

Appendices

Appendix 1 Full CGNF Tree – Step by Step Example

This appendix will demonstrate how to calculate the volume for a tree using Kozak's taper equation, and will provide the associated regression coefficients and inflexion points. The volume is calculated for three sections of the tree. Section 1 is the stump, section two is the merchantable volume, and section 3 is the top of the tree. Hence, by applying these steps, both the total biological volume and the merchantable volume are calculated.

The merchantable portion of the tree is between the stump height and the height where the merchantability requirement top diameter is achieved. This portion is divided into logs based on the cruiser's selection of preferred lengths up to the merchantable top.

The last merchantable log is generally shorter than the other logs. If the last log is less than the minimum allowable length for the grade of the log, then its length and volume is added to the second to last log. The grade of the last log will take on the grade of the second to last log and the net factors are combined and weighted based on the log lengths.

There are two equations that must be used in order to determine the volume of the tree. The first is the taper equation, used to determine the diameter inside bark at a specified height above the ground. The second equation calculates the volume of a log given an upper and lower height above the ground, with associated diameters.

Taper Equation

$$d_i = a_1 D^{a_2} a_3^D X^{exp}$$

Where:

d_i = diameter inside bark in cm at height h_i from the ground

exp = $a_4 z^2 + a_5 \ln(z + 0.001) + a_6 \sqrt{z} + a_7 (D/H) + a_8 e^z$

D = diameter at breast height in cm

X = $(1 - \sqrt{h_i/H}) / (1 - \sqrt{p})$

H = total height of tree in meters

h_i = height from ground in meters

z = h_i/H

p = inflection point, see the end of this Appendix

$a_1...a_8$ = regression coefficients, see the end of this Appendix

$\ln$ = natural logarithm

e = 2.718281828

Volume Calculation

The CGNF compiler uses Smalian's formula for calculating log volumes. To derive a tree's merchantable volume, calculate and accumulate each individual log's volume.

Calculation of Log Volumes

The log is first cut into smaller segments and the volume of each segment is calculated and summed. The segment length used is 10 cm.

The "i" subscript in the following formulas refers to a segment's attribute.

$$Vl = \sum_{i=1}^n Vs_i \quad \text{Volume of the Log in m}^3$$

$$Vs_i = \frac{Ab_i + At_i}{2} \times Ls \quad \text{Volume of a segment, using Smalian's Formula in m}^3$$

$$Ls = \frac{L}{n} \quad \text{Segment Length in m}$$

$$A = \frac{D^2 \times \pi}{4} \quad \text{Cross section Area in m}^2$$

Where:

Vl = Log Volume (m³)

Vs = Volume of a Segment (m³)

Ab = Area of the Segment's Top (m²)

Ls = Segment Length (m)

L = Log Length (m)

n = Number of Segments in a Log

D^2 = Diameter squared (m)

A = Cross section area (m²)

Last Log Logic:

If the last log in a tree is shorter than the minimum for the species and grade assigned, then the last log is combined with the second to last log and assigned the second to last log's grade. The log lengths are combined, the net factors are combined and weighted by the log's length. See Appendix 1, step 2.3 and 2.4.

Steps for Calculating the Volume of a Tree

An example of the volume calculations for a single tree is given. Please refer to Appendix 2 for log grade validations, Appendix 3 for CGNF breakage tables, and Appendix 4 for net volume adjustment factors.

Example #1:

The tree parameters are:

Species:	Cypress
DBH:	110.0 cm
Total Height:	41.0 m
F.I.Z.	C
Stump Height:	30 cm
Top Diameter:	15.0 cm
Maturity:	Mature
Live/Dead:	Live

The log parameters are (as recorded by the cruiser):

Log #	Grade	Log len (m)	Net factor (%)
1	Z	1	100
2	D	8	100
3	H	13	90
4	U	11	93
5	X	99*	70

* A “99” log length instructs the compiler program to extend the length of the last log up to the merch height of the tree (to the utilization limit).

Step 1 Look up the appropriate regression coefficients, a_1 , a_2 , a_8 and the inflection point, p . These parameters are dependent on species and Forest Inventory Zone. They are provided in the tables in the back of this Appendix.

Cypress taper parameters for FIZs A, B and C are:

$$p = 0.30$$

$$a_1 = 0.928138$$

$$a_2 = 0.945293$$

$$a_3 = 0.999206$$

$$a_4 = 0.301423$$

$$a_5 = -0.040792$$

$$a_6 = -1.235630$$

$$a_7 = 0.030743$$

$$a_8 = 0.672879$$

Step 2 Determine the biological and gross merchantable volume.

2.1 Calculate the diameter inside bark at stump height using the taper equation. Substitute the stump height for h_i (if the resultant diameter is less than the specified top diameter, return 0 volume).

Solve the taper equation using 0.3 m as h_i (only 9 decimal places are shown).

$$\begin{aligned}
 X &= (1 - \sqrt{0.3/41.0}) / (1 - \sqrt{0.3}) \\
 &= (0.914460107...) / (0.452277442) \\
 &= 2.021900767 \\
 \text{Exp} &= a_4 z^2 + a_5 \ln(z + 0.001) + a_6 \sqrt{z} + a_7(D/H) + a_8 e^z \\
 &= 0.301423(0.30 / 41.0)^2 - 0.040792 \ln((0.30 / 41.0) + 0.001) \\
 &\quad - 1.235630 \sqrt{0.3/41} + 0.030743(110.0 / 41.0) \\
 &\quad + 0.672879(2.718281828)^{0.30/41.0} \\
 &= 0.84999330 \\
 d_{30} &= (0.928138(110.0)^{0.945293})(0.999206)^{110.0}(2.02190)^{0.84999330} \\
 &= 131.61 \text{ cm}
 \end{aligned}$$

2.2 Calculate the merchantable height of the tree.

There are many ways to find the solution for the merchantable height. However, all methods use a binary search to iterate the proportion of the height at which merch height occurs. This method starts by substituting 0.9 (proportion of the total height to estimate the merch height) into the 'z0' variable in the exp equation calculated in step 2.1 above. Once the exp variable is calculated, it is substituted into the taper equation for (h_i/H). This provides a new estimate of the proportion h_i/H at the merch ht. The first estimated proportion is compared to the new estimated proportion. When the two proportions are less than 0.00001 different, then the iteration ends. This proportion is multiplied by the total height of the tree to obtain the merchantable height.

- a. Start $h_i/H = z_0 = 0.9$

Substitute 0.9 into the formula:

$$\begin{aligned}
 \text{Exp} &= a_4 z_0^2 + a_5 \ln(z_0 + 0.001) + a_6 \sqrt{z_0} + a_7(D/H) + a_8 e^{z_0} \\
 &= 0.301423(0.9)^2 - 0.040792 \ln((0.9) + 0.001) \\
 &\quad - 1.235630 \sqrt{0.9} + 0.030743(110.0 / 41.0)
 \end{aligned}$$

$$+ 0.672879(2.718281828)^{0.9}$$

$$= 0.81368015$$

- b. Substitute exp into the taper formula and solve for proportion $h_i/H = z_1$

$$z_1 = [1 - ((d_i / (a_1 * D^{a_2} * a_3^D))^{1/exp}) * (1 - \sqrt{p})]^2$$

$$= [1 - ((15 / (0.928138 * (110.0)^{0.945293} *$$

$$0.999206^{110.0}))^{1/0.81368015}) * (1 - \sqrt{0.3})]^2$$

$$= 0.87345586$$

- c. Compare results of z_0 with z_1 . Subtract one proportion from the other. If the result is < 0.00001 and number of iterations is $< 10,000$ then stop the iteration.

$$= 0.9 - 0.87345586$$

$$= 0.026544$$

- d. Since the result of the test was > 0.00001 , therefore, continue iteration by halving the estimate of the proportion until result is < 0.00001 .

$$\text{New } z_0 = (z_0 + z_1) / 2$$

$$= (0.9 + 0.87345586) / 2$$

$$= 0.88672793$$

- e. Continue back to step 2.2.a until the test results in < 0.00001 .

Here are the results of the iteration until a solution was found:

exp	z0	z1	z0-z1 (<0.00001)	
0.813680155		0.9	0.87345587	0.026544
0.793992663	0.886727934		0.87918892	0.007539
0.788486514	0.882958425		0.88079644	0.002162
0.786914461	0.881877432		0.88125569	0.000622
0.786462942	0.881566559		0.88138761	0.000179
0.786333036	0.881477085		0.88142557	0.000052
0.786295642	0.881451327		0.88143650	0.000015
0.786284877	0.881443912		0.88143964	0.000004

$$z_0 - z_1 = 0.881443912 - 0.88143964 = 0.000004 < 0.00001$$

Therefore, the iteration can stop.

- f. Solve for merchantable height.

$$\begin{aligned}\text{Merchantable height} &= \text{last } z0 * \text{Total height} \\ &= 0.881443912 * 41.0 \\ &= 36.139 \text{ m} \\ &= 36.1 \text{ m}\end{aligned}$$

- 2.3 Calculate the length of the last log. Use this calculation even when a cruiser calls a length for the top log instead of 99.

Last log = merch. Height – (sum of log lengths) – stump height.

$$\begin{aligned}\text{Last log} &= 36.14 - (1+8+13+11) - 0.30 \\ &= 3.14 - 0.30 \\ &= 2.84 \text{ m for last log of grade X}\end{aligned}$$

If the last log is less than the minimum log length for the species and grade, then append it to the second to last log.

For this example, since the last log is shorter than the minimum log length of 5.0m for X grade Yellow Cedar, the last log must be combined with the second to last log.

The last log now becomes 13.84m of U grade. There are now only 4 merchantable logs for this tree. Note: The remainder of the example will use only 4 logs in the calculations.

- 2.4 Calculate the new net factor for the last log ONLY if the last log is combined with the second to last log.

The log parameters are:

Log #	Grade	Log len (m)	Net factor (%)
1	Z	1	100
2	D	8	100
3	H	13	90
4	U	11	93
5	X	2.84	70

To calculate a new net factor for log # 4, simply weight the net factor of log # 4 and log # 5 by the log length of each and combine.

$$\text{New Net Factor for log 4} = \text{log 4 NF} * \text{log 4 len} / \text{sum (log 4\&5) +}$$

$$\log 5 \text{ NF} * \log 5 \text{ len/sum (log 4\&5)}$$

$$= 93\%*(11/13.84) + 70\%*(2.84/13.84)$$

$$\text{NF log 4} = 88.3\%$$

Log #	Grade	Log len (m)	Net factor (%)
1	Z	1	100
2	D	8	100
3	H	13	90
4	U	13.84	88.3
5	Combined with log 4		

- 2.5 Calculate the top diameter of each merchantable log using the taper equation.

Consider a tree with four merchantable logs, with the following top heights and top diameters. See Step 2.1 above, for example of top diameter calculation.

Log #	Grade	Log len (m)	Top Diameter
1	Z	1	109.69
2	D	8	76.87
3	H	13	56.81
4	U	13.84	15.00
5	Combined with log 4		

- 2.6 Calculate the volume of the log using Smalian's volume equation, using 10cm segments.

Gross Merch volume of a Single Log - Use the taper equation to determine the 10 diameters for log # 1- grade Z, 1m length.

Position	h_i	d_i - taper equation	Area (m^2)	Gross Volume (m^3)
stump	0.3 m	131.60 cm	1.3603	-
1	0.4 m	127.75 cm	1.2817	0.1321
2	0.5 m	124.60 cm	1.2193	0.1250
3	0.6 m	121.92 cm	1.1674	0.1193
4	0.7 m	119.59 cm	1.1232	0.1145
5	0.8 m	117.52 cm	1.0848	0.1104
6	0.9 m	115.67 cm	1.0508	0.1068
7	1.0 m	113.98 cm	1.0204	0.1036
8	1.1 m	112.44 cm	0.9929	0.1007
9	1.2 m	111.01 cm	0.9679	0.0980
10	1.3 m	109.69 cm	0.9450	0.0956

Volume of Log # 1: sum each 10cm segment of the log for volume.

$$\begin{aligned}
 \text{Vol Log}_1 = & \text{Section 1 length} * (\text{Area (stump dia)} + \text{Area section 1}) / 2 + \\
 & \text{Section 2 length} * (\text{Area (section 1 dia)} + \text{Area section 2}) / 2 + \\
 & \text{Section 3 length} * (\text{Area (section 2 dia)} + \text{Area section 3}) / 2 + \\
 & \text{Section 4 length} * (\text{Area (section 3 dia)} + \text{Area section 4}) / 2 + \\
 & \text{Section 5 length} * (\text{Area (section 4 dia)} + \text{Area section 5}) / 2 + \\
 & \text{Section 6 length} * (\text{Area (section 5 dia)} + \text{Area section 6}) / 2 + \\
 & \text{Section 7 length} * (\text{Area (section 6 dia)} + \text{Area section 7}) / 2 + \\
 & \text{Section 8 length} * (\text{Area (section 7 dia)} + \text{Area section 8}) / 2 + \\
 & \text{Section 9 length} * (\text{Area (section 8 dia)} + \text{Area section 9}) / 2 + \\
 & \text{Section 10 length} * (\text{Area (section 9 dia)} + \text{Area section 10}) / 2
 \end{aligned}$$

$$\text{Vol Log}_1 = 0.1 * (1.3603 + 1.2817) / 2 +$$

$$0.1 * (1.2817 + 1.2193) / 2 +$$

$$0.1 * (1.2193 + 1.1674) / 2 +$$

$$0.1 * (1.1674 + 1.1232) / 2 +$$

$$0.1 * (1.1232 + 1.0848) / 2 +$$

$$0.1 * (1.0848 + 1.0508) / 2 +$$

$$0.1 * (1.0508 + 1.0204) / 2 +$$

$$0.1 * (1.0204 + 0.9929) / 2 +$$

$$0.1 * (0.9929 + 0.9679) / 2 +$$

$$0.1 * (0.9679 + 0.9450) / 2$$

Vol Log 1 = 1.1061 m³

Summary of volume by log:

Log Position	Grade	Length (m)	hi (m)	Butt Dia (cm)	Top Dia (cm)	Gross Volume (m ³)
1	Z	1	1.3	131.61	109.69	1.1061
2	D	8	9.3	109.69	76.87	4.9096
3	H	13	22.3	76.87	56.81	4.6556
4	U	13.84	36.14	56.81	15.00	1.7283
Gross Merch Vol						12.4000

- 2.7a Calculate the biological volume. Calculate the stump volume and top volumes and then sum with the gross merchantable volume.

If the stump height ≤ 30 cm, then:

$$\frac{\text{Stump volume}}{(30\text{cm \& below})} = C * d_{30}^2 * (\text{stump height})$$

Where $C = 0.00007854$

d_{30} = diameter at 30 cm

$$\text{Stump volume} = (0.00007854) * (0.30) * (131.60)^2 = 0.4081 \text{ m}^3$$

If the stump height is greater than 30 cm, then calculate the stump volume below 30 cm as shown above. Then, apply the appropriate log volume equation using the lower bound parameters (30 cm, d_{30}) and the upper bound parameters (stump height, diameter at stump height).

- 2.7b Calculate the top volume

Apply the same log volume equation as used in the merchantable log calculation. The lower parameters of merch. height and top diameter of 15cm and the upper bound parameters of total height and 0.0cm would be used. The section length would continue in 10cm segments until the top of the tree was reached.

The top log length is $41.0 - 36.14 = 4.86$ m. The total volume of the tip would be 0.0266 m³.

- Step 3 Determine the biological and gross merchantable volume.

Apply net downs. Cruiser estimated net factors by log for decay volume, cruiser called Z grades for waste volume, CGNF lookup table for breakage volume, and NVAF corrections from CGNF process.

For a list of the terms used in the following calculations see *Chapter 3, step 3*.

For the net down example, log # 3 will be used:

H grade, NF = 90%, Gross vol = 4.6556m³.

- 3.1 For each log, calculate the log breakage volume. Use the CGNF breakage % table by species, and maturity. The NVAF process did not include breakage volume, therefore, the breakage volume must be taken out before the remainder of the volume is adjusted. See

Appendix 3 for the CGNF breakage table.

$$B_i = V_i \times Fb$$

$$\text{Breakage volume} = 4.6556 * 7\% = 0.3259 \text{ m}^3$$

Calculate log gross volume minus breakage.

$$VmB_i = V_i(1 - Fb)$$

The breakage factor for Yellow Cedar is 7%.

$$\text{Gross volume minus breakage} = \text{Gross volume} * (1 - 7\%)$$

$$= 4.6556 * (93\%)$$

$$= 4.3297 \text{ m}^3$$

- 3.3 Apply the taper correction factor. The taper correction is used to correct the known bias in the gross volume of taper equations. These factors are corrected by species, maturity and live/dead. See Appendix 4 for the NVAF adjustment table.

$$VmBc_i = VmB_i \times Ft$$

The taper adjustment factor for live Yellow Cedar is: 1.050

Gross Volume minus breakage after taper correction

$$= \text{Gross volume minus breakage} * \text{taper correction factor.}$$

$$= 4.3297 \text{ m}^3 * 1.050$$

$$= 4.5462 \text{ m}^3$$

- 3.4 Calculate the corrected gross volume.

$$Vc_i = VmBc_i + B_i$$

Gross volume after correction

$$= \text{Gross Volume minus breakage after taper correction} + \text{breakage volume}$$

$$= 4.5462 \text{ m}^3 + 0.3259 \text{ m}^3$$

$$= 4.8720 \text{ m}^3$$

- 3.5 Calculate the tree decay factor. Take the average of all the log's net factors weighted by the sum of each log's gross volume minus breakage after taper correction calculated in step 3.3 above.

$$Fd = \frac{\sum_{i=1}^n (Fd_i \times VmBc_i)}{\sum_{i=1}^n VmBc_i}$$

$$= (100\% * 1.0801) + (100\% * 4.7943) + (90\% * 4.5462) + (88.3\% * 1.6876) / 12.1082 \text{ m}^3$$

$$= 11.45613 \text{ m}^3 / 12.1082 \text{ m}^3$$

$$= 94.6\%$$

- 3.6 Correct the tree decay factor using the NVAF coefficients

$$Fdc = Fr \times Fd^{Fp}$$

Fr = NVAF correction ratio = 0.954 for live Yellow Cedar

Fp = NVAF correction power = 1.270 for live Yellow Cedar

NVAF corrections are found in *Appendix 4*.

NVAF corrected Net factor

$$= \text{NVAF correction ratio} * \text{tree decay factor}^{\text{NVAF correction}}$$

$$= 0.954 * 94.6\%^{1.270}$$

$$= 88.9\%$$

- 3.7 Calculate the adjusted decay factor by the NVAF factor. This is the net corrected volume for all logs except Z grade logs. For Z grade logs, the VmBDC_i is the waste volume.

$$VmBDC_i = VmBc_i \times Fd_i \times \frac{Fdc}{Fd}$$

Gross vol corrected minus breakage and decay volume =

Gross vol corrected minus breakage volume * NF%log3 * correction

Decay factor/ cruiser's estimate of net %

$$= 4.5462 \text{ m}^3 * 90\% * 88.9\% / 94.6\%$$

$$= 3.8454 \text{ m}^3 -$$

- 3.8 Calculate the decay volume

$$D_i = VmBc_i \times (1 - (Fd_i \times \frac{Fdc}{Fd}))$$

Decay corrected volume = Gross vol corrected minus breakage vol *

(1- (NF% log3 * corr Decay factor / cruiser's estimate of net %))

$$= 4.5462 \text{ m}^3 * (1 - (90\% * 88.9\% / 94.6\%))$$

$$= 4.5462 \text{ m}^3 * (0.1542)$$

$$= 0.7008 \text{ m}^3$$

Note: Data as presented has been rounded for summary purposes. The final value is calculated based on the full intermediate significant figures (see Appendix 16 of the *Cruise Compilation Manual*).

- 3.9 Calculate the waste volume. (Only logs in the tree with “Z” grade)

$$Vw_i = VmBDC_i$$

$$Vn_i = 0$$

otherwise:

$$Vw_i = 0$$

$$Vn_i = VmBDC_i$$

If the log is a Z grade, the VmBDC = waste volume.

If the log is any grade except N or Z then the VmBDC = net volume.

Note that N contributes to the decay/missing wood volume and Z contributes to the waste component.

- 3.10 Calculate the net volume. (Gross volume corrected – DWB volumes)

$$Vn = \sum_{i=1}^n Vn_i$$

Note – the volumes in these tables are summed for all trees and reported as a percentage of the total volume by species, coniferous and all species.

Log Position	Grade	Length (m)	Gross Volume (m ³)	Gross Volume Corr. (m ³)	Decay Volume Corr. (m ³)	Waste Volume Corr. (m ³)	Breakage Volume Uncorr. (m ³)	Net Volume Corr. (m ³)
1	Z	1	1.1061	1.1575	0.0650	1.0151	0.0774	0.0000
2	D	8	4.9096	5.1379	0.2884		0.3437	4.5058
3	H	13	4.6556	4.8720	0.7008		0.3259	3.8454
4	U	13.84	1.7283	1.8086	0.2874		0.1210	1.4002
Totals		35.84	12.3996	12.9761	1.3416	1.0151	0.8680	9.7515

Example 2: Specifically designed for trees that contain N grade logs (missing sections in a tree).

The tree parameters are:

Species:	Douglas-fir
DBH:	89.6 cm
Total height:	36.9 m
F.I.Z.	C
Stump height:	30 cm
Top diameter:	15.0 cm
Maturity:	Mature
Live/Dead:	Dead

The log parameters are (as recorded by the cruiser):

Log #	Grade	Log Length (m)	Net Factor (%)
1	N*	1	00
2	H	8	95
3	I	7	98
4	N*	3	00
5	U	11	89
6	N*	99**	00

* an N grade indicates that the log is missing and therefore, no volume is present. The N grade can be any log length as shown in this example.

** a 99 log length instructs the compiler program to extend the length of the last log up to the merch height of the tree (to the utilization limit).

Douglas-fir taper parameters for FIZs A, B and C are:

Step 1 Look up the appropriate regression coefficients, a_1 , a_2 , a_8 and the inflection point, p . These parameters are dependent on species and Forest Inventory Zone. They are provided in the tables in the back of this Appendix.

p	= 0.25
a_1	= 1.012675
a_2	= 0.899136
a_3	= 1.000123
a_4	= 0.968978
a_5	= -0.190913
a_6	= 0.825961
a_7	= 0.048766
a_8	= -0.426214

Step 2 Determine the biological and gross merchantable volume.

2.1 Calculate the diameter inside bark at stump height using the Taper equation. Substitute the stump height for h_i (if the resultant diameter is less than the specified top diameter, return 0 volume).

$$d_{30} = 86.54 \text{ cm}$$

- 2.2 Calculate the merchantable height of the tree.

$$\text{Merchantable height} = 32.57\text{m}$$

- 2.3 Calculate the length of the last log. Use this calculation even when a cruiser calls a length for the top log instead of 99.

$$\text{Last log} = \text{merch. Height} - (\text{sum of log lengths}) - \text{stump height}$$

$$\text{Last log}$$

$$= 32.57 - (8+1+7+3+11) - 0.30$$

$$= 2.57 - 0.30$$

$$= 2.27 \text{ m for last log of grade N}$$

If the last log is less than the minimum log length for the species and grade, then append it to the second to last log.

For this example, since the last log is longer than the minimum log length of 0.0m for N grade Douglas-fir, the last log remains the last log.

There remains 6 merchantable logs for this tree.

- 2.4 Calculate the new net factor for the last log ONLY if the last log is combined with the second to last log.

Since the last logs remains as the last log, this step is not required.

- 2.5 Calculate the top diameter of each merchantable log using the taper equation.

Log #	Grade	Log len (m)	Top Diameter
1	N	1	73.11
2	H	8	58.22
3	I	7	50.71
4	N	1	46.42
5	U	11	21.77
6	N	2.27	15.00

- 2.6 Calculate the volume of the log using Smalian's volume equation, using 10cm segments.

Gross Merch volume of a Single Log - Use the taper equation to determine the 10 diameters for log # 1- grade N, 1m length.

Position	h_i	d_i - taper equation	Area (m^2)	Gross Volume (m^3)
stump	0.3 m	86.54 cm	0.5881	-
1	0.4 m	83.72 cm	0.5505	0.0569
2	0.5 m	81.59 cm	0.5228	0.0537
3	0.6 m	79.88 cm	0.5012	0.0512
4	0.7 m	78.47 cm	0.4836	0.0492
5	0.8 m	77.27 cm	0.4689	0.0476
6	0.9 m	76.23 cm	0.4564	0.0463
7	1.0 m	75.32 cm	0.4456	0.0451
8	1.1 m	74.51 cm	0.4360	0.0441
9	1.2 m	73.77 cm	0.4275	0.0432
10	1.3 m	73.11 cm	0.4198	0.0424

Volume of Log # 1: sum each 10cm segment of the log for volume = $0.4796 m^3$.

Summary of volume by log:

Log Position	Grade	Length (m)	hi (m)	Butt Dia (cm)	Top Dia (cm)	Gross Volume (m ³)
1	N*	1	1.3	86.54	73.11	0.4796
2	H	8	9.3	73.11	58.22	2.5357
3	I	7	16.3	58.22	50.71	1.6449
4	N*	3	19.3	50.71	46.42	0.5578
5	U	11	30.3	46.42	21.77	1.1214
6	N*	2.27	32.57	21.77	15.00	0.0612
Gross Merch Vol						6.4007

* N grade logs are portions missing from the tree. CGNF procedures do not separate the procedures for calculating missing wood and decay volume. Logs with missing wood (scars, mechanical damage), catfaces with missing wood, and logs with large hollow bores are net factored. Net factoring, technically is a process that removes decay volume from the gross volume of the log. In order to be consistent with this process, N grade logs' gross merchantable volume will be reported as full gross merchantable volume. A net factor of zero will be assigned to these logs so that net volume is zero. The procedure for dealing with missing wood versus decay volume may be reviewed in the future.

- 2.7a Calculate the biological volume. Calculate the stump volume and top volumes and then sum with the gross merchantable volume.

$$\text{Stump volume} = (0.00007854) * (0.30) * (86.54)^2 = 0.1764 \text{ m}^3$$

- 2.7b Calculate the top volume

Apply the same log volume equation as used in the merchantable log calculation. The lower parameters of merch. height and top diameter

of 15cm and the upper bound parameters of total height and 0.0cm would be used. The section length would continue in 10cm segments until the top of the tree was reached.

The top log length is $36.9 - 32.57 = 4.33$ m. The total volume of the tip would be 0.0291 m^3 .

Step 3 Apply net downs. Cruiser estimated net factors by log for decay volume, cruiser called Z grades for waste volume, CGNF lookup table for breakage volume, and NVAF corrections from CGNF process.

For a list of the terms used in the following calculations see Chapter 3, step 3.

For the net down example, log # 4 will be used:

N grade, NF = 00%, Gross vol = 0.5578 m^3 .

3.1 For each log, calculate the log breakage volume. Use the CGNF breakage % table by species, and maturity. The NVAF process did not include breakage volume, therefore, the breakage volume must be taken out before the remainder of the volume is adjusted. See *Appendix 3* for the CGNF breakage table.

$$B_i = V_i \times Fb$$

$$\text{Breakage volume} = 0.5578 * 5\% = 0.0279 \text{ m}^3$$

3.2 Calculate log gross volume minus breakage.

$$VmB_i = V_i(1 - Fb)$$

The breakage factor for Douglas-fir is 5%.

$$\text{Gross volume minus breakage} = \text{Gross volume} * (1-5\%)$$

$$= 0.5578 * (95\%)$$

$$= 0.5299 \text{ m}^3$$

3.3 Apply the taper correction factor. The taper correction is used to correct the known bias in the gross volume of taper equations. These factors are corrected by species, maturity and live/dead. See *Appendix 4* for the NVAF adjustment table.

$$VmBc_i = VmB_i \times Ft$$

The Taper adjustment factor for dead Douglas-fir is: 0.855

Gross Volume minus breakage after taper correction.

$$= \text{Gross volume minus breakage} * \text{taper correction}$$

factor.

$$= 0.5299 \text{ m}^3 * 0.855$$

$$= 0.4531 \text{ m}^3$$

- 3.4 Calculate the corrected gross volume.

$$Vc_i = VmBc_i + B_i$$

Gross volume after correction.

= Gross Volume minus breakage after taper correction + breakage volume

$$= 0.4531 \text{ m}^3 + 0.0279 \text{ m}^3$$

$$= 0.4810 \text{ m}^3$$

- 3.5 Calculate the tree decay factor. Take the average of all the log's net factors weighted by each log's gross volume minus breakage after taper correction calculated in step 3.3 above.

$$Fd = \frac{\sum_{i=1}^n (Fd_i \times VmBc_i)}{\sum_{i=1}^n VmBc_i}$$

$$(0\% * 0.3896) + (95\% * 2.0596) + (98\% * 1.3361) + (0\% * 0.4531) / 5.1990 \text{ m}^3$$

$$= 4.0767 \text{ m}^3 / 5.1990 \text{ m}^3$$

$$= 78.4\%$$

- 3.6 Correct the tree decay factor using the NVAF coefficients.

$$Fdc = Fr \times Fd^{Fp}$$

Fr = NVAF correction ratio = 0.860 for dead Douglas-fir.

Fp = NVAF correction power = 1.000 for dead Douglas-fir.

NVAF corrections are found in Appendix 4.

NVAF corrected Net factor.

$$= \text{NVAF correction ratio} * \text{tree decay factor}^{\text{NVAF correction}}$$

$$= 0.860 * 78.4\%^{1.000}$$

$$= 67.4\%$$

- 3.7 Calculate the adjusted decay factor by the NVAF factor. This is the

net corrected volume for all logs except Z grade logs. For Z grade logs, the $VmBDc_i$ is the waste volume.

$$VmBDc_i = VmBc_i \times Fd_i \times \frac{Fdc}{Fd}$$

Gross vol corrected minus breakage and decay volume =.

Gross vol corrected minus breakage volume * NF%log4 * corrected.

Decay factor/ cruiser's estimate of net %.

$$= 0.4531 \text{ m}^3 * 0\% * 67.4\% / 78.4\%.$$

$$= 0.0000 \text{ m}^3$$

3.8 Calculate the decay volume:

$$D_i = VmBc_i \times (1 - (Fd_i \times \frac{Fdc}{Fd}))$$

Decay corrected volume = Gross vol corrected minus brk vol *

(1- (NF% log4 * corr Decay factor / cruiser's estimate of net %))

$$= 0.4531 \text{ m}^3 * (1 - (0\% * 67.4\% / 78.4\%))$$

$$= 0.4531 \text{ m}^3 * (1.0000)$$

$$= 0.4531 \text{ m}^3$$

Note: Data has been rounded for summary purposes. The final value is calculated based on intermediate significant figures (see Appendix 16 of the *Cruise Compilation Manual*).

3.9 Calculate the waste volume. (Only logs in the tree with “Z” grade).

Since log 4 is an N grade, there is no waste volume from log 4.

$$Vw_i = VmBDc_i$$

$$Vn_i = 0$$

otherwise:

$$Vw_i = 0$$

$$Vn_i = VmBDc_i$$

If the log is a Z grade, the $VmBDc$ = waste volume.

If the log is any other grade, except N then the $VmBDc$ = net volume.

3.10 Calculate the net volume (gross volume corrected – DWB volumes).

$$V_n = \sum_{i=1}^n V_{n_i}$$

Log Position	Grade	Length (m)	Gross Volume (m ³)	Gross Volume Corr. (m ³)	Decay Volume Corr. (m ³)	Waste Volume Corr. (m ³)	Breakage Volume Uncorr. (m ³)	Net Volume Corr. (m ³)
1	N	1	0.4796	0.4136	0.3896		0.0240	0.0000
2	H	8	2.5357	2.1864	0.3789		0.1268	1.6827
3	I	7	1.6449	1.4183	0.2100		0.0822	1.1260
4	N	3	0.5578	0.4180	0.4531		0.0279	0.0000
5	U	11	1.1214	0.9669	0.2137		0.0561	0.6972
6	N	2.27	0.0612	0.0528	0.0497		0.0031	0.0000
Totals		32.27	6.4007	5.4560	1.6950		0.3201	3.5059

Appendix 2 Log Grade Validations

Please see Section 2.2.3 for examples of errors and warnings associated with the tables in Appendix 2.

Douglas-fir (except heli-log = 4m):

Species	Grade	Min Log Len (m)	Min Top Dia (cm)	Max Top Dia (cm)	Min Net Factor (%)
F	B	5	60	9999	80
F	C	5	38	9999	80
F	D	5	76	9999	75
F	F	5	60	9999	75
F	H	5	38	50	75
F	H	5	50	9999	50
F	I	5	38	50	75
F	I	5	50	9999	50
F	J	5	15	38	75
F	U	5	38	9999	50
F	U	5	15	38	67
F	U	5	10	15	75
F	X	5	10	9999	33
F	Y	3	10	9999	10
F	N	1	10	9999	0
F	Z	1	10	9999	0

Cedar (except heli-log = 4m):

Species	Grade	Min Log Len (m)	Min Top Dia (cm)	Max Top Dia (cm)	Min Net Factor (%)
C	D	5	60	120	75
C	D	5	120	9999	67
C	F	5	50	9999	75
C	H	5	38	9999	75
C	I	5	38	50	75
C	I	10	50	9999	50
C	K	4	50	9999	50
C	L	4	38	9999	50
C	M	4	38	9999	50
C	J	5	15	38	75
C	U	5	38	9999	50
C	U	5	15	38	67
C	U	5	10	15	75
C	X	5	10	9999	33
C	Y	3	10	9999	10
C	N	1	10	9999	0
C	Z	1	10	9999	0

Hemlock (except heli-log = 4m):

Species	Grade	Min Log Len (m)	Min Top Dia (cm)	Max Top Dia (cm)	Min Net Factor (%)
H	D	5	66	9999	75
H	F	5	50	9999	75
H	H	5	38	9999	75
H	I	5	38	9999	50
H	J	5	15	38	75
H	U	5	38	9999	50
H	U	5	15	38	67
H	U	5	10	15	75
H	X	5	10	9999	33
H	Y	3	10	9999	10
H	N	1	10	9999	0
H	Z	1	10	9999	0

Balsam (except heli-log = 4m):

Species	Grade	Min Log Len (m)	Min Top Dia (cm)	Max Top Dia (cm)	Min Net Factor (%)
B	D	5	66	9999	75
B	F	5	50	9999	75
B	H	5	38	9999	75
B	I	5	38	9999	50
B	J	5	15	38	75
B	U	5	38	9999	50
B	U	5	15	38	67
B	U	5	10	15	75
B	X	5	10	9999	33
B	Y	3	10	9999	10
B	N	1	10	9999	0
B	Z	1	10	9999	0

Spruce (except heli-log = 4m):

Species	Grade	Min Log Len (m)	Min Top Dia (cm)	Max Top Dia (cm)	Min Net Factor (%)
S	F	5	76	9999	75
S	G	5	60	9999	75
S	H	5	38	9999	75
S	H	5	60	50	50
S	I	5	38	50	75
S	I	5	50	9999	50
S	J	5	15	38	75
S	U	5	38	9999	50
S	U	5	15	38	67
S	U	5	10	15	75
S	X	5	10	9999	33
S	Y	3	10	9999	10
S	N	1	10	9999	0
S	Z	1	10	9999	0

Cypress (except heli-log = 4m):

Species	Grade	Min Log Len (m)	Min Top Dia (cm)	Max Top Dia (cm)	Min Net Factor (%)
CY	D	5	60	9999	75
CY	F	5	50	9999	75
CY	H	5	38	9999	50
CY	I	5	38	9999	50
CY	J	5	15	38	75
CY	U	5	38	9999	50
CY	U	5	15	38	67
CY	U	5	10	15	75
CY	X	5	10	9999	33
CY	Y	3	10	9999	10
CY	N	1	10	9999	0
CY	Z	1	10	9999	0

White Pine (except heli-log = 4m):

Species	Grade	Min Log Len (m)	Min Top Dia (cm)	Max Top Dia (cm)	Min Net Factor (%)
PW	D	5	76	9999	75
PW	F	5	60	9999	75
PW	H	5	38	9999	75
PW	H	5	50	9999	50
PW	I	5	38	50	75
PW	I	5	50	9999	50
PW	J	5	15	38	75
PW	U	5	38	9999	50
PW	U	5	15	38	67
PW	U	5	10	15	75
PW	X	5	10	9999	33
PW	Y	3	10	9999	10
PW	N	1	10	9999	0
PW	Z	1	10	9999	0

Lodgepole Pine (except heli-log = 4m):

Species	Grade	Min Log Len (m)	Min Top Dia (cm)	Max Top Dia (cm)	Min Net Factor (%)
PL	D	5	76	9999	75
PL	F	5	60	9999	75
PL	H	5	38	50	75
PL	H	5	50	9999	50
PL	I	5	38	50	75
PL	I	5	50	9999	50
PL	J	5	15	38	75
PL	U	5	38	9999	50
PL	U	5	15	38	67
PL	U	5	10	15	75
PL	X	5	10	9999	33
PL	Y	3	10	9999	10
PL	N	1	10	9999	0
PL	Z	1	10	9999	0

Ponderosa Pine (except heli-log = 4m):

Species	Grade	Min Log Len (m)	Min Top Dia (cm)	Max Top Dia (cm)	Min Net Factor (%)
PY	D	5	76	9999	75
PY	F	5	60	9999	75
PY	H	5	38	50	75
PY	H	5	50	9999	50
PY	I	5	38	50	75
PY	I	5	50	9999	50
PY	J	5	15	38	75
PY	U	5	38	9999	50
PY	U	5	15	38	67
PY	U	5	10	15	75
PY	X	5	10	9999	33
PY	Y	3	10	9999	10
PY	N	1	10	9999	0
PY	Z	1	10	9999	0

Larch (except heli-log = 4m):

Species	Grade	Min Log Len (m)	Min Top Dia (cm)	Max Top Dia (cm)	Min Net Factor (%)
L	D	5	76	9999	75
L	F	5	60	9999	75
L	H	5	38	50	75
L	H	5	50	9999	50
L	I	5	38	50	75
L	I	5	50	9999	50
L	J	5	15	38	75
L	U	5	38	9999	50
L	U	5	15	38	67
L	U	5	10	15	75
L	X	5	10	9999	33
L	Y	3	10	9999	10
L	N	1	10	9999	0
L	Z	1	10	9999	0

Cottonwood (except heli-log = 4m):

Species	Grade	Min Log Len (m)	Min Top Dia (cm)	Max Top Dia (cm)	Min Net Factor (%)
AC	C	5	25	9999	80
AC	I	5	25	9999	50
AC	U	5	25	9999	50
AC	U	5	15	25	67
AC	U	5	10	15	75
AC	Y	3	10	9999	10
AC	N	1	10	9999	0
AC	Z	1	10	9999	0

Alder (except heli-log = 4m):

Species	Grade	Min Log Len (m)	Min Top Dia (cm)	Max Top Dia (cm)	Min Net Factor (%)
D	I	5	25	9999	50
D	U	5	25	9999	50
D	U	5	15	25	67
D	U	5	10	15	75
D	Y	3	10	9999	10
D	N	1	10	9999	0
D	Z	1	10	9999	0

Maple (except heli-log = 4m):

Species	Grade	Min Log Len (m)	Min Top Dia (cm)	Max Top Dia (cm)	Min Net Factor (%)
MB	I	5	25	9999	50
MB	U	5	25	9999	50
MB	U	5	15	25	67
MB	U	5	10	15	75
MB	Y	3	10	9999	10
MB	N	1	10	9999	0
MB	Z	1	10	9999	0

Birch (except heli-log = 4m):

Species	Grade	Min Log Len (m)	Min Top Dia (cm)	Max Top Dia (cm)	Min Net Factor (%)
E	I	5	25	9999	50
E	U	5	25	9999	50
E	U	5	15	25	67
E	U	5	10	15	75
E	Y	3	10	9999	10
E	N	1	10	9999	0
E	Z	1	10	9999	0

Aspen (except heli-log = 4m):

Species	Grade	Min Log Len (m)	Min Top Dia (cm)	Max Top Dia (cm)	Min Net Factor (%)
AT	I	5	25	9999	50
AT	U	5	25	9999	50
AT	U	5	15	25	67
AT	U	5	10	15	75
AT	Y	3	10	9999	10
AT	N	1	10	9999	0
AT	Z	1	10	9999	0

Whitebark Pine (except heli-log = 4m):

Species	Grade	Min Log Len (m)	Min Top Dia (cm)	Max Top Dia (cm)	Min Net Factor (%)
PA	D	5	76	9999	75
PA	F	5	60	9999	75
PA	H	5	38	50	75
PA	H	5	50	9999	50
PA	I	5	38	50	75
PA	I	5	50	9999	50
PA	J	5	15	38	75
PA	U	5	38	9999	50
PA	U	5	15	38	67
PA	U	5	10	15	75
PA	X	3	10	9999	33
PA	Y	3	10	9999	10
PA	N	1	10	9999	0
PA	Z	1	10	9999	0

Appendix 3 CGNF Breakage Table

These breakage factors are to be used for CGNF compilations only.

Species	Maturity	%
All conifers	Second Growth	2%
All deciduous	Second Growth	4%
Pl, Py	Mature	2%
L	Mature	4%
F, S, Pw, Pa	Mature	5%
H, B	Mature	5.5%
Cw, Yc	Mature	7%
All deciduous	Mature	5%

Appendix 4 Net Volume Adjustment factors (NVAF)

Species	Live/Dead	Age Class	Taper Ratio	NVAF Ratio	NVAF Power
F	D	ALL	0.855	0.86	1
F	L	2 nd Growth	1.006	1	1
F	L	MAT	0.964	0.976	1.296
C	D	ALL	0.998	0.956	1
C	L	2 nd Growth	0.998	0.981	1
C	L	MAT	1.078	0.994	1.085
HW	D	ALL	0.855	0.86	1
HW	L	2 nd Growth	1.019	0.998	1
HW	L	MAT	0.988	0.947	0.844
B	D	ALL	0.855	0.86	1
B	L	2 nd Growth	0.967	1	1
B	L	MAT	0.998	0.93	1
S	D	ALL	0.855	0.86	1
S	L	2 nd Growth	1.015	0.997	1
S	L	MAT	1	1	1
CY	D	ALL	0.998	0.956	1
CY	L	ALL	1.05	0.954	1.27
PW	D	ALL	0.855	0.86	1
PW	L	ALL	1	1	1
PL	D	ALL	0.855	0.86	1
PL	L	ALL	1	1	1
PY	D	ALL	0.855	0.86	1

Species	Live/Dead	Age Class	Taper Ratio	NVAF Ratio	NVAF Power
PY	L	ALL	1	1	1
L	D	ALL	0.855	0.86	1
L	L	ALL	1	1	1
AC	D	ALL	0.855	0.86	1
AC	L	ALL	1	1	1
D	D	ALL	0.855	0.86	1
D	L	ALL	0.967	1	1
MB	D	ALL	0.855	0.86	1
MB	L	ALL	1	1	1
E	D	ALL	0.855	0.86	1
E	L	ALL	1	1	1
AT	D	ALL	0.855	0.86	1
AT	L	ALL	1	1	1
PA	D	ALL	0.855	0.86	1
PA	L	ALL	1	1	1
HM	D	ALL	0.855	0.86	1
HM	L	2 nd Growth	0.984	1	1
HM	L	MAT	0.9	0.945	1

Appendix 5 Spruce High Grade Table

Percentages within Spruce Grades

Natural Resource District	G	F
	E	D
Campbell River	85	74
	15	26
Chilliwack	100	0
	0	0
South Island	83	81
	17	19
Coast Mountain	74	44
	26	56
North Island - Central Coast	67	48
	33	52
Haida Gwaii	80	60
	20	40
Sea to Sky	100	0
	0	0
Sunshine Coast	92	100
	8	0

Source of the table is the Coast Grade Distribution Report 2013-04-01 to 2015-03-31.

Example:

In the South Island District when a log is recorded as G, 83% of the log net volume will be deemed to be G grade and 17% will be deemed to be E grade. Similarly, when a log is recorded as an F grade, 81% will be F grade and 19% will be D grade.

Appendix 6 Taper Coefficients for BC Commercial Species

Inflection Points

p

Species	F.I.Z. A, B & C	F.I.Z. D - J	F.I.Z. K & L
F	0.25	0.25	0.25
C	0.25	0.30	0.30
H	0.20	0.25	0.25
B	0.25	0.30	0.30
S	0.25	0.30	0.30
Y	0.30	0.30	0.30
PW	0.25	0.25	0.25
PL	0.25	0.25	0.25
PY	0.25	0.25	0.25
L	0.30	0.30	0.30
AC	0.25	0.25	0.25
D	0.30	0.30	0.30
MB	0.25	0.25	0.25
E	0.25	0.25	0.25
AT	0.20	0.20	0.20
PA	0.25	0.25	0.25

Regression Coefficients a_1

Species	F.I.Z. A, B & C	F.I.Z. D - J	F.I.Z. K & L
F	1.012675	0.920840	0.920840
C	1.218296	1.033575	1.033575
H	0.830874	0.752027	0.752027
B	0.988964	1.008741	0.764353
S	0.924126	0.897311	0.897595
Y	0.928138	0.928138	0.928138
PW	0.868943	0.984019	0.984019
PL	0.774601	0.774601	0.793793
PY	0.856592	0.856592	0.856592
L	0.746827	0.746827	1.164819
AC	0.802839	0.802839	0.852579
D	0.718188	0.718188	0.718188
MB	0.802839	0.802839	0.852579
E	0.648830	0.648830	0.633306
AT	0.855966	0.855966	0.891641
PA	1.078961	1.078961	1.078961

a₂

Species	F.I.Z. A, B & C	F.I.Z. D - J	F.I.Z. K & L
F	0.899136	0.923867	0.923867
C	0.855983	0.896971	0.896971
H	1.005210	1.028970	1.028970
B	0.951803	0.916357	1.053220
S	0.950707	0.957090	0.957499
Y	0.945293	0.945293	0.945293
PW	0.976312	0.941322	0.941322
PL	1.040320	1.040320	1.049320
PY	0.936402	0.936402	0.936402
L	1.003900	1.003900	0.831995
AC	0.993776	0.993776	0.952969
D	1.052190	1.052190	1.052190
MB	0.993776	0.993776	0.952969
E	1.121390	1.121390	1.110510
AT	0.987014	0.987014	0.957835
PA	0.894083	0.894083	0.894083

a₃

Species	F.I.Z. A, B & C	F.I.Z. D - J	F.I.Z. K & L
F	1.000123	1.000568	1.000568
C	0.999921	0.999079	0.999079
H	0.999142	0.998660	0.998660
B	0.999789	1.001159	0.994711
S	0.999518	0.999370	0.998952
Y	0.999206	0.999206	0.999206
PW	0.999773	0.999700	0.999700
PL	0.996984	0.996984	0.995709
PY	1.002104	1.002104	1.002104
L	0.997233	0.997233	1.003909
AC	0.998974	0.998974	1.000477
D	0.997551	0.997551	0.997551
MB	0.998974	0.998974	1.000477
E	0.992077	0.992077	0.994733
AT	0.999828	0.999828	1.001450
PA	1.001749	1.001749	1.001749

a₄

Species	F.I.Z. A, B & C	F.I.Z. D - J	F.I.Z. K & L
F	0.968978	1.095560	1.095560
C	2.037620	1.598260	1.598260
H	1.770670	1.174800	1.174800
B	2.336270	1.415990	1.381630
S	1.750510	1.532270	1.110150
Y	0.301423	0.301423	0.301423
PW	1.676930	1.571030	1.571030
PL	0.745750	0.745750	0.583403
PY	0.566217	0.566217	0.566217
L	0.747048	0.747048	1.880250
AC	0.706093	0.706093	0.731911
D	0.599235	0.599235	0.599235
MB	0.706093	0.706093	0.731911
E	0.865974	0.865974	1.021680
AT	0.424473	0.424473	0.695143
PA	1.377540	1.377540	1.377540

a₅

Species	F.I.Z. A, B & C	F.I.Z. D - J	F.I.Z. K & L
F	-0.190913	-0.202191	-0.202191
C	-0.486492	-0.411541	-0.411541
H	-0.329190	-0.263576	-0.263576
B	-0.502311	-0.325671	-0.306534
S	-0.408021	-0.364679	-0.281544
Y	-0.040792	-0.040792	-0.040792
PW	-0.372195	-0.369344	-0.369344
PL	-0.130177	-0.130177	-0.077654
PY	-0.087141	-0.087141	-0.087141
L	-0.133729	-0.133729	-0.401856
AC	-0.096789	-0.096789	-0.084192
D	-0.033036	-0.033036	-0.033036
MB	-0.096789	-0.096789	-0.084192
E	-0.106757	-0.106757	-0.141481
AT	-0.037553	-0.037553	-0.039652
PA	-0.286807	-0.286807	-0.286807

a₆

Species	F.I.Z. A, B & C	F.I.Z. D - J	F.I.Z. K & L
F	0.825961	0.967329	0.967329
C	2.632080	2.402420	2.402420
H	2.185610	2.233330	2.233330
B	4.154490	2.793270	2.637080
S	2.659000	2.741210	2.125100
Y	-1.235630	-1.235630	-1.235630
PW	2.567510	2.703200	2.703200
PL	0.558818	0.558818	-0.036267
PY	-0.063450	-0.063450	-0.063450
L	0.397110	0.397110	3.082780
AC	0.312724	0.312724	0.196339
D	-0.261339	-0.261339	-0.261339
MB	0.312724	0.312724	0.196339
E	0.257139	0.257139	0.641499
AT	-0.517540	-0.517540	-0.603404
PA	1.038780	1.038780	1.038780

a₇

Species	F.I.Z. A, B & C	F.I.Z. D - J	F.I.Z. K & L
F	0.048766	0.081696	0.081696
C	0.109094	0.094283	0.094283
H	0.105050	0.045184	0.045184
B	0.086560	0.108427	0.163996
S	0.092651	0.117756	0.148340
Y	0.030743	0.030743	0.030743
PW	0.071928	0.049628	0.049628
PL	0.198687	0.198687	0.142531
PY	0.071720	0.071720	0.071720
L	0.078345	0.078345	0.276300
AC	0.119634	0.119634	0.148285
D	0.215536	0.215536	0.215536
MB	0.119634	0.119634	0.148285
E	0.254574	0.254574	0.258921
AT	0.102211	0.102211	0.193706
PA	0.072537	0.072537	0.072537

a₈

Species	F.I.Z. A, B & C	F.I.Z. D - J	F.I.Z. K & L
F	-0.426214	-0.514604	-0.514604
C	-1.486550	-1.252170	-1.252170
H	-1.192970	-1.002020	-1.002020
B	-2.186240	-1.326790	-1.292080
S	-1.396760	-1.362760	-1.005560
Y	0.672879	0.672879	0.672879
PW	-1.340830	-1.334700	-1.334700
PL	-0.324178	-0.324178	-0.022523
PY	0.051415	0.051415	0.051415
L	-0.183542	-0.183542	-1.661550
AC	-0.080057	-0.080057	-0.069852
D	0.123059	0.123059	0.123059
MB	-0.080057	-0.080057	-0.069852
E	-0.149926	-0.149926	-0.359508
AT	0.303931	0.303931	0.209159
PA	-0.647372	-0.647372	-0.647372

This page is intentionally left blank.