**Riparian Rule Analysis: Additional analyses of riparian prescriptions and considerations for Board decisions**

## INTRODUCTION AND OUTLINE

This document describes the results of the analyses completed since the June 2015 Board of Forestry (Board) meeting, outlines policy decisions and background and offers staff recommendations. As outlined below, Section I describes additions to the Decision Matrix (Attachment 1), including additional results requested by the Board, e.g., south-sided buffer prescription temperature estimates, and information not included in the June meeting material, i.e., fish response and information by geographic region. Section II presents additional science analyses completed, including marginal returns for temperature and wood recruitment, effective shade from additional north-sided buffers on streams with east-west orientation, geographic regions, and stream extent. Section III presents a policy analysis framework for the Board's use in discussing alternatives, considering concerns raised above. Section IV presents alternative packages, utilizing the policy framework, and concludes with recommendations in Section V.

**I) Decision Matrix Additions**

- Additional temperature response information (i.e., estimates for south-sided riparian prescriptions)
- Fish response
- Acres Encumbered by Geographic Region, Stream Type, and Ownership
- Land and Timber Value of these Additional Encumbered Acres
  For details matrix data not discussed here, see Attachments 1 and 3 from the June 2015 Board meeting (http://www.oregon.gov/odf/Pages/board/BOF_060315_Meeting.aspx).

**II) Additional Analyses**

- Marginal returns for temperature and wood recruitment
- RipStream Temperature Results and Other Scientific Studies
- Effective shade from north-side buffers
- Geographic Regions
- Stream reach extent

**III) Considerations for Board Decisions and Policy Analysis Framework**

- Board decisions
- Policy background and Board concerns
- Prescription Package Options and Analyses
- Stratification of protections according to stream size
- The geographic extent to which these prescriptions apply

**IV) Riparian Prescription Packages**

**V) Recommendations**

## I) DECISION MATRIX ADDITIONS

We made changes to the June Board Meeting matrix to incorporate additional analyses requested by the Board, which are marked with bold text. These changes are discussed below.

### ***South-sided riparian prescriptions***

Temperature response

We did not explicitly model south-sided buffer prescriptions (AOL-C, OFIC-F, AND RFPC-C), as the predictive model was not informed by stream orientation. At the June meeting the Board requested an estimate for these prescriptions.

The ODF systematic review found that south-sided prescriptions had few studies with less rigorous study designs than the others, so these studies' had a high range of variability and the results were inconclusive. The systematic review (Czarnomski *et al*., 2013) contained two references on one study that can provides information about south-sided buffer temperature results (two publications: Dent and Walsh, 1997; Zwieniecki and Newton, 1999). The study had three south-sided buffer sites with theses temperature responses (Table 1).

Table 1. South-sided buffer effectiveness (Dent and Walsh (1997), Zwieniecki, and Newton (1999)).

| Stream | Buffer width (left, right; ft.)* | Change in 7-day maximum through the unit (°C) |
|---|---|---|
| Cascade | Not available | 0.1 |
| Mill | 85, 82 | 0.0 |
| Scheele | 62, 31 | 1.4 |

*Report does not indicate stream azimuth.

These data range from a 0.0 to 1.4°C increase. This increase may be less than what would be expected from the south-sided buffer prescriptions in these analyses since the reported buffer widths for these study sites are larger than what would likely be implemented using the AOL-C, OFIC-F, or RFPC-C proposals (Attachment 1).

Changes to the Decision Matrix

South-sided buffer prescriptions would either have basal area targets specific to streams running within a prescription-specific range of East-West orientation, or the base prescription listed under the Variable Retention prescriptions (Table 2).

Table 2. Relation between South-sided prescriptions and their respective, associated base prescription.

| South-sided Prescription | Associated "base" Variable Retention Prescription used if stream is outside of South-sided prescription's applicable azimuth range |
|---|---|
| AOL-C | AOL-B |
| OFIC-F | OFIC-E |
| RVPC-C | RFPC-A |

Equivalent fixed widths are either that of the base prescription, or were calculated for south-side buffer prescriptions assuming linear relationships, based on basal area and width of prescription(s) with nearest basal area retention targets. (See Attachment 1)

For the additional encumbered acres per mile and associated land and timber value, the ranges are listed when the widths (averages of north and south sides) of south-sided prescriptions are different than those of the associated base prescription. The spread depicts the extreme values from having all to no streams within the azimuth range for the specific south-sided prescription.

We adjusted large wood recruitment values for the Alternate Prescriptions. With this adjustment the one-sided-staggered harvest prescriptions (RFPC-B, AOL-A, and OFIC-C) could eventually be harvested down to the current FPA distance. Thus, their large wood recruitment values are expected to be the same. South-sided prescriptions would retain more basal area further from the stream than the associated base prescription. This increased distance decreases the probability that large wood would enter the stream. However, we do not know by how much, so we list the upper extreme of that value from the associated base prescription. We did not adjust the shade values for alternate prescriptions since we did not have good data or models to estimate them.

Finally, we re-calculated the western Oregon per acre Land and Timber value for private industrial and private non-industrial. Thus, all the Land and Timber Values of additional encumbered acres per stream mile were slightly adjusted.

***Fish Response***

The department received responses from the five fish biologists about fish response to the proposed prescriptions. The fish biologists represent state and federal agencies, landowners, and the environmental community. We selected them based on the June 2014 Board workshop's diverse views. The biologists selected also assisted with that workshop. One biologist, Dunham, convened two separate sessions to gather information from 12 scientists representing Oregon State University, United States Forest Service, and United States Geological Survey.

The rows in the decision matrix represent the summary responses received from the biologists[1]. We did not limit fish responses to a single metric, so the rows include response by the metric evaluated. A response could be "Positive" (+), "Negative" (-), "Unchanged" (0), or "Unknown" (?). The biologists provided a brief narrative containing any thoughts, uncertainties, or assumptions about potential fish responses. (See Appendix 1)

The decision matrix shows the fish biologists' different assumptions and metrics, including fish response, potential growth, and population response. The decision matrix reflects the Board workshop's broad discussion among the biologists as well as the complexity and uncertainty about quantifying fish response at the stream reach level. The decision matrix contains many

[1] Note that one of the biologists, Bateman, participated in the sessions convened by Dunham, and concurred with Dunham's response.

unknown fish responses. A given prescription (column) contains responses that differ by biologist, usually reflecting different assumptions or metrics.

Some common themes emerged. Two responses, Bilby and Dunham et al. (potential growth), qualified their rating by the existing temperature condition of the stream, i.e., was the stream colder than 16°C or warmer/close to 16°C. For streams colder than 16°C, these biologists identified that small temperature increases may not significantly impact fish and that increasing light levels may increase primary productivity and benefit fish growth and survival. However, for streams that are above or close to 16°C, potential impacts to fish from stream temperature increases may negatively impact fish.

Two biologists, Jepsen and Frissell, made assumptions that allowed larger scale evaluation, but took different approaches to reference condition. Jepson indicated positive fish responses to wider buffers, with the FPA set at 0 or unchanged. Frissell indicated that all prescriptions would have a negative fish response, with the impact decreasing as stream buffers widths approach 100' or wider (resulting in unknown response for 100-foot no harvest and FMP prescriptions).

The biologists described the complexity in accurately attempting to predict fish response on a watershed scale without including factors such as large wood recruitment, food availability, climate change, cumulative effects, and other variables. For example, while Dunham et al. estimated responses for potential growth, they indicated that realized growth was unknown because of other factors. Another common theme was that increases in stream temperature at a site or reach scale of around 1°C are difficult to evaluate for overall fish response and given the complex physical and biological stream systems. To provide this detail, fish response would need to be evaluated on using multiple space and time scales.

***<u>Additional Acres Encumbered by Geographic Region, Stream Type, and Ownership</u>***

The amount of stream-miles for salmon, steelhead and bull trout (SSBT) and fish-bearing (Type-F) streams varies by Regions (Figure 1). The Coast Range has the most stream miles for each type and ownership, except the Interior has the most miles within the Non-Industrial ownership on Type-F streams. The Interior has the second highest stream miles, followed by the Siskiyou. The Western Cascades has the least miles of SSBT streams for both ownerships, whereas South Coast has the least miles of Fish streams for both ownerships. SSBT streams account for about 30% of Western Oregon fish stream miles.

For all of western Oregon, the additional encumbered acres for SSBT streams across prescriptions ranges from 0 to 34,000 and from 0 to 35,000 acres for industrial and non-industrial (0 to 0.8% and 0 to 1.3% of total ownership), respectively (Attachment 1; see Appendix 2 for calculations). For all of western Oregon, the range of additional encumbered acres for Fish streams across prescriptions extends from 0 to 118,000 and from 0 to 115,000 acres for industrial and non-industrials (0 to 2.9% and 0 to 4.3% of total ownership), respectively. Figure 2 illustrates how four prescriptions, representing most of the prescription width ranges encumber more acres and the associated ownership percentage as compared to the FPA. The FPA and FMP prescriptions represent the least and most encumbered acres, respectively, with the remaining prescriptions lying on the continuum based on their respective equivalent fixed widths.

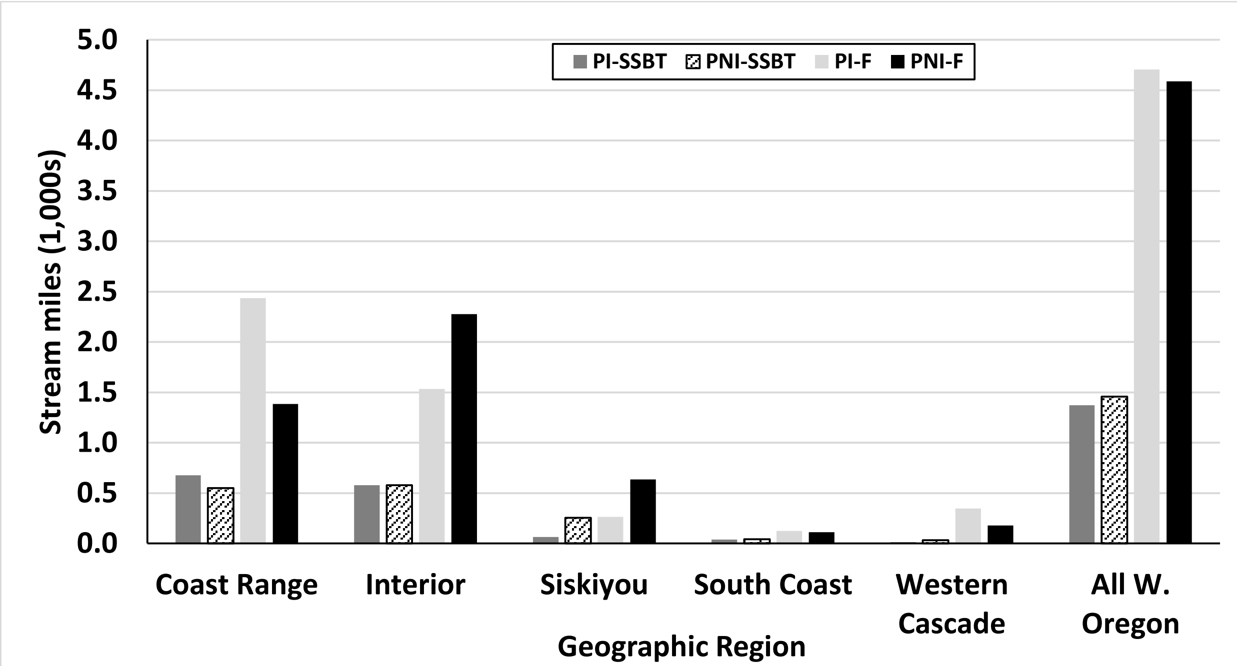



Figure 1. Total stream miles by Geographic Region, stream type, and ownership. Private Industrial (PI), Private Non-Industrial (PNI), Salmon, Steelhead, or Bull Trout (SSBT), and ODF-designated Fish Type F (F) streams.

While the total encumbered acres are about the same for Private Industrial and Private Non-Industrial for any given prescription and stream type, Private Non-Industrial forestland owners own less acres, which results in a higher percent of their property encumbered. For example, a 90 foot no-cut prescription on SSBT streams encumbers 0.6% of Private Non-Industrial forestland compared to 0.4% for Industrial forestland (Figure 2).

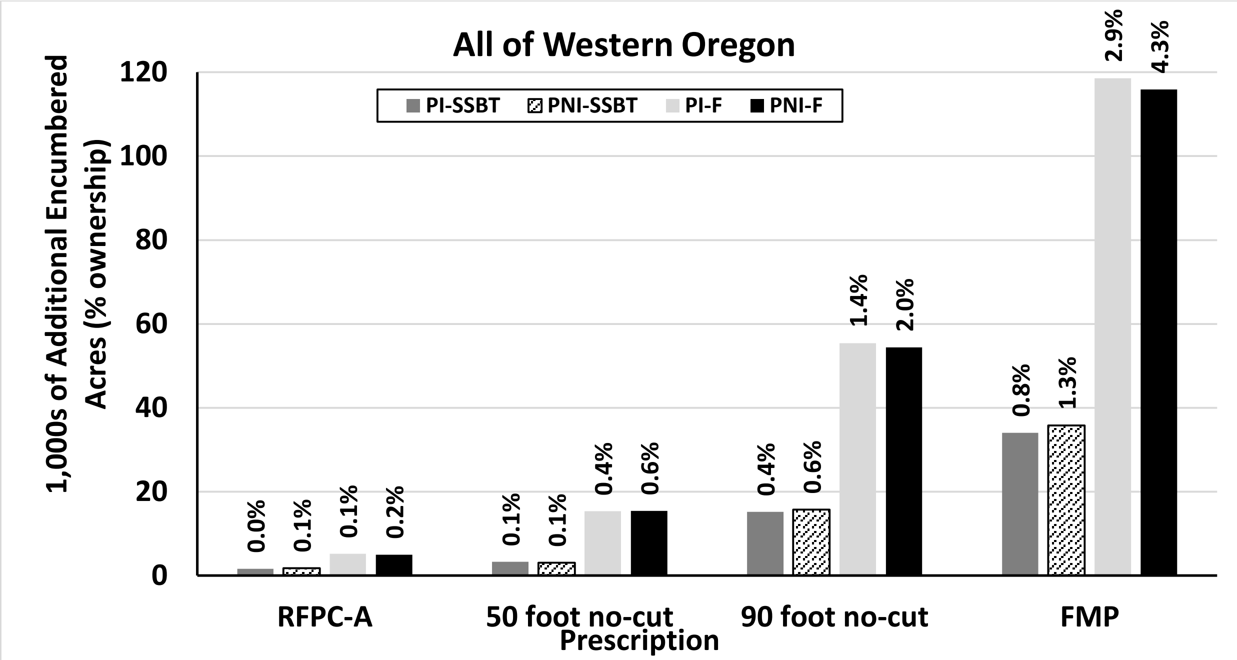



Figure 2. Additional encumbered acres in all of Western Oregon for four prescriptions representative of the range of prescriptions, based on ownership and stream type. The number above each bar is the percentage of total ownership encumbered for each prescription, ownership, and stream type. Private Industrial (PI), Private Non-Industrial (PNI), Salmon, Steelhead, or Bull Trout (SSBT), and ODF-designated Fish Type F (F) streams.

For SSBT Streams, the Coast Range has the most encumbered acres, with a range across prescriptions from 0 to 16,700 and from 0 to 13,600 additional encumbered acres for private industrial and non-industrial (0 to 1.1% and 0 to 2.2% of ownership), respectively (Attachment 1). For Fish Streams, the Coast Range has the widest range across prescriptions from zero to 62,100 additional encumbered acres (0 to 4.0% of ownership), whereas that of the Interior is the largest for non-industrials at zero to 58,000 additional encumbered acres (0 to 4.3% of ownership).

For SSBT Streams, the Western Cascades has the fewest encumbered acres, with a range across prescriptions from 0 to 300 and from 0 to 800 additional encumbered acres for private industrial and non-industrial (0 to 0.1% and 0 to 0.8% of ownership), respectively. For Fish Streams, the South Coast has the narrowest range across prescriptions from 0 to 2,900 and 0 to 2,800 additional encumbered acres (0 to 2.2% and 0 to 3.2% of ownership) for industrial and non-industrial owners, respectively.

To assess a prescription’s relative impact across Regions, it is helpful to examine the range of percent ownership encumbered for a prescription (Attachment 1). For example, on SSBT streams in different Regions, the FMP encumbers ranges of 0.1% to 1.1% and 0.8% to 2.2% on PI and PNI, respectively. Similarly, on Type F streams, the FMP encumbers ranges of 1.7% to 4.0% and 2.8% to 5.8% on PI and PNI, respectively, in different Regions.

***Land and Timber Values of Additional Acres Encumbered by Geographic Region, Stream Type, and Ownership***

There is a wide range of Land and Timber Values for the various Regions and Ownerships (Figure 3). This range is due to differences in the distribution of productivity (site index) classes and estimated standing volume of timber by geographic area. The Coast Range has the highest values at $4,655 and $7,896 per acre for private industrial and private non-industrial, respectively. The Siskiyou has the lowest values at $1,323 and $2,265 per acre for private industrial and private non-industrial, respectively.

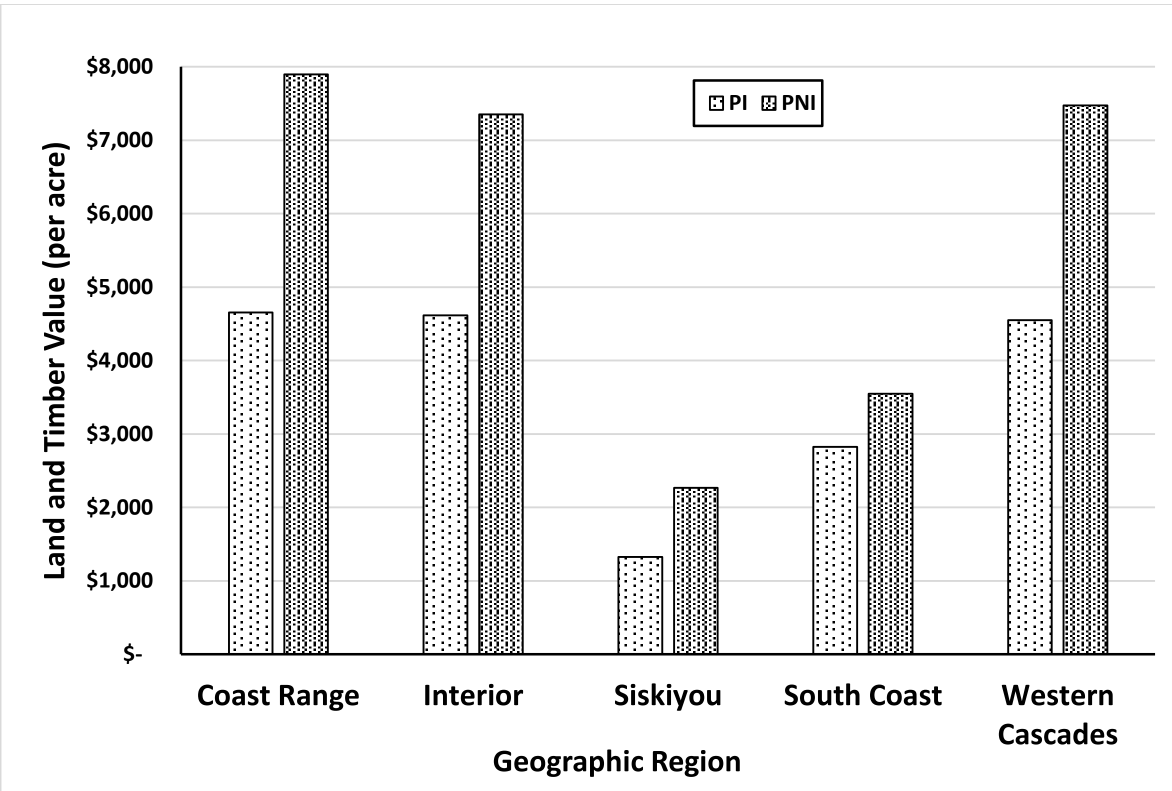
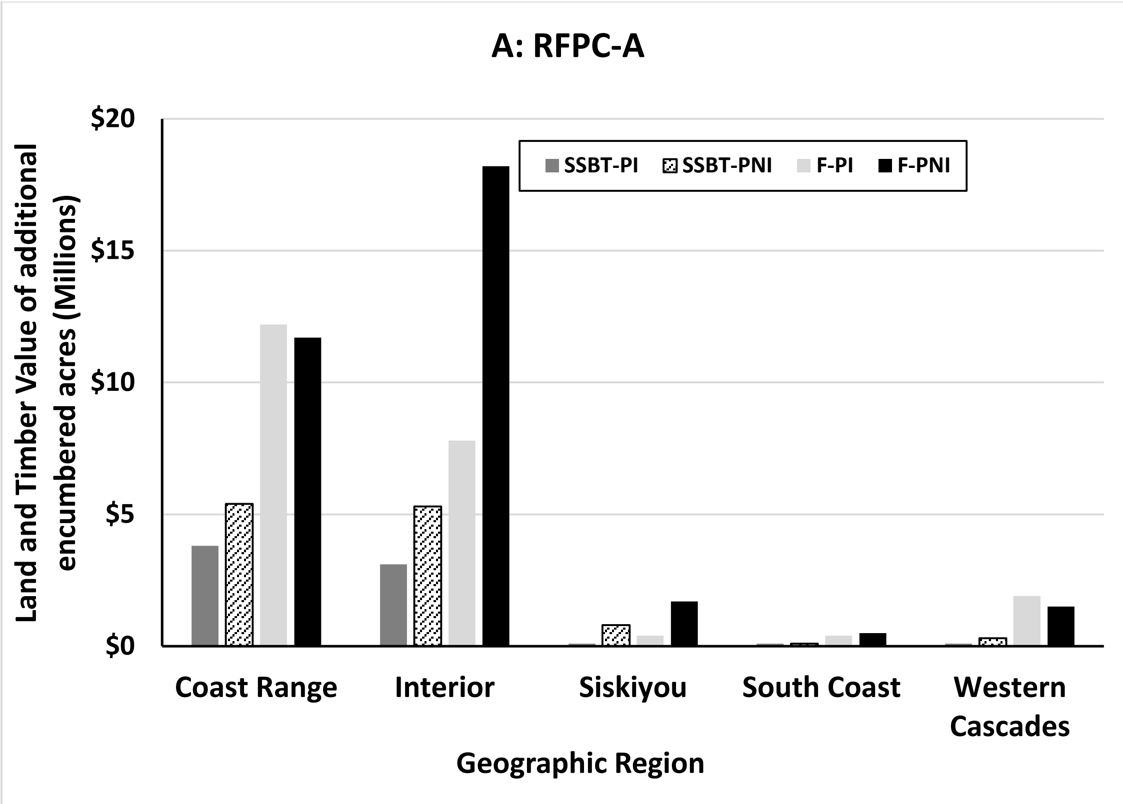
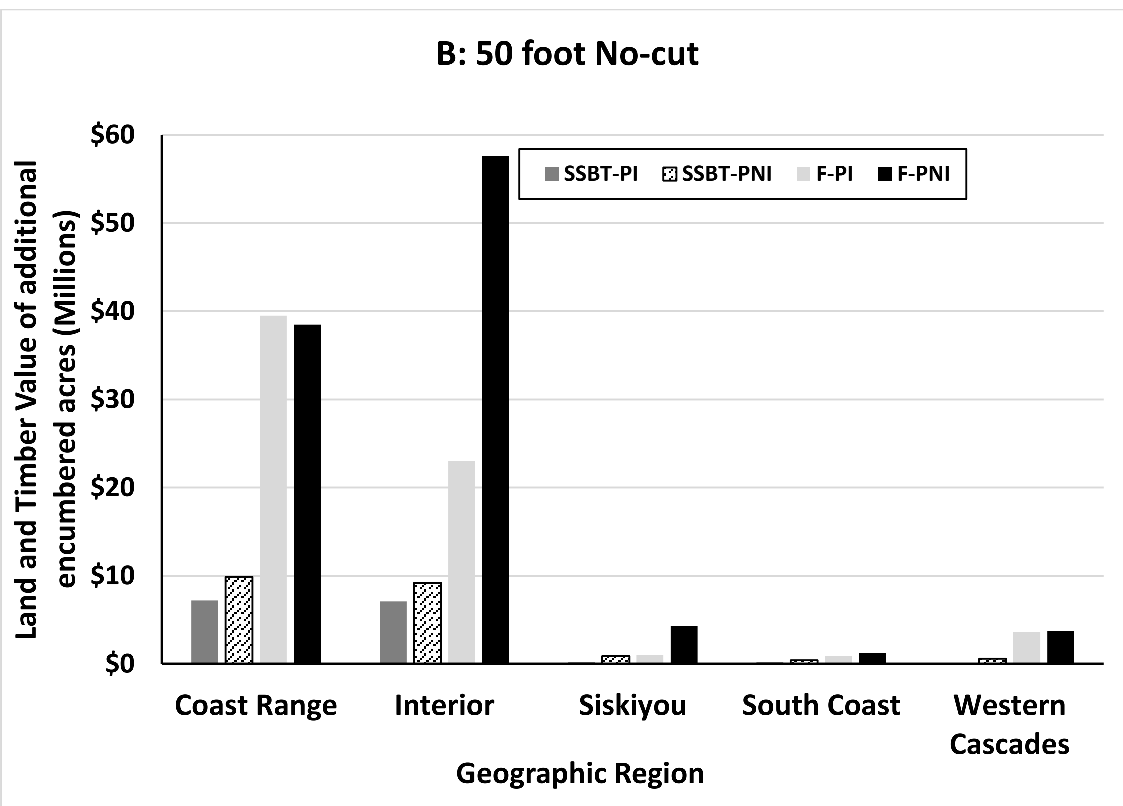
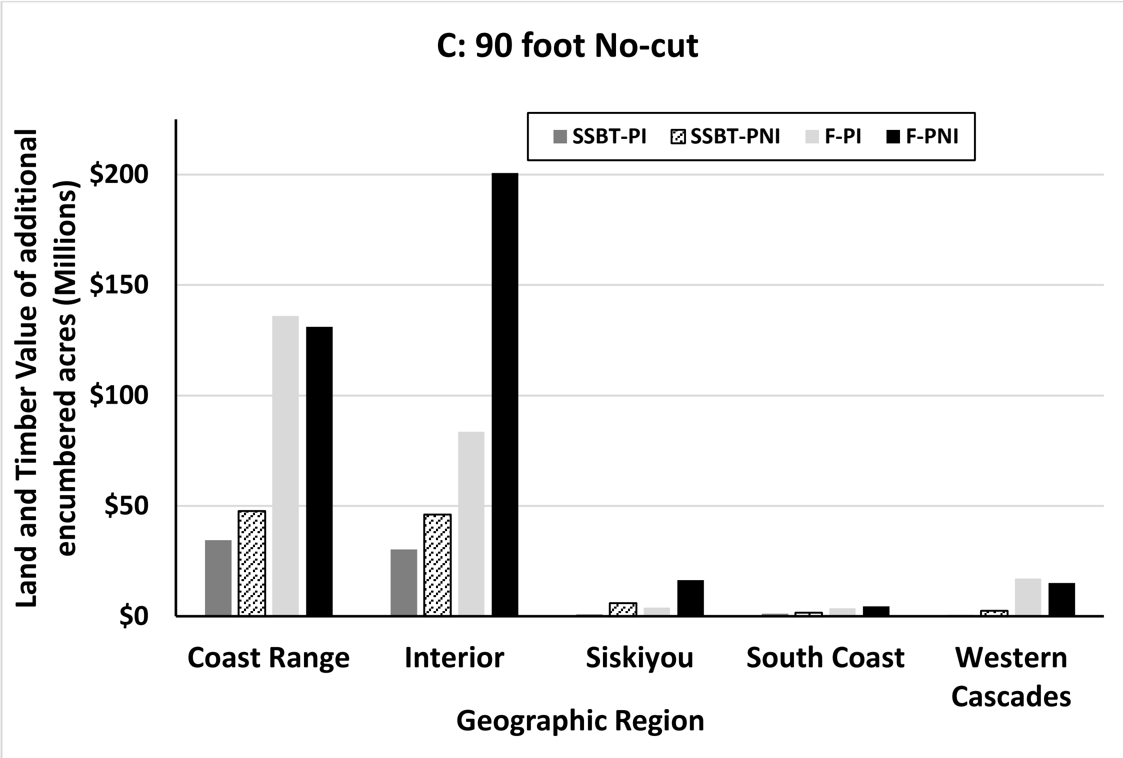


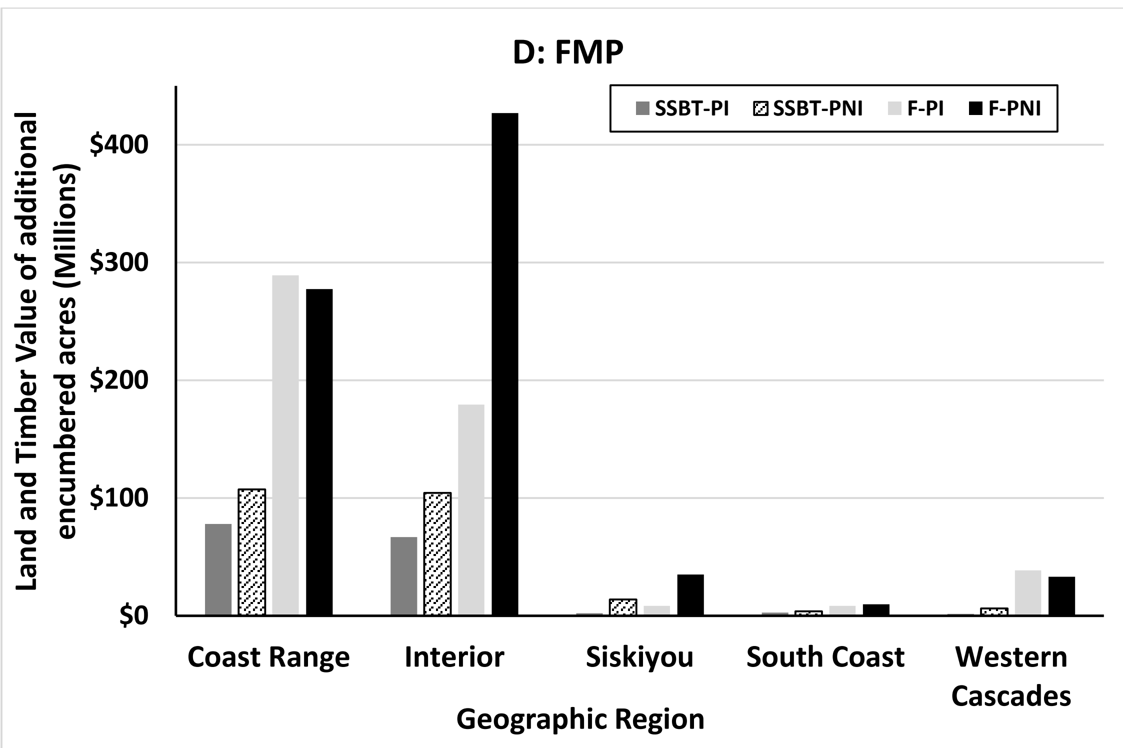

Figure 3. Land and Timber Value for each Geographic Region and Ownership. PI refers to private Industrial, PNI refers to Private Non-Industrial ownerships.

These per acre values and stream miles per Region differences (Figure 1), create a wide range of total encumbered acre values for a given Region, prescription, ownership, and stream type (Figures 4A-D; these use the same prescriptions as Figure 2). These charts look the same except they have different Y-axis scales (this scale ranges from $0-20 million for RFPC-A to $0-450 million for FMP); the scales differ due to the respective scale multipliers for Land and Timber Value per acre illustrated in Figure 3 combined with the areas illustrated in Figure 2.


A: RFPC-A
Land and Timber Value of additional encumbered acres (Millions)
$20
$15
$10
$5
$0
SSBT-PI
SSBT-PNI
F-PI
F-PNI
Coast Range
Interior
Siskiyou
South Coast
Western Cascades
Geographic Region


B: 50 foot No-cut
Land and Timber Value of additional encumbered acres (Millions)
$60
$50
$40
$30
$20
$10
$0
SSBT-PI
SSBT-PNI
F-PI
F-PNI
Coast Range
Interior
Siskiyou
South Coast
Western Cascades
Geographic Region




Figures 4A-D. Land and Timber Values of additional encumbered acres by Geographic Region for four prescriptions: A) RFPC-A, B) 50 No-cut; C) 90 foot No-cut; D) FMP.

For all of western Oregon, the range of Land and Timber Values of additional encumbered acres for SSBT streams across prescriptions range from $0 to 158.5 and from $0 to 282.4 million for industrial and non-industrials, respectively (Attachment 1; see Appendix 2 for calculations). For all of western Oregon, the range of Land and Timber Values of additional encumbered acres for Fish streams across prescriptions ranges from $0 to 552.1 and from $0 to 915.3 million for industrial and non-industrials, respectively. The total Land and Timber Values for all of western Oregon are $17.4 and $17.0 billion for private industrial and private non-industrial, respectively.

Figure 5 illustrates how four prescriptions, representing most of the prescription width ranges, encumber additional Land and Timber Values for all of western Oregon as compared to the FPA.

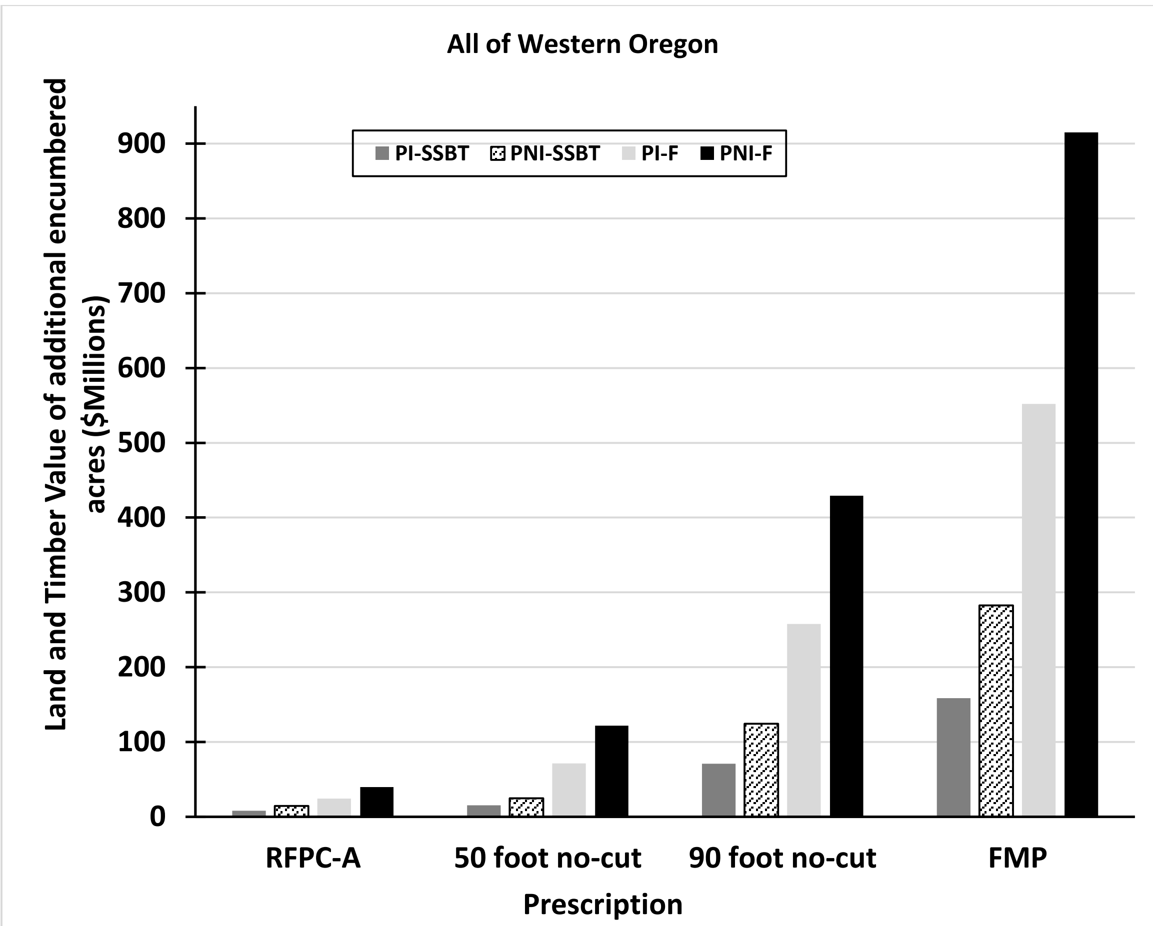



Figure 5. Land and Timber Value of additional encumbered acres in all of Western Oregon for four prescriptions representing most of the prescription ranges, based on ownership and stream type. Private Industrial (PI), Private Non-Industrial (PNI), Salmon, Steelhead, or Bull Trout (SSBT), and ODF-designated Fish Type F (F) streams.

For SSBT Streams, the Coast Range has the highest Land and Timber Values of encumbered acres, with a range across prescriptions from $0 to 77.9 and from $0 to 107.4 million for private industrial and non-industrial, respectively (Attachment 1). For Fish Streams, the Coast Range has the widest range across prescriptions from $0 to 289.0 million, whereas that of the Interior is the largest for non-industrials at $0 to 426.9 million.

For SSBT Streams, Western Cascades has the smallest Land and Timber Values range for encumbered acres from $0 to 1.6 million for private industrial, whereas Siskiyou and South Coast each range from $0 to 3.8 million for private non-industrial (Attachment 1). For Fish Streams, the South Coast has the narrowest ranges across prescriptions from $0 to 3.8 and $0 to 9.8 million for private industrial and private non-industrial owners, respectively.

## II) ADDITIONAL ANALYSES

Based on the June 2015 Board discussion, we completed additional analyses including marginal returns for temperature and wood recruitment, effective shade from additional north-sided buffers on streams with east-west orientation, geographic regions, and stream extent.

### ***Marginal returns for temperature and wood recruitment***

The Board must ultimately decide if proposed restrictions on practices directly relate to and substantially advance the rule objective; and choose the least burdensome alternative with resource benefits proportional to the harm caused (i.e., temperature increase). The absolute anticipated temperature increases help inform this decision but do not provide the full picture of temperature response with increasing riparian protection. The marginal temperature change avoided by increasing protection can help complete the picture of temperature response.

Figure 6 below displays the marginal curves for both temperature change and wood recruitment. These are based on values gleaned from the same methodologies used to create the temperature and wood data for the Decision Matrix (Attachment 1). Superimposed on this figure are different zones (1-3) showing where temperature and wood recruitment improvements are expected to be the largest per change in buffer width (Zone 1), where significant improvements are still gained but diminish per additional width (Zone 2), and where the threshold for further gains has likely been reached (Zone 3). These zones are used as the basis for additional analyses in the "Prescription Package Options and Analyses" section.

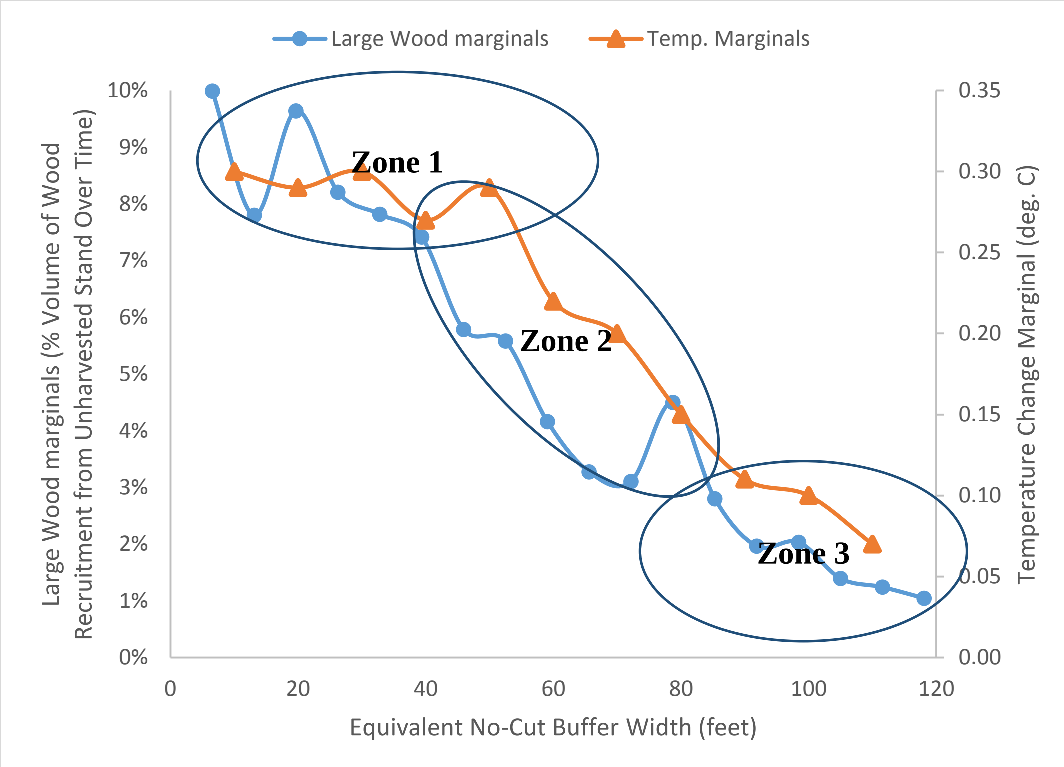



Figure 6: Marginal curves for stream temperature change with harvest and wood recruitment (change per 10-foot equivalent no-cut buffer width). "Zones" identify areas with high marginal return from additional buffer width (Zone 1), improved temperature performance, but diminishing marginal return (Zone 2), and where the threshold for further gains has likely been reached, low marginal return (Zone 3).

## ***RipStream Temperature Results and Other Scientific Studies***

At the June workshop, the Board heard from three scientists on the effects of contemporary forest practices on stream temperature. This section summarizes these results and places the RipStream temperature results in the context of other scientific studies. The Board has heard testimony about various studies and their relative strengths and weaknesses. These discussions often frame results of studies as opposed to each other, rather than viewing the body of science as complementary, forming a coherent whole to inform policy.

The workshop discussed the dissimilar, yet complimentary, study designs and implications of results from paired watershed-scale versus reach-scale studies. Reach-scale studies, such as RipStream, focus on the effects of practices on the individual reach. Their strength lies in the ability to have many sites (n=33 in the case of RipStream) and statistical inference in modeling the relationships between buffer width, density, shade, and temperature. Watershed-scale studies, such as Hinkle Creek, use a whole-watershed, integrated design that links biological with physical studies. They are designed to quantify effects of contemporary forest practices on the physical, chemical and biological characteristics of streams at multiple spatial scales. Because of the complexity and size, replication of sites is challenging (n=1 in the case of Hinkle Creek at bottom of watershed). Together these studies provide a picture of how the system works (watershed-scale) and what the relationships are across many sites (reach-scale).

The department commissioned a systematic review of the science from the Pacific Northwest on the effectiveness of forest harvest buffers at protecting stream temperature and shade. The workshop discussed the site-specific data extracted from studies included in the Systematic Review. These data were collected with a variety of methods and metrics, mostly from second-growth forests, although some were from old-growth forests. While the data show there is a wide range in shade and temperature responses to harvest, it generally shows that post-harvest shade increases with basal area and buffer width, and change in temperature decreases with larger buffer widths. Moreover, variability in changes in shade and temperature decrease with increasing buffer width and basal area. These results are consistent with the RipStream temperature results in terms of magnitude and pattern of temperature change and buffer widths.

The workshop also covered research findings on stream temperature responses at the Hinkle Creek and Alsea River Watershed studies. The main objective of the Hinkle Creek study was to look at cumulative effects. The study developed a calibration relationship between the north and south forks then treated the south fork watershed. The study harvested 13 percent of the watershed on non-fish streams in 2005 and an additional 13 percent involving small and medium fish streams in 2008. The daily maximum temperature increases on the four non-fish streams ranged from -1.45 to 1.52$^0$ C. There was no detectable change at the bottom of the watershed. One year after the 2008 harvest on small and medium streams, the study found an average of 0.5 C increase in daily maximum temperatures (range of -1.8 to 2.5$^0$ C, n=7). Over the study, there was a statistical increase in maximum and slight decrease in minimum stream temperatures across harvested watersheds, no change in maximum or minimum stream temperatures at the outlet of Hinkle Creek, and no cumulative effect if downstream response is the measure. Increased stream flow following harvest indicated that increased inputs of cold groundwater moderated stream temperature effects from harvest. Long stream-water residence time also negated downstream temperature increases from upstream sources. The results from the Alsea study showed a 0.5° C post-harvest increase at the bottom of non-fish streams (n=1). The increase was marginally statistically significant. The gage near the bottom of the harvest unit on the fish stream showed a significant average post-harvest temperature increase of 0.7° C. The study detected a 0.3° C post-harvest increase in temperature at the lowermost gage, about 3000 feet downstream from harvest unit on fish stream. This value was inconsistently statistically significant, as based on multiple calculations of significance on differing sets of randomly drawn temperature.

The RipStream temperature findings indicate that current forest practices rules meet Oregon's numeric temperature criteria of 16 and 18° C. Harvests following State Forests' Forest Management Plan (FMP) standards meet DEQ's Protecting Cold Water (PCW), but FPA standard harvests did not, with a 40% probability that a post-harvest year's temperatures would exceed a pre-harvest year's by more than 0.3$^0$ C. The mean temperature increase in streams was 0.0° C for State Forests. The Ripstream value for private forests was 0.7° C, at or nearly identical to the values found in the Alsea and Hinkle Creek studies (0.7° C and 0.5° C, respectively). The 5-year post-harvest analysis indicated that the greater the initial post-harvest change in shade or temperature, the faster it returned towards pre-harvest conditions. The downstream temperature analysis indicated that at approximately 1,000 feet (300m) downstream of harvest, 1-84% of the post-harvest change in temperature remained. The predictive temperature model used to evaluate rule prescriptions shows good agreement with RipStream data. For all sites harvested for maximum tree removal following FMP and FPA standards, the model predicts mean temperature increase of 0.2° C and 1.45° C, respectively. The large difference between modeled and measured differences in temperature for FPA rules are likely due to many sites having substantially higher basal area retention than the required FPA targets.

The RipStream temperature results are consistent with the body of temperature science in the systematic review and the stream-reach results on small and medium fish streams from the Hinkle Creek and Alsea watershed studies. The two watershed studies also provide additional information on downstream temperature impacts, and when published will provide two more data points to the body of literature described below in the stream extent discussion. They may also provide additional information on the mechanisms that control downstream heat transfer.

***Effective shade from north-sided buffers***

In examining approaches to estimate the temperature change for south-sided buffers, we worked with the Department of Environmental Quality (DEQ) to estimate effective shade for north-sided buffers using the Heat Source model (Boyd and Kasper 2003). The approach didn't work for estimating south-sided buffer prescriptions temperatures because of the number of assumptions we would have to make about implementing the prescription. However, the analysis provides useful information for the Board decision.

Heat Source is a computer model that simulates stream thermodynamics and hydrology. Heat Source includes a subroutine, Shade-a-Lator, that estimates effective shade produced by riparian vegetation. Working with DEQ, we estimated the effective shade gained by leaving additional buffer on the north side of streams with an East-West orientation (see Table 3). For streams with a 90˚ azimuth orientation, the effective shade gained by leaving a buffer beyond 20 feet was 0.4 percent, essentially no additional shade. For streams with an orientation of 45˚ or 135˚ azimuth, the effective shade gained beyond 20 feet was 4.0 percent, with no significant gain beyond 60 feet.

Table 3 indicates that medium streams with orientations between 60 and 120 degrees azimuth would gain less than 1 percent shade from north-side buffers wider than current FPA buffers. The gain for small streams would less than 3 percent. Since additional buffers on the north side of east-west oriented streams add little effective shade, they would not significantly contribute to meeting the PCW temperature criterion.

Table 3. Average percentage point change in effective shade during the month of June on different stream orientations after increasing the north side buffer from 20 feet to the indicated width. South side buffers remain constant and are set at the width indicated. These estimates assume the 30 meter tall vegetation and no shading from topographic features..

| Azimuth | Stream Orientation | 40 feet | 60 feet | 70 feet | 80 feet | 90 feet | 100 feet |
|---|---|---|---|---|---|---|---|
| 45 \| 225 | northeast \| southwest | 4.0% | 5.3% | 5.6% | 5.7% | 5.8% | 5.9% |
| 50 \| 230 | | 3.1% | 4.0% | 4.3% | 4.4% | 4.5% | 4.5% |
| 60 \| 240 | | 2.1% | 2.7% | 2.8% | 2.9% | 2.9% | 2.9% |
| 70 \| 250 | | 1.7% | 2.0% | 2.0% | 2.0% | 2.0% | 2.0% |
| 80 \| 260 | | 0.8% | 0.8% | 0.9% | 0.9% | 0.9% | 0.9% |
| 90 \| 270 | east \| west | 0.4% | 0.4% | 0.4% | 0.4% | 0.4% | 0.4% |
| 100 \| 280 | | 0.8% | 0.8% | 0.9% | 0.9% | 0.9% | 0.9% |
| 110 \| 290 | | 1.7% | 2.0% | 2.0% | 2.0% | 2.0% | 2.0% |
| 120 \| 300 | | 2.1% | 2.7% | 2.8% | 2.9% | 2.9% | 2.9% |
| 130 \| 310 | | 3.1% | 4.0% | 4.3% | 4.4% | 4.5% | 4.5% |
| 135 \| 315 | southeast \| northwest | 4.0% | 5.3% | 5.6% | 5.7% | 5.8% | 5.9% |

### ***Geographic Regions and Stream Size***

In September 2014, the Board directed the department to analyze to which Geographic Regions in western Oregon the prescriptions should apply. The regions to consider include the Coast Range, South Coast, Interior, Western Cascades, and Siskiyou (Figure 7). We discuss available empirical and theoretical information, associated factors, and how this information may assist the Board's decision-making process. We propose the Board must make a related decision to continue stratification of stream protection measures according to stream size for streams included in this rule analysis.

The current 1994 rules for fish-bearing streams riparian protection are based on empirical and theoretical approaches. The 1994 rules broke the state into Regions and set corresponding streamside protection levels, refined further by stream size. These regions were based on the U.S. Environmental Protection Agency ecoregions. Streamside protection levels were developed by using growth and yield or other stand information to predict conifer stand conditions at maturity (see Policy Background, page 23) and then used available science to support assumptions about riparian stand disturbance rates and functional needs according to stream size such as contributions to shade and stream temperature outcomes and other factors (e.g. a functional key piece of wood in a small stream could be smaller than a key piece in a medium stream). Different landscape-scale characteristics (e.g., forest type, climate, topography, hydrology, stream size) dictated stream protection standards, as did the knowledge that different stream sizes respond differently to harvest or stand conditions. The 1994 work informed the current policy where overstory protection measures for all small fish-bearing streams are identical across western regions and have lower tree-retention requirements than medium-size streams, indicating that overstory contributions to maintain functions are lower for small streams and may be achieved with a universal protection standard. Medium streams have larger overstory protection standards but differ between regions, though some are grouped (4 overstory protection standards across a total of 7 regions). Specifically, the following three tree retention target groupings exist for medium streams in the western regions: Coast Range and South Coast; Interior and Western Cascades; and Siskiyou.

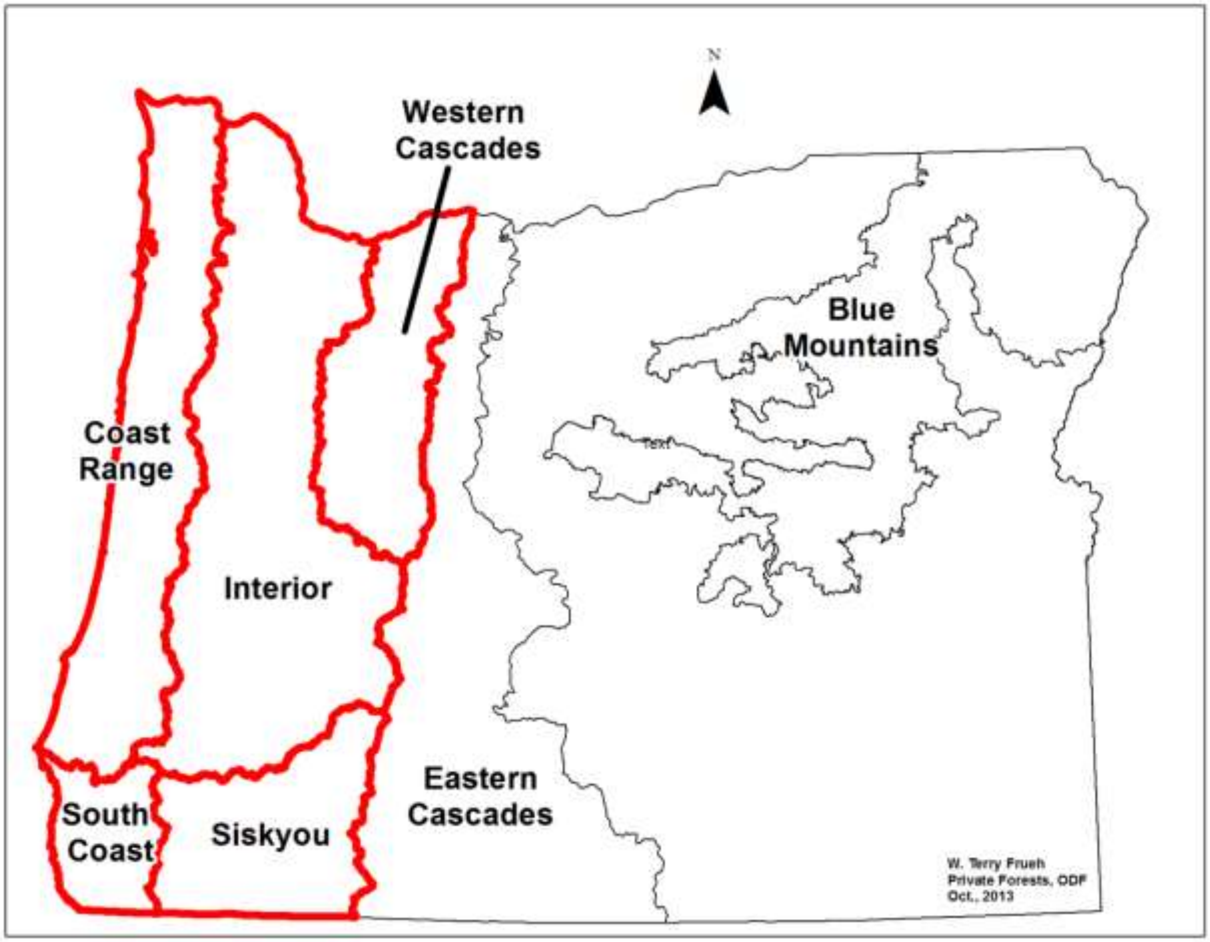



**Figure 7.** Geographic regions in red considered in the westside Riparian Rule Analysis.

The 1994 approach has the benefits that it is grounded in empirical science and affords the opportunity to theorize efficient and effective streamside protection measures tailored to regional conditions. A drawback is the complexity of rules for some of the regulated community and the state who must administer the rules. Another detractor is the cost and time to the state created by the expectation that monitoring studies must be stratified according to stream size and region to assess effectiveness or examine their underlying assumptions. RipStream (the ODF Riparian Function and Stream Temperature study) started in the Coast Range in 2002. Data analysis and policy work continues; another six regions remain to be studied.

The department's Systematic Review (SR) used an empirical approach (Czarnomski et al. 2013). The Systematic Review collected all publications on the effects of near-stream forest management on stream temperature or riparian shade in areas within, or similar to, Oregon west of the Cascade crest. The SR's primary purpose was to provide scientific guidance to the Board on the efficacy of rule alternatives in addressing the riparian rule analysis objective.. A secondary SR purpose was to inform the Board's decision on the rule analysis' geographic extent. The SR did not explicitly examine the question of stream size. The results of the SR were equivocal on the question of differences in stream temperature response between regions.

A related factor to an empirical approach is the question of how appropriate it is to extrapolate the degradation finding based on RipStream results to other regions west of the Cascades' crest. Extrapolating scientific studies' results beyond their range of data increases the risk of error. For the regions question, a risk-adverse approach would constrain application of RipStream results to the Coast Range region only. A more risk-tolerant approach could include the South Coast region as these two are already grouped in rule or include the Interior geographic region since two RipStream sites were located there and the Hinkle Creek paired watershed study indicated temperature response to harvest similar to the RipStream results. Even greater risk-tolerance would allow for extrapolating the RipStream results to most or all western regions. This approach uses the current policy framework and assumes that the current regions and associated stream protection measures are correctly defined to maintain stream functions.

Regarding stream size, the RipStream study did not detect significant differences in stream response according to stream size. Its study design and sample size may limit its ability to make this distinction. On the other hand, it may be that small and medium streams are in a narrow-enough range of conditions that their temperature regimes respond similarly to changes in shade. How far you want to extrapolate results depends on your risk-tolerance.

## ***Stream Reach Extent***

In September 2014, the Board directed the department to analyze to which stream reaches prescriptions should apply. To begin this delineation, consider the Board-approved objective for this rule analysis:

> *Establish riparian protection measures for small and medium fish-bearing streams that maintain and promote shade conditions that insure, to the maximum extent practicable, the achievement of the Protecting Cold Water criterion.*

The PCW criterion states:

> *"[The PCW]…applies to all sources taken together at the point of maximum impact where salmon, steelhead or bull trout are present" [OAR 340-041-0028 (11)].*

Thus, the PCW focuses on a subset of fish-bearing streams, i.e., those that have salmon, steelhead, or bull trout (SSBT) present. This subset can be considered the least amount of streams to which new prescriptions would apply. In contrast, all small and medium Type F streams (i.e., those mentioned in the rule analysis objective) are the most streams to which new prescriptions would apply, and thus we have two bookends for the streams to be covered by new prescriptions.

In terms of which streams have SSBT, the Department of Fish and Wildlife has GIS data delineating SSBT habitat. We recommend using these data since experts determined them using a rigorous process. These data have been combined with ODF's small and medium stream GIS data as a starting point for the stream reaches to which this rule analysis should apply.

Returning to the PCW for additional guidance on where the rule should apply, we have "all sources taken together at the point of maximum impact [POMI] . . .." This statement indicates that water flowing into reaches with SSBT need to be protected such that the receiving stream does not increase the temperature more than 0.3 °C, the PCW limit. The rule analysis objective focuses on meeting the PCW, so it seems logical to constrain any new prescriptions to small and medium streams with SSBT present, plus some portion of incoming streams that are likely to affect the temperature of the SSBT stream reaches. However, crucial questions remain such as: Which of these incoming streams? How far upstream from their confluence with SSBT streams do these contributing waters need additional protection?

When considering the upstream waters, it helps to divide them between those that simply lie upstream from the end of SSBT (i.e., the main stem segment upstream of the end of SSBT delineation), and those where the water flowing into the SSBT stream are from non-SSBT tributaries.

<u>Main stems immediately upstream of the upper extent of SSBT use</u>
Data suggest that FPA harvest immediately upstream of the SSBT upper termination point would tend to increase stream temperature in the SSBT reach. This increase is due to having the water flowing into the SSBT reach warmed by the harvest immediately upstream. However, the question remains: how far upstream should riparian protections extend to prevent the warming of the SSBT stream by > 0.3 ˚C?

To address this upstream protection question, we examined the science around downstream cooling, which is not well developed and contains much uncertainty. We know that streams warmed by harvest tend to transmit warmed water some distance into unharvested reaches (reviews provided by Moore et al. 2005, Webb et al. 2008). Some important questions that are not fully answered by existing data include: How far downstream do these temperature signals persist? Why do elevated temperatures persist farther downstream in some streams than others?

Table 4 presents research illustrating that temperature decreases downstream of harvest are highly variable. This table presents the findings from several studies that convey the amount of temperature decrease measured or modeled over specified distances. The studies' methodology and quality differ. They may lack controls across time (what was the stream's pre-harvest temperature regime?) and/or space (was there a nearby unharvested reach with which to compare results?) Some distances represent points at which a temperature increase was no longer present, while others were stations at which increases persisted but were reduced from original amounts. Studies used different metrics for evaluating stream temperatures (e.g., daily maximum, 7 Day maximum) and different methods for considering how to determine downstream temperature decreases. Regardless, we see a variety of temperature decreases with distance, and no pattern emerging. Figure 8 presents the same data as Table 4, with each point representing a different study. Some points are coarse averages of findings from multiple sites.

Table 4. Temperature decreases over specified downstream distances in closed-canopy stream reaches below diminished-shade reaches. Temperature metrics vary between studies (e.g., daily maximum, 7 Day maximum).

| Source | Temperature metric | Decrease (˚C) | Distance (feet) | Notes |
|---|---|---|---|---|
| Rutherford et al. 2004 | daily max/min | 4.2 | 2,140 | |
| | | 3.7 | 3,150 | |
| | | 0.6 | 2,930 | |
| | | 1.9 | 1,640 | |
| | | 1 | 790 | |
| Bartholow 2000 | N/A | 1 | 32,810 | Computer model |
| Zwieniecki and Newton 1999 | 7 Day max | 0.69 | 490 | Mean decrease of 16 sites |
| Caldwell et al. 1991 | daily max/mean/min | 1 | 980 | |
| | | 1 | 980 | |
| | | 1.5 | 430 | |
| Storey et al. 2003 | daily max/min | 4 | 660 | 2 sites |
| Wilkerson et al. 2006 | 7 Day max, daily flux | 0.75-1.1 C | 330 | 6 sites; warming did not persist 2$^{nd}$ year post-harvest |
| Keith et al. 1998 | daily max/mean | 2-5 C | 100-300 | 4-6 reaches |
| Garner et al. 2014 | instantaneous | 1 C | 3,450 | Instantaneous, 1 site |

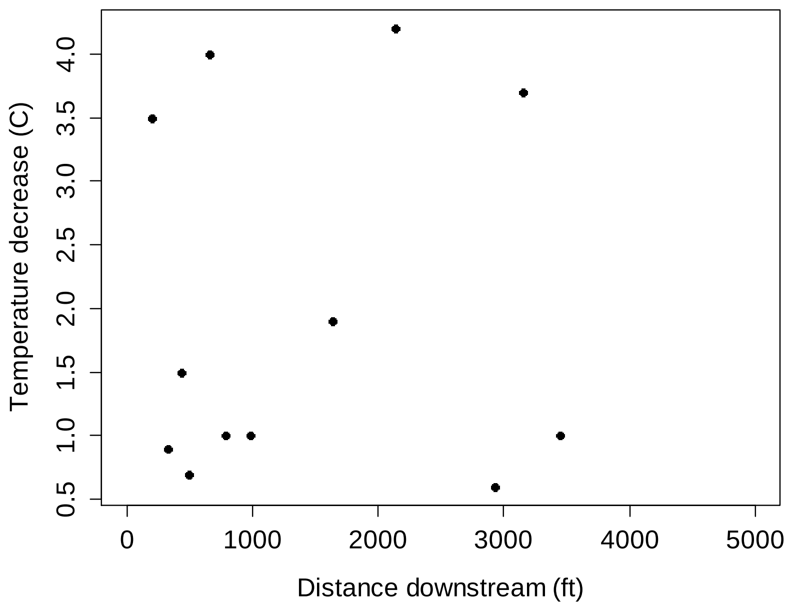



Figure 8. Plotted results from Table 2, without the point for Bartholow et al. 2000 (1 ˚C decrease over 32,810 feet). Each point represents values from one study, averaged across values within studies.

The RipStream downstream analysis results, presented to at the June 2014 Board workshop, provide some explanation as to why streams exhibit a great variability in temperature decreases with distance. However, the findings are limited to the first 1000 feet below a harvest. We found that the fifteen downstream reaches available for analysis differed widely in their temperature change rates. The amount of cooling that could occur at each stream depended on two factors:

1) how much heating occurred upstream; and

2) the stream's physical characteristic (i.e., depth, width, and gradient).

The greater the temperature increase above background conditions, the greater the absolute temperature decline. Stream width and depth relate to the water's thermal mass: it requires less energy to heat up and cool a narrow, shallow stream than a large river. However, gradient temperature is critical to assessing thermal recovery downstream since it determines how long a parcel of water will stay within the 1000 foot downstream reach. If the parcel passes through a reach in a few minutes, we would expect there to have been little opportunity for the warmed water to cool. If it resides within the reach for many hours, we expect it to have time to cool towards the equilibrium temperature of the shaded reach.

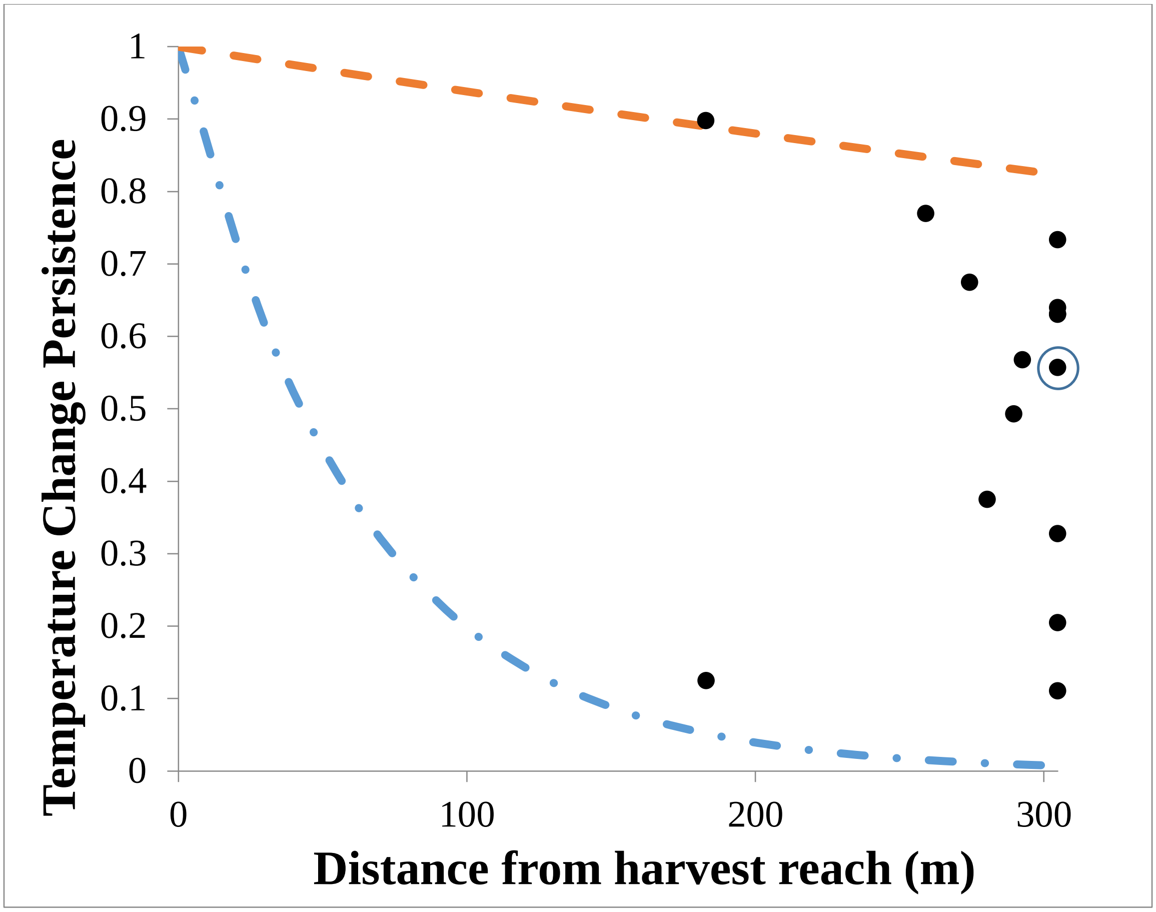


Figure 9. Temperature change persistence as a function of distance for 15 RipStream sites. The orange dashed line indicates the lowest rate of temperature change persistence possible among site variables while the blue line represents the fastest. Black dots are individual site data. The blue circle highlights an example site discussed in the text.

Figure 9 conveys the variable nature of the RipStream downstream reaches. On the y-axis, temperature change persistence is the proportion of a temperature change (e.g., increase due to harvest) remaining at a downstream location. At 0 meters downstream, whatever the temperature gain occurred immediately upstream, remains. At 300 meters (1000 feet) downstream, we see that along the orange line streams would maintain about 80 percent of their original increase, while the blue line indicates that virtually no temperature change remains. The point with the blue circle depicts a site that exhibits about a 55% temperature change persistence. If the temperature increased 10 ˚C in the treatment reach, it would be 5.5 ˚C 1000 feet downstream. If the treatment reach warmed by 1.0 ˚C, 1000 feet downstream the temperature increase would be 0.55 ˚C. The average temperature change persistence at 1000 feet for all 15 RipStream sites was 0.5, or 50%, at 1000 feet.

<u>Non-SSBT tributaries</u>

To assess the influence of harvest-induced temperature increases from non-SSBT tributaries on SSBT streams, we would need to know:

a) The tributary stream temperature increase due to harvests based on prescription differences (i.e., the analysis above);
b) The discharge of each non-SSBT tributary relative to that of the receiving SSBT stream (the relative discharge would enable a volume-weighted temperature increase calculation for the SSBT stream); and
c) The rate of tributary temperature change and distance between the harvest and SSBT stream.

It would be difficult to accurately know or estimate discharge at many tributary and SSBT junctions throughout western Oregon, much less values for the other variables. A preliminary model of relative discharges conducted by DEQ suggests that non-SSBT tributaries only pose a risk of warming SSBT segments in the headwater portion of watersheds where the tributaries are closer to being the same size as SSBT portions. While a model of all the variables could be developed, doing so would be a significant investment. The model results would contain the same uncertainty mentioned above and about the veracity of the tributary effect modeling effort.

Another approach would be to establish a largely theoretical model to apply in the field and not attempt to map such contributing waters in advance. A set of assumptions could be established regarding the factors above and corresponding protection standards. This would be like the current policy for classifying streams of unknown fish use through observing physical habitat characteristics and subsequently applying streamside protection standards. The same uncertainty caveats discussed above would apply.

How far upstream along a main stem SSBT reach or to which non-SSBT tributaries should stream protections extend to prevent warming of SSBT streams by more than 0.3 ˚C? In summary, the variability in the RipStream downstream data and results within the literature indicate that the science provides no conclusive recommendation.

## III) CONSIDERATIONS FOR BOARD DECISIONS AND POLICY ANALYSIS FRAMEWORK

### ***Board decisions***

There are three primary decisions for the Board to make at the July 23, 2015 meeting:

1. Which prescription(s), if any, to move into rule language,
2. The geographic extent to which these prescriptions apply, including:
    - Which Geographic Regions, and
    - Which small and medium streams [i.e., those with Salmon/Steelhead/Bull Trout, ODF fish-bearing (Type F), or some combination thereof]), including the extent upstream to avoid warming from contributing waters; and
3. Whether the rules are regulatory, voluntary, or a combination thereof.

The Board's deliberation of these decisions occurs under the ORS527.714 findings; the remaining ORS527.714 findings are:

- Restrictions on practices directly relate to, and substantially advance the objective 527.714(5)(d)

- Must choose the least burdensome alternative 527.714(5)(e) and resource benefits achieved by the rule must be proportional to the harm caused by the forest practices 527.714(5)(f).

***Policy Background and Board Concerns***

At its January 2012 meeting, the Board started a rule analysis of riparian protection standards on small and medium fish streams. The monitoring results leading to this analysis only identified an issue with the Protecting Cold Water (PCW) criterion as based on sample sites in the Coast Range and Interior Geographic Regions of Oregon. At its April 2012 meeting, the Board adopted the following rule objective focused on this criterion (rather than on the complete set of goals for the water protection rules):

> Establish riparian protection measures for small and medium fish-bearing streams that maintain and promote shade conditions that insure, to the maximum extent practicable, the achievement of the Protecting Cold Water criterion.

While the core decisions are related to the Board's responsibility to meet the PCW standard to the maximum extent practical, Board members have raised concerns about how to also consider the effects of any rule change on fish and other aspects of the stream protection rules. Key recurring themes during Board discussions about the riparian rule analysis include a desire to consider the **desired future condition** (DFC) of fish-bearing streams and the **potential for unintended consequences** from their decisions. The overall policy goals and DFC of fish-bearing streams as described in rule are discussed and summarized below, followed by a framework to use as a roadmap for ensuring these rule elements and the Board's specific areas of concern are addressed.

The purpose and goals of the water protection rules re-emphasize the leading use of private forestlands as "the growing and harvesting of trees, consistent with sound management of soil, air, water, fish and wildlife resources" (OAR 629-635-0100(1)). The specific purpose of the water protection rules is "to protect, maintain and, where appropriate, improve the functions and values . . ." of waters of the state and riparian areas (OAR 629-635-0100(3)). These functions and values include water quality, hydrologic functions, the growing and harvesting of trees, and fish and wildlife resources. Active management is encouraged to meet this purpose, as appropriate. The Board has expressed concerns about the economic consequences to working forests and how those impacts may differ according to landowner type. While these economic impacts will be estimated as part of the analysis required under statute (ORS 527.714(7)), the Board has asked the department to provide preliminary economic impact information to help inform their decision (provided in June 2015, plus information in this document).

The overall protection goal specific to fish-bearing streams is :

> The overall goal of the water protection rules is to provide resource protection during operations adjacent to and within streams, lakes, wetlands and riparian management areas so that, while continuing to grow and harvest trees, the protection goals for fish, wildlife, and water quality are met (OAR 629-635-0100(7)).

The rules go further to specify goals particular to water quality, fish and wildlife:

> (a) The protection goal for water quality . . . is to ensure through the described forest practices that, to the maximum extent practicable, non-point source discharges of pollutants resulting from forest operations do not impair the achievement and maintenance of the water quality standards.
>
> (b) The protection goal for fish is to establish and retain vegetation consistent with the vegetation retention objectives . . . that will maintain water quality and provide aquatic habitat components and functions such as shade, large wood, and nutrients.
>
> (c) The protection goal for wildlife is to establish and retain vegetation consistent with the vegetation retention objectives … that will maintain water quality and habitat components such as live trees of various species and size classes, shade, snags, downed wood, and food within riparian management areas. For wildlife species not necessarily reliant upon riparian areas, habitat in riparian management areas is also emphasized in order to capitalize on the multiple benefits of vegetation retained along waters for a variety of purposes.

Meeting water quality standards to the maximum extent practicable is already included in the rule objective. There is a risk that insufficient or imprecise information regarding riparian prescription performance could result in a Board decision that results in ongoing direct and/or cumulative effects to stream temperature. The Board has struggled with competing views of the available science on temperature impacts to fish. Impacts to other wildlife have not been part of Board conversations.

The Board’s greatest authority and opportunity to meet the protection goals for fish-bearing streams is through setting protection standards for forest operations, especially those relating to streamside vegetation. The Vegetation Retention Goals and Desired Future Condition (DFC) for fish-bearing streams are as follows:

> 2) The desired future condition for streamside areas along fish use streams is to grow and retain vegetation so that, over time, average conditions across the landscape become similar to those of mature streamside stands. Oregon has a tremendous diversity of forest tree species growing along waters of the state and the age of mature streamside stands varies by species. Mature streamside stands are often dominated by conifer trees. For many conifer stands, mature stands occur between 80 and 200 years of stand age. Hardwood stands and some conifer stands may become mature at an earlier age. Mature stands provide ample shade over the channel, an abundance of large woody debris in the channel, channel-influencing root masses along the edge of the high water level, snags, and regular inputs of nutrients through litter fall (OAR 629-640-0000).

The rule states that current rule standards were based on information for unmanaged, conifer streamside stands at age 120 for each region. Different expectations for conifer and hardwood stands are established, though there is an expressed preference for increasing the conifer-component of riparian areas because of the historic dominance of large conifers adjacent to streams and the benefits to fish and wildlife habitat, as appropriate given site conditions. The DFC does not seek to establish contiguous old-growth stands along fish-bearing streams for all locations and times. Rather, its goal is to result in stands with characteristics similar to average mature stands.

The current standard targets are typically intended to meet the DFC in a "timely manner." Where streamside stand conditions are not likely to result in the DFC in a "timely manner,"[2] such as where disturbances resulted in a hardwood-dominated stand, management actions beyond implementing the standard targets are recommended (e.g. restoration activities). Figure 10 demonstrates how these different elements interact, including their hierarchy in the policy context and the potential for tension and overlap.

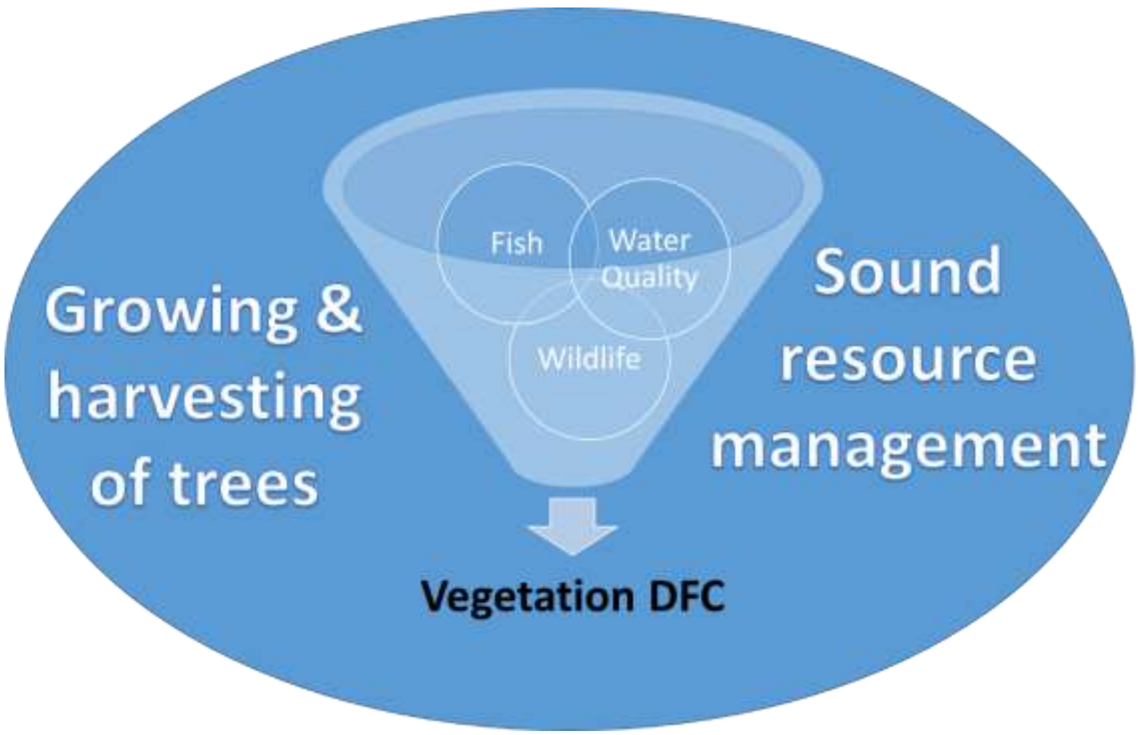



Figure 10: Hierarchy and interaction of streamside protection goals and riparian vegetative desired future condition (DFC).

Finally, the statutes require the Board to consider a list of factors when establishing best management practices (ORS 527.765(1)). These factors have been an implicit part of discussions and work to date and are linked in Table 5 below.

[2] "Timely" for many sites is considered to be 50 years (OAR 629-640-0000(9)).

Table 5. Relationship between ORS 527.765 factors to consider and specific elements for the Riparian Rule Analysis.

| **ORS 527.765(1a-e) Factor** | **Element from Riparian Rule Analysis** |
|---|---|
| Beneficial uses of waters potentially impacted | Salmon, Steelhead, and Bull Trout [SSBT] (*OAR 340-041-0028 (11)*) |
| The effects of past forest practices on beneficial uses of water | Designed to ensure that practices do not degrade cold water in which SSBT live; also, most RipStream sites were harvested previously, thus their control reflects what happened with previous harvests. June 2014 Board workshop summarizing biological outcomes of current research from Oregon State University Watershed Research Cooperative studies. |
| Appropriate practices employed by other forest managers | Considered what other states have done, Oregon State Forests, and studies from the Systematic Review (outcomes in Oregon, British Columbia, Washington and Alaska). |
| Technical, economic and institutional feasibility | Considered economic information from the department, discussed institutional feasibility with departmental staff, and technical feasibility with Regional Forest Practices Committees. |
| Natural variations in geomorphology and hydrology | Addressed via Systematic Review, breadth of RipStream sites, and differences across Geographic Regions. |

***Framing the key decision factors***

To assist the Board in their deliberations, the information from sections I, II and III above and the Decision Matrix (Attachment 1) have been summarized in Tables 6 and 7 below. These tables associate Board decisions with key factors to consider such as goals and vegetative desired future conditions for fish-bearing streams described in the FPA and rules and unintended consequences. Table 6 begins by grouping proposed riparian protection prescriptions according to similar outcomes for stream temperature and then associating anticipated outcomes with different prescription groupings. Table 7 focuses on Board decisions regarding spatial extent. Together, these tables illustrate the range of choices and the possible consequences as the Board moves the dial from less to more restrictive packages, allowing the Board to evaluate various potential scenarios and outcomes.

***Prescription Choices and Analyses***

Table 6 groups prescription choices by expected outcomes for stream temperature, i.e., the likelihood that the prescription will met the PCW criterion.

Table 6. Proposed riparian protection prescriptions, consideration, anticipated outcome, and decision ranges

| Consideration | Anticipated Outcomes | Decision Range | | |
|---|---|---|---|---|
| | | Unchanged or Small Temperature Performance | Improved Temperature Performance | Threshold Temperature Performance |
| Goal - Water Quality (Temperature) | Prescriptions that have similar responses. *Note: Repeating prescriptions across decision range indicates uncertainty* | No-Cut: ≤~70 feet<br>FPA, OFIC-A, AOL-B, RFPC-A<br>Variable: ≤~250 $ft^2$/1000 ft.<br>Staggered-Harvest options | No-Cut: ~70-90 feet<br>Variable: ~250-275 $ft^2$/1000 ft. | No-Cut: ≥~90 feet<br>Variable: ≥~275 $ft^2$/1000 ft. |
| | Likelihood that range of temperature change outcomes includes 0.3°C (PCW). | Low | Moderate to high | High |
| | Likelihood that temperature improvements will occur (Improved) | Zero - Moderate | Moderate to high | High |
| | Range of predicted or estimated **mean** temperature increases (Range) | 0.64-1.45°C | 0.29-0.64°C | 0.2-0.33°C |
| | Marginal returns for temperature | Zone 1- high marginal rate[1] | Zone 2- moderate, start of diminishing marginal return | Zone 3- low to very low marginal return |
| Water protection rule purpose | Protect, maintain and improve fish resources | Unknown | Unknown | Unknown |
| Goal – Fish (Wood recruitment) | Associated range of wood recruitment rates relative to unharvested stands for small and medium streams (Range) | Small: ~40-78%<br>Medium: ~62-78% | Small: ~76-88%<br>Medium: ~76-88% | Small: ~84-100%<br>Medium: ~84-100% |
| | Likelihood of active wood placement (Active) | Moderate | Low | Low |
| Unintended consequence | Increasing encumbrance and economic cost to forest landowners | Lower | Moderate | High |

[1] While the marginal rate for temperature change is high, the expected temperature change for many of these prescriptions is too small to make the high rate meaningful.

Unchanged or Small Temperature Performance

This group represents prescriptions with a low likelihood of meeting the PCW criterion. They make no change (i.e., current FPA) or minor changes to restrictions on practices (e.g., OFIC-A, AOL-B, RFPC-A). The group has a low likelihood that the range of temperature change outcomes includes 0.3 °C. The likelihood that temperature improvements will occur is zero to moderate, with a range of predicted or estimated mean temperature increases of 0.64-1.45 °C. This range brackets the mean predicted temperature values of the prescriptions in the group, not the 95 percent credibility interval of the prescriptions. While the marginal rate for temperature change is high, the expected temperature change for many of these prescriptions is too small to make the high rate meaningful.

This group also has the lowest range of wood recruitment rates relative to unharvested stands for small (40-78%) and medium (62-78%) streams. The likelihood of feasibility of active wood placement is moderate, as the buffer widths are narrower. This group has the lowest encumbrance and economic cost to forestland owners.

Improved Temperature Performance

This group represent prescriptions with a moderate to high likelihood of meeting the PCW criterion. The group is defined by the marginal temperature zone 2, from the start of decreasing marginal returns (about a 60-70 foot width) to the point where additional returns are very low (e.g., > 90-foot width). From the lower end to upper end, the group has a moderate to high likelihood that the range of temperature change outcomes includes 0.3°C. The likelihood that temperature improvements will occur is moderate to high, with a range of predicted or estimated mean temperature increases of 0.29-0.64°C.

The group has a moderate range of wood recruitment rates relative to unharvested stands, about 76-88% for small and medium streams. The likelihood of feasibility of active wood placement is low, the buffer widths are wider which increases the challenge of wood placement. This group has a moderate to high encumbrance on acres and economic cost to forestland owners.

Threshold Temperature Performance

This group represent prescriptions with a high likelihood of meeting the PCW criterion. The group is defined by the marginal temperature zone 3, starting at the point where additional returns are very low (e.g., > 90-foot width). The group has a high likelihood that range of temperature change outcomes includes 0.3°C. The likelihood that temperature improvements will occur is moderate to high, with a range of predicted or estimated mean temperature increases of 0.29-0.33°C.

This group has a high range of wood recruitment rates relative to unharvested stands about 84-100% for small and medium streams.

This package significantly limits the range of riparian management options. Without an Alternate Prescription to allow landowners to address stocking and forest health issues, or the use of a Plan for Alternate Practice, there is a high risk that some riparian stands will not reach mature conifer forest conditions in a timely manner. It creates a high disincentive to actively place wood in stream channels. This package would have the greatest economic impact on all forestland owners.

Vegetative Desired Future Condition (DFC)
All groups have risk associated with the likelihood that riparian prescriptions will result in mature stand conditions across the landscape in a timely manner. Only FPA and FMP prescriptions explicitly identify a goal and pathway to meet a specified vegetative goal or desired future condition for mature streamside stands.

All other prescriptions have some risk of not achieving DFC in a timely manner due to overstocked stands or insect and disease issues. For no-cut buffer prescriptions, the risk depends on the existing stand condition. The risk increases as stand density diverges from desired density. A Plan for Alternate Practice or Alternate Prescription that allows harvest entry for forest health treatments or restoration could mitigate this risk.

Variable retention prescriptions that allow tree retention requirements to be met by leaving trees closest to the stream may increase the likelihood of incentivizing narrow, high density buffers. Anecdotally, the RipStream sites exhibited the tendency to implement the current FPA variable retention prescription as a hard-edged clearcut adjacent to the leave trees in the riparian management area (RMA) as opposed to thinning within the RMA. Headquarter's staff regularly receive questions from field staff about the riparian protection rules' intent, specifically if hard-edged RMAs are acceptable as opposed to being implemented as a thinning prescription if they meet tree retention targets. The policy is silent on this issue. Future analysis of RipStream data is planned to look specifically at whether riparian protections as currently implemented put riparian stands on a trajectory to meet the DFC. The outcome of hard-edged RMAs raises the question of whether variable retention buffers without more specific density targets effectively result in no-cut buffers and come with the risks discussed above. Again, this risk could be mitigated by a distribution requirement for leave trees throughout the full riparian management area.

Finally, the risk of not achieving DFC goals for maximizing conifer retention or composition of riparian stands increase for prescriptions that allow hardwoods to count towards variable retention targets.

***Geographic Extent Policy Considerations***

Based on earlier discussions, it appears that Board decisions on geographic regions and stream extent cannot rely on a purely empirical approach. The decisions require balancing risks and uncertainty to meet the rule objective.

Geographic Regions
Science does not provide clear answers for the Board's decision to which regions new rules should apply or if new rules should continue to be stratified according to stream size.

In earlier deliberations, the Board raised the question of how this riparian rule analysis may intersect with concerns raised in the disapproval by EPA and NOAA of Oregon's coastal nonpoint source pollution control program, also known as CZARA. Most of the CZARA nonpoint program area coincides with the Coast Range and South Coast regions (Figure 11). A significant portion of the Siskiyou and to a lesser extent the Interior region is included via the Rogue and Umpqua basins, respectively. The Interior region is also affected through the Nehalem, Siuslaw and Smith Rivers. Only the Western Cascades remain outside the CZARA nonpoint program area.

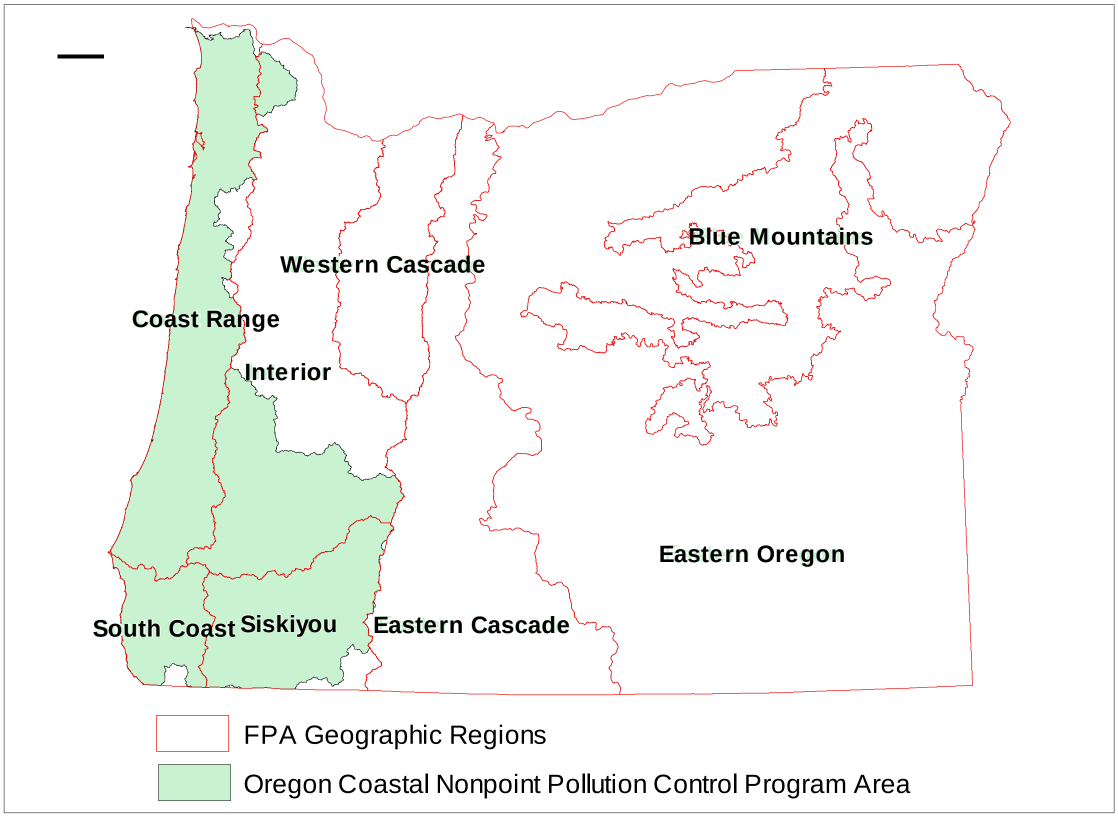



Figure 11. Map of the Coastal Nonpoint Pollution Control Program Area and the Forest Practices Act (FPA) Geographic Regions.

We offer these factors and questions to assist the Board's region and stream size discussions:

- There is insufficient science to support a purely empirical Board decision.
- Does the Board wish to reaffirm or alter current policy for tailoring stream protection measures according to geographic region and stream size for the streams in question?
    - Reaffirm policy – Limit the rule analysis to the Coast Range region and assume a risk-intolerant position relative to extrapolating RipStream results.
    - Alter policy – Assume a more risk-tolerant position relative to RipStream results and alter current policy by including one or more additional regions, defining one or more new regions, and/or establish a single protection standard across all streams regardless of size.
- CZARA Disapproval – The Board's only obligation in this rule analysis process is to consider and fulfill the statutory findings and analyses in ORS 527.714 and ORS

527.765. Should the Board wish to adapt its decision-making process to seek a degree of alignment with CZARA temperature concerns, the decision on geographic scope will play an important role.

For geographic regions Table 7 illustrates the decision range with three groups, Coast Range only, two or more regions, and most or all regions. The table illustrate the effect on goals of temperature and large wood, as well as unintended consequences.

The **"Coast Range only"** geographic extent has a high risk of not addressing temperature and wood recruitment concerns raised across large areas (all other regions in western Oregon). It does not extrapolate RipStream results beyond their range of data, resulting in a low risk that estimated outcomes may be incorrect, statistically speaking. It also has the lowest economic costs to forestland owners. At a landscape scale, this alternative could differentially affect industrial forest landowners given their predominant ownership in this region (see Figure 1). An unintended consequence includes a high risk of not addressing CZARA temperature concerns on small and medium fish-bearing streams.

The **"Two or more regions"** geographic extent has a moderate risk that large areas have unaddressed temperature and wood recruitment concerns. The forest practice rules already group all western regions for small streams and the following regions for medium Type F streams based on expected similarities between stand conditions and stream response: Coast Range and South Coast; Interior and Western Cascade. Most Ripstream study sites are in the Coast Range but reach to the Interior, strengthening inferences to this region. These factors can inform the decision to include regions beyond the Coast Range. It has an unintended moderate to high risk of not addressing CZARA temperature concerns, depending on which regions are included. It does extrapolate RipStream results beyond their range of data, creating a moderate risk that estimated outcomes are incorrect. It increases economic costs to forestland owners.

The **"Most or all regions"** geographic extent has a low risk that large areas have unaddressed temperature and wood recruitment concerns. It minimizes the risk of not addressing CZARA temperature concerns. It has the highest risk that estimated outcomes may be incorrect by extrapolating RipStream results to most or all regions. Given the current groupings of regions in rule and the distribution of Ripstream sites that reach into the Interior, there is a logical basis to support the inclusion of all western geographic regions. It makes intuitive sense that landscape-scale characteristics (e.g., forest type, climate, topography, and hydrology) are similar enough between the Geographic Regions that a similar degradation finding would be supported if RipStream studies were conducted in each region, although this reasoning is conjecture. A possible exception to this reasoning is the Siskiyou Geographic Region, which appears to have drier and sparser forests, and a much lower site index (Lorensen et al. 1994). This extent group has the highest economic costs for forestland owners.

Table 7. Board decisions regarding geographic regions and stream extent.

| **Decision** | **Consideration** | **Risk statement** | **Decision Range** | | |
|---|---|---|---|---|---|
| | | | **Coast Range only** | **Two or more regions** | **Most or all regions** |
| **Geographic Region Extent** | Goals - Water Quality and Fish | Risk of large areas with unaddressed temperature and wood recruitment concerns | Temperature – High<br>Wood - High | Temperature – Moderate<br>Wood - Moderate | Temperature – Low<br>Wood - Low |
| | Water protection rule purpose | Risk that outcome will protect, maintain and improve fish resources | Unknown | Unknown | Unknown |
| | Unintended consequence | Risk of extrapolating RipStream results (Statistical perspective) | Low | Moderate | High |
| | Unintended consequence | Risk of unaddressed CZARA temperature concerns | High | Moderate - High | Low |
| | Unintended consequence | Risk of increasing economic costs to forest landowners | Lower | Moderate | Higher |
| **Stream Reach Extent (Above SSBT main stems and SSBT tributaries)** | **Consideration** | **Risk statement** | **Zero (0) feet Upstream** | **1000 feet Upstream** | **One mile Upstream** |
| | Goals - Water Quality & Fish | Risk of significant length of stream reaches with unaddressed temperature and wood recruitment concerns | Temperature – High<br>Wood - High | Temperature – Moderate<br>Wood - Moderate | Temperature – Low<br>Wood - Low |
| | Water protection rule purpose | Risk that outcome will protect, maintain and improve fish resources | Unknown | Unknown | Unknown |
| | Unintended consequence | Risk of incorrect and/or complex and layered assumptions, modeling, and difficult field implementation | Main stem – none<br>Tributaries – none | Main stem - Moderate<br>Tributaries - High | Main stem - High<br>Tributaries - High |
| | Unintended consequence | Increasing risk of economic costs to forest landowners | None | Moderate | Higher |

Another consideration is the cost of doing RipStream type studies, which are multi-million dollar projects that require over a decade to complete. The Board may consider whether it is good public policy to require a RipStream type study, at large cost, in each Region to test riparian rule effectiveness. These considerations suggest that the Board should either include all five western Oregon Regions, or all except the Siskiyou. Whichever decision the Board chooses will be based on arbitrary values rather than well-supported science.

Stream Extent

Table 7 also illustrates tradeoffs and risks associated with decisions on stream extent, using a range of distances.

Applying prescriptions only to SSBT streams, i.e., zero (0) feet upstream on main stem portions, has the benefit of being simple to implement and has no risk of incorrect and/or complex and layered assumptions and modeling. It has a high risk that significant lengths of stream reaches will have unaddressed temperature and wood recruitment concerns. Harvest immediately upstream of SSBT reaches has the potential to raise stream temperatures above 0.3 ˚C. A portion of the SSBT reaches would therefore also have a high probability of increasing by greater 0.3 ˚C. Since no additional land is encumbered by this choice, it has a no risk of additional economic cost.

Applying prescriptions a set distance such as 1000 feet upstream on main stem portions of SSBT streams increases implementation difficulty and poses a moderate risk of incorrect and/or complex and layered assumptions and modeling. The 1000-foot extension would provide a moderate degree of protection for SSBT streams from upstream warming as discussed in the Stream Reach Extent section as a potential mid-range distance that would address approximately 50% of potential stream temperature increases (Figure 9). In some circumstances (depending on initial temperature increases and stream characteristics) the distance would be more than sufficient for allowing temperature increases to fall below 0.3 ˚C before reaching the SSBT portion of the reach. 1000 feet coincides with the average distance at which RipStream sites would have lost 50% of whatever temperature increase they experienced upstream (but recall the wide variation of all sites). It isn't clear that 1000 feet would generally be a sufficient distance to return temperature increases on privately-owned sites to less than 0.3 ˚C. Our data suggest that several streams would not reach the threshold. The 1000-foot extension would result in additional encumbrance and economic costs for landowners.

Applying prescriptions one mile upstream on main stem portions of SSBT streams increases implementation difficulty and poses a high risk of incorrect or complex and layered assumptions and modeling. The one-mile extension would provide a higher degree of certainty that most streams will return to within 0.3 C of their thermal equilibrium. The one-mile extension would result in higher encumbrance and economic costs for landowners.

As with the geographic extent, an additional consideration is whether the Board wants to use this riparian rule analysis decision to address CZARA temperature concerns. There is a risk that not addressing upstream reaches as part of the rule analysis may mean continued concerns about coastal zone stream temperatures.

## IV) RIPARIAN PRESCRIPTION PACKAGES

Using Tables 6 and 7, a range of potential Board decision combinations and anticipated outcomes are described below as packages with associated themes. Given the large number of potential "packages", these are intended to help facilitate Board discussion and possibly form the basis for statutory findings.

### Package 1 – Minimize Temperature Concerns

This package minimizes temperature concern by selecting the no-cut and/or variable retention prescriptions that have a predicted temperature change at or below the PCW threshold. Based on the RipStream modeling results, these would be the 90-foot no-cut and a variable retention target of 275 $ft^2$ per1000 ft. The spatial extent of this package includes all western regions and a 1,000-foot upstream extent of on main stem portions of SSBT.

The risk of temperature and wood recruitment concerns remaining unaddressed for small and medium fish bearing streams is low, incidentally including CZARA temperature concerns. The expected temperature increase would be 0.29 and 0.33 °C for the no-cut and variable retention, respectively with a range (credibility interval) of 0.07 to 0.56°C. Wood recruitment rates would approach those of unharvested stands reaching about 84-88 %.

The risk associated with extrapolating RipStream results into other regions is high. There would be increased difficulty with field implementation of upstream extent, requiring GIS modeling or field protocols.

Concerns regarding temperature effects of tributaries and potential cumulative effects could be addressed with voluntary measures for upstream portions, beyond 1,000 feet and tributaries in the headwater portion of watersheds.

Without an Alternate Prescription to allow landowners to address stocking and forest health issues, or the use of a Plan for Alternate Practice, there is a high risk that some riparian stands will not reach mature conifer forest conditions in a timely manner. There is also a risk that variable retention buffers may be implemented as no-cut buffers (hard-edge clear cut) and not address stocking density issues. It also creates a high disincentive to active wood placement in stream channels. This package would have high economic costs for all forestland owners and disproportionally greater for some non-industrial owners.

### Package 2 – Mitigate Direct Temperature Concerns

This package mitigates direct temperature concern by balancing predicted temperature with diminishing marginal returns, model uncertainties, and operational considerations. The package selects the no-cut and/or variable retention prescriptions that fall in the middle of zone 2 of diminishing marginal returns for temperature. These prescriptions would be the 70-foot no-cut and a variable retention target of about 225 $ft^2$/1000 ft. The spatial extent of this package includes all western regions and current-use SSBT streams.

The risk of temperature and wood recruitment concerns remaining unaddressed is significantly reduced, including CZARA concerns since all regions within that sphere are included. However, some risk remains and concerns about warm water contributions from farther upstream and tributaries are not addressed. The expected temperature increase would be 0.64 °C and 0.59-0.84 °C for the no-cut and variable retention, respectively with a credibility interval range of 0.42 to 0.98°C. Similarly, wood recruitment rates improve to about 68-78% relative to unharvested stands for both small and medium streams.

The risk associated with extrapolating RipStream results into other regions is high. However, field implementation is simplified by limiting prescriptions to current-use SSBT streams.

Concerns regarding temperature effects of upstream of SSBT segment, tributaries, and potential cumulative effects could be addressed with voluntary measures for upstream sections and tributaries in the headwater portion of watersheds.

Without an Alternate Prescription to allow landowners to address stocking and forest health issues, or the use of a Plan for Alternate Practice, there remains a risk that some riparian stands will not reach mature conifer forest conditions in a timely manner. There is a risk that variable retention buffers may be implemented as no-cut buffers and therefore not address stocking density issues. The package creates a moderate disincentive for active wood placement in stream channels. This package would have lower economic costs for forestland owners than Package 1 due to lower encumbrances on acres for the selected prescriptions, but still significant due to the geographic extent.

**Package 3 – Balance Temperature Concerns with Avoidance with Unintended Consequence**

This package balances temperature concerns with avoiding unintended consequence by selecting elements of packages 1 and 2 to create flexibility and explicit incentives that address unintended consequences. For example, the no-cut prescriptions could be a range between 70 and 100 feet, with an average of 85-foot across the harvest unit to allow for operational flexibility. The range and average could be lowered, e.g., 60 and 90 feet, with an average of 75-foot, if active wood placement and forest health prescription are completed. The variable retention prescriptions could set a lower basal area target range, with the addition of a distributional requirement to retain trees throughout the riparian management area.

The stream extent of this package could include current-use SSBT streams and a mid-range distance upstream of SSBT mainstems (hundreds to thousands of feet upstream). The package could create flexibility by linking the required average width on SSBT streams to distance upstream or additional buffers on non-SSBT tributaries.

Constructed appropriately, this approach affords a higher range of riparian management options, allowing landowners to address stocking and forest health issues that may otherwise result in a stand not reaching mature conifer forest conditions in a timely manner. It also could incentivize active wood placement in stream channels. This package would likely have economic costs for forestland owners between Packages 1 and 2.

## V) RECOMMENDATIONS

The Department recommends that the Board discuss the policy issues, using the above framework and all the information it has received to develop a set of prescription components that meet the PCW criterion to the maximum extent practicable, consistent with the ORS 527.765 factors and required ORS 527.714 findings.

The Department also recommends that the Board include more than one prescription choice, e.g., a no-cut prescription, a variable retention prescription, and/or alternate prescription approach to increase forestland owner flexibility and minimize unintended consequences.

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## Appendix 1  Fish Response: Questions and Narrative Responses from Biologists

***Background***

The department contacted five fish biologists about quantifying fish response to proposed prescriptions.  The fish biologists represent state and federal agencies, landowners, and the environmental community. We based the selection on the range of presenters at the June 2014 Board workshop, and all of these fish biologists assisted with that workshop.  One biologists, Dunham, convened two separate sessions to gather information from 12 scientists in the Oregon State University, United States Forest Service, and United States Geological Survey research community.

As described at the April 2014 Board meeting, we aligned the questions asked of the biologists with the groups of prescriptions included in the matrix.  Fish response metrics include, but are not limited to, changes in fish size, fish abundance, and fish distribution.  We defined “Fish” as salmonids, e.g. coastal cutthroat, Oregon coastal coho, summer/winter steelhead, etc.  A response could be “Positive”, “Negative”, “Unchanged”, or “Unknown.”  We also provided background information on the riparian rule analysis process, current Forest Practices Act riparian standards, and the range of potential riparian prescriptions, including information contained in the Matrix to help provide context and frame the responses.  In addition to answering the questions (i.e., filling in the matrix) we requested a brief narrative summary of any thoughts or comments regarding potential fish response.

The remainder of this appendix contains the questions asked and the narrative responses received.

***Request sent to Biologists***

Greetings,

As you know, the Board of Forestry is currently evaluating results of the Riparian Function and Stream Temperature Monitoring Project (commonly referred to as RipStream).  Results from the data analysis suggest that current stream side buffer zones on private forestland along small and medium fish bearing streams allowed streams to warm more than the allowable state standard of 0.3C.  Over the past couple years, the Board has worked to understand this information (thanks again for your participation in the June 2014 workshop), evaluate policy implications, and develop potential new streamside buffer prescriptions that may provide greater protection against stream temperature increases to the maximum extent practicable.

A few months ago, I contacted you in hopes that you might provide insight into potential fish response from new streamside buffer prescriptions that have been developed.  New streamside buffer prescriptions have been presented to ODF and we would like to present this information in the context of several attributes including potential fish response.  Please note that the new streamside buffer prescriptions along with other data attributes will be presented as information only to the Board on June 3, 2015. The decision on which prescription(s), if any, to adopt will likely come at the July, 2015 Board meeting.

Please review the attached table which provides summary information on the range of prescriptions. In the "Riparian Function" grouping of attributes you will find a row titled "Fish Response (qualitative)". Fish response could include, but is not limited to, fish size, fish abundance, fish health, fish distribution. "Fish" is defined as salmonids, e.g. coastal cutthroat, Oregon coastal coho, summer/winter steelhead, etc. A response could be "Positive", "Negative", "Unchanged", or "Unknown". If there are differences in potential responses based on specific species please note that as well. We are looking for high-level information for potential fish response and a brief summary (a paragraph or two) of any thoughts or comments that you might have regarding potential fish response.

We would like you to use information in the column that represents the individual prescription and answer the following questions:

1. No-Entry Buffer Prescription:
    a. Based on your professional experience, what may be likely fish responses from increasing current riparian management prescriptions from current FPA rules to a no harvest buffer of 50, 70, 80, 90, and 100 feet slope distance? (see No Cut Buffer columns)

2. Variable Retention Prescription (Buffers with limited entry):
    a. Based on your professional experience, what may be a likely fish response from increasing current riparian management prescriptions from the current FPA basal area requirement (Small Fish = 40 sq. ft. /Acre) (Medium Fish = 110 to 140 sq. ft. /Acre)[3] to a variable retention buffer with basal area requirements ranging from 200-275 sq. ft. /Acre Small and Medium Fish? (see Variable Retention columns, also please note that the Variable Retention buffers were modeled as a fixed width buffer)

3. Alternate Prescription:
    a. Based on your professional experience, what may be the likely fish response to a 1-sided harvest following current FPA rules then harvesting the other side 4-5 years later? (See Staggered Harvest columns)
    b. Based on your professional experience, what may be the likely fish response to a variable width buffer based on stream azimuth? (see South-sided buffer columns) For example, a stream flowing east / west may receive a buffer that is wider on the south side of the stream and a narrower buffer on the north side of the stream

[3] Note – The letter mistakenly presented these as stocking values per acre rather than per 1000 feet. These values were correctly presented as values per 1000 feet in the Decision Matrix table provided to the biologists. When informed of the error, all biologists responded that they based their responses on the values in the Decision Matrix table and that it did not change their responses.

***Response Received From Biologists***

R. Bilby, Weyerhaeuser

*From email transmittal:*
My estimates of fish response to the buffer options is attached. I also include some discussion about the rationale and assumptions behind my predictions. I hope this exercise is of some use to ODF and the board in making a decision. But I would bet that the primary value is in highlighting how much we still need to learn about the relationship between forest management and aquatic ecosystems. Let me know if you have any questions.

**Potential Fish Response to Buffer Options**
R. Bilby

Responses associated with changes in shade and temperature, which will occur immediately after application of the buffer treatment and persist for a decade or less, will be on a different time scale than reposes associated with the provision of large wood. Full expression of the capacity of a given buffer design to deliver wood may take decades, long after effects associated with changes in shade and water temperature have disappeared. Therefore, the fish response must be evaluated separately for wood and temperature/shade. There also is relatively little information available on the amount of in-stream wood required to maximize production of salmonid fishes. This lack of information makes it nearly impossible to provide a meaningful assessment of the potential fish response to the levels of wood generated by the various buffer options. This point is discussed in detail below.

**Response to Changes in Temperature and Shade**

It is not possible to predict salmonid fish response to temperature and shade changes under the riparian buffer alternatives without understanding the pre-harvest thermal characteristics of the affected stream reach. The predicted increases in mean 7-day maximum temperatures associated with the various options in the Decision Matrix range from $0.18^{o}C$ to $1.45^{o}C$. Temperature increases of this magnitude will have relatively small impacts on fish populations unless baseline temperatures are approaching levels stressful for salmonid fishes. Therefore, negative effects would be expected only in streams that exhibit water temperatures close to those that are stressful for salmonid fishes ($>15^{o}$) prior to harvest. In these thermally sensitive systems the level of negative impact would be related to the level of temperature increase, with the greatest increases having the largest negative impact.

However, in streams with pre-harvest thermal regimes that are below stressful levels, an increase in temperature may benefit fish growth and survival and increase population production. Growth rate of coho with relatively abundant food availability (60%-100% of full ration) peaks at around $14^{o}C$. The temperature at which peak growth occurs is lower under conditions where food is limited but even at food availability levels less than half the maximum ration, temperatures at which peak growth rates are expressed only drop about $1^{o}C$.

Temperature increases associated with harvest are caused primarily by increased sunlight reaching the stream channel. Higher light levels also have been shown to increase primary production in streams, which can enhance invertebrate production and increase food availability for fish. The positive response of salmonid fishes to increases in light has been well documented (see list below). In streams that have pre-harvest water temperatures below that for optimal growth, increased light and increased water temperature can act in concert to enhance fish growth and production. In stream reaches where water temperature is elevated to levels potentially stressful for fish after harvest, increased light levels may mitigate negative effects of warmer water.

The fish response associated with post-harvest increases in temperature and light will be relatively short-lived. Full recovery of shade along western Oregon streams impacted by debris torrents occurred in a little over a decade (D'Souza et al. 2011). Shade recovery after timber harvest would be expected to occur more rapidly than this, given that all the buffer options retain a substantial amount to vegetation along the stream following harvest.
The two tables below provide an assessment of the potential fish response to changes in temperature and shade associated with the various buffer options. The first table provides predictions for streams where post-harvest temperatures would not be stressful for the fish. The second table provides predictions for streams that exhibit background temperatures approaching stressful levels for salmonid fishes and increased channel exposure following harvest would increase temperatures above 16$^{o}$C.

**Response to Changes in Wood Delivery**

As noted above, the effect of the buffer options on wood abundance generally will occur at a different time scale than that for responses associated with temperature and shade. Wood delivery to streams from riparian areas can occur as a result of chronic processes, such as natural mortality of trees as a stand ages or through bank cutting. Wood input from these processes would occur over very long time scales, decades to centuries. Catastrophic processes also deliver of wood to channels. Severe wind storms and floods can deliver enormous quantities of wood to channels and, in the steep topography common in western Oregon, debris torrents often are a major mechanism of wood delivery to streams (May and Gresswell 2003). These catastrophic input mechanisms occur infrequently. Therefore, the effect on fish of wood provided by buffers will rarely occur simultaneously with the effects associated with of alterations in shade and temperature on fish. For this reason, it is necessary to estimate fish response to wood input from the buffer options independently from predictions of response to shade/temperature changes.

Predicting a fish response to the various levels of wood provided by the buffer options is further complicated by the fact that there is little available information on how much in-channel wood is required to maximize fish abundance, production or survival. Therefore, any predictions of fish response to the levels of wood provided by the buffer options will be speculative, at best. There are very few studies that contain information relevant to this issue. A review of the literature on fish response to riparian logging in British Columbia did conclude that retaining wood in the channel after harvest (i.e., not deliberately removing wood from the channel) was associated with higher density and biomass of salmonid fishes (Mellina and Hinch 2008). But there is no indication in this paper of the amount of wood required to maximize fish production. There also is a considerable amount of published information about the response of salmonid fishes to wood placement in streams. Most of these studies have documented a positive response by salmonid fishes following wood additions (Roni et al. 2014). However, some evaluations have found no obvious fish response and a few studies have documented negative effects (Roni et al. 2014). The variation in response suggests that the relationship between wood abundance and fish population performance varies spatially but, generally is positive. However, given this variability, generating a general prediction of how fish are likely to respond to the amount of wood provided under the buffer options is a very uncertain undertaking. And the studies that have evaluated fish response to wood-addition projects do not address the fundamental question relevant to making a prediction about fish response to the buffer options: How much wood is enough?.

Without a better understanding of the relationship between wood abundance and fish population performance, a prediction of fish response to the level of wood provided by the different buffer options is essentially a wild guess. For this reason, I have not provided any assessment of the relative response of fish to wood input. Future discussions about forest buffers in Oregon would benefit from some targeted research on this topic. Simply assessing fish population levels in streams with varying amounts of wood would provides some basis for predicting fish response to the buffer options under consideration or any future buffering proposal.
*From description of matrix for temperature relative to 16°C.*

**Fish response to changes in temperature and shade for streams where post-harvest 7-day mean maximum temperature does not exceed 16°C.** Fish response is relative to the site prior to harvest. **+** indicates a positive response, **0** indicates no response and – indicates a negative response. The assumption is made that a reduction of shade of at least 10% is required to stimulate primary production and increase food availability for the fish.

**Fish response to changes in temperature and shade for streams where post-harvest 7-day mean maximum temperature exceeds 16°C.** Fish response is relative to fish production at the site prior to harvest. **+** indicates a positive response, **0** indicates no response and – indicates a negative response. The assumption is made that thermal stress associated with an increase in temperature >1°C would not be mitigated by the increase in primary production related to reduced shade. Increased production would be sufficient to offset negative effects of higher temperature at sites where temperature increase are <1°C.

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Jason Dunham, Supervisory Aquatic Ecologist, USGS

*From email transmittal:*
Please see attached. Jeremy did a great job to keep us on track. You'll see a lot of uncertainty expressed in our replies. There was definitely a diversity of opinions among those involved, but everyone agreed that it would be extremely difficult to see measurable differences in responses of fish to <1C temperature changes at sites. Our focus was on sites or reaches and not landscapes, and on the immediate responses to small increases in temperature - not those you could anticipate in the face of climate warming. I made the call to give you one matrix that effectively summarized our collective replies. See what you think. Cheers, jd

Notes on fish responses – 19 June 2015

Process for obtaining responses – Jason Dunham hosted two 2-3 hour workshops involving about 12 scientists in the OSU/USFS/USGS research community with strong expertise in fish, forestry, and thermal ecology (range = ~5 to >50 years of experience) to provide feedback on potential fish responses to forest harvest alternatives described by ODF. The following represents a best approximation of feedback from these scientists, although Dunham is ultimately responsible for what is presented here.

Discussion of responses provided.

1. We partitioned our responses into two zones separated by a "/" indicating less than (to the left) or greater than (to the right) 16C, which corresponds to the State of Oregon's Core Coldwater Use Criterion (State of Oregon Administrative Rules: http://arcweb.sos.state.or.us/pages/rules/oars_300/oar_340/340_041.html). We considered both warm (>16C) and cold (<16C) temperatures as biological responses are generally nonlinear. This binary classification of temperature and our categorization of responses into positive, negative, none, or unknown represents a simplification, but is hopefully presented at a level of resolution that is sufficient for decision making purposes.

2. Our focus in this effort was on short-term responses of fish to changes in sites linked to the potential effects of forest harvest practices described in the matrix provided. With this narrow focus, we were unable to address several important considerations, such as:
    a. The importance of broader-scale processes, including those operating on long timeframes (e.g., recruitment of large wood, disturbance-driven channel dynamics, climate change) and large extents (e.g., watersheds or stream networks, regions), These broader scale processes could be very important in determining how fish respond to forest harvest alternatives listed here.
    b. Factors other than those listed in the response table, including but not limited to effects of other species on species of interest (e.g., salmon and steelhead), effects of other land use impacts related to forest harvest (e.g., roads), and so on (we readily identified a host of factors).
    c. We were unable to adequately address cumulative effects, given our limited focus.

3. We considered a variety of fish responses, but most were very difficult to predict, thus leading us to fill in most of our responses as "unknown" for the selected subset of possible responses.
    a. By saying "unknown" we do not mean to say that it is not possible to anticipate fish responses to forestry, but that fish responses to stream temperature and/or wood depend on a variety of complex factors that are often themselves unknown.
        i. For example, growth of fish under natural conditions can be influenced by temperature, but temperature influences a host of physiological processes, as well as processes in food webs (e.g., food availability), all of which can interact in complex ways to influence realized growth.
        ii. Fish responses to increased temperature can include increased metabolism; therefore, and availability of food or ability to move to other microhabitats can influence fish responses
        iii. Other factors that are independent of those directly driving growth may influence growth, for example, 1) fish may not feed when flows are extremely low because they are avoiding predators, or 2) temperature-dependent pathogens may influence fish performance.
    b. Another major source of uncertainty pertained to interactions among fish responses.
        i. For example, abundance of fish may influence fish growth (e.g., lower growth at high population densities).
    c. The described changes in temperature were relatively small, and thus it was difficult for us to make definitive predictions. In relation to other factors that modify fish responses, responses to change of around 1C could be difficult to confidently separate from other factors that affect fish in the wild.

4. In addition to the above uncertainties, participants in this process noted many others and scores reported herein are only crude approximations of potential fish responses to forest harvest alternatives. Accordingly, **an adaptive management approach to evaluating responses to actual treatments may be most beneficial** to ensure that any given management is not having a detrimental influence on fish.

Doug Bateman, Oregon State University, Senior Research Faculty Assistant

I went to the group meeting with Jason Dunham and a number of other fish folks here in Corvallis and I am in agreement with the group response that Jason has sent you. This is pretty complex and expected responses are very context dependent. A prescription may have positive implications for fish in some places and negative implications at another. The same would also occur in time with possible short term positive responses turning into the long term negatives. Based on Hinkle Creek, Alsea, and the Trask Watershed Studies and a study Bob Gresswell and I did (we looked 40 randomly selected watersheds in western Oregon) there is little evidence of short term negative effects of forestry on headwater fish in previously harvested watersheds. I think the current rules have stabilized things and if headwater fish are being negatively effected by forest management it is at spatial and temporal scales we have not evaluated. If it were my money, I would not be buying more resources to protect fish in small forested streams in western Oregon. My first priority would be to apply our new knowledge about how watersheds work to reallocate the existing resources (move away from one-size fits all prescriptions) so that we gained a greater benefit with essentially the same cost, while continuing to monitor fish response to logging over longer periods of time and larger watersheds. That is my two cents.

Dave Jepsen, Oregon Department of Fish and Wildlife

Fish response: The functional biological unit for fish response is the population level. Data for salmonids in coastal streams indicate population dynamics influenced by density dependent mortality, suggesting strongly that habitat capacity is limiting salmonid abundance and productivity. Streams that are temperature limited for salmonids are part of the habitat capacity limitation. Wider riparian buffers provide more certainty that Protecting Cold Water criteria (based on fish needs) can be achieved (fewer stream miles that are temperature limited), and by extension are a principal means to increase the amount of salmonid habitat capacity. In addition, wider buffers with a larger composition of large wood (variable retention scenarios) better reflects natural conditions; large wood recruited to streams has a different structural and ecological role to habitat formation and habitat use than smaller wood. Over time, this combination of wider buffer width and LWD recruitment creates more lateral stream habitat (side channels, alcoves, etc.) and reconnects subsurface flows with surface flows. Together they create high quality (complex) habitat that directly increases habitat capacity and directly increases population-level resistance and resilience to stochastic events such as flooding, forest fires, or protracted droughts. Wider buffers in streams with higher gradients (not typically SSBT streams), reduce the risk that fine sediment is transported and embedded downstream to salmonid production zones where it can limit the quality and amount of spawning and incubation substrates.

Chris Frissell, Ph.D.

Frissell **&** Raven

Hydrobiological & Landscape Sciences

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24 June 2014

MEMO FROM: Chris Frissell, Ph.D.
ph. 406.471.3167

TO: Kyle Abraham, Oregon Department of Forestry

RE: Fish response Survey, Riparian Function and Stream Temperature Monitoring Project

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This memo summarizes my responses to the survey query you recently sent regarding my professional opinion about potential fish response to numeous streamside forest management rule scenarios for private forest lands in western Oregon.

Before offering best-guess opinions on the specific questions you posed, I would like to briefly discuss some important uncertainties and assumptions.

1) *Fish response of particular interest.* Your query left open the metric of fish response, to include abundance, size, distribution, etc. You also sugggested discriminating responses by species where appropriate. I think species and life stage response will likely vary, and some responses such as changes in population survival might be partially compensated by changes in per capita growth or size at age. Other biological responses, such as changes in growth rate and outmigration timing of anadromous fish in response to temperature changes may not necessarily be compensated by other factors. Moreover there is evidence from number of studies that the response of a particular fish species and age class to habitat change can vary quantitatively and qualitiatively depending on what other species are cooccuring in the same stream. Therefore, for purposes of this memo I will assume that the focus is on ESA listed salmonid fishes, including coho salmon, steelhead

and bull trout, and I am going to assume the populations of interest are living in sympatry with other fish species, including coastal cutthroat trout. Where particular species might depart widely from others in their sensitivity or response I will try to note that. However, most such nuances are well below the resolution allowed by the level of specification provided by DOF, and further limited by the time available to me to respond.

2) *Varied forms of fish biological response.* I am going to assume that an adverse effect in any biological category—abundance, survival, distribution, life history diversity, or population productivity—is a harm or potential harm to the population of concern and should be recognized as such. I am also going to assume that though they have been sometimes posited, "beneficial" effects of logging (which migh tin theory offset some adverse effects) are too uncertain, infrequent, or transient to warrant recognition here. That is, the responses of interest are those potential harms to sensitive fishes that arise from the removal of timber from streamside areas, and "null" responses wherein no harm occurs. A corollary assumption is that the logging of concern here occurs primarily in mature or maturing forest stands that are on a recovery trajectory from previous logging entries, or other disturbance (e.e., past fire), including with regard to shade and stream temperature, large wood, channel stability and complexity, and sediment conditions. In other words, new logging entries under these scenarios should be judged with regard to the degree to which they likely prevent or retard ongoing natural recovery processes.

3) *Variability of response; mean response metrics can obscure biological harms.* Another key assumption concerns the consistency or prevalence of the expected fish response, given that responses are affected by a host of stream-specific and sitespecific factors, both natural and man-caused. We know that fish responses will be variable across time and among streams. However, the biological impact of concern is the likelihood of harm or adverse biological effect of a practice—even if that effect occurs at only a portion of sites and streams, and the null response occurs in many or even most cases. That is, a species can be considered harmed by a practice even if that practice does not cause harm at all times and places it is applied. In part this assumption is tenable because as suggested above, there is little credible evidence that logging in riparian areas can consistently or reliably benefit the species of concern, relative to their response to natural succession in the absence of logging. In simple terms, there is little reason to believe the species of concern here materially and lastingly benefit from water temperature that is increased over natural background (given the current prevailign climate and water temperature regimes in western Oregon), sediment levels increasing over natural background or current condition, or large wood recruitment decreased from potential natural recruitment rates. *It is also very important to recognize that ecological responses characterized as a mean condition across multiple streams or sites — such as presented in DOF's query for expected temperature increases--inherently underestimate adverse impact, because the mean response does not account for the number of streams or sites at which greater than mean impact occurred.* For normally distributed responses, in fact, we can expect that more serious harm than the mean (or more precisely, the median) occurred in about half the cases. That means given a "mean" temperature response of 0.3 degrees C, presumed to meet Oregon's Protecting Cold Waters (PCW)

temperature standard, across the landscape approximately half the cases in fact showed (or can be expected to show) greater temperature increases and therefore numerous violations of the standard occurred. In my view, “estimated mean compliance” is sufficient niether to meet the plain requirement of the standard nor to assure that no biological harm occurs.

4) *Cumulative effects arising from multiple applications are intrinsic.* The implication of the preceding point that reporting mean responses obscures the actual biological impact that is evident in the more severe cases is critical when we recognize the practices in question will be applied over and over again at hundreds or thousands of sites across the landscape. Even if biological harm occurs in only a relatively small percentage of cases, unless it is very transient, these individual, incremental impacts can cumulatively add up to very significant harmful impact to fish populations and species. The actual outcome will depend on the pattern and frequency at which logging occcurs with the specified practices, yet, recognized by ODF, current modeling does not account for overlapping, multiple, or cumulative effects. In my responses I assume the pattern and practice under each scenario involves frequent application over time and space within watersheds, on something that approximates the 30- to 80-year logging rotation commonly seen on private forest lands in western Oregon in recent decades.

5) *Existing conditions are also important.* For example, streams that are presently depleted of large wood may be particularly strongly affected by changes in recruitment of large wood from streamside forests over time. Similarly, in streams that presently carry elevated sediment loads , even small additional sediment loadings can stymie recovery of favorable channel bed and stability conditions. I’m going to assume here that the typical condition for streams on private timberlands in western Oregon is depleted of large wood from past logging or wood removal, impacted by sustained erosion and sediment input from nearby logging and forest roads, recently thermally impacted by some riparian logging under current rules in headwaters or adjacent stream reaches, and has channels, bed and banks simplified by past management practices to the extent that there are relatively few sources of cooler groundwater to buffer fish against additional temperature increase and other impacts.

Brief Responses to specific questions

1. *No-Entry Buffer Prescription:*

*Based on your professional experience, what may be likely fish responses from increasing current riparian management prescriptions from current FPA rules to a no harvest buffer of 50, 70, 80, 90, and 100 feet slope distance? (see No Cut Buffer columns).*

Response: At 50, 70, 80, and 90 feet no-cut, expect a fairly high incidence of harm to fish from shade loss and temperature change, loss of large wood recruitment, ground disturbance near streams and reduced slope stability, root strength, and sediment and nutrient retention capability. The likely magnitude and extent of harm to fish decreases with no-cut width within this range.

At 100 feet slope distance,  harms start to diminish more widely, but still measurable warming in one third or more of streams is likely to harm sensitive species like bull trout and in streams with warmer background temperatures, coho salmon. In steeper slope areas buffer widths exceeding 100-120 feet will measureably reduce slope erosion and near-stream landsliding, as well as improving the mediation of delivery of sediment and wood from up-slope landslides to streams and wetlands.

2. *Variable Retention Prescription (Buffers with limited entry): Based on your professional experience, what may be a likely fish response from increasing current riparian management prescriptions from the current FPA basal area requirement (Small Fish = 40 sq. ft. /Acre) (Medium Fish = 110 to 140 sq. ft. /Acre) to a variable retention buffer with basal area requirements ranging from 200-275 sq. ft. /Acre Small and Medium Fish? (see Variable Retention columns, also please note that the Variable Retention buffers were modeled as a fixed width buffer)*

Response: Clearly all of these prescriptions, in the absence of a no-cut inner zone of 100+ feet to pretect stream shade, will allow warming in many or most streams, and in many cases to a degree that potentially impairs survival and growth of salmon, steelhead and bull trout. Modeling studies of thinning effects also indicate thinning to these basal areas will likely reduce laerge and medium sized wood recruitment to streams below the level that would occur through self-thinning in no-cut riparian areas, harming all fish species in the medium and long term through continued depletion of wood and loss of channel complexity and sediment storage functions. Thinned or partial cut riparian areas are also highly likely to be less effective than uncut riparian areas at filtering or retaining sediment and nutrients derived from adjacent disturbed slopes. Moreover, operations near the stream necessary to log within this zone (assuming standard practices, including ground-based yarding) greatly incvrease the likely extent of ground disturbance near stremas and wetlands,. and generation and delivery of sediment via skid trails and traces in near-stream areas.

3. *Alternate Prescription:*

*a. Based on your professional experience, what may be the likely fish response to a 1-sided harvest following current FPA rules then harvesting the other side 4-5 years later? (See Staggered Harvest columns).*

Response:  This alternative brings a certainty of widespread, both short-and long term harm to fish, stream habitat and water quality.  Ripstream results strongly imply (even of they do not explicitly model this) there is no way to implement a “half-side” a rule without large increases in maximum temperature in most streams; in fact two spikes would occur, one with each entry. More important, this rule would likely eliminate large wood recruitment from both sides of the stream, in both the short and long terms, and would severely decimate sediment and nutrient retention functions of riparian areas, plus allowing logging operations virtually to the streambank, resulting in ground disturbance directly adjacent to channels and surface waters.

b. *Based on your professional experience, what may be the likely fish response to a variable width buffer based on stream azimuth? (see South-sided buffer columns) For example, a stream flowing east / west may receive a buffer that is wider on the south side of the stream and a narrower buffer on the north side of the stream?*

Response: I believe a close examination of RipStream data and results implies, if not specifically demonstrates, that substantial and harmful shade loss and stream temperature change should be expected under an azimuth-depended alternative. More important, this rule would likely eliminate large wood recruitment from both sides of the stream, in both the short and long terms, and would severely decimate sediment and nutrient retention functions of riparian areas, plus allowing logging operations virtually to the streambank, resulting in ground disturbance directly adjacent to channels and surface waters. I would anticipate widespread, frequent, and sustained harm to fish populations from such an alternative.

**Appendix 2**

Additional encumbered acres per Geographic Region, Stream Type, and Ownership

These additional encumbered acres are calculated on a linear interpolation as follows:

[1] Additional acres encumbered = $\Delta A_{Rx,GR,ST,O} = A_{Rx,GR,ST,O} - A_{FPA,GR,ST,O}$

Where A is the acreage specified by subscripts Rx (buffer prescription) or FPA (Forest Practices Act buffers), GR (Geographic Region), ST (Stream Type), and O (Ownership), calculated from:

[2] $$A_{Rx,GR,ST,O} = (W_{Rx,k}/W_{n20'})A_{n20',GR,ST,O}$$

[3] $$A_{FPA,GR,ST,O} = (W_{FPA,k}/W_{n20'})A_{n20',GR,ST,O}$$

Where $W_{Rx,k}$ is the mean horizontal buffer width (feet) of the prescription, $W_{FPA,k}$ is the mean horizontal buffer width (feet) for sites where every tree harvestable under the FPA is removed, $W_{n20'}$ is the horizontal width of the nearest 20-foot increment, and $A_{n20',GR,ST,O}$ is the acreage of buffers of that 20-foot increment based on Geographic Region, Stream Type, and Ownership. $W_{Rx,k}$ and $W_{FPA,k}$ are determined by simulating harvest using data from RipStream vegetation plots. Subscript k indicates widths that may be specific for small and medium streams, depending on the prescription.

There are two methods for determining $A_{n20',GR,ST,O}$. For Type F (fish) streams, these acres were calculated by buffering streams, in increments of 20 feet from 20 to 100 feet, and removing any overlap of buffers. We recently discovered an error in the GIS modeling on Salmon, Steelhead, and Bull Trout (SSBT) streams, and therefore did not have sufficient time to re-run the GIS scripts to determine these acreages. We therefore calculated $A_{n20',GR,ST,O}$ as a linear calculation:

[4] $$A_{n20',GR,ST,O} = 2\ W_{n20'} M_{GR,SSBT,O}(5{,}280 \text{ feet/mile})/[43{,}560 \text{ ft.}^2\text{/acre}]$$

Where $M_{GR,SSBT,O}$ is stream miles per Geographic Region, SSBT Stream Type, and Ownership; and 2 is due to buffers occurring on both sides of streams. This calculation overestimates the acres in the 20-foot increment of buffer since it does not account for overlap of buffers at e.g., stream junctions. However, an analysis of differences between the GIS method and this calculation indicates it overestimates by 1.5% at most, and thus we accept it as sufficiently close for this analysis.

An assumption for these calculations is that RipStream sites are representative of stand conditions and slopes of sites in western Oregon. We made these assumptions since we did not have adequate data specific to the five Geographic Regions considered in this analysis to calculate otherwise.

Land and Timber Values of additional encumbered acres per Prescription, Geographic Region, Stream Type, and Ownership

These values are calculated from:

[5] $$LTV_{Rx,GR,ST,O} = LTV_{GR,O}\Delta A_{Rx,GR,ST,O}$$

Where is the Land and Timber Value of additional encumbered acres per Prescription, Geographic Region, Stream Type, and Ownership (in dollars); $LTV_{GR,O}$ is the Land and Timber Value per Geographic Region and Ownership (in dollars/acre); and $\Delta A_{Rx,GR,ST,O}$ is from equation [1].