APPENDIX C

FOREST MANAGEMENT MODELING

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1. Basic Principles

This document describes the techniques used to model forest management and harvest schedules for state trust lands within the South Puget Habitat Conservation Plan (HCP) Planning Unit. This computer modeling was undertaken to determine the management necessary to achieve economic, ecological, and social objectives within defined constraints, while simultaneously providing a sustainable yield of forest services, products and values. The following three components were developed for the computer modeling:

(a) Area database: A user-defined classification system is applied to the forested land base. A Geographic Information System (GIS) is then used to spatially delineate and report the area of the land base in each class or groups of classes. Spatially discontinuous areas with the same unique combination of classes are calculated and reported separately for the modeling purposes.

(b) Yield: Growth and yield modeling is used to generate stand level yield tables showing various forest attributes and how they change during stand development under various silvicultural treatments. An array of yield tables is provided to predict stand conditions and outcomes under a wide range of silvicultural management regimes. A range of silvicultural options provides the forest manager with flexibility in harvest scheduling, enables the regulation of the flow of forest products under different management scenarios, and is used to achieve and maintain target forest conditions.

(c) Forest estate computer modeling: Forest estate models are used to determine the management necessary to achieve economic, ecological, and social objectives within defined constraints, while simultaneously providing a sustainable yield of forest services, products and values. The forest estate model provides a schedule of harvest and other silvicultural treatments required to meet the forecasted sustainable wood supply capacity and achieve a desired future condition.

1.1 Growth and Yield Model

A growth and yield model is an abstraction of natural stand dynamics and the effects of silvicultural intervention. A growth and yield model is used to predict the growth, yield (outputs), and future conditions of forest stands under different types of silvicultural management. The various forest attributes simulated by the model are user-defined, and may include current and future growth, mortality, recruitment, commercial timber volume, habitat quality, structure, diversity, snags, level of coarse woody debris, or other structural or compositional values.

Yield is the amount of a selected stand attribute present at a given point in time, such as the volume of commercial timber, average stand height, basal area, quadratic mean diameter (QMD), volume of coarse woody debris, habitat quality, stand structure, or forest development stage. Forest *growth* is the change in a selected stand attribute over a specified time period. Many economic, ecological and social interests are related to stand attributes. The various features of the yield tables are outlined in section 5 of this appendix.

The USDA Forest Service *Forest Vegetation Simulator* (FVS) was used to generate the necessary yield tables. FVS is a distant-independent, individual tree-level growth and yield model. This type of model is designed to process detailed individual tree data from inventory plots to forecast how a given stand of trees will grow and change under different management prescriptions.

The condition of a given stand is modeled in successive 10 year growth cycles, using the tree list from the current inventory as a starting point. At the beginning of the growth cycle, the model selects each tree on the list for harvesting, natural mortality, or continued growth depending on the silvicultural prescription. New small trees occurring as a result of ingrowth or reproduction are added to the tree list. Trees are grown in height, diameter and crown size, to the end of the growth cycle. The model calculates the growth and volume for each tree and aggregates the data to provide area characteristics of growth and yield. The growth cycles were repeated for the 100 year planning horizon. The silvicultural prescriptions modeled are outlined in section 5 below.

Growth and yield models are used to model stand dynamics, attributes and values at the stand level. Forest level management objectives, policies, regulations and various management or market constraints are excluded. The dynamics of managing a forest estate for different objectives, often with multiple constraints, are addressed using models for harvest scheduling and wood supply forecasting.

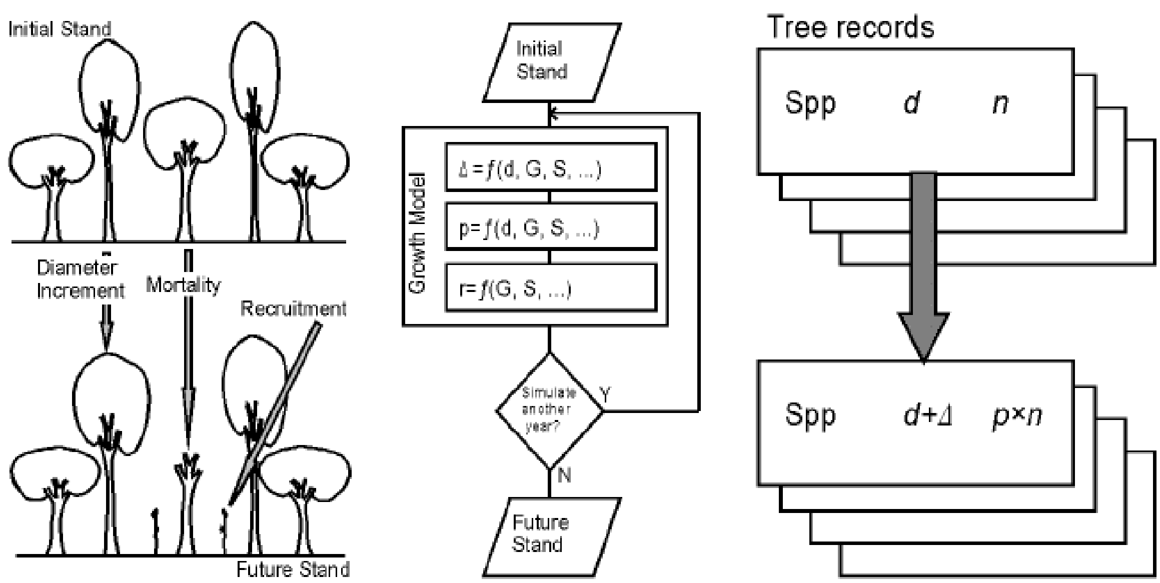


Figure C1. Tree Records Representing a Forest Stand

Growth is modeled by incrementing the diameter in each record (d + Δ). Mortality is accommodated by reducing expansion factors (p x n). Source: Vanclay (1994).

1.2 Forest Estate Model

The management of forest land for the simultaneous production of economic, social, and ecological values is complex. Computer models are used to represent current and future characteristics and their interactions across the landscape. Such models are used to evaluate management options and how changes in individual elements affect the landscape.

A forest estate model represents the essential parameters and conditions of an existing forest resource and predicts future forest conditions and outputs. The model enables the user to find analytical solutions to forest land management problems that may include economic, ecological and social goals, policies, and regulatory constraints.

Spatial Woodstock, a commercial forest estate model developed by Remsoft Inc. Canada, was used to model the forested landscape in the South Puget Sound region. The model uses mathematical optimization techniques to provide solutions to land management scenarios.

Spatial Woodstock enables the user to build a long-term sustainable management model of wood supply, habitat, biodiversity, watershed management and other forest services, products and values. The model schedules the silvicultural operations and harvesting events required to achieve the wood supply forecast. Woodstock can be structured to model both physical (e.g., area, yield, habitat) and financial attributes, enables spatial mapping of forest parameters and activities, and can report changes to the forest conditions and yield flows over time.

The forest estate model requires four categories of information as input:

(a) Forest area classification: The forest area is classified according to site quality, forest cover (forest type composition, structure, condition), and silvicultural status.

(b) A range of yield tables (forecast of forest values) for each unique combination of land productivity / forest area classifications is used to reflect the forest condition and outputs under different silvicultural regimes.

(c) Management objectives: A standard objective is to maximize the forest estate net present value; other objectives can be expressed as constraints.

(d) Constraints (temporal and pseudo-spatial) represent the array of economic, ecological and social objectives, expectations and restrictions required for effective forest land management. Constraints may be either area specific or timber production related:

Area specific constraints include:

- management practices and policies (permissible silviculture or restrictions) for different land classes (e.g., unstable slopes, visual corridor areas, deferred areas, riparian management)
- regulations guiding replanting, the retention of legacy trees, Habitat Conservation Plan targets, minimum canopy cover within watershed, maximum canopy opening size, green-up adjacency constraint, etc.
- special provisions, such as those outlined in *Washington Environmental Council et al, v. Sutherland et al, 2006* (hereafter, the “Settlement Agreement”)

Timber production related constraints include:

- wood supply agreements (minimum volumes)
- flow constraints (regulating the level of change in production over time and within geographical areas or ownership classes)
- minimum revenue or net cashflow required

- existing planned harvest (2 – 3 year forward planning of harvest operations)

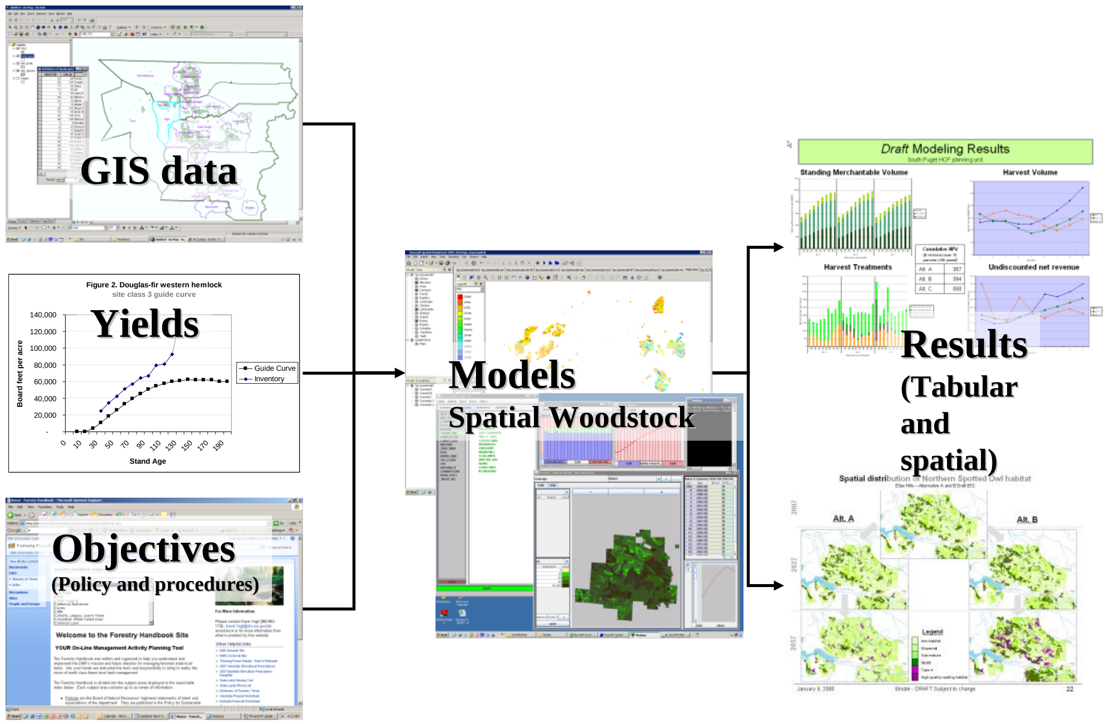


Figure C2. Schematic Representation of Forest Estate Modeling

Spatial data, including forest area classifications from a GIS are combined with Growth and Yield data and management objectives to produce a long-term sustainable management model of wood supply, habitat, biodiversity, watershed management and other forest values.

Spatial Woodstock uses linear programming technique to solve land management problems. The problems may be expressed as either a pure linear (no constraints can be violated) or a goal programming (constraints can be violated at certain costs) formulation. Conflicting constraints on land use may preclude a feasible solution. Constraints are coded as either hard (those that cannot be violated) or soft (those that may be violated at a cost). All soft constraints incur an assigned penalty cost if violated. The penalty is deducted from the objective function. Since the model was structured to maximize the objective function, violation of soft constraints is minimized in achieving a solution.

2. Land Classification

The classification system used in the model was constructed from an overlay of several GIS data layers for the South Puget HCP Planning Unit (Large Data Overlay – reference February 3rd, 2009). The GIS data layers formed the basis for the creation of 13 *themes* for use with Spatial Woodstock, listed in Table C1 and described in greater detail in following sections of this document.

The intersected polygons, formed from the overlay of the multiple GIS data layers, were then grouped according to the unique combination of attributes to create modeling units. Approximately 286,600 modeling units were used, representing the combinations of various administrative, ecological, hydrologic, and forest attributes. Attributes included ownership, land class, watershed administrative unit (WAU), spotted owl management unit (SOMU), stand composition, condition, productivity, and silvicultural status.

Table C1. Spatial Woodstock Themes

No.	Theme	Data Source
1	Forest type	FRIS
2	Site class	FRIS
3	Size class	FRIS
4	Stocking class	FRIS
5	Silvicultural status	P&T
6	Administrative Area (Locals)	LDO
7	Spotted Owl Management Unit (SOMU)	LDO
8	Watershed (WAU)	LDO
9	Surface and timber ownership groups	LDO
10	Deferrals	LDO
11	Land class	LDO
12	Rain-on-snow sub-basins	LDO
13	Road access	LDO

FRIS: Forest Resource Inventory System
P&T: Planning and Tracking
LDO: Large Data Overlay

2.1 Forest Types

A four character forest type code was used to classify the primary and secondary overstory tree species groups found in a given area. The following twelve forest type codes were used in the model:

DFMA Douglas-fir dominated, with hardwoods
DFRA Douglas-fir dominated, with red alder
DFRC Douglas-fir dominated, with western red cedar
DFWH Douglas-fir dominated, with western hemlock
RADF Red alder dominated, with Douglas-fir

RAMA	Red alder dominated, with other hardwoods
RAWH	Red alder dominated, with western hemlock
SFWH	Silver fir dominated, with western hemlock
WHDF	Western hemlock dominated, with Douglas-fir
WHRA	Western hemlock dominated, with red alder
WHRC	Western hemlock dominated, with western red cedar
WHSF	Western hemlock dominated, with silver fir

Each species group is a combination of several individual species. Twenty-six species were identified and assigned to eight species groups. The individual species and associated attributes are described in Table C8. Ninety-six primary and secondary species combinations were identified, which correspond to 12 primary and secondary species group (forest type) combinations. Table C9 describes the species combinations and the corresponding forest type.

2.2 Site Class

The land base was stratified into five site productivity classes, based on the 50 year site index (SI_{50}). The site index is the height of the dominant tree species (in feet) at a given location at age 50 years. Table C2 lists the site productivity classes and the corresponding range of site index values. The number of site classes was reduced from five to three within the model since site class 1 and site class 5 represented a small proportion of the total land base. Site class 1 was combined with site class 2, and site class 4 was combined with site class 5.

Table C2. Site class

Site Class	Site Index (SI_{50}) (feet)
SIC1	$137 \leq SI_{50}$
SIC2	$119 \leq SI_{50} < 137$
SIC3	$97 \leq SI_{50} < 119$
SIC4	$76 \leq SI_{50} < 97$
SIC5	$0 \leq SI_{50}$ 76

2.3 Stocking Class

The land base was stratified into four stocking classes using Curtis relative density (RD). Relative density is the basal area of a stand divided by the square root of the quadratic mean diameter of the stand (Eq C2). Only live trees with a dbh ≥ 3.5 inches (8.9 cm) were included in the calculation. Table C3 lists the stocking classes and the corresponding range of RD values.

Eq. C2. $$RD = \frac{BA}{\sqrt{QMD}}$$

Table C3. Stocking class

Stocking Class Name	Stocking Class Code	RD (shade tolerant)	RD (shade intolerant)
Extremely over-stocked	EXSTK	$100 \geq RD$	$90 \geq RD$
Grossly over-stocked	GOSTK	$75 \geq RD < 100$	$70 \geq RD < 90$

Mortality induced stocking	MISTK	55 ≥ RD < 75	45 ≥ RD < 70
Optimal stocking	OPSTK	0 ≥ RD < 55	0 ≥ RD < 45

2.4 Size Class

The land base was stratified into five forest size classes based on quadratic mean diameter (QMD) for given stand. Only live trees with a dbh ≥ 3.5 inches (8.9 cm) were included in the calculation. The quadratic mean diameter is the square root of the mean square diameter for the stand (Eq. C1). Table C4 lists the size classes and the corresponding range of QMD values.

Table C4. Size class

Size Class	QMD (inches)
SIZE1	0 ≤ QMD < 8
SIZE2	8 ≤ QMD < 14
SIZE3	14 ≤ QMD < 18
SIZE4	18 ≤ QMD < 24
SIZE5	24 ≤ QMD

Eq. C1. $$QMD = \sqrt{\frac{\sum_{i=1}^{n} dbh_i^2}{n}}$$

Table C5. Individual Species

Species Code	Common Name	Scientific Name	Species Group	Wood Type	Shade Tolerance	Acres	Hectares
AS	Aspen	*Populus tremuloides*	MA	Hardwood	Intolerant	129.0	52.2
BC	Black cottonwood	*Populus balsamifera* ssp. *trichocarpa*	MA	Hardwood	Intolerant	5,452.3	2,206.5
CA	Cascara	*Frangula purshiana*	NC	Hardwood	Intolerant	2,976.0	1,204.3
DF	Douglas-fir	*Pseudotsuga menziesii*	DF	Softwood	Intolerant	141,784.8	57,378.3
ES	Engelmann spruce	*Picea engelmannii*	DF	Softwood	Intolerant	127.9	51.8
GF	Grand fir	*Abies grandis*	DF	Softwood	Intolerant	1,283.1	519.3
LP	Lodgepole pine	*Pinus contorta*	WP	Softwood	Intolerant	8,527.9	3,451.1
MA	Bigleaf maple	*Acer macrophyllum*	MA	Hardwood	Intolerant	15,235.3	6,165.5
MD	Pacific madrone	*Arbutus menziesii*	NC	Hardwood	Intolerant	1,244.5	503.6
MH	Mountain hemlock	*Tsuga mertensiana*	WH	Softwood	Tolerant	91.0	36.8
NC	Mixed non-commercial hardwoods		NC	Hardwood	Intolerant	8.5	3.4
NF	Noble fir	*Abies procera*	SF	Softwood	Tolerant	4,890.6	1,979.2
OA	Oregon ash	*Fraxinus latifolia*	MA	Hardwood	Intolerant	1,186.6	480.2
OO	Oregon oak	*Quercus garryana*	MA	Hardwood	Intolerant	18.0	7.3
PP	Ponderosa pine	*Pinus ponderosa*	WP	Softwood	Intolerant	5.5	2.2
PY	Pacific yew	*Taxus brevifolia*	NC	Softwood	Intolerant	118.6	48.0
RA	Red alder	*Alnus rubra*	RA	Hardwood	Intolerant	72,922.6	2,9510.7
RC	Western red cedar	*Thuja plicata*	RC	Softwood	Tolerant	30,911.7	12,509.5
SF	Pacific silver fir	*Abies amabilis*	SF	Softwood	Tolerant	16,760.7	6,782.8
SS	Sitka spruce	*Picea sitchensis*	DF	Softwood	Intolerant	113.2	45.8
TF	True fir	*Abies spp.*	SF	Softwood	Tolerant	2,198.5	889.7
VM	Vine maple	*Acer circinatum*	NC	Hardwood	Intolerant	156.8	63.5
WH	Western hemlock	*Tsuga heterophylla*	WH	Softwood	Tolerant	98,909.6	40,027.3
WO	Willow	*Salix* spp.	NC	Hardwood	Intolerant	1,610.3	651.7
WP	White pine	*Pinus monticola*	WP	Softwood	Intolerant	10,545.9	4,267.8
YC	Alaska yellow cedar	*Cupressus nootkatensis*	RC	Softwood	Tolerant	37.6	15.2

Table C6. Species Group to Forest Type

Species Group Code	Species Group Name	Forest Type Code	Forest Type Name	Shade Tolerance
ASDF	Aspen / Douglas-fir	DFMA	Douglas-fir / Bigleaf maple	Intolerant
BCDF	Black cottonwood / Douglas-fir	DFMA	Douglas-fir / Bigleaf maple	Intolerant
BCRA	Black cottonwood / Red alder	RAMA	Red alder / Bigleaf maple	Intolerant
CADF	Cascara / Douglas-fir	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DF	Douglas-fir	DFWH	Douglas-fir / Western hemlock	Intolerant
DFAS	Douglas-fir / Aspen	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DFBC	Douglas-fir / Black cottonwood	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DFCA	Douglas-fir / Cascara	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DFGF	Douglas-fir / Grand fir	DFWH	Douglas-fir / Western hemlock	Intolerant
DFLP	Douglas-fir / Lodgepole pine	DFWH	Douglas-fir / Western hemlock	Intolerant
DFMA	Douglas-fir / Bigleaf maple	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DFMD	Douglas-fir / Pacific madrone	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DFNC	Douglas-fir / Mix-Noncommercial hardwoods	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DFNF	Douglas-fir / Noble fir	DFWH	Douglas-fir / Western hemlock	Intolerant
DFOA	Douglas-fir / Oregon ash	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DFPY	Douglas-fir / Pacific yew	DFWH	Douglas-fir / Western hemlock	Intolerant
DFRA	Douglas-fir / Red alder	DFRA	Douglas-fir / Red alder	Intolerant
DFRC	Douglas-fir / Western red cedar	DFRC	Douglas-fir / Western red cedar	Intolerant
DFSF	Douglas-fir / Pacific silver fir	DFWH	Douglas-fir / Western hemlock	Intolerant
DFTF	Douglas-fir / True fir	DFWH	Douglas-fir / Western hemlock	Intolerant
DFVM	Douglas-fir / Vine maple	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DFWH	Douglas-fir / Western hemlock	DFWH	Douglas-fir / Western hemlock	Intolerant
DFWO	Douglas-fir / Willow	DFMA	Douglas-fir / Bigleaf maple	Intolerant
DFWP	Douglas-fir / White pine	DFWH	Douglas-fir / Western hemlock	Intolerant
GF	Grand fir	SFWH	Pacific silver fir / Western hemlock	Tolerant
GFDF	Grand fir / Douglas-fir	DFSF	Douglas-fir / Pacific silver fir	Intolerant
LP	Lodgepole pine	DFWH	Douglas-fir / Western hemlock	Intolerant
LPDF	Lodgepole pine / Douglas-fir	DFWH	Douglas-fir / Western hemlock	Intolerant
MA	Bigleaf maple	RAMA	Red alder / Bigleaf maple	Intolerant
MADF	Bigleaf maple / Douglas-fir	DFMA	Douglas-fir / Bigleaf maple	Intolerant
MARA	Bigleaf maple / Red alder	RAMA	Red alder / Bigleaf maple	Intolerant
MARC	Bigleaf maple / Western red cedar	DFMA	Douglas-fir / Bigleaf maple	Intolerant
MAWH	Bigleaf maple / Western hemlock	WHRA	Western hemlock / Red alder	Tolerant
MDDF	Pacific madrone / Douglas-fir	DFMA	Douglas-fir / Bigleaf maple	Intolerant
MDMA	Pacific madrone / Bigleaf maple	RAMA	Red alder / Bigleaf maple	Intolerant
NC	Mix-Noncommercial hardwoods	RAMA	Red alder / Bigleaf maple	Intolerant

Species Group Code	Species Group Name	Forest Type Code	Forest Type Name	Shade Tolerance
NCDF	Mix-Noncommercial hardwoods / Douglas-fir	DFMA	Douglas-fir / Bigleaf maple	Intolerant
NCMA	Mix-Noncommercial hardwoods / Bigleaf maple	RAMA	Red alder / Bigleaf maple	Intolerant
NCRA	Mix-Noncommercial hardwoods / Red alder	RAMA	Red alder / Bigleaf maple	Intolerant
NF	Noble fir	SFWH	Pacific silver fir / Western hemlock	Tolerant
NFDF	Noble fir / Douglas-fir	DFWH	Douglas-fir / Western hemlock	Intolerant
NFMH	Noble fir / Mountain hemlock	SFWH	Pacific silver fir / Western hemlock	Tolerant
NFOA	Noble fir / Oregon ash	WHRA	Western hemlock / Red alder	Tolerant
NFRA	Noble fir / Red alder	WHRA	Western hemlock / Red alder	Tolerant
NFSF	Noble fir / Pacific silver fir	SFWH	Pacific silver fir / Western hemlock	Tolerant
NFWH	Noble fir / Western hemlock	SFWH	Pacific silver fir / Western hemlock	Tolerant
OODF	Oregon oak / Douglas-fir	DFMA	Douglas-fir / Bigleaf maple	Intolerant
PPDF	Ponderosa pine / Douglas-fir	DFWH	Douglas-fir / Western hemlock	Intolerant
RA	Red alder	RAMA	Red alder / Bigleaf maple	Intolerant
RABC	Red alder / Black cottonwood	RAMA	Red alder / Bigleaf maple	Intolerant
RADF	Red alder / Douglas-fir	RADF	Red alder / Douglas-fir	Intolerant
RAES	Red alder / Engelmann spruce	WHRA	Western hemlock / Red alder	Tolerant
RAGF	Red alder / Grand fir	WHRA	Western hemlock / Red alder	Tolerant
RAMA	Red alder / Bigleaf maple	RAMA	Red alder / Bigleaf maple	Intolerant
RAMD	Red alder / Pacific madrone	RAMA	Red alder / Bigleaf maple	Intolerant
RANC	Red alder / Mix-Noncommercial hardwoods	RAMA	Red alder / Bigleaf maple	Intolerant
RANF	Red alder / Noble fir	WHRA	Western hemlock / Red alder	Tolerant
RAOA	Red alder / Oregon ash	RAMA	Red alder / Bigleaf maple	Intolerant
RARC	Red alder / Western red cedar	RADF	Red alder / Douglas-fir	Intolerant
RASF	Red alder / Pacific silver fir	RAWH	Red alder / Western hemlock	Intolerant
RAWH	Red alder / Western hemlock	RAWH	Red alder / Western hemlock	Intolerant
RAWO	Red alder / Willow	RAMA	Red alder / Bigleaf maple	Intolerant
RC	Western red cedar	DFRC	Douglas-fir / Western red cedar	Intolerant
RCDF	Western red cedar / Douglas-fir	DFRC	Douglas-fir / Western red cedar	Intolerant
RCMA	Western red cedar / Bigleaf maple	RADF	Red alder / Douglas-fir	Intolerant
RCRA	Western red cedar / Red alder	DFRA	Douglas-fir / Red alder	Intolerant
RCWH	Western red cedar / Western hemlock	WHRC	Western hemlock / Western red cedar	Tolerant
SF	Pacific silver fir	SFWH	Pacific silver fir / Western hemlock	Tolerant
SFDF	Pacific silver fir / Douglas-fir	DFWH	Douglas-fir / Western hemlock	Intolerant
SFMA	Pacific silver fir / Bigleaf maple	WHRA	Western hemlock / Red alder	Tolerant
SFNF	Pacific silver fir / Noble fir	SFWH	Pacific silver fir / Western hemlock	Tolerant
SFOA	Pacific silver fir / Oregon ash	WHRA	Western hemlock / Red alder	Tolerant
SFRA	Pacific silver fir / Red alder	WHRA	Western hemlock / Red alder	Tolerant
SFRC	Pacific silver fir / Western red cedar	WHRC	Western hemlock / Western red cedar	Tolerant

Species Group Code	Species Group Name	Forest Type Code	Forest Type Name	Shade Tolerance
SFWH	Pacific silver fir / Western hemlock	SFWH	Pacific silver fir / Western hemlock	Tolerant
SFYC	Pacific silver fir / Alaska yellow cedar	WHSF	Western hemlock / Pacific silver fir	Tolerant
TF	True fir	SFWH	Pacific silver fir / Western hemlock	Tolerant
TFDF	True fir / Douglas-fir	DFSF	Douglas-fir / Pacific silver fir	Intolerant
TFNC	True fir / Mix-Noncommercial hardwoods	SFWH	Pacific silver fir / Western hemlock	Tolerant
TFWH	True fir / Western hemlock	SFWH	Pacific silver fir / Western hemlock	Tolerant
WH	Western hemlock	WHSF	Western hemlock / Pacific silver fir	Tolerant
WHBC	Western hemlock / Black cottonwood	WHRA	Western hemlock / Red alder	Tolerant
WHDF	Western hemlock / Douglas-fir	WHDF	Western hemlock / Douglas-fir	Tolerant
WHMA	Western hemlock / Bigleaf maple	WHRA	Western hemlock / Red alder	Tolerant
WHNC	Western hemlock / Mix-Noncommercial hardwoods	WHRA	Western hemlock / Red alder	Tolerant
WHNF	Western hemlock / Noble fir	WHSF	Western hemlock / Pacific silver fir	Tolerant
WHOA	Western hemlock / Oregon ash	WHRA	Western hemlock / Red alder	Tolerant
WHPY	Western hemlock / Pacific yew	WHSF	Western hemlock / Pacific silver fir	Tolerant
WHRA	Western hemlock / Red alder	WHRA	Western hemlock / Red alder	Tolerant
WHRC	Western hemlock / Western red cedar	WHRC	Western hemlock / Western red cedar	Tolerant
WHSF	Western hemlock / Pacific silver fir	WHSF	Western hemlock / Pacific silver fir	Tolerant
WHWP	Western hemlock / White pine	WHDF	Western hemlock / Douglas-fir	Tolerant
WO	Willow	RAMA	Red alder / Bigleaf maple	Intolerant
WORA	Willow / Red alder	RAMA	Red alder / Bigleaf maple	Intolerant
WPDF	White pine / Douglas-fir	DFWH	Douglas-fir / Western hemlock	Intolerant
WPWH	White pine / Western hemlock	WHDF	Western hemlock / Douglas-fir	Tolerant

2.5 Silvicultural Status

The silvicultural status describes the current forest condition of a given stand as a result of its management history. The code consists of a combination of thinning and regeneration harvest designations plus the stand age at the time of the operation.

Thinning designation:

UT unthinned
CT commercial thin, including thin from below
MT light variable density thinning treatment, principally with the management objective of NSO Movement, Roosting & Foraging (MoRF) and sub-mature habitat conditions
AT heavy variable thinning treatment, principally with the management objective of higher quality northern spotted owl habitat (Type A and better) or older forests conditions

Regeneration harvest designation:

R0 regeneration harvest with 0 legacy trees per acre
R1 variable retention harvest with 8-10 legacy trees per acre dispersed or clumped
R2 variable retention harvest with 15-20 legacy trees per acre dispersed or clumped

Stand age at the time of the operation is represented by a two-digit code for the decadal age class

01 = 10 year age class
02 = 20 year age class, etc

Combinations of the above designations are used to represent stand management history. For example:

1AT03 First heavy variable density thinning in a previously unthinned stand. Thinning operation completed when the stand was in the 30 year age class.

"1" represents the first thinning in the planning period for the stand
"AT" indicates heavy variable density thinning
"03" indicates the stand was in the 30 year age class

Table C7. Silvicultural Status Based on 2007 Forest Condition

Stand Management History	Silvicultural Status
First commercial thinning in previously unthinned stands	1CT00, 1CT01, 1CT02, 1CT03, 1CT04, 1CT05, 1CT06, 1CT07, 1CT08, 1CT09, 1CT10, 1CT11, 1CT12, 1CT13, 1CT14, 1CT15, 1CT16, 1CT17, 1CT18, 1CT19, 1CT20, 1CT21, 1CT22, 1CT23, 1CT24, 1CT25, 1CT26, 1CT27, 1CT28, 1CT29, 1CT30, 1CT31
First light variable density thinning in previously unthinned stands	1MT00, 1MT01, 1MT02, 1MT03, 1MT04, 1MT05, 1MT06, 1MT07, 1MT08, 1MT09, 1MT10, 1MT11, 1MT12, 1MT13, 1MT14, 1MT15, 1MT16, 1MT17, 1MT18, 1MT19, 1MT20, 1MT21, 1MT22, 1MT23, 1MT24, 1MT25, 1MT26, 1MT27, 1MT28, 1MT29, 1MT30, 1MT31

Stand Management History	Silvicultural Status
First heavy variable density thinning in previously unthinned stands	1AT00, 1AT01, 1AT02, 1AT03, 1AT04, 1AT05, 1AT06, 1AT07, 1AT08, 1AT09, 1AT10, 1AT11, 1AT12, 1AT13, 1AT14, 1AT15, 1AT16, 1AT17, 1AT18, 1AT19, 1AT20, 1AT21, 1AT22, 1AT23, 1AT24, 1AT25, 1AT26, 1AT27, 1AT28, 1AT29, 1AT30, 1AT31
First commercial thinning in regenerated stands with no legacy trees	R0-1CT03, R0-1CT04, R0-1CT05, R0-1CT06, R0-1CT07, R0-1CT08, R0-1CT09, R0-1CT10
First light variable density thinning in regenerated stands with no legacy trees	R0-1MT03, R0-1MT04, R0-1MT05, R0-1MT06, R0-1MT07, R0-1MT08, R0-1MT09, R0-1MT10
First heavy variable density thinning in regenerated stands with no legacy trees	R0-1AT03, R0-1AT04, R0-1AT05, R0-1AT06, R0-1AT07, R0-1AT08, R0-1AT09, R0-1AT10
Second commercial thinning in regenerated stands without legacy trees	R0-1CT03-2CT06, R0-1CT03-2CT07, R0-1CT03-2CT08, R0-1CT03-2CT09, R0-1CT04-2CT07, R0-1CT04-2CT08, R0-1CT04-2CT09, R0-1CT04-2CT10, R0-1CT05-2CT08, R0-1CT05-2CT09 , R0-1CT05-2CT10, R0-1CT06-2CT09, R0-1CT06-2CT10, R0-1CT07-2CT09, R0-1CT07-2CT10, R0-1CT08-2CT09, R0-1CT08-2CT10, R0-1CT09-2CT09, R0-1CT09-2CT10, R0-1CT10-2CT10
First commercial thinning in regenerated stands with 10 legacy trees per acre	R1-1CT03, R1-1CT04, R1-1CT05, R1-1CT06, R1-1CT07, R1-1CT08, R1-1CT09, R1-1CT10
First light variable density thinning in regenerated stands with 10 legacy trees per acre	R1-1MT03, R1-1MT04, R1-1MT05, R1-1MT06, R1-1MT07, R1-1MT08, R1-1MT09, R1-1MT10
First heavy variable density thinning in regenerated stands with 10 legacy trees per acre	R1-1AT03, R1-1AT04, R1-1AT05, R1-1AT06, R1-1AT07, R1-1AT08, R1-1AT09, R1-1AT10
Second commercial thinning in regenerated stands with 10 legacy trees per acre	R1-1CT03-2CT06, R1-1CT03-2CT07, R1-1CT03-2CT08, R1-1CT03-2CT09, R1-1CT04-2CT07, R1-1CT04-2CT08, R1-1CT04-2CT09, R1-1CT04-2CT10, R1-1CT05-2CT08, R1-1CT05-2CT09, R1-1CT05-2CT10, R1-1CT06-2CT09, R1-1CT06-2CT10, R1-1CT07-2CT09, R1-1CT07-2CT10, R1-1CT08-2CT09, R1-1CT08-2CT10, R1-1CT09-2CT09, R1-1CT09-2CT10, R1-1CT10-2CT10
First commercial thinning in regenerated stands with 20 legacy trees per acre	R2-1CT03, R2-1CT04, R2-1CT05, R2-1CT06, R2-1CT07, R2-1CT08, R2-1CT09, R2-1CT10
First light variable density thinning in regenerated stands with 20 legacy trees per acre	R2-1MT03, R2-1MT04, R2-1MT05, R2-1MT06, R2-1MT07, R2-1MT08, R2-1MT09, R2-1MT10
First heavy variable density thinning in regenerated stands with 20 legacy trees per acre	R2-1AT03, R2-1AT04, R2-1AT05, R2-1AT06, R2-1AT07, R2-1AT08, R2-1AT09, R2-1AT10
Second commercial thinning in regenerated stands with 20 legacy trees per acre	R2-1CT03-2CT06 , R2-1CT03-2CT07, R2-1CT03-2CT08, R2-1CT03-2CT09, R2-1CT04-2CT07, R2-1CT04-2CT08, R2-1CT04-2CT09, R2-1CT04-2CT10, R2-1CT05-2CT08, R2-1CT05-2CT09, R2-1CT05-2CT10, R2-1CT06-2CT09, R2-1CT06-2CT10, R2-1CT07-2CT09, R2-1CT07-2CT10, R2-1CT08-2CT09 , R2-1CT08-2CT10, R2-1CT09-2CT09, R2-1CT09-2CT10 , R2-1CT10-2CT10

2.6 Administrative Units

The following codes were used to identify the smallest administrative unit, the local. These data are sourced from Cadastre and are used for reported to field foresters.

The ADMIN_CLS codes were included in the model. ADMIN_CD and ADMIN_NM are provided as reference

Table C8. Administrative Code Names

ADMIN_CLS	ADMIN_CD	ADMIN_NM
Nw-cas-bou	1924	Boulder
Pc-bhl-blr	441	Black-River
Pc-bhl-cap	442	Capitol
Sp-bdi-gra	943	Grass-Mountain
Sp-bdi-mcr	942	McDonald-Ridge
Sp-bdi-tra	941	Transitional-Assets
Sp-bel-grm	992	Green-Mountain
Sp-bel-tah	993	Tahuya
Sp-bel-tra	991	Transitional-Assets
Sp-elb-elb	972	Elbe-Hills
Sp-elb-plv	973	Pleasant-Valley
Sp-elb-tho	974	Tahoma
Sp-elb-tra	971	Transitional-Assets
Sp-hoo-swd	983	Sherwood
Sp-hoo-tra	981	Transitional-Assets
Sp-sno-rar	934	Raging-River
Sp-sno-tig	935	Tiger-Mountain
Sp-sno-tra	931	Transitional-Assets

2.7 Spotted Owl Management units (SOMU)

The Spotted Owl Management Unit (SOMU) is a land classification used for the analysis of habitat conditions and tracking of required amounts of suitable habitat for the Northern Spotted Owl per the 1997 Habitat Conservation Plan. SOMU boundaries were derived from watershed administrative units, and essentially retain the 1997 WAU boundaries with minor changes. See *PR 14-004-120 Northern Spotted Owl Management (Westside)* for additional information.

The following SOMU codes were included in the model:

ASHFORD
BIG-CATT
BUSY-WILD
GRASS-MOUNTAIN
GREEN
MINERAL-CREEK
NORTH-FORK-GREEN
NORTH-FORK-MINERAL
PLEASANT-VALLEY-DISP
PLEASANT-VALLEY-NRF
REESE-CREEK

2.8 Watersheds (WAU and SOMU)

The following codes were used to identify the Watershed Administrative Unit (WAU). As established by WAC 222-22-020, the state is divided into areas known as watershed administrative units (WAUs). WAU boundaries were defined by the DNR in cooperation with the departments of Ecology, Fish and Wildlife, affected Indian tribes, local governments, forest land owners, and the public. WAU's are the basic hydrologic units used for watershed analysis. WAU boundaries are mainly along drainage divides (ridges), with some along rivers and other DNR management boundaries. In the forested areas of the state, the WAUs range in size from 3,822 to 297,614 acres with a mean of 40,187 acres.

The following WAUs (WAU_CLS) were included in the model. The WAU_CD and WAU_NM are provided as reference.

Table C9. Watershed (WAU) Code Names

WAU_CLS	WAU_CD	WAU_NM	Acres
Bangor-por	150203	BANGOR-PORT-GAMBLE	47
Black-rv	230602	BLACK-RIVER	31
Carbon	100418	CARBON	3
Catt	110108	CATT	6,469
Cedar-rv-t	80106	CEDAR-RIVER/TAYLOR-CREEK	5
Chambers-c	120101	CHAMBERS-CLOVER	23
Chico-ck	150108	CHICO-CREEK	2,381
Colvos-pas	150103	COLVOS-PASSAGE/CARR-INLET	380
Cumberland	90202	CUMBERLAND	2,647
Dyes-inlet	150109	DYES-INLET	24
East-ck	110113	EAST-CREEK	3,808
Electron	100519	ELECTRON	307
Goat-lk	110106	GOAT-LAKE	223
Great-bend	150201	GREAT-BEND	15,027
Grwater	100205	GREENWATER	106
Harstine-i	140104	HARSTINE-ISLAND	263
Howard-han	90103	HOWARD-HANSEN	15,466
Kennedy-ck	140102	KENNEDY-CREEK	8,378
Key-penins	150106	KEY-PENINSULA	1,083
Liberty-mi	150110	LIBERTY-MILLER-APPLETREE	866
Little-nis	110114	LITTLE-NISQUALLY-RIVER	237
Lk-sammami	80304	LAKE-SAMMAMISH	90
Low-deschu	130203	LOWER-DESCHUTES	16
Lower-ceda	80105	LOWER-CEDAR-RIVER	14
Lower-puya	100601	LOWER-PUYALLUP	2
Lower-whit	100302	LOWER-WHITE	9
Low-gr-duw	90301	LOWER-GREEN-DUWAMISH	1,456
Low-skokom	160106	LOWER-SKOKOMISH	13
Low-skooku	230404	LOWER-SKOOKUMCHUCK	460

WAU_CLS	WAU_CD	WAU_NM	Acres
Lynch-cove	150204	LYNCH-COVE	10,205
Mashel	110204	MASHEL	14,318
Mason	140101	MASON	3,109
Mcallister	110317	MCALLISTER	26
Mclane-ck	130202	MCLANE-CREEK	3,437
Mid-deschu	130104	MIDDLE-DESCHUTES	12
Mid-white	100204	MIDDLE-WHITE	1
Mineral-ck	110110	MINERAL-CREEK	4,450
Mox-chehal	220106	MOX-CHEHALIS	12
Muck-ck	110301	MUCK-CREEK	182
Mud-mtn	100203	MUD-MTN	508
Newaukum	90209	NEWAUKUM	242
Nf-gr	90104	NF-GREEN	6,229
Nf-mineral	110112	NF-MINERAL-CREEK	13,166
N-lk-washi	80409	N-LAKE-WASHINGTON	0
Ohop-ck	110203	OHOP-CREEK	146
Patterson-	70429	PATTERSON-CREEK	1
Porter-ck	230522	PORTER-CREEK	15
Possession	80501	POSSESSION-SOUND-N-ELLIOT-BAY	3
Powell-ck	110215	POWELL-CREEK	280
Raging-rv	70408	RAGING-RIVER	14
Reese-ck	110109	REESE-CREEK	11,188
Sammamish-	80402	SAMMAMISH-RIVER	236
Scatter-ck	230403	SCATTER-CREEK	3
S-elliott-	90410	S-ELLIOTT-BAY/E-PASSAGE	25
Silver	260338	SILVER	3
S-prairie	100416	SOUTH-PRAIRIE	198
Squaxin-is	140103	SQUAXIN-ISLAND	299
S-sinclair	150107	S-SINCLAIR-INLET	2
Sunday-ck	90107	SUNDAY-CREEK	21
Tanwax-ck	110202	TANWAX-CREEK	0
Teeley-ck	110107	TEELEY-CREEK	304
Tiger	80303	TIGER	9,718
Up-gr-rv	90108	UPPER-GREEN-RIVER	270
Vashon-isl	150102	VASHON-ISLAND	43
Waddel-ck	230601	WADDEL-CREEK	41
W-kitsap	150202	W-KITSAP	6,779
Woodland-c	130201	WOODLAND-CREEK	608
Yelm-ck	110316	YELM-CREEK	246
Grand Total			146,173

2.9 Surface and Timber Ownership Groups

The surface and timber ownership theme includes three ownership categories: non-trust lands, federally granted trusts and purchased lands, and state forest board transfer lands. Each category is a grouping of several classes listed below.

Non-Trust Lands

NAP	Natural Area Preserves
NRCA	Natural Resource Conservation Area
WPCD	Water Protection Cooperative District
ADMIN-SITE	Administrative Site

Federally Granted Trusts and Purchased lands (FED-GRANT)

AGRIC-SCH	Agricultural School
CAPITOL-GRNT	Capitol Grant
CEP&RI	Charitable/Educational/Penal & Reformatory Institute
CEP&RI-TRANS	Charitable/Educational/Penal & Reformatory Institute / Transferred CMNTY-COLL – Community College
COM-SCHL/IND	Common School and Indemnity
ESCHEAT	Escheat
FOR-BD-PURCH	State Forest Board Purchase
NORMAL-SCH	Normal School
SCIENTIC-SCH	Scientific School
UNIV-ORIG	University - Original
UNIV-TRANS	University - Transferred

State Forest Board Transfer lands (SFB-TRNF) for each county

- FBT-KING
- FBT-KITSAP
- FBT-LEWIS
- FBT-MASON
- FBT-PIERCE
- FBT-SNOHOMISH
- FBT-THURSTON

Only Pierce and Kitsap counties are completely contained with the South Puget HCP Planning unit.

2.10 Deferrals

Forest land deferrals follow designations in the *Policy for Sustainable Forests*, the *Habitat Conservation Plan*, and the *Settlement Agreement*.

Long-term deferred areas include:

- Parks
- Gene pools
- NAPs and NRCAs
- Selected local operational constraints

Marbled murrelet occupied sites, reclassified and non-occupied
Buffer around location of NRF management nest core areas (2052)
300 acre nest patch core areas (2052)

Short-term deferred areas include:
Settlement Agreement owl areas and habitat classes
Selected local operational constraints (varied)

Long-term means harvest deferrals beyond the first period, in this case 2017. Short-term means harvest deferrals that are released at the end of the first period (2017). The year in brackets means the year of release.

A six-digit alphanumeric code was used to identify and classify deferral areas, as described in Table C10 below.

Table C10. Six-Digit Alphanumeric Code Used to Identify and Classify Deferral Areas

Posi	Type	Name	Description	Values
1-2	Num	Deferral years	2 digit numeric code representing the year area is released from deferral. Release begins on Jan 1 of the given year.	00 = no deferral 07 = 2007, stand is released 1/1/2007 14 = 2014, stand is released 1/1 2014 99 = permanent deferral
3	Char	Murrelet habitat	1 character code indicating whether deferral area is classified as marbled murrelet habitat	M = murrelet habitat N = non-habitat
4	Char	NSO habitat	1 character code indicating northern spotted owl habitat classification, per Forestry Handbook procedure PR 14-004-120 *Northern Spotted Owl Management (Westside)*. Codes were reclassified and regrouped for use within the model. See table C2 below.	A = type A high quality nesting habitat B = type B high quality nesting habitat S = sub-mature habitat Y = young forest marginal D = dispersal habitat X = next best stands N = non-habitat
5	Char	Old growth index	1 character classification of the potential for the presence of old growth forest conditions, per assessment of structural conditions as outlined in the Westside Old Growth Index	H = high potential for old growth (WOGHI[1] ≥ 60) M = moderate potential for old growth ($50 \leq$ WOGHI < 60) N = not old growth (WOGHI < 50) O = OESF old growth
6	Char	Thinning per concurrence letter	1 character code indicating deferral area includes timber sales eligible for thinning to RD 45 and 125 trees per acre as identified in the USFS / DNR concurrence letter (Berg 2005)	C = included in concurrence letter N = not included in concurrence letter

Old Growth Habitat Index (WOGHI) is a screening tool that uses data from DNR's Forest Resource Inventory System (FRIS) to compare the structure of stands on DNR-managed land with a reference condition from known old growth stands in Western Washington. The WOGHI integrates four key elements of old forests: (1) large trees (number of trees per hectare > 100 cm dbh); (2) large snags (number of standing dead trees oer hectare > 50 cm dbh and > 15 m tall); (3) volume of down woody debris (cubic meters per hectare); and (4) tree size diversity. (DNR 2005).

Existing NSO habitat management codes were reclassified and regrouped for use within the model, as described in Table C11 below.

Table C11. Crosswalk of Northern Spotted Owl Management to Habitat Coding

NSO-MGT-CD	Description	NSO-HAB
-1	Non-habitat (outside of NSO range)	N
A	High quality habitat	A
B	High quality habitat	B
D	Dispersal habitat	D
DS	Dispersal habitat (settlement)	D
DS	Next best (settlement)	X
N	Next best	X
N	Non-habitat, within NSO range	N
S	Sub-mature habitat	S
SS	Next best (settlement)	X
U	Next best	X
U	Unknown stands	U
Y	Young forest marginal habitat	Y
YS	Next best (settlement)	X

Table C12. Northern Spotted Owl Habitat Definitions

ATTRIBUTES	HIGH QUALITY NESTING	TYPE "A" SPOTTED OWL	TYPE "B" SPOTTED OWL	MoRF	SUB-MATURE	YOUNG FOREST MARGINAL	DISPERSAL
LIVE TREES							
Species Requirement (West Side)	none	Multi-species (2nd Species: 20.0+% Trees/Ac)	Multi-species (2nd Species: 20.0+% Trees/Ac)	30.0+% Conifer, Trees/Ac	30.0+% Conifer, Trees/Ac	30.0+% Conifer, Trees/Ac	
Layers Requirement	None	2+	2+	none	none	none	none
Canopy Cover Requirement	none	none	none-	70+%	70+%	70+%	70+%
Canopy closure	70+%	70+%	70+%	none	none	none	
Deformity Requirement	Broken Tops: 21 in. DBH class,	Broken Tops: 21 in. DBH Class,	Broken Tops: 21 in. DBH Class				
LIVE TREES							
Min. Top Height (ft.) *(40 Largest Trees)*	none	None	none	85.0	85.0	85.0	85.0
Min. QMD (in.) *(100 Largest Trees)*	none	none	none	none	none	none	11.0
LIVE TREES (#1)							
Min. DBH Class	21	30	20				
Min. Stems/Ac	31.0+	15.0	75.0	115.0	115.0	115.0	100.0+
Max. Stems/Ac	none	75.0	100.0	280.0	280.0	280.0	none
LIVE TREES (#2)							
Min. DBH Class	31						
Min. Stems/Ac	15.0+	none	None	none	none	none	none

Max. Stems/Ac	none						
SNAGS							none
Min. DBH Class	21	30	20	15	20	20	
Min. Stems/Ac	12.0+	2.5+	1.0+	3.0+	3.0+	2.0+ (or down wood requirement)	
DOWN WOOD							none
Ground Covered	5.0+ %	5.0+ %	5.0+ %	5.0+ %	5.0+ %	5.0+ %	
Cu. Ft. / Ac	2400	2400	2400	2400	2400	4800 (or 2 snags per acre requirement)	

Notes:

(1) Minimum DBH Class for all live trees is 4 inches.
(2) Minimum tree diameter for live trees and snags is the nominal class value less 0.5 inches (e.g. 4-inch class minimum tree size is 3.5 inches).
(3) Deformity requirements are NOT applied at this time (i.e. 9/9/2005).
(4) Down woody debris is an inferred parameter not directly found in Final Habitat Conservation Plan, Sept. 1997, Part IV, Habitat Definitions, p.11-19.
(5) Shrub cover requirements for OESF are NOT applied at this time (i.e. 9/9/2005).
Canopy cover and closure requirements are met if Curtis' relative density is greater than or equal to RD 48

Next best stands are the non-habitat stands within a given Spotted Owl Management Unit (SOMU), judged by a wildlife biologist as the soonest to reach the desired habitat threshold. Next best stands were only selected from SOMUs that are currently under the 50 percent target threshold level.

Unknown stands lack a sample inventory and therefore could not be screened for Northern Spotted Owl habitat. In the modeling process, all stands are assigned to various forest strata, containing a representation of all yield variables, including habitat. Overestimation of habitat in the some of the SOMU is a likely a result of this process of assigned stands to strata.

The following 68 deferral codes were used in the model:

00NDMC	00NNMC	00NYHC	00NAHN	00NBMN	00NBNN
00NDMN	00NDNC	00NDNN	00NNHN	00NNMN	00NNNC
00NNNN	00NSHN	00NSMN	00NSNC	00NSNN	00NUNC
00NUNN	00NXMN	00NXNC	00NXNN	00NYHN	00NYMN
00NYNC	00NYNN	10NDNC	10NDNN	10NNNC	10NNNN
10NUNC	10NUNN	10NXNC	10NXNN	14NNNN	15NNNN
15NUNN	17NNNN	22NNNN	47NNNN	47NSMN	47NUNN
47NXNN	47NNNC	47NSMC	47NXNC	99NSMC	99NSNC
99NXNC	99NUNC	99NAHN	99NBNN	99NDMN	99NDNC
99NDNN	99NNHN	99NNMN	99NNNC	99NNNN	99NSHN
99NSMN	99NSNN	99NUNN	99NXMN	99NXNN	99NYHN
99NYMN	99NYNN				

2.11 Land Classes

A land class code was used to classify management objectives, permitted silvicultural activities, and management constraints for a given area. The code consists of a composite of several fields, as described in table C16.

Table C13. Land Class Code

Field	Description	Value(s)
1	Planning area	SPS South Puget HCP Planning unit
2	Land class	GEM General Ecological Management. Upland areas for which there are general (i.e., no species-specific) wildlife habitat requirements. All silviculture applies. Constraints on GEM lands are not spatially explicit, and include areas such as those used to meet leave tree and wildlife tree requirements for timber sales, or other other local, not spatially explicit operational constraints. GEM areas may have additional visual or slope stability constraints. RIP Riparian areas, wetlands, and associated management zones as defined and managed according to Forestry handbook procedure PR 14-004-150 *Identifying and Protecting Riparian and Wetland Management Zones in the Westside HCP Planning Units, Excluding the OESF Planning Unit.* RIP areas are managed for ecosystem restoration, and are modeled such that only one future thinning is permitted. RIP areas may have additional visual or slope stability constraints. UPL Upland areas with specific stand-level objectives. UPL areas were defined along WAU boundaries, and are used to model management constraints. For example, continuous maintenance of forest cover[2] is required for a percentage of the watershed. Upland areas include those managed to meet the habitat requirements of specific wildlife species, areas with spatially explicit local operational constraints, transition lands. UPL areas may have additional visual or slope stability constraints.
3	Additional constraints, represented as a suffix of the GEM, UPL, or RIP land classed.	S Areas of potentially unstable slopes, with at least 20% of the area identified with the potential for shallow rapid landslides. V visual management areas Either, neither, or both codes may be used. Silvicultural operations are more restricted in lands identified with the S or V suffix.

Other landscape-level management strategies, including those that apply to Northern Spotted Owl Nesting, Roosting & Foraging (NRF) and Dispersal Management areas, and rain-on-snow sub-basins, are represented in individual themes in the model. Local knowledge was collected and digitized during the planning process from DNR forest managers and local stakeholder groups. These data were incorporated into the GEMS, UPL, and visual management areas.

[2] Relative density (RD) was used as a measure of forest cover. For thinning group 1, RD ≥ 48; for thinning group 2, RD ≥ 25.

The following land class codes were used in the model:

SPS-GEM	
SPS-GEM-V	
SPS-GEM-S	
SPS-GEM-V-S	
SPS-RIP	
SPS-RIP-V	
SPS-RIP-S	
SPS-RIP-V-S	
SPS-UPL	
SPS-UPL-ALL	The upland class aggregate "UPL-ALL" was used to represent areas of potentially deep seated and shallow rapid unstable slopes, recreation areas, and local knowledge, including visual management areas.
SPS-UPL-V	
SPS-UPL-S	
SPS-UPL-V-S	

2.12 Rain-on-Snow Sub-Basins

The rain-on-snow zone is an area, generally defined as an elevation zone, where it is common for the snowpack to be partially or completely melted during rainstorms several times during the winter. Within the South Puget HCP Planning Unit, 50,043 acres of land are located within the rain-on-snow zone. Rain-on-snow sub-basins are identified in accordance with the Forestry Handbook procedure PR 14-004-060 *Assessing Hydrologic Maturity*. The requirements outlined in the procedure are designed to minimize adverse impacts caused by peak flows associated with rain-on-snow events to ecosystems that support salmonids. Hydrologic maturity is accomplished by maintaining an adequate amount of forest land within rain-on-snow zones in forests that are hydrologically mature with respect to rain-on-snow events.

A modeling target for hydrologic maturity was defined as having a relative density (RD) ≥ 25 over at least 66% of the total area within rain-on-snow critical sub-basins.

Development types containing basins within the rain-on-snow zone were assigned a unique number. Development types without basins in the rain-on-snow zone are assigned a code of "NOT-ROS".

The following rain-on-snow basin codes were used in the model:

08030306	09010301	09010304	09010305	09010306	09010308
09010401	09020203	11010801	11010803	11010901	11010903
11010905	11010906	11010907	11011201	11011202	11011203
11011204	11011205	11011206	11011207	11011304	11020402
11020403	11020405	23052203	NOT-ROS		

2.13 Road Access

Areas in the model GIS inputs were identified by their proximity to an existing road. The proximity was defined as 800 feet from an existing road. The distant of 800 feet was considered an average yarding distance for cable harvest operations. The following codes were used to identify the existing road proximity

Harv-acces
No-access

3. Forest Inventory Stratification

Combinations of the above described forest inventory parameters (Forest Type, Site Class, Stocking Class, and Size Class) were used to stratify the planning unit. Since representative data (tree lists) were only available for stands sampled as part of the DNR inventory process; only sampled stands were used to generate yield tables in the Forest Vegetation Simulator (FVS). Table C14 lists the amount of the planning unit in each inventory type.

Table C14. Inventory Type Within the South Puget HCP Planning Unit

Resource Inventory Unit (RIU) type	Number of RIUs	Acres	Hectares	Percent of area
Legacy inventory (L)	601	29,253	11,838	20%
Sampled (P)	2,232	113,917	46,001	79%
Newly regenerated (R)	24	1,355	548	1%
Grand Total	2,857	144,525	58,487	100%

The stratification resulted in 303 strata out of a possible 780. In addition to the existing strata, three additional strata were added to represent newly regenerated stands and inventory stands, making a total of 306 strata. Table C18 presents basic inventory statistics for the top 42 strata representing 70 percent of the land base.

Table C15. Forest Stratification for the South Puget HCP Planning Unit:Top 42 strata, Ranked by Area, Representing 70 Percent of the Forested Land Base

Strata	Inventory units (RIUs)	Sum of ACRES	Average of SI	StdDev of SI	Average of BA3D5	StdDev of BA3D5	Average of TOPHT	StdDev of TOPHT	Average of QMD3D5	StdDev of QMD3D5	Average of TPA3D5	StdDev of TPA3D5	Average of RD3D5	StdDev of RD3D5	Average of BFMV	StdDev of BFMV	Average of Age	StdDev of Age	Max of Age	Min of Age	percent of Total	Cumulative Percent
DFWH_SIC3_GOSTK_Size2	208	12,093	106	7	259	21	115	12	11.6	1.1	361	59	76	5	34	5	45	25	112	1	8.4%	8%
DFWH_SIC3_MISTK_Size2	288	10,872	105	5	198	23	108	12	11.6	1.1	276	48	58	6	26	5	33	26	117	1	7.5%	16%
DFWH_SIC2_MISTK_Size3	176	7,202	125	6	255	17	135	12	15.7	1.1	192	25	64	4	40	4	38	27	111	1	5.0%	21%
DFWH_SIC4_MISTK_Size2	127	6,147	87	7	200	23	100	14	11.1	1.2	305	61	60	6	25	5	49	29	137	1	4.3%	25%
DFRA_SIC2_MISTK_Size3	134	4,482	126	5	243	21	134	12	15.9	1.1	178	26	61	5	38	4	43	30	108	1	3.1%	28%
DFRA_SIC3_MISTK_Size2	106	4,202	108	6	199	33	109	18	11.9	1.6	263	54	58	8	26	7	42	27	86	1	2.9%	31%
DFWH_SIC4_GOSTK_Size2	82	3,902	87	7	249	22	108	12	10.7	1.3	413	89	76	5	31	6	56	32	132	1	2.7%	34%
DFWH_SIC3_MISTK_Size3	105	3,866	110	5	239	30	126	11	15.3	0.7	189	27	61	8	36	6	40	34	223	1	2.7%	37%
DFWH_SIC2_GOSTK_Size2	67	3,197	125	5	272	21	126	20	12.4	1.0	329	44	77	5	39	6	46	27	83	1	2.2%	39%
DFRA_SIC3_MISTK_Size3	82	2,940	110	6	243	26	127	17	15.7	0.9	181	25	61	6	37	7	55	30	114	1	2.0%	41%
DFWH_SIC2_GOSTK_Size3	73	2,903	127	6	298	21	142	15	15.4	1.1	233	33	76	5	48	6	51	32	122	1	2.0%	43%
DFWH_SIC2_MISTK_Size2	45	2,220	124	4	219	22	117	22	12.2	1.2	276	52	63	6	31	6	46	30	140	2	1.5%	44%
DFMA_SIC2_MISTK_Size3	56	1,934	126	4	243	25	137	11	16.2	1.1	171	27	60	6	39	4	45	40	215	1	1.3%	46%
DFWH_SIC3_OPSTK_Size1	57	1,930	103	3	64	24	52	12	5.7	1.0	365	127	27	9	2	3	35	18	118	21	1.3%	47%
WHDF_SIC3_GOSTK_Size2	34	1,802	106	6	277	20	111	9	11.4	1.2	407	97	82	7	36	4	54	15	77	13	1.2%	48%
DFWH_SIC4_OPSTK_Size2	42	1,770	82	11	113	29	76	16	10.3	1.9	206	70	35	8	11	4	50	13	100	34	1.2%	49%
WHDF_SIC4_GOSTK_Size2	49	1,708	79	11	289	23	107	12	11.3	1.4	433	116	86	8	35	7	75	26	122	5	1.2%	51%
DFWH_SIC3_GOSTK_Size3	45	1,678	110	4	284	21	129	15	15.1	1.2	231	23	73	4	44	6	69	39	145	7	1.2%	52%
WHDF_SIC4_MISTK_Size2	26	1,500	83	9	223	21	92	22	11.5	1.3	317	73	66	6	26	7	50	23	125	16	1.0%	53%
DFWH_SIC4_OPSTK_Size1	50	1,423	80	15	59	27	44	12	5.7	1.0	332	131	24	10	2	2	41	29	131	19	1.0%	54%
SFWH_SIC4_MISTK_Size2	25	1,413	79	12	213	13	92	7	10.7	0.5	345	33	65	3	27	4	27	18	85	12	1.0%	55%

Strata	Number of Inventory units (RIUs)	Sum of ACRES	Average of SI	StdDev of SI	Average of BA3D5	StdDev of BA3D5	Average of TOPHT	StdDev of TOPHT	Average of QMD3D5	StdDev of QMD3D5	Average of TPA3D5	StdDev of TPA3D5	Average of RD3D5	StdDev of RD3D5	Average of BFMV	StdDev of BFMV	Average of Age	StdDev of Age	Max of Age	Min of Age	Strata area percent of Total	Cumulative Percent
DFRA_SIC3_GOSTK_Size2	38	1,340	110	5	267	17	117	16	12.1	1.1	343	61	77	5	36	5	44	28	87	1	0.9%	56%
DFWH_SIC2_MISTK_Size4	26	1,261	129	6	257	19	149	12	19.5	1.3	126	19	58	5	45	5	65	22	86	5	0.9%	57%
WHSF_SIC4_GOSTK_Size2	30	1,163	83	13	295	31	98	16	11.0	1.6	470	116	89	6	34	10	56	22	120	2	0.8%	57%
DFMA_SIC3_MISTK_Size3	31	1,161	110	6	231	24	129	14	16.0	1.1	167	23	58	5	36	5	51	38	156	2	0.8%	58%
DFRA_SIC2_GOSTK_Size2	36	1,158	126	6	272	18	125	18	12.8	1.1	312	54	76	4	38	5	38	28	93	1	0.8%	59%
WHDF_SIC3_MISTK_Size3	23	1,149	107	7	270	23	126	16	15.7	1.3	204	28	68	5	41	6	75	30	166	2	0.8%	60%
DFWH_SIC4_EXSTK_Size2	19	1,145	82	11	321	31	111	20	10.2	1.7	597	163	101	9	38	10	78	22	130	47	0.8%	61%
DFMA_SIC3_MISTK_Size2	37	1,144	110	5	210	28	115	17	12.1	1.4	267	51	60	7	28	7	29	29	85	1	0.8%	61%
WHDF_SIC4_OPSTK_Size2	16	1,119	83	9	145	27	79	13	10.8	1.5	235	72	44	8	15	4	45	16	74	1	0.8%	62%
DFRA_SIC2_MISTK_Size2	30	1,108	127	6	221	23	118	19	12.1	1.3	283	52	64	5	30	5	40	28	76	1	0.8%	63%
DFRA_SIC2_MISTK_Size4	45	1,096	129	5	256	24	147	12	19.2	1.2	129	20	58	6	43	5	50	32	88	2	0.8%	64%
SFWH_SIC4_OPSTK_Size1	32	1,056	77	11	53	34	36	9	5.1	0.7	353	193	23	14	1	1	31	8	48	21	0.7%	64%
RADF_SIC2_MISTK_Size3	32	1,013	130	4	240	21	121	11	16.2	1.1	171	26	60	5	36	4	61	22	91	1	0.7%	65%
WHDF_SIC2_GOSTK_Size2	16	966	127	9	281	15	120	11	11.4	1.1	411	99	84	7	38	3	57	9	72	44	0.7%	66%
DFRC_SIC2_MISTK_Size3	22	928	124	5	249	16	136	12	16.1	1.0	177	26	62	5	40	4	57	47	215	6	0.6%	66%
DFRA_SIC3_OPSTK_Size2	17	927	106	6	121	26	79	15	10.2	2.0	223	60	38	6	13	4	36	14	79	6	0.6%	67%
WHSF_SIC3_GOSTK_Size2	18	926	102	6	297	32	103	13	11.3	1.6	451	132	89	8	36	8	57	15	91	20	0.6%	68%
DFRA_SIC3_OPSTK_Size1	27	898	105	5	73	30	57	10	6.3	1.0	341	144	29	12	3	2	33	13	67	21	0.6%	68%
DFWH_SIC4_MISTK_Size3	28	891	89	7	234	31	122	10	15.1	0.7	189	27	60	8	35	6	46	32	120	1	0.6%	69%
WHDF_SIC3_MISTK_Size2	15	850	104	5	229	33	107	16	12.1	1.2	290	52	66	8	30	7	48	19	77	1	0.6%	70%
DFRA_SIC2_GOSTK_Size3	36	809	128	7	296	18	143	14	15.6	1.1	226	29	75	4	48	5	52	33	97	1	0.6%	70%

4. Silviculture

4.1 Silvicultural Treatments and Regimes

The silvicultural treatment(s) applied to the forest resource depend on management objectives, regulations, policies and suitability of the forest types and land class. Considerations include the HCP regulations, Settlement Agreement status, habitat designation, visual corridor, upland stability characteristics, rain on snow targets (hydrological maturity), and economic factors. Permissible, restricted and modified silvicultual practices are outlined in the sections that follow.

In upland zones (GEM and UPL), forests are treated as even-aged stands unless variable retention harvest are implemented for habitat creation, or cover is maintained for visual or slope stability reasons. Riparian areas are only thinned once; these areas are to be restored to natural ecosystems without active forest management.

The general sequence of treatments that are applied in creating and maintaining even-aged stands are as follows:

Treatment options include:

- No thinning treatments: stands remain unthinned during simulation (UT).

- Regeneration harvest retaining nil, 10, or 20 trees per acre, followed by planting and natural regeneration.

  R0: Regeneration harvest without residual trees during simulation runs
  R1: Regeneration harvest with 10 residual trees during simulation runs
  R2: Regeneration harvest with 20 residual trees during simulation runs

- Thinning: light (retaining 70% RD) and heavy (retaining 50% RD):

  CT: Commercial thinning
  MT: light intensity variable density thinning to create Northern Spotted Owl Movement, roosting, and forging (MoRF) habitat
  AT: Heavy intensity variable density thinning to create Northern Spotted Owl Type A habitat

- Planting Douglas-fir at 250 trees per acre and Red Cedar at 50 trees per acre with a 90% survival rate for all regeneration harvest treatments.

- Natural regeneration occurs regardless of silvicultural treatment. Naturally regenerate Western Hemlock at 550 trees per acre for West Cascades (WC) FVS variant or 150 trees per acre for Pacific Northwest (PN) variant with a 60% survival rate for all regeneration harvest treatment.

4.2 Modeled Silvicultural Regimes

The yield tables used in Woodstock are based on the predominant silvicultural regimes that DNR uses or plans to use for stand-level forest management. Regimes have been modeled both for existing stands over 30 years of age, and those which are less than 30 years or will be regenerated in the future.

A range of permitted potential silvicultural pathways is modeled for each stand. The options provide the flexibility to achieve the forest estate level objectives that address a multitude of competing and often conflicting land use targets (e.g., trade-offs between timber harvest and habitat development or riparian restoration).

A range of silvicultural pathways, coupled with flexible rotation lengths, is necessary to regulate the flow of timber in a heterogeneous forested land base, variable with respect to stand development stage, species composition, structure, geographic distribution, and growth rate.

The range of possible regime pathways is illustrated in the following diagrams:

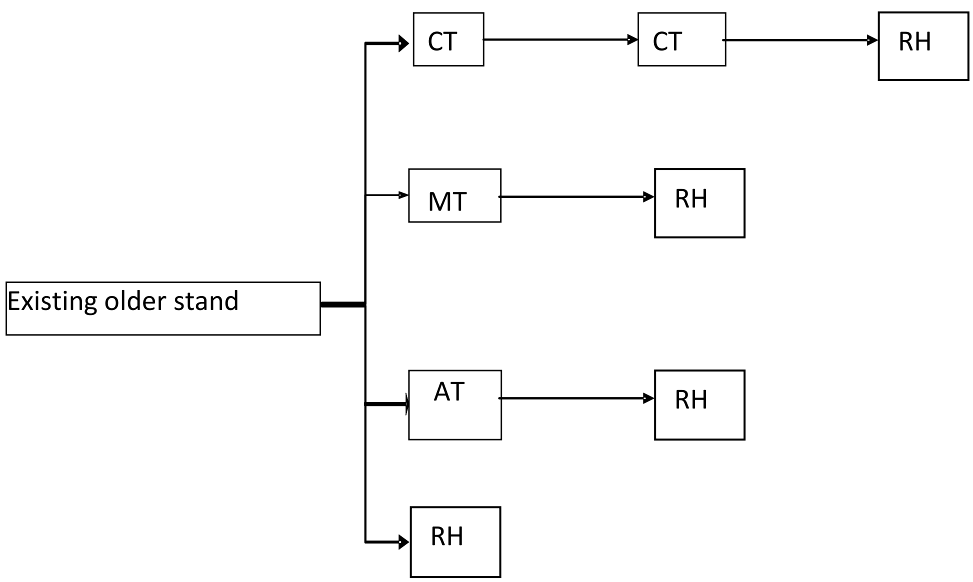


Figure C3. Silvicultural Pathways for Existing Forest Stands Older Than 30 Years

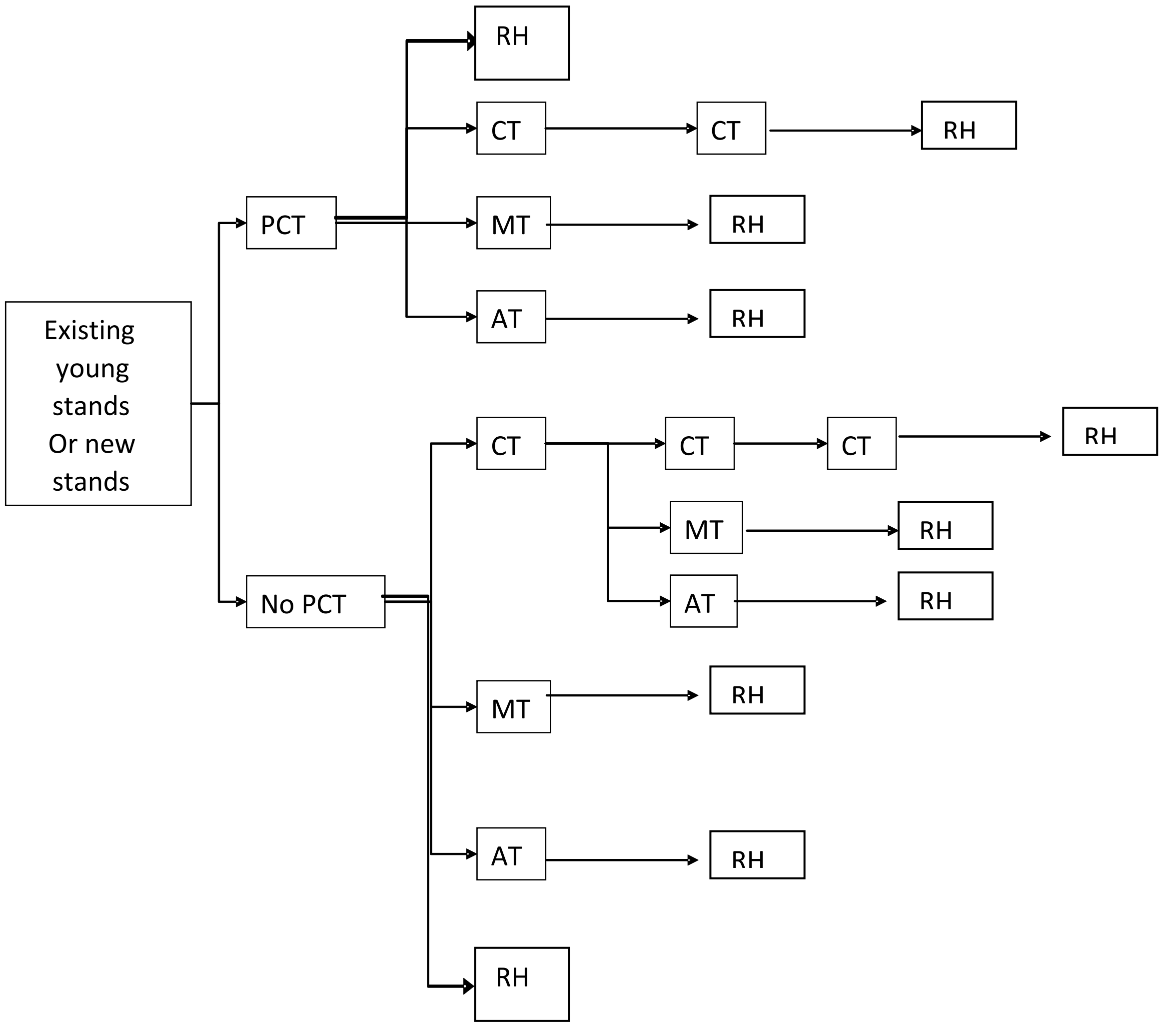


Figure C4. Silvicultural Pathways for Newly Regenerated Forest Stands and Stands Less Than 30 Years of Age

Thinning:

CT Commercial thinning

MT Light variable density thinning with an objective of Movement, roosting, and foraging (MoRF) and Sub-mature habitat

AT Heavy variable density thinning with an objective of Northern spotted owl (NSO) Type A habitat thinning

Regeneration harvest:

RH Regeneration harvest. May include a final harvest without any residual legacy trees or with retention of 10 and 20 largest legacy trees per acre, denoted by R0, R1 and R2 respectively. All harvested stands are replanted and natural regeneration also assumed to occur.

Note: Any two treatments within a given stand will be at least 20 years apart

Upland areas

Stands newly established after a regeneration harvest were modeled with and without a subsequent thinning operation. Only one thinning operation (CT, AT and MT) was modeled for all stands with legacy trees (R1 and R2 stands); two commercial thinnings were modeled for R0 stands. Note: Woodstock has the option for nil, one or two thinnings. These are elective, not prescriptive. Two commercial thinning treatments or a commercial thinning and regeneration harvest were modeled at least 20 years apart.

Stands that are currently biologically and economically mature were grown within FVS, and the merchantable timber volumes were reported for regeneration harvests with nil, 10 or 20 legacy trees over the full range of potential regeneration harvest ages.

All stands that are regeneration harvested are planted and subject to subsequent natural regeneration.

Riparian Areas

Thinning in riparian areas is based on the WA Department of Natural Resources (2006) riparian desired future condition.

4.2.1 Treatment Specifications

The following treatment descriptions provide a linkage with between the actual harvest strategies employed by foresters, forest model assumptions, and potential environmental impacts. These descriptions are intended to supplement but not replace the more general ones found in *Standard Forestry Terms and Tree Names - A training and reference pamphlet for DNR Management of Forested Trust Lands* (DNR, March 2007) Actual harvest types over the next 10 to 20 years will not be limited to these descriptions, although most actual harvest will likely fall into one of these categories.

DNR is currently proposing to name all regeneration harvests as “variable retention harvests”.

Table C16. Treatment Descriptions

Forest Model Treatment Name	Timber Harvest Type	Sustainable harvest type (EIS terminology)	Notes	Reference
Commercial thinning (CT)	Commercial thinning	*Thinning*	Objective: Improve the stand condition and growth of the timber crop trees, maintain positive discounted cash-flow Target residual tree density: Curtis's RD 40 (±10) Methods: Thinning from below. The thinning is conducted to maintain an even spatial distribution of trees for full site utilization and maximum growth on all crop trees.	Holmberg and Aulds, 2007
Light variable density thinning (MT)	Light variable density thinning	*Thinning*	Objective: Improve the stand condition and growth of the timber crop trees, maintain positive discounted cash-flow. In specific cases the treatment is used to develop northern spotted owl habitat (MoRF and sub-mature habitats). Target residual tree density: 125 trees per acre (±25) Methods: Thinning from below. The harvest treatment retains small areas of un-thinned trees, removes all trees in small gaps and thins the remainder of the stand with one of two or three residual densities levels to create vertical and horizontal variation across the forest stand canopy.	Holmberg and Aulds, 2007
Heavy variable density thinning (AT)	Heavy variable density thinning	*Partial harvest*	Objective: Improve the stand condition and growth of the timber crop trees, maintain positive discounted cash-flow In specific cases the treatment is used to develop northern spotted owl habitat (A-Type habitat or better). Target residual tree density: 75 trees per acre (±15) Methods: Thinning from below. The harvest treatment retains small areas of un-thinned trees, removes all trees in small gaps and thins the remainder of the stand with one of two or three residual densities levels to create vertical and horizontal variation across the forest stand canopy.	Holmberg and Aulds, 2007, Carey 2003

Forest Model Treatment Name	Timber Harvest Type	Sustainable harvest type (EIS terminology)	Notes	Reference
Regeneration harvest with 20 legacy trees	Variable Retention Harvest (VRH) – between 10 and 20 trees per acre	*Regeneration harvest*	Objective: Final harvest of the commercial cohort and regeneration of the next commercial cohort while retaining key structural elements of the existing stand. In some cases, the objective is high quality northern spotted owl habitat (high-quality nesting, Type A and B habitats) in others, visual management. Target residual density differs for this harvest type because a standard prescription would be insufficient for to manage the variety of cohorts. Regeneration is typically practiced through planting in openings and matching silvics to planted seedlings; site preparation is practiced as needed. Methods: The management activity area would encompass the all-continuous harvest units, including the riparian management areas and leave areas. A Variable Retention Harvest is characterized by at least three major purposes must be addressed in the silvicultural prescription objectives: (a) "lifeboating" of species and processes immediately after harvesting and before forest cover is reestablished; (b) "enriching" the reestablished forest stands with structural features that would otherwise be absent; and (c) "enhancing connectivity" in the managed landscape VRH is utilized in cases where a forest stand's response to commercial thinning (or other forms of harvest) is likely to be poor or there is a high risk of increased wind damage or forest health will deteriorate.	Franklin et. al., 1997

Forest Model Treatment Name	Timber Harvest Type	Sustainable harvest type (EIS terminology)	Notes	Reference
Regeneration harvest with 10 legacy trees	Variable Retention Harvest (VRH) – between 8 and 10 trees per acre	*Regeneration harvest*	Objective: Final harvest of the commercial cohort and regeneration of the next commercial cohort. Target residual density: 5 to 10 percent of the stand is retained post harvested, leaving a minimum of 8 large trees or more per acre (including the structurally unique and/or trees species such as western red cedar, Sitka spruce, and Pacific silver fir and conserving existing large snags (over 20 inches in diameter) and coarse woody debris (CWD)). Regeneration is typically though planting and establishment of the appropriate tree species to the site. Site preparation is practiced as needed.	Holmberg and Aulds, 2007

Residual tree density calculated for trees ≥3.5 inches dbh.

Table C17. Treatment Classes

Treatment Class	Description	Residual Trees Per Acre Post Treatment (4” ≤ dbh ≤ 30”)	Target Residual Tree RD
1AT03	Heavy variable density thinning	75	
1AT04	Heavy variable density thinning	75	
1AT05	Heavy variable density thinning	75	
1AT06	Heavy variable density thinning	75	
1AT07	Heavy variable density thinning	75	
1AT08	Heavy variable density thinning	75	
1AT09	Heavy variable density thinning	75	
1AT10	Heavy variable density thinning	75	
1CT02	Commercial thinning		40
1CT03	Commercial thinning		40
1CT04	Commercial thinning		40
1CT05	Commercial thinning		40
1CT06	Commercial thinning		40
1CT07	Commercial thinning		40
1CT08	Commercial thinning		40
1CT09	Commercial thinning		40
1CT10	Commercial thinning		40
1CT20	Commercial thinning		40
1MT03	Light variable density thinning	125	
1MT04	Light variable density thinning	125	
1MT05	Light variable density thinning	125	
1MT06	Light variable density thinning	125	
1MT07	Light variable density thinning	125	
1MT08	Light variable density thinning	125	
1MT09	Light variable density thinning	125	
1MT10	Light variable density thinning	125	
1MT20	Light variable density thinning	125	
R0	Regeneration harvest with no legacy trees (clear cut)	0	
R0-1AT05	Future stand with A-Type thinning	75	
R0-1CT04	Future stand with Commercial thinning		40
R0-1CT05	Future stand with Commercial thinning		40
R0-1CT05-2	Future stand with Commercial thinning		40
R0-1CT06	Future stand with Commercial thinning		40
R0-1CT06-2	Future stand with Commercial thinning		40
R0-1CT07	Future stand with Commercial thinning		40
R0-1CT08	Future stand with Commercial thinning		40
R0-1CT09	Future stand with Commercial thinning		40
R0-1MT04	Future stand with light variable density thinning	125	
R0-1MT05	Future stand with light variable density thinning	125	
R0-1MT07	Future stand with light variable density thinning	125	
R0-1MT08	Future stand with light variable density thinning	125	
R1	Regeneration harvest with 10 legacy trees	10	
R1-1AT04	Future stand with heavy variable density thinning	75	

Treatment Class	Description	Residual Trees Per Acre Post Treatment (4" ≤ dbh ≤ 30")	Target Residual Tree RD
R1-1AT05	Future stand with heavy variable density thinning	75	
R1-1CT04	Future stand with Commercial thinning		40
R1-1CT05	Future stand with Commercial thinning		40
R1-1CT05-2	Future stand with 2ndCommercial thinning		40
R1-1CT06	Future stand with Commercial thinning		40
R1-1CT06-2	Future stand with 2ndCommercial thinning		40
R1-1CT07	Future stand with Commercial thinning		40
R1-1CT08	Future stand with Commercial thinning		40
R1-1MT04	Future stand with light variable density thinning	125	
R1-1MT05	Future stand with light variable density thinning	125	
R2	Regeneration harvest with 20 legacy trees	20	
R2-1CT05	Future stand with Commercial thinning		40
R2-1CT05-2	Future stand with 2ndCommercial thinning		40
R2-1CT06	Future stand with Commercial thinning		40
R2-1CT06-2	Future stand with 2ndCommercial thinning		40
R2-1CT07	Future stand with Commercial thinning		40
R2-1MT05	Future stand with light variable density thinning	125	
UT	Unthinned stand		

4.2.1.1 Commercial Thinning (CT)

Existing stands greater than 30 years of age

Objectives:

- Maximize revenue in a manner consistent with other objectives, through the maintenance and/or improvement of residual tree growth.

Prescription[3]: B-GEM-WH

- Thinning trigger: ≥ RD 65 (not a condition set in yield table generator)
- Thinning target: RD 45
- Thinning ratio: from below

FVS Keywords:

```
* 1st commercial thinning
IF                0
 Int(Mod(Rx,100)/10) EQ 1 AND Int(Rx/100) EQ 0 AND Period EQ T1p
Then
ThinRDen          0     Parms(45., 1., All, 0., 999., 1)
ENDIF
```

[3] Holmberg, P. and B. Aulds. 2007. Developing Westside Silvicultural Prescriptions: an Inter-Active Self Study and Reference Pamphlet. Washington State Department of Natural Resources. Olympia, WA.

Notes: An alternative prescription could be developed in the post process to reflect the addition of 3 snags per acre and 2,400 cubic feet per acre of coarse woody debris. Suitable notation in the yield should be applied as it is likely these types of additional treatment would only occur in HCP northern spotted conservation management areas (i.e. NRF and dispersal landscapes).

Regenerated stands and stands less than 30 years of age

Objectives:

- Maximize revenue in a manner consistent with other objectives, through the maintenance and/or improvement of residual tree growth.

Prescription: B-GEM-WH

- Thinning trigger: RD 65 (for trees ≥ 3.5 and ≤ 29 inches dbh)
- Thinning target: RD 45 (for trees ≥ 3.5 and ≤ 29 inches dbh)
- Thinning ratio: from below
- Tree diameters eligible for thinning: ≥ 3.5 and ≤ 29 inches dbh

FVS Keywords:

```
* 1st commercial thinning after regeneration cut
IF                0
 Int(Mod(Rx,100)/10) EQ 1 AND Int(Rx/100) GT 0 AND Period EQ T1p
Then
ThinRDen          0     Parms(45., 1., All, 3.5, 29., 1)
ENDIF

* 2nd commercial thinning
IF                0
 Mod(Rx,10) GT 0 AND Period EQ T2p
Then
ThinRDen          0     Parms(45, 1., All, 0., 999., 1)
ENDIF
```

Notes:

Following 3 or more 10 year growth cycles, the 2nd commercial thinning would be simulated if stand conditions met or exceeded the same criteria for the 1st commercial thinning.

An alternative prescription could be developed in the post process to reflect the addition of 3 snags per acre and 2,400 cubic feet per acre of coarse woody debris. Suitable notation in the yield should be applied as it is likely these types of additional treatment would only occur in HCP northern spotted conservation management areas (i.e., Nesting, Roosting & Foraging and Dispersal landscapes).

4.2.1.2 Light Variable Density Thinning Treatment (MT)

Existing stands greater than 30 years of age

Objectives:

1. Maximize revenue in a manner consistent with other objectives, through the maintenance and/or improvement of residual tree growth
2. Attain Movement, Roosting & Foraging (MoRF) and sub-mature habitat for northern spotted owls

Prescription:

- Thinning trigger: RD 65 for trees greater than or equal to 3.5 inch dbh (not a condition set in FVS)
- Thinning target: 125 trees per acre
- Thinning ratio: Variable density thinning (VDT)
- Snags and CWD treatment: 3 snags ≥ 20 inches added and 2,400 cubic feet per acre of coarse woody debris added.
- Understory development: assume that if removal of more than 40 percent of the pre-treatment basal area, 50 western hemlock trees per acre natural regenerate – survival at 90 percent.

FVS Keywords:

```
* NSO MoRF thinning or NSO MoRF thinning after regeneration cut
IF                  0
 Int(Mod(Rx,100)/10) EQ 2 AND Period EQ T1p
Then
ThinBTA             0     Parms(125., 1., 3.5, 29.0, 0., 999.)
* Simulate advanced regeneration
ThinBTA             0     Parms( 20., 1., 0.0,  3.5, 0., 999.)
ENDIF
```

ADD COMPUTE and POST PROCESS:
Add 3 20 inch SNAGS per acre
And
2400 cubic feet of coarse woody debris

Regenerated stands and stands less than 30 years of age

Objectives:

- Maximize revenue in a manner consistent with other objectives, through the maintenance and/or improvement of residual tree growth.
- Attain Movement, Roosting, & Foraging (MoRF) and sub-mature habitat for northern spotted owls

Prescription: B-GEM-WH

- Thinning trigger: RD 65 (for trees ≥ 3.5 and ≤ 29 inches dbh)
- Thinning target: RD 45 (for trees ≥ 3.5 and ≤ 29 inches dbh)
- Thinning ratio: from below
- Tree diameters eligible for thinning: ≥ 3.5 and ≤ 29 inches dbh
- Understory development: assume 15 trees per acre of advanced regeneration (0-7.5 inches dbh) survive harvesting treatment and that 200 western hemlock trees per acre naturally regenerated and 50 western red cedar trees per acre are planted – survival at 90 percent.
- Snags and CWD treatment: 3 snags ≥ 20 inches added and 2,400 cubic feet per acre of coarse woody debris added

FVS Keywords:

```
* NSO MoRF thinning only or NSO MoRF thinning after regeneration cut
IF                 0
 Int(Mod(Rx,100)/10) EQ 2 AND Period EQ T1p
Then
ThinBTA            0     Parms(125., 1., 3.5, 29.0, 0., 999.)
* Simulate advanced regeneration
ThinBTA            0     Parms( 20., 1., 0.0,  3.5, 0., 999.)
ENDIF
```

ADD COMPUTE and POST PROCESS:
Add 3 20 inch SNAGS per acre
And
2400 cubic feet of coarse woody debris

4.2.1.3 Heavy Variable Density Thinning Treatment for Type A Habitat and Older Forests (AT)

Existing stands greater than 30 years of age

Objectives:
- Maximize revenue in a manner consistent with other objectives, through the maintenance and/or improvement of growth of residual trees
- Attain Type A habitat for northern spotted owls and/or older forest conditions

Prescription:
- Thinning trigger: RD ≥ 50 for trees greater than or equal to 3.5 inch dbh (not a condition set in FVS)
- Thinning target: 75 trees per acre between 7.5-999 inches dbh; 15 trees per acre between 0-7.5 inches dbh
- Thinning ratio: Variable density thinning (VDT)
- Understory development: assume 15 trees per acre of advanced regeneration (0-7.5 inches dbh) survive harvesting treatment and that 200 western hemlock trees per acre naturally regenerated and 50 western red cedar trees per acre are planted – survival at 90 percent.
- Snags and CWD treatment: 3 snags per acre ≥ 20 inches added and 2,400 cubic feet per acre of coarse woody debris added

FVS Keywords:

```
* NSO Type A thinning only or NSO Type A thinning
* after regeneration cut
IF                0
 Int(Mod(Rx,100)/10) EQ 3 AND Period EQ T1p
Then
ThinBTA           0      Parms(75., 1., 7.5, 999., 0., 999.)
* Simulate advanced regeneration
ThinBTA           0      Parms(15., 1., 0.0, 7.5, 0., 999.)
* Natural regeneration
Estab
NoSprout
Natural           1     Parms(WH, 200., 60., 1., 0., 1)
Natural           1     Parms(RC,  50., 60., 1., 0., 1)
End
ENDIF
```

ADD COMPUTE and POST PROCESS:
Add 3 20 inch SNAGS per acre
And
2400 cubic feet of coarse woody debris

Regenerated stands and stands less than 30 years of age

Objectives:

- Maximize revenue in a manner consistent with other objectives, through the maintenance and/or improvement of residual tree growth.
- Attain Type A habitat for northern spotted owls and/or older forest conditions

Prescription:

- Thinning trigger: RD ≥ 50 for trees greater than or equal to 3.5 inch dbh (not a condition set in FVS)
- Thinning target: 75 trees per acre between 7.5-999 inches dbh; 15 trees per acre between 0-7.5 inches dbh
- Thinning ratio: Variable density thinning (VDT)
- Understory development: assume 15 trees per acre of advanced regeneration (0-7.5 inches dbh) survive harvesting treatment and that 200 western hemlock trees per acre naturally regenerated and 50 western red cedar trees per acre are planted – survival at 90 percent.
- Snags and CWD treatment: 3 snags per acre ≥ 20 inches added and 2,400 cubic feet per acre of coarse woody debris added

FVS Keywords:

```
* NSO Type A thinning only or NSO Type A thinning
* after regeneration cut
IF                0
 Int(Mod(Rx,100)/10) EQ 3 AND Period EQ T1p
Then
ThinBTA           0     Parms(75., 1., 7.5, 999., 0., 999.)
* Simulate advanced regeneration
ThinBTA           0     Parms(15., 1., 0.0, 7.5, 0., 999.)
* Natural regeneration
Estab
NoSprout
Natural           1    Parms(WH, 200., 60., 1., 0., 1)
Natural           1    Parms(RC,  50., 60., 1., 0., 1)
End
ENDIF
```

ADD COMPUTE and POST PROCESS:
Add 3 20 inch SNAGS per acre
And
2400 cubic feet of coarse woody debris

4.2.1.4 Variable Retention Harvests with 10 Residual Trees per Acre (R1)

Objectives:

- Maximize revenue in a manner consistent with other objectives, through the maintenance and/or improvement of residual tree growth.

Prescription:

- Harvest target: 10 trees per acre from largest cohort
- Thinning ratio: from below
- SNAGS and CWD: preserved
- Reforestation strategy: plant 250 Douglas-fir trees per acre, 50 western red cedar trees per acre with 90 percent survival; assume for FVS West Cascade variant 550 western hemlock trees per acre naturally seed in with 60 percent survival; for FVS Pacific Northwest variant assume 150 western hemlock trees per acre naturally seed in with 60 percent survival.

FVS Keywords:

```
* Regeneration cut
IF                0
 Int(Rx/100) GT 0 AND Period EQ Cp
Then
* Arguments: ResTPA, CutEff, SmDBH, LgDBH, SmHt, LgHt
ThinBTA           0     Parms(ResTPA, 1., 0., 999., 0., 999.)
Estab
Plant             1DF             250.0      90.0        2.         1
Plant             1RC              50.0      90.0        2.         1
* Arguments: Species, trees, survival, age, Ht,
* ShadeCode 0=uniform, 1=shade, 2=sun
NoSprout
*Natural          10    Parms(WH, WHtpa, 60., 1., 0., 2)
Natural           1    Parms(WH, WHtpa, 60., 1., 0., 2)
End
```

4.2.1.5 Variable Retention Harvests with 20 Residual Trees per Acre (R2)

Objectives:

- Maximize revenue in a manner consistent with other objectives, through the maintenance and/or improvement of residual tree growth.

Prescription:

- Harvest target: 20 trees from the largest cohort
- Thinning ratio: from below
- SNAGS and CWD: preserved
- Reforestation strategy: plant 250 Douglas-fir trees per acre, 50 western red cedar trees per acre with 90 percent survival; assume for FVS West Cascade variant 550 western hemlock trees per acre naturally seed in with 60 percent survival; for FVS Pacific Northwest variant assume 150 western hemlock trees per acre naturally seed in with 60 percent survival.

FVS Keywords:

```
* Regeneration cut
IF                 0
 Int(Rx/100) GT 0 AND Period EQ Cp
Then
* Arguments: ResTPA, CutEff, SmDBH, LgDBH, SmHt, LgHt
ThinBTA            0     Parms(ResTPA, 1., 0., 999., 0., 999.)
Estab
Plant              1DF            250.0      90.0        2.          1
Plant              1RC             50.0      90.0        2.          1
* Arguments: Species, trees, survival, age, Ht,
* ShadeCode 0=uniform, 1=shade, 2=sun
NoSprout
*Natural           10    Parms(WH, WHtpa, 60., 1., 0., 2)
Natural            1    Parms(WH, WHtpa, 60., 1., 0., 2)
End
ENDIF
```

4.2.1.6 Planting / Natural Regeneration

Prescription:

- Plant 250 Douglas-fir trees per acre and 50 western red cedar trees per acre with a 90% survival rate for all regeneration harvest treatments.
- Naturally regenerate 550 western hemlock trees per acre for FVS West Cascade variant or 150 trees per acre for FVS Pacific Northwest variant with a 60% survival rate for all regeneration harvest treatment.
- Natural regeneration will occur regardless of treatments if the basal area is less than 200 ft^2/acre.
- Regardless the types of thinning, natural regeneration has been simulated if the basal area is less than 200 square feet per acre for live trees with a dbh ≥ 3.5 inches

FVS Keywords:

```
* Natural regeneration regardless treated or not
IF                0
 BA3d5 LE 200 AND Period GE 1
Then
Estab
NoSprout
Natural          30    Parms(WH, 200., 60., 1., 0., 1)
Natural          30    Parms(RC,  50., 60., 1., 0., 1)
End
ENDIF
```

4.2.1.7 Pre-commercial Thinning (PCT)

Prescription:

- Upon completion of one 10-year growth cycle following a regeneration harvest, stands with more than 325 live trees per acre with dbh ≥ 8 inches were pre-commercially thinned.
- Upon completion of two 10-year growth cycles following a regeneration harvest, stands with more than 400 trees per acre were per-commercially thinned

FVS Keywords:

```
* Precommercial thinning
IF                   0
Int(Rx/100) GT 0 AND SpMcDBH(1,All,0,0.0,8.0, 0.0,999.0,0,0.) GT 325 &
 AND Period EQ Cp+1
Then
* Compute variables needed for routine. _CE1 and _CE2 are intermediate
* variables used to compute the cutting efficiency (CE).  Cutting
* efficiency variables are not used in ThinSDI and ThinCC keywords.
* T_SP and D_SP * represent the stand attribute of targeted and
* desired species, respectively.
Compute              0
D_SP = MAX(0,SPMCDBH(1,0,0,0.,999.)/PROPSTK- &
 SPMCDBH(1,All,0,0.,999.)/PROPSTK)
T_SP = SPMCDBH(1,All,0,0.,999.)/PROPSTK
_CE1 = 1.0-0.
_CE2 = T_SP-325.
_CE = linint(325.,1,1,1.0,linint(_CE1*T_SP,_CE2,_CE2,_CE2/T_SP,_CE1))
End
SPECPREF             0       All        50
TCONDMLT             0         5
ThinBTA              0     Parms((D_SP+325.),_CE,0.,999.,0,999)
!!ThinATA              0    Parms((D_SP+325.),_CE,0.,999.,0,999)
!!ThinABA              0    Parms((D_SP+325.),_CE,0.,999.,0,999)
!!ThinSDI              0    Parms(325.,1.0-0.,All,0.,999.,2)
!!ThinCC               0    Parms(325.,1.0-0.,All,0.,999.,2)
ENDIF
```

5. Yield tables

5.1 Scale and Structure of Yield Settings

The yield tables used for modeling South Puget Sound HCP forested lands are stratum based, age-dependent yield tables. *Stratum based yield tables* were used in place of specific yield tables for every management unit area. The yield tables were derived from tree level data for stands with the same unique combinations of stand and site characteristics, as outlined previously in section 3.

Stratum based modeling involves classifying the resource into homogeneous units, defined by groupings with similar forest crop attributes, silvicultural history and site quality. Administrative and management boundaries were not considered. Strata may be discontiguous or discrete contiguous units.

Age dependent yield tables report yield as a function of stand age. The yield tables contain values for each stand age in 10-year growth periods, including: harvested product volumes, stand parameters , and forest structural characteristics that are used to ascertain habitat quality. The full list of variables modeled are described in Table C21 below.

5.2 Yield table Variables

Table C18. Yield Table Variables

No	Variable	Description	Source
1	Accr	Accretion (ft³/acre)	FVS Compute: ACCR
2	AccrMort	Accretion-Mortality class	Post-process
3	Age	Stand age (years) = current year - origin year	FRIS and post-process
4	AgeCls	Age class = Int(age/10) + 1	Post-process
5	Area	Stand area (acres)	FRIS
6	BA	Basal area (ft²/acre) of all live trees (ft²/acre)	FVS Compute: BA
7	BA3d5	Basal area (ft²/acre) of live trees with DBH ≥ 3.5"	FVS Compute: BA3D5
8	BA7d5	Basal area (ft²/acre) of live trees with DBH ≥ 7.5"	FVS Compute: BA3D7
9	BAcns	Basal area (ft²/acre) of chip & saw with 7.5" ≤ DBH < 11.5" and height ≥ 16'	FVS Compute: BACNS
10	BAplp	Basal area (ft²/acre) of pulpwood with 4.5" ≤ DBH < 7.5" and height ≥ 16'	FVS Compute: BAPLP
11	BAsaw	Basal area (ft²/acre) of sawlog with DBH ≥ 11.5" and height ≥ 16'	FVS Compute: BASAW
12	BAswd	Basal area per acre (ft²/acre) of all softwoods with DBH ≥ 3.5"	FVS Compute: BASWD
13	BF	Volume (bf/acre) of all live trees	FVS Compute: BF
14	BF20	Volume (bf/acre) of live trees with DBH ≥ 19.5"	FVS Compute: BF20
15	BF3d5	Volume (bf/acre) of live trees with DBH ≥ 3.5"	FVS Compute: BF3D5
16	BF7d5	Volume (bf/acre) of live trees with DBH ≥ 7.5"	FVS Compute: BF7D5
17	BFcns	Volume (bf/acre) of chip & saw with 7.5" ≤ DBH < 11.5" and height ≥ 16'	FVS Compute: BFCNS
18	BFmv	Merchantable volume (bf/acre) with DBH ≥ 7.5" and height ≥ 16'	FVS Compute: BFMV
19	BFplp	Volume (bf/acre) of pulpwood with 4.5" ≤ DBH < 7.5" and height ≥ 16'	FVS Compute: BFPLP
20	BFsaw	Volume (bf/acre) of sawlog with DBH ≥ 11.5" and height ≥ 16'	FVS Compute: BFSAW

No	Variable	Description	Source
21	BPI	Berger-Parker Index = TPA_total/TPA_max	FVS Compute: BPI
22	BPI1TPA	Live trees per acre with 6.6' ≤ height < 13.1'	FVS Compute: BPI1TPA
23	BPI2TPA	Live trees per acre with 13.1' ≤ height < 26.2'	FVS Compute: BPI2TPA
24	BPI3TPA	Live trees per acre with 26.2' ≤ height < 52.5'	FVS Compute: BPI3TPA
25	BPI4TPA	Live trees per acre with 52.5' ≤ height < 105.0'	FVS Compute: BPI4TPA
26	BPI5TPA	Live trees per acre with 105.0' ≤ height < 157.5'	FVS Compute: BPI5TPA
27	BPI6TPA	Live trees per acre with 157.5' ≤ height < 210.0'	FVS Compute: BPI6TPA
28	BPI7TPA	Live trees per acre with height ≥ 210.0'	FVS Compute: BPI7TPA
29	CC	Canopy cover (%/acre)	FVS Compute: CC
30	CC3d5	Canopy cover (%/acre) of live trees with DBH ≥ 7.5"	FVS Compute: CC3D5
31	CC7d5	Canopy cover (%/acre) of live trees with DBH ≥ 3.5"	FVS Compute: CC7D5
32	CF	Volume (ft^3/acre) of all live trees	FVS Compute: CF
33	CF20	Volume (ft^3/acre) of live trees with DBH ≥ 19.5"	FVS Compute: CF20
34	CF3d5	Volume (ft^3/acre) of live trees with DBH ≥ 3.5"	FVS Compute: CF3D5
35	CF7d5	Volume (ft^3/acre) of live trees with DBH ≥ 7.5"	FVS Compute: CF7D5
36	CFcns	Volume (ft^3/acre) of chip & saw with 7.5" ≤ DBH < 11.5" and height ≥ 16'	FVS Compute: CFCNS
37	CFmv	Merchantable volume (ft^3/acre) with DBH ≥ 7.5" and height ≥ 16'	FVS Compute: CFMV
38	CFplp	Volume (ft^3/acre) of pulpwood with 4.5" ≤ DBH < 7.5" and height ≥ 16'	FVS Compute: CFPLP
39	CFsaw	Volume (ft^3/acre) of sawlog with DBH ≥ 11.5" and height ≥ 16'	FVS Compute: CFSAW
40	CrnDept	Crown depth of the top strata with canopy cover ≥ 5%	FVS Compute: CRNDEPT
41	CrnLift	Crown lift of the bottom strata with canopy cover ≥ 5%	FVS Compute: CRNLIFT
42	CWDv	Volume (ft^3/acre) of coarse woody debris	FVS Compute: CWDV
43	DBHavg	Estimated average of DBH for all live trees per acre	Post-process
44	DBHcv	Estimated coefficient of variance of DBH for all live trees per acre	Post-process
45	DBHskew	Estimated skewness of DBH for all live trees per acre	Post-process
46	DBHstd	Estimated standard deviation of DBH for all live trees per acre	Post-process
47	DDI	Diameter diversity index	FVS Compute: DDI
48	DDI1TPA	Live trees per acre with 2" ≤ DBH < 9.8" (median TPA = 295, weight = 1)	FVS Compute: DDI1TPA
49	DDI2TPA	Live trees per acre with 9.8" ≤ DBH < 19.7" (median TPA = 87, weight = 2)	FVS Compute: DDI2TPA
50	DDI3TPA	Live trees per acre with 19.7" ≤ DBH < 39.4" (median TPA = 70, weight = 3)	FVS Compute: DDI3TPA
51	DDI4TPA	Live trees per acre with DBH ≥ 39.4" (median TPA = 28, weight = 4)	FVS Compute: DDI4TPA
52	FDS1	Forest development stage - definition 1	Post-process
53	FDS2	Forest development stage - definition 2	Post-process
54	ForType	Forest type (2 or 4 letters)	FRIS and post-process
55	FSHabTyp	Habitat type defined by USFS	FVS Compute: HABFS
56	HabDis	Dispersal habitat (1 = yes, 0 = no)	FVS Compute: HABDIS
57	HabHQN	High-quality nesting habitat (1 = yes, 0 = no)	FVS Compute: HABHQN
58	HabI	Habitat index (range: 0 - 127)	FVS Compute: HABI
59	HabMRF	Movement of Roosting Foraging Habitat (1 = yes, 0 = no)	FVS Compute: HABMRF
60	HabSoA	Type A spotted owl habitat (1 = yes, 0 = no)	FVS Compute: HABSOA
61	HabSoB	Type B spotted owl habitat (1 = yes, 0 = no)	FVS Compute: HABSOB
62	HabSub	Sub-mature habitat (1 = yes, 0 = no)	FVS Compute: HABSUB
63	HabYFM	Young forest marginal habitat (1 = yes, 0 = no)	FVS Compute: HABYFM
64	HT	Average height (ft) of all live trees	FVS Compute: HTAVG

No	Variable	Description	Source
65	HT3d5	Average height (ft) of live trees with DBH ≥ 3.5"	FVS Compute: HT3D5
66	HT7d5	Average height (ft) of live trees with DBH ≥ 7.5"	FVS Compute: HT7D5
67	HTcns	Average height (ft) of chip & saw with 7.5" ≤ DBH < 11.5" and height ≥ 16'	FVS Compute: HTCNS
68	HTplp	Average height (ft) of pulpwood with 4.5" ≤ DBH < 7.5" and height ≥ 16'	FVS Compute: HTPLP
69	HTsaw	Average height (ft) of sawlog with DBH ≥ 11.5" and height ≥ 16'	FVS Compute: HTSAW
70	Mort	Mortality (ft^3/acre)	FVS Compute: DEAD
71	NoHtCls	Number of height class	FVS Compute: NOHTCLS
72	NoHtStra	Number of height strata with height differences ≥ 15% and canopy cover ≥ 5%	FVS Compute: NOHTSTRA
73	NoSpp	Number of species per acre with percentage live trees ≥ 5% and DBH >= 3.5"	FVS Compute: NOSPP
74	OFC1TPA	Live trees per acre with 0" ≤ DBH < 3.5"	FVS Compute: OFC1TPA
75	OFC2TPA	Live trees per acre with 3.5" ≤ DBH < 11.5"	FVS Compute: OFC2TPA
76	OFC3TPA	Live trees per acre with 11.5" ≤ DBH < 19.5"	FVS Compute: OFC3TPA
77	OFC4TPA	Live trees per acre with 19.5" ≤ DBH < 29.5"	FVS Compute: OFC4TPA
78	OFC5TPA	Live trees per acre with DBH ≥ 29.5"	FVS Compute: OFC5TPA
79	OFCI	Older forest condition index (range: 0 - 31)	FVS Compute: OFCI
80	PAI	Periodic annual increment (ft^3/acre) = accretion - mortality	Post-process
81	PBAswd	Percentage basal area per acre (ft^2/acre) of all softwoods with DBH ≥ 3.5"	Post-process
82	Period	Time index (10-year increment)	FVS Compute: PERIOD
83	PTPAswd	Percentage live trees per acre of softwoods with DBH ≥ 3.5"	FVS Compute: PTPASWD
84	QMD	Quadratic mean diameter (inches) of all live trees per acre	Formula: 24*Sqrt(BA/TPA/4/Atn(1))
85	QMD100	Estimated quadratic mean diameter (inches) of 100 largest live trees per acre	FVS Compute: QMD100
86	QMD3d5	Quadratic mean diameter (inches) of lives trees with DBH ≥ 3.5"	FVS Compute: QMD3D5
87	QMD7d5	Quadratic mean diameter (inches) of lives trees with DBH ≥ 7.5"	Formula: 24*Sqrt(BA7d5/TPA7d5/4/Atn(1))
88	Rate4R	Rating for possible regeneration cut treatment	Post-process
89	Rate4T	Rating for possible thinning treatment	Post-process
90	RD	Curtis' relative density	FVS Compute: RD
91	RD3d5	Relative density of live trees per acre with DBH ≥ 3.5"	FVS Compute: RD3D5
92	RD7d5	Relative density of live trees per acre with DBH ≥ 7.5"	Formula: BA7d5/Sqrt(QMD7d5)
93	RIU_ID	Current resource inventory ID	FRIS
94	Rx	Regime code	FVS Compute: RX
95	SDI	Stand density index = $TPA/(QMD/10)^{1.605}$	Post-process
96	SDI3d5	SDI of live trees per acre with DBH ≥ 3.5"	FVS Compute: SDI3D5
97	SDI7d5	SDI of live trees per acre with DBH ≥ 7.5"	FVS Compute: SDI7D5
98	SI	Site index (ft) at breast height age 50	FRIS and post-process
99	SIC	Site index class	Post-process
100	SizeCls	QMD class by live trees per acre with DBH ≥ 3.5"	Post-process
101	Snag15	Snags per acre with diameter ≥ 14.5" and length ≥ 16'	FVS Compute: SNAG15
102	Snag20	Snags per acre with diameter ≥ 19.5" and length ≥ 16'	FVS Compute: SNAG20
103	Snag21	Snags per acre with diameter ≥ 20.5" and length ≥ 16'	FVS Compute: SNAG21
104	Snag30	Snags per acre with diameter ≥ 29.5" and length ≥ 16'	FVS Compute: SNAG30
105	StandID	Stand ID (same as master resource inventory ID, but in text type)	FVS Compute: StandID

No	Variable	Description	Source
106	StkCls	RD class by live trees per acre with DBH ≥ 3.5"	Post-process
107	Strata	ForType_SIC_StkCls_SizeCls_Rx	FRIS and post-process
108	StrCls	Structural class	FVS Compute: STRCLS
109	StrName	Name of structural class	Post-process
110	TopHt	Average height (ft) of 40 largest live trees on an acre	FVS Compute: TOPHT
111	TPA	Live trees per acre (trees/acre)	FVS Compute: TPA
112	TPA0002	Live trees per acre with 0" ≤ DBH < 2"	Post-process
113	TPA20	Live trees per acre with DBH ≥ 19.5"	FVS Compute: TPA20
114	TPA21	Live trees per acre with DBH ≥ 20.5"	FVS Compute: TPA21
115	TPA30	Live trees per acre with DBH ≥ 29.5"	FVS Compute: TPA30
116	TPA31	Live trees per acre with DBH ≥ 30.5"	FVS Compute: TPA31
117	TPA3d5	Live trees per acre with DBH ≥ 3.5"	FVS Compute: TPA3D5
118	TPA40	Live trees per acre with DBH ≥ 39.5"	FVS Compute: TPA40
119	TPA7d5	Live trees per acre with DBH ≥ 7.5"	FVS Compute: TPA7D5
120	TPAalder	Live trees per acre of the "alder" group with DBH ≥ 3.5"	FVS Compute: TPAALDER
121	TPAcns	Live trees per acre of chip & saw with 7.5" ≥ DBH < 11.5"	FVS Compute: TPACNS
122	TPAdfir	Live trees per acre of the "Douglas-fir" group with DBH ≥ 3.5"	FVS Compute: TPADFIR
123	TPAhwd	Live trees per acre of all hardwoods with DBH ≥ 3.5"	FVS Compute: TPAHWD
124	TPAmxhwd	Live trees per acre of the "mixed hardwoods" group with DBH ≥ 3.5"	FVS Compute: TPAMXHWD
125	TPAmxswd	Live trees per acre of the "mixed softwoods" group with DBH ≥ 3.5"	FVS Compute: TPAMXSWD
126	TPApicea	Live trees per acre of the "picea" group with DBH ≥ 3.5"	FVS Compute: TPAPICEA
127	TPApine	Live trees per acre of the "pine" group with DBH ≥ 3.5"	FVS Compute: TPAPINE
128	TPAplp	Live trees per acre of pulpwood with 4.5" ≤ DBH < 7.5"	FVS Compute: TPAPLP
129	TPAsaw	Live trees per acre of sawlog with DBH ≥ 11.5"	FVS Compute: TPASAW
130	TPAswd	Live trees per acre of all softwoods with DBH ≥ 3.5"	FVS Compute: TPASWD
131	TPAwwd	Live trees per acre of the "white wood" group with DBH ≥ 3.5"	FVS Compute: TPAWWD
132	YrOrg	Origin year	FRIS and post-process

6. Financial Assumptions

The costs and revenues used within the model are current day real prices, assumed to remain constant over the 100 year planning horizon. Inflationary adjustments and real changes were excluded.

The forest modeling is structured to maximize the discounted net present value (NPV), so the DNR pre-tax real discount rate of 5% was applied. Since 10 year planning periods are used for the computer modeling. Within each 10 year period the silvicultural costs incurred and revenues are assumed to occur equally each year. In accordance with periodic financial modeling convention, the annual cashflow within each period was discounted from the mid-point of each period

6.1 Revenue

Prices used in Woodstock woody supply forecasting and harvest scheduling are listed in Table C19 below. Stumpage prices are based on an analysis of DNR timber sale prices received between 1999 and 2004, inclusive, and were used in the 2004 sustainable harvest analysis. *Saw* prices are based on regeneration harvest stumpage values; *pulp* prices are based on small-wood, commercial thinning DNR stumpage values; and *chip and saw* (CNS) prices are based on older-stand thinning stumpage values.

Table C19. Stumpage Prices Used in Woodstock Wood Supply Forecasting and Harvest Scheduling

Forest Type	Stumpage Price ($ / MBF)		
	Saw	CNS	Pulp
DFRA	321	160	111
DFRC	478	278	166
DFWH	332	233	132
RADF	296	173	108
WHDF	286	174	106
WHRA	175	92	68
WHRC	415	219	161
WHSF	212	88	82
Other	286	174	106

Pulp: *4" ≤ dbh < 8"*
CNS: *8" ≤ dbh < 12"*
Saw: *dbh ≥ 12"*

6.2 Costs

Table C20. 2004 Base Year Costs

Operation	Cost	Units
Regeneration harvest	18.00	$ per MBF
Thinning	54.00	$ per MBF
Indirect variable DNR costs for harvesting operations	307.84	$ per acre
Stand establishment planting cost ($0.50 per seedling, 300-400 seedlings per acre)	175.00	$ per acre
Brush control, typically applied twice between 4 and 12 years	160.00	$ per acre
Pre-commercial thinning	160.00	$ per acre
Fertilization (Douglas-fir stands only)	90.00	$ per acre

7. Modeling Alternatives for Puget Sound

DNR's conservation objective for the northern spotted owl (NSO) is to provide habitat that makes a significant contribution to demographic support, maintenance of species distribution, and facilitation of dispersal. Demographic support refers to the contribution of individual territorial spotted owls or clusters of spotted sites to the stability and viability of the entire population. Maintenance of species distribution refers to supporting the continued presence of the spotted owl in as much of its historic range as possible. Dispersal is the movement of juvenile, sub-adult, and adult spotted owls from one sub-population to another.

The intent of the spotted owl conservation strategy within the west-side HCP planning units (including the South Puget HCP planning unit) is twofold. First, the strategy is intended to provide nesting, roosting, and foraging (NRF) habitat and dispersal habitat in strategic areas in order to achieve the conservation objective. Second, in areas designed to provide NRF habitat, the strategy is intended to create a landscape in which active forest management plays a role in the development and maintenance of the structural characteristics that constitute such habitat (WDNR 1997).

The South Puget HCP planning unit contains approximately half (roughly 70,000 acres) of the designated dispersal management areas on state lands managed under the HCP. As a result of past timber management activities, forests within these areas are currently dominated by *competitive exclusion* and *understory development* stage forests, and young, overstocked second growth stands. In general, current forest conditions do not contribute to the habitat requirements of dispersing northern spotted owls.

During the Draft EIS, DNR examined three approaches to managing designated dispersal management areas to meet the conservation objectives of the 1997 Habitat Conservation Plan.
Between the draft and the final EIS, the forest models and proposed strategies were reviewed with region, division staff and with Federal Services. Data and code corrections were made to the model and modifications were made to the preferred alternative (Alternative B) northern spotted owl strategies. These modification and corrections are described.

7.1 General Model Updates

A set of updates to the model and underlying data are listed in following table

- Ending period inventory controls were added to ensure continued reinvestment in silviculture and the maintenance of growing stock at the planning horizon. Without such controls, the objective of the linear programming model to maximize net present value would result in a harvest rate in excess of growth rate.

Upland Management targets were redefined such that areas in Thinning Group 1 (Belfair, Hoodsport, Snoqualmie (Tiger Mountain), Black Hills, Boulder) can be thinned to a relative density of of 48, while areas in Thinning Group 2 (Elbe-Hills and Black Diamond) can be thinned to a relative density of 25.

Table C21. Updates to Model

No.	Updates or Modifications
1.	**Model Structure** The number of modeling themes was increased from 10 to 13 for improved transparency and flexibility. One of the original themes was split, and two new themes were added. The *watershed* theme, originally containing both WAU and SOMU data, was split into two themes. An *administrative unit* theme was added containing boundaries for counties, DNR regions, districts, locals, and HCP Planning Units. A *harvest access* theme was added.
2.	**District Even-Flow** The South Puget HCP Planning Unit and DNR administrative regions were integrated for the purposes of applying 2007 sustainable harvest calculation volume targets. An even-flow constraint of +/-15% by District was implemented in Alternative B and C
3.	**Modifications to yield tables** Alternative A used yield tables developed for draft EIS. Alternative B and C used modified yield tables that reflected modifications to correct for the discontinuous NSO habitat yields and included snag and down-woody debris treatments for light (MT) and heavy (AT) variable density thinnings. A royalty premium (120%) was applied to Tahuya stumpages to reflect higher wood quality. A volume yield discount (80%) was used to address lower removal levels in the Tahuya. In Elbe, a review of variable density thinning sales suggested higher removals than what the yield tables reflected. An adjustment of 150% was made to light variable density (MT) removal yields.
4.	**NSO habitat rules** In Alternative A, 50% of each SOMU must be maintained as mapped dispersal habitat until 2014. Mapped habitat was represented by a combination of Settlement Agreement and HCP habitat data. After 2014, only the forecasted dispersal habitat must be maintained at the 50% threshold. Thinning specifications were modified in settlement and concurrence letter areas.
5.	**Ending period inventory controls** Ending period inventory controls were added to ensure continued reinvestment in silviculture and the maintenance of growing stock at the planning horizon. Without such controls, the objective of the linear programming model to maximize net present value would result in a harvest rate in excess of growth rate. These were applied to all models
6.	**Locks** Removed locks from recently thinned timber sales if : 1. A regeneration is activity planned in P&T for the next decade (414 acres) or, 2. the thinning sale occurred more than 5 years ago (older than 2004, 636 acres)
7.	**Pole Sales** Pole sales (Sold_ty = "SELECT PROD", 1,874 acres) silvicultural status (TH5) was reassigned from a commercial thinning status (1CT??) to untreated status (UT)
8.	**Riparian** Local knowledge riparian and wetland management zones from Planning and Tracking were added to the riparian land class (where LCL_RP_FLG = 1 and (Old_th11 <> “RIP” or Old_th11 <> “RIP-S”) added approximately 35,576 acres to the riparian land class Thinning treatments in riparian areas was limited to commercial (CT) and light variable density (MT) treatments. Thinning actions were constrained by riparian stand having to meet the following citeria: Topht >= 50 and _AGE <= 6 and RD3d5 >= 55 and RD3d5 <= 85 and y1ctmv >= 5
9.	**GIS data** GIS data on cliffs updated
10.	**Thinning and Regeneration harvest operability constraints** Operability constraints based on age were changed to top height A) Thinnings (CT, MT and AT) Topht >= 50 to represent a minimum of: 1) One 26ft saw log to a 6 inch top and, 2) One 16ft log (mostly likely pulp) B) Variable retention harvest (R1, R2) Topht >= 65 to represent a minimum of: 1) At least one 40 ft log to an 8 inch top (a #3 saw)

Individual Strata Updates

i. DFRC-SIC3-OPSTK-Size1-UT (15,372 acres)for records below agecls 10 and greater than AgeCls 1 updated to DFRC-SIC3-OPSTK-Size1-R0 (14,859 acres), AgeCls 1 to DFRC-SIC3-OPSTK-Size1-R1 (480 acres)

ii. DFRC-SIC4-OPSTK-Size1-UT (11,570 acres) for DATA_SRC="L" and AgeCls >= 2 updated to DFRC-SIC4-OPSTK-Size1-R0 ((10,430 acres), AgeCls 1 to DFRC-SIC4-OPSTK-Size1-R1 (198 acres). And DATA_SRC="R" and AgeCls >= 2 updated to DFRC-SIC4-OPSTK-Size1-R0 (917 acres)

iii. All stands greater than AgeCls 3 with a zero volume Strata changed (WHDF-SIC4-MISTK-Size3-UT, DFWH-SIC4-GOSTK-Size3-UT, DFMA-SIC4-MISTK-Size3-UT) with a Size3 to Size2. Agecls was unchanged (approximately 1,650 acres)

GIS area file

New Area file was compiled using a more recently Large Data Overlay – February 3rd, 2009 version (ldo_20090203).

An additional version of this February Large Data Overlay (ldo_20090203b) was created to include the proposed North Fork Green exchanges lands.

7.2 Scenario Description

7.2.1 Alternative A – No Action

The model scenario representing Alternative A remained unchanged from the Draft EIS, except for the changes listed in 7.1 and the following:

1. Modification to modeling NSO habitat strategies

The modification to modeling NSO habitat strategies between the draft and the final EIS was the inclusion of explicit controls on NSO habitat during periods 1 through 3

2. Using foresters schedule harvest and activities in period 1

DNR foresters develop harvest schedules on a rolling annual basis. These schedules are stored in DNR Planning and Tracking system (P&T). As part of the forest land planning exercise, South Puget Sound foresters delineated in GIS forest management units (FMUs) polygons across the planning unit and developed initial activity schedules for these polygons. These initial schedule are expected the change over time due to new information and changing marketing conditions, they provide a perspective of the foresters on what forest areas are suitable for what types of the management under the landscape management strategies represented in Alternative A. These schedules were converted into modeling code and an LPschedule was developed for Remsoft Spatial Planning System (RSPS). The LPSchedule forced the model to adopt the schedule in period 1 of the model. The model then added any additional activities that would improved the attainment of the objectives.

7.2.2 Alternative B – Preferred Direction

Under Alternative B, DNR incorporated into dispersal management the northern spotted owl life history requirements of roosting and foraging. A modified strategy for northern spotted owl dispersal management areas in the South Puget HCP Planning Unit was developed. The modified strategy incorporates two components:

1) Two new stand-level habitat definitions,
2) A new geographic scale to account for habitat

1. <u>Two new stand-level definitions</u>

The proposed stand-level habitat definitions include the species' life history requirements for movement, roosting, and foraging. Following are the new spotted owl habitat definitions in the South Puget HCP Planning Unit:

Table C22. Habitat Definitions

South Puget NSO Movement Habitat	South Puget Movement, Roosting and Foraging (MoRF) Habitat
▪ Forest community dominated by conifers with at least 30 percent conifers (measured as stems per acre dominant, co-dominant, and intermediate trees)	▪ Forest community dominated by conifers with at least 30 percent conifers (measured as stems per acre dominant, co-dominant, and intermediate trees)
▪ Canopy closure at least 70 percent	▪ Canopy closure at least 70 percent
▪ Quadratic mean diameter of 11 inches dbh for the 100 largest trees greater than or equal to 3.5 inches dbh	▪ Tree density of between 115 and 280 trees greater than or equal to 3.5 inches dbh per acre
▪ Tree density no more than 280 trees per acre greater than or equal to 3.5 inches dbh	▪ Dominant and co-dominant trees at least 85 feet tall
▪ Dominant and co-dominant trees at least 85 feet tall	▪ At least five percent coverage of down woody debris
▪ At least four trees per acre from the largest size class retained for future snag and cavity tree recruitment	▪ At least three snags or cavity trees per acre that are at least 15 inches dbh
	▪ At least two canopy layers

The adaptive management component of the HCP is an important tool for ongoing modifications of DNR's conservation strategies in order to respond to monitoring information and new scientific developments. The refinement of the definition of northern spotted owl dispersal habitat is one such example of the use of adaptive management to successfully implement the conservation objectives outlined in the HCP.

2. <u>New Geographic Scale to Account for Habitat</u>

The proposed modification aggregates the existing geographic habitat accounting scale of Spotted Owl Management Units (SOMU's; aka watershed scale) to a landscape scale (i.e. combined watersheds). The modified approach discussed in detail in *A Strategy for Northern Spotted Owl Dispersal Habitat in the South Puget HCP Planning Unit* (attached) and the Final EIS (WADNR, 2009). The approach will create four distinct Dispersal Management Landscapes: Elbe Landscape, Tahoma Landscape, Pleasant Valley Dispersal Landscape, and Black Diamond Landscape (see C5).

The management objectives for each Dispersal Management Landscape are as follows:

1. To attain and maintain at least 50 percent of DNR-managed forest lands targeted in a combination of South Puget Movement northern spotted owl habitat or higher quality habitat that will incorporate movement, roosting and foraging components necessary for dispersing owls.
2. Within the 50 percent habitat objective (point 1), the target is to have 70 percent in a condition of Movement, Roosting and Foraging (MoRF) or higher quality northern spotted owl habitat and 30 percent in South Puget Movement habitat or higher quality habitat by year 2067 or earlier.

In other words, at least 35 percent of a Dispersal Management Landscape will be targeted to attain and maintain MoRF or higher quality habitat and 15 percent will be targeted to attain and maintain South Puget Movement or higher quality habitat totaling a 50 percent landscape habitat target.

7.2.3 Alternative C – Exploratory Options

Under Alternative C, DNR explored another way to manage dispersal habitat within the context of the HCP. All the life history requirements of northern spotted owls (nesting, roosting, foraging, and dispersal) were incorporated into this alternative. A target threshold of 50 percent South Puget Movement or better habitat is applied at the landscape unit level. Within this 50 percent, 2/3 (or 30 percent of the total landscape area) is targeted to be Type B[4] or better habitat. Is was assumed that South Puget Movement or better habitat will not be available for regeneration harvest activities for the first three decades. All existing high-quality nesting habitat is deferred from harvest. Distribution of habitat is tracked through monitoring associated with the planning process. Multiple entries are used to create snags, recruit coarse woody debris (CWD), and increase the diameter of the dominant trees.

[4] Type B habitat (west side planning units) has the following characteristics: (1) Few canopy layers, multispecies canopy dominated by large (greater than 20 inches dbh), overstory trees (typically 75-100 trees per acre, but can be fewer if larger trees are present; (2) greater than 70 percent canopy closure; (3) some large trees with various deformities; (4) large (greater than 20 inches dbh) snags present; and (5) accumulations of fallen trees and other woody debris on the ground. (DNR 1997, Trust Lands HCP, IV. 11.)

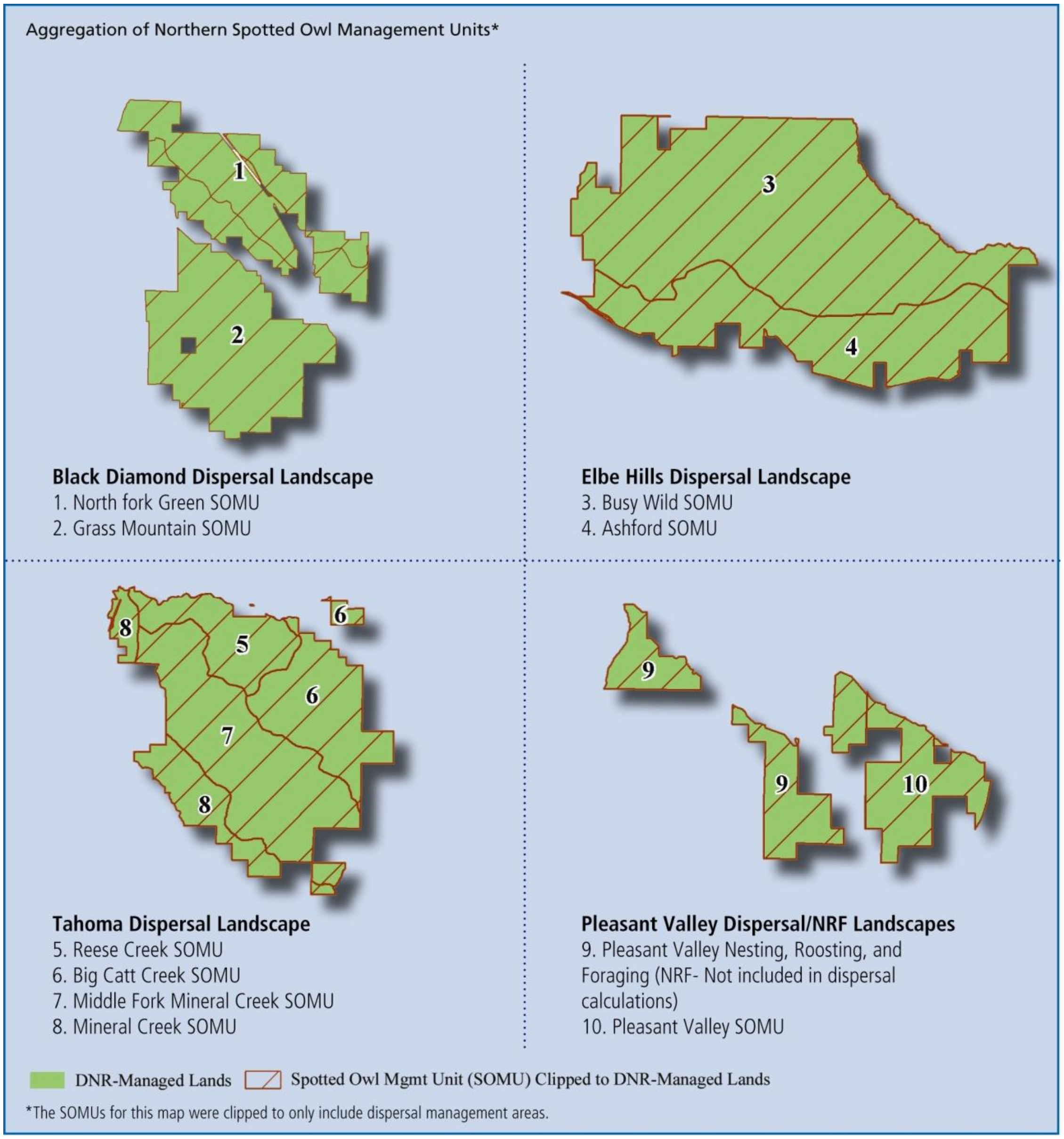


Figure C5. Aggregation of SOMU's into Landscapes

7.3 Representing Non-Spatial Policy and Procedures

7.3.1 Harvesting Settings

Table C23. Harvesting Settings

	Alternative		
	A	**B**	**C**
General thinning prescriptions			
	GROUP 1 (Hoodsport, Belfair, and Snoqualamie) thinning up to 50 years in all upland land classes	GROUP 1 (Hoodsport, Belfair, and Snoqualamie) thinning up to 50 years in all upland land classes	GROUP 1 (Hoodsport, Belfair, and Snoqualamie) thinning up to 100 years in all upland land classes
	GROUP 2 (Elbe-District, Black Diamond) thinning up to 100 years on all upland land classes	GROUP 2 (Elbe-District, Black Diamond) thinning up to 100 years on all upland land classes	GROUP 2 (Elbe-District, Black Diamond) thinning up to 100 years on all upland land classes
	Riparian land class (GROUP 1 and 2) only thinning up to age 70 years	Riparian land class (GROUP 1 and 2) only thinning up to age 100 years	Riparian land class (GROUP 1 and 2) only thinning up to age 100 years
Specific thinning restrictions			
Tahoma	No thinning to residual densities below RD 40 in low site class (SIC4) WH dominated stands	No thinning to residual densities below RD 40 in low site class (SIC4) WH dominated stands	No thinning to residual densities below RD 40 in low site class (SIC4) WH dominated stands
Concurrence Sales	VDT Light Intensity Thinning permitted in concurrence sales (identified in deferral code 6th position character = "C")	N/A	N/A VDT Light Intensity Thinning permitted in concurrence sales (identified in deferral code 6th position character = "C")
Visual Areas	Regeneration harvests with 20 legacy trees (R2) in Elbe Hills visual areas (identified with "V" flag in Land Class code)	Regeneration harvests with 20 legacy trees (R2) in Elbe Hills visual areas (identified with "V" flag in Land Class code)	Regeneration harvests with 20 legacy trees (R2) in Elbe Hills visual areas (identified with "V" flag in Land Class code)
Tiger Mountain	Regeneration harvest limited to 600 acres per year	Regeneration harvest limited to 600 acres per year	Regeneration harvest limited to 600 acres per year
Existing Northern Spotted Owl (NSO) habitat			
High Quality Nesting, Type A Habitat, Type B Habitat	Regeneration harvest or thinning operations prohibited		
Movement, Roosting & Foraging (MoRF), Sub-Mature, Young Forest Marginal, Dispersal	Commercial thinning	Commercial thinning, Variable Density Thinning (light & heavy)	Commercial thinning, Variable Density Thinning (light & heavy)
Next Best	Commercial thinning	Commercial thinning, Variable Density Thinning (light & heavy)	N/A
Deferrals from harvest			

	Alternative		
	A	B	C
activities			
For entire planning period	Lands slated for transfer to NRCA/NAP (identified in X_ACTION_TY = ”T”)_lock 99	Lands slated for transfer to NRCA/NAP (identified in X_ACTION_TY = ”T”)_lock 99	Lands slated for transfer to NRCA/NAP (identified in X_ACTION_TY = ”T”)_lock 99
For period 1 only	Recent thinning harvest (SOLD_CD ≥ 2) _ Lock 1	Recent thinning harvest (SOLD_CD ≥ 2) _ Lock 1	Recent thinning harvest (SOLD_CD ≥ 2) _ Lock 1

Note: VDT Light Thinning is designed to create MoRF habitat, VDT Heavy Thinning is designed to create Type A habitat

7.2.2 Production Commitments

Production commitments were not included in the final EIS runs. These were evaluated in the model outputs.

7.2.3 Forest Management and Silvicultural Policy

Table C24. Forest Management and Silvicultural Policy

	Alternative		
	A	B	C
Model formulation	GOAL	GOAL	GOAL
Objective	Maximize discounted net revenue	Maximize discounted net revenue	Maximize discounted net revenue
Discount rate	5%	5%	5%
Cashflow Constraint	N/A	N/A	N/A
Replant constraint	Replanting constraint to ensure planting occurs on 100% of regeneration harvested areas - WA Forest Practices requirement	Replanting constraint to ensure planting occurs on 100% of regeneration harvested areas - WA Forest Practices requirement	Replanting constraint to ensure planting occurs on 100% of regeneration harvested areas - WA Forest Practices requirement
Ending of planning horizon constraint	After the 5 decade, a sequential flow constraint allows for +/-10 percent proportional increases and decreases between periods on the upland inventory	After the 5 decade, a sequential flow constraint allows for +/-10 percent proportional increases and decreases between periods on the upland inventory	After the 5 decade, a sequential flow constraint allows for +/-10 percent proportional increases and decreases between periods on the upland inventory
Long-term Sustainable harvest volume flow per Policy for Sustainable Forests	Modulating even-flow constraint +/- 25% between periods is applied to the sustainable harvest units per PSF	Modulating even-flow constraint +/- 25% between periods is applied to the sustainable harvest units per PSF Modulating even-flow constraint +/- 15% between periods is applied at the District level	Modulating even-flow constraint +/- 25% between periods is applied to the sustainable harvest units per PSF

	Alternative		
	A	**B**	**C**
Permissible silviculture	Include Regeneration harvest (R1 on all sites and R2 for visual sites), commercial thinning (CT), MoRF habitat thinning (MT) and Type A habitat thinning (AT). Exclude R0	Include Regeneration harvest (R1 on all sites and R2 for visual sites), commercial thinning (CT), MoRF habitat thinning (MT) and Type A habitat thinning (AT). Exclude R0	Include Regeneration harvest (R1 on all sites and R2 for visual sites), commercial thinning (CT), MoRF habitat thinning (MT) and Type A habitat thinning (AT). Exclude R0

7.2.4 Northern Spotted Owl Habitat Policies

Table C25. Northern Spotted Owl Habitat Policies

	Alternative		
	A	**B**	**C**
Settlement Agreement	No regeneration of yield table NSO habitat between period 1 and 3. Harvesting is permanently deferred in all Type A and Type B habitat. (Locked 99 periods).	No regeneration of yield table Movement and better NSO habitat between periods 1 and 3. Harvesting is permanently deferred in all Type A and Type B habitat. (Locked 99 periods).	No regeneration of yield table Movement and better NSO habitat between periods 1 and 3. Harvesting is permanently deferred in all Type A and Type B habitat. (Locked 99 periods).
Concurrence Letter	Maintain area of existing NSO dispersal-plus habitat (D, Y, S, U, N, X) excluded from concurrence sales with RD3d5 ≥48. (No loss of dispersal habitat if thin down to RD =48). Can thin forest (Habitat D, Y, S, U, N, X) down to RD3d5 = 40 in stands approved under the concurrence letter. Applicable in model Period I only.	N/A	N/A
HCP Nesting, Roosting & Foraging management areas	Current procedure to maintain 50 percent of Nesting Roosting and Foraging (NRF) habitat class (Sub-mature plus) in the Green, Pleasant Valley, North & South Snoqualimie Spotted Owl Management Units (SOMU). Applicable Whole Planning Period.	Current procedure to maintain 50 percent of Nesting Roosting and Foraging (NRF) habitat class (Sub-mature plus) in the Green, Pleasant Valley, North & South Snoqualimie Spotted Owl Management Units (SOMU). Applicable Whole Planning Period.	Current procedure to maintain 50 percent of Nesting Roosting and Foraging (NRF) habitat class (Sub-mature plus) in the Green, Pleasant Valley, North & South Snoqualimie Spotted Owl Management Units (SOMU). Applicable Whole Planning Period.
HCP Dispersal management area	Current procedure - Each Spotted Owl Management Unit (SOMU) based on modified 1996 Watershed Administrative Unit (WAU) targeted to restore and maintain 50 percent of its area in a dispersal or better habitat class (HQN, A,B MoRF, S,Y,D). Applicable Whole Planning Period.	Each Spotted Owl Management Landscape targeted to restore and maintain 50 percent of its area in a South Puget Movement habitat and target to restore and maintain 35% Movement, Roosting and Foraging (MoRF) or better (HQN, A, B) habitat class. Elbe, Enmuclaw, and Tahoma	Each Spotted Owl Management Landscape targeted to restore and maintain at least 50 percent of its area in a Movement or better (HQN, A,B) habitat class. Target of 35 percent Type B habitat in Elbe, Enmuclaw, and Tahoma LPU's

	Alternative		
	A	B	C
		LPU's. Pleasant Valley Dispersal SOMU maintain at least 50% movement habitat	Pleasant Valley Dispersal SOMU maintain at least 50% Movement dispersal habitat

7.2.5 Forest Landscape Management Policies

Table C26. Forest Landscape Management Policies

	Alternative		
	A	B	C
Rain on snow sub-basin targets	Target forecast of hydrological maturity (RD ≥ 25) in Rain-On-Snow basins at least 66% of Rain-On-Snow basin total area.	Target forecast of hydrological maturity (RD ≥ 25) in Rain-On-Snow basins at least 66% of Rain-On-Snow basin total area.	Target forecast of hydrological maturity (RD ≥ 25) in Rain-On-Snow basins at least 66% of Rain-On-Snow basin total area.
Upland management constraint representing management in sensitive areas	Forecast target of 80% of UPLANDS area in each watershed (WAU) that has Relative Density ≥ 48 Thinning Group No. 1: WAU RD ≥ 48, SOMU RD ≥ 25 Thinning Group No. 2: WAU RD ≥ 25, SOMU RD ≥ 25	Forecast target of 80% of UPLANDS area in each watershed (WAU) that has Relative Density ≥ 48 Thinning Group No. 1: WAU RD ≥ 48, SOMU RD ≥ 25 Thinning Group No. 2: WAU RD ≥ 25, SOMU RD ≥ 25	Forecast target of 80% of UPLANDS area in each watershed (WAU) that has Relative Density ≥ 48 Thinning Group No. 1: WAU RD ≥ 48, SOMU RD >= 25 Thinning Group No. 2: WAU RD ≥ 25, SOMU RD ≥ 25
Visual management	No specific constraint for general visual area Tiger Mtn - constain regeneration harvest to no more that 1/6 (600 acres) of each Watershed Administrative Unit (WAU) per decade and harvest age of at least 60 years.	Regenerate visual area with 20 trees acre (R2). Constrain regeneration harvest to 40 years or more. Tiger Mtn - constrain regeneration harvest to no more that 1/6 (600 acres) of each Watershed Administrative Unit (WAU) per decade and harvest age of at least 40 years.	Regenerate visual area with 20 trees acre (R2). Constrain regeneration harvest to 40 years or more. Tiger Mtn - constrain regeneration harvest to no more that 1/6 (600 acres) of each Watershed Administrative Unit (WAU) per decade and harvest age of at least 40 years.
Hydrological maturity (watershed systems) for Lake Tahuya	Target forecast of hydrological maturity (RD ≥ 25) of at least 66% of inventory area in Lake Tahuya Basin	N/A	N/A
Older forest targets	As per current procedure. All forest stands that meet at least FDS 4 or better are constrained from regeneration harvest. 12.5% of total area that is NDS + FFS are targeted.	As per current procedure. All forest stands that meet at least FDS 4 or better are constrained from regeneration harvest. 12.5% of total area that is NDS + FFS are targeted.	As per current procedure. All forest stands that meet at least FDS 4 or better are constrained from regeneration harvest. 12.5% of total area that is NDS + FFS are targeted.

7.3 Representing Future Forest Condition

7.3.1 Forest Development Stages

Future forest conditions are represented using a classification of forest stand development stages. Forest ecosystems can be explained in terms of their composition, function and structure (Franklin et al 2002, Bormann and Likens 1979). Composition refers to the variety of organisms or species found in forests. Function refers to the "work" carried out by the ecosystem, such as primary productivity or providing wildlife habitat. Forest structure refers to the measureable physical attributes of forests which affect forest function, such as; size and number of trees; number of vertical canopy layers; amount of snags and down woody debris (Franklin et al 2002, Carey 2007). Forest structure provides a readily-measured surrogate for ecosystem functions that are otherwise difficult to measure directly, and also can be used to assess a forest's value in terms of products or services provided (DNR 2004 Appendix B-31).

Table C27. Forest Stand Development Stages

Stand Development Stages		Forest Development Stage Index (FDS)
EIS	Ecosystem initiation stage	1
CES	Competitive exclusion stage	2
UDS	Understory development stage	3
BDS	Botanical diversity or biomass accumulation stage	4
NDS	Niche diversification stage	5
FFS	Fully functional stage	6

Forest stand development stages were modeled using FVS Keyword StrClass based on Crockson and Stage (1999) stand structure statistics, number of large trees, an old-growth condition index (OFC index), number of large snags, and amount of down woody debris.

The older forest condition index (OFCI) was developed from the 24 high potential old growth stands (WOGHI score greater than or equal to 60) in the South Puget Sound HCP Planning unit. For these stands, a diameter distribution index procedure was developed, similar to a Berger-Parker index[5], and a diameter index score of 20 or greater was determined to represent the diameter distribution of older forests in the South Puget planning unit. The index procedure was calculated as a yield variable for all the strata, in all periods under all treatments.

The computation of the older forest condition index (OFCI) is as follows:

$$\begin{aligned} OFCI = {} & \mathrm{Min}(\mathrm{Max}(\mathrm{Int}(TPA_1-507.3698)+1,0),1)\cdot \mathrm{Min}(\mathrm{Max}(\mathrm{Int}(1966.4251-TPA_1)+1,0),1)+ \\ & \mathrm{Min}(\mathrm{Max}(\mathrm{Int}(TPA_2-49.1553)+1,0),1)\cdot \mathrm{Min}(\mathrm{Max}(\mathrm{Int}(190.5374-TPA_2)+1,0),1)\cdot 2+ \\ & \mathrm{Min}(\mathrm{Max}(\mathrm{Int}(TPA_3-17.1190)+1,0),1)\cdot \mathrm{Min}(\mathrm{Max}(\mathrm{Int}(66.3246-TPA_3)+1,0),1)\cdot 4+ \\ & \mathrm{Min}(\mathrm{Max}(\mathrm{Int}(TPA_4-15.5868)+1,0),1)\cdot \mathrm{Min}(\mathrm{Max}(\mathrm{Int}(60.3984-TPA_4)+1,0),1)\cdot 8+ \\ & \mathrm{Min}(\mathrm{Max}(\mathrm{Int}(TPA_5-10.4915)+1,0),1)\cdot \mathrm{Min}(\mathrm{Max}(\mathrm{Int}(40.6998-TPA_5)+1,0),1)\cdot 16 \end{aligned}$$

where TPA_i (i = 1, 2, …, 5) is the number of trees per acre in the DBH class i.

[5] The Berger-Parker index expresses the proportional abundance of the most dominant species or class.

Table C28. Lower and Upper Bounds of Tree Densities (TPA) by Diameter Class Used in the Older Forest Condition Index

Diameter Class	DBH (inches)	Trees per Acre (TPA)	Weight
1	0.0 ≤ DBH < 3.5	507.4 ≤ TPA ≤ 1,966.4	1
2	3.5 ≤ DBH < 11.5	49.2 ≤ TPA ≤ 190.5	2
3	11.5 ≤ DBH < 19.5	17.1 ≤ TPA ≤ 66.3	4
4	19.5 ≤ DBH < 29.5	15.6 ≤ TPA ≤ 60.4	8
5	29.5 ≤ DBH	10.5 ≤ TPA ≤ 40.7	16

Table C29. Parameters Used to Model Forest Development Stage (FDS)

Code	Label	FDS name	FVS StrClass	TPA30	OFCI	SNAG20	CWD (ft^3/ac)
0	BG	Bare Ground	Less than 5 percent crown cover and fewer than 200 trees per acre				
1	EIS	Ecosystem Initiation	Less than 5 percent crown cover and greater than or equal to 200 trees per acre, or one stratum with a nominal dbh. less than 5 inches; a stratum must have more than 5 percent crown cover to be considered a valid stratum).				
2	CES	Competitive Exclusion	One stratum with an nominal dbh. between 5 and 25 inches. This classification is changed to *ecosystem initiation* if the stand density index is below 30 percent of the maximum allowed for the stand.				
3	UDS	Understory Development	Two strata with the uppermost having a dbh between 5 and 25 inches				
4	BAS	Biomass Accumulation	Two strata with the uppermost having a dbh. between 5 and 25 inches	≥ 15			
					≥ 20		
5	NDS	Niche Diversification	Two strata with the uppermost having a dbh. between 5 and 25 inches	≥ 15		≥ 1.5	≥ 1200
					≥ 20		
6	FFS	Fully Functional	Two strata with the uppermost having a dbh. between 5 and 25 inches	≥ 15	≥ 20	≥ 1.5	≥ 1200

Note: *For the BAS, NDS, and FFS forest development stages, either of the 2 strata meet the FDS definition criteria*
TPA30 = Live trees per acre with DBH ≥ 29.5"
OFCI = Old Forest Condition Index
Snag20 = Snags per acre with diameter ≥ 19.5" and length ≥ 16'

7.3.2 Northern Spotted Owl Future Habitat

The forecasted habitat class is derived from the projected forest condition. The forest condition changes over time due to natural stand dynamics and through silvicultural management events such as thinning, regeneration harvesting, and planting. The change in habitat quality over time (represented by the habitat index HABI) is reflected in the yield tables for the corresponding forest type, site quality, and silvicultural regime.

The Habitat Index values were derived from structural and composition characteristics modeled within FVS. The values for each habitat type are outlined below in Table C33. Two habitat yield variables were created: HABI and HABI6. HABI was used in the yield tables for Alternative A. HABI6 was used in the Alternative B and C and includes the following modifications:

1) The minimum northern spotted owl habitat definition is South Puget Movement (or Movement for short) habitat
2) Snag and down woody debris treatments (i.e. additional qualities are added to the stand) are included in the light (MT) and heavy (AT) variable density thinning treatments
3) Habitat yields for with a minimum trees per acre (i.e. young forest marginal, sub-mature and movement, roosting and foraging NSO habitat classes were adapted so that once a strata reach these habitat classes, it would not regress based on solely a reduction of trees per acre below the minimum threshold[6]

Table C30. Northern Spotted Owl Habitat Index by Habitat Class

Northern Spotted Owl Habitat Class	Composite Habitat Index (HABI)		Composite Habitat Index (HABI6)
	Min	Max	Max
None (N)	0	0	0
Dispersal (D)	1	1	
Movement (M)	1		1
Young Forest Marginal (YFM)	2	3	3
Sub-mature (S)	4	7	7
Movement, Roosting, & Foraging MoRF)	8	15	15
Type B	16	31	31
Type A	32	63	63
High Quality Nesting (HQN)	64	127	127

[6] In the Draft EIS it was noted that some habitat yield represented a discontinuous nature, changing from habitat to non-habitat and back to habitat over three decades (see Appendix C, Draft EIS, pages 64-65)

Table C31. Threshold Values Northern Spotted Owl Habitat Classification and Calculation of Habitat Index (HABI)

Variables	Habitat							
	Dispersal	Movement	Young Forest Marginal	Sub-mature	MoRF	Type B	Type A	High Quality Nesting
Number of Tree Species						≥ 2	≥ 2	
Number of Canopy Layers					≥ 2	≥ 2	≥ 2	
Top Height	≥ 85	≥ 85	≥ 85	≥ 85	≥ 85			
QMD100	≥ 11	≥ 11						
RD3d5	≥ 48	≥ 48	≥ 48	≥ 48	≥ 48	≥ 48	≥ 48	≥ 48
TPA3d5		≤ 280	≥ 115 & ≤ 280	≥ 115 & ≤ 280	≥ 115 & ≤ 280			
TPA20						≥ 75 & ≤ 100		
TPA21								≥ 31
TPA30								
TPA30							≥ 15 & ≤ 75	
TPA31								≥ 15
(Conifer TPA3d5) / TPA3d5		≥ 0.3	≥ 0.3	≥ 0.3	≥ 0.3			
SNAG15					≥ 3.0			
SNAG20			≥ 2.0*	≥ 3.0		≥ 1.0		
SNAG21								≥ 12
SNAG30							≥ 2.5	
CWD (ft^3/ac)			≥ 4800*	≥ 2,400	≥ 2,400	≥ 2,400	≥ 2,400	≥ 2,400
Habitat value (n)	0		1	2	3	4	5	6
If all conditions are met, then binary value = 1, else 0. Habitat Index (HABI) = $(2 \times \text{binary value})^n$	1	1	2	4	8	16	32	64
Maximum composite HABI (sum of all habitat types that exist simultaneously)	1	1	3	7	15	31	63	127

Note: YFM habitat, either condition (*) meets the criteria

Canopy layers are determined using an algorithm in an extension for the USDA Forest Vegetation Simulator (Dixon 2003). "The canopy strata are initially defined by naturally occurring gaps in the distribution of tree eights. The gaps are found when the heights of two trees in a list sorted by height differ by more than [15] percent of the height of the taller and at least [20] feet. The two largest gaps define three potential strata. If there is only one gap, two potential strata are defined and if there are no gaps, one potential stratum is defined. Trees in the sorted list that have very small sampling probability are skipped until the sum of the skipped trees' sampling probability accounts for over two trees per acre. Initially defined strata must have over 5 percent canopy cover or they are rejected" (Crookston and Stage 1999). Square brackets indicate the DNR value replacing the default.

8. Summary of the Outputs

A summary of the forest modeling outputs are provided and comparison between the alternatives in terms of Net Present Value, harvest volume, growing stock both standing and operable volume, old forest, northern spotted owl habitat and riparian forests are provided.

Table C32. Summary Outputs

Management Alternative	Harvest Level decade 1	Gross Revenue decade 1	Long-term sustainable harvest level[1]	Cumulative NPV[2] after 100 years	% of Unit in Older Forest Conditions[3] by 2067	Date NSO Dispersal Mgmt Area reach 50 percent SP Movement Habitat	Date NSO NRF Mgmt Area reach 50 percent SP Movement Habitat	Growing Stock Change after 100 years
	MMBF	$ Millions	MMBF	$ Millions	Acres	Decade	Decade	Percent
A	374	95	378	178	16%	*[4]	2057	152%
B	367	106	320	171	21%	2047	2057	170%
C	410	126	313	179	26%	2037	2057	162%

1. Average over a projection of 100 years
2. Net Present Value
3. Niche diversification and Fully functional forest development stages
4. Alternative does not reach a 50 percent target of South Puget Movement habitat in the dispersal management are in the 100 year projection

The all Alternatives demonstrate significantly different harvest volume trends over time to the sustainable harvest project made in 2007 when examined either at the HCP unit or model level (combined area of South Puget Sound Region and South Puget HCP unit). The differences arise in part from the scale of the model and differences in modeling techniques and data. The sustainable harvest 2007 modeled was constructed to represent all the Westside DNR-managed land base, while the models constructed for this planning process only included those DNR-managed lands that fell within the South Puget Sound Region or the Sound Puget HCP unit (see Figure C6).

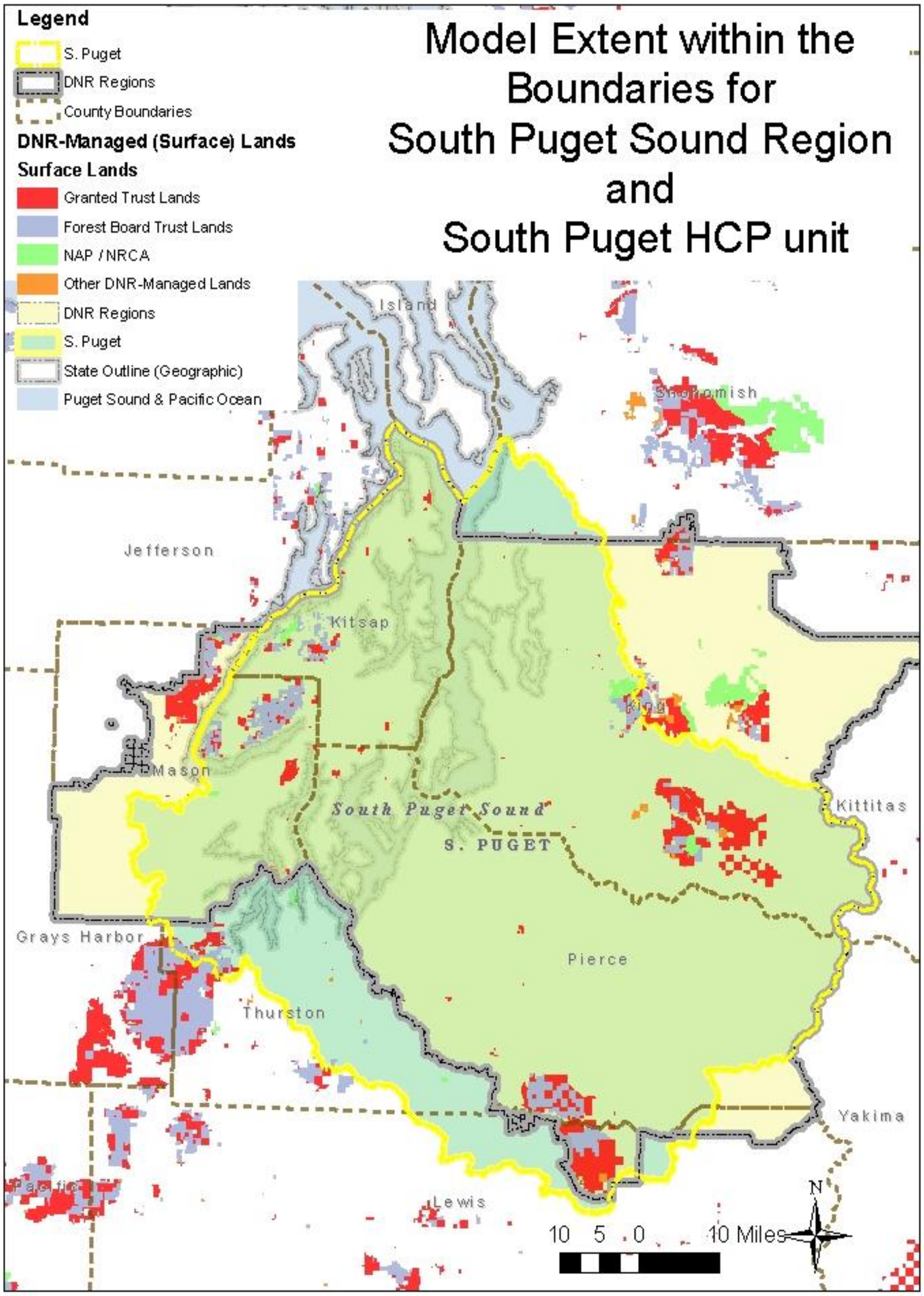


Figure C6. Map of Model Extent

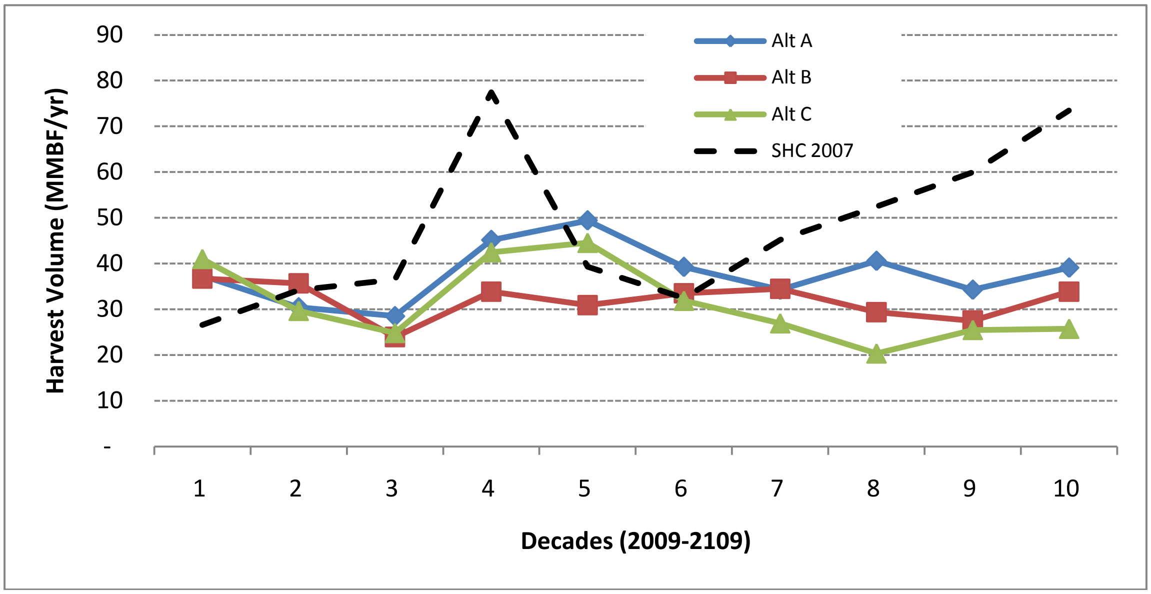


Figure C7. Harvest Volumes for the South Puget HCP Planning Unit by Alternative

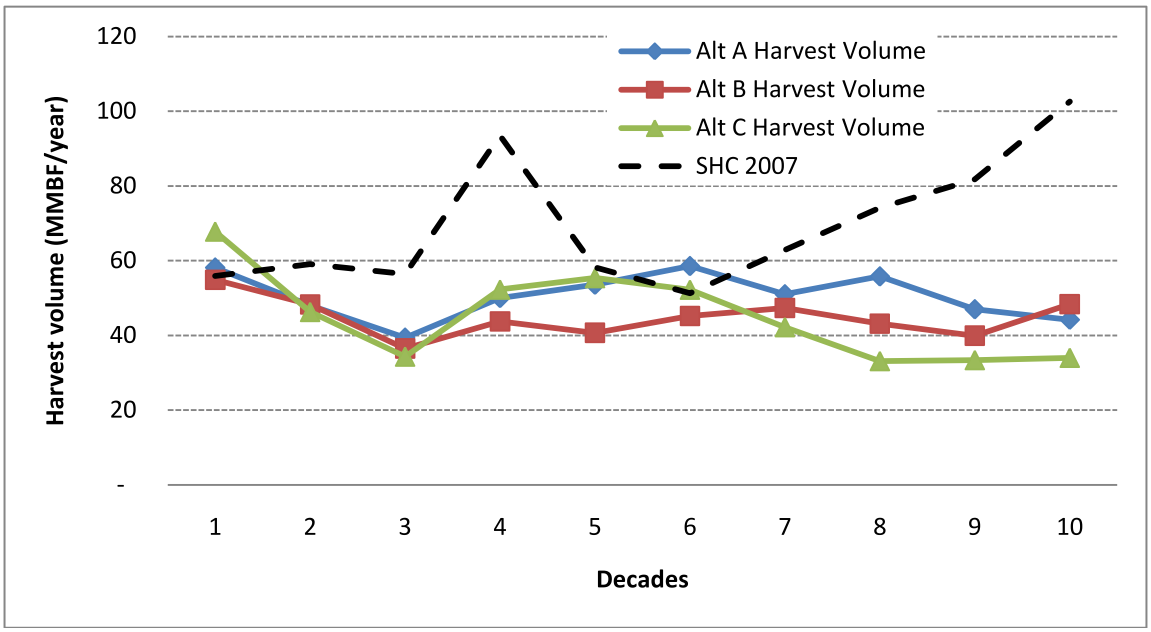


Figure C8. Harvest Volume by Alternative at the Combined South Puget Sound Region and South Puget HCP Planning Unit Scale

8.1.2. Recommended Changes to Sustainable Harvest Levels as a Result of the South Puget HCP Planning Unit Analysis

Differences in the harvest volumes between the 2007 sustainable harvest and the current model project may lead one to the conclusion that the sustainable harvest levels for the region should be updated.

The South Puget Habitat Conservation Plan (HCP) planning unit contains the following acreage distributions (Table C36) of state trust forest lands categorized by their Sustainable Harvest Units (SHU) per DNR 2006 *Policy for Sustainable Forests*, p. 29. Only two of the SHUs are completely contained within the planning unit: Kitsap and Pierce County State Forest Transfer lands.

Table C33. Distribution of Sustainable Harvests Units (SHU) in South Puget HCP Planning Unit

	South Puget HCP unit			
	Sustainable Harvest Unit		Acres	Percent of sustainable area in South Puget HCP unit
1	Federally Granted Trust Lands		81,085	12.7%
2	Capitol Forest		11,762	13.9%
3	OESF			
4	State Forest Transfer lands	Clallam		
5		Clark		
6		Cowlitz		
7		Grays-Harbor		
8		Jefferson		
9		King	10,454	46.5%
10		Kitsap	7,365	100.0%
11		Lewis	8,410	22.2%
12		Mason	17,461	66.2%
13		Pacific		
14		Pierce	8,375	100.0%
15		Skagit		
16		Skamania		
17		Snohomish		
18		Thurston	1,272	14.9%
19		Wahkiakum		
20		Whatcom		
	Total		**146,185**	**10.3%**

Note: data source LDO-20090203, includes forested area (codes 1 and 2) and road buffer area

The 2007 Sustainable Harvest calculation set the harvest levels for each of these SHUs. The harvest level forecast to come from the South Puget HCP planning unit is presented in Table C37, columns A and B. It should be noted that these harvest levels do not reflect the sustainable harvest levels, since not all the SHUs are contained completely within the South Puget HCP unit (Table C36).

Since fiscal year 2005, the start of the sustainable harvest decade (2004-2014), the Regions (South Puget Sound and Pacific Cascade) have sold 213 MMBF or 80 percent of the forecasted decadal sustainable harvest volume from the planning unit (Table C37, column C). Examining the sold harvest records, it could be assumed that a number of the sustainable harvest units within South Puget HCP unit appear to be over harvested. However, this could be an erroneous conclusion unless the whole land-base and sold harvests were examined at a Westside level. What is apparent from the data is the harvest level in South Puget HCP portions of Capitol, Mason and Pierce have been higher than what was forecasted in the 2007 SHC analysis.

The forest land planning process constructed and ran detailed forest models to verify the 2007 sustainable harvest levels and examine alternative management strategies per direction of the 2006

Policy for Sustainable Forests. The forest planning models accounted for the depletions (sold timber harvests) in inventory from FY 2005 through the first half of FY 2009. The harvest levels forecast for the preferred alternative (Alternative B) are presented in Table C37, column E for the first decade (2009-2019). This value provides the potential harvest by sustainable harvest unit (column F) for the remainder of the sustainable harvest decade (2009-2014).

Table C34. Harvest Level Information for South Puget HCP Planning Unit

	A	B	C	E	F
Sustainable Harvest Unit	**Forecasted Harvest level from South Puget HCP unit for decade 1 (2004-2014)**		**Sold Volume FY05 to FY09**	**Alt B - harvest level in decade 1 - 2009-2019**	**Potential harvest available for remainder of SHC decade 1 (2004-2014)**
	MMBF	Percent of SHC level in South Puget HCP	MMBF	MMBF	MMBF
Federally Granted lands and State Forest Purchase	124	5%	86	186	93
CAPITOL	36	7%	42	40	20
KING	25	29%	7	20	10
KITSAP	25	100%	8	19	9
LEWIS	3	1%	12	30	15
MASON	33	52%	29	60	30
PIERCE	12	100%	28	12	6
THURSTON	6	12%	2	0	0
Grand Total	266	5%	213	367	184

Table C35. Harvest Level Recommendation for Kitsap and Pierce State Forest Transfer Sustainable Harvest Units

	A	B	C	E	F	G	H
Sustainable Harvest Unit	**Forecasted Harvest level from South Puget HCP unit for decade 1 (2004-2014)**		**Sold Volume FY05 to FY09**	**Alt B - harvest level in decade 1 - 2009-2019**	**Potential harvest available for remainder of SHC decade 1 (2004-2014)**	**Potential new harvest level by SHC for 2004-2014**	**Potential change in harvest level is South Puget (highlights = recommended change in SHC)**
	MMBF	Percent of SHC level in South Puget HCP	MMBF	MMBF	MMBF	MMBF	MMBF
KITSAP	25	100%	8	19	9	17	(8)
PIERCE	12	100%	28	12	6	33	21

For the two SHUs that are contained completely within the South Puget HCP planning unit, Kitsap and Pierce, a more conclusive recommendation can be made (Table C38). For Kitsap County State Forest Transfer the recommendation is to reduce the harvest level by 8 MMBF from 25 MMBF to 17 MMBF for the decade 2004 to 2014. The forest land planning analysis provided a more detailed opportunity to model the forest growth and correct the yield values on the Kitsap peninsula with the use of site specific forest inventory data and localized modeling assumptions.

In Pierce County State Forest Transfer the recommendation is to increase the sustainable harvest level by 21 MMBF, from 12 to 28. The increased harvest results from a significant changed proposed in the preferred alternative's northern spotted owl dispersal management strategy and in localized modeling assumptions for harvest removals with variable density thinning.

8.2 Growing Stock

All alternatives are forecast to increase merchantable volume across all land classes. The changes in the northern spotted owl dispersal management strategies in Alternative B and C generally, result in higher inventories in upland areas (Figure C9).

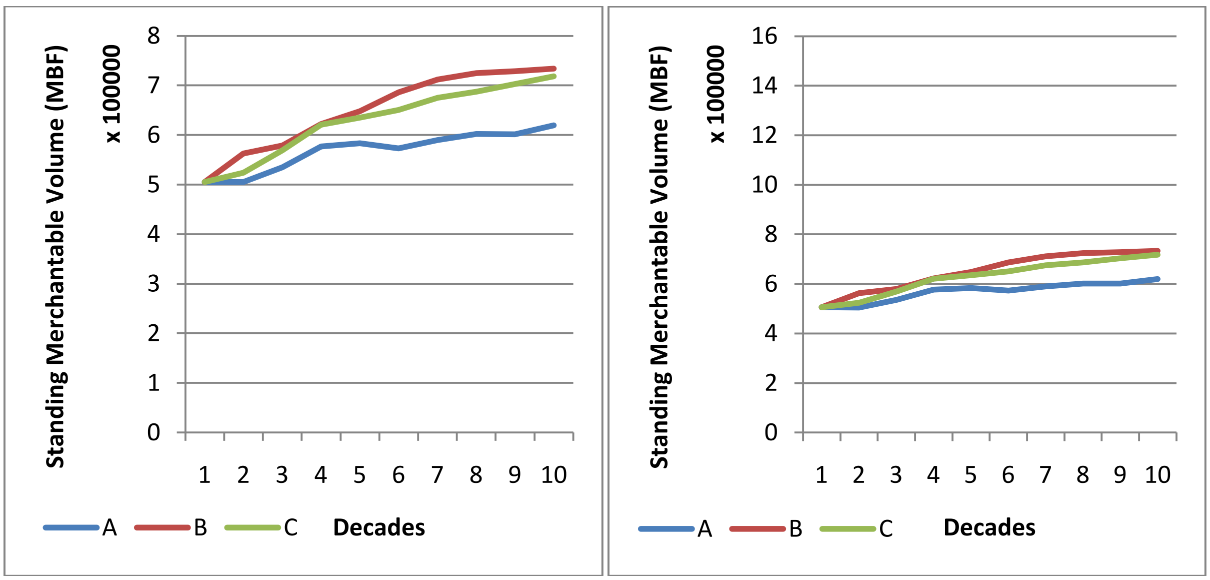


Figure C9. Standing Merchantable Volume by Alternative

Left Figure all Land Classes - Right Figure Upland (GEMS and UPLAND) Land Classes

The average forest growth rate for the entire land base over the planning horizon range is 326 bf/acre/year for Alternative A, 386 bf/acre/year for Alternative C, and 439 bf/acre/year for Alternative B. For upland areas (GEMS and UPLANDS combined) growth rates range from 87 bf/acre/year (Alternative A), 162 bf/acre/year (Alternative C) to 173 bf/acre/year (Alternative B).

Figure C10 provides comparative information on growing stock, operable volume for regeneration harvest and harvest volume for Alternative B. Harvests are approximately 50-60 percent of operable volume in the initial part of the planning period, with the expectation that harvest levels will increase as a percentage of operable in the future as rotation ages on upland areas without specific objectives (GEMS) are shorten. This latter phenomenon does not occur until after the 7 decade.

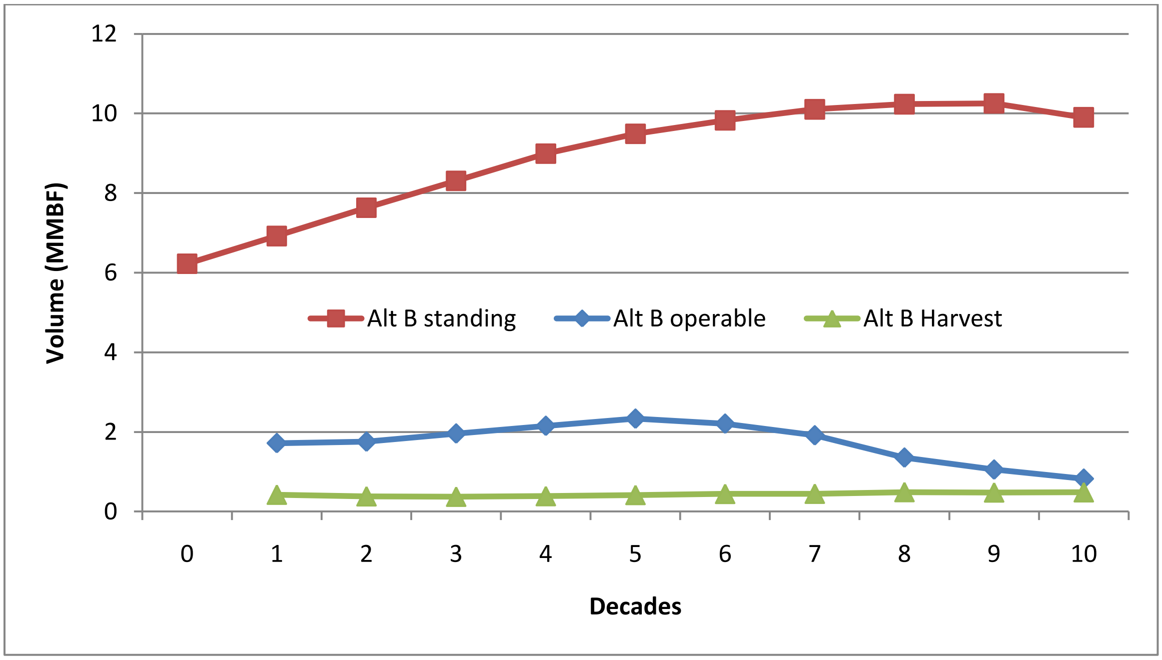
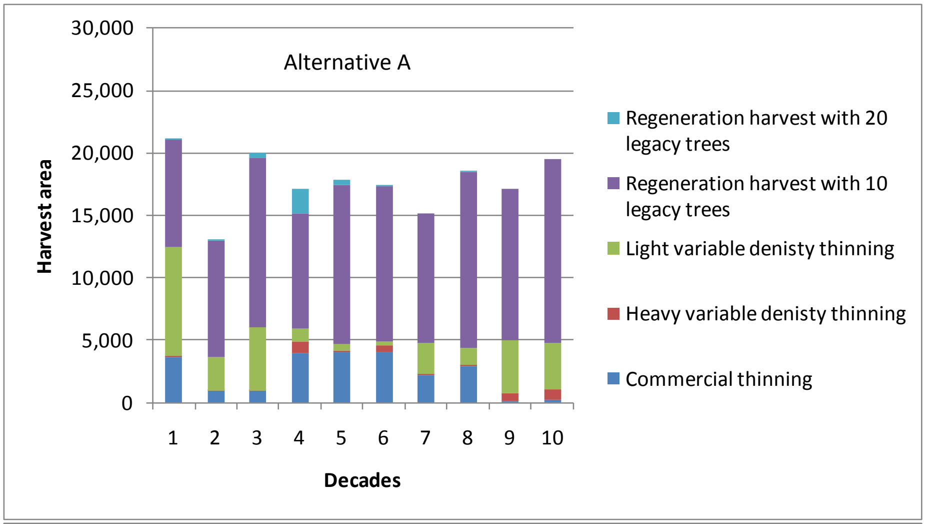
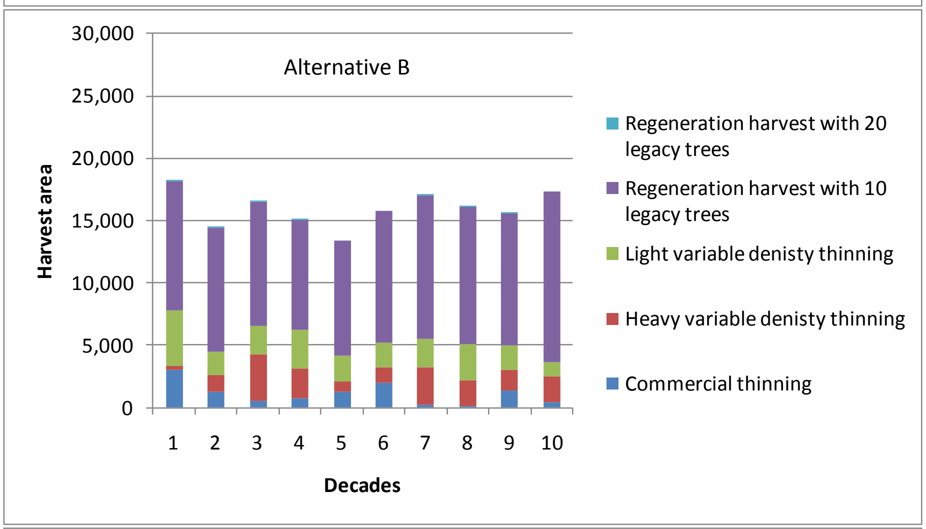


Figure C10. Model Extent Standing, Operable and Harvest Volume for Alternative B

8.3 Harvest Area

Harvest areas and there impacts are extensively discussed in this Final EIS. Figure C11 provides a summary of the harvest areas by harvest type for each alternative.





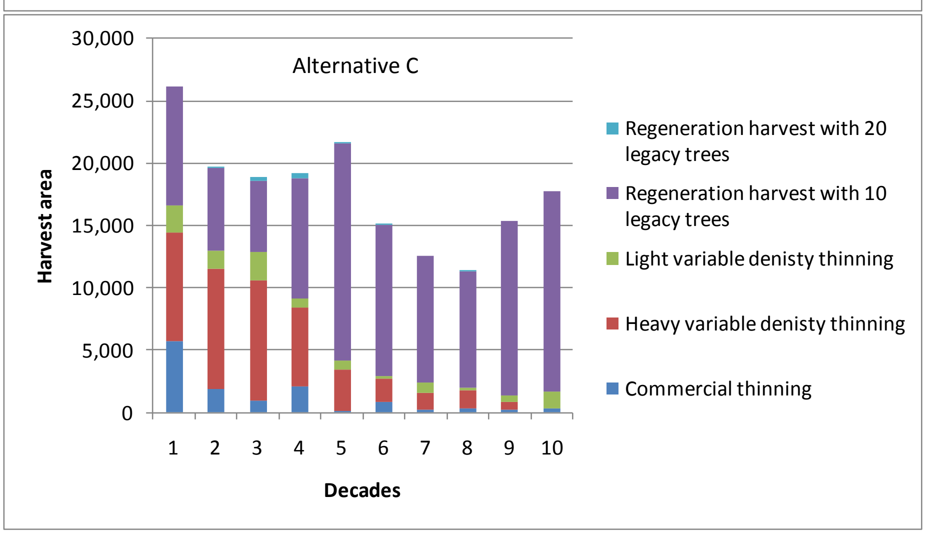


Figure C11. Harvest Area by Harvest Type by Alternative for South Puget HCP Planning Unit

8.4 Harvest Age, Age Class and Forest Structure

Average regeneration ages by period are presented in Table C39. These values are not weighted by acres. Regeneration ages are expected to increase over the planning period before lowering to a range in the "economic" rotation ages, with Alternative expected to reach lower regeneration harvest ages that Alternatives A or B.

Table C36. Average Regeneration Harvest Ages by Alternative for South Puget HCP Planning Unit

Decade	A	B	C
1	50-59	50-59	50-59
2	60-69	60-69	50-59
3	50-59	50-59	50-59
4	80-89	70-79	80-89
5	90-99	70-79	70-79
6	70-79	70-79	50-59
7	70-79	70-79	60-69
8	70-79	60-69	60-69
9	60-69	70-79	40-49
10	60-69	50-59	40-49

Age class distribution trends for all Alternatives are similar. Figures C12 through C15 display the age class trends for Alternative B. Two trends are of note. First, by 2069 the majority of the riparian and wetland land classes are expected have forests 70 years and older. Second, by 2069 a bimodal age class distribution appears and is accentuated by 2099. An older forest, which is predominately in the riparian and wetland land class, is created across the landscape. The implication of a bimodal age-class distribution raises the question of how these forests will replace themselves in the event of natural succession and/or natural disturbances. Current policies and management provide no active management for replacement of forests in these land classes.

All alternatives have similar trends in forest development stages (Figures C16, C17 and C18), substantial increases in older forests classes (niche diversification and full functional development stages) with a corresponding reduction in competitive exclusion stages (competitive exclusion, understory development and biomass accumulation). By the end of contract of the HCP (circa 2069), competitive exclusion classes will have been reduced from 76 percent of the forest area to 55 percent within the planning unit.

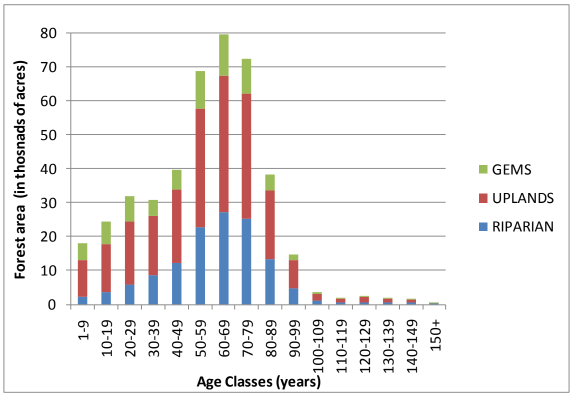


Figure C12. Age Class 2009 Alternative B South Puget HCP Planning Unit

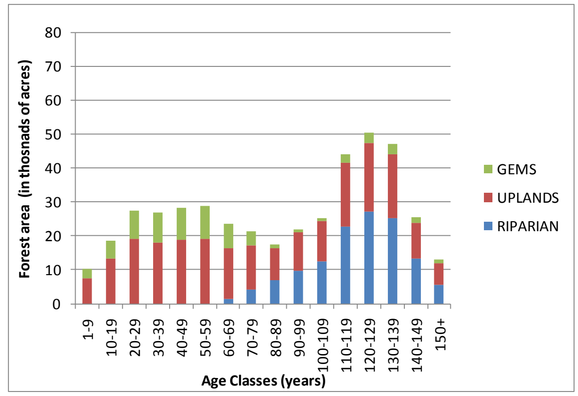


Figure C1. Age Class 2069 Alternative B South Puget HCP Planning Unit

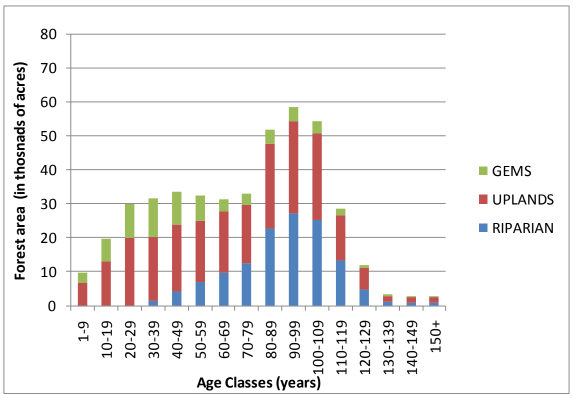


Figure C14. Age Class 2039 Alternative B South Puget HCP Planning Unit

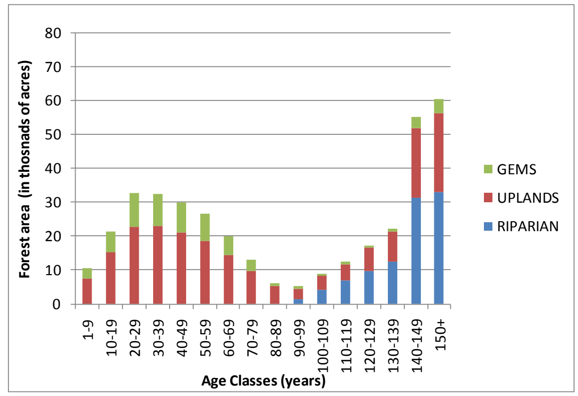


Figure C15. Age Class 2099 Alternative B South Puget HCP Planning Unit

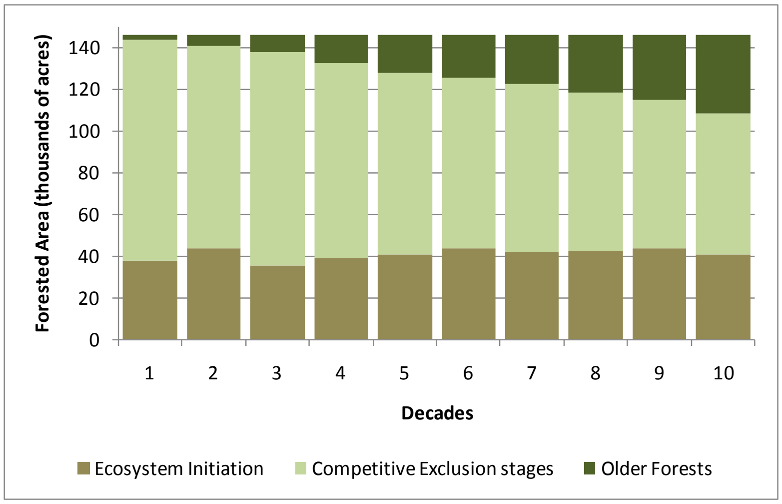


Figure C16. Forest Development Stages - Alternative A

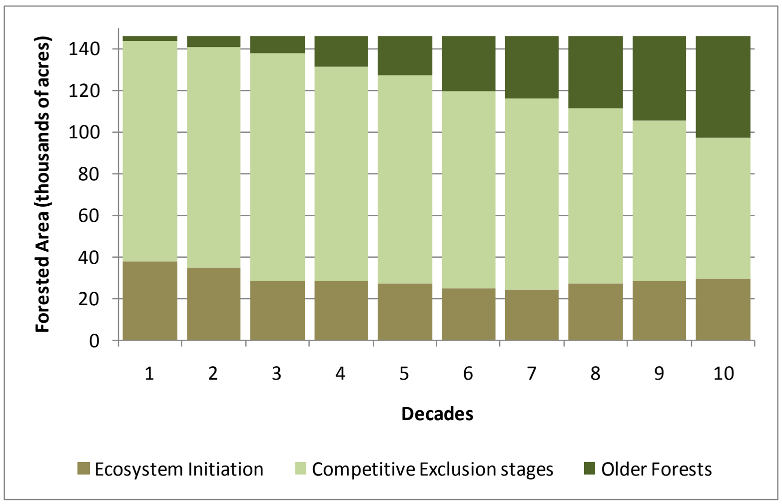


Figure C27. Forest development Stages - Alternative B

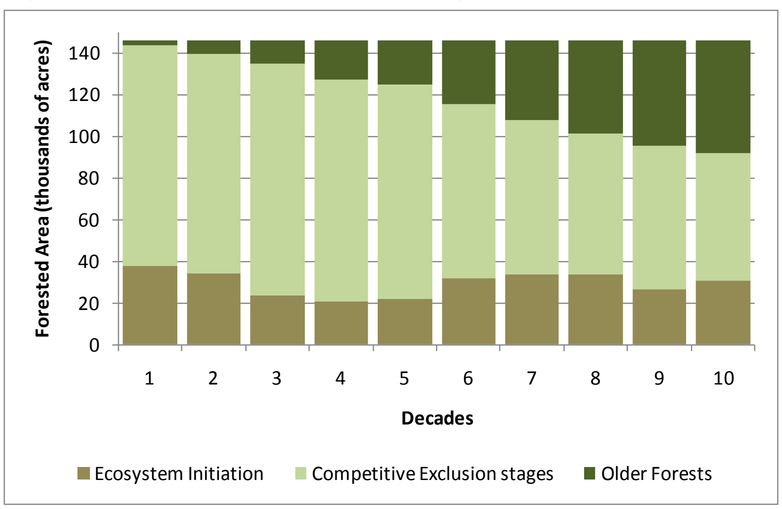


Figure C38. Forest development Stages - Alternative C

8.5. Sensitivity Analysis of Timber Flow Constraints

8.5.1 Background:

The Washington State DNR utilizes a generalized linear programming (LP) based harvest scheduling model (HSM) in its forest land planning process in order to identify planned harvest acres and other silvicultural interventions across forest landscape over time. The HSM is developed using a commercial software—Remsoft Spatial Planning System (RSPS) ™ (Remsoft Inc.) — demonstrate sustainability of both timber and non-timber resources to various stakeholders of the agency. At the core of this HSM are stratified (by major species composition, site classes, current stocking levels, treatment status) description of the land base acres, number of age classes and the growth and yield trajectories of such attributes as top tree height, trees/acre, basal area, relative density, merchantable volume/acre, northern spotted owl habitat value/acre for each stratum, a set of silvicultural prescriptions and the resulting states of each stratum.

In a HSM, the growth and yield trajectories of any given stratum attributes (e.g., total volume/acre or height growth at a specified age) are presumed to occur deterministically based on an average condition of that stratum and a specific silvicultural prescription. In reality, however, such trajectories may veer from their deterministic pathways, due to influence of unforeseen future events such as catastrophic fire, pandemic infestation and/ or the general climate change on forest conditions. Similarly, other such exogenous inputs as timber prices, operations costs and interest rates may also change significantly due to future economic uncertainty. Without an estimate of the likely range of fluctuations of any given HSM, confidence on its projections beyond a decade or two diminishes substantially. Notwithstanding the deterministic model inputs, forest modelers can instill a reasonable confidence in the HSM outcome by examining the ranges of some critical input variables (e.g., a 5-10% increase/decrease in volume yield) and assess the impact on desired model outcomes such as the Net Present Value (NPV), amount of habitat acres, or the total harvest acres over time.

The objective of this paper is to demonstrate the sensitivity of the HSM model in terms of: 1) six levels of volume yield assumptions (+-5%, +-10%, +-15% change with respect to the base volume yield), 2) three levels of interest rates (3%, 8% and 11% compared to the base 5% rate) and, 3) four levels of price recovery rates (3%, 5%, 8%, 11%) to the historical average price used in the base model.

8.5.2. Methods

For the sensitivity analysis, a slightly less constrained version of the Alternative- B used in the final Environmental Impact Statement (EIS) was chosen as the base scenario. The base scenario represented Alternative-B without the presence of district-level even-flow constraints on total volume output, and the regions foresters' preference for incorporating the first decade harvest blocks in the overall schedule. The idea behind freeing these constraints was to enable the model achieve more flexibility in terms of making decisions pertaining to the non-volume related objectives in the model. For each of the input variables and their selected levels of change from the base scenario, we created a new scenario and ran the model while all other input variables remained unchanged. Thus, a total of 13 scenarios were created: 6 examining the impact of changing volume yield; 3 examining the impact of interest rate changes; and, 4 for analyzing the impact of different price-gain-rates. Each of these scenarios was independently ran and summarized for the outcome of interest within the South Puget Sound HCP area.

Table C37. Alternative B ScenariosU for the SPS Model Sensitivity Analysis

Scenarios	*Description*	*Scenario Type*
AltB_base	Modified Alternative-B	Base scenario
AltB_vol_up_5pct	Alt-B volume yields up 5%	Volume yield scenarios
AltB_vol_up_10pct	Alt-B volume yields up 10%	ditto
AltB_vol_up_15pct	Alt-B volume yields up 15%	ditto
AltB_vol_low_5pct	Alt-B volume yields down 5%	ditto
AltB_vol_low_10pct	Alt-B volume yields down 10%	ditto
AltB_vol_low_15pct	Alt-B volume yields down 15%	ditto
AltB_Int_rate_3pct	Alt-B with 3% interest rate	Interest rate scenarios
AltB_Int_rate_8pct	Alt-B with 8% interest rate	ditto
AltB_Int_rate_11pct	Alt-B with 11% interest rate	ditto
AltB_price_gain_3pct	Stumpage gain 3%/year	Price gain scenarios
AltB_price_gain_5pct	Stumpage price gain 5%/year	ditto
AltB_price_gain_8pct	Stumpage price gain 8%/year	ditto
AltB_price_gain_11pct	Stumpage price gain 11%/year	ditto

8.5.3. Results

Results of the sensitivity analysis are presented with respect to the three yield variables, respectively harvest volume, interest rates and the price gain rates.

8.5.3.1. Effect of Volume Yield Assumptions

For all six volume scenarios that represent variations of the base scenario (AltB_base) with respect to volume yield, projected total volume output ('x 106 BF) showed a linear relationship to the respective increases or decreases in volume yield assumptions for all three time steps i.e., end of first decade, HCP and the planning horizon (see Table 2a). The total harvest acres also demonstrated linear relationship with respect to the base scenario although differences in harvest rates among these scenarios became very marginal by the end of HCP and of planning horizon (Table C38). As a result, the NPV generated from these scenarios also followed a linear relationship (Table C39).

Table C38. Total Harvest Volume Under the Volume Based Scenarios

Scenarios	Decade-1 end (year 2019		Decade-6 end (year 2069)		Decade 10 end (year 2109)	
	Volume (10^6 bf)	**% Change**	**Volume (10^6 bf)**	**% Change**	**Volume (10^6 bf)**	**% Change**
AltB_base	635	0%	2,760	0%	4,459	0%

Scenarios	Decade-1 end (year 2019		Decade-6 end (year 2069)		Decade 10 end (year 2109)	
AltB_vol_low_5pct	604	-5%	2,628	-5%	4,256	5%
AltB_vol_low_10pct	561	-12%	2,489	-10%	4,017	10%
AltB_vol_low_15pct	535	-16%	2,337	-15%	3,804	15%
AltB_vol_up_5pct	661	4%	2,891	5%	4,700	-5%
AltB_vol_up_10pct	690	9%	3,020	9%	4,914	-10%
AltB_vol_up_15pct	721	14%	3,163	15%	5,125	-15%

Note: - %, + % change respectively indicates reduction and increase with respect to base scenario output. Decade 6 marks the end of current Habitat Conservation Plan (HCP) in 2067.

Table C39. Total Harvest Acres (x 103) Under the Volume Based Scenarios

Scenarios	Decade-1 end (year 2019		Decade-6 end (year 2069)		Decade 10 end (year 2109)	
	Acres (x 10^3)	**% Change**	**Acres (x 10^3)**	**% Change**	**Acres (x 10^3)**	**% Change**
AltB_base	30	0%	126	0%	213	0%
AltB_vol_low_5pct	29	-1%	124	-1%	211	-1%
AltB_vol_low_10pct	28	-5%	123	-2%	209	-2%
AltB_vol_low_15pct	26	-12%	120	-4%	205	-4%
AltB_vol_up_5pct	30	1%	127	1%	215	1%
AltB_vol_up_10pct	31	3%	128	2%	215	1%
AltB_vol_up_15pct	31	6%	129	3%	217	2%

Table C40. Total NPV (x 106) Under the Volume Yield Scenarios

Scenarios	Decade-1 end (year 2019		Decade-6 end (year 2069)		Decade 10 end (year 2109)	
	NPV ('$ x 10^6)	***% Change***	***NPV ('$ x 10^6)***	***% Change***	***NPV ('$ x 10^6)***	***% Change***
AltB_base	111	0%	214	0%	223	0%
ALtB_vol_low_5pct	104	-6%	202	-5%	211	-5%
ALtB_vol_low_10pct	97	-12%	190	-11%	198	-11%
ALtB_vol_low_15pct	92	-17%	179	-16%	188	-16%
ALtB_vol_up_5pct	116	5%	225	5%	236	5%
ALtB_vol_up_10pct	122	11%	237	11%	248	11%
ALtB_vol_up_15pct	129	16%	249	17%	261	17%

The model output from the volume based scenarios was rather expected since the assumed changes in volume yield were arbitrarily decided, and were not based on changes in forest structural attributes such as average tree height, basal area and tree diameter. It is noteworthy that under all scenarios, no changes were assumed to occur in these attributes while changing the selected input variables (i.e. volume yield, interest rate and price gain rate). All scenarios were also subjected to the same level of forest structural objectives. As such, harvest window remained more or less the same regardless of the level of volume yield. This means harvest trajectory, as reflected in the base scenario, would not change its course regardless of the volume yield assumptions as long as the model is required to satisfy the same level of forest structural objectives.

8.5.3.2. Effect of Interest Rates

The model used in this analysis is based on maximizing net present value of the harvest schedule in which case the interest rate has real implications on the outcome of the harvest schedule because it affects the time preference for revenue generated through harvest volume. As a result, a lower interest rate (i.e. 3 percent instead of 5 percent) produced less total volume than the base scenario in the first decade, while higher rates produced high harvest levels during the same period (Table C41 and C42).

Table C41. Total Harvest Volume (x 106 bf) Under the Interest rate Based Scenarios

Scenarios	Decade-1 end (year 2019		Decade-6 end (year 2069)		Decade 10 end (year 2109)	
	Volume (10^6 bf)	**% Change**	**Volume (10^6 bf)**	**% Change**	**Volume (10^6 bf)**	**% Change**
AltB_base	635	0%	2,760	0%	4,459	0%
AltB_Int_Rate_3pct	586	-8%	2,729	-1%	4,598	3%
AltB_Int_Rate_8pct	660	4%	2,705	-2%	4,116	-8%
AltB_Int_Rate_11pct	663	4%	2,663	-4%	4,026	-10%

Table C42. Total harvest acres (x 10^3) under the interest rate based scenarios

Scenarios	Decade-1 end (year 2019)		Decade-6 end (year 2069)		Decade 10 end (year 2109	
	Acres ($x10^3$)	**% Change**	**Acres (x 10^3)**	**% Change**	**Acres (x 10^3)**	**% Change**
AltB_base	30	0%	126	0%	213	0%
AltB_Int_Rate_3pct	27	-11%	120	-4%	203	-5%
AltB_Int_Rate_8pct	31	4%	133	6%	225	5%
AltB_Int_Rate_11pct	31	5%	134	7%	226	6%

The reason for this is the change in the time value of money. Higher rates put a greater preference on today over the future. In the short-term (1 decade), the difference between an interest of 8 and 11 percent is negligible. Over the longer-term (6 to 10 decades), then influence of a higher interest rate on the management on the land base is accentuated with lower harvest volumes. It is also important to note that at the lowest interest rate i.e., 3%, the model produced higher total volume from the lowest amount of harvest acres compared to the ones with higher interest rates. This suggests that interest rate, when kept *at par* forest growth rate, is likely to produce higher overall value over the higher rates that not only produced lesser overall value but also forced accelerated liquidation of resource at its biologically non-optimum time frame.

8.5.3.3. Effect of Price Gain Rates

The different price recovery rates to the base model price structure (As of April 2009, average stumpage = 0.6 * base model price) had a significant impact on the first decade harvest level and consequently, on the total harvest volume and the NPV. Both the first decade harvest volume and harvest acres would be reduced by14% and 17% respectively with the current stumpage price gaining at 3-5% per year to the base price level (Table C46 and C47). When the current stumpage price gained between 8-11% per year, the loss in harvest volume was relatively quite low. Nonetheless, once the current stumpage reached the base level after first decade, differences in both harvest volume and harvest acres became marginal for all recovery rates.

Table C43. Total Harvest Volume (10^6 bf) Under the Price Gain Scenarios

Scenarios	Decade-1 end (year 2019)		Decade-6 end (year 2069)		Decade 10 end (year 2109)	
	Volume (10^6 bf)	**% Change**	**Volume (10^6 bf)**	**% Change**	**Volume (10^6 bf)**	**% Change**
AltB_base	635	0%	2,760	0%	4,459	0%
AltB_price_gain_3pct	548	-14%	2,828	2%	4,482	1%
AltB_price_gain_5pct	546	-14%	2,816	2%	4,477	0%
AltB_price_gain_8pct	612	-4%	2,776	1%	4,493	1%
AltB_price_gain_11pct	626	-1%	2,773	0%	4,459	0%

Table C44. Total Harvest Acres Under the Price Gain Scenarios

Scenarios	Decade-1 end (year 2019)		Decade-6 end (year 2069)		Decade 10 end (year 2109)	
	Acres ($x10^3$)	**% Change**	**Acres ($x10^3$)**	**% Change**	**Acres ($x10^3$)**	**% Change**
AltB_base	30	0%	126	0%	213	0%
AltB_price_gain_3pct	25	-17%	124	-1%	212	1%
AltB_price_gain_5pct	25	-17%	124	-1%	212	1%

Scenarios	Decade-1 end (year 2019)		Decade-6 end (year 2069)		Decade 10 end (year 2109)	
AltB_price_gain_8pct	28	-7%	124	-1%	211	1%
AltB_price_gain_11pct	29	-3%	125	0%	212	0%

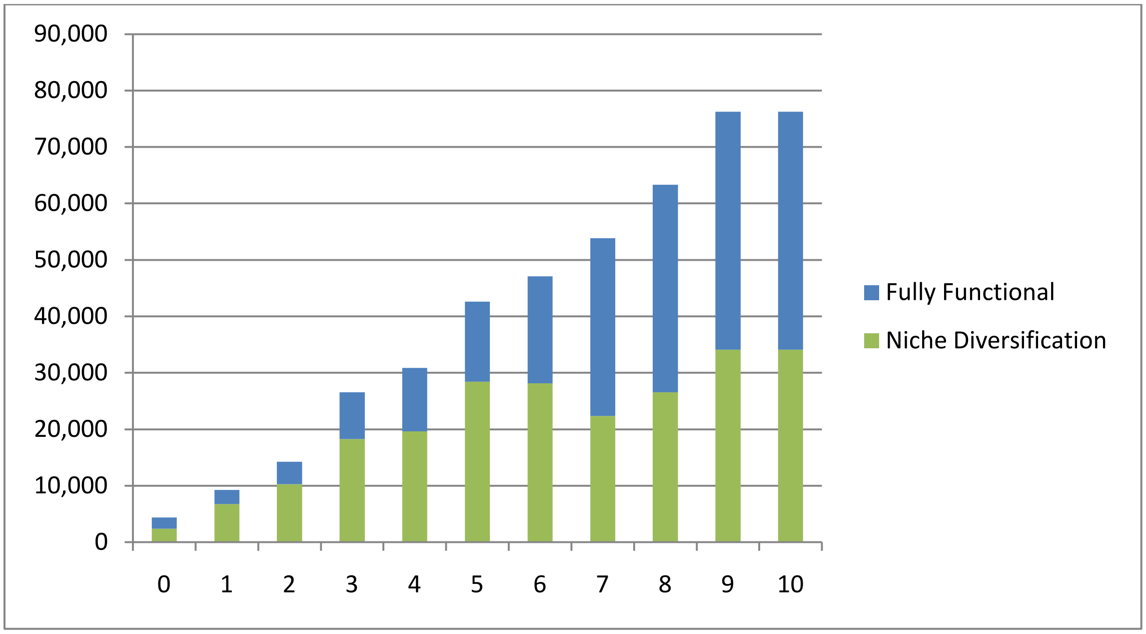
At a relatively lower price recovery rates (3-5% per year) resulting in a significant reduction in harvest levels during the first decade is quite reasonable since the model produced better value at these rates by waiting until the price reached an asymptotic level. This can be evidenced from table 4a and 4b that the total harvest volume at lower recovery rates surpassed the base scenario by a slight margin but could not reap the opportunity for a significantly elevated harvest level because of the planting level constraint that forced the inter-decadal harvest acres to remain within +- 10%.

Nonetheless, the price recovery rates had a significantly higher impact on the NPV as compared to the volume loss (Table C48). The revenue lost during the first decade could not be compensated at a later date because the model was bounded by the 10% variation in the inter-decadal harvest level. Had this constraint been freed up, the revenue loss could have been augmented significantly. This is perhaps a reasonable conjecture since the model was not tested with the relaxed planting constraint for the price gain scenarios.

Table C45. NPV Under the Price Gain Scenarios

Scenarios	Decade-1 end (year 2019)		Decade-6 end (year 2069)		Decade 10 end (year 2109)	
	NPV (x 10^6 $)	**% Change**	**NPV (x 10^6 $)**	**% Change**	**NPV (x 10^6 $)**	**% Change**
AltB_base	111	0%	214	0%	223	0%
AltB_price_gain_3pct	58	-48%	169	-21%	179	-20%
AltB_price_gain_5pct	65	-41%	182	-15%	192	-14%
AltB_price_gain_8pct	86	-23%	193	-10%	203	-9%
AltB_price_gain_11pct	100	-10%	204	-4%	214	-4%

Figure C19. Acres Under Fully Functional and Niche Diversification Stand Development Stages Over Time



8.5.4. Discussion and Conclusions

This study was conducted to measure the relative sensitivity of four model outcomes, namely 1) total volume output, 2) acres harvested, 3) NPV, and 4) acres in two late seral stages with respect to independent changes in three key input variables of the base model that include per acre volume yield, interest rate, and stumpage price recovery rate.

Result shows that any linear level increase or decrease in volume yield assumptions will have a more or less linear effect on the total volume output and consequently on the overall NPV. This outcome is reasonable given the fact either an increase or decrease in volume yield assumptions did not consider potential changes in any other structural variables such as top height, RD or QMD. A question may arise, however, that, would the base harvest schedule be similar to the ones generated under the changed volume yield assumptions? Although we did not compare the harvest schedule of each scenario with respect to the base scenario schedule, we can assume that there will be some changes in the schedule generated under the changes in volume yield. In other words, the same stratum may not be picked up under every scenario for the same activity in the same time frame.

Unlike the volume yield assumptions, different interest rate will have different consequence on the total volume outcome as well as on NPV. One may consider interest rate an artificial variable in the model in the sense that NPV would be different even if the volume produced with two different interest rates are the same. But interest did have a real effect on the harvest schedule. At a 3% interest rate, for example, first decadal total volume was lower but the overall total volume and NPV was higher than the base scenario because additional volume growth achieved by delaying the harvest outweighed the potential losses in revenue due to discounting factor. As a result, at a higher interest rate, the model expedited the harvest manifested in higher first decadal total volume compared to the base but was significantly lower in the later part of the planning horizon because of the heavy discounting effect that comes with higher interest rate.

Stumpage recovery rate and the span of time over which such recovery would occur, will also affect the total volume output and the NPV. In the analysis, neither the volume nor the NPV showed any significant response until current stumpage price (60% lower than the base) regains at 11% or more per year over the next five years to come at par the base scenario. Depending on the price recovery rate, the model showed as much 19% loss in NPV compared to the base scenario by the end of HCP and planning horizon.

The other mode outcome of interest was the amount of acres in two late seral stages under all scenarios. Invariably all scenarios produced similar acres because all these acres were mostly in non-harvestable areas such as riparian buffers, unstable slopes or high elevation where regeneration harvest was constrained in the model. As such, regardless of the harvest influencing assumptions, their levels continued to grow over time and were unaffected.

In conclusion, variations in all three input variables affected the total volume output and NPV with no significant changes in late seral stage acres. The model responded approximately linearly to the relative changes in volume yield assumptions. At a higher than base interest rate, the model expedited harvest rates, nonetheless produced less in terms of total volume output and NPV. Unless price gain rises above 11% per year, the model suggested significant reduction in first decade harvest level. Overall, the sensitivity analysis provided a rational basis in using the base model under potential changed situations in the future.

8.6. Forest Carbon Sequestration

Forests have the capacity to both emit and sequester carbon dioxide (CO_2), a leading greenhouse gas that contributes to climate change. Trees, through the process of photosynthesis, naturally absorb CO_2 from the atmosphere and store the gas as carbon in their biomass, i.e. trunk (bole), leaves, branches, and roots. Carbon is also stored in the soils that support the forest, as well as the understory plants and litter on the forest floor. Wood products that are harvested from forests can also provide long term storage of carbon.
When trees are disturbed, through events like fire, disease, pests or harvest, some of their stored carbon may oxidize or decay over time releasing CO_2 into the atmosphere. The quantity and rate of CO_2 that is emitted may vary, depending on the particular circumstances of the disturbance. Forests function as reservoirs in storing CO_2. Depending on how forests are managed or impacted by natural events, they can be a net source of emissions, resulting in a decrease to the reservoir, or a net sink, resulting in an increase of CO_2 to the reservoir. In other words, forests may have a net negative or net positive impact on the climate.

This analysis is a first attempt by the Department at estimating and analyzing the impacts of different management scenarios on carbon sequestration. The method used in the estimation use Smith et al (2006) publication for calculating forest ecosystem and harvest carbon. Smith et al (2006) methods are designed as generalized standard estimates for forest types in the United States and rely on a process of lookup tables between traditional forest yields (age based volume yield tables) and the average carbon estimates. The purpose of this analysis is not to provide specific estimates but to provide an analysis of the relative differences between alternatives and a first approximation of value of the sequestered carbon.

8.6.1 Methods

Yield tables used in the Woodstock models were linked to Smith et al (2006) published tables to estimate carbon. We matched the 12 forest types from the South Puget yield tables to fit Smith et. al. generalized table (C46).

Table C46. Forest Type Matches for Carbon Estimation

DNR South Puget Yield table Forest stratification		Smith et al (2006) Forest classes
DFMA	Douglas-fir dominated, with hardwoods	Douglas-fir
DFRA	Douglas-fir dominated, with red alder	Douglas-fir
DFRC	Douglas-fir dominated, with western red cedar	Douglas-fir
DFWH	Douglas-fir dominated, with western hemlock	Douglas-fir
RADF	Red alder dominated, with Douglas-fir	Alder-maple
RAMA	Red alder dominated, with other hardwoods	Alder-maple
RAWH	Red alder dominated, with western hemlock	Alder-maple
SFWH	Silver fir dominated, with western hemlock	Fir-spruce-m.hemlock
WHDF	Western hemlock dominated, with Douglas-fir	Hemlock-Sitka spruce
WHRA	Western hemlock dominated, with red alder	Hemlock-Sitka spruce
WHRC	Western hemlock dominated, with western red cedar	Hemlock-Sitka spruce
WHSF	Western hemlock dominated, with silver fir	Hemlock-Sitka spruce

Once forest types were matched, merchantable cubic foot volume (CFmv) from the South Puget yields was used as the intercept on Smith et. al. (2006) "reforestation" carbon stocks tables (Smith et al (2006); Appendix A tables). The component of softwood and hardwood volume was estimated using the percent of softwood basal area (PBAswd; Percentage basal area per acre (ft²/acre) of all softwoods with DBH >= 3.5") from the South Puget yield tables. Carbon stocks for standing inventory in the forest were estimated for forest ecosystem carbon pools (Table C47).

Table C47. Classification of Carbon in Forest Ecosystems and in Harvested Wood from Smith et. al. (2006)

Forest ecosystem carbon pools	
Live trees	Live trees with diameter at breast height (d.b.h.) of at least 2.5 cm (1 inch), including carbon mass of coarse roots (greater than 0.2 to 0.5 cm, published distinctions between fine and coarse roots are not always clear), stems, branches, and foliage.
Standing dead trees	Standing dead trees with d.b.h. of at least 2.5 cm, including carbon mass of coarse roots, stems, and branches.
Understory	Live vegetation that includes the roots, stems, branches, and foliage of seedlings (trees less than 2.5 cm

Forest ecosystem carbon pools	
vegetation	d.b.h.), shrubs, and bushes.
Down dead wood	Woody material that includes logging residue and other coarse dead wood on the ground and larger than 7.5 cm in diameter, and stumps and coarse roots of stumps.
Forest floor	Organic material on the floor of the forest that includes fine woody debris up to 7.5cm in diameter, tree litter, humus, and fine roots in the organic forest floor layer above mineral soil.
Soil organic carbon	Belowground carbon without coarse roots but including fi ne roots and all other organic carbon not included in other pools, to a depth of 1 meter.
Categories for Disposition of Carbon in Harvested Wood	
Products in use	End-use products that have not been discarded or otherwise destroyed, examples include residential and nonresidential construction, wooden containers, and paper products.
Landfills	Discarded wood and paper placed in landfills where most carbon is stored long-term and only a small portion of the material is assumed to degrade, at a slow rate.
Emitted with energy capture	Combustion of wood products with concomitant energy capture as carbon is emitted to the atmosphere.
Emitted without energy capture	Carbon in harvested wood emitted to the atmosphere through combustion or decay without concomitant energy recapture.

Carbon disposition in harvested products was also derived by a similar process as the standing inventory estimation, using the forest type lookup (Table C4C46) and merchantable cubic foot volume harvested (converted from board foot volume). The percentage of softwood and hardwood volume was similarly estimated using percent basal area for the forest strata from the yield tables. Carbon stocks were estimated for the in categories listed in Table C47. Depreciation and loss of carbon from harvested carbon stocks was accounted for by calculating the carbon for each period after the harvest period per Smith et al (2006 methods; Example 4 p.10). All results are reported in metric tonnes.

8.6.2. Results

The rate of carbon sequestered during the first three decades varied between 0.4 tonnes per acre per year for Alternative A to 0.7 tonnes per acre per year for Alternative B and C. After the third decade, the rate of sequestration for all alternatives declines to 0.2 to 0.3 tonnes per acre per year. The trajectories of carbon sequestrated mirror those of standing volume (Figure C20).

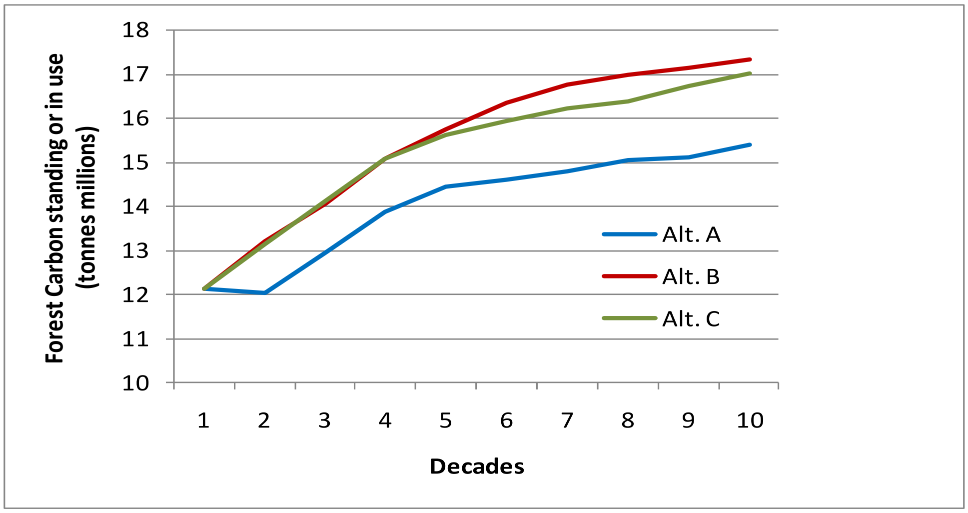


Figure C20. A Comparison of Carbon Stored and in Use by Alternative

According to the Climate Action Reserve Forest Project Protocol (version 3.0) (Broekhoff, D; Nickerson, J and Raven, H. 2009), the increased carbon sequestered in comparison to a base line could be sold as carbon credits under an "improved forest management program". In this case, we have assumed Alternative A reflects the baseline, while Alternative B represents the improved management program. Under these assumptions, Alternative B sequestered 24 millions tonnes of additional carbon than Alternative A (Table C51).

Using a range of prices for sequestered carbon from $0.15/tonne[7] to $7.40/tonne[8] the present value of the additional sequestered carbon over the first decade is between $0.11 and $5.60 million dollars. This value assumes a 5 percent annual discount rate, a 20 percent carbon reserve pool as an insurance against catastrophic losses and does not include the costs of certification and verification. As a percentage of the forest estate value, this represents a potential addition revenue source of between 0.1 to 6.7 percent of the total forest value.

Table C48. Additional Sequestered Carbon Under Alternative B with a Baseline of Alternative A

Decade	Additional Carbon in the forest	Additional Carbon in use	Additional total Carbon
		Millions of tonnes	
1	1.18	0.36	1.54
2	1.13	0.55	1.68
3	1.30	0.78	2.08
4	1.34	0.85	2.19
5	1.78	0.97	2.75
6	2.04	1.18	3.22
7	2.01	1.28	3.29
8	2.22	1.45	3.66
9	2.10	1.53	3.63
Total	15.09	8.94	24.03

8.7. Analysis of Forest Stewardship Council (FSC) Maximum Harvest Size and Green Up Requirements

This section provides an analysis of the potential impact of implementing the Forest Stewardship Council (FSC) certification requirements of maximum unit size of 60 acres and green up of 7 feet between regeneration harvest units over the long-term. The requirement, Principle 6.3.f. Even-aged silvicultural systems states:

> *6.3.f.4. Regeneration harvest blocks in even-aged stands average 40 acres or less. No individual block is larger than 60 acres (see 6.3.e.4. and 6.3.e.5. for provisions of within stand retention in openings larger than 6 acres).*
> *6.3.f.5. Regeneration in previously harvested areas reaches a mean height of at least seven feet or achieves canopy closure (see Glossary) before adjacent areas are regeneration harvested*

[7] Chicago Climate Exchange (CCX CFI) prices from November 3rd, 2009
[8] Chicago Climate Exchange (CCX CFI) prices from May 30th 2008

8.7.1.Methods

This analysis was carried out using Remsoft's Spatial Planning System[9] (RSPS) and a forest estate model formulated for DNR-managed lands that cover DNR's South Puget Sound Region and South Puget Habitat Conservation Plan (HCP) planning units. Total number of acres in the model is approximately 237,000 acres. This forest estate model and software were used to the developed South Puget HCP forest land plan.

Various model scenarios were developed during the forest land planning process. This analysis uses a model formulation of Alternative B for the final Environmental Impact Statement but does not include the South Puget forester planning and tracking (P&T) harvest schedule for the first decade. The scenario is labeled as AltB-DistrictEvenFlow.

The model was formulated in Woodstock (a component of RSPS) as a goal programme with an objective function to maximize the net present value of the forest estate over the 100 year planning period. Once the model was compiled and solved the solution was then allocated to GIS polygons using Stanley. Stanley is a spatial heuristic model component of RSPS and is used to develop spatial harvest schedules through a process that automates creating and scheduling harvest blocks or units.

Scenarios were developed to test the impact of maximize harvest opening size of regeneration harvests (variable retention harvest) on the optimal harvest schedule generated by Woodstock. Two scenarios of maximum opening size were: 1) 100 acres and, 2) 60 acres. DNR's current management is reflected in the 100 acre maximum opening size scenario while the 60-acre opening size is the FSC requirement.

In addition to the two scenarios examining opening size, one additional scenario was developed to examine the impacts of a 7 feet green-up requirement. Currently, DNR manages green-up of adjacent regeneration stands to 4 feet. The FSC requirement is 7 feet and this requirement would increase the cause a green-up delay from approximately 5 to 6-years of to over 10-years for most of DNR-managed lands.

The modeling parameters for the scenarios are as follows:

Table 1 Harvest Size and Green Up Modeling Assumptions

	Maximum Opening Size		
	100	**60**	**60 with green up**
Adjacent distance (feet)	300	300	300
Minimum block size (acres)	20	20	20
Target block size (acres)	75	40	40
Proximal distance (feet)	300	300	300
Greenup delay (decades)	0	0	1
Maximum opening size (acres)	100	60	60
Allow multi-period openings	Yes	Yes	Yes

[9] http://www.remsoft.com/

8.7.2. Results

The impact of the combined FSC requirements, if implemented across the planning unit over the first decade is estimated to result in approximately 30 percent decline in harvest volume, revenue and corresponding net present value.

Table C50. Harvest Size and Green Up Modeling Results

South Puget HCP planning unit level impacts			Maximum opening size	
	Optimal	100	60	60 with green up
Harvest volume (MMBF/yr)	27.31	24.22	21.60	17.04
Gross Revenue (undiscounted, Millions/yr)	8.40	7.45	6.65	5.24
Net Present Value (Millions)	5.54	4.92	4.38	3.46

South Puget HCP planning unit level impacts	Maximum opening size		
	100	60	60 with green up
Performance compared to optimal gross revenue objective	-11%	-21%	-38%
Performance compared to 100-acre scenario		-11%	-30%

8.7.3. Discussion

This analysis provides a "ballpark" of the impact of limiting the harvest opening size for variable retention harvests. Between fiscal year 2000 and 2010, South Puget Sound Region has implemented a range of regeneration harvest[10] unit sizes between 1 acre and 180 acres. The average unit size has been the range of 25 to 50 (
Table C51.2C53), while the majority of the regeneration area (approximately 60 percent) has been in harvest unit sizes of 60 acres and greater (Figure C21). These results are a result of implementing the current policy on maximum opening size and green-up.

[10] Regeneration harvest include the following P&T codes: Clear cut, Patch Regen and Two Age Mgt

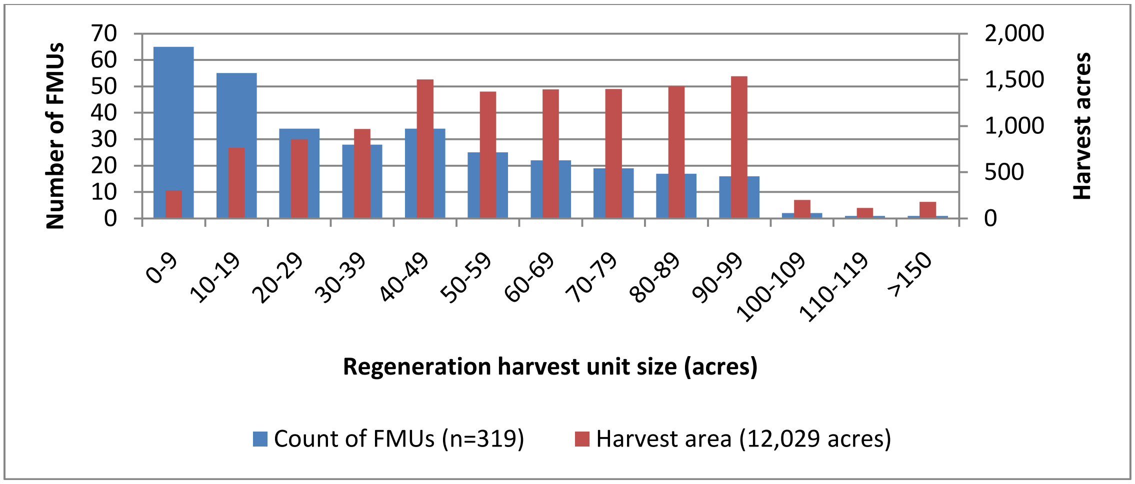


Figure C21. Regeneration Harvest Unit Sizes in South Puget HCP Planning Unit FY 2000-2010

Table C51.2 Average Harvest Unit Size (FY 2000 - FY 2010)

Fiscal Year	Average unit size of regeneration harvest units (acres)
2000	35
2001	45
2002	28
2003	40
2004	50
2005	43
2006	46
2007	25
2008	38
2009	32
2010	37
Average	**35**

The analysis does ignore the additional costs of smaller units in terms of the increase road costs and operational difficulties. These are hard to estimate and were not included in this analysis.
Full implementation of the FSC requirements would have both positive and negative impacts on the environment. In general smaller opening size would be positive to atheistically appeal of the landscape and would also have positive impact for some wildlife species. The negative impacts would likely be related to increased fragmentation, road density and edge effects. These aspects were not analyzed as part of this environmental impact statement.

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