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Simpson Northwest Timberlands Temperature Total Maximum Daily Load

Submittal Report

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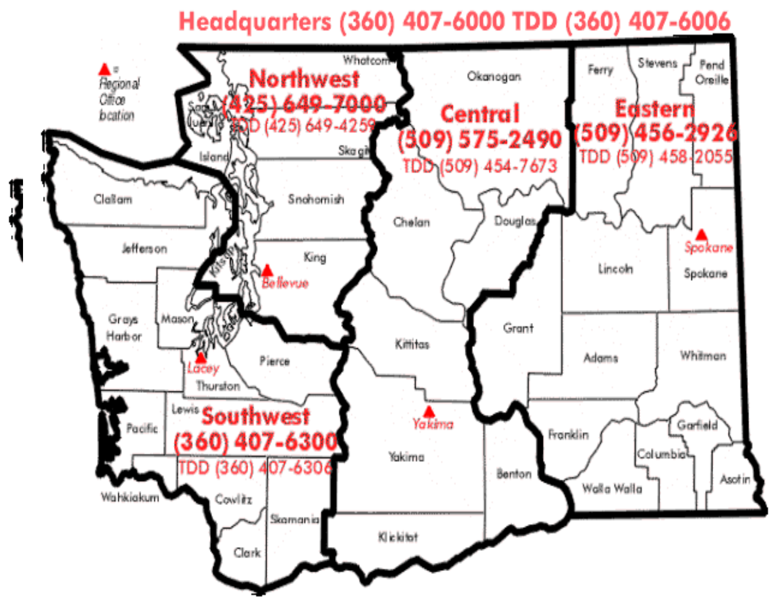

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Simpson Northwest Timberlands Temperature Total Maximum Daily Load

Submittal Report

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Introduction

Section 303(d) of the federal Clean Water Act mandates that the state establish Total Maximum Daily Loads (TMDLs) for surface waters that do not meet standards after application of technology-based pollution controls. The U.S. Environmental Protection Agency (EPA) has promulgated regulations (40 CFR 130) and developed guidance (EPA, 1991) for establishing TMDLs.

Under the Clean Water Act, every state has its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of designated uses, such as cold water biota and drinking water supply, and criteria, usually numeric criteria, to achieve those uses. When a lake, river or stream fails to meet water quality standards after application of required technology-based controls, the Clean Water Act requires the state to place the water body on a list of "impaired" water bodies and to prepare an analysis called a **Total Maximum Daily Load (TMDL)**.

The goal of a TMDL is to ensure the impaired water will attain water quality standards. A TMDL includes a written, quantitative assessment of water quality problems and of the pollutant sources that cause the problem. The TMDL determines the amount of a given pollutant which can be discharged to the water body and still meet standards, the **loading capacity,** and allocates that 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 it comes from a diffuse source (referred to as a **nonpoint source**) such as a farm, that facility's share is called a **load allocation**.

The TMDL must also consider seasonal variations and include a **margin of safety** that takes into account any lack of knowledge 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 loading capacity.

This TMDL is being established for two pollutants: heat (i.e. incoming solar radiation) and sediment. The TMDL is designed to address impairments in the 1996 303(d) list due to surface water temperature increases on four water quality-limited segments located within Simpson's 261,575 acres of Northwest Timberlands in the state of Washington. The 1998 303(d) list, which became available in January of 2000 includes two of the four segments. However, this TMDL sets allocation limits to protect all 1,398 milesof the area streams from becoming water quality limited. Because of the unique and comprehensive approach used in the development of this non-point TMDL, more detail will be included in this submittal report than usual for better understanding. The appendices contain the entire technical assessment report and key chapters of the related Habitat Conservation Plan.

The two pollutants considered in this TMDL, singly and in concert, are major determinants of water quality that affect aquatic life. These factors vary naturally in their characteristics across the landscape (as a function of geology, topography and climate) as well as over time. The influence of both pollutants on water quality can also be significantly affected by changes associated with land use.

The five elements of this TMDL as required by federal statute and regulation are summarized below:

Loading Capacity: The loading capacity for heat (or solar radiation) is based on effective shade levels in the riparian corridor needed to meet state water quality standards for temperature. Using information about each channel class (e.g. drainage area, active channel width, range of flows, etc) effective shade targets can be developed. The channel classification system is used to assess stream reaches according to temperature groups, e.g. the dominant control(s) which influence water temperature, specifically shade, groundwater, or channel morphology. This approach leads to effective shade targets that recognize the variability in channel and riparian characteristics that occurs across the landscape. As such, these targets reflect the range of active channel widths within the TMDL area.

The loading capacity for sediment is based on the volume of sediment delivered to stream systems through various hill slope erosion processes. Information in watershed analysis reports from the area were used to establish partial sediment budgets. Erosion processes include bank erosion, surface erosion and mass wasting (shallow rapid landslides, debris torrents, and large persistent deep-seated slides). Each process (or source of material) in each lithotopo unit was given a separate loading capacity.

Load Allocations: Allocations in this TMDL are derived using effective shade and sediment delivery targets. These measures can be linked to source areas and, thus to actions (specifically riparian management and mass wasting and erosion control measures) needed to address processes which influence water temperature. Because factors that affect water temperature are interrelated, both measures are dependent upon each other to produce the desired responses.

Wasteload Allocation: There are no permitted discharges within the area covered by the TMDL. As such, the wasteload allocation is zero.

Margin of Safety: The margin of safety is represented by several elements:

- Allocations for effective shade contain an explicit margin of safety that is expressed as an unallocated portion of the loading capacity.

- Allocations for effective shade also contain an implicit margin of safety, specifically the point of measurement for the Riparian Conservation Reserve.

- Allocations give no *"credit"* for instream sediment storage because current excessive levels of instream stored sediment are contributing to temperature increases in one channel group (C-1). The allocation is lower than would be the case if legacy sediment levels didn't exist and instream storage credit could be provided.

- The TMDL is intended to be adaptive in management implementation. This plan allows for future changes in loading capacities and surrogate measures (allocations) in the event that new information or scientifically valid reasons support alterations.

Seasonal Variation: Existing conditions for stream temperatures in the Simpson HCP area reflect seasonal variation. Water quality standards for temperature are exceeded between May and October. In addition, the data show that the highest seven-day average maximum water temperatures occur between mid-July and mid-August. This time frame is used as the critical period for development and analysis of allocations in the TMDL.

Background

A Total Maximum Daily Load (TMDL) has been developed to address fisheries concerns on several tributaries of the lower Chehalis and Skokomish Rivers as well as several streams draining to South Puget Sound and Hood Canal. The scope of this TMDL includes waters located on land owned by Simpson Timber Company (STC) in the state of Washington. These forested watersheds include Simpson's long term commercial timberland in Thurston, Mason, and Grays Harbor counties. The area lies near Shelton and extends into the southern foothills of the Olympic Mountains across the Wynoochee River.

Excessive summer water temperatures in some of these streams reduce the quality of rearing habitat for coho salmon as well as for steelhead and cutthroat trout. Primary watershed disturbance activities that contribute to surface water temperature increases include forest management within riparian areas, timber harvest in sensitive areas outside the riparian zone, and roads. In light of current and pending fish listings under the Endangered Species Act, Simpson initiated a Habitat Conservation Plan (HCP) for this same area. This created the opportunity for the federal Services and EPA along with Department of Ecology to coordinate their parallel programs to protect and enhance water quality and aquatic habitat.

This TMDL is designed to address impairments due to surface water temperature increases on listed water quality-limited segments located within Simpson's 261,575 acres of Northwest Timberlands in the state of Washington. In addition, this TMDL sets allocation limits to protect other streams within the Simpson HCP area from becoming water quality limited.

This TMDL is being established for two pollutants: heat and sediment. Both heat and sediment are considered pollutants under Section 502(6). These pollutants contribute to water temperature increases in two ways. First, heat transfer from excess amounts of solar radiation reaching the stream surface provides energy to raise water temperatures. Second, excessive delivery of sediment increases channel width through deposition and lateral scour. Wider channels then increase the amount of surface area exposed to heat transfer from solar radiation.

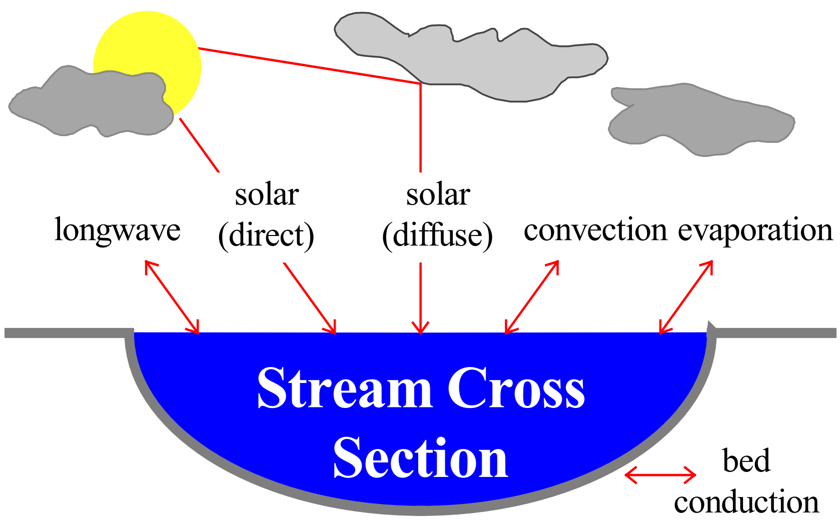
The two pollutants considered in this TMDL, singly and in concert, are major determinants of water quality that affect aquatic life. These factors vary naturally in their characteristics across the landscape (as a function of geology, topography and climate) as well as over time. The influence of both pollutants on water quality can also be significantly affected by changes associated with land use.

Landscape level TMDLs are useful in addressing systemic non-point pollution parameters such as temperature and sediment. They can lead to more complete understanding of conditions, and more importantly, can lead to more comprehensive management to improve conditions. This TMDL is unique in that a single landowner offered to coordinate their forest land management planning with development of the TMDL. The decision was made early in the process to limit the physical scope of the TMDL to the ownership rather than try to expand to cover all of the effected watersheds. In addition, the parameters were limited to those heavily impacted by forest management activities However the analysis and implementation elements should prove very useful if and when a temperature or sediment TMDL is required in the adjacent areas.

Water Temperature and Solar Radiation

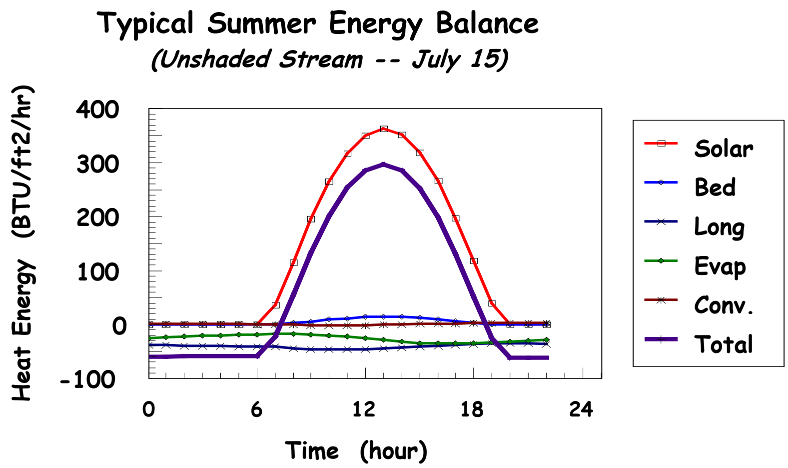
Stream temperature is an expression of heat energy per unit volume, or an indicator of the rate of heat exchange between a stream and its environment (Figure 1). In terms of water temperature increases, the principle source of heat energy is solar radiation directly striking the stream surface (Brown, 1970). Energy is acquired by a stream system when the heat entering the stream is greater than the heat leaving the stream. When there is a net addition of heat energy to the stream, the water temperature will increase.

Figure 1. Heat Transfer Processes that Affect Water Temperature



As discussed in many studies (Brown 1969, Beschta et al 1987, Holaday 1992, Li et al 1994), the daily profile for water temperature increases typically follows the same pattern as solar radiation delivered to an unshaded stream (Figure 2*)*. Other processes, such as longwave radiation and convection, also introduce energy into the stream, but at much smaller amounts when compared to solar radiation.

Figure 2. Typical Summer Energy Balance for an Unshaded Stream



This TMDL uses information from the HCP prepared by Simpson Timber Company (STC) for more than 80 percent of its Northwest Timberland holdings in the State of Washington. The plan area includes nearly 1,400 miles of streams that drain STC lands bordering the southern extent of the Olympic Mountains. The largest portion of these lands encompass major northern tributaries to the Chehalis River, including the Satsop and Wynoochee Rivers, which eventually drains to the Pacific Ocean. A smaller portion includes several Skokomish River tributaries draining to Hood Canal. A final portion includes streams draining to South Puget Sound (i.e. Goldsborough and Kennedy Creeks).

Rather than individually list stream segments for all 1,400 stream miles, information in the TMDL is summarized using lithotopo units (LTUs), channel types, or Riparian Management Strategies (RMSs) as defined in the HCP. There are five LTUs, 49 channel types, and eight RMSs described in the Simpson HCP which apply to all streams in the Plan area (both perennial and intermittent). Principle drainages within the HCP area include:

WRIA 14 => Kennedy - Goldsborough Watershed
WRIA 16 => Skokomish River (North & South Forks)
WRIA 22 => Chehalis River Basin (Lower), Satsop River (including the West, Middle, & East Forks), Decker Creek, Wildcat Creek, and the Wynoochee River.

Management activities can increase the amount of solar radiation delivered to a stream system, both by harvesting riparian shade trees and through the introduction of bedload sediment which can lead to channel widening. The Simpson HCP area has experienced a long history of forest land management, stemming back to the early twentieth century. This has resulted in degradation of the watershed condition.

Riparian Area Management and Timber Harvest

Riparian vegetation can effectively reduce the total daily solar radiation load. Without riparian shade trees and shrubs, most incoming solar energy would be available to heat the stream. Harvest of riparian area trees can result in loss of shade. Limited work has been done to estimate the amount of shade loss due to source activities. The W.F. Satsop Watershed Analysis summarized causes for not meeting target shade requirements. The report indicated that approximately 59 percent of the stream miles assessed met the shade target. Of the remainder, 13 percent were too wide to be fully shaded and 28 percent did not meet the shade target because of riparian condition.

Sediment, Hillslope Failures, and Roads

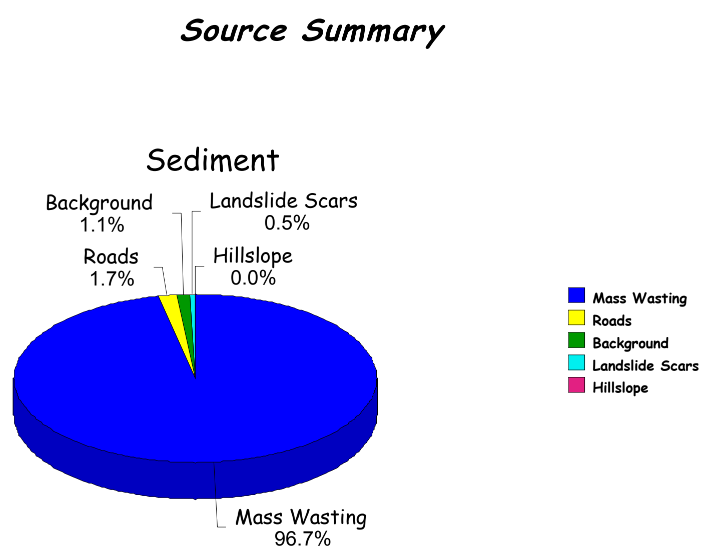
The sediment supply that enters stream channels in forested watersheds is generated by several processes: mass wasting (landsliding), surface erosion (especially from roads), soil creep (especially in unstable areas), and bank erosion (from streamside terraces) [*see* Paulson, 1997]. This is especially true where steep unstable terrain is subjected to major weather events that saturate hillslopes with large volumes of precipitation.

Unstable slope failures can occur, which deliver large amounts of surface soils to stream channels. These events can overwhelm the capacity of the channel to transport this material downstream, which in turn can lead to substantial channel widening, attendant bank erosion, and shallowing of surface flows. Important habitat features for salmonids and other aquatic life can be significantly affected by these processes. These features include stable spawning areas, pools and side channel rearing areas.

Controllable sediment is sediment delivered as a result of human activities which affects water quality and can be reasonably controlled. Rates of delivery have been estimated for these sources using several Watershed Analyses conducted within the Simpson HCP area *(Note: Watershed Analysis has not yet been conducted for the entire area, however, certain modules will be completed as part of the HCP).*

In addition, the W.F. Satsop Watershed Analysis developed an estimate of sediment from all sources to illustrate relative contributions (Figure 3). This estimate showed that the contribution from mass wasting is far greater than that from surface erosion. It should be noted, though, that the mass wasting value includes both fine and coarse sediment while the background and surface erosion values represent only fine sediment.

Figure 3. West Fork Satsop Sediment Yield



Applicable Criteria

Within the state of Washington, water quality standards are published pursuant to Chapter 90.48 of the Revised Code of Washington (RCW). Authority to adopt rules, regulations, and standards necessary to protect the environment is vested with the Department of Ecology. Under the federal Clean Water Act, the EPA Regional Administrator must approve the water quality standards adopted by the state (Section 303(c)(3)). Through adoption of these water quality standards, Washington has designated certain characteristic uses to be protected and the criteria necessary to protect these uses [Washington Administrative Code (WAC), Chapter 173-201A]. These standards were last adopted in November 1997.

This TMDL is designed to address impairments of characteristic uses caused by high temperatures and polluting material, i.e. sediment. The characteristic uses of Class A and AA waters that are designated for protection in the TMDL area streams are as follows:

> *"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."*

WAC 173-201A-030(2)

The water quality standards describe criteria for temperature and polluting material such as sediment for the protection of characteristic uses. Streams in the TMDL area are designated either as Class AA or as Class A. These waters have temperature criteria assigned to protect the characteristic uses:

For Class AA waters:

> *"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."*
>
> *"Incremental increases resulting from nonpoint activities shall not exceed 2.8°C."*

WAC 173-201A030(1)(c)(iv)

For Class A waters:

> *"Temperature shall not exceed 18.0°C…due to human activities. When natural conditions exceed 18.0°C…, no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C."*
>
> *"Incremental increases resulting from nonpoint activities shall not exceed 2.8°C."*

WAC 173-201A-030(2)(c)(iv)

Finally, the applicable water quality standard for sediment states:

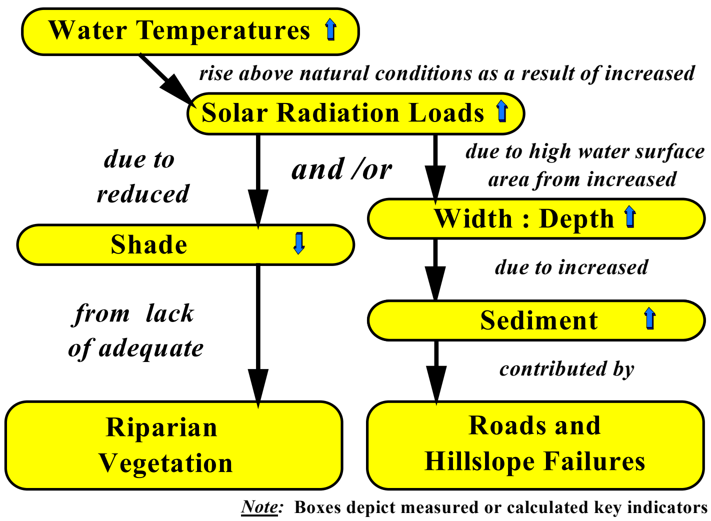
> *"deleterious material concentrations shall be below those which may adversely affect characteristic water uses ..."*

WAC 173-201A-045(1)(c)(vii)

Surrogate Measures Used to Meet Criteria

Although a loading capacity for heat energy can be derived, it is of limited value in guiding management activities needed to solve identified water quality problems. Instead, the TMDL uses *"other appropriate measures"* (or surrogates) as provided under EPA regulations [40 CFR §130.2(i)]. The specific surrogates used are percent effective shade and sediment delivery. The relationship of water temperature increases to these surrogates is described in Figure 4.

Figure 4. Relationship of Water Temperatures to Surrogates



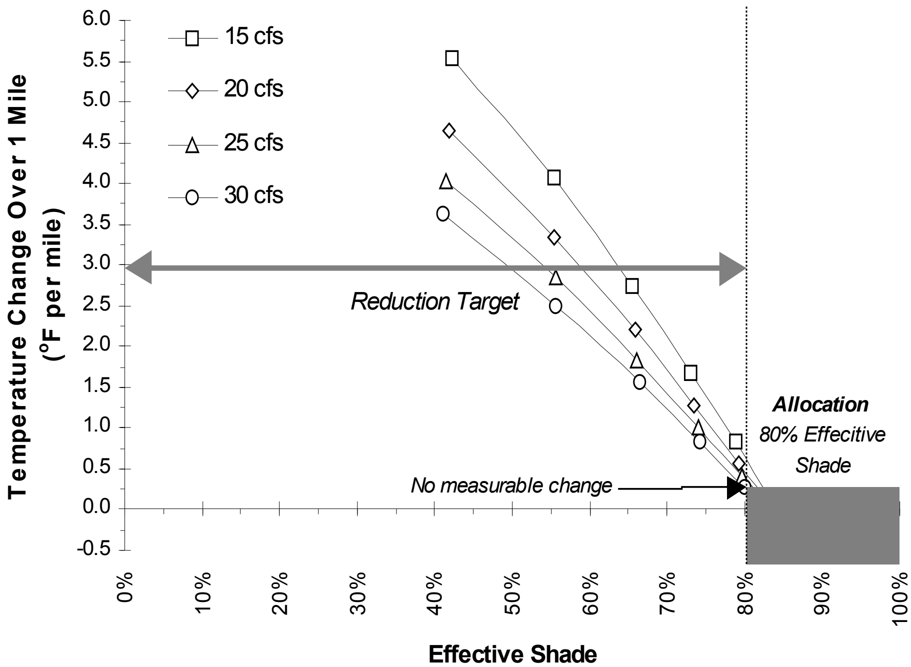
The *"Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program"* (FACA Report, July 1998) offers a discussion on the use of surrogate measures for TMDL development. The FACA Report indicates:

> *"When the impairment is tied to a pollutant for which a numeric criterion is not possible, or where the impairment is identified but cannot be attributed to a single traditional "pollutant," the state should try to identify another (surrogate) environmental indicator that can be used to develop a quantified TMDL, using numeric analytical techniques where they are available, and best professional judgment (BPJ) where they are not. The criterion must be designed to meet water quality standards, including the waterbody's designated uses. The use of BPJ does not imply lack of rigor; it should make use of the "best" scientific information available, and should be conducted by "professionals." When BPJ is used, care should be taken to document all assumptions, and BPJ-based decisions should be clearly explained to the public at the earliest possible stage.*
>
> *If they are used, surrogate environmental indicators should be clearly related to the water quality standard that the TMDL is designed to achieve. Use of a surrogate environmental parameter should require additional post-implementation verification that attainment of the surrogate parameter results in elimination of the impairment. If not, a procedure should be in place to modify the surrogate parameter or to select a different or additional surrogate parameter and to impose additional remedial measures to eliminate the impairment."*

The concept regarding the effect of solar radiation loads on stream temperatures is illustrated in

Figure 5. Information is presented in terms of the percent reduction of potential daily solar radiation load delivered to the water surface. This provides an alternative target (or *"other appropriate measure"*) which relates to stream temperatures, in this case, an 80% reduction in potential solar radiation delivered to the water surface.

Figure 5. Effect of Solar Radiation Reduction (Effective Shade) on Water Temperature



Water Quality and Resource Impairments

As a result of measurements that show temperature criteria are exceeded, four stream segments in the Simpson HCP area were included on the Washington 1996 Section 303(d) list. The Rabbit Creek segment in Township 21N- Range 06W- Section 28 and Wildcat Creek segment in Township18N – Range 05W- Section 14 are still listed for exceeding temperature standards in the 1998 list (available since January of 2000). Rabbit Creek is a tributary to the Satsop River and therefore subject to Class AA Standards. Wildcat Creek is a tributary to the Chehalis River and therefore subject to Class A standards.

While a simple TMDL addressing just impaired segments could be done, Simpson's work to develop their HCP quickly led to dealing with the larger landscape area. Consequently, this TMDL uses broader resource functions and conditions to develop appropriate allocations across a diversity of local stream conditions and functions. In doing so, the TMDL allocations help guide better protection of existing conditions to prevent future impairments.

Because of the unique opportunity for Simpson, state and federal agencies to coordinate development of a TMDL and HCP together, a decision was made early in the process to limit the TMDL to the ownership boundaries and temperature and sediment impariments. The assumption made is that future temperature TMDLs developed in the same watersheds, including the U.S. Forest Service will be guided by the current TMDL analysis and implementation plan.

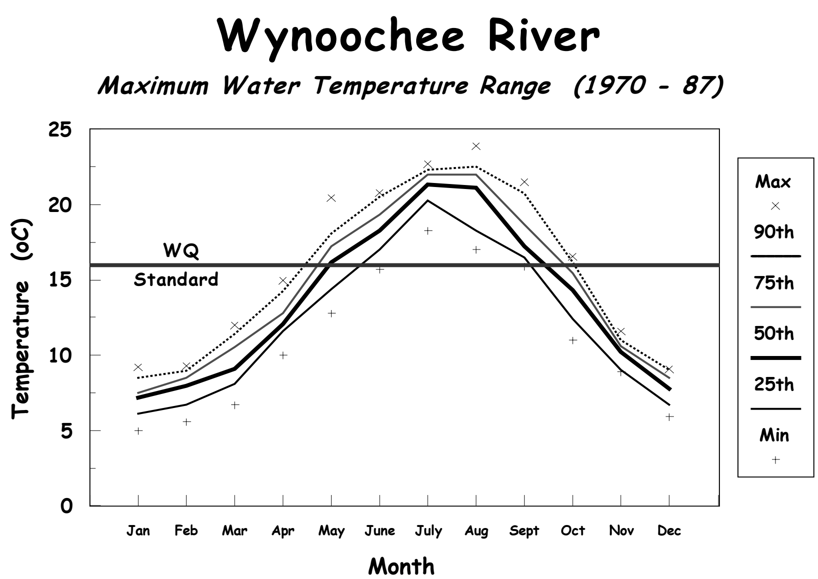
Seasonal Variation

Section 303(d)(1) requires that TMDLs *"be established at level necessary to implement the applicable water quality standards with seasonal variations"*. The current regulation also states that determination of *"TMDLs shall take into account critical conditions for stream flow, loading, and water quality parameters" [40 CFR 130.7(c)(1)]*. Finally, Section 303(d)(1)(D) suggests consideration of normal conditions, flows, and dissipative capacity. This information is summarized in the following discussion.

Existing Conditions

Existing conditions for stream temperatures in the Simpson HCP area reflect seasonal variation. Cooler temperatures occur in the winter, while warmer temperatures are observed in the summer. Historical data has been collected by the U.S. Geological Survey (USGS) of stream temperatures in the Wynoochee River. Figure 6 summarizes the distribution of highest daily maximum water temperatures for each month between 1970 and 1987. The data indicates that the highest seven-day average maximum water temperatures occur between mid-July and mid-August. This time frame is used as the critical period for development and analysis of allocations in the TMDL.

Figure 6. Seasonal Variation of Wynoochee Temperature Levels

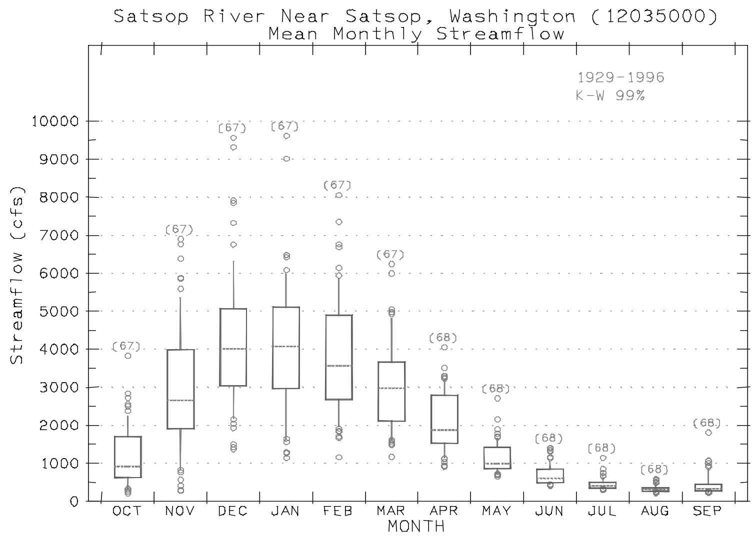


Stream Flow

Monthly flow data is another way to describe seasonal variation that affects temperature. As illustrated in Figure 7 (shown by water year), flows decline through the summer reaching baseflow conditions in August, the same time we anticipate highest water temperatures. Flows then peak in December as a result of winter storm runoff. Because of the overlap between low flows and elevated temperatures, it is useful to know more about the pattern of low flows. The

USGS data has also been used to describe the variation of 7Q2 (seven-day two year average) values across the HCP area (Amerman and Orsborn, 1987). From this information, a relationship has been developed to estimate 7Q2 values for various LTU's within the HCP area. This value is important because it tends to coincide with the highest temperatures. In addition, the pattern of high flows is significant for eroding channel surfaces and moving sediment through the system

Figure 7. Flow Patterns for Satsop River



Solar Radiation

Potential solar radiation varies throughout the year. The highest value occurs on the first day of summer when the earth's tilt towards the sun is greatest. Figure 8 illustrates the effect of seasonal variation on shadow length associated with different tree heights. As shown, shadows are shortest in mid-June. Figure 9 illustrates the effect of seasonal variation on maximum potential solar radiation. Mid-June is the period when solar radiation values are at their peak. As a result, mid-June can be used as a starting point for identifying the loading capacity for effective shade. This is the time that the water surface receives the maximum potential solar radiation and when riparian shade is least effective in reducing heat. This approach adds to the margin of safety because low flows and maximum water temperatures typically occur one to two months later.

Figure 8. Seasonal Variation of Shadow Lengths

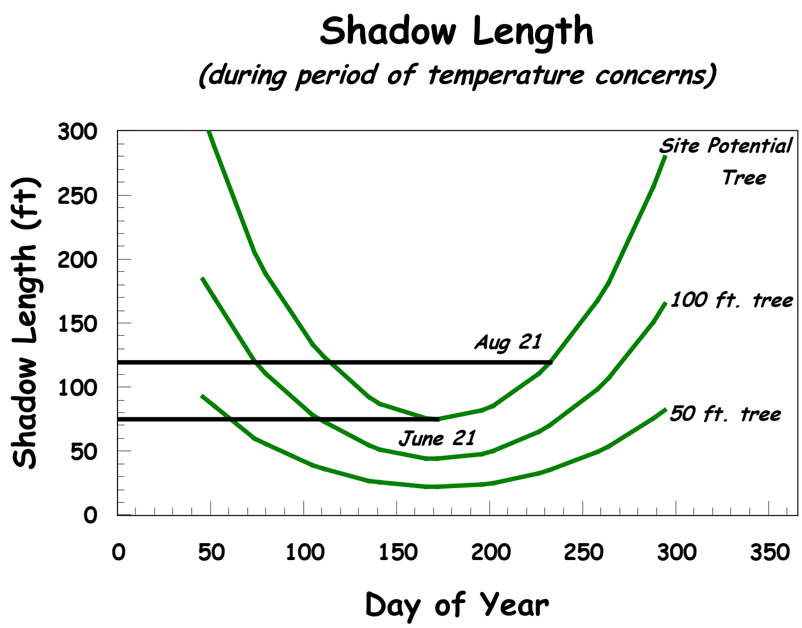
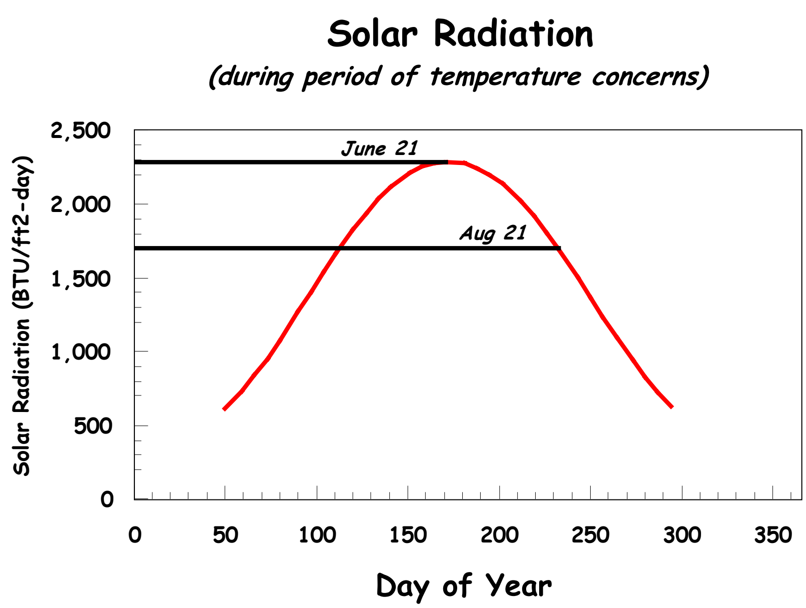


Figure 9. Seasonal Variation of Maximum Potential Solar Radiation



Critical Temperature Conditions

Estimates for streamflow, solar loading, and water quality parameters need to be taken into account in development of this TMDL. The analysis demonstrating the relationship of channel and riparian conditions to solar radiation loads requires a framework for identifying critical conditions. Based on historical data for the Wynoochee River (Figure 10*)*, the critical period used for the analysis is mid-July. This represents the time frame for which solar radiation is highest when the earliest summer maximum water temperatures were observed. This timeframe is also consistent with water temperature monitoring data collected by Simpson (Figure 11).

Figure 10. Wynoochee River Summer Water Temperatures

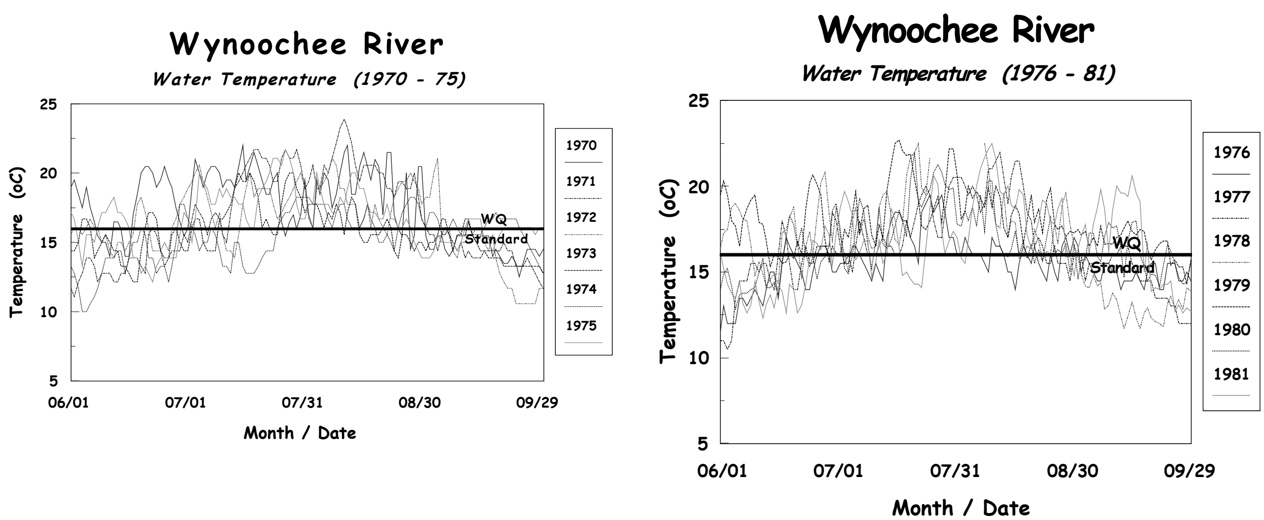
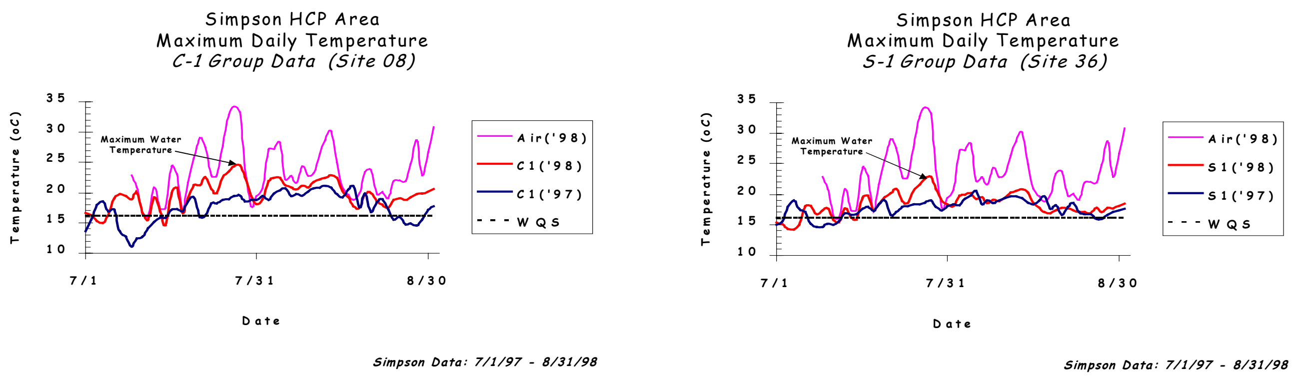


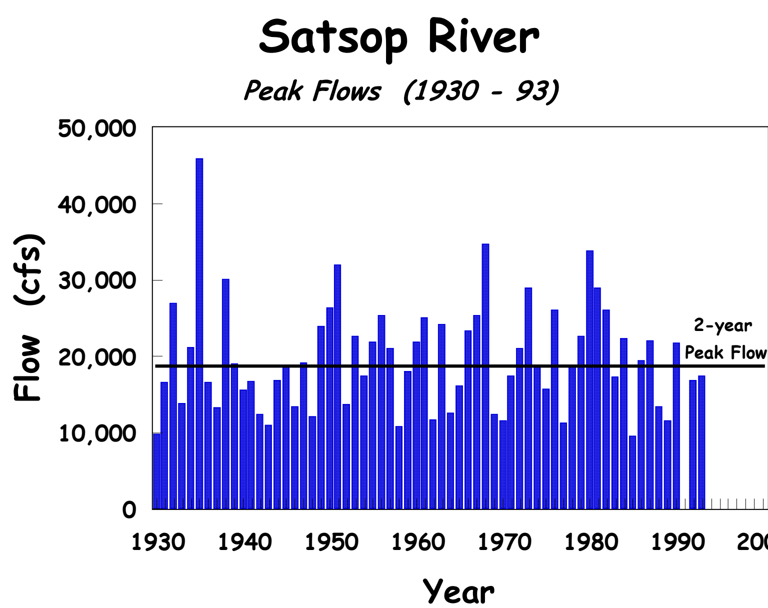
Figure 11. Simpson HCP Area Summer Water Temperatures



Annual Variability and Sediment

The annual variability of peak flows effects sediment delivery. USGS (1971) described sediment yield in the Chehalis basin. Consistent with sediment studies in other areas, the report noted that the greatest percentage of sediment transport occurred during peak flows. Figure 12 shows the variation in peak flows for the Satsop River.

Figure 12. Satsop River Peak Flow History



Technical Analysis

Under the current regulatory framework for development of TMDLs, identification of the loading capacity for pollutants is the first step. The loading capacity provides a reference for calculating the amount of pollutant reduction needed to bring a water into compliance with standards. By definition, TMDLs are the sum of the allocations *[40 CFR §130.2(i)]*. Allocations are defined as the portion of a receiving water's loading capacity that is allocated to point or nonpoint sources and natural background. EPA's current regulation defines loading capacity as *"the greatest amount of loading that a water can receive without violating water quality standards"*. Following is a summary of the extensive technical analysis that was done for this TMDL. The complete Technical Assessment Report (TAR) is found in Appendix A, it can also be found as Appendix G of the Simpson Habitat Conservation Plan.

Landscape Scale Analyses

TMDL development for nonpoint sources presents some inherent challenges. Diffuse sources are often associated with watershed or landscape scale features and processes occurring over time. Consequently, water quality concerns associated with nonpoint source (NPS) pollutants require a different approach from traditional point source problems.

Landscape Stratification: The foundation of the proposed HCP lies within the system Simpson has developed to better understand the inherent characteristics and sensitivities of their lands, and how their long-term forest management plans interact with them. In short, these features are *geological settings, climatic factors and their interaction.*

Influences of geologic setting and associated physical processes within the HCP area are captured by stratifying the landscape into *"lithotopo"* units (LTU), i.e. areas of similar lithology and topography. LTU boundaries are determined by geology, geological history, and topographic relief. This approach divides Simpson's HCP area into units that share similar erosion, mass wasting and channel forming processes. The LTUs are:

- Alpine glacial (AGL)
- Crescent islands (CIS)
- Crescent uplands (CUP)
- Recessional outwash plain (ROP)
- Sedimentary inner gorges (SIG)

Channel Classification: Conditions in a stream are a function of channel morphology (e.g. source, transport, or response reaches). Methods exist to assess the condition of a stream, as well as departure from its potential (Rosgen, 1996). These methods, built around channel classification, are a useful starting point to develop specific TMDL surrogate measures for streams in the Simpson HCP area. Consequently, a second lower level of stratification consists of classifying stream segments of the channel network within each of the LTU's.

There are 49 individual stream segment types developed within this system. Riparian management strategies are keyed to each of the stream types. A description of these can be found within the HCP document. Additional details on channel characteristics, geology, morphology, large woody debris characteristics and recruitment processes, sediment delivery and processing mechanisms, riparian characteristics and biological community features are described in the HCP appendices. A summary table of the 49 types can also be found in Appendix C of this document.

Mechanistic Models

A loading capacity for heat (expressed as BTU/ft^2 per day) can be derived using mechanistic models. One of the most basic forms of these models is the fundamental equation applied by Brown (1969) for forest streams *(*Table 1*)*.

Table 1. Mathematical Relationship between Water Temperature and Heat

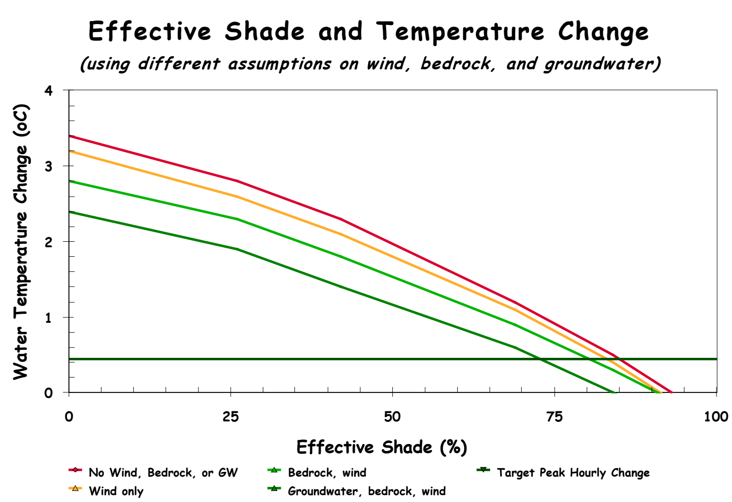
$$\Delta T = \Delta H * A \;/\; (V * \rho * c_p)$$

where:

- ΔT = temperature change (°F / hour)
- ΔH = rate that heat is received (BTU / hour)
- A = surface area (ft^2)
- V = volume (ft^3)
- ρ = density of water (62.4 lb / ft^3)
- c_p = specific heat of water (BTU/ lb / □F)

The calculation of water temperature by a mechanistic model follows the basic relationship described in Table 1. A mechanistic model is essentially bookkeeping of different heat transfer processes to determine potential water temperature changes. Using such an approach, a family of curves can be developed which describes different ΔH values designed to achieve a known temperature change. Figure 13 illustrates one such set of curves for a class of streams in the Simpson HCP area.

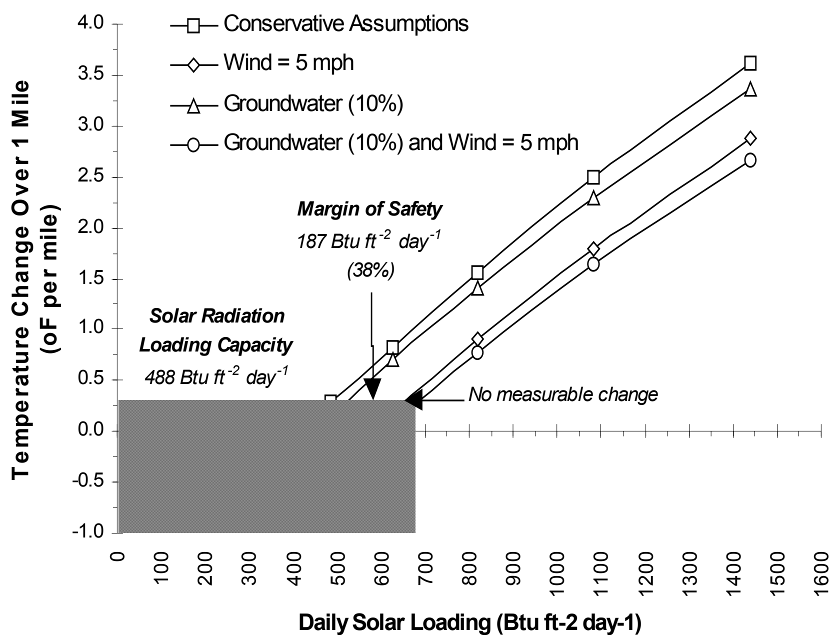
Figure 13. Simpson HCP Area Pool Riffle Channels



Other models have been developed based on a heat budget approach that estimates water temperature under different heat balance and flow conditions. Brown (1969) was the first to apply a heat budget to estimate water temperatures on small streams affected by timber harvest. Using mathematical relationships to describe heat transfer processes, the rate of change in water temperature on a summer day can be estimated. Relationships include both the total energy transfer rate to the stream (i.e. the sum of individual processes) and the response of water temperature to heat energy absorbed. Heat transfer processes considered in the analysis include solar radiation, longwave radiation, convection, evaporation, and bed conduction (Wunderlich 1972, Jobson and Keefer 1979, Beschta and Weatherred 1984, Sinokrot and Stefan 1993).

Figure 2 (Page 4) showed that solar radiation is the predominant energy transfer process which contributes to water temperature increases. A general relationship between solar radiation loads and stream temperature can be developed by quantifying heat transfer processes (Figure 14). In this example, average unit solar radiation loads greater than 675 BTU / ft^2 per day result in a noticeable increase in water temperature. This could represent a starting point to define a loading capacity (i.e. the greatest amount of loading that a water can receive without violating water quality standards).

Figure 14. General Relationship between Solar Radiation Loads and Water Temperature



A drawback to the use of mechanistic models, however, is the difficulty in determining solar radiation loads over each stream mile of a large watershed. The curves that result from numerical calculations are influenced by a number of factors. These include stream flow, channel width, upstream water temperature, wind speed, relative humidity, stream bed composition, and groundwater contribution. Higher stream flows, for example, result in higher allowable solar radiation loads when width:depth ratios are held constant. Likewise, narrower channels result in higher allowable loads when stream flows are held constant.

Natural Conditions

Another complication in using mechanistic models to develop allowable loads is that the result may be the identification of loading capacities that are not achievable. This occurs when the vegetative height associated with a mature riparian forest is not tall enough to shade the entire active channel. For instance, on June 21 the shadow length of a 170 foot tall Douglas fir at 1pm (daylight time) is about 75 feet. This means that an active channel wider than 75 feet will not be completely shaded on that date. For such cases and for cases where the numeric criteria is naturally exceeded, the natural conditions clause of Washington's water quality standards is applied *[WAC 173-201A-070(2)]*. This means that where mature riparian vegetation will not fully shade the active channel, the temperature which results from shade achievable by a mature riparian forest becomes the standard. The loading capacity is then the solar load associated with these natural conditions.

To better quantify the linkage between solar loads associated with the natural conditions and the anticipated effect on water temperature, a discussion of diurnal variation is helpful. Diurnal variation in water temperature occurs naturally in stream systems. The magnitude of the temperature change (both diurnal range and peak hourly increase) has meaning for this TMDL because it is designed to decrease the pollutant load. Assessing the peak hourly change as a result of load reduction is much more straightforward than predicting attainment of an absolute water temperature. This approach incorporates natural conditions by looking at the change from a base temperature as opposed to making multiple site-specific evaluations to establish base temperatures.

In the absence of site-specific criteria modifications, this TMDL is developed by stratifying the landscape into temperature groups. From this framework, effective shade targets are identified for channel types within each temperature group that are needed to achieve a maximum peak hourly increase.

Temperature Groups

The channel classification system, in conjunction with some temperature data and field evaluations, was used to group stream reaches by the dominant control(s) which affect water temperature. Using information about each stream class in the HCP area (e.g. the range of stream flows, active channel widths, etc), effective shade targets can be developed for each group of streams. Table 2 identifies the seven groups and describes watershed process features that exert the greatest influence on water temperature in those channel classes. Dominant features include shade, groundwater, and channel morphology. '*RMS* 'in the table stands for Riparian Management Strategy. Each strategy was developed for the HCP to meet the functional needs of the various stream classes.

Table 2. Groups for Identifying Targets to Address Water Temperature

Group	Features	HCP Channel
Shade		
S-1	(see next page)	ROP-Qc1, -Qc2

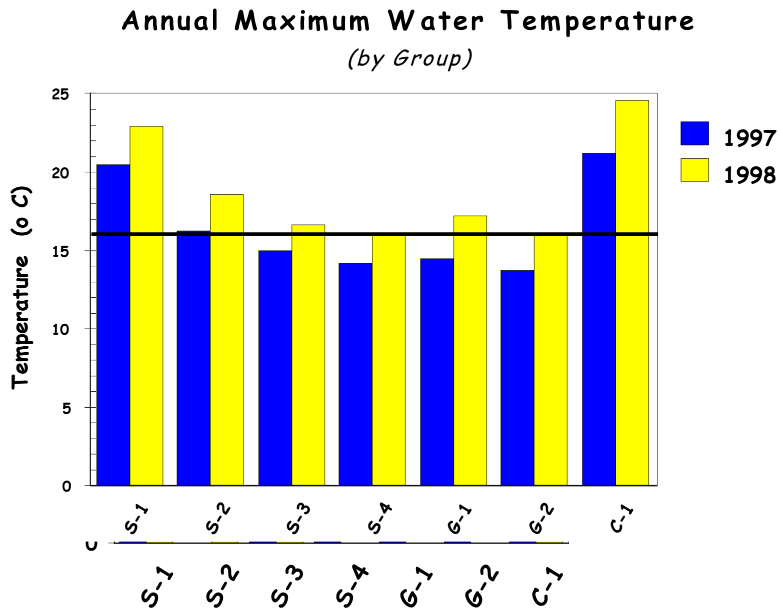
S-1	Small to medium sized pool riffle and forced pool riffle / plane bed channels of the ROP and SIG. Water temperature is driven by shade and low flows (poor water storage in these watersheds over glacial tills and shallow soils). Headwaters of these systems are usually in wetlands or bogs and beavers frequently pond water within the channel. *RMS: Temperature Sensitive*.	ROP-Qc3 SIG-Qc3
S-2	Small to medium sized channels in the AGL and SIG. These systems most often have hardwood dominated riparian systems and subtle groundwater influence through wet side slopes. They are subject to heating with the loss of riparian shade which can happen through damage to riparian leave areas by natural factors or through insufficient leave area. *RMS: Alluvial Bedrock Transition or Reverse Break in Slope*.	AGL-Qo2, -Qo4 SIG-L1, -L2, -L3 SIG-M1, -M2, -M3 SIG-M4, -M6 SIG-Qo2
S-3	Small to medium sized streams in the recessional outwash sediments of the CIS and SIG. These channels have low summer flows, but the storage and character of the flows is different from the ROP in that lower terraces, floodplains, and valley walls of these systems are composed of fine, but fairly well draining unconsolidated outwash sediments. These materials do not store great quantities of water. However, there is a slow release of groundwater that appears to moderate temperatures, but it is not sufficient to offset heating as a result of riparian canopy loss. With loss of shade, these streams can heat up to moderate levels. *RMS: Channel Migration or Unstable Slopes / Intermittent*.	CIS-Qc1, -Qc2 CIS-Qc3 SIG-Qc1, -Qc2
S-4	Small to medium sized channels in glacial till landscape of the AGL and SIG with pool riffle and forced pool riffle / plane beds. These systems have moderate to low flows in summer with varying amounts of groundwater influence. Along the continuum, those with minimal groundwater influence are susceptible to elevated water temperatures with loss of shade. Those with significant amounts of groundwater influence are resistant to temperature changes. *RMS: Break in Slope*.	AGL-Qo3, -Qo5 AGL-Qo6, -Qo7 SIG-Qo3, -Qo4

Table 2. (cont) Groups for Identifying Targets to Address Water Temperature

Group	Features	HCP Channel
	Groundwater	
G-1	Small to medium sized pool riffle and forced pool riffle / plane bed channels of the CIS and ROP that are strongly influenced by groundwater. These systems are resistant to changes to water temperature because flow is strong and comes from a cool source. Shade is a secondary influence, except during extreme low flow years. *RMS: Channel Migration*.	CIS-C5 ROP-Qc4, -Qc5 ROP-Qc6, -Qc7
G-2	Small to medium sized highly confined channels of the AGL, CIS, CUP, and SIG. These are topographically shaded and are *"near"* their water source with substantial groundwater influence which shows as side seeps and springs. These systems are typically cool and are resistant to water temperature changes, even in the absence of riparian vegetation. *RMS: Canyon*.	AGL-Qo1, -Qo8 CIS-C1 CUP-C1, -C2, -C3 CUP-C4, -C5, -C6 CUP-C8 SIG-Qo1
	Channel Morphology	
C-1	Large rivers of the AGL, ROP, and SIG are affected by high sediment supply and multiple thread channels over at least some of their length. Applies to the West and Middle Forks of the Satsop, the Canyon, Little and Wynoochee Rivers. Temperatures in these systems are strongly influenced by channel pattern and open canopies. Current and past sediment supply, long residence times, and channel pattern make it unlikely that water temperatures here will change for decades. *RMS: Inner Gorge or Channel Migration*.	AGL-Qa6 ROP-C7, -Qa7 ROP-Qc8 SIG-L4, -M5, -Qa6

These seven temperature groups allow refinement of assumptions used to develop effective shade targets. Development of effective shade targets is then based on a better description of site specific conditions. In addition, actual data collected on streams in the Simpson HCP area is used to validate anticipated responses. Figure 17 depicts information collected in 1997 and 1998 from sites representative of each temperature group. Maximum observations between July 1 and August 31 are shown for each year. This corresponds with the seasonal time frame when maximum water temperatures occur. Figure 18 shows the percentage of streams in the Simpson HCP area that lie within each temperature group. Figure 18 also shows the percentage of time that the 16°C was exceeded at each site used to represent the temperature group.

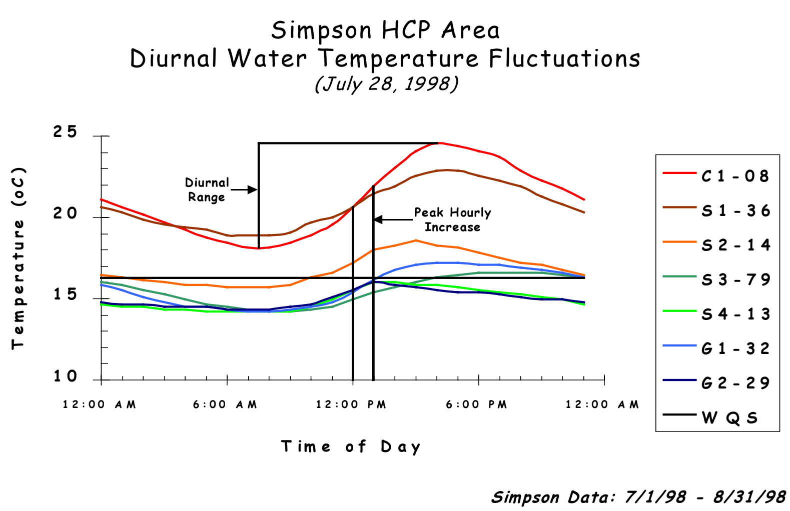
Figure 15. Annual Maximum Water Temperature by Group



Peak Hourly Change

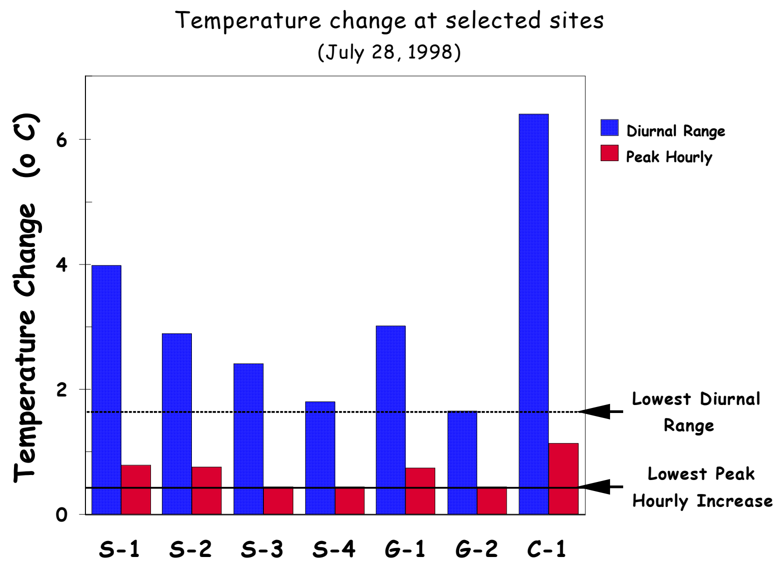
Development of loading capacities and allocations that focus on either maximum diurnal range or peak hourly water temperature increase is possible. An analysis can be constructed which evaluates solar radiation inputs and resultant water temperature change through a heat budget analysis. Figure 19 depicts the diurnal variation of the temperature group monitoring sites on July 28, 1998. This is the day when maximum water temperatures were observed over the two-year period for monitoring data provided by Simpson.

Figure 16. Temperature Group Summary - Diurnal Water Temperature Fluctuations



July 28, 1998 also corresponds to the date when the maximum water temperature was observed by the U.S. Forest Service over a five-year period in the Humptulips watershed (immediately west of the Simpson HCP area). Figure 16 shows both the diurnal change and peak hourly water temperature increase for each temperature group. Based on this relationship, the lowest peak hourly increase observed (0.45°C) is used to derive effective shade targets.

Figure 17. Temperature Group Summary - Temperature Change at Selected Sites



Loading Capacity

Identification of the loading capacity is an important step in developing TMDLs. The loading capacity provides a reference for calculating the amount of pollutant reduction needed to bring a water into compliance with water quality standards. By definition, a TMDL is the sum of the allocations. An allocation is defined as the portion of a receiving water's loading capacity that is assigned to a particular source. EPA defines the loading capacity as "the greatest amount of loading that a water can receive without violating water quality standards."

Effective Shade

Using information about each channel class (e.g. drainage area, range of flows, etc) effective shade targets can be developed. The channel classification system is used to assess stream reaches according to temperature groups. This approach leads to effective shade targets that recognize the variability in channel and riparian characteristics that occurs across the landscape. As such, these targets reflect the range of active channel widths and riparian vegetation heights by LTU within the HCP area (Table 3).

Table 3. Effective Shade Loading Capacity Targets

Active Channel Width[1] *(meters)*	**Effective Shade[2] — *by temperature group (%)***						
	C-1	**G-1**	**G-2**	**S-1**	**S-2**	**S-3**	**S-4**
2			68-CUP		82-AGL 84-SIG		
4			51-AGL 71-CIS 68-CUP 56-SIG	90-ROP	84-SIG	85-CIS 80-SIG	76-AGL 78-SIG
6		85-CIS 85-ROP	68-CUP		82-AGL		
8	89-ROP		68-CUP				76-AGL
10				87-SIG			
12		75-ROP	68-CUP	89-ROP	85-SIG		
15		75-ROP					
16	86-ROP					87-CIS	80-AGL 82-SIG
18		75-ROP					
20	72-SIG		72-CUP				
25	77-AGL 83-ROP 77-SIG		58-AGL				
35	72-SIG						

[1] This table summarizes the effective shade loading capacity targets by active channel width. Active channel width determines the surface area requiring effective shade.

[2] Effective shade targets calculated using a heat budget for channel types within each temperature group that are needed to achieve a maximum peak hourly increase of 0.45°C.

Sediment Delivery

The effect of sediment and its relationship to numeric water quality standards is incorporated into this TMDL through a temperature group approach as well. Stream Groups as described earlier are defined according to the dominant control which influences water temperature. One of those controls is channel morphology. *Group C-1* represents streams where temperatures are strongly influenced by channel patterns affected by high sediment supply. Changes in sediment input can lead to an alteration of channel form (Leopold et al, 1964; Megahan et al, 1980) through deposition and lateral scour. Water temperatures for *Group C-1* streams are among the warmest monitored.

Developing a load capacity for sediment considers Washington's Water Quality Standards that state *"deleterious material concentrations shall be below those which may adversely affect characteristics water uses"*. The approach includes:

- Focus on *up-slope sediment source targets* rather than looking exclusively at the suite of instream features that reflect the outcome of both natural and management related factors.

- Establish *quantifiable targets for sediment delivery* by erosion process (e.g. cubic yards delivered per mile per averaging period) associated with each channel class.

Up-slope sediment source targets are included because focusing on instream indicators would ignore the sediment input dynamics. Hillslope targets supplement instream criteria by providing measurable goals that are not subject to the variability of climatic conditions. Hillslope and road-related targets are easier to measure and are more controllable. Hillslope and road-related targets also have the advantage to a landowner of being easily converted to implementation plans and management practices that can be evaluated more frequently than instream targets. Finally, without addressing hillslope sources, the cycle of degradation could potentially be repeated until some beneficial use of the system could no longer recover.

Quantifiable targets for sediment delivery enable a focus on source input and hazard reduction. Sediment delivery targets for this TMDL are expressed in terms of cubic yards. Development of sediment delivery targets, i.e. the loading capacity, uses a framework suggested in the TFW Watershed Analysis Manual, specifically construction of a partial sediment budget (Reid and Dunne, 1992). This serves several purposes including:

- tie sediment problems recognized in streams to specific hillslope sources or activities;
- discriminate among the rates, effects, and hazards of various mass wasting, surface, and bank erosion processes in basins where all are significant sediment sources; and
- document the relative contributions of sediment delivery processes (e.g. road surface versus deep seated landslides).

Erosion processes considered in the partial sediment budget include mass wasting (shallow rapid landslides (SR), debris torrents (DT), large persistent deep-seated slides (LPD)), surface erosion, and bank erosion. Sediment delivery targets are based on information contained in three completed Watershed Analysis reports conducted in the Simpson HCP area (W.F. Satsop, S.F. Skokomish, Kennedy Creek). Included is landslide inventory data developed from air photos between 1946 - 96 described in the assessment reports. Loading capacities are summarized by lithotopo unit within the HCP area (Table 4).

Table 4. Sediment Delivery Loading Capacity by Lithotopo Unit

Lithotopo Unit[1]	Area *(sq. mi.)*	Channel Length *(miles)*	Loading Capacity[2]	
			(yd^3 / sq. mi. per year)	*(yd^3 / stream. mile per year)*
AGL	32.7	137.7	880	209.0
CIS	49.0	163.7	110	33.6
CUP	45.0	265.2	1,000	169.5
ROP	183.9	376.7	50	24.7
SIG	98.1	454.5	1,000	215.8
Total	408.7	1,397.8	456	133.3

NOTES:

[1] There are nearly 1,400 stream miles that lie within the HCP area. Available data and methods do not allow determination of loading capacities for each individual segment. Instead, targets have been developed that utilize the landscape stratification system used to organize information in the HCP.

[2] Loading capacities expressed as long term annual average values and do not reflect the wide range spatial and temporal variation observed in natural erosion processes. As new data and methods are developed to better describe sediment delivery mechanisms, these loading capacities may be revised.

Although an annual averaging period is used to express the loads, it is simply a referencing mechanism. Erosion processes which are responsible for sediment inputs to the system are highly dynamic, change from year-to-year, and vary in different locations in the basin.

Load Allocations

Once the Loading Capacity has been developed, then contributing sources can be allocated their fair contribution. This TMDL is designed to address impairments due to surface water temperature increases on one water quality-limited segment located in the Simpson HCP area. In addition to the listed Section 303(d) waters, this TMDL also applies to other potential water quality impairments from heat and sediment for all streams in the plan area. In developing the allocations, this TMDL has benefited from portions of the analysis used in preparation of Simpson's HCP. Allocations in the TMDL are designed to achieve properly functioning aquatic systems in the HCP area.

Regulatory Framework: Under the current regulatory framework for development of TMDLs, flexibility is allowed for specifying allocations in that *"TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure"*. This TMDL does use other measures to fulfill requirements of Section 303(d). Although a loading capacity for heat can be derived [e.g. BTU/ft^2 per day], it is of limited value in guiding management activities needed to solve identified water quality problems.

Allocation Development: Allocations in this TMDL are derived using effective shade and sediment delivery targets. These measures can be linked to specific source areas, and thus to actions (specifically riparian management and erosion control) needed to solve problems which cause water temperature increases. Because factors that affect water temperature are interrelated, both measures are dependent upon each other to achieve desirable responses. Using riparian vegetation exclusively to reduce heat (e.g. increase shade) is difficult to achieve if sediment delivered from upland sources continues to deposit and widen channels. Likewise, narrower channels still require riparian vegetation to provide channel stability and shade, thus reducing heat loads (unless confined by canyon walls or shaded by topography).

The TMDL develops load allocations for each channel class in the Plan area, then summarizes them into eight separate groups. Streams within each group share common characteristics that relate to potential input of pollutants into those streams and point towards possible management strategies.

The HCP divides the stream segments into the same eight groups with corresponding individual riparian management strategies *(Table 5)*. These strategies have been developed to integrate the applicable physical processes and ecological functions. For ease of reference, each of the eight groups of streams analyzed separately in this TMDL is given the same name as the corresponding riparian management strategy in the HCP.

Table 5. HCP Riparian Management Strategy Summary

Strategy	Purpose	Management Function
Canyon	Maintain sediment and organic matter storage capacity of the upper channel network, keep convective heat transfer to a minimum, and supply detritus to the channel as it's principle energy source.	Provision of LWD from off-site, and maintenance of on site shade and detrital inputs. Applied in the CUP along highly confined channel network of the Olympic foothills.
Channel Migration	Maintain the floodplain processes that contribute nutrient processing within the soil and hyporheic zone and ensure continued development of topographic complexity of floodplain surfaces.	Retention of sediment and organic matter and maintenance of nutrient processing. Applied to either very large meandering alluvial channels inset within well defined terrace systems or those low gradient smaller channels with highly erodible banks.
Temperature Sensitive	Mediation of water temperatures in channels that are vulnerable to summer time increases.	Protection of shade and control of streamside air temperature. RCRs established that provide the greatest shade from mid-day to early afternoon ensuring wide, denser leave area on south and west aspects.

Inner Gorge	Provide wood large enough to maintain position or lodge in channel classes like SIG-L4, SIG-L5, AGL-Qo8, and AGL-Qa6.	Provision of wood from unstable slopes to enhance development of productive main river habitat. Retain largest trees that have the highest likelihood of recruiting to the river.
Alluvial Bedrock Transition	Maintenance of an alluvial channel bed in channel classes likely to scour to bedrock in the absence of LWD.	Provision of LWD, particularly along channel classes SIG-M3 and SIG-M4. Protect principal recruitment zone for high value LWD.
Reverse Break in Slope	Maintain opportunity for conifer germination sites in an otherwise unfavorable environment by protecting LWD and providing nurse logs.	Provision of LWD and nurse logs. Settings typified by wet understory plant communities whose early seral stages are dominated by red alder.
Unstable Slopes / Intermittent Flow	Maintain important functional linkages between channel segments and their riparian areas for channel classes that typically have low average fish resource value.	Recognition of physical processes that may transmit significant impacts from these channel classes to other segments downstream for which on-site biological resource value is high.

Effective Shade Allocations The objective of the effective shade TMDL is to reduce heat from incoming solar radiation delivered to the water surface. The basis for effective shade allocations follows an analysis of processes that affect water temperature. Development of the effective shade allocations uses information about riparian management strategies described in the HCP. Minimum Riparian Conservation Reserve (RCR) widths described in the HCP recognize the relationship between active channel width and effective shade.

Effective shade allocations have been developed from targets based on channel class width and characteristics of mature riparian vegetation for that channel class including vegetative density. Effective shade allocations are a function of the vegetation that will shade the widest active channel for each class. The active channel width, the vegetative density associated with a particular RCR width, and the height associated with the expected riparian community (e.g. mixed conifer/hardwood) is used to determine effective shade allocations.

As channels become wider, larger RCR widths are needed to provide more effective shade, as well as to protect other riparian functions. This is reflected in the HCP where wider channels have larger RCR widths identified. Small channels (≤ 4m), on the other hand, can benefit from dense, emergent vegetation. Consequently, narrower RCR widths may still provide a high level of effective shade to these small streams. However, the benefit of the RCR to these smaller channels may go beyond effective shade. As indicated in the HCP, the purpose of the RCR is also to provide slope stability and a supply of large woody debris (LWD).

The TMDL and allocations for effective shade are summarized in Table 6. Because of the channel groupings, it becomes apparent that there are variations between active channel widths and minimum RCR widths. In many instances, channels of the same width size actually have different RCR widths. The temperature group and other considerations (e.g. LWD supply, sediment supply concerns) become important factors, particularly in terms of uncertainty for channel response and increasing the margin of safety.

Table 6. Effective Shade TMDL and Load Allocations Summary for Simpson HCP Area

Segment Name / *Riparian Management Strategy*	*(length in mi.)*	**TMDL**	**TMDL Components[1]** *(Effective Shade as percent)*		
			WLA[2]	LA[2]	MOS[2]
Temperature Sensitive	*53.3*	88.7%	0%	90.0%	(1.3%)
Break in Slope	*171.1*	85.4%	0%	91.6%	(6.3%)
Canyon	*59.4*	68.0%	0%	94.1%	(26.1%)
Channel Migration	*83.7*	79.7%	0%	84.4%	(4.7%)
Inner Gorge	*50.4*	70.6%	0%	77.5%	(6.9%)
Alluvial Bedrock Transition	*15.6*	85.0%	0%	88.4%	(3.4%)
Reverse Break in Slope	*42.8*	83.9%	0%	95.0%	(11.1%)
Unstable Slopes / Intermittent Flow	*921.5*	77.0%	0%	93.0%	(16.0%)
TMDL					

***Notes*:**

[1] Specific streams to which an RMS applies are identified in the HCP and are defined by LTU / channel class. The effective shade TMDL and allocations are designed to achieve a loading capacity that provides sufficient shade needed to minimize water temperature increases. Shade targets developed through use of temperature groups which consider topography, active channel width, groundwater, and potential natural riparian vegetation.

[2] **WLA**: Waste load allocation; **LA**: Load allocation; **MOS**: Margin of Safety. There are no point sources within the HCP area covered by the TMDL, so the WLA for effective shade is 0.

Sediment Delivery Allocations: *Sediment Delivery Allocations:* The TMDL and allocations for sediment delivery are summarized in Table 7. The resultant load allocations for sediment are: 1) developed for erosion processes; 2) associated with land use activities where feasible; and 3) based on the source analysis of various erosion processes. The load allocations are expressed as long term annual average load delivered per mile at the channel class scale. Sediment delivery targets expressed as annual average cubic yards per stream mile for each channel class is consistent with current EPA regulations. The regulations indicate that load allocations are *"best estimates of the loading which may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading" [40 CFR §130.2(g)]*.

The estimated total allowable sediment load is derived from targets based on lithotopo unit, channel class and erosion process (cubic yards per mile per averaging period). Sediment delivery allocations use information from three completed Watershed Analysis Reports in the area and from several inventories that supported preparation of the HCP. A quantitative comparison of estimated loading rates and controllable portions of various types of loading was considered. The load allocations incorporate sediment reductions from management activities into the sediment delivery targets. Sediment delivered from shallow rapids landslides and debris torrents as a result of management activities is assumed to be 80% controllable. This is based on information used for development of prescriptions in the W.F. Satsop Watershed Analysis. Sediment ten percent controllable. The retention of large wood in RCRs and reducing peak flows due to hydrologic effects of the road network will address sediment delivery from bank erosion that result from management activities.

The loading capacity and allocations for sediment delivery are summarized in Table 9 using the same eight channel groups/strategies. The estimated total allowable sediment load is derived from targets based on lithotopo unit, channel class and erosion process (cubic yards per mile per averaging period). Sediment delivery information for the period 1946-96 was used from three completed Watershed Analysis reports conducted in the Simpson HCP area.

Sediment delivery allocations use information from three completed Watershed Analysis Reports in the area and from several inventories that supported preparation of the HCP. The quantitative comparison of estimated loading rates and controllable portions of various types of loading was considered. It is estimated that a 50 percent reduction in the frequency of catastrophic failures (e.g. sidecast or fill failures) over the rate observed for the previous 20-year period can be achieved during the first ten years of the plan. This represents an interim target for measuring progress relative to achieving the load allocations. In addition, a target of 50 percent reduction of fine sediment input from roads during the first ten years of the plan is also included in the HCP.

The load allocations incorporate sediment reductions from management activities into the sediment delivery targets. Sediment delivered from shallow rapids landslides and debris torrents as a result of management activities is assumed to be 80 percent controllable. This is based on information used for development of prescriptions in the W.F. Satsop Watershed Analysis. Sediment delivered from large persistent deep-seated landslides as a result of management activities is assumed to be 50 percent controllable. The retention of large wood in RCRs and reducing peak flows due to hydrologic effects of the road network will address sediment delivery from bank erosion that resulted from management activities.

Sediment delivery targets expressed as annual average cubic yards per stream mile for each channel class is consistent with current EPA regulations. The regulations indicate that load allocations are *"best estimates of the loading which may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading" [40 CFR §130.2(g)]*.

The resultant load allocations for sediment are: 1) developed for erosion processes; 2) associated with land use activities where feasible; and 3) based on the source analysis of various erosion processes. The load allocations are expressed as long term annual average load delivered per mile at the channel class scale.

Table 7. Sediment Delivery TMDL and Load Allocations Summary for Simpson HCP Area

Riparian Strategy *(length in mi.)*	TMDL[1]	WLA[2]	Load Allocations[1] *(yd^3 / stream mile per year)* Mass Wasting					MOS
			SR	*DT*	*LPD*	Surface Erosion	Bank Erosion / Channel Storage	
AGL 137.7	209.0	0	6.0	1.0	3.2	4.0	98.4	96.4
CIS 163.7	33.6	0	1.0	0.0	1.0	2.0	27.7	1.9
CUP 265.2	169.5	0	12.	7.0	1.0	3.0	19.9	126.5
ROP[3] 376.7	24.7	0	1	0.0	1.0	1.0	12.3	94
SIG 454.5	215.8	0	1.0	1.0	32.8	6.0	47.7	122.0
			6.3					

NOTES:

[1] Allocations expressed as long term annual average values. As new data and methods are developed to better describe sediment delivery mechanisms, the loading capacities may be refined and the TMDL revised.

[2] There are no point sources within the HCP area covered by the TMDL, so the WLA for sediment delivery is 0.

[3] Does not include LA for bank erosion / channel storage on ROP-Qa7 (3.7 miles — Vance Creek).

Summary: Detailed allocations for effective shade by each channel type are described in Appendix A. Similarly, Appendix B describes detailed allocations for sediment delivery by each channel type.

Margin of Safety

The Clean Water Act requires that each TMDL be established with a margin of safety (MOS). The statutory requirement that TMDLs incorporate a margin of safety is intended to account for uncertainty in available data or in the actual effect controls will have on loading reductions and receiving water quality. A margin of safety is expressed as unallocated assimilative capacity or it can be conservative analytical assumptions used in establishing the TMDL (e.g., derivation of numeric targets, modeling assumptions or effectiveness of proposed management actions).

The margin of safety may be implicit, as in conservative assumptions used in calculating the loading capacity, WLAs, and LAs. The margin of safety may also be explicitly stated as an added, separate quantity in the TMDL calculation. In any case, assumptions should be stated and the basis behind the margin of safety documented. The margin of safety is not meant to compensate for a failure to consider known sources.

Assumptions

Effective Shade: Development of effective shade allocations results from an analysis of processes that affect water temperature and from information about Riparian Management Strategies described in the HCP. Table 8 summarizes uncertainties associated with development of effective shade targets. Adjustments that were made to account for these uncertainties are also described.

Table 8. Supporting Information for Margin of Safety - Effective Shade

Uncertainties in TMDL	Adjustments to Account for Uncertainties
Natural conditions of upstream ambient water temperature regimes for some segments may be above state criteria of 16°C.	Focus analysis on identifying heat input and effective shade targets to achieve a peak hourly temperature increase of 0.45°C which serves as a numeric interpretation of the *"natural conditions"* clause in Washington's water quality standards. As new data and methods are developed to better describe *"Natural conditions"*, the peak hourly temperature increase target may be refined.
Maximum water temperatures can occur over a range of days that vary from mid-July to mid-August.	Effective shade allocations are based on shadows cast on June 21 when shade angle and solar radiation are at their peak.
Very little information exists regarding factors that affect water temperature in the Simpson HCP area, particularly wind speed, relative humidity, stream-bed composition, and groundwater contribution.	Once the HCP agreement is in place, monitoring of water temperature will continue with a focus on temperature group patterns. Information from this network will support modifications to assumptions, as warranted.

Allocations for effective shade contain an explicit margin of safety which is expressed as an unallocated portion of the loading capacity. In many cases, this portion is unallocated because of other factors in the Riparian Management Strategy, which applies to that particular channel class. Considerations include providing for slope stability or future recruitment of large wood (e.g. Break in Slope, Canyon strategies).

In addition, allocations for effective shade also contain an implicit margin of safety, specifically the point of measurement for the Riparian Conservation Reserve (RCR). These buffer widths, identified in the HCP and in the load allocations, were determined by identifying the primary zones adjacent to each channel class where the functional interactions with the riparian forest are most pronounced. Because of the functional point of measurement, the HCP buffers reflected in the load allocations are sometimes wider than more traditional approaches that use the ordinary high water (OHW) mark as the measurement benchmark.

Sediment Delivery: Development of sediment budget values is an *"order of magnitude"* estimate which may result in over prediction or under prediction of loadings from different erosion processes. Uncertainties about mass wasting and streambank erosion portions of the analysis can be significant. Table 9 summarizes uncertainties from the sediment delivery source analysis. Adjustments that were made to account for these uncertainties are described.

Table 9. Supporting Information for Sediment Margin of Safety

Uncertainties in TMDL	Adjustments to Account for Uncertainties
Instream indicators of sediment not used because of lack of site specific information for these parameters. Extrapolation of values derived from dissimilar areas may have limited relevance in development of instream targets for Simpson HCP area.	Once an HCP agreement is in place, the expectation is that such habitat information will be collected from the extensive monitoring program commitments made by Simpson. This issue can be revisited at year 10 of the plan implementation, and adjustments made, as deemed appropriate by the participants. Note that this alternative approach makes good use of the fundamental landscape and channel classification system Simpson has developed for the HCP.
The role of sediment storage in channel systems as both a source and sink for sediment is poorly understood.	The TMDL gives no *"credit"* for instream storage as a consideration in TMDL determination because current excessive levels of instream stored sediment are contributing to temperature increases in C-1 group. The TMDL is lower than would be the case if instream storage credit were provided.

Adaptive Management

"Adaptive management" is often defined as the reliance on scientific methods to test the results of actions taken so that the management and related policy can be changed promptly and appropriately. Above all it requires clear focus on elements with the greatest uncertainties or risks.

Some TMDL analytical techniques are widely used and applied in evaluating source loading and determining impacts on waterbodies. However, for certain pollutants, such as heat and sediment, the methods used are newer or still in development. The selection of analysis techniques is based on scientific rationale coupled with interpretation of observed data. Without the benefit now of long term experience and testing of the methods used to derive TMDLs, the potential for the estimates to require refinement is quite high. This uncertainty underscores the need for adaptive management. The selection of the margin of safety has clarified the implications for monitoring and implementation planning in refining the estimate if necessary.

A TMDL and margin of safety that is reasonable and results in an overall allocation represents the best estimate of how standards can be achieved.

The TMDL process accommodates the ability to track and ultimately refine assumptions within the implementation component. This TMDL plan allows for future changes in loading capacities and surrogate measures (allocations) in the event that scientifically valid reasons support alterations. It is important to recognize the continual study and progression of understanding of water quality parameters addressed in this TMDL (e.g. stream temperature, sediment, riparian condition, habitat). The Simpson HCP addresses future monitoring plans. In the event that data show that changes are warranted in the Simpson TMDL, these changes will be made.

Summary Implementation Strategy

Overview

The TMDL provides the framework and targets for long term monitoring and implementation activities. However, it does not include the details for what to do or the mechanisms that will ensure that water quality improvements will occur. This section summarizes the strategy and elements that should ensure effective actions to meet the established targets as well as to maintain compliance with water quality and temperature standards.

Temperature violations occur in late summer. However, the causes for elevated temperatures in forested environments are systemic conditions. These are past and current deficiencies in riparian conditions, road management and accelerated erosion and mass wasting from management activities. These are conditions that result from a variety of management actions taken throughout the years and across the landscape.

The Simpson TMDL benefits from the concurrent development under the Endangered Species Act (Section 10) of an aquatic Habitat Conservation Plan (HCP) for the same geographic area. In this unique coordination of two federal programs, TMDL implementation is fundamentally based on the companion HCP developed by Simpson and proposed to the National Marine Fisheries Service (NMFS) and the US Fish and Wildlife Service (USFW) (known collectively as the Services) for approval. EPA and Ecology were parties to the HCP negotiations, while NMFS and USFW participated in some aspects of the TMDL development. Development of the HCP also included cooperative input from state agencies, environmental groups and tribal representatives supporting the core group of Simpson, NMFS, USFWS and EPA.

The TMDL temperature and sediment analysis have been adopted by the Services as the analytical basis for validating the effectiveness of the riparian prescriptions and sediment management prescriptions (including roads) in the HCP and for guiding monitoring efforts and subsequent adaptive management. The TMDL relies on the HCP for articulating the management activities, broad environmental outcomes, monitoring requirements, and the adaptive management process.

Operational assurance that the HCP will be faithfully carried out falls within several avenues: 1) direct oversight by the Services; 2) participation by tribal representatives and state agencies along with the Services on the Scientific Advisory Team; and 3) prescriptions are incorporated into Forest Practice Permits under the Forest Practice Rules of the state of Washington. The Forest Practice Rules are the regulatory tool for Clean Water Act compliance of forest management activity in Washington State.

Implementation Plan Development

The core of the HCP was developed by Simpson in consultation with NMFS, USFWS, and EPA. At that time, STC entered a state pilot program to develop a landscape plan that addressed the same basic resource elements. Through that pilot, DOE, DNR and DFW, Audubon, the Quinault, Squaxin, Skokomish tribes, the Point No Point Treaty Council, and the North West Indian Fish Commission began working with Simpson and the federal agencies to further develop details of the plan. One purpose of the state pilot was to help landowners coordinate meeting both state and federal requirements for resource protection.

Ecology and EPA are confident that the STC TMDL will be implemented for three key reasons. First, we believe that the TMDL has STC's support and commitment at the highest levels of management. Second, STC will receive an Incidental Take Permit (ITP) from the Services conditioned on implementation of the HCP. The permit would be withdrawn if STC for whatever reason, does not implement the HCP. The HCP directly complements the TMDL since the outcomes for sediment reduction activities and temperature maintenance in the HCP will, in the long term and with adaptive management, meet water quality standards.

Finally, regulatory authority over the basic management prescriptions in the HCP comes from the state of Washington Forest Practices Act (FPA). As Simpson initiates forest management activities and receives forest practice permits from DNR, their actions will need to show consistency with the HCP. The Department of Natural Resources (DNR) would oversee conformance with harvest and road elements of the HCP, consistent with their statutory responsibilities under state law. In any event, STC remains subject to the state Forest Practices Act and Hydraulic Projects Approval code requirements. DNR and Ecology have clear authority and regulatory process to ensure compliance. DFW will administer the Hydraulic Project Approval for any in-water activity in the area consistent with the HCP.

Simpson's conservation program emphasizes the development and protection of riparian forests as a primary strategy to satisfy ESA Section 10 and to address requirements of the Clean Water Act (CWA). Activities to be covered by the HCP include all aspects of Simpson's forest practices and related land management (mechanized timber harvest, log transportation, road construction / maintenance / restoration, etc). Specific management prescriptions designed to reduce the input of pollutants into streams within the HCP area include:

- Riparian Conservation Reserves
- Road Management
- Unstable Slope Protection
- Hydrologic Mature Forest Development
- Wetlands Conservation Program

The HCP prescriptions and TMDL implementation activities are based on the principles of adaptive management. The approach for meeting the various load allocations is to increase shade amount and quality, increase LWD supply, shut down the sediment supply and maintain natural patterns of water routing and timing through sub-basins. The prescriptions involve setting appropriate riparian and wetland buffer widths and management constraints, completing inventory and mapping of sensitive areas, completing a schedule for road inventory, repair and removal, and annual reporting of monitoring results, activities and future plans. Compliance and effectiveness monitoring will be done by the company.

To better engage the agencies and tribes routinely in plan implementation, STC has agreed to convene a Scientific Advisory Team (SAT) that will meet annually to review progress, help interpret monitoring data, and determine if adjustments to the monitoring program or plan prescriptions are necessary. EPA, Ecology, Department of Fish and Wildlife, the Services and Tribes are members of the SAT. This will be the principal means to engage the adaptive management feature of the TMDL and the HCP. The SAT will be advisory only, but it will allow each participant to actively participate in consideration of the evidence at hand, and to make independent judgements as to the overall effectiveness of the plan components. While the SAT meets at least annually, at year 15, a TMDL Summit will be held to rigorously evaluate progress towards the TMDL goals. Finally, a dispute resolution process also exists to facilitate constructive negotiation of differences.

The SAT will also work with STC in the first few years of the HCP to develop more detailed monitoring plans that will address the background conditions and key questions set out in the Monitoring Section.

TMDL implementation will be assessed through site visits, review of monitoring results and the annual meetings established within the HCP. The HCP spells out a series of milestones and monitoring requirements. Systemic watershed conditions that result in elevated temperatures need time to respond to changed management. It also takes time to complete field and assessment work in conjunction with operational activities.

During the first five years, STC will complete an inventory and prioritization of all road segments for remediation. Remediation of known problem areas will be carried out by priority completing 75 percent in the first ten years and all of the inventoried problems by year 15.

Within the first five years, STC will complete analysis for slope stability and mass wasting outside the areas already completed through the formal watershed analysis process. They will use WSA or equivalent and use a multi- disciplinary team to develop appropriate prescriptions.

Within the first five years, STC will establish an experimental pilot in wood placement in conjunction with habitat monitoring activities.

During the first ten years, STC will inventory and classify all wetlands by hydro-geomorphic category and Cowardin vegetation classes. This will include delineating the local watershed boundary for wetlands in the ROP to maintain proper hydrology and fish connectivity.

STC is committed to an extensive monitoring program to track annual compliance, effectiveness of management activities and general background resource conditions. Table 21 in the HCP(see Appendix C) provides a chart of monitoring and assessment activities over the first ten years.

Certain temperature and hydrologic monitoring will be done on an annual basis. Other monitoring, including sediment related, will occur at different time frames.

At year five and ten, and continuing increments, a more formal review session on progress of the plan, resource conditions and will occur in conjunction with the Services, state agencies, interested tribes and environmental groups. At a minimum this would include the SAT. This will be coordinated as one major element of the Adaptive Management process for the HCP. Future monitoring subjects, timing and assessment schedules would be adjusted at that time.

At year 15, Simpson will convene a TMDL Summit with the SAT to closely assess road and sediment conditions. Recommendations for change at that time will trigger adaptive management. Following the initial summit, the Services or Simpson may call further summits to consider progress towards TMDL objectives.

Implementation Activities

The TMDL responsible parties are Simpson Timber Company as the land manager and Ecology as the CWA delegated authority. The primary CWA tool is the Forest Practice Permit followed by standard Ecology enforcement of actions causing water quality violations. Based on the level of cooperation developed among the company, state, tribal representatives and federal agencies, it is anticipated that good communication and coordination will continue. The HCP includes substantial commitments of money over time to cover inventory work, monitoring and roadwork. It also incorporates a 'bank' of acreage available to expand buffers as needed through adaptive management. Should the HCP or take permit be withdrawn, the prescriptions will revert to the forest practice rules in effect at the time.

The riparian management prescriptions and expected outcomes contained in the HCP, and as they may be amended, are incorporated by reference into the TMDL. In summary, the overall conservation program includes:

- riparian and wetland buffers of various widths and management regimes designed to provide effective levels of stream shading to address temperature concerns;

- sediment source reduction actions (using basin specific estimates of sediment source areas, prioritized actions will be applied through unstable slope harvest restrictions, road construction, maintenance, and decommissioning commitments); and

- certain harvest limitations to minimize changes in precipitation runoff patterns during storm events.

Riparian and Shade Conditions: The key component of the HCP is a classification of channels across the landscape based on geomorphology and recruitment processes for wood and sediment. A series of riparian conservation reserve strategies (RCRs) were then set out to protect the key features and functions for groups of channels.

Riparian forest functions which are the focus of HCP management prescriptions include: (1) wildlife habitat; (2) recruitment of woody debris to streams and forest floor; (3) shade and control of stream side air temperature; (4) stream bank stabilization; (5) detrital inputs; (6) capture of sediment and organic matter on the floodplain7) maintenance and augmentation of nutrient dynamics and processing; and (8) provision of nurse logs.

In total, the RCRs represent a minimum estimate of 11.6 percent of the entire C Plan area. These will be distributed throughout the HCP area along all stream classes, and will encompass the stream system components of channel migration zones, riparian areas, wetlands and to minimize sediment inputs, some adjoining upland areas. Outer boundaries of the RCR are determined in two ways: by functional widths as designated in the HCP *(see Appendix B, Table 25)* or by the extent of adjacent unstable slopes as determined through provisions in the HCP, whichever is greater. Details regarding the basis for RCR boundaries and implementation guidelines for the RCR are described in the HCP, Chapter 5.

Road Management Program: Implementation of road management prescriptions should reduce this source of chronic fine sedimentation input into streams, and the catastrophic sources of sediment input from failure of road fills and sidecast that generate and propagate hillslope and channel failures. Prescriptions include road inventory and remediation, upgrading culvert sizes, minimizing ditch-line water routing and direct delivery, wet weather road use restrictions, storm patrols and road removal.

Unstable Slope Protection: The HCP recognizes the role unstable slopes play in delivering coarse sediment and woody debris to many channel classes in the plan area. Protection of unstable slopes is considered pivotal in the riparian strategies. Consequently, RCR boundaries are defined not only by the functional needs of the channel classes, but also by the extent of unstable side slopes that, if disturbed, pose a threat to fail and thereby deliver significant sediment volumes into stream courses. In addition, STC will not harvest on unstable slopes that have been identified.

Timing and Process: Roughly speaking, about half of the stream miles in the plan area are forested with mature timber, while the other half has been harvested sometime in the last 40 years or so. In a significant number of stream miles with adequate shade and adjacent timber available for harvest, the riparian management practices under this plan should be sufficient to protect stream shade to improve stream temperatures or prevent ecologically significant changes.

For those streams that currently exceed temperature standards, lack sufficient shade, or carry excessive levels of sediment due to management, exact projections of when water quality standards will be attained are not possible. Where stream temperatures are largely a function of shade, and past timber harvest has already occurred in the required riparian zone, re-growth of trees of suitable size to meet shade functions may take many years. Where temperatures are related to high sediment, it will take years for existing loads to move through the system and for channel morphology to adjust to more natural levels. The speed of that adjustment will depend on how effective road and harvest management practices are to reduce new sediment sources.

Monitoring Strategy

The monitoring and adaptive management provisions of the HCP are thorough if carried forward through time. Some monitoring will address compliance issues, some the effectiveness of management strategies and background resource conditions. STC has incorporated required reporting and tracking elements of the Plan into their operational record keeping and GIS system. These records will be compiled and reported, some annually and others less frequently, to the Services, EPA, and Ecology as part of the annual meeting review. See the Appendix C Section 8 Implementation Monitoring and Section 9 Resource Monitoring Program.

Temperature monitoring across a variety of stream types, including above and below harvest units, will evaluate the performance of the shade component of the riparian prescriptions. Other monitoring will evaluate additional factors that may have a role in affecting stream temperatures in particular geomorphic contexts such as groundwater contributions or wetland/shallow aquifer influences.

Selected habitat assessment and monitoring will be conducted by Simpson in the spirit of adaptive management to validate assumptions and to evaluate the effectiveness of specific management prescriptions.

Adaptive management based on monitoring results over time and new information or conditions is a key component of the HCP. It is anticipated that the TMDL load allocations will not require revisions until at least year fifteen of the Plan to allow for adaptive management adjustments. Events that could trigger a review and subsequent TMDL revision would include: new ESA listings, new water quality standards that apply to this area, and some unforeseen event affecting the landscape.

Potential Funding Sources

Ecology and EPA find that STC is a large and viable company, and has sufficient assets to meet its obligations. STC and cooperating agency staff have worked hard to keep HCP requirements operationally realistic and easily tracked as well as effective. The annual expenditures described in the HCP for monitoring and road remediation are reasonable and deemed sufficient to accomplish the objectives of the TMDL.

Public Participation

Public involvement has occurred in a number of forms and at several times. As a part of the LLP process, Simpson held an evening meeting in Shelton in the fall of 1998. The management approach and resource issues were presented. It was sparsely attended by adjacent landowners but extensive discussions occurred with those present. Before and after the meeting, there was some newspaper coverage of the project.

The Services issued a NEPA scoping notice for the HCP in January of 1999 with the draft EIS and draft HCP going out for formal public review in September of 1999. In coordination with Ecology and the TMDL process, that notice included reference to the TMDL. As part of the TMDL development process, Ecology held a public meeting in September of 1999. Ecology's public notice for the meeting and to solicit comments on the TMDL coincided with the Services' review period for the HCP. Comments received on the TMDL were reviewed by both Ecology and EPA. Responses to those comments can be found in Appendix A.

The public comments received resulted in substantial discussions among the agencies and STC in order to reach a final and acceptable TMDL and HCP.

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Appendix A:

Public Involvement and Response

Public Involvement and Response

Simpson Northwest Timberlands
Temperature Total Maximum Daily Load

Introduction

A public meeting to discuss this Total Maximum Daily Load (TMDL) was held by the Department of Ecology on November 16,1999 in Shelton, WA. At the same meeting, elements of the related Simpson Habitat Conservation Plan (HCP) were presented as the primary tool for implementation to meet the TMDL targets. The meeting attracted seventeen members of the general public. In addition to standard notice and press releases to local papers and radio, announcements were sent to a large mailing list of potentially interested parties for both the TMDL and the HCP. Approximately 50 copies were distributed for review and a copy was posted on the Department of Ecology (Ecology) website.

Ecology received five letters of comment specific to the TMDL. In addition, six letters directed to the National Marine Fisheries Service and the U.S. Fish and Wildlife Service (the Services) about the HCP contained comments on the TMDL. The Services forwarded these on to Ecology for response.

The following people or organizations provided comments. They provided valuable guidance to us for clarifying the analysis and documentation. They also challenged us to better refine certain aspects of the TMDL and to better address the relationship of the TMDL to the Simpson HCP.

American Lands Alliance
Northwest Indian Fisheries Commission
Pacific Rivers Council
Guy L. Parsons
Washington Environmental Council

Referred from the Services:

WA Department of Fish and Wildlife

National Audubon Society
Point No Point Treaty Council
Quinault Indian Nation
Skokomish Tribe
Squaxin Island Tribe

The Simpson Timber Company (Simpson) has made numerous and substantive changes to the HCP in response to public comment and agency guidance. Many of these improve the quality and certainty of implementation for the TMDL as well. The final Environmental Impact Statement (EIS) document for the HCP issued by the Services includes comments and responses on the HCP itself. Review of the final HCP and EIS will provide additional information and understanding that is helpful in looking at implementation of the TMDL.

New sediment information developed during the comment period for the TMDL has been used to improve the sediment targets. Refinements in analysis and adjustments that address changes to the HCP have resulted in some other minor changes in the analysis. Finally, additional information has been provided in appendices to the Technical Assessment Report (TAR) that more clearly explains elements of the TMDL analysis.

General Comments

Comments received on the TMDL addressed issues that fell into four major categories. These included: 1) the relationship of the TMDL to water quality standards, 2) the analytical basis that supports various components of the TMDL, 3) implementation linkages between the TMDL and the HCP, and 4) general questions of validity. Because many of the comments raised similar points, responses have been grouped by category and subcategory.

Relationship to Water Quality Standards: TMDLs are to be established for waters listed under §303(d). They set pollutant loads at levels necessary to attain and maintain the applicable narrative and numerical water quality standards [40 CFR §130.7(c)(1)]. Comments pertaining to the proposed Simpson TMDL and its relationship to water quality standards fell into two subcategories that include:

- Protection of Bull Trout and Other Aquatic Life
- Water Quality Standards — Other Indicators

Analytical Basis: Concerns were expressed on analytical issues relative to target development for several components of the TMDL. In particular, technical concerns were raised about the basis for the proposed shade and sediment delivery targets. There were also questions about if these targets provide an accurate expression of conditions required to meet water quality standards.

- General Approach towards Temperature Targets
- Use of Peak Hourly Increase as an Indicator
- Derivation of Peak Hourly Increase Target
- Equilibrium Temperature and Peak Hourly Targets
- Development of Effective Shade Targets
- Consideration of Groundwater
- Appropriate Indicators for Sediment
- Sediment Budget Framework
- Development of Sediment Delivery Targets
- Allocations — General
- Effective Shade Allocations
- Allocations — Use of Annual Average Values
- Allocations — Consideration of Cumulative Effects
- Margin of Safety

Link to Implementation: Concerns were expressed that the proposed implementation plan does not provide reasonable assurance that water quality standards will be met. Specifically, several commenters expressed the belief that the proposal provides an inadequate basis to conclude that proposed riparian protection in the HCP is commensurate with the proposed targets. Similarly, several commenters believed that it is unclear how goals based on sediment delivery targets mesh with limits on road remediation. Finally, there was concern that the draft documents show no real connection between the TMDL targets and the implementation commitments in the HCP so that long term compliance and enforcement were questionable.

- Implementation — Relationship of Allocations to HCP Prescriptions
- Implementation — Enforceability
- •Monitoring and Adaptive Management

Validity of the TMDL as a Whole: Two primary comments were raised based on draft guidance from EPA on TMDL coverage: 1) the area selected for coverage is incomplete because it doesn't extend out to complete watershed boundaries; and 2) not all the impaired water quality parameters in the affected watersheds were analyzed for loading capacity or allocations.

Relationship to Water Quality Standards

Protection of Bull Trout and Other Aquatic Life

Comment (ALA #229, #236, #237, #240,DFW #4, PNPTC #76 PRC #9): These comments all focus on concern that load allocations will not produce water cold enough for bull trout, protect cold water refugia and provide for other temperature sensitive species. Concern was also expressed over the apparent lack of consideration for other aquatic life and beneficial uses of water in the planning area. Particularly that the Technical Assessment Report (TAR) and HCP *"fail"* to use macroinvertebrates as one means to understand the link between physical processes and stream biota.

> *Response:* These comments address to a certain extent issues on the adequacy of the applicable state water quality standards. These water quality standards have been adopted by the State of Washington to protect designated beneficial uses that include bull trout and other aquatic life. The state is currently completing an extensive assessment of current standards and has developed revisions that will be subject to public review before final adoption. Any changes that impact waters in the HCP area will be incorporated into appropriate changes to the TMDL.
>
> The TMDL is designed to address impairments due to surface water temperature increases documented on four listed stream segments located on Simpson's Northwest Timberlands, as required by CWA §303(d). However, the TMDL will apply across the Simpson ownership. The TAR describes the applicable water quality standards that will be met by the TMDL *(see Section 2, page 2-1)*.
>
> Washington State's water quality standards include numeric criteria, narrative criteria, beneficial (characteristic) use designation and protection, and anti-degradation. Compliance with the State's water quality standards is explicitly stated in the TAR and TMDL. Current state rules attendant to these standards (i.e. anti-degradation) requires no increases in stream temperatures beyond what they are at present. So, a cold water stream should remain a cold water stream. Additional explanations can be found in the discussion below of peak hourly increase used as an indicator.
>
> Bull trout surveys to date have suggested that present distribution of this char in the subject area is limited. It is the intention of the HCP and this TMDL to ensure protection and recovery of this species to its historic range within the Plan area, whenever possible.

The monitoring commitments made by Simpson should provide opportunities to document both their compliance and the effectiveness of prescriptions. The adaptive management process in the Plan will focus on maintaining natural temperature regimes.

Ecology and EPA also acknowledge the use of macroinvertebrates as an indicator of water quality and are aware of the advances in these methods, having funded many of Dr. Karr's efforts in the past decades. Their use in the State of Washington's water quality standards is still under consideration. In conclusion, no specific information was provided by the commenter which shows that the criteria adopted by the State will fail to protect aquatic life, including invertebrates and other beneficial uses. If such information were to be made available to the State and the applicable water quality criteria modified for these segments, the TMDL would be revised accordingly.

WATER QUALITY STANDARDS — OTHER INDICATORS

Comment (ALA #235,, WEC # 12): The attempt to examine the issue of "hydrologically mature" is considered too restricted to be meaningful.

> *Response:* Currently, there is no water quality standard for basin hydrology in the forested context, or in other land use categories. This provision is an honest attempt to better understand the effects of timberland management on seasonal basin hydrology and stream temperatures (synergy between summer low flows, sedimentation and thermal heating, beyond the typical concern for changes in peak flow discharge characteristics alone). To the agency's knowledge, no other forest landowner has agreed to examine this issue in quite this way. Given the relative accuracy of measuring streamflow (± 15% of actual) and the confounding factor of inter-annual variability, the agencies are unclear of what a hydrologic standard should look like. ALA does not suggest what an appropriate standard measure of conformity should be. Although it may not meet the test of rigor that ALA envisions, this hydrologic element should be an important incremental step to better understand these interactions.

Analytical Basis

GENERAL APPROACH TOWARDS TEMPERATURE TARGETS

Comment (PRC #11,): This comment raised the following question: The rate of temperature increase is not the key variable under all circumstances: maximum temperatures reached at key reaches is also important therefore, are the targets an accurate and appropriate expression of riparian conditions required to meet water quality standards?

Response: We readily admit that there are numerous factors that contribute to water temperatures in any one stream reach. However, energy input is the primary driver throughout the entire stream system. By focusing on the rate of temperature increase (energy input) the analysis provides useable targets without having to collect additional information reach by reach. We do believe that the targets are appropriate to meet water quality standards.

USE OF PEAK HOURLY INCREASE AS AN INDICATOR

Comment (ALA #228, PRC #11, PRC #42, PRC #46, PRC #70): These comments relate to concerns that actual measurements of stream temperature will be ignored and the *"maximum hourly rate of increase"* of 0.45?C at a site then supplants the state temperature standard; that the empirical basis for the maximum rate of increase to represent *"natural conditions"* is unclear and most likely highly dependent
upon stream size; that the target rate of temperature increase exceeds *'natural conditions'* assuming that natural conditions mean those conditions providing the most moderated thermal regimes at a site and downstream in its range of influence."

> *Response:* An analysis of actual water temperature is important, as suggested by the comments. However, a total reliance on temperature, in particular maximum water temperature, only considers symptoms. The purpose of the TMDL, on the other hand, is to go beyond the symptoms and address the causes. Development of the TMDL uses an analysis of heat transfer processes to describe factors which increase stream temperature

in the Simpson HCP area and to evaluate potential solutions. The use of *"peak hourly increase"* to identify loading capacity targets is intended to reduce stream heating that goes beyond natural levels. The excess heating arises

primarily from local increases in solar radiation due to removal of streamside vegetation, stream widening due to increased sedimentation within channel systems, and the transport of excess heat to downstream reaches.

The heat budget analysis is used to identify the pollutant (heat) load during a critical time frame. In the case of this TMDL, the critical time frame used is the middle of daylight hours when the solar radiation flux has the greatest potential to deliver large quantities of heat energy into the stream. This time frame, with the highest potential solar radiation load entering the stream, can also lead to a very rapid increase in water temperature. The highest rate of increase is known as the maximum peak hourly increase. As a result, the stream temperature target used in the heat budget analysis is expressed as a maximum peak hourly increase. The loading capacity used is the maximum net change in heat energy delivered to the stream during the same period that will keep the water temperature increase below the peak hourly increase target. This loading capacity can then be expressed as the percent reduction from the maximum potential for solar radiation input, or load. We use the term "effective shade" as the measurable component controlling the level of solar radiation input.

Comment PRC #46 expressed concern about the relationship between the peak hourly change target and interpretation of natural conditions. The narrative portion of Washington's water quality standards, as it applies to temperature and other parameters with numeric criteria, states: *"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" [WAC 173-201A-070(2)]*. The peak hourly change target is not a substitute for the water quality criteria (both numeric and narrative) which have been adopted by the State of Washington. However, the peak hourly change does relate directly to heat load, which is the pollutant contributing to elevated water temperatures. Based on real data, the peak hourly change does in fact correlate to maximum daily stream temperatures in the Simpson HCP area. The target of 0.45?C corresponds to the peak hourly change value within the data set used for the Simpson HCP area. The target of 0.45?C is a conservative value. One site in the HCP area (S-4) had a peak hourly change of 0.60?C even though the daily maximum temperature did not exceed the 16?C numeric criteria on the hottest day of the 2-year period. Data from the Humptulips drainage (located just west of the Simpson HCP area) had several sites which also exceeded the 0.45?C peak hourly increase target and had daily maximum water temperatures well below 16?C.

DERIVATION OF PEAK HOURLY INCREASE TARGET

Comment (PRC #11, PRC #42, PRC #46): Comments acknowledge potential usefulness of approach but feel scientific justification is lacking; express concerns that if effective shade reflects a single target rate of temperature then that appears to confer authority to this rate of increase to arbitrate the condition that is attainable. Therefore, if the target shade is available but temperature standards are not achieved then it could be said that the standard is not attainable, however the level of accuracy in measuring effective shade could lead to highly variable results to control stream heating.

<u>Response</u>: A reasonable scientific justification for the use of a peak hourly temperature increase target <u>is</u> presented in the TAR attached to the HCP and the TMDL submittal document. The basis for the use of peak hourly change is supported by an analysis of heat transfer processes that contribute directly to increased stream temperatures. The daily profile for water temperature typically follows the same pattern as that of solar radiation delivered to an unshaded stream, as described in the TAR *(<u>see</u> Figure 2-2, page G-14)*. Identifying a target for peak hourly temperature change is designed to provide the maximum protection from excess heat at the time of the day when the stream is most sensitive to incoming solar radiation. This time frame is between 11am and 3pm (daylight time) when the solar altitude is highest and the potential solar radiation load that can be delivered to the water surface is greatest.

Development of the target peak hourly increase went beyond heat transfer theory and used actual stream temperature data collected in the Simpson HCP area. As described in the TAR *(<u>see</u> Figure 3-5, page G-24)*, monitoring data collected on the hottest day over a 2-year period (July 28, 1998) was used to evaluate a *"worst case"* scenario. The peak hourly change for each site on this date was plotted against the daily maximum water temperature at the respective site as shown in the TAR *(<u>see</u> Figure 3-7, page G-25)*. A linear regression on the data results in a peak hourly change value of 0.46?C that corresponds to a daily maximum water temperature of 16?C ($r^2 = 0.76$).

Because of this correlation, the peak hourly change target of 0.45?C was deemed to be a technically supported surrogate to represent the 16?C numeric criteria for development of the TMDL. Again, the focus of the TMDL is the reduction of excess heat input. One analogy is establishing a TMDL for biochemical oxygen demand (BOD) when the water quality parameter that exceeds criteria values is dissolved oxygen (DO). In this example, BOD is the cause of the problem, while the DO violations reflect symptoms. Similarly, excess heat and the corresponding temperature change above normal are better linked to the cause, while the maximum daily temperatures actually reached simply reflect symptoms of the problem.

Comment PRC #46 also noted concern over the *"error in measurement of effective shade"*. There are additional benefits of a peak hourly change target in developing a TMDL that uses effective shade to address water temperature concerns. First, hourly changes in water temperature can be easily related to changes in incoming heat load, particularly solar radiation. Using riparian vegetation to reduce the solar radiation load (i.e. increase effective shade) is better understood in terms of management practices to implement the TMDL.

Second, actual hourly stream temperature data collected through water quality monitoring efforts can also be used to *"back-calculate"* the change in heat load. This is accomplished by using the basic heat transfer equation described in the TAR *(<u>see</u> Table 3-1, page G-20)* and knowledge of stream characteristics (e.g. flow and average depth). The change in heat load is another way to cross-check actual improvement in effective shade as streams in the HCP area receive the benefit of riparian management strategies.

<u>Comment (PRC #60)</u>*:* This comment expressed concern that focus on the target rate of change regardless of stream size obscures biological consequences and may not prevent undesirable changes. Target conditions appear to be based upon only modeled results from very small and probably damaged stream channel conditions." Figure 3-6 shows three monitoring sites (temperature groups) where a peak hourly temperature of 0.75-0.85 is able to produce a maximum temperature of from 17 to 23?C. Variation in maximum daily temperature of this magnitude has important biological ramifications. Given the apparent insensitivity of maximum temperatures to hourly rate of change in water temperature, it appears less than certain that a rate of change limited to 0.45?C/h would necessarily be equated with benign maximum temperatures (i.e. 16?C). From Figure 3-5, it appears that temperatures on the warmest stream varied from approximately 18 to 25?C. Temperature gain was nearly linear for approximately a 10-h period. At a rate of 0.45?C/h, 4.5?C diurnal increase would occur. The peak hourly change on this stream was about 1.25?C/h and the diurnal change was about 6.5?C (Figure 3-6, top). That is, even at a rate of change of 0.45?C/h, if sustained for a 10-h period, could produce diurnal changes that are approximately 70% of the diurnal change produced by the stream with the highest temperatures in the Plan area."

> *Response*: As stated earlier, loading capacities for effective shade were developed using a heat budget analysis to achieve a target peak hourly change. The peak hourly change target was derived from an analysis of actual stream temperature monitoring data. Sites that met the peak hourly change target also had shade levels ranging from 85-95%, contrary to the commenters' suggestion that these were small damaged streams. Comment PRC #60 is correct to point out the biological ramifications of large variations in daily water temperature change. The intent of the peak hourly change target is to reduce the total input of solar radiation. This reduction of solar radiation input will also minimize the large diel changes in water temperature.
>
> Maximum water temperatures are sensitive to the peak hourly change, contrary to statements in comment PRC #60. This was pointed out above in a discussion on the correlation of the two factors. Furthermore, the commenters' statement that temperature gain is nearly linear for approximately a 10-hour period has no technical basis. In fact, the stream temperature monitoring information from the HCP area shows that hourly water temperature changes reflect the change in potential solar radiation input. Thus, the commenters' statement that a peak hourly target of 0.45?C will lead to a 4.5?C diurnal water temperature increase is not supported either by actual data or by an understanding of stream heating principles. Thus, the conclusion the commenter draws that a peak hourly target of 0.45?C could produce diurnal changes that are approximately 70% of the diurnal change produced by the stream with the highest stream temperature simply has no scientific basis. In fact, two streams that met the peak hourly target of 0.45?C had diurnal fluctuations of 1.7?C and 2.4?C respectively. Another stream that had a peak hourly change of 0.60?C had a diurnal fluctuation of 1.8?C.

Comment (PRC #61, PRC #69): Comment PRC #61 expressed the concern that the current effective shade condition for the stream with a peak hourly increase of only 0.45?C was not identified empirically. " It is not clear that a fixed diurnal rate of increase should apply to all temperature groups (or stream sizes). The lowest peak hourly rate of increase observed (0.45?C) was used to derive effective shade targets (G-24). However, it appears that this was the rate of increase observed on the warmest day in a 2-year period only. Figure 3-2 shows that there was a large difference in heating between 1997 and 1998. There is no way to set a standard based upon only 2-years of monitoring data without also doing a significant analysis of corresponding air temperatures for a long period of record. Years that were much hotter than either 1997 or 1998 should be expected. In addition, the problem with consecutive hot days is not considered in this analysis. If nighttime cooling does not take place after a very hot day, the subsequent day's heating, even if at the same standard heating rate (0.45?C/h, or the heating rate considered to represent “natural conditions”, G-23) could produce even greater maximum temperatures. This process of setting shade targets starts from some sort of reference riparian condition (presumably), identifies a heating rate, and then works back from this via use of a model to infer what the required shade should be. One would wonder what the level of confidence would be in estimating, even for a single reference stream that produced the standard rate of heating, the effective shade required.” Comment PRC #69 expressed the concern that water temperatures used to characterize target conditions were based on an exceptionally limited historic record. Effects of normal variation in low flows were not considered. “The highest water temperatures observed for the 2-year monitoring period at the Satsop River gage were produced coincidentally with the 7Q2 water yield. It is commendable that Simpson recognizes the relationship between streamflow, channel condition, sediment delivery, and water temperature. However, a 2-year recurrence interval for low flows is not especially conservative. Low flows that occur less frequently are, nonetheless, common and riparian conditions need to be adequate to prevent excessive stream warming. Although the Satsop River reached a maximum of approximately 25?C in 1998, this is not sufficient data to indicate whether maximum temperatures greater than this occur. Higher water temperatures would occur under climatic control given either lower streamflows, higher air temperatures, or more consecutive days of high temperature. Combinations of these factors could also lead to excessive water temperatures. That is, any low flow statistic alone is not a sufficient indicator of how conservative the approach taken in the Plan is.”

> Response: from a purely technical perspective, it is always desirable to have more information. However, Congressional intent and agency policies regarding §303(d) support the development of TMDLs using existing data, even if that information is limited. A review of water temperature data from the Humptulips drainage (located just west of the Simpson HCP area) confirm that 1998 was an unusually warm year. The commenter did not provide information to identify years that had warmer air or water temperatures for the southern Olympic peninsula. Likewise, conjecture by the commenter regarding consecutive hot days and the lack of night time cooling is simply not supported by the data. No hard information was provided to support the hypothetical situation suggested by comment PRC #61.
>
> Focusing on the water quality concerns, the intent of a target peak hourly temperature change is to reduce heat input from solar radiation. Attainment of effective shade allocations designed to meet the peak hourly change target will result in lower daily maximum water temperatures, regardless of the interannual variability that does occur. Also, as discussed earlier, an analysis of data from the Humptulips indicates that there may be a basis to identify higher peak hourly change targets for some channel classes.

EQUILIBRIUM TEMPERATURE AND PEAK HOURLY TARGETS

Comment (PRC #48, PRC #49): Comment PRC #48 states that “For any stream, once it has reached equilibrium with air temperature, shading at the site becomes a less dominant control on the rate of temperature gain at the site. The idea that it is the rate of temperature gain rather than the actual temperature that is important (G-8) is flawed. If water temperature is already high because of past riparian logging upstream, then the ability to gain further temperature at the site is controlled by local air temperature. But riparian shade in the upstream reaches controls the rate of gain in temperature longitudinally and the maximum temperatures reached at sites along the way to achieving equilibrium.” Comment PRC #49 continues by stating that “Once a large stream has reached equilibrium with air temperature, removal of riparian vegetation along the stream channel would not lead to the same rate of temperature increase as if the same reach had had cold water delivered to it just upstream, and consequently had not yet reached equilibrium. Monitoring of rate of temperature increase in a large stream reach subjected to canopy removal would not appear to show a major influence of canopy removal, whereas if water temperatures had started colder in this reach, the effect would be easier to detect, and conversely, the value of retaining the vegetation would be clear. This merely emphasizes that given sufficient restoration of upstream riparian zones, subsequent delivery of colder water to the large stream reaches in restored watersheds would necessitate retention of shade along even the large channel."

> Response: Comment PRC #48 reflects a continued focus on symptoms, specifically daily maximum water temperatures, rather than causes. Again, the focus of the TMDL is to reduce excess heat throughout the system that causes the high daily maximum water temperatures. The logic behind this approach is not flawed, as indicated by the commenter but in fact is supported by basic fundamental scientific principles that underlie any routine analysis of water temperature. Using data collected in the Simpson HCP area, diurnal water temperature patterns were shown in the TAR *(see Figure 3-5, page 3-6)*. Daily maximum water temperatures shown in Figure 3-5 for the two warmest streams were 24.55?C (site C1-08) and 22.89?C (site S1-36). Maximum air temperature for the day was nearly 35?C. Because these streams are not in equilibrium with air temperature, this comment lacks technical merit relative to the proposed Simpson HCP area TMDL.
>
> Although equilibrium with air temperature is not an issue for these particular streams, a discussion about its actual role in stream heating adds support to the approach used. This approach provides a focus on the reduction of excess heat from high solar radiation loads. Heating by convection between the air and stream surface occurs at a very slow rate. The methodology used to describe convection is based on physical relationships that have been added to the TAR as Section H. The rate at which heat flows between air and water is a function of thermal conductivity, a factor that depends on the material. Solids have the highest thermal conductivity and conduct heat faster than gases, which have very low thermal conductivities. Air has a very low thermal conductivity (0.026 W/m*k) compared to water (0.595 W/m*k). The amount of convective heat transfer between the stream and air is low (Parker and Krenkel, 1969; Brown, 1983). In a heat budget, convection is a function of Bowen's Ratio (1926) — terms include atmospheric pressure as well as water and air temperatures. For an unshaded stream at the same latitude as the Simpson HCP area on a day when air temperatures reach 35?C, the rate of heat transfer from convection in the middle of the day is less than ten percent that of solar radiation. Thus, excess heat from solar radiation can be an order of magnitude greater than convection from air. Thus, the focus of the TMDL on reducing excess heat through the use of effective shade to minimize water temperature increase is technically justified. This focus results in the maximum retention of effective shade along even large channels, as suggested by the commenter.

DEVELOPMENT OF EFFECTIVE SHADE TARGETS

Comment (WDF&W #5 - #7): These comments requested information on how the effective shade loading capacity targets compare with the protection given by the current shade rule, and if targets take into consideration long-term shade as well as current shade. Questions were also raised on the details of the model and assumptions used to develop these targets.

Response: The effective shade loading capacity targets don't compare directly with the current shade rule (temperature screen) because the temperature groups are only loosely related to elevation. However, it's apparent that at least some targets result in less shade than the current rule would allow, while others would result in more. We believe the monitoring program as outlined, and as developed with input from the SAT will provide the necessary information to evaluate effectiveness of the management measures and how appropriate the targets are. The targets in the TMDL are expected conditions for long term effective shade. The analytical approach (or model) used to develop effective shade loading capacities or targets is based on the fundamental heat budget equation applied by Brown (1969) for forested streams *[see TAR, page 3-1]*. As described in the TAR, the heat budget technique utilizes six variables (solar radiation, long wave radiation, evaporation, convection, bed conduction, and advection) *[see TAR, page 2-3]* to determine the net gain or loss of stored heat (**?**H) in a known volume of water. The change in **?**H is then converted to a water temperature change. More reference information on the heat transfer processes has been added to the TAR as Section H.

Comment (PRC #11, PRC #44, PRC #47, PRC #49): Comment PRC #47 states that "Information is not available to make clear how for a stream of any given active channel width class, effective shade requirements would vary so greatly. For example, for very narrow channels (?4m) effective shade targets vary from 65 to 90%. Within any given temperature group, the variation in effective shade targets is less. For example, for the C-1 temperature group, effective shade targets vary from 72 to 89%, corresponding to variation in active channel width of 6 to >25m. However, it would seem that for wide, deep rivers, the target rate of temperature increase would be far less than for a shallow stream. The rate of heat gain is a function of stream width, shade, and average depth or volume of flow. Effective shade varies with vegetation height, density, and quality. Because streams of different sizes have different sets of controls on potential rates of heating, it does not appear to be accurate to assign a fixed rate of temperature increase to all stream sizes. It seems likely that this might be appropriate only in medium sized streams but be too great a rate of increase in small streams having potentially dense shading and also in large streams having some shade but also a large thermal inertia. Also, because in-channel storage volume is a function of available primary pools (which in turn is partially a function of LWD availability and sediment storage and delivery), channels that are sensitive to temperature increase may also have excessive fine sediment." Comments PRC #11, PRC #44, and PRC #49 state that monitoring results and interpretation are dependent on ecological context and decisions to do site-specific "tailoring" of prescriptions in such contexts is frequently inadequate due to our lack of understanding of the magnitude of restoration possible.

Response: As pointed out by the comments, there is a wide range of stream characteristics across the landscape to be considered in TMDL development. The landscape stratification and channel classification system was used as the method to address this inherent variability that challenge development of all TMDLs for nonpoint sources *(see TAR, 2-5)*. Reference information considered in development of the channel classification system summarizes watershed characteristics (e.g. geology, drainage area / active channel width relationships, water yield) and has been added to the TAR as Section B.

This is the same information that was used to assist in the identification of effective shade targets *(see TAR pages 3-8&9)*. The variation in effective shade loading capacity targets, noted by the commentor, is a function of different characteristics associated with each temperature group and channel class.

Reference information considered in development of the TMDL for each temperature group which summarizes important channel characteristics by class (area, width, slope, temperature patterns) has been added to the TAR as Section C.

Comment PRC #47 correctly points out that the rate of heat gain is a function of stream width, average depth, volume of water, and shade. Key relationships were summarized throughout the TAR *(see pages 1-3, 2-2&3)*. As pointed out by the commenter, a wide shallow stream will heat up faster than a narrower, deeper stream with the same discharge. However, this factor is more important in determining the allowable amount of heat input to the particular stream than it is to the target rate of temperature increase. A narrow, deep stream can absorb more heat than a wide, shallow stream to meet the same target rate of increase.

Information used in the interpretation of different channel characteristics relative to water temperature has been added to the TAR as Section D.

In response to the comment regarding a need for different temperature increase targets on different streams, Simpson also expressed this concern. Comment PRC #47 is correct in pointing out that streams of different sizes have different sets of controls on potential rates of heating. As described earlier, one site (S-4) shows that 0.60?C may be more appropriate to meet at numeric criteria of 16?C. Similarly, one site in the Humptulips had a peak hourly increase of 0.62?C with a daily maximum water temperature of 12.71?C while another Humptulips site had a peak hourly increase of 0.79?C with a daily maximum of 15.62?C (both occurred on the same day — July 28, 1998 — as the Simpson analysis). Regardless, the clear need to address the effect of past practices points to placing a high priority on maximum protection. Consequently, the lower peak hourly increase target (0.45?C) was used to provide an additional margin of safety.

Some small streams do receive more potential dense shading, as indicated by Comment PRC #47. Based on data collected in the HCP area, temperatures in these same small streams can also be influenced significantly by groundwater (both the contributing volume and its temperature). This is the reason that a temperature group approach was used for identifying effective shade loading capacity targets in the TMDL. This approach allows consideration of watershed process features that exert the greatest influence on water temperature, as described in the TAR *(see page 3-3&4)*. Thus, the temperature group approach does provide an ecological context that allows development of site-specific prescriptions. As more data is collected and a better understanding of the relationship of channel functions to stream temperature is gained, peak hourly increase targets may be adjusted, if appropriate.

Information and assumptions used to develop specific effective shade loading capacity targets has been added to the TAR as Section E.

Comment PRC #47 seemed to believe that effective shade, as influenced by vegetation height, was used to establish loading capacity targets. This confusion seems to be the result of the column labeled *"Vegetation Height"* in the TAR *(see Table 3-2, page G-27)*. Vegetation height is important in identifying allocations to meet effective shade loading capacity targets. However, the loading capacities themselves are driven by the need to reduce excess heat input as determined through the use of the peak hourly change target. To eliminate this confusion, the *"Vegetation Height"* column has been removed from Table 3-3 (was Table 3-2) in the TAR.

Comment (PRC #62, PRC #92): Comment PRC #92 expressed a desire to see a clearer presentation of the interaction and factors that affect development of effective shade targets. Comment PRC #62 raised similar questions. The comment stated that "The target rate of diel temperature change was produced by varying effective shade for medium streams from 78 to 90%, considering the expected ranges of various parameters (e.g. wind, bedrock, groundwater) (p. G-26). This is the model uncertainty, given the model parameters and assumptions. Empirical studies of this relationship were not given. In addition, the target was based only upon two stream sizes called small and medium representing only one stream type (SIG) that differed by only 1 cfs and had identical W/D ratios. This W/D ratio (25) is extremely high for a small stream and probably reflects a degraded channel. The range of stream sizes used to establish a target condition was extremely small, did not represent all stream types, and should have considered the effect of W/D ratio alteration, and should have had empirical support."

Response: Effective shade targets were not based upon only two stream sites, as suggested by comment PRC #62. A separate analysis to identify effective shade targets was developed for each of the 49 channel classes. The two channel types referenced by comment #62 were used simply to illustrate the effect of different assumptions. Assumptions for each individual channel class have been added to the TAR as Section E.

Comment PRC #62 is correct that a W:D ratio of 25 is extremely high for a small stream. However, the process of identifying effective shade targets sought to be conservative relative to key assumptions. A lower W:D ratio assumption for that channel class would result in a lower effective shade target.

Comment (PRC #63, PRC #92): Comment PRC #63 stated that the relationship between effective shade and target riparian vegetation condition (especially tree height) was unclear. "There is a large difference in effective shade targets among the 7 temperature group streams, even within streams of the same active channel width class. For example, the C-1 stream, which has the highest diurnal temperature and rate of heating, has effective shade targets of 77-83%. Trees of 170.0 ft height are needed to effectively shade the channel on June 21. It is unclear, though, whether this is intended to be a target riparian tree condition. Also, since the description of the method for monitoring involved use of aerial photography to estimate canopy density or canopy closure without knowledge of tree height, there would be no way to estimate what the effective shading would be on any stream reach. If this is the case, one would have to wonder whether the effective shading referred to in Table 3-2 is shading of the stream or the riparian floor. Likewise, is 170 ft the target riparian vegetation height? Is this the mean tree height producing shading over the stream surface?"

Response: Riparian conditions that were assumed in developing the effective shade allocations are identified in the TAR *(see Table 6-3, pages 6-5,6,7&8)*. The intent in developing these allocations was to use expected conditions from implementation of the riparian management strategies (both vegetative type and riparian conservation reserve widths). Load allocations are based on effective shade over the stream surface. Additional information has been summarized in the TAR as Section F

Comment (PRC #64, PRC #66): Comment PRC #64 states that air photo interpretation is a rough method for estimating canopy closure and riparian shade. Shade categories for recording monitoring are so crude as to allow considerable stream degradation. "Estimation of canopy closure and thereby, riparian shade, made from air photo interpretation has a very crude level of accuracy (Figure 4-2, G-32). For example, 20% of the riparian stands surveyed visually from aerial photos had between 30 and 50% canopy closure. Correlation of canopy closure with percentage full sunlight was not made. Also, as stated, without knowledge of canopy height, estimates of shading cannot really be made. Approximately 10% of the canopy length surveyed was estimated to have between 90 and 100% canopy closure (Figure 4-2). The highest target condition was for 89% effective shading (Table 3-2). Given the classes for canopy closure used in monitoring (e.g. 70-90%), what would be considered adequate to meet the 89% effective shade standard? If it is considered adequate to fall somewhere within the 70-90% shade class, there is a great latitude to foster stream degradation." Comment PRC # 66 expresses concern that "Thermal recovery will be impaired by allowing canopy removal; no natural recovery alternative is offered. Although focusing management on sources of sediment or thermal pollution are good, the linkage of water temperature and in-channel fine sediment must be recognized by monitoring these parameters. Two principles were listed for watershed management: to focus on upslope sediment source targets rather than instream features, and to establish quantifiable sediment delivery targets. These are very worthy principles. This approach targets the source rather than symptoms of the problem. This focus would then lead managers to avoid or reverse actions that lead to accelerated sediment delivery. It does not rely on in-channel restoration via the use of sediment settling basins, dredging of fines, etc., which is all good. However, it is probably seldom during recovery, that in-channel fine sediment would indicate excellent conditions, but the upslope sediment delivery potential is high. Consequently, it is always necessary to monitor in-channel conditions as well as sediment delivery hazards to ensure that target conditions are reached. Fine sediment has a definite associated biological response that has been revealed by extensive laboratory and field experimentation and monitoring. It is not valid to ignore the biological effects and assume that by taking essentially a BMP approach to land management that the desired results will ensue. A corollary to this is to ignore what the actual water temperature is and to adopt just a shade target. In terms of temperature, the Plan needs to reveal the time frame for thermal recovery of each salmon-producing watershed using the HCP versus using the most ecologically sensitive alternative. Because options are limited for improving the temperature condition on large streams and because sediment and temperature control are linked, the Plan should make an estimate of recovery time under the HCP alternative and the alternative that is best for salmon. Prolonging the recovery time frame appears to be inevitable given the diminishing effect of canopy cover with stream size on large streams and the freedom provided for canopy removal in other temperature group streams by using the standard temperature increase rate."

> Response: Comment PRC #64 is correct in pointing out that air photo interpretation can be a rough method of estimating canopy closure. One reason for using a peak hourly change target was to provide a link to effective shade in a way that utilizes actual water temperature monitoring data. The monitoring program will continue to use documented methods to collect canopy closure and riparian shade information. However, progress towards meeting load allocations and attaining water quality standards will be measured through assessment of the actual stream temperature monitoring data. Likewise, inventory information on sediment delivery hazards will be expanded under the monitoring and adaptive management program. This will include evaluation of the effects of sediment delivery on stream channels in the HCP area. Adjustments will be made to the TMDL, as necessary, if supported by information from monitoring and

assessment efforts.

<u>CONSIDERATION OF GROUNDWATER</u>

<u>Comment (WEC #18)</u>: Clearcut harvesting alone, regardless of riparian buffer width characteristics, may affect stream temperatures by warming groundwater input to surface flows. One study indicates a relationship between the proportion of a sub-basin in late seral stage forest and water temperatures.

> *<u>Response</u>*: Ecology and EPA agree that there may be other factors, as yet poorly understood, that affect stream temperatures besides effective shade. Contemporary wisdom is that direct solar radiation likely is the most prevalent factor contributing to stream temperature increases following adjacent logging. At present, the state of knowledge on other factors is not extensive, and to our knowledge no analytical tool has yet been developed to incorporate these factors with any confidence. As part of the monitoring and evaluation program, the relative contribution of factors other than shade on stream temperature increases will be investigated.

<u>APPROPRIATE INDICATORS FOR SEDIMENT</u>

<u>Comment (Aud #13 - #15)</u>: These comments express concern over the use of historic patterns of mass wasting to project appropriate targets in the future and a desire to see very aggressive management controls. Past logging and road building activity have resulted in sometimes extremely degraded conditions across the landscape, which could lead to lower than required targets.

> *<u>Response:</u>* Ecology does not have specific water quality standards for sediment loads and turbidity doesn't work well for coarse sediment management. Consequently, the analysis focussed on reducing the amount of sediment delivered to the stream system. The existing fine sediment numeric target for Total Suspended Solids can be used to help judge the overall effectiveness of surface erosion from roads. We agree that the amount of mass wasting in the historical record reflects the impact of management activity and that residual impacts will continue. However, we believe that the targets will bring about real progress towards a more historic normal pattern of disturbance.

<u>SEDIMENT BUDGET FRAMEWORK</u>

<u>Comment (PNPTC #77, PRC #50, PRC #54)</u>: Comment PRC #54 expressed concern that "The method for identifying what would be a natural background level of sediment delivery per land type is not specified. Further, there is no specific indication what principle guides the selection of target loading capacities. Are these loading capacities considered to be levels that represent pre-development rates or are they rates believed to be able to result in channel restoration under a continuing level of accelerated sediment delivery attributable to management impacts. The TMDL created for sediment delivery represents a significant attempt to control sedimentation in stream channels. However, it is questionable how the loading capacities of the five lithotopo units were derived. "The sediment assessment used to develop the loading capacity is based primarily on historical data (e.g. landslide inventories), streamflow patterns, and channel responses" (G-9). Judgements made about which mass failures were or were not caused by management influence may have rendered estimates of target loading capacities to be inflated." Comment PNPTC #77 indicated that the time frame used to determine background versus management induced sediment production is not appropriate because it gives an artificially high figure for background.

> *Response*: The method to determine sediment delivery targets started with a review of available sediment yield data for streams draining from the Simpson HCP area. The U.S. Geological Survey (Glancy, 1971) conducted a sediment transport study of several tributaries to the Chehalis which included several streams that drain the HCP area. The purpose of the review was to gain a coarse understanding of sediment production and transport processes in the Simpson HCP area. This provided a frame of reference for developing a partial sediment budget to identify sediment reduction needs in the TMDL. The USGS report shows a wide range of sediment yield across the Chehalis basin. Values from the Satsop / Wynoochee watersheds highlight the difficulty of determining natural background for this landscape.
>
> EPA regulations acknowledge the challenge associated with establishing load allocations for nonpoint sources, e.g. sediment in a forested setting. The current regulation states: *"Load allocations are best estimates of the loading, which may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading" [40 CFR §130.2(g)]*. Agency guidance for development of sediment TMDLs recognizes that erosion is a natural process and some sedimentation is needed to maintain healthy stream systems. Consequently, it is often necessary to evaluate the degree to which sediment discharge in a particular watershed exceeds natural rates or patterns (EPA, 1999). This analysis can be complicated because sedimentation processes in many systems are highly variable from year to year. This type of analysis is particularly important in settings that are vulnerable to high natural sediment production rates and are particularly sensitive to land disturbance (e.g. the Pacific Northwest).
>
> Following a review of the USGS report, development of loading capacity targets in the Simpson TMDL used calculations of sediment delivery based on areal estimates of erosion features. This general approach was used in northern California for development of sediment TMDLs to address similar concerns, e.g. road-related sources, timber harvest, landslides *(see TMDLs for Garcia River, S.F. Trinity River)*. The method used to develop loading capacity targets for the Simpson HCP area TMDL goes beyond the approach used in northern California. The landscape stratification system was used as an added refinement to loading capacity targets, so that differences in lithology and topography, which affect erosion processes could be considered. This is in contrast to using the same target applied across the entire watershed for a particular source or process.
>
> As described in the TAR, development of sediment delivery targets (the loading capacity) uses a framework suggested in the TFW Watershed Analysis Manual. That framework is the construction of a partial sediment budget (Reid and Dunne, 1996). Erosion processes considered in the partial sediment budget include mass wasting (shallow rapid landslides, debris torrents, large persistent deep-seated slides), surface erosion, and bank erosion. Sediment delivery targets are based on information found in several completed Watershed Analysis reports conducted in the Simpson HCP area. Included is landslide inventory data developed from air photos between 1946-96 *(see TAR, page 3-10&11)*. No photo record exists that would allow a pre-disturbance estimate of background levels, prior to the onset of commercial scale logging in the HCP area.

The landslide inventory data includes a geographic identifier, type of slide, year initiated, size of failure, land use activity associated with failure, and if sediment delivered to stream. The geographic identifier was used to cross-reference the landslide location to the appropriate lithotopo unit (LTU). Because timber harvest in the HCP area was occurring prior to the earliest air photo records, it is difficult to determine pre-development landslide rates. Instead, an approach was used similar to the one applied in the northern California TMDLs. This approach involved estimating the amount of sediment that is controllable relative to the total volume. A more detailed description of this method has been added to the TAR as Section G.

The initial estimates for loading capacity targets were based on a limited subset of all inventoried landslide information (due to data availability). Recognizing these limitations coupled with a desire to refine targets by channel class, a re-analysis of the sediment delivery information was conducted by the registered geologist who developed the original landslide inventory data. This re-analysis was developed at the request of Ecology, Simpson, and EPA. Results have been incorporated into the TAR and loading capacities / allocations revised accordingly.

DEVELOPMENT OF SEDIMENT DELIVERY TARGETS

Comment (PRC #51, PRC #55): This comment questions the appropriateness of expressing "target loading capacities in terms of yd^3/stream mile/yr. For example, the CUP lithotopo unit has a total stream length of 265.2 miles and comprises 11% of the HCP area (p. G-8; p. 13). However, there are small, medium, and large streams on this unit (p. B-5). The CUP-C1 channel class (p. D-5) has a high risk for debris flows. These are able to flow great distances and deliver sediment to the mainstem river, which is routed to alluvial depositional areas. Despite this high risk, the riparian management widths required are a minimum of 20 m (windward) and 10 m (leeward). The windward / leeward designations have meaning primarily in a shading context. As far as prevention of debris flows, a 10-m buffer is neither sufficient to prevent initiation of the flow or to prevent delivery of a flow to the channel. Further, there are approximately 6 miles of CUP-C8 streams. These are large streams in the CUP lithotopo units. Minimum required buffer widths on the C8 streams are 25m (p. B-50). The CUP landscape has a high drainage density on massive basalts and with thin soils (p. 90). Is the sediment loading to stream channels within the CUP units a fixed value and independent of stream size? If so, why are there different riparian buffer requirements for streams in this unit. Is sideslope gradient relatively fixed among streams of various widths within the CUP unit? There is no indication that this is the case. If sideslope gradient is relatively constant, this might explain the use of a fixed loading capacity for any stream in this unit."

Response: The intent of expressing target loading capacities in terms of yd^3/stream mile/year is to add a refinement that takes advantage of the landscape stratification and channel classification systems. Information from lithotopo units allows consideration of differences in lithology and topography that affect erosion processes. Based on limited information, a fixed value for sediment delivery was used for each LTU, with the exception of bank erosion in the Sedimentary Inner Gorge (SIG) where differences in channel size (e.g. small, medium, large) were considered.

The proposed approach was an advancement in development of sediment TMDLs for forested areas in that landscape stratification information was used with source assessment data to provide refined targets. However, as pointed out by the commenter, improvements could be made to provide better estimates of targets with respect to channel classes. As stated previously, a re-analysis of sediment delivery information was conducted. Results have been incorporated into the TAR and loading capacities / allocations revised accordingly.

The commenter raised several questions regarding riparian management widths. However, no information was provided in the comment to demonstrate that these widths would not meet the proposed sediment delivery allocations for the Simpson HCP area.

Comment (SQUAX #16): This comment expresses concerns regarding the baseline for determining desired future conditions, particularly related to development of sediment delivery targets. The comment suggests that "pristine" undisturbed conditions should be the template that is strived for.

Response: This would be ideal, but not practical considering that nearly the entire Plan area has been intensively logged in the past. The recovery opportunities attendant with the riparian and sediment reduction prescriptions should not be underestimated. Riparian management zones will be allowed to mature into perpetuity under this plan (if extended beyond the initial 50 year HCP agreement). This means that for those areas where riparian zones are currently populated with commercially mature trees, in 50 years we will see extensive areas of riparian zone vegetation that will be > 100 years old, that will begin to show characteristics of old growth forests. Sediment from past management activity will continue moving through the various river systems. But the ongoing supply should be greatly reduced. Road management will likely continue to be closely scrutinized as the plan is implemented to ensure successful reduction in sediment generation.

Comment (PRC #52, PRC #53, PRC #56): These comments raise the issue of differences in channel classes and the appropriate level of consideration given to these differences. "Runout distances vary among streams of different sizes. Consequently, it is logical that the in-channel consequences of a single debris torrent event initiated in small streams is potentially much greater than single events initiated adjacent to larger streams, such as in the CUP unit. Sediment loading to small streams then at a fixed rate can have greater risks than loading of the same rate per lineal foot to larger streams. Because of the ability of delivered material to mobilize in high gradient channels and flow great distances, there is increased incentive to both limit the initiation of debris flows and to reduce loading rates. This necessitates tree retention in high gradient swales as well as provision of buffers greater than 10-m minimum, such as required for the CUP-C1 channels. Once sediment is delivered, the catastrophic down channel transport of material appears not to be considered. Again, bank erosion that may occur in the CUP unit is considered to be at a fixed rate of 6 yd^3/stream mile/yr despite variation in channel width. Reduction in severity on in-channel scouring in the large width CUP channels can be achieved by increased prevention of initiation of flows in the smaller CUP channels, reduction in loading rates in smaller channels relative to larger channels on a lineal basis, and provision of large, key LWD pieces in the large streams to restrict runout."

Response: Load capacity targets for sediment delivery have been revised to reflect channel class differences based on a re-analysis of the limited sediment delivery information. Both comment PRC #56 and the re-analysis point out that shallow rapid and debris torrent mass wasting processes are relatively well understood. Management related triggering mechanisms are relatively well documented in the scientific literature. A large portion of these landslide types are due to road construction techniques as well as inadequate drainage design and maintenance practices. A significant, but smaller proportion of these failures were attributable to clear cut harvest techniques on excessively steep slopes where post-harvest decline in root strength was presumed to be the triggering process. As a result, targets for shallow rapid and debris torrent mass wasting have been set to achieve an 80% reduction based on current conditions from the landslide inventory.

As stated previously in response to comment PRC #55, the commenter raised several questions regarding riparian management widths. However, no information was provided in the comment to demonstrate that these widths would not meet the proposed sediment delivery allocations for the Simpson HCP area. Although not related to the development of allocations and the TMDL, the HCP has been revised so that no harvest will occur on unstable slopes.

Comment (PRC #59, PRC #67) (Aud #24): These comments relate to how sediment targets were developed and how they relate to management activity. Comment Aud #24 suggests projecting sediment delivery based upon current BMPs. Comment PRC #59 raised questions regarding the determination of surface erosion targets. The commenter was "unclear how road sediment delivery will be calculated. No basis offered to support effectiveness of harvest techniques on unstable slopes. Sediment loading is to be reduced by decreasing road surface erosion and % hillslope failures by use of sediment delivery targets (yd^3/mile/year). It is not clear how Simpson intends to calculate sediment delivery from its road system. It is also unclear how the percentage hillslope failures will be reduced by altered management in cutting units. What evidence is there for the various land types present that new harvest techniques have been effective in reducing hillslope failures? What evidence is there that 10- or 20-m wide buffers alone are effective in either preventing initiation of failures or in restricting their delivery to channels?"

Comment PRC #67 expressed the concern that sediment loading capacity targets appear not to be based upon all forms of erosion. "The sediment assessment used to develop the loading capacity is based primarily on historical data (e.g. landslide inventories), streamflow patterns, and channel responses to erosion effects". However, because the erosion processes of note in the Plan area include debris torrents, large persistent deep-seated slides, surface erosion, and bank erosion, it appears that the estimation of surface erosion is not effectively considered. In what manner is surface erosion from road surfaces or cut- and fill-slopes estimated; or surface erosion from clearcut harvesting on various land types?

Response: To project sediment delivery rate by management activity with any useful accuracy is currently beyond our level of knowledge. Surface erosion sources of sediment in the proposed TMDL include processes related to hillslopes, those that result from landslide scars, and fine sediment from roads. Estimates of sediment contributions from surface erosion within the HCP area were compiled from Watershed Analysis Reports developed for two drainages in the HCP area (W.F. Satsop, S.F. Skokomish). This information has been summarized and incorporated into Section G of the TAR.

ALLOCATIONS — GENERAL

Comment (ALA #230): This comment reflects the belief that the TMDL *"fails to address the* *adequacy of canopy closure (i.e. effective shade) and sediment targets identified in the Technical Assessment Report (TAR) in relation to independent and objective standards that assure full compliance with the ESA or CWA".* The same comment also states that the TAR *"fails"* to address the role of sediment impacts to salmon production, invertebrates, other ecosystem components, and that different sediment standards might be needed to address the needs of these other biota.

> *Response:* The purpose of the TMDL is to establish load allocations that address the overall past, present and future (through avoidance or mitigation) sediment and temperature impacts on designated beneficial uses (primarily salmonids) and other ecosystem components (such as amphibians). Other ecosystem components, while not specifically addressed, will benefit from the sediment reduction efforts as well as the retention of riparian functions. Testing the overall effectiveness is built into the monitoring and adaptive management framework, described in the HCP. Its important to emphasize that a great deal of timber harvest has occurred on this landscape over the last 100+ years, which means that from a sediment production and temperature shading standpoint, some areas are in recovery. Time and judicious application of sediment reduction practices should help promote recovery of these areas. Other areas, now mature enough for harvest will be conducted under the Plan's prescriptions, that we believe, will afford a reasonable level of protection to riparian functions, thermal shading and restrict the input of sediments that would threaten aquatic life.

EFFECTIVE SHADE ALLOCATIONS

Comment (PRC #11, PRC #43, PRC #46, PRC #65, PRC #68)*:* Comments PRC #11 and PRC #43 express the concern that shade targets should not be used to justify reduction in shade in parts of impaired watersheds exceeding shade targets, nor should these targets replace moderation of temperature increases as a management goal. Comment PRC #46 indicates that many of the riparian areas on the Plan area have been totally clearcut in the past, placing a priority on maintaining existing levels of stream shading where they are found to meet or exceed effective shade targets. If shade targets are exceeded on any reaches, it would be imprudent to remove shade via timber harvest. It could not be justified to claim that by removing riparian trees to reduce shade to the target level, the desired rate of temperature increase would be attained as well as full protection of the thermal environment for salmon on a watershed basis. Comment PRC #65 expresses the concern that "Lower effective shade targets on G-2 channels appear to anticipate degradation of cold water refugia. Topographic shading and cold groundwater inflow appear to be local rationales for degrading water quality. Why should the effective shade target be as low as 58% on G-2 group channels? Table 3-2 notes that the G-2 group channels (small to medium streams) are topographically shaded and are near cold groundwater sources. It is also mentioned that the large C-1 group rivers have high water temperatures and open canopies caused by a legacy of high sediment supply. "[I]t is unlikely that water temperatures here will change for decades". If this is so, the only way to restore these channels is to control sediment sources on a watershed basis and also to control effective shading on a watershed basis. However, based on the kind of site-specific "tailoring" done, such as on G-2 channels, there seems to be little hope of controlling these problems systematically. G-2 channels have a large proportion of their surface water contributed by groundwater. Because of this cold water thermal resource, the HCP anticipates having latitude to degrade these waters by applying the 0.45?C/h rate of heating. These waters would have historically resisted heating at this rate. Consequently, it is unwise to permit canopy removal by citing the topographic shading and also to rely on groundwater to moderate the impacts of canopy removal on water heating.

This is equivalent to forcing a natural cold water refuge to conform to a standard rate of heating by canopy removal. For the streams that had recently been clearcut in the riparian zone, they would not be suitable for a second harvest until the end of the HCP period anyway. Therefore, on these channels there is little economic consequence of instituting a restrictive standard because they couldn't meet the target rate of temperature increase anyway." Comment PRC #68 believes that the "Plan appears to anticipate degradation of water quality of small streams. Natural temperature conditions seem to be defined as either meeting state standards or a target rate of temperature increase, either of which would permit stream warming. G-31. Stream groups S-4 and G-2 did not exceed Washington's temperature standards due to their resistance to temperature change attributable to high groundwater influence. Under the Plan guidance, is it anticipated that effective shading on these streams will be reduced from current conditions because of their inherent resistance to heating? If so, this would be counter to antidegradation policy. Contrarily, is it assumed that no improvement in shading is necessary on these streams because they meet current state standards? If so, it is likely that the Plan assumes that any stream that meets standards is operating at "natural" condition level. In this event, Simpson is not making full use of watershed-wide control on temperature. Any indication that these alternatives are not the case would be welcome, but from information provided it is not clear that such is not the case."

> *Response:* These comments appear to reflect confusion about the relationship between various components of the TMDL, in particular the load allocations for effective shade and the margin of safety. The specific concern appears rooted in comment PRC #65 relative to temperature group G-2. Development of loading capacity targets takes advantage of inventory information from the landscape stratification and channel classification systems. As stated in the TAR *(see Table 3-2, page 3-3)*, streams which fall into the G-2 temperature group are small to medium sized highly confined channels of the AGL, CIS, CUP, and SIG. These streams are topographically shaded with substantial groundwater influence. Because these systems are typically cool and resistant to water temperature changes, the heat budget analysis identifies lower effective shade loading capacity targets for G-2 streams. This analysis is supported by water temperature monitoring data collected in the HCP area. None of the comments provided actual data for streams within this temperature group that shows otherwise.
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> Although loading capacity targets for G-2 streams are lower, actual load allocations for these same streams are proposed at much higher effective shade levels *(see TAR Tables 6-3b,c,d — pages 6-6 to 6-8)*. As clearly shown in the proposed TMDL, streams in temperature group G-2 have significantly higher margins of safety for a variety of reasons. Included are uncertainty in identifying the loading capacity targets for effective shade as well as consideration of downstream effects.

Comment (Aud #26, PRC #70)*:* AUD #26 states that the TMDL should do no further harm to those waterbodies already impaired from a water quality standpoint. PRC #70 reasons that "planned reductions in stream shading, in conjunction with…interacting natural factors, can exacerbate the more extreme natural conditions and further jeopardize salmon populations dependent on moderate water temperatures."

> *Response:* The agencies agree that the TMDL (and the HCP) should result in not increased harm to the aquatic resources. The load allocations for effective shade have been established to define expectations based on water quality needs, and are not based on current conditions. If monitoring and adaptive management show that the

prescriptions fail to provide adequate protection, discussions will be initiated and steps taken to reach a solution. As indicated, some of this landscape has been harvested in recent years and does not now have riparian zone stand characteristics that equal those described in the TMDL. These areas are essentially, in a recovery mode from an effective shade standpoint. Sixty percent of the riparian reserves currently have stream trees at least 50 years. old in their riparian zone, which imparts levels of effective shade that are reflected in the TMDL allocation table.

Comment (PRC #93, PRC #94, PRC #96): These comments relate to the meaning of effective shade and how the load allocations translate to on the ground conditions of riparian vegetation and buffer, the need to validate the allocations and a suggestion to stick with the site potential tree height given the uncertainty of models.

Response: Section F of the TAR contains a detailed description of effective shade as it relates to vegetation and buffer widths. The load allocations are based on mature vegetation and, as acknowledged elsewhere, much of the riparian area is not in mature vegetation. This condition affects the length of time to reach the TMDL targets, it doesn't reflect that the targets are not appropriate. However, models are only tools and the test to validate the targets will be through the monitoring and adaptive management elements of the HCP. The SAT, which includes Department of Ecology, will work with Simpson to evaluate results, progress and the potential need to make changes to the prescriptions or the targets.

ALLOCATIONS — USE OF ANNUAL AVERAGE VALUES

Comment (PRC #58): This comment expresses the concern that there is "No clear mechanism for determining whether desired long-term average loads are being achieved. Sediment delivery information was averaged for the period 1946-96. Load allocations are expressed as long-term annual average load delivered per mile of channel. Although there is mention that loading capacities may be refined in time, thereby changing the TMDL, it is unclear how a monitoring program will be able to determine whether the desired long-term average loads are being achieved. A single year of high intensity precipitation, such as 1996, may deliver more sediment than the next 50 years cumulatively, even under natural conditions. How will the sediment delivery of a single year be evaluated? If the Plan area had any remaining intact forest areas, it might be possible to compare rates from developed and undeveloped landscapes. However, when reference conditions are no longer present, the comparison of perturbed vs. highly perturbed landforms is ineffective in revealing accelerated erosion conditions. Without this basis for comparison, monitoring may simply have to average a 20-year period of annual sediment delivery estimates to compare with the target condition. This is a very long time to commit to a potentially ineffective management scheme and does not permit meaningful adaptive management. It also places premium on accurately identifying a target sediment delivery that will result in habitat recovery."

Response: You raise good points and there is still much for us to learn. TMDLs that are expressed as long term annual average sediment loadings meet the regulatory definition which states that: *"TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure" [40 CFR §130.2(i)]*. The annual average targets could be converted into daily loads. However, expressing the TMDL as an annual average value better reflects the dynamic nature of sediment movement throughout a watershed over time. The sediment TMDLs developed in northern California were established as tons /

square mile / year expressed as a 10-year rolling annual average. In that case, the longer term annual average time step was deemed an appropriate approach to account for the large interannual variability in sediment loading.

With respect to the Simpson HCP area TMDL, the initial focus will be to complete the landslide inventory. This will ensure that a more accurate baseline data base is in place from which to determine progress towards meeting sediment reduction targets. Ecology and EPA totally agree with the concern expressed that a single year of high intensity precipitation may deliver more sediment that the next 50 years cumulatively, even under natural conditions. As a result, assessment of the sediment delivery data will use the same approach as the sediment TMDLs in northern California (i.e. a 10-year rolling annual average). In addition, a 10-year rolling annual average of peak flows will be considered to account for single years of high intensity precipitation.

Comment (ALA #231): This comments expresses the concern that the TAR appears to rely solely on average annual values, and not on individual exceedances that may occur on the landscape.

Response: There are clearly statistical and practical challenges of relying on averages, especially given the variation of expression across this diverse landscape, seasonally and interannually. The subsequent adaptive management and monitoring will provide sufficient opportunities to evaluate assumptions and make adjustments to knowledge about cause and effect. No information was provided to confirm the importance of the concern of using annual average sediment loads. Therefore, it was not currently possible to address this potential factor in the TMDL.

ALLOCATIONS — CONSIDERATION OF CUMULATIVE EFFECTS

Comment (PRC #57): This comment raises the issue of ensuring that sediment delivery on a watershed-wide scale is considered. "Due to the greater density of type 4 and 5 CUP channels, these channel types contribute predominantly to total sediment delivery on a watershed basis compared to type 1 or 2 CUP streams. With development in heavily dissected lands, such as the CUP unit, there is often an extension of the channel network. If developed lands have increased network extension, their total drainage density increases. On a lineal basis, it would be possible to specify a fixed sediment delivery rate, but as the drainage network grows in length, so does the total basin sediment delivery. This is the rate of significance to the mainstem rivers that must cope with deposited sediment. Consequently, unless there is a program capable of reducing sediment delivery on a watershed-wide basis, attempting to restrict sediment only on a lineal basis will be ineffective."

Response: Loading capacity targets and allocations for sediment delivery are based on limited data using areal estimates (e.g. tons / square mile / year). As a result, the sediment delivery targets do maintain a focus on a watershed-wide basis, as recommended by the commenter. Allocations in the proposed TMDL gave primary consideration to drainage density differences in each LTU, so that there would not be a cumulative increase on a watershed-wide basis. Lineal targets were utilized in the proposed TMDL to allow consideration of differences in channel types, as suggested by comments PRC #55 and #56 (but contrary to comment PRC #57). To minimize confusion, Section G of the TAR includes a discussion of the linkage between channel specific allocations and cumulative sediment yield on a watershed basis for each LTU. If information shows that the drainage density is increasing, allocations will be adjusted so that the overall watershed scale targets will still be met.

Comment (NWIFC #8,#9): These comments express the concern that the TMDL is *"inadequate"* because it fails to address all inputs into the affected waterbodies (e.g. sediment sources from USFS lands).

Response: The commenter is correct in inferring that a TMDL must include all sources of the pollutant(s) addressed by the TMDL in the waters within the scope of the TMDL. The commenter is also correct in that the TAR does describe the scope of the Simpson HCP area to include the Wynoochee River (from mouth to headwaters) and the N.F. Skokomish River (no geographic description included). See Table 1-1, page 1-2 of the TAR. However, the scope of the TAR and the proposed "Simpson Northwest Timberlands Temperature Total Maximum Daily Load" is to address two pollutants, heat and sediment, only within the Simpson Timber Company's 261,575 acres of timberlands. Although this includes portions of the Wynoochee River and tributaries of the N.F. Skokomish River, neither the TAR nor the TMDL were intended to address all of the heat and sediment related causes in the entire Wynoochee River and the mainstem N.F. Skokomish River.

The *"Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program" [FACA Report]* also offers recommendations on basic principles defining the appropriate size of TMDLs under various circumstances. As stated in the introductory material to the proposed TMDL, the plan area covers over 261, 000 acres and includes nearly 1,400 stream miles. Thus, the HCP area alone is fairly large. The FACA Report suggested that where the size of affected watersheds or area of source contribution is too large, so that monitoring, source identification, identification and selection of solutions, public participation and implementation cannot be conducted efficiently, the TMDL process may be *"nested"* such that appropriate monitoring, public participation, and implementation is conducted at the appropriate geographic scale.

We recognize the historical and ongoing significance of the connection between the USFS and Simpson lands. However, the USFS is moving forward with their Forest wide priorities for addressing water quality. Based on their involvement developing the TMDL in the Humptulips basin, we anticipate close coordination with the Simpson TMDL when they move into the upstream basins. We also anticipate that whether it is the USFS or areas downstream of Simpson, the same channel classification system developed by Simpson and used in their TMDL could be applied. As a result, the same loading targets could serve as a starting point to expand the TMDL to segments outside the HCP area.

Comment (SKOK #18): concern for use of baseline conditions of today rather than pre-disturbance, perception that the TMDL only addresses temperature problems in those few waterbodies already listed on the 303(d) list.

Response: See responses above, esp. SQUAX #16. Commenter mis-read intent of TMDL. Its application is throughout the Plan area, not just the few listed waterbodies but other potentially impaired waterbodies and as preventive measures for healthy streams. It also attempts to track both recovery and protection needs for those areas subsequently harvested under the Plan prescriptions.

Margin of Safety

Comment (ALA #232): This comment believes that the TAR and DEIS *"fail"* to include analyses to support the conclusion that an adequate margin of safety (MOS) is provided in the face of uncertainty and insufficient information.

> *Response:* The TAR does provide the assumptions and analytical basis for calculating a *"MOS"*. The commenter provides no specific mention or critique of this analysis, nor are specific shortcomings in the existing data cited. Although, the data that were available were limited by circumstance, the agencies believe that it was sufficient to make the initial estimates of load allocations and MOS. Adjustments to these calculations will be made as new information becomes available through the monitoring program implementation.
>
> The agencies also believe the adaptive management process set out in the HCP and the involvement of SAT members in developing monitoring plans increases the certainty that useful information will be collected and appropriately used.

Linkage to Implementation

Implementation — Relationship of Allocations to HCP Prescriptions

Comment (ALA #234, AUD #5&9, PRC, Skokomish, Squaxin, Quinault) raise the issue of sediment indicators, particularly the perception that *"specific standards"* to be attained by the road and unstable slopes provisions are *"unknown"* and therefore are insufficient to implement the TAR and its WQ targets. Comment ALA #234 also expresses concern that the failure to address road densities directly is not acceptable.

> Response: We acknowledge the data tying increased road densities with increased sediment production. However, it can be argued that the relationship is tied in part to road conditions. Reducing the road density per se would not provide the same level of oversight and accountability that the HCP approach provides. In addition, prescribing discrete road management response to specific conditions can never anticipate all conditions, or predict the appropriate combination of responses. The company has agreed to a be judged on their ability to design and implement a road generated sediment abatement program that includes a complete inventory and prioritization (by problem) of their road network, annual audits of their road maintenance and abandonment activities and monitoring of outcomes in terms of measuring runoff to streams.

Comment (ALA #91, #225, #233, #248 and #249): These comments express concern that the TAR, HCP and DEIS *"fail"* to demonstrate that the various prescriptions in the agreement will actually meet the WQ targets as well as the CWA's broader goals and requirements.

> *Response:* The agencies believe that the Technical Assessment Report which is a component of both the HCP and the proposed Simpson Northwest Timberlands Temperature Total Maximum Daily Load Submittal, does link the proposed targets and proposed prescriptions to attainment of the state's water quality standards. However, it is also recognized that there are levels of uncertainties in the science of the analysis. Where these uncertainties are not found to be conservative enough based on monitoring results, prescription modifications can be made via the adaptive management process. No

specific recommendations were provided by the commenter for adjusting or improving the analysis.

Comment (ALA#236a, NWEA #24, AUD-Rainier #5): These comments expressed doubt that the HCP measures will be sufficient to reach the water quality targets and question how the HCP could be held to the TMDL targets without incorporating the targets into the HCP itself.

Response: Following public comments, Simpson agreed to more tightly connect the Habitat Conservation Plan with the targets of the TMDL. The final HCP incorporates sediment and temperature targets into the monitoring program that is included in the Implementation Agreement. Consequently, the TMDL targets will guide the monitoring and adaptive management elements over the life of the Plan. Specific riparian management, road management and erosion control measures needed to address processes which lead to attainment of the targets are the prescriptions in the HCP. The HCP includes an adaptive management process that involves the responsible agencies and affected tribes in evaluating monitoring results and potential management changes.

If the proposed HCP is implemented as designed, it is the belief of the agencies that the TMDL targets will be attained and, more importantly, full designated use support of the waters covered by the HCP will be achieved.

IMPLEMENTATION — ENFORCEABILITY

Comment (Audubon #4, #5, #6, #23, #29, WEC #13, PNPTC #75, SQUAX #15): These comments reflect concerns regarding the enforceability of the load allocations described in the TMDL since the allocations do not appear as requirements of the HCP. The comments recommend that the HCP Implementation Agreement be more explicit in making the connection with the TMDL and the enforceability of its load allocations and performance targets. There is also concern over apparent confusion among the federal and state agencies on their various enforcement roles.

Response: TMDLs do not carry any enforcement authority in themselves. Compliance and enforcement rely on other regulatory tools and agreements. The HCP can be one of those tools. Following public comments, Simpson agreed to include the TMDL targets in the monitoring section that is incorporated into the Implementation Agreement. In addition, while the HCP includes certain caps on expenditures and the amount of acreage dedicated to reserve areas, the attainment of water quality is not subject to those limitations. At some point in the future, if the caps are reached and water quality impairments have not improved, then separate action under the Clean Water Act could be taken to achieve compliance.

In addition, at the state level regulatory authority over the basic management prescriptions in the HCP comes from the State of Washington Forest Practices Act (FPA). As Simpson initiates forest management activities and receives forest practice permits from DNR, their actions will need to show consistency with the HCP. The Department of Natural Resources (DNR) with coordination from Ecology would oversee conformance with harvest and road elements of the HCP, consistent with their statutory responsibilities under state law. In any event, STC remains subject to the state Forest Practices Act and Hydraulic Projects Approval code requirements. DNR and Ecology have clear authority and regulatory process to ensure compliance. DFW will administer the Hydraulic Project Approval for any in-water activity in the area consistent with the HCP.

MONITORING AND ADAPTIVE MANAGEMENT

Comment (WDF&W #8, #9): Is shade or canopy cover measured from the ordinary high water mark using a standard densiometer, or from the channel migration zone, when present? How is effective shade measured in the field.

> *Response:* With respect to the proposed TMDL, percent effective shade can be measured at the stream surface using a Solar Pathfinder®. As stated previously, actual hourly stream temperature data collected through water quality monitoring efforts can also be used to *"back-calculate"* the change in heat load. This is accomplished by using the basic heat transfer equation described in the TAR *(see Table 3-1, page 3-1)* and knowledge of stream characteristics (e.g. flow and average depth). The change in heat load is another way to cross-check actual improvement in effective shade as streams in the HCP area receive the benefit of riparian management strategies.
>
> A number of references are available which describe shade or canopy cover measurements. Included are *"Monitoring Guidelines to Evaluate the Effects of Forestry Activities in the Pacific Northwest and Alaska"* [EPA/910/9-91-001, May 1991] and *"Monitoring Protocols to Evaluate Water Quality Effects of Grazing Management on Western Rangeland Streams"* [EPA 910/R-93-017, October 1993].

Comment (SKOK #19): This comment expressed the desire to see assurances that the TMDL standards (load allocations and targets) can be adjusted as new information becomes available and at predictable time frames.

> Response: This is a reasonable request and is the intent of the Adaptive Management framework and the function, in part, of the Science Advisory Team. The monitoring program established in the Habitat Conservation Plan lays out schedules for monitoring and reporting results. Regular meetings of the SAT will evaluate progress and new information and provide a forum for recommendations. These will regularly include temperature results and STC has committed to closely evaluating sediment conditions at year 15 in a 'TMDL Summit' that will be repeated as required throughout the remainder of the HCP. We agree that it is important to keep participants informed about the progress of implementation and it's effectiveness. Specific time frames for evaluation of progress are specified in Sections 9 & 10 of the HCP.

Appendix B:

Technical Assessment Report

Simpson Northwest Timberlands
Temperature Total Maximum Daily Load (TMDL)
Technical Assessment Report

This report presents a series of analysis that lead to the development of load allocations for shade and sediment delivery within the Simpson Habitat Conservation Plan (HCP) area. It forms the technical basis for the TMDL Submittal Report. The report was prepared primarily by EPA staff with early input from Department of Fish and Wildlife, and continuing guidance from National Marine Fisheries Service and Department of Ecology. The same document is included in the Simpson HCP and is identified there as Appendix G. The main elements of the technical report have been summarized in the Submittal Report. The full text is enclosed.

Simpson Northwest Timberlands Total Maximum Daily Load (TMDL)

Technical Assessment Report

June 2000

A Total Maximum Daily Load (TMDL) has been developed to address fisheries concerns on several tributaries of the lower Chehalis and Skokomish Rivers as well as several streams draining to South Puget Sound and Hood Canal. The scope of this TMDL includes waters located on land owned by Simpson Timber Company (STC) in the State of Washington. These forested watersheds include Simpson's commercial timberland in Thurston, Mason, and Grays Harbor counties. The area lies near Shelton and extends into the southern foothills of the Olympic mountains across the Wynoochee River.

Excessive summer water temperatures in some of these streams reduce the quality of rearing habitat for coho salmon as well as for steelhead and cutthroat trout. Primary watershed disturbance activities which contribute to surface water temperature increases include forest management within riparian areas, timber harvest in sensitive areas outside the riparian zone, and roads. As a result of water quality standards (WQS) exceedances for temperature, four waters in this TMDL area are included on Washington's 1996 §303(d) list. The TMDL also addresses sediment inputs associated with road management and hillslope failures that contribute to temperature problems.

A Habitat Conservation Plan (HCP) was developed by Simpson in accordance with the Endangered Species Act [ESA §10]. It describes a suite of management, assessment, and monitoring actions. A lithotopo classification and channel description system serve as its fundamental basis. Simpson's conservation program emphasizes the protection of riparian forests coupled with erosion control as a primary strategy to satisfy ESA §10. Activities to be covered include all aspects of Simpson's forest practices and related land management (mechanized timber harvest, log transportation, road construction / maintenance / restoration, etc). Specific management prescriptions designed to reduce the input of pollutants into streams within the Plan area include:

- Riparian Conservation Reserves
- Road Management
- Unstable Slope Protection
- Hydrologic Mature Forest Development
- Wetlands Conservation Program

Habitat assessment and monitoring will also be conducted by Simpson using adaptive management to validate assumptions made as a *"margin of safety"* within the TMDL and to evaluate the effectiveness of specific management prescriptions.

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Table of Contents (cont.)

Table of Contents (cont.)

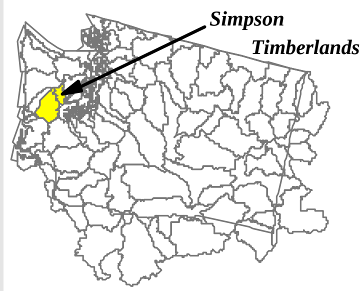
Simpson Northwest Timberlands Total Maximum Daily Load (TMDL)

Technical Assessment Report

June 2000

TMDL AT A GLANCE:

Subbasins:	***Lower Chehalis, Skokomish, S. Puget Sound***
Key Resource:	***Chinook, Coho, & Chum Salmon*** ***Steelhead Trout*** ***Cutthroat Trout***
Uses Affected:	***Salmonid Spawning & Rearing***
Impairment:	***Water Temperature Increases***
Pollutants:	***Heat (Solar Radiation)*** ***Sediment***
Sources Considered:	***NPS - Forest Practices, Road Construction***



1. SUMMARY

This Total Maximum Daily Load (TMDL) is being established for two pollutants: heat and sediment. The TMDL is designed to address impairments due to surface water temperature increases on four listed water quality-limited segments located within Simpson's 261,575 acres of Northwest Timberlands in the State of Washington. The two pollutants considered in this TMDL, singly and in concert, are major determinants of water quality that affect aquatic life. These factors vary naturally in their characteristics across the landscape (as a function of geology, topography and climate) as well as over time. The influence of both pollutants on water quality can also be significantly affected by changes associated with land use.

This TMDL uses two *"other appropriate measures"* (or surrogates) to address water temperature increases: percent effective shade and sediment delivery. Higher heat load values, which elevate surface water temperatures, result from a combination of riparian vegetation removal and / or channel widening. Riparian vegetation removal decreases shade available to block sunlight (i.e. incoming solar radiation) and the resultant heat transfer to the stream. Sediment affects water temperature by increasing channel widths and the water surface area exposed to sunlight.

Scope

This TMDL uses information from a Habitat Conservation Plan (HCP) prepared by Simpson Timber Company (STC) for more than 80 percent of its Northwest Timberland holdings in the State of Washington. The plan area (about 261,575 acres) includes nearly 1,400 miles of streams that drain STC lands bordering the southern extent of the Olympic Mountains. The largest portion of these lands encompass major northern tributaries to the Chehalis River, including the Satsop and Wynoochee Rivers. A smaller portion includes several Skokomish River tributaries. A final portion includes streams draining to South Puget Sound (i.e. Goldsborough and Kennedy Creeks) and Hood Canal.

As a result of water quality standards (WQS) exceedances for temperature, four waters (Rabbit Creek, Wildcat Creek, Wynoochee River, N.F. Skokomish River) in the HCP area were included on Washington's 1996 §303(d) list. In addition to the listed §303(d) waters, this TMDL also applies to other potential water quality impairments from heat and sediment for all streams within Simpson's HCP area *(Table 1-1)*. This expanded coverage is accomplished by using inventory information assembled in development of the HCP.

***Table 1-1*.** Scope of *"Simpson HCP Area"* TMDL including §303(d) Listed Segments

§303(d) Listed Segments ***Lithotopo Unit*** *(stream miles)*	***Applicable Water Quality Standards***
Rabbit Creek *(mouth to headwaters)* Wildcat Creek *(mouth to headwaters)* Wynoochee River *(mouth to headwaters)* N.F. Skokomish River *Alpine Glaciated (AGL)* *(137.7)* *Crescent Islands (CIS)* *(163.7)* *Crescent Uplands (CUP)* *(265.2)* *Recessional Outwash Plain (ROP)* *(376.7)* *Sedimentary Inner Gorge (SIG)* *(454.5)*	WAC 173-201A-045(1)(c)(iv)*** WAC 173-201A-045(2)(c)(iv) WAC 173-201A-045(1)(c)(vii) WAC 173-201A-070(2) *** WAC 173-201-080 describes the use classifications for waters of the State of Washington.

***Note*:**

There are nearly 1,400 stream miles that lie within the HCP area. Rather than individually list each stream and segment, information in the TMDL is summarized using either lithotopo units (LTUs), channel types, or Riparian Management Strategies (RMSs) defined in the HCP. There are five LTUs (named above), 49 channel types, and eight RMSs described in the Simpson HCP which apply to all streams in the Plan area (both perennial and intermittent). Principle drainages within the HCP area include:

WRIA 14 = Kennedy - Goldsborough Watershed
WRIA 16 = Skokomish River (North & South Forks) 16.0001-0013
WRIA 22 = Chehalis River Basin (lower) including portions of 22.0260-.0290, 22.0291-.0301; Satsop River 22.0360-0464, West, Middle, and East Fork Satsop River, Decker Creek, Wildcat Creek, Wynoochee River

Water Quality Impairments

The *"Simpson HCP area"* TMDL addresses fisheries concerns resulting from impairments due to water temperature increases in several tributaries of the lower Chehalis and Skokomish Rivers. The applicable water quality standard (WQS) states that: *"Temperature shall not exceed 16.0EC (freshwater) or 13.0EC (marine water) due to human activities ... When natural conditions exceed 16.0EC (freshwater) or 13.0EC (marine water), no temperature increase will be allowed which will raise the receiving water temperatures by greater than 0.3EC ... 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"*.

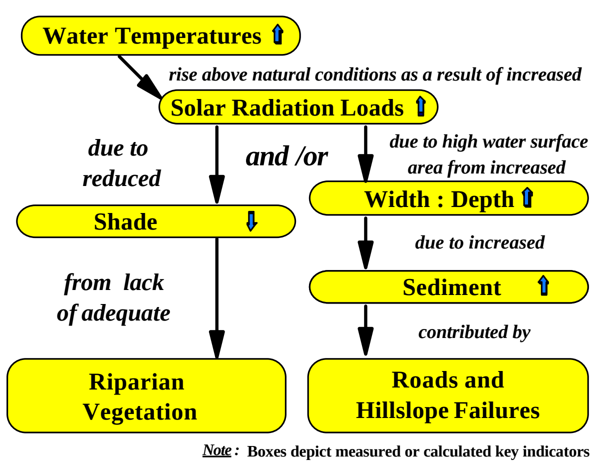
Pollutants

The *"Simpson HCP area"* TMDL has been developed for the following pollutants: heat (i.e. incoming solar radiation) and sediment. Both heat and sediment are considered pollutants under CWA §502(6). These pollutants contribute to water temperature increases in two ways. First, heat transfer from excess amounts of solar radiation reaching the stream surface provides energy to raise water temperatures. Second, excessive delivery of sediment increases channel width through deposition and lateral scour. Wider channels then increase the amount of surface area exposed to heat transfer from solar radiation.

Surrogate Measures

The *"Simpson HCP area"* TMDL incorporates measures other than *"daily loads"* to fulfill requirements of §303(d). Although a loading capacity for heat can be derived [e.g. British Thermal Units (BTU) per square foot per day], it is of limited value in guiding management activities needed to solve identified water quality problems. Instead, the *"Simpson HCP area"* TMDL uses *"other appropriate measures"* (or surrogates) as provided under EPA regulations [40 CFR §130.2(i)]. The specific surrogates used are percent effective shade and sediment delivery. Decreased effective shade is the result of a lack of adequate riparian vegetation available to block sunlight (i.e. heat from incoming solar radiation). Excessive delivery of sediment is associated with road management and hillslope failures that contribute to channel widening. The relationship of water temperature increases to these surrogates is described in Figure 1-1.

***Figure 1-1*.** Relationship of Water Temperature to Surrogates



Loading Capacity

Loading capacities in the *"Simpson HCP area"* TMDL address heat from incoming solar radiation (expressed as percent effective shade) and sediment delivery (expressed as average annual cubic yards per lineal stream mile). Analysis of energy transfer processes indicate that water temperatures can increase above natural daily fluctuations at some point when the heat load from solar radiation is greater than the heat leaving the system.

Using information about each channel class (e.g. drainage area, active channel width, range of flows, etc) effective shade targets can be developed. The channel classification system is used to assess stream reaches according to temperature groups, e.g. the dominant control(s) which influence water temperature, specifically shade, groundwater, or channel morphology. This approach leads to effective shade targets which recognize the variability in channel and riparian characteristics that occurs across the landscape. As such, these targets reflect the range of active channel widths and riparian vegetation heights within the HCP area *(Table 1-2)*.

Table 1-2. Effective Shade Loading Capacity Targets

Active Channel Width[1] *(meters)*	**Effective Shade[2] — *by temperature group (%)***						
	S-1	**S-2**	**S-3**	**S-4**	**G-1**	**G-2**	**C-1**
#4	90	84	84	77		65	
6 - 10	87	82		76	85	68	89
12 - 15	89	85			85	68	
16 - 18			83	81	75		85
20 - 25						65	76
>25							72

[1] This table summarizes the effective shade loading capacity targets by active channel width. Active channel width determines the surface area requiring effective shade. The HCP identifies 49 channel classes (summarized in Section 2 of this Technical Assessment) which are used to identify 7 temperature groups. These temperature groups are described in Section 3. Section 6 describes information on active widths associated with each LTU, channel class, and Riparian Management Strategy.

[2] Effective shade targets calculated using a heat budget for channel types within each temperature group that are needed to achieve a maximum peak hourly increase of 0.45EC (described in Section 3).

The effect of sediment and its relationship to numeric water quality standards is incorporated into the *"Simpson HCP area"* TMDL through the temperature group approach. One group, *C-1*, represents streams where temperatures are strongly influenced by channel patterns affected by high sediment supply. Development of a loading capacity for sediment considers Washington's Water Quality Standards which state *"deleterious material concentrations shall be below those which may adversely affect characteristic water uses"*. To maintain a focus on source input and hazard reduction, the loading capacity for sediment uses a framework suggested in the TFW Watershed Analysis Manual, specifically construction of a partial sediment budget (Reid and Dunne, 1996).

Sediment delivery targets for this TMDL are expressed in terms cubic yards per stream mile per year. This has several advantages which recognize the *"order of magnitude estimate"* that the values actually represent. Weight could be estimated either through assumptions or measurements of the bulk density of soil (e.g. tons per cubic yard). However, cubic yards is more easily related to a wider range of individuals (e.g. a 10 $yard^3$ dump truck). Loading capacities are summarized by lithotopo unit within the HCP area *(Table 1-3)*. Although an annual averaging period is used to express the loads, it is simply a referencing mechanism. Erosion processes which are responsible for sediment inputs to the system are highly dynamic, change from year-to-year, and vary in different locations in the basin. Consequently, the sediment delivery targets define a framework which place erosion processes into the appropriate context relative to the varied lithology and topography of the HCP area.

Table 1-3. Sediment Loading Capacity by Lithotopo Unit

Lithotopo Unit[1]	**Area** ***(sq. mi.)***	**Channel Length** ***(miles)***	**Loading Capacity**[2]	
			(yd^3 / sq. mi. per year)	***(yd^3 / stream. mile per year)***
AGL	32.7	137.7	880	209.0
CIS	49.0	163.7	110	33.6
CUP	45.0	265.2	1,000	169.5
ROP	183.9	376.7	50	24.7
SIG	98.1	454.5	1,000	215.8
Total	408.7	1,397.8	456	133.3

NOTES:

1 There are nearly 1,400 stream miles that lie within the HCP area. Available data and methods do not allow determination of loading capacities for each individual segment. Instead, targets have been developed that utilize the landscape stratification system used to organize information in the HCP.

2 Loading capacities expressed as long term annual average values and do not reflect the wide range spatial and temporal variation observed in natural erosion processes. As new data and methods are developed to better describe sediment delivery mechanisms, these loading capacities may be revised.

Allocations

Allocations in the "*Simpson HCP area"* TMDL are derived using effective shade and sediment delivery targets. These measures can be linked to source areas and, thus to actions (specifically riparian management and erosion control measures) needed to address processes which influence water temperature. Because factors that affect water temperature are interrelated, both measures are dependent upon each other to produce the desired responses.

Effective Shade: The *"Simpson HCP area"* TMDL and allocations for effective shade are summarized in Table 1-4. The objective of the effective shade TMDL is to reduce heat from incoming solar radiation delivered to the water surface. The basis for effective shade allocations results from an analysis of processes that affect water temperature. Development of these effective shade allocations also uses information about riparian management strategies described in the HCP. Effective shade allocations have been developed from targets based on channel class width and characteristics of mature riparian vegetation for that channel class including vegetative density.

Table 1-4. Effective Shade TMDL and Load Allocations Summary for Simpson HCP Area

Segment Name *Riparian Management Strategy*	*(length in mi.)*	**TMDL**	**TMDL Components**[2] *(Effective Shade as percent)*		
			WLA	LA	MOS
Rabbit Creek					
Wildcat Creek					
Wynoochee River					
Temperature Sensitive	*53.3*	88.7%	0%	90.0%	(1.3%)
Break in Slope	*171.1*	85.4%	0%	91.6%	(6.3%)
Canyon	*59.4*	68.0%	0%	94.1%	(26.1%)
Channel Migration	*83.7*	79.7%	0%	84.4%	(4.7%)
Inner Gorge	*50.4*	70.6%	0%	77.5%	(6.9%)
Alluvial Bedrock Transition	*15.6*	85.0%	0%	88.4%	(3.4%)
Reverse Break in Slope	*42.8*	83.9%	0%	95.0%	(11.1%)
Unstable Slopes / Intermittent Flow	*921.5*	77.0%	0%	93.0%	(16.0%)
TMDL					

NOTES:

[1] Specific streams to which each RMS applies are identified in the HCP and are defined by LTU / channel class. The effective shade TMDL and allocations are designed to achieve a loading capacity that provides sufficient shade needed to minimize water temperature increases.

[2] **WLA**: Waste load allocation; **LA**: Load allocation; **MOS**: Margin of Safety. There are no point sources within the HCP area covered by the TMDL, so the WLA for effective shade is 0.

Sediment Delivery: The TMDL and allocations for sediment delivery are summarized in Table 1-5. The load allocations are expressed as long term annual average load delivered per mile at the channel class scale. Sediment delivery targets expressed as annual average cubic yards per stream mile for each channel class is consistent with current EPA regulations. The regulations indicate that load allocations are *"best estimates of the loading which may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading" [40 CFR §130.2(g)]*.

The estimated total allowable sediment load is derived from targets based on lithotopo unit, channel class and erosion process (cubic yards per stream mile per year). Sediment delivery allocations use information from three completed Watershed Analysis Reports in the area and from several inventories that supported preparation of the HCP. A quantitative comparison of estimated loading rates and controllable portions of various types of loading was considered. The load allocations incorporate sediment reductions from management activities into the sediment delivery targets. Sediment delivered from shallow rapid landslides and debris torrents as a result of management activities is assumed to be 80% controllable. This is based on information used for development of prescriptions in the W.F. Satsop Watershed Analysis. Sediment delivered from large persistent deep-seated landslides as a result of management activities is assumed to be 10% controllable. The retention of large wood in RCRs and reducing peak flows due to hydrologic effects of the road network will address sediment delivery from bank erosion that result from management activities.

Table 1-5. Sediment Delivery TMDL and Load Allocations Summary for Simpson HCP Area

Riparian Strategy (length in mi.)		TMDL[1]	WLA[2]	Load Allocations[1] (yd^3 / stream mile per year)					MOS
				Mass Wasting			Surface Erosion	Floodplain Storage / Bank Erosion	
				SR	*DT*	*LPD*			
AGL	*137.7*	209.0	0	6.0	1.0	3.2	4.0	98.4	96.4
CIS	*163.7*	33.6	0	1.0	0.0	1.0	2.0	27.7	1.9
CUP	*265.2*	169.5	0	12.1	7.0	1.0	3.0	19.9	126.5
ROP [3]	*376.7*	24.7	0	1.0	0.0	1.0	1.0	12.3	9.4
SIG	*454.5*	215.8	0	6.3	1.0	32.8	6.0	47.7	122.0

NOTES:

1 Allocations expressed as long term annual average values. As new data and methods are developed to better describe sediment delivery mechanisms, the loading capacities may be refined and the TMDL revised.

2 There are no point sources within the HCP area covered by the TMDL, so the WLA for sediment delivery is 0.

3 Does not include LA for floodplain storage / bank erosion on ROP-Qa7 (3.7 miles — Vance Creek) which is uniquely affected by channel migration across floodplain terraces as documented by a review of air photo records.

Document Organization

Preparation of the "*Simpson HCP area*" TMDL considered a number of issues regarding surface water temperatures and the relationship to requirements of §303(d). These issues have been divided into topic areas which include target identification (quantified end-points that will lead to attainment of water quality standards), source identification (a description of hazard areas that contribute to the problem), allocations designed to reduce pollutant inputs to those waters exceeding water quality standards, and a margin of safety. In order to provide a framework for discussing these issues, this TMDL development document is organized into the following sections:

- Target Identification
- Deviation from Target
- Source Assessment
- TMDL / Allocations
- Margin of Safety
- Seasonal Variation
- Implementation and Monitoring

Highlights of each TMDL development document section are summarized in Table 1-6.

Table 1-6. *"Simpson HCP area"* TMDL Components

State/Tribe: Washington
Waterbody Name(s): The following §303(d) listed waters: Rabbit Creek, Wildcat Creek, Wynoochee River plus other potential water quality impairments on unlisted streams in the HCP area

Point Source TMDL: ___ Nonpoint Source TMDL: X (check one or both)
Date: June 8, 2000

Component	Comments
Loading Capacity *CWA §303(d)(1)* *40 CFR §130.2(f)*	***Applicable Water Quality Standards*** ! Water temperature shall not exceed 16.0EC due to human activities. No increase allowed that raises water temperatures by more than 0.3EC. *[WAC 173-201A-045(1)(c)(iv)]*. ! Deleterious material concentrations shall be below those which may adversely affect characteristic water uses ... *[WAC 173-201A-045(1)(c)(vii)]*. ! Whenever natural conditions are of lower quality than the criteria, natural conditions shall constitute the water quality criteria... *[WAC 173-201A-070(2)]*. ***Loading Capacities*** ! Reduce incoming solar radiation load by using % effective shade targets. ! Reduce sediment by decreasing road surface erosion and % hillslope failures through sediment delivery targets *(yd^3 / mile per year)*. These loading capacities are designed to bring water temperatures and sediment regimes to the water quality standards by restoring natural channel conditions.
Existing Sources *CWA §303(d)(1)*	Anthropogenic sources of thermal gain result from riparian vegetation removal and delivery of sediment from increased hillslope failures due to: ! Forest management within riparian areas ! Timber harvest in sensitive areas outside the riparian zone ! Roads
Seasonal Variation *CWA §303(d)(1)*	*Condition:* Based on TFW and USGS data. *Flow:* Low flow associated with maximum water temperature. *Critical Conditions:* Maximum temperatures typically occur between mid-July and mid-August. Use LTUs / channel classification as analysis framework. Increase riparian vegetation and/or decrease sediment from roads hillslope failures. *Inputs:* Solar radiation increased by more exposed stream surface area as a result of decreased shade & increased sediment from roads and hillslope failures.
TMDL / Allocations *40 CFR §130.2(g)* *40 CFR §130.2(h)*	*WLAs:* *(No point sources)* *LAs:* Effective shade levels determined by active channel width, riparian vegetation height, and shade quality. Sediment delivery targets determined by lithotopo unit and channel class.
Margin of Safety *CWA §303(d)(1)*	! Margin of safety described through documentation of assumptions, e.g. contribution of groundwater, critical conditions. ! Allocations for effective shade contain an explicit margin of safety which is expressed as an unallocated portion of the loading capacity. ! Allocations for effective shade also contain an implicit margin of safety, specifically the point of measurement for Riparian Conservation Reserves.

2. WATER QUALITY CONCERNS

The *"Simpson HCP area"* TMDL is being established for heat and sediment to address fisheries concerns related to water temperature increases. The Simpson HCP area includes approximately 261,575 acres of forested watersheds located near Shelton, Washington. Salmon, steelhead, and cutthroat trout occur throughout Simpson HCP area watersheds. Significant fish-bearing streams are the Wynoochee River, the Satsop River including key tributaries (West Fork, Middle Fork, East Fork, Canyon River, Bingham Creek, Stillwater River), the S.F. Skokomish River as well as several drainages to South Puget Sound (e.g. Goldsborough Creek, Kennedy Creek) and Hood Canal.

Applicable Water Quality Standards

Within the State of Washington, water quality standards are published pursuant to Chapter 90.48 of the Revised Code of Washington (RCW). Authority to adopt rules, regulations, and standards as are necessary and feasible to protect the environment and health of the citizens of the State is vested with the Department of Ecology. Through the adoption of water quality standards, Washington has identified the designated uses to be protected in each of its drainage basins and the criteria necessary to protect these uses [Washington Administrative Code (WAC), Chapter 173-201].

In Washington, *"specific fresh waters of the state of Washington are classified ..." [WAC 173-201-080]*. The Simpson HCP area lies within the Satsop (East Fork, Middle Fork, West Fork), Skokomish, and Wynoochee drainages. WAC 173-201-080 identifies these watersheds as class *"AA"*. Water quality standards not to be exceeded are described in WAC 173-201-045. For *"AA"* streams:

> *"Temperature shall not exceed 16.0EC (freshwater) or 13.0EC (marine water) due to human activities. ... When natural conditions exceed 16.0EC (freshwater) or 13.0EC (marine water), no temperature increase will be allowed which will raise the receiving water temperatures by greater than 0.3EC" [WAC 173-201A-045(1)(c)(iv)].*

For *"A"* streams:

> *"Temperature shall not exceed 18.0EC (freshwater) or 16.0EC (marine water) due to human activities. ... When natural conditions exceed 18.0EC (freshwater) or 16.0EC (marine water), no temperature increase will be allowed which will raise the receiving water temperatures by greater than 0.3EC" [WAC 173-201A-045(2)(c)(iv)].*

The applicable water quality standard for sediment states:

> *"deleterious material concentrations shall be below those which may adversely affect characteristic water uses ..." [WAC 173-201A-045(1)(c)(vii)].*

Finally, during critical periods, natural conditions may exceed the numeric criteria for temperature identified in the water quality standards. In these cases, the following applies:

> *"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" [WAC 173-201A-070(2)].*

Water Temperature and Solar Radiation

Stream temperature is an expression of heat energy per unit volume, or an indicator of the rate of heat exchange between a stream and its environment *(Figure 2-1)*. In terms of water temperature increases, the principle source of heat energy is solar radiation directly striking the stream surface (Brown, 1970). Energy is acquired by a stream system when the heat entering the stream is greater than the heat leaving the stream. When there is a net addition of heat energy to the stream, the water temperature will increase.

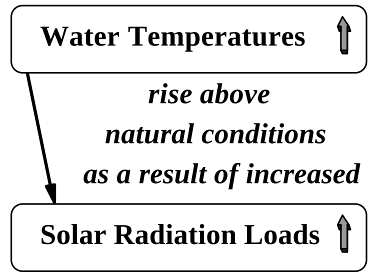
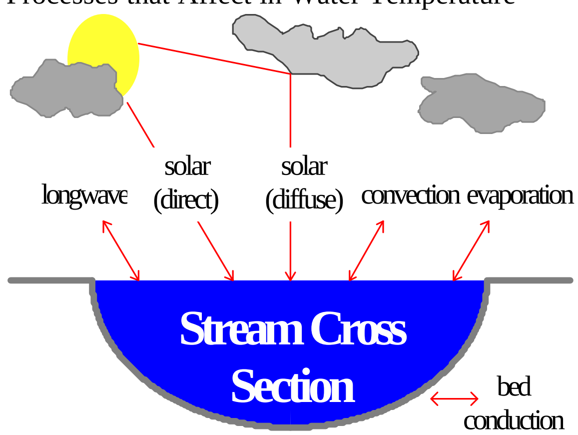
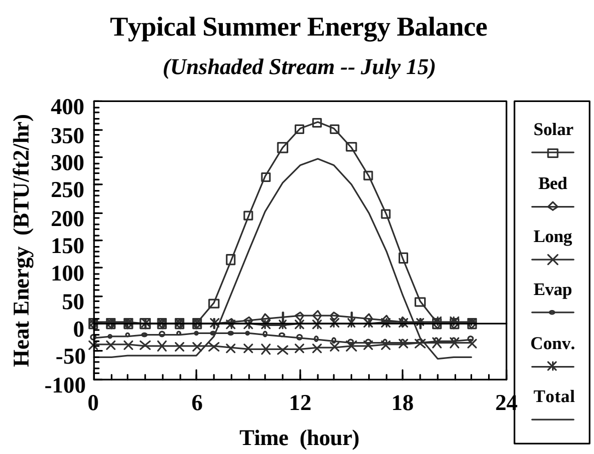


Figure 2-1. Heat Transfer Processes that Affect in Water Temperature



As discussed in other studies (Brown 1969, Beschta et al 1987), the daily profile for water temperature typically follows the same pattern of solar radiation delivered to an unshaded stream *(Figure 2-2)*. Other processes, such as longwave radiation and convection also introduce energy into the stream, but at much smaller amounts when compared to solar radiation. If a stream is completely unshaded, as is the case in Figure 2-2, the solar radiation flux has the potential to deliver large quantities of heat energy, resulting in a rapid increase in water temperature.

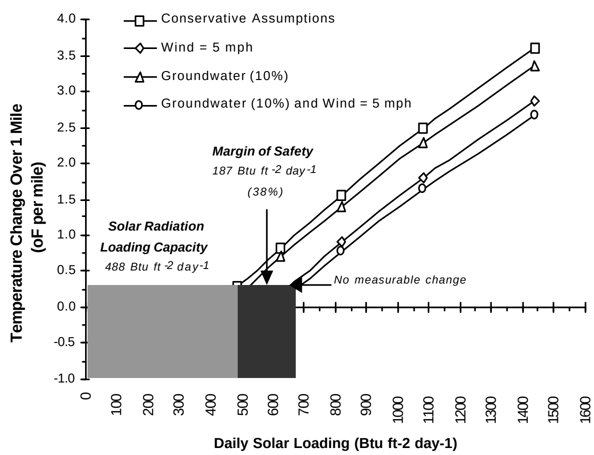
Figure 2-2. Typical Summer Energy Balance for an Unshaded Stream



Mechanistic models have been developed based on a heat budget approach which estimate water temperature under different heat balance and flow conditions. Brown (1969) was the first to apply a heat budget to estimate water temperatures on small streams affected by timber harvest. This heat budget technique utilizes six variables (solar radiation, long wave radiation, evaporation, convection, bed conduction, and advection) to determine the net gain or loss of stored heat (ªH) in a known volume of water. This change in ªH can then be converted to a temperature change. Using mathematical relationships to describe heat transfer processes, the rate of change in water temperature on a summer day can be estimated. Relationships include both the total energy transfer rate to the stream (i.e. the sum of individual processes) and the response of water temperature to heat energy absorbed. Heat transfer processes considered in the analysis include solar radiation, longwave radiation, convection, evaporation, and bed conduction (Wunderlich 1972, Jobson and Keefer 1979, Beschta and Weatherred 1984, Sinokrot and Stefan 1993).

Figure 2-2 shows that solar radiation is the predominant energy transfer process which contributes to water temperature increases. A general relationship between solar radiation loads and stream temperature can be developed by quantifying heat transfer processes, such as the Sucker / Grayback TMDL in Oregon (*Figure 2-3)*. In this example, average unit solar radiation loads greater than 675 BTU / ft^2 per day result in a noticeable increase in water temperature. This could represent a starting point to define a loading capacity (i.e. the greatest amount of loading that a water can receive without violating water quality standards).

<u>Figure 2-3</u>. General Relationship between Solar Radiation Loads and Water Temperature



<u>Explanation</u>:

Figure 2-3 describes the relationship between solar radiation load and water temperature change. The response of water temperature to solar radiation loads was determined by evaluating the sum of individual heat transfer processes, or:

$$M_{total} = M_{solar} + M_{longwave} + M_{evaporation} + M_{convection} + M_{conduction}$$

Individual heat transfer rates were estimated using the location of the Simpson HCP area (i.e. same latitude / longitude range) and conservative assumptions. The graph contains four curves representing different assumptions on groundwater inflow and wind speed.

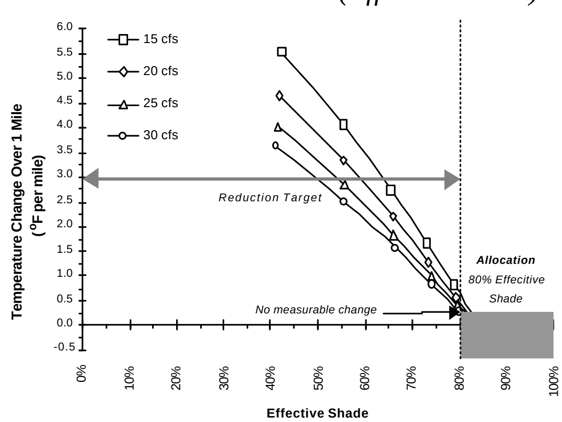
Surrogate Measures

The *"Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program"* (FACA Report, July 1998) offers a discussion on the use of surrogate measures for TMDL development. The FACA Report indicates:

> *"When the impairment is tied to a pollutant for which a numeric criterion is not possible, or where the impairment is identified but cannot be attributed to a single traditional "pollutant," the state should try to identify another (surrogate) environmental indicator that can be used to develop a quantified TMDL, using numeric analytical techniques where they are available, and best professional judgment (BPJ) where they are not. The criterion must be designed to meet water quality standards, including the waterbody's designated uses. The use of BPJ does not imply lack of rigor; it should make use of the "best" scientific information available, and should be conducted by "professionals." When BPJ is used, care should be taken to document all assumptions, and BPJ-based decisions should be clearly explained to the public at the earliest possible stage.*
>
> *If they are used, surrogate environmental indicators should be clearly related to the water quality standard that the TMDL is designed to achieve. Use of a surrogate environmental parameter should require additional post-implementation verification that attainment of the surrogate parameter results in elimination of the impairment. If not, a procedure should be in place to modify the surrogate parameter or to select a different or additional surrogate parameter and to impose additional remedial measures to eliminate the impairment."*

The *"Simpson HCP area"* TMDL utilizes measures other than *"daily loads"* to fulfill requirements of §303(d). Although a loading capacity for heat can be derived [e.g. BTU/ft2 per day], it is of limited value in guiding management activities needed to solve identified water quality problems. The concept regarding the effect of solar radiation loads on stream temperatures is illustrated in Figure 2-4. Information is presented in terms of the percent reduction of potential daily solar radiation load delivered to the water surface. This provides an alternative target (or *"other appropriate measure"*) which relates to stream temperatures, in this case, an 80% reduction in potential solar radiation delivered to the water surface. Thus, as an alternative, the *"Simpson HCP area"* TMDL uses *"other appropriate measures"* (or surrogates) as provided under EPA regulations [40 CFR §130.2(i)].

Figure 2-4. Effect of Solar Radiation Reduction *(Effective Shade)* on Water Temperature



Watershed / Landscape Scale Analyses

TMDL development for nonpoint sources presents some inherent challenges. Diffuse sources are often associated with watershed or landscape scale features. Consequently, water quality concerns associated with nonpoint source (NPS) pollutants require a different approach from traditional point source problems. The *"Simpson HCP area"* TMDL employs several concepts applied at a broader scale. These watershed / landscape scale concepts are evaluated in order to determine the best targets for the *"Simpson HCP area"* TMDL. Watershed / landscape scale concepts used to organize the target identification include:

- Landscape stratification
- Channel classification

Landscape Stratification: The foundation of the proposed HCP lies within the system Simpson has developed to better understand the inherent characteristics and sensitivities of their lands, and how their long-term forest management plans interact with these features. The proposed HCP notes that *"...at a fundamental level, ecosystem structure and dynamics are influenced by geological settings, climatic factors and their interaction. Any site specific, science-based approach to landscape planning must account for these essential influences because they are largely responsible for much of the natural variation in habitat types at various spatial and temporal scales"*.

Influences of geologic setting and associated physical processes within the HCP area are captured by stratifying the landscape into *"lithotopo"* units (LTU), i.e. areas of similar lithology and topography. LTU boundaries are determined by geology, geological history, and topographic relief. This approach divides Simpson's HCP area into units that share similar erosion and channel forming processes. LTUs include:

- Alpine glacial (AGL)
- Crescent islands (CIS)
- Crescent uplands (CUP)
- Recessional outwash plain (ROP)
- Sedimentary inner gorges (SIG)

Channel Classification: Conditions in a waterbody are a function of channel morphology (e.g. source, transport, or response reaches). Methods exist to assess the condition of a stream, as well as departure from its potential (Rosgen, 1996). These methods, built around channel classification, are a useful starting point to develop specific TMDL surrogate measures for streams in the Simpson HCP area. Consequently, a second lower level of stratification consists of classifying stream segments of the channel network within each of the LTU.

There are 49 individual stream segment types within this system *(Table 2-1)*. Riparian management strategies are keyed to each of the stream types. A description of these can be found within the HCP document. Additional details on channel characteristics, geology, morphology, large woody debris (LWD) characteristics and recruitment processes, sediment delivery and processing mechanisms, riparian characteristics and biological community features are described in HCP appendices. Information on the linkage to instream biological resources is also provided. Small intermittent streams (of varying type) are often quite unstable and if not properly protected may account for substantial inputs of sediments triggered by management activities. The HCP defines which types these are and describes what protective measures will be taken to address the risks they pose.

Table 2-1a. Simpson HCP Area Channel Classes

Lithotopo Unit	Channel Class	Stream Miles	Riparian Management Strategy	Streams
AGL	Qa6	12.7	Channel Migration	Wynoochee
	Qo1	61.3	Unstable / Intermittent	
	Qo2	22.5	Unstable / Intermittent	
	Qo3	7.3	Break in Slope	
	Qo4	2.6	Reverse Break in Slope	
	Qo5	8.8	Break in Slope	
	Qo6	13.6	Break in Slope	Schafer
	Qo7	3.7	Break in Slope	Schafer
	Qo8	5.2	Inner Gorge	Wynoochee
CIS	C1	83.9	Unstable / Intermittent	
	C5	1.7	Reverse Break in Slope	Rock
	Qc1	33.3	Unstable / Intermittent	
	Qc2	28.0	Unstable / Intermittent	
	Qc3	16.8	Channel Migration	Kennedy
CUP	C1	199.9	Unstable / Intermittent	
	C2	22.9	Canyon	
	C3	24.5	Canyon	
	C4	4.9	Canyon	North Mountain
	C5	3.5	Canyon	Dry Bed
	C6	3.6	Canyon	Baker
	C8	5.9	Inner Gorge	Middle Fork Satsop

Table 2-1b. Simpson HCP Area Channel Classes

Lithotopo Unit	Channel Class	Stream Miles	Riparian Management Strategy	Streams
ROP	C7	9.4	Channel Migration	North Mountain
	Qa7	3.7	Channel Migration	Vance
	Qc1	167.3	Unstable / Intermittent	
	Qc2	103.4	Break in Slope	
	Qc3	44.2	Temperature Sensitive	Glenn
	Qc4	9.1	Break in Slope	
	Qc5	12.1	Break in Slope	Bingham
	Qc6	9.5	Channel Migration	Decker
	Qc7	15.2	Channel Migration	Stillwater
	Qc8	2.8	Channel Migration	East Fork Satsop
SIG	L1	160.0	Unstable / Intermittent	
	L2	38.5	Reverse Break in Slope	
	L3	6.3	Break in Slope	
	L4	24.2	Inner Gorge	West Fork Satsop
	M1	67.8	Unstable / Intermittent	
	M2	18.5	Unstable / Intermittent	
	M3	9.6	Alluvial / bedrock	
	M4	6.0	Alluvial / bedrock	Sandstone
	M5	15.1	Inner Gorge	Canyon
	M6	2.3	Channel Migration	Cook
	Qa6	11.3	Channel Migration	West Fork Satsop
	Qc1	12.8	Unstable / Intermittent	
	Qc2	8.9	Unstable / Intermittent	
	Qc3	9.1	Temperature Sensitive	
	Qo1	38.3	Unstable / Intermittent	North Fork Abyss
	Qo2	19.0	Unstable / Intermittent	
	Qo3	4.8	Break in Slope	
	Qo4	2.0	Break in Slope	Devils Club

3. TARGET IDENTIFICATION

Loading Capacity

Regulatory Framework: Under the current regulatory framework for development of TMDLs, identification of the loading capacity is an important first step. The loading capacity provides a reference for calculating the amount of pollutant reduction needed to bring a water into compliance with standards. By definition, TMDLs are the sum of the allocations *[40 CFR §130.2(i)]*. Allocations are defined as the portion of a receiving water's loading capacity that is allocated to point or nonpoint sources and natural background. EPA's current regulation defines loading capacity as *"the greatest amount of loading that a water can receive without violating water quality standards"*.

Approach: A loading capacity for heat (expressed as BTU/ft^2 per day) can be derived using an analysis of heat transfer processes in water. One of the most basic forms of a heat transfer analysis is the fundamental equation applied by Brown (1969) for forest streams *(Table 3-1)*.

Table 3-1. Mathematical Relationship between Water Temperature and Heat

$$aT = aH * A / (V * D * c_p)$$

where:

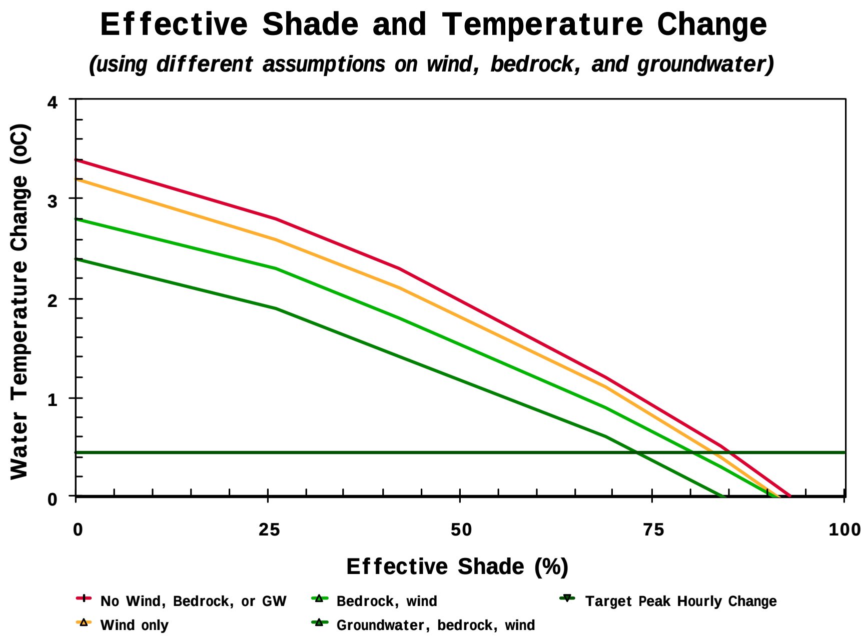
- aT = temperature change (EF / hour)
- aH = rate that heat received (BTU / hour)
- A = surface area (ft^2)
- V = volume (ft^3)
- D = density of water (62.4 lb / ft^3)
- c_p = specific heat of water (BTU/ lb / EF)

The change in water temperature follows the change in heat received, as described by the basic relationship in Table 3-1. The analysis is essentially a bookkeeping of heat transfer, also known as a heat budget, to determine potential water temperature changes. The heat budget technique utilizes six variables (solar radiation, long wave radiation, evaporation, convection, bed conduction, and advection) to determine the net gain or loss of stored heat (aH) in a known volume of water. The change in aH is then converted to a water temperature change. Section H provides a summary of heat transfer processes and water temperature.

An advantage of the heat budget approach is that it goes beyond a narrow focus on maximum water temperatures. Maximum water temperatures simply reflect symptoms when criteria values are exceeded. Because the TMDL is designed to decrease the pollutant load during a critical time frame, the analysis of heat transfer processes allows a more direct assessment of causes. As discussed in Section 2, the daily profile for water temperature increases typically follows the same pattern of solar radiation delivered to an unshaded stream *(Figure 2-2)*. Thus, one critical time frame for development of loading capacity targets is the period of the day when the solar radiation flux has the greatest potential to deliver large quantities of heat energy to the stream.

As described earlier, excess heat loads when the potential solar radiation flux is highest could lead to a rapid increase in water temperature. As a result, the stream temperature target used in the heat budget analysis is expressed as a maximum peak hourly increase. The loading capacity is then the maximum net change in heat energy delivered to the stream during that period. The loading capacity can also be expressed the percent reduction from the maximum potential solar radiation load (also referred to as "*effective shade*"). Using a heat budget approach, a family of curves can be developed which describes different ΔH values designed to achieve a known or desired water temperature change, such as a peak hourly increase. Figure 3-1 illustrates one such set of curves for a class of streams in the Simpson HCP area.

Figure 3-1. Simpson HCP Area Pool Riffle Channels



One drawback to the use of a heat budget or any mechanistic model, however, is the difficulty in determining solar radiation loads over each stream mile of a large watershed. The curves that result from numerical calculations are influenced by a number of factors. These include stream flow, channel width, upstream water temperature, wind speed, relative humidity, stream bed composition, and groundwater contribution. Higher stream flows, for example, result in higher allowable solar radiation loads when width:depth ratios are held constant. Likewise, narrower channels result in higher allowable loads when stream flows are held constant.

The landscape stratification and channel classification system are used to address challenges associated with identifying appropriate loading capacity targets for the nearly 1,400 stream miles in the HCP area. As stated in Section 2, the landscape stratification system is a science-based approach designed to account for the essential influences (e.g. geologic setting, climatic factors) that are largely responsible for much of the natural variation in habitat types at various spatial and temporal scales. The landscape stratification combined with information compiled in development of the channel classification system also provide a technical basis to support assumptions used in the heat budget analysis. The use of this information is summarized in the following discussion on temperature groups.

Table 3-2. Groups for Identifying Targets to Address Water Temperature

Group	Features	Channel
Shade		
S-1	Small to medium sized pool riffle and forced pool riffle / plane bed channels of the ROP and SIG. Water temperature is driven by shade and low flows (poor water storage in these watersheds over glacial tills and shallow soils). Headwaters of these systems are usually in wetlands or bogs and beavers frequently pond water within the channel. *RMS: Temperature Sensitive.*	ROP-Qc1, -Qc2 ROP-Qc3 SIG-Qc3
S-2	Small to medium sized channels in the AGL and SIG. These systems most often have hardwood dominated riparian systems and subtle groundwater influence through wet side slopes. They are subject to heating with the loss of riparian shade which can happen through damage to riparian leave areas by natural factors or through insufficient leave area. *RMS: Alluvial Bedrock Transition or Reverse Break in Slope.*	AGL-Qo2, -Qo4 SIG-L1, -L2, -L3 SIG-M1, -M2, -M3 SIG-M4, -M6 SIG-Qo2
S-3	Small to medium sized streams in the recessional outwash sediments of the CIS and SIG. These channels have low summer flows, but the storage and character of the flows is different from the ROP in that lower terraces, floodplains, and valley walls of these systems are composed of fine, but fairly well draining unconsolidated outwash sediments. These materials do not store great quantities of water. However, there is a slow release of groundwater that appears to moderate temperatures, but it is not sufficient to offset heating as a result of riparian canopy loss. With loss of shade, these streams can heat up to moderate levels. *RMS: Channel Migration or Unstable Slopes / Intermittent.*	CIS-Qc1, -Qc2 CIS-Qc3 SIG-Qc1, -Qc2
S-4	Small to medium sized channels in glacial till landscape of the AGL and SIG with pool riffle and forced pool riffle / plane beds. These systems have moderate to low flows in summer with varying amounts of groundwater influence. Along the continuum, those with minimal groundwater influence are susceptible to elevated water temperatures with loss of shade. Those with significant amounts of groundwater influence are resistant to temperature changes. *RMS: Break in Slope.*	AGL-Qo3, -Qo5 AGL-Qo6, -Qo7 SIG-Qo3, -Qo4
Groundwater		
G-1	Small to medium sized pool riffle and forced pool riffle / plane bed channels of the CIS and ROP that are strongly influenced by groundwater. These systems are resistant to changes to water temperature because flow is strong and comes from a cool source. Shade is a secondary influence, except during extreme low flow years. *RMS: Channel Migration.*	CIS-C5 ROP-Qc4, -Qc5 ROP-Qc6, -Qc7
G-2	Small to medium sized highly confined channels of the AGL, CIS, CUP, and SIG. These are topographically shaded and are *"near"* the water source with substantial groundwater influence which shows as side seeps and springs. These systems are typically cool and are resistant to water temperature changes, even in the absence of riparian vegetation. *RMS: Canyon.*	AGL-Qo1, -Qo8 CIS-C1 CUP-C1, -C2, -C3 CUP-C4, -C5, -C6 CUP-C8 SIG-Qo1
Channel Morphology		
C-1	Large rivers of the AGL, ROP, and SIG are affected by high sediment supply and multiple thread channels over at least some of their length. Applies to the West and Middle Forks of the Satsop, the Canyon, Little and Wynoochee Rivers. Temperatures in these systems are strongly influenced by channel pattern and open canopies. Current and past sediment supply, long residence times, and channel pattern make it unlikely that water temperatures here will change for decades. *RMS: Inner Gorge or Channel Migration.*	AGL-Qa6 ROP-C7, -Qa7 ROP-Qc8 SIG-L4, -M5, -Qa6

Temperature Groups: Using information about each stream type (e.g. the range of stream flows, active channel widths, etc), effective shade targets can be developed for each class of streams. The channel classification system is used to group stream reaches by the dominant control(s) which affect water temperature. Table 3-2 identifies seven groups and describes watershed process features which exert the greatest influence on water temperature in those channel classes. Dominant features include shade, groundwater, and channel morphology.

These seven temperature groups allow refinement of assumptions used to develop effective shade targets. Development of effective shade targets is based on a better description of site specific conditions. In addition, actual data collected on streams in the Simpson HCP area is used to validate anticipated responses. Figure 3-2 depicts information collected in 1997 and 1998 from sites representative of each temperature group. Maximum observations between July 1 and August 31 are shown for each year. This corresponds with the seasonal time frame when maximum water temperatures occur. Figure 3-3 illustrates temperature group patterns by showing the difference in cumulative frequency distribution at several sites. Figure 3-4 shows the percentage of streams in the Simpson HCP area that lie within each temperature group. Figure 3-4 also show the percentage of time that the 16EC was exceeded at each site used to represent the temperature group.

Figure 3-2. Annual Maximum Water Temperature by Group

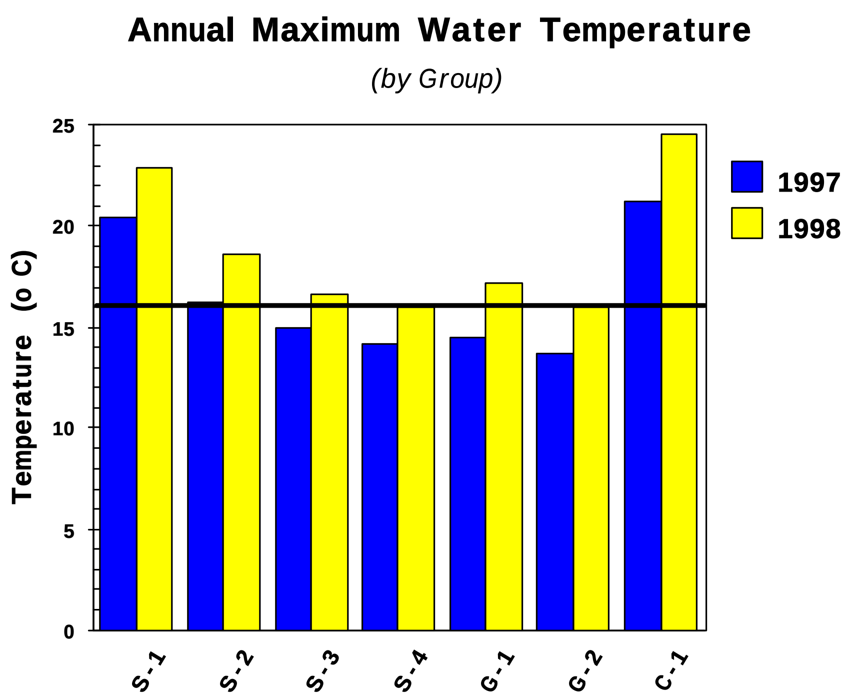


Figure 3-3. Comparison of Cumulative Frequency Distribution by Temperature Group

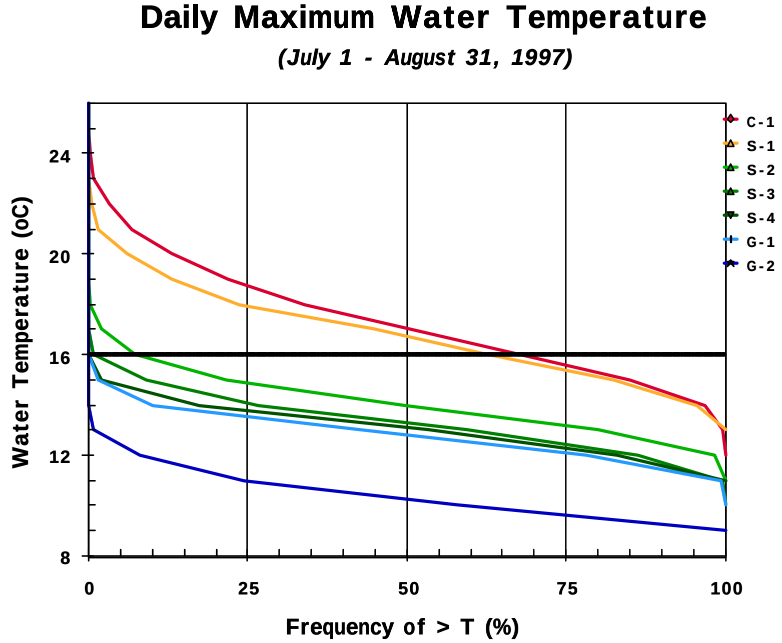
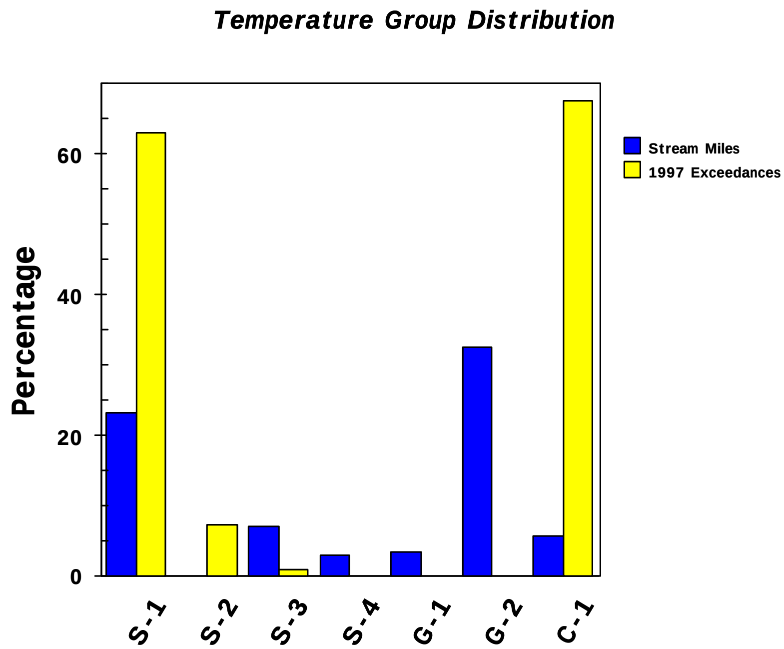


Figure 3-4. Distribution of Temperature Groups



Peak Hourly Change. Diurnal variation in water temperature occurs naturally in stream systems. The magnitude of the temperature change (both diurnal range and peak hourly increase) has greater meaning in TMDL development for nonpoint sources than a "*no threshold*" criteria (e.g. 16EC). This is because a TMDL is designed to decrease the pollutant load. Assessing the peak hourly change as a result of load reduction is much more straightforward than predicting attainment of an absolute water temperature. This approach incorporates consideration of natural conditions by looking at the increase from a base temperature (as opposed to engaging in a debate about the actual level of the base temperature). From this framework, effective shade targets are identified for channel types within each temperature group that are needed to achieve a target maximum peak hourly increase.

Actual data collected in the Simpson HCP area is used to illustrate the effect of diurnal variation as it relates to water temperature. Figure 3-5 depicts the diurnal variation of the temperature group monitoring sites on July 28, 1998. This is the day when maximum water temperatures were observed over the 2-year period for monitoring data provided by Simpson. This also corresponds to the date when the maximum water temperature was observed by the U.S. Forest Service over a 5-year period in the Humptulips watershed (immediately west of the Simpson HCP area). Figure 3-6 shows both the diurnal change and peak hourly water temperature increase for each temperature group. Figure 3-7 shows the relationship between peak hourly increase and daily maximum water temperature. Based on this relationship, the lowest peak hourly increase observed (0.45EC) is used to derive effective shade targets.

Figure 3-5. Temperature Group Summary

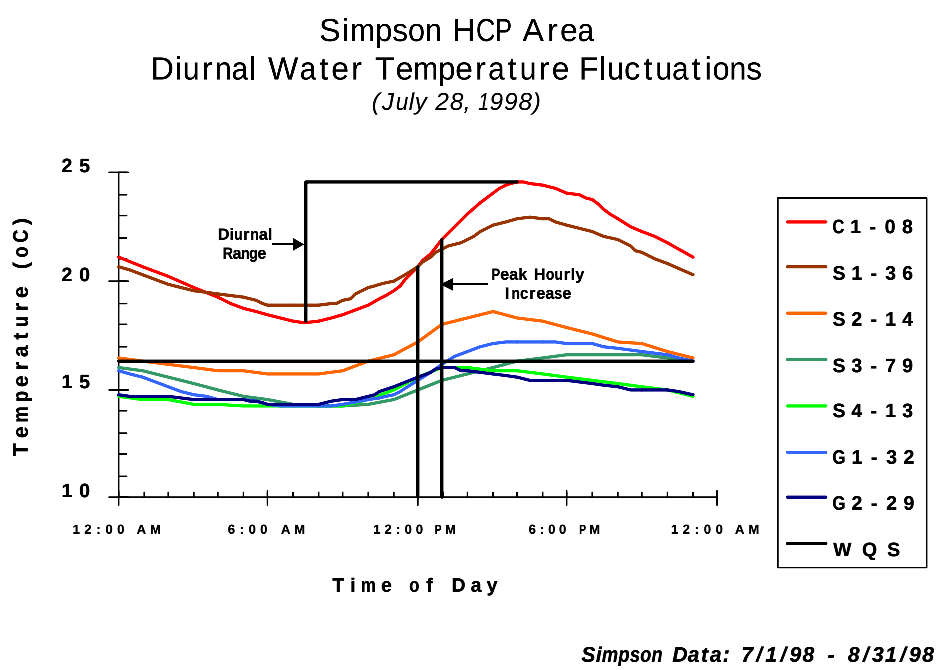


Figure 3-6. Temperature Group Summary

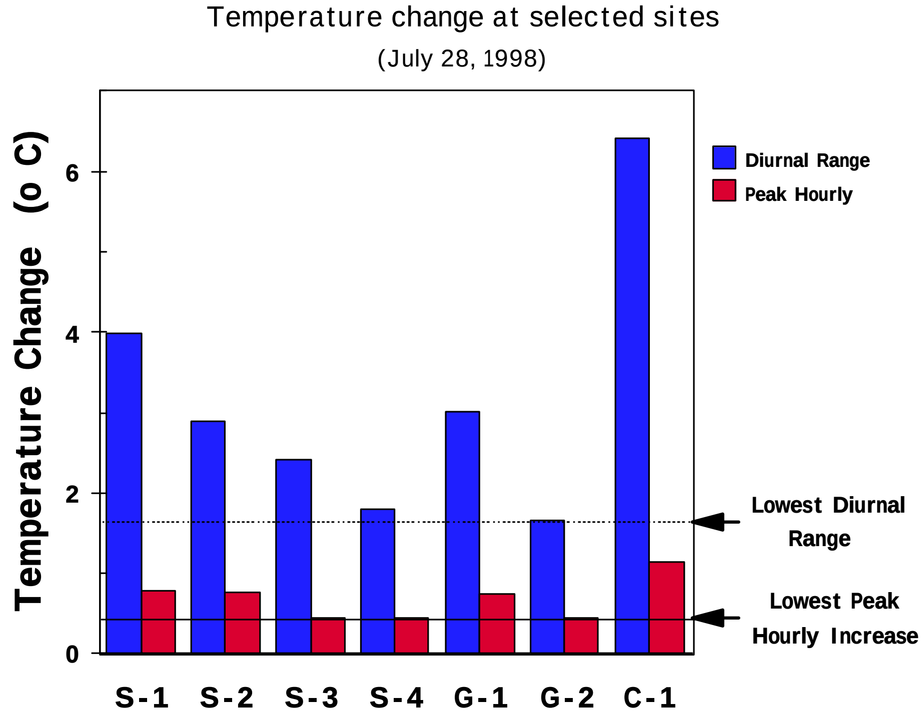
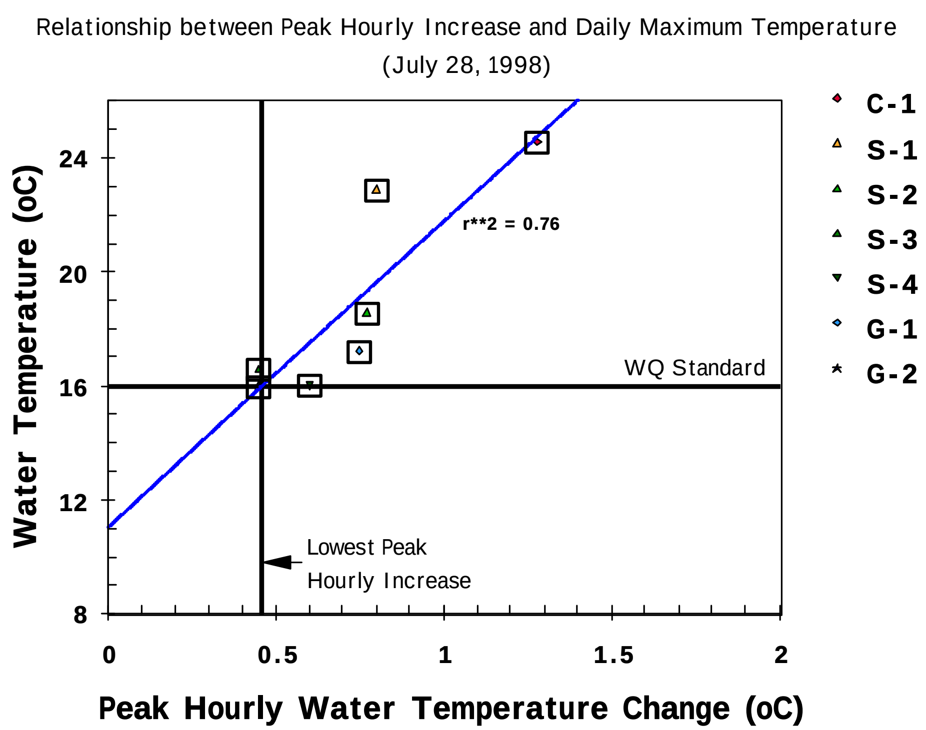


Figure 3-7. Temperature Group Summary



Development of Targets

Effective Shade. Figure 3-8 shows the theoretical relationship between effective shade and peak hourly water temperature change for small channels (ACW # 4m) in the ROP. The relationship is based on a heat budget analysis using a range of assumptions (e.g. wind speed, stream bed composition, groundwater contribution,) that reflect these types of channels within the S-1 group. Figure 3-9 shows a similar relationship for medium channels in the SIG within the S-1 group. As discussed earlier, a heat budget is useful to show general relationships, but not as an absolute predictor due to the high degree of uncertainty with assumptions.

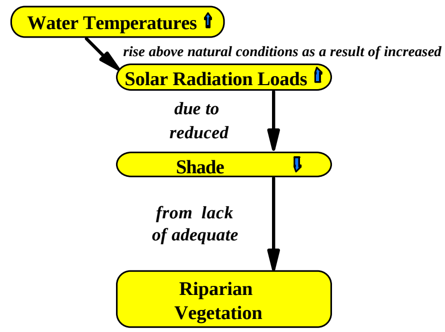


Figure 3-8. Target Development: Group S-1 Small Streams

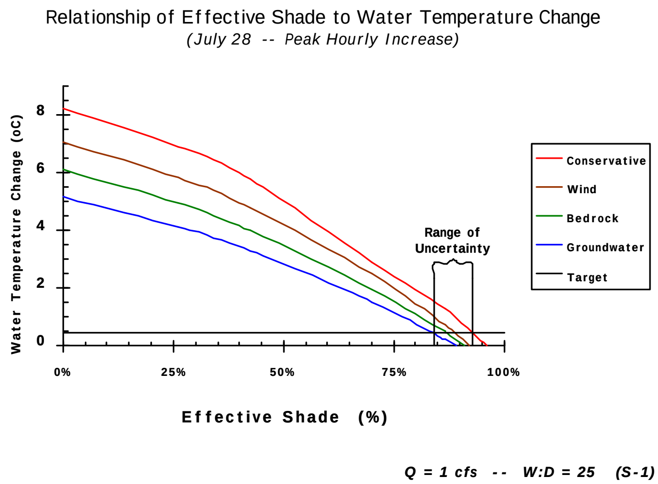
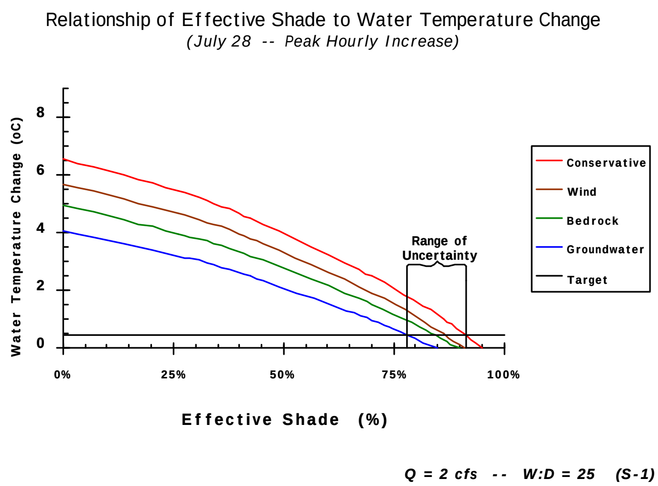


Figure 3-9. Target Development: Group S-1 Medium Stream (SIG)



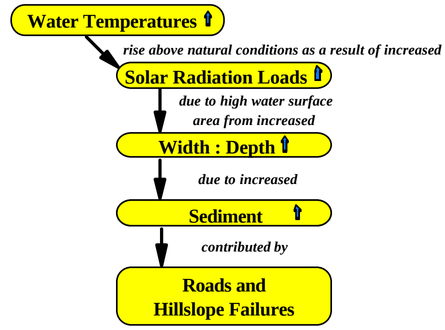
Using information about each channel class (e.g. drainage area, range of flows, etc) effective shade targets can be developed. The channel classification system is used to assess stream reaches according to temperature groups. This approach leads to effective shade targets which recognize the variability in channel and riparian characteristics that occurs across the landscape. As such, these targets reflect the range of active channel widths and riparian vegetation heights by LTU within the HCP area *(Table 3-3)*.

Table 3-3. Effective Shade Loading Capacity Targets

Active Channel Width[1] *(meters)*	Effective Shade[2] — *by temperature group (%)*						
	C-1	**G-1**	**G-2**	**S-1**	**S-2**	**S-3**	**S-4**
2			68-CUP		82-AGL 84-SIG		
4			51-AGL 71-CIS 68-CUP 56-SIG	90-ROP	84-SIG	85-CIS 80-SIG	76-AGL 78-SIG
6		85-CIS 85-ROP	68-CUP		82-AGL		
8	89-ROP		68-CUP				76-AGL
10				87-SIG			
12		75-ROP	68-CUP	89-ROP	85-SIG		
15		75-ROP					
16	86-ROP					87-CIS	80-AGL 82-SIG
18		75-ROP					
20	72-SIG		72-CUP				
25	77-AGL 83-ROP 77-SIG		58-AGL				
35	72-SIG						

1 This table summarizes the effective shade loading capacity targets by active channel width. Active channel width determines the surface area requiring effective shade.

2 Effective shade targets calculated using a heat budget for channel types within each temperature group that are needed to achieve a maximum peak hourly increase of 0.45EC.



<u>Sediment Delivery</u>*:* The effect of sediment and its relationship to numeric water quality standards is incorporated into the *"Simpson HCP area TMDL"* through a temperature group approach. Groups are defined according to the dominant control(s) which influence water temperature, specifically shade, groundwater, or channel morphology. *Group C-1* represents streams where temperatures are strongly influenced by channel patterns affected by high sediment supply. Changes in sediment input can lead to an alteration of channel form (Leopold et al, 1964; Megahan et al, 1980) through deposition and lateral scour. Water temperatures for *Group C-1* streams are among the warmest monitored.

When delivery of sediment increases over the transport capability of the stream, deposition occurs. Water quality and associated beneficial uses can be affected by deposition of sediment. Within the Simpson HCP area, large rivers of the AGL, ROP, and SIG are affected by high sediment supply and multiple thread channels over at least some of their length. Temperatures in these systems are strongly influenced by channel pattern and open canopies. Deposition of sediment can result in channel filling which leads to increases in channel width. An increase in channel width will increase the amount of solar radiation entering a stream. A wide, shallow will heat up faster than a narrow, deeper stream with the same discharge (Brown, 1972). During storm events, management related sources can increase sediment inputs over background. This contributes to channel widening and stream temperature increases.

Development of a loading capacity for sediment considers Washington's Water Quality Standards which state *"deleterious material concentrations shall be below those which may adversely affect characteristics water uses"*. The approach includes:

- **P** Focus on *<u>up-slope sediment source targets</u>* rather than looking exclusively at the suite of instream features that reflect the outcome of both natural and management related factors.

- **P** Establish *<u>quantifiable targets for sediment delivery</u>* by erosion process (e.g. cubic yards delivered per mile per averaging period) associated with each channel class.

Up-slope sediment source targets are included because focusing on instream indicators would not achieve water quality improvements. Hillslope targets supplement instream criteria by providing measurable goals that are not subject to the variability of climatic conditions. Hillslope and road-related targets are easier to measure and are more controllable. Hillslope and road-related targets also have the advantage to a landowner of being easily converted to implementation plans and management practices that can be evaluated more frequently than instream targets. In addition, including these targets address the problem of instream indicators which suggest that conditions are good, while hillslope conditions of sediment to be delivered in the next large storm event continue to pose potential delivery hazards. In short, without addressing hillslope sources, the cycle of degradation could potentially be repeated until some species of aquatic life could no longer recover.

Quantifiable targets for sediment delivery enable a focus on source input and hazard reduction. Sediment delivery targets for this TMDL are expressed in terms of cubic yards. This has several advantages which recognize the *"order of magnitude estimate"* that the values actually represent. First, initial calculations of sediment delivery are based on linear or areal estimates of erosion features (e.g. inches per year of bank erosion, feet of soil depth, square yards of landslide feature). Second, weight could be estimated either through assumptions or measurements of the bulk density of soil (e.g. tons per cubic yard). Lastly, cubic yards is more easily related to a wider range of individuals (e.g. a 10 yard^3 dump truck). Development of sediment delivery targets, i.e. the loading capacity, uses a framework suggested in the TFW Watershed Analysis Manual, specifically construction of a partial sediment budget (Reid and Dunne, 1996). This serves several purposes including:

- tie sediment problems recognized in streams to specific hillslope sources or activities;
- discriminate among the rates, effects, and hazards of various mass wasting, surface, and bank erosion processes in basins where all are significant sediment sources; and
- document the relative contributions of sediment delivery processes (e.g. road surface versus deep seated landslides).

Loading capacities are summarized by LTU *(Table 3-4)*. Although an annual averaging period is used to express the loads, it is simply a referencing mechanism. Erosion processes which are responsible for sediment inputs to the system are highly dynamic, change from year-to-year, and vary in different locations in the basin. Consequently, the sediment delivery targets define a framework which place erosion processes into the appropriate context relative to the varied lithology and topography of the HCP area. A more detailed description of information used to develop the sediment loading capacities is presented in Section G.

Table 3-4. Sediment Loading Capacity by Lithotopo Unit

Lithotopo Unit[1]	Area *(sq. mi.)*	Channel Length *(miles)*	Loading Capacity[2]	
			(yd^3 / sq. mi. per year)	*(yd^3 / stream. mile per year)*
AGL	32.7	137.7	880	209.0
CIS	49.0	163.7	110	33.6
CUP	45.0	265.2	1,000	169.5
ROP	183.9	376.7	50	24.7
SIG	98.1	454.5	1,000	215.8
Total	408.7	1,397.8	456	133.3

NOTES:

1 There are nearly 1,400 stream miles that lie within the HCP area. Available data and methods do not allow determination of loading capacities for each individual segment. Instead, targets have been developed that utilize the landscape stratification system used to organize information in the HCP.

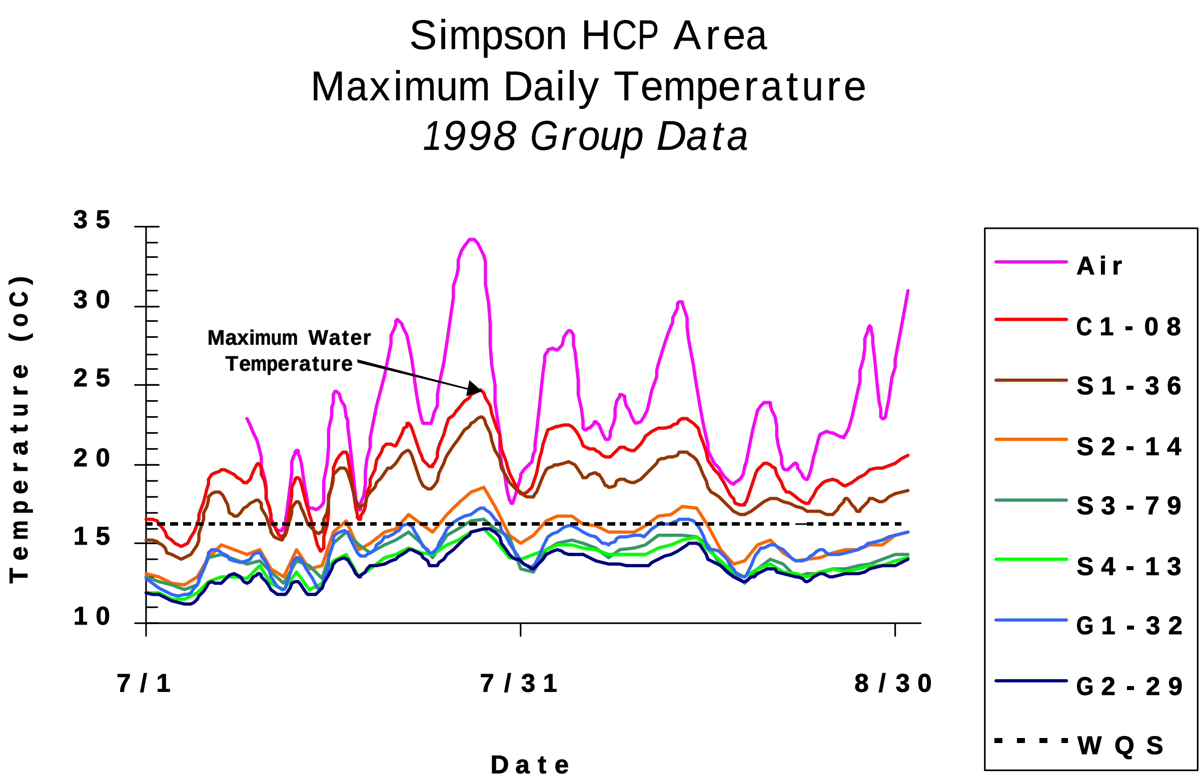
2 Loading capacities expressed as long term annual average values and do not reflect the wide range spatial and temporal variation observed in natural erosion processes. As new data and methods are developed to better describe sediment delivery mechanisms, these loading capacities may be revised.

4. DEVIATION FROM TARGETS

Water Temperature

To put this information in the context of Simpson HCP area streams, limited data has been collected. Figure 4-1 summarizes maximum daily summer water temperature data for streams in the Simpson HCP area. Additional temperature data for the Simpson HCP area is described in the seasonal variation discussion *(Section 8 and Section C)*.

Figure 4-1. Water Temperature for Simpson HCP Area Streams



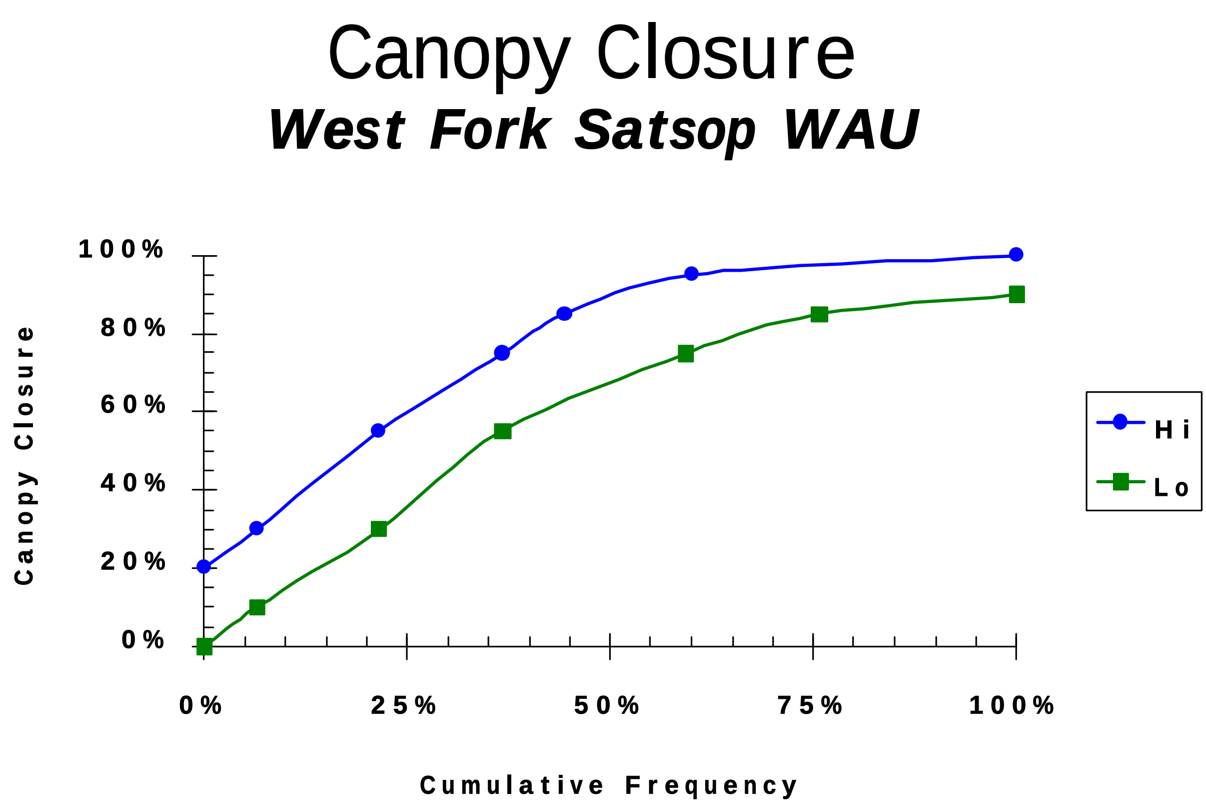
Simpson Data: 7/1/98 - 8/31/98

As discussed earlier, water temperatures vary across the landscape which is the reason for developing a *"group"* approach. In 1998, two of the groups *(S-4 and G2)* did not exceed Washington's water quality criteria for temperature. This is largely because the strong groundwater influence on these groups makes them more resistant to temperature change. In 1997, a cooler summer, only three of the groups exceeded the water quality criteria. In two cases *(S-1 and S-2)*, shade is the dominant control. The third group *(C-1)* is affected by high sediment supply.

Effective Shade

Targets for effective shade have been developed to address water temperature concerns in the Simpson HCP area. Although no direct measurements of effective shade have been made in the Simpson HCP area, riparian conditions have been evaluated in the Watershed Analysis Reports. The West Fork Satsop Watershed Analysis contains a canopy closure assessment conducted to estimate shade by evaluating existing riparian stands based on air photo information. Canopy closure assessments were done in bracket ranges per the Watershed Analysis Manual (0-20%, 20-40%, 40-70%, 70-90% 90%+). Approximately 160 stream miles were assessed for canopy closure in the Watershed Analysis Unit (WAU). A summary indicates that approximately 60% of the stream miles in the W.F. Satsop watershed are estimated to have adequate canopy closure *(Figure 4-2)*.

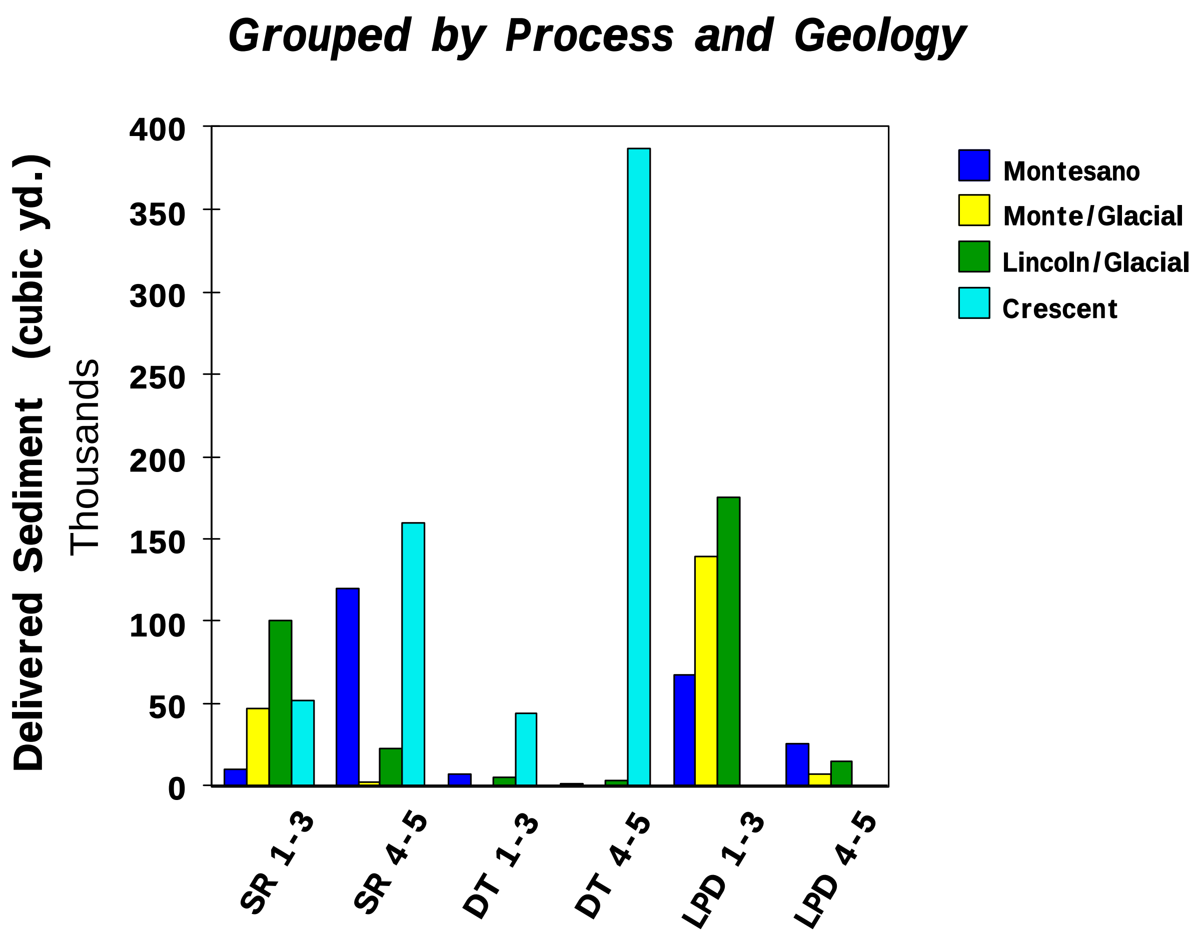
***Figure 4-2*.** W.F. Satsop Canopy Closure Summary



Sediment Delivery

The W.F. Satsop Watershed Analysis provided estimates of sediment delivery from mass wasting to stream channels in the WAU *(Figure 4-3)*. These sediment delivery estimates are apportioned by mass wasting process, receiving water type, and geologic conditions. The W.F. Satsop Watershed Analysis describes the method used to compute sediment delivery volumes from landslide inventory information. The high proportion of large persistent deep-seated (LPD) slides in the Sedimentary Inner Gorge (SIG) results from the prevalence of weak, deeply weathered bedrock, the presence of major incised stream valleys that create riverine escarpments, and the accelerated weathering and valley incision associated with glacial processes.

***Figure 4-3*.** W.F. Satsop Mass Wasting Summary



5. EXISTING SOURCES

Management activities can increase the amount of solar radiation delivered to a stream system, both by harvesting riparian shade trees and through the introduction of bedload sediment which can lead to channel widening. The Simpson HCP area has experienced a long history of land management, stemming back to the early twentieth century. This has resulted in degradation of the watershed condition. In the Simpson HCP area, anthropogenic sources of thermal gain and other nonpoint source pollution come from land management practices, specifically:

- Forest management within riparian areas
- Timber harvest in sensitive areas outside the riparian zone
- Sediment, hillslope failures, and roads

Riparian Area Management and Timber Harvest

Riparian vegetation can effectively reduce the total daily solar radiation load. Without riparian shade trees, most incoming solar energy would be available to heat the stream. Harvest of riparian area trees from management activities can result in loss of shade. Limited work has been done to estimate the amount of shade loss due to source activities. The W.F. Satsop Watershed Analysis summarized causes for not meeting target shade requirements. The report indicated that approximately 59% of the stream miles assessed met the shade target. Of the remainder, 13% were too wide to be fully shaded and 28% did not meet the shade target because of riparian condition.

Sediment, Hillslope Failures, and Roads

Most of the sediment supply that enters stream channels in forested watersheds is generated by several processes: mass wasting (landsliding), surface erosion (especially from roads), soil creep (especially in unstable areas), and bank erosion (from streamside terraces) [*see* Paulson, 1997]. This is especially true where steep unstable terrain is subjected to major weather events that saturate hillslopes with large volumes of precipitation. Mass hillslope failures can occur, which deliver large amounts of surface soils to stream channels. These events can overwhelm the capacity of the channel to transport this material downstream, which in turn can lead to substantial channel widening, attendant bank erosion, and shallowing of surface flows. Important salmonid (and associated life forms) habitat features (such as stable spawning areas, pools, side channel rearing areas) can be significantly affected by these processes.

Categories of sediment delivery identified in the Simpson HCP area, several of which are to some extent controllable, include:

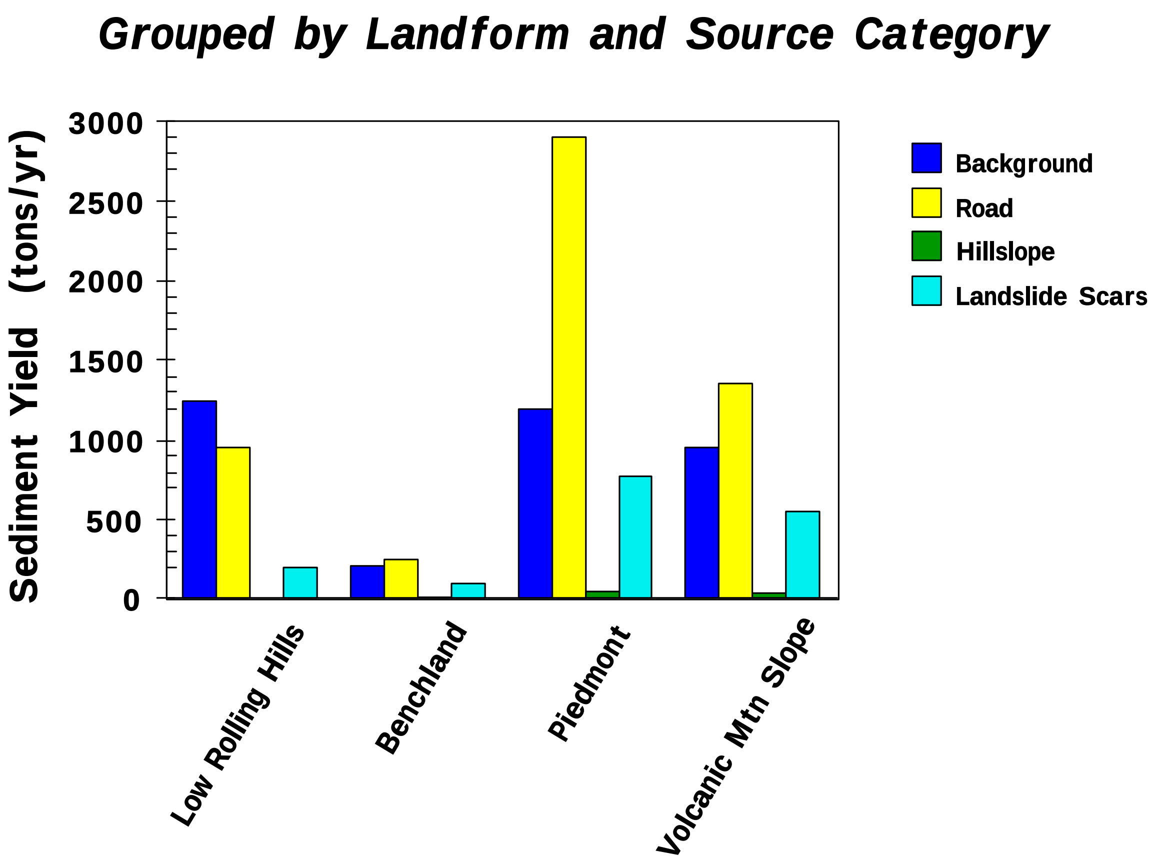
- background sediment yield
- erosion associated with roads, skid trails, and landings
- hillslope erosion
- mass wasting (landslides)
- surface erosion from bare ground (e.g. landslide scars)
- bank erosion

Controllable sediment is sediment delivered as a result of human activities which can affect water quality and can be reasonably controlled. Rates of delivery have been estimated for these sources using several Watershed Analyses conducted within the Simpson HCP area.

Surface Erosion

Information currently available to develop a detailed sediment budget analysis is fairly limited. However, the W.F. Satsop Watershed Analysis provided an estimate of contributions of fine sediment from various sources in the Watershed Analysis Unit (WAU). This estimate was developed in the Surface Erosion Assessment for comparative purposes to illustrate the approximate quantities of sediment from background and other sources *(Figure 5-1)*.

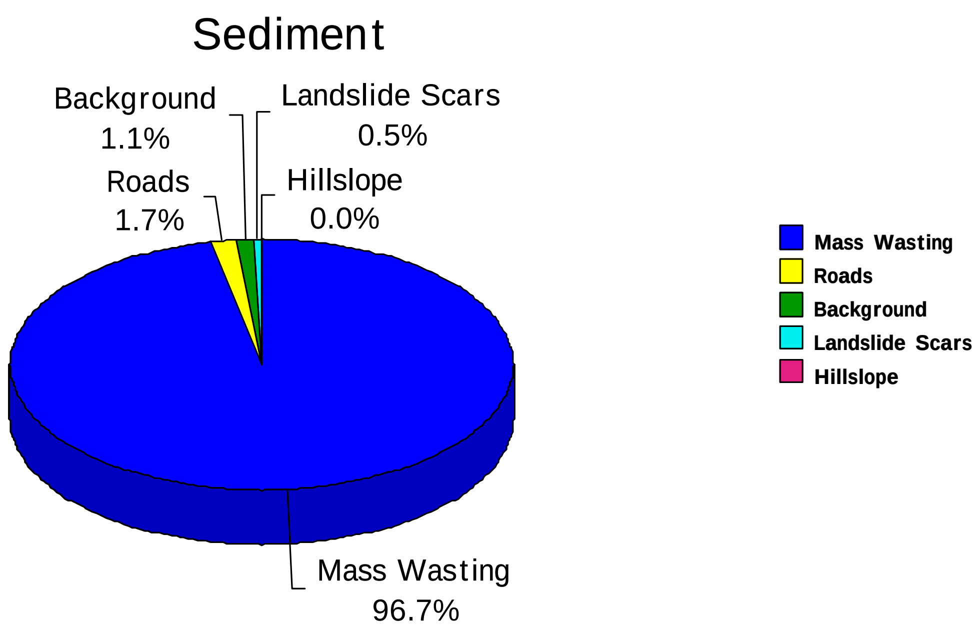
***Figure 5-1*.** W.F. Satsop Surface Erosion Sediment Yield



In addition, the W.F. Satsop Watershed Analysis developed an estimate of sediment from all sources to illustrate relative contributions *(Figure 5-2)*. This estimate showed that the contribution from mass wasting is far greater than that from surface erosion. It should be noted, though, that the mass wasting value includes both fine and coarse sediment while the background and surface erosion values represent only fine sediment.

***Figure 5-2*.** West Fork Satsop Sediment Yield

Source Summary



6. TMDL / ALLOCATIONS

This TMDL is designed to address impairments due to surface water temperature increases on four water quality-limited segments located in the Simpson HCP area. In addition to the listed §303(d) waters, this TMDL also applies to other potential water quality impairments from heat and sediment for all streams in the Plan area. In developing the allocations, this TMDL has benefitted from portions of the analysis used in preparation of Simpson's HCP. Although not identical, the goals and legal standards under the ESA and the Clean Water Act for aquatic resources are similar in many respects. Riparian management strategies in the HCP have been designed to eliminate temperature increases due to human activities and to prevent the delivery of excess sediment to the streams. Allocations in the TMDL are designed to achieve similar results.

Regulatory Framework

Under the current regulatory framework for development of TMDLs, flexibility is allowed for specifying allocations in that *"TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure"*. The "*Simpson HCP area TMDL"* utilizes measures other than "*daily loads"* to fulfill requirements of §303(d). Although a loading capacity for heat can be derived [e.g. BTU/ft^2 per day], it is of limited value in guiding management activities needed to solve identified water quality problems. In addition to heat loads, the *"Simpson HCP area TMDL"* uses *"other appropriate measures"* (or surrogates) as provided under EPA regulations [40 CFR §130.2(i)].

Allocations

Allocations in the "*Simpson HCP area TMDL"* are derived using effective shade and sediment delivery targets. These measures can be linked to specific source areas, and thus to actions (specifically riparian management and erosion control) needed to solve problems which cause water temperature increases. Because factors that affect water temperature are interrelated, both measures are dependent upon each other to achieve desirable responses. Using riparian vegetation exclusively to reduce heat (e.g. increase shade) is difficult to achieve if sediment delivered from upland sources continues to deposit and widen channels. Likewise, narrower channels still require riparian vegetation to provide channel stability and shade, thus reducing heat loads (unless confined by canyon walls or shaded by topography).

In establishing the load allocations for this TMDL, certain information has been used that was developed in preparation of the HCP. Sediment delivery information from three completed Watershed Analysis Reports in the Plan area has also been useful. The TMDL develops load allocations for each channel class in the Plan area, then summarizes them into eight separate groups. Streams within each group share common characteristics that relate to potential input of pollutants into streams covered by the TMDL.

The HCP also divides the stream segments into the same eight groups which are identified as individual riparian management strategies *(Table 6-1)*. These strategies have been developed using an approach that integrates the mediation of physical processes and ecological functions. For ease of reference, each of the eight groups of streams analyzed separately in this TMDL is given the same name as is used in identifying the corresponding riparian management strategy in the HCP.

***Table 6-1*.** HCP Riparian Management Strategy Summary

Strategy	Purpose	Management Function
Canyon	Maintain sediment and organic matter storage capacity of the upper channel network, keep convective heat transfer to a minimum, and supply detritus to the channel as it's principle energy source.	Provision of LWD from off-site, and maintenance of on site shade and detrital inputs. Applied in the CUP along highly confined channel network of the Olympic foothills.
Channel Migration	Maintain the floodplain processes that contribute nutrient processing within the soil and hyporheic zone and ensure continued development of topographic complexity of floodplain surfaces.	Retention of sediment and organic matter and maintenance of nutrient processing. Applied to either very large meandering alluvial channels inset within well defined terrace systems or those low gradient smaller channels with highly erodible banks.
Temperature Sensitive	Mediation of water temperatures in channels that are vulnerable to summer time increases.	Protection of shade and control of streamside air temperature. RCRs established that provide the greatest shade from mid-day to early afternoon ensuring wide, denser leave area on south and west aspects.
Inner Gorge	Provide wood large enough to maintain position or lodge in channel classes like SIG-L4, SIG-L5, AGL-Qo8, and AGL-Qa6.	Provision of wood from unstable slopes to enhance development of productive main river habitat. Retain largest trees that have the highest likelihood of recruiting to the river.
Alluvial Bedrock Transition	Maintenance of an alluvial channel bed in channel classes likely to scour to bedrock in the absence of LWD.	Provision of LWD, particularly along channel classes SIG-M3 and SIG-M4. Protect principal recruitment zone for high value LWD.
Break in Slope	Protect inner side slopes adjacent to channel and provide for LWD recruitment from above the break in slope.	Provision of LWD by establishing RCR back away from the break in slope with emphasis given to wind and shade protection of south and west aspects.
Reverse Break in Slope	Maintain opportunity for conifer germination sites in an otherwise unfavorable environment by protecting LWD and providing nurse logs.	Provision of LWD and nurse logs. Settings typified by wet understory plant communities whose early seral stages are dominated by red alder.
Unstable Slopes / Intermittent Flow	Maintain important functional linkages between channel segments and their riparian areas for channel classes that typically have low average fish resource value.	Recognition of physical processes that may transmit significant impacts from these channel classes to other segments downstream for which on-site biological resource value is high.

Effective Shade Allocations: The objective of the effective shade TMDL is to reduce heat from incoming solar radiation delivered to the water surface. The basis for effective shade allocations follows an analysis of processes that affect water temperature. Development of the effective shade allocations uses information about riparian management strategies described in the HCP. Minimum Riparian Conservation Reserve (RCR) widths described in the HCP recognize the relationship between active channel width and effective shade.

Effective shade allocations have been developed from targets based on channel class width and characteristics of mature riparian vegetation *(Table 6-2)* for that channel class including vegetative density. Effective shade allocations are a function of the vegetation that will shade the widest active channel for each class. The active channel width, the vegetative density associated with a particular RCR width, and the height associated with the expected riparian community (e.g. mixed conifer / hardwood) is used to determine effective shade allocations.

Table 6-2. Mature Riparian Vegetation Classes in HCP Area

ID	Stage	Vegetation Description
H-M	**Mature**	**Hardwood:** Salmonberry, Thimbleberry (< 6 ft) Devil's Club (< 15 ft) Vine Maple (< 50 ft) Red Alder, Big Leaf Maple
M-M	**Mature**	**Mixed:** Listed Hardwoods Listed Conifers
C-M	**Mature**	**Conifer:** Douglas Fir, Red Cedar Western Hemlock, Sitka Spruce

As channels become wider, larger RCR widths are needed to provide more effective shade, as well as to protect other riparian functions. This is reflected in the HCP where wider channels have larger RCR widths identified. Small channels (# 4m), on the other hand, benefit from dense, emergent vegetation. Consequently, narrower RCR widths may still provide a high level of effective shade to these small streams. However, the benefit of the RCR to these smaller channels may go beyond effective shade. As indicated in the HCP, the purpose of the RCR is also to provide slope stability and a supply of large woody debris (LWD).

The *"Simpson HCP area TMDL"* and allocations for effective shade are summarized in Table 6-3. Some items to note relative to the effective shade allocations include variations between active channel width and minimum RCR widths. In many instances, channels of the same width size have different RCR widths. The temperature group and other considerations (e.g. LWD supply, sediment supply concerns) become important factors, particularly in terms of uncertainty and increasing the margin of safety. The 8-meter active channel width is used to illustrate this point. AGL-Qo5 and AGL-Qo6 streams are in temperature group S-4 (i.e. those streams strongly influenced by groundwater and more resistant to temperature change). As a result, this class of streams has a lower margin of safety. In contrast, CUP-C4 and ROP-C7 are in areas where sediment supply is a potential concern. Therefore, larger RCR widths are identified in the HCP for this class of streams.

Sediment Delivery: The "*Simpson HCP area TMDL*" and allocations for sediment delivery are summarized in Table 6-4. The estimated total allowable sediment load (TMDL) is derived from targets based on lithotopo unit, channel class and erosion process (cubic yards per mile per averaging period). Sediment delivery information for the period 1946-96 was used from three completed Watershed Analysis reports conducted in the Simpson HCP area.

Analysis of sediment delivery information from landslide inventories indicates two major concerns that contribute to management caused hillslope instability. First, riparian area management can affect sediment delivery through bank stability and sediment retention. For instance, the W.F. Satsop Watershed Analysis identified the main potential management influence in the SIG as declining root reinforcement of hillslopes following harvest. The second concern relates to roads, particularly in the Crescent Uplands. Again, the W.F. Satsop Watershed Analysis indicated that road sidecast and cutslope problems are the source of more than half the inventoried slides in the CUP.

Sediment delivery allocations use information from three completed Watershed Analysis Reports in the area and from several inventories that supported preparation of the HCP. The quantitative comparison of estimated loading rates and controllable portions of various types of loading was considered. It is estimated that a 50% reduction in the frequency of catastrophic failures (e.g. sidecast or fill failures) over the rate observed for the previous 20-year period can be achieved during the first ten years of the Plan. This represents an interim target for measuring progress relative to achieving the load allocations. In addition, a target of 50% reduction of fine sediment input from roads during the first ten years of the plan is also included in the HCP. Furthermore, the HCP provides funding to road maintenance and abandonment efforts for the duration of the HCP. Finally, STC will apply mass wasting prescriptions across the HCP area to address unstable slope concerns.

The load allocations incorporate sediment reductions from management activities into the sediment delivery targets. Sediment delivered from shallow rapids landslides and debris torrents as a result of management activities is assumed to be 80% controllable. This is based on information used for development of prescriptions in the W.F. Satsop Watershed Analysis. Sediment delivered from large persistent deep-seated landslides as a result of management activities is assumed to be 10% controllable. The retention of large wood in RCRs and reducing peak flows due to hydrologic effects of the road network will address sediment delivery from bank erosion that result from management activities.

Sediment delivery targets expressed as annual average cubic yards per stream mile for each channel class is consistent with current EPA regulations. The regulations indicate that load allocations are *"best estimates of the loading which may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading" [40 CFR §130.2(g)]*.

The resultant load allocations for sediment are: 1) developed for erosion processes; 2) associated with land use activities where feasible; and 3) based on the source analysis of various erosion processes. The load allocations are expressed as long term annual average load delivered per mile at the channel class scale. Temporal and spatial variability in erosion and stream responses are considered in several ways including:

- *Temporal Considerations* **--** The TMDL and specific load allocations are expressed in terms of annual rates over a 50-year period in recognition that trends are not discernible within shorter time frames and to allow for natural variation due to seasonal and annual differences.

- *Spatial Considerations* **--** Targets were derived based primarily on analysis of conditions in different watersheds and lithotopo units within the Simpson HCP area. These conditions represent different geologies and associated vulnerabilities to erosion.

Table 6-3a. Summary of Effective Shade TMDL and Load Allocations for Simpson HCP Area

Channel Class	Group	Active Channel Width *(m)*	Avg. RCR Width *(m)*	Riparian Condition	Length *(miles)*	Load Allocations (Effective Shade as percent)		
						TMDL	LA	MOS
Temperature Sensitive Strategy								
ROP-*Qc3*	S-1	6 - 12	30/25	C-M	44.2	89%	90%	(1%)
SIG-*Qc3*	S-1	4 - 10	25/15	C-M	9.1	87%	90%	(3%)
Total for Strategy					53.3	88.7%	90.0%	(1.3%)
Break in Slope Strategy								
AGL-*Qo3*	S-4	2 - 4	25/15	M-M	7.3	76%	96%	(20%)
AGL-*Qo5*	S-4	4 - 8	20/10	C-M	8.8	76%	93%	(17%)
AGL-*Qo6*	S-4	6 - 8	30/20	C-M	13.6	76%	92%	(16%)
AGL-*Qo7*	S-4	12 - 16	30/20	C-M	3.7	80%	82%	(2%)
ROP-*Qc2*	S-1	2 - 4	3	M-M	103.4	90%	92%	(2%)
ROP-*Qc4*	G-1	4 - 6	20/15	C-M	9.1	85%	96%	(11%)
ROP-*Qc5*	G-1	12 - 18	30/20	C-M	12.1	75%	81%	(6%)
SIG-*L3*	S-2	2 - 4	20/15	M-M	6.3	84%	97%	(13%)
SIG-*Qo3*	S-4	4	25/15	M-M	4.8	78%	96%	(18%)
SIG-*Qo4*	S-4	8 - 16	30	C-M	2.0	82%	84%	(2%)
Total for Strategy					171.1	85.4%	91.6%	(6.3%)
TMDL								

Notes:

[1] TMDL currently refers to temperature group described in Section 3. Development of allocations based on representative conditions for mature riparian condition, maximum active channel width for class, and minimum Riparian Conservation Reserve (RCR) width.

Table 6-3b. Summary of Effective Shade TMDL and Load Allocations for Simpson HCP Area

Channel Class	Group	Active Channel Width *(m)*	Avg. RCR Width *(m)*	Riparian Condition	Length *(miles)*	Load Allocations *(Effective Shade as percent)*		
						TMDL	LA	MOS
Canyon Strategy								
CUP-*C2*	G-2	2 - 4	25	M-M	22.9	68%	95%	(27%)
CUP-*C3*	G-2	2 - 4	25	M-M	24.5	68%	95%	(27%)
CUP-*C4*	G-2	6 - 8	25	C-M	4.9	68%	91%	(23%)
CUP-*C5*	G-2	4 - 6	25	C-M	3.5	68%	95%	(27%)
CUP-*C6*	G-2	12	30	C-M	3.6	68%	86%	(18%)
Total for Strategy					59.4	68.0%	94.1%	(26.1%)
Channel Migration Strategy								
AGL-*Qa6*	C-1	> 25	40/30	C-M	12.7	77%	77%	(0%)
CIS-*Qc3*	S-3	8 - 16	30/20	C-M	16.8	83%	85%	(2%)
ROP-*C7*	C-1	6 - 8	40	C-M	9.4	89%	94%	(5%)
ROP-*Qa7*	C-1	> 16	50/40	C-M	3.7	85%	85%	(0%)
ROP-*Qc6*	G-1	12	40/30	C-M	9.5	75%	89%	(14%)
ROP-*Qc7*	G-1	15	65/40	C-M	15.2	75%	86%	(11%)
ROP-*Qc8*	C-1	25	40	C-M	2.8	82%	82%	(0%)
SIG-*M6*	S-2	6 - 12	50/30	C-M	2.3	85%	89%	(4%)
SIG-*Qa6*	C-1	> 25	40	C-M	11.3	77%	77%	(0%)
Total for Strategy					83.7	79.7%	84.4%	(4.7%)
TMDL								

Notes:

[1] TMDL currently refers to temperature group described in Section 3. Development of allocations based on representative conditions for mature riparian condition, maximum active channel width for class, and minimum Riparian Conservation Reserve (RCR) width.

Table 6-3c. Summary of Effective Shade TMDL and Load Allocations for Simpson HCP Area

Channel Class	Group	Active Channel Width *(m)*	Avg. RCR Width *(m)*	Riparian Condition	Length *(miles)*	Load Allocations *(Effective Shade as percent)*		
						TMDL	LA	MOS
Inner Gorge Strategy								
AGL-*Qo8*	G-2	15 - 25	30	C-M	5.2	58%	74%	(16%)
CUP-*C8*	G-2	20	35	C-M	5.9	72%	81%	(9%)
SIG-*L4*	C-1	35	40	C-M	24.2	72%	72%	(0%)
SIG-*M5*	C-1	20	40	C-M	15.1	72%	86%	(14%)
Total for Strategy					50.4	70.6%	77.5%	(6.9%)
Alluvial Bedrock Transition Strategy								
SIG-*M3*	S-2	4 - 12	30/15	C-M	9.6	85%	88%	(3%)
SIG-*M4*	S-2	4 - 12	40/25	C-M	6.0	85%	89%	(4%)
Total for Strategy					15.6	85.0%	88.4%	(3.4%)
Reverse Break in Slope Strategy								
AGL-*Qo4*	S-2	4 - 6	30/20	C-M	2.6	82%	95%	(13%)
CIS-*C5*	G-1	4 - 6	40/30	C-M	1.7	85%	95%	(10%)
SIG-*L2*	S-2	2 - 4	30/20	M-M	38.5	84%	95%	(11%)
Total for Strategy					42.8	83.9%	95.0%	(11.1%)
TMDL								

Notes:

1 TMDL currently refers to temperature group described in Section 3. Development of allocations based on representative conditions for mature riparian condition, maximum active channel width for class, and minimum Riparian Conservation Reserve (RCR) width.

Table 6-3d. Summary of Effective Shade TMDL and Load Allocations for Simpson HCP Area

Channel Class	**Group**	**Active Channel Width** *(m)*	**Avg. RCR Width** *(m)*	**Riparian Condition**	**Length** *(miles)*	**Load Allocations** *(Effective Shade as percent)*		
						TMDL	LA	MOS
Unstable Slopes / Intermittent Flow Strategy								
AGL-*Qo1*	G-2	0 - 4	8	M-M	61.3	51%	93%	(42%)
AGL-*Qo2*	S-2	< 2	8	M-M	22.5	82%	93%	(11%)
CIS-*C1*	G-2	0 - 4	8	M-M	83.9	71%	93%	(22%)
CIS-*Qc1*	S-3	0 - 4	8	M-M	33.3	85%	93%	(8%)
CIS-*Qc2*	S-3	2 - 4	8	M-M	28.0	85%	93%	(8%)
CUP-*C1*	G-2	0 - 2	8	M-M	199.9	68%	93%	(25%)
ROP-*Qc1*	S-1	2 - 4	8	M-M	167.3	90%	93%	(3%)
SIG-*L1*	S-2	0 - 2	8	M-M	160.0	84%	93%	(9%)
SIG-*M1*	S-2	1 - 2	8	M-M	67.8	84%	93%	(9%)
SIG-*M2*	S-2	2 - 4	8	M-M	18.5	84%	93%	(9%)
SIG-*Qc1*	S-3	2 - 4	8	M-M	12.8	80%	93%	(13%)
SIG-*Qc2*	S-3	2 - 4	8	M-M	8.9	80%	93%	(13%)
SIG-*Qo1*	G-2	0 - 4	8	M-M	38.3	56%	93%	(37%)
SIG-*Qo2*	S-2	2 - 4	8	M-M	19.0	84%	93%	(9%)
Total for Strategy					921.5	77.0%	93.0%	(16.0%)
TMDL								

Notes:
[1] TMDL currently refers to temperature group described in Section 3. Development of allocations based on representative conditions for mature riparian condition, maximum active channel width for class, and minimum Riparian Conservation Reserve (RCR) width.

Table 6-4a. Summary of Sediment Allocations by Channel Class for Simpson HCP Area

Channel Class	Length *(miles)*	TMDL	Mass Wasting			Surface Erosion	Floodplain Storage / Bank Erosion	MOS
			SR	*DT*	*LPD*			
Alpine Glaciated (AGL)								
AGL-*Qa6*	12.7		6	1	10	4	928	
AGL-*Qo1*	61.3		6	1	1	4	16	
AGL-*Qo2*	22.5		6	1	1	4	8	
AGL-*Qo3*	7.3		6	1	5	4	9	
AGL-*Qo4*	2.6		6	1	5	4	13	
AGL-*Qo5*	8.8		6	1	5	4	12	
AGL-*Qo6*	13.6		6	1	5	4	17	
AGL-*Qo7*	3.7		6	1	5	4	17	
AGL-*Qo8*	5.2		6	1	10	4	22	
Total	137.7	209.0	6.0	1.0	3.2	4.0	98.4	96.4
Crescent Islands (CIS)								
CIS-*C1*	83.5		1	0	1	2	20	
CIS-*C5*	1.7		1	0	1	2	16	
CIS-*Qc1*	33.0		1	0	1	2	24	
CIS-*Qc2*	27.0		1	0	1	2	8	
CIS-*Qc3*	15.9		1	0	1	2	106	
Total	163.7	33.6	1.0	0.0	1.0	2.0	27.7	1.9

Table 6-4b. Summary of Sediment Allocations by Channel Class for Simpson HCP Area

Channel Class	Length *(miles)*	TMDL	Mass Wasting			Surface Erosion	Floodplain Storage / Bank Erosion	MOS
			SR	***DT***	***LPD***			
Crescent Uplands (CUP)								
CUP-*C1*	199.9		11	7	1	3	21	
CUP-*C2*	22.9		30	7	1	3	10	
CUP-*C3*	24.5		7	7	1	3	10	
CUP-*C4*	4.9		7	7	1	3	24	
CUP-*C5*	3.5		11	7	1	3	14	
CUP-*C6*	3.6		7	7	1	3	61	
CUP-*C8*	5.9		9	7	1	3	31	
Total	265.2	169.5	12.1	7.0	1.0	3.0	19.9	126.5
Recessional Outwash Plain (ROP)								
ROP-*C7*	9.4		1	0	1	1	51	
ROP-*Qa7* [1]	3.7		1	0	1	1	5,193	
ROP-*Qc1*	167.3		1	0	1	1	2	
ROP-*Qc2*	103.4		1	0	1	1	3	
ROP-*Qc3*	44.2		1	0	1	1	4	
ROP-*Qc4*	9.1		1	0	1	1	4	
ROP-*Qc5*	12.1		1	0	1	1	20	
ROP-*Qc6*	9.5		1	0	1	1	91	
ROP-*Qc7*	15.2		1	0	1	1	104	
ROP-*Qc8*	2.8		1	0	1	1	189	
Total [1]	376.7	24.7	1.0	0.0	1.0	1.0	12.3	9.4

NOTES:

[1] Does not include LA for floodplain storage / bank erosion on ROP-Qa7 (3.7 miles — Vance Creek) which is uniquely affected by channel migration across floodplain terraces as documented by a review of air photo records.

Table 6-4c. Summary of Sediment Allocations by Channel Class for Simpson HCP Area

Channel Class	Length *(miles)*	TMDL	Mass Wasting			Surface Erosion	Floodplain Storage / Bank Erosion	MOS
			SR	*DT*	*LPD*			
Sedimentary Inner Gorge (SIG)								
SIG-*L1*	160.0		5	1	16	5	19	
SIG-*L2*	38.5		5	1	5	5	17	
SIG-*L3*	6.3		5	1	5	8	19	
SIG-*L4*	24.2		25	1	105	12	95	
SIG-*M1*	67.8		5	1	26	5	18	
SIG-*M2*	18.5		5	1	20	5	18	
SIG-*M3*	9.6		5	1	5	8	19	
SIG-*M4*	6.0		13	1	5	8	19	
SIG-*M5*	15.1		5	1	240	12	42	
SIG-*M6*	2.3		5	1	45	8	230	
SIG-*Qa6*	11.3		8	1	225	12	937	
SIG-*Qc1*	12.8		5	1	1	5	18	
SIG-*Qc2*	8.9		5	1	1	5	18	
SIG-*Qc3*	9.1		5	1	35	8	21	
SIG-*Qo1*	38.3		5	1	19	5	25	
SIG-*Qo2*	19.0		5	1	1	5	18	
SIG-*Qo3*	4.8		5	1	5	8	21	
SIG-*Qo4*	2.0		14	1	5	8	29	
Total	454.5	215.8	6.3	1.0	32.8	6.0	47.7	122.0

7. MARGIN OF SAFETY

The Clean Water Act requires that each TMDL be established with a margin of safety (MOS). The statutory requirement that TMDLs incorporate a margin of safety is intended to account for uncertainty in available data or in the actual effect controls will have on loading reductions and receiving water quality. A margin of safety is expressed as unallocated assimilative capacity or conservative analytical assumptions used in establishing the TMDL (e.g., derivation of numeric targets, modeling assumptions or effectiveness of proposed management actions).

The margin of safety may be implicit, as in conservative assumptions used in calculating the loading capacity, WLAs, and LAs. The margin of safety may also be explicitly stated as an added, separate quantity in the TMDL calculation. In any case, assumptions should be stated and the basis behind the margin of safety documented. The margin of safety is not meant to compensate for a failure to consider known sources. Table 7-1 presents six approaches for incorporating a margin of safety into TMDLs.

***Table 7-1*.** Approaches for Incorporating a Margin of Safety into a TMDL

Type of Margin of Safety	Approaches
Explicit	1. Set numeric targets at more conservative levels than analytical results indicate 2. Add a safety factor to pollutant loading estimates 3. Do not allocate a portion of available loading capacity; reserve for MOS
Implicit	4. Conservative assumptions in derivation of numeric targets 5. Conservative assumptions when developing numeric model applications 6. Conservative assumptions when analyzing prospective feasibility of practices and restoration activities.

The following factors may be considered in evaluating and deriving an appropriate margin of safety:

- Limitations in available data to characterize the waterbody / pollutant and to address the components of the TMDL development process.
- Analysis and techniques used in to evaluate components of the TMDL and to derive an allocation scheme.
  - characterization and estimates of source loadings (e.g., confidence regarding data limitation, analysis limitation or assumptions)
  - analysis of relationships between the source loading and instream impact
  - prediction of response of receiving waters under various allocation scenarios. (e.g., the predictive capability of the analysis, simplifications in the selected techniques)

- Expression of analysis results in terms of confidence intervals or ranges. Confidence may be addressed as a cumulative effect on the load allocation or for each of the individual components of the analysis.

- Implications of the MOS on the overall load reductions identified in terms of reduction feasibility and implementation time frames.

Assumptions

Effective Shade: Development of effective shade allocations results from an analysis of processes that affect water temperature and from information about Riparian Management Strategies described in the HCP. The analysis of processes that affect water temperature include use of a heat budget. There are a number of uncertainties in the analysis regarding these processes that both add and subtract heat from a stream system. Assumptions that affect analytical results include factors such as flow, channel width, upstream water temperature, wind speed, relative humidity, stream bed composition, and groundwater contribution. Figure 7-1 illustrates an example of the range of uncertainty associated with different assumptions in developing effective shade targets.

***Figure 7-1*.** Example of Range of Uncertainty in Developing Effective Shade Targets

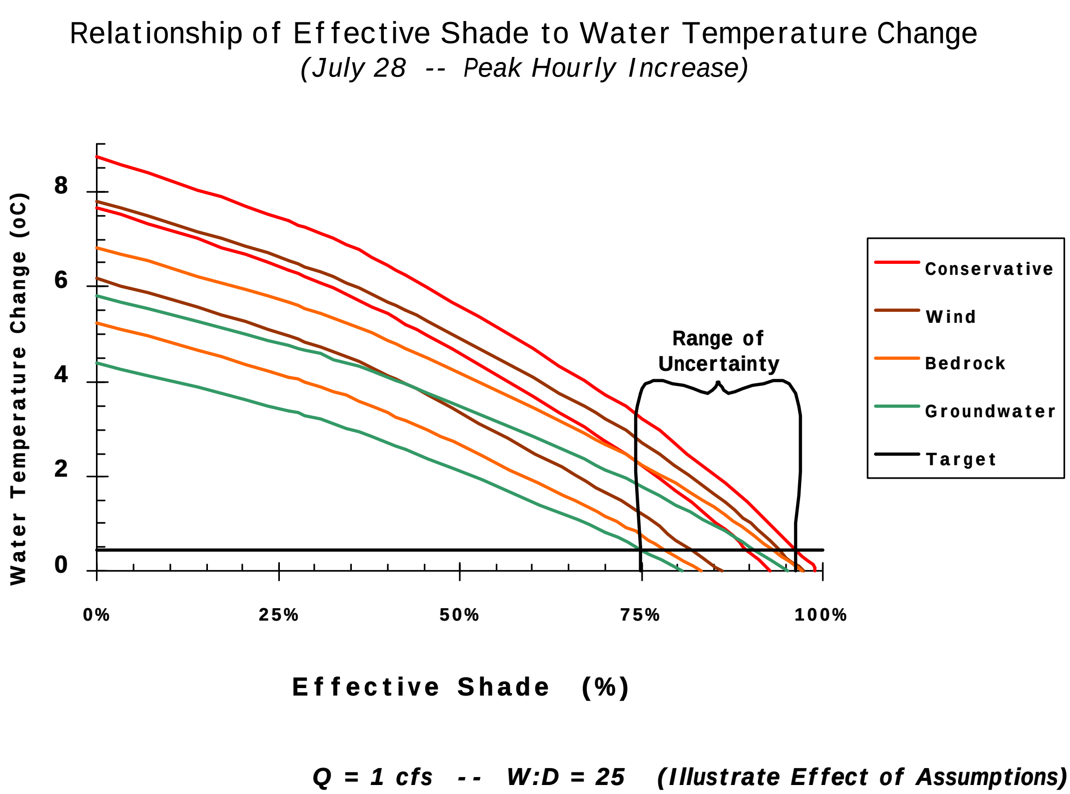


Table 7-2 summarizes uncertainties associated with development of effective shade targets. Adjustments that were made to account for these uncertainties are also described.

***Table 7-2*.** Supporting Information for Effective Shade Margin of Safety

Uncertainties in TMDL	Adjustments to Account for Uncertainties
Natural conditions of upstream ambient water temperature regimes for some segments may be above state criteria of 16EC.	Focus analysis on identifying heat input and effective shade targets to achieve a peak hourly temperature increase of 0.45EC which serves as a numeric interpretation of the *"natural conditions"* clause in Washington's water quality standards. As new data and methods are developed to better describe *"Natural conditions"*, the peak hourly temperature increase target may be refined.
Maximum water temperatures can occur over a range of days which vary from mid-July to mid-August.	Effective shade allocations are based on shadows cast on June 21 when shade angle and solar radiation values are at their peak.
Very little information exists regarding factors that affect water temperature in the Simpson HCP area, particularly wind speed, relative humidity, stream bed composition, and groundwater contribution.	Once the HCP agreement is in place, monitoring of water temperature will continue with a focus on temperature group patterns. Information from this network will support modifications to assumptions, as warranted.

Allocations for effective shade contain an explicit margin of safety which is expressed as an unallocated portion of the loading capacity. In many cases, this portion is unallocated because of other factors in the Riparian Management Strategy which applies to that particular channel class. Considerations include providing for slope stability or future recruitment of large wood (e.g. Break in Slope, Canyon strategies).

In addition, allocations for effective shade also contain an implicit margin of safety, specifically the point of measurement for the Riparian Conservation Reserve (RCR). These buffer widths, identified in the HCP and in the load allocations, were determined by identifying the primary zones adjacent to each channel class where the functional interactions with the riparian forest are most pronounced. The HCP buffer widths reflected in the load allocations differ from other traditional approaches that use the ordinary high water (OHW) mark as the measurement benchmark. In the HCP, both the channel migration zone and side slope surfaces are accorded full, no harvest protection by the *"Break in Slope"* riparian strategy. The width of these width of these zones are actually measured from the break in slope instead of the OHW and do not count the side slope distance from the start of the RCR to the edge of the channel migration zone.

<u>Sediment Delivery</u>: Development of sediment budget values is an "*order of magnitude*" estimate which may result in over prediction or under prediction of loadings from different erosion processes. Uncertainties about mass wasting, floodplain storage, and streambank erosion portions of the analysis can be significant. The uncertainties include:

- A single volume assigned to an individual landslide for the entire budget period could inaccurately represent volumes of sediment production during the budget period, depending on when the landslide first appeared and whether it enlarged during the budget period.
- Assumptions about the volumes of sediment delivery from landslide types or slope positions may be incorrect.
- Errors can be made in identifying landslides and in estimating sizes from aerial photographs.
- The two sources of landslide inventories differed slightly in assumptions, e.g. soil depth.
- It is difficult to accurately identify management activities associated with individual landslides generated by cumulative effects of land management activities above the landslides (e.g. failures within an inner gorge).
- Bank erosion causes cannot be accurately assigned to management or non-management activities.
- Surface erosion estimates cannot account for roads that are not included in the coverage, nor can it account for skid trails and landings unless they generated mass wasting failures.

Figure 7-2 illustrates the margin of safety reserved for the Crescent Uplands (CUP) and Sedimentary Inner Gorge (SIG) lithotopo units. Table 7-3 summarizes uncertainties from the sediment delivery source analysis. Adjustments that were made to account for these uncertainties are described.

<u>Figure 7-2</u>. Sediment Delivery Load Allocations for the CUP and SIG Lithotopo Units

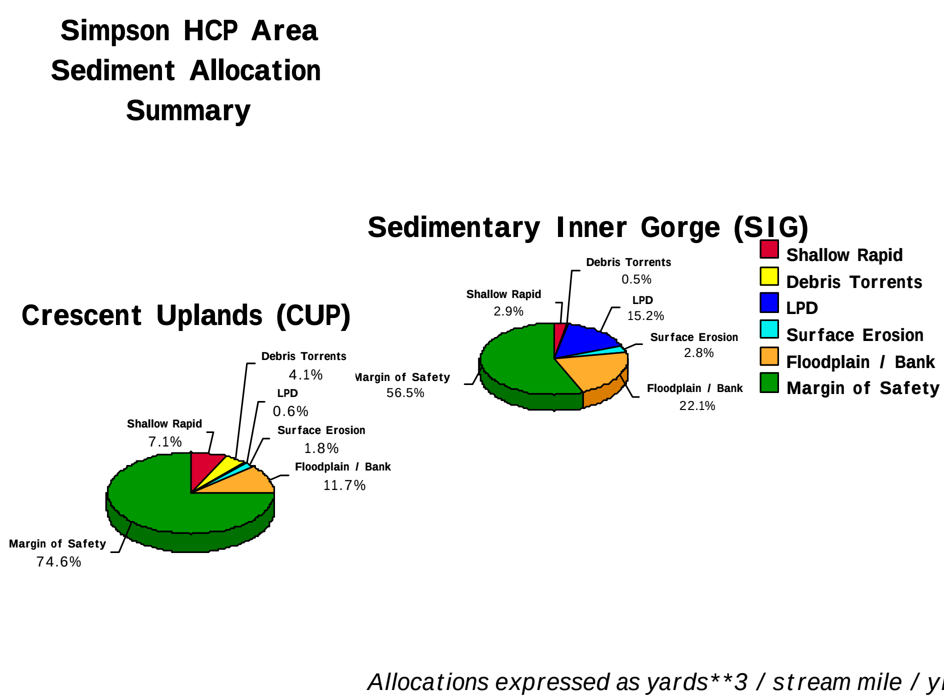


Table 7-3. Supporting Information for Sediment Delivery Margin of Safety

Uncertainties in TMDL	Adjustments to Account for Uncertainties
Instream indicators of sediment not used because of lack of site specific information for these parameters. Extrapolation of values derived from dissimilar areas may have limited relevance in development of instream targets for Simpson HCP area.	Once an HCP agreement is in place, the expectation is that such habitat information will be collected from the extensive monitoring program commitments made by Simpson. This issue can be revisited at year 10 of the plan implementation, and adjustments made, as deemed appropriate by the participants. Note that this alternative approach makes good use of the fundamental landscape and channel classification system Simpson has developed for the HCP.
The role of sediment storage in channel systems as both a source and sink for sediment is poorly understood.	The TMDL recognizes instream storage as a consideration in TMDL determination because current excessive levels of instream stored sediment are contributing to temperature increases in C-1 group. Because volumes already in the channel system are not controllable, an allocation has been designated. The uncertainty surrounding development of these targets is high. As a result, a relatively high margin of safety has been identified.

Adaptive Management

Establishing TMDLs employs a variety of analytical techniques. Some analytical techniques are widely used and applied in evaluation of source loading and determination of the impacts on waterbodies. For certain pollutants, such as heat and sediment, the methods used are newer or in development. The selection of analysis techniques is based on scientific rationale coupled with interpretation of observed data. Concerns regarding the appropriateness and scientific integrity of the analysis have been defined and the approach for verifying the analysis through monitoring and implementation addressed. Without the benefit of long term experience and testing of the methods used to derive TMDLs, the potential for the estimate to require refinement is high.

A TMDL and margin of safety which is reasonable and results in an overall allocation represents the best estimate of how standards can be achieved. The selection of the MOS can also clarify the implications for monitoring and implementation planning in refining the estimate if necessary (adaptive management). *"Adaptive management"* is often defined as the reliance on scientific methods to test the results of actions taken so that the management and related policy can be changed promptly and appropriately. The FACA report indicated that *"adaptive management involves setting goals and developing implementation plans based on existing data, providing for additional data gathering and monitoring of results achieved, and revising goals and implementation plans as appropriate in light of the subsequent data and monitoring"*.

The TMDL process accommodates the ability to track and ultimately refine assumptions within the TMDL implementation planning component. The *"Simpson HCP area TMDL"* is intended to be adaptive in management implementation. This plan allows for future changes in loading capacities and surrogate measures (allocations) in the event that scientifically valid reasons support alterations. It is important to recognize the continual study and progression of understanding of water quality parameters addressed in this TMDL (e.g. stream temperature, sediment, riparian condition, habitat). The Simpson HCP addresses future monitoring plans. In the event that data show that changes are warranted in the Simpson TMDL, these changes will be made.

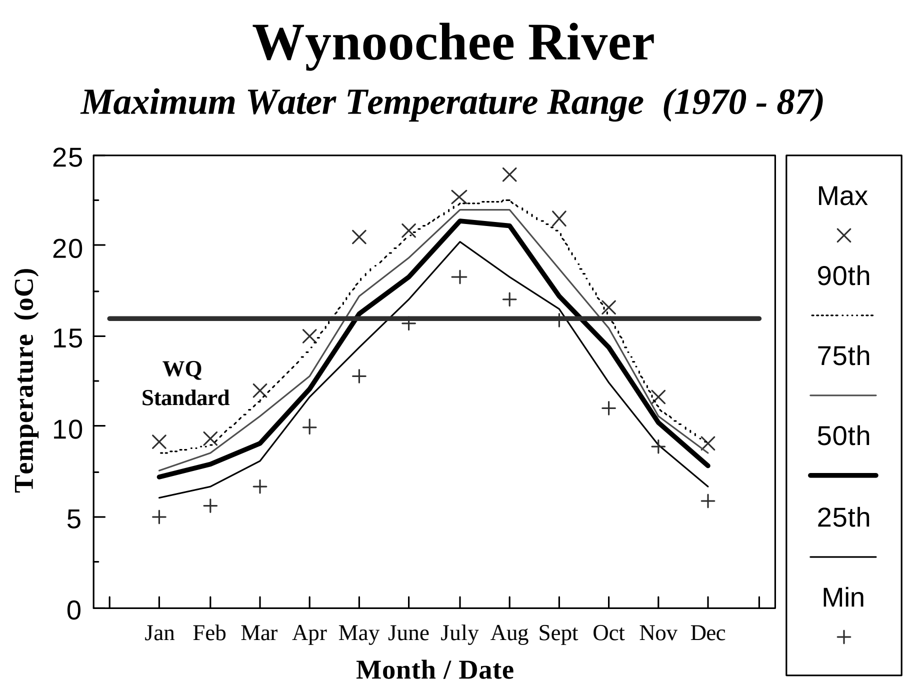
8. SEASONAL VARIATION

Section 303(d)(1) requires that TMDLs *"be established at level necessary to implement the applicable water quality standards with seasonal variations"*. The current regulation also states that determination of *"TMDLs shall take into account critical conditions for stream flow, loading, and water quality parameters" [40 CFR 130.7(c)(1)]*. In addition, §303(d)(1)(D) suggests consideration of normal conditions, flows, and dissipative capacity. This information is summarized in the following discussion.

Existing Conditions

Existing conditions for stream temperatures in the Simpson HCP area reflect seasonal variation. Cooler temperatures occur in the winter, while warmer temperatures are observed in the summer. Historical data has been collected by the U.S. Geological Survey (USGS) of stream temperatures in the Wynoochee River. Figure 8-1 summarizes the distribution of highest daily maximum water temperatures for each month between 1970 and 1987. Although the data was collected in the 1970's and 80's, it is the most comprehensive record for water temperature taken at one site over an extended period of time in the vicinity of the Simpson HCP area. As shown, water quality standards for temperature are only exceeded between May and October. In addition, the data shown in Figure 8-1 indicates that the highest seven-day average maximum water temperatures occur between mid-July and mid-August. This time frame is used as the critical period for development and analysis of allocations in the TMDL.

***Figure 8-1*.** Seasonal Variation of Wynoochee Temperature Levels



Stream Flow

Monthly flow data is another way to describe seasonal variation. As illustrated in Figure 8-2, flows peak in December as a result of winter storm runoff. Flows decline through the summer reaching baseflow conditions in August. Figure 8-3 depicts the variability of seven-day low flows using data from the Satsop River near Satsop. The seven-day low flow recurring every ten years (7Q10) is also shown in Figure 8-3. The USGS data has been used to describe the variation of 7Q2 values across the HCP area (Amerman and Orsborn, 1987). From this information, a relationship has been developed to estimate 7Q2 values for various LTU's within the HCP area.

Figure 8-2. Flow Patterns for Satsop River

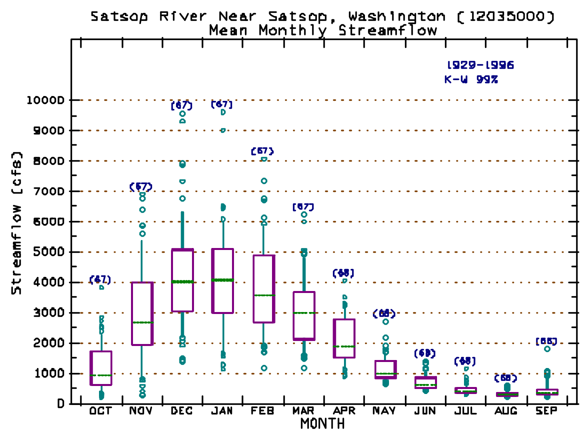
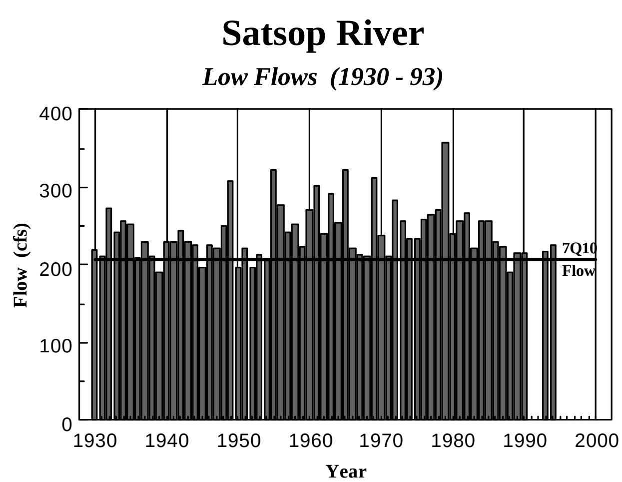


Figure 8-3. Satsop River Low Flow History



Solar Radiation

Potential solar radiation varies throughout the year. The highest value occurs on the first day of summer when the earth's tilt towards the sun is greatest. Figure 8-4 illustrates the effect of seasonal variation on shadow length associated with different tree heights. As shown, shadows are shortest in mid-June. Figure 8-5 illustrates the effect of seasonal variation on maximum potential solar radiation. Mid-June is the period when solar radiation values are at their peak. As a result, mid-June can be used a starting point for identifying the loading capacity for effective shade. This is the time that the water surface receives the maximum potential solar radiation and when riparian shade is least effective in reducing heat. This does add to the margin of safety because low flows and maximum water temperatures typically occur between mid-July and mid-August.

Figure 8-4. Seasonal Variation of Shadow Lengths

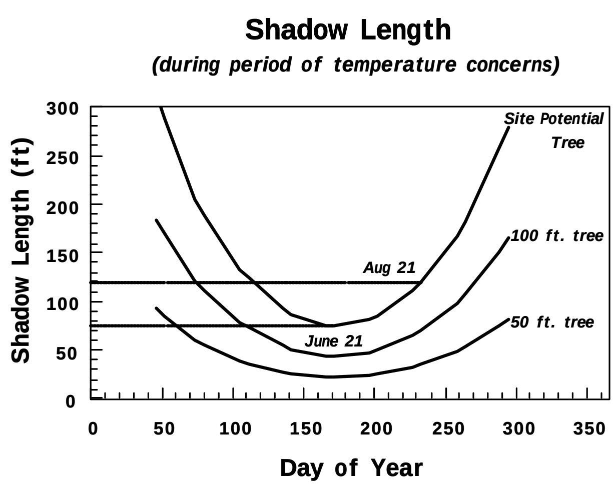
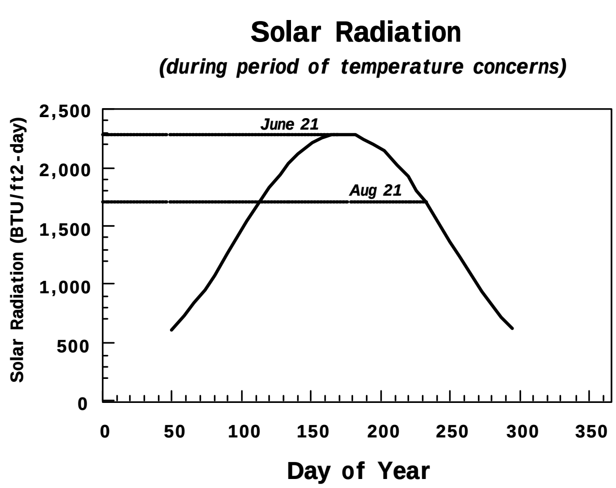


Figure 8-5. Seasonal Variation of Maximum Potential Solar Radiation



Critical Temperature Conditions

Estimates for streamflow, loading, and water quality parameters need to be taken into account in development of the TMDL. The analysis demonstrating the relationship of channel and riparian conditions to solar radiation loads requires a framework for identifying critical conditions. Based on historical data for the Wynoochee River *(Figure 8-6)*, the critical period used for the analysis is mid-July. This represents the time frame for which solar radiation is highest when the earliest summer maximum water temperatures were observed. This time frame is also consistent with water temperature data collected by Simpson *(Figure 8-7)*.

Figure 8-6. Wynoochee River Summer Water Temperatures

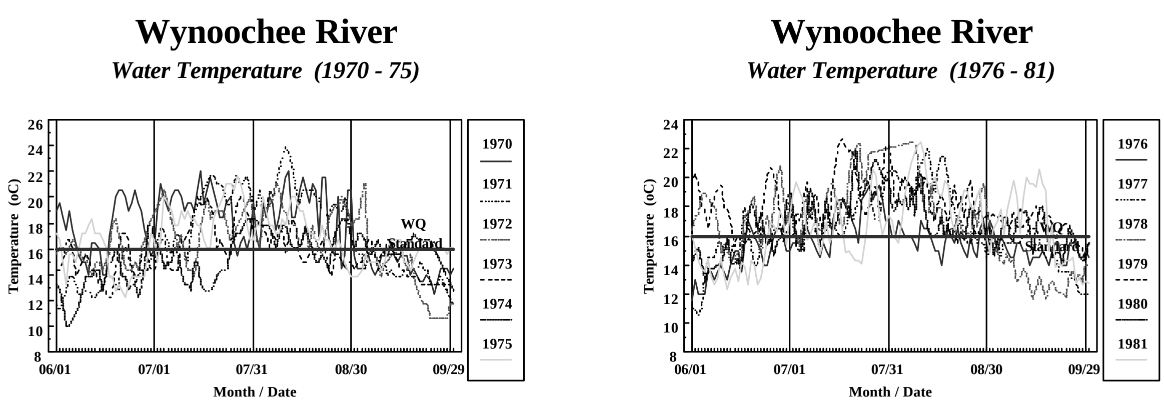
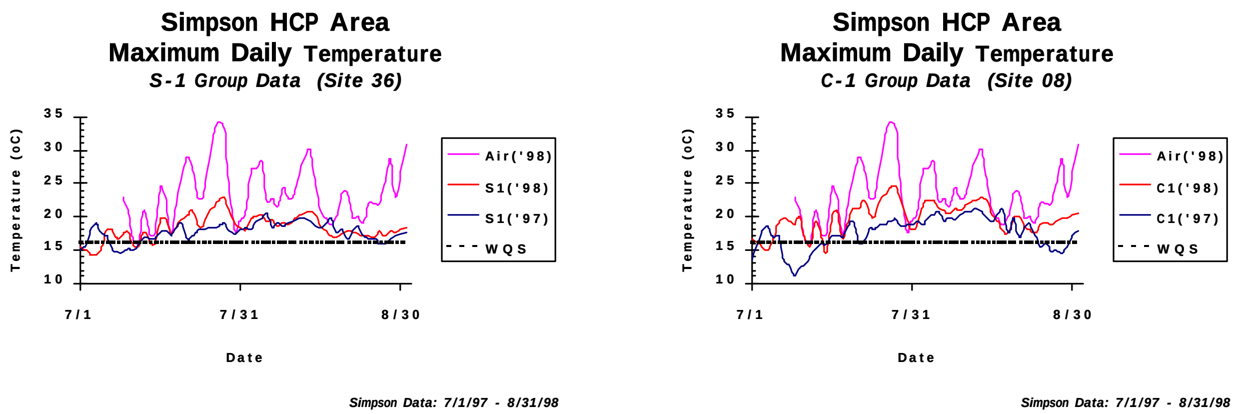


Figure 8-7. Simpson HCP Area Summer Water Temperatures

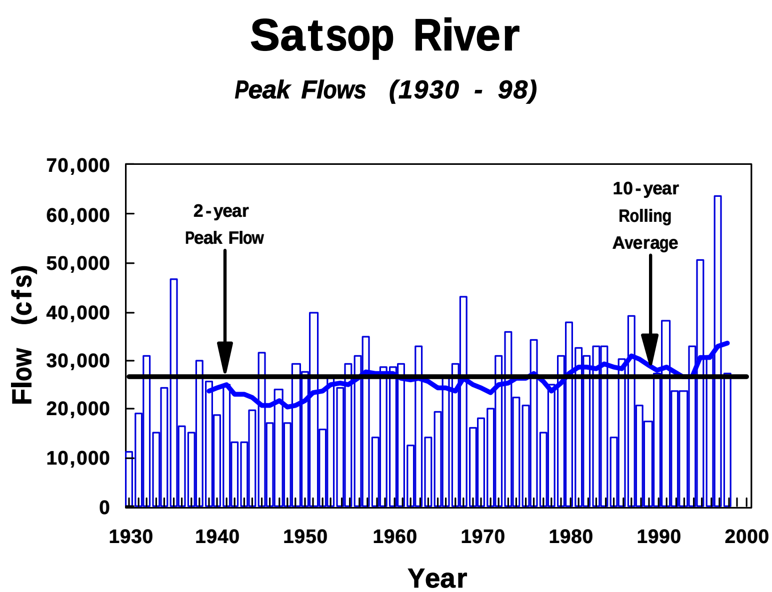


Streamflow estimates were identified using data from the USGS gage on the Satsop River near Satsop. Water yield for the 7-day low flow, 2-year recurrence interval (7Q2), which is also associated with the highest water temperatures observed at the gage, was used as a starting point. This represents a conservative approach and can be refined as additional flow data is collected in the Simpson HCP area. The same conservative approach was used to identify parameters for calculation of solar radiation load (e.g. cloud cover) and water quality (e.g. air temperature, upstream water temperature, etc). Given the importance of stream type in evaluating critical conditions, information will be collected by Simpson to characterize riparian and channel conditions in the HCP area.

Annual Variability and Sediment

It is important to discuss the annual variability of peak flows and its effect on sediment delivery. USGS (1971) described sediment yield in the Chehalis basin. Consistent with sediment studies in other areas, the report noted that the greatest percentage of sediment transport occurred during peak flows. Figure 8-8 shows the variation in peak flows for the Satsop River.

Figure 8-8. Satsop River Peak Flow History



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SECTION A
Water Quality Assessment --
Objectives and Approach

INTRODUCTION

Water quality is an important characteristic that affects the value of aquatic resources. These resources include rivers, streams, lakes, reservoirs, estuaries, and wetlands. The value of aquatic resources is reflected by their ability to support a variety of uses. The public is interested in quality water to supply domestic, agricultural, and industrial needs. Quality water is also important for recreational activities, such as swimming, boating, and fishing. Finally, aquatic life depends on suitable water quality for survival. Land management activities, combined with natural watershed processes, influence water quality which in turn affects these beneficial uses.

Management of water quality is carried out through of the Federal Clean Water Act (CWA). The primary objective of the CWA is to *"restore and maintain the chemical, physical, and biological integrity of the Nation's waters."* Taken together, the interaction of chemical, physical, and biological conditions define the overall ecological integrity of an aquatic system over time. Characteristics addressed include indicators such as dissolved oxygen concentrations, sediment, nutrients, temperature, and bacteria as well as habitat structure and processes, species composition, and diversity / abundance of aquatic dependent flora and fauna.

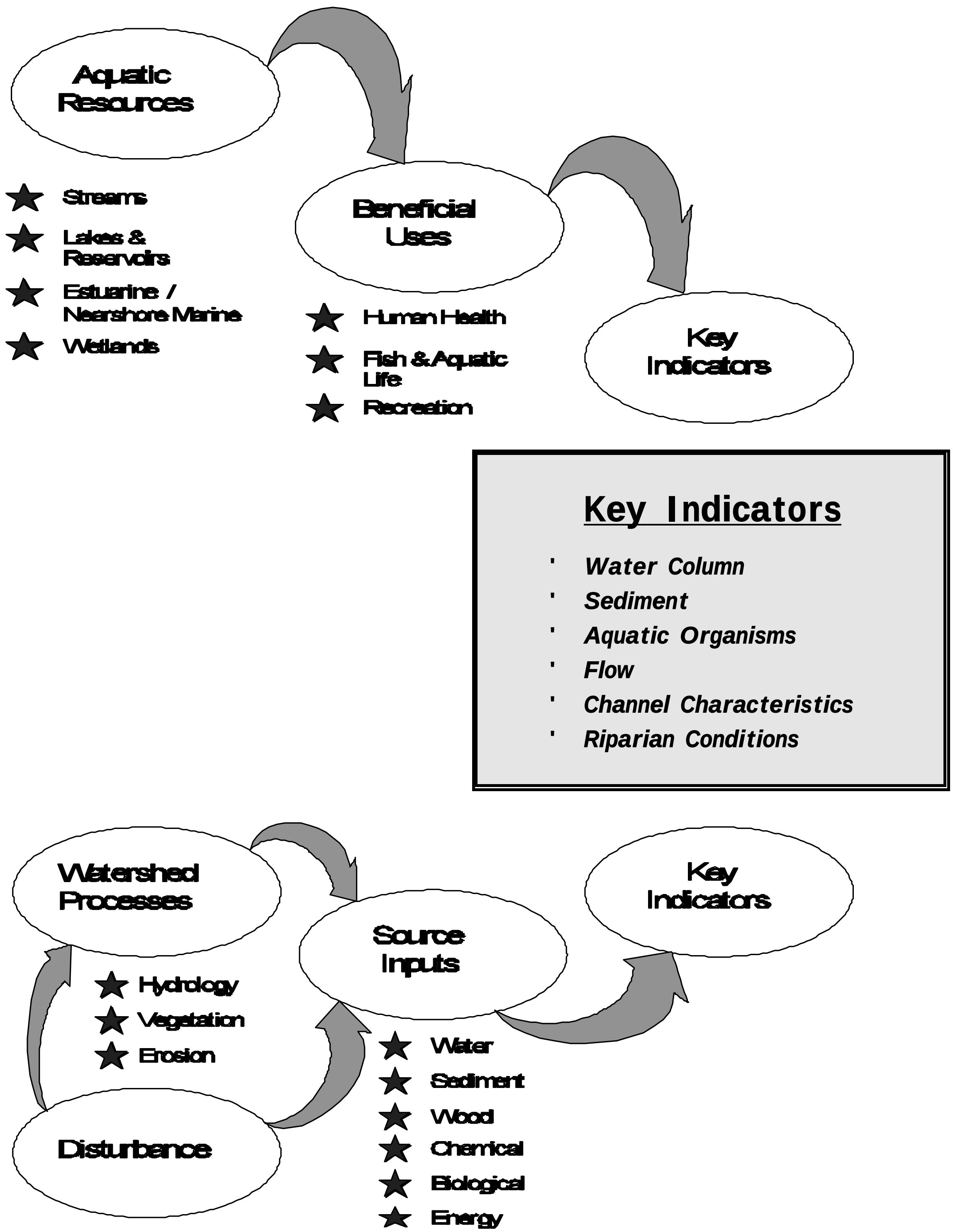
OBJECTIVES AND KEY QUESTIONS

The purpose of this assessment is to describe water quality in the Simpson Habitat Conservation Plan (HCP) area. Specifically, the water quality assessment is intended to:

- describe water quality concerns in the context of the setting, the aquatic resources, beneficial uses, applicable standards, and the condition of key indicators;
- evaluate pollution sources and disturbance activities that contribute to water quality problems; and
- outline water quality management needs including identification of those waters which still require total maximum daily loads (TMDLs).

Assessment of water quality is often viewed from two perspectives *(Figure A-1)*. The first centers on setting objectives. This involves describing the aquatic resources (i.e. streams, lakes, etc), the beneficial uses associated with these resources, and a set of indicators which reflect conditions. The objectives set are reflected in Washington's water quality standards. The second water quality assessment perspective relates to program management. Here, the focus is on how watershed processes and disturbance activities, through changes to input variables (e.g. sediment, water, wood, chemicals, etc.) affect beneficial uses as reflected through the same indicators used to assess conditions.

Figure A-1. Water Quality Assessment -- The Context



The following critical questions help frame the assessment of water quality in the Simpson HCP area:

- ***What beneficial uses dependent on aquatic resources occur in the watershed and which water quality parameters are critical to these uses?***
- ***What are the current conditions and trends of beneficial uses and associated water quality parameters?***
- ***What were the historic water quality characteristics of the subbasin?***
- ***What are the natural and human causes of change between historic and current water quality conditions?***
- ***What are the influences and relationships between water quality and other watershed processes in the subbasin (e.g. mass wasting, fish habitat, stream channel, etc.)?***

Subbasin Scale

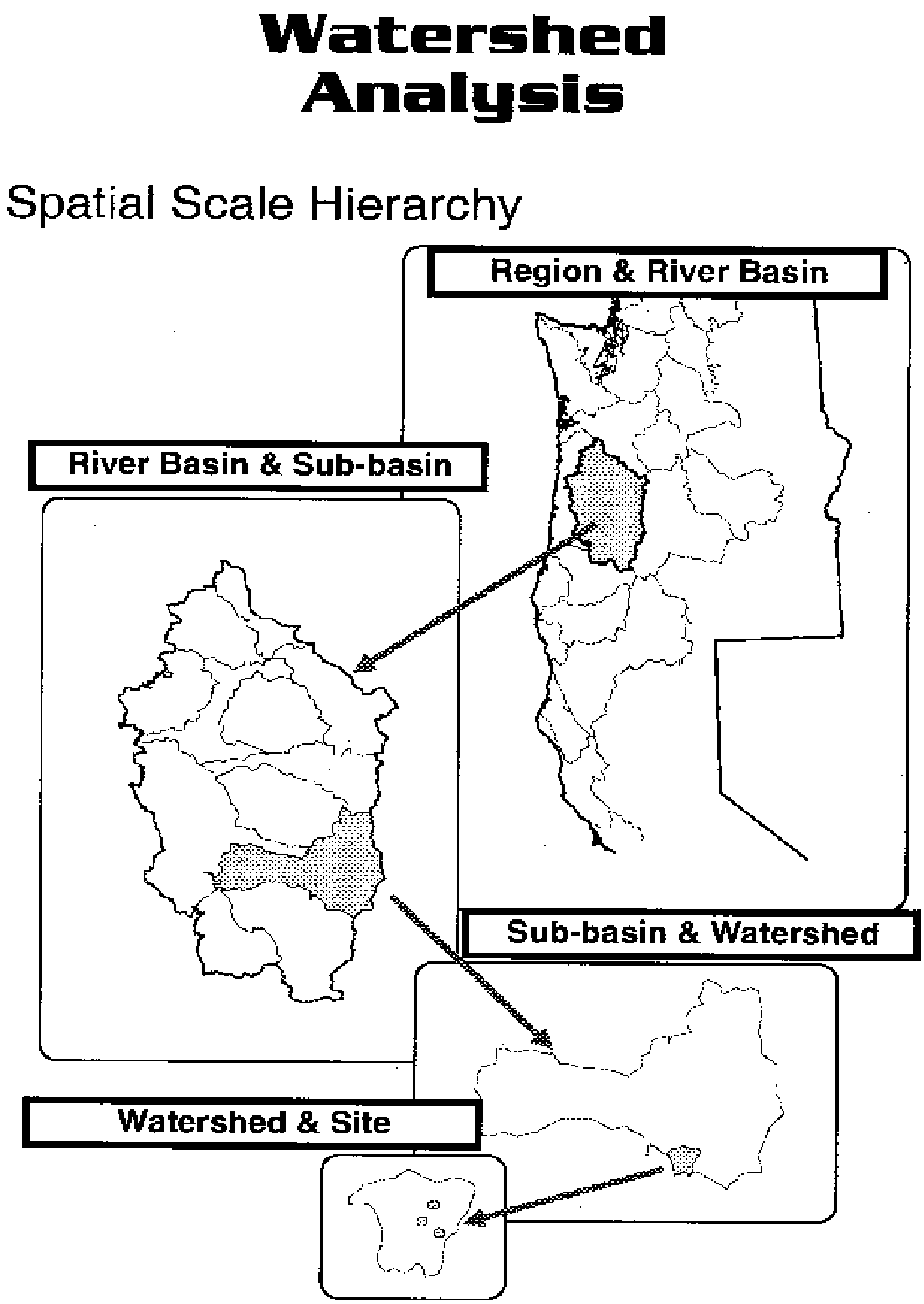
Water quality assessment is not a rigid, *"one-size-fits-all"* approach. Watershed management can be conducted at several scales (or resolutions) to meet a variety of needs. Different scales of watershed management units are utilized. The Department of Ecology, charged with managing water quality in Washington, divides the state into Water Resource Inventory Areas (WRIAs) and manages water quality basin-wide. Local governments, on the other hand, concerned about protecting source water supplies, for instance, focus on watersheds that drain to surface- or ground-water supply intakes or recreational areas.

Watershed cataloging units reflect scales of resolution, with small subwatersheds nesting within larger watersheds that nest within subbasins which nest within river basins *(Figure A-2)*. Different agencies collect and assess data for analysis efforts at all scales of resolution. Using a common set of geographic management units for assessment greatly improves opportunities for sharing data and coordinating management activities. This coordination is particularly important when using Geographic Information Systems (GIS) technology, which has the capability to scale up or down. The U.S. Geological Survey (USGS) has developed an 8-digit system of hydrologic cataloging units (HCUs or HUCs). These units, referred to from here on as subbasins, also provide a foundation for CWA assessments. The Simpson HCP area lies within three USGS subbasins: the Lower Chehalis (17100104), the Skokomish (17110017), and Puget Sound (17110019).

REGULATORY FRAMEWORK

Within the State of Washington, water quality standards are published pursuant to Chapter 90.48 of the Revised Code of Washington (RCW). Authority to adopt rules, regulations, and standards as are necessary and feasible to protect the environment and health of the citizens of the State is vested with the Department of Ecology. Through the adoption of water quality standards, Washington has identified the designated uses to be protected in each of its drainage basins and the criteria necessary to protect these uses Water quality standards are located in Chapter 173-201 of the Washington Administrative Code (WAC).

Figure A-2. Water Quality Assessment -- Scales of Resolution



Washington also has a comprehensive framework in place for the Department of Ecology to monitor state waters and implement pollution control strategies, including development of total daily maximum loads (TMDLs). Waterbodies not fully supporting beneficial uses are prioritized depending upon the severity of pollution and the uses of the water. These waters are then subject to TMDL development or equivalent processes consistent with the Clean Water Act and Washington law. For these waters, appropriate limitations are placed on point sources. In addition, appropriate changes are made to best management practices (BMPs) for nonpoint sources.

APPROACH

The water quality assessment attempts to identify, for waterbodies occurring in the drainage, those situations where beneficial uses dependent on water quality are impaired, or are likely to be impaired, as a result of disturbance activities. The approach taken in preparing these assessments is to summarize information on water quality within the watershed(s). The subbasin assessment is then used to support watershed analyses and TMDL development within the subbasin. The water quality assessment consists of three components which follow as a separate section for each. These include:

- Characterization (Section B)
- Condition Assessment (Section C)
- Interpretation (Section D)

The focus of these subsequent efforts is then used to evaluate information on how water quality within the watershed is affected by the cumulative effects of disturbance activities and to develop solutions to problems and concerns. In particular, the assessment describes technical considerations for developing appropriate measures for water quality-based controls which include:

CONSIDERATIONS -- Developing Appropriate Measures	
CONDITIONS	***Normal water quality conditions***, *i.e. a condition assessment using appropriate indicators.*
FLOWS	***Flow rates*** *affect water quality. Analysis of hydrology, as appropriate to concern.*
VARIABILITY	***Seasonal variations*** *are important, both in terms of timing of beneficial uses and effects on water quality. Seasonal considerations allow the proper time frame to be applied.*
INPUTS	***Existing source inputs***, *or other appropriate source inputs should be put in perspective to develop solutions.*
WATER TYPE	***Dissipative capacity*** *is affected by the water type.*

SECTION B
Characterization

Characterization
Index

The purpose of this characterization is to provide background information about the Simpson Habitat Conservation Plan (HCP) area, particularly those aspects important to development of the Total Maximum Daily Load (TMDL). The intent is to summarize basic information on physical characteristics, land use, aquatic resources, beneficial uses, land ownership, and available data. This characterization focuses on the question: ***"What beneficial uses dependent on aquatic resources occur in the watershed and which water quality parameters are critical to these uses?"*** In addressing this question, subtopics considered include:

Characterization --- *Other Considerations*

What characteristics in the watershed are important to water quality?

- What waterbodies and beneficial uses occur in the watershed and where are they located?
- Which water quality parameters best reflect the condition of beneficial uses in the watershed relative to development of water quality-based controls?

SETTING

This Simpson HCP area water quality assessment has been developed to address fisheries concerns on several tributaries of the lower Chehalis and Skokomish Rivers as well as several streams draining to South Puget Sound and Hood Canal. The assessment uses information from a Habitat Conservation Plan prepared by Simpson Timber Company (STC) for 80 percent of its holdings in the State of Washington. Simpson proposes to manage approximately 261,575 acres of its Northwest Timberlands pursuant to the HCP. These forested watersheds include Simpson's commercial timberland in Thurston, Mason, and Grays Harbor counties. The plan area lies near Shelton, north of Highway 8 and west of Highway 101 *(Figure B-1)*.

The plan area includes nearly 1,400 miles of streams that drain STC lands bordering the southern extent of the Olympic Mountains. Salmon, steelhead, and cutthroat trout occur throughout Simpson HCP area watersheds. Significant fish-bearing streams within the HCP area encompass major northern drainages to the Chehalis River including the Wynoochee River, the Satsop River and key tributaries (West Fork, Middle Fork, East Fork, Canyon River, Bingham Creek, Stillwater River). Smaller portions of the HCP area include several Skokomish River tributaries as well as streams draining to South Puget Sound (i.e. Goldsborough and Kennedy Creeks) and Hood Canal.

***Figure B-1*.** Vicinity Map of Simpson HCP Area

Insert map from WMF Zip

PHYSICAL CHARACTERISTICS

Climate

Climate in the Simpson HCP area is mild and moist due to air masses that advance inland from the Pacific Ocean. The strong maritime influence includes seasonal changes that result from shifts in the pathways of the dominant westerly tradewinds. Major rain and wind storms that occur in the fall and winter most often approach the Olympic Peninsula from the Pacific Ocean following a southwest-to-northeast path. Winters (generally mid-October through mid-March) are influenced by low pressure systems and associated storms. These storms may develop into "superstorms" that can bring occasional devastating winds. Northerly shifts in the westerly tradewinds result in relatively dry summers.

Rainfall ranges from 40 inches in the low elevations to over 160 inches in the upper areas. Seasonal and annual variations in precipitation are evident based on data collected at Wynoochee Dam from 1971 to 1998. Precipitation patterns in the Wynoochee are similar to those in much of the Simpson HCP area. The weather station is located at the west end of the HCP area at an elevation of 820 feet. Precipitation at the station is concentrated in the winter months beginning in October with few breaks in wet weather until April or May. Monthly averages range from a low of 2.7 inches in July to 25 inches in November. Air temperatures at the station are somewhat moderate, averaging from around 38EF in December and January to about 61EF in July and August.

Landform

Landforms vary across the Simpson HCP area. The influences of the geologic setting and associated physical processes that affect aquatic habitats have been captured in the HCP by stratifying the landscape into *"lithotopo units"* (LTUs). The HCP area has been divided into five LTUs that share similar erosional and channel forming processes. The LTUs include:

- Alpine glacial (AGL)
- Crescent islands (CIS)
- Crescent uplands (CUP)
- Recessional outwash plain (ROP)
- Sedimentary inner gorges (SIG)

LTU boundaries are determined by geology, geological history, and topographic relief. Summaries of characteristics for each LTU are found in the HCP.

Geology and Soils

Geology within the Simpson HCP area is marked by sharp contrasts. Major geologic units have been incorporated into the HCP channel classification system. Geologic units include:

C = Crescent formation basalt
L = Lincoln formation siltstones and mudstones
M = Montesano formation sandstone
Qa = Alluvial sediments
Qc = deposits of continental glaciers
Qo = deposits of Olympic alpine glaciers

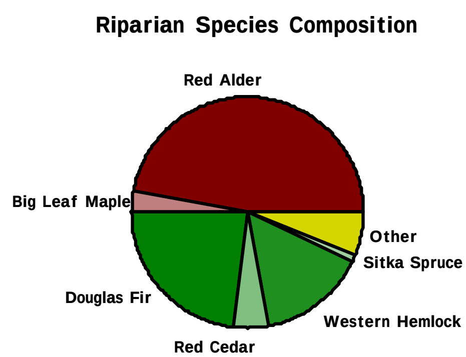
Vegetation

Potential vegetation on the south side of the Olympic mountains falls into five zones. These include (from low to high): Sitka Spruce, Western Hemlock, Silver Fir, Mountain Hemlock, and Subalpine zones. Moist maritime plant associations are more common than dryer associations in each zone. The Sitka Spruce Zone occupies the lower valleys and foothills where maritime fog is common. The Silver Fir Zone and above are the areas of permanent winter snowpack. The Subalpine Zone is the area where snowpacks are too deep and last too long to permit all but minimal tree growth.

Current plant communities are younger and more fragmented than past plant communities. Young stands lack structural and biological diversity that was present in older stands. Clearcutting, slash burning, and replanting have resulted in a greater proportion of Douglas fir and red alder on the landscape than was present historically. Major vegetation disturbance regimes in the past were fire, wind, flooding (including channel migration), snow avalanche, and mass wasting. Although these factors still exist in the HCP area, timber harvest and associated road construction have become the most important disturbance regimes.

Riparian vegetation in the Simpson HCP area ranges from hardwood stands (red alder, big leaf maple) to conifers (Douglas fir, western hemlock) of varying ages. In 1996, Simpson conducted a monitoring project of 30 riparian sites in the HCP area. A summary of information collected on species composition is shown in Figure B-2.

***Figure B-2*.** Simpson HCP Area Riparian Vegetation Composition



LAND USE

Land use in the HCP area is predominantly commercial forest. Upper portions of the watersheds where the HCP area is located originate in the Olympic National Park and Olympic National Forest. Some valley bottom land in these watersheds consist of small farms.

AQUATIC RESOURCES

Aquatic resources in the Simpson HCP area are summarized in Table B-1.

***Table B-1*.** Aquatic Resources -- Simpson HCP Area

LTU	**Watershed Name**	**Area (mi^2)**	**Waterbody Type**		
			Streams (mi.)	**Lakes & Ponds** (acres)	**Wetlands** (acres)
AGL	Alpine Glacial	34.6	137.7		nn.n
CIS	Crescent Islands	48.4	163.7		
CUP	Crescent Uplands	43.5	265.2		nn.n
ROP	Recessional Outwash Plain	183.7	376.7		nn.n
SIG	Sedimentary Inner Gorge	98.5	454.5		nn.n

Stream characteristics within the Simpson HCP area vary across the landscape. Although there is very little streamflow data available for the HCP area, methods have been developed to estimate flow from basin area for the Olympic Peninsula (Amerman and Orsborn, 1987). The channel classification system described in the HCP identifies streams as being small (active channel width # 4m), medium (4m < active channel width # 16m), or large (active channel width > 16m). Figure B-3 illustrates the relationship between drainage area and channel width in the Simpson HCP area. Table B-2 summarizes drainage characteristics in the HCP area by LTU.

***Figure B-3*.** Simpson HCP Area

Drainage Area / Active Channel Width Relationships

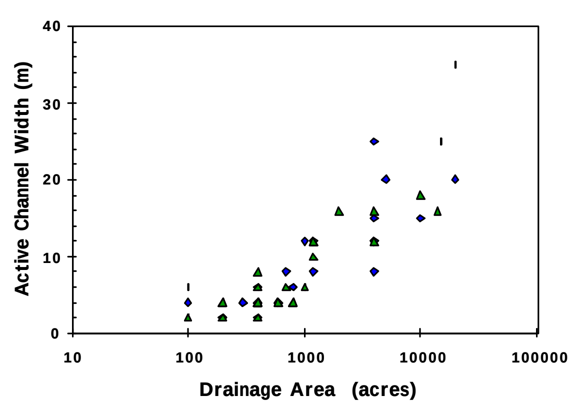


***Table B-2*.** Lithotopo Unit / Drainage Characteristics

Lithotopo Unit	HCP Area	Stream Miles	Density *(mi / mi²)*	Yield *(cfs / mi²)*	Inflow *(cfs / mi)*
AGL	8%	137.7	3.98	1.0	0.251
CIS	12%	163.7	3.38	0.5	0.148
CUP	11%	265.2	6.10	1.0	0.164
ROP	45%	376.7	2.05	0.3	0.146
SIG	24%	454.5	4.61	1.0	0.217

- Flow yield estimated for each LTU from Amerman and Orsborn, 1987 (Figure 10-5). Represents seven-day, two-year (7Q2) low flow based on Olympic Peninsula gage information.
- Inflow is the flow yield divided by the drainage density to provide a rough estimate of flow derived per mile of stream (rough indicator of potential groundwater contribution).

BENEFICIAL USES / APPLICABLE STANDARDS

Aquatic Life

The primary designated use requiring protection in the Simpson HCP area is aquatic life. Thirty aquatic species have been specifically identified for Endangered Species Act (ESA) coverage and conservation under provisions of the HCP. The aquatic species list is composed of species that are either entirely dependent on aquatic habitat or are closely associated with the margins of channels and riparian habitats for all or a portion of their life. These species include all of the salmonids, stream breeding amphibians, VanDyke's salamanders, two species of lamprey, and the western toad.

Primary native salmonid species include coho, chinook, chum, steelhead, coastal cutthroat trout, resident rainbow trout, mountain whitefish, and the non-native Eastern brook trout. Distribution of the species is very broad in the HCP area. Current distribution is similar to the historical areas used by salmonids except where culverts block migration. Coho use many of the tributaries for spawning and rearing. Cutthroat trout may occur well up into high gradient tributaries. The HCP provides more detail on current and historic species distribution of native salmonids.

Within the HCP, aquatic species have been grouped by "*associations*" that represent groups of species occupying similar reach or segment levels of the channel network (e.g. headwater species association, steep tributary species, flat tributary species, mainstream species, and lentil species). This grouping facilitates the association of species with such landscape features as the dominant hillslope and channel processes that are associated with different reaches of the channel network. As such, these groupings provide insight into the formative processes for their habitats. Because management prescriptions are targeted at forest management activities that often upset the natural balance of these processes, groupings also establish a linkage between species associations and management prescriptions.

Applicable Water Quality Standards

Within the State of Washington, water quality standards are published pursuant to Chapter 90.48 of the Revised Code of Washington (RCW) and are located in Chapter 173-201 of the Washington Administrative Code (WAC). In Washington, *"specific fresh waters of the state of Washington are classified ..." [WAC 173-201-080]*. The Simpson HCP area lies within the Satsop (East Fork, Middle Fork, West Fork), Skokomish, and Wynoochee drainages. WAC 173-201-080 identifies these watersheds as class *"AA"*. Water quality standards not to be exceeded are described in WAC 173-201-045. For class *"AA"* streams:

> *"Temperature shall not exceed 16.0EC (freshwater) or 13.0EC (marine water) due to human activities. ... When natural conditions exceed 16.0EC (freshwater) or 13.0EC (marine water), no temperature increase will be allowed which will raise the receiving water temperatures by greater than 0.3EC" [WAC 173-201A-045(1)(c)(iv)].*

The applicable water quality standard for sediment states:

> *"deleterious material concentrations shall be below those which may adversely affect characteristic water uses ..." [WAC 173-201A-045(1)(c)(vii)].*

Finally, during critical periods, natural conditions may exceed the numeric criteria for temperature identified in the water quality standards. In these cases, the following applies:

> *"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" [WAC 173-201A-070(2)].*

LAND OWNERSHIP

The HCP area generally consists of a contiguous block of Simpson land surrounded by a matrix of lands owned by federal, state, tribal governments, large timber companies, and small private landowners. The HCP provides a map of these ownerships and their location relative to the Plan area. The following provides a general overview land ownership patterns and their percentage of total lands within five miles of the HCP boundary.

- Northern Boundary: Olympic National Forest (95%); City of Tacoma (3%); small landowners (2%).
- Western Boundary: Weyerhaeuser (32%); Rayonier (30%); John Hancock Mutual Life Insurance (15%); Olympic National Forest (10%); City of Aberdeen (5%); Port Blakely Tree Farms L.P. (3%); Mason County (2%); small landowners (2%); and Washington Department of Fish & Wildlife (1%).
- Southern Boundary: Weyerhaeuser (35%); Washington State Department of Natural Resources (25%); Port Blakely Tree Farms (20%); small landowners (20%).
- Eastern Boundary: Small landowners (95%); Skokomish Tribe (5%).

These lands encompass usual and accustomed fishing areas of the Quinalt, Squaxin, Skokomish, and Port Gamble S'Klallam tribes.

AVAILABLE DATA

Temperature conditions in the Simpson HCP area reflect the range of watershed characteristics, interannual variation, and the effect of management activities. Table B-4 identifies monitoring sites which were used to assess water temperature conditions in the Simpson HCP area.

***Table B-4*.** Temperature Monitoring Sites

Group	Validation Site					Maximum Temperature	
	ID	Class	Name	*(acres)*	Shade	1997	1998
S-1	36	ROP-Qc3	Glenn Creek	1,777	90 - 95%	20.47EC	22.89EC
S-2	14	SIG-M4	Bell Creek	763	80%	16.22EC	18.60EC
S-3	79	CIS-Qc3	Gosnell Creek	2,240	85%	14.96EC	16.61EC
S-4	13	AGL-Qo6	Schafer Creek	3,997	90%	14.18EC	16.00EC
G-1	32	ROP-Qc5	Bingham Creek	9,959	65 - 70%	14.46EC	17.22EC
G-2	29	CUP-C4	N. Mountain Creek	893	95%	13.71EC	16.00EC
C-1	8	SIG-L4	Canyon River	12,942	20%	21.18EC	24.55EC

Table B-5 identifies sites where the U.S. Geological Survey (USGS) has collected water resource data, either in or near the Simpson HCP area.

***Table B-5a*.** USGS Data -- Simpson HCP Area

Gage ID	Gage Name	River Mile	Area	Elev.	Flow Period of Record	Other WQ Data
12032500	Cloquallum Creek at Elma		64.9 mi^2		1942 - 72	
12033500	E.F. Satsop River near Matlock		23.7 mi^2		1945 - 47	
12034000	Bingham Creek near Matlock				1946 - 48	
12034200	E.F. Satsop River near Elma		65.9 mi^2		1957 - 71	
12034500	M.F. Satsop near Satsop					
12035000	Satsop River near Satsop	2.3	299 mi^2	20	1929 - 98	[WQ Records]

***Table B-5b*.** USGS Data -- Simpson HCP Area

Gage ID	Gage Name	River Mile	Area	Elev.	Flow Period of Record	Other WQ Data
12035400	Wynoochee River near Grisdale	51.3	41.3 mi^2	630	1965 -	
12035450	Big Creek near Grisdale	0.6	9.57 mi^2	600	1972 - 96	
12036000	Wynoochee above Save Creek	40.6	74.1 mi^2	401	1925 -	
12036400	Schafer Creek near Grisdale	1.0	12.1 mi^2	280	1986 - 96	
12036650	Anderson Creek near Montesano	1.0	2.72 mi^2	150	1972 -	
12037400	Wynoochee above Black Creek	5.9	155 mi^2	40	1956 -	[WQ Records]
12059800	S.F. Skokomish near Hoodsport		26.0 mi^2		1963 - 70	
12060000	S.F. Skokomish near Potlatch		65.6 mi^2		1923 - 32 1946 - 64	
12060500	S.F. Skokomish near Union	3.2	76.3 mi^2	103	1931 -	
12061500	Skokomish River near Potlatch	5.3	227 mi^2	11	1943 -	[WQ Records]

SECTION C
Condition Assessment

Condition Assessment
Index

OVERVIEW

After characterization, the next level of water quality analysis involves assessing conditions of waterbodies using key indicators (or parameters). The focus of the condition assessment is to answer the questions: ***"What are the current conditions and trends of beneficial uses and associated water quality parameters?"*** and ***"What were historic water quality characteristics of the watershed?"***. In addressing this question, other subtopics could be considered which include:

Condition Assessment --- *Other Considerations*

Are waterbodies within the subbasin adversely affected by water quality based on information about current and past conditions?

- How does water quality in the watershed compare to State Water Quality Standards?
- What do current conditions or changes from past conditions indicate about the effect of input variables on the function of waterbodies?

EXISTING DATA

Flow

The U.S. Geological Survey (USGS) has collected streamflow data at several locations in the HCP area. The longest continuous record for flow data is the USGS gage on the Satsop River near Satsop (12035000). Figure C-1 depicts seasonal patterns. Highest flows occur in December and January while the lowest flows are typically in August and September. Figure C-2 shows both peak and low flow history for the Satsop gage.

***Figure C-1*.** Flow Patterns for Satsop River

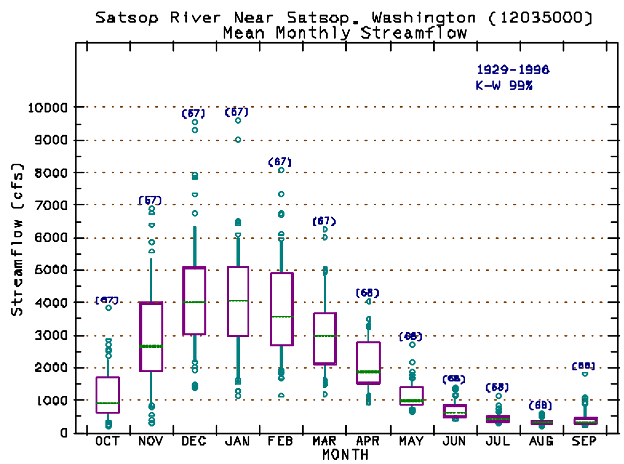
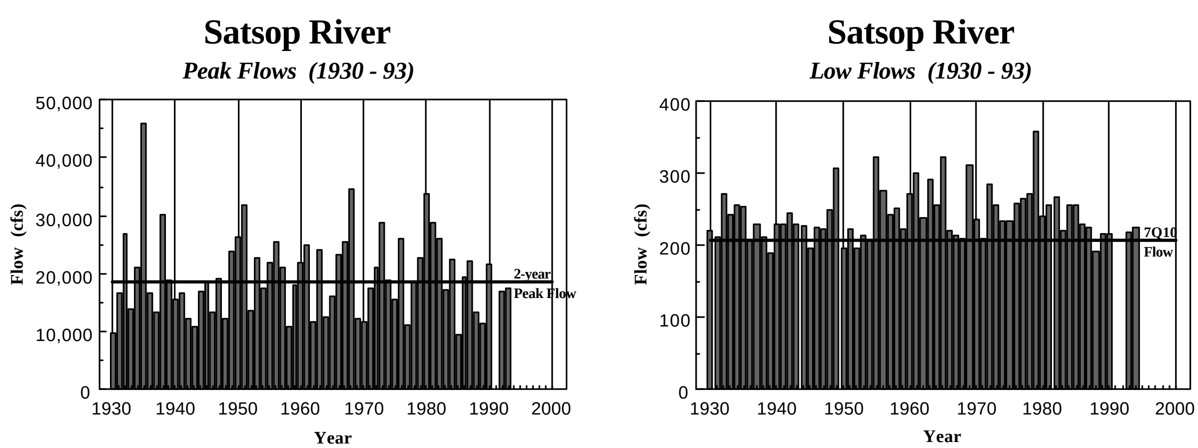


***Figure C-2*.** Satsop River Peak and Low Flow History



Stream Temperature

Stream temperatures have been monitored by Simpson. Temperature conditions in the HCP area are influenced by several dominant controls which include shade, groundwater flow, and channel morphology. The channel classification system, described in the HCP and in Section D of this technical report, has been used to group stream reaches by the dominant control(s) that affect water temperature. Figures C-3 through C-6 show conditions for those temperature groups where shade is the dominant control. Conditions for those temperature groups where groundwater is the dominant control are shown in Figures C-7 and C-8. Figure C-9 shows conditions for the temperature group where channel morphology is the dominant control.

Group S-1. These are small to medium sized pool riffle and forced pool riffle / plane bed channels of the ROP and SIG. Water temperature is driven by shade and low flows (poor water storage in these watersheds over glacial tills and shallow soils). Headwaters of these systems are usually in wetlands or bogs and beavers frequently pond water within the channel. Table C-1 identifies those channel classes which comprise temperature group S-1. Several basic characteristics associated with each channel class in this group are also summarized.

Table C-1. Characteristics of Temperature Group S-1

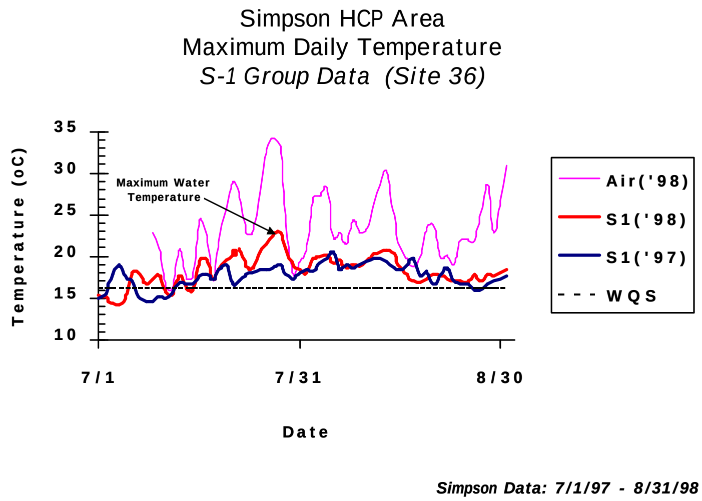
LTU	Class	mi.	Basin Area *(acres)*	Active Channel Width *(m)*	Slope	RMS	Stream(s)
ROP	Qc1	167.3	100 - 400	2 - 4	0.5 - 2%	U/I	Overlook Creek
	Qc2	103.4	100 - 400	2 - 4	2% - 6%	BIS	*Frigid*
	Qc3	44.2	400 - 4,000	6 - 12	0.5% - 2%	TS	Glenn, *Beaver, Dry Bed, Outlet, Bingham*
SIG	Qc3	9.1	300 - 1,200	4 - 10	2% - 16%	TS	
Total		324.0					

- **P** Small (CMZ # 4m) to medium (4 < CMZ # 12m) channels
- **P** Continental glacial till landscape
- **P** Low elevations of HCP area (largely ROP)
- **P** Moderate to unconfined channels (W:D # 25)
- **P** Low flow range: 0 - 4 cfs (drainage area < 10 mi^2)

ROP-Qc3	Glenn Creek – 8/5/97	16.61 ==> 20.47EC	1,777 acres
	7/28/98	18.91 ==> 22.89EC	90 - 95% shade

Monitoring data collected in Glenn Creek *(Site 36)* is used to summarize temperature group S-1. Figure C-3 compares daily maximum water temperatures observed on Glenn Creek for 1997 and 1998 along with 1998 air temperature data. Daily maximum temperatures observed in 1997 included 61 days that the 16.0EC water quality criteria was exceeded. In 1998, there were 68 days that exceeded this value.

Figure C-3. Maximum Water Temperature Patterns: Group S-1



Group S-2. These are small to medium sized channels in the AGL and SIG. These systems most often have hardwood dominated riparian systems and subtle groundwater influence through wet side slopes. They are subject to heating with the loss of riparian shade which can happen through damage to riparian leave areas by natural factors or through insufficient leave area. Table C-2 identifies those channel classes which comprise temperature group S-2. Several basic characteristics associated with each channel class in this group are also summarized.

Monitoring data collected in Bell Creek *(Site 14)* is used to summarize temperature group S-2. Figure C-4 compares daily maximum water temperatures observed on Bell Creek for 1997 and 1998 along with 1998 air temperature data. Daily maximum temperatures observed in 1997 included 4 days that the 16.0EC water quality criteria was exceeded. In 1998, there were 19 days that exceeded this value.

Figure C-4. Maximum Water Temperature Patterns: Group S-2

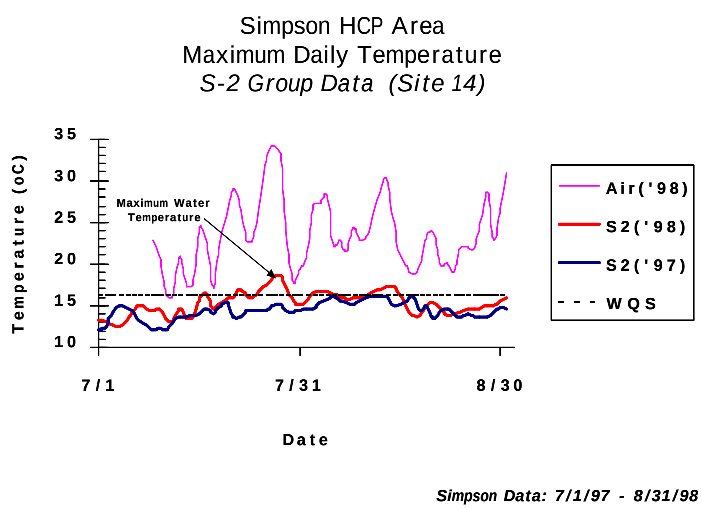


***Table C-2*.** Characteristics of Temperature Group S-2

LTU	Class	mi.	Basin Area *(acres)*	Active Channel Width *(m)*	Slope		Stream(s)
AGL	Qo2	22.5	< 200	< 2	0.5 - 2%	U/I	
	Qo4	2.6	300 - 700	4 - 6	2.5 - 4%	RBIS	
SIG	L1	160.0	< 400	0 - 2	4 - 32%	U/I	
	L2	38.5	< 400	2 - 4	1.5 - 4%	RBIS	
	L3	6.3	400 - 800	2 - 4	4 - 16%	BIS	
	M1	67.8	< 100	1 - 2	> 8%	U/I	
	M2	18.5	100 - 600	2 - 4	2 - 8%	U/I	
	M3	9.6	600 - 1,200	4 - 12	1 - 4%	ABT	Replinger
	M4	6.0	600 - 1,200	4 - 12	1 - 4%	ABT	Sandstone
	M6	2.3	> 1,000	6 - 12	0.5 - 2%	CM	Cook
	Qo2	19.0	200 - 800	2 - 4	2 - 4%	U/I	Stouder Cr., Sandstone tr.
Total		353.1					

- **P** Small (CMZ # 4m) to medium (4 < CMZ # 12m) channels
- **P** Lincoln siltstone, Montesano sandstone, Continental glacial till landscape
- **P** Moderate elevations of HCP area (largely AGL and SIG)
- **P** Moderate to unconfined channels (12 < W:D # 25)
- **P** Low flow range: 0 - 2 cfs (drainage area < 2 mi^2)

SIG-M4 Bell Creek – 8/11/97		13.56 ==> 16.22EC	763 acres
	7/28/98	15.70 ==> 18.60EC	80% shade

<u>Group S-3</u>. These are small to medium sized streams in the recessional outwash sediments of the CIS and SIG. These channels have low summer flows, but the storage and character of the flows is different from the ROP in that lower terraces, floodplains, and valley walls of these systems are composed of fine, but fairly well draining unconsolidated outwash sediments. These materials do not store great quantities of water. However, there is a slow release of groundwater that appears to moderate temperatures, but it is not sufficient to offset heating as a result of riparian canopy loss. With loss of shade, these streams can heat up to moderate levels. Table C-3 identifies those channel classes which comprise temperature group S-3. Several basic characteristics associated with each channel class in this group are also summarized.

Table C-3. Characteristics of Temperature Group S-3

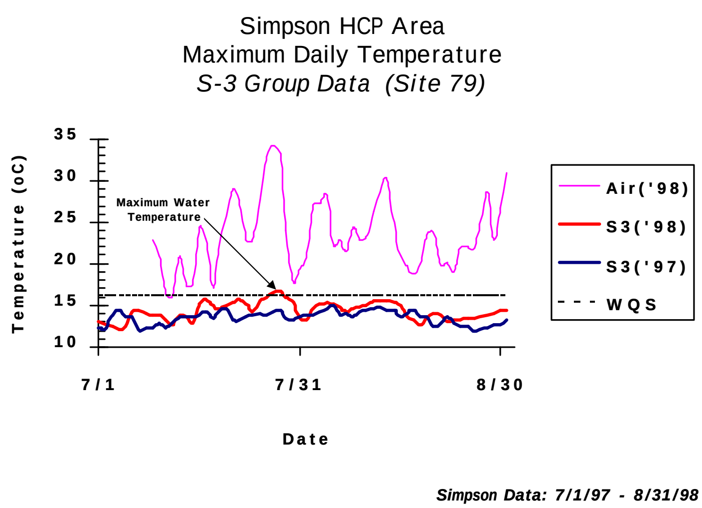
LTU	Class	mi.	Basin Area *(acres)*	Active Channel Width *(m)*	Slope	RMS	Stream(s)
CIS	Qc1	33.3	100 - 400	0 - 4	10 - 24%	U/I	
	Qc2	28.0	200 - 800	0 - 4	2 - 6%	U/I	Gosnell Creek trib.
	Qc3	16.8	4,000 - 14,000	8 - 16	0.5 - 2%	CM	Kennedy Creek
SIG	Qc1	12.8	100 - 400	2 - 4	2 - 16%	U/I	
	Qc2	8.9	100 - 400	2 - 4	2 - 16%	U/I	
Total		99.8					

- P Small (CMZ # 4m) to medium (4 < CMZ # 16m) channels
- P Continental glacial till landscape
- P Low to moderate elevations of HCP area (largely CIS and SIG)
- P Ranges from high to unconfined channels (W:D # 25)
- P Flow range: 0 - 8 cfs (drainage area < 25 mi^2)

CIS-Qc3 Gosnell Creek – 8/5/97 12.16 ==> 14.96EC 2,240 acres
7/28/98 14.20 ==> 16.61EC 85% shade

Monitoring data collected in Gosnell *(Site 79)* Creek is used to summarize temperature group S-3. Figure C-5 compares daily maximum water temperatures observed on Gosnell Creek for 1997 and 1998 along with 1998 air temperature data. As indicated, all daily maximum temperatures observed in 1997 were below the 16.0EC water quality criteria, while in 1998 there were 2 days that exceeded this value.

Figure C-5. Maximum Water Temperature Patterns: Group S-3



Group S-4. These are small to medium sized channels in glacial till landscape of the AGL and SIG with pool riffle and forced pool riffle / plane beds. These systems have moderate to low flows in summer with varying amounts of groundwater influence. Along the continuum, those with minimal groundwater influence are susceptible to elevated water temperatures with loss of shade. Those with significant amounts of groundwater influence are resistant to temperature changes. Table C-4 identifies those channel classes which comprise temperature group S-4. Several basic characteristics associated with each channel class in this group are also summarized.

Table C-4. Characteristics of Temperature Group S-4

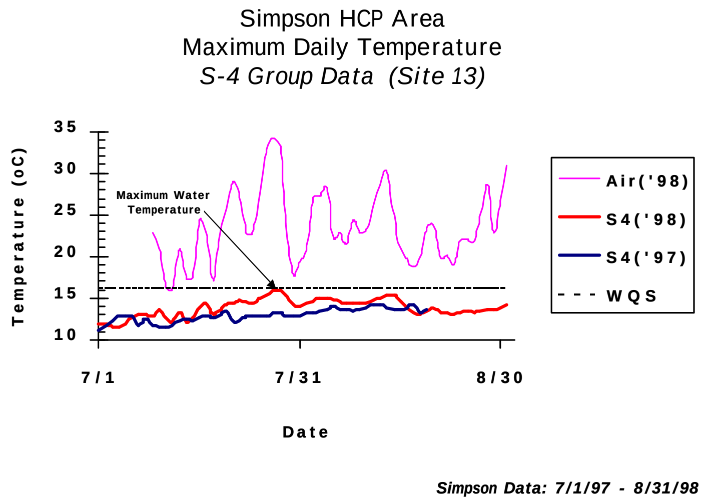
LTU	Class	mi.	Basin Area *(acres)*	Active Channel Width *(m)*	Slope		Stream(s)
AGL	Qo3	7.3	200 - 600	2 - 4	2 - 6%	BIS	
	Qo5	8.8	> 600	4 - 8	2 - 4%	BIS	
	Qo6	13.6	> 800	6 - 8	2 - 4%	BIS	Upper Schafer, Save
	Qo7	3.7	> 1,200	12 - 16	0.5 - 2%	BIS	Schafer
SIG	Qo3	4.8	400 - 1,000	4	2 - 4%	BIS	Devils Club
	Qo4	2.0	700 - 2,000	8 - 16	1.5 - 4%	BIS	Devils Club
Total		40.2					

- Small (CMZ # 4m) to medium (4 < CMZ # 16m) channels
- Olympic alpine glacial till landscape
- Mid upper elevations of HCP area (Wynoochee tribs & WF Satsop tribs subbasin J)
- Moderate to high channel confinement (W:D # 20)
- Flow range: 4 - 8 cfs (drainage area < 10 mi^2)

AGL-Qo6	Schafer Creek – 8/11/97	12.47 ==> 14.18EC	3,997 acres
	7/28/98	14.20 ==> 16.00EC	90% shade

Monitoring data collected in Schafer Creek *(Site 13)* is used to summarize temperature group S-4. Figure C-6 compares daily maximum water temperatures observed on Schafer Creek for 1997 and 1998 along with 1998 air temperature data. As indicated, all daily maximum temperatures observed both in 1997 and in 1998 were below the 16.0EC water quality criteria.

Figure C-6. Maximum Water Temperature Patterns: Group S-4



Group G-1 are small to medium sized pool riffle and forced pool riffle / plane bed channels of the CIS and ROP that are strongly influenced by groundwater. These systems are resistant to changes to water temperature because flow is strong and comes from a cool source. Shade is a secondary influence, except during extreme low flow years. Table C-5 identifies those channel classes which comprise temperature group G-1. Several basic characteristics associated with each channel class in this group are also summarized.

Monitoring data collected in Bingham Creek *(Site 32)* is used to summarize temperature group G-1. Figure C-7 compares daily maximum water temperatures observed on Bingham Creek for 1997 and 1998 along with 1998 air temperature data. As indicated, all daily maximum temperatures observed in 1997 were below the 16.0EC water quality criteria, while in 1998 there were 10 days that exceeded this value.

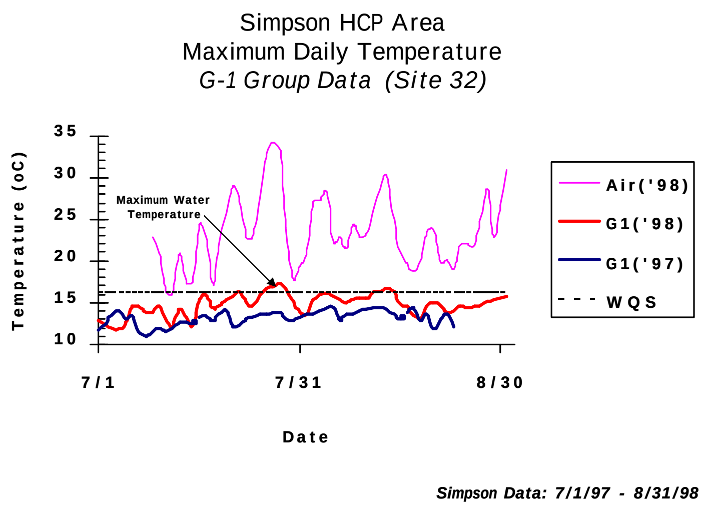
Table C-5. Characteristics of Temperature Group G-1

LTU	Class	mi.	Basin Area *(acres)*	Active Channel Width *(m)*	Slope		Stream(s)
CIS	C5	1.7	100 - 400	4 - 6	4 - 8%	RBIS	Rock
ROP	Qc4	9.1	400 - 1,000	4 - 6	1 - 4%	BIS	
	Qc5	12.1	4,000 - 10,000	12 - 18	1 - 2.5%	BIS	Bingham
	Qc6	9.5	4,000 - 10,000	12	1 - 2.5%	CM	Decker
	Qc7	15.2	4,000 - 10,000	15	0.5 - 1.5%	CM	Stillwater
Total		47.6					

- P Medium (4 < CMZ # 16m) channels
- P Mostly continental glacial till landscape
- P Low elevations of HCP area (ROP)
- P Ranges from high to unconfined channels
- P Flow range: 0 - 16 cfs (drainage area < nn mi^2)

ROP-Qc5 Bingham Creek – 8/5/97 11.36 ==> 14.46EC 9,959 acres
7/28/98 14.20 ==> 17.22EC 65 - 70% shade

Figure C-7. Maximum Water Temperature Patterns: Group G-1



<u>*Group G-2*</u> are small to medium sized highly confined channels of the AGL, CIS, CUP, and SIG. These are topographically shaded and are *"near"* the water source with substantial groundwater influence which shows as side seeps and springs. These systems are typically cool and are resistant to water temperature changes, even in the absence of riparian vegetation. Table C-6 identifies those channel classes which comprise temperature group G-2. Several basic characteristics associated with each channel class in this group are also summarized.

<u>Table C-6</u>. Characteristics of Temperature Group G-2

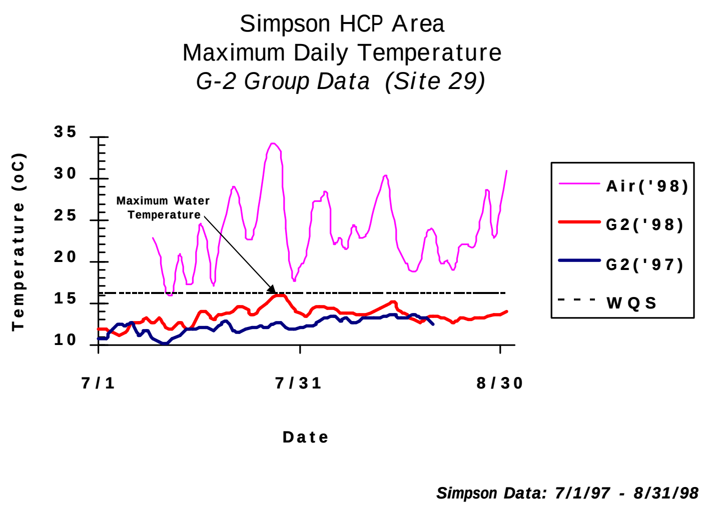
LTU	**Class**	**mi.**	**Basin Area *(acres)***	**Active Channel Width *(m)***	**Slope**		**Stream(s)**
AGL	Qo1	61.3	< 200	0 - 4	4 - 32%	U/I	Carter Creek trib.
	Qo8	5.2	> 10,000	15 - 25	0.5 - 2%	IG	Wynoochee
CIS	C1	83.9	< 200	0 - 4	8 - 24%	U/I	
CUP	C1	199.9	< 100	0 - 2	> 30%	U/I	Little, Canyon
	C2	22.9	100 - 400	2 - 4	8 - 32%	Canyon	
	C3	24.5	100 - 400	2 - 4	8 - 16%	Canyon	
	C4	4.9	100 - 400	6 - 8	4 - 8%	Canyon	N.Mtn, Little, Canyon, MF Satsop
	C5	3.5	100 - 400	4 - 6	4 - 8%	Canyon	
	C6	3.6	100 - 400	12	3%	Canyon	Baker
	C8	5.9	> 5,000	20	0.5 - 2%	IG	MF Satsop, WF Satsop
SIG	Qo1	38.3	< 200	0 - 4	4 - 32%	U/I	NF Abyss, Black Cr. trib
Total		453.9					

- **P** Small (CMZ # 4m) to large (CMZ # 25m) channels
- **P** Olympic alpine glacial till and Crescent basalt landscape
- **P** Mid upper elevations of HCP area (AGL, CIS, CUP, SIG)
- **P** High channel confinement (W:D # 20)
- **P** Flow range: 2 - 10 cfs (drainage area < 20 mi^2)

CUP-C4	N. Mountain Creek – 8/14/97	12.47 ==> 13.71EC	893 acres
	7/28/98	14.35 ==> 16.00EC	95% shade

Monitoring data collected in North Mountain Creek *(Site 29)* is used to summarize temperature group G-2. Figure C-8 compares daily maximum water temperatures observed on North Mountain Creek for 1997 and 1998 along with 1998 air temperature data. As indicated, all daily maximum temperatures observed both in 1997 and in 1998 were below the 16.0EC water quality criteria.

Figure C-8. Maximum Water Temperature Patterns: Group G-2



<u>*Group C-1*</u> are large rivers of the AGL, ROP, and SIG are affected by high sediment supply and multiple thread channels over at least some of their length. Applies to the West and Middle Forks of the Satsop, the Canyon, Little and Wynoochee Rivers. Temperatures in these systems are strongly influenced by channel pattern and open canopies. Current and past sediment supply, long residence times, and channel pattern make it unlikely that water temperatures here will change for decades. Table C-7 identifies those channel classes which comprise temperature group C-1. Several basic characteristics associated with each channel class in this group are also summarized.

Monitoring data collected in Canyon River *(Site 8)* is used to summarize temperature group C-1. Figure C-9 compares daily maximum water temperatures observed on Canyon River for 1997 and 1998 along with 1998 air temperature data. Daily maximum temperatures observed in 1997 included 58 days that the 16.0EC water quality criteria was exceeded. In 1998, there were 84 days that exceeded this value.

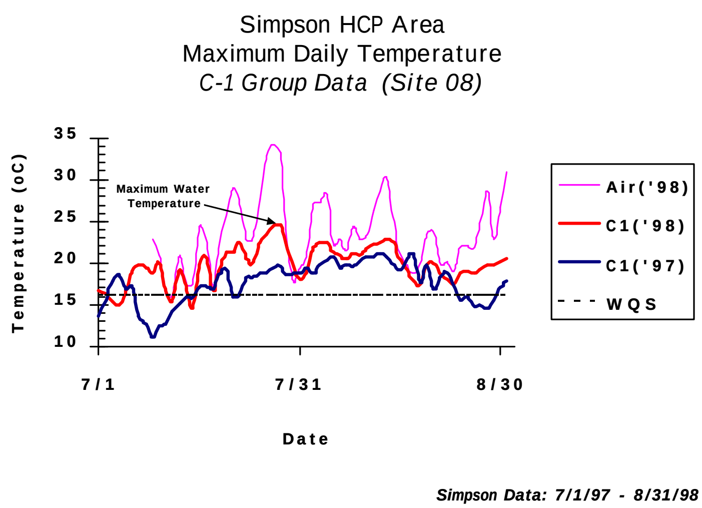
Table C-7. Characteristics of Temperature Group C-1

LTU	Class	mi.	Basin Area *(acres)*	Active Channel Width *(m)*	Slope		Stream(s)
AGL	Qa6	12.7	> 15,000	> 25	< 0.5%	CM	Wynoochee
ROP	C7	9.4	> 800	6 - 8	0.5 - 2%	CM	N.Mtn., Rabbit
	Qa7	3.7		>16	< 1%	CM	Vance
	Qc8	2.8	4,000 - 10,000	25	0.5 - 15.%	CM	IF Satsop, Bingham
SIG	L4	24.2	> 20,000	35	0.5 - 1%	IG	WF Satsop, Little, Canyon, MF Satsop
	M5	15.1	> 20,000	20	0.5 - 2%	IG	Canyon, WF Satsop, MF Satsop
	Qa6	11.3	> 15,000	> 25	< 0.5%	CM	WF Satsop, MF Satsop
Total		79.2					

- **P** Medium (4 < CMZ # 16m) to large (16 < CMZ # 50m) channels
- **P** Alluvial sediments, Lincoln, Montesano, Crescent basalt, and continental glacial till landscape
- **P** Lower to mid elevations of HCP area (AGL, ROP, SIG)
- **P** Highly confined to unconfined channels (W:D # 50)
- **P** Flow range: 4 - 30 cfs (drainage area < 30 mi^2)

SIG-L4	Canyon River – 8/12/97	14.87 ==> 21.18EC	12,942 acres
	7/28/98	18.14 ==> 24.55EC	20% shade

Figure C-9. Maximum Water Temperature Patterns: Group C-1



Riparian Vegetation

The importance of riparian shade to increase effective shade has been well studied. Reports have been prepared for three Watershed Analysis Units (WAUs) in the Simpson HCP area (West Fork Satsop, South Fork Skokomish, Kennedy Creek). A component of each Watershed Analysis is an assessment of riparian conditions intended to address the following questions:

- *What is the condition of the riparian zone relative to its ability to supply large woody debris to the stream in the near-term?*
- *What is the current degree of canopy closure provided by riparian vegetation relative to what is needed to maintain desirable stream temperatures?*

Riparian vegetation in the Simpson HCP area ranges from hardwood stands (Red Alder, Big Leaf Maple) to conifers (Douglas Fir, Western Hemlock) of varying ages. In 1996, Simpson conducted a monitoring project of 30 riparian sites in the HCP area. The purpose of the project was to document certain aspects of riparian forest baseline conditions. A summary of species composition information collected in the Simpson HCP area was described in Section B of this technical assessment. Riparian stand condition was also assessed in the W.F. Satsop Watershed Analysis *(Figure C-10)*. As shown, the watershed analysis found that the most predominant riparian condition is mature dense hardwood.

Figure C-10. W.F. Satsop Riparian Stand Condition

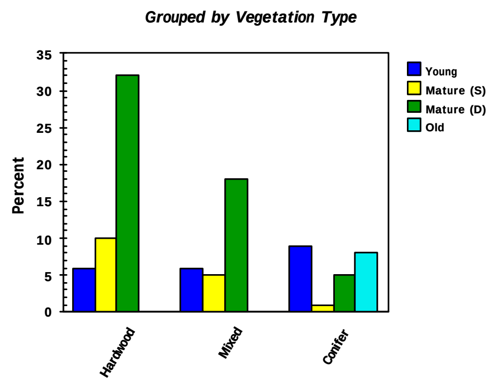
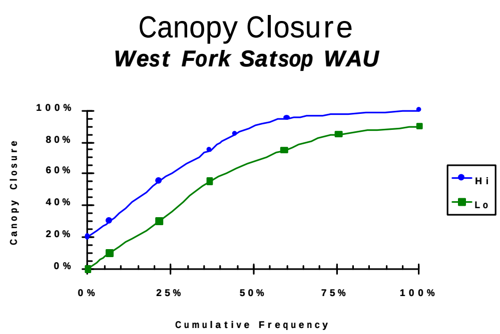
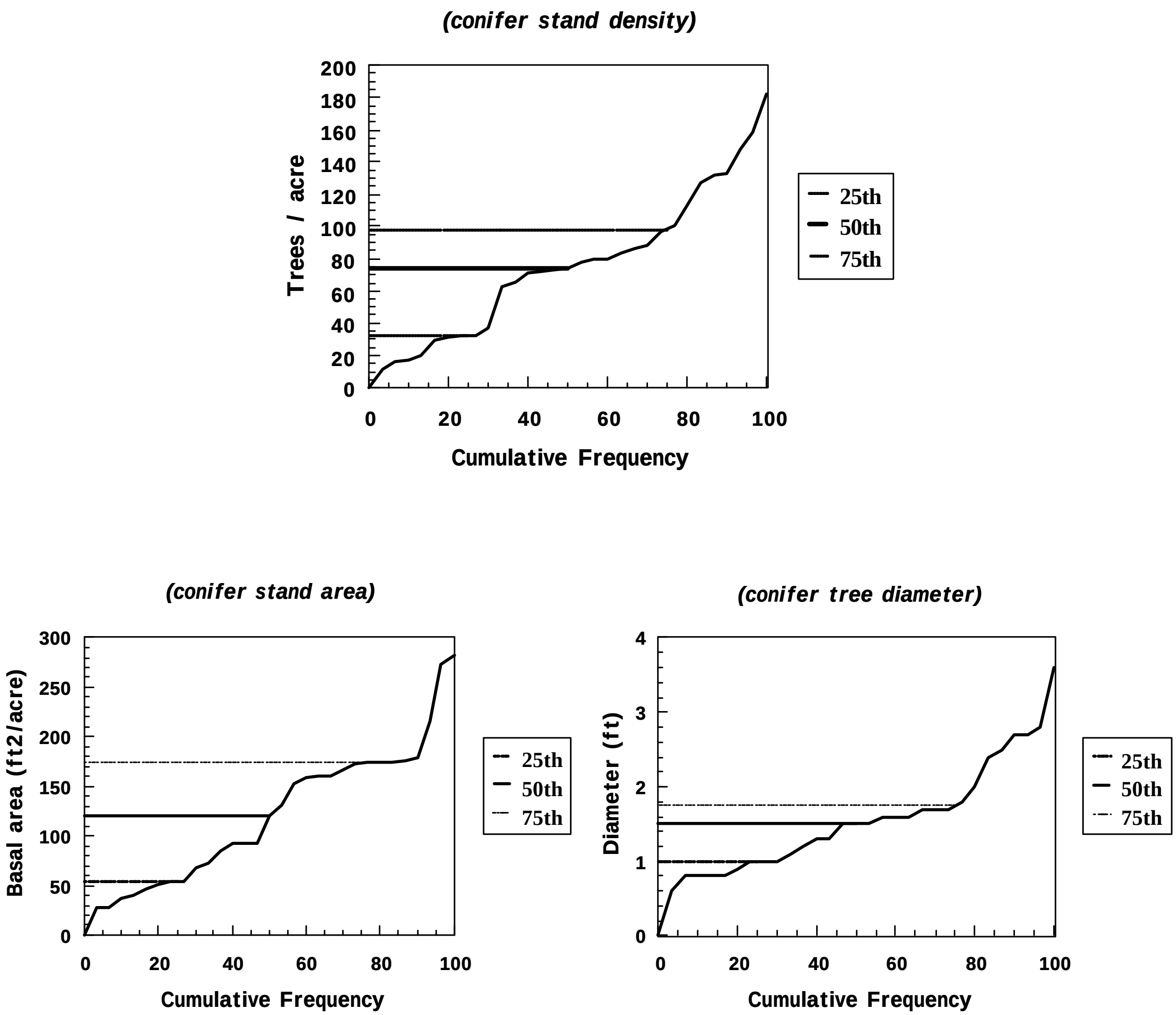


Figure C-11. W.F. Satsop Canopy Closure Summary



Several riparian area characteristics have an important effect on the amount of effective shade potentially available to the stream surface, notably stand density, basal area, and average tree size. This information is useful in determining estimates of canopy density relative to the stream channel width and riparian buffer size. The baseline information collected by Simpson has been summarized for conifers within the Simpson riparian monitoring sites *(Figure C-12)*.

Figure C-12. Simpson HCP Area Riparian Monitoring Site Summary



Channel Condition

Reports have been prepared for three Watershed Analysis Units (WAUs) in the Simpson HCP area (West Fork Satsop, South Fork Skokomish, Kennedy Creek). A component of each Watershed Analysis is an assessment of stream channel conditions intended to address the following questions:

- *What is the spatial distribution of channel response types?*
- *Is there evidence of channel change from historic conditions?*
- *What do existing channel conditions indicate about past and present active geomorphic processes?*
- *What are the likely responses of channel reaches to potential changes in input factors?*
- *What are the dominant channel and habitat forming processes in different parts of the channel network?*

Concerns which relate to effects of sediment supply on channel conditions were also noted in the W.F. Satsop Watershed Analysis. Historical disturbance patterns in mainstem channels showed that *"after 1946, stream channels widened substantially, migrated or shifted in many locations, and the size and number of gravel bars increased"*. (*see* W.F. Satsop Watershed Analysis, Stream Channel Assessment pg. 10). The assessment also describes the influence of bedrock geology on erosion and sedimentation, notably that *"the sedimentary rocks of the Montesano Formation and the Lincoln Creek Formation do not tend to form gravel. Rather, these rocks weather rapidly, primarily to lay and silt"*. (*see* pg. 15). In assessing the persistence of bed sediment, the report noted that the "*stronger, more durable rocks of the Crescent Formation that underlie the Olympic Mountain landform do not break down rapidly in stream channels. Coarse sediment entering streams in the Olympic Mountains is ultimately transported downstream and accounts for most of the coarse sediment in mainstem stream channels"*. (*see* pg. 15-16).

Two key paragraphs from the W.F. Satsop Watershed Analysis highlight the effect of sediment supply in the Crescent Uplands on large mainstem channels downstream *(Table C-8)*. For this reason, development of sediment targets for the TMDL gives a high priority to upslope sources.

Table C-8. W.F. Satsop Watershed Analysis – Stream Channel and Sediment

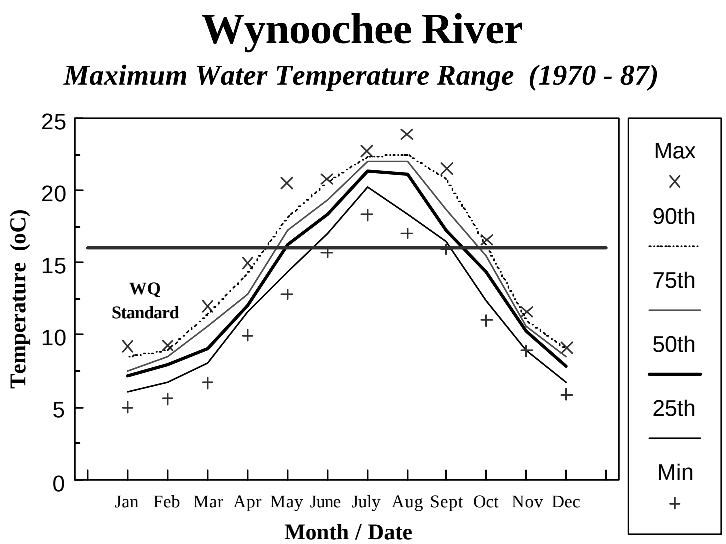
excerpt from ***"West Fork Satsop Watershed Analysis"*** ***"Appendix E — Stream Channel Assessment"*** *2/20/96 — page 18*
"In the mainstem GMU's (M1-6), although there is a variety of channel conditions, stream power is relatively high everywhere, so fine sediment tends to be routed downstream during peak flow events. Local inputs of coarse sediment from large deep seated landslides on river escarpments create local coarse sediment accumulations and bar deposition, but these effects do not extend far downstream because the coarse sediment weathers quickly to fine sediment, which is susceptible to transport and downstream routing. Temporary fine sediment accumulations occur in pool bottoms, and in backwaters associated with gravel bars and LWD accumulations. Fine sediment deposits in mainstem channels were not observed to fill mainstem pools; persistent and significant deposits appeared to be in low-energy channel margins above the base-flow stream stage and on terraces and floodplains. Coarse sediment in mainstem channels is primarily from the Crescent Formation (see section above). *Overall, because of the influence of geology on mass wasting, the propensity of sedimentary rocks to break down to suspendible sizes, and the high likelihood that annual floods are capable of mobilizing the streambed, fine sediment is both abundant and transient in the WAU watershed. Fine sediment is produced in significant quantity by large mainstem landslides and bank erosion, is transformed by attrition to sizes transported as suspended load, and is routed through the system quickly. Although of suspended sediment in the streambed occurs, the power of the mainstem channels and the regularity of long-duration rainstorms indicates that accumulations in spawning gravels are flushed out regularly by bed-mobilizing flows."*

SEASONAL VARIATION

Stream Temperatures

Existing conditions for stream temperatures in the Simpson HCP area reflect seasonal variation. Cooler temperatures occur in the winter, while warmer temperatures are observed in the summer. Historical data has been collected by the U.S. Geological Survey (USGS) of stream temperatures in the Wynoochee River. Figure C-13 summarizes the distribution of highest daily maximum water temperatures for each month between 1970 and 1987. Although the data was collected in the 1970's and 80's, it is the most comprehensive record for water temperature taken at one site over an extended period of time in the vicinity of the Simpson HCP area. As shown, water quality standards for temperature are only exceeded between May and October. In addition, the data shown in Figure C-13 indicates that the highest seven-day average maximum water temperatures occur between mid-July and mid-August. This time frame is used as the critical period for development and analysis of allocations in the TMDL.

Figure C-13. Seasonal Variation of Wynoochee Temperature Levels



Stream Flow

Monthly flow data is another way to describe seasonal variation. As illustrated earlier in Figure C-1, flows peak in December as a result of winter storm runoff. Flows decline through the summer reaching baseflow conditions in August. Figure C-2 depicted the variability of seven-day low flows using data from the Satsop River near Satsop. The seven-day low flow recurring every ten years (7Q10) was also shown in Figure C-2. The USGS data has been used to describe the variation of 7Q2 values across the HCP area (Amerman and Orsborn, 1987). From this information, a relationship has been developed to estimate 7Q2 values for various LTU's within the HCP area.

Solar Radiation

Potential solar radiation varies throughout the year. The highest value occurs on the first day of summer when the earth's tilt towards the sun is greatest. Figure C-14 illustrates the effect of seasonal variation on shadow length associated with different tree heights. As shown, shadows are shortest in mid-June. Figure C-15 illustrates the effect of seasonal variation on maximum potential solar radiation. Mid-June is the period when solar radiation values are at their peak. As a result, mid-June can be used a starting point for identifying the loading capacity for effective shade. This is the time that the water surface receives the maximum potential solar radiation and when riparian shade is least effective in reducing heat. This does add to the margin of safety because low flows and maximum water temperatures typically occur between mid-July and mid-August.

Figure C-14. Seasonal Variation of Shadow Lengths

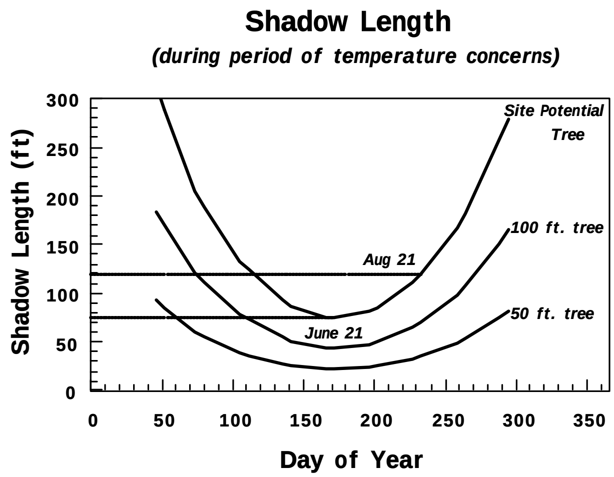
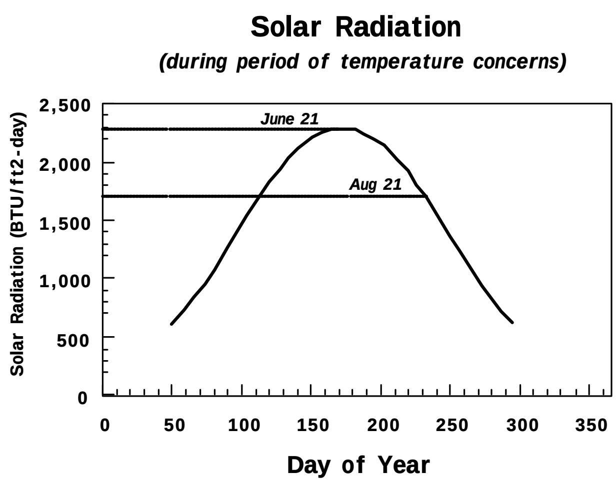


Figure C-15. Seasonal Variation of Maximum Potential Solar Radiation



Critical Temperature Conditions

Estimates for streamflow, loading, and water quality parameters need to be taken into account in development of the TMDL. The analysis demonstrating the relationship of channel and riparian conditions to solar radiation loads requires a framework for identifying critical conditions. Based on historical data for the Wynoochee River *(Figure C-13)*, the critical period used for the analysis is mid-July. This represents the time frame for which solar radiation is highest when the earliest summer maximum water temperatures were observed. This time frame is also consistent with water temperature data collected by Simpson *(Figure C-3 through C-9)*.

Streamflow estimates were identified using data from the USGS gage on the Satsop River near Satsop. Water yield for the 7-day low flow, 2-year recurrence interval (7Q2), which is also associated with the highest water temperatures observed at the gage, was used as a starting point. This represents a conservative approach and can be refined as additional flow data is collected in the Simpson HCP area. The same conservative approach was used to identify parameters for calculation of solar radiation load (e.g. cloud cover) and water quality (e.g. air temperature, upstream water temperature, etc). Given the importance of stream type in evaluating critical conditions, information will be collected by Simpson to characterize riparian and channel conditions in the HCP area.

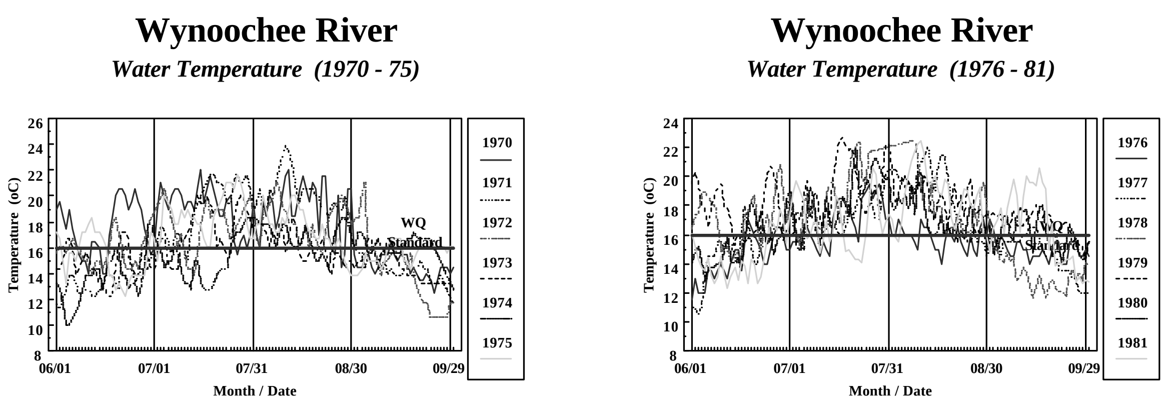
Annual Variability and Sediment

It is important to discuss the annual variability of peak flows and its effect on sediment delivery. USGS (1971) described sediment yield in the Chehalis basin. Consistent with sediment studies in other areas, the report noted that the greatest percentage of sediment transport occurred during peak flows. Figure C-2 showed the variation in peak flows for the Satsop River.

HISTORIC CONDITIONS AND TRENDS

Historic data con water temperature conditions prior to the start of management activities is not available. The U.S. Geological Survey collected water temperature data on the Wynoochee River from 1970 to 1981 *(Figure C-16)*. As shown, seasonal patterns can be seen, as discussed above. However, long term trends are not evident.

Figure C-16. Wynoochee River Summer Water Temperatures



SECTION D
Interpretation

Interpretation
Index

OVERVIEW

Interpretation is the place to synthesize water quality information in the context of watershed processes. Within interpretation, similarities, differences, and trends in water quality conditions are explained. Interpretation also involves identifying the capability of the system to achieve water quality management objectives. In short, the focus of interpretation is to answer the question: ***"What are the influences and relationships between water quality and other ecosystem processes in the watershed (e.g. mass wasting, fish habitat, stream channel, etc.)?***. In addressing this question, other subtopics could be considered which include:

Interpretation --- *Other Considerations*

What watershed processes contribute or could potentially contribute input variables to waterbodies adversely affected by water quality?

- What potential sources of input variables (e.g. sediment, water, solar radiation, or chemicals) could enter waterbodies not meeting water quality standards?
- What is the delivery potential of input variables to waterbodies not meeting water quality standards and at what levels?

AQUATIC RESOURCE CONSIDERATIONS

Interpretation of water quality information for streams affected by nonpoint sources presents some inherent challenges. Diffuse sources are often associated with watershed or landscape scale features. Consequently, water quality concerns associated with nonpoint source (NPS) pollutants require a different approach from traditional point source problems. Assessment of water quality data collected within the Simpson Habitat Conservation Plan (HCP) area employs several concepts applied at a broader scale. These watershed / landscape scale concepts are evaluated in order to provide an analytical framework. Watershed / landscape scale concepts used to organize information include:

- Landscape stratification
- Channel classification

Landscape Stratification: The foundation of the HCP lies within the system Simpson has developed to better understand the inherent characteristics and sensitivities of their lands, and how their long-term forest management plans interact with these features. The proposed HCP notes that *"...at a fundamental level, ecosystem structure and dynamics are influenced by geological settings, climatic factors and their interaction. Any site specific, science-based approach to landscape planning must account for these essential influences because they are largely responsible for much of the natural variation in habitat types at various spatial and temporal scales"*.

Influences of geologic setting and associated physical processes within the HCP area are captured by stratifying the landscape into "*lithotopo*" units (LTU), i.e. areas of similar lithology and topography. LTU boundaries are determined by geology, geological history, and topographic relief. This approach divides Simpson's HCP area into units that share similar erosional and channel forming processes. LTUs include:

- Alpine glacial (AGL)
- Crescent islands (CIS)
- Crescent uplands (CUP)
- Recessional outwash plain (ROP)
- Sedimentary inner gorges (SIG)

Channel Classification: Conditions in a waterbody are a function of channel morphology (e.g. source, transport, or response reaches). Methods exist to assess the condition of a stream, as well as departure from its potential (Rosgen, 1996). These methods, built around channel classification, are a useful starting point to interpret water quality data for streams in the Simpson HCP area. Consequently, a second lower level of stratification consists of classifying stream segments of the channel network within each of the LTU.

There are 49 individual stream segment types within this system *(Table D-1)*. Riparian management strategies are keyed to each of the stream types. A description of these can be found within the HCP document. Additional details on channel characteristics, geology, morphology, large woody debris (LWD) characteristics and recruitment processes, sediment delivery and processing mechanisms, riparian characteristics and biological community features are described in HCP appendices. Information on the linkage to instream biological resources is also provided. The small intermittent streams (of varying type) are often quite unstable and if not properly protected may account for substantial inputs of sediments triggered by management activities. The HCP defines which types these are and describes what protective measures will be taken to address the risks they pose.

Table D-1a. Simpson HCP Area Channel Classes

Lithotopo Unit	Channel Class	Stream Miles	Riparian Management Strategy	Streams
AGL	Qa6	12.7	Channel Migration	Wynoochee
	Qo1	61.3	Unstable / Intermittent	
	Qo2	22.5	Unstable / Intermittent	
	Qo3	7.3	Break in Slope	
	Qo4	2.6	Reverse Break in Slope	
	Qo5	8.8	Break in Slope	
	Qo6	13.6	Break in Slope	Schafer
	Qo7	3.7	Break in Slope	Schafer
	Qo8	5.2	Inner Gorge	Wynoochee
CIS	C1	83.9	Unstable / Intermittent	
	C5	1.7	Reverse Break in Slope	Rock
	Qc1	33.3	Unstable / Intermittent	
	Qc2	28.0	Unstable / Intermittent	
	Qc3	16.8	Channel Migration	Kennedy
CUP	C1	199.9	Unstable / Intermittent	
	C2	22.9	Canyon	
	C3	24.5	Canyon	
	C4	4.9	Canyon	North Mountain
	C5	3.5	Canyon	Dry Bed
	C6	3.6	Canyon	Baker
	C8	5.9	Inner Gorge	Middle Fork Satsop
ROP	C7	9.4	Channel Migration	North Mountain
	Qa7	3.7	Channel Migration	Vance
	Qc1	167.3	Unstable / Intermittent	
	Qc2	103.4	Break in Slope	

Table D-1b. Simpson HCP Area Channel Classes

Lithotopo Unit	Channel Class	Stream Miles	Riparian Management Strategy	Streams
ROP	Qc3	44.2	Temperature Sensitive	Glenn
	Qc4	9.1	Break in Slope	
	Qc5	12.1	Break in Slope	Bingham
	Qc6	9.5	Channel Migration	Decker
	Qc7	15.2	Channel Migration	Stillwater
	Qc8	2.8	Channel Migration	East Fork Satsop
SIG	L1	160.0	Unstable / Intermittent	
	L2	38.5	Reverse Break in Slope	
	L3	6.3	Break in Slope	
	L4	24.2	Inner Gorge	West Fork Satsop
	M1	67.8	Unstable / Intermittent	
	M2	18.5	Unstable / Intermittent	
	M3	9.6	Alluvial / bedrock	
	M4	6.0	Alluvial / bedrock	Sandstone
	M5	15.1	Inner Gorge	Canyon
	M6	2.3	Channel Migration	Cook
	Qa6	11.3	Channel Migration	West Fork Satsop
	Qc1	12.8	Unstable / Intermittent	
	Qc2	8.9	Unstable / Intermittent	
	Qc3	9.1	Temperature Sensitive	
	Qo1	38.3	Unstable / Intermittent	North Fork Abyss
	Qo2	19.0	Unstable / Intermittent	
	Qo3	4.8	Break in Slope	
	Qo4	2.0	Break in Slope	Devils Club

<u>*Temperature Groups*</u>: The channel classification system can be used to group stream reaches by the dominant control(s) which affect water temperature. Table D-2 identifies seven groups and describes watershed process features which exert the greatest influence on water temperature in those channel classes. Dominant features include shade, groundwater, and channel morphology.

<u>Table D-2</u>. Groups for Identifying Targets to Address Water Temperature

Group	Features	Channel
Shade		
S-1	Small to medium sized pool riffle and forced pool riffle / plane bed channels of the ROP and SIG. Water temperature is driven by shade and low flows (poor water storage in these watersheds over glacial tills and shallow soils). Headwaters of these systems are usually in wetlands or bogs and beavers frequently pond water within the channel. *RMS: Temperature Sensitive*.	ROP-Qc1, -Qc2 ROP-Qc3 SIG-Qc3
S-2	Small to medium sized channels in the AGL and SIG. These systems most often have hardwood dominated riparian systems and subtle groundwater influence through wet side slopes. They are subject to heating with the loss of riparian shade which can happen through damage to riparian leave areas by natural factors or through insufficient leave area. *RMS: Alluvial Bedrock Transition or Reverse Break in Slope*.	AGL-Qo2, -Qo4 SIG-L1, -L2, -L3 SIG-M1, -M2, -M3 SIG-M4, -M6 SIG-Qo2
S-3	Small to medium sized streams in the recessional outwash sediments of the CIS and SIG. These channels have low summer flows, but the storage and character of the flows is different from the ROP in that lower terraces, floodplains, and valley walls of these systems are composed of fine, but fairly well draining unconsolidated outwash sediments. These materials do not store great quantities of water. However, there is a slow release of groundwater that appears to moderate temperatures, but it is not sufficient to offset heating as a result of riparian canopy loss. With loss of shade, these streams can heat up to moderate levels. *RMS: Channel Migration or Unstable Slopes / Intermittent*.	CIS-Qc1, -Qc2 CIS-Qc3 SIG-Qc1, -Qc2
S-4	Small to medium sized channels in glacial till landscape of the AGL and SIG with pool riffle and forced pool riffle / plane beds. These systems have moderate to low flows in summer with varying amounts of groundwater influence. Along the continuum, those with minimal groundwater influence are susceptible to elevated water temperatures with loss of shade. Those with significant amounts of groundwater influence are resistant to temperature changes. *RMS: Break in Slope*.	AGL-Qo3, -Qo5 AGL-Qo6, -Qo7 SIG-Qo3, -Qo4
Groundwater		
G-1	Small to medium sized pool riffle and forced pool riffle / plane bed channels of the CIS and ROP that are strongly influenced by groundwater. These systems are resistant to changes to water temperature because flow is strong and comes from a cool source. Shade is a secondary influence, except during extreme low flow years. *RMS: Channel Migration*.	CIS-C5 ROP-Qc4, -Qc5 ROP-Qc6, -Qc7
G-2	Small to medium sized highly confined channels of the AGL, CIS, CUP, and SIG. These are topographically shaded and are *"near"* the water source with substantial groundwater influence which shows as side seeps and springs. These systems are typically cool and are resistant to water temperature changes, even in the absence of riparian vegetation. *RMS: Canyon*.	AGL-Qo1, -Qo8 CIS-C1 CUP-C1, -C2, -C3 CUP-C4, -C5, -C6 CUP-C8 SIG-Qo1
Channel Morphology		
C-1	Large rivers of the AGL, ROP, and SIG are affected by high sediment supply and multiple thread channels over at least some of their length. Applies to the West and Middle Forks of the Satsop, the Canyon, Little and Wynoochee Rivers. Temperatures in these systems are strongly influenced by channel pattern and open canopies. Current and past sediment supply, long residence times, and channel pattern make it unlikely that water temperatures here will change for decades. *RMS: Inner Gorge or Channel Migration*.	AGL-Qa6 ROP-C7, -Qa7 ROP-Qc8 SIG-L4, -M5, -Qa6

Water temperature data, discussed in Section C, can be used to look at actual responses for different channel types. Figure D-1 depicts information collected in 1997 and 1998 from sites representative of each temperature group. Maximum observations between July 1 and August 31 are shown for each year. This corresponds with the seasonal time frame when maximum water temperatures occur. Patterns shown in the data reflect features described for each temperature group, such as the influence of groundwater (G-1) or the effect of channel morphology (C-1). Figure D-2 illustrates temperature group patterns by showing the difference in cumulative frequency distribution at several sites. Figure D-3 shows the percentage of streams in the Simpson HCP area that lie within each temperature group as well as the percentage of time that 16EC was exceeded at each site used to represent the temperature group.

***Figure D-1*.** Annual Maximum Water Temperature by Group

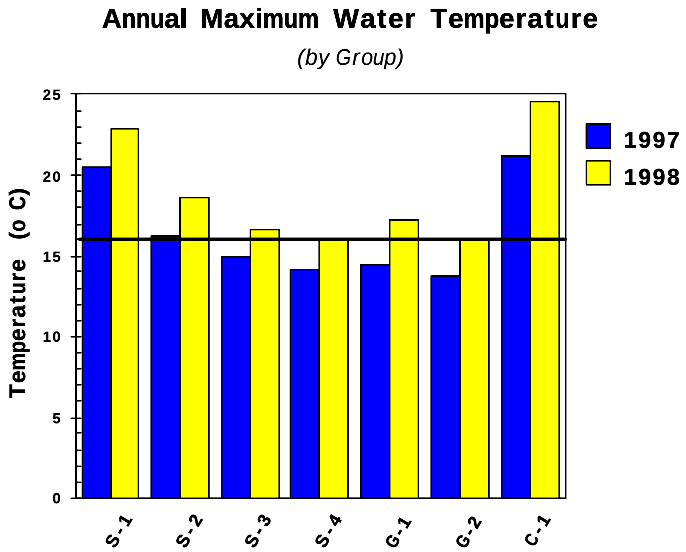


***Figure D-2*.** Comparison of Cumulative Frequency Distribution by Temperature Group

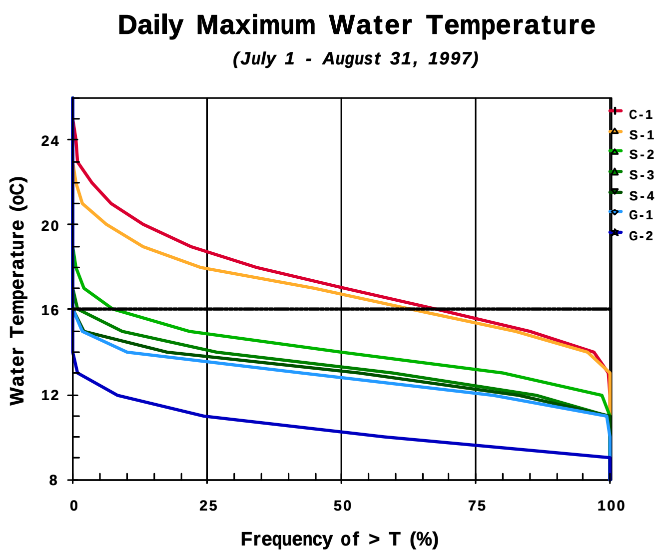
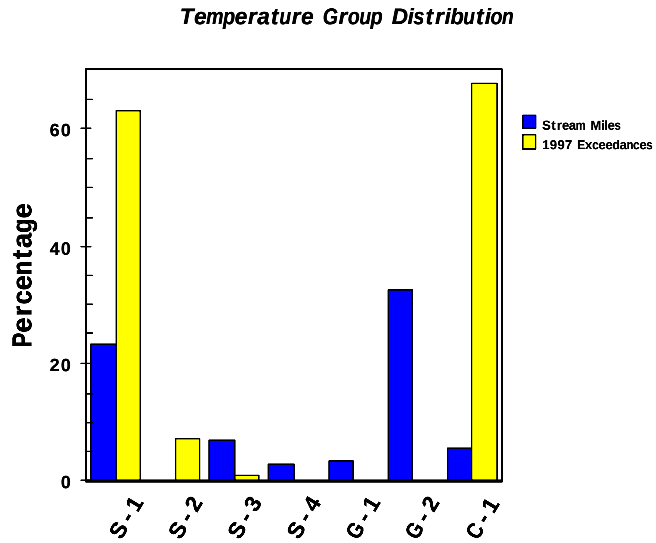


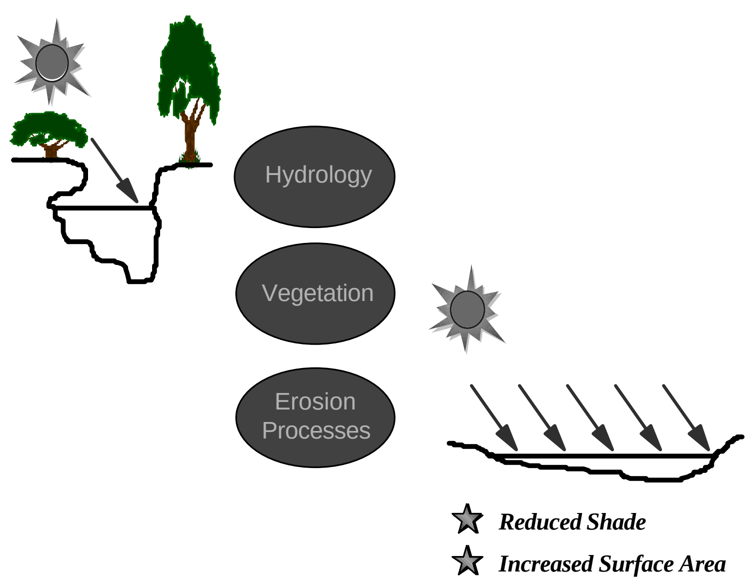
Figure D-3. Distribution of Temperature Groups



RELATIONSHIP TO WATERSHED PROCESSES

Stream temperatures can increase as a result of land management activities which alter basic watershed processes *(Figure D-4)*. Temperature conditions are affected by the amount of stream surface area exposed to direct solar radiation (i.e. sunlight). In forested situations, temperature increases in streams occur when riparian vegetation is reduced (resulting in decreased shade), channels are widened and shallowed from excess sediment (resulting in increased surface area), or the cooling effects of groundwater flows are diminished (resulting in lower dissipative capacity). The result is wide and shallow streams with little shading which experience higher summer water temperatures due to the increased input of solar radiation.

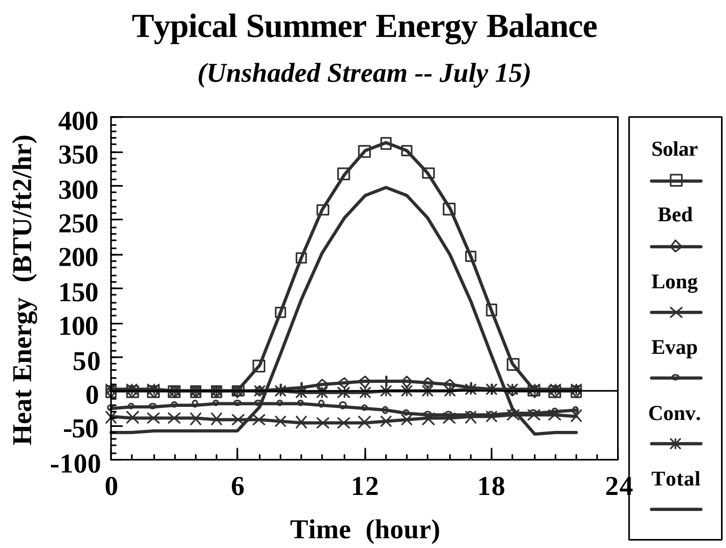
Figure D-4. Watershed Processes Affecting Stream Temperature



Stream temperature is an expression of heat energy per unit volume, or an indicator of the rate of heat exchange between a stream and its environment, as discussed in Section H *(Figure H-1)*. In terms of water temperature increases, the principle source of heat energy is solar radiation directly striking the stream surface (Brown, 1970). Energy is acquired by a stream system when the heat entering the stream is greater than the heat leaving the stream. When there is a net addition of heat energy to the stream, the water temperature will increase.

As discussed in other studies (Brown 1969, Beschta et al 1987), the daily profile for water temperature typically follows the same pattern of solar radiation delivered to an unshaded stream *(Figure D-5)*. Other processes, such as longwave radiation and convection also introduce energy into the stream, but at much smaller amounts when compared to solar radiation. If a stream is completely unshaded, as is the case in Figure D-5, the solar radiation flux has the potential to deliver large quantities of heat energy, resulting in a rapid increase in water temperature.

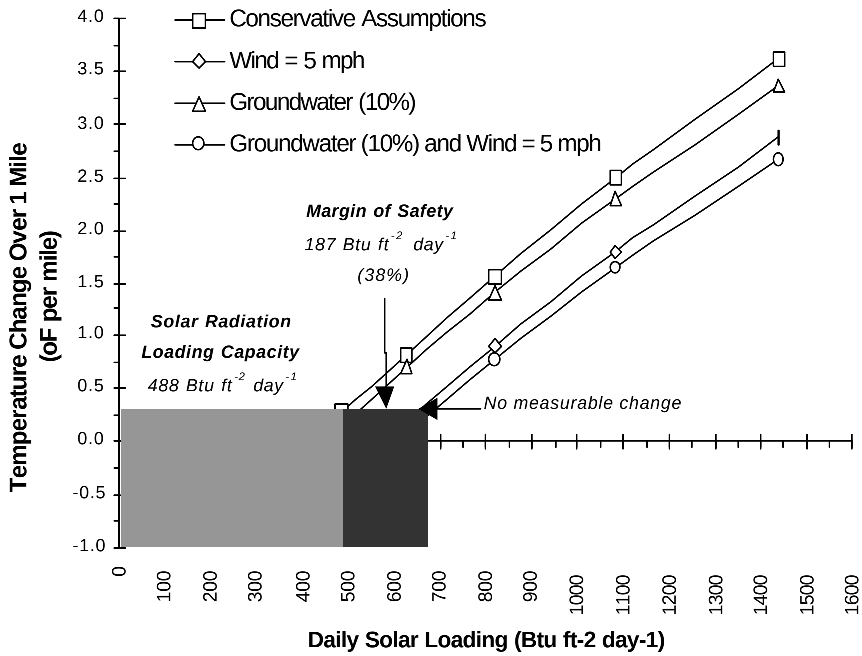
Figure D-5. Typical Summer Energy Balance for an Unshaded Stream



Landscape features (e.g. riparian vegetation) directly control the extent of stream surface exposure to solar energy. Natural watershed processes that are most influential in determining stream temperature include solar radiation, air temperature, stream width, stream depth, shading, and water inflow. Temperature regimes altered by forest practices result from changes in the amount of solar radiation striking the water surface. Loss of riparian vegetation and channel widening increase the water surface exposed to sunlight.

Mechanistic models have been developed based on a heat budget approach which estimate water temperature under different heat balance and flow conditions. Brown (1969) was the first to apply a heat budget to estimate water temperatures on small streams affected by timber harvest. This heat budget technique utilizes six variables (solar radiation, long wave radiation, evaporation, convection, bed conduction, and advection) to determine the net gain or loss of stored heat (ªH) in a known volume of water. This change in ªH can then be converted to a temperature change. Using mathematical relationships to describe heat transfer processes, the rate of change in water temperature on a summer day can be estimated. Relationships include both the total energy transfer rate to the stream (i.e. the sum of individual processes) and the response of water temperature to heat energy absorbed. Heat transfer processes considered in the analysis include solar radiation, longwave radiation, convection, evaporation, and bed conduction (Wunderlich 1972, Jobson and Keefer 1979, Beschta and Weatherred 1984, Sinokrot and Stefan 1993). Figure D-5 shows that solar radiation is the predominant energy transfer process which contributes to water temperature increases. A general relationship between solar radiation loads and stream temperature can be developed by quantifying heat transfer processes (*Figure D-6)*.

Figure D-6. General Relationship between Solar Radiation Loads and Water Temperature



Explanation:

Figure D-6 describes the relationship between solar radiation load and water temperature change. The response of water temperature to solar radiation loads was determined by evaluating the sum of individual heat transfer processes, or:

$$M_{total} = M_{solar} + M_{longwave} + M_{evaporation} + M_{convection} + M_{conduction}$$

Individual heat transfer rates were estimated using the location of the Simpson HCP area (i.e. same latitude / longitude range) and conservative assumptions. The graph contains four curves representing different assumptions on groundwater inflow and wind speed.

Vegetation

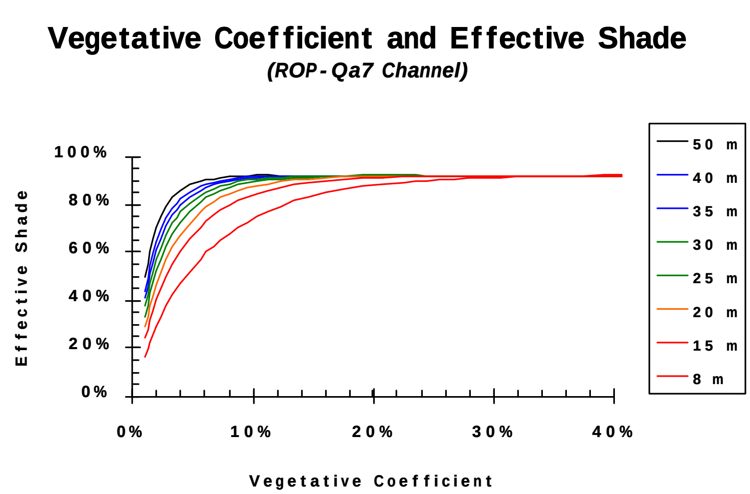
The purpose of evaluating components of shade is to develop meaningful measures which relate riparian characteristics to solar radiation reduction targets. It is important to remember the role that shade plays with respect to stream temperature. Solar radiation is a *"one way"* heating process for the stream. Heat energy gained from the sun must be dissipated by other energy processes, namely: *longwave radiation, evaporation, or convection*. For this reason, while shade does not cool stream water, it does prevent or reduce heating by solar radiation.

In order to assess the ability of riparian vegetation to shield a stream from solar radiation, one needs to consider two basic characteristics of shade: *shade duration* and *shade quality*. Shade duration is the length of time that a stream receives shade. Shade quality is the amount of solar radiation blocked by the shade. To minimize stream heating from solar radiation, two components of shade must occur. First, the stream surface shade must persist throughout the day, even when the sun is very high in the sky. Second, shade quality must be adequate to block the majority of the incoming solar radiation.

Effective shade screens the water's surface from direct rays of the sun. Highly shaded streams often experience cooler stream temperatures due to reduced input of solar energy (Brown 1969, Beschta et al 1987, Holaday 1992, Li et al 1994). Stream surface shade is dependent on both topography as well as riparian vegetation type, condition, and shade quality.

From a management perspective, riparian vegetation has the greatest potential to influence shade, and thus stream temperatures. Over the years, the term shade has been used in several contexts, including its components such as shade angle or shade density. For purposes of this TMDL, effective shade is defined as the percent reduction of potential daily solar radiation load delivered to the water surface. Thus, the role of shade in this TMDL is to prevent or reduce heating by solar radiation. Figure D-7 depicts the relationship between the vegetative coefficient and effective shade is shown for a ROP-Qa7 channel using buffer or Riparian Conservation Reserve (RCR) widths that range from 8 meters to 50 meters.

Figure D-7. Effect of Vegetative Coefficient on Effective Shade

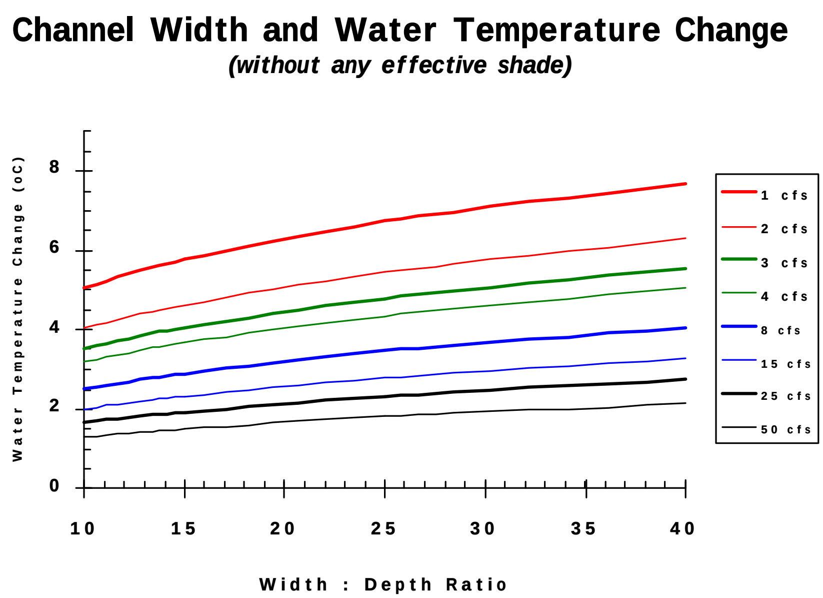


Erosion

Within the Simpson HCP area, large rivers of the AGL, ROP, and SIG are affected by high sediment supply and multiple thread channels over at least some of their length. Temperatures in these systems are strongly influenced by channel pattern and open canopies. Deposition of sediment can result in channel filling which leads to increases in channel width.

An increase in channel width will increase the amount of solar radiation entering a stream. A wide, shallow will heat up faster than a narrow, deeper stream with the same discharge (Brown, 1972). The effect of an increased channel width : depth ratio in the peak hourly water temperature change is illustrated in Figure D-8. During storm events, management related sources can increase sediment inputs over background. This contributes to channel widening and stream temperature increases.

Figure D-8. Effect of Channel Width on Water Temperature



The Implementation part of the HCP provides information on sediment issues, both delivery and processing mechanisms, for each channel class. This information is summarized in Table D-3.

Table D-3a. Summary Sediment Issues by Channel Class for Simpson HCP Area

Channel Class	Length (miles)	Sediment	
		Delivery	Processing
Alpine Glaciated (AGL)			
AGL-*Qa6*	12.7	Fluvial transport from channel segments in headwaters, erosion of low terraces and entrainment of lateral bars, shallow rapid landslides where channels abutt confining valley walls composed of marine sediments.	Storage 1
AGL-*Qo1*	61.3	Roads, side slope failure scars associated with windthrow	Transport 4,5,9
AGL-*Qo2*	22.5	Roads	Storage in impoundments and wetlands 4,5,9
AGL-*Qo3*	7.3	Roads, side slope failure associated w/ windthrow	Transport of fines, storage of coarse fraction behind LWD 3,4
AGL-*Qo4*	2.6	Tributary network of Qo2 channels, bank erosion, roads	Storage in forced bars and terraces, otherwise transport 3
AGL-*Qo5*	8.8	Side slope failures, associated with windthrow	Transport 3
AGL-*Qo6*	13.6	Bank erosion and road surface runoff	Transport in straight plane bed reaches and storage in forced bars otherwise 2,3
AGL-*Qo7*	3.7	Side slope failure and road surface runoff	Transport in straight plane bed reaches & storage in lateral bars, in lee of obstructions otherwise 2,3
AGL-*Qo8*	5.2	Upstream canyon channel network	Transport to downstream Qa6 segments 1
Total	137.7		
Crescent Islands (CIS)			
CIS-*C1*	83.5	Shallow rapid landslides, road surface	Transport 3,4,5,9
CIS-*C5*	1.7	Roads, bank erosion	Storage behind woody obstructions, gradual transport. 3
CIS-*Qc1*	33.0	Road surface runoff, small streamside slumps	Transport 4,5,9
CIS-*Qc2*	27.0	Roads and streamside slumps	Storage behind LWD, gradual transport 3,4,5
CIS-*Qc3*	15.9	Bank erosion, road surface runoff	Storage in lateral bars and behind LWD 2,3
Total	163.7		

Table D-3b. Summary Sediment Issues by Channel Class for Simpson HCP Area

Channel Class	**Length *(miles)***	**Sediment** Delivery	**Sediment** Processing	
Crescent Uplands (CUP)				
CUP-*C1*	199.9	Shallow rapid landslides, debris flows	Transport	5,9
CUP-*C2*	22.9	Shallow rapid landslides, debris flows	Transport, storage behind debris dams	4
CUP-*C3*	24.5	Shallow rapid landslides, debris flows	Transport, storage behind debris dams	4
CUP-*C4*	4.9	Debris flows from C1 channels, shallow rapid landslides from side slopes	Transport, minor storage behind valley jams	4
CUP-*C5*	3.5	Debris flows from tributary C1 channels, shallow rapid landslides from side slopes	Transport, storage behind valley jams and in short discontinuous debris flow terraces	4
CUP-*C6*	3.6	Debris flows from C1, C2, or C3 channels	Transport	3
CUP-*C8*	5.9	Debris flows from upstream canyon network	Transport with some storage in discontinuous and narrow terraces	1
Total	265.2			
Recessional Outwash Plain (ROP)				
ROP-*C7*	9.4	Bedload from canyon network upstream	Depositional / storage	3
ROP-*Qa7*	3.7	Fluvial transport from headwater and canyon reaches, erosion of low terraces and entrainment of lateral bars, shallow rapid landslides where channels abutt confining valley slopes	Storage	1
ROP-*Qc1*	167.3	Road surface runoff	Storage of all but suspended materials	4,5,9
ROP-*Qc2*	103.4	Side slope erosion	Storage behind LWD, gradual transport	3,4
ROP-*Qc3*	44.2	Bank erosion, road surface runoff	Storage in lateral bars and behind LWD	3
ROP-*Qc4*	9.1	Side slope erosion	Transport	3,4
ROP-*Qc5*	12.1	Bedload from upper channel network, bank erosion	Transport	2,3
ROP-*Qc6*	9.5	Bank erosion	Storage in lateral bars	1
ROP-*Qc7*	15.2	Road surface runoff, delivery from Qc2 channels	Storage in lateral bars	1
ROP-*Qc8*	2.8	Terrace erosion and bedload transport from upper portions of the channel network	Storage in lateral bars	1
Total	376.7			

Table D-3c. Summary Sediment Issues by Channel Class for Simpson HCP Area

Channel Class	Length *(miles)*	Sediment	
		Delivery	Processing
Sedimentary Inner Gorge (SIG)			
SIG-*L1*	160.0	Shallow rapid landslides, channel bed incision, (increased frequency of slope failure with channel incision and slope undercutting and over steepening)	Storage behind woody obstructions, gradual transport 4,5
SIG-*L2*	38.5	Shallow rapid landslides, mining of fine textured terraces, episodically from head wall failures in L1 channels	Storage behind woody obstructions, gradual transport 4,5
SIG-*L3*	6.3	SR landslides, channel bed incision, (increased frequency of slope failure with channel incision and slope undercutting and over steepening)	Storage behind woody obstructions, in absence of obstructions rapid transport 3,4
SIG-*L4*	24.2	Shallow rapid landslides on inner gorge slopes, and deep seated mass wasting from adjacent landscape	Storage in lateral bars 1
SIG-*M1*	67.8	Shallow rapid landslides on stream side slopes and hollow failures above channel heads	Transport 4,5,9
SIG-*M2*	18.5	Shallow rapid landslides on stream side slopes and road surface runoff	Storage behind LWD, gradual transport otherwise 4,5,9
SIG-*M3*	9.6	Shallow rapid landslides on valley side slopes	Storage behind LWD, transport otherwise 3,4
SIG-*M4*	6.0	Shallow rapid landslides on stream side slopes	Storage behind LWD, gradual transport otherwise 3
SIG-*M5*	15.1	Shallow rapid landslides on valley side slopes	Transport, limited storage behind LWD and in small lateral bar system within the canyon 1
SIG-*M6*	2.3	Bank erosion of floodplain deposits	Storage in lateral bars, gradual transport of smaller fraction 3
SIG-*Qa6*	11.3	Fluvial transport from channel segments in headwaters, erosion of low terraces and entrainment of lateral bars, shallow rapid where channels abutt valley walls	Storage in lateral bars 1
SIG-*Qc1*	12.8	Shallow rapid landslides and streamside slumps	Storage behind LWD, gradual transport 4,5,9
SIG-*Qc2*	8.9	Bank erosion	Storage behind LWD, gradual transport 4,5
SIG-*Qc3*	9.1	Bank erosion	Storage behind LWD, gradual transport 3,4
SIG-*Qo1*	38.3	Roads, side slope failure scars associated with windthrow	Transport 4,5,9

Table D-3d. Summary Sediment Issues by Channel Class for Simpson HCP Area

Channel Class	**Length *(miles)***	**Sediment**	
		Delivery	Processing
Sedimentary Inner Gorge (SIG)			
SIG-*Qo2*	19.0	Roads	Transport 4,5,9
SIG-*Qo3*	4.8	Sideslope failure, associated w/ windthrow	Transport 3,4
SIG-*Qo4*	2.0	LPD landslides and smaller streamside slumps	Storage in forced bars/terraces, otherwise transport 3
Total	454.5		

Hydrology

The effect of hydrology, specifically stream flow and groundwater inputs, on water temperature is through the effect on dissipative capacity. Aquatic systems in forested watersheds subject to low flows (e.g. through poor water storage over glacial tills and shallow soils) tend to respond quickly to increased heat. Aquatic systems with headwaters in wetlands or bogs as well as those streams affected by beaver ponds tend to have higher background temperatures. Other drainages may be affected by subtle groundwater influences through wet side slopes. Finally, streams that are "near" the water source with substantial groundwater influence (e.g. side seeps and springs) are typically cool and are more resistant to water temperature changes.

The effect of hydrology on stream temperature is illustrated in two ways. First, Figure D-9 shows the effect of streamflow on peak hourly water temperature. Note that as streamflows increase, water temperature changes become less pronounced. Second, as the relative percentage of groundwater flow increases, the amount of cooling in the stream also increases.

Figure D-9. Relationship between Streamflow and Temperature Change

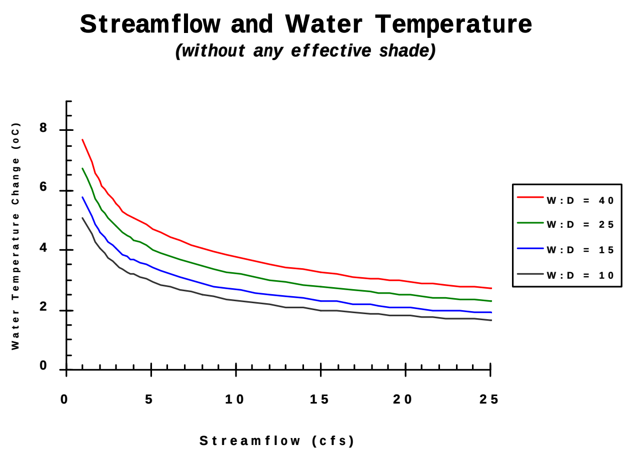
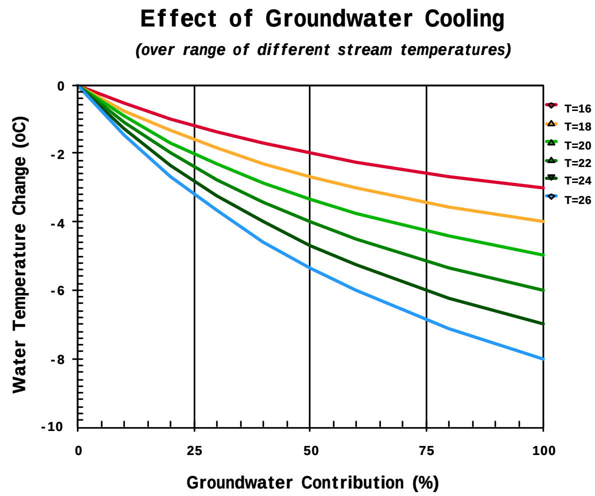


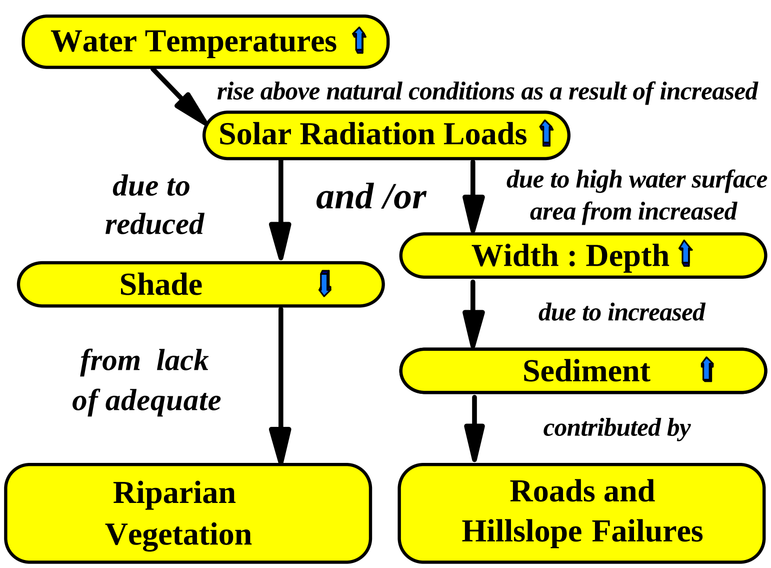
Figure D-10. Relationship between Groundwater Contribution and Temperature Change



ROLE OF SOURCE INPUTS

Heat delivered through increased solar radiation causes water temperatures to rise above natural conditions. The specific surrogates used in development of the TMDL are percent effective shade and sediment delivery. Decreased effective shade is the result of a lack of adequate riparian vegetation available to block sunlight (i.e. heat from incoming solar radiation). Excessive delivery of sediment is associated with road management and hillslope failures that contribute to channel widening. The relationship of water temperature increases to these surrogates is described in Figure D-11.

Figure D-11. Relationship of Water Temperature to Surrogates



Note: **Boxes depict measured or calculated key indicators**

Management activities can increase the amount of solar radiation delivered to a stream system, both by harvesting riparian shade trees and through the introduction of bedload sediment which can lead to channel widening. The Simpson HCP area has experienced a long history of land management, stemming back to the early twentieth century. This has resulted in degradation of the watershed condition. In the Simpson HCP area, anthropogenic sources of thermal gain and other nonpoint source pollution come from land management practices, specifically:

- Forest management within riparian areas
- Timber harvest in sensitive areas outside the riparian zone
- Sediment, hillslope failures, and roads

Riparian Area Management and Timber Harvest

Riparian vegetation can effectively reduce the total daily solar radiation load. Without riparian shade trees, most incoming solar energy would be available to heat the stream. Harvest of riparian area trees from management activities can result in loss of shade. Limited work has been done to estimate the amount of shade loss due to source activities. The W.F. Satsop Watershed Analysis summarized causes for not meeting target shade requirements. The report indicated that approximately 59% of the stream miles assessed met the shade target. Of the remainder, 13% were too wide to be fully shaded and 28% did not meet the shade target because of riparian condition.

Sediment, Hillslope Failures, and Roads

Most of the sediment supply that enters stream channels in forested watersheds is generated by several processes: mass wasting (landsliding), surface erosion (especially from roads), soil creep (especially in unstable areas), and bank erosion (from streamside terraces) [*see* Paulson, 1997]. This is especially true where steep unstable terrain is subjected to major weather events that saturate hillslopes with large volumes of precipitation. Mass hillslope failures can occur, which deliver large amounts of surface soils to stream channels. These events can overwhelm the capacity of the channel to transport this material downstream, which in turn can lead to substantial channel widening, attendant bank erosion, and shallowing of surface flows. Important salmonid (and associated life forms) habitat features (such as stable spawning areas, pools, side channel rearing areas) can be significantly affected by these processes.

Categories of sediment delivery identified in the Simpson HCP area, several of which are to some extent controllable, include:

- background sediment yield
- erosion associated with roads, skid trails, and landings
- hillslope erosion
- mass wasting (landslides)
- surface erosion from bare ground (e.g. landslide scars)
- bank erosion

Controllable sediment is sediment delivered as a result of human activities which can affect water quality and can be reasonably controlled. Rates of delivery have been estimated for these sources using several Watershed Analyses conducted within the Simpson HCP area.

SECTION E
Effective Shade Targets

Effective Shade Targets
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OVERVIEW

Stream temperatures in western Washington change seasonally, increasing during the summer months, reaching their peak between mid-July and mid-August. Seasonal peak temperatures can be exacerbated through altering heat transfer processes (e.g. increasing channel exposure to solar heating due directly to a harvesting of riparian forests or indirectly as a consequence of channel widening and increased solar exposure in response to sediment accumulations from upstream sources). In some cases, streams with headwaters in perched wetland areas may have naturally elevated temperatures.

Different stream temperature regimes occur naturally across the landscape based on watershed characteristics such as geology, elevation, topography, vegetation, and hydrology (both ground and surface water). These variations are considered in the Simpson HCP area TMDL through use of the lithotopo classification scheme.

TARGET IDENTIFICATION

Approach

Because of the difficulty in determining solar radiation loads over each stream mile, initial analyses of water temperature focus on examining patterns associated with different stream types. Studies of longitudinal trends indicate that small headwater stream temperatures are primarily regulated by local channel, riparian, and aquifer conditions. These conditions control the amount of vegetative and topographic shade on the stream surface as well as important cool groundwater inflow. Using information about each stream type (e.g. the range of flows, channel widths, desired riparian vegetation conditions, etc), effective shade targets can be developed for each class of streams.

The temperature groups described in Section D allow refinement of assumptions used to develop effective shade targets. Development of effective shade targets is then based on a better description of site specific conditions. In addition, actual data collected on streams in the Simpson HCP area is used to validate anticipated responses. The approach to develop effective shade targets is as follows:

- P *Characterize each temperature group* to describe conditions that reflect stream types and to define reasonable assumptions for development of effective shade targets.
- P *Evaluate monitoring data* and develop framework for comparison of assessment to results of heat budget analysis method.
- P *Analyze* heat budget over a range of expected conditions for each temperature group to examine patterns and confirm that effective shade targets will lead to attainment of water quality standards.

It should be noted that this approach considers channel conditions and desired riparian vegetation in identifying targets. A heat budget analysis is developed for comparison to actual water temperature data. The heat budget (or mechanistic model) describes the linkage between surrogate measures (i.e. effective shade) and improvements in water temperatures.

Assessment Framework

Diurnal variation in water temperature occurs naturally in stream systems. The magnitude of the temperature change (both diurnal range and peak hourly increase) has greater meaning in TMDL development for nonpoint sources than a *"no threshhold"* criteria (e.g. 16EC). This is because a TMDL is designed to decrease the pollutant load. Assessing hourly water temperature change when the potential solar radiation load is at its peak is much more straightforward than predicting attainment of an absolute water temperature. This approach incorporates consideration of natural conditions by looking at the increase from a base temperature (as opposed to engaging in a debate about what is the actual level of the base temperature).

For instance, water temperatures observed at a site located in a wilderness area situated in an old growth forest (basically natural conditions) might exceed the State criteria of 16EC on a day when air temperatures reach 100EF. It would be nearly impossible to develop a TMDL for that stream which guarantees attainment of the 16EC water quality standard for "AA" waters. The only way to provide that assurance would be to first complete a site specific criteria modification in support of a more appropropriate water quality standard.

It is possible to develop a TMDL (e.g. loading capacity and allocations) that focuses on an hourly water temperature increase when the potential solar radiation load is at its peak. An analysis can be constructed which evaluates solar radiation inputs and resultant water temperature change through a heat budget analysis (Section H). Figure E-1 depicts the diurnal variation of the temperature group monitoring sites on July 28, 1998. This is the day when maximum water temperatures were observed over the 2-year period for monitoring data provided by Simpson. This also corresponds to the date when the maximum water temperature was observed by the U.S. Forest Service over a 5-year period in the Humptulips watershed (immediately west of the Simpson HCP area). Figure E-2 shows both the diurnal change and peak hourly water temperature increase. Figure E-3 shows the relationship between peak hourly increase and daily maximum water temperature. Based on this relationship, the lowest peak hourly increase observed (0.45EC) is used to derive effective shade targets.

***Figure E-1*.** Temperature Group Summary

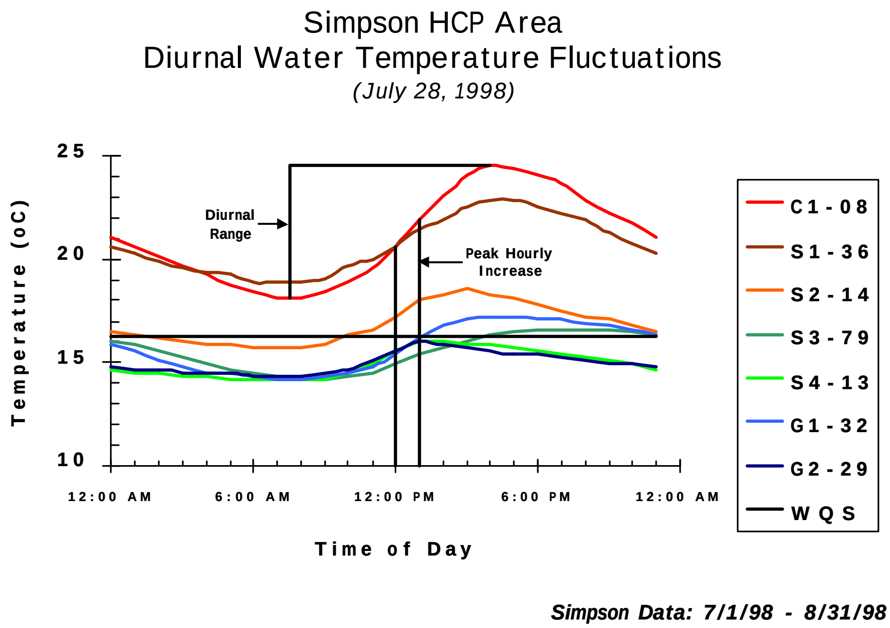
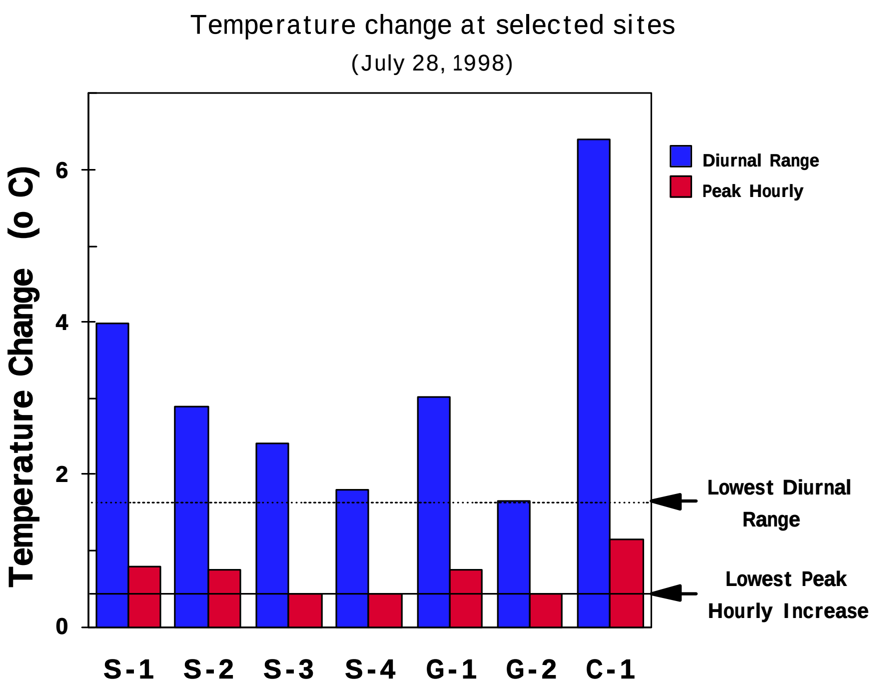
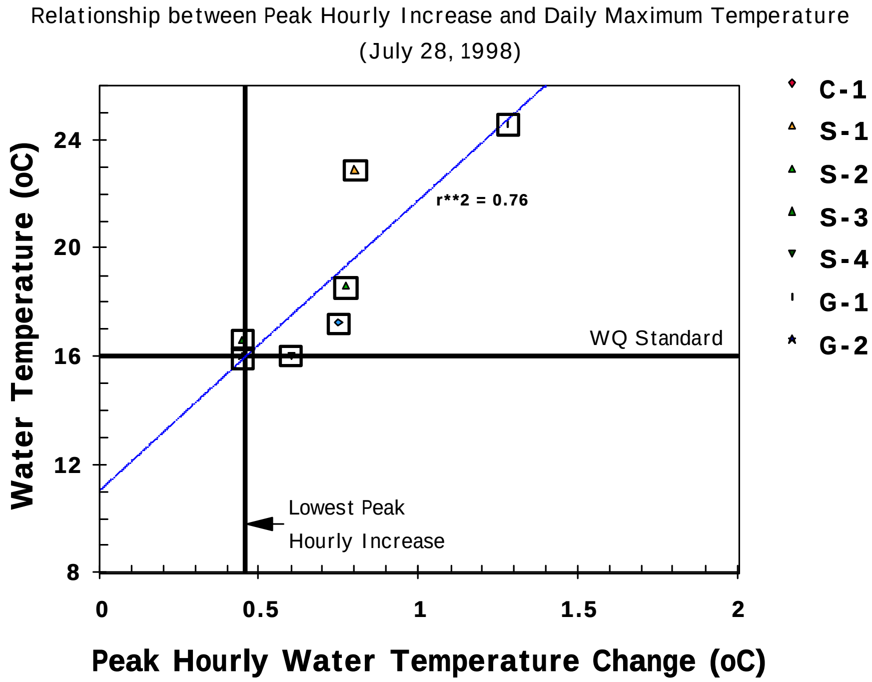


***Figure E-2*.** Temperature Group Summary



<u>Figure E-3</u>. Temperature Group Summary



<u>Temperature Change and Heat Loads</u>: As discussed in Section H, the temperature of water is an indicator of its internal energy per unit volume *(e.g. temperature % BTU / ft^3).* The mathematical relationship between water temperature and heat,

$$)T =)H * A / (V * D * c_p)$$

can also be used to estimate the hourly change in heat load when the hourly change in water temperature is known.

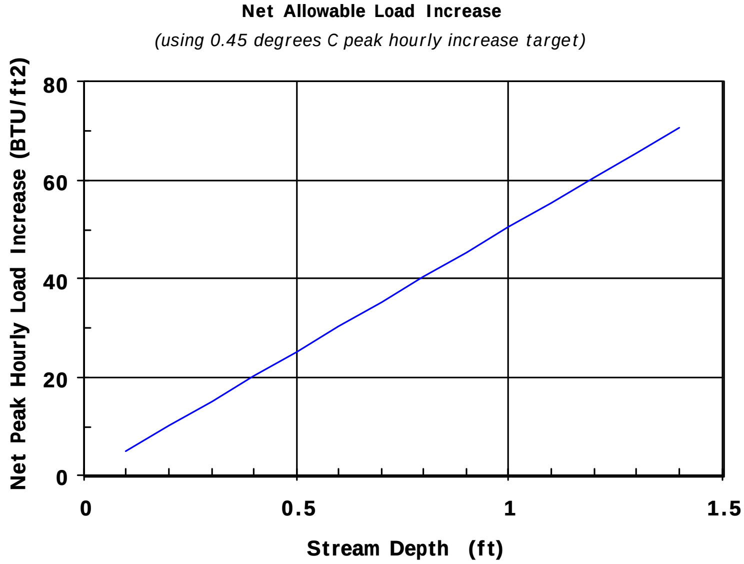
$$)H =)T * (V * D * c_p) / A$$

Because the volume divided by the surface area (V/A) is the average stream depth (d), the net change in heat load is:

$$)H =)T * 62.4 * d$$

Figure E-4 shows the relationship between the net allowable hourly increase in heat load and average stream depth when a target peak hourly water temperature increase of 0.45EC (or 0.81EF) is used.

Figure E-4. Relationship between Stream Depth and Net Heat Load Increase



Stream characteristics within the Simpson HCP area vary across the landscape. Although there is very little streamflow data available for the HCP area, methods have been developed to estimate flow from basin area for the Olympic Peninsula (Amerman and Orsborn, 1987). The channel classification system described in the HCP identifies streams as being small (active channel width # 4m), medium (4m < active channel width # 16m), or large (active channel width > 16m). Figure E-5 illustrates the relationship between drainage area and channel width in the Simpson HCP area. Table E-1 summarizes drainage characteristics in the HCP area by LTU.

Figure E-5. Simpson HCP Area

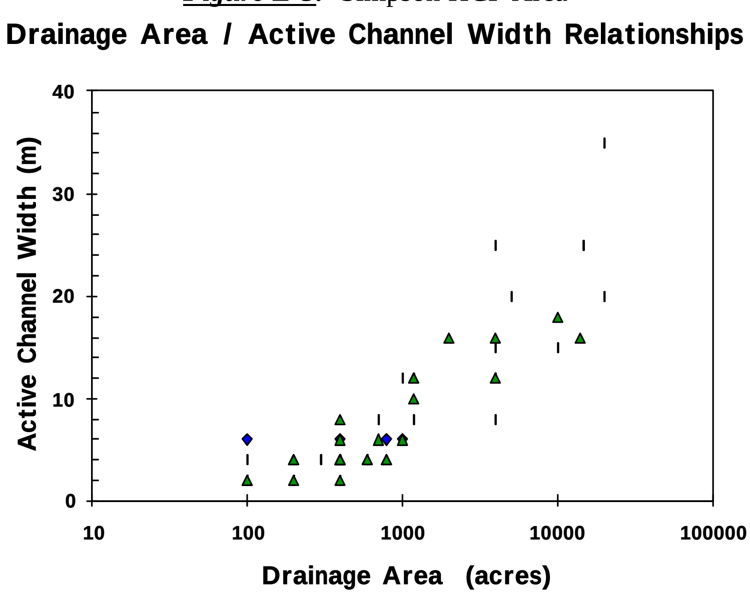


Table E-1**.** Lithotopo Unit / Drainage Characteristics

Lithotopo Unit	HCP Area	Stream Miles	Density *(mi / mi^2)*	Yield *(cfs / mi^2)*	Inflow *(cfs / mi)*
AGL	8%	137.7	3.98	1.0	0.251
CIS	12%	163.7	3.38	0.5	0.148
CUP	11%	265.2	6.10	1.0	0.164
ROP	45%	376.7	2.05	0.3	0.146
SIG	24%	454.5	4.61	1.0	0.217

- Flow yield estimated for each LTU from Amerman and Orsborn, 1987 (Figure 10-5). Represents seven-day, two-year (7Q2) low flow based on Olympic Peninsula gage information.
- Inflow is the flow yield divided by the drainage density to provide a rough estimate of flow derived per mile of stream (rough indicator of potential groundwater contribution).

TARGET DEVELOPMENT

Effective shade targets can be developed for each temperature group using a quantitative analysis of heat transfer processes. Simpson has compiled information about each channel class which includes basin area, size of the active channel, slope, etc. Reasonable assumptions can be defined for key factors that affect water temperature, e.g. stream depth, groundwater buffering. A heat budget analysis is then developed based on these assumptions to identify effective shade targets for each channel class.

The heat budget analysis used July 28 as the critical day. This is based on an analysis of stream temperature monitoring data from the Simpson HCP area. A wind speed of five miles per hour was used across the landscape based on sparse meteorological data that is available. To estimate conduction, a value of 75% was assumed to represent bedrock conditions.

Assumptions for base flow, average idth:depth ratio, groundwater flow, and groundwater temperature are summarized in Table E-2. Groundwater flow rates are based on water yield and inflow estimates described above. For several channel types, the percent inflow was increased to account for the effect of intergravel flow. This was based on patterns observed in reviewing stream temperature data. Groundwater temperature was also based on patterns observed in the stream monitoring data. Values assumed used the coolest water temperature for that group on the warmest day in 1997. The assumed groundwater temperatures are actually higher that a standard 10EC used in other modeling efforts which provides some margin of safety.

Table E-2a. Effective Shade Target Development — Channel Class Assumptions

LTU	Class	mi.	Basin Area *(acres)*	Active Channel Width *(m)*	Flow	W:D	Groundwater		Effective Shade Target
							(%)	*(EC)*	
Temperature Group: S-1									
ROP	Qc1	167.3	100 - 400	2 - 4	1	25	14.2	14.65	89.7%
	Qc2	103.4	100 - 400	2 - 4	1	25	14.2	14.65	89.7%
	Qc3	44.2	400 - 4,000	6 - 12	2	25	7.1	14.65	88.6%
SIG	Qc3	9.1	300 - 1,200	4 - 10	2	25	11.4	14.65	87.3%
Temperature Group: S-2									
AGL	Qo2	22.5	< 200	< 2	1	15	25.6	13.56	82.4%
	Qo4	2.6	300 - 700	4 - 6	1	15	25.6	13.56	82.4%
SIG	L1	160.0	< 400	0 - 2	1	15	22.8	13.56	83.6%
	L2	38.5	< 400	2 - 4	1	15	22.8	13.56	83.6%
	L3	6.3	400 - 800	2 - 4	1	15	22.8	13.56	83.6%
	M1	67.8	< 100	1 - 2	1	15	22.8	13.56	83.6%
	M2	18.5	100 - 600	2 - 4	1	15	22.8	13.56	83.6%
	M3	9.6	600 - 1,200	4 - 12	2	15	11.4	13.56	85.4%
	M4	6.0	600 - 1,200	4 - 12	2	15	11.4	13.56	85.4%
	M6	2.3	> 1,000	6 - 12	2	15	11.4	13.56	85.4%
	Qo2	19.0	200 - 800	2 - 4	1	15	22.8	13.56	83.6%
Temperature Group: S-3									
CIS	Qc1	33.3	100 - 400	0 - 4	1	15	14.2	12.16	84.6%
	Qc2	28.0	200 - 800	0 - 4	1	15	14.2	12.16	84.6%
	Qc3	16.8	4,000 - 14,000	8 - 16	4	15	8.0	12.16	83.1%
SIG	Qc1	12.8	100 - 400	2 - 4	1	15	22.8	12.16	79.5%
	Qc2	8.9	100 - 400	2 - 4	1	15	22.8	12.16	79.5%

Table E-2b. Effective Shade Target Development — Channel Class Assumptions

LTU	Class	mi.	Basin Area *(acres)*	Active Channel Width *(m)*	Flow	W:D	Groundwater (%)	Groundwater (EC)	Effective Shade Target
Temperature Group: S-4									
AGL	Qo3	7.3	200 - 600	2 - 4	1	15	25.6	11.50	75.6%
	Qo5	8.8	> 600	4 - 8	1	15	25.6	11.50	75.6%
	Qo6	13.6	> 800	6 - 8	1	15	25.6	11.50	75.6%
	Qo7	3.7	> 1,200	12 - 16	2	15	12.8	11.50	80.4%
SIG	Qo3	4.8	400 - 1,000	4	1	15	22.8	11.50	77.5%
	Qo4	2.0	700 - 2,000	8 - 16	3	15	7.6	11.50	82.3%
Temperature Group: G-1									
CIS	C5	1.7	100 - 400	4 - 6	1	25	21.8	12.75	84.5%
ROP	Qc4	9.1	400 - 1,000	4 - 6	1	25	21.3	12.75	84.7%
	Qc5	12.1	4,000 - 10,000	12 - 18	15	25	4.3	12.75	75.4%
	Qc6	9.5	4,000 - 10,000	12	15	25	4.3	12.75	75.4%
	Qc7	15.2	4,000 - 10,000	15	15	25	4.3	12.75	75.4%
Temperature Group: G-2									
AGL	Qo1	61.3	< 200	0 - 4	1	10	38.4	10.00	50.9%
	Qo8	5.2	> 10,000	15 - 25	15	10	7.7	10.00	58.3%
CIS	C1	83.9	< 200	0 - 4	1	10	21.8	10.00	70.8%
CUP	C1	199.9	< 100	0 - 2	1	10	24.3	10.00	68.0%
	C2	22.9	100 - 400	2 - 4	1	10	24.3	10.00	68.0%
	C3	24.5	100 - 400	2 - 4	1	10	24.3	10.00	68.0%
	C4	4.9	100 - 400	6 - 8	1	10	24.3	10.00	68.0%
	C5	3.5	100 - 400	4 - 6	1	10	24.3	10.00	68.0%
	C6	3.6	100 - 400	12	1	10	24.3	10.00	68.0%
	C8	5.9	> 5,000	20	8	10	6.1	10.00	71.6%
SIG	Qo1	38.3	< 200	0 - 4	1	10	34.2	10.00	56.0%

Table E-2c. Effective Shade Target Development — Channel Class Assumptions

LTU	Class	mi.	Basin Area *(acres)*	Active Channel Width *(m)*	Flow	W:D	Groundwater		Effective Shade Target
							(%)	*(EC)*	
Temperature Group: C-1									
AGL	Qa6	12.7	> 15,000	> 25	15	40	1.7	14.65	77.4%
ROP	C7	9.4	> 800	6 - 8	1	40	14.2	14.65	89.5%
	Qa7	3.7		>16	4	40	3.6	14.65	86.0%
	Qc8	2.8	4,000 - 10,000	25	8	40	1.8	14.65	82.6%
SIG	L4	24.2	> 20,000	35	25	40	0.9	14.65	71.7%
	M5	15.1	> 20,000	20	25	40	0.9	14.65	71.7%
	Qa6	11.3	> 15,000	> 25	15	40	1.5	14.65	77.5%

SECTION F
Riparian Vegetation and Shade

Riparian Vegetation and Shade
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BASIC PRINCIPLES OF SHADE

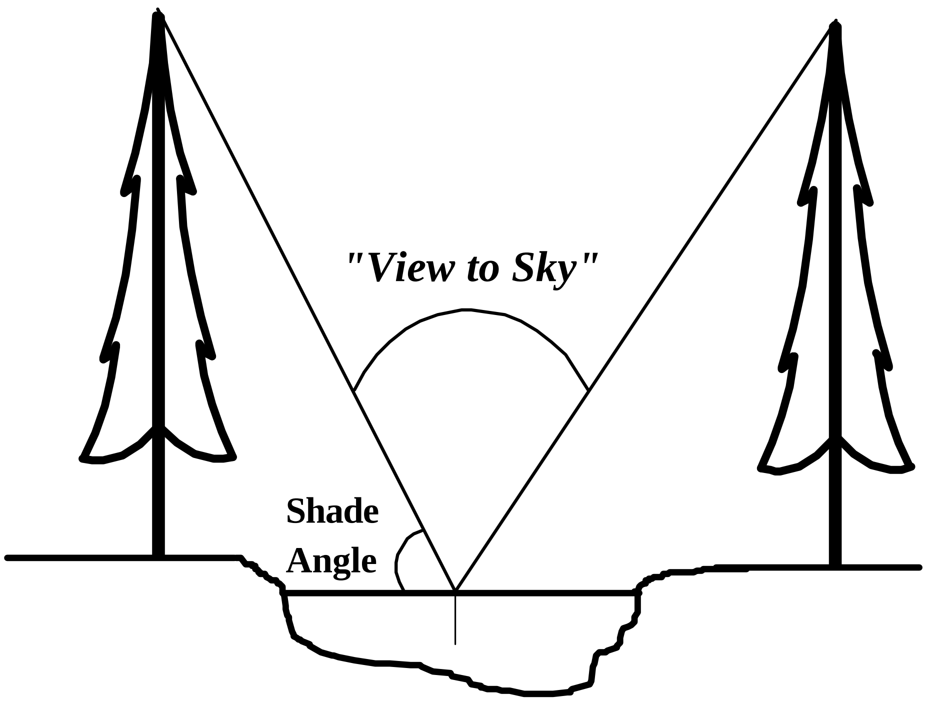
Riparian Shade: The purpose of evaluating components of shade is to develop meaningful measures which relate riparian characteristics to solar radiation reduction targets. It is important to remember the role that shade plays with respect to stream temperature. Solar radiation is a *"one way"* heating process for the stream. Heat energy gained from the sun must be dissipated by other energy processes, namely: *longwave radiation, evaporation, or convection*. For this reason, while shade does not cool stream water, it does prevent or reduce heating by solar radiation.

In order to assess the ability of riparian vegetation to shield a stream from solar radiation, one needs to consider two basic characteristics of shade: *shade duration* and *shade quality*. Shade duration is the length of time that a stream receives shade. Shade quality is the amount of solar radiation blocked by the shade. To minimize stream heating from solar radiation, two components of shade must occur. First, the stream surface shade must persist throughout the day, even when the sun is very high in the sky. Second, shade quality must be adequate to block the majority of the incoming solar radiation.

The earth tilts on its axis, varying throughout the year -- the earth tilts away from the sun in winter and towards the sun in summer. Days get longer in the summer months and the sun gets higher in the sky. The vertical position of the sun is known as the *solar altitude*. Due to the northern latitude of the Pacific Northwest, the sun never really gets directly overhead. In summer, the highest the sun gets is about 70E. When applied to riparian shading of a stream, one can ensure that shade spans the full length of a day if the stream side vegetation is tall enough to block the sun when it is at the highest solar altitude.

The *vegetation shade angle* is the angle that exists from the top of the vegetation canopy to the center of the stream surface. As can be seen in Figure F-1, the interaction between the shade angle and the sun's angle (solar altitude) controls the timing and duration of stream shading. Clearly, the *vegetation height* and the position of vegetation relative to the stream play a role in determining the vegetation shade angle. An increased vegetation shade angle lengthens the duration of shading at the stream surface.

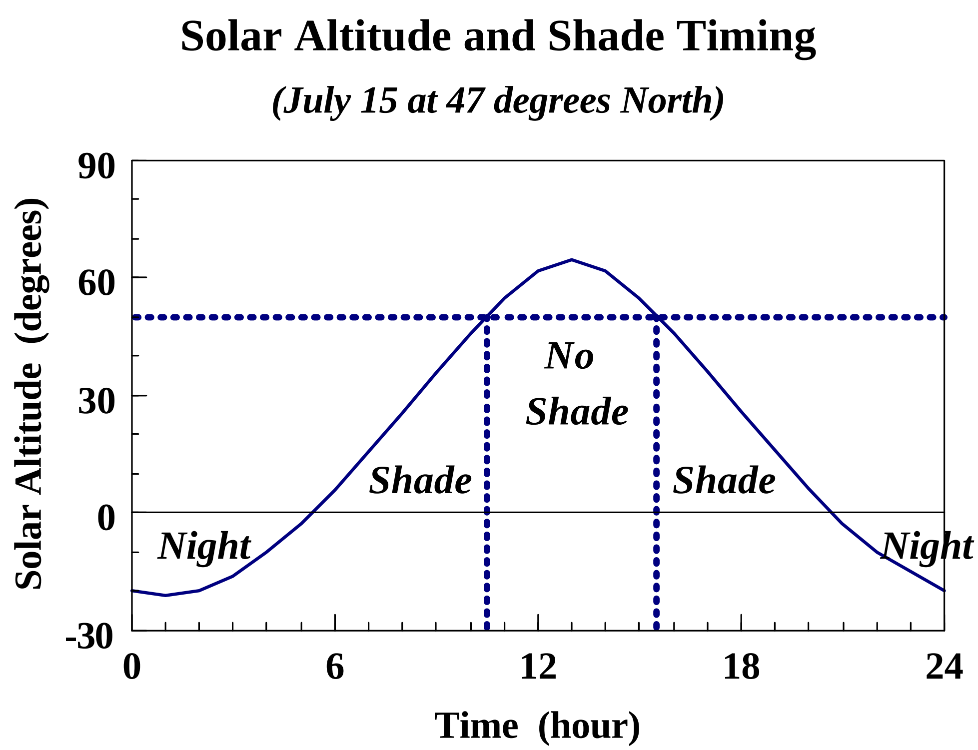
***Figure F-1*.** Vegetation Shade Angle



The stream receives shade when the solar altitude (or angle of the sun above the horizon) is less than the vegetation shade angle. Once the solar altitude exceeds the vegetation shade angle, the stream no longer is shaded. Figure F-2 describes the solar altitude in the Simpson HCP area on July 15. By comparing the relationship between vegetation shade angle and solar altitude, the timing and duration of shade that a stream receives can be determined.

As illustrated in Figure F-2, one can see that when the vegetation shade angle is 50E, the stream is completely unshaded between 10:30am and 3:30pm. This level of shading exposes the stream to over five hours of solar radiation. Furthermore, the heat transfer from solar radiation is greatest in the unshaded portion of the day as discussed in Section E and Section H. If the stream were to receive a complement of shade that lasted for the entire day length, the vegetation shade angle must be increased to about 70E (approximately equal to the highest daily solar altitude). In summary, vegetation shade angle controls shade duration.

Figure F-2. Solar Altitude and Shade Timing

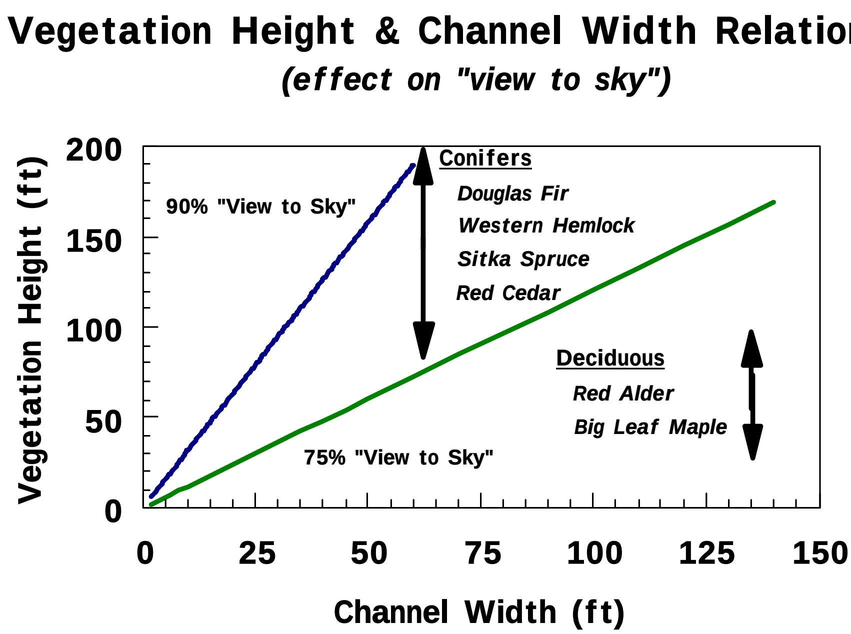


Shade Angle and "View to Sky": The State of Washington has developed a procedure for water temperature assessment within Watershed Analysis (WFPB, March 1997). This procedure addresses water temperature changes associated with the removal of riparian vegetation using the concept of maximum allowable *"view to sky"*. The *"view to sky"* is the fraction of the horizon above the stream that is void of canopy / and or topographic barriers (e.g. stream bank slope, hills, ridges).

In essence, this percentage of open sky is a measure of the absence of shade. *"View to sky"* is calculated by taking the percentage of the half circle (180E) which may be open to the sky and does not block incoming solar radiation. A shade angle of 72E, for example, along each stream bank blocks a total of 144E above the stream (each bank or two times 72E). This represents 80 percent (144E divided by 180E) or 20 percent *"view to sky"*.

In areas where sufficient topographic shading does not exist, riparian vegetation is critical to achieving *"view to sky"* targets. Figure F-3 illustrates the relationship between vegetative height and *"view to sky"* using several riparian community types.

Figure F-3. Channel Width and Vegetative Height Relationship to *"View to Sky"*



Shade Quality and Riparian Vegetation: The role of shade in this TMDL is to prevent or reduce heating by solar radiation. Riparian vegetation, particularly coniferous and deciduous trees, can provide significant amounts of shade because of their heights and extensive canopies (Beschta 1997). As discussed earlier, stream surface shade is dependent on riparian vegetation type and condition. The angle of the shade affects shade duration and is controlled by the average height of riparian vegetation and / or adjacent topography.

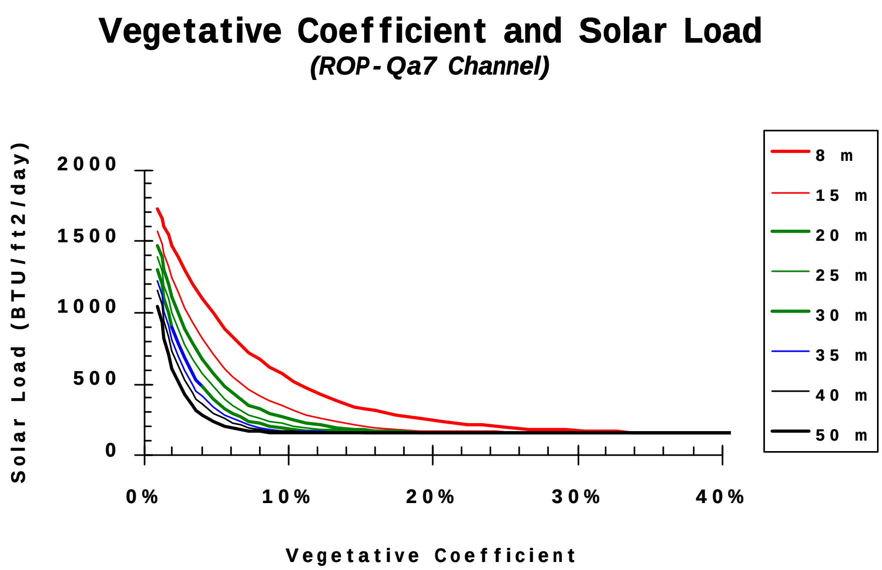
In the Simpson HCP area, undisturbed riparian areas generally progress towards late seral staged woody (mixed hardwood and coniferous) vegetative communities. Few, if any riparian areas in the Simpson HCP area are unable to support either late seral riparian vegetation or tall growing herbaceous vegetation. Furthermore, the climate and topography are well suited for growth of large woody vegetative species in riparian areas. A key part of target identification relative to shade quality is to evaluate the amount of shade provided by riparian vegetation.

The quality of shade provided to the stream surface is controlled by *vegetation density* and the *vegetation width*. The vegetation density is the average screening factor of the shade-producing vegetation along the stream. The canopy density reflects the quality of the shade-producing strata of vegetation along the stream. It represents the percent of light filtered by the vegetation's leaves and trunks (i.e. shade quality). Examples of shade quality cited in the literature (Bartholow, 1989; Reifsnyder and Lull, 1965; Brazier and Brown, 1973; Lafferty, 1987) range from about 65% for open pine stands to 90% for dense emergent vegetation. Vegetation density is actually composed of two parts (USFWS, 1989): the continuity of the vegetative coverage along the stream (quantity) and the percent of light filtered by the vegetation leaves and trunks (quality). For instance, if there is vegetation along 25% of the stream and the average density of that coverage is 50%, the total vegetation density is 12.5% (0.25 times 0.50).

Shade is enhanced by increasing the chance of collision between incoming photons from the sun and riparian vegetation. This is accomplished by augmenting the quantity of vegetation in the riparian zone, either by increasing vegetation density, and / or increasing vegetation width. Wide riparian vegetation corridors and a dense riparian canopy increase the quality of shade offered to the stream. The vegetative coefficient is one measure to evaluate the effect of riparian vegetation corridors on shade.

Attenuation of solar radiation can be calculated as a function of the vegetative coefficient (C_{veg}) and the solar path length through the vegetation (SPL_{veg}). The vegetation coefficient is the fraction of volume within the vegetation zone that attenuates and/or scatters incoming solar radiation (e.g. 0 - 100%). Beschta and Weatherred (1984) describe the vegetative transmissivity coefficient ($TRANS_{veg}$) determined as a function of the vegetative coefficient. Attenuation of incoming solar radiation due to vegetation is then estimated as a function of vegetation transmissivity and the solar path length through the vegetation. Figure F-4 illustrates the effect of the vegetative coefficient (Beschta and Weatherred, 1984) on solar radiation delivered to the stream.

<u>Figure F-4</u>. Effect of Vegetative Coefficient on Solar Radiation Loads



<u>*Effective Shade*</u> screens the water's surface from direct rays of the sun. Highly shaded streams often experience cooler stream temperatures due to reduced input of solar energy (Brown 1969, Beschta et al 1987, Holaday 1992, Li et al 1994). Stream surface shade is dependent on both topography as well as riparian vegetation type, condition, and shade quality *(Table F-1)*. While the interaction of solar mechanics and shade variables may seem complex, the math that describes them is relatively straightforward geometry (much of which was developed decades ago by the solar energy industry).

Table F-1. Factors that Influence Stream Surface Shade

Description	Measure
Season	Date
Stream Characteristics	Aspect, Active Channel Width
Geographic Position	Latitude, Longitude
Vegetative Characteristics	Species Composition, Height, Density
Solar Position	Solar Altitude, Solar Azimuth

The percent effective shade is a fairly straightforward determination. It is the difference between the potential daily solar radiation load and the actual daily solar radiation load at the stream surface (expressed as a percentage). The potential daily solar radiation load is determined from solar tables or calculations. The actual solar radiation load can be measured with a Solar Pathfinder© or estimated mathematically using procedures such as SHADOW (Park, 1993). From a management perspective, riparian vegetation has the greatest potential to influence shade, and thus stream temperatures. Over the years, the term shade has been used in several contexts, including its components such as shade angle or shade density. For purposes of this TMDL, effective shade is defined as the percent reduction of potential daily solar radiation load delivered to the water surface. Thus, the role of shade in this TMDL is to prevent or reduce heating by solar radiation.

Figure F-5 illustrates the same concept discussed earlier regarding the effect of solar radiation loads on stream temperatures. However, the information is presented in a manner consistent with the definition of effective shade in this TMDL (i.e. the percent reduction of potential daily solar radiation load delivered to the water surface). This provides an alternative target (or surrogate) which relates to stream temperatures, in this case, an 80% reduction in potential solar radiation delivered to the water surface. Figure F-6 depicts the relationship between the vegetative coefficient and effective shade for a ROP-Qa7 channel using buffer or Riparian Conservation Reserve (RCR) widths that range from 8 meters to 50 meters.

Figure F-5. Effect of Solar Radiation Reduction *(Effective Shade)* on Water Temperature

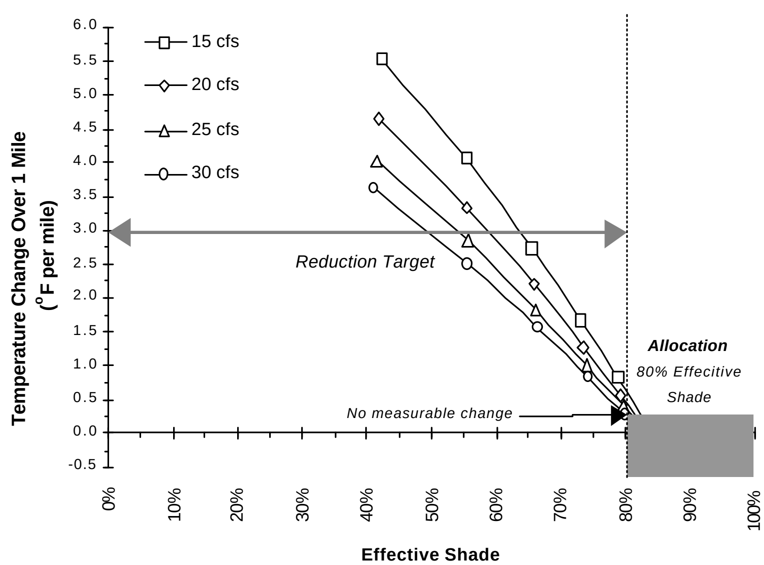
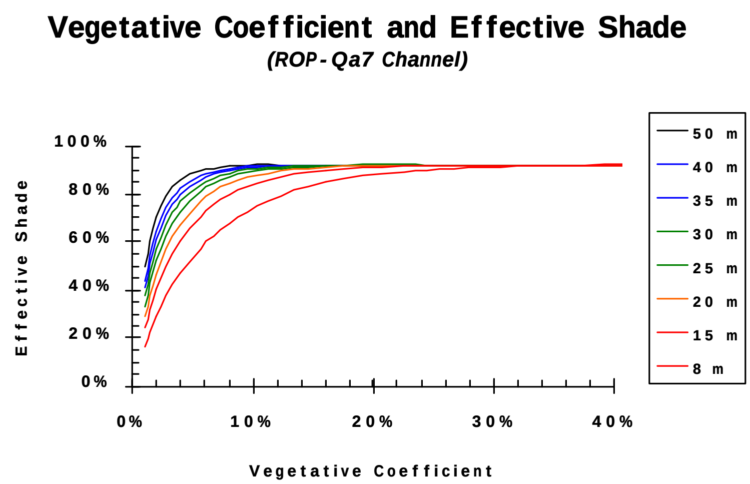
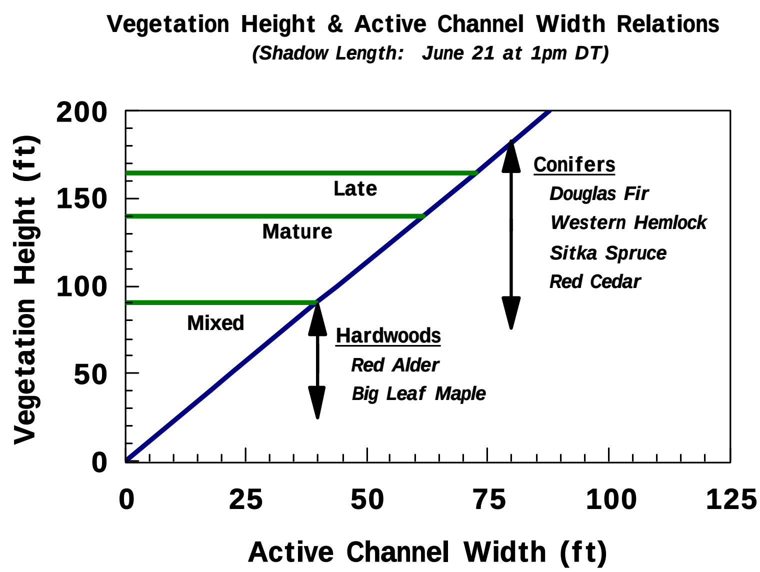


Figure F-6. Effect of Vegetative Coefficient on Effective Shade



Relationship Between Effective Shade and Channel Width: One significant consideration in identifying load allocations for effective shade is the relationship between the physical characteristics of the stream and the adjacent riparian zone. In addition to topography, riparian vegetation height and canopy density determine the physical barriers between the stream and the sun that can block incoming solar radiation (i.e. produce shade). In developing targets, the amount of shade provided by riparian vegetation must be considered. A starting point is an analysis of the length of shadow cast by potential riparian vegetation. Figure F-7 depicts the relationship between active channel width and the vegetative height required to completely shade the channel on June 21 when solar altitude is the highest of the year.

Figure F-7. Vegetative Height Needed to Shade Channel Width



As shown in Figure F-7, smaller channels can be completely shaded with shorter vegetation, as long as the riparian buffer is wide enough to provide adequate canopy density. However, for larger streams, there are situations where the vegetative height associated with a mature riparian forest is not tall enough to shade the entire active channel. For instance, on June 21 the shadow length of a 170 foot tall Douglas fir at 1pm (daylight time) is only about 75 feet.

ALLOCATIONS AND TMDL

The objective of the effective shade TMDL is to reduce heat from incoming solar radiation delivered to the water surface. The basis for effective shade allocations follows an analysis of processes that affect water temperature. Development of the effective shade allocations uses information about riparian management strategies described in the HCP. Riparian Conservation Reserve (RCR) widths described in the HCP recognize the relationship between active channel width and effective shade *(Table F-2)*.

Table F-2. Relationship Between Channel Width and RCR Width

Channel Width *(m)*	**Channel Class *(as function of RCR width)***						
	2m	***8m***	***10m***	***15m***	***20m***	***25m***	***30m***
2		AGL-Qo2 CUP-C1 SIG-L1,-M1					
4	ROP-Qc2	AGL-Qo1 ROP-Qc1 CIS-C1,-Qc1,-Qc2 SIG-M2,-Qc1,-Qo1,-Qo2	AGL-Qo3 SIG-L3 SIG-Qo3	CUP-C2 CUP-C3	SIG-L2		
6			ROP-Qc4	CUP-C5	AGL-Qo4 CIS-C5		
8			AGL-Qo6	CUP-C4	AGL-Qo5 ROP-C7		
10			SIG-Qc3				
12			SIG-M3		CUP-C6 SIG-M4 ROP-Qc3,-Qc6		SIG-M6
15							ROP-Qc7
16			AGL-Qo7		SIG-Qo4 CIS-Qc3		ROP-Qa7
18				ROP-Qc5			
20						CUP-C8 SIG-M5	
25					AGL-Qo8	AGL-Qa6 SIG-Qa6	ROP-Qc8
35						SIG-L4	

Effective shade allocations have been developed from targets based on channel class width and characteristics of mature riparian vegetation *(Table F-3)* for that channel class including vegetative density. Effective shade allocations are a function of the vegetation that will shade the widest active channel for each class. The active channel width, the vegetative density associated with a particular RCR width, the height associated with the expected riparian community (e.g. mixed conifer / hardwood), and the gorge depth associated with each channel class are used to determine effective shade allocations.

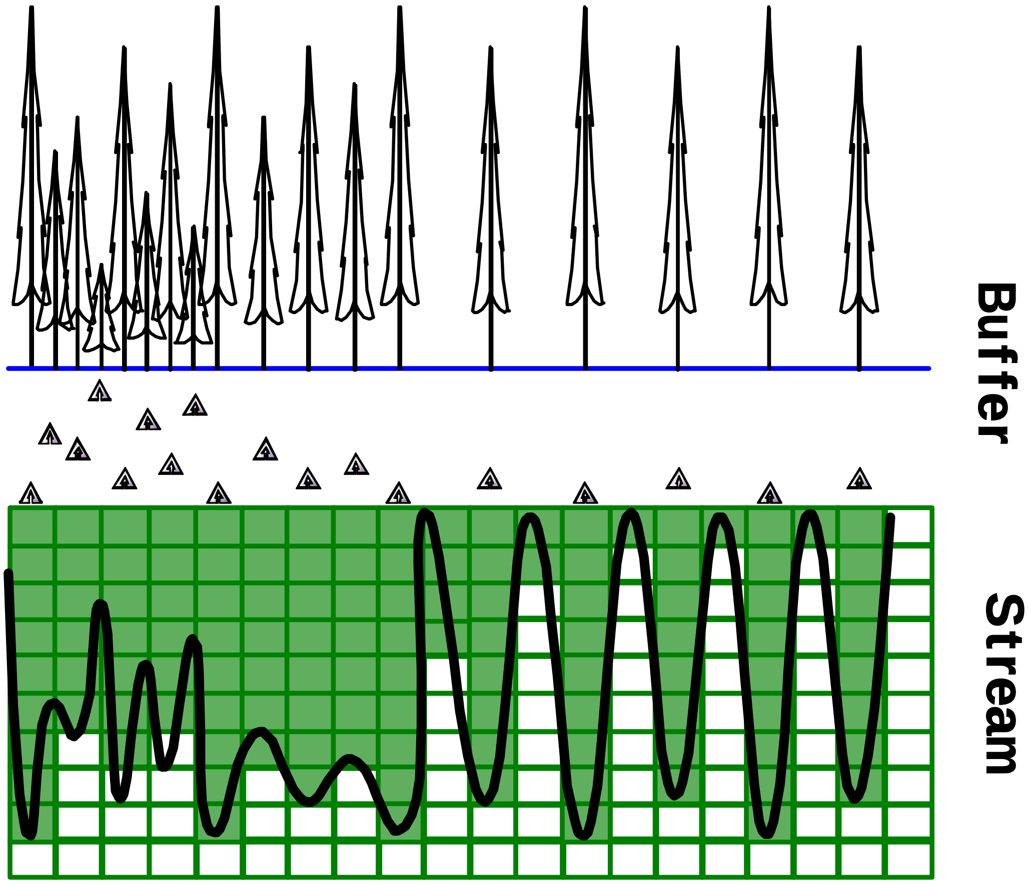
Table F-3. Mature Riparian Vegetation Classes in HCP Area

ID	Stage	Vegetation Description
H-M	**Mature**	**Hardwood:** Salmonberry, Thimbleberry (< 6 ft) Devil's Club (< 15 ft) Vine Maple (< 50 ft) Red Alder, Big Leaf Maple
M-M	**Mature**	**Mixed:** Listed Hardwoods Listed Conifers
C-M	**Mature**	**Conifer:** Douglas Fir, Red Cedar Western Hemlock, Sitka Spruce

As channels become wider, larger RCR widths are needed to provide more effective shade *(Figure F-8)*, as well as to protect other riparian functions. This is reflected in the HCP where wider channels have larger RCR widths identified. Small channels (# 4m), on the other hand, benefit from dense, emergent vegetation. Consequently, narrower RCR widths may still provide a high level of effective shade to these small streams. However, the benefit of the RCR to these smaller channels may go beyond effective shade. As indicated in the HCP, the purpose of the RCR is also to provide slope stability and a supply of large woody debris (LWD).

To date, very little work has been done in developing methods to determine the effective shade that results from a fixed riparian buffer width. Many variables and interactions contribute to the complexity of the problem. Figure F-8 depicts the basic framework that was used to estimate base effective shade allocations given an active channel width and RCR dimensions. EPA regulations acknowledge the challenge associated with establishing load allocations for nonpoint sources. The current regulation states: *"Load allocations are best estimates of the loading, which may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading" [40 CFR §130.2(g)]*.

Figure F-8. Framework for Evaluating Buffer / Stream Interaction



The framework shown in Figure F-8 allows a conceptual view of several factors that are important in developing estimates for effective shade allocations. These include consideration of the effect of dense, emergent vegetation on both small channels and on the *"sunward"* side of larger channels. It also allows recognition of the maximum shadow cast by a mature tree relative to its position within the RCR and the physical ability of that shadow to reach the stream. These estimates of base effective shade are summarized in Table F-4.

Other methods which could be used to assist in development of effective shade allocations include air photo interpretation of canopy closure. However, current availability of such information is limited. Also, estimation of canopy closure (and riparian shade) using air photo interpretation has a very crude level of accuracy. Recognizing the rough nature used to develop estimates for base effective shade allocations, information from instream monitoring will be used to evaluate effectiveness. One reason for using a peak hourly change target was to provide a link to effective shade in a way that utilizes actual water temperature monitoring data. The monitoring program will continue to use documented methods to collect canopy closure and riparian shade information. However, progress towards meeting load allocations and attaining water quality standards will be measured through assessment of the actual stream temperature monitoring data. Adjustments will be made to the TMDL, as necessary, if supported by information from monitoring and assessment efforts.

Table F-4. Relationship Between Active Channel Width and Base Effective Shade

Active Channel Width[1] *(m)*	Vegetation Height[2] *(feet)*	Effective Shade							
		3m	*8m*	*20m*	*25m*	*30m*	*35m*	*40m*	*50m*
2	21.1		93%						
4	42.3	92%	93%	95%	95%	95%			
6	63.4			92%	95%	95%		95%	
8	84.6			90%	91%	91%		91%	
10	105.7				88%				
12	126.8					85%		85%	
15	158.5								82%
16	169.2					80%		80%	
18	170.0					78%			
20	170.0						76%	76%	
25	170.0					72%		72%	
35	170.0							68%	

NOTES:

1 This table summarizes estimated base effective shade levels by active channel width. Active channel width determines the surface area requiring effective shade.

2 Riparian vegetation that completely shades a 45E aspect stream at 1pm (daylight time) on 6/21.

Key assumptions and allocations for effective shade are summarized in Table F-5. Gorge depth is used to account for *"near field"* topographic shade within each channel class. Some items to note relative to the effective shade allocations include variations between active channel width and minimum RCR widths. In many instances, channels of the same width size have different RCR widths. The temperature group and other considerations (e.g. LWD supply, sediment supply concerns) become important factors, particularly in terms of uncertainty and increasing the margin of safety. The 8-meter active channel width is used to illustrate this point. AGL-Qo5 and AGL-Qo6 streams are in temperature group S-4 (i.e. those streams strongly influenced by groundwater and more resistant to temperature change). As a result, this class of streams has a lower margin of safety. In contrast, CUP-C4 and ROP-C7 are in areas where sediment supply is a potential concern. Therefore, larger RCR widths are identified in the HCP for this class of streams.

Table F-5a. Summary of Parameters Used to Calculate Effective Shade LAs for Simpson HCP Area

Channel Class	Group	Active Channel Width (m)	Avg. RCR Width (m)	Mature Riparian Condition	Length (miles)	Assumptions (for key parameters)		
						Base Shade	Gorge Depth	Load Allocation
Temperature Sensitive Strategy								
ROP-*Qc3*	S-1	6 - 12	30/25	C(140)	44.2	85%		90%
SIG-*Qc3*	S-1	4 - 10	25/15	C(140)	9.1	88%		90%
Total for Strategy					53.3			90.0%
Break in Slope Strategy								
AGL-*Qo3*	S-4	2 - 4	25/15	M(90)	7.3	95%	3	96%
AGL-*Qo5*	S-4	4 - 8	20/10	C(140)	8.8	90%	9	93%
AGL-*Qo6*	S-4	6 - 8	30/20	C(140)	13.6	91%	2	92%
AGL-*Qo7*	S-4	12 - 16	30/20	C(140)	3.7	80%	3	82%
ROP-*Qc2*	S-1	2 - 4	3	M(90)	103.4	92%		92%
ROP-*Qc4*	G-1	4 - 6	20/15	C(140)	9.1	92%	4	96%
ROP-*Qc5*	G-1	12 - 18	30/20	C(140)	12.1	78%	5	81%
SIG-*L3*	S-2	2 - 4	20/15	M(90)	6.3	95%	5	97%
SIG-*Qo3*	S-4	4	25/15	M(90)	4.8	95%	3	96%
SIG-*Qo4*	S-4	8 - 16	30	C(140)	2.0	80%	7	84%
Total for Strategy					171.1			91.6%
TMDL								

Notes:

[1] TMDL currently refers to temperature group described in Section 3. Development of allocations based on representative conditions for mature riparian condition, maximum active channel width for class, and Riparian Conservation Reserve (RCR) width. As new data and methods are developed to better estimate effective shade that results from specific RCR for a particular channel class, the TMDL may be revised.

Table F-5b. Summary of Parameters Used to Calculate Effective Shade LAs for Simpson HCP Area

Channel Class	Group	Active Channel Width *(m)*	Avg. RCR Width *(m)*	Mature Riparian Condition	Length *(miles)*	Assumptions *(for key parameters)*		
						Base Shade	Gorge Depth	Load Allocation
Canyon Strategy								
CUP-*C2*	G-2	2 - 4	25	M(90)	22.9	95%		95%
CUP-*C3*	G-2	2 - 4	25	M(90)	24.5	95%		95%
CUP-*C4*	G-2	6 - 8	25	C(140)	4.9	91%		91%
CUP-*C5*	G-2	4 - 6	25	C(140)	3.5	95%		95%
CUP-*C6*	G-2	12	30	C(140)	3.6	85%		86%
Total for Strategy					59.4			94.1%
Channel Migration Strategy								
AGL-*Qa6*	C-1	> 25	40/30	C(140)	12.7	72%	10	77%
CIS-*Qc3*	S-3	8 - 16	30/20	C(140)	16.8	80%	10	85%
ROP-*C7*	C-1	6 - 8	40	C(140)	9.4	91%	10	94%
ROP-*Qa7*	C-1	> 16	50/40	C(140)	3.7	80%	2	85%
ROP-*Qc6*	G-1	12	40/30	C(140)	9.5	85%	10	89%
ROP-*Qc7*	G-1	15	65/40	C(140)	15.2	82%	10	86%
ROP-*Qc8*	C-1	25	40	C(140)	2.8	72%	10	82%
SIG-*M6*	S-2	6 - 12	50/30	C(140)	2.3	85%	10	89%
SIG-*Qa6*	C-1	> 25	40	C(140)	11.3	72%	10	77%
Total for Strategy					83.7			84.4%
TMDL								

Notes:

[1] TMDL currently refers to temperature group described in Section 3. Development of allocations based on representative conditions for mature riparian condition, maximum active channel width for class, and Riparian Conservation Reserve (RCR) width. As new data and methods are developed to better estimate effective shade that results from specific RCR for a particular channel class, the TMDL may be revised.

Table F-5c. Summary of Parameters Used to Calculate Effective Shade LAs for Simpson HCP Area

Channel Class	Group	Active Channel Width *(m)*	Avg. RCR Width *(m)*	Mature Riparian Condition	Length *(miles)*	Assumptions *(for key parameters)*		
						Base Shade	Gorge Depth	Load Allocation
Inner Gorge Strategy								
AGL-*Qo8*	G-2	15 - 25	30	C(140)	5.2	72%	5	74%
CUP-*C8*	G-2	20	35	C(140)	5.9	76%	10	81%
SIG-*L4*	C-1	35	40	C(140)	24.2	68%	30	72%
SIG-*M5*	C-1	20	40	C(140)	15.1	76%	30	86%
Total for Strategy					50.4			77.5%
Alluvial Bedrock Transition Strategy								
SIG-*M3*	S-2	4 - 12	30/15	C(140)	9.6	85%	7	88%
SIG-*M4*	S-2	4 - 12	40/25	C(140)	6.0	85%	10	89%
Total for Strategy					15.6			88.4%
Reverse Break in Slope Strategy								
AGL-*Qo4*	S-2	4 - 6	30/20	C(140)	2.6	95%		95%
CIS-*C5*	G-1	4 - 6	40/30	C(140)	1.7	95%		95%
SIG-*L2*	S-2	2 - 4	30/20	M(90)	38.5	95%		95%
Total for Strategy					42.8			95.0%
TMDL								

Notes:

1 TMDL currently refers to temperature group described in Section 3. Development of allocations based on representative conditions for mature riparian condition, maximum active channel width for class, and Riparian Conservation Reserve (RCR) width. As new data and methods are developed to better estimate effective shade that results from specific RCR for a particular channel class, the TMDL may be revised.

Table F-5d. Summary of Parameters Used to Calculate Effective Shade LAs for Simpson HCP Area

Channel Class	Group	Active Channel Width *(m)*	Avg. RCR Width *(m)*	Riparian Condition	Length *(miles)*	Assumptions *(for key parameters)*		
						Base Shade	Gorge Depth	Load Allocation
Unstable Slopes / Intermittent Flow Strategy								
AGL-*Qo1*	G-2	0 - 4	8	M(90)	61.3	93%		93%
AGL-*Qo2*	S-2	< 2	8	M(90)	22.5	93%		93%
CIS-*C1*	G-2	0 - 4	8	M(90)	83.9	93%		93%
CIS-*Qc1*	S-3	0 - 4	8	M(90)	33.3	93%		93%
CIS-*Qc2*	S-3	2 - 4	8	M(90)	28.0	93%		93%
CUP-*C1*	G-2	0 - 2	8	M(90)	199.9	93%		93%
ROP-*Qc1*	S-1	2 - 4	8	M(90)	167.3	93%		93%
SIG-*L1*	S-2	0 - 2	8	M(90)	160.0	93%		93%
SIG-*M1*	S-2	1 - 2	8	M(90)	67.8	93%		93%
SIG-*M2*	S-2	2 - 4	8	M(90)	18.5	93%		93%
SIG-*Qc1*	S-3	2 - 4	8	M(90)	12.8	93%		93%
SIG-*Qc2*	S-3	2 - 4	8	M(90)	8.9	93%		93%
SIG-*Qo1*	G-2	0 - 4	8	M(90)	38.3	93%		93%
SIG-*Qo2*	S-2	2 - 4	8	M(90)	19.0	93%		93%
Total for Strategy					921.5			93.0%
TMDL								

Notes:

[1] TMDL currently refers to temperature group described in Section 3. Development of allocations based on representative conditions for mature riparian condition, maximum active channel width for class, and Riparian Conservation Reserve (RCR) width. As new data and methods are developed to better estimate effective shade that results from specific RCR for a particular channel class, the TMDL may be revised.

SECTION G
Sediment Assessment

Sediment Assessment
Index

OVERVIEW

The effect of sediment and its relationship to numeric water quality standards is incorporated into the Simpson HCP area TMDL through the temperature group approach. Groups are defined according to the dominant control(s) which influence water temperature, specifically shade, groundwater, or channel morphology. *Group C-1* represents streams where temperatures are strongly influenced by channel pattern affected by high sediment supply. Changes in sediment input can lead to an alteration of channel form (Leopold et al, 1964; Megahan et al, 1980). When delivery of sediment increases over the transport capability of the stream, deposition occurs. Water quality and associated beneficial uses can be affected by deposition of sediment. Table G-1 provides a summary of water quality concerns associated with excess sediment, including the relationship to water quality standards. Developing numeric targets for use in a sediment TMDL presents challenges. With the exception of total suspended solids, applicable water quality standards are typically narrative.

Table G-1. Water Quality Concerns Related to Sediment

Sediment --- The Concern
Sediment sources associated with past and present timber harvest activities can be a fundamental problem for aquatic habitat quality. The influence of coarse and fine sediments on salmonid fishes is both direct and indirect. Several excellent reviews have been written (*see* Chapman 1988, Burton et al. 1990, MacDonald 1992, Cook-Tabor 1995, Klein 1998). The consequences of these sediment inputs to stream channels and their aquatic habitat can range from mild to severe, involving recovery periods from months to possibly centuries where the channel has been scoured to bedrock. The effects are more significant where inadequate large woody debris exists within the channel and adjacent riparian zone, because LWD can play a significant role in gravel storage and habitat complexity. The nature of dominant sediment processes varies depending upon the characteristics of the landscape. This variability is captured in the *landscape stratification system* that Simpson has developed for purposes of structuring their land management planning and fulfilling the terms of the Habitat Conservation Plan [5 lithotopo units (LTUs) and 49 channel types nested within the LTUs]. A brief summary of key characteristics is provided in the HCP. For example, in the steep mountainous terrain typical of the Crescent Uplands LTU, past logging on unstable hillslopes, interception of groundwater and runoff concentration in ditch lines associated with roads -- all can contribute to increased rates of erosion from this landscape and into the network of stream channels that support anadromous and resident trout. On the network of logging haul roads, the density, location, construction details and volume of traffic during periods of rain and snowmelt, can increase surface erosion of silts and sands that then enter streams.
Relationship to Water Quality Standards
Numeric sediment criteria in Washington State Water Quality Standards rely solely on a measure of suspended sediment expressed as total suspended solids (TSS). This may have only an indirect correlation with sediment factors that affect salmonids, such as embeddedness of spawning gravels with sediment particles <0.85 mm in diameter. In addition, the applicable water quality standard for sediment in the State of Washington is narrative and states that: *"deleterious material concentrations shall be below those which may adversely affect characteristic water uses" [WAC 173-201A-045(1)(c)(vii)]*. As a result, instream habitat targets cannot be reliably defined that truly reflect the potential expression of habitat variables within the respective channel systems (Bauer and Ralph, 1999). For purposes of constructing an effective approach to a sediment TMDL, an alternative approach is proposed that integrates all of the factors contributing to deleterious sediment effects on aquatic biota, rather than relying on a single in-stream measure such as TSS. This alternative approach targets erosion processes that contribute sediment to streams in the HCP area through construction of a partial sediment budget. This framework is then used to identify sediment reduction needs related to major erosion processes that deliver sediment.

Streams in the Simpson HCP area are particularly prone to storm-induced events, and experience erosion even under natural conditions. However, land management patterns and practices have contributed to erosion above natural rates through processes such as mass wasting (e.g. landsliding). Timber harvest and road construction associated with forestry can significantly alter the rate and pattern of sediment sources across the range of landform types. The resultant erosion has caused increased sediment to enter streams in the Simpson HCP area. In some streams, this has overwhelmed the ability of channels to efficiently move delivered sediment.

From a water quality standards perspective, there is only a limited means to address sediment issues from nonpoint sources (NPS) associated with land uses. Traditional point source approaches are not directly applicable in these circumstances. In landscapes where silviculture is the predominant land use, monitoring of precipitation-event spikes in the turbidity, while possible, provides only limited information about the consequences of excess sediment on beneficial uses.

Measures Considered

Numeric targets which have been used in other sediment TMDLs (e.g. S.F. Salmon River, Garcia River, Redwood Creek, S.F. Trinity River) include percent fines, pool - riffle structure, pool depth, median particle size (d_{50}), large woody debris, and decreased hillslope / road-related sediment production. Although several of these sediment TMDLs make use of numeric target values for a suite of instream habitat variables (e.g. Redwood Creek TMDL, Northern California), their values are based by a substantial amount of site specific data gathered over many years (see Nolan et al. 1995). In such cases, instream target values may be appropriate. In other cases where data and information was not available to support the delineation of specific numeric targets, an improving trend target was deemed appropriate (e.g. Redwood Creek large woody debris).

Limited instream sediment data has been collected in the Simpson HCP area. Most of the information that exists is associated with observations from several Watershed Analysis developed for drainages within the HCP area (W.F. Satsop, S.F. Skokomish, Kennedy Creek). Several measures considered in other sediment TMDLs will be discussed in the context of existing information associated with these watershed analyses, specifically the stream channel assessment.

Fine Sediment: Example measures considered include:

- Percent fines
- Pool depth

Measurement of fine sediment composition in potential spawning gravels has been used in the S.F. Salmon River, Idaho as well as in several northern California TMDLs. Rationale for use of a percent fines target is described in supporting material associated with each TMDL. Peterson et al. (1992) summarized many studies in developing recommendations for Washington's TFW program, and noted that 11% was the average observed in unmanaged streams in the Pacific Northwest. Relative to the HCP area, fine sediment does not appear to be a major problem. Information from the S.F. Skokomish and W.F. Satsop watershed analyses indicate that, based on field observations, sensitivity to fine sediment is low to moderate.

Width / Depth Ratio: The shape and dimensions of a stream channel, for a given location, are sensitive to the balance between sediment load and stream flow or energy (Leopold et al. 1964). When sediment loads become excessive a channel will aggrade, becoming shallower with a loss of pools and an increased width to depth ratio. Expected width to depth ratios are dependent upon the geomorphic setting of a stream or channel type (Rosgen 1996). To avoid the effect of differences in stream flow on measurement, width and depth must be based upon a fixed stage. The bankfull width and depth of a stream are most characteristic of channel cross-section. Such measurements are quite quickly and easily obtained. Calculation of a stream's average width/depth ratio is best based upon several (3-6) permanent transects representing a given reach. Although general guidelines for width/depth can be suggested based upon published literature, no absolute values can be offered.

Pool Parameters: Numerous studies have demonstrated a link between management activities, sediment production, and reduction in pool frequency, depth, and volume (Overton et al. 1993; Meehan 1991; Sedell and Everest 1990; MacDonald et al. 1991). As a result, pool measures like pool frequency and residual pool volume (V*), can be practical and effective sediment targets. Pool frequency as a sediment target is a measure of fish habitat availability in a given stream reach where the number of existing pools in a reach is related to the desired number of pools. The ideal number of pools for a stream reach is a function of geology, valley-channel morphology, stream flow, and sometimes large woody debris. Leopold et al. (1964) and Rosgen (1996) show that there are relationships between channel characteristics and pool frequency. The best way to determine the proper or desired pool frequency in a given stream reach is to use reference conditions (Overton et al. 1995).

Residual pool volume (V*) is a measure of the fraction of pool volume filled with fine sediment (Lisle and Hilton 1991). Residual pool depth is a measure of pool depth which is not dependent upon discharge at the time of measurement (Lisle 1989). These measure are effective sediment targets because they primarily reflect chronic sediment sources (Lisle and Hilton 1991). The desired pool volume is related to pool frequency. As V* is reduced, the pool frequency and residual pool depth increase. Much like pool frequency, the ideal pool volume and depth are related to stream characteristics, so that the status of the stream in question should be compared to a reference stream. Moreover, V* and pool frequency can likely be used as combined sediment targets with the conditions in a reference stream providing an accurate method to determine desired conditions.

Changes in Peak Flow: Management activities (i.e., activities which remove vegetation and increase soil compaction) are known to increase the magnitude and frequency of peak flow events (Jones and Grant 1996; Harr et al. 1975; MacDonald et al. 1991). Increased peak flows disrupt the balance between channel form and sediment flux. A stream out of equilibrium with sediment input is typically limiting to beneficial uses. If changes in peak flow magnitude and/or frequency can be statistically demonstrated, then a possible sediment target might be a measurable decrease in peak flow events. The applicable statistical method is ANOVA using two periods of time (pre and post-TMDL) (Grant and Jones 1996; Riggs 1968). The target might be a statistically significant decrease ($p < 0.05$) in the magnitude and frequency of peak flow events following implementation of the TMDL.

Sediment Rating Curves: A stream's discharge of sediment is highly variable due to variation in stream flow. Suspended sediment concentrations and bedload typically have a strong correlation with flow, although they can exhibit hysteresis (i.e., the relation is different between increasing and decreasing flow) (Leopold 1994; Mount 1995; Leopold and Emmet, 1997). As a result, sediment discharge ranges widely from time to time due primarily to timing of weather events and the supply of hillslope and streambed sediment (Ketcheson, 1986). This can render individual measurements of limited value, make longer term load estimation suspect, and effects of human influence hard to detect through direct measurement of either concentration or load.

The relation of suspended sediment concentration and bedload to stream discharge (also known as the sediment rating curve) is much more characteristic of erosional processes and long-term sediment discharge rate than any one concentration or load. This is because the sediment rating curve provides a characterization of sediment discharge over a range of flows thus overcoming day to day, or even year to year, differences in flow. A sediment rating curve can be established with as few as ten to fifteen measurements, if spread out across the full range of flows in an annual hydrograph (Ketcheson 1986). Using a sediment rating curve, reasonably accurate estimates of periodic sediment discharge can be made based upon more or less continuous records of discharge and relatively few sediment measurements (Campbell and Bauder 1940; Lewis 1996). Thus annual or partial-year loads can be estimated based upon an annual hydrograph or other record of flows.

It is possible to use a sediment rating curve to relate a given flow to an estimated concentration of total suspended solids (TSS). Thus, a record of flows could be used to determine the likely frequency of exceedance of a suspended solids target. Reductions in erosion and/or sediment delivery to a stream will be reflected in a decrease in the slope and/or intercept of the sediment rating curve (Rosgen 1996). This can be used to monitor post-implementation effectiveness of control measures. Sediment rating curves can also have direct application in the setting of TMDL targets and determination of needed load reductions. For example, using an average or typical hydrograph, a desired reduction in the frequency of exceedance of a TSS target and/or bedload can be related to a reduction in the slope of the sediment rating curve and a corresponding reduction in average annual or typical sediment load. While any particular series of post-implementation sediment discharge measurements might show an increase or decrease in sediment load, due primarily or even solely to differences in flow, a reduction in the slope of the sediment rating curve is evidence of improved conditions independent of wet or dry years.

Use of sediment rating curves as an indicator of changes in sediment discharge is usually only applicable where there exists a continuous flow gaging station and a companion record of suspended sediment and/or bedload measurements adequate to produce a reliable rating curve. However, for a given site with a limited flow record (i.e., 1 or 2 years of continuous record) which is near sites with long-term continuous records, the hydrograph can be extended using techniques summarized by Hirsch (1982) and Alley and Burns (1983). An alternative sediment rating curve method, proposed by Rosgen (1996), uses existing stream discharge-sediment load data in a more general way. Leopold et al. (1964) suggest rating curves for different stream systems are very similar and can be converted to dimension-less curves by expressing flow (Q) and TSS as ratios of their bankfull values (Q_i/Q_{bf}) and (TSS_i/TSS_{bf}) [where Q_i and TSS_i are values for a range of flows, and QBF and TSSBF are the discharge and sediment concentration at bankfull flow. These dimension-less curves are stratified by channel type, watershed characteristics, and land use for comparison to other watersheds of interest. In effect, these curves are landform specific sediment-discharge relations and provide expected values for the relations.

At least one pair of measurements for a watershed needs to be at bankfull to construct the dimension-less ratio. Thus, for a watershed with no data, the TSS, bedload, and stream discharge are measured at bankfull flow. These measurements are used to calculate a ratio which should fall near the dimension-less sediment rating curve for watersheds with similar physical characteristics. A TSS or bedload target could then be set by taking into account the departure of this ratio from the dimension-less sediment rating curve.

Decreased hillslope / road-related sediment production: Sediment delivery to streams in the Simpson HCP area is influenced by episodic events. Linkages between hillslope sediment production and instream sediment detection are complicated by time lags from production to delivery, instream storage, and transport through the system. In limited areas, the linkages can be clarified somewhat. For example, where diversion of water from the road drainage system is possible, sediment can be carried from the road drainage and diverted into the stream. In addition, the crossing itself can fail, potentially delivering the volume of the crossing fill to the stream and possibly adding to the volume by triggering a debris flow.

Measuring instream water and substrate conditions, for example, is simply an indirect measurement of assumed *"cause-and-effect"* relations. More importantly, it is an *"after the fact"* measurement of the impairment which may prevent adequate protection of the beneficial uses of water. In many cases, timely road inspection and maintenance can prevent many of the failures and associated deliveries from occurring. Appropriate location, design, construction and maintenance of roads can frequently result in minimal sediment delivery. Likewise, some timber harvest activities can result in additional sediment delivery to stream systems, but appropriate practices can eliminate that delivery.

Hillslope and road-related targets are included because focusing on instream indicators alone would not achieve water quality improvements. Hillslope targets supplement instream criteria by providing measurable goals that are not subject to the variability of climatic conditions. Hillslope and road-related targets are easier to measure and are more controllable. Hillslope and road-related targets also have the advantage to a landowner of being easily converted to implementation plans and management practices that can be evaluated more frequently than instream targets.

In addition, including these targets address the problem of instream indicators which could suggest that conditions are good, while hillslope conditions of sediment to be delivered in the next large storm event continue to pose potential delivery hazards. In short, without addressing hillslope sources, the cycle of degradation could potentially be repeated until some species of aquatic life could no longer recover.

Approach

Without the opportunity to gain and apply site specific information, extrapolation of values derived from dissimilar areas may have limited relevance in development of appropriate instream targets. Instead, an alternative approach is employed that makes good use of the fundamental landscape and channel classification system Simpson has developed for the HCP. The lithotopo units (LTU) define the initial area to focus the components described below. The proposed approach includes the following elements:

- ***Focus on the up-slope sources of sediment*** rather than looking exclusively at the suite of instream features that reflect the outcome of both natural and management related factors. For example, mass wasting and surface erosion from roads are significant contributors to sediment problems in streams. Road density (miles of road/sq. mi. of basin area) for each lithotopo unit within the plan area are presented the HCP. The sediment abatement program includes an approach to address the mass wasting and surface erosion components of the overall sediment budget.

P ***Establish quantifiable targets for sediment delivery*** by erosion process (e.g. cubic yards delivered per mile per averaging period) associated with each channel class.

P ***Estimate sediment source reduction targets*** (e.g. 50% reduction in first 10 years of HCP implementation) of sediment inputs associated with hillslope and road/landing failures, shallow rapid landslides in headwater streams, and the contribution to streams of fine sediments attributable to surface erosion from roads.

a. For ***non-road related sediment sources*** (hillslope and channel) these reduction targets are based on an examination of aerial photos and the distribution and volume of slope failures in the previous three decades. An estimate of annual sediment input, both natural and induced will be estimated, and the reduction target keyed to that estimate. Simpson will be responsible for employing whatever measures deemed appropriate and effective to show progress towards attainment of reduction targets. At the 5 year mid- point and again at the end of the 10 year plan implementation period, an accounting will be provided as to the effectiveness of sediment reduction measures taken.

b. For ***sediment associated with roads***, the road/sediment model described in the WSA module will be used to estimate the volume of sediment throughout the existing road network. This will be done concurrently with the comprehensive road inventory, and identify a priority list of those roads most at risk of contributing sediment. Factored into the model will be a forecasting of which roads will receive what level of actual use, and during what seasons so the model can anticipate the temporal use aspect of road generated sediment. This will be an iterative process of calibrating the model projections with empirical observations seen in the field. Field observations of surface erosion from road segments of different design will be used to test assumptions and make refinements on model projections, for each LTU. This would be done in conjunction with a monitoring element to measure actual amounts of sediment generated and delivered to streams.

Changes made in road maintenance procedures will be monitored to document what effect it has on reducing road generated sediment. An annual audit report will be prepared to the agencies and tribes that documents what road remediation work was done, where and for what express purpose. Demonstrated reductions in road generated sediment will be key to showing an improving trend towards attainment of the sediment reduction targets. Simpson commits to conducting a monitoring program to determine the amount of surface sediment delivered to streams from their road network, and to document the merits of actions taken to reduce these amounts. In addition, Simpson will commit to defining new road design standards, informed by the previous years experience, within 5 years of plan approval, and specific for each LTU.

4. ***Use partial sediment budget*** to refine targets and allocations for watersheds of concern. Refinement of targets and allocations to distinguish between background levels and management sources of sediment. These estimated sediment budgets would be developed for watersheds, stratified by use of the LTUs described in the HCP. This system provides a useful understanding of the predominant sediment input processes that operate within watersheds nested in each LTU.

5. ***Track key in-channel habitat features linked to beneficial use support.*** For selected locations where excessive amounts of sediment input have occurred, certain channel features and instream habitat variables will be monitored. Channel cross sections and longitudinal profiles will be included in certain of these locations to document the response of certain reaches, which will document the spatial distribution of pool and riffle features, changes in the width and depth of selected channel locations, and bed elevation changes over time. Bed particle size distribution will also be tracked in these locations to better understand the suitability of spawning sites. Where salmon spawning occurs coincident with known sediment problem areas, some limited egg-to-emergence survival studies will be conducted to determine if bed scour has occurred. The remedies available to treat excessive sediment within particular stream reaches is very limited, but tracking of the fate of sediment waves may be helpful in understanding recovery rates and characteristics (Madej and Ozaki 1996). Distribution and characteristics of in-channel woody debris and pool features will monitored, and as information from geomorphically similar sites is collected, we will have a clearer picture of what mix of habitat features a given site is capable of.

SOURCE ASSESSMENT

Most of the sediment supply that enters steam channels in forested watersheds is generated by three major processes: mass wasting (landsliding), surface erosion (e.g. harvest areas, roads, landslide scars), and bank erosion (e.g. alluvial terraces, soil creep). This is especially true where steep unstable terrain is subjected to major weather events that saturate hillslopes with large volumes of precipitation. Mass hillslope failures can occur, which deliver large amounts of surface soils to stream channels. These events can overwhelm the capacity of the channel to transport this material downstream, which in turn can lead to substantial channel widening. Important salmonid (and associated life forms) habitat features (such as stable spawning areas, pools, side channel rearing areas) can be significantly affected by these processes.

Categories of sediment delivery identified in the Simpson HCP area, several of which are to some extent controllable, include:

@ erosion associated with roads, skid trails, and landings
@ hillslope erosion
@ mass wasting (landslides)
@ surface erosion from bare ground (e.g. landslide scars)

Controllable sediment is sediment delivered as a result of human activities which can affect water quality and can be reasonably controlled.

Partial Sediment Budget

The source assessment for this TMDL is framed around a partial sediment budget with a focus on erosion processes. Major erosion processes that deliver sediment to the channel network include mass wasting, surface erosion, and bank erosion as well as the remobilization of stored sediment in the channel. The sediment source analysis presented in this section draws from information contained in several watershed analyses conducted in the Simpson HCP area. Information and techniques from other partial sediment budget efforts conducted in the Pacific Northwest have also been utilized. Dunne (1984), for example, developed a budget for the South Fork Snoqualmie by attempting to calculate annual contributions of sediment from soil creep, mass wasting, and surface erosion. These estimates for suspended sediment loading were then compared against those presented in a U.S. Geological Survey report (Nelson, 1971).

As a starting point, the U.S. Geological Survey (USGS) conducted a sediment transport study of tributaries to the Chehalis (Glancy, 1971). This study, which included several streams that drain the Simpson HCP area, utilized sediment rating curves to establish loading relationships. The study noted that the Satsop River system generated over one-fourth of the suspended sediment load in the entire Chehalis River basin. Annual suspended sediment yield per unit watershed area in the W.F. Satsop (1500 tons/mi^2/year), for instance, is five times the average for the Chehalis River system (300 tons/mi^2/year). To provide a frame of reference for a partial sediment budget, Table G-2 presents a summary of annual average sediment yield data from the USGS report.

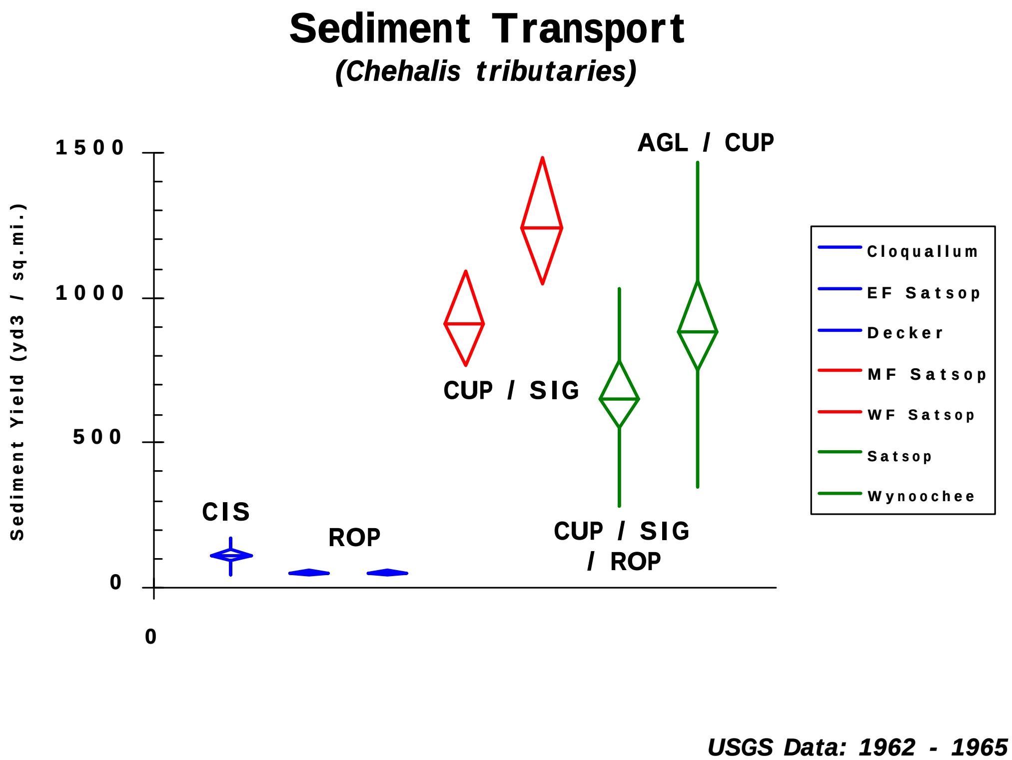
Table G-2. Summary of Annual Average Sediment Yield

Site	**Lithotopo Unit**	**Annual Average Sediment Yield**		
		USGS Report [1] *(ton / mi^2 / year)*		**Average Volume Estimate [2] *(yd^3 / mi^2/ year)***
		(average)	***(range)***	
Cloquallum Creek	CIS	136	*(65 - 169)*	112
E.F. Satsop River	ROP	60	-----	50
Decker Creek	ROP	60	-----	50
M.F. Satsop River	CUP / SIG	1,100	-----	908
W.F. Satsop River	CUP / SIG	1,500	-----	1,238
Satsop River	CUP / ROP / SIG	787	*(401 - 1,040)*	650
Wynoochee River	AGL / CUP	1,070	*(497 - 1,480)*	883

Note: [1] Data from USGS Water Supply Paper 1798 reported as tons / mi^2 / year.
[2] Values increased by 4% to account for bedload. Conversion to yd^3 assumes a bulk density of soil = 1500 kg / m^3 (or 1.26 tons / yd^3). Range could vary from 1200 to 1700 kg / m^3.

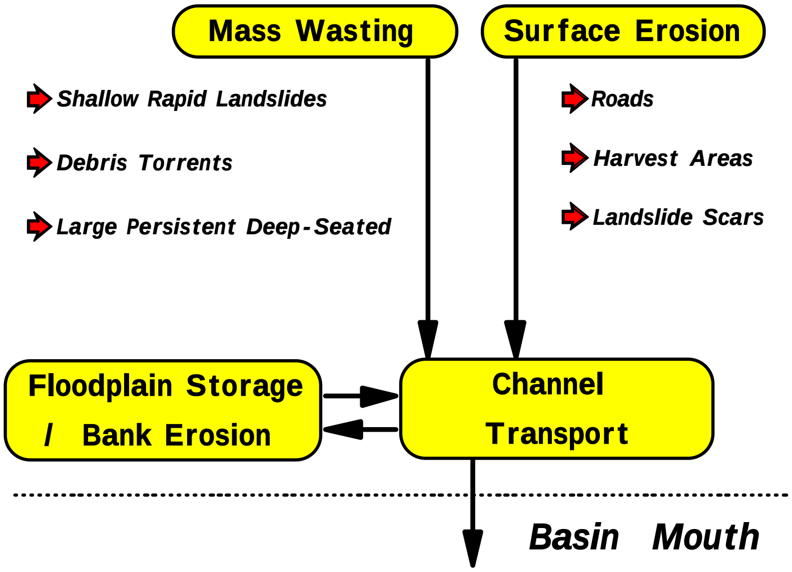
The intent of this framework is to gain a coarse understanding of sediment production and transport processes in the Simpson HCP area. The USGS study does not account for bedload which is a component of some sediment delivery processes, e.g. mass wasting and bank erosion. In a gravel transport study of three rivers draining the southern Olympic Mountains (Collins and Dunne, 1989), bedload was estimated to be 4 percent of the suspended load. Thus, the volume estimate in Table G-2 was developed by increasing the USGS value by 4 percent to account for bedload. Because of the absence of data on bulk density for soil in the Simpson HCP area, a value of 1500 kg/m^3 was assumed, as suggested by TFW. Figure G-1 presents a visual comparison to illustrate the wide range of differences in sediment yield for streams that headwater in the AGL, CUP, and SIG relative to those streams that flow from the CIS and ROP.

Figure G-1. Sediment Yield Summary



There are different approaches towards structuring a partial sediment budget. Methods used depend on the nature of the problem and available data. Leopold (1994) recognized this tremendous challenge when he stated: "*To describe how much sediment is transported by rivers is a difficult task because of variability in space and time, region to region, and year to year. Data are usually inadequate; they may deal with bedload, but not suspended load, or the opposite. Records are not long*". In providing an overview, Leopold has developed comparisons as orders of magnitude in tons per square mile per year. Recognizing the limitations, the partial sediment budget framework used to develop load allocations for the Simpson HCP area TMDL has a focus on key erosion processes *(Figure G-2)*.

Figure G-2. Partial Sediment Budget Framework for Simpson HCP Area TMDL



Mass Wasting

The assessment of mass wasting processes includes large persistent deep-seated slides (LPD), debris torrents (DT), and shallow rapid landslides (SR). Estimates of sediment contributions from mass wasting within the Simpson HCP area were compiled from the following sources:

- West Fork Satsop Watershed Analysis Report
- South Fork Skokomish Watershed Analysis Report

For the W.F. Satsop, landslide inventories were developed using aerial photographs from 1946, 1967, 1973, 1990, 1992, and 1993. Observations made in 24 days of field work and a helicopter overflight indicated that most of the approximately 1,100 inventoried landslides were in fact present on the ground. Landslides were classified according to:

- Process (DT -- debris torrents, LPD -- large persistent deep-seated landslides, and SR -- shallow rapid)
- Cause or associated land use (f, hp, hr, rh, rs)

Because a single volume was assigned for the entire budget period, regardless of changes in size over that time, volumes could not be segregated according to the interim periods within the overall budget period. The W.F. Satsop Watershed Analysis provides estimates of sediment delivery to stream channels in the WAU *(Figure G-3)*. These sediment delivery estimates are apportioned by mass wasting process, receiving water type, and geologic conditions. Table G-3 describes the method used in the Watershed Analysis to compute sediment delivery volumes from landslide inventory information. The high proportion of large persistent deep-seated (LPD) slides in the Sedimentary Inner Gorge (SIG) results from the prevalence of weak, deeply weathered bedrock, the presence of major incised stream valleys that create riverine escarpments, and the accelerated weathering and valley incision associated with glacial processes.

Table G-3. W.F. Satsop Watershed Analysis – Sediment Delivery Estimates

excerpt from ***"West Fork Satsop Watershed Analysis"***
"Appendix A — Mass Wasting Assessment"
2/20/96 — pages 13 - 14

"Measurement and computation of sediment delivery was accomplished primarily from inventory data. Mass wasting features that delivered sediment to the stream channel network were distinguished from those that did not on the basis of the original interpretation of each feature. If sediment produced from a mass wasting feature was clearly deposited in a location that did not deliver to a stream channel, then it was classified as a non-delivering feature. Otherwise, if delivery to stream channel was observed or appeared to be likely or possible, it was classified as a delivering feature. These criteria tend to overestimate actual delivery. In the Dissected landform, and to a lesser extent in the Glacial landform, delivery was often uncertain owing to the presence of wide terraces and the dense forest canopy; in many cases it could only be determined that mass wasting appeared to deliver to a valley floor. In addition, when a mass wasting feature delivered, the Water Type to which it delivered was observed and classified as either Type 1-3 or Type 4-5.

The volume of delivered sediment was estimated on the basis of typical soil depths and landslide geometry observed in the field and on aerial photographs. For SR's, sediment delivery was calculated as:

$$(D)(SA)(0.5) \qquad (1)$$

where D is typical soil depth equal to 3 ft., SA is scarp area as measured on aerial photographs, and 0.5 is the proportion of the landslide material delivered to the stream. The latter proportion was selected based on field observations of SR landslide deposits. This proportion may overestimate actual delivery in the Olympic Mountain landform owing to the variable length of hillslope over which landslide sediment was deposited. It is possible that significantly more than half produced sediment was delivered to hillslopes and not stream channels.

Sediment delivery from DT's included the same volume computed for SR's according to Eqn. 1, but also included an estimate of stream channel and valley floor erosion caused by scour. DT sediment delivery was computed as:

$$[(D)(SA)(0.5)] + [(RL)(VS)] \qquad (2)$$

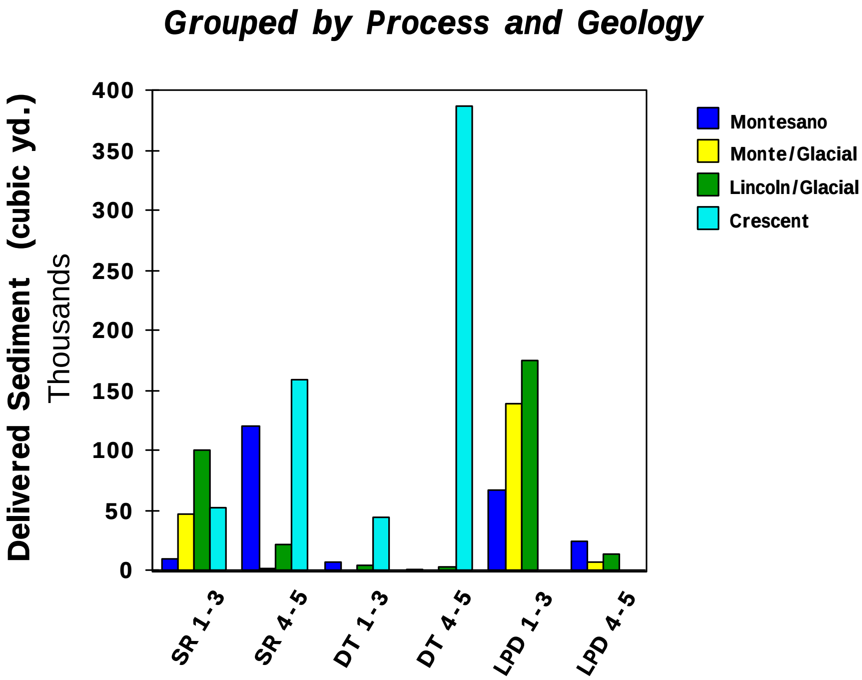
where the terms D, SA, and 0.5 are the same as Eqn. 1, RL is debris flow run length observed on aerial photographs, and VS is valley and channel sediment storage equal to 45 ft^3 per lineal ft of stream channel. This is a lower, but comparable estimate of sediment storage than that inferred from measurements of stream channel erosion caused by debris flow in the Oregon Coast Range (Benda and Dunne, 1987). VS is based on field observations indicating that typical valley width is 15ft and valley fill is 3 ft deep in steep Type 4 and 5 streams where DT's occur.

Sediment delivery from LPD's was calculated as:

$$(D)(BA)(0.2) \qquad (3)$$

where D is the estimated average depth of the landslide toe, equal to 9 ft. and based on field observations, BA is area of the body of the LPD measured on aerial photographs, and 0.2 is estimated proportion of the body volume delivered to a channel, also based on observations in the field and on aerial photographs."

Figure G-3. W.F. Satsop Mass Wasting Summary



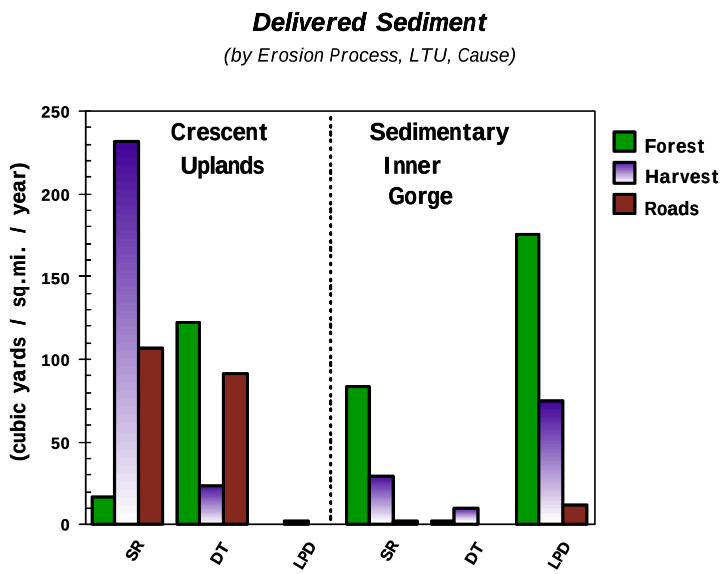
A preliminary estimate was developed of current sediment loads due to mass wasting. A subset of the landslide inventory information was used from the W.F. Satsop Watershed Analysis Report which included portions of the CUP and SIG lithotopo units. Sediment delivery values from the landslide inventory information was divided by the inventoried area (i.e. number of sections included) and the inventory period (50 years). These estimates, expressed as cubic yards per square mile, are presented in Table G-4 and displayed in Figure G-4.

Table G-4. W.F. Satsop Mass Wasting Summary

LTU	Inventoried Area	Mass Wasting *(yd^3 / mi^2)*			
		SR	DT	LPD	Total
CUP	24	355.7	236.1	1.7	593.5
SIG	34	114.3	11.0	261.7	387.0

Note: Numbers presented solely to provide an initial frame of reference. Values averaged over a 50-year period and include 1946 air photos that likely reflect effects which pre-date this period.

Figure G-4. W.F. Satsop Mass Wasting Summary



Surface Erosion

Surface erosion sources of sediment in the HCP area include those that originate on the hillslopes, those that result from landslide scars, and those related to fine sediment from roads. Estimates of sediment contributions from surface erosion within the Simpson HCP area were compiled from the following sources:

- West Fork Satsop Watershed Analysis Report
- South Fork Skokomish Watershed Analysis Report

Assessment of hillslope erosion in the HCP area has been conducted through remote methods (aerial photography, geologic and soils map evaluation) combined with field reconnaissance. Methods and results are discussed in the W.F. Satsop Watershed Analysis. It was estimated that hillslope erosion contributes 70 cubic yards annually, or 0.11 yd^3/mile per year.

Surface erosion of landslide scars was determined using inventory data from the mass wasting assessment. Exposed landslide areas that deliver sediment to the stream system was multiplied by the average annual depth of erosion (2 mm/year) obtained through several field measurements. Methods and results are discussed in the W.F. Satsop Watershed Analysis. It was estimated that surface erosion of landslide scars contributes 850 cubic yards annually, or 1.38 yd^3/mile per year.

The Watershed Analysis concluded that fine sediment inputs from hillslope erosion alone probably could not be detected in the channel on a subbasin scale. Fine sediment inputs from landslide scars are at low rates and limited to the northern third of the W.F. Satsop watershed. Fine sediment generated from surface erosion of roads is primarily a function of: road length, traffic, geologic parent material, road surfacing, road prism dimensions, vegetative cover of cutslopes and fillslopes, rate of delivery to the stream system. The method used to estimate the total annual contribution of sediment from road erosion is summarized in Table G-5.

Table G-5. Method to Estimate Surface Erosion from Roads

Step	Description
U	A partial inventory of roads in the Watershed Analysis Unit (WAU) was developed. The inventory provided representative data for each of the road parameters identified above.
U	All roads were categorized according to their slope position for the purposes of extrapolating road dimensions, characteristics, and delivery. The three slope positions used are: ! Ridge roads *(occur on ridges for at least ~1000 feet or more)* ! Stream adjacent roads *(parallel streams within ~200 feet)* ! Midslope roads *(all other roads)*
U	A representative parent material was assigned to each subbasin
U	Road surfacing was identified for each road segment, based on filed observations / interviews.
U	Traffic assessed as follows: 1) all roads simply classified as mainline, secondary, or abandoned based on field / interview information; 2) mainline roads assumed to have heavy traffic, abandoned roads assumed to have no traffic, secondary roads assigned heavy traffic level if they serve as major haul routes to proposed harvest unit over next 5 years. All other secondary roads are assumed to be under light traffic. Projections based on five year harvest plans by landowners.
U	GIS provided the total length of roads in each sub-basin by traffic level, surfacing type, and road position.
U	Extrapolations of road prism dimensions, cover, and percent delivery were made from field observed roads to remaining roads in same sub-basin by traffic level, surfacing type, and road position.
U	Sediment yield was calculated for each road segment based on extrapolated characteristics, using a base erosion rate obtained from research in similar geologic settings, then modified by factors for the W.F. Satsop WAU road dimensions, road surfacing, vegetative cover, traffic, and delivery.
U	The sediment yields for all roads was summed for each subbasin to compare this number with the background rate. This comparison led to conclusions on the sensitivity of each subbasin to the road sediment inputs. If the road rate inputs were found to be at least 50% of the background rates then further analysis is warranted to identify the specific roads segments or types of roads that are delivering sediment to streams at the greatest rates.
U	A rate of sediment input per length of road was then calculated for each road segment. This number, in tons per mile per year, was used to sort the roads in each of the two data bases (field observed road segments and GIS road segment types).
U	The frequency distribution of these rates of input was then analyzed to assign a hazard rating (*"high", "moderate", or "low"*) to each of the road segments. Ratings were assigned based on natural breaks in the data and the magnitude of the rate of input relative to a comparable background rate per mile of stream. The ratings were also checked against the comparison of total sediment inputs per subbasin versus background to see if the individual road segment ratings fairly represent the ratings for the subbasin as a whole.

Methods and results are discussed in the W.F. Satsop Watershed Analysis. It was estimated that road erosion contributes 4500 cubic yards annually, or 7.6 yd^3/mile per year. The W.F. Satsop Watershed Analysis also used a procedure to assign erosion hazard ratings in order to prioritize and group road segments in the WAU. The procedure used is summarized in Tables G-6 and G-7.

Table G-6. Method to Assign Road Erosion Hazard

Step	Description
U	Calculate a length-normalized erosion rate in tons per mile for each of the field-observed roads.
U	Sort the database in decreasing order of length-normalized erosion rate.
U	Graph each observed road segment against its length-normalized erosion rate in decreasing order.
U	Determine natural breaks in the graphed distribution to delineate high, moderate, and low hazard ratings. *(See page 38 W.F. Satsop Surface Erosion Assessment)*.
U	Use same procedure to sort and graph the GIS road types to ensure that the same breaks could be used on both the field observed roads and the extrapolated roads in the GIS database.

Table G-7. Uncertainties in Road Surface Erosion Calculations

	Description
U	There are numerous possible small inaccuracies inherent to this process of estimations and extrapolations. The results should be used as relative indicators of sediment yields and not absolute numbers of tonnages. The purpose of the assessment is to provide an overall evaluation of erosion of the road system, not to provide a comprehensive inventory of actual sediment inputs.
U	The base erosion rate may not accurately represent the rate of sediment production from the roads in this WAU. However, the numbers are based on measurements made in the Mack Creek drainage approximately 50 miles to the southeast where topography, geology, precipitation, and traffic levels are comparable to those in this WAU.
U	Because the partial road inventory concentrated on the Simpson and Weyerhaeuser roads, more extrapolation had to be made to other roads, such as the USFS roads. The USFS WIN database provides a detailed inventory of road related erosion within their ownership and helped to provide a more accurate extrapolation to these areas.
U	Abandoned roads may be under represented in the analysis.

Although information currently available to develop a detailed sediment budget is fairly limited, the W.F. Satsop Watershed Analysis provides an estimate of fine sediment contributions from various sources in the WAU. This estimate was developed in the Surface Erosion Assessment to illustrate the approximate quantities of sediment from background and other sources *(Figure G-5)*. In addition, the W.F. Satsop Watershed Analysis developed an estimate of sediment from all sources to illustrate relative contributions *(Figure G-6)*. This estimate showed that the contribution from mass wasting is far greater than that from surface erosion. It should be noted, though, that the mass wasting value includes both fine and coarse sediment while the background and surface erosion values represent only fine sediment.

Figure G-5. W.F. Satsop Surface Erosion Sediment Yield

Grouped by Landform and Source Category

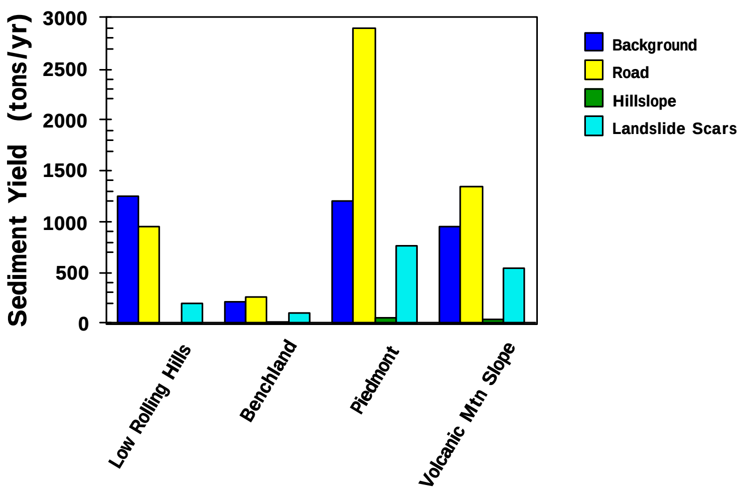
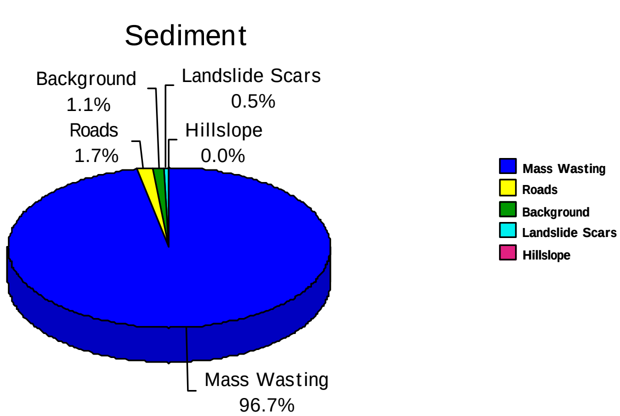


Figure G-6. West Fork Satsop Sediment Yield

Source Summary



Floodplain Storage and Bank Erosion

Assessment of sediment contributions from bank erosion include background from soil creep, side slope failures, erosion of alluvial terraces, and consideration of other factors (e.g. lack of LWD from riparian harvest and increased peak flows due to roads). Types of bank erosion vary through channel networks. In headwater areas, bank erosion can be conceptualized as roughly equivalent to soil creep rates. Estimates of bank erosion in the initial TMDL analysis relied solely on soil creep.

In an effort to refine sediment delivery targets by channel class (for all erosion processes), a re-analysis of sediment delivery information was requested. The re-analysis was conducted by the registered geologist who developed the mass wasting and channel assessments for the W.F. Satsop and S.F. Skokomish Watershed Analyses. The re-analysis indicated that using soil creep rates for headwater areas may be appropriate because there is relatively little storage of alluvium in floodplains or terraces. In larger channels, however, where significant deposits of alluvium accumulate in terraces or floodplains, the relationship between watershed sediment production (as from landslides), sediment storage (in floodplains & terraces), and sediment routing (transport to downstream locations) becomes complex.

The re-analysis indicated that some theories of sediment routing, for example, hold that there is an approximate balance between sediment inputs from upstream areas and bank erosion of opposing banks. However, if bank erosion affects a terrace surface of much greater depth, or hillslope materials, then there may be a net input of material. In addition, the removal of sediment from alluvial storage is largely controlled by watershed-scale hydrologic factors which are controlled primarily by climatic events, and only secondarily by management practices.

Targets for bank erosion appear extremely difficult to justify or predict, as a result of concerns identified in the re-analysis. Because of the close linkage between sediment storage in floodplains and terraces, targets for bank erosion were combined to include consideration of channel storage mechanisms. The following provides a brief discussion of processes considered in developing estimates for bank erosion / channel storage targets.

Soil Creep: A by-product of the surface erosion module in watershed analysis is an estimate of "*background*" erosion for comparative purposes with other erosion processes. The background erosion is based on the rate of downslope soil movement, or soil creep, which is delivered to the stream system through bank erosion. The rationale in watershed analysis is that soil creep rates have been measured and range from 0.5 mm/yr in flat-lying valley fill to 3 mm/yr in uplands. Earthflow and large deep-seated persistent failures with accelerated soil creep rates are accounted for in the mass wasting assessment. Soil depth values used in the surface erosion module ranged from 80 inches in the lower gradient valleys to 40 inches in the uplands. Dunne (1984) also used this approach to estimate soil creep for the South Fork Snoqualmie. Calculations are based on the following equation:

$$S = 2 * h * V_c * C$$

where:

- S = sediment delivered *(yard^3 / mile per year)*
- 2 = number of stream banks *(each side)*
- h = average soil depth *(feet)*
- V_c = soil creep rate *(feet/year)*
- C = conversion *(5280 feet per mile / 27 feet^3 per yard^3)*

Values assumed for variables used to estimate soil creep are summarized by lithotopo unit (LTU) in Table G-8. These assumed values are based on discussions with professionals familiar with the watershed.

Table G-8. Summary of Sediment Delivery for Soil Creep

LTU	Soil Depth (feet)	Soil Creep Rate		Sediment Delivery (yd^3/mile per year)
		(mm/year)	(ft/year)	
AGL	3.0	2.0	0.00656	8
CIS	3.0	1.0	0.00328	4
CUP	1.5	3.0	0.00984	6
ROP	3.0	0.5	0.00164	2
SIG	6.5	2.0	0.00656	17

Side Slope Failures and Erosion of Alluvial Terraces were also considered in the analysis of bank erosion. The W.F. Satsop Watershed Analysis presented a methodology to estimate the magnitude of potential bed and bank erosion. The methodology was developed because the stream channel assessment revealed that large woody debris (LWD) was an important source of bed and bank stability in most Type 4 and 5 channels. The role of LWD in routing sediment in Type 4 and 5 streams has not been exhaustively studied. One report indicated that LWD obstructions are significant storage sites for coarse sediment, and that a reduction in the abundance of LWD obstructions would increase the rate of sediment routing to channels downstream (O'Connor, 1994).

To gain a coarse understanding of potential sediment delivery related to bed and bank erosion, an estimate was developed based on typical cross-sectional dimensions of stream channels and hypothetical erosion potential. Erosion potential was estimated using an average depth of active deposits. These estimates were consistent in magnitude with measurements of scour depth, and with observed bar heights / mean pool depths *(see W.F. Satsop Stream Channel Assessment)*. The method presented in the W.F. Satsop Watershed Analysis assumed that the potential mass of sediment attributed to bank erosion / channel storage was eroded over a 50-year period. This assumption was chosen to be consistent with the time required for LWD to be recruited from second growth forests, and from field observations indicating that LWD function in the W.F. Satsop appears to decline due to decay about 40 to 70 years after clear-cut harvest. In the W.F. Satsop, Type 4 channels were assumed to generate a potential erodible sediment volume of 8 ft^3 per foot of channel length (or approximately 30 yd^3 / mile per year). For Type 5 streams, the resulting potential erosion was 1 ft^3 per foot of channel length (or approximately 3 yd^3 / mile per year) *(see W.F. Satsop Mass Wasting Module, pages 18-22)*.

Channel Storage: The S.F. Skokomish Watershed Analysis described a coarse analysis of management-related mass wasting relative to observed changes in channel width and sediment storage. The Channel Assessment suggested that, for certain channel types, the erosion of fluvioglacial terraces and / or increased rates of sediment transport are important processes influencing in-channel sediment storage, particularly prior to 1965. The report indicated that channel shifting in one area of the S.F. Skokomish River probably removed sediment from storage in alluvial and fluvioglacial terraces, introducing significant quantities of coarse sediment to active channels. The assessment made a conservative estimate of coarse sediment liberated from storage in the analysis period by new channel cutting over a 3.5 mile reach that was on the order of 270,000 m^3.

TARGET IDENTIFICATION

Loading Capacity

General Approach: Development of a loading capacity for sediment considers Washington's Water Quality Standards which state *"deleterious material concentrations shall be below those which may adversely affect characteristics water uses"*. Interpretation of this narrative criteria poses some challenges. As discussed earlier, the use of instream indicators was considered. However, using such parameters for target values would add little value in the development of a TMDL designed to address temperature problems caused by watershed erosion processes. Reasons for not using instream indicators include a general lack of data on parameters considered, the fact that it may take decades to see changes, and that instream conditions reflect both existing source inputs plus stored sediment in the channel.

EPA regulations acknowledge the challenge associated with establishing load allocations for nonpoint sources, e.g. sediment in a forested setting. The current regulation states: *"Load allocations are best estimates of the loading, which may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading" [40 CFR §130.2(g)]*. Agency guidance for development of sediment TMDLs recognizes that erosion is a natural process and some sedimentation is needed to maintain healthy stream systems. Consequently, it is often necessary to evaluate the degree to which sediment discharge in a particular watershed exceeds natural rates or patterns (EPA, 1999). This analysis can be complicated because sedimentation processes in many systems are highly variable from year to year. This type of analysis is particularly important in settings that are vulnerable to high natural sediment production rates and are particularly sensitive to land disturbance (e.g. the Pacific Northwest).

To maintain a focus on source input and hazard reduction, the loading capacity for sediment uses a framework suggested in the TFW Watershed Analysis Manual, specifically construction of a partial sediment budget (Reid and Dunne, 1996). This serves several purposes including:

- tie sediment problems recognized in streams to specific hillslope sources or activities;
- discriminate among the rates, effects, and hazards of various mass wasting, surface, and bank erosion processes in basins where all are significant sediment sources; and
- document the relative contributions of chronic and intermittent processes (e.g. related to large events).

Sediment Delivery Loading Capacities: The method to determine sediment delivery targets started with a review of available sediment yield data which was described earlier. The purpose of the review was to gain a coarse understanding of sediment production and transport processes in the Simpson HCP area. This provides a frame of reference for developing a partial sediment budget to identify sediment reduction needs in the TMDL. Erosion processes considered in the partial sediment budget include mass wasting (shallow rapid landslides, debris torrents, large persistent deep-seated landslides), surface erosion, and floodplain storage / bank erosion.

Following a review of the USGS report, development of loading capacity targets used calculations of sediment delivery based on areal estimates of erosion features. This general approach was used in northern California for development of sediment TMDLs to address similar concerns, e.g. road-related sources, timber harvest, landslides *(see TMDLs for Garcia River, S.F. Trinity River, Redwood Creek)*. The method used to develop loading capacity targets for the Simpson HCP area TMDL goes beyond the approach used in northern California. The landscape stratification system offers an opportunity to provide an added refinement to loading capacity targets, so that differences in lithology and topography which affect erosion processes can be considered. This is opposed to using the same target applied across the entire watershed for a particular source or process.

Sediment delivery targets for this TMDL are expressed in terms cubic yards. This has several advantages which recognize the *"order of magnitude estimate"* that the values actually represent. First, initial calculations of sediment delivery are based on linear or areal estimates of erosion features (e.g. inches per year of bank erosion, feet of soil depth, square yards of landslide feature). Second, weight could be estimated either through assumptions or measurements of the bulk density of soil (e.g. tons per cubic yard). Lastly, cubic yards is more easily related to by a wider range of individuals (e.g. a 10 $yard^3$ dump truck). Loading capacities are summarized by lithotopo unit within the HCP area *(Table G-9)*. These sediment delivery targets are based on information contained in several completed Watershed Analysis reports conducted in the Simpson HCP area which have been described earlier.

Table G-9. Sediment Delivery Loading Capacity by Lithotopo Unit

Lithotopo Unit[1]	Area *(sq. mi.)*	Channel Length *(miles)*	Loading Capacity[2]	
			(yd^3 / sq. mi. per year)	*(yd^3 / stream. mile per year)*
AGL	32.7	137.7	880	209.0
CIS	49.0	163.7	110	33.6
CUP	45.0	265.2	1,000	169.5
ROP	183.9	376.7	50	24.7
SIG	98.1	454.5	1,000	215.8
Total	408.7	1,397.8	456	133.3

NOTES:

1 There are nearly 1,400 stream miles that lie within the HCP area. Available data and methods do not allow determination of loading capacities for each individual segment. Instead, targets have been developed that utilize the landscape stratification system used to organize information in the HCP.

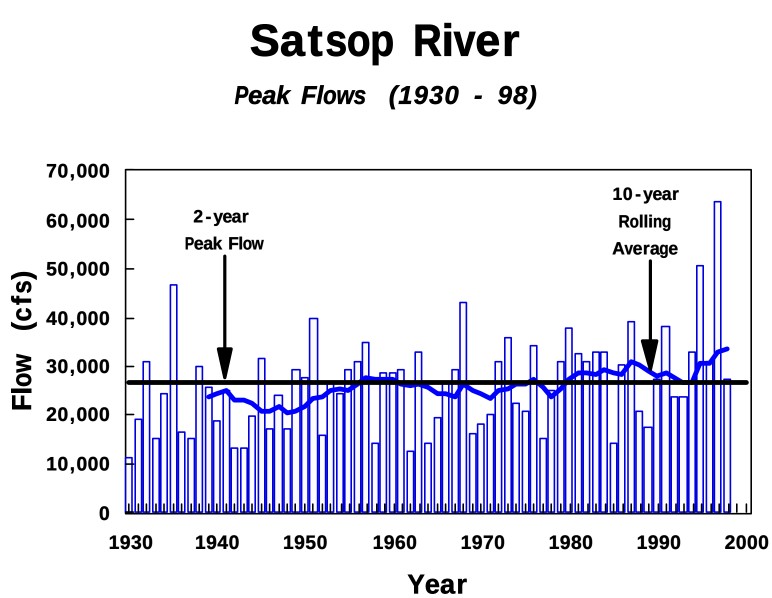
2 Loading capacities expressed as long term annual average values and do not reflect the wide range spatial and temporal variation observed in natural erosion processes. As new data and methods are developed to better describe sediment delivery mechanisms, these loading capacities may be revised.

<u>*Averaging Period*</u>*:* An annual averaging period is used to express the loads. TMDLs expressed as long term annual average sediment loadings meet the regulatory definition which states that: *"TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure" [40 CFR §130.2(i)]*. The annual average targets could be converted into daily loads. However, it is simply a referencing mechanism. Expressing TMDL targets as annual average values better reflects the dynamic nature of sediment movement throughout a watershed over time. Erosion processes which are responsible for sediment inputs to the system are highly dynamic, change from year-to-year, and vary in different locations in the basin. The main driving factor which affects erosion and sediment inputs from year to year is variability in precipitation, particularly periodic high magnitude storms.

The sediment assessment used to develop the loading capacity is based primarily on historical data (e.g. landslide inventories), streamflow patterns, and channel responses to erosional effects. It is difficult to predict future erosion and associated effects because of highly variable weather patterns and changing management practices. It is also infeasible to develop a dynamic, predictive model of future erosion amounts, timing, and locations based on existing information and scientific knowledge.

The sediment TMDLs developed in northern California were established as tons / square mile / year expressed as a 10-year rolling annual average. In that case, the longer term annual average time step was deemed an appropriate approach to account for the large interannual variability in sediment loading. With respect to the Simpson HCP area TMDL, the initial focus will be to complete the landslide inventory. This will ensure that a more accurate baseline data base is in place from which to determine progress towards meeting sediment reduction targets. Concerns have been expressed that a single year of high intensity precipitation may deliver more sediment in the next 50 years cumulatively, even under natural conditions. As a result, assessment of the sediment delivery data will use the same approach as the sediment TMDLs in northern California (i.e. a 10-year rolling annual average). A 10-year rolling annual average of peak flows can also be considered to account for single years of high intensity precipitation *(Figure G-7)*.

<u>Figure G-7</u>. Rolling Annual Average of Satsop River Peak Flows



ALLOCATIONS AND TMDL

The Simpson HCP area TMDL and allocations for sediment delivery are summarized in Tables G-10 and G-11. The estimated total allowable sediment load (TMDL) is derived from targets based on lithotopo unit, channel class and erosion process (cubic yards per mile per averaging period). Sediment delivery information for the period 1946-96 was used from three completed Watershed Analysis reports conducted in the Simpson HCP area.

Analysis of sediment delivery information from landslide inventories indicates two major concerns that contribute to management caused hillslope instability. First, riparian area management can affect sediment delivery through bank stability and sediment retention. For instance, the W.F. Satsop Watershed Analysis identified the main potential management influence in the SIG as declining root reinforcement of hillslopes following harvest. The second concern relates to roads, particularly in the Crescent Uplands. Again, the W.F. Satsop Watershed Analysis indicated that road sidecast and cutslope problems are the source of more than half the inventoried slides in the CUP. Problems to be addressed through implementation of the HCP include removal of sidecast, culverts that are undersized which may plug, and places where diversions of excess water onto fill slopes or ditch lines may occur.

The basis for sediment delivery allocations flows from prescriptions in the HCP. The quantitative comparison of estimated loading rates and controllable portions of various types of loading was considered. It is estimated that a 50% reduction in the frequency of catastrophic failures (e.g. sidecast or fill failures) during the first ten years of the plan over the rate observed for the previous 20-year period can be achieved and represents an interim target for measuring progress relative to achieving the load allocations. In addition, a target of 50% reduction of fine sediment input from roads during the first ten years of the plan is also included in the HCP. Furthermore, the HCP provides funding to road maintenance and abandonment efforts for the duration of the HCP. Finally, STC will apply mass wasting prescriptions across the HCP area to address unstable slope concerns.

The load allocations incorporate sediment reductions from management activities into the sediment delivery targets. Sediment delivered from shallow rapids landslides and debris torrents as a result of management activities is assumed to be 85% controllable. This is based on information used in recent TMDLs developed in northern California. Sediment delivered from large persistent deep-seated landslides as a result of management activities is assumed to be 50% controllable. The retention of large wood in RCRs and reducing peak flows due to hydrologic effects of the road network will address sediment delivery from bank erosion that result from management activities.

Sediment delivery targets expressed as annual average cubic yards per stream mile for each channel class is consistent with current EPA regulations. The regulations indicate that load allocations are "*best estimates of the loading which may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading" [40 CFR §130.2(g)]*.

The resultant load allocations for sediment are: 1) developed for erosion processes; 2) associated with land use activities where feasible; and 3) based on the source analysis of various erosion processes. The load allocations are expressed as long term annual average load delivered per mile at the channel class scale. Temporal and spatial variability in erosion and stream responses are considered in several ways including:

- *Temporal Considerations* -- The TMDL and specific load allocations are expressed in terms of annual rates over a 50-year period in recognition that trends are not discernible within shorter time frames and to allow for natural variation due to seasonal and annual differences.

- *Spatial Considerations* -- Targets were derived based primarily on analysis of conditions in different watersheds and lithotopo units within the Simpson HCP area. These conditions represent different geologies and associated vulnerabilities to erosion.

Consideration of Cumulative Effects: Loading capacity targets for sediment delivery are based on limited data using areal estimates, as described earlier. The sediment delivery load allocations maintain a focus on a watershed-wide basis, so that there is not a cumulative increase. Lineal targets have been utilized in the TMDL to allow consideration of differences in channel types. Table G-10 summarizes allocation by lithotopo unit. As can be seen, a margin of safety has been included in each LTU to account for uncertainty. The highest margin of safety values are applied to those LTU's where the management inputs from sediment are greatest, notably the AGL, CUP, and SIG. These allocations are illustrated in Figures G-8 and G-9. Allocations for each channel class are summarized in Table G-11.

Table G-10. Sediment Load Allocation Summary for Simpson HCP Area by LTU

Riparian Strategy	(length in mi.)	TMDL[1]	WLA[2]	Load Allocations[1] (yd³ / stream mile per year): Mass Wasting					MOS
				SR	*DT*	*LPD*	Surface Erosion	Bank Erosion / Channel Storage	
AGL	*137.7*	209.0	0	6.0	1.0	3.2	4.0	98.4	96.4
CIS	*163.7*	33.6	0	1.0	0.0	1.0	2.0	27.7	1.9
CUP	*265.2*	169.5	0	12.1	7.0	1.0	3.0	19.9	126.5
ROP [3]	*376.7*	24.7	0	1.0	0.0	1.0	1.0	12.3	9.4
SIG	*454.5*	215.8	0	6.3	1.0	32.8	6.0	47.7	122.0

NOTES:

1 Allocations expressed as long term annual average values. As new data and methods are developed to better describe sediment delivery mechanisms, the loading capacities may be refined and the TMDL revised.

2 There are no point sources within the HCP area covered by the TMDL, so the WLA for sediment delivery is 0.

3 Does not include LA for bank erosion / channel storage on ROP-Qa7 (3.7 miles — Vance Creek) which is uniquely affected by channel migration across floodplain terraces as documented by a review of air photo records.

Figure G-8. Load Allocation Summary for the AGL and CIS Lithotopo Units

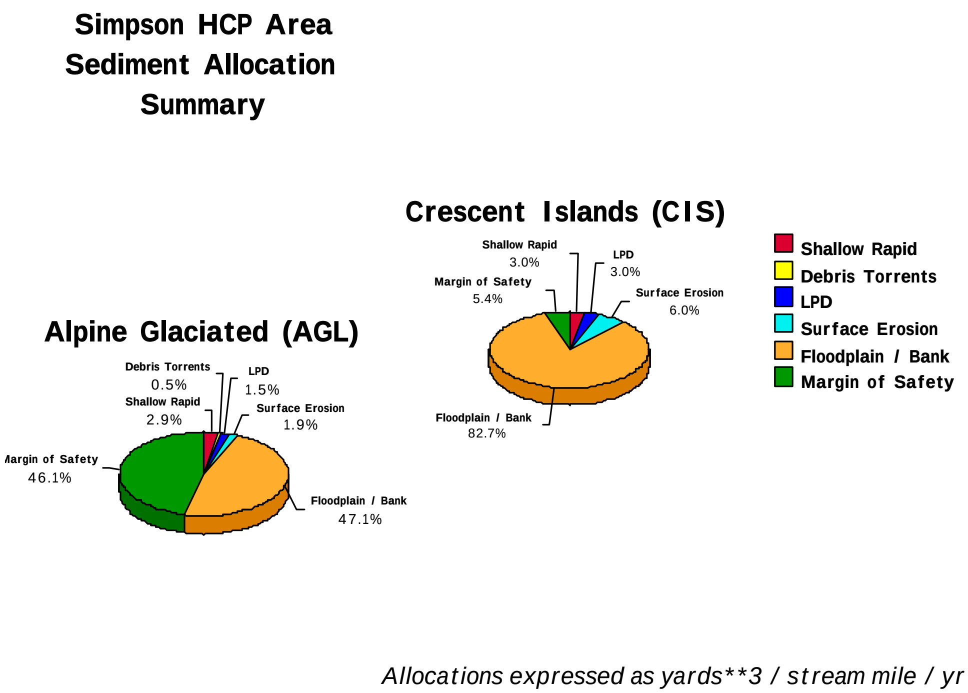


Figure G-9. Load Allocation Summary for the CUP and SIG Lithotopo Units

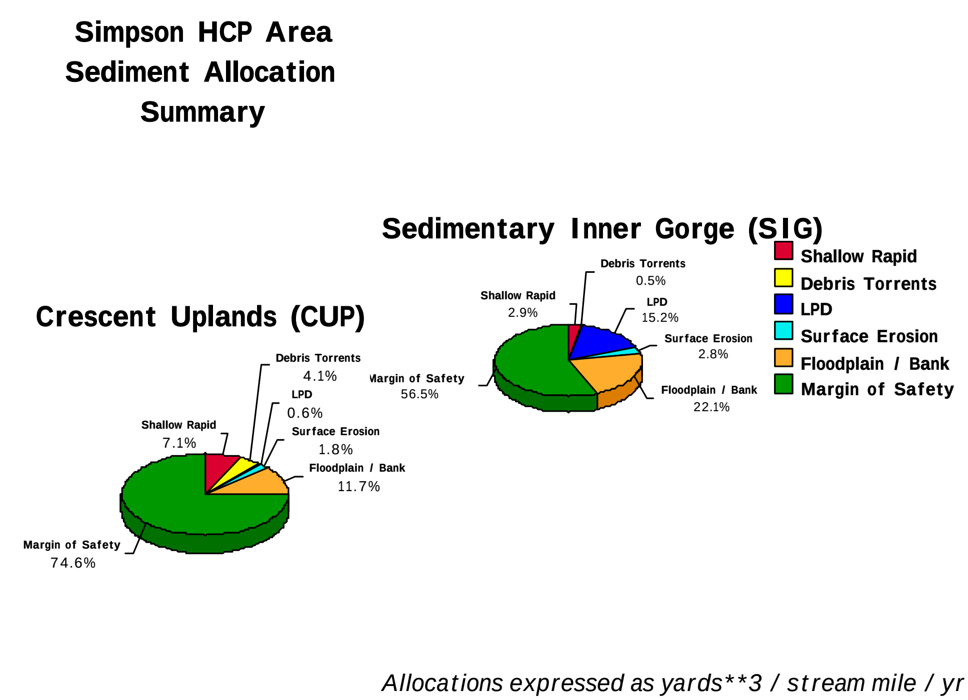


Table G-10a. Sediment Allocations by Channel Class for Simpson HCP Area

Channel Class	Length *(miles)*	TMDL	Mass Wasting			Surface Erosion	Floodplain Storage / Bank Erosion	MOS
			SR	***DT***	***LPD***			
Alpine Glaciated (AGL)								
AGL-*Qa6*	12.7		6	1	10	4	928	
AGL-*Qo1*	61.3		6	1	1	4	16	
AGL-*Qo2*	22.5		6	1	1	4	8	
AGL-*Qo3*	7.3		6	1	5	4	9	
AGL-*Qo4*	2.6		6	1	5	4	13	
AGL-*Qo5*	8.8		6	1	5	4	12	
AGL-*Qo6*	13.6		6	1	5	4	17	
AGL-*Qo7*	3.7		6	1	5	4	17	
AGL-*Qo8*	5.2		6	1	10	4	22	
Total	137.7	209.0	6.0	1.0	3.2	4.0	98.4	96.4
Crescent Islands (CIS)								
CIS-*C1*	83.5		1	0	1	2	20	
CIS-*C5*	1.7		1	0	1	2	16	
CIS-*Qc1*	33.0		1	0	1	2	24	
CIS-*Qc2*	27.0		1	0	1	2	8	
CIS-*Qc3*	15.9		1	0	1	2	106	
Total	163.7	33.6	1.0	0.0	1.0	2.0	27.7	1.9

Table G-10b. Sediment Allocations by Channel Class for Simpson HCP Area

Channel Class	Length (miles)	TMDL	Mass Wasting			Surface Erosion	Floodplain Storage / Bank Erosion	MOS
			SR	*DT*	*LPD*			
Crescent Uplands (CUP)								
CUP-*C1*	199.9		11	7	1	3	21	
CUP-*C2*	22.9		30	7	1	3	10	
CUP-*C3*	24.5		7	7	1	3	10	
CUP-*C4*	4.9		7	7	1	3	24	
CUP-*C5*	3.5		11	7	1	3	14	
CUP-*C6*	3.6		7	7	1	3	61	
CUP-*C8*	5.9		9	7	1	3	31	
Total	265.2	169.5	12.1	7.0	1.0	3.0	19.9	126.5
Recessional Outwash Plain (ROP)								
ROP-*C7*	9.4		1	0	1	1	51	
ROP-*Qa7* [1]	3.7		1	0	1	1	5,193	
ROP-*Qc1*	167.3		1	0	1	1	2	
ROP-*Qc2*	103.4		1	0	1	1	3	
ROP-*Qc3*	44.2		1	0	1	1	4	
ROP-*Qc4*	9.1		1	0	1	1	4	
ROP-*Qc5*	12.1		1	0	1	1	20	
ROP-*Qc6*	9.5		1	0	1	1	91	
ROP-*Qc7*	15.2		1	0	1	1	104	
ROP-*Qc8*	2.8		1	0	1	1	189	
Total [1]	376.7	24.7	1.0	0.0	1.0	1.0	12.3	9.4

NOTES:

[1] Does not include LA for floodplain storage / bank erosion on ROP-Qa7 (3.7 miles — Vance Creek) which is uniquely affected by channel migration across floodplain terraces as documented by a review of air photo records.

Table G-10c. Sediment Allocations by Channel Class for Simpson HCP Area

Channel Class	Length *(miles)*	TMDL	Mass Wasting			Surface Erosion	Floodplain Storage / Bank Erosion	MOS
			SR	*DT*	*LPD*			
Sedimentary Inner Gorge (SIG)								
SIG-*L1*	160.0		5	1	16	5	19	
SIG-*L2*	38.5		5	1	5	5	17	
SIG-*L3*	6.3		5	1	5	8	19	
SIG-*L4*	24.2		25	1	105	12	95	
SIG-*M1*	67.8		5	1	26	5	18	
SIG-*M2*	18.5		5	1	20	5	18	
SIG-*M3*	9.6		5	1	5	8	19	
SIG-*M4*	6.0		13	1	5	8	19	
SIG-*M5*	15.1		5	1	240	12	42	
SIG-*M6*	2.3		5	1	45	8	230	
SIG-*Qa6*	11.3		8	1	225	12	937	
SIG-*Qc1*	12.8		5	1	1	5	18	
SIG-*Qc2*	8.9		5	1	1	5	18	
SIG-*Qc3*	9.1		5	1	35	8	21	
SIG-*Qo1*	38.3		5	1	19	5	25	
SIG-*Qo2*	19.0		5	1	1	5	18	
SIG-*Qo3*	4.8		5	1	5	8	21	
SIG-*Qo4*	2.0		14	1	5	8	29	
Total	454.5	215.8	6.3	1.0	32.8	6.0	47.7	122.0

SECTION H
Heat and Water Temperature

Heat and Water Temperature
Index

OVERVIEW

A discussion of heat and temperature begins with a brief review of what each measures. Temperature is simply an indicator of the level of internal energy that an object has. Thus, the temperature of water is an indicator of its internal energy per unit volume *(e.g. temperature % BTU / ft^3)*. Heat, on the other hand, is the passage of energy from one object to another.

It takes a certain amount of energy to heat a volume of water, a phenomena known as the *specific heat*. The specific heat of a substance is the amount of energy transfer needed to raise the temperature of a unit mass of a substance (e.g. one pound or one gram). In the metric system, one calorie will raise the temperature of one gram of water by one degree Celsius. The unit in the English system is known as a British Thermal Unit (BTU). One BTU will raise the temperature of one pound of water by one degree Fahrenheit.

Water has a relatively high specific heat, which is to say that it requires large quantities of heat energy to increase the temperature just 1EF (Wetzel, 1983). Similarly, water must release large quantities of heat energy before the temperature decreases. Table H-1 describes the mathematical relationship between water temperature and heat.

***Table H-1*.** Mathematical Relationship between Water Temperature and Heat

)T =)H * A / (V * D * c_p)
where:)T = temperature (EF / hour))H = rate that heat received (BTU / hour) A = surface area of water (ft^2) V = volume of water (ft^3) D = density of water (62.4 lb / ft^3) c_p = specific heat of water (BTU / lb / EF)

The change in heat to or from a waterbody falls into three major categories which include:

P Heat transfer through the water surface. This represents a key component of a heat budget.
P Inflowing / outflowing water which represent heat changes through temperature differences.
P Heat conduction to or from the earth through the bottom of the waterbody.

The calculation of water temperature by a mechanistic model follows the basic relationship described in Table H-1. A mechanistic model is essentially a bookkeeping of heat transfer to determine potential water temperature changes. Thus, most of the focus on water temperature modeling involves the computation of energy transfer processes.

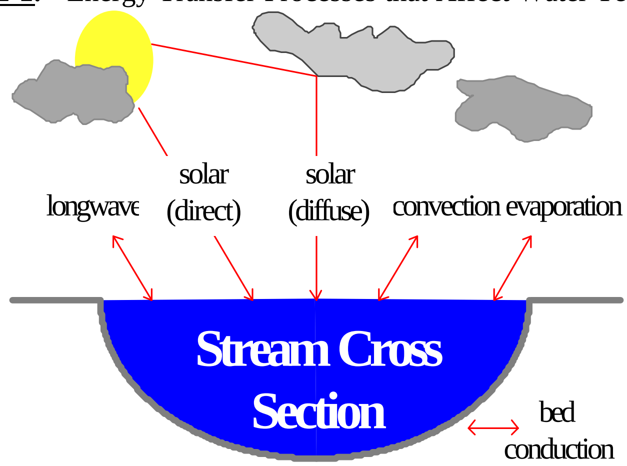
ENERGY TRANSFER PROCESSES

Stream temperature is an indicator that reflects the rate of heat exchange between a stream and its environment. When water temperature is described in terms of heat transfer, the processes that cause a stream to gain or lose energy become important. Thus, one approach towards water temperature assessment is built around an analysis of mechanisms that transfer energy across a water surface. There are six major processes that allow heat energy exchange between a stream and its environment which include:

þ solar radiation
þ longwave radiation
þ convection
þ evaporation
þ stream bed conduction
þ groundwater inflow / outflow

These energy processes occur in all streams, rivers, lakes, and water troughs. Furthermore, all of these energy processes have been closely studied and are well understood. Each transfer process contributes to the total heat energy contained in a stream system. While some have a greater effect than others, all processes are significant because land use activities that affect the stream or its surrounding environment may result in changing one or more of the energy transfer processes. Figure H-1 depicts the processes that affect the heat energy contained in a stream system. All of these energy processes, except solar radiation, are capable of both introducing or removing heat energy from the stream system. Solar radiation can only deliver heat energy.

Figure H-1. Energy Transfer Processes that Affect Water Temperature

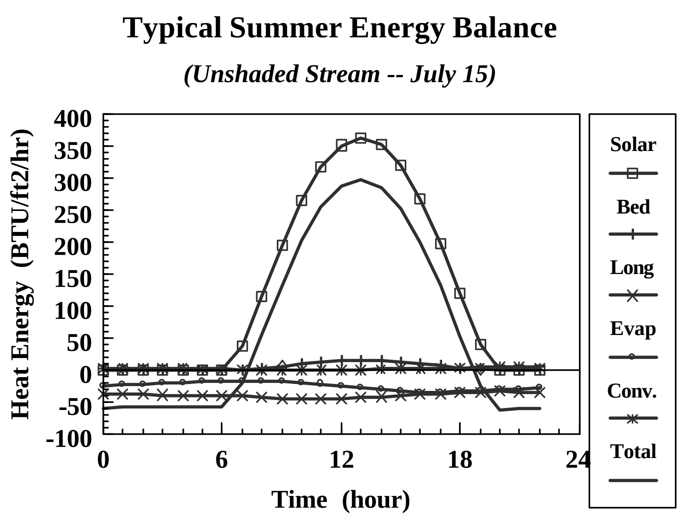


The predominant potential source of heat energy to an aquatic system is *solar radiation*. Secondary sources of heat energy include *longwave radiation* (from both the atmosphere and riparian vegetation), *convection*, *stream bed conduction*, and *groundwater exchange*. Several processes dissipate heat energy at the air-water interface, namely *evaporation* and *back radiation*. The instantaneous heat transfer rate in an aquatic system is the summation of the individual processes:

$$\ddot{O}_{Total} = \ddot{O}_{Solar} + \ddot{O}_{Longwave} + \ddot{O}_{Evaporation} + \ddot{O}_{Convection} + \ddot{O}_{Conduction}$$

Energy is acquired by a stream when the heat energy entering the stream is greater than the heat energy leaving the stream. When there is an addition of heat energy to the stream, the temperature will increase. The converse is also true. If the effect of the six energy processes results in reducing the total heat energy of the stream, the temperature will decrease. Figure H-2 illustrates the energy processes occurring on an unshaded stream over the course of a clear, summer day.

Figure H-2. Typical Summer Energy Balance for an Unshaded Stream

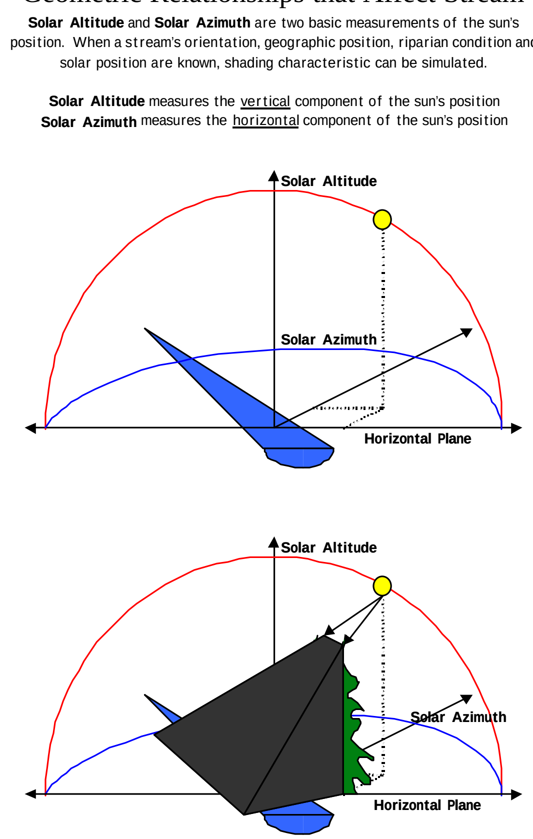


Solar Radiation

In terms of stream heating, the majority of energy is contributed by solar radiation *(Figure H-2)*. Once emitted from the sun, photons travel through space to the edge of the earth's atmosphere. While passing through the atmosphere, a portion of solar radiation is absorbed and scattered by water vapor and other particulates. The remainder continues its journey towards the earth's surface (McCutcheon, 1989). Some of the radiation that is scattered in the atmosphere eventually reaches the earth's surface as *diffuse solar radiation* (Ibqal, 1983). The solar radiation that travels through the atmosphere unobstructed is known as *direct solar radiation*.

In the heat budget, *solar radiation* ($\ddot{O}_{Solar}$) is a function of the solar angle (or altitude), solar azimuth, atmosphere, topography, location, and riparian vegetation *(Figure H-3)*. Simulation of solar radiation is based on methodologies developed by Ibqal (1983) and Beschta and Weatherred (1984). When a stream surface is exposed to midday solar radiation, large quantities of heat will be delivered to the stream system (Brown 1969, Beschta et al. 1987). Some of the incoming solar radiation will reflect off the stream surface, depending on the elevation of the sun. All solar radiation outside the visible spectrum (0.36mm to 0.76mm) is absorbed in the first meter below the stream surface and only visible light penetrates to greater depths (Wunderlich, 1972). Sellers (1965) reported that 50% of solar energy passing through the stream surface is absorbed in the first 10 cm of the water column. Assuming there are no topographic barriers between the sun and the stream, solar radiation has one last barrier to pass before reaching the water surface: riparian vegetation.

Figure H-3. Geometric Relationships that Affect Stream Surface Shade

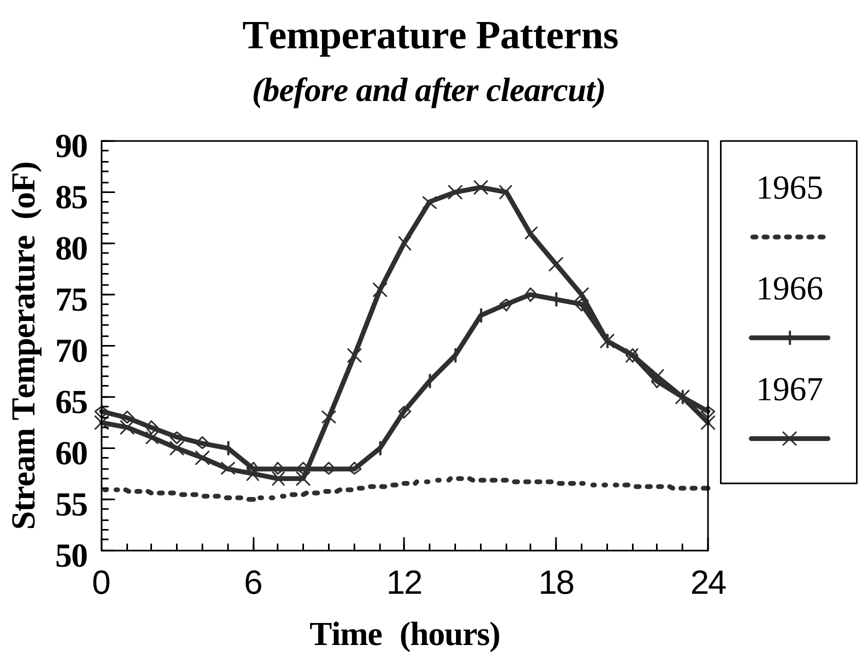


Depending on the characteristics of stream side vegetation, the time of year, and the time of day, an individual photon may or may not encounter riparian vegetation before arriving at the water surface. Removal of riparian vegetation, and the shade it provides, can contribute to elevated stream temperatures (Rishel et al., 1982; Brown, 1983; Beschta et al., 1987). It follows that land use activities that affect riparian vegetation will alter the quality and quantity of shade offered to the stream. When a stream surface is exposed to midday solar radiation, large quantities of heat energy will be delivered to the stream system, usually resulting in a dramatic water temperature increase. When shaded throughout the entire duration of the daily solar cycle, far less heat energy will be transferred to the stream. The ability of riparian vegetation to shade the stream throughout the day depends on vegetation height, density and position relative to the stream.

Anthropogenic increase in heat energy is derived from solar radiation when increased levels of sunlight reach the stream surface and raise water temperature. Some of the largest increases in stream temperatures have been caused by forest practices that removed riparian vegetation. Meehan et. al. (1969) found that an Alaskan stream experienced a 7EF increase in the maximum temperature following a clear cut. Green (1950) reported a maximum weekly temperature that was 13EF greater on a clear cut stream than that recorded on another nearby stream.

One of the most significant studies designed to highlight the importance of riparian vegetation for stream temperature control was part of the Alsea Watershed Study (Brown and Krygier, 1970). Two similar watersheds were selected in the Alsea basin, located in the Oregon Coast Range. One watershed was left undisturbed as a control, while the other was clear cut, fully exposing the stream. Figure H-4 illustrates daily stream temperature profiles observed on days in which the annual maximum temperature occurred.

Figure H-3. Stream Temperature Profiles Following Clear Cut



Longwave Radiation

Both the atmosphere and vegetation along stream banks emit longwave radiation that when received by the stream surface has a warming influence. The longwave radiation flux ($Ö_{Longwave}$) is comprised of both positive and negative components. The intensity of incoming longwave radiation experienced by the stream surface is proportional to atmospheric moisture (Anderson, 1954). Humidity and air temperature greatly influence longwave radiation, while carbon dioxide and other molecules in the atmosphere have less of an influence. Further, Anderson (1954) found that the height of cloud cover affects the intensity of longwave radiation. A water surface generally reflects 3% of incoming longwave radiation, while the remaining 97% is absorbed (McCutcheon, 1989).

The vegetation canopy is assumed to emit longwave radiation that is readily absorbed by the stream surface. The radiating surface of the streamside vegetation is a function of the maximum angles of vegetation, the average path length through the vegetation on both banks, and the canopy transmissivity. Longwave radiation directed downward from the canopy is the product of the radiating surface area, the canopy emissivity, the Stefan-Boltzmann constant, and the air temperature (Beschta, 1984). Incoming longwave heat energy originating from the atmosphere which is delivered to the stream surface is simply the summation of incoming longwave flux components multiplied by the reflectance of the stream surface (Boyd, 1996).

Water is nearly opaque to longwave radiation and complete absorption of all wavelengths greater than 1.2mm occurs in the first 5 cm below the surface (Wunderlich, 1972). Longwave radiation has a cooling influence when emitted from the stream surface. This factor, termed back radiation, is the second most important component in dissipating heat energy from the stream system (Parker and Krenkel, 1969).

The net transfer of heat via longwave radiation usually balances so that the amount of heat entering is similar to the rate of heat leaving the stream (Beschta and Weatherred, 1984; Boyd, 1996). In the heat budget, *longwave radiation* ($Ö_{Longwave}$) is derived by the Stefan-Boltzmann Law and is a function of the emissivity of the body, the Stefan-Boltzmann constant and the temperature of the body (Wunderlich, 1972).

Convection

Convection transfers heat between the stream and the air via molecular and turbulent conduction (Beschta and Weatherred, 1984). Sensible heat will be transferred across the air / water interface when the respective temperatures of the stream and the ambient air are different. From Furrier's heat transfer studies, the rate of heat energy transfer is proportional to the heat gradient (McCutcheon, 1989). The Bowen Ratio is a constant of proportionality between the convection flux and the evaporation flux at the air / water interface. This ratio is a function of the stream and air temperature as well as the vapor pressure (Bowen, 1926).

Heat is transferred in the direction of warmer to cooler. Air can have a warming influence on the stream when the stream is cooler. The opposite is also true. The amount of convective heat transfer between the stream and air is low (Parker and Krenkel, 1969; Brown, 1983). In the heat budget, *convection* ($Ö_{Convection}$) is a function of Bowen's Ratio (1926) and terms include atmospheric pressure, and water and air temperatures.

Evaporation

Evaporation occurs in response to internal energy of the stream (molecular motion) that randomly expels water molecules into the overlying air mass. Evaporation is the most effective method of dissipating heat from water (Parker and Krenkel, 1969). The evaporation flux is the energy process in which a stream loses the most heat energy. As a result, evaporation contributes most to a decrease in stream temperature. The rate of evaporation is derived by assuming that turbulent mixing is responsible for the transport of momentum, heat, and water vapor in the atmospheric boundary layer directly above the stream surface (McCutcheon, 1989).

As stream temperatures increase, so does the rate of evaporation. Air movement (wind) and low vapor pressures increase the rate of evaporation and accelerate stream cooling (Harbeck and Meyers, 1970). In the heat budget, *evaporation* ($Ö_{Evaporation}$) relies on a Dalton-type equation that utilizes an exchange coefficient, the latent heat of vaporization, wind speed, saturation vapor pressure and vapor pressure (Wunderlich, 1972).

Stream Bed Conduction

Heat energy conduction between the streambed and the stream is driven by heat gradient. Streambed characteristics affect the solar absorption properties of a stream, especially shallow streams. Solid rock, in particular, will absorb solar energy, which will conduct to the stream during and after solar radiation has diminished for the day. Conductive heat from the streambed will broaden the temperature profile, rather than increase the maximum daily water temperature (Beschta, 1984).

The heat energy available for absorption by streambed material is a function of stream depth. Depending on streambed composition, shallow streams (less than 20 cm) may allow solar radiation to warm the streambed (Brown, 1969). Large cobble (> 25 cm diameter) dominated streambeds in shallow streams may store and conduct heat as long as the bed is warmer than the stream. Bed conduction may cause maximum stream temperatures to occur later in the day, possibly into the evening hours. In the heat budget, *bed conduction* ($Ö_{Conduction}$) simulates the theoretical relationship ($Ö_{conduction} = K * dT_b/dz$), where calculations are a function of thermal conductivity of the bed (K) and the temperature gradient of the bed (dT_b/dz) (Sinokrot and Stefan, 1993). Bed conduction is solved with empirical equations developed by Beschta and Weatherred (1984).

Groundwater Inflow / Outflow

The interaction between a stream and connected groundwater can affect surface water temperatures. Generally, a particular stream reach is classified as gaining, losing, or impermeable. This can be determined by comparing the magnitude of upstream and downstream flows. A volume of water that adds to the streamflow contributes heat energy (positive or negative) which is proportional to the temperature and flow rate of the groundwater. An energy relationship that reflects this effect can be developed to account for stream / groundwater temperature mixing. The water temperature change is derived from the following relationship:

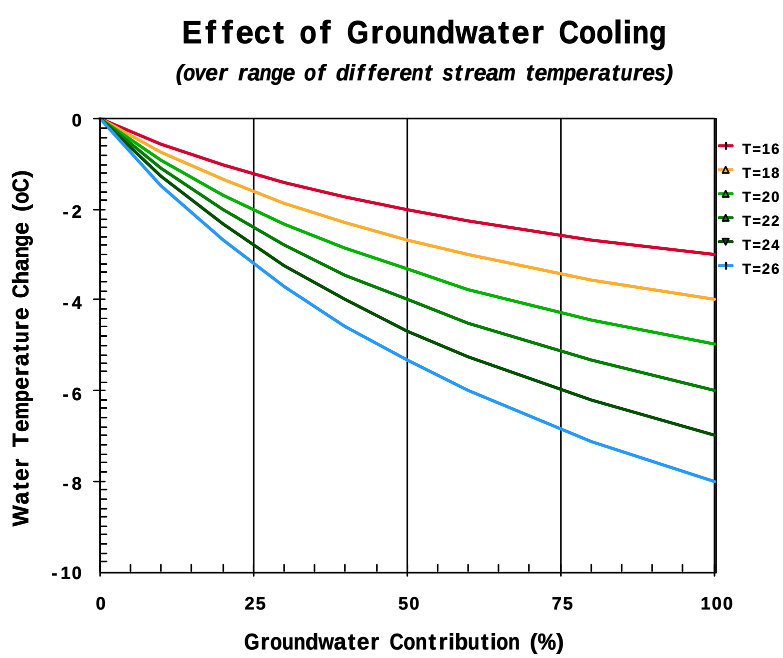
$$\text{Ä}\,T = T_{upstream} - \{[(T_{upstream} * Q_{upstream}) + (T_{GW} * Q_{GW})] \;/\; (Q_{upstream} + Q_{GW})\}$$

where:

Ä T	=	water temperature change (EC)
$T_{upstream}$	=	upstream water temperature prior to groundwater (EC)
$Q_{upstream}$	=	upstream flow rate (ft^3 / sec)
T_{GW}	=	groundwater temperature (EC)
Q_{GW}	=	groundwater flow rate (ft^3 / sec)

The potential effect of groundwater cooling is shown in Figure H-3. This example assumes a groundwater temperature of 10EC and depicts the relationship across a range of different percent contributions for groundwater flow.

Figure H-4. Relationship between Groundwater Contribution and Temperature Change



HEAT BUDGET

In summary, assessment of water temperature based upon a heat budget uses the basic relationship:

$$Ö_{Total} = Ö_{Solar} + Ö_{Longwave} + Ö_{Evaporation} + Ö_{Convection} + Ö_{Conduction}$$

Chen (1996) has provided a summary of each energy transfer process considered in the heat budget and described the general equation used to quantify each term *(Table H-2)*.

Table H-2. Heat Budget Components *(from Chen, 1996)*

Heat Transfer Process	General Equation
Net shortwave solar radiation (M_{Solar})	(1) Obtained from solar ephemeris, depending on solar angle which is, in turn, a function of season, time of day, and latitude (2) Calculated by using various empirical equations
Net longwave radiation of atmosphere, canopy, and water ($M_{Longwave}$)	Stefan-Boltzmann Law: $M_{Longwave} = g F T^4$ where g is the emmissivity of the body; F is the Stefan - Boltzmann constant; T is the surface temperature.
Evaporative heat flux at the water surface ($M_{Evaporation}$)	Dalton-type equation: $M_{Evaporation} = k L U (e_w - e_a)$ where k is exchange coefficient; L is the latent heat of vaporization; U is wind speed; e_w is saturated vapor pressure at the stream temperature; e_a is ambient atmospheric vapor pressure.
Convective heat flux ($M_{Convection}$) at the air - water interface	Bowen ratio: $R = M_{Convection} / M_{Evaporation}$ $R = 0.61 \frac{(T_w - T_a)}{(e_w - e_a)} \frac{P}{1000}$ where T_w is water temperature; T_a is ambient air temperature; P is atmospheric pressure.
Conductive heat flux ($M_{Bed\ Conduction}$) between bedrock and water	(1) Theoretical formula: $M_{Bedrock\ Conduction} = K * dT / dZ$ where K is thermal conductivity of bottom material; dT / dZ is temperature gradient in the bottom material. (2) Empirical equations for calculating the heat fluxes absorbed by water, transmitted through water, and absorbed by stream bed.
Advective heat flux ($M_{Advection}$) from groundwater and tributaries	Energy balance: $\text{Adjusted temperature} = \frac{(Q_m * T_m) + (Q_t * T_t)}{Q_m + Q_t}$ where Q_m and T_m are flow rate and water temperature of the mainstem; Q_t and T_t are flow rate and temperature of tributary.

Appendix C:

Simpson Habitat Conservation Plan - Selected Elements

Bound Separately

Appendix C

Habitat Conservation Plan - Selected Elements

NOTE: At the time of TMDL submittal, the final copy of the Habitat Conservation Plan (HCP) for the Simpson Timber Company, Northwest Operations was not available. Rather than risk confusion by including outdated drafts of the critical Chapters, we will list the chapters here and attach the final copy when it is available.

As explained in the Submittal Report, the implementation strategy to achieve the TMDL targets is to rely on the Simpson HCP. We consider the management prescriptions, monitoring and adaptive management elements of the HCP as appropriate implementation measures to achieve the TMDL targets. We are confident that the adaptive management process including the Scientific Advisory Team will ensure that temperature conditions will improve throughout the life of the Plan.

This appendix will include the following elements, all of which are part of Simpson's commitment in their Implementation Agreement with the Services.

Chapter 5	Management Prescriptions
Chapter 8	Implementation Monitoring
Chapter 9	Resource Monitoring Program
Chapter 10	Adaptive Management
Chapter 14	Continuing Involvement and Dispute Resolution
Appendix B	Riparian Guidelines

The entire HCP should be consulted for more complete information and background. Copies of the final Environmental Impact Statement and the final HCP will be available from:

Mr. Craig Hanson
U.S. Fish and Wildlife Service HCP Program
510 Desmond Dr. SE. Ste 102
Lacey WA 98503-1273
(360) 753-9440.