5. HYDROLOGY - STREAMFLOW

Streamflow represents the final phase of water in the hydrologic cycle, barring consumptive losses, as it moves from the watershed. It is the easiest variable to measure and therefore often used for regulatory controls. In this section methods of analyzing streamflow will be presented along with existing data. The goal of this section is to build a basis for understanding how streamflow is affected by natural variability and use in the basin, and how it compares to the regulatory framework under which it is currently managed.

5.1 Background Issues

Streamflow is one of the most commonly measured hydrologic variables. However, characterization and interpretation of streamflow data must acknowledge a number of different factors, including:

- Natural variability: Natural variability of streamflow occurs both spatially and temporally. The precipitation pattern in the Methow basin is characterized by greater precipitation on the west side of the basin and decreasing precipitation levels to the east and south. Therefore, streamflow must be evaluated on a scale that accounts for this spatial variation. In addition, climate variability causes the hydrologic regime to change from year to year. The volume of water held in snow storage and the timing of its release varies annually, affecting streamflow levels in the summer, and often into early fall. Therefore understanding how climate variability affects steamflow within a year, as well as between years, is necessary.
- Hydraulic continuity: Hydraulic continuity of groundwater and surface water can play an important role in flow levels, particularly during dryer periods. While hydraulic continuity throughout much the Methow Valley is documented, exactly how much, how quickly and where groundwater and surface water interacts is crucial to understanding streamflow.
- Accuracy and precision of measurements: Stream gaging sites are generally chosen specifically to provide precise and accurate results. However, measurement errors are inherently introduced when collecting streamflow data. Inaccuracies can also be introduced through, changing technology, geomorphic variability, human error, and machine error. These errors typically range from 5% to 20%, depending on site conditions.
- Timing and location of water use: The timing and location of water use can influence streamflow and baseflow levels through almost every aspect of the hydrologic cycle. The affects of these withdrawals vary with the magnitude of use.
- Land cover and land use: Land use and land cover changes can affect interception and evapotranspiration timing and rates, as well as how much and how quickly water infiltrates or runs-off to streams.

Ultimately, each of these physical variables must be balanced against regulatory issues and multiple streamflow needs including in-stream uses for fish habitat, environmental considerations and aesthetics, and out-of-stream uses for irrigation and domestic uses. Streamflow is also the most commonly regulated hydrologic variables, and is usually the ultimate basis for legal allocation of water.

5.2 Objective and Level of Detail

Water quantity is a required component of Watershed Planning and fulfilling the basic planning requirements under the watershed planning act (RCW 90.82) requires an assessment of:

- Surface and groundwater present in the basin;
- Water rights, in the form of claims, permits, certificates and regulatory baseflows;
- Water use estimates for historic, current and future conditions;
- Hydraulic continuity between surface water and groundwater;
- Water availability, based on a comparison of appropriation and presence; and
- Potential strategies for increasing or better managing water resources in the basin.

To suit these purposes, the basin has been divided geographically into 8 sub-basins. The sub-basins vary in size, location and elevation and provide enough detail to capture variations across the basin without complicating down the analysis in unnecessary detail. The size and elevation of these sub-basins is summarized in Table 3-1. The sub-basins are displayed in Figure 5-1 along with the location of streamflow monitoring stations. Streamflow data are presented at varying temporal resolution ranging from daily to seasonally to inter-annually to capture both inter-annual and intra-annual flow variability.

5.3 Previous Studies

Many studies have been completed over the last 40 years that examined streamflow in the Methow Basin. The “core references” used for the current presentation of data include:

- Washington State Department of Ecology. Technical Supplement to the Hydrologic Atlas Okanogan-Methow River Basins Study Area. 1973.
- U.S. Geological Survey. Water in the Methow River Basin, Washington. U.S. Geological Survey Water Supply Bulletin 38. 1974.
- Milhous, R. T.; Greg Sorlie., and Don Richardson (Washington State Department of Ecology, Water Resources Analysis and Information Section). Water Resources of the Methow Basin. Olympia, WA; Office Report No. 56. 57 pages. 1976

- Larson, Arthur G. (Washington State Department of Ecology, Water Resources Management Program). Hydraulic Continuity in the Methow River Valley. Office Report ed. Sep 1991.
- U.S. Geological Survey. Use of a Precipitation-Runoff Model to Simulate Natural Streamflow Conditions in the Methow River Basin, Washington. U.S. Government Printing Office; Water Resources Investigations Report 01-4198. 2001.

5.4 Existing Data

There are abundant streamflow records throughout the Methow basin. Several continuous recording streamflow gages have been in place in various sub-basins for roughly the last decade or longer.

Continuous gages are operated by the US Geological Survey (USGS) at a number of locations along the Methow mainstem and major tributaries. The longest period of record exists at the Methow River gage at Pateros; it has been in operation since 1919. Since 1991, there have been a total of 7 continuous gages in operation. Continuous gage summaries are displayed in Table 5-1; the locations of these gages are depicted in Figure 5-1.

In addition to these continuous records, individual streamflow measurements have been collected by local, state, and federal agencies dating back to the late 1800s. Figure 5-2 presents the locations of all historically documented streamflow gages.

- USGS Open-File Report 84-145B, “Streamflow Statistics, and Drainage-Basin Characteristics for the Southwestern and Eastern Regions, Washington.”
- USGS Open-File Report 89-380, “Miscellaneous Streamflow Measurements in the State of Washington, January 1961 to September 1985.”
- USGS Water Supply Bulletin 23, “Miscellaneous Streamflow Measurements in the State of Washington, 1899 to January 1961.”

The US Forest Service has collected numerous flow measurements throughout the basin, focusing primarily on tributary flows. Flow measurements collected by the USFS are a combination of continuous and individual flow measurements.

Additional miscellaneous measurements have been collected by agencies and individuals for a singular period of time (i.e., 1-day or 1-week) to provide a “snap-shot” assessment of streamflow. Some of these data have been prepared in an electronic database, while other data are simply hard-copy measurements. The STORET database (a water quality management system operated by the EPA) contains over 27 megabytes of electronic streamflow and water quality data for the basin (see Table 8-1 for a summary of streamflow measurement locations).

5.5 New Data

The Methow Basin Planning Unit and Okanogan County initiated a comprehensive streamflow-monitoring program in the Methow Basin in 2000. A plan, *Streamflow Monitoring Plan for the Methow Basin*, was prepared by Golder Associates in April 2000, and put into practice to provide streamflow data for use in watershed planning.

The objective of the collection program was to establish a network of streamflow gages throughout the basin, focusing on tributaries to the Methow River, to provide quantification of flow regimes, particularly summer low-flow. The program focuses on collecting information on natural stream channels.

Twenty gages were installed within the Methow Basin by both the USGS and Golder Associates. Table 5-2 summarizes the gage sites and types of gages that were installed. Figure 5-1 depicts the locations of these gages within the basin. Three types of gages were installed through this program:

1. Continuous, year-round or seasonally operated recording stations installed, operated and maintained by Okanogan County and/or the Planning Unit.
2. Seasonal non-recording staff gages operated and maintained by Okanogan County, the Planning Unit, or other stakeholders.
3. Continuous, year-round recording stations installed, operated, and maintained by the U.S. Geological Survey (USGS). Six new USGS continuous gaging stations were installed.

Detailed gage information can be found in the report titled, Technical Memorandum on Streamflow Data Collection Program (Golder, 2002) (Approved by MBPU March 12, 2002).

5.6 Presentation of Data

Hydrologic data is complex, highly variable, and cannot be represented by a single presentation or analysis of data. It is necessary to utilize several methods to represent each aspect of a system, and to understand the benefits and shortcomings of each method. This section describes and presents data using several methods to characterize the hydrologic regime.

5.6.1 Annual Aggregate

Annual averages are commonly used to evaluate inter-year trends. A total monthly or yearly flow volume plot can be useful in visualizing or calculating if there has been a change in streamflow levels over the long term.

Mean annual flows for continuous USGS gages within the basin are presented in Table 5-1. Average Annual Flows for each gage over the available period of record are displayed in Figure 5-3(a-g). These plots can provide an indication of inter-annual flow variations.

5.6.2 Monthly Aggregate

Monthly averages can be used to evaluate inter-year trends on a monthly basis as well as intra-year trends. Monthly averages aid in visualizing the relative contribution of monthly flows to total annual flows as well as how these monthly flows relate to each other. In addition, monthly averages can indicate how monthly values vary with annual increases or declines in precipitation, snowpack and flow.

Monthly average flows for continuous gages in the basin are displayed in Table 5-3 annually for 1992-2000. Peak flows generally occur at all gages in June or sometimes May, low flow months occur from September to February. Methow at Twisp, Twisp at Twisp, Methow at Winthrop, and Methow at Goat Creek all record a slight rise in average monthly flows for November and December before returning to low flow levels again in January.

5.6.3 Time-Series Hydrographs

A hydrograph presents streamflow in a basic form - streamflow (or stage) versus time. A hydrograph can provide very detailed information on a watershed when completed on a daily or hourly time step. Actual hydrographs, as opposed to aggregates, are used to describe the elements, or phases of the hydrologic cycle and provide the best insights into the drivers that cause each element's response. Unfortunately, because of the complexity of hydrograph response, it is difficult to automate or numerically analyze individual hydrographs. Therefore, analysis is often best completed through observation.

The basic elements of a hydrograph are shown on Figure 5-4 include the following:

- Baseflow (late fall to winter);
- Rising limb (spring);
- Peak flow (spring);
- Peak flow recession (summer); and
- Baseflow recession (summer/fall).

In the Methow basin the baseflow recession and baseflow periods represent the most important period due to the combination of out-of-stream and in-stream needs: A description of each element and possible drivers are discussed in the paragraphs below.

- Baseflow is defined as the "component of streamflow derived from groundwater inflow or discharge" (Sinclair et al, 1999). Baseflow represents streamflow, or runoff, which results from precipitation that infiltrates into the soil and eventually moves through the soil to the stream channel. It is often the primary source of water during dry periods when there is little or no surface water runoff. The rate and volume of baseflow can also be influenced by surface water leakage from storage sites, well operations, and groundwater withdrawals. During baseflow periods it is easier to see anthropogenic (human-related) effects because few other hydrologic inputs are active during these dry periods.

- The rising limb is the period of time when run-off from both small (rain) and large (snowmelt) events begins to reach the stream. The shape and rate of streamflow increase on rising limb is affected by the size and shape of the watershed, as well as snow storage, temperature, land cover, and infiltration capacity.
- Peak streamflow represents the largest rate of streamflow during a year. Annual averages of streamflow are often greatly influenced by peak flow, because peak flows often represent the greatest volume of water, being 1 or 2 orders of magnitude greater that normal and low flow conditions during the rest of the year.
- Peak flow recession follows the peak flow period. The recession limb is the period when snowmelt begins to decrease. The slope and length of this recession period is affected by snow storage volume, temperature, land cover, and infiltration capacity. This portion of the hydrograph is very important in the Methow, because the timing and slope of the recession limb largely determines when baseflow conditions are reached and when in-stream flow levels will be reached during the irrigation season.
- Baseflow recession represents a transition period when streamflows become increasingly supported by groundwater baseflow. This slope of this recession is much less than during peakflow, but is greater than during true baseflow. During this period, some water in the stream is still directly derived from snowmelt and shallow interflow.

Example daily hydrographs for continuous USGS gages in the basin are presented in Figures 5-5(a – f). Each figure displays two hydrographs with data from years with different average annual flow values. From these graphs the baseflow period is seen extending from October through February for both 1994 and 1999 at all gages. The rising limb begins in mid-March for both 1999 and 1994, but from there the two periods diverge. In 1994 flows are actually higher initially but reach peak levels in May, recession from the peak extends from May, approximately, to the end of June in 1994. Baseflow recession is visible from the decline in the slope that occurs in July and early August. Baseflow is reached by mid-August. Similar results can be seen at all the continuous USGS gages presented. Chewuch River at Winthrop commences baseflow recession earlier than the other gages, but on the whole shows the same response.

Figure 5-6 shows an overlay of several hydrographs of consecutive gages in the Methow River for an example year - 1997. From this plot the relative flow contribution of each consecutive gage is plotted to highlight the contribution of each consecutive gage to the observed streamflow at Pateros. Contribution is calculated as the percentage of total flows at the Methow near Pateros gage. The plots show that, at the beginning of the water year (during baseflow), approximately 60% of flow is contributed by the Chewuch sub-basin (represented by the Methow River at Winthrop). Moving into the spring melt season the percentage of flows contributed by the Upper Methow sub-basin (represented by the Methow River at Goat Creek) rises considerably from 0 to 40%, equaling the percentage contributed by the Chewuch sub-basin. The relative contribution of the lower reaches of the Methow is low in comparison to these upper sub-basins.

5.6.4 Naturalized Hydrograph Reconstruction

In the Methow during the summer/fall baseflow period, the hydrograph commonly “rebounds” during early-mid October, when the irrigation ditches are shut down. If the rate of irrigation return flow has reached an equilibrium by the time the rebound occurs, then the amount of rebound should approximate the net consumptive use of water diverted upstream of the stream gage (including water transferred around the stream gage in some cases). If the rate of return flow has not reached equilibrium, then the amount of rebound should approximate consumptive use plus irrigation inefficiencies that have not yet returned to the stream.

Naturalized hydrographs are the basis from which watershed-planning decisions are often made. Reconstructing a naturalized flow regime is, however, difficult and statistically aggregated streamflow data are often not suitable for this type of analysis. A year-by-year analysis of hydrograph data can be used to re-construct a hydrograph that would likely have occurred in the absence of anthropogenic effects. When rebound is clearly visible in the hydrograph, the amount of rebound can be simply added back to create a naturalized hydrograph.

The reconstruction approach used to develop naturalized hydrographs is sensitive to the rebound amount that is added back. If greater or lesser amounts are added back, the resulting naturalized hydrograph would not have a natural shape. This hydrograph reconstruction method is therefore considered to be fairly robust and accurate.

An example of a naturalized hydrograph developed through reconstruction for the Chewuch River, 1994 water year is shown in Figure 5-7. This hydrograph is plotted on a log scale so that the difference between the actual and naturalized hydrograph is more visible. Similar effects can be observed at the Pateros gage on some, but not all, years. The effects at Pateros (when they are apparent in the hydrograph) represent the total net effect of all consumptive uses in the basin.

5.6.5 Inter-Annual Variability in Streamflow

Inter-annual variability in stream flow is a metric used to assess hydrologic conditions in relation to aquatic habitats. The timing of the life stages of various species encompasses a broad range of flow magnitudes, and the timing of these flow levels varies from year to year. An example of the streamflow hydrograph for the Chewuch River and corresponding life histories for chinook salmon and bull trout is shown in Figures 5-7 and 5-8. With a variable hydrograph, it is difficult to identify exact dates when certain flow levels are observed, or to identify what flow levels are present on certain dates.

Inter-annual variability provides a tool for evaluating this variability. It is defined as the magnitude of year-to-year flow variation, based on monthly, weekly, or daily flow data. It expresses the entire range of flows that could be expected for a given day, week, or month. It is a specified parameter in the Ecosystem Diagnostic Treatment (EDT) method (Mobrand Biometrics) and is implied in the US Fish and Wildlife Services Matrix of Diagnostics/Pathways and Indicators Methodology (USFWS, 1998), as a way to assess existing or proposed changes to peak flow, baseflow or flow timing from specified actions.

Figure 5-10 shows an example of inter-annual variability for the Chewuch River for the 10-year flow record. The magnitude of variability is greatest during peak flow, and lowest during baseflow.

5.6.6 Cumulative Departure Analysis

Generally, it is difficult to identify long-term climatic changes from hydrograph data that is aggregated. Rescaled Cumulative Departure (RCD) analysis provides a method for assessing long-term, cyclic hydrologic trends (Kresch, 1994). An RCD plot displays whether a system is exhibiting above or below average flows, how severe current conditions are (i.e. how far from average conditions) and the duration of the wet or dry period. A declining slope of a RCD plot indicates that flow was below average during much of the interval (a dry or drought period) while an increasing slope indicates that flow was above average during much of the interval. The slope of the RCD plot and duration of the cycle indicate the relative severity of the drought, for example a high rate of decline persisting for a long period of time indicates a severe drought.

In order to calculate the cumulative departure it is necessary to first determine a time frame representative of a normal cycle of wet and dry seasons, called the base period. The base period could be the entire period of record or a shorter representative period. In a study completed by the USGS (Kresch, 1994) it was determined that a base period of 1937-1976 accurately reflected long-term average conditions in Washington (mean-monthly values and standard deviations of the base period accurately represent long-term average conditions). Comparison of results for precipitation in the Methow basin using the 1937-1976 base period and the 1960-2000 base period show that a base period of 1960-2000 also adequately represents the long-term average conditions.

Rescaled Cumulative Departure (RCD) plots provide a concise view of climate variability taking into account the current location in the climate cycle. The USGS gage Methow at Pateros has more than 40 years of record, from 1960-2000. Comparison of RCD analysis at the precipitation station Winthrop 1 WSW (see Section 4) using two base periods from 1937-1976 (per Kresch, 1994) and 1960-2000 indicates that the latter period adequately represents climatic variations in the Methow Basin. RCD results for the Methow near Pateros gage are displayed in Figure 5-11. Comparison of this figure with that of the precipitation RCD for Winthrop 1 WSW shows that both precipitation and climate display similar trends.

5.6.7 Range of Variability Statistics

Richter et. al. (1996 and 1997) have used what is termed threshold analysis in an attempt to characterize streamflow and habitat parameters in a manner that describes periods of streamflow flow. The method developed by Richter (1996) is termed Range of Variability Analysis (RVA), which identifies a suite of 32 “biologically relevant” hydrologic parameters. The method is similar to inter-annual variability. Parameters include standard hydrologic statistics, but also include threshold-type parameters that relate to specific events in the streamflow record. RVA can be evaluated from historical streamflow records, or synthetic naturalized records developed through modeling. The various parameters can be differentially weighted or used “as-is” to quantitatively define the current hydrologic regime and potential future hydrologic regimes and conduct sensitivity analysis. These RVA parameters are summarized below:

1. Monthly flow magnitudes,
2. Magnitude and duration of annual extremes,
3. Timing of annual extremes,
4. Frequency and duration of high and low pulses, and
5. Rate and frequency of hydrograph changes.

One use of these variability statistics for watershed planning purposes is to assess the statistical significance of changes in streamflow resulting from possible changes in water use, relative to natural year-to-year variability caused by climate and snowpack. In order for changes in water use patterns to have a statistically measurable effect on observed streamflow, the changes in streamflow have to be greater than the current variability in the dataset. Otherwise, it would not be possible to distinguish between “naturally occurring” variability, and a change resulting from changes in water use practices.

Range of Variability statistics (RVA) are presented in Table 5-4. The statistics were derived from historical streamflow records for the Methow River at Pateros (gage #12450500, period 1959-1999), and therefore include the net effects of water use in the basin.

5.6.8 Exceedance Probability Analysis

Exceedance probability plots are used to understand how often, or how probable, it is that that a certain flow will be equaled or exceeded in a specified time frame. Exceedance probabilities are also called recurrence intervals, or, more generally, frequency analysis. Frequency analysis techniques were primarily developed by civil engineers, who needed to determine design criteria for hydrologic structures, particularly during hydrologic extremes (e.g. floods and droughts). The source of data for these types of analysis is purely historical. Therefore, the “reliability” of frequency analysis increases with the length of the historical period of record. One of the most difficult problems faced by hydrologic engineers relate to extrapolating the “tails” of frequency distributions to represent extreme events, and extrapolating frequency analyses at one location to other locations. Also, the occurrence of a certain exceedance probability flow in one month does not mean that the same exceedance probability will occur in the next month. Therefore, frequency analysis is useful in setting design criteria, but less useful for deciding how to respond to specific conditions.

Table 5-5 summarizes flows for the 10%, 50%, and 90% exceedance probability levels for flows at the various stream gages.

5.7 QA/QC

The U.S. Geological Survey (USGS) stream-gaging program provides streamflow data for a variety of purposes that range from current needs, such as flood forecasting, to future or long-term needs, and allows for detection of changes in streamflow due to human activities or global warming. The reliability and accuracy of USGS data are considered high, based on the internal quality control used by the USGS in recording and maintaining the gages.

TABLE 5-1

Existing USGS Streamflow Gages for the Methow River Mainstem and Major Tributaries

Gage #	**Description**	**Sub-basin**	**Period of Record Available**	**Mean Annual Flow (cfs)**	**Max Annual Flow (cfs)**	**Minimum Annual Flow (cfs)**
				WY 1991-2000 Used		
12447390	Andrews Creek near Mazama	Chewuch	6/1/68-9/30/00	35	45	22
12448998	Twisp at Twisp	Twisp	5/1/75-9/30/79, 10/1/89-9/30/00	294	413	152
12448000	Chewuch at Winthrop	Chewuch	10/1/91-9/30/00	432	630	223
12447383	Methow abv Goat Creek	Methow Headwaters	4/20/91-9/30/00	761	1,522	286
12448500	Methow at Winthrop	Upper Methow	11/10/89-9/30/00	1,279	1,729	758
12449500	Methow at Twisp	Middle Methow	6/10/19-9/30/29, 10/1/33-9/30/62, 4/10/91-9/30/00	1,582	3,296	901
12449950	Methow near Pateros	West and East Lower Methow	4/1/59-9/30/00	1,674	2,251	963
12450500	Methow at Pateros	West and East Lower Methow	6/19/03-9/30/20	N/A	N/A	N/A

TABLE 5-2

Okanogan County/MBPU
Stream Gage Sites in the Methow River Basin

Gage ID	Gage Name (Stream)	Location	Gage Type	Temperature	Lead Agency
1	Gold Creek at Gold Creek Loop Road Bridge	At Gold Creek Loop Road Bridge	Staff and Transmitter	YES	County/ Planning Unit
2	Libby Creek at State Highway 153 Bridge	At the State Highway Bridge	Staff and Transmitter	YES	County/ Planning Unit
3	Little Bridge Creek at Twisp River Road	At Twisp River Road	Staff	NO	County/ Planning Unit
4	Buttermilk Creek at West Fork Buttermilk Road	At W. Fork Buttermilk Rd. Bridge	Staff	NO	County/ Planning Unit
5	Beaver Creek downstream of Frazer Creek	Downstream of Frazer Creek	Staff and Transmitter	YES	County /Planning Unit
6	Wolf Creek at Perrow Ditch	Wolf Creek at County Road	Staff and Transmitter	YES	County/ Planning Unit
7	Chewuch River upstream of Fulton Ditch Diversion	140 W. Chewuch Road	Staff and Transmitter	YES	County/ Planning Unit
8	Chewuch River between Skyline/Boulder	Between Skyline Ditch Diversion and Boulder Creek	Staff and Transmitter	YES	County/ Planning Unit
9	Cub Creek at West Chewuch Road	Chewuch Confluence	Staff	NO	County/ Planning Unit
10	Chewuch River at Eightmile Ranch	Downstream of Eightmile Creek, Road #5100, mile 8.7	Staff	NO	County/ Planning Unit
11	Eight Mile Creek upstream of Diversion	Above Mason Diversion	Staff and Transmitter	YES	County/ Planning Unit
12	Methow River At Weeman Bridge	At Weeman Bridge, Hwy 20	Staff	NO	County/ Planning Unit
13	Early Winters Creek above Early Winters Diversion	Highway 20 Crossing, Upstream of Campground	Staff	NO	County/Planning Unit
14	Goat Creek at Lost River Road	Lost River Road	Staff and Transmitter	YES	County/ Planning Unit
12447370	Lost River near Mazama	Near Mazama	Continuous		USGS
12447382	Early Winters Creek near Mazama	Near Mazama	Continuous		USGS
12447387	Wolf Creek Near Winthrop	Below Diversion	Continuous		USGS
12447500	Chewuch River near Winthrop	Below Boulder Creek	Continuous		USGS
12448998	Twisp River near Twisp	Above Newby Creek	Continuous		USGS
12449710	Beaver Creek near Twisp	Near the mouth	Continuous		USGS

TABLE 5-3

Mean Monthly Flows for USGS Gages (1990-2001)

Month	Year		Month/Year	Andrews Creek 12447390	Chewuch at Winthrop 12448000	Methow at Winthrop 12448500	Methow nr Pateros 12449950	Methow at Goat Creek 12447383	Twisp R. at Twisp 12448998	Methow at Twisp 12449500
1	1992	30	Jan-92	3.1	60.5	213.1	323.1	-	45.90	267.00
1	1993	30	Jan-93	3.6	40.2	197.2	262.9	-	31.65	197.10
1	1994	30	Jan-94	3.8	61.9	196.6	279.3	-	32.52	247.35
1	1995	30	Jan-95	3.3	53.9	181.3	248.0	-	41.65	204.16
1	1996	30	Jan-96	5.7	100.9	459.2	614.6	123.97	147.42	524.23
1	1997	30	Jan-97	4.5	84.5	256.0	328.2	-	60.23	289.10
1	1998	30	Jan-98	5.4	83.6	296.6	441.8	24.65	63.68	350.23
1	1999		Jan-99	3.9	73.5	224.1	375.1	-	58.65	275.77
1	2000		Jan-00	8.6	111.3	391.9	652.6	98.03	99.10	496.71
1	2001		Jan-01	nd	50.0	182.8	294.1	-	21.45	nd
			MEAN	4.7	72.0	259.9	382.0	24.7	60.2	316.8
2	1992	28	Feb-92	3.0	68.2	251.2	364.7	1.83	63.93	314.93
2	1993	28	Feb-93	3.4	49.1	179.5	279.7	-	34.86	209.50
2	1994	28	Feb-94	3.3	58.3	185.3	268.2	-	29.21	238.93
2	1995	28	Feb-95	3.3	72.9	222.6	354.1	3.50	107.71	308.68
2	1996	28	Feb-96	5.1	100.3	452.0	630.1	93.28	167.52	509.90
2	1997	28	Feb-97	4.4	81.0	249.9	417.9	0.48	74.93	329.57
2	1998	28	Feb-98	4.8	88.9	324.8	490.1	20.57	67.00	381.07
2	1999		Feb-99	4.1	72.5	215.5	380.0	-	56.64	274.14
2	2000		Feb-00	5.6	102.5	295.8	522.8	31.59	74.52	366.90
2	2001		Feb-01	nd	49.3	175.1	262.0	-	19.91	nd
			MEAN	4.1	74.3	255.2	396.9	15.1	69.6	326.0
3	1992	31	Mar-92	6.5	152.7	878.4	1,015.9	405.48	174.19	996.71
3	1993	31	Mar-93	3.0	48.5	183.8	273.5	-	43.13	232.90
3	1994	31	Mar-94	3.6	76.4	224.9	319.5	9.53	59.10	294.97
3	1995	31	Mar-95	3.6	144.3	568.6	794.7	192.61	215.39	712.32
3	1996	31	Mar-96	5.4	168.5	767.3	1,097.6	234.58	269.77	917.39
3	1997	31	Mar-97	4.9	101.2	370.5	598.3	57.03	130.97	498.77
3	1998	31	Mar-98	4.8	134.5	533.6	738.2	127.13	121.90	636.84
3	1999		Mar-99	4.6	101.2	297.3	564.2	25.26	93.84	418.29
3	2000		Mar-00	4.3	104.6	334.8	556.6	35.06	80.84	414.61
3	2001		Mar-01	nd	57.1	189.5	287.5	-	23.57	nd
			MEAN	4.5	108.9	434.9	624.6	108.7	121.3	569.2
4	1992	30	Apr-92	27.6	320.1	1,561.7	1,791.7	823.37	306.60	1,794.00
4	1993	30	Apr-93	3.2	78.8	245.5	366.5	20.43	89.27	346.33
4	1994	30	Apr-94	47.0	568.6	1,767.9	2,110.7	820.73	394.70	2,110.17
4	1995	30	Apr-95	7.1	460.5	1,531.3	2,034.0	514.17	452.17	1,871.67
4	1996	30	Apr-96	26.5	761.3	2,474.6	3,364.0	1,080.07	722.53	3,121.87
4	1997	30	Apr-97	10.0	404.4	1,414.2	1,940.3	542.57	385.80	1,789.20
4	1998	30	Apr-98	13.9	423.0	1,443.0	1,897.0	548.23	351.20	1,770.53
4	1999		Apr-99	11.9	420.5	1,455.2	2,142.0	598.10	376.83	1,842.03
4	2000		Apr-00	29.1	572.5	1,909.4	2,383.5	923.03	425.63	2,375.80
4	2001		Apr-01	nd	59.9	194.5	308.5	10.03	44.28	nd
			MEAN	19.6	407.0	1,399.7	1,833.8	588.1	354.9	1,891.3
5	1992	31	May-92	110.8	835.3	3,146.8	3,691.3	1,779.68	668.97	3,700.32
5	1993	31	May-93	133.6	1,263.6	4,091.1	4,781.2	2,030.65	910.48	4,750.90
5	1994	31	May-94	149.4	1,414.8	3,343.5	4,048.4	1,516.74	663.68	3,980.65

TABLE 5-3

Mean Monthly Flows for USGS Gages (1990-2001) (Continued)

Month	Year		Month/Year	Andrews Creek 12447390	Chewuch at Winthrop 12448000	Methow at Winthrop 12448500	Methow nr Pateros 12449950	Methow at Goat Creek 12447383	Twisp R. at Twisp 12448998	Methow at Twisp 12449500
5	1995	31	May-95	146.6	2,299.5	6,243.5	7,447.4	2,781.16	1,382.58	7,315.81
5	1996	31	May-96	69.6	1,192.8	3,191.9	4,105.8	1,409.13	737.26	3,823.55
5	1997	31	May-97	155.5	2,437.8	6,528.1	7,903.2	3,122.81	1,454.90	7,417.74
5	1998	31	May-98	202.0	2,670.6	7,125.2	9,155.2	3,297.10	1,415.48	8,296.77
5	1999		May-99	79.8	1,384.9	4,159.4	5,269.0	1,778.77	826.58	4,752.90
5	2000		May-00	78.4	1,059.8	2,811.9	3,537.7	1,434.00	595.10	3,405.16
5	2001		May-01	nd	341.0	1,629.0	1,923.8	937.23	225.30	nd
			MEAN	125.1	1,490.0	4,227.0	5,186.3	2,008.7	888.0	5,271.5
6	1992	30	Jun-92	56.6	463.9	2,032.3	2,584.0	1,250.30	502.63	2,509.33
6	1993	30	Jun-93	66.6	654.2	1,988.1	2,597.3	1,023.33	491.43	2,462.00
6	1994	30	Jun-94	80.7	666.2	1,675.7	2,106.0	802.23	344.07	1,974.00
6	1995	30	Jun-95	235.8	2,376.0	5,571.3	7,055.3	2,518.67	1,174.03	6,803.00
6	1996	30	Jun-96	222.5	2,512.7	5,907.7	7,168.0	2,752.67	1,263.57	6,999.00
6	1997	30	Jun-97	239.8	2,631.0	6,691.7	8,470.3	3,358.00	1,488.73	7,745.33
6	1998	30	Jun-98	117.4	1,497.2	3,743.3	5,223.7	1,879.93	813.57	4,492.67
6	1999		Jun-99	251.2	3,348.3	8,133.3	9,833.0	3,907.33	1,516.77	9,071.00
6	2000		Jun-00	114.2	1,113.2	3,369.7	4,373.7	1,932.33	857.13	4,140.67
6	2001		Jun-01	nd	272.2	1,256.9	1,583.0	642.43	146.52	nd
			MEAN	153.9	1,553.5	4,037.0	5,099.4	2,006.7	859.8	5,133.0
7	1992	31	Jul-92	28.2	382.5	1,028.1	1,307.7	438.03	158.68	1,195.13
7	1993	31	Jul-93	36.9	479.5	1,066.7	1,293.7	354.71	171.65	1,162.42
7	1994	31	Jul-94	21.4	180.3	614.6	779.5	234.29	120.55	685.48
7	1995	31	Jul-95	56.9	523.9	1,669.6	2,329.3	875.71	440.26	2,142.10
7	1996	31	Jul-96	112.4	913.1	2,682.6	3,538.7	1,396.06	700.81	3,363.23
7	1997	31	Jul-97	56.5	617.7	2,156.1	2,953.5	1,173.52	579.77	2,644.52
7	1998	31	Jul-98	42.7	543.8	1,335.7	1,870.2	562.00	252.58	1,551.65
7	1999		Jul-99	124.8	1,414.0	3,831.9	4,960.0	2,526.77	762.39	4,338.71
7	2000		Jul-00	39.4	334.8	1,327.9	1,821.4	711.42	340.03	1,618.90
7	2001		Jul-01	nd	113.3	501.1	656.3	190.55	53.05	nd
			MEAN	57.7	550.3	1,621.4	2,151.0	846.3	358.0	2,078.0
8	1992	31	Aug-92	10.6	132.1	390.1	508.0	117.52	50.77	442.55
8	1993	31	Aug-93	27.8	345.3	780.7	921.2	210.35	95.16	801.13
8	1994	31	Aug-94	8.1	47.6	218.6	311.2	35.06	28.03	231.52
8	1995	31	Aug-95	13.8	140.6	477.3	654.2	140.55	95.74	579.19
8	1996	31	Aug-96	19.0	181.6	626.6	857.8	220.29	151.13	739.77
8	1997	31	Aug-97	15.0	173.5	642.1	903.3	253.16	143.94	733.06
8	1998	31	Aug-98	13.4	157.1	453.3	620.9	101.97	61.45	476.81
8	1999		Aug-99	32.4	349.1	1,208.2	1,633.5	610.03	221.19	1,279.65
8	2000		Aug-00	10.1	84.9	411.4	575.6	136.77	74.94	464.58
8	2001		Aug-01	nd	40.2	203.9	301.0	29.03	18.07	nd
			MEAN	16.7	165.2	541.2	728.7	185.5	94.0	638.7
9	1992	30	Sep-92	5.5	45.1	204.5	305.9	14.90	23.97	227.10
9	1993	30	Sep-93	11.0	128.7	319.3	438.9	34.83	35.47	338.43
9	1994	30	Sep-94	5.0	29.8	150.3	251.7	0.65	16.40	167.40
9	1995	30	Sep-95	6.5	60.4	243.4	364.9	28.24	42.40	308.60
9	1996	30	Sep-96	10.3	102.9	340.6	514.0	59.67	62.37	401.27
9	1997	30	Sep-97	11.0	120.2	387.4	583.0	100.13	73.60	437.00

TABLE 5-3

Mean Monthly Flows for USGS Gages (1990-2001) (Continued)

Month	Year		Month/Year	Andrews Creek 12447390	Chewuch at Winthrop 12448000	Methow at Winthrop 12448500	Methow nr Pateros 12449950	Methow at Goat Creek 12447383	Twisp R. at Twisp 12448998	Methow at Twisp 12449500
9	1998	30	Sep-98	5.7	63.9	245.3	380.7	14.49	31.60	238.73
9	1999		Sep-99	12.9	129.7	417.6	584.8	102.00	60.47	458.57
9	2000		Sep-00	5.3	48.6	221.2	341.1	20.28	31.60	238.03
9	2001		Sep-01	nd	26.2	152.0	237.8	1.48	12.66	nd
			MEAN	8.1	75.6	268.2	400.3	37.7	39.1	312.8
10	1992	31	Oct-92	4.6	66.0	235.8	373.6	10.58	53.00	319.39
10	1993	31	Oct-93	4.3	72.2	219.2	332.2	0.62	35.65	269.65
10	1994	31	Oct-94	7.4	113.9	259.3	401.0	3.30	46.97	325.42
10	1995	31	Oct-95	3.7	58.4	181.3	305.0	-	37.68	240.48
10	1996	31	Oct-96	6.2	97.9	288.9	444.0	16.65	84.32	404.06
10	1997	31	Oct-97	7.1	107.4	305.6	477.2	18.19	67.13	387.16
10	1998	31	Oct-98	13.7	176.3	575.1	793.6	213.55	144.00	690.48
10	1999		Oct-99	4.8	88.2	265.7	425.8	0.05	46.61	294.13
10	2000		Oct-00	7.9	113.9	314.3	459.5	37.00	66.00	407.42
10	2001		Oct-01	nd	69.1	236.3	368.1	6.99	27.48	nd
			MEAN	6.6	96.3	288.1	438.0	30.7	60.9	370.9
11	1992	30	Nov-92	4.5	78.6	244.4	380.4	11.63	57.53	328.43
11	1993	30	Nov-93	4.1	73.9	224.9	339.2	-	46.23	277.37
11	1994	30	Nov-94	5.1	79.9	223.7	342.9	1.45	45.53	269.93
11	1995	30	Nov-95	3.6	63.4	188.5	323.8	-	46.43	241.47
11	1996	30	Nov-96	5.9	100.0	726.7	979.0	384.20	290.43	1,008.17
11	1997	30	Nov-97	7.1	100.6	325.9	492.7	31.93	81.10	397.60
11	1998	30	Nov-98	11.5	156.6	564.4	746.6	189.67	125.77	648.30
11	1999		Nov-99	4.5	89.0	262.5	418.9	-	53.37	304.07
11	2000		Nov-00	22.1	209.6	900.9	1,211.8	451.57	204.27	1,083.83
11	2001		Nov-01	nd	63.4	218.3	345.5	0.17	26.75	nd
			MEAN	7.6	101.5	388.0	558.1	107.1	97.7	506.6
12	1992	31	Dec-92	3.6	65.1	223.2	338.9	2.54	49.77	287.26
12	1993	31	Dec-93	3.5	44.1	201.5	305.1	-	45.65	241.65
12	1994	31	Dec-94	4.4	66.9	206.1	301.9	0.34	36.29	255.48
12	1995	31	Dec-95	3.3	60.4	188.7	269.8	-	48.87	233.45
12	1996	31	Dec-96	8.9	135.5	957.0	1,360.5	523.16	323.45	1,204.90
12	1997	31	Dec-97	5.7	91.2	286.0	399.8	13.50	63.61	336.19
12	1998	31	Dec-98	7.7	99.9	346.8	494.0	53.42	73.10	407.00
12	1999		Dec-99	4.1	78.5	237.5	373.3	-	47.74	272.81
12	2000		Dec-00	13.4	147.6	533.9	859.0	198.32	135.03	671.94
12	2001		Dec-01	nd	56.9	195.3	323.7	-	23.78	nd
			MEAN	6.1	84.6	337.6	502.6	79.1	84.7	434.5

TABLE 5-4

Range of Variability Outputs, Methow near Pateros (stn. 12449950), 1959-1999)

Monthly Magnitude

	Mean Discharge (cfs)	**Standard Deviation (cfs)**	**Mean + 1 Std Dev (cfs)**	**Mean - 1 Std Dev (cfs)**
January	423.2	164.2	587.4	259.0
Febuary	423.8	139.1	562.9	284.7
March	614.6	293.9	908.5	320.7
April	1601.7	684.2	2285.9	917.5
May	5060.6	1922.3	6982.9	3138.3
June	6039.5	2805.8	8845.3	3233.7
July	2211.2	1211.1	3422.3	1000.1
August	719.5	368.4	1087.9	351.1
September	454.6	187.9	642.5	266.7
October	486.0	195.4	681.4	290.6
November	531.2	243.1	774.3	288.1
December	480.0	257.5	737.5	222.5

Magnitude and Duration of Annual Extremes

	Mean Discharge (cfs)	**Standard Deviation (cfs)**	**Mean + 1 Std Dev (cfs)**	**Mean - 1 Std Dev (cfs)**
1 day minimum	282.7	76.5	359.2	206.2
3 day minimum	287.1	75.5	362.6	211.6
7 day minimum	295.2	73.0	368.2	222.2
30 day minimum	323.7	76.7	400.4	247.0
90 day minimum	406.7	208.2	614.9	198.5
1 day maximum	12207.8	4946.5	17154.3	7261.3
3 day maximum	11393.4	4588.1	15981.5	6805.3
7 day maximum	10153.2	3961.3	14114.5	6191.9
30 day maximum	7391.9	2778.2	10170.1	4613.7
90 day maximum	4640.9	1632.4	6273.3	3008.5

Timing of annual Extremes

	Mean (Julian Day)	**Standard Deviation (Julian Day)**	**Mean + 1 Std Dev (Julian Day)**	**Mean - 1 Std Dev (Julian Day)**
Annual Minimum	328.0	63.0	26.0	265.1
Annual Maximum	149.0	13.2	162.2	135.8

Frequency and Duration of High and Low Pulses

	Mean	**Standard Deviation**	**Mean + 1 Std Dev**	**Mean - 1 Std Dev**
Count (number)				
Low Pulses	5.9	2.1	8.0	3.8
High Pulses	2.2	0.9	3.1	1.3
Duration (days)				
Low Pulses	18.0	7.6	25.6	10.4
High Pulses	50.5	26.1	76.6	24.4

Rate and Frequenct of Hydrograph Changes

	Mean	**Standard Deviation**	**Mean + 1 Std Dev**	**Mean - 1 Std Dev**
Count (number)				
Fall	48.4	9.2	57.6	39.2
Rise	43.6	7.8	51.4	35.8
Rate (cfs/day)				
Fall	-123.5	52.5	-70.9	-176.0
Rise	190.5	78.0	268.5	112.6

TABLE 5-5

Summary of Exceedance Flow Probability for USGS Gages

	Methow R. above Goat Cr. (STN 12447383)			Chewuch River at Winthrop (STN 12448000)			Methow River at Winthrop (STN 12448500)			Twisp River near Twisp (STN 12448998)			Methow River near Pateros (STN 12449950)		
Day of Year	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%
01/01 - 01/14	148.4	0.0	0.0	112.9	68.4	38.1	496.0	228.8	181.2	158.9	53.5	23.6	707.9	333.2	241.4
01/15 - 01/28	106.2	0.0	0.0	109.0	66.7	42.0	416.8	219.3	181.0	137.8	59.4	23.5	606.0	316.4	251.7
01/29 - 02/11	64.4	0.0	0.0	107.8	69.9	49.7	375.4	225.1	178.0	126.7	60.9	22.4	545.7	378.5	258.3
02/12 - 02/25	99.0	0.4	0.0	99.6	72.5	49.2	464.1	251.1	175.6	171.6	67.9	21.5	653.5	377.6	263.3
02/26 - 03/11	100.6	13.2	0.0	99.9	81.0	46.1	495.0	286.1	174.5	184.1	70.3	23.2	717.3	492.1	263.7
03/11 - 03/25	473.7	33.8	0.0	183.5	102.0	49.3	977.4	346.5	187.3	289.5	128.2	28.2	1,217.7	570.5	273.4
03/25 - 04/08	767.2	279.6	0.0	317.6	171.9	53.6	1,422.9	659.4	187.3	355.3	203.4	34.2	1,690.6	1,001.2	294.9
04/08 - 04/22	1,308.6	465.6	0.0	800.3	337.5	49.9	2,756.4	1,250.4	183.0	821.0	320.0	41.0	3,693.3	1,702.1	294.3
04/22 - 05/06	2,366.0	1,114.0	110.4	1,592.5	789.3	95.5	4,929.1	2,391.4	358.9	1,117.0	598.5	94.1	6,179.0	3,110.7	483.5
05/06 - 05/20	3,795.3	1,892.9	719.9	2,665.6	1,274.4	288.0	7,610.1	3,892.1	1,436.5	1,719.2	797.1	215.4	9,316.4	4,877.1	1,643.5
05/20 - 06/03	3,734.6	2,187.9	1,326.7	3,411.4	1,595.4	583.6	8,271.3	4,472.9	2,591.9	1,774.1	984.0	391.3	9,898.6	5,576.4	3,197.2
06/03 - 06/17	4,114.1	2,330.0	718.6	3,292.7	1,486.8	325.1	8,283.1	4,398.6	1,452.9	1,754.6	1,009.6	197.4	10,116.0	6,222.9	1,828.9
06/17 - 07/01	4,001.0	1,934.3	500.7	3,389.5	995.1	225.4	7,572.6	3,233.6	1,033.9	1,458.5	869.3	145.2	9,614.7	4,272.9	1,302.3
07/01 - 07/15	3,130.4	940.8	234.9	1,834.3	593.8	131.4	4,729.6	1,862.9	639.4	1,144.6	459.4	85.2	6,118.4	2,620.7	826.4
07/15 - 07/29	1,770.4	559.4	117.1	953.9	351.0	108.9	2,701.4	1,147.3	408.2	585.8	258.1	45.4	3,629.6	1,557.9	534.6
07/29 - 08/12	960.0	266.4	51.0	461.1	222.4	57.8	1,589.4	622.1	251.8	334.9	131.1	25.3	2,174.0	844.9	358.1
08/12 - 08/26	386.6	111.6	21.7	328.7	126.0	32.8	944.2	428.4	187.6	157.5	82.7	18.5	1,270.6	588.3	278.2
08/26 - 09/09	184.4	51.9	4.5	189.4	77.2	27.4	574.0	287.1	161.5	89.5	47.1	13.5	775.3	414.8	248.4
09/09 - 09/23	100.4	25.9	0.0	132.2	59.2	23.5	400.0	237.4	145.9	74.4	34.4	13.6	585.3	370.1	236.5
09/23 - 10/07	109.0	16.2	2.5	113.6	81.9	45.9	382.0	241.8	189.1	85.6	44.9	20.5	564.9	378.0	303.2
10/07 - 10/21	199.4	7.8	0.0	170.0	97.7	57.9	529.0	269.0	187.6	129.3	53.1	29.1	742.8	431.9	307.5
10/21 - 11/04	186.4	5.7	0.0	177.3	86.0	73.9	536.3	258.8	211.7	134.9	51.4	32.0	738.0	413.6	346.7
11/04 - 11/18	465.7	7.7	0.0	212.0	84.7	65.1	913.7	255.8	199.6	256.6	59.6	31.0	1,157.0	411.4	334.0
11/18 - 12/02	760.3	6.0	0.0	215.5	84.5	59.0	1,246.2	272.9	185.7	511.1	57.6	29.1	1,798.7	429.1	306.8
12/02 - 12/16	699.8	2.4	0.0	162.7	75.3	45.7	1,085.6	245.1	184.8	370.9	51.1	26.9	1,570.9	382.8	280.3
12/16 - 12/30	242.5	0.0	0.0	131.4	69.0	44.8	614.5	224.3	194.5	189.3	47.1	25.4	872.0	355.9	265.5