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Forest Management Planning

The Effects of Hurricane Juan on Managed Stands Commercially Thinned in Central Nova Scotia

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Abstract

Many commercially thinned (CT) stands in Nova Scotia were severely damaged by hurricane Juan in September 2003. Despite this it was observed that some commercially thinned stands were not impacted. In an attempt to determine whether stand conditions affected damage levels in commercially thinned stands, a survey was made in the winter of 2003/2004 with assistance from several Nova Scotia Forest Industry firms and the Nova Scotia Department of Natural Resources (NSDNR). A relationship was discovered to exist between the number of trees removed in the thinning, the slenderness of the trees and the wind damage. Stands with an average slenderness ratio of between 80-85 were damaged by Juan when removal levels exceeded 40% of the trees (30% of the basal area) . When stands had stouter trees with H/D ratios averaging between 70 and 75, tree removal levels could be up to 50% (40% of the basal area) before wind damage occurred.

Introduction

Hurricane Juan arrived in Nova Scotia on Monday, September 29, 2003 at 12:10 a.m. Atlantic Daylight time (1). It will be remembered as one of the great weather disasters in Nova Scotian history (2). Damage was widespread and included downed power lines, overturned boats, damaged buildings and wind-damaged forests (3). The landfall and subsequent track, with corresponding recorded wind speeds is shown in Figure 1. Most forest damage occurred within a 70 km wide corridor in central Nova Scotia on the eastern side of the storm, stretching from Halifax in the south to almost Tatamagouche in the north, as shown in Figure 2 (4). This corridor contains 680,000 hectares, with estimated volume losses exceeding 2 million m^3 of pulpwood and logs (4). These losses were not restricted to the natural, unmanaged forests. Managed forests were also hit; especially commercially thinned stands. However, not all thinned stands blew down, providing an opportunity to explore the factors contributing to wind damage. If such factors could be identified, management guidelines for commercial thinning that would reduce losses to wind could be developed. With that in mind, a survey was initiated to find out why some thinned stands blew down and others did not. This survey was funded by members of the Nova Scotia Forest industry (5), and supported by the Nova Scotia Department of Natural Resources (NSDNR), as well as the Forest Products Association of Nova Scotia.

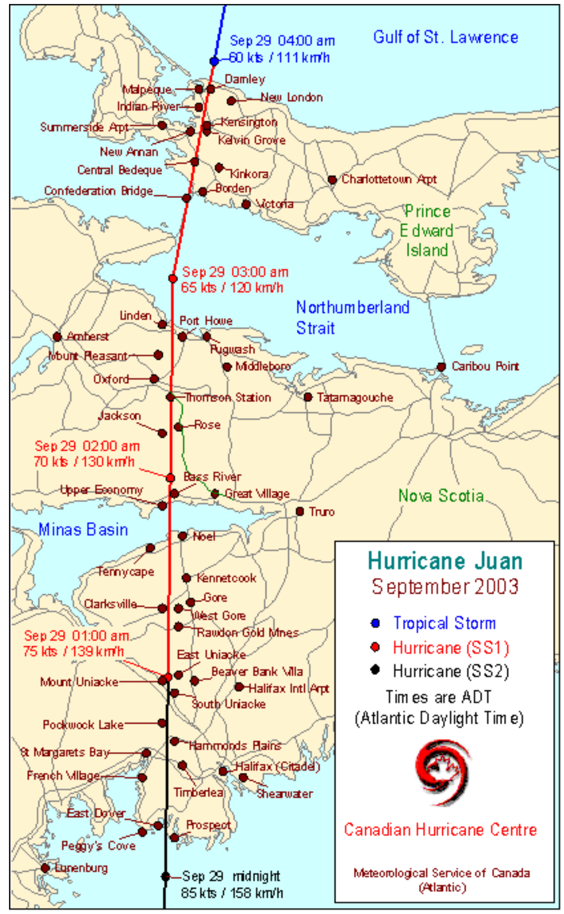


Figure 1. Juan Path (1)

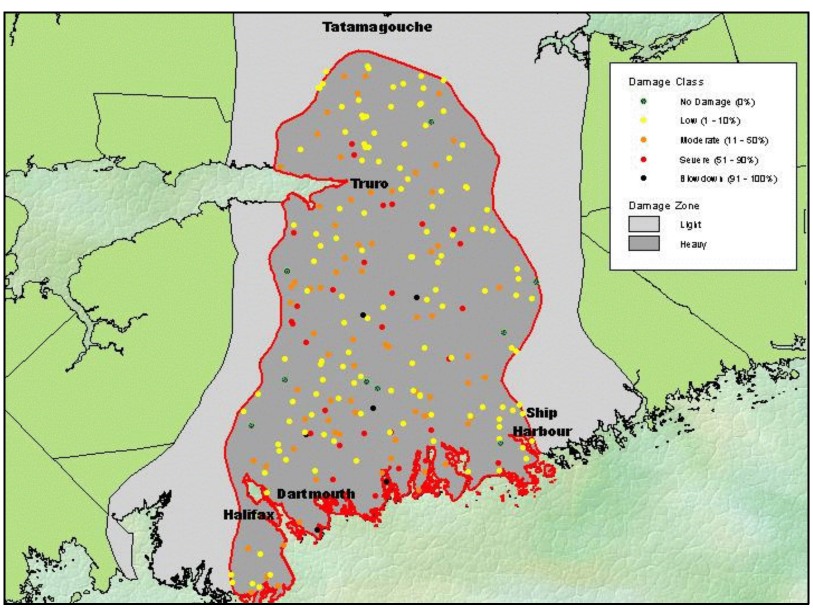


Figure 2. Preliminary Estimate of Juan Forest Damage.

In the days following Juan, speculation took place regarding the type of wind that caused forest damage. Discussions with the Canadian Hurricane Centre in Dartmouth determined that no evidence had been found indicating the presence of tornadoes, cyclones or micro bursts (6). The radar images did, however, show horizontal bands of different velocity winds within the hurricane. These bands were several miles wide, and did not fit the checkerboard damage pattern found. It therefore was theorized that the footprint effect observed from the air was caused by forest stand conditions. The question remained, what were these conditions? It is recognized that elevation, exposure, soil characteristics and tree species play an important role in determining wind firmness (7). However, it was hypothesized that tree slenderness and harvesting intensity could explain a large portion of the damage. In fact, Kenk (8) states that tree slenderness expressed as the ratio of tree height to diameter (H/D) is a good indicator of wind damage in Europe. Navratil (9) also states the importance of H/D and adds that removal levels have an influence on wind damage when discussing Boreal Mixedwoods.

Therefore, the following two factors were examined:

1) The percentage of trees removed in the thinning operation between the extraction trails, and

2) the slenderness ratio of the stand.

Methods

In the initial survey, mainly stands that had little or no damage were surveyed due to the difficulty of surveying stands with high levels of damage. In the course of surveying "low damage" stands some wind damage was encountered and recorded. The damage severity, in these cases was not recorded. It was hoped that if enough of these stands were examined, the levels of harvesting intensity and slenderness ratio where damage was less likely could be identified. It was recognized that the initial sample was biased towards selecting undamaged stands and that no severely damaged stands could be sampled due to practical considerations. To alleviate this situation, it was decided to follow up with a sample of pre-exiting NSDNR research permanent sample plots (PSPs) within the hurricane zone. It was not known prior to the survey which of the PSP's were damaged by Juan. Detailed data could be used from PSP measurements to characterize stand conditions and to determine damage severity. A sample of 6 commercially thinned PSP's were found within the hurricane zone. These were selected to be previously treated (plantations or pre-commercially thinned) stands of spruce species that were commercially thinned within 5 years of Juan. These data were combined and analyzed together with the initial sample. These PSP's were also analyzed separately to explore damage severity. Only stands that were either pre-commercially thinned or plantations were selected for this survey.

Initial Sample

Where possible, several plots were established in each stand without a PSP. Each plot was analyzed separately as they varied in condition and damage within stands. Plot centres were located between extraction trails. The following data were collected at each plot:

1) dominant height (Suunto)
2) breast height age (increment borer)
3) basal area (2 factor prism)
4) trees left and removed in the thinning were counted within a 100 m^2 circular plot centred at the same point as #3
5) occurrence of wind damage recorded within the plot (stem breakage or uprooting)

Knowing the basal area and the number of trees remaining, the mean diameter was estimated as follows.

Example:	BA	= Basal area per hectare	= 28 m^2
	TPH	= Number of trees per hectare	= 1400
	D	= Quadratic mean diameter at breast height	= sqrt (BA/(TPHx0.00007854)) =16cm
	sqrt	= Square root	

Average stand height was estimated by subtracting 2.0 m for spruce and 0.5 m for pine from the dominant height. This rule of thumb was obtained from PSP data.

The slenderness factor (H/D) was then calculated by dividing the average tree height in centimetres with the mean diameter in centimeters.

Example: Tree Height (H) = 11 m = 1100 cm
Tree Diameter (D) = 16 cm
Slenderness Ratio = H/D = 1100/16 = 69

The percentage of trees removed was calculated by dividing the number of stumps by the sum of standing trees and stumps times 100.

Example: Standing trees = 8
Stumps = 6
Initial density = 14
% Removed = 6/14 *100 = 43%

PSP Sample

The same calculations were made for PSP samples with the following differences:

1) mean diameter was calculated based on direct Dbh measurements of trees in the plots
2) average height was based on a sample of 15 tree height measurements within the plots
3) thinning removal levels were calculated based on the basal area of the trees removed within the plot
4) damage levels were calculated as the % of trees with wind damage (wind induced stem breakage or uprooting)

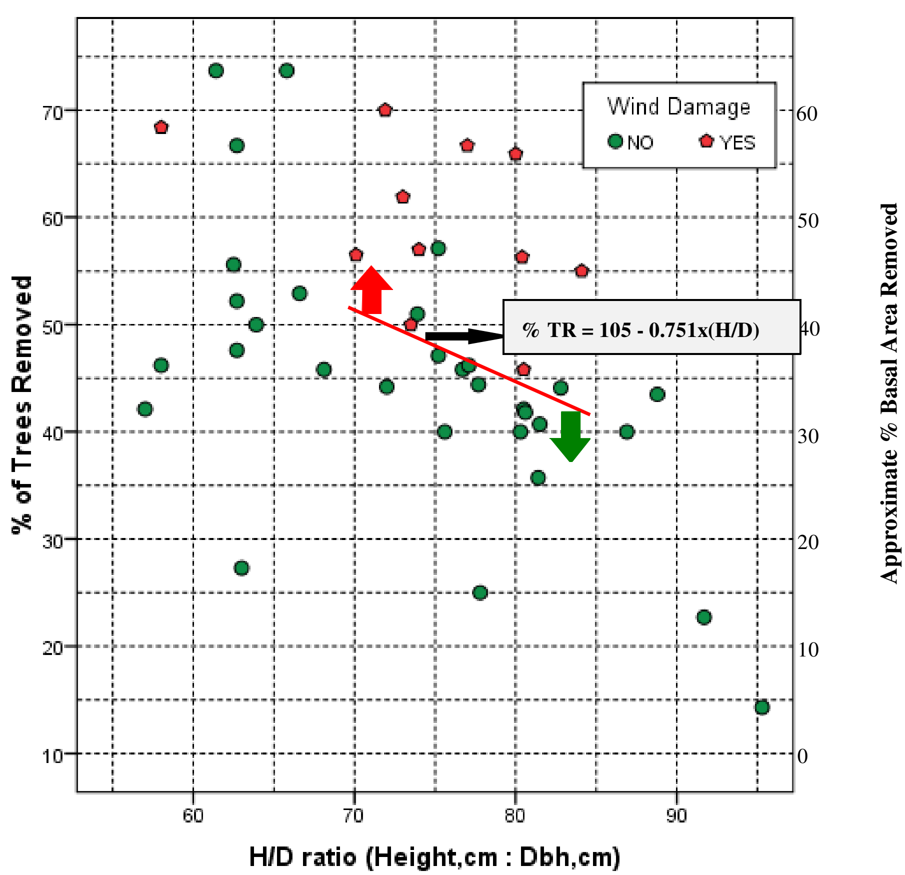
Results

A total of 26 sites were visited during this survey, with data from 42 sample points taken. Data from 6 NSDNR PSP's were included. The PSP data accounted for 15% of the sampled sites.

The results from this survey is shown in Figures 3 and 4. Figure 3 shows the occurrence of wind damage plotted against % of trees removed and slenderness ratio (H/D) for each plot sampled. The species breakdown of the overall samples was: White Spruce - 12%, Norway Spruce - 26%, Red Pine - 26%, Spruce/Fir - 14%, and Red Spruce - 21%. Elevation ranged from 15 to 258 meters.

By examining Figure 3, it can be observed that the damaged stands surveyed occurred at a combination of higher removals and slenderness ratios. This leads one to conclude that the risk to wind damage is higher for commercially thinned stands that have more trees removed during harvest and for those that are taller for a given diameter. A trend can be observed where the most slender stands with ratios between 80 and 85 encountered wind damage at tree removals starting at 45%. Stands with ratios between 70 and 75 show damage starting at 50% tree removal. No damage was incurred in plots with less than 45% of the trees removed.

Figure 3. Occurrence of Wind Damage in Surveyed Commercial Thinnings



These initial results are supported by the results based on only PSP data; shown in Figure 4. In these stands, the level of wind damage was recorded in addition to occurrence. The removal levels were recorded in percent basal area removal as well as percent of trees removed. The data indicates that the percent of the trees removed is approximately equal to the percent basal area removal plus 10 (Appendix I).

Damage started to occur at 38% basal area removal (46% tree removal) for stands with an H/D around 80; similar to conclusions based on Figure 3. At an H/D of approximately 75, 46% basal area removal (57% tree removal) resulted in damage. This figure also corresponds well with conclusions based on Figure 3. The highest level of damage (60% of trees) was encountered when the H/D was 80 at a basal area removal level of 57% (66% tree removal, Figure 5). No damage was measured for PSPs where less than 42% of the basal area was removed (51% of trees) between extraction trails. Again this result is equivalent to the findings from Figure 3.

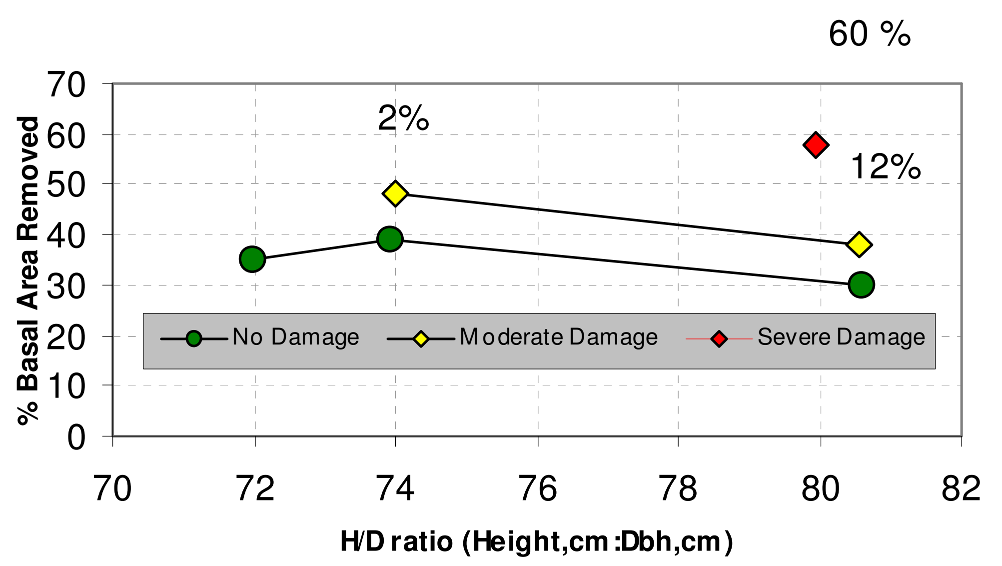


Figure 4. Percent Damage from Juan in CommerciallyThinned PSPs.

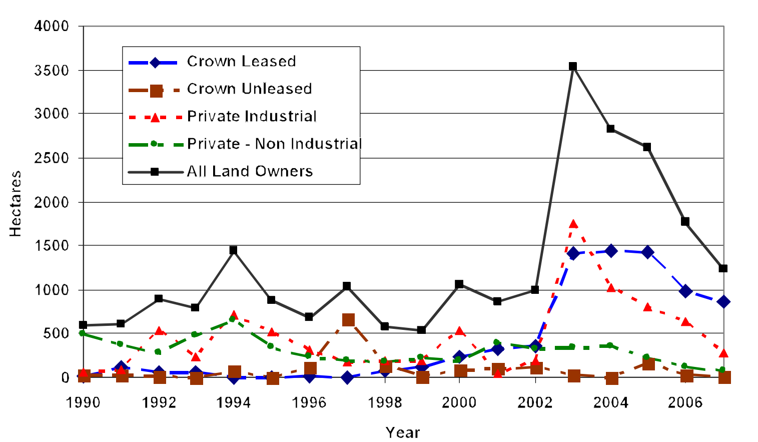
Figure 5. Wind damage in a Norway spruce plantation at Berichan, Colchester Co.

Discussion

This study is based on a limited sample of stands. Despite the limitation in data, there appears to be a relationship between the amount of wood taken out in a commercial thinning, the slenderness of the trees and the amount of wind damage. This relationship is comparable with European results looking at H/D ratio and wind damage (8). The ratio of 80 appears to be a valid threshold for risk to severe wind damage in Nova Scotia as was identified by Kenk (8). There also appears to be an interaction between this ratio and the amount of wood taken out when predicting wind damage. Where the ratio is lower than 80, damage starts to occur at removals exceeding 40% of the basal area, while damage starts to occur above 30% basal area removal when the H/D ratio exceeds 80.

G.D. Dwyer, in his study of blowdown in Nova Scotia in 1958, suggests that "cutting should not exceed 20 to 30% removed by volume where selective; selection or partial cutting is carried out" (10). This recommendation was presumably made for unmanaged stands unlike the stands studied and reported on here. The stands surveyed for this study were either pre-commercially thinned or planted before being commercially thinned. The stands studied by Dwyer therefore probably had higher slenderness ratios and were more likely to become wind damaged. Early density management using pre-commercial thinning or well spaced plantations results in stouter trees with higher diameters for a given height than for unmanaged stands. These types of stands would be more likely to withstand wind at higher removal rates than those recommended by Dwyer.

Figure 5. Commercial Thinning Area - Nova Scotia 1990-2007.



It is also noted that hurricane Juan occurred shortly after commercial thinning became more frequently implemented in Nova Scotia (Figure 5). This meant there was a large number of recently thinned stands when Juan hit Nova Scotia. These stands were more susceptible to wind damage than if they had more time to acclimate to the additional growing space before being buffeted by Juan (9).

Preliminary Recommendations

Commercial Thinning of managed stands is a viable silviculture treatment in Nova Scotia, as long as appropriate removal rates are taken during harvest. Wind damage can be avoided when less than 30% of the basal area is removed from stands with H/D ratios between 80 and 85 or less than 40% of the basal area is removed for H/D's less than 80. Stands with H/D's exceeding 85 should be commercially thinned only with extreme caution using minimal removals (<30% of the basal area) and only on sheltered, deep soiled sites. Soil conditions, and exposure conditions should be considered in all cases.

Wind conditions encountered by the stands surveyed for this report were extreme. Damage levels would likely be less severe under "normal" wind events. Despite this, extreme wind events are predicted to occur more frequently (11). If these predictions are realized it is more important than ever to design commercial thinnings to reduce susceptibility to wind damage.

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Appendix I. Data for Commercial Thinnings Surveyed

Plot	Location	PSP	Spec	Trt	Yr- CT	Exp	Elev	Age	AHT	TF-bef.	RBA	TD	H/D	Trees rem	BAR	Wind	Damage
#		#					(m)		(m)	(t/ha)	(m2/ha)	(cm)	(cm:cm)	(%)	(%)	Damage	(%)
1	Burnside	NA	Sp-Fir	PCT	2000	ND	ND	49	9.5	1900	24.0	16.7	57.0	42.1	ND	NO	ND
2	Burnside	NA	Sp-Fir	PCT	2000	ND	ND	49	11.0	1900	ND	0.0	58.0	68.4	ND	NO	ND
3	Burnside	NA	Sp-Fir	PCT	2000	ND	ND	49	10.5	1300	18.0	18.1	58.0	46.2	ND	YES	ND
4	Manganes Mines	NA	wS	PLT	2000	SW	130	29	12.4	1900	16.0	20.2	61.4	73.7	ND	NO	ND
5	Tatamagouche	NA	wS/wP	PCT	ND	ND	ND	35	10.0	1800	ND	16.0	62.5	55.6	ND	NO	ND
6	Reid Rd	NA	NS	PLT	2002	S	158	19	10.0	2100	22.0	16.0	62.7	47.6	ND	NO	ND
7	Reid Rd	NA	NS	PLT	2002	S	158	19	10.0	2300	22.0	16.0	62.7	52.2	ND	NO	ND
8	Earltown	NA	NS	PLT	2001	NW	255	33	10.0	2700	18.0	16.0	62.7	66.7	ND	NO	ND
9	Old Barns	NA	rS/wS	PCT	2002	ND	70	65	16.5	1100	ND	26.2	63.0	27.3	ND	NO	ND
10	Perch Lake Rd	NA	rS	PCT	ND	ND	197	49	13.0	1600	26.0	20.3	63.9	50.0	ND	NO	ND
11	Cox Brk Rd	NA	rP	PLT	2002	ND	ND	22	10.5	1900	10.0	16.0	65.8	73.7	ND	NO	ND
12	Middle Musquodobit	NA	rP	PLT	1195	S	65	30	15.5	1700	34.0	23.3	66.6	52.9	ND	NO	ND
13	Reid Rd	NA	NS	PLT	2002	S	158	19	10.0	2400	22.0	14.7	68.1	45.8	ND	NO	ND
14	Reid Rd	NA	NS	PLT	2002	S	158	19	10.0	2300	16.0	14.3	70.1	56.5	ND	NO	ND
15	Manganes Mines	NA	wS	PLT	2000	SW	130	29	12.4	2000	14.0	17.2	71.9	70.0	ND	YES	ND
16	**Reid Rd**	**8902**	NS	PLN	2002	S	150	19	10.2	2580	22.7	14.2	72.0	**44.2**	**35.3**	YES	**0**
17	Perch Lake Rd	NA	rS	PCT	ND	ND	197	49	13.0	2100	ND	0.0	73.0	61.9	ND	NO	ND
18	Reid Rd	NA	NS	PLT	2002	S	158	19	10.0	2200	16.0	13.6	73.5	50.0	ND	YES	ND
19	**Maganese Mines**	**8346**	wS	PLN	2000	SW	130	29	12.3	2550	27.2	16.6	73.9	51.0	**39.0**	YES	**0**
20	**Maganese Mines**	**"0018**	wS	PLN	2000	SW	135	29	12.4	2500	23.7	16.8	74.0	**57.0**	**47.6**	NO	**2**
21	Old Burnside Rd	NA	Sp-Fir	PCT	2000	ND	ND	49	12.0	1700	18.0	16.0	75.2	47.1	ND	YES	ND
22	Middle Musquodobit	NA	rP	PLT	1195	S	65	30	15.5	2100	30.0	20.6	75.2	57.1	ND	NO	ND
23	Tatamagouche	NA	rP	PLT	2003	NE	15	35	14.5	1500	26.0	19.2	75.6	40.0	ND	NO	ND
24	Earltown	NA	NS	PLT	2001	NW	255	33	12.0	2400	25.0	15.6	76.7	45.8	ND	NO	ND
25	Earltown	NA	NS	PLT	2001	NW	255	33	12.0	2400	ND	0.0	77.0	66.7	ND	NO	ND
26	Farm Lk Rd	NA	rS	PCT	2000	S	258	45	12.0	3900	40.0	15.6	77.1	46.2	ND	YES	ND
27	Tatamagouche	NA	rP	PLT	2003	NE	15	35	13.0	1800	22.0	16.7	77.7	44.4	ND	NO	ND
28	Old Barns	NA	rS/bS	PCT	1992	ND	50	62	12.0	2000	28.0	15.4	77.8	25.0	ND	NO	ND
29	**Berichan**	**8206**	NS	PLN	2001	NW	255	28	12.8	2200	15.1	16.0	80.0	**65.9**	**56.5**	NO	**60**
30	Balfron	NA	rP	PLT	ND	ND	20	30	13.5	1500	20.0	16.8	80.3	40.0	ND	YES	ND
31	Balfron	NA	rP	PLT	ND	ND	20	30	13.5	1600	ND	16.8	80.4	56.3	ND	NO	ND
32	**Berichan**	**8205**	NS	PLN	2001	NW	255	33	10.1	2400	16.1	12.5	80.5	**45.8**	**38.0**	YES	**12**
33	Lake Mulgrave	NA	Sp-Fir	PCT	ND	ND	ND	55	14.5	1900	28.0	18.0	80.5	42.1	ND	YES	ND
34	**Farm Lk Rd**	**9922**	rS	PCT	1999	SW	280	54	11.6	4125	39.1	14.4	80.6	**41.8**	**31.5**	NO	**0**
35	Old Barns	NA	rS	PCT	1992	ND	ND	62	15.0	1400	24.0	18.4	81.4	35.7	ND	NO	ND
36	Perch Lake Rd	NA	rS	PCT	ND	ND	197	49	13.0	2700	32.0	16.0	81.5	40.7	ND	NO	ND
37	Cox Brk	NA	rP	PLT	ND	E	191	22	10.5	3400	24.0	12.7	82.8	44.1	ND	NO	ND
38	Middle Musquodobit	NA	rP	PLT	1195	S	65	30	15.5	2000	24.0	18.4	84.1	55.0	ND	NO	ND
39	Middle Musquodobit	NA	rP	PLT	1195	S	65	30	15.5	2000	30.0	17.8	86.9	40.0	ND	YES	ND
40	Farm Lk Rd	NA	rS	PCT	2000	S	258	45	16.2	2300	34.0	18.2	88.8	43.5	ND	NO	ND
41	New Anan	NA	rP	PLT	1994	ND	79	36	16.5	2200	ND	18.0	91.7	22.7	ND	NO	ND
42	Lake Mulgrave	NA	Sp-Fir	PCT	ND	ND	ND	ND	17.0	1400	30.0	17.8	95.3	14.3	ND	NO	ND

Spec - Species: Sp-Fir = Spruce Fir, w S = White Spruce, w P = White Pine, NS = Norw ay Spruce, rS = Red Spruce, rP = Red Pine

Trt - Treatment before Commercial Thinning : PCT = Pre-commercial Thinning, PLT = Plantation

Yr-CT - Year of Commercial Thinning **Exp** - Compass Direction of Exposure **Elev** - Elevation in Metres **Age** - Age in years at Breast Height

AHT - Average Height in Metres **TF-bef.** - Density of trees before Commercial Thinning in trees per hectare

RBA - Residual Basal Area of Stand after Commercial Thinning in metres sqaured per hectare **TD** - Average Diameter at Bresat height

H/D - Height to Diameter ratio, Height in centimteres and Diamteer in centimetres **Trees rem** - Precent of the trees removed in Commercial Thinning

BAR - Percent of Basal Area Removed in Commercial Thinning **Damage** - None - no damge, Wind - uprooting or stem breakage of trees in plot due to w ind

Damage % - Percent of Trees damaged in plot **NA** - Not Applicable **ND** - No Data