Stream Temperature in the Umpqua Basin
Characteristics and Management Implications

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The objective of this document is to provide watershed managers with information relevant to stream temperature in the Umpqua Basin. While an attempt was made to make it comprehensive, undoubtedly it would benefit from corrections and additions. The plan is to upgrade this document regularly as new information is made available.

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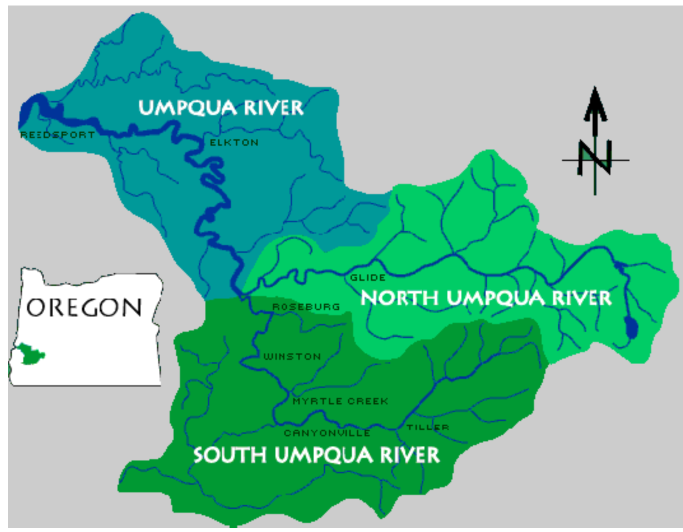
Background



This report is the continuation of the Umpqua Basin Stream Temperature Characterization project that was conducted by the Umpqua basin Watershed Council (UBWC) from 1998 through 2001. A principal objective of the study was to establish the range of variability of the stream temperature data, under current conditions, on both a temporal and a spatial basis. The temperature study sampled most of the basin with the exception of the North Umpqua watershed above Glide, the estuary area and Smith River. The sampling distribution was typically about one site per 10 square miles. Annual reports were developed which presented the data and provided a preliminary analysis (Smith 2001).

This report continues the analysis on a basin scale and discusses the various factors that contribute to the variability patterns. This is followed by a discussion of the management implications. To keep the document readable for a wide range of readers, the main section contains the core material and supporting documentation is in the appendices. The companion CD (Umpqua Basin Stream Temperature Data) contains all of the temperature data, aquatic inventory information, flow data, programs to facilitate analysis and reference documents.

Stream temperature - Current Conditions

Figure 1 shows the typical stream temperature pattern for three medium sized streams within the basin. It is apparent that the streams experience a diurnal influence as well as a common seasonal influence. Various statistics are commonly used to compare the data from the different sites. The preliminary analysis documents looked at the

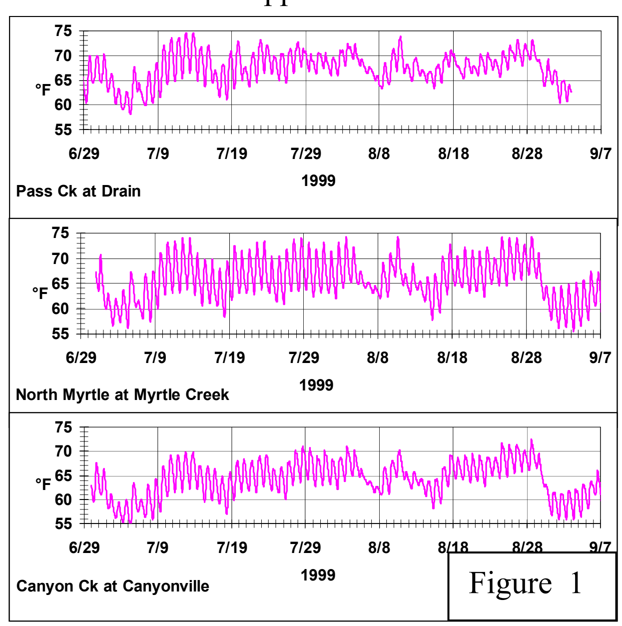
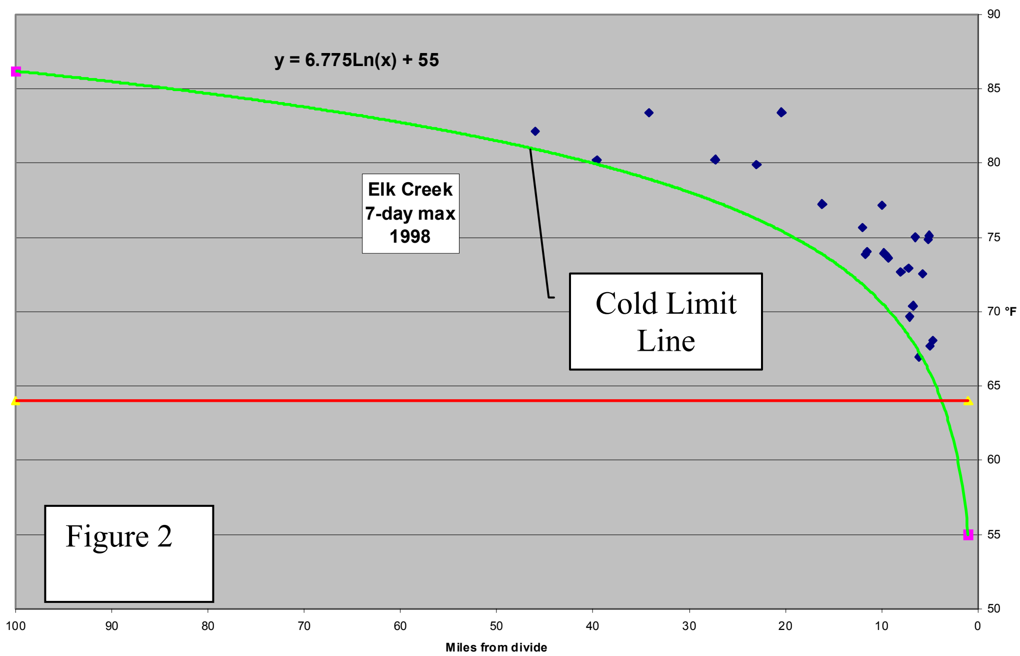


Figure 1

seasonal maximum and the corresponding minimum values for all of the sites in each watershed sampled. As a continuation, this report looks at the seasonal maximum of the **seven day moving average of the daily maximum values** (maximum **7DADM**) for 269 sites throughout the central Umpqua basin. This statistic is of particular interest because the Oregon water quality criterion for summer temperatures is a maximum 7DADM value of 64°F.

Results compared to the Oregon 64°F 7DADM criterion

A key finding from the project was that the summer maximum 7DADM stream temperatures consistently ranged from about 54°F at the source headwater areas to about 75°F on the lower portion of the river. The data typically formed a cluster that defines a distinctive range of values at each downstream monitoring point (See Appendix 1:C. for the analysis). The data cluster characteristically has a lower edge that has a logarithmic



form and is referred to in this report as the Cold Limit Line. Figure 2 shows a typical chart for Elk Creek using the seasonal maximum 7DADM values. Note that the maximum 7DADM value is plotted as a function of the distance from the watershed divide. This is a conventional method of plotting stream temperature data that tends to arrange the sample points by stream size since stream size usually increases from the source to the mouth. The lower edge of the data cluster denotes sites with optimal conditions for producing low temperatures. The analysis compared this optimal condition line (Cold Limit Line) for all of the watersheds and found that it was consistent from year to year and that there were distinct differences between watersheds. The analysis also showed the sites that exceeded the 64°F value. Using the data from the analysis, the following questions can be answered:

1. **To what extent is the 7DADM criterion currently exceeded in the Umpqua Basin?**

   Answer: In this study only 28% of the 269 sites met the 7DADM criterion. While the sample distribution was not randomly selected, the sample sites were chosen to provide a cross-section sample of all stream types. It is clear that more sites near the watershed divide will yield more sites that meet the 64°F criterion.

2. **Is there a spatial distribution pattern of stream temperatures in the Umpqua Basin?**
   Answer: Data from the other watersheds consistently confirmed the general pattern for the watershed scale shown in Figure 2. Theoretical analysis suggests that the temperature profile of streams adjusting from a cold source condition to a warmer climate will change in a logarithmic manner similar to the Cold Limit Line in Figure 2 (See Appendix 2:I.). The Cold Limit Line appears to represent a lower bound for the range of the bulk stream temperature (See ambient temperature, Appendix 2:G). However, if the temperature data logger is placed directly in a groundwater inflow zone, lower values will be recorded. Though groundwater inflow is common in all streams, the influence zone is relatively small (2% commonly reported) and generally not sampled (Bartholow 1989; Ebersole, Liss et al. 2003) See also Appendix 2:G.2).
   The higher temperatures above the Cold Limit Line are the result of "less ideal" local conditions which include factors such as less shade, adverse

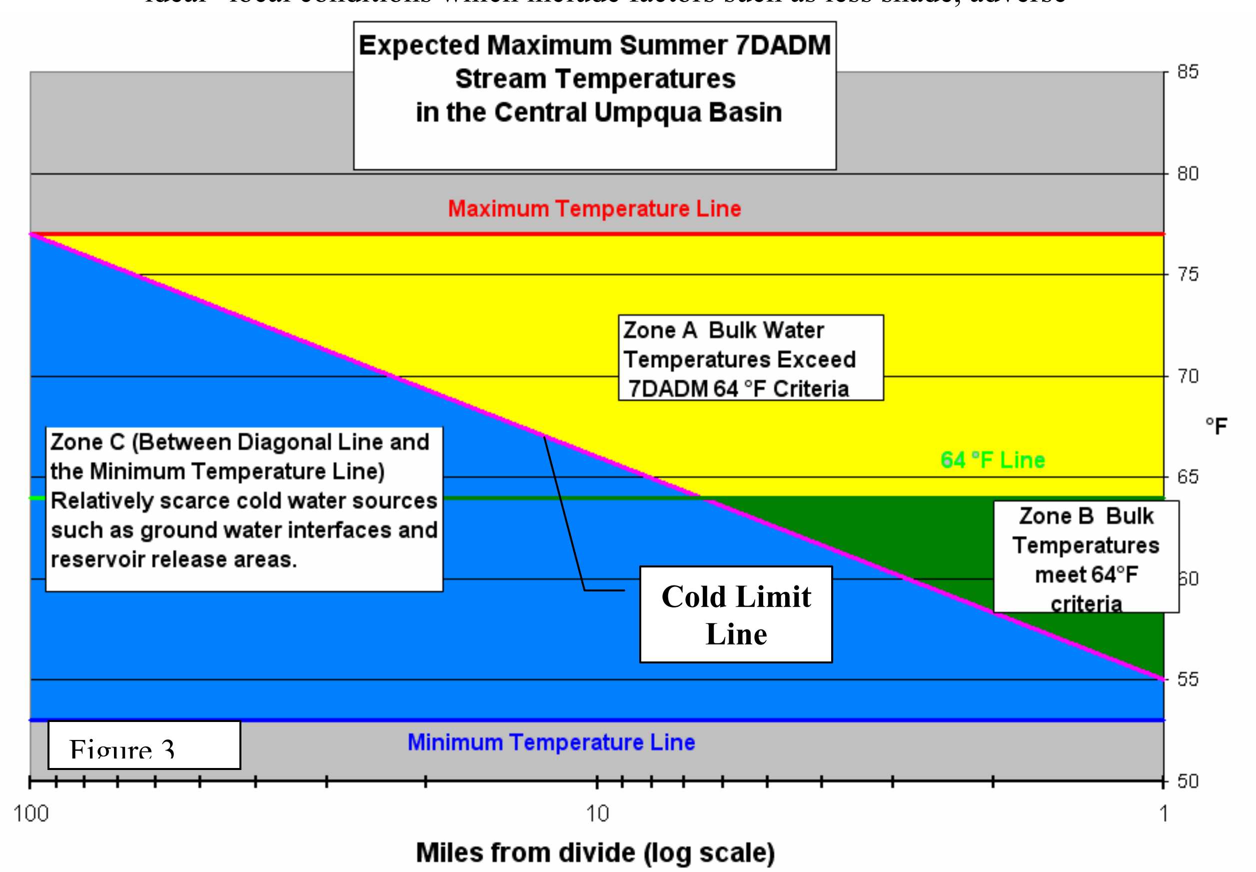


Figure 3

topography, and relatively less groundwater exchange, all of which can influence the net heat flux in the stream and produce a higher temperature (See Appendix 2:H.2).

Figure 3 shows the Cold Limit Line plotted on a logarithmic scale. Note that the line crosses the criteria line at about 7 miles from the watershed divide. This indicates that bulk water temperature at sites greater than seven miles from the divide will typically have maximum 7DADM values that exceed the criteria. For sites less than 7 miles from the divide, the bulk water temperature will either be in zone A or zone B. If a data logger happens to be deployed in local (scarce) groundwater inflow area, a lower value between the Cold Limit Line and 54°F may be recorded (Zone C).

3. **If streams start out at 52°F, and they gain heat in the downstream direction, at what downstream point will the criterion be exceeded?**
   Answer: For the Calapooya and Elk Creek watersheds it appears that streams more than 4-5 miles from the watershed divide generally do not meet the 64°F criterion. For the other watersheds in the study, this distance is in the 6-7 mile range. Streams that do not exceed this distance may or may not exceed the criterion depending upon local conditions (See Figure 3).

Factors that influence stream temperature

The data suggest that stream temperature is strongly affected by local conditions (See Appendix 1:C.). The timing of the diurnal variation consistently coincides with the arrival and departure of the daily solar input (See Appendix 1:B.2). The existence of "cool" reaches indicates that the local conditions can override the effect of the upstream inflow. In particular, temperature "recovery" has been observed in shaded reaches of small streams downstream from exposed areas (See Appendix 1:C.8).

The factors that contribute to stream temperature at a given location include direct and indirect shortwave solar radiation, longwave radiation (both directions), air temperature, surface and subsurface water flow (in and out of the area), evaporation/condensation, conduction, and groundwater inflow (See Appendix 2:H.1).

The extent that these conditions change in a systematic manner results in a systematic change in stream temperature. In particular, as flow accumulates, several important factors change such as channel width, bed composition, local climate, and the percent of groundwater. The net effect of these systematic changes results in a systematic increase in downstream temperature. Conversely, exceptions to the systematic change generally cause higher local stream temperatures which are represented as points above the Cold Limit Line.

Management considerations

The following section discusses watershed management issues as they relate to the UBWC stream temperature data. Some sections contain a summary with more information in the appendices. The intent is to present published material and compare that information with the Umpqua data.

M.1 Historic condition

Data concerning historical stream temperatures is limited. It is acknowledged that there have been significant influences on the streams which can affect local temperatures (See M.2 below). Also, long-term climate changes can affect both the emergent groundwater temperature and the downstream "threshold" temperature (See Appendix 1:A.). It is expected that the summer stream temperatures in the lower valley of the Umpqua Basin were constrained to values between the emergent groundwater and the mean air temperature. An examination of historical climate records could show a shift in these "sideboard" values.

Data from a 1937 study in the Tiller area of the South Umpqua (Roth 1937) showed that some streams flowing from unmanaged (pristine) forested areas were exceeding 64°F some of the time. Comparison of the data with current measurements indicated that the 1937 data matched current values within the 2°F error range of the study (Smith 2000). This area is presently under Forest Service management and has riparian management areas consistent with the Northwest Forest Plan.

Data from well-shaded headwater areas show a rate of temperature increase consistent with the "Cold Limit Line" developed in the analysis (See Appendix 1:C.7). This suggests that the slope of the line has not shifted much from historical shade conditions. However, it is very likely that some of the sites in other areas have shifted further above the Cold Limit Line as a consequence of human management activities.

The EPA Issue Paper 3: Spatial and Temporal Patterns (Poole, Risley et al. 2001) on page 14 uses the following reasoning to determine historical stream temperatures:

1. Historical accounts show that salmonids were once abundant and well distributed.
2. Tests have shown that high temperatures are stressful to fish.
3. The large rivers and tributaries currently have high temperatures.
4. Salmonids now appear to be less abundant and less well distributed.
5. Therefore the thermal regimes in many rivers are warmer than at historical times.

There is no question that features along the streams have been significantly altered and that some of these changes may have adversely affected fish populations. In particular the opening of the streams (log jam removal) for transportation and log transport has vastly altered the hydrological character of the larger systems and reduced available habitat. However, reduced fish numbers do not conclusively prove that bulk stream temperatures have increased.

The variability of the bulk temperatures of the larger streams and rivers tend to decrease as the streams get larger and the bulk temperature values may not have changed much from historic values. However, changes in structural features and water uses have reduced the complexity of the large rivers and have likely caused a reduction in the number and quality of cold-water refuge sites. Consequently, bulk stream temperature should not be the sole criteria when evaluating the thermal regime of the larger rivers.

The temperature of the smaller streams is more easily affected by changes in the local environment (See Appendix 2:H.2). Consequently, streams that have experienced significant changes in their riparian vegetation, channel configuration or groundwater availability may have stream temperatures that lie further above the Cold Limit Line than during historic times. Appropriate stream and riparian management may be able to lower the temperatures at these sites.

M.2 Effect of human activities on stream temperature

Various land management activities are frequently cited as having affected stream temperature in a wide variety of different ways (See Appendix 2:L). It is helpful to be aware of these issues while considering management options.

The recent technical synthesis developed by the EPA (Poole, Dunham et al. 2001) identifies the following activities as causal agents for increased stream temperatures:

(1) Reduced connectivity between streams, riparian areas, floodplains, ground water and uplands.
(2) Altered floodplain function, wetlands, water tables and base flows.
(3) Elevated fine sediment yields; making streams wider and shallower with fewer pools.
(4) Reduced instream and riparian large woody debris.
(5) Reduced or eliminated riparian vegetation.
(6) Altered peak flow volumes and timing.

The interrelationship between management activities and stream temperature response can be complex, as illustrated in the example in Figure 4.

It has been shown elsewhere (See Appendix 2:H.2) that subsurface interaction can be particularly crucial to stream temperature in the Umpqua Basin during the summer low-flow period. In an EPA document, Charles Coutant emphasizes management effects on subsurface flows which tend to cool streams in the summer and warm streams in the winter. He suggests that irrigation of floodplain fields in summer recharges the subsurface with warm water rather than the historical recharge with cold spring floodwater. Also, he states that siltation can reduce infiltration and the effect of cooling groundwater inflow (Coutant 1999).

More information on the net effects of irrigation would be helpful. It is conceivable that water removed from a stream for irrigation could return in a relatively cooler state due to flow desynchronization and subsurface cooling. The related effect of water withdrawal is also complex. In losing reaches, reduced surface water may cause higher temperatures since less volume is being heated by the same amount of solar flux. In gaining reaches, a reduction in surface water can result in a higher proportion of cool groundwater with a net decrease in temperature (Bartholow 1989).

Local hydrology and groundwater patterns can be altered in many ways through management activities. Roads can intercept and drain off groundwater or, through compaction, can impede downslope drainage, resulting in increased storage. Activities that affect the channel gravel accumulation can alter the hyporheic interaction and may consequently reduce important refuge areas in the larger streams. Some management activities can improve local thermal conditions. Since, as shown in Figure 4, the interactions are complex, care must be taken to assure a net positive effect.

Stream shade modification can significantly affect stream temperatures as is discussed in section M.6 below and Appendix 2:J.

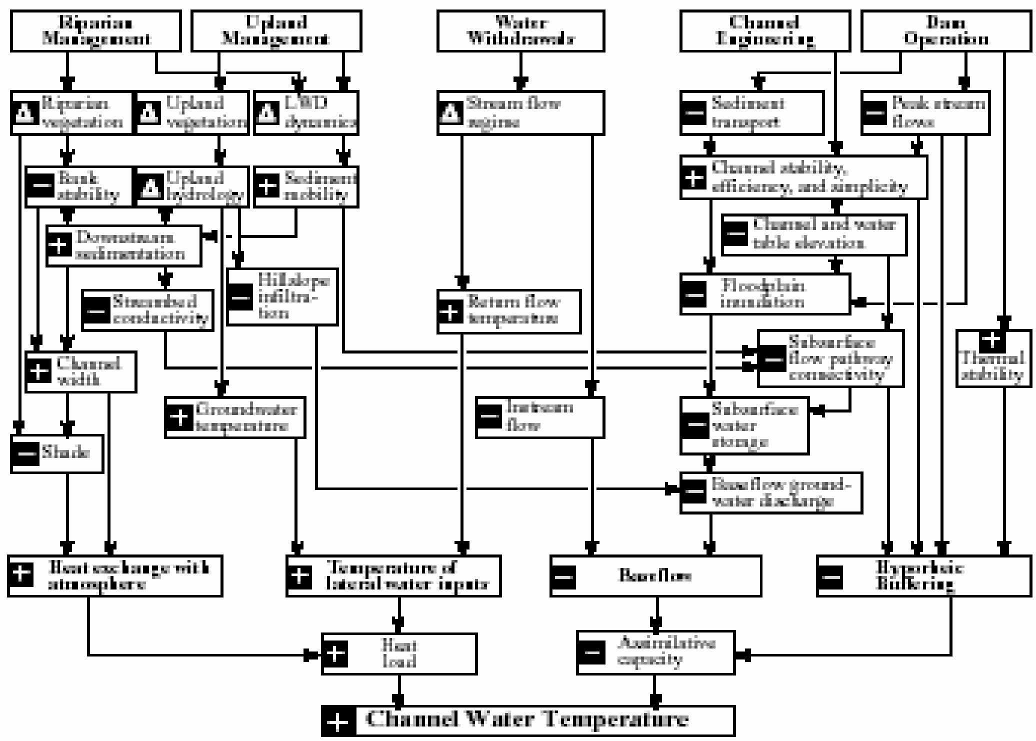


Figure 4. Some pathways of human-caused warming of stream channels (From Poole and Berman 2001.). The symbol "+" indicates an expected (but not certain) increase, "–" an expected (but not certain) decrease, and "Δ" either an expected increase or decrease depending on the specific circumstance or measurement used. This graphic is designed to illustrate the complexity associated with stream temperature dynamics. It is not intended to be a comprehensive summary. Additional arrows and boxes are possible under various conditions.

M.3 The Oregon state temperature standard

Compliance with the Oregon sate water temperature standard is often a concern of land managers in the Umpqua Basin. This section contains some general information related to the current standard and some notes from the EPA Region 10 Temperature Water Quality Criteria Guidance Development Project that is developing recommendations for updating the existing criteria.

The following summary of the current standard was provided by Bobbi Lindberg of DEQ:

> The Clean Water Act Section 303 requires states implementing the Clean Water Act to adopt standards for water quality. The current Oregon temperature standard was adopted in 1996, and establishes numeric criteria for certain salmonid life stages. The criterion for salmonid rearing is 64 degrees F; for spawning, the criterion is 55 degrees F. When Bull trout are present, the criterion is 50 degrees F.
>
> The numeric criteria are only a portion of Oregon's temperature standard. The standard requires a management plan when the moving average of the daily maximum values over a seven day period exceeds the appropriate numeric criterion (64 for rearing; 55 for spawning). Sources which are in compliance with the management plan shall not be considered as causing or contributing to a violation of the numeric criterion. Once all feasible steps have been taken under the management plan to meet the criterion, the actual temperature achieved will be the temperature criterion for the waters covered by the management plan.

This standard was designed to protect the native aquatic species that are most sensitive to warm temperatures (chinook coho, steelhead, salmon, bull trout and the first-year tadpoles of tailed frogs) (1995).

As indicated above, the temperature data from the Umpqua Basin shows that many streams in the basin exceed the 64°F criteria.

Since 1996 more information has been developed about the needs of the aquatic species as well as current stream temperature conditions. An EPA Temperature Criteria Task Group has been actively working on developing criteria for a new stream temperature standard. This group has produced a series of "issue papers" (Materna 2001; Poole, Risley et al. 2001; Sauter, McMillan et al. 2001; Dunham, Lockwood et al. 2002) as well as a draft guidance paper (2002). This group identifies difficulties in implementing a single threshold as a standard (Figure 6) and suggests that there is a need for criteria that will best ensure the thermal conditions necessary to support viable salmonid population while reducing the instances where naturally warm water is deemed out of compliance. The public comments to the draft guidance are available on the Region 10 EPA website (http://yosemite.epa.gov/R10/water.nsf/) Appendix 2:K. contains specific excerpts. Note: on April 28, 2003, final guidance was released and the Oregon temperature standard is currently being revised.

Figure From (Poole, Dunham et al. 2001)

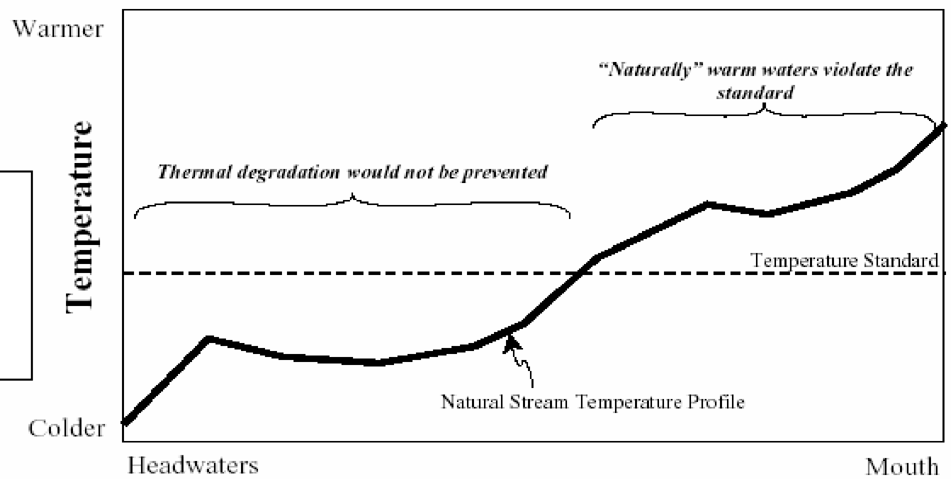


Figure 6. Two difficulties of implementing a single threshold as a temperature standard. First, a single numeric standard may fail to prevent degradation of the highest quality (coldest) habitat. Second, natural temperatures may violate the standard thus requiring an attempt to determine whether the violation is natural or the result of human-caused temperature changes.

M.4 Habitat and stream temperature

Much scientific information concerning the relationship of salmonids and stream temperature supports the 64°F 7DADM criterion for rearing (1995). The 7DADM analysis (See Appendix 1:C.) indicates that streams that are more than 7 miles from the watershed divide will probably not meet this criterion (See Figure 3). Likewise, it appears that many of the streams in the zero-seven -mile interval also do not meet the criterion. For example, Lookingglass Creek has maximum 7DADM values exceeding 70°F up to the 2.5 mile point (Ref. 51). However, Lookingglass / Olalla Creek is known to support healthy numbers of fall chinook, coho, steelhead and cutthroat trout.

It is not fully known how survive in streams with high bulk stream temperatures but it is apparent that thermal refugia play an important role. The fishery in these streams can greatly benefit from improvements in habitat and riparian condition and should receive a priority for restoration planning.

A recent study in the Mattole River in Northern California showed that small streams with 7DADM temperatures of less than 64°F were highly favored by juvenile coho salmon. A spatial analysis was not included in the study, but it appeared that all of the streams were within 5 miles of the watershed divide (Welsh, Hodgson et al. 2001).

It is apparent that more information is needed in the Umpqua Basin in order to develop a sound management strategy (Coutant 1999). A detailed temperature inventory at the site level is labor intensive. Cool inflow points can be quite small, and a large number of temperature readings would be needed to fully map the local temperature distribution. Airborne thermal imagery can help identify the larger source areas but, since it detects only surface temperatures (Torgersen, Price et al. 1999) it may not fully describe local temperature patterns, including the temperature of spawning beds.

Snorkeling and/or radio tagging to identify high summer use areas may be feasible but is a labor intensive approach. It is unlikely that detailed knowledge of the subsurface conditions of the entire system will ever be available. However, identification of some of the high use areas could serve as a surrogate for the large stream conditions. Monitoring and adaptive management in these areas would provide information that could be used in other areas that have similar characteristics (Coutant 1999). In particular, more information about the relationship between shade and fish use could be obtained. The inventory could look at characteristics such as rearing volume, food, and cover to establish the limiting factors. This information could be used for habitat development and enhancement.

Areas with potentially high quality habitat can be identified by looking at local channel characteristics. The ODFW Aquatic Inventory is on the companion CD and can be used to evaluate potential habitat. See Appendix 2:F.1 for a useful rating system developed by the Roseburg ODFW.

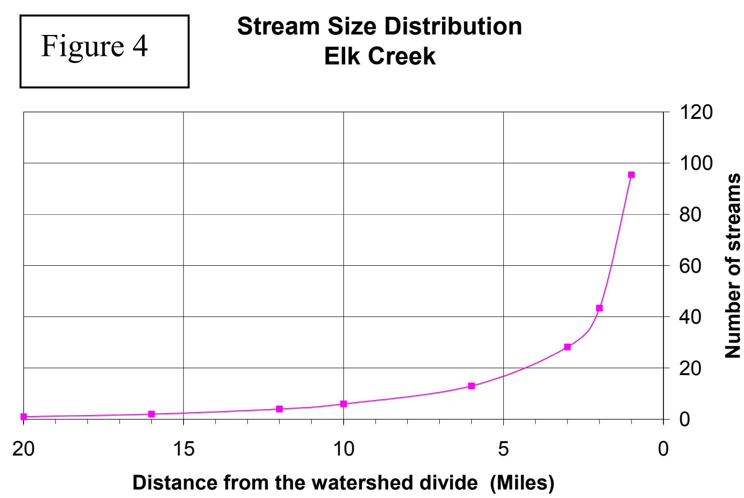
In the meantime, current restoration techniques and procedures are probably beneficial. Large wood placement to add structure and cover can improve stream temperature, and has been shown to provide improved instream habitat for salmonids.

An adaptive management program to add shade clusters which would serve as "oasis" zones along the stream should be implemented (oasis zones are discussed in more detail in section M.9 below). The development of off-channel habitat is another adaptive management option (Blackwell, Picard et al. 1999).

M.5 Small streams are important

Figure 3 shows that large streams tend to be excessively warm with respect to the 64°F criterion. However, it should be kept in mind that the stream drainage pattern is hierarchal and there are many more small streams than large ones. For example, Figure 4 shows that there may be about four times as many three-mile streams as there are seven-mile streams. Streams in this range may meet the stream temperature criterion if conditions are favorable (See Appendix 1:C.). Currently many of these streams exceed the criterion, but with appropriate management, some of them could provide quality habitat with cooler bulk water temperatures.

Figure 4



The particular challenge with small streams is that the low flow reduces the amount of habitat. Often, isolated pools contain cool water that can sustain a small population if there is sufficient food and cover to protect from predators. There may be opportunities to increase the frequency and the productivity of these areas.

It should be noted that streams that lose some of their surface flow during the later summer period may be important spawning areas. French Creek near Glide is a notable example.

M.6 Shade management

As discussed above, there are many activities that can affect stream temperature. This section emphasizes stream-side shade enhancement since it is one of the more “doable” projects available to the typical landowner.

Since the solar path is predictable, it is possible to design a “shade wall” that will reduce the amount of direct solar energy that is directed to the stream (See Appendix 2:J.). In small streams this action may reduce maximum stream temperature of exposed streams by several degrees. In larger streams the effect of additional local shade may not result in a noticeable change in temperature, but it has been noted that fish often favor the shady areas on hot days. Perhaps they are sensitive to the light or are less vulnerable to predation while in the shade or both.

How much shade is needed?

Streams that are above the Cold Limit Line in Figure 3, in particular, may benefit from additional shade. There are several reasons why a stream may be above the Cold Limit Line and exposure to direct solar radiation is just one of them. In cold headwater streams that are entirely below 64°F, the food source may become limiting and the stream may benefit from some thermal diversity (while still maintaining the sub 64°F value) (Materna 2001). However, generally streams in the two to twelve mile range with a maximum 7DADM greater than 64°F will probably benefit from additional shade. In forested areas so called reference conditions indicate that 75% of the streams had 68% closure, and 25% of the streams had 90% closure (1998), see Appendix 2:J.1). There doesn’t appear to be as much information about a reference condition for the lower elevation lands. In general, additional shading of the small warm streams will result in cooler temperatures with a net benefit to the local salmonid fishery.

Reduction of direct solar radiation is only one function of a riparian shade zone. The zone will also affect the local micro-climate with corresponding effects on air temperature, evaporation, wind speed etc. all of which also influence the stream temperature (See Appendix 2:H).

Costs and benefits of shade management

Riparian management can be relatively costly compared to tillable acreage. Often dominant brush needs to be cleared, equipment access may be limited, and chemical uses restricted. Typically the planting and release of riparian trees involves extensive hand work over a period of several years. Livestock control may be needed while the seedlings are young and vulnerable.

Benefits include eventually having a stand of mature trees and an associated riparian ecosystem. The tree roots can provide bank stability and structure to small channels. The area can provide good habitat for terrestrial and aquatic life that is beneficial to the area. Tree-lined buffers may pass flood flows more efficiently than brush-lined buffers resulting in lower flood levels and less flood damage to structures. Also, the trees are an eventual source of woody material, which can eventually provide essential structure needed to maintain high water tables and diverse aquatic habitat.

There is evidence that a shaded reach in an otherwise exposed stream can have significant benefit to the local fishery. In 1984 a restoration project on Rice Creek produced shade for about one mile in an area that had very little vegetation. The property owner reports that, prior to the project, the reach would go dry in the summer. Now there are shaded pools and surface flow that provide coho and steelhead rearing areas (Rice Ck Study pending). This effect is sometimes referred to as the "Oasis Effect" and can be a useful management option when only a portion of a stream can be shaded (See M.9 below).

Shade versus water

It is well known that trees use water, and in small streams the transpiration of the riparian vegetation causes a definite fluctuation in streamflow. This fact may be a consideration in planning riparian planting along streams with limited flows.

While it is true that trees use water, paradoxically, surface streamflow often appears to increase in riparian restoration projects (Elmore and Beschta 1987). One possible explanation is that the litter accumulation and root systems add structure and trap sediments, building up the floodplain and redefining the channel. More groundwater is then stored in the area, with an increase in summer surface flow.

More studies are needed to fully resolve this issue.

Effectiveness of shade management

Since shade is one of several factors that determine stream temperature, the net effect of changes in the shade regime will depend upon the relative contribution of direct solar exposure. There are many studies that document the effect of shade removal associated with timber harvest, and they typically show a marked increase in local stream temperatures on small streams during the low flow conditions (Poole, Risley et al. 2001).

However, shade restoration may not necessarily result in full temperature recovery. A 1995 study (Hatten and Conrad 1995) sponsored by the Northwest Fisheries Commission looked at several variables associated with stream heating in eleven unmanaged streams and fifteen managed streams in the temperate rain forests of the Olympic Peninsula. No significant differences in mean air temperatures were found between the monitoring sites in unmanaged and managed sub-basins. However, significant differences were found between group means of all five variables used to characterize the water temperatures of the study sites. For all water temperature variables, the managed group had significantly warmer mean temperatures than the unmanaged group. These significant differences between group means persisted even when the effects of environmental variables that may influence water temperatures such as stream elevation and amount of shade were removed. Only after controlling for the differences between the unmanaged and managed groups in the portion of each sub-basin classified as late seral stage forest did the differences in mean stream temperatures become non-significant. The portion of sub-basin classified as later seral stage forest was also the best single variable for predicting mean average hourly and mean maximum water temperatures at both managed and unmanaged sites.

This result appears to be consistent with a study in Oregon (Beschta and Taylor 1988) that also found a relationship between stream temperature and extent of watershed management.

These studies suggest that shade recovery alone may not be sufficient to eliminate all of the stream heating increases due to disturbance activities. The exact mechanisms of the other contributing factors are complex, highly variable, and difficult to measure. For example, they may involve differences in quality of riparian shade such as height of the shade canopy, groundwater quantity and temperature, channel characteristics such as width, stream depth or hyporheic flow patterns. These results support the three-component cumulative effect concept (see M.7 below). In some cases, restoring vegetative cover may not be sufficient to restore the thermal regime.

M.7 Cumulative effects

Changes in stream temperature are often cited as being manifestations of cumulative effects related to specific management activities. On federal projects, cumulative effects need to be specifically addressed as part of the environmental assessment (NEPA) process. The regulations for implementing the National Environmental Policy Act (NEPA) define cumulative effects in **Sec. 1508.7 Cumulative impact:**

> "Cumulative impact" is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

Types of cumulative effects

The EPA Issue paper 3 (Poole, Risley et al. 2001)on page 20 identifies three types of cumulative effects that may occur within a watershed:

1. The additive effect of human impacts which can affect stream temperature. For example, increased sedimentation caused by human activities could affect the hyporheic flow regimen causing a change in stream temperature.

2. The downstream accumulation of heat that may occur when heated water is transported downstream and additional heat is added to it.

3. The third type is multiplicative (or synergistic), resulting from land use and natural disturbances. For example, activities could result in local shade as well as significant alteration to the stream channel which would affect several of the processes that determine stream temperature.

The second effect is of particular interest because it suggests that the stream temperature at downstream points will be affected by activities upstream. While it is expected that heated water will flow downstream, the excess heat will tend to be absorbed by the local environment. Small streams with slower effective velocity will tend to "recover" more quickly than larger streams because they have less thermal mass and will equilibrate with the local environment faster than larger streams (See Appendix 2:G.2).

The management implications are very important. One issue is knowing the extent to which an upstream exposed area will affect the downstream temperatures. If recovery occurs and the recovery distance can be determined, then appropriate management decisions can be made. For example, if a small stream that is relatively exposed has an "oasis" reach that is long enough to allow for local recovery, than the stream temperatures at the recovery point may approach the optimal condition on the Cold Limit Line. This area could serve as a thermal refuge zone and provide a toe-hold for salmonid species in that stream system.

M.8 Flow Management

Low flow conditions represent a unique (and critical) condition where subtle influences on stream flow and channel characteristics can have a measurable effect on both the temperature and the quantity of the water available for fish habitat use (See Appendix 2:E). Surface flow is only one component. Groundwater inflow, hyporheic flow, and even isolated pools, all contribute significantly to the quality of habitat. Careful consideration needs to be taken to avoid adverse effects to any of these components.

M.9 The Oasis effect

Patches of cool water in an otherwise warm stream provide "oases" where fish and other mobile organisms can avoid stressful temperatures (Poole, Risley et al. 2001). To some extent, these sites can be managed to improve the amount of cool water available and the usefulness to the fish.

Groundwater inflow is an important component. Highly incised channels tend to drain the local areas faster and reduce the amount of groundwater available during the summer periods. Conversely, non-incised streams will have a better groundwater supply. Local environment is also a factor. Areas with shaded pools will detain water that is passing through and allow it to become cooler.

Other features, such as food supply and hiding cover, add to the overall quality of an oasis. These sites can become essential for survival during the extreme heating periods of the summer. During the rest of the season the fish can disperse to other areas with a net increase in utilization of a previously unused system. As a result, oasis development can extend salmonid utilization into streams that been previously avoided.

M.10 Action needed

The Technical Synthesis developed by the EPA for the Water Temperature Criteria Guidance Project (Poole, Dunham et al. 2001) suggests the following actions to provide appropriate thermal regimes:

> In an ideal world, we might eliminate thermal degradation by restoring stream temperatures to presettlement thermal regimes that historically supported viable salmonid populations. However, restoration of historical conditions can be an unreasonable goal given that restoration opportunities may be limited to varying degrees by certain "irreversible" human-caused or natural landscape changes, such as development of major urban centers and volcanic eruptions. Yet, the continuing collapse of salmonid populations suggests that the existing amount and distribution of suitable habitat in the Pacific Northwest is inadequate to maintain viable salmonid populations. Therefore, based on the scientific review contained in the technical summaries, the Technical Workgroup concludes water temperature criteria should ideally address thermal regimes, and that four actions relevant to thermal regimes may be necessary and should be strongly considered in order to ensure adequate amounts and distributions of cold water to support salmonid populations.
>
> 1) Immediate protection of remaining suitable habitat from thermal degradation.
> 2) Restoration of some amount of thermally degraded habitat. Given that thermal degradation in many streams may not be reversible due to policy considerations or social and economic realities, it is likely that much or even all habitat that can be restored will need to be restored in order to support viable populations.
> 3) Implementation of restoration across a broad spectrum of habitats from headwaters to ocean because the life histories of salmonids span entire watersheds.
> 4) Protection and restoration targets based on consideration of a wide array of evidence with an emphasis on natural temperature dynamics. Engineering artificial thermal regimes may entail greater uncertainty and risk than attempting to mimic natural processes and patterns (see Poff et al. 1997 for a discussion of the importance of maintaining or restoring natural regimes).

The protection of suitable habitat as stated in point one makes sense. A sufficiency analysis developed jointly by the ODF and ODEQ indicates that, with current knowledge, the Forest Practices Act is sufficient to protect streams on non-federal lands (See Appendix 2:K5 and (2002)). The key requirement to implement this action is the identification of the suitable habitat.

The restoration of thermally degraded habitat identified in point two requires a methodology to identify thermally degraded habitat. The evidence from the Umpqua Basin suggests that a bulk temperature exceeding 64°F does not necessarily imply that the has low fishery potential. Appropriate management in these areas can have a significant benefit to the local fish population. Changes in the extent and quality of the thermal refugia in the large warmer stream may be a better indicator of habitat condition but difficult to discern. More work is necessary to fully address this issue. In a report contracted by the EPA, (Coutant 1999) Charles Coutant recommends that temperature management should be focused to locations and times relevant to use. If thermal refuges are critical, they should be specifically monitored.

Point 3 recommends implementation of restoration across the basin. This is consistent with current ongoing restoration in the Umpqua Basin. However, much work remains to be done.

Point 4 identifies the need for more evidence to establish restoration targets. While mimicking nature may be an ideal approach, the reality is that much of the Umpqua Basin is highly managed and innovative solutions need to be found. The adaptive management approach provides a means to find these solutions in a systematic and careful manner.

In general, for the Umpqua Basin, a continued effort to better understand fish distribution and habitat utilization is needed to optimize the watershed management effort. Management practices that result in cooler temperatures will generally be beneficial if they don't adversely affect habitat or water quality.

M.11 Expected future condition

The Umpqua is a relatively warm basin with relatively high groundwater temperatures and warm summer air temperatures (See Appendix 1:A.). Consequently, the lowest achievable temperature through management may be higher than in some of the other basins within the state. Certainly, summer 7DADM temperatures less than 52°F would be unlikely to be found in the central Umpqua Basin.

Management activity may be able to reduce local water temperatures in many steams, but this work should be closely related to habitat considerations. Global warming may have the effect of raising both the groundwater temperature and the threshold temperature. This reality of global warming will continue to drive a need for innovative fishery management that includes stream temperature management.

Models are usually used to predict the lowest achievable temperature. However, as described in section Appendix 2:G.1, the various factors associated with low flow conditions make realistic modeling difficult, especially in the smaller streams (Poole, Risley et al. 2001). It should be mentioned that most flow models will predict the bulk temperature and cannot be used to identify small refuge areas associated with groundwater seeps which may be extremely important during the high temperature periods. The Airborne thermal sensing data and perhaps a stream density analysis will be helpful.

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Helpful Resources

The following resources can assist or provide information regarding watershed management issues.

Umpqua Basin Watershed Council	673-5756	
Oregon Department Fish and Wildlife	440-3353	
Douglas Soil and Water Conservation District	673-8316	
Umpqua Soil and Water Conservation District	271-2611	Toll free 1-877-495-8803
Oregon Department of Environment Quality	440-3338	Ext 224

Helpful web sites:

EPA region 10
For Sake of the Salmon
UO Solar Radiation Monitoring Laboratory
National Climatic Data Center
Oregon Climate Service