Appendix 1
Supplemental Data and Analysis

A. Climate considerations

Air temperature has been shown to have a strong association with stream temperature with stream temperature approaching equilibrium air temperature on a weekly time scale in large basins (Sullivan and Adams 1990; Sinokrot and Stefan 1993; Mohseni and Stefan 1999). The lowest stream temperatures are observed in source areas and are associated with the emergent groundwater temperature. Some researchers suggest that the emergent groundwater temperature will correspond to the mean annual air temperature (Bartholow 1989) while another source (Mohseni and Stefan 1999) indicates that groundwater temperature is 1-2°C higher than the mean annual temperature of a region. The temperature data from the Umpqua basin as well as local well logs indicates that the emergent groundwater in the central Umpqua Basin is in the 52-54 °F range.

A.1 Mean annual temperature

Table 1 below, contains state-wide data that was obtained from the state climate site at www.ocs.orst.edu. It should be noted that air temperature data from urban areas may be higher than that from the surrounding rural areas. The EPA Global Warming web site indicates that urban air can be 2-10 °F hotter than the surrounding countryside. The context of the report suggests that this temperature change is associated with maximum summer temperatures. The effect of urban heating on the mean annual temperature is thought to be in the range of 1-2°F. (Bruce and Clark 1966; Linsley, Kohler et al. 1975).

Table 1

Rank	Zone	Station	Annual Mean
1	Zone 7	Dayville	56.6
2	Zone 3	Grants Pass	55.1
3	Zone 6	The Dalles	55.0
4	Zone 1	Elkton	54.7
5	Zone 2	Portland KGW	54.5
6	Zone 6	Arlington	54.4
7	Zone 2	Oregon City	54.2
8	Zone 3	Roseburg KQEN	54.2
9	Zone 3	Riddle	54.0
10	Zone 3	Medford WSO	53.9
11	Zone 1	Brookings	53.8
12	Zone 2	St Helens	53.6
13	Zone 1	Powers	53.5
14	Zone 2	Portland WSO	53.5
15	Zone 6	Milton-Freewater	53.5
16	Zone 3	Ruch	53.4
17	Zone 1	Gold Beach	53.2
18	Zone 1	Tidewater	53.2
19	Zone 1	Port Orford	53.1
20	Zone 3	Cave Junction	53.1
21	Zone 3	Drain	53.1
22	Zone 3	Medford Exp. St.	52.9
23	Zone 2	Bonneville Dam	52.8
24	Zone 4	McKenzie Bridge	52.8
25	Zone 2	Forest Grove	52.7
26	Zone 2	Eugene WSO	52.6
27	Zone 1	North Bend	52.5
28	Zone 2	Leaburg	52.5
29	Zone 6	Hermiston	52.5
30	Zone 8	Huntington	52.4
31	Zone 2	Silverton	52.3
32	Zone 3	Lost Creek Dam	52.3
33	Zone 6	Pendleton WSO	52.3
34	Zone 2	Hillsboro	52.2
35	Zone 2	N. Willamette Exp. St.	52.2
36	Zone 3	Ashland	52.2
37	Zone 8	Richland	52.2
38	Zone 2	Dallas	52.1
39	Zone 2	Foster Dam	52.1
40	Zone 2	Salem WSO	52.1
41	Zone 2	Corvallis	52.0
42	Zone 2	Headworks	52.0
43	Zone 1	Honeyman	51.9
44	Zone 2	Estacada	51.9
45	Zone 1	Bandon	51.8
46	Zone 1	Cloverdale	51.8
47	Zone 2	Cottage Grove	51.8
48	Zone 1	Seaside	51.7
49	Zone 3	Idelyld Park	51.6
50	Zone 9	Owyhee Dam	51.6
51	Zone 9	Ontario	51.5
52	Zone 2	Lacomb	51.4
53	Zone 4	Oakridge	51.4
54	Zone 9	Vale	51.1
55	Zone 4	Detroit Dam	51.0
56	Zone 9	Nyssa	51.0
57	Zone 1	Astoria	50.9
58	Zone 2	Corvallis Water Bureau	50.9
59	Zone 6	Pilot Rock	50.9
60	Zone 3	Prospect	50.8
61	Zone 1	Otis	50.7
62	Zone 3	Toketee Falls	50.7
63	Zone 6	Heppner	50.7
64	Zone 1	Newport	50.5
65	Zone 6	Hood River	50.5
66	Zone 9	Malheur Exp St	50.5
67	Zone 1	Tillamook	50.4
68	Zone 2	Cascadia	50.3
69	Zone 8	Monument	50.1
70	Zone 4	Three Lynx	49.7
71	Zone 9	Burns Junction	49.6
72	Zone 2	Silver Creek	49.5
73	Zone 7	Adel Lake	49.5
74	Zone 7	Andrew Weston Mine	49.5
75	Zone 6	Dufur	49.4
76	Zone 9	Beulah	49.2
77	Zone 9	Rome	49.0
78	Zone 6	Antelope	48.8
79	Zone 6	Moro	48.8
80	Zone 9	Riverside	48.8
81	Zone 6	Pine Grove	48.7
82	Zone 8	John Day	48.6
83	Zone 5	Summer Lake	48.5
84	Zone 8	La Grande	48.5
85	Zone 9	Westfall	48.4
86	Zone 9	Danner	48.3
87	Zone 4	Belknap Springs	48.2
88	Zone 9	Mc Dermitt	48.1
89	Zone 8	Elgin	47.9
90	Zone 6	Kent	47.7
91	Zone 9	Ironside	47.6
92	Zone 7	Alkali Lake	47.5
93	Zone 6	Condon	47.4
94	Zone 7	Fossil	47.3
95	Zone 7	Double O	47.2
96	Zone 7	Drewsey	46.7
97	Zone 8	Cove	46.7
98	Zone 8	Halfway	46.3
99	Zone 4	Marion Forks	46.2
100	Zone 7	Bend	46.2
101	Zone 8	Baker	45.9
102	Zone 9	Sheaville	45.7
103	Zone 8	Long Creek	45.6
104	Zone 7	Barnes	45.4
105	Zone 7	Grizzly	45.1
106	Zone 7	Burns	44.9
107	Zone 4	Santiam Junction	44.3
108	Zone 7	Hart Mtn Refuge	44.1
109	Zone 7	Chiloquin	43.9
110	Zone 5	Wickiup Dam	43.7
111	Zone 7	Brothers	43.4
112	Zone 8	Enterprise	42.0
113	Zone 4	Government Camp	41.9
114	Zone 5	Fremont	41.7
115	Zone 5	Odell Lake E	40.3
116	Zone 8	Austin	40.3
117	Zone 8	Seneca	39.9
118	Zone 5	Crater Lake	37.4

A.2 Mean August temperatures

The state climate site also provides data for the monthly mean air temperatures. Table 2 shows state-wide data for the month of August when streams often reach their warmest temperatures. The urban effect error associated with these values may be higher than the error expected for the annual mean since the urban effect is apparently more pronounced during the summer.

Rank	Zone	Station	August Mean
1	Zone 8	Huntington	76.70
2	Zone 6	Arlington	75.30
3	Zone 9	Ontario	73.90
4	Zone 6	The Dalles	73.50
5	Zone 9	Vale	73.20
6	Zone 9	Nyssa	72.90
7	Zone 8	Richland	72.90
8	Zone 6	Milton-Freewater	72.90
9	Zone 9	Malheur Exp St	72.80
10	Zone 3	Medford WSO	72.10
11	Zone 9	Owyhee Dam	72.00
12	Zone 6	Pendleton WSO	72.00
13	Zone 6	Hermiston	71.80
14	Zone 7	Andrew Weston Mine	71.50
15	Zone 9	Westfall	71.40
16	Zone 7	Dayville	71.30
17	Zone 3	Grants Pass	71.30
18	Zone 9	Burns Junction	70.60
19	Zone 9	Beulah	70.10
20	Zone 9	Rome	69.60
21	Zone 9	Riverside	69.50
22	Zone 6	Pilot Rock	69.50
23	Zone 3	Medford Exp. St.	69.50
24	Zone 9	Ironside	69.40
25	Zone 3	Ruch	69.40
26	Zone 3	Roseburg KQEN	69.20
27	Zone 8	Monument	69.10
28	Zone 3	Lost Creek Dam	69.10
29	Zone 8	La Grande	68.70
30	Zone 6	Heppner	68.70
31	Zone 3	Ashland	68.70
32	Zone 2	Portland KGW	68.70
33	Zone 3	Cave Junction	68.50
34	Zone 2	Oregon City	68.50
35	Zone 2	Portland WSO	68.50
36	Zone 2	St Helens	68.40
37	Zone 9	Mc Dermitt	68.20
38	Zone 7	Adel Lake	68.10
39	Zone 3	Riddle	68.10
40	Zone 1	Elkton	68.00
41	Zone 2	Bonneville Dam	67.70
42	Zone 6	Kent	67.60
43	Zone 8	John Day	67.50
44	Zone 3	Toketee Falls	67.50
45	Zone 2	Forest Grove	67.50
46	Zone 6	Antelope	67.40
47	Zone 6	Pine Grove	67.40
48	Zone 5	Summer Lake	67.10
49	Zone 6	Moro	67.00
50	Zone 2	Eugene WSO	67.00
51	Zone 9	Sheaville	66.90
52	Zone 3	Prospect	66.90
53	Zone 8	Halfway	66.80
54	Zone 4	McKenzie Bridge	66.80
55	Zone 7	Drewsey	66.70
56	Zone 3	Drain	66.70
57	Zone 9	Danner	66.60
58	Zone 6	Hood River	66.60
59	Zone 2	Salem WSO	66.60
60	Zone 2	Silverton	66.50
61	Zone 8	Elgin	66.40
62	Zone 6	Dufur	66.40
63	Zone 2	Leaburg	66.40
64	Zone 4	Oakridge	66.20
65	Zone 2	Corvallis	66.20
66	Zone 2	N. Willamette Exp. St.	66.20
67	Zone 2	Hillsboro	66.10
68	Zone 7	Alkali Lake	66.00
69	Zone 6	Condon	65.90
70	Zone 4	Detroit Dam	65.90
71	Zone 8	Baker	65.80
72	Zone 2	Dallas	65.80
73	Zone 2	Headworks	65.70
74	Zone 7	Double O	65.40
75	Zone 2	Estacada	65.40
76	Zone 3	Idelyld Park	65.30
77	Zone 2	Foster Dam	65.20
78	Zone 2	Corvallis Water Bureau	64.80
79	Zone 2	Cottage Grove	64.70
80	Zone 1	Powers	64.70
81	Zone 7	Burns	64.50
82	Zone 7	Fossil	64.50
83	Zone 4	Belknap Springs	64.50
84	Zone 2	Lacomb	64.40
85	Zone 4	Three Lynx	64.30
86	Zone 8	Cove	64.00
87	Zone 1	Tidewater	64.00
88	Zone 2	Cascadia	63.80
89	Zone 7	Barnes	63.60
90	Zone 8	Long Creek	63.00
91	Zone 7	Bend	62.70
92	Zone 4	Marion Forks	62.40
93	Zone 7	Grizzly	62.10
94	Zone 2	Silver Creek	62.10
95	Zone 7	Hart Mtn Refuge	61.90
96	Zone 7	Chiloquin	61.10
97	Zone 5	Wickiup Dam	61.00
98	Zone 7	Brothers	60.90
99	Zone 1	Astoria	60.90
100	Zone 1	Cloverdale	60.70
101	Zone 1	Otis	60.50
102	Zone 1	Port Orford	60.40
103	Zone 1	Seaside	60.40
104	Zone 1	Gold Beach	60.10
105	Zone 1	North Bend	60.10
106	Zone 1	Honeyman	60.00
107	Zone 8	Austin	59.90
108	Zone 1	Brookings	59.80
109	Zone 5	Fremont	59.60
110	Zone 1	Tillamook	59.00
111	Zone 4	Santiam Junction	58.80
112	Zone 1	Bandon	58.70
113	Zone 8	Enterprise	58.10
114	Zone 8	Seneca	57.90
115	Zone 1	Newport	57.60
116	Zone 4	Government Camp	57.20
117	Zone 5	Odell Lake E	57.00
118	Zone 5	Crater Lake	54.40

Table 2

Part of the Umpqua Stream Characterization project involves air and water temperature data collection from five riparian references sites on tributary sized streams that are distributed across the central basin. These data make possible a direct comparison with the state climate stations.

Table 3

Year	Mean August Air Temperatures State Data °F					Mean August Air Temperatures UBWC Data °F				
	Roseburg	Winchester	Riddle	Tokatee	Elkton	Camp Ck	Pass Ck	Calapooya	N Myrtle	Windy
2000	70.06	68.11	67.95	66.74	67.40	63.51	64.47	65.38	67.98	62.88
2001	70.74	68.29	69.56	68.74	66.69	63.18	64.88	66.26	69.05	63.98
2002	71.02	68.81	68.26	66.10	67.50	62.88	65.57	66.39	67.28	61.98

It should be noted that the N Myrtle and Pass Creek riparian sites are in urban areas. The data from Myrtle Creek is thought to be influenced by an adjacent road fill that receives more summer heat. It is apparent that the mean August riparian temperatures tend to be in the sixty degree range. Based on the discussion above, the mean monthly stream temperature should approach this figure for streams that are sufficiently far from the watershed divide. The daily maximum stream temperature and the maximum 7DADM value would typically be somewhat above this value.

B. Interaction: Radiation, Air and Water

Air temperature has been identified as an important component of the stream heating process in the Umpqua Basin (See Appendix 2:H.). On small streams it influences the rate of heating that occurs as the channel widens. In large streams it coincides with the threshold temperature (See Appendix 2:G.3 and I.1).

It is common knowledge that the sun is the ultimate source of essentially all of the energy that we experience on this planet. Likewise, it is the motion of the earth relative to the sun that results in the reception of different levels of energy thus causing seasonal and diurnal variations in the amount of heat affecting the environment.

Since air has very different thermal characteristics than soil, rock, vegetation and water, it responds to changes more rapidly. Typically during heating and cooling periods, air temperature changes more rapidly than the rest of the environment. This effect is noticeable on both the daily and seasonal time scale. As a result, using instantaneous values typically requires some sort of time adjustment. However, this effect can also be reduced or eliminated by using mean values over a longer time period such as a week or month (Mohseni and Stefan 1999).

B.1 Interaction at different time scales

Monthly data

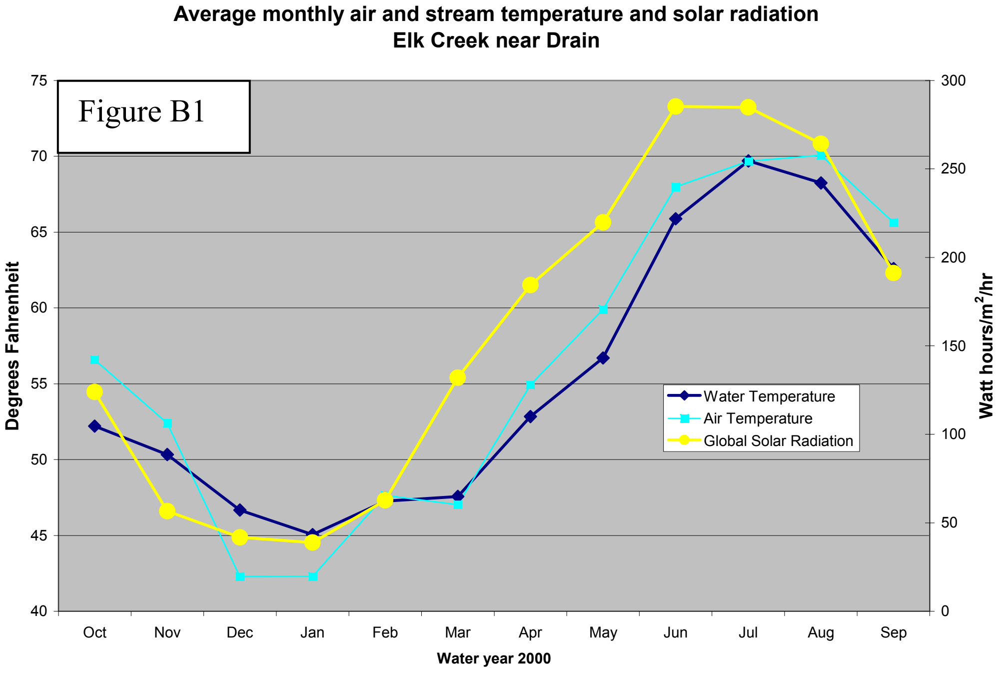


Figure B1 shows typical monthly data over a one year period for a medium sized stream (19 miles to watershed divide). Note that the air temperature generally responds more rapidly to changes in the solar radiation than the water. However, on an annual basis, the mean value of the air and the water temperatures are similar. Surface temperatures respond to the diurnal and seasonal extremes, but below the surface, this temperature fluctuation dampens out to the annual mean value. This is the reason that groundwater temperatures are similar to the mean annual air temperature.

Daily Data

Figure B2 shows instantaneous values of August air and water temperature and radiation. The chart indicates that the periods of low radiation caused by cloud cover do correspond with lower temperature periods. The seasonal temperature patterns are also affected by the moving air mass which does not necessarily obstruct radiation. Water temperatures are also influenced by wind speed and the dew point.

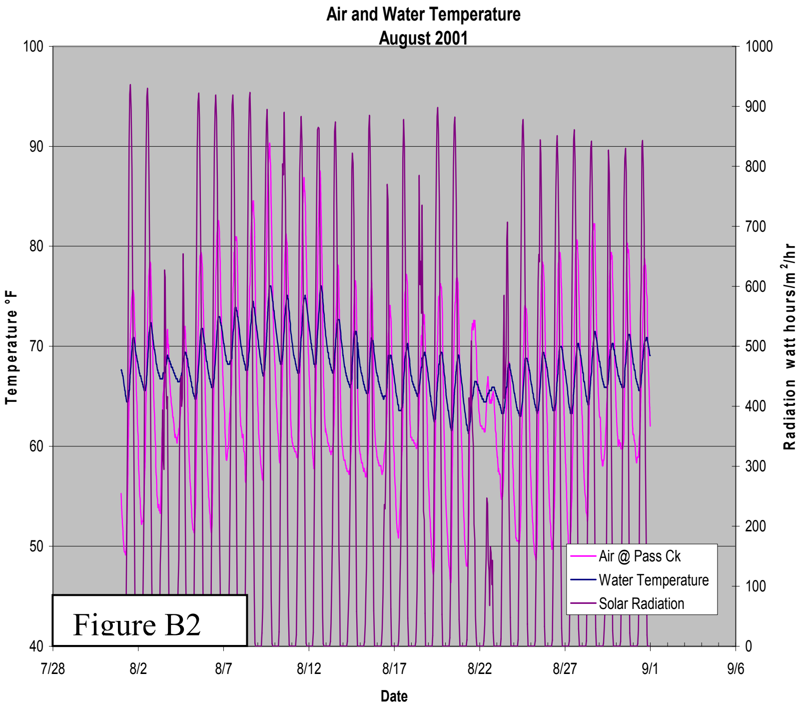
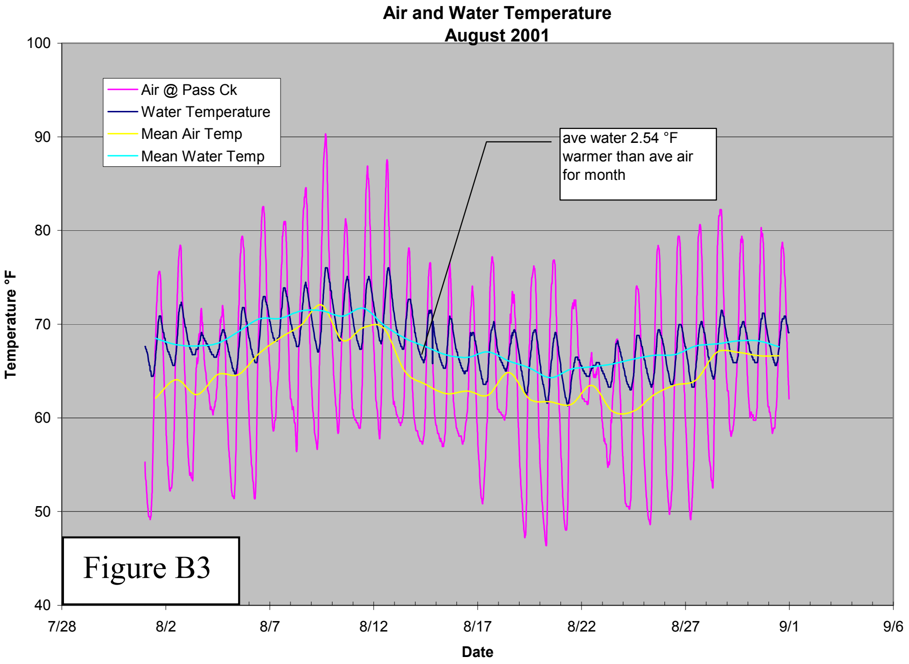


Figure B2

Note: that the daily radiation pattern shows a declining trend over the month as expected for August.

Note 2: Relationship between radiation and temperature. Consecutive days of high radiation tend to produce higher stream temperatures. However, the day of exceptionally low radiation on 8/23 did not produce low night temperatures. A possible explanation: the overcast night sky reduced night time long-wave radiant heat loss to space.

Figure B3 shows the same temperature data with the mean daily values added.



ave water 2.54 °F warmer than ave air for month

Figure B3

Note that the mean air value tends to rise and fall faster than the mean water temperature - a direct result of the differences in thermal properties. However, on a monthly average, it appears that air temperature is about 2.5 °F lower than average water temperature in August for this site which is located about 13 miles from the watershed divide. A possible explanation is that the water temperature is the result of the effective local environment and the air temperature represents only one point in the area. For example, the stream may be experiencing some direct solar input that is not reaching the shaded air temperature unit.

Hourly Data

Figure B4 shows the same data over a two day cycle. Note again, that the radiation changes more rapidly than the air, which is more responsive than the water. It is instructive to note that the maximum water temperature corresponds with a point far down on the declining limb of the radiation curve. This is the point where heat losses from the water start to exceed the net heat input.

B.2 Thermal equilibrium

An object will tend to reach a temperature that is in equilibrium with the temperature of its environment over a period of time, at which point the net heat exchange becomes zero and the temperature remains constant. However, if the temperature of the environment keeps changing, the temperatures of the objects in the environment will also change.

Research indicates that at the moderate temperature range (32-68°F) stream equilibrium temperatures tend to change linearly with air temperatures with a slope close to one. At higher temperatures the water temperature increases at a slower rate due to increases in surface evaporation (Mohseni and Stefan 1999). It has been observed that, in the Pacific Northwest, an “equilibrium threshold” point tends to occur between 40 to 60 km (25 to 37 miles) from the watershed divide (Sullivan and Adams 1990).

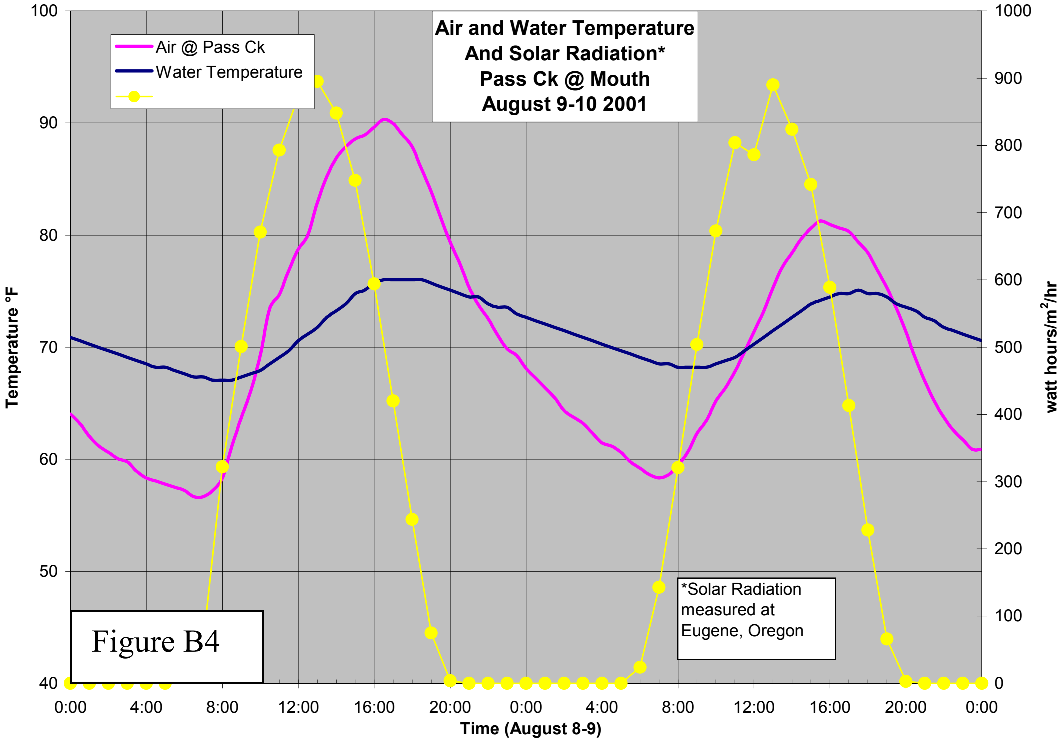


Figure B4

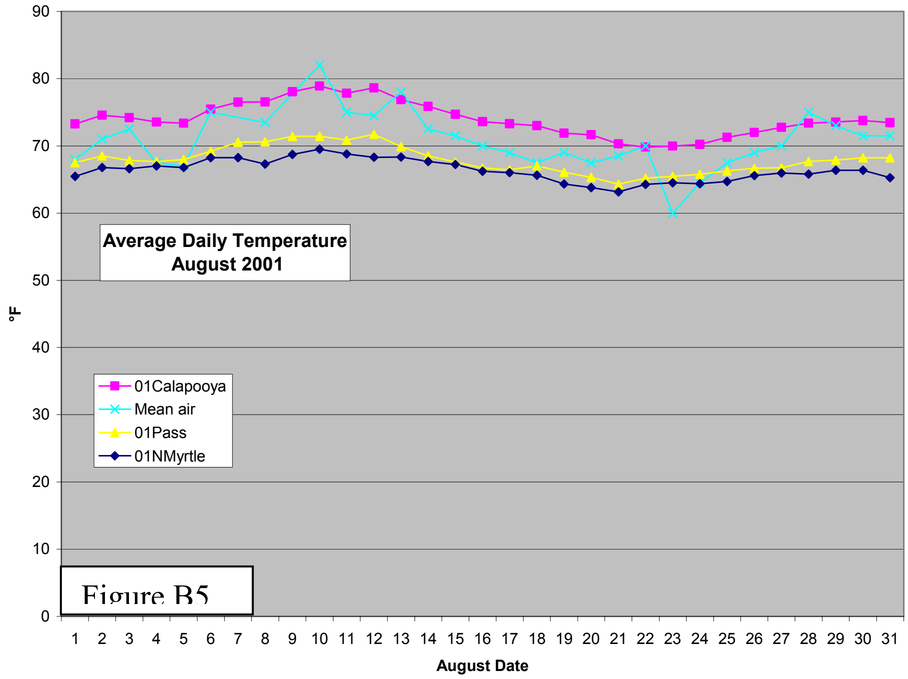


Figure B5

Figure B5 shows average August temperatures for three streams and average daily air temperature as measured at the Roseburg climatological station. The distances from the watershed divide and the corresponding "Cold Limit" values (Figure 3, main document) are:

Creek	Distance from divide (miles)	"Cold Limit" value
Pass Creek	13.3	67.4 °F
North Myrtle Creek	18.3	68.9 °F
Calapooya Creek	28.5	71.0 °F

The data shows that, under current conditions, the Umpqua stream temperature pattern is consistent with the temperature threshold concept and that these streams are near their cold water limit value at these locations. If this threshold point represents the environmental equilibrium value then, under typical conditions, bulk stream temperatures will not be lower than this threshold value. Exceptions would involve atypically large groundwater contributions. Streams significantly above the cold limit line are experiencing atypical thermal loading.

B.3 Air temperature in buffer strips

It has been shown that the microclimate in a riparian area can affect (See Appendix 2:H.2). However, there hasn't been much work comparing the microclimate of a buffered stream with an unharvested area. It has been shown that, in western Washington forests, air temperatures tend to be slightly cooler on the bank compared to temperatures 15-25 meters upslope perpendicular to the bank (Sullivan, Tooley et al. 1990). The evaporation of the surface and of the saturated soils probably contributes to this effect. The differences observed were higher (2% vs. 1%) in exposed areas with no buffer. This is consistent with the fact that evaporative cooling effects become more pronounced with higher temperatures (Mohseni and Stefan 1999).

In areas that had buffers, the air temperatures in the harvest area beyond the buffer were typically 15% higher ((Sullivan, Tooley et al. 1990).

Figure B6 shows the results of a study from the Six Rivers National Forest that measured air temperatures and relative humidity above the stream as a function of the buffer width over the course of a summer (Ledwith 1996). These results represent only one scenario and may vary with different conditions. However, they do suggest that a forested microclimate can be influenced to some extent for a distance of over 100 meters from an opening. Unfortunately this study does not provide any corresponding stream temperature data or details about the layout of the study or the condition/ composition of the buffers.

Additional information is needed on the inter-relationship between the buffer, the local microclimate, and stream temperature in order to specify riparian areas with an optimum thermal environment.

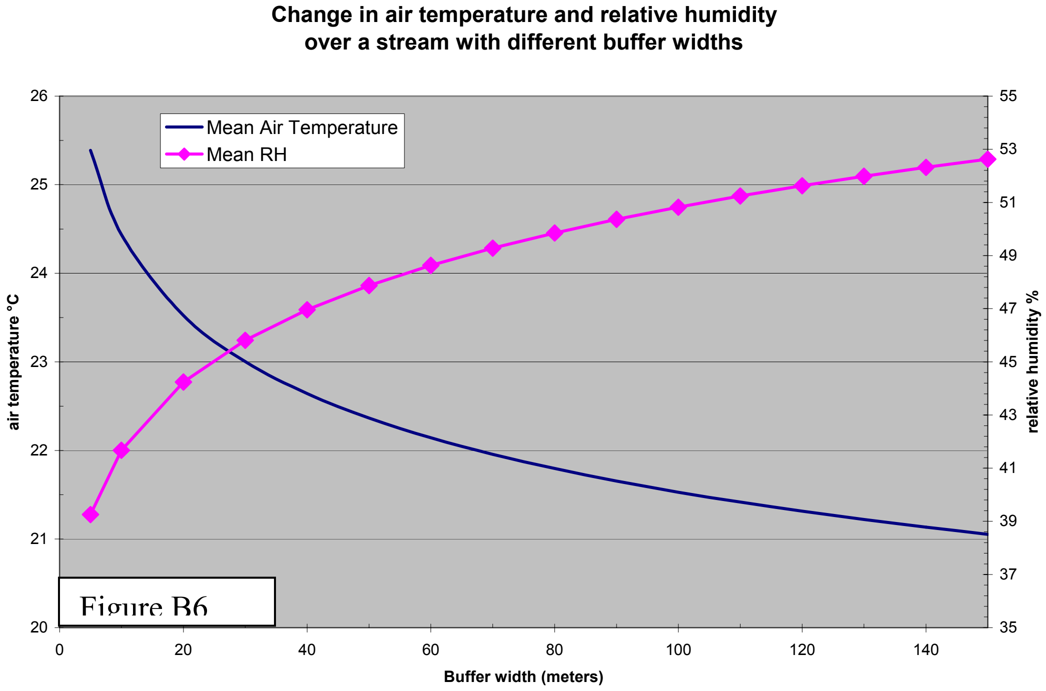


Figure B6

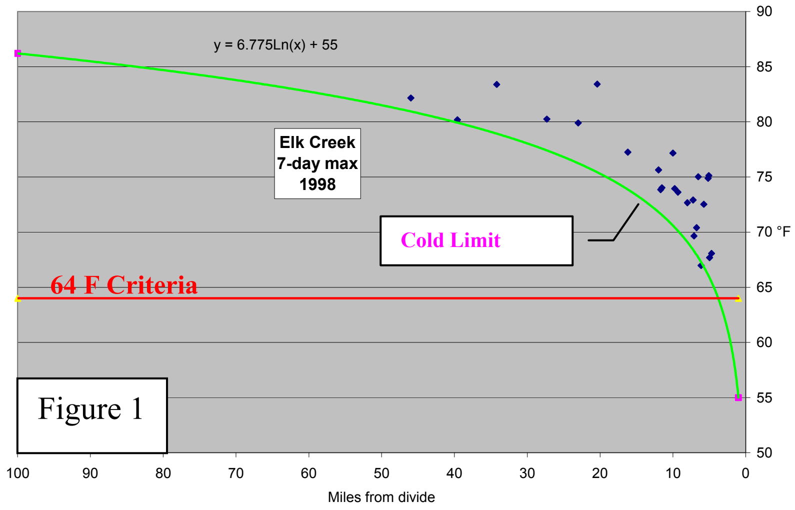
C. Spatial distribution of maximum 7DADM Values in the Umpqua Basin:

The objective of this analysis is to observe how the maximum 7DADM statistic varies spatially across Umpqua Basin. This statistic was chosen because it is directly related to the state water quality temperature standard. A similar analysis can be done using other statistics which may have somewhat different results.

Table 1

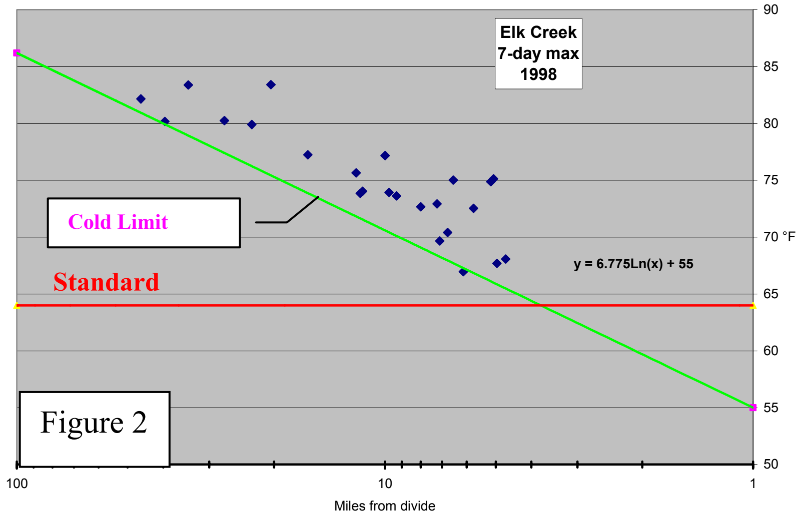
PassCreek	7DADM
1998	77.2
1999	73.3
2000	74.5
2001	74.8
2002	74.9

Data were used from 269 sites collected between 1998 and 2002. Data from Pass creek at Drain, Oregon, were collected every year (Table 1) and used to make seasonal adjustments.



C.1 1998 Elk Creek

Figure 1 shows the distribution of the various 7DADM values from the data collected in Elk Creek in 1998 plotted against the distance to the watershed divide. Note that the divide is on the right and the stream is flowing left (west). Note also that sites on different tributaries will have different source points. The curved line (Cold Limit Line) was fit to the lower edge of the data cluster to represent the theoretical expected temperature under optimal conditions (See Appendix 2:G.3 and I.1 for details). In a real watershed there are local differences in the conditions that are less than optimal and affect the local net thermal exchange, causing the local temperature to increase into the zone between the Cold Limit Line and the air temperature which is, in this case, about 83°F at Elkton. Also, if a data logger is placed directly in a groundwater inflow point, the temperature recorded at the point will be lower but it may not represent the ambient (bulk) temperature of the stream.



The equation of the Cold Limit Line is shown for reference. The horizontal line at 64°F provides a reference for the temperature criterion.

Figure 2 shows the same data plotted on a logarithmic scale. This scale has the advantage of making the distribution of the data cluster clearer and the Cold Limit Line linear.

C.2 1999 Calapooya Creek data

Figure 3 shows the same type of chart for Calapooya Creek. The 1998 logarithmic Cold Limit Line from Elk Creek was adjusted for seasonal variation by using the 7DADM data for the reference site at Pass Creek.

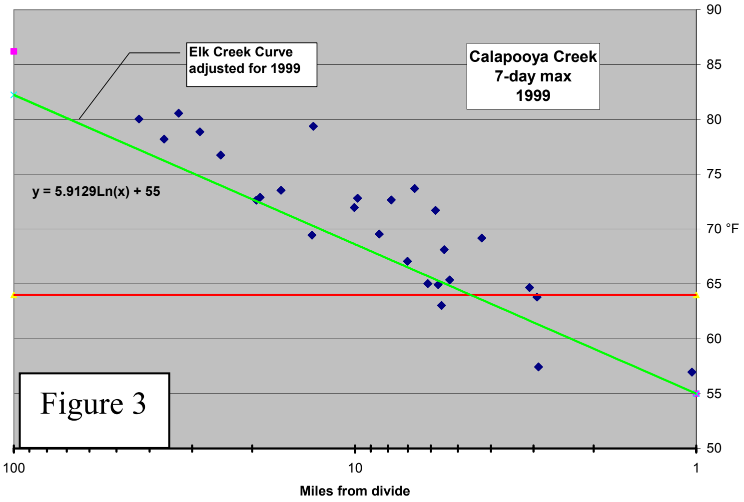


Figure 3

It appears that the Calapooya pattern is very similar to that of Elk Creek. The outliers are points of interest. The point @ (2.9 miles, 57°F) indicates a strong local water influence such as a source spring. These areas are generally small and are not typically monitored (See appendix 2:G.1).

The point at (5.6 miles, 63°F) is at the mouth of Dodge Canyon. It was found in the study that flows out of canyon areas were frequently cooler. This effect may be the result of a larger groundwater inflow associated with the canyon feature (See Appendix 2:E.3), lower local groundwater temperature, topographic shading, different wind patterns, bed composition etc. The point is that this outlier is associated with significantly different geologic and topographic conditions which can result in a different response curve.

C.3 1999 South Umpqua data

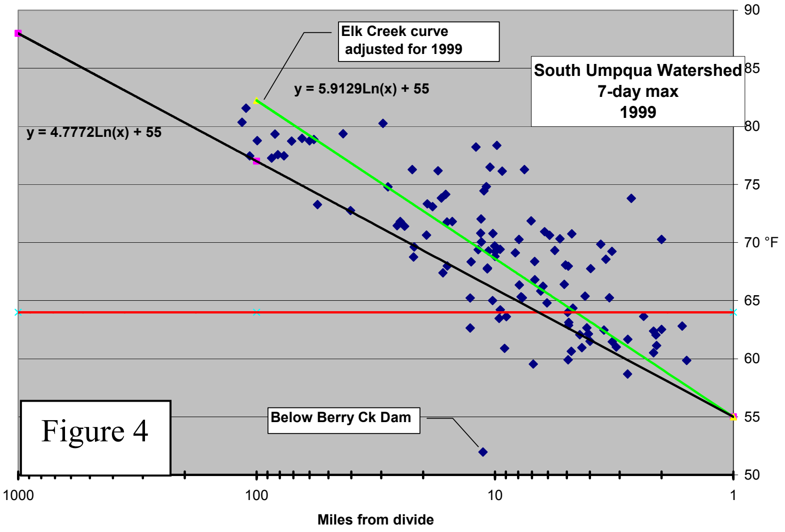


Figure 4

Figure 4 shows the 1999 data for the South Umpqua River and many of its tributaries. A reference curve for the South Umpqua was drawn and the Elk Creek curve, adjusted for the 1999 pattern is also shown. Note that the South Umpqua has the surprising result of having some areas with a cooler spatial thermal response than the previous streams. A preliminary explanation is that geological differences such as large alluvial deposits have produced watersheds with deeper soils and lower stream gradients which tend to be better sources of cold water inflow.

Many of the points below the Cold Limit Line in this chart are Forest Service sites on headwater streams for the S. Umpqua and Cow Creek. These are high elevation sites with characteristics that are not found in the lower basin. However, the watershed also has many warm streams. This is a very large watershed (1820 square miles) and further analysis may identify distinct sub areas with individual spatial temperature response properties.

Note that the output from the Berry Creek reservoir supplies cold water into the Lookingglass Creek system.

C.4 2000 Main Umpqua data

Figure 5 shows a similar pattern for the Main Umpqua watershed which includes the Mill Creek system. The curve from the South Umpqua appears to match the data fairly well.

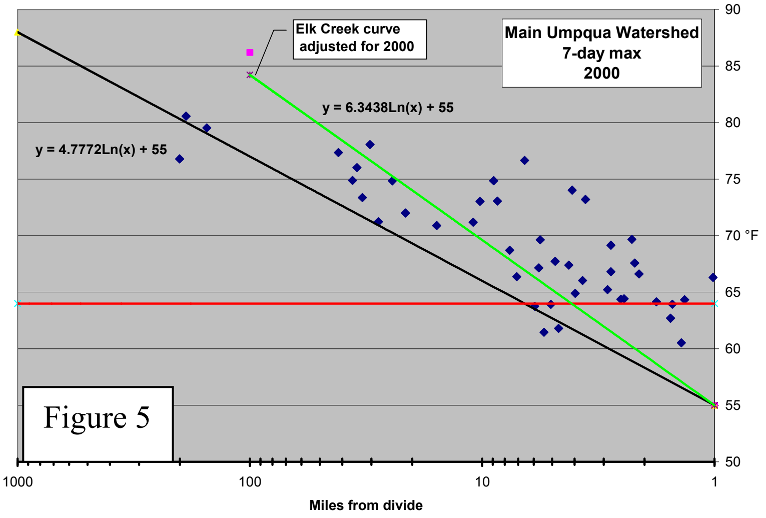


Figure 5

C.5 2000 Cow Creek data

Figure 6 shows 2000 data from the Cow Creek watershed. The logarithmic curves from Elk Creek and the Main Umpqua are shown for reference.

The pattern for Cow Creek is more complex since points past twenty miles are strongly influenced by the Galesville Dam. From this data, it appears that the effect of Galesville persisted in a diminishing manner about 15 miles downstream. This effect is due to the colder temperature of the released water as well as the much larger quantity of water and the faster downstream movement.

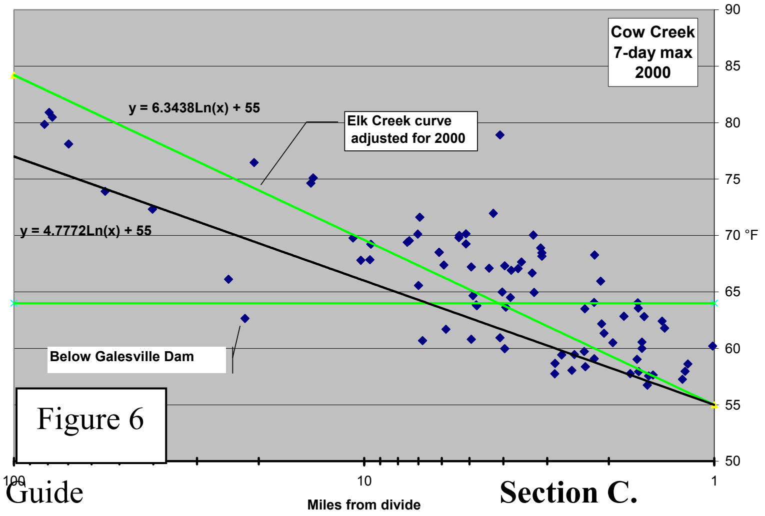


Figure 6

Most of the sites in the less than 10 mile range that are below the Cold Limit Line are the same sites identified in the South Umpqua 1999 study.

C.6 2001 Lower North Umpqua data

Figure 7 shows 2001 data from the Lower North Umpqua watershed (Below Rock Creek). The tributaries sampled include Sutherlin Creek. The data from the tributaries show a consistency with the other watersheds. The sites greater than 50 miles from the divide are on the North Umpqua River and may indicate a distinctive pattern for the North Umpqua. If the Rock Creek value is representative, then it appears that the river was still exceptionally cold at that point but proceeded to heat very rapidly at points downstream. The river is recognized as being unique (Duncan 2002) due in part to its high summer flows coming from large aquifers in the Diamond Lake area. More data needs to be obtained to verify this scenario.

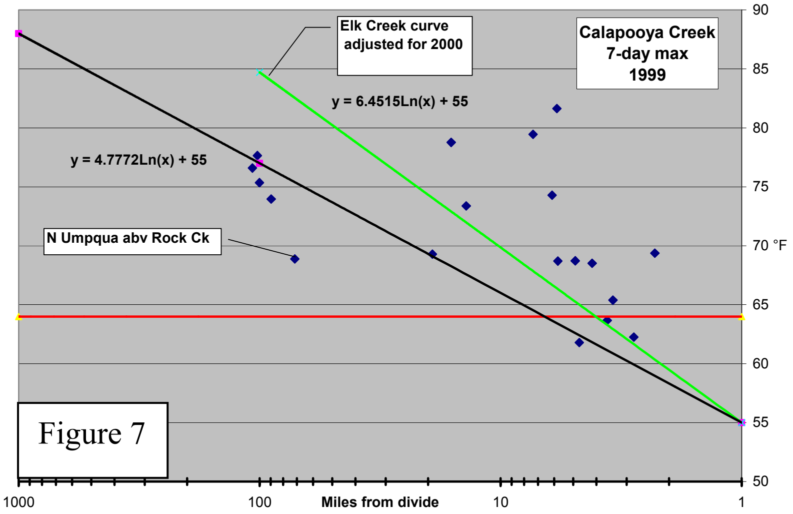


Figure 7

C.7 2002 Hinkle Creek data

The studies from 1998 through 2001 used extensive sampling to partially characterize large watersheds. In 2002 a project concentrated the stream temperature sampling to two headwater watersheds in Hinkle Creek, a tributary of Calapooya Creek. Most of the sites were within two miles of the watershed divide and several of the tributaries had multiple measurements that yielded individual profiles. Figure 8 shows 7DADM results from the project area along with some downstream data to provide a perspective. It is apparent that the response on lower Hinkle Ck and the Calapooya is similar to the 1999 study.

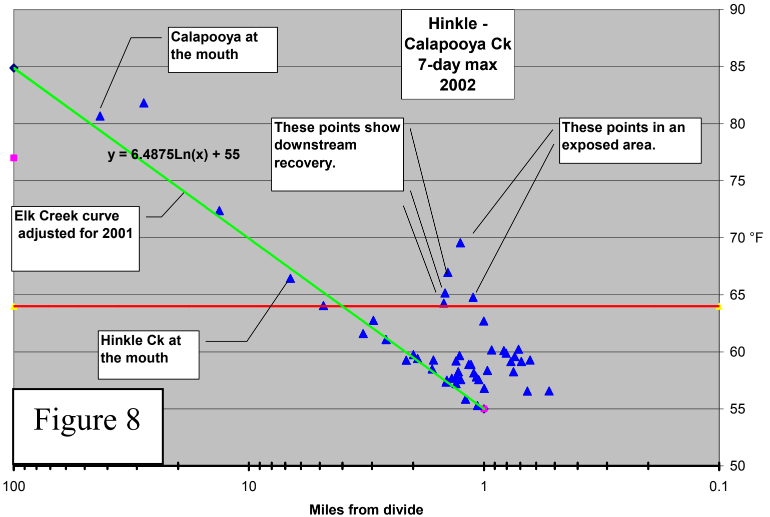


Figure 8

Most of the streams sampled in the Hinkle Creek area were well forested and had ample shade with one exception. A temperature profile was established for a small, non fish bearing stream that passed through a recent timber harvest unit. Three data loggers were placed in the unit. The middle unit recorded the peak value and the lower unit, which had some shade from brush and slash, showed a reduced value. The profile continued to drop as the stream returned to a wooded condition. As shown on the chart, the temperatures rose rapidly about 8°F within the unit and then proceeded to recover to pre-exposure levels. This 8°F peak and subsequent downstream recovery in a heavily-shaded reach is consistent with numerous other studies that monitored the effects of timber harvest on stream temperature.

The clustering of data around the one-mile point shows the limitation of using the "mile from divide" as a surrogate for stream size. At points close to the divide, the distance should be measured from the point of flow emergence because that is the point where the surface water begins to heat. This emergent point tends to move downstream as the drought season progresses and an accurate measurement would require a great deal of field work (See Appendix 2:E.1). As a result, the distance to the watershed divide metric isn't particularly useful at this scale for comparing one tributary against another. However, the example shows that, for larger distances, the results are consistent with the other studies.

C.8 2002 Hinkle Creek project– general results

Preliminary Analysis Report
Hinkle Creek Stream temperature
2002

Kent Smith
InSight Consultants

In July of 2002, forty-five Vemco data loggers, sampling at 30-minute intervals, were placed in the headwaters of Hinkle Creek as part of an extensive study of the local aquatic ecosystem led by Roseburg Forest Products (see attached map). Twenty-four of the units were placed in locations designed to provide overall pretreatment calibration data for a pair of watersheds; one control and one pretreatment. The remaining twenty-one units were placed in the treatment watershed to establish local pretreatment temperature profiles in individual tributaries. One set of sites included three placements in a recent harvest unit (2001) that showed a distinctive rise and recovery pattern. The supplemental study had the added benefit of providing detailed synoptic profiles from several tributaries in the same area.

Data from an ongoing project by the Umpqua Basin Watershed Council (UBWC) were available to provide a watershed and basin context to the Hinkle Creek Data.

Temporal Variation

Past work from the UBWC study has shown that an annual characteristic summer seasonal pattern is typically apparent on all of the stream temperature data in the central Umpqua basin.

The top chart in Figure 1 shows 2002 downstream data from the Oakland area. The middle chart is from the mouth of the treatment watershed and the lower chart is representative of data from the upper reaches of the control watershed.

Note the diminishing amplitude of the diurnal variation and the persistence of the seasonal pattern. Also, while the Hinkle Creek data loggers were deployed

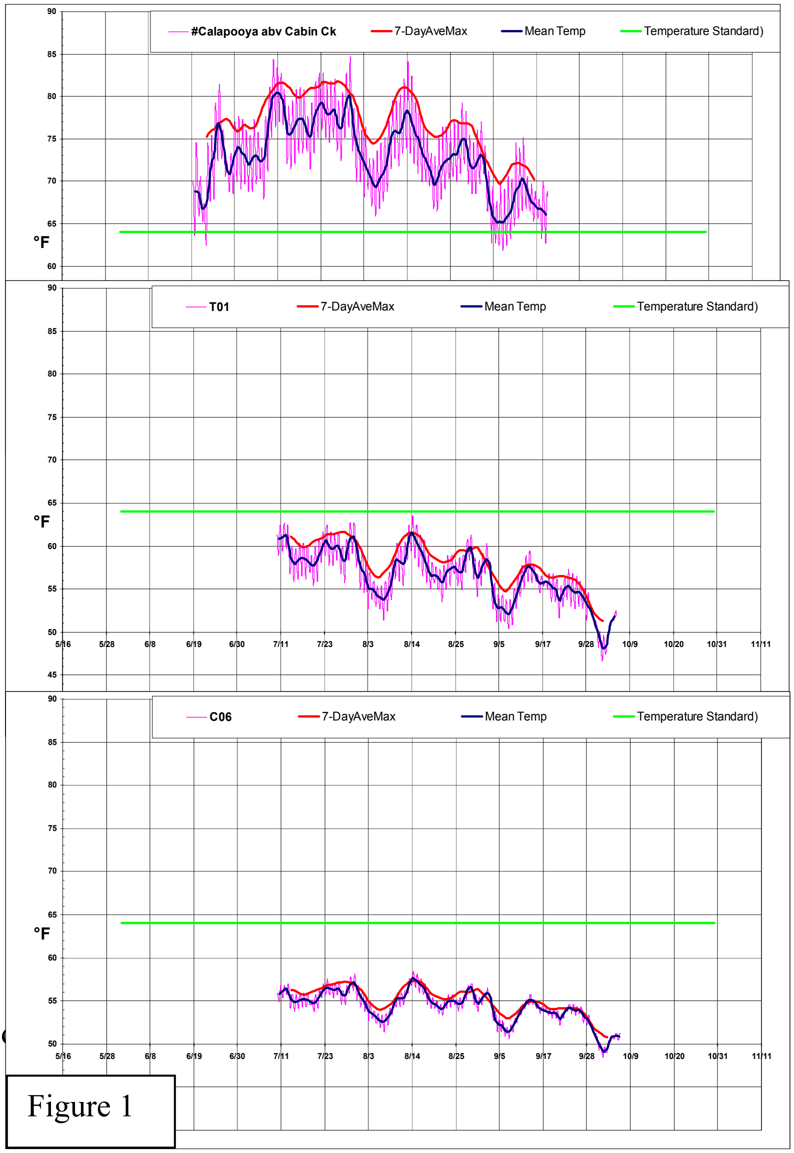


Figure 1

later in the season, it is apparent that, with the exception of early July, all of the summer high temperature events were recorded.

Spatial Distribution

The UBWC data has shown that, on a watershed scale, plotting a temperature statistic against distance from the watershed divide is often a useful indication of the downstream heating characteristics of a particular watershed. For example, Figure 2 shows the result using the 7 day moving average of the maximum daily values (7DADM) statistic.

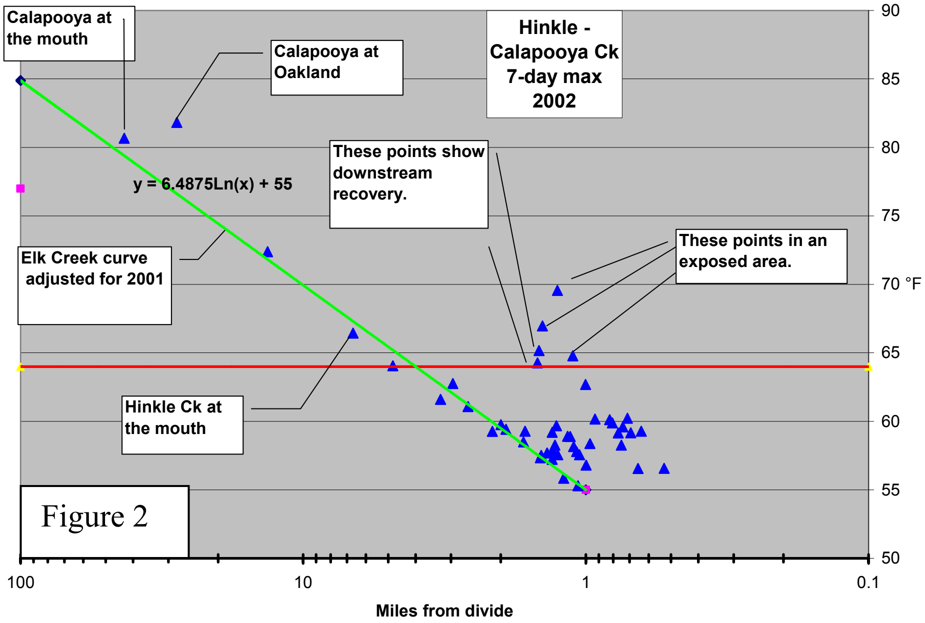


Figure 2

Note the logarithmic scale on the horizontal axis. The line shown on the chart represents a similar fit from a study in the Elk Creek (Elkton-Drain area) in 1998 and was also consistent with the 1999 Calapooya watershed temperature study. As a point of interest, the data from the rest of the interior basin, Cow Ck, South Umpqua, lower North Umpqua and the Main Umpqua showed a lower rate of increase (about 77°F at 100 miles).

At the local sub-watershed scale, using the watershed divide as the reference point has limitations due, at least in part, to the variability of the source water emergence point which causes horizontal scatter. However, at this local scale, the distance between consecutive points on a stream can be measured accurately and the resulting temperature profile can provide some information about the variability between sites in terms of the local rate of heating.

For example, Figure 3 shows a comparison of data from the main branch of the South Fork with data from the first two tributaries in the South Fork. The data shown is the maximum, mean and minimum values measured on 8/14/02. It is interesting to note that the *X1, *X2 and *X3 segment is located within a recent (2001) harvest area and shows the expected temperature increase however, the down-unit site has a lower value than the mid-unit site, suggesting that local conditions can exceed the cumulative effect (the *X3 site has more brush and debris shading). Also note that the minimum (night) temperatures are noticeably lower in the exposed area which is consistent with night radiant cooling concepts. The net effect of these changes is that the maximum temperature increased about 8°F at site *X2 while the mean temperature increased only about 2°F.

The local temperature profiles may also be providing a relative indication of the groundwater hydrology in the area. For example, the upper curve has a mid-slope road within about 400 feet of the east side of the tributary that could be affecting the groundwater contribution to this portion of the stream. Likewise, the site *B3 is located on the downstream side of a skidroad crossing that could be responsible for more cold groundwater inflow.

The blip associated with T03 and *A2 could be associated with the road crossing immediately above T03. Both increased solar exposure and reduced groundwater could be contributing to this effect.

It should be noted that the unit *A1 was, at times, partially covered with silt which could account for a lower value.

The data from the other tributaries show similar patterns and can be examined in a similar manner. Since there wasn't a pre-project control, interpretation is somewhat speculative. However, it is apparent that this type of detailed temperature information can provide a better understanding of the local environmental factors that affect stream temperature in small, headwater streams during the critical low-flow conditions.

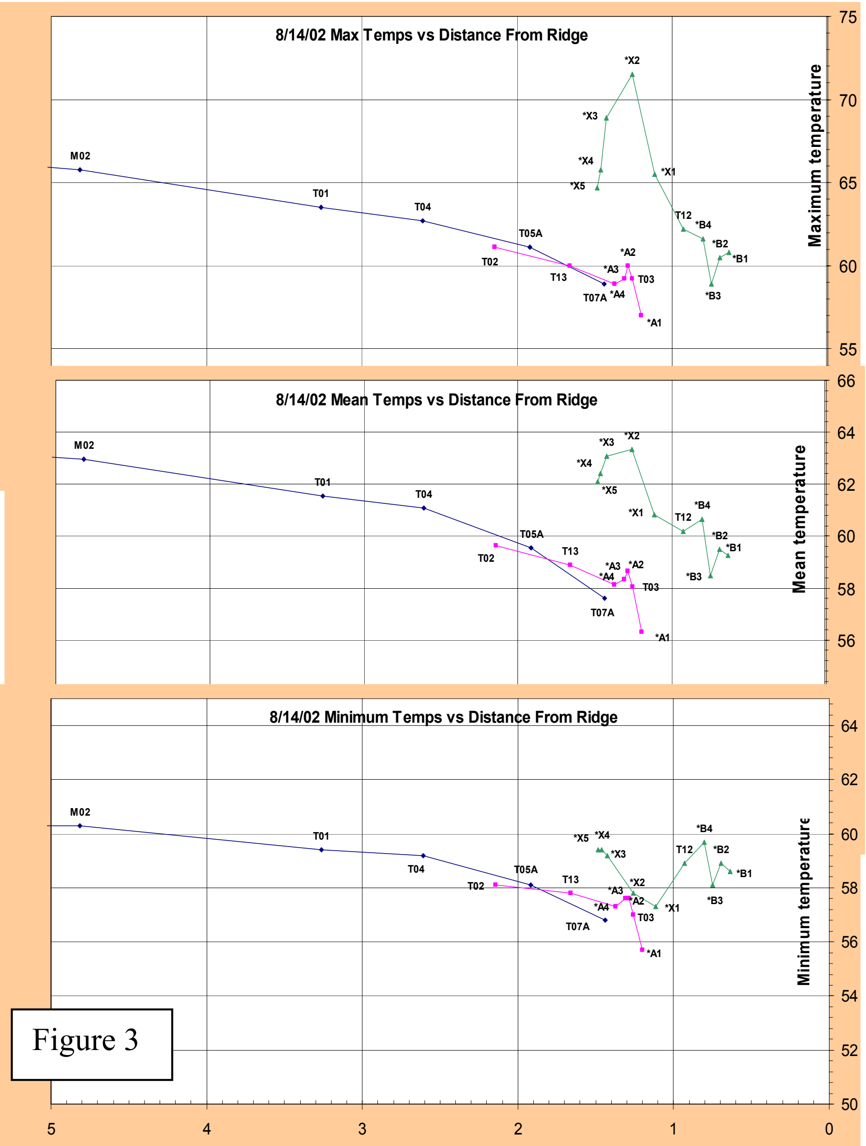


Figure 3

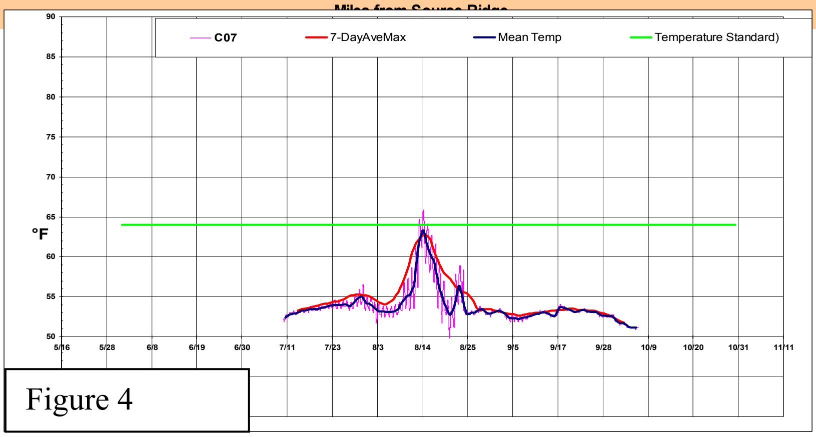


Figure 4

During the midseason audit, one site was found exposed due to receding streamflow. The data is of interest because it shows the temperature conditions on the exposed gravel surface. The small diurnal variation is characteristic of the small stream near the point of emerging flow.