8.0 WATER QUALITY

8.1 INTRODUCTION

The Clean Water Act of 1977 set federal standards for water quality (see Appendix F). In accordance with the Act, and after developing standards that met or exceeded the federal standards, the State of Washington was designated by the US Environmental Protection Agency (EPA) to administer the Washington State water quality program. The WDOE is the state agency with the primary responsibility for water quality management and monitoring. The state established 5 classes of surface water, and defined numeric and narrative water quality criteria designed to protect characteristic uses listed for each classification. Standards define general attributes, characteristic uses, and water quality criteria.

8.1.1 Water Quality Classes

The state water classifications that apply to the Entiat River include:

- Class AA (extraordinary) from the Entiat headwaters to the National Forest Boundary (RM 26). Class AA waters shall have water quality that markedly and uniformly exceeds the requirements for all, or substantially all uses.
- Class A (excellent) from below the National Forest Boundary to the river mouth. Class A waters shall have water quality that meets or exceeds the requirements for all, or substantially all uses.

8.1.2 Characteristic Uses

Characteristic uses include, but are not limited to: water supply (domestic, industrial, and agricultural), stock water, fish and wildlife habitat, recreation and navigation. Refer to Appendix G for a complete discussion of characteristic uses, and state water quality standards and criteria.

8.1.3 Water Quality Parameters and Criteria

Five water quality parameters have associated state criteria: temperature, fecal coliform bacteria, dissolved oxygen, pH, and turbidity. These and nine other water quality parameters of interest (conductivity, flow, ammonia-nitrogen, nitrate-nitrite, dissolved organophosphates, air pressure, suspended solids, total phosphorous and total persulfate nitrogen) are monitored by the WDOE at ambient water quality station 46A070, on the lower mainstem Entiat River adjacent to the Entiat near Entiat (Keystone) USGS gage. State water quality criteria and parameters particularly important for assessment of freshwater ecology are summarized in Table 8-1 on the next page. Refer to Appendix G for additional parameter information and discussion of marine and fresh water quality criteria.

Table 8-1. Summary of select water quality parameters and associated state criteria.

Parameter	Importance	State Class AA Criteria	State Class A Criteria
Temperature	Affects aquatic ecology; cold water fish species such as trout and salmon are particularly sensitive to very high and very low temperatures.	≤ 16°Celsius (60.8° Fahrenheit; Forest Plan standard is 61°Fahrenheit).	≤ 18°Celsius (64.4° Fahrenheit).
Fecal coliform bacteria	Indicative of possible human health risk due to fecal contamination by warm blooded animals.	Geometric mean value ≤ 50 colonies/100mL and not more than 10% of all samples obtained > 100 colonies/100mL.	Geometric mean value ≤ 100 colonies/100mL and not more than 10% of all samples obtained > 200 colonies/100mL.
Dissolved oxygen (DO)	Related to temperature and stream productivity. Low concentrations can stress fish.	> 9.5mg/L	> 8.0mg/L
pH	Dependent on geomorphology and stream productivity. Very low and very high pH can stress fish. PH also affects the solubility of many chemicals.	Within range of 6.5 to 8.5, with human-caused variation within a range of < 0.2 units.	Within range of 6.5 to 8.5, with human-caused variation within a range of < 0.5 units.
Turbidity	A measure of the clarity of the water. High turbidities can affect sight-feeding organisms, including fish, and may be indicative of watershed disturbance.	Turbidity shall not exceed 5 nephelometric turbidity units (NTU) over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10% increase in turbidity when the background turbidity is more than 50 NTU. <u>Note:</u> **No background turbidity values have been established for waters within the Entiat WRIA.**	
Total persulfate nitrogen (TPN) and Total Phosphorous (TP)	Two nutrients most often limiting production in aquatic systems. High levels of nitrogen can result in excessive plant growth and algae growth, which can in turn cause wide fluctuations in DO/pH.	N/A	

8.1.4 <u>Clean Water Act 303(d) List</u>

Section 303(d)(1) of the Clean Water Act requires the State to list and monitor surface water body segments that are not expected to attain water quality standards after implementation of technology-based controls, thus requiring additional management activities (See Appendix F for a copy of Section 303(d)). The first state "303(d) List" was created in 1992 and is updated by WDOE every two years. Types of water quality problems that can lead to 303(d) listings include: water temperature, fecal coliform bacteria, toxic substances, excessive organic waste and/or nutrients.

The Class AA reach of the Entiat River (Headwaters to RM 26) has never been placed on the State's 303(d) list; however, the Class A portion of the Entiat has been listed in the past. The 1996/1998 instream flow listings resulted from instream flow recommendations that were proposed based on the results of a PHABSIM conducted in 1995 (Caldwell 1995).

Table 8-2. Summary of Entiat River Class A reach 303(d) listings.

Biennial List Year	Parameter(s) Listed
1992	pH
1994	pH and temperature
1996	pH, temperature, instream flow
1998	Instream flow
2000	n/a; the EPA did not require states to submit a 303(d) list in 2000
2002/2004 (draft)	No parameters proposed for 303(d) listing; proposed as Category 4b

Following guidance from the EPA contained in the *2002 Integrated Water Quality Monitoring and Assessment Report*, the state's listing process was altered to include a much more comprehensive assessment of Washington's waters. The new listing process and data requirements are described in a recent update to the Water Quality Program Policy 1-11, "Assessment of Water Quality for the Section 303(d) List", which was finalized and submitted to the State Register in September 2002. Five unique assessment categories were used by WDOE as part of their 2002 303(d) listing process:

Table 8-3. 2002 303(d) list assessment categories and definitions.

Assessment Category	Definition
Category 1	Waters that meet tested standards
Category 2	Waters of concern
Category 3	Waters with no data available
Category 4	Impaired waters but one of the following conditions exist: Category 4a. Water has a TMDL Category 4b. Water has a pollution control plan Category 4c. Water is impaired by a non-pollutant
Category 5	The 303(d) list

The WDOE has prepared a 2002/2004 list for submittal to the USEPA; however, until the new list is approved the 1998 list remains in effect. ***The WDOE has proposed to the EPA that the lower Entiat River be classified as a Category 4b stream in 2002/2004*** as a result of the Planning Unit's previous and current efforts.

8.1.5 Total Maximum Daily Load

The Clean Water Act requires that once a water body is placed on the 303(d) list, a Total Maximum Daily Load (TMDL) study be completed. A TMDL can be describes as the calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. In other words, a TMDL helps identify the sources of pollutants that are causing water quality exceedences, quantifies how much of the given pollutant(s) a water body can accept and still meet water quality standards, and recommends actions that should be taken to reduce the pollutant to this level so that the impaired water may meet water quality standards again.

A 1996 needs assessment of the Wenatchee Water Quality Management Area, which includes the Entiat watershed, set priorities for water quality-related actions (WDOE 1996). The development of a TMDL for temperature in the Entiat River was given a low priority. This determination was based largely on the need for further analysis of the specific causes of excursions beyond water quality standards. Since 1996, the USFS Entiat Ranger District has collected additional temperature data and examined the causes of excursions (see Appendix 1-N), and WDOE modeled temperature and various management alternatives for the Entiat River using the Stream Network Temperature (SNTEMP) model (Hendrick and Monahan 2003; see section 8.5).

In 2003 the WDOE modeled heat loads to streams on the USFS Wenatchee National Forest in order to develop a TMDL analysis to address impairment of characteristic uses by elevated water temperatures on the WNF (Whiley and Cleland 2003). The forest was classified the forest into five basins: Chelan (17% of WNF area); Entiat (11%), Wenatchee (33%), Yakima (18%), and Naches (22%). Subsections of each basin that considered elevation, precipitation and primary landscape setting; drainage area; bankfull width and Rosgen Stream Classification were also developed. Temperature data were used to develop an approximation of effective shade for each. A TMDL was then developed to establish forest-wide riparian shade levels (in terms of percent effective shade) to maintain maximum water temperatures at, or below, water quality standards (Whiley and Cleland 2003). For more information about the WNF TMDL, refer to http://www.ecy.wa.gov/biblio/0310063.html

For more information on 303(d) listings, TMDL's, and other Federal Clean Water Act issues in general, please refer to the following sources:
http://www.epa.gov/owow/tmdl/intro.html
http://www.ecy.wa.gov/programs/wq/303d/index.html
http://www.epa.gov/watertrain/cwa/index.htm

8.2 DATA SOURCES

Data from various sources were compiled and examined to assess historic and current water quality in the Entiat WRIA. The WDOE ambient water quality monitoring site provided the longest comprehensive record; data have been collected there since July 1959. The WDOE continues to collect monthly data at this ambient water quality monitoring site. Details about the WDOE Keystone station and parameters monitored may be downloaded directly from:
http://www.ecy.wa.gov/apps/watersheds/riv/station.asp?theyear=&tab=notes&scrolly=1&wria=46&sta=46A070

In addition to monitoring water quality parameters at Keystone, the WDOE currently records water temperature data at eight continuous recording gages that were installed in fall 2002 throughout WRIA 46 by the Planning Unit. The temperature data collected at these sites are considered provisional and have not at this date undergone internal quality control/quality assurance review by the WDOE. Historic WDOE data are also contained in the U.S. Environmental Protection Agency's (EPA) LEGACY national water quality database.

The USFS has conducted water quality monitoring at various sites in the Entiat subbasin both on and off National Forest System lands. Data collected in the Entiat Experimental Forest (1957-1977) focused on water quantity and quality in the three study drainages (McCrea, Burns and Fox Creeks). The Entiat Barometer Watershed program, which operated from 1996-1978, emphasized climatic and streamflow measurements and also included water temperature monitoring at a mainstem Entiat station. Sediment transport data were collected after the 1970 fires and documented in the 1979 Entiat Cooperative River Basin Study. The Forest Service and Chelan County Conservation District collected water quantity and quality data at nine mainstem and tributary stations in 1995 and 1996 in order to characterize conditions after the 1994 Tyee Fire.

Other water quality data collection by the USFS (particularly in the tributaries) has been event or project driven—not intended to assemble a long-term record. These data are spatially dispersed and temporally discontinuous throughout the subbasin. USFS water quality data collected prior to 1995 are contained in the EPA LEGACY database. Forest Service water quality efforts are currently focused on water temperature monitoring at multiple stations and annual measurement of fine sediment in the substrate in reference reaches (see Chapter 7, Habitat, Section 7.1.1 for more information on fine sediment).

The U.S Geological Survey (USGS) has performed very limited water quality sampling at three sites (USGS site numbers 12452800, 12452990 and 12453000) within WRIA 46. USGS gage site 12452990, Entiat River near Entiat, is coincident with WDOE site 46A070 (Keystone). These data were at one time maintained by both USGS and EPA LEGACY; however, USGS water quality data entries have been removed from the EPA LEGACY database. All historic and current water quality data associated with the three USGS gages are now maintained solely by the USGS.

The City of Entiat and the WDOE maintain records associated with a NPDES (National Pollution Discharge Elimination System) permit issued to the city for its wastewater treatment plant. The ENFH also has an NPDES permit associated with hatchery discharges. Although the city and hatchery lie within the Entiat WRIA, point source water quality issues associated with these NPDES permits are currently not known to exist. Refer to Figure 8-1 for a map of historic and current monitoring sites in WRIA 46.

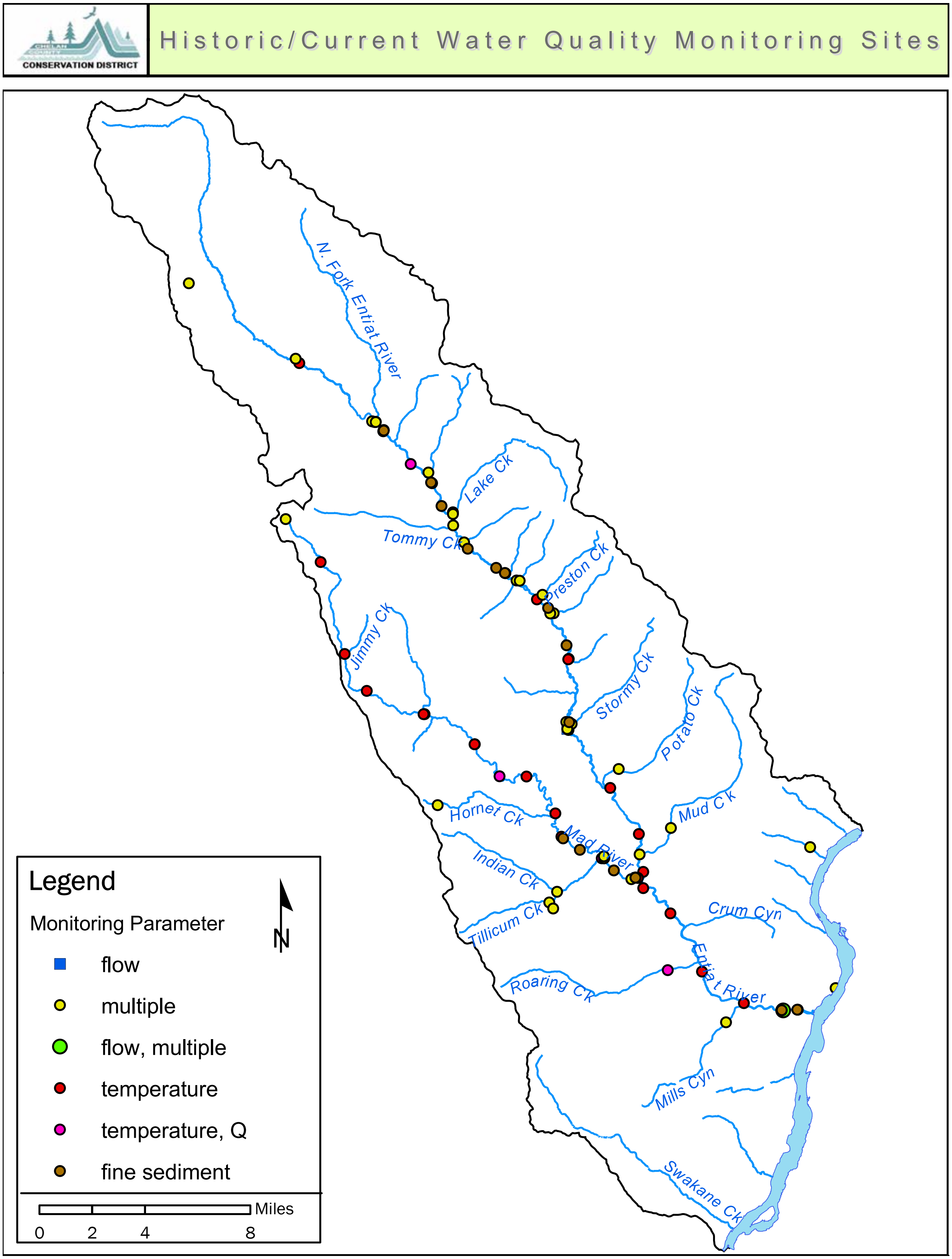


Figure 8-1. Summary of WRIA 46 historic and current water quality monitoring sites and parameters.

8.3 WATER QUALITY FINDINGS

8.3.1 Temperature

Temperature exceedences in the Entiat WRIA occur during late summer when low flows, high air temperatures and high insolation rates coincide. They are usually of short duration and diurnal in nature, a conclusion supported by temperature monitoring performed over the past years by the USFS Entiat RD. A 1994 review of ambient monitoring results by WDOE for Water Years (WY) 1978 - 1991 noted that high water temperature in the afternoon during late-summer and fall was the major water quality standard not met (Ehinger 1994). Ambient water quality data collected at the Keystone site from July 1959 to September 2003 also show a pattern of late summer temperature exceedences occurring during the months of July, August and September. Figure 8-2 and Figure 8-3 on pages 8-8 and 8-9 provide a summary of annual stream temperature data collected at the Keystone site during the 1970s, 1980s, 1990s, and 2000s, and a depiction of the months in these decades during which exceedences of Class A standards (18°C) have occurred. As mentioned previously, the lower Entiat River was included on the 1996 303(d) list of impaired or threatened waters for temperature and instream flows, and is currently listed on the draft 2002 303(d) list for temperature.

USFS Entiat RD thermograph data indicate that exceedences of the Forest Plan water temperature standard (61°F; State Class AA = 60.8°F) most frequently occur in streams at or below 2000 feet in elevation (Archibald and Johnson 2002). In 2002, three locations in the WRIA under 2000 feet in elevation did not exceed Forest Plan standards: the Entiat River at RM31, Indian Creek, and Tillicum Creek. Factors such as topography, geology, groundwater storage landforms, riparian conditions and orientation of the drainages with respect to the surrounding landscape are most likely very influential in maintaining lower water temperatures in these streams (Archibald and Johnson 2002). The EWPU has also examined the influence of the aforementioned factors on summer water temperature exceedence issues in the mainstem Entiat River using the Stream Network Temperature (SNTEMP) model (Hendrick and Monahan 2003). The model, calibrated and run by the EWPU, predicted the effects changes to riparian shade, channel geometry, and stream flows may have on overall stream temperatures. A detailed discussion of SNTEMP methods and results can be found in Section 8.5.

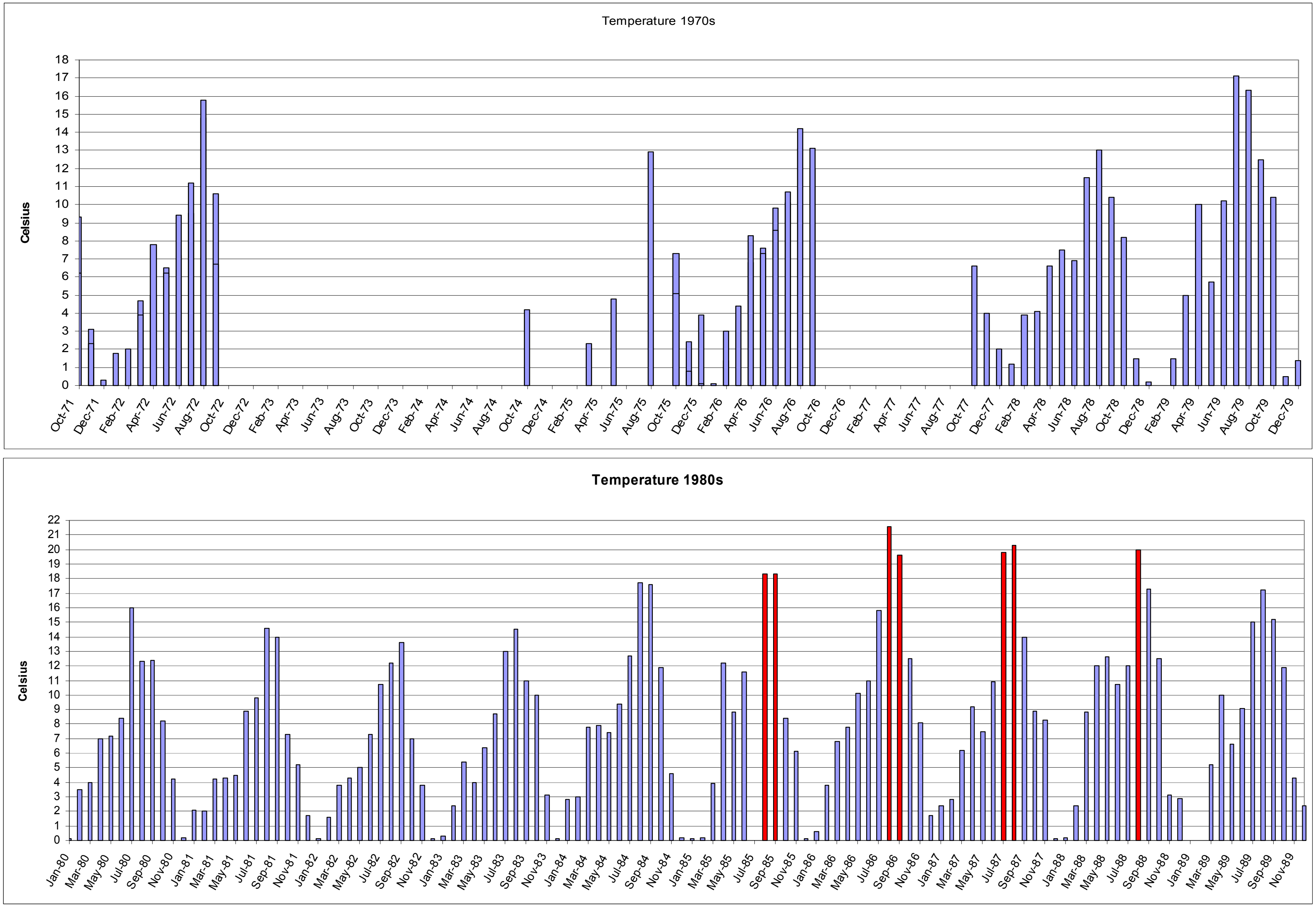
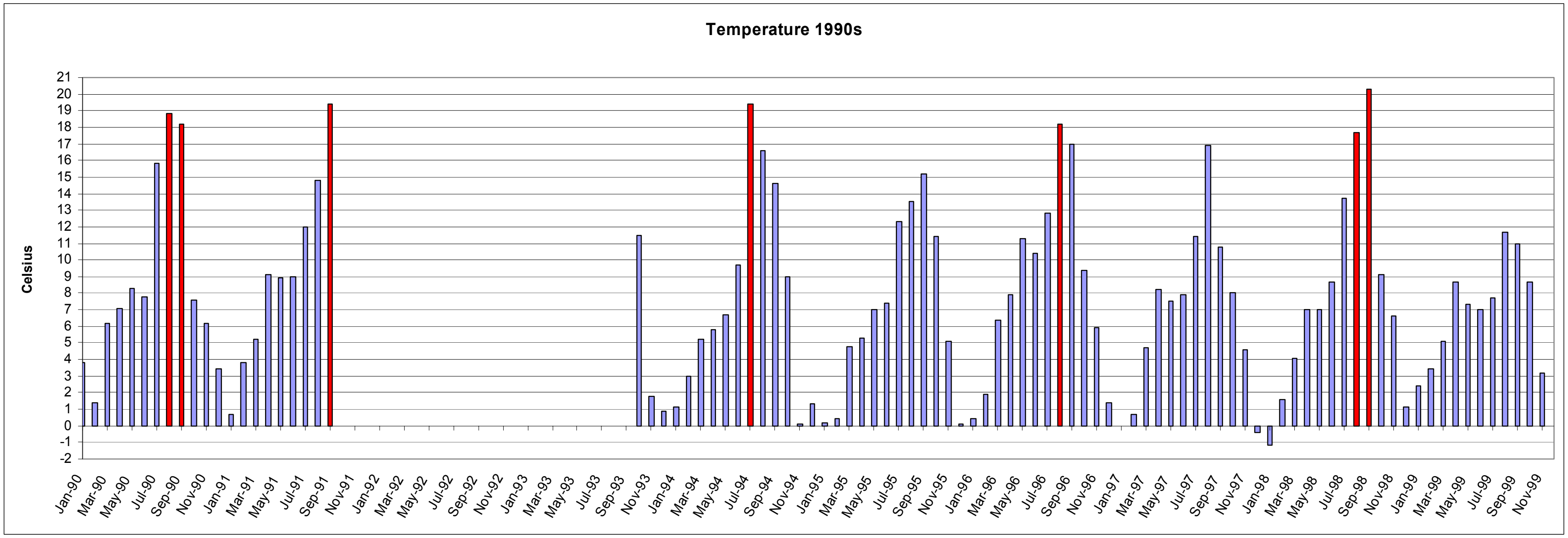


Figure 8-2. Entiat River water temperature data collected at WDOE 46A070 site during the 1970s (above) and 1980s (below).



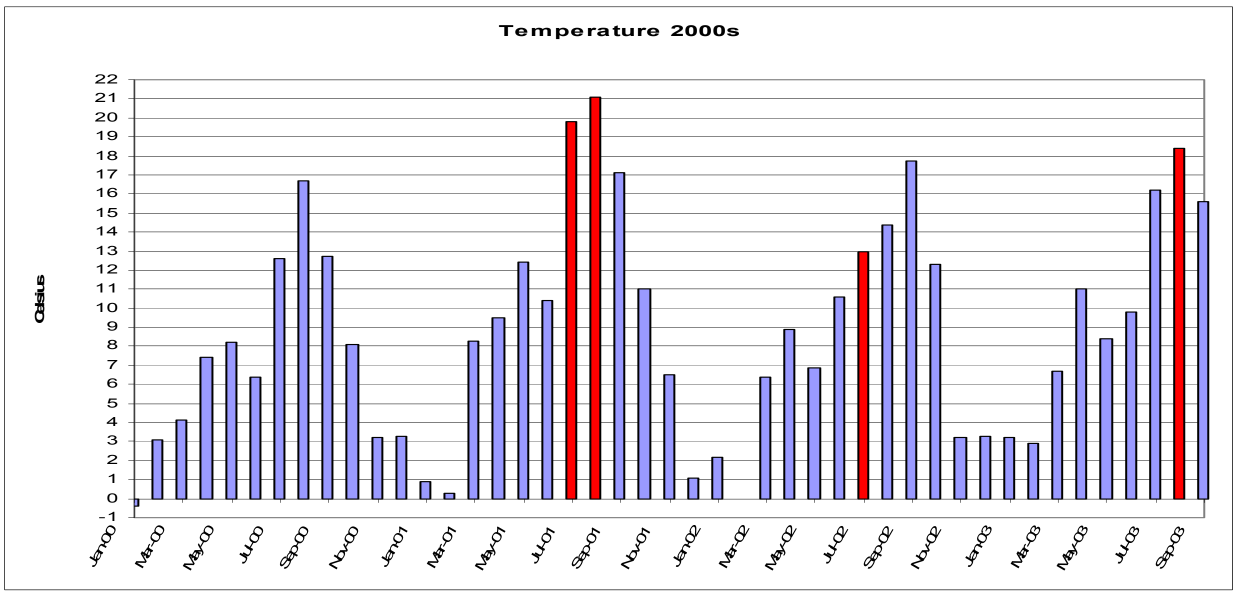


Figure 8-3. Entiat River water temperature data collected at WDOE 46A070 site during the 1990s (above) and 2000s (below).

Thermal Regime in the Entiat River
Archibald and Johnson (2002) observed the following trend in summer stream temperatures based on their analyses of 1999-2002 data:

- The North Fork of the Entiat River near its confluence with the Entiat River tends to be warmer than the mainstem from the middle of July until early September;
- Substantial warming tends to occur between RM 38 (Cottonwood campground) and RM 21 (Dill Creek Bridge);
- A “moderating zone” extends from RM 18 (Stormy gage; USGS Entiat near Ardenvoir) downstream to RM 15 (Roundy Creek confluence) during the hottest part of the summer, with maximum stream temperatures differing by only tenths of a degree from late July to early October;
- Between RM 10.8 and RM 10.2, where the Mad River flows into the Entiat River, stream temperatures tend to be equivalent indicating that the Mad River does not have a great influence on Entiat River water temperatures;
- In 2002, another “moderating zone” extended from RM 8.5 downstream to RM 5.3;
- Stream temperatures gradually warm from RM 5.3 to RM 1.4, with maximum temperatures recorded near the Keystone bridge; and
- Exceedences about RM 20 generally occur from early August to early September; from RM 21 downstream, exceedences are of progressively longer duration, beginning in late July and continuing until mid-September.

Temperature monitoring data, gain/loss analysis results, and information about the Entiat valley’s geology and alluvial valley comport well with one another and support hypotheses about stream temperature trends observed in the mainstem Entiat River.

Differences in stream temperatures near the confluence of the North Fork with the Entiat River mainstem are likely related to several factors. First, the mainstem and the North Fork of the Entiat have different primary sources of summer flows. The Entiat mainstem receives summer flows from snowmelt, glaciers and perennial snowfields within the Glacier Peak Wilderness area located farther west and at higher elevation (7000-8000 feet) than the headwaters of the North Fork. In contrast, the North Fork receives summer flows from yearly snow melt and runoff not associated with glaciers or perennial snowfields and the headwaters are at a lower elevation (6000 feet).

Other factors that may have a large influence on North Fork stream temperatures include the aspect of the stream (north-south versus the east-west orientation of the mainstem) and the presence of massive rock outcrops that constrain the channel from RM 0.5 to RM 1 potentially serving as heat sinks during the summer. Additionally, aquifer depth near the mouth of the North Fork Entiat River was modeled at 40 feet and approximately 47 acres in size (Dixon 2003), indicating that the volume of cooler groundwater input to this reach during the months of June through September, which showed a decreasing trend in aquifer storage, would not likely be substantial enough to provide a moderating influence on warmer water temperatures.

In the mainstem Entiat from the North Fork confluence at RM 34 to the USFS monitoring site at RM 26 (Forest Service boundary, near McCrea Creek confluence), stream temperatures would be expected to rise naturally due to the warmer North Fork contributions, an elevational decline of about 900 feet and the presence of the Box Canyon near RM 29 which confines the channel to a narrow bedrock gorge that likely serves as a heat sink/source as well. Modeled aquifer depth from the North Fork confluence downstream to Box Canyon ranged from 45 to 65 feet, which is still relatively shallow given the range of aquifer thickness estimated in the valley (25 to 197 feet) (Dixon 2003). Although aquifer storage was shown to decrease between July and September, indicating that baseflows are supporting overall stream flow during this period, gain loss data show an overall net loss of 12.85 cfs per mile for the 4.67 mile reach between the North Fork confluence and the top of Box Canyon (CCCD 2003b). Almost all of the loss recorded in the September gain/loss analysis occurred in the 0.4 miles between the North Fork confluence and Entiat Falls (-12.85 cfs per mile). This significant decrease in surface flow may also be contributing to warmer water temperatures in the reach from the North Fork to Box Canyon; however, DNR surficial geology data indicate a pocket of alluvium here, which confounds interpretation of surface/ground water exchange in this area.

From the USFS boundary at RM 26 downstream to RM 18, the river flows through an increasingly wider U-shaped valley where it exhibits increased sinuosity and a lower gradient compared to all other areas of the Entiat River. In this "stillwaters" reach where stream temperatures would be naturally expected to increase as well, a temperature moderating influence was observed in 1999-2002. The moderating zone lies between RM 21 and RM 16, and is most likely related to a ground aquifer created by glacial till. Much of the landform in the upper and mid-Entiat Valley was shaped by a glacier that extended from the west towards the Columbia River ending at about RM 16. The area near RM 16 is a terminal moraine, with a U-shaped valley present above this point and a V-shaped valley downstream. However, movement of the cooling zone downstream during late fall indicates that the area of glacial till serving as groundwater storage may actually extend downstream further than RM 16.

Model data show that alluvial aquifer depth and aquifer polygon size increase significantly in the stillwater reach from RM 26 downstream to the Stormy Creek confluence near RM 18, with the majority of aquifer polygons estimated to be 100 feet or more deep (Dixon 2003). The deepest aquifer polygon (197 feet) and five aquifer areas estimated at over 100 acres in size, and ranging in depth from 129 to 180 feet, are found within this portion of the valley. This supports the hypothesis that the large volume of groundwater stored in this area may provide a moderating influence on stream temperatures. DNR data indicate a large fault between RM 19 and RM 20, which may also contribute cooler subsurface water to this reach.

Predicted aquifer depth begins to decrease around RM 17 although tends to remain between 60 and 80 feet until about RM 14. Two modeled areas of approximately 50 acres and 70 feet deep fell between RM 16 and 15, with a larger polygon of approximately 100 acres in size and 79 feet in depth between RM 14 and 15. Gain/loss data show a gain of 10.09 cfs per mile between RM 16 and approximately RM 14.3, which may be explained by groundwater contributions from these larger, moderately deep aquifer areas (CCCD 2003b). Their presence also contributes to the idea that areas of deeper alluvium and groundwater storage do exist downstream of the terminal moraine.

Stream temperatures in the Mad River near the confluence with the Entiat River were somewhat cooler than those observed at the Entiat RM 10.8 or RM 10.2 during the 11 weeks of data collected during the 2002 Mad River monitoring period (Archibald and Johnson 2002). Overall the Mad River appeared to have a slight (mean = 0.95°F, range = 0.2ºF to 2.0°F) cooling influence on mainstem Entiat stream temperatures although the Mad River in August and September generally contributes 10-20% of the Entiat River flow (Archibald and Johnson 2002). Gain/loss data collected in September above and below the Mad River confluence showed a loss of 7.02 cfs per mile in this area (CCCD 2003b), which may also help explain why the Mad has very little moderating influence on temperatures of the mainstem Entiat River in this reach.

The moderating zone that lies between RM 8.5 and RM 5.3 may be related to groundwater aquifers created by glacial Lake Missoula flood deposits located at the mouth of Roaring Creek (C. Narcisco, pers. comm. 2003). Aquifer model data show an area approximately 92 feet deep near the mouth of Roaring Creek, which supports the notion of a deeper deposit and the potential influence of groundwater in that area. Gain/loss data also indicated a net gain of 0.02 cfs over the 0.9mi stretch from just above the Roaring Creek alluvial fan to its mouth.

"In addition to the glacial outwash gravels there are geologic controls, both bedrock and structural features likely contribute to the occurrence of groundwater in the area. A wedge of the Mad River schist extends from the headwaters of the Mad River down to the Columbia. It begins to thicken in plan view near Dinkelman Canyon, and mid to lower Roaring Creek is largely underlain by this rock type. It weathers to a finer textured soil than is common with the granitic or gneissic bedrock in the area with potential for clay intergrades. This rock is the same as that seen on the southwest slope of the Mad River, where the large and seepy slumps occur. Additionally, there is a (thrust) fault contact within this unit and the Swakane biotite gniess which crosses the mid drainage of Roaring Creek and near the mouth of Mills Canyon" (C. Narcisco, pers. comm. 2003). DNR data also show three normal faults oriented towards the mainstem Entiat contacting a Napeequa unit and Entiat Pluton in the Saunders Canyon area (between RM 5 and RM 4). Fault zones can serve as conduits which transmit increased groundwater; gain/loss data show a tremendous increase in flow (30.51 cfs per mile) between Dissmore and Dinkelman Canyons (approximately RM 5.2 to 4.3) (CCCD 2003b). Another potential factor is that the foliation plane in both the Mad River schist and the Swakane gneiss (in this area) dips toward the Entiat valley and could provide for some recharge of groundwater to the aquifer" (C. Narcisco, pers. comm. 2003).

From RM 5.3 to the river mouth, warming continued at a rate similar to that between RM 21 and RM 31. This is likely related to changes in stream morphology and reduced riparian cover in the most populated segment of the river (Archibald and Johnson 2002).

Figure 8-4 on page 8-13 depicts the aforementioned thermal regime in the Entiat River in longitudinal profile, and the relationship of stream temperatures to land type associations, channel gradient, stream flow, and fish distribution within the watershed.

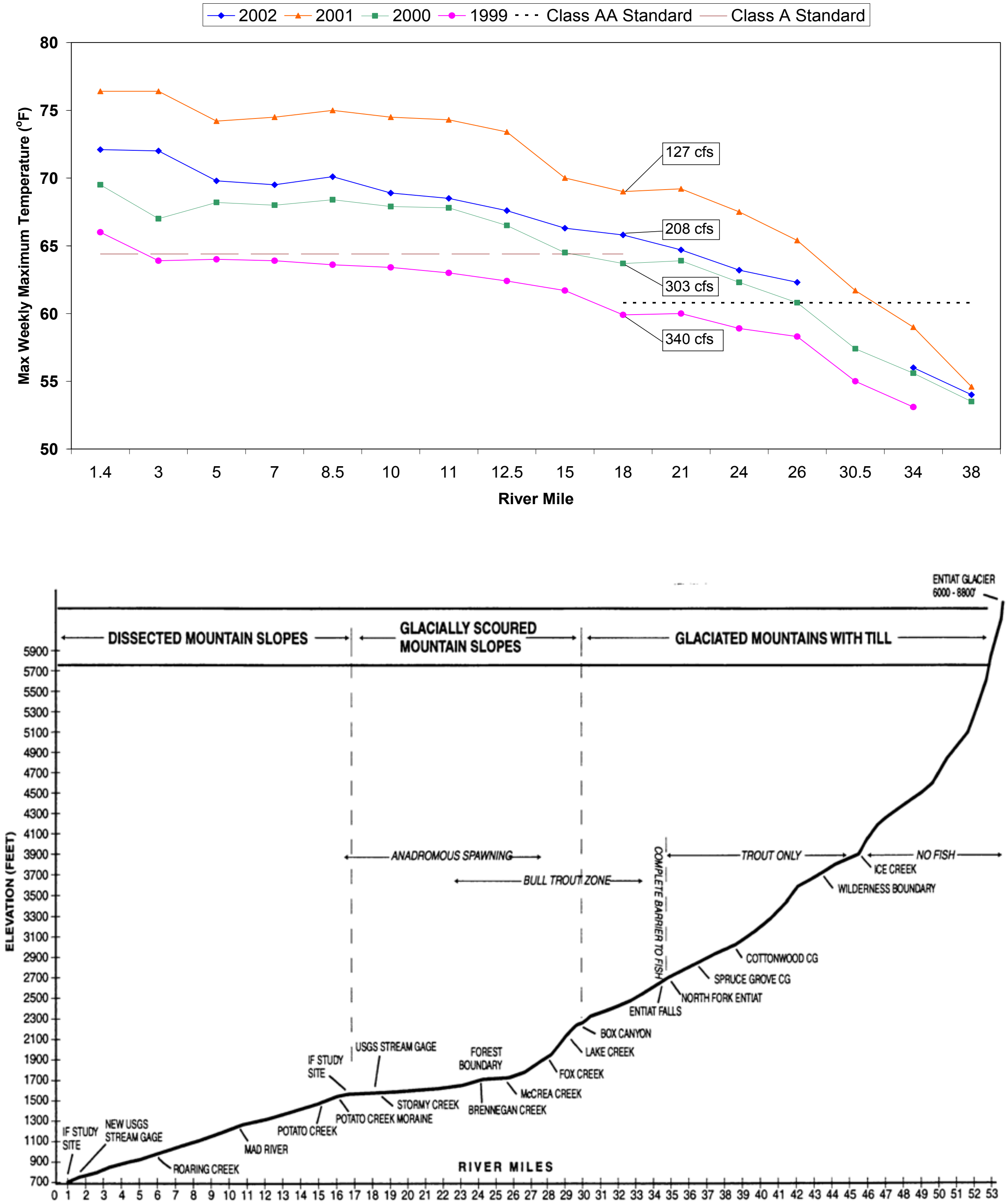


Figure 8-4. Relationship between weekly maximum water temperatures (°F) for the Entiat River, land type associations, channel gradient, stream flow and fish distribution.

Thermal Regime in the Mad River

The Mad River temperature data set spans 63 years, making it the longest-term record available for the Entiat subbasin. As the Mad River is essentially unaffected by direct management of riparian and valley bottom vegetation from RM 4.0 to the headwaters, a distance of nearly 20 miles, it represents a possible "reference" stream useful for assessing "natural variability" and may provide an important piece of information for natural water temperature regimes in similar land type associations.

Thermograph data collected by the USFS Entiat RD from 1993-2002 indicate that maximum water temperatures in excess of 61°F in the lower Mad River occur consistently. In 1997 fisheries biologists at the Entiat RD identified the following trend in Mad River summer water temperatures:

- At Mad Lake where the river originates, stream temperatures are substantially warmer at the outlet of this high elevation (5900 feet) shallow lake;
- Stream temperatures gradually cool going downstream until reaching the Cougar Creek area (3400 feet);
- Re-warming progressively occurs from Cougar Creek downstream to Tillicum Creek (1400 feet); and
- Tillicum Creek then provides a cooling influence evidenced by lower stream temperatures at the confluence with the Entiat River than those observed just above the Tillicum confluence.

Three historic sources of Mad River water temperature data (stream surveys from 1935-36 Bureau of Fisheries), 1972 (Holtby WNF), and 1990 (Haskins WNF), were reviewed to provide context and support for the observed trend; all historic data coincided with and reinforced the trend hypothesized in 1997. Thermal Infrared (TIR) imagery data for the Mad River collected during a flight on August 12th, 2001 helped to explain observed trends (Watershed Sciences, LLC 2001). The TIR imagery showed that cold water inputs from springs and tributaries contributed to the observed spatial temperature variations in the Mad River, and analysis revealed that reach-scale patterns may influence downstream heating in five identified “response” reaches (Faux and Archibald 2002).

The Mad River originates relatively warmer at the small (5 acres) and shallow (<20 feet deep) Mad Lake. It then flows through high elevation meadows with little shading from vegetation or topography. TIR imagery revealed that the temperature pattern in this reach (Reach 1, RM 26 to RM 20.5) is characterized by rapid increases in temperature over relatively short spatial scales due to direct solar radiation; however, stream temperatures in this reach also respond dramatically to tributary and spring inputs as a result of relatively low flow conditions, (Faux and Archibald 2002). Thus, a high degree of spatial thermal variability exists from Mad Lake downstream to this point.

Reach 2 (RM 20.5 to RM 17.4) showed an overall cooling trend. A spring was detected near RM 20.5, and vegetative shading also increases. Most importantly, the valley bottom consists of deep glacial till which stores and cools groundwater that contributes to Mad River streamflow. The combination of ground water influx, topographic and vegetative shading reduces the warming effects of direct solar radiation in this reach (Faux and Archibald 2002).

Reach 3 (RM 17.4 to 14.3) temperatures remained consistently cool, although no longer showed a general cooling trend. Deposits of glacial till are also present in this reach indicating the continued contribution of ground water as a buffer to stream warming; however, cooling influences decrease as the glacial till ends below Cougar Creek. The river also has an easterly aspect through this reach, which may also increase the amount of solar radiation. Downstream of this reach, Mad River temperature begins to increase again.

In Reach 4 (RM 14.3 to RM 10), from below Cougar Creek to around Camp Nine, a rapid increase in the heating rate was observed that accounted for most of the warming observed over the full length of the profile (Faux and Archibald 2002). The likely explanation is the transition from glacial till and associated groundwater inputs to more exposed steep bedrock along the north side of the Mad River valley. The vegetation is also less dense in this reach due in part to the 1994 Tyee Fire. It is tempting to attribute some of the warming to the 1994 Tyee Fire which killed most overstory riparian vegetation in the vicinity of Young Creek and Camp Nine. Although the magnitude of temperature increases may be a result of the Tyee Fire, the warming trend was observed in the 1930's, 1972, and 1990, when the riparian canopy was intact. The visible band color images also showed both vegetative and topographic shading at the time of the August 2001 survey (Faux and Archibald 2002), indicating that the mass of bedrock outcroppings likely acts as a heat sink which warms the Mad River by conduction and possibly by reflection as the sun declines from its zenith in the months of July and August.

Reach 5 (RM10 to mouth) showed a slight warming trend with some local spatial variability at several points. A marked cooling in temperature was noted at around RM 8.7 where the channel gradient increases over the next two miles, suggesting possible groundwater upwelling in this area. Tillicum Creek (about RM 2) has also been identified as a cooling source to the Mad River.

Figure 8-5 on page 8-16 depicts the longitudinal temperature profile and aforementioned thermal regime in the Mad River, and the relationship of stream temperatures to land type associations, channel gradient, stream flow, and fish distribution within the watershed.

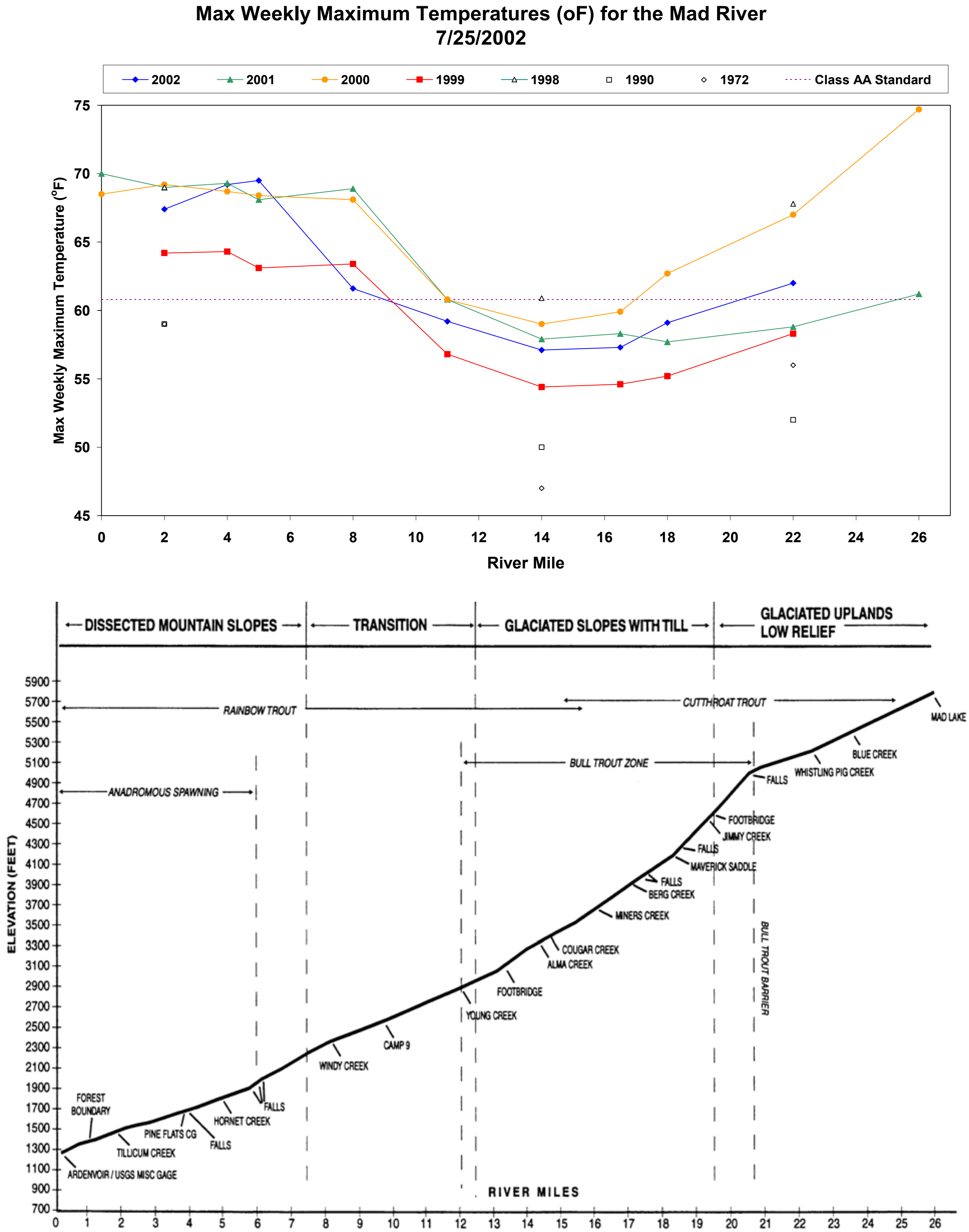


Figure 8-5. Relationship between maximum weekly maximum water temperatures (°F) for the Mad River, land type associations, channel gradient, stream flow and fish distribution.

8.3.2 <u>Fecal Coliform Bacteria</u>

The Planning Unit examined fecal coliform water quality data collected at the Keystone ambient water quality monitoring site by WDOE from November 1971 to September 2003; Class A criteria apply to this site. Fecal coliform colony samples were generally well within state water quality standards for Class A and even Class AA streams (see Table 8-1 on page 8-2). A previous review of Keystone ambient data 1978-1991 also noted that fecal coliform counts were usually low Ehinger (1994).

Occasional historic exceedences above Class A standards exist but are infrequent, exhibit no particular pattern, and have thus far not posed a water quality concern. The most recent exceedence of Class A standards occurred in April 1981, and only two excursions for fecal coliform above Class AA standards have been measured in the mainstem Entiat River since October 1996. Some elevated values for fecal coliform were measured in the tributaries (Mud and Potato Creeks) during post-Tyee Fire water quality sampling in 1995 and 1996; however, values for the mainstem Entiat were well within expected ranges. Although fecal coliform counts have been and continue to be low, future growth in the Entiat valley may present the potential for water quality problems associated with septic systems. Similarly, although no fecal coliform problems associated with livestock inputs have been noted, monitoring and Best Management Practices (BMPs), e.g. limiting livestock access to streams, should be used to help protect water quality. Figure 8-6 on this and the following page provides a summary of fecal coliform data collected at Keystone during the 1970s, 1980s, 1990s and 2000s, and compares data to Class A (and Class AA) water quality criteria for this parameter.

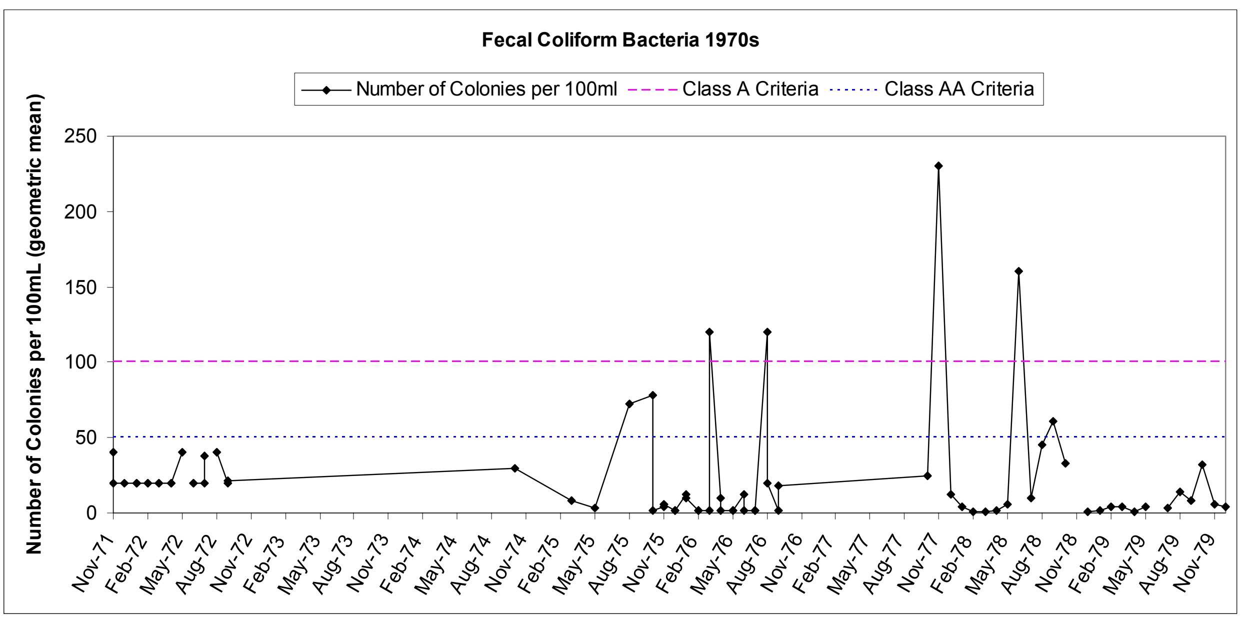


Figure 8-6a. Summary of Entiat River fecal coliform bacteria data collected by the WDOE at monitoring station 46A070 during the 1970s.

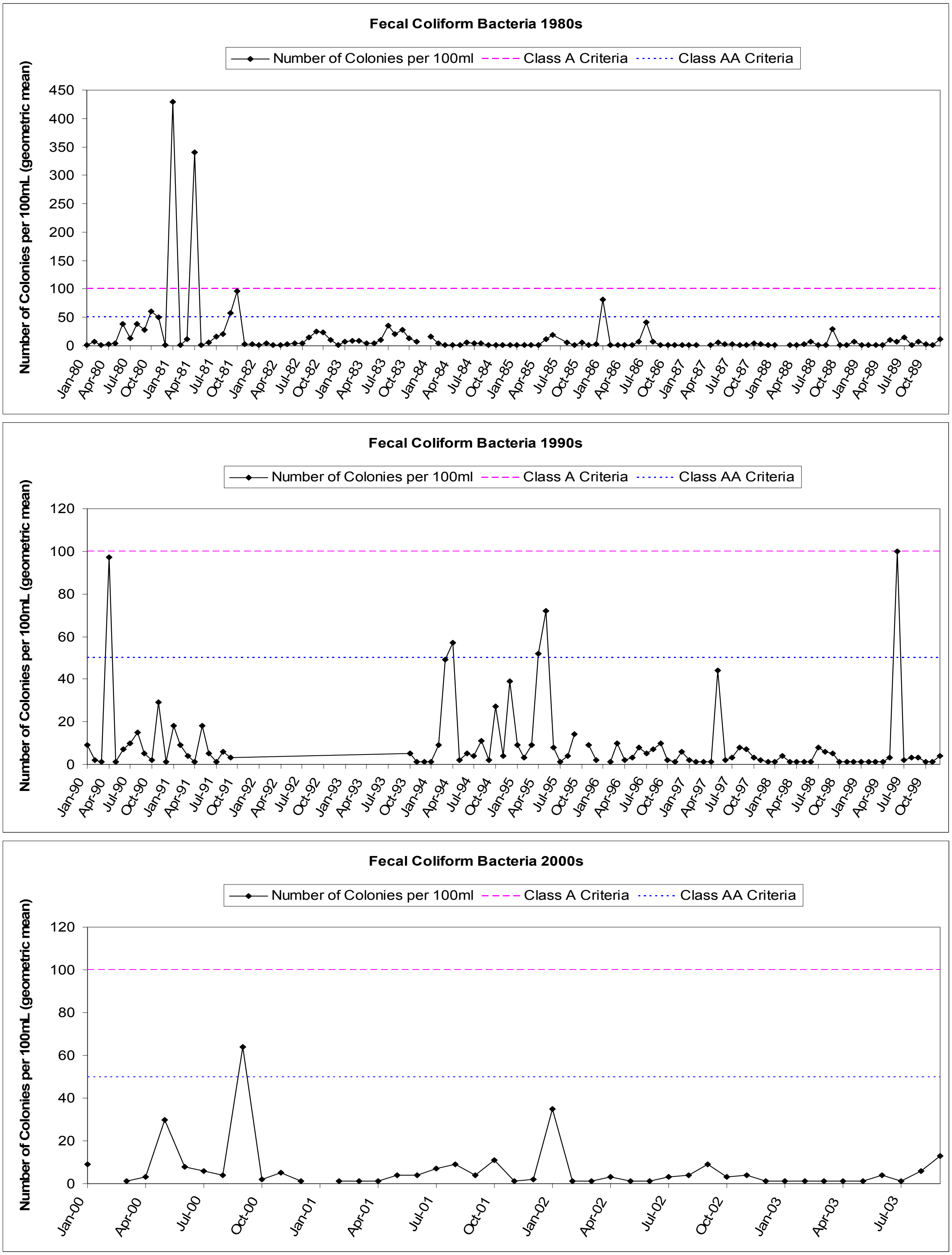
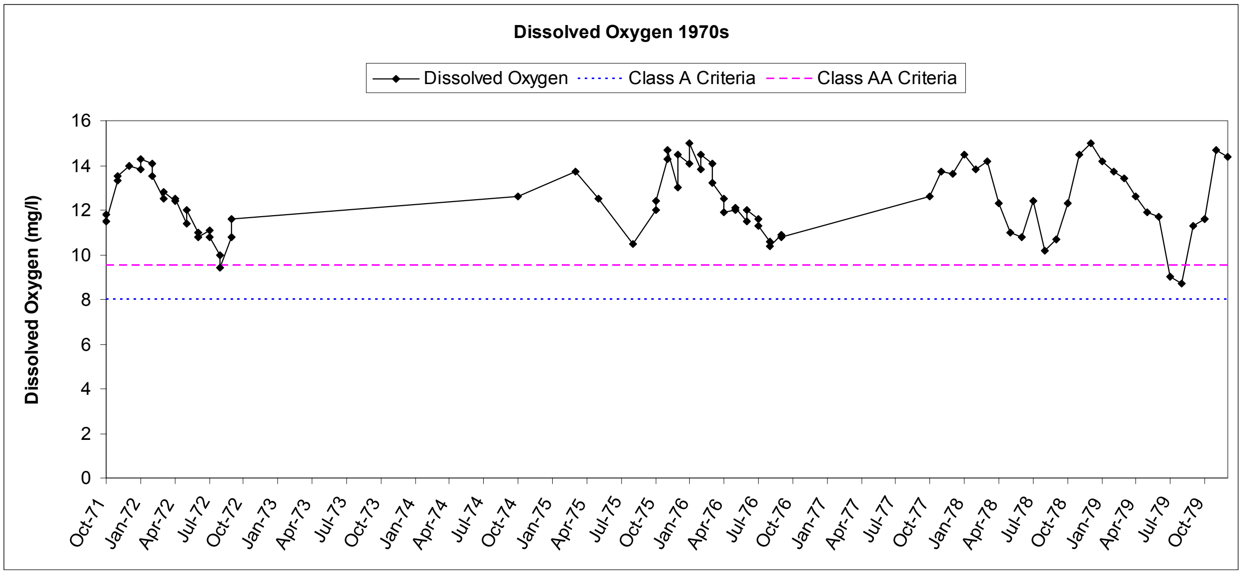


Figure 8-6b. Summary of Entiat River fecal coliform bacteria data collected by the WDOE at monitoring station 46A070 during the 1980s, 1990s, and 2000s.

8.3.3 Dissolved Oxygen

Entiat River ambient water quality data collected at the Keystone site from October 1971 to September 2003 show that the Class A water quality standard for dissolved oxygen has never been exceeded. Only one to two dissolved oxygen samples per decade have not met the standard for Class AA streams. Post-1994 Tyee Fire water quality sampling data collected in 1995 and 1996 showed that dissolved oxygen levels were well within expected ranges for the mainstem Entiat River. Refer to Figure 8-7 below and on the following page for a summary of dissolved oxygen data.



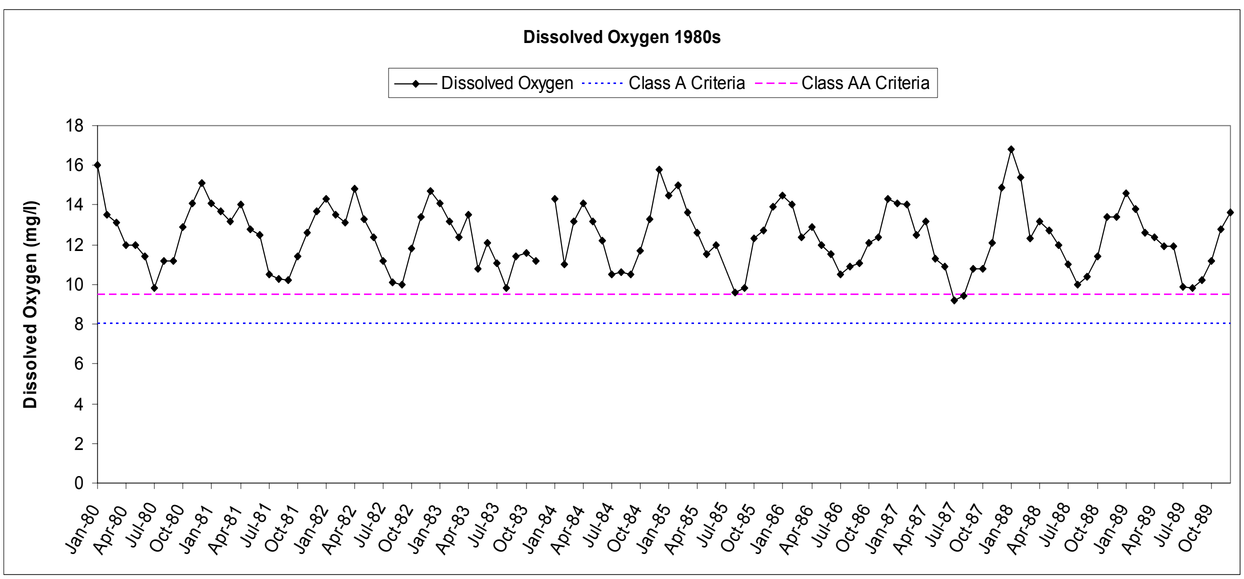
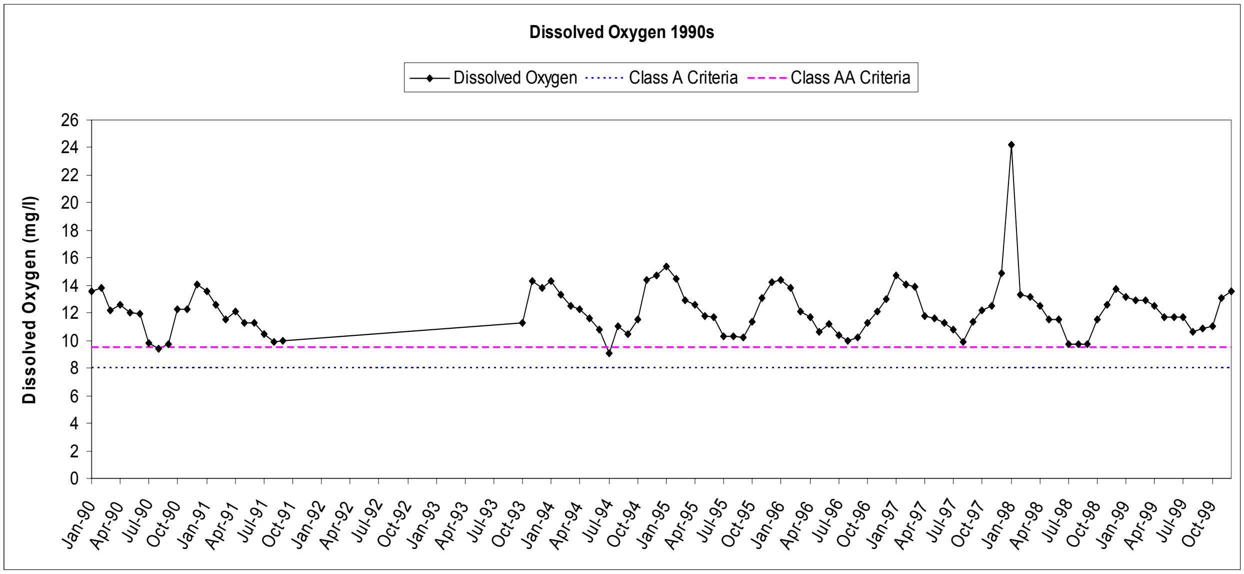


Figure 8-7a. Summary of Entiat River dissolved oxygen data collected by the WDOE at monitoring station 46A070 during the 1970s and 1980s.



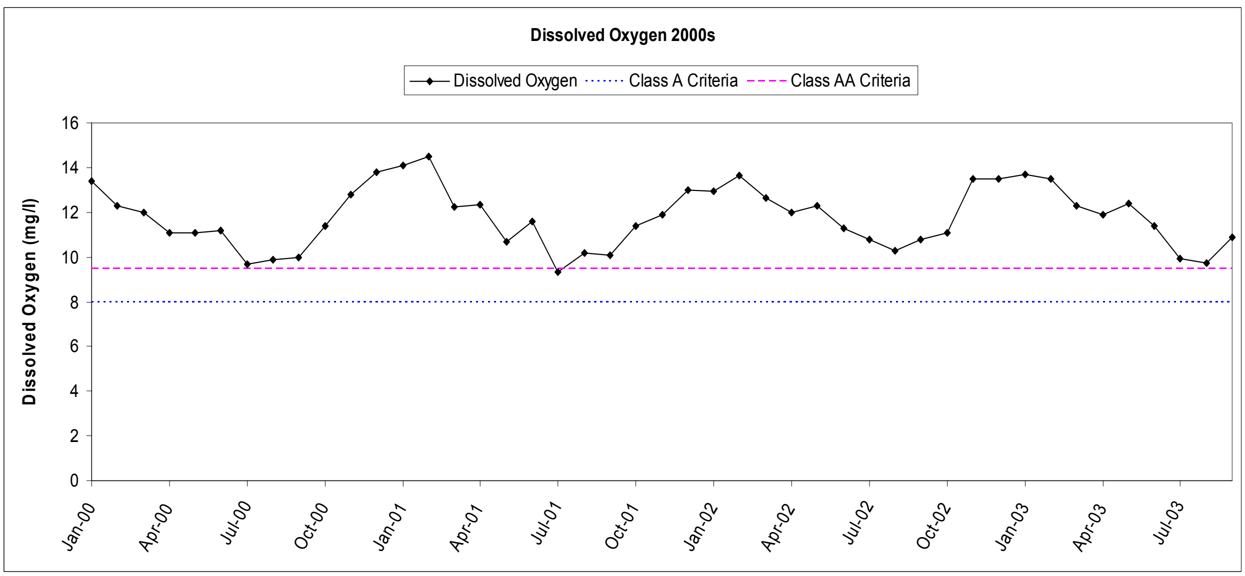


Figure 8-7b. Summary of Entiat River dissolved oxygen data collected by the WDOE at monitoring station 46A070 during the 1990s and 2000s.

8.3.4 pH

A 1994 review of ambient monitoring results by WDOE for Water Years (WY) 1978 - 1991 noted that pH excursions above 8.5 were relatively infrequent (Ehinger 1994). A Planning Unit review of Keystone data from October 1971 to September 2003 noted that occasional pH excursions above Class A/AA standards have occurred; however, values are generally within both Class A and Class AA criteria. WDOE hydrolab data collected in August 1998 showed that pH fluctuations were diurnal in nature and probably a result of photosynthetic activity; elevated pH levels typically peaked in late afternoon, coinciding with maximum insolation of the stream. Insufficient data are available to conclude that pH excursions recorded in other months and years are also a result of diurnal oscillations.

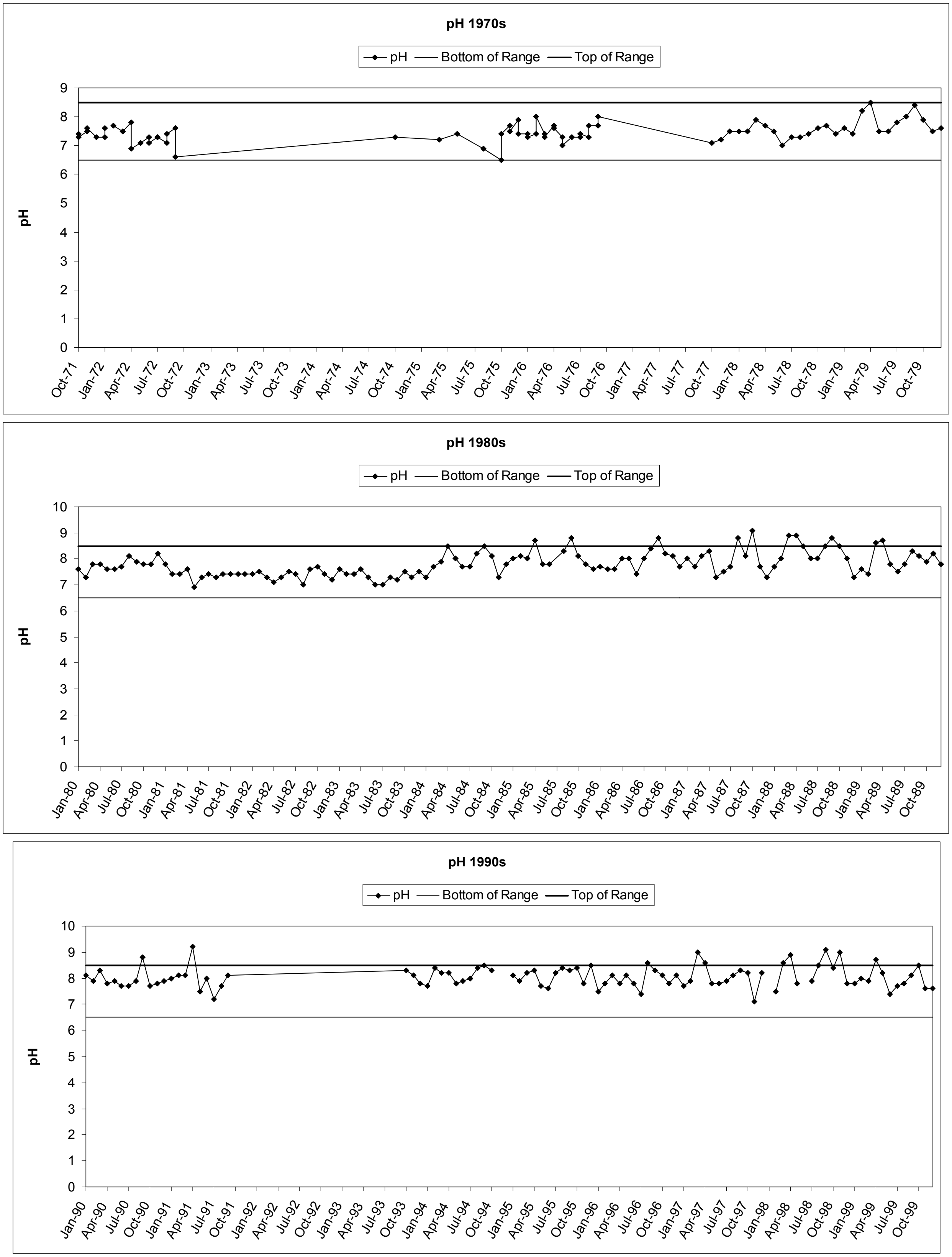


Figure 8-8a. Summary of Entiat River pH data collected by WDOE at monitoring site 46A070 during the 1970s, 1980s and 1990s.

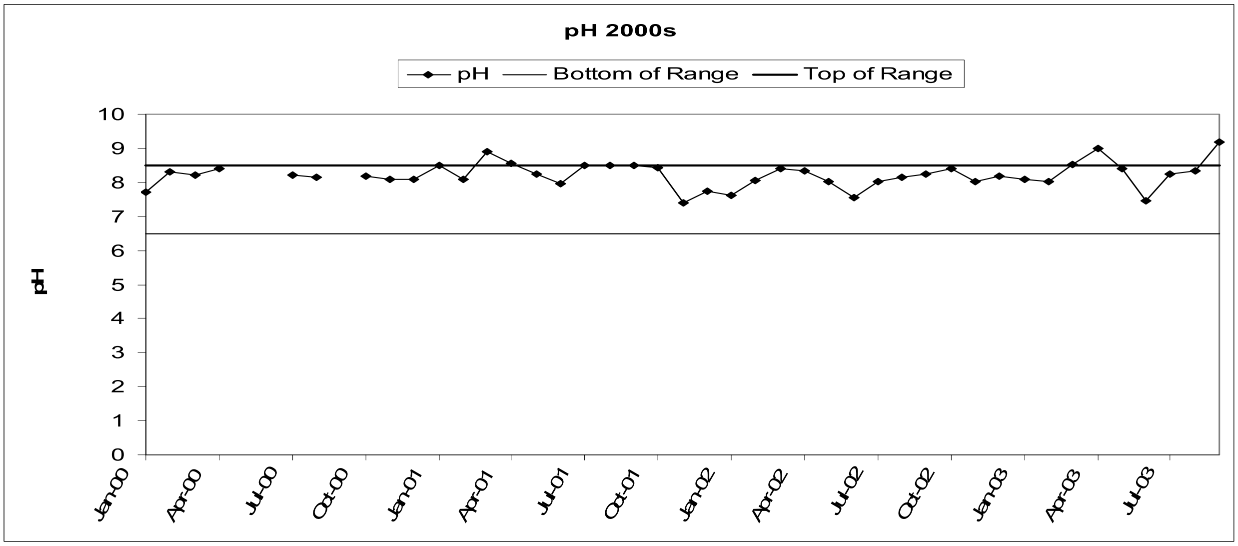


Figure 8-8b. Summary of Entiat River pH data collected by WDOE at monitoring site 46A070 during the 2000s.

8.3.5 Turbidity

Reviews of Keystone data by Ehinger (1994) and the Planning Unit noted that there have been infrequent spikes in turbidity levels; however, these turbidity spikes have occurred during high flow periods with resultant sediment transport. It is important to note that no background turbidity value has been officially determined for the Entiat River. Data showed a correlation between increased turbidity and suspended solids levels.

8.3.6 Suspended Solids

Suspended solids are also monitored at the WDOE Keystone site. May 1995 post-Tyee Fire data showed extremely high suspended solid concentrations, reflecting an initial flush of fine material as streamflow began to rise the first spring after the fire. Subsequent suspended solids data reflect a similar concentration versus flow relationship for both pre- and post-fire monitoring; however, the sampling frequency is limited for this event-dependent parameter (B. Ehinger, pers. comm. 1995).

8.3.7 Nutrients

A 1994 review of nutrient data collected by the WDOE at Keystone noted that ammonia-N, total phosphorus and soluble reactive phosphorus levels were generally low, with nitrate/nitrite-N concentrations well within the range expected of natural conditions and decreasing (Ehinger 1994). Post-1994 Tyee Fire water quality sampling data collected by the USFS, CCCD and WDOE in 1995 and 1996 showed annual nitrate loads exceeded 30,000 kg/year, compared to an estimated pre-fire annual load of 10,000 kg/year. Although post-fire nitrate concentrations were elevated, maximum concentrations did not increase notably and stayed within the natural range experienced in similar watersheds. Increased nitrate loading was associated with increased, sustained streamflows and expected post-fire release. Soluble phosphorus levels showed no change, suggesting that the phosphorus being transported was attached to sediment. Given the low availability of phosphorus, stimulation of algal growth as a result of increased nitrate levels after the fire was considered unlikely (B. Ehinger, pers. comm. 1995). No trend was seen that indicated a general increase in nutrient concentrations.

Current nutrient concentrations in the mainstem Entiat River are well within the range of expected natural conditions. Increased use of “soft” agricultural practices, like application of coddling moth mating disruption pheromones, indicates that nutrient levels from that source are not likely to increase in the future. WRIA 46 lies within U.S.Environmental Protection Agency (EPA) level III Ecoregion 10 (Columbia Plateau), a subdivision of Nutrient Ecoregion III (arid portions of the northwestern United States). The EPA has published regional numeric reference standards for nitrogen and phosphorus levels specific to both regions; however, the EPA recommends that local entities refine these criteria to reflect local conditions. Criteria have not been refined to reflect local reference conditions for WRIA 46. Thus, although nitrogen and phosphorus levels in the Entiat River and its tributaries have occasionally exceeded EPA criteria, it is difficult to ascertain the significance of these exceedences. Figure 8-9 on this and the following page and Figure 8-10 on page 8-25 summarize nutrient data collected from the Entiat River during the past three and a half decades.

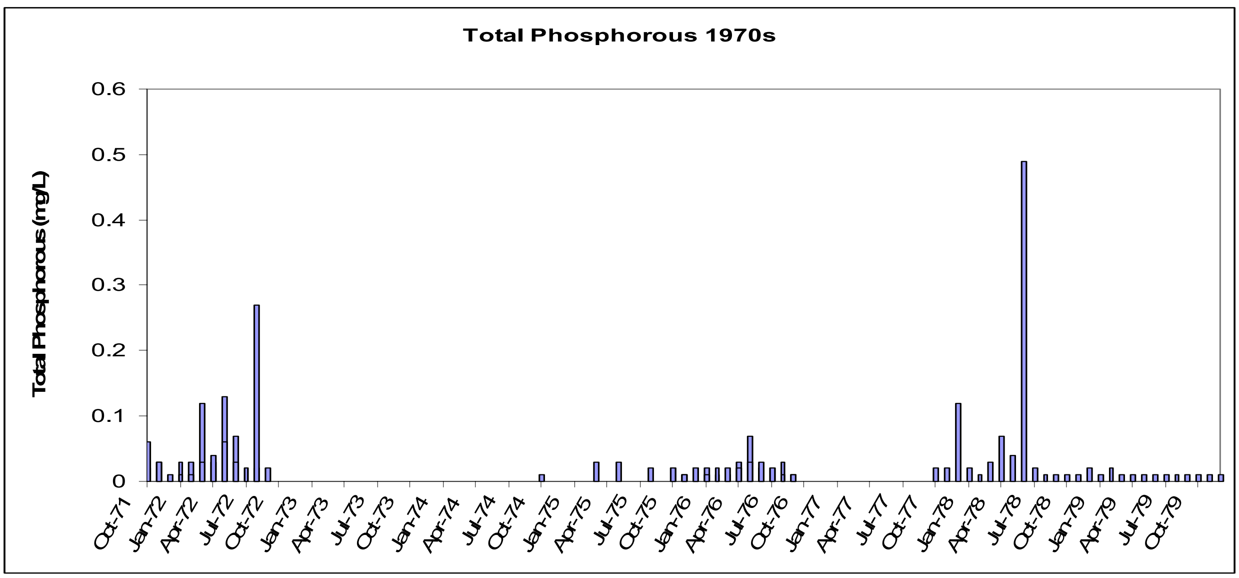


Figure 8-9a. Summary of Entiat River total phosphorous data collected by WDOE at monitoring site 46A070 during the 1970s.

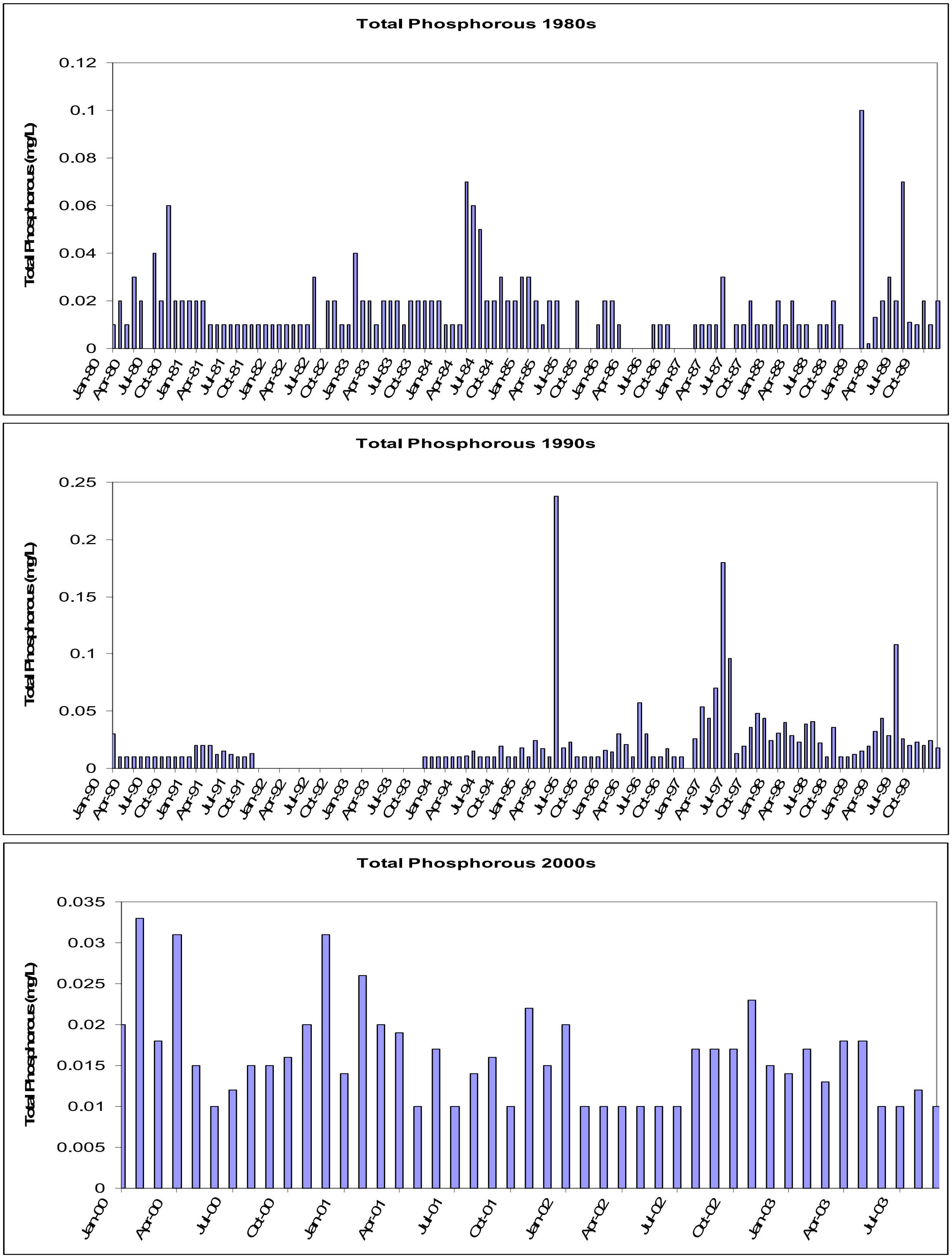
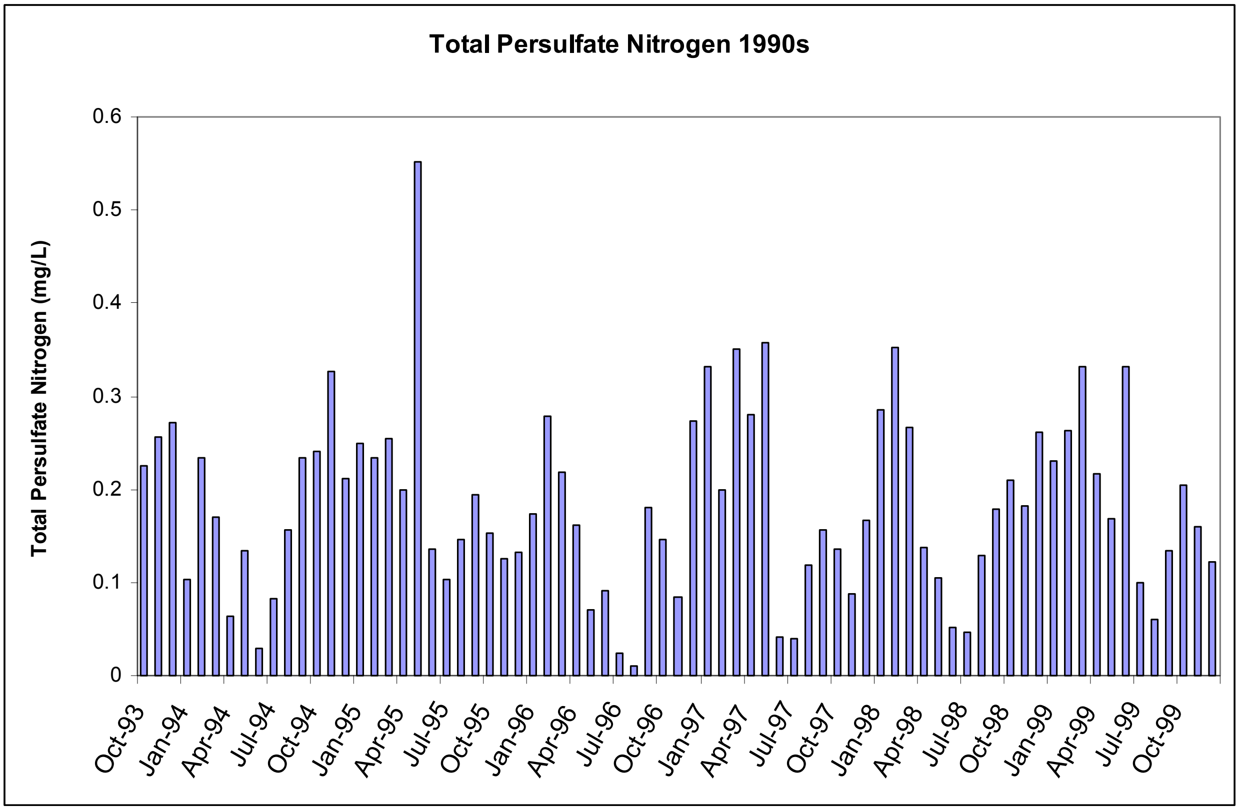


Figure 8-9b. Summary of Entiat River total phosphorous data collected by WDOE at monitoring site 46A070 during the 1980s,1990s and 2000s.



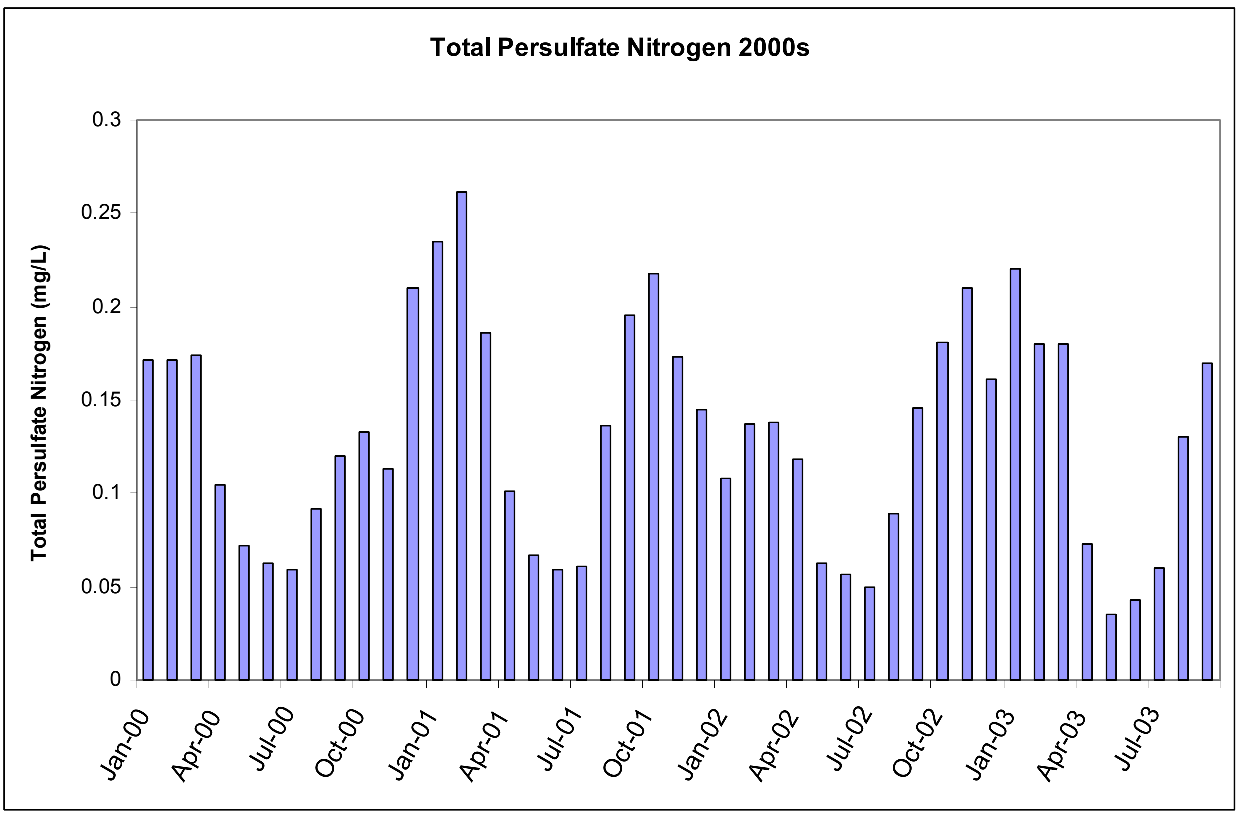


Figure 8-10. Summary of Entiat River total persulfate nitrogen data collected by WDOE at monitoring site 46A070 during the 1990s and 2000s.

8.3.8 Toxic Substances (DDT and metabolites)

In 1994, the WDOE initiated a composite sampling effort for 43 pesticides and breakdown products, as well as seven polychlorinated binphenyl mixtures (PCBs), using fish tissue and sediment samples from six sites in the state. Whole samples of bottom feeding fish (largescale suckers) were collected to assess potential wildlife impacts, while sport fish were collected to evaluate potential risk to human health (Davis and Serdar 1996). As part of the study, two replicate samples of large-scale suckers *(Catostomus sp)* were obtained from the Entiat River about one-half mile upstream from the mouth; no sport fish were obtained from this site for fillet analysis (Davis and Serdar 1996). Elevated levels of total[1] DDT and its breakdown products were the main contaminants found in the Entiat River sucker samples, with low levels of HCB and PCBs also detected.

Given that samples were taken from fish inhabiting the lower portion of the Entiat River near its confluence with Lake Entiat on the Columbia River, the data may not be representative of Entiat River resident fish populations. Furthermore, the risk to human health is unknown because no sport fish were sampled. The WDOE toxics monitoring program identified the Entiat River as a potential site for resampling in order to help verify 1994 t-DDT data and collect additional information (D. Norton, pers. comm. 2002); however, the priority assigned to such a re-sampling effort is low and it is not likely to receive additional funding. Additional sampling from a site further upstream is warranted to clarify results and contaminant source, as well as determine potential risk to human health. Davis and Serdar (1996) also recommended collection of additional whole fish samples to confirm DDT contamination levels and fillet sampling to evaluate potential human health risks.

8.4 SUMMARY

The Entiat River is classified as a Class A (excellent) stream from its confluence with the Columbia River to the boundary of the Wenatchee National Forest at approximately RM 26, and as a Class AA (extraordinary) stream from the National Forest boundary to its headwaters. It supports beneficial uses including domestic, industrial and agricultural water supply and primary contact recreation. Overall water quality at WDOE ambient water quality monitoring station 46A070 (Keystone) met or exceeded expectations in water year 2002, and is of lowest concern according to WDOE's Water Quality Index (WQI). For more information on the Entiat River's overall WQI score, and scores for individual parameters and months, see the following link: http://www.ecy.wa.gov/apps/watersheds/riv/station.asp?theyear=&tab=wqi&scrolly=0&mapscale=935&wria=46&sta=46A070. Refer to http://www.ecy.wa.gov/pubs/0203052.pdf for a detailed description of the WQI methodology.

Water quality in the Entiat River has been affected in the past by practices including flood control, logging and related roading, livestock grazing, and past agriculture practices. Significant positive changes and/or reductions have been made in several of these land uses. Logging and grazing in the watershed has declined significantly, and agricultural

[1] Total DDT refers to the sum of 4,4'- and 2,4'-isomers of DDT, DDD, and DDE.

practices have improved significantly with new technology. Watershed restoration emphasizing road rehabilitation has become a major focus of federal land managers. Furthermore, the amount and type of flood rehabilitation and control measures used and/or financed by federal agencies earlier in the century will probably not re-occur, due to a better understanding of the environmental sensitivity of the watershed.

With the exception of the post-1994 Tyee Fire sampling, and ongoing USFS temperature data collection, very little of the available tributary data are more recent than the mid-1980s. Temperature exceedences are the most common type of water quality issue in the tributaries, with infrequent excursions for dissolved oxygen, fecal coliform and pH also occurring. No increasing trends were seen.

There is no indication of any significant degradation within the WRIA with respect to fecal coliform, dissolved oxygen, pH, or turbidity. Temperature exceedences in the summer months have been identified throughout the record, beginning in 1960. Occasional temperature exceedences may have occurred naturally prior to settlement of the Entiat valley; however, it is impossible to determine the magnitude or frequency of this type of historic exceedence given the existing data record. It is likely that the number and frequency of exceedences has increased due to a combination of historic manipulation of channel geometry and removal of riparian plants, coupled with natural flood and wildfire events, which have also affected streamside vegetation.

Ongoing monitoring of water quality by the WDOE ensures that any trends indicating degradation of the Entiat River will be quickly identified. Maintaining current efforts and practices, and the future implementation of specific projects aimed at improving water quality will ensure that the Entiat River and its tributaries continue to regularly meet or exceed state standards in the foreseeable future.

8.5 STREAM NETWORK TEMPERATURE MODEL (SNTEMP)

The Following discussion is a summary of the report: *"An assessment of Water Temperatures of the Entiat River, Washington Using the Stream Network Temperature Model (SNTEMP)"* (Hendrick and Monahan 2003).

8.5.1 Introduction

As mentioned in section 8.3.1, water temperature excursions have been measured at various locations in both the Entiat and Mad Rivers. The Class A reach of the Entiat River was listed on the 303(d) list in 1996 as exceeding water temperature standards based on ambient water quality samples collected at WDOE monitoring station 46A070 (Keystone) (see section 8.1.4 for 303(d) list information). Although the Entiat was delisted for temperature in 1998, the draft 2002 303(d) list again lists the Class A segment of the Entiat River as exceeding water temperature standards. Therefore, the EWPU was interested in treating water temperature issues as a key part of the water quality component of its watershed plan. The EWPU specifically requested the development of a means to evaluate what actions can be taken to reduce water temperatures in the Entiat River watershed during critical high temperature periods.

The EWPU Water Quality subcommittee recommended to the EWPU that water temperatures in the Entiat watershed be assessed and evaluated using a stream network temperature model like the United States Fish and Wildlife Service's (USFWS) Stream Network Temperature (SNTEMP) model (Theurer et al 1984). SNTEMP is a one dimensional heat transport model that can, as a function of stream distance and environmental heat flux, predict daily mean and maximum water temperatures based on a dynamic temperature-steady flow equation (Bartholow 1989). Results from the modeling work were used to evaluate the effectiveness of different management actions, and develop strategic recommendations to reduce water temperatures in the Entiat River watershed during critical high temperature periods.

8.5.2 Methods

SNTEMP requires information defining the hydrology, geomorphology, climate, and observed water temperatures within the watershed being modeled. Data defining these processes within the Entiat watershed were collected from the numerous agencies performing other watershed management studies within the Entiat watershed, including the USFS, USGS, CCCD, NRCS, ENTRIX Inc., and WDOE. Figure 8-11 shows a longitudinal profile of the Entiat River node network used for this application of SNTEMP. A node is defined as a location along the river system to which some type of modeling information is assigned, such as hydrology or geomorphology data. Points along the profile depict categories of node type including headwater (H), change (C), validation (V), branch (B), terminal (T) junction (J), and end (E) types.

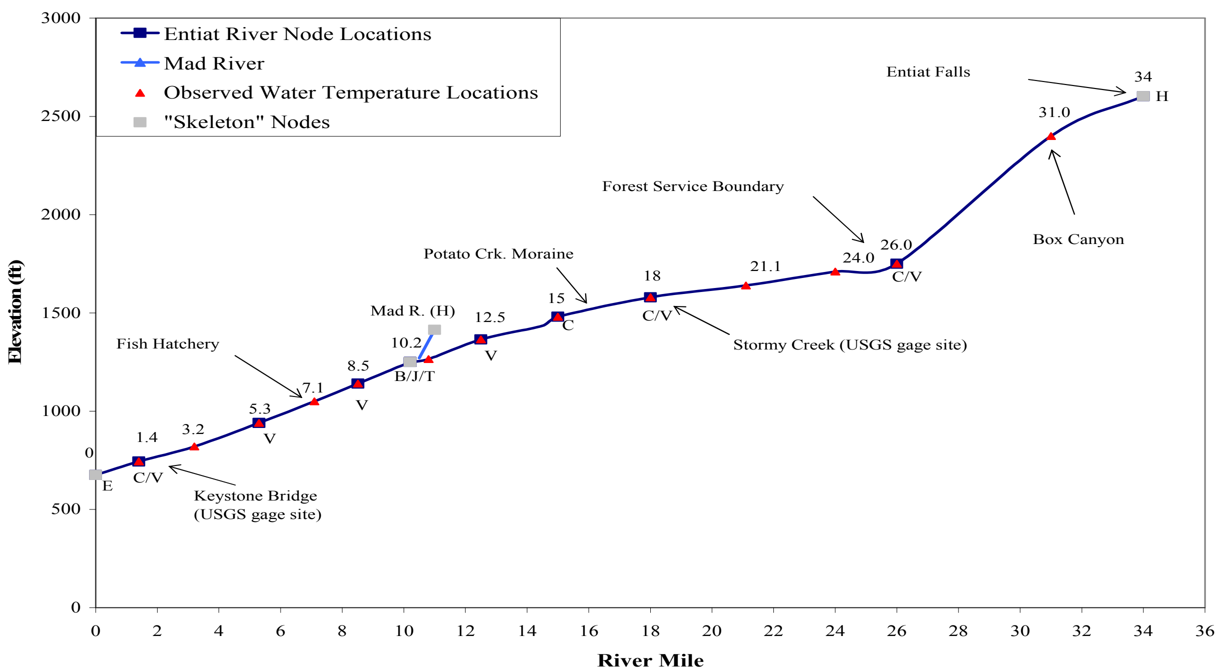


Figure 8-11. Longitudinal profile of the Entiat River illustrating the composite node network of the river and relative river gradient.

The time period August 2 - September 14 during the years 1997-2002 was chosen for modeling based on data availability and model objectives (Hendrick and Monahan 2003). Many years were modeled so that seasonal variability could be captured, assuring that any recommendations based on the results of the modeling effort would be valid for various types of seasons and conditions. After information defining the Entiat River watershed was collected and entered into the SNTEMP model, and a time period was selected, initial calibration model runs were made to assure that the model was accurately and precisely predicting water temperature values, and maximize the reliability of the model in estimating the effects of alternative treatments on water temperature. The model was considered calibrated and therefore accurately and precisely predicting water temperatures, when simulated water temperatures matched observed water temperatures at similar locations for the same time periods within a pre-determined and scientifically accepted range of errors. Figure 8-12 illustrates a linear regression of observed and predicted daily mean water temperatures (˚C) for the Entiat River for the entire modeled period of record. This relationship was evident across the range of temperatures simulated, with close correlation occurring from just below 10 °C to just over 20 °C. The calibrated model showed no trend in error and suggests that it performed well in predicting daily mean water temperatures (Hendrick and Monahan 2003).

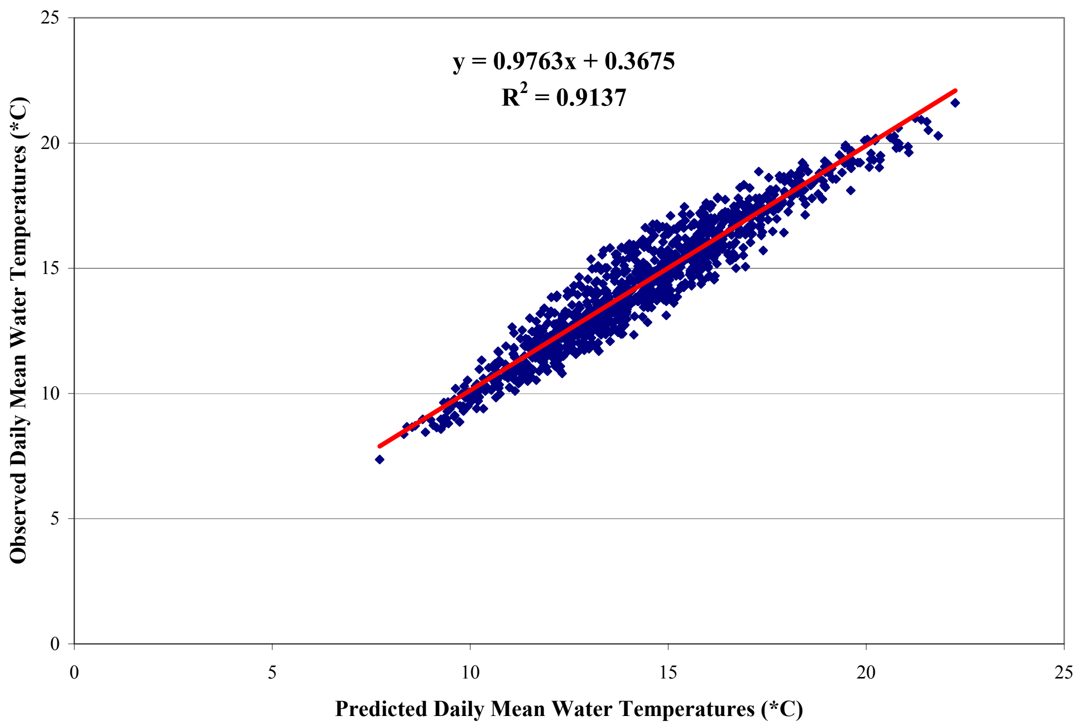


Figure 8-12. Final calibration results showing observed vs. predicted daily mean water temperatures at all validation (V) nodes for all years and time periods simulated.

Table 8-4 on page 8-30 illustrates the summary statistics of the final calibration run. The model performed well and produced a correlation coefficient of 0.9137, a mean error of -0.03°C, a maximum error of -2.34 °C, and a dispersion error of 5.94%. These values are well within the acceptable range of error (see the full SNTEMP Report for more discussion).

Table 8-4. Summary statistics for final SNTEMP model calibration run.

Correlation Coefficient (R^2)	0.9137
Mean Error (°C)	-0.03
Maximum Error (°C)	-2.34
Dispersion Error (%)	5.94

8.5.3 Model Alternatives and Results

With calibration complete, three distinct actions were simulated using SNTEMP: system wide (RM 0-34) increase in streamflow, system wide increase in riparian shade and reduction in stream channel width in the lower river (RMs 0-10) with all other parameters held constant. Ranges of change for each of the alternatives modeled included: increases in streamflow by 10%, 25%, 50%, 150%, 200%, 250%, and 300%; reduction in channel width by 10%, 25%, and 50%; and increases in shade by 10%, 25%, 50%, and 100%. As shade model inputs were already in a percent form, increases in shade were calculated by adding the percent change amount to the observed percent shade condition, Thus, in an area where existing shade was estimated at 10% canopy cover, a 10% increase in shade equates to 10% + 10%, or 20% resultant shade overall. Alternative actions that included combinations of the three actions and ranges of change were also performed to determine which single action or combination of actions best reduced high water temperatures. Alternative actions were developed using guidance from the EWPU and Water Quality subcommittee, and examples from others. Although all aforementioned ranges of change were simulated, not all were considered feasible to implement, e.g. a 25% increase in streamflow, given the current resources and goals of the EWPU.

The SNTEMP model simulated daily maximum water temperatures at 16 nodes over a period of 44 stream-days (08/02 – 09/14) in a year (Hendrick and Monahan 2003). A stream-day is defined as a complete 24 hour period in which daily mean and maximum water temperature data were modeled. Thus, a total of 704 "measurement points" (16 nodes x 44 stream-days = 704) were used to determine the number of temperature exceedences that occurred from 08/02 - 09/14 for each year modeled. Eleven nodes were between RM 0-20 (State water quality Class A, ≤18°C), and five nodes were between RM 20-34 (State water quality Class AA, ≤16°C). Refer to Figure 8-13 on page 8-31 for a depiction of node locations with respect to Class A and Class AA reaches. For each year modeled, the number of times that simulated daily maximum water temperature was above 18°C at each node between RM 0-20, and above 16°C at each node between RM 20-34 was counted, and then compared to the total number of measurement points. For example, in 2001, the number of overall stream-day water temperature exceedences simulated was 510. Therefore, knowing that out of 704 "chances" modeled water temperature exceeded standards 510 times, it can be said that standards were exceeded 72% of the time in 2001 (Hendrick and Monahan 2003).

The total number of temperature exceedences simulated for baseline conditions was compared against the number of exceedences simulated for each "feasible" alternative in order to determine how each alternative action reduced the number of predicted exceedences. Figure 8-14 on page 8-32 summarizes the number of stream day exceedences modeled for select alternative actions. Table 8-5 on page 8-33 shows the number of stream-day exceedences for the Class AA water quality standard, Class A water quality standard, as well as the system-wide total number (Class AA + Class A) of exceedences for each year simulated (1997-2002). The table also shows the percent value of exceedences. Table 8-6 on page 8-34 shows similar values but is limited to RMs 0-10 in order to illustrate effects of alternative actions in this reach. This was necessary to understand the predicted effects of alternative actions that included reducing channel width in the lower 10 RMs.

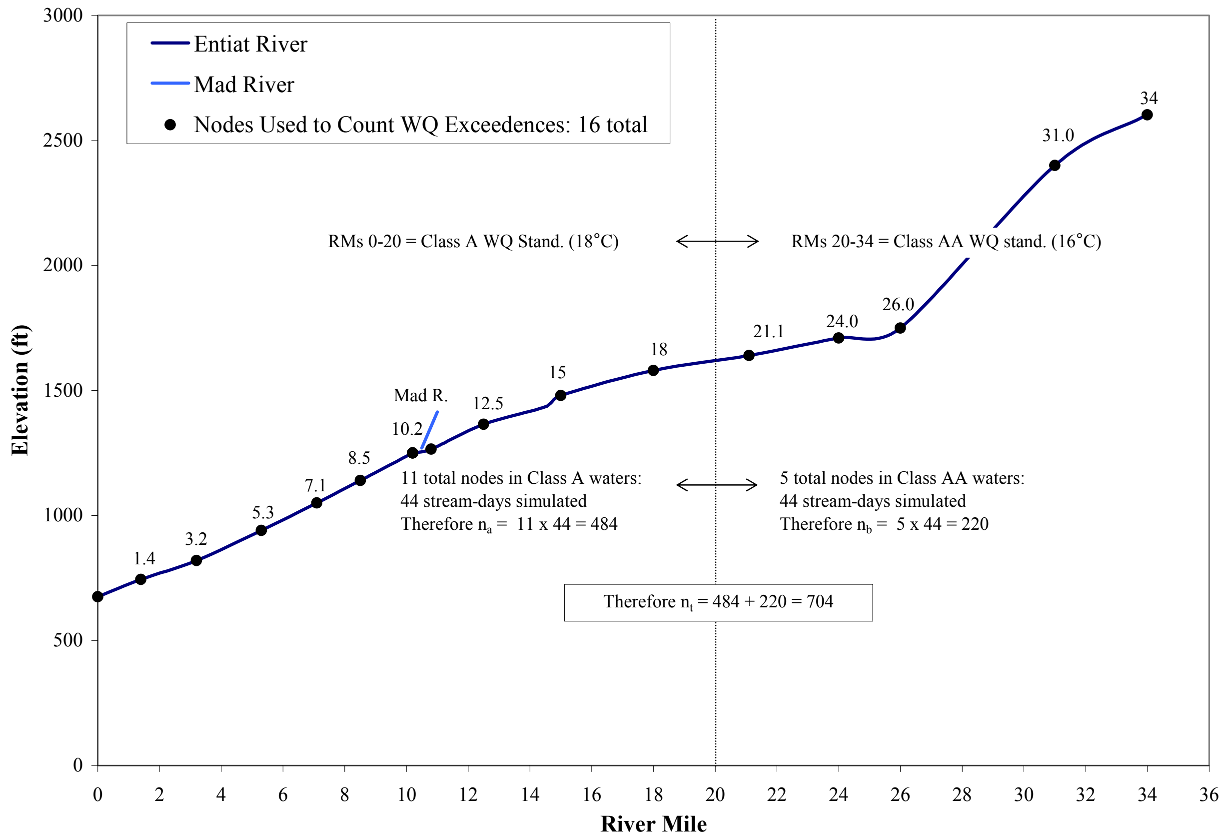
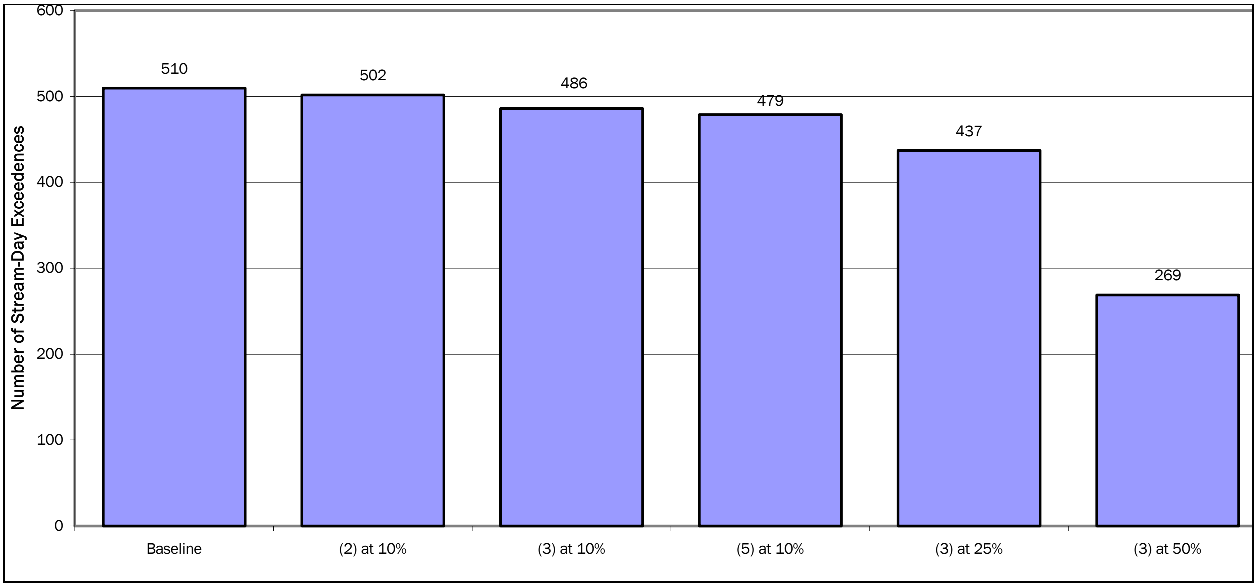


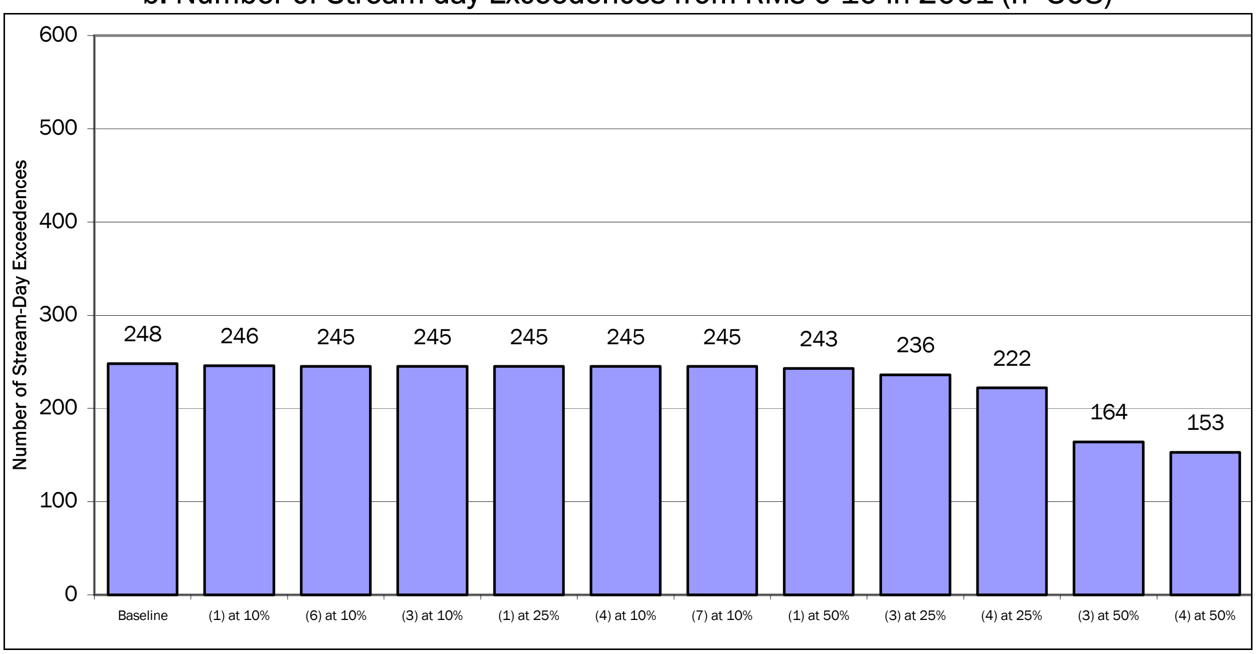
Figure 8-13. Longitudinal profile of Entiat River showing the location and total number of nodes (labeled by RM) used as simulated "measurement points" for counting exceedences for each time period/year simulated.

a. Number of Stream-day Exceedences from RMs 0-34 in 2001 (n=704)



Alternative Action Number Key:
(2) = Increase Streamflow in RMs 0-34
(3) = Increase Riparian Shade in RMs 0-34
(5) = Increase Streamflow AND Riparian Shade in RMs 0-34

b. Number of Stream-day Exceedences from RMs 0-10 in 2001 (n=308)



Alternative Action Number Key:
(1) = Decrease Channel Width in lower 10 RMs; (3) = Increase Riparian Shade in RMs 0-34
(4) = Increase Riparian Shade (in RMs 0-34) AND Decrease Channel Width (in lower 10 RMs)
(6) = Increase Streamflow (in RMs 0-34) AND Decrease Channel Width (in lower 10 RMs)
(7) = Increase Streamflow AND Riparian Shade (in RMs 0-34) AND Decrease Channel Width (in lower 10 RMs)

Figure 8-14. Number of stream-day water temperature exceedences for simulated baseline conditions and alternative actions for RMs 0-34 (a) and RMs 0-10 (b) during the 8/2/01-9/14/01 (44 day) time period.

Table 8-5. Exceedence table showing the number of state water quality exceedences for simulated baseline conditions, percent of exceedences based on total number of "measurement" points (n), and proposed alternative actions system wide (RMs 0-34).

Alt. Action	Exceedences		Alt. Action	Exceedences		Alt. Action	Exceedences		Alt. Action	Exceedences		Alt. Action	Exceedences		Alt. Action	Exceedences	
	#	%		#	%		#	%		#	%		#	%		#	%
Class AA	*n*=220																
1997			1998			1999			2000			2001			2002		
Baseline	33	15.00	Baseline	146	66.36	Baseline	3	1.36	Baseline	54	24.55	Baseline	141	64.09	Baseline	102	46.36
(2) at 10%	26	11.82	(2) at 10%	141	64.09	(2) at 10%	3	1.36	(2) at 10%	46	20.91	(2) at 10%	137	62.27	(2) at 10%	95	43.18
(3) at 10%	17	7.73	(3) at 10%	133	60.45	(3) at 10%	2	0.91	(3) at 10%	32	14.55	(3) at 10%	130	59.09	(3) at 10%	78	35.45
(5) at 10%	12	5.45	(5) at 10%	125	56.82	(5) at 10%	2	0.91	(5) at 10%	25	11.36	(5) at 10%	126	57.27	(5) at 10%	67	30.45
(3) at 25%	1	0.45	(3) at 25%	94	42.73	(3) at 25%	0	0.00	(3) at 25%	8	3.64	(3) at 25%	109	49.55	(3) at 25%	39	17.73
(3) at 50%	0	0.00	(3) at 50%	29	13.18	(3) at 50%	0	0.00	(3) at 50%	0	0.00	(3) at 50%	60	27.27	(3) at 50%	0	0.00
Class A	*n*=484																
1997			1998			1999			2000			2001			2002		
Baseline	194	40.08	Baseline	396	81.82	Baseline	56	11.57	Baseline	226	46.69	Baseline	369	76.24	Baseline	318	65.70
(2) at 10%	174	35.95	(2) at 10%	381	78.72	(2) at 10%	44	9.09	(2) at 10%	217	44.83	(2) at 10%	365	75.41	(2) at 10%	294	60.74
(3) at 10%	155	32.02	(3) at 10%	361	74.59	(3) at 10%	34	7.02	(3) at 10%	194	40.08	(3) at 10%	356	73.55	(3) at 10%	271	55.99
(5) at 10%	137	28.31	(5) at 10%	350	72.31	(5) at 10%	25	5.17	(5) at 10%	175	36.16	(5) at 10%	353	72.93	(5) at 10%	255	52.69
(3) at 25%	88	18.18	(3) at 25%	310	64.05	(3) at 25%	16	3.31	(3) at 25%	129	26.65	(3) at 25%	328	67.77	(3) at 25%	206	42.56
(3) at 50%	12	2.48	(3) at 50%	179	36.98	(3) at 50%	0	0.00	(3) at 50%	34	7.02	(3) at 50%	209	43.18	(3) at 50%	79	16.32
Total	*n*=704																
1997			1998			1999			2000			2001			2002		
Baseline	227	32.24	Baseline	542	76.99	Baseline	59	8.38	Baseline	280	39.77	Baseline	510	72.44	Baseline	420	59.66
(2) at 10%	200	28.41	(2) at 10%	522	74.15	(2) at 10%	47	6.68	(2) at 10%	263	37.36	(2) at 10%	502	71.31	(2) at 10%	389	55.26
(3) at 10%	172	24.43	(3) at 10%	494	70.17	(3) at 10%	36	5.11	(3) at 10%	226	32.10	(3) at 10%	486	69.03	(3) at 10%	349	49.57
(5) at 10%	149	21.16	(5) at 10%	475	67.47	(5) at 10%	27	3.84	(5) at 10%	200	28.41	(5) at 10%	479	68.04	(5) at 10%	322	45.74
(3) at 25%	89	12.64	(3) at 25%	404	57.39	(3) at 25%	16	2.27	(3) at 25%	137	19.46	(3) at 25%	437	62.07	(3) at 25%	245	34.80
(3) at 50%	12	1.70	(3) at 50%	208	29.55	(3) at 50%	0	0.00	(3) at 50%	34	4.83	(3) at 50%	269	38.21	(3) at 50%	79	11.22

Alternative Action (#) Legend
(2) = Increase Streamflow in RMs 0-34
(3) = Increase Riparian Shade Values in RMs 0-34
(5) = Increase Streamflow AND Increase Riparian Shade in RMs 0-34

Table 8-6. Exceedence table showing the number of state water quality exceedences for simulated baseline conditions, percent exceedences based on total number of "measurement" points (n), and proposed alternative actions in the lower 10 RMs.

Alt. Action	Exceedences		Alt. Action	Exceedences		Alt. Action	Exceedences		Alt. Action	Exceedences		Alt. Action	Exceedences		Alt. Action	Exceedences	
	#	%		#	%		#	%		#	%		#	%		#	%
	n=308																
1997			1998			1999			2000			2001			2002		
Baseline	171	55.52	Baseline	279	90.58	Baseline	52	16.88	Baseline	191	62.01	Baseline	248	80.52	Baseline	250	81.17
(1) at 10%	158	51.30	(1) at 10%	275	89.29	(1) at 10%	43	13.96	(1) at 10%	187	60.71	(1) at 10%	246	79.87	(1) at 10%	242	78.57
(1) at 25%	145	47.08	(6) at 10%	268	87.01	(1) at 25%	34	11.04	(6) at 10%	177	57.47	(6) at 10%	245	79.55	(6) at 10%	230	74.68
(6) at 10%	144	46.75	(3) at 10%	267	86.69	(3) at 10%	33	10.71	(1) at 25%	174	56.49	(3) at 10%	245	79.55	(1) at 25%	229	74.35
(3) at 10%	140	45.45	(1) at 25%	266	86.36	(6) at 10%	32	10.39	(3) at 10%	168	54.55	(1) at 25%	245	79.55	(3) at 10%	223	72.40
(4) at 10%	132	42.86	(4) at 10%	265	86.04	(4) at 10%	27	8.77	(4) at 10%	160	51.95	(4) at 10%	245	79.55	(4) at 10%	215	69.81
(7) at 10%	114	37.01	(7) at 10%	262	85.06	(7) at 10%	23	7.47	(7) at 10%	149	48.38	(7) at 10%	245	79.55	(7) at 10%	204	66.23
(1) at 50%	101	32.79	(1) at 50%	255	82.79	(1) at 50%	21	6.82	(1) at 50%	146	47.40	(1) at 50%	243	78.90	(1) at 50%	198	64.29
(3) at 25%	87	28.25	(3) at 25%	243	78.90	(3) at 25%	16	5.19	(3) at 25%	121	39.29	(3) at 25%	236	76.62	(3) at 25%	176	57.14
(4) at 25%	57	18.51	(4) at 25%	225	73.05	(4) at 25%	10	3.25	(4) at 25%	93	30.19	(4) at 25%	222	72.08	(4) at 25%	155	50.32
(3) at 50%	12	3.90	(3) at 50%	158	51.30	(3) at 50%	0	0.00	(3) at 50%	34	11.04	(3) at 50%	164	53.25	(3) at 50%	78	25.32
(4) at 50%	0	0.00	(4) at 50%	109	35.39	(4) at 50%	0	0.00	(4) at 50%	8	2.60	(4) at 50%	153	49.68	(4) at 50%	26	8.44

Alternative Action (#) Legend
(1) = Decrease Channel Width in lower 10 RMs
(3) = Increase Riparian Shade Values in RMs 0-34
(4) = Increase Riparian Shade (in RMs 0-34) AND Decrease Channel Width (in lower 10 RMs)
(6) = Increase Streamflow (in RMs 0-34) AND Decrease Channel Width (in lower 10 RMs)
(7) = Increase Streamflow AND Increase Riparian Shade (in RMs 0-34) AND Decrease Channel Width (in lower 10 RMs)

The SNTEMP model predicted reductions in water temperatures for all three system-wide alternative actions, suggesting that implementation of any of the three actions will help reduce summer water temperatures to some extent (Hendrick and Monahan 2003). Of the feasible alternatives, SNTEMP predicted the largest reduction in water temperature exceedences when riparian shade was increased over the long term by 50% throughout the system (Alternative Action 3). Alternative Action 4, which included a 50% increase in riparian shade in RMs 0-34[2] *and* a 50% reduction in channel width in the lower 10 miles of the Entiat River, produced the most significant change in the number of temperature exceedences in that portion of the system (Hendrick and Monahan 2003).

Although none of the alternative actions completely reduce water temperatures to or below current state water quality standards during the hottest day of each year simulated (see full report), increasing riparian shade and decreasing channel width (Alternative Actions 3 and/or 4) could produce, in addition to reductions in high water temperatures, other positive effects on the overall health of the Entiat River watershed. Increasing current riparian shade conditions system-wide has the potential to increase biological diversity within the watershed and increase nutrient sources for fish species (Andonaegui 1999). Increases in riparian vegetation and shade could also provide a potential source for large woody debris placement (an important component of fish habitat), refuge from predators and extreme environmental events, and buffer the effects of erosive forces (Andonaegui 1999).

Decreasing channel width in the lower 10 RMs has the potential to improve fish passage, and further enhance the effectiveness of increased riparian vegetation in the summer as well as the winter, when low temperatures are also a concern (CCCD 2002). The Planning Unit installed three rock cross vanes in the lower river in 2001 to help restore habitat complexity (resting pools) and modify channel geometry. Installing additional instream structures to reduce width to depth ratios would also support habitat improvement objectives.

For additional information on riparian condition, channel morphology, temperature and fish habitat conditions, refer to Chapter 7, Habitat.

[2] Due to variation over this 34 mile reach riparian restoration and enhancement efforts will not be applied systematically throughout. The goal is to attain a certain percentage of site potential shade. Sites will be prioritized for planting.