WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Flow Summary of Ten Streams and Irrigation Ditches in the Upper Yakima River Basin

A Component of the Upper Yakima River
Suspended Sediment TMDL

August 2000

Publication No. 00-03-028
Printed on Recycled Paper

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Flow Summary of Ten Streams and Irrigation Ditches in the Upper Yakima River Basin

A Component of the Upper Yakima River Suspended Sediment TMDL

by
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and
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August 2000

Water Body Numbers:
WA-39-1037, WA-40-1400, WA-41-3000, WA-42-1035, WA-43-1025, WA-44-1012

Publication No. 00-03-028

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Abstract

During the 1999 irrigation season (April through October), the Washington State Department of Ecology (Ecology) Stream Hydrology Unit (SHU) measured streamflow on 10 selected streams and irrigation returns in the Upper Yakima River Basin. These measurements and corresponding rating curves were completed to support the Ecology Upper Yakima River Total Maximum Daily Load (TMDL) Study. The objectives of this TMDL were to:

◊ Evaluate the suspended sediment load in the Upper Yakima River during the irrigation season.

◊ Evaluate the contributions from the major tributaries.

◊ Set suspended sediment TMDL targets for the upper river basin during the irrigation season.

◊ Evaluate the effect of the upper basin TMDL targets on the lower basin suspended sediment TMDL (Dickes and Joy, 1999).

The ten sites assigned to SHU were on Crystal Creek, Swauk Creek, Dry Creek, Packwood Ditch, Manastash Creek, Reecer Creek, Sorenson Creek, Naneum Creek, Umtanum Creek, and Wenas Creek.

Four to seven instream wading measurements were done at each station covering the full range of flows for the irrigation season. All measurements and calculations were done following the U.S. Geological Survey's Mid-section method of streamflow measurement (USBR, 1997). The measured flows ranged from a high of 143 cfs to a low of 0.6 cfs. Regression analysis was used in the development of rating curves and daily discharge averages. The rating curves were developed by regressing instantaneous flow measurements to staff gage readings. These regressions produced curves with r^2 values ranging from 0.99 to 0.60. The daily discharge averages were calculated from the continuous stage records. These continuous records were regressed against Ecology staff gage readings. This produced r^2 values ranging from 0.96 to 0.99.

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Introduction

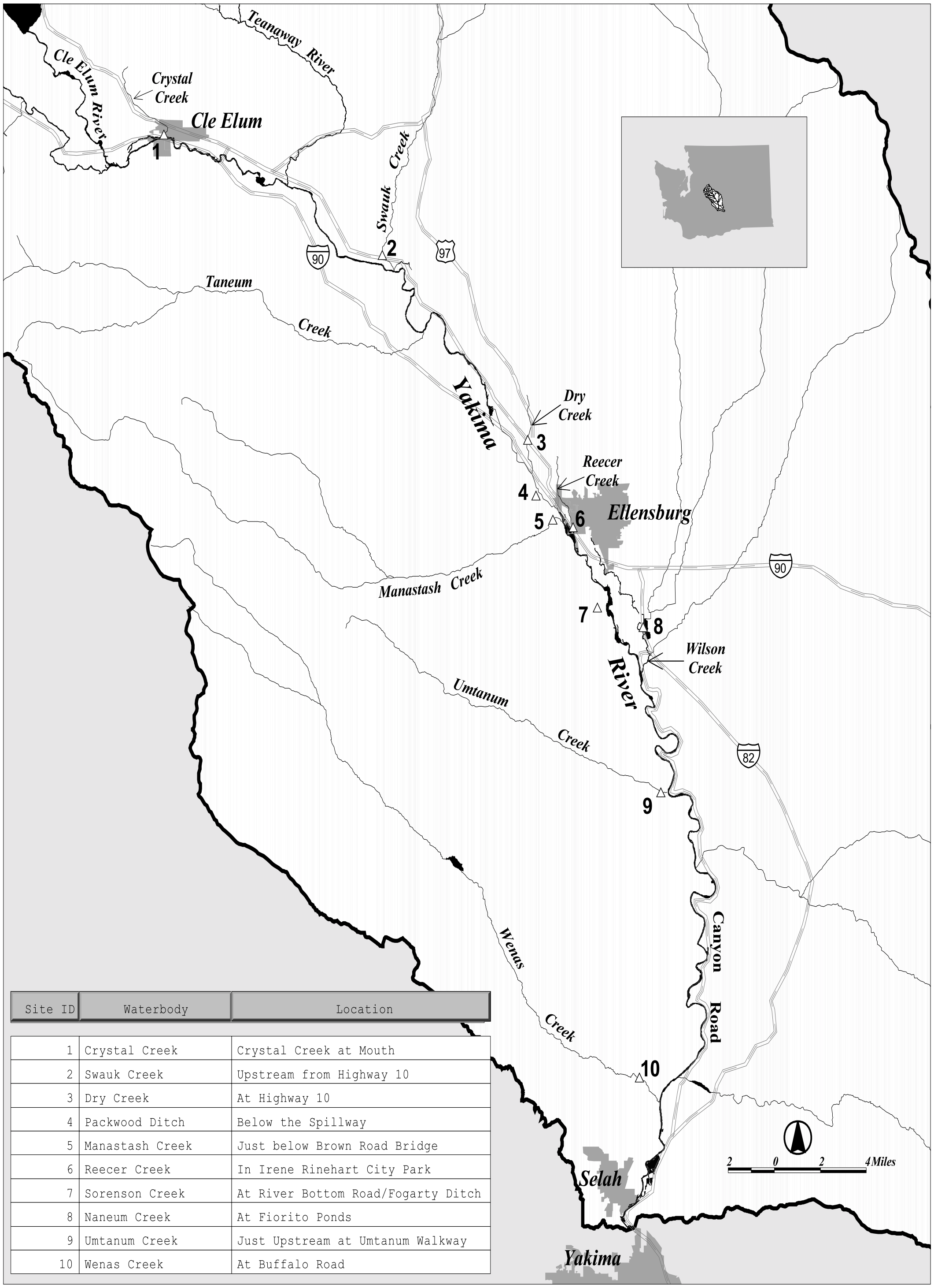
The Stream Hydrology Unit (SHU) was asked to provide streamflow data for ten sites in support of the Ecology Upper Yakima River Suspended Sediment Total Maximum Daily Load Study (TMDL). The objectives for this TMDL were to evaluate the suspended sediment load in the Upper Yakima River during the irrigation season, evaluate contributions from the major tributaries, set suspended sediment TMDL targets for the upper river basin during the irrigation season, and evaluate the effect of the upper basin TMDL targets on the lower basin suspended sediment TMDL (Dickes and Joy, 1999). This project encompassed the 1999 irrigation season of April through October and extended from Cle Elum, Washington downstream to Selah, Washington (Figure 1).

Of the selected project streams and ditches, ten were assigned to SHU. The assigned sites were:

◊ Crystal Creek
◊ Swauk Creek
◊ Dry Creek
◊ Packwood Ditch
◊ Manastash Creek
◊ Reecer Creek
◊ Sorenson Creek
◊ Naneum Creek
◊ Umtanum Creek
◊ Wenas Creek.

The site descriptions are presented in Appendix A.

All stream stations were located as close to their confluence with the Yakima River as possible, and all irrigation ditch sites were located as close to their returns as possible. Cross-section quality, backwater affects, access, and vulnerability to vandalism were all considerations in the final siting of the stations. Christopher Evans and Art Larson, with field support from SHU staff, undertook the flow monitoring of these stations.



Site ID	Waterbody	Location
1	Crystal Creek	Crystal Creek at Mouth
2	Swauk Creek	Upstream from Highway 10
3	Dry Creek	At Highway 10
4	Packwood Ditch	Below the Spillway
5	Manastash Creek	Just below Brown Road Bridge
6	Reecer Creek	In Irene Rinehart City Park
7	Sorenson Creek	At River Bottom Road/Fogarty Ditch
8	Naneum Creek	At Fiorito Ponds
9	Umtanum Creek	Just Upstream at Umtanum Walkway
10	Wenas Creek	At Buffalo Road

Figure 1. Upper Yakima TMDL Flow Stations.

Methods

With the exception of Dry Creek and Umtanum Creek, each station consisted of a staff gage and a continuous data logger programmed to record stage height every fifteen minutes. The stage at the remaining two stations was tracked by recording the staff gage value, as well as, corresponding tape down measurements from a reference point (RP). An RP was established at all 10 stations to confirm staff gage and sensor readings. Stations with continuous stage height recorders were equipped with Unidata Starlog ™ dataloggers and either one-meter Unidata capacitance probes or two-meter Unidata pressure transducers. The capacitance probes measured stage height in meters and the pressure transducers measured in pounds per square inch (psi).

During each site visit the most recent data files were downloaded into a laptop computer and the logging system, as well as the files, were checked for errors. The staff gage reading and a tape down measurement were recorded and, if needed, a flow measurement was completed. The datalogger downloads were transferred to an Excel spreadsheet upon return to the office. Streamflow was measured using a Swoffer ™ velocity meter and a top-set wading rod. Velocities were measured within sections, or cells, across the distance of a cross-section. Each cross-section was divided into approximately 20 cells following the U.S. Geological Survey (USGS) Mid-section method for instream flow measurements (USBR, 1997). Following this protocol, each measured cell did not exceed more then ten percent of the overall flow. In ideal flow conditions, flow measurements are assumed to have a built in error of +/- 5 percent. To limit this assumed error, we measured velocities of each cell until two readings within .05 ft./s were attained. All recorded velocities were then averaged to give the mean velocity for the given cell (Hopkins, 1999).

The flow rating curves were developed using regression analysis of the stage and instantaneous flow measurements from each site. The conversion of datalogger records into streamflow was a two step process. First, we regressed the staff gage readings against their respective data logger records and then the raw data logger records were converted to stage in feet (as would have been measured on the staff gage). The next step was to develop flow-rating curves by regressing our instantaneous flow measurements against their respective staff gage readings. The resulting curves (equations) were used to convert stage (ft) to streamflow (cfs). Where the rating curve did not cover the full range of the recorded stage, the curve was extended to equal twice the measured highest or lowest flow. Any flows outside this range are qualified as an estimate. These estimated flows can be identified by the bold type in the daily average tables (Appendix B).

For this study, all rating curves were developed from a correlation between discharge measurements and staff gage readings. Daily discharge averages were calculated by applying these rating equations to their respective station continuous records.

Quality Assurance

Based on product specifications, the theoretical precision of the capacitance probes is +/- 0.003 ft., while that of the pressure transducers is less, about +/- 0.006 ft. Electrical "noise" and aged equipment lower the transducer accuracy. The staff gage versus transducer regressions demonstrate the accuracy of each probe for the study period. In most cases, the data logger record is in error by one percent or less over the one to two foot range of stage encountered during the study. Likewise, based on experience, the reading of the staff gage is accurate to within +/- 0.01 ft. Based on a regression of staff gage versus probe, the conversion of the continuous data logger records to feet (as read from the staff gage) may have increased the potential error from +/- 1 to +/- 2 percent. However, the errors associated with the conversion of stage in feet to streamflow in cfs (the stream rating) possesses a minimum error of +/- 5 percent and overshadows any of the potential equipment errors.

The majority of error involved with a discharge measurement is in the velocity measurement. The actual instream discharge measurements were made using the Mid-section method of stream flow measurement used by the USGS. In general, the cross-section is divided into cells so that a maximum of 5% to 10% of the total discharge passes through any single cell. In practice, the cross-section is divided into about 20 cells when stream width allows. The width of the individual cells may vary in keeping with the 5% to 10% discharge criteria. The velocity is measured at 0.6 ft of the stream depth when the total depth is less than 1.5 ft. and at 0.2 ft and 0.8 ft of the stream depth when the depth is greater than 1.5 ft (Hopkins, 1999).

Results

Rating an irrigation return system presented some unique problems. During this study the random manipulation of irrigation control gates, backwater, and apparent exponential in-stream weed growth each played a role in the final development of the individual station flow curves.

United States Bureau of Reclamation (USBR) flow records for the Yakima River were used to determine mainstem flow influences on project stations. For the sites where weed growth was an issue, flow curves were split into “flow before weeds” and “flow after weeds”. The determination of when weed growth begins to impact the flow of a stream is a gray area. So, to determine the point when the project streams were impacted by weed growth, we assumed discharge increased with an increase in stage height. With this assumption, we split the rating curves at the point where discharge decreased and stage height increased or remained the same. In doing so, splitting the curves created a transition area between the period of no weeds and the period of weed growth. This transition period is addressed by using the measured transition flow as the high point on the low curve and as the low point on the high curve. This extends the rating curve through the period of transition providing an equation for continuous record calculations within the transition range.

Estimates of zero flow were done at stations with extreme low-flows. Using zero flow data points for Crystal Creek and Wenas Creek improved the rating curve throughout the range of the low flows. These estimates were made by subtracting the thalweg depth of the cross-section from the staff gage and recording that calculated point as an assumed zero flow point on the rating curve. All daily discharge averages are presented in Appendix B.

Crystal Creek

The daily average discharge of Crystal Creek ranged from about 20 cfs at the start of the study period to less than 0.3 cfs during late summer. Our rating curve encompassed most of this range, with actual flow measurements ranging from a high of 14 cfs to a low of 0.6 cfs. In addition, a stage of zero flow was estimated to improve the low end of the curve. The regression of streamflow against stage, using four wading measurements and the zero flow stage, produced a rating equation with an r^2 of 0.999 (Figure 2). The correlation between the staff gage and the data logger was also good, resulting in an equation with an r^2 of 0.998 (Figure 3). Throughout the study, the Crystal Creek continuous record showed few abrupt fluctuations in stage height. Two apparent flood events in June had flows increasing from less than one cfs to about 20 cfs over a period of two to three days. However, streamflow declined to pre-flood levels within two days. In general, the streamflow of Crystal Creek declined through the spring and summer of the study, increasing slightly in early fall. We found no fluctuations in the streamflow that could be interpreted as upstream flow diversions and we detected no problems associated with weed growth at this station.

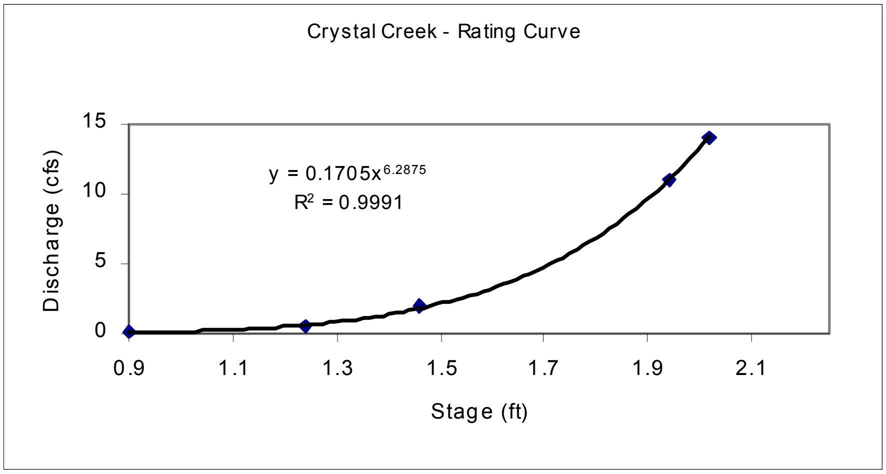


Figure 2. Crystal Creek Rating Curve. The curve was calculated from four wading measurements and an assumed zero flow point. The discharge measurements ranged from 0.6 cfs to 14 cfs. The stage of zero flow was estimated at 0.90ft.

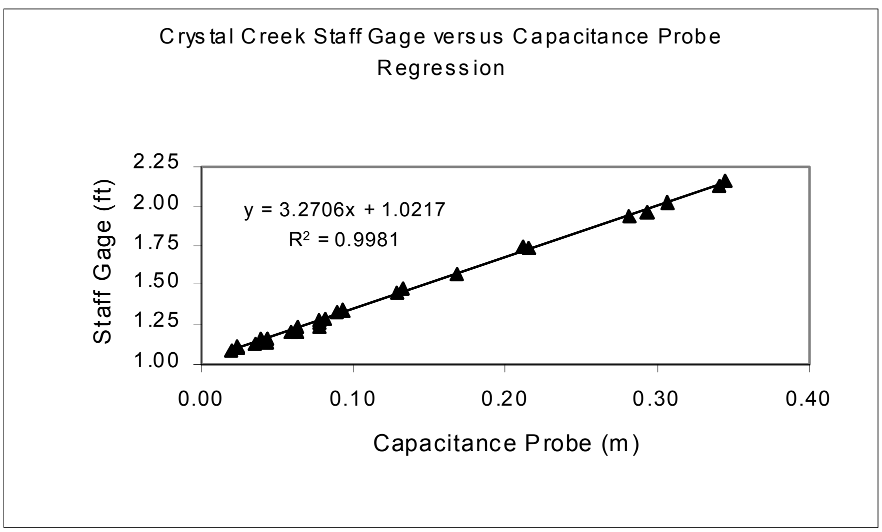


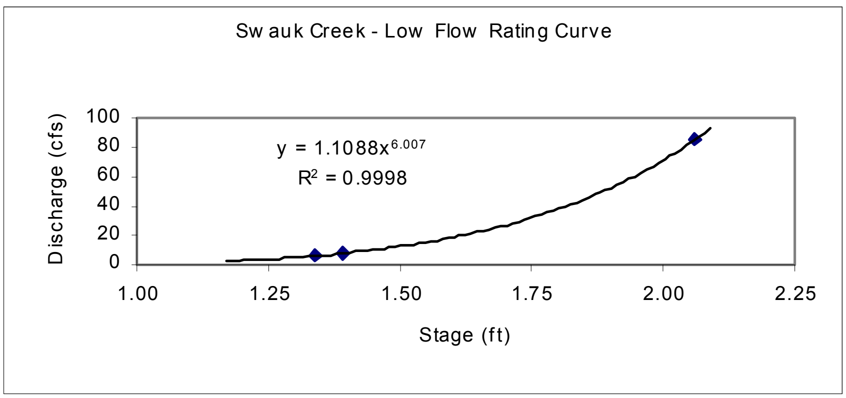
Figure 3. Crystal Creek staff gage versus probe regression. This regression relates all recorded staff gage readings to their corresponding probe values and is used to correlate the accuracy of the probe with the staff gage readings. A strong correlation gives confidence to the continuous record which can then be used to calculate hourly and daily discharge averages.

Swauk Creek

The daily average discharge of Swauk Creek ranged from a high of 384 cfs during April (spring snowmelt) to a low of about 7 cfs in late September. During the study, we made, five wading measurements ranging from a high of 143 cfs to a low of 6.3 cfs. During late

April, Swauk Creek was unwadable and instream discharge measurements were not possible. Therefore, no actual flow measurements were attained during the peak snowmelt runoff. Because flow measurements were not possible during these peaks, we recommend flagging the data that exceeds two times the measured highest flow of 143 cfs as an estimate.

Two flow curves were developed to rate Swauk Creek (Figure 4). It was decided that the use of two flow curves at Swauk Creek created a better correlation throughout the measured range of discharge and subsequently improved the lower end of the rating curve where the majority of flow was concentrated. The low flow curve was used to calculate streamflow for all stage height readings below 2.0 ft. and has an r^2 of 0.999. The high flow curve was used to calculate daily flow for all stage height readings above 2.0 ft and has an r^2 of 0.992. The relationship between the pressure transducer readings (psi) and the staff gage readings (ft.) was also good with an r^2 of 0.964 (Figure 5).



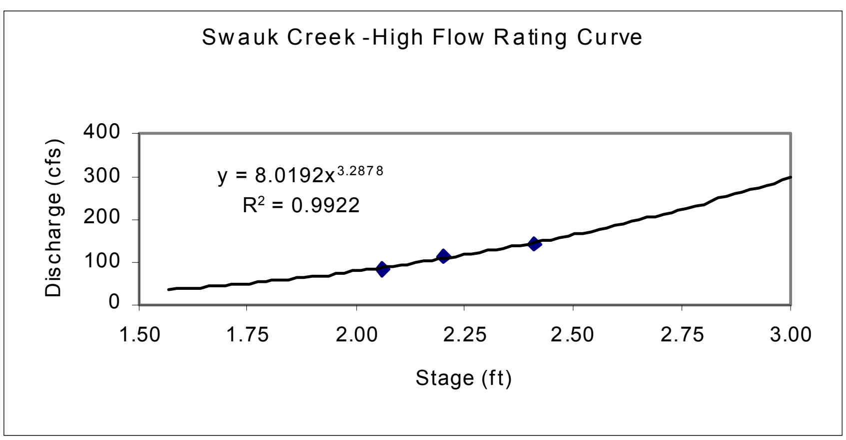


Figure 4. Swauk Creek rating curves. The low flow curve is used to rate flows with a stage below 2.0 ft. The high flow curve is used to rate flows with a stage above 2.0 ft. The high point on the low curve is used as the low point on the high curve.

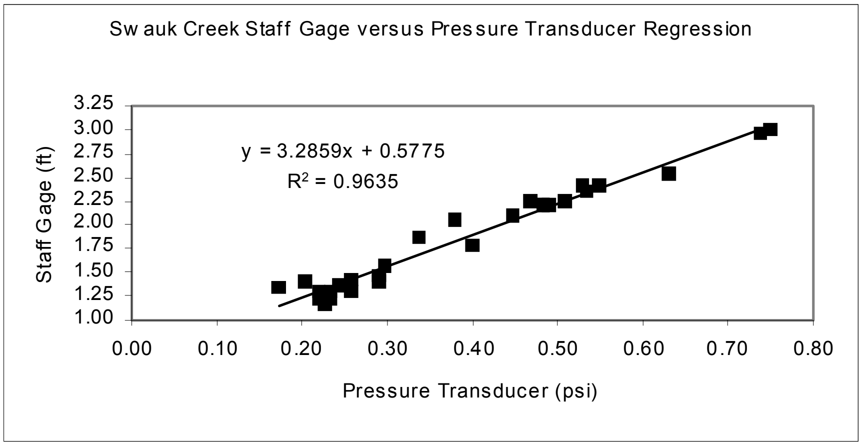
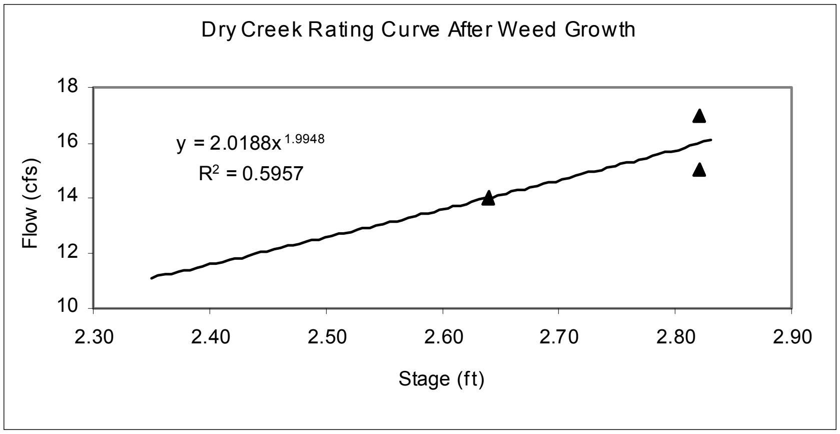


Figure 5. Swauk Creek staff gage versus transducer regression. This regression relates all recorded staff gage readings to their corresponding probe values and is used to correlate the accuracy of the probe with the staff gage readings. A strong correlation gives confidence to the continuous record for hourly and daily cfs calculations.

Dry Creek

The discharge at Dry Creek ranged from a low of 1.5 cfs in April to a high of 19 cfs by early summer (at the beginning of the irrigation season). Seven wading measurements were taken to develop the rating curve. Dry Creek was one of two stations that did not have a continuous recorder installed. Therefore, hourly and daily averages were not calculated. In late June, the channel became choked with long stranded weeds. To improve flow measurement quality, we cleared the transect of weeds three feet above and three feet below the measured section prior to each wading measurement. The rating curve was split into a “Before Weed Growth” curve and an “After Weed Growth” curve.(Figure 6). All measurements taken before June 6th apply to the “Before Weed Growth” curve and all later measurements apply to the “After Weed Growth” curve. The “Before Weed Growth” curve produced an r^2 of 0.998. The “After Weed Growth” curve produced an r^2 of 0.597.



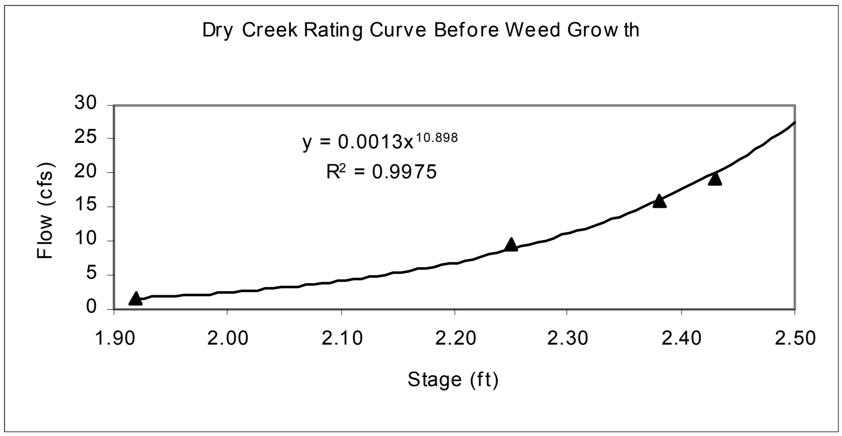


Figure 6. Dry Creek rating curve. The "Before Weed Growth" curve was applied to dates before June 6th and the "After Weed Growth" curve was applied to dates after June 6th.

Packwood Ditch

The daily average discharge at Packwood Ditch ranged from a high of 60 cfs in April to a low of 2 cfs in December. From May until the end of the project in October, flows fluctuated in the low 50 cfs range. Six wading measurements were taken in the spillway just upstream from the station ranging from a high of 58 cfs to a low of 37 cfs. Moss growth on the bottom of the spillway influenced the flow measurements at this site. The shallow depth and high velocities in the spillway made it difficult to detect interference between the moss and the velocity meter. Because of this, one of the six wading measurements was dropped from the rating curve. This flow measurement fell well below the curve and was a duplicate flow of a previously measured stage. The low cfs is believed to be the direct result of moss interfering with the velocity measurement. An r^2 of 0.980 for the included points strengthens the argument for the excluded flow being an erroneous measurement (Figure7). Subsequently, daily averages were calculated without the outlying data point.

The staff gage versus transducer regression produced an r^2 of 0.988 (Figure 8). A small seasonal stream of <1 cfs entered Packwood Ditch below our gaging station. This small input was not considered significant enough to be included as part of the discharge of Packwood Ditch.

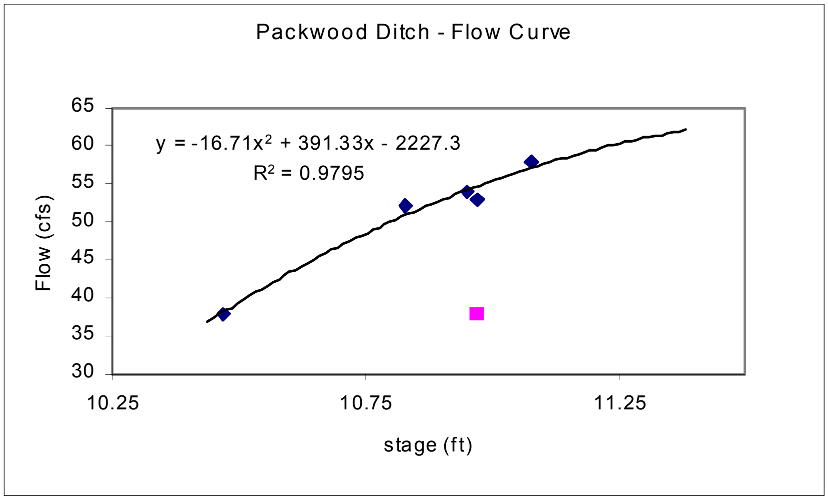


Figure 7. Packwood Ditch rating curve. The curve was calculated using wading measurements ranging from 38 cfs to 58 cfs. The outlying data point is believed to be an erroneous flow measurement and was not included in the rating calculation.

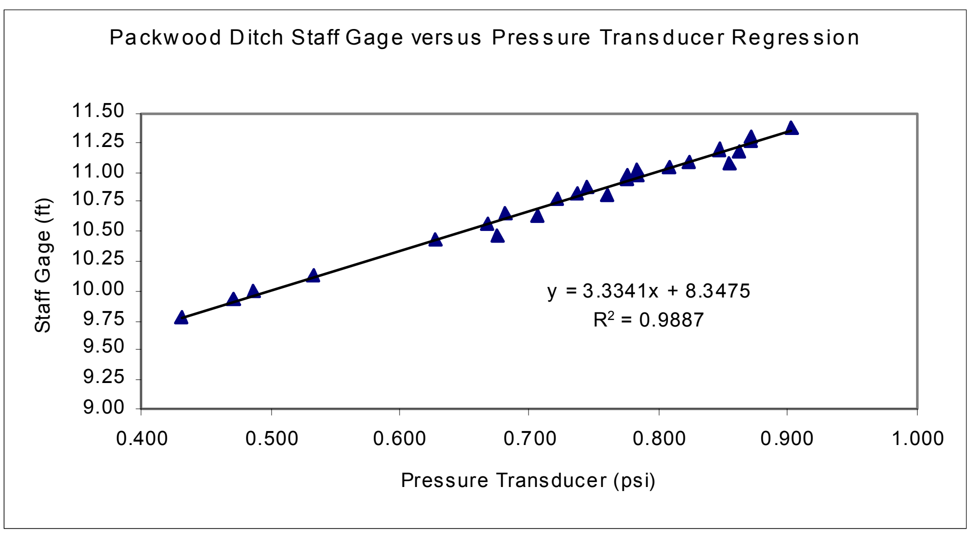


Figure 8. Packwood Ditch staff gage versus pressure transducer regression. . This regression relates all recorded staff gage readings to their corresponding probe values and is used to correlate the accuracy of the probe with the staff gage readings. A strong correlation adds confidence to the continuous record for hourly and daily cfs calculations.

Manastash Creek

Daily discharge averages at Manastash Creek ranged from a high of nearly 195 cfs in late May to a low of about 6 cfs in late July. Our rating curve included six wading measurements ranging from a high of 138 cfs to a low of 7 cfs. The rating curve produced an r^2 of 0.998 (Figure 9). The staff gage versus the pressure transducer regression produced an r^2 of 0.991 (Figure 10).

The only notable event in the continuous record of Manastash Creek occurred in late July. At this time, the stage height decreased nearly 0.5 meters (as measured by the capacitance probe) in about a one-week period. Not having knowledge of the channel upstream from the station, we assume the drop in stage is related to irrigation control gate changes.

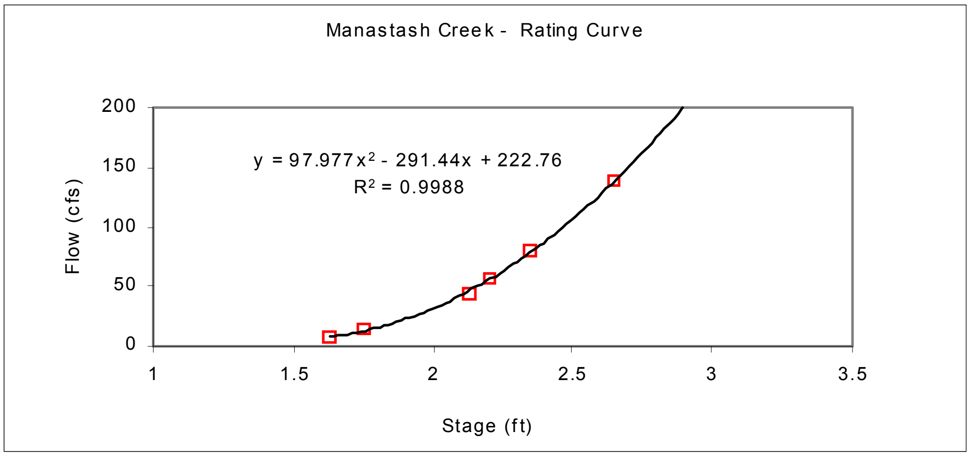


Figure 9. Manastash creek rating curve. Six flow measurements were used to develop this curve. Measurements ranged from 7.3 cfs to 138 cfs.

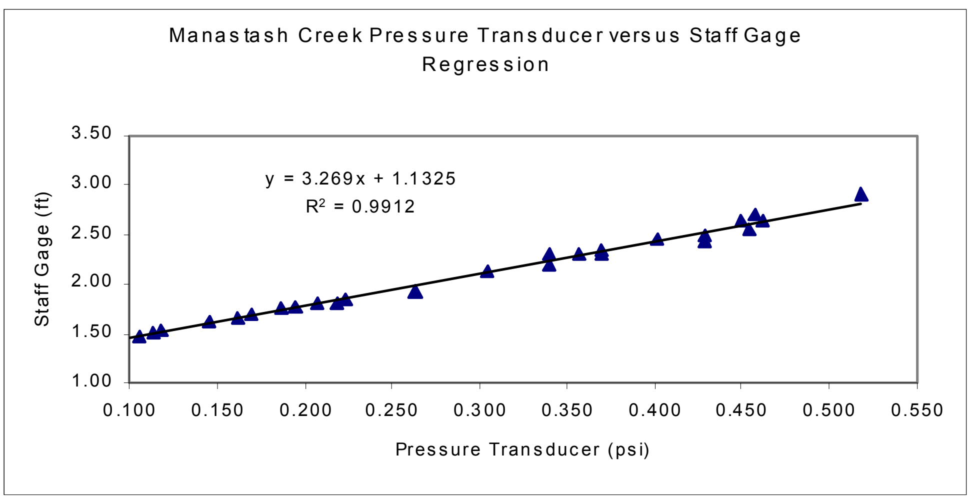


Figure 10. Manastash Creek pressure transducer versus staff gage regression. This regression relates all recorded staff gage readings to their corresponding probe values and is used to correlate the accuracy of the probe with the staff gage readings. A strong correlation gives confidence to the daily and hourly discharge calculations.

Reecer Creek

The daily average discharge of Reecer Creek ranged from a high of about 68 cfs to a low of about 4 cfs. Seven wading measurements were taken at Reecer Creek ranging from a low of 7 cfs to a high of 47 cfs. One measurement was taken when the Yakima River had risen to a point where it influenced the flow at the Reecer Creek station. This created a pooled condition at the station that produced artificially high staff gage readings and lowered velocity readings. From the remaining six measurements a rating equation was developed with an r^2 of 0.917 (Figure 11). The staff gage versus the capacitance probe regression produces an $r^2$of 0.989 (Figure 12).

When this station was installed, Reecer Creek was flowing unobstructed. At that time, we believed backwater from the Yakima River would not effect Reecer Creek as far upstream as our datalogger. We were wrong. On subsequent visits, we found the Yakima River had backed water up to our gage several times. In addition to backwater from the Yakima River, the gaging station was also impacted by the operation of an upstream diversion dam. When the majority of Reecer Creek was being diverted away from the Yakima River, the effects of backwater reached further upstream.

The combination of occasional high flows in the Yakima River and the periodic changes of the diversion dam created ever-changing flow conditions in Reecer Creek while maintaining similar stage heights at the station. To determine the backwater effect of the Yakima River on the station, flow records from the United States Bureau of Reclamation (USBR) were consulted. From this flow record we determined that backwater did not have an effect on the recorded stage until the flow of the Yakima River exceeded approximately 4000 cfs (Figure 13). Above this flow, we assumed that backwater caused a linear increase in the stage of Reecer Creek as the streamflow of the Yakima increased. From a simple graph of daily flow of the Yakima River versus the recorded stage of Reecer Creek, we estimated the stage of Reecer Creek increased approximately 0.033 ft. for every 100 cfs increase in the Yakima River (above 4000 cfs). Therefore, to correct for the backwater, we subtracted 0.033 ft. per 100 cfs >4000 cfs from the stage of Reecer Creek. As an example, if the Yakima River daily mean flow was 4800 cfs, we subtracted 0.264 ft. (8 times 0.033) from the stage for each record for that day. Daily averages for days when the station was affected by backwater are identified in the daily tables (Appendix B).

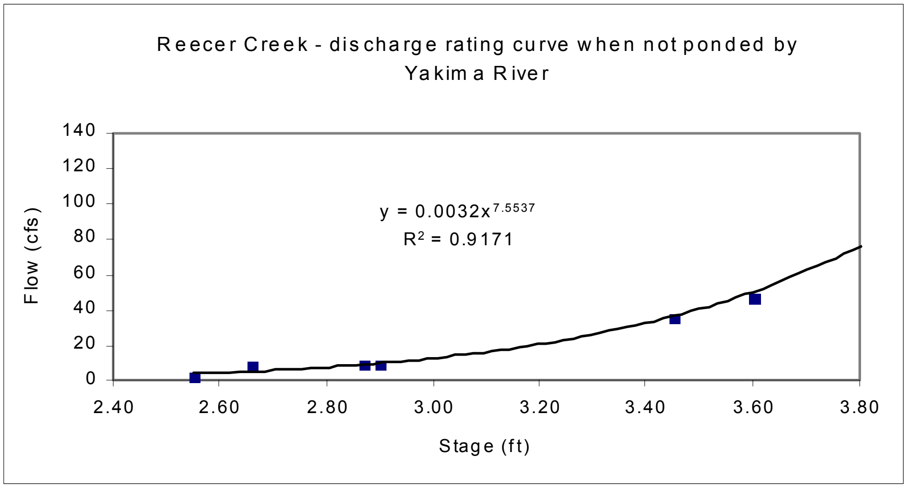


Figure 11. Reecer Creek rating curve. The curve is developed from flows that were not impacted by backwater from the Yakima River.

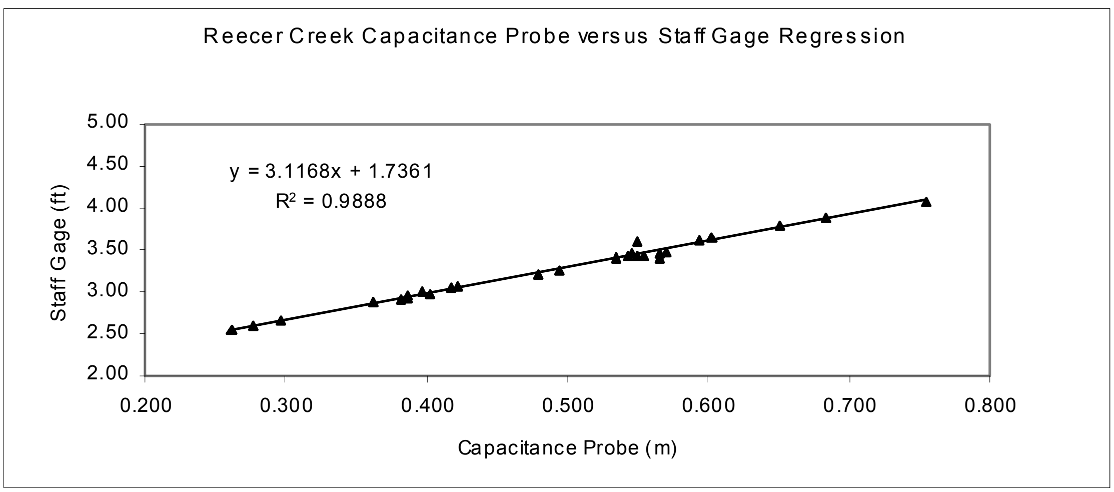


Figure 12. Reecer Creek capacitance probe versus staff gage regression. This regression relates all recorded staff gage readings to their corresponding probe values and is used to correlate the accuracy of the probe with the staff gage readings. A strong correlation gives confidence to the daily and hourly discharge calculations.

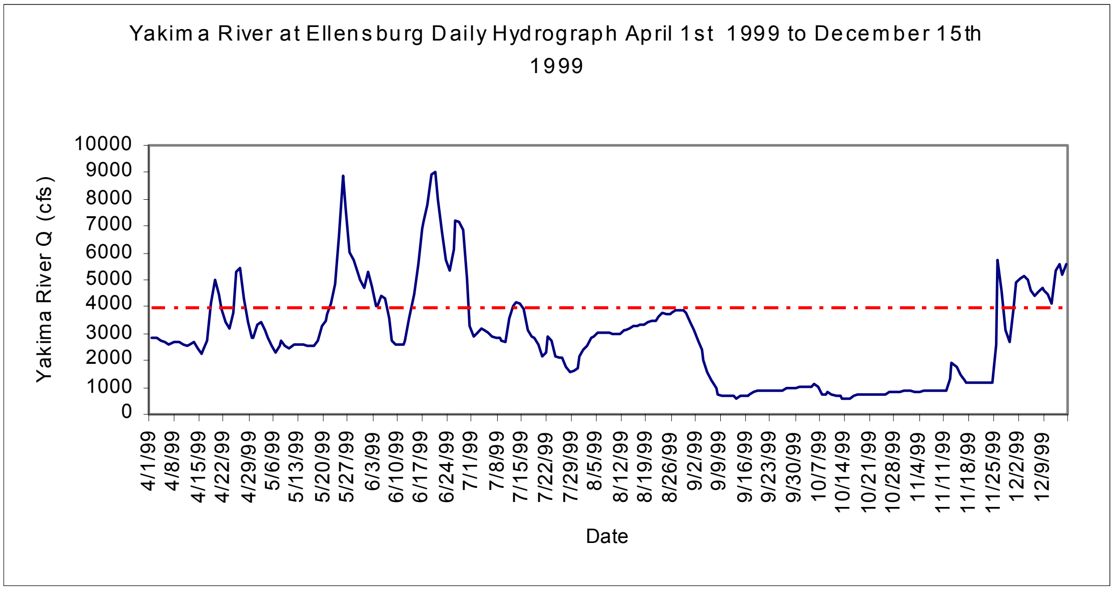
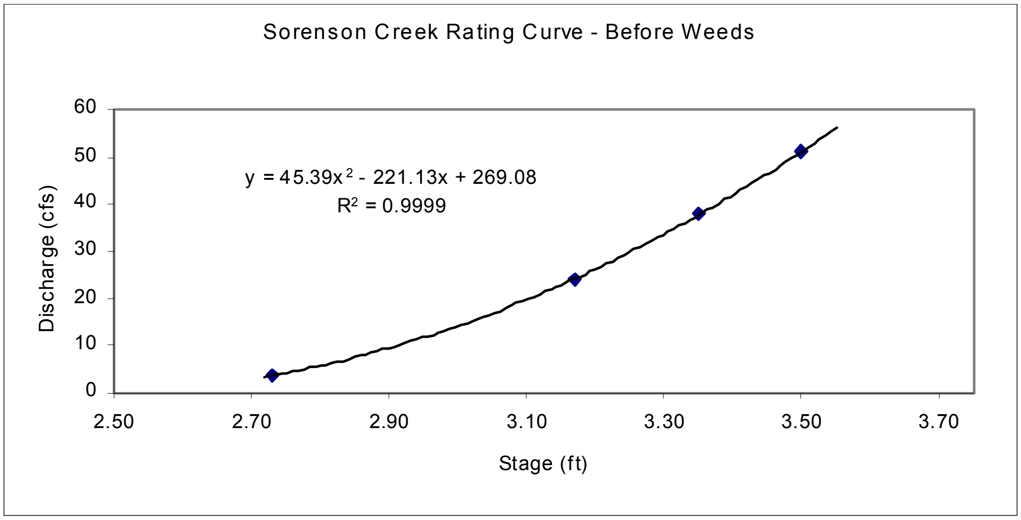


Figure 13. Yakima River at Ellensburg Daily Average Hydrograph. Graphed data is taken from USBR gaging station (ELNW). ELNW is located on the Yakima River approximately 1 mile upstream from the confluence with Reecer Creek. The 4000 cfs line is an estimate of when backwater began to affect the Reecer Creek station. The time periods when the Yakima River exceeds 4000 cfs are the periods when the Reecer Creek stage height is adjusted 0.033 ft per 100 cfs. The time period is scaled in 7-day increments.

Sorenson Creek at Fogarty Ditch

The average daily discharge of Sorenson Creek ranged from a high of about 94 cfs in July to a low of about 6 cfs at the beginning of the project. Seven wading measurements were taken at this site ranging from a low of 3.7 cfs to a high of 53 cfs. Beginning in July, instream weed growth began to affect our discharge determination. Because of this influence, the rating curve was split between " Before Weeds" and "After Weeds" (Figure 14). The "Before Weeds" rating equation produced an r^2 of 0.999. The "After Weeds" rating equation produced an r^2 of 0.995. The regression of staff gage versus pressure transducer produced an r^2 of 0.978 (Figure 15). To find the transition point for flows with weeds and flow without weeds, we assumed that flow increased with an increased stage height. With this assumption we found that around July 7, 1999 this trend reversed. Stage increased while flow remained the same or decreased. Any flows measured before this date were included in the "Before Weeds" curve and any flows measured after this date were included in the "After Weeds" curve.



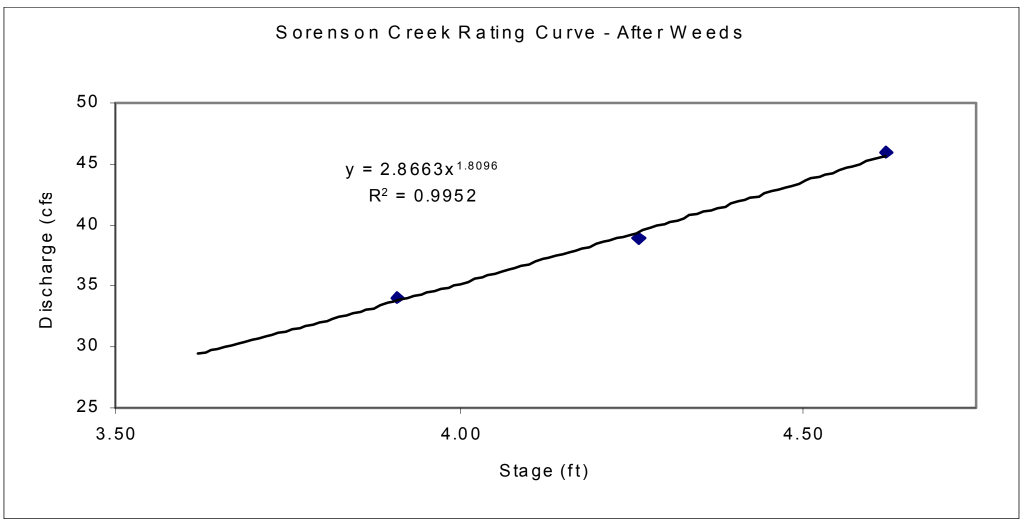


Figure 14. Sorenson Creek at Fogarty Ditch rating curves. Curves were divided on July 7th into flows 'Before Weeds" and flows "After Weeds".

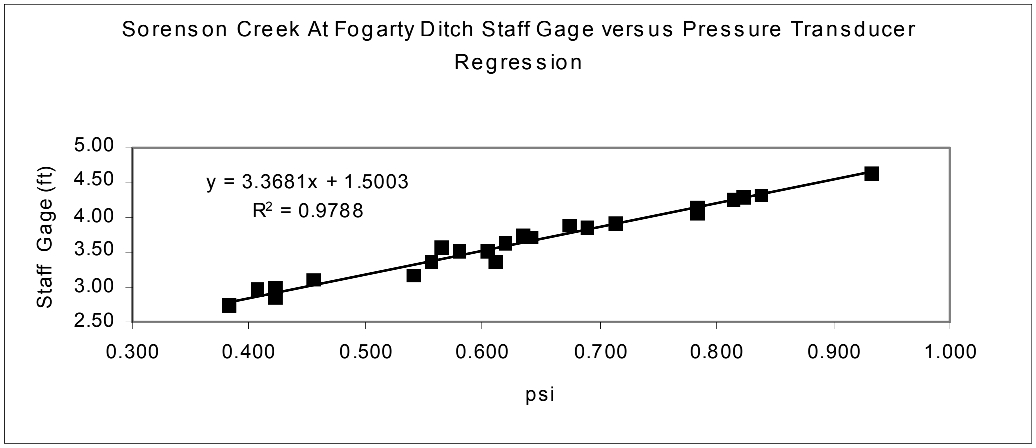


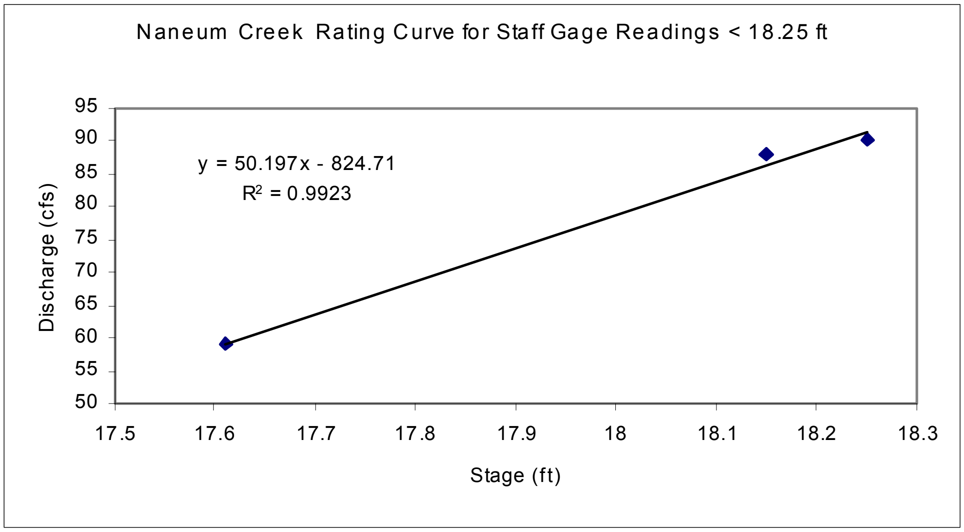
Figure 15. Sorenson Creek at Fogarty Ditch staff gage versus pressure transducer regression. This regression relates all recorded staff gage readings to their corresponding probe values and is used to correlate the accuracy of the probe with the staff gage readings. A strong correlation gives confidence to the daily and hourly discharge calculations.

Naneum Creek

Daily average discharge at Naneum Creek ranged from a high of 333 cfs near the end of May to a low of about 45 cfs in November. Five wading measurements were made ranging from a high of 178 cfs in June to a low of 49 cfs at the beginning of the project. The high turbidity of Naneum Creek kept a bottom growth of weeds undetected until late into the summer. So, to develop a curve for the days that were impacted by weed growth, the curve was divided at a staff reading of 18.25ft (Figure 16). For the curve of staff readings >18.25ft produced an r^2 of .738 and the curve for staff readings < 18.25ft produced an r^2 of .992. The regression of staff gage versus the data logger records resulted in an r^2 of 0.958 (Figure 17).

Small discrepancies in stage and pressure transducer readings were detected early in the project. However, these discrepancies were not attributed to weed growth until mid summer. The variable transducer readings were thought to be caused by sediment build-up around the probe, but cleaning the probe did not change the logged values. In addition, the variable readings diminished as the stage increased. Unable to find a problem with the equipment, we began looking at the stream for answers.

The cross-section appeared to be ideal for flow measurements with stable banks and a good bottom consisting of loose gravel and fines. At the start of the study, the bottom appeared free of weeds. Beginning in late July, however, a heavy growth of long stranded weeds became very prominent within the cross-section. It was at this time that we assumed the station discrepancies were a result of the weed growth.



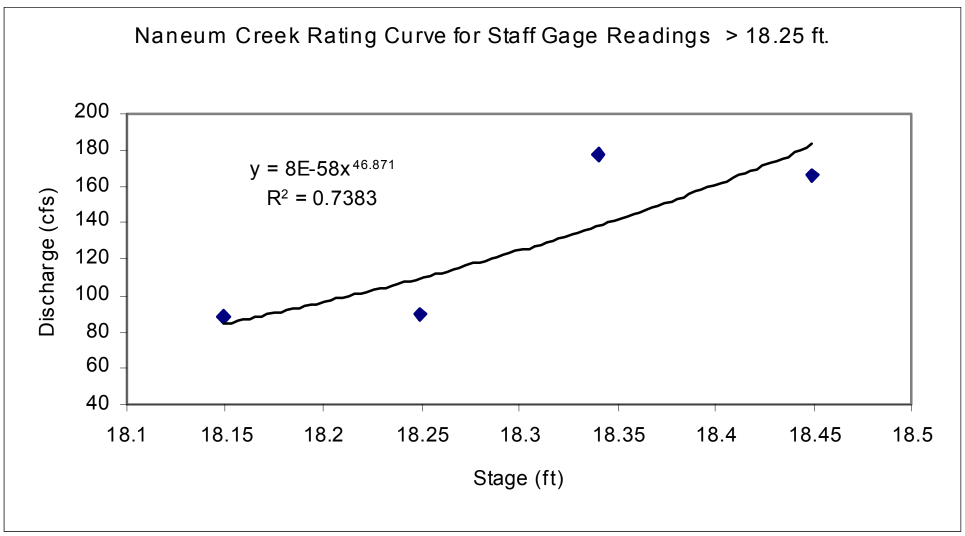


Figure 16. Naneum Creek rating curves. The rating curve has been divided into flows that exceed 18.25 ft. on the staff gage and flows that are below 18.25 ft. The high data points on the low curve are used as the low data points on the high curve.

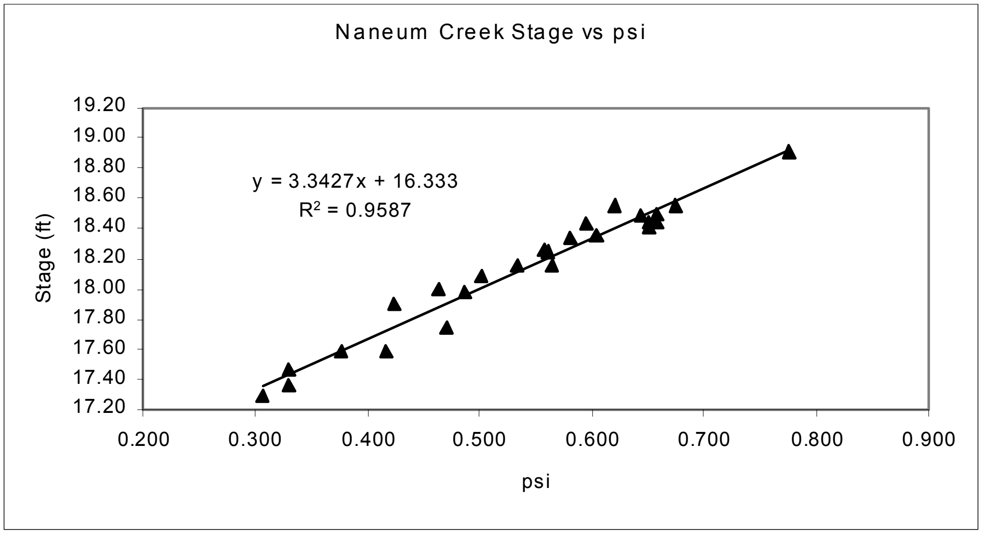


Figure 17. Naneum Creek pressure transducer versus staff gage regression. This regression relates all recorded staff gage readings to their corresponding probe values and is used to correlate the accuracy of the probe with the staff gage readings. A strong correlation gives confidence to the daily and hourly discharge calculations.

Umtanum Creek

Umtanum Creek was the second of the two stations without a continuous recorder. Measured flows ranged from a high of 13.7 cfs at the beginning of the project to a low of 0.7 cfs at the end of the summer. Four wading measurements were taken to develop a rating equation with an r^2 of 0.990 (Figure 18). This site showed a constant decline in stage until October when it leveled out very near zero flow.

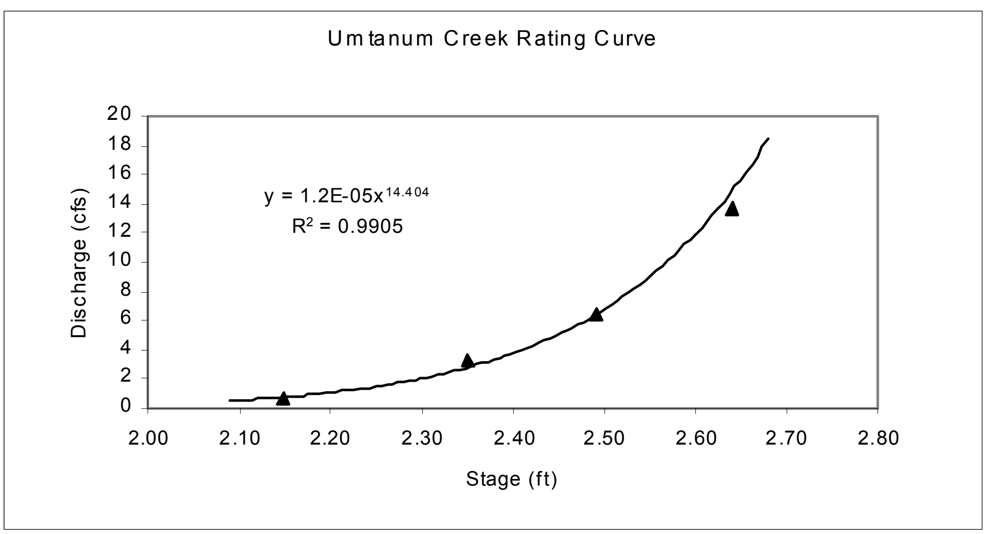


Figure 18. Umtanum Creek Rating Curve. Four wading measurements were taken ranging from a high of 13.7 cfs to a low of 0.7 cfs.

Wenas Creek

Daily average discharge at Wenas Creek ranged from a high of 147 cfs in late April to a low of almost zero in early July. The measured flows ranged from a high of 85 cfs to a low of 2.5 cfs. Five flow measurements and a zero flow point were used to produce a curve with an r^2 of 0.999 (Figure19). For the continuous record, the staff versus probe regression produced an r^2 of 0.993 (Figure 20). The measurement of the late April high flows was not possible due to property access issues. The highest flow, 170 cfs, was within our rating guidelines, not more than two times our maximum measured flow of 85 cfs. Because of this, the rating equation was applied to the entire continuous record.

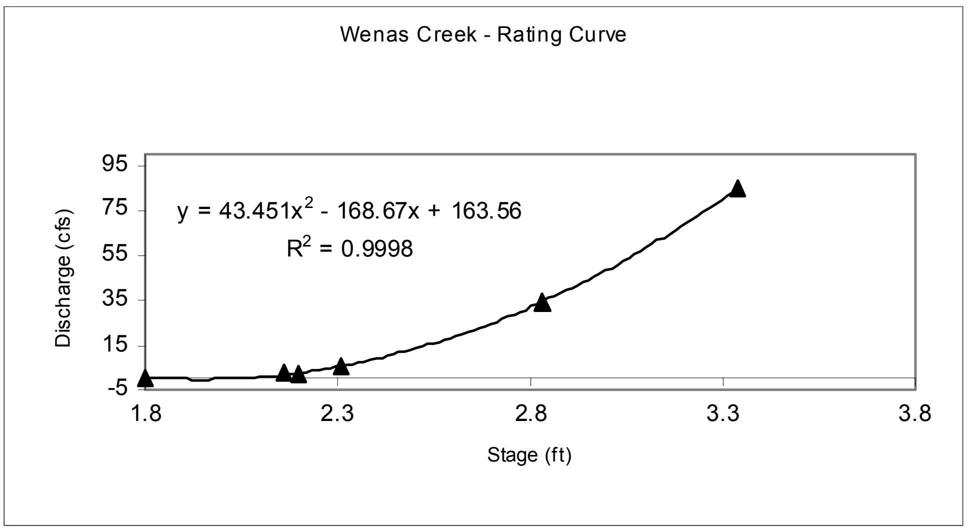


Figure 19. Wenas Creek rating curve. The zero flow point was estimated at 1.8 ft. on the staff gage. Wading measurements ranged from a high of85 cfs to a low 2.5 cfs.

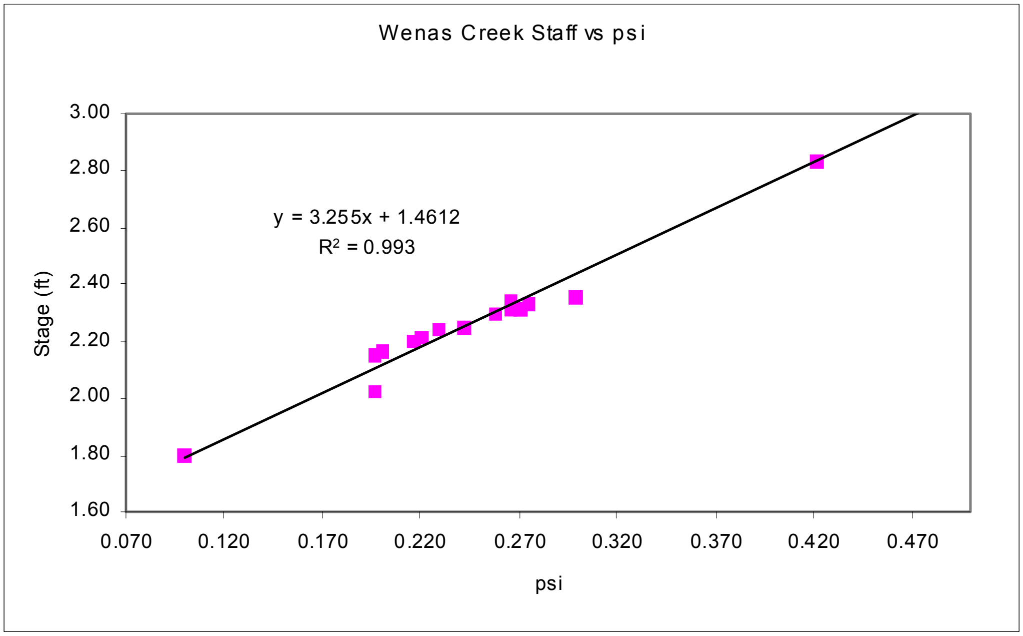


Figure 20. Wenas Creek pressure transducer versus staff gage regression. This regression relates all recorded staff gage readings to their corresponding probe values and is used to correlate the accuracy of the probe with the staff gage readings. A strong correlation gives confidence to the daily and hourly discharge calculations.

References

Dickes, Betsy and J. Joy, October 1999. *Upper Yakima River Suspended Sediment Total Maximum Daily Load, Quality Assurance Project Plan.* Washington State Department of Ecology, Olympia, Washington.

Hopkins, Brad, 1999. Determination of Instantaneous Flow Measurements on Rivers and Streams: Washington State Department of Ecology, Olympia, Washington. Draft Paper. p.6

United State Bureau of Reclamation, 1997. *Water Measurement Manual.* U.S.G.P.O., Denver, Colorado.

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Appendix A

Station Descriptions

1) Crystal Creek runs from near the town of Roslyn, Washington through Cle Elum and empties into the Yakima River from the North. The Crystal Creek station was located just South of Cle Elum. The datalogger, capacitance probe, and staff gage were placed along the right edge of water (REW) just upstream from the box culvert under I-90 to the river.

2) Swauk Creek runs below Blewett Pass, South along Highway 97 into Hidden Valley and empties into the Yakima River at Highway 10. The Swauk Creek station was located just above Highway 10 between Cle Elum and Ellensburg, Washington on property owned by the Kittitas Reclamation District (KRD). The datalogger, pressure transducer and staff gage were placed along the REW approximately 300 ft. upstream from the Highway 10 bridge and 500 ft. from the confluence with the Yakima River.

3) Dry Creek runs South to the Yakima River just West of Ellensburg. The Dry Creek station was located on Highway 10 approximately a quarter mile West of the Highway 10/ Highway 97 interchange. A staff gage was placed beneath the bridge along the LEW and an RP was established on the bridge.

4) Packwood Ditch crosses under the Thorpe Hwy and enters the Yakima River from the South via a privately owned spillway. The Packwood Ditch station was located at the base of this spillway. The datalogger, pressure transducer, and staff gage were placed approximately 30 ft downstream from the spillway fallout. A reference point (RP) was established on a culvert connecting Packwood Ditch with the Yakima River.

5) Manastash Creek runs Northeast under Brown Rd. to the Yakima River. The station was located at Brown Rd. and Peavine Rd. The datalogger, pressure transducer, and staff gage were placed along the REW approximately 100 ft. downstream from the Brown Rd. bridge.

6) Reecer Creek empties into the Yakima River inside Irene Rinehart Park just West of Ellensburg. The station was installed approximately 200 ft upstream from the confluence with the Yakima River between a car bridge and a footbridge. The datalogger, staff gage and capacitance probe were placed in a pool along the left edge of water (LEW) at the base of a 10 ft. box culvert and 3 ft. high control gate.

7) Sorenson Creek flows under River Bottom Rd. and empties into the Yakima River from the Southwest. The station was installed at Acheson Ranch approximately 50 ft. downstream from the inflow of Fogarty Ditch. The data logger, pressure transducer, and staff gage were placed along the REW.

8) <u>Naneum Creek</u> is comprised of a series of irrigation return ditches that consolidate at Fiorito Ponds. The creek crosses beneath I-82 at Fiorito Ponds and approaches the Yakima River from the Northeast. The station was installed at the upstream side of the culvert that crosses beneath I-82. The datalogger, pressure transducer, and staff gage were placed along the LEW beneath a tree approximately 30 ft upstream from the culvert.

9) <u>Umtanum Creek</u> runs from the Southwest and empties into the Yakima River in the Yakima Canyon at the suspension footbridge. This station was located approximately 200 ft. upstream from the railroad tracks. A staff gage was placed along the REW and a RP was established upstream 100 ft. on an abandoned bridge trestle.

10) <u>Wenas Creek</u> empties into the Yakima River from the West just above Selah, Washington. The station was located on private property approximately one mile upstream from the confluence with the Yakima River and was accessed from Buffalo Rd. The datalogger and capacitance probe were placed just below a check dam along the REW and the staff gage was located in the pool closer to the LEW.

Appendix B

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Table 1. Crystal Creek Average Daily Streamflow (cfs) Upper Yakima River TMDL 1999

		Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Day	1	19.5	5.7	1.0	0.5	0.3	0.5	0.6	0.9	1.3
	2	19.2	5.3	1.0	0.5	0.3	0.5	0.5	0.8	1.6
	3	18.3	5.0	0.9	0.6	0.3	0.5	0.5	0.8	1.5
	4	17.8	4.7	0.9	0.5	0.3	0.5	0.5	1.0	1.4
	5	15.7	4.0	0.9	0.5	0.3	0.5	0.6	0.9	1.4
	6	14.4	3.7	0.9	0.5	0.3	0.5	0.6	1.1	1.4
	7	14.2	3.5	0.8	0.5	0.3	0.5	0.6	1.0	1.5
	8	13.7	3.2	0.8	0.5	0.3	0.5	0.6	1.0	1.3
	9	13.1	3.0	0.8	0.5	0.3	0.5	0.5	0.9	1.2
	10	12.3	2.9	0.8	0.5	0.3	0.6	0.7	0.9	1.2
	11	11.5	2.8	0.7	0.4	0.3	0.5	0.7	1.1	3.8
	12	12.1	2.6	0.7	0.4	0.3	0.5	0.6	1.5	3.6
	13	11.3	2.3	0.7	0.5	0.3	0.5	0.7	1.3	2.8
	14	11.4	2.1	0.8	0.5	0.3	0.5	0.6	1.0	2.7
	15	11.6	1.9	0.8	0.5	0.3	0.5	0.6	0.9	3.2
	16	12.4	1.8	0.6	0.4	0.3	0.4	0.6	0.9	-
	17	14.0	1.8	0.8	0.8	0.3	0.4	0.6	0.9	-
	18	16.8	1.8	5.8	0.5	0.3	0.5	0.6	0.8	-
	19	19.9	1.6	18.3	0.4	0.3	0.4	0.6	0.7	-
	20	19.4	1.5	18.6	0.4	0.3	0.4	0.7	0.8	-
	21	17.4	1.3	7.3	0.5	0.3	0.5	0.7	0.8	-
	22	14.9	1.3	1.5	0.4	0.3	0.5	0.7	0.8	-
	23	13.1	1.2	0.6	0.4	0.4	0.5	0.7	0.8	-
	24	11.8	1.2	0.9	0.3	0.3	0.5	0.9	1.0	-
	25	11.2	1.1	5.5	0.3	0.3	0.5	1.2	7.4	-
	26	11.0	1.2	23.9	0.3	0.4	0.5	1.1	4.6	-
	27	10.4	1.1	23.7	0.3	0.4	0.6	0.8	2.3	-
	28	9.1	1.0	15.0	0.3	0.4	0.6	1.3	1.8	-
	29	7.6	1.0	0.9	0.3	0.4	0.5	1.1	1.5	-
	30	6.3	0.9	0.5	0.3	0.4	0.5	0.9	1.4	-
	31	-	0.9	-	0.3	0.5	-	0.9	-	-

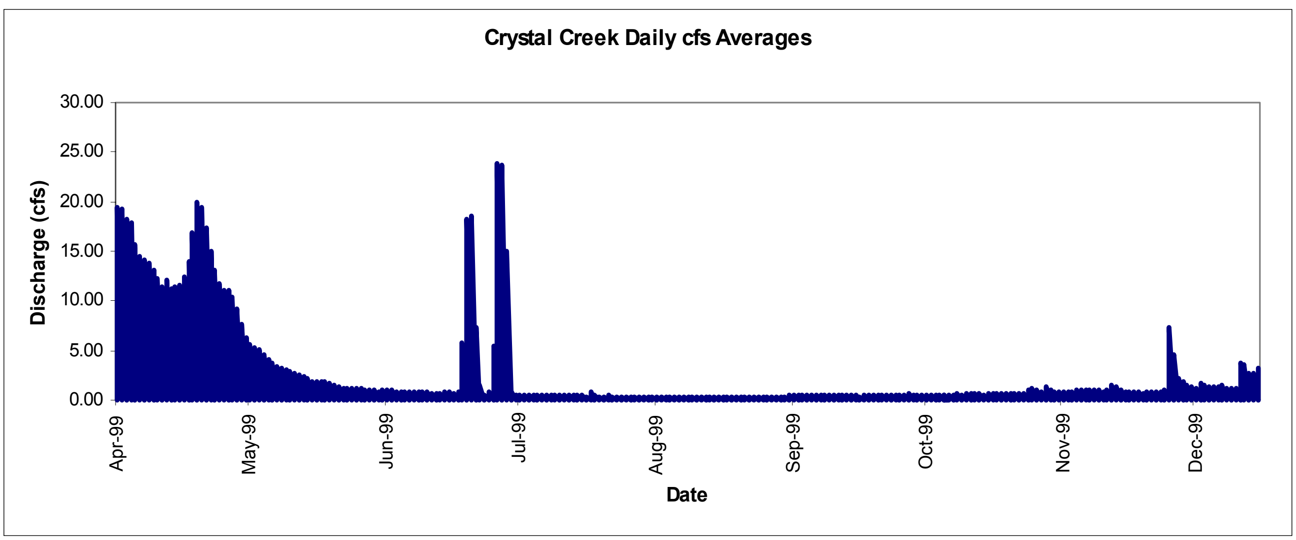

Table 2. Swauk Creek Average Daily Streamflow (cfs) Upper Yakima River TMDL 1999
Values in bold exceed two times the highest measured flow and are considered estimates.

Day		Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Day	**1**	126.3	239.1	159.4	45.6	11.7	10.9	11.5	14.4	25.8
	2	125.3	223.6	148.1	44.4	12.7	10.2	11.4	12.2	28.2
	3	121.1	214.8	124.3	44.9	12.8	9.9	10.3	10.8	31.1
	4	118.8	202.7	132.0	49.9	9.6	8.0	9.6	16.7	19.5
	5	108.9	172.2	137.7	38.1	10.2	7.9	8.6	13.1	19.0
	6	102.3	163.5	134.6	32.6	11.0	9.0	9.8	12.2	18.9
	7	108.0	194.7	120.2	46.0	15.9	8.5	9.0	12.9	25.5
	8	120.0	172.2	107.9	30.7	14.2	7.2	8.8	15.1	18.0
	9	111.8	159.7	95.9	31.4	12.8	9.0	10.9	13.6	19.8
	10	103.6	145.0	90.7	30.5	14.2	9.1	8.6	16.5	18.2
	11	96.1	138.8	88.4	28.8	16.8	10.2	8.1	14.8	22.5
	12	115.5	133.7	82.7	27.4	15.3	9.0	7.8	19.4	48.8
	13	146.7	133.9	89.9	25.3	12.4	7.5	8.3	25.5	76.3
	14	160.2	131.5	87.0	31.2	13.1	7.2	11.0	21.4	57.0
	15	163.3	125.2	95.7	22.7	15.4	7.6	10.3	17.9	49.2
	16	175.7	120.2	111.0	23.6	11.5	8.2	10.3	14.6	-
	17	215.2	117.3	100.2	29.1	12.6	7.4	7.9	21.9	-
	18	**313.6**	123.3	99.2	21.0	9.7	7.3	9.5	17.4	-
	19	**370.9**	127.1	91.2	22.0	9.6	8.0	9.4	13.4	-
	20	**340.0**	133.6	83.1	23.0	9.7	7.7	8.9	17.7	-
	21	**292.9**	135.7	78.9	21.2	10.3	6.8	9.6	20.0	-
	22	268.0	140.6	75.6	20.9	7.7	7.1	8.6	16.9	-
	23	236.4	156.2	67.7	19.9	7.4	8.7	8.2	16.0	-
	24	267.6	210.3	68.6	20.2	7.7	7.8	10.8	13.6	-
	25	**384.1**	281.1	74.0	18.6	8.1	10.3	8.0	44.7	-
	26	**375.7**	241.5	63.9	16.4	7.4	10.5	10.8	92.1	-
	27	**312.7**	201.8	60.0	18.3	7.6	11.5	9.5	51.9	-
	28	254.6	195.6	54.8	18.2	7.3	10.9	11.0	36.4	-
	29	218.9	176.6	47.5	16.9	8.2	9.0	14.0	24.0	-
	30	214.4	167.6	44.8	11.7	8.8	10.5	10.5	25.9	-
	31	-	153.1	-	11.4	8.9	-	19.5	-	-

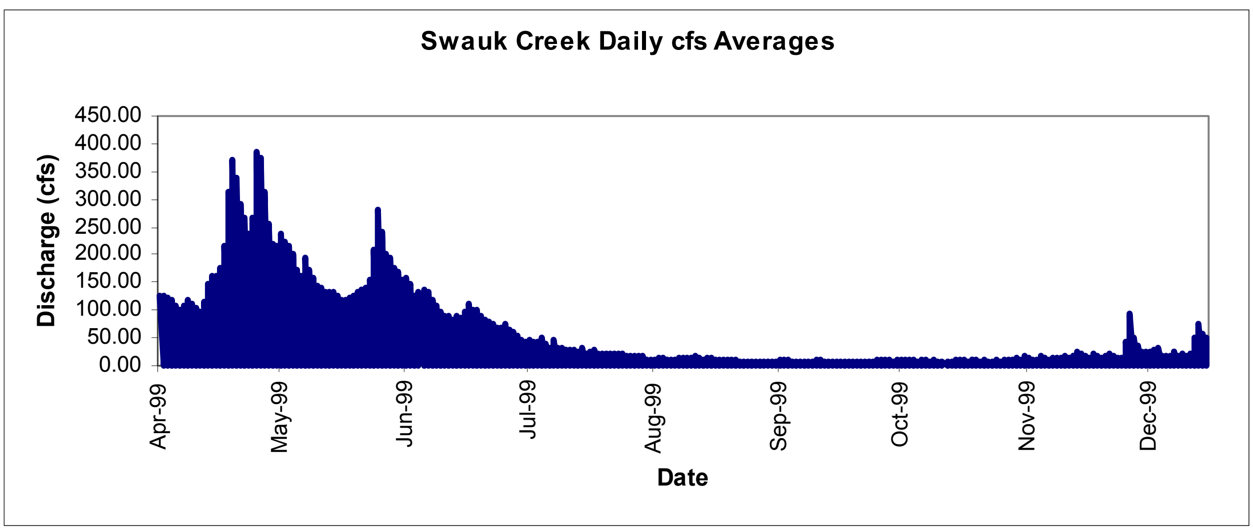

Table 3. Packwood Ditch Average Daily Streamflow (cfs) Upper Yakima River TMDL 1999

		Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Day	**1**	-	47.2	45.3	42.9	44.8	61.7	51.8	14.2	8.7
	2	-	50.4	49.9	43.3	46.4	60.9	54.2	13.6	8.8
	3	-	55.7	56.8	35.8	43.6	60.6	54.5	13.1	8.6
	4	-	57.9	56.5	38.7	44.8	60.8	52.1	15.9	8.5
	5	-	55.9	56.2	39.7	48.8	61.4	50.3	13.5	8.4
	6	-	54.6	51.9	45.1	55.7	58.3	49.4	13.7	8.5
	7	-	58.6	41.1	48.2	52.7	58.8	51.9	13.1	7.3
	8	43.4	59.7	44.5	53.8	60.3	56.5	52.8	12.8	5.5
	9	40.7	59.4	45.9	53.8	59.2	57.6	46.7	12.0	3.7
	10	42.8	56.5	44.8	53.2	58.8	54.4	40.5	11.8	2.4
	11	43.2	53.6	50.0	55.9	55.2	52.0	42.5	12.6	2.6
	12	46.2	58.4	54.6	53.2	55.0	51.8	42.5	12.9	2.7
	13	49.2	40.6	57.9	42.1	53.3	43.6	36.6	12.8	2.1
	14	43.2	47.4	58.1	40.2	54.3	48.2	32.9	11.1	1.9
	15	23.9	36.5	53.2	45.6	57.2	50.7	30.8	10.6	1.8
	16	35.2	37.9	50.1	45.9	54.9	52.1	25.2	10.1	-
	17	24.3	37.0	48.2	52.5	52.2	52.1	23.7	10.1	-
	18	34.4	42.8	51.0	56.4	53.4	51.6	21.6	9.9	-
	19	49.0	45.9	53.0	53.5	56.0	49.8	21.4	9.7	-
	20	49.3	52.6	52.4	55.5	54.6	53.3	19.1	9.1	-
	21	53.5	53.8	53.9	56.7	57.2	46.8	14.3	8.5	-
	22	53.9	45.5	55.1	59.4	59.1	45.6	13.5	8.5	-
	23	57.7	40.9	59.5	58.9	58.5	41.0	14.7	8.4	-
	24	60.4	39.0	61.5	47.2	59.3	42.4	13.8	9.2	-
	25	58.8	49.6	59.3	52.6	60.3	44.4	18.6	10.1	-
	26	60.0	41.0	52.1	57.1	52.2	50.8	18.9	13.0	-
	27	59.1	39.1	54.4	54.8	54.6	53.0	18.6	10.1	-
	28	53.8	47.2	46.0	51.1	53.5	53.1	18.5	9.7	-
	29	49.8	51.5	37.1	51.4	58.3	55.3	16.3	8.7	-
	30	44.6	45.3	39.4	43.0	62.4	50.6	15.9	8.5	-
	31	-	44.2	-	44.4	62.8	-	15.0	-	-

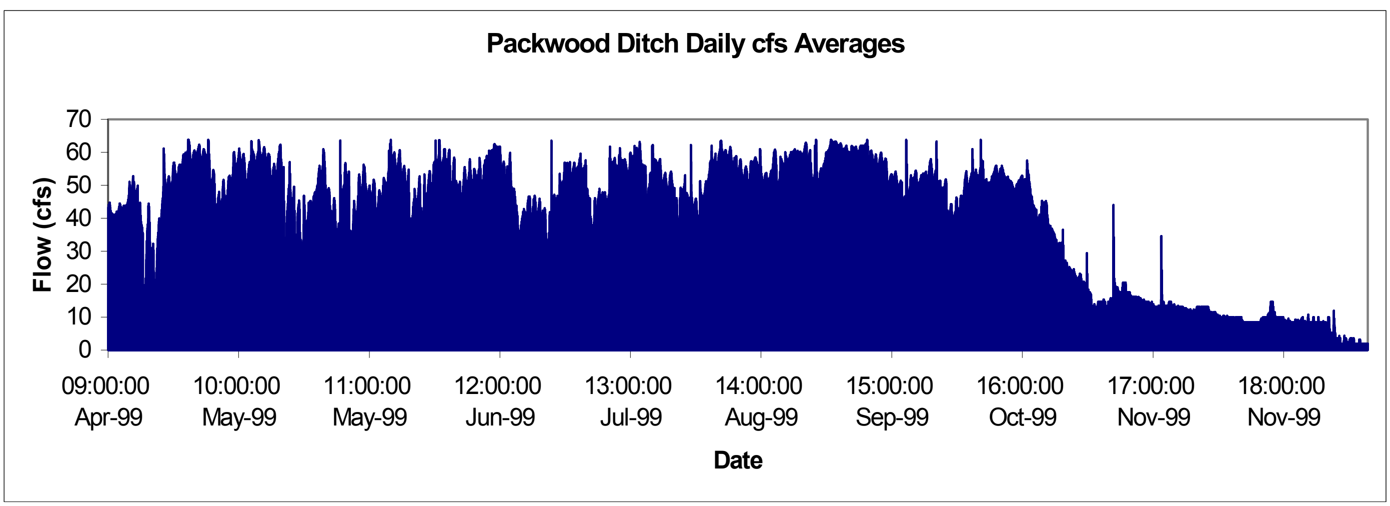

Table 4. Manastash Creek Average Daily Streamflow (cfs) Upper Yakima River TMDL 1999

		Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Day	**1**	-	120.0	170.0	85.7	7.7	6.1	6.6	7.5	20.2
	2	72.3	118.7	143.3	82.2	7.5	7.7	6.6	7.1	18.7
	3	71.7	122.0	118.9	82.8	7.8	10.6	6.7	7.4	16.3
	4	68.6	108.3	119.7	83.7	7.3	8.6	10.5	7.5	15.4
	5	63.4	96.0	131.1	65.4	6.6	6.1	15.7	10.5	15.1
	6	58.1	91.4	130.6	48.0	8.9	6.2	14.6	10.8	14.9
	7	59.7	98.2	114.3	43.8	13.2	6.2	12.4	9.7	13.2
	8	68.7	85.7	98.8	42.1	14.5	6.4	10.7	7.4	11.6
	9	66.3	80.4	86.2	28.7	12.0	6.6	13.4	7.4	13.5
	10	62.6	70.3	77.2	26.4	9.5	7.2	9.7	8.1	12.6
	11	56.3	63.0	74.2	22.7	7.7	13.7	7.4	9.0	14.2
	12	65.3	65.2	69.6	17.7	10.9	27.9	7.4	19.2	23.6
	13	68.6	73.1	80.6	7.1	9.5	28.4	8.7	23.9	20.2
	14	59.4	75.9	105.2	6.7	12.6	27.2	7.4	17.0	18.3
	15	84.6	76.8	125.9	6.3	15.0	26.3	7.1	12.0	18.4
	16	58.8	81.7	166.8	6.5	10.7	18.1	7.4	10.4	-
	17	74.6	96.1	182.2	6.2	9.8	16.4	8.2	10.0	-
	18	108.4	97.4	182.5	6.1	11.6	14.7	10.9	9.4	-
	19	125.9	94.5	164.1	6.1	10.4	10.2	13.1	9.0	-
	20	119.8	88.9	155.4	6.1	7.9	7.8	10.2	9.1	-
	21	107.6	83.3	156.7	11.0	6.7	6.4	6.4	8.8	-
	22	96.3	85.2	152.8	7.4	6.3	6.9	7.6	7.9	-
	23	101.9	112.7	146.7	6.5	6.1	10.3	12.5	7.3	-
	24	125.7	145.7	154.9	8.7	6.6	9.0	14.2	7.0	-
	25	169.2	179.7	155.1	13.0	7.2	8.3	14.6	35.1	-
	26	162.9	195.0	144.0	18.8	7.5	8.2	11.0	69.5	-
	27	134.9	173.6	128.0	11.1	6.5	6.3	6.7	43.4	-
	28	111.8	160.0	115.8	7.1	6.4	6.2	6.3	31.6	-
	29	96.3	151.0	108.3	7.0	6.5	6.2	6.1	25.6	-
	30	104.0	141.8	97.8	7.0	6.3	6.4	6.8	22.7	-
	31	-	140.6	-	8.5	6.2	-	6.4	-	-

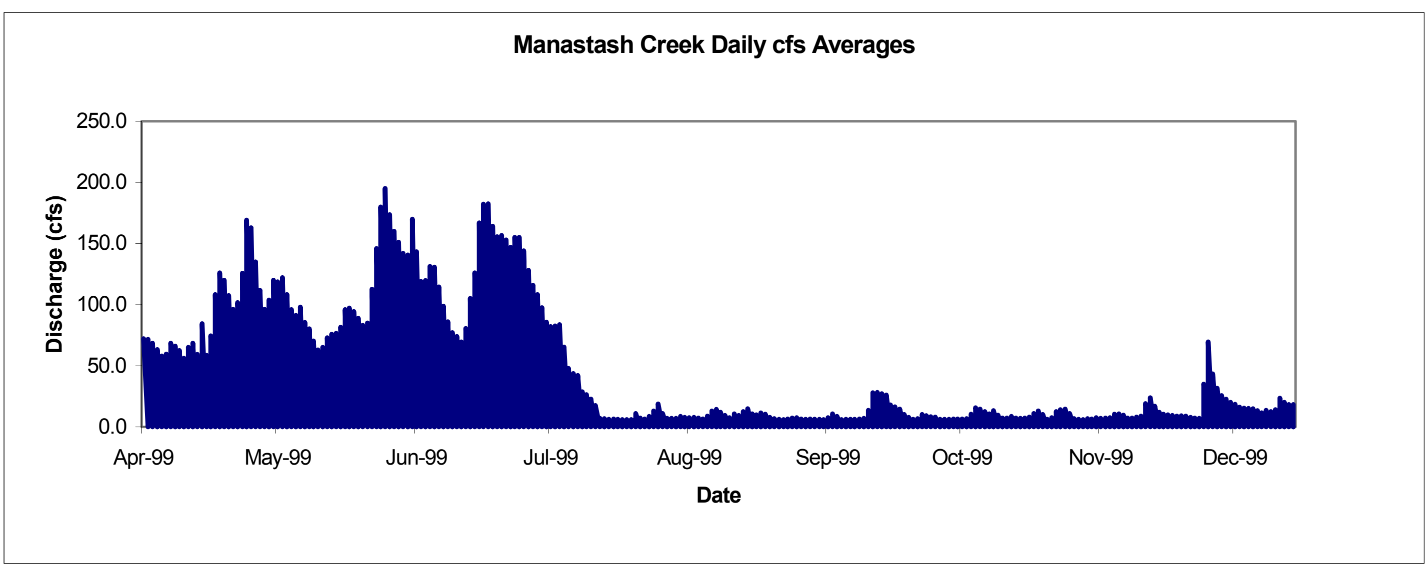

Table 5. Reecer Creek Average Daily Streamflow (cfs) Upper Yakima River TMDL 1999.
Bold type values represent days the Yakima river exceeded 4000 cfs

Day	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	15	28	**25**	52	6	27	24	10	**21**
2	16	32	**32**	48	20	28	24	10	**23**
3	13	33	**35**	43	25	31	27	11	**22**
4	14	30	**40**	40	21	38	19	11	**21**
5	10	25	**42**	41	24	41	12	11	**16**
6	5	26	**44**	41	33	40	11	11	**13**
7	4	30	37	38	41	38	9	11	**14**
8	4	31	25	38	43	31	19	11	**16**
9	4	28	23	32	42	30	32	10	**16**
10	4	15	24	34	28	26	28	11	**14**
11	3	10	25	43	23	26	26	11	**12**
12	5	10	24	**44**	22	25	20	13	-
13	17	14	37	**33**	36	25	20	14	-
14	18	18	**32**	**29**	48	26	18	13	-
15	11	15	**25**	30	48	27	15	12	-
16	11	16	**31**	15	43	27	15	11	-
17	19	9	**37**	26	41	31	16	10	-
18	**39**	9	**28**	40	40	31	16	10	-
19	**38**	20	**21**	40	40	32	18	11	-
20	**37**	33	**19**	36	38	33	17	11	-
21	33	42	**27**	39	39	34	16	11	-
22	21	**45**	**31**	46	50	36	15	11	-
23	18	**37**	**39**	42	42	32	15	11	-
24	29	**32**	**56**	34	26	32	14	11	-
25	**31**	**19**	**53**	34	22	32	14	12	-
26	**31**	**27**	**51**	23	22	31	11	**44**	-
27	**31**	**30**	**52**	12	36	33	8	**19**	-
28	18	**28**	**53**	10	51	32	13	11	-
29	11	**24**	**63**	8	54	29	11	11	-
30	18	**27**	68	7	49	27	10	12	-
31	-	**26**	-	4	38	-	10	-	-

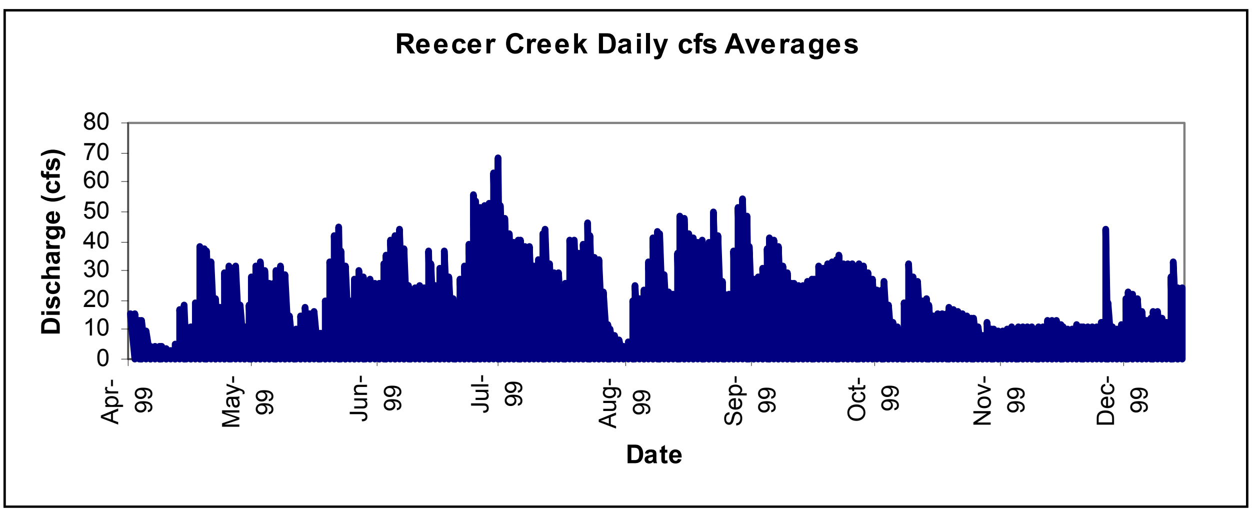

Table 6. Sorenson Creek @ Fogarty Ditch Average Daily Streamflow (cfs)
Upper Yakima River TMDL 1999

Day	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	-	76	49	79	35	35	34	21	21
2	-	77	51	90	35	35	33	22	21
3	-	67	57	94	34	34	34	21	21
4	-	51	56	83	35	35	36	21	21
5	-	50	56	74	37	37	38	21	20
6	-	44	58	41	38	38	39	20	20
7	-	42	51	22	40	40	38	20	20
8	6	47	29	25	41	41	38	20	20
9	6	48	22	26	41	41	38	20	20
10	6	43	36	29	39	39	36	20	19
11	6	40	50	30	38	38	36	20	19
12	6	50	59	32	36	36	35	20	19
13	6	51	65	33	39	39	35	21	20
14	10	50	75	33	42	42	35	20	20
15	12	48	70	34	42	42	35	20	20
16	10	45	71	34	44	44	31	20	-
17	8	44	79	36	46	46	29	20	-
18	8	43	90	38	46	46	28	20	-
19	14	49	92	37	45	45	28	20	-
20	10	48	85	37	44	44	27	19	-
21	11	43	76	39	42	42	26	19	-
22	9	45	70	38	40	40	25	20	-
23	10	38	78	37	37	37	25	20	-
24	14	39	68	37	36	36	24	19	-
25	36	34	66	39	32	32	24	20	-
26	50	48	69	39	31	31	23	21	-
27	37	39	64	35	31	31	23	21	-
28	52	29	59	32	36	36	22	21	-
29	54	39	61	31	36	36	22	20	-
30	71	47	71	33	38	38	22	20	-
31	-	44	-	33	38	38	21	-	-

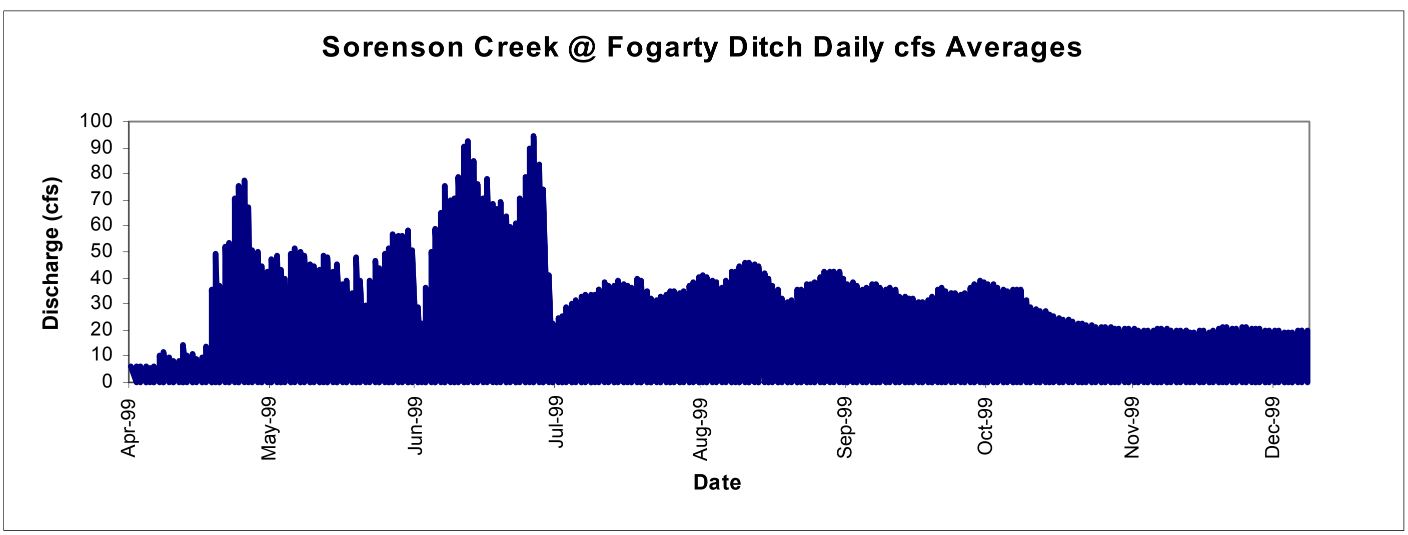

Table 7. Naneum Creek @ Fiorito Ponds Average Daily Streamflow (cfs)
Upper Yakima River TMDL 1999

		Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Day	**1**	-	197	295	102	72	164	85	55	48
	2	-	222	286	119	73	182	85	55	48
	3	-	241	230	134	70	183	86	54	48
	4	-	205	216	120	74	174	88	54	45
	5	-	160	230	103	75	161	89	53	45
	6	-	154	244	91	82	138	93	52	45
	7	67	230	231	83	90	130	89	47	46
	8	69	217	196	75	115	126	103	48	42
	9	70	209	157	69	125	115	121	46	45
	10	66	187	131	67	129	105	84	47	45
	11	65	160	120	66	128	110	78	46	45
	12	65	158	127	64	125	93	75	48	46
	13	73	157	141	61	141	85	71	51	47
	14	76	158	147	64	134	83	70	51	46
	15	66	155	175	65	143	80	69	49	45
	16	65	162	219	69	142	81	72	48	-
	17	65	172	224	89	118	80	67	49	-
	18	67	187	238	109	116	80	66	47	-
	19	74	170	236	108	115	82	68	45	-
	20	76	166	235	93	86	83	67	47	-
	21	78	169	249	112	86	83	66	47	-
	22	77	164	223	118	87	81	63	46	-
	23	76	185	218	122	92	82	63	46	-
	24	78	245	217	121	89	75	63	45	-
	25	125	282	198	114	106	75	62	46	-
	26	189	310	184	115	99	83	60	58	-
	27	182	333	188	83	90	86	57	55	-
	28	182	306	187	77	88	83	60	51	-
	29	173	278	171	73	97	83	58	48	-
	30	178	261	131	68	137	84	56	49	-
	31	-	258	-	68	170	-	58	-	-

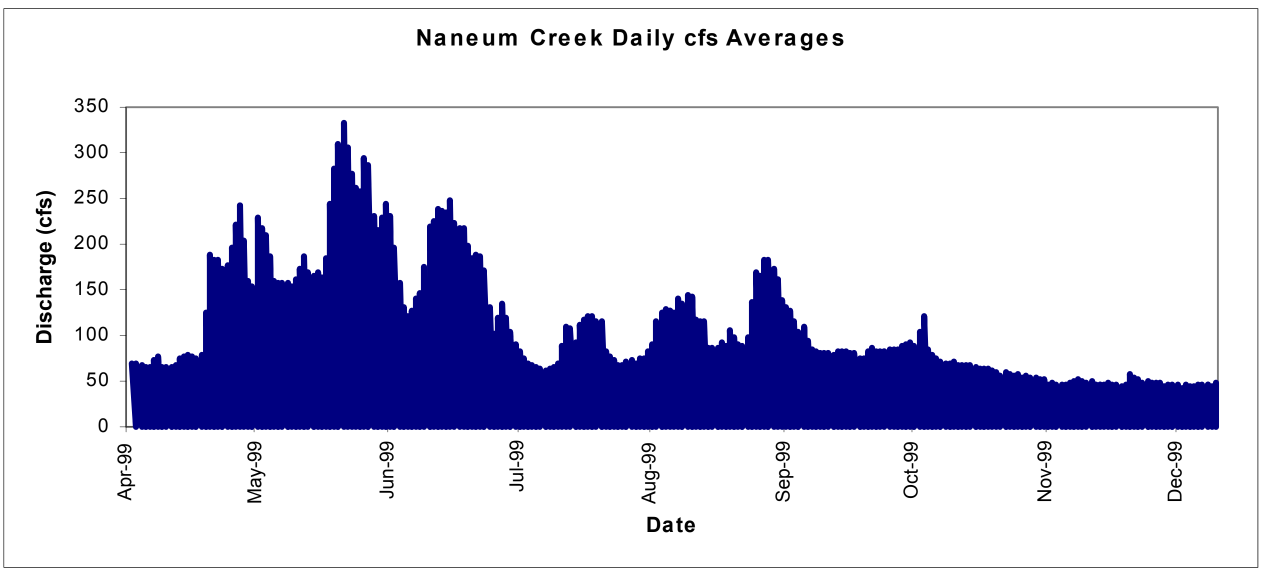

Table 8. Wenas Creek Average Daily Streamflow (cfs)   Upper Yakima River TMDL 1999

		Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Day	1	89.7	89.6	68.4	2.4	0.5	3.5	6.7	7.0	8.1
	2	88.8	89.6	62.4	1.6	0.2	3.2	5.8	7.1	8.8
	3	87.5	85.9	52.7	0.7	0.0	2.5	7.2	6.8	8.5
	4	84.1	74.3	53.1	0.9	0.0	3.1	7.2	6.9	8.8
	5	80.1	65.5	56.9	1.0	1.3	2.4	7.4	7.2	8.5
	6	75.7	63.7	56.6	0.3	7.9	1.8	7.5	7.3	10.2
	7	76.3	63.3	49.1	0.3	6.1	2.1	6.2	6.8	9.0
	8	84.2	60.3	43.9	0.5	2.7	1.7	7.9	6.6	8.5
	9	78.9	55.0	38.1	0.1	1.0	0.9	8.4	6.5	8.9
	10	78.5	40.7	34.0	0.9	1.1	1.9	8.8	7.2	8.6
	11	72.4	48.8	30.9	0.8	0.3	0.6	8.2	8.7	10.6
	12	80.5	48.0	29.7	1.0	5.1	0.9	7.1	8.1	10.5
	13	96.7	44.3	31.3	0.9	3.0	0.6	6.6	7.2	9.2
	14	95.4	43.6	30.8	0.7	3.9	0.5	6.3	7.0	9.0
	15	96.1	42.6	36.0	1.3	5.1	0.3	7.0	6.2	9.7
	16	103.8	41.8	41.8	1.9	0.7	0.7	6.0	6.5	-
	17	116.3	42.8	40.0	9.8	1.1	0.8	5.6	6.1	-
	18	147.6	43.8	35.7	11.0	3.0	0.9	5.3	6.6	-
	19	171.0	44.7	30.5	8.4	3.3	1.4	5.2	8.0	-
	20	158.4	44.9	26.5	3.9	3.1	1.8	6.9	7.2	-
	21	136.8	44.4	25.7	3.8	1.3	2.8	6.4	6.7	-
	22	117.0	49.9	23.0	3.4	3.5	3.6	6.3	6.9	-
	23	109.8	53.3	19.6	3.8	3.8	4.4	6.3	7.2	-
	24	120.8	63.5	23.4	3.9	3.3	5.7	5.6	7.7	-
	25	143.0	82.8	19.4	2.3	3.2	4.6	5.9	9.0	-
	26	147.5	86.5	12.7	2.4	3.1	4.1	6.0	8.9	-
	27	124.3	75.8	11.4	1.3	2.8	5.0	8.3	8.3	-
	28	107.0	71.9	9.1	1.5	2.0	5.0	7.2	8.7	-
	29	90.0	64.5	6.1	0.5	1.8	6.5	6.2	9.3	-
	30	86.9	61.1	4.5	0.3	5.0	7.3	6.0	8.8	-
	31	-	58.6	-	1.5	5.3	-	6.4	-	-