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Review of the Basis for Riparian Management Relative to Water Temperature Control in the USDI Bureau of Land Management (BLM) Draft Environmental Impact Statement (DEIS) for its Western Oregon Plan Revisions (WOPR)

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Key Findings/Table of Contents

The DEIS Recommends Riparian Management Guidelines that Deviate Significantly from the Protective FEMAT Guidelines

FEMAT (1994) guidelines were summarized by Pacific Rivers Council (PRC, Image[1] 1-3). Guidelines applied to perennial fish bearing streams on the Westside forests were 340 ft (or approximately 2 SPTH, site potential tree heights) from the edge of the active channel. Buffers for perennial as well as seasonal, non-fish bearing streams were 170 ft. Only minor and occasional thinning was permitted within these zones.

The USDI-BLM (2007) WOPR recommendations allow high levels of incursions into all these stream classes by contrast to FEMAT. Pacific Rivers Council diagrams (PRC, Image 4-6) indicate that for perennial, fish-bearing streams and perennial, non-fish bearing streams the BLM-recommended buffer width is 100 ft, where the first 25 ft are no-cut but the outer 75 ft allow extensive thinning. Between 0-25 ft, the buffer is intended to be no-cut, but the "operational reasons" would permit frequent skyline corridors. Between 25-60 ft, 80% effective shade or potential shade, whichever is less, would be retained. However, timber harvest would also be allowed if it could be claimed that the riparian buffers were not mature or diverse enough. This opens a significant amount of discretion that could increase stream heating. Between 60-100 ft only 50% canopy cover needs to be retained after riparian harvest. This threatens perennial channels with significant amounts of stream heating.

On intermittent, non-fish bearing tributaries having high erosion risk, the no-cut buffer is only 25 ft. The outer 75 ft permits extensive thinning where it can be claimed that the stand is not diverse enough. For all other intermittent, non-fish bearing tributaries a buffer of only 25 ft is required with a minimum of 12 trees per acre. This equates to a "buffer" consisting of a single row of trees 145.2 feet apart, if evenly spaced (1 acre = 43,560 ft^2; a 25-ft-wide acre is 1742.4 feet long). The BLM rules would even permit slopes above non-fish-bearing intermittent streams having high erosion risk to be harvested totally in the outer 75-ft zone if they can claim that LWD would not be delivered to a fish-bearing stream due to stream junction angle. This provision does nothing to reduce fine sediment loading of downstream fish-bearing channels. Elevated fine sediment delivery reduces water quality and aggravates water temperature regulation downstream. The WOPR rules are not protective of water quality relative to retention of hillslope sediment and debris on steep slopes, especially on small, headwater tributaries. Pertinent to these comments, the WOPR rules are not protective of water temperatures supporting aquatic life.

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[1] "Image" refers to the snapshots of figures or tables from various literature sources assembled in the Appendix. The original Figure or Table captioning was preserved. A few original figures were replotted to illustrate various points. "Images" copied from the literature were sorted alphabetically by author and then were numbered sequentially.

The DEIS Promotes a Very Limited and Selective View of Riparian Science in Order to Advocate for Riparian Timber Harvest and Overturning FEMAT Guidelines

In 1994 teams of prominent USFS and BLM scientists reviewed the available literature on the characteristics of riparian buffers needed to provide a wide range of ecological functions. This resulted in the FEMAT (1994) guidelines for riparian management. A section from this review relative to water quality protection is cited below.

> *Castelle et al. (1992) provide a thorough literature review of widths of riparian areas required to protect water quality functions. In general, the authors found that widths of riparian areas required to protect water quality ranged from 12-860 feet. Widths varied as a function of geomorphic characteristics such as slope and soil type and by vegetative structure and cover. Effectiveness of buffers at improving water quality adjacent to logging operations was studied by Broderson (1973), Darling et al. (1982), Lynch et al. (1985), and Corbett and Lynch (1985). Broderson studied three watersheds in western Washington and found that 200 foot buffers, or about one site-potential tree height, would be effective to remove sediment in most situations if the buffer were measured from the edge of the floodplain.* (FEMAT 1994).

Although new studies have been conducted since FEMAT guidelines were put in place for Northwest forests, there is abundant evidence from new scientific literature to continue to support FEMAT guidelines as the best and most risk-averse means of protecting streams of federal lands. FEMAT rules were designed to provide high level protection for all the functions that riparian zones contribute (Rhodes et al. 1994, Image 1; Chan et al. 2004, Image 1). The USDI-BLM DEIS is heavily skewed toward consideration only of the shade function among all riparian functions. Even the science of shade protection is significantly skewed to favor harvest ambitions.

The BLM presents the scientific rationale for its stream and riparian management proposals in a highly selective manner and omits mention of the large body of literature that would demonstrate that its position is one of high risk to the resource. To credibly claim adherence to best available science, BLM must demonstrate more than that results in just one or a handful of studies could (arguably) be interpreted as supporting the proposed reductions in protection of riparian function and resulting stream temperatures. Rather, it must disclose the full range of relevant scientific information, including that which conflicts with or contradicts the sources it chooses to cite in purported support of its proposals. Further, the agency must provide credible justification that the scientific information on which it chooses to base its proposals is more credible or valid than the conflicting or contradictory information it chooses to ignore, with credible explanation of how and why this is so. Merely citing one or a handful of studies that purportedly justify its proposals while ignoring the rest of the vast body of relevant scientific evidence, as the BLM has done in this DEIS, utterly fails the test of scientific adequacy and credibility.

Among the Numerous Land Management-Related Mechanisms for Water Temperature Increases, the WOPR Considers Only Qualitative Estimates of Angular Canopy Density

There are numerous mechanisms that result in temperature increases in streams. Temperature increases result from the following types of alterations to a watershed: (1) reduction in total canopy cover (dominant and subdominant tree, shrub, grass, forb), (2) increased coarse and fine sediment delivery to stream channels, which can lead to channel widening and loss of pools, (3) reduction in LWD, which results in reduction of primary pools, a reduced channel capacity, and loss of thermal buffering and coldwater refugia, (4) increased heating of riparian soils, (5) interception of shallow groundwater by road systems that route runoff to surface flows, which become heated, (6) increased air temperature over streams by loss of microclimate buffering, (7) riparian roads, which reduce the interaction of the floodplain with the channel and impose permanent losses in riparian cover while the road exists, (8) loss of off-channel wetlands due to reduction in shading and increased drying of these habitats, (9) loss of streambank stability due to streamside harvest or livestock grazing damage, leading to increased sediment delivery and channel widening, (10) increase in basin-wide sediment delivery due to forest-related road systems, leading to pool loss and channel widening, and (11) reduction in streamflow via irrigation, resulting in stream heating. The combined effects of these types of ongoing actions relative to heating of stream water were not described, nor were they described in relation to the current level of habitat degradation. These types of interactions have been described in many reports, such as Rhodes et al. (1994) and Poole and Berman (2001).

Aquatic Ecosystems and Water Quality Protection Cannot be Assured with a High Probability without Maintaining Intact, Extensive, Late-Seral Riparian Communities Throughout Entire Drainage Networks

Oregon's Independent Multidisciplinary Science Team (IMST 2004), set up by the Oregon governor to review available science under Oregon's salmon recovery planning extensively reviewed the available literature on management impacts to stream system water temperature and found no doubt about the causes. They also recognized that temperature is perturbed by four major types of human impact.

> *Of the 48 studies we found, 45 showed that when you removed riparian vegetation, stream temperatures increased. In these 44 studies, the stream temperatures increased from as little as 1.09 °C [2 °F] to as much as 12.7 °C [22.9 °F] after vegetation was removed. (IMST 2004). The IMST concludes that only four major factors that influence stream temperature–riparian shade, channel morphology, discharge, and subsurface exchange– are modified by human actions. IMST has found that the vast majority of published studies document that riparian shade has a significant effect on stream temperature. Additionally, riparian vegetation also plays a major role in influencing other factors that, in turn, affect stream temperature. For example, plant roots are important because they keep stream banks from eroding and channels from*

> *becoming wide and shallow. The scientific literature reviewed by the IMST indicates that removal of vegetation along small- to medium-sized streams usually results in increased surface water temperature. In addition, most scientists agree that riparian vegetation provides many benefits to stream and terrestrial ecosystems, in addition to shading streams (IMST 2000). Therefore, despite the level of public controversy, the IMST does not find substantial scientific disagreement on the topic of the importance of riparian vegetation to maintaining stream temperatures.* (IMST 2004).

Quigley and Arbelbide (1997) also recognized the multiple controls on water temperature.

> *Stream temperature is affected by eliminating stream-side shading, disrupted subsurface flows, reduced stream flows, elevated sediments, and morphological shifts toward wider and shallower channels with fewer deep pools (Beschta and others 1987; Chamberlain and others 1991; Everest and others 1985; MacDonald and others 1991; Reid 1993; Rhodes and others 1994).* Quigley and Arbelbide (1997).

A TMDL analysis on Navarro Creek, California showed clearly the linkage between stream temperature and buffer width between 0 and 150 m width.

> *For both 1995 and 1996, MWAT [i.e., maximum weekly average temperature) values show a good correlation with reach-averaged effective shade (r^2 =0.762 and r^2=0.707 for 1995 and 1996, respectively, where r^2 is the proportion of variation explained by the model). These results appear to be consistent with observations made by Cafferata (1990) in a study conducted on the North Fork Caspar Creek.* (CRWQCB 2000).

The regression noted in this TMDL for Navarro Creek indicated a decline in MWAT from 22.6 to 17.8°C as the reach average effective shade increased from 10 to 95%. Temperature reductions of this magnitude attributable to effective shade are highly significant biologically. The effective shade measurements in this TMDL work were made using the solar pathfinder to evaluate only that shade value that is responsible for reducing direct solar radiation..

An energy balance model of riparian effectiveness by Sridhar et al. (2004) clearly shows the multiple controls on stream heating and the importance of canopy characteristics, tree height, and buffer width. Sridhar et al. (2004) developed an energy balance stream temperature model that utilizes GIS technology and physical process modeling for forested headwater streams. This model allows exploration of maximum annual stream temperatures under conditions of low flows and maximum annual solar radiation and air temperature. These authors concluded that stream orientation was a physical feature that produced a significant difference in potential warming, with N-S oriented streams heating the most. LAI (leaf area index) was the vegetation factor with the greatest effect on stream temperatures. Average tree height controls both shade and penetration of solar radiation and was second in importance. Third in importance in the energy balance was buffer width. The greatest reduction in stream temperature occurred for streams with high LAI and with buffer widths of about 30 m.

EPA (2003) is clear on the need to protect temperatures throughout a drainage system on a holistic basis:

> *Because the temperatures of many waters in the Pacific Northwest are currently higher than the summer maximum criteria recommended in this guidance, the high quality, thermally optimal waters that do exist are likely vital for the survival of ESA-listed salmonids. Additional warming of these waters will likely cause harm by further limiting the availability of thermally optimal waters. Further, protection of these cold water segments in the upper part of a river basin likely plays a critical role in maintaining temperatures downstream. Thus, in situations where downstream temperatures currently exceed numeric criteria, upstream temperature increases to waters currently colder than the criteria may further contribute to the non-attainment downstream, especially where there are insufficient fully functioning river miles to allow the river to return to equilibrium temperatures (Issue Paper 3).*

In a similar manner, EPA (2003) emphasized restoration and recovery of populations based on a holistic view of habitat from headwater stream protection to the downstream reaches:

> *The following are three important ways that temperature WQS, and measures to meet WQS, can protect salmonid populations and thereby aid in the recovery of these species. The first is to protect existing high quality waters (i.e., waters that currently are colder than the numeric criteria) and prevent any further thermal degradation in these areas. The second is to reduce maximum temperatures in thermally degraded stream and river reaches immediately downstream of the existing high quality habitat (e.g., downstream of wilderness areas and unimpaired forest lands), thereby expanding the habitat that is suitable for coldwater salmonid rearing and spawning. The third is to lower maximum temperatures and protect and restore the natural thermal regime in lower river reaches in order to improve thermal conditions for migration.*

EPA, NMFS, and USFWS, in their Review of December 2001 [sic] Draft Sufficiency Analysis: Stream Temperature (Feb. 2001) at 1 ("SAST"), criticized Oregon for focusing primarily on shade and fixed temperature targets *"rather than how forest practices affect the suite of temperature-related factors relevant to riparian and stream channel functions that are critical to supporting designated beneficial uses such as salmonid spawning and rearing."* Id. The USDI-BLM now proposes in their WOPR DEIS to take a similar approach that is not a holistic, ecosystem approach. These federal agencies specifically pointed out that extensive cumulative harvest on a watershed scale can also lead to a worsening thermal regime and criticized the lack of a landscape scale/cumulative effects framework. Id. at 3. EPA also noted that other factors affecting temperature, such as air temperatures, groundwater, and flow, must be considered. Id. at 6.

Guidelines Recommended by FEMAT Still Represent the Best Science of Riparian Zone Protection

Riparian zones moderate the impact of some upland disturbances, buffer the input of nutrients and sediments, and contribute large woody debris. Trees and vegetation in riparian zones provide shade and moderate water temperatures. Riparian zones also help control channel morphology and stabilize streambanks. Forest cover adjoining the stream zone also maintains cool soil temperatures that help maintain the cold temperatures of groundwater inputs to streams. Because of the unique importance of riparian zones, the creation of riparian buffers has become the predominant way to protect their functions. Although riparian buffers alone are insufficient to ensure healthy salmonid habitats, there is consensus in the scientific community that protection of riparian ecosystems should be central to all salmonid conservation efforts on both public and private lands.

However, negative impacts to stream channels also are produced from management activity on the general landscape, and it cannot be expected that even a fully intact riparian zone can counteract all effects of development at a basin scale. The question that must be answered is whether the USDI-BLM WOPR is sufficiently protective of riparian zone condition to maintain full riparian zone functions, maintain or restore water quality, and overcome the sacrifices made to ecosystem health outside the stream corridor. One place to start answering that question is to compare the riparian management guidance with the requirements expressed in the best available science. This comparison shows that the USDI-BLM WOPR deviates substantially from the best scientific evidence regarding the restrictions on forest practices that are necessary to meet state water quality standards, to provide a high level of protection to listed or sensitive fish and wildlife, and to protect ecosystem health.

In 1993, the federal government assembled an interdisciplinary team of scientists into the Forest Ecosystem Management Assessment Team (FEMAT) to look at management standards on federal lands within the range of the northern spotted owl. It is widely acknowledged that this is the best scientific assessment of Westside aquatic conservation strategies to date. FEMAT described riparian reserves as areas used to maintain and restore riparian structures and functions of intermittent streams, confer benefits to riparian-dependent and associated species other than fish, and to provide a high level of fish habitat and riparian protection until watershed and site analysis can be completed. FEMAT at V-32-34.

The FEMAT report emphasized the importance of protection for intermittent or seasonal streams.

> *Intermittent streams store sediment and wood and are sources of these materials for permanently flowing streams. Removing the connection between intermittent and permanently flowing streams may have detrimental consequences to the*

> *physical and biological components of stream ecosystems, particularly in the long term.* FEMAT at V-36-38.

Protection for perennial and intermittent non-fish bearing streams was a crucial issue for the protection of salmonids. FEMAT's Aquatic Conservation Strategy included a survey of leading scientists that asked them to rate various conservation strategies for their likelihood of maintaining populations of salmonids across federal lands in the Pacific Northwest. Three basic riparian options were presented. All three proposals had a riparian buffer equal to two site potential tree heights on fish bearing streams; these buffers were essentially "no-cut" zones. In addition, the most conservative proposal included one site potential tree height buffer widths on all other streams, the intermediate proposal provided one site potential tree height buffer on perennial streams and one-half site potential tree height buffer on intermittent streams, while the least protective proposal provided one-half site potential tree height buffer on perennial streams and one-sixth site potential tree height buffer on intermittent streams. For most salmonids, the scientists rated the most conservative proposal as having about an 80% chance of success; the intermediate proposal a 65% chance of success; and the least protective proposal a 30% chance of success. The key difference in the buffer widths on non-fish bearing streams was what altered the likelihood of success for salmonid survival between the proposals. FEMAT at V-67 – 74.

The FEMAT standards provide the basis for national forest management on the Westside of the Cascades. On fish-bearing streams, riparian reserves equal the height of two site potential trees or 300 feet, whichever is greater. Permanently flowing non-fish bearing stream riparian reserves are equal to one site potential tree height or 150 feet, whichever is greater; intermittent non-fish bearing stream riparian reserves are equal to either one site potential tree height (or 100 feet). Record of Decision, Amendments to Forest Service and BLM Planning Documents within the Range of the Northern Spotted Owl ("Northwest Forest Plan") (April 1994) at C-30-31.

In the Assessment of Ecosystem Components in the Interior Columbia Basin, Broadscale Assessment of Aquatic Species and Habitats (June 1997), the importance of small streams was again stressed. Id. at 1365-67. *"Small perennial and intermittent non-fish bearing streams are especially important in routing water, sediment, and nutrients to downstream fish habitat."* Id. at 1366. The two current protection schemes for federal land on the Eastside (known as PACFish and INFish) require riparian buffers of one-half to one site potential tree height on all non-fish bearing streams.

EPA, along with the National Marine Fisheries Service and the Fish and Wildlife Service, funded what is known as the "ManTech Report" to compile the best available scientific information and to develop technical standards for meeting the water quality and habitat needs of imperiled salmonids on nonfederal lands. The ManTech Report (Spence et al. 1996) calls for riparian buffers of sufficient size and with sufficient limitations on logging activities to protect riparian functions. ManTech Report at 216. It also calls for the adaptation of prescriptions to account for existing conditions because using strategies "without regard for other activities that have occurred or are occurring within a watershed or region will generally fail to protect salmonid populations against cumulative impacts." Id. at 27. The analysis "should include an overall assessment of cumulative effects and maps of current riparian conditions." Id. at 216.

The ManTech Report specifically discusses the need for protection of upstream reaches, including seasonal and perennial non-fish bearing streams.

> *Sediments generated from unprotected upstream reaches are transported and deposited downstream, filling pools and decreasing channel stability. Removal of large trees from headwater areas may reduce recruitment of wood to downstream areas. Temperature increases caused by canopy removal in small streams can also affect downstream reaches. Because these influences of land management propagate downstream, protection of riparian zones along non-fish bearing streams and ephemeral channels is also needed to maintain salmonid habitat.* Id. at 216; see also Id. at 166.

For riparian buffers, the ManTech Report calls for a minimum width of a fully protected riparian buffer of approximately one site potential tree height. Id. at 229.
On the issue of water quality, the ManTech Report calls for an identification of water quality problems throughout the watershed, an identification of the specific factors causing those problems, and a comparison of current temperature regimes with undisturbed reference conditions. Id. at 231. "In areas where existing water quality problems are impairing ecological function, conservation plans should seek to alleviate the causes of water quality degradation and maintain all water quality parameters within the range required for specific species and life stages." Id. In my opinion, the ManTech recommendations are generally in line with the best available science. Nonetheless, there are instances where additional site evaluation, such as indicated in a watershed analysis, might reveal the need for greater riparian width, such as in floodplain protection, sediment retention on steep hillslopes, protection of wildlife habitat, protection of microclimate, and control of soil heating on slopes contributing significant groundwater.

The Wide Disparity in Riparian Protection between Fish and Nonfish Streams puts Fish Communities at High Risk due to Stream Misclassification

In assigning higher quality stream protection only to those stream reaches confirmed to support fish and relegating "nonfish" streams to a lower level care, the BLM does not take a cautionary approach to ecosystem management, but instead errs on the side of increased timber harvest. It is far less risky for aquatic resources to fully protect all headwater streams, whether or not fish are present. Also, if additional care is to be taken, streams with potential for fish or wildlife habitat should be identified via extrapolation from characteristics of other inhabited streams (see Dunham et al. 2001). Many currently valid fish-bearing streams are never properly categorized because of issues in detectability of fish at low abundance, fish with crepuscular habits, fish in habitat with high complexity and hiding cover, and/or fish with seasonal or periodic use of habitats (Dunham et al. 2001, Thurow et al. 2001, Bayley and Peterson 2001). Stream typing based on confirmed sightings of fish also lead to making irreversible management decisions, allowing excessive impact and habitat degradation that terminate the potential of a stream as future habitat that can be colonized. Such actions lead to seriously weakening an already weak habitat system and threatening the future viability of listed fish and wildlife populations.

Protection of headwater streams, given the rules established in forest practices, often depends upon proper classification of the stream as either perennial or intermittent. If a stream is assigned a designation as an intermittent stream on the basis that it is not mapped on a USGS map at 1:24K, there is high potential for error. Perennial streams of order 1 or 2 can make up >80% of total stream length in many landscapes (Richardson et al. 2005). Many small, permanently flowing streams do not appear on topographic maps (Meyer and Wallace 2001, as cited by Richardson et al. 2005). Streams that are typically perennial can become intermittent occasionally.

USFS/BLM Water Temperature Methodology Ignores the Breadth of Available Science to Select only Those Assumptions that Provide the Maximum Flexibility to Harvest Riparian Timber

The USFS/BLM (2005) TMDL ISE methodology is simply a white-paper on temperature modeling upon which the BLM DEIS riparian management is based. This white-paper, however, is a flawed basis for riparian management. It is technically weak and incomplete despite its many iterations. It selects the Brazier and Brown (1973) shade curve rather than the Steinblums et al. (1987) shade curve (the competing shade curve that has traditionally been reported jointly with Brazier and Brown) because it permits narrower buffers. This approach increases risk to aquatic resources greatly. Some assumptions in the white-paper do not comport even with Brazier and Brown. Others are not internally consistent. The Brazier and Brown model itself is so poorly documented and ridden by technical flaws that its use is highly suspect. In addition, shade and temperature modeling by the BLM is not consistent with ODEQ TMDL standards and goals.

The USFS/BLM (2005) TMDL ISE methodology is reliant on a series of relationships from selected literature to estimate the effective shade provided by riparian vegetation. USFS/BLM (2005, Image 1) cited Brazier and Brown (1972) (note: correct date of this report is 1973) for their relationship between angular canopy density (ACD) and buffer strip width. The value of such a "shade curve" is that, given an average forest community occupying a vegetated buffer strip, one can expect an average ACD to be produced by the riparian buffer. Next, they employed a relationship (USFS/BLM 2005, Image 2) between ACD and percentage effective shade from Park (1991). This curve indicates that when ACD is approximately 20%, effective shade is approximately 60%; when ACD is approximately 80%, effective shade is approximately 80%. This is in apparent conflict with the Brazier and Brown (1973) findings that in Upper Reynolds Creek, where the ACD was 18.3%, the heat blocked was 0 BTU/ft^2*min. USFS/BLM stated that further increases in angular canopy density beyond 80% do not yield additional improvement in effective shade, but the diagram from Park (1991) indicates no decline in the rate of improvement in effective shade with increase in ACD. Also, this is in direct conflict with relationships between solar radiation loading and effective shade expressed by ODEQ (1999, Image 1)

Riparian harvest is permitted by the USDI-BLM WOPR (2007) on perennial fish-bearing and non-fish-bearing streams in the outer 75-ft zone of the 100-ft buffer, unless this zone is deemed mature and complex. On the non-fish-bearing, intermittent streams there is very little restriction to harvest and shade reduction. Significant reduction in shade is excused on perennial streams based on an assumed future improvement. Significant reduction in shade on intermittent streams is excused in the WOPR by the assumption (without regard to literature that would caution against this) that there will be no cumulative heating of ecological consequence during the season of surface flow or subsurface flow. Water temperature impacts of the BLM management assumptions are apt to be significant on the perennial streams and especially significant on the intermittent streams.

USFS/BLM are totally reliant on the Brazier and Brown (1973) shade curve, although Beschta et al. (1987, Image 1) illustrated two competing curves: Brazier and Brown (1973) and Steinblums et al. (1984). Also, see WDOE (2005, Image 1). The conclusion in Beschta et al. (1987) from these studies is that a buffer width of 30-145 feet is needed to maintain an ACD of 75-90%. WDOE (2007, Images 5 and 6) indicates very clearly the contrast in model predictions stemming from the two different shade curves in their Tables 7 and 8. Table 7 (WDOE 2007, Image 5) indicates for a channel width of 10 ft with a riparian buffer of 50 ft and streamflow of 7.1 cfs, the Brazier and Brown shade curve predicts that over the course of a 1500 ft-long channel length, a baseline water temperature of 14.6°C increases to 14.96°C (i.e., a $\Delta T = 0.36$°C). In terms of a rate of change per mile, this is 1.27°C/mile based on assumptions that the shading curve implied by Brazier and Brown (1973) is applicable (WDOE 2007, Image 7). On the other hand, if one uses the Steinblums (1984) curve, the rate of change in temperature is 2.15°C/mile (WDOE 2007, Image 7).

The WDOE modeling can demonstrate the differences in prediction of rate of stream heating caused merely by which model is selected. In the case of the 10-ft stream channel with a flow of 7.1 cfs and canopy density of 85%, if the Brazier/Brown model is used and one increases the buffer width from 30 ft to 50 ft, the rate of temperature change in a 500-ft adjacent harvest unit is -0.53°C/mile. In a 1500-ft harvest unit the rate of temperature change is -0.56°C/mile. This indicates basically that any harvest unit has an impact on stream temperature in relationship to its length along the channel direction. Openings caused by clearings down to the stream channel for logging corridors would create far more substantial impacts cumulatively to stream heating within a basin. When the Steinblums shade model is assumed for the buffer increase from 30 ft to 50 ft, an identical improvement in rate of temperature increase (i.e., a lower rate of temperature increase is predicted) for the 500-ft and 1500-ft harvest units.

The WDOE modeling also provides the data that can be used to show the incremental value of increasing buffer width from 50 ft to 75 ft. With the Brazier/Brown model assumed, the rate of increase in temperature between 50 and 75 ft is nearly as substantial as that for the increase from 30 ft to 50 ft. For the 500-ft and 1500-ft harvest units, the estimates were 0.42 and 0.39°C/mile improvement, respectively (WDOE 2007, Images 5 and 7). In the case of the 500-ft harvest unit, this means that, instead of a temperature increase rate of 1.37°C/mile, the temperature increase rate would be 0.95°C/mile. When the Steinblums model is assumed, the rate of temperature improvement is the same or better when increasing from a width of 50 ft to 75 ft as it was in increasing from 30 ft to 50 ft. That is, there is no significant reduction in the rate of improvement in temperature as the buffer width is increased over the range in widths from 30 to 75 ft. (Note: the first modeled increase in buffer width is 20 ft increment and the next increment was 25 ft.). Further, there is reason to believe that there would be additional improvement in temperature with an even wider buffer.

There is a substantial difference in the predicted rate of temperature change per mile when modeling is done with the Brazier/Brown shade model vs. the Steinblums model. In the case of the stream channel that is 10-ft wide, flow is 7.1 cfs, canopy density is 85%, harvest unit length is 500 ft, and buffer width is 30 ft, the predicted rate of heating is 1.90°C/mile with Brazier/Brown as the shade model component of the deterministic model, and is 2.75°C/mile with Steinblums (WDOE 2007, Images 5 and 7). This is a difference of 0.84°C/mile. A very similar difference in heating rate of these two shade models was computed for the 1500-ft harvest unit (i.e., 0.88°C/mile). When the 50-ft buffer was modeled, all other parameters being held the same as above for the 500-ft harvest unit, the Steinblums shade model produced a heating rate that was 0.74°C/mile greater than that calculated with the Brazier/Brown shade model assumed (WDOE, Image 7). This is a substantial difference with significant biological consequences.

When the WDOE (2007, Images 6 and 7) modeling was run on a stream channel that was 20 ft wide and with a flow of 14.2 cfs, generally similar results were produced, thereby validating the significance of model choice. When the Brazier/Brown model was run on a 500-ft harvest unit, the reduction in heating rate by going from a 30-ft buffer to a 50-ft buffer was 0.84°C/mile. The Steinblums shade model predicted a reduction in rate of heating for the 30-ft to 50-ft buffer condition of 0.53°C/mile, the same as for the 10-ft wide channel. The Brazier/Brown model appears to show that there is a significant ***improvement in rate*** of stream heating ***(i.e., a decreased rate of heating)*** created by increasing buffer width from 30 to 50 ft. For the same 500-ft harvest unit using the Brazier/Brown model, the WDOE model results show a 0.53°C/mile reduction in heating rate when increasing the buffer width from 50 to 75 ft. Although this is a slight diminishment in effectiveness per foot of buffer width, there is still significant value in the additional width of buffer. Interestingly, the Steinblums model shows that when buffer width is increased from 50 to 75 ft, the rate of temperature change decreases by 0.74°C/mile.

USFS/BLM claim that (USFS/BLM, Image 3): as "shade increases beyond 40% there is a corresponding reduction in stream temperature to a point (e.g., approximately 80%) beyond which further reduction in stream temperature as a function of shade is not measurable." More accurately, this figure would indicate that as effective shade increases, the rate of stream heating declines until it reaches 0°F/mile at 85-90% effective shade. At 80% effective shade, this same figure indicates that the rate of stream heating is approximately 0.3°F/mile (0.17°C/mile) at 30 cfs and about 0.5°F/mile (0.28°C/mile) at 15 cfs. Assuming that a canopy density of 85% is typical of old growth, as used in the WDOE (2007) model, the rate of stream heating for 10-ft and 20-ft wide channels according to the Brazier/Brown model is 0.95 and 1.06°C/mile for a 500-ft harvest unit. With use of the Steinblums model, the heating rate is 1.69 and 1.80°C/mile for the two channel widths. Both these heating rates are much greater than the minimal rates anticipated in the USFS/BLM model (0.17-0.28°C/mile), regardless which shade model is used. This calls into question the model results of the USFS/BLM. And it is also clear that the USFS/BLM selected the shade model that would minimize their predicted impact of reduced buffer widths.

The Brazier and Brown Shade Study is Significantly Flawed, Making its Selection as a Model for Shade Production Risky for Listed Fish

The research paper by Brazier and Brown (1973) is a central element in the USFS/BLM temperature modeling framework used to justify the thinning plan for riparian lands. USFS/BLM (2005) state:

> *A study on the Umpqua and Siuslaw National Forests measured the changes in ACD with varying riparian buffer widths (Brazier and Brown, 1972). The sites, located adjacent to clearcut harvest units had variable buffer widths.*

- **ACD is a key predictor of ΔH. Consequently, the high correlation of ACD and ΔH is not unexpected. Also, as ACD increases, there is no physical reason why ΔH would not increase. Brazier and Brown's (1973) data do not support the conclusion that ACD of 80% produces maximum ΔH or that 80% of maximum potential ΔH is the highest value physically possible.**

Brazier and Brown (1973) concluded from this work that the maximum shading ability of the average buffer strip was reached within a width of 80 feet, while 90% of the maximum was reached within 55 feet. They concluded that ACD (angular canopy density) is well-correlated with the ability to reduce stream heating. They employed a temperature model developed by Brown (1969) to predict expected change in stream temperature from the upstream to downstream ends of a clearcut harvest unit with different levels of riparian buffering. The original Brown temperature model calculated radiation input to the stream by distinguishing time periods of shade (no input) from sun (full input potential). The Brazier and Brown (1973) application of the stream temperature model used ACD as one of the key variables to predict temperature change. The conceptual basis of this is that ACD is an inverse measure of direct solar radiation input to stream water. As ACD becomes greater, the percentage reduction in heat loading (effectiveness of "heat blockage" as termed by the authors) increases. For example, Brazier and Brown (1973) would refer to a heat blocking value of 3.8 BTU/ft^2*min out of a potential 4.0 BTU/ft^2*min as a 95% reduction in heat loading from potential. Because stream temperature and the heat blocking (i.e., ΔH, BTU/ft^2*min) effect of the riparian buffer are a direct function of ACD in the temperature model, the ΔH is directly expressed by ACD. Brazier and Brown (1973) take the linear regression between ΔH and

ACD as confirmation of the importance of ACD, but the use of ACD as a surrogate for heat blocking capability merely restates the original assumption--that ACD is a measure of heat blocking. It confirms the utility of ACD essentially by correlation with itself and a mixture of a few other variables that went into the temperature model used to calculate heat blocking.

Brazier and Brown (1973, Image 2) argued that the reduction in heat loading produced by a riparian buffer reaches a maximum at about 80% ACD. USFS/BLM (2005) have translated this to mean that an effective shade value of 80% results in a maximum reduction in heat loading. The USFS/BLM acknowledge that shade curves are available from both Brazier and Brown (1973) and Steinblums et al. (1984, Image 1) but they imply that there are valid reasons for not using the Steinblums et al. curve.

> *Steinblums et al. (1984) conducted a similar study on the Willamette and Mt Hood National Forests and in the North Umpqua Resource Area of BLM. Results of the two studies illustrated lower ACD for the Willamette, Mt Hood, and North Umpqua than for sites with similar buffer widths in the Umpqua and Siuslaw National Forests. Steinblums et al. (1984) focused on the effects of windthrow in riparian areas adjacent to clear-cut harvest units. Of the 22 study sites, 13 sites contained 50 to 88% of the original buffer volume still standing at the time ACD measurements were recorded. This could account for the lower ACD measurement results from that study.* (USFS/BLM 2005)

ACD readings reported in Steinblums et al. (1984, Image 1) ranged from approximately 15 to 90%. ACD values reported in Brazier and Brown (1973, Image 2) ranged from 18 to 80%. The slightly lower ACD in Steinblums et al. amounts to 3%. What accounts for the low upper end of the range of ACD in Brazier and Brown? A lowered expectation in canopy shading is more of a concern in developing a shade curve than having a slightly lower bottom end of the range.

The ODF/ODEQ Sufficiency Analysis (2002, Image 1) provided a different interpretation of the Brazier and Brown and Steinblums et al. shade curves. They stated:

> *Considering 'small' streams only (under the FPA stream classification some of the streams in this study are considered medium and large in size), Figure 1 demonstrates the relatively high variability of buffer width as a determinant of effective shade. For example, 75- 90 percent shading can be achieved with a buffer width of anywhere from 30 to 145 feet. Looking at it a different way, a 50-foot buffer width might provide anywhere from 18-80 percent shading.* (ODF/ODEQ Sufficiency Analysis).

Given the large variation in percentage shading provided by different buffer widths, and the capability of buffers of 145 feet to provide up to 90% shade, it would not be considered prudent to assume that any narrow buffer (e.g., <<100-ft no-harvest buffer) can currently or at any time in the future be expected, with a high level of confidence, to provide a high level of shading comparable to site potential with a buffer of 145 ft.

The study by Brazier and Brown (1973) and methodology constructed by USFS/BLM (2005) reliant solely on Brazier and Brown are based on some questionable reasoning. Points that will be critiqued below involve the basis for arguing that:

(1) ACD reaches an asymptote at 80%.
(2) Heat blockage reaches an asymptote at 80% of maximum insolation
(3) A buffer strip of 55 ft provides 90% effectiveness in blocking heat.
(4) Shrubs are just as important as trees in preventing stream heating; or commercial timber volume alone is not an important criterion.
(5) The Brazier and Brown shade curve is preferable to the Steinblums et al. curve.

The Brown (1969) temperature model was a very innovative advance in understanding the heating of streams as related to riparian cover. The study by Brazier and Brown (1973) makes use of this temperature model to estimate the temperature that would result from a streamflow length past a riparian buffer corridor adjacent to a clearcut. The riparian buffers each have a streamflow discharge, stream width, water temperature above and below the clearcut, ACD as a measure of canopy cover, bd-ft of commercial conifers, and % shade contributed by conifers associated with them. It appears that the authors used a potential solar radiation intercepted at the ground of 4.0 BTU/ft^2*min as a maximum potential (Brazier and Brown 1973, Images 1, 7, 10, 11) for the general latitude and time period during which the temperature models were run. Presumably, ACD, stream width, and other factors were used to calculate a predicted increase in stream temperature that would occur after removing a portion of the timber volume in the riparian buffer. [Note: this interpretation of the Brazier and Brown paper cannot be derived from the paper directly because not enough description was given of its methods. However, this interpretation is that provided by USFS/BLM (2005) and seems to be logical. See below for more explanation of this interpretation]. The predicted temperature was compared with the observed. In many cases the predicted temperatures were very far different from observed. For example, on Griffith Creek, the Brown temperature model was used to predict water temperature; the observed change was 3.0°F while the predicted temperature change was 21.7°F. This indicates some serious difficulties in using the temperature model. The authors apparently correlated the volume of commercial conifers removed (bd-ft/ft of riparian length) with the amount of heat blocked (ΔH). They claim there is no clear relationship between standing volume of commercial conifers and heat blocked because of the weak linear regression. However, the likelihood that shrubs were considered as shade in the ACD estimate would significantly remove the importance of riparian timber as a shade producing factor. Because the significance of the shrub shading variable is totally uncontrolled, it is not really possible from this study to examine the effectiveness of different levels of riparian conifer stocking. Removal of riparian conifers definitely has an effect, but its effect is confounded with other variables.

USFS/BLM (2005) reported that Brazier and Brown interpreted the bd-ft/ft data from their Table 2 as a conifer volume removed. Values computed in column 5 (Table 1 below) correspond well with data from USFS/BLM (column 6), so it appears they interpret Brazier and Brown's data as timber removed. However, if this is the correct interpretation, there is an error in the Lower Reynolds Creek data for either timber removed or initial timber volume, given the negative value for conifer volume remaining after harvest. Brazier and Brown provided the commercial volume in Lower Francis in their Table 2, but gave no data on timber volume in their Table 1 for this stream.

Table 1. Selected data and computations from Brazier and Brown (1973).

Stream No.	Brazier and Brown	* Table 1 Buffer strip width (ft)	** Table 2 Commercial volume in conifers bd-ft	*** Table 1 Calculated bd-ft/acre removed	**** USFS/BLM bd-ft/acre removed	***** bd-ft/acre remaining
1	Little Rock	47	75000	46340	46296	28660
2	Upper Reynolds	10		0		
3	Lower Reynolds	40	25118	45738		-20620
4	Upper Francis	50	187885	67954	68322	119931
5	Upper Deer	100		4792		
6	Lower Deer	100	138830	44431		94399
7	Lake	30		2904		
8	Upper Grant	60	36073	30492		5581
9	Lower Grant	60	36073	30492		5581
10	Griffith	50	411625	119354	120134	292271
11	Upper Needle Branch	8				

*	Data from Brazier and Brown, Table 1
**	Data from Brazier and Brown, Table 2
***	Data from Brazier and Brown, Table 1, calculated from bd-ft/ft
****	Data reported by USFS/BLM for Brazier and Brown's study
*****	computed as difference between initial commercial volume (column 5) and volume removed (column 6)

- **The Brazier and Brown (1973) study appears to represent a wide range of riparian conditions from poorly stocked communities where shade is dependent on salmonberry to mature conifer stands. This is hardly a basis for claiming that the Steinblums model should not be used.**

There is also a huge difference in initial riparian timber volume of commercial conifers. Conifer volume ranges from 25,118 to 411,625 bd-ft/acre, a factor of 16. One can assume that deciduous trees could comprise an unknown portion of the riparian canopy, but it appears that there would still be huge differences in initial timber volume. As an example, comparing Little Rock with Griffith Creek, there was 75,000 and 411,625 bd-ft/acre of conifers initially, respectively, and conifer shading was 87.5% and 74.2%.

Given the similarity in conifer shading, one would conclude that other shade producing trees accounted for <26% of the shade. These streams represent enormous differences in standing timber volume. Consequently, the Brazier and Brown study provided a range of riparian types that were probably far from late seral in many or most cases. Also, they hardly represent the full benefit that could be derived from full riparian stocking even in their initial condition. If a riparian buffer initially is sparsely stocked, the temperature increment caused by removing more trees would be less than if it were initially fully stocked. In addition, these data indicate that the Steinblums et al. data may provide a more convincing representation of late seral riparian vegetation despite having some blowdown in 13 of 22 streams.

Much is made out of the supposed non-relationship between commercial conifer volume and the ability of the canopy to block heat. However, there are serious errors in the paper in reporting the available board feet of conifers in the riparian buffer. The USFS/BLM TMDL ISE report provides their calculation of the number of board feet of commercial timber. Timber volumes for four streams were given: Lower Francis, Little Rock, Upper Francis, and Griffith. The board-ft values presented by USFS/BLM (Table 2 below) were calculated from Brazier and Brown's (1973, Image 12) Table 1 from the column "timber volume/foot of strip, bd-ft." The method is to multiply the buffer width (ft) by 1 ft of stream length to calculate the area in which the timber volume was distributed. This was then converted to a bd-ft/acre basis. The problem is that in their Table 2, Brazier and Brown also provided data on commercial volume in conifers. For Little Rock, data from Table 1 indicate a timber volume of 46,340 bd-ft/acre, while from Table 2 a volume of 75,000 bd-ft/acre is indicated. USFS/BLM claim that the first volume is volume removed, but Brazier and Brown do not state that this is the case. In addition, Brazier and Brown do not provide the bd-ft/ft data from which to calculate volume/acre as reported by USFS/BLM. But taking the USFS/BLM interpretation as an accurate reflection of the study, there would be 28,660 bf-ft of conifers remaining after riparian harvest (Table 1 above).

- **Excluding streams from analysis because they require topographic shading to compensate for lack of buffer width is invalid and biases the analysis against wider buffers**

Lower Reynolds Creek had a buffer of 40 ft and an ACD of 46.9%, yet increased in temperature by 1.4°F relative to the predicted temperature. Brazier and Brown discounted this stream because it didn't have topographic shading like other streams and solar radiation penetrated to the stream from low in the canopy by side-lighting. This is precisely the reason why focusing on canopy coverage solely between 10 am and 2 pm is not sufficient. It is especially important on streams flowing on gentle terrain to have wide multistoried buffers so that solar radiation penetrating the canopy at a variety of heights can be screened out.

Table 2. Buffer width and ACD for selected streams of Brazier and Brown (1973) (as reported by USFS/BLM (2005) in their Table 1.

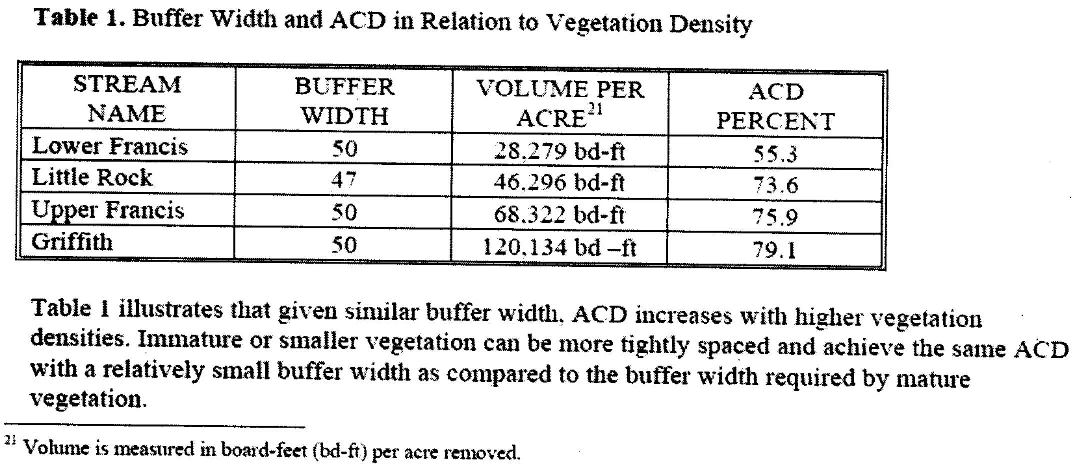

Table 1. Buffer Width and ACD in Relation to Vegetation Density

STREAM NAME	BUFFER WIDTH	VOLUME PER ACRE[21]	ACD PERCENT
Lower Francis	50	28,279 bd-ft	55.3
Little Rock	47	46,296 bd-ft	73.6
Upper Francis	50	68,322 bd-ft	75.9
Griffith	50	120,134 bd –ft	79.1

Table 1 illustrates that given similar buffer width, ACD increases with higher vegetation densities. Immature or smaller vegetation can be more tightly spaced and achieve the same ACD with a relatively small buffer width as compared to the buffer width required by mature vegetation.

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[21] Volume is measured in board-feet (bd-ft) per acre removed.

- **Uncertainty in what data are plotted in Brazier and Brown's study lead to either spurious or confused relationships between ΔH and timber volume**

Brazier and Brown (Image 1) plotted ΔH vs. timber volume as bd-ft/ft. The timber volumes they plotted corresponded to values presented in their Table 1 (Image 12). However, values for 13 streams were plotted, but a regression based on only 10 streams was calculated. The volumes plotted correspond to those identified by USFS/BLM as bd-ft/acre removed rather than commercial volume in conifers as presented by Brazier and Brown in their Table 2. The authors do not indicate that they removed any timber. How would they expect that the heat blocking (ΔH) would be a function of the timber removed from the riparian buffer rather than the standing trees in the riparian buffer when on streams such as Upper Needle Branch and Upper Reynolds there was 0 timber volume/foot of strip (i.e., no commercial timber removed)? In this case the ΔH is a function of the non-commercial timber volume, but these data were not provided or plotted. This was not described as a study of the effects of thinning of a buffer. It was stated that timber volume was determined by conventional timber cruising, not by measuring the volume of logs loaded. Brazier and Brown's study was presented as a study of the effectiveness of riparian buffers against upslope clearcutting, not clearcutting combined with riparian thinning. The confusion in Brazier and Brown's report concerning their methods and what they are actually plotting makes their tables and figures very uncertain expressions of an underlying hypothesis.

- **Uncontrolled influence of shading by salmonberry makes prediction of the influence of conifer shading and buffer width ambiguous. In addition, the shade provided by deciduous trees or non-commercial conifers adds more uncertainty about the significance of commercial conifers**

Brazier and Brown (e.g., p. 4, p. 6) noted repeatedly that salmonberry have no commercial volume but are excellent sources of shade for small streams. It is not clear in this publication whether they included shrub cover as a component of ACD. In their Table 2 the commercial volume of conifers is labeled simply as bd-ft but it appears to be bd-ft/acre (Brazier and Brown, Image 13). The commercial volume in Griffith Creek is the greatest at 411,625 bd-ft/acre. It is claimed that board feet is not an indicator of ability to block heat. Griffith Creek has a 50-ft buffer as does Upper Francis. ACD values of these streams are comparable: 79.1% vs 75.9%, respectively (see Table 3 and Image 12). And, the estimated heat blockage factors were 3.5 vs. 3.8 BTU/ft^2*min. Griffith has 74.2% shade provided by conifers vs. Upper Francis's 79.2%. In most respects this appears to confirm that there is little difference in heat blockage between the two streams given the large difference in bd-ft/acre. However, it is unclear in Brazier and Brown whether the percentage of shade "contributed by conifers" means all conifers or only commercial conifers.

If we adopt the USFS/BLM interpretation that the Brazier and Brown study reported bd-ft removed from riparian buffers, Upper Francis had half the bd-ft of conifers removed that were removed from Griffith. Still, the heat blocking value of the conifers on Upper Francis was greater than for Griffith, and was the greatest of all the streams studied. If removal of only 36% (i.e., 68,322/187,885) of the commercial conifers on Upper Francis can account for 95% (i.e., 3.8/4.0) of the heat blocking that occurred on Upper Francis due to the riparian buffer, one would have to ask what is the value of the remaining 119,931 bd-ft/acre of commercial conifers in terms of heat blocking?

Another significant problem is that the predicted temperature change on Upper Francis Creek is 41.9°F, which appears to be highly spurious. On Upper Francis Creek the model predicts a temperature of 101.9°F, whereas only 62.0°F was observed, while on Griffith Creek a predicted temperature of 80.5°F was estimated but only 67.0°F was observed. If the temperature model predicted such different temperatures from what was observed, it seems likely that the estimates of blocked heat are not accurate.

Table 3. Data selected from Brazier and Brown (1973) and USFS/BLM (2005) for two streams in the Brazier and Brown study.

Stream No.	Brazier and Brown	* Table 1 Buffer strip width (ft)	** Table 2 Commercial vol. in conifers bd-ft	*** Table 1 calculated bd-ft/acre removed	**** USFS/BLM bd-ft/acre removed	***** bd-ft/acre remaining	Heat blocked BTU/ft^2*min	ACD %	Shade from conifers %
4	Upper Francis	50	187885	67954	68322	119931	3.8	75.9	79.2
10	Griffith	50	411625	119354	120134	292271	3.5	79.1	74.2

* Data from Brazier and Brown, Table 1
** Data from Brazier and Brown, Table 2
*** Data from Brazier and Brown, calculated from bd-ft/ft
**** Data reported by USFS/BLM for Brazier and Brown's study
***** computed as difference between initial commercial volume and volume removed

Upper and Lower Grant Creeks had a relatively low commercial, conifer timber volume (36,073 bd-ft/acre) and only 10% of shade was "contributed by conifers." Buffer widths were 60 ft on each stream reach. ACD values were 59.1 and 65.2% on Upper and Lower Grant and heat blocked was 2.3 and 3.2 BTU/ft^2*min, respectively. It is difficult to compare this with reports from other streams with greater amounts of commercial timber because obviously a large percentage of the shade is contributed by deciduous trees or shrubs with Upper and Lower Grant. But if "shade contributed by conifers" means that the 10% shade was contributed only by commercial conifers, then it is unclear whether there could be non-commercial conifer volume that creates the major difference heat blocking capability in the canopy cover. Or if "shade contributed by conifers" means all conifers (commercial and non-commercial), then the identical values of commercial conifer bd-ft/acre (36,073 bd-ft/acre) could mean in one stream that the 10% shade is comprised by 36,073 bd-ft/acre of commercial and the remaining 90% would then be comprised by shrubs or deciduous trees. In the other stream, the remaining 90% shade could be contributed only by salmonberry. The differences in interpretation confound identifying the value of standing timber vs. shrub cover. The confusion created by this research document makes it impossible to conclude what the effect of commercial conifer volume is.

The height of commercial timber is not given in this report nor is the length of the affected reach. A large volume of commercial timber that is predominantly at a height that provides poor shading cannot be compared with an equal volume of timber that is at a height that does provide good shading that, in addition, has non-commercial timber in the understory. The lack of detail provided in this report makes conclusions about the value of buffer width unsubstantial. The report is used to justify the value of ACD generated by any type of vegetation, whether it be salmonberry or commercial timber. There is a blurring of value of commercial timber by not specifying the height of the timber available and the distribution of height classes.

Lower Deer Creek has a relatively high volume of commercial conifers (138,830 bd-ft/acre), yet has only 25% of the shade produced by conifers (Brazier and Brown's Table

2, Image 13). The ACD value involves only that vegetation intercepted by a line of sight from the stream to the canopy at an angle equal to the solar altitude and azimuth for the day on which the temperature model was run. [One can only assume that this is what was done for the actual individual study sites in the case of each stream modeled, because nothing was indicated to affirm this point in this very sparsely described study.] This would imply that if 25% of the shade was produced by conifers that this shade was provided either by commercial conifers or by a combination of commercial and non-commercial conifers. This means then that the remaining 75% shade was provided by either non-commercial conifers or by hardwoods and shrubs. Under any circumstances, Brazier and Brown make it clear that they value the shade provided by salmonberry. This means that they were probably recording ACD values that had a substantial, and probably highly variable, shrub component to the shade. If there is a high shrub shade component, then it is likely that the % shade contributed by conifers means very little about the potential shading capability of the conifers standing in the riparian zone. It is not clear whether % shade means the percentage of shade as indexed by the ACD, which could include salmonberry, or whether this means percentage of the potential shade produced by tree cover that is conifer vs. deciduous, excluding shade by grasses or shrubs.

Assume that there are two riparian buffers, each with an identical commercial timber volume (e.g., 150,000 bd-ft/acre), and we know that the tree height and canopy characteristics (leaf area index, canopy cover density) are identical, but salmonberry provides 50% of the available stream shade on one stream and 0% on the other. If the ACD for each of these streams is 80% and there were no streamside shrub layer at either, each stream would have 100% of the ACD provided by conifers. But if one stream has a border of salmonberry in addition, this stream might then be reported as having 50% of its ACD provided by conifers and 50% of the ACD provided by salmonberry. This situation obscures the value of the commercial timber in the riparian zone. Data such as these were improperly used to infer that there is no value in commercial timber volume (or by inference, vegetation height). This does not mean that commercial timber has no value in shading the stream. One would have to assume that (1) there is no value in multiple layers of vegetation in shading a stream, and (2) there is no difference between having a canopy height comprised only of shrubs relative to a canopy height provided by uniform commercial timber.

- **There is no technical justification for excluding the Steinblums et al. shade model**

The inference that the Steinblums et al. study was somehow compromised by blowdown in the riparian zone (USFS/BLM 2005), leaving only 50-88% of original timber volume in 13 of 22 streams, is not a legitimate reason for discounting the findings in this report. The Steinblums et al. (1984, Image 1) study illustrates the point that ACD of approximately 85% can be achieved at a buffer width of 140 ft. In addition, there is no indication from this plot that there might not be even greater buffering at even wider riparian buffer strip widths. Brazier and Brown (Image 2) did not study riparian buffers that were wider than 100 ft, yet they and others have concluded that wider buffers yield no additional benefits.

Steinblums et al.'s study was discounted with the claim that the riparian stands had lost some timber volume, leading to a lower than natural canopy density. However, the Brazier and Brown study had a very large variation in commercial timber volume, ranging from 25,118 to 411,625 bd-ft/acre of commercial timber. It is not totally clear what the remaining shade was produced by. For example, the authors noted that Savage Creek had a commercial timber volume of 194,980 bd-ft/acre, but that 0% shade was contributed by conifers. This came about because the commercial timber was all on the north side of the stream. This leaves the mistaken impression that a large volume of commercial timber produces no shade. This stream was not plotted in the figure for bd-ft vs. BTU/ft^2*min, yet if the commercial volume in conifers reported includes the volume on both sides of the stream in Brazier and Brown's Table 2 (Image 13) and there is variation in volume/acre between sides of the stream, yet it does not contribute to production of shade that is used in their temperature model, spurious results would be produced. Why would Brazier and Brown report commercial volume that is not remotely involved in creating screening of direct solar radiation when attempting to create meaningful regressions of ΔH against commercial volume?

- **The Brazier and Brown study has been widely used, but presumably only because its general form (i.e., shade and heat blocked increase with buffer width) appears logical. It has survived primarily as a hypothesis. Some streams were deleted whose inclusion argues for wider buffers. Its poor technical documentation, numerous errors in plotting points, reporting regressions, and interpreting its own empirical data, and biases in selecting streams to plot make its use highly suspect as the preferred model to provide a quantitatively low risk. It is not scientifically justifiable to take this deeply flawed single study as reliable evidence to claim that 90% of maximum ACD is reached within 55 feet or that maximum shading is reached in buffers of 80 feet as general rules.**

The Brazier and Brown study would have been much improved if it had been conducted on a uniform basis of comparison among streams. Their study involves riparian buffers varying widely in bd-ft/acre of commercial conifers with unknown variation in salmonberry canopy cover. In addition, there are unknown effects of variation in riparian canopy cover between the north and south sides of the streams. If all streams had equal commercial timber volumes on each side of the stream, there would be an equal basis of comparison, but the Savage Creek example shows this not to be the case. Consequently, there is no basis for concluding that commercial timber volume is irrelevant. The only way to make a proper conclusion from this is to have all streams with a similar standing volume/acre of commercial conifers that are of the same height and canopy characteristics. The only factor that would vary would be buffer width. By this method, the effect of different buffer widths could be clearly shown. The Brazier and Brown study starts with the hypothesis that ACD, no matter how it is derived, is the only important descriptor for riparian canopy. Brazier and Brown acknowledge that there are qualitative differences in shade produced by conifers relative to deciduous vegetation, but even though there is a mixture of conifer and deciduous vegetation in the streams of this study, there is no independent method used for adjusting ACD for the qualities of vegetation producing the ACD. ACD was not compared against measurements from a pyrheliometer.

Brazier and Brown (1973, Image 11) described the relationship between heat blocked (ΔH) and buffer strip width based on data collected on an original total of 11 streams. Of these 11 streams, two were omitted because they were "physiographically different from the other streams (Image 10). Both streams were located in broad, flat valleys rather than V-shaped canyons." These streams indicate the influence of topography on stream shading, according to Brazier and Brown. Because there were no canyon walls providing shading, these streams received extra energy by "side lighting." For this reason, the authors discarded the results from these streams. This is not a valid reason for omitting these results from the analysis. On Lower Reynolds Creek, the buffer strip width was 40 ft wide, yet the ΔH was 0 (Table 1 and Brazier and Brown, Image 12). Lower Reynolds had an ACD of 46.9%, yet it reportedly did not have any heat blocking ability. This would argue for a buffer wider than 40 ft or a greater volume of conifers (i.e., the commercial conifer volume in this stream was the lowest recorded at 25,118 bd-ft/acre). There are many streams without significant topographic shading found in broad, alluvial floodplains. Side lighting of these streams would be more easily reduced by wider riparian buffers. Discarding these streams makes it appear that a conclusion calling for wider buffers is an unacceptable outcome. The study results for the other streams then are confounded by varying levels of topographic shading. If heat blockage on one stream is 5% due to topographic shading, but it is 20% on another stream, the significance of both commercial conifer volume and riparian buffer strip width would vary in the temperature model. The unaccounted-for variations in this study make many of its conclusions tenuous.

In addition to the two streams omitted owing to physiographic issues (streams 2 and 3), two others (streams 1 and 5) were discarded because their buffer strips varied greatly in width, making it difficult to define a mean. However, another stream (stream 11) was accidentally omitted from the analysis. Of the original 11 streams (see Table 1, Image 12), the plot of ΔH on buffer strip width (ft) was then computed on the basis of only streams 4, 6, 7, 8, 9, and 10 (Brazier and Brown, Image 10). Because a fixed potential solar intensity at ground level of 4.0 BTU/ft^2*min was used in the plot (Brazier and Brown, Image 10), one would have to assume that temperature modeling for all streams was done on the same day of the year (e.g., August 1, as recommended in the USFS/BLM TMDL ISE). The Brazier and Brown study does not indicate on what dates temperature modeling was done for each stream. Observed temperature changes over the affected study reaches were recorded, but if these were measured on days other than a fixed date such as August 1, there is no mention of how variations in potential solar radiation were accounted for. One would have to assume that all studies were conducted very close to August 1, for example, and that on all dates of temperature measurement, the sky conditions were identical, producing equal potential insolation. Otherwise, each stream would have a different daily potential value. Because no methodology was noted for making adjustments and no assurance was given that dates and atmospheric conditions were comparable, it is difficult to assume that all streams are plotted on an equal basis.

- **Brazier and Brown (1973) produced response curves that reflected their hypotheses more than their data**

The Brazier and Brown plot (Image 10) of ΔH on buffer strip width (ft), using only 6 of 11 original points was fit with a logistic equation. The curve was plotted to imply that there is an upper limit of a buffer strip width to produce effective heat blocking equal to exactly 80% of potential. If the data for stream 4 (Upper Francis) are to be believed, the heat blocking potential is 95% (i.e., 3.8/4.0 of the 4.0 BTU/ft^2*min potential).

Although the authors ascribe an asymptote to the relationship between ΔH and buffer strip width by selection of their curve fit (which was only by eye because their computer program was not working), other curve fits that are just as meaningful produce different results and conclusions. Brazier and Brown stated that the R^2 of 0.8749 in this logistic fit "indicates that the curve is a good approximation of the relation." However, Brazier and Brown also force their curve through the origin, thereby essentially adding another point to their curve fit. This is a logical decision, indicating that if the buffer width is 0 ft, the effective heat blocking (ΔH) is 0, except for the topographic shading effect, which is an unaccounted-for variable in this study. If we use the same procedure to produce a set of points to plot (i.e., selecting only 6 of 11 streams and forcing the equation through the origin), but a logarithmic plot is produced (Brazier and Brown, Image 5 and 9), a comparable R^2 results (0.8527), but the curve is not horizontal between buffer strip widths of 30 ft and 100 ft. Rather, it continues to increase gradually. Obviously, the curve cannot exceed 100% shading, but there is no logic presented for claiming that anything greater than 80% is impossible. If 7 points are plotted, the R^2 is 0.8321 (Image 8). A logarithmic plot of all 11 streams, without forcing the regression through the origin, yields an R^2 of 0.1255 (Brazier, Image 4).

Brazier and Brown's data (Image 8) indicate that heat blockage on Lower Deer is 92.5%, while that on Upper Francis is 95%. In addition, the fact that commercial timber volumes can vary greatly between north and south sides of the streams indicates that the only vegetation cover considered in producing the ACD is the cover on the south side of the streams. This means that only direct, not global (i.e., including reflected), radiation is accounted for. So 100% shade does not necessarily indicate total darkness on the stream but simply total exclusion of direct radiation. It is not proven by the Brazier and Brown study that no heat transfer to streams is made from global radiation or that there is no value in terms of radiation or microclimatic effect in having significant buffers on both north and south sides of the stream. Given this additional source of uncontrolled variation in this study, there is further uncertainty in ability of the temperature model to predict temperature changes due to clearcutting accurately.

When plotting ΔH against ACD (%) (Brazier and Brown, Image 7) the authors state that "two streams again are omitted from the analysis because of the surrounding terrain." Inexplicably, the streams that are omitted in this plot are streams 1 and 5, whereas the streams omitted because of surrounding terrain in their Image 11 are streams 2 and 3. Data for stream 11 is plotted very incorrectly and data for streams 4, 6, and 10 are plotted incorrectly but the error is not great (Image 6 and 7). Rather than a regression of ΔH = -

$0.73 + 0.053ACD$ ($R^2 = 0.8136$) as reported by Brazier and Brown (1973), the actual linear regression from their data is $\Delta H = -1.612 + 0.066ACD$ ($R^2 = 0.7991$) (Image 6).

Brazier and Brown (Image 7) noted, relative to their Figure 4, that "line segment B is the section of increasing buffer-strip effectiveness with increasing ACD. The line fits the data well with an R^2 value of 0.8939." (Brazier and Brown, p. 7). This is an error too, because the reported R^2 was 0.8136 in their Figure 4 (Brazier and Brown, Image 7). The authors also stated that "once the maximum protection has been reached, increases in ACD offer no greater protection." Brazier and Brown imposed their hypothesis that ACD reaches a maximum at 80% by selection of their curve fitting method (Image 2). Then in Image 7 they claimed that there is no further benefit to ACD above 80% in terms of ΔH, despite not having any ACD data above 80% with which to calculate ΔH. USFS/BLM (2005) then claims that at an effective shade of 80% there is no further benefit to stream temperature, despite the fact that Brazier and Brown reported a 92.5-95% reduction in ΔH with an ACD of 80%. TMDLs conducted by ODEQ frequently reported shade values in the 90%+ range.

Brazier and Brown (1973, Image 2) then plotted "the relation between angular canopy density and strip width for all the streams studied." Anomalies in plotting points crop up in this figure also (Images 2 and 3). First, the authors plot 13 points but report data for only 11 streams. A plot of data for the 11 streams would include the 4 streams that were excluded in the other plots. Streams 5 and 6 had buffer widths of 100 ft and represent the highest ACD values. However, we know nothing about the site potential for these streams, the height of the canopy, the potential ACD values that these sites could produce. We also know nothing about the amount of blowdown in these streams or the lack of vegetation in the buffers that are provided. Consequently, it is impossible to say that the Brazier and Brown streams represent anything comparable to a site potential level of riparian vegetation cover where the only variable is buffer width. So, it is not possible to claim that their shade curve is preferable to that of Steinblums et al. Both curves may not represent site potential shading where the only variable is buffer width. Consequently, greater buffer widths may be important in producing additional ACD.

In Brazier and Brown's Figure 5 (Image 2), stream 1 is plotted very incorrectly. Two other points appear that are not associated with any data presented in Table 1. Again, the authors fitted a line by eye that reaches an asymptote and also indicated that the maximum ACD is reached within a buffer width of 80 ft. A plot of the data actually provided yields a logarithmic regression of $y = 15.912\mathrm{Ln}(x) + 5.8952$, where x = buffer width (ft) and y = ACD ($R^2 = 0.4741$) (Image 3). This curve is not horizontal at a buffer width of 100 ft but indicates an increasing ACD with buffer width. Obviously, it is possible to have ACD values greater than 80%. This depends upon site potential, which is never addressed in this paper.

Alternate Riparian Buffer Methodologies Exist that Account for Shade but Also Other Functions of Riparian Buffer Zones

Reliance on only shade models for specifying buffer widths is not ecologically appropriate. Kondolf et al. (1996) proposed a holistic method for specifying buffer widths that accounts for all ecological benefits of riparian zones. Their method defines a means to minimize disturbance to ecological processes within riparian buffers that accounts for the community area and energy area of riparian areas. The buffer width specified is sensitive to sideslope gradient and soil detachability. Their formula for buffer width is: buffer width (ft) = minimum width $\cdot\ e^{(1+a+b-a \cdot b)}$, where a is the slope coefficient and b is the soil detachability coefficient. The minimum width specified is that width that meets the minimum requirements for community area and energy area functions. Community area satisfies the requirements for aquatic and terrestrial-dependent species. Energy area functions are provided by a buffer in delivering site potential levels of LWD and organic inputs (quality and quantity). A site-potential tree height is a useful index to the energy input area.

Shade Models are Based upon a Variety of Assumptions that Have not Been Fully Tested and Carry Inherent Risk

Estimation of shading on streams has improved in recent years. For many years forest practices researchers? recommended use of the spherical densiometer as a device for estimating riparian canopy density, but it has been found that this device has little bearing on the transfer of solar radiation to the stream because it focused on parts of the canopy that were not involved in creating effective shade for a particular month of the year (Teti and Pike 2005). This device was widely acknowledged to be very subjective. Even in recent years state forest practices rules advised landowners that it was acceptable to remove buffer trees that could not be easily seen from a vantage point in the channel. This procedure was based on the theory that there is no shade value in a tree behind a tree. This same theory is carried into the USFS/BLM temperature TMDL position paper for application to federal lands. This view might seem logical if tree canopies were impenetrable opaque objects extending to their outer canopy edges. However, this is not the case, making filtration of light through multiple layers of canopy valuable.

The creation of the concept of angular canopy density by Brazier and Brown (1973) was a valuable contribution in riparian buffer scientific investigation. Documentation of their reference sites and methods for developing their shade curve, however, is sparse, poorly described, and subject to a high level of personal interpretation. There is also great subjectivity in the use of modern ACD devices. The theory is that by observing only that portion of the canopy intersected by the sun at the azimuth and solar angle coinciding with the period between 10am and 2pm (i.e., the most effective heating portion of the day) the potential of a stream to heat, given its canopy characteristics, could be defined. The ACD meter assists in locating those segments of the canopy to focus on, corresponding to the "critical" 4-hr portion of the day. But this device simply creates a framework in which subjective evaluations of shading values can be made. Error in making subjective assessment is typically greatest under such circumstances where irregular objects fill about 50% of a space as opposed to near 0 or 100% (Teti and Pike 2005, Image 1).

Development and use of a new device, such as the ACD meter, is typically accompanied by calibration of it against another method considered to be more reliable, or a standard. It is difficult to know what method actually gives the most reliable estimates in many cases. However, most people assume that the hemispherical digital estimation of angular canopy density by evaluation of pixels on fish-eye digital imagery is most reliable. It offers permanent documentation of canopy and careful evaluation of each pixel of an image, allowing distinction of canopy from sky. The canopy in the direction of the sun at various time increments during the day can be estimated, assuming that the south point can be located accurately and the lens was correctly leveled. Teti and Pike (2005, Image 2) showed the correspondence between estimates of ACD made by digital fish-eye imagery by use of a computer and the visual estimate made with an ACD meter in the field. For a coniferous riparian canopy they found that when ACD measured with the digital imagery method was approximately 75%, the ACD measured by the ACD meter was approximately 30 to 80%. It is acknowledged too that the digital imagery method also has issues that cause variation in multiple readings of the same canopy, such as light intensity (Teti and Pike 2005). Erman and Ligon (ca. 1985) observed a high level of correlation between ACD and total mean daily radiation measured by a photometer. Four values taken during the day were sufficient to express the mean daily radiation. Highest ACD values were related to approximately 94% light blockage, not 80% as suggested by USFS/BLM. While there is no method that is perfect and the digital imagery method may be a reasonable standard, with the ACD meter a promising tool for field applications, the level of error in all these tools creates great cause for not attempting to reduce riparian buffers to minimal extents. More accurate may be a pyranometer or quantum sensor (Minshall and Rugenski 2006), although these devices would require integration of solar radiation at a point for the daylight period (or for the 4-hour period recommended by USFS/BLM for comparability). Also, care needs to be exercised to ensure that wavelengths sensed are related to stream heating. These devices, however, would establish the relationship between ACD and energy input to the stream. The Solar Pathfinder is a tool for estimating ACD, but the connection between ACD and effective shade is not entirely clear (Teti and Pike 2005).

The assumption that the 4-hour sweep of the sun through the canopy would be sufficient to indicate the potential for stream heating does not appear to be reliable in all cases. For example, a stream reach that has a 90° orientation (flowing east-west) with an average canopy density of 85% has the lowest directional effective shade at approximately 8:30am and 5:30 pm (WDOE 2007, Images 2 and 3). If the channel width is 20 ft, the effective shade between 10am and 2pm can be approximately 80%, but the effective shade at 8:30am and 5:30 pm can be as low as 50%. Solar intensity is lower at this time than at noon, but the lower ACD can compensate for the reduced intensity due to solar angle.

A stream oriented at 45° and having a riparian community with a uniform canopy density of 85% can have its lowest effective shade at approximately 3pm. USFS and BLM

(2007) indicate that between 10am and 2pm one can expect potential radiation to be 58% of the total daily radiation, but 42% of total radiation occurs during the remainder of the day. The remainder of the day, though, has the sun at a lower solar altitude so that shading, especially by topography is more likely. However, canopy shading with solar altitude can vary according to extent of understory canopy. Consequently, there may be no substitute for a more complete evaluation of actual ACD throughout the daylight period rather than simply focusing on a 4-hour period.

Studies directed at measuring the change in solar input to a stream with increasing riparian buffer width have shown that solar radiation decreases exponentially with width so that radiation intensity (kW/m^2) at the stream is minimal where buffer width approaches 80 m (Brosofske et al. 1997, Image 1).

Although the USFS/BLM model assumes that all shade is equal, it is critical to allow trees in the riparian buffers to achieve site potential tree height and for understory vegetation to occur in addition. Claims that recovery can occur on small streams rapidly merely by development of streamside brush are premature and probably are highly dependent upon size of riparian clearing. Hewlett and Fortson (1982) and Macdonald et al. (2003)(as cited by Moore et al. 2005) showed that cover by short streamside vegetation was not as effective as the same amount of shade from trees at controlling water temperature. It seems likely that there is great value in a thick layer of cool air in riparian zones provided by a wide buffer, well shielded from lateral wind intrusion. Forest canopies provide a thick layer of cool air in which turbulence is reduced from higher level air flow. This would likely reduce advection of heat to the adjacent stream and streamside zone. If a stream is merely covered by brush that is 2-m high, for example, and warm air temperatures have extended to within 2 m of the stream surface, there is less resistance to heat transfer to the layer below this canopy. The effectiveness of canopy thickness or effectiveness of multilayered canopies has not been well studied, but this is just one more potential effect that is ignored in the current attempt to downgrade riparian standards.

One of the most comprehensive summations of the science of microclimate response to riparian management is presented by Moore et al. (2005). These authors state "Riparian microclimates appear to have been relatively little studied, both in general and specifically in relation to the effects of different forest practices. Further research needs to address these knowledge gaps." Also, *"Further research should focus on the application of hemispherical photography, including an assessment of sampling variability and bias."* And *"Further research should address the thermal implications of surface/subsurface hydrologic interactions."* There actually has been enough significant research done on effects of riparian management on stream temperatures and microclimatic effects to justify maintaining significant no-cut buffers (similar to those recommended under FEMAT). Knowledge gaps that do exist in this research field would argue forcefully for a cautionary approach to additional forest management rather than making the rash assumption as with USFS/BLM that all the answers are in now to drive the streams to some vaguely specified level of acceptable impact but no further.

The USFS/BLM Proposed Shade Model does not Include a Margin of Safety to Account for Uncertainty in Shade Calculations and in Addition Ignores all Other Functions of Riparian Buffers

The Clean Water Act requires that each TMDL include a margin of safety (MOS) to account for uncertainty in data and the effectiveness of land management actions in controlling loading of pollutants (heat in the case of water temperature) (ODEQ 2002a, Upper Klamath Lake TMDL). The MOS can be included implicitly by use of conservative assumptions in calculating the loading or numeric targets. The MOS can also be inserted explicitly by setting more conservative numeric targets or adding a safety factor to loadings. All assumptions should be stated and the basis for the MOS needs to be documented (ODEQ 2002a, Upper Klamath Lake TMDL). Unfortunately, the USFS/BLM shading methodology does not include any MOS but aims at the minimum buffer width possible that can be claimed by very crude methodology built on innumerable untested assumptions to meet a shading target that is not necessarily related to the natural potential of the stream.

Allen and Dent (2001) state:

> *"The DEQ is required to develop total maximum daily loads (TMDLs) for streams that do not meet the WQS. A key component of DEQ's approach for meeting the temperature standard is developing TMDL allocations for non-point sources to reduce solar loading. Temperature TMDLs are often based on predicted levels of "effective shade" that, in turn, are derived from a prediction of "system potential" vegetation and channel morphology. The DEQ defines system potential vegetation and effective shade in the following manner: System potential, as defined in the TMDL, is the combination of potential nearstream vegetation condition and potential channel morphology conditions. Potential near-stream vegetation is that which can grow and reproduce on a site, given: elevation, soil properties, plant biology and hydrologic processes. A maximum height is predicted for that vegetation type and used, in turn, to predict shade provided to the stream. This, combined with topographic shade, is used to predict the effective shade provided to the stream channel."*

The USFS/BLM reverse this emphasis on site potential by finding only the minimum height of trees needed to meet the minimal shade targets that it established. These shade targets are not even the targets selected in ODEQ TMDLs. The abandonment of site potential by favoring only shade concerns leads in the WOPR to lack of provision for microclimate characteristics of the riparian zone that would promote cool water temperatures. In addition, it results in a reduction in potential LWD suitable to provide essential geomorphic functions.

The USDI-BLM Riparian Buffer Proposal Ignores Cumulative Thermal Effects Associated with Providing Bare Minimum Buffers on Perennial Streams and High Risk Treatment to the Vast Network of Headwater Channels

The number of stream crossings (roads, utility corridors), miles of riparian roads, and miles of railway right-of-ways within riparian zones often imposes a high level of cumulative impairment in the ability of a stream network to maintain a distribution of water temperatures near the natural potential of the system (USDI-BLM 2007, Image 1). In addition to this background level of degradation, there are numerous cross-channel logging corridors for skyline logging, whereby all standing trees and snags are removed to facilitate transport of logs from hillslopes to loading areas. Given that cleared riparian zones are accepted as an excluded form of system impact and that the increase in stream temperature tends to be proportional to the cumulative length of opened riparian zone, streams within the project area operate at a baseline that begins at a high water temperature regime that frequently is not highly supportive of salmonids requiring cold water. Even if logging corridors are spaced at intervals throughout the forest, the cumulative length of canopy openings will result in a cumulative elevation of the thermal regime due to the fact that physical loss of heat does not occur readily, even when streams flow through shaded reaches (Beschta et al. 1987). Allen et al. (2007) demonstrated using a physically-based, data-validated, GIS-driven temperature model on 1st and 2nd order headwater basins that cumulative riparian tree removal leads to significant elevation of water temperatures. These authors recommend far greater protection of non-fish bearing headwater streams than is typically provided.

The rate of stream heating on a linear basis has been reported as between 0.7°C/100 m in SE Alaska to 15.8°C/100 m in the Oregon Cascades (Beschta et al. 1987, Images 2 and 3). Moore et al. (2005) indicated that the literature documents downstream warming of 7°C/46 m in Oregon (Brown et al. 1971), and 2°C/50 m, 1.4°C/30 m, and 0.4°C/20 m (Herunter et al. 2003) in various cross-channel rights-of-way. For clearcuts of various dimensions, stream temperature increases have ranged from 0.5 to 11.6°C (Beschta et al. 1987, Moore et al. 2005). In addition to the outright impacts of legacy crossings, corridors, and new skyline corridors, the O&C lands are significantly affected by cumulative impacts from current and past logging in a checkerboard land ownership pattern. Current forestry rules on private lands in this checkerboard are weak and unprotective and historically were substantially worse. The proposed WOPR rules, rather than attempting to maintain a high standard on federal lands that might compensate to some extent for private land forestry, are aimed more at matching the lowest common denominator. Despite arguments by the timber industry that streams cool rapidly when they pass into shaded reaches (assuming some remain), this is not necessarily the case (Beschta et al. 1987, Moore et al. 2005, SER 2000, NOAA 2005). This means that each increment of warming from the combined road and logging or utility corridor crossings in a watershed produces a further degradation of water quality. Many apparent decreases in water temperature that are observed are either due to extremely low and slow streamflow volumes in headwater streams or mixing of surface flows with hyporheic or groundwater flows (Story et al. 2003). Ignored in the process is the longitudinal water temperature pattern at these sites that existed prior to canopy opening.

The cumulative warming from existing canopy openings and watershed condition should place a greater responsibility on federal land managers to shore up the impaired function of the streams draining these impacted watersheds by taking increased precautions within federal ownership. Rather than using a precautionary approach, the federal proposal is to use recent and lightly tested theories to push the envelope in riparian protection to a point where one would have to assume that significant biological impacts are occurring, even though they may be statistically difficult to detect against a backdrop of existing impact level. It is far more prudent to approach thresholds of impact (assuming that that was even what was being proposed), after the functions of the system have been restored. But in taking already damaged streams and withdrawing the last semblances of safeguards, it is clear that the USBLM is taking the viewpoint that the highest priority is timber production rather than restoration of salmon populations.

> ***Condition of landscape matrix:*** *The landscape matrix in which corridors are embedded greatly influences corridor use. If conditions in the matrix are suitable (e.g., sufficient original vegetation cover exists), then species reliance on corridors may be minimized. On the other hand, if matrix conditions are inhospitable or degraded (e.g., are highly developed or fragmented; have disrupted ecological processes or disturbed conditions; or are highly invaded by exotic species), then corridor systems linking remnant patches may be required to retain landscape connectivity (Rosenburg et al. 1997 as cited in Lindenmayer and Franklin 2002).* (Environmental Law Institute 2003).

The USDI-BLM does not assess the riparian condition required for maintenance of all riparian functions. For example, as described above, in order to maximize the ability of a riparian zone to provide for the needs of numerous species of wildlife, the riparian condition must be considered within the context of the level of fragmentation of the matrix lands. Matrix lands are typically subjected to far greater levels of impact than even riparian lands. By directing riparian condition to be minimized with respect to meeting only the USFS/BLM shade targets at some future date and ignoring the corresponding condition of the matrix lands, it is not possible to assess the cumulative effects on riparian lands for all riparian functions.

The Minimal Protection to Headwater Streams Jeopardizes Downstream Water Quality and Fish Populations

Under the NW Forest Plan non-fish-bearing, seasonal streams on the west side had 170-ft buffers designated. These buffers permitted occasional salvage and thinning, if and only if assessment using best available science concluded these activities would promote attainment of the NWFP's Aquatic Conservation Strategy riparian management objectives. However, the current proposal (USDI-BLM 2007, Alternative 2, Table 31) abandons this protection in favor of a mere 25-ft buffer. Actually, this buffer width is specified as 0 to 25 ft, which is in deference to the concept that fixed buffers of any dimension are not flexible to meet "ecological needs." It is not clear what ecological needs, though, are met with a 0-m buffer. Only 12 conifers per acre are required in this buffer (no size requirement is specified). Referring to WDOE (2007, Image 4), it is clear that severe reductions in canopy density will have an enormous impact on solar radiation loading on these channels. As a consequence, an added level of uncertainty is created by this "flexibility." This amounts to a carte-blanche provision of buffers that are infinitesimally small. This carries no pretense of protection of streambank stability, shading, nutrient retention, sediment retention and filtering, microclimate protection, wildlife protection, stabilization of debris flows, or any other normal riparian function.

With regard to thermal protection of individual stream reaches or protection from cumulative warming of entire drainages, the ability to provide minuscule buffer widths or none at all ensures that there will be minimal to no protection from stream heating of perennial, fish-bearing streams originating from management of intermittent, non-fish-bearing streams. This is typically excused by forest managers who claim that if a stream does not have surface flow during the summer there could be no downstream impacts on fish-bearing streams. Evidence to the contrary has been available in scientific literature for the past 2 to 3 decades.

First, non-thermal sources of impairment to the stream temperature regime can originate from the increased fine sediment delivery from headwater streams owing to reduced streambank protection and inability of minimal buffers to retain sediments released from steep sideslopes. This increased sediment delivered to stream systems collects downstream in lower gradient fish-bearing streams where it contributes to filling of pools and widening of stream channels (Beschta and Taylor 1988, Rhodes et al. 1994). This results in increased W/D ratios and loss of channel capacity. Both of these effects lead to increased solar inputs to streams.

Past headwater clearcutting has left a legacy of channel incisement, draining of stream adjacent wetlands, and altered seasonality of streamflows. Channel incision drains shallow groundwater, reduces summer baseflows (Ponce 1989), and can lead to loss of riparian vegetation (Sandecki 1989, as cited by Spence et al. 1996). The increased solar inputs to forest soils, streamside slopes, and streambeds can result in reduction and elimination of surface flows in channels altogether. These channels then become classified as intermittent channels, whereas historically they many have either flowed year-round or had a much higher probability of year-round flows.

Headwater streams contribute over 70% of the mean annual surface water volume carried by stream systems (Alexander et al. 2007). It has also been documented that shallow groundwater comprises the majority of surface water runoff even during peak flow events (Abdula and Gilham 1989). Shallow groundwater entry to channels frequently acts as a source of cold water to stream systems (Ozaki 1988, as cited by Ebersole et al. 2003). The presence of concentrated flows of shallow groundwater in streamside areas can be predicted by topographic analysis (O'Loughlin 1986) and can frequently be observed by use of FLIR imagery (Boyd and Kasper 2002). In headwater watersheds, road cuts typically intercept shallow groundwater and route it to roadside ditches, which then deliver it to the stream directly or through culverts crossing the road (ODF and ODEQ 2002) and passing onto the floodplain (Gucinski et al. 2001). This premature exposure of subsurface flows to solar heating prior to entering a headwater channel increases the temperature of surface water flows. It also tends to alter the seasonality of flows from the watershed by causing a rapid outflow of annual precipitation. Less water held in soils results in an expansion of intermittent channel length. Clearcutting of headwater slopes can result in increased solar heating of forest soils, thereby increasing the temperature of shallow groundwater passing through these soils (Bren 1997, Peck and Williamson 1987, as cited by Curry et al. 2002; Hewlett and Fortson 1982, Brosofske et al. 1997, Van Wijk 1966, Meisner et al. 1988; Holtby 1988, as cited by Ebersole et al. 2003). Even with no surface flow, the lack of riparian cover can raise the temperature of shallow groundwater relative to wooded area (Pluhowski and Kantrowitz 1963). Intermittent, non-fish bearing streams with adjacent clearcuts are not shielded from strong solar heating. Direct heating of the dewatered channel substrates has the potential to significantly heat shallow, subsurface flows that contribute downstream to fish-bearing waters. Olson (1998) (as cited by Pollock and Kennard 1998) estimated that upland forest removal can increase groundwater temperatures as much as 6 feet deep. Childs and Flint (1987)(as cited by Bartholow (2000) contrasted the effect of clearcut vs. shelterwood harvest in southwestern Oregon on soil temperatures and found differences of 17°C at a depth of 2 cm and 5°C at 32 cm. Hewlett and Fortson's (1982) studies in forests of the Piedmont region revealed a significant potential for cumulative stream heating from ground surface heating. The effects of heating of hillslope soils exposed in upslope clearcuts can affect stream heating by heat advection to the stream. This effect requires application of wider buffers (Moore et al. 2005).

In a cumulative manner, it is likely that heating of headwater, non-fish-bearing streams cause significant elevation of downstream salmonid waters. Hatten and Conrad (1995) found that the quantity of late-seral forests in watersheds was a good predictor of maximum stream temperature. Their study suggested strongly that even if buffers are provided along fish-bearing streams, watersheds with higher levels of harvest had water temperatures in fish-bearing zones that were higher than in watersheds with less harvest. Despite professions of concern for ecosystem processes, restoring watershed function, and maintaining linkages among components in the watershed, the new BLM proposal is for renewed attempts to compartmentalize and reduce the system to the smallest units possible with minimal connectivity and resiliency.

The importance of heating of shallow groundwater and impacts to a myriad of microclimatic characteristics of headwater riparian zones from headwater timber harvest is not captured at all in models such as Heat Source. Despite the power of this and similar water temperature models in dealing with stream heating at a basin scale, their temperature predictions in downstream mainstem areas are dependent upon assumptions of boundary conditions. The temperature inputs that initiate modeling tend to be either groundwater temperatures from headwater areas or input temperatures from headwaters affected by varying levels of headwater logging. Heating processes linked to alterations in heating of shallow groundwater or microclimatic effects are not able to be modeled with Heat Source directly as a physical process.

Maintenance of shallow groundwater in streamside areas is important for creating the conditions for establishment of many riparian communities that stabilize streambanks.

The concepts expressed above about the connectivity between shallow groundwater flow generation, upslope soil heating, transfer of the heat load to these shallow flows, and alteration of stream temperatures via this heating effect was captured by the USFWS in their ESA consultation on bull trout relative to the implementation of the NW Forest Plan:

> *Timber harvest from upland areas exposes the soil surface to greater amounts of solar radiation than under forested conditions (Carlson and Groot 1997), elevating daytime temperatures of both air and soil (Fleming et al. 1998, Buckley et al. 1998, Morecroft et al. 1998) and increasing diurnal temperature fluctuations (Carlson and Groot 1997). Relationships between shallow source groundwater flows and air and soil temperatures indicate that harvest activities in upland areas may increase stream temperatures (depending on ambient air and soil temperatures), via increasing the temperature of shallow groundwater inflows. Other pathways for harvest actions to influence stream temperature include changing the volume and timing of peak flows, elevating suspended sediment levels, and altering channel characteristics (Chamberlin et al. 1991, Spence et al. 1996, USDA and USDI 1998).* USFWS (2004).

The USFWS (1998) previously explained their protection of bull trout via management procedures for headwater fish-bearing and non-fish bearing streams:

> *While we acknowledge that a one size fits all caution zone fails to account for biophysical differences among stream and riparian systems, for this interim range-wide strategy we have identified caution zones for each issue, often using the 100-year floodplain plus one site-potential tree height distance on both sides of the stream. For some issues, such as roads, the entire watershed is identified as the caution zone. One site-potential tree is approximately 150' on the west side of the Cascade Mountains; 90' to 150' on the east side dependent on forest Potential Vegetation Type (PVG = cold, moist, or dry). "The 100-year floodplain was chosen based on the need to fully incorporate the channel migration zone (CMZ) on low gradient alluvial streams. These stream channels provide critical spawning and rearing habitat for bull trout. An additional 150 feet on either side of the 100-year floodplain is required for the following reasons: 1) it encompasses one site-potential tree height at most locations; 2) provides sufficient width to filter most sediment from non-channeled surface runoff from most slope classes; 3) provides some microclimate and shallow groundwater thermal buffering to protect aquatic habitats inside the channel and the channel migration zone; and 4) provides an appropriate margin of error for unanticipated channel movement, hillslope and soil stability, blowdown, wildfire, operator error, disease, and certain other events that may be difficult or impossible to foresee on a site specific basis" (MBTSG 1998). The caution zone may also include non-fish bearing tributaries, seeps, springs, and wetlands in order to capture the linkages in a watershed critical to aquatic system function: stream, riparian, and sub-surface networks (Stanford and Ward 1992). In the caution zone the site-potential tree distance is measured horizontally from the edge of the floodplain. Although horizontal measurement may be slightly more cumbersome*