An Overview of the DFC Model and an Analysis of Westside Type F Riparian Prescriptions and Projected Stand Basal Area per Acre

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WASHINGTON STATE DEPARTMENT OF
Natural Resources
Doug Sutherland - Commissioner of Public Lands

Cooperative Monitoring
Evaluation & Research

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Forest Practices Adaptive Management Program

The Washington Forest Practices Board (FPB) has adopted an adaptive management program in concurrence with the Forests and Fish Report (FFR) and subsequent legislation. The purpose of this program is to:

> Provide science-based recommendations and technical information to assist the board in determining if and when it is necessary or advisable to adjust rules and guidance for aquatic resources to achieve resource goals and objectives. (Forest Practices Rules, WAC 222-12-045)

To provide the science needed to support adaptive management, the FPB made the Cooperative Monitoring, Evaluation and Research Committee (CMER) a participant in the program. The FPB empowered CMER to conduct research, effectiveness monitoring, and validation monitoring in accordance with guidelines recommended in the FFR.

CMER Exploratory Report

This exploratory report was prepared for the Cooperative Monitoring, Evaluation and Research Committee (CMER) and contains scientific information, which was intended to improve or focus the science underlying the Forest and Fish Adaptive Management program. The project is part of the Riparian Monitoring Program, and was conducted under the oversight of the Riparian Scientific Advisory Group.

Disclaimer

This document was reviewed by CMER but was not assessed through the Adaptive Management Program's independent scientific peer review process. CMER has approved this document for distribution as an official document, and is in consensus on the scientific merit of the document. However, any conclusions, interpretations, or recommendations contained within this document are those of the authors and may not reflect the views of all CMER members.

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ABSTRACT

New Forest Practices Rules (Rules) that took effect in July, 2001, introduced a Desired Future Condition (DFC) concept for managing riparian forests. The intent of rules (WAC 222-30-021) was to allow for timber harvest from riparian forests while protecting and improving water quality and habitat for fish and selected amphibians (WDNR 1999). DFC rules use a systematic approach for making site-specific prescriptions that consider site attributes and current and projected future stand conditions. For riparian forests along Type F streams in western Washington, timber harvest is allowed only in riparian stands that are projected, using the DFC Model, a stand growth Model developed to implement Rules, to "meet" a rule-prescribed target condition when stands are mature. For DFC rules, "mature" stands are 140-yrs old, and the target condition stand growth is measured against is basal area per acre (bapa). For riparian stands that meet DFC, two riparian prescriptions allowing for some timber harvest were developed; thinning from below (Option 1) and leave trees closest to the water (Option 2). The DFC Model determines if stands meet requirements to be eligible for timber harvest and provides stand specific prescription details and projected stand age 140 bapa for each stand modeled.

There was little information available to determine appropriate target bapa for Rules, thus validating these was a high priority for the Adaptive Management program that was re-emphasized and enhanced as part of new Rules. It was commonly assumed that the criterion that determined stand eligibility in Rules would also be the primary constraint to timber harvest and that managing by DFC Rules would put stands on a trajectory towards the DFC Target bapa at stand age 140. A preliminary analysis of DFC Model outputs, however, indicated that other rule constraints were in fact more important in limiting timber harvest and that stand age 140 bapa usually exceeded the Rule target bapa because of other constraints to timber harvest. This study is a structured follow-up to that preliminary analysis. The objectives are to: 1) determine the rule component that most constrains timber harvest, and 2) quantify stand age 140 bapa projected for each sample stand for both "active management" riparian prescriptions and a no-cut treatment.

DFC Model outputs were analyzed using data from 150 randomly selected, approved Forest Practices Applications (FPAs) in which timber harvest was proposed along west-side Type F streams. These analyses showed that for Option 1, bapa was the primary constraint to timber harvest on only 7 FPAs (4.6%) while the required 57 inner zone leave tpa was the primary constraint to timber harvest on 142 FPAs (94.6%). One FPA (0.7%) was constrained equally by bapa and the required number of leave trees. For Option 2, bapa constrained timber harvest on 40 FPAs (37%), while the required minimum no cut floor widths constrained timber harvest on 68 FPAs (63%).

Stand age 140 bapa (average and standard deviation) for each prescription, for all FPAs, across all Site Classes, stream sizes and other possible covariates was: no-cut, 364.1 ± 43.7, Option 1, 335.5 ± 45.9, and Option 2, 301.1 ± 40.8 with the trees in the outer part of the inner zone excluded and 333.0 ± 31.4 with the trees in the outer part of the inner zone included.

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ACKNOWLEDGEMENTS
I would like to thank the following individuals and organizations for their contribution to this project: Bonnie Thompson, Department of Natural Resources, entered data from Forest Practices Applications into DFC Model compatible files. Chris Mendoza (Aquatic Resource Consultants) and Pete Heide (Washington Forest Protection Association) engaged often and provided many valuable suggestions that added to the content, context and utility of this report. Other CMER reviewers also provided many useful comments ranging from minor editorial to substantive and involved. These reviewers were: Dick Miller (Washington Farm Forestry Association), Todd Baldwin (Kalispel Tribe of Indians), Ash Roorbach (CMER staff), Jim Van Der Ploeg (Hancock Forest Management), Jeff Madsen (Timber Industry), Lyle Almond (Makah Tribe). Jeff Welty (Weyerhaeuser) provided valuable assistance in understanding the origins, design and outputs of the DFC Model in addition to providing direct contributions to analyses of trees not accounted for (by rule design) in the DFC Model. Cynthia Piez (University of Idaho, Department of Mathematics) reviewed equations used in spreadsheet analyses to ensure their accuracy. Darin Cramer (AMPA) and Dawn Hitchens (Contact Specialist), both with the DNR, helped mentor me in the world of consulting and keep the project moving forward with attention to both CMER process and scientific rigor. Much of this work was done while I was an employee of the Northwest Indian Fisheries Commission and with the Upper Columbia United Tribes and I appreciate the time both entities allowed me to develop this work.

INTRODUCTION

REPORT TYPE AND CONTEXT

1. Report Type

The Forest Practices Application (FPA) Desktop Analysis is a model-based examination of "standard-prescription"[1] rules for riparian forests along Type F streams in western Washington (WAC 222-30-021). There is no field component to this study.

2. Purpose

One of the purposes of the FPA Desktop Analysis is to provide quantitative information to Forest and Fish Report (FFR) / Timber Fish and Wildlife (TFW) stakeholders on the effect riparian rule prescription components have in determining Desired Future Condition (DFC) Model[2] generated, harvest-age prescription details and stand age 140 basal area per acre (bapa) projected values. The other purpose is to identify assumptions embedded in the DFC Model many of which have not yet been validated, and describe what effect they may have that should be considered to interpret and understand outcomes of this report.

3. CMER Context

The FPA Desktop Analysis project was implemented at the request of FFR Policy[3] (Policy). Without presuming to speak for them, Policy apparently requested this project because results from a stakeholder[4] initiated DFC Model analysis of FPAs appeared relevant to Policy discussion and potential decision-making on DFC rules. No formal study plan was prepared for the FPA Desktop Analysis, nor were Scientific Advisory Groups (SAGs) or the Cooperative Monitoring, Evaluation and Research (CMER) committee consulted to provide input into the study design[5]. There has been Riparian Scientific Advisory Group (RSAG) and CMER review of report drafts[6], but no Independent Scientific Peer Review (ISPR) review of either a study plan or a completed report. CMER and/or Policy could request ISPR review of both methodology and results among other decisions they will make in regards to this report.

4. Related Reports

The reports described in this section are part of a "package" of reports that began with the FPA Desktop Analysis. The follow-on reports provide either important supporting analyses that provide context to the results of the FPA Desktop Analysis ("Field Check"

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[1] For this paper, standard prescriptions are those contained in WAC 222-30-021(1)(ii) and include: a) no-cut, b) thinning from below (Option 1) and leaving trees closest to the water (Option 2). This definition excludes hardwood conversions and alternate plans.

[2] Available on-line at: http://www.dnr.wa.gov/forestpractices/dfc/

[3] The CMER Protocols and Standards Manual (Pleus and Rowton 2005) does not identify Policy request as one of the means by which projects may be introduced into CMER.

[4] Steve McConnell, then (Autumn, 2004) an employee of the Northwest Indian Fisheries Commission

[5] I did not participate in RSAG or CMER from Nov. 2005 to October 2006 and did not participate in the May 2006 DFC Workshop sponsored by RSAG so I do not know for certain whether there was discussion of the study design for the Desktop Analysis by RSAG and/or CMER. There was, obviously, ample opportunity for such discussion, and a draft report submitted to RSAG on Nov. 12, 2005, that could serve to focus discussion on possible methodological problems. However, no such concerns were communicated to me prior to my taking this on as contractor with a contract finally signed in August, 2006.

[6] The first draft was dated December 12, 2005 and the second draft was dated November 26, 2006.

project and "Sensitivity Analysis"), or convey information and insights that were gained while conducting the work required to implement these studies ("Model and Manual" report). A report has also been prepared that synthesizes key findings from all of the DFC related reports (the "Synthesis" report). An overview of site attribute and stand characteristics of the riparian stands used in the Desktop Analysis are provided in Appendix A.

There are in addition, other CMER studies completed, ongoing or under development, that are related to the FPA Desktop Analysis in that they address some component of west-side Type F riparian DFC rules (RSAG, in review).

OVERVIEW OF DFC RULES

1. West-side Type F Riparian Zone DFC Rules: a Synopsis

New Forest Practices Rules (Rules) based on a Desired Future Conditions (DFC) concept for managing riparian forests became effective in Washington State in July, 2001. The intent of rules was to allow for timber harvest from riparian forests while protecting and improving water quality and habitat for fish and selected amphibians. The Rules are designed to provide a systematic approach for implementing site-specific management across a range of site and stand conditions to provide riparian functions (shade and wood input in particular). Forest structure is presumed to provide function. Timber harvest is allowed only if a riparian forest is suitably stocked with conifers and on trajectory towards a desirable structure. The spatial location from which structure (and hence functions) originate is also incorporated into rules. More timber harvest is allowed as distance from stream increases because most riparian functions are provided by near-stream trees. Timber harvest is restricted for a greater distance perpendicular to stream edge along large streams as compared to small streams because input of more and larger wood is required to provide riparian functions in large streams.

2. RMZ Widths: Systematically determined, based on site attributes

theoretically a continuum exists from which structures required for function are decreasingly important as distance from stream increases, but for management simplicity, discrete units, riparian management zones (RMZs), the core, inner and outer are designated and similar management applied throughout. Similarly, although a theoretical continuum exists, discrete measures of site productivity and stream size were adopted and used to represent different productive capabilities and functional requirements, respectively. The stream width set as the threshold amount at which function was presumed to differ, measured by bankfull width, is ≤ 10' wide (small streams) and >10' wide (large streams). The total width of the RMZ, including core, inner and outer zones, was set in Rules to equal site potential tree height (SPTH) for 100-yr old Douglas-fir trees. So, for each of Site Classes 1-5, total RMZ widths are, respectively, in feet, 200, 170, 140, 110 and 90.

The core zone is always 50' wide and begins at the outer edge of bankfull width or the channel migration zone (CMZ) and extends 50' perpendicular to the stream. The inner zone adjoins both the core and outer zones, lying between these. The outer zone extends from the outer edge of the inner zone to the full extent of SPTH for a given Site Class. Inner and outer zone widths vary by Site Class, stream size and the riparian prescription landowners choose. Inner zone widths are greater where site productivity, measured by Site Class is higher, and where streams are large. Since total RMZ and core zone widths are constant, where inner zone widths are wider, the outer zone width is correspondingly narrower.

Riparian zone widths also vary by the management choice made by landowners. Only two standard prescriptions involving timber harvest in the inner zones are available to landowners for Type F streams in western Washington (described in more detail in subsequent sections of this report). These are: 1) thinning from below (Option 1) or 2) leaving trees closest to the water (Option 2). Landowners can also opt to use a "no-cut" prescription in the inner zone but cut in the outer zone. For Option 1 the outer limit of inner zone widths were negotiated to be a percentage of SPTH; 2/3 for small streams and 3/4 for large streams (Fairweather 2001). These dimensions are also used for the no-cut prescription. For Option 2, inner and outer zone widths were negotiated and do not vary formulaically (Fairweather 2001).

The relationship between RMZ widths for all three zones, by Site Class, stream size, and management choice are presented graphically for Option 1 (Figure 1) and Option 2 (Figure 2). Inner zone widths are greater for large streams for all Site Classes in Option 1 (Figure 1) and differ by a maximum of 17' on Site Class 1 and a minimum of 8' on Site Class 5, with the rest falling between these values and lessening with Site Class. For Option 2 (Figure 2), inner zone widths are the same for both large and small stream for Site Class 1 and differ by only 6' for Site Class 2.

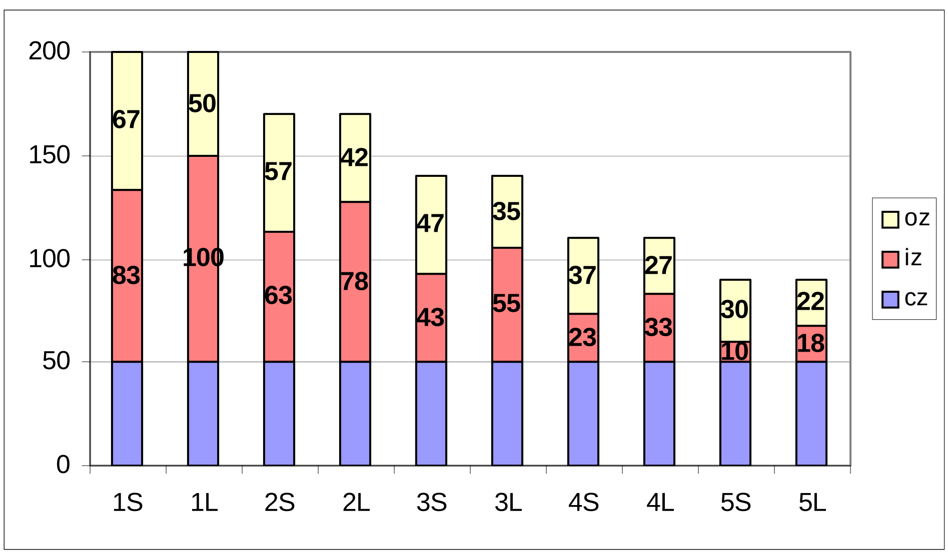

Figure 1 – Riparian Management Zone widths by Site Class, and stream size for Option 1 or for no inner zone timber harvest. The zones, cz, iz and oz denote, respectively, the core, inner and outer zones. The numbers on the x axis are Site Class (1-5) and the letters denote stream size: Small (≤ 10' wide), and Large (> 10' wide) The numbers overlaid on

zones are widths are in feet (the core zone is always 50'). Bars extend to Site Potential Tree Height for each Site Class: 1) 200', 2) 170', 3) 140', 4) 110' and 5) 90'.

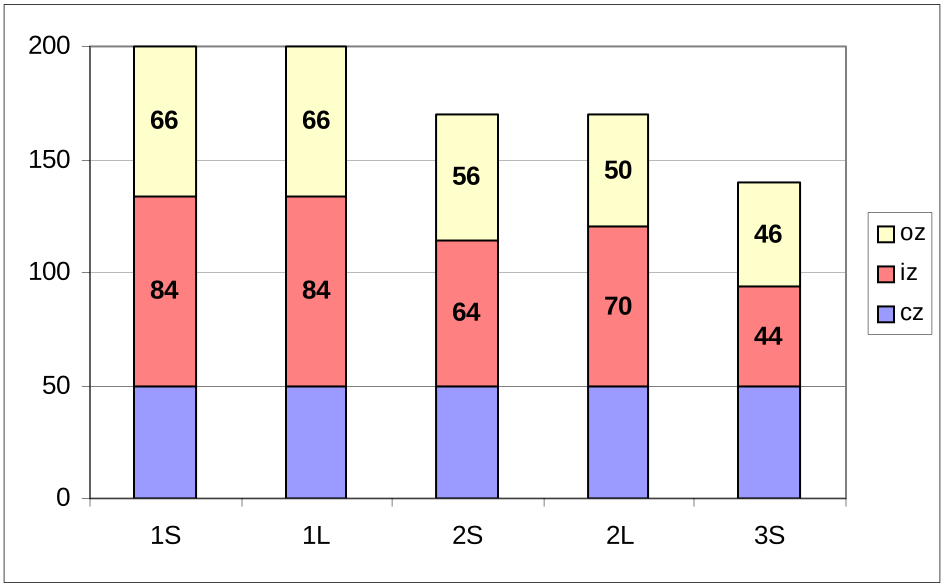

Figure 2 – Riparian Management Zone widths by Site Class, and stream size for Option 2. The zones, cz, iz and oz denote, respectively, the core, inner and outer zones. The numbers on the x axis are Site Class (1-5) and the letters denote stream size: Small (≤ 10' wide), and Large (> 10' wide) The numbers overlaid on zones are widths are in feet (the core zone is always 50'). Bars extend to Site Potential Tree Height for each Site Class: 1) 200', 2) 170', 3) 140', 4) 110' and 5) 90'. Option 2 is not allowed on Site Classes 4 and 5, nor on Site Class 3 along large streams.

3. Activities Allowed by Riparian Management Zone

No timber harvest is allowed in the core zone. Some timber harvest is allowed in the inner zone subject to the stand meeting eligibility requirements (see next section). More timber harvest is allowed in the outer zone. Timber harvest in the outer zone is not restricted by a riparian stand meeting eligibility requirements for inner zone harvest, but more outer zone timber harvest is permitted in some circumstances in stands that do (WAC 222-30-021(B)(II)).

4. Determining Eligibility for Timber Harvest in the Inner Zone

Stand eligibility for timber harvest in the inner zone is based on forest growth model (DFC Model) projections of a complete inventory of core and inner zone trees and site attribute data that it is required for landowners to collect and submit with FPAs (see section B. f.). Stands eligible for timber harvest must have a projected stand age 140 bapa that meets or exceeds basal area targets in Rules (DFC Targets) which, for Site Classes 1-5 respectively are, in ft^2/acre, 285, 275, 258, 224, 190. Stand age 140 was agreed by rule negotiators to represent a mature stand and was therefore used as the target age against which to judge basal area growth (Fairweather 2001). No stand inventory data is collected for outer zone trees. The outer zone is not considered in determining whether the inner zone of a stand is eligible for timber harvest.

5. Riparian Prescriptions

There are two prescriptions that allow for timber harvest in the inner zone of riparian stands along Type F streams in western Washington that meet eligibility requirements and other qualifying criteria. These prescriptions are: 1) a thinning from below (Option 1) and 2) leaving trees closest to the water (Option 2). Option 2 is only allowed on Site Classes 1 and 2 and Site Class 3 along small streams. The stand age 140 bapa DFC Target used to determine whether the stand is eligible to have inner zone harvest is a constraint common to both prescriptions that excludes some stands from being entered for timber harvest in the inner zone. Both prescriptions have one other rule component that also may serve to limit inner zone timber harvest although unlike the DFC Target, these components do not of themselves exclude the possibility of inner zone timber harvest in riparian stands. For Option 1, inner zone timber harvest must leave the 57 largest conifer trees un-cut. For Option 2, no cutting is allowed in a portion of the inner zone that lies adjacent to the core zone. Called the "floor", the minimum width of the no-cut inner zone adjacent to the core zone along small streams is 30' and along large streams it is 50'.

6. Data used to run the DFC Model

The DFC Model runs on site attribute and stand inventory data (Table 1) that landowners are required to collect. Landowners report these data on DFC Worksheets that are included as part of the FPA they submit to the Washington Department of Natural Resources (WDNR). Site class, species type and the stand inventory data are used to "grow" the stand by the DFC Model. Other site attribute data, for example RMZ length, provide inputs used to calculate the area of the core and inner zones, tpa and current and future bapa. Site Class is also used by the DFC Model, along with stream size to determine whether Option 2 is allowed. Stand inventory and site attribute data are used to calculate specific quantitative elements of prescription's for landowners, for example the basal area credit and/or required floor width (Option 2) and the specific number of inner zone leave tpa and the maximum diameter of trees that can be cut so that the thinning implemented is from below (Option 1).

7. DFC Model Characteristics and use

The DFC Model consists of three pages (Figures 3-5). These are labeled respectively, from page one to page three as, "Worksheet" (Figure 3), "Option 1 –Thinning from below" (Figure 4), and "Option 2 –Leaving trees closest to stream" (Figure 5). DFC Model calculations of core and inner zone area, tpa, bapa, % conifer (on a basal area basis) and projected stand age 140 bapa for the core and inner zones are obtained on the "Worksheet" page. The prescribed number of leave trees or the leave "floor" area for the two active management prescriptions are calculated on respectively page 2 (Option 1) or page 3 (Option 2) of the DFC Model.

Table 1 – Data required to run the DFC Model, data attributes, and data source

Data Attribute	Units or Characteristics	Source of Data
Stream Size	Large (> 10' wide) or Small (≤ 10'wide)	Landowner
Site Class	1-5	Landowner - from maps available on the WDNR website using the Forest Practices Application Review System
Major Species	Douglas-fir or western hemlock	Landowner - determines which species has a majority or plurality of total stand basal area
RMZ Length	Feet	Landowner – no specific method is prescribed for making this measurement.
Stand Age	Years	Landowner – using stand inventory records and/or coring trees
Number of trees in dbh class	Number	Landowner – a simple count of the number of 2" dbh classes populated
Stand Inventory Data	Number of trees by 2" dbh class and species type – conifer and hardwood. Smallest diameter class is 6" (trees 5.0" to 6.9").	Landowner – must collect tree data from the core and inner zones, using widest possible width for the given Site Class, stream size and prescription.

8. The Worksheet page of the DFC Model

The "Worksheet" page of the DFC Model is where stand inventory and site attribute data are entered. Site attributes required by the DFC Model include stream size, Site Class, major species (Douglas-fir or western hemlock), and RMZ length (ft'). Stand inventory data includes stand (entered separately for the core and inner zone) age (yrs) and the number of trees by species type (conifer or hardwood), by two-inch diameter class.

Once site and stand inventory information is entered, pushing the "Calc" function key on the right side of the boxes titled "core zone stand table" and "inner zone stand table" causes the DFC Model to calculate (separately) inner and outer zone stand area, tpa, bapa, % conifer and projected stand age 140 bapa (as a percent of the DFC Target).

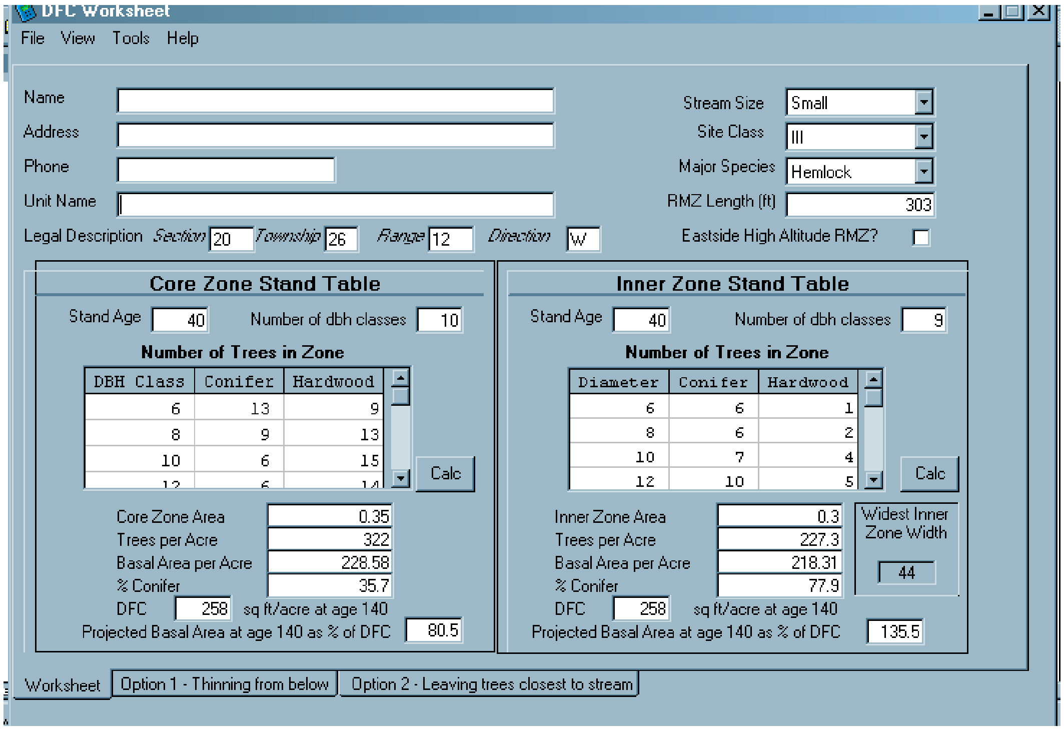

Figure 3 – The "Worksheet" page of the DFC Model.

9. The Option 1 – Thinning from below" page of the DFC Model

The DFC Model provides outputs of "projected basal area" and "required basal area" on the "Option 1 – thinning from below" page of the DFC Model. These numbers refer to (only) the inner zone bapa projected to stand age 140 (although core zone bapa is part of the calculation used to determine the required or projected, respectively, stand age 140 bapa). "Projected basal area" must be equal to or greater than "required basal area" in order for DFC to be met. Projected bapa changes after pushing the "suggest thinning" toggle on this page as the Model calculates a new projected basal area for the trees remaining after thinning from below, along with a positive growth response to thinning incorporated into the Model.

The Model user will be provided prescription information on the graphic that includes the width of the inner and outer zones for that Site Class / stream size configuration, the number of trees that must be left in the inner zone (absolute number, not per acre) and the size of the largest tree that can be cut (by scrolling down in the spreadsheet below the graphic to find the diameter of the smallest tree left after thinning). The other information contained on this worksheet is not required by the user to implement prescriptions. This information includes the post-thinning projected bapa, the required bapa, and, on the Table to the right, the number of inner zone trees left (expressed as tpa) and the post-thinning stand basal area per acre.

Figure 4 – The "Option 1 – Thinning from below" page of the DFC Model

10. The "Option 2 – Leaving trees closest to stream" page of the DFC Model
DFC Model outcomes for Option 2 are obtained from the page labeled "Option 2 – Leaving trees closest to the stream". Information available to the user on this page include the width of the inner zone, the width of the no-cut portion of the inner zone required for each stand and the number of trees that must be left in the outer part of the inner zone and in the outer zone. Unlike as for Option 1, no interaction with the Model is required to obtain Option 2 outcomes once the calc buttons on the Worksheet page of the Model are toggled. The outputs for Option 2 are more limited than for Option 1 in that estimates of stand basal area acre at age 140 are not provided, nor are there estimates of inner zone stand density or post-harvest stand bapa. Instead, outputs are limited to those required to implement the DFC Rules.

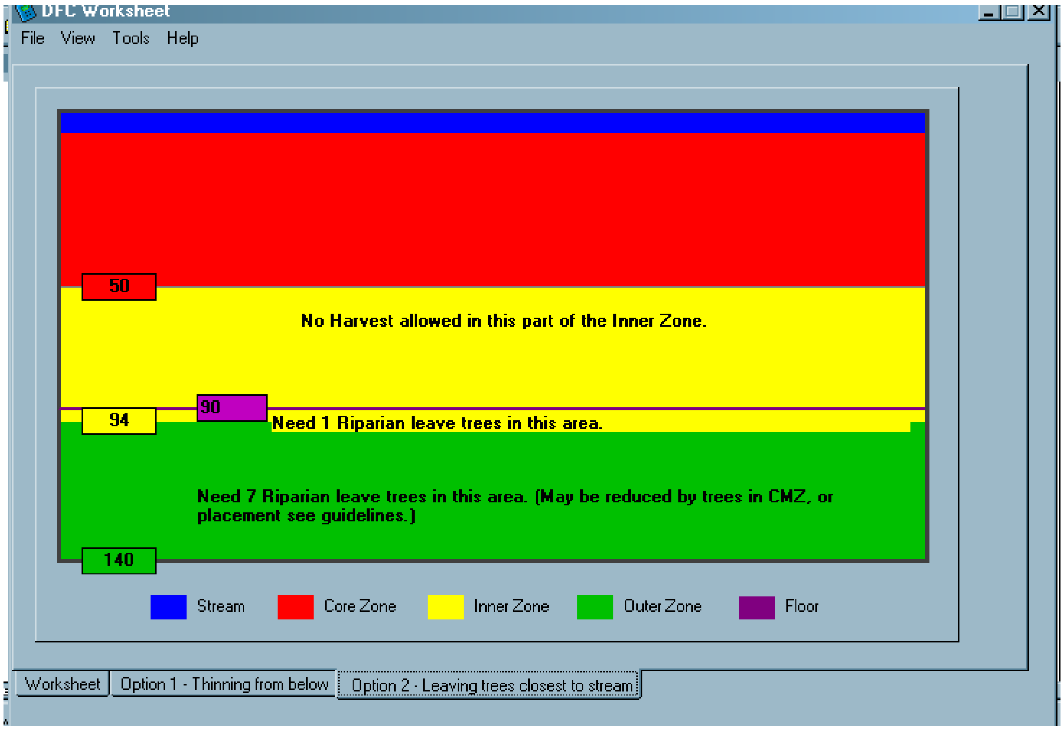

Figure 5 – The "Option 2 – leaving trees closest to stream" page of the DFC Model

11. Calculating Basal Area Per Acre in the DFC Model

The bapa used by the DFC Model to determine if a stand meets DFC, and is therefore eligible for inner zone timber harvest, is calculated by projecting the bapa of each of the core and inner zones and then calculating an area-adjusted average value for the core and inner zones combined. For example, for a riparian stand that is on Site Class 2, along a large stream, the core zone is 50' wide and the inner zone is 78' wide[7]. The area of each of the core and inner zones is the product of RMZ length times zone width. Since RMZ length is the same for both zones, width can be used as a surrogate for area to simplify calculations. For this example, the DFC Model projected basal area for the core zone at stand age 140 is 424.6 and for the inner zone (with no timber harvest) it is 411.1. The DFC Model projected stand age 140 bapa is calculated using the equation below. For this equation cz = core zone width in ft and iz = inner zone width in feet.

$$\begin{array}{ccccc} ((cz/(cz+iz) & & ((iz/(cz+iz) & & \text{DFC Model projected,} \\ * & + & * & = & \text{area-adjusted,} \\ \text{cz bapa 140)} & & \text{iz bapa 140))} & & \text{stand age 140 bapa} \end{array}$$

Using the numbers from the randomly selected for this example, these calculations are:

$$((50/128) * 424.6) + ((78/128) * 411.1) = 416.4$$

[7] This example uses a stand from this analysis that was selected at random.

In the above example, each of the values were weighted proportionally to their area, the core zone at 39% (50/128) and the inner zone at 61% (78/128). Inner zone width varies by Site Class, stream size and management option selected from as small as 10' wide on Site Class 5 small streams to as much as 100' wide on Site Class 1 large streams while the core zone is constant at 50' wide. Because of this, the relative importance of the core and inner zone varies. The core zone may account for as little as 33% or as much as 83% of the projected bapa used to calculate core+inner zone stand age 140 bapa, against which DFC targets are compared.

12. Riparian zone width as a factor in meeting DFC Targets

The variable width of the inner zone of riparian stands has a potentially important effect on whether or not stands meet DFC. As noted above, projected stand basal area is calculated for the core and inner zones and it is the area-adjusted combined basal from these zones, projected to stand age 140 that determines whether a stand will meet DFC. Because inner zone widths vary, the relative importance of the core zone relative to the inner zone also varies across Site Class, stream size and management option configurations (Figures 3 and 4). Calculating the ratio of core to inner zone area (or width, as they have a common length) indicates the relative importance of each zone. If the ratio is 1.0, then the core and inner zones are equally important in DFC (stand age 140 bapa) calculations. If the ratio is less than 1.0, the inner zone has more influence. Where the ratio is greater than 1.0, the core zone has more influence.

For Option 1 (Figure 6), the core zone is more influential than the inner zone on DFC Model calculated stand age 140 bapa for less productive sites (Site Classes 4 and 5, and Site Class 3 along small streams). The inner zone is more influential than the core zone on Site Classes 1 and 2 and Site Class 3 along large streams (Figure 6). For all Site Classes, the core zone is relatively more influential than the inner zone on small streams and the inner zone more influential on large streams (Figure 6).

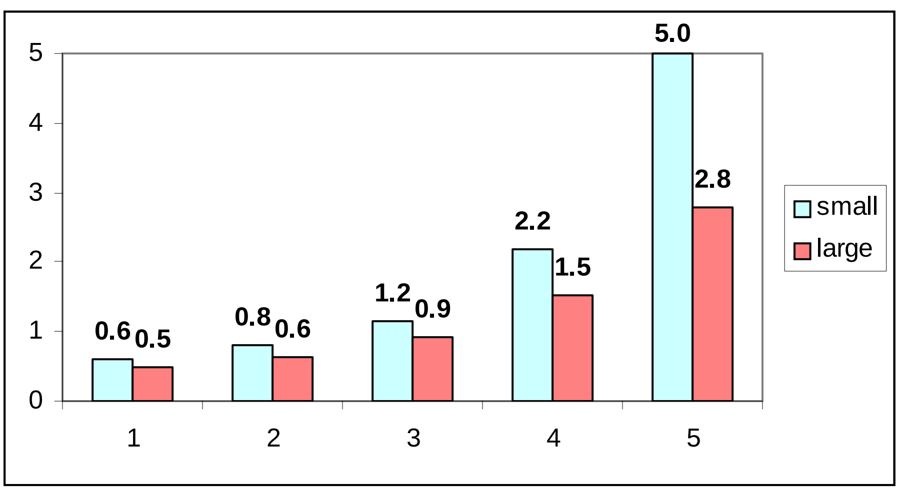

Figure 6 – Option 1, core over inner zone stand area (or width as both zones have a common length) ratios. Site Class (1-5) is on the x axis. Ratio values (unit-less) are on the y axis . Streams are "small" (≤ 10' wide) and "large" (> 10' wide).

For Option 2, Site Class 1, the core and inner zone widths are the same for both large and small streams, thus the core over inner zone ratio is the same (Figure 7). For both stream sizes, the inner zone is more influential than the core zone in DFC target calculations. For Site Class 2 also, the core zone also is less influential than the inner zone in DFC target calculations. The core zone, however, is more important on small streams than on large streams (Figure 7). Option 2 can only be used along small streams on Site Class 3 and for this configuration, the core zone has more influence than the inner zone on DFC target calculations (Figure 7).

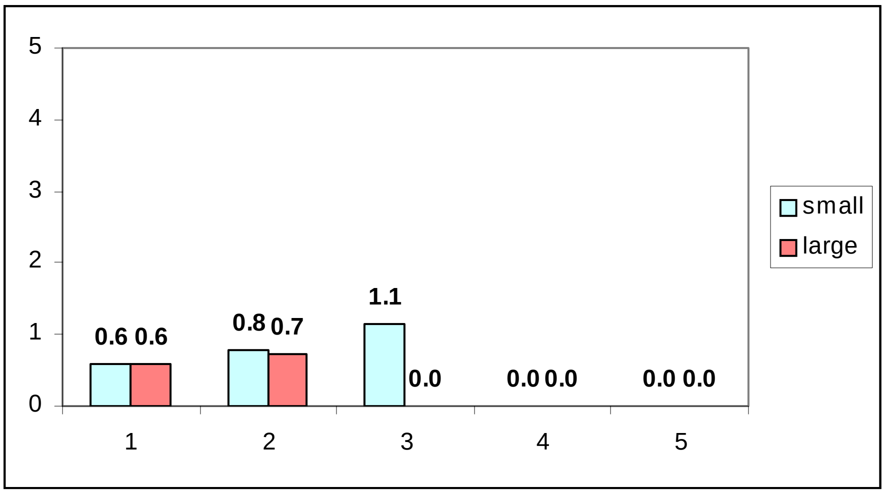

Figure 7 – Option 2, core over inner zone stand area (or width as both zones have a common length) ratios. Site Class (1-5) is on the x axis. Ratio values (unit-less) are on the y axis . Streams are "small" (≤ 10' wide) and "large" (> 10' wide).

13. Characteristics of Option 1

The Option 1 prescription can be implemented on all Site Classes on both small and large streams. According to the Rules (WAC 222-30-021(2)(B)(I)) "The objective of thinning is to distribute stand requirement trees in such a way as to shorten the time required to meet large wood, fish habitat and water quality needs. This is achieved by increasing the potential for leave trees to grow larger than they otherwise would without thinning." Option 1 requires that the "Residual trees left in the combined core and inner zones must meet stand requirements necessary to be on a trajectory to desired future conditions." This is therefore, the component of the rule that establishes the eligibility requirement for inner zone timber harvest, e.g. that the residual stand must meet DFC. The other component of the Rule for Option 1 is that the treatment applied must be a thinning from below and that there must be at least 57 residual tpa after thinning[8]. DFC Model outputs calculate the largest inner zone tree (dbh) that may be harvested, and the number of trees in this diameter class that must be left.

14. Characteristics of Option 2

[8] I've found through experimentation that if 57 conifer trees are not available but the stand meets DFC, the DFC Model prescribes leaving the largest hardwood trees present after all conifer are accounted for if still short of 57 tpa. This occurred on only one of the 150 stands analyzed for this report.

The Option 2 prescription is allowed only on sites mapped as Site Class 1 and 2 and on Site Class 3 with streams that are less than or equal to 10' wide. Option 2 results in a no-cut zone adjacent to the core zone. On small streams this no-cut portion of the inner zone is 30' and on large streams it is 50' wide. Timber harvest is implemented by "Trees are selected for harvest starting from the outer most portion of the inner zone first, then progressively closer to the stream" (WAC 222-30-021(ii)(B)(II)", remembering that "A minimum of 20 conifers per acre with a minimum 12" dbh, will be retained in any portion of the inner zone where harvest occurs." Option 2, therefore, provides a wider no-cut riparian buffer adjacent to the stream than does Option 1.

The ecological basis for Option 2 is that wood recruitment to streams is directly related to the distance from streams at which trees grow[9]. Option 2 is designed to retain more trees near the stream. Timber harvest is constrained to the portion of the inner zone furthest from water where trees provide proportionally much lower amounts to riparian functions as compared to trees nearer to the water. The rationale for leaving 20 conifer tpa that are at least 12" dbh in the outer part of the inner zone is not provided[10]. Depending on the quality of trees left, however, and how affected by windthrow they are, there could be a thinning release effect to these trees similar to that for Option 1. A response to more growing space would hasten the growth of the trees furthest from the water, lessening the time for inner zone trees furthest from the water to provide functions.

Another distinguishing characteristic of Option 2 is the division of the inner zone into different portions, e.g. the "floor" and the outer part of the inner zone, to which different rules apply. For Option 1, in contrast, the entire inner zone is treated as a single unit with the same rules applied throughout.

The DFC Model makes some different calculations for Option 2 than it does for Option 1. The calculation common to both options is using the full stand inventory data from the core and inner zones to calculate stand age 140 bapa to determine whether the stand meets the DFC Target for the given Site Class and is therefore eligible for inner zone timber harvest. Like as for Option 1, the DFC Model does this by weighting projected core and inner zone contribution to bapa from each zone, in proportion to stand area.

For Option 2, the DFC Model then makes some additional area-based calculations. First, the area-adjusted, projected stand age 140 bapa that would result from the core zone and the floor portion of the inner zone are calculated. If this amount exceeds the DFC target, then the entire outer part of the inner zone (the part further from the stream than the floor out to where the outer zone begins) can be harvested, leaving 20 tpa of conifers greater than or equal to 12" dbh. If there is bapa from the core + floor that is in excess of the DFC Target, then up to half of the normally required outer zone trees (20 per acre) can be cut (down to a minimum of 10 per acre), on a basal area for basal area basis. "Basal area for basal area" means that if the credit basal area is, for example, 3.3 ft^2/acre, then only

[9] Other important riparian functions, shade, nutrients, etc. are affected by distance from stream. The negotiations leading to Rules, however, primarily centered on wood recruitment (Fairweather 2001, p. 9)
[10] Not discussed in any of: 1) Forest Practices Rules WAC 222-30-021 (WDNR, 2001), 2) Forest Practices Board Manual, Section 7 (WDNR, 2001), or 3) Fairweather (2001)

3.3 ft^2/acre could be harvested from the 10 outer zone leave trees available for cutting. A 12" tree has about 0.78 ft^2/acre basal area, so for this example, only four 12" inch tpa could be cut (4 trees * 0.78 ft^2/tree = 3.12 ft^2).

If the DFC Target will not be met from the area-adjusted combined core and floor portion of the inner zone, then the DFC Model makes calculations that extend the no-cut area into the outer part of the inner zone until a width, measured in feet, is reached at which the DFC Target is reached. Extending the width of the no cut portion of the inner zone adds basal area because the calculation is made over the entire inner zone and any part of the inner zone that is outside the no-cut portion is considered by the DFC Model to have no basal area. As you add more basal area by adding width, you increase the numerator without changing the denominator and may eventually get a high enough basal area within the inner zone to meet the DFC Target.

For example, a Site Class 2 stand along a large stream has a 50' core zone width and a 70' inner zone width, with 50' of the inner zone being in the no-cut floor. For a stand with DFC Model projected stand age 140 bapa of 280 and 349 in the core zone and inner zones, respectively, calculations to determine the floor width are as follows, where cz = core zone width (ft), iz = inner zone width (ft), :

((cz/(total cz+iz) * cz bapa 140)	+	((floor / total cz+iz) * iz bapa 140))	+	((opiz / total cz+iz) * iz bapa 140)	=	Total DFC Model projected, area-adjusted, cz+iz combined bapa 140

((50/120)*280) + ((50/120)*349) + ((20/120)*349) = 336.2

To calculate the width from the outer part of the inner zone required to obtain a stand age 140 bapa that meets or exceeds the DFC Target of 275, requires solving for **X** in the following equation:

((50/120)*280) + ((50/120)*349.0) + ((**X**/120)*349) = 275 or (more)

The equations for doing this are algebraic and not included here. The result, however, is:

116.7 + 145.4 + ((**5**/120)*349) = 276.6

Thus the floor width for this example from one of the stands used in this analysis is 50' core zone + 50' floor width + 5' from the outer part of the inner zone = a total no-cut width of 105'.

If the width at which a stand meets DFC is equal to combined width of the core+inner zone, the stand technically "meets DFC" but no cutting is permitted because this would reduce projected stand age 140 bapa to below the DFC Target. Stands on which this occurs, however, may still be entered for inner zone harvest using Option 1. And, because all or most hardwood trees can be cut, thinning is from below for which a "release" (post-harvest accelerated growth) response is programmed in to the DFC Model, stands on which no cutting is allowed for Option 2 can allow for timber harvest using Option 1[11].

If the projected core zone + floor stand age 140 bapa exceeds the basal area target, timber harvest is allowed in the outer part of the inner zone, except that at least 20 conifer tpa 12" dbh or larger must be left. Unlike Option 1, Option 2 can affect the amount of timber available for harvest from the outer zone. Where the combined core zone + floor bapa exceeds the DFC Target, the DFC Model will tally the amount of "excess" basal area above the required target amount, reporting this as a basal area "credit". This credit can be used to cut up to half of the required 20 outer zone trees left on a basal area for basal area basis as described earlier in this report[12].

Because the core width, the floor widths and the DFC Target by Site Class are fixed, the bapa required from the core + floor zones to meet the DFC Target from each Site Class, stream size configuration can be calculated (Table 2). The required core+floor stand age 140 bapa decreases with Site Class (Table 2) and is lower on Large streams than it is on small streams, within the same Site Class.

The core+floor required stand age 140 bapa targets change by Site Class and stream size for several reasons. First the required DFC Targets decrease with Site Class (Site Classes 1-3 respectively are, in ft^2/acre, 285, 275 and 258) meaning stands must have less projected basal area to meet targets. Second, because inner zone widths are wider on more productive sites, the core+floor combined, area-adjusted bapa account for proportionally less of the core+inner zone width. Therefore, more bapa is required for the core+floor for stands to meet the DFC Target across a larger area (wider inner zone). Third, for small streams, the core zone + floor width is 20' less than for large streams because the floor minimum for each are 30' and 50', respectively, for small and large streams. Therefore, the basal area in the core+floor zone has to be higher in order to meet DFC across the full core+inner zone combined, area-adjusted bapa. Referring back to Figure 2 and considering floors in addition to zone widths can help understand this dynamic.

[11] The one stand in this analysis on which DFC was met at the total width of the core+inner zones, meaning that no timber harvest was allowed for Option 2 allowed for, using Option 1, cutting 43.4 ft^2/acre (6.3 conifer and 37.1 hardwood) distributed between 76.8 tpa (25.3 conifers and 51.5 hardwoods).

[12] Note that there are problems with how the DFC Model reports outer zone trees available for harvest. In brief, where the DFC Model lists the number of outer zone trees that must remain, it infers that up to half may be removed if there is a basal area credit but fails to note that this is supposed to be on a "basal area for basal area basis". Thus the number of outer zone trees that can be removed is over-reported when the basal area credit is less than the basal area of trees potentially removed.

Table 2 – Minimum stand age 140 basal area per acre required from the combined core zone + floor in order for the DFC Target to be met at the minimum floor width (e.g. without extending the no-cut portion of the inner zone beyond the minimum no-cut width required), by Site Class (1-3) and stream size (small ≤.10' wide, large > 10' wide).

Site Class	Small	Large
1	477.4	381.9
2	391.9	330.0
3	303.2	

More details of the riparian prescriptions used in FFR rules are provided in the Forest Practices Rules, WAC 222-30-021 (WDNR, 2001). Implementation guidelines are located in the Forest Practices Board Manual, Section 7 (WDNR, 2001). Background information on how and why rules were devised, alternatives to the rules adopted that were considered and rejected, and a description of how the DFC Model was constructed was prepared by Fairweather (2001).

OBJECTIVES

The objective of this study was to quantify DFC Model calculated (current stand age) and projected (stand age 140) outputs from a random sample of approved FPAs for west-side Type F streams on which inner zone timber harvest was proposed in order to:

1) Quantify the effect of rule components to determine their effect to constraining timber harvest for each of the three standard riparian prescriptions using DFC Model outputs[13].

   The prescriptions are:
   a. no-cut,
   a. Option 1 (thinning from below) and,
   b. Option 2 (Leaving trees closest to the stream).

   The Rule constraints are:
   a. the stand age 140 bapa "DFC" target,
   b. the required 57 inner zone leave tpa required for Option 1, and
   c. the required minimum no-cut inner zone "floor" required for Option 2.

2) Quantify the projected bapa for riparian stands at stand age 140 for the three standard prescriptions permitted in current rules: 1) no-cut, 2) Option 1 and 3) Option 2.

[13] This report is entirely a modeling exercise and operational constraints, field conditions or other rationale which may cause landowners to make different decisions than those that result from the DFC Model outputs are not considered.

METHODS

1. Overview

One-hundred and fifty approved FPAs reporting inner zone timber harvest in west-side forests along Type F streams were randomly selected, using the Forest Practices Application Review System (FPARS) available on the WDNR website[14]. The DFC Worksheet data included in these FPAs were entered into the DFC Model, the Model run, and outputs from these Model runs analyzed. Seventy-five FPAs were selected for each of 2003 and 2004. FPAs encountered that were not for one of the standard prescriptions, did not meet DFC, had data entry problems or lacked needed data were rejected and the next FPA from the randomized list selected.

DFC Model outcomes of all three prescriptions available to landowners (no-cut, Option 1 and Option 2) were projected, not just the prescription selected by landowners for a given FPA. Analyses were then made of projections from all three scenarios to determine if rule components within each of Options 1 (stand age 140 bapa target and the requirement to leave the 57 largest inner zone conifer trees) and Options 2 (stand age 140 bapa target and the required no-cut "floor") constrained timber harvest equally or if there were differences in the constraining effect exerted by each rule component. Additionally, the DFC Model projected stand age 140 bapa outcome from each prescription, for each FPA, was projected and these outputs summarized using descriptive statistics and compared graphically.

2. Data acquisition and data entry

All FPAs with inner zone timber harvest in west-side forests along Type F streams that were approved by the DNR in both 2003 and 2004 were identified using FPARS. These FPAs were randomized by year, and 75 FPAs from each year selected for analysis. The selected FPAs, available as .pdf files, were accessed electronically using the public domain "Adobe Reader" program. Reading each FPA from front to back, the first DFC Worksheet encountered (some FPAs had multiple stream segments in a given FPA, each with a different Worksheet), was selected and data from this Worksheet entered into the DFC Model and saved as a .dcf file with a unique name for each stand. Data from .pdf files cannot be transferred electronically to spreadsheets and .dcf files were not available from landowners, so .dcf files used in this analysis were re-created by re-entering data manually[15].

The DFC Model must be "run" to obtain most of the data required by this analysis. Running the model consists simply of opening the file and pressing some toggles that cause the model to make calculations and generate outputs. The data used in this analysis, by DFC Model action required are: 1) site attribute data (no interactive component to obtaining these other than opening the .dcf file), 2) stand attribute data (need to push calc buttons on the "Worksheet" page to generate outputs), 3) Option 2 data (need to push calc buttons on first page, then turn to the third page), and 4) DFC Model

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[14] http://www3.wadnr.gov/dnrapp4/fparsweb/login.aspx?RedirectURL=FPASearch.aspx

[15] Bonnie Thompson from WDNR did much of the data entry for this project.

pre- and post-harvest outputs for the Option 1 option (need to push the “suggest thinning” toggle to generate post-harvest data).

The DFC Model provides outputs that are keyed to its primary use as a regulatory tool for implementing Forest Practices Rules so it is not possible to obtain from it many outputs that are common to other growth and yield models. For example, ORGANON (Hann et al. 1997)[16] and FVS (Dixon 2003)[17] allow for simulations of different user-specified time periods while the DFC Model allows only for simulations to stand age 140. Similarly, using ORGANON or FVS, different cutting prescriptions can be evaluated, different outputs (besides stand bapa) can be obtained, among other factors for which other models offer more flexibility. To work around this, spreadsheets were used extensively to make calculations not provided directly by DFC Model outputs.

Because the DFC Model has not previously been rigorously tested, calculated attributes were compared against DFC Model outputs to ensure that calculations were made correctly. Some errors in DFC Model calculations were in fact identified by checking calculations.[18] The spreadsheets used in these analyses, including equations used to derive each outcome or analysis variable are provided to the DNR and will be retained in the project file for this work along with a “data dictionary” for each spreadsheet (available upon request from either the DNR or the report author). The services of a qualified mathematician were secured to ensure that all calculations made for this analysis are correct.[19]

3. Quantifying constraints to timber harvest for Option 1

The DFC Model does not identify which constraint, the required stand age 140 bapa or the required 57 inner zone leave trees serves as the primary constraint to timber harvest. If the basal area target is not met, the DFC Model will provide a message on p. 2 of the DFC Model in the inner zone portion of the graphic that says “No harvesting allowed”. Returning to p. 1, a message will appear that says “DFC not met, TPA too low, or % conf reduced.”

Therefore, to distinguish the effect of rule components and determine which was the primary constraint, the effect to current tpa and stand age 140 bapa of removing one additional tree (Table 5) was calculated for stands that were near threshold values for basal area or required leave tree number. If taking away one additional tree reduced tpa to less than 57 and basal area was not limiting, then tpa is the primary constraint to timber harvest. Conversely, if taking away one additional tree put projected stand age 140 basal

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[16] Available on-line at: http://www.cof.orst.edu/cof/fr/research/organon/downld.htm
[17] Available on-line at: http://www.fs.fed.us/fmsc/fvs/index.shtml
[18] Two errors in DFC Model calculations were identified. These are described in the “Model and Manual” report (in prep). One error was the use of the wrong inner zone width for small streams in site classes 1, 2, and 3 on the DFC Worksheet. The other error was in calculating and reporting the number of inner zone trees to leave after thinning for the thin-from-below prescription on the “Option 1 – Thinning from below” page of the DFC Model. The first error has only a minor effect (quantified in the Model and Manual” report), and the second error has no effect on the analyses conducted in this report.
[19] Cynthia Piez, Department of Mathematics, University of Idaho

area too low while more than 57 tpa remained, then the DFC basal area target was the primary constraint.

The effect of removing one tree was evaluated using both external calculations with data obtained from stand yield tables (McArdle 1961, Figure 4) and the DFC Model itself. A yield table was used because the DFC Model does not provide a tree list (number and size of trees) for stand age 140, only a projected stand basal area. Therefore, to calculate the effect to stand basal area of subtracting one additional tree I estimated, by Site Class, tree diameter growth of the smallest dbh tree remaining in the inner zone after thinning from its starting age and size (dbh) to stand age 140. The starting diameter is obtained from the Stand Table on the "Option 1" page of the DFC Model after pushing the "suggest thinning" toggle. Basal area is calculated from the final (stand age 140 basal area) using the equation: basal area = .005454 * $(\text{dbh})^2$ (Husch et al. 1972).

This method provided an approximate but repeatable basis for evaluating the effect of cutting (from below) one more tree in each stand and estimating the effect of doing so to stand age-140 basal area per acre for the few stands for which both bapa and tpa were possible constraints to timber harvest. This method was also used because the DFC Model has been found to contain some errors (McConnell, in review), thus should not be relied on exclusively to quantify results when other methods are available.

To estimate the effect to stand age 140 bapa of removing one additional tree using the DFC Model, the data using the full stand inventory was run first. The stand was "thinned" using the "suggest thinning" toggle, and the inner zone tree inventory reduced on the DFC Worksheet to the number and size of inner zone trees left after the thinning suggested and then one additional tree taken beyond that. The "calc" button was then pressed, re-setting the inner zone characteristics quantified by the Model and outputs evaluated to determine what happens to current tpa and projected bapa after removing one additional tree. If taking one additional tree set the inner zone below the 57 tpa and "projected bapa" still exceeds "required bapa", then it is tpa that is the primary constraint. Conversely, if the stand has inner zone trees in excess of 57 tpa but projected bapa does not meet required bapa, it is bapa that is the primary constraint to additional timber harvest.

4. Calculating basal area for trees not considered by the DFC Model for Option 2
Rules require that for Option 2 timber harvest, 20 conifer tpa with a minimum dbh of 12" be left in the outer part of the inner zone. These trees are not counted towards the DFC Targets, thus are not considered by the DFC Model. To make calculations comparable across prescriptions, the basal area of these trees was calculated. The equation used for this was obtained from Jeff Welty (Weyerhaeuser) who developed it from ORGANON outputs specifically for this analysis. The equation is:

Contribution to stand bapa from trees in the outer part of the inner zone	=	initial bapa (ft^2/acre)	+	(-1.0599 + Site Class – 0.00004563* Site Class^2 + 0.0142 * starting dbh)	*	(140 – current stand age)

The values used for Site Class are: 1) 139', 2) 119' and 3) 98'

Initial bapa = 15.71 because this is the bapa of 20 trees, 12" in diameter, calculated as follows: 20 * .005454 * $(dbh)^2$ = 20 * .005454 * $(12)^2$ = 15.71.

A sample calculation for a Site Class 2 stand that is 55 yrs old is as follows:.

=15.71 + (-1.0599 +0.0311*119 -0.00004563*119*119+0.0142*12)*(140-55)

= 199.8' ft^2/acre

CAVEATS AND ASSUMPTIONS

The following assumptions and caveats must be kept in mind to thoughtfully interpret results presented.

CAVEATS

1. I did not evaluate other rule attributes that might apply in the course of implementing prescriptions or that could be considered in a field study, for example:
   1) Whether a thinning from below decreased the proportion of conifer in the stand. The DFC Model will not propose a prescription, and landowners presumably would not implement, a timber harvest that had that effect.
   2) The shade rule may override the Option 1 prescription for timber harvest occurring within 75' of any Type S or F water. The data required to consider this are not available for this model analysis so possible shade rule effects were not considered.

2. The DFC Model has not been comprehensively compared against other common growth and yield models used in the Pacific Northwest, for example, ORGANON or FVS. The extent that DFC Model outputs differ from these more standard tools is not known.

3. The DFC Model does not consider ingrowth - growth of trees that establish after timber harvest occurs or that are less than 5" dbh at the time the stand inventory is collected. The basal area modeled, therefore, accrues only on trees that were part of the stand inventory at the time the FPA was submitted. Stand age 140 basal area might be higher if the basal area from trees established after timber harvest were included.

4. Leave trees in the outer part of the inner zone under Option 2 are not included in stand age 140 bapa projections made by the DFC Model as per rule intent. I account for these trees (20 tpa with a 12" minimum dbh) in some of the analyses reported using calculations made outside of the DFC Model. It is not known how different the outputs I calculated are from what would result had growth of these trees been included in the model. It is not known what the actual growth of these trees would be as compared to the growth I attribute to them.[20]

5. The DFC Model assumes that all trees in the core and inner zones left after timber harvest will survive and contribute to stand basal area at age 140. Negotiators recognized that there would be windthrow mortality (Welty 1999, included as Appendix A in Fairweather 2001) and rules were written with this in mind. Windthrow is highly variable in its effect causing high mortality in some stands while leaving others intact. The rules are designed around average expected mortality rather than the range of possible effects. It is not known how much stand outcomes will differ from DFC Model projected stand age 140 outputs because of tree mortality.

ASSUMPTIONS

1. Implementation of Rules through the DFC Model process assumes that stands are relatively homogeneous throughout the core and inner zones, respectively. The composition and structure of forest trees throughout stands may in fact vary with distance from the stream because of changing ecological conditions and along the length of the riparian stands because of different management history. Other factors may also cause stand heterogeneity. Heterogeneity could affect management outcomes. If for example:
    a. Trees on one end of a riparian stand are uniformly large and uniformly small on the other, following the size guidelines for Option 1 would result in heavy cutting in one area and little or no cutting in another and post-harvest tree growth would likely be different from the spacing assumptions incorporated into the DFC Model.
    b. If large trees are unevenly distributed and Option 2 is used, stand basal area could be substantially lower or higher than growth modeled from stands on which tree diameter variations were evenly distributed throughout the stand.

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[20] The equation I used to calculate growth of trees in the outer part of the inner zone (opiz) was provided to me by Jeff Welty, Weyerhaeuser. This equation was the product of a relatively quick analysis and should not be considered definitive. Jeff and I considered this equation to be adequate to illustrate the point that there is additional basal area that is unaccounted for by the DFC Model in these trees because the rules and hence the DFC Model do not account for these trees. Ash Roorbach (personal communication) used the DFC Model to project the basal area contribution of trees in the opiz and got values that were about half those obtained from the "Welty equation". However, the 20 tpa in the opiz are substantially less than the smallest tpa parameter used in developing the DFC Model. Using age values that were less than the minimum from which the Model was programmed resulted in inaccurate results. Using tpa values that are outside the parameters used to program the DFC Model may also not be reliable. The equations developed by Welty were at least developed specifically for this question using ORGANON model outputs for the number of trees being evaluated (20 tpa). Neither method can account accurately for windthrow or the possible effects of other disturbance agents.

c. If, for Option 2, conifer trees are concentrated towards the inner part of the inner zone and there are hardwood trees throughout the outer part of the inner zone, the 20 conifers per acre it is required to leave in the outer part of the inner zone may not exist.

2. All of the required leave trees in the outer part of the inner zone (Option 2) were 12" diameter, the minimum required by rules.

RESULTS

RULE COMPONENT EFFECTS TO TIMBER HARVEST ALLOWED

1. The no-cut riparian prescription

Three of the 150 stands included in this analyses were projected by the DFC Model to have a combined core + inner zone basal area that would not meet the stand age 140 bapa Target <u>unless</u> Option 1 is implemented (Table 3). Two of these stands were mapped as Site Class 3 and one as Site Class 2; all occurred along large streams. Without thinning these stands were projected by the DFC Model to be short of meeting the DFC Target by 27, 57 and 58 ft^2/acre, respectively. With a thinning from below harvest, these stands were projected to make up this basal area and meet the DFC Target according to DFC Model projections.

Table 3 – Projected stand age 140 inner zone bapa (ft^2/acre) with no thinning and with thinning from below in the inner zone. With thinning, stands meet DFC, with no thinning, stands do not meet DFC.

Stand #	Site Class	Inner Zone No Thin Projected BAPA	Inner Zone Required BAPA	Difference With No Thinning	Inner Zone After Thin Projected BA	Difference With Thinning
24	3	272	330	-58	333	3
104	3	207	264	-57	265	1
22	2	320	347	-27	348	1
Average		266	314	-47	315	1

This DFC Model projected response to thinning from below is not typical to all stands (McConnell, unpublished data). The large thinning response of these stands is attributable (see Discussion section of this report) to the particular characteristics of these stands (Table 4). The stands that did not meet DFC under a no-cut prescription according to DFC Model projections, but did meet DFC using Option 1, have less conifer as a percent of total basal area than most stands in this analysis. The average % conifer across all stands for the core and inner zones, respectively is 80.3% and 90.1% (McConnell, Site and Stand Report, in Review) as compared to an average of 37.0 and 56.0, respectively, for these three stands (Table 4).

Table 4 – Attribute data for stands that are projected by the DFC Model to meet current DFC targets only is an Option 1 (thinning from below) timber harvest is implemented

Stand #	Site Class	Stream Size	Major Species	Core Zone % Conifer	Inner Zone % Conifer
24	3	L	D	35.8	55.3
104	3	L	H	45.6	38.6
22	2	L	D	29.2	74.7
Average				37	56

Stand # 22, on Site Class 2 (Table 3) also did not meet the DFC Target for Option 2 although, by virtue of Site Class and stream size it would be eligible for harvest using Option 2 if it qualified based on projected stand age 140 bapa. There were Model interactions that occurred with these stands, in particular Stand #22, that were not encountered in other stands, presumably because projected stand basal area is so near to the stand age 140 bapa targets for these stands. This DFC Model response is a model implementation result so is described here.

The DFC Model Option 1 responses to the stands that did not meet DFC unless Option 1 was projected are as follows. After pressing the "calc" buttons on the DFC Worksheet page and moving to the "Option 1 – Thinning from below" page, the projected basal area from each of these stands is highlighted in red, indicating that the stand does not meet DFC. The Model, therefore, already "knows", that by implementing Option 1, the stand will meet DFC. It "knows" this because all relevant Site Class and stand inventory information is contained within the Model, needing only a user to push the appropriate toggle to call up post-thinning outputs. For each of these three stands, after pushing the "suggest thinning" toggle, the projected stand age 140 bapa for each (barely) exceeded the DFC Target and the red highlighting on projected basal area went away. In stands that will not meet DFC even with a thinning from below, a different message appears informing users that the stand does not meet DFC and no projected basal area numbers are provided.

The DFC Model Option 2 response for the Site Class 2, large stream stand on which Option 2 would be allowed subject to the stand meeting the DFC Target were as follows. Going first to the "Option 2 – Leave trees closest to the stream" page yielded a message stating that DFC was not met and inner zone timber harvest could not occur. After going to the Option 1 page and pressing "suggest thinning" and returning to the Option 2 page, however, a different message appeared. This message indicated that DFC was met but, since the no-cut portion of the floor + inner zone width prescribed exactly matched the total inner zone, no inner zone timber harvest could occur using Option 2. Independent spreadsheet calculations of projected stand age 140 bapa also confirmed that this stand does not meet DFC using Option 2 thus, the Model is apparently programmed to reconcile differing abilities of stands to meet DFC using one prescription but not the other, in this case by making a distinction without a difference, e.g. indicating that Option

2 was allowed but that the no-cut portion of the inner zone exactly matched the full inner zone width, meaning no-cutting allowed.[21]

2. Option 1

Both rule components were found to be the primary constraint to timber harvest in some stands. The requirement for 57 inner zone leave tpa was the primary constraint on 142 of 150 (94.7%) stands, while the DFC Target was the primary constraint to timber harvest on 7 (4.7%) stands. On 1 (0.7%) stand, the leave tree requirement and the DFC Target constrained timber harvest equally (Table 5).

The first 7 stands in Table 5 have less basal area than is required to meet the DFC Target but still have more than 57 tpa even after one additional tree is removed. By the eighth stand (# 192) there is a substantial excess of basal area, and slightly more than 57 tpa calculated[22]. Stand # 199 was constrained by both basal area and the required number of leave tpa as both of these will be less than required if one additional tree were removed[23].

[21] Interestingly, the landowner selected Option 2 for this FPA even though DFC Printouts (that were referred to by the landowner in the FPA) indicated no inner-zone harvest was allowed. These messages were: "Inner Zone (50 to 120 feet), no harvesting allowed", and, "Clearcut Inner Zone (120 to 120 feet), Need 0 Riparian leave trees in this area". That Option 2 was selected and the FPA approved leads to questions as to whether landowners and DNR foresters know that Model results will sometimes require wider inner zone widths than the minimum allowed for Option 2 AND understand what is contained in DFC Worksheet printouts well enough to interpret the results accurately.

[22] The DFC Model prescription for this stand should have removed one more tree than it did. The number of tpa does not drop below 57 until two additional trees are removed beyond what the DFC Model reported. It is unclear why this error occurs and how often it may occur as the limits of DFC Model prescriptions were evaluated to this level of detail only on these 8 stands.

[23] Using the alternative method of using the DFC Model to evaluate stand response, tpa went below 57 while projected basal area just equaled required basal area. The projected basal area result does not have any decimal points so it is not known if this number was rounded. The DFC Model is designed to round "up", thus, using only the DFC Model the conclusion would be that tpa alone was the primary constraint.

Table 5 – DFC Model projected stand age 140 basal area (no-cut, required, and after thinning); harvest age leave tpa and the number of tpa and BA-140 that would be left if one more tree were cut; and the difference between projected BA-140 from BA-140 less one tree. The * indicates 55 stands in column 6 that have tpas of between 56.97 and 56.75. The ** indicates 83 stands with column 6 tpa values of between 56.73 and 52.47.

1	2	3	4	5	6	7	8
#	Inner Zone No-Cut Projected BA-140	Inner Zone Required BA-140	Inner Zone After Thin Projected BA-140	After Thin Tpa	After Thin Tpa if One More Tree is Cut	BA-140 if One More Tree is Cut at Harvest Age	Difference BA-140 with One Less Tree from Required BA-140 (Column 7 minus Column 3)
180	349	317	319	97.0	93.67	315.3	-1.7
263	207	264	265	73.1	72.98	263.9	-0.1
251	357	302	302	72.8	72.43	297.7	-4.3
195	353	288	289	71.5	70.66	286.6	-1.4
164	320	347	348	70.9	69.93	345.8	-1.2
295	306	254	254	64.9	64.35	250.9	-3.1
154	358	347	347	58.6	58.04	343.3	-3.7
192	386	160	255	58.0	57.04	250.4	90.4
173	355	144	252	58.0	57.04	247.7	103.7
228	414	125	394	57.2	57.02	389.4	264.4
166	370	260	327	57.5	57.01	321.8	61.8
299 *	373	198	269	57.2	56.98	263.8	65.8
199 **	349	272	274	57.6	56.74	270.0	-2.0

For almost all stands there was excess bapa even after cutting one additional tree and only a few stands required more than the required minimum number of trees in order to meet DFC targets (Figure 8). The stands that dip below 0 bapa in Figure 8 are the stands for which removing one more trees causes stands to fail to meet the DFC target because of lack of basal area. And, except for these few stands, the number of trees per acre remains constant while excess basal area amounts increase to the right, indicating that if the basal area target were the only constraint, additional trees could be cut if not limited by the minimum number of leave tpa required.

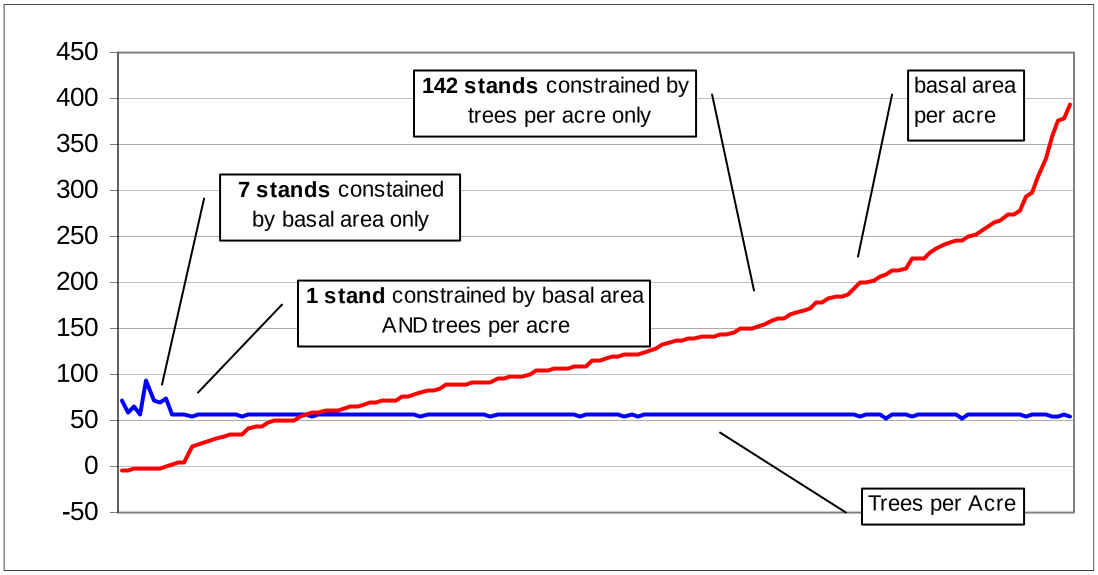


Figure 8 – The number of inner zone leave trees per acre vs. the difference between DFC Model inner zone "projected basal area" and "required basal area" at stand age 140, after removing one additional tree from the point at which DFC was met. Across the x axis are the 150 stands represented as point values (they appear as lines rather than points because of their number). Stand values for tpa and bapa match up by "stacking" points vertically. The y axis is, for trees per acre, in individual trees; for basal area per acre, it is in ft^2/acre. Stands are sorted by ascending basal area.

3. Option 2

For the Option 2 Prescription, the no-cut portion of the inner zone or "floor" that it is required to leave adjacent to the core zone was the dominant constraint to timber harvest on 63% of FPAs evaluated (68 of 108). The proportion of stands constrained by each factor varied by Site Class and stream size (Table 6). The average floor width also varied by Site Class and stream size. The average floor width for Site Class 1 small streams exceeded the widths for Site Class 1 large streams, despite the required minimum being 20' less. No Site Class 1 small stream stands had enough basal area to limit timber harvest by minimum floor width; wider widths up to the basal area target were required for each of these stands. The stand with the highest core zone to inner zone ratio, Site Class 3 small stream, had the lowest percentage of stands constrained by the basal area target. Almost all Site Class 3 small stream stands had excess basal area (a basal area credit) and timber harvest was constrained to the minimum width in 38 of 40 (95%) of these stands.

Table 6 – Rule component constraints to timber harvest for the leave-trees-closest-to-the-stream prescription, by Site Class and stream size.

Site Class	Steam Size	Floor Width	Average floor width plus and minus one standard deviation	Number of Stands Constrained by Floor Width	Number of Stands Constrained by Basal Area Target	Total
1	Small	80’	103.0 ± 12.6	0	5	5
1	Large	100’	102.0 ± 4.0	3	1	4
2	Small	80’	87.4 ± 7.1	7	25	32
2	Large	100’	102.6 ± 5.7	20	7	27
3	Small	80’	80.4 ± 1.8	38	2	40

Unlike the Option 1 prescription, it is not difficult to determine the factor constraining timber harvest on stands on which the Option 2 is used. Stands that are constrained by basal area have a wider inner zone than the minimum required and no basal area credit. Stands that are constrained by the minimum floor width will have a basal area credit and the floor width generated by the DFC Model will be the minimum allowed. Figures 9 through 13 show the distribution of floor widths and their accompanying basal area credits, by Site Class and stream size from which constraining factors were determined. For each figure, the number in the boxes marked as being in feet are, from left to right, the maximum and minimum widths. The boxes with no units are the basal area credit in ft^2/acre.

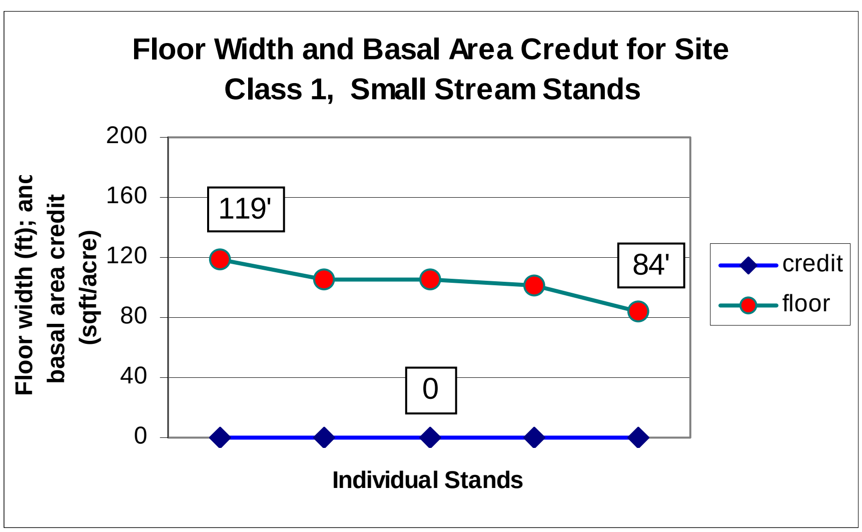


Figure 9 – Distribution of floor widths (feet) and basal area credits (ft^2/acre) for Site Class 1, small stream stands. Minimum floor width for small stream stands is 80’. Numbers in boxes marked in feet are, from left to right, the maximum and minimum

floor widths. The numbers that have no units are the basal area credit in ft²/acre. "n" = 5 for this Site Class, stream size configuration.

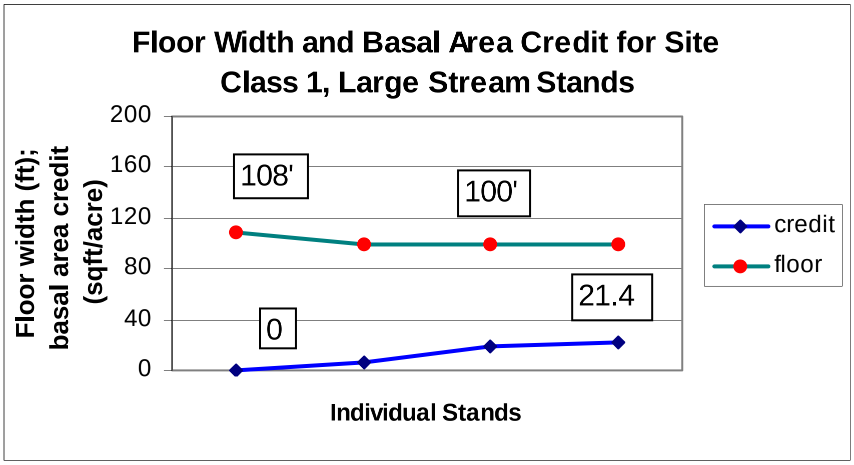


Figure 10 - Distribution of floor widths (feet) and basal area credits (ft²/acre) for Site Class 1, large stream stands. Minimum floor width for large stream stands is 100'. Numbers in boxes marked in feet are, from left to right, the maximum and minimum floor widths. The numbers that have no units are the basal area credit in ft²/acre, with minimum values on the left and maximum values on the right. "n" = 4 for this Site Class, stream size configuration.

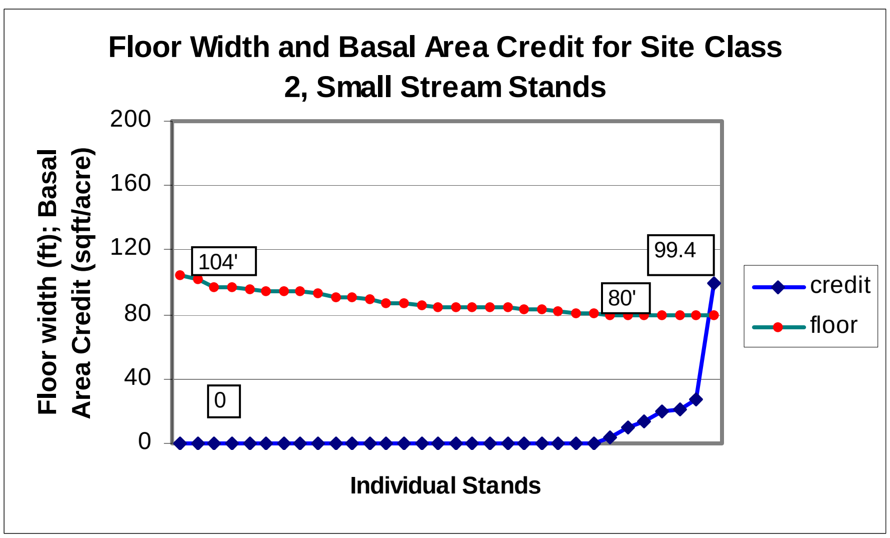


Figure 11 - Distribution of floor widths (feet) and basal area credits (ft²/acre) for Site Class 2, small stream stands. Minimum floor width for small stream stands is 80'. Numbers in boxes marked in feet are, from left to right, the maximum and minimum floor widths. The numbers that have no units are the basal area credit in ft²/acre, with minimum values on the left and maximum values on the right. "n" = 32 for this Site Class, stream size configuration.

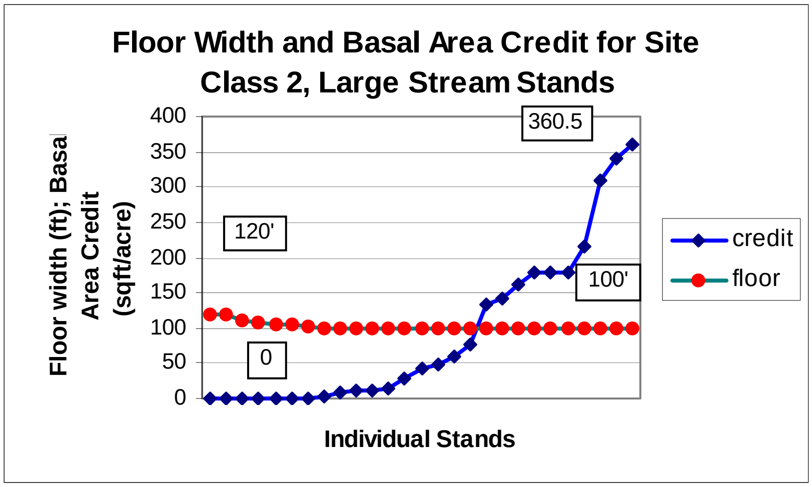


Figure 12 - Distribution of floor widths (feet) and basal area credits (ft^2/acre) for Site Class 2, large stream stands. Minimum floor width for large stream stands is 100'. Numbers in boxes marked in feet are, from left to right, the maximum and minimum floor widths. The numbers that have no units are the basal area credit in ft^2/acre, with minimum values on the left and maximum values on the right. "n" = 27 for this Site Class, stream size configuration.

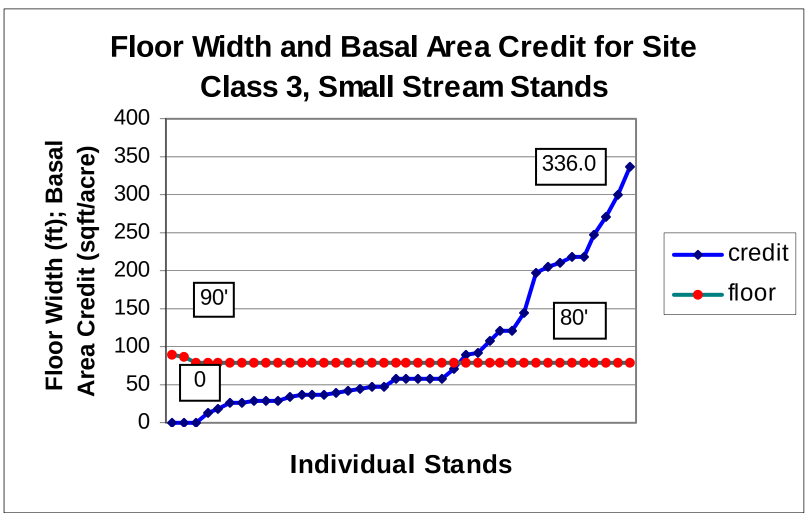


Figure 13 - Distribution of floor widths (feet) and basal area credits (ft^2/acre) for Site Class 3, small stream stands. Minimum floor width for small stream stands is 80'. Numbers in boxes marked in feet are, from left to right, the maximum and minimum floor widths. The numbers that have no units are the basal area credit in ft^2/acre, with minimum values on the left and maximum values on the right. "n" = 40 for this Site Class, stream size configuration.

PROJECTED STAND AGE 140 BASAL AREA PER ACRE

1. Mean BAPA across Site Classes, by prescription

The DFC Model projected mean bapa plus or minus one standard deviation, at stand age 140, for all 150 FPAs for the no-cut and Option 1 prescriptions are respectively, 366.3 ± 45.3 and 335.9 ± 46.5 (Figure 14). The mean bapa for the 108 FPAs meeting the Site Class and stream size criteria for the Option 2 prescription was 301.1 ± 40.8. The value for Option 2 considers only the core +no-cut "floor" portion of the inner zone. If the basal area of the 20 leave tpa (12" minimum dbh) in the outer part of the inner zone are included, mean bapa for the Option 2 prescription is 333.0 ± 31.4 (Figure 14).

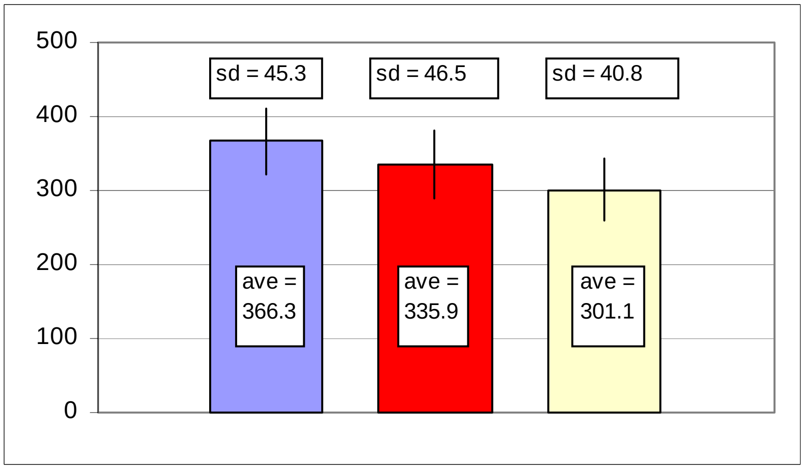
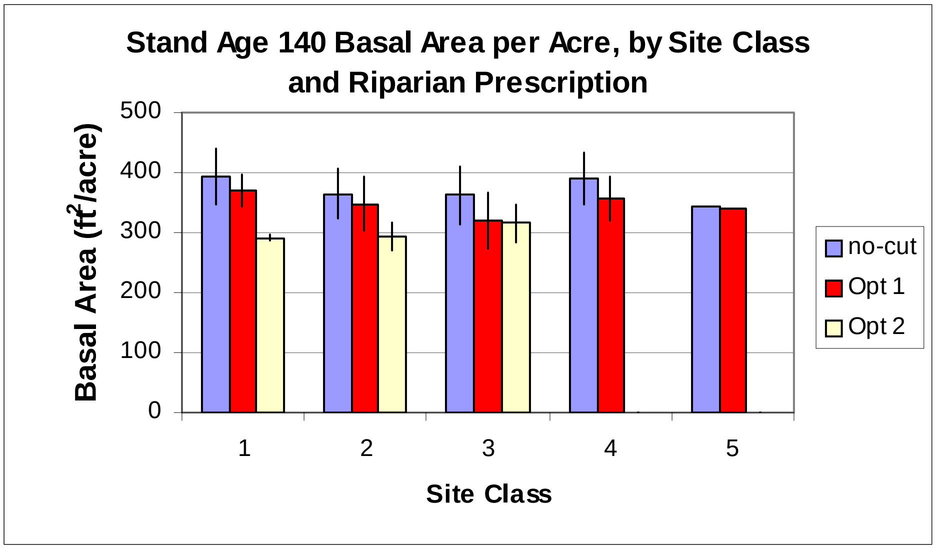


Figure 14 – DFC Model projected mean basal area per acre (bapa) at stand age 140 for, from left to right, the no-cut, Option 1 and Option 2 riparian prescriptions, across all Site Classes. The error bars are one standard deviation. The values on bars are DFC Model projected stand age 140 mean basal area per acre. For the no-cut and Option 1 prescriptions, n = 150; for Option 2, n = 108.

2. Mean bapa by Site Class and prescription

Mean values and one standard deviation from the mean for all three prescriptions are presented in Figure 15 with the trees for the outer part of the inner zone (Option 2) excluded and in Figure 16 with these trees included. There is no standard deviation reported for Site Class 5 because there was only one stand with this Site Class. There are no bapa reported for Option 2 on Site Classes 4 and 5 as this prescription is not used on these Site Classes. No statistical analysis has been conducted to determine whether differences observed between means by prescription are statistically meaningful so any interpretation users may make of trends observed are, necessarily, the limited to ocular estimates.



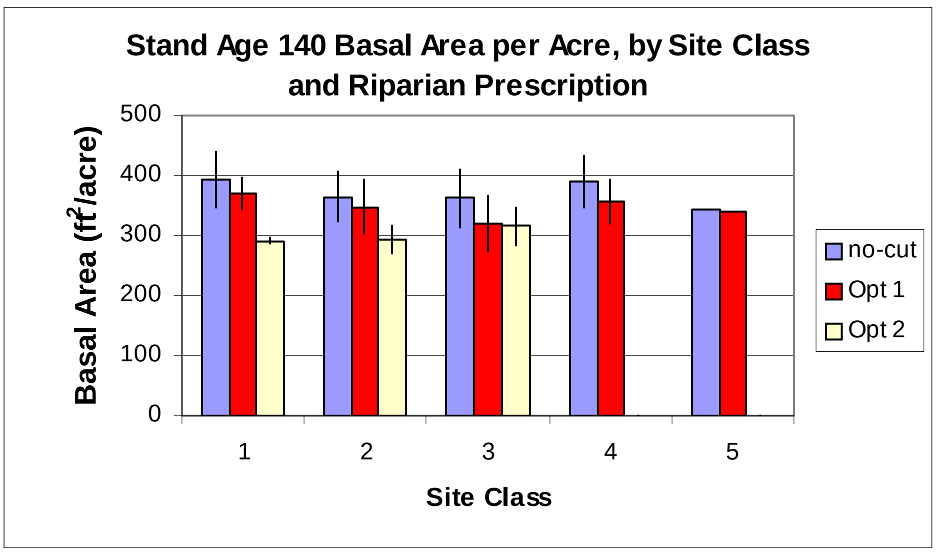


Figure 15 (top) and Figure 16 (bottom)- DFC Model projected mean basal area per acre (ft^2/acre) at stand age 140 for the no-cut, thin-from-below (Option 1) and leave-trees-closest-to-the-stream (Option 2) prescriptions, by Site Class. The error bars show one standard deviation. Sample size (n) are as follows: Site Class 1 (9); Site Class 2 (59); Site Class 3 for the no-cut and Option 1 prescriptions (74), for the Option 2 prescription (40); for Site Class 4 (4), for Site Class 5 (1). The Option 2 prescription is not permitted on Site Class 4, 5 and 3-large stream. In Figure 15 (top) the Option 2 results consider only the core + floor portion of the inner zone; they do not include trees in the outer part of the inner zone. In Figure 16 (bottom) the Option 2 results include trees in the outer part of the inner zone.

The highest mean bapa projected was 393.3 ± 46.7 for a no-cut treatment on Site Class 1 (Figures 15 and 16). The lowest mean bapa projected was 287.9 ± 5.7 on Site Class 1 for Option 2 with trees in the outer part of the inner zone not included (Figure 15). Where trees from the outer part of the inner zone are included, the lowest mean bapa is 320.8 ± 46.0 for Option 1 on Site Class 3 (Figure 16). Variability is relatively low compared to mean values for all Site Classes and prescription's (Figures 15 and 16). The no-cut prescription had the highest variability across all Site Classes. Option 2 had the least variability.

3. Distribution of Stand Age 140 Basal Area by Site Class and Stream Size

There are apparent differences in DFC Model projected stand age 140 bapa values by prescription, Site Class and stream size (Figure 17) for stands that are on Site Classes 1, 2 and 3, small stream, with trees in the outer part of the inner zone included. Relying on ocular estimates only, the no-cut prescription has a higher projected stand age 140 bapa than does Option 1 or Option 2 for Site Classes 1 and 2 (large stream) and Site Class 3 (small stream). Option 1 stand age 140 bapa is most variable across all Site Class/stream size combinations. Option 1 and Option 2 stand age 140 bapa values track closely on Site Class 2 (large stream) and Site Class 3 (small stream). The no-cut prescription and Option 1 track more closely on Site Class 2 (small stream).

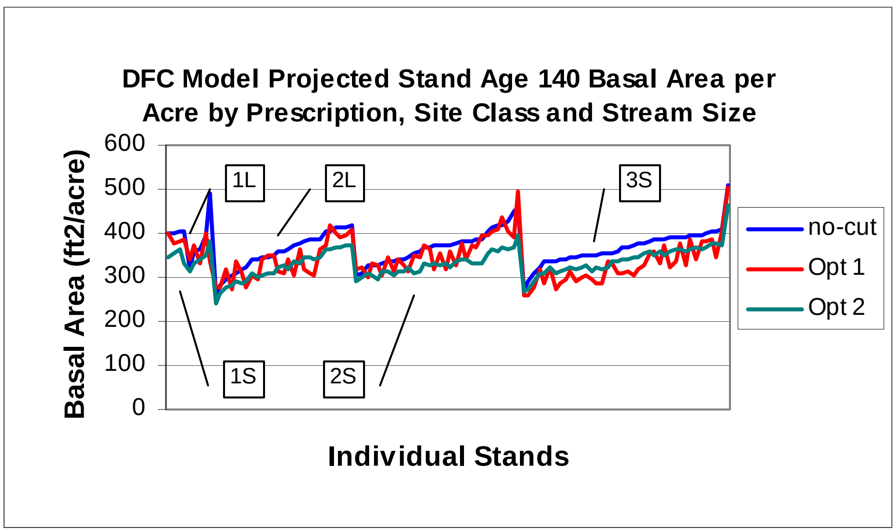


Figure 17 – Stand Age 140 basal area per acre (ft^2/acre) for the no-cut, thin from below (Option 1) and leave trees closest to the stream (Option 2) riparian prescriptions, by Site Class and stream size. Boxes show Site Class as a numeric value and stream size (L = large or S = small); the arrows point to the region on the figure where stands for each Site Class, stream size combination reside. Stands are sorted by Site Class, stream size and ascending basal area per acre for the no-cut prescription. Sample size (n) are as follows, by Site Class and stream size: 1L (4); 1 S (5), 2L (27); 2S (32), 3L (34); 3S (40). The Option 2 Prescription is not permitted on Site Class 4, 5 and 3-large stream. The Option 2 results include the core + floor portion of the inner zone and trees in the outer part of the inner zone.

DISCUSSION

RULE COMPONENT EFFECTS TO TIMBER HARVEST ALLOWED

1. The no-cut riparian prescription

The DFC Model responds to site attributes and stand inventory it is provided. Thus, it is the characteristics of this input data that explain why these stands meet DFC only if a thinning from below is implemented. This could be demonstrated by making a formal analysis of Model calculations or by comparing against empirical data from other Model runs but both approaches are outside the scope of this report. However, the responses observed are logical from a silvicultural perspective. These three stands had low percentages, as compared to other stands, of conifer in the core and inner and inner zones (Table 4). Two of these three stands were among the 7 that required that more than 57 tpa be left when a thinning from below was implemented (see Option 1 results).

Without thinning to release inner zone conifers, the DFC Model maintains the basal area occupied by hardwoods in hardwood trees over the short term. The DFC Model, however, is programmed to "kill" hardwood over time (Welty (date unknown) in Fairweather (2001), Appendix B, p. 6), thus hardwood basal area eventually decreases and stand basal area with it. Conifers that would have occupied this growing space are suppressed or crowded out by the hardwoods and are no longer present, or are no longer in a condition to respond vigorously to increased light when hardwood trees die later in the rotation, or do not have enough time following release to reach the required target basal area by stand age 140.

With a thinning from below, however, more growing space is allocated to conifers while they are still present, still vigorous and while there is still time to add growth before the DFC target age. Conifers occupying more of the site causes the Model to allocate more modeled basal area growth to conifers. Further, the DFC Model projects a positive (enhanced) response to thinning from below if there are core and residual inner zone conifer trees on which basal area growth can accrue. The net result is that stands that were projected to be below the DFC target with no inner zone timber harvest, are projected to meet DFC by implementing Option 1. While the modeling effect is logical from silvicultural perspective, it is not known how well Model simulations reflect the actual effect of thinning treatments or competition between hardwood and conifer trees as these have not yet been validated.[24]

2. Option 1

DFC Model outputs are narrowly structured to provide landowners the information they need to implement DFC Rules. They are not, however, broadly informative for other uses. For example, the DFC Model reports the number of inner zone trees that must be left after pressing the "suggest thinning" toggle in two places on the "Option 1" page. One is on the graphic where the number reported is in absolute numbers, not on a per acre

[24] These stands also pose an interesting Policy question. Since DFC is met on these stands ONLY if a thinning from below is implemented, does that mean that a treatment that does not result in meeting DFC should not be allowed? In this case, the no-cut treatment is not projected to meet DFC so, is inner zone thinning required?

basis. This number is always rounded up[25], thus with any fraction above an integer for a tpa calculation, the number or required inner zone trees was rounded to the next highest integer. The other place the required number of leave trees is reported is in the Table on the right side of the "Option 1" page of the Worksheet, where it is reported on a per acre basis.

In both places, the number of required trees is not very useful to a limiting constraints analysis. The absolute (as opposed to per acre) number of trees reported on the graphic, having been rounded up, are already an over-estimate of tpa. Further, for both numbers, the size of stands can have a profound effect on the number of trees reported. For example, one tree on the DFC Model graphic can represent as many as 9.2 tpa[26] in very small stands or as few as 0.11 tpa in large stands. Thus, depending on the size of the stand, calculations made for inner zone post-harvest tpa could exceed 57 by as much as 9.2 trees while the constraining element in rules may in fact be tpa (that is, if one more tree were removed, the stand would fall below 57 tpa), even for stands on which the reported per acre trees exceeds 60.

Further, the link between the link between the "Projected Basal Area at age 140 as % of DFC" for the core and inner zones on the Worksheet page of the DFC Model to the Projected and Required, respectively, Basal Area for the inner zone only on the Option 2 page of the DFC Model is confusing at best. Even if understood, in instances where projected basal area was at or near required basal area such that it was possible to determine that basal area was limiting, it was not possible to determine if the constraint had been the basal area target or if the tpa value reported exceeded 57 in order for DFC to be met.

These problems were solved by working outside the Model to calculate the effect of removing one additional tree and determining the effect of that to bapa and tpa in regards to which dropped below the required target value. Using this approach, it was possible to discern which was the primary constraint to timber harvest.

3. Option 2

Determining which rule component was the primary constraint to timber harvest was much easier for Option 2 than for Option 1. Where there was a basal area credit and the inner zone width was limited to the no-cut floor width, the primary constraint to timber harvest was the required floor width that. Where the no-cut portion of the inner zone extended beyond the required minimum floor width and there was no basal area credit, the DFC target constrained timber harvest.

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[25] It was found that the number reported in the graphic was inaccurate almost half the time (49.3%) and did not accurately reflect the number of inner zone leave trees that were reported in the spreadsheet below the graphic. When there was an error, the error amount was always 1, and the result was that more trees than should have been were reported. The effect of the error would have been to cause landowners to leave more, not less, trees than were required to meet the prescription. This error is described in more detail in the "Model and Manual" report (McConnell, in review).

[26] Using the data from the 150 stands used in this analysis. Obviously, the tpa represented by one tree can be still higher if stand sizes are smaller than the 87' RMZ length that was the minimum for this data set.

The outcome of this analysis demonstrates characteristics of Rules for Option 2 that may have been unintended, for example, the effect of the core to inner zone ratios to the likelihood of a stand meeting the DFC Target. Where the no-cut portion of the inner zone is large as compared to the core + floor portion of the stand as in for example Site Classes 1 and 2, small stream configurations, more stand area (wider no-cut portion of the inner zone) must be added in order for the DFC Target to be met. Where the no-cut portion of the stand is small as compared to the core + floor portion of the stand as in for example, Site Class 2, large stream and (especially) Site Class 3, small stream, timber harvest is almost always constrained by the floor width rather than the need to add width to increase basal area up to the target level.

PROJECTED STAND AGE 140 BASAL AREA PER ACRE

There were no statistical analyses done to compare DFC Model projected results for each prescription to each other, to DFC Targets or to the results of other studies. Outcomes are instead reported graphically, with error bars marking one standard deviation where applicable.

Recognizing that statistical certainty is lacking, there are some trends that it may be useful to investigate further. For example, DFC Model stand age 140 bapa projected values by Site Class exceed the DFC Target values set in Rules. For Options 1 and 2, this effect is caused by the constraint imposed by rule components other than the basal area target for each prescription.

Predicted average stand basal areas by Site Class at age 140 are similar to the basal area values that were measured in the DFC Target Validation study (Schuett-Hames et al., 2005). The DFC Target Validation study was a field study in which data was collected from mature, unmanaged, conifer-dominated riparian stands along Type F streams in western Washington. In the DFC Target Validation Study, a bapa mean value of 333.8 ft^2/acre was measured for Site Class 2 stands. The DFC Model projected mean bapa values for Site Class 2 stands were 364.4 for the no-cut prescription, 347.2 for Option 1 and 330.3 for Option 2 (with trees in the outer part of the inner zone included). For Site Class 3, the DFC Target Validation study mean bapa value was 307.7 ft^2/acre, while for the Desktop Analysis values were 362.6 for the no-cut prescription, 320.8 for Option 1 and 339.8 for Option 2 (the Option 2 value is only for stands along small streams and includes trees in the outer part of the inner zone). For Site Class 4, the DFC Target Validation study mean bapa value was 353.1 ft^2/acre while for the Desktop Analysis, the values were, for the no-cut prescription 389.3 and for Option 1 357.0 (Option 2 is not allowed on Site Class 4). The DFC Target Validation Study had only one site for Site Class 5 and there was only one Site Class 5 site in the Desktop Analysis so values for these Site Classes are presented.

It is important to recognize the differences between the DFC Target Validation Study and the Desktop Analysis. First and foremost, the DFC Target Validation study collected field data while the Desktop Analysis uses a Model of uncertain reliability to project stand growth. Additionally, there are a number of uncertainties as to whether DFC

Model projected outcomes are reliable. The most important of these is that the effect of windthrow on abruptly opened riparian stands is not known; windthrow can account for significant mortality in riparian buffer stands. No commonly used stand growth model was calibrated using data that were highly prone to windthrow, thus even if it is found that DFC Model results compare favorably to other models, it will remain uncertain how riparian buffers grow in comparison to the intact, interior stands from which other commonly used growth models were developed. It is also uncertain how closely landowners implement timber harvest in comparison to DFC Model prescriptions. Differences in treatment can affect stand trajectory. Lastly, it is not known how much ingrowth there may be in riparian stands from newly regenerated trees or from trees with dbh's less than 5.0" at the time riparian stands were inventoried. Careful review of the Caveats and Assumptions in this report is important to interpreting the results of this study, in particular the comparison made against DFC Targets in Rules and the results of the DFC Target Validation Study (Schuett-Hames et al. 2005).

Other trends are apparent from a graphic analysis but of unknown reliability statistically. For example, the no-cut prescription usually has the highest stand age 140 bapa, but sometimes Option 1 values surpass the no-cut prescription values. Option 2 consistently has the lowest stand age 140 bapa values although if the trees in the outer part of inner zone are left in a dispersed pattern, the difference between this prescription and the others is less, and it is greater than the Option 1 prescription on Site Class 3.

Projected stand age 140 bapa values are influenced by a number of factors including different Site Class/stream size configuration core to inner zone ratios, DFC Targets that change with Site Class in addition to differences in stand composition and structure. The differences in Option 2 core zone, inner zone and floor width ratios appears to affect projected stand age 140 bapa and therefore prescriptions for current stands. For example, on both Site Class 1 and Site Class 2 small streams, most stands managed under Option 2 need to expand the no-cut portion of the inner zone in order to meet the DFC Target. The result of this is that for most stands with these configurations, the projected stand bapa will just equal the stand age 140 bapa target, exceeding it slightly in instances where there are enough trees in the outer part of the inner zone to make a difference in projected stand age 140 bapa.

For Option 1, the high residual basal area that comes from leaving the 57 largest trees on the site and the release effect from thinning from below keep projected stand age 140 bapa in the same range of values for most stands, as for the no-cut prescription. For Option 2 Site Class, stream size configurations, for example Site Class 2 / large stream and Site Class 3 / small stream, that have a high proportion of the stand in the no-cut (core and minimum floor) portions of the stand, the difference in DFC Model projected stand age 140 bapa between Option 2 and the other prescriptions is less (based on ocular estimates of graphed values in Figure 17). This result occurs because the core+floor bapa values are a greater proportion of stand area and these stands will often have excess basal area on to which the Model projects additional growth (and will have growth on trees in the outer part of the inner zone where this is included in calculations).

CONCLUSIONS

These analyses demonstrated that the DFC Basal Area Target was a less consequential constraint on timber harvest amount, than other rule components. For Option 1, the 57 required inner zone leave trees per acre that result from a thinning from below was the usually the primary constraint to timber harvest amount.

For Option 2, the required minimum floor widths was also more often the primary constraint, although its effect varied by Site Class and stream size. The higher Site Class stands have higher DFC Target values and lower core+floor ratios in relation to core+inner zone widths and are thus more often constrained by the DFC (basal area) Target as wider no-cut inner zone widths are required to increase area-adjusted basal area to the Target required. This is especially true along small streams. Stands with lower Site Class (Site Class 3) have more favorable core+floor ratios in relation to the core+inner zone as well as having a lower DFC (basal area) Target. Site Class 3 stands therefore almost always are constrained by the minimum required floor width and excess basal area, expressed as a basal area credit.

The result of the constraints to timber harvest amount was that, on average, more trees are left using both Option 1 and Option 2 than are required to meet the DFC Targets. The DFC Model projected stand age 140 bapa values that result, therefore, on average exceed the DFC Targets and were similar to the measured values obtained for Site Classes 2, 3, and 4 from the DFC Target Validation Study. The no-cut prescription almost always resulted in stands that met DFC but a few stands required active management in order to meet the DFC Target.

There remain uncertainties about the reliability of the DFC Model, how it compares against other growth and yield models and how well any model performs in stands that can reasonably be expected to be subject to high mortality from the effects of windthrow.

This report concludes with some bullet conclusions that may be useful for considering some of the details of this report.

1) The current rule basal area targets are rarely the limiting factor in determining how much timber can be harvested from the inner zone for Option 1. Only 5.3% of stands evaluated required that more than the minimum number of trees be left in order for basal area targets to be met.
2) The basal area target constrained inner zone timber harvest on 40 of 108 Option 2 stands (37%). On these stands, there was no basal area credit and the no-cut portion of the inner zone had to be increased in order for the DFC Target to be met.
3) For the Option 2 Prescription, the minimum inner zone “floor” width constrained timber harvest on 68 of the 108 (63%) stream segments evaluated.
4) For Option 2, high Site Class, small stream stands are more likely to require extending the no-cut portion of the inner zone above the minimum required than are low Site Class, large streams stands.

5) Of the 150 FPAs evaluated, 108 (72%) could be managed using the Option 2 Prescription.
6) The 57 leave trees required in the inner zone (Option 1) and the floor widths (Option 2) constrain harvest such that the DFC Model projected growth stand age age 140 bapa values exceed DFC Targets.
7) In general, the highest mean stand age 140 bapa projected by prescription was from the no-cut prescription, intermediate was Option 1 and the lowest stand age 140 bapa was projected for Option 2.
8) There was little difference in DFC Model projected stand age 140 bapa by Site Class for any of the presriptions.
9) The projected results from the Desktop Analysis for Site Classes 2, 3 and 4 were similar to the results measured in the DFC Target Validation Study (Schuett-Hames et al. 2005).
10) There is a long list of caveats and assumptions that need to be considered carefully in interpreting the results of this report.

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GLOSSARY

BAPA – Basal Area Per Acre in ft^2

CMER – Cooperative Monitoring, Evaluation and Research Committee

Core Zone – One of three Riparian Management Zones designated by Rules. Closest to the stream. Always 50' wide. No timber harvest is allowed in the core zone.

DFC – Desired Future Condition

DFC Model – A computerized growth and yield model that projects stand basal area growth to age 140 (negotiated age of a "mature" forest) to determine whether a given stand may be entered for timber harvest and, if so, analyzes site and stand data to provide landowners harvest prescription details

FFR – Forest and Fish Report

FPARS – Forest Practices Application Review System. Section on DNR's website used to obtain information about Forest Practices Applications. Contains Site Class maps landowners need to fill out their FPAs. Provides a means to search for FPAs of interest and review them in .pdf files.

Floor – The minimum no-cut portion of the inner zone. Defined by width, it extends either 30' (small stream) or 50' (large stream) from the outer edge of the core zone into the inner zone. The width of the no-cut floor can exceed these minimum distances as per rules and DFC Model outputs, but they cannot be less than these minimum amounts under current rules.

Inner Zone – The zone that lies between the core zone (next to water) and the outer zone (next to the upslope timber harvest area). The characteristics of the inner zone, along with the core zone, are considered in the DFC Model calculations that determine whether inner zone timber harvest can occur and the specific requirements of that harvest if allowed.

Large Stream - > 10' bankfull width

Option 1 – A riparian stand timber harvest prescription that allows for thinning from below in inner zone trees.

Option 2 - A riparian stand timber harvest prescription that mandates leaving inner zone trees that are closest to the water and cutting trees in the outer part of the inner zone down to a density of 20 tpa

Outer Zone – The outermost (furthest from the stream) of the three designated riparian management zones. Outer zone width varies with Site Class and stream size. More activity is allowed in the outer zone than in core and inner zones.

RMZ – Riparian Management Zone

SAG – Scientific Advisory Group

Site Potential Tree Height – The expected height of a tree at stand age 100 for a given Site Class. For Forest Practices Rules on the west-side, Douglas-fir growth was used to determine SPTH.

Small Stream - ≤ 10' bankfull width

SPTH – Site Potential Tree Height

Stream size – Determined by measuring the bankfull width of a stream and determining if it is less than or equal to 10' (small stream) or greater than 10' (large stream)

TFW – Timber Fish and Wildlife

TPA – trees per acre

Type F – A fish-bearing stream in Washington Forest Practices Rules

West-side – western Washington as defined by Forest Practices Rules