Memorandum **July 1, 2020**

To: Hawk Stone, Idaho DEQ

From: Peter Leinenbach, R10USEPA

Subject: Evaluation of a proposed mitigation measure to address excessive shade loss associated with a 60/30 harvest when the preharvest Inner Riparian Zone is below the RS 60 target.

Background

USEPA previously provided comments on Idaho Department of Lands' (IDL) proposed shade rule changes to the Streamside Protection Rule (SPR) of the Idaho Forest Practices Act (IFPA) (September 25, 2013 letter from Dan Opalski), and in particular we expressed our concerns about the non-concurrent application of the Relative Stocking (RS) targets in the inner and the outer harvest zones. In particular, USEPA expressed concern that **low** pre-harvest density conditions within the inner zone would likely result in much higher than expected stream shade losses if harvest activities occurred in the outer zone. Partially in response to this concern, IDL and Idaho Department of Environmental Quality (IDEQ) designed and implemented a "Shade Study" that was intended to evaluate the stream shade response to the IFPA shade rule changes.

USEPA reviewed field data collected as part of the "Shade Study" and found high shade losses were observed at sites exposed to thinning in the Outer Riparian Zone (ORZ) (i.e., 25' to 75' from the stream) when the Inner Riparian Zone (IRZ) had low preharvest Relative Stocking (RS) conditions (i.e., RS < 60) [1]. During a 5/14/2020 phone call with IDEQ, EPA staff shared that these observations confirmed the concerns raised in 2013. In response, Hawk Stone (IDEQ) proposed implementing a "Weighted Average RS 40 correction factor" (hereafter referred to as WA40) to mitigate excessive shade loss at 60/30 harvest sites with low preharvest RS levels in the Inner Riparian Zone (IRZ) (i.e., 0'-25' from high water mark). This memorandum presents preliminary modeling results intended to evaluate the proposed WA40 mitigation measure. Additionally, preliminary modeling was conducted to evaluate if WA50 could provide additional benefit over WA40 as a mitigation measure to compensate for low pre-harvest RS levels in the IRZ.

Proposed Weighted Average Correction Factors (WA40 and WA50)

The correction factors would only apply to 60/30 harvest sites when preharvest RS is below the RS 60 target for the IRZ. In these situations, additional vegetation will be left within the ORZ to maintain a weighted average condition across the entire riparian zone (i.e., between 0' and 75' from the stream). It is important to note that the application of the 60/30 harvest results in a weighted average RS of 40[2]. Therefore, the WA40 factor would result in an amount of vegetation within the riparian zone that is mathematically equal to a fully implemented 60/30 harvest. However, the trees would be distributed differently since there are fewer trees in the IRZ prior to harvest. Finally, the WA50 scenario would result in a weighted average RS condition of 50 within the 0ft to 75ft zone.

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[1] 4/8/2020 USEPA Memorandum **-** Excessive stream shade loss measured at Shade Study sites with pre-harvest tree densities in the inner riparian zone below IFPA shade rule targeted condition.

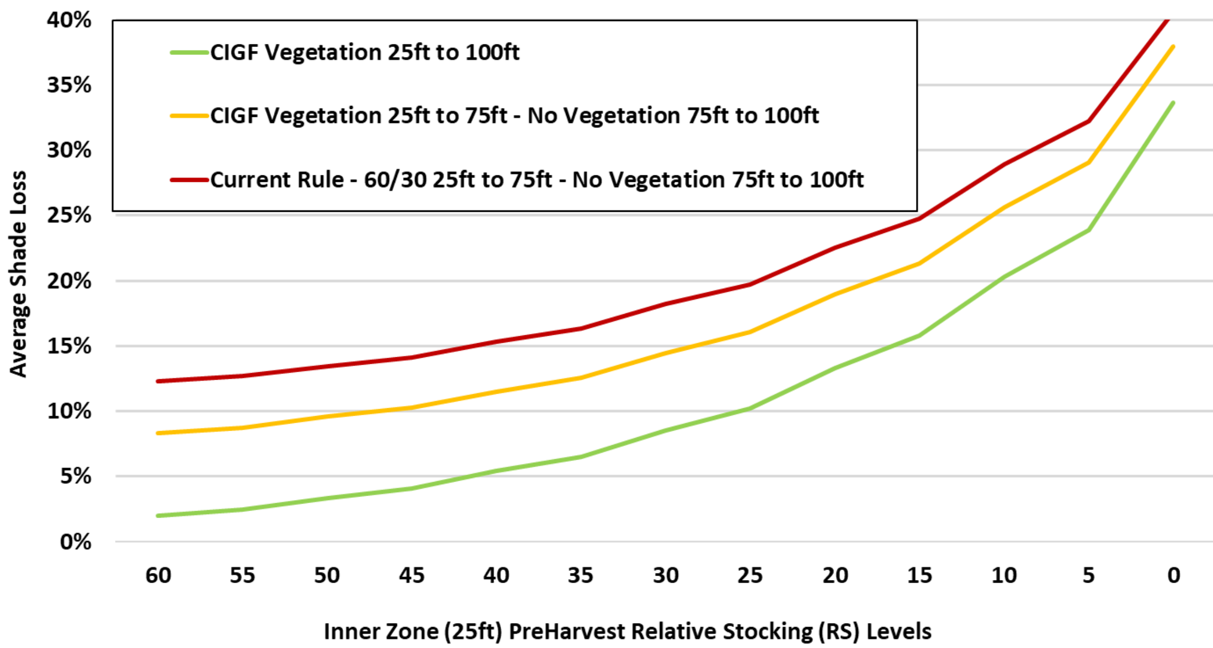
[2] ((25ft/75ft)*RS60)+((50ft/75ft)*RS30) = RS40

Methods and Results

The "Shade.xls" model[3] was used to evaluate the proposed WA40 and WA50 correction factors, while utilizing all methods highlighted in two USEPA memorandums previously presented to IDL/IDEQ during the 2014 SPR process[4]. Details of the modeling assessment used in this effort are presented in Appendix A of this memorandum.

Harvest activities associated with IFPA riparian management can impact stream shade conditions in three distinct ways: 1) removal of vegetation outside of 75' from the streams edge; 2) thinning within the IRZ; and 3) thinning within the ORZ (see **Figure A-1 in Appendix A**). For example, thinning the IRZ to RS 60 results in a 2% shade loss (i.e., the difference between the green line and zero in **Figure 1**). The current rule also allows removing vegetation outside of 75ft from the stream and was shown to result in an additional 6% shade loss (i.e., the difference between the orange and green lines in **Figure 1**). In addition, thinning to a RS 30 in the ORZ was shown to result in an additional 4% shade loss within this 60/30 harvest stand (i.e. the difference between orange and red lines in **Figure 1**). Finally, this figure shows that the relative amount of shade loss increases at lower IRZ RS levels.

Figure 1. Average[5] Stream Shade Loss Resulting from the Application of the Current 60/30 Rule at Riparian Stands[6] with Low Preharvest Relative Stocking (RS) Levels in the Inner Riparian Zone (IRZ).



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[3] This is the same shade model used by an IDL contractor (i.e., Mark Teply) and USEPA (i.e., Peter Leinenbach) to develop harvest targets used in support of the 2014 IFPA rule change effort.

[4] 4/24/2012 USEPA Memorandum "Evaluation of shade modeling in the Cramer Fish Sciences report, and potential solutions." and 3/13/2013 USEPA Memorandum "Shade modeling of riparian management scenarios proposed for CGIF stands". Excerpts from the 3/13/2013 memorandum are presented in **Appendix A** of this memorandum.

[5] The "average" condition is the average of 36 stream modeling scenarios: 1) Three stream aspect conditions (i.e., N/S. NE/SW, and E/W), 2) four CIGF vegetation conditions and 3) three channel widths - 10ft, 20ft and 30ft.

[6] "CIGF Vegetation" is the theoretical maxima derived from IDL CFI plots for the Central Idaho Grand Fir (CIGF) and was used as the basis for the initial riparian pre-harvest conditions (see **Table A3** in Appendix A of this memo).

Modeling showed that the Current Rule (i.e., RS60/30) was able to mitigate[7] shade loss when preharvest IRZ RS conditions were ≥ 55, but shade loss levels associated with this treatment were elevated at lower preharvest IRZ RS levels (see red triangle in **Figure 2**). The WA40 scenario was shown to mitigate shade loss when preharvest IRZ RS conditions were ≥ 45, while the WA50 scenario was shown to mitigate shade loss when preharvest IRZ RS was ≥ 35 (see blue line and blue circle, and black line and black square in **Figure 2**, respectively). The results also indicated that no additional harvest can occur within the ORZ when the preharvest IRZ conditions where ≤ 35. In other words, preharvest IRZ RS conditions below 35 will result in "excessive" shade loss even if the ORZ is maintained at RS 100 conditions (see orange box in **Figure 2**). These findings are summarized in **Table 1**.

Figure 2. Average Stream Shade Loss Resulting from Various WA40 Riparian Management Scenarios at Riparian Stands with Low Preharvest Relative Stocking (RS) Levels in the Inner Riparian Zone (IRZ).

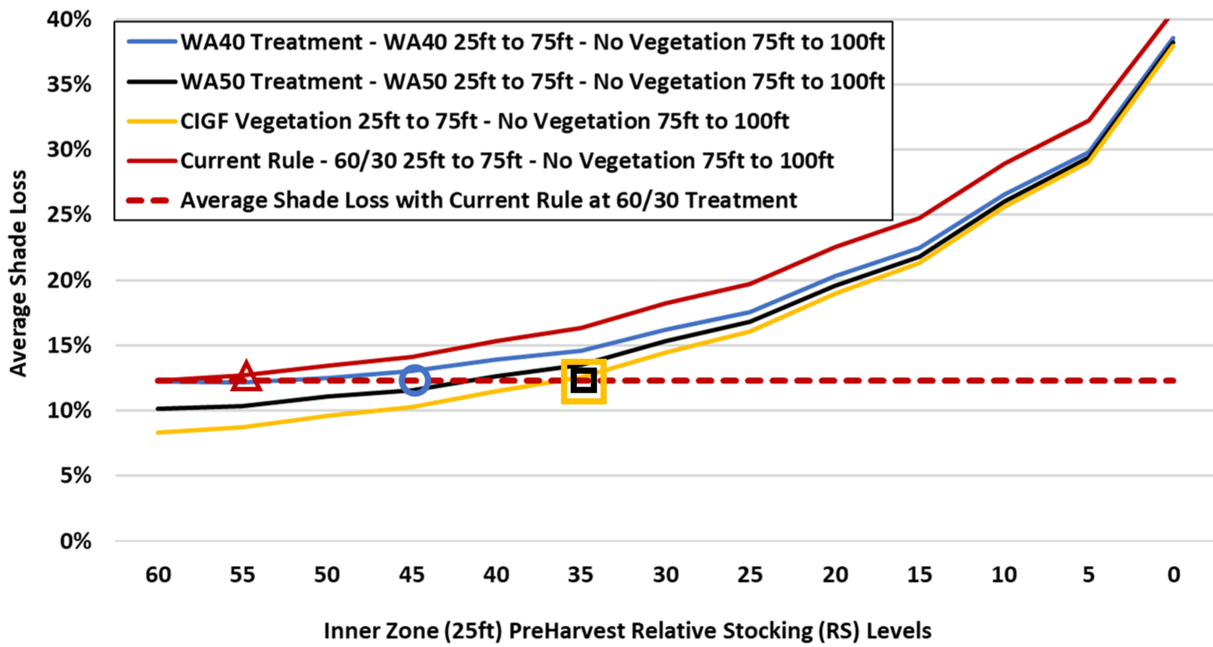

Table 1. Estimated Outer Riparian Zone (ORZ) RS Targets at Various Preharvest Inner Riparian Zone (IRZ) Conditions

IRZ (0ft to 25ft) Preharvest RS	ORZ (25ft to 75ft) RS Target
Between RS 60 and RS 55	Original 60/30
Between RS 55 and RS 45	Weighted Average 40 (WA40)
Between RS 45 and RS 35	Weighted Average 50 (WA50)
Less than RS 35	No Harvest

[7] That is, less than a 1% shade loss above calculated for a 60/30 harvest (Red dashed line in **Figure 2**).

Discussion

Modeling results indicate that no additional shade producing vegetation can be removed from a 60/30 harvest, beyond what is allocated with the 60/30 target[8]. In other words, modeling also showed that preharvest IRZ RS conditions below RS 60 would result in additional "missing" riparian vegetation and therefore could result in "excessive" shade loss resulting from thinning within the ORZ. This result was previously predicted/reported by the modeling support for the 2014 IFPA rule revision. For example, Mark Teply recently articulated during his 1/23/2020 review of the New Shade Rule proposal that it is necessary to maintain inner zone RS levels to ensure limited shade loss occurs with IFPA harvest actions:

> "It will also be essential to assure minimum stocking in the stream-adjacent no-harvest buffer. . . . Both [*60/30 and 60/10*] showed minimum stocking (55% RS) was needed to limit shade loss. This minimum was carried forward in our rule revision analysis [*in support of 2014 IFPA rule changes*]."

Also for example, as highlighted above, USEPA submitted comments to the IFPA Shade Rule committee in 2013 that articulated that this "minimum" preharvest IRZ target was not included in the final rule adopted in 2014 and could likely lead to "excessive" shade loss associated with the application of the IFPA rules.

Treatments tested in this effort evaluated the effects of 1) redistributing vegetation associated with the 60/30 treatment within the IRZ/ORZ (i.e., WA40), and 2) a similar redistribution within the IRZ/ORZ except that the final weighted average RS condition was increased to 50 (i.e., WA50). It is important to point out again that the number of retained trees associated with the WA40 scenario is the same as what would be prescribed in the 60/30 treatment when the IRZ is at RS60. However, it was determined that the WA40 treatment provided higher mitigation against the effects of low preharvest IRZ RS conditions (i.e., comparison between red triangle and blue circle in **Figure 2**). The WA50 treatment resulted in an additional mitigation as a result of leaving additional trees within treatment area (i.e., comparison between blue circle and black box in **Figure 2**). Finally, it is important to point out again that no additional harvest in the ORZ will be possible when the preharvest IRZ RS levels are below 35 (see orange box in **Figure 2**), however the three tested treatment scenarios (i.e., 60/30, WA 40, and WA50) could provide protection against excessive stream shade loss for preharvest IRZ RS conditions ≥ 35 (see **Table 1**).

Finally, this modeling effort, along with the original modeling effort used to support the IFPA rule revision in 2014, assumed that the vegetation within each of the riparian management zones (i.e., IRZ/ORZ) was evenly distributed throughout the respective zone[9]. As a result, presented results for both modeling efforts will less likely represent expected conditions if this harvest assumption is not implemented at the treatment site.

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[8] Total shade loss associated with the 60/30 harvest presented in **Figure 1** corresponds to findings reported to IFPA members during previous shade rule modeling efforts in 2013 (see **Scenario C-3** in **Tables A1 and A2** in **Appendix A** of the memorandum). Although shade loss reported for the 60/30 scenario in **Figure 1** is over the 10% threshold, it was determined in 2013 to be within the uncertainty/variability associated with the application of the shade model and therefore these results were considered to represent similar findings as developed by Mark Teply during the 2012 IFPA shade modeling work.

[9] For example, tree distribution within the ORZ for a 60/30 treatment assumes that the trees will be evenly distributed throughout the 25ft to 75ft zone and NOT packed within a narrow portion (i.e., 55ft to 75ft) of the ORZ.

Appendix A – Excerpts From 3/13/13 Memo to IDL/IDEQ on Shade Modeling for the IFPA Rule

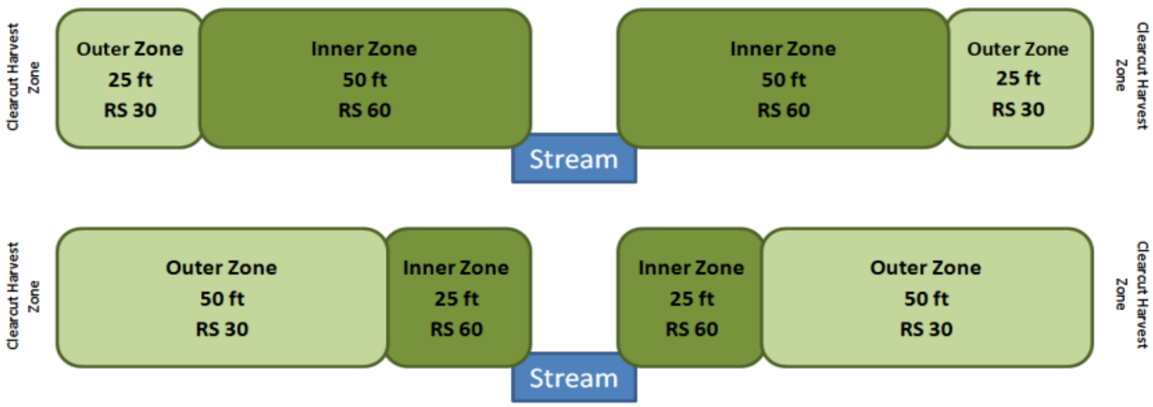
Summary

The shade modeling effort presented in this memorandum evaluated the potential shade loss associated with proposed riparian management scenarios reported to the Idaho Forest Protection Act (IFPA) shade rule subcommittee[10]. Specifically, riparian management scenarios proposed to the subcommittee consisted of a combination of three different forest management components:

1) clearcut removal of all trees located outside of the inner and outer riparian buffer zone;
2) variable riparian thinning levels within a variable **inner** riparian buffer zone width[11]; and
3) variable riparian thinning levels within a variable **outer** riparian buffer zone width[12] (**Figure A1**).

It is important to note that harvest actions within each zone will influence the potential shade production associated within the other buffer zones. This interaction will be described in this memorandum.

Figure A1. Examples of possible harvest buffer configurations.



Results of this analysis for CIGF forests stands are presented in **Table A1** and values in this table are expressed as the average shade loss associated with harvest along 10ft, 20ft, and 30ft wide stream channels.

It is important to point out that there was a good correspondence in predicted shade loss between the two modeling efforts (**Table A2**). However, the predicted shade loss associated with this effort is slightly higher for most of the compared scenarios. This result is expected because this new modeling effort incorporated several solutions outlined in the USEPA letter to the IFPA shade rule sub-committee in April 2012, as presented in the following pages.

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[10] Memorandum titled "Using Stream Shade and Large Wood Recruitment Simulation Models to Inform Forest Practices Regulations in Idaho", by Mark Teply, Cramer Fish Sciences, January 2012.
[11] Inner riparian zone refers to the riparian zone located between the stream and the outer riparian zone.
[12] Outer riparian zone refers to the riparian zone located between the inner riparian zone and the clearcut zone.

Appendix A – Excerpts From 3/13/13 Memo Continued

Table A1. Modeled shade loss associated with various riparian buffer configurations for CIGF stands

Scenario (Two Bank Treatments)[13]	Average Shade Loss (Range)[14]	Scenario (Two Bank Treatments)	Average Shade Loss (Range)
A-1 Inner and Outer Zones 75 ft RS 100 Stream	**6** (4 to 8)	C-1 Outer Zone 50 ft RS 60 | Inner Zone 25 ft RS 100 Stream	**7** (5 to 9)
A-2 Inner and Outer Zones 75 ft RS 60 Stream	**9** (7 to 11)	C-2 Outer Zone 50 ft RS 30 | Inner Zone 25 ft RS 100 Stream	**11** (8 to 14)
A-3 Inner and Outer Zones 75 ft RS 30 Stream	**17** (13 to 22)	C-3 Outer Zone 50 ft RS 30 | Inner Zone 25 ft RS 60 Stream	**12** (9 to 16)
B-1 Inner and Outer Zones 50 ft RS 100 Stream	**14** (10 to 17)	C-4 Outer Zone 50 ft RS 10 | Inner Zone 25 ft RS 60 Stream	**18** (14 to 24)
B-2 Outer Zone 25 ft RS 60 | Inner Zone 25 ft RS 100 Stream	**14** (11 to 19)	D-1 Outer Zone 25 ft RS 60 | Inner Zone 50 ft RS 100 Stream	**6** (4 to 8)
B-3 Outer Zone 25 ft RS 30 | Inner Zone 25 ft RS 100 Stream	**16** (12 to 22)	D-2 Outer Zone 25 ft RS 30 | Inner Zone 50 ft RS 100 Stream	**8** (6 to 10)
B-4 Outer Zone 25 ft RS 30 | Inner Zone 25 ft RS 60 Stream	**18** (14 to 24)	D-3 Outer Zone 25 ft RS 30 | Inner Zone 50 ft RS 60 Stream	**10** (8 to 13)
B-5 Outer Zone 25 ft RS 10 | Inner Zone 25 ft RS 60 Stream	**22** (16 to 28)	D-4 Outer Zone 25 ft RS 10 | Inner Zone 50 ft RS 60 Stream	**12** (9 to 16)

[13] Two bank treatments with clearcut harvest located outside of the outer buffer zone.
[14] Average of 10ft, 20ft, and 30ft stream channels, averaged for the four CIGF forest groups listed in Table 3. "Range" is the minimum and maximum shade loss associated with the 10ft, 20ft, and 30ft stream channels for the four forest groups listed in Table 3.

Appendix A – Excerpts From 3/13/13 Memo Continued

Table A2. Comparison of predicted shade loss associated with riparian management for CIGF stands presented in the CFS modeling effort and this current effort.

Scenario (Two Bank Treatments)	Results reported in Current Modeling Effort Average Shade Loss (Range)	Results reported in CFS Modeling Effort[15] Average Shade Loss
A-1: Inner and Outer Zones 75 ft RS 100; Stream	**6** (4 to 8)	**4**
A-2: Inner and Outer Zones 75 ft RS 60; Stream	**9** (7 to 11)	**10**
A-3: Inner and Outer Zones 75 ft RS 30; Stream	**17** (13 to 22)	**30**
B-1: Inner and Outer Zones 50 ft RS 100; Stream	**14** (10 to 17)	**12**
B-2: Outer Zone 25 ft RS 60; Inner Zone 25 ft RS 100; Stream	**14** (11 to 19)	**13**
B-3: Outer Zone 25 ft RS 30; Inner Zone 25 ft RS 100; Stream	**16** (12 to 22)	**16**
C-1: Outer Zone 50 ft RS 60; Inner Zone 25 ft RS 100; Stream	**7** (5 to 9)	**5**
C-2: Outer Zone 50 ft RS 30; Inner Zone 25 ft RS 100; Stream	**11** (8 to 14)	**8**
C-3: Outer Zone 50 ft RS 30; Inner Zone 25 ft RS 60; Stream	**12** (9 to 16)	**10**

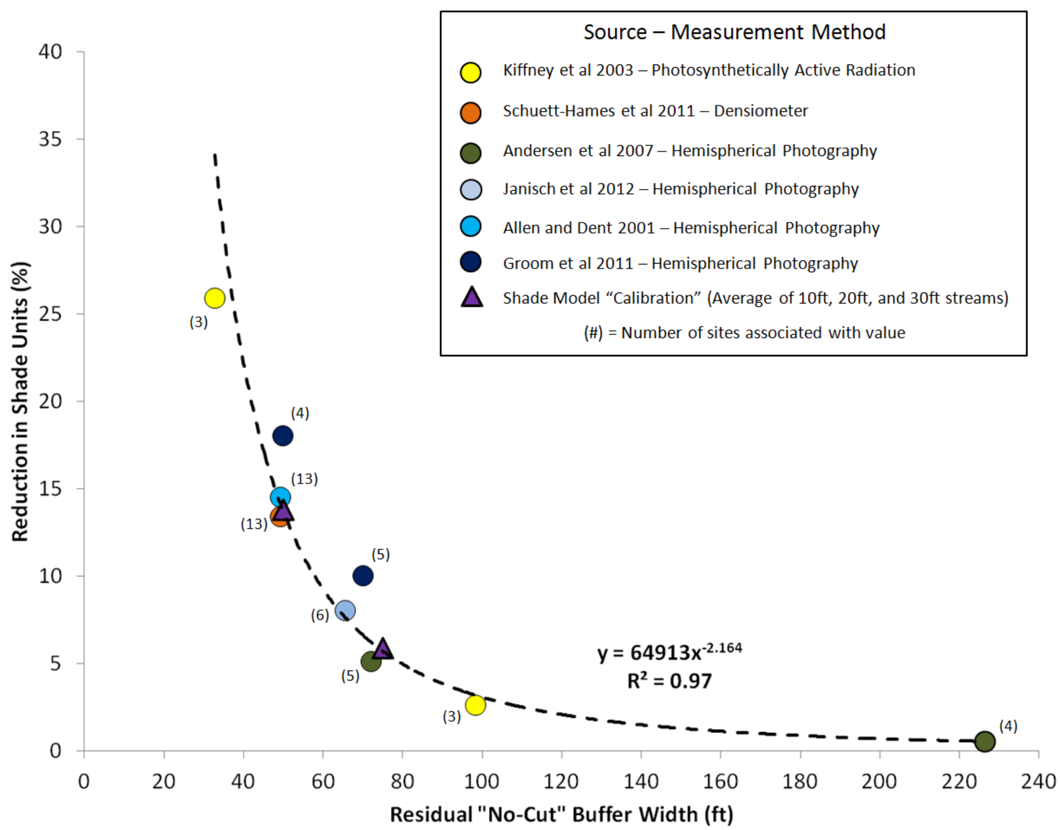
[15] Values obtained from Teply and Ceder (2012) and "Shade Rule Handout-FRAAC Mtg-2-4-13.pdf"

Appendix A – Excerpts From 3/13/13 Memo Continued

Methods

The "shade.xls" modeling tool, developed by the Washington Department of Ecology[16], was used to develop estimates of shade loss associated with riparian harvest along CIGF forest stands. Specifically, the Chen et al (1998) shade algorithms in the "shade.xls" shade modeling tool were used to estimate shade conditions. An attempt was made to use similar modeling parameters used during the "January 2012 CFS Report" modeling effort[17]. Other modeling details include: 1) utilized the "delta Chen" modeling procedure (as described in the 4/2012 USEPA letter to the IFPA shade subcommittee), 2) utilized the "Riparian Extinction" coefficient; 3) utilized the Bras solar radiation model; and 4) calibrated (i.e., parameter estimation) the shadow density factor for the additivity of overlapping buffers ("shddenadd") to 0.4. That is, this "shddenadd" value produced the best fit between modeled and measured shade loss associated with a narrowing of the buffer width (**Figure A2**).

Figure A2. Observed shade loss in field studies and modeled shade loss[18]
[Model results are purple triangles represent results associated with scenarios A-1 and B-1 in Table A1]



[16] This modeling tool can be downloaded from - http://www.ecy.wa.gov/programs/eap/models.html.
[17] i.e., 8/1 modeling date, modeling location was central Idaho, and used Central Idaho Grand Fir summary stand data which was obtained from Mark Teply at Cramer Fish Sciences.
[18] "Residual "No-Cut" Buffer Width" refers to the un-cut riparian forest zone located between the stream and the outer clearcut harvest zone.

Appendix A – Excerpts From 3/13/13 Memo Continued

Modeling Assumptions

It was assumed in the modeling effort that all of the trees were removed within the designated "clearcut" harvest zone. Also, it was assumed that thinning activities uniformly removed trees among the different size classes within the stand (i.e., thinning activities did not affect the average height of the stand). Finally, it was assumed that thinning activities did have an effect on the stand canopy cover (canopy closure) conditions. This last factor was explicitly estimated during modeling efforts.

Initial Riparian Stand Conditions Used in the Model (i.e., Pre-Harvest Conditions)

The theoretical maxima derived from IDL CFI[19] plots for the Central Idaho Grand Fir (CIGF) was used as the basis for the initial riparian pre-harvest conditions. Of particular note was that the theoretical maximum Relative Density (RDsum) for CIGF stands was designated as 70.6. Each of the four reported CIGF forest types were evaluated during this analysis (**Table A3**).

Table A3. Central Idaho Grand Fir (CIGF) Vegetation Characteristics

CIGF Category Name	Average Height (m)	Average Canopy Cover (%)
Group 1 - Stands with Relative Stocking > 55 & Avg Ht > 22.5m	28.2 (93 ft)	57
Group 2 - Stands with Relative Stocking > 55 & Avg Ht < 22.5m	18.5 (61ft)	72
Group 3 - Stands with Relative Stocking > 55 & Avg Ht > 22.5 & Max CC	26.7 (88ft)	74
Group 4 - Stands with Relative Stocking > 55 & Max Avg Ht	35.8 (118 ft)	64

Evaluation of Proposed Buffer Width Reduction on Stream Shade Conditions

This section of the document presents the methods used to evaluate the effects of tree removal ("clearcut") in the outer section of the riparian buffer (see **Figure A1**). This effect was addressed in the model in two ways.

The first method (and most the direct) was addressed through directly reducing the width of the riparian **buffer width** in the model. For example, if the residual buffer[20] width was 75ft, then the model input parameter for the buffer width was set at 75 feet.

The second method was developed through evaluating the effects of the harvest management on the **canopy cover** associated with the residual buffer. A detailed description of the methods used to estimate this parameter is presented in the following 6 pages[21].

[19] Idaho Department of Lands Continuous Forest Inventory plots
[20] Residual buffer is defined as the riparian buffer which is located between the stream and the clearcut harvest
[21] This method was also described in detail in the 4/2012 USEPA letter to the IFPA shade sub-committee.

Appendix A – Excerpts From 3/13/13 Memo Continued

Background Information for the Evaluation of Proposed Buffer Width Reduction

The canopy density of the stand determines the rate at which the direct beam solar radiation is blocked, with greater levels of blockage occurring with higher canopy densities. Accordingly, the canopy density of the riparian vegetation stand directly affects stream shade. Canopy density is accounted for in the Chen shade model through an extinction coefficient (λ):

$$\lambda = \frac{\ln(1 - canopy\ density)}{Vegetation\ Height}$$

(Equation 16a in Chen et al 1998)

The extinction coefficient (λ) is then used to estimate the effective shade density (SHDDEN):

$$SHDDEN = 1 - \exp(-\lambda * The\ pathlength\ of\ the\ sunlight\ through\ the\ riparian\ stand)$$

(Equation 16f in Chen et al 1998)

It is important to point out that the canopy density parameter in the equation above **is not** associated with the vertical projection of the canopy onto a horizontal surface[22] (**Figure A3**). Rather, it is an estimate of the canopy measured at the angle above the horizon at which direct-beam solar radiation passes through the riparian canopy (**Figure A4**).

Accordingly, the stream shade response resulting from a narrow riparian buffer will be underestimated if the "canopy cover" definition of canopy density is used as an input parameter for calculating the extinction coefficient (λ) in the Chen model. For example, the bottom image associated with **Figure A3** illustrates that it is possible for the vertical projection of "canopy cover" to not change with a narrowing of the riparian buffer width. Alternatively, the bottom image associated with **Figure A4** shows that the canopy density is directly influence by the width of the riparian buffer when measured from an angle above the horizon. In other words, as the buffer width decreases, horizontal canopy density also decreases, ultimately resulting in lower stream shade conditions. In summary, narrowing the riparian buffer decreases the density of the riparian canopy through which solar radiation passes (i.e., canopy density), which subsequently reduces stream shade conditions.

Accordingly, the canopy density input parameter used to calculate the riparian extinction coefficient (λ) must account for this effect for the model to accurately simulate stream shade response associated with a narrowing of the riparian buffer.

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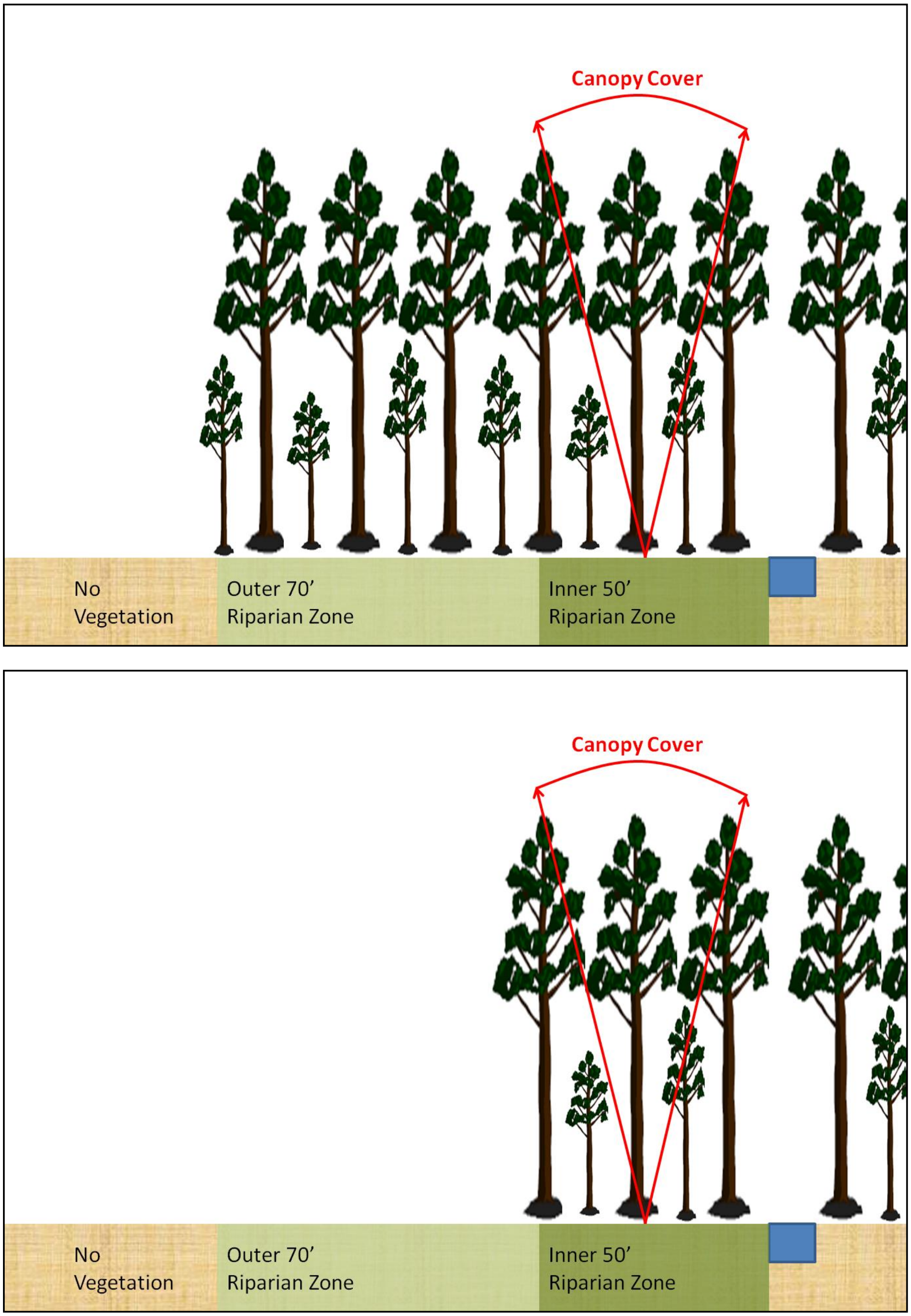
[22] This vertical measure of canopy density is often referred to as "canopy cover" and is measured with devices such as a spherical densitometer.

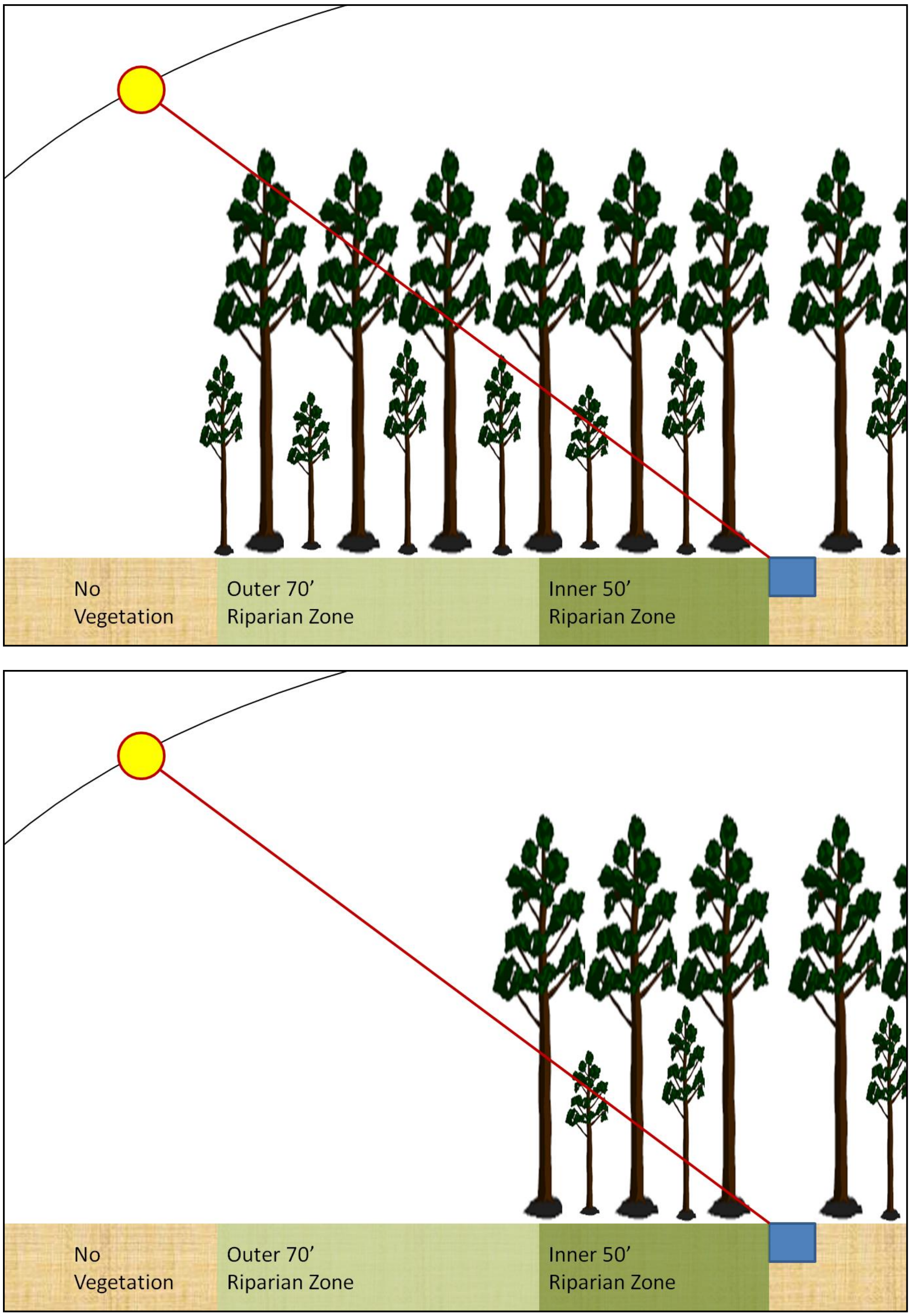
Appendix A – Excerpts From 3/13/13 Memo Continued

Figure A3. Illustration of the relationship between vertical canopy density (canopy cover) and buffer width



Appendix A – Excerpts From 3/13/13 Memo Continued

Figure A4. Illustration of the relationship between horizontal canopy density and buffer width



Appendix A – Excerpts From 3/13/13 Memo Continued

Estimating the effect of a narrowing of the riparian buffer width on canopy cover conditions

Beschta et al (1987) reported that the effectiveness of a buffer strip in providing stream shade can be determined by measuring the angular canopy density (ACD). ACD evaluates the horizontal plane of canopy density for the portions of the riparian stand which provide shade during the mid part of the day (usually between 10 am and 2 pm) (**Figure A5**). **Figure A6** illustrates the relationship between ACD and the riparian buffer width (Brazier and Brown, 1973). While it is theoretically possible for natural forest vegetation to have ACDs of 100%, indicating complete shading from incoming solar radiation, the ACD of mature undisturbed stands generally falls between 75 and 90% (Brazier and Brown 1973, Steinblums et al., 1984, Erman et al., 1977). In addition, ACD increases become negligible at some buffer strip width as a result of the "tree behind a tree" phenomenon, and/or the vegetation in distant portions of the riparian stand not being tall enough to cast a shadow over the stream surface.

The trend line presented in **Figure A6** can be used as a tool to evaluate the influence that riparian buffer width reductions have on the riparian canopy density (**Table A4**). Specifically, the estimated reduction in canopy density presented in this table can be used as a weighting factor to evaluate the effects of narrowing of the riparian buffer width on the canopy cover conditions of the residual buffer (**Table A5**). For example, narrowing of the riparian buffer to 75ft will result in a 5% loss of the "effective" canopy cover associated with the residual buffer: Using the example in **Table A5**, a 5% reduction in canopy density would result in a 4 unit loss of canopy density within the remaining riparian buffer (i.e., 74% - (0.95*74%) = 70%).

Table A4. Calculated Effect of Buffer Width on Angular Canopy Density

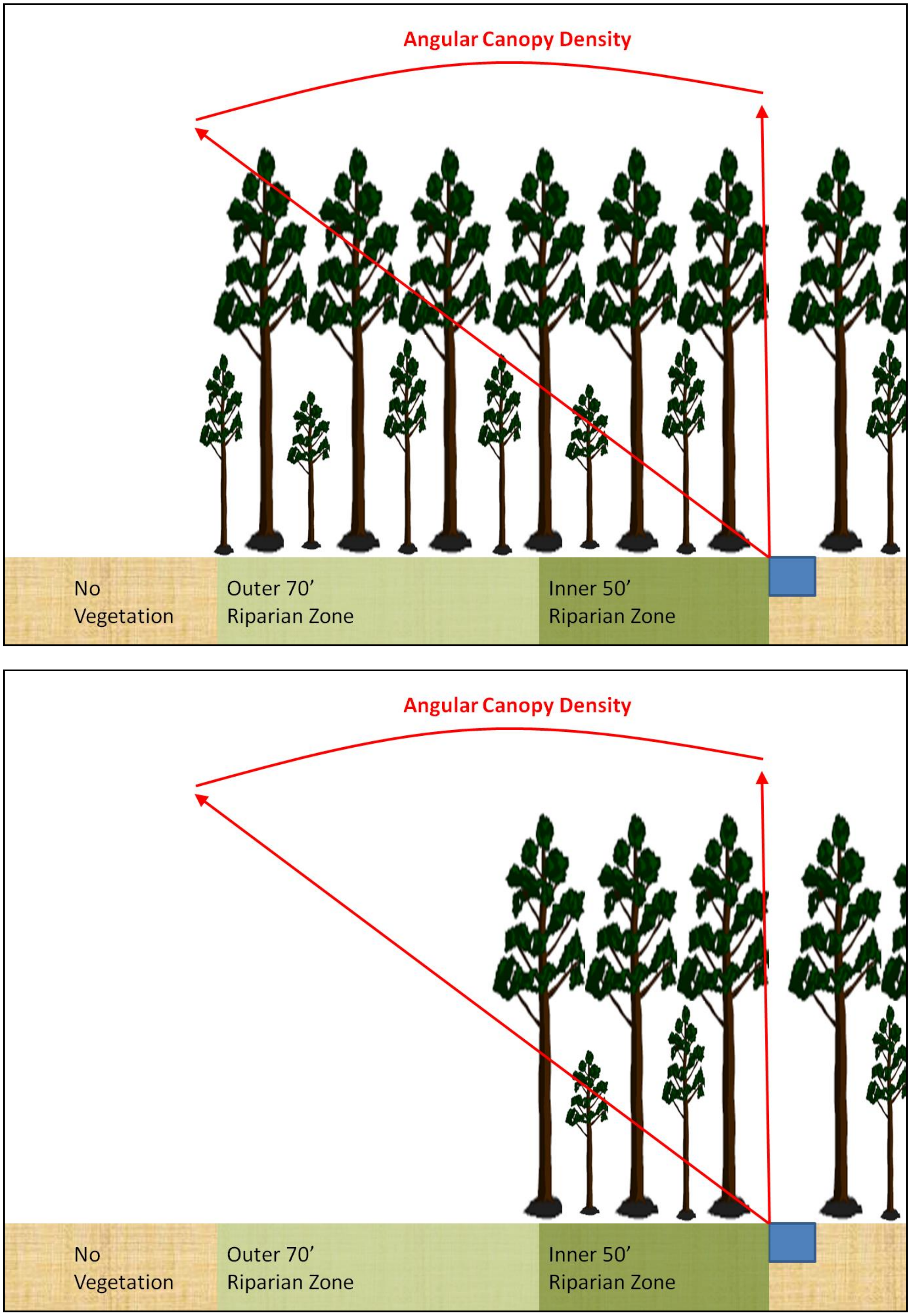
Buffer Strip Width (feet)	Estimated ACD	Percent Reduction from 100' buffer
100 (or 30.5 meters)	77	0%
75 (or 22.9 meters)	73	5%
50 (or 15.2 meters)	67	13%
25 (or 7.6 meters)	57	25%

Table A5. Example of Canopy Density Change for Narrowing Buffer Width Conditions

Buffer Strip Width (feet)	Percent Reduction from 100' buffer	Observed Canopy Cover at a 100' Buffer	Estimated Canopy Density at new buffer width conditions
100 (or 30.5 meters)	0%	74%	74%
75 (or 22.9 meters)	5%	74%	70%
50 (or 15.2 meters)	13%	74%	65%
25 (or 7.6 meters)	25%	74%	55%

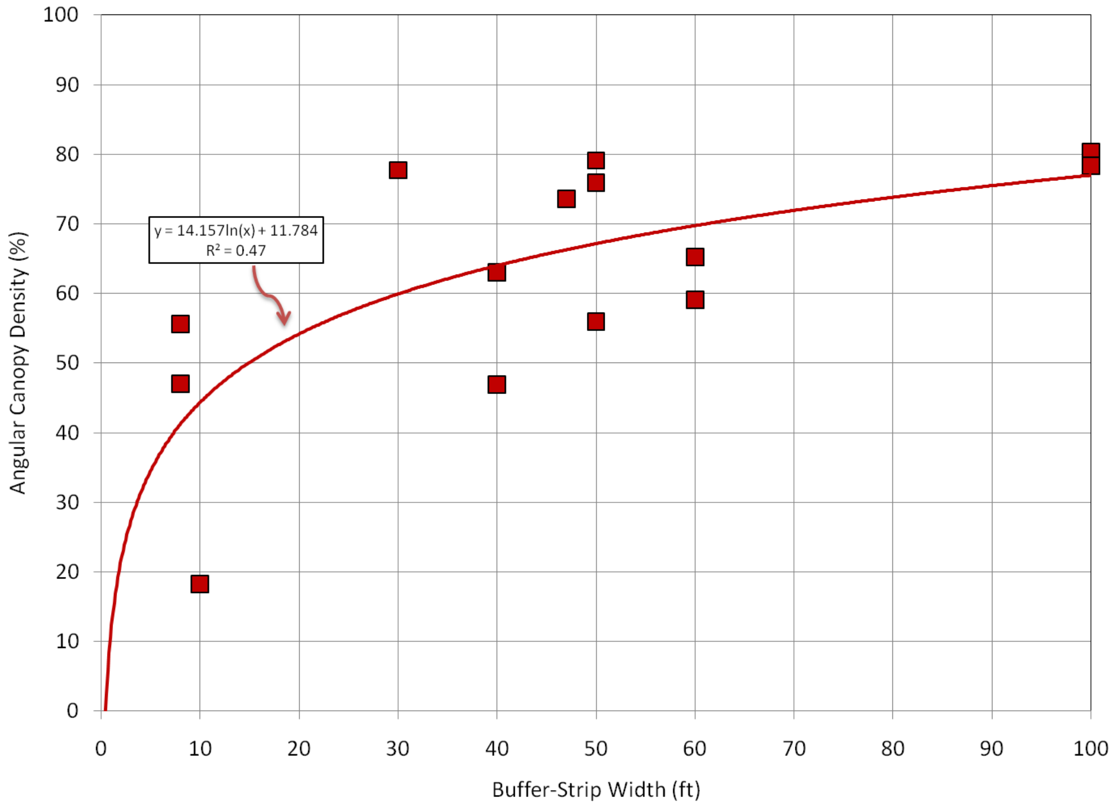
Appendix A – Excerpts From 3/13/13 Memo Continued

Figure A5. Illustration of the relationship between angular canopy density (ACD) and buffer width



Appendix A – Excerpts From 3/13/13 Memo Continued

Figure A6. The relationship between measured Angular Canopy Density (ACD) and buffer strip width (Data from Table 1 in Brazier and Brown 1973).



Evaluation of Proposed Thinning Harvest Activities

The next step evaluates the effect of thinning harvest activities on stream shade conditions.

During past modeling efforts[23], thinning activities within riparian stands are described in terms of Relative Stocking (RS). Available shade models do not directly utilize RS as an input parameter, and therefore this variable needs to be translated into an appropriate model input variable: The three steps outlined below present the methods used to accomplish this task.

Step One – Define RS in terms of RDsum

RS is defined as the percent difference of the observed RDsum at a site from the theoretical maximum RDsum for that stand. Recall that in the case for CIGF, the theoretical maximum RDsum was 70.6, which corresponds with a RS of 100 (i.e., (70.6/70.6)*100 = 100). Accordingly, a RS of 60 for a CIGF stand would be associated with a RDsum of 42 (i.e., 70.6 * 0.6 = 42). Similarly, a RS of 30 and 10 would be associated with a RDsum of 21 and 7, respectively (**Table A6**).

[23] 1/2012 and 11/2012 CFS reports to the IFPA shade sub-committee

Appendix A – Excerpts From 3/13/13 Memo Continued

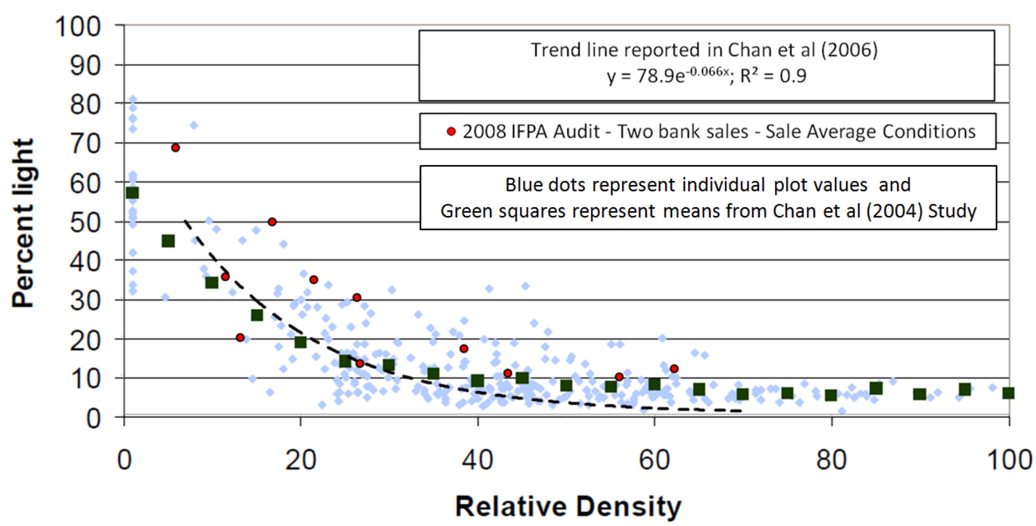
Table A6. Association between RS and RDsum for CIGF stands	
Relative Stocking	Corresponding Relative Density
100	70.6
60	42
30	21
10	7

Step Two – Associate RDsum in terms of stand openness

Field studies have shown that the "openness" of a forest stand generally increases as the stand becomes less dense (**Figure A7**) [24]. In other words, more light penetrates through the stand at lower stocking levels (i.e., RDsum levels). However, this relationship is not linear; little change in skylight occurs with changes in RD within the upper range (i.e., > 50), and large changes of "openness" occurs with changes in RD within the lower range (i.e., < 25)

Proposed thinning activities will reduce the vegetation density within the stand. Therefore, based on the relationship presented in **Figure A7**, thinning activities are anticipated to increase the amount of light transmitted through the thinned stand. For example, the dashed trend line presented in **Figure A7** indicates that stand openness will increase by 4.3% when the RDsum is 42, as compared to RDsum maximum (i.e., 70.6). In other words, thinning a CIGF stand to an RS of 60 will result in a 4.3% loss of canopy cover. Stand "openness" associated with various RS conditions are presented in **Table A7**.

Figure A7. The association between relative density and percent skylight in forest stands.



[24] "Openness" is defined as the amount of light transmitted through the forest stand. "Openness" is the inverse of canopy closure.

Appendix A – Excerpts From 3/13/13 Memo Continued

Table A7. Association between RDsum and increases "openness" of for CIGF stands	
Relative Density	Corresponding Increase in stand "openness"
70.6	0.0%
42	4.3%
21	19.3%
7	49.4%

Step Three – Estimate the canopy cover associated with a RS level

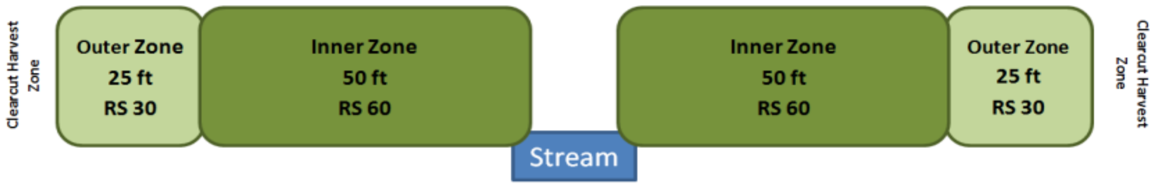
The canopy cover condition associated with a particular RS level can be estimated using the information presented in the previous two steps. For example, it was estimated that a RS of 60 for the CIGF stand was associated with a RDsum of 42 (Step One – **Table A6**). It was subsequently shown that a RDsum of 42 corresponds with a 4.3% loss of canopy cover (Step Two – **Table A7**). Thus, if the initial pre-harvest canopy cover condition was 72% (i.e., Group 2 in **Table A3**), the canopy cover condition following a targeted RS 60 stand thinning would be 68.9% (i.e., 72 – (72*0.043) = 68.9).

Appendix A – Excerpts From 3/13/13 Memo Continued

Evaluation of Scenarios Which Both Buffer Width Reduction and Thinning Harvest Activities Occurred

Many of the proposed harvest activities include both 1) a narrowing of the riparian buffer (i.e., clearcut harvest outside of the inner and the outer riparian buffer), and 2) thinning within the inner and outer riparian buffer zones (**Figure A7**)[25].

Figure A7. An example illustration of a potential riparian harvest scenario with multiple factors



There are several interrelated effects on the potential stream shade production associated with a riparian stand exposed to such a riparian management regime. The steps listed below describe the methods used to evaluate these effects during the shade modeling effort:

- The model input parameter for the buffer width is set at 75ft (i.e., clearcut outside of this zone).

- The model input parameter for the canopy cover condition within the **outer buffer zone** reflects the influence of two factors.

  1) The <u>first factor</u> is the effects associated with a narrowing of a riparian buffer to 75ft (5% loss of canopy cover - **Table A4**). Thus, if the pre-harvest canopy cover condition was 72% (Group 2 - **Table A3**), then the "effective" canopy cover would be 68.4 (i.e., 72 – (72 * 0.05) = 68.4).

  2) The <u>second factor</u> is associated with thinning within this outer buffer zone: Targeted thinning to a RS of 30 (i.e., 19.3% loss of canopy cover - **Table A7**). Thus, if the "effective" canopy cover condition was 68.4 then the resulting model canopy cover input parameter for the outer buffer zone following both thinning harvest and buffer narrowing would be 55.2 (i.e., 68.4 – (68.4*(0.193)) = 55.2).

- The model input parameter for the canopy cover condition within the **inner buffer zone** reflects the influence of three factors.

  1) Similar to calculations associated with the outer buffer zone, the <u>first factor</u> is associated with a narrowing of the riparian buffer to 75 ft (i.e., 5% loss of canopy cover - **Table A4**). Thus, if the pre-harvest canopy cover condition was 72% (Group 2 - **Table A3**), then the "effective" canopy cover would be 68.4 (i.e., 72 – (72 * 0.05) = 68.4).

  2) The <u>second factor</u> accounts for the affect which thinning activities occurring in the outer buffer zone have on canopy cover conditions within the inner buffer zone. That is, thinning in the outer buffer zone will reduce the "effective" buffer width of the outer buffer zone through tree removal in the outer buffer zone. Specifically, the light transmissivity for the outer buffer

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[25] The riparian harvest scenario depicted in this image is similar to Scenario D-3 in **Table 1**.

zone will increase by 19.3% when the RS is reduced to 30 (**Table A7**). It is proposed that the canopy cover loss associated with this factor is linearly proportional to the canopy cover loss within the outer zone (i.e., 19.3% * 8% = 1.5%)[26]. Thus, if the "effective" canopy cover condition was 68.4, then including the influence of the second factor would result in a new "effective" canopy cover condition of 67.3 (i.e., 68.4 – (68.4*(0.015)) = 67.3).

3) The <u>third factor</u> is associated with thinning within this inner buffer zone: Targeted thinning to a RS of 60 (i.e., 4.3% loss of canopy cover - **Table A7**). Thus, if the "effective" canopy cover condition was 67.3, then the resulting model canopy cover input parameter for the inner buffer zone following 1) thinning harvest in the inner zone, 2) thinning harvest in the outer zone, and 3) buffer narrowing would be 64.4 (i.e., 67.3 – (67.3*(0.043)) = 64.4).

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[26] The estimated canopy cover loss associated with a 50 ft residual buffer is 13% (**Table 4**). This corresponds with an expected loss of 8% of canopy cover conditions within the residual buffer width between 75ft and 50ft (i.e., 13% (expected at 50ft) - 5% (expected at 75ft) = 8%).

Appendix A – Excerpts From 3/13/13 Memo Continued

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