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Inland Empire (IE) Variant Overview of the Forest Vegetation Simulator

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Inland Empire (IE) Variant Overview of the Forest Vegetation Simulator

Authors and Contributors:

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.

FVS Staff. 2008 (revised October 5, 2021). Inland Empire (IE) Variant Overview – Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 60p.

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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)	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	LP	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	LP	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, singleleaf pinyon, Rocky Mountain juniper, Pacific yew, quaking aspen, cottonwood, Rocky mountain maple, paper birch, and other hardwood. Growth equations for mountain hemlock are the original North Idaho variant equations for other softwood, 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; singleleaf pinyon, 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 hardwood use the other hardwood 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 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 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.

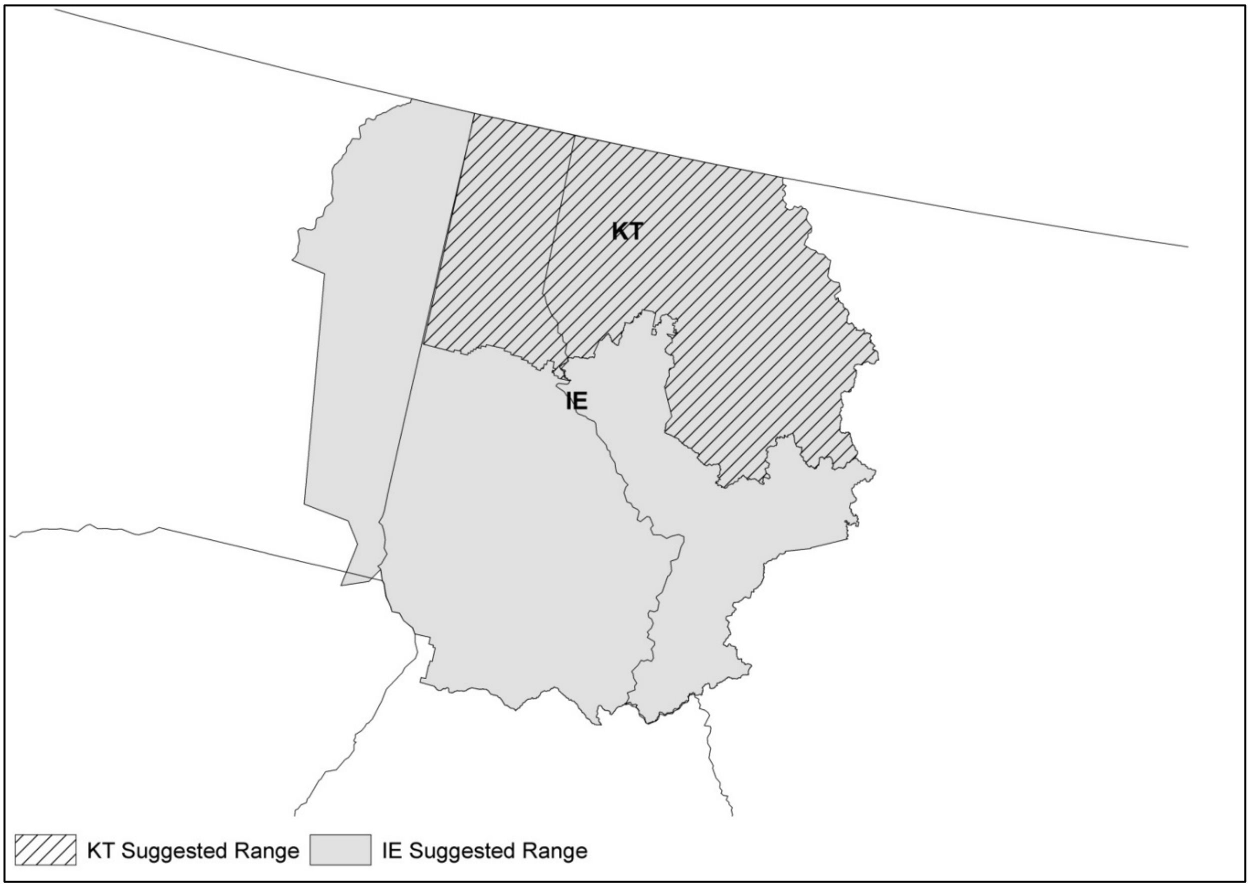

Figure 2.0.1 Suggested geographic range of use for the IE and KT variants.

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 available in the FVS interface or they are read from an FVS input database using the Database Extension.

3.1 Location Codes

The location code is a 3- or 4-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. 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).

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. Location codes recognized in the IE variant are shown in tables 3.1.1 and 3.1.2.

Table 3.1.1 Location codes used in the IE variant.

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

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

Location Code	Location
8106	Colville Reservation (mapped to 621)
8107	Nez Perce Reservation (mapped to 117)
8109	Kootenai Off-Reservation Trust Land (mapped to 113)
8131	Spokane Reservation (mapped to 621)
8132	Kalispel Reservation (mapped to 113)
8133	Flathead Reservation (mapped to 110)

Location Code	Location
8137	Coeur D'Alene Reservation (mapped to 118)

3.2 Species Codes

The IE variant recognizes 21 species, plus two other composite species categories. 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 softwood” 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 IE variant.

When entering tree data, users should substitute diameter at root collar (DRC) for diameter at breast height (DBH) for woodland species (singleleaf pinyon and Rocky Mountain juniper).

Table 3.2.1 Species codes used in the IE 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
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	MH	264	TSME	*Tsuga mertensiana*	mountain hemlock
12	WB	101	PIAL	*Pinus albicaulis*	whitebark pine
13	LM	113	PIFL2	*Pinus flexilis*	limber pine
14	LL	072	LALY	*Larix lyallii*	subalpine larch
15	PM	133	PIMO	*Pinus monophylla*	singleleaf pinyon
16	RM	066	JUSC2	*Juniperus scopulorum*	Rocky Mountain juniper
17	PY	231	TABR2	*Taxus brevifolia*	Pacific yew
18	AS	746	POTR5	*Populus tremuloides*	quaking aspen
19	CO	740	POPUL	*Populus*	cottonwood
20	MM	321	ACGL	*Acer glabrum*	Rocky Mountain maple
21	PB	375	BEPA	*Betula papyrifera*	paper birch

Species Number	Species Code	FIA Code	PLANTS Symbol	Scientific Name[1]	Common Name[1]
22	OH	998	2TB		other hardwood[2]
23	OS	299	2TN		other softwood[2]

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

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, singleleaf pinyon, Rocky Mountain juniper, Pacific yew, quaking aspen, cottonwood species, Rocky mountain maple, paper birch, and other hardwood. 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 Code								
	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

Habitat Code	Species Code								
	LM	PI	RM	PY	AS	CO	MM	PB	OH
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
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 affected species in the IE variant.

Species Code	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.

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 proportion, 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 equivalent NI original habitat type in the IE variant.

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

Habitat Code	Maximum Basal Area
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 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.

Species Code	Default B_1	B_2
WP	5.19988	-9.26718
WL	4.97407	-6.78347
DF	4.81519	-7.29306
GF	5.00233	-8.19365
WH	4.97331	-8.1973
RC	4.89564	-8.39057
LP	4.62171	-5.32481
ES	4.9219	-8.30289
AF	4.76537	-7.61062
PP	4.9288	-9.32795
MH	4.77951	-9.31743
WB	4.97407	-6.78347
LM	4.192	-5.1651
LL	4.76537	-7.61062

Species Code	Default B_1	B_2
PI	3.2	-5.0
RM	3.2	-5.0
PY	4.192	-5.1651
AS	4.4421	-6.5405
CO	4.4421	-6.5405
MM	4.4421	-6.5405
PB	4.4421	-6.5405
OH	4.4421	-6.5405
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.

Species Code	b_1	b_2	Equation Source
WP	0.964	0	Wykoff, et. al. 1982
WL	0.851	0	Wykoff, et. al. 1982
DF	0.867	0	Wykoff, et. al. 1982
GF	0.915	0	Wykoff, et. al. 1982
WH	0.934	0	Wykoff, et. al. 1982
RC	0.950	0	Wykoff, et. al. 1982
LP	0.969	0	Wykoff, et. al. 1982
ES	0.956	0	Wykoff, et. al. 1982
AF	0.937	0	Wykoff, et. al. 1982
PP	0.890	0	Wykoff, et. al. 1982
MH	0.934	0	Wykoff, et. al. 1982
WB	0.851	0	Uses WL equation
LM	0.969	0	TT limber pine
LL	0.937	0	Uses subalpine fir
PI*	0.9002	-0.3089	

Species Code	b_1	b_2	Equation Source
RM*	0.9002	-0.3089	
PY	0.969	0	Uses LM equation
AS	0.950	0	UT aspen
CO	0.892	-0.086	CR cottonwood
MM	0.950	0	Uses AS equation
PB	0.950	0	Uses AS equation
OH	0.892	-0.086	Uses CO equation
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 $0.05 \le CR \le 0.95$)
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	Species 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	Species 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} $Y = 1 - \exp(-((X-A)/B)^C)$

{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_{0-1}, c_{0-1}, and d_{0-1} 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.

Species Code	Model Coefficients						
	a_0	b_0	b_1	c_0	c_1	d_0	d_1
LM	1.0	-0.82631	1.06217	3.31429	0	6.19911	-0.02216
PY	1.0	-0.82631	1.06217	3.31429	0	6.19911	-0.02216
AS	0	-0.08414	1.14765	2.77500	0	4.01678	-0.01516
MM	0	-0.08414	1.14765	2.77500	0	4.01678	-0.01516
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} $\ln(CR) = HAB + (b_1 * BA) + (b_2 * BA^2) + (b_3 * \ln(BA)) + (b_4 * CCF) + (b_5 * CCF^2) + (b_6 * \ln(CCF)) + (b_7 * DBH) + (b_8 * DBH^2) + (b_9 * \ln(DBH)) + (b_{10} * HT) + (b_{11} * HT^2) + (b_{12} * \ln(HT)) + (b_{13} * PCT) + (b_{14} * \ln(PCT))$

where:

CR is predicted crown ratio expressed as a proportion

HAB is a habitat-dependent coefficient shown in table 4.3.1.4
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	Species 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	Species 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	1.112	-	0.705	-	0	0	-	0.03667	0.1513	-	0.345

Habitat Class	Species Code									
	WP	WL, WB	DF	GF	WH	RC	LP	ES	AF, LL	PP	MH, OS
	6	0.05018	5	0.4879			0.4087			1.0103	
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	Species 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

Habitat	Species Code										
Code	WP	WL, WB	DF	GF	WH	RC	LP	ES	AF, LL	PP	MH, OS
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

Singleleaf pinyon, Rocky Mountain juniper, cottonwood, and other hardwood 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. Singleleaf pinyon and Rocky Mountain juniper use equation {4.3.1.8}. Cottonwood and other hardwood 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 singleleaf pinyon and Rocky Mountain juniper use equation {4.3.1.8}. Live cottonwood and other hardwood 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 $0.2 \le CR \le 0.9$)

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 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

$DBH \geq MinD$: $CW = a_1 + (a_2 * DBH) + (a_3 * DBH\text{^}2)$

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

{4.4.2} Bechtold (2004); Equation 02

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

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

{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

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

{4.4.5} Crookston (2005); Equation 05

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

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

{4.4.6} Donnelly (1996); Equation 06

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

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.

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	1.02460	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	01903	1.02886	1.01255	0.30374	0.37093	-0.13731	0
PP	12203	1.02687	1.49085	0.1862	0.68272	-0.28242	0
MH	26405	3.7854	0.54684	-0.12954	0.16151	0.03047	-0.00561
WB	10105	2.2354	0.6668	-0.11658	0.16927	0	0
LM	11301	4.0181	0.8528	0	0	0	0
LL	07204	2.2586	0.68532	0	0	0	0
PI	10602	-5.4647	1.966	0	-0.0395	0.0427	-0.0259
RM	06602	-4.1599	1.3528	-0.0233	0.0633	0	-0.0423
PY	23104	6.1297	0.45424	0	0	0	0
AS	74605	4.7961	0.64167	-0.18695	0.18581	0	0
CO	74902	4.1687	1.5355	0	0	0	0.1275
MM	32102	5.9765	0.8648	0	0.0675	0	0
PB	37506	5.8980	0.4841	0	0	0	0
OH	74902	4.1687	1.5355	0	0	0	0.1275
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.

Species Code	Equation Number*	*MinD*	EL min	*EL* max	*HI* min	*HI* max	*CW* max
WP	11903	1.0	n/a	n/a	n/a	n/a	35
WL	07303	1.0	n/a	n/a	n/a	n/a	40
DF	20203	1.0	n/a	n/a	n/a	n/a	80
GF	01703	1.0	n/a	n/a	n/a	n/a	40
WH	26303	1.0	n/a	n/a	n/a	n/a	54
RC	24203	1.0	n/a	n/a	n/a	n/a	45
LP	10803	0.7	n/a	n/a	n/a	n/a	40
ES	09303	1.0	n/a	n/a	n/a	n/a	40
AF	01903	1.0	n/a	n/a	n/a	n/a	30
PP	12203	2.0	n/a	n/a	n/a	n/a	46
MH	26405	1.0	10	79	n/a	n/a	45
WB	10105	1.0	n/a	n/a	n/a	n/a	40
LM	11301	5.0	n/a	n/a	n/a	n/a	25
LL	07204	1.0	n/a	n/a	n/a	n/a	33
PI	10602	5.0	n/a	n/a	-40	11	25
RM	06602	5.0	n/a	n/a	-37	19	29
PY	23104	1.0	n/a	n/a	n/a	n/a	30
AS	74605	1.0	n/a	n/a	n/a	n/a	45
CO	74902	5.0	n/a	n/a	-26	-2	35
MM	32102	5.0	n/a	n/a	n/a	n/a	39
PB	37506	1.0	n/a	n/a	n/a	n/a	25
OH	74902	5.0	n/a	n/a	-26	-2	35
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 Limber pine, singleleaf pinyon, pacific yew, quaking aspen, Rocky Mountain maple, paper birch 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 Limber pine, singleleaf pinyon, pacific yew, quaking aspen, Rocky Mountain maple, paper birch and 0.1" < *DBH* < 10.0" for all other species:

$$CCF_t = R_4 * DBH^{R5}$$
$$DBH \leq 0.1\text{"}: CCF_t = 0.001$$

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.

Species Code	Model Coefficients				
	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	0.01925	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
MH	0.03	0.0215	0.00363	0.011109	1.7250
WB	0.02	0.0148	0.00338	0.007244	1.8182
LM	0.01925	0.01676	0.00365	0.009187	1.7600
LL	0.03	0.0216	0.00405	0.011402	1.7560
PI	0.01925	0.01676	0.00365	0.009187	1.7600
RM	0.01925	0.01676	0.00365	0.009187	1.7600
PY	0.01925	0.01676	0.00365	0.009187	1.7600
AS	0.03	0.0238	0.00490	0.008915	1.7800
CO	0.03	0.0215	0.00363	0.011109	1.7250
MM	0.03	0.0238	0.00490	0.008915	1.7800
PB	0.03	0.0238	0.00490	0.008915	1.7800
OH	0.03	0.0215	0.00363	0.011109	1.7250
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 hardwood, and is set to 3.0" for all other species. Rocky Mountain juniper and singleleaf pinyon 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 equations predict 5-year or 10-year height growth (*HTG*) for small trees in the IE variant depending on species. The IE western larch equation is used for whitebark pine, the IE subalpine fir equation is used for subalpine larch, and the original NI equation for "other" species, which is really mountain hemlock, is used for mountain hemlock and other softwood in the IE variant.

Potential 5-year height growth is estimated using equation {4.6.1.1} and coefficients shown in tables 4.6.1.1 - 4.6.1.3 for western white pine, western larch, Douglas-fir, grand fir, western hemlock, western redcedar, lodgepole pine, Engelmann spruce, subalpine fir, ponderosa pine, mountain hemlock, whitebark pine, subalpine larch, and other softwood.

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

$$X = [LOC + HAB + SPP + c_1 * \ln(HT) + c_2 * CCF + c_3 * BAL/100 + 0.22157 * SL * \cos(ASP) - 0.12432 * SL * \sin(ASP) - 0.10987 * SL]$$

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 ($c_1 - c_3$) and SPP values for equation {4.6.1.1} in the IE variant.

Species Code	Model Coefficients			
	c_1	c_2	c_3	SPP
WP	0.4214	-0.00591	-0.37199	1.4700
WL	0.2716	-0.00654	-0.41532	1.6204
DF	0.3907	-0.00591	-0.40043	1.4932
GF	0.3487	-0.00391	-0.25355	0.9981
WH	0.3417	-0.00391	-0.34693	1.0202
RC	0.2354	-0.00391	-0.12013	0.8953
LP	0.5843	-0.00654	-0.24172	1.2336
ES	0.2827	-0.00391	-0.25300	1.0964
AF	0.3740	-0.00391	-0.22957	1.0667
PP	0.4485	-0.00654	-0.47299	1.7311

Species Code	Model Coefficients			
	c_1	c_2	c_3	SPP
MH	0.2354	-0.00391	-0.25349	0.8953
WB	0.2716	-0.00654	-0.41532	1.6204
LL	0.3740	-0.00391	-0.22957	1.0667
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.

Species Code	*HAB*	Habitat types (see Table 3.3)
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
WL	-0.2146	420, 470, 510, 520, 620
	-0.0941	530
	-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
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
	0	540, 550, 570, 610
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
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
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

Species Code	*HAB*	Habitat types (see Table 3.3)
	0	540, 550, 570, 610
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
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
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
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
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
WB	-0.2146	420, 470, 510, 520, 620
	-0.0941	530
	-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
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
OS	-0.2146	520, 620

Species Code	*HAB*	Habitat types (see Table 3.3)
	-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 hardwood use equations from the Central Rockies variant; singleleaf pinyon, 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 and other hardwood, 10-year 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 {4.6.1.3} and {4.6.1.4} respectively, to determine an estimated height growth as shown in equation {4.6.1.5}.

{4.6.1.2} $POTHTG = (SI / 5.0) * ((SI * 1.5) - HT) / (SI * 1.5) * 0.83$

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

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

{4.6.1.4} $VIGOR = (150 * CR^3 * \exp(-6 * CR)) + 0.3$

{4.6.1.5} $HTG = POTHTG * PCTRED * VIGOR$

where:

POTHTG	is 10-year potential height growth
PCTRED	is reduction in height growth due to stand density (bounded: $0.01 \le PCTRED \le 1.0$)
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 $VIGOR \le 1.0$)
CR	is a tree's live crown ratio (compacted) expressed as a proportion
HTG	is estimated 10-year height growth
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

For singleleaf pinyon and Rocky Mountain juniper, 10-year potential height growth is estimated using equation {4.6.1.2}. The reduction proportion due to stand density (*PCTRED*) is computed with equation {4.6.1.3} 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 {4.6.1.5}.

{4.6.1.6} $VIGOR = 1 – [(1 – ((150 * CR^3 * \exp(-6 * CR)) + 0.3)) / 3]$

where:

VIGOR	is reduction in height growth due to tree vigor (bounded to *VIGOR* ≤ 1.0)
CR	is a tree's live crown ratio (compacted) expressed as a proportion

Ten-year height growth for quaking aspen, Rocky mountain maple, and paper birch is obtained using an aspen height-age curve (Shepperd 1995) shown in equation {4.6.1.7}. A tree height is estimated from the trees' current age, and then its current age plus 10 years. Ten-year height growth, equation {4.6.1.8}, is the difference between these two height estimates modified by an adjustment for relative site index (equation {4.6.1.9}) and converted from centimeters to feet. If tree age is not entered during data input, an estimate of the tree's current age is obtained at the start of a projection for these three species using the tree's height and solving equation {4.6.1.7} for age. If the species' 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 species' 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.

{4.6.1.7} *H* = 26.9825 * *A*^1.1752

{4.6.1.8} *HTG* = (0.75 * (*H2* – *H1*) / (2.54 * 12)) * (0.5 * [1 + RELSI])

{4.6.1.9} *RELSI* = (*SI* – *SITELO*) / (*SITEHI* – *SITELO*)])

where:

H	is tree height in centimeters
A	is tree age in years
H1	is estimated tree height in centimeters at the beginning of a projection cycle
H2	is estimated tree height in centimeters 10 year after the beginning of a projection cycle
HTG	is estimated 10-year height growth in feet
RELSI	is relative site index
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

Five-year height growth for limber pine (13) and Pacific yew (17) is estimated using equation {4.6.1.9}.

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

where:

HTG	is estimated 5-year height growth
CR	is a tree's live crown ratio (compacted) expressed as a percent
TPCCF	is total crown competition factor on the inventory point where the tree is established (bounded to 25 ≤ *TPCCF* ≤ 300)

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

Species Code	*SITELO*	*SITEHI*
PI	5	20
RM	5	15
AS	30	70
CO	30	120
MM	30	70
PB	30	70
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}

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

{4.6.1.11} 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.

Species Code	X_{min}	X_{max}
WP	2.0	10.0

Species Code	X_{min}	X_{max}
WL	2.0	10.0
DF	2.0	10.0
GF	2.0	10.0
WH	2.0	10.0
RC	2.0	10.0
LP	1.0	5.0
ES	2.0	10.0
AF	2.0	10.0
PP	2.0	10.0
MH	2.0	10.0
WB	2.0	10.0
LM	1.5	3.0
LL	2.0	10.0
PI	90.0	99.0
RM	90.0	99.0
PY	1.5	3.0
AS	2.0	4.0
CO	0.5	2.0
MM	2.0	4.0
PB	2.0	4.0
OH	0.5	2.0
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, 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, ponderosa pine, mountain hemlock, whitebark pine, subalpine larch, and other softwood, these two predicted diameters are estimated using equations {4.6.2.1} – {4.6.2.4} and coefficients shown in table 4.6.2.1.

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

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

{4.6.2.3} $RELH = (HT – 4.5) / (AH – 4.5)$

{4.6.2.4} $DELMAX = (AH / 36) * (0.01232 * CCF – 1.75)$

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 $0 \leq RELHT \leq 1$)
AH	is average height of the 40 largest diameter trees
DELMAX	is an adjustment factor based on relative tree size and stand density (bounded $DELMAX \leq 0$)
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 IE variant.

Species Code	C_1	C_2
WP	0.0781	1.1645
WL	0.0751	1.1176
DF	0.0828	1.1713
GF	0.1155	1.0688
WH	0.0729	1.1988
RC	0.0730	1.2343
LP	0.0988	1.0807
ES	0.0658	1.3817
AF	0.0658	1.3817
PP	0.2160	1.0049
MH	0.0729	1.1988
WB	0.0751	1.1176
LL	0.0658	1.3817
OS	0.0729	1.1988

Singleleaf pinyon (15) and Rocky Mountain juniper (16) use equation {4.6.2.5} to estimate the two diameters.

{4.6.2.5} $DHAT = (HT – 4.5) * 10 / (SI – 4.5)$

where:

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

Limber pine (13) and Pacific yew (17) use equation {4.6.2.6} to estimate the two diameters.

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

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

Quaking aspen (18), cottonwood species (19), Rocky Mountain maple (20), paper birch (21), and other hardwood (22) use the species-specific height-diameter relationships discussed in section 4.1 to estimate the diameters.

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 hardwood, and is set to 3.0" for all other species. Rocky Mountain juniper and singleleaf pinyon 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.

Western white pine, western larch, Douglas-fir, grand fir, western hemlock, western redcedar, lodgepole pine, Engelmann spruce, subalpine fir, ponderosa pine, mountain hemlock, whitebark pine, limber pine, subalpine larch, Pacific yew, and other softwood use diameter growth equation {4.7.1.1}. Coefficients for these equations are shown in tables 4.7.1.1 - 4.7.1.9. Pacific yew uses the same coefficients as limber pine, other softwood use the same coefficients as mountain hemlock, subalpine larch uses the same coefficients as subalpine fir, and whitebark pine uses the same coefficients as western larch. Diameter growth for the other species in the IE variant is shown later in this section.

{4.7.1.1} Used for western white pine, western larch, Douglas-fir, grand fir, western hemlock, western redcedar, lodgepole pine, Engelmann spruce, subalpine fir, ponderosa pine, mountain hemlock, whitebark pine, limber pine, subalpine larch, Pacific yew, and other softwood

$$\ln(DDS) = b_1 + (b_2 * EL) + (b_3 * EL^2) + (b_4 * \sin(ASP) * SL) + (b_5 * \cos(ASP) * SL) + (b_6 * SL) + (b_7 * SL^2) + (b_8 * CCF / 100) + (b_9 * \ln(DBH)) + (b_{10} * BAL / 100) + (b_{11} * CR) + (b_{12} * CR^2) + (b_{13} * DBH^2) + (b_{14} * BAL / (100 * (\ln(DBH + 1.0)))) + (b_{15} * SI) + HAB$$

where:

DDS is the predicted periodic change in squared inside-bark diameter
EL is stand elevation in hundreds of feet
ASP is stand aspect (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
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_{15} are species-specific coefficients shown in table 4.7.1.1

Table 4.7.1.1 Coefficients (b_2- b_{15}) for equation {4.7.1.1} in the IE variant.

	Species 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
b_{15}	0	0	0	0	0	0

	Species Code					
Coefficient	**LP**	**ES**	**AF, LL**	**PP**	**MH, OS**	**LM, 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
b_{15}	0	0	0	0	0	-0.00199592

[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	Species 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	Species Code											
	WP	WL, WB	DF	GF	WH	RC	LP	ES	AF, LL	PP	MH, OS	LM, PY
103 - Bitterroot	2	1	5	6	3	4	4	3	4	1	3	1
104 - Idaho Panhandle	1	1	4	5	2	1	2	1	1	2	2	1
105 - Clearwater	2	1	1	1	3	1	1	1	1	2	1	1
106 - Coeur d'Alene	2	2	2	2	1	1	1	1	2	2	1	1
110 - Flathead	2	3	3	3	3	2	4	2	3	4	3	1
113 - Kaniksu	2	2	2	2	3	3	3	3	3	3	3	1
114 - Kootenai	2	5	3	4	3	4	3	3	4	1	3	1
116 - Lolo	2	5	5	6	3	2	4	3	4	4	1	1

Location Code	Species Code											
	WP	WL, WB	DF	GF	WH	RC	LP	ES	AF, LL	PP	MH, OS	LM, PY
117 - Nezperce	2	4	1	2	3	1	2	1	2	3	3	1
118 - St. Joe	1	1	4	5	2	1	2	1	1	2	2	1
621 - Colville	2	3	3	2	3	2	2	3	2	1	3	1

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

Habitat Class	Species 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 original NI habitat code for b8 in equation {4.7.1.1} in the IE variant. See tables 11.1.1 and 11.1.2 for conversion from currently recognized habitat and plant association codes to the original NI habitat codes.

Habitat Code	Species 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
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

Habitat Code	Species Code											
	WP	WL, WB	DF	GF	WH	RC	LP	ES	AF, LL	PP	MH, OS	LM, PY
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	Species 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	**Species Code**					
	LP	**ES**	**AF, LL**	**PP**	**MH, OS**	**LM, 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	Species 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

Location Code	Species Code											
	WP	WL, WB	DF	GF	WH	RC	LP	ES	AF, LL	PP	MH, OS	LM, PY
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	Species 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 original NI habitat code for *HAB* values in equation {4.7.1.1} in the IE variant. See tables 11.1.1 and 11.1.2 for conversion from currently recognized habitat and plant association codes to the original NI habitat codes.

Habitat Code	Species 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
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

Habitat Code	Species Code										
	WP	WL, WB	DF	GF	WH	RC	LP	ES	AF, LL	PP	MH, OS
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

Diameter growth for singleleaf pinyon and Rocky Mountain juniper for trees of all sizes is predicted using the small-tree diameter growth equations shown in section 4.6.2.

Large-tree diameter growth for aspen, Rocky mountain maple, and paper birch is predicted using the aspen equation from the UT variant identified in equation set {4.7.1.2}. 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.

{4.7.1.2} Used for quaking aspen, Rocky mountain maple, and paper birch

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

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 and other hardwood is predicted using equations from the CR 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 cottonwood and other hardwood

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

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
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, large tree height growth is estimated using species-specific equations. Western white pine, western larch, Douglas-fir, grand fir, western hemlock, western redcedar, lodgepole pine, Engelmann spruce, subalpine fir, ponderosa pine, mountain hemlock, whitebark pine, subalpine larch and other softwood all use a single equation form as shown in equation {4.7.2.1}.

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

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 estimated 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 IE variant.

	Species 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	-0.5720	-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 IE variant.

Habitat Codes	Coefficient		
	b_1	b_4	*HAB*
10, 100, 110, 130, 140, 160, 170, 180, 190, 210, 220, 230, 460, 630, 660, 700, 730, 770, 790, 800, 810, 820, 830, 840, 850, 860, 870, 890, 900, 930, 940, 999, CDG311, CEF211, CES412, CLS521, CAG112	-0.000134	0.62144	2.03035
200, 250, 260, 280, 290, 310, 320, 330, 340, 350, 360, 370, 380, 430, 910, CDG131, CDS632, CDS633, CDS637, CDS715, CDS716, CDS813, CDS814, CDG123	-0.0000381	1.02372	1.72222
400, 410, 420, 440, 470, 480, CEM211	-0.0000372	0.85493	1.19728
450, 505, 506, 510, 515, 590, 620, 635, 640, 650, 670, 675, 680, 685, 740, 920, CEF421, CEF422, CEF423, CES210, CES211, CES422, CWS421, CWS821	-0.0000261	0.75756	1.81759
500, 516, 520, 529, CWF411, CWS214, CWS422	-0.000052	0.46238	2.14781
501, 530, 545, 555, CCF221, CCF222, CCS311	-0.0000161	0.49643	1.76998
502, 540, 550, 560, 565, 570, 575, 610, CHF311, CHF312, CHF422, CHF521, CCS211, CHS411	-0.0000363	0.37042	2.21104
579, 600, 690, 701, 710, 720, 750, 780, 925, 950, CEF111, CEG311, CES312, CES313, CHS711	-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

$FBY1 = \ln[Y1/(1 - Y1)]$
$FBY2 = \ln[Y2/(1 - Y2)]$
$Y1 = (DBH - 0.1) / C_1$
$Y2 = (HT - 4.5) / C_2$

where:

HT is tree height at the beginning of the cycle
DBH is tree diameter at breast height at the beginning of the cycle (bounded to be $\geq$ 0.2 inch)
$C_1 - C_7$ 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 cottonwood species, Rocky Mountain Maple, paper birch, and the other hardwood category.

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

{4.7.2.3} $Z = Z + (0.1 - 0.10273 * Z + 0.00273 * Z^2)$ bounded $Z \geq 0$

For limber pine, Pacific yew, quaking aspen, cottonwood species, Rocky Mountain Maple, paper birch, and other hardwood, 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 greater than 10 years and less than 40 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
CR	is tree crown ratio expressed as a percent

Estimated height 10 years into the future 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} $H10 = [(PSI / (1 + PSI)) * C_2] + 4.5$

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

{4.7.2.6}Height Growth equation

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

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
HTG	is estimated 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

Singleleaf pinyon 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.

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 $-70 \leq X \leq 70$

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 coefficients used in the mortality equation set {5.0.1} in the IE 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	0.2118
PP	0.2118
MH	0
WB	-0.17603
LM	0
LL	0.2118
PI	0
RM	0
PY	0
AS	0
CO	0
MM	0
PB	0
OH	0
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	National Forest by Location Code										
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 singleleaf pinyon 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 softwood equation {5.0.2} is modified by 40%.

6.0 Regeneration

The IE 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 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).

Table 6.0.1 Regeneration parameters by species in the IE 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
MH	No	0.2	0.5	22.0
WB	No	0.3	1.0	27.0
LM	No	0.3	1.0	27.0
LL	No	0.3	0.5	18.0
PI	No	0.4	0.5	6.0
RM	No	0.3	0.5	6.0
PY	Yes	0.3	1.0	27.0
AS	Yes	0.2	6.0	16.0
CO	Yes	0.2	3.0	16.0
MM	Yes	0.2	6.0	16.0
PB	Yes	0.2	6.0	16.0
OH	No	0.2	3.0	16.0
OS	No	0.2	0.5	22.0

One sprouting record is created for Pacific yew, Mountain Mahoghany, and paper birch; two sprouting records are created for quaking aspen, and logic rule {6.0.1} is used to determine the number of sprouting records for root suckering cottonwood species. The trees-per-acre represented by each sprout record is determined using the general sprouting probability equation {6.0.2}. See table 6.0.2 for species-specific sprouting probabilities, number of sprout records created, and reference information.

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.

{6.0.1} For root suckering hardwood species

$DSTMP_i \leq 5$: $NUMSPRC = 1$
$5 < DSTMP_i \leq 10$: $NUMSPRC = \text{NINT}(-1.0 + 0.4 * DSTMP_i)$
$DSTMP_i > 10$: $NUMSPRC = 3$

{6.0.2} $TPA_s = TPA_i * PS$

{6.0.3} $PS = (TPA_i / (ASTPAR * 2)) * ((ASBAR / 198) * (40100.45 - 3574.02 * RSHAG^2 + 554.02 * RSHAG^3 - 3.5208 * RSHAG^5 + 0.011797 * RSHAG^7))$

where:

$DSTMP_i$	is the diameter at breast height of the parent tree
$NUMSPRC$	is the number of sprout tree records
NINT	rounds the value to the nearest integer
TPA_s	is the trees per acre represented by each sprout record
TPA_i	is the trees per acre removed/killed represented by the parent tree
PS	is a sprouting probability (see table 6.0.2)
$ASBAR$	is the aspen basal area removed
$ASTPAR$	is the aspen trees per acre removed
$RSHAG$	is the age of the sprouts at the end of the cycle in which they were created

Table 6.0.2 Sprouting algorithm parameters for sprouting species in the IE variant.

Species Code	Sprouting Probability	Number of Sprout Records	Source
PY	0.4	1	Minore 1996 Ag. Handbook 654
AS	{6.0.3}	2	Keyser 2001
CO	0.9	{6.0.1}	Gom and Rood 2000 Steinberg 2001
MM	0.7	1	Anderson 2001
PB	0.7	1	Hutnik and Cunningham 1965 Bjorkbom 1972

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”.

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 volume merchantability standards and equation numbers for the IE variant are shown in tables 7.0.1-7.0.3.

Table 7.0.1 Default volume merchantability standards for the IE variant.

Merchantable Cubic Foot Volume Specifications:		
Minimum DBH / Top Diameter	LP	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	LP	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.

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 codes	I00FW2W073	Flewelling's 2-Point Profile Model
western larch	621	I11FW2W073	Flewelling's 2-Point Profile Model
Douglas-fir	All Region 1 codes	I00FW2W202	Flewelling's 2-Point Profile Model
Douglas-fir	621	I11FW2W202	Flewelling's 2-Point Profile Model
grand fir	All Region 1 codes	I00FW2W017	Flewelling's 2-Point Profile Model
grand fir	621	I11FW2W017	Flewelling's 2-Point Profile Model
western hemlock	All Region 1 codes	I00FW2W260	Flewelling's 2-Point Profile Model
western hemlock	621	I11FW2W017	Flewelling's 2-Point Profile

Common Name	Location Code	Equation Number	Reference
			Model
western redcedar	All Region 1 codes	I00FW2W242	Flewelling's 2-Point Profile Model
western redcedar	621	I11FW2W242	Flewelling's 2-Point Profile Model
lodgepole pine	All Region 1 codes	I00FW2W108	Flewelling's 2-Point Profile Model
lodgepole pine	621	I11FW2W108	Flewelling's 2-Point Profile Model
Engelmann spruce	All Region 1 codes	I00FW2W093	Flewelling's 2-Point Profile Model
Engelmann spruce	621	I13FW2W093	Flewelling's 2-Point Profile Model
subalpine fir	All Region 1 codes	I00FW2W019	Flewelling's 2-Point Profile Model
subalpine fir	621	I11FW2W202	Flewelling's 2-Point Profile Model
ponderosa pine	All Region 1 codes	I00FW2W122	Flewelling's 2-Point Profile Model
ponderosa pine	621	I12FW2W122	Flewelling's 2-Point Profile Model
mountain hemlock	All Region 1 codes	I00FW2W260	Flewelling's 2-Point Profile Model
mountain hemlock	621	I11FW2W017	Flewelling's 2-Point Profile Model
whitebark pine	All Region 1 codes	I00FW2W012	Flewelling's 2-Point Profile Model
whitebark pine	621	616BEHW101	Behre's Hyperbola
limber pine	All Region 1 codes	I00FW2W073	Flewelling's 2-Point Profile Model
limber pine	621	616BEHW113	Behre's Hyperbola
subalpine larch	All Region 1 codes	I00FW2W019	Flewelling's 2-Point Profile Model
subalpine larch	621	616BEHW072	Behre's Hyperbola
singleleaf pinyon	All Region 1 codes	102DVEW106	Kemp Equation
singleleaf pinyon	621	616BEHW106	Behre's Hyperbola
Rocky mountain juniper	All Region 1 codes	102DVEW106	Kemp Equation
Rocky mountain juniper	621	616BEHW066	Behre's Hyperbola

Common Name	Location Code	Equation Number	Reference
Pacific yew	All	616BEHW231	Behre's Hyperbola
quaking aspen	All Region 1 codes	102DVEW746	Kemp Equation
quaking aspen	621	616BEHW746	Behre's Hyperbola
cottonwood species	All Region 1 codes	102DVEW740	Kemp Equation
cottonwood species	621	616BEHW740	Behre's Hyperbola
Rocky mountain maple	All Region 1 codes	200DVEW746	Edminster Equation
Rocky mountain maple	621	616BEHW321	Behre's Hyperbola
paper birch	All Region 1 codes	101DVEW375	N. Central Station Equation
paper birch	621	616BEHW375	Behre's Hyperbola
other hardwood	All Region 1 codes	200DVEW746	Edminster Equation
other hardwood	621	616BEHW998	Behre's Hyperbola
other softwood	All Region 1 codes	I00FW2W260	Flewelling's 2-Point Profile Model
other softwood	621	616BEHW298	Behre's Hyperbola

Table 7.0.3 Citations by Volume Model

Model Name	Citation
Behre's Hyperbola	USFS-R6 Sale Preparation and Valuation Section of Diameter and Volume Procedures - R6 Timber Cruise System. 1978.
Edminster Equation	Edminster, Carleton B., H. Todd Mowrer, and Thomas E. Hinds. 1982. Volume Tables and Point-Sampling Factors for Aspen in Colorado. Rocky Mtn Forest and Range Experiment Station Research Paper RM-232
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.
Kemp Equations	Kemp, P.D. 1958. Unpublished report on file at USDA, Forest Service, Rocky Mountain Research Station, Interior West Resource Inventory, Monitoring, and Evaluation Program, Ogden, UT.
N. Central Station Equation	Hahn, Jerold T. 1984. Tree Volume and Biomass Equations for the Lake States. Research Paper NC-250. St. Paul, MN: U.S. Dept. of Agriculture, Forest Service, North Central Forest Experiment Station

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 for dwarf mistletoe and western root disease have been developed for the IE 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).

10.0 Literature Cited

Alexander, R.R., Tackle, D., and Dahms, W.G. 1967. Site Indices for Lodgepole Pine with Corrections for Stand Density Methodology. Res. Pap. RM-29. Forest Service, Rocky Mountain Research Station. 18 p.

Anderson, Michelle D. 2001. Acer glabrum. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer).

Bechtold, William A. 2004. Largest-crown-diameter Prediction Models for 53 Species in the Western United States. WJAF. Forest Service. 19(4): pp 241-245.

Bjorkbom, John C. 1972. Stand changes in the first 10 years after seedbed preparation for paper birch. USDA Forest Service, Research Paper NE-238. Northeastern Forest Experiment Station, Upper Darby, PA. 10 p.

Burns, R. M., & Honkala, B. H. 1990. Silvics of North America: 1. Conifers; 2. Hardwoods Agriculture Handbook 654. US Department of Agriculture, Forest Service, Washington, DC.

Cole, D. M.; Stage, A. R. 1972. Estimating future diameters of lodgepole pine. Res. Pap. INT-131. Ogden, UT: U. S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 20p.

Crookston, Nicholas. 2003. Internal Document on File. Moscow, ID: Data provided from region 1.

Crookston, Nicholas L. 2005. Draft: Allometric Crown Width Equations for 34 Northwest United States Tree Species Estimated Using Generalized Linear Mixed Effects Models.

Dixon, G. E. 1985. Crown ratio modeling using stand density index and the Weibull distribution. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 13p.

Dixon, Gary E. comp. 2002 (revised frequently). Essential FVS: A user's guide to the Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Forest Management Service Center.

Donnelly, Dennis. 1996. Internal document on file. Data provided from Region 6. Fort Collins, CO: Forest Service.

Edminster, Carleton B., H. Todd Mowrer, and Thomas E. Hinds. 1982. Volume Tables and Point-Sampling Factors for Aspen in Colorado. Rocky Mtn Forest and Range Experiment Station Research Paper RM-232

Edminster, Carleton B., Mowrer, Todd H., and Shepperd, Wayne D. 1985. Site index curves for aspen in the central Rocky Mountains. Res. Note RM-453. Fort Collins, CO: Forest Service, Rocky Mountain Forest and Range Experiment Station. 4p.

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.

Gom, L. A., & Rood, S. B. (2000). Fire induces clonal sprouting of riparian cottonwoods. Canadian Journal of Botany, 77(11), 1604-1616.

Hahn, Jerold T. 1984. Tree Volume and Biomass Equations for the Lake States. Research Paper NC-250. St. Paul, MN: U.S. Dept. of Agriculture, Forest Service, North Central Forest Experiment Station

Hamilton, D. A., Jr. 1986. A logistic model of mortality in thinned and unthinned mixed conifer stands of northern Idaho. For. Science 32(4): 989-1000.

Hutnik, Russell J., and Frank E. Cunningham. 1965. Paper birch (Betula papyrifera Marsh.). In Silvics of forest trees of the United States. p. 93-98. H. A. Fowells, comp. U.S. Department of Agriculture, Agriculture Handbook 271. Washington, DC.

Kemp, P.D. 1958. Unpublished report on file at USDA, Forest Service, Rocky Mountain Research Station, Interior West Resource Inventory, Monitoring, and Evaluation Program, Ogden, UT.

Keyser, C.E. 2001. Quaking Aspen Sprouting in Western FVS Variants: A New Approach. Unpublished Manuscript.

Krajicek, J.; Brinkman, K.; Gingrich, S. 1961. Crown competition – a measure of density. For. Science 7(1):35-42.

Minore, D., & Weatherly, H. G. (1996). Stump sprouting of Pacific yew. General Technical Report. PNW-GTR-378. Portland, Or.: U.S. Dept. of Agriculture, Pacific Northwest Research Station.

Pfister, R. D.; Kovalchik, B. L.; Arno, S. F.; Presby, R. C. 1977. Forest habitat types of Montana. Gen. Tech. Rep. INT-34. Ogden, UT: U. S. Department of Agriculture, Forest Service, Intermountain Research Station. 38p.

Rebain, Stephanie A. comp. 2010 (revised frequently). The Fire and Fuels Extension to the Forest Vegetation Simulator: Updated Model Documentation. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 379 p.

Reinhardt, Elizabeth; Crookston, Nicholas L. (Technical Editors). 2003. The Fire and Fuels Extension to the Forest Vegetation Simulator. Gen. Tech. Rep. RMRS-GTR-116. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 209 p.

Schreuder, H.T. and W.L. Hafley. 1977. A Useful Distribution for Describing Stand Structure of Tree Heights and Diameters. Biometrics 33, 471-478.

Shepperd, Wayne D. 1995. Unpublished equation. Data on file. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Stage, A. R. 1973. Prognosis Model for stand development. Res. Paper INT-137. Ogden, UT: U. S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 32p.

Steinberg, Peter D. 2001. Populus balsamifera subsp. trichocarpa. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer).

USFS-R6 Sale Preparation and Valuation Section of Diameter and Volume Procedures - R6 Timber Cruise System. 1978.

Van Dyck, Michael G.; Smith-Mateja, Erin E., comps. 2000 (revised frequently). Keyword reference guide for the Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center.

Wykoff, W. R. 1990. A basal area increment model for individual conifers in the northern Rocky Mountains. For. Science 36(4): 1077-1104.

Wykoff, William R., Crookston, Nicholas L., and Stage, Albert R. 1982. User's guide to the Stand Prognosis Model. Gen. Tech. Rep. INT-133. Ogden, UT: Forest Service, Intermountain Forest and Range Experiment Station. 112p.

-----. 2009(revised frequently). Volume Estimator Library Equations. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center.

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

Habitat Code	Abbreviation	Habitat Type Name	Original Habitat Type
440	PICEA /GATR	*Spruce/sweetscented bedstraw*	470
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 redcedar 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/wildginger*	520
520	ABGR/CLUN	*Grand fir/bride's bonnet*	520
529	ABGR/SETR	*Grand fir/arrowleaf ragwort*	520
530	THPL/CLUN	*Western redcedar/bride's bonnet*	530
540	THPL/ATFI	*Western redcedar/common ladyfern*	540
545	THPL/ASCA	*Western redcedar/British Columbia wildginger*	530
550	THPL/OPHO	*Western redcedar/devilsclub*	550
555	THPL/GYDR	*Western redcedar/western oakfern*	530
560	THPL/ADPE	*Western redcedar/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*	620

Habitat Code	Abbreviation	Habitat Type Name	Original Habitat Type
		twistedstalk	
680	TSME/MEFE	*Mountain hemlock/menziesia*	680
685	TSME/CLUN	*Mountain hemlock/bride's bonnet*	620
690	ABLA/XETE	*Subalpine fir/beargrass*	690
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
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/LIB OL	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/XET E	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 &	730

Plant Assoc FVS Seq Number Code	Plant Association Code	Plant Association Abbreviation	Description	Mapped to Habitat Type
			Colville	
25	CES422	ABLA2/VACA	Subalpine fir/Dwarf huckleberry	640
26	CHF311	TSHE/CLUN	Western hemlock/Queencup beadlily	570
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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