Taper-volume equations for major tree species of the Yukon Territory

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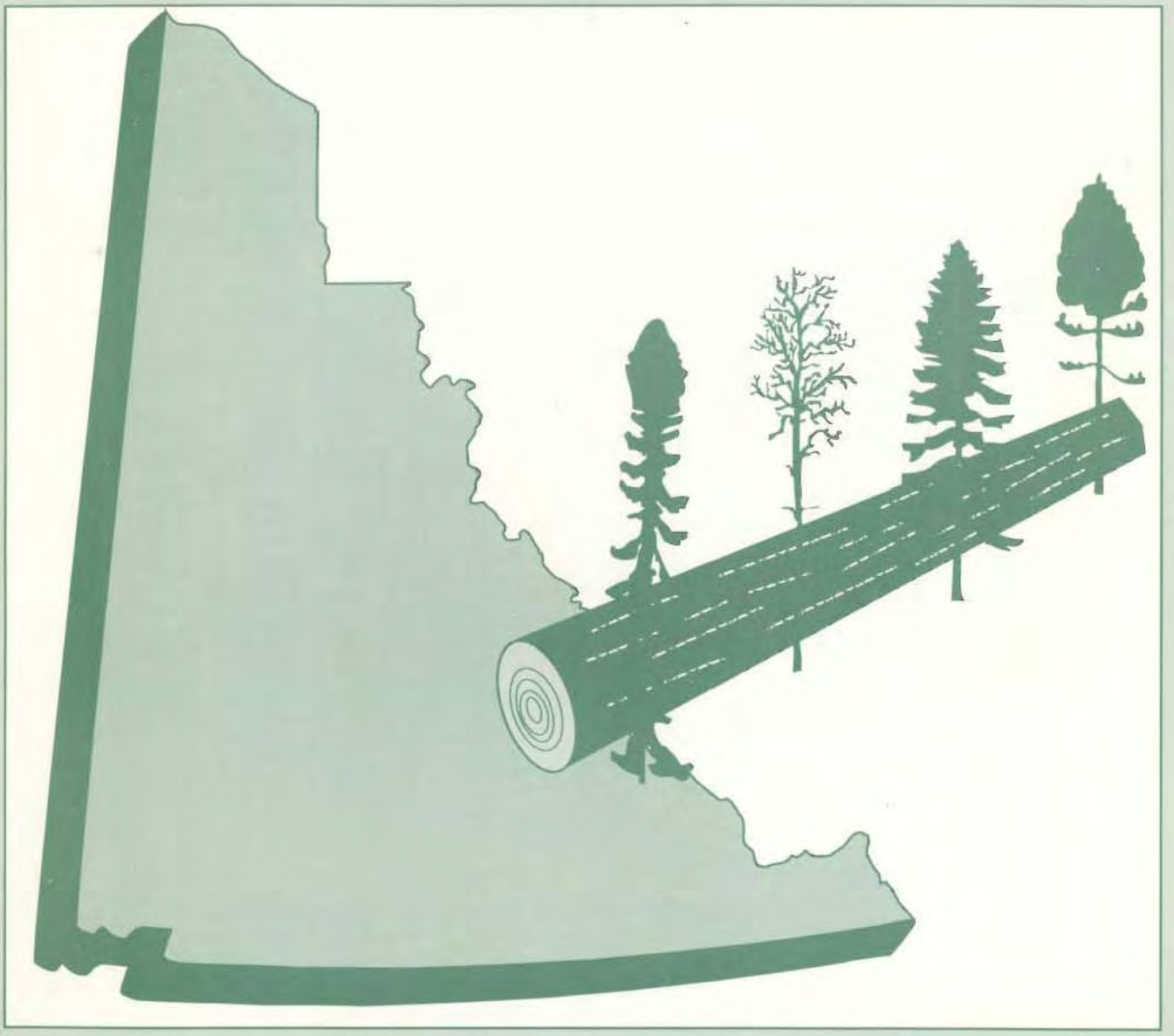
G.M. Bonnor and P. Boudewyn



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Abstract

Using stem analysis data from 1248 trees in the Yukon Territory and a previously published variable-exponent taper equation, taper-volume equations were derived for each ecoregion for four species: lodgepole pine, white spruce, black spruce and aspen. Tests were made to determine if significant differences existed among the ecoregions, or if equations could be derived for ecoregion groups. The practical aspects of using such ecoregion-based equations were also evaluated.

For white spruce, a single equation is recommended; for each of the other three species, separate equations for two ecoregion groups are recommended.

Résumé

À l'aide de données d'analyse de tige portant sur 1248 arbres des Territoires du Yukon et d'une équation de défilement à exposant variable déjà publiée, on a dérivé des formules de cubage du défilement pour chacune des régions écologiques dans le cas des quatre espèces suivantes: le pin de Murray, l'épinette blanche, l'épinette noire et le tremble. On a effectué des tests pour déterminer s'il existe des différences significatives entre les régions écologiques, ou s'il était possible de dériver des équations pour les groupes de régions écologiques. Les aspects pratiques de l'emploi de telles équations, élaborées pour les groupes de régions, ont également fait l'objet d'une évaluation.

Dans le cas de l'épinette blanche, on recommmande l'emploi d'une seule équation; dans le cas des trois autres espèces, on recommande des équations distinctes pour deux groupes de régions écologiques.

Introduction

The Yukon Forest Service recently began a series of forest land inventories designed to yield information suitable for management purposes. To calculate tree volumes to different utilization levels, existing volume equations (Massie *et al.* 1983) were found to be of insufficient range, and extrapolations yielded erroneous results. This study was therefore initiated to derive a new set of volume equations whereby compatible volumes for different utilization standards were calculated.

The combined taper volume equation approach was chosen, and Kozak's (1988) variable exponent taper equation was the specific model selected (appendix 1). This choice was based on a review of available methods by the British Columbia Ministry of Forests (S.M. Smith, 1989, A review of three taper estimating systems. Report produced for the Inventory Branch. 80 p.).

The taper volume approach is based on a taper equation which describes the profile of a tree stem. From this profile, stem diameters can be derived; from the stem diameters can be calculated stem section volumes, which in turn yield tree volumes when summed. Appendix 2 contains a description of the methodology. By setting different upper and lower height or diameter limits, volumes to different utilization standards are calculated. One advantage of the approach is that it satisfies a trend toward production of multiple products from a single tree stem; another is that compatibility among volumes derived for different standards is assured. Increasing availability and power of computers makes the construction and application of such equations practical.

Stem analysis data from 1248 trees, available from previous studies, were used to construct equations for the four main species of the Yukon Territory: lodgepole pine (*Pinus contorta* Dougl.), white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.) B.S.P.), and trembling aspen (*Populus tremuloides* Michx.).

In this study, the effect of ecoregions (Oswald and Senyk 1977) on equations was explored. Tests were made to determine if significant differences existed among the ecoregions or if they could be grouped, and comparisons were made with existing equations. The practical aspects of using such ecoregion based equations were also evaluated.

Results and recommendations are as follows. Volume-taper equations for the following ecoregion groups should be used when good accuracy is required:

- for lodgepole pine, one equation for ecoregions 4 and 5, another for ecoregions 2 and 12;

- for white spruce, one equation for all ecoregions;

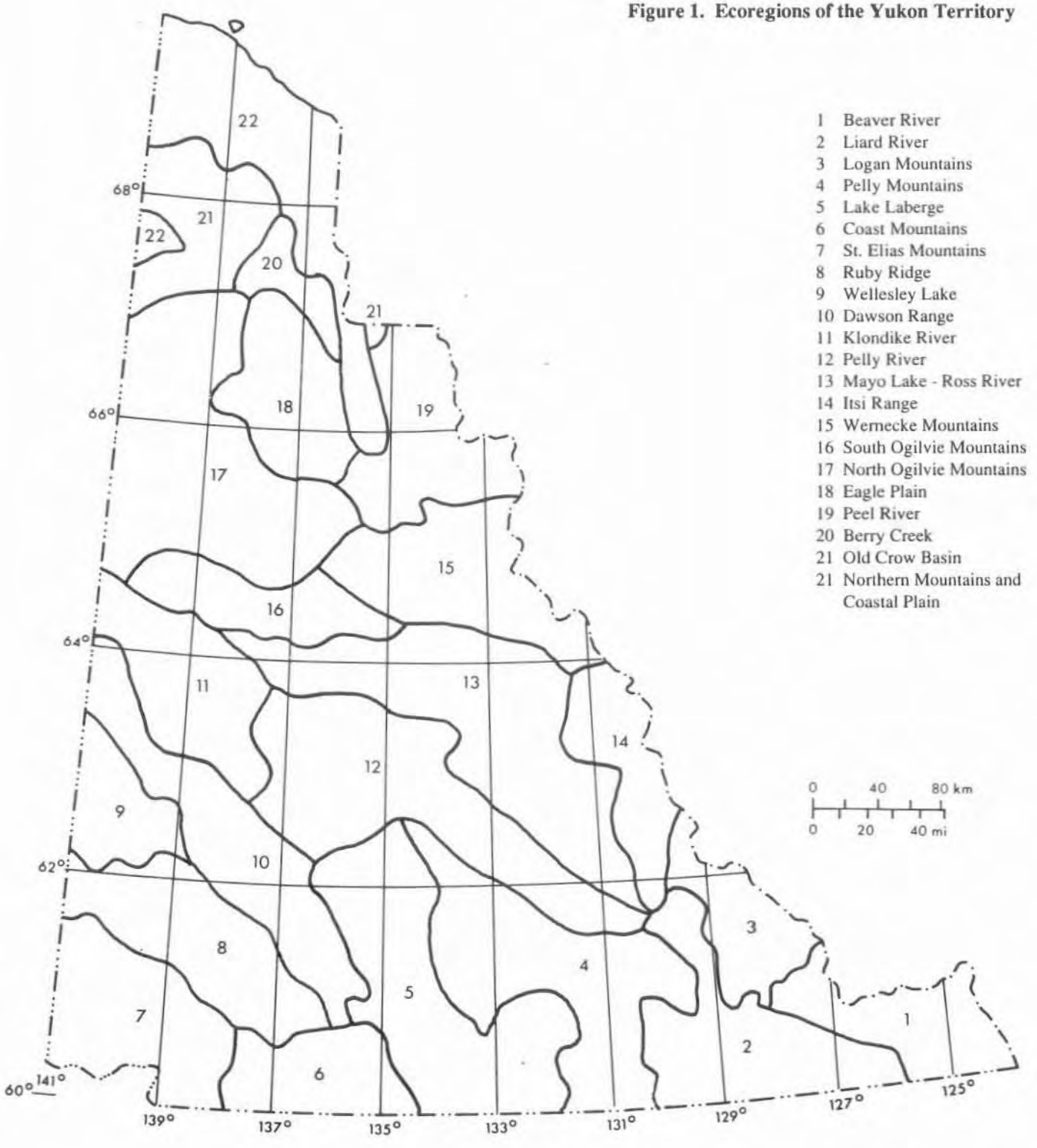
- for black spruce, one equation for ecoregion 2, 4, 5 and 11, another for ecoregions 8, 9 and 12.

- for aspen, one equation for ecoregions 4, 5 and 8, another for ecoregions 2, 9, 11 and 12;

If less accuracy is required, one equation for each species will suffice.

Volume tables derived from equations constructed for these ecoregion groups are given on the following pages. For each equation, gross total and gross merchantable volume are calculated. Equation coefficients and relevant statistics for the equations by these ecoregions and ecoregion groups are given in Appendix 1.

Figure 1. Ecoregions of the Yukon Territory



Total volumes (m^3) for lodgepole pine in ecoregions 4 and 5 of the Yukon Territory

DBH (cm)	Height (m)											
	4	6	8	10	12	14	16	18	20	22	24	26
4	0.002	0.003	0.005	0.006	0.007	.	.	.	.	.	.	.
6	0.005	0.008	0.010	0.013	0.016	0.019	0.021	.	.	.	.	.
8	0.009	0.014	0.019	0.024	0.029	0.033	0.038	0.043	.	.	.	.
10	0.014	0.022	0.029	0.037	0.045	0.052	0.060	0.068	.	.	.	.
12	0.020	0.031	0.042	0.053	0.064	0.075	0.087	0.098	0.109	0.120	.	.
14	0.028	0.042	0.057	0.072	0.087	0.102	0.117	0.133	0.148	0.163	.	.
16	.	0.055	0.074	0.093	0.113	0.132	0.152	0.172	0.192	0.212	0.232	.
18	.	0.069	0.092	0.117	0.141	0.166	0.191	0.216	0.241	0.267	0.292	0.317
20	.	.	0.113	0.143	0.173	0.203	0.234	0.264	0.295	0.326	0.357	0.388
22	.	.	0.136	0.171	0.207	0.243	0.280	0.317	0.354	0.391	0.428	0.466
24	.	.	.	0.202	0.244	0.287	0.330	0.373	0.417	0.461	0.505	0.549
26	.	.	.	0.235	0.283	0.333	0.383	0.433	0.484	0.535	0.586	0.637
28	.	.	.	0.270	0.325	0.381	0.439	0.496	0.554	0.613	0.671	0.730
30	.	.	.	.	0.369	0.433	0.498	0.563	0.629	0.695	0.762	0.828
32	.	.	.	.	.	0.487	0.559	0.633	0.707	0.781	0.856	0.931
34	.	.	.	.	.	0.543	0.624	0.705	0.788	0.871	0.954	1.038
36	.	.	.	.	.	0.602	0.691	0.781	0.872	0.963	1.056	1.148
38	.	.	.	.	.	.	.	0.859	0.959	1.060	1.161	1.263
40	.	.	.	.	.	.	.	0.940	1.049	1.159	1.269	1.381
42	.	.	.	.	.	.	.	1.023	1.141	1.260	1.381	1.502
44	.	.	.	.	.	.	.	.	.	.	1.495	1.626
46	.	.	.	.	.	.	.	.	.	.	1.612	1.752
48	.	.	.	.	.	.	.	.	.	.	.	1.882

Merchantable volumes* (m^3) for lodgepole pine in ecoregions 4 and 5 of the Yukon Territory

DBH (cm)	Height (m)											
	4	6	8	10	12	14	16	18	20	22	24	26
4	.	.	.	.	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.	.	.
10	0.008	0.014	0.020	0.027	0.033	0.039	0.045	0.052	.	.	.	.
12	0.013	0.023	0.033	0.043	0.053	0.063	0.074	0.084	0.094	.	.	.
14	0.019	0.033	0.047	0.062	0.076	0.090	0.105	0.120	0.134	0.148	.	.
16	.	0.044	0.063	0.082	0.101	0.120	0.139	0.159	0.178	0.197	0.217	.
18	.	0.056	0.079	0.104	0.128	0.152	0.177	0.202	0.226	0.252	0.276	0.301
20	.	.	0.098	0.128	0.158	0.188	0.219	0.248	0.279	0.310	0.340	0.371
22	.	.	0.118	0.153	0.190	0.226	0.263	0.299	0.336	0.373	0.410	0.447
24	.	.	.	0.181	0.224	0.267	0.310	0.353	0.397	0.441	0.485	0.529
26	.	.	.	0.211	0.260	0.310	0.361	0.411	0.462	0.513	0.564	0.615
28	.	.	.	0.242	0.298	0.355	0.414	0.471	0.529	0.588	0.646	0.705
30	.	.	.	.	0.339	0.404	0.470	0.535	0.601	0.667	0.735	0.801
32	.	.	.	.	.	0.454	0.527	0.602	0.676	0.750	0.826	0.901
34	.	.	.	.	.	0.506	0.588	0.670	0.754	0.837	0.920	1.005
36	.	.	.	.	.	0.560	0.651	0.742	0.834	0.925	1.019	1.111
38	.	.	.	.	.	.	.	0.816	0.917	1.019	1.120	1.223
40	.	.	.	.	.	.	.	0.892	1.002	1.113	1.224	1.337
42	.	.	.	.	.	.	.	0.970	1.090	1.210	1.332	1.454
44	.	.	.	.	.	.	.	.	.	.	1.442	1.574
46	.	.	.	.	.	.	.	.	.	.	1.554	1.695
48	.	.	.	.	.	.	.	.	.	.	.	1.820

* Stump height=30 cm
Top diameter inside bark=7.5 cm

Total volumes (m^3) for lodgepole pine in ecoregions 2 and 12 of the Yukon Territory

DBH (cm)	Height (m)												
	4	6	8	10	12	14	16	18	20	22	24	26	28
4	0.003	0.004	0.006	0.007	0.009	0.010	.	.	.	.	.	.	.
6	0.006	0.009	0.012	0.015	0.019	0.022	0.025	.	.	.	.	.	.
8	0.010	0.015	0.020	0.026	0.031	0.037	0.043	0.048	.	.	.	.	.
10	0.015	0.023	0.031	0.039	0.047	0.056	0.064	0.073	.	.	.	.	.
12	0.021	0.032	0.043	0.054	0.066	0.078	0.090	0.101	0.113	.	.	.	.
14	0.029	0.042	0.057	0.072	0.087	0.103	0.119	0.135	0.151	.	.	.	.
16	0.038	0.054	0.073	0.092	0.112	0.132	0.152	0.172	0.192	.	.	.	.
18	.	0.068	0.091	0.114	0.139	0.163	0.188	0.214	0.239	.	.	.	.
20	.	.	0.111	0.139	0.169	0.198	0.229	0.260	0.290	0.322	0.353	0.384	0.416
22	.	.	0.133	0.167	0.201	0.237	0.273	0.310	0.347	0.384	0.421	0.458	0.496
24	.	.	0.158	0.197	0.237	0.279	0.321	0.364	0.407	0.451	0.495	0.539	0.583
26	.	.	.	0.230	0.276	0.324	0.373	0.423	0.473	0.524	0.575	0.626	0.677
28	.	.	.	0.265	0.318	0.373	0.429	0.486	0.543	0.601	0.660	0.719	0.778
30	.	.	.	0.304	0.364	0.425	0.489	0.553	0.618	0.685	0.751	0.818	0.886
32	.	.	.	0.347	0.413	0.482	0.553	0.625	0.699	0.773	0.848	0.924	1.000
34	.	.	.	.	0.465	0.542	0.621	0.702	0.784	0.867	0.951	1.036	1.121
36	.	.	.	.	0.522	0.606	0.693	0.783	0.874	0.967	1.060	1.155	1.250
38	.	.	.	.	.	0.675	0.771	0.869	0.970	1.072	1.176	1.280	1.385
40	.	.	.	.	.	.	0.853	0.961	1.071	1.183	1.297	1.412	1.528
42	.	.	.	.	.	.	.	1.057	1.178	1.300	1.425	1.551	1.677
44	.	.	.	.	.	.	.	.	1.290	1.423	1.559	1.696	1.835
46	.	.	.	.	.	.	.	.	.	1.553	1.700	1.849	1.999
48	.	.	.	.	.	.	.	.	.	.	1.848	2.009	2.172
50	.	.	.	.	.	.	.	.	.	.	.	2.176	2.352
52	.	.	.	.	.	.	.	.	.	.	.	.	2.540

Merchantable volumes* (m^3) for lodgepole pine in ecoregions 2 and 12 of the Yukon Territory

DBH (cm)	Height (m)												
	4	6	8	10	12	14	16	18	20	22	24	26	28
4	.	.	.	.	.	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.	.	.	.
10	0.008	0.015	0.022	0.029	0.035	0.043	0.050	0.057	.	.	.	.	.
12	0.013	0.023	0.034	0.044	0.055	0.066	0.078	0.088	0.099	.	.	.	.
14	0.019	0.032	0.047	0.062	0.076	0.091	0.107	0.122	0.138	.	.	.	.
16	0.025	0.042	0.061	0.080	0.100	0.120	0.139	0.159	0.179	.	.	.	.
18	.	0.053	0.077	0.101	0.126	0.150	0.174	0.200	0.225	.	.	.	.
20	.	.	0.095	0.123	0.154	0.183	0.214	0.245	0.275	0.306	0.337	0.368	0.400
22	.	.	0.113	0.149	0.183	0.220	0.256	0.293	0.330	0.367	0.404	0.441	0.479
24	.	.	0.134	0.175	0.216	0.259	0.302	0.345	0.388	0.432	0.476	0.520	0.564
26	.	.	.	0.204	0.252	0.301	0.351	0.401	0.451	0.503	0.554	0.605	0.656
28	.	.	.	0.235	0.290	0.347	0.403	0.461	0.519	0.577	0.636	0.695	0.755
30	.	.	.	0.269	0.332	0.394	0.460	0.525	0.590	0.658	0.724	0.792	0.860
32	.	.	.	0.306	0.375	0.447	0.520	0.593	0.668	0.743	0.818	0.895	0.971
34	.	.	.	.	0.422	0.502	0.583	0.666	0.749	0.833	0.918	1.003	1.089
36	.	.	.	.	0.472	0.560	0.650	0.742	0.834	0.929	1.023	1.118	1.214
38	.	.	.	.	.	0.623	0.722	0.823	0.925	1.029	1.134	1.239	1.345
40	.	.	.	.	.	.	0.798	0.909	1.021	1.135	1.250	1.366	1.483
42	.	.	.	.	.	.	.	0.999	1.122	1.246	1.373	1.500	1.628
44	.	.	.	.	.	.	.	.	1.228	1.363	1.501	1.640	1.780
46	.	.	.	.	.	.	.	.	.	1.487	1.636	1.787	1.939
48	.	.	.	.	.	.	.	.	.	.	1.777	1.941	2.106
50	.	.	.	.	.	.	.	.	.	.	.	2.101	2.279
52	.	.	.	.	.	.	.	.	.	.	.	.	2.460

* Stump height=30 cm
Top diameter inside bark=7.5 cm

Total volumes (m^3) for white spruce in all ecoregions of the Yukon Territory

DBH (cm)	Height (m)																		
	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
4	0.002	0.003	0.005	0.006	0.007	0.008	0.009	.	.	.	.	.	.	.	.	.	.	.	.
6	0.005	0.007	0.010	0.012	0.015	0.017	0.019	0.022	.	.	.	.	.	.	.	.	.	.	.
8	0.008	0.013	0.017	0.021	0.025	0.029	0.033	0.037	0.042	.	.	.	.	.	.	.	.	.	.
10	0.013	0.019	0.025	0.032	0.038	0.044	0.051	0.057	0.063	0.070	.	.	.	.	.	.	.	.	.
12	0.018	0.027	0.036	0.045	0.054	0.063	0.072	0.081	0.090	0.099	0.107	.	.	.	.	.	.	.	.
14	0.025	0.037	0.048	0.060	0.072	0.084	0.096	0.108	0.120	0.132	0.144	0.156	0.168	.	.	.	.	.	.
16	0.033	0.048	0.063	0.078	0.093	0.109	0.124	0.140	0.155	0.171	0.186	0.202	0.217	.	.	.	.	.	.
18	0.042	0.060	0.079	0.098	0.117	0.136	0.156	0.175	0.194	0.214	0.233	0.253	0.272	.	.	.	.	.	.
20	0.053	0.074	0.097	0.120	0.144	0.167	0.191	0.215	0.238	0.262	0.286	0.310	0.334	0.357	.	.	.	.	.
22	.	0.091	0.118	0.145	0.173	0.202	0.230	0.258	0.287	0.315	0.344	0.373	0.401	0.430	0.459	.	.	.	.
24	.	.	0.140	0.173	0.206	0.239	0.273	0.306	0.340	0.374	0.408	0.442	0.475	0.509	0.543	0.577	.	.	.
26	.	.	0.165	0.203	0.241	0.280	0.319	0.359	0.398	0.437	0.477	0.516	0.556	0.596	0.635	0.675	.	.	.
28	.	.	0.192	0.236	0.280	0.325	0.370	0.415	0.461	0.506	0.552	0.598	0.643	0.689	0.735	0.781	.	.	.
30	.	.	.	.	0.322	0.373	0.425	0.476	0.528	0.580	0.633	0.685	0.737	0.790	0.842	0.895	.	.	.
32	.	.	.	.	0.367	0.425	0.483	0.542	0.601	0.660	0.719	0.779	0.838	0.898	0.957	1.017	1.077	1.137	.
34	.	.	.	.	.	0.481	0.546	0.612	0.679	0.745	0.812	0.879	0.946	1.013	1.080	1.148	1.215	1.282	1.350
36	.	.	.	.	.	0.541	0.614	0.688	0.762	0.836	0.911	0.986	1.061	1.136	1.211	1.287	1.362	1.438	1.513
38	.	.	.	.	.	.	0.686	0.768	0.850	0.933	1.016	1.100	1.183	1.267	1.351	1.435	1.519	1.603	1.687
40	.	.	.	.	.	.	0.763	0.853	0.944	1.036	1.128	1.220	1.313	1.406	1.498	1.591	1.684	1.778	1.871
42	.	.	.	.	.	.	.	0.944	1.044	1.145	1.247	1.348	1.450	1.552	1.655	1.757	1.860	1.963	2.065
44	.	.	.	.	.	.	.	1.040	1.150	1.260	1.372	1.483	1.595	1.707	1.820	1.932	2.045	2.158	2.271
46	.	.	.	.	.	.	.	.	1.261	1.382	1.504	1.626	1.748	1.871	1.994	2.117	2.240	2.363	2.487
48	.	.	.	.	.	.	.	.	.	1.511	1.643	1.776	1.909	2.043	2.177	2.311	2.445	2.580	2.714
50	.	.	.	.	.	.	.	.	.	.	1.789	1.933	2.078	2.223	2.369	2.515	2.661	2.807	2.953
52	.	.	.	.	.	.	.	.	.	.	.	2.099	2.256	2.413	2.571	2.728	2.887	3.045	3.204
54	.	.	.	.	.	.	.	.	.	.	.	.	2.442	2.612	2.782	2.952	3.123	3.294	3.466
56	.	.	.	.	.	.	.	.	.	.	.	.	.	2.820	3.003	3.187	3.371	3.555	3.740
58	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3.235	3.432	3.630	3.828	4.027
60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3.688	3.900	4.113	4.326
62	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4.183	4.410	4.638

Merchantable volumes* (m^3) for white spruce in all ecoregions of the yukon territory

DBH (cm)	Height (m)																		
	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
10	0.006	0.011	0.015	0.020	0.024	0.028	0.033	0.037	0.041	0.046	.	.	.	.	.	.	.	.	.
12	0.011	0.018	0.026	0.034	0.041	0.049	0.056	0.064	0.071	0.079	0.085	.	.	.	.	.	.	.	.
14	0.016	0.028	0.038	0.049	0.059	0.070	0.081	0.092	0.103	0.114	0.124	0.135	0.146	.	.	.	.	.	.
16	0.022	0.037	0.052	0.066	0.080	0.095	0.109	0.124	0.138	0.153	0.167	0.182	0.196	.	.	.	.	.	.
18	0.028	0.047	0.066	0.085	0.103	0.121	0.141	0.159	0.177	0.196	0.215	0.234	0.252	.	.	.	.	.	.
20	0.036	0.059	0.082	0.105	0.129	0.151	0.175	0.198	0.220	0.244	0.267	0.290	0.314	0.336	.	.	.	.	.
22	.	0.073	0.101	0.128	0.156	0.185	0.212	0.240	0.268	0.296	0.324	0.353	0.380	0.408	0.437	.	.	.	.
24	.	.	0.120	0.153	0.187	0.220	0.253	0.286	0.320	0.353	0.387	0.420	0.453	0.486	0.520	0.553	.	.	.
26	.	.	0.142	0.181	0.219	0.258	0.297	0.337	0.376	0.414	0.454	0.493	0.532	0.572	0.611	0.650	.	.	.
28	.	.	0.165	0.210	0.255	0.300	0.346	0.391	0.436	0.481	0.527	0.573	0.617	0.663	0.709	0.754	.	.	.
30	.	.	.	.	0.294	0.345	0.398	0.449	0.501	0.553	0.606	0.657	0.709	0.762	0.814	0.866	.	.	.
32	.	.	.	.	0.335	0.394	0.452	0.512	0.571	0.630	0.689	0.749	0.808	0.867	0.926	0.986	1.046	1.106	.
34	.	.	.	.	.	0.446	0.512	0.578	0.645	0.712	0.779	0.846	0.913	0.980	1.046	1.114	1.181	1.248	1.316
36	.	.	.	.	.	0.501	0.575	0.650	0.725	0.799	0.874	0.949	1.024	1.099	1.174	1.250	1.325	1.401	1.476
38	.	.	.	.	.	.	0.643	0.726	0.809	0.892	0.975	1.060	1.143	1.227	1.311	1.395	1.479	1.563	1.647
40	.	.	.	.	.	.	0.715	0.806	0.898	0.991	1.083	1.176	1.269	1.362	1.454	1.547	1.640	1.734	1.827
42	.	.	.	.	.	.	.	0.892	0.993	1.095	1.198	1.299	1.402	1.504	1.607	1.709	1.812	1.916	2.018
44	.	.	.	.	.	.	.	0.983	1.094	1.205	1.318	1.430	1.542	1.655	1.768	1.880	1.993	2.106	2.219
46	.	.	.	.	.	.	.	.	1.199	1.322	1.445	1.568	1.690	1.814	1.937	2.060	2.184	2.307	2.431
48	.	.	.	.	.	.	.	.	.	1.445	1.578	1.712	1.846	1.981	2.115	2.249	2.384	2.519	2.653
50	.	.	.	.	.	.	.	.	.	.	1.718	1.863	2.009	2.155	2.302	2.448	2.595	2.741	2.887
52	.	.	.	.	.	.	.	.	.	.	.	2.023	2.181	2.339	2.498	2.655	2.815	2.973	3.133
54	.	.	.	.	.	.	.	.	.	.	.	.	2.361	2.532	2.703	2.873	3.045	3.217	3.389
56	.	.	.	.	.	.	.	.	.	.	.	.	.	2.733	2.917	3.102	3.287	3.471	3.657
58	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3.142	3.340	3.539	3.738	3.938
60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3.589	3.802	4.016	4.230
62	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4.077	4.306	
4.534																			

* stump height=30 cm
top diameter inside bark=7.5 cm

Total volumes (m^3) for black spruce in ecoregions 2, 4, 5, and 11 of the Yukon Territory

DBH (cm)	Height (m)										
	4	6	8	10	12	14	16	18	20	22	24
4	0.002	0.004	0.005	0.006	0.007	0.008	.	.	.	.	.
6	0.005	0.007	0.010	0.012	0.015	0.017	0.020	.	.	.	.
8	0.008	0.012	0.017	0.021	0.025	0.029	0.034	.	.	.	.
10	0.013	0.019	0.025	0.032	0.038	0.045	0.051	0.058	0.064	.	.
12	0.019	0.028	0.036	0.045	0.054	0.064	0.073	0.082	0.091	.	.
14	0.027	0.038	0.050	0.062	0.074	0.086	0.099	0.111	0.124	0.136	.
16	0.037	0.051	0.066	0.081	0.097	0.113	0.130	0.146	0.162	0.179	0.195
18	0.050	0.066	0.085	0.104	0.124	0.145	0.166	0.186	0.207	0.228	0.249
20	.	0.085	0.107	0.131	0.156	0.182	0.207	0.233	0.260	0.286	0.312
22	.	0.107	0.134	0.163	0.193	0.224	0.256	0.287	0.319	0.352	0.384
24	.	0.134	0.165	0.200	0.236	0.273	0.311	0.349	0.388	0.427	0.466
26	.	.	0.201	0.242	0.285	0.329	0.374	0.420	0.466	0.512	0.559
28	.	.	.	0.291	0.341	0.392	0.445	0.499	0.554	0.609	0.664
30	.	.	.	0.347	0.404	0.465	0.526	0.589	0.653	0.717	0.782
32	.	.	.	.	0.477	0.546	0.618	0.691	0.765	0.840	0.915
34	.	.	.	.	.	.	.	0.805	0.890	0.976	1.063
36	.	.	.	.	.	.	.	.	.	1.129	1.229
38	.	.	.	.	.	.	.	.	.	1.300	1.414
40	.	.	.	.	.	.	.	.	.	.	1.619

Merchantable volumes* (m^3) for black spruce in ecoregions 2, 4, 5, and 11 of the Yukon Territory

DBH (cm)	Height (m)										
	4	6	8	10	12	14	16	18	20	22	24
4	.	.	.	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.	.
10	.	0.011	0.015	0.020	0.024	0.029	0.033	0.039	0.043	.	.
12	0.011	0.019	0.026	0.034	0.042	0.051	0.058	0.066	0.074	.	.
14	0.016	0.028	0.039	0.051	0.062	0.073	0.085	0.096	0.108	0.120	.
16	0.023	0.039	0.054	0.069	0.084	0.100	0.116	0.132	0.147	0.163	0.179
18	0.031	0.051	0.071	0.090	0.110	0.131	0.151	0.171	0.192	0.212	0.233
20	.	0.066	0.090	0.115	0.140	0.166	0.191	0.217	0.243	0.269	0.295
22	.	0.083	0.113	0.143	0.174	0.206	0.238	0.269	0.301	0.334	0.365
24	.	0.103	0.139	0.176	0.214	0.252	0.290	0.328	0.367	0.406	0.445
26	.	.	0.169	0.214	0.259	0.304	0.350	0.396	0.443	0.489	0.536
28	.	.	.	0.256	0.309	0.362	0.416	0.471	0.527	0.582	0.638
30	.	.	.	0.305	0.366	0.430	0.492	0.557	0.622	0.686	0.752
32	.	.	.	.	0.432	0.504	0.579	0.653	0.728	0.804	0.880
34	.	.	.	.	.	.	.	0.761	0.847	0.935	1.023
36	.	.	.	.	.	.	.	.	.	1.081	1.183
38	.	.	.	.	.	.	.	.	.	1.245	1.360
40	.	.	.	.	.	.	.	.	.	.	1.557

* Stump height=30 cm
Top diameter inside bark=7.5 cm

Total volumes (m^3) for black spruce in ecoregions 8, 9, and 12 of the Yukon Territory

DBH (cm)	Height (m)									
	4	6	8	10	12	14	16	18	20	22
4	0.002	0.004	0.005	0.006	0.007	.	.	.	.	.
6	0.005	0.008	0.010	0.013	0.016	0.018	0.021	.	.	.
8	0.009	0.013	0.018	0.022	0.027	0.031	0.036	.	.	.
10	0.014	0.020	0.027	0.034	0.041	0.048	0.054	.	.	.
12	0.020	0.029	0.038	0.048	0.057	0.067	0.076	0.086	.	.
14	0.027	0.039	0.051	0.063	0.076	0.088	0.101	0.114	0.127	0.140
16	0.036	0.050	0.065	0.081	0.097	0.113	0.129	0.145	0.161	0.178
18	.	0.063	0.081	0.100	0.120	0.140	0.160	0.180	0.200	0.220
20	.	0.078	0.099	0.122	0.145	0.169	0.193	0.217	0.241	0.265
22	.	.	0.119	0.146	0.173	0.201	0.229	0.257	0.286	0.314
24	.	.	.	0.171	0.202	0.235	0.267	0.300	0.333	0.366
26	.	.	.	0.198	0.234	0.271	0.308	0.346	0.383	0.422
28	.	.	.	.	0.268	0.309	0.351	0.394	0.437	0.480
30	.	.	.	.	.	0.350	0.396	0.444	0.492	0.541
32	.	.	.	.	.	0.392	0.444	0.497	0.550	0.604
34	.	.	.	.	.	.	0.494	0.552	0.611	0.670
36	.	.	.	.	.	.	.	0.610	0.674	0.739
38	.	.	.	.	.	.	.	.	0.739	0.810
40	.	.	.	.	.	.	.	.	.	0.883

Merchantable volumes* (m^3) for black spruce in ecoregions 8, 9, and 12 of the Yukon Territory

DBH (cm)	Height (m)									
	4	6	8	10	12	14	16	18	20	22
4	.	.	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.
10	0.007	0.012	0.017	0.023	0.028	0.033	0.037	.	.	.
12	0.012	0.020	0.028	0.037	0.045	0.054	0.061	0.070	.	.
14	0.017	0.029	0.041	0.052	0.064	0.075	0.087	0.099	0.111	0.123
16	0.023	0.038	0.053	0.069	0.084	0.100	0.115	0.130	0.146	0.162
18	.	0.049	0.068	0.087	0.106	0.126	0.146	0.165	0.184	0.204
20	.	0.061	0.084	0.107	0.130	0.154	0.178	0.201	0.225	0.248
22	.	.	0.101	0.129	0.156	0.184	0.212	0.240	0.269	0.296
24	.	.	.	0.151	0.183	0.216	0.249	0.282	0.314	0.347
26	.	.	.	0.175	0.212	0.250	0.288	0.326	0.363	0.402
28	.	.	.	.	0.244	0.286	0.328	0.372	0.415	0.458
30	.	.	.	.	.	0.324	0.371	0.419	0.468	0.517
32	.	.	.	.	.	0.362	0.416	0.470	0.523	0.578
34	.	.	.	.	.	.	0.462	0.522	0.581	0.641
36	.	.	.	.	.	.	.	0.576	0.641	0.707
38	.	.	.	.	.	.	.	.	0.703	0.775
40	.	.	.	.	.	.	.	.	.	0.845

* Stump height=30 cm
Top diameter inside bark=7.5 cm

Total volumes (m^3) for trembling aspen in ecoregions 4, 5, and 8 of the Yukon Territory

DBH (cm)	Height (m)										
	4	6	8	10	12	14	16	18	20	22	24
4	0.002	0.003	0.004	0.005	0.006	0.008	.	.	.	.	.
6	0.004	0.007	0.009	0.012	0.014	0.017	0.019	.	.	.	.
8	0.008	0.012	0.016	0.020	0.025	0.029	0.033	.	.	.	.
10	0.012	0.018	0.024	0.031	0.037	0.044	0.051	.	.	.	
12	0.016	0.025	0.034	0.043	0.053	0.062	0.071	0.081	0.090	0.100	.
14	0.022	0.033	0.045	0.058	0.070	0.082	0.095	0.108	0.120	0.133	0.145
16	.	0.043	0.058	0.074	0.089	0.105	0.121	0.138	0.154	0.170	0.186
18	.	0.053	0.072	0.091	0.111	0.131	0.151	0.171	0.191	0.211	0.232
20	.	0.065	0.087	0.110	0.134	0.158	0.183	0.207	0.232	0.256	0.281
22	.	0.077	0.104	0.131	0.159	0.188	0.217	0.246	0.275	0.305	0.334
24	.	.	0.122	0.153	0.186	0.220	0.253	0.287	0.322	0.356	0.391
26	.	.	0.141	0.177	0.215	0.253	0.292	0.331	0.371	0.411	0.451
28	.	.	.	0.202	0.245	0.289	0.333	0.378	0.423	0.469	0.514
30	.	.	.	0.229	0.277	0.326	0.376	0.427	0.478	0.529	0.581
32	.	.	.	.	0.311	0.365	0.421	0.478	0.535	0.592	0.650
34	.	.	.	.	.	0.406	0.468	0.531	0.594	0.658	0.723
36	.	.	.	.	.	.	0.517	0.586	0.656	0.726	0.798
38	.	.	.	.	.	.	.	0.643	0.720	0.797	0.875
40	.	.	.	.	.	.	.	.	0.786	0.870	0.955
42	.	.	.	.	.	.	.	.	.	0.945	1.037
44	.	.	.	.	.	.	.	.	.	.	1.122

Merchantable volumes* (m^3) for trembling aspen in ecoregions 4, 5, and 8 of the Yukon Territory

DBH (cm)	Height (m)										
	4	6	8	10	12	14	16	18	20	22	24
4	.	.	.	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.	
10	.	0.010	0.014	0.020	0.024	0.029	0.035	.	.	.	.
12	0.009	0.017	0.024	0.032	0.041	0.049	0.056	0.065	.	.	.
14	0.013	0.024	0.035	0.047	0.058	0.069	0.081	0.093	0.104	0.115	0.126
16	.	0.032	0.047	0.062	0.076	0.092	0.107	0.123	0.138	0.153	0.168
18	.	0.041	0.060	0.078	0.098	0.117	0.136	0.155	0.175	0.194	0.214
20	.	0.050	0.073	0.096	0.119	0.143	0.167	0.191	0.215	0.238	0.263
22	.	0.060	0.088	0.115	0.143	0.171	0.200	0.228	0.257	0.286	0.315
24	.	.	0.103	0.135	0.168	0.202	0.234	0.268	0.303	0.336	0.371
26	.	.	0.119	0.156	0.195	0.233	0.272	0.310	0.350	0.390	0.429
28	.	.	.	0.178	0.222	0.266	0.310	0.355	0.400	0.446	0.491
30	.	.	.	0.202	0.251	0.301	0.351	0.402	0.453	0.504	0.556
32	.	.	.	.	0.282	0.337	0.394	0.451	0.508	0.565	0.623
34	.	.	.	.	.	0.375	0.438	0.501	0.564	0.628	0.693
36	.	.	.	.	.	.	0.483	0.553	0.624	0.694	0.766
38	.	.	.	.	.	.	.	0.607	0.685	0.762	0.840
40	.	.	.	.	.	.	.	.	0.747	0.832	0.917
42	.	.	.	.	.	.	.	.	.	0.904	0.996
44	.	.	.	.	.	.	.	.	.	.	1.078

* Stump height=30 cm
Top diameter inside bark=7.5 cm

Total volumes (m^3) for trembling aspen in ecoregions 2, 9, 11, and 12 of the Yukon Territory

DBH (cm)	Height (m)											
	4	6	8	10	12	14	16	18	20	22	24	26
4	0.002	0.003	0.004	0.006	0.007	0.008	.	.	.	.	.	.
6	0.005	0.007	0.010	0.012	0.015	0.017	0.020	.	.	.	.	.
8	0.008	0.012	0.017	0.021	0.026	0.030	0.035	.	.	.	.	.
10	0.012	0.019	0.026	0.033	0.040	0.047	0.054	0.061	.	.	.	.
12	0.017	0.027	0.036	0.046	0.056	0.066	0.076	0.086	0.097	.	.	.
14	.	0.036	0.049	0.062	0.075	0.089	0.103	0.116	0.130	.	.	.
16	.	0.046	0.063	0.080	0.097	0.115	0.132	0.150	0.168	.	.	.
18	.	0.058	0.078	0.100	0.121	0.143	0.165	0.187	0.210	0.232	0.254	0.277
20	.	.	0.096	0.122	0.148	0.175	0.202	0.229	0.256	0.283	0.311	0.338
22	.	.	.	0.145	0.177	0.209	0.241	0.274	0.307	0.339	0.372	0.405
24	.	.	.	0.171	0.208	0.246	0.284	0.323	0.361	0.400	0.439	0.478
26	.	.	.	0.199	0.242	0.286	0.330	0.375	0.420	0.465	0.510	0.556
28	.	.	.	0.229	0.278	0.328	0.379	0.431	0.482	0.534	0.587	0.639
30	.	.	.	.	.	0.374	0.431	0.490	0.549	0.608	0.668	0.727
32	.	.	.	.	.	0.422	0.487	0.553	0.619	0.686	0.753	0.821
34	.	.	.	.	.	0.472	0.545	0.619	0.693	0.768	0.843	0.919
36	.	.	.	.	.	.	0.606	0.688	0.771	0.854	0.938	1.023
38	.	.	.	.	.	.	.	0.761	0.852	0.944	1.037	1.131
40	.	.	.	.	.	.	.	.	0.937	1.038	1.141	1.243
42	.	.	.	.	.	.	.	.	.	1.137	1.248	1.361
44	.	.	.	.	.	.	.	.	.	.	1.360	1.483
46	.	.	.	.	.	.	.	.	.	.	.	1.610

Merchantable volumes* (m^3) for trembling aspen in ecoregions 2, 9, 11, and 12 of the Yukon Territory

DBH (cm)	Height (m)											
	4	6	8	10	12	14	16	18	20	22	24	26
4	.	.	.	.	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.	.	.	.	.
10	.	0.011	0.016	0.022	0.027	0.033	0.038	0.043	.	.	.	.
12	0.010	0.019	0.027	0.035	0.044	0.053	0.062	0.070	0.080	.	.	.
14	.	0.027	0.039	0.051	0.063	0.076	0.089	0.101	0.114	.	.	.
16	.	0.035	0.052	0.068	0.085	0.102	0.118	0.135	0.152	.	.	.
18	.	0.045	0.065	0.087	0.107	0.129	0.150	0.172	0.194	0.215	0.237	0.259
20	.	.	0.081	0.107	0.133	0.160	0.186	0.213	0.239	0.265	0.293	0.319
22	.	.	.	0.128	0.160	0.192	0.224	0.256	0.289	0.320	0.353	0.385
24	.	.	.	0.152	0.189	0.227	0.265	0.303	0.341	0.380	0.418	0.457
26	.	.	.	0.177	0.220	0.264	0.308	0.353	0.398	0.443	0.488	0.533
28	.	.	.	0.203	0.253	0.304	0.355	0.407	0.458	0.510	0.563	0.614
30	.	.	.	.	.	0.347	0.404	0.463	0.522	0.581	0.641	0.700
32	.	.	.	.	.	0.391	0.457	0.523	0.590	0.657	0.724	0.792
34	.	.	.	.	.	0.437	0.511	0.586	0.660	0.736	0.811	0.887
36	.	.	.	.	.	.	0.568	0.651	0.735	0.818	0.903	0.988
38	.	.	.	.	.	.	.	0.720	0.812	0.905	0.998	1.092
40	.	.	.	.	.	.	.	.	0.893	0.995	1.098	1.201
42	.	.	.	.	.	.	.	.	.	1.090	1.201	1.315
44	.	.	.	.	.	.	.	.	.	.	1.309	1.433
46	.	.	.	.	.	.	.	.	.	.	.	1.555

* Stump height=30 cm
Top diameter inside bark=7.5 cm

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Appendix 1
Taper equation model and statistics

Equation model:

$$\ln(d_i) = \ln(a_0) + a_1\ln(D) + \ln(a_2)D + b_1\ln(X)Z^2 + b_2\ln(X)\ln(Z+0.001) + b_3\ln(X)Z^{(1/2)} + b_4\ln(X)e^Z + b_5\ln(X)(D/H) \quad (1)$$

where d_i = diameter inside bark at height h_i (cm)
D = dbh outside bark (cm)
$X = (1-(h_i/H)^{(1/2)})/(1-p^{(1/2)})$
with h_i = height from ground (m)
H = tree height (m)
p = (HI/H)
where
HI = height of inflection point (m)
= 0.30 for the spruces, 0.25 for pine, and 0.20 for aspen (Kozak 1988)
$Z = h_i/H$
a,b = coefficients

Equation statistics:

Species	Ecoregion	Equation coefficients								Number of trees	R^2
		a_0	a_1	a_2	b_1	b_2	b_3	b_4	b_5		
Lodgepole pine	4 and 5	0.77995	1.06248	0.99571	0.64964	-0.03431	0.28829	-0.1064	0.155545	99	0.90
	2 and 12	1.03004	0.92727	1.00155	0.55191	-0.06790	0.90356	-0.3764	0.205381	129	0.95
White spruce	all	0.90754	0.92481	1.00213	0.11603	-0.08441	1.21302	-0.2705	0.110240	493	0.95
Black spruce	2,4,5,11	0.98714	0.84287	1.01197	0.18757	-0.05451	0.82599	-0.2030	0.193647	179	0.97
	8,9,12	0.91046	0.96768	0.99635	0.36304	-0.13772	2.15920	-0.7757	0.176394	147	0.97
Aspen	4,5,8	0.91487	0.99355	0.99732	1.39100	-0.23648	3.57623	-1.5851	0.189703	84	0.97
	2,9,11,12	0.90414	0.99438	0.99927	1.09922	-0.16723	2.51179	-1.0888	0.178431	117	0.97

Appendix 2
Methodology and results of comparisons

Methodology

The study data were obtained from two sources: the Yukon Forest Sevice provided stem analysis data for 292 trees measured from 1977 to 1985, and stem analysis data for 976 trees were available from a biomass study undertaken by the Pacific Forestry Centre from 1980 to 1982. The distribution of the trees by species and ecoregion (Figure 1) is shown in Table A1, while Table A2 provides some mensurational data.

The variable density taper function used in this study (Kozak 1988) is given in Appendix 1. The stem analysis data were separated by species and ecoregion groups (Table A3) and fitted to the taper equation to obtain the regression coefficients. A total of 49 equations were derived.

Construction of these equations was followed by the first test, an analysis of covariance to determine if significant differences existed among ecoregions. For each species, the equations constructed for individual ecoregions (Set A in Table A3) were compared with equations constructed for groups of ecoregions (sets B, C, D and E in Table A3). Differences in residual sums of squares were derived, and F-values were calculated and assessed. For example, in Set C of Table A3, the black spruce data were separated into two groups, one comprising ecoregions 4, 8 and 9, the other comprising ecoregions 2, 5, 11 and 12. One equation was then derived for each group and an analysis of covariance was made to determine if the group equation showed any statistically significant difference from individual ecoregion equations, e.g., if the one combined equation for ecoregions 4, 8 and 9 differed significantly from the three individual equations.

The second test consisted of a comparison of tree volumes: for each species, three tree sizes (small, medium and large) were specified, and tree volumes were calculated using the individual ecoregion equations (from Set A in Table A3). These volumes were compared with volumes from equations for the other groups in Table A3. Thus, instead of comparing equations, volumes derived from the equations were compared. On the assumption that volume variability might be concentrated in the stump, the procedure was repeated with the bottom 30 cm removed from equations and volume calculations. Finally, volumes from individual ecoregions (Set A in Table A3) were compared with volumes derived from two other sets of equations: (i) the equations used by the British Columbia Ministry of Forests applicable to the Fort Nelson-Cassiar area, and (ii) the equations given by Massie *et al.* (1983).

To derive the volume of a tree, the height was divided into 10 equal sections and the stem diameters were calculated from the taper equation (Appendix 1) at the ends and midpoint of each section. The diameters were used with Newton's formula to calculate stem section volumes, which then were summed to yield the tree volumes.

$$V = [(A_1+4A_2+A_3)/6]\,L$$

where V = tree section volume (m^3)
A_1 = area of small end of section (m^2)
A_2 = area of the midpoint of the section (m^2)
A_3 = area of large end of section (m^2), and
L = section length (m) = H/10

Results of area comparisons

1. Analysis of covariance

All 49 equations had a good fit; R^2 values ranged from 0.92 to 0.98. Of all the comparisons, the only equation grouping that was found to have no statistically significant difference from the individual equations was the group comprised of ecoregions 4 and 5. This result was common to all four species. This result indicates that, with the exception of ecoregions 4 and 5, individual ecoregion equations should be used.

2. Comparison of tree volumes

These tests were undertaken to find out what practically significant (as opposed to statistically significant) differences would occur if equations for groups of ecoregions, or equations from other sources, were used instead of equations for individual ecoregions. Assuming that the equations for individual ecoregions (Set A of Table A3) were the most accurate, the volumes derived from them were used as a benchmark for

comparison of volumes derived from the other equations.

The first volume comparison paralleled the analysis of covariance test which compared tree volumes derived from individual ecoregions (Set A of Table A3) with volumes derived from ecoregion groups (Sets B, C, D and E of Table A3). Volume differences of 10% or more were considered unacceptable.

In comparisons of tree volumes calculated from the combined equation (Set B of Table A3), only white spruce had no differences exceeding 10%. Comparisons with other groupings (Sets C, D, and E of Table A3) revealed the following:

- for lodgepole pine, one acceptable grouping was ecoregions 2 and 5, and ecoregions 4 and 12. Another acceptable grouping was ecoregions 4 and 5, and ecoregions 2 and 12. In each case, only one of the 12 volume differences exceeded 10%.

- for black spruce, acceptable groupings were ecoregions 2, 4, 5 and 11, and ecoregions 8, 9 and 12. Only one of the 14 volume differences exceeded 10%.

- for aspen, acceptable groupings were ecoregions 4, 5 and 8, and ecoregions 2, 9, 11 and 12. Only two of the 21 volume differences exceeded 10%.

The second volume comparison, in which the stump was eliminated from equation construction and volume calculations, revealed that the volume differences did not decrease materially. The conclusion to be drawn from this result is that differences in the equations are not specific to the lower 30 cm of the tree; hence, there is no advantage to this approach.

In the third and final comparison, volumes from equations for individual ecoregions (Set A of Table A3) were compared with volumes from the equations used by the British Columbia Ministry of Forests and equations from Massie *et al.* (1983). The number of differences exceeding 10% were used as an error index. In comparison with the acceptable groupings defined above, both equation sets had considerably more differences exceeding 10%, i.e., greater error.

The results of the volume comparisons indicate that tree volumes calculated from different ecoregion equations vary considerably. While most differences are small (less than 10%), some exceed 30%. This variability is supported by the results of the analyses of covariance. The variability may be real, or it may be the result of the relatively small sample sizes (Table A1) which may cause equations to exhibit greater differences than the parent populations. At the same time, if the variability is due to the small sample sizes, the individual ecoregion equations may not represent the "true" relationships and the error due to small sample size may be larger than the error due to combining ecoregions. Thus, the analyses and comparisons must be carefully interpreted; large or significant differences do not necessarily indicate that the groupings in question should be disregarded. Rather, the limitations of the tests must be acknowledged, and other factors, such as the balance between convenience and cost, must be considered. Also, one must remember that in most practical applications the accuracy of estimating individual tree volumes is not as important as that of estimating plot or stand volumes. For that purpose, equations based on ecoregion groupings may be less biased than the individual ecoregion equations.

Table A1. Distribution of sample trees by species and ecoregion

Species	Ecoregion								Total
	1	2	4	5	8	9	11	12	
White spruce	75	74	44	78	51	33	50	88	493
Black spruce	.	54	36	42	41	53	47	53	326
Lodgepole pine	.	102	30	69	.	.	.	27	228
Trembling aspen	.	34	28	30	26	20	40	23	201
All	75	264	138	219	118	106	137	191	1248

Table A2. Mensurational characteristics of sample trees by species

Species	Number of Trees	Diameter (cm)			Height (m)		
		Average	Range	CV %	Average	Range	CV %
White spruce	493	19	3 - 95	57	15	3 - 39	46
Black spruce	326	13	3 - 28	43	10	3 - 21	39
Lodgepole pine	228	14	2 - 43	52	12	2 - 24	39
Trembling aspen	201	14	3 - 44	54	12	4 - 22	34

Table A3. Grouping of ecoregions for analyses

Set	Species	Ecoregion Groups
A	Each	Individual ecoregions
B	Each	All ecoregions combined
C	Lodgepole pine	2 and 5 4 and 12
	White spruce	4, 5 and 8 1, 2, 9, 11 and 12
	Black spruce	4, 8 and 9 2, 5, 11 and 12
D	Each	1 and 2 4 and 5 11 and 12
E	Black spruce	8 and 9 2, 4, 5, 11 and 12 8, 9 and 12 2, 4, 5 and 11
	Aspen	4 and 5 4, 5 and 8 4, 5, 8 and 11 2, 8, 9, 11 and 12 2, 9, 11 and 12 2, 9 and 12