DEQ Western Region

Applegate Subbasin Temperature Assessment

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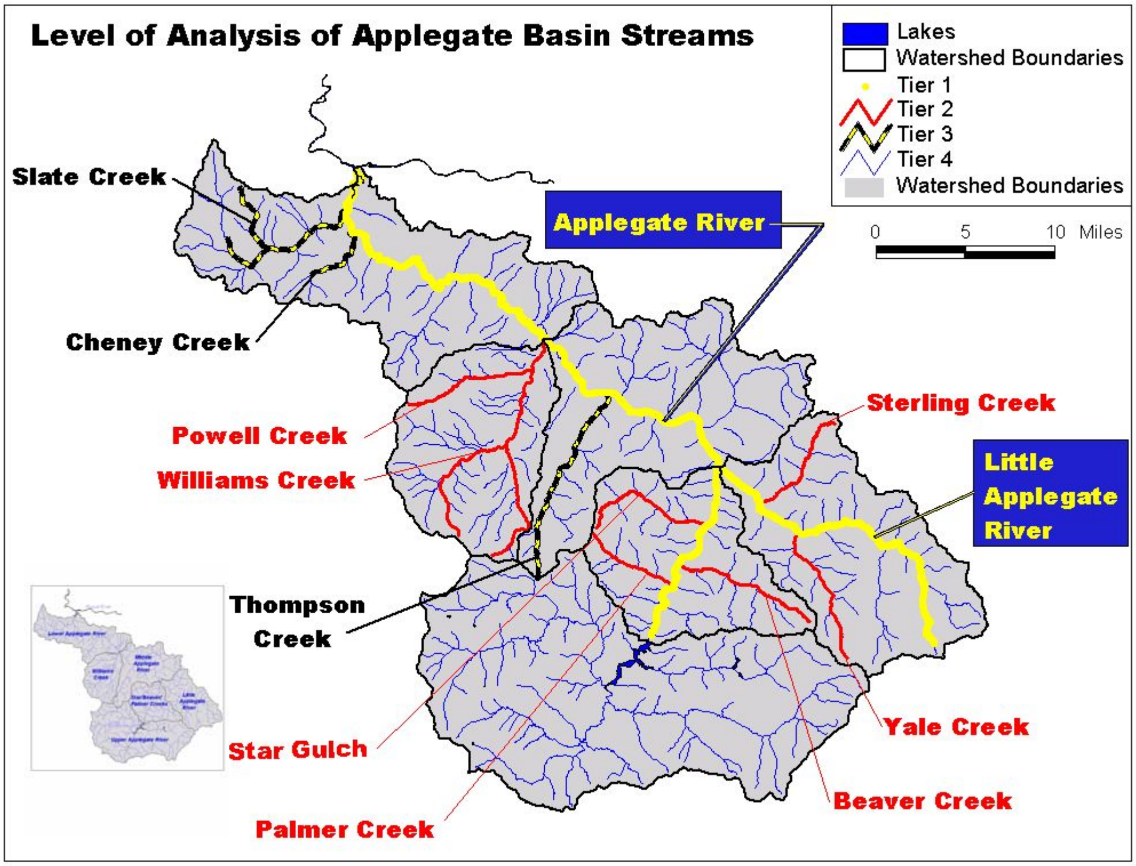
Oregon Department of Environmental Quality

Applegate Subbasin Technical Methodology

Many types of data have been collected in the Applegate Subbasin within the last decade. Different kinds of data require different methods of assessment. For this document, assessment will follow four "Tiers" of data analysis. Map 1 shows which methods will occur in which areas.

Map 1



A brief description of the data/assessment method follows.

Tier1

Locale: Undertaken for the Little Applegate and mainstem Applegate from Applegate Reservoir down to the confluence with the Rogue River. Highest level of assessment.

Data Sets Used: Data used includes full description of instream temperatures measured at calibration points, flow volume, channel characteristics and adjacent riparian vegetation character.

Model*:* HEATSOURCE 6.0

Data Outputs: Analysis will include expected stream temperatures and the percent effective shade values at system potential conditions.

Data Resolution: Data input at 100 ft resolution, data output averaged to 100 meter (328 ft) segments.

Tier 2:
Locale: Beaver, Palmer, Powell, Star Gulch, Sterling, Williams and Yale Creeks.
Data Sets Used: Extensive riparian vegetative and active channel descriptions. Data lacks quantitative measures of flow volume, stream velocities/depths and correction for topographic shading.
Model: *SHADOW*
Data Outputs: Percent of solar energy reaching the active channel area (output is percent shade).
Data Resolution: Varies due to vegetation variability, but data tends to be averaged over larger areas than in the Tier 1 analysis.

Tier 3:
Locale: Cheney, Thompson, Slate and Waters Creeks.
Data Sets Used: Oregon Department of Fish and Wildlife stream surveys define active channel widths. Reach breaks and reach aspects are calculated via GIS. System potential shade height and shade density are derived from soil-plant community data or taken from data used in the Little Applegate Tier 1 analysis.
Model: Modified *HEATSOURCE* – only shade calculation subroutines are used, energy thermodynamics are ignored.
Data Outputs: Percent shade over the active channel width. Topographic shading is ignored.
Data Resolution: Varies, but data tends to be averaged over larger distances than in the Tier 3 datasets.

Tier 4:
Locale: All areas not covered by Tier 1, 2, or 3 analysis. Lowest level of analysis.
Data Sets Used: STATSGO soils database to define vegetative communities, shade heights and canopy densities.
Model: Modified *HeatSource* – only shade calculation subroutines are used, energy thermodynamics are ignored.
Data Outputs: Shade curves which define percent shade in the NSDZ if site soil type, dominant vegetation and NSDZ are know.
Data Resolution: Likely low due to multiple extrapolations used in processing soil and vegetation data. Soil and vegetation data are also very low resolution to begin with.

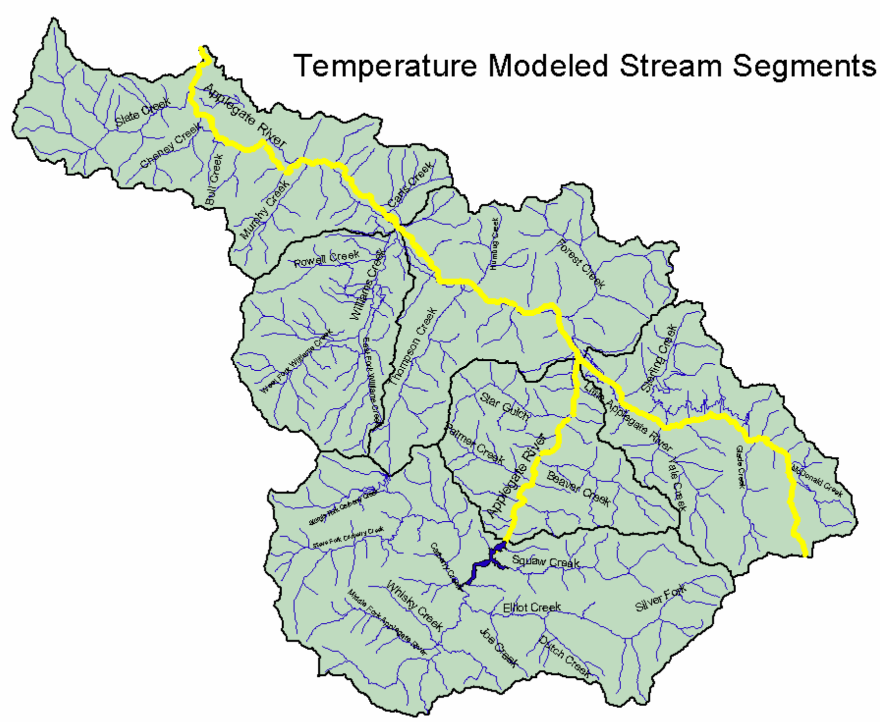
TIER 1 ANALYSIS

Heat Source Model of the Mainstem Applegate and Little Applegate Rivers

Overview

Field measured data was used to calibrate a stream temperature model, *Heat Source 6.0*. Data from late July was used so that the conditions used to calibrate the model will be as close to a seasonal worst case condition as possible. The mainstem Applegate (Applegate Dam to mouth) and the Little Applegate were modeled. See Map 1-1 for modeled reaches.

The model uses field measurements and model-derived parameters as input to simulate how stream temperatures respond to unique conditions within the subbasin. Once the model parameters have been adjusted, so that the simulation accurately describes the conditions measured in the field (the calibration step), "future conditions" are entered into the model. The model sums the amount of energy reaching the stream and re-calculates stream temperatures based on those future condition(s) that are assumed. Equilibrium conditions are calculated for each of the 2490 segments that make up the Applegate and 1034 segments that make up the Little Applegate models (segments are 100 feet long).



Map 1-1. Streams, Subbasins and Modeled Reaches of the Applegate

Like any model that attempts to "look into the future", there is a disparity between what is predicted and what will actually come to pass. Our understanding of the processes that determine stream temperature is imperfect, and any predictions using them are similarly imperfect. While only the broadest suggestions of possible management strategies are shown by the model, they should point us in the right direction.

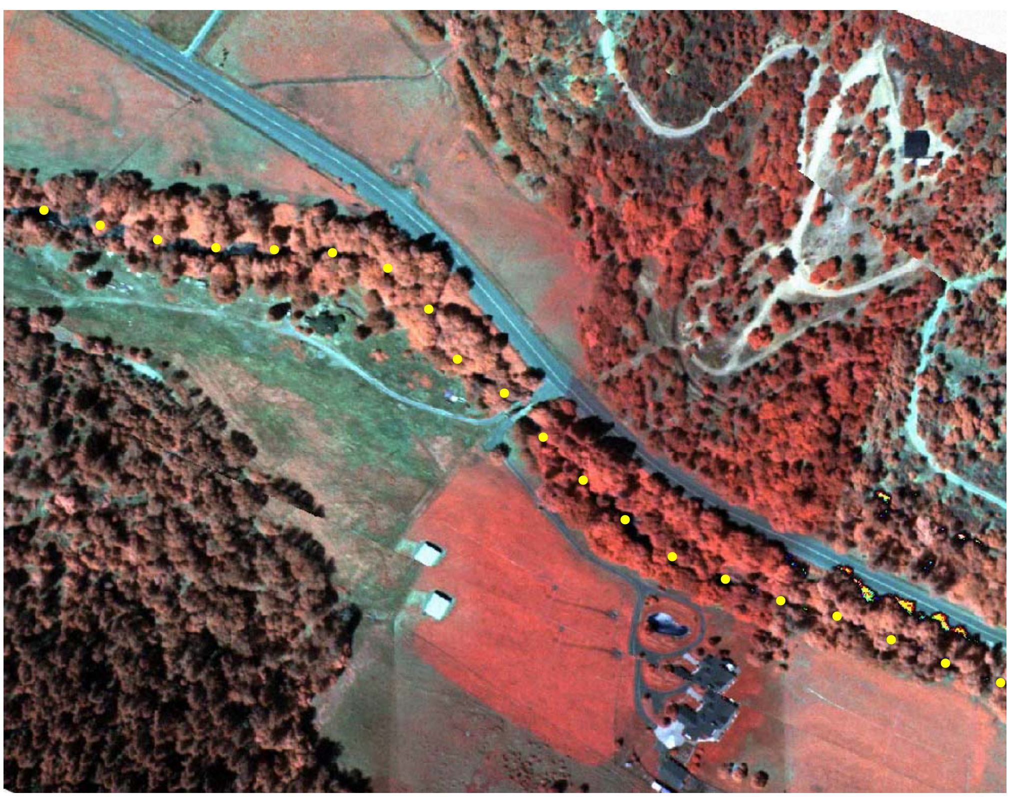
Input Parameters for *HeatSource* modeling

Data collected for the Applegate modeling has allowed the development of temperature simulation methodology that is both spatially continuous and spans full day lengths (diurnal). *HeatSource* input parameters were similar for both the mainstem Applegate and Little Applegate modeling, however, different methods were employed for riparian vegetation characterization. Vegetation along the mainstem Applegate was hand digitized using high resolution color infrared photos, while the Little Applegate was assessed using a dataset created for use in the SHADOW model. These methodologies will be described in further detail later in this document. A description of data types used in the Applegate and Little Applegate models follows.

GIS Derived Parameters

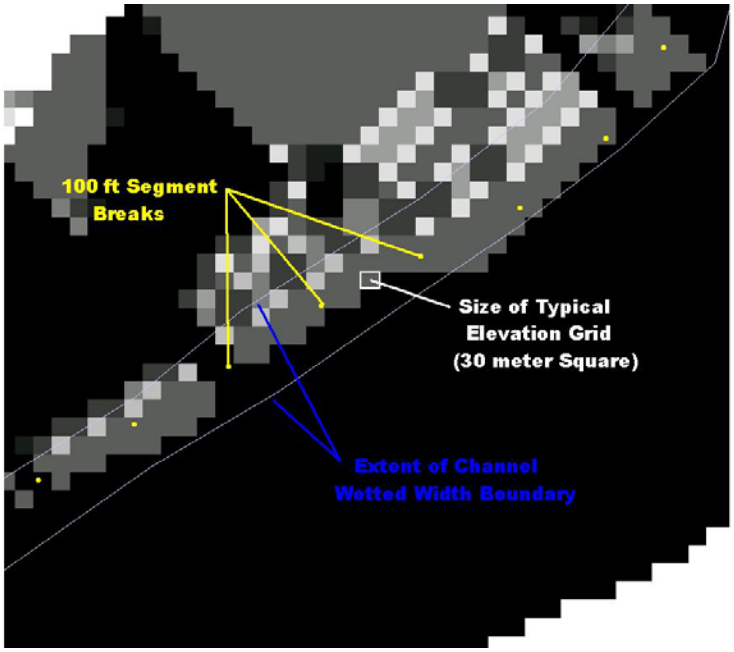
<u>Longitudinal Flow-Path Distance:</u> Defines the reaches to which spatial input parameters are referenced. Model reaches are 100 feet long and are derived from high resolution (1.2 ft pixels) color-infrared digital camera imagery from August of 2000 that is mosaiced and georeferenced to a DOQ (Digital Orthophoto Quad) base map. See Figure 1-1. The river flow path was digitized from these photos and then broken up into the proper segment length using a GIS utility.

Figure 1-1: Color Infrared Image Showing Segment Breaks.



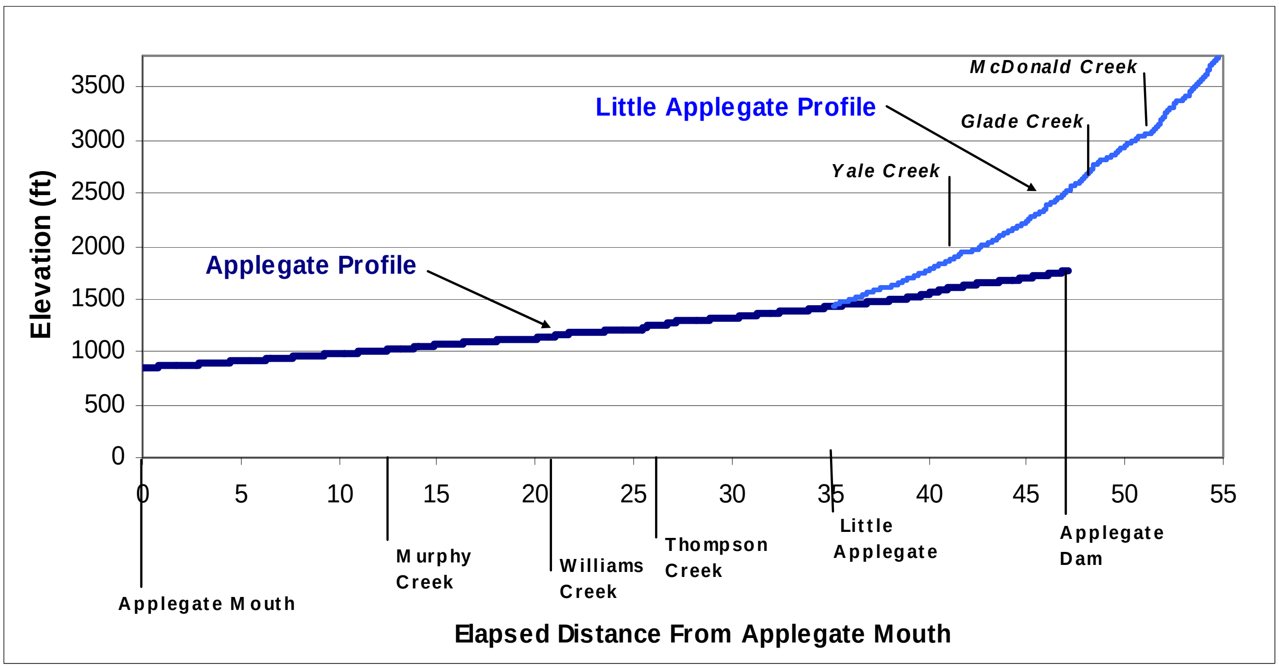
Segment Break Elevation: Sampled at each 100' segment break using the USGS 1:24,000 Digital Elevation Model (DEM). This data is in the form of a 30 meter grid with an elevation value associated with each grid. See Figure 1-2.

Figure 1-2: USGS DEM Grid-Data Set Showing Channel Outline and Segment Breaks



When each segment elevation is then shown associated with it's distance from the mouth of the river, a longitudinal elevation profile can be constructed. See Figure 1-3.

Figure 1-3: Elevation Profile of the Applegate and Little Applegate Rivers



Segment Gradient: The difference between the upstream and downstream elevations divided by the reach length determines the gradient of the reach. Figure 1-4 shows the gradient profiles of the Applegate and Little Applegate systems. Blue dots are individual segment gradient data, the red line is a 5-reach moving average of gradient values.

Figure 1-4(a): Gradient Profile of the Applegate River

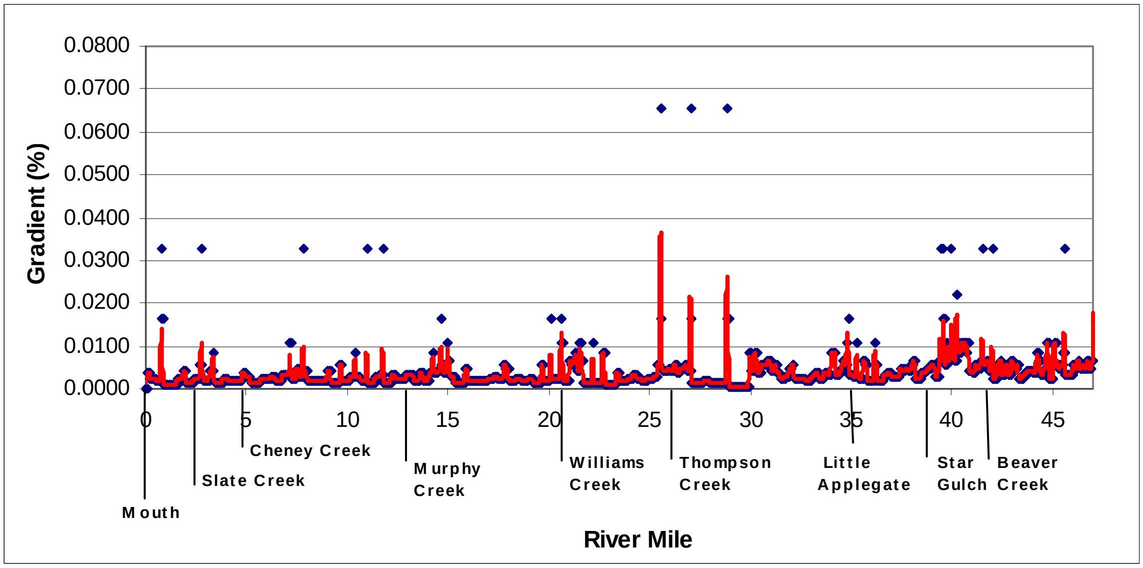
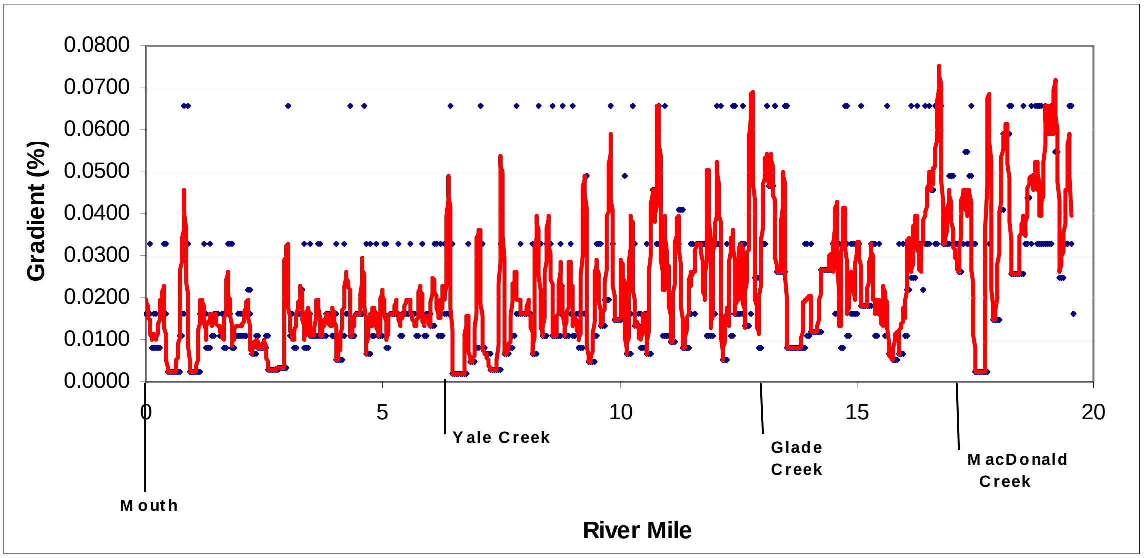
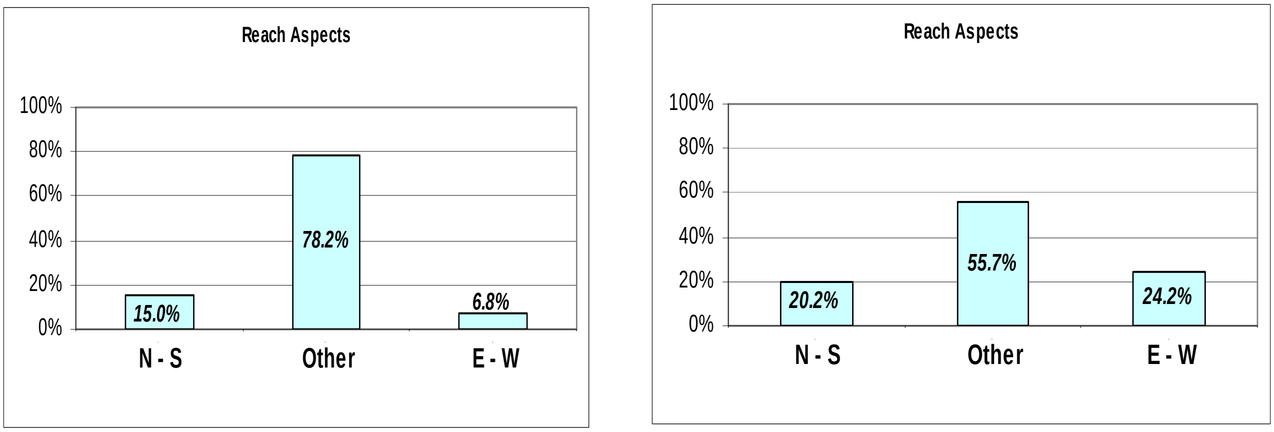


Figure 1-4(b): Gradient Profile of the Little Applegate



Segment Aspect: Calculated at each 100' segment break, the aspect is the compass heading that the river travels along this reach. Aspects are important because with the sun always being on the southern horizon, shading is more effective in controlling temperature along reaches with an East-West aspect than a North-South Aspect. Figure 1-5 shows the percentage of the reaches that are orientated in three aspect groupings.

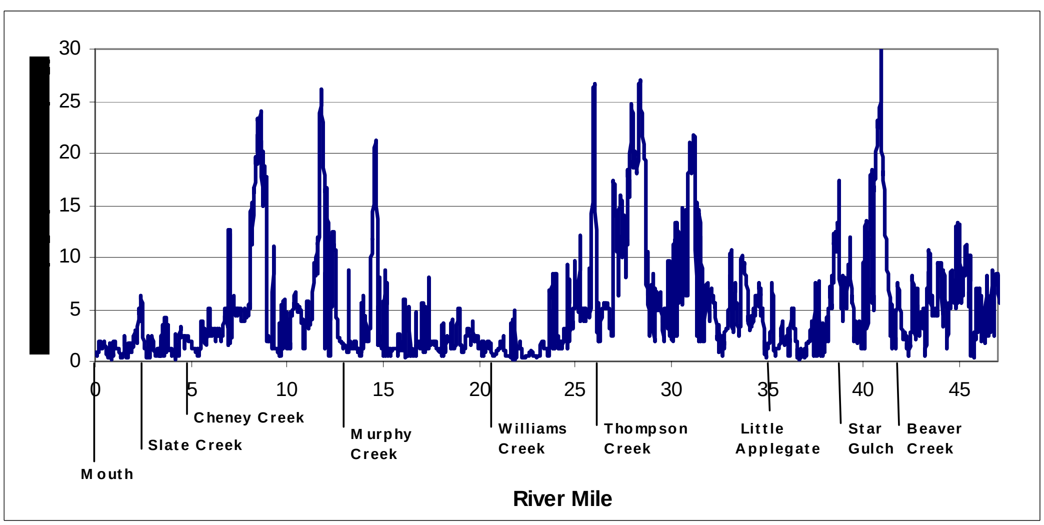
Figure 1-5: Distribution of Reach Aspects in the Applegate and Little Applegate Rivers



Applegate **Little Applegate**

Topographic Shade Angle: The angle made between the stream surface and the highest topographic features to the west, east and south as calculated from DEM data at each reach break. Features which provide shade to the stream include distant mountain ranges, canyons walls or other near stream relief. Topographic shading to the south blocks solar flux throughout the day. Topographic shading to the east delays sunrise, while shading to the west hastens sunset. Topographic shading is extremely localized and unique for each system. Figure 1-6 shows a typical Topographic shading data set, this example being the south shading of the Applegate River mainstem. East and West shading, as well as shading data for the Little Applegate are not shown.

Figure 1-6: Southern Topographic Shading (in Degrees Above the Horizon) for the Applegate River Modeled Reach



Wetted Width: Directly measured from aerial photos.

Near-Stream Disturbance Zone Width (NSDZ): Defined as the distance from the vegetation line of one bank to the vegetation line of the opposite bank, the "hole" in the vegetative cover that the stream occupies. This zone of disturbance allows solar energy to reach the river. Digitized from color infrared photos. See Figure 1-7.

Figure 1-7: Near Stream Disturbance Zone Drawn on Photo. A GIS utility is then used to measure this distance at each segment break.

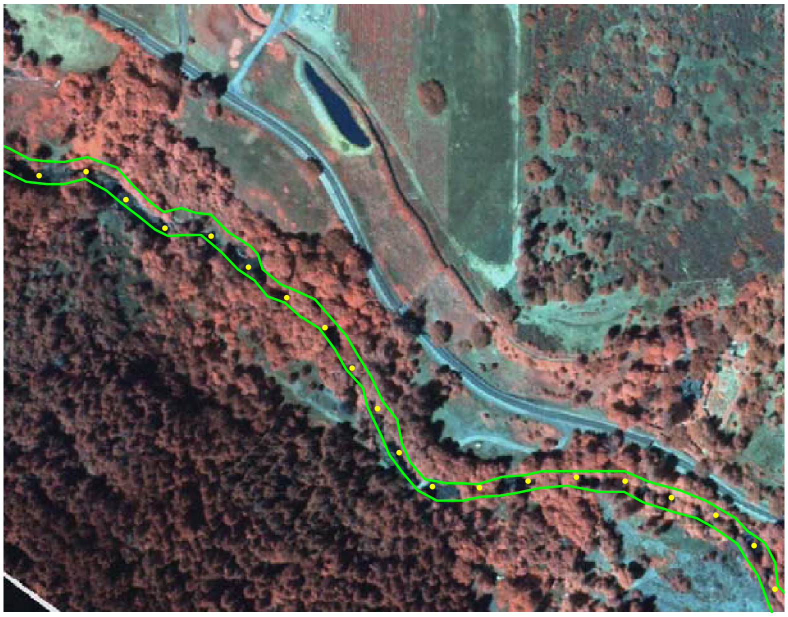


Figure 1-8 shows the longitudinal profiles of wetted widths (red line) and NSDZ widths (blue line) measured for the Applegate and Little Applegate.

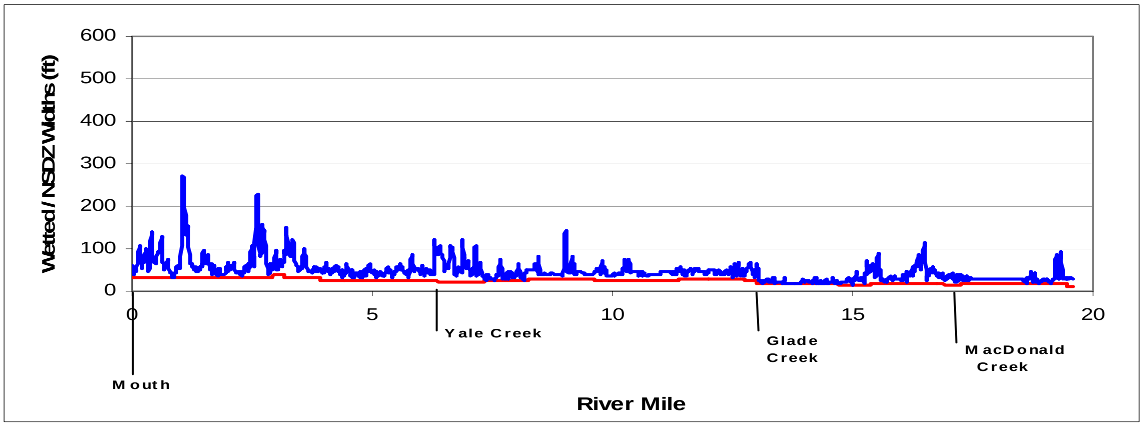


Figure 1-8(a): Wetted Width/NSDZ Width for the Applegate River

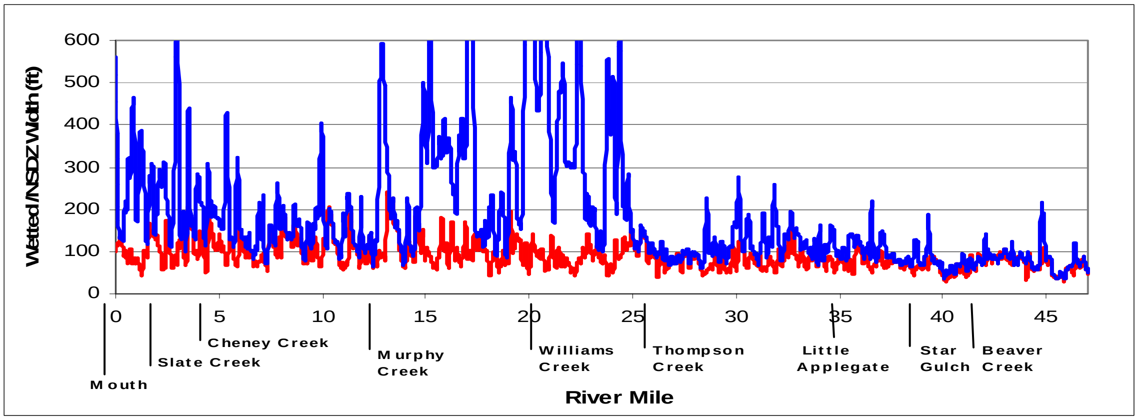


Figure 1-8(b): Wetted Width/NSDZ Width for the Little Applegate River

Hydraulic Parameters

Flow Volume: Field measured (see Map 1-3 for measurement locations) by staff from ARWC, OWRD and DEQ using standard USGS protocols. Data from three mainstem Applegate USGS stream gages was also used for the day picked for model calibration. Figure 1-9 shows the flow profiles constructed for the Applegate and Little Applegate rivers. Note differences in y-axis scales. Blue dots show actual data measurements, the blue line connecting them is extrapolated between the points of known discharge. The open circles are discharge measurements taken at sites near the mouths of major tributaries.

Figure 1-9(a): Flow Profile of the Applegate River

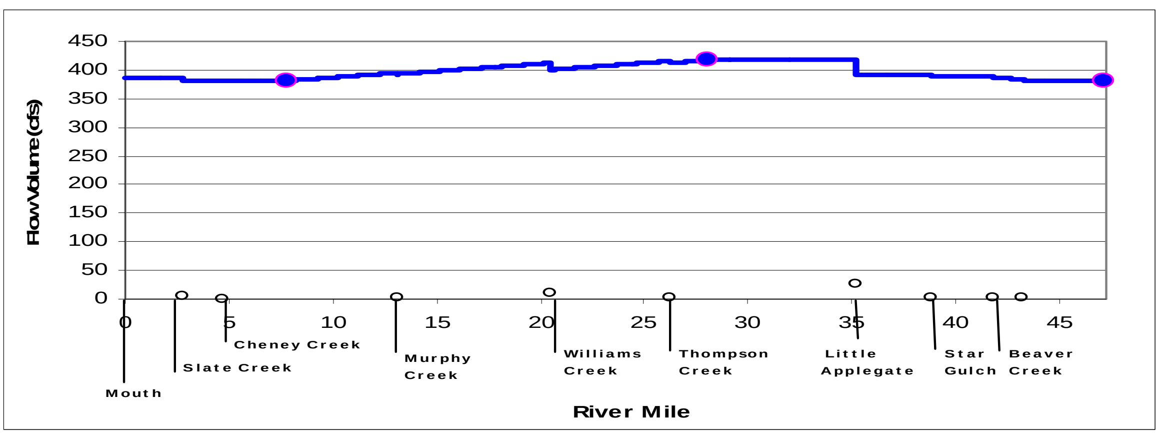
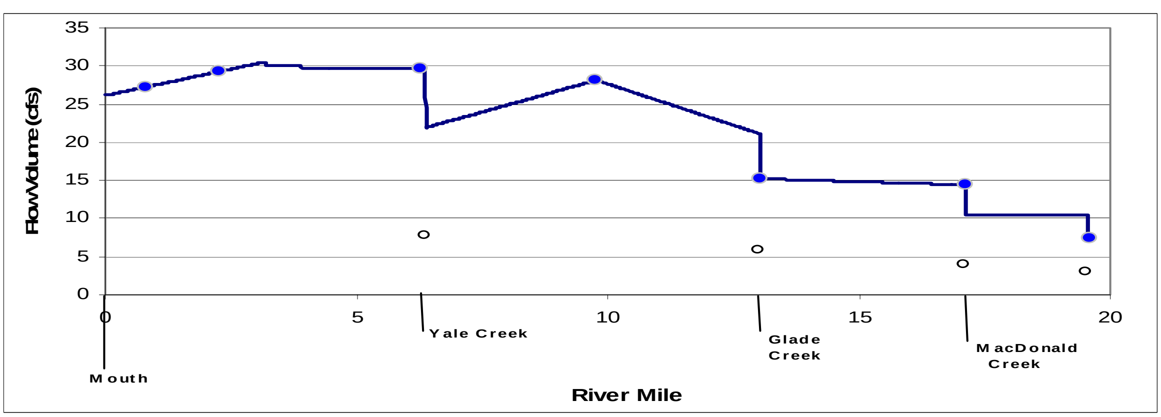
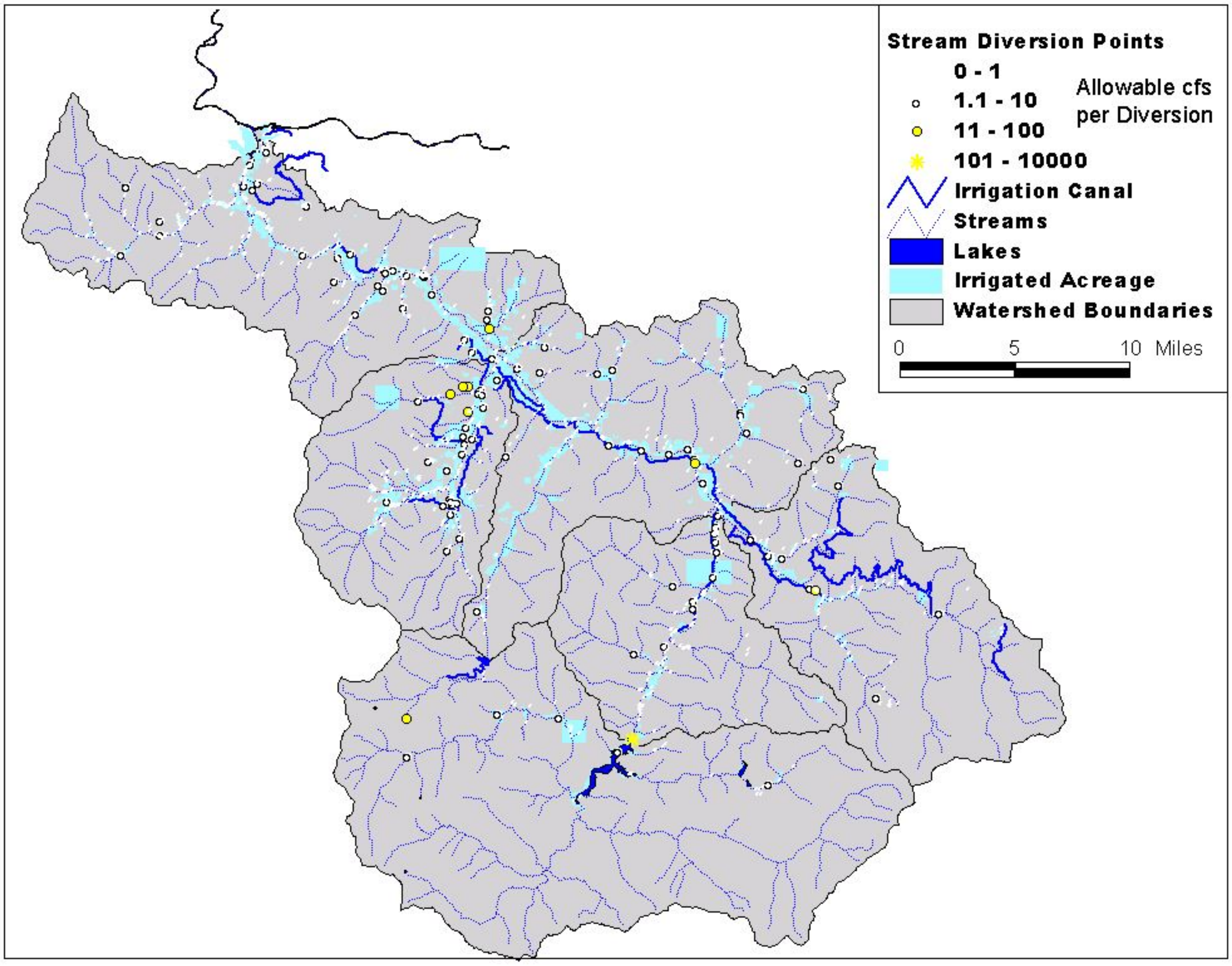


Figure 1-9(b): Flow Profile of the Little Applegate River



Significant flow in the mainstem and Little Applegate is allocated for irrigation, mining and domestic use. Map 1-2 shows the points of stream diversion, and the approximate allowable diversion amounts in the Applegate Basin. The Applegate Basin has the two oldest water rights in the state, granted in 1854 when Oregon was still a territory.

Map 1-2: Water Diversion Points in the Applegate



Water use unquestionably affects stream temperatures. Diversions reduce stream volume while the ambient solar flux remains the same. Irrigation water warms up on its passage through fields, and is then re-introduced to the river. With the number of potential diversions in action on the day of modeling, it was simply impossible to monitor all of them. The flow profiles shown in Figures 9(a&b) assume a straight-line connection between points of actual field flow-measurement. Diversions that may or may not have been active on the day picked for calibration cannot be exactly identified. It must be assumed that in the system potential analysis (or any other future condition analysis) that conditions that affect flow are exactly the same as on the day picked for calibration. Although this uncertainty introduces a non-quantifiable error in the modeling analysis, Forward Looking Infra-Red Radiometry (FLIR) temperature data from 1998 and 1999 show that year-to-year variation of instream temperatures is not large. See Figure 1-10(a&b), stream temperatures are in Degrees Fahrenheit. The dotted line is at 64 DegF, an important benchmark for the state 7-day water temperature standard. Note that the HeatSource model simulates temperature during one hour of a single day so output is not directly comparable to the state temperature standard.

Figure 1-10(a): FLIR Temperature Data Taken Along the Applegate River. Temperature data was taken between 1505 and 1545 on August 18th 1998 and between 1535 and 1615 on July 19th 1999.

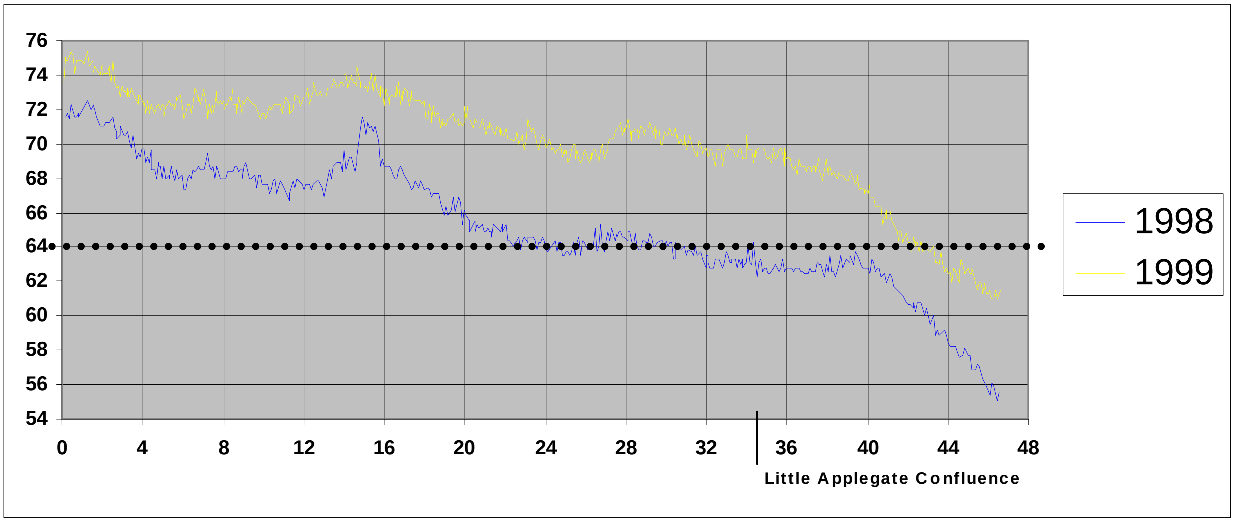
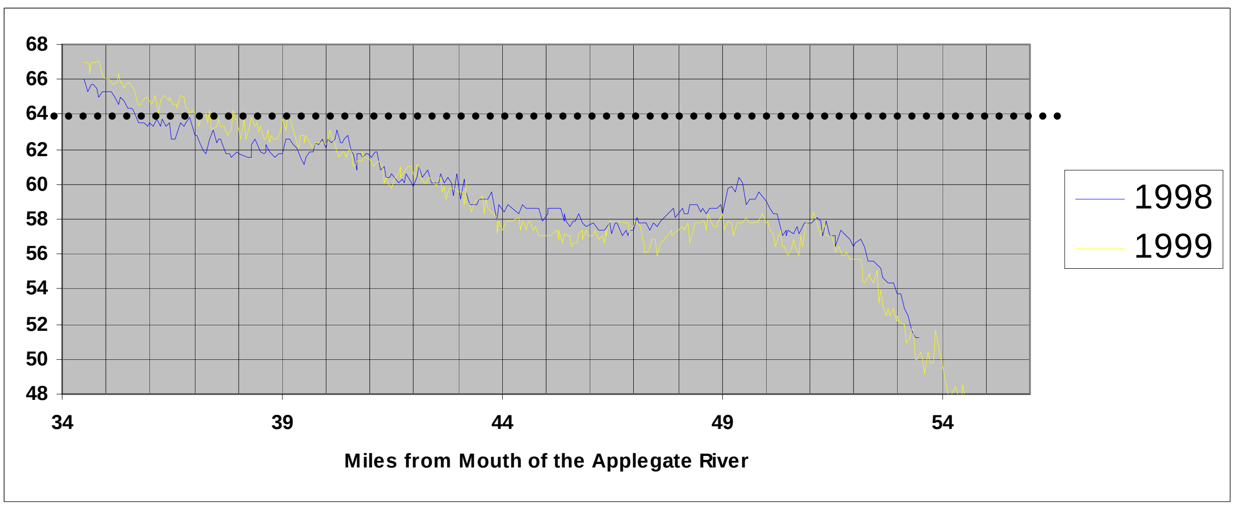


Figure 1-10(b): FLIR Temperature Data Taken Along the Little Applegate River. Temperature data was taken between 1330 and 1350 on August 19th 1998 and between 1425 and 1445 on July 21st 1999.



Temperature profiles in the Little Applegate are extremely close to each other between the two years. The mainstem Applegate, while not as consistent as the Little Applegate, still shows a remarkable similarity between 1998 and 1999 temperatures. The areas where heating and cooling occur, as well as the relative rate at which the temperature changes, produces a comparable pattern.

<u>Flow Velocity</u>: Derived from segment gradient, Manning's equation and Leopold power functions in comparison to sites where velocity data was directly measured. Figure 1-11 shows the flow velocity data used by the models. Blue dots are individual segment velocity data, the red line is a 5-reach moving average of velocity data. Figure 1-12 shows the velocity data converted into time-of-travel information.

Figure 1-11(a): Assumed Flow Velocities for the Applegate River Model

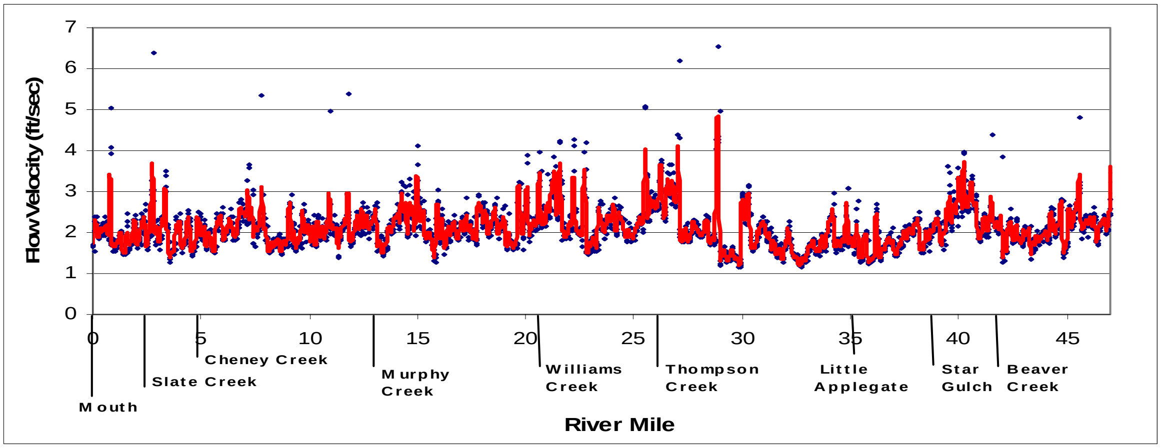


Figure 1-11(b): Assumed Flow Velocities for the Little Applegate River Model

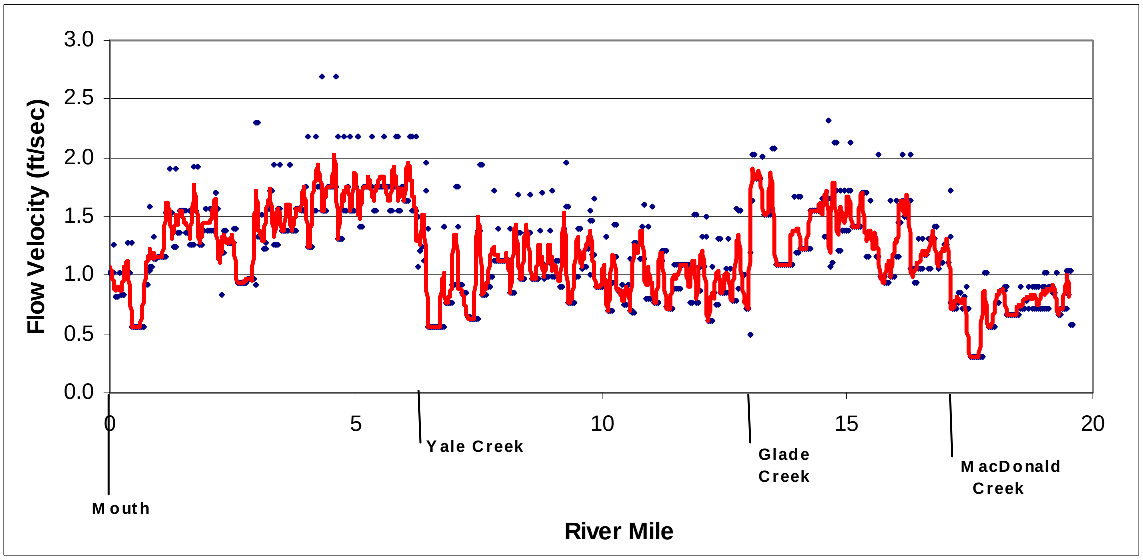


Figure 1-12(a): Assumed Time-of-Travel in the Applegate River Model

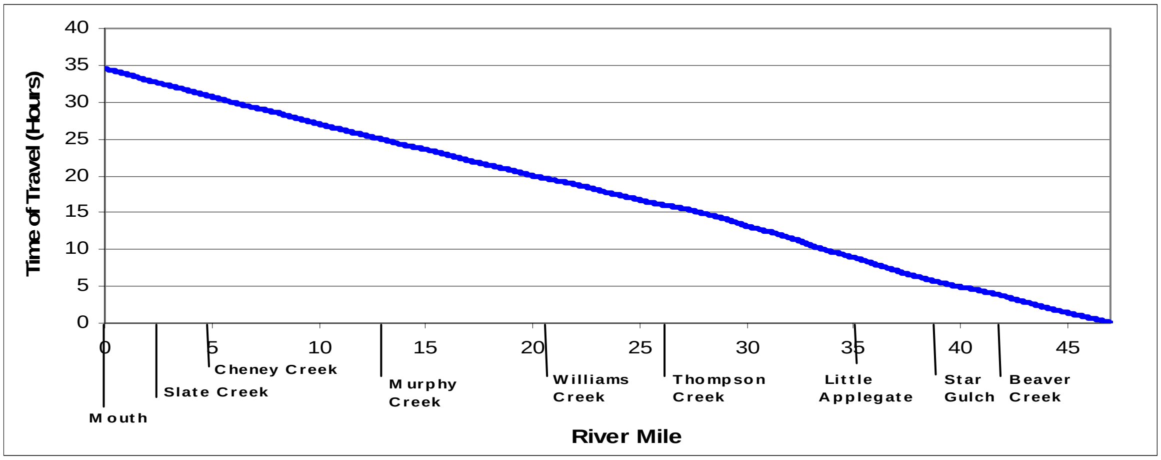
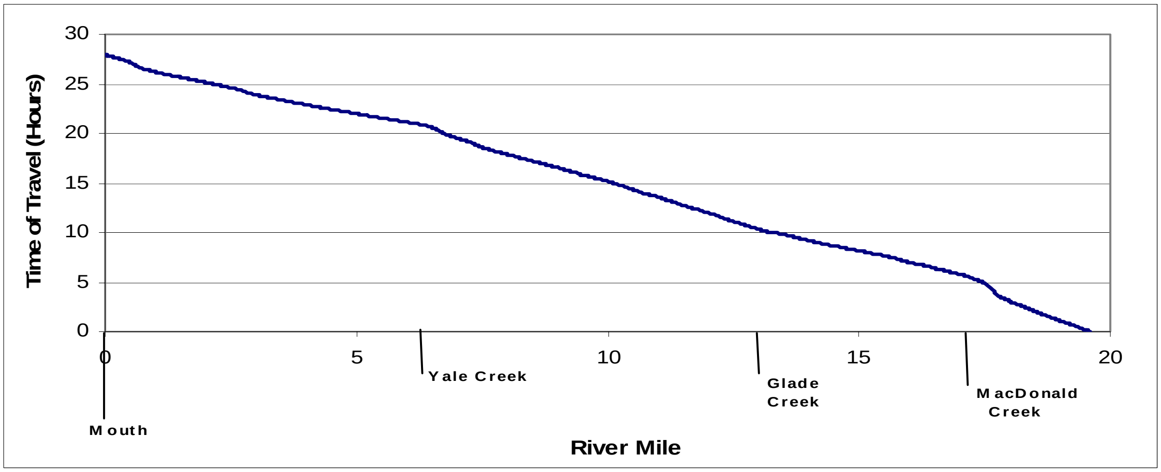


Figure 1-12(b): Assumed Time-of-Travel in the Little Applegate Model



Average Depth: Derived from Manning's equation and Leopold power functions in comparison to sites where depth data was directly measured. Calculated based on assuming a rectangular channel cross sections. See Figure 1-13, the blue dots are individual segment data and the red line is a 5-reach moving average of channel depth data.

Figure 1-13(a): Assumed Channel Depths in the Applegate River

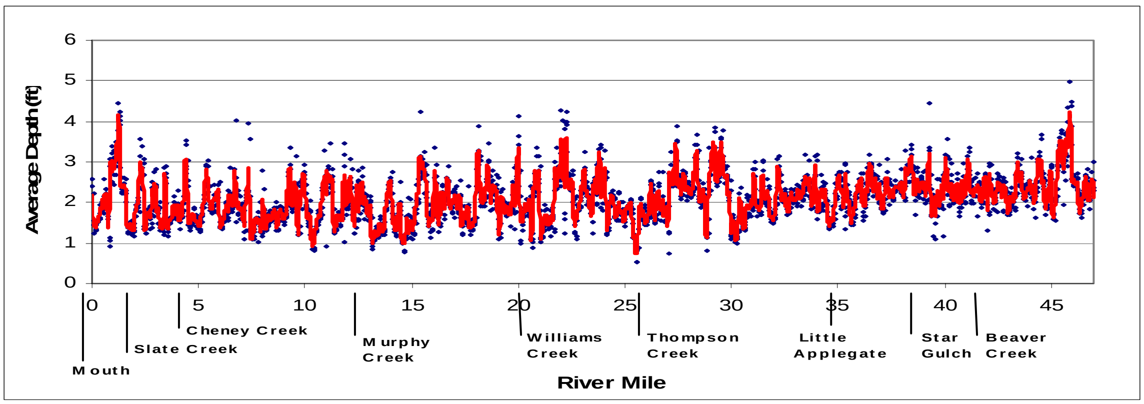
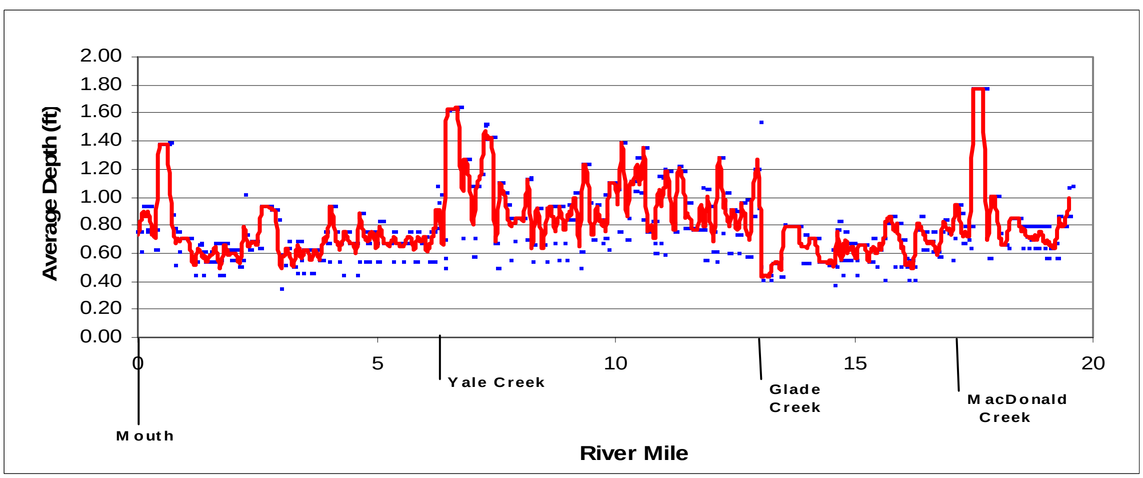


Figure 1-13(b): Assumed Channel Depths in the Little Applegate River



Percent Channel Bedrock: The percent of streambed material that has a diameter of 25 cm or greater. Values are derived from stream survey data or best available data.

Continuous Data Parameters

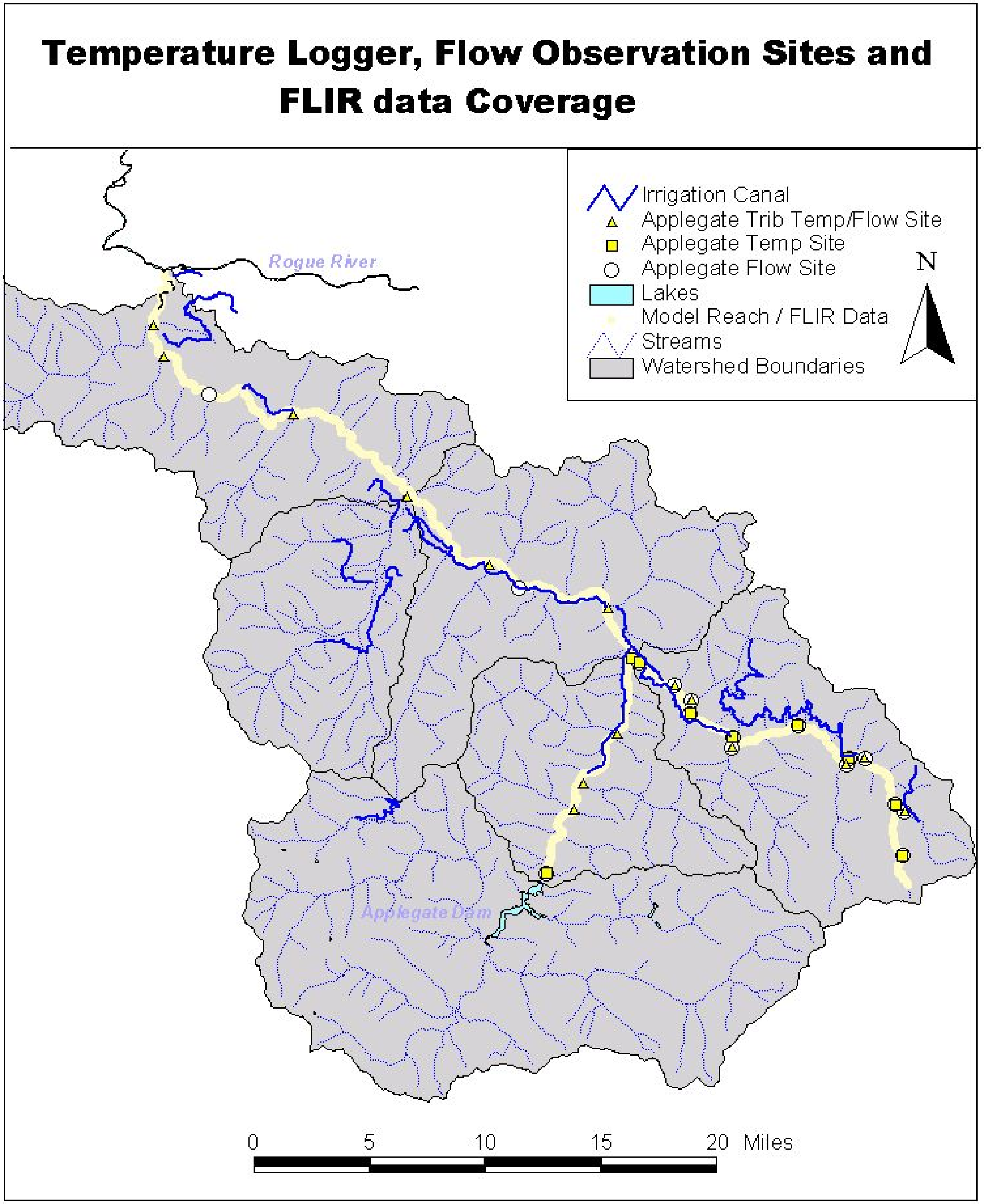
Wind Speed: Hourly values measured at the Star Ranger Station (USFS)

Relative Humidity: Hourly values measured at the Star Ranger Station (USFS)

Air Temperature: Hourly values measured at the Star Ranger Station (USFS)

Tributary Temperature: Hourly values measured by U.S. Forest Service, BLM and ARWC.
Stream Temperature: Hourly values measured by U. S Forest Service, BLM, and ARWC data loggers and helicopter mounted Forward Looking Infra-Red Radiometry (FLIR) instrumentation. Temperature data used for calibrating the model of the mainstem and Little Applegate was collected in 1999 using deployable instream temperature data loggers and FLIR over flight. Sites of logger deployment and FLIR data collection are shown in Map 1-3. The FLIR data was collected between 1530 and 1615 on 7/19/1999 for the mainstem and between 1425 and 1445 on 7/21/1999 for the Little Applegate. Loggers collected data for the majority of the summer season and data taken on the day of the FLIR over flight was used in calibration.

Map 1-3: Locations of FLIR Data, Instream Loggers and Flow Measurements



Riparian Shade Parameters

Concern over water quality in the Applegate Subbbasin has launched many monitoring and assessment efforts over the last decade. Many of those efforts have dealt with attempting to understand the health of riparian vegetation and it's effect on stream temperature. Because of the different methods used and the constantly changing state-of-the-art science used in those methods, the Little Applegate and mainstem vegetation assessments used different techniques to measure the quality and quantity of riparian shade. The Little Applegate used the assessment method used for collecting data for the SHADOW model. That methodology is covered in the next section - TIER 2 analysis.

Mainstem vegetation data was digitized directly off of aerial infra-red photos (such as shown in figure 1-1) for use in the *Heat Source* model. Once the vegetation type is identified, the assumptions used for vegetation height and density are taken from Table 1-1. Width and overhang of the vegetative stands are measured by drawing them off of the digital maps and then using a GIS utility to measure the unique values at each 100' segment break.

Table 1-1 - Current Vegetation Conditions

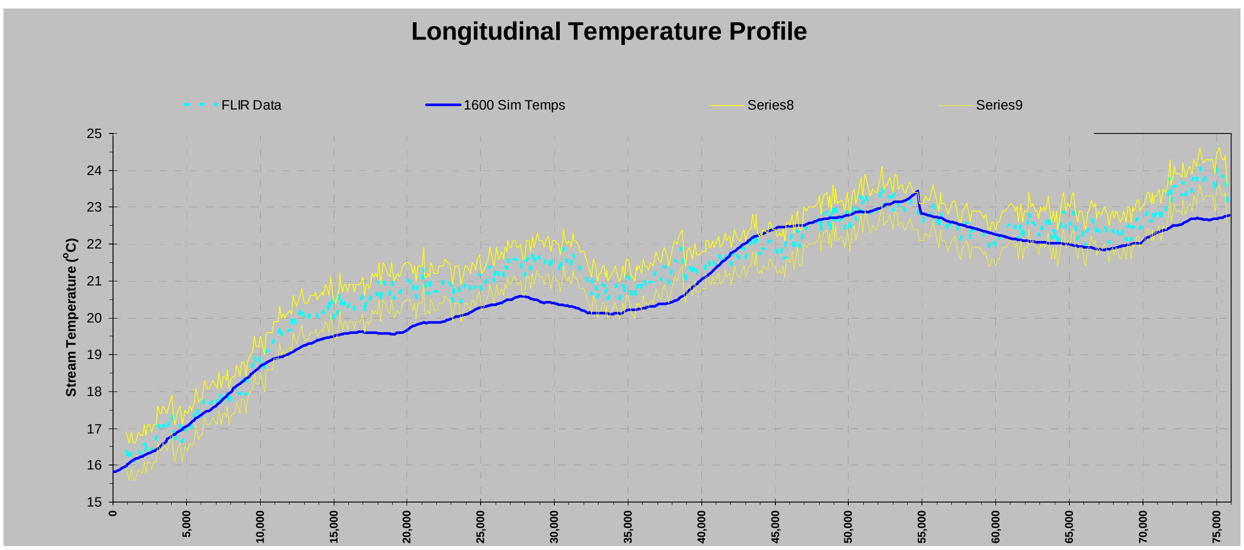
Code	Source	Description	Height (m)	Density (%)
301	DEQ	Water	0.0	0%
302	DEQ	Pastures/Cultivated Field/lawn	0.5	75%
303	DEQ	Orchard (Provolt Seed Orchard-BLM)	6.1	70%
304	DEQ	Barren - Rock	0.0	0%
305	DEQ	Barren - Embankment	0.0	0%
308	DEQ	Barren - Clearcut	0.0	0%
309	DEQ	Barren - Soil	0.0	0%
400	DEQ	Barren - Road	0.0	0%
401	DEQ	Barren - Forest Road	0.0	0%
500	DEQ	Large Mixed Con/Hard	30.5	55%
501	DEQ	Small Mixed Con/Hard	15.2	55%
550	DEQ	Large Mixed Con/Hard	30.5	25%
551	DEQ	Small Mixed Con/Hard	15.2	25%
555	DEQ	Large Mixed Con/Hard	30.5	10%
556	DEQ	Small Mixed Con/Hard	15.2	10%
600	DEQ	Large Hardwood	24.4	65%
601	DEQ	Small Hardwood	12.2	65%
602	DEQ	Hardwood Mix	18.3	65%
650	DEQ	Large Hardwood	24.4	30%
651	DEQ	Small Hardwood	12.2	30%
655	DEQ	Large Hardwood	24.4	10%
656	DEQ	Small Hardwood	12.2	10%
700	DEQ	Large Conifer	36.6	60%
701	DEQ	Small Conifer	18.3	60%
750	DEQ	Large Conifer	36.6	30%
751	DEQ	Small Conifer	18.3	30%
752	DEQ	Large Conifer	36.6	10%
753	DEQ	Small Conifer	18.3	10%
802	DEQ	Shrubs (>50% den)	3.0	75%

803	DEQ	Shrubs (<50% den)	3.0	25%
902	DEQ	Grasses	0.5	75%
3011	DEQ	Active Channel Bottom	0.0	0%
3248	DEQ	Development - Residential	6.1	100%
3249	DEQ	Development - Industrial	9.1	100%
3252	DEQ	Dam/Weir	0.0	0%
3255	DEQ	Canal	0.0	0%
4001	DEQ	Riparian Willows	4.5	90%

Model Calibration

Applegate Mainstem: The model was calibrated to a FLIR data set flown on July 19, 1999 between the hours of 1537 and 1616 (local time). Model input data was adjusted to make the simulation match the observed FLIR data set. Only Manning's number and weather data was changed. The relationship between model simulation and FLIR data is shown in Figure 1-14. Note that temperature degrees are in Celsius and the longitudinal distance is in meters.

Figure 1-14 – Model Calibration vs. FLIR for the Applegate Mainstem

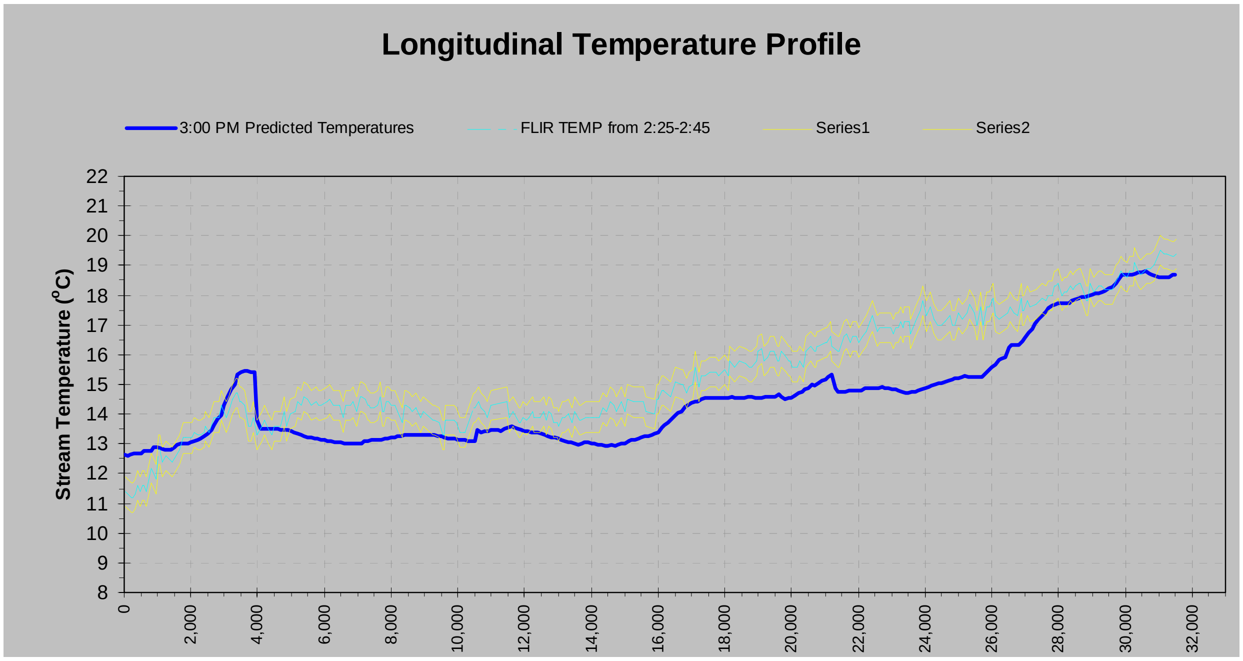


The FLIR dataset is shown as the dashed light blue line, the two yellow solid lines are +/- 0.5 degrees Celsius added to or subtracted from the FLIR value. The calibration simulation is shown as the thick dark blue line.

In most cases, the simulation is within 0.5 degrees of the FLIR data. In all cases, the simulation is within 0.75 degrees Celsius.

Little Applegate: The model was calibrated to a FLIR data set flown on July 21, 1999 between the hours of 1426 and 1445 (local time). Figure 1-15 shows the simulation compared to the FLIR data set. Note that temperature degrees are in Celsius and the longitudinal distance is in meters.

Figure 1-15– Model Calibration vs. FLIR for the Little Applegate



The FLIR dataset is shown as the dashed light blue line, the two yellow solid lines are +/- 0.5 degrees Celsius added to or subtracted from the FLIR value. The calibration simulation is shown as the thick dark blue line.

The closeness of fit between the model simulation and the FLIR data set is somewhat less than for the mainstem. This is probably due to the use of SHADOW type data inputs rather than the GIS-developed data used for the mainstem. SHADOW uses many of the same input parameters, but those parameters are averaged over several to many segment breaks. The GIS derived datasets allow custom numbers to be developed at each and every segment break. The resolution of the GIS derived data allows a better representation of watershed conditions to be fed into the model.

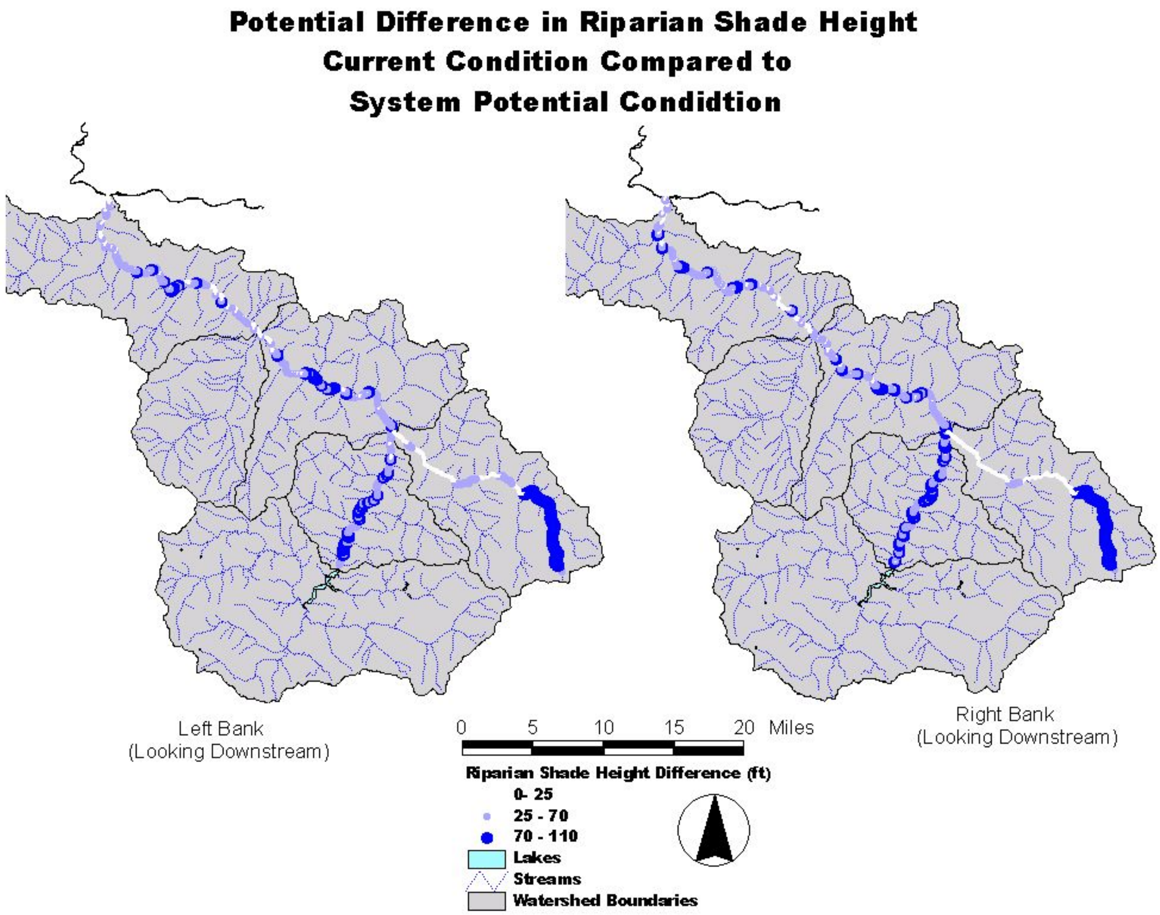
System Potential Analysis

A myriad of conditions could be changed within the model to try and reflect future conditions in the Applegate Subbasin. This is in fact is why the calibrated model is such a useful tool in planning watershed restoration and recovery projects – many future conditions can be envisioned and run through the model to see how much effect they are likely to have. To determine a formal system potential, which will help to determine TMDL load allocations, it is important to expressly state which assumptions about the future the model is using. In this Tier 1 assessment, all conditions of flow, channel form, groundwater interaction and weather are unchanged from those used for calibration. The only changes used for system potential analysis are in riparian height and riparian shade. The model changes these inputs to values that can reasonably be expected for mature vegetation that grows in these soils, with this rainfall and in this ecoregion. Table 1-2 shows the data used for simulating system potential conditions.

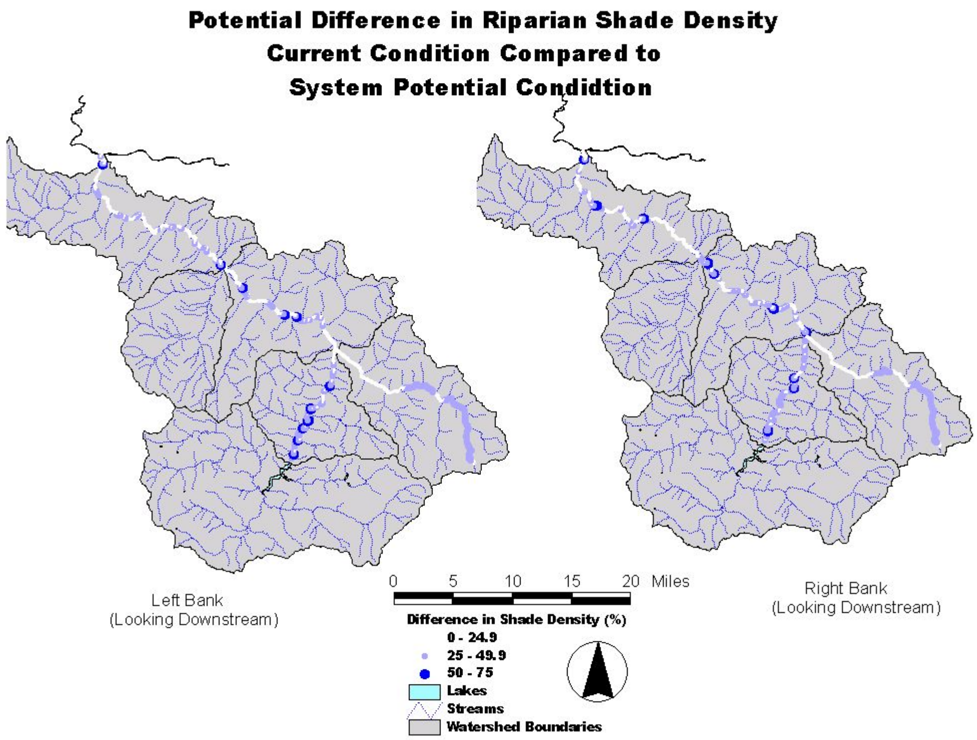
Table 1-2- System Potential Assumed Conditions

Code	Source	Description	Height (m)	Density (%)
301	DEQ	Water	0.0	0%
302	DEQ	Pastures/Cultivated Field/lawn	0.5	75%
303	DEQ	Orchard (Provolt Seed Orchard-BLM)	6.1	70%
304	DEQ	Barren - Rock	0.0	0%
305	DEQ	Barren - Embankment	0.0	0%
308	DEQ	Barren - Clearcut	0.0	0%
309	DEQ	Barren - Soil	0.0	0%
400	DEQ	Barren - Road	0.0	0%
401	DEQ	Barren - Forest Road	0.0	0%
500	DEQ	Large Mixed Con/Hard	42.0	70%
501	DEQ	Small Mixed Con/Hard	42.0	70%
550	DEQ	Large Mixed Con/Hard	42.0	70%
551	DEQ	Small Mixed Con/Hard	42.0	70%
555	DEQ	Large Mixed Con/Hard	42.0	70%
556	DEQ	Small Mixed Con/Hard	42.0	70%
600	DEQ	Large Hardwood	29.3	85%
601	DEQ	Small Hardwood	26.8	85%
602	DEQ	Hardwood Mix	28.1	85%
650	DEQ	Large Hardwood	29.3	85%
651	DEQ	Small Hardwood	26.8	85%
655	DEQ	Large Hardwood	29.3	85%
656	DEQ	Small Hardwood	26.8	85%
700	DEQ	Large Conifer	43.0	80%
701	DEQ	Small Conifer	43.0	80%
750	DEQ	Large Conifer	43.0	80%
751	DEQ	Small Conifer	43.0	80%
752	DEQ	Large Conifer	43.0	80%
753	DEQ	Small Conifer	43.0	80%
802	DEQ	Shrubs (>50% den)	3.0	75%
803	DEQ	Shrubs (<50% den)	3.0	25%
902	DEQ	Grasses	0.5	75%
3011	DEQ	Active Channel Bottom	0.0	0%
3248	DEQ	Development - Residential	6.1	100%
3249	DEQ	Development - Industrial	9.1	100%
3252	DEQ	Dam/Weir	0.0	0%
3255	DEQ	Canal	0.0	0%
4001	DEQ	Riparian Willows	4.5	90%

Map 1-4


Potential Difference in Riparian Shade Height
Current Condition Compared to
System Potential Condidtion
Left Bank
(Looking Downstream)
Right Bank
(Looking Downstream)
0 5 10 15 20 Miles
Riparian Shade Height Difference (ft)
0- 25
25 - 70
70 - 110
Lakes
Streams
Watershed Boundaries

Map 1-5


Potential Difference in Riparian Shade Density
Current Condition Compared to
System Potential Condidtion
Left Bank
(Looking Downstream)
Right Bank
(Looking Downstream)
0 5 10 15 20 Miles
Difference in Shade Density (%)
0 - 24.9
25 - 49.9
50 - 75
Lakes
Streams
Watershed Boundaries

Map 1-4 shows where differences in riparian shade height are expected when compared to conditions today. The numbers show how many additional feet of shade height are expected to grow when system potential conditions are achieved. Because our area of interest along the near-stream riparian corridor is so narrow compared to the basin as a whole, the vegetation on the left bank and on the right bank are presented as separate images.

Map 1-5 shows its information in the same way, but here the data presented is the difference in shade densities (expressed as % of the solar flux blocked) expected between today and at system potential condition.

The Little Applegate model gives a reasonable estimate of future temperatures at system potential conditions. Therefore, those system potential simulation temperatures are used as an input to the simulation of the mainstem at system potential. It is highly likely to expect that many, if not all, of the small basin tributaries will also cool when system potential conditions are reached. However, it is difficult to judge just how much they will cool with the level of certainty needed to enter them as model inputs. Therefore, all basin tributaries, except for the Little Applegate, are held at the same temperature as they experience currently for the future condition modeling. This introduces a positive margin of safety to the analysis - future instream conditions are almost certain to be cooler than what the model will show.

Model Output

Solar Flux

Figure 1-16 shows the longitudinal solar flux profiles for the mainstem and Little Applegate. In each graph, the black line is the ambient solar load that reaches the top of the streamside vegetation. The slight non-uniformity in this value is due to topographic shading of the solar energy by surrounding topography. The red line is the solar energy that currently reaches the stream through the riparian vegetation. The blue line is the amount of solar energy expected to reach the stream surface at system potential conditions.

Figure 1-16(a) -Solar Flux Along the Applegate River

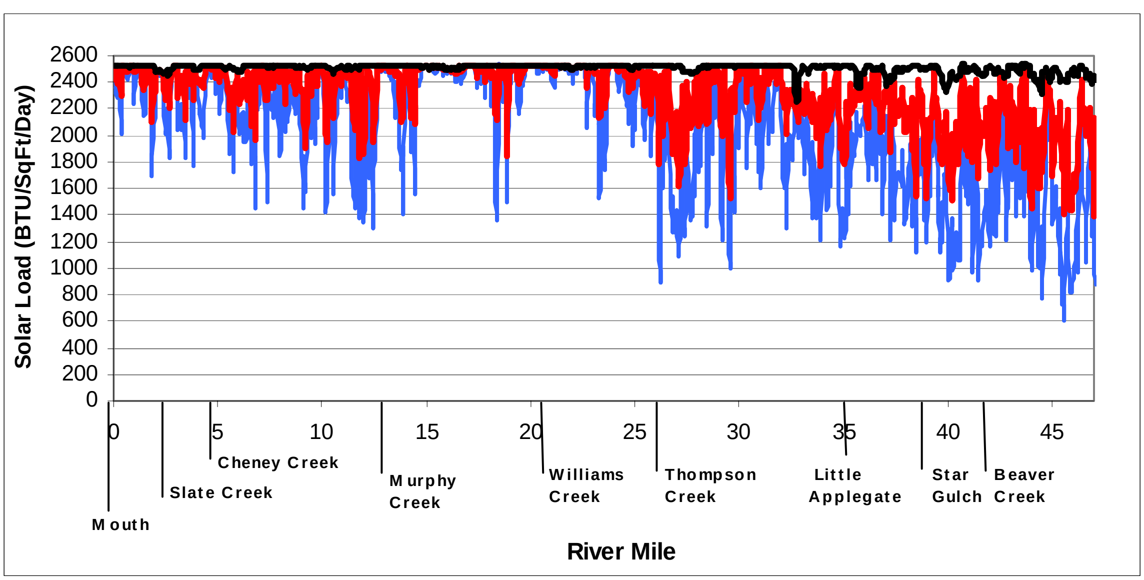
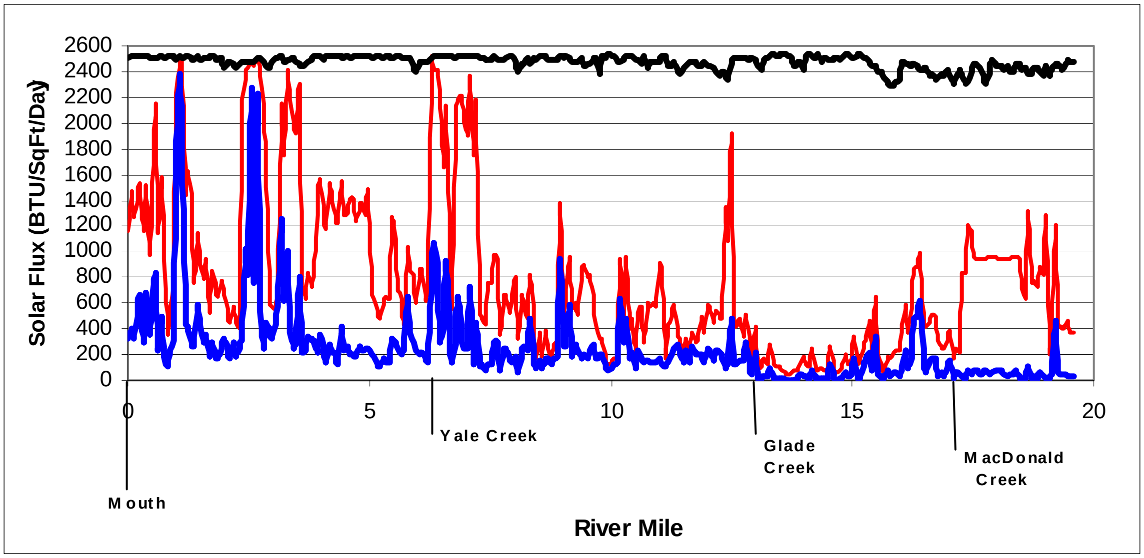


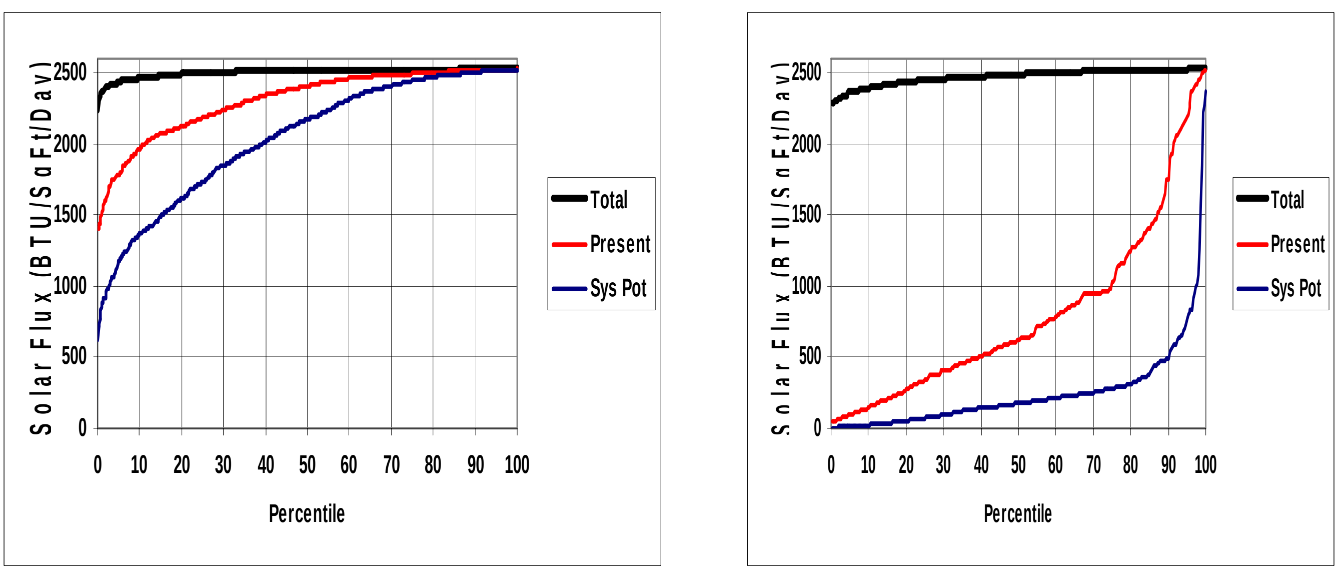
Figure 1-16(b) -Solar Flux Along the Little Applegate



Marked differences are seen in these two systems. The mainstem riparian shade blocks much less solar energy than does the shade in the Little Applegate. The mainstem, having almost ten times the flow volume of the Little Applegate, has a much wider stream surface and a wider near stream disturbance zone. This allows much higher levels of solar energy to enter the stream and raise temperatures. The Little Applegate currently has several zones of high solar throughput, but system potential vegetation will be effective in shading many of those areas. Figure 1-17 shows this same solar flux data as a cumulative frequency plot. This gives a better idea of the relative solar flux values experienced and expected in each system. The line colors are identical to Figure 1-16 (Black-Ambient, Red-Current conditions, Blue-system potential conditions).

Figure 1-17 – Cumulative Frequency Plot of Solar Fluxes

Applegate River **Little Applegate**



Percent Effective Shade

Reducing the amount of solar flux available to the stream is the basic physical process involved in lowering stream temperatures. This is a scientifically well-understood principle, but can be somewhat hard to envision. Another measure, percent effective shade, has been developed to aid in showing what kind of reductions in solar energy are available when corrected for current vegetation and local topographic shading. Percent effective shade is the percent of available solar energy that is blocked by topographic features or stream side vegetation. Figure 18 shows the % effective shade profiles, Figure 1-19 shows the Cumlative frequency plots for percent effective shade and Map 6 shows where changes in % effective shade occurs for the Applegate and Little Applegate. Figures 1-18 and 1-19 use red for current conditions, and blue for system potential conditions. Map 1-6 color codes are explained in the map legend.

Figure 1-18(a) – Percent Effective Shade Along the Applegate River

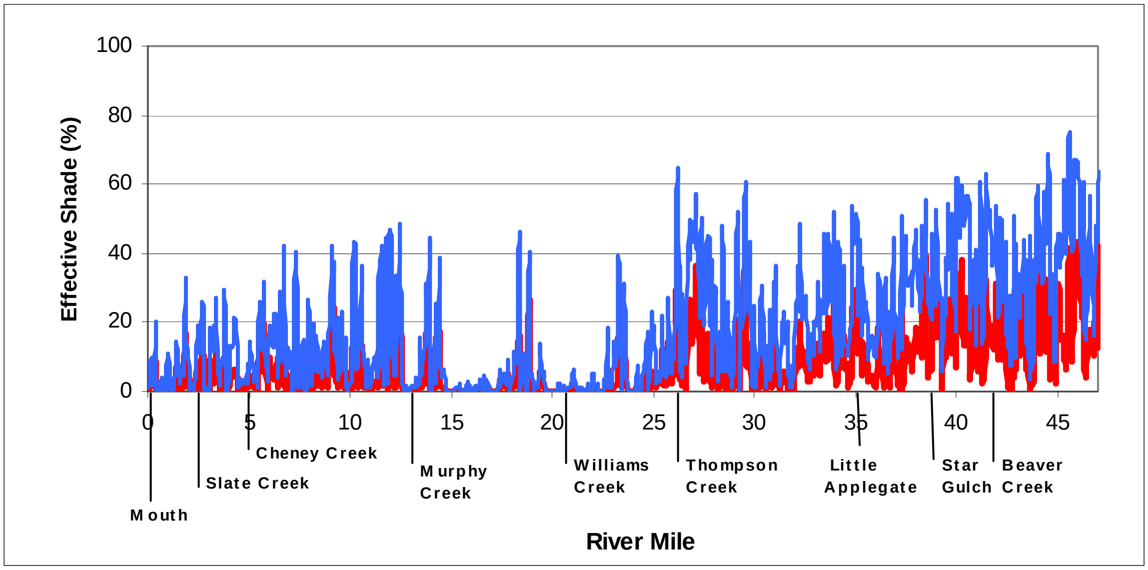


Figure 1-18(b) – Percent Effective Shade Along the Little Applegate

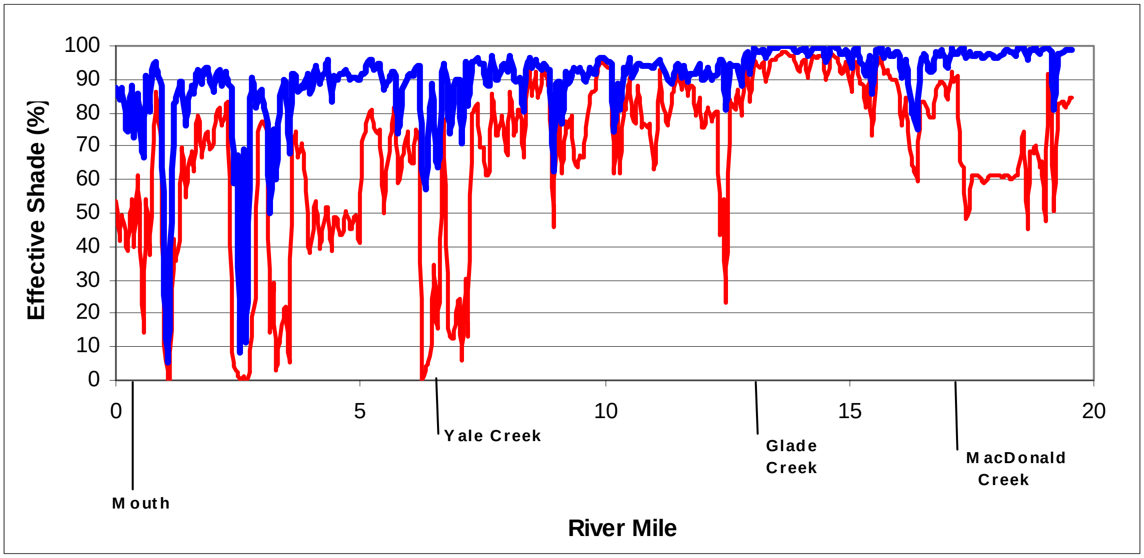
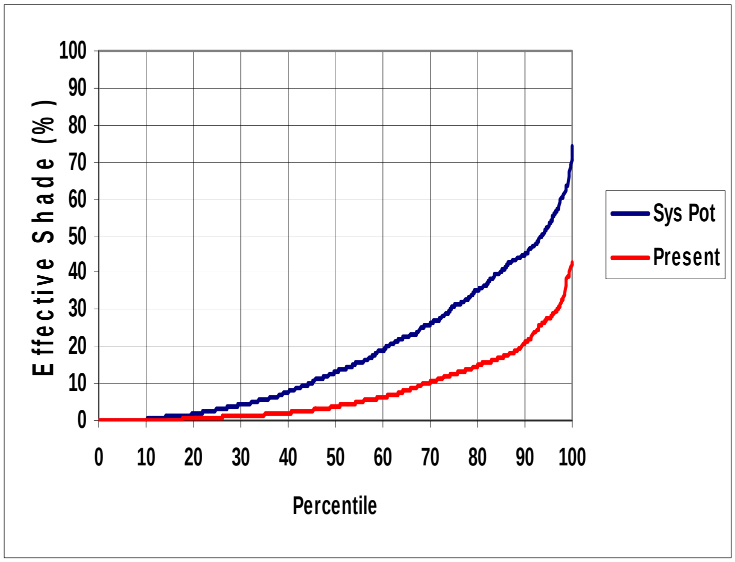
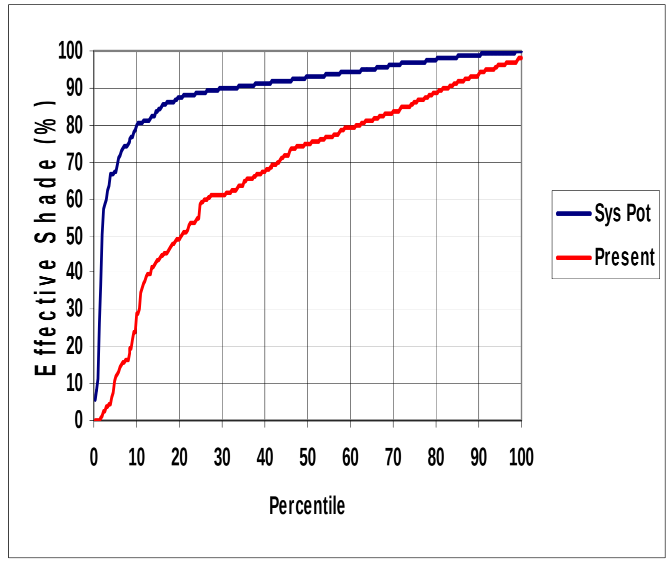


Figure 1-19 – Cumlative Frequency of Percent Effective Shade

Applegate



Little Applegate



Map 1-6

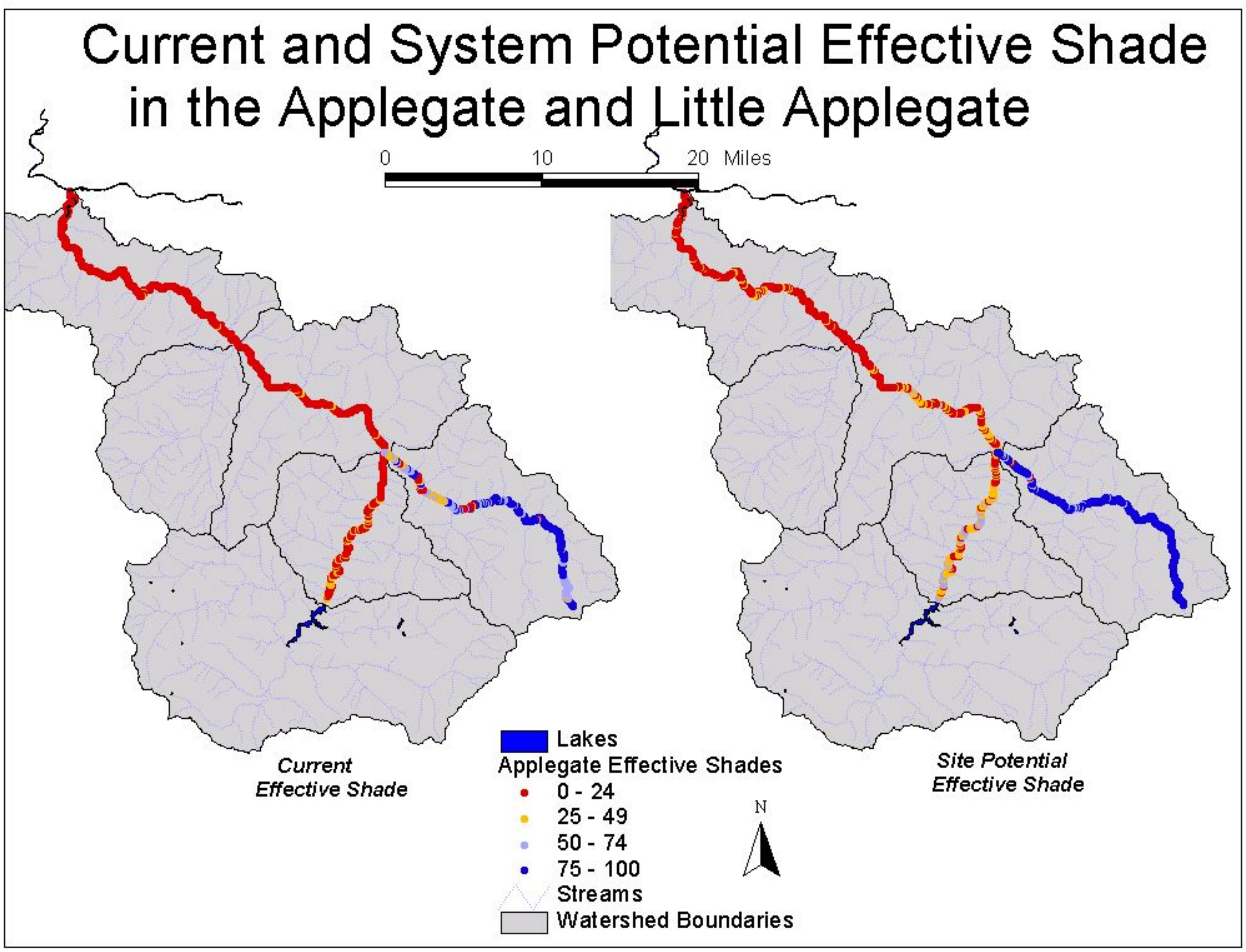


Table 1-3 is a summary of 50th percentile (median) solar flux energies reaching the water and % Effective Shade values based on simulations of current conditions and at system potential conditions for the Applegate mainstem and Little Applegate.

Table 1-3: Unblocked Solar Flux and % Effective Shade – Flux Units are BTU/SqFt/Day

	Current Flux (%Effective Shade)	System Potential Flux (%Effective Shade)
Mainstem Applegate	2,409 (4%)	2,173 (13%)
Little Applegate	617 (75%)	177 (93%)

Stream Temperature

Figures 1-20, 1-21 and Map 1-7 show stream temperatures for the Applegate and Little Applegate. Color choices are the same, red for current temperature, blue for system potential temperature and Map 1-7 has its own legend. These model simulations estimate temperatures at **4:00 pm for the Applegate** and for **3:00 pm for the Little Applegate** during a late July afternoon. The time difference is due to the time of day that the FLIR calibration data was collected.

Figure 1-20(a) – Longitudinal Temperature Profile for the Applegate River

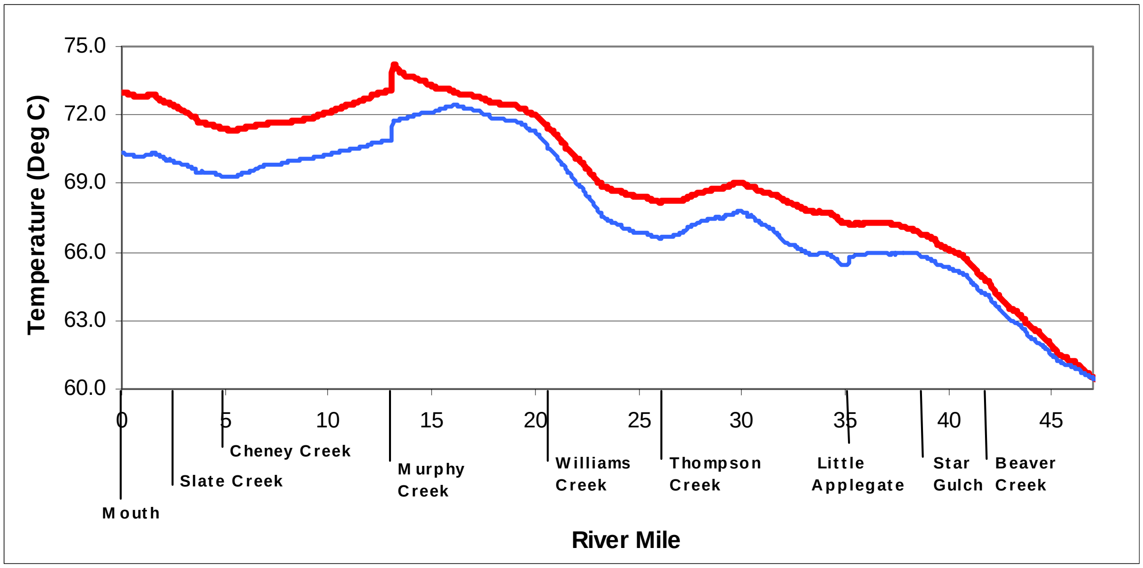


Figure 1-20(b) – Longitudinal Temperature Profile for the Little Applegate

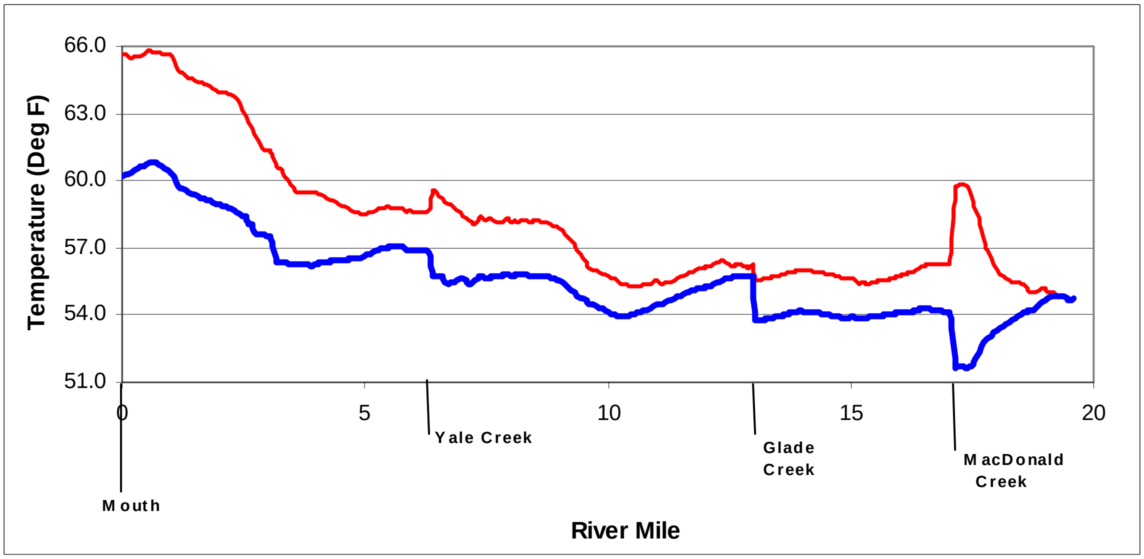
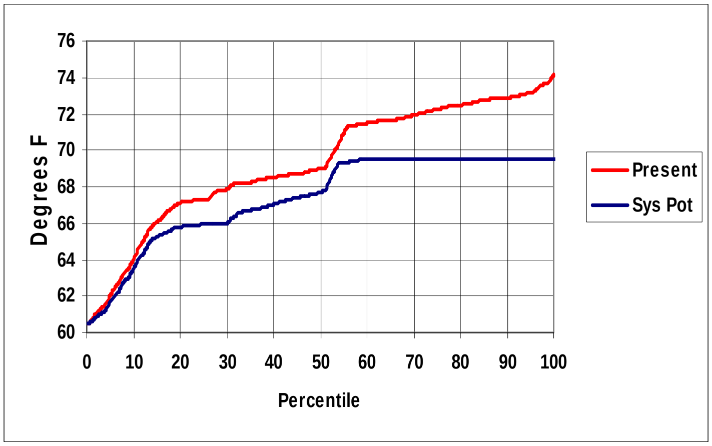
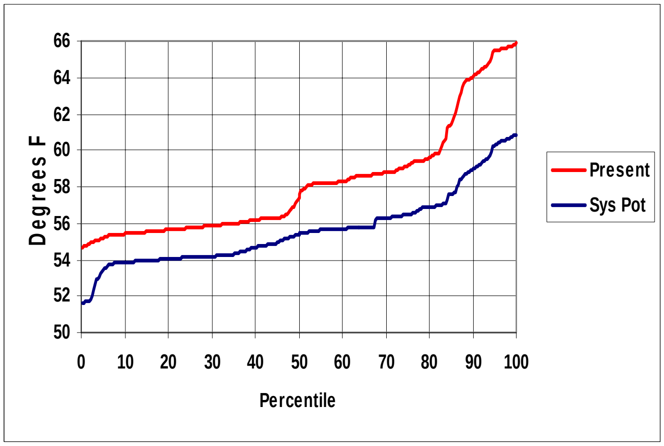


Figure 1-21 – Cumlative Frequency Plot for Temperatures

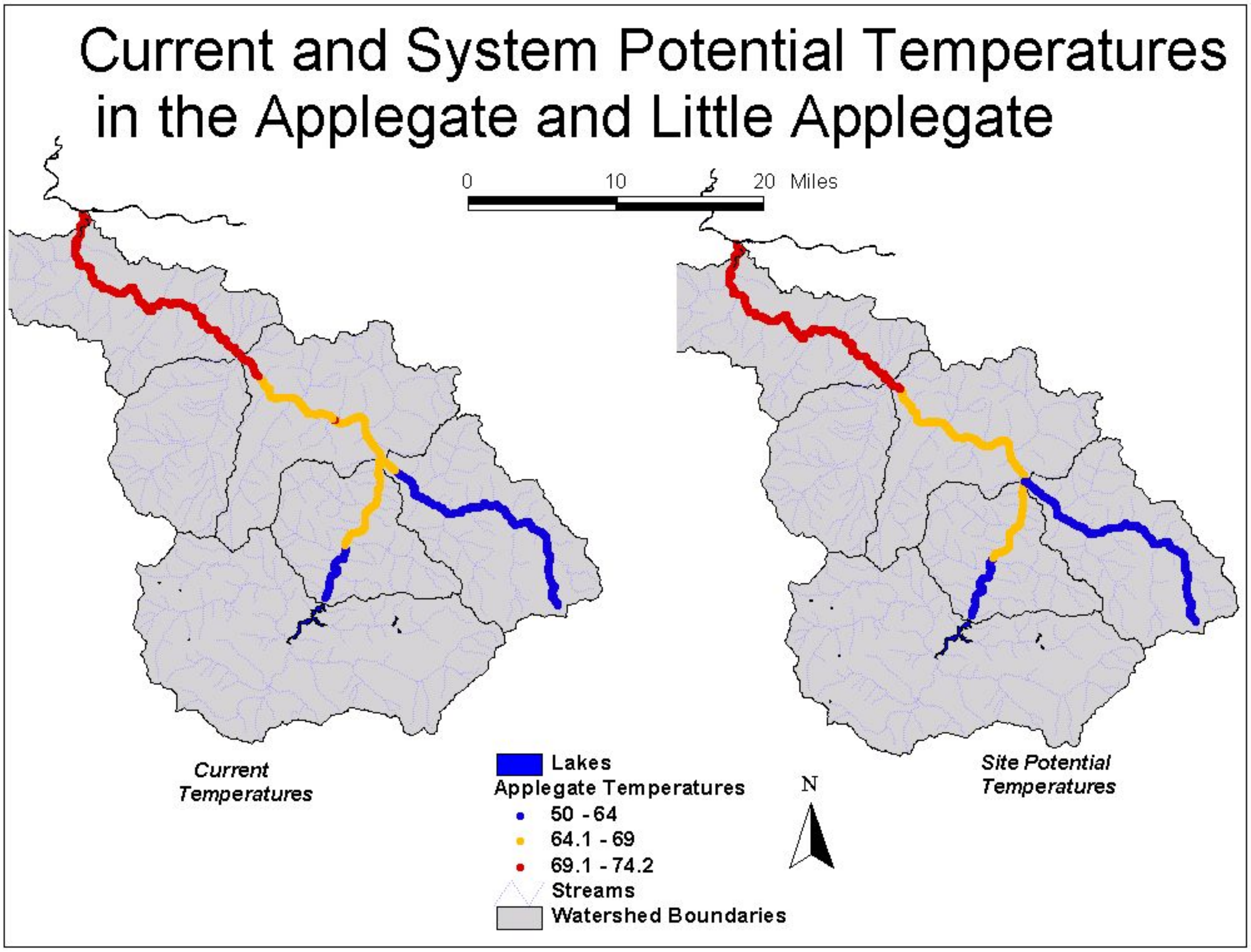
Applegate



Little Applegate



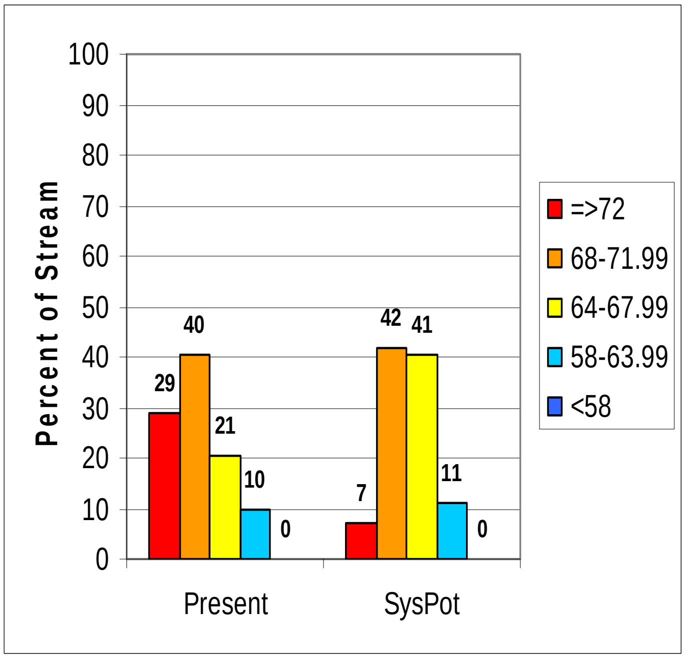
Map 1-7

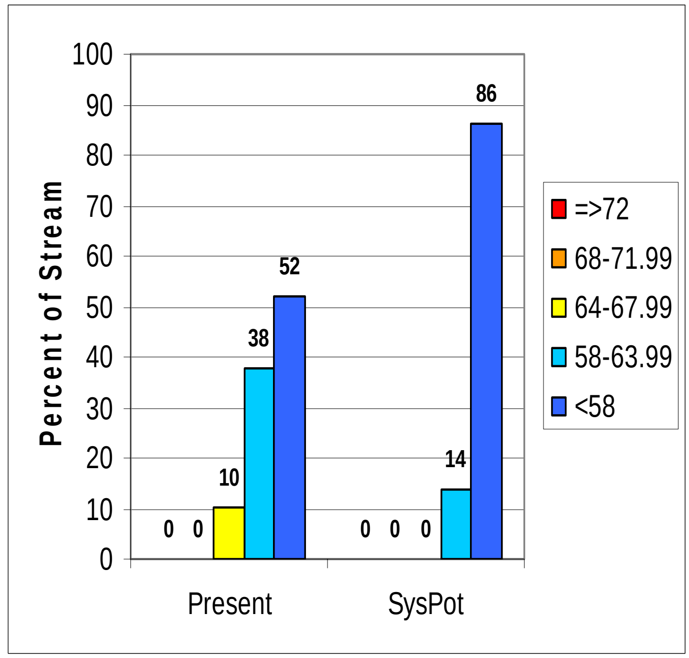


Temperature Distributions

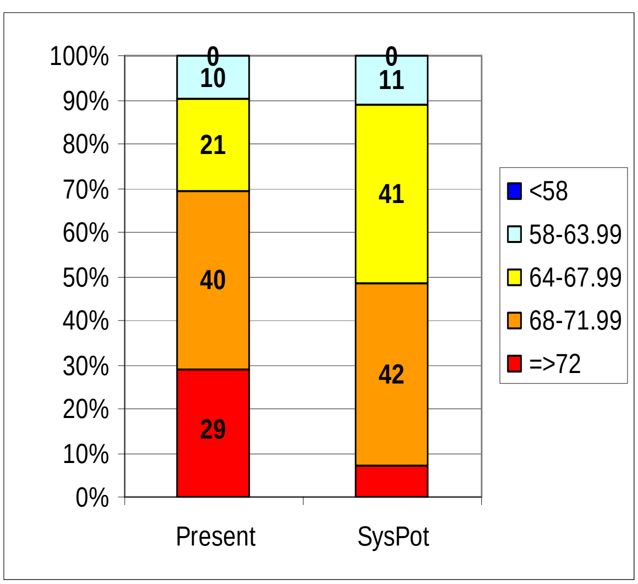
Figure 1-22 shows how many model segments in each system are in, or are expected to be in several temperature classes. These temperature intervals are generally consistent with temperatures needed at several of the life-stages for salmonids. The top and bottom graphs show the same information in two different formats.

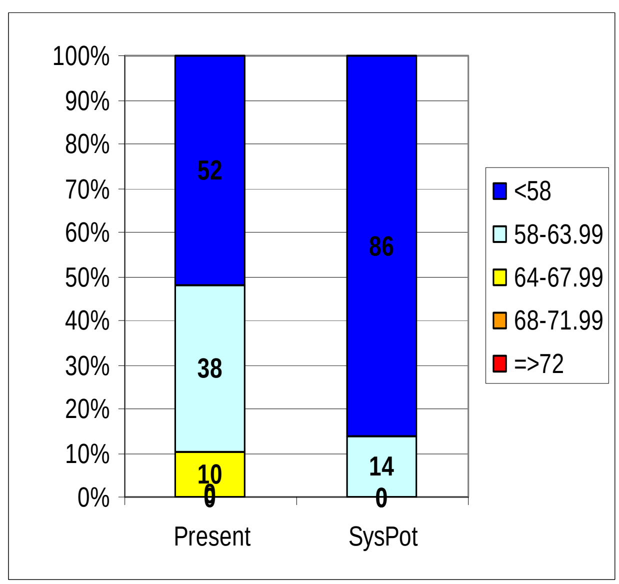
Figure 1-22 – Temperature Distributions in the Applegate and Little Applegate





Applegate **Little Applegate**





Tier 2 Analysis

SHADOW Modeling

This section contains the Shadow Modeling reports for Williams Creek, Star/Boaz, Beaver/Palmer, Glade, Sterling, and Yale Creeks.

TMDL ASSESSMENT REPORT:
Riparian Shade

WILLIAMS CREEK, OR
Rogue River Basin
Middle Rogue River Subbasin

OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY

Coos Bay / Medford Offices

October 20, 1999

Williams Creek Watershed – Overview	
Hydrologic Unit Code (Identification)	1710030905
Watershed Area / Ownership	Total: 51,971 acres BLM Ownership: 26,990 ac. (52%) USFS Ownership: 819 ac. (2%) Non-Fed. Ownership: 24,162 ac. (46%)
Stream Miles Assessed	Total: 78.5 miles BLM Ownership: 35.6 mi. (45%) USFS Ownership: 0.8 mi. (1%) Non-Fed. Ownership: 42.1 mi. (54%)
303(d) Listed Parameters	Temperature
Key Resources and Uses	Salmonid, domestic, agricultural, aesthetic
Known Impacts	Water withdrawals, timber harvests, roads, agriculture

TABLE OF CONTENTS

LEGEND OF TERMS, ABBREVIATIONS, AND ACRONYMS

GENERAL

BLM – Bureau of Land Management
BTU – British Thermal Unit
cfs – cubic feet per second
DEQ – Department of Environmental Quality
FPA – Forest Practices Act
NMFS – National Marine Fisheries Service
OAR – Oregon Administrative Rule
ODF – Oregon Department of Forestry
TMDL – Total Maximum Daily Load
Qa – average annual discharge (stream flow)
USFS – United States Forest Service
USGS – United States Geologic Service
WSC – Watershed Council

ASSESSED PARAMETERS (TABLE 1, APPENDIX C)

Stream Name – name of primary stream or location of named tributary confluence.
Reach Identifier – alphanumeric code: stream name (3 letters); reach #; special condition indicator (i.e. **e/w** = east/west; **p** = lake, pond, or impoundment). NOTE: unnamed tributaries are indicated by a decimal number following the reach number where it enters (e.g. if a tributary enters reach WFM4, it would be labeled WFM4.1, WFM4.2, etc.).
Overhang % – percent vegetative cover when the sun is directly overhead on the stream.
Wetted Channel – width of the stream at late summer or base flow.
Active Channel – bankfull channel width.
Reach Length – linear stream distance.
Tree Height – average height of the primary shade producing trees or vegetation.
Slope – terrain slope from the active channel's edge to the riparian shade vegetation (usually measured from topographic map contour spacing).
Aspect Class – **0** = N-S; **+45** = NE-SW; **-45** = NW-SE; **90** = E-W (class intervals: 30 degrees).
Tree-to-Channel Dist. – slope distance from the bankfull edge to base of riparian vegetation.
Shade Density – percent shade quality with current vegetative conditions.
Stream Class – 1998 ODF FPA definitions:
L = large (Q_a >= 10 cfs); **M** = medium (2 cfs $< Q_a <$ 10 cfs); **S** = small (Q_a $<$ 2 cfs)
F = fish bearing; **D** = domestic use; **N** = neither F or D designation
Land Use – BLF – Bureau of Land Management: Forested
BLN – Bureau of Land Management: Non-Forested

BLM – Bureau of Land Management: Mixed
FS – United States Forest Service
AG – Agricultural Lands (tillage, orchard, etc.)
PR – Private Resource Lands (County, pasture, mining, etc.)
PF – Private Forestry Lands
PN – Private Non-Resource Lands (i.e. rural residential)

Imperv. Surface – presence/absence of a non-removable impervious surface (i.e. paved road) that would inhibit the growth of riparian vegetation within 100 ft (non-federal lands) or 300 ft (federal lands) of the stream.

Stream Diversion – observable flow transfer in or out of the stream channel.

Stream Order – numeric ranking system of relative stream size (1st order stream are usually intermittent; stream ordered increases at the junction of two like ordered streams; contour crenulations are not counted).

Rosgen Level 1 Channel – stream channel classification based on channel slope, sinuosity, valley type, and stream pattern and form.

Bank Stability – **Y** = vegetated banks, no evidence of erosion or mass wasting.
N = no vegetation present; erosion or channel widening evident.

Existing Shade - Curve – percent shade from modeled shade curve value based on current tree height and active channel width.

Density Adjust – reduction of percent shade from shade curve value based on actual shade density for reach. (**NOTE**: shade curves are modeled at 80% shade density).

Existing Shade - Adjusted – (existing shade) – (density adjust.)

Wted Shade - Trib. – reach weighted shade for a tributary stream.

Wted Shade - Stream – reach weighted shade for a named stream.

Future Veg. – projected riparian vegetation based on current species composition.

cw – cottonwood
f/a – Doug fir / red alder
f/poc – Doug fir / Port Orford cedar
pp - ponderosa pine
pp/f – ponderosa pine / Doug fir
df – Doug fir
wf/a – white fir / red alder
wf – white fir

Fut. Veg. Height – site potential tree he9ight based on forest growth models.

Future Shade - Curve – percent shade from modeled shade curves based on future tree height and active channel width. (**NOTE**: shade curves are modeled at 80% shade density).

Future Density – assumed future shade density of riparian vegetation based on management of the stand for optimal tree growth and shade values.

Future Shade - Adjusted – (future shade) – (density adjust.)

Delta Shade – (future shade) – (existing shade)

Recovery Time – years to site potential tree height given current tree height – from forest growth models.

STEP 1

Aerial photo interpretation and mapping was performed using BLM supplied 1996 color air photos at 1:12,000 scale, 7½' USGS quadrangle maps, and ODF stream classification maps. Streams and tributaries were included in the assessment if they were: 1) on the state's 303(d) list (for temperature); 2) the tributary drainage area is 5% or greater of the watershed drainage area above its confluence with the receiving stream; 3) fish-bearing status as per ODF stream classification maps and protocols; and 4) perennial stream flow. Note: tributary streams that area listed as intermittent on the USGS quadrangles may have also been included in this assessment if they cross non-federal lands to get a comprehensive overview of the existing conditions.

Reach breaks were established using the following criteria: 1) confluence of perennial streams; 2) change in ODF stream classification; 3) ownership boundaries (BLM; USFS; state; county; private); 4) significant changes in terrain slope; 5) changes in aspect; 6) changes in riparian vegetation. Each reach was given a unique alphanumeric identification using (generally) the first three letters of the stream name followed by a number. Reaches were numbered sequentially from confluence to headwaters.

The riparian assessment consisted of interpretation or measurement of shade parameters, riparian vegetation, and channel conditions. These values were taken either from the color aerial photos or USGS quadrangle map (Table 1). Table 2 lists the percent ownership by land area (acre) and stream miles assessed with in the basin.

Modeling results for existing and target shade values, years to shade recovery and general disturbance types observed area reported in Watershed Summary Tables (Tables 3 and 4). Tables are presented for all assessed stream reaches (Table 3) and for only federally administered reaches with the watershed (Table 4).

STEP 2

Field verification (ground truthing) was conducted at 16 of 17 identified sites. Ground truthing sites were spread across the entire basin with 4 sites on lower Williams Creek (below the East/West Fork confluence), 6 in the East Fork sub-watershed, and 7 in the West Fork sub-watershed. One site near the headwaters of Right Hand Fork, Rock Creek could not be accessed because the field crew was locked out at a gate.

Field measurements followed standard DEQ procedures and protocols for Shadow model ground truthing. Ground truthing reaches were 200' in length with the shade values assessed for only this length (Appendix A). Sampling was conducted at three transects (lower, middle, and upper) along the 200' reach. If the active channel was less than 25' wide then only on Solar Pathfinder measurement was taken at center channel. For channels greater than 25', two or three pathfinder measurements were taken across the channel. All of the values were then computed to obtain an average for the reach. Field measurements were compared to interpreted values and adjustments made as indicated (Table 5).

STEP 3

303(D) LISTING

Location	Parameter
Williams Creek, Mouth to East/West Fork Confluence (1996 listing)	Temperature
Powell Creek, Mouth to headwaters (1996 listing)	Temperature

BENEFICIAL USES BY STREAM LOCATION IN THE ROGUE BASIN

Beneficial Uses	Rogue River Estuary & Adjacent Marine Waters	Rogue River Mainstem from Estuary to Lost Creek Dam	Rogue River Mainstem above Lost Creek Dam & Tributaries	Bear Creek Main Stem	**All Other Tributaries to Rogue River & Bear Creek**
Public Domestic Water Supply[1]		X	X	*	**X**
Private Domestic Water Supply[1]		X	X		**X**
Irrigation	X	X	X	X	**X**
Livestock Watering		X	X	X	**X**
Anadromous Fish Passage	X	X	X	X	**X**
Salmonid Fish Rearing	X	X	X	X	**X**
Salmonid Fish Spawning		X	X	X	**X**
Resident Fish & Aquatic Life	X	X	X	X	**X**
Wildlife & Hunting	X	X	X	X	**X**
Fishing	X	X	X	X	**X**
Boating	X	X	X	X	**X**
Water Contact Recreation	X	X	X	X	**X**
Aesthetic Quality	X	X	X	X	**X**
Hydro Power			X		**X**
Commercial Navigation & Transportation	X	X	X		

*** Designation for this use is presently under study**
1 With adequate pretreatment (filtration and disinfection) and natural quality to meet drinking water standards

WATER QUALITY STANDARDS & CRITERIA OF CONCERN

The water quality standard of concern is temperature. The temperature standard for the Rogue Basin tributary streams id defined in OAR 340-41-362, "The rolling seven (7) day average of the daily maximum shall not exceed… 64 deg. F (17.8 deg. C)". Williams Creek (mouth to the East Fork - West Fork confluence) and Powell Creek (mouth to headwaters) were placed on the State of Oregon 1996 303(d) list for failing to meet this standard.

The beneficial uses affected by high summer stream temperatures on Williams and Powell Creeks are: Resident Fish & Aquatic Life, Salmonid Fish Spawning and Rearing. Williams Creek has populations of winter Steelhead, Coho, fall Chinook salmon and resident cutthroat trout. Powell Creek has populations of winter Steelhead, Coho, and resident cutthroat trout (Williams Watershed Analysis, Medford District Office – BLM, 1996). In 1998, the USFW and NMFS listed Coho as a Threatened Species under the Endangered Species Act.

POLLUTION SOURCE

Williams Creek, below the East / West Fork confluence traverses along 7.25 river miles of fluvial valley with a large, active floodplain. The valley is primarily irrigated pasture, agricultural, and rural residential property. Federal ownership along this length consists of 0.40 miles (6%) where the BLM operates a seed orchard near state highway 238 at the mouth of Williams Creek.

Riparian over-story vegetation along the floodplain is predominantly black cottonwood, red alder, western red cedar, and some ponderosa pine. Along 5.00 miles (69%) of stream, there is no affective overhanging vegetation and vegetation densities are very low. The remaining 2.25 miles (31%) have a small amount of vegetation overhang and low to moderate densities. These vegetation characteristics are coupled with a bankfull stream channel ranging from 60 to 120 feet in width.

Channel conditions indicate an "F-type" stream channel (Rosgen Stream Channel Classification System) along this entire section. Steep, unstable banks characterize F-type channels with the incised stream attempting to rebuild a floodplain with in the incised banks. Ensuing bank erosion creates wider, shallower stream channels decreasing the width and quality of the riparian vegetation. Sediment is also being contributed t the lower stream reaches from the upper watershed from sources related to timber harvests and roads.

Water withdrawals appear to have a significant impact along the lower portion of Williams Creek and it's tributaries. Flow reductions contribute to stream warming by decreasing the amount of water volume remaining in the stream channel and exposed to insolation (incoming solar radiation). Lower Williams Creek has had years when surface flow is not continuous along its lower reaches. Field monitoring by the Applegate River Watershed Council observed dry stream bed from river mile (RM) 1.0 to RM 1.3 in 1997. The source of surface flow below RM 1.0 was identified as irrigation water supply or return flow from an irrigation system on the east side of Williams Creek (Stream Monitoring and Ecology Report, Applegate River WSC, 1997).

Powell Creek traverses approximately 2.3 miles of valley bottom before joining Williams Creek. Riparian vegetation is predominantly cottonwood, red alder, western red cedar, and some ponderosa pine across the valley giving was to a red alder / Doug fir dominant community along the upper reaches.

From the confluence with Williams Creek to roughly RM 1.5 Powell Creek's riparian vegetation is variable, wit low to moderate shade densities and/or narrow vegetative widths. Assessment of Powell Creek and tributaries above RM 1.5 identified a riparian corridor with relatively good vegetation conditions and few roads that negatively impact riparian vegetation.

Low stream flows are a primary reason for the high water temperature recorded in Powell Creek. Contributing factors to low stream flows are changes in upland forest characteristics and water withdrawals. Much of the Powell Creek sub-watershed has undergone timber harvests and road building during the past 50-60 years. This change in forest conditions can impact the timing and volume of annual peak flows and the nature of late summer low flows. Snowmelt is accelerated and ground water storage is usually reduced. Historically, the winter snowpack would melt slower delivering a steady supply of cold water to the streams (Williams Watershed Analysis, Medford District Office – BLM, 1996). Reduced late summer flows are then exacerbated by water withdrawals leaving a minimal stream flow that is easily heated. DEQ ground truthing field crew in August 1999 observed a dry stream bed at the mouth of Powell Creek extending "upstream" at least 100 yards.

STEP 4

GOALS FOR FEDERAL LANDS

Element	Goal	Passive Restoration	Active Restoration
Temperature *Shade Component*	Achieve coolest water possible through achievement of potential shade values.	Allow riparian vegetation to grow up to reach target values.	• Bank stabilization. • Prescriptions that increases growth rate and survival of riparian vegetation. • Prescriptions to ensure long-term vegetation health.
Temperature *Channel Form Component*	• Return channel to Rosgen type that existed historically (type C), focusing on width-to-depth ratios. • Decrease bedload contribution to channels during large storm events. • Increase wood-to-sediment ratio during mass failures.	• Allow natural channel evolution to continue. Time required varies with channel type. • Allow historic failures to revegetate. • Follow Standards and Guidelines in the NW Forest Plan for Riparian Reserves, and unstable lands.	• Rx's that actively manipulate form. • Treat roads, esp. sites with diversion potentials. • Minimize future failures through stability review and land reallocation if necessary if necessary. • Insure that unstable sites retain large wood to increase wood-to-sediment ratio. • Maintain and improve road surfacing. • Increase pipes to 100-yr flow size and/or provide for overtopping during floods.
Temperature *Stream Flow - Withdrawals*	• Maintain optimum flows for fish life. Maintain minimum flows for fish passage.		• Work with state Watermaster to identify and stop illegal diversions. • Eliminate clear-cut logging practices. • Improve efficiency of withdrawal systems (ditch to pipe). • Educate water users on effective use and conservation. • *(Purchase/lease floodplain easements.)* • *(Purchase/lease water rights with a focus on high consumptive use and old priority date.)* • *(Enforce existing regulations, including monitoring.)*

OBJECTIVES FOR FEDERAL LANDS

Element[1]	Assessed Factors	Target Solar Load[2]	Contributing Factors	Change in Solar Load[3]	Management Measures
Temperature *Shade* (Williams Ck.: Federal Only)	Percent Shade	780 BTU/ft^2/day (70% shade)	Unstable banks Agriculture Roads	-963 BTU/ft^2/day Decrease in current solar loading by 37%	Treatments to increase growth and long-term health of riparian vegetation.
Temperature *Shade* (Powell Ck.: Federal only)	Percent Shade	208 BTU/ft^2/day (92% shade[4])	Roads	-364 BTU/ft^2/day Decrease in current solar loading by 14%	Treatments to increase growth and long-term health of riparian vegetation.
Temperature *Shade* (All other Federal reaches in watershed)	Percent Shade	130 BTU/ft^2/day (95% shade)	Unstable banks Agriculture Harvest/roads	-234 BTU/ft^2/day Decrease in current solar loading by 9%	Treatments to increase growth and long-term health of riparian vegetation.
Temperature *Channel Form* **F to C** (Williams Ck.: Federal Only)	Sinuosity Slope W / D Ratio	624 BTU/ft^2/day (76% shade[4]) @ site potential vegetation and channel width reduced 40 ft.	Harvest/roads Natural background Unstable banks	-1119 BTU/ft^2/day Decrease solar loading by 43% (if bankfull width is reduced 40 ft)	Bank stabilization Upland sediment abatement
Temperature *Stream Flow*	OR WRD water rights maps	Pending temperature modeling	Irrigation and domestic water withdrawals	Current conditions?	Education regarding water conservation *(Enforcement of water rights)*

1 – Reach location definitions:
Williams Creek: from mouth to confluence of East and West Forks of Williams Creek; Federal Only refers to reach "Wil3", BLM's seed orchard near state highway 238.
Powell Creek: mouth to headwaters. Federal Only refers to all federally managed (BLM) reaches on Powell Creek and it's tributaries.
All other Federal reaches in watershed: all federally managed (BLM and USFS) reaches along the East and West Forks of Williams Creek and tributaries.

2 – Target Solar Load (Loading Capacity); based on 2,601 BTU/ft^2/day (maximum July I insolation at Medford, OR; collector: flat-plat, facing south at a fixed tilt; +/- 9% uncertainty)
Calculation: **[(1.0 - decimal percent shade) * 2,601 BTU/ft^2/day]**

3 – Change in Solar Load (Load Allocation); (Target Shade) - (Existing Shade); refer to TMDL Allocation Tables, page 10.

4 – Reach weighted value.

TMDL ALLOCATION FOR FEDERALLY-ADMINISTERED LANDS

Solar Loading[1] / TMDL (Lower Williams Creek: BLM Seed Orchard (reach WIL3))			
Target Shade	**70%**	Target Shade Load	**780 BTU/ft²/day**
Existing Shade	**33%**	Existing Shade Load / TMDL	**1743 BTU/ft²/day**
Change in Shade	**37%**	Change in Shade Load	**-963 BTU/ft²/day**

Solar Loading[1] / TMDL (Powell Creek: federal reaches only)			
Target Shade (reach weighted ave.)	**93%**	Target Shade Load	**182 BTU/ft²/day**
Existing Shade (reach weighted ave.)	**82%**	Existing Shade Load / TMDL	**468 BTU/ft²/day**
Change in Shade	**11%**	Change in Shade Load	**-286 BTU/ft²/day**

Solar Loading[1] / TMDL (Lower Williams and Powell Creek: combined federal reaches)			
Target Shade (reach weighted ave.)	**91%**	Target Shade Load	**234 BTU/ft²/day**
Existing Shade (reach weighted ave.)	**75%**	Existing Shade Load / TMDL	**650 BTU/ft²/day**
Change in Shade	**16%**	Change in Shade Load	**-416 BTU/ft²/day**

Solar Loading[1] / TMDL (all other federal reaches in watershed)			
Target Shade (reach weighted ave.)	**95%**	Target Shade Load	**130 BTU/ft²/day**
Existing Shade (reach weighted ave.)	**86%**	Existing Shade Load / TMDL	**364 BTU/ft²/day**
Change in Shade	**9%**	Change in Shade Load	**-234 BTU/ft²/day**

1 – based on 2,601 BTU/ft²/day (maximum July insolation at Medford, OR; collector: flat-plat, facing south at a fixed tilt; +/- 9% uncertainty)
Calculation: **[(1.0 - decimal percent shade) * 2,601 BTU/ft²/day]**

MARGIN OF SAFETY: RIPARIAN ASSESSMENT

A conservative assessment was used in the measurement of shade density and vegetation overhang. Shade density accounted for the composition of the riparian vegetation with a maximum value of 80% (heavily stocked hardwood stand). Vegetation overhang was measured by estimating the percent of stream channel covered with vegetation. The highest overhang value recorded was 80%, even for closed canopy reaches.

MARGIN OF SAFETY: SHADE CURVE ASSUMPTIONS

The shade model Shadow was used to calculate percent shade. Shade is based on the earth-sun-terrain/vegetation relationship on August 1 for specified latitudes. During the development of shade curves, three parameters are averaged for the basin: terrain slope, vegetation overhang, and tree-to-channel distance. Valley and upland reaches were segregated and averaged to assess the magnitude of difference between them.

Averaged values were:

	Valley Reaches (n = 42)	Upland Reaches (n = 163)	All Reaches	Shadow Inputs Used
Terrain Slope	10%	30%	30%	30%
Vegetation Overhang	40%	50%	50%	50%
Tree-to-Channel Distance	5 ft	5 ft	5 ft	5 ft

The averaged slope value used for the model (30%) would b conservative for the upland reaches where there are more areas of steeper terrain slopes. For valley reaches, the slope value may be somewhat higher than observed in some locations. However, the overall impact of terrain slope is nominal given an average Tree-to-Channel Distance of five feet.

MARGIN OF SAFETY: FUTURE CONDITIONS MODELING

Forest growth models were used to project growth rates and maximum height for the dominant riparian tree species. However, cottonwood is a dominant species in the valley reaches and there are no readily available growth curves for black cottonwood in natural settings. Growth rates for cultivated stands of hybrid cottonwoods were used and downgraded to account for natural conditions. Hybrids grow at roughly ten feet per year in cultivated settings. A rate of three feet per year was used to project cottonwood growth in the Williams Creek watershed.

Riparian corridors are assumed to be manage to reach their full site potential condition. Shade densities for site potential conditions were set at 70% for a conifer dominant, mixed old growth stand and 80% for a mature hardwood dominant stand.

Vegetation overhang is likely to increase in most cases as riparian stands grow and mature. The extent of this increase is difficult to project, so overhang values for site potential were left at the average existing conditions level. In most cases, this would be a conservative value at a site potential condition.

Table 1. Photo and map assessed attributes.

Assessment Parameter	*Resolution*	Comments
Shade		
Percent Overhang	10%	Photo Estimated
Percent Shade Density	10%	Photo Estimated
Terrain Slope	10%	Photo or map
Aspect Class	60 deg.	Map
Tree-to-Channel Distance	5 ft.	Photo Estimated
Tree Height	20 ft.	Average of primary shade vegetation
Width – Active Channel	10 ft.	Photo measure if possible
Width – Wetted Channel	10 ft.	Photo estimated
Reach Length	100 ft.	Map wheeled
Vegetation		
Tree Heights	20 ft.	Average of primary shade vegetation
Species / Composition mix	Spp / 10%	If possible or Deciduous / Conifer
Buffer Width	10 ft.	Non-federal land only
Percent of Reach	10%	Non-federal land only
Channel		
Stream Order (Strahler)		USGS 7½' quadrangles
Valley Slope	1%	Slope gradient / Valley length (map)
Channel Sinuosity	0.1	Stream Length / Valley length (photo)
Stream Slope	0.001-0.1%	Valley slope / Sinuosity
Rosgen Channel – Level 1		A, B, C, E, F, G, D
Bank Stability		Yes / No
Comments		Disturbance type and notes
Others		
ODF Stream Class		Lg./Med./Sm/; Fish/None/Domestic
Land Use		BLF,BLN, BLM, FS, AG, PR, PF, PN
Impervious Surface		Yes / No (affecting riparian veg.)
Stream Diversions		In / Out (observable on photo)

Land Use

BLF – Bureau of Land Management: Forested
BLN – Bureau of Land Management: Non-Forested
BLM – Bureau of Land Management: Mixed
FS – United States Forest Service
AG – Agricultural Lands (tillage, orchard, etc.)
PR – Private Resource Lands (County, pasture, mining, etc.)
PF – Private Forestry Lands
PN – Private Non-Resource Lands (i.e. rural residential)

Table 2. Percent ownership by land area and stream length assessed.

Ownership	**Acres**	**Percent**	**Stream Length (mi.)**	**Percent**
BLM	26,990	52%	35.6	45%
USFS	891	2%	0.8	1%
Non-Federal	24,162	46%	42.1	54%
Total	51,971	100%	78.5	100%

Table 3. Watershed Summary: Solar TMDL as Percent Shade (All Reaches).

Stream	Area (ac) / % area of drainage above stream[1]	Existing Percent Shade[2]	Site Potential Shade[2]	Percent Improved Shade	Years to Recovery[2]	Pvt Land Non-Fish Stream (mi.)	Pvt Land Non-Fish Stream (%)	Disturbance[3]
Williams Ck (mouth to Forks)	20,600 / 40%	56	73	17	6			Ag; roads; unstable banks
Powell	7,625 / 15%	71	90	19	66			Ag: hvst/road
Wallow	1,225 / 32%	92	96	4	65			
Honeysuckle	825 / 17%	91	91	3	81			
West Fork Williams	21,375 / 68%	75	85	10	64	0.8	1.1	Ag: hvst
Munger	4,600 / 27%	83	93	10	78			Ag: hvst/road
North Fork Munger	725 / 41%	76	92	16	80			Hvst
Goodwin	725 / 6%	89	96	7	67	0.5	0.7	Hvst/road
Lone	1,400 / 14%	89	96	7	78	0.4	0.5	Hvst
Tree Branch	525 / 40%	88	94	6	83	1.3	1.8	Hvst/road
Bill	5,950 / 71%	76	95	21	87	0.3	0.4	Hvst/road
Rt. Hand Fk, WF Williams	2,250 / 27%	87	92	5	88			Hvst
Bear Wallow	1,350 / 28%	80	95	15	88	0.8	1.1	Hvst/road
East Fork Williams	9,975 / 32%	85	91	6	45			Ag; unstable banks; hvst/road
Clapboard	1,625 / 17%	91	93	2	69	0.8	1.1	Hvst
Sugarloaf	725 / 54%	89	95	6	73	0.8	1.1	Hvst/road
Rock	3,275 / 45%	87	92	5	66	0.8	1.1	Hvst/road
Rt Hand Fk, Rock	975 / 42%	89	97	8	70			Hvst/road
Glade	1,075 / 31%	94	97	3	35			Hvst/road
Basin	~ 52,000	80	90	10	63	5.8	7.6	

1 – Area of sub-watershed named / percent area of sub-watershed relative to the remaining Williams Creek drainage above this tributary.
2 – Calculated by averaging reach values weighted by reach length.
3 – Disturbance: noted if it has a negative affect on present or future riparian vegetation.

Ag; Harvest (hvst) – within 100 ft of stream on non-federal land or 300 ft on federal land.
Roads – riparian roads that parallel the stream for any distance (not stream crossings).

Table 4. Watershed Summary: Solar TMDL as Percent Shade (Federal Reaches Only).

Stream	Existing Percent Shade[1]	Site Potential Shade[2]	Percent Improved Shade	Years to Recovery[1]	Disturbance[2]
Williams Ck (mouth to Forks)	33	70	37	12	Ag; roads; unstable banks
Powell	78	92	14	75	Ag: hvst/road
Wallow	92	96	4	65	
Honeysuckle	91	94	3	81	
West Fork Williams	84	95	11	91	Ag: hvst
Munger	82	96	14	81	Ag: hvst/road
North Fork Munger	54	92	38	85	Hvst
Lone	88	97	9	84	Hvst
Tree Branch	89	95	6	85	Hvst/road
Bill	72	96	24	89	Hvst/road
Rt. Hand Fk, WF Williams	87	92	5	94	Hvst
Bear Wallow	80	94	14	86	Hvst/road
East Fork Williams	91	93	2	46	Ag; unstable banks; hvst/road
Clapboard	91	94	3	54	Hvst
Sugarloaf	89	97	8	40	Hvst/road
Rock	90	93	3	52	Hvst/road
Rt Hand Fk, Rock	89	96	7	66	Hvst/road
Glade	94	97	3	36	Hvst/road
Basin	84	94	10	71	

1 – Calculated by averaging reach values weighted by reach length.
2 – Disturbance: noted if it has a negative affect on present or future riparian vegetation.
Ag; Harvest (hvst) – within 100 ft of stream on non-federal land or 300 ft on federal land.
Roads – riparian roads that parallel the stream for any distance (not stream crossings).

TMDL ASSESSMENT REPORT:
Riparian Shade

APPLEGATE-STAR/BOAZ
Rogue River Basin
Applegate River Sub-Basin

OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY

Coos Bay / Medford Offices

January 28, 2000

Applegate-Star-Boaz Watershed – Overview	
Hydrologic Unit Code (Identification)	17100310902*
Watershed Area / Ownership	Total: 17,651 acres BLM Ownership: 14,811 ac. (84%) USFS Ownership: 544 ac. (3%) Non-Fed. Ownership: 2,296 ac. (13%)
Stream Miles Assessed	Total: 35.8 miles BLM Ownership: 23.3 mi. (65%) USFS ownership: 0.3 mi. (1%) Non-Fed. Ownership: 12.2 mi. (34%)
303(d) Listed Parameters	Temperature, Flow Modification
Key Resources and Uses	Salmonid, domestic, agricultural, aesthetic
Known Impacts	Timber harvests, roads, water withdrawals, residential structures, transportation infrastructures

* HUC code for the Applegate-Star-Beaver-Palmer 5th field watershed

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LEGEND OF TERMS, ABBREVIATIONS, AND ACRONYMS

GENERAL

BLM – Bureau of Land Management
BTU – British Thermal Unit
cfs – cubic feet per second
DEQ – Department of Environmental Quality
FPA – Forest Practices Act
NMFS – National Marine Fisheries Service
OAR – Oregon Administrative Rule
ODF – Oregon Department of Forestry
TMDL – Total Maximum Daily Load
Qa – average annual discharge (stream flow)
USFS – United States Forest Service
USGS – United States Geologic Service
WSC – Watershed Council

ASSESSED PARAMETERS

Stream Name – name of primary stream or location of named tributary confluence.
Reach Ident – alphanumeric code: stream name (3 letters); reach #; special condition indicator (i.e. **e/w** = east/west; **p** = lake, pond, or impoundment). NOTE: unnamed tributaries are indicated by a decimal number following the reach number where it enters (e.g. if a tributary enters reach Sta4, it would be labeled Sta4.1, Sta4.2, etc.).
Overhang % – percent vegetative cover when the sun is directly overhead on the stream.
Active Channel – bankfull channel width.
Reach Length – linear stream distance.
Tree Height – average height of the primary shade producing trees or vegetation.
Terrain Slope – terrain slope from the active channel edge to the riparian shade vegetation.
Aspect Class – **0** = N-S; **+45** = NE-SW; **-45** = NW-SE; **90** = E-W (class intervals: 60 degrees).
Tree-to-Channel Dist. – slope distance from the bankfull edge to base of riparian vegetation.
Shade Density – percent shade quality with current vegetative conditions.
Stream Class – 1998 ODF FPA definitions:
L = large (Q_a >= 10 cfs); **M** = medium (2 cfs < Q_a < 10 cfs); **S** = small (Q_a < 2 cfs)
F = fish bearing; **D** = domestic use; **N** = neither F or D designation
Land Use – BLF – Bureau of Land Management: Forest Lands
BLM – Bureau of Land Management: Mixed Lands
BFN – Bureau of Land Management: Non-Forest Lands
PRS – Private Resource Lands (i.e. agricultural / pasture)
PRN – Private Non-Resource Lands (i.e. rural residential)

Imperv. Surface – presence/absence of a non-removable impervious surface (i.e. paved road) that would inhibit the growth of riparian vegetation within 100 ft (non-federal lands) or 300 ft (federal lands) of the stream.
Irrigation Flow – observable diversions or points of return flow.
Stream Order – numeric ranking system of relative stream size (1st order stream are usually intermittent; stream ordered increases at the junction of two like ordered streams; base map is standard USGS 1:24,000 topographic).
Rosgen Level 1 Channel – stream channel classification based on channel slope, sinuosity, valley type, and stream pattern and form.
Bank Stability – **Y** = vegetated banks, no evidence of erosion or mass wasting.
N = no vegetation present; erosion or channel widening evident.
Buffer Width – horizontal distance / location of riparian vegetation (forested stands).
Percent of Reach – percent of reach length with described buffer (non-federal lands only)
Present Veg. Species – existing riparian tree composition (D = deciduous, C = conifer).
Present Age - age of dominant riparian trees based on forest growth models using average stand heights.
Existing % Shade: Curve – percent shade from modeled shade curve value based on current tree height, active channel width, and shade density.
Wted Shade - Trib. – reach weighted shade for a tributary stream.
Wted Shade - Stream – reach weighted shade for a named stream.
Future Veg. – projected riparian vegetation based on current species composition.
CW – cottonwood
DF – Douglas fir
RA – red alder
PP – Ponderosa pine
O – oak
Fut. Veg. Height – site potential tree height based on forest growth models.
Future Density – assumed potential shade density of riparian vegetation based on management of the stand for optimal tree growth and shade values.
Future % Shade: Curve – potential percent shade from modeled shade curves based on site potential tree height, active channel width, and shade density.
Delta Shade – (future shade) – (existing shade)
Recovery Time – years to site potential tree height from forest growth models given current tree heights.

STEP 1

Aerial photo interpretation and mapping was performed using BLM supplied 1996 color air photos at 1:12,000 scale, 7½' USGS quadrangle maps, and ODF stream classification maps. Streams and tributaries were included in the assessment if they were: 1) on the state's 303(d) list (for temperature); 2) the tributary area is 5% or greater of the watershed area above its confluence with the receiving stream; 3) fish-bearing status as per ODF stream classification maps and protocols; and/or 4) perennial stream flow. Note: tributary streams that are listed as intermittent on the USGS quadrangles or have an area less than 5% may have been included in

this assessment if they cross non-federal lands to get a comprehensive overview of the existing conditions.
Reach breaks were established using the following criteria: 1) confluence of perennial streams; 2) change in ODF stream classification; 3) ownership boundaries as identified in the Applegate-Star-Boaz Watershed Analysis (Medford District BLM, Aug. 1998. Map 4); 4) significant changes in terrain slope; 5) change in aspect class; 6) change in riparian vegetation. Each reach was given a unique alphanumeric identification using (generally) the first three letters of the stream name followed by a number. Reaches were numbered sequentially from mouth to headwaters.

The riparian assessment consisted of interpretation or measurement of shade parameters, riparian vegetation, and channel conditions. These values were taken either from the color aerial photos or USGS quadrangle map (Table 1). Table 2 lists the percent ownership by land area and stream miles assessed with in the basin.

Modeling results for existing and potential shade values, years to shade recovery and general disturbance types observed are reported in Watershed Summary Tables (Appendix A, Tables A1 and A2). Tables are presented for all assessed stream reaches (Table A1) and for only federally administered reaches within the watershed (Table A2).

Table 1. Photo and map assessed attributes.

Assessment Parameter	***Resolution***	**Comments**
Shade		
Percent Overhang	10%	Photo Estimated
Percent Shade Density	10%	Photo Estimated
Terrain Slope	10%	Photo or map
Aspect Class	60 deg.	Map
Tree-to-Channel Distance	5 ft.	Photo Estimated
Tree Height	20 ft.	Average of primary shade vegetation
Width – Active Channel	10 ft.	Photo measure if possible
Reach Length	100 ft.	Map wheeled
Vegetation		
Buffer Width	10 ft.	Fed. = 300’ max; Non-fed. = 100’ max
Percent of Reach	10%	Non-federal land only
Veg. / Composition mix	10%	Percent deciduous / conifer
Channel		
Stream Order (Strahler)		USGS 7½’ quadrangles
Valley Slope	1%	Slope gradient / Valley length (map)
Channel Sinuosity	0.1	Stream Length / Valley length (photo)
Stream Slope	0.001-0.1%	Valley slope / Sinuosity
Rosgen Channel – Level 1		A, B, C, E, F, G, D
Bank Stability		Yes / No
Comments		Disturbance type and notes
Others		
ODF Stream Class		Size and classification

Land Use		BLF,BLM, BLN, PRS, PRN
Impervious Surface		Yes / No (affecting riparian veg.)
Stream Diversions		In / Out (observable on photo)

Land Use
BLF – Bureau of Land Management: Forest Lands
BLM – Bureau of Land Management: Mixed Lands
BFN – Bureau of Land Management: Non-Forest Lands
PRS – Private Resource Lands (pasture, mining, urban infrastructure, county)
PRN – Private Non-Resource Lands (i.e. rural residential)

Table 2. Percent ownership by land area and assessed stream length.

Ownership	**Acres**	**Percent**	**Stream Length (mi.)**	**Percent**
BLM	14,811	84	23.3	65
USFS	544	3	0.3	1
Non-Federal	2,296	13	12.2	34
Total	17,651	100	35.8	100

STEP 2

Field verification (ground truthing) is to be conducted at 5 identified sites (Appendix B). These sites are all located in Star Gulch and it's tributary streams.

Field measurements will follow standard DEQ procedures and protocols for Shadow model ground truthing. Ground truthing reaches are 200' in length with the shade values assessed for only this length. Sampling is conducted at three transects (lower, middle, and upper) along the 200' reach. If the active channel width is less than 25' then one Solar Pathfinder measurement are taken at center channel. For channels greater than 25', two or three pathfinder measurements will be taken across the channel. A reach value for each parameter is computed by averaging all measurements taken. Field measurements will be compared to photo-interpreted values and adjustments made to existing conditions if indicated.

STEP 3: 303(D) LISTING

Location	Parameter / Season	Listed Segment
Applegate River	Temperature / summer	Mouth to reservoir
Applegate River	Flow Modification / summer	Mouth to reservoir
Star Gulch	Temperature / summer	Mouth to 1918 Gulch

BENEFICIAL USES BY STREAM LOCATION IN THE ROGUE BASIN

Beneficial Uses	Rogue River Estuary & Adjacent Marine Waters	Rogue River Mainstem from Estuary to Lost Creek Dam	Rogue River Mainstem above Lost Creek Dam & Tributaries	Bear Creek Main Stem	**All Other Tributaries to Rogue River & Bear Creek**
Public Domestic Water Supply[1]		X	X	*	**X**
Private Domestic Water Supply[1]		X	X		**X**
Irrigation	X	X	X	X	**X**
Livestock Watering		X	X	X	**X**
Anadromous Fish Passage	X	X	X	X	**X**
Salmonid Fish Rearing	X	X	X	X	**X**
Salmonid Fish Spawning		X	X	X	**X**
Resident Fish & Aquatic Life	X	X	X	X	**X**
Wildlife & Hunting	X	X	X	X	**X**
Fishing	X	X	X	X	**X**
Boating	X	X	X	X	**X**
Water Contact Recreation	X	X	X	X	**X**
Aesthetic Quality	X	X	X	X	**X**
Hydro Power			X		**X**
Commercial Navigation & Transportation	X	X	X		

*** Designation for this use is presently under study**
1 With adequate pretreatment (filtration and disinfection) and natural quality to meet drinking water standards

WATER QUALITY STANDARDS & CRITERIA OF CONCERN

The water quality standard of concern is temperature and flow modification. The temperature standard for the Rogue Basin tributary streams is defined in OAR 340-41-362, "The rolling seven (7) day average of the daily maximum shall not exceed… 64 deg. F (17.8 deg. C)". The standard for flow modification is defined in OAR 340-41-027, " **The creation of** tastes or odors or toxic or other **conditions that are deleterious to fish or other aquatic life** or affect the potability of drinking water or the palatability of fish or shellfish shall not be allowed.

The Applegate River was placed on the State of Oregon 1996 303(d) list for failing to meet both of these standards. Star Gulch was a 1998 addition to the State of Oregon 303(d) list for failing to meet the temperature standard. **Note:** this assessment deals specifically with temperature as affected by riparian vegetation and channel conditions and does not address specific flow related issues.

The beneficial uses affected by high summer stream temperatures and/or low flow regimes on these streams are Resident Fish & Aquatic Life and Salmonid Fish Spawning and Rearing. Fish use and distributions are documented in the Applegate-Star/Boaz Watershed Analysis (Medford District BLM, Aug. 1998. Maps 11-14).

POLLUTION SOURCE

Disturbances to the stream channel and riparian vegetation include timber harvests, agricultural activity (non-cultivated), local and forest access roads, state or county highways, rural residential, and water withdrawals. Disturbances that are relevant to federally managed lands are timber harvests and roads. Impacts are noted if they occur with in 300 ft of the stream on federal lands or 100 ft on non-federal lands. Although disturbances may be present, their overall impact on riparian shade can be variable.

Applegate River: no federally managed lands along this stretch with the exception of the Star Ranger District Office, Rogue River National Forest. Disturbances include paved highways, agricultural pastures, and rural residential structures. Much of this section has an incised channel that is disconnected from the floodplain. Stream channel characteristics are indicative of a Rosgen F-type channel for much of the length.

Star Gulch: all but the first half-mile of stream in federally managed lands. Disturbance from the main access road up Star Gulch is continuous as it follows the channel for its length up to a gravel pit near the headwaters. Timber harvests also occur along the main stem, but are intermittent and variable in the impact.

Benson Gulch: drainage-wide timber harvests.

1917 Gulch: drainage-wide timber harvests.

Alexander Gulch: drainage-wide timber harvests.

STEP 4: GOALS FOR FEDERAL LANDS

Element	Goal	Passive Restoration	Active Restoration
Temperature *Shade Component*	• Achieve coolest water possible through achievement of potential shade values.	• Allow riparian vegetation to grow up to reach target values.	• Bank stabilization where indicated. • Prescriptions that increases growth rate and survival of riparian vegetation. • Prescriptions to ensure long-term vegetation health.
Temperature *Channel Form Component*	• Maintain or improve Rosgen channel types that exist – types A, B, and C, focusing on width-to-depth ratios. • Decrease bedload contribution to channels during large storm events. • Increase wood-to-sediment ratio during mass failures.	• Allow historic failures to revegetate. • Follow Standards and Guidelines in the NW Forest Plan for Riparian Reserves, and unstable lands. • *Allow natural channel evolution to continue. Time required varies with channel type.*	• Treat roads, esp. sites with diversion potentials. • Minimize future failures through stability review and land reallocation if necessary. • Maintain and improve road surfacing. • Increase pipes to 100-yr flow size and/or provide for overtopping during floods. • *Insure that unstable sites retain large wood to increase wood-to-sediment ratio.*
Temperature *Stream Flow Components:* *- Withdrawals* *- Hydrograph*	• Maintain optimum flows for fish life. • Maintain minimum flows for fish passage.		• Work with state Watermaster to identify and stop illegal diversions. • Eliminate clear-cut logging practices. • Educate water users on effective use and conservation. • Reduce road densities by decommissioning non-essential roads. • *Improve efficiency of withdrawal systems (ditch to pipe).* • *(Purchase/lease floodplain easements.)* • *(Purchase/lease water rights with a focus on high consumptive use and old priority date.)* • *(Enforce existing regulations, including monitoring.)*

OBJECTIVES FOR FEDERAL LANDS

Element	Assessed Factors	Target Solar Load[1]	Contributing Factors	Change in Solar Load[2]	Management Measures
Temperature *Shade*	Percent Shade	234 BTU/ft^2/day (91% shade[3])	Harvest/roads	Decrease in current solar loading by 20%[3]	Treatments to increase growth and long-term health of riparian vegetation.
Temperature *Channel Form* **Rosgen A, B, C**	W / D Ratio	N/A	Harvest/roads Natural background Unstable banks	N/A, maintain current conditions	Upland sediment abatement Bank stabilization, if indicated.
Temperature *Stream Flow*	OR WRD water rights maps	Pending temperature modeling	Irrigation and domestic water withdrawals	Current conditions?	Education regarding water conservation *(Enforcement of water rights)*

1 – Target Solar Load (Loading Capacity); based on 2,601 BTU/ft^2/day (maximum July insolation at Medford, OR; collector: flat-plat, facing south at a fixed tilt; +/- 9% uncertainty)
Calculation: **[(1.0 - decimal percent shade) * 2,601 BTU/ft^2/day]**

2 – Change in Solar Load (Load Allocation); (Target Shade) - (Existing Shade); refer to TMDL Allocation Tables, page 10.

3 – Reach weighted value for the Star Gulch watershed.

TMDL ALLOCATION FOR FEDERALLY-ADMINISTERED LANDS

Solar Loading[1] / TMDL Star Gulch Watershed			
Target Shade	**91%**	Target Solar Load	**234 BTU/ft^2/day**
Existing Shade	**71%**	Existing Solar Load / TMDL	**754 BTU/ft^2/day**
Change in Shade	**20%**	Change in Solar Load	**-520 BTU/ft^2/day**

1 – based on 2,601 BTU/ft^2/day (maximum July insolation at Medford, OR; collector: flat-plat, facing south at a fixed tilt; +/- 9% uncertainty). **Calculation: [(1.0 - decimal percent shade) * 2,601 BTU/ft^2/day]**

NOTE: values are reach-weighted averages.

MARGIN OF SAFETY: RIPARIAN ASSESSMENT

A conservative assessment was used in the measurement of shade density and vegetation overhang. Shade density accounted for the composition of the riparian vegetation with a maximum value of 80% (heavily stocked hardwood stand). Vegetation overhang was measured by estimating the percent of stream channel covered with vegetation. The highest overhang value recorded was 80%, even for closed canopy reaches.

MARGIN OF SAFETY: SHADE CURVE ASSUMPTIONS

Shade is based on the earth-sun-terrain/vegetation relationship on August 1 for specified latitudes. The shade model Shadow was used to calculate percent shade.

Three different shade curves/tables (Appendix C) were used based on the channel size and the landscape that the stream traverses. Curves are stratified by large streams and small streams with channel widths ranging from 30 to 120 feet and 5 to 25 feet, respectively and by large, open valleys with channel widths ranging from 10 to 120 feet. Tree heights ranged from 20 to 180 feet. Percent shade was calculated for each channel width - tree height combination with shade densities varied from 10% to 80%, at 10% steps. The base assumptions used for each set of curves are listed in Table 3. Valley curves were used for the Applegate River.

Table 3. Base assumptions for Shade Curves (Tables).

Shade Variable	Large Streams	Small Streams	Valley Streams
Vegetation Overhang	0%	0%	0%
Tree to Channel Slope	30%	50%	20%
Tree to Channel Distance	25 feet	10 feet	10 feet

MARGIN OF SAFETY: FUTURE CONDITIONS MODELING

Forest growth models were used to project growth rates and heights for the dominant riparian tree species. Growth models are constructed by species and delineated by site index (SI) values that relate to growing conditions. Tree species in the Applegate-Star/Boaz watershed and associated SI values are listed in Table 4.

Riparian corridors are assumed to be manage to reach their full site potential condition. Shade densities for site potential conditions were set at 70% for a conifer dominant, mixed old growth stand and 80% for a mature hardwood dominant stand. Stand densities and recovery times (e.g. years to grow to site potential heights) assumes the existing vegetation will continue to grow through seral progressions to a late seral stage. Natural events such as floods or fires may alter the progression rate and achievement of late seral stand conditions.

Vegetation overhang is likely to increase in most cases as riparian stands grow and mature. The extent of this increase is difficult to project, but may exceed 90% on small headwater streams. Shade curves were constructed with an assumed overhang of 0%, which is an extremely conservative assumption for site potential conditions.

Table 4. Tree species and forest growth model SI values.

Tree Species	Site Index	Height	Years
Cottonwood	N/A	100	35
Douglas fir	85	148	120
Ponderosa pine	85	153	120

APPENDIX A – WATERSHED SUMMARIES

Table A1. **Solar TMDL as Percent Shade - All Stream Reaches.**

Stream	Area (ac) / % area of drainage above stream[1]	Existing Percent Shade[2]	Site Potential Shade[2]	Percent Improved Shade	Years to Recovery[2]	Pvt Land Non-Fish Stream (mi.)	Pvt Land Non-Fish Stream (%)	Disturbance[3]
Applegate River		8	41	33	37	0	0	Highway, roads, rural residential, ag/pasture, harvest
Star Gulch	10830 ac. / 87%[4]	60	86	26	74	0	0	Harvest, roads, rural residential, highway
Benson Gulch	715 ac. /8%	64	94	30	103	0	0	Harvest
Lightning Gulch	1330 ac. / 17%	82	93	11	59	0	0	Harvest, roads
1918 Gulch	640 ac. / 11%	62	90	28	83	0	0	Harvest, roads
1917 Gulch	210 ac. / 5%	63	89	26	76	0	0	Harvest, roads
Ladybug Gulch	925 ac. / 23%	70	92	22	125	0	0	Harvest, roads
Alexander Gulch	705 ac. / 24%	75	92	17	72	0	0	Harvest, roads
Deadman Gulch	235 ac. / 12%	94	97	3	40	0	0	No disturbance
Applegate-Star/Boaz Watershed	***17,651 acre***	***65***	***86***	***21***	***73***	***0***	***0***	

1 – Watershed considered is from the Little Applegate River to just above China Gulch (Sect 33 T39S R2W).
2 – Calculated by averaging reach values weighted by reach length.
3 – Disturbance: noted if it has a negative affect on present or future riparian vegetation.
Harvest, pasture, rural residential (res.) – within 100 ft of stream on non-federal land or 300 ft on federal land.
Roads – riparian roads that parallel the stream for any distance; generally for forest or local access.
Highway – paved Federal, State, or county routes.
4 – Watershed area of the Applegate River above the Little Applegate River is approximately 200,370 acres.
Star Gulch would encompass 6% of this drainage area.

Table A2. **Solar TMDL as Percent Shade – Federally Administered Reaches Only.**

Stream	**Existing Percent Shade[1]**	**Site Potential Shade[1]**	**Percent Improved Shade**	**Years to Recovery[1]**	**Disturbance[2]**
Applegate River					
Star Gulch	61	86	25	73	Harvest, roads
Benson Gulch	64	94	30	103	Harvest
Lightning Gulch	82	93	11	59	Harvest, roads
1918 Gulch	62	90	28	83	Harvest, roads
1917 Gulch	63	89	26	76	Harvest, roads
Ladybug Gulch	70	92	22	125	Harvest, roads
Alexander Gulch	75	92	17	72	Harvest, roads
Deadman Gulch	94	97	3	40	No Disturbance
Applegate-Star/Boaz Watershed	**71**	**91**	**20**	**76**	

1 – Calculated by averaging reach values weighted by reach length.
2 – Disturbance: noted if it has a negative affect on present or future riparian vegetation.
Harvest, pasture, rural residential (res.) – within 100 ft of stream on non-federal land or 300 ft on federal land.
Roads – riparian roads that parallel the stream for any distance; generally for forest or local access.
Highway – paved Federal, State, or county routes.

APPLEGATE SUBBASIN

BEAVER PALMER SHADOW MODELING

USFS, ROGUE RIVER NATIONAL FOREST

2000

FUTURE CONDITIONS MODELING

Forest growth models were used to project growth rates and heights for the dominant riparian tree species. Shadow model was used to determine current and system potential percent effective shade. Growth models were constructed by species and delineated by site index (SI) values that relate to growing conditions. Tree species in the Applegate-Beaver/Palmer watershed are listed in Table 1 below.

Table 1

Age	**Siskiyou Mixed Conifer Average Stand Height**	**Siskiyou True Fir Average Stand Height**
10	22	15
20	33	26
30	42	35
40	52	45
50	61	54
60	69	62
70	77	69
80	83	76
90	89	81
100	95	86
110	99	91
120	104	95
130	108	98
140	111	101
150	114	104
160	117	**106**
170	**120**	108
180	122	110
190	125	112
200	126	113
220	130	115
240	133	117
260	135	118
280	137	120
300	138	120

Riparian corridors are assumed to be managed to reach their full site potential condition. Site potential condition was set as 160 years, 106 feet for true fir and 170 years, 120 feet for Siskiyou Mixed Conifer for the purposes of this analysis. Years to recovery was also estimated for all reaches analyzed. It is important to note that natural events such as floods or fires may alter the progression rate and achievement of late seral stand conditions and are not accounted for in this analysis.

Summary of Analysis and Ownership.

Applegate Mainstem	Length Feet	RM	Ht	Den	Current % ShadeAdj	System Potential % Shade-Adj	Estimated Time to Recovery. Years
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	11500	2.2	41.0	35.1	51.4	81.1	141.4
Private	13100	2.5	47.2	46.8	56.6	79.4	134.9
Total	**24600**	**4.7**	**44.3**	**41.3**	**54.2**	**80.2**	**137.9**

Armstrong Gulch	Length	RM	Ht	Den	Cur%ShadeAdj	SP%Shade-Adj	TTR
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	5,400	1.0	80.0	83.3	90.8	93.8	88.7
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**5,400**	**1.0**	**80.0**	**83.3**	**90.8**	**93.8**	**88.7**

Bailey Gulch	Length	RM	Ht	Den	Cur%ShadeAdj	SP%Shade-Adj	TTR
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	8200	1.6	72.6	77.2	94.2	96.8	102.6
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**8200**	**1.6**	**72.6**	**77.2**	**94.2**	**96.8**	**102.6**

Bailey Gulch Trib	Length	RM	Ht	Den	Cur%ShadeAdj	SP%Shade-Adj	TTR
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	1600	0.3	110.0	90.0	93.0	92.0	33.0
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**1600**	**0.3**	**110.0**	**90.0**	**93.0**	**92.0**	**33.0**

Beaver Cr	Length	RM	Ht	Den	Cur%ShadeAdj	SP%Shade-Adj	TTR
BLM	6200	1.2	87.1	89.5	90.5	91.7	82.2
USFS	24000	4.5	80.9	87.0	84.5	90.2	89.5
Private	13400	2.5	58.2	64.9	76.8	90.8	122.9
Total	**43,600**	**8.3**	**74.8**	**80.6**	**83.0**	**90.6**	**98.7**

Brushy Gulch	Length	RM	Ht	Den	Cur%ShadeAdj	SP%Shade-Adj	TTR
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	9600	1.8	77.5	81.7	95.3	98.0	95.9
Private	600	0.1	25.0	30.0	52.0	98.0	157.0
Total	**10200**	**1.9**	**74.4**	**78.6**	**92.8**	**98.0**	**99.5**

Charlie Buck Gulch	Length	RM	Ht	Den	Cur%ShadeAdj	SP%Shade-Adj	TTR
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	3400	0.6	79.1	90.0	92.5	94.4	80.4
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**3400**	**0.6**	**79.1**	**90.0**	**92.5**	**94.4**	**80.4**

Hanley Gulch	Length	RM	Ht	Den	Cur%ShadeAdj	SP%Shade-	TTR

						Adj	
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	10800	2.0	96.5	86.7	92.2	92.7	59.3
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**10800**	**2.0**	**96.5**	**86.7**	**92.2**	**92.7**	**59.3**

Hanley Trib	**Length**	**RM**	**Ht**	**Den**	**Cur%ShadeAdj**	**SP%Shade-Adj**	**TTR**
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	10000	1.9	88.2	83.8	95.0	95.4	80.0
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**10000**	**1.9**	**88.2**	**83.8**	**95.0**	**95.4**	**80.0**

Haskins Gulch	**Length**	**RM**	**Ht**	**Den**	**Cur%ShadeAdj**	**SP%Shade-Adj**	**TTR**
BLM	400	0.1	100.0	90.0	93.0	92.0	58.0
USFS	9000	1.7	68.1	83.6	91.9	92.0	100.0
Private	2800	0.5	65.7	81.4	90.1	92.0	106.0
Total	**12200**	**2.3**	**68.6**	**83.3**	**91.6**	**92.0**	**100.0**

Kinney Cr	**Length**	**RM**	**Ht**	**Den**	**Cur%ShadeAdj**	**SP%Shade-Adj**	**TTR**
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	13000	2.5	46.3	64.2	76.4	98.0	130.1
Private	400	0.1	75.0	65.0	90.0	96.0	102.0
Total	**13400**	**2.5**	**47.2**	**64.2**	**76.8**	**97.9**	**129.3**

Lime Gulch	**Length**	**RM**	**Ht**	**Den**	**Cur%ShadeAdj**	**SP%Shade-Adj**	**TTR**
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	4200	0.8	60.0	65.0	91.0	92.0	121.0
Private	2000	0.4	65.0	70.0	92.0	92.0	115.0
Total	**6200**	**1.2**	**61.6**	**66.6**	**91.3**	**92.0**	**119.1**

Mule Cr	**Length**	**RM**	**Ht**	**Den**	**Cur%ShadeAdj**	**SP%Shade-Adj**	**TTR**
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	16600	3.1	82.8	66.3	85.8	92.7	87.6
Private	1600	0.3	60.0	30.0	74.0	91.0	121.0
Total	**18200**	**3.4**	**80.8**	**63.1**	**84.8**	**92.6**	**90.5**

Mule Cr Trib	**Length**	**RM**	**Ht**	**Den**	**Cur%ShadeAdj**	**SP%Shade-Adj**	**TTR**
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	3200	0.6	110.0	80.0	93.0	92.0	33.0
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**3200**	**0.6**	**110.0**	**80.0**	**93.0**	**92.0**	**33.0**

Nine Dollar Gulch	**Length**	**RM**	**Ht**	**Den**	**Cur%ShadeAdj**	**SP%Shade-Adj**	**TTR**
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	2800	0.5	110.0	90.0	93.0	92.0	33.0
Private	0	0.0	0.0	0.0	0.0	0.0	0.0

Total	**2800**	**0.5**	**110.0**	**90.0**	**93.0**	**92.0**	**33.0**

Nine Dollar Gulch Trib	Length	RM	Ht	Den	Cur%ShadeAdj	SP%Shade-Adj	TTR
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	5200	1.0	110.0	90.0	96.1	95.1	33.0
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**5200**	**1.0**	**110.0**	**90.0**	**96.1**	**95.1**	**33.0**

Palmer Cr	Length	RM	Ht	Den	Cur%ShadeAdj	SP%Shade-Adj	TTR
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	28200	5.3	54.8	63.7	80.6	93.9	126.1
Private	1200	0.2	30.0	30.0	45.0	92.0	153.0
Total	**29400**	**5.6**	**53.7**	**62.3**	**79.1**	**93.8**	**127.2**

Palmer Trib	Length	RM	Ht	Den	Cur%ShadeAdj	SP%Shade-Adj	TTR
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	15200	2.9	75.4	84.5	95.7	96.6	99.1
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**15200**	**2.9**	**75.4**	**84.5**	**95.7**	**96.6**	**99.1**

Petes Camp Cr	Length	RM	Ht	Den	Cur%ShadeAdj	SP%Shade-Adj	TTR
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	1800	0.3	110.0	90.0	93.0	92.0	33.0
Private	7000	1.3	70.6	83.1	90.9	94.4	107.4
Total	**8800**	**1.7**	**78.6**	**84.5**	**91.3**	**93.9**	**92.2**

Rock Gulch	Length	RM	Ht	Den	Cur%ShadeAdj	SP%Shade-Adj	TTR
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	0	0.0	0.0	0.0	0.0	0.0	0.0
Private	1800	0.3	70.0	50.0	86.0	96.0	109.0
Total	**1800**	**0.3**	**70.0**	**50.0**	**86.0**	**96.0**	**109.0**

Waters Gulch	Length	RM	Ht	Den	Cur%ShadeAdj	SP%Shade-Adj	TTR
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	9400	1.8	56.9	50.5	84.5	97.6	121.4
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**9400**	**1.8**	**56.9**	**50.5**	**84.5**	**97.6**	**121.4**

Waters Gulch Trib	Length	RM	Ht	Den	Cur%ShadeAdj	SP%Shade-Adj	TTR
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	5000	0.9	83.0	55.0	95.0	98.0	90.2
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**5000**	**0.9**	**83.0**	**55.0**	**95.0**	**98.0**	**90.2**

Sterling Creek Channel & Riparian Assessment

Reporting Period: 2001-2002

Contractor: Applegate River Watershed Council

Project Results:

Table 1

Sterling Creek Watershed – Overview	
Hydrologic Unit Code (Identification)	171003090305*
Watershed Area / Ownership	Total: 11,930 acres BLM Ownership: 7279 ac. (61%) Non-Fed. Ownership: 4651 ac. (39%)
Stream Miles Assessed	Total: 6.8 miles (13.6 miles of stream bank) Non-Fed. Ownership: 12.76 miles of stream bank BLM ownership: .87 miles of stream bank (6.3%)
303(d) Listed Parameters	Temperature
Key Resources and Uses	Salmonid, domestic, agricultural, aesthetic
Known Impacts	Mining, roads, water withdrawals, residential structures, and timber harvests.

*HUC code is for Lower Little Applegate 6th field watershed.

Sterling Creek is a small, low-elevation watershed. Much of the watershed divide lies between 3000 and 5000 feet in elevation, and reaches its highest point at 5195-foot Anderson Butte. Sterling Creek discharges into the Little Applegate River at approximately 1680 feet above sea level.

Although 61% of the watershed is managed by the USDI Bureau of Land Management, Sterling Creek runs through primarily private lands from its headwaters to its mouth. Of the 71944 feet of bank assessed, 4592 (6.4%) is under the management of BLM. All tributaries are seasonal, going dry during mid to late summer, depending on the water year. Sterling Creek itself carries very little water. Late summer flows typically drop below 1 cfs at the mouth, with numerous upstream reaches limited to hyporheic (sub-surface) flow (ARWC monitoring program, 1997 - 2002). While water rights total 2.95 cfs, virtually all of the rights are recent (post 1941), and low summer flow levels limit users without storage facilities such as ponds (Oregon Water Resources Department water rights data base). Sterling Creek Low annual precipitation, an absence of significant snow pack accumulation, and highly fractured bedrock contribute to minimal natural stream flow in this watershed. Additionally, extensive mining during the late 1800s and early 1900s profoundly altered the Sterling Creek valley bottom and reduced floodplain storage capacity and connectivity to the stream. Data and imagery collected using forward-looking infrared cameras indicate that high summer stream temperatures in Sterling Creek have little effect on stream temperatures in the Little Applegate River, likely due to the very small amount of flow the Sterling Creek contributes to the Little Applegate (McIntosh et al., 1999). Steelhead use the lowermost reaches of the stream, but low summer stream flows provide for very little rearing habitat.

Mining along most of Sterling Creek removed much of the streamside vegetation as well as the floodplain soil and substrate in which it was rooted. The legacy of these activities is an incised and often confined stream channel bordered by low fertility, excessively drained, unstable mine tailings or mining headwalls for much of the stream’s length. Such conditions influence potential riparian conditions. In some cases, harsh site conditions promote the development of native ponderosa pine forests while limiting the establishment of invasive species such as Himalayan blackberries. However, the potential for the development of a diverse and extensive native riparian forest generally has been eliminated or diminished.

ARWC staff worked with the Department of Environmental Quality to establish general site potential vegetation conditions for Little Applegate riparian communities based on community type (deciduous, mixed conifer-deciduous, and conifer). Site potential conditions are intended to serve as a reference for current riparian communities, to facilitate the establishment of riparian management goals, and to provide a benchmark with which restoration progress can be measured. Degraded conditions along Sterling Creek may limit site potential conditions relative to other areas in the Little Applegate stream system.

Table 2 displays the results of the SHADOW model, Version X15 (Park, 1993; see Appendix I for a description of the riparian analysis methodology and model parameter descriptions). Years to recovery were estimated using existing tree height, seral stage, species composition, and tree growth curves developed by Michael Pipp, DEQ, together with regional foresters and soil scientists (Pipp, 1999, Appendix II). Attached maps display seral stage and existing percent unshaded stream to provide a visual display of current conditions along Sterling Creek, “improvement potential” to identify those areas likely to benefit most from restoration efforts, and restoration sites where ARWC has begun restoration of native vegetation communities during the last few years. The map of restoration sites and potential for improvements in stream shade indicates that efforts should be expanded to the upper Sterling Creek stream reaches, where early seral, willow-dominated communities or grass pasture dominate.

Ground truthing data was collected at reaches S3, S13, S16, and S20. Solar pathfinder readings indicate that percent shade varies widely within each reach, but SHADOW estimates fall within the range of measured values. SHADOW model results, therefore, may be less reliable that in areas with more uniform riparian conditions (e.g., large commercial or government managed tracts vs. the small residential and commercial acreages found along Sterling Creek.

Table 2. Shadow Model Results. Improvement potential is equal to the difference between existing and site potential shade values. S1 is located at Sterling Creek's headwater and S21 is at the confluence with the Little Applegate River.

Reach	Existing % shade	Site Potential	Improvement Potential	Years to Recovery
S1	51	96	46	50
S2	58	96	38	50
S3	70	89	20	40
S4	87	90	04	20
S5	72	91	19	40
S6	70	93	22	40
S7	79	89	11	25
S8	48	88	40	50
S9	89	91	1	10
S10	79	88	9	30
S11	59	87	28	40
S12	75	88	13	30
S13	87	91	4	20
S14	91	93	2	10
S15	72	88	16	30
S16	64	85	21	30
S17	84	92	9	25
S18	27	87	60	50
S19	27	87	60	50
S20	94	96	2	25
S21	74	85	11	20

Glade, Yale, Applegate Creek Channel & Riparian Assessment

Reporting Period: 2001-2002

Contractor: Applegate River Watershed Council

Project Results:

Table 3

Applegate/Glade/Yale Creeks Watershed – Overview	
Hydrologic Unit Code (Identification)	171003090305*
Watershed Area / Ownership	Little Applegate: 72242 acres Yale Creek 15229 acres Glade Creek 8727 acres
Stream Miles Assessed	Little Applegate: 20.1 miles Yale Creek: 14.8 miles Glade Creek: 17.0 miles
303(d) Listed Parameters	Temperature
Key Resources and Uses	Salmonid, domestic, agricultural, aesthetic
Known Impacts	Mining, roads, water withdrawals, residential structures, and timber harvests.

*HUC code is for Lower Little Applegate 6th field watershed.

ARWC staff worked with the Department of Environmental Quality to establish general site potential vegetation conditions for Little Applegate riparian communities based on community type (deciduous, mixed conifer-deciduous, and conifer). Site potential conditions are intended to serve as a reference for current riparian communities, to facilitate the establishment of riparian management goals, and to provide a benchmark with which restoration progress can be measured. Degraded conditions along streams may limit site potential conditions relative to other areas in the Little Applegate stream system.

Table 3 displays the results of the SHADOW model, Version X15 (Park, 1993; see Appendix I for a description of the riparian analysis methodology and model parameter descriptions). Years to recovery were not estimated as part of the assessment of Yale, Little Applegate and Glade Creeks.

Table 4. Shadow Model Results by ownership for Little Applegate River, Sterling Creek, Yale Creek, and Glade Creek

Little Applegate	Miles	Height	Density	Current % Shade	System Potential % Shade	Percent Change in Shade
BLM	6.3	89.3	75.5	93.7	95.8	2.1
USFS	10.7	109.7	71.6	92.7	96.2	3.5
Private	18.4	79.3	62.8	87.7	94.8	7.1
Total	**20.1**	**100.6**	**71.7**	**92.9**	**95.9**	**2.9**

Glade Creek	Miles	Height	Density	Current % Shade	System Potential % Shade	Percent Change in Shade
BLM	0.0	0.0	0.0	0.0	0.0	0.0
USFS	12.0	103.1	67.7	91.7	95.5	3.8
Private	2.8	100.8	70.5	92.6	94.4	1.8
Total	**14.8**	**102.6**	**68.2**	**91.9**	**95.3**	**3.4**

Sterling Creek	Miles	Height	Density	Current % Shade	System Potential % Shade	Percent Change in Shade
BLM	1.0	70.3	56.8	86.7	94.9	8.2
USFS	0.0	0.0	0.0	0.0	0.0	0.0
Private	12.6	59.2	52.7	85.2	95.7	10.5
Total	**13.6**	**60.0**	**53.0**	**85.3**	**95.6**	**10.3**

Yale Creek	Miles	Height	Density	Current % Shade	System Potential % Shade	Percent Change in Shade
BLM	3.3	128.3	77.5	98.0	98.2	0.2
USFS	6.3	114.3	69.0	95.5	97.4	1.9
Private	7.5	97.6	72.1	95.6	97.1	1.5
Total	**17.0**	**109.7**	**72.0**	**96.0**	**97.4**	**1.4**

Evaluation of Project Implementation and Effectiveness

Products are already in use by the DEQ to model stream temperature and develop Applegate TMDLs.

Possible Improvements

Additional funding for systematic field data collection would provide better input data, and likely better model results.

References

1. McIntosh, B, R Faux, and J Sedell. 1999. Aerial Survey of the Applegate River: Thermal
2. Infrared and Color Videography. Report submitted to the Appelgate River Watershed Council and the US Forest Service.
3. Park, C. 1993. SHADOW: Stream Temperature Management Program. US Forest Service, Siskiyou National Forest, Grants Pass, OR.
4. Pipp, M. 1999. Common growth curve models: Basis for decision and future models. Oregon Department of Environmental Quality, Medford, OR.

Appendix I: Methodology and Data Descriptions

Data parameters were determined using several sources and methods: 1) Vegetation was categorized using mosaics of infrared imagery from July 2000, stereoscopic interpretation of 1998 and 1996 aerial photographs and 1994 digital ortho-photos, 2) stream orientation and percent slope were obtained from U.S.G.S. topographic maps, 3) active channel width and flow width were obtained from stream surveys conducted by ODFW and ARWC. All data is recorded in meters except tree height, which is in feet. Line segments documenting stream reaches were drawn in Arcview™. An accompanying layer was generated in Arcview™ to identify key features and stream habitat survey reaches from which data was obtained.

Shadow Model Definitions

Selected	Yes, for incorporating data into model. No, to exclude data from reach when running the model.
Length	Reach lengths were automatically calculated in Arcview.
Bank	E for east bank. W for west bank.
Percent Slope	The distance between lines on the U.S.G.S. topographic maps was measured and correlated to the closest slope value using a U.S.G.S. Timesaver Land and Slope Indicator.
Orientation	Determined by overlaying Shadow Orientation Scale tool onto U.S.G.S. topographic maps.
Channel Width	From most recent stream surveys conducted by ODFW or ARWC.
Flow Width	From most recent stream surveys conducted by ODFW or ARWC.
ODF fish bearing classification	From ODF classifications. L, M, S for Large, medium and small streams respectively.
Tree channel distance	Rough estimate based on tree line distance to bankfull width of stream habitat surveys conducted by ODFW or ARWC.
Tree height	Stereoscopic interpretation of aerial photos was used and correlated with field measurements using an Impulse™ laser instrument. Older (taller) deciduous stands had larger tree top circumferences often with more of a continuous and thicker canopy. These parameters became smaller and reduced with mid and early seral stages. Additionally, changes in color and depth from one canopy to the next indicate a mixture of deciduous species. Late seral coniferous canopies exhibit high relief, varying degrees of irregularity and density, and are uniformly dark green. The older (taller) the stand, the less pointed the cone-shaped shadows.
Percent overhang	Determined by how much of the underlying stream channel could be seen looking through vegetation from directly above.

Shade density	Seral stage, percent slope, vegetation classification and vegetation spacing were indicators of shade density. Dense canopies with little "openings" are correlated with higher shade densities. Lower shade densities were characterized by larger or more frequent openings in the canopy where more light penetrated through to the stream floor.
Vegetation width	Measured using the Arcview™ measuring tool. Distances measured incorporated moderate changes in vegetation where vegetation was continuous. For example, if the vegetation within the immediate riparian area was classified as mid seral deciduous and then changed to mid seral coniferous, measurement incorporated both communities. If vegetation changed from a mid seral deciduous to a grass/forbs community, only the immediate riparian vegetation was incorporated into the measurement.
Species composition	D, C, M for deciduous, coniferous and mixed species composition respectively. A stand having less than 66% of either coniferous or deciduous species was categorized as mixed.
Vegetation age	E, M, L for early, mid and late successional stages respectively. Age range for deciduous is early 0-10 years, mid 10-40 years, late 40-100 years. Coniferous age range is early 0-30 years, mid 30-100 years and late greater than 100 years. Early deciduous stands were dominated by alder, willows, blackberries and/or grasses and forbs with an average dbh of less than 8 inches and range of 0-39 feet. Mid seral deciduous stands were dominated by ash, cottonwood, big leaf maple, alder and understory shrubs with a height range of 40-79 feet and dbh 8-17 inches. Late deciduous communities were dominated by cottonwood, Oregon ash, big leaf maple, and understory shrubs with an absence of willows, alders and blackberries that were prevalent in the mid seral stage. Dbh range was 18 inches and greater and heights of greater than 80 feet. Early coniferous dominated by Douglas-fir, white fir, incense cedar and/or ponderosa pine with average dbh less than 12 inches and heights less than 60 feet. Mid seral coniferous had a dbh range of 13-24 inches and height range of 60—109 feet. Late seral coniferous communities were characterized by a dbh of 25 inches or greater and tree heights greater than 110 feet.
Ground-truthed	G if most of the data was obtained from field surveys.
Notes	Applicable notes.

Site Potential Conditions

Vegetation Type	Tree Height [ft (m)]	Shade Density (%)
Conifer (>66% Douglas-fir, white fir, ponderosa pine, incense cedar)	141 (43)	80
Hardwood (> 66% alder/cottonwood, with Oregon ash & bigleaf maple present)	88 (26.8)	85
Mixed (conifer/hardwood)	138 (42)	70

Appendix II
Data Tables

Tier 3 Analysis

Calculation of System Potential Percent Shade Using Oregon Department of Fish and Wildlife (ODFW) Stream Habitat Data

Overview

Four of the streams not done in the Tier 1 or 2 analysis - Cheney, Slate, Thompson and Waters Creeks - have a significant body of stream assessment data from surveys done by ODFW from October 1991 through September of 1996. Without detailed flow volumes, channel characteristics and instream temperature calibration sets it is impossible to use *HeatSource* to calculate system energy thermodynamic and resulting stream temperatures. The data collected in the ODFW stream surveys is consistent with several parameters needed for Tier 2 SHADOW modeling, but the ODFW data has gaps and is averaged over reaches of greater length than that done in Tier 2. We are left with an opportunity to develop a courser, but still useful data set for feeding into a modified *HeatSource* model to calculate system potential percent shading in these streams. Those percent shadings of the NSDZ are shown in Map 3-1 and 3-2.

Model Preparation

Segmentation of the four streams and calculation of the reach aspect at each reach break was done identically to the procedure used in the Tier 1 analysis. ODFW reaches were matched up to the proper segments using GIS.

Model segments were 100 meters (328 ft) feet long. Cheney Creek has 71 segments covering river mile 0-4.4, Thompson Creek had 210 segments covering river mile 0-12.5, Slate Creek had 158 segments covering river mile 0-9.8, and Waters Creek had 29 segments covering river mile 0-1.8.

Topographic shading was not calculated for Tier 3 analysis.

ODFW data collected as “active channel width” was used as the NSDZ model input.

System potential values for vegetative height were taken from the values used for the Little Applegate system potential *HeatSource* simulation.

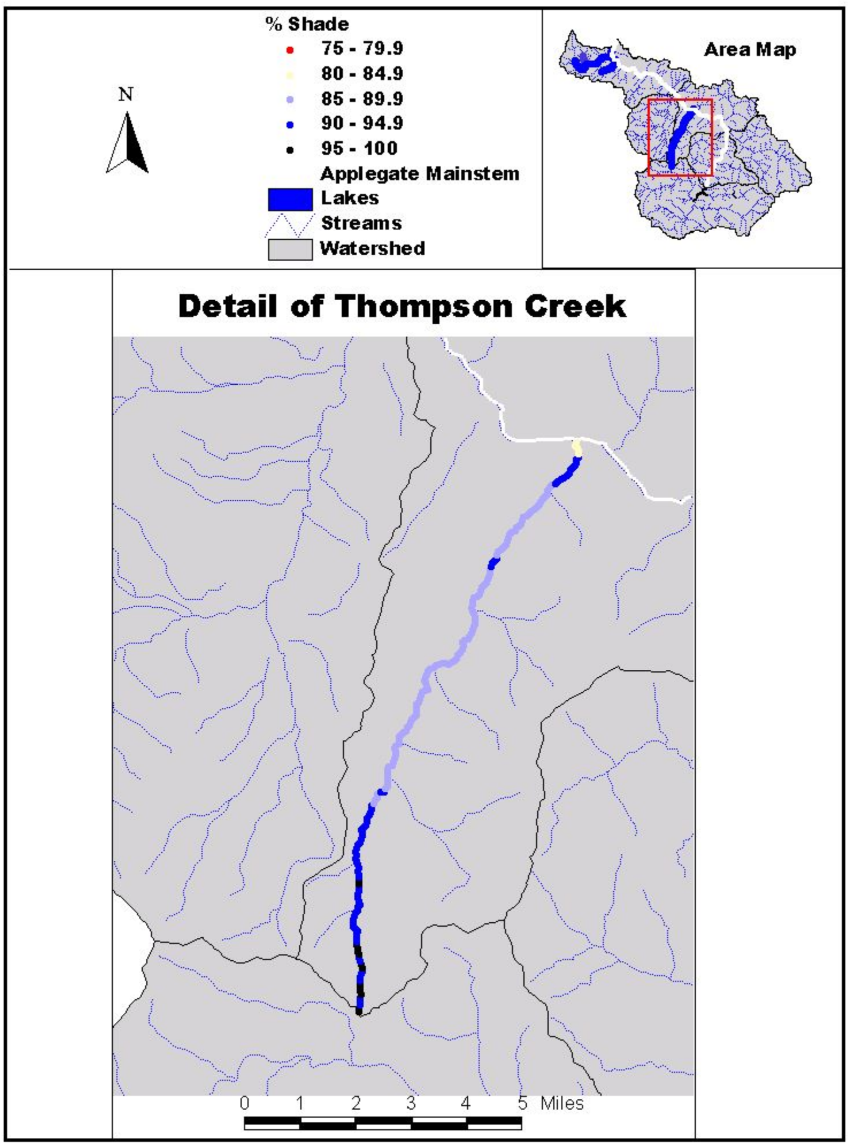
System potential values for shade density were calculated from two methods. Method one was to use the 80% shade density value used for the system potential analysis of the Little Applegate. This value was used in areas whose predominate substrate was disturbed, alluvial soils. See Map 1 in the Tier 4 analysis section, these areas are defined in the map legend as “No Data”. Method 2 was to determine system potential shade based on the adjacent soil characteristics. This method is described in more detail in Tier 4 analysis. In all cases, for Tier 3 analysis, areas that fell outside of the 80% shade density locations were in the same soil class which used 84%

density. The segments of each system and the shade density used are detailed below in Table 3-1.

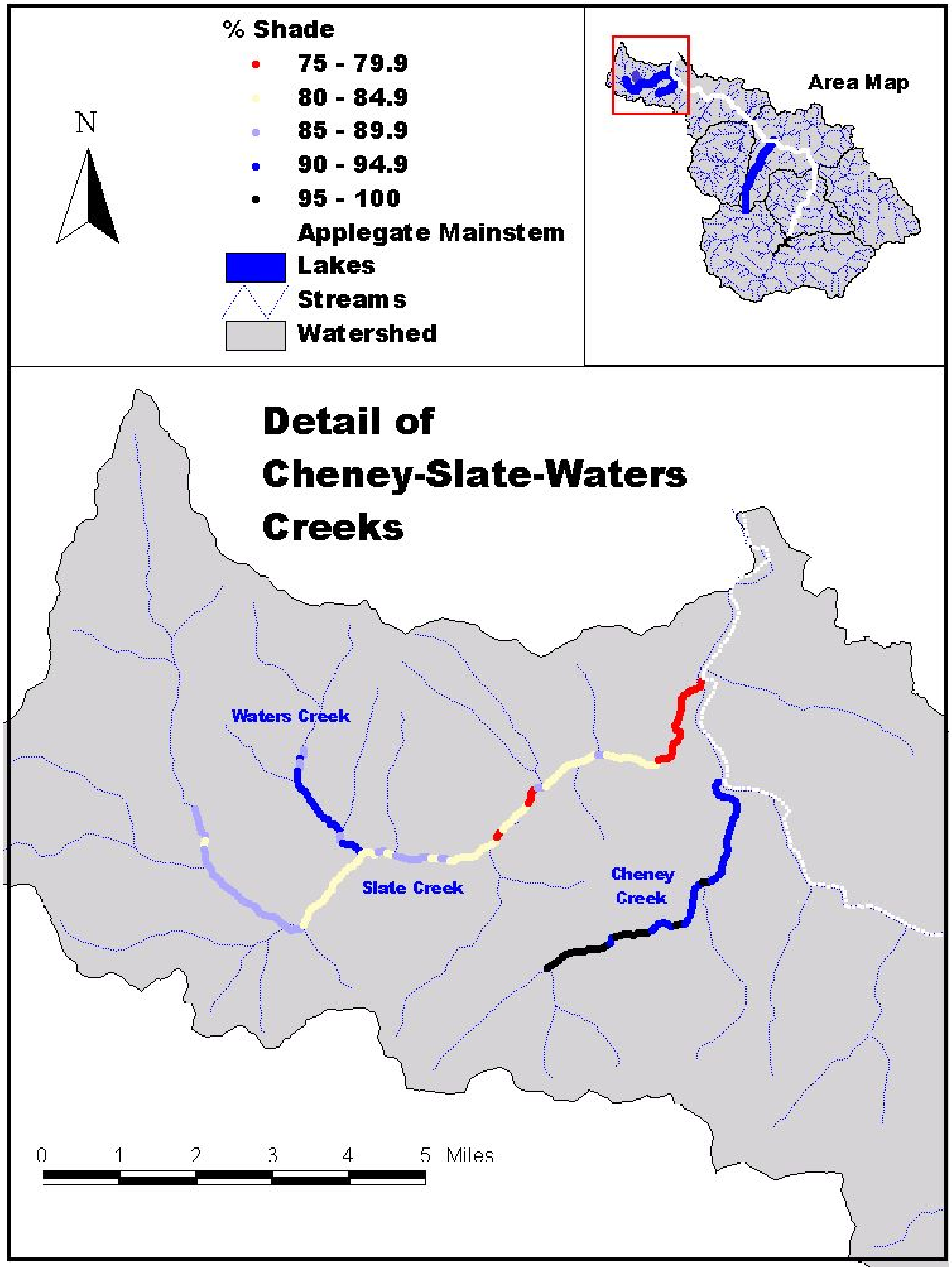
Table 3-1 – Shade Densities Used for Calculation Percent Shade

Creek		84% Shade		80% Shade
Cheney		Segments 0-8		Segments 9-71
Thompson		Segments 0-62		Segments 63-201
Slate		Segments 0-25		Segments 26-158
Waters		Segments 0-25		Segments 26-29

Map 3-1 – System Potential Shade for Thompson Creek



Map 3-2 – System Potential Shade for Cheney, Slate and Waters Creeks



Percent shadings for the four systems can be be converted into percentile values and shown as cumlative frequency plots like those shown in Figure 3-1. Further conversion to BTU/SqFt/Day loadings can be shown as the cumlative frequency plot shown in Figure 3-2. Table 3-2 highlights the 50th percentile (median) values for percent shade provided and solar flux entering the active channel for each of these four streams at system potiential conditions.

Figure 3-1-Cumlative Frequency plot of Percent Shade to NSDZ for Cheney, Slate, Thompson and Waters Creeks.

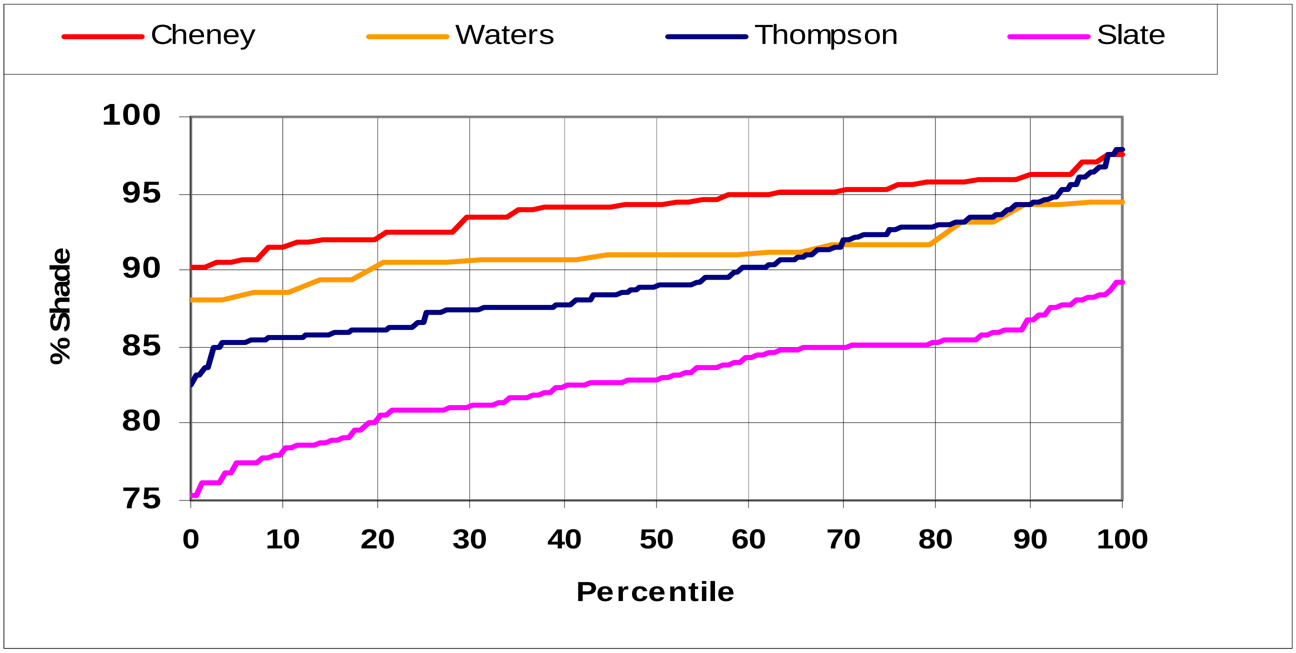


Figure 3-2-Cumlative Frequency plot of Solar Loading to NSDZ for Cheney, Slate, Thompson and Waters Creeks.

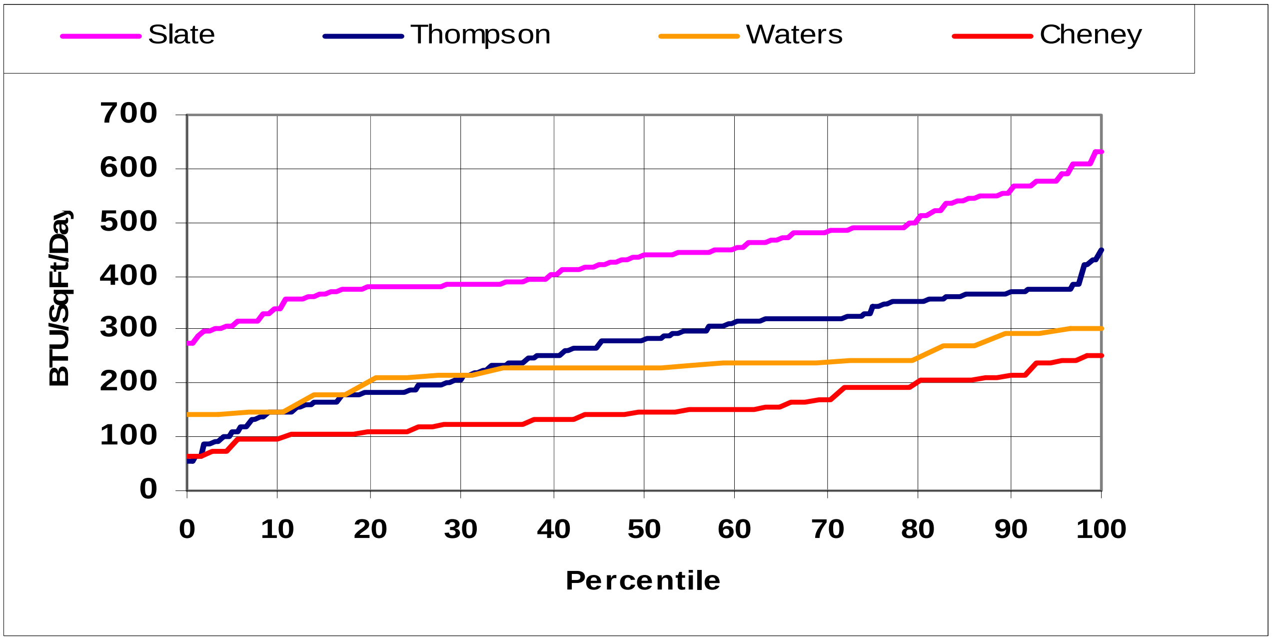


Table 3-2
Median percent shade and median solar flux entering Cheney, Thompson, Slate and Waters Creeks at system potential conditions.

Stream	Median Percent Shade	Solar Flux BTU/SqFt/Day
Cheney	94	148
Thompson	89	281
Slate	83	438
Waters	91	231

Tier 4 Analysis

Calculation of Vegetative Shade Using General Soil Characteristics

Overview

The method described here allows a percent shade to be calculated for almost any stream reach in the basin not already covered by Tier 1, 2, or 3 analysis. More general data, averaged over greater areas makes this the least precise method described in this document, but does allow its use over almost the entire basin. This method uses soil data to describe associated vegetative communities. Characteristics of these communities define the height of the vegetation and the canopy density of these areas at their system potential conditions. Those parameters were entered into a modified *HeatSource* model which calculated the daily percent shade at a range of near stream disturbance zones (NSDZ). Output from multiple simulations (51) was used to construct a graph showing the NSDZ vs. Percent Shade relationship for a series of defined conditions.

For use in the field, the user must identify which soil zone they are in (using Map 4-1), identify dominant vegetation to identify proper shade curve and system potential vegetation height to use (Table 4-1) and then use a field-measured NSDZ to scale the associated percent shade from the shade curve.

Soil Data

Tier 4 uses general soil characteristics as described in the nationwide USGS STATSGO data series. STATSGO maps where soils of similar types are found, and also defines many of the physical, agricultural and engineering properties of these soils. Each soil type lists the associated plant communities found upon it and also identifies the site index of the larger tree species. The resolution of this data is at a fairly gross scale but does cover almost the entire basin. In the Applegate, there are five types of soil defined by STATSGO. Those soil types are identified in Table 4-1. Table 4-1 also shows the dominant vegetative types, site indexes and corresponding vegetative height for each community-soil pair. The spatial distribution of these soil types is shown in Map 4-1. In terms of basin area, Soils 16, 17, 18, 50 and 56 make up 3.6%, 54.5%, 21.9%, 4.5% and 4.3% of the basin respectively. The category of “no data” is made up of unsorted alluvial material prone to semi-regular high flow disturbances that do not allow long-term stability in their vegetative communities.

Vegetative Height

System potential vegetative heights for Douglas Fir, Ponderosa Pine, Jeffery Pine (using Lodgepole data) and Incense Cedar were scaled from site quality curves contained in “Log Scaling & Timber Cruising “ (Bell and Dillworth – OSU Press – 1988), pages 225-236. The system potential height for White Fir stands in southwestern Oregon was taken from the USFS web site: www.na.fs.fed.us/spfo/pubs/silvics_manual/Volume_1/abies/concolor.htm

Canopy Density

The soil – defined plant communities were matched with Applegate basin-specific communities defined in the reference "Field Guide to Forested Plant Associations of Southwest Oregon" (USDA/USFS – 1996). Those match-up are:

Soil Type	Plant Community	Page
Type 16	Western White Pine-Common Beargrass	PIMO – 3,4
Type 17	Douglas Fir-Incense Cedar	PSME – 21-22
Type 18	Shasta Red Fir-White Fir	ABMAS - 10,11
Type 50	Ponderosa Pine-Douglas Fir	PIPO – 4,5
Type 56	Ponderosa Pine-California Black Oak	PIPO – 6,7

Each of these plant communities have associated canopy closures for the high, middle and low vegetative layers. These closures were converted into a single, overall canopy density. This was used as the shade density value in the *HeatSource* modeling that developed shade curves 4-1 to 4-5.

Model Assumptions

There were 17 unique combinations of soil/system potential height/system potential canopy closure. Three simulations were run for each of those 17 combinations, one at stream aspect of North-South, one at stream aspect of East-West and one at stream aspect of Northwest-Southeast/Northeast-Southwest. The data from those three simulations was averaged into one NSDZ-percent shade relationship, and that is the relationship show in shade curves 4-1 to 4-5. The data from all 51 simulations is contained at the end of this section. No correction was made for topographic shading for any simulations in the tier 4 analysis.

Map 4-1

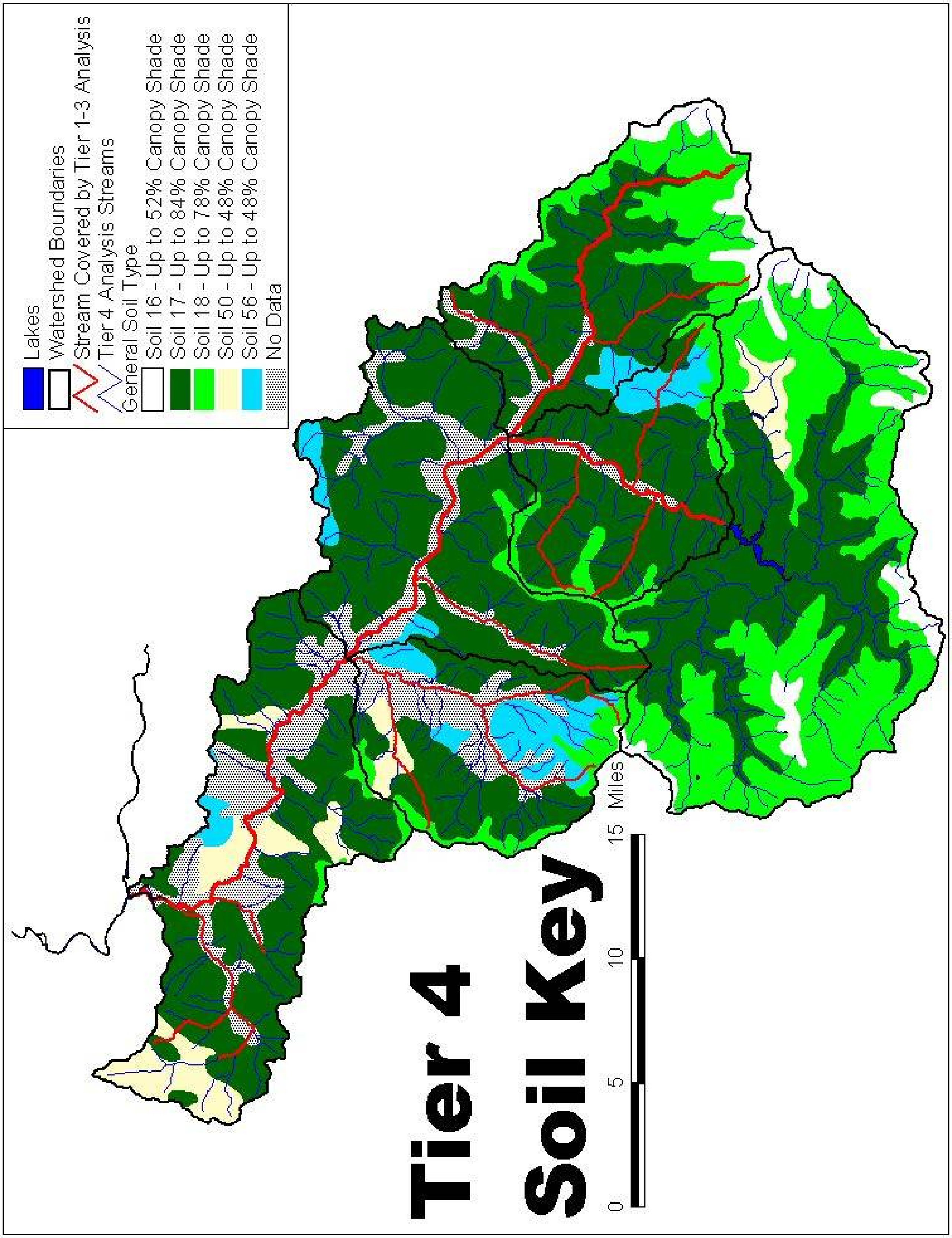
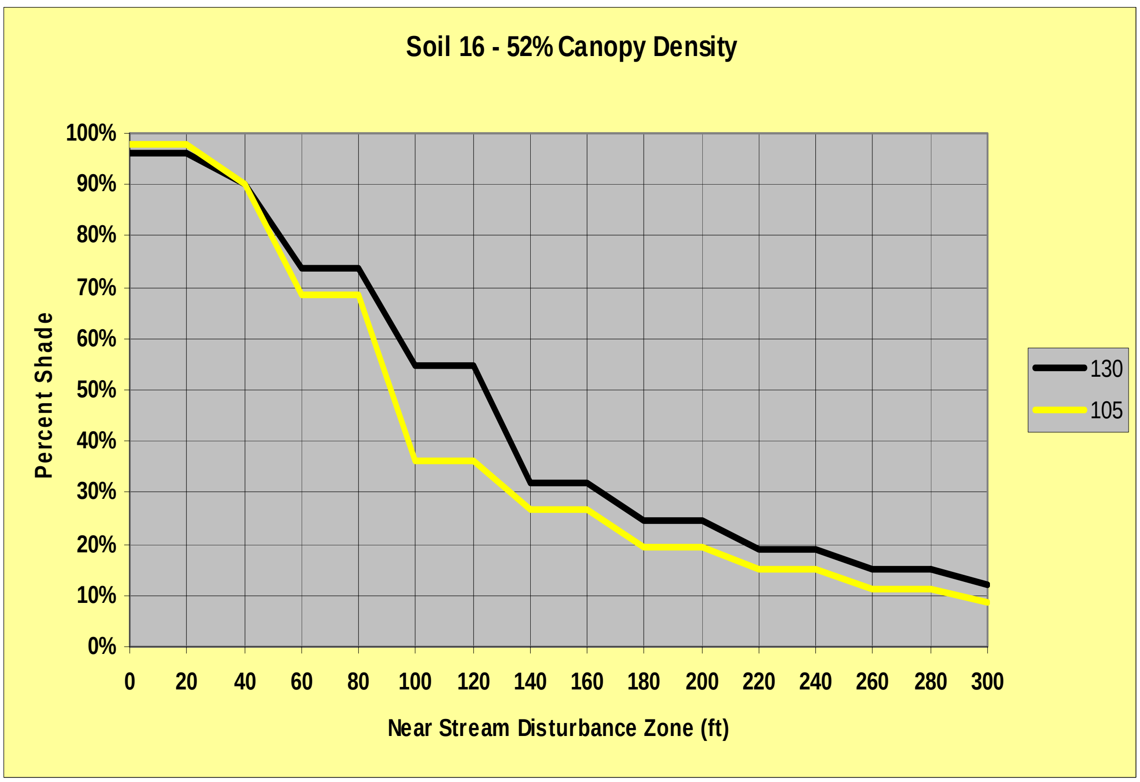

Lakes
Watershed Boundaries
Stream Covered by Tier 1-3 Analysis
Tier 4 Analysis Streams
General Soil Type
Soil 16 - Up to 52% Canopy Shade
Soil 17 - Up to 84% Canopy Shade
Soil 18 - Up to 78% Canopy Shade
Soil 50 - Up to 48% Canopy Shade
Soil 56 - Up to 48% Canopy Shade
No Data
Tier 4
Soil Key
0
5
10
15
Miles

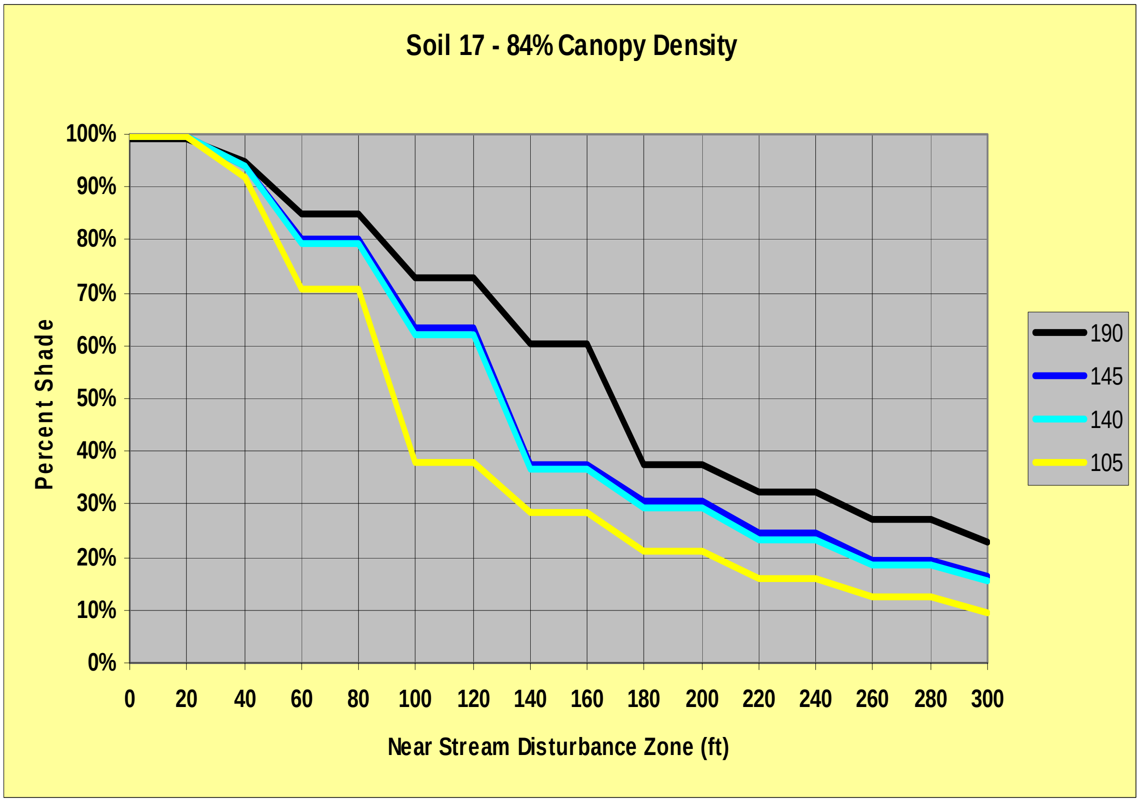
Table 4-1

Soil Type	Typical Canopy Shade (%)	Dominant Species	Species Site Index	System Potential Tree Height (ft)	Shade Curve Figure
16 Crannler-Bigelow-Woodseye	52	Douglas Fir	95	105	1
	52	White Fir	70	130	1
17 Beekman-Josephine-Vannoy	84	Douglas Fir	65 - 94	105 - 145	2
	84	Ponderosa Pine	75 - 115	140 - 190	2
18 Jayer-Althouse-Woodseye	78	Douglas Fir	60 - 95	105 -145	3
	78	White Fir	70 - 80	130	3
50 Pearsoll-Dubakella-Cornutt	48	Douglas Fir	76 - 90	105 - 145	4
	48	Ponderosa Pine	60	120	4
	48	Jeffery Pine	60	70	4
	48	Incense Cedar	60	95	4
56 Tallowbox-Siskiyou-Shefflein	48	Douglas Fir	60 - 110	105 - 185	5
	48	Ponderosa Pine	90 - 114	160 - 190	5

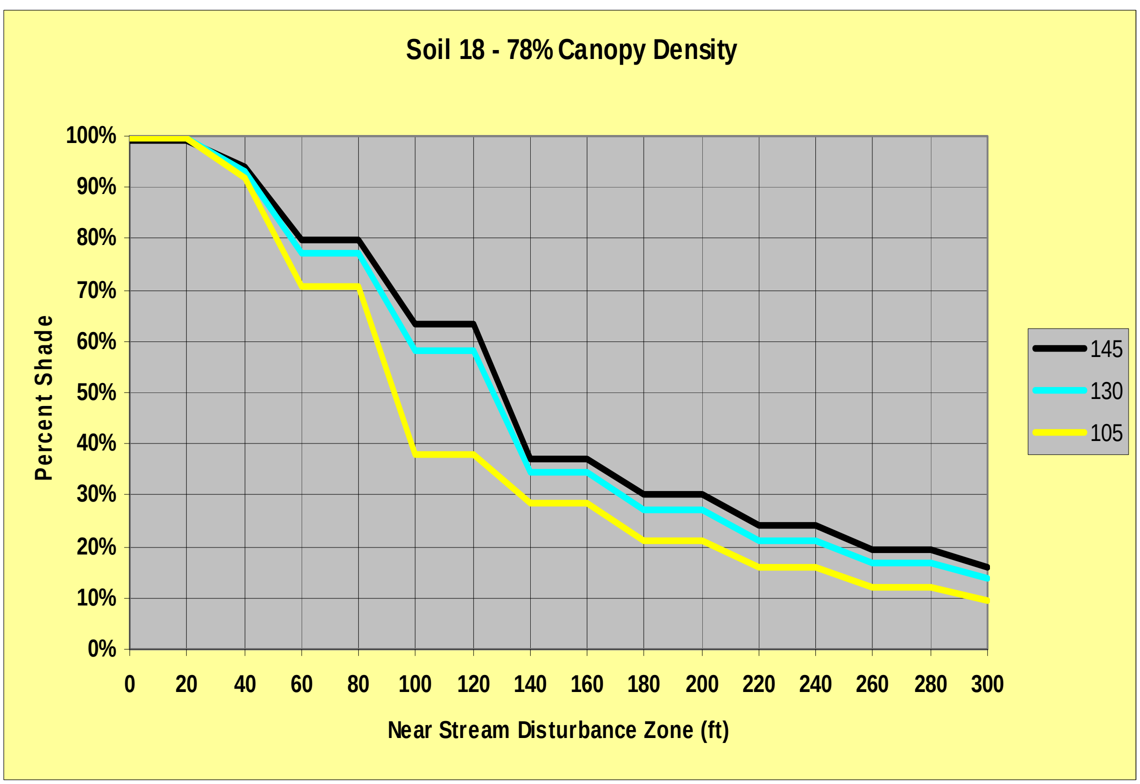
Shade Curve # 4-1



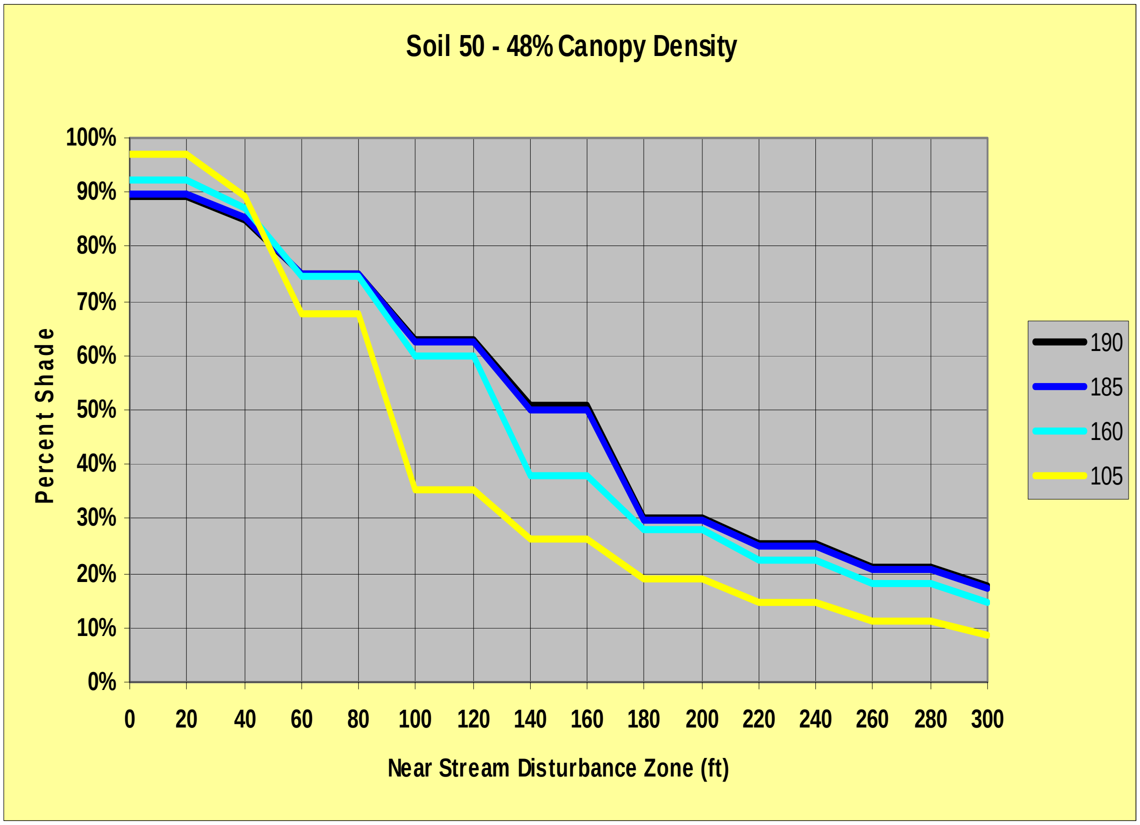
Shade Curve # 4-2



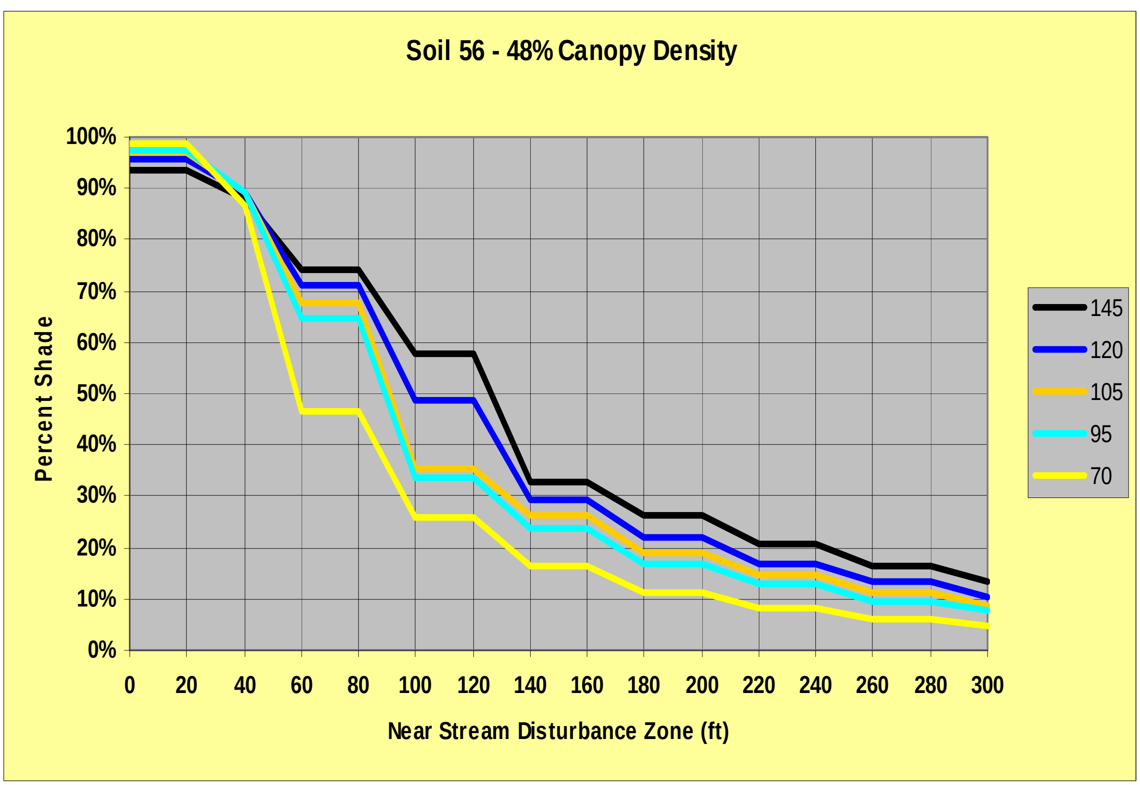
Shade Curve # 4-3



Shade Curve # 4-4



Shade Curve # 4-5



Data from All Model Runs for all Combinations of Soil-Vegetation-Aspect

	Soil Type 16	SP Height 105	SP Density 52	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.5%	97.4%	96.3%	**97.7%**
20	99.5%	97.4%	96.3%	**97.7%**
40	94.5%	88.3%	87.3%	**90.1%**
60	78.4%	58.1%	69.5%	**68.7%**
80	78.4%	58.1%	69.5%	**68.7%**
100	4.7%	49.5%	53.9%	**36.0%**
120	4.7%	49.5%	53.9%	**36.0%**
140	3.7%	35.5%	41.4%	**26.9%**
160	3.7%	35.5%	41.4%	**26.9%**
180	2.9%	24.1%	31.8%	**19.6%**
200	2.9%	24.1%	31.8%	**19.6%**
220	2.4%	17.6%	24.7%	**14.9%**
240	2.4%	17.6%	24.7%	**14.9%**
260	1.9%	12.6%	19.4%	**11.3%**
280	1.9%	12.6%	19.4%	**11.3%**
300	1.5%	9.4%	15.6%	**8.8%**

	Soil Type 17	SP Height 140	SP Density 84	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.9%	99.5%	99.4%	**99.6%**
20	99.9%	99.5%	99.4%	**99.6%**
40	96.3%	92.7%	92.7%	**93.9%**
60	86.7%	72.0%	79.0%	**79.2%**
80	86.7%	72.0%	79.0%	**79.2%**
100	65.7%	54.3%	66.3%	**62.1%**
120	65.7%	54.3%	66.3%	**62.1%**
140	4.6%	50.8%	55.1%	**36.8%**
160	4.6%	50.8%	55.1%	**36.8%**
180	3.8%	39.1%	45.5%	**29.5%**
200	3.8%	39.1%	45.5%	**29.5%**
220	3.2%	29.4%	37.6%	**23.4%**
240	3.2%	29.4%	37.6%	**23.4%**
260	2.7%	22.3%	31.1%	**18.7%**
280	2.7%	22.3%	31.1%	**18.7%**
300	2.3%	18.2%	25.9%	**15.5%**

	Soil Type 16	SP Height 130	SP Density 52	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	98.8%	95.7%	94.0%	**96.2%**
20	98.8%	95.7%	94.0%	**96.2%**
40	94.8%	88.3%	86.8%	**90.0%**
60	84.0%	65.4%	72.1%	**73.8%**
80	84.0%	65.4%	72.1%	**73.8%**
100	56.3%	49.8%	58.8%	**55.0%**
120	56.3%	49.8%	58.8%	**55.0%**
140	4.3%	43.9%	47.3%	**31.9%**
160	4.3%	43.9%	47.3%	**31.9%**
180	3.5%	32.3%	38.0%	**24.6%**
200	3.5%	32.3%	38.0%	**24.6%**
220	2.9%	23.5%	30.6%	**19.0%**
240	2.9%	23.5%	30.6%	**19.0%**
260	2.5%	17.9%	24.8%	**15.0%**
280	2.5%	17.9%	24.8%	**15.0%**
300	2.1%	14.4%	20.3%	**12.3%**

	Soil Type 17	SP Height 145	SP Density 84	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.9%	99.5%	99.3%	**99.6%**
20	99.9%	99.5%	99.3%	**99.6%**
40	96.4%	92.9%	92.8%	**94.1%**
60	87.3%	73.1%	79.6%	**80.0%**
80	87.3%	73.1%	79.6%	**80.0%**
100	68.6%	54.6%	67.3%	**63.5%**
120	68.6%	54.6%	67.3%	**63.5%**
140	4.7%	51.3%	56.3%	**37.4%**
160	4.7%	51.3%	56.3%	**37.4%**
180	3.9%	40.7%	46.8%	**30.5%**
200	3.9%	40.7%	46.8%	**30.5%**
220	3.3%	31.0%	38.9%	**24.4%**
240	3.3%	31.0%	38.9%	**24.4%**
260	2.8%	23.5%	32.4%	**19.6%**
280	2.8%	23.5%	32.4%	**19.6%**
300	2.4%	19.1%	27.1%	**16.2%**

	Soil Type 17	SP Height 105	SP Density 84	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.9%	99.6%	99.6%	**99.7%**
20	99.9%	99.6%	99.6%	**99.7%**
40	94.9%	90.5%	90.6%	**92.0%**
60	78.9%	60.2%	72.7%	**70.6%**
80	78.9%	60.2%	72.7%	**70.6%**
100	4.7%	51.6%	57.1%	**37.8%**
120	4.7%	51.6%	57.1%	**37.8%**
140	3.7%	37.4%	44.3%	**28.5%**
160	3.7%	37.4%	44.3%	**28.5%**
180	2.9%	25.6%	34.4%	**21.0%**
200	2.9%	25.6%	34.4%	**21.0%**
220	2.4%	18.9%	26.9%	**16.1%**
240	2.4%	18.9%	26.9%	**16.1%**
260	1.9%	13.6%	21.4%	**12.3%**
280	1.9%	13.6%	21.4%	**12.3%**
300	1.6%	10.1%	17.2%	**9.6%**

	Soil Type 17	SP Height 190	SP Density 84	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.9%	99.1%	98.6%	**99.2%**
20	99.9%	99.1%	98.6%	**99.2%**
40	97.2%	94.1%	93.6%	**95.0%**
60	91.0%	80.6%	83.4%	**85.0%**
80	91.0%	80.6%	83.4%	**85.0%**
100	81.7%	63.3%	73.6%	**72.9%**
120	81.7%	63.3%	73.6%	**72.9%**
140	62.5%	53.4%	64.5%	**60.1%**
160	62.5%	53.4%	64.5%	**60.1%**
180	4.7%	51.0%	56.2%	**37.3%**
200	4.7%	51.0%	56.2%	**37.3%**
220	4.1%	43.6%	48.7%	**32.2%**
240	4.1%	43.6%	48.7%	**32.2%**
260	3.6%	35.5%	42.2%	**27.1%**
280	3.6%	35.5%	42.2%	**27.1%**
300	3.2%	28.7%	36.6%	**22.8%**

	Soil Type 18	SP Height 105	SP Density 78	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.9%	99.5%	99.4%	**99.6%**
20	99.9%	99.5%	99.4%	**99.6%**
40	94.9%	90.4%	90.5%	**91.9%**
60	78.9%	60.1%	72.6%	**70.5%**
80	78.9%	60.1%	72.6%	**70.5%**
100	4.7%	51.5%	57.0%	**37.7%**
120	4.7%	51.5%	57.0%	**37.7%**
140	3.7%	37.4%	44.2%	**28.4%**
160	3.7%	37.4%	44.2%	**28.4%**
180	2.9%	25.5%	34.3%	**20.9%**
200	2.9%	25.5%	34.3%	**20.9%**
220	2.4%	18.8%	26.8%	**16.0%**
240	2.4%	18.8%	26.8%	**16.0%**
260	1.9%	13.5%	21.3%	**12.2%**
280	1.9%	13.5%	21.3%	**12.2%**
300	1.6%	10.1%	17.2%	**9.6%**

	Soil Type 18	SP Height 130	SP Density 78	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.9%	99.4%	99.1%	**99.5%**
20	99.9%	99.4%	99.1%	**99.5%**
40	96.0%	92.0%	91.9%	**93.3%**
60	85.1%	69.1%	77.2%	**77.1%**
80	85.1%	69.1%	77.2%	**77.1%**
100	57.2%	53.4%	63.8%	**58.1%**
120	57.2%	53.4%	63.8%	**58.1%**
140	4.3%	47.4%	52.1%	**34.6%**
160	4.3%	47.4%	52.1%	**34.6%**
180	3.6%	35.3%	42.3%	**27.1%**
200	3.6%	35.3%	42.3%	**27.1%**
220	3.0%	25.9%	34.4%	**21.1%**
240	3.0%	25.9%	34.4%	**21.1%**
260	2.5%	19.9%	28.2%	**16.9%**
280	2.5%	19.9%	28.2%	**16.9%**
300	2.1%	16.1%	23.2%	**13.8%**

	Soil Type 18	SP Height 145	SP Density 78	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.9%	99.2%	98.8%	**99.3%**
20	99.9%	99.2%	98.8%	**99.3%**
40	96.4%	92.6%	92.3%	**93.8%**
60	87.3%	72.8%	79.1%	**79.7%**
80	87.3%	72.8%	79.1%	**79.7%**
100	68.6%	54.3%	66.8%	**63.2%**
120	68.6%	54.3%	66.8%	**63.2%**
140	4.7%	51.0%	55.8%	**37.2%**
160	4.7%	51.0%	55.8%	**37.2%**
180	3.9%	40.5%	46.4%	**30.2%**
200	3.9%	40.5%	46.4%	**30.2%**
220	3.3%	30.8%	38.4%	**24.2%**
240	3.3%	30.8%	38.4%	**24.2%**
260	2.8%	23.3%	32.0%	**19.4%**
280	2.8%	23.3%	32.0%	**19.4%**
300	2.4%	18.9%	26.7%	**16.0%**

	Soil Type 50/56	SP Height 70	SP Density 48	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.7%	98.6%	98.1%	**98.8%**
20	99.7%	98.6%	98.1%	**98.8%**
40	91.9%	82.9%	84.7%	**86.5%**
60	28.4%	51.9%	59.5%	**46.6%**
80	28.4%	51.9%	59.5%	**46.6%**
100	3.5%	33.3%	40.4%	**25.7%**
120	3.5%	33.3%	40.4%	**25.7%**
140	2.5%	19.6%	27.5%	**16.5%**
160	2.5%	19.6%	27.5%	**16.5%**
180	1.8%	11.9%	19.4%	**11.0%**
200	1.8%	11.9%	19.4%	**11.0%**
220	1.3%	8.7%	14.2%	**8.1%**
240	1.3%	8.7%	14.2%	**8.1%**
260	0.9%	7.0%	10.8%	**6.2%**
280	0.9%	7.0%	10.8%	**6.2%**
300	0.6%	5.7%	8.5%	**4.9%**

	Soil Type 50/56	SP Height 95	SP Density 48	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.4%	97.3%	96.1%	**97.6%**
20	99.4%	97.3%	96.1%	**97.6%**
40	93.9%	87.0%	86.2%	**89.1%**
60	73.7%	53.7%	66.7%	**64.7%**
80	73.7%	53.7%	66.7%	**64.7%**
100	4.4%	46.5%	50.2%	**33.7%**
120	4.4%	46.5%	50.2%	**33.7%**
140	3.4%	30.6%	37.4%	**23.8%**
160	3.4%	30.6%	37.4%	**23.8%**
180	2.6%	20.2%	28.0%	**16.9%**
200	2.6%	20.2%	28.0%	**16.9%**
220	2.1%	15.0%	21.3%	**12.8%**
240	2.1%	15.0%	21.3%	**12.8%**
260	1.6%	9.9%	16.6%	**9.4%**
280	1.6%	9.9%	16.6%	**9.4%**
300	1.3%	8.2%	13.2%	**7.6%**

	Soil Type 50/56	SP Height 105	SP Density 48	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.2%	96.5%	95.1%	**96.9%**
20	99.2%	96.5%	95.1%	**96.9%**
40	94.2%	87.4%	86.2%	**89.3%**
60	78.1%	57.2%	68.3%	**67.9%**
80	78.1%	57.2%	68.3%	**67.9%**
100	4.7%	48.6%	52.8%	**35.4%**
120	4.7%	48.6%	52.8%	**35.4%**
140	3.7%	34.8%	40.4%	**26.3%**
160	3.7%	34.8%	40.4%	**26.3%**
180	2.9%	23.5%	30.9%	**19.1%**
200	2.9%	23.5%	30.9%	**19.1%**
220	2.3%	17.2%	23.9%	**14.5%**
240	2.3%	17.2%	23.9%	**14.5%**
260	1.9%	12.3%	18.8%	**11.0%**
280	1.9%	12.3%	18.8%	**11.0%**
300	1.5%	9.1%	15.1%	**8.6%**

	Soil Type 50/56	SP Height 120	SP Density 48	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	98.6%	95.3%	93.5%	**95.8%**
20	98.6%	95.3%	93.5%	**95.8%**
40	94.3%	87.3%	85.6%	**89.1%**
60	81.9%	61.9%	69.9%	**71.2%**
80	81.9%	61.9%	69.9%	**71.2%**
100	41.1%	48.7%	55.8%	**48.5%**
120	41.1%	48.7%	55.8%	**48.5%**
140	4.0%	40.0%	44.0%	**29.4%**
160	4.0%	40.0%	44.0%	**29.4%**
180	3.3%	28.5%	34.7%	**22.1%**
200	3.3%	28.5%	34.7%	**22.1%**
220	2.7%	20.2%	27.4%	**16.8%**
240	2.7%	20.2%	27.4%	**16.8%**
260	2.2%	15.9%	22.0%	**13.4%**
280	2.2%	15.9%	22.0%	**13.4%**
300	1.9%	11.6%	17.8%	**10.4%**

	Soil Type 50/56	SP Height 185	SP Density 48	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	94.4%	88.9%	85.7%	**89.7%**
20	94.4%	88.9%	85.7%	**89.7%**
40	91.6%	83.8%	80.6%	**85.3%**
60	85.1%	69.8%	70.2%	**75.0%**
80	85.1%	69.8%	70.2%	**75.0%**
100	75.4%	52.4%	60.4%	**62.7%**
120	75.4%	52.4%	60.4%	**62.7%**
140	55.1%	43.8%	51.5%	**50.1%**
160	55.1%	43.8%	51.5%	**50.1%**
180	4.4%	41.5%	43.8%	**29.9%**
200	4.4%	41.5%	43.8%	**29.9%**
220	3.8%	34.1%	37.1%	**25.0%**
240	3.8%	34.1%	37.1%	**25.0%**
260	3.3%	27.1%	31.5%	**20.6%**
280	3.3%	27.1%	31.5%	**20.6%**
300	2.9%	21.5%	26.8%	**17.1%**

	Soil Type 50/56	SP Height 145	SP Density 48	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	97.3%	92.9%	90.6%	**93.6%**
20	97.3%	92.9%	90.6%	**93.6%**
40	93.7%	86.4%	84.1%	**88.0%**
60	84.6%	66.6%	70.8%	**74.0%**
80	84.6%	66.6%	70.8%	**74.0%**
100	66.1%	48.3%	58.7%	**57.7%**
120	66.1%	48.3%	58.7%	**57.7%**
140	4.6%	45.1%	48.1%	**32.6%**
160	4.6%	45.1%	48.1%	**32.6%**
180	3.8%	35.2%	39.3%	**26.1%**
200	3.8%	35.2%	39.3%	**26.1%**
220	3.2%	26.4%	32.1%	**20.6%**
240	3.2%	26.4%	32.1%	**20.6%**
260	2.7%	19.7%	26.4%	**16.3%**
280	2.7%	19.7%	26.4%	**16.3%**
300	2.3%	15.9%	21.8%	**13.3%**

	Soil Type 50/56	SP Height 190	SP Density 48	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	94.0%	88.4%	85.1%	**89.2%**
20	94.0%	88.4%	85.1%	**89.2%**
40	91.3%	83.4%	80.2%	**84.9%**
60	85.0%	70.0%	70.0%	**75.0%**
80	85.0%	70.0%	70.0%	**75.0%**
100	75.8%	53.0%	60.4%	**63.1%**
120	75.8%	53.0%	60.4%	**63.1%**
140	57.6%	43.6%	51.7%	**51.0%**
160	57.6%	43.6%	51.7%	**51.0%**
180	4.4%	41.3%	44.1%	**30.0%**
200	4.4%	41.3%	44.1%	**30.0%**
220	3.8%	34.8%	37.6%	**25.4%**
240	3.8%	34.8%	37.6%	**25.4%**
260	3.3%	27.8%	32.0%	**21.1%**
280	3.3%	27.8%	32.0%	**21.1%**
300	2.9%	22.2%	27.3%	**17.5%**

	Soil Type 50/56	SP Height 160	SP Density 48	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	96.3%	91.4%	88.7%	**92.1%**
20	96.3%	91.4%	88.7%	**92.1%**
40	93.1%	85.5%	82.8%	**87.1%**
60	85.2%	68.3%	70.8%	**74.8%**
80	85.2%	68.3%	70.8%	**74.8%**
100	71.4%	48.1%	59.7%	**59.7%**
120	71.4%	48.1%	59.7%	**59.7%**
140	19.3%	44.7%	49.8%	**37.9%**
160	19.3%	44.7%	49.8%	**37.9%**
180	4.0%	38.4%	41.4%	**27.9%**
200	4.0%	38.4%	41.4%	**27.9%**
220	3.4%	29.7%	34.3%	**22.5%**
240	3.4%	29.7%	34.3%	**22.5%**
260	2.9%	22.7%	28.6%	**18.1%**
280	2.9%	22.7%	28.6%	**18.1%**
300	2.5%	17.7%	23.9%	**14.7%**