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Western Sierra Nevada (WS) Variant Overview

Forest Vegetation Simulator

Mixed conifer Stand, Tahoe National Forest
(Rich Johnson, FS-R5)

Western Sierra Nevada (WS) Variant Overview

Forest Vegetation Simulator

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The FVS staff has maintained model documentation for this variant in the form of a variant overview since its release in 1987. 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. Stephanie Rebain cross-checked information contained in this variant overview with the FVS source code. Gary Dixon expanded the species list and made significant updates to this variant overview in 2011. Current maintenance is provided by Chad Keyser.

Keyser, Chad E., Dixon, Gary E., comp. 2008 (revised October 2, 2019). Western Sierra Nevada (WS) Variant Overview – Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 84p.

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Quick Guide to Default Settings

Parameter or Attribute	Default Setting	
Number of Projection Cycles	1 (10 if using Suppose)	
Projection Cycle Length	10 years	
Location Code (National Forest)	517 – Tahoe National Forest	
Plant Association Code	0 (Unknown)	
Slope	5 percent	
Aspect	0 (no meaningful aspect)	
Elevation	45 (4500 feet)	
Latitude / Longitude	Latitude	Longitude
All location codes	39	120
Site Species	PP	
Site Index	100	
Maximum Stand Density Index	Species specific	
Maximum Basal Area	Based on maximum stand density index	
Volume Equations	National Volume Estimator Library	
Merchantable Cubic Foot Volume Specifications:		
Minimum DBH / Top Diameter	Hardwoods	Softwoods
Region 5	7.0 / 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	Hardwoods	Softwoods
Region 5	10.0 / 6.0 inches	10.0 / 6.0 inches
Stump Height	1.0 foot	1.0 foot
Sampling Design:		
Large Trees (variable radius plot)	40 BAF	
Small Trees (fixed radius 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 the United States.

The Western Sierra Nevada (WS) variant was developed in 1987 covering the mixed-conifer forest type in California and extreme western Nevada. Data used to fit the model included Forest Service forest inventories and stand examinations, and PSW research study plots throughout the area. Leroy Dolph from the PSW Research Station fit some of the model relationships along with the FMSC staff.

Since the variant's development in 1987, some of the functions have been adjusted and improved as more data has become available, and as model technology has advanced. In 2011, this variant was expanded from 11 species to 43 species. The two species groupings, black oak / other hardwoods and tanoak / giant chinquapin, were split into individual species and 30 new species were added. For the newly added species, equations for sugar pine were used for western white pine and mountain hemlock; Douglas-fir equations were used for bigcone Douglas-fir; white fir equations were used for Pacific silver fir; giant sequoia equations were used for redwood; black oak / other hardwood equations were used for California live oak, canyon live oak, blue oak, California white oak / valley oak, interior live oak, and bigleaf maple; ponderosa pine equations were used for Monterey pine; tanoak / giant chinquapin equations were used for quaking aspen, California-laurel, Pacific madrone, and Pacific dogwood; lodgepole pine equations from the Inland California and Southern Cascades (CA) variant were used for lodgepole pine and whitebark pine; knobcone pine equations from the CA variant were used for singleleaf pinyon, knobcone pine, foxtail pine, Coulter pine, limber pine, gray or California foothill pine, Washoe pine, western juniper, Utah juniper, and California juniper; curlleaf mountain-mahogany equations from the South Central Oregon and Northeast California (SO) variant were used for curlleaf mountain-mahogany; and bristlecone pine equations from the Central Rockies (CR) variant were used for Great Basin bristlecone pine.

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

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

This publication can be downloaded from the Forest Management Service Center (FMSC), Forest Service website or obtained in hard copy by contacting any FMSC FVS staff member. Other FVS publications may be needed if one is using an extension that simulates the effects of fire, insects, or diseases.

2.0 Geographic Range

The WS variant was fit to data representing the mixed-conifer forest type in California and extreme western Nevada. Data used in initial model development came from Forest Service forest inventories and stand examinations, and PSW research study plots throughout the area. Distribution of data samples for species fit from this data are shown in Appendix A.

The WS variant covers forest areas in eastern California and western Nevada. The suggested geographic range of use for the WS variant is shown in figure 2.0.1.

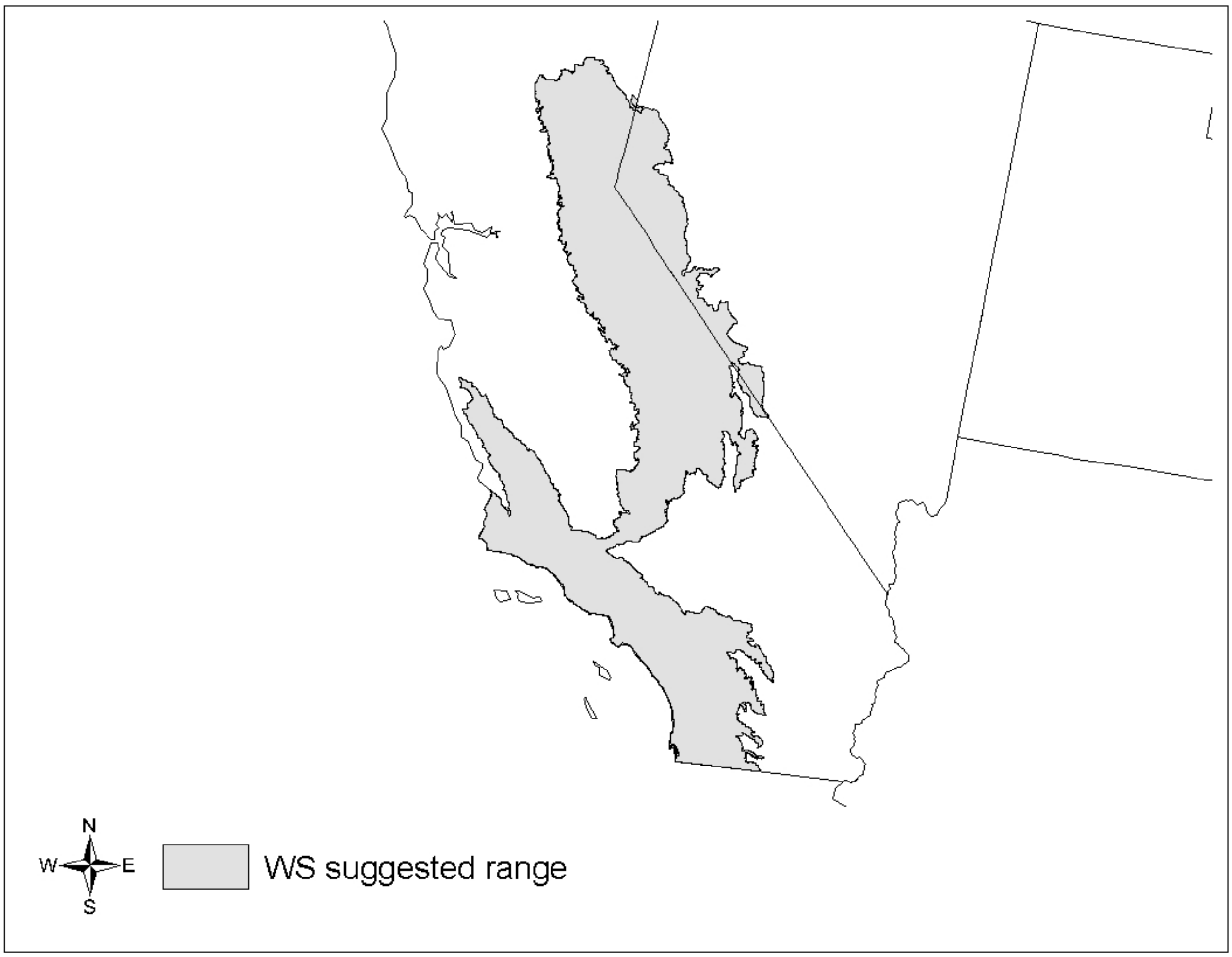

Figure 2.0.1 Suggested geographic range of use for the WS variant.

Within USFS Region 5, the following forests and districts should use the WS variant: all districts of the Plumas NF, San Bernardino NF, Sequoia NF, Sierra NF, Stanislaus NF, Tahoe NF, and Toiyabe NF (Warbington 2004, based on Spreadsheet provided by Ralph Warbington, R5 Ecosystem Planning Staff, Remote Sensing Lab, http://www.fs.fed.us/r5/rsl/).

3.0 Control Variables

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

3.1 Location Codes

The location code is a 3- 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 the WS variant, a 5-digit code may be entered where the last two digits represent the District Number. 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, Indian Reservations, Industry Lands, or other lands).

The default value for latitude, which is used as a growth predictor variable, is set by Forest Service Forest and District codes. If the District code is not entered, a default is set by Forest. If the location code is missing or incorrect in the WS variant, a default forest code of 517 (Tahoe National Forest) will be used. Location codes recognized in the WS variant are shown in tables 3.1.1. and 3.1.2.

Table 3.1.1 Location codes used in the WS variant.

USFS National Forest	Forest Code	District	District Code	Latitude
Eldorado	503	Not Specified	--	38
		Amador	51	38
		Georgetown	53	39
		Pacific	55	38
		Placerville	56	38
Plumas	511	Not Specified	--	39
		Beckworth	01	40
		Greenville	52	40
		La Porte	53	39
		Oroville	54	39
		Milford	55	39
		Quincy	56	39
Sequoia	513	Not Specified	--	35
		Hume Lake	51	36
		Western Divide	52	36
		Hot Springs	53	35
		Green Horn	54	35
		Cannell Meadows	56	35
Sierra	515	Not Specified	--	37

USFS National Forest	Forest Code	District	District Code	Latitude
		Mariposa	51	37
		Pineridge	53	37
		Kings River	54	36
		Minarets	55	37
		Bass Lake	57	37
Stanislaus	516	Not Specified	--	38
		Mi-Wok	51	38
		Calaveras	52	38
		Summit	53	38
		Groveland	54	37
Tahoe	517	Not Specified	--	39
		Yuba River	53	39
		American River	54	39
		Nevada City	55	39
		Sierraville	56	39
		Truckee	57	39
Toiyabe (mapped to 516)	417	All	--	38
Angeles (mapped to 513)	501	All	--	35
Cleveland (mapped to 513)	502	All	--	35
Inyo (mapped to 513)	504	All	--	35
Los Padres (mapped to 513)	507	All	--	35
San Bernadino (mapped to 513)	512	All	--	35
Lake Tahoe Basin Management Unit (mapped to 503)	519	All	--	38

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

Location Code	Location
7712	Pyramid Lake Paiute Reservation (mapped to 417)
7713	Reno-Sparks Indian Colony (mapped to 417)
7715	Walker River Reservation (mapped to 417)
7801	Berry Creek Rancheria (mapped to 511)
7808	Enterprise Rancheria (mapped to 511)
7814	Fort Independence Reservation (mapped to 504)
7817	North Fork Off-Reservation Tl (mapped to 515)
7825	Bishop Reservation (mapped to 504)
7827	Tule River Reservation (mapped to 513)
7828	Lone Pine Reservation (mapped to 504)

Location Code	Location
7832	Tuolumne Rancheria (mapped to 516)
7835	Timbi-Sha Shoshone Reservation (mapped to 504)
7847	Agua Caliente Indian Reservation (mapped to 512)
7849	Cahuilla Reservation (mapped to 512)
7850	Campo Indian Reservation (mapped to 502)
7851	Capitan Grande Reservation (mapped to 502)
7852	Barona Reservation (mapped to 502)
7853	Ewiiaapaayp Reservation (mapped to 502)
7854	Inaja And Cosmit Reservation (mapped to 502)
7855	La Jolla Reservation (mapped to 502)
7856	Los Coyotes Reservation (mapped to 502)
7857	Manzanita Reservation (mapped to 502)
7858	Mesa Grande Reservation (mapped to 502)
7859	Morongo Reservation (mapped to 512)
7860	Pala Reservation (mapped to 502)
7861	Pauma And Yuima Reservation (mapped to 502)
7862	Pechanga Reservation (mapped to 502)
7863	Santa Rosa Rancheria (mapped to 512)
7865	Santa Ysabel Reservation (mapped to 502)
7866	Soboba Reservation (mapped to 512)
7867	Viejas Reservation (mapped to 502)

3.2 Species Codes

The WS variant recognizes 43 species. 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 codes identifying species not recognized by the variant will be mapped to the most similar species in the variant. The species mapping crosswalk is available on the variant documentation webpage of the FVS website. Any non-valid species code will default to the other hardwoods category.

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 WS variant.

Table 3.2.1 Species codes used in the WS variant.

Species Number	Species Code	Common Name	FIA Code	PLANTS Symbol	Scientific Name
1	SP	sugar pine	117	PILA	*Pinus lambertiana*
2	DF	Douglas-fir	202	PSME	*Pseudotsuga menziesii*
3	WF	white fir	015	ABCO	*Abies concolor*
4	GS	giant sequoia	212	SEGI2	*Sequoiadendron giganteum*
5	IC	incense-cedar	081	CADE27	*Libocedrus decurrens*
6	JP	Jeffrey pine	116	PIJE	*Pinus Jeffreyi*
7	RF	California red fir	020	ABMA	*Abies magnifica*
8	PP	ponderosa pine	122	PIPO	*Pinus ponderosa*
9	LP	lodgepole pine	108	PICO	*Pinus contorta*
10	WB	whitebark pine	101	PIAL	*Pinus albicaulis*
11	WP	western white pine	119	PIMO3	*Pinus monticola*
12	PM	singleleaf pinyon	133	PIMO	*Pinus monophylla*
13	SF	Pacific silver fir	011	ABAM	*Abies amabilis*
14	KP	knobcone pine	103	PIAT	*Pinus attenuate*
15	FP	foxtail pine	104	PIBA	*Pinus balfouriana*
16	CP	Coulter pine	109	PICO3	*Pinus coulteri*
17	LM	limber pine	113	PIFL2	*Pinus flexilis*
18	MP	Monterey pine	124	PIRA2	*Pinus radiata*
19	GP	Gray or California foothill pine	127	PISA2	*Pinus sabiniana*
20	WE	Washoe pine	137	PIWA	*Pinus washoensis*
21	GB	Great Basin bristlecone pine	142	PILO	*Pinus longaeva*
22	BD	bigcone Douglas-fir	201	PSMA	*Pseudotsuga macrocarpa*
23	RW	redwood	211	SESE3	*Sequoia sempervirens*
24	MH	mountain hemlock	264	TSME	*Tsuga mertensiana*
25	WJ	western juniper	064	JUOC	*Juniperus occidentalis*
26	UJ	Utah juniper	065	JUOS	*Juniperus osteosperma*
27	CJ	California juniper	062	JUCA7	*Juniperus californica*
28	LO	California live oak	801	QUAG	*Quercus agrifolia*
29	CY	canyon live oak	805	QUCH2	*Quercus chrysolepsis*
30	BL	blue oak	807	QUDO	*Quercus douglasii*
31	BO	California black oak	818	QUKE	*Quercus kelloggii*
32	VO	California white oak / valley oak	821	QULO	*Quercus lobata*
33	IO	interior live oak	839	QUWI2	*Quercus wislizeni*
34	TO	tanoak	631	LIDE3	*Lithocarpus densiflorus*
35	GC	giant chinquapin	431	CHCHC4	*Chrysolepis chrysophylla*
36	AS	quaking aspen	746	POTR5	*Populus tremuloides*

Species Number	Species Code	Common Name	FIA Code	PLANTS Symbol	Scientific Name
37	CL	California-laurel	981	UMCA	*Umbellularia californica*
38	MA	Pacific madrone	361	ARME	*Arbutus menziesii*
39	DG	Pacific dogwood	492	CONU4	*Cornus nuttallii*
40	BM	bigleaf maple	312	ACMA3	*Acer macrophyllum*
41	MC	curlleaf mountain-mahogany	475	CELE3	*Cercocarpus ledifolius*
42	OS	other softwoods	298	2TE	
43	OH	other hardwoods	998	2TD	

3.3 Habitat Type, Plant Association, and Ecological Unit Codes

In the WS variant, plant association codes are only used in the Fire and Fuels Extension (FFE) to set fuel loading in cases where there are no live trees in the first cycle. Plant association codes recognized in the WS variant are shown in Appendix B. If an incorrect plant association code is entered or no code is entered, FVS will use the default plant association code, which is 0 (unknown). Users may enter the plant association code or the plant association FVS sequence number on the STDINFO keyword, when entering stand information from a database, or when using the SETSITE keyword without the PARMS option. If using the PARMS option with the SETSITE keyword, users must use the FVS sequence number for the plant association.

3.4 Site Index

Site index is used in some of the growth equations in the WS variant. Users should always use the same site curves that FVS uses as shown in table 3.4.1. If site index is available, a single site index for the whole stand can be entered, a site index for each individual species in the stand can be entered, or a combination of these can be entered. A site index value must be greater than or equal to 8, otherwise the value is considered a R5 site class code, see section 3.4.1. If site index is missing or incorrect, the site species is set to ponderosa pine with a default site index set to 100.

Table 3.4.1 Site index reference curves for species in the WS variant.

Species Code	Reference	BHA or TTA*	Base Age
SP, DF, WF, GS, IC, JP, PP, WP, PM, SF, MP, BD, RW, MH, OS	Dunning (1942); Dunning and Reineke (1933)	TTA	50
LO, CY, BL, BO, VO, IO, TO, GC, AS, CL, MA, DG, BM, OH	Powers (1972)	BHA	50
LP, WB, KP, FP, CP, LM, GP, WE, WJ, UJ, CJ	Dunning (1942); Dunning and Reineke (1933)	TTA	50
RF	Dolph (1991)	BHA	50
MC	Curtis, Herman, Francis, and Demars (1974)	BHA	100

Species Code	Reference	BHA or TTA*	Base Age
GB	Alexander (1967)	TTA	100
* Equation is based on total tree age (TTA) or breast height age (BHA)			

For all species except Great Basin bristlecone pine and curlleaf mountain-mahogany, default site indices for species not assigned a site index are determined based on the site index of the site species (height at base age) with an adjustment for the reference age differences between the site species and the target species.

Site index values can be entered directly using the sources listed above or as a Region 5 site class as described in section 3.4.1. Default values for all species except Great Basin bristlecone pine and mountain-mahogany are then assigned as described above or in section 3.4.1. Default values for Great Basin bristlecone pine and mountain-mahogany are assigned based on the ratio of the California red fir site index to its' potential site index range and the potential site index ranges of GB and MC. Potential site index ranges for this calculation are limited to10-134 for RF, 20-60 for Great Basin bristlecone pine, and 5-23 for mountain-mahogany. Equation {3.4.1} is used to assign the default site index for Great Basin bristlecone pine and equation {3.4.2} is used for mountain-mahogany.

{3.4.1} $SI_{gb} = 20 + (((SI_{rf}-10) / (134 – 10))*(60 – 20))$

{3.4.2} $SI_{mc} = 5 + (((SI_{rf}-10) / (134 – 10))*(23 – 5))$

where:

SI_{gb} is the estimated default site index for Great Basin bristlecone pine
SI_{mc} is the estimated default site index for curlleaf mountain-mahogany
SI_{rf} is the site index for California red fir

3.4.1 Region 5 Site Class

In Region 5 forests, the site index values can either be entered directly or based on the Region 5 site class (0-7) as shown in table 3.4.1.1. Site class codes of 0-5 were adapted for Region 5 by Jack Levitan from Duncan Dunning's site index curves (Dunning 1942, Dunning & Reineke 1933).

If a Region 5 site class is entered, it is converted to a site index for each species within the model using a two-step process. First, the Region 5 site class is converted to a 50-year site index as shown in table 3.4.1.1 (personal communication with Ralph Warbington in March 2008).

Table 3.4.1.1 Region 5 site class values converted into 50-year site index in the WS variant.

REGION 5 SITE CLASS	(BREAST HT AGE) 50-YEAR SITE INDEX
0	106
1	90
2	75
3	56
4	49
5	39
6	31

REGION 5 SITE CLASS	(BREAST HT AGE) 50-YEAR SITE INDEX
7	23

Second, site index for an individual species is determined by multiplying the 50-year site index by a species-specific adjustment factor which is shown in table 3.4.1.2.

Table 3.4.1.2 Region 5 adjustment factors for 50-year site index values in the WS variant.

Species Code	Adjustment Factor
SP	0.90
DF	1.00
WF	1.00
GS	1.00
IC	0.76
JP	1.00
RF	1.00
PP	1.00
LP	0.90
WB	0.90
WP	0.90
PM	1.00
SF	1.00
KP	0.90
FP	0.90
CP	0.90
LM	0.90
MP	1.00
GP	0.90
WE	0.90
GB	0*
BD	1.00
RW	1.00
MH	0.90
WJ	0.90
UJ	0.90
CJ	0.90
LO	0.60
CY	0.45
BL	0.45
BO	1.00
VO	0.60
IO	0.50

Species Code	Adjustment Factor
TO	0.60
GC	0.50
AS	0.75
CL	0.55
MA	0.60
DG	0.50
BM	0.50
MC	0*
OS	0.90
OH	0.57

3.5 Maximum Density

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

The default maximum SDI is set by species or a user specified basal area maximum. If a user specified basal area maximum is present, the maximum SDI for all species is computed using equation {3.5.1}; otherwise, species SDI maximums are assigned from the SDI maximums shown in table 3.5.1. SDI is calculated and SDI maximums were calculated using the Zeide calculation method (Dixon 2002).

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

where:

$SDIMAX_i$ is species-specific SDI maximum
BAMAX is the user-specified stand 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 Stand density index maximums by species in the WS variant.

Species Code	SDI Max	Source*	Mapped to
SP	561	Shaw	
DF	570	Shaw	
WF	800	PSW	
GS	576	Shaw	incense-cedar
IC	576	Shaw	
JP	365	PSW	

Species Code	SDI Max	Source*	Mapped to
RF	1000	PSW	
PP	365	PSW	
LP	679	Shaw	
WB	621	Shaw	
WP	272	Shaw	
PM	358	Shaw	
SF	790	Shaw	
KP	679	Shaw	lodgepole pine
FP	409	Shaw	limber pine
CP	365	PSW	Jeffrey pine
LM	409	Shaw	
MP	365	PSW	ponderosa pine
GP	214	Shaw	blue oak
WE	365	PSW	Jeffrey pine
GB	409	Shaw	limber pine
BD	570	Shaw	Douglas-fir
RW	1052	Shaw	
MH	687	Shaw	
WJ	272	Shaw	
UJ	497	Shaw	
CJ	272	Shaw	western juniper
LO	667	Shaw	canyon live oak
CY	667	Shaw	
BL	214	Shaw	
BO	406	Shaw	
VO	440	Shaw	Oregon white oak
IO	667	Shaw	canyon live oak
TO	785	Shaw	
GC	785	Shaw	tanoak
AS	562	Shaw	
CL	406	Shaw	California black oak
MA	515	Shaw	
DG	406	Shaw	California black oak
BM	629	Shaw	
MC	501	Shaw	
OS	365	PSW	Jeffrey pine
OH	406	Shaw	California black oak

*Sources include an unpublished analysis of FIA data by John Shaw (Shaw) and a review of current data/literature by Pacific Southwest Research Station (PSW).

4.0 Growth Relationships

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

4.1 Height-Diameter Relationships

Height-diameter relationships in FVS are primarily used to estimate tree heights missing in the input data, and occasionally to estimate diameter growth on trees smaller than a given threshold diameter. In the WS variant, the method used to dub in heights depends on species, tree diameter, and whether or not calibration of the height-diameter relationship to the input data has occurred. By default, the WS variant will use the Wykoff logistic form as shown in equation {4.1.1} (Wykoff, et.al 1982), an alternate dubbing function based on the location code as shown in equation {4.1.2}, or the Curtis-Arney functional form as shown in equation {4.1.3} (Curtis 1967, Arney 1985). Coefficients (B_1, B_2) for equation {4.1.1} are shown in Table {4.1.1}. Coefficients (a, b, c) for equation {4.1.2} are shown in Table {4.1.2}. Coefficients for equation {4.1.3} are shown in Table {4.1.3}.

For sugar pine, Douglas-fir, white fir, giant sequoia, incense-cedar, Jeffrey pine, California red fir, ponderosa pine, western white pine, Monterey pine, bigcone Douglas-fir, redwood, mountain hemlock, and other softwoods: If calibration of the height-diameter relationship does not occur, then equation {4.1.1} is used for trees with a diameter of 3.0 inches or less, and equation {4.1.2} is used for trees with a diameter larger than 3.0 inches. If calibration of the height-diameter relationship does occur, then equation {4.1.1} is used for trees of all sizes. Estimated heights for incense-cedar are modified using equation {4.1.5}.

For Pacific silver fir, Great Basin bristlecone pine, California live oak, canyon live oak, blue oak, California black oak, California white or valley oak, interior live oak, tanoak, giant chinquapin, quaking aspen, California-laurel, Pacific madrone, Pacific dogwood, bigleaf maple, and other hardwoods: equation {4.1.1} is used for all trees regardless of whether calibration of the height-diameter relationship has occurred or not.

For lodgepole pine, whitebark pine, singleleaf pinyon, knobcone pine, foxtail pine, Coulter pine, limber pine, Gray or California foothill pine, Washoe pine, western juniper, Utah juniper, and California juniper: If calibration of the height-diameter relationship does not occur, then equation {4.1.3} is used. If calibration of the height-diameter relationship does occur, then equation {4.1.1} is used.

For curlleaf mountain-mahogany: If calibration of the height-diameter relationship does not occur then equation {4.1.3} is used. If calibration of the height-diameter relationship does occur, then trees with a diameter less than 5.0 inches use equation {4.1.3} and trees with a diameter of 5.0 inches or larger use equation {4.1.1}

If the input data contains at least three measured heights for a species, then FVS can calibrate the Wykoff height-diameter function and recalculate the value of B_1 in equation {4.1.1} from the input data. The calculated value, specific to the stand, 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. For lodgepole pine, whitebark pine, singleleaf pinyon, knobcone pine, foxtail pine, Coulter pine, limber pine, Gray or California foothill pine, Washoe pine, western juniper, Utah juniper, and California juniper calibration of the height-diameter relationship does not happen by default but it can be turned on using the NOHTDREG keyword by entering “1” in field 2. For all other species, calibration of the height-diameter relationship is turned on by default.

{4.1.1} Wykoff height-diameter relationship:

$HT = 4.5 + \exp(B_1 + B_2 / (DBH + 1.0))$

{4.1.2} R5 forest-level height-diameter relationship:

$HT = a + b * DBH^{0.5} + c * DBH^{0.5} * (6.0 - SC)^{0.5}$

{4.1.3} Curtis-Arney height-diameter relationship:

$DBH \geq Z$: $HT = 4.5 + P_2 * \exp(-P_3 * DBH^{P_4})$
$DBH < Z$: $HT = ((4.5 + P_2 * \exp(-P_3 * Z^{P_4}) - 4.51) * (DBH - 0.3) / (Z - 0.3)) + 4.51$

{4.1.4} Height-diameter relationship for curlleaf mountain-mahogany with DBH < 5.0”

$HT = 0.0994 + 4.9767 * DBH$

{4.1.5} Adjustment made for incense-cedar

$HT = HT * 0.76$

where:

HT	is tree height
DBH	is tree diameter at breast height
SC	is the region 5 site class (as described in section 3.4)
B_1 - B_2	are species-specific coefficients shown in table 4.1.1
a, b, c	are location-specific coefficients shown in table 4.1.2
Z	is the DBH value shown in table 4.1.3
P_2 - P_4	are species-specific coefficients shown in table 4.1.3

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

Species Code	Default B_1	B_2
SP	4.86039	-9.32795
DF	4.86039	-9.32795
WF	4.86039	-9.32795
GS	4.86039	-9.32795
IC	4.86039	-9.32795
JP	4.86039	-9.32795
RF	4.86039	-9.32795
PP	4.86039	-9.32795
LP	4.8358	-9.2077
WB	4.8358	-9.2077
WP	4.86039	-9.32795

Species Code	Default B_1	B_2
PM	4.6843	-6.5516
SF	4.86039	-9.32795
KP	4.6843	-6.5516
FP	4.6843	-6.5516
CP	4.6843	-6.5516
LM	4.6843	-6.5516
MP	4.86039	-9.32795
GP	4.6843	-6.5516
WE	4.6843	-6.5516
GB	4.1920	-5.1651
BD	4.86039	-9.32795
RW	4.86039	-9.32795
MH	4.86039	-9.32795
WJ	4.6843	-6.5516
UJ	4.6843	-6.5516
CJ	4.6843	-6.5516
LO	4.80420	-9.92422
CY	4.80420	-9.92422
BL	4.80420	-9.92422
BO	4.80420	-9.92422
VO	4.80420	-9.92422
IO	4.80420	-9.92422
TO	4.80420	-9.92422
GC	4.80420	-9.92422
AS	4.80420	-9.92422
CL	4.80420	-9.92422
MA	4.80420	-9.92422
DG	4.80420	-9.92422
BM	4.80420	-9.92422
MC	5.1520	-13.5760
OS	4.86039	-9.32795
OH	4.80420	-9.92422

Table 4.1.2 Coefficients for the height-diameter equation {4.1.2} in the WS variant.

Location Code	USFS National Forest	a	b	c
503	Eldorado	-17.7893	8.4685	7.6272
511	Plumas	-17.2775	10.4642	6.2137
513	Sequoia	-16.5610	8.8542	7.3138
515	Sierra	-15.4964	9.7091	6.4437
516	Stanislaus	-12.4808	7.7915	7.1568

517	Tahoe	-14.7932	8.3094	6.9113

Table 4.1.3 Coefficients and *Z* values for equation {4.1.3} in the WS variant.

Species Code	Curtis-Arney Coefficients			
	P_2	P_3	P_4	Z
LP	99.1568	12.1300	-1.3272	5.0
WB	99.1568	12.1300	-1.3272	5.0
PM	101.5170	4.7066	-0.9540	2.0
KP	101.5170	4.7066	-0.9540	2.0
FP	101.5170	4.7066	-0.9540	2.0
CP	101.5170	4.7066	-0.9540	2.0
LM	101.5170	4.7066	-0.9540	2.0
GP	101.5170	4.7066	-0.9540	2.0
WE	101.5170	4.7066	-0.9540	2.0
WJ	101.5170	4.7066	-0.9540	2.0
UJ	101.5170	4.7066	-0.9540	2.0
CJ	101.5170	4.7066	-0.9540	2.0
MC	1709.7229	5.8887	-0.2286	3.0

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} $BRATIO = b_1 - b_2 * (1/DBH)$

where:

BRATIO is species-specific bark ratio (for curlleaf mountain-mahogany: bounded to $0.8 \leq BRATIO \leq 0.99$)
$b_1 - b_2$ are species-specific coefficients shown in table 4.2.1
DBH is tree diameter at breast height (bounded to $DBH \geq 1.0$)

Table 4.2.1 Coefficients (b_1) for equation {4.2.1} in the WS variant.

Species Code	b_1	b_2
SP	0.8863	0.
DF	0.8839	0.
WF	0.8911	0.
GS	0.8863	0.
IC	0.8374	0.
JP	0.8967	0.
RF	0.8911	0.

Species Code	b_1	b_2
PP	0.8967	0.
LP	0.9	0.
WB	0.9	0.
WP	0.8863	0.
PM	0.9329	0.
SF	0.8911	0.
KP	0.9329	0.
FP	0.9329	0.
CP	0.9329	0.
LM	0.9329	0.
MP	0.8967	0.
GP	0.9329	0.
WE	0.9329	0.
GB	0.9625	0.1141
BD	0.8839	0.
RW	0.8863	0.
MH	0.8863	0.
WJ	0.9329	0.
UJ	0.9329	0.
CJ	0.9329	0.
LO	0.8374	0.
CY	0.8374	0.
BL	0.8374	0.
BO	0.8374	0.
VO	0.8374	0.
IO	0.8374	0.
TO	0.8374	0.
GC	0.8374	0.
AS	0.8374	0.
CL	0.8374	0.
MA	0.8374	0.
DG	0.8374	0.
BM	0.8374	0.
MC	0.9	0.
OS	0.8967	0.
OH	0.8374	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 WS variant, crown ratios missing in the input data are predicted using different equations depending on tree species and size. For all species except Great Basin bristlecone pine, live trees less than 1.0” in diameter and dead trees of all sizes use equation {4.3.1.1} and one of the equations listed below, {4.3.1.2} - {4.3.1.4}, to compute crown ratio. Species group assignment and equation number used by species is found in table 4.3.1.1. Equation coefficients are found in table 4.3.1.2.

{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 $(X + N(0,SD)) < 86$

{4.3.1.3} $CR = (((X + N(0,SD)) - 1) * 10 + 1) / 100$

{4.3.1.4} $CR = ((X - 1) * 10 + 1) / 100$

where:

CR is crown ratio expressed as a proportion (bounded to $0.10 \leq CR \leq 0.95$)
DBH is tree diameter at breast height
HT is tree height
BA is total stand basal area
$PCCF$ is crown competition factor on the inventory point where the tree is established
HT_{Avg} is average height of the 40 largest diameter trees in the stand
MAI is stand mean annual increment
$N(0,SD)$ is a random increment from a normal distribution with a mean of 0 and a standard deviation of SD
$R_1 – R_9$ are species-specific coefficients shown in table 4.3.1.1

Table 4.3.1.1 Species group and equation assignment by species in the WS variant.

Species Code	Species Group	Equation Number	Species Code	Species Group	Equation Number
SP	1	{4.3.1.2}	RW	2	{4.3.1.2}
DF	2	{4.3.1.2}	MH	1	{4.3.1.2}
WF	2	{4.3.1.2}	WJ	3	{4.3.1.3}
GS	2	{4.3.1.2}	UJ	3	{4.3.1.3}
IC	2	{4.3.1.2}	CJ	3	{4.3.1.3}
JP	2	{4.3.1.2}	LO	1	{4.3.1.2}
RF	2	{4.3.1.2}	CY	1	{4.3.1.2}
PP	1	{4.3.1.2}	BL	1	{4.3.1.2}
LP	3	{4.3.1.3}	BO	1	{4.3.1.2}
WB	3	{4.3.1.3}	VO	1	{4.3.1.2}
WP	1	{4.3.1.2}	IO	1	{4.3.1.2}
PM	3	{4.3.1.3}	TO	4	{4.3.1.2}

Species Code	Species Group	Equation Number
SF	2	{4.3.1.2}
KP	3	{4.3.1.3}
FP	3	{4.3.1.3}
CP	3	{4.3.1.3}
LM	3	{4.3.1.3}
MP	1	{4.3.1.2}
GP	3	{4.3.1.3}
WE	3	{4.3.1.3}
BD	2	{4.3.1.2}

Species Code	Species Group	Equation Number
GC	4	{4.3.1.2}
AS	4	{4.3.1.2}
CL	4	{4.3.1.2}
MA	4	{4.3.1.2}
DG	4	{4.3.1.2}
BM	1	{4.3.1.2}
MC	5	{4.3.1.4}
OS	1	{4.3.1.2}
OH	1	{4.3.1.2}

Table {4.3.1.2} Coefficients by species group for equation {4.3.1.1} in the WS variant.

Coefficient	1	2	3	4	5
R_1	-1.66949	-0.426688	6.489813	-2.19723	5
R_2	-0.209765	-0.093105	0	0	0
R_3	0	0.022409	-0.029815	0	0
R_4	0.003359	0.002633	-0.009276	0	0
R_5	0.011032	0	0	0	0
R_6	0	-0.045532	0	0	0
R_7	0.017727	0	0	0	0
R_8	-0.000053	0.000022	0	0	0
R_9	0.014098	-0.013115	0	0	0
SD	0.5*	0.6957**	2.0426	0.2	0.5

*0.4942 for ponderosa pine and Monterey pine; 0.6124 for California live oak, canyon live oak, blue oak, California black oak, valley oak, interior live oak, bigleaf maple and other hardwoods.
**0.9310 for incense-cedar

For all species except Great Basin bristlecone pine, a Weibull-based crown model developed by Dixon (1985) as described in Dixon (2002) is used to predict crown ratio for all live trees 1.0" in diameter or larger. To estimate crown ratio using this methodology, the average stand crown ratio is estimated from stand density index using equation {4.3.1.5}. Weibull parameters are then estimated from the average stand crown ratio using equations in equation set {4.3.1.6}. Individual tree crown ratio is then set from the Weibull distribution equation {4.3.1.7} based on a tree's relative position in the diameter distribution and multiplied by a scale factor, shown in equation {4.3.1.8}, 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 are shown in table 4.3.1.3.

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

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

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

$A = a_0$
$B = b_0 + b_1 * ACR \quad (B \geq 3)$
$C = c_0 + c_1 * ACR \quad (C \geq 2)$

{4.3.1.7} $Y = 1-exp(-((X-A)/B)^C)$

{4.3.1.8}

Used for sugar pine, Douglas-fir, white fir, giant sequoia, incense-cedar, Jeffrey pine, California red fir, ponderosa pine, western white pine, Pacific silver fir, Monterey pine, bigcone Douglas-fir, redwood, mountain hemlock, California live oak, canyon live oak, blue oak, California white oak, interior live oak, tanoak, giant chinquapin, quaking aspen, California-laurel, Pacific madrone, Pacific madrone, Pacific dogwood, bigleaf maple, other softwoods, and other hardwoods :
$SCALE = 1 – 0.00333 * (CCF – 50)$
Used for lodgepole pine, whitebark pine, singleleaf pinyon, knobcone pine, foxtail pine, Coulter pine, limber pine, California foothill pine, Washoe pine, western juniper, Utah juniper, California juniper.:
$SCALE = 1.5 – CCF$
Used for MC:
$SCALE = 1 – 0.00167 * (CCF – 100)$

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 tree's 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 4.3.1.3

Table 4.3.1.3 Coefficients for the Weibull parameter equations {4.3.1.5} and {4.3.1.6} in the WS variant.

Species Code	Model Coefficients						
	a_0	b_0	b_1	c_0	c_1	d_0	d_1
SP	0	0.32957	1.03916	-0.83314	0.91493	7.12189	-0.02817
DF	0	0.39996	1.03150	-0.98287	0.88449	5.91609	-0.00943
WF	0	0.17606	1.07984	-0.89140	0.76518	6.86237	-0.03278
GS	0	0.32957	1.03916	-0.83314	0.91493	7.12189	-0.02817
IC	0	0.15500	1.08747	0.85877	0.40125	6.32336	-0.02987
JP	2	-1.24580	0.94476	-10.54490	2.45822	7.33055	-0.01539
RF	0	0.16601	1.08150	0.91420	0.45768	6.14578	-0.02781
PP	0	0.20199	1.07198	0.75409	0.52191	6.15172	-0.01994

Species Code	Model Coefficients						
	a_0	b_0	b_1	c_0	c_1	d_0	d_1
LP	0	-0.13121	1.15976	2.59824	0	4.89032	-0.01884
WB	0	-0.13121	1.15976	2.59824	0	4.89032	-0.01884
WP	0	0.32957	1.03916	-0.83314	0.91493	7.12189	-0.02817
PM	0	0.16267	1.07340	3.28850	0	6.48494	-0.02325
SF	0	0.17606	1.07984	-0.89140	0.76518	6.86237	-0.03278
KP	0	0.16267	1.07340	3.28850	0	6.48494	-0.02325
FP	0	0.16267	1.07340	3.28850	0	6.48494	-0.02325
CP	0	0.16267	1.07340	3.28850	0	6.48494	-0.02325
LM	0	0.16267	1.07340	3.28850	0	6.48494	-0.02325
MP	0	0.20199	1.07198	0.75409	0.52191	6.15172	-0.01994
GP	0	0.16267	1.07340	3.28850	0	6.48494	-0.02325
WE	0	0.16267	1.07340	3.28850	0	6.48494	-0.02325
BD	0	0.39996	1.03150	-0.98287	0.88449	5.91609	-0.00943
RW	0	0.32957	1.03916	-0.83314	0.91493	7.12189	-0.02817
MH	0	0.32957	1.03916	-0.83314	0.91493	7.12189	-0.02817
WJ	0	0.16267	1.07340	3.28850	0	6.48494	-0.02325
UJ	0	0.16267	1.07340	3.28850	0	6.48494	-0.02325
CJ	0	0.16267	1.07340	3.28850	0	6.48494	-0.02325
LO	0	-0.14217	1.15448	0.59185	0.37245	4.00579	-0.00522
CY	0	-0.14217	1.15448	0.59185	0.37245	4.00579	-0.00522
BL	0	-0.14217	1.15448	0.59185	0.37245	4.00579	-0.00522
BO	0	-0.14217	1.15448	0.59185	0.37245	4.00579	-0.00522
VO	0	-0.14217	1.15448	0.59185	0.37245	4.00579	-0.00522
IO	0	-0.14217	1.15448	0.59185	0.37245	4.00579	-0.00522
TO	0	-0.14217	1.15448	0.59185	0.37245	4.00579	-0.00522
GC	0	-0.14217	1.15448	0.59185	0.37245	4.00579	-0.00522
AS	0	-0.14217	1.15448	0.59185	0.37245	4.00579	-0.00522
CL	0	-0.14217	1.15448	0.59185	0.37245	4.00579	-0.00522
MA	0	-0.14217	1.15448	0.59185	0.37245	4.00579	-0.00522
DG	0	-0.14217	1.15448	0.59185	0.37245	4.00579	-0.00522
BM	0	-0.14217	1.15448	0.59185	0.37245	4.00579	-0.00522
MC	0	-0.23830	1.18016	3.04	0	4.62512	-0.01604
OS	0	-0.09800	1.11809	4.05181	0	6.35669	-0.00846
OH	0	-0.14217	1.15448	0.59185	0.37245	4.00579	-0.00522

Great Basin bristlecone pine uses equations {4.3.1.9} and {4.3.1.10} to estimate crown ratio for live and dead trees missing crown ratios in the inventory.

{4.3.1.9} $CL = -0.59373 + 0.67703 * HT$

{4.3.1.10} $CR = (CL / HT) * 100$

where:

CL	is crown length in feet (bounded $1.0 \leq CL \leq HT$)
CR	is crown ratio expressed as a percent (bounded to $0.10 \leq CR \leq 0.95$)
HT	is total tree height

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 tree records using the Weibull distribution, equations {4.3.1.5}-{4.3.1.8}, for all species except Great Basin bristlecone pine. For Great Basin bristlecone pine, crown ratio predicted at the end of the projection cycle is estimated using equations {4.3.1.9} and {4.3.1.10}. 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. Equations {4.3.1.1} – {4.3.1.4} are not used when estimating crown ratio change.

4.3.3 Crown Ratio for Newly Established Trees

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

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

where:

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

4.4 Crown Width Relationships

The WS 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 canopy cover (*PCC*) calculations in the model.

4.4.1 Region 5 Crown Width

The WS 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 canopy cover (*PCC*) calculations in the model. Crown width is calculated by using equations {4.4.1.1} – {4.4.1.5}. If a tree has a *DBH* greater than or equal to its threshold diameter (given as DBH_T), then it uses equation {4.4.1.1}, {4.4.1.2}, or {4.4.1.3} depending on the species. If a tree has a *DBH* less than its threshold diameter, then it uses equation {4.4.1.4} or {4.4.1.5} depending on the height of the tree. Coefficients, equation reference, and threshold diameter values for these equations are shown in table 4.4.1.1 by species.

{4.4.1.1} $DBH \geq DBH_T$: $CW = a_1 + a_2 * DBH$

{4.4.1.2} $DBH \geq DBH_T$: $CW = a_1 * DBH^{a_2}$

{4.4.1.3} $DBH \geq DBH_T$: $CW = a_1 + a_2 * DBH + a_3 * DBH^2$

{4.4.1.4} HT < 4.5' and $DBH < DBH_T$: $CW = HT * s_1$

{4.4.1.5} $HT \geq$ 4.5' and $DBH < DBH_T$: $CW = d_1 + d_2 * DBH$

where:

CW is maximum tree crown width
DBH is tree diameter at breast height
DBH_T is threshold diameter shown in table 4.4.1.1
HT is tree height
s_1, d_{1-2}, and a_{1-3} are species-specific coefficients shown in table 4.4.1.1

Table 4.4.1.1 Coefficients and equation reference for R5 Crown Width equations {4.4.1.1} – {4.4.1.5} in the WS variant.

Species Code	Equation Used*	DBH_T	d_1	d_2	a_1	a_2	a_3	s_1
SP	{4.4.1.1}	7.4	3.5	0.338	-1.476	1.01	0	0.7778
DF	{4.4.1.1}	5	3.62	1.37	6.81	0.732	0	0.7778
WF	{4.4.1.1}	5	3.26	1.103	5.82	0.591	0	0.7778
GS	{4.4.1.1}	5	3.5	1.1	6	0.6	0	0.7778
IC	{4.4.1.1}	5	3.5	1.192	7.11	0.47	0	0.7778
JP	{4.4.1.2}	5	3.5	0.5754	1.52	0.891	0	0.7778
RF	{4.4.1.1}	5	3.5	1.063	6.71	0.421	0	0.7778
PP	{4.4.1.2}	5	3.77	0.7756	2.24	0.763	0	0.7778
LP	{4.4.1.2}	5	3.5	0.6492	1.91	0.784	0	0.7778
WB	{4.4.1.2}	5	3.5	0.8496	2.37	0.736	0	0.7778
WP	{4.4.1.1}	7.6	3.5	0.329	-0.997	0.92	0	0.7778
PM	{4.4.1.1}	5	3.5	1.1	6	0.6	0	0.7778
SF	{4.4.1.1}	5	3.26	1.103	5.82	0.591	0	0.7778
KP	{4.4.1.1}	5	3.5	1.1	6	0.6	0	0.7778
FP	{4.4.1.1}	5	3.5	1.1	6	0.6	0	0.7778
CP	{4.4.1.2}	5	3.5	1.7618	3.9347	0.7086	0	0.7778
LM	{4.4.1.1}	5	3.5	1.1	6	0.6	0	0.7778
MP	{4.4.1.1}	5	3.5	1.1	6	0.6	0	0.7778
GP	{4.4.1.2}	5	3.5	1.9108	3.8273	0.7624	0	0.7778
WE	{4.4.1.1}	5	3.5	1.1	6	0.6	0	0.7778
GB	{4.4.1.1}	5	3.5	1.1	6	0.6	0	0.7778
BD	{4.4.1.1}	5	3.5	5.5672	27.030	0.8612	0	0.7778
RW	{4.4.1.2}	5	3.5	3.1654	9.0684	0.4702	0	0.7778
MH	{4.4.1.1}	5	3.5	0.852	4.72	0.608	0	0.7778
WJ	{4.4.1.2}	5	3.5	1.6684	4.31	0.628	0	0.7778
UJ	{4.4.1.2}	5	3.5	1.6684	4.31	0.628	0	0.7778

Species Code	Equation Used*	DBH_T	d_1	d_2	a_1	a_2	a_3	s_1
CJ	{4.4.1.2}	5	3.5	1.6684	4.31	0.628	0	0.7778
LO	{4.4.1.2}	5	2.5	3.2150	5.3732	0.7707	0	0.5556
CY	{4.4.1.1}	5	2.5	2.19	5	1.69	0	0.5556
BL	{4.4.1.2}	5	2.5	2.2175	4.49	0.688	0	0.5556
BO	{4.4.1.1}	5	2.5	2.7	10	1.2	0	0.5556
VO	{4.4.1.2}	5	2.5	2.2816	4.5628	0.6925	0	0.5556
IO	{4.4.1.1}	5	2.5	1.4	2	1.5	0	0.5556
TO	{4.4.1.1}	13.4	2.23	1.63	10	1.05	0	0.5556
GC	{4.4.1.3}	5	2.15	1.646	2.98	1.55	-0.014	0.5556
AS	{4.4.1.1}	5	2.5	1.22	0.5	1.62	0	0.5556
CL	{4.4.1.1}	5	2.5	4.2956	12.733	2.249	0	0.5556
MA	{4.4.1.1}	5	3.11	1.008	1.0	1.43	0	0.5556
DG	{4.4.1.1}	5	2.5	1.4	2	1.5	0	0.5556
BM	{4.4.1.1}	5	2.5	1.4	2	1.5	0	0.5556
MC	{4.4.1.1}	5	2.5	1.4	2	1.5	0	0.5556
OS	{4.4.1.1}	5	3.5	1.1	6	0.6	0	0.7778
OH	{4.4.1.1}	5	2.5	1.4	2	1.5	0	0.5556

*Equation refers to the species-specific equation used when $DBH \geq DBH_T$

4.5 Crown Competition Factor

The WS 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 sugar pine, Douglas-fir, white fir, giant sequoia, incense-cedar, Jeffrey pine, California red fir, ponderosa pine, Western white pine, Pacific silver fir, Monterey pine, bigcone Douglas-fir, redwood, mountain hemlock, California live oak, canyon live oak, blue oak, California black oak, California white oak/valley oak, interior live oak, tanoak, giant chinquapin, quaking aspen, California-laurel, Pacific madrone, Pacific dogwood, bigleaf maple, other softwoods, and other hardwoods is calculated using equation {4.5.1}. Coefficients for the species using these equations are shown in table 4.5.1.

{4.5.1} CCF_t equations

$DBH \geq 1.0"$: $CCF_t = ((R_1 + DBH * R_2)^{\wedge}2.0) * 0.001803$
$0.1" < DBH < 1.0"$: $CCF_t = R_{DA} * DBH^{\wedge}R_{DB}$
$DBH \leq 0.1"$: $CCF_t = 0.001$

where:

CCF_t is crown competition factor for an individual tree
DBH is tree diameter at breast height
R_1, R_2, R_{DA}, R_{DB} are species-specific coefficients shown in table 4.5.1

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

Species Code	Model Coefficients			
	R_1	**R_2**	**R_{DA}**	**R_{DB}**
SP	6.74	0.623	0.007244	1.8182
DF	6.81	0.732	0.017299	1.5571
WF	5.82	0.591	0.015248	1.7333
GS	5.82	0.591	0.011109	1.725
IC	7.11	0.47	0.008915	1.78
JP	3.1	0.839	0.007875	1.736
RF	6.71	0.421	0.011402	1.756
PP	5.13	0.658	0.007813	1.778
WP	6.74	0.623	0.007244	1.8182
SF	5.82	0.591	0.015248	1.7333
MP	5.13	0.658	0.007813	1.778
BD	6.81	0.732	0.017299	1.5571
RW	5.82	0.591	0.011109	1.725
MH	6.74	0.623	0.007244	1.8182
LO	10	1.2	0.009187	1.76
CY	10	1.2	0.009187	1.76
BL	10	1.2	0.009187	1.76
BO	10	1.2	0.009187	1.76
VO	10	1.2	0.009187	1.76
IO	10	1.2	0.009187	1.76
TO	10	1.05	0.011109	1.725
GC	10	1.05	0.011109	1.725
AS	10	1.05	0.011109	1.725
CL	10	1.05	0.011109	1.725
MA	10	1.05	0.011109	1.725
DG	10	1.05	0.011109	1.725
BM	10	1.2	0.009187	1.76
OS	7.07	0.551	0.009884	1.6667
OH	10	1.2	0.009187	1.76

Crown competition factor for lodgepole pine, whitebark pine, singleleaf pinyon, knobcone pine, foxtail pine, Coulter pine, limber pine, Gray or California foothill pine, Washoe pine, western juniper, Utah juniper, and California juniper is computed from crown width using equation {4.5.2}. Crown width equations for these species were shown in section 4.4.

{4.5.2} $CCF_t = 0.001803 * CW^2$

where:

CCF_t	is crown competition factor for an individual tree
CW	is maximum tree crown width

Crown competition factor for curlleaf mountain-mahogany is computed using equation {4.5.3}.

{4.5.3} CCF_t equations:

$DBH < 1.0''$: $CCF_t = 0.0524 * DBH$
$DBH \geq 1.0''$: $CCF_t = 0.0204 + 0.0246 * DBH + 0.0074 * DBH^2$

where:

CCF_t	is crown competition factor for an individual tree
DBH	is tree diameter at breast height

Crown competition factor for Great Basin bristlecone pine is computed using equation {4.5.4}.

{4.5.4} CCF_t *equations*:

$DBH \leq 0.1''$: $CCF_t = 0.001$
$0.1'' < DBH < 10.0''$ $CCF_t = 0.009187 * DBH^{1.76}$
$DBH \geq 10.0''$: $CCF_t = 0.01925 + 0.01676 * DBH + 0.00365 * DBH^2$

where:

CCF_t	is crown competition factor for an individual tree
DBH	is tree diameter at breast height

4.6 Small Tree Growth Relationships

Trees are considered “small trees” for FVS modeling purposes when they are smaller than some threshold diameter. The threshold diameter is set to 3.0” for all species in the WS variant except for Great Basin bristlecone pine which has a threshold diameter of 99.0”. The equations presented in this section are used to model growth on trees of all sizes for Great Basin bristlecone pine.

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

4.6.1 Small Tree Height Growth

The small-tree height increment model predicts 10-year height growth for Great Basin bristlecone pine and curlleaf mountain-mahogany, and 5-year height growth for all other species. Height growth for all species in the WS variant, except for Great Basin bristlecone pine and curlleaf mountain-mahogany, is estimated by using equations {4.6.1.1} – {4.6.1.4}. Equation reference and site index adjustment factors are shown in table 4.6.1.1.

{4.6.1.1} Used for: sugar pine, incense-cedar, Jeffrey pine, ponderosa pine, lodgepole pine, whitebark pine, western white pine, singleleaf pinyon, knobcone pine, foxtail pine, Coulter pine, limber pine, Monterey pine, Gray / California foothill pine, Washoe pine, mountain hemlock, western juniper, Utah juniper, California juniper, and other softwoods

$HTG = c_1 * \exp(0.7452 - (0.003271 * BAL) - (0.1632 * CR) + (0.0217 * CR^2) + (0.00536 * SI)) * (0.8 + (0.004 * (SI - 50)))$

{4.6.1.2} Used for: Douglas-fir, white fir, giant sequoia, California red fir, Pacific silver fir, bigcone Douglas-fir, and redwood

$$HTG = (c_1 + \exp(-0.2495 - (0.00111 * BAL) + (0.01 * CR^2))) * c_2 * [0.8 + (0.004 * (SI - 50))]$$

{4.6.1.3} Used for: California live oak, canyon live oak, blue oak, California black oak, California white oak / valley oak, interior live oak, bigleaf maple, and other hardwoods

$$HTG = \exp(3.817 - (0.7829 * \ln(BAL)))$$

{4.6.1.4} Used for: tanoak, giant chinquapin, quaking aspen, California-laurel, Pacific madrone, Pacific dogwood

$$HTG = \exp(3.385 - (0.5898 * \ln(BAL)))$$

where:

HTG	is estimated 5-year height growth
BAL	is total basal area in trees larger than the subject tree
CR	is crown ratio expressed as a percent divided by 10
SI	is species site index
c_1, c_2	are species-specific coefficients shown in table 4.6.1.1

Table 4.6.1.1 Equation reference, diameter bounds, and coefficients by species for small-tree height growth in the WS variant.

Species Code	*HTG* Equation	c_1	c_2	X_{min}	X_{max}
SP	{4.6.1.1}	1.75	0	2.0	3.5
DF	{4.6.1.2}	1.00	2.5	2.0	3.5
WF	{4.6.1.2}	0.75	2.0	2.0	3.5
GS	{4.6.1.2}	1.00	2.5	2.0	3.5
IC	{4.6.1.1}	1.75	0	2.0	3.5
JP	{4.6.1.1}	1.50	0	2.0	3.5
RF	{4.6.1.2}	0.75	2.0	2.0	3.5
PP	{4.6.1.1}	1.50	0	2.0	3.5
LP	{4.6.1.1}	1.75	0	2.0	4.0
WB	{4.6.1.1}	1.75	0	2.0	4.0
WP	{4.6.1.1}	1.75	0	2.0	3.5
PM	{4.6.1.1}	1.75	0	2.0	4.0
SF	{4.6.1.2}	0.75	2.0	2.0	3.5
KP	{4.6.1.1}	1.75	0	2.0	4.0
FP	{4.6.1.1}	1.75	0	2.0	4.0
CP	{4.6.1.1}	1.75	0	2.0	4.0
LM	{4.6.1.1}	1.75	0	2.0	4.0
MP	{4.6.1.1}	1.50	0	2.0	3.5
GP	{4.6.1.1}	1.75	0	2.0	4.0
WE	{4.6.1.1}	1.75	0	2.0	4.0

Species Code	*HTG* Equation	c_1	c_2	X_{min}	X_{max}
GB	n/a	n/a	n/a	99.0	199.0
BD	{4.6.1.2}	1.00	2.5	2.0	3.5
RW	{4.6.1.2}	1.00	2.5	2.0	3.5
MH	{4.6.1.1}	1.75	0	2.0	3.5
WJ	{4.6.1.1}	1.75	0	2.0	4.0
UJ	{4.6.1.1}	1.75	0	2.0	4.0
CJ	{4.6.1.1}	1.75	0	2.0	4.0
LO	{4.6.1.3}	0	0	1.0	3.5
CY	{4.6.1.3}	0	0	1.0	3.5
BL	{4.6.1.3}	0	0	1.0	3.5
BO	{4.6.1.3}	0	0	1.0	3.5
VO	{4.6.1.3}	0	0	1.0	3.5
IO	{4.6.1.3}	0	0	1.0	3.5
TO	{4.6.1.4}	0	0	2.0	3.5
GC	{4.6.1.4}	0	0	2.0	3.5
AS	{4.6.1.4}	0	0	2.0	3.5
CL	{4.6.1.4}	0	0	2.0	3.5
MA	{4.6.1.4}	0	0	2.0	3.5
DG	{4.6.1.4}	0	0	2.0	3.5
BM	{4.6.1.3}	0	0	1.0	3.5
MC	n/a	n/a	n/a	2.0	4.0
OS	{4.6.1.1}	1.50	0	2.0	3.5
OH	{4.6.1.3}	0	0	1.0	3.5

Potential height growth for Great Basin bristlecone pine is estimated using equation {4.6.1.5}.

{4.6.1.5} $POTHTG = ((SI / 5.0) * (SI * 1.5 - H) / (SI * 1.5)) * 0.83$

where:

POTHTG is potential 10-year height growth
SI is species site index on a base-age basis
H is total tree height

Potential height growth is then adjusted based on stand density (*PCTRED*) as computed with equation {4.6.1.6}, and crown ratio (*VIGOR*) as shown in {4.6.1.7}. Height growth is then estimated using equation {4.6.1.8}.

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

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

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

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

where:

HTG	is estimated height growth for the cycle
POTHTG	is potential 10-year height growth
PCTRED	is reduction in height growth due to stand density (bounded to $0.01 \leq PCTRED \leq 1$)
HT_{Avg}	is average height of the 40 largest diameter trees in the stand
CCF	is stand crown competition factor
VIGOR	is reduction in height growth due to tree vigor (bounded to $VIGOR \leq 1.0$)
CR	is a tree's live crown ratio (compacted) expressed as a proportion

Potential height growth for curlleaf mountain-mahogany is computed using equation {4.6.1.9}. Potential height growth is then modified as shown in {4.6.1.8} with the PCTRED adjustment shown in {4.6.1.6} and the VIGOR adjustment shown in {4.6.1.10}.

{4.6.1.9} $POTHTG = ((1.47043 + 0.23317 * SI) / (31.56252 – 0.05586 * SI)) * 10$

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

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

Height growth estimates from the small-tree model are weighted with the height growth estimates from the large tree model over a range of diameters (X_{min} and X_{max}) in order to smooth the transition between the two models. For example, the closer a tree's *DBH* value is to the minimum diameter (X_{min}), the more the growth estimate will be weighted towards the small-tree growth model. The closer a tree's *DBH* value is to the maximum diameter (X_{max}), the more the growth estimate will be weighted towards the large-tree growth model. If a tree's *DBH* value falls outside of the range given by X_{min} and X_{max}, then the model will use only the small-tree or large-tree growth model in the growth estimate. The weight applied to the growth estimate is calculated using equation {4.6.1.11} and applied as shown in equation {4.6.1.12}. The range of diameters where this weighting occurs for each species is shown in table 4.6.1.1.

{4.6.1.11}

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

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

where:

XWT	is the weight applied to the growth estimates
DBH	is tree diameter at breast height
X_{max}	is the maximum *DBH* where weighting between small and large tree models occurs
X_{min}	is the minimum *DBH* where weighting between small and large tree models occurs
STGE	is the growth estimate obtained using the small-tree growth model
LTGE	is the growth estimate obtained using the large-tree growth model

4.6.2 Small Tree Diameter Growth

As stated previously, for trees being projected with the small tree equations, height growth is predicted first, and then diameter growth. So, both height at the beginning of the cycle and height at the end of the cycle are known when predicting diameter growth. Small tree diameter growth for trees over 4.5 feet tall is calculated as the difference of predicted diameter at the start of the projection period and the predicted diameter at the end of the projection period, adjusted for bark ratio. In the WS variant, for all species except Great Basin bristlecone pine and curlleaf mountain-mahogany, diameter growth of small trees is a weighted average of the small-tree and large tree predictions when the *DBH* is between 1.5” and 3.0”. By definition, diameter growth is zero for trees less than 4.5 feet tall. Small-tree diameter at the start and end of the projection period are estimated using equations {4.6.2.1} – {4.6.2.5} or the height-diameter equations discussed in section 4.1 depending on species.

{4.6.2.1} Used for sugar pine, incense cedar, Jeffrey pine, ponderosa pine, western white pine, Monterey pine, mountain hemlock, and other softwoods

$DBH = -0.6197 + (0.2626 * HT)$

{4.6.2.2} Used for Douglas-fir, white fir, giant sequoia, California red fir, Pacific silver fir, bigcone Douglas-fir and redwood

$DBH = -0.6096 + (0.2433 * HT)$

{4.6.2.3} Used for California live oak, canyon live oak, blue oak, California black oak, California white / valley oak, interior live oak, tanoak, giant chinquapin, quaking aspen, California-laurel, Pacific madrone, Pacific dogwood, bigleaf maple, and other hardwoods

$DBH = [-9.92422 / (\ln(HT - 4.5) - 4.80420)] - 1.0$

where:

DBH	is tree diameter at breast height
HT	is tree height

Lodgepole pine, whitebark pine, singleleaf pinyon, knobcone pine, foxtail pine, Coulter pine, limber pine, Gray or California foothill pine, Washoe pine, western juniper, Utah juniper, and California juniper use the same height-diameter relationship discussed for these species in section 4.1, solved for diameter as a function of height.

Great Basin bristlecone pine uses equation {4.6.2.4}.

{4.6.2.4} $DBH = 10 * (HT - 4.5) / (SI - 4.5)$

where:

DBH	is tree diameter at breast height
HT	is tree height
SI	is site index

Curlleaf mountain-mahogany uses the inventory equation discussed in section 4.1 to calculate the two diameters as discussed at the beginning of this section. If calibration of the height-diameter curve is turned off or does not take place, equation {4.6.2.5} is used to calculate a direct estimate of diameter growth.

{4.6.2.5} $DG = 0.1 * HTG$

where:

DG	is estimated tree diameter growth
HTG	is estimated tree height growth

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. In the WS variant, this threshold diameter is set to 99.0" for Great Basin bristlecone pine and 3.0" for all other species.

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. Great Basin bristlecone pine uses the equations discussed in section 4.6 for trees of all sizes and is not discussed in this section.

4.7.1 Large Tree Diameter Growth

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

The WS variant predicts diameter growth using equation {4.7.1.1} for sugar pine, incense-cedar, ponderosa pine, western white pine, Monterey pine, mountain hemlock, and other softwoods trees of all sizes, and Douglas-fir, white fir, Jeffrey pine, Pacific silver fir, and bigcone Douglas-fir with a DBH greater than or equal to 10.0". Equation {4.7.1.2} is used to estimate an adjustment factor to more closely represent observed growth data for incense-cedar. Coefficients for equation {4.7.1.1} are shown in tables 4.7.1.1 – 4.7.1.3.

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

{4.7.1.2} Adustment factor equation for IC (CADJ = 0.0 for all other species)

$CADJ = 0.30 * (0.80 + 0.004 * (SI – 50))$

where:

DDS	is the square of the 10-year diameter growth increment
EL	is stand elevation in hundreds of feet
SI	is species site index
ASP	is stand aspect
SL	is stand slope
CR	is crown ratio expressed as a proportion
DBH	is tree diameter at breast height
BAL	is total basal area in trees larger than the subject tree
PCCF	is crown competition factor on the inventory point where the tree is established

BA is total stand basal area
CADJ is an adjustment factor for incense cedar
b_1 is a location-specific coefficient shown in table 4.7.1.2
b_2- b_{16} are species-specific coefficients shown in table 4.7.1.1

Table 4.7.1.1 Coefficients (b_2 – b_{16}) for equation 4.7.1.1 in the WS variant.

Coefficient	Species Code						
	SP, WP, MH	DF, BD	WF, SF	IC	JP	PP, MP	OS
b_2	0.01919	0.00489	0	-0.00919	0.00304	0.00323	0
b_3	-0.00025	0	0	0.00019	0	0	0
b_4	0.5827	0.504	0.526	0.3737	0.96412	0.6828	0.4401
b_5	-0.0035	0	-0.1183	0	0.05342	0.09668	0
b_6	0.01664	0	-0.1804	0	-0.16447	0.26986	0
b_7	0.7603	0	0	0	-0.05469	0.90804	0
b_8	-2.2339	0	0	0	0	-2.04028	0
b_9	1.0857	0.8641	1.2854	1.29079	0.51047	0.96103	1.1783
b_{10}	0.391	0.4246	-1.0191	-0.0906	0.91422	0.4126	0.9492
b_{11}	0	0	0.9104	0	0.27758	0	0
b_{12}	-0.000288	-0.00029	-0.000584	-0.00061	-0.000222	-0.000375	-0.00066
b_{13}	-0.00579	-0.01127	-0.00628	-0.00544	-0.01282	-0.01265	-0.00016
b_{14}	-0.00058	-0.00018	-0.00091	-0.00098	-0.00099	-0.00084	0
b_{15}	-0.1313	0	-0.21056	-0.23182	-0.0188	-0.1431	-0.327
b_{16}	0	0	– 0.15032	0	0	0	0

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

Location Class	Species Code						
	SP, WP, MH	DF, BD	WF, SF	IC	JP	PP, MP	OS
1	-0.70344	-0.526	0.0755	0.02786	-1.81306	-0.8882	-0.02772
2	-0.90272	-0.9842	-0.3099	0.21393	0	-1.0712	0.1327
3	0	0	-0.044	-0.04927	0	0	0

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

Location Code – USDA National Forest	Species Code						
	SP, WP, MH	DF, BD	WF, SF	IC	JP	PP, MP	OS
503 – Eldorado 519 – Lake Tahoe Basin Mgmt Unit	1	1	1	1	1	1	1
511 – Plumas	2	1	2	1	1	2	1
513 – Sequoia 501 – Angeles 502 – Cleveland 504 – Inyo 507 – Los Padres 512 – San Bernadino	2	2	3	2	1	2	1
515 – Sierra	2	1	3	3	1	1	1
516 – Stanislaus	1	1	1	1	1	2	2
517 – Tahoe	2	1	3	1	1	1	1

Diameter growth for giant sequoia and redwood trees of all sizes and California red fir with diameter greater than or equal to 10.0" is predicted using equation {4.7.1.3}. Coefficients for equation {4.7.1.3} are shown in tables 4.7.1.4 and 4.7.1.5.

{4.7.1.3} $\ln(DDS) = b_1 + (b_2 * EL) + (b_3 * SI) + (b_4 * SL^2) + (b_5 * \ln(DBH)) + (b_6 * (DBH^2 / 1000)) + (b_7 * (PBAL / (\ln(DBH + 1.0) * 100))) + (b_8 * \ln(PBA)) + (b_9 * CRID)$

{4.7.1.4} $CRID = (ICR^2) / (\ln(DBH + 1) * 1000)$

where:

DDS	is the square of the 10-year diameter growth increment
EL	is stand elevation in hundreds of feet
SI	is species site index
SL	is stand slope
DBH	is tree diameter at breast height
PBAL	is total basal area in trees larger than the subject tree on the inventory point where the tree is located
PBA	is total stand basal area on the inventory point where the tree is located
ICR	is tree crown ratio expressed as a percent
CRID	is a transformation of crown ratio and tree diameter (equation {4.7.1.4})
b_1	is a location-specific coefficient shown in table 4.7.1.5
b_2- b_9	are species-specific coefficients shown in table 4.7.1.4

Table 4.7.1.4 Coefficients (b_2 – b_9) for equation 4.7.1.3 in the WS variant.

Coefficient	Species Code	
	GS, RW	RF
b_2	0	-0.007
b_3	0.01401	0.00734
b_4	0	-0.834
b_5	1.26883	1.53339
b_6	-0.35325	-0.47442
b_7	-0.79922	-0.44256
b_8	0	-0.12359
b_9	0.27986	0.35739

Table 4.7.1.5 b_1 values by latitude for equation {4.7.1.3} in the WS variant.

Latitude	Species Code	
	GS, RW	RF
$\leq$ 35	-0.4297	0.1434
36	-0.4297	0.3191
37	-0.4297	0.1434
38	-0.2777	0.2246
$\geq$39	-0.4297	0.1434

The WS variant predicts diameter growth using equation {4.7.1.5} for Douglas-fir, white fir, Jeffrey pine, California red fir, Pacific silver fir, and bigcone Douglas-fir with a DBH less than 10.0”. Coefficients for equation {4.7.1.5} are shown in tables 4.7.1.6 – 4.7.1.8.

{4.7.1.5} $\ln(DDS) = b_1 + (b_2 * EL) + (b_3 * \ln(SI)) + (b_4 * \sin(ASP) * SL) + (b_5 * \cos(ASP) * SL) + (b_6 * SL) + (b_7 * \ln(DBH)) + (b_8 * CR) + (b_9 * \ln(BA)) + (b_{10} * BAL / (\ln(DBH + 1.0))) + (b_{11} * PCCF)$

where:

DDS	is the square of the 10-year diameter growth increment
EL	is stand elevation in hundreds of feet
SI	is species site index
ASP	is stand aspect
SL	is stand slope
CR	is crown ratio expressed as a proportion
DBH	is tree diameter at breast height
BAL	is total basal area in trees larger than the subject tree
PCCF	is crown competition factor on the inventory point where the tree is established
BA	is total stand basal area
b_1	is a location-specific coefficient shown in table 4.7.1.7
b_2- b_{11}	are species-specific coefficients shown in table 4.7.1.6

Table 4.7.1.6 Coefficients (b_2 – b_{11}) for equation 4.7.1.5 in the WS variant.

Coefficient	Species Code	
	DF, WF, RF, SF, BD	JP
b_2	0	-0.00164
b_3	0.233713	0.40657
b_4	0	0.26785
b_5	0	-0.14671
b_6	0	0.56709
b_7	1.64163	1.23864
b_8	0	0.64311
b_9	-0.52776	-0.48754
b_{10}	-0.00205	-0.00189
b_{11}	-0.00105	-0.00096

Table 4.7.1.7 b_1 values by location class for equation {4.7.1.5} in the WS variant.

Location Class	Species Code	
	DF, WF, RF, SF, BD	JP
1	1.53962	0.74162
2	0	0.59493
3	0	0.854515

Table 4.7.1.8 Location class by species index and location code for equation {4.7.1.5} in the WS variant.

Location Code – USDA National Forest	Species Code	
	DF, WF, RF, SF, BD	JP
503 – Eldorado 519 – Lake Tahoe Basin Mgmt Unit	1	1
511 – Plumas	1	2
513 – Sequoia 502 – Cleveland 504 – Inyo 507 – Los Padres	1	1

Location Code – USDA National Forest	Species Code	
	DF, WF, RF, SF, BD	JP
512 – San Bernadino		
501 – Angeles	1	3
515 – Sierra	1	1
516 – Stanislaus	1	1
517 – Tahoe	1	1

Diameter growth is predicted using equations {4.7.1.6} and {4.7.1.7} for California live oak, canyon live oak, blue oak, California black oak, California white/valley oak, interior live oak, tanoak, giant chinquapin, quaking aspen, California-laurel, Pacific madrone, Pacific dogwood, bigleaf maple, and other hardwoods. Coefficients for equation {4.7.1.7} are shown in table 4.7.1.9.

{4.7.1.6} $\ln(DDS) = \ln(e^{\wedge}(TDDS) * 2)$

{4.7.1.7} $TDDS = b_1 + (b_2 * \ln(SI)) + (b_3 * \sin(ASP) * SL) + (b_4 * \cos(ASP) * SL) + (b_5 * SL) + (b_6 * SL^{\wedge}2) + (b_7 * \ln(DBH)) + (b_8 * CR) + (b_9 * CR^{\wedge}2) + (b_{10} * DBH^{\wedge}2) + (b_{11} * BAL / (\ln(DBH + 1.0))) + (b_{12} * PCCF) + (b_{13} * RELHT)$

where:

DDS	is the square of the 10-year diameter growth increment
TDDS	is the natural logarithm of the square of the 5-year diameter growth increment
SI	is species site index
ASP	is stand aspect
SL	is stand slope
CR	is crown ratio expressed as a proportion
DBH	is tree diameter at breast height
BAL	is total basal area in trees larger than the subject tree
PCCF	is crown competition factor on the inventory point where the tree is established
RELHT	is tree height divided by average height of the 40 largest diameter trees in the stand
b_1- b_{13}	are species-specific coefficients shown in table 4.7.1.9

Table 4.7.1.9 Coefficients (b_1 – b_{13}) for equation 4.7.1.7 in the WS variant.

Coefficient	Species Code	
	LO, CY, BL, BO, VO, IO, BM, OH	TO, GC, AS, CL, MA, DG
b_1	-2.68349	-0.94563
b_2	0.32093	0.012
b_3	-0.11954	-0.03587
b_4	0.08632	-0.19935

b_5	0.85815	0.7353
b_6	-1.17209	-0.99561
b_7	1.23911	0.99531
b_8	-1.20841	2.08524
b_9	2.31782	-0.98396
b_{10}	-0.000338	-0.000373
b_{11}	-0.00199	-0.00147
b_{12}	0	-0.0018
b_{13}	0	0.50155

Diameter growth for curl-leaf mountain mahogany of all sizes is predicted using equation {4.7.1.8}.

{4.7.1.8} $\ln(DDS) = -0.107648 + (-0.75986 * EL) + (0.001193 * EL^2) + (0.227307 * \ln(SI)) + (-0.86398 * \sin(ASP) * SL) + (0.085958 * \cos(ASP) * SL) + (0.889596 * \ln(DBH)) + (1.732535 * CR) + (-0.001265 * BAL / (\ln(DBH + 1.0))) + (-0.000981 * BA)$

Large tree diameter growth for lodgepole pine, whitebark pine, singleleaf pinyon, knobcone pine, foxtail pine, Coulter pine, limber pine, Gray or California foothill pine, Washoe pine, western juniper, Utah juniper, and California juniper is predicted using equation {4.7.1.9}. Coefficients for equation {4.7.1.9} are shown in table 4.7.1.10.

{4.7.1.9} $DDS = b_1 + (b_2 * \ln(SI)) + (b_3 * \sin(ASP) * SL) + (b_4 * \cos(ASP) * SL) + (b_5 * \ln(DBH)) + (b_6 * CR) + (b_7 * CR^2) + (b_8 * DBH^2) + (b_9 * PCCF) + (b_{10} * \ln(BA)) + (b_{11} * BAL)$

where:

DDS	is the square of the diameter growth increment
SI	is species site index
ASP	is stand aspect
SL	is stand slope
CR	is crown ratio expressed as a proportion
DBH	is tree diameter at breast height
BAL	is total basal area in trees larger than the subject tree
PCCF	is crown competition factor on the inventory point where the tree is established
BA	is total stand basal area
BAL	is total stand basal area in trees larger than the subject tree
b_1- b_{11}	are species-specific coefficients shown in table 4.7.1.10

Table 4.7.1.10 Coefficients ($b_1 – b_{11}$) for equation 4.7.1.9 in the WS variant.

	Species Code	
Coefficient	**LP, WB**	**PM, KP, FP, CP, LM, GP, WE, WJ, UJ, CJ**
b_1	-2.05883	0.56440
b_2	0.566946	0

	Species Code	
Coefficient	LP, WB	PM, KP, FP, CP, LM, GP, WE, WJ, UJ, CJ
b_3	0	0.951834
b_4	0	0.64987
b_5	1.218279	1.077154
b_6	3.167164	-0.276387
b_7	-1.568333	1.063732
b_8	-0.001418	0
b_9	-0.000338	0
b_{10}	-0.267873	0
b_{11}	0	-0.000893

Diameter growth for Great Basin bristlecone pine is estimated using the equations shown in section 4.6.2 for trees of all sizes.

For sugar pine, Douglas-fir, white fir, giant sequoia, incense-cedar, Jeffrey pine, California red fir, ponderosa pine, western white pine, Pacific silver fir, Monterey pine, bigcone Douglas-fir, redwood, mountain hemlock, California live oak, canyon live oak, blue oak, California black oak, California white/valley oak, interior live oak, bigleaf maple, other softwoods, and other hardwoods, the 10-year *DDS* estimate is bounded to not exceed a maximum value computed with equation {4.7.1.10} with coefficients shown in table 4.7.1.11.

{4.7.1.10} $DDSMAX = a_1 + a_2 * (\ln(CR) * DBH)$

where:

DDSMAX is the maximum 10-year ln(*DDS*) allowed for the tree
CR is tree crown ratio expressed as a percent
DBH is tree diameter at breast height
a_1 - a_2 are coefficients shown in table 4.7.1.11

Table 4.7.1.11 Coefficients for the maximum ln(*DDS*) equation in the WS variant.

Species Code	a_1	a_2
SP, GS, WP, RW, MH	-3.91	1.42
DF, BD	-3.06	1.27
WF, RF, SF	-2.81	1.24
IC, LO, CY, BL, BO, VO, IO, BM, OH	-2.20	1.08

Species Code	a_1	a_2
JP, OS	-3.71	1.25
PP, MP	-2.07	1.09

For some species, diameter growth is checked to make sure diameter growth is between zero and a maximum allowed value, set by equation {4.7.1.11} by Dolph and Dixon (1993). If diameter growth exceeds the estimate in equation {4.7.1.11}, diameter growth is set to the maximum growth allowed.

{4.7.1.11} $DGMax = a_1 * (DBH \hat{} a_2) * \exp(a_3 * DBH)$

where:

DGMax is maximum diameter growth allowed
DBH is tree diameter at breast height
$a_1 - a_3$ are species-specific coefficients shown in table 4.7.1.12

Table 4.7.1.12. Coefficients for the maximum diameter growth equation in the WS variant.

Species Code	a_1	a_2	a_3
SP	4.9094	0.4678	-0.04365
DF	1.8388	0.7319	-0.05194
WF	3.8681	0.5043	-0.04492
GS	4.9094	0.4678	-0.04365
IC	1.9557	0.4655	-0.05613
JP	3.7202	0.386	-0.03852
RF	3.8681	0.5043	-0.04492
PP	3.7202	0.386	-0.03852
WP	4.9094	0.4678	-0.04365
SF	3.8681	0.5043	-0.04492
MP	3.7202	0.386	-0.03852
BD	1.8388	0.7319	-0.05194
RW	4.9094	0.4678	-0.04365
MH	4.9094	0.4678	-0.04365
LO	1.9557	0.4655	-0.05613

Species Code	a_1	a_2	a_3
CY	1.9557	0.4655	-0.05613
BL	1.9557	0.4655	-0.05613
BO	1.9557	0.4655	-0.05613
VO	1.9557	0.4655	-0.05613
IO	1.9557	0.4655	-0.05613
TO	1.9557	0.4655	-0.05613
GC	1.9557	0.4655	-0.05613
AS	1.9557	0.4655	-0.05613
CL	1.9557	0.4655	-0.05613
MA	1.9557	0.4655	-0.05613
DG	1.9557	0.4655	-0.05613
BM	1.9557	0.4655	-0.05613
OS	3.7202	0.386	-0.03852
OH	1.9557	0.4655	-0.05613

4.7.2 Large Tree Height Growth

The height growth equations used in the WS variant depends on species. The equation used for sugar pine, Douglas-fir, white fir, giant sequoia, incense-cedar, Jeffrey pine, California red fir, ponderosa pine, western white pine, Pacific silver fir, Monterey pine, bigcone Douglas-fir, redwood, mountain hemlock, California live oak, canyon live oak, blue oak, California black oak, California white/valley oak, interior live oak, tanoak, giant chinquapin, quaking aspen, California-laurel, Pacific madrone, Pacific dogwood, bigleaf maple, other softwoods, and other hardwoods was developed by Dolph (1988), and is shown in equation {4.7.2.1}. Coefficients for this equation are shown in table 4.7.2.1.

{4.7.2.1} $HTG = [LAT + (b_1 * EL) + (b_2 * EL^2) + (b_3 * SL) + (b_4 * SI) + (b_5 * DG) + (b_6 * DG^{0.5}) + (b_7 * BA) + (b_8 * BAI) + (b_9 * \ln(BA)) + (b_{10} * BAL) + (b_{11} * (BAL / DBH)) + (b_{12} * CR) + (b_{13} * DBH^2)] * b_{14}$

where:

HTG	is estimated height growth for the cycle
LAT	is a location dependent latitude coefficient shown in table 4.7.2.2
EL	is stand elevation in hundreds of feet
SL	is stand slope
SI	is species site index
DG	is estimated 10-year inside-bark diameter growth for the cycle
BA	is total stand basal area
BAI	is the basal area increment [$BAI = (DBH + DG)^2 – DBH^2$]
BAL	is total basal area in trees with a larger diameter than the subject tree
DBH	is tree diameter at breast height (bounded $DBH \geq 0.001$)
CR	is a tree's live crown ratio (compacted) expressed as a percent
b_1 - b_{14}	are species-specific coefficients shown in table 4.7.2.1

Table 4.7.2.1 Coefficients (b_1 - b_{14}) for equation 4.7.2.1 in the WS variant.

	Species Code										
Coefficient	**OS**	**SP, WP, MH**	**DF, BD**	**WF, SF**	**GS, RW**	**IC**	**LO, CY, BL, BO, VO, IO, BM, OH**	**JP**	**RF**	**PP, MP**	**TO, GC, AS, CL, MA, DG**
b_1	0	0	0	-0.0453	0	0	0	0	-0.0453	0	0
b_2	0	0	0	0	0	-0.0007	-0.0007	0	0	0	-0.0007
b_3	0	0	0	3.218	0	0	0	0	3.218	0	0
b_4	0.0687	0.0881	0.0974	0.0713	0.0881	0.0643	0.0643	0.0687	0.0713	0.0598	0.0643
b_5	2.962	0	0	0	0	0	0	2.962	0	3.7974	0
b_6	0	10.189	15.382	8.7587	10.189	6.5757	6.5757	0	8.7587	0	6.5757
b_7	0	0	-0.0285	0	0	0.008	0.008	0	0	0	0.008
b_8	0	0	-0.0694	0	0	0	0	0	0	0	0
b_9	0	1.2845	6.119	1.2324	1.2845	0	0	0	1.2324	1.4843	0
b_{10}	0	0	0	0	0	-0.0079	-0.0079	0	0	-0.0142	-0.0079
b_{11}	0	0	0	-0.0399	0	0	0	0	-0.0399	0	0
b_{12}	0	0	0	0.0363	0	0	0	0	0.0363	0	0
b_{13}	-0.0082	-0.0098	0	-0.0098	-0.0098	0	0	-0.0082	-0.0098	-0.0086	0
b_{14}	1.50	1.00	1.25	1.50	1.10	1.20	1.00	1.50	1.20	1.15	0.75

Table 4.7.2.2 *LAT* values by latitude for equation {4.7.2.1} in the WS variant.

Latitude	Species Code									
	OS	SP, WP, MH	DF, BD	WF, SF	GS, RW	IC	LO, CY, BL, BO, VO, IO, BM, OH	JP	RF	PP, MP	TO, GC, AS, CL, MA, DG
35	-0.268	-14.053	-39.027	-12.246	-14.053	-3.831	-3.831	-0.268	-12.246	-5.554	-3.831
36	-0.268	-14.053	-39.027	-10.685	-14.053	1.711	1.711	-0.268	-10.685	-5.554	1.711
37	-0.268	-14.053	-39.027	-10.685	-14.053	-3.831	-3.831	-0.268	-10.685	-5.554	-3.831
38	3.097	-14.053	-39.027	-10.685	-14.053	-2.898	-2.898	3.097	-10.685	-4.282	-2.898
39	-0.268	-14.053	-39.027	-10.685	-14.053	-3.831	-3.831	-0.268	-10.685	-5.554	-3.831

Two checks are done after computing height growth in order to limit the maximum height growth. Jeffrey pine and other softwoods have their maximum height growth limited by equation {4.7.2.2}. Equation {4.7.2.3} affects all species and predicts maximum height for a given diameter and is used to limit height growth by checking to make sure current height plus height growth does not exceed the maximum height for that diameter. Species specific coefficients for equation {4.7.2.3} are shown in table 4.7.2.3.

{4.7.2.2} Used as a check for Jeffrey pine and other softwoods

$MAXHTG = -2.16 + (4.22 * \ln(BAI))$

{4.7.2.3} Used as a check for sugar pine, Douglas-fir, white fir, giant sequoia, incense-cedar, Jeffrey pine, California red fir, ponderosa pine, western white pine, Pacific silver fir, Monterey pine, bigcone Douglas-fir, redwood, mountain hemlock, California live oak, canyon live oak, blue oak, California black oak, California white oak / valley oak, interior live oak, tanoak, giant chinquapin, quaking aspen, California-laurel, Pacific madrone, Pacific dogwood, bigleaf maple, other softwoods, and other hardwoods

$HT_{max} = \exp(A + B / (DBH + DG + 1.0)\text{^}C]) + 4.5$

Equation {4.7.2.4} is used to keep height and diameter growth estimates consistent with each other for large trees. For trees with *DBH* > 30”, if the estimated 10-year inside-bark diameter growth is less than 1.0 for the cycle, then equation {4.7.2.4} is used to limit the height growth to prevent unusually large height growth on large trees with little or no diameter growth.

{4.7.2.4} Used as a modification for sugar pine, Douglas-fir, white fir, giant sequoia, incense-cedar, Jeffrey pine, California red fir, ponderosa pine, western white pine, Pacific silver fir, Monterey pine, bigcone Douglas-fir, redwood, mountain hemlock, California live oak, canyon live oak, blue oak, California black oak, California white oak / valley oak, interior live oak, tanoak, giant chinquapin, quaking aspen, California-laurel, Pacific madrone, Pacific dogwood, bigleaf maple, other softwoods, and other hardwoods when *DBH* > 30” and *DG* < 1.0

$HTG = HTG * DG$

where:

MAXHTG is the maximum height growth for the tree

BAI is the basal area increment, $BAI = (DBH + DG)^2 - DBH^2$
HT_{max} is the estimated maximum height for the tree relative to the tree *DBH*
DBH is tree diameter at breast height
DG is estimated 10-year inside-bark diameter growth for the cycle
A, B, C are species-specific coefficients for equation {4.7.2.3} shown in table 4.7.2.3

The final height growth estimate is bounded to be greater than or equal to 0.1 foot.

Table 4.7.2.3 Coefficients (A, B, and C) for equation {4.7.2.3} in the WS variant.

	Species Code										
Coefficient	**OS**	**SP, WP, MH**	**DF, BD**	**WF, SF**	**GS, RW**	**IC**	**LO, CY, BL, BO, VO, IO, BM, OH**	**JP**	**RF**	**PP, MP**	**TO, GC, AS, CL, MA, DG**
A	5.4916	5.4918	5.4191	5.4283	5.4918	5.2011	4.6570	5.4916	5.4283	5.4916	5.2011
B	-9.5992	-12.6438	-8.8274	-9.1641	-12.6438	-7.7610	-21.9333	-9.5992	-9.1641	-9.5992	-7.7610
C	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0	1.0	1.0	1.0

For curl-leaf mountain mahogany, if tree height at the beginning of the projection cycle is greater than or equal to the maximum species height of 20 feet, then height growth is computed using equation {4.7.2.5} and adjusted for cycle length and user supplied growth multipliers.

{4.7.2.5} $HTG = 0.1$

where:

HTG is estimated 10-year tree height growth

For curl-leaf mountain mahogany, when tree height at the beginning of the projection cycle is less than the maximum species height, but the estimated tree age at the beginning of the projection cycle is greater than the species maximum age of 400, height growth is calculated using equation {4.7.2.6} and adjusted for cycle length and user supplied growth multipliers.

{4.7.2.6} $HTG = 0.1 * HTGMOD$

where:

HTG is estimated 10-year tree height growth
HTGMOD is the weighted height growth multiplier shown below

For curl-leaf mountain mahogany, when estimated tree age at the beginning of the projection cycle is less than or equal to the species maximum age and tree height at the beginning of the projection cycle is less than the species maximum height, then potential height growth is obtained by subtracting estimated current height from an estimated future height. Potential height growth is then adjusted according to the tree's crown ratio and height relative to other trees in the stand.

Estimated current height (ECH) and estimated future height (H10) are both obtained using equation {4.7.2.7} (Curtis et al, 1974). Estimated current height is obtained using estimated tree age at the start of the projection cycle and site index. Estimated future height is obtained using estimated tree age at the start of the projection cycle plus 10-years and site index.

{4.7.2.7} $H = [(SI – 4.5) / [b_0 + (b_1 / (SI – 4.5))] + [A\text{^}-1.4 * (b_2 + (b_3 / (SI – 4.5)))]] + 4.5$

where:

H	is estimated height of the tree
SI	is species site index
A	is estimated age of the tree

$b_0 = 0.6192$, $b_1 = -5.3394$, $b_2 = 240.29$, $b_3 = 3368.9$

Potential height growth is estimated using equation {4.7.2.8}. Height increment is computed using equation {4.7.2.9} and adjusted for cycle length and user supplied growth multipliers.

{4.7.2.8} $POTHTG = H10 – ECH$

{4.7.2.9} $HTG = POTHTG * HTGMOD$

where:

POTHTG	is potential height growth
H10	is estimated height of the tree in ten years
ECH	is estimated height of the tree at the beginning of the cycle
HTG	is estimated 10-year tree height growth (bounded $0.1 \leq$ HTG)
HTGMOD	is the weighted height growth multiplier shown below

The potential height growth modifier, HTGMOD, is based upon a tree's crown ratio (equation {4.7.2.10}), and relative height and shade tolerance (equation {4.7.2.11}). Equation {4.7.2.12} uses the Generalized Chapman – Richard's function (Donnelly et. al, 1992) to calculate a height-growth modifier. Final height growth is calculated using equation {4.7.2.13} as a product of the modifier and potential height growth.

{4.7.2.10} $HGMDCR = (100 * (CR)\text{^}{3}) * \exp(-5 * (CR))$

{4.7.2.11} $HGMDRH = [1 + ((1 / b_{\square})\text{^}(b_2 - 1) – 1) * \exp((-1 * (b_3 / (1 – b_4)) * RELHT\text{^}(1 – b_4))\text{^}(-1 / (b_2 - 1))$

{4.7.2.12} $HTGMOD = (0.25 * HGMDCR) + (0.75 * HGMDRH)$

{4.7.2.13} $HTG = POTHTG * HTGMOD$

where:

POTHTG	is potential 10-year height growth
HGMDCR	is a height growth modifier based on crown ratio, bounded so HGMDCR ≤ 1.0
HGMDRH	is a height growth modifier based on relative height and shade tolerance
HTGMOD	is a weighted height growth modifier, bounded $0.1 \leq$ HTGMOD ≤ 2.0
CR	is crown ratio expressed as a proportion
RELHT	is tree height divided by average height of the 40 largest diameter trees in the stand (bounded so that *RELHT* ≤ 1.5)

$b_1 = 0.1$, $b_2 = 1.1$, $b_3 = 15.0$, $b_4 = -1.45$

Lodgepole pine, whitebark pine, singleleaf pinyon, knobcone pine, foxtail pine, Coulter pine, limber pine, gray or California foothill pine, Washoe pine, western juniper, Utah juniper, and California juniper use Dunning/Levitan site curves, equation {4.7.2.14}, to estimate large tree height growth. Using the species site index and tree height at the beginning of the projection cycle, an estimated tree age is computed using the site index curves. Estimated current height (ECH) and estimated future height (H10) are both obtained using equation {4.7.2.14}. Estimated current height is obtained using estimated tree age at the start of the projection cycle and site index. Estimated future height is obtained using estimated tree age at the start of the projection cycle plus 10-years and site index. Height increment is obtained by subtracting estimated current height from estimated future height, then adjusting the difference according to tree's crown ratio and height relative to other trees in the stand.

{4.7.2.14} Dunning/Levitan site curves

$A > 40: HT = D_1 + D_2 * \ln(A)$
$A \leq 40: HT = D_3 * A$

where:

HT	is total height of the tree
A	is estimated tree age
$D_1 – D_3$	are coefficients based on Region 5 site codes shown in table 4.7.2.4

Table 4.7.2.4 Coefficients for the Dunning/Levitan site curves, nominal site index by site class, and range of site values for which the coefficients are used in the WS variant.

Region 5 Site Class	Nominal Site Index	Site Index Range Used	D_1	D_2	D_3
0	106	99+	-88.9	49.7067	2.375
1	90	83 - 98	-82.2	44.1147	2.025
2	75	66 - 82	-78.3	39.1441	1.650
3	56	53 - 65	-82.1	35.4160	1.225
4	49	45 - 52	-56.0	26.7173	1.075
5-7	39	0 - 44	-33.8	18.6400	0.875

Potential 10-year height growth (*POTHTG*) is calculated using equation {4.7.2.8}. Modifiers are applied to the potential height growth based upon a tree's crown ratio (equation {4.7.2.15}) and relative height (equation {4.7.2.16}). Equation {4.7.2.17} calculates a height-growth modifier by combining the crown ratio and relative height modifiers. Final height growth is calculated using equation {4.7.2.18} as a product of the modifier and potential height growth.

{4.7.2.15} $HGMDCR = 1 – \exp(-4.26558 * CR)$

{4.7.2.16} $HGMDRH = e \wedge [2.54119 * (RELHT \wedge 0.250537 – 1.0)]$

{4.7.2.17} $HTGMOD = 1.016605 * HGMDCR * HGMDRH$

{4.7.2.18} $HTG = POTHTG * HTGMOD$

where:

POTHTG	is potential height growth
HGMDCR	is a height growth modifier based on crown ratio
HGMDRH	is a height growth modifier based on relative height and shade tolerance
HTGMOD	is a weighted height growth modifier
CR	is crown ratio expressed as a proportion

RELHT is tree height divided by average height of the 40 largest diameter trees in the stand (bounded so $RELHT \leq 1.0$; if crown competition factor for the point on which the tree is located is less than 100, then *RELHT* is set equal to 1.0)

The large tree height growth estimate for all species is adjusted for cycle length and user supplied growth modifiers.

Height growth for Great Basin bristlecone pine of all sizes is estimated using the small tree logic described in section 4.6.

5.0 Mortality Model

The WS variant uses an SDI-based mortality model as described in Section 7.3.2 of Essential FVS: A User's Guide to the Forest Vegetation Simulator (Dixon 2002, referred to as EFVS). This SDI-based mortality model is comprised of two steps: 1) determining the amount of stand mortality (section 7.3.2.1 of EFVS) and 2) dispersing stand mortality to individual tree records (section7.3.2.2 of EFVS). In determining the amount of stand mortality, the summation of individual tree background mortality rates is used when stand density is below the minimum level for density dependent mortality (default is 55% of maximum SDI), while stand level density-related mortality rates are used when stands are above this minimum level.

The equation used to calculate individual tree background mortality rates for all species is shown in equation {5.0.1}, and this is then adjusted to the length of the cycle by using a compound interest formula as shown in equation {5.0.2}. Species mapping and coefficients for these equations are shown in tables 5.0.1 and 5.0.2. The overall amount of mortality calculated for the stand is the summation of the final mortality rate (*RIP*) across all live tree records.

{5.0.1} $RI = [1 / (1 + \exp(p_0 + p_1 * DBH))] * 0.5$

{5.0.2} $RIP = 1 – (1 – RI)^Y$

where:

RI	is the proportion of the tree record attributed to mortality
RIP	is the final mortality rate adjusted to the length of the cycle
DBH	is tree diameter at breast height
Y	is length of the current projection cycle in years
p_0 and p_1	are species-specific coefficients shown in table 5.0.1

Table 5.1.1 Coefficients used in the background mortality equation {5.0.1} in the WS variant.

Species Code	p_0	p_1
SP	6.5112	-0.0052485
DF	7.2985	-0.0129121
WF	5.1677	-0.0077681
GS	9.6943	-0.0127328
IC	5.1677	-0.0077681
JP	9.6943	-0.0127328
RF	5.1677	-0.0077681
PP	5.5877	-0.005348
LP	5.9617	-0.0340128
WB	5.9617	-0.0340128
WP	6.5112	-0.0052485
PM	6.5112	-0.0052485
SF	5.1677	-0.0077681
KP	6.5112	-0.0052485

Species Code	p_0	p_1
FP	6.5112	-0.0052485
CP	6.5112	-0.0052485
LM	6.5112	-0.0052485
MP	5.5877	-0.005348
GP	6.5112	-0.0052485
WE	6.5112	-0.0052485
GB	5.1677	-0.0077681
BD	7.2985	-0.0129121
RW	9.6943	-0.0127328
MH	6.5112	-0.0052485
WJ	6.5112	-0.0052485
UJ	6.5112	-0.0052485
CJ	6.5112	-0.0052485
LO	5.9617	-0.0340128
CY	5.9617	-0.0340128
BL	5.9617	-0.0340128
BO	5.9617	-0.0340128
VO	5.9617	-0.0340128
IO	5.9617	-0.0340128
TO	5.1677	-0.0077681
GC	5.1677	-0.0077681
AS	5.1677	-0.0077681
CL	5.1677	-0.0077681
MA	5.1677	-0.0077681
DG	5.1677	-0.0077681
BM	5.9617	-0.0340128
MC	5.9617	-0.0340128
OS	6.5112	-0.0052485
OH	5.9617	-0.0340128

When stand density-related mortality is in effect, the total amount of stand mortality is determined based on the trajectory developed from the relationship between stand SDI and the maximum SDI for the stand. This is explained in section 7.3.2.1 of EFVS.

Once the amount of stand mortality is determined based on either the summation of background mortality rates or density-related mortality rates, mortality is dispersed to individual tree records in relation to a tree's percentile in the basal area distribution (*PCT*) using equation {5.0.3}. This value is then adjusted by a species-specific mortality modifier (representing the species' tolerance) to obtain a final mortality rate as shown in equations {5.0.4} and {5.0.5}.

The mortality model makes multiple passes through the tree records multiplying a record's trees-per-acre value times the final mortality rate (*MORT*), accumulating the results, and reducing the trees-per-acre representation until the desired mortality level has been reached. If the stand still exceeds the basal area maximum sustainable on the site, the mortality rates are proportionally adjusted to reduce the stand to the specified basal area maximum.

{5.0.3} $MR = 0.84525 – (0.01074 * PCT) + (0.0000002 * PCT^3)$

{5.0.4} Used for all species except curlleaf mountain-mahogany

$MORT = MR * MWT * 0.1$

{5.0.5} Used for curlleaf mountain-mahogany

$MORT = = MR * ((100-CR)/100) * MWT * 0.1$

where:

MR	is the proportion of the tree record attributed to mortality (bounded: $0.01 \le MR \le 1$)
PCT	is the subject tree's percentile in the basal area distribution of the stand
MORT	is the final mortality rate of the tree record
MWT	is a mortality weight value based on a species' tolerance shown in table 5.0.3
CR	is tree crown ratio expressed as a percent

Table 5.0.3 *MWT* values for the mortality equations {5.0.4} and {5.0.5} in the WS variant.

Species Code	*MWT*
SP	0.70
DF	0.65
WF	0.55
GS	0.80
IC	0.60
JP	0.85
RF	0.50
PP	0.85
LP	0.90
WB	0.90
WP	0.70
PM	0.90
SF	0.55
KP	0.90
FP	0.90
CP	0.90
LM	0.90
MP	0.85
GP	0.90
WE	0.90
GB	0.90
BD	0.65

RW	0.80
MH	0.70
WJ	0.90
UJ	0.90
CJ	0.90
LO	1.00
CY	1.00
BL	1.00
BO	1.00
VO	1.00
IO	1.00
TO	0.55
GC	0.55
AS	0.55
CL	0.55
MA	0.55
DG	0.55
BM	1.00
MC	1.10
OS	0.75
OH	1.00

6.0 Regeneration

The WS variant contains a partial establishment model which may be used to input regeneration and ingrowth into simulations. A more detailed description of how the partial establishment model works can be found in section 5.4.5 of the Essential FVS Guide (Dixon 2002).

The regeneration model is used to simulate stand establishment from bare ground, or to bring seedlings and sprouts into a simulation with existing trees. 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 WS variant.

Species Code	Sprouting Species	Minimum Bud Width (in)	Minimum Tree Height (ft)	Maximum Tree Height (ft)
SP	No	0.3	2.0	27.0
DF	No	0.3	2.0	21.0
WF	No	0.3	2.0	21.0
GS	No	0.2	2.0	22.0
IC	No	0.2	2.0	20.0
JP	No	0.3	2.0	18.0
RF	No	0.3	2.0	18.0
PP	No	0.5	2.0	17.0
LP	No	0.4	1.0	20.0
WB	No	0.4	1.0	20.0
WP	No	0.3	2.0	27.0
PM	No	0.5	1.0	20.0
SF	No	0.3	2.0	21.0
KP	No	0.5	1.0	20.0
FP	No	0.5	1.0	20.0
CP	No	0.5	1.0	20.0
LM	No	0.5	1.0	20.0
MP	No	0.5	2.0	17.0
GP	No	0.5	1.0	20.0
WE	No	0.5	1.0	20.0
GB	No	0.4	0.5	9.0
BD	No	0.3	2.0	21.0
RW	Yes	0.2	2.0	22.0
MH	No	0.3	2.0	27.0
WJ	No	0.5	1.0	20.0
UJ	No	0.5	1.0	20.0
CJ	No	0.5	1.0	20.0
LO	Yes	0.4	2.0	24.0
CY	Yes	0.4	2.0	24.0

Species Code	Sprouting Species	Minimum Bud Width (in)	Minimum Tree Height (ft)	Maximum Tree Height (ft)
BL	Yes	0.4	2.0	24.0
BO	Yes	0.4	2.0	24.0
VO	Yes	0.4	2.0	24.0
IO	Yes	0.4	2.0	24.0
TO	Yes	0.2	2.0	22.0
GC	Yes	0.2	2.0	22.0
AS	Yes	0.2	2.0	22.0
CL	Yes	0.2	2.0	22.0
MA	Yes	0.2	2.0	22.0
DG	Yes	0.2	2.0	22.0
BM	Yes	0.4	2.0	24.0
MC	No	0.2	1.0	20.0
OS	No	0.4	2.0	23.0
OH	No	0.4	2.0	24.0

The number of sprout records created for each sprouting species is found in table 6.0.2. For more prolific stump sprouting hardwood species, logic rule {6.0.1} is used to determine the number of sprout records, with logic rule {6.0.2} being used for root suckering species. The trees-per-acre represented by each sprout record is determined using the general sprouting probability equation {6.0.3}. 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 stump sprouting hardwood species

$DSTMP_i \leq 5$: $NUMSPRC = 1$
$5 < DSTMP_i \leq 10$: $NUMSPRC = \mathrm{NINT}(0.2 * DSTMP_i)$
$DSTMP_i > 10$: $NUMSPRC = 2$

{6.0.2} For root suckering hardwood species

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

{6.0.3} $TPA_s = TPA_i * PS$

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

{6.0.5} $PS = ((93.2669 - 0.4303 * DSTMP_i) / 100)$

{6.0.6} $PS = ((70.7857 - 2.6071 * DSTMP_i) / 100)$

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 WS variant.

Species Code	Sprouting Probability	Number of Sprout Records	Source
RW	{6.0.5}	1	Neal 1967 Boe 1975 Griffith 1992
LO	0.5	{6.0.1}	See canyon live oak (CY)
CY	0.5	{6.0.1}	Conard 1987 Thornburgh 1990 Paysen et al. 1991
BL	{6.0.6}	{6.0.1}	McCreary et al. 2000 Standiford et al. 2011
BO	0.9	{6.0.1}	McDonald 1978 McDonald 1990
VO	0.9	{6.0.1}	Howard 1992
IO	0.5	{6.0.1}	See canyon live oak (CY)
TO	0.9	{6.0.2}	Harrington et al. 1992 Wilkinson et al. 1997 Fryer 2008
GC	0.9	{6.0.2}	Harrington et al. 1992 Meyer 2012
AS	{6.0.4}	2	Keyser 2001
CL	0.9	{6.0.2}	Paysen et al. 1991 Ag. Handbook 654
MA	0.9	{6.0.2}	McDonald et al. 1983 McDonald and Tappenier 1990
DG	0.9	{6.0.2}	Gucker 2005
BM	0.9	{6.0.2}	Roy 1955 Tappenier et al. 1996 Ag. Handbook 654

Regeneration of seedlings must be specified by the user with the partial establishment model by using the PLANT or NATURAL keywords. Height of the seedlings is estimated in two steps. First, the height is estimated when a tree is 5 years old (or the end of the cycle – whichever comes first) by using the small-tree height growth equations found in section 4.6.1. Users may override this value by entering a height in field 6 of the PLANT or NATURAL keyword; however, the height entered in field 6 is not subject to minimum height restrictions and seedlings as small as 0.05 feet may be established. The second step also uses the equations in section 4.6.1, which grow the trees in height from the point five years after establishment to the end of the cycle.

Seedlings 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

In the WS variant, 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 WS variant are shown in tables 7.0.1-7.0.3.

Table 7.0.1 Volume merchantability standards for the WS variant.

Merchantable Cubic Foot Volume Specifications:		
Minimum DBH / Top Diameter	**Hardwoods**	**Softwoods**
All location codes	**7.0 / 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	**Hardwoods**	**Softwoods**
All location codes	**10.0 / 6.0 inches**	**10.0 / 6.0 inches**
Stump Height	**1.0 foot**	**1.0 foot**

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

Common Name	Location Code	Equation Number	Reference
sugar pine	All	500WO2W117	Wensel and Olsen Profile Model
Douglas-fir	All	500WO2W202	Wensel and Olsen Profile Model
white fir	All	500WO2W015	Wensel and Olsen Profile Model
giant sequoia	All	500DVEW212	Pillsbury and Kirkley Equations
incense-cedar	All	500WO2W081	Wensel and Olsen Profile Model
Jeffrey pine	All	500WO2W116	Wensel and Olsen Profile Model
California red fir	All	500WO2W020	Wensel and Olsen Profile Model
ponderosa pine	All	500WO2W122	Wensel and Olsen Profile Model
lodgepole pine	All	500WO2W108	Wensel and Olsen Profile Model
whitebark pine	All	500WO2W108	Wensel and Olsen Profile Model
western white pine	All	500WO2W117	Wensel and Olsen Profile Model
singleleaf pinyon	All	500WO2W116	Wensel and Olsen Profile Model
Pacific silver fir	All	500WO2W015	Wensel and Olsen Profile Model
knobcone pine	All	500WO2W108	Wensel and Olsen Profile Model
foxtail pine	All	500WO2W108	Wensel and Olsen Profile Model
Coulter pine	All	500WO2W108	Wensel and Olsen Profile Model
limber pine	All	500WO2W108	Wensel and Olsen Profile Model
Monterey pine	All	500WO2W108	Wensel and Olsen Profile Model
Gray or California foothill pine	All	500WO2W108	Wensel and Olsen Profile Model

Common Name	Location Code	Equation Number	Reference
Washoe pine	All	500WO2W117	Wensel and Olsen Profile Model
Great Basin bristlecone pine	All	500WO2W108	Wensel and Olsen Profile Model
bigcone Douglas-fir	All	500WO2W202	Wensel and Olsen Profile Model
redwood	All	500WO2W211	Wensel and Olsen Profile Model
mountain hemlock	All	500WO2W015	Wensel and Olsen Profile Model
western juniper	All	500DVEW060	Pillsbury and Kirkley Equations
Utah juniper	All	500DVEW060	Pillsbury and Kirkley Equations
California juniper	All	500DVEW060	Pillsbury and Kirkley Equations
California live oak	All	500DVEW801	Pillsbury and Kirkley Equations
canyon live oak	All	500DVEW805	Pillsbury and Kirkley Equations
blue oak	All	500DVEW807	Pillsbury and Kirkley Equations
California black oak	All	500DVEW818	Pillsbury and Kirkley Equations
California white oak / valley oak	All	500DVEW821	Pillsbury and Kirkley Equations
interior live oak	All	500DVEW839	Pillsbury and Kirkley Equations
tanoak	All	500DVEW631	Pillsbury and Kirkley Equations
giant chinquapin	All	500DVEW431	Pillsbury and Kirkley Equations
quaking aspen	All	500DVEW818	Pillsbury and Kirkley Equations
California-laurel	All	500DVEW981	Pillsbury and Kirkley Equations
Pacific madrone	All	500DVEW361	Pillsbury and Kirkley Equations
Pacific dogwood	All	500DVEW807	Pillsbury and Kirkley Equations
bigleaf maple	All	500DVEW312	Pillsbury and Kirkley Equations
curlleaf mountain-mahogany	All	500DVEW801	Pillsbury and Kirkley Equations
other softwoods	All	500WO2W108	Wensel and Olsen Profile Model
other hardwoods	All	500DVEW839	Pillsbury and Kirkley Equations

Table 7.0.3 Citations by Volume Model

Model Name	Citation
Pillsbury and Kirkley Equations	Norman H Pillsbury and Michael L Kirkley 1984 Equations for Total, Wood, and saw-Log Volume for Thirteen California Hardwoods. Pacific Northwest Forest and Range Experiment Station Research Note PNW-414.
Wensel and Olsen Profile Model	Wensel, L. C. and C. M. Olson. 1993. Tree Taper Models for Major Commercial California Conifers. Research Note No. 33. Northern Calif. Forest Yield Cooperative. Dept. of Forstry and Mgmt., Univ. of Calif., Berkeley. 28 pp.

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 WS 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 WS 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

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11.0 Appendices

11.1 Appendix A. Distribution of Data Samples

Data used to develop the model came from the following sources:

- Tahoe 1990 Inventory
- Tahoe 1990 Plantation Inventory
- Stanislaus 1991 Inventory
- Stanislaus 1991 Plantation Inventory
- Sierra 1985 Inventory
- Sierra 1985 Plantation Inventory
- Sequoia 1990 Inventory
- Sequoia 1990 Plantation Inventory
- PSW Research Station study plots throughout the area
- Leroy Dolph's Red Fir Study- Sierra Nevadas and Klamath Mountains

The following tables contain distribution information of data used to fit species relationships in this variant's geographic region (information from original variant overview).

Table 11.1.1. Distribution of samples by species.

	Total Number of Observations		
Species	**diameter growth model**	**height growth model**	**crown, mortality, and bounding functions**
White Pine			340
Mountain Hemlock			58
white Fir	3301	407	8209
incense-cedar	1339	208	3393
Douglas-fir	480	46	976
ponderosa pine	1528	158	4941
sugar Pine	650	68	1322
Jeffrey Pine	1144	31	114
lodgeple Pine	419	0	951
Red Fir			3860
Other Species			1916

11.2 Appendix B: Plant Association Codes

Table 11.2.1 Plant association codes recognized in the WS variant.

FVS Sequence Number = Plant Association Species Type	Alpha Code	Reference
1 = 2TE/BEOC2 Conifer/water birch	43014	501 – Manning & Padgett
2 =2TE/ROWO	43015	501 – Manning & Padget

FVS Sequence Number = Plant Association Species Type	Alpha Code	Reference
Conifer/wood's rose		
3 = 2TE/2FORB Conifer/tall forb	43016	501 – Manning & Padgett
4 = 2TE/2FORB Conifer/mesic forb	43017	501 – Manning & Padget
5 = PICO/CASC12 Lodgepole pine/mountain sedge	43031	501 – Manning & Padgett
6 = POTR5/BEOC2 Quaking aspen/water birch	43061	501 – Manning & Padget
7 = POTR5/COSE16 Quaking aspen/redosier dogwood	43062	501 – Manning & Padgett
8 = POTR5/SALIX Quaking aspen/willow	43063	501 – Manning & Padget
9 = POTR5/ROWO Quaking aspen/woods' rose	43064	501 – Manning & Padgett
10 = POTR5/BRCA5 Quaking aspen/California brome	43065	501 – Manning & Padget
11 = POTR5/POPR Quaking aspen/Kentucky bluegrass	43066	501 – Manning & Padgett
12 = POTR5/2FORB Quaking aspen/mesic forb	43067	501 – Manning & Padget
13 = POPUL/BEOC2 Cottonwood/water birch	43071	501 – Manning & Padgett
14 = POPUL/COSE16 Cottonwood/redosier dogwood	43072	501 – Manning & Padget
15 = POPUL/SALIX Cottonwood/willow	43073	501 – Manning & Padgett
16 = POPUL/ROWO Cottonwood/woods' rose	43074	501 – Manning & Padget
17 = POPUL/RHAR4 Cottonwood/fragrant sumac	43075	501 – Manning & Padgett
18 = POPUL Cottonwood (stream bar)	43076	501 – Manning & Padget
19 = ALIN2 Gray alder (bench)	43106	501 – Manning & Padgett
20 = BEOC2/2GRAM Water birch/mesic graminoid	43153	501 – Manning & Padget
21 = BEOC2/EQAR Water birch/field horsetail	43154	501 – Manning & Padgett
22 = BEOC2 Water birch (bench)	43156	501 – Manning & Padget

FVS Sequence Number = Plant Association Species Type	Alpha Code	Reference
23 = SAEX/ROWO Narrowleaf willow/woods' rose	43246	501 – Manning & Padgett
24 = SAEX Narrowleaf willow (bench)	43247	501 – Manning & Padget
25 = SALE/CASC12 Lemmons willow/mountain sedge	43261	501 – Manning & Padgett
26 = SALE/2GRAM Lemmons willow/mesic graminoid	43262	501 – Manning & Padget
27 = SALE/2FORB Lemmons willow/mesic forb	43263	501 – Manning & Padgett
28 = SALE/2FORB Lemons willow/tall forb	43264	501 – Manning & Padget
29 = SALE Lemmons willow (seep)	43265	501 – Manning & Padgett
30 = SALE Lemmons willow (bench)	43266	501 – Manning & Padget
31 = SALU2/2GRAM Yellow willow/ mesic graminoid	43272	501 – Manning & Padgett
32 = SALU2/2FORB Yellow willow/mesic forb	43273	501 – Manning & Padget
33 = SALU2/ROWO Yellow willow/woods' rose	43274	501 – Manning & Padgett
34 = SALU2/POPR Yellow willow/Kentucky bluegrass	43275	501 – Manning & Padget
35 = SALU2 Yellow willow (bench)	43276	501 – Manning & Padgett
36 = SADR Drummond's willow	43282	501 – Manning & Padget
37 = SALUL/2FORB Pacific willow/mesic forb	43284	501 – Manning & Padgett
38 = SALUL Pacific willow (bench)	43285	501 – Manning & Padget
39 = SALA6/ROWO Arroyo willow/woods' rose	43287	501 – Manning & Padgett
40 = SALA6 Arroyo willow (bench)	43288	501 – Manning & Padget
41 = SALIX/CARO6 Willow/beaked sedge	43289	501 – Manning & Padgett
42 = SALIX/2GRAM Willow/mesic graminoid	43290	501 – Manning & Padget
43 = SALIX/2FORB	43291	501 – Manning & Padgett

FVS Sequence Number = Plant Association Species Type	**Alpha Code**	**Reference**
Willow/mesic forb		
44 = SALIX/2FORB Willow/tall forb	43292	501 – Manning & Padget
45 = SALIX/ROWO Willow/woods' rose	43293	501 – Manning & Padgett
46 = SALIX/POPR Willow/Kentucky bluegrass	43294	501 – Manning & Padget
47 = SAWO/CASC12 Wolf's willow/mountain sedge	43304	501 – Manning & Padgett
48 = SAPL2/CASC12 Diamondleaf willow/mountain sedge	43325	501 – Manning & Padget
49 = SAEA/CASC12 Mountain willow/mountain sedge	43327	501 – Manning & Padgett
50 = SAOR/2FORB Sierra willow/tall forb	43328	501 – Manning & Padget
51 = SALIX/2FORB Willow/mesic forb	43329	501 – Manning & Padgett
52 = COSE16 Redosier dogwood	43351	501 – Manning & Padget
53 = COSE16/SALIX Redosier dogwood-willow	43352	501 – Manning & Padgett
54 = PRVI/ROWO Chokecherry/woods' rose	43451	501 – Manning & Padget
55 = ROWO Woods' rose	43500	501 – Manning & Padgett
56 = DAFL3/LIGR Shrubby cinquefoil/gray's licorice-root	43554	501 – Manning & Padget
57 = ARCA13/2GRAM Silver sagebrush/graminoid (dry)	43605	501 – Manning & Padgett
58 = ARCA13/2GRAM Silver sagebrush/graminoid (mesic)	43606	501 – Manning & Padget
59 = ARTRT/ROWO Basin big sagebrush/woods' rose	43651	501 – Manning & Padgett
60 = CADO2 Douglas' sedge	43803	501 – Manning & Padget
61 = CASC12 Mountain sedge	43811	501 – Manning & Padgett
62 = DECA18-CANE2 Tufted hairgrass-Nebraska sedge	43872	501 – Manning & Padget
63 = POSE Sandberg bluegrass	43883	501 – Manning & Padgett

FVS Sequence Number = Plant Association Species Type	**Alpha Code**	**Reference**
64 = DOJE Sierra shootingstar	43905	501 – Manning & Padget
65 = LUPO2-SETR Bigleaf lupine-arrowleaf ragwort	43911	501 – Manning & Padgett
66 = IRMI/2GRAM Western iris/dry graminoid	43915	501 – Manning & Padget
67 = IRMI/2GRAM Western iris/ mesic graminoid	43916	501 – Manning & Padgett
68 = AGST2 Creping bentgrass	43991	501 – Manning & Padget
69 = HOBR2 Meadow barley	43995	501 – Manning & Padgett
70 = CHLA Port Orford cedar	CCOCCO00	510 – Jimerson, 1994
71 = Port Orford cedar/salal (1)	CCOCCO11	510 – Jimerson, 1994
72 = Port Orford cedar/pacific rhododendron-salal(1)	CCOCCO12	510 – Jimerson, 1994
73 = Port Orford cedar/western azalea (1)	CCOCCO13	510 – Jimerson, 1994
74 = Port Orford cedar-western white pine/huckleberry oak (1)	CCOCCO14	510 – Jimerson, 1994
75 = CHLA-ABCO Port Orford cedar-white fir	CCOCFW00	510 – Jimerson, 1994
76 = CHLA-ABCO/QUVA Port Orford cedar-white fir/huckleberry oak	CCOCFW11	510 – Jimerson, 1994
77 = CHLA-ABCO-PIMO3/QUVA Port Orford cedar-white fir-western white pine/huckleberry oak	CCOCFW12	510 – Jimerson, 1994
78 = CHLA-ABCO/RHOB Port Orford cedar-white fir/western azalea	CCOCFW13	510 – Jimerson, 1994
79 = CHLA-ABCO/2FORB Port Orford cedar-white fir/forbs	CCOCFW14	510 – Jimerson, 1994
80 = CHLA-ABCO/QUSA2 Port Orford cedar-white fir/deer oak	CCOCFW15	510 – Jimerson, 1994
81 = CHLA-ABSH/QUSA2-VAME Port Orford cedar-Shasta red fir/deer oak-thinleaf huckleberry	CCOCFW16	510 – Jimerson, 1994
82 = CHLA-PSME/QUVA Port Orford cedar-Douglas-fir/huckleberry oak	CCOCFW17	510 – Jimerson, 1994

FVS Sequence Number = Plant Association Species Type	**Alpha Code**	**Reference**
83 = CHLA-CADE27-ALRH2 Port Orford cedar-incense cedar-white alder	CCOCFW18	510 – Jimerson, 1994
84 = PSME Douglas-fir	CD000000	513 – Jimerson et al, 1996
85 = PSME-CADE27 Douglas-fir-incense cedar	CD0CCI00	513 – Jimerson et al, 1996
86 = PSME-CADE27/FECA Douglas-fir-incense cedar/California fescue	CD0CCI11	513 – Jimerson et al, 1996
87 = PSME-PIJE Douglas-fir-Jeffrey Pine	CD0CPJ00	513 – Jimerson et al, 1996
88 = PSME-PIJE/FECA Douglas-fir-Jeffrey pine/California fescue	CD0CPJ11	513 – Jimerson et al, 1996
89 = PSME-ALRU2 Douglas-fir-red alder	CD0HAR00	513 – Jimerson et al, 1996
90 = PSME-ALRU2/ACCI/CLSIS Douglas-fir-red alder/vine maple/Siberian springbeauty	CD0HAR11	513 – Jimerson et al, 1996
91 = PSME-UMCA Douglas-fir-California laurel	CD0HBC00	513 – Jimerson et al, 1996
92 = PSME-UMCA/TODI Douglas-fir-California laurel/Pacific poison oak	CD0HBC11	513 – Jimerson et al, 1996
93 = PSME-UMCA/HODI Douglas-fir-California laurel/ocean spray	CD0HBC12	513 – Jimerson et al, 1996
94 = PSME-CHCHC4 Douglas-fir-giant chinquapin	CD0HGC00	513 – Jimerson et al, 1996
95 = PSME-CHCHC4-LIDE3 Douglas-fir-giant chinquapin-tanoak	CD0HGC11	513 – Jimerson et al, 1996
96 = PSME-CHCHC4/XETE Douglas-fir-giant chinquapin/common beargrass	CD0HGC12	513 – Jimerson et al, 1996
97 = PSME-CHCHC4/RHMA3-GASH Douglas-fir-giant chinquapin/Pacific rhododendron-salal	CD0HGC13	513 – Jimerson et al, 1996
98 = PSME-CHCHC4/RHMA3-MANE2 Douglas-fir-giant chinquapin/pacific rhododendron-Cascade barberry	CD0HGC14	513 – Jimerson et al, 1996
99 = PSME-CHCHC4/RHMA3-QUSA2/XETE Douglas-fir-giant chinquapin/pacific rhododendron-deer oak/common beargrass	CD0HGC15	513 – Jimerson et al, 1996
100 = PSME-CHCHC4-LIDE3/MANE2 Douglas-fir-giant chinquapin-tanoak/cascade barberry	CD0HGC16	513 – Jimerson et al, 1996
101 = PSME-CHCHC4/RHA3-QUSA-GASH	CD0HGC17	513 – Jimerson et al, 1996

FVS Sequence Number = Plant Association Species Type	**Alpha Code**	**Reference**
Douglas-fir-giant chinquapin/pacific rhododendron-deer oak-salal		
102 = PSME-ACER Douglas-fir-maple	CD0HMA00	513 – Jimerson et al, 1996
103 = PSME-ACMA3/POMU Douglas-fir-bigleaf maple/western swordfern	CD0HMA11	513 – Jimerson et al, 1996
104 = PSME-ACMA3/PHLE4 Douglas-fir-bigleaf maple/Lewis' mock orange	CD0HMA12	513 – Jimerson et al, 1996
105 = PSME/ACCI-MARE11 Douglas-fir/vine maple-Cascade barberry	CD0HMA13	513 – Jimerson et al, 1996
106 = PSME-QUKE Douglas-fir-California black oak	CD0HOB00	513 – Jimerson et al, 1996
107 = PSME-QUKE Douglas-fir-California black oak (metamorphic)	CD0HOB11	513 – Jimerson et al, 1996
108 = PSME-QUKE Douglas-fir-California black oak (sandstone)	CD0HOB12	513 – Jimerson et al, 1996
109 = PSME-QUKE-QUGA4/2GRAM Douglas-fir-California black oak-Oregon white oak/grass	CD0HOB13	513 – Jimerson et al, 1996
110 = PSME-QUCH2 Douglas-fir-canyon live oak	CD0HOL00	513 – Jimerson et al, 1996
111 = PSME-QUCH2 Douglas-fir-canyon live oak (rockpile)	CD0HOL11	513 – Jimerson et al, 1996
112 = PSME-QUCH2-ARME/TODI Douglas-fir-canyon live oak-Pacific madrone/pacific poison oak	CD0HOL12	513 – Jimerson et al, 1996
113 = PSME-QUCH2-LIDE3 Douglas-fir-canyon live oak-tanoak	CD0HOL13	513 – Jimerson et al, 1996
114 = PSME-QUGA4 Douglas-fir-Oregon white oak	CD0HOO00	513 – Jimerson et al, 1996
115 = PSME-QUGA4/2GRAM Douglas-fir-Oregon white oak/grass	CD0HOO11	513 – Jimerson et al, 1996
116 = PSME-QUGA4/HODI Douglas-fir-Oregon white oak/oceanspray	CD0HOO12	513 – Jimerson et al, 1996
117 = PSME-LIDE3 Douglas-fir-tanoak	CD0HT000	513 – Jimerson et al, 1996
118 = PSME-LIDE3/WHMO Douglas-fir-tanoak/common whipplea	CD0HT011	513 – Jimerson et al, 1996
119 = PSME-LIDE3/QUVA-HODI Douglas-fir-tanoak/huckleberry oak-oceanspray	CD0HT012	513 – Jimerson et al, 1996
120 = PSME/2SHRUB	CD0SM000	513 – Jimerson et al, 1996

FVS Sequence Number = Plant Association Species Type	**Alpha Code**	**Reference**
Douglas-fir/shrub (moist)		
121 = PSME/COCOC Douglas-fir/California hazelnut	CD0SM011	513 – Jimerson et al, 1996
122 = PSME/QUVA Douglas-fir/huckleberry oak	CD0SOH00	513 – Jimerson et al, 1996
123 = PSME/QUVA/LIDEE Douglas-fir/huckleberry oak-tanoak	CD0SOH12	513 – Jimerson et al, 1996
124 = PSME/QUVA-RHMA3 Douglas-fir/huckleberry oak-Pacific rhododendron	CD0SOH13	513 – Jimerson et al, 1996
125 = PIJE Jeffrey pine	CPJ00000	512 – Jimerson et al, 1995
126 = PIJE-CADE27 Jeffrey Pine – Incense cedar	CPJCCI00	512 – Jimerson et al, 1995
127 = PIJE-CADE27-ABCO/QUVA Jeffrey Pine-Incense cedar-white fir/huckleberry oak	CPJCCI11	512 – Jimerson et al, 1995
128 = PIJE-CADE27/QUVA/XETE Jeffrey Pine-Incense cedar/huckleberry oak/common beargrass	CPJCCI12	512 – Jimerson et al, 1995
129 = PIJE-CADE27/CEPU Jeffrey Pine-incense cedar/dwarf ceanothus	CPJCCI13	512 – Jimerson et al, 1995
130 = PIJE-CADE27/CECU Jeffrey Pine-incense cedar/buckbrush	CPJCCI14	512 – Jimerson et al, 1995
131 = PIJE-ABCO/IRIS Jeffrey Pine-white fir/iris	CPJCFW11	512 – Jimerson et al, 1995
132 = PIJE-ABCO/QUSA2/XETE Jeffrey pine-white fir/deer oak/common beargrass	CPJCFW12	512 – Jimerson et al, 1995
133 = PIJE/FEID Jeffrey pine/Idaho fescue	CPJGFI00	512 – Jimerson et al, 1995
134 = PIJE/FEID Jeffrey pine/Idaho fescue	CPJGFI11	512 – Jimerson et al, 1995
135 = PIJE/QUVA-ARNE/FEID Jeffrey pine/huckleberry oak-pinemat manzanita/Idaho fescue	CPJGFI12	512 – Jimerson et al, 1995
136 = PIJE/QUSA2-ARNE/FEID Jeffrey pine/deer oak-pinemat manzanita/Idaho fescue	CPJSOD11	512 – Jimerson et al, 1995
137 = PICO Lodgepole pine	CPL00000	512 – Jimerson et al, 1995
138 = PICO/QUVA Lodgepole pine/huckleberry oak	CPLSOH00	512 – Jimerson et al, 1995
139 = PICO/QUVA-FRCAO4 Lodgepole pine/huckleberry oak-California buckthorn	CPLSOH11	512 – Jimerson et al, 1995

FVS Sequence Number = Plant Association Species Type	Alpha Code	Reference
140 = PICO/QUVA/LIDE3 Lodgepole pine/huckleberry oak-tanoak	CPLSOH12	512 – Jimerson et al, 1995
141 = PICO/LIDE3 Lodgepole pine/shrub tanoak	CPLST000	512 – Jimerson et al, 1995
142 = PICO/LIDE3-RHMA3 Lodgepole pine/tanoak-Pacific rhododendron	CPLST011	512 – Jimerson et al, 1995
143 = PILA Sugar pine	CPS00000	512 – Jimerson et al, 1995
144 = PILA-PICO Sugar pine-lodgepole pine	CPSCPL00	512 – Jimerson et al, 1995
145 = PILA-PICO/QUVA-LIDEE Sugar pine-lodgepole pine/huckleberry oak-tanoak	CPSCPL11	512 – Jimerson et al, 1995
146 = PILA-PICO/LIDEE-RHMA3 Sugar pine-lodgepole pine/tanoak-Pacific rhododendron	CPSCPL12	512 – Jimerson et al, 1995
147 = PILA-PIMO3 Sugar pine-western white pine	CPSCPW00	512 – Jimerson et al, 1995
148 = PILA-PIMO3/QUVA-GABU2 Sugar pine-western white pine/huckleberry oak-dwarf silktassel	CPSCPW11	512 – Jimerson et al, 1995
149 = PILA-CHCHC4 Sugar pine-giant chinquapin	CPSHGC00	512 – Jimerson et al, 1995
150 = PILA-CHCHC4/Quva-QUSA2 Sugar pine-giant chinquapin/huckleberry oak-deer oak	CPSHGC11	512 – Jimerson et al, 1995
151 = PIMO3 Western white pine	CPW00000	512 – Jimerson et al, 1995
152 = PIMO3-PSME Western white pine-Douglas-fir	CPWCD000	512 – Jimerson et al, 1995
153 = PIMO3-PSME/QUVA-LIDEE Western white pine-Douglas-fir/huckleberry oak-tanoak	CPWCD011	512 – Jimerson et al, 1995
154 = PIMO3/PIMO3 Western white pine/white pine	CPWCFW00	512 – Jimerson et al, 1995
155 = PIMO3-ABCO/QUVA/ANEMO Western white pine-white fir/huckleberry oak/western anemone	CPWCFW11	512 – Jimerson et al, 1995
156 = PIMO3-PICO Western white pine-lodgepole pine	CPWCPL00	512 – Jimerson et al, 1995
157 = PIMO3-PICO/LIDEE-RHMA3 Western white pine-lodglepole pine/tanoak-Pacific rhododendron	CPWCPL11	512 – Jimerson et al, 1995

FVS Sequence Number = Plant Association Species Type	Alpha Code	Reference
158 = PIMO3-PILA Western white pine-sugar pine	CPWCPS00	512 – Jimerson et al, 1995
159 = PIMO3-PILA/QUVA-LIDEE Western white pine-sugar pine/huckleberry oak-tanoak	CPWCPS11	512 – Jimerson et al, 1995
160 = LIDE3 Tanoak	HT000000	513 – Jimerson et al, 1996
161 = LIDE3/CADE27 Tanoak-incense cedar	HT0CCI00	513 – Jimerson et al, 1996
162 = LIDE3-CADE27/FECA Tanoak-incense cedar/California fescue	HT0CCI11	513 – Jimerson et al, 1996
163 = LIDE3-CHLA Tanoak-Port Orford cedar	HT0CCO00	513 – Jimerson et al, 1996
164 = LIDE3-CHLA-UMCA/VAOV2 Tanoak-Port Orford cedar-California laurel/California huckleberry	HT0CCO11	513 – Jimerson et al, 1996
165 = LIDE3-CHLA/VAOV2-RHOC Tanoak-Port Orford cedar/California huckleberry-western azalea	HT0CCO12	513 – Jimerson et al, 1996
166 = LIDE3-CHLA/VAOV2 Tanoak-Port Orford cedar/California huckleberry	HT0CCO13	513 – Jimerson et al, 1996
167 = LIDE3-CHLA/MANE2/LIBOL2 Tanoak-Port Orford cedar/Cascade barberry/longtube twinflower	HT0CCO14	513 – Jimerson et al, 1996
168 = LIDE3-CHLA-ALRH2 Tanoak-Port Orford cedar-white alder (riparian)	HT0CCO15	513 – Jimerson et al, 1996
169 = LIDE3-CHLA/ACCI Tanoak-Port Orford cedar/vine maple	HT0CCO16	513 – Jimerson et al, 1996
170 = LIDE3-CHLA/VAPA Tanoak-Port Orford cedar/red huckleberry	HT0CCO17	513 – Jimerson et al, 1996
171 = LIDE3-CHLA/GASH Tanoak-Port Orford cedar/salal	HT0CCO18	513 – Jimerson et al, 1996
172 = LIDE3-CHLA-TSHE/VAOV2 Tanoak-Port Orford cedar-western hemlock/California huckleberry	HT0CCO19	513 – Jimerson et al, 1996
173 = LIDE3-UMCA Tanoak-California laurel	HT0HBC00	513 – Jimerson et al, 1996
174 = LIDE3-UMCA/TODI Tanoak-California laurel/Pacific poison oak	HT0HBC11	513 – Jimerson et al, 1996
175 = LIDE3-UMCA/VAOV2 Tanoak-California laurel/California huckleberry	HT0HBC12	513 – Jimerson et al, 1996

FVS Sequence Number = Plant Association Species Type	**Alpha Code**	**Reference**
176 = LIDE3-CHCHC4 Tanoak-giant chinquapin	HT0HGC00	513 – Jimerson et al, 1996
177 = LIDE3-CHCHC4/GASH Tanoak-giant chinquapin/salal	HT0HGC11	513 – Jimerson et al, 1996
178 = LIDE3-CHCHC4/GASH-RHMA3 Tanoak-giant chinquapin/salal-Pacific rhododendron	HT0HGC12	513 – Jimerson et al, 1996
179 = LIDE3-CHCHC4/RHMA3/XETE Tanoak-giant chinquapin/Pacific rhododendron/common beargrass	HT0HGC13	513 – Jimerson et al, 1996
180 = LIDE3-CHCHC4/PTAQL Tanoak-giant chinquapin/western brackenfern	HT0HGC14	513 – Jimerson et al, 1996
181 = LIDE3-CHCHC4/MANE2 Tanoak-giant chinquapin/Cascade barberry	HT0HGC15	513 – Jimerson et al, 1996
182 = LIDE3CHCHC4/VAOV2-GASH Tanoak-giant chinquapin/California huckleberry-salal	HT0HGC16	513 – Jimerson et al, 1996
183 = LIDE3/ACER Tanoak-maple	HT0HM000	513 – Jimerson et al, 1996
184 = LIDE3-ACMA3/POMU Tanoak-bigleaf maple/swordfern	HT0HM011	513 – Jimerson et al, 1996
185 = LIDE3/ACCI-GASH Tanoak/vine maple-salal	HT0HM012	513 – Jimerson et al, 1996
186 = LIDE3/ACCI Tanoak/vine maple	HT0HM013	513 – Jimerson et al, 1996
187 = LIDE3/QUKE Tanoak-California black oak	HT0HOB00	513 – Jimerson et al, 1996
188 = LIDE3/QUKE Tanoak-California black oak	HT0HOB11	513 – Jimerson et al, 1996
189 = LIDE3-QUCH2 Tanoak-canyon live oak	HT0HOL00	513 – Jimerson et al, 1996
190 = LIDE3-QUCH2 Tanoak-canyon live oak (rockpile)	HT0HOL11	513 – Jimerson et al, 1996
191 = LIDE3-QUCH2/VAOV2 Tanoak-canyon live oak/California huckleberry	HT0HOL12	513 – Jimerson et al, 1996
192 = LIDE3-QUCH2/GASH-MANE2 Tanoak-canyon live oak/salal-Cascade barberry	HT0HOL13	513 – Jimerson et al, 1996
193 = LIDE-QUCH2-QUKE/TODI Tanoak-canyon live oak-California black oak/Pacific poison oak	HT0HOL14	513 – Jimerson et al, 1996
194 = LIDE3-QUCH2/TODI Tanoak-canyon live oak/Pacific poison oak	HT0HOL15	513 – Jimerson et al, 1996
195 = LIDE3-QUCH2/MANE2	HT0HOL16	513 – Jimerson et al, 1996

FVS Sequence Number = Plant Association Species Type	Alpha Code	Reference
Tanoak-canyon live oak/Cascade barberry		
196 = LIDE3/2SHRUB Tanoak/shrub (dry)	HT0SD000	513 – Jimerson et al, 1996
197 = LIDE3/TODI/LOHIV Tanoak/Pacific poison oak/pink honeysuckle	HT0SD011	513 – Jimerson et al, 1996
198 = LIDE3/MANE2 Tanoak/Cascade barberry	HT0SD012	513 – Jimerson et al, 1996
199 = LIDE3/VAOV2-GASH Tanoak/California huckleberry-salal	HT0SEH12	513 – Jimerson et al, 1996
200 = LIDE3/VAOV2-RHMA3 Tanoak/California huckleberry-Pacific rhododendron	HT0SEH13	513 – Jimerson et al, 1996
201 = LIDE3/2SHRUB Tanoak/shrub (moist)	HT0SM000	513 – Jimerson et al, 1996
202 = LIDE2/COCOC Tanoak/California hazelnut	HT0SM011	513 – Jimerson et al, 1996
203 = LIDE3/QUVA Tanoak/huckleberry oak	HT0SOH00	513 – Jimerson et al, 1996
204 = LIDE3/QUVA-RHMA3 Tanoak/huckleberry oak-Pacific rhododendron	HT0SOH11	513 – Jimerson et al, 1996
205 = LIDE3/GASH-RHMA3 Tanoak/salal-Pacific rhododendron	HT0SSG12	513 – Jimerson et al, 1996
206 = LIDE3/GASH-MANE2 Tanoak/salal-Cascade barberry	HT0SSG13	513 – Jimerson et al, 1996
207 = LIDE3/VAOV2 Tanoak/California huckleberry	HT0SEH00	513 – Jimerson et al, 1996
208 = LIDE3/VAOV2 Tanoak/California huckleberry	HT0SEH11	513 – Jimerson et al, 1996
209 = LIDE3/GASH Tanoak/salal	HT0SSG00	513 – Jimerson et al, 1996
210 = LIDE3/GASH Tanoak/salal	HT0SSG11	513 – Jimerson et al, 1996
211 = CADE27-PIPO-PSME/CHFO Incense cedar-ponderosa pine-Douglas-fir/mountain misery	CC0311	502 – Benson (1988)
212 = PIJE-ABCO/POA Jeffrey pine-white fir/bluegrass (granite)	CPJGBW11	502 – Benson (1988)
213 = PIPO-PIJE-ABCO/ACOCO Ponderosa pine-Jeffrey pine-white fir/western needlegrass (ash)	CPJGNG11	502 – Benson (1988)
214 = PIPO-PIJE-QUKE/AMPA2 Ponderosa pine-Jeffrey pine-California black oak/pale	CPJSAM11	502 – Benson (1988)

FVS Sequence Number = Plant Association Species Type	Alpha Code	Reference
serviceberry		
215 = PIPO-PIJE-ABCO/AMPA2-MARE11 Ponderosa pine-Jeffrey pine-white fir/pale serviceberry-creeping barberry	CPJSAM12	502 – Benson (1988)
216 = PIJE-QUKE/RHTRQ Jeffrey pine-California black oak/skunkbush sumac	CPJSBB11	502 – Benson (1988)
217 = PIJE/PUTR2-CELE3/ACOCO Jeffrey pine/antelope bitterbrush-curl-leaf mountain mahogany/western needlegrass	CPJSBB12	502 – Benson (1988)
218 = PIJE/PUTR2-SYORU/POA Jeffrey pine/antelope bitterbrush-Utah snowberry/bluegrass	CPJSBB13	502 – Benson (1988)
219 = PIJE/PUTR2/WYMO Jeffrey pine/antelope bitterbrush/woolly mule-ears	CPJSBB14	502 – Benson (1988)
220 = PIPO-PIJE-PSME/PUTR2/WYMO Ponderosa pine-Jeffrey pine-Douglas-fir/antelope bitterbrush/woolly mule-ears	CPJSBB15	502 – Benson (1988)
221 = PIPO-PIJE-QUKE/POA Ponderosa pine-Jeffrey pine-California black oak/bluegrass (granite)	CPJSBB16	502 – Benson (1988)
222 = PIPO-PIJE/ARTRV-PUTR2 Ponderosa pine-Jeffrey pine/mountain big sagebrush-antelope bitterbrush	CPJSBB17	502 – Benson (1988)
223 = PIPO-PIJE/PUTR2/FEID Ponderosa pine-Jeffrey pine/antelope bitterbrush/Idaho fescue	CPJSBB18	502 – Benson (1988)
224 = PIPO-PIJE/PUTR2/FEID Ponderosa pine-Jeffrey pine/antelope bitterbrush/Idaho fescue (granite)	CPJSBB19	502 – Benson (1988)
225 = PIPO-PIJE/PUTR2/SEINM Ponderosa pine-Jeffrey pine/antelope bitterbrush/lambstongue ragwort (granite)	CPJSBB20	502 – Benson (1988)
226 = PIPO-PIJE/FRRUM/POSE Ponderosa pine-Jeffrey pine/Modoc buckthorn/Sandberg bluegrass	CPJSBB21	502 – Benson (1988)
227 = PIPO-PIJE-ABCO/QUW12 Ponderosa pine-Jeffrey pine-white fir/interior live oak	CPJSBB23	502 – Benson (1988)
228 = PIJE/CELE3 Jeffrey pine/curl-leaf mountain mahogany	CPJSMC11	502 – Benson (1988)
229 = PIPO-PIJE/CELE3/PSSPS Ponderosa pine-Jeffrey pine/curl-leaf mountain	CPJSMC12	502 – Benson (1988)

FVS Sequence Number = Plant Association Species Type	**Alpha Code**	**Reference**
mahogany/ bluebunch balsamroot		
230 = PIPO-PIJE/CELE3/BASA3 Ponderosa pine-Jeffrey pine/curl-leaf mountain mahogany/ arrowleaf balsamroot	CPJSMC13	502 – Benson (1988)
231 = PIPO-PIJE-ABCO/QUVA/WYMO Ponderosa pine-Jeffrey pine-white fir/huckleberry oak/woolly mule-ears	CPJSOH11	502 – Benson (1988)
232 = PIJE/ARTRV/FEID Jeffrey pine/mountain big sagebrush/Idaho fescue	CPJSSB11	502 – Benson (1988)
233 = PIPO-PIJE-ABCO/SYAC/WYMO Ponderosa pine-Jeffrey pine-white fir/sharpleaf snowberry/ woolly mule-ears	CPJSSS12	502 – Benson (1988)
234 = PIJE-ABCO/SYORU/PONE2 Jeffrey pine-white fur/Utah snowberry/Wheeler bluegrass	CPJSSY11	502 – Benson (1988)
235 = PIWA/ARNE Washoe pine/pinemat manzanita	CPOSMP11	502 – Benson (1988)
236 = PIWA-ABCO/SYORU/PSJA2 Washoe pine-white fir/Utah snowberry/tuber starwort	CPOSSY11	502 – Benson (1988)
237 = PIPO/AMPA2-MARE11/ARCO9 Ponderosa pine/pale serviceberry-creeping barberry/ heartleaf arnica	CPPSAM11	502 – Benson (1988)
238 = PIPO/AMPA2-PRUNU Ponderosa pine/pale serviceberry-prunus	CPPSAM12	502 – Benson (1988)
239 = PIPO-ABCO-PICO/AMPA2 Ponderosa pine-white fir-lodgepole pine/pale serviceberry	CPPSAM13	502 – Benson (1988)
240 = PIPO-ABCO-QUVA/AMPA2 Ponderosa pine-white fir-black oak/pale serviceberry	CPPSAM14	502 – Benson (1988)
241 = PIPO-ABCO/AMPA2-MARE11 Ponderosa pine-white fir/pale serviceberry-creeping barberry	CPPSAM15	502 – Benson (1988)
242 = PIPO-ABCO/AMPA2-CEVE/BROR2 Ponderosa pine-white fir/pale serviceberry-snowbrush ceonothus/Orcutt’s brome	CPPSAM16	502 – Benson (1988)
243 = PIPO-CADE27/PUTR2/BASA3 Ponderosa pine-incense cedar/antelope bitterbrush/ arrowleaf balsamroot	CPPSBB11	502 – Benson (1988)
244 = PIPO-QUKE/PUTR2/ACOCO Ponderosa pine-California black oak/antelope bitterbrush/ western needlegrass	CPPSBB12	502 – Benson (1988)

FVS Sequence Number = Plant Association Species Type	Alpha Code	Reference
245 = PIPO/CELE3-PUTR2/FEID Ponderosa pine/curl-leaf mountain mahogany-antelope bitterbrush/Idaho fescue	CPPSBB13	502 – Benson (1988)
246 = PIPO/PURT2-CEVE-ARPA6/BROR2 Ponderosa pine/antelope bitterbrush-snowbrush ceanothus-greenleaf manzanita/Orcutt's brome	CPPSBB14	502 – Benson (1988)
247 = PIPO/PURT2-PRUNU/BROR2 Ponderosa pine/antelope bitterbrush-prunus/Orcutt's brome	CPPSBB15	502 – Benson (1988)
248 = PIPO/PUTR2-PRUNU/PSSPS Ponderosa pine/antelope bitterbrush-prunus/bluebunch wheatgrass	CPPSBB16	502 – Benson (1988)
249 = PIPO/PUTR2-RICE/BROR2 Ponderosa pine/antelope bitterbrush-wax current/Orcutt's brome	CPPSBB17	502 – Benson (1988)
250 = PIPO/PUTR2/BASA3 Ponderosa pine/antelope bitterbrush/arrowleaf balsamroot	CPPSBB18	502 – Benson (1988)
251 = PIPO/PUTR2/FEID Ponderosa pine/antelope bitterbrush/Idaho fescue	CPPSBB19	502 – Benson (1988)
252 = PIPO/PUTR2/ACOCO Ponderosa pine/antelope bitterbrush/western needlegrass (pumice)	CPPSBB20	502 – Benson (1988)
253 = PIPO-ABCO/CEVE/ACOCO Ponderosa pine-white fir/snowbrush ceonothus/western needlegrass	CPPSBB21	502 – Benson (1988)
254 = PIPO-ABCO/PUTR2-ARPA6/ACOCO Ponderosa pine-white fir/antelope bitterbrush-greenleaf manzanita/western needlegrass	CPPSBB22	502 – Benson (1988)
255 = PIPO/ARTRV/FEID Ponderosa pine/mountain big sagebrush/Idaho fescue	CPPSSB11	502 – Benson (1988)
256 = PSME-PIPO/TODI Douglas-fir-ponderosa pine/Pacific poison oak	DC0811	502 – Benson (1988)
257 = PSME-PIPO/CHFO/POCOC Douglas-fir-ponderosa pine/mountain misery/Sierra milk wort	DC0812	502 – Benson (1988)
258 = PSME-PINUS-QUCH2/CEIN3 Douglas-fir-pine-canyon live oak/deerbrush	DC0813	502 – Benson (1988)
259 = PSME-ABCO-LIDE3/PTAQL Douglas-fir-white fir-tanoak/western brackenfern	DC0911	502 – Benson (1988)
260 = PSME-CONU2-LIDE3/COCOC/GAAP2	DH0711	502 – Benson (1988)

FVS Sequence Number = Plant Association Species Type	**Alpha Code**	**Reference**
Douglas-fir-mountain dogwood-tanoak/California hazelnut/ stickywilly		
261 = PIPO-ABCO/CEVE3-CEPR Ponderosa pine-white fir/tobaccobrush-squawcarpet	PC0611	502 – Benson (1988)
262 = PILE-PIMO3/QUVA-ARNE2 Sugar pine-western white pine/huckleberry oak-pinemat manzanita	QS0111	502 – Benson (1988)
263 = ABCO-PSME-LIDE3/COCOC White fir-Douglas-fir-tanoak/California hazelnut	WC0911	502 – Benson (1988)
264 = ABCO-PSME/????/???? White fir-Douglas-fir-mountain dogwood/bush chinquapin	WC0912	502 – Benson (1988)
265 = ABCO-PSME/SYACC-????/???? White fir-Douglas-fir/sharpleaf snowberry/thimbleberry	WC0913	502 – Benson (1988)
266 = ABCO-PILA/SYAC/CARO5 White-fir-sugar pine/sharpleaf snowberry/Ross' sedge	WC0914	502 – Benson (1988)
267 = ABCO-PSME/CHME2 White fir-Douglas-fir/prince's pine	WC0915	502 – Benson (1988)
268 = ABCO-PSME-CADE27/AMPA2 White fir-Douglas-fir-incense cedar/pallid serviceberry	WC0916	502 – Benson (1988)
269 = ABCO-PSME-PIJE/???? White fir-Douglas-fir-Jeffrey pine/rosy everlasting	WC0917	502 – Benson (1988)
270 = PSME-PINUS-CADE27/ASDE6 Douglas-fir-pine-incense cedar/Indian dream	CC0411	
271 = PSME-PILA/LIDEE/PTAQL Douglas-fir-sugar pine/tanoak/western brackenfern	DC1011	
272 = PSME-PILA/LIDEE/TRIEN Douglas-fir-sugar pine/tanoak/broadleaf starflower	DC1012	
273 = PSME-PIPO/FRCAO4/PTAQL Douglas-fir-ponderosa pine/California buckthorn/western brackenfern	DC1013	
274 = PSME-PIPO/CEIN3/COHE2 Douglas-fir-ponderosa pine/deerbrush/variableleaf collomia	DC1014	
275 = PSME-PIPO/FECA Douglas-fir-ponderosa pine/California fescue	DC1015	
276 = PSME-PIPO/QUVA/POMU Douglas-fir-ponderosa pine/huckleberry oak/western swordfern	DC1016	
277 = PSME-PINUS-CADE27/TRBR3	DC1017	

FVS Sequence Number = Plant Association Species Type	Alpha Code	Reference
Douglas-fir-pine-incense cedar/forest clover		
278 = PSME-PINUS-CADE27/CECU/TRBR3-FECA Douglas-fir-pine-incense cedar/buckbrush/forest clover-California fescue	DC1018	
279 = PSME-PINUS-CADE27/XETE Douglas-fir-pine-incense cedar/common beargrass	DC1019	
280 = PSME/COCOC/POMU Douglas-fir/California hazelnut/western swordfern	DS0911	
281 = PIJE-CADE27/CECU/HECAS2 Jeffrey pine-incense cedar/buckbrush/Shasta heliathella	PG0611	
282 = PIJE-CADE27/MAAQ2/FEID Jeffrey pine-incense cedar/hollyleaved barberry/Idaho fescue	PG0612	
283 = PIJE/CELE3/PSSPS Jeffrey pine/curl-leaf mountain mahogany/bluebench wheatgrass	PG0613	
284 = PIJE/ERPAA2/PHDI3 Jeffrey pine/Parry's rabbitbrush/spreading phlox	PG0614	
285 = PIJE-CADE27/QUVA/ASDE6 Jeffrey pine-incense cedar/huckleberry oak/Indian's dream	PS0911	
286 = ABCO-PSME-PILA/CONU4 White fir-Douglas-fir-sugar pine/Pacific dogwood	WC1011	
287 = PSME-ABCO/RHOC Douglas-fir-white fir/western azalea	WC1012	
288 = PSME-ABCO-PIPO/ARNE/CHUMO2 Douglas-fir-white fir-ponderosa pine/pinemat manzanita/ pipsisseqa	WC1013	
289 = 2TE Mixed conifer series	CX000000	
290 = Mixed conifer dry group	CX0D0000	
291 = Ponderosa pine-mixed conifer/Bolander's bedstraw-milkwort	CX0FBB11	
292 = White fir-mixed conifer/false Solomon's seal-Hooker's fairybells	CX0FFS11	
293 = Ponderosa pine-mixed conifer/rosy everlasting-naked	CX0FRE11	

FVS Sequence Number = Plant Association Species Type	**Alpha Code**	**Reference**
stemmed		
294 = White fir-mixed conifer/troul plant	CX0FTP11	
295 = Douglas-fir-mixed conifer/starflower	CX0FWS11	
296 = White fir-mixed conifer/Ross' sedge	CX0GCR11	
297 = Douglas-fir-mixed conifer-white alder/Indian rhubarb	CX0HAW11	
298 = Mountain dogwood group	CX0HDP00	
299 = Douglas-fir-mixed conifer-mountain dogwood/California hazel buckwheat	CX0HDP13	
300 = Douglas-fir-mixed conifer-mountain dogwood/trail plant	CX0HDP14	
301 = Douglas-fir-mixed conifer-bigleaf maple/trail plant	CX0HMB12	
302 = QUCH2 Canyon live oak	CX0H0L00	
303 = Ponderosa pine-mixed conifer-canyon live oak/bearclover	CX0H0L15	
304 = Ponderosa pine-mixed conifer/Bolander's bedstraw	CX0H0L16	
305 = Douglas-fir-mixed conifer-canyon live oak/sword fern	CX0H0L17	
306 = LIDE3 Tanoak	CX0HT000	
307 = PSME-2TE-LIDE3/CONU4 Douglas-fir-mixed conifer-tanoak/Pacific dogwood	CX0HT012	
308 = PSME-2TE-LIDE3/CHFO Douglas-fir-mixed conifer-tanoak/mountain misery	CX0HT013	
309 = PSME-2TE-LIDE3/COCOC Douglas-fir-mixed conifer-tanoak/California hazelnut	CX0HT011	
310 = PSME-2TE-LIDE3/IRIS Douglas-fir-mixed conifer-tanoak/iris	CX0HT014	
311 = Mixed conifer moderate group	CX0M0000	
312 =	CX0R0000	

FVS Sequence Number = Plant Association Species Type	**Alpha Code**	**Reference**
Mixed conifer riparian group		
313 = Douglas-fir-mixed conifer/serviceberry	CX0SAM12	
314 = Evergreen shrub group	CX0SE000	
315 = White fir-mixed conifer/vine maple-bush chinquapin	CX0SE011	
316 = White fir-mixed conifer/bush chinquapin	CX0SE012	
317 = Ponderosa pine-mixed conifer/shrub canyon live oak, huckleberry oak	CX0SE013	
318 = Ponderosa pine-mixed conifer/huckleberry oak (serpentine)	CX0SE014	
319 = Douglas-fir-mixed conifer/California hazelnut	CX0SHN12	
320 = Douglas-fir-mixed conifer/Sierra laurel	CX0SLS11	
321 = White fir-mixed conifer/mountain alder/sedge	CX0SMA11	
322 = White fir-mixed conifer/mountain alder/monkshood	CX0SMA12	
323 = Bearclover group	CX0SMM00	
324 = Ponderosa pine-mixed conifer/manzanita bearclover	CX0SMM11	
325 = Ponderosa pine-mixed conifer/bearclover/Bolander's bedstraw	CX0SMM12	
326 = White fir-mixed conifer/creeping snowberry/kelloggia	CX0SSS13	
327 = Mixed conifer moist group	CX0W0000	
328 = Douglas-fir-mixed conifer/American dogwood	CX0SDA11	
329 = ABMAS/RHMA Red fir/Pacific rhododendron	RS0511	
330 = ABCO-PILA-ABMAS/PTAQL White fir-sugar pine-red fir/bracken	WC0413	
331 = JUOC/WYMO	JC0111	

FVS Sequence Number = Plant Association **Species Type**	**Alpha Code**	**Reference**
Western juniper/woolly mule-ears		
332 = JUOC Western juniper	JC0112	
333 = TSME Mountain hemlock (steep)	MC0211	
334 = PIJE/QUVA Jeffrey pine/huckleberry oak	PS0811	
335 = PIJE/ARPA6-CEVE Jeffrey pine/greenleaf manzanita-snowbrush ceonothus	PS0812	
336 = PIJE/CECO-ARTR2 Jeffrey pine/whitethorn ceanothus-big sagebrush	PS0813	
337 = POTR5 Quaking aspen (flats)	QC0211	
338 = POTR5 Quaking aspen (uplands)	QC0212	
339 = ABMA California red fir	RC0011	
340 = ABMA/ABCO California red fir/white fir	RC0331	
341 = ABMA-TSME California red fir-mountain hemlock	RC0421	
342 = PIMO3/ARNE Western white pine/pinemat manzanita	RC0511	
343 = PIMO3-PICO Western white pine-lodgepole pine	RC0512	
344 = PIMO3 Western white pine	RC0513	
345 = PICO/HIAL2 Lodgepole pine/white hawkweed	RC0611	
346 = PICO/LIGR Lodgepole pine/Gray's licorice-root	RC0612	
347 = PICO Lodgepole pine	RC0613	
348 = ABMA/ASBO2 California red fir/Bolander's locoweed	RF0411	
349 = ABMA/WYMO California red fir/wooly mule-ears	RF0412	
350 = ABMA/ARNE California red fir/pinemat manzanita	RS0114	
351 = ABCO-PIJE	WC0711	

FVS Sequence Number = Plant Association Species Type	Alpha Code	Reference
White fir-Jeffrey pine		
352 = ABCO-ABMA White fir-California red fir (mixed conifer)	WC0712	
353 = PSME/QUVA Douglas-fir/huckleberry oak	CD0SOH11	507-513 – Jimerson et al, 1996
354 = SESE3 Redwood	CN00000	507-514 – Borchert, Segotta, & Purser
355 = SESE3 Redwood (Gamboa-Sur)	CN00011	507-514 – Borchert, Segotta, & Purser
356 = SESE3/PTAQ-WOFI Redwood/western brackenfern-giant chainfern (steamsides)	CNF0111	507-514 – Borchert, Segotta, & Purser
357 = SESE3/POMU-TROV2 Redwood/western swordfern-Pacific trillium (Gamboa-Sur)	CNF0211	507-514 – Borchert, Segotta, & Purser
358 = SESE3/MAFA3-VISAN2 Redwood/California manroot-garden vetch (Gamboa-Sur)	CNF0311	507-514 – Borchert, Segotta, & Purser
359 = SESE3-ACMA3/POCA12 Redwood-bigleaf maple/California polypody (Gamboa)	CNHB011	507-514 – Borchert, Segotta, & Purser
360 = SESE3-LIDE3/CAGL7-IRDO Redwood-tanoak/roundfruit sedge-Douglas iris (Gamboa)	CNHT011	507-504 – Smith
361 = PIPO-ABCO/SYAC Ponderosa pine-white fir/sharpleaf snowberry	CPPSSS11	507-515 – Borchert, Cunha, Krosse, & Lawrence
362 = QUDO Blue oak	HOD00000	507-515 – Borchert, Cunha, Krosse, & Lawrence
363 = QUDO/2GRAM Blue oak/annual grass	HODGA000	507-515 – Borchert, Cunha, Krosse, & Lawrence
364 = QUDO/HOMUL-VIPE3 Blue oak/leporinum barley-Johnny-jump-up	HODGA011	507-515 – Borchert, Cunha, Krosse, & Lawrence
365 = QUDO/LOWR2-NAPU4 Blue oak/Chilean bird's foot trefoil-purple tussockgrass	HODGA012	507-515 – Borchert, Cunha, Krosse, & Lawrence
366 = QUDO/EUSP-PETR7 Blue oak/warty spurge-goldback fern	HODGA013	507-515 – Borchert, Cunha, Krosse, & Lawrence
367 = QUDO/GAAN-LUCO Blue oak/phloxleaf bedstraw-scarlet lupine	HODGA014	507-515 – Borchert, Cunha, Krosse, & Lawrence
368 = QUDO/ERMO7-HOMUL Blue oak/musky stork's bill-leporinum barley	HODGA015	507-515 – Borchert, Cunha, Krosse, & Lawrence
369 = QUDO/DEPA2-PHIM Blue oak/San Bernardino larkspur-imbricate phacelia	HODGA016	507-515 – Borchert, Cunha, Krosse, & Lawrence

FVS Sequence Number = Plant Association Species Type	Alpha Code	Reference
370 = QUDO/LUCO-MEAL12 Blue oak/scarlet lupine-foothill clover	HODGA017	507-515 – Borchert, Cunha, Krosse, & Lawrence
371 = QUDO/AMME12-PLNO Blue oak/common fiddleneck-rusty popcornflower	HODGA018	507-515 – Borchert, Cunha, Krosse, & Lawrence
372 = QUDO/EREL6/LOWR2-PLER3 Blue oak/longstem buckwheat/Chilean bird's-foot trefoil-dotseed plantain	HODGA019	507-515 – Borchert, Cunha, Krosse, & Lawrence
373 = QUDO/COSP-RILE2 Blue oak/spinster's blue eyed Mary-wireweed	HODGA020	507-515 – Borchert, Cunha, Krosse, & Lawrence
374 = QUDO/CEMOG/BOIN3-LIAF Blue oak/birchleaf mountain mahogany/hoary bowlesia-San Francisco woodland-star	HODGA021	507-515 – Borchert, Cunha, Krosse, & Lawrence
375 = QUDO/RICA/BRDI3 Blue oak/hillside gooseberry/ripgut brome	HODGA022	507-515 – Borchert, Cunha, Krosse, & Lawrence
376 = QUDO-QUWI2/2GRAM Blue oak-interior live oak/grass	HODHOI00	507-515 – Borchert, Cunha, Krosse, & Lawrence
377 = QUDO-QUWI2/LICY3 Blue oak-interior live oak/mission woodland-star	HODHOI11	507-515 – Borchert, Cunha, Krosse, & Lawrence
378 = ADFA Chamise	SA000000	511 – Gordon & White, 1994
379 = ADFA/ERFA2-SAAP2 Chamise/Eastern Mojave buckwheat-white sage	SA0SB000	511 – Gordon & White, 1994
380 = ADFA/SAME3 Chamise/black sage	SA0SBS00	511 – Gordon & White, 1994
381 = ADFA-CEGRP Chamise-desert ceanothus	SA0SCC00	511 – Gordon & White, 1994
382 = ADFA-CECR Chamise-hoaryleam ceanothus	SA0SCH00	511 – Gordon & White, 1994
383 = ADFA-CETO-CYBI Chamise-woolyleaf ceanothus-mission manzanita	SA0SCT00	511 – Gordon & White, 1994
384 = ADFA-CECU Chamise-buckbrush	SA0SCW00	511 – Gordon & White, 1994
385 = ADFA-ARGL4 Chamise-bigberry manzanita	SA0SMB00	511 – Gordon & White, 1994
386 = ADFA-ARGL3 Chamise-Eastwood's manzanita	SA0SME00	511 – Gordon & White, 1994
387 = ERFA2-SAAP2 Eastern Majove buckwheat-white sage	SB0SSW00	511 – Gordon & White, 1994
388 = CEMOG Birchleaf mountain mahogany	SBM00000	511 – Gordon & White, 1994
389 = CECR	SCH00000	511 – Gordon & White, 1994

FVS Sequence Number = Plant Association Species Type	**Alpha Code**	**Reference**
Hoaryleaf ceanothus		
390 = ARGL4 Bigberry manzanita	SMB00000	511 – Gordon & White, 1994
391 = ARGL3 Eastwood's manzanita	SME00000	511 – Gordon & White, 1994
392 = QUCH2 Canyon live oak	SOC00000	511 – Gordon & White, 1994
393 = QUW12 Interior live oak	SOI00000	511 – Gordon & White, 1994
394 = QUW12-CELE2 Interior live oak-chaparral whitethorn	SOISCL00	511 – Gordon & White, 1994
395 = QUW12-QUCH2 Interior live oak-canyon live oak	SOISOC00	511 – Gordon & White, 1994
396 = QUW12-QUBE5 Interior live oak-scrub oak	SOISOS00	511 – Gordon & White, 1994
397 = QUBE5 Scrub oak	SOS00000	511 – Gordon & White, 1994
398 = QUBE5-ADFA Scrub oak-chamise	SOSSA000	511 – Gordon & White, 1994
399 = QUBE5-CEMOG Scrub oak-birchleaf mountain mahogany	SOSSBM00	511 – Gordon & White, 1994
400 = QUBE5-CEOL-HEAR5 Scrub oak-hairy ceanothus-toyon	SOSSCH00	511 – Gordon & White, 1994
401 = QUBE5-CELE2 Scrub oak-chaparral whitethorn	SOSSCL00	511 – Gordon & White, 1994
402 = ADSP Redshank	SR000000	511 – Gordon & White, 1994
403 = ADSP-ADFA Redshank-chamise	SR0SA000	511 – Gordon & White, 1994
404 = ARCA11 Coastal sagebrush	SSC00000	511 – Gordon & White, 1994
405 = ARCA11-ERFA2 Coastal sagebrush-Eastern Majave buchwheat	SSCSB000	511 – Gordon & White, 1994
406 = ARCA11-SAME3 Coastal sagebrush-black sage	SSCSSB00	511 – Gordon & White, 1994

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