WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Colville National Forest
Temperature, Bacteria, pH and Dissolved Oxygen Total Maximum Daily Load (Water Cleanup Plan)

Submittal Report

June 2005
Publication Number 05-10-047

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Washington State Department of Ecology

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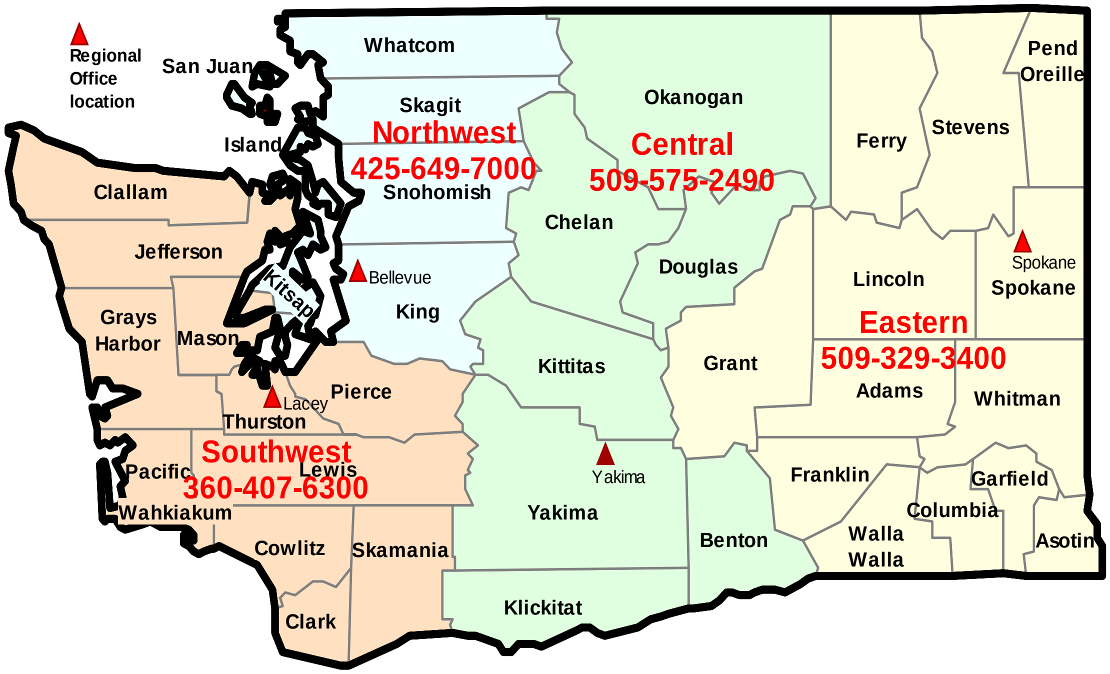

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Acknowledgements

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We acknowledge the help and assistance of the many individuals and agencies noted above; without their efforts, the study would not have been successful.

Definitions

Adaptive management: a process for reviewing the status of implementation activities and adjusting activities and BMPs in the detailed implementation plan based upon the amount of progress being made toward achieving water quality standards.

Critical period: time of year when a particular water quality parameter is most elevated and negatively effecting vulnerable resources.

Load allocation: the portion of the loading capacity that is allocated to non-point (diffuse) sources of pollution and natural background.

Loading capacity: amount of a pollutant that can be released into a water body and continue to meet water quality standards. The loading capacity is divided among the various sources of the pollutant.

Margin of safety: an allowance or conservative calculation made when determining load and waste load allocations that takes into account any lack of knowledge in the relationship between the loading capacity and water quality standards.

Natural potential vegetation: the specific tree species that an area on the forest can grow given the available moisture, temperature and soil type.

Percent effective shade: the amount of solar, shortwave radiation that is blocked by vegetation and topography.

Seasonal variation: an analysis of how much the data for a particular stream varies throughout the year and between seasons

TMDL: acronym for total maximum daily load, which is a process that determines the loading capacity as well as identifies actions to reduce pollutant levels.

Waste load allocation: the portion of the loading capacity that is allocated to point (discrete) sources of pollution.

Study Summary

Section 303, part (d) of the Clean Water Act requires that each state compile a list of surface waters within their jurisdiction that are not achieving water quality criteria. Once a water body is included on the list (known as the "303(d) list"), a total maximum daily load (TMDL) study is required to address the water quality problem. The United States Environmental Protection Agency (EPA) has promulgated regulations (40 CFR 130) and developed guidance for establishing TMDLs (EPA, 1991). The primary objectives of the TMDL study are to examine pollutant sources and determine the pollutant reductions (allocations) necessary to achieve the water quality criteria.

Surface waters within the Colville National Forest included on Washington's most current 1998 303(d) list include: four streams due to elevated water temperature; four streams for elevated pH levels; twelve streams due to elevated fecal coliform bacteria levels, and one stream for low dissolved oxygen. The Colville Forest has a Class AA water quality designation which requires that water temperatures within the forest not exceed 16^{o} Celsius (^{o}C); that pH remain within the range of 6.5 to 8.5 standard units; that fecal coliform bacteria levels, based on a set of samples, not have a geometric mean above 50 colonies per 100 milliliters with the 90th percentile of the samples not exceeding 100 colonies per 100 milliliters; and that dissolved oxygen levels remain above 9.5 milligrams per liter.

In addition to the four listed water segments, water temperature data collected during this study found 34 additional water segments within the forest with water temperatures exceeding the 16^{o}C criteria. For these locations, this study established allocations or recommendations for lowering maximum water temperatures to meet the temperature criteria. The allocations are based on establishing higher percent effective shade levels. Effective shade is the fraction of incoming solar shortwave radiation blocked from reaching the stream surface by riparian vegetation and topography. For streams within the forest, an approximately 80 percent effective shade level is required to maintain maximum water temperatures at or below 16^{o}C. This analysis also provides a method for establishing effective shade allocations to achieve the temperature criteria for any stream within the Colville Forest.

Of the twelve 1998 303(d) listings for fecal coliform bacteria, six currently meet both parts of the criteria, while the other six have maintained chronically elevated concentrations. Fecal coliform data, collected by the United States Forest Service, allowed for the examination of 57 additional locations. Of these sites, seven were found to also have bacteria concentrations above the criteria. Allocations, based on a percent reduction in concentration to achieve the water quality criteria, were established for 13 streams within the forest. The range in reduction levels required to meet the criteria is 6 to 74 percent with an overall median level of 48 percent.

The elevated pH levels, common to the forest, appear to be the result of regional limestone geology. Dissolved calcite ($CaCO_3$) has the effect of naturally raising pH levels due to hydrogen ion bonding, reducing hydrogen ion concentrations. For this reason, the upper range in pH for forest streams has been extended from 8.5 to 9.0.

Indications of nonpoint source impacts to water quality were evident within the stream included on the 303(d) list for low dissolved oxygen. These indications included chronically elevated fecal coliform concentrations and among the highest levels and variation in pH. However, these impacts appear to have a limited effect on dissolved oxygen at this location; 93 percent of the samples have been observed above the criteria. In addition, when concentrations were observed below the criteria they did so by only 0.5 milligrams per liter. Therefore, the dissolved oxygen load allocation has been described in terms of achieving the water quality criteria of 9.5 mg/L. It is expected that the implementation of best management practices to reduce fecal coliform bacteria levels will ultimately result in increased dissolved oxygen concentrations.

This TMDL, and its recommendations for achieving water quality criteria, apply solely to surface waters within the Colville National Forest.

Summary of Colville USFS water bodies considered in this TMDL

Waterbody Name	Old ID No.	New ID No. (98)	Township Range Section T R S	1996 Listing Parameters	1998 Listing Parameters
Sherman	WA-58-2000	ZX69DW	36 / 36 / 36	Temperature	Temperature
Sherman	WA-58-2000	ZX69DW	36 / 37 / 27	Temperature	Temperature
SF Sherman	WA-58-2500	ZZ61AF	36 / 36 / 32	Temperature	Temperature
Cottonwood	WA-59-6110	GT96PS	32 / 41 / 36	Fecal Coliform	Fecal Coliform
SF Chewelah	WA-59-6010	FU01VK	33 / 41 / 23	Fecal Coliform; Dissolved Oxygen	Fecal Coliform Dissolved Oxygen,
Cottonwood	WA-60-6400	SV51QB	40 / 33 / 33	Fecal Coliform	Fecal Coliform
Lambert	WA-60-2100	FJ42JJ	37 / 33 / 01	Fecal Coliform	Fecal Coliform
NF Lone Ranch SF Lone Ranch	WA-60-6000 WA-60-6000	IK82JJ ZY38QL	40 / 34 / 23	Fecal Coliform	Fecal Coliform
Smackout	WA-61-7200	CZ33CZ	38 / 41 / 03	Fecal Coliform	Fecal Coliform
Smackout	WA-61-7200	CZ33CZ	38 / 41 / 11	Fecal Coliform	Fecal Coliform
Lost	WA-62-1960	EK49EK	36 / 43 / 17	Temperature	Temperature
Unlisted Impaired					
Addy	WA-59-3995	JHOOAA	33 / 39 / 13		Temperature
Barnaby		JI88RM	35 / 36 / 33		Temperature
Big Muddy		N165UD	37 / 42 / 12		Temperature
Boulder		QB85EN	39 / 36 / 36		Temperature
Brown's Lake Outlet		FZ73XO	37 / 42 / 36		Temperature
Calispell		PXD5BC	32 / 43 / 20		Temperature
Cedar Creek (Lower)		AS86PH	38 / 42 / 26		Temperature
Cedar Creek (Upper)		0	38 / 42 / 14		Temperature
Cee Cee Ah		LT37BK	34 / 44 / 33		Temperature
Cusick		ND50LM	34 / 43 / 11		Temperature
Deadman		QP45RI	37 / 36 / 28		Temperature
Deep		FC43HB	40/36/12		Temperature
EF Crown		NZ68WD	39/38/02		Temperature
EF LeClerc		CG54YF	35 / 44 / 05		Temperature
Jim		XW31UQ	38 / 42 / 26		Temperature
LaFleur		KT60HA	39 / 33 / 02		Temperature
Lambert		FJ42JJ	37 / 33 / 01		Temperature
Lime		QE15FX	40 / 43 / 14		Temperature
Little Muddy		ZE63YQ	38 / 42 / 35		Temperature

Waterbody Name	Old ID No.	New ID No. (98)	Township Range Section T R S	1996 Listing Parameters	1998 Listing Parameters
Lost (Upper)	WA-62-1960	0	37 / 42 / 27	listed	Temperature
MF LeClerc		DK73YU	36 / 44 / 29		Temperature
NF Chewelah		CN30MG	33 / 41 / 08		Temperature
Nile Lake (Inflow)		0	37 / 42 / 35		Temperature
Nile Lake (Outflow)		0	37 / 42 / 35		Temperature
Rocky Cr		TQ58ST	37 / 41 / 22		Temperature
Ruby		MY62NH	35 / 43 / 10		Temperature
SF Boulder		AM83GR	38 / 36 / 03		Temperature
SF Lost		TO92QK	36 / 43 / 22		Temperature
SF Mill		TK01JT	36 / 40 / 15		Temperature
SF O'Brien		KC65AZ	36 / 33 / 26		Temperature
Sullivan		SN79HL	39 / 43 / 22		Temperature
Tacoma		OE10XI	34 / 43 / 21		Temperature
Tonata		NK42RZ	39 / 32 / 10		Temperature
Winchester		HN21PO	32 / 43 / 05		Temperature
Lost		EK49EK	36 / 43 / 22		Fecal Coliform
North Fork San Poil		JH55WC	37 / 33 / 25		Fecal Coliform
Ruby		MY62NH	35 / 43 / 10		Fecal Coliform
South Fork Lost		IO92QK	36 / 43 / 22		Fecal Coliform
South Fork Mill		TK01JT	36 /40 / 15		Fecal Coliform
West Fork Trout		MW58UZ	38 / 32 / 34		Fecal Coliform
Winchester		HN21PO	32 / 43 / 06		Fecal Coliform
Recommended Delisting					
SF Chewelah	WA-59-6010	FU01VK	33 / 41 / 23		Temperature
EF Crown	WA-61-5100	NZ68WD	39 / 38 / 02		Fecal Coliform
Flat	WA-61-5000	VO11DV	39 / 38 / 09		Fecal Coliform
Martin	WA-60-1015	VO98QQ	39 / 36 / 15		Fecal Coliform
Meadow	WA-61-7250	XH79GB	38 / 41 / 33		Fecal Coliform
NF Trout	WA-60-2250	BE85IS	38 / 32 / 15		Fecal Coliform
SF St. Peter	WA-60-2050	SH98QR	38 / 34 / 30		Fecal Coliform
Addy		JH00AA	33 / 39 / 13		pH
Barnaby		JI88RM	35 / 36 / 33		pH
Cottonwood		SY51QB	32 / 41 / 36		pH
Deep		FC43HB	40 / 36 / 12		pH
East Fork Cedar		GN46SA	40 / 42 / 17		pH
East Fork Crown		NZ68WD	39 / 38 / 02		pH
Fisher		TG60ZC	40 / 37 / 33		pH
Flat		YO11BY	39 / 38 / 09		pH
Harvey		NM19BF	38 / 44 / 30		pH
Jump-off-Joe		0	36 / 40 / 09		pH
Little Boulder		TM27TS	39 /36 /04		pH

Waterbody Name	Old ID No.	New ID No. (98)	Township Range Section T R S	1996 Listing Parameters	1998 Listing Parameters
M & N Fork Harvey		NM19BF	38 / 44 / 35		pH
Meadow		XH79GB	38 / 41 / 33		pH
Middle Fork Mill		KF46MZ	36 / 40 / 15		pH
Noisy		WN27DL	38 / 44 / 18		pH
North Fork Boulder		MS52FD	38 / 36 / 03		pH
North Fork Mill		NH98NQ	37 / 40 / 24		pH
North Fork O'Brien		CG47ME	36 / 34 / 22		pH
North Fork San Poil		JH55WC	37 / 33 / 26		pH
Pierre		EH27CN	40 / 37 / 33		pH
Rocky		TD58ST	37 / 41 / 22		pH
Silver		WP65NI	39 / 41 / 12		pH
Slate		HD76QQ	40 / 44 / 30		pH
Smackout		CZ33CZ	38 / 41 / 03		pH
Smalle		UN55BJ	33 / 43 / 29		pH
South Fork Boulder		AM83GR	38 / 36 / 03		pH
South Fork Chewelah		FU01VK	33 / 41 / 23		pH
South Fork O'Brien		KC65AZ	36 / 33 / 26		pH
South Fork Sherman		ZZ61AF	36 / 36 / 32		pH
Tonata		NK42RZ	39 / 32 / 11		pH
US		QN69US	39 / 36 / 04		pH

Introduction

Total Maximum Daily Load Background

Section 303, part (d) of the federal Clean Water Act requires that states establish Total Maximum Daily Loads (TMDLs) for surface waters not meeting water quality standards. The United States Environmental Protection Agency (EPA) has promulgated regulations (40 CFR 130) and developed guidance for establishing TMDLs (EPA, 1991).

Under the Clean Water Act, each state has water quality standards designed to protect, restore, and preserve water quality. Water quality standards are usually in the form of numeric criteria established to achieve beneficial uses, such as protection of cold water biota or drinking water supplies. When a lake, river, or stream fails to meet water quality criteria, the Clean Water Act requires that states place it on a list of impaired water bodies (known as the "303(d) list"), and to prepare an analysis called a **Total Maximum Daily Load (TMDL)**.

The ultimate goal of a TMDL analysis is to ensure that impaired waters will ultimately attain water quality criteria. A TMDL includes a quantitative assessment of the extent of the water quality problem(s), and the pollutant sources causing the problem. The TMDL determines the load capacity, or the amount of a given pollutant that can be discharged to the water body and still meet criteria, and allocates the load among the various sources. If the pollutant comes from a discrete source (referred to as a point source) such as an industrial facility's discharge pipe, that facility's share of the loading capacity is called a **wasteload allocation**. If the pollutant is associated with a diffuse source (referred to as a nonpoint source) such as surface water runoff, it is referred to as a **load allocation**.

The TMDL assessment must also consider **seasonal variations** in pollutant levels and include a **margin of safety** that takes into account uncertainty about the causes of the water quality problem or its loading capacity. The sum of the individual allocations and the margin of safety must be equal to or less than the capacity.

This TMDL analysis addresses temperature, fecal coliform bacteria, pH, and dissolved oxygen observed within surface waters of the greater Colville National Forest at levels beyond their respective criteria. The scope of this analysis, and the allocations or recommendations for achieving each parameter's respective criteria, applies solely to surface waters within the Colville National Forest. A discussion of the factors considered in the analysis of temperature, fecal coliform bacteria, pH and dissolved oxygen are presented below.

Discussion of Water Temperature

Water temperature is a measure of the intensity of stored heat within a given volume. Riparian vegetation, stream channel shape, hydrology, climate, and geographic setting all influence water temperature and therefore, the movement, or flux of heat to and from a surface water. For this reason, in order to understand changes in water temperature, a budget, or an accounting of the major gains and losses of heat must be considered. A heat budget expresses this in mathematical form:

$$\mathbf{J_{net} = J_{longwave} + J_{shortwave} + J_{convection} + J_{evaporation} + J_{bed} + J_{hyporheic} + J_{in\ (surface\ or\ ground)} + J_{out}}$$

The J_{net} term is the net flux of heat to a water body over a defined time interval and is expressed in units of Watts per square meter per time. Jnet can be either positive or negative depending on the magnitude of the energy flow to or from the surface water. Figure 1 displays the various energy pathways important in understanding the heat flux from surface waters.

Objects emit absorbed heat in the form of long-wave radiation ($J_{longwave}$). Surface waters receive and absorb long-wave radiation from the atmosphere, but more radiation tends to be emitted than absorbed, resulting in an overall net loss of heat from this source.

Solar short-wave radiation, ($J_{shortwave}$) is the greatest source of heat to surface waters, particularly where shade levels are low. Of the various pathways, solar shortwave radiation is solely a positive source of heat. Its inputs levels peak at mid-day and do not occur at night. Important, in terms of this TMDL, is that the solar shortwave load to a stream can be controlled (depending on the stream width and vegetation growing conditions) by managing riparian vegetation. Riparian vegetation blocks the total potential shortwave radiation load from entering the stream, limiting potential temperature increases. This is the reason why this TMDL analysis uses the percent effective shade, or the fraction of the potential solar shortwave radiation that is blocked by vegetation and topography before it reaches the stream surface, as the variable used to establish allocations, or recommendations for cooling streams with elevated temperatures.

Heat can be transferred through convection ($J_{convection}$). If the temperature of water is warmer than the air temperature above it, heat is transferred from the water to the air. Wind transfers heat horizontally, dissipating air temperature gains next to the stream surface while maintaining the heat transfer process, driving heat loss from the stream. If air temperature is higher than the water temperature, heat is transferred into the stream. However, the magnitude of this heat pathway tends to be small relative to the others. Evaporation ($J_{evaporation}$) results in a transfer of latent heat from the water body to the air and is the primary pathway of heat loss from surface waters. Finally, heat can be transferred to or from the streambed through advective exchange of water containing heat ($J_{hyporheic}$) or by conduction (J_{bed}) from sediments. In addition, heat can be transported through advection in (J_{in}) and out (J_{out}) of a stream reach by tributary and groundwater inflow.

As it will be discussed later in this report, groundwater inflow (spring discharge) can have a significant cooling effect on stream temperature during warm summer months. Subsurface flow, surface water inflow, and rain are the primary advective heat transfer mechanisms. The influence of advection on stream temperature depends on the volume of groundwater or tributary inputs relative to the total stream discharge. For this reason, the influence of groundwater cooling tends to diminish in a downstream direction.

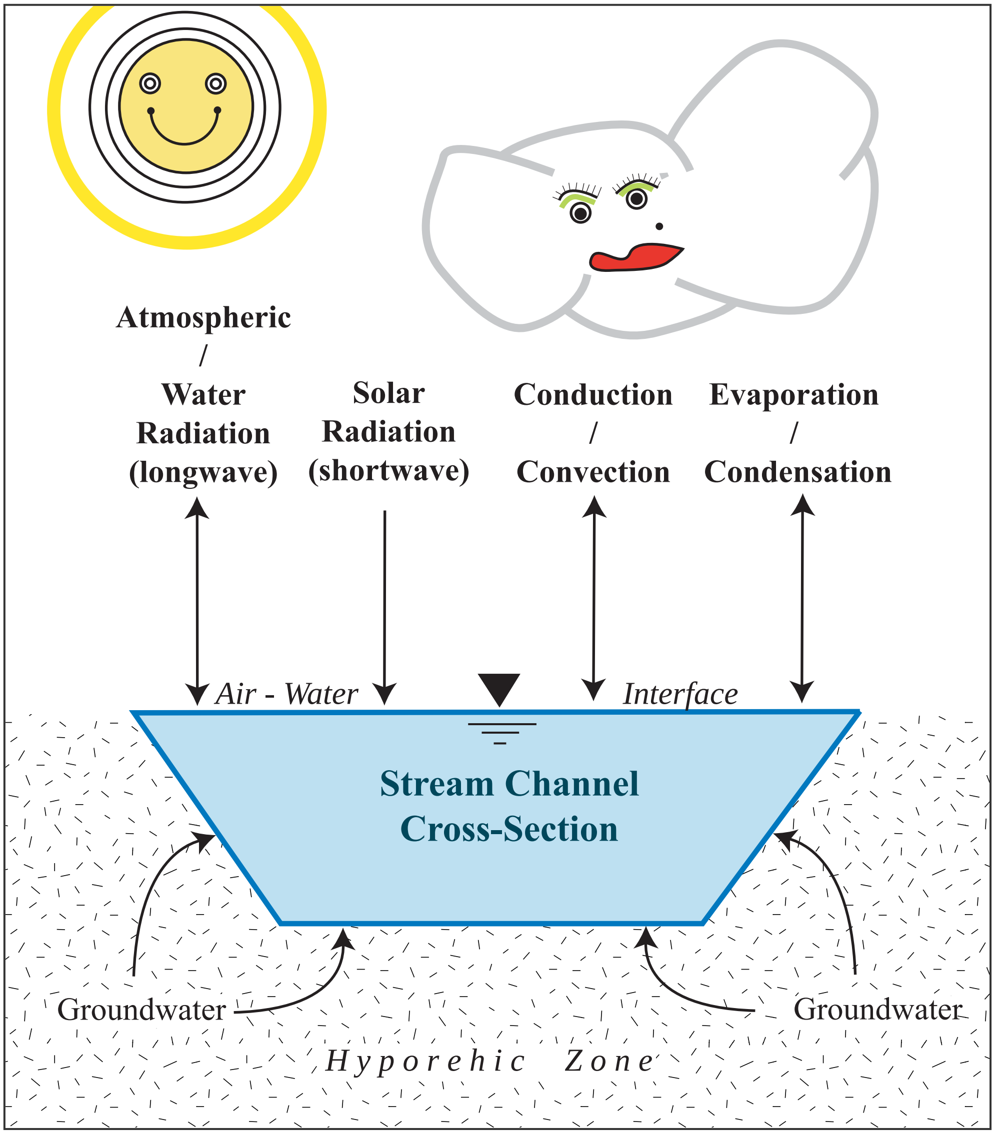

Figure 1. Sources of heat and their pathways in a representative stream cross-section.

Overview of Heating Processes

While climate and geographic location are outside of human control, riparian vegetation characteristics, channel morphology, and hydrology are affected by land use activities. The following processes affect water temperature in the Colville National Forest:

- Riparian vegetation disturbance reduces stream surface shading through decreased riparian vegetation height, width, and density, allowing an increased amount of solar radiation to reach the stream surface.
- Channel widening, the result of elevated sediment loading, increases the stream surface area exposed to solar radiation while importantly, decreasing the average water depth.
- Though a relatively minor influence on the forest, stream temperature can be affected when summer-time base flows are reduced from both in-stream and hydraulically

connected groundwater withdrawals resulting in decreased flow depth and increased exposure.

Figure 2 outlines the major pathways that result in higher levels of solar shortwave radiation to reach surface waters and are among the factors considered in the analysis of water temperature. The amount of solar shortwave radiation that reaches a stream surface is a primary factor in the maximum water temperature that is realized. The amount of the solar load delivered to a stream is, in turn, determined by two pathways: a vegetation-related component and the other sediment-related.

Effective shade is determined primarily by the height and density of riparian vegetation; decreased height and density of riparian vegetation results in decreased effective shade. The stream channel width-to-depth ratio, the result of geologic setting and watershed hydrology is, in turn, affected by external sediment supply. These factors determine a stream's bankfull width and depth and thus, the potential surface area exposed to solar radiation and the depth of flow. Sediment introduction to streams occurs naturally for instance, associated with hillslope processes like landslides. However, sediment levels can be significantly increased due to historic and current human activities associated with existing unimproved forest roads (and those under construction). Excessive delivery of sediment to channels can also affect riparian vegetation through compensating channel morphological changes that result in streambank failure.

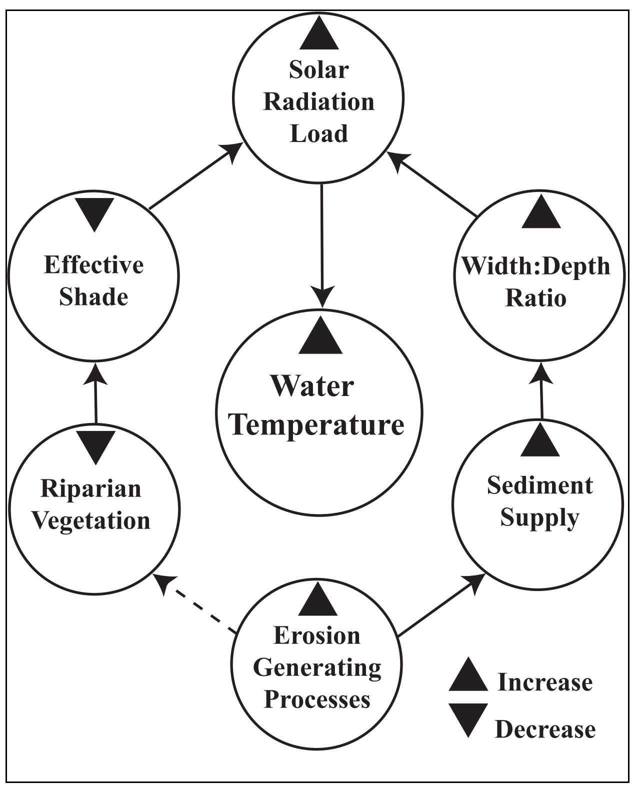

Figure 2. The relationship of water temperature to external influences.

Heat Equation

The change in water temperature with time, as a result of changes in heat flux, is described by the equation below. The mechanistic Response Temperature Model, used later in the temperature analysis portion of this study, applies this equation to calculate the change in water temperature with time. The J_{net} term is, as noted above, the net flux of heat from the stream over a defined time interval. The model accounts for different heat transfer processes to calculate changes in water temperature based on fundamental heat transfer equations (Chapra, 1997). The net heat flux is divided by the mean water depth and two constants - the density of water, and the specific heat. Of particular importance in the equation is the effect of water depth on temperature. As water depth increases, for a given net heat flux, the rate of change in temperature declines. This is important, particularly in forest-managed landscapes, where higher levels of road systems, depending on physical and environmental factors, generate increased levels of suspended and bedload sediment to surface waters. Increased bedload has the effect of widening and shallowing channel cross-sections, reducing pool habitat, ultimately leading to decreased overall flow depth.

$$dT/dt = J_{net} / d * \sigma * \rho$$

dT/dt = change in water temperature with time (^{o}C/hr)
d = mean depth of the water column (m)
J_{net} = net surface heat exchange (W/m^2-hr)
ρ = density of water (1000 kg/m^3)
σ = specific heat of water (4182 Joules/kg-^{o}C)

Discussion of Fecal Coliform Bacteria

Fecal coliform bacteria are associated with the digestive tracts of warm-blooded animals and therefore, their detection is an indication of the introduction of fecal matter to surface water. The primary bacterial species represented within this group are *Escherichia coli* and *Klebsiella* species. Because of this association and that fecal coliform bacteria are commonly found in surface water, they are used an indicator of the potential presence of pathogenic, or disease causing, bacteria. The detection of fecal coliform bacteria does not confirm that pathogenic bacteria are present. However, when fecal coliform bacteria are detected at more elevated concentrations there is a greater risk of pathogenic bacteria being present.

Water is a common medium for transmission of pathogenic organisms. The effectiveness with which pathogenic bacteria are transported in water depends upon the physical and chemical characteristics of water, and the degree to which the organisms can tolerate these characteristics. Fecal coliform bacteria following their introduction to the environment tend to die rapidly but can survive under favorable conditions. For instance, microorganisms can survive for extended periods in fecal deposits on pasturelands, in soils, and in sediments.

The primary routes of introduction of fecal coliform bacteria to surface water are direct deposition and external transport forces by, for instance, wind or more commonly surface runoff associated with precipitation. Within the forest, potential fecal coliform sources are numerous. Numerous bacterial sources were identified based on bacterial samples collected by the Ferry Conservation District for three streams within the Colville Forest, and utilizing the Microbial

Source Tracking techniques developed by Dr. Samadpour of the University of Washington (Tretter, 2002). For instance, on Lone Ranch Creek, a tributary to the Kettle River, 16 bacterial sources were identified including wildlife (11), domestic animal (4), and human.

The human influence on in-stream bacteria levels provided the dispersed camping methods utilized on the Colville Forest, and the relatively low level of human use across the forest suggest that humans likely have a low level of influence on overall bacteria levels. Wildlife can have a significant influence on bacterial levels, particularly associated with wetland systems where animals congregate, residing within a relatively small area for an extended period. Livestock grazing is permitted within the forest, with cattle typically being present from May through September. Cattle range free through most allotments (permitted grazing areas), allowing access to riparian zones for grazing and surface waters for drinking.

Bacteria populations may fluctuate seasonally as the source which produces them varies. For example, recreational sources may cause concentrations to increase on holidays or weekends during summer, and grazing animals may cause concentrations to fluctuate with seasonal use or migration patterns.

Discussion of pH

In its pure form at 25^{o}C, water (H_2O) dissociates or ionizes into equal concentrations of H^+ (hydrogen ion) and OH^- (hydroxyl ion). At concentrations of 10^{-7} moles per liter (M/L) these ion concentrations are very small. (For the hydrogen ion, a one molar solution is achieved at 1 gram H^+ per liter, therefore, 0.0000001 grams of H+ dissociates per liter.) The extent of ionization of pure water into H^+ and OH^- is known as the ionization constant of water (K_w) and is equal to 10^{-14}. $Kw=10^{-14} = [H^+][OH^-]= (10^{-7})(10^{-7})$. While for the majority of surface waters, the concentrations of H^+ and OH^- will range between 10^{-6} to 10^{-9} moles per liter, it is possible, under certain conditions, that concentrations range between 10^{-1} moles per liter to 10^{-14} moles per liter, a range of 14 orders of magnitude. Due to this potential wide range in concentration, a convention of reporting the concentration of H^+ as the negative log of the concentration or pH is used ($pH= -\log_{10} [H^+]$). Therefore, when the hydrogen ion concentration is present at 10^{-7} moles per liter, the pH is 7. With the pH scale extending from 1 to 14, a pH of 7 is defined as a neutral solution; both H^+ and OH^- are found at equal concentrations. When pH levels are observed at levels greater than 7, the solution is alkaline, while pH values less than 7 are acidic. Because of the log scale, a solution with a pH of 2 representing 0.01 moles of H+ ions per liter, has ten times greater a H+ concentration in comparison to a solution with a pH of 3 (0.001 moles/liter H+).

The pH of freshwater systems is influenced by biological activities such as primary productivity, the transfer of carbon dioxide between the gas to the dissolved state, and mineral dissolution associated with, for instance, carbonate-based geology.

Fundamental to establishing pH in natural systems is the reaction of carbon dioxide with water. Carbon dioxide gas from the atmosphere reacts with water, ultimately causing the release of hydrogen ions, resulting in the lowering of pH. In natural systems pH levels are typically encountered between 6.5 and 8.5. (Rainwater is slightly acidic at approximately 5.6.)

pH levels below 6.5 have been found to result in adverse biological reactions. Among the consequences of acidic pH levels is the increased solubility of potentially toxic metals and a shift in dissolved pollutants toward toxic states.

Commonly, in freshwater systems, when pH levels are observed exceeding 8.5, it is an indication of elevated primary productivity, typically stimulated by excessive nutrient (phosphorus) inflow. Primary producers, through the process of photosynthesis, incorporate dissolved carbon dioxide during daylight, and release carbon dioxide by respiration at night. This occurs naturally. However, if primary production is excessively large, stimulated by an elevated nutrient (phosphorus) supply, then wide swings in pH may occur with maximum levels exceeding 9.0.

Algae, and other aquatic autotrophs, use carbon dioxide in their photosynthetic activity for cellular growth. During periods of high algal growth, decreasing CO_2 concentrations within the water column can result in significantly elevating pH levels. As pH increases, the alkalinity forms change, with the result that carbon dioxide can also be extracted for algal growth both from bicarbonates and from carbonates. Thus the removal of carbon dioxide by algae tends to cause a shift in the forms of alkalinity present from bicarbonate to carbonate, and from carbonate to hydroxide. When the bicarbonate ion is used as a source of cell carbon, high diurnal variations in the pH may be observed. During the dark hours of the day, algae produce rather than consume carbon dioxide. This is because their respiratory processes in darkness exceed their photosynthetic processes. This carbon dioxide production has the opposite effect and tends to reduce the pH. For this reason, diurnal variations in pH due to algal photosynthesis and respiration are an indication of elevated levels of primary production in surface waters.

Forest practices do not typically lead to elevated primary productivity. Although phosphorus can be introduced to surface waters, associated with sediment runoff from roads, it is not typically in a soluble form that can be incorporated into cellular growth. However, much of the Colville Forest is also managed for grazing, and waste deposition within streams can, depending on its level of introduction, be a significant source of nutrients potentially leading to conditions that stimulate primary production.

Another cause of elevating pH levels occurs when surface water contains an excess of calcite ($CaCo_3$). Limestone (calcite) dissociates in water into calcium (Ca^{+2}) and carbonate (CO_3^{-2}). Depending on physical and environmental factors, free hydrogen ion will bond with carbonate to form bicarbonate, raising pH levels (lower concentrations of free H^+). For this reason, the pH of surface water, given an excess of calcite, in equilibrium with air, is 8.4 (Garrels, 1965). A geological feature of the Colville Forest, particularly prominent in its northeast section, is limestone formations.

Discussion of Dissolved Oxygen

Oxygen is perhaps the most vital element sustaining life as so many organisms are dependent on it for maintaining metabolic processes for growth and reproduction.

Within forested systems, the dissolved oxygen concentrations measured in streams are primarily the result of the physical and environmental factors that influence re-aeration and the level of primary production.

Similar to pH, wide diurnal variation in dissolved oxygen concentrations can be a reflection of high primary productivity stimulated by elevated nutrient loading and higher exposure to solar radiation. When higher levels of periphyton (attached algae) are present, diurnal maximum dissolved oxygen concentrations correspond to periods of peak photosynthesis and minimum concentrations during periods of respiration.

In addition to primary production, dissolved oxygen is introduced to surface water through re-aeration. The rate that re-aeration occurs is influenced by water depth, turbulence, and water temperature. The solubility of atmospheric oxygen in fresh water is inversely related to temperature. As temperature increases, solubility decreases. For instance, through the summer period, considering the variation in water temperature observed within the forest, solubility ranges between 11 mg/L (11^{o}C) to 8 mg/L (26^{o}C) assuming one atmosphere of pressure.

Background

Description of Study Area – Colville National Forest

The approximately 5,500 square kilometer Colville National Forest created in 1906 and located in northeast Washington, approximately 100 kilometers north of Spokane, encompasses a landscape of unique geology and vegetation.

The forest is situated within Pend Oreille, Stevens, and Ferry counties where the primary economic base is lumber, wood products, and mining. Communities immediately adjacent to the forest include Colville, Chewelah, Kettle Falls, Republic, Newport, Ione, and Metaline Falls. Borders to the forest include Canada to the north, Okanogan National Forest to the west, Idaho and the Idaho Panhandle National Forests situated to the east, and Colville Confederated Tribal lands along a southern portion of the forest.

Management of the forest is divided into three ranger districts including Three-Rivers (2213 km^2), Republic (989 km^2), and Pend Oreille Valley (2294 km^2).

Distinct zones, each with its own unique climate, topography, and vegetation, are created by the major river drainages that divide the forest. They include the San Poil-Curlew River valleys, the Kettle-Colville-Columbia River valleys, and the Pend Oreille River valley. All of these river systems ultimately drain into the Columbia River. Both the Kettle and Colville River discharge to the Columbia River in close proximity to the town of Kettle Falls. Within the eastern region of the forest, the Pend Oreille River flows north into Canada where it merges with the Columbia River. Along the western section of the forest, the Kettle River flows north into Canada then south to its confluence with the Columbia River. Along this circuitous route, the Kettle River receives surface water runoff from much of the western forest. The Colville River receives drainage from the central forest with its major tributaries - Chewelah and Mill Creek.

Separating these river valleys are the Selkirk and Kettle ranges located in the northeast and western sections of the forest, respectively. The average elevation within the forest is 1173 meters with a range between 425 and 2223 meters (Figure 3). Approximately 12,000 kilometers of streams are located within the Colville Forest with 50 percent of the total stream kilometers situated between 425 meters, the lowest elevation within the forest, and 900 meters. Seventy-four percent of the stream kilometers are situated below the average elevation of the forest.

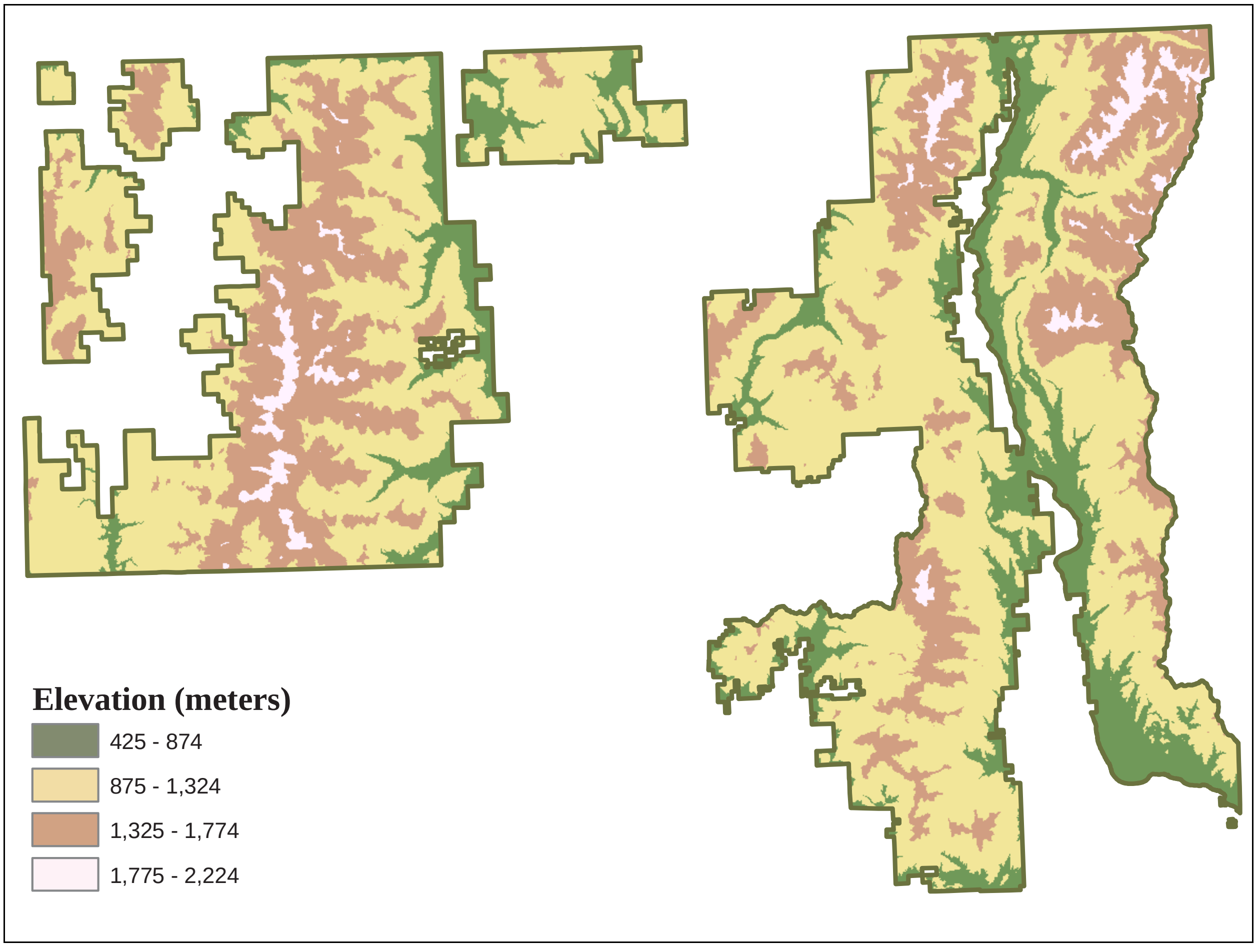

Figure 3. The range in elevation (meters) within the Colville Forest.

The Selkirk and Kettle mountain ranges have a significant effect on the pattern of the annual precipitation (Figure 4). Annual precipitation varies between 10 to 55 inches per year with an overall average of 26 inches. The western-most section of the forest is arid with annual precipitation levels of 10 to 15 inches per year occurring throughout much of the area. In contrast, within the far eastern sections of the forest, greater annual precipitation levels occur with annual levels between 45 to 55 inches per year. The greater precipitation levels are largely due to the orographic effect of the Selkirk mountains where the lifting of the prevailing winds results in significant increases in precipitation at higher elevations.

Differences in the annual precipitation levels are closely reflected in the magnitude of the water yield (Figure 4). The water yield is based on the median flow level (cubic feet per second (cfs)) observed historically during July and August divided by the upstream drainage area (square miles). The water yield is a reflection of storage capacity (geology) and the annual precipitation levels among other factors. In general, within the drier western section of the forest water, water yields are within the range .01-.15 cubic feet per second per square mile (cfs/mi^2), while within the northeastern section, water yields of greater than 1 cfs/mi^2 are found. In addition to its effect on base flow, the variation in annual precipitation levels is a major determinant on the type and density of vegetation found throughout the forest.

Within the drier western portion of the forest, Ponderosa pine and Douglas fir are the dominant tree species, while western red cedar and hemlock dominate the east side of the forest.

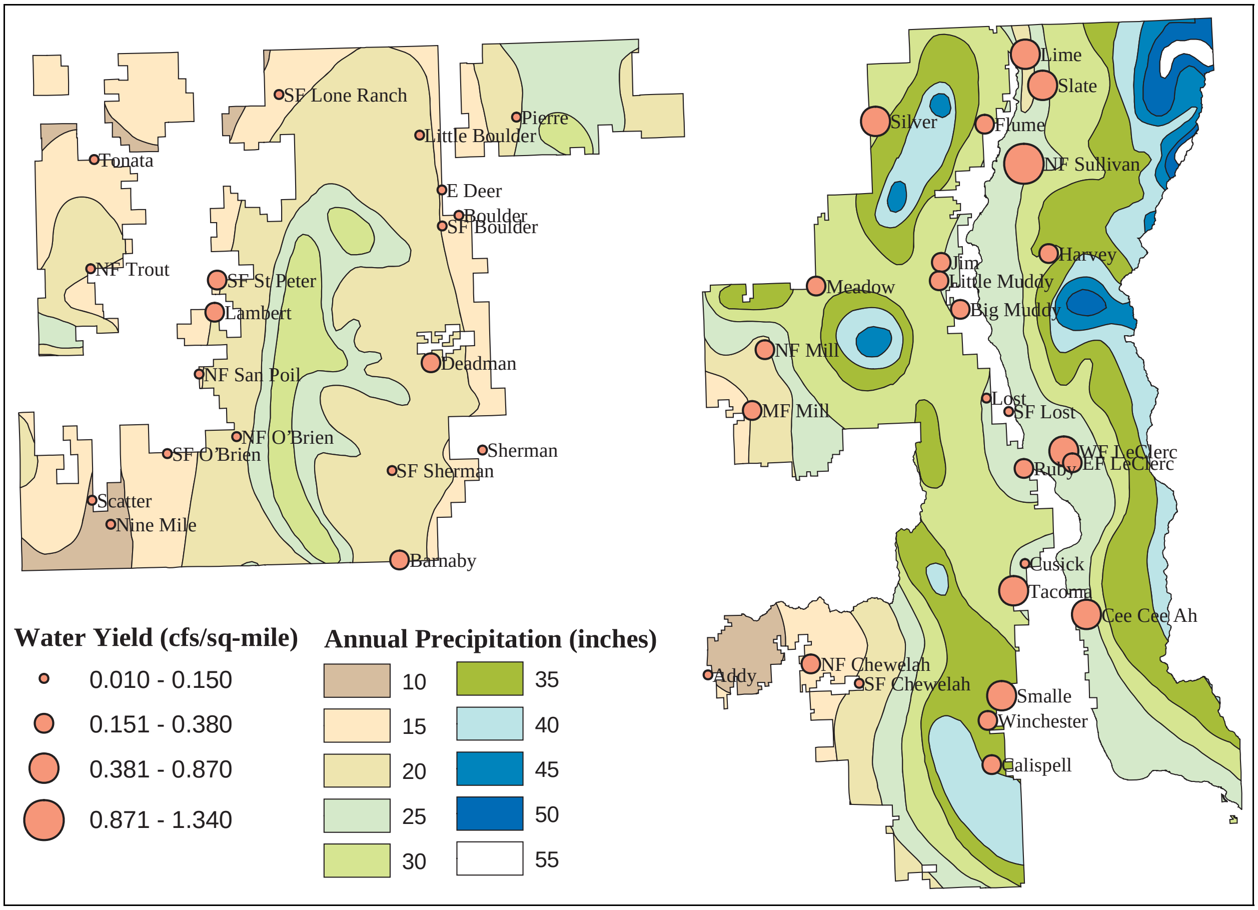

Figure 4. The range in annual precipitation (inches) within the Colville National Forest along with the range in water yield (July-August) observed at water quality monitoring stations.

In addition to forestry, cattle grazing and recreation are additional uses of the forest. Currently, about 7,000 head of cattle graze on the Colville Forest annually within 45 active allotments, or permitted grazing areas. Hunting, camping, picnicking, and fishing are popular recreational activities. About two-thirds of all recreational use is outside of the forest's 32 developed campgrounds. Recreational use of the forest also includes motorcycle trails, snowmobile trails, lakes with boat launches, interpretive trails, fishing derbies, and scenic drives.

Watershed protection and the maintenance of clean water are important management concerns within the forest for both natural resource and human health protection. The communities of Orient and Metaline Falls use two forest watersheds - East Deer Creek and North Fork Sullivan Creek, respectively - for their domestic water supply. In addition, many surrounding domestic water systems depend on forest-based water sources, as do wildlife and livestock.

Monitoring Site Overview

The water quality parameters addressed in this TMDL include: temperature, fecal coliform bacteria, pH, and dissolved oxygen. For the analysis of fecal coliform bacteria, pH, and dissolved oxygen, this study used both USFS historic data as well as data collected specifically for this study. To better understand factors influencing water temperature within the forest, an expanded data collection effort was undertaken. The water quality data were collected by the United States Forest Service and the collection methods are contained in the *Colville National Forest Water Quality Monitoring, Quality Assurance Project Plan* (Wasson, 2004). The Colville Forest maintains a state certified water quality laboratory.

Water Temperature

Water temperature data was collected at 62 monitoring locations throughout the forest during the summer months of 2002, 2003, and 2004. Most of the major surface water drainages within the forest were included in the monitoring effort. Onset® Computer Corporation temperature data loggers were used to collect temperature measurements between June and September at a half-hour frequency for most locations. Temperature probes were located primarily at the forest boundary, though placement considered variation in elevation, drainage area, geology, vegetation, and hydraulic influences. Appendix B contains site locations and additional data specific to each monitoring site including elevation, drainage area, bankfull width, and flow.

Fecal Coliform Bacteria / pH

The Forest Service has collected water quality data, at over 300 locations within the forest. For the analysis of pH and fecal coliform bacteria, a subset of this data was used. The criteria used to select monitoring locations for analysis required that the data be no older than 1990 and include at least ten measurements. Data collected since 1990 reflects current forest management activities and therefore a consistent influence on water quality as well as representing current analysis and analytical procedures. For pH and fecal coliform bacteria, 85 and 69 monitoring stations met this criteria, respectively (fecal coliform and pH monitoring locations are included in Tables 13 and 14, respectively).

Statement of Problem

The results of water quality monitoring conducted within the major drainages of the Colville Forest indicate, in particular locations, chronically elevated water temperature, fecal coliform bacteria concentrations, and pH. Low dissolved oxygen levels were observed in one stream draining from the forest. These water quality characteristics are indicative of nonpoint source pollution impacts. Collectively, this data led to the inclusion of numerous water bodies within the forest on the United States Environmental Protection Agency's 1998 303(d) list of impaired waters.

Four separate water segments within the forest are on the state's 1998 303(d) list of impaired waters for temperature including: Sherman Creek, South Fork Sherman Creek, Lost Creek, and South Fork Chewelah Creek. Based on a more intensive examination of water temperature throughout the forest by the USFS and Washington State Department of Ecology at 62 monitoring stations during the summer months of 2002, 2003, and 2004, 34 more water bodies were found to be impaired, with maximum water temperatures exceeding Washington's water temperature criteria of 16^{o} Celsius (^{o}C). In addition to temperature, twelve stream segments within the forest are included on the 1998, 303(d) list for elevated fecal coliform levels, four segments on the list for elevated pH levels, and one for low dissolved oxygen concentrations.

Applicable Criteria

This TMDL analysis addresses the impairment of characteristic uses caused by water temperature, fecal coliform bacteria, pH and dissolved oxygen observed at levels beyond the relevant water quality criteria. The water quality standards, set forth in Chapter 173-201A of the Washington Administrative Code (WAC), include designated beneficial uses, classifications, numeric criteria, and narrative standards for surface waters of the state. The characteristic uses designated for protection in the Colville National Forest are as follows (Chapter 173-201A WAC):

> *"Characteristic uses. Characteristic uses shall include, but not be limited to, the following:*
> *(i) Water supply (domestic, industrial, agricultural).*
> *(ii) Stock watering.*
> *(iii) Fish and shellfish:*
> *Salmonid migration, rearing, spawning, and harvesting.*
> *Other fish migration, rearing, spawning, and harvesting.*
> *Clam and mussel rearing, spawning, and harvesting.*
> *Crayfish rearing, spawning, and harvesting.*
> *(iv) Wildlife habitat.*
> *(v) Recreation (primary contact recreation, sport fishing, boating, and aesthetic enjoyment).*
> *(vi) Commerce and navigation."*

The state water quality standards describe criteria for temperature, fecal coliform bacteria, and pH for the protection of characteristic uses. Streams in the Colville National Forest are designated as Class AA, waters of extraordinary quality.

The *temperature criteria* for Class AA waters are as follows:

> "Temperature shall not exceed 16.0°C…due to human activities. When natural conditions exceed 16.0°C…, no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C."

The *fecal coliform bacteria criteria* for Class AA waters are as follows:

> "Fecal coliform organism levels shall both not exceed a geometric mean value of 50 colonies/100 mL and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 100 colonies/100 mL."

Additional provisions relevant to the application of the fecal coliform criteria are included within WAC 173-201A-060, general considerations, paragraph 3.

> "In determining compliance with the fecal coliform criteria in WAC 173-201A-030, averaging of data collected beyond a thirty-day period, or beyond a specific discharge event under investigation, shall not be permitted when such averaging would skew the data so as to mask noncompliance periods."

The *pH criteria* for Class AA water are as follows:

> "pH shall be within the range of 6.5 to 8.5 with a human caused variation within the above range of less than 0.2 units."

The *dissolved oxygen criteria* for Class AA water are as follows:

> "Dissolved oxygen shall exceed 9.5 mg/L.

During critical periods, *natural conditions* may exceed the numeric temperature criteria mandated by the water quality standards. In these cases, the anti-degradation provisions of those standards apply as follows:

> "Whenever the natural conditions of said waters are of a lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria."

The natural conditions provision applies only during the critical period and after all human efforts have been made to achieve the water quality standard.

Water Quality and Resource Impairments

Water bodies within the Colville National Forest that have historically not met water quality criteria are included in Table 1. These water bodies represent those within the forest that appear on the 1998, 303(d) list. Water bodies are located by township/range/section, by water resource inventory area (WRIA) and Washington State Department of Ecology's 1996 and 1998 303(d) water body identification numbering system (WBID). Ecology included these water bodies on the 303(d) list based primarily on historic water quality data collected by the United States Forest Service.

Table 1. Water bodies included on the 1996 and 1998 303(d) list due to water quality impairments.

Water Body	1996 & 1998 303(d) Identification Number	Township (N) / Range (E) / Section	Listing Parameter
Water Resource Inventory Area 52 Sanpoil Watershed			
South Fork O'Brien Creek	WA-52-2920 / KC65AZ	36 / 33 / 26	pH
Water Resource Inventory Area 58 Middle Lake Roosevelt Watershed			
Sherman Creek	WA-58-2000 / ZX69DW	36 / 36 / 36	Temperature
South Fork Sherman Creek	WA-58-2500 / ZZ61AF	36 / 36 / 32	Temperature
Water Resource Inventory Area 59 Colville River Watershed			
Cottonwood Creek	WA-59-6110 / GT96PS	32 / 41 / 36	Fecal Coliform
South Fork Chewelah Ck	WA-59-6010 / FU01VK	33 / 41 / 23	Temperature, pH, Dissolved Oxygen, Fecal Coliform
Water Resource Inventory Area 60 Kettle River Watershed			
Cottonwood Creek	WA-60-6400 / SV51QB	40 / 33 / 33	Fecal Coliform
Lambert Creek	WA-60-2100 / FJ42JJ	37 / 33 / 1	Fecal Coliform
North Fork Lone Ranch Ck South Fork Lone Ranch Ck	WA-60-6000 / IK82JJ WA-60-6000 / ZY38QL	40 / 34 / 23 40 / 34 / 23	Fecal Coliform Fecal Coliform
Martin Creek	WA-60-1015 / VO98QQ	39 / 36 / 15	Fecal Coliform
North Fork Trout Creek	WA-60-2250 / BE85IS	38 / 32 / 15	Fecal Coliform
Pierre Creek	WA-60-3250 / EH27CN	40 / 37 / 32	pH
South Fork St. Peter Creek	WA-60-2050 / SH98QR	38 / 34 / 30	Fecal Coliform
Water Resource Inventory Area 61 Upper Lake Roosevelt Watershed			
East Fork Crown Creek	WA-61-5100 / NZ68WD	39 / 38 / 2	Fecal Coliform
Flat Creek	WA-61-5000 / VO11DV	39 / 38 / 9	Fecal Coliform
Meadow Creek	WA-61-7250 / XH79GB	38 / 41 / 33	Fecal Coliform
Smackout Creek	WA-61-7200 / CZ33CZ	38 / 41 / 3	pH, Fecal Coliform
Water Resource Inventory Area 62 Pend Oreille Watershed			
Lost Creek	WA-62-1960 / EK49EK	36 / 43 / 17	Temperature

Water Temperature

Water temperatures have routinely been observed exceeding the 16°C maximum water temperature criteria at Lost Creek, South Fork Chewelah, South Fork Sherman, and along the mainstem of Sherman Creek. The primary reason for elevated water temperatures in the forest's streams is high exposure to solar shortwave radiation. Increased exposure can occur naturally, for instance, the result of fires, or in the case of lake or wetland systems. However, exposure can also be related to human activities such as the loss of riparian vegetation, the result of forestry activities, grazing, road proximity to stream channels, or high levels of sediment input to surface waters, the result of forest road building practices.

Fecal Coliform

Elevated levels of fecal coliform bacteria are the most common reason for the 1998, 303(d) listings within the Colville Forest. Potential sources include cattle, humans, and wildlife. Cattle grazing occurs within 45 active allotments throughout the forest. The Forest Service monitors fecal coliform levels in surface waters to ensure compliance with provisions specified in each grazing permit. (A requirement of each permit is compliance "with the federal laws or regulations, or state and local laws relating to livestock control and protection of air, water, soils and vegetation, fish and wildlife, and other environmental values.")

The Colville Forest primarily uses dispersed camping as opposed to centralized campgrounds. To minimize human sources of fecal coliform bacteria from entering surface waters, waste needs to be buried to a sufficient depth below the ground surface to allow for biological decomposition. Unfortunately, this rarely occurs, resulting in heavily used recreational sections of the forest being potential bacterial source areas.

pH

From the 1998 and 1996 303(d) listings for Washington State, there are four water bodies within the Colville National Forest where pH levels have been observed exceeding the criteria of 8.5, indicating alkaline conditions. These water bodies include South Fork O'Brien Creek, South Fork Chewelah Creek, Pierre Creek, and Smackout Creek (Table 1). When these streams were proposed for the 1998 303(d) list, the Forest Service petitioned the Department of Ecology to remove these sites from consideration believing that the elevated levels were a reflection of the regional carbonate geology as opposed to a result of nonpoint source pollution.

Dissolved Oxygen

Both the 1998 and 1996 303(d) list include South Fork Chewelah Creek due to several observations of low dissolved oxygen concentrations. Concentrations were observed at 9 mg/L, 0.5 mg/L below the criteria that applies to the forest.

Overview of Analysis Approach

This TMDL analysis is directed toward analyzing the current condition(s) within the forest that have resulted in surface water quality impairments. It addresses water temperature, fecal coliform bacteria, pH, and dissolved oxygen. For the surface waters with elevated water temperatures, the analysis focused on the condition of the riparian vegetation and on the physical condition of the channel. Because of the complexities in understanding water temperature particularly given the scale of the analysis, a series of computer models were used.

The fecal coliform analysis identified surface waters with bacterial levels exceeding the criteria and determined the level of reductions necessary to achieve the water quality criteria. The pH and dissolved oxygen analyses examined the environmental conditions that have resulted in altering the range expected for the forest. In common with all of these parameters, will be an initial discussion of the monitoring data. This discussion will then serve as the foundation for the analysis approach.

Seasonal Variation

Section 303(d) of the Clean Water Act requires that TMDLs be established at levels necessary to implement the applicable water quality standards with seasonal variations. An understanding of seasonal variation is important to define the critical period, or the time when a particular parameter is most elevated, and affected resources are most vulnerable.

Water Temperature

Temperatures of surface waters within the Colville National Forest vary seasonally with the coldest temperatures occurring during the winter months (December-January) and the warmest temperature during the summer months (July-August). For this analysis, the critical period occurs July through August. For both 2002 and 2003, the peak water temperatures occurred in late July. For most of the stations in 2004, peak water temperatures occurred in early-August. Seasonal variation in stream flow, solar flux, and climatic variables were considered in developing critical conditions used for the temperature modeling analysis. The level of effective shade present above each of the monitoring locations was determined on August 1. The critical period used to evaluate stream water temperatures in the forest through modeling was July 15 to August 15, bracketing when effective shade was evaluated. Mid-July to mid-August is the period when water temperatures are typically at their seasonal peak coincident with low flow levels.

Fecal Coliform Bacteria

The data used to evaluate fecal coliform bacteria levels within surface waters of the Colville Forest were collected from late-spring (April) to early-fall (November). This sampling period spans the time when bacterial sources associated with, for instance, recreational use, cattle grazing, and wildlife, are at their greatest level on the forest. Based on an evaluation of bacterial data collected at 69 monitoring locations throughout the forest, the highest bacterial concentrations were observed during the months of June through September (refer to Figure 10) defining the critical period for analysis of bacterial levels. For the majority of the monitoring locations, lower bacterial levels were observed April-May and October-November. During the winter months nonpoint bacterial sources are reduced; camping within the forest is minimal, and grazing non-existent. In addition, environmental conditions during the winter limit bacterial viability in surface waters due to freezing conditions.

pH

pH data used in this analysis was typically collected from April through November. Similar to the evaluation of temperature and bacteria, the greatest pH levels occur during the summer period with lower levels during winter. During the summer months, wide variation in pH can be indicative of the effects of nonpoint source pollution. Elevated nutrient loading to surface waters, along with increased exposure to shortwave radiation, stimulates primary production (plant growth) resulting in wide swings in pH. These relationships are most evident during the summer months (June through August) when potential nutrient sources are more numerous coincident with favorable growing conditions therefore, defining the critical period for the evaluation of pH.

Dissolved Oxygen

Similar to the other parameters included in this TMDL, dissolved oxygen concentrations display seasonal variation. Dissolved oxygen saturation is temperature dependent and as water temperature increases, saturation concentrations decrease (assuming a constant air pressure). The highest water temperatures on the forest occur during July and August. Therefore, this is the period when the lowest dissolved oxygen concentrations can be expected naturally. In addition, during the summer months, wide variation in dissolved oxygen concentrations, the result of elevated photosynthetic and respiration processes, can be indicative of the effects of nonpoint source pollution. As was discussed for pH, this variation is the result of elevated primary production stimulated by nutrient loading. Because both of these influences are at their peak during the summer, the months of July and August define the critical period for the evaluation of dissolved oxygen.

Technical Analysis

Water Temperature

Discussion of the Water Temperature Data

From each year's data set, the daily maximum, minimum, and diurnal range statistics were calculated for each monitoring station for the period July through August for 2002, 2003, and 2004. An overview of these data is presented in Table 2. Additional information regarding each monitoring location is provided in Appendix B. In addition to each year's annual maximum water temperature, Table 2 also includes the minimum and diurnal range temperatures observed on the day the maximum was observed, and the median diurnal range observed during the period July through August.

The Washington State water temperature criteria that applies to surface waters within the Colville Forest, which are designated Class AA, is that water temperatures not exceed 16 degrees Celsius (^{o}C). In 2002, of the 50 streams monitored, 29 or 58 percent of them exceeded the criteria. A similar percentage of sites exceeded the criteria in 2003 (64 percent) and 2004 (60 percent). As observed from Table 2, the same sites that exceeded the criteria in 2002 tended to be those that exceeded the criteria in 2003 and 2004, indicating that these sites experience chronically elevated temperatures. In addition, the similarity in the magnitude of the annual maximum water temperature at the monitoring locations over the analysis period indicates a consistency in the pattern of heating at each particular site.

Diurnal Range / Maximum / Minimum

The diurnal temperature range is the difference between the daily maximum and minimum water temperatures. When the diurnal range is considered for the period July through August (when the warmest temperatures can be expected), it is apparent that each station exhibits a characteristic level. To illustrate this relationship, the daily minimum and maximum water temperatures observed at the Sherman Creek and Flume Creek monitoring stations during July and August of 2003 are presented in Figure 5.

Table 2. Summary of the water temperature data (^{o}C) .

Monitoring Station	Annual Maximum			Minimum (on day max. recorded)			Diurnal Range (on day max. recorded)			Median Diurnal Range (July – August)		
	2004	**2003**	**2002**	**2004**	**2003**	**2002**	**2004**	**2003**	**2002**	**2004**	**2003**	**2002**
Addy	18.4			15.8			2.6			3.0		
American Fork	15.8			11.9			3.9			3.9		
Barnaby	17.3	16.2	16.2	14.1	12.3	13.1	3.2	3.9	3.2	3.9	3.2	3.2
Big Muddy	17.0	16.8	16.7	14.3	13.1	14.0	2.7	3.8	2.7	3.4	3.4	2.7
Boulder	19.7	19.1	20.1	16.6	14.2	15.3	3.1	4.9	4.8	4.0	4.5	4.7
Brown's (outlet)	22.3	20.8	21.4	17.9	17.2	19.5	4.4	3.6	2.0	2.4	3.4	1.9
Calispell	20.1	20.4	18.9	14.9	14.9	15.4	5.2	5.5	3.5	5.2	4.8	3.7
Cee Cee Ah	16.3	16.4	15.8	12.5	12.2	12.7	3.8	4.2	3.1	3.7	3.7	3.3
Cedar (lower)	20.3	20.7	20.3	15.2	13.6	14.3	5.1	7.0	6.1	6.7	6.4	6.1
Cedar (upper)	17.9	17.7		14.9	13.5		3.0	4.3		3.9	4.2	
Cusick	21.0	21.8	20.5	15.5	15.8	16.6	5.5	6.0	3.9	5.4	5.4	3.8
Deadman	17.5	17.3	16.5	12.8	12.4	12.0	4.7	4.9	4.5	4.5	3.9	4.3
Deep	16.2			13.7			2.5			3.3		
East Deer		15.5	15.2		13.3	13.2		2.2	2.0		2.0	1.9
EF Crown	17.9			15.8			2.1			2.7		
EF LeClerc	20.7	20.7	21.3	13.7	14.1	15.4	7.0	6.6	6.0	7.1	6.2	6.1
Flat	13.1			11.6			1.5			1.9		
Flume	13.7	13.4	12.6	11.9	11.0	10.7	1.8	2.3	1.9	2.0	2.2	1.7
Harvey	15.9		14.9	12.0		11.9	3.9		3.0	3.6		2.9
Jim	17.0	17.0	16.8	14.9	13.9	14.1	2.1	3.0	2.7	2.8	2.9	2.3
Little Boulder	15.6	14.9	14.3	14.0	13.0	12.7	1.6	1.9	1.5	1.9	1.7	1.6
Little Muddy	17.9	17.6	17.5	14.9	13.4	14.6	3.0	4.3	2.9	3.1	3.8	3.4
LaFleur	17.4	17.6	17.1	13.2	12.1	11.2	4.2	5.5	5.9	5.1	5.0	5.0
Lambert	17.1	19.2	18.1	11.7	12.6	13.6	5.4	6.7	4.5	5.5	5.9	4.9
Lime		18.8	17.1		16.0	14.5		2.9	2.5		3.0	2.5
Lost (lower)	19.7		21.0	13.2		14.2	6.5		6.8	6.5		6.1
Lost (upper)	16.6	17.5	17.2	13.3	13.0	13.7	3.3	4.6	3.5	3.8	4.1	3.4
Meadow	15.9	15.9	15.5	14.1	12.7	13.4	1.8	3.2	2.1	2.8	2.5	2.1
MF LeClerc	19.8	20.4		14.9	14.9		4.9	5.5		5.0	5.4	
MF Mill	14.1	14.0	14.0	11.3	11.2	11.5	2.8	2.8	2.5	2.6	2.8	2.3
NF Chewelah			18.9			13.7			5.2			4.7
NF Mill	12.7	12.4	12.0	11.3	10.2	9.9	1.4	2.1	2.1	1.8	1.8	1.4
NF O'Brien	14.6	14.6	13.6	12.6	11.6	11.6	2.0	2.9	2.0	2.2	2.6	2.3
NF SanPoil	15.5	16.0		10.7	11.2		4.8	4.8		4.0	4.3	
NF Sullivan			12.2			10.2			2.0			1.4
NF Trout		15.6	14.4		12.5	11.9		3.1	2.5		2.6	2.5
Nile (inlet)	18.3		18.6	13.7		14.8	4.6		3.8	4.3		4.7
Nile (outlet)	25.0		22.3	18.9		15.7	6.1		6.6	5.9		5.6
Nine-Mile	11.6			9.5			2.1			3.0		
Pierre	14.7	13.5	13.2	12.7	11.2	11.5	2.0	2.3	1.7	2.5	2.2	1.9
Rocky		16.2	16.2		13.8	12.4		2.5	3.9		2.5	3.2
Ruby	19.6	20.6	20.4	14.6	14.6	15.9	5.0	5.9	4.5	5.2	5.3	4.1
Scatter	14.0	13.5	13.4	11.8	10.9	11.4	2.2	2.6	2.0	2.8	2.6	2.6
SF Boulder	20.0	20.5		15.4	15.5		4.6	5.0		4.6	4.3	
SF Chewelah	15.4	15.4	15.4	12.0	11.6	12.3	3.4	3.7	3.1	3.4	3.4	3.1
SF Lone Ranch	15.2	14.9	14.4	12.7	11.5	11.6	2.5	3.4	2.8	2.6	3.1	2.5
SF Lost	18.3	18.6	16.9	14.1	12.7	13.7	4.2	6.0	3.2	4.6	4.6	3.7
SF Mill	17.7	17.4	17.2	15.3	14.1	14.7	2.4	3.3	2.5	3.1	3.0	2.3
SF O'Brien	17.2	18.4	18.2	12.4	13.2	12.8	4.8	5.2	5.4	4.8	4.9	4.3
SF Sherman	23.0			14.2			8.8			8.4		
SF St. Peter	12.0	11.5	11.2	10.0	8.3	8.4	2.0	3.3	2.8	2.6	2.6	2.5
Sherman	23.2	23.6	21.5	16.2	16.2	16.2	7.0	7.4	5.3	6.5	6.6	5.3
Silver	12.7	13.1	12.4	10.2	11.0	10.2	2.5	2.1	2.1	2.0	2.1	1.8
Slate	13.5		12.5	11.8		10.8	1.7		1.7	1.9		1.6
Smackout	15.5	15.2	15.5	14.5	12.7	13.8	1.0	2.5	1.8	2.1	2.1	1.8
Smalle	15.6		15.0	13.8		13.3	1.8		1.7	2.2		1.7
Sullivan	18.9		17.9	16.5		15.5	2.4		2.4	3.0		2.5
Tacoma	17.6	17.7	16.6	12.7	12.7	13.0	4.9	5.0	3.6	4.7	4.4	3.7
Tonata		16.7	17.5		12.1	12.9		4.6	4.6		4.0	3.9
WF Crown	10.7			9.2			1.5			1.1		
WF LeClerc	12.1		13.0	9.7		10.7	2.4		2.3	2.0		1.9
Winchester	16.9	16.9	16.4	13.4	13.4	13.4	3.5	3.5	3.0	3.1	3.1	2.6

EF = east fork **MF = middle fork** **NF = north fork** **SF = south fork** **WF = west fork**

As observed from Figure 5, despite varying maximum water temperatures observed during this period, the diurnal range remained fairly consistent in magnitude. This indicates that as the maximum water temperature changes so does the minimum water temperature, typically by an approximately equivalent amount.

There were times, during the study years, when the diurnal range significantly deviated from its characteristic magnitude (shown in dashed lines in Figure 5) for instance, in early-August 2003, following a peak on August 1. During the period from August 2 through August 4, maximum temperatures decreased at both Sherman and Flume Creeks, while the minimum temperatures increased resulting in a deviation from the typical diurnal range. An examination of the meteorological data for this period indicates that the rapid decrease in the maximum water temperature was due to a weather front that moved through the forest during this period bringing cooler air temperatures and, importantly in terms of water temperature, cloud cover. Cloud cover reduced the amount of solar shortwave radiation able to influence the heating of the streams while insulating the earth's heat loss during the night. These periods never coincide with when the warmest water temperatures occur within the forest and, for this reason, were excluded from the data analysis.

Because the diurnal range at each monitoring site remains consistent over varying levels of maximum temperature, it is not a reliable predictor of what the maximum water temperature will be on a daily basis. However, when considering the stations collectively, the comparison between the median diurnal range (the median observed July through August) and the annual maximum water temperature, both observed at each of the monitoring sites, a significant relationship is apparent. These relationships are presented in Figure 6 for 2002, 2003 and 2004.

As the diurnal range increases so does the annual maximum water temperature (Figure 6). This relationship is similar for 2002, 2003, and 2004. When considering the data collectively, the average slope is 1.6 indicating that for each degree increase in the diurnal range there is a 1.6 degree increase in the observed annual maximum water temperature. The y-intercept, or the point of zero diurnal range, was similar for each of the study years at approximately 11^{o}C, a level reflective of the expected average groundwater temperature for the forest. [A similar comparison between diurnal range and the annual maximum water temperature was generated for streams within the Wenatchee National Forest (n=112) resulting in the relationship or y=1.5x+9.6 (r^2=0.79). (Whiley, 2003)]

The greatest maximum water temperatures were observed at stations with the highest diurnal ranges. As will be discussed later in the report, for the majority of the monitoring stations, the magnitude of the diurnal range is a reflection of the amount of exposure to solar shortwave radiation, the major source of heat to streams during the summer period. Exposure is typically the result of channel cross-section alteration or low effective shade levels resulting from riparian vegetation alteration, or a combination of these factors.

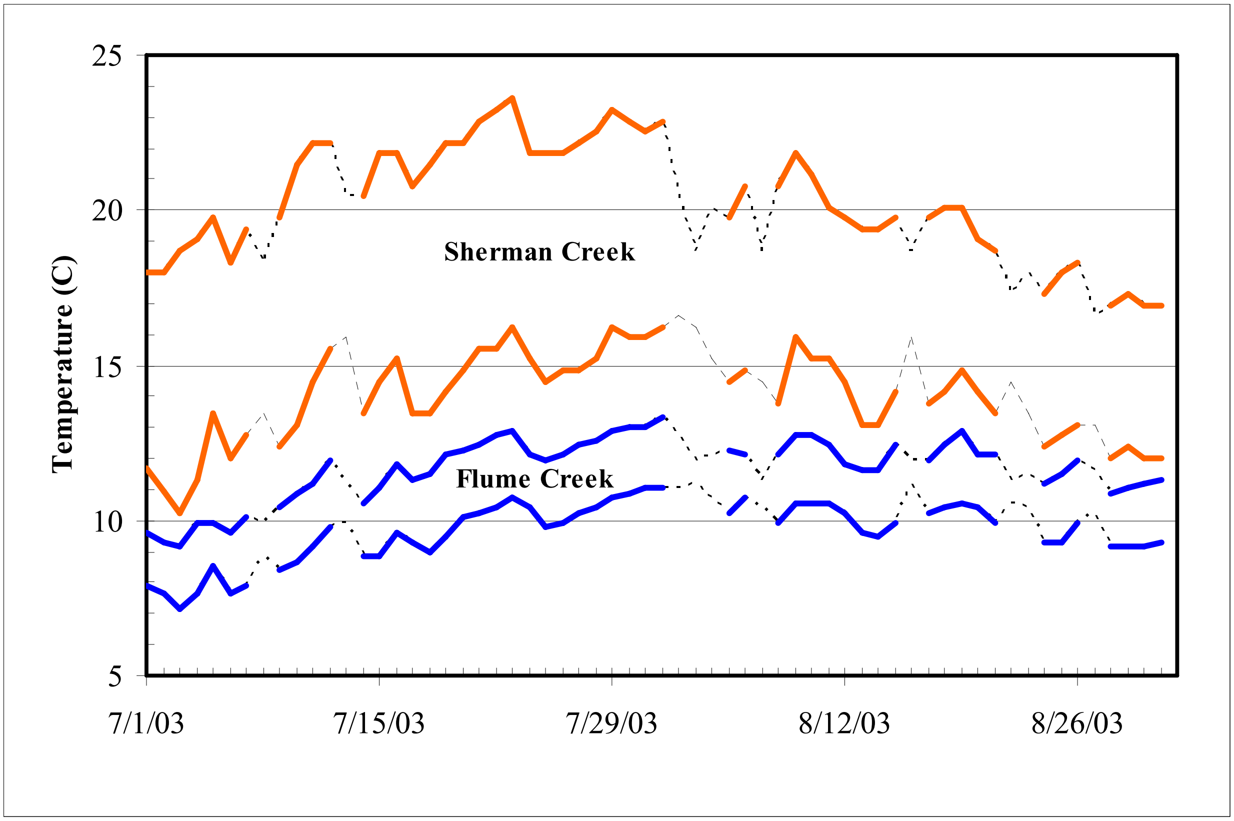

Figure 5. The daily minimum and maximum water temperatures observed at the Sherman Creek and Flume Creek monitoring stations during July and August of 2003.

From these relationships and, assuming that these stations are representative of conditions found throughout the forest, for streams to meet the 16°C temperature criteria they should have a diurnal range of approximately 3°C. The relationships between the annual maximum temperature and the minimum temperature observed on the day of the maximum, for 2002, 2003, and 2004 are also presented in Figure 6. Applying these relationships, on the day when the maximum water temperature occurs, for a particular stream to remain below 16°C, the minimum should be approximately 12 to 13°C and therefore, have a diurnal range of between 3 and 4°C. These relationships will be discussed further within the water temperature modeling section of this report.

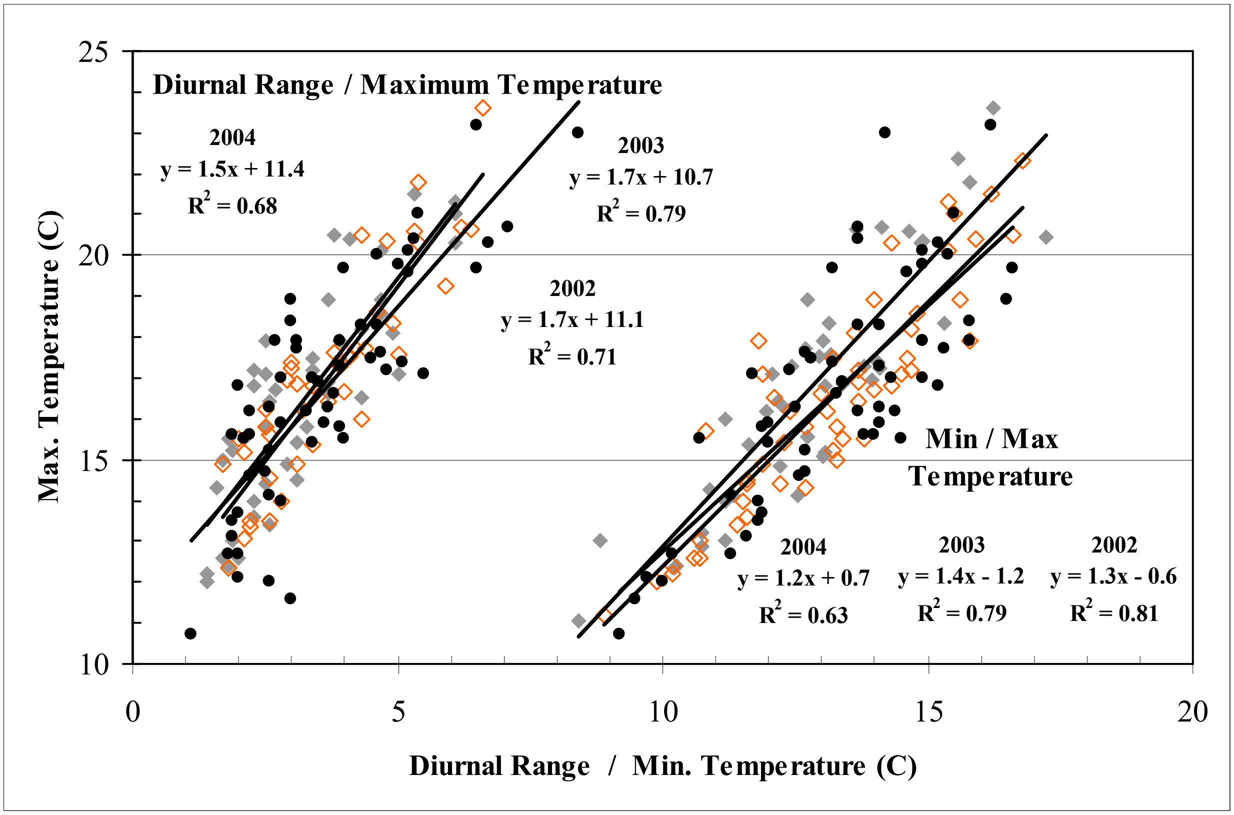

Figure 6. The relationship between the diurnal range and minimum temperature (x-axis) and the annual maximum (y-axis) observed at the monitoring stations for 2002 (shaded diamonds) and 2003 (white diamonds) and 2004 (black dots).

Monitoring Site Heating Characteristics

Based on the water temperature characteristics (maximum, minimum, and diurnal range) observed at the monitoring stations, five groups can be defined. They include:

1. Those that receive drainage from stored water in the form of lakes, reservoirs, or wetlands
2. Those that receive high levels of groundwater discharge in proximity to where temperature was measured.
3. Sites with high levels of exposure to solar shortwave radiation.
4. Moderate levels of exposure to solar shortwave radiation.
5. Low levels of exposure to solar shortwave radiation.

Water temperature heating patterns characteristic of each of these groups is presented in Figure 7 for July 23, 2003, the day when the majority of the stations experienced their warmest temperatures that year. A discussion of the temperature characteristics that define each of these groups is presented below with reference to Figure 7. In addition, the median temperature values among the stations represented within each of these groups are presented in Table 3.

Groundwater-Influenced

As observed from Figure 7 and Table 3, stations that receive a high level of groundwater discharge (as represented by Silver Creek) tend to have a low diurnal range (approximately 2^{o}C) and a low minimum water temperature (approximately 10 ^{o}C). (As discussed earlier, this is close to the temperature represented in Figure 6 when the diurnal range equals zero (the y-intercept).) In terms of this TMDL, stream locations that experience high levels of groundwater discharge will tend to meet the water quality criteria despite varying riparian shade levels.

Storage-Influenced

The heating pattern of monitoring stations that receive discharge from wetlands, lakes, or reservoirs (represented by Lime Creek) have an elevated minimum water temperature at approximately 16 ^{o}C (Table 3) and so begin the day right at the temperature criteria, while also having a low diurnal range of approximately 3 ^{o}C. As observed from Figure 7, a similar heating pattern is shared between the storage and groundwater-influenced stations; both share a low diurnal range. The real difference between these groups is that the minimum for the storage sites is shifted up by approximately 6 ^{o}C. For these stations, the storage of heat results in the elevated minimum water temperatures observed. But heat storage also has a moderating influence on maximum water temperatures which is reflected in the relatively low diurnal range observed within this group. The storage and groundwater-influenced sites are functioning in a similar way; both have a heat reservoir that has a moderating effect on the diurnal range. For these reasons, streams within this group will likely always naturally exceed the water quality criteria during the summer months.

Low-Exposure

The water temperature pattern representative of this group is that of North Fork Trout Creek (Figure 7). Monitoring stations within this group meet the temperature criteria and tend to have a minimum water temperature of approximately 13 ^{o}C and a diurnal range of approximately 3 ^{o}C (Table 3). The channel morphology and riparian vegetation characteristics within this group are representative of the type of conditions desirable for streams that exceed the temperature criteria, represented by the moderate to high exposure groups.

Moderate-Exposure

Monitoring stations within the moderate exposure group tend to exceed the temperature criteria (16^{o}C) though not chronically (represented by Tacoma Creek). While having a minimum water temperature similar to the stations that meet the criteria (about 13 ^{o}C), the diurnal range is slightly higher at about 4 ^{o}C. These stations tend to have channel or riparian characteristics that allow greater input of solar shortwave radiation in comparison to the stations that meet the criteria.

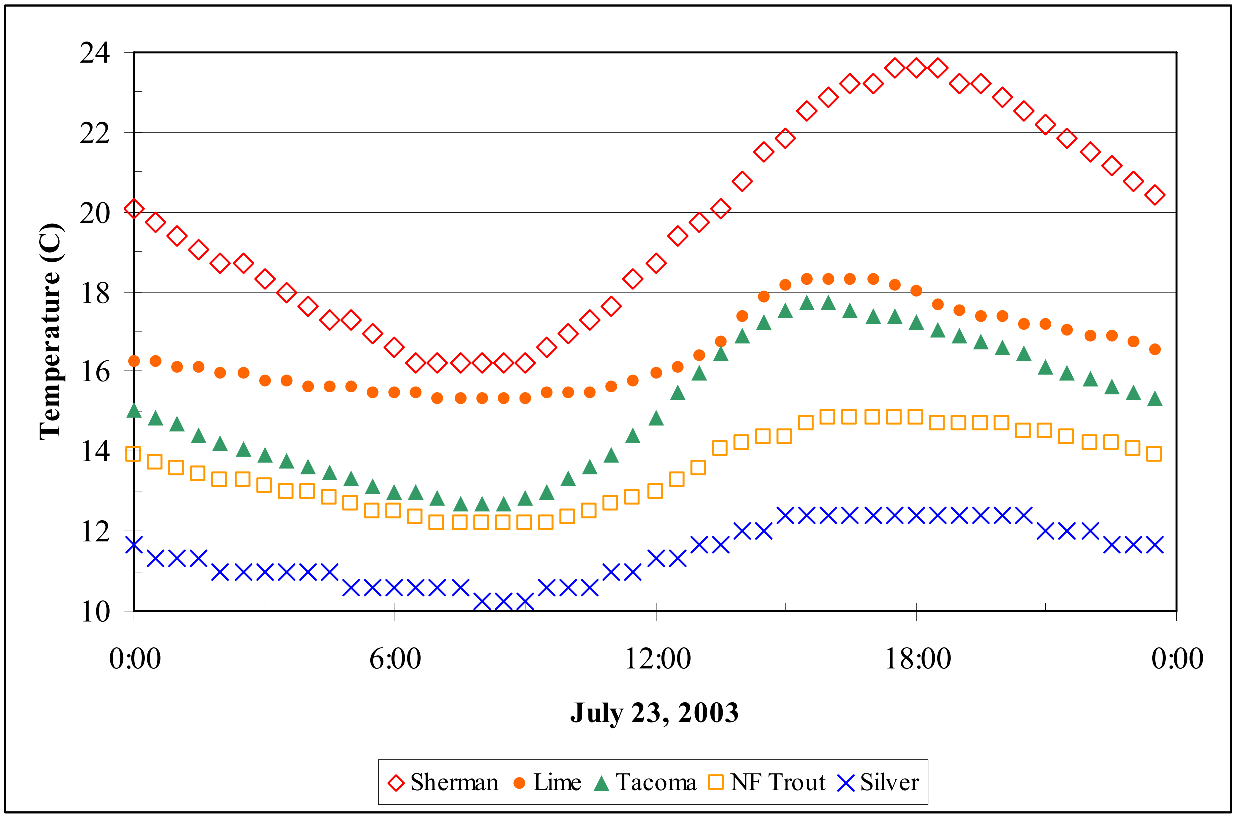

Figure 7. Water temperature heating patterns characteristic of the five temperature groups observed on July 23, 2003.

High-Exposure

Streams within this group (as represented by Sherman Creek) share a similar elevated minimum water temperature as the group with storage (15-16 °C), but are also characterized by having large diurnal ranges (6 °C) resulting in elevated maximum water temperatures (20+ °C). The elevated diurnal range indicates that there is high exposure (low effective shade levels) to solar shortwave radiation resulting in a large input of heat. The heat supply and its storage within these streams, is sufficiently large that minimum temperatures are similar to the streams influenced by storage.

Table 3. Median water temperature measurements by group.

Category	Maximum Temperature			Minimum Temperature			Diurnal Range		
	2002	2003	2004	2002	2003	2004	2002	2003	2004
Groundwater	12.6	13.5	13.1	10.7	11.0	11.3	2.0	2.5	2.0
Storage	19.7	19.8	20.6	15.6	16.6	17.2	2.5	3.2	3.4
High Exposure	20.2	20.5	19.9	15.1	14.6	14.8	5.0	6.0	5.2
Moderate Exposure	16.9	17.4	17.6	13.6	13.1	14.2	3.4	4.2	3.2
Low Exposure	15.2	15.6	15.9	12.7	12.4	13.8	2.5	3.3	2.5

The monitoring stations have been placed into these five temperature groups based on their respective heating patterns (Table 4).

Table 4. The temperature monitoring stations arranged by group.

High Exposure	Moderate Exposure	Low Exposure	Groundwater	Storage
Boulder	Addy	Barnaby	Flat	Brown's (O)
Calispell	Big Muddy	CCA	Flume	EF Crown
Cedar (lower)	Cedar (U)	Deep	MF Mill	Lime
Cusick	Deadman	E Deer	Nine-Mile	Nile (O)
EF LeClerc	Jim	Harvey	NF Mill	Sullivan
Lambert	LaFleur	L Boulder	NF O'Brien	
Lost (L)	L Muddy	Meadow	NF Sullivan	
MF LeClerc	Lost (U)	NF San Poil	Pierre	
Nile (I)	Rocky	NF Trout	Scatter	
NF Chewelah	SF Lost	American Fork	Silver	
Ruby	SF Mill	SF Chewelah	Slate	
Sherman	Tacoma	SF Lone Ranch	SF St. Peter	
SF Boulder	Tonata	Smackout	WF Crown	
SF O'Brien	Winchester	Smalle	WF LeClerc	
SF Sherman				

Water Temperature Analysis Methods

The analysis of water temperature initially focused on determining the level of effective shade present above each of the 62 monitoring locations. Solar shortwave radiation is the major source of heat to surface waters and the level of shade is a critical factor in a stream's vulnerability to heating. This assessment was conducted largely through geographic information system (GIS) analysis using USFS data. Once complete, this information along with the water temperature data, physical characteristics of the channel, flow characteristics, and meteorological information served as input to a water temperature model. For those surface waters where water temperature was observed above the water quality criteria, the model was used to determine effective shade levels necessary to reduce temperatures to meet the 16^{o}C criteria. The shade model (Shade) and temperature model (rTemp) used for this analysis are available on the Washington State Department of Ecology's website at: (http://www.ecy.wa.gov/programs/eap/models/). In addition, Chapra (1997) provides an overview of the fundamental equations used in the determination of the amount of heat gained and lost from surface water. These equations were used to determine variations in stream temperature within the rTemp model.

An additional component to this analysis was a determination of the level of effective shade provided by late-successional tree growth. This analysis provided a check on the initial analyses because (for certain monitoring locations) greater effective shade is required to meet the water temperature criteria than can be provided by optimal tree growth. An overview of these analyses is provided below.

Current Effective Shade Levels

Effective shade is defined as the percent reduction in solar shortwave radiation due to topography and vegetation. For this analysis, an average effective shade level was determined over a 2-kilometer stream length above each monitoring location. Two primary analysis methods were used. The first involved sampling two USFS grid files using an Arc-View 3.2 extension developed by the Oregon Department of Environmental Quality called T-Tools. (The T-Tools extension and user manual are available at: www.deq.state.or.us/wq/TMDLs/WQAnalTools.)

Two 25-meter resolution grid files covering the entire Colville Forest, served as a primary data source used to examine vegetation characteristics above each water temperature monitoring location. The grid files included a determination of the diameter at breast height (dbh) and the other, canopy density (BioWest, 1999). (The grid files and additional GIS information for the Colville Forest are available at www.reo.gov.) Prior to using T-Tools, the two grids were combined using the Arc-View 3.2 extension, CRWR-Raster. In addition, a 10-meter digital elevation model (DEM) grid was used for the determination of elevation and topographic shade angles.

Cell values within the canopy density grid used four ranges, based on percent cover, including:1-19 percent, 20-39 percent, 40-59 percent, and 60-100 percent. Another cell value for this grid, designated as background, was assumed to have a canopy density of 5 percent. Cell values for the tree size class grid, described by diameter at breast height (dbh) include: 1-9.9 inches, 10-19.9 inches, and 20 inches and greater. The overall accuracy of the dbh and canopy density grids, based on field verification, are 52 percent and 57 percent, respectively (BioWest, 1999).

The initial part of the Arc-View analysis involved establishing a centerline (polyline coverage) to the stream for the 2-kilometer length of analysis above each of the monitoring sites. The T-Tools extension was then used to create a point shape file from the poly-line. Points were established every 30.5 meters. At each point, T-Tools generated the following data: aspect, elevation, gradient, and topographic shade angles. In addition, T-Tools sampled the combined grid, perpendicular to the stream aspect, each 4.6 meters from the stream centerline, to a distance of 41 meters each side of the stream determining dbh and canopy density levels. This data, generated by T-Tools, then served as input to the Excel-based Shade model used to calculate effective shade.

Tree Species Height and Canopy Density

As mentioned previously, one of the USFS grid files, used to determine effective shade, was in the form of diameter at breast height (dbh). However, tree height - not dbh)- is the parameter of interest in determining shade levels. For this reason, it was necessary to determine the association between dbh and tree height by species. A Colville Forest database containing approximately 2000 records of tree plot sampling was examined. Initially, the relationship between dbh hand stand height by species was determined (Table 5). The coefficient of determination (r^2) of this relationship ranged between 0.34 for lodge-pole pine to 0.84 for western red cedar. Because the composition of trees within the Colville Forest is mixed, the data were also analyzed collectively providing an overall relationship for the forest (Table 5). From the all-species relationship, the average tree height, by dbh category, can be determined. For instance, for the dbh category, 10-19.9", and applying the all species regression relationship, an average tree height of 90 feet (27.5 meters) is calculated.

Table 5. The relationship between diameter at breast height (dbh, inches) and tree height (feet) by species.

Common Name (Genius species)	**DBH / Height Equation**	**n**	r^2
Grand Fir (*Abies grandis*)	$Y=19.43(dbh)^{0.58}$	108	0.54
Sub-Alpine Fir (*Abies lasiocarpa*)	$Y=14.66(dbh)^{0.63}$	179	0.42
W. Larch (*Larix occidentalis*)	$Y=21.52(dbh)^{0.55}$	386	0.61
Lodgepole Pine (*Pinus contorta*)	$Y=30.96(dbh)^{0.38}$	208	0.34
Englemans Spruce (*Picea engelmannii*)	$Y=18.99(dbh)^{0.58}$	165	0.57
W. White Pine (*Pinus monticola*)	$Y=34.33(dbh)^{0.42}$	20	0.74
Ponderosa Pine (*(Pinus ponderosa*)	$Y=34.64(dbh)^{0.35}$	83	0.34
Douglas Fir (*Pseudotsuga menziesii*)	$Y=21.61(dbh)^{0.51}$	492	0.52
W. Red Cedar (*Thuja plicata*)	$Y=17.86(dbh)^{0.56}$	116	0.84
W. Hemlock (*Tsuga heterophylla*)	$Y=25.34(dbh)^{0.48}$	101	0.49
All Species	$Y=21.48(dbh)^{0.53}$	1858	0.58

n = sample number r^2 = coefficient of determination

A further analysis of the database information of dbh and height by species was conducted (Table 6). The database information was used to further examine the association between tree height and dbh. Tree heights were analyzed by species based on the three ranges in dbh presented in the grid file. Referring to Table 6 and the dbh category 10-19.9", the average height for this group is 89.5 feet (27.5 meters), close to the height generated by the regression relationship. For the 20"+ dbh group, the average height generated by the regression is 105 feet (32 meters) while the average height for this dbh group is slightly higher at 115.9 feet (35.3 meters).

Shade Produced by Potential Natural Vegetation

Major divisions of the forest, applicable to the temperature portion of this TMDL study, are the potential natural vegetation zones (Davis, 2000). These are delineated areas of the forest where specific tree species have been identified as representative of a late-successional forest. This type of delineation is useful for the temperature analysis because these potential natural vegetation areas considered the variation in physical and environmental factors across the forest including elevation, meteorology, and geology. In addition, stand height and canopy density, both important factors in the examination of riparian shade, represented by the various potential natural vegetation zones are critical when examining the shade levels that can be expected given optimal growth conditions. For this reason, the effective shade produced by the potential natural vegetation provides an estimate of optimal levels.

Six potential natural vegetation zones have been identified within the forest (Figure 8). They include Douglas fir, parkland, western hemlock, sub-alpine fir, Douglas fir/western hemlock, and Douglas fir/grand fir. In terms of the percent of the total forest occupied by these six vegetation zones, western hemlock represents the largest at approximately 35 percent. The area occupied by the other vegetation zones include Douglas fir (22 percent), Douglas fir/grand fir (6 percent), Douglas fir/western hemlock (18 percent), sub-alpine fir (16 percent), and parkland (3 percent).

Table 6. The relationship between several ranges in diameter at breast height (dbh), and associated tree height, by species.

DBH Range (inches)	Common Name	Median DBH (inches)	Tree Height by Group (feet)			
			Mean	**Median**	**Standard Deviation**	**Count**
1-9.9”	Grand Fir	=====	=====	=====	=====	=====
	Sub-Alpine Fir	9.1	58.8	61.0	8.4	25
	W. Larch	9.2	74.4	74.5	8.7	22
	Lodgepole Pine	8.9	70.4	71.0	9.5	89
	Englemans Spruce	=====	=====	=====	=====	=====
	W. White Pine	=====	=====	=====	=====	=====
	Ponderosa Pine	=====	=====	=====	=====	=====
	Douglas Fir	9.1	63.9	63.0	6.0	7
	W. Red Cedar	=====	=====	=====	=====	=====
	W. Hemlock	=====	=====	=====	=====	=====
	All Species	**9.0**	**68.6**	**68.0**	**10.4**	**151**
10-19.9”	Grand Fir	15.4	94.4	92.0	15.0	90
	Sub-Alpine Fir	13.4	76.2	74.5	16.3	142
	W. Larch	14.2	94.9	93.0	17.4	277
	Lodgepole Pine	13.6	82.0	82.0	10.2	118
	Englemans Spruce	15.5	92.7	96.0	16.5	105
	W. White Pine	16.2	111.6	108.0	14.5	11
	Ponderosa Pine	17.0	94.6	95.0	12.0	45
	Douglas Fir	15.9	89.6	89.0	13.7	344
	W. Red Cedar	15.0	81.4	80.0	11.7	53
	W. Hemlock	16.7	98.0	98.0	14.9	51
	All Species	**14.8**	**89.5**	**89.0**	**16.3**	**1236**
20+”	Grand Fir	21.7	120.1	121.0	16.4	17
	Sub-Alpine Fir	21.9	110.3	124.0	22.4	12
	W. Larch	23.6	126.5	124.0	18.9	87
	Lodgepole Pine	=====	=====	=====	=====	=====
	Englemans Spruce	23.4	122.8	120.0	14.4	58
	W. White Pine	25.4	133.1	132.0	14.3	7
	Ponderosa Pine	23.6	106.5	107.5	14.5	38
	Douglas Fir	22.2	107.6	106.0	14.8	141
	W. Red Cedar	25.9	116.6	116.5	15.9	60
	W. Hemlock	23.4	116.8	113.5	15.5	50
	All Species	**23.1**	**115.9**	**116.0**	**17.8**	**471**

Six potential natural vegetation zones have been identified within the forest (Figure 8). They include Douglas fir, parkland, western hemlock, sub-alpine fir, Douglas fir/western hemlock, and Douglas fir/grand fir. In terms of the percent of the total forest occupied by these six vegetation zones, western hemlock represents the largest at approximately 35 percent. The area occupied by the other vegetation zones include Douglas fir (22 percent), Douglas fir/grand fir (6 percent), Douglas fir/western hemlock (18 percent), sub-alpine fir (16 percent), and parkland (3 percent).

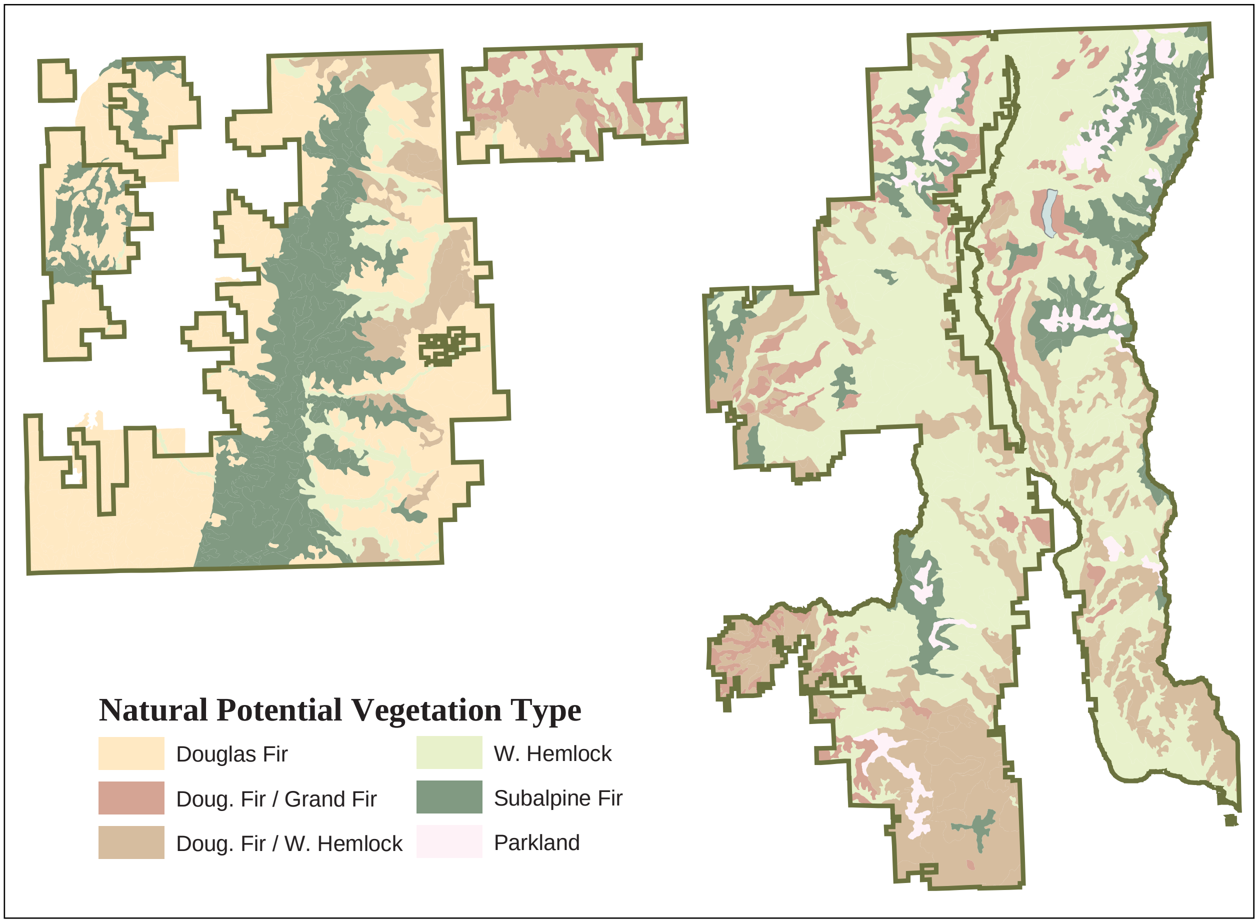

Figure 8. The potential natural vegetation types and their distribution within the Colville National Forest.

Based on a 1:24,000 scale digitized stream layer, there are 11,622 stream kilometers within the Colville Forest. Approximately 40 percent of the total stream kilometers are located within the western hemlock potential natural vegetation zone. Both Douglas fir and Douglas fir/western hemlock each have 20 percent of the total. Fifteen percent of the forest's streams are located within the sub-alpine fir vegetation zone with lesser levels within the Douglas fir/grand fir (4 percent) and parkland (1 percent) zones.

Potential natural vegetation (PNV) areas within the forest have been digitized into an Arc-View cover (www.reo.gov). The following methods were used to determine the tree height and canopy density most representative of each potential natural vegetation type.

- Streams located within each of the six potential natural vegetation types were individually clipped from a 1:24,000 scale stream layer specific to the Colville Forest.
- Once the streams were separated by PNV type, a 46-meter buffer was placed around the stream poly-line to create a polygon cover.
- The polygon covers, specific to each PNV type, were then used to clip the combined dbh (surrogate tree height) and canopy density grids.
- Each clipped grid was then analyzed for the area, represented as a percent of the total area, of the various ranges of dbh/tree height and canopy density. The results of this analysis are presented in Tables 7 and 8.

An overall composite canopy density and dbh (tree height) specific to each potential natural vegetation type was determined based on the analysis results. In calculating the composite values, it is assumed that for the vast majority of the Colville Forest, the canopy densities and tree heights, as represented by the grid values, depict optimal levels. This is reflected in the analysis results where all of the potential natural vegetation types have the highest percent representation of canopy density within the highest category, 60 to 100 percent (Table 7). The percent representation, within the 60-100 percent canopy density range, are also similarly represented regardless of PNV type, at approximately 63 percent. Exceptions include the Douglas Fir and Parkland potential natural vegetation types where lower representation of the highest canopy density levels are expected. Background, or areas of low (assumed a level of 5 percent) canopy density were represented for all vegetation types at the next highest level. The average area designated to background for all vegetation types is 20 percent.

The average level of the forest riparian area represented by the various dbh categories including background, 1-9.9" dbh, 10-19.9" dbh, and 20'+ dbh are 20 percent, 56 percent, 22 percent, and 2 percent, respectively. So a large percent of the riparian vegetation is represented by the smallest dbh range with only minor representation (2 percent) by the largest dbh (20"+).

An additional indication that the results of these analyses provide a reasonable indication of optimal vegetation growth is the similarity in the percent representation of the various ranges of canopy density, by vegetative group. A highly fractured representation of canopy density levels, between vegetative groups, would be indicative of large scale riparian disturbance. However, based on the analysis results, that is not the case within the Colville National Forest.

Based on the percent representation, within each canopy density and dbh (tree height) range, a weighted average was calculated for each PNV type. The canopy density and dbh (tree height) value used within each of the ranges was the maximum one. For instance, for the Douglas fir group, in calculating canopy density where 47.4 percent of the streamside area is represented by the 60-100 percent canopy density range, a value of 47.4 percent canopy density was calculated. Referring to Table 7, the 66 percent canopy density levels associated for Douglas fir was calculated in the following way: (16.8*0.05)+(3.0*0.19)+(12.1*0.39)+(20.6*0.59)+(47.4*1.00)=66 percent. The reason for the use of the highest range value in these calculations is because they are directed toward determining optimal canopy density levels. Although the use of the weighted average as a means of calculating optimal canopy density and dbh (tree height) likely includes observations from impacted areas, it is assumed that the overall extent of the impacted areas is relatively minor in comparison to the total analysis area for each potential natural vegetation group. The results of this analysis, for canopy density and dbh (tree height), are also included in Tables 7 and 8, respectively.

Table 7. The percent representation of various canopy density (%) ranges by potential natural vegetation type along with the respective composite canopy density.

Potential Natural Vegetation	Percent Representation of Canopy Density Ranges					Composite
	Background	1 – 19%	20 – 39%	40 – 59%	60 – 100%	Density (%)
Douglas Fir	16.8	3.0	12.1	20.6	47.4	66
Douglas Fir / Grand Fir	13.1	0.7	7.7	16.1	62.4	76
Douglas Fir / W. Hemlock	21.8	0.3	4.6	11.8	61.5	71
W. Hemlock	20.9	0.3	2.4	8.9	67.5	75
Sub-Alpine Fir	19.0	1.7	6.4	11.6	61.3	72
Parkland	26.4	1.0	6.7	14.3	51.6	64

Table 8. The percent representation of various ranges in dbh (in) by potential natural vegetation type along with the respective composite dbh and tree height (ft).

Potential Natural Vegetation	Percent Representation by DBH Ranges				Composite
	Background	1 – 9.9"	10 – 19.9"	20"+	dbh (in)/ tree height (ft)
Douglas Fir	17.0	63.5	17.6	1.9	11.0 / 77
Douglas Fir / Grand Fir	13.1	59.7	24.5	2.7	12.0 / 80
Douglas Fir / W. Hemlock	21.8	52.9	23.1	2.2	11.4 / 78
W. Hemlock	20.9	55.5	21.4	2.2	11.2 / 77
Sub-Alpine Fir	19.0	59.9	19.8	1.3	11.1 / 77
Parkland	26.4	45.7	26.5	1.5	11.4 / 78

Once the dbh composite levels were determined, the power equation relating dbh to tree height (refer to Table 5, all species) was applied to estimate tree height for each PNV group.

Using another approach, a USFS generated polygon cover of old growth designated stands was used to determine optimal tree heights and canopy densities. The old growth stands were qualified by four criteria including its use by the Barred Owl, tree stands of age 250 years or greater, stands with ages between 100 to 250 years, and stands with old growth characteristics identified by each forest district (www.reo.gov). Old growth stands occupy approximately 973 square kilometers or about 17 percent of the total Colville Forest area. Approximately 40 percent of the old growth is located within the Douglas fir potential natural vegetation zone. The sub-alpine fir and western hemlock potential natural vegetation zones occupy approximately 24 percent and 20 percent, respectively. Twelve percent of the old growth is located within the Douglas fir / western hemlock vegetation zone. Lesser old growth stand levels are present within the Douglas fir/grand fir (3 percent) and parkland (2 percent) zones.

Initially, a polygon shape file was created for each of the six potential natural vegetation zones (Douglas fir, Douglas fir/Grand fir, Douglas fir/western hemlock, western hemlock, sub-alpine fir and parkland) found within the Colville Forest.

Following the separation, the old growth cover was then used to clip the area within each of the potential natural vegetation types identified as old growth. So in the end, six shape files were created, each representing the old growth area present within each of the six potential natural vegetation types. These six old growth shape files were then used to clip the canopy density and diameter at breast height grids. From this analysis, six additional grid files were created each representing the canopy density and dbh characteristics of old growth present within each of the potential natural vegetation types. These grid files were then analyzed for the percent of the total area represented by the various ranges in dbh and canopy density and an overall weighted average determined for each potential natural vegetation type. This approach, unlike the previous analysis, does not select exclusively for riparian growth. The results of this analysis are present in Tables 9 and 10.

Table 9. Representation of canopy density within old growth designated stands by potential natural vegetation types.

Potential Natural Vegetation	Percent Representation of Canopy Density Ranges					Composite Density (%)
	Background	1 – 19%	20 – 39%	40 – 59%	60 – 100%	
Douglas Fir	13.7	3.6	8.4	23.0	51.3	70
Douglas Fir / Grand Fir	11.3	0.9	8.7	11.6	67.5	78
Douglas Fir / W. Hemlock	20.9	0.3	4.2	7.3	67.3	74
W. Hemlock	20.0	0.1	1.6	5.0	73.3	78
Sub-Alpine Fir	17.6	2.4	5.4	12.0	62.6	73
Parkland	20.2	0.3	2.5	10.0	66.9	75

Table 10. Representation of dbh within old growth designated stands by potential natural vegetation types.

Potential Natural Vegetation	Percent Representation by DBH Ranges				Composite dbh (in)/ tree height (ft)
	Background	1 – 9.9 (inches)	10 – 19.9 (inches)	20+ (inches)	
Douglas Fir	13.7	59.9	23.4	3.0	11.9 / 80
Douglas Fir / Grand Fir	11.3	65.3	21.7	1.7	11.7 / 79
Douglas Fir / W. Hemlock	20.9	56.7	21.1	1.3	11.1 / 77
W. Hemlock	20.0	53.6	24.7	1.7	11.6 / 79
Sub-Alpine Fir	17.6	52.9	27.6	1.9	12.0 / 80
Parkland	20.2	40.9	37.6	1.3	12.8 / 83

Overall, these two methods used to determine optimal canopy density and stand height by potential natural vegetation type, produce similar results. The analysis, using the old growth stand information, determined an average increase in canopy density for all the natural potential vegetation types of 5 percent, in comparison to the riparian analysis method. The average increase in dbh for old growth, in comparison to the riparian method, was 0.5 inches or an average increase in stand height of 5 feet (1.5 meters). The parkland zone had the greatest difference in canopy density with an increase of 11 percent. (This is largely a result of the lower level of riparian area present within this potential natural vegetation type.) In terms of dbh, the old growth analysis determined an increase in both parkland and sub-alpine fir zones of 1.3 and 0.9 inches, respectively.

When each of the six vegetation zones are examined for the area represented by each of the canopy density ranges, there was an overall decrease for the lower ranges (background, 1-19 percent, 20-39 percent, and 40-59 percent) by an average of approximately 2 percent while the highest density levels (60-100 percent) increased by approximately 7 percent. For dbh and tree height, the area represented for old growth within the background and 1-9.9 inches decreased by approximately 2 percent, while the 10-19.9 increased by 4 percent. There was little difference between the two methods for the highest 20+ range between the riparian and old growth analysis results.

The results of this second analysis support the initial findings for tree height and canopy density as the two methods compare favorably and indicate that the use of the riparian analysis numbers are conservative, offering some margin of safety. The values of tree height and canopy density levels, presented in Tables 7 and 8, served as input to the Shade model. The Shade model estimated effective shade levels, based on stream bankfull width, for each vegetative group (Figure 9).

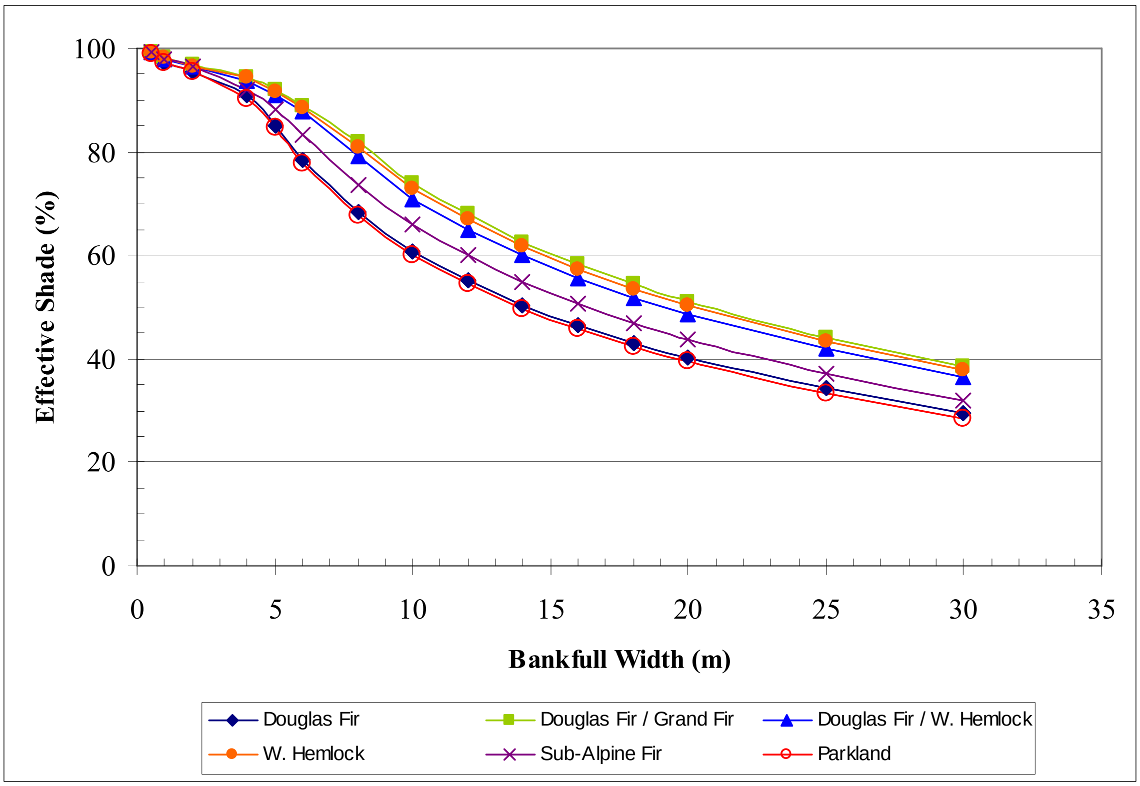

Figure 9. The relationship between bankfull width (m) and effective shade (%) by potential natural vegetation type.

Response Temperature Model Overview

A temperature model was used to examine the variation in water temperature over time at each of the monitoring locations. The model, known as the Response Temperature Model (rTemp), is based on the assumption that the water temperature within a fully mixed column of water is solely a reflection of the heat fluxes across the water surface. Additional modifications have also been made to the model to consider the temperature response to heat flux from the stream bed, and groundwater inflow.

The fundamental equation to the Response Temperature Model is presented below and includes the following terms:

$$dT/dt = J_{net} / d * \sigma * \rho$$

dT/dt = rate of change of water temperature with time (°C/hr)
d = mean depth of the water column (m)
J_{net} = net rate of surface heat exchange including: solar shortwave, longwave atmospheric, longwave back, convection, evaporation, streambed conduction, groundwater inflow (W/m^2-hr).
ρ = density of water (1000 kg/m^3)
σ = specific heat of water (4182 Joules/kg-C)

Temperature Response Model Calibration

Meteorological data, driving the Response Temperature Model, includes: air temperature (°C), dew point temperature (°C), wind speed (m/s), cloud cover (percent of sky), and shortwave radiation (Watts per square meter (W/m^2-hr)). Hourly data is collected at several remote automated weather stations (RAWS) located within, or in proximity to, the Colville Forest (Table 11). The data collected at these stations served as the primary model input. The model was run for the majority of the monitoring sites based on 2003 data. However, in some cases where temperature data was not collected in 2003, then 2002 or 2004 model runs were conducted. Regardless of year, the analysis period was from July 15 to August 15, the period when the warmest water temperatures typically occur in the Colville Forest.

Table 11. RAWS meterological stations located within, or within close proximity to, the Colville National Forest.

RAWS Station Name	Location (Lat. / Long.)	Elevation (m)
Deer Mountain*	48.80194 / 117.61027	1006
Teepee Seed Orchard	48.66389 / 117.48194	1024
Tacoma Creek	48.48889 / 117.43166	1006
Flowery Trail	48.29750 / 117.40388	792
Pal Moore Orchard*	48.35583 / 117.58277	951
Little Pend Oreille NWR	48.46083 / 117.73305	614
Owl Mountain (East)*	48.94694 / 118.30194	1073
Kettle Falls	48.60833 / 118.11944	399
Lane Creek*	48.61667 / 118.25555	1372
Brown Mountain	48.53527 / 118.68888	991

* shortwave radiation measured

Average hourly values were calculated, from the full set of RAWS stations, for air temperature, dew point temperature, wind speed, and shortwave radiation. The daily average cloud cover levels observed during the analysis period were obtained from the National Weather Service station in Spokane (http:newweb.wrh.noaa.gov/otx/climate/lcd/lcd.php). At this station, which is located approximately 97 kilometers south of the town of Colville, cloud cover is measured indirectly as daily percent possible sunshine. This figure, when subtracted from 100 percent provides the percent cloud cover level used in the model. In model application, the daily average cloud cover was assumed to remain at a constant level throughout the day.

Important input variables to the Response Temperature Model, specific to each monitoring location, are presented in Appendix B. Two parameters were adjusted to calibrate the model including water depth (to adjust predicted diurnal range) and groundwater inflow (if the predicted water temperatures required cooling). In addition, 33 of the 62 monitoring sites required slight adjustments to the previously calculated effective shade levels. This occurred when relatively minor adjustments to heating or cooling were required. The median level of adjustment to effective shade was 4 percent, ranging from 1 percent (SF Lost Creek) to 30 percent (Sherman Creek). The larger adjustment required for Sherman Creek is because the resolution ($25m^2$) of the dbh and canopy density grids does not adequately document exposure caused by Highway 20 which parallels the creek through the analysis reach.

An assessment of model error is included in Appendix C.

Temperature Response Model Results

The median effective shade level estimated for monitoring sites with water temperatures measured above 16°C ranged between 36 percent and 79 percent. The corresponding annual maximum water temperatures (2003 data) had a median level of 18.5 °C, with a range between 16.2 °C and 23.6 °C. Based on the model results, the median effective shade level required to meet the water quality criteria at these sites is 80 percent but ranged between 67 to 85 percent. This spread in effective shade levels is largely explained by the variation in the quantity of groundwater inflow and average flow depth present at particular monitoring sites.

The influence of percent effective shade, flow depth, and groundwater inflow was considered for the overall effect on the maximum water temperatures observed at the monitoring sites. A multiple regression was determined with effective shade, flow depth, and amount of groundwater inflow as the independent variables, and annual maximum water temperature as the dependent variable. The data set was derived from the calibrated Response Temperature Model runs conducted at each of the monitoring locations. Excluded from consideration were sites where water temperature is influenced by water storage (lakes, reservoirs, wetlands), locations where effective shade levels have minor influence on water temperatures. The result of this analysis is presented in Table 12.

The resulting equation provides a useful method to approximate the influence of each variable on water temperature (applicable solely for the Colville National Forest). If median conditions are considered for water depth (0.3 m) and groundwater inflow is considered to be minimal and, therefore, reflect the most vulnerable situations for heating, an effective shade level of 80 percent is needed to maintain maximum water temperatures at or below 16°C. From an initial setting of a depth of 0.3 m, assuming no groundwater inflow, and an effective shade of 80 percent, each variable was adjusted independently to examine its influence on water temperature. From this analysis, the annual maximum water temperature decreased by 0.5°C for each 0.1 m increase in depth, decreased by 0.4°C for each 0.1 m/s increase in groundwater inflow, and decreased by 1.7°C for each 10 percent increase in effective shade. So, for the most vulnerable locations, those with little spring discharge through the reach monitored, and assuming an average flow depth (0.3 m) then the real importance of shade becomes evident.

Table 12. Results of multiple variate regression as a determinate of annual maximum water temperature (^oC) on the Colville National Forest using output from the Response Temperature Model runs.

Regression Statistics						
Multiple R	0.95					
R Square	0.90					
Adjusted R Square	0.89					
Standard Error	0.94					
Observations	49.00					
ANOVA						
	Df	*SS*	*MS*	*F*	*Significance F*	
Regression	3.00	346.39	115.46	130.70	3.14E-22	
Residual	45.00	39.75	0.88			
Total	48.00	386.14				
	Coefficients	*Standard Error*	*T Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	30.74	0.83	36.93	2.68E-35	29.06	32.41
Effective Shade (%)	-0.17	0.01	-15.21	2.38E-19	-0.19	-0.15
Groundwater (m/s)	-3.88	0.28	-14.10	4.02E-18	-4.44	-3.33
Water Depth (m)	-4.47	0.97	-4.63	3.11E-05	-6.41	-2.53

When the results of the 57 stream model runs for 2003 are examined collectively, a familiar pattern is evident. Excluding monitoring locations affected by storage, when streams are provided adequate effective shade to maintain annual maximum water temperatures at 16°C, the median minimum and diurnal range water temperatures were 12.4°C and 3.2°C, respectively. These are the ideal water temperature values derived from the empirical relationships presented in Figure 6 of a stream within the forest that meets the temperature criteria. The empirical relationships in Figure 6 are based on the temperature data collected at the monitoring locations during 2002, 2003, and 2004 and use the daily minimum and diurnal range as a means to predict the maximum water temperature. Applying the empirical relationships to predict the annual maximum based on a minimum of 12.4°C and a diurnal range of 3.2°C, results in the predictions of 15.9°C and 16.3°C, respectively. These results indicate a close association between the empirical relationships, based on the monitoring data, and model output, providing an increased assurance of the model results.

Fecal Coliform Bacteria

Discussion of the Fecal Coliform Data

An analysis of fecal coliform bacterial levels was conducted at 69 monitoring locations within the Colville National Forest. These stations were selected, among a larger base of monitoring stations, based on two criteria 1) that data had been collected since 1990 and; 2) within that period at least ten bacteria samples had been collected from June through September. Historically, water samples, for bacterial analysis, have been collected annually by the Forest Service from April through November. To use this data collectively, the bacteria data specific to each site were grouped by month. For example, at a particular monitoring location, all of the data collected during the month of April, since 1990, were grouped together as were data collected during May, June, etc. The underlying assumption behind this method is that the management practices, recreational use, wildlife populations, and potential contributing sources of fecal coliform have remained relatively consistent on a monthly basis since 1990. For this reason, each site was analyzed individually and not compared among other stations.

Critical Period

Following the monthly grouping of data, the definition of a critical period was necessary. For this study, the critical period is defined as the months when the highest bacterial levels are expected on the forest and therefore, the period when the bacteria criteria are most likely to be exceeded. Establishing a narrow interval for the critical period provides an increased margin of safety should particular locations require reductions in bacteria concentrations. To determine the critical period, bacteria data from monitoring stations with elevated bacterial levels (those from the 1998 303(d) list) were grouped by month and the geometric mean and 90th percentile statistics calculated (Figure 10). Based on the results of this analysis, the four highest months, June through September, were chosen as the critical period used for further analysis. Using a four-month period also provided an increased dataset from which to conduct the analysis.

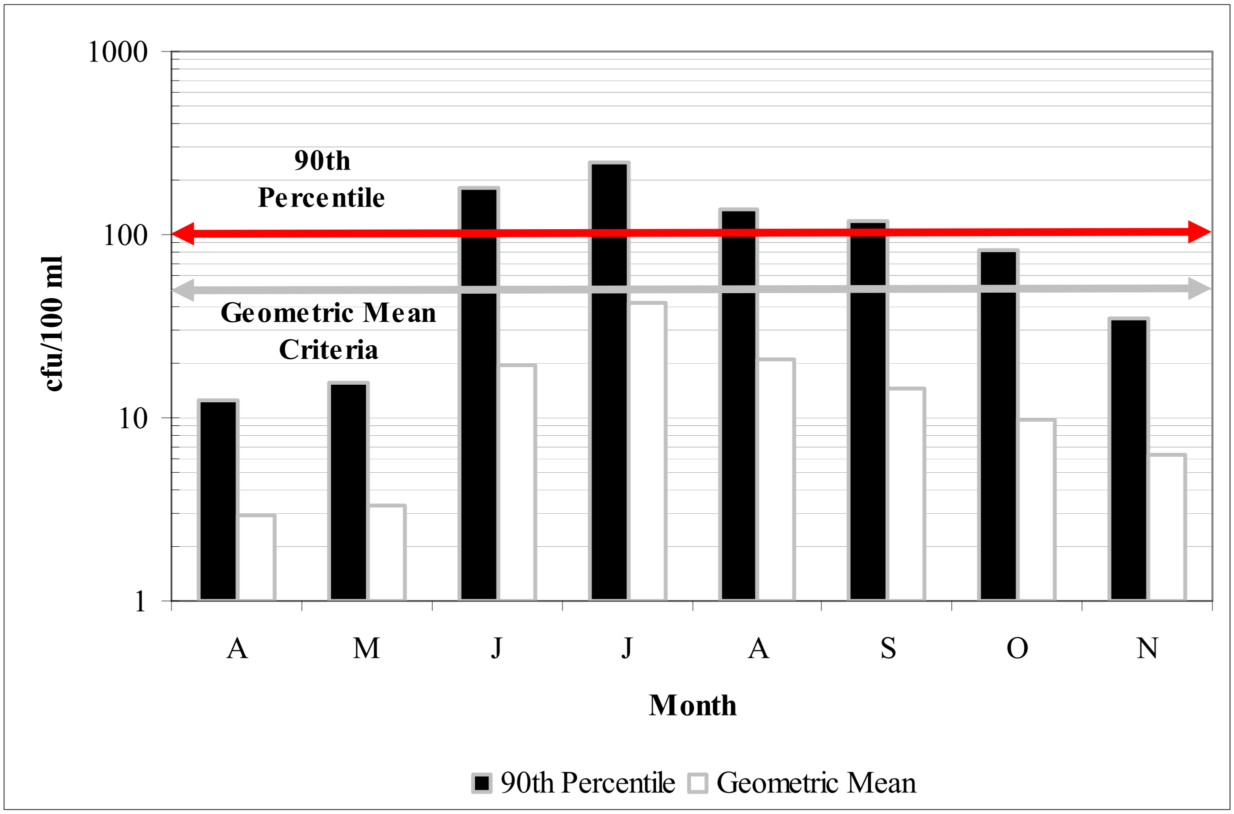

Figure 10. The geometric mean and 90th percentile of bacterial levels observed at 303(d) listed monitoring stations.

With the critical period defined for each monitoring location, all of the data collected from June through September (since 1990) were grouped together and the geometric mean and 90th percentile calculated. The monitoring stations, their location within the forest, the number of samples used in the analysis (n) along with the geometric mean and 90th percentile are included in Table 13.

To determine the geometric mean and the 90th percentile for each monitoring site's dataset, initially a $logarithm_{10}$ (x+1) transformation, was applied to the fecal coliform concentrations collected during the critical period. Taking the $logarithm_{10}$(x+1) normalizes the typically skewed distribution commonly found with fecal coliform bacteria concentrations. From the log-transformed dataset, the average and the 90th percentile were determined. For each dataset, the 90th percentile was calculated by the average of the $logarithm_{10}$(x+1) concentration plus 1.281 times the standard deviation. The anti-logarithm was then applied to these calculations to arrive at the geometric mean and the 90th percentile concentrations.

There are two parts to the fecal coliform Class AA criteria, based on a dataset of fecal coliform bacteria results, that: 1) the geometric mean remain below 50 colony forming units per 100 milliliters (cfu/100 mL) and; 2) that the 90th percentile of the dataset remain below 100 cfu/100 mL. As observed from Figure 10 and Table 13, for the majority of the stations where bacterial levels exceeded the criteria it was due primarily to an exceedance of the 90th percentile part of the criteria. Of the 69 stations where analysis was conducted, 45 (or approximately 65 percent) met both parts of the bacterial standard. For stations that exceeded the criteria in Table 13, reductions will be necessary. Further analysis to determine the level of reduction is discussed in the load allocation section of this report.

Table 13. Fecal coliform bacterial levels in terms of the geometric mean and 90th percentile observed at monitoring locations within the Colville National Forest, June through September, from 1990 to 2004.

Water Body	Township/Range/Section	n	Geometric Mean (cfu/100mL)	90th Percentile (cfu/100mL
American Fork	40 / 38 / 14	12	3	14
Beestrom Creek	36 / 41 / 20	15	21	**204**
Beestrom Creek	36 / 41 / 20	23	26	**236**
Calispell Creek	32 / 43 / 21	20	17	53
Cottonwood Creek (Colville)	32 / 41 / 36	74	**55**	**305**
Cottonwood Creek (Kettle)	40 / 33 / 33	10	15	**207**
Cusick Creek	34 / 43 / 10	24	19	97
Cusick Creek	35 / 43 / 34	18	8	38
Deadman Creek	37 / 36 / 28	24	6	39
Deep Creek	40 / 36 / 12	17	5	25
EF LeClerc Creek	35 / 44 / 17	10	9	36
East Deer Creek	39 / 36 / 27	53	4	16
EF Crown Creek	39 / 38 / 02	67	8	45
Fisher Creek	40 / 37 / 33	13	14	84
Flat Creek	39 / 38 / 09	68	6	50
Green Mountain Creek	36 / 41 / 20	19	34	**397**
Green Mountain Creek	36 / 41 / 20	31	44	**624**
Gypsy Creek	39 / 45 / 19	11	1	2
Harvey Creek	38 / 44 / 30	21	2	7
Healey Creek	33 / 41 / 23	26	14	78
Independent Creek	40 / 35 / 15	31	5	30
Ione/Jim/Cedar Creek	38 / 43 / 31	21	6	22

Water Body	Township/Range/Section	n	Geometric Mean (cfu/100mL)	90th Percentile (cfu/100mL
Lambert Creek	37 / 33 / 01	47	39	**181**
Little Boulder Creek	39 / 36 / 04	11	2	7
Little Muddy Creek	38 / 42 / 35	15	10	63
Lost Creek	36 / 43 / 22	10	38	**229**
Martin Creek	39 / 36 / 15	47	10	91
McGahee Creek	36 / 35 / 15	34	3	12
Meadow Creek	38 / 41 / 33	59	9	40
MF Calispell Creek	32 / 43 / 19	10	15	49
Mill Creek	35 / 44 / 33	14	3	12
NF Chewelah Creek	33 / 41 / 18	22	17	47
NF Lone Ranch Creek	40 / 34 / 13	33	23	**151**
NF Lone Ranch Creek	40 / 34 / 23	11	72	**387**
NF St. Peter Creek	38 / 34 / 16	31	6	32
NF St. Peter Creek	38 / 33 / 24	10	46	**430**
NF San Poil River	37 / 33 / 25	16	16	**221**
NF Sullivan Creek	39 / 43 / 23	45	2	7
NF Trout Creek	38 / 32 / 15	52	5	34
Pierre Creek	40 /37 / 33	21	8	34
Pierre Creek	40 / 37 / 33	12	3	12
Rocky Creek	37 / 41 / 22	27	7	57
Ruby Creek	35 / 43 / 10	46	18	**112**
Scatter Creek	35 / 32 / 11	13	6	39
Sherman Creek	36 / 36 / 36	15	11	35
Smackout Creek	38 / 41 / 03	94	16	**114**
SF Boulder Creek	38 / 36 / 03	47	3	16
SF Boulder Creek	38 / 36 / 03	25	3	15
SF Chewelah Creek	33 / 41 / 23	92	36	**191**
SF Chewelah Creek	33 / 41 / 24	34	**83**	**390**
SF Chewelah Creek	33 / 42 / 19	26	2	7
SF Lone Ranch Creek	40 / 34 / 23	72	11	88
SF Lost Creek	36 / 43 / 22	18	**53**	**389**
SF Mill Creek	36 / 40 / 15	13	9	89
SF Mill Creek	36 / 40 / 24	56	24	**131**
SF Mill Creek	36 / 41 / 20	58	23	**125**
SF Mill Creek	36 / 41 / 21	15	31	**305**
SF O'Brien Creek	36 / 33 / 26	10	7	70
SF Sherman Creek	36 / 36 / 32	55	8	41
SF St. Peter Creek	38 / 34 / 29	56	11	79
Sullivan Creek	39 / 44 / 30	23	2	3
Tacoma Creek	34 / 43 / 22	20	6	33
Three-Mile Creek	39 / 43 / 12	29	1	3
Tonata Creek	39 / 32 / 11	57	5	32
WF LeClerc Creek	35 / 44 / 07	13	3	10
WF Trout Creek	38 / 32 / 34	21	12	**107**
Wilson	33 / 41 / 23	23	**63**	**415**
Wilson	33 / 41 / 24	16	39	**163**
Winchester Creek	32 / 43 / 06	15	17	**163**

Streams exceeding criteria **n= sample number**

pH

Discussion of the pH Data

A review was conducted of pH data collected by the Forest Service at 84 monitoring stations located throughout the Colville Forest. At these locations, the pH measurements were typically collected bi-monthly from April through November, though sampling frequency or the period of record was not uniform for all of the stations. Station names, their locations within the forest, the number of observations (n), and a statistical overview of the data are included in Table 14.

While pH was collected at more than 84 monitoring stations, those selected for analysis required at least 10 pH measurements collected since 1990. Because some of the monitoring sites have a larger data record than others, the analysis was directed toward providing a generalized overview of pH variation across the forest as opposed to a station-by-station comparison. For each station's dataset, percentile statistics were generated including a determination of the median (50^{th}) , 75^{th} percentile, 25^{th} percentile, minimum, and maximum (Table 14).

Table 14. pH levels by percentile based on each monitoring stations dataset.

Monitoring Station	T / R / S	n	pH Percentiles					Median Conductivity	Group
			Max	75th	50th	25th	Min		
Addy	33 / 39 / 13	22	8.8	8.3	8.1	8.0	7.5	125	B
American Fork	40 / 38 / 14	22	8.4	8.3	8.2	7.9	7.7	180	A
Barnaby	35 / 36 / 33	20	8.8	8.2	8.0	7.9	7.4	83	D
Calispell	32 / 43 / 21	21	8.2	8.0	7.9	7.8	7.0	40	B
Cee Cee Ah	34 / 44 / 28	20	8.3	8.0	7.8	7.7	7.6	50	B
Cottonwood (Colville)	32 / 41 / 36	40	8.6	8.0	7.7	7.3	7.1	65	B
Cottonwood (Kettle)	40 / 33 / 33	17	8.3	8.1	8.0	7.9	7.6	130	F
Cusick	34 / 43 / 10	19	8.4	8.1	8.0	7.8	7.6	210	B
Deadman	37 / 36 / 28	40	8.4	8.2	8.0	7.9	7.5	150	D
Deemer	39 / 45 / 03	16	8.4	8.3	8.2	8.0	7.9	120	C
Deep	40 / 36 / 12	21	8.6	8.4	8.3	8.1	7.6	209	A
E Deer	39 / 36 / 27	59	8.5	8.3	8.1	8.0	7.4		
EB LeClerc	35 / 44 / 17	26	8.5	8.1	7.9	7.9	7.1	83	B
EF Cedar	40 / 42 / 17	19	8.7	8.5	8.3	8.3	8.0	225	A
EF Crown	39 / 38 / 02	49	8.6	8.3	8.2	8.1	7.7	408	E
EF Smalle	33 / 43 / 27	18	8.3	7.8	7.5	7.4	7.3	40	B
Fisher	40 / 37 / 33	11	8.6	8.5	8.4	8.3	8.1		
Flat	39 / 38 / 09	47	8.8	8.2	8.1	8.0	7.7	383	E
Gypsy	39 / 45 / 19	26	8.3	8.2	8.2	8.1	8.0	140	C
Hall	35 / 34 / 35	21	8.4	8.1	7.9	7.8	7.1	60	D
Hande	36 / 42 / 19	18	8.4	8.1	8.0	7.9	7.6	143	B
Harvey	38 / 44 / 30	43	8.7	8.3	8.1	7.9	7.0	105	C
Harvey (upper)	37 / 44 / 02	14	8.5	8.3	8.2	8.0	7.6		
Independent	40 / 35 / 15	33	8.5	8.1	8.0	7.9	7.5	100	F
Ione/Jim/Cedar	38 / 43 / 31	40	8.4	8.2	8.0	7.8	7.2	163	C
Jump-off-Joe	36 / 40 / 09	12	8.6	8.4	8.3	8.2	8.1		
L. Boulder	39 / 36 / 04	26	8.7	8.4	8.3	8.2	7.9	250	E
L. Muddy	38 / 42 / 35	32	8.4	8.1	8.0	7.9	7.2	103	C
LaFleur	40 / 33 / 28	16	8.4	8.1	8.0	7.9	7.6	120	F
Lambert	37 / 33 / 01	26	8.5	8.2	8.1	8.0	6.5		
Lost	36 / 43 / 22	27	8.4	8.0	7.8	7.6	7.1	76	B
M/N F Harvey	38 / 44 / 35	11	8.6	8.2	8.1	8.0	7.9		
Martin	39 / 36 / 15	17	8.5	8.5	8.4	8.2	7.6	420	E
McGahee	36 / 35 / 15	54	8.4	7.9	7.8	7.6	7.4	90	D
Meadow	38 / 41 / 33	35	8.7	8.5	8.4	8.2	6.5	289	A
MF Calispell	32 / 43 / 19	27	8.2	8.0	7.8	7.7	7.2	40	B
MF Mill	36 / 40 / 15	15	8.7	8.4	8.4	8.3	8.1	265	A
Mill (Pend Oreille)	35 / 44 / 33	31	8.3	8.0	7.9	7.8	7.4	60	B
N/S Fk Tacoma	34 / 43 / 34	14	8.0	7.8	7.7	7.5	7.2		
NF Boulder	38 / 36 / 03	23	8.8	8.3	8.2	7.9	7.5		
NF Chewelah	33 / 41 / 07	35	8.5	8.2	8.0	7.9	7.4	80	B
NF Lone Ranch	40 / 34 / 23	24	8.5	8.3	8.2	8.0	7.4	300	E
NF Mill	37 / 40 / 24	16	8.6	8.4	8.3	8.2	8.1	227	A
NF O'Brien	36 / 34 / 22	21	8.6	8.1	7.9	7.8	7.5	80	D
NF San Poil	37 / 33 / 26	36	8.6	8.1	8.0	7.8	7.1	118	D
NF St. Peter	38 / 33 / 24	17	8.2	8.1	7.9	7.8	7.7		
NF Sullivan	39 / 43 / 23	62	8.5	8.2	8.1	7.9	7.2	108	C

Monitoring Station	T / R / S	n	pH Percentiles					Median Conductivity	Group
			Max	75th	50th	25th	Min		
NF Trout	38 / 32 / 15	24	8.5	8.1	8.1	8.0	6.5	188	F
Nine-Mile	35 / 33 / 18	17	8.4	8.3	8.2	8.0	7.6	150	D
Nine-Mile (upper)	35 / 33 / 02	12	8.3	7.9	7.8	7.6	7.1		
Noisy	38 / 44 / 18	15	8.6	8.3	8.2	8.1	7.9		
Pierre	40 / 37 / 33	43	8.8	8.4	8.3	8.1	7.9	320	E
Pierre	40 / 37 / 33	16	8.5	8.3	8.2	8.2	8.0	350	E
Rocky	37 / 41 / 22	33	8.7	8.4	8.2	8.1	7.7	180	A
Ruby	35 / 43 / 11	26	8.3	8.0	7.9	7.7	7.5	80	B
Ruby	35 / 43 / 10	76	8.4	8.0	7.8	7.6	6.9	67	B
Scatter	35 / 32 / 12	25	8.5	8.3	8.2	8.0	7.7	220	F
SF Boulder	38 / 36 / 03	55	8.6	8.4	8.2	7.9	7.3		
SF Boulder	38 / 36 / 03	75	8.6	8.3	8.1	7.9	7.2		
SF Chewelah	33 / 41 / 23	77	8.8	8.1	8.0	7.8	6.5	80	B
SF Lone Ranch	40 / 34 / 23	44	8.5	8.3	8.1	8.0	7.6	280	E
SF Lost	36 / 43 / 22	33	8.5	8.1	7.9	7.7	7.3	70	B
SF Mill	36 / 40 / 15	27	8.5	8.4	8.3	8.2	7.4	220	A
SF Mill	36 / 40 / 24	15	8.5	8.4	8.3	8.2	7.7		
SF Mill	36 / 41 / 20	17	8.4	8.2	8.2	8.1	7.9		
SF O'Brien	36 / 33 / 26	40	8.8	8.2	8.0	7.8	6.5	100	D
SF Sherman	36 / 36 / 32	81	8.9	8.0	7.9	7.7	7.3	71	D
SF St Peter	38 / 34 / 29	24	8.5	8.4	8.3	8.2	7.8	340	E
Sherman	36 / 36 / 36	31	8.5	8.2	8.0	7.9	7.4	100	D
Silver	39 / 41 / 12	21	8.7	8.5	8.3	8.3	8.1	250	A
Slate	40 / 44 / 30	19	8.6	8.3	8.2	8.2	8.0	250	A
Smackout	38 / 41 / 03	80	9.0	8.5	8.4	8.2	7.5	250	A
Smalle	33 / 43 / 29	18	8.6	8.0	7.7	7.5	7.2	39	B
Sullivan (lower)	39 / 44 / 30	38	8.4	8.3	8.1	8.0	7.8	140	C
Sullivan (upper)	39 / 45 / 03	16	8.5	8.3	8.2	8.1	7.5	105	C
Tacoma	34 / 43 / 22	25	8.4	7.9	7.8	7.6	7.0	40	B
Thirteen-Mile	35 / 33 / 31	18	8.4	8.1	8.1	7.9	7.7	102	D
Three-Mile	39 / 43 / 12	49	8.5	8.1	8.0	7.7	7.1	350	E
Tonata	39 / 32 / 11	35	8.6	8.5	8.4	8.3	8.1	300	A
U.S.	39 / 36 / 04	13	8.8	8.3	8.1	7.9	7.7		
WB LeClerc	35 / 44 / 07	33	8.4	8.1	8.0	7.9	7.0	115	B
WF Trout	38 / 32 / 35	10	8.3	8.1	8.1	7.9	7.8		
Winchester	32 / 43 / 06	33	8.5	7.9	7.7	7.6	7.0	45	B

n= sample number

Wide swings in pH can be indicative of surface waters impacted by excessive nutrient inputs. A high nutrient supply leads to elevated primary productivity which, through photosynthesis and respiration, can result in heightened variation in pH. In order to assess for this type of impact, sampling typically takes the form of examining the diurnal variation in pH during periods when peak primary productivity is expected. Unfortunately, the Colville Forest pH data was collected as a single daily measurement as opposed the more frequent (i.e., hourly) measurements required to determine whether there is a connection between nonpoint source impacts and elevated pH levels. However, for the majority of the stations, the data was collected during periods when peak productivity is expected (mid-day during the summer months) as well as during periods of lower productivity (early-spring and late-fall). For this reason, when the data for each station are examined collectively, the difference between the maximum and minimum observed pH levels provides some indication as to whether a particular monitoring location is impacted by excessive nutrient inputs leading to elevated primary productivity.

Maximum pH levels observed at the monitoring locations varied between 8.0 and 9.0 standard units with an overall median of 8.5 (Table 15). Of the 84 monitoring locations considered, 32 (or 38 percent) had maximum pH levels above 8.5 - the upper level of the pH water quality criteria. Minimum pH values for the majority of the stations were also elevated. The range for the minimum levels was 6.5 to 8.1, with an overall median of 7.5. As a reference, within the forest North Fork Sullivan Creek serves as a source of drinking water and therefore, has restricted access, limiting potential sources of nonpoint source pollution, has maximum, minimum, and median pH levels of 8.5, 7.3, and 8.1, respectively.

Stations with more elevated minimum pH levels had lower overall ranges (difference between the minimum and maximum pH values). Stations with minimum pH levels between 7.9 and 8.1 had an overall median range of 0.6 as opposed to stations with minimum pH levels of 7.0 to 7.1, with overall median range of 1.4. This indicates that both of these groups, while sharing a similar upper pH level (the overall median of the maximum pH levels for both groups is approximately 8.5), have different factors that affect their pH levels.

Of the 84 monitoring locations, 43 (or 51 percent) have an overall range of less than 1. For the other 41 stations, the range varied between 1.0 and 2.3 with an overall median level of 1.3. Three locations had pH variation greater than 2 including: South Fork Chewelah, Meadow, and South Fork O'Brien. The maximum variation of 2.3 was observed at South Fork O'Brien Creek and South Fork Chewelah Creek.

In summary, pH levels observed at the majority of the monitoring stations are elevated with 32 of the 85 sites monitored having maximum pH levels observed above the water quality criteria of 8.5. However, minimum pH levels were also observed at elevated levels, resulting in only minor overall variation in pH. This indicates that for the majority of the monitoring locations factors other than nonpoint source pollution have a greater affect on pH within the Colville Forest suggesting geologic setting as a primary influence.

pH Analysis Approach

To analyze the connection between surface geology and pH, an ArcView geographic information systems (GIS) project was created. GIS covers utilized in the analysis included: the pH monitoring locations (refer to Table 14), the Colville Forest boundary, a 1:24,000 scale stream layer, and the 1:250,000 scale Northeast Quadrant geologic map of Washington **(**Stoffel, 1991**)**. The attribute table of the monitoring site point cover was modified with the pH analysis results presented in Table 14. In addition, the attribute table of the geology polygon cover was modified by grouping various individual geologic units into a more generalized classification scheme based on their origin. These geologic groups included meta-sedimentary, metamorphic, volcanic, sedimentary, intrusive, and mixed igneous/metamorphic.

Analysis Results

Initially, the monitoring stations were sorted in ascending order based on their respective median pH level. As discussed earlier, median pH levels across the forest were uniformly elevated with a range from approximately 7.7 (there was a single station with a median pH of 7.5) to 8.4. Based on the spread in the median pH levels, the monitoring stations were then divided into four groups, 7.7-7.8, 7.9-8.0, 8.1-8.2, 8.3-8.4. When the pH data are presented in this way, it is evident that there is a distinct spatial pattern to the location of the monitoring stations and observed median pH levels. This relationship is particularly evident for stations with the highest and lowest pH levels.

Of the twelve stations with the lowest median pH levels (7.7-7.8), nine are tributaries to the Pend Oreille River, situated south of the Lost Creek confluence. These stations include East Fork Smalle Creek, North and South Fork Tacoma Creek, Winchester Creek, Smalle Creek, Middle Fork Calispell Creek, Ruby Creek, Tacoma Creek, and Cee Cee Ah Creek. Similarly, the thirteen stations with the highest median pH levels, nine are located in tight proximity within the Alladin Valley north of the town of Colville. These stations include Jump-Off-Joe Creek, North Fork Mill Creek, Silver Creek, South Fork Mill Creek, East Fork Cedar Creek, Middle Fork Mill Creek, Smackout Creek, and Meadow Creek. Supporting the case for a geological explanation to the variation in pH levels, as opposed to nonpoint source pollution, is that while the Alladin Valley streams drain to three separate drainages including Mill Creek (tributary of the Colville River), Deep Creek (tributary to the Columbia River), and Cedar Creek (tributary to the Columbia River), they share similar geology.

A major feature of the geology within the Colville National Forest, particularly evident in its northeast section, is the presence of the Metaline Formation, a calcium-carbonate (limestone) deposit. The geology represented by the marine meta-sedimentary and the meta-carbonate series, both within the meta-sedimentary grouping of rocks are comprised of carbonate. Among the meta-carbonate series are the geologic units, Ocb (Ordovician, meta-carbonate), OCcb (Ordovician/Cambrian, meta-carbonate), and Ccb (Cambrian, meta-carbonate) representing the Metaline Formation.

The association between carbonate-based geology and monitoring stations with the highest median pH values was examined. As discussed earlier, the majority of the stations within the highest median pH levels are located within the Alladin Valley, situated just outside the town of Colville. Of the thirteen monitoring stations with median pH values between 8.3 – 8.4, the dominant geology within the drainage area of 9 of them is the carbonate meta-sedimentary grouping. The dominant geologic units represented in these drainages include Pmm (Permian meta-sedimentary), OCcb (Ordovician/Cambrian meta-carbonate), Cmm (Cambrian marine meta-sedimentary), and Pmcb (Permian meta-carbonate).

Further confirmation of the effect of the local geology on pH is evident for the monitoring stations that drain to the south flowing section of the Kettle River, lying to the west of the river in Ferry County. Within this section of the forest are the drainages of Little Boulder Creek, Martin Creek, East Deer Creek, and Boulder Creek (including its north and south forks). The dominant geologic type within all of these drainages is metamorphic with all of the above monitoring stations having the geologic unit of pTmb (marble of pre-Tertiary origin) represented among the metamorphic types of rocks. Marble is compressed limestone and, depending on its level of exposure to erosive forces, can have a similar effect on surface water pH as limestone. The monitoring stations located within this section of the forest, from Little Boulder Creek to Boulder Creek, all have similar pH levels with an overall median and range of 8.2 and 1.1, respectively. Additional marble geology (pTmb) is present in the Scatter Creek and St. Peters Creek drainages.

In contrast, the dominant geology represented within drainage areas for monitoring stations within the lowest median pH levels (7.5 to 7.7) included: Kiat (Cretaceous, intrusive two-mica granite), Qgo (Pleistocene glacial outwash), Qgd (Pleistocene glacial drift), pChm (Precambrian heterogeneous metamorphic), and Yms (1&2) (Proterozoic Prichard Formation and Ravalli Group, respectively). This geology is dominant within the drainage areas of tributaries that flow to the Pend Oreille River below Lost Creek.

However, the presence or the absence of the meta-sedimentary geology is not always predictive of a particular range in pH. For instance, Tonata Creek (Kettle River basin, Ferry County) is included among the group of stations with the highest median pH ranges but does not share carbonate rock geology. This may be the result of the 1:250,000 scale resolution where the definition needed to analyze the geology present within these smaller drainages likely exceeds the mapping definition. In addition, the marine meta-sedimentary geology is less common as surface geology west of the southern flowing section of the Kettle River though there are identified outcroppings that extend beyond the western boundary of the Colville Forest.

In review, an initial analysis of the pH data suggests that, for the majority of the monitoring locations within the Colville Forest, geologic setting may be an important factor in understanding variation in pH levels. This is based on the following.

1) pH levels observed in surface waters across the forest are uniformly elevated.

2) The pH observed at all of the monitoring stations display relatively low variation in median levels.

3) The pH variation that is present within the forest occurs among groupings of stations and so has spatial influences.

Conductivity measurements were also collected at the time pH measurements were taken. The conductivity measurements were examined as a separate means to analyze the connection between surface geology and pH. Median conductivity levels for the pH monitoring stations have been included in Table 14. Conductivity provides an indirect measurement of the level of ions present in a solution through the ability of the solution to carry an electric current. In general, the greater the ion content of the solution the greater ability of the solution to carry an electric current resulting in a higher conductivity levels. (Conductivity is reported in units of micro-mhos per centimeter at 25^{o}C.) The reason for examining conductivity is that the concentrations of ions present within surface water are a reflection of the drainage geology particularly during the base flow period. For this reason, the level of conductivity is used as a surrogate indicator of geology and its influence on water quality and pH in particular.

The relationship between conductivity and ions (salts), reported as total dissolved solids, was examined. Median values of total dissolved solids and conductivity were determined from the same water quality dataset as used to analyze pH. This relationship is presented in Figure 11. As observed, there is a positive linear relationship between conductivity and total dissolved solids. Increases in total dissolved solids concentrations results in higher conductivity levels because the water has a greater capacity carry an electric current.

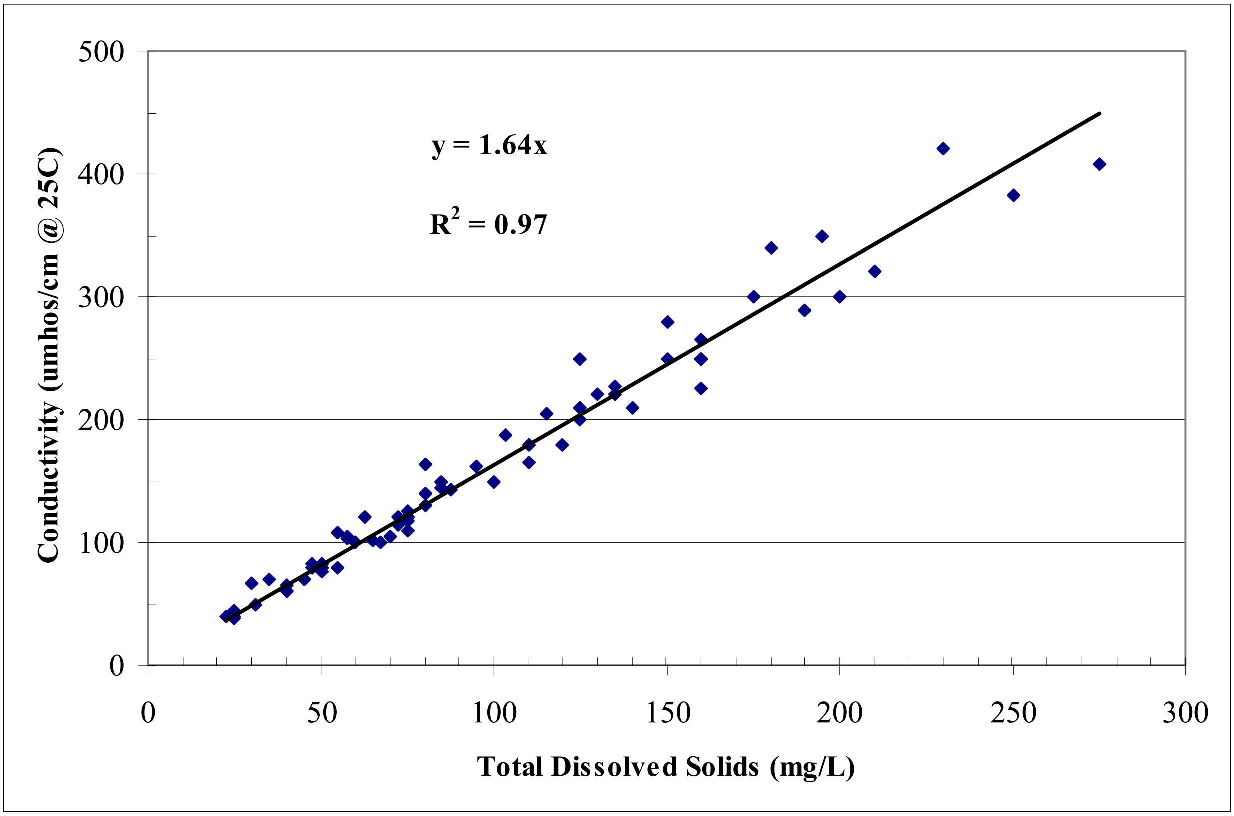

Figure 11. The relationship between total dissolved solids and conductivity observed at Colville Forest water quality monitoring stations.

As discussed earlier, a unique geological characteristic of the Colville Forest is the presence of major limestone deposits most pronounced in its northeast section. As limestone is dissolved, within certain streams of the forest, it dissociates into Ca^{+2} and CO_3^{-2} and in the process, increases conductivity. Free hydrogen ions (H^+) in solution will bond to negatively charged ions (cations) such as carbonate forming the common ion bicarbonate (HCO_3^-). When this occurs, free H+ is removed from solution, reducing its concentration and, therefore, resulting in an increase in pH. The measurement of pH only considers the level of the hydrogen ion (H^+) present in solution, while conductivity reflects the level and type of ions present in water (which includes H^+. However, the hydrogen ion is present at insignificant levels in relation to the major ions typically present. Unfortunately, no data are available which identify the types and levels of the major ions present in the forest streams monitored. But the level of conductivity and total dissolved solids provides an indication of the relative concentration of ions present in a surface water.

The relationship between median values of pH and conductivity at the monitoring stations was examined based on four pH ranges (7.7-7.8, 7.9-8.0, 8.1-8.2, and 8.3-8.4) (Figure 12). As evident from Figure 12, increasing pH levels are associated with increases in conductivity.

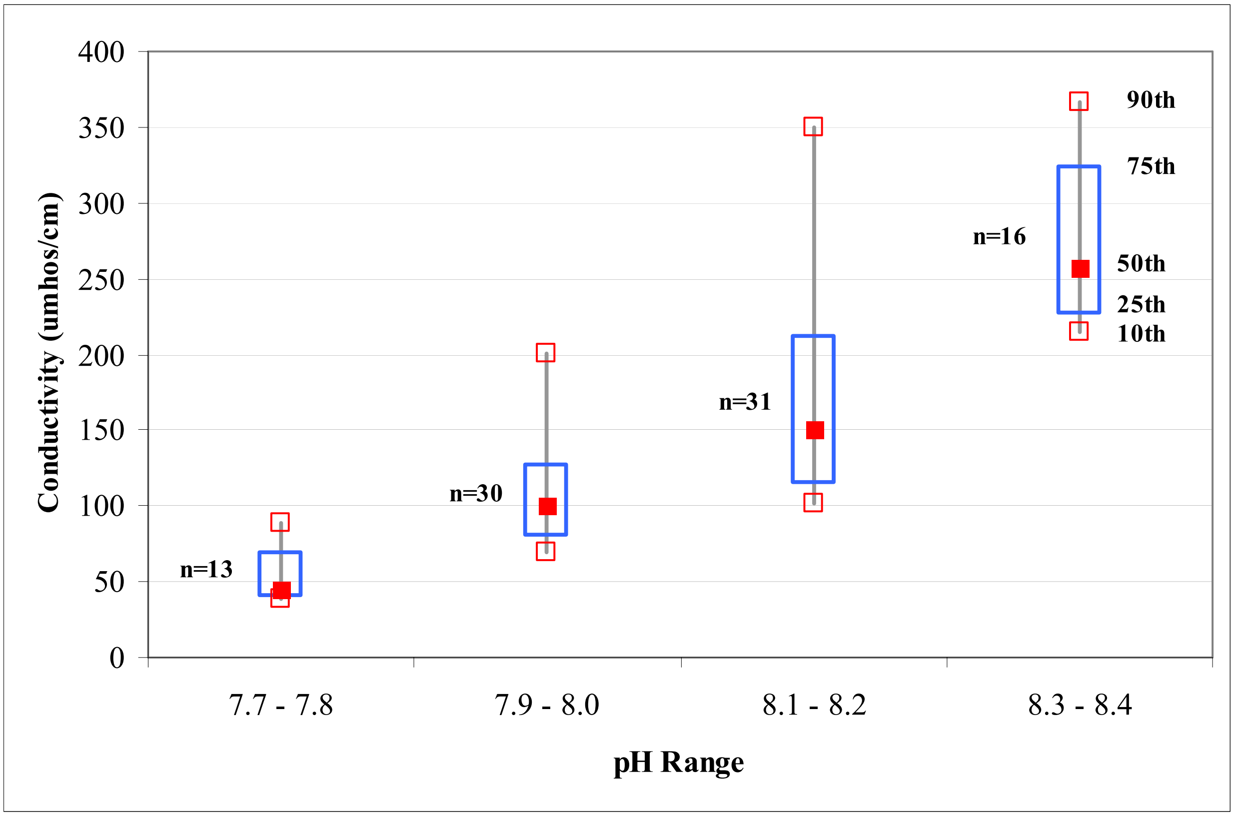

Figure 12. Box plots of the relationship between median ranges in pH and conductivity for monitoring stations within the Colville Forest.

To examine the relationship between pH and conductivity further, the monitoring stations were spatially grouped based on similar median pH values (Figure 13). It was the intention to form relatively tight clusters so that the water quality of the monitoring stations, as represented by pH and conductivity, was reflective of the dominant geology present within the group. In total, seven groups were determined (identified in Figure 13 as A through G). Figure 13 also displays the major geologic classifications for the forest. Once the groups were formed, median conductivity levels were plotted against median pH levels observed at each of the monitoring stations (Figure 14).

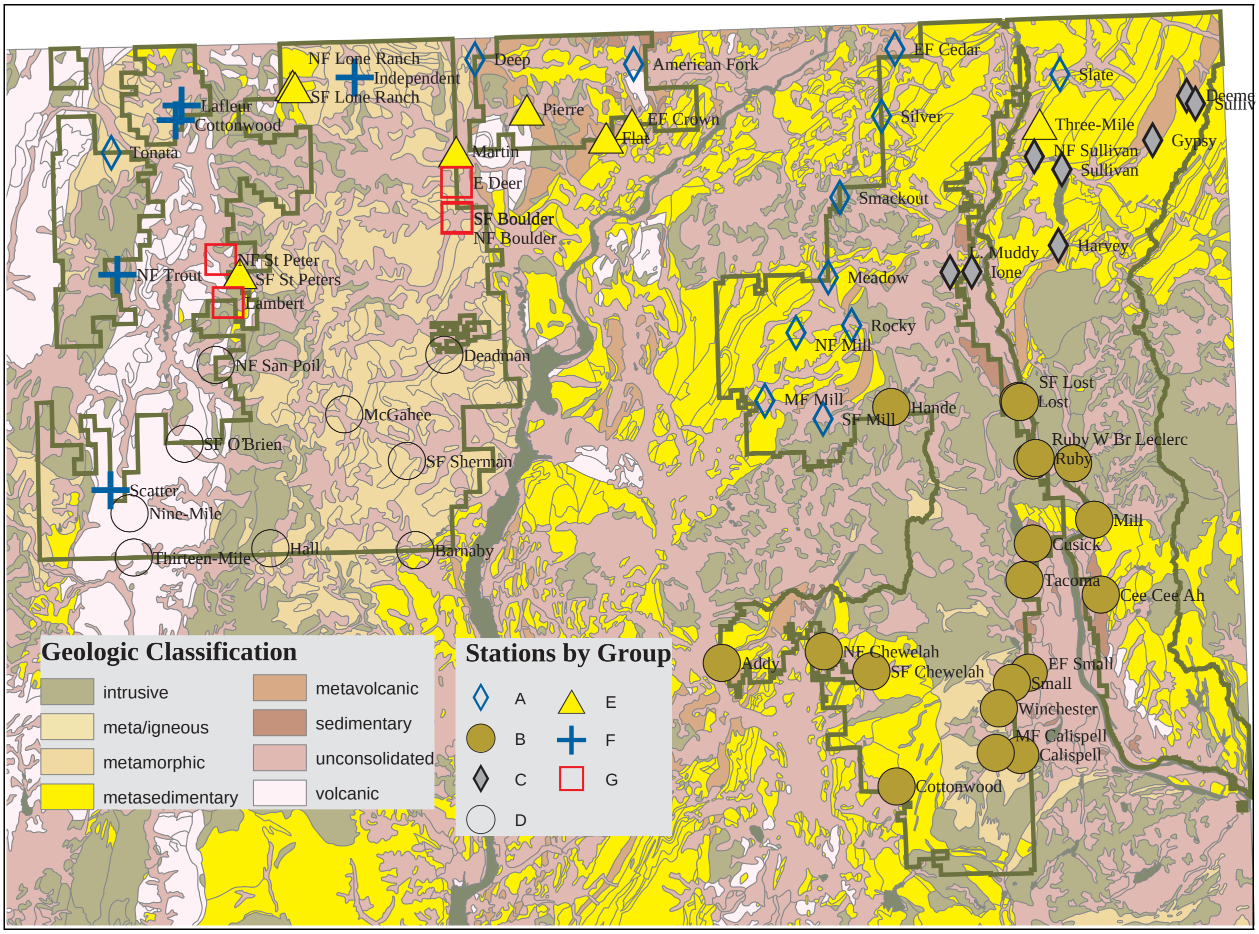

Figure 13. Monitoring stations grouped by common pH characteristics along with the generalized regional geologic classification.

The monitoring stations exhibit a relatively close relationship between pH and conductivity (the power relationship for the data set has a coefficient of determination equal to 0.67). An important characteristic of Figure 14 is that while the majority of the stations tend to display a positive relationship between pH and conductivity, the groups occupy differing positions along the overall trend line depending on their collective pH and conductivity levels. This further indicates that across the forest geologic influences, as expressed by conductivity, have a significant influence on pH.

At the extreme lower end of the relationship are the monitoring stations represented by group B with median pH and conductivity levels of 7.9 and 70 umhos/cm, respectively, as opposed to group A with median pH and conductivity levels of 8.3 and 238 umhos/cm. The dominant geology of the group A sites is meta-sedimentary (limestone), while the geology of group B is primarily of intrusive origin. Less well defined are groups such as E and C which have a tenuous relationship between pH and conductivity though the highly discontinuous geology common to these areas may be the explanation. The majority of the stations forming group E are outliers

with more elevated conductivity levels in relation to their pH when compared to the other stations. The stations forming this group are all situated within meta-sedimentary geology and are primarily situated within the most northern boundary of the forest. To determine why these streams are distinguished, ion analyses and a more detailed understanding of the geology is required.

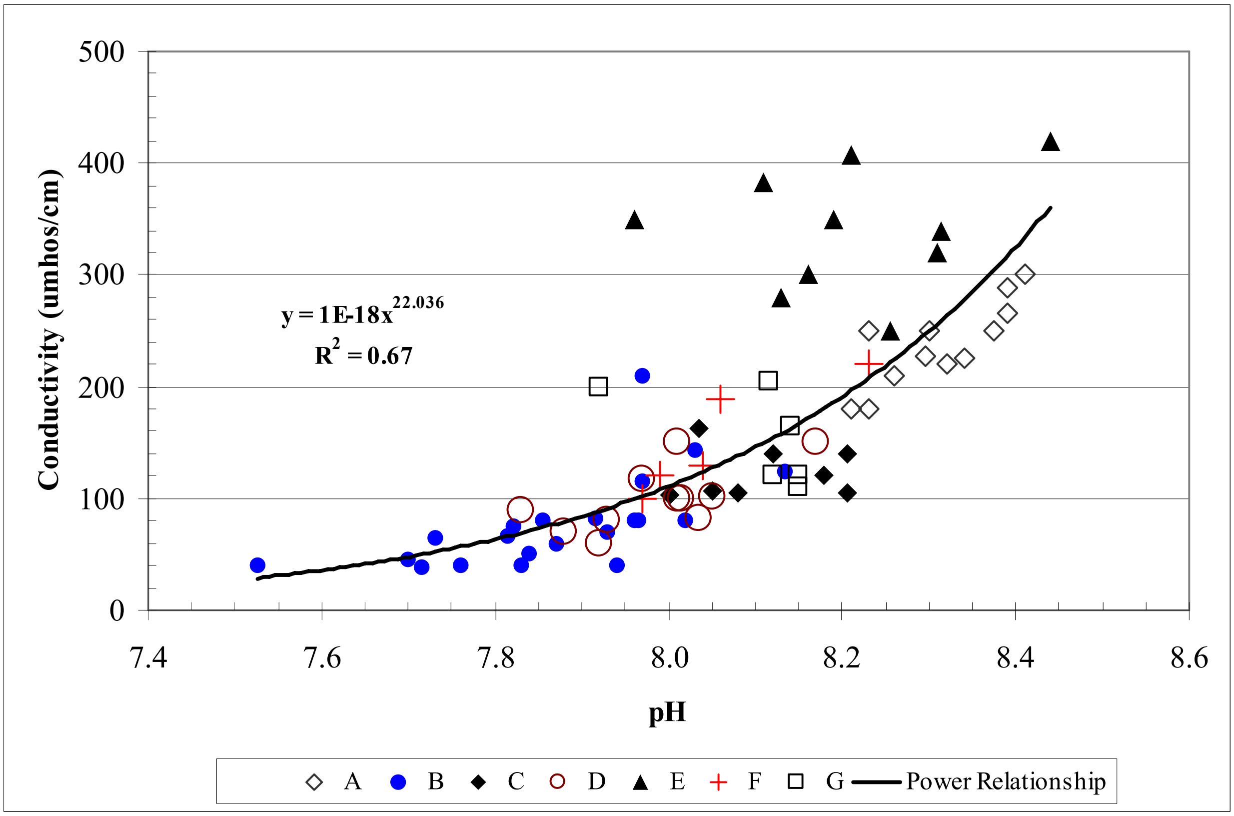

Figure 14. The relationship between median pH and conductivity levels observed at forest monitoring locations.

Dissolved Oxygen

Discussion of Dissolved Oxygen Data

Thirty-eight dissolved oxygen measurements have been collected at the South Fork Chewelah monitoring station since 1990. Approximately 80 percent of these measurements were collected in 1993. During that year, measurements were collected bi-monthly from April through October. The most recent measurements were collected in 2001. All of these data were grouped together and analyzed collectively.

The dissolved oxygen criteria that applies to the forest, which has a class AA designation, is that concentrations remain above 9.5 mg/L. Of the thirty-eight dissolved oxygen readings, three have been measured below the criteria. This occurred on August 16 and 30 of 1993 and August 30 of 2001.

The dissolved oxygen concentrations on all of these occasions were observed at 9.0 mg/L, 0.5 mg/L below the criteria. The 1993 readings resulted in South Fork Chewelah's inclusion on the 1998 303(d) list for dissolved oxygen impairment.

A box plot displaying the dissolved oxygen percentiles of the 38 measurements is presented in Figure 15. As observed, the majority of the dissolved oxygen concentrations are above the criteria. In interpreting the box plot, the dissolved oxygen concentration of 11.0 mg/L corresponds to the 75th percentile. This means that based on the samples collected, 25 percent are above and 75 percent are below 11.0 mg/L. Assuming the dataset provides a good representation of the variability in dissolved oxygen concentrations during the period April through October, then the 9.5 mg/L criteria is exceeded approximately 93 percent of the time. Because of the low frequency that dissolved oxygen levels have been observed below the criteria and, when it occurred, concentrations were only 0.5 mg/L below the criteria, together indicate that impacts associated with nonpoint source pollution are limited.

As a comparison, a box plot of dissolved oxygen concentrations observed in North Fork Sullivan Creek has also been included in Figure 15. North Fork Sullivan Creek is largely free from nonpoint source pollution impacts and serves as the drinking water source for the town of Metaline Falls. As observed, there is no significant difference in the dissolved oxygen concentrations between the two monitoring locations. In fact, North Fork Sullivan Creek has a greater range in dissolved oxygen concentrations with a low of 8 mg/L.

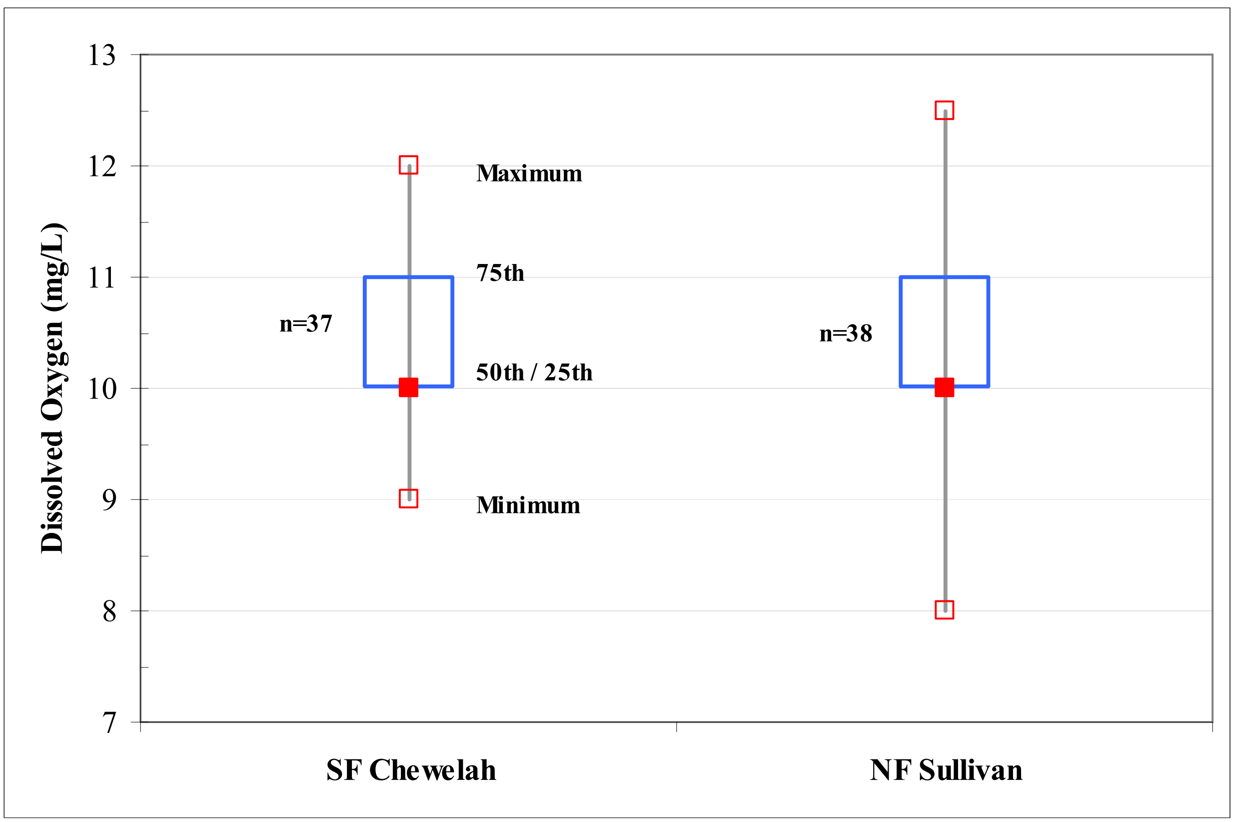

Figure 15. Box plots of dissolved oxygen concentrations observed at the South Fork Chewelah and North Fork Sullivan monitoring locations.

The South Fork Chewelah monitoring location was included on the 1998 303(d) list for pH, dissolved oxygen, temperature, and fecal coliform. The number of parameters listed, the most of any location on the forest, provides an indication that this location does have some nonpoint source pollution impacts.

In terms of water temperature, sampling conducted during this TMDL found that temperatures during the summer period, were consistently below the 16°C criteria. However, the analysis of fecal coliform concentrations at the South Fork Chewelah monitoring location found concentrations consistently measured at levels exceeding criteria (Figure 16). High levels of fecal coliform bacteria are an indication that nutrient enrichment could be a concern at this location. Nutrient (phosphorus) inputs to streams can lead to increased primary productivity resulting in heightened variation in pH and dissolved oxygen.

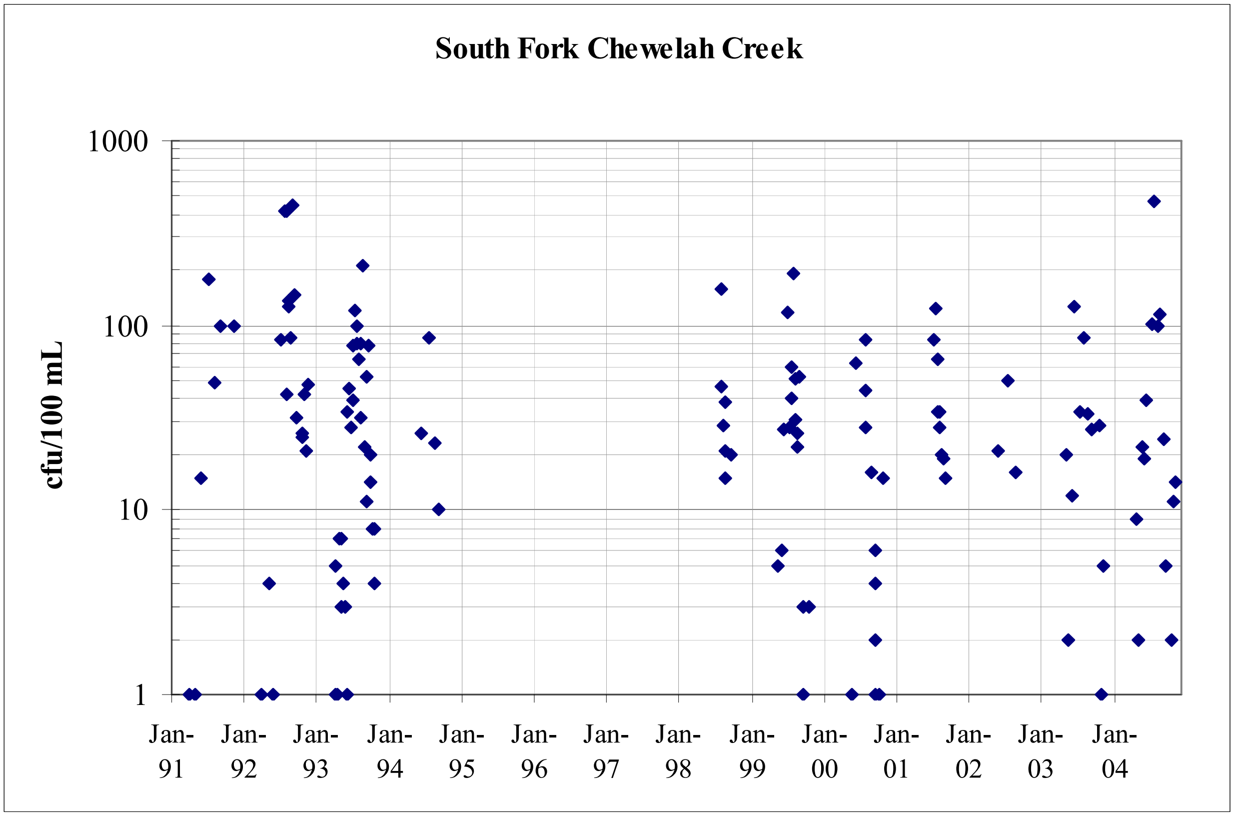

Figure 16. Fecal coliform bacteria levels (cfu/100ml) observed at the South Fork Chewelah monitoring station.

The connection between nonpoint source pollution and observed pH levels was determined by comparing pH levels measured during peak primary productivity periods (July/August) to those observed during periods when lower productivity is expected (April/October). This analysis was conducted on all 84 pH monitoring locations. The result of this analysis indicates that the South Fork Chewelah monitoring location has the greatest difference in pH between these two periods in comparison to the other monitoring stations. Only the South Fork O'Brien monitoring station had a similar level at 2.3. Its range was greater than 82 of the 84 stations. In addition, the South Fork Chewelah monitoring location has among the greatest maximum pH levels at 8.8.

The critical period for dissolved oxygen coincides with that of pH, July through August. This is when wide swings in dissolved oxygen can occur, depending on the level of primary productivity. If elevated primary productivity is present, the result of nonpoint source nutrient loading, then dissolved oxygen concentrations can have a heightened diurnal fluctuation corresponding to periods of peak photosynthesis and respiration. August was when the lowest dissolved oxygen concentrations were observed, though as mentioned previously, they were observed only 0.5 mg/L below the criteria. The highest dissolved oxygen concentrations in 1993 were observed in April averaging 11.5 mg/L and similar levels were observed in October. Both April and October are periods when primary productivity occurs at lower levels in comparison to July and August. The difference between average April/October and July/August dissolved oxygen concentrations which average 11 mg/L and 9.8 mg/L, respectively was 1.2 mg/L.

In summary, the higher range and maximum level of pH and chronically elevated fecal coliform bacterial levels both indicate that nonpoint sources impacts affect the water quality at South Fork Chewelah, though its effect on dissolved oxygen levels appears more limited.

Loading Capacity

Regulatory Framework

The foundation of a TMDL analysis is the water quality criteria. It provides the basis for the fundamental TMDL calculations, among them, the load capacity and load allocation.

Under the current regulatory framework for development of TMDLs, identification of the loading capacity is a critical element. The loading capacity provides a reference for calculating the amount of pollutant reduction needed to bring an impaired water into compliance with the water quality criteria. The United States Environmental Protection Agency (EPA) defines loading capacity as “the greatest amount of loading that a water can receive without violating water quality standards.” Allocations are defined as the portion of a receiving water’s loading capacity that is allocated to point, nonpoint, and natural sources. By definition, TMDLs are the sum of the allocations *[40 CFR §130.2(i)]*.

Water Temperature

Heat is a pollutant when excessive heating of water to levels above the water temperature criteria result from human activities. In this analysis, rather than setting the load capacity based on heat, the surrogate measure, percent effective shade, has been used. Percent effective shade is the amount of solar shortwave radiation blocked by vegetation and topography.

The major source of heat to surface waters within the Colville Forest is solar shortwave radiation. Greater exposure to solar shortwave radiation leads to increased maximum water temperatures. Exposure within forested environments is primarily based on the level of shade, a function of riparian vegetation (tree height, canopy density, buffer width) and topographic characteristics. For this reason, the load capacity and load allocations are described in terms of percent effective shade. The percent effective shade presented in this report is the daily average observed on August 1 over a two-kilometer reach above the monitoring location. In addition, within this analysis, the load allocation is the percent effective shade level necessary to reduce water temperatures to the water quality criteria of 16^{o}C while the load capacity is the percent effective shade provided by potential natural vegetation (refer to Table 15).

Fecal Coliform Bacteria

The load capacity for fecal coliform bacteria is defined by meeting both parts of the criteria during the critical period (June through September) with overall concentrations remaining at or below 50 cfu/100mL and the 90th percentile (from the same dataset) remaining at or below 100 cfu/100mL (refer to Table 16).

pH

Geologic setting is a significant factor influencing pH for the majority of the monitoring stations. The determination of load capacity and allocations for the forest recognizes that natural factors as opposed to nonpoint pollution sources result in elevating the expected pH range.

Dissolved Oxygen

The load capacity for dissolved oxygen is defined by achieving the criteria during the critical period (June through September) with concentrations remaining above 9.5 mg/L.

Natural Conditions

Water Temperature

A complication in using mechanistic models to develop load allocations (in terms of effective shade) is that the result may not be achievable. This occurs when the vegetative height, associated with mature riparian vegetation, is not tall enough or of sufficient density to shade the entire active channel. In these cases, and for situations where the numeric criteria is naturally exceeded such as outflow from lakes and wetlands, the natural conditions clause of Washington's water quality standards is applied [WAC 173-201A-070(2)]. This means that the temperature that results from shade provided by mature riparian vegetation becomes the criteria, and the effective shade level associated with these conditions becomes the loading capacity. Therefore, a component of the temperature analysis looked at the effective shade that resulted from the potential natural vegetation. The potential natural vegetation is then compared with the effective shade level estimated by the model as necessary to meet the temperature criteria.

Fecal Coliform Bacteria

North Fork Sullivan Creek, serving as a drinking water source for the community of Metaline Falls, has been monitored for fecal coliform bacteria levels over an extended period (Figure 17). This drainage, because of its importance as a water supply, has restricted access to both cattle and humans though wildlife can access the drainage freely. For this reason, the levels and variation in bacterial levels observed in North Fork Sullivan Creek are representative of natural conditions. Historically, bacterial concentrations have all been observed well within criteria.

pH

Analysis results of pH data indicate that natural sources are a significant factor in explaining elevated pH levels found at many locations throughout the Colville Forest. This is largely the result of carbonate geology common to the area. pH levels are uniformly elevated throughout the forest, and what little variation that does exist can be explained by the prominence or absence in carbonate geology.

Dissolved Oxygen

The variation in dissolved oxygen concentrations expected under natural conditions were considered by examining the concentrations observed at North Fork Sullivan Creek. North Fork Sullivan Creek is a drinking water source for the town of Metaline Falls with limited potential nonpoint source pollution impacts.

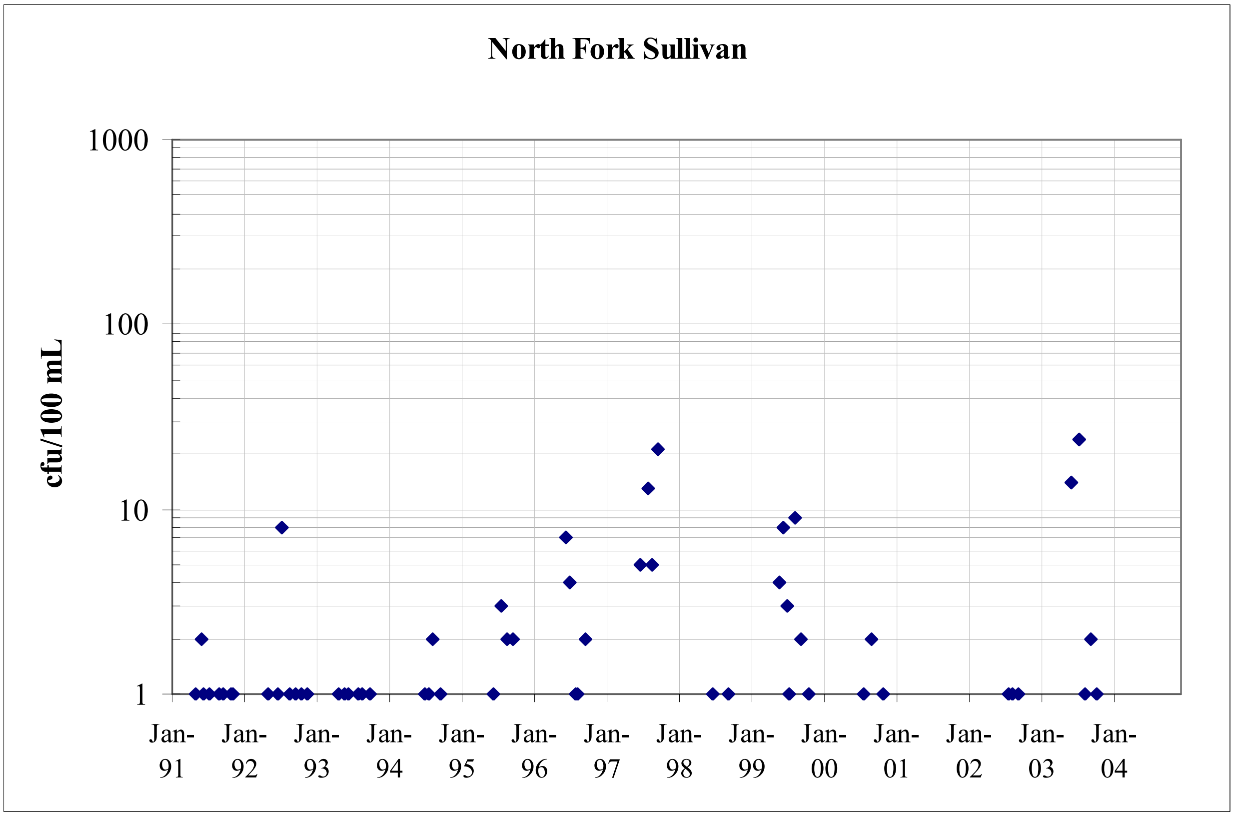

Figure 17. The variation in fecal coliform bacterial levels observed at the North Fork Sullivan monitoring station are reflective of natural conditions.

Load Allocations

Water Temperature

Under the current regulatory framework for development of TMDLs, flexibility is allowed for specifying allocations. Load allocations can be expressed in terms of either mass per time, toxicity, or other appropriate measures. This TMDL assessment uses percent effective shade as a surrogate measure of solar shortwave radiation to fulfill the requirements of Section 303 part (d) of the Clean Water Act.

Effective shade is defined as the fraction of the potential solar shortwave radiation that is blocked by vegetation and topography before it reaches the stream surface. In contrast, allocations could have taken the form of energy per unit area per time (heat load) such as Watts/square meter per hour, however, that measure is less relevant in guiding management activities needed to solve identified water quality problems. Percent effective shade can be linked to specific source areas and therefore to corrective riparian management actions. For this reason, percent effective shade is used as a surrogate to the thermal load as allowed under EPA regulations (defined as “other appropriate measure” in 40 CFR §130.2(i)).

Shade Allocations

Following calibration, each water temperature model run, for a particular monitoring location, provides a reflection of the current condition. However, the primary utility of the model is to determine, for those stations with elevated water temperatures, the level of effective shade necessary to reduce water temperatures to meet the 16^{o}C water quality criteria. By this process, once the temperature model was calibrated for a specific stream reach, only the effective shade input was altered to effect a change in water temperature. This was the method used to determine the load allocations for the 303(d) listed and impaired water bodies on the Colville Forest.

Water bodies within the Colville National Forest that are included on the 1996 and 1998 303(d) list for temperature along with those found to have temperatures exceeding the water quality criteria (impaired) during this study, are included in Table 15. (The 303(d) listed streams in Table 15 are indicated in bold type.) For each of the listed and impaired sites, Table 15 includes the current effective shade level. An additional column displays the percent effective shade level required to achieve the temperature criteria (16^{o}C). These shade levels were determined using the Temperature Response Model and are the TMDL load allocations. The difference between the allocation and current shade level is the increase necessary to achieve the water quality criteria at each monitoring site. The last column in Table 15 is the effective shade provided by the potential natural vegetation and is therefore, the shade level expected, provided optimal vegetative growth conditions. Its level is determined from Figure 9 based on the bankfull width and potential natural vegetation setting. The effective shade levels associated with the natural potential vegetation is the load capacity. The average bankfull width for a particular stream reach within the Colville National Forest can be estimated using the regression relationship between drainage area and bankfull width based on monitoring site data (Appendix B).

Table 15. Shade allocations for 303(d) listed and temperature impaired sites.

Water Body	Current Effective Shade (%)	Load Allocation (Effective Shade to Achieve 16°C) (%)	Increase in Shade Needed (%)	Load Capacity (Site Potential Effective Shade) (%)
Addy Creek	67	74	7	95
Barnaby Creek	66	70	4	92
Big Muddy Creek	75	82	7	93
Boulder Creek	50	81	31	58#
Brown's Lake Outlet	===	===	===	98
Calispell Creek	58	76	18	79
Cee Cee Ah Creek	84	84	0	92
Cedar Creek (Lower)	51	79	28	95
Cedar Creek (Upper)	74	84	10	95
Cusick Creek	53	82	29	96
Deadman Creek	70	77	7	81
Deep Creek	81	81	0	93
EF Crown	66	80	14	95
EF LeClerc Creek	55	80	25	85
Jim Creek	75	80	5	96
Little Muddy Creek	66	76	10	94
LaFleur Creek	62	72	10	93
Lambert Creek	70	85	15	91
Lime Creek	88	===	===	97
Lost Creek (Lower)	39	67	28	92
Lost Creek (Upper)	75	84	9	96
MF LeClerc Creek	60	84	24	96
NF Chewelah Creek	52	74	22	89
Nile Lake (Inflow)	51	72	21	96
Nile Lake (Outflow)	===	===	===	94
Rocky Creek	78	79	1	94
Ruby Creek	60	83	23	89
SF Boulder Creek	55	80	25	75#
SF Chewelah Creek	===	===	===	Meets Criteria
SF Lost Creek	70	83	13	94
SF Mill Creek	62	74	12	89
SF O'Brien Creek	69	84	15	93
SF Sherman Creek	32	81	49	87
Sherman Creek	36	78	42	58#
Sullivan Creek	===	===	===	64
Tacoma Creek	70	81	11	87
Tonata Creek	79	84	5	88
Winchester Creek	74	81	7	94

303(d) list water bodies
Site potential shade

For water bodies where an increase in percent effective shade necessary to achieve the temperature criteria is below approximately ten percent, then likely no active implementation of best management practices are necessary. Instead, priority should be given to water bodies with required increases above approximately fifteen percent and particular attention to those above eighteen percent. For example, water bodies such as Calispell Creek, Ruby Creek, Nile Creek (Inlet), North Fork Chewelah Creek, the Middle and East Forks of LeClerc Creek, and the lower reaches of Lost Creek, should all be evaluated for active implementation of best management practices such as riparian exclusion from grazing and the re-establishment of riparian vegetation.

Among the water bodies with elevated water temperatures that also were found to require some of the greatest increases in shading were Cusick Creek and lower Cedar Creek. However, both of these creeks are known to have substantial associated wetlands, particularly Cusick Creek. And therefore, it is necessary for more specific temperature monitoring that targets the influence of the wetlands on water temperature, and an evaluation of whether the current riparian vegetation is adequate in its shading potential..

The allocation of site potential shade was determined for the lake (or reservoir) outlet streams of Brown's Lake, Nile Lake, lower Lime Creek, and lower Sullivan Creek. Because of heat storage within these types of water bodies, the temperature of the discharge from them is greater. For this reason, these sites are not expected to achieve the water temperature criteria during the critical period, even when provided with optimal effective shade levels.

Other exceptions include water bodies requiring greater shade levels than can ever be achieved given site potential vegetation conditions. These water bodies include the mainstem and South Fork of Boulder Creek and Sherman Creek. The average bankfull width for these streams, in the monitoring reach, is 11 meters. The effective shade provided by potential natural vegetation for Boulder Creek (Douglas Fir) is 58 percent. Because its current effective shade level is 50 percent, a major change in the current temperature regime is not expected. However, for Sherman and South Fork Boulder Creeks, greater improvement in maximum water temperatures are possible because the difference between current and site potential shade conditions is approximately 21 percent.

For Sherman Creek, given site potential shade levels (58 percent) and using the 2003 calibrated temperature response model for the monitored reach, maximum water temperatures would be reduced from the observed 23.6^{o}C to 19.7^{o}C, reducing the diurnal range from 6.8 C to 5.0^{o}C. For South Fork Boulder, the site potential shade level applied to the 2003 model would reduce the maximum water temperature from 20.5^{o}C to 17.2^{o}C, decreasing the diurnal range from 4.8 to 3.1^{o}C. For mainstem Boulder Creek, the increase of 8 percent from the current shade level would decrease the annual maximum by 2.1^{o}C.

These monitoring locations had among the greatest drainage areas of the study locations and therefore also have among the greatest bankfull widths. Drainage areas for South Fork Boulder, Boulder Creek, and Sherman Creek, at the monitoring locations, are 178 km^2, 263 km^2, and 278 km^2. Excluding locations with high groundwater inflow, on average, approximately 80 percent effective shade is required to maintain annual maximum water temperatures below the temperature criteria of 16^{o}C (Table 15). Referring to Figure 9, an 80 percent effective shade level provided by site potential vegetation can occur, depending on the vegetation type, between a maximum bankfull width of approximately 6 meters (Douglas Fir, Parkland) to 8 meters (Douglas Fir/Grand Fir, Douglas Fir/Western Hemlock, Western Hemlock).

For bankfull widths greater than approximately 9-10 meters, site potential shade levels drop rapidly. Referring to Figure A, Appendix B, on average the drainage area represented by bankfull widths between 6 and 8 meters are 69 to 123 km^2. So it can be expected within the

Colville Forest, for stream reaches that receive drainage from areas greater than approximately 123 km^2 (even with optimal riparian growth conditions present), enough exposure will occur (due to a wider bankfull width) to elevate temperatures potentially above the temperature criteria.

A compensating factor to this potential increase in temperature is that flow and water depth also tend to increase with greater drainage area. So water yield, or the amount of flow per area, becomes an important factor in assessing a stream's vulnerability to heating. Large drainage areas with low water yields during the critical period (July-August) are susceptible to increased heating. Referring to Figure 4, the lowest water yields observed within the forest are primarily located in its western half - an area that includes Sherman and Boulder Creeks.

Simplified Approach to Landscape Shade Allocations

Continuous measurements of water temperature were collected at 62 monitoring locations within the Colville Forest during the summer months of 2002, 2003, and 2004. An overview of these data are presented in Table 2. As observed in Table 2, whether indicated by the annual maximum or the diurnal range, the water temperatures measured at each monitoring station do not vary significantly year to year.

For monitoring stations where water temperature was recorded for all three summer periods, (n=34) the median difference (maximum minus minimum of the annual maximum water temperature) was less than 1°C (0.85°C). The maximum difference was 2.1°C for Sherman Creek. So while there is considerable variation among the monitoring stations in terms of the annual maximum water temperature, from a low of approximately 11°C at West Fork Crown to a high of 25°C for the outlet of Nile Lake, the variation observed at each particular monitoring location is relatively low. This indicates that at each monitoring location, the factors influencing the heat flux are consistent year-to-year. Factors affecting water temperature that have little annual variability include: the channel cross-section, flow levels during the critical period, and effective shade levels. In addition, on the day the maximum water temperature occurs, many of the meteorological factors also have annual consistency.

- Channel Characteristics – Excluding major alterations in watershed hydrology or sediment supply, the average channel cross-section profile (through a study reach) remains relatively consistent year to year**.**

- Discharge Characteristics - During the critical period (July-August) when the warmest water temperatures occur, stream flow is maintained primarily by groundwater discharge. With the exception of an extended drought that resulted in a significant drop in the water table and therefore the storage of water, flow levels tend to remain at a fairly consistent level during the July-August period with only minor year-to-year variation. For this reason, the average depth of water through a reach (an important factor in influencing water temperature) also remains at consistent levels.

- Shade Characteristics - The height and density of riparian vegetation, while undergoing continual change, does so at a relatively small level particularly when assessed on a year-to-year basis. Riparian vegetation characteristics can change rapidly particularly given forces such as fire, catastrophic flood events, or major changes in the sediment supply, but across the forest landscape, changes to tree height and canopy density occur slowly. This low level of change means that riparian vegetation (height and density) effectively remains fixed in terms of effecting water temperature.

- Meteorological Characteristics - In terms of weather, the day the warmest water temperatures occur will be cloudless. For this reason, impedance on solar shortwave radiation will be solely a result of topographic setting and the riparian vegetation characteristics present above the study reach. The solar shortwave radiation load between mid-July to mid-August approaches the earth's atmosphere at a predictable level. So this factor, among the most important influences in the heating of surface waters, can also be considered relatively constant.

This indicates that most of the variables that determine the annual maximum water temperature of a particular stream location on the forest are relatively fixed. Continual change occurs for most of the variables though at a relatively insignificant level to affect dramatic shifts in water temperature when examined on an annual basis. Excluding streams with high localized spring discharge (groundwater stations) and locations below lakes, reservoirs, and wetlands (storage stations), the main factor that results in a particular monitoring location having an annual maximum water temperature of 16^{o}C as opposed to 22^{o}C, is the level of effective shade upstream of the monitoring location.

Recognizing the consistency in many of the variables that determine the annual maximum water temperature, a linear relationship was determined between the level of effective shade present above the monitoring stations and the maximum water temperature observed (Figure 18). In applying this relationship, the effective shade reported in this study is the average occurring over a 2-kilometer reach above the monitoring location. In addition, the relationship assumes that the forest streams share a common flow depth during the critical period of approximately 0.33 meters. In addition, the broad application of this relationship across the forest assumes that the physical and environmental characteristics present at the monitoring locations are representative of the variability found throughout the forest.

The groundwater and storage based monitoring locations have been removed from this relationship. (Refer to Table 4 for the categorization of the monitoring stations.) Streams that receive high levels of spring discharge, which on the forest will have a temperature between 9 and 11^{o}C, are largely buffered from increased exposure to shortwave radiation. For this reason, there is not a significant relationship between effective shade and the annual maximum water temperature for groundwater channels. The same is true for the streams with higher levels of storage present within their drainages. Lakes, wetlands, and reservoirs are highly exposed to solar shortwave radiation, and downstream reaches will typically have maximum water temperatures exceeding the criteria despite varying levels of shade. So the storage and groundwater channels are not as sensitive to shade, and including them in the relationship would result in bias. In addition, the exclusion of the groundwater stations also provides a more conservative estimate for this relationship.

The relationship between the annual maximum water temperature and percent effective shade provides a quick assessment tool. Annual maximum water temperature can be determined from an understanding of the effective shade. From this relationship, the level of effective shade required to meet the 16 °C temperature criteria is approximately 80 percent. (This is the same level found previously through the application of the temperature model.) The 80 percent confidence limits for the shade level required to achieve the temperature criteria is between 64 and 98 percent.

On average, for the 16°C temperature criteria to be achieved, a minimum of 80 percent effective shade is required at all stream locations within the forest. A margin of safety is achieved in this broad application through also evaluating the effective shade provided by natural potential vegetation. The effective shade goal should be to provide between 80 percent and what is possible by natural potential vegetation. It is recognized that in some limited cases even achieving the natural potential vegetation effective shade level will not be sufficient to maintain temperatures at or below 16°C. In these circumstances, the natural potential shade level becomes the default load allocation. As outlined previously, the shade level provided by natural potential vegetation for a particular location within the forest is determined by the following method: 1) identify the natural potential vegetation setting; 2) directly measure the bankfull width or estimate based on drainage area (refer to Figure A, Appendix B); 3) from the bankfull width determine the effective shade level based on the natural potential vegetation shade curves (Figure 9).

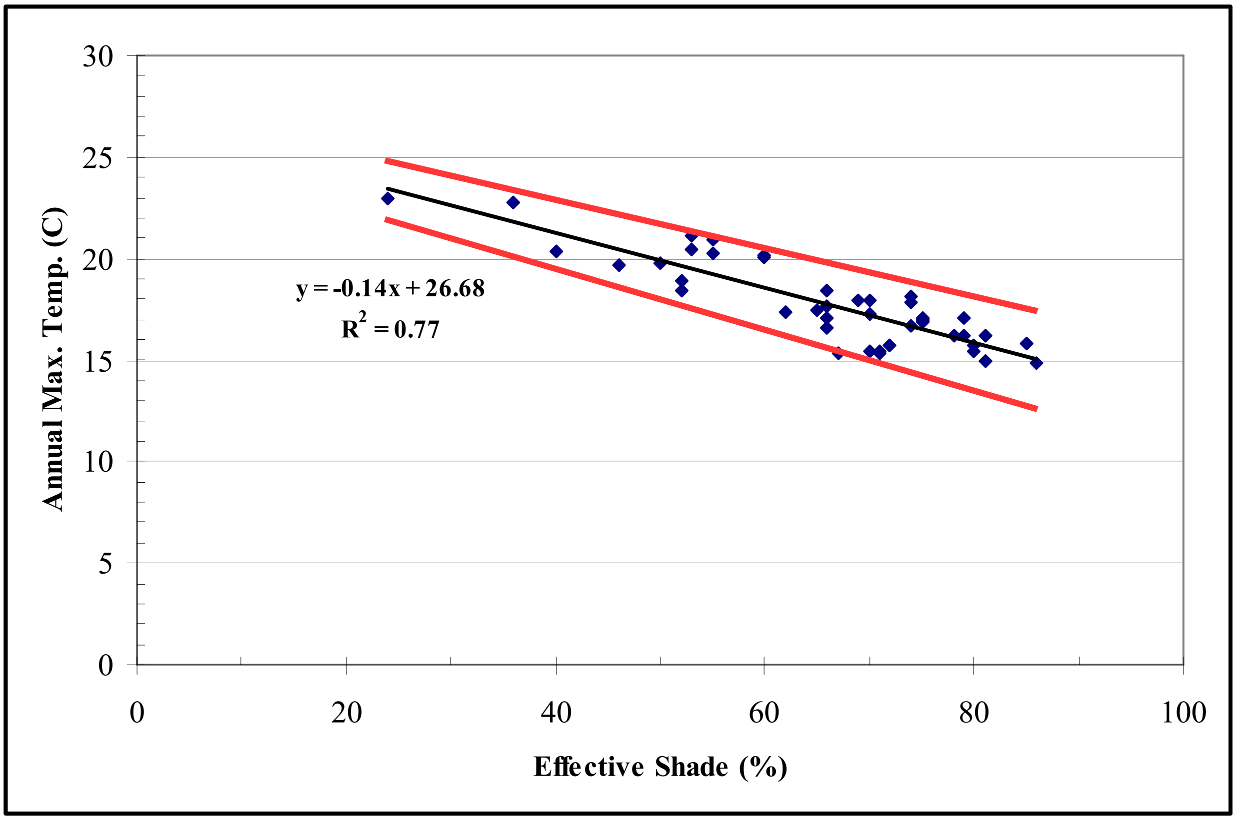

Figure 18. The relationship between effective shade (%) and the annual maximum water temperature observed at Colville Forest temperature monitoring locations along with the 80 percent confidence limits.

Fecal Coliform Bacteria

From the Class AA criteria, fecal coliform bacteria levels, based on a series of samples should have a geometric mean no greater than 50 cfu/100 mL and not more than 10 percent of the samples used for calculating the geometric mean exceed 100 cfu/100 mL.

For streams with elevated fecal coliform bacteria levels, the "statistical theory of rollback" (Ott, 1995) was used to determine concentration reductions needed to achieve the water quality criteria during the critical period, June through September. This technique provides a percent reduction statistic.

Table 16 summarizes the fecal coliform reduction percentages needed to meet both the geometric mean and the 90th percentile of the water quality criteria. The 90th percentile water quality criteria was generally more limiting than the geometric mean for estimation of the rollback percentage reported in Table 16.

Table 16. Allocations in terms of percent reduction in concentration to achieve the 90th percentile fecal coliform bacteria criterion for the listed and impaired monitoring locations.

Water Body	Geometric Mean (cfu/100 ml)	90th Percentile (cfu/100 ml)	Required Reduction (%)
Cottonwood Creek (Colville)	55	305	67
Cottonwood Creek (Kettle)	15	207	52
East Fork Crown Creek	8	45	Meets criteria
Flat Creek	6	50	Meets criteria
Lambert Creek	39	181	45
Lost Creek	38	229	56
Martin Creek	10	91	Meets criteria
Meadow Creek	9	40	Meets criteria
North Fork Lone Ranch Creek	72	387	74
North Fork San Poil River	16	221	55
North Fork Trout Creek	5	34	Meets criteria
Ruby Creek	18	112	10
Smackout Creek	16	115	13
South Fork Chewelah Creek	36	191	48
South Fork Lost Creek	53	389	74
South Fork Mill Creek	24	131	23
South Fork St. Peter Creek	11	79	Meets criteria
West Fork Trout Creek	12	107	6
Winchester Creek	17	163	39

303(d) listed water bodies

Of the twelve separate 1998, 303(d) listings for fecal coliform bacteria, six of those sites currently meet both parts of the water quality criteria while the other six will require reductions (Table 16). In addition to the original twelve listings, there are seven additional locations where bacterial levels were observed above the criteria. The range in reduction levels required to meet the criteria is 6 percent (West Fork Trout) to 74 percent (North Fork Lone Ranch, South Fork Lost Creek) with an overall median level of 48 percent.

pH

Typically, when pH levels are observed in surface waters at levels beyond the water quality criteria, it is a reflection of external influences such as acid mine drainage or a nonpoint source phosphorus supply. For this reason, the allocation to control pH is typically described in terms of allocating or controlling the source.

Thirty-two of the 84 pH monitoring stations analyzed had maximum levels above 8.5 - the upper level of the pH water quality criteria (Table 17). The more elevated pH levels common to the forest, appear to be the result of regional limestone geology. Dissolved calcite ($CaCO_3$) has the effect of naturally raising pH levels due to hydrogen ion bonding. (Reduced hydrogen ion concentrations result in increased pH.) Because the source for the unusual variation in pH is primarily a result of the regional geology it is assumed a natural condition.

It is recognized that there may be nutrient sources affecting pH levels of certain streams within the forest. However, distinguishing those streams, as opposed to those primarily affected by the regional geology, is difficult, and would require a more in depth stream by stream analysis. Given the fractured distribution of the limestone geology across the forest, the result of such an analysis would likely be inconclusive.
The only potential nutrient supply large enough to affect pH on the forest is from cattle. However, there is not a clear association between monitoring locations with more elevated levels of bacteria, and by association, phosphorus and elevated pH levels. For this reason, the expected upper range in pH for forest streams has been extended from 8.5 to 9.0.

Table 17. Monitoring locations within the Colville National Forest with maximum pH levels measured above the water quality criteria.

Water Body	Township / Section/ Range	n	Percentiles					Range
			Max	75	50	25	Min	
Addy Creek	33 / 39 / 13	22	8.8	8.3	8.1	8.0	7.5	1.3
Barnaby Creek	35 / 36 / 33	20	8.8	8.2	8.0	7.9	7.4	1.4
Cottonwood Creek	32 / 41 / 36	40	8.6	8.0	7.7	7.3	7.1	1.5
Deep Creek	40 / 36 / 12	21	8.6	8.4	8.3	8.1	7.6	1.0
East Fork Cedar Creek	40 / 42 / 17	19	8.7	8.5	8.3	8.3	8.0	0.7
East Fork Crown Creek	39 / 38 / 02	49	8.6	8.3	8.2	8.1	7.7	0.9
Fisher Creek	40 / 37 / 33	11	8.6	8.5	8.4	8.3	8.1	0.5
Flat Creek	39 / 38 / 09	47	8.8	8.2	8.1	8.0	7.7	1.1
Harvey Creek	38 / 44 / 30	43	8.7	8.3	8.1	7.9	7.0	1.7
Jump-off-Joe Creek	36 / 40 / 09	12	8.6	8.4	8.3	8.2	8.1	0.5
Little Boulder Creek	39 / 36 / 04	26	8.7	8.4	8.3	8.2	7.9	0.8
M & N Fork Harvey Creek	38 / 44 / 35	11	8.6	8.2	8.1	8.0	7.9	0.7
Middle Fork Mill Creek	36 / 40 / 15	15	8.7	8.4	8.4	8.3	8.1	0.6
Meadow Creek	38 / 41 / 33	35	8.7	8.5	8.4	8.2	6.5	2.2
North Fork Boulder Creek	38 / 36 / 03	23	8.8	8.3	8.2	7.9	7.5	1.3
North Fork Mill Creek	37 / 40 / 24	16	8.6	8.4	8.3	8.2	8.1	0.5
North Fork San Poil River	37 / 33 / 26	36	8.6	8.1	8.0	7.8	7.1	1.5
Noisy Creek	38 / 44 / 18	15	8.6	8.3	8.2	8.1	7.9	0.7
North Fork O'Brien Creek	36 / 34 / 22	21	8.6	8.1	7.9	7.8	7.5	1.1
Pierre Creek	40 / 37 / 33	43	8.8	8.4	8.3	8.1	7.9	0.9
Rocky Creek	37 / 41 / 22	33	8.7	8.4	8.2	8.1	7.7	1.0
South Fork Boulder Creek	38 / 36 / 03	55	8.6	8.4	8.2	7.9	7.3	1.3
South Fork Boulder Creek	38 / 36 / 03	75	8.6	8.3	8.1	7.9	7.2	1.4
South Fork Chewelah Creek	33 / 41 / 23	77	8.8	8.1	8.0	7.8	6.5	2.3
South Fork O'Brien Creek	36 / 33 / 26	40	8.8	8.2	8.0	7.8	6.5	2.3
South Fork Sherman Creek	36 / 36 / 32	81	8.9	8.0	7.9	7.7	7.3	1.6
Silver Creek	39 / 41 / 12	21	8.7	8.5	8.3	8.3	8.1	0.6
Slate Creek	40 / 44 / 30	19	8.6	8.3	8.2	8.2	8.0	0.6
Smackout Creek	38 / 41 / 03	80	9.0	8.5	8.4	8.2	7.5	1.5
Smalle Creek	33 / 43 / 29	18	8.6	8.0	7.7	7.5	7.2	1.4
Tonata Creek	39 / 32 / 11	35	8.6	8.5	8.4	8.3	8.1	0.5
US Creek	39 / 36 / 04	13	8.8	8.3	8.1	7.9	7.7	1.1

303(d) list water bodies

Dissolved Oxygen

Overall, approximately 93 percent of the observations of dissolved oxygen at the South Fork Chewelah monitoring location were observed above the 9.5 mg/L criteria. On three occasions, concentrations were measured at 9.0 mg/L, 0.5 mg/L below the criteria. When these observations were compared to those collected at the North Fork Sullivan Creek, a drinking water supply for Metaline Falls having limited nonpoint source pollution impacts, there was no significant difference. However, fecal coliform bacteria concentrations at the South Fork Chewelah site have been chronically elevated beyond criteria, requiring a load allocation. In addition, maximum pH levels and overall variation were among the highest observed of the monitoring sites on the forest. Both of these water quality characteristics are indicative of nonpoint source pollution impacts, though its effect on dissolved oxygen appears limited. For this reason, the dissolved oxygen load allocation will be described in terms of achieving the water quality criteria of 9.5 mg/L. It is expected that implementation measures to reduce fecal coliform bacteria levels will improve dissolved oxygen concentrations.

Margin of Safety

Uncertainty is accounted for in this TMDL analysis through the use of conservative assumptions and analysis methods, and therefore, provides a margin of safety that ensures that the prescribed load allocations are protective of water quality. The significant analysis assumptions and methods that provide this margin of safety are described by parameter.

Temperature

- At the majority of the monitoring locations water temperature data was collected over three summer periods (2002, 2003, and 2004) and so captured how variation in environmental factors affects temperature.
- The analysis used for establishing allocations for the majority of the monitoring locations, was based on meeting the water temperature criteria for the 2003 critical period, July 15-August 15. July 15 through August 15 is the period when water temperatures are typically at their seasonal peak coincident with low flow levels. Regionally, the summer months of 2003 and 2004 were noted for being unusually hot and dry and so are reflective of critical environmental conditions.
- Two methods were used to evaluate tree height and canopy density variation across the forest. The results of both methods compared favorably.
- Model output when analyzed collectively displayed similar temperature relationships as observed with the empirical data, providing an increased assurance of the model results.

Fecal Coliform Bacteria

- Based on an analysis of bacteria data collected on the forest at 69 monitoring locations, it was determined that the most elevated bacterial levels occur during the period from June through September. For this reason, June through September was chosen as the critical period when data analysis and the establishment of the allocations were determined. Establishing a narrow interval for the critical period provides an increased margin of safety.
- Allocations, established for the critical period, allow management measures used for source control to reduce bacterial loading throughout the year and therefore, serves as an implicit margin of safety.
- Application of the "rollback method" to determine reduction levels (allocations) assumes that the variance of the pre-management data set will be equivalent to the variance of the post-management data set. However, as pollution sources are managed, the occurrence of high bacterial concentrations are likely to be less frequent, resulting in a further reduction in the variance and the 90^{th} percentile of the post-management condition.

Summary Implementation Strategy

A summary implementation strategy (SIS) is needed to meet the requirements of a TMDL submittal for approval as outlined in the 1997 Memorandum of Agreement between the U.S. Environmental Protection Agency and the Washington State Department of Ecology (Ecology). Its purpose is to present a clear, concise, and sequential concept (i.e., vision statement) of how the waters covered in the TMDL will achieve water quality standards. The SIS includes an outline of how a more detailed implementation plan will be developed, those implementation activities that are planned or already underway by the Colville National Forest, a strategy for developing follow-up monitoring plans, a summary of the public involvement methods, and potential funding needs and sources to make implementation of the plan a reality.

Implementation Overview

Several plans guide the management of the Colville National Forest. These plans, summarized below, provide information on how activities should be conducted on the forest so that natural resources, such as water, are not degraded. Multiple explanations exist for exceeding temperature and fecal coliform bacteria standards on the forest. Further monitoring, public education and implementation of best management practices (BMPs) will address the possible sources of the water quality impairments. Ecology staff will assist Colville National Forest personnel wherever possible to help achieve the targets in this plan. Possible sources of funding to implement this plan will be identified and applied when possible.

The Colville National Forest will work with other agencies, organizations, and individuals concerned with water resources draining from the National Forest. These may include conservation districts, Natural Resources Conservation Service, city and county officials, watershed planning groups, Ecology, and the Colville, Spokane, and Kalispel Tribes. Such partnerships may be used to assist with monitoring and funding opportunities.

Following the approval of this TMDL by the United States Environmental Protection Agency, Ecology, USFS, grazing permit holders, and other interested parties will develop a detailed implementation plan (DIP). The DIP will provide greater detail to all of the elements presented in this section (Strategic Implementation Strategy).

If the activities outlined in this plan continue or are carried out, waters within the Colville National Forest should meet the temperature water quality standard in fifty years, and the bacteria water quality standard should be met in seven years. Due to the length of time required to increase shade (grow vegetation) and variability in growing conditions, the interim target for shade allocations will be a combination of a decrease in water temperature and an increase in shade at five to ten year intervals. Five years after the implementation plan is completed, fecal coliform levels should have dropped by fifty percent of the reduction needed to meet water quality standards.

If forest streams are found to meet water quality standards for temperature and fecal coliform, but do not meet the load allocations, the objectives of this TMDL will have been accomplished.

However, if the load allocations are met but the water quality standards for temperature and/or fecal coliform are not met, the TMDL objective has not been satisfied and adaptive management will be applied.

Implementation Plan Development and Activities

The USFS and Ecology are the two principal agencies involved in this TMDL and with its subsequent implementation and monitoring activities. Establishing this partnership is a Memorandum of Agreement signed in 2000. In addition, and crucial to the implementation of this TMDL, is direction under the 1988 Colville National Forest Plan (as amended by the Inland Native Fish Strategy or INFISH) regarding riparian corridors, grazing and recreational activities, as well as water quality throughout the Colville National Forest.

Approaches that will primarily be used to meet load allocations are outlined in the amended Colville National Forest Plan (Forest Plan). Such approaches may include:

> 1) Increasing the public's awareness of how they may be contributing to the water quality impairments. One possible activity may be to post signs at established and dispersed camping areas.
>
> 2) Reducing impacts to riparian vegetation to the greatest extent possible during road improvement and/or maintenance.
>
> 3) Continuing the use of riparian corridor protection methods during timber harvest activities.
>
> 4) Working with grazing permit holders to identify potential BMPs that could be applied.

USFS and Ecology staff along with grazing permit holders and other interested parties will work closely together to set reasonable, achievable, and effective strategies for meeting the load allocations established in this TMDL and will include these activities in the DIP. Ecology will utilize its existing resources and authorities under RCW 90.48 to implement this TMDL. Standards listed in the Forest Plan for forest uses affecting temperature and fecal coliform levels will serve as benchmarks for TMDL assessments.

Reasonable Assurance

Assurance that allocations will be met relies on following the standards and guidelines within the amended Forest Plan, and the cooperative partnership between Ecology and the United States Forest Service (USFS).

Ecology / USFS Memorandum of Agreement (MOA)

This TMDL analysis is a cooperative effort between Ecology and the USFS. The partnership was formed through a Memorandum of Agreement (MOA) signed in 2000. The initial impetus for the MOA was a joint recognition that inadequately maintained roads on USFS lands were resulting in significant water quality problems throughout the state. For this reason, the agreement established a schedule for planning and implementation of road maintenance and abandonment.

Importantly, in terms of this TMD, the MOA also recognized the USFS as the designated management agency for meeting Clean Water Act (CWA) requirements on national forest lands. The USFS agreed to meet or exceed the water quality requirements in state and federal law. To meet this goal, the MOA recognized the necessity that the USFS and Ecology share responsibility for developing TMDLs on national forest lands. Ecology and the USFS meet annually to determine compliance with the MOA. The MOA provides reasonable assurance for TMDL implementation and restoration of water quality for federal lands.

Colville National Forest Land and Resource Management Plan (Forest Plan)

Forest plans are required by the National Forest Management Act (NFMA) of 1976 for each National Forest (NFMA 1976). These plans establish goals, objectives, standards, and guidelines that direct how national forest lands are managed. The act states that forest plans must be compatible with environmental laws and regulations such as the CWA.

The Colville National Forest Plan was adopted in 1988. The goal of the plan is to "provide a management program reflective of a mixture of management activities that allow use and protection of the forest resources; fulfill legislative requirements; and address local, regional, and national issues and concerns" (CNF 1988). Management standards and guidelines were established for all natural resource management activities in the plan.

An objective of the Forest Plan is to protect Washington State waters through planning, application, and monitoring BMPs. According to the plan, BMPs will be based on site-specific conditions, as well as technical and economic feasibilities. Monitoring should be conducted to determine the effectiveness of these practices in meeting expectations and in attaining water quality standards. In addition, BMP design standards may be adjusted if beneficial uses are not protected and water quality standards are not achieved to the desired level.

Included in the Forest Plan is a range improvement program that lists annual goals for noxious weed control and BMP implementation. The Forest Plan also directs the creation of range allotment management plans. The allotment management plans provide guidance for grazing domestic livestock and include a strategy to manage riparian areas for a variety of resource uses. Guidance for the implementation of BMPs, duration of grazing in the pastures, actions needed to meet riparian objectives, and monitoring are discussed in the plans. BMPs such as fencing, water developments, and hardened crossings have been installed in various allotments on the forest. Forest Service staff and grazing permit holders will continue to work together to install a variety of BMPs in allotments to help reduce fecal coliform and temperature levels.

Recreational opportunities provided on the forest include hunting, fishing, gathering forest products, viewing scenery, camping, hiking, and floating. Developed recreation facilities within riparian areas are to be minimized and all sanitary facilities are to meet state and federal standards. Improved dispersed campsites have been relocated further away from the streams and most unsealed outhouses have been replaced. The forest also has an educational campaign encouraging visitors to protect water quality.

One amendment made to the Forest Plan that further guides how riparian areas are managed on the forest is the Inland Native Fish Strategy (INFISH). INFISH provides direction for establishing riparian protection levels for timber sales. This amendment limits the type of timber harvest activity that may occur within 100 to 300 feet of intermittent and perennial streams as well as wetlands, ponds, and lakes. INFISH allows specific types of minimum disturbance harvest activity within riparian corridors on the forest.

Road construction in riparian zones is limited to stream crossings unless determined necessary by site-specific analysis. The numbers of stream crossings are minimized and constructed to minimize water quality impacts.

Per the directive of the Forest Plan, implementation and effectiveness monitoring are conducted by the USFS. Implementation monitoring is used to determine if activities are implemented as designed, whereas effectiveness monitoring evaluates if the activities had the desired result. These monitoring activities will continue to be performed in order to locate the appropriate areas within the forest to apply BMPs and/or protect and enhance shading along the creek. In addition to recording water quality, visitor use patterns and wildlife grazing locations may also be monitored.

According to the NFMA, forest plans must be revised every ten to fifteen years. As such, the Colville National Forest Plan is in the process of being revised. The revised Forest Plan is anticipated to be released to the public in March 2006. Approval of the revised Forest Plan is planned for December 2006. Habitat sustainability will be one of the principals upon which the new plan will be based. Also guiding the development of the plan is the Interior Columbia Basin Ecosystem Management Project (ICBEMP). ICBEMP is an ecosystem based management strategy for federal lands within the Columbia River Basin and portions of the Klamath and Great basins in Oregon.

Adaptive Management

Adaptive management is required when results from water monitoring show that load allocations and/or interim targets in this TMDL are not being met. An adaptive management strategy will also be used if the load allocations and/or targets are met, but the stream(s) still does not meet temperature and fecal coliform water quality standards. Effectiveness monitoring will be conducted at approximately five to ten year intervals after the detailed implementation plan is finalized.

If implementation activities are not producing expected or required results, Ecology and/or the USFS may choose to conduct additional studies to identify the significant sources of fecal coliform bacteria or heat input to the river system. If the causes can be determined, implementation of additional BMPs, educational efforts, or a combination of these will likely be taken. However, if some unforeseen event affects the landscape, such as a wildfire, the timelines to meet the load allocations in this TMDL may need some modification.

Monitoring Strategy

Monitoring is necessary in order to measure the application of implementation activities and achievement of interim targets and water quality standards. Details about the monitoring strategy will be provided in the DIP. The monitoring strategy will include the following measures.

1. The USFS will monitor water temperatures on listed streams.
2. Sampling for fecal coliform will continue by the USFS in those streams that exceed standards. Streams exceeding standards will have incremental samples collected in hopes of discovering the sources of the bacteria.
3. The USFS and Ecology will jointly review the monitoring information, along with other aspects of the TMDL implementation.
4. Ecology will conduct effectiveness monitoring of fecal coliform levels after five years and shade levels within a five to ten year interval after the completion of the DIP.
5. Ecology will track USFS planning and implementation activities to ensure that the TMDL is carried out.

Potential Funding Sources

The Colville National Forest funds restoration activities implemented on lands it administers. The types of restoration activities include road decommissioning, riparian plantings, water development, fencing, and hardened crossings. Several types of funds have been used to complete this work, including emergency repair for federally-owned roads, supplemental emergency flood, and appropriated funds. In addition, a portion of the fees for grazing allotments is re-invested in BMPs for the allotments.

Summary of Public Involvement

Several meetings have been held with various interested parties to explain this TMDL for the forest. In January of 2003, a public meeting was advertised and held in Colville to update people about the TMDL as well as provide some initial technical study results. The USFS also hosted tours with grazing permit holders in 2003. In the spring of 2005, meetings were held with county commissioners from Ferry, Pend Oreille and Stevens counties. Meetings were also held with the Confederated Tribes of the Colville Reservation and the Kalispel Tribe. Public meetings were advertised and held in Colville, Ione, Newport, and Republic.

A 30-day public comment period was held, after which responses to the comments were generated (see Appendix A). Notification about the public comment period was announced in news releases to all media within the three counties. Display ads were also placed in the Colville Statesman Examiner, Chewelah Independent, Newport Miner, Republic News Miner, and Selkirk Sun. Copies of the draft were available at the Colville National Forest's supervisor's office in Colville, as well as the ranger districts in Newport, Republic, Sullivan Lake, and Three Rivers (Kettle Falls).

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Appendix A
Response to Comments

Appendix A. Response to Comments

Comment:

May 13, 2005

Re: Total Maximum Daily Load

Karin Baldwin
Washington State Department Of Ecology
4601 North Monroe
Spokane, Washington 99205

Greetings,

This is to inform you we totally disapprove of the way the TMDL tests were done. In the first place they were done only where it would seem cattle could be the problem. They were done by persons who would like to see cattle disappear. They have no concept of what the range would be like with no grazing by cattle. Do they even think of wild fires? The tests were flawed because they only used one testing station. The Conservation District personnel did tests that prove these done by your people were flawed.

Thank you for your time and the option to comment.

Sincerely,

Ed and Stella Windsor

Ed and Stella Windsor

Response:

Monitoring data collected on the Colville National Forest since 1990 was used for the TMDL analysis. In 2004, an additional season of monitoring was also conducted to verify the data. All water quality monitoring done by the Colville National Forest was done by following established sampling protocols and analyzed using standard methods. Several testing stations throughout the forest, including stations that were not located within grazing allotments, were studied and analyzed for the TMDL. The Forest Service will continue to offer an invitation to anyone wanting to observe the sample collection, transport and analysis of water samples according to their published schedule, or to sample independently using an accredited lab and compare results.

Other sources of fecal coliform bacteria besides cattle were identified in the report, such as recreating humans. The Forest Service does not have any plans to eliminate grazing on the forest. Rather best management practices will be designed and applied to reduce fecal coliform from livestock entering forest streams.

The possibility of wildfires was addressed in the document. The Inland Native Fish Strategy (INFISH) provides guidance for management activities near streams. Both the TMDL and INFISH allow for some minimum-disturbance management activities to occur along streams to reduce the risk of wildfire and to increase shade.

The microbial source tracking (MST) study conducted by the Ferry County Conservation District showed that several sources of fecal coliform bacteria exist. The data reported the possible sources in numbers of isolates and not in colonies of fecal coliform; therefore, the data can not be compared. In addition, the MST study was not able to determine how much bacteria each particular animal species was contributing to the total amount of bacteria present.

Comment:

Att. Karin Baldwin

05-15-05

RECEIVED
MAY 18 2005
DEPARTMENT OF ECOLOGY
EASTERN REGIONAL OFFICE

This is a response letter to the Washington State Department of Ecology and Colville National Forest Temperature, Bacteria, and pH, Total Maximum Daily Load (Water Cleanup Plan) Submittal Report Draft. April 2005. Publication Number 05-10-047

This report would seem to have the best intentions for all citizens that have an interest or use water. But like all good intentions there is a down side to some of the unanticipated results that come from this submittal report. For example what if we cannot reach some of these lofty goals for temperature or fecal coliform. There are not any clear rules to guide for attaining these standards. There seems to be belief that fencing all surface water would help to attain these goals, but this is not practical for wildlife needs or good for the land. The cost of maintenance and injury to wildlife would be prohibitive. Another example if some streams don't meet the 16 degrees C. do we have variance or do we have to start taking roads out that are too close to the steam? Why force a standard that may have never existed naturally?
This would also pertain to fecal coliform standards, do we know what kind of fecal coliform were in these streams prior to white mans existence? Didn't a great deal of these steams have beaver, muskrat and otter in them, and weren't the trees widely spaced, with the occurrence of frequent fires?

Not only does your historical information seem to be lacking insight so does your scientific information. For example what, by who and what labs did the scientific analysis? Did these labs do any analysis to test for the difference between Domestic or Wildlife fecal coliform or use information and or studies conducted, in the past, in the general area? In other words if all Best Management Practices were implemented and the fecal coliform is above standards with out cattle running in that allotment, how can cattle be allowed in the allotment if TMDL is at maximum allowed?

In summary the standard of requiring class AA drinking water, combined with open range rules are in direct contradiction. These, if followed could be a economic hardship, as well as a cultural shock, since many families would be required to move and seek employment elsewhere.

Bryan Gotham

President of Republic Ranger District Grazing Association

Bryan Gotham

Response:

The goals for the TMDL are believed to be achievable within the seven and fifty year timeframes using best management practices (BMPs) and Inland Native Fish Strategy (INFISH) guidelines. Recent management techniques using INFISH guidance and BMPs applied on the forest have been shown to be effective in reducing temperature and fecal coliform in other areas throughout the Northwest and within the Colville National Forest. After the Environmental Protection Agency approves the TMDL, the Colville National Forest and Ecology will work with interested parties to develop a detailed implementation plan which will provide a list of possible actions the forest may use to meet the goals within the plan and water quality standards.

Approximately five years following the development of the detailed implementation plan, Ecology will conduct monitoring to determine if the management techniques and BMPs used by the forest have improved water quality. If the data indicates that water quality is not improving then new strategies or technology may be researched and applied. In addition, if human sources have been reduced as far as possible and the problem remains, a natural condition study may be initiated.

Numerous BMPs may be applied on the forest to improve temperature and fecal coliform levels. A determination as to which BMP to use will have to be made at each site. The report states that off-stream water and fencing have already been used on the forest to help improve water quality and fish habitat, but does not claim that all surface water will be fenced. The forest has guidelines for different styles of fencing that take into account wildlife, such as using smooth wires, poles, etc. Money collected from grazing permits can be used for BMP installation costs. Other sources of funding will continue to be sought.

The report does acknowledge that the standards may not be able to be met in some locations. For example, in the northeast sections of the forest, due to the underlying geology, the pH levels exceed that state standard so a maximum pH of 8.8 becomes the natural condition or standard at those locations. The report also recognizes that some sites on the forest will likely not be able to produce the shade necessary to meet the 16 degree standard. In those cases the maximum amount of shade that can be produced becomes the natural condition. A site specific determination will need to be made where temperatures exceed the water quality standard as to which management techniques will result in lower temperatures (i.e., an increase in effective shade). Portions of some roads could be relocated, as was the case in Pend Oreille County, but depending upon the site's geology, funding, etc., some roads will likely not be re-routed. In those cases, management activities up and downstream of the site may be able to help reduce temperatures.

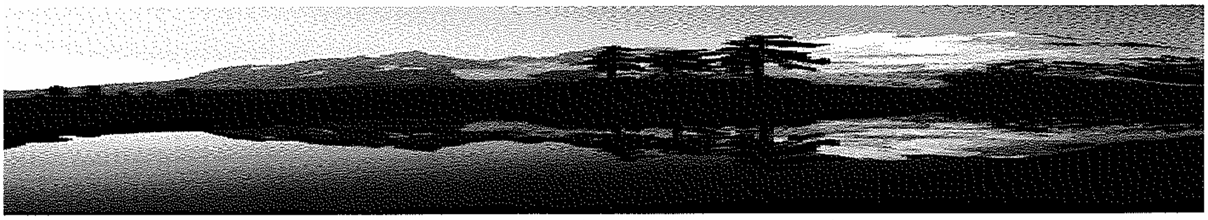
Additional monitoring will continue to occur throughout the plan so that sources of fecal coliform and high temperature can be identified and resolved. This monitoring will also help determine where high fecal coliform bacteria and temperature levels may be due to natural conditions. Sampling data taken from within municipal watersheds, where very little human disturbance of the environment is allowed, were found to be in compliance with temperature and fecal coliform water quality standards. In addition, soils adjacent to streams are moist and usually with many different types of vegetation that provide shade to keep water temperatures lower. Therefore, it is likely that the water quality standards for the forest can be attained. State water quality standards are based upon how people use the water and the need to protect the people engaged in those uses.

The data used in this TMDL study was collected by the Forest Service. The sampling locations, water quality parameters measured, analysis methods, instruments, and laboratory procedures were documented in the Forest Service's quality assurance project plan or water quality monitoring plans. The water quality parameters used in this study that were measured in the field are: water temperature and pH. Fecal coliform bacteria analysis was conducted in the Colville Forest's Ecology approved water quality laboratory.

A bacteria source tracking (BST) method was not used for this TMDL. A BST method has not yet been identified that is accurate, able to report how much bacteria a species contributes, and can be repeated. Current BST methods can only indicate, with less than 30 percent confidence, the species that fecal coliform may be coming from.

If all BMPs were installed and there are no grazing livestock and fecal coliform levels are still high, then monitoring should occur upstream to determine if there is any recreational activity that may be contributing. If no recreational sources are located, then a case can be made for making a natural condition call. If the bacteria level coming into the allotment is the same as the level downstream then the source must be upstream.

Comment:



Ferry County Natural Resource Board

350 East Deleware P.O. Box 115 Republic, WA 99166

May 18, 2005

RECEIVED
MAY 19 2005
DEPARTMENT OF ECOLOGY

Karin Baldwin
4601 N. Monroe Street
Spokane, Washington 99205

Re: Water Cleanup Plan – Colville National Forest – Publication #05-10-047

Mr. Anthony J. Whiley, Ms Karin Baldwin and Mr. Bruce Cleland

We are very concerned as to how this proposed Water Cleanup Plan for the Colville National Forest will affect our timber and cattle producing industries in Ferry, Stevens and Pend Orielle counties.

Best Management Practices in the Cleanup Plan are riparian exclusion from grazing and the re-establishment of riparian vegetation. (page 52 paragraph 1, lines 7 and 8.)

Table 16, page 52 lists all the streams in the Colville National Forest for 303(d) listed and temperature impaired sites proposed in the Water Cleanup Plan.

Water Temperature criteria used in this document is highly flawed as noted from the following statement. "Heat is a pollutant when excessive heating of water to levels above the water temperature criteria results from human activities. However, as it was discussed earlier, rather than setting the load capacity based on heat, ***the surrogate measure, percent effective shade, has been used.*** (Page 48 Loading Capacity Water Temperature)

Using the surrogate measure, percent effective shade, the document states:

"Other exceptions include water bodies requiring greater shade levels than can ever be achieved given site potential vegetation conditions." (Page 53 paragraph 3, lines 1 and 2.) "...even with optimal riparian growth conditions present, enough exposure will occur, due to a wider bankfull width, to elevate temperatures potentially above the temperature criteria." (Page 53 paragraph 6, lines 4,5 and 6.)

"Water temperature data was collected at 62 monitoring locations throughout the forest during the summer months of 2002, 2003, and 2004. Temperature probes were located primarily at the forest boundary though placement considered variation in elevation, drainage area, geology, vegetation, and hydraulic influences. Appendix B contains site locations and additional data specific to each monitoring site including: elevation, drainage area, bankfull width, and flow." (Page 11 paragraph 1 Water Temperature)

> Washington WAC 173-201A-260 states: "It is recognized that portions of many water bodies cannot meet the assigned criteria due to the natural conditions of the water body. When a water body does not meet its assigned criteria (16°C being applied forest wide) due to a natural climatic or landscape attributes, the natural conditions constitute the water quality criteria."

With 62 monitoring locations for the years 2002, 2003, and 2004 it is highly unlikely that the natural temperature of these waters is unknown and using the surrogate measure, percent effective shade, the document is highly flawed to list streams due to temperature.

From the Summary Implementation Strategy it is stated "waters within the Colville National Forest should meet the temperature water quality standard in 50 years." "If forest streams are found to meet water quality standards for temperature and fecal coliform, but do not meet the load allocations, the objectives of this TMDL will have been accomplished." (Page 59 paragraph 5 line 1 and 2 and paragraph 6 lines 1 and 2)

What are the objectives of this TMDL? Regulatory framework (page 48) states: "Allocations are defined as the portion of a receiving water's loading capacity that is allocated to point, nonpoint and natural sources. By definition, TMDLs are the sum of the allocations [40 CFR § 130.2(i)]. Upon retrieving this regulation *(Revised as of July 1, 2004)* from the Code of Federal Regulations, we found the following.

> "If Best Management Practices (BMPs) or other nonpoint source pollution controls make more stringent load allocations practicable, then wasteload allocations can be made less stringent. **Thus, the TMDL process provides for nonpoint source control tradeoffs."**

We are opposed to the listing of the streams contained in this submittal to EPA for TMDL allocations due to temperature. Is it possible our timber industry is being sacrificed as a nonpoint source control tradeoff for downstream effluent producers?

pH AS A WATER QUALITY IMPAIRMENT

Table 1, page 15 lists four streams included on the 1996 and 1998 303(d) list due to water quality impairments of pH.

"When these streams were proposed for the 1998 303(d) list, the Forest Service petitioned the Department of Ecology to remove these sites from consideration believing that the elevated levels were a reflection of the regional carbonate geology as opposed to a result of nonpoint source pollution." (Page 16, pH paragraph 1, lines 4.5.6 and 7.)

"The elevated pH levels, common to the forest, appear to be the result of regional limestone geology. Dissolved calcite ($CaCO_3$) has the effect of naturally raising pH levels due to hydrogen ion bonding, reducing hydrogen ion concentrations. For this reason, the upper range in pH for forest streams has been extended from 8.5 to 8.8." (Page 1 paragraph 5)

"For this reason, the allocation to control pH, is typically described in terms of allocating or controlling the source. For this TMDL, the source for the unusual variation in pH observed within surface waters of the Colville Forest is primarily a result of the regional geology and so is a natural condition." (Page 56 paragraph 1 lines 3,4,5 and 6.)

Best Management Practices include riparian exclusions from grazing trying to reduce the elevated pH levels. The higher pH levels are indicative of a natural condition.

We are opposed to the listing of the streams contained in this submittal to EPA for TMDL allocations due to pH as we feel possibly our cattle industry is also being sacrificed as a nonpoint source control tradeoff for downstream wasteload allocations as noted in 40 CFR.130.2(i).

Fecal Coliform

Many streams are listed in Table 1, Page 15 due to water quality impairments of Fecal Coliform. However, there are no monitoring stations of natural conditions for the Non-Allotment and Vacant allotments to compare what is a natural condition of the fecal coliform bacteria criteria.

Allotments not sampled, which are vacant include Bangs, Empire, First Thought, Gillette Mountain, Henry Creek, Renner. Non-Allotments include Cottonwood (Colville), E. Deer, Gypsy, Harvey, Little Muddy, Mill (Pend Oreille), NF Sullivan, Rocky, Sullivan, Tacoma, Three-mile, Winchester. (Table D. page B-6.)

"Based on bacterial samples collected by the Ferry Conservation District for three streams within the Colville Forest, and utilizing the Microbial Source Tracking techniques developed by Dr. Samadpour of the University of Washington, numerous bacterial sources were identified. For instance on Lone Ranch Creek, a tributary to the Kettle River, 16 bacterial sources were identified. Wildlife (11), domestic animals (4), and humans were among the bacterial sources identified." (Page 7 paragraph 6)

"If the activities outlined in this plan continue or are carried out, the bacteria water quality standard should be met in seven years." "Five years after the implementation plan is completed, fecal coliform levels should have dropped by 50% of the reduction needed to meet water quality standards." (Page 59 paragraph 5 lines 1, 2, 3, 6, and 7)

Ecology does not know if the fecal coliform is attributable to cattle or wildlife and to assume that cattle are the contributing factor, implementation of the Best Management

Practices (riparian exclusion of grazing) proposed to reduce fecal coliform would (has) resulted in substantial and widespread economic and social impact of the cattle industry.

Therefore we are opposed to the listing of streams contained in this submittal to EPA for TMDL allocations due to Fecal Coliform as we feel this is another tool being used to sacrifice our cattle industry as a tradeoff for downstream effluent producers.

Memorandums of Agreement between USDA Forest Service, Region 6 and the Washington State Department of Ecology does not eliminate Ecology's responsibility to do a cumulative effects analysis of the proposals contained in this document nor does it eliminate Ecology's responsibility to do an environmental/economic impact statement (RCW 43.21C.030(c)).

NEPA compliance is also not being met for the Colville National Forest Temperature, Bacteria, and pH Total Maximum Daily Load (Water Cleanup Plan)

For the above mentioned reasons we are adamantly opposed for this document to be submitted to EPA as a Cleanup Plan for the Colville National Forest.

Sincerely

Sharon Shumate

Sharon Shumate - Chairman
Ferry County Natural Resource Board

Response:

On page 15, the report states that water temperatures have routinely been observed exceeding the 16^{o}C maximum water temperature where there is high level of solar shortwave radiation. Effective shade is defined as the fraction of the potential solar shortwave radiation that is blocked by vegetation and topography before it reaches the stream surface. Therefore, load allocations have been determined for effective shade. In contrast, allocations could have taken the form of energy per unit area per time (heat load) such as Watts/square meter per hour; however, that measure is less relevant in guiding management activities needed to solve identified water quality problems. Surrogates, such as effective shade, are allowed under EPA regulations [40 CFR 130.2(i)].

The 62 temperature monitoring locations were chosen to reflect the environmental diversity found throughout the Colville Forest including: variation in vegetation, hydrology, geology, and elevation among other factors. The evaluation of these factors and their effect on water temperature allowed for an understanding of the environmental conditions necessary to achieve the water temperature criteria while also allowing for an understanding of natural water temperature variability. It is recognized that there are many environmental factors that cannot be controlled, for instance, the amount of incoming solar shortwave radiation to the earth. However, for the majority of the streams within the Colville Forest, maximum water temperatures are a reflection of riparian vegetation characteristics. Low exposure to the sun when shade is provided by tall and dense tree growth, results in lower water temperatures. Riparian vegetation has historically been affected by forest management activities.

Prior to the TMDL study, four streams were placed on the 1998 303(d) list for temperature. A requirement of the federal Clean Water Act is to conduct TMDLs on streams placed on the 303(d) list. During the study, additional streams were identified that did not meet temperature standards. Including these additional unlisted streams in this TMDL is more efficient, because the need for expending time and effort on another future TMDL is eliminated.

The objectives of the TMDL are to determine how much pollution needs to be reduced to meet water quality standards, and to provide some methods that may be used to meet the standards. The goal of the TMDL is that streams meet water quality standards. A non-point/point source control tradeoff is not possible due to the distance between the forest and any existing point sources. The effects from BMPs and different management techniques used on the forest could not be measured after the input from many different tributaries, and after flowing through miles of multiple land ownership and land uses. Streams listed on the 303(d) list due to elevated pH levels were determined to be due to natural conditions. Therefore, no load allocations have been assigned. BMPs were not identified in the report as a possible solution to the high pH levels since the natural underlying geology is likely the source.

There were several sites monitored where human influence on the forest is minimized. For example, two municipal watersheds were analyzed (East Deer Creek and North Fork Sullivan Creek). Data from these sites can be expected to reflect naturally occurring fecal coliform levels. East Deer Creek was found to have a geometric mean and 90^{th} percentile fecal coliform concentration of 4 and 16 colony forming units per 100 milliliters, respectively. The bacterial levels at North Fork Sullivan were similar at 2 and 7 colony forming units per 100 milliliters, respectively. These sites met water quality standards. (The fecal coliform criteria that applies to waters within the forest are a geometric mean not exceeding 50 colony forming units per 100 milliliters and a 90^{th} percentile not exceeding 100 colony forming units per 100 milliliters.) Therefore, these monitoring locations represent natural conditions to which other sites may be compared. In addition, Cottonwood Creek in Stevens County was also monitored and does not have any permitted grazing.

All forest users are suspected of contributing fecal coliform. Continued water monitoring will be conducted in an attempt to determine the source of the fecal coliform. The document identifies education of forest visitors, and the installation of BMPs where practicable to reduce bacteria levels. Fencing and off-stream watering were mentioned in the summary implementation strategy because they have already been applied in some active allotments. As was stated at a the Ferry County Commissioners' meeting, the Forest Service feels that implementing some of the available BMPs will allow streams within grazing allotments to reach the fecal coliform standards. Reductions in permitted livestock to help reach TMDL standards are not foreseen.

Since TMDLs must be approved by a federal agency, they do not meet the definition of an action under SEPA [Washington Administrative Code (WAC) 197.11.704(2)(b)(3)]; therefore there is no responsibility to complete an environmental impact statement. TMDLs are also not considered to be a major federal action requiring NEPA analysis, as defined by EPA's implementing regulations for the NEPA program at 40 CFR Part 6; therefore, NEPA analyses are not completed for TMDLs. However, individual projects that may be constructed to implement the TMDL may require SEPA/NEPA review. In other words, an environmental impact statement is not required since a specific course of action has not been proposed for a specific location.

Economic impact statements are also not required since a TMDL is neither a rule nor a general permit. For example, small business economic impact statements, cost-benefit analyses, or small business economic analyses mandated by the Regulatory Fairness Act [Revised Code of Washington (RCW) 19.85] and Administrative Procedure Act (RCW 34.05) apply only to rules. In addition, the waste discharge general permit program (WAC 173.226) requires an economic impact assessment for rules only.

Comment:

STEVENS COUNTY FARM BUREAU

PO BOX 618, Colville, Washington 99114

MAY 23 2005

(509)258-4041

May 20, 2005

Attn: Karin Baldwin
Department of Ecology
4601 N. Monroe Street
Spokane, WA 99205

Re: Colville National Forest Temperature, Bacteria, and pH TMDL
Draft Submittal Report – dated April 2005
Publication #05-10-047

On behalf of the Stevens County Farm Bureau, our members, and myself, I would like to submit the following comments. Stevens County Farm Bureau appreciates the willingness of the Department of Ecology (on behalf of the State of Washington) to include our comments and to listen to our concerns.

There is no mention of the fact that this TMDL process in the State of Washington is proceeding due to a lawsuit settlement agreement between U.S. EPA and Northwest Environmental Advocates and Northwest Environmental Defense Center. We believe this is an important fact that has been left out of this document and should be included.

Further, we remain opposed to the basic premise that has driven this TMDL process. Namely, the settlement agreement entered into on behalf of the State by the Environmental Protection Agency with several environmental organizations. We believe it is bad policy for the State to base decisions on the threat of legal action. Sound policy should be based on credible data and an assessment of the actual needs of each watershed.

I would suggest adding a definitions section listing some of the more technical terms. This would lead to clarity and would enhance the readability and understanding.

On the third paragraph on page 3, a definition or description of load allocation is given. A "Farm" is given as an example of a diffuse source of pollution, while "nonpoint" is put in parenthesis as if not important. The idea is to describe the difference between wasteload allocation and load allocation. No example is needed. I take great exception to the fact that a farm is given as an example. This seems to lead one to the conclusion that all "farms" or agriculture is polluting, and this is absolutely NOT true. Further, to my knowledge there are no farms on the Colville National Forest. I would ask that this be removed and a generic explanation be given with no examples.

STEVENS COUNTY FARM BUREAU

PO BOX 618, Colville, Washington 99114 *(509)258-4041*

On page 6, regarding figure 2. The explanation in regards to Width:Depth Ratio and Sediment does not seem to follow the figure and the numbering. I would suggest that the two circles be switched or the explanation changed to allow for clarity.

On page 7, third paragraph. The end of the paragraph talks about conditions that promote die-off of microorganisms. "High temperature" is given as one of the reasons for die-off, yet stream temperature that exceed the standard favor increased growth of microorganisms. Clarity could be achieved here by stating extreme high temperatures, or temperatures above the normal range.

Page 10, first paragraph states that there are three ranger districts, yet four are listed. Please clarify whether there are three or four and there locations.

Page 13, Applicable Criteria. Domestic water supply and stock watering are uses that are stated in the plan, yet they are not highlighted or discussed here. Why are they excluded? There are grazing allotments that require stock watering and two towns derive their water from streams in the national forest.

On page 14, the standard for dissolved oxygen is given for Class AA waters. There is one violation for dissolved oxygen. Nowhere else in this study is dissolved oxygen talked about. Should it be addressed here, or should it be left out? If it is not part of the TMDL, it should not even be mentioned, but if it needs to be address to avoid another lengthy TMDL process, then shouldn't it be address completely within the plan?

On page 16, Fecal Coliform is addressed. There is no inclusion of data as to the total area being grazed in relation to the total number of acres in the national forest. There are no data on the numbers of visitors that recreate in the National Forest, or the types of activities. A statement is made that campers waste is "assumed" to be buried to a proper depth. On what basis is this assumption made? Further, to what effect does wildlife contribute to the Fecal Coliform? Since wildlife numbers do not count towards water quality violations, to what extent is data being collected to address this question?

Table 2, on page 19-21 has repeated data as the table moves from page to page. This repeat of data on tables occurs throughout the plan on various tables, and needs to be corrected. (Addy, American Fork, Barnaby appears on all three pages.)

On page 23, the first paragraph comes to the conclusion that for streams to meet the 16 degrees Celsius temperature criteria, they should have a diurnal range of approximately 3 degrees Celsius. This conclusion does not follow the discussion, or is not drawn from the preceding discussion. How was this conclusion drawn? If it is drawn from one of the studies, then that study should be referenced.

STEVENS COUNTY FARM BUREAU

PO BOX 618, Colville, Washington 99114 *(509)258-4041*

On page 27 under "Current Effective Shade Levels", the third paragraph talks about dbh and canopy density grids used for creating the models. Field verification shows an overall accuracy of 52% and 57%. Much of this study addresses temperature and effective shade. This type of result being inaccurate almost one half the time leads one to question the credibility of the data used to allocate loads for temperature. As one builds a model using data of only 52% accuracy, the confidence level in this model can only further be degraded. Please explain how with this degree of inaccuracy, any confidence can be give to the results that have lead to effective shade, and the load allocations for temperature.

Another question on the accuracy and credibility of the data is the cloud cover data referred to on page 35. This data was obtained from Spokane, some 60 miles (97 kilometers) away and lying in a completely different topographical area. Having my residence approximately half the distance away from both Spokane and the National Forest, I would have to question the cloud cover data. I have personally seen it clear here and to the north, yet watched Doppler radar and observed rain and cloud cover in Spokane. How is this difference accounted for in the model, and how does that affect the accuracy of your load allocations?

Many of the tables such as table 5 on page 28, table 13 on page 37, table 15 on page 44-45 (note: what is n?), and others do not have a "key" to the symbols being used. Please consider adding a key to all of the tables as needed.

On page 36 at the end of paragraph one, the date is given as July 15 to August "20". Is this accurate, or should it be August "15"? The August 20 date does not relate to other years.

On page 48, Loading Capacity, under water temperature. The first sentence describes heat as a pollutant when excessive heating of the water is above the water temperature criteria resulting from "human activities." Nowhere in this study does it talk about what human activity has lead to a lack of shading or effective shading. If the temperature of the water body is not directly affected by an identified human activity, it should be assumed natural and exempt from listing and exempt from load allocations or need to increase shading. Natural conditions should always be assumed, or are we holding our National Forest presumed guilty until proven innocent?

This conversation in continue on page 49 under natural conditions, water temperature. The department of ecology is obligated under state statue to use only "credible data." Are the credible data criteria being met when you assume the level of "potential natural vegetation", or the "estimated effective shade level" done by modeling?

STEVENS COUNTY
FARM BUREAU

PO BOX 618, Colville, Washington 99114 *(509)258-4041*

Also on page 49, background conditions are talked about in relation to fecal coliform bacteria. How do elevated pH levels affect the fecal coliform bacteria levels?

Page 52 talks about implementation of best management practices such as riparian exclusion from grazing to build effective shading and reduce temperature. Effective shading and the conversations throughout this document refer to cooling being obtained by tree height. This statement about a specific BMP excluding grazing should be eliminated. If properly managed, grazing can enhance the environment and reduce competition thereby allowing trees to grow faster and healthier. This document should not presume to mention specific BMP's, but allow the management of the National Forest Service to use what best works on the site to obtain the desired results. I ask that any reference made to a specific BMP be deleted.

On page 54, under Landscape Approach to Establishing Shade Allocations for the Colville Forest, we are referred to "Table 6." Should this be "Table 16"?

Stevens County Farm Bureau members realize the importance of clean water and make every effort to enhance the quality of the waters that sustain us, our families, livestock, and crops. We again thank you for allowing us to comment and look forward to your reply. Please do not hesitate to contact me if you have any questions regarding our comments.

Sincerely,

Wesley L. McCart
President
Stevens County Farm Bureau
(509) 258-4041
E-mail: wpmccart@juno.com

Response:

Development of TMDLs is required by section 303(d) of the 1972 federal Clean Water Act and not the result of a lawsuit settlement agreement. The lawsuit that led to the 1998 Washington settlement agreement was filed in part because TMDLs were not being completed quickly enough for 303(d) listed waters. For example, as of 1992, the Environmental Protection Agency (EPA) had approved only ten TMDLs in Washington. The main component of the 1998 settlement agreement is a schedule that requires Ecology to complete 1566 TMDLs by 2013.

TMDLs must be prepared for waters that do not meet water quality standards and are placed on the state's list of impaired waters [the 303(d) list]. The water quality data submitted to Ecology is technically scrutinized before a decision is made to place a water body on the 303(d) list. For example, a quality assurance plan must have been used to collect and analyze the water samples and the data quality must also be assessed. As a result, only credible data is used to list a water body on the 303(d) list and in the development of TMDLs.

At your request and the Environmental Protection Agency's request**,** the dissolved oxygen 303(d) listing on the south fork of Chewelah Creek will be included in the final version of this TMDL.

Educational programs are aimed at reducing the impact of national forest visitors on the environment and provided the basis for making the assumption that campers bury their waste to a proper depth. On subsequent review, this statement has been removed from the report since it is unknown to what extent this practice is applied within the Colville National Forest.

Since it is unknown what influence wildlife has at most locations, further monitoring has been proposed to determine the effect various sources, including wildlife, have upon fecal coliform levels at different sites. However, applying BMPs to remove fecal coliform from any potential human source will ensure that any remaining fecal coliform bacteria is from natural sources.

The conclusion that a 3^{o}C diurnal range is needed to meet temperature standards was drawn from a collective assessment of the water temperature data measured over the summer period of 2002, 2003 and 2004 and presented in Figure 6 in the TMDL document.

It is recognized that there will be differences in cloud cover between Spokane (where the cloud cover information was determined) and the greater Colville National Forest. The forest has a substantial area at approximately 5,500 square kilometers so cloud cover across the forest will be highly variable. Cloud cover is not a measure collected at the weather station located within the forest and is not a measure typically collected even at larger weather stations. So the information from Spokane is the best available information for the area and provides an estimate.

The cloud cover information is most important in the model in providing an understanding of the overall variation in water temperature over the analysis period. Fortunately, it is not as critical on the days when the most elevated water temperatures occur because clouds intercept solar shortwave radiation reducing heating from this most important source. So on the day when the maximum water temperatures occur, it will be largely cloudless. For this reason, the shade allocations were not affected by this measurement.

On page 15, the study mentions several possible human activities that resulted in lower shade levels including a loss of riparian vegetation due to forestry activities, grazing or road proximity. Therefore, high temperatures can not always be presumed to be the result of natural conditions.

An assessment of the accuracy of the diameter at breast height and canopy density grids, used to examine variation in effective shade characteristics, determined levels ranged between 30 and 80 percent. In general, greater accuracy was determined for the extremes of the grid values than those in the middle. For instance, the canopy density grid, which was comprised of four ranges including 1-19 percent percent, 20-39 percent, 40-59 percent, and 60-100 percent, had an accuracy of 70 percent in predicting the 1-19 percent and 60-100 percent but only 35 percent for the 20-39 percent and 40-59 percent values. The tendency was to predict the 20-39 percent levels as 1-19 percent and 40-59 percent levels as 60-100 percent. Recognizing this range in accuracy, a couple of checks were placed on the use of the grid data.

At each monitoring station where shade levels were determined, the grid data were evaluated qualitatively using digital orthophotos. For instance, was a clear-cut area indicating 60-100 percent canopy density values or more appropriate values. In application, the information from the sampled grids was averaged over a two-kilometer reach reducing bias associated with potential site specific error. A final check on the grid data was provided when the average effective shade level calculated at each monitoring station was used as input to the temperature model. The overall result was that the effective shade estimates proved reliable. While 33 of the 62 monitoring sites where model run were conducted required an adjustment to the effective shade the median level of that adjustment was 4 percent. More substantial adjustments were required for streams with adjacent roads such as Sherman Creek (Highway 20) or streams with open water (such as the wetland system of Cusick Creek).

Fecal coliform may be affected by pH levels near nine and above. High pH levels may result in little to no reproduction and some die off.

The memorandum of agreement between the U.S. Environmental Protection Agency (EPA) and the Department of Ecology regarding the implementation of the Section 303(d) of the federal Clean Water Act, states that approaches to meet load allocations need to be included in the submittal report. Specific BMPs were mentioned in the report to meet this requirement, as well as provide reasonable assurances that work is underway to achieve water quality standards. The summary implementation strategy states that

Forest Service staff will work with grazing permit holders to identify potential BMPs and increasing public awareness through educational signs are some strategies that may be used to improve water quality. Riparian exclusion from grazing and dispersed camping, may be necessary in some locations to protect tree saplings until they mature enough to withstand the effects of these uses.

The changes you requested have been made to the document.

Comment:

Ferry Conservation District

Comments regarding
Colville National Forest TMDL (Water Cleanup Plan)
May 20, 2005

Ferry Conservation District has been involved actively in water quality protection, problem identity and problem solving for a long time. We have been active partners in the Colville National Forest TMDL process since its beginning. From 1998 through 2000 we conducted an extensive water quality study program on Sherman Creek. We also have done pioneering work in the area of coliform source identification.

The staff and Board of Supervisors are concerned that much of our work and contributions to the water quality knowledge in the Colville National Forest seems to have been either dismissed or ignored in this draft report. It is unfortunate that our work in the area of fecal coliform source identification is dismissed. If that data is not used, then we would ask the responsible agencies to reexamine the sources of coliform before they propose solutions that could be detrimental to agricultural operations in and bordering the CNF.

Another concern we have is that DOE will no longer allow the Conservation Districts to use Centennial Clean Water Fund monies to assist the USFS in water quality implementation projects on public land. If surface waters belong to the State of Washington (DOE thus having control over them), why is the state unwilling to help fund remedial work that happens to need done on USFS land? Regardless of MOAs or MOUs, or any formal document, this policy demonstrates an unwillingness to look for real problem solutions.

As the CNF TMDL process has evolved, it has become less people-inclusive, and more agency-oriented. County governments and Conservation Districts represent the land and resource users within the National Forest, yet we have not been invited to take an active role.

In conclusion, FCD disagrees with the Draft Report in several areas. We recommend that DOE authorize source identification studies for fecal coliform bacteria. We recommend that Conservation Districts be allowed to use CCWF monies to implement water quality improvement projects on public land, in cooperation with the USFS. We also recommend that the agencies involved make a greater effort to include private landowners, and those that represent them, in the decision making process.

Response:

The fecal coliform source identification work performed by the Ferry Conservation District was mentioned in the TMDL document on page 7. The Kettle Tri-Watershed Project Water Quality Summary Report that documents the results of the microbial source tracking (MST) study stated that "…quantification is not yet certain using the MST…" A recent study conducted by the United States Geological Survey to test the accuracy of current MST methods found that all methods identified less than 30 percent of the sources correctly (USGS 2004). In addition, the EPA concluded from their review of existing methods that they "will require further development before they can be considered appropriate for source tracking of fecal contamination" (Simpson et. al. 2002). Therefore, while the study demonstrated some of the various sources of fecal coliform, it is not certain how much of the problem is attributed to any one source. Future monitoring is planned on the forest in an attempt to identify where fecal coliform is entering the streams, which will also narrow down possible sources of the bacteria. Perhaps in the future an accurate MST method will emerge and be used during the implementation of the TMDL.

The Clean Water Act is a federal law and all federal agencies are expected to comply with that law. Ecology has the responsibility for developing TMDLs on Forest Service managed lands within the state. Support for implementation of the TMDL is the responsibility of the federal agency. Ecology does have a policy that restricts grant money from being used to implement projects on state and federal lands. However, water quality monitoring with grant funds is allowed when a project addresses a larger area that may include state and/or federal lands. The reasoning behind this policy is that state and federal agencies are tasked with providing clean water and have their own sources of money available to implement BMPs. If grant money was used for implementation activities on state and federal lands, it would take away grant funds from other entities that do not have other sources of funding.

County commissioners were updated on the TMDL and four meetings were held to explain the information in the report prior to the release of the report for public comment. The county commissioners will receive periodic updates as we continue with TMDL monitoring and BMP development and implementation.

Few opportunities exist for other entities and organizations to participate during the TMDL study and submittal report development. Rather, participation and cooperation from these groups as well as forest users, such as grazing permit holders, is important and will be sought during the implementation phase of the TMDL. Grazing permit holders were invited to observe the water sampling in 2004. That offer will continue through the seven years of post TMDL monitoring. The permit holders will also be heavily involved in the development of the detailed implementation plan which will be developed within one year after TMDL approval by EPA.

Comment:

-----Original Message-----
From: Tveten, Richard [mailto:TvetenR@wsdot.wa.gov]
Sent: Wednesday, May 11, 2005 10:11 AM
To: Knight, David T. (ECY ERO)
Subject: FW: Colville National Forest TMDL & Hwy 20

Dear Mr. Knight,

Thank you for providing us with the opportunity to review and comment on the attached.

As a former fire ecologist I suggest that you consider the following:

It appears that the attached does not take forest fires into consideration when estimating "potential natural vegetation" and the "shade level expected provided optimal vegetative growth conditions". Historically, the forests of eastern Washington burned more frequently than they do now and forest cover percentages in many areas are artificially higher than their historic norms at the present time due to a century of fire suppression. Ecology should take into account that huge fires will periodically burn entire watersheds because they are currently overstocked with trees. Such fires will greatly impact stream shading and greatly overshadow human activities. Accordingly, the potential natural vegetation values in Table 16 appear to be unrealistically high.

Response:

The attachment that the Department of Transportation was sent to review was an excerpt with the shade allocations and did not include the explanation as to how the shade allocations were developed. Wildfires were cited in the report as a possibility, and the adaptive management section in the summary implementation strategy states that "if some unforeseen event affects the landscape, such as a wildfire, the timelines to meet the load allocations in this TMDL may need some modification." Regardless, we must constantly strive to meet load allocations and water quality standards.

Comment:

David Heflick
Conservation Associate, Colville National Forest
Northwest Ecosystem Alliance
3714-F Sand Creek Road
Kettle Falls WA 99141
Voice: 509-684-8287
dheflick@kettlerange.org

May 20, 2005

Karin Baldwin, Dept of Ecology / Water Quality
N. 4601 Monroe
Spokane, WA 99205-1295
(509) 329-3472
kbal461@ecy.wa.gov

Dear Ms. Baldwin,

Please accept these comments on behalf of Northwest Ecosystem Alliance (NWEA). Among NWEA's missions and objectives are the defense of wilderness, biodiversity, and ecosystems of Washington State.

Upon review of *Colville National Forest Fecal Coliform, pH and Temperature Total Maximum Daily Load (TMDL)* we feel that there are a number of items that need clarification or provision of more information.

In the table below, excerpts from the document are presented in the left column and the associated concerns are presented in the right column.

Excerpts	Concerns/Questions
Grazing animals may cause concentrations to fluctuate with seasonal use or migration patterns. (p.8)	What attempts were made to further analyze/determine the relationship between grazing and fecal coliform levels? Were measurements taken immediately before and after seasonal introduction and removal of grazing animals?
Two drainages within the forest, North Fork Sullivan and East Fork Deer both serve as drinking water sources for the communities of Metaline Falls and Orient, respectively. Both drainages have been monitored for fecal coliform bacteria levels over an extended period. For this reason, these drainages reflect background conditions with bacterial levels reflective of natural (without human or domestic animal contribution) levels. (p 49)	Why couldn't fecal coliform levels (and the seasonal variation) in these basins be used as a baseline against which to compare levels and seasonal variations in watersheds where grazing does occur? Would such a comparison not help to establish or dismiss a connection between elevated fecal coliform levels and grazing?

Elevated levels of fecal coliform bacteria are the most common reason for the 1998, 303(d) listings within the Colville Forest. Potential sources include: sheep and cattle, humans, and wildlife. Sheep and cattle grazing occur within 45 active allotments throughout the forest. The Forest Service monitors fecal coliform levels in surface waters to ensure compliance with provisions specified in each grazing permit. A requirement of each permit is compliance "with the federal, laws or regulations or state and local laws relating to livestock control and to protection of air, water, soils and vegetation, fish and wildlife, and other environmental values." (p. 24)	Questions here are very similar to the above items: What efforts have been made to determine, or at least significantly clarify, which of these various sources is the most likely "potentially responsible party" for the high fecal coliform levels? The answer to this question is obviously a prerequisite to truly corrective and effective management actions.
For the majority of the monitoring locations, lower bacterial levels were observed April-May and October-November. During the winter months nonpoint bacterial sources are reduced; camping within the forest is minimal and grazing non-existent. In addition, environmental conditions during the winter limit bacterial viability in surface waters due to freezing conditions. (p.17)	Again, very similar questions. What does the "curve" of the change in readings look like? Is it a steady rise in spring and a steady decrease in fall that one would expect from seasonal changes in recreation and wildlife patterns, or is it a more pronounced increase/decrease pattern that one might expect from the abrupt introduction and removal of grazing?
Elevated nutrient loading to surface waters, along with increased exposure to shortwave radiation (increasing temperature) stimulates primary production (plant growth) resulting in wide swings in pH is most evident during the summer months (June through August) when nutrient sources and growing conditions are most favorable and, therefore, define the critical period for the evaluation of pH for this TMDL analysis. (p 18)	What is the primary source of the elevated nutrient loading?
However, much of the Colville Forest is also managed for grazing and waste deposition within streams can, depending on its level of introduction, be a significant source of nutrients and, therefore, could lead to conditions that stimulate primary production. (p. 17)	What attempts were made to establish connections between areas where waste deposition was high and where primary production was stimulated?

For water bodies where an increase in percent effective shade necessary to achieve the temperature criteria is below approximately 10 percent, then likely no active implementation of best management practices are necessary. (p. 52)	Wouldn't this depend upon how close the temperature was to falling within the temperature criteria? If the stream temperature was only exceeding the threshold by a small amount, then a 10 percent increase in PES could make the difference between compliance with or exceedance of the standard.
The only potential nutrient supply large enough to affect pH on the forest is from cattle. However, there is not a clear association between monitoring locations with more elevated levels of bacteria, and by association, phosphorus, and elevated pH levels. For this reason, this TMDL advocates that streams with maximum pH levels that exceed the upper limit of the criteria (8.5) their more elevated range is a reflection of geological influences (Table 18). For this reason, the expected upper range in pH for forest streams has been extended from 8.5 to 8.8. (p. 52)	This is a very confusing passage that begs for clarification and substantiation. What is the basis for the position that cattle are the "only potential nutrient supply large enough to affect pH on the forest"? What efforts were made to establish a clear connection between elevated levels of bacteria and pH levels? Without this information, it appears that the raising of the pH criteria constitutes a raising of the standard to meet existing levels, rather than a lowering of the levels to meet the existing standard.

In the course of informal conversation with agency personnel, we have learned that many of these concerns are shared by agency staff. Therefore, we request that Ecology provide an official forum for the questions to be answered and clarifications provided.

Thank you for your consideration of these comments.

Sincerely,

David Heflick

Response:

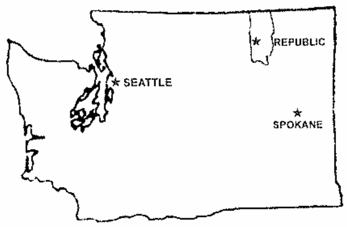
Concerns/Questions	Response
What attempts were made to further analyze/determine the relationship between grazing and fecal coliform levels? Were measurements taken immediately before and after seasonal introduction and removal of grazing animals?	The emphasis of this study was not on identifying specific bacterial sources within the Colville Forest rather it was directed on identifying stream locations within the forest with fecal coliform levels exceeding criteria. For streams found to have more elevated bacterial levels requiring reductions, the next phase of this work, the detailed implementation plan, may collect water samples using a segmented approach to identify sources.
Why couldn't fecal coliform levels (and the seasonal variation) in these basins be used as a baseline against which to compare levels and seasonal variations in watersheds where grazing does occur? Would such a comparison not help to establish or	Since the North Fork Sullivan Creek and East Fork Deer Creek monitoring sites do meet standards, they may be used to compare bacteria levels in other watersheds. However, caution must be used when making such comparisons because the source of fecal coliform is not always apparent. For example, livestock, wildlife and campers are often observed in the same open meadows

dismiss a connection between elevated fecal coliform levels and grazing?	throughout the summer. In addition, monitoring locations were often located near the Forest Service boundary, so there may be other sources further upstream such as dispersed campsites. For this reason more water monitoring in upstream increments will need to be conducted to determine where the bacteria may be entering the streams. Therefore, comparing the data from the municipal watersheds to that from grazing allotments does neither establish nor dismiss a connection between elevated fecal coliform levels and grazing. Moreover, Cottonwood Creek (in Stevens County) is not located within a grazing allotment and yet it does not meet the fecal coliform bacteria standard. Therefore, studies will need to be completed to identify the bacteria source(s) at this location.
Questions here are very similar to the above items: What efforts have been made to determine, or at least significantly clarify, which of these various sources is the most likely "potentially responsible party" for the high fecal coliform levels? The answer to this question is obviously a prerequisite to truly corrective and effective management actions.	During the implementation phase of the TMDL, additional monitoring is planned to identify where bacteria is entering forest streams. Once the locations are identified, possible sources may be narrowed down and the appropriate corrective action can be taken. This TMDL submittal report only needs to set load allocations for impaired streams and identify possible sources of the impairments. Load allocations are derived from the data and establish how much the pollution needs to be decreased to meet water quality standards. Identifying the "potentially responsible party" is one task of TMDL implementation and the allocations are targets to be achieved through implementation of BMPs and innovative activities.
Again, very similar questions. What does the "curve" of the change in readings look like? Is it a steady rise in spring and a steady decrease in fall that one would expect from seasonal changes in recreation and wildlife patterns, or is it a more pronounced increase/decrease pattern that one might expect from the abrupt introduction and removal of grazing?	Annually, bacterial samples have been typically collected from April through November, bracketing the period when grazing occurs on the forest. The highest bacterial concentrations tend to occur June through September. Higher concentrations are a result of greater use of the forest by a variety of sources of bacteria including cattle, wildlife and humans.
What is the primary source of the elevated nutrient loading?	Elevated nutrient loading to streams may be the result of fertilizers, increased sediment load, fecal deposition, and geology. The discussion about the critical period for pH on page 18 includes an overview of how primary plant productivity results in an increase in pH levels and when the critical period is likely to occur as a result. This discussion does not conclude that primary production is the cause of high pH levels within the forest. Rather, pages 41 through 47 explain that the underlying geology was influencing the majority of sites on the 303(d) list for pH.

What attempts were made to establish connections between areas where waste deposition was high and where primary production was stimulated?	As discussed above, the elevated pH levels were determined to be due to carbonate geology and not the result of primary productivity. Therefore, no attempts were made at establishing a connection between areas with high waste deposition and primary productivity.
Wouldn't this depend upon how close the temperature was to falling within the temperature criteria? If the stream temperature was only exceeding the threshold by a small amount, then a 10 percent increase in PES could make the difference between compliance with or exceedance of the standard.	Stream locations that require an increase of less than ten percent shade exceed the temperature criteria less often than sites requiring larger amounts of shade. The thought is that riparian vegetation at sites requiring less than ten percent shade only need time to grow to produce the necessary shade. Spending resources on those areas requiring larger amounts of shade would be more efficient and effective. However, all sites will be evaluated to determine the best management strategy to use to meet temperature standards.
This is a very confusing passage that begs for clarification and substantiation. What is the basis for the position that cattle are the "only potential nutrient supply large enough to affect pH on the forest"? What efforts were made to establish a clear connection between elevated levels of bacteria and pH levels? Without this information, it appears that the raising of the pH criteria constitutes a raising of the standard to meet existing levels, rather than a lowering of the levels to meet the existing standard.	In order for primary productivity to affect pH levels, nutrient levels must be high. In forested environments, nutrient levels are typically low. Cattle concentrated in one area may contribute enough manure to supply the needed nutrients. However, carbonate geology was found to be influencing the pH levels. Therefore, no efforts were made to connect high bacteria levels with the pH levels. The TMDL proposed raising the pH level to 8.8 (an increase in .3 pH units) in the Colville National Forest to coincide with the naturally occurring pH levels.

Public meetings were advertised and held in Ione, Newport, Colville and Republic prior to the release of the report for public comment. During these meetings, the technical study was reviewed and people were given the opportunity to ask questions. If you have additional questions please contact Karin Baldwin at (509) 329-3472 or via email at kbal461@ecy.wa.gov. You may also contact Don Gonzalez with the Colville National Forest at (509) 684-7000.

Comment:



FERRY COUNTY
BOARD OF COMMISSIONERS

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TELEPHONE (509) 775-5229 · FAX (509) 775-5230

BRAD L. MILLER, Curlew-District #1
RONALD L. BACON, Republic-District #2
MIKE L. BLANKENSHIP, Boyds-District #3

JOY OSTERBERG, Clerk of the Board
joy@co.ferry.wa.us

RECEIVED
2005
DEPARTMENT OF ECOLOGY
EASTERN REGIONAL OFFICE

May 3, 2005

Karin Baldwin
WA Department of Ecology
4601 North Monroe
Spokane, WA 99215-1295

Re: Ferry County Commissioners Response to Draft TMDL Plan

Dear Ms. Baldwin,

Ferry County Commissioners are totally opposed to the Washington State Department of Ecology's COLVILLE NATIONAL FOREST Temperature, Bacteria, and pH Total Maximum Daily Load (Water Cleanup Plan).

The integrity of the original samples, and the data obtained from those water quality samples that were used to list the 303(d) streams and water bodies in the Colville National Forest (including Ferry County) is extremely questionable and has been considered biased at best. There are multiple agencies that have commented as to the ethically "challenged" data, including employees of both the Forest Service and Ecology. Aside from quality sampling and the transportation and handling of those water samples, there was no Quality Assurance Plan in place when those samples that were taken, and labs used in the testing and analysis of those samples were not certified or accredited.

We feel that this plan emphasizes continued studies throughout the forest where several studies in our N.E. Counties have already provided the direction needed to implement strategies beneficial for TMDL compliance without the "fix" being an excessive burden on the Forest Service, Land Managers, Operators, Producers, Permittee's, or private land owners.

With both the national and state budget shortfalls creating loss of jobs and resources within the agencies, and their ability to perform these types of services, we believe this continued approach to more studies and proposed types of BMP's to be implemented can't assure the compliance of the EPA's standards, and is not a wise use of public funding. Mandating the Forest Service to follow this plan through the use of MOA's or any other agreement is considered forcing them to spend resources and funding that they don't have available to implement a program that would produce uncertain outcomes, and effects that can't guarantee EPA compliance. This plan also promotes implementation projects being forced on land users in which there is a high probability (in many cases) aren't the source of the pollution that is causing the exceedances of the standards.

Sincerely

BOARD OF FERRY COUNTY COMMISSIONERS

Mike L. Blankenship (by JO)(as approved via phone)(5/4/05)
MIKE L. BLANKENSHIP, Chairman

ABSENT
RONALD L. BACON, Vice Chairman

Brad L Miller
BRAD L. MILLER, Member

Response:

TMDLs must be prepared for waters that do not meet water quality standards and are placed on the state's list of impaired waters [the 303(d) list]. The water quality data submitted to Ecology is scrutinized before a decision is made to place a water body on the 303(d) list. For example, a quality assurance plan must have been used to collect and analyze the water samples and the data quality must also be assessed. As a result, only credible data is used to list a water body on the 303(d) list and in the development of TMDLs. The Colville National Forest did develop a quality assurance project plan for the sampling during 2004. Prior to 2004, water quality monitoring plans were written. The Colville National Forest water lab has been accredited by Ecology for analyzing fecal coliform samples since 2003. All water quality monitoring done by the Colville National Forest was done by following established sampling protocols and analyzed using standard methods. The Forest Service will continue to offer an invitation to anyone wanting to observe the sample collection, transport and analysis of water samples according to their published schedule, or to sample independently using an accredited lab and compare results.

The Colville National Forest TMDL only applies to Forest Service managed lands and not to the private land that may be located within the forest boundary. Most of the monitoring conducted and the resulting 303(d) listings are at or near the forest boundary. Therefore, the additional monitoring mentioned in the report would occur upstream of these locations to determine if humans recreating, previous timber harvest, livestock grazing, or a natural condition such as wildfire or wildlife are contributing to the temperature and fecal coliform problems. Any existing information that could help reduce temperature and fecal coliform levels at the identified sites is welcome and will be taken into consideration.

The Forest Service is required to manage national forests consistent with environmental laws and regulations such as the federal Clean Water Act. The act gives states the authority to establish water quality standards and requires TMDLs to be completed for 303(d) listed waters. The MOA between the Colville National Forest and Department of Ecology provides details on how the two agencies will work together to meet the requirements of the Clean Water Act. The BMPs mentioned in the report are examples of BMPs that have been recently applied on the forest. The type of BMPs applied to area depends upon the result of a site assessment and consultation with affected forest users. The BMPs that have been installed on the forest have been shown to be effective in reducing fecal coliform and temperature levels.

Comment:

Aladdin Allotment Complex
comments

May 19, 2005

Dear Dept. of Ecology,

I support cattle grazing on the Smackout, Meadow Creek and Aladdin allotments. Livestock provide an important tool for managing our public lands. Grazing is the most efficient means of removing plant material. Without grazing, after producing seed, weeds and grasses die and become a fire accelerant during the dry summer months. A popular new age management practice is to allow burning. My belief is these managers have never seen the devastation after a burn. Stream choked with ash, killing fish and other aquatic life. Runoff further devastates stream life.

I have reviewed the water study on theses allotments. I would have liked to seen the samples taken on the same date each month, at the same time of day, over a twelve month period. I would have liked to have known the location of the sample drawings. Was it at the USFS border? Have DNA samples been taken to determine the source, (wildlife, man or livestock,) of the elevated counts on a couple of the readings? What was the weather like? Were the readings taken after heavy rains?

Modern environmentalist take a no use stance on our public lands. I find that ironic when many of our public lands where set aside by Theodore Roosevelt. His view of conservation was to make it utilitarian. (Roosevelt set aside 230 million acres.) From a 1910 speech, " Conservation means development as much as it does protection." " I recognize the right and duty of this generation to develop and use the natural resources of our land, but I do not recognize the right to waste them...."

Sincerely,

L. Hill

Response:

In order to ensure that data is representative of the water quality in an area, samples are collected at various times of the day and month. Data analyzed for this TMDL were collected as frequently as twice per month. The number of samples collected each month and the time of day the samples are collected has varied due to access, logistics (number of sites to visit, distance between sites, holding times, etc.), and available resources. Samples are not collected year long on the forest because access to the sites is restricted by high snow levels, the creeks freeze over, and data indicates that by late fall, water quality standards are met.

All the monitoring locations for fecal coliform are listed in Table 14 on page 14 in the report. Most of the sites were located at or near the Forest Service boundary. At each site, field data sheets are completed to document information and observations relevant to the data, such as the weather and water level in the creek. Data has been collected during spring runoff events, summer rain storms, and hot summer days. Therefore, the data analyzed for this study was representative of various weather conditions. The Forest Service has offered, and will continue to offer, an invitation to anyone wanting to observe the sample collection, transport and analysis of water samples according to their published schedule, or to sample independently using an accredited lab and compare results.

Microbial source tracking (MST) or DNA studies were not performed to determine the source of fecal coliform bacteria. Although prior to the TMDL technical study, the Ferry Conservation District performed a study that demonstrated some of the various sources of fecal coliform, it could not determine how much of the problem is attributed to any one source. A recent study conducted by the Unites States Geological Survey to test the accuracy of current MST methods found that all methods identified less than 30 percent of the sources correctly (USGS 2004). In addition, the EPA concluded from their review of existing methods that they "will require further development before they can be considered appropriate for source tracking of fecal contamination" (Simpson et. al. 2002).

Grazing is useful in reducing fuel loading and invigorating grasses, which is a benefit to the land. Reductions in dried grass loads will reduce the flame intensity of wildfires and lessen the chance of damage to the plant crowns.

Comment:

-----Original Message-----
From: John Gross [mailto:jgross@knrd.org]
Sent: Thursday, May 19, 2005 1:36 PM
To: Baldwin, Karin K.
Subject: Colville NF TMDL

Karin,

pH extended to 8.8 due to regional limestone. The limey geology is not Colville forest wide. For example, in southern Pend Oreille county, the geology is much less limey than in the north. I am not asking that anything be changed; our upper pH is 9.0 per EPA recommendation.

-John

Response:

Page 47 of the report notes that south of Lost Creek in Pend Oreille County, lower pH levels (7.5-7.7) were observed. The geology of the area was found to be granite, glacial outwash, glacial drift, and heterogeneous metamorphic rock.

Comment:

STEVENS COUNTY CATTLEMAN'S ASSOCIATION

MAY 23 2005

Stevens County Cattlemen
614 Highway 20 E
Colville, Washington 99114

May 18, 2005

Anthony J. Whiley
Washington State Department of Ecology
Eastern Regional Office
4601 N. Monroe Street
Spokane, Washington 99205-1295

Dear Sir:

Re: Washington State Department of Ecology and Colville National Forest Temperature, Bacteria, and pH, total Maximum Daily Load (Water Cleanup Plan) Submittal Report Draft. April, 2005. Publication Number 05-10-047.

We are responding to Rick Brazell, Colville National Forest Supervisor's letter requesting response to the Department of Ecology comments on water quality and the T.M.D.L. documents for the Colville National Forest.

First, the standards are set too high on fecal coliform. They should be 100, not 50 colonies units per 100 milliliters. With other influences other than man caused, (mostly wildlife), we can't (without real science, DNA) determine what is causing the extremes in highs.

Second, the temperature is a very hard and slow process to make changes with most of the influences being from roads, and timber harvests over the last fifty years. Grazing of livestock has little influence.

There are some concerns on why the listings are on the 303D list? Was all testing done with integrity? Our concerns are for the livestock grazers, their profitability, economics of the communities, and a better environment. We support BMPs that make sense, will help the grazing allotment and environment, and are cost effective.

We want to be part of the future discussions on any problems that affect these grazing allotments.

Sincerely,

G. T. Wishon JR
Press. Stevens county cattlemen
Stevens County Cattlemen

Response:

Headwaters in National Forests have more stringent water quality standards in recognition that they are capable of providing a higher extent of protection for recreational uses, and in order to supply downstream uses with clean water. The criteria assigned to the downstream waters are set at levels that also protect public health, but that recognize that even under the best of circumstances some increased contributions in bacterial pollution will occur as the water flows through the watershed. Since the water coming from the forest has a more stringent standard than waters downstream, other land uses and activities can occur downstream and continue to meet water quality standards.

While microbial source tracking (MST) or DNA analyses have been found to have a low accuracy rate, additional incremental water monitoring can narrow down the area where fecal coliform bacteria are entering streams. Once an area contributing high fecal coliform levels has been identified, the possible sources of bacteria are further refined and appropriate actions may then be taken.

Areas requiring an increase in percent effective shade will need to be evaluated in order to determine the appropriate management technique or BMP that should be applied. Research has shown that grazing livestock can damage and hinder regeneration of shrubs and trees which decreases the amount of riparian vegetation and reduces the amount of shading available. Allotment management plans written for the grazing allotments include measures to reduce the impact of livestock on riparian vegetation.

Waters that do not meet state water quality standards are placed on the state's list of impaired waters [the 303(d) list]. The water quality data submitted to Ecology is scrutinized before a decision is made to place a water body on the 303(d) list. For example, a quality assurance plan must have been used to collect and analyze the water samples and the data quality must also be assessed. As a result, only credible data is used to list a water body on the 303(d) list and in the development of TMDLs. All water quality monitoring done by the Colville National Forest was done by following established sampling protocols and analyzed using standard methods.

The Colville National Forest will work with grazing permit holders and other forest users during the development and implementation of the detailed implementation plan to ensure that cost effective, reasonable and appropriate management techniques and BMPs are used to meet water quality standards. Your support of BMPs is appreciated.

Comment:

Cattle Producers of Washington

PO Box 103
131 Second Ave SE
Soap Lake WA 98851

Phone: 509-246-1618
Fax: 509-246-2066

RECEIVED
JUN - 9 2005
DEPARTMENT OF ECOLOGY
EASTERN REGIONAL OFFICE

Department of Ecology
Water Quality Program
MAY 31 2005

May 18, 2005

Anthony J. Whiley
Washington State Department of Ecology
Eastern Regional Office
4601 N. Monroe Street
Spokane, Washington 99205-1295

Dear Sir:

This is a response letter to the Washington State Department of Ecology and Colville National Forest Temperature, Bacteria, and pH, Total Maximum Daily Load (Water Cleanup Plan) Submittal Report Draft. April, 2005. Publication Number 05-10-047.

Our concern as a State Cattlemen organization is to protect the livestock industry in the State of Washington and on the Colville National Forest. We want to be part of any discussion, now and future, on the effects of livestock grazing. With integrity on water testing questionable, placing the streams on the 303D list, we have some reservations, like quality assurance programs, etc.

Your water standards are set too high, with the influence of wildlife and not enough proper science. You can't reach Class AA drinking water standards. Some of your highest tested streams do not have any livestock grazing. Temperature has been influenced by roads and logging practices over a long time period, not grazing of livestock.

Our concern is that Best Management Practices, that will affect grazing allotments, be implemented that are not practical, cost effective and cause hardship to ranchers. This will also trickle down to the ranching communities. We are for a better environment, BMP practices and improving the economic future of our ranchers.

Sincerely,

Chad I. Denman

Cattle Producers of Washington

"Cattle bred, born and raised in Washington State"

Response:

*Note: this document was post-marked on May 20 and therefore, was included here. The date stamps reflect the dates they were received at the Ecology offices in Lacey and Spokane.

Ranchers with grazing permits will be involved in the development of the TMDL detailed implementation plan along with representatives from the Forest Service and Ecology.

All water quality monitoring done by the Colville National Forest was done by following established sampling protocols and analyzed using standard methods. The Colville National Forest did develop a quality assurance project plan for the sampling during 2004. Prior to 2004, water quality monitoring plans were written. The Colville National Forest water lab has been accredited for analyzing fecal coliform samples by Ecology since 2003. Waters that do not meet water quality standards are placed on the state's list of impaired waters [the 303(d) list]. The water quality data submitted to Ecology is scrutinized before a decision is made to place a water body on the 303(d) list. For example, a quality assurance plan must have been used to collect and analyze the water samples and the data quality must also be assessed. As a result, only credible data is used to list a water body on the 303(d) list and in the development of TMDLs.

Headwaters in National Forests have more stringent water quality standards in recognition that they are capable of providing a higher extent of protection for recreational uses and in order to supply downstream uses with clean water. The criteria assigned to the downstream waters are set at levels that also protect public health but that recognize that even under the best of circumstances some increased contributions in bacterial pollution will occur as the water flows through the watershed. Since the water coming from the forest has a more stringent standard than waters downstream, other land uses and activities can occur downstream and continue to meet water quality standards.

Class AA water quality standards are not drinking water standards. Class AA water quality standards are intended to provide extraordinary protection against waterborne disease. Information about drinking water standards can be found on the Washington State Department of Health's webpage at: http://www.doh.wa.gov/ehp/dw/default.htm.

Water quality standards are achievable on most streams on the Colville National Forest. Roughly 40 percent of sampled streams met the water temperature criteria. In addition, page 40 of the report states that 65 percent of streams analyzed during this study met the fecal coliform bacteria standard. There are some streams requiring a reduction in fecal coliform that will need to be monitored and evaluated to determine the sources of the high bacteria concentrations.

Areas requiring an increase in percent effective shade will need to be evaluated in order to determine the appropriate management technique or BMP that should be applied. Research has shown that grazing livestock can damage and hinder regeneration of shrubs and trees which decreases the amount of riparian vegetation and reduces the amount of shading available. Allotment management plans written for the grazing allotments include measures to reduce the impact of livestock on riparian vegetation.

The Colville National Forest will work with grazing permit holders and other forest users during the implementation phase of the TMDL plan to ensure that cost effective, reasonable and appropriate management techniques and BMPs are used to meet water quality standards.

Comment:

John and Melva Dawson
554 Larsen Road
Colville, Washington 99114

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JUN - 9 2005
DEPARTMENT OF ECOLOGY
EASTERN REGIONAL OFFICE

Department of Ecology
Water Quality Program
MAY 31 2005

May 18, 2005

Anthony J. Whiley
Washington State Department of Ecology
Eastern Regional Office
4601 N. Monroe Street
Spokane, Washington 99205-1295

Dear Sir:

This is a response letter to the Washington State Department of Ecology and Colville National Forest Temperature, Bacteria, and pH, Total Maximum Daily Load (Water Cleanup Plan) Submittal Report Draft. April, 2005. Publication Number 05-10-047.

Thanks for making time to tour some of the ranges on the Colville National Forest. I want to make a few comments. I think it is important for us (if and when the environmentalists file objections) to be at the table.

We all want good water quality and want to improve on what we have.

Fecal Coliform Bacteria levels are set to high. With the influence of wildlife, it should be the same as the rest of the area. 100 colonies per 100 mil. Without real science (DNA), we can not make best management practices. Some of our grazing practices and improvements have been implemented and ongoing for many years. The value of grazing livestock on forest lands is very important for a healthy environment. Grazing enhances plant communities, wildlife, fire suppression, recreation, and water quality. Maybe stubble height should be reconsidered. The latest science suggests shorter, down to 1 or 2 inches. The taller stubble under heavy run off will fold over, when shorter stands act as a better filter.

Water temperature is a difficult fix and a very long term solution. Grazing has little influence.

There is some question on the integrity of some of the early water sampling and listing of some of these streams.

Grazing on the Forest Allotments is very important to the ranchers, and in return to the local economy. Water quality is important to us and I am willing to work on improvements that make sense, are practical and cost effective.

Sincerely,

Melva Dawson John Dawson

John and Melva Dawson

Response:
*Note: this document was post-marked on May 20 and therefore was included here. The date stamps reflect the dates they were received at the Ecology offices in Lacey and Spokane.

Headwaters in National Forests have more stringent water quality standards in recognition that they are capable of providing a higher extent of protection for recreational uses and in order to supply downstream uses with clean water. The criteria assigned to the downstream waters are set at levels that also protect public health but that recognize that even under the best of circumstances some increased contributions in bacterial pollution will occur as the water flows through the watershed. Since the water coming from the forest has a more stringent standard than waters downstream, other land uses and activities can occur downstream and continue to meet water quality standards.

While microbial source tracking (MST) or DNA analyses have been found to have a low accuracy rate, additional incremental water monitoring can narrow down the area where fecal coliform bacteria are entering streams. Once an area contributing high fecal coliform levels has been identified, the possible sources of bacteria are further refined and appropriate actions may then be taken.

The Smackout Allotment (your grazing allotment) is an example of how implementation of BMPs will lead to lower fecal coliform readings and improved riparian habitat. One study on stubble height in the Journal of Range Management indicated that bent vegetation may create a slide for sediment. The critical period for fecal coliform is June through September when runoff events are not as common. However, any BMPs installed will be appropriate for the uses, needs, and goals for that particular site.

Areas requiring an increase in percent effective shade will need to be evaluated in order to determine the appropriate management technique or BMP that should be applied. Research has shown that grazing livestock can damage and hinder regeneration of shrubs and trees which decreases the amount of riparian vegetation and reduces the amount of shading available. Allotment management plans written for the grazing allotments include measures to reduce the impact of livestock on riparian vegetation.

All water quality monitoring done by the Colville National Forest was done by following established protocols and analyzed using standard methods. Waters that do not meet water quality standards and are placed on the state's list of impaired waters [the 303(d) list]. The water quality data submitted to Ecology is scrutinized before a decision is made to place a water body on the 303(d) list. For example, a quality assurance plan must have been used to collect and analyze the water samples and the data quality must also be assessed. As a result, only credible data is used to list a water body on the 303(d) list and in the development of TMDLs.

The Colville National Forest will work with grazing permit holders and other forest users during the implementation phase of the TMDL plan to ensure that cost effective, reasonable and appropriate management techniques and BMPs are used to meet water quality standards.

Comment:

Jeff D. Dawson
554 Larsen Road
Colville, Washington 99114

May 18, 2005

Anthony J. Whiley
Washington State Department of Ecology
Eastern Regional Office
4601 N. Monroe Street
Spokane, Washington 99205-1295

Dear Sir:

I am writing this in response to the Colville National forest T.M.D.L. Report.

I feel the standards of water quality that were set by the State of Washington for the Colville National Forest to try and achieve will be difficult and in some cases unobtainable, due to natural conditions (Wildlife, etc.). We don't know what effect they are having on water quality. I also feel that past monitoring by Forest Service personnel was biased and falsified. As a rancher I believe in clean water as much as anybody, but I also believe that there is an agenda to remove livestock grazing from our Federal Lands by special interest groups, without concern for families and the communities that they live in and support.

I look forward to hearing from you Anthony. Thanks.

Sincerely,

Jeff D. Dawson

Jeff D. Dawson

Response:

*Note: this document was post-marked on May 20 and therefore, was included here. The date stamps reflect the dates they were received at the Ecology office in Lacey.

Natural conditions are defined in the water quality standards (WAC173-201A-020) as the quality of surface water that is present before any human-caused pollution. Natural conditions apply "when a water body does not meet its assigned criteria due to natural climatic or landscape attributes" (WAC 173-201A-260). In other words, any possible human source must be removed before a natural condition could be considered. Although rare and applied to limited settings, the possibility does exist that natural conditions on the forest may be higher than state water quality standards. In those circumstances, the natural condition would become the standard and apply downstream until human influences, such as campsites, logging activities, or grazing allotments are encountered. Further, if natural conditions were to be designated, they would only apply during the critical period (June-September). Additional water monitoring will be needed to determine if and where fecal coliform bacteria levels on the forest are the result of natural conditions.

All water quality monitoring done by the Colville National Forest was done by following established sampling protocols and analyzed using standard methods. The Colville National Forest did develop a quality assurance project plan for the sampling during 2004. Prior to 2004, water quality monitoring plans were written. The Colville National Forest water lab has been accredited by Ecology for analyzing fecal coliform samples since 2003. The Forest Service will continue to offer an invitation to anyone wanting to observe the sample collection, transport and analysis of water samples according to their published schedule, or to sample independently using an accredited lab and compare results. There is no evidence that data has been falsified. In the past, some monitoring has been conducted in areas outside of grazing allotments. We have received comments for more sampling on streams outside grazing allotments for comparison to streams within allotments. Monitoring of these areas will be conducted as resources allow.

Comment:

May 18, 2005

WA Dept. of Ecology
4601 N. Monroe Street
Spokane, WA 99205
Attn: Karin Baldwin

RE: Comment Submittal: Draft Colville National forest Temperature, Bacteria, and pH TMDL Submittal Report

Below please find my comments and questions concerning your Draft TMDL Submittal Report:

1. How can Ecology assume that campers bury their waste and at the same time assume that cattle are the major fecal coliform bacteria source in the CNF surface waters?
2. Why does this TMDL draft not mention the Ecology funded BST study in the Kettle Tri-Watershed that shows cattle were not the major source of bacteria and in fact, cattle were down the list of bacteria sources, behind deer/elk and birds?
3. It is mentioned in the Monitoring Strategy that Ecology and the USFS will jointly review the monitoring results. Since the USFS and the grazing permittees will be working together installing a variety of BMPs to help reduce fecal coliform levels, why are the permittees not included to review the monitoring results? After all, they are much more the "eyes and ears" in the forest than Ecology.
4. Title 40 CFR Part 130, *Water Quality Planning and Management*, requires that each State provide an estimate of the economic and social costs needed to achieve the objectives of the CWA. Why has Ecology not provided an estimate of the economic and social costs needed to achieve the objectives of this TMDL?
5. Why has Ecology not provided an estimate of the implementation costs of this TMDL?
6. The EPA approved *Colville River Watershed Bacteria TMDL* was designed to address the water quality impairments of characteristic uses in the Colville River watershed due to elevated fecal coliform bacteria levels. Why are the Colville National Forests tributary headwaters in the Colville River watershed not being addressed with the EPA approved watershed TMDL, the *Colville River Watershed Bacteria TMDL?*
7. Why is Ecology addressing other tributary headwaters on private land in the Colville River watershed with the *Colville River Watershed Bacteria TMDL* and not the tributary headwaters on public land?
8. The Colville National Forest comprises 17% of the total Colville River watershed area, why is Ecology not addressing the Colville National Forest waters with the *Colville River Watershed Bacteria TMDL?*
9. Why does Ecology not mention that for the *Colville River Watershed Bacteria TMDL,* the Colville National Forest partnered with Ecology to perform TMDL implementation "source search" monitoring on the same Forest land waters that this TMDL addresses? Why is Ecology ignoring this monitoring work that was performed?
10. Ecology uses fecal coliform bacteria as an indicator for Washington's surface waters, why does Ecology not mention that scientists have determined that these indicators often can not be used to accurately predict the presence of pathogens?

11. Since the grazing permittees and other interested parties will be assisting with the development of the Detailed Implementation Plan, does Ecology plan on engaging the public with the TMDL implementation and monitoring activities, such as observing water sampling?
12. Why does Ecology not mention that bacteria concentrations per gram of feces of adult animals ranges from 20 to 200 times greater in pigs, sheep, chickens, dogs, cats and humans than that of cattle?
13. Title 40 Part 25 CFR states the requirements for public participation activities under the Clean Water Act. Since these regulations apply to agencies receiving EPA financial assistance, why did Ecology not include the Ferry Conservation District, an important partner and TMDL team member in this particular TMDL for over three years, in this draft TMDL?
14. Is Ecology going to determine the actual source(s) of the fecal coliform bacteria prior to implementing bacteria reducing BMPs?
15. Agencies and other entities receiving federal and/or state funds through Ecology water quality grants are required to have an approved Quality Assurance Project Plan prior to performing any water quality sampling and testing. This TMDL is based on water quality data that did not follow any water quality sampling quality assurance protocol. In addition to not following any laboratory quality control protocol, the laboratories performing the analyses were not Ecology or EPA accredited. How does Ecology find it possible to base the bacteria portion of this TMDL on water quality data having these major water quality study deficiencies?
16. Were the stream water samples for bacteria collected properly?
17. Were the sample bottles sterilized properly prior to collecting samples?
18. Were the samples refrigerated properly during transport to the laboratory?
19. Were Chain of Custody records used?
20. Were proper laboratory procedures followed?
21. For this TMDL, did Ecology perform differentiation of coliform types to determine if the source of increased coliform densities were a result of the multiplication of organisms on or in organic materials?
22. Since fecal coliform bacteria are a possible indicator of disease-causing pathogens, do they accurately reflect the potential for human health effects?
23. Ecology states in this TMDL Draft that the recreational opportunities provided on the Forest include: hunting, fishing, gathering forest products, viewing scenery, camping, hiking, and floating. None of these recreations involve complete submergence; in fact a person could not obtain complete submergence in the streams listed for bacteria in the Colville National Forest. Why then, is Ecology attempting a TMDL on streams that do not match the water quality standards?

Thank you,

Dennis

Dennis Murray
33654 Park Drive
Valley, WA 99181

Response:

1. The report does not assume that livestock are the major fecal coliform source of fecal coliform. Rather the report mentions that livestock are one of the possibilities.
2. The report does refer to Ferry Conservation District's microbial source tracking (MST) or BST study in the Kettle Tri-Watershed on page 7. The report concluded that several sources of fecal coliform bacteria exist and that some could not be identified. The data reported the possible sources in numbers of isolates and not in colonies of fecal coliform. In addition, the BST study was not able to determine how much bacteria each particular animal species was contributing to the total amount of bacteria present. Therefore, the major source of fecal coliform can not be determined with any certainty based on this study.
3. Ecology will need to review the monitoring results in order to determine if the interim targets set in the TMDL are met. The forest has been sharing monitoring data with grazing permit holders and will continue to do so.
4. The regulations at 130.6(c)(6) which discuss economic and social impacts are specific to the development of statewide water quality management plans and do not apply to individual TMDLs.
5. The TMDL only provides an overview of the implementation measures that may be used to achieve water quality standards. The detailed implementation plan will be completed within a year after the Environmental Protection Agency approves the TMDL. However, the implementation plan does not specifically state what management technique or BMP will be applied and where. (The Forest Service and grazing permit holder will be working together to identify BMPs that may be applied in their allotments.) Therefore, completing an estimate of implementation costs during any phase of the TMDL would be impossible. Moreover, economic impact statements are also not required since a TMDL is neither a rule nor a general permit. For example, small business economic impact statements, cost-benefit analyses, or small business economic analyses mandated by the Regulatory Fairness Act [Revised Code of Washington (RCW) 19.85] and Administrative Procedure Act (RCW 34.05) apply only to rules. In addition, the waste discharge general permit program (WAC 173.226) requires an economic impact assessment for rules only.
6. The 303(d) fecal coliform listings on the forest that are located within the Colville River watershed were not addressed in the *Colville River Watershed Fecal Coliform Bacteria TMDL*. In other words, no load allocations, or percent reductions in the case of fecal coliform, were previously assigned to the listings on the forest.
7. The tributary headwaters on public land within the Colville River watershed are being addressed. Please see the *Draft Colville River Watershed Fecal Coliform Bacteria TMDL Detailed Implementation Plan* located on the internet at http://www.ecy.wa.gov/pubs/0510045.pdf.
8. The Colville National Forest has decided to conduct certain actions to improve water quality in the Colville River watershed. Please see the *Draft Colville River Watershed Fecal Coliform Bacteria TMDL Detailed Implementation Plan* located at http://www.ecy.wa.gov/pubs/0510045.pdf.

9. Any monitoring conducted with an approved quality assurance project plan (QAPP) or an equivalent plan was included in the data analysis for the TMDL. Any other data that may have been collected (i.e., without a QAPP or equivalent) did not meet Ecology's standards for credible data.
10. Page 7 of the report does state that "While the detection of fecal coliform bacteria does not confirm that pathogenic bacteria are present, when detected at more elevated concentrations, there is a greater risk of their presence."
11. The Forest Service has invited grazing permit holders and others to observe water sampling and will continue to do so. The Colville National Forest continues to offer an invitation to anyone wanting to observe the sample collection, transport and analysis of water samples according to their published schedule, or to sample independently using an accredited lab and compare results. Since work on the detailed implementation plan for this TMDL will not commence until EPA approves this report, other activities that the public may engage in have not yet been identified.
12. The report mentions that recreation and livestock grazing are possible sources of bacteria. Therefore, humans, cattle, and dogs are likely the only human influenced sources you mention that one would expect to find on the forest. The question then becomes which source contributes the most grams of feces? To answer this question, additional incremental monitoring will forest streams. Once the source is identified the appropriate management techniques or BMPs can be applied.
13. During the course of the technical study and prior to public comment period for this TMDL, several public meetings were advertised and held. The Ferry Conservation District did participate in the TMDL technical study by graciously allowing the forest to borrow multiple temperature probes with which to gather data that was included in the temperature analysis. Few additional opportunities exist for other entities and organizations, such as the Ferry Conservation District, to participate during the TMDL study and submittal report development. Rather, participation and cooperation from these groups as well as forest users is important and will be sought during the implementation phase of the TMDL.
14. The forest will conduct additional incremental monitoring to narrow down the locations from which fecal coliform is entering forest streams. Once the source is identified the appropriate management techniques or BMPs can be applied.
15. The fecal coliform data used in the TMDL analysis is credible. All water quality monitoring done by the Colville National Forest followed established sampling protocols and was analyzed using standard methods. The Colville National Forest did develop a quality assurance project plan for the sampling during 2004. Prior to 2004, water quality monitoring plans were written. The Colville National Forest was accredited by Ecology in 2003.
16. Yes
17. Yes
18. Yes
19. Yes

20. Yes
21. No, Ecology did not test for regrowth of bacteria within the forest streams because there was no indication that the proper environment existed for regrowth to occur. Moreover, this TMDL submittal report only needs to set load allocations for impaired streams and identify possible sources of the impairments. Load allocations are derived from the data and establish how much the pollution needs to be decreased to meet water quality standards. Identifying specific sources is one task of TMDL implementation and the allocations are targets to be achieved through implementation of BMPs and innovative activities.
22. The criteria values used in the state standards are set at levels that have been shown through studies of human exposure to maintain low rates of serious intestinal illness (gastroenteritis) in people.
23. Headwaters in National Forests have more stringent water quality standards in recognition that they are capable of providing a higher extent of protection for recreational uses and in order to supply downstream uses with clean water. The possibility does exist that children or adults recreating in forest streams or lakes could ingest water. Further, it is important that the definition of primary contact recreation be considered along with the definition of secondary contact recreation. Primary contact use is appropriate in situations where adults or children would not choose to actively avoid exposing their eyes, ears, respiratory or digestive systems, or urogenital areas to waterborne pathogens. Secondary contact use is appropriate where such exposure would normally be avoided by people.

References

United States Geological Survey (USGS). 2004. Study Urges Caution in Contaminant Source Tracking. Website. http://www.sciencedaily.com/releases/2004/12/041206191533.htm

Simpson, Joyce M. et al. 2002. Microbial Source Tracking: State of the Science. Environmental Science & Technology. 36(24), 5279-5288

Appendix B
Study Data, Tables and Figures

Table B-A. Temperature monitoring site background data.

Station	T / R / S	Elevation (m)	Drainage Area (km^2)	Bankfull Width (m)	Bankfull Depth (m)	Average July-August Flow (cfs)	Wetted Width (m)	Average Flow Depth (m)	Current Effective Shade (%)
Addy	33 / 39 / 13	506	8.97	2.0	0.21	0.27	0.98	0.05	67
American Fork	40 / 38 / 14	667							85
Barnaby	35 / 36 / 33	682	47.28	5.8	0.91	4.41	5.21	0.09	66
Big Muddy	37 / 42 / 12	890	37.29	7.0	0.46				79
Boulder	39 / 36 / 36	527	263.32	7.9	0.62	7.65	4.11	0.14	41
Brown's (Outlet)	37 / 42 / 36	963	1.67	1.2	0.15				
Calispell	32 / 43 / 20	789	128.92	13.4	0.87	6.62	10.33	0.22	47
Cee Cee Ah	34 / 44 / 33	713	39.65	6.7		7.89	5.18	0.12	85
Cedar (lower)	38 / 42 / 26	733	25.71	6.7	0.40	2.79	2.74	0.08	53
Cedar (upper)	38 / 42 / 14	864	22.63	4.0	0.40	3.93	3.66	0.14	74
Cusick	34 / 43 / 11	751	19.57	3.0	0.55	1.28	2.50	0.08	67
Deadman	37 / 36 / 28	763	113.42	7.0	0.53	7.42	5.21	0.16	49
Deep		584	37.3						81
E. Deer	39 / 36 / 27	606	47.89	6.1	0.43	2.43	2.99	0.07	73
EF Crown		659	8.8						62
EF LeClerc	35 / 44 / 05	728	82.82	6.4	0.61	8.60	4.27	0.18	62
Flat									80
Flume	39 / 43 / 04	795	29.26	3.4	0.65	1.90	2.74	0.11	85
Harvey	38 / 44 / 30	830	92.26	11.1	0.50	10.41	6.77	0.17	73
Jim	38 / 42 / 26	733	12.32	6.1	0.46	0.80	1.68	0.07	75
L. Boulder	39 / 36 / 04	744	50.28	6.1	0.55	2.71	2.22	0.09	60
L. Muddy	38 / 42 / 35	763	25.45	5.2	0.61	2.28	3.41	0.07	67
LaFleur	39 / 33 / 02	855	11.89						62
Lambert	37 / 33 / 01	969	33.37	5.5	0.19	1.33	2.90	0.06	74
Lime	40 / 43 / 14	727	6.20	2.1	0.41	0.76	1.07	0.07	90
Lost (lower)	36 / 43 / 17	727	48.78	6.7	0.52	2.24	3.35	0.09	40
Lost (upper)	37 / 42 / 27	1047	14.98						76
Meadow	38 / 41 / 33	747	37.37	3.5	0.08	3.22	2.62	0.06	81
MF LeClerc	36 / 44 / 29	854	18.70	3.4	0.52	0.31	2.10	0.08	71
MF Mill	36 / 40 / 15	718	33.62	3.4	0.30	0.72	1.98	0.09	68
NF Chewelah	33 / 41 / 08	713	63.15	5.8	0.31	4.69	5.15	0.10	52
NF Mill	37 / 40 / 26	837	12.55	3.0	0.61	0.98	1.98	0.07	
NF O'Brien	36 / 33 / 26	1267	17.98	3.4	0.37	0.61	1.89	0.03	72
NF SanPoil	37 / 33 / 25	946	44.57	7.3	0.57	1.14	2.29	0.04	72
NF Sullivan	39 / 43 / 23	721	26.37						86
NF Trout	38 / 32 / 15	994	10.67	2.4	0.36				90
Nile (inlet)	37 / 42 / 35	981	21.09						52
Nile (outlet)	37 / 42 / 35	968	22.21			0.72	4.27	0.04	
Nine-Mile	35 / 33 / 18	654	67.69	4.3	0.20	1.31	2.10	0.06	
Pierre	40 / 37 / 33	728	36.64	4.0	0.38	1.28	1.77	0.09	76
Rocky	37 / 41 / 22	872	26.84	4.4	0.28	0.40	2.90	0.04	80
Ruby	35 / 43 / 10	675	79.63	7.3	0.37	5.61	3.96	0.16	63
Scatter	35 / 32 / 11	757	52.53	5.5	0.50	0.96	3.29	0.04	45
SF Boulder	38 / 36 / 03	584	177.90	11.3	0.56	4.54	6.71	0.10	36
SF Chewelah	33 / 41 / 23	919	31.06	3.5	0.30	1.80	2.68	0.06	72
SF Lone Ranch	40 / 34 / 24	778	35.43	5.2	0.52		1.83	0.03	86
SF Lost	36 / 43 / 22	660	25.83	2.4	0.57	1.03	2.19	0.06	71

Station	T / R / S	Elevation (m)	Drainage Area (km^2)	Bankfull Width (m)	Bankfull Depth (m)	Average July-August Flow (cfs)	Wetted Width (m)	Average Flow Depth (m)	Current Effective Shade (%)
SF Mill	36 / 40 / 15	702	72.33	4.6	0.70	1.52		0.17	65
SF O'Brien	36 / 33 / 26	931	38.76	4.6	0.62	0.67	1.55	0.04	78
SF Sherman	36 / 36 / 32	762	87.69	9.4	0.76	3.47	4.27	0.12	24
SF St. Peter	38 / 34 / 30	1002	13.77						76
Sherman	36 / 37 / 28	534	278.50	9.9	0.73	14.27	6.86	0.15	66
Silver	39 / 42 / 07	772	25.34	6.9	0.30	2.85	2.19	0.10	84
Slate	40 / 43 / 30	802	63.62						78
Smackout	38 / 41 / 03	892	33.60						86
Smalle	33 / 43 / 29	791	25.59	5.5	0.56	3.32	2.50	0.09	92
Sullivan	39 / 43 / 22	714	368.47						
Tacoma	34 / 43 / 21	743	91.42	8.8	0.77	11.24	6.71	0.20	66
Tonata	39 / 32 / 10	716	47.12	3.0	0.48	0.17	2.44	0.03	83
WF Crown									85
WF LeClerc	35 / 44 / 07	681	86.74	8.8	0.46	19.07	8.44	0.17	35
Winchester	32 / 43 / 05	780	33.94	4.3	0.34	0.97	2.16	0.11	80

Table B-B. Response temperature model parameters used in calibration by monitoring location.

Station	Effective Shade (%)	Water Depth (m)	Groundwater Inflow (m/s)	Groundwater Temperature (°C)	Year Modeled
Addy	66	0.45	===	===	2004
American Fork	85	0.25	===	===	2004
Barnaby	66	0.40	0.20	10	2003
Big Muddy	75	0.30	===	===	2003
Boulder	46	0.35	===	===	2003
Calispell	50	0.35	0.10	10	2003
Cee Cee Ah	79	0.25	===	===	2003
Cedar (lower)	53	0.25	0.05	10	2003
Cedar (upper)	74	0.25	===	===	2003
Cusick	53	0.30	===	===	2003
Deadman	66	0.30	0.10	10	2003
Deep	81	0.25	===	===	2004
E. Deer	71	0.60	0.12	10	2003
EF Crown	66	0.60	===	===	2004
EF LeClerc	55	0.30	0.05	10	2003
Flat	80	0.60	0.60	10	2004
Flume	84	0.50	0.35	10	2003
Harvey	70	0.40	0.30	10	2002
Jim	75	0.40	===	===	2003
L. Boulder	60	0.80	0.40	10	2003
L. Muddy	66	0.50	0.05	10	2003
LaFleur	62	0.30	0.22	10	2003
Lambert	74	0.20	===	===	2003
Lost (lower)	40	0.35	0.35	10	2002
Lost (upper)	75	0.25	===	===	2003
Meadow	80	0.35	===	===	2003
MF LeClerc	60	0.30	===	===	2003
MF Mill	65	0.50	0.65	10	2003
NF Chewelah	52	0.35	0.15	10	2002
NF Mill	85	0.60	0.50	10	2004
NF O'Brien	85	0.25	===	===	2003
NF SanPoil	72	0.25	0.25	10	2003
NF Sullivan	85	0.40	0.60	10	2002
NF Trout	81	0.35	===	===	2003
Nile (inlet)	52	0.35	0.20	10	2002
Pierre	76	0.80	0.30	10	2003
Rocky	78	0.50	===	===	2003

Station	Effective Shade (%)	Water Depth (m)	Groundwater Inflow (m/s)	Groundwater Temperature (°C)	Year Modeled
Ruby	60	0.30	===	===	2003
Scatter	44	0.60	2.0	10	2003
SF Boulder	55	0.35	===	===	2003
SF Chewelah	71	0.35	0.35	10	2003
SF Lone Ranch	86	0.25	===	===	2003
SF Lost	70	0.25	===	===	2003
SF Mill	65	0.45	0.05	10	2003
SF O'Brien	69	0.25	===	===	2003
SF Sherman	24	0.25	0.20	10	2004
SF St. Peter	76	0.25	1.50	8	2003
Sherman	36	0.35	0.05	10	2003
Silver	83	0.50	0.60	10	2003
Slate	78	0.60	0.80	10	2002
Smackout	80	0.50	===	===	2003
Smalle	67	0.50	0.20	10	2002
Tacoma	70	0.30	===	===	2003
Tonata	79	0.25	===	===	2003
WF Crown	85	0.80	1.50	8	2004
WF LeClerc	55	0.80	1.50	9	2002
Winchester	74	0.35	===	===	2003

Table B-C. The percent representation of various ranges in canopy density and dbh within 46 meters of streams located within each of the natural potential vegetation types.

Canopy Range	DBH Range	Natural Potential Vegetation					
		Doug. Fir	Doug. Fir Grand Fir	Doug. Fir W. Hemlock	W. Hemlock	Sub-Alpine	Parkland
Open	Open	16.8	13.1	21.8	20.9	19.0	26.4
	1-9.9"	===	===	===	===	===	===
	10-19.9"	===	===	===	===	===	===
	20'+	===	===	===	===	===	===
1-19%	Open	===	===	===	===	===	===
	1-9.9"	2.1	0.6	0.3	0.2	1.3	1.0
	10-19.9"	0.9	===	===	===	0.3	0.1
	20'+	0.1	===	===	===	===	===
20-39%	Open	===	===	===	===	===	===
	1-9.9"	11.0	6.6	3.9	2.1	5.7	4.9
	10-19.9"	1.2	1.1	0.7	0.4	0.7	1.8
	20'+	===	===	===	===	===	===
40-59%	Open	===	===	===	===	===	===
	1-9.9"	16.1	11.7	8.5	6.3	9.2	7.0
	10-19.9"	3.9	4.4	3.3	2.6	2.2	7.3
	20'+	0.5	===	===	===	0.2	===
60-100%	Open	===	===	===	===	===	===
	1-9.9"	34.4	40.8	40.2	46.9	43.7	32.9
	10-19.9"	11.7	18.9	19.2	18.5	16.6	17.3
	20'+	1.3	2.7	2.1	2.1	1.1	1.4

Table B-D. Monitoring stations by grazing allotment.

Allotment	**Status**	**Monitoring Station Within**
Bulldog (Lambert)	Active	SF Boulder (1), (2)
CC Mountain	Active	Deadman
Calispell	Active	Calispell, MF Calispell
Churchill	Active	Deep, Fisher, Pierre (1), (2)
Copper-Mires / (Lambert)	Active	**Lambert**
Copper-Mires / (Bracken)	Active	**NF San Poil**
Cusick – Gardiner	Active	Cusick (1), Cusick (4)
Elbow Lake	Active	American Fork, EF Crown, Flat
Jasper	Active	Martin, (Little Boulder)
LeClerc / (non-allotment)	Active	M/EB LeClerc, WB LeClerc
Little Boulder	Active	Independent
Little Boulder / (Jasper)	Active	Little Boulder
Lone Ranch	Active	**NF Lone Ranch (1), (2),** SF Lone Ranch
Lost Creek	Active	**Lost**
Lost Lake (non-allotment)	Active	Ione/Jim/Cedar
Meadow Creek	Active	Meadow
NF Chewelah	Active	NF Chewelah
Quartz	Active	SF O'Brien
Ruby	Active	**Ruby, SF Lost**
Smackout	Active	**Smackout**
SF Chewelah	Active	**SF Chewelah (1), (2),** (3), Healey, **Wilson (1), (2)**
SF Mill	Active	**Beestrom (1), (2), Green Mtn. (1), (2), SF Mill** (1), **(2), (4), (5)**
SF St. Peter	Active	SF St. Peter
SF St. Peter / NF St. Peter		NF St. Peter (2)
Swan Lake	Active	Scatter
Tonata Creek	Active	NF Trout (2), Tonata
Trout Creek	Active	**WF Trout (1)**
Vulcan Mountain	Active	**Cottonwood (Kettle)**
Graves	Vacant	McGahee, SF Sherman, Sherman
Non-Allotment	===	**Cottonwood (Colville),** E. Deer, Gypsy, Harvey, Little Muddy, Mill (Pend Oreille), NF Sullivan, Rocky, Sullivan, Tacoma, Three-mile, **Winchester**
Allotments not sampled	Vacant	Bangs, Empire, First Thought, Gillette Mountain, Henry Creek, Renner
Allotments not sampled	Active	Aladdin, Bamber, Boyds, Cliff Ridge, Day Creek, Graphite, Hope Mountain, Jungle Hill, Lake Ellen, McKinley, MF Mill, Nancy, NF St. Peter, Silver, Snowcap, Tiger Mountain, Twelve-Mile, Z-Canyon

Bolded Streams exceeded fecal coliform bacteria criteria

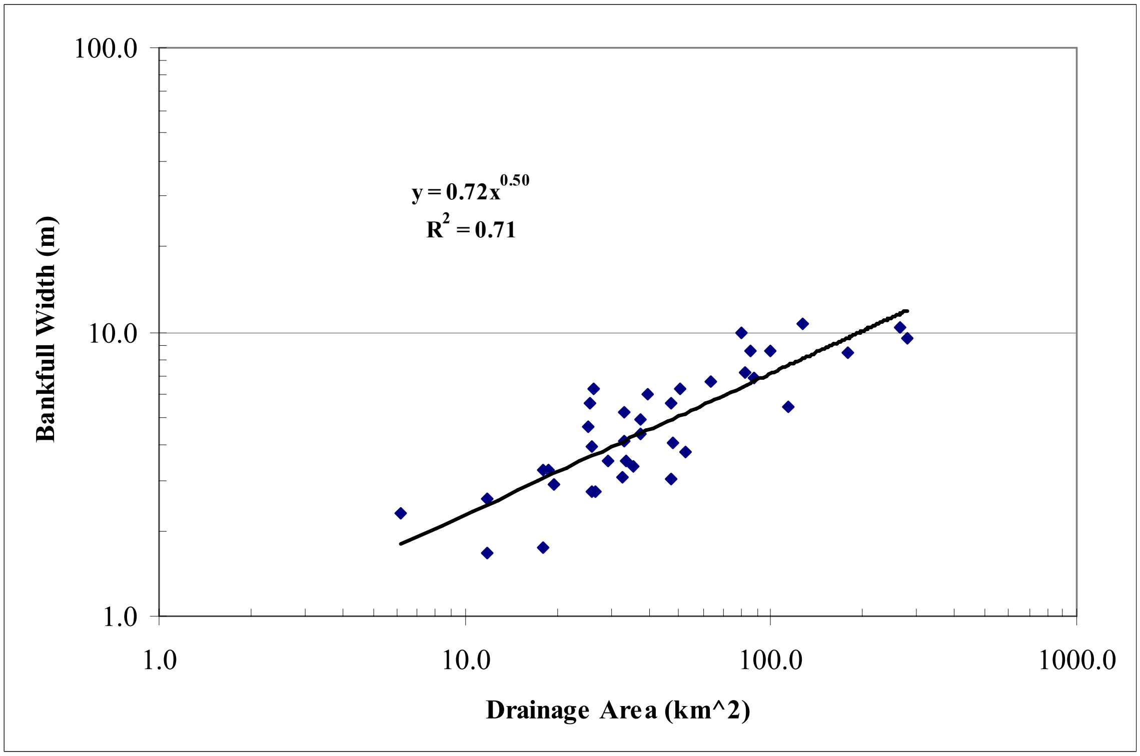

Figure B-A. The relationship between drainage area (km²) and bankfull width (m) observed at the temperature monitoring sites.

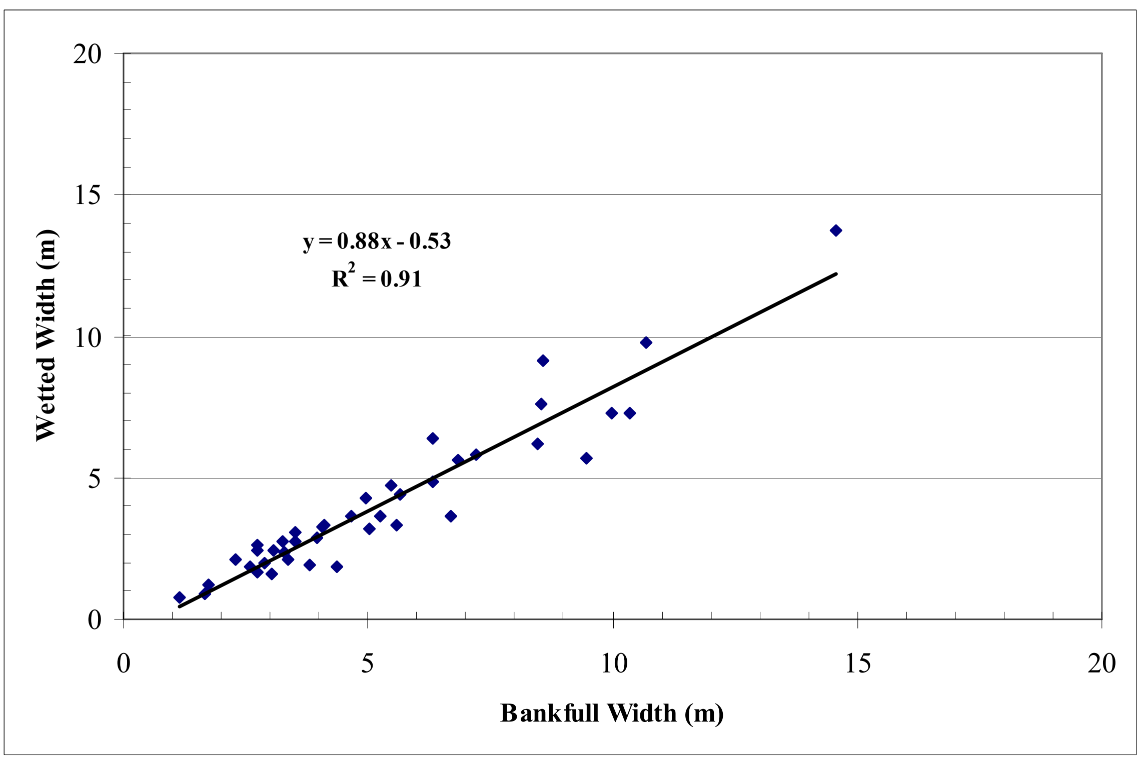

Figure B-B. The relationship between bankfull width (m) and wetted width (m) observed at the temperature monitoring locations.

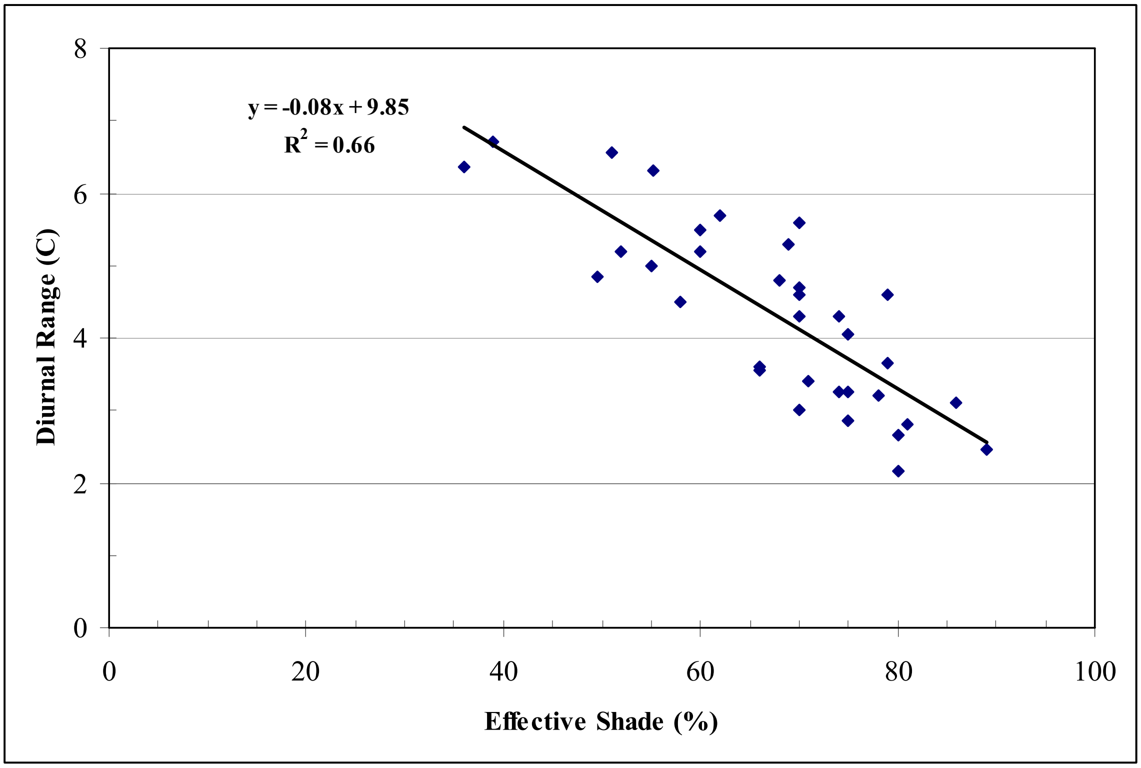

Figure B-C. The relationship between effective shade (%) and diurnal range (°C).

Appendix C
Assessment of Temperature
Model Error

Response Temperature Model Error

The response temperature model was calibrated, for the majority of the monitoring locations, based on 2003 temperature data. In order to assess the model's accuracy in predicting water temperature, the 2003 model calibration parameters, specific to each site, were used as input to a 2004 model run. The only model input changed with the 2004 run was the meteorology and the temperature monitoring data. Again, the meteorology data was collected from the same RAWS sites as the previous years (2003 and 2002) and the analysis period was from July 15 to August 20, spanning the period when the warmest water temperature were observed in the forest streams that summer.

Approximately 20 percent of the 2004 monitoring stations were chosen at random for analysis and are included in Table C-A. The determination of model accuracy was based on its ability to predict the measured daily maximum and minimum temperature, observed at each of the monitoring locations, over the analysis period, July 15 to August 15. The model error is represented by the root mean square error (RMSE) along with the median absolute value difference between observed and predicted for the maximum and minimum water temperatures.

Table C-A. Model error represented by the RMSE and median difference, for a subset of the temperature monitoring locations, based on the 2004 dataset.

Monitoring Station	Root Mean Square Error		Median Difference	
	Maximum Temperature	Minimum Temperature	Maximum Temperature	Minimum Temperature
Cedar (upper)	0.6	0.6	0.5	0.4
Deadman	0.9	0.7	0.5	0.4
Jim	0.9	0.8	0.5	0.5
Little Boulder	0.6	0.6	0.3	0.4
Little Muddy	0.8	0.9	0.5	0.7
LaFleur	0.9	0.5	0.5	0.4
Middle Fork Mill	0.3	0.3	0.3	0.2
Scatter	0.5	0.7	0.3	0.6
South Fork Boulder	1.2	0.8	0.6	0.4
South Fork Lost	1.2	1.0	0.5	0.6
Smackout	0.6	0.5	0.3	0.3
Winchester	0.9	0.8	0.6	0.6
Overall Average	0.8	0.7	0.5	0.5

The model provided a reasonable level of accuracy in predicting both maximum and minimum water temperatures with an overall RMSE for the 2004 model run of less than 1^{o}C. The RMSE is sensitive to outlier errors and a rainstorm, occurring across the forest on July 18-19, 2004, which leads to considerably lower water temperatures than predicted by the model leading to a greater level of error. (The response temperature model is not sensitive to advective-type heat influences.) The median absolute value of the temperature difference was used as another way of examining the model error while considering the outlying storm-event data. By this method, the overall median difference values for the analysis period were 0.5 ^{o}C for both the maximum and minimum temperatures. The relatively low level of error represented by both of these measures, observed at a subset of the monitoring stations, indicates that the model provides a high level of accuracy in predicting water temperatures under a variety of conditions.