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Kootenai, Kaniksu, and Tally Lake (KT) Variant Overview of the Forest Vegetation Simulator

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Flathead National Forest
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Authors and Contributors:

The FVS staff has maintained model documentation for this variant in the form of a variant overview since its release in 1994. The original authors were Renate Bush and Jim Brickell. In 2008, the previous document was replaced with this updated variant overview. Gary Dixon, Christopher Dixon, Robert Havis, Chad Keyser, Stephanie Rebain, Erin Smith-Mateja, and Don Vandendriesche were involved with this update. Robert Havis cross-checked information contained in this variant overview with the FVS source code.

FVS Staff. 2008 (revised October 5, 2021). Kootenai, Kaniksu, and Tally Lake (KT) Variant Overview – Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 50p.

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Quick Guide to Default Settings

Parameter or Attribute	**Default Setting**	
Number of Projection Cycles	1 (10 if using FVS GUI)	
Projection Cycle Length	10 years	
Location Code (National Forest)	114 – Kootenai National Forest	
Plant Association Code	571(TSHE/CLUN/CLUN)	
Slope	30 percent	
Aspect	45 degrees	
Elevation	35 (3500 feet)	
Latitude / Longitude	Latitude	Longitude
All location codes	48.5	116
Site Species	Not used	
Site Index	Not used	
Maximum Stand Density Index	Based on maximum basal area	
Maximum Basal Area	Habitat type specific	
Volume Equations	National Volume Estimator Library	
Merchantable Cubic Foot Volume Specifications:		
Minimum DBH / Top Diameter	LP	All Other
All other location codes	6.0 / 4.5 inches	7.0 / 4.5 inches
Stump Height	1.0 foot	1.0 foot
Merchantable Board Foot Volume Specifications:		
Minimum DBH / Top Diameter	LP	All Other
All other location codes	6.0 / 4.5 inches	7.0 / 4.5 inches
Stump Height	1.0 foot	1.0 foot
Sampling Design:		
Basal Area Factor	40 BAF	
Small-Tree Fixed Area Plot	1/300th Acre	
Breakpoint DBH	5.0 inches	

1.0 Introduction

The Forest Vegetation Simulator (FVS) is an individual tree, distance independent growth and yield model with linkable modules called extensions, which simulate various insect and pathogen impacts, fire effects, fuel loading, snag dynamics, and development of understory tree vegetation. FVS can simulate a wide variety of forest types, stand structures, and pure or mixed species stands.

New "variants" of the FVS model are created by imbedding new tree growth, mortality, and volume equations for a particular geographic area into the FVS framework. Geographic variants of FVS have been developed for most of the forested lands in United States.

The original North Idaho (NI) variant included the Kootenai, Kaniksu, and Flathead National Forests. Validation studies using the NI variant showed some biases in simulations for the Kootenai NF, Kaniksu NF, and Tally Lake Ranger District of the Flathead National Forest. As a result, Region 1 requested a new variant covering these areas. The KT variant, sometimes called the KOOKANTL variant, was developed in 1994.

Data used to develop the KT variant came from growth sample trees (GST) from National Forests in northern Idaho and western Montana. Due to the small number of mountain hemlock in the database, no new small- or large-tree growth equations were formulated for this species, equations and coefficients from the North Idaho (NI) variant were used for these species.

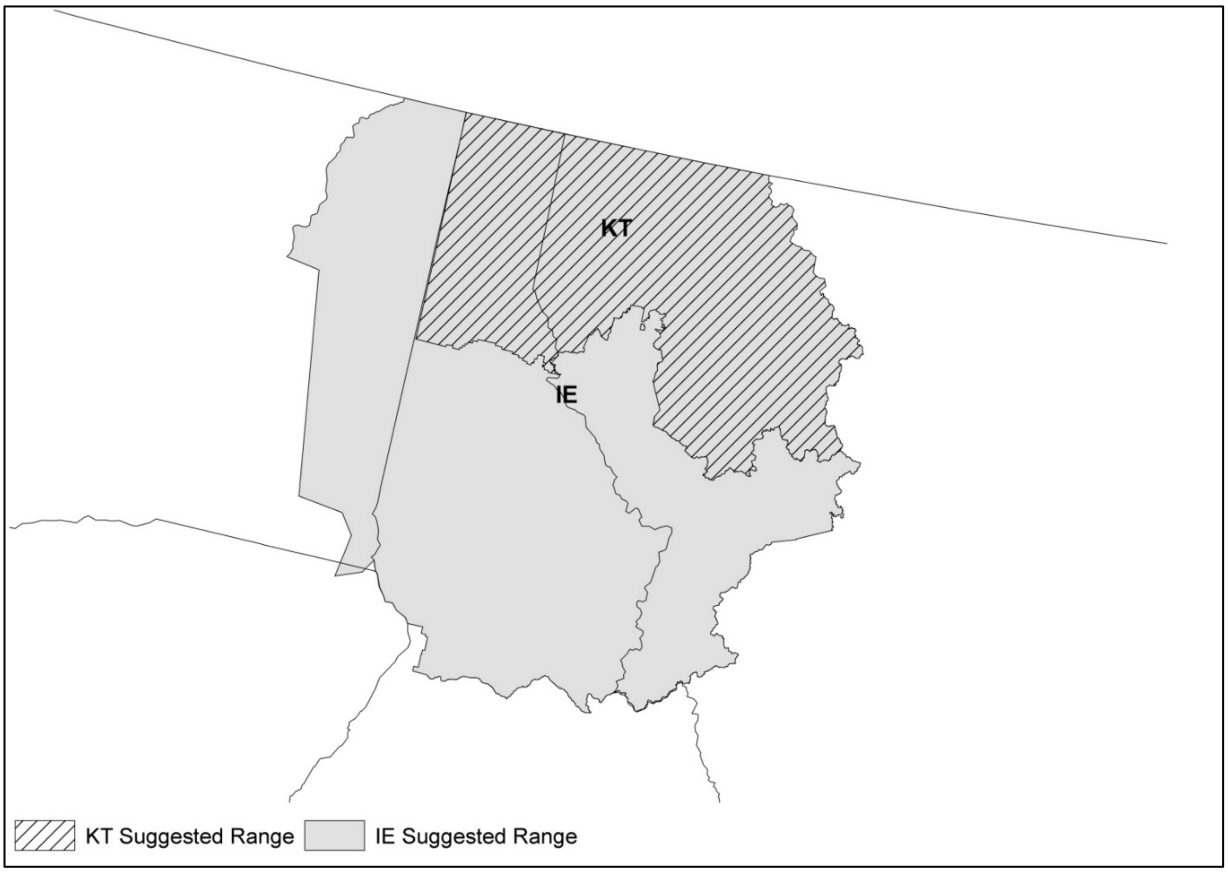
To fully understand how to use this variant, users should also consult the following publication:

- Essential FVS: A User's Guide to the Forest Vegetation Simulator (Dixon 2002)

This publication may be downloaded from the Forest Management Service Center (FMSC), Forest Service website. Other FVS publications may be needed if one is using an extension that simulates the effects of fire, insects, or diseases.

2.0 Geographic Range

The KT variant covers forest areas in the northern tip of Idaho and the northwestern corner of Montana. This includes Kootenai National Forest, Kaniksu National Forest, and Tally Lake Ranger District of the Flathead National Forest. The KT variant may also be used to model some forests in eastern Washington and northern Montana. The geographic range of the KT variant overlaps the range of the Inland Empire variant; however, where the variants overlap, users may choose to use the KT variant. The suggested geographic range of use for the KT and IE variants is shown in figure 2.0.1.



3.0 Control Variables

FVS users need to specify certain variables used by the KT variant to control a simulation. These are entered in parameter fields on various FVS keywords available in the FVS interface or they are read from an FVS input database using the Database Extension.

3.1 Location Codes

Locations codes in the KT variant are delineated by Forest Service region, forest, district and compartment number. The location code is a 8-digit code where the first digit of the code represents the Forest Service Region Number(R), the next two digits represent the Forest Number (FF), the next two digits represent the district number (DD), and the last three digits represent the compartment number (CCC) resulting in the 8-digit code RFFDDCCC. The location code is used to assign a national forest code (RFF) and geographic area code that are used in the mortality model and growth equations, respectively. For example, user's having stand data in compartment 5 of the Rexford West area of the Kootenai NF should enter a location code of "11401005" which would then map the stand to geographic area "2".

If the location code is missing or incorrect in the KT variant, a default forest code of 114 (Kootenai National Forest) will be used and the geographic area will be set to area "8". The geographic area assignment by location code combinations recognized in the KT variant is shown in table 3.1.1.

In some cases, a location code beginning with a "7" or "8" is used to indicate an administrative boundary that doesn't use a Forest Service Region number (for example, other federal agencies, state agencies, or other lands). Recognized Bureau of Indian Affairs reservation codes are located in table 3.1.2.

Table 3.1.1 Geographic area assignment by location code combinations used in the KT variant.

Geographic Area	Name	Region (R)	Forest (FF)	District (DD)	Compartment (CCC)
1	Rexford East, Kootenai NF	1	14	1	16-27
2	Rexford West, Kootenai NF	1	14	1	all but 16-27
2	Yaak, Kootenai NF	1	14	2	all
3	Fortine, Kootenai NF	1	14	3	all
4	Troy, Kootenai NF	1	14	4	all
4	Bonners Ferry, Idaho Panhandle NF	1	4	7	all
5	Libby West, Kootenai NF	1	14	5	1-4,8-19,27
6	Fisher River West, Kootenai NF	1	14	6	1-4
7	Cabinet-Sandpoint, Kootenai NF	1	14	7	all
7	Cabinet-Sandpoint, Idaho Panhandle NF	1	4	6	all
8	Swan Lake Island Unit, Flathead NF	1	10	1	1-12

Geographic Area	Name	Region (R)	Forest (FF)	District (DD)	Compartment (CCC)
8	Tally Lake, Flathead NF	1	10	8	all
8	Default for any other Flathead NF	1	10		
8	Default for any other Idaho Panhandle NF	1	4		
8	Fisher River East, Kootenai NF	1	14	6	all but 1-4
8	Bitterroot NF	1	3		
8	Clearwater NF	1	5		
8	Coeur d'Alene NF	1	6		
8	Colville NF	6	21		
8	Kaniksu NF	1	13		
8	Lolo NF	1	16		
8	Nezperce NF	1	17		
8	St. Joe NF	1	18		
9	Fisher River East, Kootenai NF	1	14	6	all but 1-4
10	Libby East, Kootenai NF	1	14	5	all but 1-4,8-19,27

Table 3.1.2 Bureau of Indian Affairs reservation codes used in the KT variant.

Location Code	Location
8109	Kootenai Off-Reservation Trust Land (mapped to 113)
8133	Flathead Reservation (mapped to 110)
8137	Coeur d'Alene Reservation (mapped to 118)

3.2 Species Codes

The KT variant recognizes 10 species, plus one other composite species category. You may use FVS species codes, Forest Inventory and Analysis (FIA) species codes, or USDA Natural Resources Conservation Service PLANTS symbols to represent these species in FVS input data. Any valid western species code identifying species not recognized by the variant will be mapped to a similar species in the variant. The species mapping crosswalk is available on the FVS website variant documentation webpage. Any non-valid species code will default to the "other" category.

Either the FVS sequence number or species code must be used to specify a species in FVS keywords and Event Monitor functions. FIA codes or PLANTS symbols are only recognized during data input and may not be used in FVS keywords. Table 3.2.1 shows the complete list of species codes recognized by the KT variant.

Table 3.2.1 Species codes used in the KT variant.

Species Number	Species Code	FIA Code	PLANTS Symbol	Scientific Name[1]	Common Name[1]
1	WP	119	PIMO3	*Pinus monticola*	western white pine
2	WL	073	LAOC	*Larix occidentalis*	western larch

Species Number	Species Code	FIA Code	PLANTS Symbol	Scientific Name[1]	Common Name[1]
3	DF	202	PSME	*Pseudotsuga menziesii*	Douglas-fir
4	GF	017	ABGR	*Abies grandis*	grand fir
5	WH	263	TSHE	*Tsuga heterophylla*	western hemlock
6	RC	242	THPL	*Thuja plicata*	western redcedar
7	LP	108	PICO	*Pinus contorta*	lodgepole pine
8	ES	093	PIEN	*Picea Engelmannii*	Engelmann spruce
9	AF	019	ABLA	*Abies lasiocarpa*	subalpine fir
10	PP	122	PIPO	*Pinus ponderosa*	ponderosa pine
11	OT	999	2TREE		other [2]

[1]Set based on the USDA Forest Service NRM TAXA lists and the USDA Plants database.
[2]Other category uses FIA codes and NRM TAXA codes that best match the other category.

3.3 Habitat Type, Plant Association, and Ecological Unit Codes

There are 175 habitat type codes recognized in the KT variant. If the habitat type code is blank or not recognized, the default 571 (TSHE/CLUN) will be assigned. The KT habitat type code is mapped to one of the 30 original NI variant habitat type codes. The KT and original NI variants' habitat type codes are used in various parts of the model as identified in the sections that follow. A list of valid KT variant habitat type codes and the NI habitat type code equivalent can be found in Appendix A.

3.4 Site Index

Site index is not used in the KT variant.

3.5 Maximum Density

Maximum stand density index (SDI) and maximum basal area (BA) are important variables in determining density related mortality and crown ratio change. Maximum basal area is a stand level metric that can be set using the BAMAX or SETSITE keywords. If not set by the user, a default value is calculated from maximum stand SDI each projection cycle. Maximum stand density index can be set for each species using the SDIMAX or SETSITE keywords. If not set by the user, a default value is assigned as discussed below.

The default maximum SDI is set based on a user-specified, or default, habitat type code or a user specified basal area maximum. If a user specified basal area maximum is present, the maximum SDI for species is computed using equation {3.5.1}; otherwise, the maximum SDI for species is computed from the basal area maximum associated with the equivalent NI original habitat type code shown in table 3.5.1 using equation {3.5.1}. Maximum stand density index at the stand level is a weighted average, by basal area, of the individual species SDI maximums.

{3.5.1} $SDIMAX_i = BAMAX / (0.5454154 * SDIU)$

where:

SDIMAX$_i$	is the species-specific SDI maximum
BAMAX	is the user-specified basal area maximum or habitat type-specific basal area maximum
SDIU	is the proportion of theoretical maximum density at which the stand reaches actual maximum density (default 0.85, changed with the SDIMAX keyword)

Table 3.5.1 Basal area maximums by original NI habitat type code in the KT variant.

Original NI Habitat Code	Maximum Basal Area
130	140
170	220
250	250
260	310
280	240
290	270
310	310
320	310
330	200
420	310
470	290
510	330
520	380
530	440
540	500
550	500
570	390
610	390
620	440
640	180
660	290
670	400
680	350
690	390
710	260
720	300
730	220
830	220
850	160
999	300

4.0 Growth Relationships

This chapter describes the functional relationships used to fill in missing tree data and calculate incremental growth. In FVS, trees are grown in either the small tree sub-model or the large tree sub-model depending on the diameter.

4.1 Height-Diameter Relationships

Height-diameter relationships in FVS are primarily used to estimate tree heights missing in the input data, and occasionally to estimate diameter growth on trees smaller than a given threshold diameter. In the KT variant, height-diameter relationships are a logistic functional form, as shown in equation {4.1.1} (Wykoff, et.al 1982). The equation was fit to data of the same species used to develop other FVS variants. Coefficients for equation {4.1.1} are shown are shown in table 4.1.1.

When heights are given in the input data for 3 or more trees of a given species, the value of B_1 in equation {4.1.1} for that species is recalculated from the input data and replaces the default value shown in table 4.1.1. In the event that the calculated value is less than zero, the default is used.

{4.1.1} For $DBH \geq 3.0$": $HT = 4.5 + \exp(B_1 + B_2 / (DBH + 1.0))$

where:

HT is tree height
DBH is tree diameter at breast height
B1 - B2 are species-specific coefficients shown in table 4.1.1

Table 4.1.1 Coefficients for the logistic Wykoff equation {4.1.1} in the KT variant.

Species Code	Default B_1	B_2
WP	5.1868	-10.4219
WL	5.0545	-8.6187
DF	4.8768	-9.1467
GF	5.0639	-9.8924
WH	4.9273	-8.7275
RC	4.8813	-9.6285
LP	4.7778	-6.3364
ES	5.0796	-10.2015
AF	4.9301	-8.8252
PP	5.0199	-12.0148
OT	4.7795	-9.3174

4.2 Bark Ratio Relationships

Bark ratio estimates are used to convert between diameter outside bark and diameter inside bark in various parts of the model. The equation is shown in equation {4.2.1} and coefficient (b_1) for this equation by species is shown in table 4.2.1.

{4.2.1} $BRATIO = b_1$

where:

BRATIO is species-specific bark ratio (bounded to $0.80 \leq BRATIO \leq 0.99$)
b_1 is a species-specific coefficient shown table 4.2.1

Table 4.2.1 Coefficients (b1) for the bark ratio equation {4.2.1} in the KT variant.

Species Code	b_1	Equation Source
WP	0.964	Wykoff, et. al. 1982
WL	0.851	Wykoff, et. al. 1982
DF	0.867	Wykoff, et. al. 1982
GF	0.915	Wykoff, et. al. 1982
WH	0.934	Wykoff, et. al. 1982
RC	0.950	Wykoff, et. al. 1982
LP	0.969	Wykoff, et. al. 1982
ES	0.956	Wykoff, et. al. 1982
AF	0.937	Wykoff, et. al. 1982
PP	0.890	Wykoff, et. al. 1982
OT	0.934	Wykoff, et. al. 1982

4.3 Crown Ratio Relationships

Crown ratio equations are used for three purposes in FVS: (1) to estimate tree crown ratios missing from the input data for both live and dead trees; (2) to estimate change in crown ratio from cycle to cycle for live trees; and (3) to estimate initial crown ratios for regenerating trees established during a simulation.

4.3.1 Crown Ratio Dubbing

In the KT variant, crown ratios missing in the input data are predicted using different equations depending on tree size. Live trees less than 3.0” in diameter and dead trees of all sizes use equations {4.3.1.1} and {4.3.1.2} to compute crown ratio. Equation coefficients are found in table 4.3.1.1.

{4.3.1.1} $X = R_1 + R_2 * DBH + R_3 * HT + R_3 * BA + N(0,SD)$

{4.3.1.2} $CR = 1 / (1 + \exp(X))$

where:

CR is crown ratio expressed as a proportion (bounded to $0.05 \leq CR \leq 0.95$)
DBH is tree diameter at breast height
HT is tree height

BA	is total stand basal area
N(0,SD)	is a random increment from a normal distribution with a mean of 0 and a standard deviation of SD
$R_1 – R_3$	are species-specific coefficients shown in table 4.3.1

Table 4.3.1 Coefficients for the crown ratio equation {4.3.1} in the KT variant.

Coefficient	Species Code					
	WP	**WL**	**DF**	**GF**	**WH**	**RC**
R_1	-0.44316	-0.83965	-0.89122	-0.62646	-0.49548	0.11847
R_2	-0.48446	-0.16106	-0.18082	-0.06141	0.00012	-0.39305
R_3	0.05825	0.04161	0.05186	0.0236	0.00362	0.02783
R_4	0.00513	0.00602	0.00454	0.00505	0.00456	0.00626
SD	0.9476	0.7396	0.8706	0.9203	0.945	0.8012
Coefficient	**Species Code**					
	LP	**ES**	**AF**	**PP**	**OT**	
R_1	-0.32466	-0.92007	-0.89014	-0.17561	-0.49548	
R_2	-0.20108	-0.22454	-0.18026	-0.33847	0.00012	
R_3	0.04219	0.03248	0.02233	0.05699	0.00362	
R_4	0.00436	0.0062	0.00614	0.00692	0.00456	
SD	0.7707	0.9721	0.8871	0.8866	0.945	

In the KT variant, equation {4.3.1.3} is used to predict missing crown ratio for live trees 3.0" in diameter or larger.

{4.3.1.3} $\ln(CR) = HAB + (b_1 * BA) + (b_2 * BA^2) + (b_3 * \ln(BA)) + (b_4 * CCF) + (b_5 * CCF^2) + (b_6 * \ln(CCF)) + (b_7 * DBH) + (b_8 * DBH^2) + (b_9 * \ln(DBH)) + (b_{10} * HT) + (b_{11} * HT^2) + (b_{12} * \ln(HT)) + (b_{13} * PCT) + (b_{14} * \ln(PCT))$

where:

CR	is predicted crown ratio expressed as a proportion
HAB	is a habitat-dependent coefficient shown in table 4.3.1.3
BA	is total stand basal area
CCF	is stand crown competition factor
DBH	is tree diameter at breast height
HT	is tree height
PCT	is the subject tree's percentile in the basal area distribution of the stand
$b_1 – b_{14}$	are species-specific coefficients shown in table 4.3.1.2

Table 4.3.2 Coefficients for the crown ratio equation {4.3.1.3} in the KT variant.

Coefficient	Species Code										
	WP	**WL**	**DF**	**GF**	**WH**	**RC**	**LP**	**ES**	**AF**	**PP**	**OT**
b_1	0	-0.00204	0	-0.00183	0	0	0	-0.00203	-0.00190	-0.00217	-0.0026
b_2	0	0	0	0	–1.902	0	0	0	0	0	0
b_3	-	0	0	0	0	0.17479	0	0	0	0	0

Coefficient	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
	0.34566										
b_4	0	0	0	0	0	-0.00183	0	0	0	0	0
b_5	0	0	0	0	0	0	0	0	0	0	5.116
b_6	0	0	-0.15334	0	0	0	-0.18555	0	0	0	0
b_7	0.03882	0	0	0	0.03027	–0.0056	0	0	0	0	0
b_8	-0.0007	0	0	0	-0.00055	0	0	0	0	0	0
b_9	0	0.30066	0.3384	0.24293	0	0	0.53172	0.29699	0.23372	0.26558	0
b_{10}	0	0	0	0	0	0	-0.02989	0	0	0	0
b_{11}	0	0	0	0	0	0	0.00011	0	0	0	0
b_{12}	-0.21217	-0.59302	-0.59685	-0.25601	-0.25776	0	0	-0.38334	-0.28433	-0.31555	-0.2514
b_{13}	0.00301	0	0	0	0	0	0.0042	0	0.00190	0	0
b_{14}	0	0.19558	0.16488	0.0726	0.06887	0.1105	0	0.09918	0	0.16072	0.0514

Table 4.3.3 HAB values by habitat class for equation {4.3.1.3} in the KT variant.

Habitat Class	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
1	0.8884	0.06533	0.8643	-0.2304	-0.2413	-1.6053	-0.3785	0.05351	0.09453	-0.9436	0.4649
2	0.7309	0.03441	0.7271	-0.5421	0	-1.7128	-0.4142	-0.05031	-0.0774	-0.8654	0.3211
3	0.9347	0.2307	0.984	-0.4343	0	0	-0.3985	0.1075	0.07113	-0.8849	0.197
4	0.9888	0.1661	0.8127	-0.3759	0	0	-0.2987	-0.1872	0.2039	-0.9067	0.2295
5	0.9945	-0.1253	0.8874	-0.4129	0	0	-0.381	0.01729	0.06176	-0.8783	0.3383
6	1.1126	-0.05018	0.7055	-0.4879	0	0	-0.4087	0.03667	0.1513	-1.0103	0.345
7	1.0263	0.11005	0.7708	-0.2674	0	0	-0.3577	0.01885	0.09086	-1.0268	0
8	0	0.08113	0.7849	-0.1941	0	0	-0.2994	0.09102	0.158	-1.005	0
9	0	0.1782	0.8038	0	0	0	-0.2486	0.1371	0.09229	-1.0301	0
10	0	0.03919	0.8742	0	0	0	-0.2863	0.08368	0.01551	0	0
11	0	0.2107	0.8232	0	0	0	-0.1968	0.123	0	0	0
12	0	0	0.8415	0	0	0	-0.4931	-0.02365	0	0	0
13	0	0	0.9759	0	0	0	-0.2676	0	0	0	0
14	0	0	0	0	0	0	-0.5625	0	0	0	0

Table 4.3.4 Habitat class by species and habitat code for HAB values in equation {4.3.1.3} in the KT variant.

Habitat Codes	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
10 - 140	2	2	2	2	1	1	2	2	2	2	1
160 - 190	2	2	2	2	1	1	2	2	2	2	1
210 - 250, 380	2	2	2	2	1	1	2	2	2	4	1
200, 260, 430	2	2	4	2	1	1	2	2	2	1	1

280	2	2	4	2	1	1	2	2	2	1	1
290	2	2	4	2	1	1	2	2	2	1	1
310, 370	2	2	6	2	1	1	4	2	2	5	1
320, 340, 350	2	3	7	2	1	1	5	3	2	6	1
330, 360, 910	2	2	4	2	1	1	5	2	2	1	1
400 - 420	2	4	8	1	1	1	2	1	2	1	1
440, 470, 480	2	4	8	1	1	1	2	1	2	1	1
505 - 515, 590	2	5	5	2	1	1	6	2	2	8	1
500, 516 - 529	3	6	9	3	1	1	7	4	2	7	2
501, 530, 545, 555	4	7	10	4	1	1	8	5	3	9	2
540	4	7	10	4	1	1	8	5	4	9	2
550, 560	4	7	10	4	1	1	8	5	4	9	2
502, 565 - 575	5	8	11	5	1	2	9	6	4	3	3
610	5	8	11	5	1	2	9	6	4	3	3
620, 635, 675, 685	5	4	8	6	1	2	10	7	5	3	4
450, 640, 650, 920	6	1	1	1	1	1	11	8	6	1	1
630, 660, 930	6	10	12	7	1	1	11	8	6	1	1
670, 740	1	9	12	7	1	1	12	9	7	1	1
680	6	10	13	7	1	1	11	8	6	1	5
579, 600, 690, 750, 780, 925, 950	1	1	1	1	1	1	1	10	1	1	1
701, 710	7	11	3	8	1	1	13	11	8	1	6
720	1	1	1	1	1	1	1	1	1	1	1
700, 730, 770, 790, 900, 940	6	1	3	7	1	1	14	1	9	1	1
800, 810, 830, 840	6	1	1	1	1	1	3	12	10	1	1
460, 820, 850 - 890	6	1	1	1	1	1	3	12	10	1	1
999	6	2	1	1	1	1	11	8	6	1	1

4.3.2 Crown Ratio Change

Crown ratio change is estimated after growth, mortality and regeneration are estimated during a projection cycle. Crown ratio change is the difference between the crown ratio at the beginning of the cycle and the predicted crown ratio at the end of the cycle. For live trees greater than 3” in dbh, crown change is predicted using equation {4.3.1.3}. Crown change is checked to make sure it doesn’t exceed the change possible if all height growth produces new crown. Crown change is further bounded to 1% per year for the length of the cycle to avoid drastic changes in crown ratio.

4.3.3 Crown Ratio for Newly Established Trees

Crown ratios for newly established trees during regeneration are estimated using equation {4.3.3.1}. A random component is added in equation {4.3.3.1} to ensure that not all newly established trees are assigned exactly the same crown ratio.

{4.3.3.1} $CR = 0.89722 – 0.0000461 * PCCF + RAN$

where:

CR	is crown ratio expressed as a proportion (bounded to $0.2 \le CR \le 0.9$)
PCCF	is crown competition factor on the inventory point where the tree is established
RAN	is a small random component

4.4 Crown Width Relationships

The KT variant calculates the maximum crown width for each individual tree based on individual tree and stand attributes. Crown width for each tree is reported in the tree list output table and used for percent cover (*PCC*) calculations in the model. Crown width is calculated using equation {4.4.1} and coefficients for this equation are shown in table 4.4.1. The minimum diameter and bounds for certain data values are given in table 4.4.2. Equation numbers in table 4.4.1 are given with the first three digits representing the FIA species code, and the last two digits representing the equation source.

{4.4.1} Crookston (2003); Equation 03

$$DBH \ge MinD: CW = [a_1 * \exp[a_2 + (a_3 * \ln(CL)) + (a_4 * \ln(DBH)) + (a_5 * \ln(HT)) + (a_6 * \ln(BA))]]$$

$$DBH < MinD: CW = [a_1 * \exp[a_2 + (a_3 * \ln(CL)) + (a_4 * \ln(MinD) + (a_5 * \ln(HT)) + (a_6 * \ln(BA))]] * (DBH / MinD)$$

where:

BF	is a species-specific coefficient based on forest code (*BF* = 1.0 in the EM variant)
CW	is tree maximum crown width
CL	is tree crown length
DBH	is tree diameter at breast height
HT	is tree height
BA	is total stand basal area
EL	is stand elevation in hundreds of feet
MinD	is the minimum diameter

$a_1 – a_6$ are species-specific coefficients shown in table 4.4.1

Table 4.4.1 Coefficients for crown width equation {4.4.1} in the KT variant.

Species Code	Equation Number*	a_1	a_2	a_3	a_4	a_5	a_6
WP	11903	1.0405	1.2799	0.11941	0.42745	0	-0.07182
WL	07303	1.02478	0.99889	0.19422	0.59423	-0.09078	-0.02341
DF	20203	1.01685	1.48372	0.27378	0.49646	-0.18669	-0.01509
GF	01703	1.0303	1.14079	0.20904	0.38787	0	0
WH	26303	1.02640	1.3522	0.24844	0.412117	- 0.104357	0.03538
RC	24203	1.03597	1.46111	0.26289	0.18779	0	0
LP	10803	1.03992	1.58777	0.30812	0.64934	-0.38964	0
ES	09303	1.02687	1.28027	0.2249	0.47075	-0.15911	0
AF	10903	1.02886	1.01255	0.30374	0.37093	-0.13731	0

Species Code	Equation Number*	a_1	a_2	a_3	a_4	a_5	a_6
PP	12203	1.02687	1.49085	0.1862	0.68272	-0.28242	0
OT	26405	3.7854	0.54684	-0.12954	0.16151	0.03047	-0.00561

*Equation number is a combination of the species FIA code (###) and source (##).

Table 4.4.2 *MinD* values and data bounds for equation {4.4.1} in the KT variant.

Species Code	Equation Number*	*MinD*	*EL min*	*EL* max	*CW* max
WP	11903	1.0	n/a	n/a	35
WL	07303	1.0	n/a	n/a	40
DF	20203	1.0	n/a	n/a	80
GF	01703	1.0	n/a	n/a	40
WH	26305	1.0	n/a	n/a	54
RC	24203	1.0	n/a	n/a	45
LP	10803	0.7	n/a	n/a	40
ES	09303	0.1	n/a	n/a	40
AF	10903	1.0	n/a	n/a	30
PP	12203	2.0	n/a	n/a	46
OT	26405	1.0	10	79	45

4.5 Crown Competition Factor

The KT variant uses crown competition factor (*CCF*) as a predictor variable in some growth relationships. Crown competition factor (Krajicek and others 1961) is a relative measurement of stand density that is based on tree diameters. Individual tree CCF_t values estimate the percentage of an acre that would be covered by the tree's crown if the tree were open-grown. Stand *CCF* is the summation of individual tree (CCF_t) values. A stand *CCF* value of 100 theoretically indicates that tree crowns will just touch in an unthinned, evenly spaced stand. Crown competition factor for an individual tree is calculated using equation {4.5.1}. All species coefficients are shown in table 4.5.1.

{4.5.1} *CCF* equations for individual trees

$DBH \geq 1''$: $CCF_t = R_1 + (R_2 * DBH) + (R_3 * DBH^2)$
$0.1'' < DBH < 1.0''$: $CCF_t = R_4 * DBH^{R_5}$
$DBH \leq 0.1''$: $CCF_t = 0.001$

where:

CCF_t is crown competition factor for an individual tree
DBH is tree diameter at breast height
$R_1 – R_5$ are species-specific coefficients shown in table 4.5.1

Table 4.5.1 Coefficients for CCF equation {4.5.1} in the KT variant.

Species	Model Coefficients

Code	R_1	R_2	R_3	R_4	R_5
WP	0.03	0.0167	0.00230	0.009884	1.6667
WL	0.02	0.0148	0.00338	0.007244	1.8182
DF	0.11	0.0333	0.00259	0.017299	1.5571
GF	0.04	0.0270	0.00405	0.015248	1.7333
WH	0.03	0.0215	0.00363	0.011109	1.7250
RC	0.03	0.0238	0.00490	0.008915	1.7800
LP	.01925	0.01676	0.00365	0.009187	1.7600
ES	0.03	0.0173	0.00259	0.007875	1.7360
AF	0.03	0.0216	0.00405	0.011402	1.7560
PP	0.03	0.0180	0.00281	0.007813	1.7680
OT	0.03	0.0215	0.00363	0.011109	1.7250

4.6 Small Tree Growth Relationships

Trees are considered "small trees" for FVS modeling purposes when they are smaller than some threshold diameter. The threshold diameter is set to 3.0" for all species in the KT variant.

The small tree model is height-growth driven, meaning height growth is estimated first and diameter growth is estimated from height growth. These relationships are discussed in the following sections.

4.6.1 Small Tree Height Growth

The small-tree height increment model predicts 5-year height growth (*HTG*) for small trees in the KT variant. Potential height growth is estimated using equations {4.6.1.1}, and coefficients for these equations are shown in table 4.6.1.1. Species numbers 1-10 use equation {4.6.1.1} and species 11 "other" uses equation {4.6.1.2}.

{4.6.1.1} Used for all species except species 11

$$HTG = HAB + LOC + c_1 * PCCF * DUM + c_2 * \ln(BA) + c_3 * HT + c_4 * CR + c_5 * CR^2 + c_6 * c_{13} * HT^2 + c_7 * EL + SL * (c_8 * \cos(ASP) + c_9 * \sin(ASP) + c_{10}) + c_{11} * SL^2 + c_{12} * BAL$$

{4.6.1.2} Used for species 11

$$HTG = \mathrm{EXP}(HAB + LOC + 0.8953 + c_1 * CCF + c_3 * \mathrm{LN}(HT) + SL * (c_8 * \cos(ASP) + c_9 * \sin(ASP) + c_{10}) + (0.01 * c_{12} * BAL))$$

where:

HTG	is estimated height growth for the cycle
LOC	is a location specific coefficient shown in table 4.6.1.2
HAB	is a habitat type dependent coefficient shown in table 4.6.1.4
CCF	is stand crown competition factor
BA	is stand basal area
CR	is tree crown ratio expressed as a proportion
HT	is total tree height in feet
EL	is stand elevation in 100's of feet

BAL	is total basal area in trees larger than the subject tree		
ASP	is stand aspect		
SL	is stand slope		
DUM	is a dummy variable depending on whether or not the stand is managed:		
	DUM = 0	for unmanaged stands	
	DUM = 1.0	for managed stands	
$c_1 - c_{13}$	are species-specific coefficients shown in table 4.6.1.1		

Table 4.6.1.1 Coefficients ($c_1 - c_{13}$) for equation {4.6.1.1} in the KT variant.

	Species Code										
Coefficient	**WP**	**WL**	**DF**	**GF**	**WH**	**RC**	**LP**	**ES**	**AF**	**PP**	**OT**
c_1	0.00273	0.00193	0.00236	0.00137	0.00032	0.00052	0.00293	0.00141	0.00196	0.00360	-0.00391
c_2	-0.22587	-0.61299	-0.58005	-0.30338	-0.31005	-0.18884	-0.52391	-0.27041	-0.33734	-0.25931	0
c_3	0.23330	0.18719	0.18550	0.19226	0.12683	0.08362	0.17563	0.16043	0.16983	0.38762	0.23540
c_4	-0.03752	1.79349	0.41613	1.38422	0.80235	0.70806	0.77147	-0.52031	-0.27436	2.97669	0
c_5	1.89581	1.71334	1.07027	0	0.34311	0.23177	2.22378	1.85953	1.21264	-0.80369	0
c_6	-0.00748	-0.00557	-0.00596	-0.00680	-0.00439	-0.00245	-0.00455	-0.00559	-0.00595	-0.01550	0
c_7	-0.01745	-0.00166	-0.00914	-0.00928	-0.00865	0.00132	-0.00796	-0.00665	-0.00556	0.00595	0
c_8	-0.31977	0.50669	0.02547	-0.01998	-0.20086	-0.14897	0.23847	-0.17454	0.04734	-0.56283	0.22157
c_9	-0.22656	-0.01932	-0.06132	-0.00293	0.03511	-0.08693	0.17146	-0.08322	-0.01602	0.56742	-0.12432
c_{10}	-0.73984	-1.15049	-0.74956	-0.73082	0.04774	-0.03444	-0.17135	-0.14074	0.45909	-1.92358	-0.01099
c_{11}	-0.34745	0	0.72632	0.75534	0	0	-1.70513	0	-1.01580	0	0
c_{12}	-0.00257	0.00274	0.00237	0.00068	0	0	0	0	0	0	-0.25349
c_{13}	0.5	0.4	0.5	0.5	0.6	0.6	0.7	0.5	0.5	0.5	1.0

Table 4.6.1.2 LOC values for equation {4.6.1.1} in the KT variant.

Location Class	Species Code										
	WP	**WL**	**DF**	**GF**	**WH**	**RC**	**LP**	**ES**	**AF**	**PP**	**OT**
1	2.26983	2.88731	2.77609	1.50804	1.85663	1.10271	3.90074	1.60506	1.40183	1.37057	0
2	2.10643	2.13803	2.73185	1.33661	1.88219	1.22721	3.81424	1.39565	1.62576	1.60481	0
3	2.64339	2.57740	2.89851	1.65346	0	1.50852	4.27475	2.30479	1.99335	1.08390	0
4	0	3.31632	0	0	0	0	0	2.05200	1.66862	0	0
5	0	0	0	0	0	0	0	1.29770	0	0	0

Table 4.6.1.3 Location class by species and geographic area (table 3.1.1) in the KT variant.

	Alpha Code										
Geographic area	**WP**	**WL**	**DF**	**GF**	**WH**	**RC**	**LP**	**ES**	**AF**	**PP**	**OT**
1	1	1	1	1	1	1	1	1	1	1	1
2	2	1	2	2	2	1	1	2	2	2	1
3	1	2	2	1	2	2	2	2	2	1	1
4	2	1	2	2	1	1	3	2	2	3	1
5	2	2	2	1	1	1	1	5	4	2	1

Geographic area	Alpha Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
6	2	2	1	1	2	2	1	4	3	1	1
7	1	3	3	1	1	1	1	3	4	1	1
8	3	1	3	3	1	3	2	1	4	3	1
9	3	3	3	2	2	1	2	5	4	2	1
10	3	4	3	3	1	2	3	1	4	2	1

Table 4.6.1.4 HAB values for equation {4.6.1.1} in the KT variant.

Habitat Class	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
1	0	0	0	0	0	0	0	0	0	0	-0.2146
2	-0.28873	0.09568	0.25958	0.11144	0.12846	-0.10742	-0.63773	0.24521	0.25263	-0.12165	-0.0941
3	0.22233	0	0.14322	0.18247	-0.11567	0	-0.80817	0.72617	0.32640	-0.37465	-0.3738
4	0	0	0.10701	0	0.27130	0	-0.39611	0.34175	0.40120	0	0
5	0	0	-0.13608	0	0	0	0.66609	0.55389	0.56825	0	0
6	0	0	0	0	0	0	0	0.42748	0.78600	0	0

Table 4.6.1.5 Habitat class by species and habitat code in the KT variant.

Habitat Code	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
10	1	1	1	1	1	1	1	1	1	1	3
65	1	1	1	1	1	1	1	1	1	1	3
70	1	1	1	1	1	1	1	1	1	1	3
74	1	1	1	1	1	1	1	1	1	1	3
79	1	1	1	1	1	1	1	1	1	1	3
91	1	1	1	1	1	1	1	1	1	1	3
92	1	1	1	1	1	1	1	1	1	1	3
93	1	1	1	1	1	1	1	1	1	1	3
95	1	1	1	1	1	1	1	1	1	1	3
100	1	1	1	1	1	1	1	1	1	1	3
110	1	1	1	1	1	1	1	1	1	1	3
120	1	2	2	1	1	1	1	2	1	1	3
130	1	1	1	1	1	1	1	1	1	1	3
140	1	2	2	1	1	1	2	1	1	2	3
141	1	1	1	1	1	1	1	1	1	1	3
161	1	1	1	1	1	1	1	1	1	2	3
170	1	2	2	1	1	1	2	1	1	2	3
171	1	1	1	1	1	1	1	1	1	1	3
172	1	1	1	1	1	1	1	1	1	1	3
180	1	1	2	1	1	1	1	1	1	2	3
181	1	1	1	1	1	1	1	1	1	1	3

Habitat Code	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
182	1	1	1	1	1	1	1	1	1	1	3
200	1	1	1	1	1	1	1	1	1	2	3
210	2	2	2	2	1	1	3	1	1	3	3
220	1	2	3	1	1	1	2	1	1	3	3
221	1	1	1	1	1	1	1	1	1	1	3
230	1	2	2	2	1	1	2	1	1	3	3
250	2	2	2	2	1	1	2	2	2	2	3
260	2	2	3	2	1	1	4	2	2	1	3
261	2	2	5	2	1	1	3	2	2	3	3
262	2	2	4	2	1	1	3	2	2	3	3
263	1	2	3	2	1	1	2	2	4	2	3
280	2	2	4	2	1	1	2	2	2	2	3
281	2	2	4	2	1	1	2	2	2	2	3
282	1	2	3	1	1	1	2	2	2	2	3
283	2	2	4	2	1	1	2	2	2	2	3
290	1	2	3	2	1	1	2	2	2	1	3
291	2	2	3	2	1	1	3	2	2	1	3
292	2	2	4	2	1	1	2	2	2	2	3
293	2	2	4	2	1	1	2	2	2	2	3
310	2	2	3	2	1	1	2	2	2	2	3
311	1	2	3	1	1	1	2	1	1	2	3
312	2	2	4	2	1	1	3	2	2	2	3
313	2	2	5	1	1	1	3	2	2	2	3
315	1	1	1	1	1	1	1	1	1	1	3
320	2	2	4	2	1	1	4	2	2	1	3
321	1	2	3	2	1	1	2	2	2	3	3
322	2	2	4	2	1	1	2	2	2	2	3
323	2	2	4	2	1	1	2	2	2	1	3
324	2	2	2	2	1	1	4	1	2	3	3
330	1	2	3	1	1	1	3	1	2	2	3
331	1	2	4	1	1	1	1	1	1	1	3
332	1	2	3	1	1	1	3	1	1	1	3
340	2	2	4	1	1	1	2	1	1	2	3
350	1	2	2	1	1	1	2	1	2	2	3
360	1	1	1	1	1	1	1	1	1	1	3
370	1	2	1	1	1	1	2	1	2	1	3
371	1	1	1	1	1	1	1	1	1	1	3
400	1	1	1	1	1	1	1	1	1	1	3
410	1	2	4	1	1	1	5	5	2	1	3
420	1	2	3	1	1	1	4	2	2	1	3

Habitat Code	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
421	1	2	3	1	1	1	3	2	2	1	3
422	1	2	3	1	1	1	3	2	2	1	3
430	1	2	1	1	1	1	2	2	1	1	3
440	1	1	1	1	1	1	1	1	1	1	3
450	1	2	3	1	1	1	2	2	2	1	3
460	1	1	1	1	1	1	2	1	1	1	3
461	1	2	3	1	1	1	2	2	2	1	3
470	1	2	3	1	1	1	2	5	2	1	3
480	1	1	1	1	1	1	4	1	1	1	3
500	1	1	3	3	1	1	1	1	1	3	3
501	1	2	3	1	4	1	4	4	4	3	3
502	1	2	2	2	2	1	4	3	3	2	3
505	1	1	3	1	1	1	4	1	1	3	3
507	1	2	2	3	1	1	1	1	1	1	3
508	1	2	3	3	1	1	4	1	1	3	3
510	1	2	3	3	4	1	2	3	4	3	3
511	1	2	2	3	1	1	4	1	1	3	3
515	1	2	3	3	1	1	1	1	1	1	3
520	1	2	3	3	4	1	4	3	4	2	1
521	1	2	4	3	4	1	4	4	4	2	1
522	1	2	4	3	1	1	4	3	6	2	1
523	1	2	3	3	1	1	2	4	4	2	1
524	1	2	3	3	4	1	4	4	1	2	1
529	1	2	4	1	1	1	1	1	1	1	1
530	1	2	2	3	2	1	4	4	4	3	2
531	1	2	4	1	2	1	4	4	4	3	2
532	1	2	2	3	2	1	4	4	4	3	2
533	1	2	4	3	2	1	2	4	4	1	2
534	1	2	4	3	2	1	4	4	5	1	2
540	1	2	2	1	4	1	4	3	5	1	2
542	1	2	3	1	2	1	2	3	5	1	2
545	1	2	3	1	1	1	1	3	1	1	2
550	1	2	4	1	4	1	4	3	5	3	4
565	1	2	2	2	2	1	2	3	4	1	4
570	3	2	2	2	2	1	4	4	3	2	4
571	3	2	3	2	2	1	2	2	4	2	4
572	1	2	2	2	2	1	4	3	3	2	4
573	1	2	2	2	2	1	4	2	4	2	4
574	1	2	2	2	2	1	2	4	3	1	4
575	1	2	2	2	2	1	2	3	4	1	4

Habitat Code	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
577	1	2	1	1	1	1	1	2	3	1	4
578	1	2	2	2	2	1	2	4	3	2	4
579	1	2	2	2	2	1	2	4	3	1	4
580	1	1	1	1	2	1	1	1	1	1	4
585	1	2	3	1	1	1	1	1	1	1	4
590	1	2	4	3	1	1	4	3	2	1	4
591	1	2	3	3	1	1	4	3	2	1	4
592	1	2	4	1	1	1	2	4	2	1	4
610	1	2	3	1	3	1	5	3	6	1	4
620	3	2	3	3	1	1	5	4	5	1	1
621	1	2	4	3	1	1	3	4	4	1	1
622	1	2	3	3	3	1	2	4	5	1	1
623	3	2	4	3	1	1	2	6	3	1	1
624	3	2	3	3	3	1	3	6	3	1	1
625	3	2	3	3	1	1	4	5	5	1	1
630	1	2	3	1	3	1	5	4	5	1	1
632	1	1	1	1	1	1	1	1	1	1	1
635	1	2	3	1	3	1	1	3	6	1	1
636	3	2	1	1	3	1	5	4	3	1	1
640	1	2	3	3	1	1	3	4	5	1	3
641	1	1	1	1	1	1	1	1	1	1	3
642	1	1	1	1	1	1	1	1	1	1	3
650	1	2	1	1	3	1	2	3	6	1	3
651	1	2	3	1	1	1	3	1	2	1	3
652	1	1	1	1	1	1	2	1	1	1	3
653	1	2	1	1	1	1	3	3	1	1	3
654	1	2	1	1	1	1	2	4	3	1	3
655	1	1	1	1	1	1	1	1	1	1	3
660	3	2	1	3	1	1	4	6	2	1	3
661	1	2	1	3	1	1	3	4	3	1	3
662	1	2	3	3	3	1	3	6	3	1	3
663	3	2	1	3	3	1	3	4	2	1	3
670	3	2	3	3	3	1	2	6	3	1	2
671	3	2	1	1	1	1	1	4	3	1	2
672	1	1	1	1	1	1	1	4	5	1	2
673	1	2	3	1	1	1	1	4	3	1	2
674	1	2	1	1	1	2	4	3	3	1	2
680	1	2	3	3	1	1	4	6	3	1	3
690	3	2	3	3	1	2	3	5	3	1	3
691	1	2	3	3	1	2	2	5	3	1	3

Habitat Code	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
692	3	2	4	3	1	2	2	6	3	1	3
693	1	1	4	1	1	1	3	5	3	1	3
700	1	1	1	1	1	1	1	1	1	1	3
710	3	2	3	3	1	2	4	4	6	1	3
712	1	1	1	1	1	1	5	3	1	1	3
720	3	2	3	3	1	1	2	4	2	1	3
730	1	2	3	3	1	2	3	4	2	1	3
731	3	2	4	3	1	2	3	6	3	1	3
732	3	2	1	1	1	2	1	4	2	1	3
733	1	2	1	1	1	1	1	4	2	1	3
734	1	2	1	1	1	1	2	1	1	1	3
740	3	2	3	3	1	2	2	5	3	1	3
750	3	2	1	1	1	2	4	5	3	1	3
751	1	2	1	1	1	1	2	1	1	1	3
761	1	1	1	1	1	1	1	1	1	1	3
770	1	1	1	1	1	1	1	1	1	1	3
780	1	1	1	1	1	1	1	1	1	1	3
790	1	1	1	1	1	1	1	1	1	1	3
791	1	1	1	1	1	1	1	1	1	1	3
792	2	2	1	3	1	2	2	4	2	1	3
810	1	1	1	1	1	1	1	1	1	1	3
820	1	2	1	1	1	1	1	6	1	1	3
830	1	1	1	1	1	1	2	1	1	1	3
831	1	1	1	1	1	1	3	1	6	1	3
832	1	2	1	1	1	1	1	5	5	1	3
850	1	2	3	1	1	1	1	6	6	1	3
860	1	2	1	1	1	1	1	6	3	1	3
870	1	1	1	1	1	1	1	1	1	1	3
900	1	1	1	1	1	1	1	1	1	1	3
910	1	1	1	1	1	1	1	1	1	1	3
920	1	1	1	1	1	1	1	1	1	1	3
930	1	1	1	1	1	1	1	1	1	1	3
940	1	2	1	1	1	1	1	1	3	1	3
950	1	1	1	1	1	1	5	1	1	1	3

For all species, a small random error is then added to the height growth estimate. The estimated height growth (*HTG*) is then adjusted to account for cycle length, user defined small-tree height growth adjustments, and adjustments due to small tree height model calibration from the input data.

Height growth estimates from the small-tree model are weighted with the height growth estimates from the large tree model over a range of diameters (X_{min} and X_{max}) in order to smooth the transition between the two models. For example, the closer a tree's *DBH* value is to the minimum diameter (X_{min}), the more the growth estimate will be weighted towards the small-tree growth model. The closer a tree's *DBH* value is to the maximum diameter (X_{max}), the more the growth estimate will be weighted towards the large-tree growth model. If a tree's *DBH* value falls outside of the range given by X_{min} and X_{max}, then the model will use only the small-tree or large-tree growth model in the growth estimate. The weight applied to the growth estimate is calculated using equation {4.6.1.3}, and applied as shown in equation {4.6.1.4}. The range of diameters for each species is shown in table 4.6.1.2.

{4.6.1.3}

$DBH \leq X_{\min}: XWT = 0$
$X_{\min} < DBH < X_{\max}: XWT = (DBH - X_{\min}) / (X_{\max} - X_{\min})$
$DBH \geq X_{\max}: XWT = 1$

{4.6.1.4} Estimated growth = [(1 - *XWT*) * *STGE*] + [*XWT* * *LTGE*]

where:

XWT is the weight applied to the growth estimates
DBH is tree diameter at breast height
X_{max} is the maximum *DBH* is the diameter range
X_{min} is the minimum *DBH* in the diameter range
STGE is the growth estimate obtained using the small-tree growth model
LTGE is the growth estimate obtained using the large-tree growth model

Table 4.6.1.6 Diameter bounds by species in the KT variant.

Species Number	Specie s Code	X_{min}	X_{max}
1	WP	2.0	10.0
2	WL	2.0	10.0
3	DF	2.0	10.0
4	GF	2.0	10.0
5	WH	2.0	10.0
6	RC	2.0	10.0
7	LP	1.0	5.0
8	ES	2.0	10.0
9	AF	2.0	10.0
10	PP	2.0	10.0
11	OT	2.0	10.0

4.6.2 Small Tree Diameter Growth

As stated previously, for trees being projected with the small tree equations, height growth is predicted first, and then diameter growth. So both height at the beginning of the cycle and height at the end of the cycle are known when predicting diameter growth. Small tree diameter growth for trees over 4.5 feet tall is calculated as the difference of predicted diameter at the start of the projection period and the predicted diameter at the end of the projection period, adjusted for bark ratio. By definition, diameter growth is zero for trees less than 4.5 feet tall.

For western white pine, western larch, Douglas-fir, grand fir, western hemlock, western redcedar, lodgepole pine, Engelmann spruce, subalpine fir, and ponderosa pine, these two predicted diameters are estimated using equations {4.6.2.1}, {4.6.2.3} – {4.6.2.5}, and coefficients shown in table 4.6.2.1. For other, these two predicted diameters are estimated using equations {4.6.2.2} – {4.6.2.5}, and coefficients shown in table 4.6.2.1.

{4.6.2.1} $DHAT = c_1 + c_2 * HT + DADJ$

{4.6.2.2} $DHAT = c_1 * (HT - 4.5)^{c2} + DADJ$

{4.6.2.3} $DADJ = DELMAX * RELH * RELH - 2 * DELMAX * RELH + 0.65$

{4.6.2.4} $RELH = (HT - 4.5) / (AH - 4.5)$

{4.6.2.5} $DELMAX = (AH / 36) * (0.01232 * CCF - 1.75)$

where:

DHAT	is estimated tree diameter at breast height
HT	is tree height
DADJ	is an adjustment factor to correct for bias, relative tree size, and stand density
RELH	is relative tree height (bounded $0 \le RELHT \le 1$)
AH	is average height of the 40 largest diameter trees
DELMAX	is an adjustment factor based on relative tree size and stand density (bounded DELMAX ≤ 0)
CCF	is stand crown competition factor

Table 4.6.2.1 Coefficients ($c_1 - c_2$) by species for equation {4.6.2.1} in the KT variant.

Species Code	C_1	C_2
WP	-0.145707	0.125404
WL	-0.111929	0.098451
DF	-0.127690	0.115066
GF	-0.125198	0.128790
WH	-0.178162	0.129191
RC	-0.233566	0.143211
LP	-0.010818	0.090927
ES	-0.186874	0.131209
AF	-0.158870	0.128174
PP	-0.185011	0.141907
OT	0.0729	1.1988

4.7 Large Tree Growth Relationships

Trees are considered "large trees" for FVS modeling purposes when they are equal to, or larger than, some threshold diameter. This threshold diameter is set to 3.0" for all species in the KT variant.

The large-tree model is driven by diameter growth meaning diameter growth is estimated first, and then height growth is estimated from diameter growth and other variables. These relationships are discussed in the following sections.

4.7.1 Large Tree Diameter Growth

The large tree diameter growth model used in most FVS variants is described in section 7.2.1 in Dixon (2002). For most variants, instead of predicting diameter increment directly, the natural log of the periodic change in squared inside-bark diameter (ln(*DDS*)) is predicted (Dixon 2002; Wykoff 1990; Stage 1973; and Cole and Stage 1972). For variants predicting diameter increment directly, diameter increment is converted to the *DDS* scale to keep the FVS system consistent across all variants.

The KT variant predicts diameter growth using equation {4.7.1.1.}. Coefficients for this equation are shown in tables 4.7.1.1 - 4.7.1.5.

{4.7.1.1} Used for all species in the KT variant

$$\ln(DDS) = b_1 + (b_2 * EL) + (b_3 * EL^2) + (b_4 * \sin(ASP) * SL) + (b_5 * \cos(ASP) * SL) + (b_6 * SL) + (b_7 * SL^2) + (b_8 * CCF) + (b_9 * \ln(DBH)) + (b_{10} * CR) + (b_{11} * CR^2) + (b_{12} * BAL / (\ln(DBH + 1.0))) + (b_{13} * CCF^2) + (b_{14} * DBH^2) + (b_{15} * \ln(BA)) + (b_{16} * PCCF * DUM_1) + (b_{17} * PCCF * DUM_2) + HAB$$

where:

DDS	is the predicted periodic change in squared inside-bark diameter
EL	is stand elevation in hundreds of feet
ASP	is stand aspect
SL	is stand slope (for "other", *SL* = 0)
CR	is a tree's live crown ratio (compacted) expressed as a proportion
DBH	is tree diameter at breast height
BA	is total stand basal area
BAL	is total basal area in trees larger than the subject tree For species 11, *BAL* = 0.01 * *BAL*
CCF	is stand crown competition factor
PCCF	is crown competition factor on the inventory point where the tree is established
HAB	is a plant association code dependent coefficient shown in table 4.7.1.7
LOC	is a location-specific coefficient shown in table 4.7.1.4
DUM_{1-2}	are dummy variables depending on whether or not the stand is managed: $DUM_1 = 0$, $DUM_2 = 1.0$ for unmanaged stands $DUM_1 = 1.0$, $DUM_2 = 0$ for managed stands
b_1	is a location-specific coefficient shown in table 4.7.1.2
b_2-b_{17}	are species-specific coefficients shown in tables 4.7.1.1

Table 4.7.1.1 Coefficients (b_2-b_{17}) for equation 4.7.1.1 in the KT variant.

Coefficient	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
b_2	-0.006	-0.0074	-0.00563	0.00159	-0.0043	-0.02275	0.00281	0.00634	0.01539	-0.00515	0.08518
b_3	0	6.9E-05	0	0	0	0.00028	-0.00011	-0.00011	-0.00021	-0.00012	-0.0009
b_4	-0.02975	-0.02172	0.06558	0.05178	-0.00462	0.00659	0.0687	0.07099	-0.0106	-0.00704	0.13363
b_5	-0.06355	-0.13645	-0.02412	-0.01643	-0.03073	0.00779	-0.07271	-0.18211	-0.10512	-0.18077	0.17935
b_6	0.05705	0.15248	0.03603	0.17354	-0.02011	-0.05252	-0.31034	0.22033	0.26053	-0.61544	0.07628
b_7	-0.30165	-0.40132	-0.50543	-0.35182	0.1642	0.18516	0	-0.45491	-0.47935	0	0
b_8	0.0025	-0.0027	-0.00178	-0.00047	0	-0.00225	0	0	-0.00055	0	-0.00107
b_9	0.89068	0.71363	0.91484	1.24554	1.03	1.00243	0.90678	0.9856	1.06324	0.85286	0.89778
b_{10}	1.33383	1.57307	2.32586	1.21753	1.0406	1.62559	1.79329	1.3533	0.75412	2.71069	1.28403
b_{11}	-0.46964	-0.56399	-1.02799	0	0	-0.25015	-0.4074	-0.18967	0.46269	-1.27309	0
b_{12}	-0.00706	-0.01026	-0.00697	-0.00483	-0.00404	-0.0043	-0.00479	-0.00614	-0.00443	-0.00527	-0.6611
b_{13}	0	8.0E-06	7.0E-06	3.0E-06	0	6.0E-06	0	4.0E-06	6.0E-06	0	0
b_{14}	-0.00036	-0.00055	-0.00082	-0.00098	-0.00055	-0.00025	-0.00124	-0.00055	-0.00114	-0.00071	-0.00048
b_{15}	-0.26312	0	0	0	-0.00308	0.09764	-0.07759	-0.14396	-0.1187	-0.07669	0
b_{16}	7.2E-05	0	-0.00041	-0.00105	-0.00056	-0.00103	0.00077	-0.00057	-0.00005	-0.00011	0
b_{17}	-0.00081	0	-0.00117	-0.00123	-0.00093	-0.00096	-0.0007	-0.00105	-0.00113	-0.00098	0

Table 4.7.1.2 b1 values by location class for equation {4.7.1.1} in the KT variant.

Location Class	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
1	1.76061	0.90538	0.28515	-0.16279	0.58335	0.60677	0.73315	0.73648	0.28606	1.27975	0
2	0	1.05703	0.47449	0.01201	0.05082	0.25734	0.80566	0.63397	0.42202	1.46166	0
3	0	0.92987	0.22243	0.21551	0.76325	0.41586	0.68869	0.86675	0.5926	0	0
4	0	1.21864	0.38244	-0.45254	0	0.84058	0.78334	1.01332	0.35594	0	0
5	0	0.85925	0.77	0	0	0.87222	1.0049	0	0	0	0
6	0	0	0.25263	0	0	0.51366	0	0	0	0	0
7	0	0	0.41726	0	0	0	0	0	0	0	0

Table 4.7.1.3 Location class by species and geographic area (table 3.1.1) for equation {4.7.1.1} in the KT variant.

Geographic Area	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
1	1	1	1	1	1	1	1	1	1	1	1
2	1	2	1	2	1	1	2	1	1	2	1
3	1	2	2	2	1	2	2	1	2	2	1
4	1	3	3	2	2	3	3	2	1	2	1
5	1	2	2	2	1	4	2	3	2	2	1
6	1	2	4	1	1	5	1	1	2	1	1
7	1	3	2	1	1	6	4	3	2	2	1

Geographic Area	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
8	1	4	5	3	3	5	5	4	3	2	1
9	1	5	6	4	1	5	1	1	4	1	1
10	1	3	7	1	1	5	4	1	4	2	1

Table 4.7.1.4 *HAB* values for equation {4.7.1.1} in the KT variant.

Habitat Class	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
1	0	0	0	0	0	0	0	0	0	0	-1.68033
2	0.46877	-0.14413	0.32102	0.04934	-0.18536	0.22308	-0.02517	0.2543	0.19307	-0.11238	-1.52111
3	0.36827	0.09463	0.26245	-0.0284	-0.03054	0.05241	0.14033	0.35826	-0.02105	-0.02699	0
4	0.2538	0.25452	0.36975	0.30154	0	-0.03541	0.09364	0.26282	0.13296	-0.26668	0
5	0	0.09901	0.20189	0	0	-0.14473	0.06392	0.33856	0.3312	0.0484	0
6	0	0.15839	0.41958	0	0	0	0.17607	0.66511	0.03795	0.17576	0
7	0	0.18736	0.2115	0	0	0	0.12434	0.47824	0	0	0
8	0	0	0	0	0	0	0.03253	0.08994	0	0	0
9	0	0	0	0	0	0	-0.04246	0.14762	0	0	0

Table 4.7.1.5 Habitat class by species and habitat code in the KT variant.

Habitat Code	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
10	1	1	1	1	1	1	1	1	1	1	2
65	1	1	1	1	1	1	1	1	1	1	2
70	1	1	1	1	1	1	1	1	1	1	2
74	1	1	1	1	1	1	1	1	1	1	2
79	1	1	1	1	1	1	1	1	1	1	2
91	1	1	1	1	1	1	1	1	1	1	2
92	1	1	1	1	1	1	1	1	1	1	2
93	1	1	1	1	1	1	1	1	1	1	2
95	1	1	1	1	1	1	1	1	1	1	2
100	1	1	1	1	1	1	1	1	1	1	2
110	1	1	1	1	1	1	1	1	1	1	2
120	1	2	2	1	1	2	1	1	1	1	2
130	1	1	1	1	1	1	1	1	1	1	2
140	1	2	2	1	1	1	2	1	1	2	2
141	1	1	1	1	1	1	1	1	1	1	2

Habitat Code	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
161	1	1	1	1	1	1	1	1	1	2	2
170	1	2	2	1	1	1	3	1	1	2	2
171	1	1	1	1	1	1	1	1	1	1	2
172	1	1	1	1	1	1	1	1	1	1	2
180	1	1	2	1	1	1	1	1	1	2	2
181	1	1	1	1	1	1	1	1	1	1	2
182	1	1	1	1	1	1	1	1	1	1	2
200	1	1	1	1	1	1	1	1	1	2	2
210	2	1	2	2	1	4	4	1	1	4	2
220	1	2	3	1	1	1	2	1	1	4	2
221	1	1	1	1	1	1	1	1	1	1	2
230	1	2	2	2	1	1	2	1	1	4	2
250	2	1	4	2	1	2	3	3	2	5	2
260	2	1	3	2	1	2	3	3	2	1	2
261	2	2	3	1	1	4	4	1	3	3	2
262	1	2	2	2	1	4	4	3	3	3	2
263	1	1	3	2	1	4	3	1	4	5	2
280	1	2	5	2	1	1	2	1	3	2	2
281	2	2	2	2	1	4	2	2	2	2	2
282	1	1	3	1	1	2	2	2	3	2	2
283	1	1	2	2	1	2	2	3	3	2	2
290	1	1	3	2	1	2	2	3	3	3	2
291	1	2	3	1	1	1	4	2	2	3	2
292	1	1	5	1	1	4	2	1	3	2	2
293	2	1	5	2	1	4	2	1	2	2	2
310	2	1	3	2	1	4	3	3	2	5	2
311	1	2	3	1	1	1	3	1	1	2	2
312	1	2	5	1	1	4	4	1	3	2	2
313	1	1	3	1	1	4	4	2	2	2	2
315	1	1	1	1	1	1	1	1	1	1	2
320	2	1	2	2	1	2	3	2	2	3	2
321	1	1	3	2	1	1	3	1	3	4	2
322	1	2	5	2	1	4	2	2	3	2	2
323	2	2	5	1	1	4	2	3	3	3	2
324	1	1	4	1	1	2	3	1	3	4	2
330	1	2	3	1	1	1	4	1	3	2	2
331	1	1	5	1	1	1	1	1	1	1	2
332	1	1	3	1	1	1	4	1	1	1	2
340	1	2	2	1	1	1	2	1	1	2	2
350	1	2	2	1	1	1	2	1	2	5	2

Habitat Code	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
360	1	1	1	1	1	1	1	1	1	1	2
370	1	2	1	1	1	1	2	1	3	1	2
371	1	1	1	1	1	1	1	1	1	1	2
400	1	1	1	1	1	1	1	1	1	1	2
410	1	4	4	1	1	1	4	3	2	1	2
420	1	1	6	1	1	2	4	3	2	1	2
421	1	7	6	1	1	1	4	2	2	3	2
422	1	6	6	1	1	2	4	2	2	3	2
430	1	1	7	1	1	1	5	2	1	1	2
440	1	1	1	1	1	1	1	1	1	1	2
450	1	7	2	1	1	1	4	2	2	1	2
460	1	1	1	1	1	1	5	1	1	1	2
461	1	4	4	1	1	1	4	3	2	1	2
470	1	4	6	1	1	2	4	3	2	3	2
480	1	1	1	1	1	1	4	1	1	1	2
500	1	1	4	1	1	1	1	1	1	6	2
501	2	3	2	3	1	3	6	5	2	6	2
502	2	3	1	2	3	3	6	5	4	5	2
505	2	1	4	1	1	2	6	1	1	6	2
507	2	1	4	1	1	2	1	1	1	1	2
508	1	3	4	1	1	2	6	1	1	6	2
510	2	3	4	1	1	2	5	2	4	6	2
511	2	4	4	1	1	1	6	1	1	6	2
515	1	1	4	1	1	2	1	1	1	1	2
520	2	5	4	2	1	2	6	2	4	5	2
521	2	3	4	1	1	2	6	4	4	5	2
522	2	3	4	1	1	2	7	2	3	5	2
523	2	1	2	1	1	2	5	4	4	5	2
524	1	3	4	1	1	2	6	4	1	5	2
529	1	1	4	1	1	1	1	1	1	1	2
530	2	5	4	1	1	3	6	3	2	6	2
531	2	5	4	3	1	4	7	5	2	6	2
532	2	5	4	1	1	3	7	3	2	6	2
533	2	4	4	1	1	3	5	5	2	1	2
534	2	1	4	1	1	3	7	5	5	1	2
540	2	3	4	3	1	3	7	6	5	1	2
542	2	4	4	3	1	3	5	6	5	1	2
545	1	4	4	1	1	3	1	6	1	1	2
550	2	3	4	4	1	3	7	6	5	6	2
565	2	5	4	1	2	1	5	5	4	1	2

Habitat Code	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
570	3	6	4	1	3	1	7	4	4	5	2
571	3	6	4	1	3	5	5	4	4	5	2
572	3	6	4	2	3	4	7	5	4	5	2
573	2	5	4	2	3	4	6	4	4	5	2
574	3	3	4	1	3	5	5	4	4	1	2
575	2	4	4	2	3	4	5	5	4	1	2
577	1	1	1	1	1	4	1	4	4	1	2
578	3	1	4	2	2	4	5	4	4	5	2
579	2	5	4	1	2	5	5	4	4	1	2
580	3	1	1	1	2	1	1	1	1	1	2
585	1	1	4	1	1	1	1	1	1	1	2
590	3	3	4	1	1	3	6	2	3	3	2
591	3	3	2	1	1	3	7	2	3	3	2
592	3	3	4	2	1	3	5	4	3	3	2
610	3	4	6	1	1	3	4	7	5	1	2
620	4	4	6	2	1	3	4	5	2	3	2
621	3	6	4	2	1	3	8	8	6	3	2
622	3	7	6	2	1	3	5	5	2	3	2
623	4	4	4	2	1	3	4	9	4	3	2
624	4	6	6	2	1	3	4	9	4	3	2
625	1	4	6	2	1	3	4	2	2	3	2
630	3	7	6	1	1	3	4	5	2	1	2
632	1	1	1	1	1	1	1	1	1	1	2
635	1	1	6	1	1	1	1	7	5	1	2
636	1	1	7	1	1	3	4	5	4	1	2
640	3	7	6	2	1	3	4	5	2	3	2
641	1	1	1	1	1	1	1	1	1	1	2
642	1	1	1	1	1	1	1	1	1	1	2
650	1	1	7	1	1	3	5	7	5	1	2
651	1	1	6	1	1	3	8	1	3	1	2
652	1	1	1	1	1	1	4	1	1	1	2
653	1	4	1	1	1	1	4	7	1	1	2
654	3	6	7	1	1	1	5	8	4	1	2
655	1	1	1	1	1	1	1	1	1	1	2
660	1	1	7	2	1	3	4	9	3	3	2
661	3	6	7	2	1	3	4	5	6	3	2
662	3	7	6	2	1	3	5	9	6	3	2
663	4	1	7	2	1	3	8	8	3	3	2
670	4	7	6	2	1	3	5	9	6	3	1
671	1	1	7	1	1	1	1	8	1	1	1

Habitat Code	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
672	1	1	7	1	1	1	1	8	2	1	1
673	1	6	6	1	1	1	1	5	6	1	1
674	3	4	1	1	1	7	4	7	4	1	1
680	3	7	6	1	1	1	4	9	4	1	2
690	4	6	6	1	1	2	4	2	1	3	2
691	3	6	6	1	1	5	5	2	6	3	2
692	1	1	4	1	1	2	5	9	6	3	2
693	1	1	4	1	1	1	4	2	4	1	2
700	1	1	1	1	1	1	1	1	1	1	2
710	4	4	6	1	1	5	4	5	5	3	2
712	1	1	1	1	1	1	4	7	1	1	2
720	4	6	6	1	1	1	5	5	3	3	2
730	1	4	6	1	1	5	4	8	3	3	2
731	4	6	4	1	1	5	9	9	1	1	2
732	1	1	7	1	1	5	1	8	3	1	2
733	1	1	7	1	1	1	1	8	3	1	2
734	1	4	1	1	1	1	5	1	1	1	2
740	1	4	6	1	1	5	5	2	4	3	2
750	4	1	7	1	1	5	4	2	6	3	2
751	1	1	7	1	1	1	5	1	1	1	2
761	1	1	1	1	1	1	1	1	1	1	2
770	1	1	1	1	1	1	1	1	1	1	2
780	1	1	1	1	1	1	1	1	1	1	2
790	1	1	1	1	1	1	1	1	1	1	2
791	1	1	1	1	1	1	1	1	1	1	2
792	1	1	7	1	1	5	5	8	3	1	2
810	1	1	1	1	1	1	1	1	1	1	2
820	1	6	1	1	1	1	1	9	1	1	2
830	1	1	1	1	1	1	2	1	1	1	2
831	1	1	1	1	1	1	4	1	5	1	2
832	1	4	7	1	1	1	1	2	2	1	2
850	1	1	6	1	1	1	1	9	5	1	2
860	1	1	1	1	1	1	1	9	4	1	2
870	1	1	1	1	1	1	1	1	1	1	2
900	1	1	1	1	1	1	1	1	1	1	2
910	1	1	1	1	1	1	1	1	1	1	2
920	1	1	1	1	1	1	1	1	1	1	2
930	1	1	1	1	1	1	1	1	1	1	2
940	1	1	1	1	1	1	1	1	4	1	2
950	1	1	1	1	1	1	4	1	1	1	2

4.7.2 Large Tree Height Growth

In the KT variant, equation {4.7.2.1} is used to estimate large tree height growth for all species.

{4.7.2.1} $HTG = \exp(HAB + b_0 + (b_1 * HT^2) + (b_2 * \ln(DBH)) + (b_3 * \ln(HT)) + (b_4 * \ln(DG))) + .4809$

where:

HTG	is estimated height growth for the cycle
HAB	is a plant association code dependent intercept shown in table 4.7.2.2
HT	is tree height at the beginning of the cycle
DBH	is tree diameter at breast height at the beginning of the cycle
DG	is 10-year diameter growth for the cycle
b_0, b_2, b_3	are species-specific coefficients shown in table 4.7.2.1
b_1, b_4	are habitat-dependent coefficients shown in table 4.7.2.2

Table 4.7.2.1 Coefficients (b_0, b_2 and b_3) for the height-growth equation in the KT variant.

Coefficient	Species Code										
	WP	WL	DF	GF	WH	RC	LP	ES	AF	PP	OT
b_0	-0.5342	0.1433	0.1641	-0.6458	-0.6959	-0.9941	-0.6004	0.2089	-0.5478	0.7316	-0.9941
b_2	-0.04935	-0.3899	-0.4574	-0.09775	-0.1555	-0.1219	-0.2454	-0.5720	-0.1997	-0.5657	-0.1219
b_3	0.23315	0.23315	0.23315	0.23315	0.23315	0.23315	0.23315	0.23315	0.23315	0.23315	0.23315

Table 4.7.2.2 Coefficients (b_1, b_4, and HAB) by habitat code (Appendix A) for the height-growth equation in the KT variant.

Habitat Codes	Coefficient		
	b_1	b_4	*HAB*
10, 65, 70, 74, 79, 91, 92, 93, 95, 100, 110, 120, 130, 140, 141, 161, 170, 171, 172, 180, 181, 182, 210, 220, 221, 230, 460, 461, 630, 632, 660, 661, 662, 663, 700, 730, 731, 732, 733, 734, 770, 790, 791, 792, 810, 820, 830, 831, 832, 850, 860, 870, 900, 930, 940	-1.34E-04	0.62144	2.03035
200, 250, 260, 261, 262, 263, 280, 281, 282, 283, 290, 291, 292, 293, 310, 311, 312, 313, 315, 320, 321, 322, 323, 324, 330, 331, 332, 340, 350, 360, 370, 371, 430, 910	-3.81E-05	1.02372	1.72222
400, 410, 420, 421, 422, 440, 470, 480	-3.72E-05	0.85493	1.19728
450, 505, 507, 508, 510, 511, 515, 590, 591, 592, 620, 621, 622, 623, 624, 625, 635, 636, 640, 641, 642, 650, 651, 652, 653, 654, 655, 670, 671, 672, 673, 674, 680, 740, 920	-2.61E-05	0.75756	1.81759
500, 520, 521, 522, 523, 524, 529	-5.20E-05	0.46238	2.14781
501, 530, 531, 532, 533, 534, 545	-1.61E-05	0.49643	1.76998
502, 540, 542, 550, 565, 570, 571, 572, 573, 574, 575, 577, 578, 610, 570	-3.63E-05	0.37042	2.21104
579, 580, 585, 690, 691, 692, 693, 710, 712, 720, 750, 751, 761, 780	-4.46E-05	0.34003	1.7409

5.0 Mortality Model

All species in the KT variant use the Prognosis-type mortality model (Wykoff and others 1982 and Hamilton 1986) that is described in detail in section 7.3.1 of Essential FVS: A User's Guide to the Forest Vegetation Simulator (Dixon 2002, abbreviated EFVS). This model independently calculates two mortality rates and then weights them to form the final mortality rate applied to an individual tree record.

The first mortality rate estimate, *RA*, predicts individual tree mortality based on habitat type, species, diameter, diameter increment, estimated potential diameter increment, stand basal area, and a trees' diameter relative to the average stand diameter. The equation used to calculate the first mortality rate for all species is shown in equation set {5.0.1}.

{5.0.1} $RA = [1 / (1 + \exp(X))] * RADJ$

$X = (b_0 + 2.76253 + 0.22231 * \sqrt{DBH} + -0.0460508 * \sqrt{BA} + 11.2007 * G + 0.246301 * RDBH + ((-0.55442 + 6.07129 * G) / DBH))$

Bounded $-70 \leq X \leq 70$

where:

RA	is the estimated annual mortality rate
RADJ	is a factor based on Reineke's (1933) Stand Density Index that accounts for expected differences in mortality rates on different habitat types and National Forests where: for $DBH > 5.0''$: $RADJ = (1 - ((0.20 + (0.05 * I)) /20 + 1)^{-1.605}) / 0.06821$ for $DBH \leq 5.0''$: $RADJ = (1 - ((0.20 + (0.05 * I)) + 1)^{-1.605}) / 0.86610$
DBH	is tree diameter at breast height
BA	is total stand basal area
RDBH	is the ratio of tree *DBH* to the arithmetic mean stand d.b.h.
DG	is periodic annual d.b.h. increment for the previous growth period
G	is periodic annual d.b.h. increment for the previous growth period adjusted for Differences in potential annual d.b.h. increment indexed by habitat type and National Forest where: for $DBH > 5.0''$: $G = 0.90 / (0.20 + (0.05 * I)) * DG$ for $DBH \leq 5.0''$: $G = 2.50 / (0.20 + (0.05 * I)) * DG$
I	is a diameter growth index value determined by habitat type and location code for *I* values of trees with *DBH* > 5.0", see table 5.0.2 for *I* values of trees with *DBH* ≤ 5.0", see table 5.0.3
b_0	is a species-specific coefficient shown in table 5.0.1

Table 5.0.1 b_0 values used in the mortality equation set {5.0.1} in the KT variant.

Species Code	b_0
WP	0
WL	-0.17603

Species Code	b_0
DF	0.317888
GF	0.317888
WH	0.607725
RC	1.57976
LP	-0.12057
ES	0.94019
AF	0.21180
PP	0.21180
OT	0

Table 5.0.2 *I* values for trees with *DBH* > 5.0" used in equation set {5.0.1} in the KT variant.

Habitat Codes	"*I*" values by Region 1 National Forest		
	104	**110**	**114**
10 - 140	15	9	9
160 - 190	15	9	9
210 - 250, 380	15	9	9
200, 260, 430	15	9	9
280	14	9	8
290	14	9	9
310, 370	12	7	7
320, 340, 350	14	8	8
330, 360, 910	13	8	7
400 - 420	14	8	8
440, 470, 480	14	9	8
505 - 515, 590	15	9	8
500, 516 - 529	15	9	9
501, 530, 545, 555	17	11	11
540	15	10	10
550, 560	15	10	10
502, 565 - 575	16	10	10
610	15	10	10
620, 635, 675, 685	15	11	10
450, 640, 650, 920	11	7	7
630, 660, 930	16	5	5
670, 740	11	6	6
680	9	4	5
579, 600, 690, 750, 780, 925, 950	12	7	7
701, 710	12	7	7

Habitat Codes	"I" values by Region 1 National Forest		
	104	110	114
720	15	9	9
700, 730, 770, 790, 900, 940	12	8	8
800, 810, 830, 840	7	3	3
460, 820, 850 - 890	10	6	6
999	15	9	9

Table 5.0.3 *I* values for trees with *DBH* < 5.0" used in equation set {5.0.1} in the KT variant.

Habitat Codes	"I" values by Region 1 National Forest		
	104	110	114
10 - 140	50	38	38
160 - 190	49	37	37
210 - 250, 380	49	37	37
200, 260, 430	49	37	37
280	48	36	37
290	48	36	37
310, 370	47	36	37
320, 340, 350	52	38	41
330, 360, 910	46	36	33
400 - 420	47	35	37
440, 470, 480	48	37	37
505 - 515, 590	53	41	41
500, 516 - 529	54	41	41
501, 530, 545, 555	54	41	42
540	52	40	39
550, 560	52	40	39
502, 565 - 575	54	41	41
610	50	40	40
620, 635, 675, 685	51	40	40
450, 640, 650, 920	41	33	33
630, 660, 930	39	32	32
670, 740	44	32	33
680	43	32	33
579, 600, 690, 750, 780, 925, 950	44	34	34
701, 710	44	33	33
720	50	38	38
700, 730, 770, 790, 900, 940	53	35	35

Habitat Codes	"*I*" values by Region 1 National Forest		
	104	**110**	**114**
800, 810, 830, 840	36	26	28
460, 820, 850 - 890	37	28	32
999	50	38	38

The second mortality rate estimate, *RB*, is dependent on the proximity of stand basal area to the site maximum (see section 3.5 of this variant overview), and the rate of basal area increment. As stand basal area approaches the maximum for the site, *RB* approaches 1. The calculation of *RB* is described in section 7.3.1.2 of EFVS (Dixon 2002) and is not shown here.

The mortality rate applied to a tree record is a weighted average of *RA* and *RB* with the weight also dependent on the proximity of stand basal area to the maximum for the site. This is also described in section 7.3.1.3 of EFVS (Dixon 2002), and is not shown here. The combined estimate is adjusted to the length of the cycle using a compound interest formula as shown in equation {5.0.2}.

{5.0.2} $RT = (1 – (1 – RC)^Y)$

where:

RT is the mortality rate applied to an individual tree record for the growth period
RC is the combined estimate of the annual mortality rate for the tree record
Y is length of the current projection cycle in years

6.0 Regeneration

The KT variant contains a full establishment model which is explained in section 5.4.2 of the Essential FVS Users Guide (Dixon 2002). In short, the full establishment model automatically adds regeneration following significant stand disturbances and adds ingrowth periodically during the simulation. Users may also input regeneration and ingrowth into simulations manually through the establishment model keywords as explained in section 5.4.3 of the Essential FVS Users Guide (Dixon 2002). The following description applies to entering regeneration and ingrowth through keywords.

The regeneration model is used to simulate stand establishment from bare ground, or to bring seedlings and sprouts into a simulation with existing trees. There are no sprouting species in the KT variant. Regeneration of seedlings may be specified by using PLANT or NATURAL keywords. Height of the seedlings is estimated in two steps. First, the height is estimated when a tree is 5 years old (or the end of the cycle – whichever comes first) by using the small-tree height growth equations found in section 4.6.1. Users may override this value by entering a height in field 6 of the PLANT or NATURAL keyword; however the height entered in field 6 is not subject to minimum height restrictions and seedlings as small as 0.05 feet may be established. The second step also uses the equations in section 4.6.1, which grow the trees in height from the point five years after establishment to the end of the cycle.

Seedlings are passed to the main FVS model at the end of the growth cycle in which regeneration is established. Unless noted above, seedlings being passed are subject to minimum and maximum height constraints and a minimum budwidth constraint shown in table 6.0.1. After seedling height is estimated, diameter growth is estimated using equations described in section 4.6.2. Crown ratios on newly established trees are estimated as described in section 4.3.1.

Regenerated trees and sprouts can be identified in the treelist output file with tree identification numbers beginning with the letters “ES”.

Table 6.0.1 Regeneration parameters by species in the KT variant.

Species Code	Sprouting Species	Minimum Bud Width (in)	Minimum Tree Height (ft)	Maximum Tree Height (ft)
WP	No	0.4	1.0	23.0
WL	No	0.3	1.0	27.0
DF	No	0.3	1.0	21.0
GF	No	0.3	0.5	21.0
WH	No	0.2	0.5	22.0
RC	No	0.2	0.5	20.0
LP	No	0.4	1.0	24.0
ES	No	0.3	0.5	18.0
AF	No	0.3	0.5	18.0
PP	No	0.5	1.0	17.0

Species Code	Sprouting Species	Minimum Bud Width (in)	Minimum Tree Height (ft)	Maximum Tree Height (ft)
OT	No	0.2	0.5	22.0

7.0 Volume

Volume is calculated for three merchantability standards: total stem cubic feet, merchantable stem cubic feet, and merchantable stem board feet (Scribner Decimal C). Volume estimation is based on methods contained in the National Volume Estimator Library maintained by the Forest Products Measurements group in the Forest Management Service Center (Volume Estimator Library Equations 2009). The default merchantability standards and equation numbers for the KT variant are shown in tables 7.0.1-7.0.3.

Table 7.0.1 Default volume merchantability standards for the KT variant.

Merchantable Cubic Foot Volume Specifications:		
Minimum DBH / Top Diameter	LP	All Other
All location codes	6.0 / 4.5 inches	7.0 / 4.5 inches
Stump Height	1.0 foot	1.0 foot
Merchantable Board Foot Volume Specifications:		
Minimum DBH / Top Diameter	LP	All Other
All location codes	6.0 / 4.5 inches	7.0 / 4.5 inches
Stump Height	1.0 foot	1.0 foot

Table 7.0.2 Volume equation defaults for each species, at specific location codes, with model name.

Common Name	Location Code	Equation Number	Reference
western white pine	All	I00FW2W119	Flewelling's 2-Point Profile Model
western larch	All Region 1	I00FW2W073	Flewelling's 2-Point Profile Model
western larch	621	I11FW2W073	Flewelling's 2-Point Profile Model
Douglas-fir	All Region 1	I00FW2W202	Flewelling's 2-Point Profile Model
Douglas-fir	621	I11FW2W202	Flewelling's 2-Point Profile Model
grand fir	All Region 1	I00FW2W017	Flewelling's 2-Point Profile Model
grand fir	621	I11FW2W017	Flewelling's 2-Point Profile Model
western hemlock	All Region 1	I00FW2W260	Flewelling's 2-Point Profile Model
western hemlock	621	I11FW2W017	Flewelling's 2-Point Profile Model
western redcedar	All Region 1	I00FW2W242	Flewelling's 2-Point Profile Model
western redcedar	621	I11FW2W242	Flewelling's 2-Point Profile

			Model
lodgepole pine	All Region 1	I00FW2W108	Flewelling's 2-Point Profile Model
lodgepole pine	621	I11FW2W108	Flewelling's 2-Point Profile Model
Engelmann spruce	All Region 1	I00FW2W093	Flewelling's 2-Point Profile Model
Engelmann spruce	621	I13FW2W093	Flewelling's 2-Point Profile Model
subalpine fir	All Region 1	I00FW2W019	Flewelling's 2-Point Profile Model
subalpine fir	621	I11FW2W202	Flewelling's 2-Point Profile Model
ponderosa pine	All Region 1	I00FW2W122	Flewelling's 2-Point Profile Model
ponderosa pine	621	I12FW2W122	Flewelling's 2-Point Profile Model
other	All Region 1	I00FW2W260	Flewelling's 2-Point Profile Model
other	621	616BEHW999	Flewelling's 2-Point Profile Model

Table 7.0.3 Citations by Volume Model

Model Name	Citation
Flewelling 2-Point Profile Model	Unpublished. Based on work presented by Flewelling and Raynes. 1993. Variable-shape stem-profile predictions for western hemlock. Canadian Journal of Forest Research Vol 23. Part I and Part II.

8.0 Fire and Fuels Extension (FFE-FVS)

The Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS) (Reinhardt and Crookston 2003) integrates FVS with models of fire behavior, fire effects, and fuel and snag dynamics. This allows users to simulate various management scenarios and compare their effect on potential fire hazard, surface fuel loading, snag levels, and stored carbon over time. Users can also simulate prescribed burns and wildfires and get estimates of the associated fire effects such as tree mortality, fuel consumption, and smoke production, as well as see their effect on future stand characteristics. FFE-FVS, like FVS, is run on individual stands, but it can be used to provide estimates of stand characteristics such as canopy base height and canopy bulk density when needed for landscape-level fire models.

For more information on FFE-FVS and how it is calibrated for the KT variant, refer to the updated FFE-FVS model documentation (Rebain, comp. 2010) available on the FVS website.

9.0 Insect and Disease Extensions

FVS Insect and Pathogen models for dwarf mistletoe and western root disease have been developed for the KT variant through the participation and contribution of various organizations led by Forest Health Protection. These models are currently maintained by the Forest Management Service Center and regional Forest Health Protection specialists. Additional details regarding each model may be found in chapter 8 of the Essential FVS Users Guide (Dixon 2002).

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11.0 Appendices

11.1 Appendix A. Habitat Codes

Table 11.1.1 KT variant habitat type codes and their corresponding original NI variant habitat type codes recognized in the KT variant (Pfister 1977).

KT Habitat Type Code	Original NI Habitat Type Code	Abbreviation	Habitat Type Name
10	130	SCREE	*Scree*
65	130	GRASS	*Grass type*
70	130	FORB	*Forb type*
74	130	SAL	*Willow*
79	130	POTRI	*Balsam poplar series*
91	130	PIFL/AGSP	*Limber pine/bluebunch wheatgrass*
92	130	PIFL/FEID	*Limber pine/Idaho fescue*
93	130	PIFL/FEID-FEID	*Limber pine/Idaho fescue/Idaho fescue*
95	130	PIFL/JUCO	*Limber pine/common juniper*
100	130	PIPO	*Ponderosa pine series*
110	130	PIPO/AND	*Ponderosa pine/bluestem*
120	130	PIPO/STCO	*Ponderosa pine/western needlegrass*
130	130	PIPO/AGSP	*ponderosa pine/ bluebunch wheatgrass*
140	130	PIPO/FEID	*Ponderosa pine/Idaho fescue*
141	130	PIPO/FEID-FEID	*Ponderosa pine/Idaho fescue/Idaho fescue*
161	170	PIPO/PUTR-AGSP	*Ponderosa pine/bitterbrush/Idaho fescue*
170	170	PIPO/SYAL	*Ponderosa pine/Common snowberry*
171	170	PIPO/SYAL-SYAL	*Ponderosa pine/common snowberry/common snowberry*
172	170	PIPO/SYAL-BERE	*Ponderosa pine/common snowberry/creeping barberry*
180	170	PIPO/PRVI	*Ponderosa pine/chokecherry*
181	170	PIPO/PRVI-PRVI	*Ponderosa pine/chokecherry/chokecherry*
182	170	PIPO/PRVI-SHCA	*Ponderosa pine/chokecherry/russet buffaloberry*
200	260	PSME	*Douglas-fir series*
210	130	PSME/AGSP	*Douglas-fir/Bluebench wheatgrass*
220	130	PSME/FEID	*Douglas-fir/Idaho fescue*
221	130	PSME/FEID-FEID	*Douglas-fir/Idaho fescue/Idaho fescue*
230	130	PSME/FESC	*Douglas-fir/altai fescue*
250	250	PSME/VACA	*Douglas-fir/Dwarf huckleberry*
260	260	PSME/PHMA	*Douglas-fir/ninebark*
261	260	PSME/PHMA-PHMA	*Douglas-fir/ninebark/ninebark*

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262	260	PSME/PHMA-CARU	*Douglas-fir/ninebark/pinegrass*
263	260	PSME/PHMA-SMST	*Douglas-fir/ninebark/false solomon's-seal*
280	280	PSME/VAGL	*Douglas-fir/blue huckleberry*
281	280	PSME/VAGL-VAGL	*Douglas-fir/thinleaf huckleberry/thinleaf huckleberry*
282	280	PSME/VAGL-ARUV	*Douglas-fir/thinleaf huckleberry/kinnikinnick*
283	280	PSME/VAGL-XETE	*Douglas-fir/thinleaf huckleberry/common beargrass*
290	290	PSME/LIBO	*Douglas-fir/twinflower*
291	290	PSME/LIBO-SYAL	*Douglas-fir/twinflower/common snowberry*
292	290	PSME/LIBO-CARU	*Douglas-fir/twinflower/thinleaf huckleberry*
293	290	PSME/LIBO-VAGL	*Douglas-fir/twinflower/thinleaf huckleberry*
310	310	PSME/SYAL	*Douglas-fir/common snowberry*
311	310	PSME/SYAL-AGSP	*Douglas-fir/common snowberry/bluebunch wheatgrass*
312	310	PSME/SYAL-CARU	*Douglas-fir/common snowberry/pinegrass*
313	310	PSME/SYAL-SYAL	*Douglas-fir/common snowberry/common snowberry*
315	310	PSME/SYAL-PIPO	*Douglas-fir/common snowberry/ponderosa pine*
320	320	PSME/CARU	*Douglas-fir/pinegrass*
321	320	PSME/CARU-AGSP	*Douglas-fir/pinegrass/bluebunch wheatgrass*
322	320	PSME/CARU-ARUV	*Douglas-fir/pinegrass/kinnikinnick*
323	320	PSME/CARU-CARU	*Douglas-fir/pinegrass/pinegrass*
324	320	PSME/CARU-PIPO	*Douglas-fir/pinegrass/ponderosa pine*
330	330	PSME/CAGE	*Douglas-fir/elk sedge*
331	330	PSME/CAGE-CAGE	*Douglas-fir/elk sedge/elk sedge*
332	330	PSME/CAGE-SYOR	*Douglas-fir/elk sedge/mountain snowberry*
340	320	PSME/SPBE	*Douglas-fir/white spirea*
350	320	PSME/ARUV	*Douglas-fir/kinnikinnick*
360	330	PSME/JUCO	*Douglas-fir/common juniper*
370	310	PSME/ARCO	*Douglas-fir/Heartleaf arnica*
371	310	PSME/ARCO-ARCO	*Douglas-fir/Heartleaf arnica/heartleaf arnica*
400	420	PICEA	*Spruce series*
410	420	PICEA/EQAR	*Spruce/common horsetail*
420	420	PICEA/CLUN	*Spruce/bride's bonnet*
421	420	PICEA/CLUN-VACA	*Spruce/bride's bonnet/dwarf bilberry*
422	420	PICEA/CLUN-CLUN	*Spruce/bride's bonnet/bride's bonnet*
430	260	PICEA/PHMA	*Spruce/mallow ninebark*

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440	470	PICEA/GATR	*Spruce/sweetscented bedstraw*
450	640	PICEA/VACA	*Spruce/dwarf bilberry*
460	850	PICEA/SEST	*Spruce/rocky mountain groundsel*
461	850	PICEA/SEST-PSME	*Spruce/rocky mountain groundsel/douglas-fir*
470	470	PICEA/LIBO	*Spruce/twinflower*
480	470	PICEA/SMST	*Spruce/starry false lily of the valley*
500	520	ABGR	*Grand fir series*
501	530	THPL	*Western red cedar series*
502	570	TSHE	*Western hemlock series*
505	510	ABGR/SPBE	*Grand fir/white spiraea*
507	510	ABGR/PHMA-COOC	*Grand fir/ninebark/Idaho goldthread*
508	510	ABGR/PHMA-PHMA	*Grand fir/ninebark/ninebark*
510	510	ABGR/XETE	*Grand fir/beargrass*
511	510	ABGR/XETE-COOC	*Grand fir/western goldthread*
515	510	ABGR/VAGL	*Grand fir/blue huckleberry*
520	520	ABGR/CLUN	*Grand fir/bride's bonnet*
521	520	ABGR/CLUN-CLUN	*Grand fir/bride's bonnet/bride's bonnet*
522	520	ABGR/CLUN-ARNU	*Grand fir/bride's bonnet/wild sarsaparilla*
523	520	ABGR/CLUN-XETE	*Grand fir/bride's bonnet/common beargrass*
524	520	ABGR/CLUN-PHMA	*Grand fir/bride's bonnet/ninebark*
529	520	ABGR/SETR	*Grand fir/*
530	530	THPL/CLUN	*Western red cedar/bride's bonnet*
531	530	THPL/CLUN-CLUN	*Western red cedar/bride's bonnet/bride's bonnet*
532	530	THPL/CLUN-ARNU	*Western red cedar/bride's bonnet/wild sarsaparilla*
533	530	THPL/CLUN-MEFE	*Western red cedar/bride's bonnet/menziesia*
534	530	THPL/CLUN-XETE	*Western red cedar/bride's bonnet/common beargrass*
540	540	THPL/ATFI	*Western red cedar/common ladyfern*
542	540	THPL/ATFI-ATFI	*Western red cedar/common ladyfern/common ladyfern*
545	530	THPL/ASCA	*Western red cedar/*
550	550	THPL/OPHO	*Western red cedar/devilsclub*
565	570	TSHE/GYDR	*Western red cedar/*
570	570	TSHE/CLUN	*Western hemlock/bride's bonnet*
571	570	TSHE/CLUN-CLUN	*Western hemlock/bride's bonnet/bride's bonnet*
572	570	TSHE/CLUN-ARNU	*Western hemlock/bride's bonnet/wild sarsparilla*

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573	570	TSHE/CLUN-XETE	*Western hemlock/bride's bonnet/common beargrass*
574	570	TSHE/CLUN-MEFE	*Western hemlock/bride's bonnet/menziesia*
575	570	TSHE/ASCA	*Western hemlock/Canadian wildginger*
577	570	TSHE/ASCA-MEFE	*Western hemlock/Canadian wildginger/menziesia*
578	570	TSHE/ASCA-ASCA	*Western hemlock/Canadian wildginger/Canadian wildginger*
579	690	TSHE/MEFE	*Western hemlock/menziesia*
580	690	ABGR/VACA	*Grand fir/dwarf huckleberry*
585	690	ABGR/CARU	*Grand fir/pinegrass*
590	510	ABGR/LIBO	*Grand fir/twinflower*
591	510	ABGR/LIBO-LIBO	*Grand-fir/twinflower/twinflower*
592	510	ABGR/LIBO-XETE	*Grand-fir/twinflower/beargrass*
610	610	ABLA/OPHO	*Subalpine fir/devilsclub*
620	620	ABLA/CLUN	*Subalpine fir/twisted stalk*
621	620	ABLA/CLUN-CLUN	*Subalpine fir/bride's bonnet/bride's bonnet*
622	620	ABLA/CLUN-ARNU	*Subalpine fir/bride's bonnet/wild sarsaparilla*
623	620	ABLA/CLUN-VACA	*Subalpine fir/bride's bonnet/dwarf bilberry*
624	620	ABLA/CLUN-XETE	*Subalpine fir/twisted stalk/beargrass*
625	620	ABLA/CLUN-MEFE	*Subalpine fir/twisted stalk/menziesia*
630	660	ABLA/GATR	*Subalpine fir/fragrant bedstraw*
632	660	ABLA/GATR3/VASC	*Subalpine fir/fragrant bedstraw/grouse whortleberry*
635	620	ABLA/STAM	*Subalpine fir/twisted-stalk*
636	620	ABLA/STAM-MEFE	*Subalpine fir/menziesia*
640	640	ABLA/VACA	*Subalpine fir/dwarf huckleberry*
641	640	ABLA/VACA-VACA	*Subalpine fir/dwarf huckleberry/dwarf huckleberry*
642	640	ABLA/VACA-CACA	*Subalpine fir/dwarf huckleberry/bluejoint*
650	640	ABLA/CACA	*Subalpine fir/bluejoint*
651	640	ABLA/CACA-CACA	*Subalpine fir/bluejoint/bluejoint*
652	640	ABLA/CACA-LICA	*Subalpine fir/canby's ligusticum*
653	640	ABLA/CACA-GATR	*Subalpine fir/bluejoint/fragrant bedstraw*
654	640	ABLA/CACA-VACA	*Subalpine fir/bluejoint/dwarf huckleberry*
655	640	ABLA/CACA-LEGL	*Subalpine fir/bluejoint/Labrador tea*
660	660	ABLA/LIBO	*Subalpine fir/twinflower*
661	660	ABLA/LIBO-LIBO	*Subalpine fir/twinflower/twinflower*
662	660	ABLA/LIBO-XETE	*Subalpine fir/twinflower/beargrass*

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663	660	ABLA/LIBO-VASC	*Subalpine fir/twinflower/grouse whortleberry*
670	670	ABLA/MEFE	*Subalpine fir/menziesia*
671	670	ABLA/MEFE-COOL	*Subalpine fir/western goldthread*
672	670	ABLA/MEFE-LUHI	*Subalpine fir/menziesia*
673	670	ABLA/MEFE-XETE	*Subalpine fir/menziesia/common beargrass*
674	670	ABLA/MEFE-VASC	*Subalpine fir/menziesia/grouse whortleberry*
680	680	TSME/MEFE	*Mountain hemlock/menziesia*
690	690	ABLA/XETE	*Subalpine fir/beargrass*
691	690	ABLA/XETE-VAGL	*Subalpine fir/beargrass/blue huckleberry*
692	690	ABLA/XETE-VASC	*Subalpine fir/beargrass/grouse whortleberry*
693	690	ABLA/XETE-COOC	*Subalpine fir/beargrass/Idaho goldthread*
700	730	TSME	*Subalpine fir, lower subalpine*
710	710	TSME/XETE	*Mountain hemlock/beargrass*
712	710	TSME/XETE-VAGL	*Mountain hemlock/beargrass/blue huckleberry*
720	720	ABLA/VAGL	*Subalpine fir/blue huckleberry*
730	730	ABLA/VASC	*Subalpine fir/grouse whortleberry*
731	730	ABLA/VASC-CARU	*Subalpine fir/grouse whortleberry/pinegrass*
732	730	ABLA/VASC-VASC	*Subalpine fir/grouse whortleberry/grouse whortleberry*
733	730	ABLA/VASC-THOC	*Subalpine fir/grouse whortleberry/western meadow rue*
734	730	ABLA/VASC-PIAL	*Subalpine fir/whitebark pine phase*
740	670	ABLA/ALSI	*Subalpine fir/sitka alder*
750	690	ABLA/CARU	*Subalpine fir/pinegrass*
751	690	ABLA/CARU-CARU	*Subalpine fir/pinegrass/pinegrass*
761	690	ABLA/OSCH-PAMY	*Subalpine fir/sweetcicely/Oregon boxleaf*
770	730	ABLA/CLPS	*Subalpine fir/rock clematis*
780	690	ABLA/ARCO	*Subalpine fir/heartleaf arnica*
790	730	ABLA/CAGE	*Subalpine fir/elk sedge*
791	730	ABLA/CAGE-CAGE	*Subalpine fir/elk sedge/elk sedge*
792	730	ABLA/CAGE-PSME	*Subalpine fir/elk sedge/douglas-fir*
810	830	ABLA/RIMO	*Subalpine fir/mountain gooseberry*
820	850	ABLA-PIAL/VASC	*Subalpine fir/whitebark pine/grouse whortleberry*
830	830	ABLA/LUHI	*Subalpine fir/smooth woodrush*
831	830	ABLA/LUHI-VASC	*Subalpine fir/smooth woodrush/grouse whortleberry*
832	830	ABLA/LUHI-MEFE	*Subalpine fir/smooth woodrush/rusty menziesia*

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850	850	PIAL-ABLA	*Whitebark pine-subalpine fir*
860	850	LALY-ABLA	*Alpine larch-subalpine fir*
870	850	PIAL	*Whitebark pine*
900	730	PICO	*Lodgepole pine*
910	330	PICO/PUTR	*Lodgepole pine/antelope bitterbrush*
920	640	PICO/VACA	*Lodgepole pine/dwarf huckleberry*
930	660	PICO/LIBO	*Lodgepole pine/twinflower*
940	730	PICO/VASC	*Lodgepole pine/grouse whortleberry*
950	570	PICO/CARU	*Lodgepole pine/pinegrass*

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