4.0 WATER QUANTITY

4.1 STREAM GAGING NETWORK

4.1.1 Mainstem Entiat and Mad Rivers

The Entiat subbasin has a relatively plentiful stream flow gaging record compared to other drainages of similar size and land use history in the region. The USGS, USFS, WDOE and CCCD have played major roles in the acquisition and long-term management of these hydrologic data. Figure 4-1 on page 4-6 shows major gaging sites past and present within the WRIA. Table 4-1 on page 4-2 summarizes basic information about these locations.

Mainstem Entiat gaging began in 1911 with the installation of a continuous recording gage at the mouth of the River (Entiat River at Entiat; USGS Gage #12453000 at RM 0.5). This gage was operated from 1911-1925 and then reactivated in 1951 in association with the construction of the Rocky Reach Dam. The Entiat at Entiat gage was operated through Water Year (WY) 1958 and then permanently decommissioned due to the backwater effect of the new Rocky Reach reservoir (Lake Entiat). Operation of this gage through 9/30/58 provided for one year of data overlap with a new gage established on the Entiat at RM 18.0 in September 1957 (Entiat River near Ardenvoir; USGS Gage #12452800). The latter gage, referred to locally as the Stormy gage, has been operated continuously since WY1958, providing a long-term flow record critical to water resource management in the Entiat subbasin.

A USGS miscellaneous measurement site was established in 1971 on the lower Entiat River at Keystone Bridge (RM 1.5) in order to provide flow data (tape-down measurements) for the WDOE long-term water quality monitoring station at that location. USGS and WDOE personnel took miscellaneous flow measurements at this site through 1996. In March 1996, the Entiat CRMP group sponsored installation of a continuous recording gage just above the Keystone Bridge (Entiat River near Entiat; USGS Gage #12452990) in response to the growing need to collect flow data for watershed plan development and project implementation. This gage is known locally as the Keystone gage, and has been operated continuously since installation, providing invaluable data on total runoff from the subbasin.

In the early to mid 1960's, the Forest Service established a nationwide network of watersheds on National Forest System lands for the purpose of collecting baseline data needed to illustrate how climatic variables interact with watersheds to yield runoff with particular characteristics of quantity, quality and timing. In 1965, the Entiat Barometer Watershed was established as part of this network to be representative of forest land on the east slope of the Cascade Range in Washington State.

Table 4-1. Summary* of Entiat and Mad River gaging sites, types of data collected, and periods of record.

Mainstem Entiat and Mad River Gaging Sites					
Site name	Agency	Gage type	Record type	Period of record	Site ID
Entiat River at Entiat	USGS	Recorder[1]	Continuous	11/1910-9/1925	12453000
	USGS	Recorder[1]	Continuous	6/1951-9/1958	12453000
Entiat River near Entiat (Keystone)	USGS	Recorder[3]	Continuous	3/1996-present	12452990
	USGS	Tape down stage	Misc. Measurements	10/1971-3/1996	
Entiat River near Ardenvoir (Stormy)	USGS	Recorder[3]	Continuous	10/1957-present	12452800
Entiat River at Dill Creek Bridge	WDOE/CCCD	Recorder[3]	Continuous	9/2002-present	46A110
Entiat River at Tommy Creek Bridge	WDOE/CCCD	Recorder[3]	Continuous	9/2002-present	46A150
Entiat River below Entiat Falls	WDOE/CCCD	Recorder[3]	Continuous	9/2002-present	46A160
	USFS	Recorder[2]	Continuous	10/1966-9/1978	
Entiat River at North Fork CG	WDOE/CCCD	Recorder[3]	Continuous	9/2002-present	46A170
	USFS	Recorder[2]	Continuous	10/1966-9/1978	
Mad River at Ardenvoir	USGS	Recorder[4]	Continuous	4/2002-present	12452890
Mad River above Camp Nine	WDOE/CCCD	Recorder[3]	Continuous	9/2002-present	46C100

** This summary is not exhaustive and does not include all miscellaneous measurement sites within the WRIA.*
1 = Strip Chart, 2 = punch tape, 3 = digital with telemetry, 4 = digital only

Hydrometeorological data were collected by Forest Service personnel in the Entiat Barometer Watershed from 1966 through 1978. Parameters measured included streamflow, water temperature, precipitation (including snow course and aerial snow stadia surveys) and other climatic related data. Continuous-recording, streamflow gaging stations were constructed and operated on the Entiat River above the North Fork confluence and below Entiat Falls (RM 33.8) in order to supplement mainstem data being collected by the USGS at the Ardenvoir gage. By 1978, Regional emphases for soil and water funding began to shift. The Barometer gages and other monitoring sites were deactivated at the end of the 1978 water year. A report compiling the data collected during operation of the Entiat Barometer Watershed was prepared in November 1978 (Copenhagen 1978). The completeness and high quality of the Entiat Barometer Watershed data are a tribute to Mr. Art Johnson, an Entiat local, who was the Ranger District employee responsible for locating, installing and operating the Barometer monitoring sites through fires and floods.

Miscellaneous flow measurements for the Mad River began in 1935 with a single flow measurement made by the Bureau of Fisheries during a habitat survey. Beginning in 1967, the USGS and the USFS began taking additional miscellaneous measurements in the lower Mad River. In 1992, the USFS installed a staff gage at the Mill Camp Bridge on the lower Mad and began taking more frequent miscellaneous measurements. In 1999, the CCCD contracted with the USGS to maintain an official miscellaneous measurement site on the Mad River at Mill Camp. In April 2002, the CCCD sponsored installation of a USGS continuous recording gaging station on the Mad River just below the Mill Camp Bridge (Mad River at Ardenvoir; USGS Gage #12452890). This new gage has already provided critical flow data for this significant tributary to the Entiat River.

In 2002, the WDOE received funds to enhance stream flow gaging in the subbasin. By September 2002, the WDOE and the CCCD had jointly installed four continuous recording gages on the mainstem Entiat River and one on the middle Mad River above Camp Nine (about RM 9). Three additional continuous recorders were also installed on tributaries (see Tributary gaging on page 4-4). These new continuous recording telemetered gages collect water stage, air and water temperature data at fifteen minute intervals. The record being compiled upstream of Camp Nine on the Mad River compliments data being collected from the USGS gage at the Mad River mouth. The importance of the upper Mad River as bull trout habitat reinforces the significance of this site. All four mainstem Entiat continuous recorders were placed upstream of the previously discussed USGS gages, and have supplied valuable information on the behavior of the upper Entiat River. The upper two gages - Entiat River below Entiat Falls and Entiat River at North Fork Campground - were installed in the USFS Barometer Watershed gage houses and have in effect reactivated those sites. The lower two gages were installed at accessible locations above and below the confluences of Fox, Burns and McCrea Creeks, in an effort to frame the Entiat Experimental Forest.

The McCrea, Burns and Fox Creek drainages comprise the Entiat Experimental Forest (EEF), an area in the subbasin on National Forest System lands allocated to forest research activities. In 1957, Forest Service scientists at the Wenatchee Forest Science Lab began measuring streamflow, precipitation and other weather and water quality variables in the three drainages. The original objective of the proposed study was to apply a paired watershed approach to evaluate the effects of road building and timber harvest on the quantity, quality and timing of runoff. Fox Creek was designated as the control watershed (no treatment). The calibration (or pre-treatment) period was almost complete when the study area was hit by wildfire in 1970. The study objective was then changed to evaluate the effects of fire and revegetation on soil and water resources in the study area. Post-fire flooding also damaged study sites.

Scientists soon recognized that post-fire recovery in the EEF would be gradual and that continuous flow and related measurements were not needed in order to define recovery trends. In the mid 1970's, a plan was implemented to measure flow and other factors for one more year and then reactivate the study sites every 3 to 5 years to obtain trend data. Measurements were phased out over the period from 1975-1977. About two years after all measurements stopped, the research mission at the Wenatchee Forest Science Lab changed, personnel who had worked on the project transferred, and plans for intermittent reactivation of the EEF study sites were never implemented.

A great deal of valuable information was collected between 1957 and 1977. Between 1970 and 1980, over 25 research papers were published based on EEF data. In 1999, in cooperation with the Wenatchee Forest Science Lab, J. David Helvey and William B Fowler (retired FS researchers who had worked on the study) completed a compilation of selected EEF data to prevent loss of information stored on various media. Their report summarizes data on streamflow, stream temperature, monthly precipitation, air temperature and humidity for the three EEF drainages (Helvey and Fowler 1999).

Recently, the Wenatchee Forest Science Lab established a staff group working on research questions with an aquatic emphasis. The Lab plans to reactivate the EEF study sites in

2004 in order to evaluate water quantity and quality conditions given over 34 years of recovery since the 1970 wildfire. Quantifying their contribution to the mainstem Entiat River will provide a valuable check to any future streamflow data collected.

4.1.2 Tributary gaging

As mentioned earlier, the USFS collected long-term streamflow data from Fox, Burns and McCrea Creeks from 1960-1977 as part of the EEF project. Numerous miscellaneous flow measurements related to various projects have also been collected by the USFS on Entiat and Mad River tributaries. The USGS collected peak flow data at crest gage sites on Tillicum Creek from 1965 to 1975, and an ephemeral Columbia River tributary, located south of the Entiat-Columbia River confluence, from 1954 to 1972.

The USFS has active continuous stage recorders (Aqua-Rods) on both Potato and Tillicum Creeks. As part the WDOE/CCCD enhanced stream flow gaging effort, continuous digital telemetered recorders were installed on Lake, Roaring and Tillicum Creeks in September 2002. Lake Creek is a major annual contributor to the upper Entiat; Roaring Creek, which occasionally supports small numbers of steelhead trout, is a perennial tributary to the lower Entiat River. Tillicum Creek is a principal tributary to the Mad River. Staff-gage-only sites were also installed on Mud, Potato, Stormy, Preston, Tommy and Pope Creeks. Table 4-2 on page 4-5 summarizes past and current tributary gaging efforts in the WRIA.

Table 4-2. Summary* of WRIA 46 tributary gaging sites, types of data collected, and periods of record.

Site name	Agency	Gage type	Record type	Period of record	Site ID
Entiat River Tributary Gaging Sites					
Mill Canyon Creek at 5210 road crossing	USFS	Staff gage	Monthly Q msmt.	5/1995-10/1996	9408
Mud Creek at mouth	USFS	Staff gage	Monthy Q msmt.	5/1995-10/1996	9404
Roaring Creek below Cada diversion	WDOE/CCCD	Recorder[1]	Continuous	9/2002-present	46B060
Mud Creek at Bisping Canyon Road	WDOE/CCCD	Staff gage	Misc. Measurements	9/2002-present	46E070
Potato Creek at FS Road culvert	WDOE/CCCD	Staff gage	Misc. Measurements	1999-present	46F060
	USFS	Recorder[2]	Continuous	1999-present	
Potato ds of North Fork	USFS	Staff gage	Monthy Q msmt.	5/1995-10/1996	9405
Stormy Creek	WDOE/CCCD	Staff gage	Misc. Measurements	9/2002-present	46G060
Stormy @ valley road	USFS	Staff gage	Monthy Q msmt.	5/1995-10/1996	9406
Preston Creek	WDOE/CCCD	Staff gage	Misc. Measurements	9/2002-present	46H050
	USFS	Staff gage	Monthy Q msmt.	5/1995-10/1996	9407
McCrea Creek	USFS	Flume with stage recorder	Continuous	1961-1975	n/a
Burns Creek	USFS	Weir with stage recorder	Continuous	1960-1977	n/a
Fox Creek	USFS	Flume with stage recorder	Continuous	1960-1975	n/a
Lake Creek	WDOE/CCCD	Recorder[1]	Continuous	9/2002-present	46K050
Tommy Creek below USFS quarry	WDOE/CCCD	Staff gage	Misc. Measurements	9/2002-present	46J080
Pope Creek	WDOE/CCCD	Staff gage	Misc. Measurements	9/2002-present	46L050
Mad River Tributary Gaging Sites					
Tillicum Creek at Tillicum Fan	WDOE/CCCD	Recorder[1]	Continuous	9/2002-present	46D050
Tillicum Creek	USGS	Crest gage	Peak	1965-1975	12452880
	USFS	Recorder[2]	Continuous	1999-present	12452880
Columbia River Tributary Gaging Sites					
Borrow Pit	USGS	Crest gage	Peak	1954-1972	12453600

** this summary is not exhaustive and does not include all miscellaneous measurement sites within the WRIA.*
1 = digital with telemetry, 2 = AquaRod stage recorder

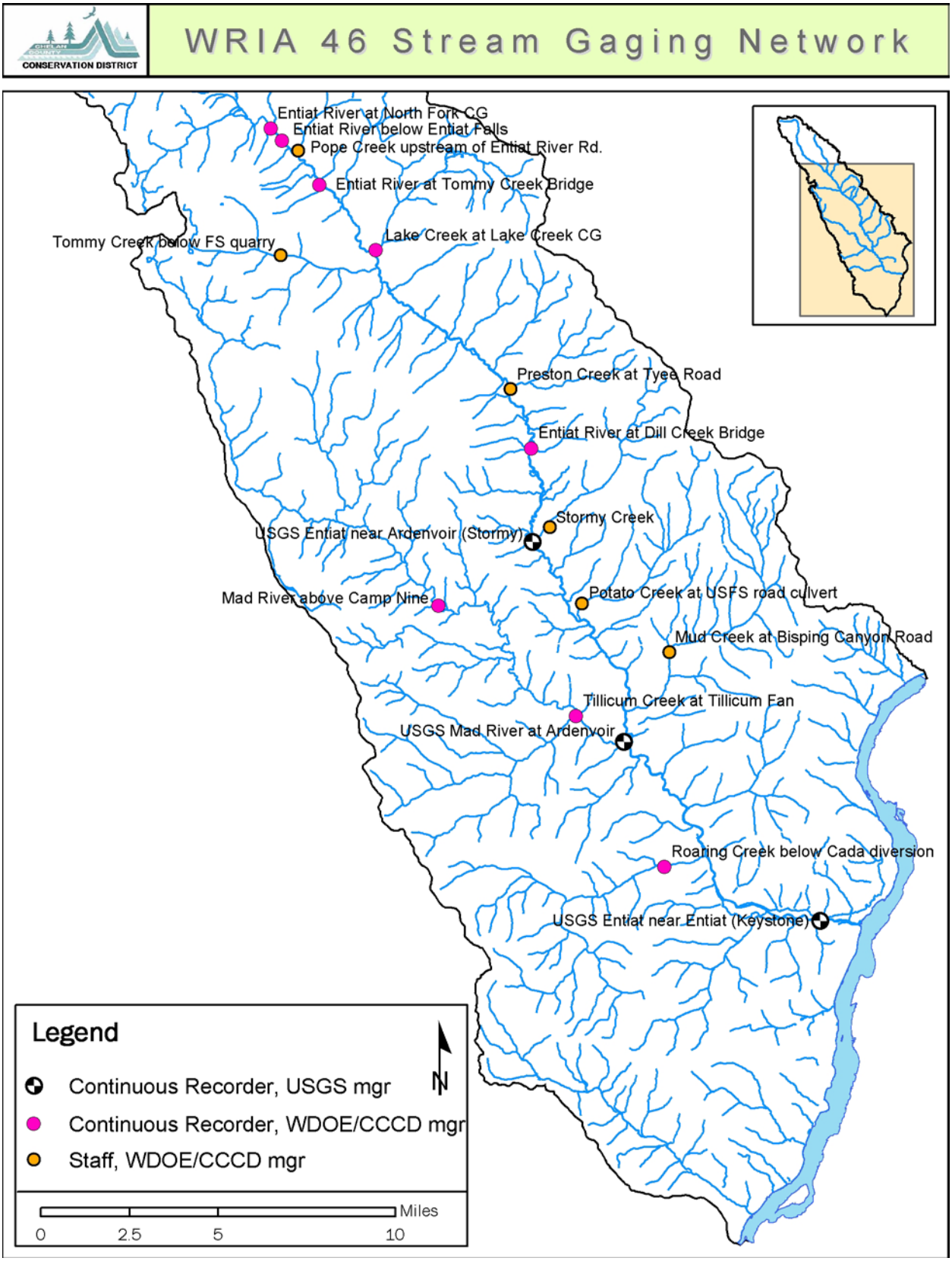


Figure 4-1. Location and types of streamflow gaging sites in the Entiat WRIA.

4.2 STREAMFLOW RECORDS SYNTHESIS

In an effort to facilitate various watershed planning efforts requiring statistical analysis of long-term discharge records, a water resources contractor worked with the USFS Entiat RD hydrologist to examine existing continuous streamflow records, and synthesize daily mean streamflows for multiple gaging sites within the subbasin. The cornerstone of this effort was the continuous record (WY 1958-present) from the USGS gage near Ardenvoir. Records from other continuous gaging sites (with shorter-term records) that temporally overlapped the Ardenvoir record made correlation possible. The water quantity and instream flow subcommittees, as well as ENTRIX personnel involved with the Entiat instream flow study, reviewed the synthesized datasets and determined they had been refined to the greatest extent possible given the measured flow data available. Discrepancies between synthesized daily mean flows and actual measured values recorded for the same time period generally fell within measurement uncertainties, particularly at low and intermediate flows. A detailed discussion of the methods applied and the limitations of the results are contained in the Flow Synthesis Data Summary Sheets (Rhodus and Edwards 2003).

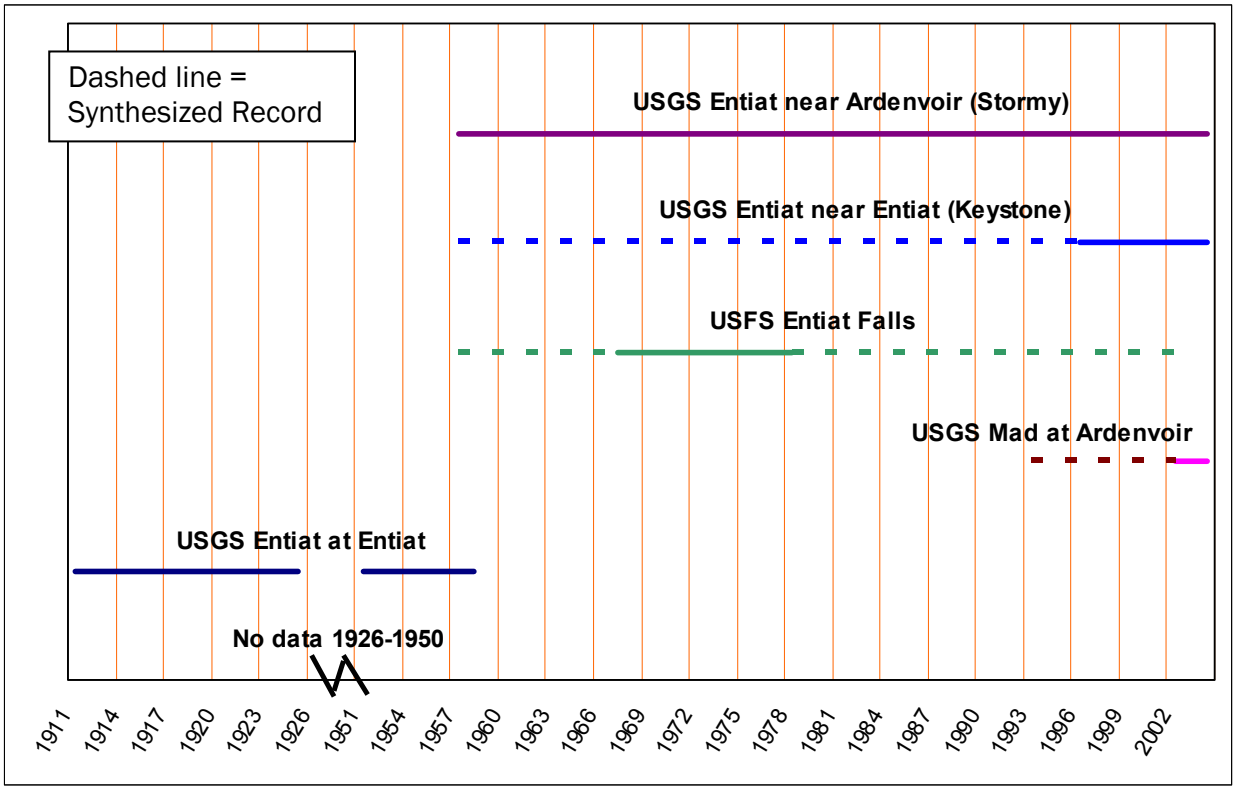


Figure 4-2. Timeline showing the periods covered by composite daily flow records at gaging stations on the mainstem Entiat and Mad Rivers.

Figure 4-2 shows the stations and periods of record for which synthesized daily mean flows were produced. The synthesized data filled important temporal gaps in the streamflow record; "splicing" the synthesized records into existing measured records created continuous, composite records of daily mean discharges. The composite records were then used in other efforts such as hydrograph separation, discussed on the following page, and instream flow analyses (see Chapter 5), and stream temperature modeling (see Chapter 8).

4.3 HYDROGRAPH SEPARATION

4.3.1 Introduction

Hydrograph separation is the process of separating a plot of stage or discharge vs. time, known as a stream hydrograph, in order to determine the baseflow and surface runoff components of a stream. Baseflow, the groundwater contribution to total streamflow, occurs when water from local aquifer material moves under the influence of gravity into a stream channel, supplying water to the stream. Surface runoff is water derived from residual snow or ice melt and precipitation.

The WDOE performed hydrograph separation on the Entiat River as part of an effort to evaluate groundwater contribution to total streamflow (baseflow) at active and inactive stream gaging stations throughout Washington State (Sinclair and Pitz 1999). The USGS hydrograph separation software program called HYSEP (Sloto and Crouse 1996) was used to analyze what percentage of total streamflow was contributed by baseflow on a month-by-month basis. HYSEP is based on algorithms that duplicate manual hydrograph separation techniques, improving the consistency of the results and the speed at which they can be produced. HYSEP analyzes daily mean streamflow records and produces monthly mean total streamflow, baseflow and surface runoff values for each year of data.

Hydrograph separation is an established technique for quantifying groundwater contribution to annual streams; however, streams affected by regulation or snowmelt conditions impose inherent limitations on results generated by using this method. HYSEP consistently *over-estimates* baseflow contribution to streams during snowmelt periods. Streams in WRIA 46 are affected by snowmelt from late winter to mid-summer, so although baseflow was calculated monthly for entire water years, only the results for August-February are valid.

The Planning Unit used HYSEP to perform hydrograph separation analyses of the following gaging sites and periods of record:

1. USGS gage 12452990 (Entiat river near Entiat) WY 1997-2001
2. USGS gage 12452990 (Entiat river near Entiat) WY 1958-2001 (composite record)
3. USGS gage 12452800 (Entiat River near Ardenvoir WY 1958-2001
4. USFS gage Entiat River below Entiat Falls WY 1967-1978
5. USFS gage Entiat River below Entiat Falls WY 1958-2001 (composite record)
6. USGS gage Mad River near Ardenvoir WY 1993-2002 (composite record)

4.3.2 Results

Figure 4-3 on page 4-10 shows mean baseflow and surface runoff volumes at the Entiat near Entiat (Keystone) gage. These values were produced using the composite daily mean streamflow record (WY 1958-2001) discussed earlier in Section 4.2. Results from the CCCD HYSEP analysis for Keystone comported well with WDOE HYSEP analysis results produced using records from the Entiat at Entiat and Entiat near Ardenvoir (Stormy) gages.

Table 4-3. Percent contribution of baseflow to total stream flow determined by CCCD HYSEP analysis of Keystone data, WDOE analysis of Entiat at Entiat and Stormy gage data.

	Jan	Feb		Aug	Sep	Oct	Nov	Dec
CCCD - Entiat near Entiat (Keystone)	83%	87%	No data Mar-Jul due to effects of snowmelt	94%	94%	89%	78%	76%
WDOE - Entiat at Entiat	81% - 95%	81% - 95%		81% - 95%	81% - 95%	81% - 95%	81% - 95%	81% - 95%
WDOE - Entiat near Ardenvoir (Stormy)	81% - 95%	66% - 80%		81% - 95%	81% - 95%	81% - 95%	66% - 80%	66% - 80%

Estimation of baseflow and surface runoff values for March-July

March-July monthly mean baseflow values were estimated based on the professional judgment of the CCCD water resources specialist (CCCD 2003a), rather than real data, due to the inability of HYSEP to accurately separate the baseflow and surface runoff components of streamflow during a snowmelt period.

The precise effects of snowmelt runoff on baseflow contribution to the Entiat River are not known; however, data and analytic results from well monitoring and aquifer storage modeling, described in Sections 4.4 and 4.5 respectively, provided clues to the behavior of baseflow during snowmelt. Results showed that annual recharge of the Entiat valley unconsolidated alluvial aquifer begins in March and reaches its peak in June. The aquifer storage model indicated that elevated in-channel water levels cause water to move *out of* the stream and *into* the depleted aquifer materials of the channel banks and valley floor during these months. This movement or "recharge" of water from channel to aquifer from March through June is the reverse of baseflow, and is seen clearly as a decreasing trend in baseflow for that period (see Figure 4-3). The March through July bars in this figure depict where professional judgment, rather than HYSEP model results were used.

Model results indicated that peak aquifer storage in the Entiat valley coincides closely with peak annual flow; the inflection point in baseflow values seen in June was judged to coincide with the inflection points of peak annual flow and aquifer storage (see Figure 4-6 on page 4-16). As peak streamflow recedes, the newly recharged aquifer begins to discharge to the channel once again, providing an increasing contribution to overall stream flow for the remainder of the year; thus, the aquifer is in a depleted state in late winter just prior to the onset of snowmelt.

Calculation of daily values

HYSEP does not produce daily values for baseflow or surface runoff. The monthly mean baseflow values estimated for March-July, described in the preceding section, were used in these calculations. Daily baseflow and surface runoff values were calculated thus:

(Monthly Mean BF/SF) x Daily Mean SF = Daily BF

Daily Mean SF – Daily Mean BF = Daily Mean SRO

BF = Baseflow; SF = Streamflow; SRO = Surface Runoff

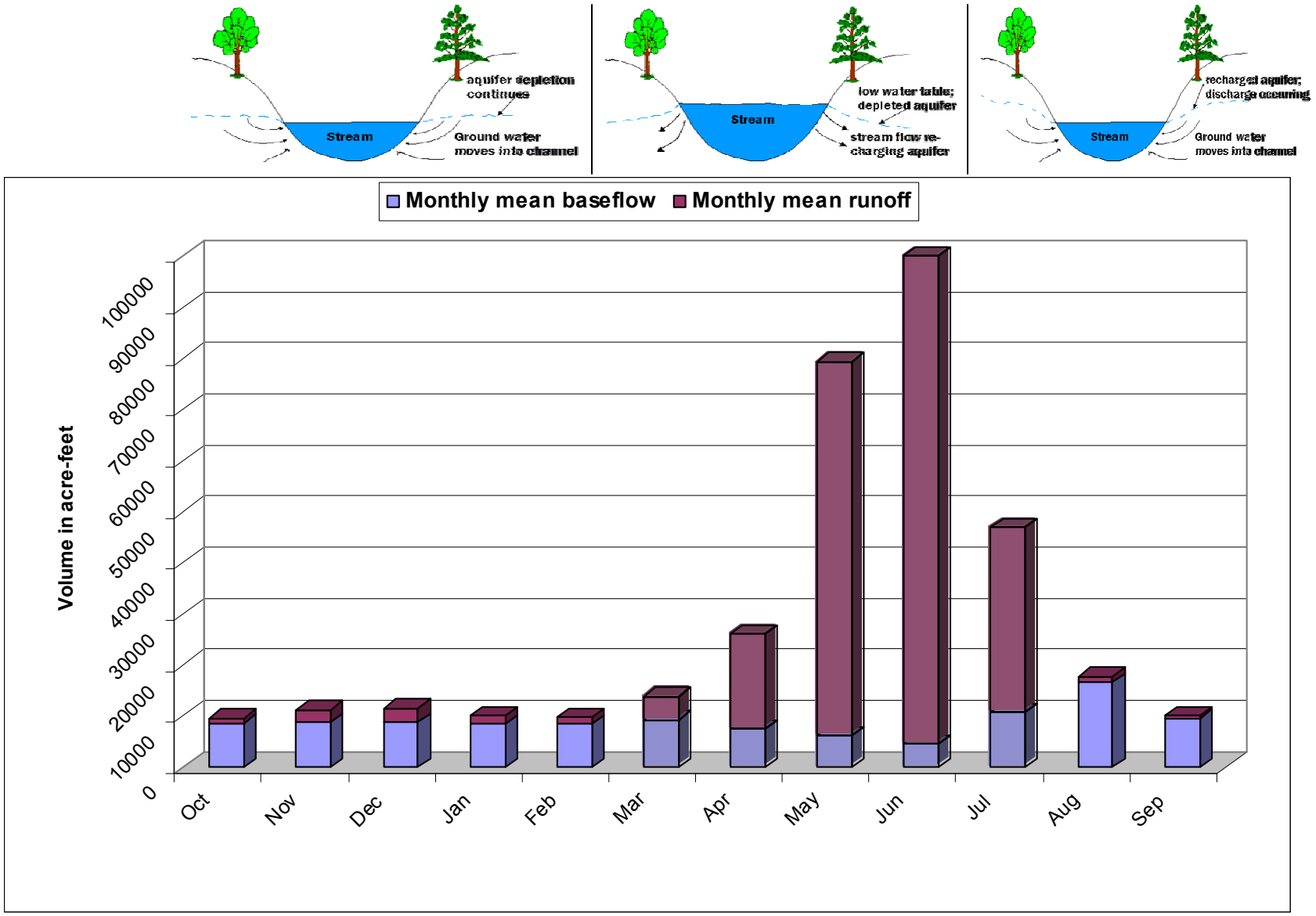


Figure 4-3. Monthly mean baseflow and surface runoff contributions (ac-ft) to the Entiat River based Keystone composite data.

**Note: Professional judgment was used in March through July rather than HYSEP model results.*

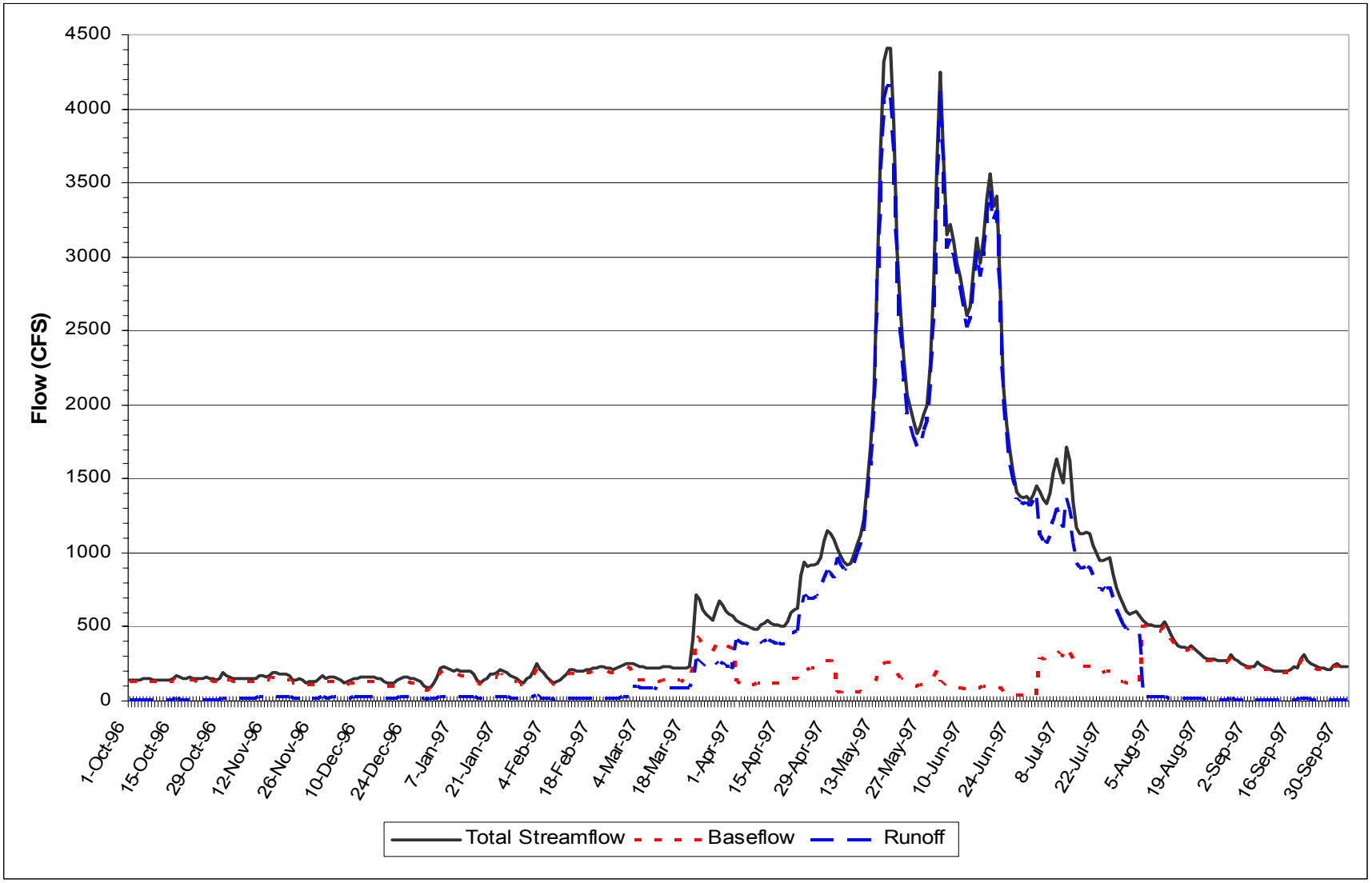


Figure 4-4. Baseflow and surface flow contribution to annual streamflow recorded at the Entiat near Entiat (Keystone) gage, WY 1997.

**Note: Professional judgment was used for March through July rather than HYSEP model results*

Figure 4-4 on page 4-11 shows the annual hydrograph at the Keystone gage for WY 1997, divided into baseflow and surface runoff components, and illustrates the daily variability of streamflow and these components. Again, the March through July lines indicate where professional judgment was used to estimate baseflow / surface runoff values due to the inability of HYSEP to calculate them because of the effects of snowmelt. The figure also shows the range of discharges occurring in the system over the course of a water year (1997 was a "wet" year; the same graph for WY 2001, a very "dry" year, would show the same pattern but with much lower overall discharge values) and depicts the hypothesized relationship of baseflow to surface runoff during the snowmelt-dominated period.

Use of measured and composite streamflow records

As mentioned earlier, HYSEP analyses were performed using both measured and composite daily mean streamflow records at the Keystone and Entiat Falls gages (CCCD 2003a). The goal of using both types of record was to compare the results obtained, and determine how significant the differences in results were. Use of the longer composite records eliminated some short-term climatic variability associated with the shorter measured records; however, the range of values was not great. Use of composite records did not result in consistently higher or lower baseflow estimates; during some months the baseflow/total streamflow ratio was higher and in other months it was lower. For a detailed description of the methods and results for all the HYSEP analyses for WRIA 46, refer to the HYSEP report (CCCD 2003a) and appendices.

4.4 WELL MONITORING

In 2001, the EWPU initiated a domestic well monitoring effort in order to collect data on groundwater levels within the unconsolidated alluvial aquifer, and examine hydraulic continuity within the Entiat valley. Planning Unit LSC members identified willing individuals within the WRIA to volunteer for the monitoring program, and letters of solicitation were sent out late in 2001. Electronic and paper copies of all exempt well logs for the Entiat area and created a database of summary statistics in support of this effort. Beginning in January 2002, the Planning Unit began monthly monitoring of 29 wells. Static water levels and ambient air temperatures were measured for all wells and well water temperature was measured whenever possible. In addition, ambient air and water temperatures were measured at a series of bridges along the mainstem Entiat River. In January 2003, the EWPU determined that another year of data collection would be beneficial, and that additional well monitoring participants should be sought. The EWPU renewed 24 of the original 29 wells for an additional year of monitoring (Jan-Dec 2003).

All wells currently monitored within the Entiat WRIA are permit exempt domestic wells. Initially, a high-capacity non-exempt well at the Entiat National Fish Hatchery was also monitored; however, it became impossible to obtain static water levels because the well was put online and continuously pumped. Monitoring wells are located from approximately RM 1.5 to RM 20. An attempt was made to select wells so that they were spatially distributed throughout the WRIA; however, due to the demographics of the area they are somewhat concentrated within the lower 12 miles of the Entiat valley.

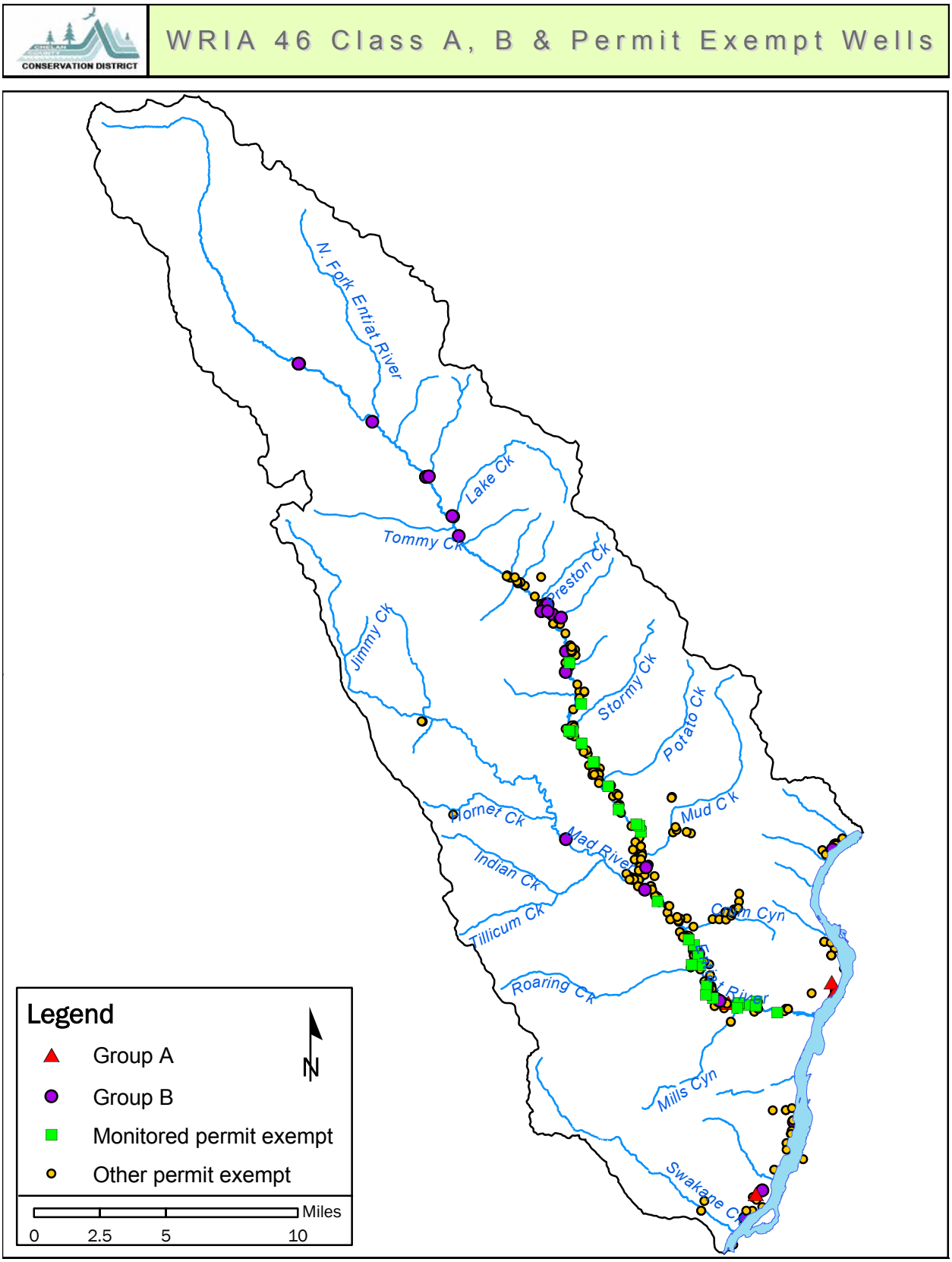


Figure 4-5. WRIA 46 Class A, B, and Permit Exempt Well locations.

Figure 4-5 on page 4-13 depicts the permit exempt well monitoring sites, as well as the location of other permit exempt, Class B, and Class A wells found within the WRIA based on WDOE well log and Department of Health Class A and Class B well data.

All but two of the monitored wells draw water from the shallow, unconfined and unconsolidated alluvial aquifer of the Entiat River. Aquifer data are discussed in detail in Section 4.5. Well monitoring data indicate a high degree of connectivity of this aquifer to flow in the Entiat River, with seasonal variations in streamflow being reflected in static water levels within the wells. Stream and well water temperatures commonly vary only a few degrees Celsius and are similar to mean annual air temperatures.

Data from the Entiat well monitoring program are maintained in paper and electronic format by the CCCD and are available upon request. These data provided the basis for the aquifer storage modeling project (Dixon 2003) discussed below.

4.5 AQUIFER STORAGE MODEL

The Entiat River valley aquifer system is bounded by igneous and metamorphic bedrock. The unconfined aquifers within the watershed are composed of glacial, colluvial, fluvial and alluvial cobbles, gravels, sands, some silts and discontinuous clays. Recharge to the unconfined aquifer is derived primarily from precipitation and potentially from irrigation return flows, but is largely dependent on surface water exchange with the Entiat River. As a result, a high degree of hydraulic connection between the Entiat River and the alluvial aquifer is recognized.

Within an alluvial system such as that described above, groundwater storage is defined as the volume of water that could be theoretically extracted if the aquifer were completely drained. Assuming that the surficial extent of the aquifer represents the lateral extent of the aquifer at depth, groundwater storage within an unconfined aquifer can be estimated by multiplying the aquifer surface area by the saturated thickness of the aquifer and the specific yield of the aquifer materials. An unconfined aquifer is one that lacks an upper confining layer; that is, the water level within the aquifer may rise and fall without restriction. Specific yield refers to the volume of water that can be withdrawn from aquifer materials relative to their total volume (due to the surface tension of water, not all the water can be withdrawn; some will always cling to the solid particles of the aquifer material). Different materials such as gravels of various sizes, sand, clay, fractured and un-fractured bedrock all have unique specific yield values. The saturated thickness of an unconfined aquifer is the vertical distance from the top of the groundwater surface (water table) to the base of the aquifer. In the case of the Entiat valley alluvial aquifer, the thickness or depth of the aquifer is assumed to be the depth to bedrock.

Change in storage volume, commonly referred to as annual recharge, is the defining factor used to determine the sustainability of a groundwater resource. A change in storage volume can be expressed as a volume flux per surface area of the aquifer due to seasonal changes in precipitation, temperature, and other factors, such as withdrawals from wells. On an annual basis, most systems display steady state conditions; e.g., discharge is approximately

equal to recharge, and the net annual change in volume is zero (Hoos 1990). When groundwater extraction combined with losses due to evapotranspiration exceeds annual recharge, water level declines should be expected; however, due to the high degree of connectivity between the Entiat and the alluvial aquifer any expected groundwater declines would be compensated for by aquifer recharge from the river.

Data from 25 monitored wells in the unconsolidated/unconfined alluvial aquifer were used to define aquifer depth (top of the bedrock surface), the top of the water table, and the aquifer's saturated thickness (Dixon 2003). Interpreted well log stratigraphy was used in conjunction with the Washington Department of Natural Resources' (WDNR's) 1:100,000 scale surficial geology Geographic Information System (GIS) data to help determine specific yield values.

A GIS was used to digitize polygons that delineated the surface area of the unconfined aquifer. A polygon in this context refers to a set of straight lines used to enclose and define a specific area of the Earth's surface that has some unique characteristic; in this case, the polygons enclosed areas of equal aquifer depth. Polygon delineation was based on similarities in well depths and surface elevation, as well as the lateral extent of the unconsolidated aquifer material. Aquifer depths were assigned to the aquifer polygons using data recorded in well logs. In instances where depth to bedrock was unknown, a conservative depth was assigned based on the deepest well occurring within that polygon. When no well data were available, aquifer depth was estimated based on data from adjacent polygons and/or geologic and topologic characteristics of the valley.

Once aquifer depths, acreages, and specific yield values were determined for all 205 polygons, a saturated thickness value was assigned to each polygon. Monthly static water levels had only been measured for 25 wells representing 25 polygons distributed spatially throughout the basin; therefore a ratio of measured water depth to total aquifer depth was calculated based on data from the 25 polygons. This ratio was assigned to adjacent polygons and used to calculate monthly saturated thickness for the remaining 180 polygons (Dixon 2003, *draft*). An estimate of groundwater storage volume was then calculated for each polygon, and the sum of storage volumes for all polygons yielded an estimate of storage volume for the entire aquifer. The lowest storage volume was subtracted from the highest storage volume to provide an estimate of total annual change in storage. This change in storage volume could also be evaluated for each individual polygon on a month by month basis by calculating the fluctuation in water levels.

Using the methods described above, the total area of the mainstem Entiat River valley aquifer was estimated to be 10,732 acres (Dixon 2003). During 2002 the saturated thicknesses within the unconfined valley aquifer ranged from 10 feet to 151 feet, with an average aquifer depth of 52 feet. Aquifer polygons ranged in size from 2 acres to as large as 3,210 acres with an average size of 52 acres. Figure 4-7 and Figure 4-8 on pages 4-18 and 4-19 depict modeled aquifer depth in the upper and lower Entiat River. Exclusion of the 3,210 acre outlier polygon, which defines the uppermost headwater aquifer for which no well data were available, reduced the average aquifer polygon size to 37 acres with a maximum polygon size of 467 acres.

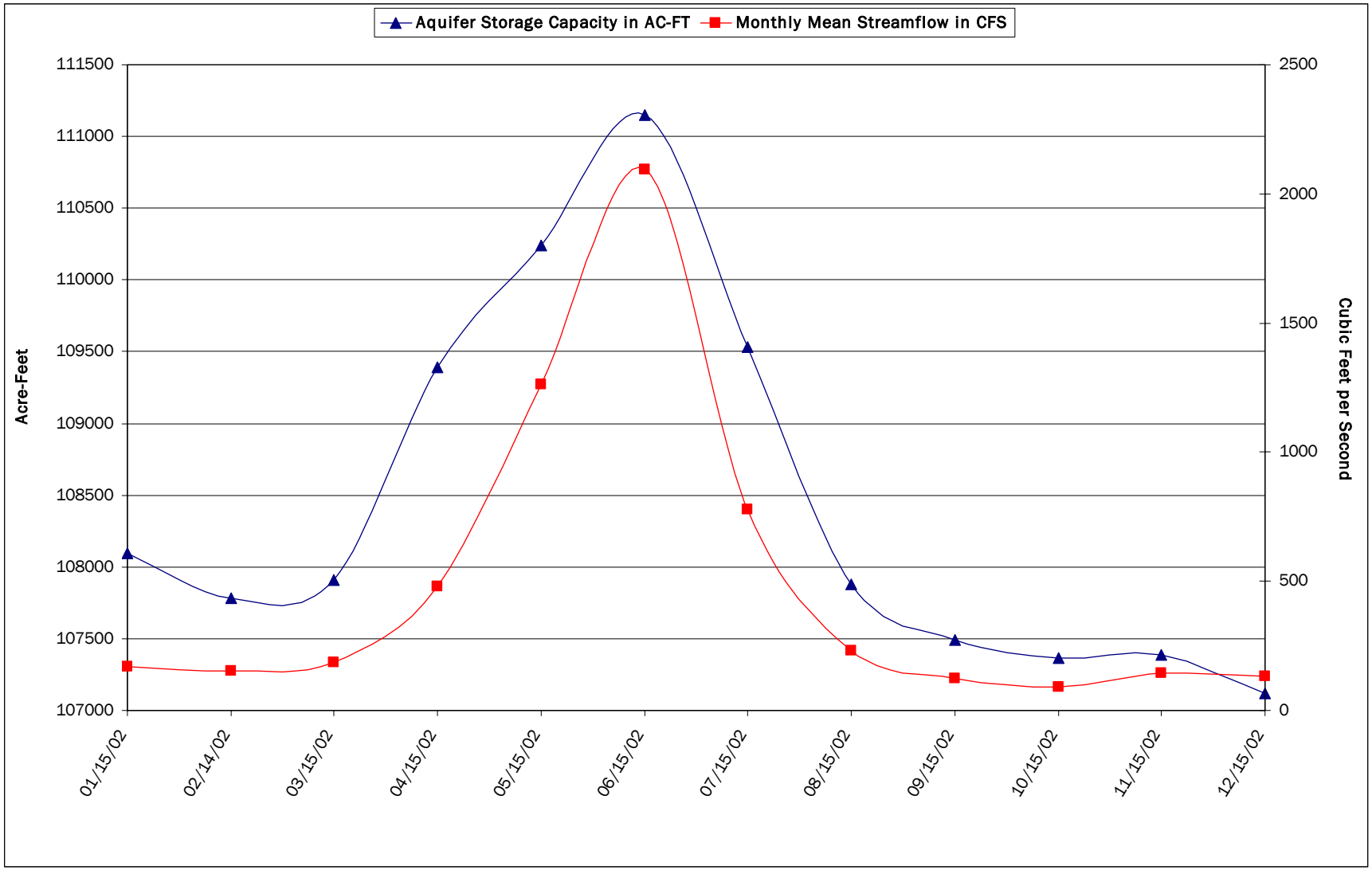


Figure 4-6. 2002 Entiat valley aquifer storage (ac-ft) vs. mean monthly streamflow (cfs) (Dixon 2003).

Figure 4-6 on page 4-16 shows 2002 groundwater storage volumes within the Entiat River valley mainstem aquifer were estimated to range from a high of 111,153 acre feet in June to a low of 107,122 acre feet in December (Dixon 2003). The change in groundwater storage volume (June high minus December low) or annual recharge for 2002 was estimated to be 4,031 acre feet. A temporal comparison of monthly aquifer storage values with mean monthly streamflow showed a strong correlation between the rise in streamflow and the rise in groundwater volumes within the Entiat valley. Refer to the draft aquifer storage report (Dixon 2003) for more information.

4.6 GAIN-LOSS ANALYSIS

A gain-loss study (also referred to as a seepage run or synoptic flow study) involves the direct measurement, over a discrete time period, of all surface water inputs to and outputs from a stream system, as well as multiple mainstem measurements that break the stream into reaches. Once these flow measurements are complete it is possible to construct a simple surface water budget for the stream, and identify (and quantify) gaining or losing reaches. A gain-loss study is best conducted when the stream is at or near "baseflow" condition, i.e. when most or all of the flow in the system is derived from groundwater sources as opposed to precipitation runoff or snowmelt. Baseflow condition in the Entiat system generally occurs in the fall, after the annual snowpack has entirely melted and the subbasin has been without substantial precipitation for some time.

USFS, USGS and CCCD staff cooperated in a gain-loss study of the Entiat River from just above the North Fork confluence downstream, and in the lower Mad River up to the Tillicum Creek confluence near RM 2, during September 25-28, 2002. The project was planned, organized and supervised by the USFS Entiat RD Hydrologist. Many willing landowners granted access to sites to make this study possible. All tributaries with surface flow and all irrigation diversion intakes/outfalls were measured. Mainstem locations identified through geological interpretation as likely areas of changing surface-water/ground-water interchange based on alluvial aquifer depth, proximity to alluvial fans, bedrock pinch points and faults were also measured (R. Dixon, J. Monahan and R. Hendrick, WDOE, pers. comm. September 2002). Additionally, all sites with long-term or recently installed continuous recording stream gages were measured. For more detail, see the 2002 Entiat/Mad River gain-loss study report (2003b).

The gain/loss figures on pages 4-18 and 4-19 show all mainstem measurement reaches, reach gain or loss in cubic feet per second (cfs), and the net rates of gain/loss per unit channel length. It is clear that the Entiat River experiences significant and widely varying ground-water / surface-water interchange within its identified reaches. Two lower mainstem Entiat reaches had a net gain in discharge per unit channel length greater than 10 ft^3/sec/mile; the overall net increase in discharge due to groundwater contribution on the mainstem Entiat River was 11.51 ft^3/sec. Overall, areas of measured gains and losses agreed well with predictions based on geologic interpretation. The Mad River also showed significant groundwater/surface water interchange within the study reaches.

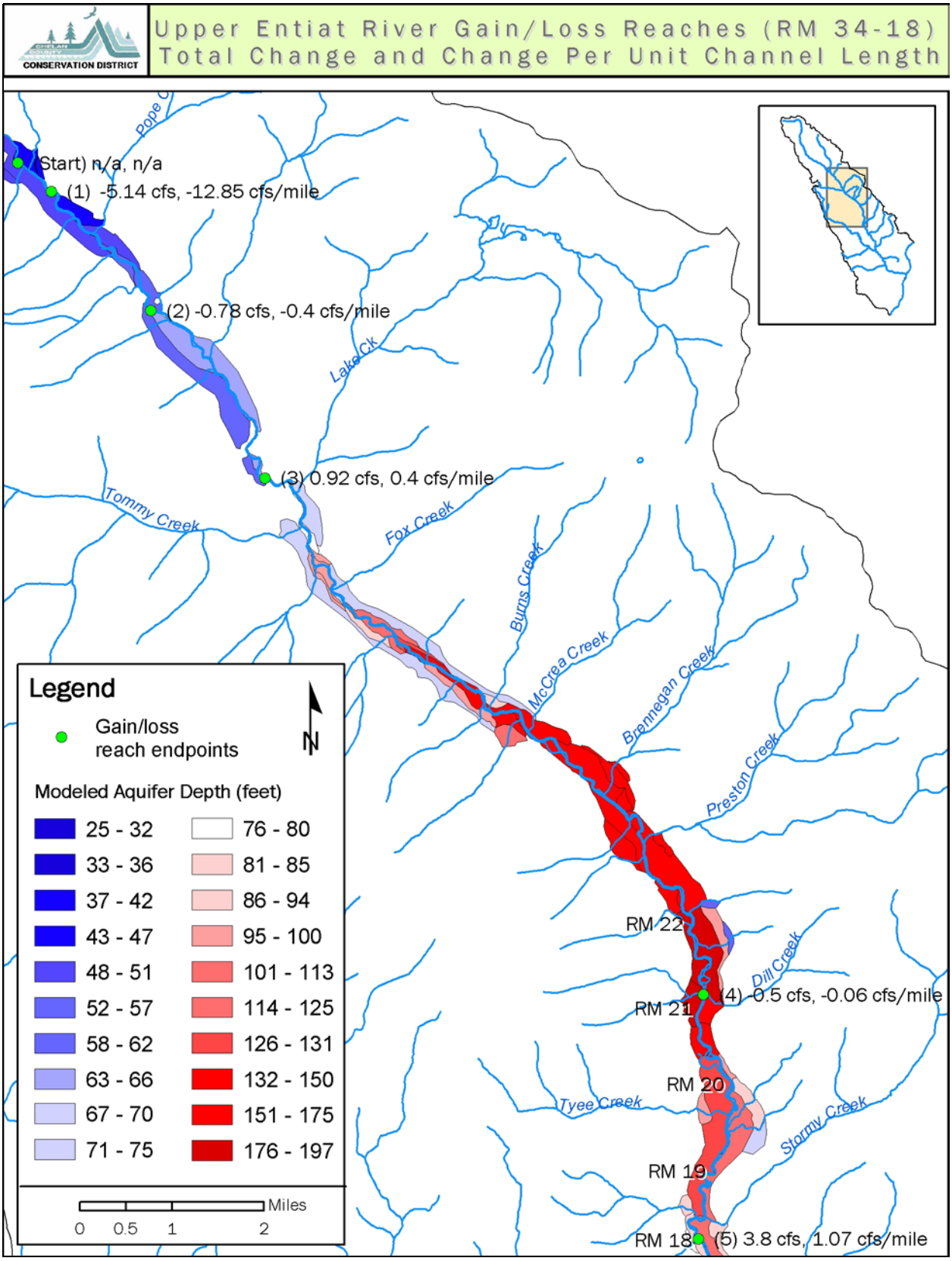


Figure 4-7. Upper Entiat River gain/loss reaches and measurements September 2002.

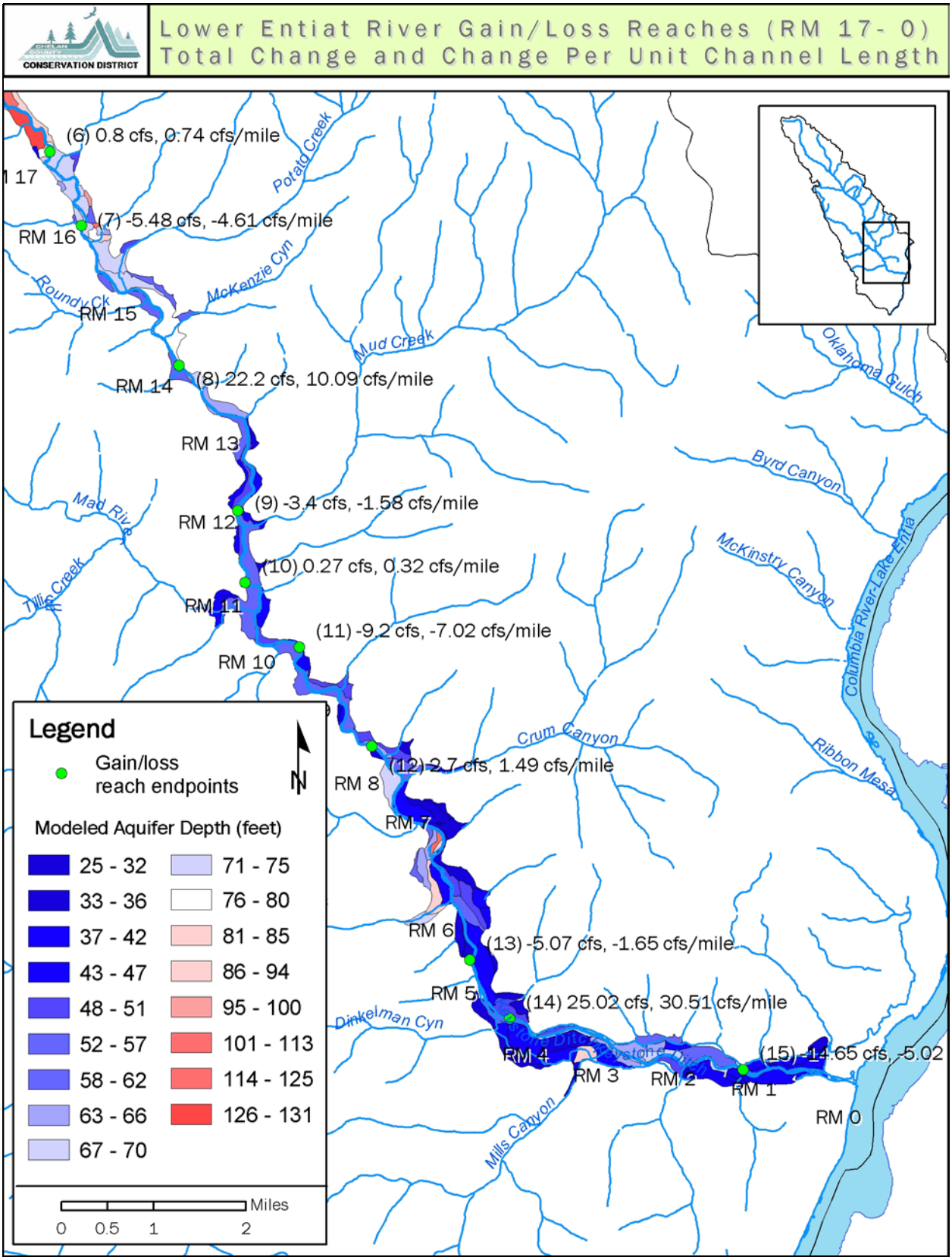


Figure 4-8. Lower Entiat River gain/loss reaches and measurements September 2002.

The results of this study are an important component of efforts to quantify ground water and identify areas of ground-water/surface-water interaction within the Entiat subbasin. The two mainstem Entiat reaches with a net gain in discharge per unit channel length of greater than 10 ft^3/sec/mile occurred in the lower portion of the river, where most land is privately owned. These gaining reaches act like "filling stations" and it is due to their large groundwater contributions that the Entiat River had an overall net gain in flow of 11.51 ft^3/sec from the North Fork confluence (approximately RM 34) to the mouth. It is not clear whether the groundwater entering the stream in these reaches is derived exclusively from the shallow alluvial aquifer, irrigation return flows, or coming from deep groundwater sources due to regional and local geology. If the latter is the case, gaining reaches may be linked to hydro-climatic conditions spatially and temporally removed from local conditions, and therefore unpredictable. Additional gain-loss and aquifer studies in other months would help to refine our understanding of aquifer/stream interactions on the Entiat and Mad Rivers.

4.7 WATER RECHARGE AREAS

Chapter 90.82.070 RCW requires watershed planning units to provide "an identification of the areas where aquifers are known to recharge surface bodies of water and areas known to provide for the recharge of aquifers from the surface". The most important and obvious cases of these relationships in WRIA 46 are the interactions between the Entiat River and the Entiat valley unconsolidated alluvial aquifer. These are discussed at length in sections 4.3 through 4.6; Figures 4-7 and 4-8 on the previous pages show details of gaining and losing (aquifer discharging and recharging, respectively) reaches of the mainstem Entiat River in late September 2002. All findings discussed in the aforementioned sections indicate that water interchange between the Entiat alluvial aquifer and Entiat River in-channel flow fluctuates both seasonally and spatially. A great deal of further study in the form of additional gain-loss analyses, continued and expanded well monitoring, and refinement and updating of the aquifer storage GIS model would be needed to adequately define reach- and season-specific areas of aquifer/river recharge.

In an attempt to identify areas of groundwater - surface water interchange not associated with the Entiat River, its tributaries and the Entiat alluvial aquifer, the Planning Unit examined USFWS National Wetlands Inventory (NWI) and USFS Land Type Association (LTA) GIS data. The USFS LTA data identified likely areas of *upwelling*; i.e., the likelihood of near surface groundwater contributing to seeps, springs, etc. An area of upwelling exhibits, to a greater or lesser degree, the expression of all the site factors affecting near surface groundwater movement and storage. Specific geologic formations, such as the Tenas Basalt and Dick Mesa basalt cap, also serve as mini-aquifer areas with several springs seeping out at or near their contact with bedrock (see Chapter 3, Section 3.3.3, Geology). During their land use study, Central Washington University classified some land uses in the subbasin as sub-irrigated pasture. An area along the Entiat River approximately 20 acres in size near the mouth of Mills Canyon (approximately RM 3.5), and additional sites between RM 19 and RM 22 were identified, indicating other likely areas of groundwater upwelling.

4.8 WATER RIGHTS, CLAIMS AND APPLICATIONS

The WDOE's Geographic Water Information System (GWIS), a GIS-based tool for display and query of water right type, location and volume information, was used to estimate the amount of water in WRIA 46 represented by water right permits and certificates, and claims. The Planning Unit analyzed water right and claim data contained in GWIS, and grouped the information according to the type of document (permit/certificate or claim), water source (surface water or groundwater withdrawal), source of water withdrawal (Mad, Entiat, or minor Columbia River tributaries), and primary beneficial use. Existing water rights within the Entiat subbasin that are conditioned by instream were also summarized, as well as water right applications. Data contained in the tables below and on the following pages were taken from water right and claim documents as reported. It is important to note that cfs values represent a maximum potential instantaneous rate of withdrawal, not a continuous withdrawal rate.

Table 4-4. Summary of surface water certificates and permits.

Source Area	# of Records	Sum of CFS	# of Records Reporting CFS	Sum of Ac-Ft	# of Records Reporting Ac-Ft	Calculated Ac-Ft[3]
Columbia River & Minor C. R. tributaries	27	210,022.2[1]	26	390,719.2[1]	16	752.2
Entiat River watershed	84	73.7	81	1,392.6	37	2,563.6
Mad River watershed	4	70.2	4	19.5	4	25.0
Totals	**115**	**210,166.1**	**111**	**392,131.3**	**57**	**3,340.8**

Table 4-5. Summary of surface water claims.

Source Area	# of Records	Sum of CFS	# of Records Reporting CFS	Sum of Ac-Ft	# of Records Reporting Ac-Ft	Calculated Ac-Ft[3]
Columbia River & Minor C. R. tributaries	28	506.5	17	5,676.7	23	2,399.2
Entiat River watershed	133	4,885.4[2]	70	377,282.4[2]	109	15,012.8
Mad River watershed	12	0.1	5	815.0	8	815.0
Totals	**173**	**5,392.0**	**92**	**383,774.1**	**140**	**18,227.0**

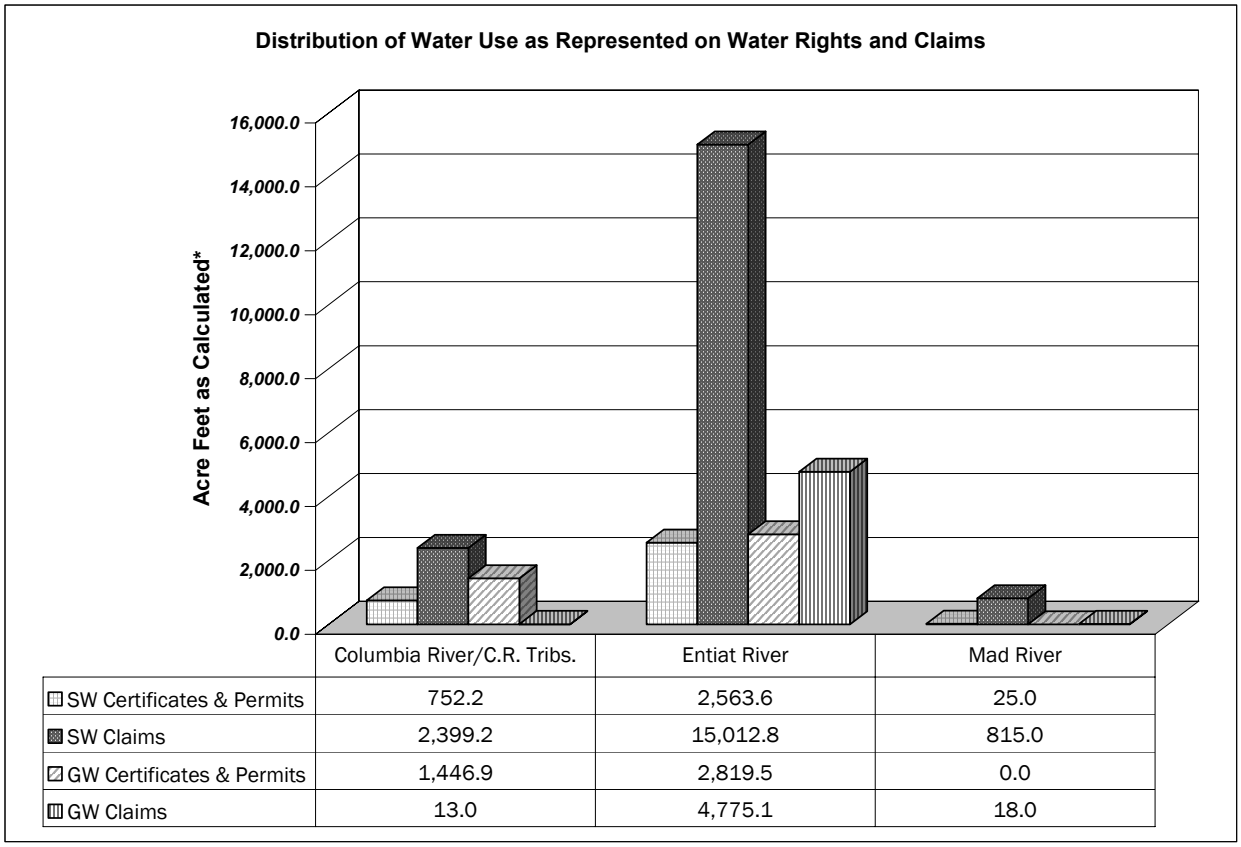
1. Includes a reported 210,000 cfs and 390,000 ac-ft for power generation.
2. Includes numerous claims with questionable reported values totaling 3,400 cfs & 370,213 ac-ft.
3. Calculated acre-feet values for surface water rights and claims are based on irrigated acres reported multiplied by 4.0 acre-feet per acre plus reported values for non-irrigation uses.

Table 4-6. Summary of ground water certificates and permits.

Source Area	# of Records	Sum of CFS	# of Records Reporting CFS	Sum of Ac-Ft	# of Records Reporting Ac-Ft
Columbia River & Minor C. R. Tributaries	13	8.2	13	1,446.9	13
Entiat River watershed	25	14.0	25	2,819.5	25
Mad River watershed	0	0.0	0	0.0	0
Totals	**38**	**22.2**	**38**	**4,266.4**	**38**

Table 4-7. Summary of ground water claims.

Source Area	# of Records	Sum of CFS	# of Records Reporting CFS	Sum of Ac-Ft	# of Records Reporting Ac-Ft
Columbia River & Minor C. R. Tributaries	9	0.2	7	13.0	7
Entiat River watershed	152	15.0	109	4,775.1	105
Mad River watershed	11	0.2	6	18.0	7
Totals	**172**	**15.4**	**122**	**4,806.1**	**119**



**Calculated acre-feet for surface water are based on irrigated acres reported multiplied by 4.0 acre-feet per acre plus reported values for non-irrigation uses.*

Figure 4-9. Geographic distribution of WRIA 46 water use as represented on rights & claims.

Table 4-8. Surface water certificates, permits and claims by primary beneficial use.

	Columbia River & Minor C. R. tributaries		Entiat River watershed		Mad River watershed	
Primary Use	Certificates & Permits	Claims	Certificates & Permits	Claims	Certificates & Permit	Claims
Commercial/Industrial	1	0	0	0	0	1
Single Domestic	1	0	4	0	2	0
Multiple Domestic	1	0	2	0	0	0
General Domestic	0	6	0	5	0	1
Frost Protection	0	0	2	0	0	0
Fish Propagation	0	0	2	0	0	0
Heat Exchange	1	0	0	0	0	0
Irrigation	14	18	63	106	2	5
Mining	0	0	0	2	0	0
Municipal	0	0	1	0	0	0
Power	3	0	0	0	0	0
Stock Watering	6	3	8	19	0	5
Wildlife Propagation	0	1	0	0	0	0
Use Not Listed	0	0	2	1	0	0
Totals	**27**	**28**	**84**	**133**	**4**	**12**

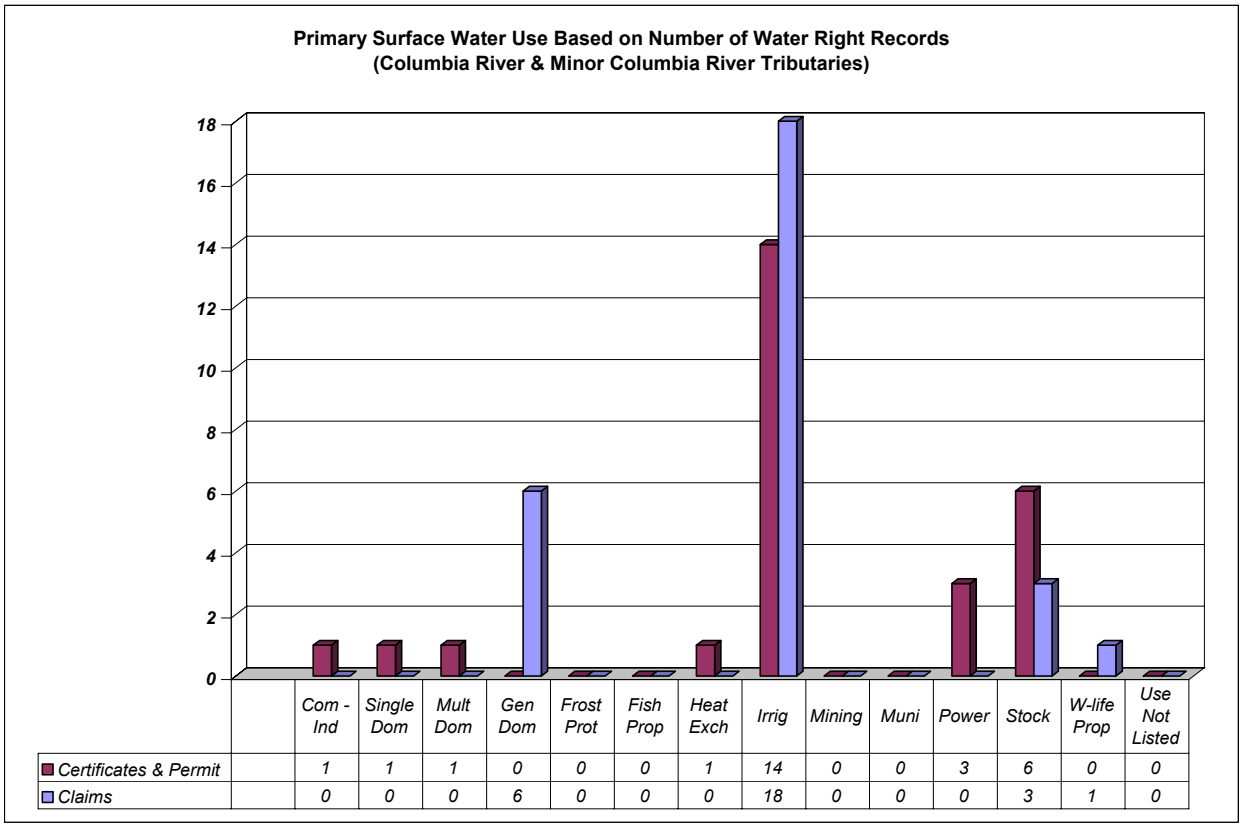
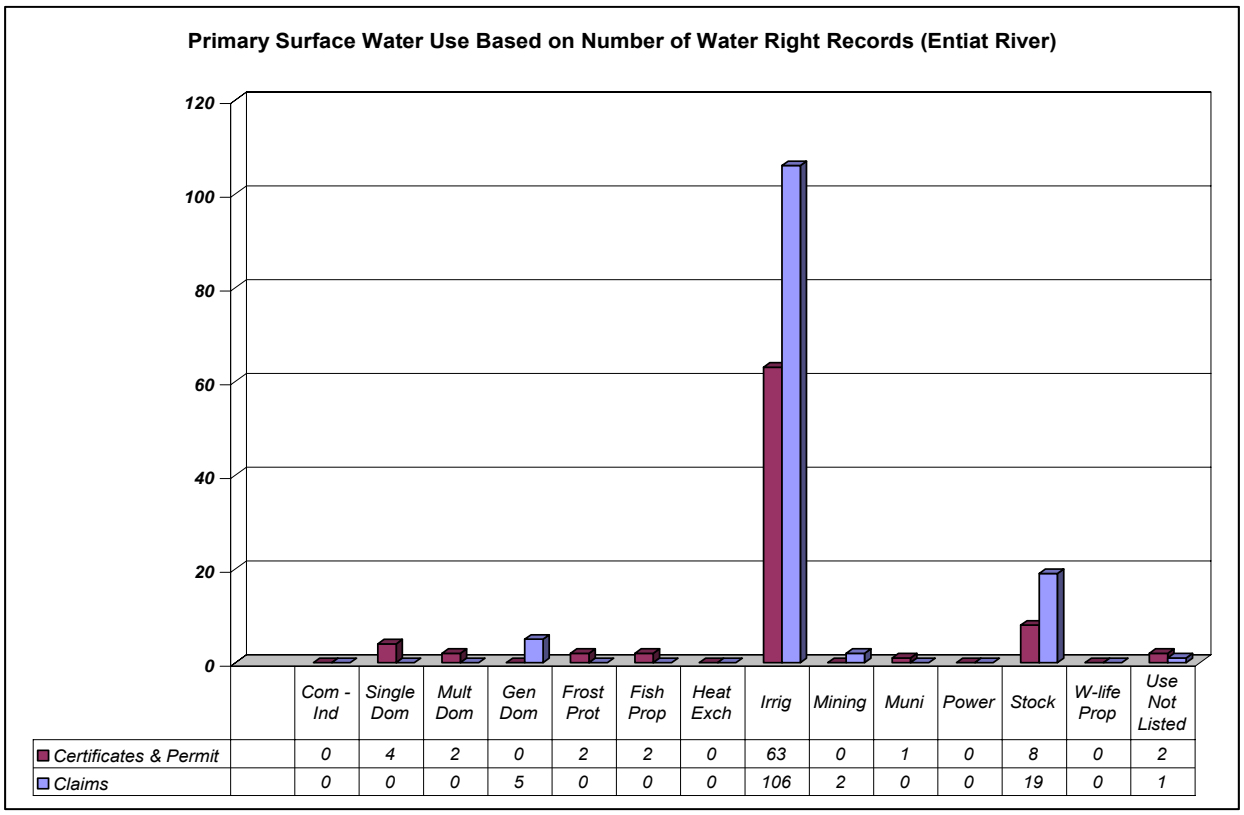
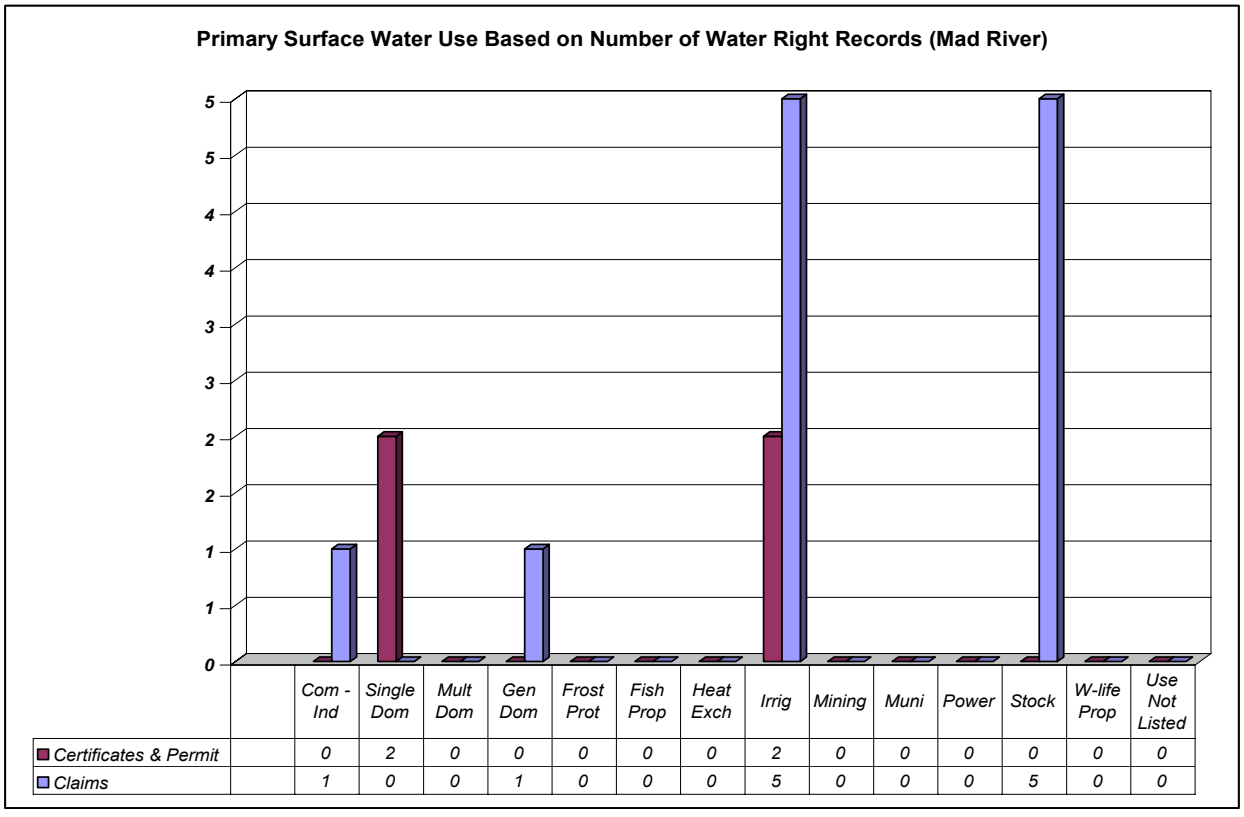


Figure 4-10. Columbia River & minor C.R. tributaries primary surface water beneficial use.



	Com - Ind	Single Dom	Mult Dom	Gen Dom	Frost Prot	Fish Prop	Heat Exch	Irrig	Mining	Muni	Power	Stock	W-life Prop	Use Not Listed
Certificates & Permit	0	4	2	0	2	2	0	63	0	1	0	8	0	2
Claims	0	0	0	5	0	0	0	106	2	0	0	19	0	1

Figure 4-11. Entiat River watershed primary surface water beneficial use.



	Com - Ind	Single Dom	Mult Dom	Gen Dom	Frost Prot	Fish Prop	Heat Exch	Irrig	Mining	Muni	Power	Stock	W-life Prop	Use Not Listed
Certificates & Permit	0	2	0	0	0	0	0	2	0	0	0	0	0	0
Claims	1	0	0	1	0	0	0	5	0	0	0	5	0	0

Figure 4-12. Mad River watershed primary surface water beneficial use.

Table 4-9. Ground water certificates, permits and claims by primary beneficial use.

	Columbia River & Minor Col. R. Tributaries		Entiat River watershed		Mad River watershed	
Primary Use	Certificates & Permits	Claims	Certificate & Permits	Claims	Certificate & Permits	Claims
Commercial/Industrial	0	0	1	1	0	0
Single Domestic	0	0	2	1	0	0
Multiple Domestic	4	0	1	7	0	0
General Domestic	0	7	0	82	0	6
Frost Protection	0	0	0	0	0	0
Fish Propagation	0	0	2	0	0	0
Heat Exchange	0	0	0	0	0	0
Irrigation	8	2	19	51	0	5
Mining	0	0	0	0	0	0
Municipal	1	0	0	0	0	0
Power	0	0	0	0	0	0
Stock Watering	0	0	0	10	0	0
Wildlife Propagation	0	0	0	0	0	0
Not Reported	0	0	0	0	0	0
Totals	**13**	**9**	**25**	**152**	**0**	**11**

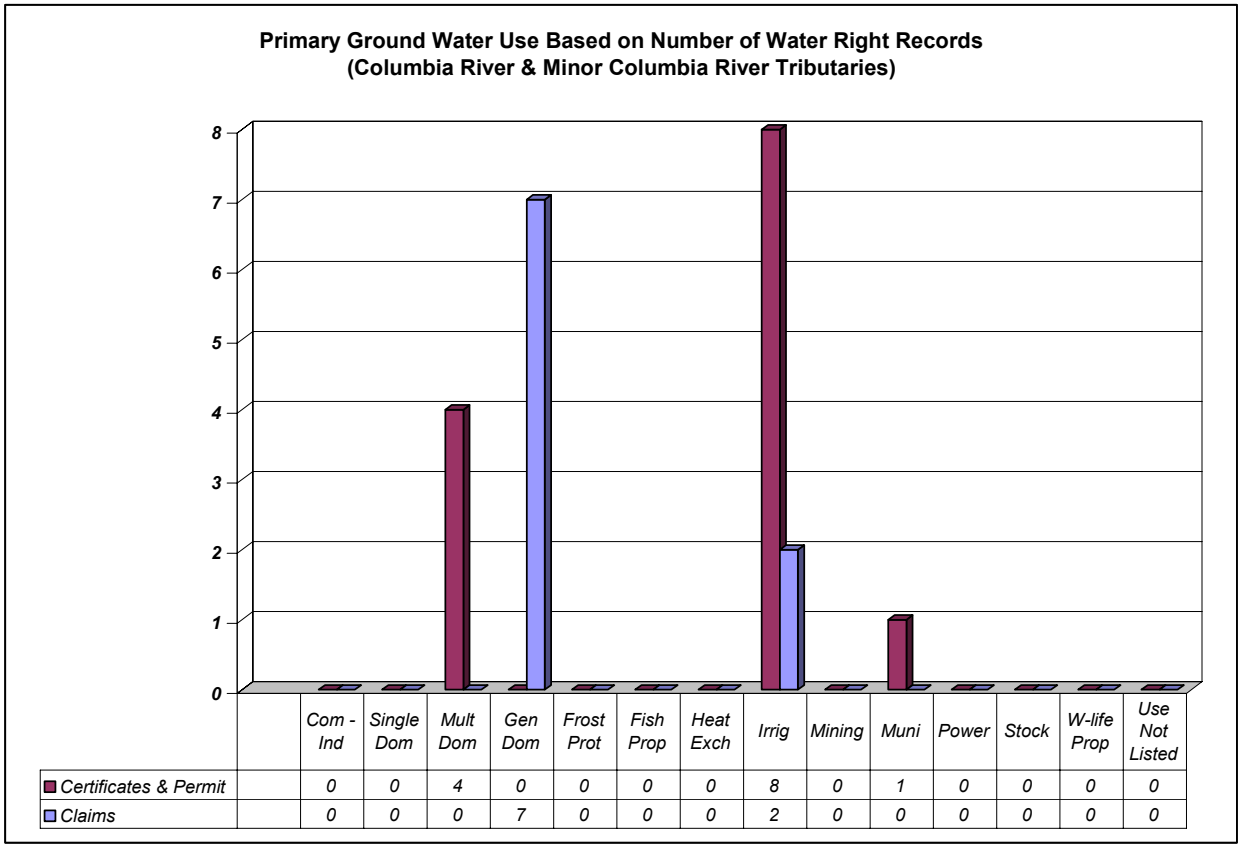
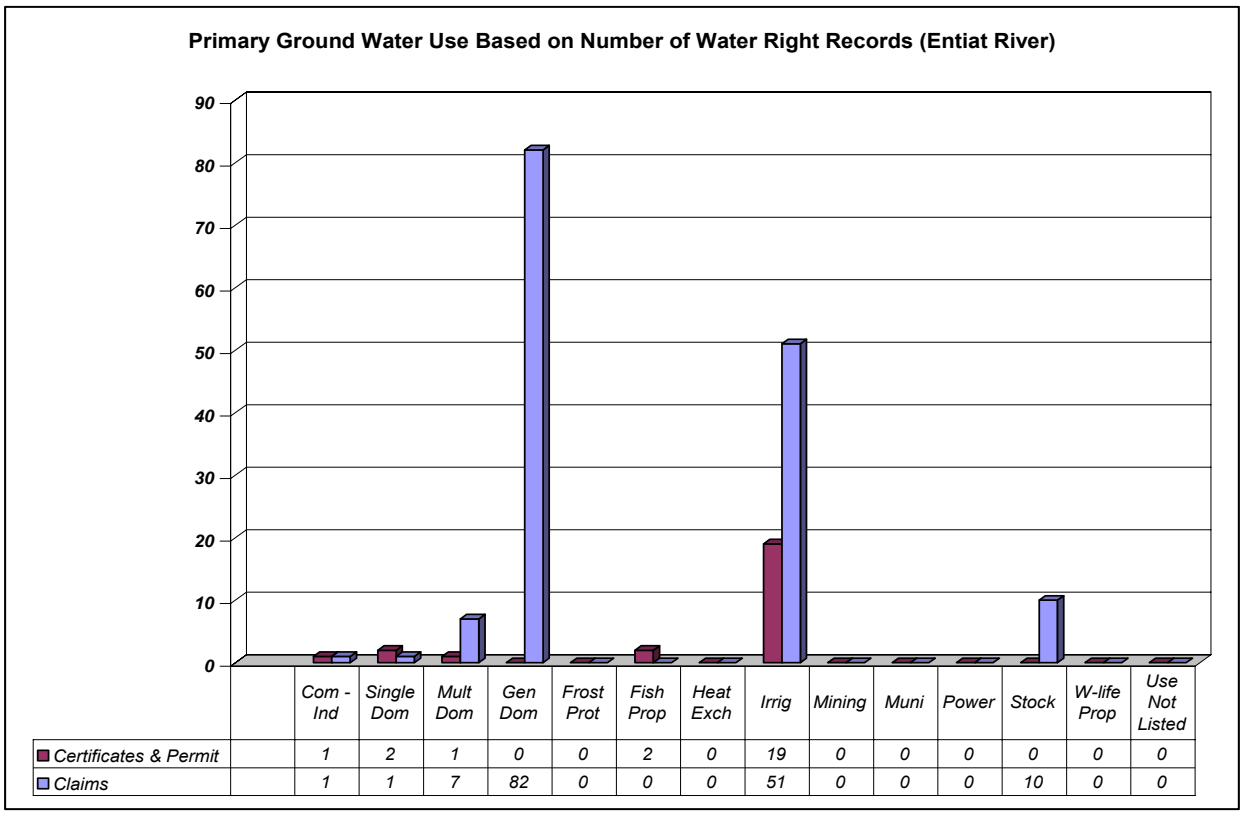
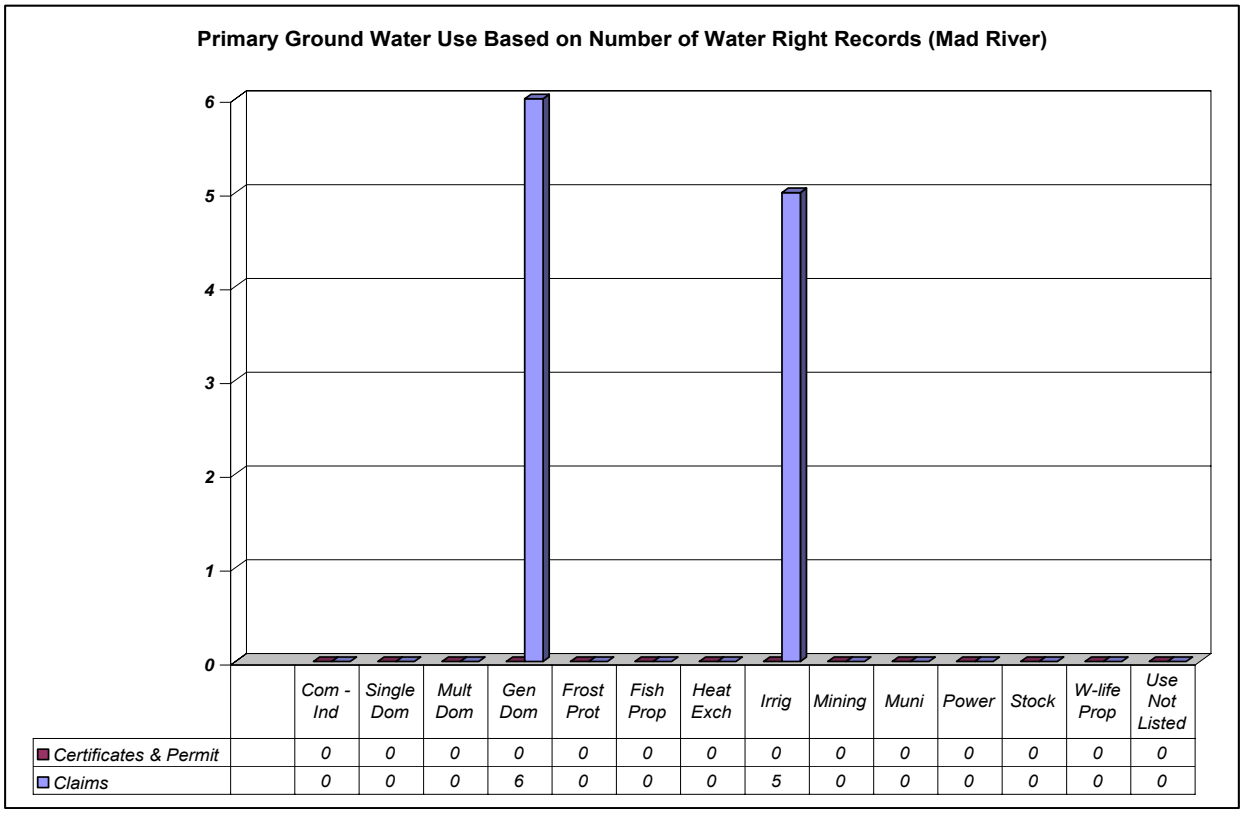


Figure 4-13. Columbia River & minor C.R. tributaries primary ground water beneficial use.



	Com - Ind	Single Dom	Mult Dom	Gen Dom	Frost Prot	Fish Prop	Heat Exch	Irrig	Mining	Muni	Power	Stock	W-life Prop	Use Not Listed
Certificates & Permit	1	2	1	0	0	2	0	19	0	0	0	0	0	0
Claims	1	1	7	82	0	0	0	51	0	0	0	10	0	0

Figure 4-14. Entiat River watershed primary ground water beneficial use.



	Com - Ind	Single Dom	Mult Dom	Gen Dom	Frost Prot	Fish Prop	Heat Exch	Irrig	Mining	Muni	Power	Stock	W-life Prop	Use Not Listed
Certificates & Permit	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Claims	0	0	0	6	0	0	0	5	0	0	0	0	0	0

Figure 4-15. Mad River watershed primary ground water beneficial use.

Analysis of the WDOE water rights registry revealed that 11 permits and one certificate issued for water use in the Entiat watershed since March 1993 are conditioned to some degree by minimum instream flows (for a complete explanation and discussion of minimum instream flows, refer to Chapter 5, Instream Flows).

Table 4-10. Conditioned surface and ground water certificates and permits.

Source Area	# of Records	Sum of CFS	# of Records Reporting CFS	Sum of Ac-Ft	# of Records Reporting Ac-Ft	Sum of Reported Irrig. Acres
Entiat River watershed *Surface water*	8	2.6	8	139.1	8	51.0
Entiat River watershed *Ground water*	4	0.0	0	115.9	4	36.5
Totals	**12**	**2.6**	**8**	**255.0**	**12**	**87.5**

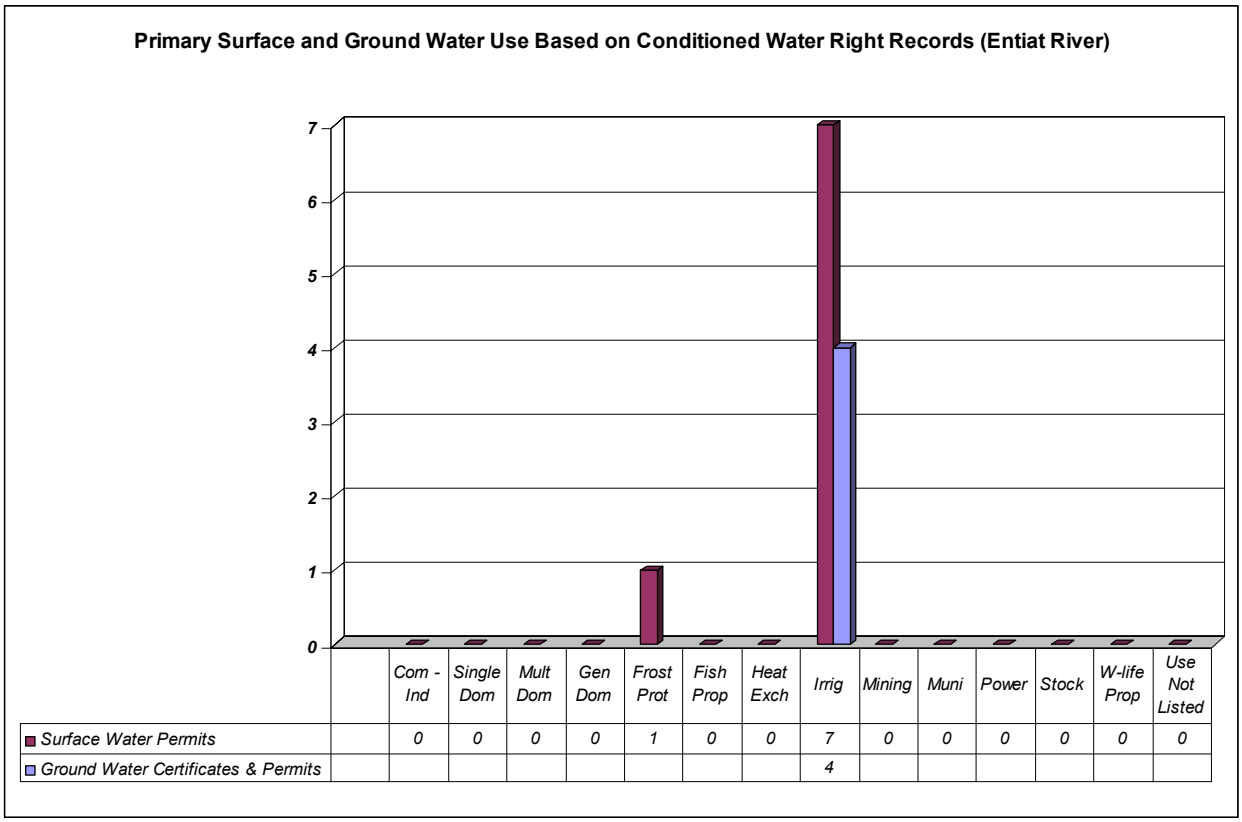


Figure 4-16. Primary surface and ground water use reported in conditioned water rights.

Language in the 12 conditioned water rights stipulates that "The irrigation portion [April 1 to October 31]…is subject to the recommendations of the Department of Fish and Wildlife minimum instream flow provisions", such that "No diversion of water…shall take place when the flow of the Entiat River falls below 116 cfs during November 1 through August 31, and 77 cfs during September 1 through October 31 as measured at the Ardenvoir gage". The minimum instream flows by which the water rights are conditioned were determined by the WDFW based on application of the Tennant Method for stream flow requirements. Stream flow exceedence values calculated based on flows recorded at the Ardenvoir gage for the

months of April - October show that sufficient water will likely be present 90% or more of the time from April through July; however, certainty of water availability decreases during the months of August-October, as evidenced by the flow exceedence values (see Table 4-11). The Record of Decision, which is part of the legal record, provides additional detail about the review process, calculations and considerations that led to these water right decisions.

Table 4-11. Minimum instream flows associated with conditioned water rights, and flow exceedence values by month based on Entiat near Ardenvoir (Stormy) gage data.

	Apr	May	Jun	Jul	Aug	Sep	Oct
Minimum Instream Flow (cfs)	116	116	116	116	116	77	77
Percent flow exceedence at Ardenvoir	90	99.5	100	100	84	63	68

The WDOE Water Rights Application Tracking System (WRATS) showed that 34 applications have been filed for water rights in WRIA 46 since 1991. Although surface water applications showed cfs, and ground water applications reported a pumping rate in gallons per minute (gpm), no acre-feet calculations were reported by either due to the fact that this volume is determined during application processing. Thus, only calculated acre-feet values are shown.

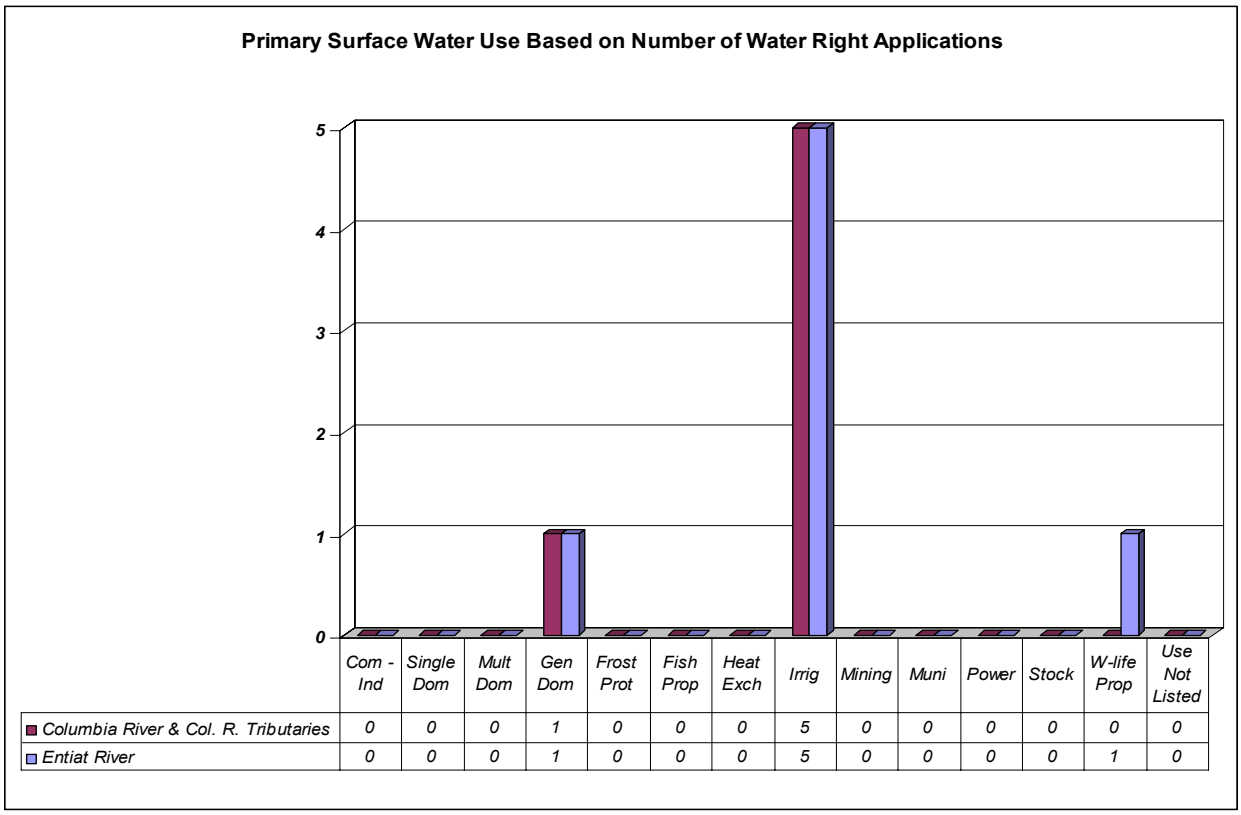
Table 4-12. Surface water right applications.

Source Area	# of Records	Sum of CFS	# of Records Reporting CFS	Sum of Reported Irrigated Acres	Calculated Irrigation Ac-Ft[1]	Sum of Reported Domestic Units	Calculated Domestic Ac-Ft[2]
Columbia River & Minor C. R. Tributaries	6	0.5	6	11.68	46.7	1	0.1
Entiat River watershed	7	0.9	7	23.00	92.0	2	0.2
Totals	**13**	**1.4**	**13**	**34.70**	**138.7**	**3**	**0.3**

Table 4-13. Ground water right applications.

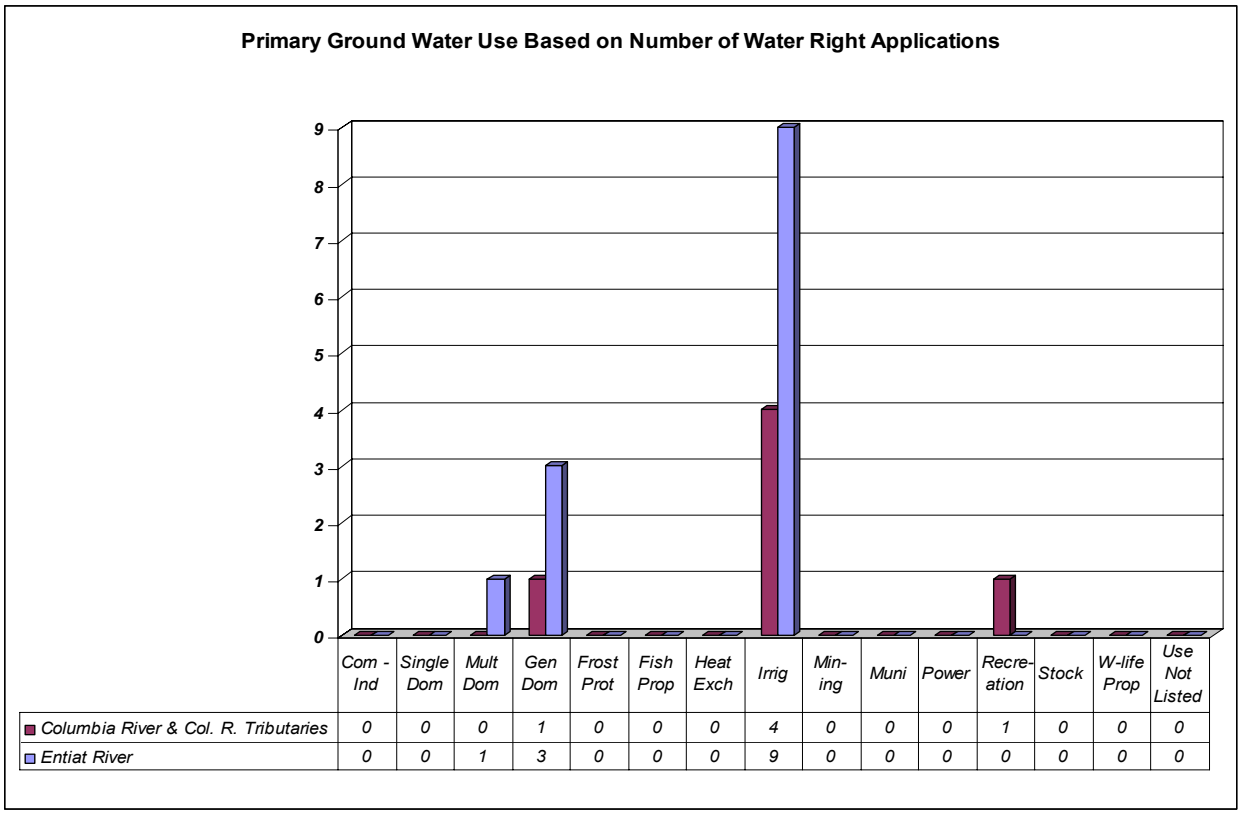
Source Area	# of Records	Sum of gpm	# of Records Reporting gpm	Sum of Reported Irrigated Acres	Calculated Irrigation Ac-Ft[1]	Sum of Reported Domestic Units	Calculated Domestic Ac-Ft[2]
Columbia River & Minor C. R. Tributaries	6	1,530	6	76.4	305.6	82	8.7
Entiat River watershed	13	1,376	13	135.50	542.0	26	2.8
Totals	**19**	**2,906**	**19**	**211.9**	**847.6**	**108**	**11.5**

1. *Calculated irrigation acre-feet values for water right applications are based on irrigated acres reported multiplied by 4.0 acre-feet per acre. Although the Planning Unit has developed irrigation water use estimates for tree fruit and lawn/pasture, 4 ac-ft was used because applications did not specify type of irrigation water use that would occur. For more information see Section 4.19, Irrigation Water Use.*
2. *Calculated domestic acre-feet values for water right applications are based on domestic units reported x 2.71 people per household x 35 gallons per capita per day net water use x 365 days in a year, and converted to acre-feet using the standard 1 acre-foot = 325,850 gallons. For more information on per capita per day domestic net water use estimates, see Section 4.9.2, Domestic In-House Net Water Use.*



	Com - Ind	Single Dom	Mult Dom	Gen Dom	Frost Prot	Fish Prop	Heat Exch	Irrig	Mining	Muni	Power	Stock	W-life Prop	Use Not Listed
Columbia River & Col. R. Tributaries	0	0	0	1	0	0	0	5	0	0	0	0	0	0
Entiat River	0	0	0	1	0	0	0	5	0	0	0	0	1	0

Figure 4-17. Primary surface water use reported in water right applications.



	Com - Ind	Single Dom	Mult Dom	Gen Dom	Frost Prot	Fish Prop	Heat Exch	Irrig	Min-ing	Muni	Power	Recre-ation	Stock	W-life Prop	Use Not Listed
Columbia River & Col. R. Tributaries	0	0	0	1	0	0	0	4	0	0	0	1	0	0	0
Entiat River	0	0	1	3	0	0	0	9	0	0	0	0	0	0	0

Figure 4-18. Primary ground water use reported in water right applications.

Many WRIA 46 water right claims contained in the WDOE registry were incomplete. Some did not list an annual volume in acre-feet, some listed a beneficial use but no volume information, some were missing both beneficial use and volume information, and some irrigation water rights were missing acres irrigated values. Additionally, there is no assurance that all of the aforementioned rights are still in use, or that the volumes contained within the paper record accurately depict water use within the WRIA. Therefore, the values contained in the preceding tables, which were generated directly from information contained in the water right documents, do not represent an accurate accounting of actual water use in the Entiat WRIA; rather, the tables presented are a summary of the information as reported in the paper water right record. The validity and extent of claims can only be determined through a general adjudication in the Superior Court of Chelan County, therefore the record will remain incomplete until they are included in a general adjudication.

4.9 ACTUAL WATER USE

Obvious inconsistencies exist between the amount of water use reported in the paper record (Section 4.8) and what is observed at gaging stations in the subbasin (see Section 4.1). Thus, the EWPU employed a variety of methods and data sources to generate estimates of actual irrigation and in-house domestic water use, which are detailed in this section.

4.9.1 Irrigation Water Use

In 2002, the CCCD contracted members of the Central Washington University (CWU) Geography and Land Studies Department to assess private land use and associated irrigation water use along the Entiat and Mad Rivers. CWU analyzed color stereopairs from 1992 and digital 1m resolution black and white orthophotographs of the valley from 1998, both provided by the USFS Wenatchee National Forest Supervisor's Office, and classified land use in the Entiat and Mad River watersheds as irrigated orchard (IO), irrigated residential (IR), non-irrigated residential (NIR), irrigated pasture (IP), non-irrigated pasture (NIP), sub-irrigated pasture (SIP), or building (BLD). Areas of pulled orchard (PO) were also classified, and project staff performed ground-truthing to verify photograph interpretation. On screen digitizing and analysis in a GIS was done to produce a land use polygon shapefile containing acreage estimates, land use type, irrigation water use, irrigation, and pulled orchard attribute data (Lillquist and Erickson 2002). In the spring of 2003, the Planning Unit performed supplemental orthophotograph interpretation and field checks to generate irrigated orchard information for the minor Columbia River tributaries area of the WRIA. A GIS was used to digitize and add these land use polygons to the original shapefile created by CWU.

Central Washington University's estimates of total tree irrigation water use were developed using information contained in the document "Irrigation Requirements for Washington: Estimates and Methodology" (James et al. 1982). This publication lists 40 locations that can be used to estimate irrigation requirements for 30 different crops, as well as return values (a 2-year return period value will be adequate, on average, one out of every two years; a 20-year return period value will be adequate, on average, 19 out of 20 years). Omak and Winthrop were the nearest locations listed in the publication for which data were

available. CWU used Omak crop irrigation requirement data to estimate irrigation water requirements in the Entiat valley, because its elevation and precipitation more closely mirrored conditions in Omak. CWU also used 20-year return period values for apples/cherries with cover and pasture/turf to provide a conservative water use estimate, and applied a 70% irrigation efficiency rate in their estimates of crop irrigation water requirements (Lillquist and Erickson 2002).

The EWPU determined that local data could be used to refine CWU's crop irrigation water use calculations and more accurately reflect irrigation water use in the Entiat valley. The Planning Unit used data collected by the WSU Cooperative Extension Program at the WSU Tree Fruit Research Center in Wenatchee to revise irrigation requirement estimates. WSU Cooperative Extension has annually recorded water use by month in acre-inches for fruit trees with cover since 1972. Data from this 31-year period of record (1972-2002) were used to determine average monthly fruit tree water requirements in acre-inches from April through September. Refer to Table 4-14 on page 4-32 for a summary of monthly tree water use data.

Due to the fact that WSU has not collected much data on tree water use in the month of October, miscellaneous data and input from WSU Cooperative Extension agent Tim Smith were used to estimate fruit tree irrigation water requirements in October at two acre-inches (T. Smith, pers. comm., April 8, 2003). Based on discussions with EWPU landowners and NRCS Resource Conservationist Gary Mitchell, the 70% application efficiency level used in CWU's calculations was changed to 65% in order to better reflect overall irrigation water application efficiency levels in the Entiat valley, and provide a more conservative estimate of irrigation water use.

Estimates of the total amount of irrigation water used in acre-feet during each month of the effective growing season (April-October), with 65% application efficiency, were made using WSU's tree water use data and CWU's irrigated orchard acreage estimates in the following formula:

$$\{[(\text{Tree Water Requirement } \textit{in ac-in} \times \text{Acres of Orchard}) / 65] \times 100\} / 12$$

WSU does not collect data on pasture/turf (lawn) irrigation water requirements. The best available information on local pasture/turf irrigation water requirements is published in USDA SCS document "State of Washington Irrigation Guide". This guide contains a value for pasture/turf irrigation water requirements in Wenatchee; it also contains data on fruit tree water use in Wenatchee. A ratio was developed using the State of Washington Irrigation Guide's published season water requirement for apples with cover and the published season value for pasture/turf to determine what percentage of fruit tree irrigation water is required to support pasture/turf. Calculations showed that pasture/turf requires 85% of the volume of water required for fruit trees with cover. The following formula was applied to the monthly average tree fruit water requirements listed in Table 4-14 to estimate monthly pasture/turf water requirements in acre-feet with 65% irrigation efficiency:

$$\{[(\text{Fruit Tree Water Requirement } \textit{in ac-in} \times 0.85 \times \text{Acres of Pasture/Turf}) / 65] \times 100\} / 12$$

Table 4-14. Monthly tree water use[1] (ac-in) at WSU Tree Fruit Research Center, 1972-2002.

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT[2]	SEASON TOTAL
1972	2.03	5.18	7.47	9.20	8.03	4.43	2.00	38.34
1973	2.28	5.40	9.22	11.48	9.80	4.60	2.00	44.78
1974	1.74	4.57	8.69	9.21	8.95	5.21	2.00	40.37
1975	1.72	5.26	8.33	10.49	8.88	4.66	2.00	41.34
1976	1.84	2.82	7.86	10.04	6.71	4.84	2.00	36.11
1977	1.69	4.49	6.67	8.32	5.43	4.32	2.00	32.92
1978	1.92	5.18	8.07	10.20	8.25	4.63	2.00	40.25
1979	2.10	3.78	8.11	9.45	8.31	3.28	2.00	37.03
1980	1.66	4.52	6.25	9.72	7.06	3.61	2.00	34.82
1981	1.61	4.26	6.19	8.53	7.63	3.76	2.00	33.98
1982	1.61	4.60	7.18	8.06	6.74	3.22	2.00	33.41
1983	1.44	5.20	6.66	7.18	6.53	3.89	2.00	32.90
1984	1.47	3.92	6.42	9.86	7.89	3.26	2.00	34.82
1985	1.72	5.18	8.34	10.71	7.93	3.13	2.00	39.01
1986	1.74	4.65	7.69	8.56	7.97	4.08	2.00	36.69
1987	1.88	4.75	7.30	8.28	8.09	4.46	2.00	36.76
1988	1.56	4.22	6.38	10.06	7.57	4.16	2.00	35.95
1989	1.79	4.47	7.65	9.40	7.13	4.43	2.00	36.87
1990	1.78	3.91	6.69	9.39	6.83	4.55	2.00	35.15
1991	1.87	4.21	6.41	10.00	7.42	4.48	2.00	36.39
1992	2.08	6.34	8.58	8.75	7.65	4.22	2.00	39.62
1993	1.10	4.75	6.36	7.46	7.20	3.90	2.00	32.77
1994	1.69	4.74	8.23	12.41	8.53	4.67	2.00	42.27
1995	1.47	5.28	7.90	10.52	7.90	4.66	2.00	39.73
1996	1.53	4.34	8.54	11.02	9.58	4.65	2.00	41.66
1997	1.14	4.27	7.22	9.16	7.30	3.48	2.00	34.57
1998	1.49	3.66	7.81	9.52	8.29	4.75	2.00	37.52
1999	1.60	4.57	8.03	9.31	7.26	4.00	2.00	36.77
2000	1.65	4.38	8.02	9.85	8.56	3.66	2.00	38.12
2001	1.39	4.98	7.06	10.23	7.65	4.35	2.00	37.66
2002	1.49	4.12	7.69	9.83	7.82	3.81	2.00	36.76
MO. AVG. SINCE 1972	1.68	4.58	7.52	9.55	7.77	4.17	2.00	37.27 ac-in

1. Data have already been adjusted using pan evaporation & KC value to approximate orchard tree water use.
2. The October value of 2 acre-inches was estimated based on miscellaneous October measurements provided by the WSU Tree Fruit Research Center, and conversations with Tim Smith, WSU Cooperative Extension. April through Sept values are based on data collected by T. Smith.

**Note: Actual irrigation rates must be 10 to 40% higher than tree use, depending on irrigation efficiency*

Table 4-15 shows the 'base' average monthly and seasonal water use values in acre-inches, and the 65% efficiency correction values that were used in the formulas listed in the Irrigation Water Use section to calculate tree fruit and pasture/turf water use estimates.

Table 4-15. Average monthly tree and pasture/turf irrigation water use (ac-in) estimates.

Description of Value	Apr	May	Jun	Jul	Aug	Sep	Oct	Season (Ac-In)
Average tree fruit water use by month, based on 1972-2002 WSU data	1.68	4.58	7.52	9.55	7.77	4.17	2.00	37.27
Average tree water use by month, with 65% application efficiency	2.58	7.05	11.57	14.69	11.95	6.42	3.08	57.34
Average Pasture/Turf water use by month (85% of WSU tree fruit water use avg. value)	1.43	3.89	6.39	8.12	6.60	3.54	1.70	31.68
Average Pasture/Turf water use by month, with 65% efficiency	2.20	5.99	9.83	12.49	10.16	5.45	2.62	48.74

Table 4-16 on page 4-34 summarizes land use acreage and irrigation water use estimates for WRIA 46. Estimates made for the minor Columbia River tributaries portion of the WRIA were based on the limited land use data generated for this area by CWU, and additional land use classification work and ground-truthing performed by the Planning Unit. The supplemental work done for the minor Columbia River tributaries area of the WRIA was focused primarily on documenting acres of irrigated orchard and larger areas of irrigated pasture/turf, due to the fact that water resource management for the Columbia River and its minor drainages is governed by Chapter 173-563 WAC (see Appendix L). Therefore, it is important to note that land and water use estimates for this portion of the WRIA are not thoroughly representative of the minor Columbia River tributaries area, especially with respect to irrigated residential land use. Land use in this area is currently very dynamic; therefore, estimates would likely have changed in the near future. It should also be noted that the minor Columbia River tributaries area data include acres of irrigated land along the lower Entiat River that are supplied by the Entiat Irrigation District, which obtains its water from the Columbia River.

Table 4-16. WRIA 46 estimated average monthly/seasonal irrigation water use in ac-ft, assuming 65% application efficiency.

Land Use	Estimated Acres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Season (ac-ft)
Entiat River watershed above ~RM 18														
Irrigated Residential (IR)	20	0	0	0	3.63	9.88	16.23	20.61	16.77	9.00	4.32	0	0	80.43
Non Irrigated Residential (NIR)	90	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0.00
Sub Irrigated Pasture (SIP)	102	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0.00
Non Irrigated Pasture (NIP)	54	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0.00
Totals	**266**	**0**	**0**	**0**	**3.63**	**9.88**	**16.23**	**20.61**	**16.77**	**9.00**	**4.32**	**0**	**0**	**80.43**
Entiat River watershed below ~RM 18														
Irrigated Orchard (IO)	835	0	0	0	179.84	490.29	805.02	1022.33	831.78	446.40	214.10	0	0	3989.77
Irrigated Residential (IO)	201	0	0	0	36.88	100.54	165.08	209.65	170.57	91.54	43.91	0	0	818.17
Non Irrigated Residential (NIR)	82	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0.00
Irrigated Pasture (IP)	206	0	0	0	37.72	102.83	168.84	214.42	174.45	93.62	44.90	0	0	836.79
Sub Irrigated Pasture (SIP)	19	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0.00
Non Irrigated Pasture (NIP)	345	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0.00
Totals	**1688**	**0**	**0**	**0**	**254.44**	**693.66**	**1138.94**	**1446.40**	**1176.81**	**631.57**	**302.91**	**0**	**0**	**5644.73**
101 acres of current NIP was formerly orchard; 10 acres of current IR/IP was formerly orchard.														
Mad River watershed														
Irrigated Orchard (IO)	21	0	0	0	4.56	12.42	20.40	25.90	21.07	11.31	5.42	0	0	101.08
Irrigated Residential (IR)	15	0	0	0	3.26	8.90	14.61	18.56	15.10	8.10	3.89	0	0	72.42
Non Irrigated Residential (NIR)	16	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0.00
Non Irrigated Pasture (NIP)	1	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0.00
Totals	**53**	**0**	**0**	**0**	**7.82**	**21.32**	**35.01**	**44.46**	**36.17**	**19.41**	**9.31**	**0**	**0**	**173.51**
Minor Columbia R. tributaries Area[1]														
Irrigated Orchard (IO)	571	0	0	0	122.98	335.26	550.46	699.06	568.76	305.24	146.40	0	0	2728.17
Irrigated Residential (IR)[2]	65	0	0	0	11.94	32.54	53.42	67.85	55.20	29.62	14.21	0	0	264.78
Non Irrigated Residential (NIR)	13	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0.00
Irrigated Pasture (IP)	12	0	0	0	2.25	6.13	10.06	12.77	10.39	5.58	2.67	0	0	49.85
Non Irrigated Pasture (NIP)	22	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0.00
Totals	**683**	**0**	**0**	**0**	**137.16**	**373.92**	**613.95**	**779.68**	**634.36**	**340.45**	**163.28**	**0**	**0**	**3042.79**
31acres of current NIR/NIP was formerly orchard; 12 acres of current IR/IP was formerly orchard.														

1. Water use estimates for Minor Columbia River tributaries area irrigated lands in the lower Entiat River that receive water from the Entiat Irrigation District, which draws its water from the Columbia River.

2. Irrigated residential values in this area of the WRIA are based on polygons originally created by CWU, and a few additional lawn polygons created by the CCCD. Time was not spent trying to capture all irrigated residential use in the minor Columbia River tributaries area because this water is drawn from the Columbia River.

4.9.2 Domestic In-house Net Water Use

Almost all of the water pumped from the Entiat valley alluvial aquifer by permit exempt wells for in-house domestic use returns to the groundwater supply via septic system drain fields, or directly through the soil. Arguably, a small portion of the water withdrawn for domestic purposes does not return to the system, e.g., water for drinking or cooking food, water that is removed from clothes in the dryer, water used by house plants.

Although most of the groundwater withdrawn by wells does return to the system, the rate of return is not instantaneous; thus, a certain volume of water is not immediately available to be withdrawn again from groundwater supplies. The EWPU decided the term "Net Water Use" should be used to describe the amount of water that is not immediately returned to the system and available for reuse. The term Net Water Use, rather than "Consumptive Use", will be used throughout the remainder of this discussion in recognition of the fact that very little water withdrawn from the Entiat valley aquifer for in-house use is truly consumed and not returned to groundwater and/or the river system over time.

The Planning Unit utilized records from the City of Entiat's municipal water system to formulate its estimates of per capita per day (pcpd) net water use. The City obtains water for its municipal system from wells adjacent to the Columbia River. Municipal wastewater is processed by the City's treatment plant and discharged back to the Columbia River. The City reports volumes of water pumped and treated in millions of gallons per day (mgd); an average daily volume is also calculated for each month. The EWPU used the City's year 2000 records to develop pcpd net water use estimates. The year 2000 records were used because they were more accurate[1] than 2001 and 2002 data, and 2000 population and household size data for the City were available from the US Census.

It was assumed that the difference between the City's average daily pumped and average daily treated water volumes represented basic municipal net water use; however, the City serves both residential and commercial/industrial customers. In order to estimate the amount of water being pumped and delivered to residences, discussions were held with the City Public Works Department. It was estimated that about 75% of the total annual volume of water that the City pumps is dedicated to residences (B. Whitehall, pers. comm. April 2003).

Average daily pumped values for each month were multiplied by 0.75 to estimate *water flowing to residences* each month. Each monthly residential estimate was divided by the number of days in the month, and then divided by the City's 2000 population to arrive at an estimate of the average amount of water flowing each day to each person during different months of the year. It was estimated that 73 gallons flow each day to each person during the months of October through March. Average daily treated volumes for each month were then subtracted from average daily pumped values and multiplied by 0.75 to estimate *average daily residential net water use* each month. Residential net water use estimates were divided by the City of Entiat's 2000 population to provide an estimate of pcpd net water use. It was estimated that during the months of October through March, pcpd net

[1] The City of Entiat pump experienced technical difficulties in 2001/2002 (B. Whitehall, pers. comm. 2003).

water use was approximately 35 gallons. Refer to Table 4-17 on page 4-37 for a summary of City of Entiat data and per capita per day net water use calculations.

The City pumps surplus water during the months of April through September for cooling and flushing water lines, filling pools, construction projects, etc. The additional water that is pumped is not returned to the City's wastewater plant, making it difficult to estimate net water use values for this period. In order to address this issue, a sample of bi-monthly meter records from different sized households was obtained from the City for March/April, May/June, July/August, and September/October. The sample of meter records showed that, even when the highest household volumes recorded for each two month period were used, the average amount of water flowing to each person each day during this period was 73 gallons. Refer to Table 4-18 on page 4-38 for bi-monthly record data and calculations. Notably, there was not an increase in domestic water use during spring and summer months as one might expect. This can be explained by the fact that the Entiat Irrigation District provides water to the City and its residents for irrigation, outdoor use, etc. during this time period.

In-house net water use analyses were focused on the area *within* the Entiat subbasin that fell *outside* of the City Urban Growth Area (UGA), as water used in the UGA and the minor Columbia River tributaries area of WRIA 46 is obtained from either the City of Entiat or other sources in hydraulic continuity with the Columbia River. Furthermore, a water resources program for the Columbia River has already been developed (see Appendix L, Chapter 173-563 WAC, Instream Resources Protection Program for the Main Stem Columbia River in Washington State). The Planning Unit obtained and analyzed 2000 census tract and block GIS data to determine which census blocks containing people and/or households fell within the subbasin. Two census blocks included data for both the minor CRTs area and the lower Entiat River; one showed 24 people and 7 households, the other 58 people and 16 households. The block with 7 households was included in the analyses, while the block with 16 households was excluded based on known population distribution patterns within these blocks, and the fact that the majority of the excluded block area fell within the minor CRTs region of the WRIA.

Table 4-17. Summary of City of Entiat municipal water system data and per capita per day water use estimates.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Gallons pumped monthly for 390 hookups	2518000	2268400	2749000	3636000	4086700	4664800	5838300	5937200	4104800	3562200	2960900	3028700	
Avg. pumped daily	81226	78221	88677	121200	131829	155493	188332	191523	136827	114910	98697	97700	
Avg. treated daily	45000	47000	53000	56000	60000	57000	64000	67000	59000	57000	48000	43000	
Difference (*Avg. net water use daily)*	36226	31221	35677	65200	71829	98493	124332	124523	77827	57910	50697	54700	
Avg. flow to homes daily *(75% of pumped daily)*	60919	58666	66508	90900	98872	116620	141249	143642	102620	86182	74023	73275	**Oct.-Mar. Daily Avg.**
Avg. flow to each person daily *(flow to homes daily / City pop*)*	64	61	69	95	103	122	148	150	107	90	77	77	**73**
Avg. home net water use daily *(75% of net water use daily)*	27169	23416	26758	48900	53872	73870	93249	93392	58370	43432	38023	41025	
Average pcpd net water use *(home net use / City pop.)*	28	24	28	51	56	77	97	98	61	45	40	43	**35**

** 2000 City of Entiat population = 957. Data provided by US Census Bureau.*

Table 4-18. Sample of City of Entiat water meter data for 19 household connections, in gallons per month*.

People per housing unit	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Highest flow to each person	Bi-monthly period
4	5550	5550	6100	6100	5450	5450	6050	6050	51	May/Jun
4	5850	5850	5100	5100	3950	3950	4550	4550	49	Mar/Apr
4	6200	6200	6250	6250	8300	8300	6550	6550	69	Jul/Aug
4	8400	8400	5700	5700	6750	6750	10250	10250	85	Sep/Oct
4	9750	9750	7900	7900	9300	9300	9100	9100	81	Mar/Apr
4	10600	10600	10850	10850	10150	10150	10250	10250	90	May/Jun
4	15250	15250	10850	10850	15550	15550	12900	12900	130	July/Aug
4	11750	11750	9050	9050	6250	6250	7250	7250	98	Mar/Apr
3	5850	5850	4500	4500	5600	5600	5150	5150	65	Mar/Apr
3	5650	5650	6200	6200	5700	5700	4550	4550	69	May/Jun
2	4700	4700	2700	2700	2750	2750	2750	2750	78	Mar/Apr
2	2500	2500	4150	4150	4450	4450	3850	3850	74	Jul/Aug
2	2200	2200	1650	1650	2500	2500	2450	2450	42	Jul/Aug
2	5650	5650	4500	4500	5200	5200	3550	3550	94	Mar/Apr
2	2850	2850	2700	2700	3000	3000	2700	2700	50	Jul/Aug
2	4350	4350	3500	3500	3900	3900	3500	3500	73	Mar/Apr
2	2350	2350	2200	2200	2700	2700	3150	3150	53	Sep/Oct
2	4200	4200	3900	3900	3750	3750	4100	4100	70	Mar/Apr
2	4550	4550	2950	2950	2100	2100	2450	2450	76	Mar/Apr
Total people = 56 Avg. people per unit=2.9									**Avg. of highest flows = 73**	
Total flow by month to 19 units	118200	118200	100750	100750	107350	107350	105100	105100		
Average flow by month to each unit	6221	6221	5303	5303	5650	5650	5532	5532		
Average flow by month to each person	2111	2111	1799	1799	1917	1917	1877	1877		
Average flow daily to each person	70	70	60	60	64	64	63	63	**March-Oct daily avg. flow = 64**	

** Meter readings are taken every two months. The total volume from each bi-monthly reading was divided in half to estimate monthly values.*

Data from the select census blocks showed there were 470 housing units. Of these, 310 were reported as supporting the year-round population of 829 people, indicating an average of 2.71 people per household in the subbasin. Vacation or part time residences comprised the remaining 160 units. As these could become full time at any point, and there is no seasonal water use restriction on the permit exempt wells associated with these homes, they have the imminent potential for year-round water use. Accordingly, all 470 units were treated as full time, year-round residences during the development of in-house water use estimates for the subbasin. The equations used to estimate total daily net water use were as follows:

470 housing units x 2.71 people per unit = 1274 people
1274 people x 35 gallons pcpd = 44,590 gallons net water use per day

Daily net water use was multiplied by the number of days in each month to approximate monthly net water use (31-day mo. = 1,382,290 gallons; 30-day mo. = 1,337,700 gallons; 28-day mo. = 1,248,520 gallons). Monthly in-house net water use estimates were converted to acre-feet using the standard 1 ac-ft = 325,850 gallons. Thus, current domestic net water use ranges from 3.8 to 4.2 ac-ft per month. The standard 1cfs for 1 day = 1.9835 ac-ft was used to convert ac-ft volumes to cfs. It was estimated that total domestic in-house net water use in the Entiat and Mad watersheds is approximately 0.07 cfs on an average monthly basis.

4.10 RESERVE WATER

It is important to note that water for homes, commercial enterprises, and other uses in the Entiat subbasin is not currently provided by a municipal water system, but via withdrawals occurring under permit exempt wells, water rights and claims. Thus, all future water withdrawals in the subbasin, whether associated with new water rights or permit exempt wells, would be conditioned by codified minimum instream flows. Codification of the Administrative Instream Flow regime proposed in Chapter 5, or for that matter the Planning Unit Flow regime (whose monthly flow exceedence values were usually higher than those of the Administrative Flow regime), would not provide a reliable year-round water supply sufficient to support new growth and associated water use in the valley. Recognizing this, the Planning Unit agreed to explore negotiation of a "Reserve" of water that would be senior to codified minimum instream flows.

The development of a Reserve was encouraged by the WDOE in recognition of the fact that a key part of Planning Unit's vision for the Entiat WRIA includes "...a balance between natural resources and human use, both current and projected; the coexistence of people, fish and wildlife while sustaining lifestyles through planned community growth, and maintaining and/or improving habitats; [and ensuring] ...economic stability in balance with natural resources". Additional rationale for the creation of a Reserve is that, in order to balance community needs with aquatic resource needs, some "unconditioned" water should be available to allow for and support future moderate growth and economic expansion in the Entiat valley. Providing the opportunity for growth to occur is integral to maintaining and enhancing the social and economic viability of the community, and augmenting the small

core property tax base from which essential community services (fire department, schools) are funded. If codified, the special Reserve would allow for future beneficial uses that require guaranteed water (available as needed), e.g. for homes, commercial agriculture, other businesses, etc.

A Reserve of 5 cfs was negotiated based on the Planning Unit's future water supply estimates and requirements discussed in Section 4.11, as well as evaluation of the potential impact of additional withdrawals. Biologists and resource specialists involved with creation of the Administrative [minimum] instream flow and Planning Unit flow recommendations described in Chapter 5 agreed that the Entiat system could support additional withdrawals up to 5 cfs without significantly impacting aquatic resources/existing beneficial uses.

The Reserve will only become "real" upon completion of the water resources management rule making process for the Entiat. Under Washington Water Law, the date on which rule making concludes will be the priority date associated with the Reserve. The Reserve will be given the same as the priority date that will be given to minimum instream flows (see Chapter 5, Administrative Instream Flows, for discussion related to the priority date of minimum instream flows). Thus, the Reserve will make water available for qualifying future beneficial uses that will be uninterruptible/unaffected by codified minimum instream flows.

As part of its preliminary discussions of criteria for qualifying future beneficial uses, the Planning Unit has proposed partitioning the Reserve so that discrete volumes may be allocated into the following general categories:

- New Residential
    - Exempt wells serving single and up to six residential units, including gardens, lawns up to ½ acre in size, and stock watering
    - Larger non-exempt residential developments
- Agriculture
    - Commercial orchard/vineyard, other commercial livestock / farming operations
- Commercial and Light industrial
    - Businesses
    - Process water / "value added" operation component of enterprises using or selling agricultural products
    - Clean industries

Partitioning has been proposed to help facilitate management of the Reserve. Additionally, the Planning Unit recognizes that new water appropriated from the Reserve for future agricultural, commercial/light industrial uses should be limited to the lower Entiat River (below RM 16.2) in order to help protect the important "stillwater" area. However, new residential development and associated water use will continue to be allowed in and above the stillwater reach.

The EWPU intends to continue its work to develop specific language for inclusion in Chapter 173-546 that will detail how:

- conditioned water rights and pending water right applications should be addressed;
- transfer of water between reserve categories may occur if warranted (e.g. if residential development occurred at a higher than anticipated rate, water from one of the other reserve categories could be used to meet additional domestic water needs);
- water use decision making institutions may be established or organized for management of the Reserve; and
- additional criteria may be used by WDOE and partners for the management of the Reserve so that this water will help to achieve community goals for the Entiat valley.

The Planning Unit is also exploring how water right banking/leasing, transfers, etc. can be used in lieu of Reserve water to satisfy new uses, so that future appropriation of Reserve water only happens after all other options have been exhausted.

Water in excess of the 5 cfs Reserve may also be available in the future through implementation of storage, water-for-water mitigation and out-of-kind mitigation options. Implementation of the management recommendations proposed in Chapter 9 (changes to channel geometry, water conveyance efficiency improvements, water conservation measures, etc.) are examples of out-of-kind mitigation.

4.11 FUTURE WATER SUPPLY REQUIREMENTS

In recognition of the fact that the City of Entiat, Entiat School District have suffered financial losses associated with the construction of Rocky Reach dam (ECONorthwest 2003), and that additional community and economic growth is essential to support the schools and facilities that serve the community, the EWPU has proposed that a Reserve of water be available for new beneficial uses that help to achieve the Planning Unit's long term vision for the valley. The Planning Unit selected a 22-year planning horizon for making their water reserve estimates in order to coincide with Chelan County's comprehensive planning horizon.

4.11.1 Future Population Estimates

Under the Growth Management Act (GMA; RCW 36.70A), Chelan County and its cities designated Urban Growth Areas (UGAs) designed to include areas and densities sufficient to permit the urban population growth that is projected to occur over a 20-year planning horizon. The planning period used by the Chelan County for its comprehensive plan is 22 years into the future, or through the year 2025. Between now and the year 2025, a goal of Chelan County and the City of Entiat is encourage development and future population growth within the Entiat UGA.

The county and cities of Wenatchee, Chelan, Cashmere, Leavenworth and Entiat used the Chelan County 'High Series' population projection for the year 2025 (101,859 people), provided by the Washington State Office of Financial Management (OFM) on January 25, 2002, as the basis for their future population predictions. They distributed the projected population among each of the seven County Census Divisions (CCDs) based on the historical contribution of each CCD to total county population. Weighted averaging was used to assign

more emphasis to recent census data. The following weighting factors were used: 1970 census, 10%; 1980 census, 20%; 1990 census, 30%; 2000 census, 40%.

Using the aforementioned methodology, it was estimated that the Entiat CCD will account for 3117 out of the 101,859 people projected to be living in the county in 2025. Year 2000 census data reported the Entiat CCD population at 2042 and City of Entiat population at 957 (US Census Bureau 2001b, 2001a). Chelan County estimated that the population living in the greater Entiat UGA in the year 2000 was 1017 (C. Wavra, pers. comm. July 30, 2003); thus, the remaining 1025 people were estimated to be living in the rural area of the Entiat CCD.

The county and City of Entiat split the projected Entiat CCD population (3117) between the UGA and the rural area using the estimate that 65% of the projected population may live in the UGA (2026 people) and 35% may live in the rural area (1091 people). If population growth and settlement patterns in the Entiat CCD occurred along these lines, the UGA would experience a 2.795% average annual rate of growth, and the rural area would grow by an annual average rate of 0.25% over the next 22 years. Stated differently, the UGA population would expand by up to 1009 people, from 1017 to 2026, and the rural area would grow by 66 people, from 1025 to 1091, between now and the year 2025.

As mentioned earlier, Chelan County and City of Entiat's projections for population growth and distribution among the urban and rural areas of the Entiat CCD are tied to goals associated with planning under the GMA, which include the efficient provision and utilization of public facilities and services, and reducing inappropriate conversion of undeveloped land into sprawling, low density development. The GMA also requires the rural element of the Chelan County comprehensive plan to provide for a variety of rural densities, uses, essential public facilities, and rural governmental services needed to serve the permitted densities and uses (Chapter 36.70A.070(5)(b) RCW). Accordingly, the county zoning designations for the Entiat CCD were designed to control the level of rural growth that can occur in this area over the next 22 years; however, even with zoning in place a number of privately held parcels of land in the subbasin still have the potential to be developed and/or divided.

A goal of the EWPU's water resources planning effort was to estimate what unconditioned reserve volume will likely be adequate to satisfy additional water needs in the Entiat subbasin through the year 2025. In doing so, the Planning Unit made a more liberal projection of the population growth that may through the year 2025. A population larger than what was predicted by the county for the rural area of the Entiat CCD may or may not exist in 2025. Given that uncertainty, the EWPU used a more liberal projection to help assure that adequate unconditioned water will be available for appropriation to beneficial uses in the Entiat valley if growth within this rural area of the Entiat CCD exceeds the county's projections. A more liberal estimate was also made to help ensure that adequate year-round water will be available to help the EWPU meet its long-term vision and goals for the subbasin, which include: providing for the coexistence of people, fish, and wildlife; sustaining lifestyles through planned community growth; and emphasizing local culture and economic stability in balance with natural resources.

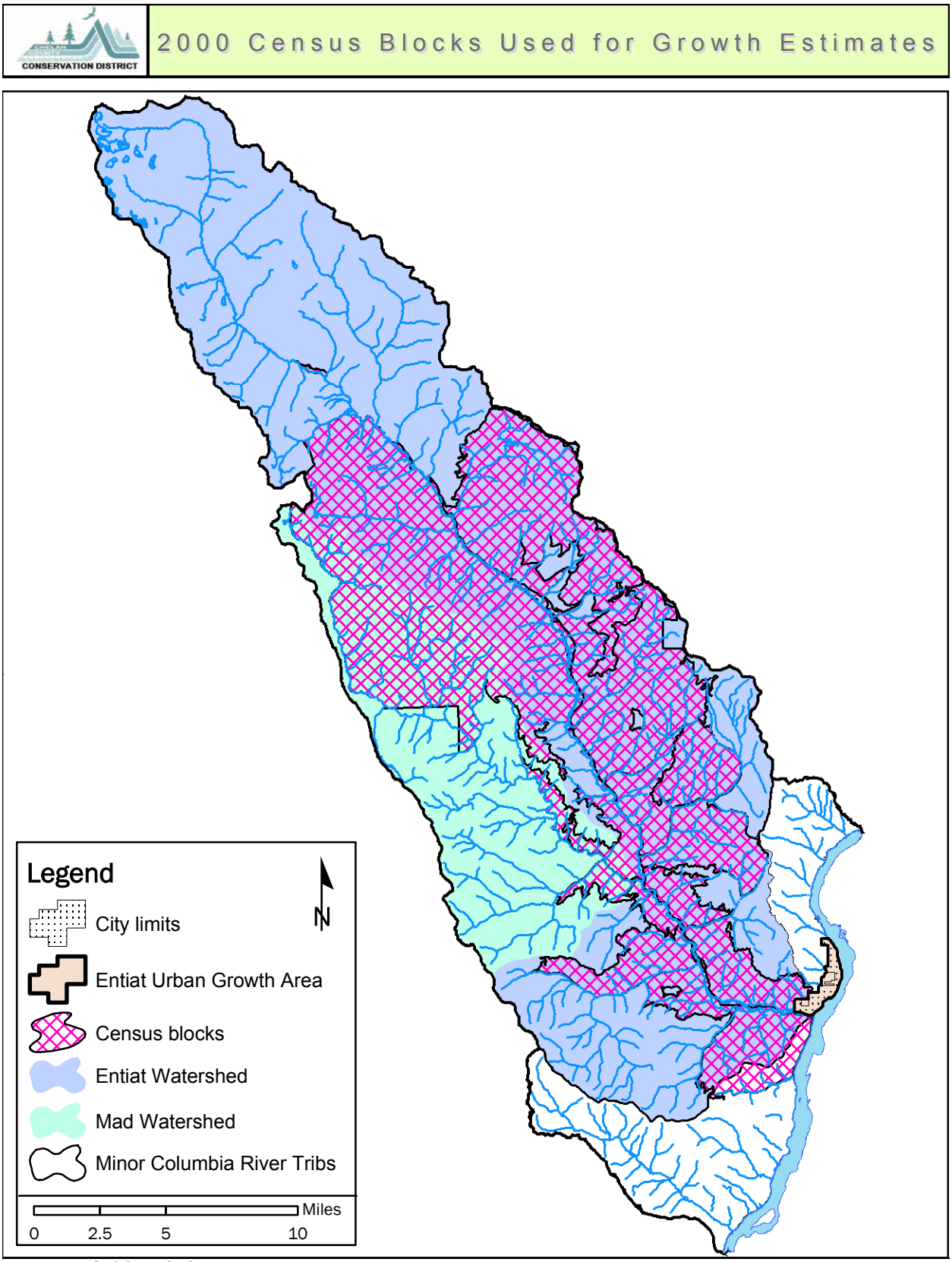


Figure 4-19. US Census blocks within the Entiat subbasin (excluding city) reporting people and houses used for future population predictions.

In an effort to estimate what population was living solely in the Entiat and Mad watersheds in the year 2000, the Planning Unit used a GIS to select census blocks from the Entiat CCD that fell entirely or largely within the Entiat and Mad River watersheds, but outside of the UGA. Refer to Figure 4-19 on page 4-43 for a depiction of the US Census blocks selected. Entiat CCD census blocks that included people living in the Entiat UGA or the minor Columbia River tributaries area were excluded from consideration. Data showed that approximately 839 people were living in the subbasin in the year 2000 (US Census Bureau 2001b).

To project what future Entiat subbasin population may require water appropriated from within this area of the WRIA, the Planning Unit analyzed census block data from 1990 and 2000. Population in the Entiat and Mad River watersheds grew from 739 to 839 people during the period 1991-2000 (US Census Bureau 1991, 2001). Thus, the average annual rate of growth in the subbasin over this decade was 1.156%. As mentioned previously on page 25 of this Chapter, the EWPU determined that all of the 470 residences reported in the 2000 census should be treated as year-round occupancy for the purpose of estimating water use (US Census Bureau 2001b). The 1.156% average annual rate of population growth was applied to the year 2004 potential population of 1274 people (470 housing units x 2.71 people per household = 1274) to derive a future population estimate of 1641 people total, or up to 367 additional people living in the Entiat and Mad watersheds in 2025.

4.11.2 Future Domestic Water Use Estimates

Domestic In-House Water

An estimate of the water needed for in-house net water use by 367 additional people was calculated using the following formula:

367 people x 35 gallons pcpd = 12,845 gallons net water use per day.

Daily net water use in gallons was multiplied by the number of days in each month to approximate monthly net water use (31-day month = 398,195 gallons; 30-day month = 385,350 gallons; 28-day month = 359,660 gallons). Monthly domestic net water use estimates were converted to acre-feet using the standard of 1 ac-ft = 325,850 gallons. Future residential net water use by 367 additional people ranges from 1.1 to 1.2 acre-feet per month, depending on the number of days in the month. Monthly acre-foot estimates were converted to cfs using the standard of 1 cfs for 1 day = 1.9835 acre-feet. It was thus estimated that 0.02 cfs of water may be necessary to satisfy future domestic in-house net water use needs through the year 2025.

Domestic Irrigation Water

The average of 2.71 people per household reported by the 2000 census was used to estimate how many new housing units may exist in the subbasin in 2025:

367 new people / 2.71 people per household = 135 new housing units.

It was assumed that each new housing unit may irrigate up to ½ an acre of lawn, with an average of 24 acre-inches, or 2 acre-feet of water required per half acre of lawn during the seven month April-October irrigation season (24 ac-in is half of the per acre value for pasture/turf in Table 4-15 on page 4-33). It is important to maintain defensible space around residences in rural areas like the Entiat subbasin for wildfire protection; therefore, it was assumed that lawn watering will occur even in 'drought' years when suburban water conservation measures may have been put into effect elsewhere. Subsequently, up to 270 acre-feet of water may be necessary between April and October to irrigate the 68.5 additional acres of lawn potentially associated with 135 new housing units. New lawn irrigation water use in July, the most consumptive month, may total approximately 71 acre-feet, or an instantaneous amount of about 1 cfs. Thus, it was estimated that about 1 cfs will likely be sufficient to accommodate future domestic in-house, irrigation and stock water needs in the Entiat and Mad River watersheds through 2025 if population growth in the subbasin continued at the rate experienced over the period 1991-2000.

4.11.3 Future Commercial Agriculture Irrigation Water Estimates

In order to help promote future agricultural economic enterprises in the Entiat subbasin, the EWPU estimated what amount of reserve water might be requested by the valley community for future appropriation for new commercial livestock operations, orchards, vineyards, etc. Water right applications for the subbasin and non-irrigated pasture acres identified by the CWU land use study were analyzed in an attempt to estimate the current/potential demand for water for commercial agriculture, and how many larger tracts of irrigable land exist in the subbasin.

The Planning Unit used a GIS to identify non-irrigated pasture parcels in single, private ownership that were shown as greater than or equal to five acres in size, and which had not been classified by the CWU land use assessment as pulled orchard. Parcels greater than or equal to five acres in size were targeted because it was assumed that smaller areas would not be commercially viable; non-irrigated pasture lands coded as pulled orchard were excluded because there were already irrigation water rights associated with these areas. Non-irrigated pasture lands much upstream of the Potato Creek confluence were also ruled out due to the fact that topography and climate shorten the effective growing season in this part of the Entiat watershed; length of growing season in the lower part of the subbasin averages about 150 days (USDA 1979). It was estimated that approximately 150 acres of non-irrigated pasture could conceivably be put into commercial agriculture in the future, if parcel owners so desired.

Estimates of how much water would be necessary to support this additional commercial agriculture were made based on the tree water use in July 1973, the highest tree water use month/year out of the 31-years of data collected by the WSU Tree Fruit Research Laboratory. The highest water use month in the highest water use year was used in order to estimate the greatest instantaneous amount of water that may be required in the future by new orchards (refer back to Table 4-14 on page 4-32 for July 1973 tree water use in ac-in). The EWPU estimated that if 150 acres of orchard were planted, about 220 acre-feet of water would be needed during a very dry year in July. This volume translated into a maximum rate of approximately 3.6 cfs. Members of the Planning Unit recognized that

grapes/vineyards and other less consumptive crops may be planted in lieu of or in combination with orchards, and that not all of the estimated acres of non-irrigated pasture may be put into commercial agriculture in the future; therefore, they determined that a reserve of approximately 3 cfs of water should be available via future water rights for commercial agriculture in the Entiat subbasin.

4.11.4 Future Commercial/Light Industrial Water Estimates

The EWPU estimated that approximately 1 cfs of water should be placed in reserve for appropriation to future commercial and light/clean industrial uses in the subbasin. This estimate was made based on discussions with the LSC and other members of the EWPU about the desire to assure that water is available to support future economic growth in the valley. Although it is likely that many, if not all new small commercial uses will draw water from permit exempt wells, new exempt well water withdrawals will be conditioned by minimum instream flows. Therefore, it was necessary estimate what amount of unconditioned reserve water may be needed to allow future commercial enterprises to operate consistently and over the long-term.

The Title 11 "Zoning Resolution" of the Chelan County Code provides examples of enterprises that are either permitted outright in the subbasin or permitted as conditional and/or administrative uses, dependent on zoning. Such activities include, but are not limited to: bed and breakfasts; the development of tourist/recreational uses; wineries; agricultural tourism related businesses; and value added operations. Chapter 11.04 of the Chelan County Code defines a value added operation as any activity or process that allows farmers to retain ownership and that alters the original agricultural product or commodity for the purpose of gaining a marketing advantage (Res. 2002-08 (part), 1-15-02). Water from this Reserve category would be used to support the value-added part of commercial agricultural operations include bagging, packaging, bundling, pre-cutting, food service etc., whereas crop irrigation water would be appropriated from the Commercial Agriculture Irrigation Water portion of the overall reserve.

4.12 WATER BANKING/LEASING OPPORTUNITIES

The 1991 Water Resources Management Act and the 1989 Yakima Basin Trust Water Rights Act created a mechanism for WDOE to acquire water rights from willing water right holders through leases, water conservation projects, donations, and other appropriate means. Some of the following legislative provisions apply to trust water rights:

- Trust water rights retain their priority date during the time they are held in trust and are not subject to relinquishment due to lack of use;
- A water right expressly conditioned to limit its use to instream purposes must be used as a trust water right in compliance with that condition;
- The trust water program can redirect the use of conserved water within a specific reach for other purposes.

The EWPU agreed to provide information to water right holders in the Entiat and Mad River watersheds about the State Trust Water Program and similar water banking/leasing programs available to prevent the relinquishment of existing water rights due to non-use, especially when orchard/agricultural land conversion occurs, and encourage use of such programs. Public outreach will also be used to explain how water banking/leasing will work in conjunction with the Reserve to satisfy future water right applications. For example, a goal is to use 'banked' rights (especially seasonally conditioned trust rights) to satisfy future water right applications for irrigation/commercial agriculture, and other beneficial uses that do not require guaranteed year round water. A review of trust water rights will be done prior to consideration of a Reserve water allocation so that, if possible, Reserve water would be used solely for appropriation to new uses that require year-round water.

4.13 WATER STORAGE OPPORTUNITIES

The EWPU determined that once Administrative Flow numbers have been met during a given month, the opportunity for water storage should be available. The Administrative Flows recommended for the beginning, middle and end of the spring freshet (approximately May 1 through July 15) were developed to protect channel maintenance flows and natural variability in the range of flows experienced by the system. WDOE also made a preliminary determination of water availability for the May 1 – July 15 time period so that a certain portion of flows that exceed recommended minimum instream flow numbers could be stored, based on the following semi-monthly basis:

Semi-Monthly Period (total 76 days)	Storage Potential
May 1 – May 15	Up to 100 cfs
May 15 – May 31	Up to 100 cfs
June 1 - June 15	Up to 100 cfs
June 16 – June 30	Up to 100 cfs
July 1 – July 15	Up to 67 cfs

During the May 1 – July 15th period in 1997 (a representative 'wet' year), proposed semi-monthly Administrative instream flow values were exceeded by a minimum of 443 cfs in each period. Using the rough estimate that 1 cfs for 1 day = 2 acre-feet, approximately 14,210 acre feet of water would have been available for storage during the 76 day period May 1 – July 15th in 1997. In 2001 (a representative 'very dry' year), proposed semi-monthly Administrative instream flow recommendations would not have been met at any time, based on an average of the mean daily flows experienced during each period. However, an examination of *daily* mean flow values showed that water would still have been available for storage on 14 days out of the 76 day period, totaling approximately 2316 ac-ft.

Refer to table 4-19 on the following page for a summary of days and amounts of water that would have been available in 2001.

Table 4-19. Water that would potentially have been available for storage in 2001, given proposed Administrative instream flows for the lower Entiat River.

Date	Daily Storage Potential (cfs)	Daily Storage Potential (ac-ft)
5/12/2001	20	40
5/13/2001	100	200
5/14/2001	100	200
5/15/2001	100	200
5/16/2001	2	4
5/23/2001	100	200
5/24/2001	100	200
5/25/2001	100	200
5/26/2001	100	200
5/27/2001	100	200
5/28/2001	100	200
5/29/2001	100	200
5/30/2001	100	200
5/31/2001	36	72
Total volume available in 14-day period = 2316 ac-ft		