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Inland Empire (IE) Variant Overview

Forest Vegetation Simulator

Jewel Basin, Flathead National Forest
(Chad Keyser, FS-WOD-FMSC)

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The FVS staff has maintained model documentation for Inland Empire variant in the form of a variant overview since its release in 2003. The original author was Gary Dixon. 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. Current maintenance is provided by Chad Keyser.

Keyser, Chad E., comp. 2008 (revised May 15, 2013). Inland Empire (IE) Variant Overview – Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 52p.

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Quick Guide to Default Settings

Parameter or Attribute	**Default Setting**	
Number of Projection Cycles	1 (10 if using Suppose)	
Projection Cycle Length	10 years	
Location Code (National Forest)	118 – St. Joe National Forest	
Plant Association Code	260 (PSME/PHME)	
Slope	5 percent	
Aspect	0 (no meaningful aspect)	
Elevation	38 (3800 feet)	
Latitude / Longitude	Latitude	Longitude
All location codes	46	116
Site Species	IE: determined from habitat type	
Site Index	IE: determined from habitat type	
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	Lodgepole Pine	All Other Species
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	Lodgepole Pine	All Other Species
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 Inland Empire (IE) variant was developed in 2003; it is the original Northern Idaho variant (NI) / Prognosis model developed under the direction of Stage (1973) and released for production use on the National Forests in northern Idaho around 1980, expanded to recognize an additional 12 species. The additional species are mountain hemlock, whitebark pine, limber pine, subalpine larch, pinyon pine, Rocky Mountain juniper, Pacific yew, quaking aspen, cottonwood, Rocky mountain maple, paper birch, and “other hardwoods”. Growth equations for mountain hemlock are the original North Idaho variant equations for “other softwoods”, which were fit for mountain hemlock. In general, whitebark pine uses the western larch equations from the North Idaho variant; limber pine and Pacific yew use equations for limber pine from the Teton variant; subalpine larch uses subalpine fir equations from the North Idaho variant; pinyon pine, Rocky Mountain juniper, and quaking aspen equations come from their respective species in the Utah variant; Rocky mountain maple and paper birch are also grown with the quaking aspen equations from the Utah variant; and cottonwood species and other hardwoods use the other hardwoods equations from the Central Rockies variant.

This document presents codes, model relationships, and logic that are specific to the Inland Empire (IE) variant.

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 can be downloaded from the Forest Management Service Center (FMSC), Forest Service website or obtained in hard copy by contacting any FMSC FVS staff member. 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 IE variant covers forest areas in northern Idaho, western Montana, and eastern Washington. The geographic range of the IE variant overlaps the entire range of the KT (KooKanTL) variant; however, where the variants overlap (Kootenai National Forest, Kaniksu National Forest, and Tally Lake Ranger District of the Flathead National Forest), users may choose to use the KT variant. The suggested geographic range of use for the IE and KT variants is shown in figure 2.0.1.

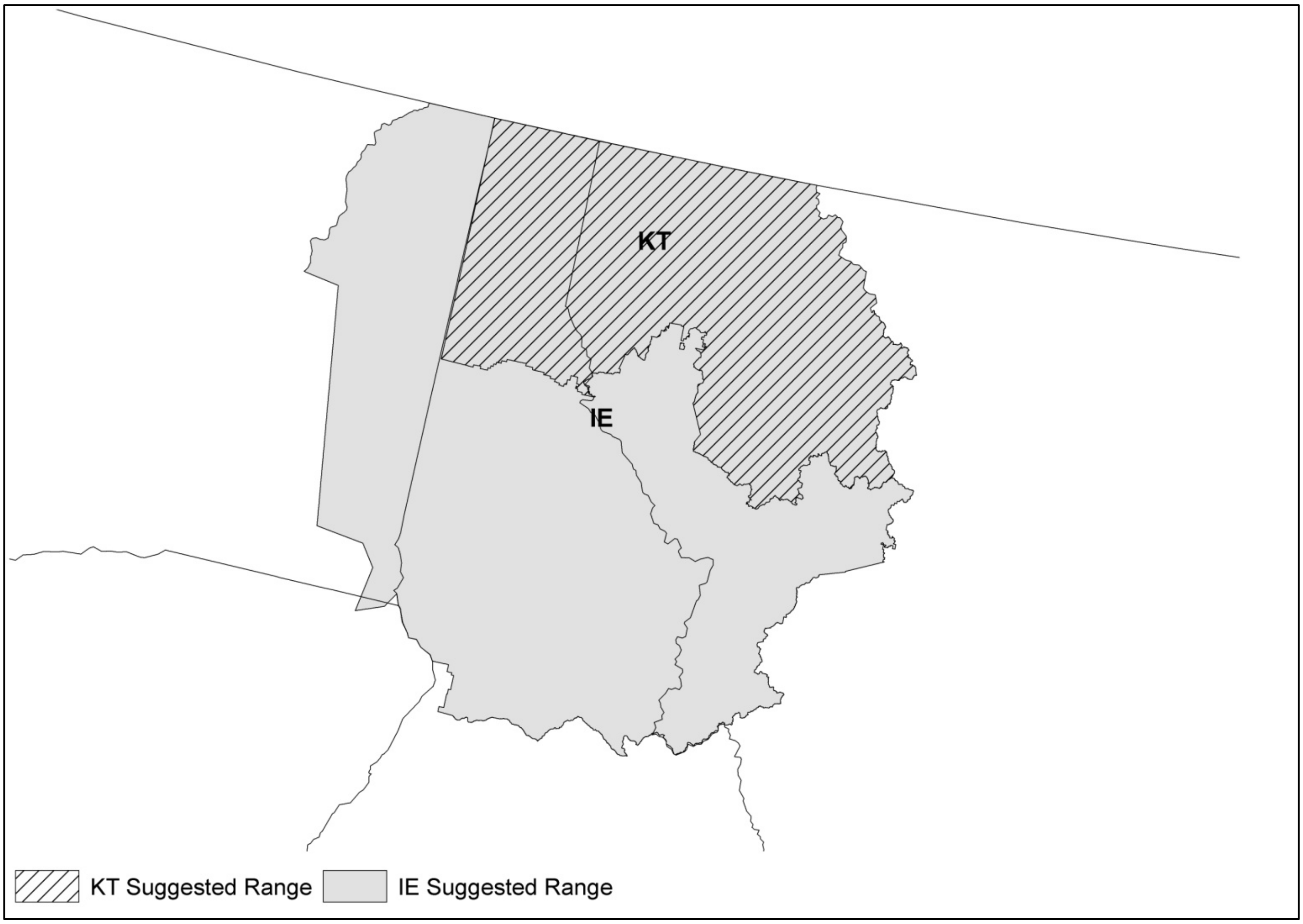

Figure 2.0.1 Suggested geographic range of use for the IE and KT variants.

3.0 Control Variables

FVS users need to specify certain variables used by the IE variant to control a simulation. These are entered in parameter fields on various FVS keywords usually brought into the simulation through the SUPPOSE interface data files or they are read from an auxiliary database using the Database Extension.

3.1 Location Codes

The location code is a 3-digit code where, in general, the first digit of the code represents the Forest Service Region Number, and the last two digits represent the Forest Number within that region.

If the location code is missing or incorrect in the IE variant, a default forest code of 118 (St. Joe National Forest) will be used. A complete list of location codes recognized in the IE variant is shown in table 3.1.1.

Table 3.1.1 Location codes used in the IE variant.

Location Code	USFS National Forest
103	Bitterroot
104	Idaho Panhandle
105	Clearwater
106	Coeur d'Alene
110	Flathead
113	Kaniksu
114	Kootenai
116	Lolo
117	Nezperce
118	St. Joe
621	Colville
102	Beaverhead (mapped to 103)
109	Deerlodge (mapped to 103)
112	Helena (mapped to 116)
613	Kaniksu Administered by Colville (mapped to 113)

3.2 Species Codes

The IE variant recognizes 23 species. You may use FVS species alpha 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 codes identifying species not recognized by the variants will be mapped to the most similar species in the variants. The species mapping crosswalk is available on the variant documentation webpage of the FVS website. Any non-valid species code will default to the "other hardwoods" category in the IE variant.

Either the FVS sequence number or alpha 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 IE variant.

Table 3.2.1 Species codes used in the IE variant.

FVS Number	Alpha Code	Common Name	FIA Code	PLANTS Symbol	Scientific Name
1	WP	western white pine	119	PIMO3	*Pinus monticola*
2	WL	western larch	073	LAOC	*Larix occidentalis*
3	DF	Douglas-fir	202	PSME	*Pseudotsuga menziesii*
4	GF	grand fir	017	ABGR	*Abies grandis*
5	WH	western hemlock	263	TSHE	*Tsuga heterophylla*
6	RC	western redcedar	242	THPL	*Thuja plicata*
7	LP	lodgepole pine	108	PICO	*Pinus contorta*
8	ES	Engelmann spruce	093	PIEN	*Picea Engelmannii*
9	AF	subalpine fir	019	ABLA	*Abies lasiocarpa*
10	PP	ponderosa pine	122	PIPO	*Pinus ponderosa*
11	MH	mountain hemlock	264	TSME	*Tsuga mertensiana*
12	WB	whitebark pine	101	PIAL	*Pinus albicaulis*
13	LM	limber pine	113	PIFL2	*Pinus flexilis*
14	LL	subalpine larch	072	LALY	*Larix lyallii*
15	PI	pinyon pine	133	PIED	*Pinus monophylla*
16	RM	Rocky Mountain juniper	066	JUSC2	*Juniperus scopulorum*
17	PY	Pacific yew	231	TABR2	*Taxus brevifolia*
18	AS	quaking aspen	746	POTR5	*Populus tremuloides*
19	CO	Cottonwood species	740	POPUL	*Populus spp.*
20	MM	Rocky Mountain maple	321	ACGL	*Acer glabrum*
21	PB	paper birch	375	BEPA	*Betula papyrifera*
22	OH	other hardwoods	998	2TD	
23	OS	other softwoods	298	2TE	

3.3 Habitat Type, Plant Association, and Ecological Unit Codes

There are 95 habitat type codes recognized in the IE variant. Habitat type is used in many relationships described in this variant and the Fire and Fuels Extension to FVS (Rebain, comp. 2010). If the habitat type code is blank or not recognized, the default 260 (PSME/PHMA) will be assigned. The 95 habitat type codes are mapped to one of the 30 original North Idaho (NI) variant habitat type codes. A list of valid IE variant habitat type codes and the original NI habitat type code equivalents can be found in table 11.1.1 of Appendix A.

Plant association codes are typically used instead of habitat type codes for the Colville National Forest in Region 6. These users can enter either the plant association code or the FVS sequence number for the plant association code when entering plant association information. The plant association code is then cross-walked to one of the original habitat type codes as depicted in table 11.1.2 of Appendix A. However, users can choose to enter a habitat type code directly.

3.4 Site Index

Site index is an input variable for some of the growth equations for some species in the IE variant. These species are limber pine, pinyon pine, Rocky Mountain juniper, Pacific yew, quaking aspen, cottonwood species, Rocky mountain maple, paper birch, and other hardwoods. Site index may not be available for some stands since habitat type is commonly used as a measure of site productivity in the geographic area covered by IE variant. If site index is not available, it is estimated from habitat type as shown in table 3.4.1. This table was created by Renate Bush, R1 Inventory Specialist, based on valid site index ranges for each species and productivity of habitat type. When possible, users should enter their own values instead of relying on model defaults. Users should always use the same site curves that FVS uses, which are shown in table 3.4.2.

Table 3.4.1 Habitat type to site index conversion for affected species in the IE variant.

Habitat Code	Species								
	LM	PI	RM	PY	AS	CO	MM	PB	OH
130	25	7	6	25	36	44	36	36	44
170	29	9	8	29	43	57	43	43	57
250	35	13	10	35	51	76	51	51	76
260	35	12	10	35	50	62	50	50	62
280	33	10	9	33	44	72	44	44	72
290	34	12	10	34	49	72	49	49	72
310	35	12	10	35	48	71	48	48	71
320	32	11	9	32	46	67	46	46	67
330	27	8	7	27	41	55	41	41	55
420	39	14	11	39	55	86	55	55	86
470	37	11	9	37	46	67	46	46	67
510	32	13	11	32	52	80	52	52	80
520	36	16	12	36	59	95	59	59	95
530	41	15	12	41	58	93	58	58	93
540	41	15	12	41	58	93	58	58	93
550	41	15	12	41	58	93	58	58	93
570	43	16	13	43	60	98	60	60	98
610	38	14	11	38	54	84	54	54	84
620	39	14	11	39	55	86	55	55	86
640	32	11	9	32	46	67	46	46	67
660	36	12	10	36	49	73	49	49	73
670	34	13	10	34	52	80	52	52	80
680	34	13	10	34	52	80	52	52	80
690	32	11	9	32	46	67	46	46	67
710	36	13	10	36	52	80	52	52	80
720	36	13	10	36	52	80	52	52	80
730	36	13	10	36	52	80	52	52	80
830	26	8	7	26	38	49	38	38	49

Habitat Code	Species								
	LM	PI	RM	PY	AS	CO	MM	PB	OH
850	22	6	6	22	33	36	33	33	36
999	26	8	7	26	38	49	38	38	49

Table 3.4.2 Recommended site index references for effected species in the IE variant.

Species	Reference	BHA or TTA*	Base Age
LM, PY	Alexander, Tackle, & Dahms (1967)	TTA	100
PI	Any pinyon 100 year base total age curve	TTA	100
RM	Any juniper 100 year base total age curve	TTA	100
AS, MM, PB	Edminster, Mowrer, & Shepperd (1985)	BHA	80
CO	Any hardwood 100 year base total age curve	TTA	100
OH	Any hardwood 100 year base total age curve	TTA	100

* Equation is based on total tree age (TTA) or breast height age (BHA)

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. Maximum stand density index at the stand level is a weighted average, by basal area proportion, of the individual species SDI maximums.

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}.

{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 equivalent NI original habitat type in the IE variant.

Habitat Code	Maximum Basal Area
130	140
170	220
250	250

Habitat Code	Maximum Basal Area
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. Users may substitute diameter at root collar (DRC) or diameter at breast height (DBH) in interpreting the relationships of woodland species (pinyon pine and Rocky Mountain juniper).

4.1 Height-Diameter Relationships

Height-diameter relationships in FVS are primarily used to estimate tree heights missing in input data, and occasionally to estimate diameter growth on trees smaller than a given threshold diameter. In the IE variant, height-diameter relationships are a logistic functional form, as shown in equation {4.1.1} (Wykoff and others 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} $HT = 4.5 + \exp(B_1 + B_2 / (DBH + 1.0))$

where:

HT is tree height
DBH is tree diameter at breast height
B_1 - B_2 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 IE variant.

FVS Number	Alpha Code	Default B_1	B_2
1	WP	5.19988	-9.26718
2	WL	4.97407	-6.78347
3	DF	4.81519	-7.29306
4	GF	5.00233	-8.19365
5	WH	4.97331	-8.1973
6	RC	4.89564	-8.39057
7	LP	4.62171	-5.32481
8	ES	4.9219	-8.30289
9	AF	4.76537	-7.61062
10	PP	4.9288	-9.32795
11	MH	4.77951	-9.31743
12	WB	4.97407	-6.78347
13	LM	4.192	-5.1651
14	LL	4.76537	-7.61062

FVS Number	Alpha Code	Default B_1	B_2
15	PI	3.2	-5.0
16	RM	3.2	-5.0
17	PY	4.192	-5.1651
18	AS	4.4421	-6.5405
19	CO	4.4421	-6.5405
20	MM	4.4421	-6.5405
21	PB	4.4421	-6.5405
22	OH	4.4421	-6.5405
23	OS	4.77951	-9.31743

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 coefficients (b_1 and b_2) for this equation by species are shown in table 4.2.1.

{4.2.1} $BRATIO = b_1 + (b_2 / DBH)$

Note: if a species has a b_2 value equal to 0, then $BRATIO = b_1$

where:

BRATIO is species-specific bark ratio (bounded to $0.80 \leq BRATIO \leq 0.99$)
DBH is tree diameter at breast height (bounded to $DBH \geq 1.0$)
b_1 and b_2 are species-specific coefficients shown in table 4.2.1

Table 4.2.1 Coefficients for bark ratio equation {4.2.1} in the IE variant.

FVS Number	Alpha Code	b_1	b_2	Equation Source
1	WP	0.964	0	Wykoff, et. al. 1982
2	WL	0.851	0	Wykoff, et. al. 1982
3	DF	0.867	0	Wykoff, et. al. 1982
4	GF	0.915	0	Wykoff, et. al. 1982
5	WH	0.934	0	Wykoff, et. al. 1982
6	RC	0.950	0	Wykoff, et. al. 1982
7	LP	0.969	0	Wykoff, et. al. 1982
8	ES	0.956	0	Wykoff, et. al. 1982
9	AF	0.937	0	Wykoff, et. al. 1982
10	PP	0.890	0	Wykoff, et. al. 1982
11	MH	0.934	0	Wykoff, et. al. 1982
12	WB	0.851	0	Uses WL equation
13	LM	0.969	0	TT limber pine
14	LL	0.937	0	Uses subalpine fir
15	PI*	0.9002	-0.3089	
16	RM*	0.9002	-0.3089	

FVS Number	Alpha Code	b_1	b_2	Equation Source
17	PY	0.969	0	Uses LM equation
18	AS	0.950	0	UT aspen
19	CO	0.892	-0.086	CR cottonwood
20	MM	0.950	0	Uses AS equation
21	PB	0.950	0	Uses AS equation
22	OH	0.892	-0.086	Uses CO equation
23	OS	0.934	0	Uses MH equation

**DBH* is bounded between 1.0 and 19.0

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 IE variant, crown ratios missing in the input data are predicted using different equations depending on species and tree size. For most species, live trees less than a minimum diameter and dead trees of all sizes use equations {4.3.1.1} and {4.3.1.2} to compute crown ratio. Species numbers 1-12, 14, and 23 use a logistic function shown in equations {4.3.1.1} and {4.3.1.2} for trees less than 3.0” in diameter. Species 13, 17, 18, 20, and 21 use equations {4.3.1.1} and {4.3.1.2} for trees less than 1.0” in diameter. Equation coefficients are found in table 4.3.1.1.

{4.3.1.1} $X = R_1 + R_2 * DBH + R_3 * HT + R_4 * BA + R_5 * PCCF + R_6 * HT_{Avg} / HT + R_7 * HT_{Avg} + R_8 * BA * PCCF + R_9 * MAI$

{4.3.1.2} $CR = 1 / (1 + \exp(X + N(0,SD)))$ where absolute value of $(X + N(0,SD)) < 86$

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
PCCF	is crown competition factor on the inventory point where the tree is established
HT_{Avg}	is average height of the 40 largest diameter trees in the stand
MAI	is stand mean annual increment
N(0,SD)	is a random increment from a normal distribution with a mean of 0 and a standard deviation of SD
$R_1 – R_9$	are species-specific coefficients shown in table 4.3.1.1

Table 4.3.1.1 Coefficients for the crown ratio equation {4.3.1.1} in the IE variant.

Coefficient	Alpha Code							
	WP	WL	DF	GF	WH	RC	LP	ES
R_1	-0.44316	-0.83965	-0.89122	-0.62646	-0.49548	0.11847	-0.32466	-0.92007
R_2	-0.48446	-0.16106	-0.18082	-0.06141	0.00012	-0.39305	-0.20108	-0.22454
R_3	0.05825	0.04161	0.05186	0.0236	0.00362	0.02783	0.04219	0.03248
R_4	0.00513	0.00602	0.00454	0.00505	0.00456	0.00626	0.00436	0.0062
R_5	0	0	0	0	0	0	0	0
R_6	0	0	0	0	0	0	0	0
R_7	0	0	0	0	0	0	0	0
R_8	0	0	0	0	0	0	0	0
R_9	0	0	0	0	0	0	0	0
SD	0.9476	0.7396	0.8706	0.9203	0.945	0.8012	0.7707	0.9721

Coefficient	Alpha Code						
	AF	PP	MH, OS	WB	LM, PY	LL	AS, CO, MM, PB, OH
R_1	-0.89014	-0.17561	-0.49548	-0.83965	-1.66949	-0.89014	-0.426688
R_2	-0.18026	-0.33847	0.00012	-0.16106	-0.209765	-0.18026	-0.093105
R_3	0.02233	0.05699	0.00362	0.04161	0	0.02233	0.022409
R_4	0.00614	0.00692	0.00456	0.00602	0.003359	0.00614	0.002633
R_5	0	0	0	0	0.011032	0	0
R_6	0	0	0	0	0	0	-0.045532
R_7	0	0	0	0	0.017727	0	0
R_8	0	0	0	0	-0.000053	0	0.000022
R_9	0	0	0	0	0.014098	0	-0.013115
SD	0.8871	0.8866	0.945	0.7396	0.5	0.8871	0.931

For live trees 1.0” in diameter or larger for species numbers 13, 17, 18, 20, and 21, a Weibull-based crown model developed by Dixon (1985) as described in Dixon (2002) is used to predict missing crown ratio. To estimate crown ratio using this methodology, the average stand crown ratio is estimated from the stand density index using equation {4.3.1.3}. Weibull parameters are then estimated from the average stand crown ratio using equations in equation set {4.3.1.4}. Individual tree crown ratio is then set from the Weibull distribution, equation {4.3.1.5} based on a tree’s relative position in the diameter distribution and multiplied by a scale factor, shown in equation {4.3.1.6}, which accounts for stand density. Crowns estimated from the Weibull distribution are bounded to be between the 5 and 95 percentile points of the specified Weibull distribution. Equation coefficients for each species for these equations are shown in table 4.3.1.2.

{4.3.1.3} $ACR = d_0 + d_1 * RELSDI * 100.0$

$RELSDI = SDI_{stand} / SDI_{max}$

{4.3.1.4} Weibull parameters A, B, and C are estimated from average crown ratio

$A = a_0$

$B = b_0 + b_1 * ACR \quad (B \geq 1)$

$C = c_0 + c_1 * ACR \quad (C \geq 2)$

{4.3.1.5} $Y = 1\text{-}\exp(-((X-A)/B)^{\wedge}C)$

{4.3.4.6} $SCALE = 1 - 0.00167 * (CCF - 100)$

where:

ACR	is predicted average stand crown ratio for the species
SDI_{stand}	is stand density index of the stand
SDI_{max}	is maximum stand density index
A, B, C	are parameters of the Weibull crown ratio distribution
X	is a tree's crown ratio expressed as a percent / 10
Y	is a trees rank in the diameter distribution (1 = smallest; ITRN = largest) divided by the total number of trees (ITRN) multiplied by *SCALE*
SCALE	is a density dependent scaling factor (bounded to $0.3 \leq SCALE \leq 1.0$)
CCF	is stand crown competition factor

a_0, $b_{0\text{-}1}$, $c_{0\text{-}1}$, and $d_{0\text{-}1}$ are species-specific coefficients shown in table 4.3.1.2

Table 4.3.1.2 Coefficients for the Weibull parameter equations {4.3.1.3} and {4.3.1.4} in the IE variant.

FVS Number	Alpha Code	Model Coefficients						
		a_0	b_0	b_1	c_0	c_1	d_0	d_1
13	LM	1.0	-0.82631	1.06217	3.31429	0	6.19911	-0.02216
17	PY	1.0	-0.82631	1.06217	3.31429	0	6.19911	-0.02216
18	AS	0	-0.08414	1.14765	2.77500	0	4.01678	-0.01516
20	MM	0	-0.08414	1.14765	2.77500	0	4.01678	-0.01516
21	PB	0	-0.08414	1.14765	2.77500	0	4.01678	-0.01516

In the IE variant, equation {4.3.1.7} is used to predict missing crown ratio missing in live trees for all trees 3.0" in diameter or larger for species numbers 1-12, 14, and 23.

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

where:

CR	is predicted crown ratio expressed as a proportion
HAB	is a habitat-dependent coefficient shown in table 4.3.1.4
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 4.3.1.3

Table 4.3.1.3 Coefficients for the crown ratio change equation {4.3.1.7} in the IE variant.

Coefficient	Alpha Code										
	WP	WL, WB	DF	GF	WH	RC	LP	ES	AF, LL	PP	MH, OS
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	-0.34566	0	0	0	0	0.17479	0	0	0	0	0
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 4.3.4 *HAB* values by habitat class for equation {4.3.1.7} in the IE variant.

Habitat Class	Alpha Code										
	WP	WL, WB	DF	GF	WH	RC	LP	ES	AF, LL	PP	MH, OS
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 4.3.5 Habitat class by species and habitat code for *HAB* values in equation {4.3.9} in the IE variant.

Habitat Code	Alpha Code										
	WP	WL, WB	DF	GF	WH	RC	LP	ES	AF, LL	PP	MH, OS
130	2	2	2	2	1	1	2	2	2	2	1
170	2	2	2	2	1	1	2	2	2	2	1
250	2	2	2	2	1	1	2	2	2	4	1
260	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	2	2	6	2	1	1	4	2	2	5	1
320	2	3	7	2	1	1	5	3	2	6	1
330	2	2	4	2	1	1	5	2	2	1	1
420	2	4	8	1	1	1	2	1	2	1	1
470	2	4	8	1	1	1	2	1	2	1	1
510	2	5	5	2	1	1	6	2	2	8	1
520	3	6	9	3	1	1	7	4	2	7	2
530	4	7	10	4	1	1	8	5	3	9	2
540	4	7	10	4	1	1	8	5	4	9	2
550	4	7	10	4	1	1	8	5	4	9	2
570	5	8	11	5	1	2	9	6	4	3	3
610	5	8	11	5	1	2	9	6	4	3	3
620	5	4	8	6	1	2	10	7	5	3	4
640	6	1	1	1	1	1	11	8	6	1	1
660	6	10	12	7	1	1	11	8	6	1	1
670	1	9	12	7	1	1	12	9	7	1	1
680	6	10	13	7	1	1	11	8	6	1	5
690	1	1	1	1	1	1	1	10	1	1	1
710	7	11	3	8	1	1	13	11	8	1	6
720	1	1	1	1	1	1	1	1	1	1	1
730	6	1	3	7	1	1	14	1	9	1	1
830	6	1	1	1	1	1	3	12	10	1	1
850	6	1	1	1	1	1	3	12	10	1	1
999	6	2	1	1	1	1	11	8	6	1	1

Pinyon pine, Rocky Mountain juniper, cottonwood, and other hardwoods use equation {4.3.1.8} or {4.3.1.9} to estimate crown ratio for live and dead trees missing crown ratios in the inventory. Pinyon pine and Rocky Mountain juniper use equation {4.3.1.8}. Cottonwood and "other hardwoods" use equation {4.3.1.9}.

{4.3.1.8} $CR = [-0.59373 + (0.67703 * HF)] / HF$

{4.3.1.9} $CR = [5.17281 + (0.32552 * HF) – (0.01675 * BA)] / HF$

where:

CR is crown ratio expressed as a proportion (bounded to 0.05 < CR < 0.95)
BA is total stand basal area
HF is end of cycle tree height (HT + height growth)

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. Crown ratio predicted at the end of the projection cycle is estimated for live limber pine, Pacific yew, quaking aspen, Rocky Mountain maple, and paper birch using the Weibull distribution, equations {4.3.1.3}-{4.3.1.6}. Live pinyon pine and Rocky Mountain juniper use equation {4.3.1.8}. Live cottonwood and "other hardwoods" use equation {4.3.1.9}. For live trees greater than 3" in dbh for all other species, crown change is predicted using equation {4.3.1.7}. 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 $0.2 \leq CR \leq 0.9$)
$PCCF$ 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 IE 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 equations {4.4.1} – {4.4.6}, and coefficients for these equations 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} Bechtold (2004); Equation 01

$DBH \geq MinD: CW = a_1 + (a_2 * DBH) + (a_3 * DBH^2)$
$DBH < MinD: CW = [a_1 + (a_2 * MinD) * (a_3 * MinD^2)] * (DBH / MinD)$

{4.4.2} Bechtold (2004); Equation 02

$DBH \geq MinD: CW = a_1 + (a_2 * DBH) + (a_3 * DBH^2) + (a_4 * CR\%) + (a_5 * BA) + (a_6 * HI)$

$DBH < MinD$: $CW = [a_1 + (a_2 * MinD) + (a_3 * MinD^2) + (a_4 * CR\%) + (a_5 * BA) + (a_6 * HI)] * (DBH / MinD)$

{4.4.3} Crookston (2003); Equation 03

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

{4.4.4 Crookston (2005); Equation 04

$DBH \geq MinD$: $CW = a_1 * DBH^{a_2}$
$DBH < Min$: $CW = [a_1 * MinD^{a_2}] * (DBH / MinD)$

{4.4.5} Crookston (2005); Equation 05

$DBH \geq MinD$: $CW = (a_1 * BF) * DBH^{a_2} * HT^{a_3} * CL^{a_4} * (BA + 1.0)^{a_5} * (\exp(EL))^{a_6}$
$DBH < MinD$: $CW = [(a_1 * BF) * MinD^{a_2} * HT^{a_3} * CL^{a_4} * (BA + 1.0)^{a_5} * (\exp(EL))a_6] * (DBH / MinD)$

{4.4.6} Donnelly (1996); Equation 06

$DBH \geq MinD$: $CW = a_1 * DBH^{a_2}$
$DBH < MinD$: $CW = [a_1 * MinD^{a_2}] * (DBH / MinD)$

where:

BF	is a species-specific coefficient based on forest code
CW	is tree maximum crown width
CL	is tree crown length
CR%	is crown ratio expressed as a percent
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
HI	is the Hopkins Index, where HI = (ELEVATION - 5449) / 100) * 1.0 + (LATITUDE - 42.16) * 4.0 + (-116.39 -LONGITUDE) * 1.25
a1 – a6	are species-specific coefficients shown in table 4.4.1

Table 4.4.1 Coefficients for crown width equations {4.4.1} – {4.4.6} in the IE variant.

FVS Number	Alpha Code	Equation Number*	a_1	a_2	a_3	a_4	a_5	a_6
1	WP	11903	1.0405	1.2799	0.11941	0.42745	0	-0.07182
2	WL	07303	1.02478	0.99889	0.19422	0.59423	-0.09078	-0.02341
3	DF	20203	1.01685	1.48372	0.27378	0.49646	-0.18669	-0.01509
4	GF	01703	1.0303	1.14079	0.20904	0.38787	0	0
5	WH	26303	1.02460	1.3522	0.24844	0.412117	-0.104357	0.03538
6	RC	24203	1.03597	1.46111	0.26289	0.18779	0	0
7	LP	10803	1.03992	1.58777	0.30812	0.64934	-0.38964	0

FVS Number	Alpha Code	Equation Number*	a_1	a_2	a_3	a_4	a_5	a_6
8	ES	09303	1.02687	1.28027	0.2249	0.47075	-0.15911	0
9	AF	01903	1.02886	1.01255	0.30374	0.37093	-0.13731	0
10	PP	12203	1.02687	1.49085	0.1862	0.68272	-0.28242	0
11	MH	26405	3.7854	0.54684	-0.12954	0.16151	0.03047	-0.00561
12	WB	10105	2.2354	0.6668	-0.11658	0.16927	0	0
13	LM	11301	4.0181	0.8528	0	0	0	0
14	LL	07204	2.2586	0.68532	0	0	0	0
15	PI	10602	-5.4647	1.966	0	-0.0395	0.0427	-0.0259
16	RM	06602	-4.1599	1.3528	-0.0233	0.0633	0	-0.0423
17	PY	23104	6.1297	0.45424	0	0	0	0
18	AS	74605	4.7961	0.64167	-0.18695	0.18581	0	0
19	CO	74902	4.1687	1.5355	0	0	0	0.1275
20	MM	32102	5.9765	0.8648	0	0.0675	0	0
21	PB	37506	5.8980	0.4841	0	0	0	0
22	OH	74902	4.1687	1.5355	0	0	0	0.1275
23	OS	12205	4.7762	0.74126	-0.28734	0.17137	-0.00602	-0.00209

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

Table 4.4.2 *MinD* values and data bounds for equations {4.4.1} – {4.4.6} in the IE variant.

FVS Number	Alpha Code	Equation Number*	*MinD*	EL min	*EL* max	*HI* min	*HI* max	*CW* max
1	WP	11903	1.0	n/a	n/a	n/a	n/a	35
2	WL	07303	1.0	n/a	n/a	n/a	n/a	40
3	DF	20203	1.0	n/a	n/a	n/a	n/a	80
4	GF	01703	1.0	n/a	n/a	n/a	n/a	40
5	WH	26303	1.0	n/a	n/a	n/a	n/a	54
6	RC	24203	1.0	n/a	n/a	n/a	n/a	45
7	LP	10803	0.7	n/a	n/a	n/a	n/a	40
8	ES	09303	1.0	n/a	n/a	n/a	n/a	40
9	AF	01903	1.0	n/a	n/a	n/a	n/a	30
10	PP	12203	2.0	n/a	n/a	n/a	n/a	46
11	MH	26405	1.0	10	79	n/a	n/a	45
12	WB	10105	1.0	n/a	n/a	n/a	n/a	40
13	LM	11301	5.0	n/a	n/a	n/a	n/a	25
14	LL	07204	1.0	n/a	n/a	n/a	n/a	33
15	PI	10602	5.0	n/a	n/a	-40	11	25
16	RM	06602	5.0	n/a	n/a	-37	19	29
17	PY	23104	1.0	n/a	n/a	n/a	n/a	30
18	AS	74605	1.0	n/a	n/a	n/a	n/a	45
19	CO	74902	5.0	n/a	n/a	-26	-2	35
20	MM	32102	5.0	n/a	n/a	n/a	n/a	39

FVS Number	Alpha Code	Equation Number*	*MinD*	EL min	*EL* max	*HI* min	*HI* max	*CW* max
21	PB	37506	1.0	n/a	n/a	n/a	n/a	25
22	OH	74902	5.0	n/a	n/a	-26	-2	35
23	OS	12205	1.0	13	75	n/a	n/a	50

4.5 Crown Competition Factor

The IE 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 4.3.1.

{4.5.1} CCF equations for individual trees

$DBH \geq 1.0''$ for LM, PI, PY, AS, MM, PB and $DBH \geq 10.0''$ for all other species:

$CCF_t = R_1 + (R_2 * DBH) + (R_3 * DBH^2)$

$0.1'' < DBH < 1.0''$ for LM, PI, PY, AS, MM, PB and $0.1'' < DBH < 10.0''$ for all other species:

$CCF_t = R_4 * DBH^{R5}$

$DBH \leq 0.1''$: $CCF_t = 0.001$

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 IE variant.

FVS Number	Alpha Code	Model Coefficients				
		R_1	R_2	R_3	R_4	R_5
1	WP	0.03	0.0167	0.00230	0.009884	1.6667
2	WL	0.02	0.0148	0.00338	0.007244	1.8182
3	DF	0.11	0.0333	0.00259	0.017299	1.5571
4	GF	0.04	0.0270	0.00405	0.015248	1.7333
5	WH	0.03	0.0215	0.00363	0.011109	1.7250
6	RC	0.03	0.0238	0.00490	0.008915	1.7800
7	LP	0.01925	0.01676	0.00365	0.009187	1.7600
8	ES	0.03	0.0173	0.00259	0.007875	1.7360
9	AF	0.03	0.0216	0.00405	0.011402	1.7560
10	PP	0.03	0.0180	0.00281	0.007813	1.7680
11	MH	0.03	0.0215	0.00363	0.011109	1.7250
12	WB	0.02	0.0148	0.00338	0.007244	1.8182
13	LM	0.01925	0.01676	0.00365	0.009187	1.7600

FVS Number	Alpha Code	Model Coefficients				
		R_1	R_2	R_3	R_4	R_5
14	LL	0.03	0.0216	0.00405	0.011402	1.7560
15	PI	0.01925	0.01676	0.00365	0.009187	1.7600
16	RM	0.01925	0.01676	0.00365	0.009187	1.7600
17	PY	0.01925	0.01676	0.00365	0.009187	1.7600
18	AS	0.03	0.0238	0.00490	0.008915	1.7800
19	CO	0.03	0.0215	0.00363	0.011109	1.7250
20	MM	0.03	0.0238	0.00490	0.008915	1.7800
21	PB	0.03	0.0238	0.00490	0.008915	1.7800
22	OH	0.03	0.0215	0.00363	0.011109	1.7250
23	OS	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 1.0” for cottonwood species and other hardwoods, and is set to 3.0” for all other species. Rocky Mountain juniper and pinyon pine only use the small-tree relationships to predict height and diameter growth for trees of all sizes.

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 and IE variant. The NI equation for western larch is used for whitebark pine in the IE variant; the NI subalpine fir equation is used for IE subalpine larch; and the NI equation for “other” species, which is really mountain hemlock, is used for “other softwoods” in the IE variant. Potential height growth is estimated using equation {4.6.1.1}, and coefficients for this equation are shown in tables 4.6.1.1 - 4.6.1.3.

{4.6.1.1} $HTG = \exp(X)$

$X = [LOC + HAB + SPP + c_1 * \ln(HT) + c_2 * CCF + c_3 * BAL + 0.22157 * SL * \cos(ASP) - 0.12432 * SL * \sin(ASP) - 0.10987 * SL]$

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 intercept shown in table 4.6.1.3
SPP is a species dependent intercept shown in table 4.6.1.1
CCF is stand crown competition factor
BAL is total basal area in trees larger than the subject tree
ASP is stand aspect
SL is stand slope
HT is tree height

$c_1 - c_3$ are species-specific coefficients shown in table 4.6.1.1

Table 4.6.1.1 Coefficients ($c_1 - c_2$) and SPP values for equation {4.6.1.1} in the IE variant.

FVS Number	Alpha Code	Model Coefficients			
		c_1	c_2	c_3	SPP
1	WP	0.4214	-0.00591	-0.37199	1.4700
2	WL	0.2716	-0.00654	-0.41532	1.6204
3	DF	0.3907	-0.00591	-0.40043	1.4932
4	GF	0.3487	-0.00391	-0.25355	0.9981
5	WH	0.3417	-0.00391	-0.34693	1.0202
6	RC	0.2354	-0.00391	-0.12013	0.8953
7	LP	0.5843	-0.00654	-0.24172	1.2336
8	ES	0.2827	-0.00391	-0.25300	1.0964
9	AF	0.3740	-0.00391	-0.22957	1.0667
10	PP	0.4485	-0.00654	-0.47299	1.7311
11	MH	0.2354	-0.00391	-0.25349	0.8953
12	WB	0.2716	-0.00654	-0.41532	1.6204
14	LL	0.3740	-0.00391	-0.22957	1.0667
23	OS	0.2354	-0.00391	-0.25349	0.8953

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

	National Forest (Location Code)										
	103	104	105	106	110	113	114	116	117	118	621
LOC	-0.2785	-0.2785	0	-0.0480	-0.2785	-0.2785	-0.2785	-0.2785	0	-0.0480	-0.2785

Table 4.6.1.3 *HAB* values for equation {4.6.1.1} in the IE variant.

FVS Number	Alpha Code	*HAB*	Habitat types (see Table 3.3)
1	WP	-0.2146	520, 620
		-0.0941	530
		-0.3141	130, 170, 250, 260, 280, 290, 310, 320, 330, 420, 470, 510, 640, 660, 670, 680, 690, 710, 720, 730, 830, 850, 999
		0	540, 550, 570, 610
2	WL	-0.2146	420, 470, 510, 520
		-0.0941	530, 620
		-0.3296	130, 170, 250, 260, 280, 290, 310, 320, 330, 640, 660, 670, 680, 690, 710, 720, 730, 830, 850, 999
		0	540, 550, 570, 610
3	DF	-0.2146	320, 510, 520, 620
		-0.0941	530
		-0.5401	660, 830
		-0.3948	130, 170, 250, 260, 280, 290, 310, 330, 420, 470, 640, 670, 680, 690, 710, 720, 730, 850, 999

FVS Number	Alpha Code	*HAB*	Habitat types (see Table 3.3)
		0	540, 550, 570, 610
4	GF	-0.2146	520, 620, 670, 680,
		-0.0941	530,
		-0.2776	130, 170, 250, 260, 280, 290, 310, 320, 330, 420, 470, 510, 640, 660, 690, 710, 720, 730, 830, 850, 999
		0	540, 550, 570, 610,
5	WH	-0.2146	130, 170, 250, 260, 280, 290, 310, 320, 330, 420, 470, 510, 520, 620, 640, 660, 670, 680, 690, 710, 720, 730, 830, 850, 999
		-0.0941	530
		0	540, 550, 570, 610
6	RC	-0.2146	130, 170, 250, 260, 280, 290, 310, 320, 330, 420, 470, 510, 520, 620, 640, 660, 670, 680, 690, 710, 720, 730, 830, 850, 999
		-0.0941	530
		0	540, 550, 570, 610
7	LP	-0.2146	280, 290, 310
		-0.0941	530
		-0.2484	670
		-0.5134	510, 520, 640, 660, 680, 730, 830
		-0.3495	130, 170, 250, 260, 320, 330, 420, 470, 690, 710, 720, 850, 999
		0	540, 550, 570, 610, 620
8	ES	-0.2146	130, 170, 250, 260, 280, 290, 310, 320, 330, 420, 470, 510, 520, 620, 640, 660, 670, 680, 690, 710, 720, 730, 850, 999
		-0.0941	530
		-0.3431	830
		0	540, 550, 570, 610
9	AF	-0.2146	620, 730
		-0.0941	530
		-0.4916	520, 830, 850
		-0.3582	130, 170, 250, 260, 280, 290, 310, 320, 330, 420, 470, 510, 640, 660, 670, 680, 690, 710, 720, 999
		0	540, 550, 570, 610
10	PP	-0.2146	130, 170, 250, 290, 310, 510, 520, 620
		-0.0941	530
		-0.4345	260, 280, 320, 330, 420, 470, 640, 660, 670, 680, 690, 710, 720, 730, 830, 850, 999
		0	540, 550, 570, 610
11	MH	-0.2146	520, 620
		-0.0941	530, 670
		-0.3738	130, 170, 250, 260, 280, 290, 310, 320, 330, 420, 470, 510, 640, 660, 680, 690, 710, 720, 730, 830, 850, 999
		0	540, 550, 570, 610

FVS Number	Alpha Code	*HAB*	Habitat types (see Table 3.3)
12	WB	-0.2146	420, 470, 510, 520
		-0.0941	530, 620
		-0.3296	130, 170, 250, 260, 280, 290, 310, 320, 330, 640, 660, 670, 680, 690, 710, 720, 730, 830, 850, 999
		0	540, 550, 570, 610
14	LL	-0.2146	620, 730
		-0.0941	530
		-0.4916	520, 830, 850
		-0.3582	130, 170, 250, 260, 280, 290, 310, 320, 330, 420, 470, 510, 640, 660, 670, 680, 690, 710, 720, 999
		0	540, 550, 570, 610
23	OS	-0.2146	520, 620
		-0.0941	530, 670
		-0.3738	130, 170, 250, 260, 280, 290, 310, 320, 330, 420, 470, 510, 640, 660, 680, 690, 710, 720, 730, 830, 850, 999
		0	540, 550, 570, 610

The remaining species in the IE variant use small-tree height growth equations taken from other variants. Cottonwood species and other hardwoods use equations from the Central Rockies variant; pinyon pine, Rocky Mountain juniper, and quaking aspen use equations from the Utah variant; and limber pine uses equations from the Tetons variant. The quaking aspen equations are also used for Rocky mountain maple and paper birch, and the limber pine equations are used for Pacific yew.

For cottonwood species (19), and other hardwoods (22), potential height growth is estimated using equation {4.6.1.2}, and then adjusted based on stand density (*PCTRED*) and crown ratio (*VIGOR*) as shown in equations {4.6.1.4} and {4.6.1.5} respectively, to determine an estimated height growth as shown in equation {4.6.1.7}.

For pinyon pine (15) and Rocky Mountain juniper (16), potential height growth is estimated using equation {4.6.1.3}. The reduction proportion due to stand density (*PCTRED*) is computed with equation {4.6.1.4} and the reduction proportion due to crown ratio (*VIGOR*) is computed with equation {4.6.1.6}, to determine an estimated height growth as shown in equation {4.6.1.7}

Height growth for quaking aspen (18), Rocky mountain maple (20), and paper birch (21) is obtained from an aspen height-age curve (Shepperd 1995). Because Shepperd's original curve seemed to overestimate height growth, the IE variant reduces the estimated height growth by 25 percent (shown in equation {4.6.1.8}). A height is estimated from the trees' current age, and then its current age plus 10 years. Height growth is the difference between these two height estimates adjusted to account for cycle length and any user defined small-tree height growth adjustments for aspen, and converted from centimeters to feet. An estimate of the tree's current age is obtained at the start of a projection using the tree's height and solving equation {4.6.1.8} for age.

Height growth for limber pine (13) and Pacific yew (17) is estimated using equation {4.6.1.9}.

{4.6.1.2} Used for cottonwood (19) and other hardwoods (22)

POTHTG = (*SI* / 5.0) * ((*SI* * 1.5) - *HT*) / (*SI* * 1.5) * 0.83

{4.6.1.3} Used for pinyon pine (15) and Rocky Mountain juniper (16)

POTHTG = (*SI* / 5.0) * ((*SI* * 1.5) - *HT*) / (*SI* * 1.5) * 0.83

{4.6.1.4} *PCTRED* = 1.1144 – 0.0115**Z* + 0.4301E-04 * *Z*^2 – 0.7222E-07 * *Z*^3 + 0.5607E-10 * *Z*^4 – 0.1641E-13 * *Z*^5

$Z = HT_{Avg} * (CCF / 100)$

{4.6.1.5} Used for cottonwood (19) and other hardwoods (22)

VIGOR = (150 * *CR*^3 * exp(-6 * CR)) + 0.3

{4.6.1.6} Used for pinyon pine (15) and Rocky Mountain juniper (16)

VIGOR = 1 – [(1 – ((150 * *CR*^3 * exp(-6 * *CR*)) + 0.3)) / 3]

{4.6.1.7} *HTG = POTHTG * PCTRED * VIGOR*

{4.6.1.8} Used for quaking aspen (18), Rocky Mountain maple (20), and Paper birch (21)

HTG = (26.9825 * *A*^1.1752) * 0.375 * (1 + [(*SI* – *SITELO*) / (*SITEHI* – *SITELO*)]

{4.6.1.9} *HTG* = exp[1.17527 - (0.42124 * ln(*TPCCF*))] + *CR* * exp[-2.56002 - (0.58642 * ln(*TPCCF*))]

where:

POTHTG	is potential height growth
PCTRED	is reduction in height growth due to stand density (bounded: $0.01 \leq PCTRED \leq 1.0$)
HT_{Avg}	is average height of the 40 largest diameter trees in the stand
CCF	is stand crown competition factor
VIGOR	is reduction in height growth due to tree vigor (bounded to $VIGOR \leq 1.0$)
CR	is a tree’s live crown ratio (compacted) expressed as a proportion
HTG	is estimated height growth for the cycle
SI	is species site index bounded by *SITELO* and *SITEHI*
SITELO	is lower end of the site range for this species shown in table 4.6.1.4
SITEHI	is upper end of the site range for this species shown in table 4.6.1.4
A	is tree age
TPCCF	is total crown competition factor on the inventory point where the tree is established (bounded to $25 \leq TPCCF \leq 300$)

If the site index for the stand is less than or equal to the lower site limit, it is set to the lower limit + 0.5 for the calculation of RELSI. Similarly, if the site index for the stand is greater than the upper site limit, it is set to the upper site limit for the calculation of RELSI.

Table 4.6.1.4 *SITELO* and *SITEHI* values for equations {4.6.1.2} and {4.6.1.3} in the IE variant.

FVS Number	Alpha Code	*SITELO*	*SITEHI*
15	PI	5	20
16	RM	5	15
18	AS	30	70
19	CO	30	120

FVS Number	Alpha Code	*SITELO*	*SITEHI*
20	MM	30	70
21	PB	30	70
22	OH	20	100

For all species, a small random error is then added to the height growth estimate. The estimated height growth is then adjusted to account for cycle length, user defined small-tree height growth adjustments, and adjustments due to small tree height increment calibration from 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 {4.6.1.10}, and applied as shown in equation {4.6.1.11}. The range of diameters for each species is shown in table 4.6.1.5.

{4.6.1.10}

$DBH \le X_{\text{min}}$: $XWT = 0$
$X_{\text{min}} < DBH < X_{\text{max}}$: $XWT = (DBH - X_{\text{min}}) / (X_{\text{max}} - X_{\text{min}})$
$DBH \ge X_{\text{max}}$: $XWT = 1$

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

where:

XWT	is the weight applied to the growth estimates
DBH	is tree diameter at breast height
Xmax	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 4.6.1.5 Diameter bounds by species in the IE variant.

FVS Number	Alpha 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

FVS Number	Alpha Code	X_{min}	X_{max}
10	PP	2.0	10.0
11	MH	2.0	10.0
12	WB	2.0	10.0
13	LM	1.5	3.0
14	LL	2.0	10.0
15	PI	90.0	99.0
16	RM	90.0	99.0
17	PY	1.5	3.0
18	AS	2.0	4.0
19	CO	0.5	2.0
20	MM	2.0	4.0
21	PB	2.0	4.0
22	OH	0.5	2.0
23	OS	2.0	10.0

*There is only one growth relationship that applies to trees of all sizes for these species. These relationships are contained in the "small" tree portion of FVS.

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. For all species except limber pine (13) and Pacific yew (17), 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. These two predicted diameters are estimated using the species-specific height-diameter relationships discussed in section 4.1, except for pinyon pine (15) and Rocky Mountain juniper (16), which use equation {4.6.2.1} to estimate the diameters. By definition, diameter growth is zero for trees less than 4.5 feet tall.

{4.6.2.1} $DHAT = (HT - 4.5) * 10 / (SI - 4.5)$

where:

DHAT is estimated tree diameter at breast height
HT is tree height
SI is species site index

Future diameter for trees over 4.5 feet tall is predicted directly for limber pine (LM) and Pacific yew (PY) using equation {4.6.2.2}. Diameter growth is then the difference between the diameter at the start of the projection period and the predicted future diameter, adjusted for bark ratio.

{4.6.2.2} $DHAT = 0.000231 * (HT - 4.5) * CR\% - 0.0005 * (HT - 4.5) * PCCF + 0.001711 * CR\% + 0.17023 * (HT - 4.5) + 0.3$

where:

DHAT	is estimated tree diameter at breast height
HT	is tree height
CR%	is crown ratio expressed as a percent
PCCF	is crown competition factor on the inventory point where the tree is established

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 1.0" for cottonwood and other hardwoods, and is set to 3.0" for all other species. Rocky Mountain juniper and pinyon pine only use the small-tree relationships to predict height and diameter growth for trees of all sizes.

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.

Species numbers 1 – 14, Pacific yew (17), and other softwoods (23) use diameter growth equations {4.7.1.1} – {4.7.1.2}. Coefficients for these equations are shown in tables 4.7.1.1 - 4.7.1.9. Limber pine, Pacific yew, and other softwoods use the same coefficients as mountain hemlock (MH), subalpine larch (LL) uses the same coefficients as subalpine fir (AF), and whitebark pine (WB) uses the same coefficients as western larch (WL). Diameter growth for the other species in the IE variant is shown later in this section.

{4.7.1.1} Used for FVS numbers 1-14, 17, and 23

$$\ln(DDS) = b_1 + (b_2 * EL) + (b_3 * EL\text{^}2) + (b_4 * \sin(ASP)) + (b_5 * \cos(ASP)) + (b_6 * SL) + (b_7 * SL\text{^}2) + (b_8 * CCF / 100) + (b_9 * \ln(DBH)) + (b_{10} * BAL) + (b_{11} * CR) + (b_{12} * CR\text{^}2) + (b_{13} * DBH\text{^}2) + (b_{14} * BAL / (\ln(DBH + 1.0))) + HAB$$

{4.7.1.2} Modification equation used for limber pine (13) and Pacific yew (17)

$$DDS = DDS + (0.001766 * SI) – (0.00199592 * CCF)$$

where:

DDS	is the predicted periodic change in squared inside-bark diameter
EL	is stand elevation in hundreds of feet
ASP	is stand aspect (for species numbers 13 and 17, *ASP* = *ASP* – 0.7854)
SL	is stand slope
CCF	is stand crown competition factor
CR	is a tree's live crown ratio (compacted) expressed as a proportion
DBH	is tree diameter at breast height

BAL	is total basal area in trees larger than the subject tree
PCCF	is crown competition factor on the inventory point where the tree is established
SI	is species site index
HAB	is a plant association code dependent coefficient shown in table 4.7.1.4
b_1	is a location-specific coefficient shown in table 4.7.1.2
b_2- b_{14}	are species-specific coefficients shown in table 4.7.1.1

Table 4.7.1.1 Coefficients (b_2- b_{14}) for equation {4.7.1.1} in the IE variant.

	Alpha Code					
Coefficient	**WP**	**WL, WB**	**DF**	**GF**	**WH**	**RC**
b_2	0.03517	0.0373	0.02591	0.00917	0.02863	-0.00175
b_3	-0.000467	-0.000433	-0.000377	-0.000117	-0.000422	-0.000067
b_4	0.03876	0.0343	0.06287	-0.04595	0.10987	0.05534
b_5	0.09817	-0.21337	-0.04562	-0.01215	0.08277	-0.06625
b_6	-0.17888	0.33523	0.78176	1.17025	0.04966	0.11931
b_7	0	-0.70216	-1.1238	-1.52006	0	0
b_8[1]						
b_9	0.56445	0.5414	0.56888	0.6881	0.68712	0.58705
b_{10}	0.42112	0.43637	0.50202	0.45142	0	0.74596
b_{11}	1.08338	1.03478	2.0685	1.93969	1.64133	1.2936
b_{12}	0	0.07509	-0.62361	-0.78258	-0.27244	0
b_{13}[2]						
b_{14}	-2.08272	-2.03256	-2.1159	-1.76812	-0.80918	-2.28375
	Alpha Code					
Coefficient	**LP**	**ES**	**AF, LL**	**PP**	**MH, OS**	**LS, PY**
b_2	-0.0048	0.06259	0.06313	0.03229	0.08518	0
b_3	-0.000058	-0.000709	-0.000676	-0.000422	-0.000943	0
b_4	0.12993	-0.06038	-0.06862	0.01192	0.13363	-0.01752
b_5	0.00325	-0.13091	-0.12473	-0.09976	0.17935	-0.609774
b_6	0.46546	0.65622	0.3007	-0.06637	0.07628	-2.05706
b_7	-0.58014	-0.90143	-0.62224	-0.4372	0	2.113263
b_8[1]						
b_9	0.89503	0.73045	0.8624	0.66101	0.89778	0.213947
b_{10}	-0.03665	0.25639	0	0	0	-0.358634
b_{11}	1.85558	1.54643	0.52044	1.31618	1.28403	1.523464
b_{12}	-0.36393	-0.26635	0.86236	0	0	0
b_{13}[2]						
b_{14}	-0.43329	-1.18218	-0.5127	-1.25881	-0.6611	0

[1]See Table 4.7.1.4 for b_8 values
[2]See Table 4.7.1.6 for b_{13} values

Table 4.7.1.2 b_1 values by location class for equation {4.7.1.1} in the IE variant.

Location Class	Alpha Code											
	WP	WL, WB	DF	GF	WH	RC	LP	ES	AF, LL	PP	MH, OS	LM, PY
1	0.1692	0.20004	0.50357	0.43443	0.10667	0.5007	0.43735	0.26262	0.42062	0.24588	0.1252	1.568742
2	0	0.07656	0.3492	0.28344	0.44357	0.17647	0.21113	-0.15871	0.14072	0.56958	0.48076	0
3	0	0.08188	0.21961	-0.14829	0	0.31745	0.14808	0	-0.13001	0.42787	0	0
4	0	0.30379	0.61812	0.20205	0	0	0	0	0	0	0	0
5	0	0	0	0.57763	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0

Table 4.7.1.3 Location class by species and location code for equation {4.7.1.1} in the IE variant.

Location Code	Alpha Code											
	WP	WL, WB	DF	GF	WH	RC	LP	ES	AF, LL	PP	MH, OS	LM, PY
103 - Bitterroot	2	1	5	6	4	4	3	4	1	3	3	1
104 - Idaho Panhandle	1	1	4	5	1	2	1	1	2	2	2	1
105 - Clearwater	2	1	1	1	1	1	1	1	2	1	3	1
106 - Coeur d'Alene	2	2	2	2	1	1	1	2	2	1	1	1
110 - Flathead	2	3	3	2	2	2	3	2	1	3	3	1
113 - Kaniksu	2	3	3	3	2	4	2	3	4	3	3	1
114 - Kootenai	2	2	2	2	3	3	3	3	3	3	3	1
116 - Lolo	2	5	3	4	4	3	3	4	1	3	3	1
117 - Nezperce	2	5	5	6	2	4	3	4	4	1	3	1
118 - St. Joe	2	4	1	2	1	2	1	2	3	3	3	1
621 - Colville	1	1	4	5	1	2	1	1	2	2	2	1

Table 4.7.1.4 b_8 values by habitat class for equation {4.7.1.1} in the IE variant.

Habitat Class	Alpha Code											
	WP	WL, WB	DF	GF	WH	RC	LP	ES	AF, LL	PP	MH, OS	LM, PY
1	-0.0243	-0.10144	-0.09046	-0.09624	0	-0.05054	-0.05576	-0.01547	-0.01598	-0.10416	-0.10744	-0.199592
2	-0.24886	-0.14793	-0.11884	-0.19544	0	-0.15356	-0.14919	-0.38386	-0.04477	-0.88809	0	0
3	-0.01079	-0.05438	-0.05529	-0.05119	0	-0.09396	-0.4064	-0.05371	-0.07392	-0.25938	0	0
4	0	0	-0.0218	0	0	0	-0.114	-0.15159	0	-0.14726	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0

Table 4.7.1.5 Habitat class by species and habitat code for b8 in equation {4.7.1.1} in the IE variant.

Habitat Code	Alpha Code											
	WP	WL, WB	DF	GF	WH	RC	LP	ES	AF, LL	PP	MH, OS	LM, PY
130	3	3	4	3	1	3	4	4	3	2	1	1
170	3	3	4	3	1	3	4	4	3	2	1	1

Habitat Code	Alpha Code											
	WP	WL, WB	DF	GF	WH	RC	LP	ES	AF, LL	PP	MH, OS	LM, PY
250	3	3	4	3	1	3	1	4	3	3	1	1
260	3	3	4	3	1	3	4	4	3	1	1	1
280	3	3	4	3	1	3	3	4	3	4	1	1
290	3	3	4	3	1	3	4	4	3	3	1	1
310	3	3	1	3	1	3	2	4	3	3	1	1
320	3	3	2	3	1	3	1	4	3	1	1	1
330	3	3	4	3	1	3	4	4	3	2	1	1
420	3	3	4	3	1	3	1	4	3	4	1	1
470	3	3	4	3	1	3	4	4	3	4	1	1
510	3	1	2	3	1	3	4	3	3	1	1	1
520	1	3	1	1	1	3	4	3	1	4	1	1
530	3	3	4	3	1	1	2	1	1	4	1	1
540	3	3	4	3	1	2	2	1	1	4	1	1
550	3	3	4	3	1	2	2	1	1	4	1	1
570	1	3	3	3	1	3	2	3	1	1	1	1
610	3	3	4	3	1	3	2	3	1	4	1	1
620	3	2	4	3	1	2	2	1	1	4	1	1
640	3	3	4	3	1	3	4	4	3	4	1	1
660	3	1	1	3	1	3	1	2	1	4	1	1
670	2	3	3	3	1	1	4	4	1	4	1	1
680	2	3	2	2	1	3	1	1	2	4	1	1
690	3	1	4	2	1	3	4	4	2	4	1	1
710	3	3	4	3	1	3	4	4	1	4	1	1
720	3	3	4	3	1	3	4	4	3	4	1	1
730	3	3	4	3	1	3	1	1	1	4	1	1
830	3	3	2	3	1	3	4	4	1	4	1	1
850	3	3	4	3	1	3	4	4	3	4	1	1
999	3	3	4	3	1	3	4	4	3	4	1	1

Table 4.7.1.6 b_{13} values by location class for equation {4.7.1.1} in the IE variant.

Location Class	Alpha Code					
	WP	WL, WB	DF	GF	WH	RC
1	-0.000439	-0.00031	-0.000252	-0.000274	-0.000225	0
2	-0.000004	-0.000566	-0.000373	-0.000089	-0.000216	0
3	0	0	-0.000502	-0.000643	-0.000429	0
4	0	0	-0.000572	0	0	0
Location Class	**Alpha Code**					
	LP	**ES**	**AF, LL**	**PP**	**MH, OS**	**LS, PY**

1	-0.00126	-0.000132	-0.000283	-0.000406	-0.000484	-0.0006538
2	-0.002168	-0.000294	-0.00078	-0.000437	-0.000306	0
3	-0.001889	-0.000427	0	-0.00014	0	0
4	-0.000867	0	0	0	0	0

Table 4.7.1.7 Location class by species and location code for b_{13} in equation {4.7.1.1} in the IE variant.

Location Code	Alpha Code											
	WP	WL, WB	DF	GF	WH	RC	LP	ES	AF, LL	PP	MH, OS	LM, PY
103 - Bitterroot	1	1	1	1	1	1	1	1	1	1	1	1
104 - Idaho Panhandle	2	2	4	1	3	1	1	1	2	2	2	1
105 - Clearwater	2	1	2	1	1	2	2	2	2	2	1	1
106 - Coeur d’Alene	2	1	2	1	2	1	2	1	1	2	1	1
110 - Flathead	1	1	3	2	1	1	1	1	1	3	1	1
113 - Kaniksu	2	1	1	2	1	1	2	3	1	3	1	1
114 - Kootenai	1	1	4	3	1	2	3	2	2	2	1	1
116 - Lolo	1	1	1	1	1	1	1	1	1	1	2	1
117 - Nezperce	1	1	1	2	1	2	4	1	1	1	1	1
118 - St. Joe	2	2	4	1	3	1	1	1	2	2	2	1
621 - Colville	2	1	2	1	3	1	1	1	2	2	1	1

Table 4.7.1.8 *HAB* values by habitat class for equation {4.7.1.1} in the IE variant.*

Habitat Class	Alpha Code										
	WP	WL, WB	DF	GF	WH	RC	LP	ES	AF, LL	PP	MH, OS
1	1.15584	0.38335	0.4778	0.66755	0.45264	1.61452	0.77399	-0.58842	-0.96389	1.16233	-1.68033
2	1.05635	0.51291	0.15228	0.60454	0	1.31772	0.67828	-0.21235	-0.72415	0.73408	-1.52111
3	0	0.45377	0.29764	0	0	0	0.64451	-0.71629	-0.57308	0.51417	0
4	0	0.71322	0	0	0	0	0.37945	-0.53954	-0.82218	0	0
5	0	0.26835	0	0	0	0	0.54337	0	-1.24093	0	0
6	0	0	0	0	0	0	0	0	-1.10746	0	0

**HAB* values for LM and PY are equal to 0.

Table 4.7.1.9 Habitat class by species and habitat code for *HAB* values in equation {4.7.1.1} in the IE variant.

Habitat Code	Alpha Code										
	WP	WL, WB	DF	GF	WH	RC	LP	ES	AF, LL	PP	MH, OS
130	2	5	3	2	1	2	5	4	6	1	2
170	2	5	3	2	1	2	5	4	6	1	2
250	2	5	3	2	1	2	5	4	6	2	2
260	2	5	3	2	1	2	5	4	6	3	2
280	2	5	3	2	1	2	1	4	6	3	2

Habitat Code	Alpha Code									
	WP	**WL, WB**	**DF**	**GF**	**WH**	**RC**	**LP**	**ES**	**AF, LL**	**PP**	**MH, OS**
290	2	5	3	2	1	2	2	4	6	2	2
310	2	5	3	2	1	2	1	4	6	2	2
320	2	5	1	2	1	2	5	4	6	3	2
330	2	5	3	2	1	2	5	4	6	3	2
420	2	1	3	2	1	2	5	4	6	3	2
470	2	1	3	2	1	2	5	4	6	3	2
510	2	2	1	2	1	2	2	1	6	2	2
520	1	1	1	1	1	2	2	1	1	2	2
530	1	2	1	2	1	2	3	4	2	2	2
540	1	2	1	2	1	1	3	2	3	3	2
550	1	2	1	2	1	1	3	2	3	3	2
570	1	3	1	2	1	2	3	4	4	3	2
610	1	3	1	2	1	2	3	2	3	3	2
620	1	2	1	2	1	2	3	1	1	2	2
640	2	5	3	2	1	2	4	4	6	3	2
660	2	2	2	2	1	2	4	4	6	3	2
670	1	1	3	1	1	2	3	4	6	3	1
680	1	1	3	2	1	2	4	4	6	3	2
690	2	1	3	2	1	2	5	4	6	3	2
710	2	5	3	1	1	2	5	4	6	3	2
720	2	5	3	2	1	2	5	4	6	3	2
730	2	4	3	2	1	2	4	4	1	3	2
830	2	5	2	2	1	2	4	3	5	3	2
850	2	5	3	2	1	2	5	4	5	3	2
999	2	5	3	2	1	2	5	4	6	3	2

Large-tree diameter growth for pinyon pine and Rocky Mountain juniper is predicted from equations used in the UT variant identified in equation set {4.7.1.3}. Diameter at the end of the growth cycle is predicted first. Then diameter growth is calculated as the difference between the diameters at the beginning of the cycle and end of the cycle, adjusted for bark ratio. While not shown here, this diameter growth estimate is eventually converted to the *DDS* scale.

{4.7.1.3} Used for pinyon pine (PI) and Rocky Mountain juniper (JU)

$$DF = 0.25897 + 1.03129 * DBH - 0.0002025464 * BA + 0.00177 * SI$$
$$DG = (DF - DBH) * BRATIO$$

where:

DF	is tree diameter at breast height at the end of the cycle
DBH	is tree diameter at breast height
BA	is total stand basal area
SI	is species site index

DG	is tree diameter growth
BRATIO	is species-specific bark ratio

Large-tree diameter growth for aspen (18), Rocky mountain maple (20), and paper birch (21) is predicted using the aspen equation from the UT variant identified in equation set {4.7.1.4}. Diameter growth is predicted from a potential diameter growth equation that is modified by stand density, average tree size and site. While not shown here, this diameter growth estimate is eventually converted to the *DDS* scale.

{4.7.1.4} Used for quaking aspen (18), Rocky mountain maple (20), and paper birch (21)

$$POTGR = (0.4755 - 0.0000038336 * DBH^{4.1488}) + (0.0451 * CR * DBH^{.67266})$$
$$MOD = 1.0 - \exp(-FOFR * GOFAD * ((310-BA)/310)^{0.5})$$
$$FOFR = 1.07528 * (1.0 - \exp(-1.89022 * DBH / QMD))$$
$$GOFAD = 0.21963 * (QMD + 1.0)^{0.73355}$$
$$PREDGR = POTGR * MOD * (.48630 + 0.01258 * SI)$$

where:

POTGR	is potential diameter growth
DBH	is tree diameter at breast height
CR	is crown ratio expressed as a percent divided by 10
MOD	is a modifier based on tree diameter and stand density
FOFR	is the relative density modifier
GOFAD	is the average diameter modifier
BA	is total stand basal area
QMD	is stand quadratic mean diameter
PREDGR	is predicted diameter growth
SI	is species site index

Large-tree diameter growth for cottonwood (19) and other hardwoods (22) is predicted using equations from the CR variant identified in equation set {4.7.1.6}. Diameter at the end of the growth cycle is predicted first. Then diameter growth is calculated as the difference between the diameters at the beginning of the cycle and end of the cycle, adjusted for bark ratio. While not shown here, this diameter growth estimate is eventually converted to the *DDS* scale.

{4.7.1.6} Used for cottonwood (CO) and "other hardwoods" (OH)

$$DF = 0.24506 + 1.01291 * DBH - 0.00084659 * BA + 0.00631 * SI$$
$$DG = (DF - DBH) * BRATIO$$

where:

DF	is tree diameter at breast height at the end of the cycle
DG	is tree diameter growth
DBH	is tree diameter at breast height
BA	is total stand basal area
SI	is species site index
DG	is tree diameter growth
BRATIO	is species-specific bark ratio

DDS is the predicted periodic change in squared inside-bark diameter

4.7.2 Large Tree Height Growth

In the IE variant, equation {4.7.2.1} is used to estimate large tree height growth. Equations were fit for each different species in the IE variant. Species numbers 1 – 12, subalpine larch (14), and other softwoods (23) all use a single equation form for large tree height growth in the IE variant as shown in equation {4.7.2.1}. Pinyon pine and Rocky Mountain juniper use the same equations described in the small tree height growth model (see section 4.6.1) to calculate height growth for large trees. All other species use equation forms shown later in this section.

{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
- *DG* is 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 IE variant.

	Alpha Code										
Coefficient	**WP**	**WL, WB**	**DF**	**GF**	**WH**	**RC**	**LP**	**ES**	**AF, LL**	**PP**	**MH, OS**
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	-0.572	-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 for the height-growth equation in the IE variant.

	Coefficient		
Habitat Codes	**b_1**	**b_4**	***HAB***
130, 170, 660, 730, 830, 850, 999	-0.000134	0.62144	2.03035
250, 260, 280, 290, 310, 320, 330	-0.0000381	1.02372	1.72222
420, 470	-0.0000372	0.85493	1.19728
510, 620, 640, 670, 680	-0.0000261	0.75756	1.81759
520	-0.000052	0.46238	2.14781
530	-0.0000161	0.49643	1.76998
540, 550, 570, 610	-0.0000363	0.37042	2.21104
690, 710, 720	-0.0000446	0.34003	1.7409

Limber pine and quaking aspen use Johnson's SBB (1949) method (Schreuder and Hafley, 1977). Height increment, using this method, is obtained by subtracting current height from the estimated future height. If tree diameter is greater than (C_1 + 0.1), or tree height is greater than (C_2 + 4.5), where C_1 and C_2 are shown in table 4.7.2.3, parameters of the SBB distribution cannot be calculated and height growth is set to 0.1. Otherwise, the SBB distribution "*Z*" parameter is estimated using equation {4.7.2.2}.

{4.7.2.2} $Z = [C_4 + C_6 * FBY2 - C_7 * (C_3 + C_5 * FBY1)] * (1 - C_7^2)$^-0.5

$FBY1 = \ln[Y1/(1 - Y1)]$
$FBY2 = \ln[Y2/(1 - Y2)]$
$Y1 = (DBH - 0.095) / C_1$
$Y2 = (HT - 4.5) / C_2$

where:

HT	is tree height at the beginning of the cycle
DBH	is tree diameter at breast height at the beginning of the cycle
$C_1 - C_7$	are coefficients based on species and crown ratio class shown in table 4.7.2.3

The equation for limber pine is from the Tetons (TT) variant, and is also used for Pacific Yew. The equation for quaking aspen is from the Utah (UT) variant, and is also used for Rocky Mountain Maple, paper birch, and the "other hardwoods" category.

Quaking aspen, Rocky Mountain maple, paper birch, and "other hardwoods" use equation {4.7.2.3} to eliminate known bias.

{4.7.2.3} Z = Z + (0.1 – 0.10273 * *Z* + 0.00273 * *Z*^2) if Z < 0; set Z = 0

If the *Z* value is 2.0 or less, it is adjusted for all younger aged trees using equation {4.7.2.4}. This adjustment is done for trees with an estimated age between 11 and 39 years and a diameter less than 9.0 inches. After this calculation, the value of *Z* is bounded to be 2.0 or less for trees meeting these criteria.

{4.7.2.4} $Z = Z * (0.3564 * DG) * CLOSUR * K$

$CCF \geq 100: CLOSUR = PCT / 100$
$CCF < 100: CLOSUR = 1$
$CR \geq 75\%: K = 1.1$
$CR < 75\%: K = 1.0$

where:

DG	is diameter growth for the cycle
PCT	is the subject tree's percentile in the basal area distribution of the stand
CCF	is stand crown competition factor

Estimated height 10 years later is calculated using equation {4.7.2.5}, and finally, 10-year height growth is calculated by subtraction using equation {4.7.2.6} and adjusted to the cycle length.

{4.7.2.5} $H10 = [(PSI / (1 + PSI)) * C_2] + 4.5$

$PSI = C_8 * [(D10 - 0.1) / (0.1 + C_1 - D10)]$^$C_9$ * [exp(*K*)]
$K = Z * [(1 - C_7$^2)^(0.5 / C_6)]

{4.7.2.6}Height Growth equation

$H10 > HT$: $POTHTG = H10 - HT$
$H10 \leq HT$: $POTHTG = 0.1$

where:

H10	is estimated height of the tree in ten years
HT	is tree height at the beginning of the cycle
D10	is estimated diameter at breast height of the tree in ten years
POTHTG	is potential height growth
$C_1 - C_9$	are coefficients based on species and crown ratio class shown in table 4.7.2.3

Table 4.7.2.3 Coefficients in the large tree height growth model, by crown ratio, for species using the Johnson's SBB height distribution in the IE variant.

Coefficient*	LM, PY	AS, CO, MM, PB, OH
C_1 ($CR \leq 24$)	37.0	30.0
C_1 ($25 \leq CR \leq 74$)	45.0	30.0
C_1 ($75 \leq CR \leq 100$)	45.0	35.0
C_2 ($CR \leq 24$)	85.0	85.0
C_2 ($25 \leq CR \leq 74$)	100.0	85.0
C_2 ($75 \leq CR \leq 100$)	90.0	85.0
C_3 ($CR \leq 24$)	1.77836	2.00995
C_3 ($25 \leq CR \leq 74$)	1.66674	2.00995
C_3 ($75 \leq CR \leq 100$)	1.64770	1.80388
C_4 ($CR \leq 24$)	-0.51147	0.03288
C_4 ($25 \leq CR \leq 74$)	0.25626	0.03288
C_4 ($75 \leq CR \leq 100$)	0.30546	-0.07682
C_5 ($CR \leq 24$)	1.88795	1.81059
C_5 ($25 \leq CR \leq 74$)	1.45477	1.81059
C_5 ($75 \leq CR \leq 100$)	1.35015	1.70032
C_6 ($CR \leq 24$)	1.20654	1.28612
C_6 ($25 \leq CR \leq 74$)	1.11251	1.28612
C_6 ($75 \leq CR \leq 100$)	0.94823	1.29148
C_7 ($CR \leq 24$)	0.57697	0.72051
C_7 ($25 \leq CR \leq 74$)	0.67375	0.72051
C_7 ($75 \leq CR \leq 100$)	0.70453	0.72343
C_8 ($CR \leq 24$)	3.57635	3.00551
C_8 ($25 \leq CR \leq 74$)	2.17942	3.00551
C_8 ($75 \leq CR \leq 100$)	2.46480	2.91519
C_9 ($CR \leq 24$)	0.90283	1.01433
C_9 ($25 \leq CR \leq 74$)	0.88103	1.01433
C_9 ($75 \leq CR \leq 100$)	1.00316	0.95244

**CR* represents percent crown ratio

5.0 Mortality Model

All species in the IE 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 $-70 \le X \le 70$

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 $DBH \le 5.0''$: $RADJ = (1 - ((0.20 + (0.05 * I)) + 1)$^-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 $DBH \le 5.0''$: $G = 2.50 / (0.20 + (0.05 * I)) * DG$
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 $DBH \le 5.0''$, see table 5.0.3
b_0	is a species-specific coefficient shown in table 5.0.1

Table 5.0.1 b_0 coefficients used in the mortality equation set {5.0.1} in the IE variant.

FVS Number	Alpha Code	b_0
1	WP	0

FVS Number	Alpha Code	b_0
2	WL	-0.17603
3	DF	0.317888
4	GF	0.317888
5	WH	0.607725
6	RC	1.57976
7	LP	-0.12057
8	ES	0.94019
9	AF	0.2118
10	PP	0.2118
11	MH	0
12	WB	-0.17603
13	LM	0
14	LL	0.2118
15	PI	0
16	RM	0
17	PY	0
18	AS	0
19	CO	0
20	MM	0
21	PB	0
22	OH	0
23	OS	0

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

Habitat Code*	National Forest by Location Code										
	103	**104**	**105**	**106**	**110**	**113**	**114**	**116**	**117**	**118**	**621**
130	7	15	14	12	9	13	9	7	15	15	10
170	6	15	14	12	9	12	9	7	15	15	10
250	6	15	14	12	9	12	9	7	15	15	10
260	6	15	14	12	9	12	9	7	15	15	10
280	6	14	13	11	9	12	8	6	14	14	9
290	6	14	13	11	9	12	9	7	14	14	9
310	5	12	11	10	7	10	7	5	9	12	8
320	6	14	14	10	8	12	8	6	13	14	9
330	5	13	12	10	8	11	7	7	13	13	8
420	6	14	14	11	8	11	8	6	14	14	9
470	6	14	14	11	9	11	8	6	14	14	10
510	6	15	14	12	9	12	8	7	13	15	10
520	6	15	14	12	9	12	9	7	14	15	10
530	8	17	17	14	11	15	11	9	18	17	12
540	7	15	14	14	10	13	10	9	14	15	11

Habitat	National Forest by Location Code										
Code*	**103**	**104**	**105**	**106**	**110**	**113**	**114**	**116**	**117**	**118**	**621**
550	7	15	14	14	10	13	10	8	14	15	11
570	7	16	15	13	10	14	10	9	14	16	11
610	7	15	15	13	10	13	10	8	14	15	11
620	7	15	15	13	11	13	10	8	14	15	11
640	5	11	11	9	7	9	7	5	10	11	8
660	3	16	9	6	5	8	5	3	9	10	6
670	4	11	10	8	6	9	6	5	9	11	7
680	3	9	8	7	4	7	5	4	8	9	5
690	4	12	11	9	7	10	7	5	11	12	7
710	4	12	11	10	7	10	7	5	11	12	7
720	6	15	15	12	9	12	9	7	15	15	10
730	5	12	11	10	8	10	8	5	9	12	8
830	1	7	5	4	3	4	3	2	6	7	6
850	1	10	10	8	6	8	6	4	8	10	7
999	6	15	15	12	9	12	9	7	15	15	10

*Habitat code shown here is the Original NI Habitat Type shown in Appendix A table 11.1.1

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

Habitat	National Forest by Location Code										
Code*	**103**	**104**	**105**	**106**	**110**	**113**	**114**	**116**	**117**	**118**	**621**
130	30	50	45	41	38	41	38	31	45	50	38
170	29	49	45	41	37	41	37	29	45	49	37
250	29	49	45	41	37	41	37	30	45	49	37
260	29	49	45	41	37	41	37	31	45	49	37
280	28	48	44	40	36	40	37	29	44	48	36
290	28	48	44	40	36	40	37	30	44	48	37
310	27	47	43	39	36	39	37	29	43	47	37
320	31	52	48	42	38	45	41	33	48	52	40
330	27	46	43	39	36	37	33	31	41	46	35
420	27	47	43	39	35	38	37	30	42	47	36
470	28	48	44	40	37	39	37	29	43	48	37
510	31	53	49	44	41	43	41	34	47	53	41
520	32	54	50	45	41	44	41	34	48	54	41
530	32	54	50	45	41	46	42	35	50	54	42
540	31	52	49	45	40	43	39	34	47	52	40
550	31	52	49	45	40	43	39	34	47	52	40
570	32	54	49	45	41	45	41	35	46	54	41
610	31	50	47	43	40	43	40	33	44	50	40
620	31	51	47	44	40	43	40	33	44	51	40
640	25	41	39	36	33	35	33	27	36	41	33

Habitat Code*	National Forest by Location Code										
	103	**104**	**105**	**106**	**110**	**113**	**114**	**116**	**117**	**118**	**621**
660	23	39	36	33	32	33	32	23	34	39	30
670	24	44	40	36	32	35	33	26	37	44	33
680	23	43	39	36	32	35	33	26	37	43	31
690	24	44	40	37	34	36	34	27	38	44	32
710	24	44	39	38	33	36	33	26	37	44	31
720	27	50	45	41	38	41	38	31	43	50	36
730	26	53	41	38	35	37	35	26	34	53	34
830	18	36	33	30	26	30	28	19	30	36	32
850	16	37	34	31	28	32	32	23	33	37	27
999	27	50	45	41	38	41	38	31	43	50	36

*Habitat code shown here is the Original NI Habitat Type shown in Appendix A, table 11.1.1

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

For pinyon pine and Rocky Mountain juniper equation {5.0.2} is modified by 60%; for limber pine, Pacific yew, quaking aspen, cottonwood species, Rocky Mountain maple, paper birch, and “other softwoods” equation {5.0.2} is modified by 40%.

6.0 Regeneration

The IE variant contain 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 how sprouting occurs and 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. In the IE variant, sprouts are automatically added to the simulation following harvest or burning of known sprouting species (see table 6.0.1 for sprouting species). Users wanting to modify or turn off automatic sprouting can do so with the SPROUT or NOSPROUT keywords, respectively. Sprouts are not subject to maximum and minimum tree heights found in table 6.0.1 and do not need to be grown to the end of the cycle because estimated heights and diameters are end of cycle values.

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 keywords; 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 and sprouts 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 IE variant.

FVS Number	Alpha Code	Sprouting Species	Minimum Bud Width (in)	Minimum Tree Height (ft)	Maximum Tree Height (ft)
1	WP	No	0.4	1.0	23.0
2	WL	No	0.3	1.0	27.0
3	DF	No	0.3	1.0	21.0
4	GF	No	0.3	0.5	21.0
5	WH	No	0.2	0.5	22.0
6	RC	No	0.2	0.5	20.0
7	LP	No	0.4	1.0	24.0

FVS Number	Alpha Code	Sprouting Species	Minimum Bud Width (in)	Minimum Tree Height (ft)	Maximum Tree Height (ft)
8	ES	No	0.3	0.5	18.0
9	AF	No	0.3	0.5	18.0
10	PP	No	0.5	1.0	17.0
11	MH	No	0.2	0.5	22.0
12	WB	No	0.3	1.0	27.0
13	LM	No	0.3	1.0	27.0
14	LL	No	0.3	0.5	18.0
15	PI	No	0.4	0.5	6.0
16	RM	No	0.3	0.5	6.0
17	PY	Yes	0.3	1.0	27.0
18	AS	Yes	0.2	6.0	16.0
19	CO	Yes	0.2	3.0	16.0
20	MM	Yes	0.2	6.0	16.0
21	PB	Yes	0.2	6.0	16.0
22	OH	No	0.2	3.0	16.0
23	OS	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 for the IE variant are shown in tables 7.0.1.

Table 7.0.1 Default volume merchantability standards for the IE variant.

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

Note: Board foot volume is not calculated for cottonwood species and paper birch when using the default equations.

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 IE 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 have been developed through the participation and contribution of various organizations led by Forest Health Protection. The models are maintained by the Forest Health Technology Enterprise Team (FHTET) and regional Forest Health Protection specialists. A complete list of the available insect and disease models for the IE variant is located in table 9.0.1. The dwarf mistletoe model is available in the base FVS variant, while the other models are available through the insect and disease extension of the IE variant available on the FVS website. Additional details regarding each model may be found in chapter 8 of the Essential FVS Users Guide (Dixon 2002); for more detailed information, users can download the individual model guides from the FHTET website.

Table 9.0.1 Available insect and disease extensions for the IE variant.

Insect and Disease Models
Dwarf Mistletoe
Douglas-Fir Beetle
Douglas-Fir Tussock Moth
Lodgepole Mountain Pine Beetle
Western Root Disease
Western Spruce Budworm Damage
White Pine Blister Rust

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11.0 Appendices

11.1 Appendix A. Habitat Codes

Table 11.1.1 Habitat type codes and their corresponding original NI variant habitat type codes recognized in the IE variant. Original codes are used in growth equations. Habitat type codes are from Pfister and others (1977). The codes given are for habitat types. Phases are treated as subsets of habitat types. For instance, the codes 261 and 262 are interpreted the same as code 260.

Habitat Code	Abbreviation	Habitat Type Name	Original Habitat Type
10	SCREE	*Scree*	130
100	PIPO	*Ponderosa pine series*	130
110	PIPO/AND	*Ponderosa pine/bluestem*	130
130	PIPO/AGSP	*Ponderosa pine/ bluebunch wheatgrass*	130
140	PIPO/FEID	*Ponderosa pine/Idaho fescue*	130
160	PIPO/PUTR	*Ponderosa pine/bitterbrush*	170
170	PIPO/SYAL	*Ponderosa pine/Common snowberry*	170
180	PIPO/PRVI	*Ponderosa pine/chokecherry*	170
190	PIPO/PHMA	*Ponderosa pine/ninebark*	170
200	PSME	*Douglas-fir series*	260
210	PSME/AGSP	*Douglas-fir/Bluebench wheatgrass*	130
220	PSME/FEID	*Douglas-fir/Idaho fescue*	130
230	PSME/FESC	*Douglas-fir/altai fescue*	130
250	PSME/VACA	*Douglas-fir/Dwarf huckleberry*	250
260	PSME/PHMA	*Douglas-fir/ninebark*	260
280	PSME/VAGL	*Douglas-fir/blue huckleberry*	280
290	PSME/LIBO	*Douglas-fir/twinflower*	290
310	PSME/SYAL	*Douglas-fir/common snowberry*	310
320	PSME/CARU	*Douglas-fir/pinegrass*	320
330	PSME/CAGE	*Douglas-fir/elk sedge*	330
340	PSME/SPBE	*Douglas-fir/white spirea*	320
350	PSME/ARUV	*Douglas-fir/kinnikinnick*	320
360	PSME/JUCO	*Douglas-fir/common juniper*	330
370	PSME/ARCO	*Douglas-fir/Heartleaf arnica*	310
380	PSME/SYOR	*Douglas-fir/mountain snowberry*	250
400	PICEA	*Spruce series*	420
410	PICEA /EQAR	*Spruce/common horsetail*	420
420	PICEA /CLUN	*Spruce/bride's bonnet*	420
430	PICEA /PHMA	*Spruce/mallow ninebark*	260
440	PICEA /GATR	*Spruce/sweetscented bedstraw*	470

Habitat Code	Abbreviation	Habitat Type Name	Original Habitat Type
450	PICEA /VACA	*Spruce/dwarf bilberry*	640
460	PICEA /SEST	*Spruce/rocky mountain groundsel*	850
470	PICEA /LIBO	*Spruce/twinflower*	470
480	PICEA /SMST	*Spruce/starry false lily of the valley*	470
500	ABGR	*Grand fir series*	520
501	THPL	*Western red cedar series*	530
502	TSHE	*Western hemlock series*	570
505	ABGR/SPBE	*Grand fir/white spiraea*	510
506	ABGR/PHMA	*Grand fir/ninebark*	510
510	ABGR/XETE	*Grand fir/beargrass*	510
515	ABGR/VAGL	*Grand fir/blue huckleberry*	510
516	ABGR/ASCA	*Grand fir/blue huckleberry*	520
520	ABGR/CLUN	*Grand fir/bride's bonnet*	520
529	ABGR/SETR	*Grand fir/arrowleaf ragwort*	520
530	THPL/CLUN	*Western red cedar/bride's bonnet*	530
540	THPL/ATFI	*Western red cedar/common ladyfern*	540
545	THPL/ASCA	*Western red cedar/British Columbia wildginger*	530
550	THPL/OPHO	*Western red cedar/devilsclub*	550
555	THPL/GYDR	*Western red cedar/western oakfern*	530
560	THPL/ADPE	*Western red cedar/northern maidenhair*	550
565	TSHE/GYDR	*Western hemlock/western oakfern*	570
570	TSHE/CLUN	*Western hemlock/bride's bonnet*	570
575	TSHE/ASCA	*Western hemlock/British Columbia wildginger*	570
579	TSHE/MEFE	*Western hemlock/rusty menziesia*	690
590	ABGR/LIBO	*Grand fir/twinflower*	510
600	ABLA	*Subalpine fir series*	690
610	ABLA/OPHO	*Subalpine fir/devilsclub*	610
620	ABLA/CLUN	*Subalpine fir/twisted stalk*	620
630	ABLA/GATR	*Subalpine fir/fragrant bedstraw*	660
635	ABLA/STAM	*Subalpine fir/twisted-stalk*	620
640	ABLA/VACA	*Subalpine fir/dwarf huckleberry*	640
650	ABLA/CACA	*Subalpine fir/bluejoint*	640
660	ABLA/LIBO	*Subalpine fir/twinflower*	660
670	ABLA/MEFE	*Subalpine fir/menziesia*	670
675	TSME/STAM	*Mountain hemlock/claspleaf twistedstalk*	620
680	TSME/MEFE	*Mountain hemlock/menziesia*	680
685	TSME/CLUN	*Mountain hemlock/bride's bonnet*	620
690	ABLA/XETE	*Subalpine fir/beargrass*	690

Habitat Code	Abbreviation	Habitat Type Name	Original Habitat Type
700	TSME	*Subalpine fir, lower subalpine*	730
701	TSME	*Mountain hemlock series*	710
710	TSME/XETE	*Mountain hemlock/beargrass*	710
720	ABLA/VAGL	*Subalpine fir/blue huckleberry*	720
730	ABLA/VASC	*Subalpine fir/grouse whortleberry*	730
740	ABLA/ALSI	*Subalpine fir/sitka alder*	670
750	ABLA/CARU	*Subalpine fir/pinegrass*	690
770	ABLA/CLPS	*Subalpine fir/rock clematis*	730
780	ABLA/ARCO	*Subalpine fir/heartleaf arnica*	690
790	ABLA/CAGE	*Subalpine fir/elk sedge*	730
800	ABLA	*subalpine fir, upper subalpine*	830
810	ABLA/RIMO	*Subalpine fir/mountain gooseberry*	830
820	ABLA-PIAL/VASC	*Subalpine fir/whitebark pine/grouse whortleberry*	850
830	ABLA/LUHI	*Subalpine fir/smooth woodrush*	830
840	TSME/LUHI	*Mountain hemlock/Hitchcock's smooth woodrush*	830
850	PIAL-ABLA	*Whitebark pine-subalpine fir*	850
860	LALY-ABLA	*Alpine larch-subalpine fir*	850
870	PIAL	*Whitebark pine series*	850
890	ABLA	*Subalpine fir, timberline*	850
900	PICO	*Lodgepole pine series*	730
910	PICO/PUTR	*Lodgepole pine/antelope bitterbrush*	330
920	PICO/VACA	*Lodgepole pine/dwarf huckleberry*	640
925	PICO/XETE	*Lodgepole pine/common beargrass*	690
930	PICO/LIBO	*Lodgepole pine/twinflower*	660
940	PICO/VASC	*Lodgepole pine/grouse whortleberry*	730
950	PICO/CARU	*Lodgepole pine/pinegrass*	690
999	Other	---	999

Table 11.1.2. Codes for Colville National Forest plant associations represented in the IE variant, and their associated habitat type.

Plant Assoc FVS Seq Number Code	Plant Association Code	Plant Association Abbreviation	Description	Mapped to Habitat Type
1	CCF221	THPL/CLUN	Western redcedar/Queencup beadlily	530
2	CCF222	THPL/ARNU3	Western redcedar/Wild sarsaparilla	530

Plant Assoc FVS Seq Number Code	Plant Association Code	Plant Association Abbreviation	Description	Mapped to Habitat Type
3	CCS311	THPL/CLUN	Western redcedar/Big huckleberry	530
4	CDG131	PSME/CARU	Douglas-fir/Pinegrass, Okanogan & Colville	320
5	CDG311	PSME-PIPO/AGIN	Douglas-fir-ponderosa pine/Wheatgrass	130
6	CDS632	PSME/SYOR	Douglas-fir/Mountain snowberry	380
7	CDS633	PSME/SYAL	Douglas-fir/Common snowberry	310
8	CDS637	PSME/SYAL/AGSP	Douglas-fir/Common snowberry/Bluebunch wheatgrass	310
9	CDS715	PSME/PHMA	Douglas-fir/Ninebark	260
10	CDS716	PSME/PHMA/LIBOL	Douglas-fir/Ninebark/Twinflower	290
11	CDS813	PSME/VACA	Douglas-fir/Dwarf huckleberry	250
12	CDS814	PSME/VAME	Douglas-fir/Big huckleberry	280
13	CEF111	ABLA2/XETE	Subalpine fir/Beargrass	690
14	CEF211	ABLA2/LIBO2	Subalpine fir/Twinflower, Okanogan & Colville	660
15	CEF421	ABLA2/CLUN	Subalpine fir/Queencup beadlily	620
16	CEF422	ABLA2/TRCA3	Subalpine fir/False bugbane	635
17	CEF423	ABLA2/COCO	Subalpine fir/Bunchberry dogwood	620
18	CEG311	ABLA2/CARU	Subalpine fir/Pinegrass	750
19	CEM211	PIEN/EQAR	Engelmann spruce/Horsetail	410
20	CES210	ABLA2/RHAL/XETE	Subalpine fir/Cascades azalea/Beargrass	670
21	CES211	ABLA2/RHAL	Subalpine fir/Cascades azalea	670
22	CES312	ABLA2/VACCI	Subalpine fir/Huckleberries	720
23	CES313	ABLA2/VAME	Subalpine fir/Big huckleberry	720
24	CES412	ABLA2/VASC	Subalpine fir/Grouse huckleberry, Okanogan & Colville	730
25	CES422	ABLA2/VACA	Subalpine fir/Dwarf huckleberry	640
26	CHF311	TSHE/CLUN	Western hemlock/Queencup	570

Plant Assoc FVS Seq Number Code	Plant Association Code	Plant Association Abbreviation	Description	Mapped to Habitat Type
			beadlily	
27	CHF312	TSHE/ARNU3	Western hemlock/Wild sarsaparilla	570
28	CHF422	TSHE/GYDR	Western hemlock/Oak-fern	565
29	CHF521	TSHE/XETE	Western hemlock/Beargrass	570
30	CHS711	TSHE/MEFE	Western hemlock/Rusty menziesia	579
31	CLS521	PICO/SHCA	Lodgepole pine/Russet buffaloberry	900
32	CWF411	ABGR/CLUN	Grand fir/Queencup beadlily	520
33	CWS214	ABGR/VAME/CLUN	Grand fir/Big huckleberry/Queencup beadlily	520
34	CWS421	ABGR/PHMA	Grand fir/Ninebark	506
35	CWS422	ABGR/ACGLD/CLUN	Grand fir/Douglas maple/Queencup beadlily	520
36	CWS821	ABGR/VACA	Grand fir/Dwarf huckleberry	590
37	CCS211	THPL/OPHO	Western redcedar/Devil's club	550
38	CHS411	TSHE/RUPE	Western hemlock/Five-leaved bramble	565
39	CAG112	PIAL/CARU	Whitebark pine/Pinegrass	850
40	CDG123	PSME/ARUV	Douglas-fir/Bearberry, Okanogan	350

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