Inland Empire

and

North Idaho

Variants

of the

Forest Vegetation Simulator

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QUICK GUIDE TO DEFAULT SETTINGS

Parameter or Attribute	Default Setting: NI variant	Default Setting: IE variant
Number of projection cycles	1	1
Projection cycle length	10 years	10 years
National Forest	118 = St. Joe NF	118 = St. Joe NF
Habitat Type (R1 Forests only)	260 = PSME/PHMA	260 = PSME/PHMA
Plant Association (Colville NF R6)	None	None
Slope	0 = level ground	0 = level ground
Aspect	0 = north	0 = north
Elevation	38 = 3800 feet	38 = 3800 feet
Site Index	0 (not used)	Determined from Habitat Type
Volume equations used	National Volume Estimator Library	National Volume Estimator Library
Cubic Foot Volume Specifications:		
Minimum DBH	6.0” dbh (lodgepole) 7.0” dbh (all other)	6.0” dbh (lodgepole) 7.0” dbh (all other)
Top diameter (inside bark)	4.5” dib	4.5” dib
Stump height	1.0 foot	1.0 foot
Board Foot Volume Specifications:		
Minimum DBH	6.0” dbh (lodgepole) 7.0” dbh (all other)	6.0” dbh (lodgepole) 7.0” dbh (all other)
Top diameter (inside bark)	4.5” dib	4.5” dib
Stump height	1.0 foot	1.0 foot
Sampling Design		
Large Trees (Variable Radius Plot)	40 BAF	40 BAF
Small Trees (Fixed Radius Plot)	1/300th acre	1/300th acre
Breakpoint DBH	5.0	5.0

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, development of understory vegetation, and fire effects. A general description of FVS structure and operation is given in Dixon (2003). This document presents codes, model relationships, and logic that are specific to the Inland Empire (IE) and Northern Idaho (NI) variants. Users referencing this document for the Northern Idaho variant should focus only on the first 11 species.

The Inland Empire variant is the Northern Idaho (NI) variant, expanded to recognize an additional 12 species. The additional species are mountain hemlock, whitebark pine, limber pine, subalpine larch, pinyon pine, western juniper, Pacific yew, quaking aspen, cottonwood, Rocky mountain maple, paper birch, and "other hardwoods". Growth equations for mountain hemlock are the original NI variant equations for "other softwoods", which were fit for mountain hemlock. In general, whitebark pine uses the western larch equations from the NI variant; limber pine and Pacific yew use equations for limber pine from the Teton variant; subalpine larch uses subalpine fir equations from the NI variant; pinyon pine, western 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 and other hardwoods use the other hardwoods equations from the Central Rockies variant. Table 2 documents this "mapping" of equations.

2.0 GEOGRAPHIC RANGE

The Inland Empire and Northern Idaho variants cover National Forest land in northern Idaho and western Montana (figure 1). Other forest land can be simulated provided stand attributes are similar to the National Forests listed in table 1.

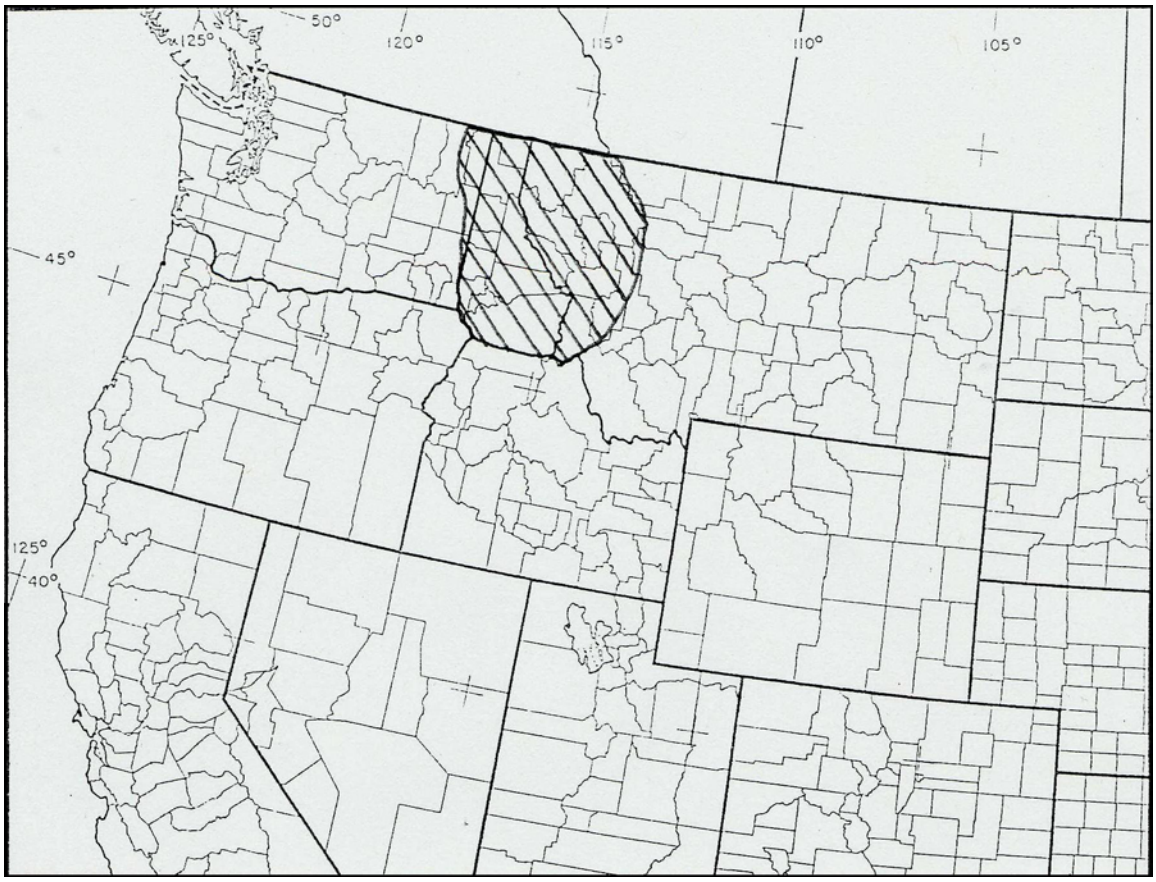

Figure 1. Approximate geographic range covered by the North Idaho and Inland Empire variants of the Forest Vegetation Simulator.

3.0 CONTROL VARIABLES

Users need to specify certain variables used by the Inland Empire and Northern Idaho variants to control a simulation. These are entered in parameter fields on various FVS keywords.

3.1 Forest Codes

Forest code is entered as a number in field 1 of the STDINFO keyword. If the forest code is missing or incorrect, a default forest code of 118, St. Joe National Forest, will be used. A complete list of forest codes recognized in the IE and NI variants is shown in table 1.

Table 1. Forest Codes used in the Inland Empire and Northern Idaho FVS variants.

Forest Code	National Forest
103	Bitterroot
104	Idaho Panhandle
105	Clearwater
106	Coeur d'Alene
110	Flathead
113	Kaniksu
114	Kootenai
116	Lolo
117	Nezperce
118	St. Joe
621	Colville

3.2 Species Codes

The Inland Empire variant recognizes 23 species codes and the Northern Idaho variant recognizes 11 species codes. Either the species alpha code or its' Forest Inventory and Analysis (FIA) code can be used in the FVS input data. The FVS sequence number or alpha code can be used to specify a species on the FVS keywords. Any unrecognized species will default to "other softwoods". A complete list of species codes recognized by the IE and NI variants is shown in tables 2 and 3.

The IE variant will also recognize the following alpha species codes in the input data: "L" for western larch, "C" for western redcedar, and "S" for Engelmann spruce. As a result, a data set containing these species codes intended for the NI variant can also be run through the IE variant. However, when running the IE variant, species codes on the keyword records must be the correct two character IE alpha code (WL, RC, ES) or the FVS sequence number (2, 6, or 8 respectively).

Table 2. Species codes used in the Inland Empire FVS variant.

FVS Number	Alpha Code	FIA Code	Common Name	Scientific Name	Origin
1	WP	119	Western white pine	Pinus monticola	NI
2	WL	073	Western larch	Larix occidentalis	NI
3	DF	202	Douglas-fir	Pseudotsuga menziesii	NI
4	GF	017	Grand fir	Abies grandis	NI
5	WH	263	Western hemlock	Tsuga heterophylla	NI
6	RC	242	Western redcedar	Thuja plicata	NI
7	LP	108	Lodgepole pine	Pinus contorta	NI
8	ES	093	Engelmann spruce	Picea Engelmannii	NI
9	AF	019	Subalpine fir	Abies lasiocarpa	NI
10	PP	122	Ponderosa pine	Pinus ponderosa	NI
11	MH	264	Mountain hemlock	Tsuga mertensiana	NI
12	WB	101	Whitebark pine	Pinus albicaulis	NI (uses WL)
13	LM	113	Limber pine	Pinus flexilis	TT
14	LL	072	Subalpine larch	Larix lyallii	NI (uses AF)
15	PI	106	Pinyon pine	Pinus monophylla	UT
16	JU	064	Western juniper	Juniperus occidentalis	UT
17	PY	231	Pacific yew	Taxus brevifolia	TT (uses LM)
18	AS	746	Quaking aspen	Populus tremuloides	UT
19	CO	740	Cottonwood	Populus spp.	CR (uses OH)
20	MM	321	Rocky mountain maple	Acer glabrum	UT (uses QA)
21	PB	375	Paper birch	Betula papyrifera	UT (uses QA)
22	OH	004	Other hardwoods		CR (uses OH)
23	OS	001	Other softwoods		NI (uses MH)

Table 3. Species codes used in the Northern Idaho FVS variant.

FVS Number	Alpha Code	FIA Code	Common Name	Scientific Name
1	WP	119	Western white pine	Pinus monticola
2	L	073	Western larch	Larix occidentalis
3	DF	202	Douglas-fir	Pseudotsuga menziesii
4	GF	017	Grand fir	Abies grandis
5	WH	263	Western hemlock	Tsuga heterophylla
6	C	242	Western redcedar	Thuja plicata
7	LP	108	Lodgepole pine	Pinus contorta
8	S	093	Engelmann spruce	Picea Engelmannii
9	AF	019	Subalpine fir	Abies lasiocarpa
10	PP	122	Ponderosa pine	Pinus ponderosa
11	OT	999	Grown as Mountain hemlock	Tsuga mertensiana

3.3 Habitat Type References and Defaults

Habitat type codes that are recognized in the IE and NI variants are listed in table 4. If the habitat type code is blank or not recognized, the default 260 (PSME/PHMA) will be used. Habitat type is used for all Region 1 forests in these variants.

Table 4 Codes for habitat types represented in the Inland Empire and Northern Idaho variants of FVS[1].

Code[2]	Abbreviation	Habitat type name
130	PIPO/AGSP	*Pinus ponderosa/Agropyron spicatum*
170	PIPO/SYAL	*Pinus ponderosa/Symphoricarpos albus*
250	PSME/VACA	*Pseudotsuga menziesii/Vaccinium caespitosum*
260	PSME/PHMA	*Pseudotsuga menziesii/Physocarpus malvaceus*
280	PSME/VAGL	*Pseudotsuga menziesii/Vaccinium globulare*
290	PSME/LIBO	*Pseudotsuga menziesii/Linnaea borealis*
310	PSME/SYAL	*Pseudotsuga menziesii/Symphoricarpos albus*
320	PSME/CARU	*Pseudotsuga menziesii/Calamagrostis rubescens*
330	PSME/CAGE	*Pseudotsuga menziesii/Carex geyeri*
420	PICEA/CLUN	*Picea/Clintonia uniflora*
470	PICEA/LIBO	*Picea/Linnaea borealis*
510	ABGR/XETE	*Abies grandis/Xerophyllum tenax*
520	ABGR/CLUN	*Abies grandis/Clintonia uniflora*
530	THPL/CLUN	*Thuja plicata/Clintonia uniflora*
540	THPL/ATFI	*Thuja plicata/Athyrium filix-femina*
550	THPL/OPHO	*Thuja plicata/Oplopanax horridum*

570	TSHE/CLUN	*Tsuga heterophylla/Clintonia uniflora*
610	ABLA/OPHO	*Abies lasiocarpa/Oplopanax horridum*
620	ABLA/CLUN	*Abies lasiocarpa/Clintonia uniflora*
640	ABLA/VACA	*Abies lasiocarpa/Vaccinium caespitosum*
660	ABLA/LIBO	*Abies lasiocarpa/Linnaea borealis*
670	ABLA/MEFE	*Abies lasiocarpa/Menziesia ferruginea*
680	TSME/MEFE	*Tsuga mertensiana/Menziesia ferruginea*
690	ABLA/XETE	*Abies lasiocarpa/Xerophyllum tenax*
710	TSME/XETE	*Tsuga mertensiana/Xerophyllum tenax*
720	ABLA/VAGL	*Abies lasiocarpa/Vaccinium globulare*
730	ABLA/VASC	*Abies lasiocarpa/Vaccinium scoparium*
830	ABLA/LUHI	*Abies lasiocarpa/Luzula hitchcockii*
850	PIAL-ABLA	*Pinus albicaulis-Abies lasiocarpa*
999	OTHER	

[1] From Pfister and others 1977.
[2] 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.

3.4 Plant Association Codes

Plant association codes are typically used instead of habitat type codes for the Colville National Forest in Region 6. The plant association code is then cross-walked to one of the habitat type codes listed in table 4. Plant association codes can be entered in field 2 of the STDINFO keyword instead of habitat type. However, users can choose to enter a habitat type code directly if they want to. Plant association codes recognized in these variants are shown in table 5.

Table 5. Codes for Colville National Forest plant associations represented in the Inland Empire and Northern Idaho variants of FVS, and their associated habitat type.

Code	Plant Association	Description	Mapped to Habitat Type
CCF221	THPL/CLUN	Western redcedar/Queencup beadlily	530
CCF222	THPL/ARNU3	Western redcedar/Wild sarsaparilla	530
CCS311	THPL/CLUN	Western redcedar/Big huckleberry	530
CDG131	PSME/CARU	Douglas-fir/Pinegrass, Okanogan & Colville	320
CDG311	PSME-PIPO/AGIN	Douglas-fir-ponderosa	130
CDS632	PSME/SYOR	Douglas-fir/Mountain snowberry	380
CDS633	PSME/SYAL	Douglas-fir/Common snowberry	310
CDS637	PSME/SYAL/AGSP	Douglas-fir/Common	310
CDS715	PSME/PHMA	Douglas-fir/Ninebark	260
CDS716	PSME/PHMA/LIBOL	Douglas-fir/Ninebark/Twinflower	290
CDS813	PSME/VACA	Douglas-fir/Dwarf huckleberry	250
CDS814	PSME/VAME	Douglas-fir/Big huckleberry	280
CEF111	ABLA2/XETE	Subalpine fir/Beargrass	690

CEF211	ABLA2/LIBO2	Subalpine fir/Twinflower, Okanogan & Colville	660
CEF421	ABLA2/CLUN	Subalpine fir/Queencup beadlily	620
CEF422	ABLA2/TRCA3	Subalpine fir/False bugbane	635
CEF423	ABLA2/COCO	Subalpine fir/Bunchberry dogwood	620
CEG311	ABLA2/CARU	Subalpine fir/Pinegrass	750
CEM211	PIEN/EQAR	Engelmann spruce/Horsetail	410
CES210	ABLA2/RHAL/XETE	Subalpine fir/Cascades	670
CES211	ABLA2/RHAL	Subalpine fir/Cascades azalea	670
CES312	ABLA2/VACCI	Subalpine fir/Huckleberries	720
CES313	ABLA2/VAME	Subalpine fir/Big huckleberry	720
CES412	ABLA2/VASC	Subalpine fir/Grouse huckleberry, Okanogan & Colville	730
CES422	ABLA2/VACA	Subalpine fir/Dwarf huckleberry	640
CHF311	TSHE/CLUN	Western hemlock/Queencup beadlily	570
CHF312	TSHE/ARNU3	Western hemlock/Wild sarsaparilla	570
CHF422	TSHE/GYDR	Western hemlock/Oak-fern	565
CHF521	TSHE/XETE	Western hemlock/Beargrass	570
CHS711	TSHE/MEFE	Western hemlock/Rusty menziesia	579
CLS521	PICO/SHCA	Lodgepole pine/Russet buffaloberry	900
CWF411	ABGR/CLUN	Grand fir/Queencup beadlily	520
CWS214	ABGR/VAME/CLUN	Grand fir/Big huckleberry/Queencup beadlily	520
CWS421	ABGR/PHMA	Grand fir/Ninebark	506
CWS422	ABGR/ACGLD/CLUN	Grand fir/Douglas maple/Queencup	520
CWS821	ABGR/VACA	Grand fir/Dwarf huckleberry	590
CCS211	THPL/OPHO	Western redcedar/Devil's club	550
CHS411	TSHE/RUPE	Western hemlock/Five-leaved bramble	565
CAG112	PIAL/CARU	Whitebark pine/Pinegrass	850
CDG123	PSME/ARUV	Douglas-fir/Bearberry, Okanogan	350

3.5 Site Index

Site index is not used in the NI variant. However, site index is an input variable for some of the growth equations for the additional species in the IE variant. These species are limber pine, pinyon pine, western juniper, Pacific yew, quaking aspen, cottonwood, Rocky mountain maple, paper birch, and other hardwoods. Site index may not be available for some stands since habitat type is commonly used as a measure of site productivity in the geographic area covered by IE variant. If site index is not available, it is estimated from habitat type as shown in table 6. This table was created by Renate Bush, R1 Inventory Specialist, based on valid site index ranges for each species and productivity of habitat type. Users should enter their own values using the SITECODE keyword, and the site index references listed in table 7, if possible.

Table 6. Habitat type to site index conversion for affected species in the IE variant.

Habitat[2]	Species								
Code	**LM**	**PI**	**JU**	**PY**	**AS**	**CO**	**MM**	**PB**	**OH**
130	25	7	6	25	36	44	36	36	44
170	29	9	8	29	43	57	43	43	57
250	35	13	10	35	51	76	51	51	76
260	35	12	10	35	50	62	50	50	62
280	33	10	9	33	44	72	44	44	72
290	34	12	10	34	49	72	49	49	72
310	35	12	10	35	48	71	48	48	71
320	32	11	9	32	46	67	46	46	67
330	27	8	7	27	41	55	41	41	55
420	39	14	11	39	55	86	55	55	86
470	37	11	9	37	46	67	46	46	67
510	32	13	11	32	52	80	52	52	80
520	36	16	12	36	59	95	59	59	95
530	41	15	12	41	58	93	58	58	93
540	41	15	12	41	58	93	58	58	93
550	41	15	12	41	58	93	58	58	93
570	43	16	13	43	60	98	60	60	98
610	38	14	11	38	54	84	54	54	84
620	39	14	11	39	55	86	55	55	86
640	32	11	9	32	46	67	46	46	67
660	36	12	10	36	49	73	49	49	73
670	34	13	10	34	52	80	52	52	80
680	34	13	10	34	52	80	52	52	80
690	32	11	9	32	46	67	46	46	67
710	36	13	10	36	52	80	52	52	80
720	36	13	10	36	52	80	52	52	80
730	36	13	10	36	52	80	52	52	80
830	26	8	7	26	38	49	38	38	49
850	22	6	6	22	33	36	33	33	36
999	26	8	7	26	38	49	38	38	49

Table 7. Recommended site index references for affected species in the Inland Empire variant of FVS.

Species	Base Age	Age Type	Reference
Limber pine	100	Total	Alexander, Tackle, & Dahms Res. Pap. RM-29 for lodgepole pine
Pinyon pine	100	Total	Any pinyon 100 year base total age curve
Western juniper	100	Total	Any juniper 100 year base total age curve
Pacific yew			Use limber pine
Quaking aspen	80	Breast Height	Edminster, Mowrer, & Shepperd Res. Note RM-453
Cottonwood	100	Total	Any hardwood 100 year base total age curve
Rocky mountain maple			Use aspen
Paper birch			Use aspen
Other hardwoods	100	Total	Any hardwood 100 year base total age curve

4.0 GROWTH MODEL RELATIONSHIPS

4.1 Height-Diameter Relationships

Height-diameter relationships are used for two purposes: (1) to estimate heights missing in the input data, and (2) to estimate diameter growth on trees smaller than some threshold diameter. In the IE and NI variants, height-diameter relationships are a logistic functional form, as shown in equation {1} (Wykoff, et.al 1982). Default equation coefficients are shown in table 8.

$$\{1\} \quad HT = 4.5 + e^{[a + b/(DBH+1)]}$$

where:

HT is the total tree height in feet
DBH is the tree diameter at breast height
a, b are species specific coefficients shown in table 8

When heights are given in the input data for 3 or more trees of a given species, the value of "a" in equation {1} for that species is recalculated from the input data and replaces the default value shown in table 8. In the event that the calculated value is less than zero, the default is used.

Table 8. Default coefficients for the height-diameter relationship in the North Idaho and Inland Empire FVS variants, see equation {1}.

FVS Number	Species	a	b
1	Western white pine	5.19988	-9.26718
2	Western larch	4.97407	-6.78347
3	Douglas-fir	4.81519	-7.29306
4	Grand fir	5.00233	-8.19365
5	Western hemlock	4.97331	-8.19730
6	Western redcedar	4.89564	-8.39057
7	Lodgepole pine	4.62171	-5.32481
8	Engelmann spruce	4.92190	-8.30289
9	Subalpine fir	4.76537	-7.61062
10	Ponderosa pine	4.92880	-9.32795
11	Mountain hemlock	4.77951	-9.31743
12	Whitebark pine	4.97407	-6.78347
13	Limber pine	4.19200	-5.16510
14	Subalpine larch	4.76537	-7.61062
15	Pinyon pine	4.19200	-5.16510
16	Western juniper	4.19200	-5.16510
17	Pacific yew	4.19200	-5.16510
18	Quaking aspen	4.44210	-6.54050
19	Cottonwood	4.44210	-6.54050
20	Rocky mountain maple	4.44210	-6.54050
21	Paper birch	4.44210	-6.54050
22	Other hardwoods	4.44210	-6.54050
23	Other softwoods	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 form use in both variants is shown in equation {2} and coefficients for these equations are shown in table 9.

{2} $BRATIO = b_1 + b_2 * [1/DBH]$

where:

BRATIO is bark ratio (bounded between .80-.99)

DBH is tree diameter at breast height ($1 \leq DBH \leq 19$ for PI, JU; $1 \leq DBH$ for all other species)

$b_1 - b_2$ are species specific coefficients

Table 9. Coefficients for the bark ratio equations in the North Idaho and Inland Empire variants of FVS, see equation {2}.

FVS Number	Species	b_1	b_2	Equation source
1	Western white pine	0.964	0.	Wykoff, et. al. 1982
2	Western larch	0.851	0.	Wykoff, et. al. 1982
3	Douglas-fir	0.867	0.	Wykoff, et. al. 1982
4	Grand fir	0.915	0.	Wykoff, et. al. 1982
5	Western hemlock	0.934	0.	Wykoff, et. al. 1982
6	Western redcedar	0.950	0.	Wykoff, et. al. 1982
7	Lodgepole pine	0.969	0.	Wykoff, et. al. 1982
8	Engelmann spruce	0.956	0.	Wykoff, et. al. 1982
9	Subalpine fir	0.937	0.	Wykoff, et. al. 1982
10	Ponderosa pine	0.890	0.	Wykoff, et. al. 1982
11	Mountain hemlock	0.934	0.	Wykoff, et. al. 1982
12	Whitebark pine	0.851	0.	Uses WL equation
13	Limber pine	0.969	0.	TT limber pine
14	Subalpine larch	0.937	0.	Uses subalpine fir
15	Pinyon pine	0.9002	-0.3089	UT ponderosa pine
16	Western juniper	0.9002	-0.3089	UT ponderosa pine
17	Pacific yew	0.969	0.	Uses LM equation
18	Quaking aspen	0.950	0.	UT aspen
19	Cottonwood	0.892	-0.086	CR cottonwood
20	Rocky Mountain maple	0.950	0.	Uses AS equation
21	Paper birch	0.950	0.	Uses AS equation
22	Other hardwoods	0.892	-0.086	Uses CO equation
23	Other softwoods	0.934	0.	Uses MH equation

4.4 Crown Competition Factor and Crown Width

The Inland Empire variant uses crown competition factor (*CCF*) as a predictor variable in some growth relationships, and crown width for each tree is reported on the tree list output table and used for percent cover calculations in the model. Crown competition factor (Krajicek and others 1961) is a relative measurement of stand density that is also 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 equations {3-5}.

{3} $CCF_t = a_1 + a_2 * DBH + a_3 * DBH^2$ $DBH \geq 1.0$ and species LM, PI, JU, PY, AS, MM, PB
or $DBH \geq 10.0$ for all other species

{4} $CCF_t = b_1 * DBH^{b2}$ $0.1 < DBH < 1.0$ and species LM, PI, JU, PY, AS, MM, PB
or $0.1 < DBH < 10.0$ and species LM, PI, JU, PY, AS, MM, PB
or $DBH < 10.0$ for all other species

{5} $CCF_t = 0.001$ $DBH \leq 0.1$ and species LM, PI, JU, PY, AS, MM, PB, LM, PI, JU, PY, AS, MM, PB

where:
CCF_t is the crown competition factor for an individual tree
DBH is the tree diameter at breast height
b_1,b_2, a_1-a_3 are species specific coefficients shown in table 10

Table 10. Coefficients for computing the contribution of each tree record to the stand estimate of crown competition factor from tree diameter, in the North Idaho and Inland Empire FVS variants, see equations {3-4}.

	Model Coeffiecients				
Species	**b_1**	**b_2**	**a_1**	**a_2**	**a_3**
Western white pine	.009884	1.6667	.03	.0167	.00230
Western larch	.007244	1.8182	.02	.0148	.00338
Douglas-fir	.017299	1.5571	.11	.0333	.00259
Grand fir	.015248	1.7333	.04	.0270	.00405
Western hemlock	.011109	1.7250	.03	.0215	.00363
Western redcedar	.008915	1.7800	.03	.0238	.00490
Lodgepole pine	.009187	1.7600	.01925	.01676	.00365
Engelmann spruce	.007875	1.7360	.03	.0173	.00259
Subalpine fir	.011402	1.7560	.03	.0216	.00405
Ponderosa pine	.007813	1.7680	.03	.0180	.00281
Mountain hemlock	.011109	1.7250	.03	.0215	.00363
Whitebark pine	.007244	1.8182	.02	.0148	.00338
Limber pine	.009187	1.7600	.01925	.01676	.00365
Subalpine larch	.011402	1.7560	.03	.0216	.00405
Pinyon pine	.009187	1.7600	.01925	.01676	.00365
Western juniper	.009187	1.7600	.01925	.01676	.00365
Pacific yew	.009187	1.7600	.01925	.01676	.00365
Quaking aspen	.008915	1.7800	.03	.0238	.00490
Cottonwood	.011109	1.7250	.03	.0215	.00363

Rocky mountain maple	.008915	1.7800	.03	.0238	.00490
Paper birch	.008915	1.7800	.03	.0238	.00490
Other hardwoods	.011109	1.7250	.03	.0215	.00363
Other softwoods	.011109	1.7250	.03	.0215	.00363

For Region 1 forests, crown width is calculated using equation {6} and coefficients shown in table 11 for all species other than MH and OS. Equations for the first 10 species listed (i.e. all the original North Idaho species except for OT which is mountain hemlock) are from Crookston (2003). The western larch coefficients are used for whitebark pine; lodgepole pine coefficients for limber pine, pinyon pine, western juniper, and pacific yew; subalpine fir coefficients for subalpine larch; western redcedar coefficients for aspen, Rocky mountain maple, and paper birch; and western hemlock coefficients for cottonwood and other hardwoods.

$$\{6\} \quad CW = b_1 * e^{(b2 + b3*\log(CL) + b4*\log(DBH) + b5*\log(HT) + b6*\log(BA))}$$

where:

CW is tree crown width in feet
CL is tree crown length in feet
DBH is tree diameter at breast height in inches
HT is total tree height in feet
BA is total stand basal area
log is the natural logarithm function

Table 11. Coefficients for the crown width equations in the North Idaho and Inland Empire variants of FVS, see equation {6}.

	Model Coeffiecients					
Species	**b_1**	**b_2**	**b_3**	**b_4**	**b_5**	**b_6**
Western white pine	1.04050	1.27990	0.11941	0.42745	0.	-0.07182
Western larch	1.02478	0.99889	0.19422	0.59423	-0.09078	-0.02341
Douglas-fir	1.01685	1.48372	0.27378	0.49646	-0.18669	-0.01509
Grand fir	1.03030	1.14079	0.20904	0.38787	0.	0.
Western hemlock	1.02460	1.35223	0.24844	0.41212	-0.10436	0.03539
Western redcedar	1.03597	1.46111	0.26289	0.18779	0.	0.
Lodgepole pine	1.03992	1.58777	0.30812	0.64934	-0.38964	0.
Engelmann spruce	1.02687	1.28027	0.22490	0.47075	-0.15911	0.
Subalpine fir	1.02886	1.01255	0.30374	0.37093	-0.13731	0.
Ponderosa pine	1.02687	1.49085	0.18620	0.68272	-0.28242	0.
Mountain hemlock	see	below				
Whitebark pine	1.02478	0.99889	0.19422	0.59423	-0.09078	-0.02341
Limber pine	1.03992	1.58777	0.30812	0.64934	-0.38964	0.
Subalpine larch	1.02886	1.01255	0.30374	0.37093	-0.13731	0.

Pinyon pine	1.03992	1.58777	0.30812	0.64934	-0.38964	0.
Western juniper	1.03992	1.58777	0.30812	0.64934	-0.38964	0.
Pacific yew	1.03992	1.58777	0.30812	0.64934	-0.38964	0.
Aspen	1.03597	1.46111	0.26289	0.18779	0.	0.
Cottonwood	1.02460	1.35223	0.24844	0.41212	-0.10436	0.03539
Rocky mountain maple	1.03597	1.46111	0.26289	0.18779	0.	0.
Paper birch	1.03597	1.46111	0.26289	0.18779	0.	0.
Other hardwoods	1.02460	1.35223	0.24844	0.41212	-0.10436	0.03539
Other softwoods	see	below				

For MH and OS in Region 1 forests, crown width is calculated using equations {7-9}. These equations were also developed by Nick Crookston using CVS data from the Colville National Forest.

{7} $CW = .8 * HT * CR$ $\qquad HT \leq 5.0$

{8} $CW = e_1 * [1.0 - (HT - 5.0) * 0.1] + e_2 * (HT - 5.0) * 0.1$ $\qquad 5.0 < HT < 15.0$

$$e_1 = 0.8 * HT * CR$$
$$e_2 = 6.90396 * DBH^{(0.55645)} * HT^{(-0.28509)} * CL^{(0.20430)}$$

{9} $CW = 6.90396 * DBH^{(0.55645)} * HT^{(-0.28509)} * CL^{(0.20430)}$ $\qquad HT \geq 15.0$

where:

CW is crown width in feet
CR is crown ratio expressed as a proportion and bounded to be $0.50 \leq CR \leq 0.99$
CL is crown length in feet
HT is total tree height in feet
DBH is tree diameter at breast height in inches

Crown width for the Colville National Forest is computed using equations {10-11} and coefficients shown in table 12. These equations were developed by Dennis Donnelly using R6 inventory data. Equations were fit for 30 species in the Pacific Northwest, however, not all the species in the Inland Empire variant were fit. The equation for lodgepole pine is used for limber pine, pinyon pine, and western juniper; the equation for big leaf maple is used for cottonwood; the equation for paper birch is used for Rocky mountain maple; the equation for aspen is used for other hardwoods; and the equation for mountain hemlock is used for other softwoods.

{10} $CW = a_0 * HT$ $\qquad HT \leq 4.5$ feet

{11} $CW = a_1 * DBH^{a2}$ $HT > 4.5$ feet

Table 12. Coefficients for computing crown width for the Colville National Forest in the North Idaho and Inland Empire variants, see equations {10-11}.

Species	a_0	a_1	a_2
Western white pine	0.476	3.4447	0.5185
Western larch	0.316	2.9571	0.6081
Douglas-fir	0.517	4.4215	0.5329
Grand fir	0.489	4.1870	0.5341
Western hemlock	0.533	5.4864	0.5144
Western redcedar	0.698	6.2318	0.4259
Lodgepole pine	0.298	2.4132	0.6403
Engelmann spruce	0.451	3.6802	0.4940
Subalpine fir	0.385	3.2348	0.5179
Ponderosa pine	0.407	2.8541	0.6400
Mountain hemlock	0.253	2.9372	0.5878
Whitebark pine	0.255	2.1606	0.6897
Limber pine	0.298	2.4132	0.6403
Subalpine larch	0.207	2.1039	0.6758
Pinyon pine	0.298	2.4132	0.6403
Western juniper	0.298	2.4132	0.6403
Pacific yew	0.468	4.5859	0.4841
Quaking aspen	0.351	4.0910	0.5907
Cottonwood	0.815	7.5183	0.4461
Rocky mountain maple	0.601	5.8980	0.4841
Paper birch	0.601	5.8980	0.4841
Other hardwoods	0.351	4.0910	0.5907
Other softwoods	0.407	2.8541	0.6400

4.5 Small-tree Growth Functions

Trees are considered "small" trees for FVS modeling purposes when they are smaller than some threshold diameter. This threshold diameter is a function of the lower diameter limit in the data used to fit the model, and how well the model formulation used to estimate growth on "large" trees fits trees in the lower end of the diameter range. The threshold diameters used in the Inland Empire and North Idaho variants is shown in table 13.

The small tree model is height-growth driven. That is to say, height growth is estimated first, then diameter growth is estimated from height growth, and finally crown ratio change is estimated.

Table 13. Threshold diameters for switching between small tree growth equations and large tree growth equations in the Inland Empire and North Idaho FVS variants, and the range of diameters (minimum and maximum) over which small tree height growth estimates are weighted with large tree estimates to assure a smooth transition between the two model formulations.

FVS Number	Species	Diameter growth Threshold dbh	Height growth Min. DBH	Height growth Max. DBH
1	Western white pine	3.0	2.0	10.0
2	Western larch	3.0	2.0	10.0
3	Douglas-fir	3.0	2.0	10.0
4	Grand fir	3.0	2.0	10.0
5	Western hemlock	3.0	2.0	10.0
6	Western redcedar	3.0	2.0	10.0
7	Lodgepole pine	3.0	1.0	5.0
8	Engelmann spruce	3.0	2.0	10.0
9	Subalpine fir	3.0	2.0	10.0
10	Ponderosa pine	3.0	2.0	10.0
11	Mountain hemlock	3.0	2.0	10.0
12	Whitebark Pine	3.0	2.0	10.0
13	Limber Pine	3.0	1.5	3.0
14	Subalpine Larch	3.0	2.0	10.0
15	Pinyon pine	999.0[1]	90.0[1]	99.0[1]
16	Western juniper	999.0[1]	90.0[1]	99.0[1]
17	Pacific yew	3.0	1.5	3.0
18	Aspen	3.0	2.0	4.0
19	Cottonwood	1.0	0.5	2.0
20	Rocky mountain maple	3.0	2.0	4.0
21	Paper birch	3.0	2.0	4.0
22	Other hardwoods	1.0	0.5	2.0
23	Other softwoods	3.0	2.0	10.0

[1]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.

4.5.1 Small Tree Height Increment Model

The small-tree height increment model for all species in the NI variant, and 14 species in the IE variant (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 softwoods), predicts periodic (5-year) height increment (*HTG*) for small trees (equation {12}). The NI equation for western larch is used for whitebark pine in the IE variant; the NI subalpine fir equation is used for IE subalpine larch; and the NI equation for "other" species, which is really mountain hemlock, is used for other softwoods in the IE variant.

$$\{12\}\quad \ln(HTG) = LOC + HAB + SPP + b_1*\ln(HT) + b_2*CCF + 0.22157*SL*\cos(ASP) - 0.12432*SL*\sin(ASP) - 0.10987*SL$$

where:

HTG is estimated height growth
LOC is a location dependent intercept (table 15)
HAB is a habitat type dependent intercept (table 16)
SPP is a species dependent intercept (table 14)
CCF is stand crown competition factor
ASP is stand aspect
SL is stand slope (percent/100)
$b_1 – b_2$ are species specific regression coefficients (table 14)

Table 14. Coefficients for the small tree height increment model for the North Idaho and Inland Empire variants of FVS, see equation {12}.

Species	b_1	b_2	*SPP*
Western white pine	0.4214	-0.00591	1.4700
Western larch	0.2716	-0.00654	1.6204
Douglas-fir	0.3907	-0.00591	1.4932
Grand fir	0.3487	-0.00391	0.9981
Western hemlock	0.3417	-0.00391	1.0202
Western redcedar	0.2354	-0.00391	0.8953
Lodgepole pine	0.5843	-0.00654	1.2336
Engelmann spruce	0.2827	-0.00391	1.0964
Subalpine fir	0.3740	-0.00391	1.0667
Ponderosa pine	0.4485	-0.00654	1.7311
Mountain hemlock	0.2354	-0.00391	0.8953
Whitebark pine	0.2716	-0.00654	1.6204
Subalpine larch	0.3740	-0.00391	1.0667
Other softwoods	0.2354	-0.00391	0.8953

Table 15. Coefficients for the *LOC* variable for the North Idaho and Inland Empire variant of FVS, see equation {12}.

National Forest	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 16. Coefficients for the HAB variable for the North Idaho and Inland Empire variant of FVS, see equation {12}.

Species	***HAB***	**Habitat types** (see table 4)
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 or	-0.2146	420, 470, 510, 520
L	-0.0941	530, 620
	-0.3296	130, 170, 250, 260, 280, 290, 310, 320, 330, 640, 660, 670, 680, 690, 710, 720, 730, 830, 850, 999
	0.	540, 550, 570, 610
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 or C	-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
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 or S	-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
	-0.0941	530, 620
	-0.3296	130, 170, 250, 260, 280, 290, 310, 320, 330, 640, 660, 670, 680, 690, 710, 720, 730, 830, 850, 999
	0.	540, 550, 570, 610
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
	-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

Remaining species in the IE variant use small tree height growth equations taken from other variants. Cottonwood and "other hardwoods" use equations from the Central Rockies variant; pinyon pine, western 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, and other hardwoods, potential height growth is estimated using equations {13-14} and modified using equations {15-17}.

{13} $RELSI = (SI - SITELO) / (SITEHI - SITELO)$

{14} $POTHTG = SI / (15.0 - 4.0 * RELSI)$

where:
RELSI is the relative site index
SI is site index
SITELO is lower end of the site range for this species (see table 17)
SITEHI is upper end of the site range for this species (see table 17)
POTHTG is potential height growth in feet

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

Table 17. Site index ranges for species in the IE variant using relative site index to predict small tree height growth, see equation {13}.

Species	SITELO	SITEHI
Pinyon pine	5	20
Western juniper	5	15
Quaking aspen	30	70
Cottonwood	30	100
Rocky mountain maple	30	70
Paper birch	30	70
Other Hardwoods	20	100

{15} $PCTRED = 1.11436 - 0.011493 * X + 0.43012E\text{-}04 * X^2 - 0.72221E\text{-}07 * X^3 + 0.5607E\text{-}10 * X^4 - 0.1641E\text{-}13 * X^5$

where:
PCTRED is the reduction proportion in height growth due to stand density, bounded between 0.01 and 1.0
X is *AVHT* * (*CCF*/100) with an upper bound of *X*=300
AVHT is average height of the 40 largest diameter trees in the stand
CCF is stand crown competition factor

{16} $VIGOR = (150 * CR^3 * e^{(-6 * CR)}) + 0.3$

where:
VIGOR is reduction proportion in height growth due to tree vigor with an upper bound of 1.0
CR is a trees' live crown ratio (compacted) expressed as a proportion

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

where:
HTG is estimated height growth in feet
POTHTG is potential height growth (equation {14})
PCTRED is reduction proportion due to stand density (equation {15})
VIGOR is reduction proportion due to tree vigor (equation {16})

For pinyon pine and western juniper potential height growth is estimated using equation {18}. The reduction proportion due to stand density (*PCTRED*) is computed with equation {15} and the reduction proportion due to crown ratio (*VIGOR*) is computed with equation {16}. The vigor modifier is reduced using equation {19} and height growth is estimated using equation {17}.

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

where:
POTHTG is potential height growth in feet
SI is site index
HT is total tree height

{19} $VIGOR = 1 – [(1-VIGOR) / 3]$

Height growth for quaking aspen, Rocky mountain maple, and paper birch is obtained from an aspen height-age curve (Shepperd 1995). Shepperd's original curve seemed to overestimate height growth and was reduced by 25 percent, equation {20}.

{20} $HT = (26.9825 * AGE^{1.1752}) * 0.75$

where:
HT is estimated tree height in centimeters
AGE is total tree age

A height is estimated from the trees' current age, and then its current age plus 10 years. Height growth is the difference between these two height estimates and converted from centimeters to feet. An estimate of a small aspen tree's current age is obtained at the start of a projection using the tree's height and solving equation {20} for age.

Height growth for limber pine and Pacific yew is estimated using equations {21-23}.

{21} $BETA1 = e^{(1.17527 – 0.42124*\ln(TPCCF))}$

{22} $BETA2 = e^{(-2.56002 – 0.58642 * \ln(TPCCF))}$

{23} $HTG = BETA1 + BETA2 * CR$

where:
HTG is estimated height growth in feet
TPCCF is total crown competition factor for the inventory point on which the tree is located, bounded between 25 and 300
CR is the trees crown ratio expressed as a percent

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

Height growth estimates from the small tree model are weighted, using equation {24}, with height growth estimates from the large tree model to assure a smooth transition between the two models.

{24} Predicted *HTG* = (small tree *HTG*)*(1 –weight) + (large tree *HTG*)*weight

where:
weight = (diameter – minimum *DBH*) / (maximum *DBH* – minimum *DBH*)
weight = 0 if diameter is less than the minimum *DBH* shown in table 13
weight = 1 if diameter is greater than the maximum *DBH* shown in table 13

4.5.2 Small Tree Diameter Increment Model

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 in the NI variant, and all species except limber pine and Pacific yew in the IE variant, small tree diameter growth for trees over 4.5 feet tall is calculated as the difference of predicted diameter at the start of the projection period and the predicted diameter at the end of the projection period, adjusted for bark ratio. These two predicted diameters are estimated using the species specific height-diameter relationships discussed in section 4.1, except for pinyon pine and western juniper in the IE variant which use equation {25} to estimate the two diameters. By definition, diameter growth is zero for trees less than 4.5 feet tall.

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

where:
DHAT is estimated diameter
HT is tree height
SI is site index for the particular species

Future diameter for trees over 4.5 feet tall is predicted directly for limber pine and Pacific yew using equation {26}. Diameter growth is then the difference between the diameter at the start of the projection period and the predicted future diameter, adjusted for bark ratio.

{26} $DHAT = 0.000231*(HT-4.5)*CR - 0.00005*(HT-4.5)*PCCF + 0.001711*CR + 0.17023*(HT-4.5) + 0.3$

where:
DHAT is estimated diameter
HT is tree height

CR is tree crown ratio expressed as a percentage
PCCF is the crown competition factor on the inventory point where the tree is located

4.5.3 Small Tree Changes in Crown Ratio

For all species in the NI variant, and those species plus whitebark pine, subalpine larch, and other softwoods in the IE variant, crown ratios are held constant until the tree reaches 3.0" in diameter. So up to that point the crown ratio will be the value entered in the input data or the estimated initial value if crown ratio was missing in the input data. Crown ratio change for trees of these species that are 3.0" and larger will be discussed in section 4.6.3.

For quaking aspen, Rocky mountain maple, paper birch, limber pine, and Pacific yew in the IE variant, crown ratios are held constant until the tree reaches 1.0" in diameter. Crown ratio change for trees of these species that are 1.0" and larger will also be discussed in section 4.6.3.

For pinyon pine, western juniper, cottonwood, and other hardwoods in the Inland Empire variant crown length is estimated using equations {27-28} (Edminster et al 1991).

{27} $CL = 5.17281 + 0.32552*HF - 0.01675*BA$

{28} $CL = 5.00215 + 0.06334*HF + 0.88236*DF - 0.03821*TBAU$

where:
CL is predicted crown length in feet, bounded between 1.0 and the height of the tree
HF is total tree height at the end of the cycle
DF is tree diameter at the end of the cycle
BA is total stand basal area
TBAU is total stand basal area in trees with diameters larger than the subject tree

Estimated crown ratio, expressed as a percent, is than obtained by dividing crown length by total tree height and multiplying by 100. The estimated crown ratio is then bounded to be $\pm$ 10% of the beginning of cycle crown ratio, and restricted to be less than or equal to the crown ratio assuming all height growth went to an increase in crown length.

4.6 Large Tree Growth Relationships

Trees are considered "large" trees for FVS modeling purposes when they are larger than some threshold diameter. The threshold diameters used in the Inland Empire and North Idaho variants is shown in table 13.

The large tree model in FVS is diameter-growth driven. That is to say, diameter growth is estimated first, then height growth is estimated from diameter growth and other variables, and finally crown ratio change is estimated.

4.6.1 Large Tree Diameter Growth

A single equation form is used for large-tree diameter growth for all species in the North Idaho variant. Three different equation forms are used in the Inland Empire variant.

The equation 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, and other softwoods, predicts log of change in diameter growth squared. The western larch coefficients are also used for whitebark pine in the Inland Empire variant, and the subalpine fir coefficients are used for subalpine larch. This equation is shown in {29} with coefficients shown in tables 18-22.

$$\{29\}\quad \ln(DDS) = HAB + LOC + b_1*\cos(ASPECT)*SLOPE + b_2*\sin(ASPECT)*SLOPE + b_3*SLOPE + b_4*SLOPE^2 + b_5*ELEV + b_6*ELEV^2 + b_7*\ln(DBH) + b_8*CR + b_9*CR^2 + b_{10}*(BAL/100) + b_{11}*BAL/\ln(DBH+1) + b_{12}*DBH^2 + b_{13}*CCF/100 + USSC + CALIB$$

where:

HAB is a habitat constant
LOC is location constant
ASPECT is stand aspect
SLOPE is stand slope
ELEV is stand elevation
DBH is current tree diameter at breast height
CR is crown ratio
BAL is basal area in larger trees
CCF is stand crown competition factor
USSC is a user supplied species correction
CALIB is calibration adjustment
b_1-b_{13} are site and species specific coefficients (see tables 18-22)

Table 18. Coefficients of the diameter increment model by species for the North Idaho and Inland Empire variant of FVS, see equation {29}.

Variables				Species[1]			
(classes)		WP	WL or L	DF	GF	WH	RC or C
			WB				
	1	1.15584	0.38335	0.47780	0.66755	0.45264	1.61452
Habitat	2	1.05635	0.51291	0.15228	0.60454		1.31772
Class	3		0.45377	0.29764			
Intercepts	4		0.71322				
(HAB)[2]	5		0.26835				
	6						
	1	0.16920	0.20004	0.50357	0.43443	0.10667	0.50070
Location	2		0.07656	0.34920	0.28344	0.44357	0.17647
Class	3		0.08188	0.21961	-0.14829		0.31745
Intercepts	4		0.30379	0.61812	0.20205		
(LOC)[3]	5				0.57763		
	6						
cos(ASP)*SL	(b_1)	0.09817	-0.21337	-0.04562	-0.01215	0.08277	-0.06625
sin(ASP) *SL	(b_2)	0.03876	0.03430	0.06287	-0.04595	0.10987	0.05534
SL	(b_3)	-0.17888	0.33523	0.78176	1.17025	0.04966	0.11931
SL^2	(b_4)	0.0	-0.70216	-1.12380	-1.52006	0.0	0.0
(*EL*)	(b_5)	0.03517	0.03730	0.02591	0.00917	0.02863	-0.00175
$(EL)^2$	(b_6)	-.000467	-.000433	-.000377	-.000117	-.000422	-.000067
ln (*DBH*)	(b_7)	0.56445	0.54140	0.56888	0.68810	0.68712	0.58705
CR	(b_8)	1.08338	1.03478	2.06850	1.93969	1.64133	1.29360
CR^2	(b_9)	0.0	0.07509	-0.62361	-0.78258	-0.27244	0.0
(*BAL*/100)	(b_{10})	0.42112	0.43637	0.50202	0.45142	0.0	0.74596
(BAL/ln(DBH+1)	(b_{11})	-2.08272	-2.03256	-2.11590	-1.76812	-0.80918	-2.28375
	1	-.000439	-.000310	-.000252	-.000274	-.000225	0.0
$(DBH)^2$	2	-.000004	-.000566	-.000373	-.000089	-.000216	
Classes	3			-.000502	-.000643	-.000429	
(b_{12})[4]	4			-.000572			
CCF/100	1	-0.02430	-0.10144	-0.09046	-0.09624	0.0	-0.05054
Classes	2	-0.24886	-0.14793	-0.11884	-0.19544		-0.15356
(b_{13})	3	-0.01079	-0.05438	-0.05529	-0.05119		-0.09396
	4			-0.02180			

[1]Species are defined in tables 2-3.
[2]Habitat classes are defined in table 19.
[3]Location classes are defined in table 20.
[4]*DBH* squared classes are defined in table 22.

Table 18 (continued). Coefficients of the diameter increment model by species, see equation {29}.

Variables				Species[1]			
(classes)		LP	ES or S	AF	PP	MH	LM
				LL		OS	PY
	1	0.77399	-0.58842	-0.96389	1.16233	-1.68033	0.00000
Habitat	2	0.67828	-0.21235	-0.72415	0.73408	-1.52111	
Class	3	0.64451	-0.71629	-0.57308	0.51417		
Intercepts	4	0.37945	-0.53954	-0.82218			
(HAB)[2]	5	0.54337		-1.24093			
	6			-1.10746			
	1	0.43735	0.26262	0.42062	0.24588	0.12520	1.568742
Location	2	0.21113	-0.15871	0.14072	0.56958	0.48076	
Class	3	0.14808		-0.13001	0.42787		
Intercepts	4						
(LOC)[3]	5						
	6						
cos(ASP)*SL	(b_1)	0.00325	-0.13091	-0.12473	-0.09976	0.17935	-0.609774
sin(ASP) *SL	(b_2)	0.12993	-0.06038	-0.06862	0.01192	0.13363	-0.01752
SL	(b_3)	0.46546	0.65622	0.30070	-0.06637	0.07628	-2.05706
SL^2	(b_4)	-0.58014	-0.90143	-0.62224	-0.43720	0.00000	2.113263
(*EL*)	(b_5)	-0.00480	0.06259	0.06313	0.03229	0.08518	0.00000
$(EL)^2$	(b_6)	-.000058	-.000709	-.000676	-.000422	-.000943	.000000
ln (*DBH*)	(b_7)	0.89503	0.73045	0.86240	0.66101	0.89778	0.213947
CR	(b_8)	1.85558	1.54643	0.52044	1.31618	1.28403	1.523464
CR^2	(b_9)	-0.36393	-0.26635	0.86236	0.0	0.0	0.0
(*BAL*/100)	(b_{10})	-0.03665	0.25639	0.0	0.0	0.0	-0.358634
(BAL/ln(DBH+1)	(b_{11})	-0.43329	-1.18218	-0.51270	-1.25881	-0.66110	0.0
	1	-.001260	-.000132	-.000283	-.000406	-.000484	-.0006538
DBH^2	2	-.002168	-.000294	-.000780	-.000437	-.000306	
Classes	3	-.001889	-.000427		-.000140		
(b_{12})[4]	4	-.000867					
CCF/100	1	-0.05576	-0.01547	-0.01598	-0.10416	-0.10744	-0.199592
Classes	2	-0.14919	-0.38386	-0.04477	-0.88809		
(b_{13})	3	-0.40640	-0.05371	-0.07392	-0.25938		
	4	-0.11400	-0.15159		-0.14726		

[1]Species are defined in tables 2-3.
[2]Habitat classes are defined in table 19.
[3]Location classes are defined in table 20.
[4]*DBH* squared classes are defined in table 22.

Table 19. Classification of habitat effects by species among habitat types for the diameter increment model for the North Idaho and Inland Empire variants of FVS, see equation {29}.

	Habitat Effects by Species[1]											
Habitat		L							AF		MH	LM
code[2]	WP	WB	DF	GF	WH	C	LP	S	LL	PP	OS	PY
130	2	5	3	2	1	2	5	4	6	1	2	1
170	2	5	3	2	1	2	5	4	6	1	2	1
250	2	5	3	2	1	2	5	4	6	2	2	1
260	2	5	3	2	1	2	5	4	6	3	2	1
280	2	5	3	2	1	2	1	4	6	3	2	1
290	2	5	3	2	1	2	2	4	6	2	2	1
310	2	5	3	2	1	2	1	4	6	2	2	1
320	2	5	1	2	1	2	5	4	6	3	2	1
330	2	5	3	2	1	2	5	4	6	3	2	1
420	2	1	3	2	1	2	5	4	6	3	2	1
470	2	1	3	2	1	2	5	4	6	3	2	1
510	2	2	1	2	1	2	2	1	6	2	2	1
520	1	1	1	1	1	2	2	1	1	2	2	1
530	1	2	1	2	1	2	3	4	2	2	2	1
540	1	2	1	2	1	1	3	2	3	3	2	1
550	1	2	1	2	1	1	3	2	3	3	2	1
570	1	3	1	2	1	2	3	4	4	3	2	1
610	1	3	1	2	1	2	3	2	3	3	2	1
620	1	2	1	2	1	2	3	1	1	2	2	1
640	2	5	3	2	1	2	4	4	6	3	2	1
660	2	2	2	2	1	2	4	4	6	3	2	1
670	1	1	3	1	1	2	3	4	6	3	1	1
680	1	1	3	2	1	2	4	4	6	3	2	1
690	2	1	3	2	1	2	5	4	6	3	2	1
710	2	5	3	1	1	2	5	4	6	3	2	1
720	2	5	3	2	1	2	5	4	6	3	2	1
730	2	4	3	2	1	2	4	4	1	3	2	1
830	2	5	2	2	1	2	4	3	5	3	2	1
850	2	5	3	2	1	2	5	4	5	3	2	1
999[3]	2	5	3	2	1	2	5	4	6	3	2	1

[1] Species codes are defined in tables 2-3.
[2] Habitat codes are defined in table 4.
[3] Types grouped with 999 were included in the overall mean for the species.

Table 20. Classification of location effects by species among National Forests for the diameter increment model in the North Idaho and Inland Empire variants of FVS, see equation {29}.

	Location effects by species											
		L							AF			LM
National Forest	WP	WB	DF	GF	WH	C	LP	S	LL	PP	MH	PY
Bitterroot	2	1	5	6	3	4	4	3	4	1	3	1
Idaho Panhandle	1	1	4	5	2	1	2	1	1	2	2	1
Clearwater	2	1	1	1	3	1	1	1	1	2	1	1
Coeur d'Alene	2	2	2	2	1	1	1	1	2	2	1	1
Colville	2	3	3	2	3	2	2	3	2	1	3	1
Flathead	2	3	3	3	3	2	4	2	3	4	3	1
Kaniksu	2	2	2	2	3	3	3	3	3	3	3	1
Kootenai	2	5	3	4	3	4	3	3	4	1	3	1
Lolo	2	5	5	6	3	2	4	3	4	4	1	1
Nezperce	2	4	1	2	3	1	2	1	2	3	3	1
St. Joe	1	1	4	5	2	1	2	1	1	2	2	1

Table 21. Classification of crown competition factor by habitat type and species for the diameter increment model in the North Idaho and Inland Empire variants of FVS, see equation {29}.

	Crown Competition Effects by Habitat Type and Species[1]											
Habitat		**L**							**AF**		**MH**	**LM**
code[2]	**WP**	**WB**	**DF**	**GF**	**WH**	**C**	**LP**	**S**	**LL**	**PP**	**OS**	**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
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	3	4	3	1	3	4	4	3	4	1	1

Table 22. Classification of diameter-squared effects by species among National Forests for the diameter increment model in the North Idaho and Inland Empire variants of FVS, see equation {29}.

	DBH squared effects by species[1]											
		L							**AF**			**LM**
National Forest	**WP**	**WB**	**DF**	**GF**	**WH**	**C**	**LP**	**S**	**LL**	**PP**	**MH**	**PY**
Bitterroot	1	1	1	1	1	1	1	1	1	1	1	1
Idaho Panhandle	2	2	4	1	3	1	1	1	2	2	2	1
Clearwater	2	1	2	1	1	2	2	2	2	2	1	1
Coeur d'Alene	2	1	2	1	2	1	2	1	1	2	1	1
Colville	2	1	2	1	3	1	1	1	2	2	1	1
Flathead	1	1	3	2	1	1	1	1	1	3	1	1
Kaniksu	2	1	1	2	1	1	2	3	1	3	1	1
Kootenai	1	1	4	3	1	2	3	2	2	2	1	1
Lolo	1	1	1	1	1	1	1	1	1	1	2	1
Nezperce	1	1	1	2	1	2	4	1	1	1	1	1
St. Joe	2	2	4	1	3	1	1	1	2	2	2	1

[1] Species codes are defined in tables 2-3.

Large-tree diameter growth for pinyon pine and western juniper is from equations used in the Utah variant. Diameter at the end of the growth cycle is predicted using equation {30}. Diameter growth is the difference between the diameters at the beginning of the cycle and end of the cycle, adjusted for bark ratio.

{30} $DF = 0.25897 + 1.03129 * D - 0.0002025464 * BA + 0.00177 * SI$

where:
DF is end of cycle diameter
D is current tree diameter (D $\geq$ 1.0 for this computation)
BA is total stand basal area
SI is species site index

Large-tree diameter growth for cottonwood and "other hardwoods" is predicted using equations from in the Central Rockies variant. Diameter at the end of the growth cycle is predicted using equation {31}. Diameter growth is the difference between the diameters at the beginning of the cycle and end of the cycle, adjusted for bark ratio.

{31} $DF = 0.24506 + 1.01291 * DBH - 0.00084659 * BA + 0.00631 * SI$

where:
DF is end of cycle diameter
DBH is current tree diameter at breast height (D $\geq$ 1.0 for this computation)
BA is total stand basal area
SI is species site index

Large-tree diameter growth for aspen, Rocky mountain maple, and paper birch is predicted using the aspen equation from the Utah variant. First potential diameter growth is estimated, and then the estimate is modified based on site index, stand density and tree diameter. Potential height growth is estimated using equation {32} and the modifier based on stand density and tree diameter in equation {33}. Diameter growth is predicted using equation {34}, and converted to an inside-bark estimate.

{32} $POTDG = .4755 - 3.8336E\text{-}6*DBH^{4.1488} + 0.04510*CR*DBH^{.67266}$

where:
POTDG is potential diameter growth
DBH is diameter breast height
CR is crown ratio percent / 10

{33} $MOD = 1.0 - \exp\{-FOFR * GOFAD * [(310.0-BA)/310]\}^{0.5}$

where:
$FOFR = 1.07582 * \{1.0 - \exp(-1.89022 * REL)\}$
$GOFAD = 0.21963 * (QMD + 1.0)^{0.73355}$

REL = *DBH*/*QMD*
QMD is quadratic mean diameter for the stand
BA is total stand basal area per acre

{34} $DG = POTDG * MOD * (0.48630 + 0.01258 * SI)$

where:
DG is estimated diameter growth (outside bark)
POTDG is potential diameter growth (equation {32})
MOD is growth modifier (equation {33})
SI is species site index

4.6.2 Large Tree Height Growth

In the North Idaho variant, and for corresponding species in the Inland Empire variant, equation {35} is used to estimate large tree height growth. Equations were fit for western white pine, western larch, Douglas-fir, grand fir, western hemlock, western redcedar, lodgepole pine, Engelmann spruce, subalpine fir, ponderosa pine, and mountain hemlock. In the Inland Empire variant, the western larch equation is also used for whitebark pine; the subalpine fir equation is used for subalpine larch; and the mountain hemlock equation is used for "other softwoods".

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

where:
HTG is height growth (feet)
HAB is habitat dependent intercept
SPP is species dependent intercept
HT is height (feet)
DBH is diameter breast height (inches)
DG is 10-year diameter increment (inches)
b_1 - b_4 are regression coefficients (table 23)
b_2 is species dependent
b_3 and b_4 are habitat dependent

Table 23. Coefficients for the large tree height increment model in the North Idaho and Inland Empire variants of FVS, see equation {35}.

	Species									
Variable	**WP**	**WL or L**	**DF**	**GF**	**WH**	**RC or C**	**LP**	**ES or S**	**AF**	**PP**
		WB				**MH OS**			**LL**	
SPP	-0.5342	0.1433	0.1641	-0.6458	-0.6959	-0.9941	-0.6004	0.2089	-.05478	0.7316
Ln (*HT*) (b_1)	0.23315	0.23315	0.23315	0.23315	0.23315	0.23315	0.23315	0.23315	0.23315	0.23315
Ln (*DBH*) (b_2)	-0.04935	-0.3889	-0.4574	-0.09775	-0.1555	-0.1219	-0.2454	-0.5720	-0.1997	-0.5657
	Habitat Class[1]									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**		
HAB	2.03035	1.72222	1.19728	1.81759	2.14781	1.76998	2.21104	1.74090		
ln(*DG*) (b_3)	0.62144	1.02372	0.85493	0.75756	0.46238	0.49643	0.37042	0.34003		
HT^2(x 10^{-5}) (b_4)	-13.358	-3.809	-3.715	-2.607	-5.200	-1.605	-3.631	-4.460		

[1] Definition of habitat classes:

1 = 130, 170, 660, 730, 830, 850, 999
2 = 250, 260, 280, 290, 310, 320, 330
3 = 420, 470
4 = 510, 620, 640, 670, 680
5 = 520
6 = 530
7 = 540, 550, 570, 610
8 = 690, 710, 720

In the Inland Empire variant, equations for limber pine and quaking aspen predict future height using a Johnson SBB relationship, rather than height increment. Height increment is obtained by subtracting current height from the estimated future height. The equation for limber pine, which is from the Tetons variant, is also used for Pacific yew; the equation for quaking aspen, which is from the Utah variant, is also used for cottonwood, Rocky Mountain maple, paper birch, and "other hardwoods".

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 24, parameters of the SBB distribution cannot be calculated and height growth is set to 0. Otherwise, the SBB distribution "*Z*" parameter is estimated using equation {36}.

$$\{36\} \quad Z = [C_4 + C_6 * FBY2 - C_7 * (C_3 + C_5 * FBY1)] * (1 - C_7^2)^{-0.5}$$

where:

$FBY1 = \mathrm{LN}[Y1/(1 - Y1)]$
$FBY2 = \mathrm{LN}[Y2/(1 - Y2)]$
$Y1 = (DBH - 0.1) / 4.5$
$Y2 = (HT - 4.5) / 90$
DBH is tree diameter at breast height
HT is total tree height at the beginning of the cycle

For aspen, cottonwood, Rocky Mountain maple, paper birch, and "other hardwoods", the Z value is adjusted using equation {37} to eliminate known bias, and bounded to be greater than 0.

{37} $Z = 0.1 - 0.10273*Z + 0.00273*Z^2$

Next, if the Z value is 2.0 or less, it is adjusted for all younger aged trees using equation {38}. This adjustment is done for trees with an estimated age between 11 and 39 years and a diameter less than 9.0 inches. After this calculation, the value of Z is bounded to be 2.0 or less for trees meeting these criteria.

{38} $Z = Z + (0.3564*DG)*PCT/100*K$

where:
DG is diameter growth adjusted for the cycle length
PCT is the trees' percentile in the basal area distribution
K = constant (1.1 if the crown ratio is 75 percent or greater; 1.0 otherwise)

Estimated height 10 years later is then calculated using equation {39}.

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

where:
$PSI = C_8 * [(D10 - 0.1) / (0.1 + C_1 - D10)]^{C_9} * [e^{(K)}]$
$K = Z*[(1-C_7^2)^{0.5/C_6}]$
$D10$ is tree diameter 10-years later

Finally, 10-year height growth is calculated by subtraction using equation {40} and adjusted to the cycle length.

{40} $HTG = H10 - HT$ if $H10 > HT$
$= 0.1$ otherwise

where:
HTG is 10-year height-growth (feet)
$H10$ is estimate height after 10-years
HT is beginning of cycle height (feet)
C_1-C_9 are regression coefficients shown in table 24.

Table 24. Coefficients in the large tree height growth model, by crown ratio, for species in the Inland Empire variant using the Johnson's SBB height distribution, see equations {36 and 39} (*CR* = percent crown ratio).

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

Height growth for pinyon pine and western juniper is estimated as described under section 4.5.1.

4.6.3 Large Tree Crown Ratio Change

For species included in the North Idaho variant (western white pine, western larch, Douglas-fir, grand fir, western hemlock, western redcedar, lodgepole pine, Engelmann spruce, subalpine fir, ponderosa pine, and mountain hemlock (aka "other softwoods')), and the same species in the Inland Empire variant, expected crown ratio is estimated using equation {41}and coefficients shown in table 25. In addition in the Inland Empire variant, whitebark pine uses the equation for western larch, subalpine larch uses the subalpine fir equation, and other softwoods uses the mountain hemlock equation.

$$\{41\}\quad \ln(CR) = HAB + b_1*BA + b_2*BA^2 + b_3*\ln(BA) + b_4 * CCF + b_5*CCF^2 + b_6*\ln(CCF) + b_7*DBH + b_8*DBH^2 + b_9*\ln(DBH) + b_{10}*HT + b_{11}*HT^2 + b_{12}*\ln(HT) + b_{13}*PCT + b_{14}*\ln(PCT)$$

where:
HAB is habitat type constant
BA is basal area
CCF is crown competition factor
DBH is diameter breast height
HT is height
PCT is trees basal area percentile
b_1-b_{14} are species specific coefficients

Table 25. Coefficients for the crown ratio equation in the North Idaho variant and corresponding species in the Inland Empire variant of FVS, see equation {41}.

			WL or L				
Variable[1]	**Class**	**WP**	**WB**	**DF**	**GF**	**WH**	**RC or C**
	1	0.8884	0.06533	0.8643	–0.2304	–0.2413	–1.6053
Habitat	2	0.7309	0.03441	0.7271	–0.5421		–1.7128
Class	3	0.9347	0.2307	0.9840	–0.4343		
Intercepts[3]	4	0.9888	0.1661	0.8127	–0.3759		
	5	0.9945	–0.1253	0.8874	–0.4129		
	6	1.1126	–0.05018	0.7055	–0.4879		
	7	1.0263	0.11005	0.7708	–0.2674		
	8		0.08113	0.7849	–0.1941		
	9		0.1782	0.8038			
	10		0.03919	0.8742			
	11		0.2107	0.8232			
	12			0.8415			
	13			0.9759			
	14						
BA		0.	–0.00204	0.	–0.00183	0.	0.
$BA^2(x10^{-6})$		0.	0.	0.	0.	–1.902	0.

ln(*BA*)		–0.34566	0.	0.	0.	0.	0.17479
CCF		0.	0.	0.	0.	0.	–0.00183
CCF^2(x10^{-6})		0.	0.	0.	0.	0.	0.
ln(*CCF*)		0.	0.	–0.15334	0.	0.	0.
DBH		0.03882	0.	0.	0.	0.03027	–0.0056
DBH^2		–0.0007	0.	0.	0.	–0.00055	0.
ln(*DBH*)		0.	0.30066	0.33840	0.24293	0.	0.
HT		0.	0.	0.	0.	0.	0.
HT^2		0.	0.	0.	0.	0.	0.
ln(*HT*)		–0.21217	–0.59302	–0.59685	–0.25601	–0.25776	0.
PCT		0.00301	0.	0.	0.	0.	0.
ln(*PCT*)		0.	0.19558	0.16488	0.07260	0.06887	0.1105

Table 25 continued. Coefficients for the crown ratio equation in the NI variant and corresponding species in the IE variant (see equation {41}.

				AF		**MH**
Variable[1]	**Class**	**LP**	**ES or S**	**LL**	**PP**	**OS**
	1	–0.3785	0.05351	0.09453	–0.9436	0.4649
Habitat	2	–0.4142	–0.05031	–0.07740	–0.8654	0.3211
Class	3	–0.3985	0.1075	0.07113	–0.8849	0.1970
Intercepts[3]	4	–0.2987	–0.1872	0.2039	–0.9067	0.2295
	5	–0.3810	0.01729	0.06176	–0.8783	0.3383
	6	–0.4087	0.03667	0.1513	–1.0103	0.3450
	7	–0.3577	0.01885	0.09086	–1.0268	
	8	–0.2994	0.09102	0.1580	–1.0050	
	9	–0.2486	0.1371	0.09229	–1.0301	
	10	–0.2863	0.08368	0.01551		
	11	–0.1968	0.1230			
	12	–0.4931	–0.02365			
	13	–0.2676				
	14	–0.5625				
BA		0.	–0.00203	–0.00190	–0.002165	–0.00264
BA^2(x10^{-6})		0.	0.	0.	0.	0.
ln(*BA*)		0.	0.	0.	0.	0.
CCF		0.	0.	0.	0.	0.
CCF^2(x10^{-6})		0.	0.	0.	0.	5.116
ln(*CCF*)		–0.18555	0.	0.	0.	0.
DBH		0.	0.	0.	0.	0.
DBH^2		0.	0.	0.	0.	0.
ln(*DBH*)		0.53172	0.29699	0.23372	0.26558	0.
HT		–0.02989	0.	0.	0.	0.
HT^2		0.00011	0.	0.	0.	0.
ln(*HT*)		0.	–0.38334	–0.28433	–0.31555	–0.25138
PCT		0.0042	0.	0.001903	0.	0.
ln(*PCT*)		0.	0.09918	0.	0.16072	0.05140

[1] Definition of variables:

BA = Stand basal area (square feet per acre)
CCF = Stand crown competition factor
DBH = Current diameter at breast height (inches)
HT = Current height (feet)
PCT = Tree's percentile in the stand basal area distribution

[2] Species codes are given in tables 2-3.

[3] Habitat types are mapped into habitat classes as shown in table 26.

Table 26. Map of habitat types into habitat classes by species for the crown ratio model in the North Idaho and Inland Empire variants of FVS (see equation {41}).

	Species										
		WL or L							**AF**		**MH**
Habitat	**WP**	**WB**	**DF**	**GF**	**WH**	**RC or C**	**LP**	**ES or S**	**LL**	**PP**	**OS**
130	2	2	2	2	1	1	2	2	2	2	1
170	2	2	2	2	1	1	2	2	2	2	1
250	2	2	2	2	1	1	2	2	2	4	1
260	2	2	4	2	1	1	2	2	2	1	1
280	2	2	4	2	1	1	2	2	2	1	1
290	2	2	4	2	1	1	2	2	2	1	1
310	2	2	6	2	1	1	4	2	2	5	1
320	2	3	7	2	1	1	5	3	2	6	1
330	2	2	4	2	1	1	5	2	2	1	1
420	2	4	8	1	1	1	2	1	2	1	1
470	2	4	8	1	1	1	2	1	2	1	1
510	2	5	5	2	1	1	6	2	2	8	1
520	3	6	9	3	1	1	7	4	2	7	2
530	4	7	10	4	1	1	8	5	3	9	2
540	4	7	10	4	1	1	8	5	4	9	2
550	4	7	10	4	1	1	8	5	4	9	2
570	5	8	11	5	1	2	9	6	4	3	3
610	5	8	11	5	1	2	9	6	4	3	3
620	5	4	8	6	1	2	10	7	5	3	4
640	6	1	1	1	1	1	11	8	6	1	1
660	6	10	12	7	1	1	11	8	6	1	1
670	1	9	12	7	1	1	12	9	7	1	1
680	6	10	13	7	1	1	11	8	6	1	5
690	1	1	1	1	1	1	1	10	1	1	1
710	7	11	3	8	1	1	13	11	8	1	6
720	1	1	1	1	1	1	1	1	1	1	1
730	6	1	3	7	1	1	14	1	9	1	1
830	6	1	1	1	1	1	3	12	10	1	1
850	6	1	1	1	1	1	3	12	10	1	1
999	6	2	1	1	1	1	11	8	6	1	1

In the Inland Empire variant, pinyon pine, western juniper, cottonwood, and other hardwoods use equations from the Central Rockies variant that predict crown length as a function of tree and stand attributes {42}, with coefficients shown in table 27. Crown length is then converted to crown ratio by dividing crown length by total tree height.

{42} $CL = a_0 + a_1 * HT + a_2 * BA$

where:
CL is predicted crown length
HT is total tree height
BA is total stand basal area
$a_0 – a_2$ are species specific coefficients shown in table 27

Table 27. Coefficients to predict crown length for pinyon pine, western juniper, cottonwood, and other hardwoods in the Inland Empire variant, see equation {42}.

Species	a_0	a_1	a_2
PI, JU	-0.59373	0.67703	0.0
CO, OH	5.17281	0.32552	-0.01675

Remaining species in the IE variant use the Weibull distribution to predict future crown ratio. Equations for limber pine, which are also used for Pacific yew, are from the Tetons variant; equations for quaking aspen, which are also used for Rocky mountain maple, and paper birch, are from the Utah variant. First average stand crown ratio is estimated from the stand density index (SDI) (Reineke, 1933) using equation {43}. Weibull parameters are then estimated from the average stand crown ratio using equations {44-46}. Individual trees are assigned a crown ratio from the Weibull distribution. The change in crown ratio from on cycle to the next is obtained from subtracting the crown ratios assigned from the crown ratio that the tree presently has. This change is bounded by 10 percent to avoid drastic changes from one cycle to the next.

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

where:
ACR is average crown ratio for the species
RELSDI = Stand *SDI* / Maximum *SDI* (*RELSDI* bounded ≤ 1.5)
d_0, d_1 are coefficients shown in table 28

{44} $A = a_0$
{45} $B = b_0 + b_1 * ACR$ (*B* bounded ≥ 1)
{46} $C = c_0 + c_1 * ACR$ (*C* bounded ≥ 2)

where:
A, *B*, *C* are parameters of the Weibull distribution of crown ratios
a_0,b_0,b_1,c_0,c_1 are coefficients shown in table 28

Table 28. Coefficients for species using the Weibull crown model in the Inland Empire variant of FVS.

Coefficient	**LM PY**	**AS MM PB**
a_0	1.0	0.
b_0	-0.82631	-0.08414
b_1	1.06217	1.14765
c_0	3.31429	2.77500
c_1	0.	0.
d_0	6.19911	4.01678
d_1	-0.02216	-0.01516

Crown ratios are then assigned based on a tree's relative position in the diameter distribution and multiplied by a scale factor (equation {47} which accounts for stand density.

{47} $SCALE = 1.0 - 0.00167 * (SCCF - 100.0)$

where:
SCALE is the density dependent scaling factor
SCCF is stand crown competition factor

Crowns estimated from the Weibull distribution are bounded between the .05 to .95 percentile points of the distribution.

4.7 Mortality

All species in both the North Idaho and Inland Empire variants use the Prognosis-type mortality model (Hamilton 1986). In the Inland Empire variant, whitebark pine uses the NI western larch mortality equations; subalpine larch uses the NI subalpine fir equations, "other softwoods" uses the NI mountain hemlock equations; pinyon pine and western juniper use the NI western white pine equations modified by 80%; and limber pine, Pacific yew, aspen, cottonwood, Rocky mountain maple, paper birch, and "other hardwoods" uses the NI western white pine equations modified by 40%.

Mortality predictions are dependent on habitat type, species, diameter, diameter increment, estimated potential diameter increment, stand basal area, and a trees' diameter

relative to the average stand diameter. Potential diameter increments are determined by equation {48}. Values for the index "I" are shown in tables 29 and 30.

{48} $PDG = 0.20 + 0.05*I$

where:
PDG is potential diameter growth
I is an index dependent on habitat type and National forest

Table 29. Values for the potential diameter growth index for trees greater than 5.0 inches in diameter, by habitat type and National Forest, for the North Idaho and Inland Empire variants of FVS (see equation {48}).

Habitat	**National Forest**										
Type	**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
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

Table 30. Values for the potential diameter growth index for trees less than, or equal to, 5.0 inches in diameter, by habitat type and National Forest, for the North Idaho and Inland Empire variants of FVS (see equation {48}).

Habitat	National Forest										
Type	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
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

The mortality model uses mortality rates based on two independent equations. These are explained in section 7.3.1 of the Essential FVS guide (Dixon 2003). The value of "g" is determined from the potential diameter growth derived from equation {48}. Values of the coefficients b_0 through b_6 in the individual tree equation for the NI and IE variant are as follows:

b_0 = species dependent constant (see table 31)

$b_1 = 0.222310$
$b_2 = -0.0460508$
$b_3 = 11.2007$
$b_4 = 0.246301$
$b_5 = -0.554421$
$b_6 = 6.07129$

Table 31. Species dependent constant (b_0) for the individual tree mortality equation shown in section 7.3.1.1 of the Essential FVS guide.

Species	**Constant (b_0)**
Western white pine	2.76253
Western larch	2.58650
Douglas-fir	3.08042
Grand fir	3.08042
Western hemlock	3.37026
Western redcedar	4.34229
Lodgepole pine	2.64196
Engelmann spruce	3.70272
Subalpine fir	2.97433
Ponderosa pine	2.97433
Mountain hemlock	2.76253
Whitebark pine	2.58650
Limber pine	2.76253
Subalpine larch	2.97433
Pinyon pine	2.76253
Western juniper	2.76253
Pacific yew	2.76253
Quaking aspen	2.76253
Cottonwood	2.76253
Rocky mountain maple	2.76253
Paper birch	2.76253
Other hardwoods	2.76253
Other softwoods	2.76253

5.0 REGENERATION

Both the NI and IE variants have the full establishment model. The first 10 species in each variant will regenerate naturally following significant disturbances or prolonged time spans with no management activity. Remaining species can be established using the PLANT or NATURAL keyword records. In addition, in the Inland Empire variant, quaking aspen, cottonwood, Rocky mountain maple, paper birch, and "other hardwoods" will sprout following harvesting of these species. Parameters and equations used in the regeneration establishment model for these two variants are described below.

5.1 Minimum and Maximum Heights

Regeneration is passed to the FVS tree list at the end of the growth cycle in which it occurs. Trees being passed are subject to the minimum and maximum height constraints shown in table 32.

Table 32. Minimum and maximum tree heights used in the North Idaho and Inland Empire variants for trees being passed to the FVS tree list.

Species	Minimum Height (ft)	Maximum Height (ft)
Western white pine	1	23
Western larch	1	27
Douglas-fir	1	21
Grand fir	0.5	21
Western hemlock	0.5	22
Western redcedar	0.5	20
Lodgepole pine	1	24
Engelmann spruce	0.5	18
Subalpine fir	0.5	18
Ponderosa pine	1	17
Mountain hemlock	0.5	22
Whitebark pine	1	27
Limber pine	1	27
Subalpine larch	0.5	18
Pinyon pine	0.5	6
Western juniper	0.5	6
Pacific yew	1	27
Quaking aspen	6	16
Cottonwood	3	16
Rocky mountain maple	6	16
Paper birch	6	16
Other hardwoods	3	16
Other softwoods	0.5	22

Equations within the regeneration/establishment extension estimate the heights of seedlings five years after seedlings are established or at the end of the cycle if the cycle boundary is within five years of the establishment date. These equations are extensive and are not presented here. If the period of time between the establishment date and the end of the growth cycle is greater than five years, equations described in section 4.5 are used to grow the trees from the time they are 5 years old to the end of the cycle.

For trees established using the PLANT or NATURAL keywords, users can override predicted heights by specifying an average seedling height in field 6 of the PLANT or NATURAL keywords. The height specified in field 6 is not subject to the minimum height restrictions shown in table 32 and seedlings as small as 0.1 foot can be established.

Regenerating trees become visible in FVS at the end of the growth cycle in which they are established. Tree records generated by the regeneration establishment model can be found in the tree list output file with tree identification numbers beginning with the letters "ES".

7.0 FIRE AND FUELS EXTENSION

The fire and fuels extension to FVS is linked to both the NI and IE variants. Documentation of the extension's relationships can be found in Crookston et al (2003) for the NI variant, and Rebain (2003) for the IE variant.

8.0 Literature Cited

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