Oregon Department of Forestry

"STEWARDSHIP IN FORESTRY"

Economic Impact Analysis

Introduction

In November, 2015 the Oregon Board of Forestry (Board) voted to adopt new stream protection rules for small and medium salmon, steelhead, or bull trout ("SSBT") streams in the Coastal, South Coast, Interior, and Western Cascade geographic regions (See OAR 629-635-0220 for definition of geographic regions). The decision was based on achieving Oregon's Protecting Cold Water Criterion of the temperature standards to the maximum extent practicable as adopted by the Environmental Quality Commission (OAR 340-041-0028(11)).

The following information is provided to meet the requirements of ORS 527.714(7). Prior to the close of the public comment period, the Board must prepare and make available to the public a comprehensive analysis of the economic impact of the proposed rule change. The analysis is comprised of a macroeconomic analysis required in sections (7)(a) through (c) and a microeconomic analysis in section (7)(d). The analysis is being conducted in coordination with Oregon State University (OSU) and the University of Oregon (UO).

The analysis is required by ownership and geography. The ownership categories considered in this analysis are private industrial and private non-industrial (when applicable). The geographic region for impact analysis is all of Western Oregon (the Cascades are used as our geographic boundary). However, the scenarios used in the model only included rule changes for the four geographic regions to which the rule applies.

A Log Market Model (LMM) developed by Darius Adams, PhD and Greg Latta, PhD at OSU was used to estimate the change in harvest, log prices, and product output in Western Oregon given the rule change criteria (a detailed description of the Log Market Model can be found in Appendix A). A portion of the raw data used in the model for volume estimates is based on data collected by the United States Forest Service Forest Inventory and Analysis (FIA) program. In the previous decade, FIA changed their methodology regarding how data is collected for each plot. One major change was the design of the plot layout from five to four sub-plots. With this change, ODF was not able to reconcile its stream layer in relation to the new FIA sample frame. Due to this, ODF and OSU used the last complete cycle of FIA data collection that relied on the five-point sample frame so that there would be an adequate overlay of FIA plots on the stream layer being used.

The LMM used two scenarios to estimate change in silvicultural regimes due to rule changes:

> Base Riparian Policy (Current Rule): no cut buffer of 23 horizontal feet on small fish bearing streams and 41 horizontal feet on medium fish bearing streams (i.e., average no-cut buffer under current policy).
>
> New Riparian Policy (New Rule): no cut buffer of 54 horizontal feet on small fish bearing streams and 72 horizontal feet on medium fish bearing streams (uses average horizontal distance, assumes no active management).

The results of the LMM are for the two policies if applied to all small and medium fish-bearing streams in the geographic regions of interest. A ratio was then applied (as a range) to the results to show the impact on streams classified as Salmon, Steelhead, and Bull-trout (SSBT). The range (25 to 35%) estimates the percent of many small and medium fish-bearing streams likely to be classified as SSBT based on work done by Department of Forestry.

Appendix B of this report describes the challenges and issues that arose using FIA plots to represent the area affected by the rule change. Further, the note in Appendix B shows how the plots and the acres represented by FIA were reconciled with data independently collected by ODF. Due to the limited number of FIA plots in the area of interest, all plots that met the criteria as small and medium fish bearing streams were used in the analysis. If the plots associated with Salmon, Steelhead, and Bull Trout (SSBT) were solely used, there would not have been enough plots for the analysis.

Required Analysis

ORS 527.714 (7): If the Board determines that a proposed rule is of the type described in subsection (1)(c) of this section, and the proposed rule would require new or increased standards for the forest practices, as part of or in additions to the economic and fiscal impact required by ORS 183.335(2)(b)(E), the Board shall, prior to the close of the public comment period, prepare and make available to the public a comprehensive analysis of the economic impact of the proposed rule. The analysis shall include but is not limited to:

ORS 527.714(7) (a) an estimate of the potential change in timber harvest as a result of the rule;

Table 1 shows the decrease in 20-year annual average private harvest between the current rule (CR) and the proposed new rule for SSBT streams.

Table 1. Change in 20-year annual average private harvest between current rule and the proposed new rule

Riparian Policy	Industrial	Non-Industrial	Total
	20-year average annual softwood harvest (mbf)		
Model Results for ALL Small and Medium fish-bearing streams			
Current Rule (CR)	1,965,380	576,419	2,541,799
New Rule	1,946,560	567,268	2,513,828
Change	18,820	9,151	27,971
% Change	-0.96%	-1.59%	-1.10%
Change for SSBT (25 to 35% of Small and Medium fish-bearing streams)			
Change if SSBT is 25%	4,705	2,288	6,993
% Change from CR	-0.24%	-0.40%	-0.28%
Change if SSBT is 35%	6,587	3,203	9,790
% Change from CR	-0.34%	-0.56%	-0.39%

The upper half of the table shows the results from the LMM if the proposed new rule applies to all small and medium fish-bearing streams. In this case, the average total potential decrease in timber harvest is slightly above one percent. The lower portion of the table shows results when scaled to SSBT stream.

The proposed new rule creates an estimated loss of approximately 7.0 to 9.8 mmbf (0.3 to 0.4 percent decrease) in annual harvest given the possible range of SSBT (25 to 35% of small and medium fish-bearing streams).

ORS 527.714(7)(b) An estimate of the overall statewide impact, in output, incomes, and employment;

The results in Table 1 are used with input-output analysis (IMPLAN) to determine the statewide, in this case – Western Oregon, impact on employment and income (Table 3). In IMPLAN, the total economic impact per million board feet harvested was estimated for western Oregon counties. This was done by calculating the 'jobs number' based off of total economic output (i.e. value of the material produced) for the sector and a knowledge of what was actually produced in Western Oregon gained from Western Wood Products Association and APA – The Engineered Wood Association. The overrun for lumber (assumed to be approximately 2.1) and the conversion factor for square feet to board feet when dealing with plywood production (assumed to be approximately 0.8633) were used to figure out a final product demand price per million board feet of timber[1].

Once the final product demand prices for lumber and plywood are calculated, they are used along with an estimate of residual demand to estimate how many jobs are associated with one million board feet of timber harvested (along with compensation). This number is 8.9 jobs per million board feet, which is then used as a scalar for the potential loss in harvest from Table 1 to calculate values in Table 2.

Table 2. Estimate of Reduction in Jobs and Employee Compensation by Potential Change in Rule for SSBT

	Jobs Affected	Compensation
Change if SSBT is 25%	62.24	$3.81 million
Change if SSBT is 35%	87.13	$5.33 million

For the statewide economic impact, the LMM estimates a decrease in net social surplus from approximately $45.97 billion to $45.87 billion for a total decrease of $99.3 million. Net social surplus in this context can be viewed as a loss in profits (producer surplus) and in the consumer's willingness to pay verses the market price (consumer surplus). The change in net social surplus also captures changes in the land value since it is part of the model's acreage constraint (there is a value change in taking away or adding a given acre of forest land to the model). Taken all together, the approximate loss of $99.3 million (a decrease of .22% in net social surplus) is the loss in profits, land values, and consumer surplus.

[1] This also relies on an estimate of how much of a log goes to lumber and plywood production (approximately 80% and 20%, respectively).

ORS 527.714(7)(c) An estimate of the total economic impact on the forest products industry and common school and county forest trust land revenues, both regionally and statewide;

It is expected that there will be no effect on common school and county forest trust lands. This is due to two reasons:

1) the assumption that the rule will not affect these lands and management practices will remain unchanged, and
2) the change in prices is not substantial enough to affect timber harvest on these lands.

The estimated decrease in harvest depicted in Table 1 will lead to changes in production of lumber and plywood. These changes are presented in Table 3.

Table 3. Change in 20-year annual average lumber and plywood production between current rule and the proposed new rule

Riparian Policy	Lumber	Plywood
	(mbf) - 20-year annual average - (msf)	
Model Results for ALL Small and Medium fish-bearing streams		
Current Rule (CR)	6,066,420	3,338,456
New Rule	6,039,871	3,304,036
Change	26,549	34,420
% Change	-0.44%	-1.03%
Change for SSBT (25 to 35% of Small and Medium fish-bearing streams)		
Change if SSBT is 25%	6,637	8,605
% Change from CR	-0.11%	-0.26%
Change if SSBT is 35%	9,292	12,047
% Change from CR	-0.15%	-0.36%

ORS 527.714(7)(d) Information derived from consultation with potentially affected landowners and timber owners and an assessment of the economic impact of the proposed rule under a wide variety of circumstances, including varying ownership sizes and the geographic location and terrain of a diverse subset of potentially affected forest parcels;

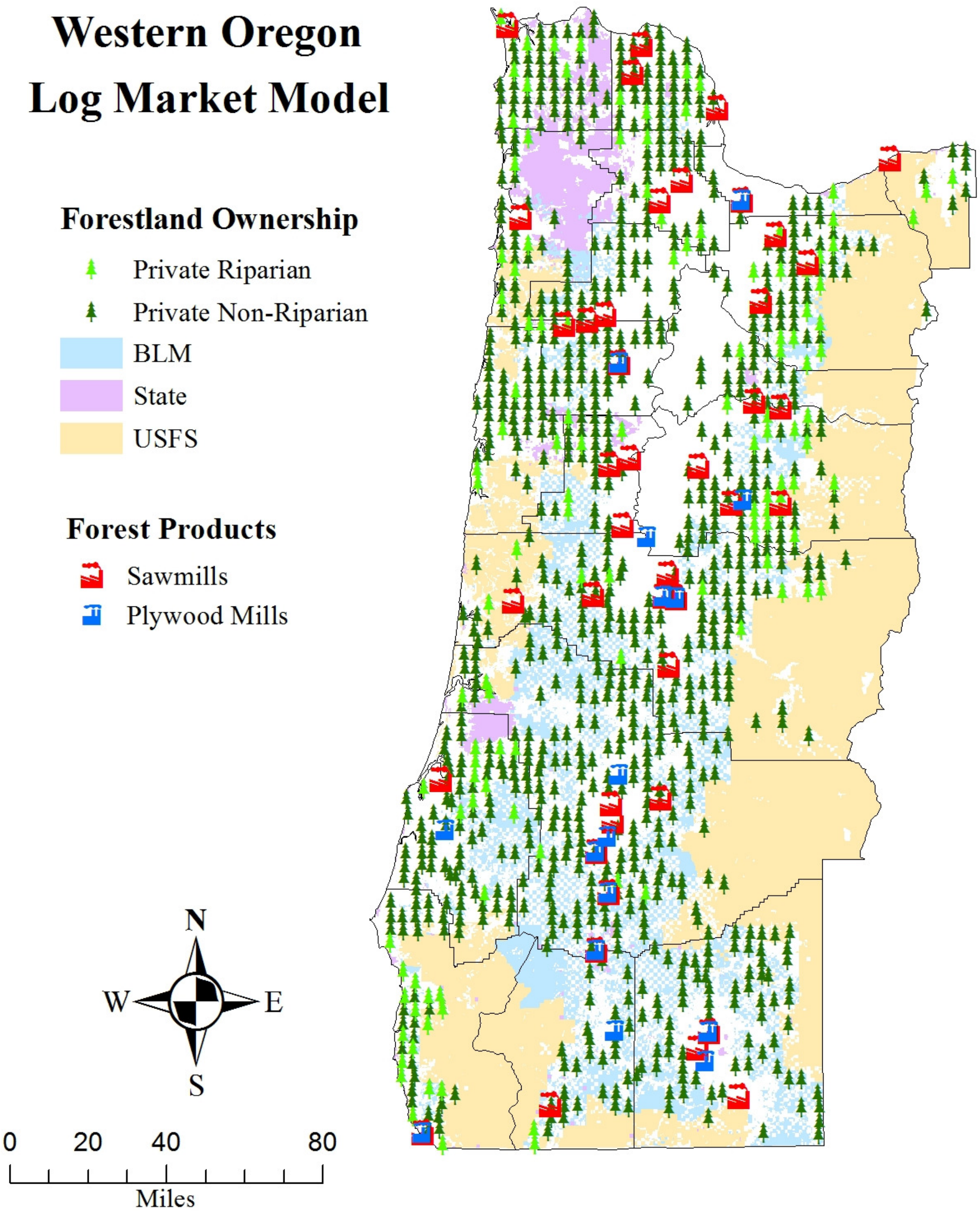
A research agreement has been entered into with UO to support ODF in fulfilling ORS 527.714(7)(d). The project titled, "Analysis of landowner perceptions regarding potential changes to riparian rules for the Oregon Department of Forestry," is being led by Cassandra Moseley, PhD, Research Professor and Director, Institute for a Sustainable Environment.

Dr. Moseley is using a Dillman multi-contact method survey. Her team prepared the methodology and survey instrument with ODF support. They will be in charge of administering the survey, compiling the results, and preparing a report that will be due by November 1, 2016.[2]

[2] The survey was mailed out in May 2016.

Appendix A

Study Region



Methods

Studies of future timber market potential have five basic components: (i) inventory data describing the lands of interest, (ii) assumptions about likely future silvicultural regimes to be applied to these lands, (iii) projections of future timber yields under the several regimes, (iv) assumptions about changes in timberland area through gains or losses to other uses or owners, and (v) a model that projects future harvests based on inventory and other assumptions, applies the management regimes, and updates the inventory over time. A detailed description of the linear programming model representing the western Oregon log market is provided in the Log Market Model Appendix. The following section outlines the five basic components above referencing the specific variables, parameters, and equations[3] from the appendix.

Inventory

The spatial distribution including timber inventory acreage and volume for all western Oregon forest land is based on the U.S. Forest Service's Forest Inventory and Analysis (FIA) annual inventory.

Current and Future Silviculture: Management Intensity Classes

A management intensity class (MIC) is a regime of silvicultural activities applied over the life of a stand. In our analysis, stands are classified as either: (i) "existing", those that are part of the original inventory at the start of the projection; or (ii) "new", and those that are regenerated during the projection. MIC's employed for both groups are summarized in Table 1. For the FIA plots in the log market model there are seven MIC's for existing stands and eight for new stands. The same stocking limits shown in the upper portion of the table for PCT and CT are applied in both new and existing stands. The shaded MICs in Table 1 are not used in the market model runs to reduce the size of the linear programming problem.

[3] For the purposes of this report a parameter is a predetermined data element of the model (such as yield data), a variable is an activity determined by the model (such as acres of strata x harvested in year y) and an equation is a model constraint (such as harvest cannot vary by more than 10% in year x).

Table 1. Management intensity classes (MIC) for existing and new stands in the western Oregon log market model.

Definitions of Management Practices

Management Action	Criteria
Precommercial Thin (PCT)	if >263 trees/acre at QMD = 2"
Commercial Thin (CT)	if > 20 mbf/acre remove 30% of volume
PARCUT HILO (no final harvest)	if > 35 mbf/acre remove 15% of volume
PARCUT LOME (no final harvest)	if > 15 mbf/acre remove 33% of volume
PARCUT MEHI (no final harvest)	if > 30 mbf/acre remove 50% of volume

Existing Stands	New Stands	
Grow only (no additional practices)	Natural Regeneration	Plant
PCT	Regeneration only	Regeneration only
CT	Regen + PCT	Regen + PCT

Yield Projections

Yields for each MIC in each stand were generated using regional variants of the USFS Forest Vegetation System (FVS, Dixon, 2003). FIA inventory surveys do not distinguish between stands of planted or natural origin. As a consequence we assumed that the stems per acre and species composition in naturally regenerated stands (by ecoregion) were the same as derived from averages for all young stands from the FIA database. Planted stands in western Oregon are assumed to have a density of 436 trees per acre for softwoods and 350 trees per acre for hardwoods. In these stands, 95% of the species composition is the planted species (e.g., Douglas-fir) and the additional 5% is assumed to be the same proportional mix of species as found in natural stands. This latter addition recognizes the contribution of volunteer seeding and legacies from previous stands.

Land Area Changes

The land use model employed by the log market model is based on a plot-level panel dataset describing the intensity of development on non-federal lands throughout western Oregon (Lettman 2011). This empirical approach to modeling land use draws heavily from prior studies of rural land use change in Oregon based on earlier versions of the Oregon plot-level panel data set (e.g. Kline 2003, Kline et al., 2003, 2007), as well as studies that have employed similar data sources (Wear and Bolstad 1998, Cho et al. 2003, Nelson et al. 2008). Previous research of building counts in western (Kline 2003, Kline et al. 2003) and eastern (Kline et al. 2007) Oregon, based on earlier versions of this panel dataset, identified several trends in associations between land development activity and land features. Higher changes in building activity, measured in terms of increasing building counts, were correlated with higher base building counts, greater access to market (or city) centers, and lower slope and elevation values. Oregon's Statewide Planning Goals and Guidelines, which were made operational in 1975 and adopted in subsequent years by communities, seemed to be steering changes to areas zoned for developed uses. Yet, increases in building counts were also observed in areas zoned for forest, range, and agricultural uses. In summary, prior research on changes in Oregon land use suggest that public land use policies, topography, market proximity, and population change influence the spatial pattern of land conversions.

The land use change data incorporated in this study makes use of additional land use data recorded for 2000 and 2005 that were unavailable to Kline et al. (2003) and Kline et al. (2007). This includes the use of explanatory variables describing returns to forestry and agricultural land uses, which had been omitted from previous Oregon building count models. In summary, these new land use change estimates take advantage of newer regional data and land rent information and is responsive to past trends identified by prior land use research in the region.

Harvest Projection Models

Timber harvest is a measure of the processing activity on the supply-side of the regional log market. From the market perspective, future levels of timber harvest will depend on developments in both log supply and demand and not on timber inventory or other resource characteristics alone, as is the case in volume-flow analysis of timber supply potential. For western Oregon a model of the region log markets is employed that explicitly recognizes the spatial dispersion of log processing facilities and the forested lands that supply logs. Demand is derived from lumber and plywood production which are sensitive to the delivered price of logs and an exogenous level of log exports. The supply of logs in the short-term is based on private owners' decisions about harvest timing to optimize the value of their timber investments given stand growth and interest rates. In the longer term, it depends on management (silvicultural) investments as these are influenced by management costs, interest rates and price expectations.

Figure B1 illustrates the general form of the model (see Adams and Latta, 2005, for details of a similar model). Log processing is grouped into specific milling or processing centers in the region. Figure B1 is the log market at a single milling center. Mills generate a demand for delivered logs at this center which varies with log price up to the point of capacity. Log demand shifts depending on housing starts and gross domestic product levels as described in Ince et al., (2011). In the arbitrage of the market, log buyers trade off possible log sources until their costs are as low as possible for their level of output. Capacity itself is not fixed but varies with product prices, equipment costs, depreciation, and interest rate.

Potential sources of private log supply lie at various distances from the processing center and have varying cost characteristics depending on the types of forest management, logging conditions, haul distances and the interest rate. The several segments of the supply "curve" in Figure 5 represent potential log supplies from different timberland locations. From the log supplier's perspective, market arbitrage involves trading off possible destinations until its net return is as high as possible. The balance between buyers' and sellers' actions sets prices in the market, harvests, flow patterns from woods to mills, and levels of output at the milling centers.

The intertemporal version of this market model is formulated as a dynamic linear programming problem. The model objective is to maximize the present value of discounted producers' and consumers' surpluses in the log market—this is equivalent to the area under the demand curve less the area under the supply curve. This solution is subject to constraints that require: (i) all of the area in the initial inventory must be committed to some harvest regime or reserved from harvest over the projection, (ii) no more area can be enrolled in available MICs in a given period than are available for reassignment in that period (e.g., harvested area) , and (iii) an array of conditions to insure that regional (and ownership where that detail is available) harvests does not depart too radically from historical behavior. A mathematical description of the model is given in Appendix B.

Additional Assumptions

The LMM requires additional parameters and assumptions too numerous to fully detail in this document; however this section will outline a number of important ones. The first consideration in an intertemporal model such as this one is the weighting of values between periods. The LMM uses a discount rate of 6% for this purpose. This value was arrived at over years of LMM application by evaluating the bare land values and comparing that with observed values from land auctions and expert opinion. Another important consideration is the contribution of harvest from public landowners. In the LMM, harvest from public lands is assumed to be determined by policies within the respective managing agencies and is not sensitive to log price over the 5-year time interval used in this analysis. As a consequence, we treat public log supply as exogenous and in the base case assume that it will remain constant at recent (2008-2012) average levels throughout the projection. Table 2 provides the values for the counties of western Oregon. The market simulations presented in this report were conducted under the assumption that current state-level forest practice regulations and any applicable federal limitations (such as rare and endangered species restrictions on harvestable area) remain unchanged in their current (early 2013) form.

Table 2. LMM exogenous softwood public harvest levels

County	State	BLM	USFS
	----------*2008-2012 average mmbf*----------		
Benton	5,458	4,530	4,333
Clackamas	4,494	6,252	15,401
Clatsop	79,726	-	596
Columbia	6,288	1,886	-
Coos	27,197	19,568	1,910
Curry	391	497	8,545
Douglas	6,486	40,620	21,076
Hood River	9,122	-	3,956
Jackson	284	9,112	12,373
Josephine	2,713	523	2,038
Lane	13,812	26,367	62,283
Lincoln	8,294	634	15,429
Linn	9,548	6,654	11,255

In the market model projections, underlying macroeconomic impacts on softwood lumber and plywood are based on the U.S. Forest Service's United State Forest Products Module (Ince et al., 2011) used in the 2010 RPA Timber Assessment Update (USFS, 2012). The softwood lumber demand has an elasticity of demand with respect to GDP of 0.39 and an elasticity of demand with respect to housing starts of 0.49. For softwood plywood the GDP demand elasticity is 0.55 and for housing starts is 0.69. Figure 2 provides the levels of macroeconomic parameters are derived from the U.S. Energy Information Agency's 2014 Annual Energy Outlook (AEO) that projects the national energy situation through 2040. The AEO 2014

Reference Case[4] assumes a return of U.S. housing activity to long-term trend levels by the fourth year of its projections (2015-2016). This return to historic levels in housing activity signals an end of the credit-spawned housing "recession" and yields a subsequent increase in forest products manufacturing activity. The USFPM macroeconomic demand shifting routines also project a continuation in the shift in market share of structural panels from softwood plywood to OSB leading to somewhat lower levels of western Oregon softwood plywood producer's response to the housing recovery and future supply expansion. Figure 3 gives the historical values for softwood lumber and plywood production in western Oregon along with the demand target projections shifted in accordance with the elasticities and levels of macroeconomic indicators. A maximum value for softwood lumber of 7 billion board feet per year was used based on conversations with Eric Kranzush.

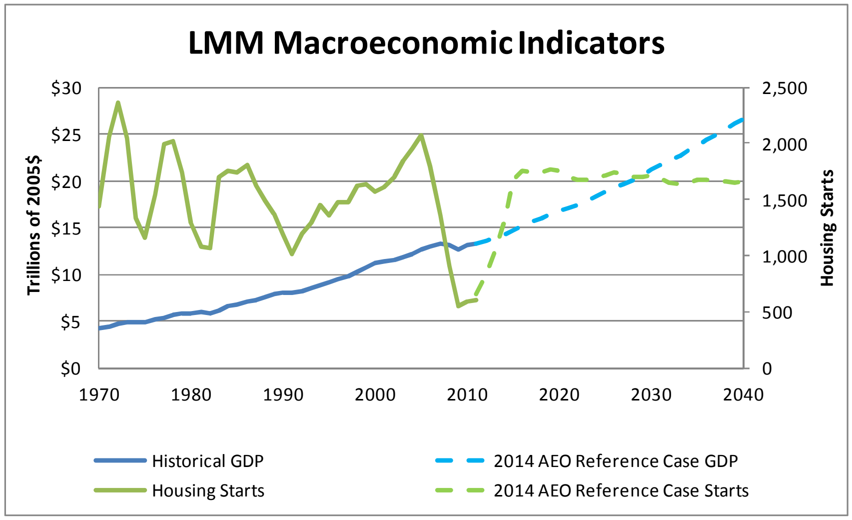


Figure 2. LMM macroeconomic indicators.

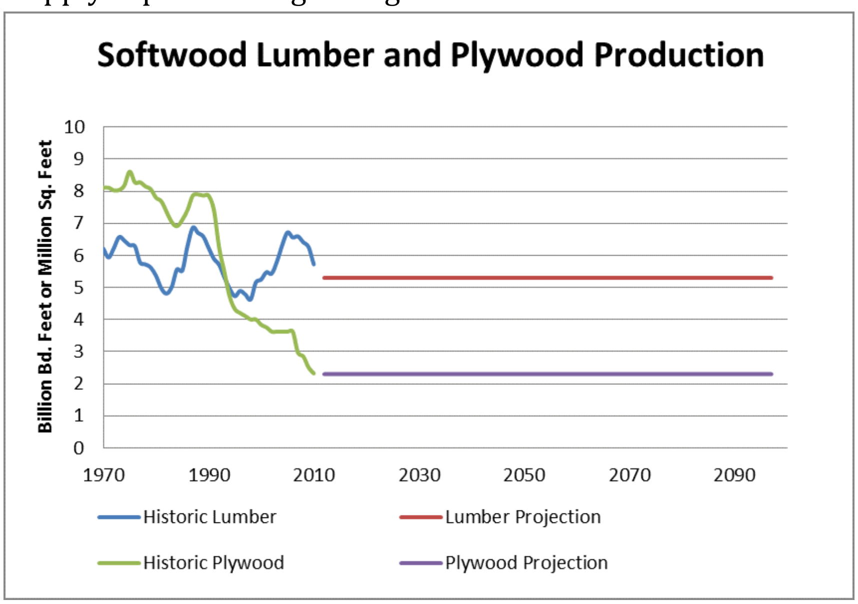


Figure 3. Historical and projected softwood log demand

[4] Data Table for the 2014 AEO can be found at http://www.eia.gov/forecasts/aeo/er/tables_ref.cfm

In addition to estimates of softwood demand for lumber and plywood estimates of log exports are also necessary. Like the exogenous public supply the export demand is exogenous based on the average values over the last five year period. In the LMM logs are exported at the ports of Astoria, Coos Bay, Longview and Portland. The (2008-2012) average values at those ports are 22, 53, 9, and 619 respectively. The future log demand for exports is given in Figure 4. It assumes that as the housing market returns to pre-recession levels the softwood log exports drop back to levels observed over the 1999-2009 decade.

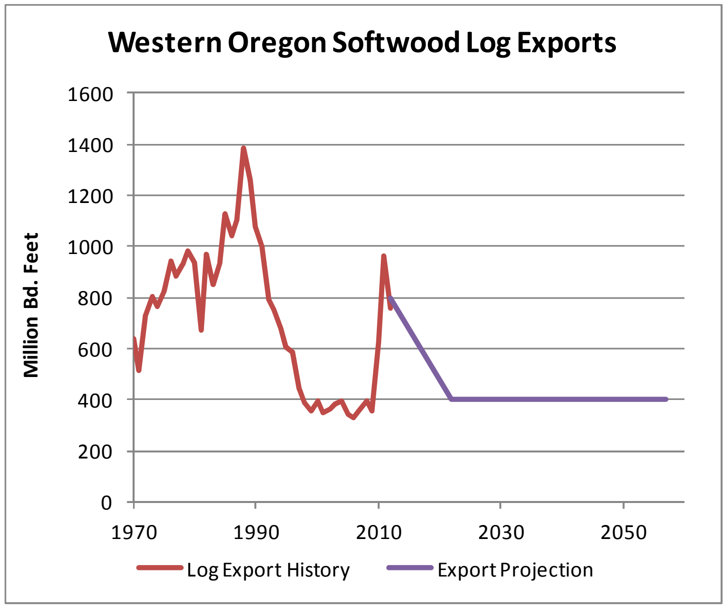


Figure 4 LMM softwood log exports

The final two important sets of parameters are the softwood log prices and log processing locations and capacities. The softwood log price used is an average of ODF reported 2S, 3S, and 4S log grades for Douglas-fir, Western Hemlock and Other Softwoods with weighted by WWPA reported lumber production for those species and the prices are deflated by the all commodity PPI to get real log prices. Figure 5 shows the historical ODF values in both nominal dollars and in real 2012 dollars. The figure demonstrates that nominal log prices have been relatively stable since the early 1990's with the exception of the recent recession related collapse of prices. The real log prices however tell quite a different story with a general upward trend in prices from 1970-1993 then a rather sharp decline through the present period as log prices have remained flat as noted above

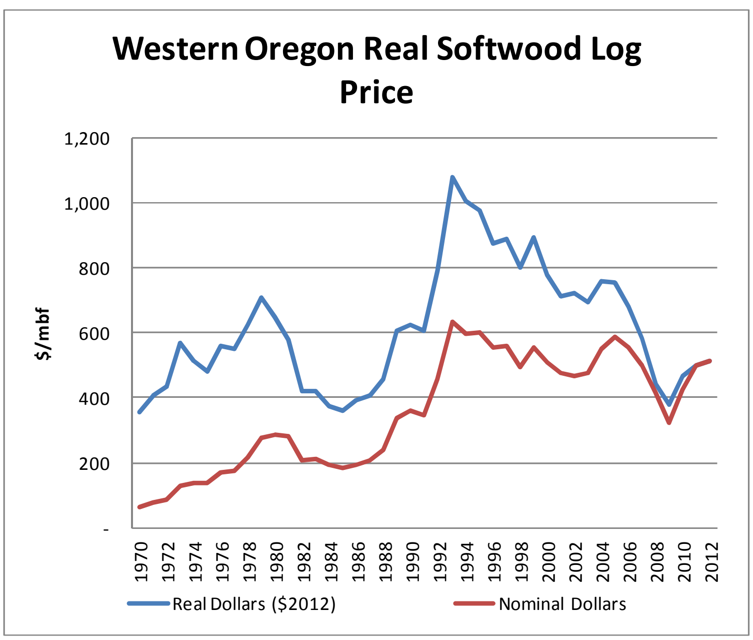


Figure 5 Western Oregon softwood log prices

while the PPI has continued its upward climb.

For softwood log processing capacity the LMM groups mills of a similar type together. Table 3 provides the locations and log processing capacities as well as the capacity

Region	Product	Mill Location	Proportion	2012 Mill Capacity (mmbf or mmsf)	2017 Mill Capacity (mmbf or mmsf)
FIAWO	Lumber	Banks	0.0184	79	107
FIAWO	Lumber	Brookings	0.0184	79	107
FIAWO	Lumber	Clatskanie	0.0111	47	64
FIAWO	Lumber	CoosBay	0.0581	249	336
FIAWO	Lumber	Corvallis	0.0074	32	43
FIAWO	Lumber	CottageGrove	0.0692	297	400
FIAWO	Lumber	Dillard	0.0830	356	480
FIAWO	Lumber	Estacada	0.0166	71	96
FIAWO	Lumber	Eugene	0.0714	306	413
FIAWO	Lumber	Gaston	0.0184	79	107
FIAWO	Lumber	Goshen	0.0074	32	43
FIAWO	Lumber	Glendale	0.0350	150	203
FIAWO	Lumber	HoodRiver	0.0074	32	43
FIAWO	Lumber	Lebanon	0.0332	142	192
FIAWO	Lumber	Lyons	0.0018	8	11
FIAWO	Lumber	MillCity	0.0148	63	85
FIAWO	Lumber	Mist	0.0406	174	235
FIAWO	Lumber	Molalla	0.0738	316	427
FIAWO	Lumber	Monroe	0.0041	17	23
FIAWO	Lumber	Norway	0.0004	2	2
FIAWO	Lumber	Noti	0.0494	212	286
FIAWO	Lumber	Philomath	0.0304	130	176
FIAWO	Lumber	Riddle	0.0148	63	85
FIAWO	Lumber	Roseburg	0.0314	134	182
FIAWO	Lumber	Springfield	0.0443	190	256
FIAWO	Lumber	Tillamook	0.0682	293	395

proportions that are used to allocate future demand to the processing locations.

Scenarios

1. Base scenario (current FPA rules for small and medium fish streams)
    a. No cut buffer of 23 horizontal feet on small fish bearing streams
    b. No cut buffer of 41 horizontal feet on medium fish bearing streams
2. New Riparian Policy
    a. No cut buffer of 54 horizontal feet on small fish bearing streams
    b. No cut buffer of 72 horizontal feet on medium fish bearing streams

Log Market Model Appendix

The western Oregon log market model uses a standard form for intertemporal market analysis, maximizing the discounted sum of producer and consumer surpluses less transport and other costs (see, for example, Berck, 1979; Sedjo and Lyon, 1990; and Adams et al, 1996). In this case consumer surplus is computed under the derived log input demand curves at each "processing center" in western Oregon (locations which can include one or more mills). Log supply is implicit in the costs of managing and harvesting timber in each condition class over time. The total area under the demand curves, less costs of management and harvesting, less transport costs yields Samuelson's (1952) "net social surplus" and is maximized subject to constraints on the disposition of the total inventory area among management-harvesting activities and demand-supply balance. At the end of the projection period some account must be taken of the residual, unharvested inventory. The model assumes that this inventory will continue to provide even-flow harvests on a perpetual basis in all future periods. The volume of this perpetual even-flow is computed using von Mantel's formula assuming that the terminal inventory is fully regulated.

Log Market Model Objective Function

The objective function is:

$$MAX_{X,N} \quad \sum_{t=1}^{T}\left[\sum_{w} D(t,w,R(w,t)) - \sum_{c}\sum_{w} H(c,w)S(c,w,t) - \sum_{c} C(c,t)\sum_{a>t} N(c,t,a,m')\right](1+i)^{-t} +$$

$$\left[\sum_{w} D(T,w,R^{T}(w))\right]\frac{(1+i)^{10}}{(1+i)^{10}-1}(1+i)^{-T}$$

market objective (B1)

Log Market Model Constraints

Subject to the constraints:

$$\sum_{t}\sum_{m} X(c,t,m) = A(c) \quad \forall c$$

allocation of all existing area (B2)

$$\sum_{t'>t,m} N(c,t,t',m) \le \sum_{m} X(c,t,m) + \sum_{t'<t,m} N(c,t',t,m) - d(c,t) \quad \forall c,t$$

future area of regenerated stands (B3)

$$h(c,t) = \sum_{m} X(c,t,m)V(c,t,m) + \sum_{t'<t}\sum_{m} N(c,t',t,m)V^{N}(c,t-t',m) + \sum_{m} X(c,t,m)V^{H}(c,t,m) \quad \forall c,t$$

harvest (B4)

$$\sum_{b,o} h(c_{\in b,o},t) = P_{b,o} \quad \forall c,t$$

public harvest (B5)

$$E(c,t) + \sum_{w} S(c,w,t) \le h(c,t) \quad \forall c,t$$

shipments from plots to processing centers (B6)

$$M(w,t) + \sum_{c} S(c,w,t) \ge R(w,t) \quad \forall w,t$$

receipts at processing centers (B7)

$$\sum_{c} h(c,t) \ge (1-\alpha^{L})\sum_{c} h(c,t-1)$$
$$\sum_{c} h(c,t) \le (1+\alpha^{U})\sum_{c} h(c,t-1) \quad \forall t > 1$$

volume flow controls (B8)

$$I(c,t) = \sum_{m^0} X(c,t,m^0)V^{I}(c,t,m^0) + \sum_{m'}\sum_{a>t} X(c,a,m')V(c,a-t,m') + \sum_{m'}\sum_{a<t}\sum_{t<k} N(c,a,k,m')V(c,t-a,m') \quad \forall c,t$$

inventory (B9)

$$I(c,T) = \sum_{w} IM(c,w,T) \quad \forall c$$
$$R^{T}(w) = \sum_{c} \frac{2}{R^*}\left[IM(c,w,T) - \sum_{m^0} X(c,T,m^0)V^{H}(c,T,m^0) \right] \quad \forall w$$

terminal conditions (B10)

Sets

c	condition class which is a homogenous part of an FIA plot. In this report the condition class represents a stand or strata,
m	silvicultural management regime, or management intensity class (MIC),
t	five-year time periods, t-1 is the preceding time period and T is the terminal time period,
w	softwood log processing centers.

Parameters

α^L, α^U — are fractions by which harvest in period t can deviate from harvest in period *t-1*, superscript *L* is the lower limit and *U* is the upper limit,

A(c) — Area of condition class *c,*

C(c,t) is the cost per acre of planting in condition class *c* at time *t*,

d(c,t) land from condition class c converted to developed use in time period *t*,

i is the discount rate,

Variables

d(c,t) land from condition class c converted to developed use in time period *t*,

D(t,w,R(w,t)) is the area under the log demand curve (willingness to pay in dollars) in processing center *w* for log receipt volume *R(w,t)* in period *t*,

E(c,t) is the exogenous volume of logs exported (leaving western Oregon for any destination) from condition class *c* in period *t*,

H(c,w) is the harvest and transport cost per unit volume from condition class *c* to processing center *w*,

I(c,t) is the inventory in condition class c at the start of period *t*,

IM(c,T) is the inventory in condition class *c* at the start of period *T* associated with future (*T+n*) harvest shipments to processing center *w*.

M(w,t) is the exogenous volume of logs imported (from any non-western Oregon source) to processing center w in period t,

R(w,t) is the volume of logs received in processing center *w* an time *t*,

$R^T(w)$ is the log volume received in processing center *w* in periods after the end of the projection,

S(c,w,t) is the volume shipped from condition class *c* to processing center *w* in period *t*,

X(c,t,m) area of existing condition class *c* assigned to management *m*, clear-cut in period *t*,

Objective function B1 maximizes the discounted sum of producer plus consumer surplus net of transport costs for the full projection period (t=1,…,T) and the willingness to pay computed under the demand curves for a fixed periodic flow of harvest in all periods after T. In a simple market for a single product, demand-supply equilibrium occurs at the price and quantity where the sum of producer and consumer surplus is maximized. This is illustrated in Figure B1 for the present case.

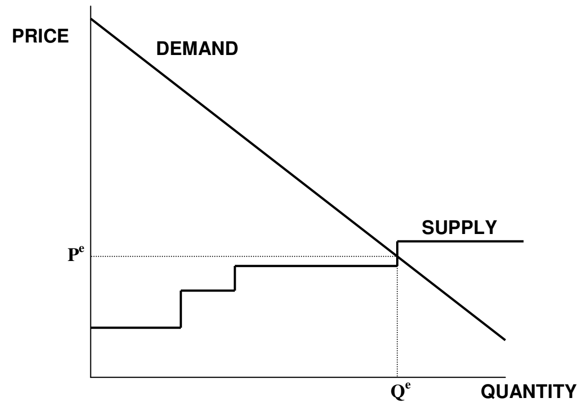


Figure B1. Supply and demand in a timber market illustrative of the mechanism used.

In the figure, the market is in equilibrium with demand equal to supply at price P^e and quantity Q^e. Consumer surplus is the large triangle above the price line but below the demand curve. Producer surplus (also called profit) is the area below the price line but above the step-like supply curve. The sum of these two areas is at a maximum when supply equals demand, so market equilibrium can be found by locating that price and quantity for which this combined surplus is maximized. In the objective function in B1, the combined surplus is computed by subtracting the area under the step-like supply curve from the total area under the demand curve—in the figure the latter would be the area below the demand curve but above the horizontal quantity axis. This area is also called the consumer's "willingness to pay." It is the maximum amount a consumer would pay to consume the quantity Q^e.

The timber demand curve is a "derived demand." It is derived from the demand by lumber, plywood and other wood products producers for logs as input to production. The process used to estimate log demand functions for the log market model Oregon is similar to Latta and Adams (2000) and is described in the appendix of Adams et al (2002). Because this demand arises from needs for input at a later stage of manufacturing, it will shift over time as the determinants of output for these products change. Key "shifters" of demand include gross domestic product and housing starts. For example, an increase in housing starts would act to increase the output of lumber and raise the demand for logs. In Figure B1, the log demand curve would shift to the right.

The log supply function is shown in Figure B1 as a step-like relation. In the log market model, timber supply comes from specific geographic locations (FIA plots) that have variable unit harvesting costs dependent on slope, stand diameter and stems per acre removed and hauling costs estimated from simple Euclidian distance from plot to demand location as well as fixed per unit area management costs. Each area has, at harvest time, some fixed amount of volume. If we array these harvest opportunities cumulatively by increasing cost, we would obtain a curve like that shown in Figure B1.[5] In a particular period only the lowest cost portion of the inventory would be harvested. The supply function steps will, thus, change over time as stands grow and are harvested.

The final block of the objective function provides some recognition of returns from harvests after the end of the projection, periods T+1, T+2, etc. Here the model simply computes the area under the demand curve (willingness to pay) that would be realized each period from steady state harvests if the forest were fully regulated on a rotation of length R*. The model employs von Mantel's formula to approximate this harvest level from the inventory volume in period T. As noted below, since the market model explicitly accounts for the distribution of harvest from each FIA plot condition class among the various processing centers, additional constraints are required to allocate the long-term steady state harvest across the centers (see equations B9).

Constraints B2 and B3 account for the distribution of area across MIC and harvest timing options while constraints B4 computes the harvest volume by period for each condition class.

Harvest from each condition class can flow to a domestic processing center or to export. Constraints B6 require that harvest be at least as large as the sum of these shipments. Similarly, processing centers can obtain logs from privately owned condition classes, government lands, and imports from other states or countries. Constraints B7 require that receipts at each processing center be no larger than the sum of the volumes from these three sources. Equations B8 limits changes in county level harvesting on private lands to be within bounds observed in the ODF reported values over the last 40 years.

Because of the need to recognize specific flows from individual condition classes to specific processing centers, inventory is tallied at the condition class level in constraints B9.

The terminal inventory conditions in constraints B10 deal directly with the links between condition classes and processing centers. The perpetual periodic flows from condition classes after period T are entirely a function of inventory in T (due to the use of von Mantel's formula). Thus, rather than allocating these long-term flows to processing centers the model can, in effect, allocate inventory. In the first of the two terminal conditions, a new set of variables is introduced, the IM(c,w,T), that associate some portion of the terminal inventory in class c with processing center w. The actual volume of flows coming into a particular processing center from all these inventory allocations is computed in the second of the two constraints. Any partial cuts are deducted in period T from the initial inventory,

[5] The model also considers the cost of harvesting now versus waiting for another period. If a plot's value is growing faster than the interest rate this opportunity cost will be non-zero.

then the residual volume is adjusted using von Mantel's formula to the equivalent steady state flow from a fully regulated forest. This does not force regulation of the final inventory, it only treats the forest as if it were regulated.

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Appendix B

Riparian Plot Depiction in Log Market Model

This note describes the challenges and choices involved in determining the appropriate representation of the new riparian rules appropriately in the FIA subplot base log market model. ODF conducted a GIS exercise identifying the acreages shown in Table A1.

Table A3. ODF GIS analysis of acreages under current and

Stream Size	Small		Medium	
Owner	PI	PNI	PI	PNI
Georegion	**Current Rule (23' Small, 41' Medium)**			
	---------------------- *acres* ----------------------			
Coast Range	7,962	4,628	10,029	5,526
Interior	4,555	7,288	7,117	9,631
South Coast	268	301	745	586
Western Cascade	591	424	2,395	1,014
Total	13,376	12,640	20,286	16,758
	New Rule (54' Small, 72' Medium)			
	---------------------- *acres* ----------------------			
Coast Range	18,694	10,865	17,612	9,705
Interior	10,695	17,110	12,497	16,913
South Coast	628	707	1,309	1,030
Western Cascade	1,388	995	4,207	1,780
Total	31,405	29,677	35,625	29,428
	Acres Affected			
	---------------------- *acres* ----------------------			
Coast Range	10,732	6,238	7,583	4,178
Interior	6,140	9,822	5,381	7,282
South Coast	361	406	564	443
Western Cascade	797	571	1,811	767
Total	18,029	17,037	15,338	12,671

Given that in a five subplot layout, an average FIA subplot would represent approximately 1,200 acres, it was anticipated that there may be issues in depicting change in the South Coast and Western Cascades geo-regions where the aggregate buffer acreages were less than an individual subplot in most cases. Table A2 shows the acreages as well as the number of plots that would fall within the current and new rule buffer widths.

Table A4. FIA acreages and subplot counts within current and new rule buffers

Stream Size	Small		Medium		Small		Medium	
Owner	PI	PNI	PI	PNI	PI	PNI	PI	PNI
Georegion	**Current Rule (23' Small, 41' Medium)**							
	acres				*subplots*			
Coast Range	12,851	10,051	12,415		7	8	10	
Interior	3,053	7,042	3,088	7,803	3	5	4	6
South Coast			811				1	
Western Cascade	1,317		4,806	2,383	1		4	1
Total	17,222	17,092	21,120	10,186	11	13	19	7
	New Rule (54' Small, 72' Medium)							
	acres				*subplots*			
Coast Range	23,307	12,411	20,699	39	12	10	16	1
Interior	4,140	10,165	7,020	13,113	4	9	9	10
South Coast			811				1	
Western Cascade	1,317		6,386	2,383	1		5	1
Total	28,764	22,577	34,916	15,535	17	19	31	12
	Acres Affected							
	acres							
Coast Range	10,456	2,361	8,285	39				
Interior	1,087	3,124	3,932	5,310				
South Coast	-	-	-	-				
Western Cascade	-	-	1,580	-				
Total	11,543	5,485	13,796	5,349				

Evaluation of this data confirmed that direct use of subplots within the buffer widths would both not represent the acreages affected by the policy change as well as not provide enough variation in forest conditions to appropriately represent the diversity of riparian forests. In an attempt to still utilize data within a reasonable proximity of streams, we then looked at the acreages and plot counts for FIA subplots within 200 feet of fish bearing streams as well as 200 feet of all streams. This gives an idea of the potential for representing the variability of riparian forests within the log market model. That data is found in Table A3.

Table A5. FIA acreages and subplot counts within 200 feet of fish bearing and all streams

Stream Size	Small		Medium		Small		Medium	
Owner	PI	PNI	PI	PNI	PI	PNI	PI	PNI
Georegion	**All Plots with 200' of Fish bearing streams**							
	acres				*subplots*			
Coast Range	54,676	45,973	44,200	9,812	37	38	36	9
Interior	18,469	38,950	13,835	25,170	16	34	16	21
South Coast	0	0	2,308	2,018	0	0	4	2
Western Cascade	1,317	0	15,527	7,148	1	0	11	3
Total	74,462	84,922	75,870	44,147	54	72	67	35
	All Plots with 200' of Fish and non-Fish bearing streams							
	acres				*subplots*			
Coast Range	408,353	93,822	49,870	9,812	280	75	41	9
Interior	291,326	160,247	20,146	25,170	197	146	20	21
South Coast	42,181	10,513	10,866	11,152	32	9	12	11
Western Cascade	147,428	20,979	18,636	7,148	100	20	14	3
Total	889,287	285,561	99,519	53,281	609	250	87	44

Given that the ultimate goal was to find the best way to represent the acreages impacted by the potential change in buffer widths it was decided that rather than have subplots be either in or out, instead we would use the full riparian plot set from Table A3 along with the ODF GIS analysis from Table A1 to generate proportions of each subplot within 200 feet of a stream that would be treated as a riparian area in the log market model. Furthermore, we would use only the subplots within 200 feet of fish bearing streams in the Coast Range and Interior but use subplots within 200 feet of all streams in the South Coast and western Cascade geo-regions. The final proportions of subplots used in the existing and proposed riparian rules in the log market model are given in Table A4.

Table A6. Final riparian plot proportions used to represent existing and proposed riparian rules in the log market model

Stream Size	Small		Medium		Small		Medium	
Owner	PI	PNI	PI	PNI	PI	PNI	PI	PNI
Georegion	**Current Riparian Rule**				**New Riparian Rule**			
	proportion within 200' of fish streams				*proportion within 200' of fish streams*			
Coast Range	0.146	0.101	0.227	0.563	0.342	0.236	0.398	0.989
Interior	0.247	0.187	0.514	0.383	0.579	0.439	0.903	0.672
	proportion within 200' of all streams				*proportion within 200' of all streams*			
South Coast	0.006	0.029	0.069	0.053	0.015	0.067	0.120	0.092
Western Cascade	0.004	0.020	0.129	0.142	0.009	0.047	0.226	0.249