Wildland Fire Operations
Western Division

Considerations for Mitigating Windthrow Due to Forest Fuel Treatments

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Introduction

Fuel management treatments frequently include partial harvesting and the removal of surface fuels. However, residual trees may be prone to windthrow and could create undesirable surface fuels within the treatment area. Aesthetics and safety are also a concern since most treatments are done around communities within or near areas of high visibility and recreational use. Techniques to reduce windthrow can be employed at the planning and treatment stages, and can provide obvious benefits in addition to reducing ongoing fuel maintenance costs within the treatment area.

This document discusses techniques to reduce windthrow loss when a mature overstorey is treated with partial harvesting and removal of surface/ladder fuels. Harvesting patterns may include patch or individual stem retention.

Objectives

The objectives of this document are to:

- Provide a brief overview of factors that influence windthrow as a result of fuel management.
- Provide suggestions on treatment design to reduce wind damage.

Windthrow Factors

Windthrow results from complex interactions of regional wind regime, local topographic modification of the wind pattern, stand and tree characteristics and conditions, soil condition, and management practices. Windthrow risk can be evaluated using field-based diagnoses, statistical windthrow risk models, and mechanistic windthrow risk models. Good statistical models have been produced for British Columbia's forests and the United Kingdom windthrow risk model "ForestGALES" is being adapted for Canadian forests[1]. Modelling results have suggested that fuel management planning (i.e., harvest design) could mitigate windthrow (Table 1).

Table 1. Importance of windthrow hazard factors.

Importance	Factor
Primary	Regional climate Topography Harvesting
Secondary	Pre-harvest stand conditions Pre-harvest tree conditions
Tertiary	Soil condition (Trees often compensate for local soil conditions by modifying their rooting characteristics, but local variability in soil moisture and depth can affect anchorage.)

[1] Steve Mitchell, PhD., Associate Professor, University of British Columbia, Department of Forest Sciences, pers. comm. February 2005.

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Diagnostic assessment of windthrow risk in field

Topographic component

Most windthrow occurs during large-scale storm events such as the passage of low pressure systems or fronts. These regional scale winds are modified by local terrain. Orientation of past windthrow is a good field indicator of local storm wind directionality.

- When prevailing winds are parallel to the direction of terrain, valley bottoms and ridge tops are at most risk, and mid-slope areas are at moderate risk.
- When prevailing winds are perpendicular to terrain, ridge tops are at most risk, mid-slope is moderate risk, and valley bottoms are low risk.
- Turbulence is caused on the lee side of hills (Figure 1).

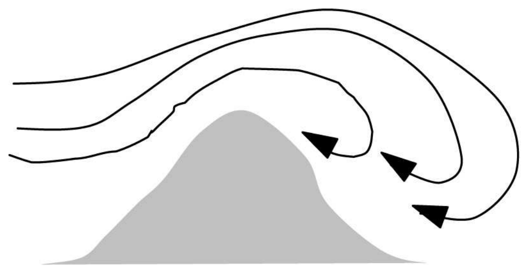

Figure 1. Topography - influenced turbulence.

The diagnostic question for assessing local topographic modification of wind is: *Are wind speeds normal for the area, or are they lower or higher due to the presence of a terrain obstacle or constriction?*

Stand and individual tree component

All trees have the capacity to acclimate to routine wind loading. Healthy, open-grown trees are seldom damaged by routine peak winds. Trees that grow in closed-canopy stands compete for light and soil resources. Wind speeds are lower within canopies than in openings, and crown collisions during sway reduce bending stresses on the roots and stem. Under these conditions, allocation of growth resources to stem and root diameter increment is a lower priority than allocation to height increment, foliage and feeder roots. In the long run, stand-grown trees become slender and have small live crown ratios. Exposing stand-grown trees through harvesting of neighbours produces an immediate increase in wind loading. Over a period of several years, vigorous residual trees will acclimate to these new conditions by reducing height increment and by thickening at the base. For less vigorous trees, foliage and branch loss reduce wind loads. Residual trees are most susceptible to damage immediately after treatment.[12]

In very dense stands (e.g., young dense lodgepole pine), trees may be so densely packed that they are unable to fall even if destabilized by wind. For these stands, stability is high provided groups of trees are left intact. Turbulent winds across the top of the canopy (Figure 2a) result in greater windthrow than smooth winds (Figure 2b).

[2] Steve Mitchell, PhD., Associate Professor, University of British Columbia, Department of Forest Sciences, pers. comm. February 2005.

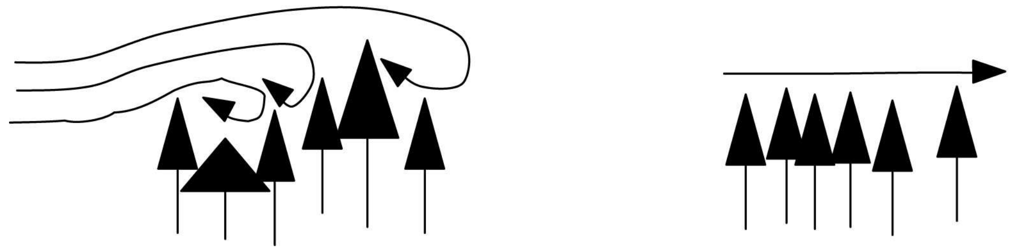

Figure 2. Turbulent (left) and smooth (right) winds across tree canopies.

Slenderness (height:diameter) and live crown ratios of trees are excellent indicators of their long-term exposure to wind before harvesting (Figure 3). Open-grown trees and veterans are well acclimated to routine peak winds. Canopy dominants are typically better acclimated than sub-dominant trees.

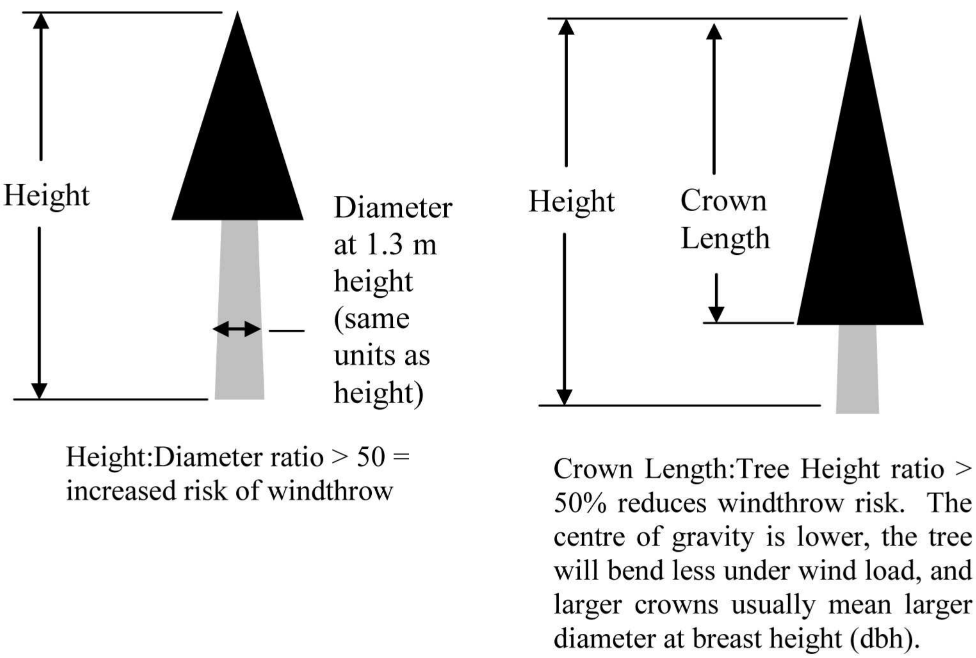

Figure 3. Individual tree characteristics that affect windthrow risk.

The relative stability of North American boreal species has not been determined. In Europe, hardwoods such as birch, oak and beech have been found to be most windfirm followed by Norway spruce, radiata pine, Douglas-fir and Sitka spruce. However, the effects of stand density and structure on tree acclimation are more important than species.[3]

Reducing crown mass is a good strategy for fuel management and windthrow mitigation. Removing 20–30% of the crown will reduce windthrow; however, topped trees are more likely to die standing. Pruning the base of trees is especially advocated for fuel management; however, it is not known how much, if any, effect this would reduce wind load. Pruning (in combination with thinning) may allow air to flow through the stand instead of being buffered, resulting in less turbulence and windthrow.

The diagnostic question for tree and stand acclimation to wind is: *Are the individual trees within the stand well used to wind loads, or are they dependent on their neighbours for shelter and damping of sway?*

[3] Steve Mitchell, PhD., Associate Professor, University of British Columbia, Department of Forest Sciences, pers. comm. February 2005.

Soil component

Rooting depth is restricted where soils are shallow due to subsurface bedrock, water table or high bulk density. On rooting-restricted sites, trees form plate root systems. The most problematic sites for windthrow are those with a combination of high fertility and restricted rooting, such as riparian zones or colluvial veneers with seepage. On lower fertility sites, stands are typically shorter, and in some cases do not have closed canopies.

The diagnostic question for assessing soil limitations to rooting is: *Is root anchorage restricted by an impeding layer, low strength soil, or poor drainage?*

Harvesting considerations

Because patches maintain some internal shelter and inter-tree damping of sway, patch retention generally results in less windthrow than individual stem retention. The exception is when highly windfirm individuals such as veteran trees are retained.

Individual stem retention

- This should be done on sites with good rooting where possible.
- Thinning dense, mature even-aged stands will result in a high risk for windthrow—patch retention is a better option.
- The wind loading on trees increases with an increase in spacing factor (inter-tree spacing:stand height).
- Mixed species and young vigorous stands are likely to be more windfirm.
- Coarse-limbed, deep-crowned veterans or dominant trees with low slenderness are more windfirm than slender sub-dominants. Thinning from below is recommended, removing trees with high slenderness coefficients.
- Buffers should be used to reduce wind pressure on treated stands (Figure 4).
- Multi-pass treatments will allow retained trees to develop windfirmness. For example, 15–20% basal area could be removed on the 1st pass with a minimum 5-year interval before the next pass.
- Unfortunately, one of the characteristics of a windfirm tree (long canopy) is the conflict with the fuel management objective to minimize crown fuel. Therefore tree selection for harvest, or scheduling pruning treatments should be done with the crown height:tree height ratio in mind.

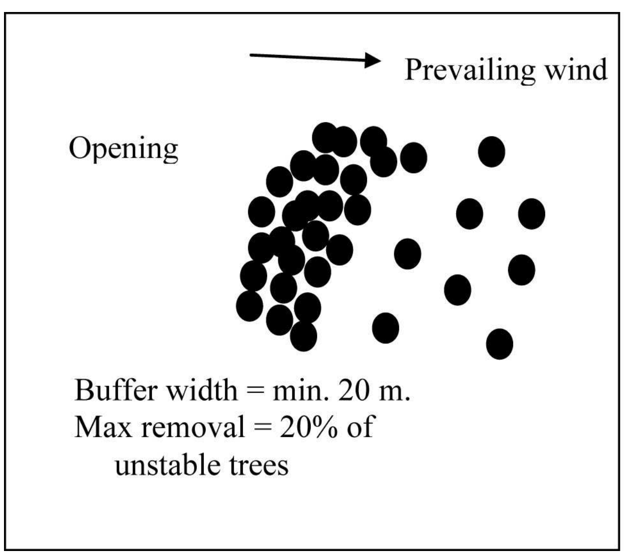

Figure 4. Use of a buffer to protect a treated stand.

Patch retention

- Damage typically concentrates within the first tree length of the edge.
- Retention patches should be greater than 1 ha on high risk sites.
- Retained patches <1 ha should be in high density stands (to prevent swaying) with the most resistant trees and on the best rooting sites.
- Canopy gaps less than two tree lengths wide provide substantial shelter to windward facing edges. Openings should be 2–3 tree lengths maximum (Figure 5).
- Avoid square edges on patches.
- Feathering the upwind edge (15–20% removal of high risk trees) can mitigate wind pressure, but is not recommended for stands with uniform canopies.

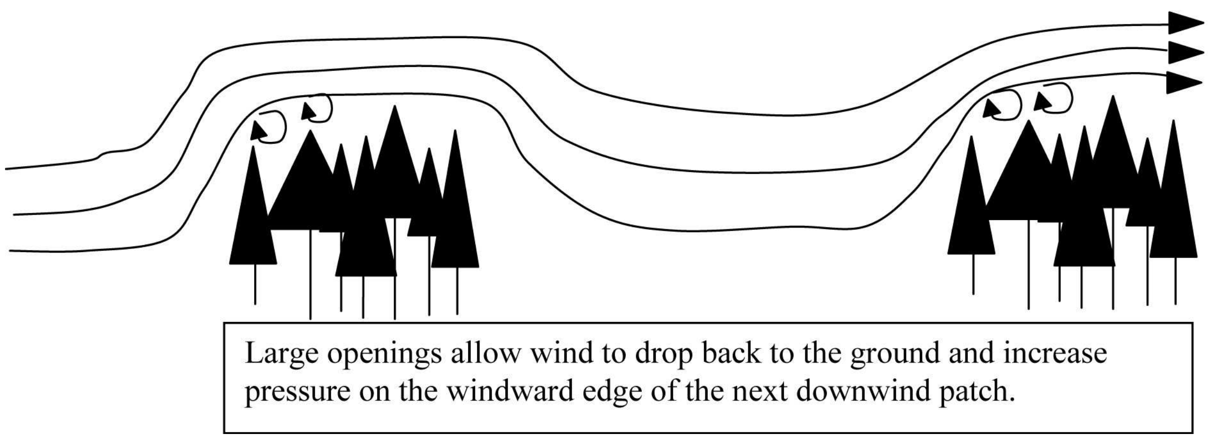

Figure 5. Canopy gaps and the effect on wind flow.

Post-treatment maintenance

- Expect most of the windthrow to occur within 3–5 years of overstorey removal.
- Overstorey removal will create opportunities for shrub growth and natural regeneration. Regular maintenance will be necessary as the accumulation of surface fuels will negate the usefulness of the treatment.
- Residual trees may expand their crowns to fill in overstorey gaps, thereby increasing crown bulk density to an undesirable level.

Long term planning

Mitigating windthrow loss may not be achieved through single treatments designed to reduce forest fuel loads. Rather, a fuel management plan should include a strategy to produce windfirm trees, and this may require several treatments. For example, multi pass shelterwood or progressive strip cuts advocated by Navratil (1995) will occur over a period of decades. Forest managers dealing with an undesirable fuel load may not have this luxury of time. In such cases thinning may not work for stands that are highly susceptible to windthrow. A possible treatment is to completely clear a designated area and replant trees at wide spacing (1000 stems/ha or less) so they grow to be windfirm. Unfortunately, one of the characteristics of a windfirm tree (long canopy) conflicts with the fuel management objective to minimize crown fuel.

Long term stand/fuel management plans should also account for potential species conversion, natural regeneration (especially conifer), and ingress of shrubs and grasses. Shade tolerant conifers may regenerate under partial harvesting and will eventually become undesirable ladder fuels. Opening the overstorey canopy may also result in increased grass and shrub productivity relative to a closed canopy stand.

Summary

Of the three primary windthrow factors, harvesting systems give forest managers the best opportunity to mitigate windthrow loss. Although sites with unfavourable topography (or soils) may be avoided in some cases, fuel management sites around permanent communities will limit flexibility with regard to topography. A multi-pass harvesting approach will result in less wind exposure to residual trees and give those same trees time to become more windfirm. Patch harvesting patterns are favoured over thinning individual stems in mature conifer stands where the majority of trees have a low crown height to tree height ratio.

This document presents a brief overview of windthrow considerations with respect to forest fuel management. More detailed information can be found in the documents listed in the references.

References and additional reading

Mattheck, C.; K. Bethge; R. Kappel; P. Mueller; and I. Tesari. 2003. Failure modes for trees and related criteria. Pages 219–230 in Ruck B.; C. Kottmeier; C. Mattheck; C.Quine; and G. Wilhelm, *eds.* Proceedings of the International Conference, Wind Effects on Trees. 16–18 September, 2003. University of Karlsruhe, Germany. Laboratory for Building- and Environmental Aerodynamics, Institute for Hydromechanics, University of Karlsruhe, Germany.

Mitchell, S.J. 1998. A diagnostic framework for windthrow risk estimation. Forestry Chronicle 74:100–105.

Moore, J.R.; S.J. Mitchell; D.A. Maguire; and C.P. Quine. 2003. Wind damage in alternative silvicultural systems: review and synthesis of previous studies. Pages 191–198 in Ruck B.; C. Kottmeier; C. Mattheck; C.Quine; and G. Wilhelm, *eds.* Proceedings of the International Conference, Wind Effects on Trees. 16–18 September, 2003. University of Karlsruhe, Germany. Laboratory for Building- and Environmental Aerodynamics, Institute for Hydromechanics, University of Karlsruhe, Germany.

Navratil, S. 1995. Minimizing wind damage in alternative silviculture systems in boreal forests. Northern Forestry Centre, Canadian Forest Service, Natural Resources Canada, Edmonton, Alberta, and Land and Forest Service, Alberta Environmental Protection. Edmonton, Alberta. 74 pp.

Stathers, R.J.; T.P. Rollerson; and S.J. Mitchell. Windthrow handbook for British Columbia forests. B.C. Ministry of Forests. Working Paper 9401. 31 pp.

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