California Board of Forestry
Policy and Management Committee
P.O. Box 944246
Sacramento, CA 94244 -2460
December 3, 2003

Dear Committee Members,

With regard to the Microclimate Petition presently before you, and Mr. Cafferata's Memorandum to Mr. Snyder of Oct. 27, 2002, we concentrate today on the following remarks by J.M. Bartholow, 2000, who is extensively quoted in the Memorandum (see http://smig.usgs.gov/SMIG/features_0902/clearcut.html for the full text of Bartholow)

- "The effects of manipulating forest shade on stream temperature have been the focus of much debate. One school of thought indicates that solar radiation is critical in controlling stream temperature (Beschta et al., 1988; Beschta, 1991; Beschta, 1997), such that riparian vegetation, and even large woody debris, is to be thoroughly protected during timber harvest. Another perspective maintains that ambient air temperature, or a warm environment in general, is the factor largely governing stream heating (Sullivan et al., 1990; Larson and Larson, 1996; Zwieniecki and Newton, 1999)."
- (Re the Stream Segment Temperature Model) -- "t**he net effect from clearcutting was a 4oC warming [in maximum daily water temperature]... Temperature increases due to clearcutting persisted 10 km downstream into an unimpacted forest segment of the hypothetical stream**"
- "To summarize, the literature from a variety of geographic locations suggests tha**t increases to mean temperatures of 3-6oC, and to maximum temperatures of 3-8oC, have been common.** Therefore, the SSTEMP model predictions for this hypothetical stream are reasonable, **perhaps even low**."
- "**Has the strict definition of 'cumulative effects' been met by this analysis? I fear that the answer is no**. Concentration on the physical dimension **ignores the far more complex biological arena** (Johnson and Jones, in press)"

Questions for Mr. Cafferata and the Committee:

Mr. Cafferata's Memorandum appears somewhat inconclusive regarding the effects of air temperature increases due to clearcutting upon stream temperature. That is, evidence is presented within the Memo which supports both sides of the question: i.e., air temperature is the most sensitive variable vs. shading is the most sensitive. The statement is made, though, that shading is the more dominant factor than air temperature. That general statement may be (will be) true of some circumstances, and false of others. Of particular concern to us is the **Gualala watershed**, which has recently been heavily impacted by clearcutting and other even-aged management systems, and which has been recently been listed as temperature impaired. To that end we ask the following.

1) The Memo reproduces a Figure 1 which shows that air temperature is second in sensitivity to shading, although still more important than any other factors. The SSTEMP model is sensitive to many parameters. This leads us to ask:

- Upon what other variables was this particular sensitivity test based? Did you attempt to adjust it for conditions to be expected upon the Gualala, for example? If so, what values were used, and how were they obtained?
- The figure caption states that the test was recalibrated with Manning's n and channel width held constant -- at what values? Were they realistic values for some reach of the Gualala?
- Air temperature in this test was assumed to increase by 2 degrees Centigrade, no doubt derived from Bartholow's statement that "in aggregate [his data] supports about a 2oC increase in ambient mean daily air temperature resulting from extensive clearcutting". Why was not any other figure used? What happens if it is? Much of Bartholow's data comes from the Pacific Northwest, a cooler environment with different topography. What would a realistic figure for reaches of the Gualala be? How much have the daily average and maximum air temperatures for that watershed increased in the past, say, 10 years, as a result of logging?
- Have such calculations been performed for other clearcut watersheds in California besides the Gualala, and is such information available to the BOF and the public?

2) We know that the Gualala has recently been **listed for temperature impacts by the Regional Water Board and the EPA**, as have several other major Northern California Rivers. What bearing or role do you see the SSTEMP model as having with respect to these listings, and to possible improvements in the Forest Practice Rules in this regard? Whether with respect to air temperature or to riparian buffers? (http://www.rrraul.org/news.html to see photograhs of present conditions upon the Gualala) I note, also, that Bartholow says that the **SSTEMP assumptions are "conservative"** and that **they don't satisfactorily address cumulative effects**. In what way could those effects be addressed, as is required by the FPRs?

Sincerely,

Jay Halcomb, RRRAUL

Discussion (Bartholow, ibid):

Quantifying the multiple effects of clearcutting has been enlightening. The model has shown that it is a complex set of factors, not simply a single factor, that governs stream temperature increases due to large-scale timber harvest. Of foremost importance, even slight alterations to stream shading during harvest (intended to emulate adherence to strict BMPs) may result in increases to maximum daily water temperature. Air temperature did not appear to be as important in governing the increase in maximum daily water temperature as direct solar radiation. Although air temperature was influential, the more subtle second-order effect of stream widening was even more important. Not all harvest-related effects generated in stream warming; increased wind speed and reduced humidity resulted in stream cooling. The **2.4oC increase in mean upstream temperature due to timber harvest persisted 10 km downstream into an unimpacted forest segment** of the hypothetical stream, but those increases translated to only a 1.4oC increase in mean temperature 10 km farther downstream because they were moderated by cooler equilibrium conditions. Thus the downstream equilibrium temperature tends to "recover" temperature increases (sensu Zwieniecki and Newton, 1999), but cannot fully mitigate those increases. The model did not suggest a "strong influence" of ground temperatures on stream temperature as suggested by Hewlett and Fortson (1982) and Brosofske et al. (1997), **but this is the subject of ongoing research** (Johnson and Jones, in press). The results did, however, confirm both the importance of riparian shade (Beschta, 1997), in contrast to the views of Larson and Larson (1996), and confirmed the hypothesis of a stream's "thermal signature" (Zwieniecki and Newton, 1999).

A more thorough investigation may be warranted for two reasons. First, attributes in downstream areas would not be expected to remain the same as upstream. **Air temperatures would warm with decreased elevation (Theurer et al., 1984) and exposure would increase given "natural" changes to stream width in the longitudinal direction** (Leopold et al., 1964). Second, **the temperature model has no memory of upstream conditions**. Therefore it cannot "remember" that incoming maximum water temperatures may be elevated from their expected value. Nevertheless, the conservative assumptions used here argue both for persistence of effects and eventual convergence on "signature" temperatures for this moderately sized stream. Smaller streams, or those even more thoroughly shaded and having an equilibrium temperature cooler than inflowing waters, might be expected to recover more quickly (Zwieniecki and Newton, 1999). From a land management perspective, however, what may be most relevant is whether factors other than water temperature, most notably stream width, are impacted downstream. **If the width were increased in a forested downstream setting due to upstream land use changes, cooling attributable to relative humidity and wind speed may no longer partially offset upstream temperature increases.**

Few models have been used in an attempt to understand cumulative effects related to stream temperatures. Brown (1970) pioneered work in this area showing how to calculate maximum changes in stream temperature from different degrees of clearcut. However, Brown's model relied almost exclusively on estimates of changes in surface area exposed to the sun and did not address cumulative effects as examined here. To get at cumulative effects, I have fabricated a stream meant to be representative of a system in the Pacific Northwest. Obviously, the simulation results would be different if I had made different assumptions, particularly on the scale of effects, as river heat budgets are highly variable in both time and space (Webb and Zhang, 1997). But do the results compare favorably with observations made from actual cases? There are many examples in the literature that can be used to assess the realism of model predictions. Some examples, however, do not reflect recent timber harvest BMPs; therefore direct comparisons should be tempered with caution.

Beschta and Taylor (1988) documented changes in the 325-km2 Salmon Creek watershed in western Oregon that accompanied removal of forest cover over a 29-year period. They calculated that average daily maximum stream temperatures increased 6oC at the watershed's mouth for the ten warmest days of each year, even although air temperatures appeared to decline over the same period. They noted that it was difficult to draw a tight cause-and-effect chain from timber harvest to stream temperature given natural hydrologic events in combination with changes in harvest activity and management practices. Levno and Rothacher (1967) reported a 2.2oC increase in weekly maximum temperatures after 100% logging of one small 61-hectare watershed in Oregon. Another similar watershed was only 25% cut, but suffered from extensive scour in a 1964 flood. This watershed showed mean monthly water temperature increases of 3.9o to 6.7oC from April through August following the flood. Brown and Krygier (1970) reported an average monthly maximum temperature increase of about 8oC after clearcutting a small Oregon watershed. They attributed changes to increased solar radiation reaching the stream. Amaranthus et al. (1989) described maximum water temperature increases ranging from 3.3o to 19oC in adjacent southern Oregon watersheds burned to varying degrees. Increases were negatively correlated with summer streamflow and remaining streamside shading, even if shading was composed largely of dead vegetation. Kopperdahl et al. (1971) reported maximum water temperature increases of 3.3 to 9.4oC in small watersheds cut and "roaded" to varying degrees in the fog belt of northern California, an area where air temperatures and solar radiation are generally moderate. However, much of the temperature increase may have been due to bulldozers "working" the streams. The report also summarized other studies documenting temperature changes in nearby watersheds of 11oC and 13.8oC. Feller (1981) recorded maximum temperature changes of 3.6 to 5.7oC in two coastal British Columbia watersheds paired with untouched areas, with effects lasting seven years or longer depending on the treatment. Holtby (1988) examined the effects of extensive (41%) clearcuts on Carnation Creek in British Columbia. Although he found no significant logging effect on air temperatures, every month exhibited an increase in mean monthly water temperature, ranging from 0.71oC in December to 3.25oC in August.

In an extensive study, Barton et al. (1985) examined the influence of the size (width and length) of buffer strips on maximum stream temperature in southern Ontario. They found a strong positive correlation between the percent of watershed forested and maximum water temperatures. Unvegetated watersheds averaged 5oC warmer than those with 100% forest coverage. Swift and Messer (1971) related maximum water temperature to a variety of timber harvest treatments in southern Appalachians hardwood forests. **Generally, maximum water temperatures increased about 4oC, but extreme clearing was accompanied by changes of up to 7oC.** Hewlett and Forston (1982) documented maximum stream temperature increases of 11oC with buffers in a clearcut loblolly pine stream in the southeast United States. Rishel et al. (1982) found average monthly maximum temperature increases of 4.4oC in the northeast after extensive clearcuts followed by herbicide treatment, although some instantaneous temperature increases approached 10oC.

To summarize, the literature from a variety of geographic locations suggests that **increases to mean temperatures of 3-6oC, and to maximum temperatures of 3-8oC, have been common**. Therefore, the SSTEMP model predictions for this hypothetical stream are reasonable, **perhaps even low**. They may be low because some reports were made prior to effective riparian management. I believe the model predictions are valuable, however, not because they may approximate the cumulative effect per se, but because they illustrate the relative magnitude of change caused by the physical variables that govern water temperature. In particular, altered stream width, when it occurs, may account for a significant proportion of increases to maximum temperature. Therefore, BMPs devoted to mitigating increases in stream width could be expected to have a relatively large influence on stream temperatures.

Has the strict definition of "cumulative effects" been met by this analysis? I fear that the answer is no. Concentration on the physical dimension ignores the far more complex biological arena (Johnson and Jones, in press). Could thermal increases be a barrier to up- or downstream migration of salmonids, growth rates or stress (Lynch et al., 1984)? Would benthic food production be adversely affected in altered habitats (Duncan et al., 1989)? This analysis alone cannot answer those questions. However, first principles models like SNTEMP and SSTEMP are good integration tools that can capture many important first-order linkages between land use changes and stream temperature (e.g., shading). They can also be used hypothetically to explore second-order cumulative effects, although they can never be conclusive. In this mode, such models are useful in five broad categories of application:

Understanding: What are the important physical processes?;
Communication: How does one visualize and communicate cumulative effects to diverse audiences?;
Sensitivity analysis: Which variables most warrant accurate measurement at a site?;
Incremental quantification: How much change in water temperature might one expect given single or cumulative changes in input variables ("what-if" analysis)?; and
Coherence of monitoring results: Does it all make sense?

It is encouraging that stringent timber management BMPs that limit the size and contiguity of clearcut parcels may be reducing the cumulative effects of harvest on stream temperatures. However, **strict BMPs do not appear to be widespread** (Young, 2000). Model applications such as the one presented here may be useful in continuing to address these and similar problems such as the cumulative effects of agricultural development or urbanization.

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Reference:

Bartholow, J.M. 2000. Estimating cumulative effects of clearcutting on stream temperatures.
Rivers 7(4): 284-297. http://smig.usgs.gov/SMIG/features_0902/clearcut.html