CHAPTER 10. WATER QUALITY

INTRODUCTION

The purpose of the water quality assessment is to complete a screening level analysis of water quality that will identify obvious areas of water quality impairment by comparing selected measurements of water quality to certain evaluation criteria. The screening level analysis uses existing data obtained from a variety of sources. The assessment does not include statistical evaluation of seasonal fluctuations or trends through time, and does not evaluate specific sources of pollution through upstream-downstream comparisons.

The first step of the analysis identifies beneficial uses of the water that are sensitive to adverse changes in water quality. The second step establishes the evaluation criteria. The third step examines the existing water quality data in light of the evaluation criteria available. Conclusions can then be made about the presence of known water quality problems in the watershed, and whether or not additional studies are necessary.

Although there are many parameters that indicate the water quality of a stream, this assessment will focus on seven that are most often measured, and that may have the most direct effect on aquatic organisms: temperature, dissolved oxygen, pH, nutrients, bacteria, turbidity, and chemical contaminants. Evaluation criteria have been determined by regulatory entities based on values of these parameters that are generally protective of aquatic life. Some other aspects of water quality, such as fine sediment, are dealt with in other sections.

Protection of water quality in Oregon is based on water quality standards developed by the Oregon Department of Environmental Quality (ODEQ). Standards are the benchmarks that indicate if water quality is sufficient to protect designated beneficial uses. When a water body meets the standards, the beneficial uses of the water body are protected. By ODEQ definition, a water quality standard is composed of: (1) designated uses of a waterbody which set the water quality goals of a waterbody (e.g. resident fish and aquatic life, water contact recreation); (2) water quality criteria that define the minimum conditions necessary to achieve the designated uses – these can be numeric, a specific temperature value for example, or narrative, stating, for example, that the water should not have oil slicks, or objectionable color or odor; and, (3) antidegradation policy that prevents existing water quality from degrading unless specific circumstances apply. The antidegradation policy complements the use of water quality criteria. While criteria provide the absolute minimum values or conditions that must be met in order to protect designated uses, the antidegradation policy offers protection to existing water quality, including instances where that water quality equals or is better than the criteria.

BENEFICIAL USES

The Clean Water Act requires that water quality standards be set to protect the beneficial uses that are present in each water body. Beneficial uses for the purpose of water quality regulation are determined by ODEQ for each of 19 river basins. The Upper Sprague River subbasin is included in the Upper Klamath Basin. Beneficial uses for the Upper Klamath Basin are given in Oregon Revised Statute 340-41-0180, and include:

X Private domestic water supply[1]
X Industrial water supply
X Irrigation
X Livestock watering
X Fish and aquatic life[2]
X Wildlife and hunting
X Fishing
X Boating
X Water contact recreation
X Aesthetic quality
X Hydro power
X Commercial navigation and transportation

The water quality requirements to meet these uses differ. For example, the requirements for domestic water supply may be more stringent in some aspects than those for livestock watering. Frequently, the most sensitive beneficial use is considered when making decisions regarding designation of a water body as water quality limited. Federal law requires that the most sensitive beneficial use be protected. The state implements this requirement through the state water quality standards. The underlying assumption is that if the water body meets the criteria for the most sensitive use, it will meet criteria for other uses as well. For most of the Upper Sprague River subbasin, the most sensitive beneficial use would be fish and aquatic life.

POLLUTANT SOURCES

Point Sources

The Clean Water Act regulates discharge of waste to surface water. In order to discharge any waste, a facility must first obtain a permit from the State. ODEQ issues two primary types of discharge permit. Dischargers with Water Pollution Control Facility (WPCF) permits are not allowed to discharge to a water body. Industries, municipal wastewater treatment facilities, fish hatcheries, and similar facilities typically have National Pollutant Discharge Elimination System (NPDES) permits. Most WPCF

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[1] With adequate pretreatment (filtration & disinfection) and natural quality to meet drinking water standards.

[2] Fish use designations for this basin are presented in ORS 340-41-0180. The following fish use designations pertain to the Upper Sprague River subbasin. Bull Trout – Long Creek, Coyote Creek, above Sycan Marsh, Skull Creek and the headwaters of the Sycan River, the Upper Reaches of North Fork Sprague River and South Fork Sprague River, and their tributaries. There is a short segment of the North Fork Sprague River designated core cold water habitat. The remainder of the river segments in the Upper Sprague River subbasin are designated as redband trout or Lahontan cutthroat trout use.

permits are issued for on-site sewage disposal systems. Holders of NPDES permits are allowed to discharge wastes to waters of the state, directly or indirectly, but their discharge must meet certain quality standards as specified in their permits. There are no dischargers with NPDES permits in the Upper Sprague River subbasin. The Bly sanitary district holds WPCF permits but is not allowed to discharge to any surface water.

Nonpoint Sources

The largest current source of pollutants to Oregon's waters is not point sources such as factories and sewage treatment plants, but rather comes from surface water runoff, often called "nonpoint source" pollution (ODEQ 2002, 2006). Rainwater, snowmelt, and irrigation water flowing over roofs, driveways, streets, lawns, agricultural lands, construction sites, and logging operations carry more pollution, such as nutrients, bacteria, and suspended solids, than discharges from industry (ODEQ 2002, 2006).

Land use can have a strong influence on the quantity and quality of water flowing from a watershed. An undisturbed watershed with healthy native vegetation in and along waterways and a diversity of habitats on the uplands typically provides clean water that supports the desirable beneficial uses of the waterway. As the watershed is affected by logging, agriculture, urban development, or other disturbances, the water quality in the waterways can become degraded. The percent of land area of the Upper Sprague River subbasin in various categories is shown in Table 10-1.

The most prominent type of land use in the Upper Sprague River subbasin is forestry, with little land in developed areas. This suggests that water quality problems associated with toxic industrial chemicals may be of relatively little importance while problems associated with sediment, turbidity, temperature, and possibly bacteria are likely to be more important. To the extent that herbicides and pesticides are used in forestry and agriculture operations, these compounds may assume greater importance. In the Sprague River dissolved oxygen total maximum daily load (TMDL; ODEQ 2002), ODEQ identifies forestry, agriculture, transportation, rural residential, and urban as existing nonpoint sources in the subbasin.

EVALUATION CRITERIA

The evaluation criteria for this watershed assessment are based on the Oregon Water Quality Standards for the Upper Klamath Basin (OAR 340-041-0001 to 340-041-0350) and on literature values where there are no applicable standards, as for example, for nutrients (WPN 1999). The evaluation criteria are not identical to the water quality standards in that not all seasonal variations are included. The evaluation criteria are used as indicators that a possible problem may exist. The criteria are listed in Table 10-2.

Table 10-1. Land cover types in the Upper Sprague River subbasin. (Data Source: USGS 1992)

Land Cover Type	Acres	Percent of Total
Open Water	730	0.1
Low Intensity	26	<0.1
Commercial/Industrial/Transportation	182	<0.1
Bare Rock/Sand/Clay	320	<0.1
Quarries/Strip Mines Gravel Pits	24	<0.1
Transitional	2,960	0.4
Deciduous Forest	260	<0.1
Evergreen Forest	483,605	67.1
Mixed Forest	474	<0.1
Shrubland	136,193	18.9
Grasslands/Herbaceous	35,215	4.9
Pasture/Hay	13,990	1.9
Row Crops	315	<0.1
Small Grains	1,144	0.2
Urban/Recreational Grasses	0	0
Woody Wetlands	2,651	0.4
Emergent Herbaceous	42,770	5.9
Total	720,859	100

The water quality evaluation criteria are applied to the available data by noting how many, if any, of the water quality data exceeded the criteria. If sufficient data are available, a judgment is made based on the percent exceedence of the criteria as shown in Table 10-3. If insufficient, or no, data were available, this is noted as a data gap to be filled by future monitoring. If any water quality constituent is rated by ODEQ as "moderately impaired" or "impaired" using these criteria, water quality in the stream reach in question is considered impaired for the purposes of the assessment. In the case of the Upper Sprague River subbasin, such decisions have already been made for some stream segments and some parameters.

WATER QUALITY LIMITED WATER BODIES

Sometimes, applying the best available treatment technology to all the point sources in a basin does not bring the stream into compliance with water quality standards. Under this circumstance, if all practicable measures have been taken to improve water quality by controlling discharges, the water body is declared by ODEQ to be "water quality limited" as required by the Clean Water Act section 303(d). Water bodies on the "303(d) list" must be analyzed to determine the total amount of pollutant that can be accommodated by the stream (the TMDL). The load is then allocated to all

Table 10-2. Water quality criteria and evaluation indicators. (WPN 1999)

Water Quality Attribute	Evaluation Criteria
Temperature	Core cold water habitat: The seven-day-average maximum temperature may not exceed 16.0° C (60.8° F); Lahontan cutthroat trout or redband trout: The seven-day-average maximum temperature may not exceed 20.0° C (68.0° F); Bull trout spawning and juvenile rearing: The seven-day-average maximum temperature may not exceed 12.0° C (53.6 ° F).
Dissolved Oxygen	For water bodies identified as active spawning areas the following criteria apply during the applicable spawning through fry emergence: (a) The dissolved oxygen may not be less than 11.0 mg/L. However, if the minimum intergravel dissolved oxygen, measured as a spatial median, is 8.0 mg/L or greater, then the DO criterion is 9.0 mg/L; Cold-water aquatic life: the dissolved oxygen may not be less than 8.0 mg/L as an absolute minimum. Where conditions of barometric pressure, altitude, and temperature preclude attainment of the 8.0 mg/L, dissolved oxygen may not be less than 90 percent of saturation.
pH	Estuarine and fresh waters: 6.5-8.5.
Nutrients	Total phosphorus, 0.022 mg/L Total nitrate, 0.38 mg/L
Bacteria	(a) Freshwaters and estuarine waters other than shellfish growing waters: (A) A 30-day log mean of 126 *E. coli* organisms per 100 milliliters, based on a minimum of five (5) samples; (B) No single sample may exceed 406 *E. coli* organisms per 100 milliliters.
Turbidity	2.34 NTU, 50 NTU maximum
Organic Contaminants	Any detectable amount
Metal Contaminants	Arsenic, 0.190 mg/L Cadmium, 0.0004 mg/L Chromium (hex), 0.011 mg/L Copper, 0.0036 mg/L Lead, 0.0005 mg/L Mercury, 0.000012 mg/L Zinc, 0.0327 mg/L

Table 10-3. Criteria for evaluating water quality impairment. (Source: WPN 1999)

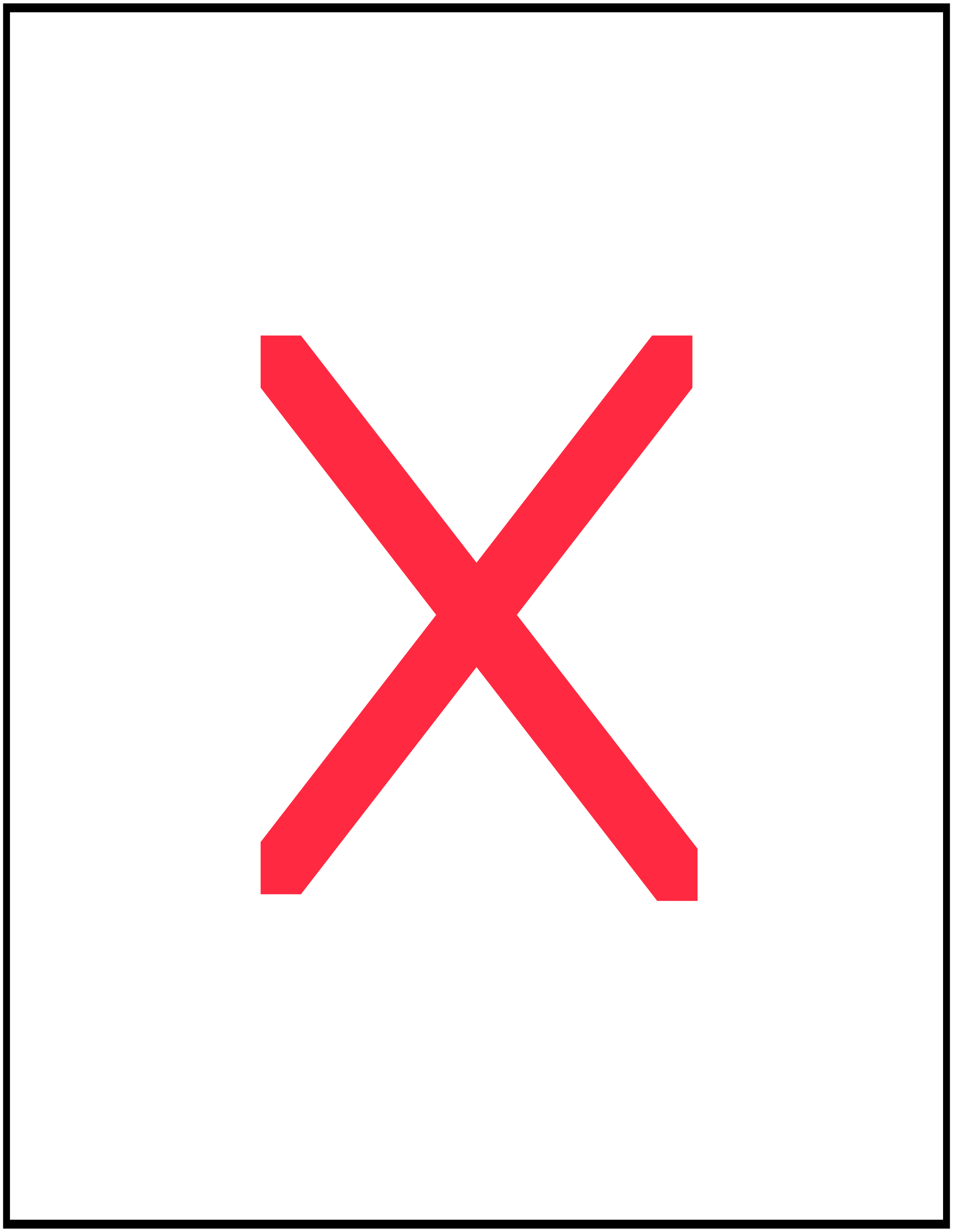
Percent of Data Exceeding the Criterion	Impairment Category
Less than 15 percent	Not impaired
15 to 50 percent	Moderately impaired
More than 50 percent	Impaired
Insufficient data	Unknown

the dischargers, including nonpoint. Dischargers must then take the steps necessary to meet their allocated load. Once a TMDL and waste load allocation is completed, the water bodies to which it applies are removed from the 303(d) list. The water quality limited stream segments in the Upper Sprague River subbasin are listed in Table 10-4, and illustrated in Map 10-1. These streams do not appear on the 2002 303(d) list because a TMDL was completed in 2002 (ODEQ 2002).

Most of the streams on the list are included because they did not meet the previous water quality standard for temperature for salmonid rearing (17.8ºC, 64ºF). A new temperature standard has been adopted for waters designated as redband trout habitat (20ºC, 68ºF) since completion of the TMDL and

Table 10-4. Water quality limited water bodies in the Upper Sprague River subbasin. (Source: ODEQ 1998)

Water Body	Segment	Constituent
Boulder Creek	Mouth to Headwaters	Temperature
Brownsworth Creek	Mouth to Hammond Creek	Temperature
Brownsworth Creek	Hammond Creek to Headwaters	Temperature
Buckboard Creek	Mouth to Headwaters	Temperature
Calahan Creek	Mouth to Hammond Creek	Temperature
Coyote Creek	Mouth to Headwaters	Temperature
Deming Creek	Campbell Reservoir Diversion to Headwaters	Temperature
Deming Creek	Mouth to Campbell Reservoir Diversion	Temperature
Fishhole Creek	Mouth to Headwaters	Temperature
Fivemile Creek	Mouth to Headwaters	Temperature
Leonard Creek	Mouth to Headwaters	Temperature
Long Creek (Sycan Marsh)	Sycan Marsh to Calahan Creek	Temperature
Paradise Creek	Mouth to Headwaters	Temperature
Pothole Creek	Mouth to Headwaters	Temperature
Sprague River	Mouth to North/South Fork	pH
Sprague River	Mouth to North/South Fork	Dissolved Oxygen (DO)
Sprague River	Mouth to North/South Fork	Temperature
Sprague River North Fork	Mouth to Dead Cow Creek	Temperature
Sprague River South Fork	Mouth to Camp Creek	Temperature
Sycan River	Mouth to Rock Creek	Temperature



Map 10-1. Water quality limited streams in the subbasin. (Data Source: ODEQ 2003)

Water Quality Management Plan (WQMP) in 2002 as a result of better understanding of the temperature tolerance of redband trout.

It should also be mentioned that, in addition to the overall WQMP, there has been a state-led process oriented toward addressing agricultural water quality issues. This process is driven by Oregon Senate Bill 1010, and includes the involvement of a Local Advisory Committee made up of interested stakeholders. This Agricultural Water Quality Plan has been included as a component of the overall WQMP and the TMDL.

Although the 303(d) list identifies water bodies that are known not to meet current water quality standards, the list is not necessarily a complete indicator of water quality in a particular basin. For many stream segments, there are not enough data to make a determination. In addition, the 303(d) listing is tied to the total amount of monitoring done, which is influenced by the number of special monitoring studies completed by ODEQ. Because special studies are frequently concentrated where water quality degradation is a concern, the list is weighted toward poorer quality waters. Consequently, the ODEQ has developed the Oregon Water Quality Index (OWQI) as a water quality benchmark that is keyed to indicator sites monitored regularly by ODEQ.

The OWQI is a single number that expresses water quality by integrating measurements of eight water quality variables (temperature, dissolved oxygen, biochemical oxygen demand, pH, ammonia+ nitrate nitrogen, total phosphorus, total solids, and fecal coliform).

No regular ODEQ monitoring site is located in the Upper Sprague River subbasin. The OWQI for waters above Upper Klamath Lake is based on a site in the Williamson River near the Williamson River Store at river mile (RM) 4.6. The Williamson River subbasin contributes approximately 50 percent of the inflow to Upper Klamath Lake.

Moderately high concentrations of total phosphates and biochemical oxygen demand are present at RM 4.6 on the Williamson River during various seasons. A high percentage of total phosphates is thought to be caused by erosion of soils that are naturally high in phosphorous. The availability of phosphorus allows the production of algae, plankton, and aquatic plants. These in turn consume oxygen as they respire or decay, increasing the biochemical oxygen demand. High pH values have been detected during the summer season. Water quality at this site in the Williamson River is better than the other sites monitored in the Klamath Basin, all of which are below Upper Klamath Lake. On the average, OWQI scores for the Williamson River site are good in the summer and excellent in the fall, winter, and spring, and based on the limited data available, water quality appears to be improving (Mrazik 2005).

WATER QUALITY DATA

Water quality data collected by ODEQ in the Upper Sprague River subbasin were retrieved from the ODEQ LASAR database (ODEQ 2005). Eleven sites in the Upper Sprague River subbasin have been sampled for water quality by ODEQ. Additional sites have been sampled by the Klamath Tribes and the Fremont-Winema National Forest. The sites are listed in Table 10-5 and shown on Map 10-1. ODEQ samples were collected on seven separate days; August 17-19, 1999, May 2, 2000, August 22-23, 2000, and September 17, 2002 (one sample). Summary information for the 12 constituents that were measured is provided in Table 10-6.

The Natural Resources Department of the Klamath Tribes has an active program of water quality monitoring in the Upper Sprague River subbasin. In addition to detailed temperature monitoring, they collect information on a variety of water quality constituents.

The Fremont-Winema National Forest has collected a considerable set of hourly temperature data from a number of sites throughout the Upper Sprague River subbasin. A summary of their data is presented in Table 10-7.

ODEQ, in response to the requirements of the Clean Water Act has completed a TMDL and Water Quality Management Plan for the Upper Klamath Lake watershed (ODEQ 2002) that incorporates and analyzes much of the data collected in the Upper Sprague River subbasin.

WATER QUALITY CONSTITUENTS

Temperature

Many of the stream segments in the Upper Sprague River subbasin are water quality limited for temperature based on the 1998 303(d) list (Map 10-1), although they do not appear on the 2002 303(d) list, having been removed following completion of the Upper Klamath Lake Drainage TMDL. A new water temperature standard that recognizes the special adaptation of redband trout and permits a higher temperature has been adopted for waters supporting redband trout use[3] since the completion of the TMDL. Figure 10-1 shows the seven-day-average maximum of hourly temperature data collected by the USFS at several sites in the Upper Sprague River subbasin. These data suggest that streams in the Upper Sycan and Sycan Marsh

[3] OAR 340-41-0028: "Temperature.

(4) Biologically Based Numeric Criteria. Unless superseded by the natural conditions criteria described in section (8) of this rule, or by subsequently adopted site-specific criteria approved by EPA, the temperature criteria for State waters supporting salmonid fishes are as follows:

(e) The seven-day-average maximum temperature of a stream identified as having Lahontan cutthroat trout or redband trout use on subbasin maps and tables set out in OAR 340-041-1010 to OAR 340-041-0340:…Figure 180A,…may not exceed 20.0 degrees Celsius (68.0 degrees Fahrenheit);…."

Table 10-5. Sites in the Upper Sprague River subbasin sampled for water quality by ODEQ, USFS, and KNRD.

Station ID	Station Description	Latitutude	Longitude	Organization[1]
31017	SF Sprague River upstream of Corral Creek	42.4556	-120.7786	USFS
26580	Sycan River upstream of Boulder Creek	42.6597	-120.7819	USFS
26571	NF Sprague River, Lee Thomas crossing	42.6039	-120.8467	USFS
26572	Paradise Creek	42.6917	-120.8919	USFS
31000	Fishhhole Creek upstream of Briggs spring	42.2336	-120.9097	USFS
26569	Fishhole Creek upstream of Briggs spring	42.2344	-120.9119	USFS
26567	Sycan River Pikes Crossing	42.6981	-120.9328	USFS
26568	Fishhole Creek	42.3044	-120.9547	USFS
31213	Lower Fishhole Creek	42.3044	-120.9547	USFS
26576	SF Sprague River picnic area	42.3694	-120.9653	USFS
21564	SF Sprague River at Sprague River Campground, Hwy 140	42.3709	-120.9681	ODEQ
SR0050	SF Sprague at Picnic Area	42.3761	-120.9694	KNRD
26965	Fishhole Creek	42.3229	-120.9859	ODEQ
SR0040	NF Sprague at 3411 Road	42.4396	-121.0056	KNRD
28148	NF Sprague River at 3411 Road	42.4970	-121.0056	USFS
26570	NF Sprague River at “the Elbow”	42.4967	-121.0058	USFS
31001	NF Sprague River elbow	42.4967	-121.0058	USFS
21563	NF Sprague River upstream of “The Elbow”	42.4986	-121.0115	ODEQ
21532	SF Sprague River at Dairy Creek Road	42.4168	-121.0146	ODEQ
28150	SF Sprague River at Campbell Road Bridge	42.4153	-121.0162	USFS
28154	Sprague River at Lone Pine Bridge	42.4153	-121.0162	USFS
21568	Fishhole Creek at Hwy 140 upstream of Bly, OR	42.3969	-121.0322	ODEQ
28151	SF Sprague River at Ivory Pine Road Bridge	42.4396	-121.0944	USFS
SR0140	S.F.Sprague at Ivory Pine Road	42.4396	-121.0944	KNRD
28149	NF Sprague River at Ivory Pine Road Bridge	42.4853	-121.0946	USFS
SR0150	N.F.Sprague at Ivory Pine Road	42.4853	-121.0946	KNRD
21533	SF Sprague River at Ivory Pine Road	42.4396	-121.0949	ODEQ
21530	NF Sprague River at Ivory Pine Road	42.4837	-121.0972	ODEQ
21531	NF Sprague River at Campbell Road	42.4554	-121.1145	ODEQ
SR0120	Five Mile Creek	42.5431	-121.1203	KNRD
21534	Sprague River Near Hwy 140 Milepost 45	42.4410	-121.1836	ODEQ
SR0130	USGS Gage	42.4481	-121.2366	KNRD
28152	Sprague River at Beatty Gap	42.4478	-121.2366	USFS
21562	Sprague River at Hwy 140 Public Access Gage Station	42.4467	-121.2381	ODEQ
SR0060	Sprague River at Godowa Road	42.4604	-121.2699	KNRD
30996	Lower Calahan meadow	42.8744	-121.2714	USFS
21565	Sycan River at Drews Road	42.4856	-121.2778	ODEQ
31018	Lower Long meadow	42.8675	-121.2956	USFS
26579	Sycan River coyote bucket	42.5739	-121.3358	USFS
31022	Sycan River coyote bucket	42.5739	-121.3358	USFS
31021	Sycan River upstream of Teddy Powers meadow	42.6589	-121.3478	USFS
26578	Sycan River upstream of Teddy Powers meadow	42.6572	-121.3481	USFS
28156	Sycan River at Elde Flat	42.6106	-121.3487	USFS
SR0070	Sycan River at Drews Road	42.4857	-121.3487	KNRD
30993	Sycan River downstream of Teddy Powers meadow	42.6289	-121.3594	USFS
26577	Sycan River downstream of Teddy Powers meadow	42.6289	-121.3611	USFS
SR0080	Sprague River at Lone Pine	42.3302	-121.6176	KNRD
SR0100	Trout Creek	42.4873	-121.6218	KNRD
SR0090	Sprague River at Power Plant	42.7678	-121.8419	KNRD

1 ODEQ – Oregon Department of Environmental Quality; USFS – U.S. Forest Service; KNRD – Klamath Tribes Natural Resources Department

Table 10-6. Summary of water quality data collected by ODEQ in the Upper Sprague River subbasin in August 1999 and August 2000. (Data Source: ODEQ 2006)

Parameter	Number of Observations	Minimum	Maximum	Mean	Median
Ammonia (mg/L)	47	<0.02	0.03	0.02	<0.02
Dissolved Orthophosphate (mg/L)	47	0.018	0.240	0.049	0.039
E. Coli (CFU/100 ml)	47	2	500	129	88
Fecal Coliform (CFU/100 ml)	47	2	650	166	94
Field Dissolved Oxygen (mg/L)	45	7.0	11.0	8.8	8.8
Percent Saturation Field Dissolved Oxygen (%)	45	82.0	144.0	105.6	104.0
Field pH	47	7.6	8.8	8.1	8.0
Field Temperature (°C)	47	5.6	22.0	17.3	18.2
Field Turbidity (NTU)	47	1.0	18.0	5.4	3.9
Nitrate/nitrite as N (mg/L)	47	0.005	0.039	0.010	0.005
Total Phosphorus (mg/L)	47	0.04	0.34	0.08	0.07
Total Suspended Solids (mg/L)	47	1.0	22.0	4.4	3.0

watersheds may meet the criteria for redband trout, but not for bull trout, while streams in the Lower Sycan Watershed do not currently provide conditions that fully support redband trout. The sites in the Sprague River Above Beatty and South Fork Sprague watersheds have relatively few instances of temperature higher than the evaluation criteria, suggesting marginal support for the beneficial use, but Fishhole Creek and North Fork Sprague watersheds do not appear to fully support conditions suitable for redband trout. Riparian area management and re-vegetation measures are proposed in the Upper Klamath Lake Drainage WQMP (ODEQ 2002) to bring these areas into compliance with relevant criteria. Since the WQMP was published there have been many accomplishments with regard to implementing the recommendations of the plan.

Dissolved Oxygen

Information for evaluation of dissolved oxygen comes primarily from data collected by the Klamath Tribes in 2001 through 2005, plus data collected by ODEQ on three days in August 1999 and three days in August 2000. The total number of samples collected by all agencies for a variety of water quality constituents is provided in Table 10-9. Of the 23 sites in the Upper Sprague River subbasin for which water quality constituent concentration measurements were available, only eight had more than 10 values.

Table 10-7. Summary statistics for hourly streamwater temperature (°C) data collected in 2001 and 2002 at various locations in the Upper Sprague River subbasin. (Data Source: USFS 2006)

Location	N	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Mean	CV
Sycan River Pikes Crossing	7,716	-0.4	10.1	12.6	16.5	24.8	13.0	0.4
Lower Calahan meadow	3,284	-0.1	6.0	8.2	11.0	18.5	8.6	0.4
Lower Long meadow	3,284	-0.1	6.2	8.5	11.6	19.6	8.9	0.4
Sycan River upstream of Teddy Powers meadow	5,883	2.3	12.0	16.3	19.7	25.6	15.6	0.3
Sycan River downstream of Teddy Powers meadow	5,882	1.8	12.7	17.0	20.5	28.4	16.5	0.3
Sycan River coyote bucket	5,881	1.5	11.9	16.0	19.7	29.7	15.8	0.4
Sycan River at Elde Flat	567	13.8	18.4	20.6	23.1	27.8	20.7	0.2
SF Sprague River at Campbell Road Bridge	1,009	14.1	17.1	19.9	21.9	26.2	19.7	0.1
SF Sprague River at Ivory Pine Road Bridge	1,608	11.0	17.2	19.7	22.7	29.1	20.0	0.2
Sprague River at Beatty Gap	1,607	13.2	17.0	18.2	19.9	23.2	18.4	0.1
Sprague River at Lone Pine Bridge	1,632	14.9	19.0	20.8	22.5	26.1	20.7	0.1
Fishhole Creek upstream of Briggs spring	6,673	0.6	12.3	15.8	19.6	29.2	15.9	0.3
Lower Fishhole Creek	3,643	1.4	12.1	15.9	19.7	29.5	15.8	0.4
NF Sprague River elbow	2,232	2.6	7.2	9.3	11.3	16.5	9.3	0.3
NF Sprague River, Lee Thomas crossing	3,357	-0.2	6.9	10.2	14.6	22.4	10.8	0.5
SF Sprague River picnic area	3,668	3.2	12.6	15.8	19.3	25.8	15.8	0.3
SF Sprague River upstream of Corral Creek	2,275	2.3	5.3	6.5	8.2	13.0	6.9	0.3

Dissolved oxygen data collected in the Upper Sprague River subbasin are presented in Figure 10-2. For dissolved oxygen at all sites combined, 16 percent of the samples were less than the evaluation criterion of 8.0 mg/L for cold water species. These values suggest that streams in the Upper Sprague River subbasin are not impaired with respect to dissolved oxygen for cold water fish habitat considering that portions of the subbasin are at elevations that might preclude attainment of these concentration values. For all sites combined, during the months of January, February, and March when trout spawning is most likely, 48 percent of dissolved oxygen values were less than 11.0 mg/L. This suggests that at least portions of the subbasin might be impaired for salmonid spawning with respect to dissolved oxygen. Care must be taken in this interpretation, however, because conditions of temperature and elevation, especially in the upper reaches of many streams, may preclude achieving the evaluation criterion of 11.0 mg/L.

Table 10-8. Sites in the Upper Sprague River subbasin with more than 10 measurements for various water quality constituents. (Data Source: ODEQ 2006)

Site Name	Number of Samples
Sprague River at Power Plant	150
Sprague River at Godowa Road	146
SF Sprague @ picnic area	137
NF Sprague @ 3411 Rd	135
Sprague River at Lone Pine	134
USGS Gage	30
SF Sprague @ Ivory Pine Road	14
NF Sprague @Ivory Pine Road	14

pH

Measurements for pH were taken at the same time as those for dissolved oxygen. Values measured for pH are presented in Figure 10-3. Of all pH measurements at all sites, fewer than 1 percent were below 6.5 and 16 percent were above 8.5. With 16 percent of values outside the acceptable evaluation range, the Upper Sprague River subbasin would be considered moderately impaired with respect to pH. The high pH values are not, however, evenly distributed across the subbasin. Of the 113 measured pH values that exceeded 8.5, 93 percent were measured at sites in the mainstem Sprague River, suggesting that pH impairment may be localized to the mainstem. The Sprague River has been listed as water quality limited for pH, and was included in the Upper Klamath Basin TMDL.

Nutrients

Algal nutrients, especially nitrogen and phosphorus, can exert an adverse influence on water quality indirectly through their effect on the growth of aquatic plants, both attached (periphyton) and suspended (phytoplankton). Excessive plant growth can result in excursions of both pH and dissolved oxygen outside the relevant criteria.

Phosphorus

Data for total phosphorus are presented in Figure 10-4. All of the measured values for total phosphorus exceed the US Environmental Protection Agency (EPA) criterion value of 0.022 mg/L, and 65 percent of measured values exceed the Oregon Watershed Assessment Board (OWEB) evaluation criterion of 0.05 mg/L. The Upper Sprague River subbasin would be considered impaired with respect to phosphorus concentration. There are no point sources discharges in the subbasin that might contribute phosphorus to subbasin streams, so the elevated concentrations are the result of nonpoint or natural sources. High phosphorus values are not localized to a particular subbasin within the assessment area.

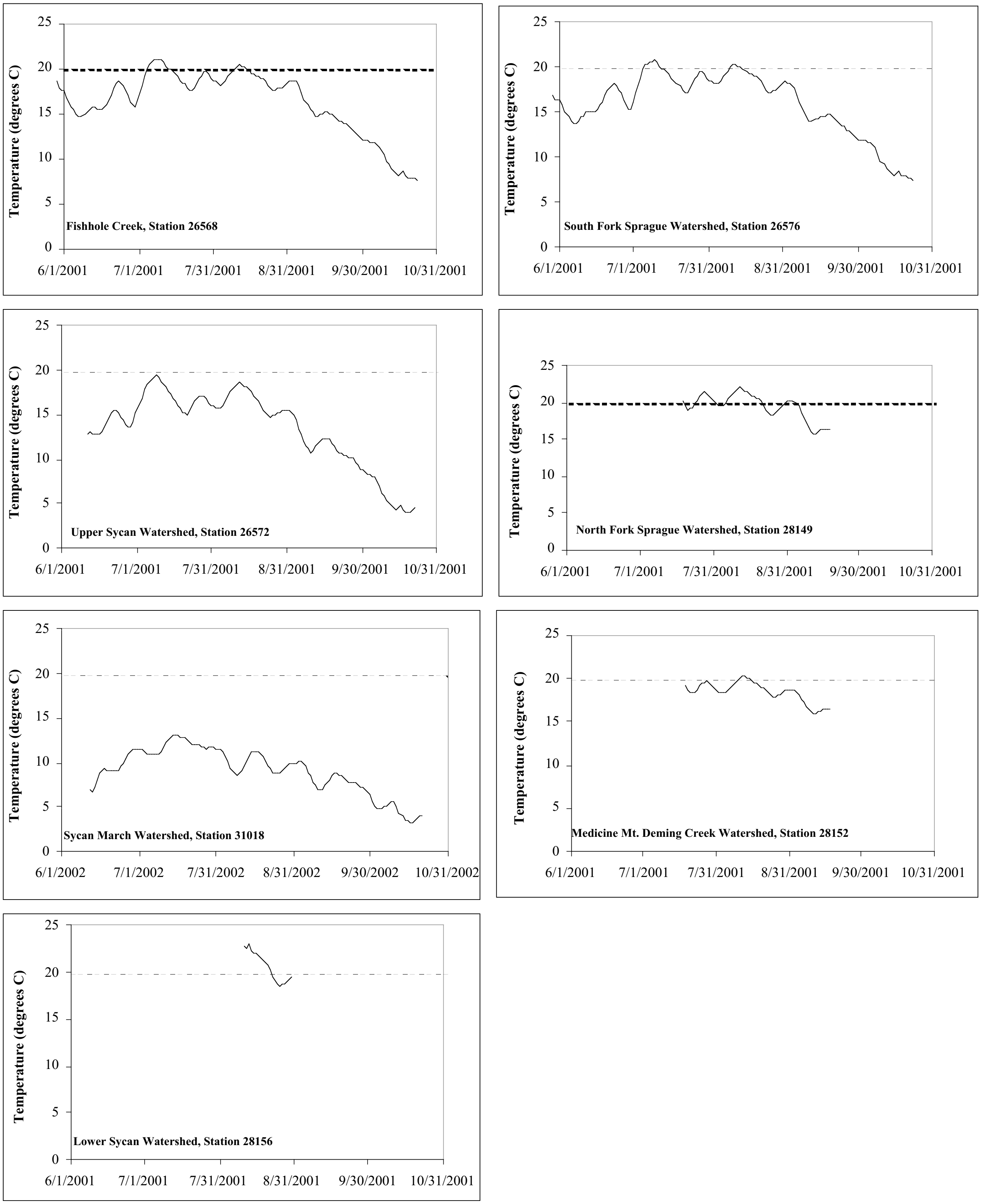


Figure 10-1. Seven-day-average maximum daily temperature at several sites in the Upper Sprague River subbasin. The dashed line represents the evaluation criterion for support of redband trout. Based on hourly data collected by the US Forest Service in 2001-2002. (Data Source: USFS 2006)

High total phosphorus concentration in subbasin streams is partially the result of high concentration in the groundwater due to volcanic soils. The average total phosphorus concentration of 14 springs in the Upper Sprague and Upper Williamson subbasins was 0.077 mg/L (ODEQ 2002). Phosphorus also tends to bind to soil particles and enters streams as a result of soil erosion. Sediment core studies in Upper Klamath Lake have shown that erosion in the Klamath Basin has increased substantially in the past 100 years as changes in land use have occurred (Eilers et al. 2001). A high correlation in the Sprague River between flow and phosphorus load indicates that increased erosion due to high runoff is contributing to high phosphorus concentration in Upper Sprague River subbasin streams (ODEQ 2002). However, there is not data that clearly determines what proportion of loading is due to natural sources, and what proportion is due to degraded riparian conditions.

Nitrogen

Nitrate-nitrogen data collected in the Upper Sprague River subbasin are presented in Figure 10-5. No measured value exceeds the evaluation criterion of 0.38 mg/L. The Upper Sprague River subbasin is not impaired with respect to nitrogen concentration in the water.

Bacteria

Bacterial contamination of water from many sources, including mammalian or avian sources, including livestock feeding operations or improperly functioning sewage treatment systems, etc., can cause the spread of disease through contact recreation or ingestion of the water itself. Bacteria of the coliform group (either *E. coli* or fecal coliform bacteria) are used as an indicator of possible fecal bacterial contamination. A limited number of samples for *E. coli* were collected during the summer in 1999 and 2000. The available data are summarized in Table 10-9.

Five samples (11 percent) exceeded the single sample maximum evaluation criterion of 406 colonies/100 mL. Those samples were generally from sites in the lower reaches of the Sprague, North Fork Sprague, and South Fork Sprague watersheds (Table 10-10). The samples were not collected in a manner that would permit proper calculation of the geometric mean for any one site; however, the geometric mean for all samples was well below the evaluation criterion of 126 colonies/100 mL.

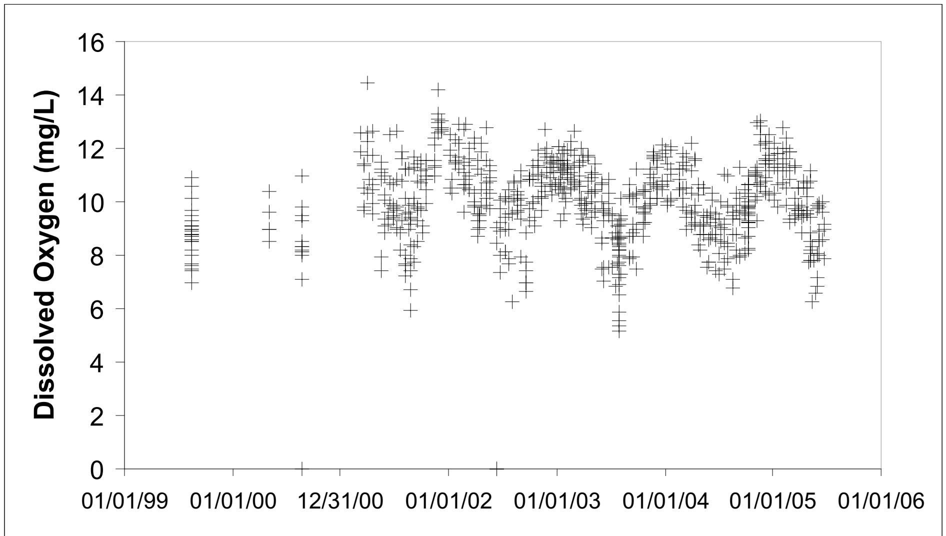


Figure 10-2. Dissolved oxygen concentration measured at several sites in the Upper Sprague River subbasin in 1999 through 2005. (Data Source: ODEQ 2006)

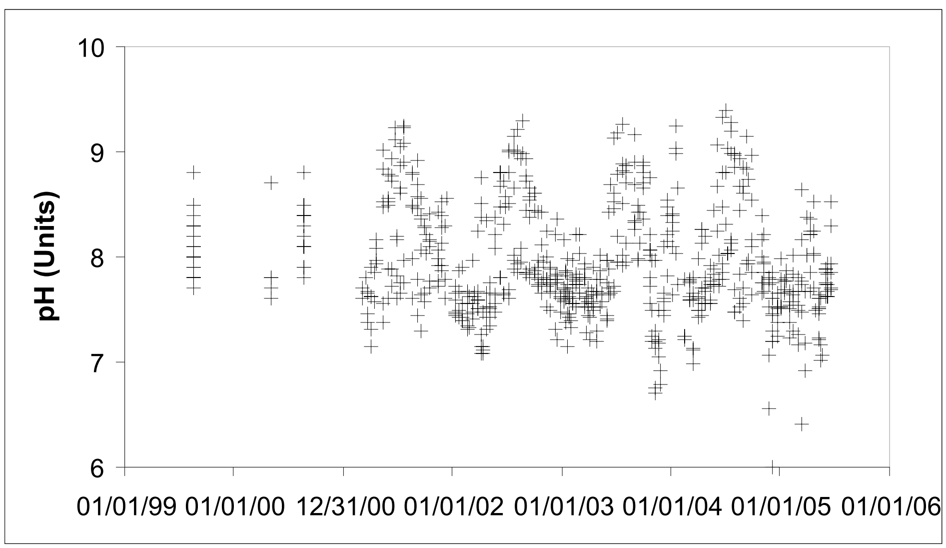


Figure 10-3. pH values measured at several sites in the Upper Sprague River subbasin in 1999 through 2005. (Data Source: ODEQ 2006)

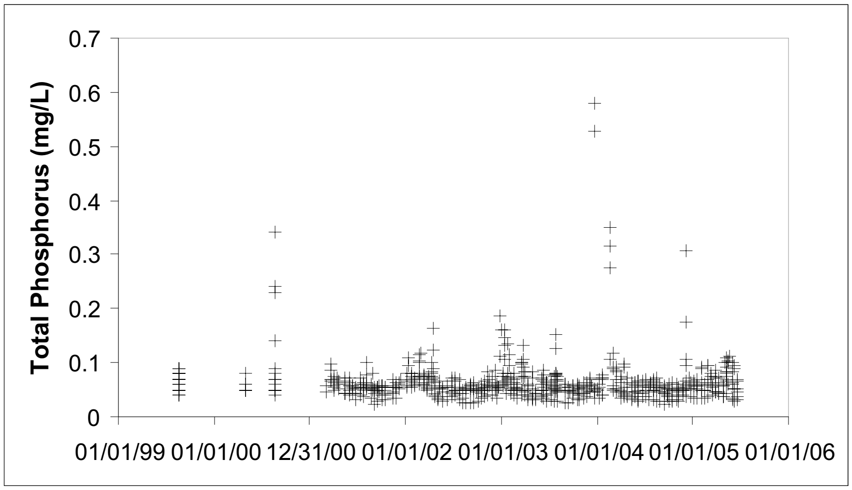


Figure 10-4. Total phosphorus values measured at several sites in the Upper Sprague River subbasin in 1999 through 2005. (Data Source: ODEQ 2006)

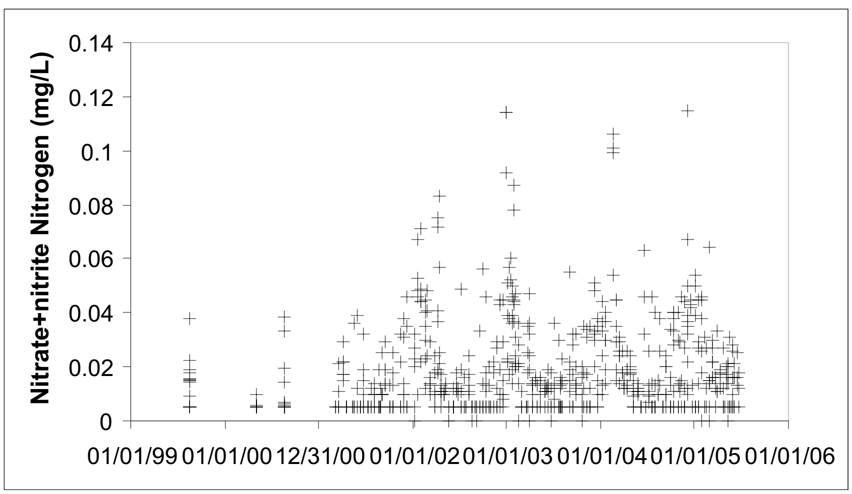


Figure 10-5. Nitrate-nitrogen values measured at several sites in the Upper Sprague River subbasin in 1999 through 2005. (Data Source: ODEQ 2006)

Table 10-9. Statistical summary of *E. coli* values collected in the Upper Sprague River subbasin in 1999 and 2000. (Data Source: ODEQ 2006)

No. of values used	47
Minimum	2
1st quartile	28
Median	88
3rd quartile	150
Maximum	500
Mean	129
Geometric mean	56
CV (standard deviation/ mean)	1

Table 10-10. Locations with *E. coli* samples that exceeded the single sample maximum evaluation criterion (406 colonies/100 mL). (Data Source: ODEQ 2006)

Date	Site Name	*E. Coli* Concentration (colonies/100 ml)
08/22/00	Sprague River at Hwy 140 Public Access Gage Station	500
08/19/99	SF Sprague River at Dairy Creek Road	490
08/22/00	SF Sprague River @ Ivory Pine Road	480
08/23/00	SF Sprague River @ Ivory Pine Road	470
08/19/99	SF Sprague River @Ivory Pine Road	410

Turbidity

Turbidity is a measure of the clarity of the water. High turbidity is associated with high suspended solids, and can be an indicator of erosion in the watershed. At high levels, turbidity can have negative effects, such as impairing the ability of salmonid fish to see their prey is impaired. A limited number of turbidity measurements were made in the Upper Sprague River subbasin in 1999 and 2000. They are summarized in Table 10-11. No value exceeded the evaluation criterion of 50 NTU; however, most of the measurements were made during the summer when turbidity values might be expected to be low. Few, if any, measurements were made during high flow periods. The available data are insufficient to determine the status of streams in the Upper Sprague River subbasin with respect to turbidity.

Table 10-11. Summary statistics for turbidity measurements (NTU) in the Upper Sprague River subbasin. (Data Source: ODEQ 2006)

Mean	5.4
Median	3.9
Mode	2.0
Standard Deviation	4.5
Minimum	1.0
Maximum	18.0
Count	46

Contaminants

Synthetic organic compounds, pesticides, and metals can be toxic to aquatic organisms, and can pose potential threats to public health. The presence of such contaminants in the water may suggest the presence of sources of pollution that could have an adverse effect on the stream ecosystem.

There were no data available to assess water quality conditions in the Upper Sprague River subbasin with respect to contaminants. However, local knowledge recognizes illegal dumping from methamphetamine laboratories and other activities (B. Hyde, pers. comm., September, 2006).

SUMMARY OF WATER QUALITY CONCERNS

At the screening level of this assessment, water quality in the major streams of the Upper Sprague River subbasin would be considered impaired because of the frequency of exceedence of the evaluation criteria for temperature, pH, phosphorus, bacteria, and possibly dissolved oxygen. Insufficient data are available to determine the status of streams with respect to inorganic or organic contaminants. These water quality impairments (e.g. temperature, pH, and dissolved oxygen) have been addressed in the Upper Klamath Lake Basin TMDL and WQMP (ODEQ 2002). Concerns have been raised, however, that the proposals of the WQMP will not be adequate to address the water quality impairment issues (NAS 2003). There are many sources of water quality impairment related to human activities in the subbasin. These include current activities associated with agriculture, forestry, recreation, illegal dumping, and urban development. In particular, however, water quality is affected by a long-term legacy of land use and water use that have developed over more than a century. The relative importance of the various water quality stresses is not completely clear, and our understanding of issues such as phosphorous loading is imcomplete. It is likely that additional data, obtained through a carefully designed water quality monitoring program, will be required in order to adequately address the causes of water quality impairment throughout the subbasin.

In many western watersheds water quality problems are linked to limited water quantity, inadequate riparian vegetation along some reaches, associated soil erosion, and loss or degradation of wetland habitats. Each of these issues can affect water quality, especially temperature, in a variety of ways depending on site-specific conditions. It would be important for any future research to confirm whether or not this is the case within the assessment area.

Water quality-limited streams are found in every watershed throughout the assessment area (Map 10-1). Water quality limitations are particularly prevalent along the lower mainstream river reaches, especially in the southern half of the subbasin. In virtually all cases, water quality limitation is associated with water temperature. Summer water temperatures are too high in many streams to support healthy fish populations.

Stream temperature is of vital importance to the health and well-being of cold-water fish species. It influences the metabolism, growth rates, availability of food, predator-prey interactions, disease-host relationships, and timing of life history events of fish and other aquatic organisms (Spence et al. 1996). Temperature requirements vary by species, season, and life stage, and conditions most frequently approach harmful levels in the late summer when air temperatures are high and streamflows are low. High water temperature also contributes to reduced dissolved oxygen levels, which in turn can affect the ability of fish to breathe.

Many studies have concluded that stream temperatures increase in response to timber harvesting, especially when vegetation is removed up to the edge of the stream (Levno and Rothacher 1967, Meehan 1970, Feller 1981, Hewlett and Fortson 1982, Holtby 1988, ODF and ODFW 2002). While the direct applicability of these studies to the assessment area is variable, allowing riparian vegetation to remain near the stream has been shown to reduce the effects of harvesting on stream temperature (Brazier and Brown 1973, Kappel and DeWalle 1975, Lynch et al. 1985, Amaranthus et al. 1989, ODF and ODFW 2002). Consequently, forest management policies now require the maintenance of a riparian vegetation buffer along streams on private, state, and federal lands.

Riparian corridors in forested areas develop a microclimate characterized by cooler air temperatures and higher relative humidity as compared with unvegetated streamside areas. Near-stream ground temperatures can be an even greater source of heat to the stream because the heat conductivity of soil is typically 500 to 3,500 times greater than that of air (Halliday and Resnick 1988).

In addition to stream shading, other factors, some of which are related to stream shading, might also be at least partially responsible for the observed high temperature of some streams within the subbasin. They include:

- prevailing watershed aspect (south- and west-facing are often warmer than north- and east-facing),
- prevalence and temperature of seeps, springs, groundwater and tailwater inflow,
- amount of exposed rock in the stream channel (which can effectively absorb solar heat),
- reduced summer flows,
- prevalence of deep pools, and

In addition to the effects of shade, a properly functioning riparian-wetland area with a well-developed floodplain and deeply-rooted riparian plants captures and stores water during the wet season, slowly releasing cool water during the dry late summer months. Many lowland valley areas and wet meadows in the Upper Sprague probably have never been heavily shaded, but are characterized by well developed floodplains and a variety of marshy and swampy areas which functioned to maintain water quality conditions, including temperature. This is a central issue in the assessment area, as many regulatory indicators of riparian health and water quality standards focus on the presence/absence of woody riparian vegetation. This topic should be a focus of future research and monitoring.

A relatively unique issue pertinent to the assessment area is the influence of groundwater pumping on water temperatures. Groundwater pumped at 59 degrees enters surface flows as tailwater, and may lower temperatures locally. Future monitoring and research should be aimed at confirming the extent to which this is the case.

Water temperature and water quantity are closely linked. A reduction in flow during low-flow periods contributes to higher water temperature. Nevertheless, even if some reaches have elevated solar radiation and stream temperature levels, an adequate supply of deep pools can provide cold-water refugia that allow fish to avoid adverse temperature conditions. Temperature differences between the stream surface and stream bottom can be substantial in deep pools (Matthews et al. 1994, Nielson et al. 1994). Deep pools are less prevalent today than in the past, mainly because of changes in the flow dynamics within stream channels. The supply of gravel in the streambed can also serve to moderate stream temperature. A large amount of water flows through gravel deposits, sheltered from the warming rays of the sun. Where gravel deposits are diminished or filled with fine sediments, such deep inter-gravel stream flow is reduced.

There are a number of large springs in the subbasin that discharge cool water to the streams and provide thermal refugia for fish. Alterations of the stream channel through ditching or diking can separate the springs from the stream, thereby removing vital habitat.

There are also a number of geothermally heated springs both near and within stream channels. These springs have measurable effect one water temperatures within the assessment area.

It is not clear whether or not summer and early fall stream temperatures in many streams within the Upper Sprague River subbasin were ever as low as the 12° C (53.6° F) spawning and rearing evaluation criterion for bull trout, or even the core cold-water habitat criterion for salmonid fish of 16° C (60.8° F). Nevertheless, efforts to reduce stream temperatures subbasin-wide would be expected to have positive effects on fish habitat quality.

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