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Pockwock - Bowater Watershed Study
Wind Damage in Streamside Management Zones

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Contents

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POCKWOCK - BOWATER WATERSHED STUDY

Wind Damage in Streamside Management Zones

Special management zones (SMZ's) are used in many jurisdictions to buffer streams and riparian habitats from the effects of forest harvesting. Special management zones can be particularly susceptible to blowdown which may significantly reduce their quality and effectiveness. This study was carried out as part of the Pockwock - Bowater Watershed Project to quantify blowdown and soil disturbance levels one year after harvest in relation to Special Management Zone widths, thinning treatments, site conditions, and edge exposure.

METHODS

Pockwock-Bowater Watershed Project Description.

The Pockwock-Bowater Watershed Project was established as a multi-partner research project to investigate the effects of clearcut harvesting on stream and lake water in relation to different special management zone practices (Anon, 2001). The project was located at two sites, which each provided 4 first order watersheds with similar physical and compositional conditions suitable for comparative study. Four treatments were tested, which included clearcut harvesting using 20 m SMZ's, 20 m thinned SMZ's, 30 m thinned SMZ's, and a control watershed with no harvesting. Treatments were randomly applied to the watersheds at each site, thus providing a study consisting of 2 replications of 4 treatments. Depending upon the mature timber available, harvest areas covered 20 to 40 percent of the watersheds (McCurdy and Stewart, 2008).

Establishment and Thinning in Special Management Zones(SMZ).

Special Management Zones (SMZ) were established along all streams (greater than 50 cm width) bordered by stands scheduled for harvesting. A *Laser Technology, Inc Impulse 200* © rangefinder was used to measure horizontal distances of 20 m and 30 m from stream edges in accordance with the project prescriptions (McCurdy and Stewart, 2008).

For Special Management Zones in which commercial thinning was prescribed merchantable trees (greater than 8 cm dbh) were harvested to uniformly retain 20 m^2/ha basal area (trees of all sizes). Thinning was conducted using mechanical harvesters, and wood was extracted using porters (McCurdy and Stewart, 2008). Narrow extraction trails (3 - 4 m), spaced approximately 15 - 20 m apart, were cut perpendicular to the buffer edge to provide machine access for thinning with a 9 meter boom. Machines were not permitted to drive within 7 m of stream edges. Harvesting was controlled by pre-marking "sample" thinnings periodically along the zones to help operators remain calibrated and consistent. Basal area was monitored during and after thinning using temporary plots (2 BAF prism) measured from the center of the special management zones. Areas too wet or steep were not thinned.

Sampling

In the treated watersheds blowdown was assessed along the full length of the Special Management Zones bordered by harvesting. In the control watersheds the Special Management Zones were assessed along the portions of streams that had merchantable forest characteristics similar to what was harvested in the treated watersheds. Special Management Zones were subdivided and classified for sampling according to differences in cover type (softwood, mixedwood, hardwood), treatment (thinned, not thinned), and presence of "flow accumulation" site conditions. Global Positioning was used to record the locations of the subdivisions for calculating the length of each class.

Flow accumulation site conditions occur where sub-surface water collects from upslope positions, resulting in locally higher water tables and a concentrated entry point for water entering the stream. It is significant to categorize these areas within Special Management Zones because the associated imperfect to poor soil drainage results in shallow rooting and increased susceptibility to blowdown. These areas may also be more sensitive to harvesting impacts (rutting, puddling, stream inputs) due to the site conditions and close relationship to the hydrological system. In this study, the expected locations of flow accumulation areas were predicted using a digital elevation model that mapped water flow. On-site verification was completed by observation of topography, vegetation changes, and soil drainage.

All merchantable-sized trees ($\geq$ 9.1 cm dbh) in the Special Management Zones damaged by uprooting or breakage following the harvest in 2001 were assessed.Trees were considered damaged when injury was sufficiently severe to expect tree mortality (eg. roots uplifted, tree leaning, $\geq$ 50 percent of live crown lost, etc). Unmerchantable-sized trees were measured if an uprooted area greater than .75 m^2 existed. Assessment included: 1) species, 2) diameter at breast height , 3) canopy dominance, 4) damage type (uproot/snap), 5) cause of blowdown, 6) dimensions of uprooting (length x width), 7) percentage of uprooted area with exposed soil, and 8) location within zone (0-5 m, 6-10m, 11-20m, 21-29m from cut edge, or within 1 m of stream edge). In addition, a Garmon 12 © Global Positioning System was used to log the location of each tree.

RESULTS

Damage Types - Uprooting and Breakage

Results indicate that 88.9 percent of the blown down trees were uprooted and 11.1 were snapped (Figure 1). The high proportion of uprooting is a reflection of the shallow rooted nature of the spruce and fir forest types that dominated the SMZ zones.

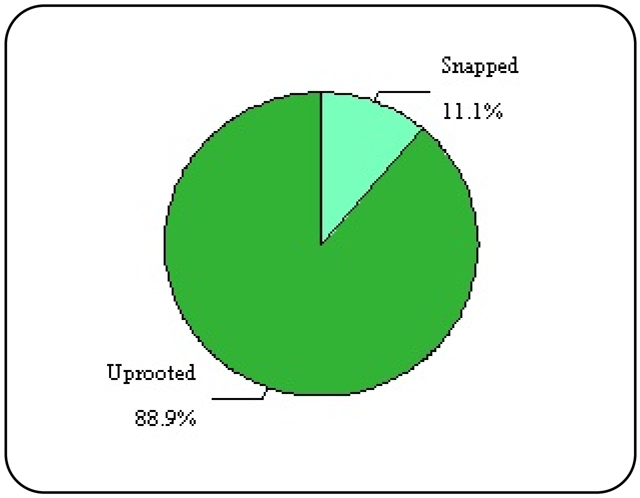

Figure 1. The proportion of uprooting and stem breakage averaged across all sites.

Thinning Effects on Blowdown and Soil Exposure

The frequency of blowdown varied considerably by treatment in the SMZ (Figure 2). Thinning to 20 m^2 basal area almost doubled the amount of trees that blew down compared to the unthinned (92 trees/ha thinned; 49 trees/ha unthinned). Very few trees (2 trees/ha) blew down in the control watersheds.

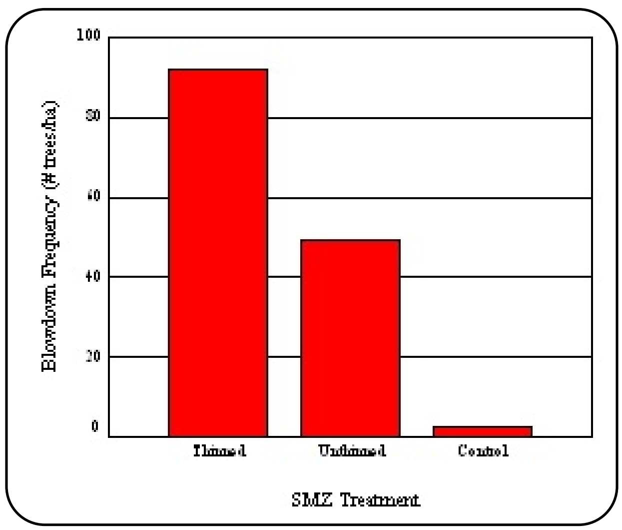

Figure 2. Effect of harvesting and thinning on wind throw frequencies (#/ha).

(Note. The 10 m strip along the stream was excluded from the 30 m buffers in order to provide equal comparison between 20m & 30m buffers)

Soil exposure due to uprooting increased dramatically in thinned watersheds (Figure 3). Thinned watersheds had 258 m^2/ha of exposed soil, unthinned watersheds had 107 m^2/ha and control watersheds had 1 m^2/ha of exposed soil.

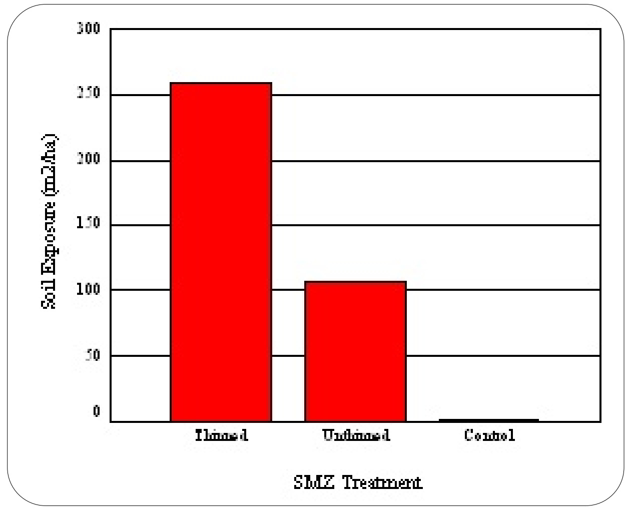

Figure 3. Effect of harvesting and thinning on the amount of soil exposure (m^2/ha).
(Note. The 10 m strip along the stream was excluded from the 30 m buffers in order to provide equal comparison between 20m & 30m buffers)

Damage in Flow Accumulation Zones

Flow accumulation areas occurred along 5 percent (average, by length) of the SMZ's in the watersheds. The frequency of blowdown in the flow accumulation zones was more than double that of non-flow accumulation zones (96 trees/ha vs 48 trees/ha)(Figure 4).

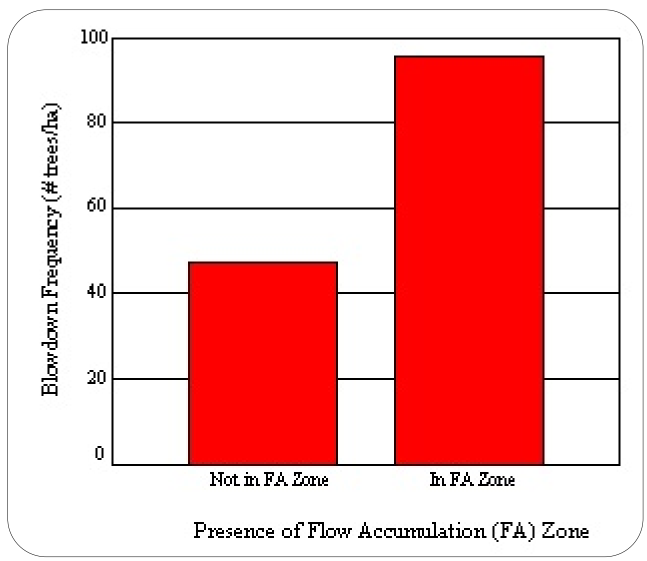

Figure 4. Influence of flow accumulation zones of the frequency of wind throw damage.

Soil exposure also doubled in the flow accumulation areas. Flow accumulation zones averaged 303 m^2/ha of soil exposure, while the rest of the SMZ averaged 124 m^2/ha of exposure (Figure 5).

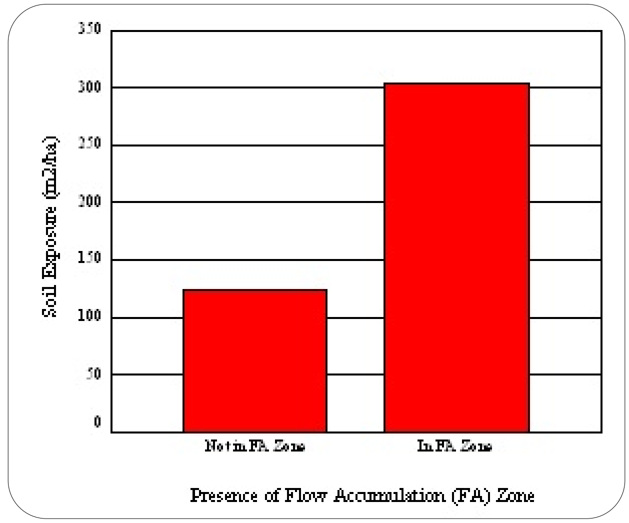

Figure 5. Influence of Flow Accumulation zones on soil exposure (m^2/ha).

Comparisons between Individual Watersheds

The thinning target in the SMZ's for treated watersheds was 20 m^2/ha basal area retention. The average basal area that was measured after harvesting ranged from 21.0 m^2/ha to 23.8 m^2/ha (Table 1). The unthinned watersheds had 33.5 and 33.7 m^2/ha basal area. The loss of basal area from blowdown ranged from 0.3 m^2/ha (1.3 percent) at Moose Cove Brook to 2.4 m^2/ha (11.3 percent) at Long Ponds.

Table 1. Basal area immediately after harvest and amount of blowdown that fell the next year.

Watershed (treeatment)	Average Post-Harvest Basal Area (m^2/ha)	Basal Area of Blowdown (m^2/ha)	Residual Basal Area (m^2/ha)	Percent Basal Area Down (%)
Long Gullies(20m no thin)	33.7	1.6	34.1	4.5
Walsh Brook (20m no thin)	33.5	1.1	32.4	3.3
Long Ponds (20m thin)	21.2	2.4	18.8	11.3
Black Brook (20m thin)	22.4	2.3	20.1	10.3
Moose Cove Brook (30m thin)	23.8	0.3	23.5	1.3
Sandy Brook West (30m thin)	21	2.3	18.7	11
Peggy's Brook (control)	Not assessed	20m 0.1 30m < 0.1		
Sandy Brook East (control)	Not assessed	20m < 0.1 30m < 0.1		

Blowdown losses were highest in the 20 m thinned SMZ's, with both sites suffering damage to more than 10 percent of the basal area (2.4 m^2/ha; 10.8 percent average) (Figure 6). Damage levels were considerably lower in the 20 m unthinned SMZ's, averaging 1.3 m^2/ha or 3.9 percent of basal area. Results were inconsistent in the 30 m thinned SMZs, with one site (Sandy Brook West) sustaining damage at levels similar to the 20 m thinned sites, and the other (Moose Cove) experiencing very little blowdown. Much of the Moose Cove Brook SMZ was located at the base of a long slope which may have afforded a measure of wind protection, although this is difficult to verify. Both of the control watersheds experienced very little blowdown damage (less than 0.1 m^2/ha basal area).

Figure 6 illustrates that exposed edges and thinning both have aggravating effects on SMZ stability. The highest concentration of blowdown occurred along the cut edge of treated watersheds. The occurrence of blowdown within 5 m of the exposed cut edge ranged from 1.1 m^2/ha at Moose Cove Brook to 9.1 m^2/ha at Sandy Brook West.

The concentration of blowdown within 1 m of the stream edges varied according to treatment within the SMZ. The 20 m thinned buffers had the highest amount of blowdown along the stream edge (6.2 m^2/ha on average). The 20 m unthinned SMZs had a moderate amount of blowdown at the stream edge (0.5 m^2/ha on average). The 30 m thinned SMZ's remained relatively intact within 10 m of the streams and had similar damage levels in this area as the control watersheds.

Watershed		Stream edge	Basal Area of Blown Down Trees (m^2/ha) by Distance to Stream Edge: 0 - 1	2 - 10	11 - 15	16 - 20	21 - 25	26 - 30	Edge
20m (No Thin)	Long Gullies	STREAM EDGE	0.9	0.3	0.7	5			CUT EDGE
20m (No Thin)	Walsh Brook	STREAM EDGE	0.1	0	0.3	4			CUT EDGE
20m (Commercial Thin)	Long Ponds	STREAM EDGE	10.6	0.7	1.7	4.6			CUT EDGE
20m (Commercial Thin)	Black Brook	STREAM EDGE	1.8	0.7	1.4	6.3			CUT EDGE
30m (Commercial Thin)	Moose Cove Brook	STREAM EDGE	0	0	0.3		0.2	1.1	CUT EDGE
30m (Commercial Thin)	Sandy Brook West	STREAM EDGE	0.1	0	1.4		1.7	9.1	CUT EDGE
Control (No Thin)	Peggy's Brook	STREAM EDGE	0.6	0	< 0.1		0	0	FOREST (NO EDGE)
Control (No Thin)	Sandy Brook East	STREAM EDGE	0	0	0.1		0	0	FOREST (NO EDGE)

Shade	Basal Area of Blowdown (m^2/ha)
	0
	Trace (< 0.1)
	0.1 - 0.5
	0.6 - 1.0
	1.1 - 4.0
	4.1 - 8.0
	> 8.0

Figure 6. Basal area (m^2/ha) of blown down trees by watershed, distance to stream, and cut edge.

The area of exposed soil from uprooting is presented in Figure 7 for each watershed. Sandy Brook West had the highest amount of soil exposure (270 m^2/ha) and Moose Cove Brook had the least (31 m^2/ha) of the treated watersheds. The 20 m thinned watersheds averaged the most soil exposure, (225 m^2/ha) while the 20 m unthinned watersheds had approximately half as much (120 m^2/ha). The control watersheds experienced virtually no soil exposure from uprooting.

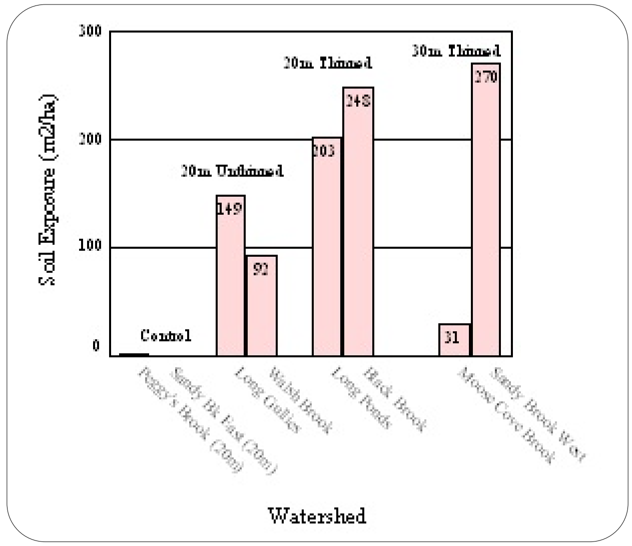

Figure 7. Soil exposure (m^2/ha) resulting from wind throw in individual watersheds, grouped by treatment.

The patterns of soil exposure resulting from uprooting are shown in Figure 8. Similar to blowdown occurrence, the highest concentration of soil disturbance occurred within 5 meters of the exposed edge bordering the clearcut. Within this area soil exposure ranged from 147 m^2/ha at Moose Cove Brook to 1 308 m^2/ha at Sandy Brook West.

Soil disturbance next to the stream was high in the 20 m thinned SMZs (191 m^2/ha at Black Brook and 908 m^2/ha at Long Ponds). The other watersheds had little exposure next to the stream (from 0 m^2/ha at Walsh Brook, Moose Cove Brook, and Sandy Brook West to 61 m^2/ha at Long Gullies).

Watershed			Soil Exposure (m²/ha) by Distance to Stream Edge						
			0 - 1	2 - 10	11 - 15	16 - 20	21 - 25	26 - 30	
20m (No Thin)	Long Gullies	STREAM EDGE	61	32	37	488	CUT EDGE		
	Walsh Brook		0	0	9	358			
20m (Commercial Thin)	Long Ponds		908	36	113	451	CUT EDGE		
	Black Brook		191	63	167	673			
30m (Commercial Thin)	Moose Cove Brook		0	0	10		16	147	CUT EDGE
	Sandy Brook West		12	0	76		157	1 308	
Control (No Thin)	Peggy's Brook		46	0	2		0	0	NO EDGE
	Sandy Brook East		0	0	1		0	0	

Shade	Soil Exposure (m²/ha)
(white)	0
(lightest)	1 - 50
(light)	51 - 100
(medium)	101 - 300
(dark)	301 - 500
(darkest)	> 500

Figure 8. Soil exposure (m²/ha) from uprooting in relation to the distance from stream and cut edges for individual watersheds.

Species Response to Blowdown

The Special Management Zones were composed primarily of red and black spruce, with moderate amounts of balsam fir and red maple, as well as scattered white pine, yellow & white birch, eastern larch, and eastern hemlock (Table 2). Red and black spruce appeared to be most susceptible to damage, and blew down in higher proportion to their composition at every site except Moose Cove Brook. Spruce are shallow-rooted and therefor susceptible to blowdown, having an average rooting depth of 33 cm and a maximum of 56 cm (red spruce) and 60 cm (black spruce) (REF - Silvics new).

Balsam fir also appeared to be susceptible to damage, and on average blew down in proportion to its original stand composition. This was not consistent across watersheds, with Moose Cove Brook having a much higher proportion of damage in fir, while Walsh Brook and Long Ponds had a lower proportion of balsam fir that blew down compared to the original stand composition. Although balsam fir is considered a shallow - rooted species with a high windfall potential, it generally has a deeper rooting system than spruce trees with average depths ranging from 60 - 75 cm and a maximum of 137 cm (REF - Silvics new).

Red maple appeared to be more resistant to blowdown than either the spruce or fir, having a much lower proportion of damage compared to the original stand composition. The proportions of the other species in the special management zones was too low to draw useful comparisons.

Table 2. Comparison of the species affected by blowdown one year after harvest to their composition in the Special Management Zones immediately after harvest (percent of basal area).

	Red & Black Spruce		Balsam Fir		Red Maple		White Pine		Other (yellow & white birch; eastern larch; eastern hemlock)	
Watershed	After Harvest. SMZ Compo-sition (% BA)	Wind-throw (% BA)	After Harvest. SMZ Compo-sition (% BA)	Wind-throw (% BA)	After Harvest. SMZ Compo-sition (% BA)	Wind-throw (% BA)	After Harvest. SMZ Compo-sition (% BA)	Wind-throw (% BA)	After Harvest. SMZ Compo-sition (% BA)	Wind-throw (% BA)
Long Gullies	51	73	30	27	10	0	6	0	3	0
Walsh Brook	73	94	13	1	13	5	1	0	<1	0
Long Ponds	58	72	34	20	7	<1	0	8	1	0
Black Brook	66	89	10	9	24	2	0	0	<1	<1
Moose Cove	80	48	8	50	6	2	3	0	3	0
Sandy Brook	77	95	4	4	19	1	<1	0	0	0
Total	68	79	16	18	13	2	2	1	1	<1

CONCLUSION

Almost 90 percent of the blowdown occurred as uprooted trees. Uprooted trees have a higher impact on the forest ecosystem than snapped trees because, in addition to the death of the tree itself, an uprooted tree can lift a large mat of forest floor exposing the soil underneath. This changes the structure of the forest floor producing mounds and pits and increases susceptibility to soil erosion.

Blowdown and soil exposure was much higher in flow accumulation areas. This implies that these areas should be protected from wind as much as possible because uprooting and soil disturbance can lead to increased erosion and sedimentation as these are the areas where sub-surface groundwater is carried into the stream. Special practices in flow accumulation areas could include the use of wider buffers, no-thin zones, and machine-exclusion zones. Other strategies could consider long-term management strategies to create wind resistant forest structure and promote windfirm species within flow accumulation and other poorly drained areas.

Commercial thinning within the Special Management Zones increased the amount of blowdown and soil exposure. The reduction in forest density resulting from thinning seems to allow greater wind penetration and increases susceptibility to windthrow. Basal area loss per unit area was greater in the thinned watersheds, where there was less basal area after harvesting compared to unthinned and control watersheds (Table 1). The 20 m thinned Special Management Zones had the highest loss of basal area, followed by the 30 m thinned SMZ's. Results in the 30 m thinned were inconsistent, with one having high blowdown levels similar to the 20 m thinned, and the other having relatively low levels of blowdown.

The highest concentration of blowdown and soil exposure occurred along the clearcut edge where the trees were most exposed. In all cases blowdown and soil exposure levels declined as distance from the cut edges increased, except in the 1 m strip along the stream edges. Blowdown and soil exposure next to the stream was highest in the 20m thinned SMZ's. Although there was more blowdown and soil exposure recorded for the 30 m thinned watersheds compared to the 20 m unthinned watersheds (average), there was less blowdown and soil exposure in the 10 m strip next to the stream in the 30 m thinned watersheds, suggesting that the penetrating effect of the wind was reduced, thereby lessening wind throw. Blowdown damage near the stream in the 30 m thinned watershed was very light, and similar to the untreated control watersheds. To maintain the highest integrity of stream side forest after a harvest, these early results suggest that the use of a 30 m SMZ is favourable in these conditions.

Red and black spruce were the most common species in all of the SMZ's, and appeared to be the most susceptible species to blowdown. Balsam fir was the second most common species, and was also relatively susceptible to damage. Red maple was only slightly less common than balsam fir and appeared to be relatively windfirm and resistant to blowdown. White pine, yellow birch, white birch, eastern larch, and eastern hemlock were present at low levels and their susceptibility to blowdown was not evident. Tree selection is an important component of riparian zone management, with the deeper rooted species appearing to provide the most stability and resistance to wind damage.

REFERENCES

Anon. (2005). *Watershed Study: Understanding the Impacts of Forest Practices on Water*. Growing ideas project note. Technical Project Note Series Publ. by Nova Forest Alliance - Model Forest Network, Stewiake, N.S. 4 pp. [accessed on April 10, 2008] Available at http://map.ns.ec.gc.ca/forest/www/en/docs/001-technote1-general.pdf

McCurdy, D., and B.J. Stewart. (2008). *Pockwock-Bowater watershed study - watershed descriptions and harvesting information*. Nova Scotia Dept. Of Natural Resources, Report FOR 2008-4 No. 85. 7 pp. Available at http://www.gov.ns.ca/natr/publications/forpubs.htm

Neily, P., E. Quigley, L. Benjamin, B. Stewart, T. Duke. (2003) *Ecological Land Classification for Nova Scotia. Vol 1 - Mapping Nova Scotia's Terrestrial Ecosystems*. Nova Scotia Dept. of Natural Resources, Forestry Division, Truro. 83 pp. [accessed on April 10, 2008] Available at http://www.gov.ns.ca/natr/forestry/ecosystem/elcpg1.htm

NSDLF. (1986) *Biophysical Land Classification for Nova Scotia*. Nova Scotia Dept. of Lands and Forests, Forestry Division, Truro. Maps and Digital Data.

Talbot, D. (ed). (1982) *Forest Access Roads Planning and Construction Manual*. Nova Scotia Dept. of Lands and Forests, Truro. 106 pp.