	1030.6	2263
1983	1130.6	1517.4	1802.9	2036.6	2541.2	3115.4	3887.4	3707.0	3441.6	2922.8	1811.0	1444.3	2447
1984	1359.4	1780.4	2442.6	2658.7	2651.6	2846.3	3615.0	3562.8	3243.7	2489.1	1601.2	1390.4	2470
1985	1522.6	2094.8	2306.9	2106.9	2121.1	1993.3	2640.1	2649.5	2030.9	1349.1	938.2	1081.7	1903
1986	1367.0	1646.5	1710.0	1863.7	2829.3	3600.2	3752.4	2792.9	2122.3	1483.0	1002.9	1032.3	2100
1987	1255.4	1522.6	1625.3	1715.7	1925.4	1894.1	2019.3	1660.0	1317.0	923.4	792.0	754.6	1450
1988	827.9	1158.7	1404.3	1690.9	1872.3	1653.9	1671.2	1428.2	1250.4	758.9	520.4	560.1	1233
1989	602.3	1103.2	1323.5	1409.1	1542.8	2025.6	3172.0	2881.5	2064.4	1184.0	721.7	712.8	1562
1990	898.5	1238.3	1281.7	1471.5	1719.5	1577.2	1670.1	1415.6	1168.5	631.2	541.6	645.3	1188
1991	695.6	1040.0	1089.6	1169.4	1332.9	1303.4	1412.5	1253.2	1076.3	524.6	393.6	424.2	976
1992	496.7	969.6	1074.8	1122.6	1247.3	1107.2	1141.4	964.0	815.4	361.9	306.0	291.2	825
1993	438.1	986.1	1135.6	1304.7	1491.2	2020.0	3145.9	2999.8	2514.7	1608.5	923.2	719.8	1607
1994	767.1	1125.2	1210.6	1290.6	1410.6	1254.6	1275.1	1139.5	953.5	405.7	322.3	375.2	961
1995	504.8	1029.7	1147.6	1326.6	1767.1	2059.0	2595.3	2379.9	2007.4	1287.3	713.5	546.3	1447
1996	625.1	1037.2	1403.6	2017.3	3131.3	3360.0	3256.3	2938.1	2416.8	1477.9	918.9	890.6	1956
1997	1067.7	1475.5	2000.9	3377.9	4295.1	3217.5	3079.7	2696.3	2121.3	1434.0	1043.6	1017.6	2236
1998	1161.8	1527.2	1624.6	1981.0	2651.3	2694.8	3009.1	3131.0	3116.7	2198.0	1227.8	954.8	2107
1999	995.0	1552.3	1997.6	2195.8	2382.5	2340.0	3084.1	3344.3	3103.7	2286.8	1494.2	1253.9	2169
2000	1187.1	1500.6	1656.5	1963.9	2497.6	2413.5	2811.9	2646.2	2001.8	1279.0	899.0	887.1	1812

References

Chow, V. T., Maidment, D. R., and Mays, L. W. 1988. *Applied Hydrology*, McGraw-Hill Book Company, New York. p. 252 ff.

Attachment G—Documentation of ukl.lkl_simulation, an Excel® Spreadsheet

Contents

Figures

Attachment G—Documentation of ukl.lkl_simulation, an Excel® Spreadsheet

Computation of the water budget for a water body, such as a natural lake or reservoir, must follow the hydrologic equation, namely,

$$i = o + \Delta s$$

where

i = inflow to the water body
o = outflow from the water body

and

Δs = change in storage of the water body.

Although the equation is a general statement that may be used to solve for one of the elements if two are known, the equation is also a statement regarding the water-balance of a natural lake. All equation elements must cause the equation to balance. Categorized parts of each element may be used in a general progression of calculations intended to achieve this balance. Each element may be a conceptualized part of a calculation subsequence ending in a net result for the desired quantity. For instance, precipitation on the lake surface is an inflow, but is accounted to evaporation resulting in net evaporation, the difference in the monthly evaporation minus the precipitation for that month. *The sum of inflow to the lake, minus losses,* such as net evaporation, and marshland net ET that is attendant to the lake, *forms the net inflow.*

As such, *the net inflow to the lake is the characterization of* "i" in the equation above, *and may be used in place of that quantity*. This method of element characterization is used because (1) stable quantities are desired in calculations using the hydrologic equation, (2) the net inflow is that part of the total inflow that has been depleted by in-place outflow processes, such as evaporation, and (3) *the important quantity needed* to calculate monthly discharge from the lake, or outfall "o," *is the storage within the lake*. *The change in storage* resulting from the net inflow and the outflow *is usable as a stable monthly quantity* that may be used in other calculations. The calculation process for discharge requires an estimate of the change in water-surface elevation to calculate the resulting gage height of the water surface so that discharge from the lake, or outfall, may be estimated. A Runge-Kutta third-order procedure is used to calculate the interaction of net inflow, change in storage, and outflow.

The general form of the computations used in the spreadsheet follows the description given in the report. Hydraulic elements are described in attachment F. Descriptive elements are presented in the notes tab of the spreadsheet. Other aspects are calculated or adjusted on tabs for ukl_gw.flux and evap.notes. Inflow from the west side of the Wood River Valley is given on tab west.side_infl. All values generally used in the computations are in acre-feet unless indicated otherwise. Descriptive documentation of the calculations tab is given below. The reported precision of the values given on the spreadsheets generally exceeds the reliable accuracy of the estimates.

As the model was reviewed, a simplified flowchart was constructed for overall user visualization of included inflow and outflow variables. Figure G-1 shows the simplified flowchart.

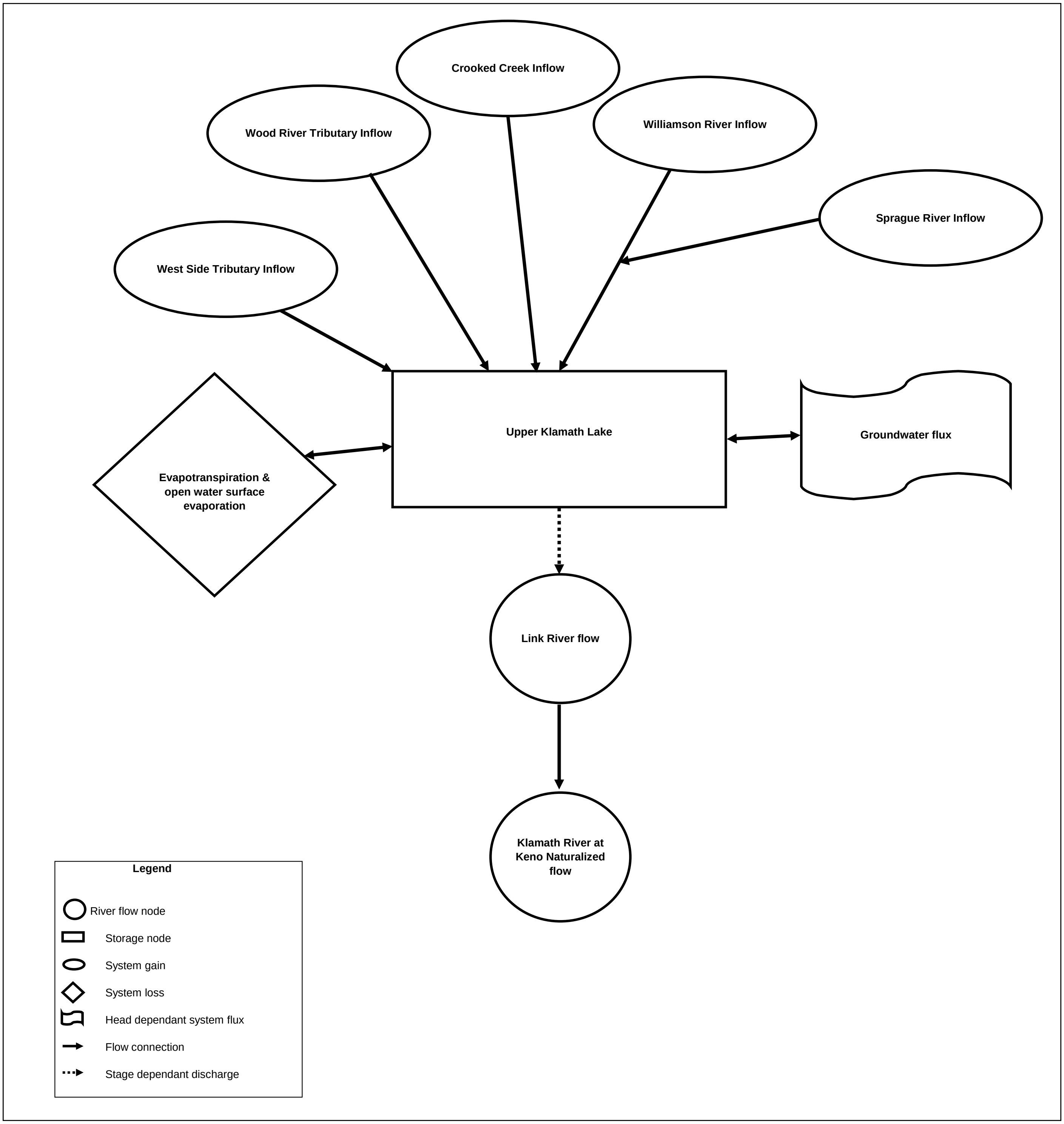

Figure G-1. Simplified flowchart of overall user visualization of included inflow and outflow variables.

Attachment H—Data Tables of Synthetic Natural Streamflow Records

Contents

Tables

Figures

Attachment H—Data Tables of Synthetic Natural Streamflow Records

Figure H-1 presents a flowchart of how the natural flows were estimated. Monthly total values in acre-feet are shown for each segment of the flowchart. The tables that follow represent the synthetic natural streamflow records for each segment.

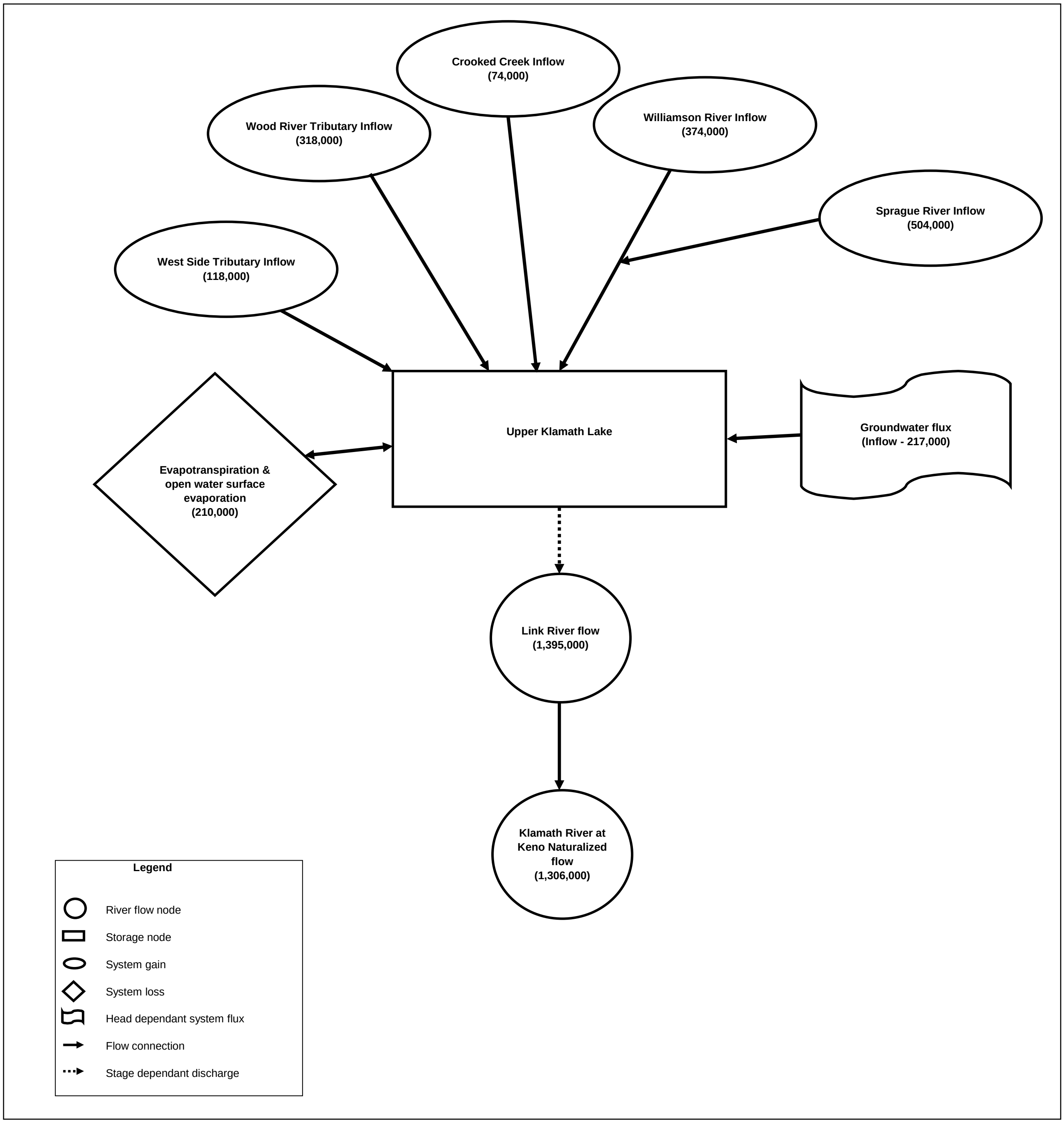

Figure H-1. Simplified flowchart of how natural flows were estimated with average annual values shown

Table H-1. West Side Tributary Estimated Natural Inflow—
Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	5318.0	5345.3	6135.8	4508.9	5168.5	6087.8	18272.5	33403.8	13170.5	5627.3	5110.7	4916.7	113066
1950	5266.5	5171.3	4745.1	6579.7	6132.2	11666.0	14236.9	27381.1	22530.9	7494.7	5499.1	4445.6	121149
1951	8376.7	12200.5	24439.6	12405.9	16593.8	7351.9	19247.8	20227.0	10602.8	6205.2	4746.2	4289.5	146687
1952	6952.7	8086.5	12151.3	7113.7	9885.7	7533.3	23381.8	36355.9	26999.2	10320.0	5038.6	4238.2	158057
1953	3930.7	3678.2	4280.5	16164.5	16280.7	6739.6	10659.5	22402.2	30669.3	10913.7	6623.9	5725.6	138068
1954	5897.9	12396.7	15610.6	10358.6	11865.7	10060.9	18261.3	20067.2	14681.8	6866.8	6108.4	5826.9	138003
1955	5579.8	5360.8	5038.8	4734.8	4818.8	4907.5	6721.3	20454.6	20509.8	5928.2	5057.9	4926.9	94039
1956	5391.9	7485.3	26783.0	26385.4	12444.3	7383.6	16188.7	32698.2	22232.6	8834.8	6363.2	5895.1	178086
1957	6725.8	7202.3	17322.9	6005.8	9462.9	22634.1	14108.6	18393.5	9857.8	5979.1	5523.7	5596.0	128813
1958	6073.1	7549.7	11037.0	14463.2	24607.7	10266.4	10965.9	24912.1	18149.6	8074.6	6115.2	5807.9	148022
1959	6304.3	7485.5	6236.4	8457.6	5990.8	6458.4	10448.5	12592.2	7831.4	5442.8	5101.3	5148.6	87498
1960	5844.9	4872.4	4366.8	4284.5	5966.6	11209.1	14035.2	20054.1	14886.2	5523.1	5067.0	4819.2	100929
1961	5162.6	6313.6	6415.1	4978.2	9946.7	8780.0	11598.6	17996.6	14816.3	5682.9	5155.2	5123.4	101969
1962	5631.0	7627.5	8028.2	6127.2	5903.9	5297.4	14928.0	16830.8	11934.3	5640.8	5237.5	4983.6	98170
1963	6125.8	7768.5	12111.8	5046.1	11962.8	6289.3	9564.5	19508.6	8572.2	5568.4	5138.4	4968.3	102625
1964	5238.1	8599.2	6545.8	6617.0	5874.7	5282.1	10201.8	20719.2	24267.0	7572.9	5372.3	5082.4	111373
1965	5020.1	5647.3	55628.6	27967.6	17057.1	9918.4	13498.1	19297.5	11544.6	6063.5	5893.2	5518.9	183055
1966	5468.7	5657.5	5129.4	6160.3	4955.5	7405.5	18699.6	14817.7	7217.4	5352.8	4871.4	4742.6	90478
1967	4990.9	6113.4	6944.2	7425.5	6741.8	6255.9	5490.3	19448.7	16780.8	5798.4	4981.2	4709.4	95681
1968	5240.3	4722.2	4437.2	4714.4	9165.3	6239.2	5344.3	9123.2	6027.0	4793.2	4737.0	4474.6	69018
1969	4930.5	7455.4	7280.0	10480.9	7134.8	5594.8	12657.1	31109.1	16328.6	6605.6	5067.1	4832.1	119476
1970	5304.9	4871.9	6683.8	22432.8	8792.4	8505.4	5935.4	14493.3	9024.0	5423.3	5028.0	4895.4	101391
1971	5308.6	11616.7	8988.1	20673.4	10690.7	13792.6	14300.8	36461.5	27226.6	10181.2	6532.4	6193.8	171966
1972	6098.9	7819.3	10028.5	16873.8	12834.6	25751.6	16824.4	28947.7	23169.7	9116.1	6690.0	6162.4	170317
1973	6038.1	5846.9	7301.8	7284.9	5491.6	5990.6	7868.8	12488.2	6452.2	4996.0	4765.9	4903.7	79429
1974	5392.9	15026.6	18571.8	21564.0	8397.7	15649.4	16987.9	26103.1	31774.2	9230.9	6548.9	6000.0	181247
1975	5922.4	5482.5	6239.5	6633.4	7392.9	11073.8	7966.8	31106.8	31892.5	9277.7	6229.8	5715.0	134933
1976	6434.0	7483.9	13926.5	10924.3	7237.0	6566.4	9221.0	23876.1	13841.3	6726.0	6798.6	5753.1	118788
1977	5617.1	5058.8	4392.0	4083.8	4375.8	4156.3	5103.1	9916.0	6606.1	4803.4	4536.8	4801.7	63451
1978	5002.9	8845.0	21795.5	9929.9	8149.1	9142.8	7639.0	10965.0	7439.2	5340.7	4934.2	5031.4	104215
1979	4896.0	4814.5	5201.1	6052.4	5673.0	8304.9	8493.4	18855.3	7147.9	5031.1	4671.7	4360.8	83502
1980	5544.7	7284.1	7417.7	14502.7	7710.9	6676.6	9309.4	11535.3	7239.3	5148.4	4710.6	4589.4	91669
1981	4917.7	5247.0	7803.1	4873.0	6778.8	5353.0	5991.6	9575.9	7907.5	4988.5	4496.6	4398.2	72331
1982	5073.8	8686.7	30826.5	11104.2	19549.2	13273.1	11993.6	23546.0	17434.1	7691.1	5786.8	5561.8	160527
1983	5974.5	5971.9	12835.9	8732.4	12685.2	16299.4	12439.1	24301.8	18837.7	9038.0	6388.5	5759.1	139264
1984	5684.4	8867.5	21738.7	12012.2	11776.5	16038.6	12440.6	25405.0	26298.3	9464.0	6578.8	6027.2	162332
1985	6562.6	12922.7	7317.6	5680.0	5676.9	6027.1	17723.0	17188.6	12608.2	5700.2	5208.6	5408.0	108024
1986	5957.5	5687.2	6094.4	9346.4	18060.6	18714.4	8127.4	14049.0	9586.9	5413.8	5094.8	5857.9	111990
1987	6304.7	7027.4	5485.0	5814.2	7968.0	7644.4	10124.4	11021.0	6140.8	5510.3	4748.0	4502.6	82291
1988	4698.8	4565.1	4992.8	5881.3	5809.5	6268.2	6901.9	10701.4	9218.0	5010.4	4485.2	4287.2	72820
1989	4538.7	6030.8	5307.2	5356.8	5172.5	18483.6	22697.8	19610.0	12153.1	5721.3	5181.0	4987.6	115240
1990	5282.7	4994.6	4921.6	5841.6	4972.9	8798.1	10801.1	10516.2	8574.3	5155.0	4802.1	4524.4	79185
1991	4862.3	4977.0	4522.0	6310.9	6240.1	8009.2	8256.6	13653.3	8631.4	5201.8	4625.4	4299.2	79589
1992	4680.9	5360.2	5866.6	4594.2	5491.5	4501.3	8040.0	7784.2	5193.1	4702.7	4228.8	4110.1	64554
1993	4659.6	5695.6	5670.1	6439.0	5672.3	21661.9	16532.6	31348.0	17730.9	7177.6	5543.5	5061.7	133193
1994	5334.2	5132.5	5608.1	5615.0	4902.0	6736.5	8962.6	10448.6	5700.6	5019.5	4761.3	4684.4	72905
1995	4909.9	5310.5	5541.1	9213.9	15077.8	15851.2	12802.4	20266.1	14854.6	7014.3	5328.8	5145.9	121317
1996	5159.4	6792.4	29315.0	18088.6	21044.3	15789.9	20524.9	25760.4	12583.6	6671.5	5826.7	5919.3	173476
1997	6092.8	13697.4	25370.3	24178.0	13040.9	12917.3	17349.5	21797.6	11229.5	7605.7	6274.8	5953.9	165508
1998	6280.5	6454.3	6218.6	17040.1	10305.9	17560.9	12599.2	20185.7	16082.4	7655.1	5883.4	5121.0	131387
1999	5426.1	9443.5	10934.9	14065.3	10156.8	11519.4	11873.7	26985.8	25795.2	8982.2	5769.6	5335.5	146288
2000	5757.9	6272.1	6965.8	9274.0	11140.5	12568.8	18655.9	18448.3	10126.9	5880.8	5455.1	5198.2	115744

Table H-2. Wood River Tributary Estimated Natural Inflow—
Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	26551.1	25991.4	26519.7	25253.5	24479.4	25075.2	27898.4	33826.3	34250.2	31768.1	30751.0	29680.4	342045
1950	30054.4	29377.2	28063.1	27449.2	26244.1	26839.8	27978.4	34626.8	35303.1	34720.9	29238.5	28630.3	358526
1951	28807.1	31626.9	30978.5	30001.9	29395.8	31245.9	35623.1	41404.6	42083.0	40417.4	38324.7	35260.0	415169
1952	36874.5	33831.1	33141.5	30692.5	29660.8	30192.2	32227.5	40922.4	40831.6	44376.5	35800.5	34537.6	423089
1953	33689.1	30743.3	30733.5	32912.5	30789.5	31341.7	32193.2	37679.5	43677.6	40512.2	36174.6	35036.1	415483
1954	33229.6	34761.8	32739.8	30536.9	29941.1	31853.3	35775.4	39328.3	41548.9	38983.5	38328.8	34980.7	422008
1955	32787.5	30460.1	28903.3	28444.4	27698.9	28597.5	28561.5	32553.9	36468.2	30245.7	28459.7	25202.7	358383
1956	25408.6	26443.4	27716.4	27696.2	26620.7	25565.3	31470.8	42390.5	46233.3	41825.6	36402.3	34423.1	392196
1957	35088.5	32747.3	32311.2	31938.7	31118.8	32070.9	34141.3	36341.0	35894.8	34778.6	33873.2	31428.5	401733
1958	29554.7	28655.8	28049.3	27846.6	27703.3	28350.7	29439.6	36862.9	40922.9	36687.1	34035.4	31126.0	379234
1959	30713.4	29173.3	27692.6	28271.3	27935.6	28526.9	28784.2	31277.1	30844.5	28865.5	27533.5	25498.4	345116
1960	25390.3	24326.2	24029.5	23575.5	22974.6	23867.0	24484.2	28116.2	30115.1	28990.4	24185.7	22297.3	302352
1961	22370.4	22815.5	21764.4	20790.6	21117.5	22626.4	23966.3	28232.8	31396.0	26984.5	26308.5	24655.6	293029
1962	24591.8	24791.5	23938.4	23400.1	22847.2	23888.2	25582.1	28237.5	30168.3	27576.4	26283.1	25429.2	306734
1963	27558.6	25081.3	24899.2	24072.8	23910.9	25253.8	26014.4	30015.9	30064.6	29806.8	29082.0	27210.0	322970
1964	26596.0	28132.2	25412.2	24780.3	23803.3	24296.1	25673.3	29167.9	27606.9	27751.3	25645.6	23857.8	312723
1965	22288.8	22359.2	28438.5	27222.2	29847.0	32495.0	37158.7	36608.0	38170.7	36382.9	34712.0	31752.1	377435
1966	30157.5	28511.3	28357.9	29126.0	28733.5	29908.8	31076.0	33557.1	33285.0	29416.6	28183.1	27046.0	357359
1967	25616.0	26154.8	24897.3	23398.7	22919.5	24018.1	24648.3	29514.4	30763.7	25071.0	23579.7	22724.3	303306
1968	22351.5	20974.3	21098.6	20764.0	20514.4	20882.5	21228.4	21538.9	21559.9	22430.3	21015.9	19277.4	253636
1969	19335.1	20801.1	19457.3	19118.6	18604.8	19350.6	20332.6	25939.2	26356.8	23138.3	21790.7	21133.1	255358
1970	20834.0	20002.4	20918.5	24047.6	22183.8	23253.1	23622.6	25009.5	27307.4	24528.2	24064.8	22376.8	278149
1971	21955.8	24184.4	21611.7	23401.4	22587.5	24123.3	27317.3	30735.8	34795.6	36025.2	30173.7	26389.7	323301
1972	27318.8	27259.7	26296.7	26913.3	25909.3	28949.5	30781.9	35789.8	40341.5	37577.5	34449.8	33249.0	374837
1973	32026.0	29539.0	29064.0	28438.7	28119.9	29428.0	29592.8	30578.5	29346.9	28089.3	27394.4	26249.4	347867
1974	26096.8	29286.4	26276.8	27143.7	24845.6	24974.5	27357.4	34314.7	41239.1	38265.9	33656.8	29458.0	362916
1975	28971.8	27541.1	26743.9	26409.2	26919.3	28507.3	29296.9	36451.5	39414.9	39983.7	32739.0	31495.1	374474
1976	31340.2	29961.2	29625.1	28961.0	28658.8	29784.1	30660.6	35093.7	36592.9	35686.0	31434.4	31226.7	379025
1977	29019.3	27900.8	27036.7	26716.6	25767.6	26560.7	26118.4	25213.0	25167.4	23632.1	23004.1	21865.7	308002
1978	21653.7	20652.6	26005.1	22853.1	21631.0	22283.9	23924.1	25689.0	29190.2	26778.7	23583.7	22272.1	286517
1979	21138.2	20505.6	20563.1	20161.9	19322.5	20428.3	20692.0	24502.0	25048.4	22602.1	21691.6	20763.7	257420
1980	19946.5	19974.1	20467.4	20732.6	19162.2	18423.4	19267.7	23146.3	21420.8	22095.6	21082.0	18987.9	244706
1981	18463.7	18333.4	18475.5	19006.7	18357.0	19335.1	19594.6	22043.2	21237.3	20283.1	19136.3	18554.8	232821
1982	18303.3	18263.4	20729.2	20046.8	19741.3	22876.8	23426.4	28303.2	35552.5	33522.5	28781.5	26581.8	296129
1983	26270.7	26141.0	25828.4	25150.4	24659.2	27035.8	28763.8	31551.4	38229.0	37491.5	33724.1	30467.2	355312
1984	29871.6	29548.4	29159.3	27808.8	27591.6	29095.3	31550.3	33762.1	38699.2	41654.4	34410.3	31726.3	384878
1985	31511.4	31464.7	30102.6	28263.5	26890.6	27006.7	28391.5	30332.2	33421.7	29905.9	27805.9	26809.5	351906
1986	26403.9	25559.0	24493.7	24240.6	23728.1	26795.9	28830.5	30081.8	38088.0	29587.1	26726.7	25705.8	330241
1987	25236.5	24931.8	24215.7	23366.8	22492.6	23258.1	24153.0	30180.7	26661.6	24294.9	22958.8	21993.3	293744
1988	21445.7	20654.0	20500.1	20416.8	19479.2	20139.5	20905.5	22326.9	23317.7	21472.3	19691.2	18898.4	249247
1989	18178.8	18039.5	17246.2	17780.3	16896.1	17871.7	20472.7	24590.4	26648.8	24592.1	21916.6	20411.7	244645
1990	20903.4	21790.8	21143.3	19965.6	18858.7	18848.4	19732.8	23211.7	22168.7	20341.0	19221.8	18494.8	244681
1991	17589.8	17022.0	16203.1	16210.9	15521.2	16302.2	15682.0	17606.4	17957.2	17520.3	16324.6	15542.0	199482
1992	15885.2	15705.1	16130.1	16592.2	15851.8	16539.8	17667.0	19371.7	17386.4	17066.2	16091.0	15072.1	199359
1993	14935.3	15215.8	14674.5	15447.4	14356.7	15916.4	18608.5	24109.6	26249.6	23856.5	21010.8	19706.7	224088
1994	19454.6	18886.0	19031.0	18631.4	18135.4	19030.1	19549.6	20696.1	18844.8	18007.4	17508.3	16867.6	224642
1995	16585.8	15962.9	15364.5	15279.5	14867.3	16566.0	16934.5	19700.6	22234.3	21739.4	18235.7	17078.0	210549
1996	16671.3	16982.2	19840.8	20074.2	21709.3	23564.1	27212.7	31628.8	32627.1	30195.0	30314.0	28190.9	299010
1997	27461.0	28863.7	28948.4	30586.4	29014.0	30405.9	32791.6	38951.2	39466.5	34888.1	31704.0	29563.2	382644
1998	28731.3	27468.3	26690.2	26513.2	25292.2	25886.6	26469.3	29388.9	33725.6	32351.5	27663.0	26310.4	336490
1999	25174.8	25120.2	24175.7	23734.5	22906.7	23606.2	25739.9	31516.0	37278.9	37355.1	31504.4	28010.5	336123
2000	27119.3	26528.6	25830.9	25310.7	24574.5	25408.2	28943.3	30765.4	31925.3	28580.8	26986.1	26232.1	328205

Table H-3. Crooked Creek Estimated Natural Inflow—
Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	6632.7	6653.9	6772.6	6539.5	6386.9	6302.1	7060.8	7378.6	7259.9	7374.4	7471.9	7548.1	83381
1950	7624.4	7641.4	7323.5	7098.9	6853.1	6776.8	7031.1	7531.2	7543.9	7484.6	6751.4	7018.4	86679
1951	7031.1	7060.8	7332.0	7582.0	7615.9	7933.8	9099.3	9887.6	9862.2	9476.5	9243.4	8828.1	100953
1952	8760.2	8421.2	8387.3	8111.8	7891.4	7789.7	8315.2	9633.3	8840.8	9001.8	8828.1	8616.2	102597
1953	8446.6	8048.2	8065.2	7955.0	7734.6	7721.9	7789.7	8620.4	8548.3	8637.3	8603.4	8756.0	98927
1954	8200.8	8179.6	8107.6	7874.5	7857.5	8179.6	9230.7	9205.3	9090.8	8722.1	8773.0	8561.1	101983
1955	8209.3	7904.1	7526.9	7387.1	7276.9	7289.6	7302.3	7243.0	6929.4	6942.1	6861.6	6251.3	87124
1956	6348.7	6412.3	6259.7	6357.2	6471.6	6264.0	7874.5	9256.1	9315.4	8972.2	8641.6	8387.3	90561
1957	8387.3	8239.0	7912.6	7819.4	7921.1	8010.1	8455.1	8611.9	8366.1	8234.7	8111.8	7819.4	97888
1958	7115.8	7103.1	6971.8	6929.4	7107.4	7302.3	7565.1	8065.2	8285.6	7984.7	7840.6	7488.8	89760
1959	7404.0	7145.5	7069.2	6997.2	7141.3	7098.9	7048.0	7459.1	7145.5	6899.7	6535.2	6196.2	84140
1960	6391.1	6251.3	6187.7	6026.6	5933.4	5937.6	6047.8	6001.2	5823.2	5721.5	5662.2	5479.9	71464
1961	5467.2	5475.7	5301.9	5276.5	5429.1	5607.1	5937.6	6102.9	6107.2	6183.5	6153.8	6018.2	69061
1962	5878.3	5810.5	5848.6	5903.7	5852.9	5908.0	6323.3	6374.2	6429.3	6382.6	6213.1	6259.7	73184
1963	6149.5	5946.1	5984.3	5929.2	6060.5	6221.6	6467.4	6666.6	6980.2	7158.2	7018.4	6814.9	77397
1964	6645.4	6573.4	6357.2	6272.5	6111.4	6009.7	6327.6	6357.2	6162.3	5742.7	5823.2	5696.1	74079
1965	5475.7	5513.8	5696.1	6141.1	6721.7	7323.5	8298.3	8802.6	8811.1	8582.2	8234.7	7887.2	87488
1966	7543.9	7315.0	7387.1	7590.5	7582.0	7675.3	7938.0	7777.0	7370.1	7154.0	6946.3	6738.7	89018
1967	6480.1	6285.2	6098.7	5861.4	5848.6	5924.9	6132.6	6208.9	6111.4	5751.2	5594.4	5454.5	71752
1968	5399.4	5318.9	5318.9	5196.0	5208.7	5060.3	5090.0	5085.8	5098.5	5187.5	5013.7	4806.1	61784
1969	4700.1	4662.0	4611.1	4594.2	4577.2	4551.8	4751.0	4869.6	4988.3	5001.0	4929.0	4903.5	57139
1970	4945.9	5001.0	5039.2	5060.3	5034.9	5204.4	5335.8	5488.4	5619.8	5687.6	5577.4	5378.2	63373
1971	5272.3	5280.7	5238.3	5251.1	5382.4	5649.4	6607.3	7166.7	6971.8	6730.2	6505.6	6259.7	72315
1972	6348.7	6480.1	6488.6	6437.7	6450.5	7141.3	7700.7	7764.3	7836.3	7883.0	7857.5	7883.0	86272
1973	7747.3	7526.9	7391.3	7272.7	7332.0	7476.1	7429.5	7374.4	7247.2	7077.7	6861.6	6645.4	87382
1974	6458.9	6327.6	6166.5	6052.1	5865.6	5751.2	6471.6	7437.9	7399.8	7348.9	7098.9	6823.4	79202
1975	6865.8	7001.4	6772.6	6692.0	6988.7	7213.3	7467.6	8145.7	8188.1	8035.5	7781.2	7628.7	88781
1976	7425.2	7348.9	7209.1	7234.5	7374.4	7484.6	7764.3	7802.4	7840.6	7832.1	7696.5	7505.8	90518
1977	7315.0	7107.4	6912.4	6827.7	6679.3	6666.6	6450.5	6399.6	6242.8	6056.3	5903.7	5636.7	78198
1978	5653.7	5407.9	5361.3	5174.8	5229.9	5318.9	5463.0	5518.1	5645.2	5501.1	5331.6	5191.7	64797
1979	5064.6	4971.3	4979.8	4814.5	4746.7	4890.8	4950.2	4992.5	4941.7	4971.3	5085.8	4945.9	59355
1980	4793.3	4734.0	4797.6	4840.0	4573.0	4242.4	4428.9	4331.4	4081.3	4526.3	4632.3	4293.2	54274
1981	4238.1	4289.0	4255.1	4263.6	4297.5	4348.3	4382.2	4543.3	4513.6	4517.9	4496.7	4386.5	52532
1982	4327.1	4289.0	4369.5	4475.5	4577.2	5234.1	5530.8	6081.7	6378.4	6293.6	6255.5	6230.1	64043
1983	6230.1	6200.4	6115.6	6132.6	6213.1	6768.3	7276.9	7463.4	7446.4	7446.4	7272.7	7111.6	81678
1984	6954.8	6895.5	6836.1	6692.0	6751.4	7132.8	7760.0	7874.5	7874.5	7849.0	7781.2	7577.8	87980
1985	7493.0	7446.4	7226.0	7005.7	6827.7	6692.0	6781.0	6738.7	6687.8	6628.5	6590.3	6475.9	82593
1986	6327.6	6166.5	6030.9	5954.6	5980.0	6293.6	6734.4	6734.4	6645.4	6560.7	6391.1	6272.5	76092
1987	6102.9	5992.7	5819.0	5687.6	5657.9	5717.3	5789.3	5814.7	5793.5	5742.7	5619.8	5475.7	69213
1988	5335.8	5183.3	5111.2	4979.8	4890.8	4852.7	4865.4	4810.3	4742.5	4640.8	4551.8	4492.4	58457
1989	4344.1	4382.2	4242.4	4246.6	4200.0	4276.3	4589.9	4581.4	4734.0	4797.6	4755.2	4636.5	53786
1990	4645.0	4742.5	4674.7	4632.3	4594.2	4496.7	4450.1	4471.2	4534.8	4534.8	4526.3	4458.5	54761
1991	4233.9	4144.9	3992.3	3810.1	3805.9	3801.6	3670.2	3572.8	3742.3	3844.0	3759.2	3666.0	46043
1992	3716.9	3763.5	3793.1	3835.5	3822.8	3865.2	4102.5	4204.2	4047.4	3966.9	3780.4	3610.9	46509
1993	3593.9	3657.5	3649.0	3619.4	3483.8	3602.4	4369.5	4700.1	4598.4	4530.6	4530.6	4484.0	48819
1994	4462.8	4458.5	4543.3	4564.5	4577.2	4594.2	4632.3	4526.3	4407.7	4348.3	4297.5	4140.7	53553
1995	3996.3	3887.4	3713.8	3624.2	3608.2	3796.5	3880.3	3899.8	3908.8	3899.8	3858.5	3816.2	45890
1996	3818.6	3916.0	4064.4	4166.1	4662.0	5424.8	6230.1	6526.7	6399.6	6611.5	7120.1	6738.7	65679
1997	6501.3	6552.2	6581.8	6831.9	7005.7	7285.4	7768.5	8031.3	8090.6	7866.0	7425.2	7107.4	87047
1998	6823.4	6611.5	6442.0	6399.6	6314.8	6230.1	6314.8	6272.5	6314.8	6272.5	6145.3	6060.5	76202
1999	5891.0	5891.0	5721.5	5636.7	5594.4	5806.3	6357.2	7247.2	7204.8	7162.5	6908.2	6526.7	75948
2000	6314.8	6272.5	6145.3	6060.5	6018.2	6230.1	6823.4	6696.3	6526.7	6484.4	6399.6	6357.2	76329

Table H-4. (Upper) Williamson River Estimated Natural Inflow—
Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	19333.6	18942.0	19077.0	18320.0	17409.0	34513.0	35111.0	25316.1	20551.7	21350.0	20711.3	19970.0	270605
1950	20634.0	21902.0	21779.0	22163.0	20495.0	40668.0	42439.3	30751.3	20826.2	20265.0	20317.3	19143.7	301384
1951	20208.0	21265.0	34315.0	32299.0	35324.0	42268.0	50469.5	43130.5	25510.9	21637.6	21470.7	20240.5	368139
1952	21162.0	20876.0	29604.0	28039.0	26476.0	35076.0	82975.2	66910.9	41945.4	32948.8	27862.1	24948.7	438824
1953	23752.1	26175.0	27049.0	39563.0	75420.0	66316.0	56549.0	56197.2	58693.1	36163.3	27219.9	25884.2	518982
1954	29469.6	41253.0	58830.0	42743.0	39942.0	73990.0	84030.9	65691.7	45860.3	36311.5	28342.0	27646.7	574111
1955	31666.8	35451.0	37327.0	32498.0	30318.0	43418.0	62547.0	44965.6	25970.6	22272.9	20583.5	21289.4	408308
1956	25968.9	34005.0	55455.0	70091.0	48051.0	51934.0	68789.5	72253.3	53671.0	41223.9	30628.5	28038.0	580109
1957	37732.0	48078.0	51516.0	40594.0	36407.0	89297.0	71262.8	53860.6	36002.1	23946.9	21330.9	22694.1	532721
1958	38570.6	42135.0	45487.0	44649.0	62559.0	91697.0	78789.4	63490.3	53225.5	46315.1	35263.8	30279.3	632461
1959	36852.4	42707.0	44912.0	51093.0	48597.0	52061.0	43381.0	36114.9	27868.3	22201.7	19560.3	21672.5	447021
1960	28921.1	32176.0	33430.0	29129.0	44326.0	57309.0	51442.0	32377.3	23453.4	19701.1	20038.0	20171.3	392474
1961	22537.0	26599.0	39426.0	34049.0	46593.0	47700.0	36326.0	25616.6	21934.8	20230.8	20997.4	19255.8	361265
1962	21363.4	25934.0	36360.0	34440.0	33993.0	40784.0	48972.0	32227.6	24447.3	20123.4	19865.2	19607.2	358117
1963	23905.0	29893.0	42921.0	31593.0	40568.0	39692.0	43078.0	37148.8	26513.9	20209.4	19694.4	19373.1	374590
1964	19709.3	26254.0	29929.0	27543.0	24221.0	29767.0	46444.0	36025.1	24489.7	21178.4	20962.9	19007.3	325531
1965	18574.2	19226.0	50991.0	68470.0	67241.0	51198.0	37615.0	34306.4	23060.1	20978.2	20137.1	19669.2	431466
1966	21109.5	29501.0	31397.0	26849.0	26065.0	44073.0	65950.1	34376.8	22804.1	20937.2	19207.4	19221.9	361492
1967	18246.1	23695.0	36318.0	30625.0	31778.0	42052.0	48229.0	40673.4	23219.7	20191.7	18429.6	18046.9	351504
1968	19967.5	20575.0	23586.0	22199.0	31659.0	51291.0	30694.0	19625.2	17116.8	17661.4	17111.7	17467.9	288955
1969	18780.6	19514.0	26834.0	26255.0	22062.0	28074.0	68054.3	37695.4	23328.5	18724.2	16904.6	17545.6	323772
1970	19272.2	19196.0	24940.0	41199.0	51724.0	48030.0	35907.0	28448.2	21645.5	18770.5	16185.5	17469.3	342787
1971	20740.0	22159.0	30421.0	29531.0	40684.0	44153.0	64999.0	54348.0	36393.1	28561.7	22832.8	20087.1	414910
1972	21838.8	26670.0	33943.0	32535.0	42947.0	83168.0	52880.0	39002.4	29252.9	24092.2	22653.2	21283.4	430266
1973	24509.9	32334.0	36483.0	42150.0	36743.0	49481.0	36376.4	24523.8	18683.5	17878.9	17042.1	17451.0	353656
1974	19510.7	33083.0	43300.0	39273.0	44663.0	50756.0	63392.0	44571.1	31239.8	25378.8	20689.1	19240.1	435097
1975	21040.1	28701.0	36977.0	32311.0	34061.0	56260.0	60572.0	56508.9	36956.3	27097.4	22782.9	21696.0	434964
1976	26599.0	37693.0	45256.0	45876.0	37177.0	50425.0	45478.0	30405.6	22236.4	19632.8	22905.3	23004.7	406689
1977	26540.3	31375.0	29933.0	22709.0	22739.0	40642.0	33967.0	31342.4	28292.8	24321.0	23372.4	21022.6	336256
1978	22437.3	26613.0	42947.0	48143.0	42197.0	44458.0	34910.0	28900.2	19538.4	17998.0	19238.7	18453.1	365834
1979	18657.7	18591.0	23005.0	22888.0	22613.0	38440.0	32575.5	25839.6	16193.5	18488.1	17671.9	17318.8	272282
1980	17579.0	19644.0	27729.0	30608.0	32149.0	36016.0	30613.0	23149.5	20804.4	20802.4	20685.5	17534.9	297315
1981	18278.0	18867.0	24413.0	31040.0	27043.0	32617.0	25528.5	18900.9	15782.1	17768.9	18059.0	17668.1	265966
1982	21017.2	19254.0	28430.0	29287.0	41449.0	67439.0	51180.0	40468.7	25934.5	23264.1	18323.6	17370.9	383418
1983	18365.5	24967.0	29159.0	32083.0	40894.0	75274.0	74263.0	58297.2	40984.8	32048.3	26038.2	22328.6	474703
1984	25509.4	34132.0	46253.0	42108.0	40118.0	65434.0	68926.0	55914.9	38165.9	27063.3	22673.8	22175.2	488474
1985	26962.0	43214.0	44553.0	36314.0	31394.0	44746.0	68667.0	42269.1	28880.5	21781.4	21353.9	23200.6	433336
1986	28683.0	32966.0	32488.0	36449.0	54106.0	82791.0	50785.6	38027.1	29363.8	26133.6	24471.8	21695.2	457960
1987	28556.4	33468.0	36989.0	33676.0	35308.0	53789.0	39158.3	27487.1	19205.3	19770.5	19830.1	18598.5	365836
1988	21195.9	26424.0	36573.0	34062.0	34305.0	42511.0	28479.6	22843.1	18833.3	18284.6	17981.9	17214.8	318708
1989	18146.1	20266.0	29399.0	30127.0	22017.0	53374.0	56494.8	38782.6	25793.4	21334.6	19101.4	17167.7	352004
1990	18744.3	20531.0	22658.0	28388.0	23361.0	38625.0	31988.8	19149.3	19089.5	18396.1	18019.3	18448.9	277399
1991	19776.4	19375.0	18536.0	18564.0	19442.0	29302.0	22088.0	14891.9	18679.4	19385.5	18207.3	18183.1	236431
1992	18045.2	18479.0	18760.0	18814.0	17221.0	20464.0	16830.3	18210.8	15903.9	17729.1	16245.1	17479.6	214182
1993	18068.7	17554.0	16263.0	14186.0	15491.0	17748.0	47824.7	26823.9	19959.7	17844.7	18234.0	17874.9	247873
1994	17975.6	17326.0	17965.0	17859.0	15971.0	22894.0	20011.9	15006.0	14005.0	16347.8	14491.3	16053.7	205906
1995	18160.3	18579.0	18592.0	16844.0	16906.0	22787.0	24144.9	24681.4	19868.8	12917.7	15074.2	16693.8	225249
1996	18514.7	18528.0	19820.0	23414.0	26881.0	37567.0	28793.5	25513.3	19316.5	15975.8	18588.6	17555.0	270467
1997	18611.5	18588.0	30072.0	64567.0	42330.0	41330.0	33083.0	27005.5	12658.7	15707.9	18163.4	16528.0	338645
1998	18487.5	19270.0	24264.0	29989.0	44266.0	46670.0	44609.0	34950.8	31506.3	24210.1	20386.8	18824.6	357434
1999	19437.3	25435.0	42687.0	39309.0	31484.0	38672.0	50877.0	40147.2	33780.1	26662.6	20571.0	24233.3	393296
2000	26067.1	31030.0	36490.0	36687.0	41703.0	50042.0	40741.6	35602.8	27126.6	23253.4	21393.5	18264.4	388401

Table H-5. Sprague River Estimated Natural Inflow—
Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	15291.3	17231.0	18524.0	16300.0	21450.0	45384.0	58558.5	61812.3	27041.1	13160.5	12800.9	14140.4	321694
1950	14881.4	15767.0	15832.0	19528.0	27938.0	51942.0	62643.8	66059.7	40230.2	16309.4	13452.9	10674.3	355259
1951	16981.8	24379.0	57458.0	28904.0	66529.0	62262.0	119773.3	91559.1	31336.1	16477.6	14326.4	14255.1	544241
1952	18983.8	20962.0	28473.0	24714.0	41257.0	50000.0	244548.7	177083.3	69954.0	36231.3	19532.9	18584.9	750325
1953	19311.5	20636.0	21481.0	69649.0	59061.0	52337.0	88045.2	133465.4	100688.7	35440.4	19763.4	21231.7	641110
1954	22755.6	31226.0	35604.0	29054.0	46995.0	87923.0	162774.0	104971.4	39479.2	23043.8	17551.4	19913.2	621291
1955	21741.8	24199.0	23610.0	22360.0	21172.0	29503.0	42233.0	42337.2	26975.2	18581.8	15940.0	15633.0	304286
1956	17884.2	21967.0	84164.0	116596.0	49379.0	100359.0	252881.9	196705.1	90620.5	34343.9	26730.1	21996.1	1013627
1957	26634.8	28307.0	29189.0	23003.0	42415.0	105126.0	71257.5	93946.3	42883.7	24486.5	17459.9	18099.2	522808
1958	31372.6	33357.0	37324.0	37468.0	151024.0	109192.0	122978.7	144964.1	66212.0	35985.0	25574.0	23435.8	818887
1959	23211.3	25307.0	27942.0	30092.0	26716.0	34340.0	38090.1	32478.6	20622.0	17769.9	16715.5	18049.8	311334
1960	21145.9	20242.0	19896.0	20976.0	28451.0	38732.0	40525.8	42760.8	30997.7	20491.4	16815.3	16486.6	317520
1961	16669.9	19186.0	23290.0	20192.0	35445.0	33743.0	38844.2	38912.6	33343.2	16522.6	14438.4	14567.8	305155
1962	17288.8	18643.0	21820.0	18008.0	32014.0	31526.0	85624.0	51114.3	24834.9	15012.8	13695.9	10278.9	339861
1963	51106.6	30320.0	54667.0	25762.0	71559.0	40045.0	93253.6	99698.1	40124.0	25526.6	18543.2	16104.8	566710
1964	17071.5	23316.0	21997.0	22445.0	18968.0	29534.0	80679.1	51684.2	41056.2	21620.4	16552.0	15929.1	360853
1965	16433.8	19748.0	175437.0	120577.0	107466.0	59620.0	72592.5	90579.8	43322.0	24683.8	20799.4	19750.5	771010
1966	18992.0	21999.0	22503.0	22084.0	19349.0	46029.0	69763.2	36037.3	20461.3	14717.0	13688.1	15711.1	321334
1967	16907.1	20170.0	34205.0	23578.0	36792.0	56171.0	65619.7	144331.8	87352.8	25997.6	17246.8	14768.3	543140
1968	18653.7	19633.0	18760.0	20962.0	50008.0	35983.0	26366.2	24593.4	18401.2	12376.2	15822.9	13501.6	275061
1969	15998.5	21041.0	23741.0	26010.0	30675.0	50522.0	160120.2	111109.5	42997.6	23625.2	16686.4	15610.2	538137
1970	19830.8	19629.0	33940.0	111304.0	71531.0	68401.0	45694.5	58064.1	36225.6	23296.3	18404.7	15717.2	522038
1971	18184.0	26609.0	38486.0	62823.0	50339.0	78249.0	131017.0	139599.3	77047.0	32755.6	19728.3	17801.4	692638
1972	22028.7	23945.0	24824.0	37976.0	40876.0	178555.0	82809.5	82369.7	38243.8	23018.4	18001.4	16703.3	589351
1973	20244.8	21459.0	25224.0	30153.0	24488.0	30256.0	32653.9	43684.1	22148.0	17717.6	15592.9	13520.3	297142
1974	17361.1	46969.0	65475.0	103190.0	41897.0	96797.0	147955.8	110388.1	56428.8	27584.1	22389.5	20077.1	756513
1975	19882.0	22356.0	24230.0	22973.0	25101.0	59557.0	65118.6	123262.8	64382.1	31590.4	21990.7	17444.8	497888
1976	20477.0	22181.0	25000.0	23001.0	22798.0	41689.0	51999.2	60024.7	26693.5	19242.3	20845.0	20668.3	354619
1977	17969.3	18365.0	18984.0	17746.0	18068.0	19875.0	16731.8	18509.9	19533.4	17464.4	13240.9	15217.8	211705
1978	15728.2	19571.0	40658.0	67376.0	43847.0	76139.0	103541.7	80436.5	38129.2	28334.1	18082.8	19887.3	551731
1979	16229.5	16580.0	18276.0	22568.0	21694.0	37962.0	29851.6	52149.8	26047.5	16215.3	17594.1	13592.3	288760
1980	15449.4	20944.0	25115.0	64634.0	51932.0	49572.0	52070.9	72297.4	28643.4	27921.7	16656.9	17523.0	442760
1981	16316.6	19666.0	24169.0	22461.0	33565.0	32888.0	38944.9	38118.0	23835.0	20883.7	18164.4	13449.5	302461
1982	15530.0	34747.0	85328.0	40215.0	153519.0	110064.0	120988.9	135370.9	61794.6	40577.0	25175.2	19077.8	842387
1983	20101.3	22332.0	33414.0	41606.0	67346.0	122263.0	117366.6	135203.4	112010.9	44977.3	32761.7	25048.3	774431
1984	20781.7	29497.0	54112.0	40130.0	41344.0	116116.0	112942.8	125577.6	77357.5	40752.0	29763.5	25043.7	713418
1985	24144.4	35118.0	26367.0	23602.0	23368.0	47130.0	111926.9	56743.9	40569.9	34615.3	23295.7	25005.8	471887
1986	22144.7	21289.0	22358.0	37579.0	103265.0	144161.0	83764.7	63937.0	50163.4	34993.1	26497.3	22194.7	632347
1987	21416.9	21005.0	21941.0	22134.0	26323.0	39912.0	42697.5	40248.7	31290.7	32166.5	28498.8	26041.7	353676
1988	17896.3	17520.0	23977.0	22289.0	28858.0	32783.0	32485.9	32251.7	35864.4	31683.0	23774.5	20548.9	319932
1989	12667.0	20416.0	20105.0	14083.0	19996.0	119091.0	122189.4	79435.9	40922.0	28026.1	19926.1	18166.6	515024
1990	19121.6	19244.0	17984.0	26644.0	18296.0	36768.0	29521.8	23658.3	27085.8	25497.7	21326.1	18956.8	284104
1991	15216.7	15947.0	15416.0	17619.0	16025.0	20797.0	25080.3	38774.8	23345.7	30148.1	23844.5	19974.6	262189
1992	13340.9	15213.0	16140.0	15858.0	16451.0	17570.0	23771.6	18393.0	16804.4	25198.3	21949.0	11908.8	212598
1993	11639.2	15513.0	17264.0	20609.0	19887.0	163290.0	117845.4	108029.1	69784.8	27374.2	24216.3	20684.3	616136
1994	18236.3	17151.0	19658.0	19018.0	16759.0	24704.0	25095.1	28211.5	19429.6	24271.2	19985.0	19138.9	251658
1995	11802.5	12980.0	15598.0	36655.0	57424.0	99756.0	97449.6	102128.1	57144.9	41383.5	26467.9	22079.0	580868
1996	16690.5	17024.5	39021.0	51049.0	165487.0	108954.0	93558.1	103623.9	48561.1	37671.2	22190.8	20493.1	724324
1997	17521.0	23530.0	49006.0	185493.0	83702.0	70123.0	82511.6	75326.8	39603.0	30742.4	24408.1	22276.1	704243
1998	17492.5	21422.0	20855.0	53219.0	48066.0	88367.0	87702.2	146731.9	96569.0	45935.9	27688.4	24668.0	678717
1999	18979.0	30988.0	38516.0	34854.0	29667.0	101958.0	138101.5	142092.3	84795.2	34328.8	32537.4	23576.0	710393
2000	20311.3	21400.0	22118.0	32400.0	41941.0	61054.0	94200.1	74889.4	37963.4	31792.4	24403.5	21696.8	484170

Table H-6. (Lower) Williamson River Estimated Natural Inflow—
Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	34624.9	36173.0	37601.0	34620.0	38859.0	79897.0	93669.5	87128.4	47592.8	34510.5	33512.1	34110.4	592299
1950	35515.5	37669.0	37611.0	41691.0	48433.0	92610.0	105083.1	96811.0	61056.4	36574.5	33770.2	29818.1	656643
1951	37189.8	45644.0	91773.0	61203.0	101853.0	104530.0	170242.7	134689.5	56847.0	38115.3	35797.1	34495.5	912380
1952	40145.8	41838.0	58077.0	52753.0	67733.0	85076.0	327523.9	243994.2	111899.4	69180.1	47395.0	43533.5	1189149
1953	43063.6	46811.0	48530.0	109212.0	134481.0	118653.0	144594.2	189662.6	159381.8	71603.7	46983.3	47115.9	1160092
1954	52225.1	72479.0	94434.0	71797.0	86937.0	161913.0	246804.9	170663.1	85339.5	59355.3	45893.5	47559.9	1195401
1955	53408.6	59650.0	60937.0	54858.0	51490.0	72921.0	104780.0	87302.8	52945.8	40854.6	36523.6	36922.4	712594
1956	43853.1	55972.0	139619.0	186687.0	97430.0	152293.0	321671.4	268958.4	144291.6	75567.7	57358.6	50034.1	1593736
1957	64366.8	76385.0	80705.0	63597.0	78822.0	194423.0	142520.2	147806.9	78885.7	48433.4	38790.7	40793.3	1055529
1958	69943.2	75492.0	82811.0	82117.0	213583.0	200889.0	201768.1	208454.4	119437.5	82300.1	60837.9	53715.1	1451348
1959	60063.7	68014.0	72854.0	81185.0	75313.0	86401.0	81471.1	68593.5	48490.4	39971.6	36275.7	39722.3	758355
1960	50067.0	52418.0	53326.0	50105.0	72777.0	96041.0	91967.8	75138.1	54451.1	40192.4	36853.2	36658.0	709995
1961	39206.9	45785.0	62716.0	54241.0	82038.0	81443.0	75170.2	64529.2	55278.0	36753.3	35435.7	33823.7	666420
1962	38652.2	44577.0	58180.0	52448.0	66007.0	72310.0	134596.0	83341.8	49282.2	35136.1	33561.1	29886.2	697978
1963	75011.6	60213.0	97588.0	57355.0	112127.0	79737.0	136331.6	136846.9	66637.9	45736.0	38237.6	35477.9	941299
1964	36780.8	49570.0	51926.0	49988.0	43189.0	59301.0	127123.1	87709.3	65545.9	42798.9	37514.9	34936.4	686383
1965	35008.0	38974.0	226428.0	189047.0	174707.0	110818.0	110207.5	124886.3	66382.1	45662.0	40936.5	39419.7	1202476
1966	40101.5	51500.0	53900.0	48933.0	45414.0	90102.0	135713.2	70414.1	43265.4	35654.2	32895.5	34933.0	682826
1967	35153.2	43865.0	70523.0	54203.0	68570.0	98223.0	113848.7	185005.2	110572.5	46189.3	35676.5	32815.2	894645
1968	38621.2	40208.0	42346.0	43161.0	81667.0	87274.0	57060.2	44218.5	35518.0	30037.6	32934.6	30969.5	564016
1969	34779.2	40555.0	50575.0	52265.0	52737.0	78596.0	228174.5	148804.9	66326.1	42349.4	33591.1	33155.8	861909
1970	39103.0	38825.0	58880.0	152503.0	123255.0	116431.0	81601.5	86512.3	57871.1	42066.8	34590.2	33186.4	864825
1971	38924.0	48768.0	68907.0	92354.0	91023.0	122402.0	196016.0	193947.3	113440.1	61317.3	42561.1	37888.5	1107548
1972	43867.5	50615.0	58767.0	70511.0	83823.0	261723.0	135689.5	121372.1	67496.7	47110.6	40654.6	37986.8	1019617
1973	44754.7	53793.0	61707.0	72303.0	61231.0	79737.0	69030.3	68207.9	40831.5	35596.5	32635.0	30971.3	650798
1974	36871.8	80052.0	108775.0	142463.0	86560.0	147553.0	211347.8	154959.2	87668.5	52962.9	43078.7	39317.2	1191609
1975	40922.2	51057.0	61207.0	55284.0	59162.0	115817.0	125690.6	179771.7	101338.4	58687.8	44773.6	39140.9	932852
1976	47076.0	59874.0	70256.0	68877.0	59975.0	92114.0	97477.2	90430.3	48929.9	38875.1	43750.4	43673.0	761308
1977	44509.5	49740.0	48917.0	40455.0	40807.0	60517.0	50698.8	49852.3	47826.2	41785.4	36613.3	36240.4	547962
1978	38165.5	46184.0	83605.0	115519.0	86044.0	120597.0	138451.7	109336.7	57667.6	46332.2	37321.5	38340.3	917564
1979	34887.2	35171.0	41281.0	45456.0	44307.0	76402.0	62427.2	77989.4	42241.0	34703.4	35266.1	30911.1	561042
1980	33028.4	40588.0	52844.0	95242.0	84081.0	85588.0	82683.9	95446.9	49447.8	48724.1	37342.4	35057.9	740074
1981	34594.6	38533.0	48582.0	53501.0	60608.0	65505.0	64473.4	57018.9	39617.1	38652.6	36223.4	31117.6	568427
1982	36547.2	54001.0	113758.0	69502.0	194968.0	177503.0	172168.9	175839.6	87729.1	63841.1	43498.8	36448.7	1225806
1983	38466.8	47299.0	62573.0	73689.0	108240.0	197537.0	191629.6	193500.6	152995.7	77025.7	58799.9	47376.9	1249133
1984	46291.1	63629.0	100365.0	82238.0	81462.0	181550.0	181868.8	181492.5	115523.5	67815.3	52437.4	47218.9	1201891
1985	51106.4	78332.0	70920.0	59916.0	54762.0	91876.0	180593.9	99013.1	69450.4	56396.7	44649.6	48206.4	905223
1986	50827.7	54255.0	54846.0	74028.0	157371.0	226952.0	134550.3	101964.1	79527.2	61126.8	50969.0	43889.9	1090307
1987	49973.2	54473.0	58930.0	55810.0	61631.0	93701.0	81855.8	67735.7	50496.0	51936.9	48328.9	44640.2	719512
1988	39092.2	43944.0	60550.0	56351.0	63163.0	75294.0	60965.5	55094.8	54697.6	49967.6	41756.4	37763.7	638640
1989	30813.1	40682.0	49504.0	44210.0	42013.0	172465.0	178684.3	118218.5	66715.4	49360.7	39027.5	35334.3	867028
1990	37865.9	39775.0	40642.0	55032.0	41657.0	75393.0	61510.6	42807.6	46175.2	43893.8	39345.5	37405.7	561503
1991	34993.2	35322.0	33952.0	36183.0	35467.0	50099.0	47168.3	53666.7	42025.1	49533.7	42051.8	38157.7	498619
1992	31386.1	33692.0	34900.0	34672.0	33672.0	38034.0	40601.9	36603.8	32708.3	42927.5	38194.2	29388.4	426780
1993	29707.9	33067.0	33527.0	34795.0	35378.0	181038.0	165670.1	134853.0	89744.5	45218.9	42450.2	38559.2	864009
1994	36211.8	34477.0	37623.0	36877.0	32730.0	47598.0	45107.1	43217.5	33434.6	40619.0	34476.4	35192.6	457564
1995	29962.8	31559.0	34190.0	53499.0	74330.0	122543.0	121594.5	126809.5	77013.7	54301.1	41542.1	38772.8	806118
1996	35205.2	35552.5	58841.0	74463.0	192368.0	146521.0	122351.7	129137.2	67877.6	53647.1	40779.4	38048.2	994792
1997	36132.5	42118.0	79078.0	250060.0	126032.0	111453.0	115594.6	102332.2	52261.7	46450.3	42571.5	38804.1	1042888
1998	35979.9	40692.0	45119.0	83208.0	92332.0	135037.0	132311.2	181682.7	128075.3	70146.0	48075.2	43492.7	1036151
1999	38416.3	56423.0	81203.0	74163.0	61151.0	140630.0	188978.5	182239.5	118575.3	60991.4	53108.4	47809.4	1103689
2000	46378.4	52430.0	58608.0	69087.0	83644.0	111096.0	134941.7	110492.2	65090.0	55045.8	45797.0	39961.2	872571

Table H-7. Estimated Natural Groundwater flux into Upper Klamath Lake—
Total monthly inflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	19245.4	19291.0	19651.2	18974.8	18486.5	18286.2	20470.6	21409.7	21048.1	21397.4	21680.3	21883.6	241825
1950	22123.0	22153.9	21249.9	20598.1	19835.8	19663.5	20384.6	21852.4	21871.3	21717.2	19589.7	20347.7	251387
1951	20401.3	20470.6	21274.5	22000.0	22043.9	23020.7	26380.8	28689.8	28592.5	27496.9	26820.6	25594.4	292786
1952	25418.7	24414.8	24336.5	23537.2	22860.1	22602.6	24107.6	27951.9	25631.2	26119.6	25615.4	24980.0	297576
1953	24508.7	23333.5	23401.9	23082.2	22387.4	22405.8	22584.0	25012.9	24783.4	25062.0	24963.7	25385.5	286911
1954	23795.4	23714.4	23524.9	22848.5	22743.1	23733.9	26761.7	26709.9	26356.2	25308.0	25455.6	24820.3	295772
1955	23820.0	22915.8	21840.1	21434.3	21062.6	21151.5	21171.0	21016.2	20089.7	20143.1	19909.4	18123.7	252677
1956	18421.5	18590.6	18163.2	18446.1	18747.2	18175.5	22829.7	26857.5	27007.4	26033.5	25074.3	24316.5	262663
1957	24336.5	23886.5	22959.2	22688.7	22927.2	23242.0	24513.1	24988.3	24255.1	23893.8	23537.2	22670.0	283897
1958	20647.3	20593.5	20229.2	20106.2	20571.9	21188.4	21932.8	23401.9	24021.6	23168.2	22750.1	21711.6	260323
1959	21483.5	20716.3	20512.0	20303.0	20670.0	20598.1	20433.7	21643.4	20716.3	20020.1	18962.5	17964.0	244023
1960	18544.4	18123.7	17954.2	17486.9	17188.0	17228.6	17533.9	17413.1	16882.7	16601.5	16429.3	15887.4	207274
1961	15863.6	15875.2	15384.0	15310.2	15714.1	16269.4	17214.5	17708.2	17706.0	17941.9	17855.8	17447.9	200291
1962	17056.5	16845.8	16970.4	17130.2	16940.8	17142.5	18332.6	18495.2	18639.8	18519.8	18027.9	18148.3	212250
1963	17843.5	17239.0	17363.9	17204.0	17541.9	18052.5	18750.4	19343.8	20237.1	20770.3	20364.4	19757.9	224469
1964	19282.3	19057.6	18446.1	18200.1	17703.7	17437.7	18344.9	18446.1	17865.7	16662.9	16896.6	16514.1	214858
1965	15888.2	15985.7	16527.7	17818.9	19455.6	21249.9	24058.5	25541.6	25545.2	24902.2	23893.8	22866.6	253734
1966	21889.3	21207.8	21434.3	22024.6	21945.8	22270.5	23014.1	22565.7	21367.6	20758.0	20155.4	19536.8	258170
1967	18802.7	18222.0	17695.9	17007.3	16928.6	17191.7	17779.7	18015.7	17718.2	16687.5	16232.5	15813.7	208096
1968	15666.9	15420.5	15433.2	15076.6	15088.6	14683.1	14757.0	14756.8	14781.6	15052.0	14547.8	13933.8	179198
1969	13637.8	13516.0	13379.5	13330.4	13248.4	13207.4	13774.0	14129.7	14462.1	14510.9	14301.8	14216.4	165714
1970	14351.0	14499.0	14621.6	14683.1	14573.3	15101.2	15469.7	15925.1	16292.9	16503.1	16183.3	15592.5	183796
1971	15297.9	15309.9	15199.6	15236.4	15579.2	16392.4	19155.9	20794.9	20212.6	19528.2	18876.5	18148.3	209732
1972	18421.5	18787.2	18827.3	18679.7	18685.9	20721.1	22326.0	22528.8	22719.2	22873.1	22799.3	22854.3	250223
1973	22479.6	21822.2	21446.6	21102.3	21222.0	21692.6	21539.6	21397.4	21011.2	20536.6	19909.4	19266.4	253426
1974	18741.2	18344.9	17892.7	17560.6	16977.6	16687.5	18762.7	21581.9	21453.6	21323.6	20598.1	19782.5	229707
1975	19921.7	20298.6	19651.2	19417.6	20228.4	20930.1	21650.2	23635.6	23739.0	23315.8	22578.0	22117.1	257483
1976	21545.0	21306.1	20917.8	20991.6	21362.3	21717.2	22510.3	22639.5	22731.5	22725.5	22332.0	21760.8	262540
1977	21225.3	20605.8	20057.0	19811.1	19332.9	19343.8	18701.2	18569.0	18099.2	17572.9	17130.2	16342.1	226790
1978	16404.7	15678.6	15556.2	15015.1	15137.6	15433.2	15838.3	16011.2	16366.6	15962.0	15470.1	15051.9	187925
1979	14695.4	14413.0	14449.4	13969.8	13739.1	14191.2	14351.5	14486.3	14327.0	14424.8	14756.8	14339.2	172144
1980	13908.3	13724.9	13920.6	14043.6	13247.1	12309.7	12840.2	12567.9	11832.6	13133.6	13441.0	12447.0	157417
1981	12297.4	12434.7	12346.6	12371.2	12438.8	12617.1	12705.0	13182.8	13085.9	13109.0	13047.5	12717.3	152353
1982	12555.6	12434.7	12678.6	12986.0	13248.4	15187.3	16034.9	17646.7	18492.3	18261.6	18150.9	18062.3	185739
1983	18077.1	17976.3	17745.1	17794.3	17983.5	19638.9	21097.2	21655.7	21588.7	21606.5	21102.3	20618.0	236884
1984	20180.0	19991.4	19835.7	19417.6	19557.5	20696.5	22498.0	22848.5	22829.7	22774.7	22578.0	21969.6	255177
1985	21741.8	21588.7	20967.0	20327.6	19762.2	19417.6	19659.6	19552.8	19389.3	19233.1	19122.4	18775.0	239537
1986	18360.0	17878.0	17499.2	17277.8	17308.8	18261.6	19524.5	19540.5	19266.4	19036.3	18544.4	18185.2	220683
1987	17708.2	17374.2	16884.3	16503.1	16376.5	16589.2	16784.4	16872.0	16796.7	16662.9	16306.3	15875.2	200733
1988	15482.4	15027.3	14830.6	14449.4	14167.9	14080.5	14105.8	13957.5	13749.5	13465.6	13207.4	13024.5	169548
1989	12604.8	12705.0	12309.7	12322.0	12156.7	12408.0	13307.1	13293.5	13724.9	13920.6	13797.7	13442.3	155992
1990	13477.9	13749.5	13564.0	13441.0	13297.5	13047.5	12901.6	12973.7	13147.4	13158.2	13133.6	12926.2	158818
1991	12285.1	12017.0	11584.1	11055.3	11015.8	11030.7	10640.8	10366.7	10849.7	11153.7	10907.8	10628.5	133535
1992	10784.8	10911.1	11006.1	11129.1	11074.0	11215.2	11894.1	12199.0	11734.3	11510.3	10969.3	10468.8	134896
1993	10428.2	10603.9	10588.0	10502.0	10083.5	10452.8	12668.2	13637.8	13331.7	13145.9	13145.9	12999.9	141588
1994	12949.1	12926.2	13182.8	13244.3	13248.4	13330.4	13430.0	13133.6	12778.8	12617.1	12469.5	12004.7	155315
1995	11595.6	11270.5	10775.9	10516.0	10443.8	11015.8	11249.8	11315.7	11332.4	11315.7	11195.7	11064.0	133091
1996	11079.9	11353.4	11793.2	12088.3	13504.9	15740.6	18062.3	18938.0	18553.8	19183.9	20659.6	19536.8	190495
1997	18864.2	18996.1	19097.8	19823.4	20277.5	21139.2	22522.6	23303.5	23456.4	22823.9	21545.0	20605.8	252455
1998	19798.8	19168.1	18692.0	18569.0	18277.9	18077.1	18308.0	18200.1	18308.0	18200.1	17831.2	17570.8	221001
1999	17093.3	17079.3	16601.5	16355.5	16192.5	16847.4	18430.9	21028.5	20888.4	20782.6	20044.7	18922.4	220267
2000	18323.1	18185.2	17831.2	17585.2	17433.6	18077.1	19782.5	19429.8	18922.4	18815.0	18569.0	18430.9	221385

Table H-8. Estimated Natural Net Evapotranspiration, Upper Klamath Lake—
Total monthly losses in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	3533.9	29323.1	-7422.1	619.6	-2557.3	-4254.7	1074.6	11873.9	21330.9	26556.2	2738.4	14459.7	97276
1950	9217.0	9958.5	6940.5	-7873.1	-40.4	-12405.5	-1666.9	16341.8	17910.2	29655.6	-2166.7	11926.7	77798
1951	1160.9	13206.6	-6441.6	-5707.1	-2947.8	-4508.4	-2235.9	13234.1	25088.1	29006.9	2763.7	15228.2	77848
1952	3695.8	12296.1	-9181.4	-4182.8	-3925.8	-9736.5	-1408.0	15299.7	12579.9	31349.4	24928.9	4691.4	76407
1953	11562.0	6533.3	-7797.9	-10318.8	-1511.9	-10667.8	-8126.1	3069.0	14914.6	28082.2	17461.9	10262.1	53463
1954	8264.5	9073.1	-6007.0	-9109.9	26.9	-9673.9	-5815.5	18773.4	14460.6	27030.8	15778.0	9729.8	72531
1955	9861.6	2931.9	-4635.6	-2072.7	890.4	-584.0	-8642.8	15686.4	21192.8	18348.8	2855.5	9189.0	65021
1956	6185.5	7163.6	-9861.7	-7580.2	-5030.7	-13314.2	-9142.5	12515.8	16624.3	23874.0	21269.8	6897.0	49601
1957	4226.9	822.8	-6442.0	-5639.0	-4115.4	-22658.8	-1843.2	11080.4	23825.1	24407.6	11745.4	6716.6	42126
1958	7511.1	-3349.7	-5994.6	-9491.9	-9558.7	-11095.5	-12917.5	15949.3	8898.2	21315.0	23846.1	7192.7	32305
1959	8186.6	373.8	-2254.5	-4116.1	-625.1	-1226.6	3870.6	10893.2	20402.1	17442.8	3367.3	10606.4	66921
1960	5594.0	10642.8	4383.8	-3810.9	-6014.0	-13473.0	-570.7	6594.0	25278.8	24602.3	4298.7	12494.4	70020
1961	7078.9	7822.0	10894.9	-1153.9	-4470.1	-10834.4	-3216.4	8746.4	22066.3	15703.4	1369.0	9923.6	63930
1962	4122.4	6649.4	-2537.0	-2289.9	-2302.2	-9110.5	-1787.1	10328.1	21575.0	21502.5	1536.3	11832.9	59520
1963	776.9	21038.9	-3465.9	-1900.0	-3817.5	-2446.9	-14389.8	15289.1	15823.5	20899.7	10710.9	6558.3	65077
1964	7369.2	5832.8	9919.7	-6148.1	1791.7	-3567.0	-2061.8	12429.6	13313.1	25301.6	-4502.7	10685.1	70363
1965	5447.8	4103.7	9148.5	-5997.7	508.2	-3450.3	-9590.6	14043.2	17939.4	23622.5	8975.1	9767.2	74517
1966	6423.5	4841.6	-2873.4	-4196.1	978.9	-4789.9	925.5	18576.0	17420.1	11150.3	3298.0	9133.8	60888
1967	6614.6	5644.5	7950.5	-7788.5	37.5	-13105.1	-18517.1	12445.4	16221.5	28565.6	25472.7	4948.9	68491
1968	11388.2	11870.8	6197.0	6577.0	-3567.2	181.1	2201.7	9136.8	12480.9	1031.9	5406.1	10910.3	73815
1969	3553.3	7676.0	8510.9	-7262.1	-1160.5	-5322.4	-7119.4	17005.9	15462.1	26414.6	9302.4	5738.6	72799
1970	6307.7	10462.4	3082.0	-6819.0	1486.6	-9302.2	-8218.9	15554.3	21735.0	2578.9	6761.5	6306.7	49935
1971	3854.2	7256.3	-2080.0	-6225.5	-703.8	-23099.0	-10548.9	4755.2	16138.5	26792.2	25194.6	1827.3	43161
1972	10302.4	4879.9	-2456.4	-9589.3	-2079.8	-25487.9	-13869.0	16107.8	22917.8	28184.2	14058.3	8523.8	51492
1973	8968.6	8281.4	-5711.0	-3939.5	-154.2	-3072.5	711.0	18835.7	23995.9	1053.6	11059.5	7843.0	67872
1974	5947.2	9968.4	-5285.4	-5728.2	-1954.6	-20830.3	-13999.9	15927.2	25691.8	24145.2	22855.4	5501.2	62238
1975	10395.0	8759.6	7075.4	-2911.2	-6878.2	-15239.8	-7716.1	15579.0	16724.7	24263.7	18811.5	4403.7	73267
1976	4662.9	2732.1	-4541.3	-2959.9	-4029.8	-4519.7	-4199.6	16373.8	17789.2	26482.1	-510.0	18133.7	65413
1977	5008.7	9493.3	2758.5	-511.6	133.1	4230.8	7842.7	3442.4	16698.2	2561.1	8489.4	4310.8	64457
1978	9386.9	1859.8	8671.2	-3381.9	-2137.8	-19041.5	-13570.1	12571.4	20000.4	25494.7	2417.2	10003.9	52274
1979	9323.8	4969.1	6867.1	3433.4	-1014.2	-190.7	-4111.0	11712.7	18397.5	-990.6	6035.2	9339.0	63771
1980	847.1	9364.2	7025.2	-7398.2	-3423.5	-6397.1	-6620.7	13078.9	15879.2	22962.1	4550.8	10699.7	60568
1981	7100.2	6772.6	6179.0	7184.0	-1638.9	-5813.5	-918.4	9896.3	17256.6	577.2	9574.6	6699.7	62869
1982	5689.7	10011.6	12099.5	-3436.4	-5562.8	-17193.2	-17489.3	16377.0	16528.0	22872.1	14991.1	1899.9	56787
1983	4292.5	4455.1	-4706.9	-3776.5	-7319.5	-16583.3	-8482.7	16072.4	19659.0	20434.5	18513.6	7770.1	50328
1984	3621.4	-1758.9	-10591.2	1002.3	-2854.0	-9258.6	-10318.0	14479.1	17947.8	29679.7	18965.4	7268.8	58184
1985	4619.7	-4538.7	-2200.6	472.0	-2045.0	-4078.6	2323.9	15487.0	22889.9	28530.8	4165.8	10071.7	75698
1986	7904.3	-908.2	-1786.8	-5621.7	-9380.7	-10655.7	-3636.3	14482.6	25191.3	23751.4	4565.7	7992.7	51899
1987	7421.7	5213.8	300.8	-5078.6	162.8	-5852.2	6342.9	18309.7	21734.6	1933.1	13611.7	5793.5	69894
1988	10250.5	5943.6	8425.2	-5091.1	1849.5	-564.4	-2910.0	11175.0	13775.3	7252.0	7518.5	7445.5	65070
1989	8699.1	4246.5	13200.8	-4314.9	230.0	-14481.4	-5325.8	12423.5	24699.2	27003.2	3021.0	9713.0	79114
1990	6095.0	7067.8	5832.5	252.9	-1541.0	-4660.8	-23.5	4811.8	17789.9	3138.8	9042.5	8084.0	55890
1991	6556.6	6110.5	5473.7	2106.4	2128.4	-10071.9	-2330.5	6395.4	11576.7	1168.0	9285.9	6668.4	45068
1992	7230.7	5606.9	7706.8	2850.4	1315.1	-782.9	-2269.8	6346.6	2267.4	6557.8	9245.3	7337.1	53411
1993	5305.3	7082.5	7494.3	2902.0	-2100.0	-17186.6	-11994.9	10218.1	15015.5	20491.9	8743.7	4357.6	50329
1994	4927.3	6070.4	3432.6	4160.5	-2598.9	2479.4	508.7	9759.0	3106.6	4635.5	7871.7	6675.2	51028
1995	8241.1	4111.9	10161.2	-982.5	1626.5	-19979.1	-12353.0	15068.7	14397.3	25478.0	-3629.5	9006.7	51147
1996	5110.6	6141.2	4896.2	15296.7	-4765.7	-10255.2	-12508.6	7636.7	18907.1	32752.7	-137.8	14023.9	77098
1997	6312.2	6235.9	-3335.6	-8926.9	836.6	-8867.8	-12551.1	19778.9	18179.7	24756.4	3052.5	11386.2	56857
1998	5211.8	5555.4	-1684.7	-8905.4	-2566.8	-13652.3	-4563.1	-2244.4	20279.4	31770.6	25726.3	5119.5	60046
1999	12339.8	5304.4	19103.2	-7759.2	-3187.1	-5436.9	-5858.5	14221.2	23195.1	24909.1	16655.1	8090.0	101576
2000	5866.1	6703.5	386.4	-10422.2	-5263.1	-8079.2	-9622.8	16345.1	26146.8	23474.8	6464.3	11055.2	63055

Table H-9. Estimated Natural Net open water surface evaporation, Upper Klamath Lake—Total monthly losses in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	9190.5	-5285.0	-14983.5	-1846.8	-3636.3	7056.8	19308.0	24558.6	37949.3	41685.0	33617.7	22787.6	170402
1950	11191.9	500.6	-1897.2	-22255.0	1864.0	-796.0	14796.0	30796.9	30286.6	44666.3	36041.8	22612.0	167808
1951	-9729.8	178.9	-17764.6	-10290.3	-4680.1	6923.3	15015.0	25914.0	39814.7	43564.4	36503.3	25378.3	150827
1952	-1830.8	-6184.3	-25566.5	-7433.5	-6914.6	3971.0	20378.2	27940.7	24512.2	46361.6	38292.6	24205.9	137732
1953	14493.1	-37.7	-19105.8	-18629.1	-2291.4	6367.7	15510.7	12545.8	29356.4	43537.0	27969.7	25223.4	134940
1954	6638.8	-18941.8	-6886.8	-17496.7	3321.0	3441.3	15638.7	32351.6	29282.9	43124.7	28678.4	19979.9	139132
1955	11186.2	381.8	-7282.7	-2906.6	2411.9	6403.3	10175.6	29754.5	37287.8	37592.2	36200.0	19081.7	180286
1956	7934.3	-18015.9	-30157.1	-23282.2	-8177.4	7561.8	17428.8	22753.7	28759.3	36738.5	32628.9	18026.2	92199
1957	-3034.5	3322.9	-6253.5	-11807.0	-6138.9	-10735.3	15077.9	23982.8	38934.7	39387.6	32671.6	9884.1	125292
1958	4073.7	-7586.0	-17136.0	-16830.8	-15868.1	5158.7	14671.0	27614.1	21602.2	36983.4	34945.1	20488.0	108115
1959	10400.6	-1104.0	-2342.7	-5853.2	113.4	7644.1	18923.7	25076.3	36186.8	43140.4	27140.8	19641.6	178968
1960	9117.5	4994.2	-463.3	-5004.0	-9811.3	-2300.5	16337.2	19698.8	39757.3	41480.6	32655.7	23696.6	170159
1961	9970.8	-15503.6	-7282.4	-59.7	-6928.3	1765.8	17624.2	20222.6	36562.5	42508.2	34897.0	16239.9	150017
1962	1915.0	-12536.2	-12558.5	-4749.6	-1463.7	3016.6	18055.8	22284.7	36999.4	39959.9	29025.3	21577.5	141526
1963	-13110.5	-1671.1	-7323.9	-1846.7	-2833.5	7426.4	4015.1	29010.6	31954.3	37002.3	31621.5	22046.9	136291
1964	8446.0	-8427.0	-2752.6	-17465.8	3363.6	4200.5	16484.4	25705.3	26949.1	40228.1	32437.0	20438.8	149607
1965	11633.0	-11970.9	-58945.2	-12212.1	4427.1	11827.7	11034.5	26986.2	32943.6	38494.3	24741.9	22049.8	101010
1966	13212.6	-9099.4	-5054.1	-6710.9	3422.5	5159.2	17245.6	31612.1	33341.7	37396.7	30603.7	23240.8	174371
1967	11481.0	-10240.8	-13481.1	-15150.0	3327.2	638.7	3454.7	26317.6	24544.9	42565.2	37767.7	25383.9	136609
1968	7172.3	2986.2	-5900.4	-3093.9	-5326.7	8186.7	17621.5	21364.2	36253.6	43027.8	23406.7	23939.3	169637
1969	8410.0	-10959.3	-7189.9	-22766.9	-3082.5	7543.3	15936.2	31632.7	27351.9	41305.5	33518.7	23337.1	145037
1970	1742.3	3392.8	-22069.1	-29524.9	3783.8	2841.3	14071.8	28924.4	34738.3	42727.5	35373.7	21923.3	137925
1971	1216.6	-15825.1	-7563.5	-8909.5	363.4	-6928.1	14626.3	16449.6	29851.0	41474.5	36117.4	16187.1	117060
1972	9759.2	-9513.6	-8376.1	-18975.0	-2508.3	-7411.0	11914.7	28731.2	37471.5	42758.3	36663.1	19494.5	140009
1973	5643.8	-97.0	-8912.7	-5668.6	1517.1	4770.2	17443.5	31721.0	38569.8	42236.0	34344.2	20119.9	181687
1974	1151.1	-21435.3	-11672.6	-9594.1	-1962.8	-4460.4	9456.0	28917.9	38987.4	38603.5	35196.0	25227.2	128414
1975	11246.7	2076.9	-7907.2	-4408.6	-12809.8	-5313.3	12122.2	29781.3	31725.5	37514.6	31286.7	25001.4	150316
1976	545.1	-1657.5	-6158.6	-3429.3	-5974.8	5092.8	16215.8	30353.6	32698.0	40930.7	13794.8	22784.0	145195
1977	13016.6	5268.6	2184.7	-423.1	2649.5	7051.8	19201.5	14420.2	34851.2	41112.2	36662.9	10471.6	186467
1978	11207.6	-15709.4	-17041.7	-3652.6	-1568.2	2213.2	9751.3	25285.1	33914.7	40398.7	30976.5	16285.8	132061
1979	14592.7	1476.3	-1650.1	-11942.2	-2381.0	8230.1	11463.1	24703.5	37268.6	40880.6	27472.7	24587.3	174702
1980	-2032.5	-24012.4	-1273.3	-12161.0	-4860.1	6477.0	15455.5	26616.3	30461.0	42139.3	33610.9	21172.9	131594
1981	10699.3	-1138.9	-7755.0	-920.9	-4631.2	4969.9	14136.3	25487.0	36306.3	40444.0	36977.6	22564.9	177139
1982	5374.7	-22883.6	-31706.1	-4130.0	-9502.9	-45.3	12168.7	28576.3	29677.2	37606.2	31842.0	19243.5	96221
1983	5358.7	-6528.7	-16273.0	-3134.2	-9398.1	-4422.6	9979.7	30277.1	33628.2	35770.2	31733.3	21699.7	128690
1984	9017.3	-19279.8	-32342.1	1199.1	-3691.2	4538.9	14013.4	28523.1	31880.3	41619.0	27866.1	21594.7	124939
1985	1219.2	-19774.3	-6019.7	683.9	-2848.0	3896.5	19591.4	28183.1	35678.7	41069.5	33939.4	10143.9	145763
1986	7802.3	-6908.8	-2184.9	-7550.1	-15386.8	4237.7	18107.1	27877.7	37399.1	39109.2	38434.3	11529.7	152467
1987	10653.7	-327.3	-558.9	-6682.4	3257.7	1505.5	20218.5	30520.8	38095.1	29843.2	36632.2	25664.2	188822
1988	14665.1	200.7	-21527.4	-12512.3	5554.0	8415.6	15517.3	23733.7	32830.9	43911.7	36424.4	24207.3	171421
1989	15030.4	-23263.5	-4875.1	-8169.4	1245.2	-6245.6	14778.4	25757.5	38760.8	38925.3	32275.3	15723.0	139942
1990	6886.8	188.8	649.1	-14465.5	-7.9	4165.6	17084.3	17576.9	36340.0	38080.7	27039.0	21905.2	155443
1991	11042.0	683.5	-3076.6	-4220.7	3107.9	-1898.6	12188.7	23360.4	34209.6	43393.8	35866.6	26513.0	181170
1992	11638.5	-4974.9	-3417.4	-1151.4	3472.7	10582.8	16243.5	35107.0	35212.2	41761.3	37605.6	22456.6	204537
1993	5137.4	-6676.0	-20626.6	-16870.0	-5875.0	-1181.9	10255.5	20461.7	28238.8	37361.1	31079.8	23683.6	104988
1994	10288.5	1551.4	-5139.0	-82.0	985.7	10553.9	17895.2	25366.5	35947.1	45309.0	36174.7	24251.9	203103
1995	11588.3	-20628.0	-3044.6	-19069.7	3407.8	-6246.9	8867.4	28535.9	27444.2	41474.9	34460.1	25440.9	132230
1996	12882.4	1689.3	-27143.9	-26744.5	-13558.4	5249.7	13447.3	20479.0	30782.5	44517.1	35591.9	19626.8	116819
1997	7004.8	-4612.5	-24834.5	-16129.6	145.8	8085.1	12033.4	30123.4	32558.0	39103.6	33086.6	19149.2	135713
1998	5557.5	-11172.8	-1611.0	-22518.7	-7484.9	-397.2	14712.1	10349.7	34106.7	45012.4	38084.9	22885.0	127524
1999	12372.4	-33853.4	-5344.6	-14571.0	-6031.2	4853.8	14697.5	26918.9	36207.8	40756.9	25483.5	24462.7	125953
2000	10939.7	-967.4	-1196.4	-26003.8	-7286.8	5028.4	10803.7	28563.4	39814.0	39768.1	36061.6	18293.3	153818

Table H-10. Link River Estimated Natural flow—Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	75273.1	78106.9	83885.8	90511.3	91498.3	102602.3	120034.0	130109.0	109140.5	68060.0	47130.9	50827.5	1047180
1950	63516.4	79828.9	88629.5	102506.7	108510.3	120957.3	142143.9	140167.3	121327.5	83664.9	48712.3	43802.2	1143767
1951	67469.8	95185.0	127365.5	149874.8	152903.2	160614.7	181852.6	196663.3	151129.8	95664.2	64359.2	58487.9	1501570
1952	80197.4	105865.1	126014.9	135963.9	133010.9	139308.4	212881.3	282911.4	246915.6	194555.1	103565.4	78220.6	1839410
1953	78916.2	91393.9	110098.7	147504.5	182948.6	186160.6	185477.5	208119.5	219542.4	202278.1	113298.5	87789.9	1813528
1954	91484.8	119509.4	151451.3	160772.0	154196.7	173129.1	230726.3	242032.4	188854.0	135906.6	91948.2	84023.4	1824034
1955	90649.3	103463.3	115714.2	118731.6	111938.1	111564.9	127836.3	131825.7	107595.3	75491.5	49836.0	47182.9	1191829
1956	63194.1	92687.0	150079.2	221040.0	218374.9	193856.8	247594.3	297535.6	268057.0	239897.0	127181.1	97643.0	2217140
1957	113026.0	128444.3	140657.4	146369.7	144155.9	191797.0	224702.0	201994.2	158094.1	104921.2	70985.0	71994.9	1697142
1958	97087.2	119780.4	139984.0	154572.9	202738.0	247878.5	248679.5	244450.8	216727.9	186246.4	112487.7	88469.4	2059103
1959	92550.2	107216.1	120522.2	130813.2	133827.7	131054.0	126460.6	114232.9	91711.9	56932.7	43424.8	52023.4	1200770
1960	67318.6	83915.2	91617.0	98251.4	109935.0	131182.4	138206.4	126142.7	99030.1	59272.7	38087.3	40158.9	1083118
1961	52698.7	77984.2	96545.4	101961.6	110584.1	125819.4	123400.5	111531.8	92457.2	57611.4	37177.3	43331.8	1031103
1962	61388.1	86088.5	104434.9	110260.5	109370.1	114216.2	133846.4	138023.3	103152.3	61849.2	42108.9	43643.5	1108382
1963	76932.9	108017.6	123782.8	128224.6	132685.3	139389.2	150138.4	165239.6	132960.9	89635.4	61372.3	52812.7	1361192
1964	60870.8	87097.3	102270.4	109326.0	105767.7	99886.5	120211.2	131535.2	114329.3	81706.7	49738.4	43849.6	1106589
1965	51622.7	74421.8	164174.4	265635.9	251505.8	213092.1	184243.5	173838.0	142126.8	100702.9	76027.3	71104.6	1768496
1966	72547.0	92581.9	109630.6	113989.6	109745.4	117260.5	147415.2	140290.1	99400.3	65077.4	46147.2	47661.8	1161747
1967	58248.8	79183.0	103407.7	119983.4	116971.9	125500.2	148010.1	172417.0	167946.1	113514.4	53672.3	34537.4	1293392
1968	47284.8	72319.8	80256.4	86552.1	101289.9	116058.9	104852.3	84869.2	64703.3	26463.6	24406.6	34104.1	843161
1969	41549.6	68940.7	83112.0	98346.8	104914.3	103864.7	151103.5	188437.5	143690.4	85645.6	44217.6	33733.9	1147557
1970	49144.9	72803.8	89373.0	146389.5	181055.3	166223.0	147931.6	120929.0	93431.5	56221.6	34452.7	36661.6	1194617
1971	53837.8	83542.8	104436.4	127425.6	139927.9	155738.5	195824.7	226296.5	205863.4	151992.0	83093.8	63777.4	1591757
1972	72326.2	93801.7	112147.3	130586.6	142392.4	207023.8	249957.9	203886.3	152312.7	103256.5	67360.7	62425.1	1597477
1973	79079.9	98309.5	113354.5	126331.0	125216.2	123754.1	121633.3	105822.0	80806.4	46148.0	37332.6	44947.8	1102735
1974	59871.9	98027.2	142608.6	178358.8	174745.1	175665.6	217820.7	221189.9	173993.0	124954.0	78649.2	60595.6	1706479
1975	65141.0	85252.6	103011.1	113461.8	119063.6	145126.5	169144.0	185778.1	181435.4	144725.0	91646.3	70915.0	1474700
1976	82696.6	106075.2	122012.2	132016.2	130133.6	133336.3	140446.1	135655.3	111825.1	77194.9	68122.1	73400.7	1312914
1977	74137.9	86559.3	94063.3	95612.8	93537.9	94612.7	90929.7	86255.2	76597.9	46782.7	35515.7	44242.7	918848
1978	56816.9	78653.8	112237.1	145704.5	145205.8	148963.4	167148.2	155358.9	112464.2	68819.7	43475.2	44369.1	1279217
1979	53171.1	67324.4	74789.3	86814.2	92515.2	96516.1	101035.5	99309.1	80766.0	41489.5	32681.4	37534.8	863946
1980	47906.0	77195.2	91011.7	112707.2	131471.4	125452.1	118283.2	110276.9	88023.5	50531.1	32326.1	33869.8	1019054
1981	43017.9	64758.3	76529.0	86637.5	93771.3	99287.0	97144.9	86567.7	67513.1	32839.1	23779.0	27006.5	798851
1982	39816.4	74680.5	124342.7	148737.4	169300.8	215381.3	220802.5	209252.9	170002.0	122376.0	77921.1	61323.5	1633937
1983	69517.9	90290.3	110860.1	125230.0	141135.2	191562.0	231318.3	227935.4	204791.2	179715.7	111355.4	85941.3	1769653
1984	83585.8	105943.1	150194.9	163478.7	147263.6	175013.7	215109.1	219070.9	193015.7	153048.2	98456.6	82732.9	1786913
1985	93619.6	124649.9	141849.7	129548.8	117800.7	122567.7	157098.6	162912.4	120850.6	82957.2	57688.5	64368.3	1375912
1986	84056.6	97974.6	105143.7	114593.8	157132.1	221370.3	223288.9	171731.0	126287.4	91185.3	61666.4	61429.5	1515860
1987	77191.6	90604.0	99936.4	105497.0	106935.2	116467.3	120158.5	102069.9	78368.0	56776.2	48696.8	44905.0	1047606
1988	50904.0	68949.7	86346.4	103968.2	103982.3	101696.5	99442.6	87818.1	74405.4	46662.9	31995.7	33329.2	889501
1989	37035.1	65647.0	81379.7	86641.8	85686.5	124552.7	188751.6	177179.0	122843.8	72803.7	44378.3	42417.2	1129316
1990	55246.3	73686.9	78812.7	90481.5	95499.6	96978.4	99379.1	87043.3	69530.4	38811.5	33302.3	38399.0	857171
1991	42768.8	61886.5	66994.9	71907.2	74029.4	80146.7	84048.5	77055.7	64045.3	32257.2	24203.1	25243.5	704587
1992	30540.7	57696.8	66089.6	69024.5	69273.4	68081.8	67916.0	59276.5	48520.6	22250.1	18818.2	17328.9	594817
1993	26941.0	58678.8	69824.6	80225.1	82819.8	124203.7	187197.1	184455.2	149640.0	98902.6	56765.0	42829.8	1162483
1994	47166.5	66958.0	74437.6	79358.3	78340.8	77143.0	75871.9	70066.5	56735.9	24947.7	19819.1	22324.6	693170
1995	31042.3	61270.5	70561.3	81568.6	98139.2	126602.4	154432.1	146336.1	119449.8	79152.1	43871.6	32505.8	1044932
1996	38434.0	61721.3	86304.5	124040.8	173904.7	206601.6	193766.5	180657.6	143811.5	90874.6	56499.6	52995.5	1409612
1997	65651.8	87798.1	123031.2	207701.3	238541.2	197838.1	183258.3	165789.6	126225.7	88175.9	64166.9	60554.6	1608733
1998	71440.3	90874.1	99892.9	121810.0	147249.8	165700.8	179055.5	192517.5	185456.9	135151.6	75494.5	56814.9	1521459
1999	61182.7	92371.3	122826.5	135018.9	132322.0	143884.9	183518.9	205638.6	184686.8	140609.1	91876.5	74612.3	1568549
2000	72995.4	89291.2	101857.2	120756.1	138710.3	148401.1	167321.4	162709.9	119119.9	78643.0	55277.8	52784.8	1307868

Table H-11. Estimated Klamath River at Keno naturalized flow in acre-feet—
Total monthly streamflow in acre-feet

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	75273.1	78106.9	83885.8	90511.3	91498.3	102602.3	120034.0	130109.0	109140.5	68060.0	47130.9	50827.5	1047180
1950	63516.4	79828.9	88629.5	102506.7	108510.3	120957.3	142143.9	140167.3	121327.5	83664.9	48712.3	43802.2	1143767
1951	67469.8	95185.0	127365.5	149874.8	152903.2	160614.7	181852.6	196663.3	151129.8	95664.2	64359.2	58487.9	1501570
1952	80197.4	105865.1	126014.9	135963.9	133010.9	139308.4	212881.3	282911.4	246915.6	194555.1	103565.4	78220.6	1839410
1953	78916.2	91393.9	110098.7	147504.5	182948.6	186160.6	185477.5	208119.5	219542.4	202278.1	113298.5	87789.9	1813528
1954	91484.8	119509.4	151451.3	160772.0	154196.7	173129.1	230726.3	242032.4	188854.0	135906.6	91948.2	84023.4	1824034
1955	90649.3	103463.3	115714.2	118731.6	111938.1	111564.9	127836.3	131825.7	107595.3	75491.5	49836.0	47182.9	1191829
1956	63194.1	92687.0	150079.2	221040.0	218374.9	193856.8	247594.3	297535.6	268057.0	239897.0	127181.1	97643.0	2217140
1957	113026.0	128444.3	140657.4	146369.7	144155.9	191797.0	224702.0	201994.2	158094.1	104921.2	70985.0	71994.9	1697142
1958	97087.2	119780.4	139984.0	154572.9	202738.0	247878.5	248679.5	244450.8	216727.9	186246.4	112487.7	88469.4	2059103
1959	92550.2	107216.1	120522.2	130813.2	133827.7	131054.0	126460.6	114232.9	91711.9	56932.7	43424.8	52023.4	1200770
1960	67318.6	83915.2	91617.0	98251.4	109935.0	131182.4	138206.4	126142.7	99030.1	59272.7	38087.3	40158.9	1083118
1961	52698.7	77984.2	96545.4	101961.6	110584.1	125819.4	123400.5	111531.8	92457.2	57611.4	37177.3	43331.8	1031103
1962	61388.1	86088.5	104434.9	110260.5	109370.1	114216.2	133846.4	138023.3	103152.3	61849.2	42108.9	43643.5	1108382
1963	76932.9	108017.6	123782.8	128224.6	132685.3	139389.2	150138.4	165239.6	132960.9	89635.4	61372.3	52812.7	1361192
1964	60870.8	87097.3	102270.4	109326.0	105767.7	99886.5	120211.2	131535.2	114329.3	81706.7	49738.4	43849.6	1106589
1965	51622.7	74421.8	164174.4	265635.9	251505.8	213092.1	184243.5	173838.0	142126.8	100702.9	76027.3	71104.6	1768496
1966	72547.0	92581.9	109630.6	113989.6	109745.4	117260.5	147415.2	140290.1	99400.3	65077.4	46147.2	47661.8	1161747
1967	58248.8	79183.0	103407.7	119983.4	116971.9	125500.2	148010.1	172417.0	167946.1	113514.4	53672.3	34537.4	1293392
1968	47284.8	72319.8	80256.4	86552.1	101289.9	116058.9	104852.3	84869.2	64703.3	26463.6	24406.6	34104.1	843161
1969	41549.6	68940.7	83112.0	98346.8	104914.3	103864.7	151103.5	188437.5	143690.4	85645.6	44217.6	33733.9	1147557
1970	49144.9	72803.8	89373.0	146389.5	181055.3	166223.0	147931.6	120929.0	93431.5	56221.6	34452.7	36661.6	1194617
1971	53837.8	83542.8	104436.4	127425.6	139927.9	155738.5	195824.7	226296.5	205863.4	151992.0	83093.8	63777.4	1591757
1972	72326.2	93801.7	112147.3	130586.6	142392.4	207023.8	249957.9	203886.3	152312.7	103256.5	67360.7	62425.1	1597477
1973	79079.9	98309.5	113354.5	126331.0	125216.2	123754.1	121633.3	105822.0	80806.4	46148.0	37332.6	44947.8	1102735
1974	59871.9	98027.2	142608.6	178358.8	174745.1	175665.6	217820.7	221189.9	173993.0	124954.0	78649.2	60595.6	1706479
1975	65141.0	85252.6	103011.1	113461.8	119063.6	145126.5	169144.0	185778.1	181435.4	144725.0	91646.3	70915.0	1474700
1976	82696.6	106075.2	122012.2	132016.2	130133.6	133336.3	140446.1	135655.3	111825.1	77194.9	68122.1	73400.7	1312914
1977	74137.9	86559.3	94063.3	95612.8	93537.9	94612.7	90929.7	86255.2	76597.9	46782.7	35515.7	44242.7	918848
1978	56816.9	78653.8	112237.1	145704.5	145205.8	148963.4	167148.2	155358.9	112464.2	68819.7	43475.2	44369.1	1279217
1979	53171.1	67324.4	74789.3	86814.2	92515.2	96516.1	101035.5	99309.1	80766.0	41489.5	32681.4	37534.8	863946
1980	47906.0	77195.2	91011.7	112707.2	131471.4	125452.1	118283.2	110276.9	88023.5	50531.1	32326.1	33869.8	1019054
1981	43017.9	64758.3	76529.0	86637.5	93771.3	99287.0	97144.9	86567.7	67513.1	32839.1	23779.0	27006.5	798851
1982	39816.4	74680.5	124342.7	148737.4	169300.8	215381.3	220802.5	209252.9	170002.0	122376.0	77921.1	61323.5	1633937
1983	69517.9	90290.3	110860.1	125230.0	141135.2	191562.0	231318.3	227935.4	204791.2	179715.7	111355.4	85941.3	1769653
1984	83585.8	105943.1	150194.9	163478.7	147263.6	175013.7	215109.1	219070.9	193015.7	153048.2	98456.6	82732.9	1786913
1985	93619.6	124649.9	141849.7	129548.8	117800.7	122567.7	157098.6	162912.4	120850.6	82957.2	57688.5	64368.3	1375912
1986	84056.6	97974.6	105143.7	114593.8	157132.1	221370.3	223288.9	171731.0	126287.4	91185.3	61666.4	61429.5	1515860
1987	77191.6	90604.0	99936.4	105497.0	106935.2	116467.3	120158.5	102069.9	78368.0	56776.2	48696.8	44905.0	1047606
1988	50904.0	68949.7	86346.4	103968.2	103982.3	101696.5	99442.6	87818.1	74405.4	46662.9	31995.7	33329.2	889501
1989	37035.1	65647.0	81379.7	86641.8	85686.5	124552.7	188751.6	177179.0	122843.8	72803.7	44378.3	42417.2	1129316
1990	55246.3	73686.9	78812.7	90481.5	95499.6	96978.4	99379.1	87043.3	69530.4	38811.5	33302.3	38399.0	857171
1991	42768.8	61886.5	66994.9	71907.2	74029.4	80146.7	84048.5	77055.7	64045.3	32257.2	24203.1	25243.5	704587
1992	30540.7	57696.8	66089.6	69024.5	69273.4	68081.8	67916.0	59276.5	48520.6	22250.1	18818.2	17328.9	594817
1993	26941.0	58678.8	69824.6	80225.1	82819.8	124203.7	187197.1	184455.2	149640.0	98902.6	56765.0	42829.8	1162483
1994	47166.5	66958.0	74437.6	79358.3	78340.8	77143.0	75871.9	70066.5	56735.9	24947.7	19819.1	22324.6	693170
1995	31042.3	61270.5	70561.3	81568.6	98139.2	126602.4	154432.1	146336.1	119449.8	79152.1	43871.6	32505.8	1044932
1996	38434.0	61721.3	86304.5	124040.8	173904.7	206601.6	193766.5	180657.6	143811.5	90874.6	56499.6	52995.5	1409612
1997	65651.8	87798.1	123031.2	207701.3	238541.2	197838.1	183258.3	165789.6	126225.7	88175.9	64166.9	60554.6	1608733
1998	71440.3	90874.1	99892.9	121810.0	147249.8	165700.8	179055.5	192517.5	185456.9	135151.6	75494.5	56814.9	1521459
1999	61182.7	92371.3	122826.5	135018.9	132322.0	143884.9	183518.9	205638.6	184686.8	140609.1	91876.5	74612.3	1568549
2000	72995.4	89291.2	101857.2	120756.1	138710.3	148401.1	167321.4	162709.9	119119.9	78643.0	55277.8	52784.8	1307868

Table H-12. Estimated Klamath River at Keno naturalized average monthly streamflow in cfs

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1949	1224.2	1312.6	1364.3	1472.0	1647.5	1668.6	2017.2	2116.0	1834.1	1106.9	766.5	854.2	1449
1950	1033.0	1341.5	1441.4	1667.1	1953.8	1967.2	2388.8	2279.6	2038.9	1360.7	792.2	736.1	1583
1951	1097.3	1599.6	2071.4	2437.4	2753.1	2612.1	3056.1	3198.4	2539.8	1555.8	1046.7	982.9	2079
1952	1304.3	1779.1	2049.4	2211.2	2395.0	2265.6	3577.5	4601.0	4149.5	3164.1	1684.3	1314.5	2541
1953	1283.4	1535.9	1790.6	2398.9	3294.1	3027.6	3117.0	3384.7	3689.5	3289.7	1842.6	1475.3	2511
1954	1487.8	2008.4	2463.1	2614.7	2776.4	2815.6	3877.4	3936.2	3173.8	2210.3	1495.4	1412.0	2523
1955	1474.2	1738.7	1881.9	1931.0	2015.5	1814.4	2148.3	2143.9	1808.2	1227.7	810.5	792.9	1649
1956	1027.7	1557.6	2440.8	3594.8	3932.0	3152.7	4160.9	4838.9	4504.8	3901.5	2068.4	1640.9	3068
1957	1838.2	2158.5	2287.5	2380.4	2595.6	3119.2	3776.2	3285.1	2656.8	1706.4	1154.4	1209.9	2347
1958	1578.9	2012.9	2276.6	2513.9	3650.4	4031.3	4179.1	3975.6	3642.2	3029.0	1829.4	1486.8	2851
1959	1505.2	1801.8	1960.1	2127.4	2409.7	2131.4	2125.2	1857.8	1541.2	925.9	706.2	874.3	1664
1960	1094.8	1410.2	1490.0	1597.9	1979.5	2133.4	2322.6	2051.5	1664.2	964.0	619.4	674.9	1500
1961	857.1	1310.5	1570.1	1658.2	1991.1	2046.2	2073.8	1813.9	1553.8	936.9	604.6	728.2	1429
1962	998.4	1446.7	1698.4	1793.2	1969.3	1857.5	2249.3	2244.7	1733.5	1005.9	684.8	733.4	1535
1963	1251.2	1815.3	2013.1	2085.3	2389.1	2266.9	2523.1	2687.3	2234.4	1457.8	998.1	887.5	1884
1964	990.0	1463.7	1663.2	1778.0	1904.4	1624.5	2020.2	2139.2	1921.3	1328.8	808.9	736.9	1532
1965	839.5	1250.7	2670.0	4320.1	4528.5	3465.6	3096.3	2827.2	2388.5	1637.8	1236.4	1194.9	2455
1966	1179.8	1555.9	1782.9	1853.8	1976.0	1907.0	2477.4	2281.6	1670.5	1058.4	750.5	801.0	1608
1967	947.3	1330.7	1681.7	1951.3	2106.2	2041.0	2487.4	2804.1	2822.4	1846.1	872.9	580.4	1789
1968	769.0	1215.4	1305.2	1407.6	1823.8	1887.5	1762.1	1380.2	1087.4	430.4	396.9	573.1	1170
1969	675.7	1158.6	1351.7	1599.4	1889.1	1689.2	2539.3	3064.6	2414.8	1392.9	719.1	566.9	1588
1970	799.3	1223.5	1453.5	2380.8	3260.0	2703.3	2486.0	1966.7	1570.1	914.3	560.3	616.1	1661
1971	875.6	1404.0	1698.5	2072.3	2519.5	2532.8	3290.9	3680.3	3459.6	2471.9	1351.4	1071.8	2202
1972	1176.3	1576.4	1823.9	2123.8	2563.9	3366.9	4200.6	3315.8	2559.7	1679.3	1095.5	1049.1	2211
1973	1286.1	1652.1	1843.5	2054.5	2254.6	2012.6	2044.1	1721.0	1358.0	750.5	607.1	755.4	1528
1974	973.7	1647.4	2319.3	2900.7	3146.4	2856.9	3660.5	3597.3	2924.0	2032.2	1279.1	1018.3	2363
1975	1059.4	1432.7	1675.3	1845.3	2143.8	2360.2	2842.5	3021.3	3049.1	2353.7	1490.5	1191.7	2039
1976	1344.9	1782.6	1984.3	2147.0	2343.1	2168.5	2360.2	2206.2	1879.3	1255.4	1107.9	1233.5	1818
1977	1205.7	1454.7	1529.8	1555.0	1684.2	1538.7	1528.1	1402.8	1287.3	760.8	577.6	743.5	1272
1978	924.0	1321.8	1825.3	2369.6	2614.5	2422.6	2809.0	2526.6	1890.0	1119.2	707.0	745.6	1773
1979	864.7	1131.4	1216.3	1411.9	1665.8	1569.7	1697.9	1615.1	1357.3	674.8	531.5	630.8	1197
1980	779.1	1297.3	1480.1	1833.0	2367.2	2040.3	1987.8	1793.5	1479.3	821.8	525.7	569.2	1415
1981	699.6	1088.3	1244.6	1409.0	1688.4	1614.7	1632.5	1407.9	1134.6	534.1	386.7	453.9	1108
1982	647.5	1255.0	2022.2	2418.9	3048.4	3502.8	3710.7	3403.1	2856.9	1990.2	1267.2	1030.6	2263
1983	1130.6	1517.4	1802.9	2036.6	2541.2	3115.4	3887.4	3707.0	3441.6	2922.8	1811.0	1444.3	2447
1984	1359.4	1780.4	2442.6	2658.7	2651.6	2846.3	3615.0	3562.8	3243.7	2489.1	1601.2	1390.4	2470
1985	1522.6	2094.8	2306.9	2106.9	2121.1	1993.3	2640.1	2649.5	2030.9	1349.1	938.2	1081.7	1903
1986	1367.0	1646.5	1710.0	1863.7	2829.3	3600.2	3752.4	2792.9	2122.3	1483.0	1002.9	1032.3	2100
1987	1255.4	1522.6	1625.3	1715.7	1925.4	1894.1	2019.3	1660.0	1317.0	923.4	792.0	754.6	1450
1988	827.9	1158.7	1404.3	1690.9	1872.3	1653.9	1671.2	1428.2	1250.4	758.9	520.4	560.1	1233
1989	602.3	1103.2	1323.5	1409.1	1542.8	2025.6	3172.0	2881.5	2064.4	1184.0	721.7	712.8	1562
1990	898.5	1238.3	1281.7	1471.5	1719.5	1577.2	1670.1	1415.6	1168.5	631.2	541.6	645.3	1188
1991	695.6	1040.0	1089.6	1169.4	1332.9	1303.4	1412.5	1253.2	1076.3	524.6	393.6	424.2	976
1992	496.7	969.6	1074.8	1122.6	1247.3	1107.2	1141.4	964.0	815.4	361.9	306.0	291.2	825
1993	438.1	986.1	1135.6	1304.7	1491.2	2020.0	3145.9	2999.8	2514.7	1608.5	923.2	719.8	1607
1994	767.1	1125.2	1210.6	1290.6	1410.6	1254.6	1275.1	1139.5	953.5	405.7	322.3	375.2	961
1995	504.8	1029.7	1147.6	1326.6	1767.1	2059.0	2595.3	2379.9	2007.4	1287.3	713.5	546.3	1447
1996	625.1	1037.2	1403.6	2017.3	3131.3	3360.0	3256.3	2938.1	2416.8	1477.9	918.9	890.6	1956
1997	1067.7	1475.5	2000.9	3377.9	4295.1	3217.5	3079.7	2696.3	2121.3	1434.0	1043.6	1017.6	2236
1998	1161.8	1527.2	1624.6	1981.0	2651.3	2694.8	3009.1	3131.0	3116.7	2198.0	1227.8	954.8	2107
1999	995.0	1552.3	1997.6	2195.8	2382.5	2340.0	3084.1	3344.3	3103.7	2286.8	1494.2	1253.9	2169
2000	1187.1	1500.6	1656.5	1963.9	2497.6	2413.5	2811.9	2646.2	2001.8	1279.0	899.0	887.1	1812