



Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Alaska (AK) Variant Overview of the Forest Vegetation Simulator

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Denali National Park, AK
(Chad Keyser, FS)

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Authors and Contributors:

In 2021, the Alaska variant was released to model forested conditions throughout all of Alaska. Mark Castle led the development work. Along the way, Mark was joined by Mike Shettles, Aaron Gagnon, Lance David, and Chad Keyser who helped fit and embed new relationships in this new variant. The Alaska variant replaces the Southeast Alaska and Coastal British Columbia (SEAPROG) variant.

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Table of Contents

Authors and Contributors:	ii
1.0 Introduction	1
2.0 Geographic Range	2
3.0 Control Variables	5
3.1 Location Codes	5
3.2 Species Codes	6
3.3 Habitat Type, Plant Association, and Ecological Unit Codes	7
3.4 Site Index	7
3.5 Maximum Density	9
4.0 Growth Relationships	11
4.1 Height-Diameter Relationships	11
4.2 Bark Ratio Relationships	12
4.3 Crown Ratio Relationships	13
4.3.1 Crown Ratio Dubbing	13
4.3.2 Crown Ratio Change	14
4.3.3 Crown Ratio for Newly Established Trees	14
4.4 Crown Width Relationships	15
4.5 Crown Competition Factor	17
4.6 Small Tree Growth Relationships	18
4.6.1 Small Tree Height Growth	18
4.6.2 Small Tree Diameter Growth	20
4.7 Large Tree Growth Relationships	20
4.7.1 Large Tree Diameter Growth	21
4.7.2 Large Tree Height Growth	23
5.0 Mortality Model	27
6.0 Regeneration	29
7.0 Volume	33
8.0 Fire and Fuels Extension (FFE-FVS)	35
9.0 Insect and Disease Extensions	36
10.0 Literature Cited	37
11.0 Appendices	40

Quick Guide to Default Settings

Parameter or Attribute	Default Setting	
Number of Projection Cycles	1 (10 if using FVS GUI)	
Projection Cycle Length	10 years	
Location Code (National Forest)	1005 – Tongass National Forest	
Slope	5 percent	
Aspect	0 (no meaningful aspect)	
Elevation	Based on location code	
Latitude / Longitude	Based on location code	
Site Species	WH	
Site Index	70 feet (breast height age; 100 years)	
Maximum Stand Density Index	Species specific	
Maximum Basal Area	Based on maximum stand density index	
Volume Equations	National Volume Estimator Library	
	Merchantable Cubic Foot (Minimum DBH / Top Diameter)	Merchantable Board Foot (Minimum DBH / Top Diameter)
Location Code		
713	6.0 / 4.0 inches	9.0 / 6.0 inches
703, 1002, 1003, 1005, 8134, 8135, 8112	9.0 / 7.0 inches	9.0 / 7.0 inches
1004	9.0 / 6.0 inches	9.0 / 6.0 inches
720, 7400, 7401, 7402, 7403, 7404, 7405, 7406, 7407, 7408	5.0 / 4.0 inches	9.0 / 6.0 inches
Stump Height	1.0 foot	1.0 foot
Sampling Design:		
Basal Area Factor	62.5 BAF	
Small-Tree Fixed Area Plot	1/300 th 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 geographic area in the FVS framework. Geographic variants of FVS have been developed for most of the forested lands in the United States.

From 2018 to 2021, new relationships were developed for twenty-three species commonly found in the coastal and northern boreal forest types of Alaska. As such, this variant should be used for all forested areas in Alaska, thus replacing the Southeast Alaska (SEAPROG) variant, which is no longer available.

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

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

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

2.0 Geographic Range

The AK variant was fit to data representing coastal and boreal forest types of Alaska. Data used in model development came from University of Alaska at Fairbanks Growth and Yield Cooperative (46%), USDA Forest Service, Forest Inventory and Analysis (41%), Tanana Chief's Conference (1%), US Department of Defense (8%), and Alaska State Department of Natural Resources (4%). A data summary is shown in table 2.0.1.

Table 2.0.1 Data summary for trees used in the development of the AK variant.

Species	Number of observations	DBH (mean, st.dev) [min, max]	Total tree height (mean, stdev) [min, max]
Pacific silver fir	12	(8.1, 3.6) [5, 15.6]	(40, 17) [16, 62]
subalpine fir	49	(10.2, 5) [4.1, 23.9]	(48, 20) [14, 102]
Alaska yellow cedar	13980	(9.2, 5.9) [1, 55.7]	(38, 21) [5, 139]
tamarack	142	(2.1, 1.4) [0.5, 7.9]	(16, 8) [7, 47]
white spruce	76904	(5.1, 3.8) [0.3, 41.3]	(34, 20) [5, 123]
black spruce	53147	(2.5, 1.9) [0.5, 21.1]	(18, 11) [5, 77]
Sitka spruce	18968	(11.4, 8.1) [1, 74]	(53, 31) [5, 238]
lodgepole pine	3411	(8.1, 4) [1, 26.6]	(30, 16) [5, 98]
western red cedar	5556	(11.6, 8.1) [1, 72]	(44, 23) [5, 151]
western hemlock	37772	(9.8, 6.8) [1, 58.7]	(48, 28) [5, 214]
mountain hemlock	23377	(9, 5.1) [1, 46.9]	(35, 18) [5, 150]
red alder	707	(7.3, 3.5) [1, 25.7]	(44, 16) [7, 120]

Species	Number of observations	DBH (mean, st.dev) [min, max]	Total tree height (mean, stdev) [min, max]
paper birch	48630	(5.7, 3.6) [0.5, 32.2]	(44, 19) [5, 98]
poplar/cottonwood	6740	(7.8, 6.1) [0.5, 59.2]	(46, 23) [5, 145]
quaking aspen	23960	(5.6, 3) [0.5, 27.6]	(42, 17) [5, 107]
salix	8	(9.7, 2.1) [7.1, 13.4]	(32, 11) [7, 44]

The AK variant covers Alaska coastal and boreal forest types found throughout the state as well as forested areas in coastal British Columbia and the northwestern tip of the Olympic Peninsula in Washington. The suggested geographic range of use for the AK variant is shown in figure 2.0.1.

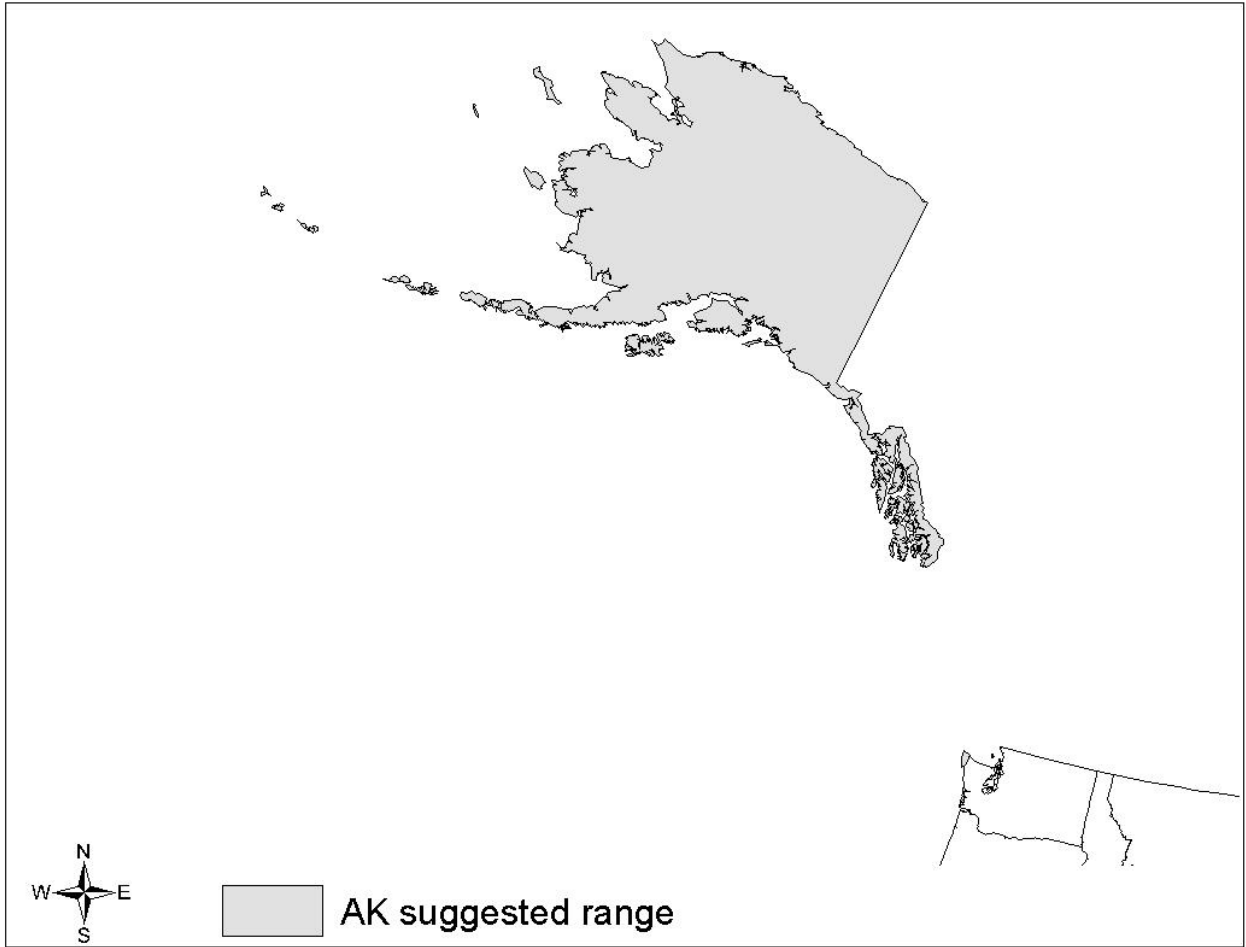


Figure 2.0.1 Suggested geographic range of use for the AK variant.

3.0 Control Variables

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

3.1 Location Codes

The location code is a 3- or 4-digit code where, in general, the first two digits of the code represents the Forest Service Region number, and the last two digits represent the Forest number/management area within that region. In some cases, a location code beginning with a “7” or “8” is used to indicate an administrative boundary that doesn’t use a Forest Service Region number (for example, other federal agencies, state agencies, or other lands).

If the location code is missing or incorrect in the AK variant, a default forest code of 1005 (Tongass National Forest) will be used. Location codes recognized in the AK variant are shown in table 3.1.1 and table 3.1.2.

When not entered by the user, the default latitude, longitude, and elevation are set based on the location code.

Table 3.1.1 Location codes used in the AK variant.

Location Code	Location	Latitude	Longitude	Elevation (ft)
1002	Tongass National Forest: Old Stikine Area (mapped to 1005)	55.34	-131.64	100
1003	Tongass National Forest: Old Chatham Area (mapped to 1005)	55.34	-131.64	100
1004	Chugach National Forest	61.22	-149.88	100
1005	Tongass National Forest ¹	55.34	-131.64	100
701	BC/Makah Old Combined code (mapped to 703)	48.53	-123.37	100
703	British Columbia	48.53	-123.37	100
713	Bureau of Land Management	61.22	-149.89	200
720	State of Alaska, Department of Natural Resources	61.22	-149.89	200
7400	Tanana Chiefs Conference (any location)	64.84	-147.71	500

¹1005 is the code used for the Tongass National Forest. 1005 represented the Ketchikan Area in the SEAPROG variant.

Table 3.1.2 Bureau of Indian Affairs location codes used in the AK variant.

Location Code	Location	Latitude	Longitude	Elevation (ft)
7401	Arctic Village Anvsa	68.13	-145.54	1000
7402	Ahtna	62.14	-145.47	1500
7403	Chugach	61.19	-149.89	100
7404	Cook Inlet	61.21	-149.81	100
7405	Doyon	64.85	-147.72	400
7406	Kongiganak Anvsa	59.99	-162.89	100
7407	Nanwalek Anvsa	59.36	-151.92	200
7408	Selawik Anvsa	66.73	-160.05	100
8112	Quileute Reservation	48.37	-124.61	300
8134	Annette Island	48.00	-124.61	100
8135	Makah Indian Reservation	55.12	-131.57	100

3.2 Species Codes

The AK variant recognizes 21 species, plus two other composite species categories. You may use FVS species codes, Forest Inventory and Analysis (FIA) species codes, or USDA Natural Resources Conservation Service PLANTS symbols to represent these species in FVS input data. Any valid western species code identifying species not recognized by the variant will be mapped to a similar species in the variant. The species mapping crosswalk is available on the FVS website variant documentation webpage. Any non-valid species code will default to the “other hardwood” 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 AK variant.

Table 3.2.1 Species codes used in the AK variant.

Species Number	Species Code	FIA Code	PLANTS Symbol	Scientific Name ¹	Common Name ¹
1	SF	011	ABAM	<i>Abies amabilis</i>	Pacific silver fir
2	AF	019	ABLA	<i>Abies lasiocarpa</i>	subalpine fir
3	YC	042	CANO9	<i>Callitropsis nootkatensis</i>	Alaska cedar
4	TA	071	LALA	<i>Larix laricina</i>	tamarack
5	WS	094	PIGL	<i>Picea glauca</i>	white spruce
6	LS		PILU	<i>Picea lutzii</i>	hybrid spruce
7	BE	095	PIMA	<i>Picea mariana</i>	black spruce
8	SS	098	PISI	<i>Picea sitchensis</i>	Sitka spruce
9	LP	108	PICO	<i>Pinus contorta</i>	lodgepole pine
10	RC	242	THPL	<i>Thuja plicata</i>	western redcedar
11	WH	263	TSHE	<i>Tsuga heterophylla</i>	western hemlock

Species Number	Species Code	FIA Code	PLANTS Symbol	Scientific Name ¹	Common Name ¹
12	MH	264	TSME	<i>Tsuga mertensiana</i>	mountain hemlock
13	OS	299	2TN		other softwood ²
14	AD	350	ALNUS	<i>Alnus</i>	alder
15	RA	351	ALRU2	<i>Alnus rubra</i>	red alder
16	PB	375	BEPA	<i>Betula papyrifera</i>	paper birch
17	AB	376	BENE4	<i>Betula neoalaskana</i>	resin birch
18	BA	741	POBA2	<i>Populus balsamifera</i>	balsam poplar
19	AS	746	POTR5	<i>Populus tremuloides</i>	quaking aspen
20	CW	747	POBAT	<i>Populus balsamifera</i> ssp. <i>trichocarpa</i>	black cottonwood
21	WI	920	SALIX	<i>Salix</i>	willow
22	SU	928	SASC	<i>Salix scouleriana</i>	Scouler's willow
23	OH	998	2TB		other hardwood ²

¹Set based on the USDA Forest Service NRM TAXA lists and the USDA Plants database.

²Other categories use FIA codes and NRM TAXA codes that best match the other category.

3.3 Habitat Type, Plant Association, and Ecological Unit Codes

Habitat type, plant association, and ecological unit codes are not used in the AK variant.

3.4 Site Index

Site index is used in the growth equations and the sprouting routine in the AK variant. When possible, users should enter their own values instead of relying on the default values assigned by FVS. If site index information is available, a single site index can be specified for the whole stand, a site index for each individual species can be specified, or a combination of these can be entered. If the user does not supply site index values, then default values will be used. When entering site index in the AK variant, the sources shown in table 3.4.1 should be used if possible. When site species and site index is not set by the user, the site species/index is set to western hemlock,70.

When site index is not specified for a species, a relative site index value is calculated from the site index of the site species using equations {3.4.1} and {3.4.2}. Lower and upper limits of site indices used in equation {3.4.1} may be found in table 3.4.1.

$$\{3.4.1\} RELSI = (SI_{site} - SITELO_{site}) / (SITEHI_{site} - SITELO_{site})$$

$$\{3.4.2\} SI_i = SITELO_i + RELSI * (SITEHI_i - SITELO_i)$$

where:

RELSI is the relative site index of the site species

SI is species site index

SITELO is the lower bound of the *SI* range for a species

SITEHI is the upper bound of the *SI* range for a species

site is the site species values
i is the species values for which site index is to be calculated

Table 3.4.1 Recommended site index references and range in the AK variant.

Species Number	Species Code	Source	Source Species ¹	SITELO	SITEHI	Base Age	Age ²
1	SF	Hegy et al. (1981)	balsam (coast)	35	105	100	TTA
2	AF	Hegy et al. (1981)	balsam (interior)	20	65	100	TTA
3	YC	Hegy et al. (1981)	yellow cedar	25	75	100	TTA
4	TA	Hegy et al. (1981)	larch	25	55	100	TTA
5	WS	Hegy et al. (1981)	spruce	30	85	100	TTA
6	LS	Hegy et al. (1981)	spruce	30	85	100	TTA
7	BE	Hegy et al. (1981)	larch	20	55	100	TTA
8	SS ³	Hegy et al. (1981) / Taylor 1934 and Payandeh (1974)	Sitka spruce	40	125	100	TTA
9	LP	Hegy et al. (1981)	lodgepole pine	15	55	100	TTA
10	RC	Hegy et al. (1981)	western red cedar (coast)	30	85	100	TTA
11	WH ³	Hegy et al. (1981) / Taylor 1934 and Payandeh (1974)	hemlock (coast)	35	105	100	TTA
12	MH ³	Hegy et al. (1981) / Taylor 1934 and Payandeh (1974)	hemlock (coast)	20	65	100	TTA
13	OS	Hegy et al. (1981)	spruce	30	85	100	TTA
14	AD	Hegy et al. (1981)	balsam poplar/black cottonwood	20	50	100	TTA
15	RA	Hegy et al. (1981)	red alder	75	135	100	TTA
16	PB	Hegy et al. (1981)	common paper birch	35	75	100	TTA
17	AB	Hegy et al. (1981)	common paper birch	45	90	100	TTA
18	BA	Hegy et al. (1981)	balsam poplar/black cottonwood	45	105	100	TTA
19	AS	Hegy et al. (1981)	aspen	45	85	100	TTA
20	CW	Hegy et al. (1981)	balsam poplar/black cottonwood	45	105	100	TTA
21	WI	Hegy et al. (1981)	balsam poplar/black cottonwood	20	50	100	TTA
22	SU	Hegy et al. (1981)	balsam poplar/black cottonwood	45	70	100	TTA
23	OH	Hegy et al. (1981)	balsam poplar/black cottonwood	20	50	100	TTA

¹ Hegyi (1981) source equation specified in table 4 of document.

² Age is total tree age (TTA).

³ Western hemlock, mountain hemlock, and Sitka spruce less than 200 years old use Taylor (1934) equation refit using methods from Payandeh (1974); western hemlock, mountain hemlock, and Sitka spruce greater than or equal to 200 years old use Hegyi (1981) equations.

Taylor-Payandeh site index equation form for Western hemlock, mountain hemlock, and Sitka spruce less than 200 years old:

$$SI = B_1 * HT^{B_2} * (1 - \text{EXP}(B_3 * TTA))^{B_4} * HT^{B_5}$$

$B_1 = 0.520027$; $B_2 = 0.999937$; $B_3 = -0.00625$; $B_4 = -0.899461$; $B_5 = -0.011825$

SI = site index base age 100; HT = total tree height; TTA = total tree age

3.5 Maximum Density

Stand density index (SDI) relative to maximum stand density index (SDImax) is used throughout the AK variant. Maximum stand density is not allowed to extend past the stand level maximum basal area and maximum SDI. If not set by the user, a default maximum value is assigned as discussed below.

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 or from user input. Maximum SDI at the stand level is a weighted average, by basal area, of the individual species SDI maximums.

Stand SDI is calculated using the Zeide calculation method (Dixon 2002).

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

where:

SDIMAX_i is the 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 AK variant.

Species Number	Species Code	SDI Maximum*	Mapped to
1	SF	790	
2	AF	602	
3	YC	592	
4	TA	387	
5	WS	412	
6	LS	412	white spruce
7	BE	500	

Species Number	Species Code	SDI Maximum*	Mapped to
8	SS	654	
9	LP	679	
10	RC	762	
11	WH	682	
12	MH	687	
13	OS	412	white spruce
14	AD	441	red alder
15	RA	441	
16	PB	466	
17	AB	466	paper birch
18	BA	384	
19	AS	562	
20	CW	452	
21	WI	447	black willow
22	SU	447	black willow
23	OH	452	black cottonwood

*Source of SDI maximums is an unpublished analysis of FIA data by John Shaw.

4.0 Growth Relationships

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

4.1 Height-Diameter Relationships

Height-diameter relationships in FVS are primarily used to estimate tree heights missing in input data, and occasionally to estimate diameter growth on trees smaller than a given threshold diameter. In the AK variant, FVS will dub in heights by one of two methods. By default, the AK variant will use the Chapman-Richards functional form as shown in equation {4.1.1} (Rijal et al., 2012).

If the input data contains at least three measured heights for a species, then FVS can switch to a logistic height-diameter equation {4.1.2} (Wykoff, et.al 1982) that may be calibrated to the input data. FVS will not automatically use equation {4.1.2} even if you have enough height values in the input data. To override this default, the user must use the NOHTDREG keyword to turn calibration on. Coefficients for equations {4.1.1} and {4.1.2} are given in table 4.1.1.

$$\{4.1.1\} HT = 4.5 + AX_1 * (1 - \exp(BX_1 * DBH))^{CX_1}$$

$$\{4.1.2\} HT = 4.5 + \exp(AX + BX / (DBH + 1.0))$$

where:

HT is tree height

DBH is tree diameter at breast height

AX₁, *BX₁*, *CX₁* are species-specific coefficients shown in table 4.1.1

AX, *BX* are species-specific coefficients shown in table 4.1.2

Table 4.1.1 Default coefficients for equations {4.1.1} and {4.2.2} in the AK variant.

Species Code	Coefficients				
	AX ₁	BX ₁	CX ₁	AX	BX
SF	173.578068	-0.034704	1.06697	5.047089	-12.629014
AF	173.578068	-0.034704	1.06697	5.047089	-12.629014
YC	118.005962	-0.04487	1.090783	4.683932	-10.690737
TA	68.53457	-0.149647	1.335243	4.350320	-5.776563
WS	115.991446	-0.068079	1.059224	4.633182	-6.81926
LS	115.991446	-0.068079	1.059224	4.633182	-6.81926
BE	68.534570	-0.149647	1.335243	4.350320	-5.776563
SS	173.578068	-0.034704	1.06697	5.047089	-12.629014
LP	71.730424	-0.096667	1.589409	4.513771	-10.853785
RC	105.741099	-0.051922	1.134463	4.716522	-11.426736
WH	141.210402	-0.054102	1.248358	5.007972	-12.085418
MH	108.158839	-0.054874	1.309823	4.701229	-12.133655

Species Code	Coefficients				
	AX ₁	BX ₁	CX ₁	AX	BX
OS	115.991446	-0.068079	1.059224	4.633182	-6.81926
AD	115.115222	-0.04711	0.795143	4.622461	-6.696442
RA	131.581959	-0.03474	0.783043	4.542755	-6.654068
PB	59.019982	-0.330044	1.482009	4.393426	-3.968868
AB	59.019982	-0.330044	1.482009	4.393426	-3.968868
BA	115.115222	-0.04711	0.795143	4.622461	-6.696442
AS	69.442183	-0.181461	1.179203	4.479633	-5.03023
CW	115.115222	-0.04711	0.795143	4.622461	-6.696442
WI	115.115222	-0.04711	0.795143	4.622461	-6.696442
SU	115.115222	-0.04711	0.795143	4.622461	-6.696442
OH	115.115222	-0.04711	0.795143	4.622461	-6.696442

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 equations used in the AK variant to calculate bark ratio are shown below {4.2.1 – 4.2.3}. Coefficients for the equations are shown in table 4.2.1. Table 4.2.1 also designates which equation is associated with each of the species present in the AK variant.

$$\{4.2.1\} DBT = a * DBH ^ b$$

$$BRATIO = (DBH - DBT) / DBH$$

$$\{4.2.2\} BRATIO = (a + (b * DBH)) / DBH$$

$$\{4.2.3\} DIB = a * DBH ^ b$$

$$BRATIO = DIB / DBH$$

where:

BRATIO is species-specific bark ratio
DBH is tree diameter at breast height
DBT is double bark thickness
DIB is diameter inside bark

Table 4.2.1 Coefficients and equations for bark ratio equations {4.2.1} – {4.2.3} in the AK variant.

Species Code	Equation Number	a	b
SF	4.2.1	0.186	0.45417
AF	4.2.1	0.186	0.45417
YC	4.2.1	0.186	0.45417
TA	4.2.3	0.796645	1.060823
WS	4.2.3	0.839825	1.039951

Species Code	Equation Number	a	b
LS	4.2.3	0.839825	1.039951
BE	4.2.3	0.796645	1.060823
SS	4.2.1	0.843047	1.030798
LP	4.2.1	0.186	0.45417
RC	4.2.1	0.186	0.45417
WH	4.2.1	0.186	0.45417
MH	4.2.3	0.743935	1.048186
OS	4.2.3	0.839825	1.039951
AD	4.2.2	0.075256	0.94373
RA	4.2.2	0.075256	0.94373
PB	4.2.3	0.899145	1.011965
AB	4.2.3	0.899145	1.011965
BA	4.2.3	0.792559	1.028571
AS	4.2.3	0.921204	0.996669
CW	4.2.3	0.784468	1.035819
WI	4.2.3	0.784468	1.035819
SU	4.2.3	0.784468	1.035819
OH	4.2.3	0.784468	1.035819

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 AK variant, crown ratios missing in the input data are dubbed using equations {4.3.1.1} - {4.3.1.2}.

$$\{4.3.1.1\} X = B_1 + B_2 * \ln(H*12/D) + B_3 * RDEN + B_4 * D/QMDPLT + N(0,SD)$$

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

where:

D is tree diameter at breast height

H is tree height

PRD is relative density of the stand (Zeide SDI / maximum SDI) on inventory point

QMDPLT is quadratic mean diameter of trees on inventory point (constrained to minimum of 1")

N(0,SD) is a random increment from normal distribution with mean 0 and standard deviation of SD which is only applied to trees less than 1.0" DBH and dead trees.

CR is crown ratio expressed as a proportion (bounded to $0.05 \leq CR \leq 0.95$)

$B_1 - B_4$ are species-specific coefficients shown in table 4.3.1.1

Table 4.3.1.1 Coefficients for the crown ratio equation {4.3.1.1-4.3.1.2} in the AK variant.

Species Code	Coefficients				
	B_1	B_2	B_3	B_4	SD
SF	-2.818788	0.623633	0.952948	-0.174337	0.1719
AF	-2.818788	0.623633	0.952948	-0.174337	0.1719
YC	0.655733	-0.064716	0.439411	-0.174337	0.159
TA	6.469047	-1.495754	0.913909	-0.051268	0.1645
WS	-4.02647	0.655230	0.914077	-0.051268	0.1542
LS	-4.02647	0.655230	0.914077	-0.051268	0.1542
BE	-2.781735	0.438826	0.970251	-0.051268	0.1894
SS	-2.818788	0.623633	0.952948	-0.174337	0.1719
LP	-0.425173	0.295262	0.732675	-0.174337	0.1568
RC	-0.449694	0.104368	0.557638	-0.174337	0.1811
WH	-0.364665	0.116994	0.573079	-0.174337	0.1582
MH	-0.47458	0.141604	0.590263	-0.174337	0.155
OS	-4.026470	0.655230	0.914077	-0.051268	0.1542
AD	0.977291	-0.314026	0.848483	-0.051268	0.1447
RA	-2.799049	0.660530	0.987503	-0.174337	0.1447
PB	-1.268650	0.147556	1.092390	-0.051268	0.144
AB	-1.268650	0.147556	1.092390	-0.051268	0.144
BA	0.977291	-0.314026	0.848483	-0.051268	0.1605
AS	0.802511	-0.143680	1.023227	-0.051268	0.1356
CW	0.977291	-0.314026	0.848483	-0.051268	0.1605
WI	-2.406592	0.347417	0.952753	-0.051268	0.0938
SU	-2.406592	0.347417	0.952753	-0.051268	0.0938
OH	0.977291	-0.314026	0.848483	-0.051268	0.1605

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 (across all species) using equations {4.3.1.1} - {4.3.1.2}. 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 decrease and 3% per year increase for the length of the cycle to avoid drastic changes in crown ratio.

4.3.3 Crown Ratio for Newly Established Trees

Crown ratios for newly established trees during regeneration are estimated using equation {4.3.3.1}. A random component is added in equation {4.3.3.1} to ensure that not all newly established trees are assigned 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 AK variant calculates the maximum crown width for each individual tree based on individual tree and stand attributes. Crown width for each tree is reported in the tree list output table and used for percent cover (*PCC*) calculations in the model.

Crown width is calculated using equations {4.4.1} – {4.4.3}, and coefficients for these equations are shown in table 4.4.1. The minimum diameter and bounds for certain data values are given in table 4.4.2. Equation numbers in table 4.4.1 are given with the first three digits representing the FIA species code, and the last two digits representing the equation source.

{4.4.1} Crookston (2005); Equation 05

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

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

{4.4.2} Donnelly (1996); Equation 06

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

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

{4.4.3} Castle (2019); Equation 08

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

where:

CW is tree maximum crown width
BF is a species-specific coefficient based on forest code (*BF* = 1.0 in the AK variant)
DBH is tree diameter at breast height
HT is tree height
CL is tree crown length
BA is total stand basal area
EL is stand elevation in hundreds of feet
MinD is the minimum diameter
a₁ – a₆ are species-specific coefficients shown in table 4.4.1

Table 4.4.1 Coefficients for crown width equations {4.4.1} – {4.4.3} in the AK variant.

Species Code	Equation Number*	a ₁	a ₂	a ₃	a ₄	a ₅	a ₆
SF	01105	4.4799	0.45976	-0.10425	0.11866	0.06762	-0.00715
AF	01905	5.8827	0.51479	-0.21501	0.17916	0.03277	-0.00828
YC	04205	3.3756	0.45445	-0.11523	0.22547	0.08756	-0.00894
TA	09508	3.391358	0.638945	-0.395285	0.264254	0	0
WS	09408	8.515316	0.630576	-0.867757	0.477791	0.10021	-0.015034
LS	09408	8.515316	0.630576	-0.867757	0.477791	0.10021	-0.015034
BE	09508	3.391358	0.638945	-0.395285	0.264254	0	0
SS	09805	8.48	0.70692	-0.38812	0.17127	0	0
LP	10805	6.6941	0.81980	-0.36992	0.17722	-0.01202	-0.00882
RC	24205	6.2382	0.29517	-0.10673	0.23219	0.05341	-0.00787
WH	26305	6.0384	0.51581	-0.21349	0.17468	0.06143	-0.00571
MH	26405	3.7854	0.54684	-0.12954	0.16151	0.03047	-0.00561
OS	09408	8.515316	0.630576	-0.867757	0.477791	0.10021	-0.015034
AD	74708	0.790658	0.551987	0.446434	0	0	-0.048415
RA	35106	7.0806	0.4771	0	0	0	0
PB	37508	2.725006	0.53601	0	0.196372	-0.015305	0
AB	37508	2.725006	0.53601	0	0.196372	-0.015305	0
BA	74708	0.790658	0.551987	0.446434	0	0	-0.048415
AS	74608	2.386015	0.63014	-0.147121	0.274356	0	0
CW	74708	0.790658	0.551987	0.446434	0	0	-0.048415
WI	74708	0.790658	0.551987	0.446434	0	0	-0.048415
SU	74708	0.790658	0.551987	0.446434	0	0	-0.048415
OH	74708	0.790658	0.551987	0.446434	0	0	-0.048415

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

Table 4.4.2 *MinD* values and data bounds for equations {4.4.1}–{4.4.3} in the AK variant.

Species Code	Equation Number*	<i>MinD</i>	<i>EL</i> min	<i>EL</i> max	<i>CW</i> max
SF	01105	1.0	4	72	33
AF	01905	1.0	10	85	30
YC	04205	1.0	16	62	59
TA	09508	n/a	n/a	n/a	16
WS	09408	n/a	1	85	40
LS	09408	n/a	1	85	40
BE	09508	n/a	n/a	n/a	16
SS	09805	1.0	n/a	n/a	50
LP	10805	1.0	1	79	40
RC	24205	1.0	1	72	45
WH	26305	1.0	1	72	54

Species Code	Equation Number*	MinD	EL min	EL max	CW max
MH	26405	n/a	n/a	n/a	45
OS	09408	n/a	1	85	40
AD	74708	1.0	n/a	n/a	35
RA	35106	1.0	n/a	n/a	35
PB	37508	n/a	n/a	n/a	53
AB	37508	n/a	n/a	n/a	53
BA	74708	n/a	n/a	n/a	56
AS	74608	n/a	n/a	n/a	48
CW	74708	n/a	n/a	n/a	56
WI	74708	n/a	n/a	n/a	56
SU	74708	n/a	n/a	n/a	56
OH	74708	n/a	n/a	n/a	56

4.5 Crown Competition Factor

The AK variant uses crown competition factor (*CCF*) as a predictor variable in some growth relationships. Crown competition factor (Krajicek and others 1961) is a relative measurement of stand density that is based on tree diameters. Individual tree CCF_t values estimate the percentage of an acre that would be covered by the tree's crown if the tree were open-grown. Stand *CCF* is the summation of individual tree (CCF_t) values. A stand *CCF* value of 100 theoretically indicates that tree crowns will just touch in an unthinned, evenly spaced stand. Crown competition factor for an individual tree is calculated using equations 4.5.1- 4.5.4:

$$\{4.5.1\} MCW = b_1 + b_2 * DBH$$

$$\{4.5.2\} MCW = b_1 + DBH^{b_2} * 3.28$$

$$\{4.5.3\} MCA = Pi * (MCW/2)^2$$

$$\{4.5.4\} DBH > 0.1 CCF_t = (MCA/43560) * 100 * P$$

$$DBH \leq 0.1 CCF_t = 0.001 * P$$

where:

<i>MCW</i>	open grown crown width for an individual tree
<i>DBH</i>	is tree diameter at breast height
<i>MCA</i>	crown area for an individual tree
<i>Pi</i>	constant of 3.14159
CCF_t	is crown competition factor for an individual tree
<i>P</i>	trees per acre representation of an individual tree
$b_1 - b_2$	are species-specific coefficients shown in table 4.5.1

Table 4.5.1 Coefficients for the *MCW* equations {4.5.1} – {4.5.2} in the AK variant.

Species Code	Equation number	Reference Species	Model Coefficients	
			b ₁	b ₂
SF	4.5.1	white and grand fir, Paine and Hann 1982	6.1880	1.0069
AF	4.5.1	white and grand fir, Paine and Hann 1982	6.1880	1.0069
YC	4.5.1	western redcedar, Smith 1966	4.0	1.6
TA	4.5.2	black spruce, Russell and Weiskittel 2011	0.535	0.742
WS	4.5.2	white spruce, Russell and Weiskittel 2011	1.50	0.496
LS	4.5.2	white spruce, Russell and Weiskittel 2011	1.50	0.496
BE	4.5.2	black spruce, Russell and Weiskittel 2011	0.535	0.742
SS	4.5.1	Sitka spruce, Smith 1966	6.5	1.8
LP	4.5.1	white and grand fir, Paine and Hann 1982	6.1880	1.0069
RC	4.5.1	western redcedar, Smith 1966	4.0	1.6
WH	4.5.1	western hemlock, Paine and Hann 1982	4.5652	1.4147
MH	4.5.1	western hemlock, Paine and Hann 1982	4.5652	1.4147
OS	4.5.2	white spruce, Russell and Weiskittel 2011	1.50	0.496
AD	4.5.1	alder, Smith 1966	8.0	1.53
RA	4.5.1	alder, Smith 1966	8.0	1.53
PB	4.5.2	paper birch, Russell and Weiskittel 2011	1.48	0.623
AB	4.5.2	paper birch, Russell and Weiskittel 2011	1.48	0.623
BA	4.5.2	ash/cottonwood, Smith 1966	0.5	1.62
AS	4.5.2	quaking aspen, Russell and Weiskittel 2011	1.31	0.586
CW	4.5.1	ash/cottonwood, Smith 1966	0.5	1.62
WI	4.5.1	ash/cottonwood, Smith 1966	0.5	1.62
SU	4.5.1	ash/cottonwood, Smith 1966	0.5	1.62
OH	4.5.1	ash/cottonwood, Smith 1966	0.5	1.62

4.6 Small Tree Growth Relationships

Trees are considered “small trees” for FVS modeling purposes when they are smaller than some threshold diameter. The threshold diameter is set to 1.0” for all species in the AK variant; however, both height and diameter growth are averaged with large tree predictions across species-specific diameter ranges.

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 growth model predicts periodic potential height growth (POTHTG) from height growth curves identified in section 3.4. Height growth is computed by subtracting the current predicted height from the predicted height 10 years in the future, as depicted in equations {4.6.1.1} and {4.6.1.2}. Coefficients for each equation are in table 4.6.1.1.

{4.6.1.1} Hegyi (et.al 1981)

$$HT = C_1 * XSITE * (1 - EXP(C_2 * AGET))^{C_3}$$

{4.6.1.2} Payandeh (1974)

$$HT = B_1 * XSITE^{B_2} * (1 - EXP(B_3 * AGET))^{(B_4 * XSITE^{B_5})}$$

where:

- HT* is predicted tree height, used for current and future height growth.
XSITE is species site index
AGET is tree age where equations are presented above are solved for age. Future age adds ten years to the *AGET* estimate.
HT tree height in feet
*C*₁ – *C*₃ are species-specific coefficients
*B*₁ – *B*₅ are species-specific coefficients

Table 4.6.1.1 Coefficients for the small tree height growth equations {4.6.1.1} and {4.6.1.2} in the AK variant.

Species Code	Equation	B ₁ or C ₁	B ₂ or C ₂	B ₃ or C ₃	B ₄	B ₅	X _{MIN}	X _{MAX}	DG _{Max}
SF	{4.6.1.1}	1.1945	-0.0236	1.7918			1.0	5.0	5.0
AF	{4.6.1.1}	1.3832	-0.0155	1.3597			1.0	5.0	5.0
YC	{4.6.1.1}	1.1243	-0.0263	1.5662			1.0	8.0	5.0
TA	{4.6.1.1}	1.1637	-0.0215	1.2243			1.0	3.0	3.0
WS	{4.6.1.1}	1.2883	-0.0181	1.4177			1.0	3.0	3.0
LS	{4.6.1.1}	1.2883	-0.0181	1.4177			1.0	3.0	3.0
BE	{4.6.1.1}	1.1637	-0.0215	1.2243			1.0	3.0	3.0
SS	{4.6.1.2}	1.5469	1.0018	-0.0114	1.0883	0.0072	1.0	5.0	5.0
LP	{4.6.1.1}	1.0236	-0.0465	2.4269			1.0	8.0	5.0
RC	{4.6.1.1}	1.1243	-0.0263	1.5662			1.0	8.0	5.0
WH	{4.6.1.2}	1.5469	1.0018	-0.0114	1.0883	0.0072	1.0	7.0	5.0
MH	{4.6.1.2}	1.5469	1.0018	-0.0114	1.0883	0.0072	1.0	8.0	5.0
OS	{4.6.1.1}	1.2883	-0.0181	1.4177			1.0	3.0	3.0
AD	{4.6.1.1}	1.1318	-0.0226	1.1233			1.0	3.0	3.0
RA	{4.6.1.1}	1.0142	-0.0421	0.9422			1.0	3.0	3.0
PB	{4.6.1.1}	1.1580	-0.0175	0.7687			1.0	3.0	3.0
AB	{4.6.1.1}	1.1580	-0.0175	0.7687			1.0	3.0	3.0
BA	{4.6.1.1}	1.1318	-0.0226	1.1233			1.0	3.0	3.0
AS	{4.6.1.1}	1.2025	-0.0158	0.7994			1.0	3.0	3.0
CW	{4.6.1.1}	1.1318	-0.0226	1.1233			1.0	3.0	3.0
WI	{4.6.1.1}	1.1318	-0.0226	1.1233			1.0	3.0	3.0
SU	{4.6.1.1}	1.1318	-0.0226	1.1233			1.0	3.0	3.0
OH	{4.6.1.1}	1.1318	-0.0226	1.1233			1.0	3.0	3.0

For all species, a small random error is then added to the height growth estimate. The estimated height growth is then adjusted to account for cycle length, user-defined, small-tree height growth adjustments, and adjustments due to small tree height increment calibration from input data. Then, the small-tree estimate is averaged with an estimate from the large-tree height growth model, explained in section 4.7.2, to obtain an average small tree height growth estimate from the initial potential estimate.

Finally, height growth estimates are weighted with the height growth estimates from the large tree model over a range of diameters (X_{min} and X_{max}), 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. The weight applied to the growth estimate is calculated using equation {4.6.1.3}, and applied as shown in equation {4.6.1.4}. The range of diameters for each species is shown in table 4.6.1.1.

{4.6.1.3}

$$DBH \leq X_{min}: XWT = 0$$

$$X_{min} < DBH < X_{max} : XWT = (DBH - X_{min}) / (X_{max} - X_{min})$$

$$DBH \geq X_{max}: XWT = 1$$

{4.6.1.4} Estimated growth = $[(1 - XWT) * ((STGE+LTGE)/2)] + [XWT * LTGE]$

where:

<i>DBH</i>	is tree diameter at breast height
<i>XWT</i>	is the weight applied to the growth estimates
X_{max}	is the maximum <i>DBH</i> in the diameter range
X_{min}	is the minimum <i>DBH</i> in the diameter range
<i>STGE</i>	is the small-tree growth estimate
<i>LTGE</i>	is the large-tree growth estimate

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 is calculated as the difference of predicted diameter at the start of the projection period and the predicted diameter at the end of the projection period, adjusted for bark ratio. These two predicted diameters are estimated using the species-specific height-diameter relationships discussed in section 4.1. By definition, diameter growth is zero for trees less than 4.5 feet tall.

Diameter growth estimates are weighted with the diameter growth estimates from the large-tree model over a range of diameters (X_{min} and DG_{max}), similar to the weighting explained in section 4.6.1.

4.7 Large Tree Growth Relationships

Trees are considered “large trees” for FVS modeling purposes when they are equal to, or larger than, some threshold diameter. This threshold diameter is set to 1.0” for all species in the AK variant.

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

4.7.1 Large Tree Diameter Growth

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

The AK variant uses the following equation set {4.7.1.1 – 4.7.1.3} to calculate annual diameter increment (outside bark) for all species. Equation {4.7.1.1}, with coefficients specified in table 4.7.1.1, is used to estimate a base diameter increment, while equations {4.7.1.2} and {4.7.1.3} are used to adjust the base rate due to permafrost presence/absence (*PFMod*) and to adjust species whose growth form is shrub/tree (*SPAdj*), respectively. Coefficients for species utilizing equation {4.7.1.2} are in table 4.7.1.2. *PFMod* is set to 1.0 for all other species. For species that are of shrub/tree form, diameter increment is adjusted lower based on a general species adjustment. The final growth rate is adjusted for base cycle length and bark thickness to attain a final estimate of the change in inside-bark diameter. There are additional adjustments to scale the estimate to cycle length and apply any user-supplied modifiers.

{4.7.1.1} Used for all species

$$BaseDG = \exp(b_1 + b_2 * DBH^2 + b_3 * \ln(DBH) + b_4 * PBAL + b_5 * PRD + b_6 * \ln(CR) + b_7 * EL + b_8 * SL + b_9 * SL * \cos(ASP) + b_{10} * \ln(SI))$$

{4.7.1.2} Used for species in Table 4.7.1.2

$$PFMod = \exp(b_1 + b_2 * PERM + b_3 * DBH^2 + b_4 * \ln(DBH) + b_5 * PBAL + b_6 * PRD + b_7 * \ln(CR) + b_8 * EL + b_9 * SL + b_{10} * SL * \cos(ASP)) / BASEDG$$

{4.7.1.3} $DI = BASEDG * PFMOD * SPAdj * YR$

where:

<i>BaseDG</i>	is annual diameter increment (in / year)
<i>DBH</i>	is tree diameter at breast height
<i>PBAL</i>	is plot basal area in trees larger than the subject tree
<i>PRD</i>	is plot level relative density (plot Zeide SDI / plot SDI max)
<i>CR</i>	is crown ratio expressed as a percentage
<i>EL</i>	is stand elevation (ft)
<i>SL</i>	is stand slope expressed as a percent
<i>ASP</i>	is stand aspect in radians

SI is species site index
PfMod is a permafrost presence modifier
PERM is the effect of permafrost presence in a stand (value of 1 if present, 0 if absent)
DI is diameter increment for the default cycle length
SPAdj is a species adjustment where AD, WI and OH = 0.45, SU = 0.65, and all others = 1.00
YR is the default cycle length (10 years)
b₁ – b₁₀ are species-specific coefficients

Table 4.7.1.1 Coefficients (*b₁ – b₁₀*) for the diameter growth equation {4.7.1.1} in the AK variant.

Species Code	<i>b₁</i>	<i>b₂</i>	<i>b₃</i>	<i>b₄</i>	<i>b₅</i>	<i>b₆</i>	<i>b₇</i>	<i>b₈</i>	<i>b₉</i>	<i>b₁₀</i>
SF	-8.58075	-0.00044	0.033655	-0.00228	0	0.819909	0	0.001604	0.00002	0.712498
AF	-8.58075	-0.00044	0.033655	-0.00228	0	0.819909	0	0.001604	0.00002	0.712498
YC	-9.48511	-0.00044	0.081005	-0.0006	0	0.819909	0	0.001604	0.00002	0.712498
TA	-6.58523	-0.00228	0.152853	-0.00151	-0.3532	0.727631	-0.00018	0.001225	-0.00242	0
WS	-6.31577	-0.00228	0.480982	-5.70E-05	-0.4555	0.727631	-0.00018	0.001225	-0.00242	0
LS	-6.31577	-0.00228	0.480982	-5.70E-05	-0.4555	0.727631	-0.00018	0.001225	-0.00242	0
BE	-6.58523	-0.00228	0.152853	-0.00151	-0.3532	0.727631	-0.00018	0.001225	-0.00242	0
SS	-8.58075	-0.00044	0.033655	-0.00228	0	0.819909	0	0.001604	0.00002	0.712498
LP	-9.29779	-0.00044	-0.00086	-0.0006	0	0.819909	0	0.001604	0.00002	0.712498
RC	-9.35712	-0.00044	0.243224	-0.0006	0	0.819909	0	0.001604	0.00002	0.712498
WH	-9.45806	-0.00044	0.175997	-0.0006	0	0.819909	0	0.001604	0.00002	0.712498
MH	-9.15538	-0.00044	0.044554	-0.00058	0	0.819909	0	0.001604	0.00002	0.712498
OS	-6.31577	-0.00228	0.480982	-5.70E-05	-0.4555	0.727631	-0.00018	0.001225	-0.00242	0
AD	-5.64634	-0.00228	0.212906	-0.00072	-0.76363	0.727631	-0.00018	0.001225	-0.00242	0
RA	-5.19589	-0.00228	0.425682	-0.00117	-0.62382	0.727631	-0.00018	0.001225	-0.00242	0
PB	-6.0157	-0.00228	0.35335	-0.00717	-0.3532	0.727631	-0.00018	0.001225	-0.00242	0
AB	-6.0157	-0.00228	0.35335	-0.00717	-0.3532	0.727631	-0.00018	0.001225	-0.00242	0
BA	-5.64634	-0.00228	0.212906	-0.00072	-0.76363	0.727631	-0.00018	0.001225	-0.00242	0
AS	-6.70493	-0.00228	0.669461	-0.00056	-0.48014	0.727631	-0.00018	0.001225	-0.00242	0
CW	-5.64634	-0.00228	0.212906	-0.00072	-0.76363	0.727631	-0.00018	0.001225	-0.00242	0
WI	-5.64634	-0.00228	0.212906	-0.00072	-0.76363	0.727631	-0.00018	0.001225	-0.00242	0
SU	-5.64634	-0.00228	0.212906	-0.00072	-0.76363	0.727631	-0.00018	0.001225	-0.00242	0
OH	-5.64634	-0.00228	0.212906	-0.00072	-0.76363	0.727631	-0.00018	0.001225	-0.00242	0

Table 4.7.1.2 Coefficients (b₁ – b₁₀) for the permafrost modifier equation {4.7.1.2} in the AK variant.

Species Code	b ₁	b ₂	b ₃	b ₄	b ₅	b ₆	b ₇	b ₈	b ₉	b ₁₀
TA	-6.52972	-0.34922	-0.00271	0.161256	-0.00187	-0.02879	0.736013	-0.00014	0.001702	-0.00182
WS	-6.27434	-0.34922	-0.00271	0.476859	-0.00053	-0.48209	0.736013	-0.00014	0.001702	-0.00182
LS	-6.27434	-0.34922	-0.00271	0.476859	-0.00053	-0.48209	0.736013	-0.00014	0.001702	-0.00182
BE	-6.52972	-0.34922	-0.00271	0.161256	-0.00187	-0.02879	0.736013	-0.00014	0.001702	-0.00182
OS	-6.27434	-0.34922	-0.00271	0.476859	-0.00053	-0.48209	0.736013	-0.00014	0.001702	-0.00182
PB	-6.09354	-0.34922	-0.00271	0.373362	-0.00735	-0.33031	0.736013	-0.00014	0.001702	-0.00182
AB	-6.09354	-0.34922	-0.00271	0.373362	-0.00735	-0.33031	0.736013	-0.00014	0.001702	-0.00182
BA	-5.52778	-0.34922	-0.00271	0.082885	-0.00132	-0.81985	0.736013	-0.00014	0.001702	-0.00182
AS	-6.86117	-0.34922	-0.00271	0.712862	-0.00053	-0.46258	0.736013	-0.00014	0.001702	-0.00182
CW	-5.52778	-0.34922	-0.00271	0.082885	-0.00132	-0.81985	0.736013	-0.00014	0.001702	-0.00182
WI	-5.52778	-0.34922	-0.00271	0.082885	-0.00132	-0.81985	0.736013	-0.00014	0.001702	-0.00182
SU	-5.52778	-0.34922	-0.00271	0.082885	-0.00132	-0.81985	0.736013	-0.00014	0.001702	-0.00182
OH	-5.52778	-0.34922	-0.00271	0.082885	-0.00132	-0.81985	0.736013	-0.00014	0.001702	-0.00182

4.7.2 Large Tree Height Growth

The AK variant uses the following equation set {4.7.2.1 – 4.7.2.3} to calculate annual height increment for all species. Equation {4.7.2.1}, with coefficients specified in table 4.7.2.1, is used to estimate a base height increment, while equations {4.7.2.2} and {4.7.2.3} are used to adjust the base rate due to permafrost presence/absence (*PFHMod*) and species whose growth form is shrub/tree (*SPAdj*), respectively. Coefficients for species utilizing equation {4.7.2.2} are in table 4.7.2.2. *PFHMod* is set to 1.0 for all other species. For species that are of shrub/tree form, height increment is adjusted lower based on a general species adjustment. The final growth rate is adjusted for base cycle length. There are additional adjustments to scale the estimate to cycle length and apply any user-supplied modifiers.

{4.7.2.1} Used for all species

$$BaseHG = \exp(b_1 + b_2 * DBH^2 + b_3 * \ln(DBH) + B_4 * EL + B_5 * \ln(SI) + b_6 * \ln(DG10))$$

{4.7.2.2} Used for species in Table 4.7.2.2

$$PFHMod = \exp(b_1 + b_2 * PERM + b_3 * DBH^2 + b_4 * \ln(DBH) + B_5 * EL + b_6 * \ln(DG10)) / BASEHG$$

{4.7.2.3} $HI = BASEHG * PFHMOD * SPAdj * YR$

where:

BaseHG is annual height increment (in / year)
DBH is tree diameter at breast height
EL is stand elevation (ft)
SI is species site index

DG10 is 10-year, outside-bark diameter growth
PFHMod is a permafrost presence modifier
PERM is the effect of permafrost presence in a stand (value of 1 if present, 0 if absent)
HI is height increment for the default cycle length
SPAdj is a species adjustment where AD, WI and OH = 0.45, SU = 0.65, and all others = 1.00
YR is the default cycle length (10 years)
b₁ – b₆ are species-specific coefficients

Table 4.7.2.1 Coefficients (*b₁ – b₆*) for height-growth equation {4.7.2.1} in the AK variant.

Species Code	<i>b₁</i>	<i>b₂</i>	<i>b₃</i>	<i>b₄</i>	<i>b₅</i>	<i>b₆</i>
SF	-2.18236	-0.000447	-0.00488	0	0.429243	0.489281
AF	-2.18236	-0.000447	-0.00488	0	0.429243	0.489281
YC	-2.955092	-0.000447	0.125393	0	0.429243	0.376732
TA	-0.663746	-0.003814	0.176358	-0.000075	0	0.560124
WS	-0.501134	-0.003814	0.209621	-0.000075	0	0.517799
LS	-0.501134	-0.003814	0.209621	-0.000075	0	0.517799
BE	-0.663746	-0.003814	0.176358	-0.000075	0	0.560124
SS	-2.18236	-0.000447	-0.00488	0	0.429243	0.489281
LP	-3.19512	-0.000447	0.166453	0	0.429243	0.342411
RC	-2.979661	-0.000447	0.130947	0	0.429243	0.374658
WH	-2.404892	-0.000447	0.044809	0	0.429243	0.469563
MH	-2.770793	-0.000447	0.099358	0	0.429243	0.408836
OS	-0.501134	-0.003814	0.209621	-0.000075	0	0.517799
AD	-0.174905	-0.003814	-0.051622	-0.000075	0	0.539313
RA	-0.710501	-0.003814	0.396143	-0.000075	0	0.195472
PB	-0.306839	-0.003814	0.062956	-0.000075	0	0.392915
AB	-0.306839	-0.003814	0.062956	-0.000075	0	0.392915
BA	-0.174905	-0.003814	-0.051622	-0.000075	0	0.539313
AS	-0.630114	-0.003814	0.068496	-0.000075	0	0.367413
CW	-0.174905	-0.003814	-0.051622	-0.000075	0	0.539313
WI	-0.174905	-0.003814	-0.051622	-0.000075	0	0.539313
SU	-0.174905	-0.003814	-0.051622	-0.000075	0	0.539313
OH	-0.174905	-0.003814	-0.051622	-0.000075	0	0.539313

Table 4.7.2.2 Coefficients (*b₁ – b₆*) for height-growth equation {4.7.2.2} in the AK variant.

Species Code	<i>b₁</i>	<i>b₂</i>	<i>b₃</i>	<i>b₄</i>	<i>b₅</i>	<i>b₆</i>
TA	-0.661722	-0.130016	-0.003807	0.17915	-0.000067	0.53748

Species Code	b ₁	b ₂	b ₃	b ₄	b ₅	b ₆
WS	-0.509243	-0.130016	-0.003807	0.221303	-0.000067	0.50946
LS	-0.509243	-0.130016	-0.003807	0.221303	-0.000067	0.50946
BE	-0.661722	-0.130016	-0.003807	0.17915	-0.000067	0.53748
OS	-0.509243	-0.130016	-0.003807	0.221303	-0.000067	0.50946
PB	-0.299268	-0.130016	-0.003807	0.057156	-0.000067	0.3977
AB	-0.299268	-0.130016	-0.003807	0.057156	-0.000067	0.3977
BA	-0.148618	-0.130016	-0.003807	-0.075692	-0.000067	0.55662
AS	-0.617425	-0.130016	-0.003807	0.060586	-0.000067	0.37556
CW	-0.148618	-0.130016	-0.003807	-0.075692	-0.000067	0.55662
WI	-0.148618	-0.130016	-0.003807	-0.075692	-0.000067	0.55662
SU	-0.148618	-0.130016	-0.003807	-0.075692	-0.000067	0.55662

A height growth bounding function is used to ensure tree heights do not exceed, to a large extent, the species height maximums. The bounding function is applied using the following concepts. For a tree with height less than the lower height-bounding limit, the height growth modifier is set to 1.0. For a tree with a height greater than or equal to the lower height-bounding limit and less than the upper height-bounding limit, a height growth modifier is computed using equation {4.7.2.4}. For a tree with a height greater than the upper height-bounding limit, the height growth modifier is set to 0.1. The species lower limits were determined from the height growth fitting data and the maximum limits were determined from HT-DBH relationships and a few judgement calls based on a literature. The bounding limits for the height growth bounding function are in table 4.7.2.3. The final height increment estimate is multiplied by the bounding function, equation {4.7.2.5}.

$$\{4.7.2.4\} HGBND = 1.0 - ((HT - HTLO) / (HTHI - HTLO))$$

$$\{4.7.2.5\} HI = HI * HGBND$$

where:

HGBND is height growth bounding modifier, limited to $0.1 \leq HGBND \leq 1.0$

HT is the total tree height (ft)

HT_{LO} is the lower height-bounding limit

HT_{HI} is the upper height-bounding limit

Table 4.7.2.3 Bounds for the height growth bounding equation {4.7.2.4} in the AK variant.

Species Code	<i>HT_{LO}</i>	<i>HT_{HI}</i>	Species Code	<i>HT_{LO}</i>	<i>HT_{HI}</i>	Species Code	<i>HT_{LO}</i>	<i>HT_{HI}</i>
SF	131	211	LP	70	98	AB	77	102
AF	83	150	RC	102	151	BA	84	130
YC	92	139	WH	130	214	AS	76	102
TA	47	77	MH	83	150	CW	84	130
WS	78	123	OS	78	123	WI	38	59

Species Code	<i>HTLO</i>	<i>HTHI</i>
LS	78	123
BE	47	77
SS	131	211

Species Code	<i>HTLO</i>	<i>HTHI</i>
AD	38	59
RA	86	120
PB	77	102

Species Code	<i>HTLO</i>	<i>HTHI</i>
SU	55	85
OH	38	59

5.0 Mortality Model

All species in the AK variant use annualized individual tree survival equations for estimating mortality. The annual probability of survival is based on a tree's size and competitive status. Equation 5.0.1 is used to calculate the annual survival rate for all species.

$$\{5.0.1\} RIP = (\text{EXP}(X)/(1 + \text{EXP}(X)))$$

$$X = b_1 + b_2*DBH + b_3*DBH^2 + b_4*PTBAL + b_5*BAL/DBH$$

where:

- RIP* is annual individual tree survival rate
DBH is tree diameter at breast height, set to *DSURV* when *DBH* is less than *DSURV*
PTBAL plot level basal area in trees larger than subject tree
*b*₁ – *b*₅ are species-specific coefficients shown in table 5.01

Table 5.0.1 Coefficients used in the survival equation {5.0.1} in the AK variant.

Species Code	<i>b</i> ₁	<i>b</i> ₂	<i>b</i> ₃	<i>b</i> ₄	<i>b</i> ₅	<i>DSURV</i>
SF	5.106086	0.036136	-0.000634	0.0	-0.010747	0.50
AF	5.106086	0.036136	-0.000634	0.0	-0.010747	0.50
YC	5.334283	0.036136	-0.001034	0.0	-0.004540	0.50
TA	5.129246	0.402707	-0.051774	-0.004365	0.0	0.10
WS	4.585373	0.402707	-0.020537	-0.004414	0.0	0.10
LS	4.585373	0.402707	-0.020537	-0.004414	0.0	0.10
BE	5.129246	0.402707	-0.051774	-0.004365	0.0	0.10
SS	5.106086	0.036136	-0.000634	0.0	-0.010747	0.50
LP	4.935148	0.036136	-0.000850	0.0	-0.008488	0.50
RC	6.090056	0.036136	-0.000745	0.0	-0.005608	0.50
WH	5.120483	0.036136	-0.00105	0.0	-0.005131	0.50
MH	5.440943	0.036136	-0.000942	0.0	-0.005375	0.50
OS	4.585373	0.402707	-0.020537	-0.004414	0.0	0.10
AD	2.651991	0.402707	-0.011288	-0.002557	0.0	0.10
RA	2.987803	0.402707	-0.014038	-0.005462	0.0	0.10
PB	3.255821	0.402707	-0.018658	-0.007307	0.0	0.10
AB	3.255821	0.402707	-0.018658	-0.007307	0.0	0.10
BA	2.651991	0.402707	-0.011288	-0.002557	0.0	0.10
AS	2.833541	0.402707	-0.015719	-0.010755	0.0	0.10
CW	2.651991	0.402707	-0.011288	-0.002557	0.0	0.10
WI	2.651991	0.402207	-0.011288	-0.002557	0.0	0.10
SU	2.651991	0.402207	-0.011288	-0.002557	0.0	0.10
OH	2.651991	0.402207	-0.011288	-0.002557	0.0	0.10

The estimated annual survival rates are adjusted for the length of a projection cycle using a compound interest formula (Hamilton 1976). The adjusted survival rates are then converted to mortality rates as defined in equation {5.0.2} and then applied to the trees per acre represented by the tree record in a stand. If the stand density is above the maximum stand density index (or basal area maximum) after the rates are applied, the predicted mortality rates are reapplied to each tree record until the stand is below the maximum density.

$$\{5.0.2\} WKI = P * (1 - RIP^Y) * X$$

where:

<i>WKI</i>	is individual tree mortality rate adjusted to the length of the cycle
<i>P</i>	is trees per acre represented by the tree record
<i>RIP</i>	is annual individual tree survival rate
<i>Y</i>	is length of the current projection cycle in years
<i>X</i>	is any user-supplied mortality multipliers

6.0 Regeneration

The AK variant contains a full establishment model which is explained in section 5.4.2 of the Essential FVS Users Guide (Dixon 2002). In short, the full establishment model automatically adds regeneration from advanced, subsequent, and excess regeneration pools following significant stand disturbances and adds ingrowth absent of disturbance every 20 years. Automatic regeneration and ingrowth occurrence are based on the user-defined or calculated forest type for the stand. If a valid forest type is not found, no species are added. Species occurrence by valid forest type is found in table 6.0.1.

Table 6.0.1 Species occurrence by valid forest types resulting in automatic regeneration and ingrowth in the AK variant.

FIA Forest Type ¹	Description	Species included in automatic tallies and ingrowth
122	white spruce	TA, WS, BE, MH, PB, BA, AS
125	black spruce	TA, WS, BE, PB, BA, AS
270, 268	mountain hemlock	YC, WS, SS, LP, WH, MH
271	Alaska cedar	YC, SS, LP, RC, WH, MH, RA
281	lodgepole pine	YC, SS, LP, RC, WH, MH, RA
301, 264	western hemlock	YC, SS, LP, RC, WH, MH, RA
304	western redcedar	YC, SS, LP, RC, WH, MH, RA
305	Sitka spruce	YC, SS, RC, WH, MH, RA
703, 704, 709	cottonwood	WS, BE, SS, WH, PB, CW
901	aspen	TA, WS, BE, PB, BA, AS
902	paper birch	TA, WS, BE, SS, MH, PB, BA, AS
904	balsam poplar	TA, WS, BE, MH, PB, BA, AS
911	red alder	SS, WH, RA

¹First forest type listed was used to fit data and additional forest types listed are mapped to first.

There are thirteen steps to predicting and adding automatic regeneration and ingrowth to a simulation, see table 6.0.2. This process is based on probability equations that take into consideration stand and plot location (latitude); abiotic factors such as slope, aspect, and elevation; density; plot composition; and forest type random effects. Further description is beyond the scope of explanation offered in this overview.

Table 6.0.2 Key processes for predicting automatic regeneration and ingrowth in the AK variant.

Step	Description
1	initialize and replicate plots
2	perform calibration tasks
3	compute years since disturbance
4	calculate stocking and species probabilities

Step	Description
5	estimate the number of regenerating trees per plot
6	estimate the number of regenerating species per plot
7	pick species to occupy plots
8	estimate heights of best trees
9	add planted trees
10	identify best trees
11	accumulate plot statistics
12	pass regeneration to treelist
13	print regeneration summary

In addition to automatic regeneration and ingrowth, sprouts are added to the simulation following harvest or burning resulting in main stem loss of known sprouting species, see table 6.0.3 for sprouting species. Users may also input regeneration and ingrowth into simulations manually through establishment model keywords as explained in section 5.4.3 of the Essential FVS Users Guide (Dixon 2002). The following description applies to how sprouting occurs and entering regeneration and ingrowth through keywords.

Table 6.0.3 Regeneration parameters by species in the AK variant.

Species Code	Sprouting Species	Minimum Bud Width (in)	Minimum Tree Height (ft)	Maximum Tree Height (ft)
SF	No	0.3	1.0	20.0
AF	No	0.3	0.5	20.0
YC	No	0.3	0.5	12.0
TA	No	0.2	0.5	13.0
WS	No	0.4	0.5	13.0
LS	No	0.4	0.5	13.0
BE	No	0.2	0.5	13.0
SS	No	0.4	0.5	20.0
LP	No	0.4	1.0	9.0
RC	No	0.3	0.5	15.0
WH	No	0.3	0.5	19.0
MH	No	0.3	0.5	10.0
OS	No	0.4	0.5	13.0
AD	Yes	0.2	1.0	7.6
RA	Yes	0.2	1.0	30.0
PB	Yes	0.1	1.0	20.0
AB	Yes	0.1	1.0	20.0
BA	Yes	0.2	1.0	16.9
AS	Yes	0.3	1.0	18.0
CW	Yes	0.2	1.0	16.9

WI	Yes	0.1	1.0	7.6
SU	Yes	0.1	1.0	11.0
OH	No	0.2	1.0	7.6

Logic rule {6.0.1} is used to determine the number of sprout records for balsam poplar and black cottonwood, two sprout records are created for quaking aspen, and one sprout record is created for all other species. The trees-per-acre represented by each sprout record is determined using general sprouting probability equation {6.0.2} and probability of sprouting equations in {6.0.3} through {6.0.7}. See table 6.0.4 for species-specific sprouting probabilities 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 6.0.3 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} Number of sprout records

$$DSTMP_i < 5: NUMSPRC = 1$$

$$5 \leq DSTMP_i < 10: NUMSPRC = NINT(-1.0 + 0.4 * DSTMP_i)$$

$$DSTMP_i \geq 10: NUMSPRC = 3$$

{6.0.2} $TPA_s = TPA_i * PS$

{6.0.3} Probability of sprouting

$$DSTMP_i < 25.9: PS = ((99.9999 - 3.8462 * DSTMP_i) / 100),$$

$$DSTMP_i \geq 25.9: PS = 0.$$

{6.0.4} Probability of sprouting

$$DSTMP_i < 6.0: PS = 0.92$$

$$6.0 \leq DSTMP_i < 9.0: PS = -0.1333 * DSTMP_i + 1.70$$

$$DSTMP_i \geq 9.0: PS = 0.50$$

{6.0.5} Probability of sprouting

$$DSTMP_i < 6.25: PS = 0.39$$

$$6.25 \leq DSTMP_i < 8.75, PS = 0.32$$

$$DSTMP_i \geq 9.0: PS = 0.25$$

{6.0.6} Probability of sprouting

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

{6.0.7} Probability of sprouting

$$PS = 0.90$$

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 AK variant.

Species Code	Sprouting Probability	Source
AD, RA	{6.0.3}	Harrington (1984) Uchytel (1989)
PB, AB	{6.0.4}	Hutnik and Cunningham (1965) Bjorkbom (1972)
BA, CW	{6.0.5}	Zasada (1981)
AS	{6.0.6}	Keyser (2001)
WI, SU	{6.0.7}	Burns and Honkala (1990)

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

Seedlings 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 6.0.3. 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 AK 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 merchantability standards and equation numbers for the AK variant are shown in tables 7.0.1 – 7.0.3.

Table 7.0.1 Volume merchantability standards by location code for the AK variant. Stump Height is set to 1.0 foot.

Location Code	Merchantable Cubic Foot (Minimum DBH / Top Diameter)	Merchantable Board Foot (Minimum DBH / Top Diameter)
713	6.0 / 4.0 inches	9.0 / 6.0 inches
703, 1002, 1003, 1005, 8134, 8135, 8112	9.0 / 7.0 inches	9.0 / 7.0 inches
1004	9.0 / 6.0 inches	9.0 / 6.0 inches
720, 7400, 7401, 7402, 7403, 7404, 7405, 7406, 7407, 7408	5.0 / 4.0 inches	9.0 / 6.0 inches

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

Species Code	Volume Category¹	Equation Number²	Model Name
SF	1	A00F32W260	Flewelling Profile-32ft Log Rule
SF	2	A01DEMW000	Demars Profile Model
AF	1	A00F32W260	Flewelling Profile-32ft Log Rule
AF	2	A01DEMW000	Demars Profile Model
YC	1	A00F32W042	Flewelling Profile-32ft Log Rule
YC	2	A00DVEW094	Larson Volume Equation
TA	1,2	A00DVEW094	Larson Volume Equation
WS	1,2	A00DVEW094	Larson Volume Equation
LS	1,2	A00DVEW094	Larson Volume Equation
BE	1,2	A00DVEW094	Larson Volume Equation
SS	1,2	A00F32W098	Flewelling Profile-32ft Log Rule
LP	1	A00F32W260	Flewelling Profile-32ft Log Rule
LP	2	A01DEMW000	Demars Profile Model
RC	1	A00F32W242	Flewelling Profile-32ft Log Rule
RC	2	A01DEMW000	Demars Profile Model
WH	1,2	A00F32W260	Flewelling Profile-32ft Log Rule
MH	1	A00F32W260	Flewelling Profile-32ft Log Rule

Species Code	Volume Category ¹	Equation Number ²	Model Name
MH	2	A01DEM000	Demars Profile Model
OS	1,2	A00DVEW094	Larson Volume Equation
AD	1,2	A00DVEW747	Larson Volume Equation
RA	1,2	A32CURW351	Curtis Profile Model-32ft Log Rule
PB	1,2	A00DVEW375	Larson Volume Equation
AB	1,2	A00DVEW375	Larson Volume Equation
BA	1,2	A00DVEW747	Larson Volume Equation
AS	1,2	A00DVEW375	Larson Volume Equation
CW	1,2	A00DVEW747	Larson Volume Equation
WI	1,2	A00DVEW747	Larson Volume Equation
SU	1,2	A00DVEW747	Larson Volume Equation
OH	1,2	A00DVEW747	Larson Volume Equation

¹ Volume category 1 location codes: 703, 1002, 1003, 1005, 8112, 8134, 8135. Volume category 2 location codes: 713, 720, 1004, 7400, 7401, 7402, 7403, 7404, 7405, 7406, 7407, 7408.

²Additional equation numbers are available using the VOLEQNUM keyword.

Table 7.0.3 Citations by Volume Model.

Model Name	Citation
Curtis Profile Model-32ft Log Rule	Curtis, Robert O, David Bruce, and Caryanne VanCoevering. 1968. Volume and Taper Tables for Red Alder. Pacific Northwest Forest and Range Exp. Sta. Research Paper PNW-56.
Demars Profile Model	Bruce, D., 1984. Volume estimators for Sitka spruce and western hemlock in coastal Alaska. In Inventorying forest and other vegetation of the high latitude and high altitude regions. SAF pub 84-11. Bethesda, MD. pp. 96-102.
Flewelling Profile-32ft Log Rule	Unpublished. Based on work presented by Flewelling and Raynes. 1993. Variable-shape stem-profile predictions for western hemlock. Canadian Journal of Forest Research Vol 23. Part I and Part II.
Larson Volume Equation	Larson, Frederic R. and Kenneth C Winterberger. 1988. Tables and Equations for Estimating Volumes of trees in the Susitna River Basin, Alaska. Pacific Northwest Research Station Research Note PNW-478.

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 AK variant, refer to the updated FFE-FVS model documentation (Rebain, comp. 2010) available on the FVS website.

9.0 Insect and Disease Extensions

The FVS Insect and Pathogen model for dwarf mistletoe has been developed for the AK variant through the participation and contribution of various organizations led by Forest Health Protection. This model is currently maintained by the Forest Management Service Center and regional Forest Health Protection specialists. Additional details regarding this model may be found in chapter 8 of the Essential FVS Users Guide (Dixon 2002).

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11.0 Appendices

There are no appendices to the AK variant.

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