Stand Density Management Diagram

Supporting Growth and Yield Decision Making

Forest Health: *Preliminary Interpretations for Wind Damage*

Stephen Mitchell, PhD, RPF

British Columbia
Ministry of Forests
Forest Practices Branch

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More Information

- *Copies of SDMDs and associated training*
  Pat Martin, RPF, Stand Development Specialist
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- *Using SDMDs to develop preliminary interpretations for wind damage*
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- *A copy of the publication*
  "Stand density management diagrams for lodgepole pine, white spruce, and interior Douglas-fir" (Farnden, C. 1996. Information report BC-X-360)
  Forestry Canada, Pacific Forestry Centre, Victoria BC
  Tel: 250.363.0600
  Fax: 250.363.0775

Overview

Topic

Forest Health: Preliminary Interpretations for Wind Damage

This document is one in a series of information booklets on using SDMDs. Topics planned for the series include using SDMDs to manage for timber production, forest health, wildlife habitat, and visual quality.

Objectives

To show practitioners how to use stand density management diagrams (SDMDs) to:

- estimate the stand component of windthrow risk
- design (modify) crop plans to account for windthrow risk

Audience

Silviculturists responsible for developing stand management prescriptions in areas with risk of windthrow

Assumptions and Limitations

SDMDs are decision support tools. They are based on the assumptions that the stand is even-aged, predominantly of a single species, and will grow like a healthy, untreated stand.

The usefulness of an SDMD depends on the user's understanding of its underlying assumptions and applications, how to collect stand and site data to locate stands on the diagram, and how to interpret the range of information contained in the diagram.

The stand hazard criteria for risk of windthrow are based on stand and tree indicators described in the international windthrow literature, not on analysis of actual damage patterns in B.C. stands. Tree form data used to identify preliminary stand hazard zones on the SDMDs were obtained from analysis of BC Ministry of Forests permanent sample plot data.

Windthrow is a complex and only partly understood phenomenon. These interpretations of stand hazard zones and windthrow risk must be tempered by local experience.

In this document, "thinning" refers to pre-commercial or commercial thinning. Recently thinned or fertilized stands may be more vulnerable than their locations on the SDMD would suggest.

The SDMDs used in this document are based on data produced using the BC Ministry of Forests model WinTIPSY to represent natural regeneration.

Acknowledgements

Windthrow interpretations and SDMD stand hazard zones courtesy of the author. Craig Farnden, RPF allowed the use of the stand density management diagrams. Graphics and illustrations were produced by Rich Rawling, Cortex Consultants Inc. Instructional format and project co-ordination were provided by Cortex Consultants Inc. Preparation of this publication was funded by Forest Renewal BC and the B.C. Ministry of Forests. Funding assistance by Forest Renewal BC does not imply endorsement of any statements or information contained herein.

Table of Contents

List of Figures

List of Tables

Introduction

SDMDs provide a framework for collecting and interpreting observations about stand structure and development. They can help silviculturists to identify the various stand density and thinning regimes by which to achieve stand management objectives.

Windthrow can interfere with achieving stand- or forest-level management objectives. If windthrow risk for a stand can be estimated, it can be considered and incorporated in crop planning.

This document uses SDMDs to provide insights into the "stand" component of windthrow risk, and discusses how windthrow risk estimates can be used in developing crop-planning prescriptions for uniform stands. The examples contained in this paper use the windthrow assessment framework taught in the B.C. Ministry of Forests Windthrow Management Workshop (Mitchell, 1998).

SDMDs can be used to provide insights into the "stand" component of windthrow risk

Windthrow Concepts

Windthrow occurs when peak winds acting on the crowns of trees produce turning moments at the base of the tree that exceed the root-soil anchorage and cause the tree to uproot. In windsnap, the stem fails—usually below the base of the live crown but above the buttswell. The terms windthrow and blowdown are used generally to describe both uprooting and breakage. Other forms of wind damage include defoliation, branch loss, flagging, asymmetric stem growth, and tilting.

Windthrow occurs when peak winds acting on tree crowns cause trees to uproot

In windthrow risk assessment, peak winds are separated into two classes: catastrophic and endemic. *Catastrophic winds* are very high-speed winds that occur at infrequent intervals causing intense but often localized damage with a high proportion of windsnap. *Endemic winds* are peak winds that occur frequently (e.g., every 1–3 years). These winds damage stands that have recently become vulnerable—such as those freshly thinned, or along cutblock edges. Endemic winds cause a high percentage of uprooting and little windsnap.

Windthrow risk assessment has traditionally focused on forecasting damage from endemic winds because these winds occur frequently and are therefore highly predictable. The windthrow risk classes described in this paper refer to risk from endemic winds. In long-term crop planning, the potential for damage from catastrophic winds should also be considered.

Windthrow risk assessment focuses on predicting damage from endemic winds

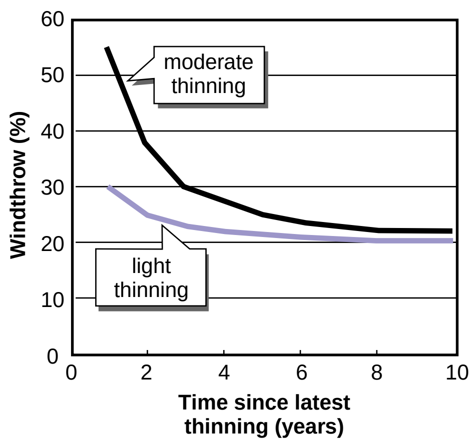
Trees acclimate to local wind loads through gradual form modification as they add annual growth and shed old foliage and limbs. Healthy open-grown trees are not damaged by endemic peak winds, but trees that have grown in the shelter of neighbours and are suddenly exposed through harvesting or thinning can be vulnerable.

Thinning or partial cutting increases the porosity of the canopy allowing more wind to act on the crowns of trees. Thinning also reduces intercrown contact and damping between neighbouring trees.

Thinning or partial cutting increases risk of windthrow

Investigators have observed that damage in thinned stands is highest immediately following thinning, declines rapidly with time since thinning, and often returns to background levels within five years (Figure 1). The most vulnerable trees are damaged early, and the remaining trees acclimate to wind by modifying their growth. Reduced height increment, more growth at the stem base and in structural roots in vigorous trees, and loss of foliage in less vigorous trees help to reduce wind loads and increase stem and root resistance. As tree crowns expand in response to the increased light levels and soil resources, the canopy porosity declines and within-canopy wind speeds are reduced.

Figure 1 Predicted probability of windthrow in spruce stands during a major storm event as a function of time since the latest thinning and thinning intensity (after Lohmander and Helles 1987)



Windthrow risk can be reduced by growing stands at densities that promote individual tree windfirmness and reducing thinning treatment intensities in vulnerable stands.

Using SDMDs in Estimating Windthrow Risk

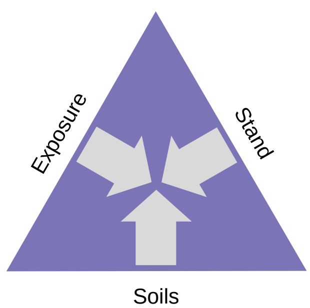
The stands for which windthrow risk is being estimated should meet the underlying assumptions of SDMDs (even-aged, predominantly single species, and have grown like healthy, untreated stands).

Windthrow risk—the level of damage expected from endemic peak winds—is determined by environmental factors ("biophysical hazard") and management factors ("treatment risk"). Biophysical hazard is the stability of the stand on a particular site relative to local peak winds prior to treatment. It is a combination of site (exposure and soils) hazard and stand hazards. Treatment risk is the degree to which a proposed treatment would increase the wind loading on the trees left behind.

Windthrow risk is determined by environmental and management factors

This paper focuses on using SDMDs to assess the stand hazard component of windthrow risk, using the windthrow assessment framework that is taught in the B.C. Ministry of Forests Windthrow Management Workshop. In this framework, the windthrow triangle (Figure 2) and three grids (Figures 4, 6, 7) are used to integrate site hazard, stand hazard, and treatment risk to provide an overall estimate of windthrow risk.

Figure 2 Windthrow triangle



The windthrow triangle represents the biophysical components of windthrow risk

Hazard Indicators

Both individual tree stability and stand stability must be considered when assessing the stand component of windthrow risk. Table 1 discusses hazard indicators for key tree and stand attributes.

Consider both individual tree and stand stability

Table 1 Hazard indicators for tree and stand attributes

Attribute	Hazard indicator	Interpretation
Live crown	live crown ratio (LCR); the percentage of stem length within the live crown	mean stand LCRs of >70% (for shade tolerant trees) and >50% (for shade intolerant trees) indicate high windfirmness; LCRs <30% indicate low windfirmness LCRs are usually highest for dominants and lowest for intermediates in the stand
Slenderness	height-diameter ratio (HDR); the total height divided by DBH	mean stand HDRs of <80% indicate high windfirmness; >100% indicate low windfirmness
Dominance	crown class	dominants are usually most stable, having had long-term wind exposure
Health	defoliation	defoliation by wind or insects may improve windfirmness in the short term, but can reduce a tree’s ability to modify stem form
	root or stem decay	root or stem decay reduces windfirmness
Uniform stands	stand height	vulnerability to wind increases as stands grow taller stands <10 m are rarely wind-damaged uniform stands with restricted rooting may reach a critical height at which they are susceptible to endemic winds critical height varies with soil condition stand mortality from wind is more closely associated with stand height than age
	high density canopies	low wind penetration mutual support can produce stable stands even where individual trees are unstable

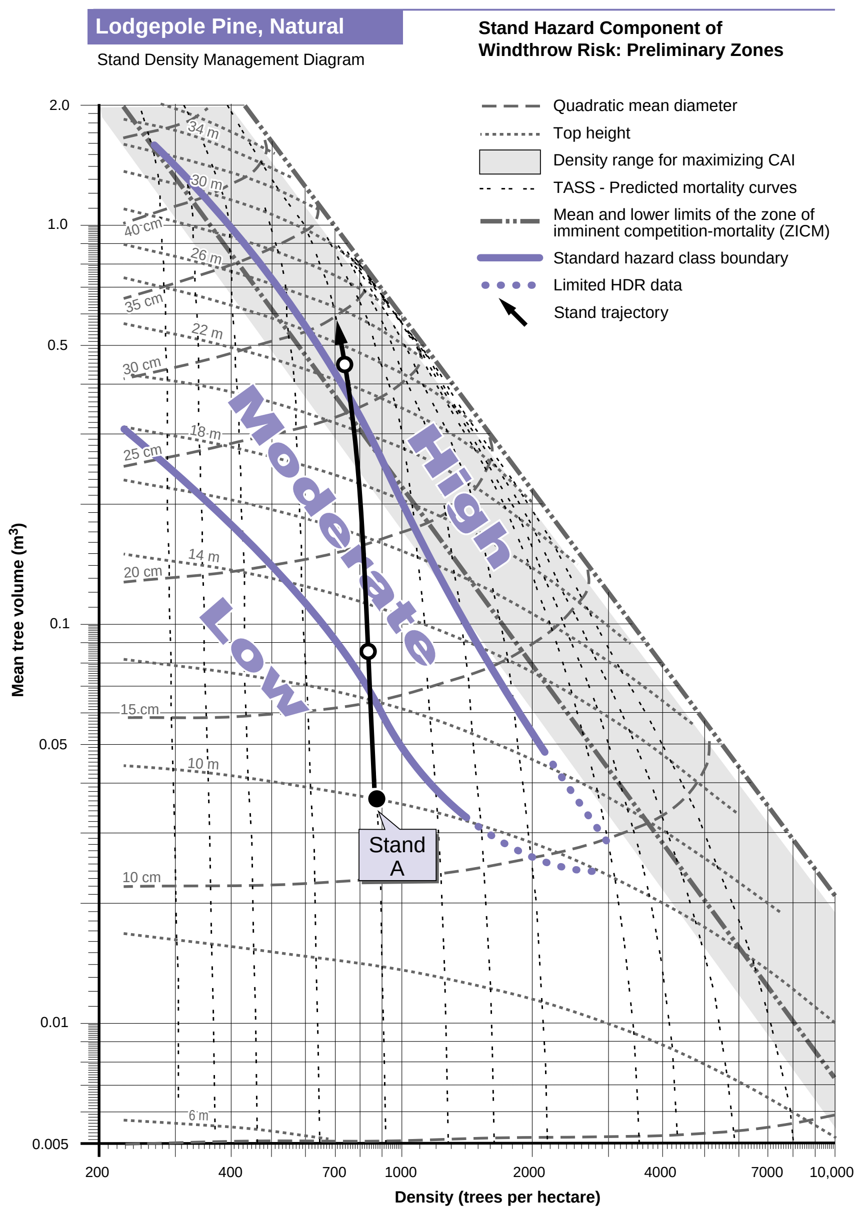
Zones of Stand Hazard

Preliminary Stand Hazard zones for common species in British Columbia were defined using information on height-stem form relationships (H, HDR) found in the literature (Appendix 1). These zones rate the stand hazard component of windthrow risk as low, moderate, or high.

Figure 3 uses an SDMD to illustrate the stand hazard component of windthrow risk in a natural stand of lodgepole pine. Example Stand A (top height=10 m, quadratic mean diameter=12 cm, density=870 tph) is currently in the Low Stand Hazard Zone. The stand's trajectory (solid line) shows how the stand will grow if not thinned: at 13 m height, Stand A would be in the Moderate Stand Hazard Zone, and at 23 m in the High Stand Hazard Zone.

Without thinning, stand A will eventually grow into the High Stand Hazard Zone

Figure 3 Using an SDMD to estimate the stand hazard component of windthrow risk



Steps in Assessing Windthrow Risk

Windthrow risk is estimated through a 6-step process that involves identifying windthrow patterns, assessing treatment risk, assessing and integrating biophysical hazard components, integrating biophysical hazard and treatment risk, and calibrating the assessment. An example stand is used to illustrate the steps. The assessment procedure can be used at both the overview planning level and at the field prescription level.

Example Stand Description and Management Objectives

The example Stand B is a 78-year old stand of interior lodgepole pine with site index=18 m, quadratic mean diameter (Dq) =21 cm, stand density=1600 tph, top height=22 m. The stand's management prescription includes a partial cut to 50% of its original volume before 90 years.

Look for evidence of wind damage and its local associations

Step 1: Identify windthrow patterns at the landscape and stand level

Start by observing windthrow patterns in opening or growth and yield datasets, or on overview maps and photographs, looking for evidence of wind damage and its local association with biophysical and management factors. Biophysical information is obtained from opening records, forest cover maps, topographic maps, and ecosystem or soils maps for an overview analysis, and from field inspection for a site-level analysis.

Step 2: Assess Treatment Risk for windthrow

To assess Treatment Risk, determine the extent to which the proposed treatment will increase windloads on residual trees.

Stand B's scheduled partial cut to 50% of its initial volume will result in a moderate increase in wind loading compared to a fully exposed downwind edge (high risk), or a 20% volume removal (low risk) (see Windthrow Field Card FS 712-2).

Step 3: Assess component biophysical hazards for windthrow

The site and stand features that determine the biophysical hazard for windthrow include topographic exposure, soils, and stand hazard (Figure 2).

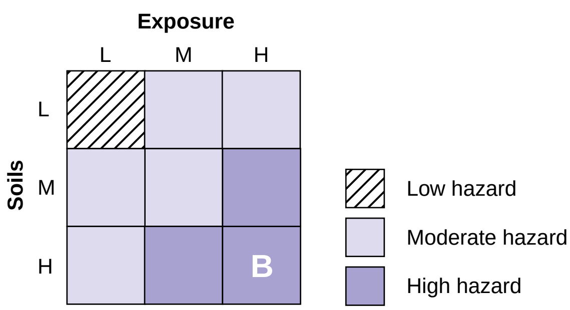
Site Hazard

Site Hazard has two variables: exposure (topography) and soils. The Site Hazard grid (Figure 4), integrates exposure and soils hazards into three classes of Site Hazard: low, medium, and high (delineated by the gradation in shading from light to dark).

Exposure and soils hazards determine Site Hazard

Example Stand B is located in an exposed saddle (high exposure hazard) with shallow, moist soils (high soils hazard); therefore the Site Hazard rating for this stand is high (see Windthrow Field Card FS 712-2).

Figure 4 Site Hazard grid



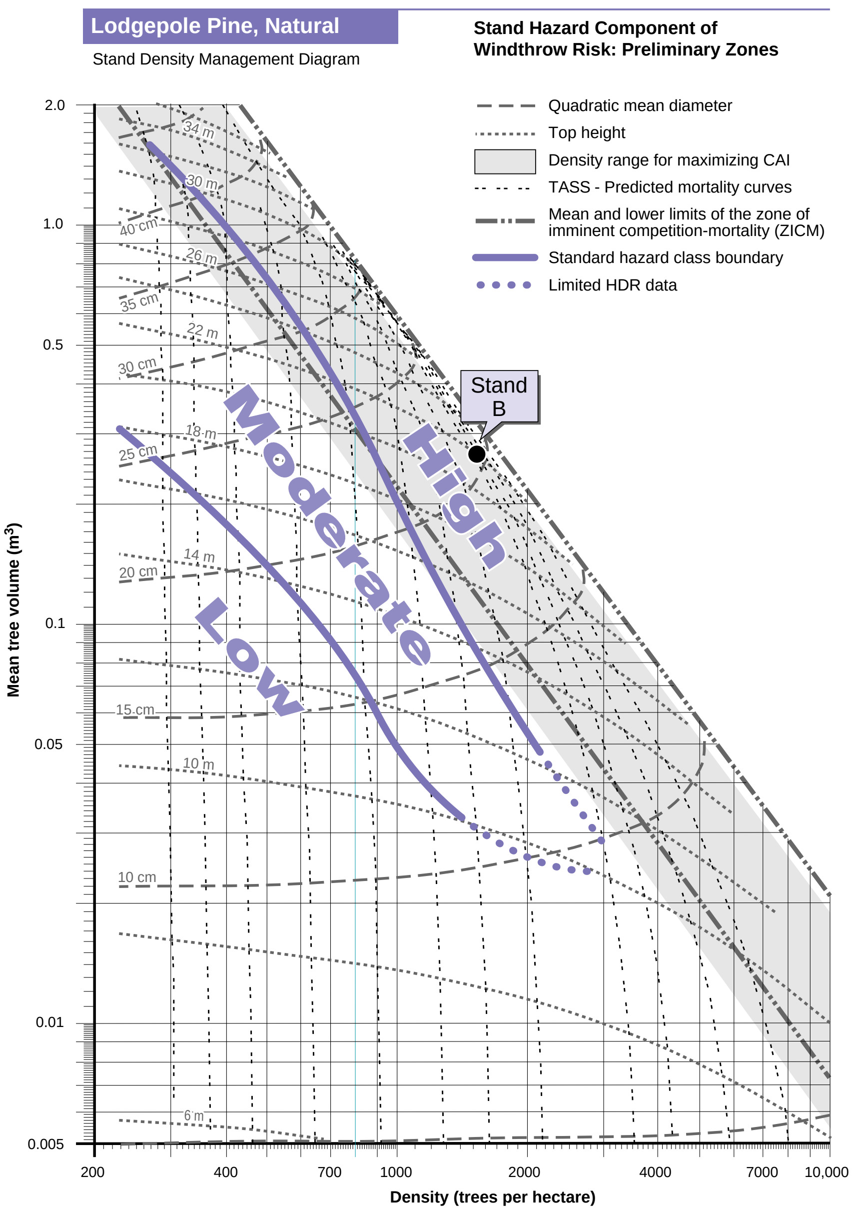
Stand Hazard

Locate the stand on the SDMD to identify Stand Hazard

Stand Hazard is obtained by locating the stand on the SDMD and identifying the stand hazard zone in which it falls. To locate a stand on the SDMD you need at least two of the three following measurements: trees per hectare, quadratic mean diameter, top height. (Use all three if you have them.)

As shown in Figure 5, Stand B is located in the high stand hazard zone.

Figure 5 Using an SDMD to estimate the stand hazard component of windthrow risk



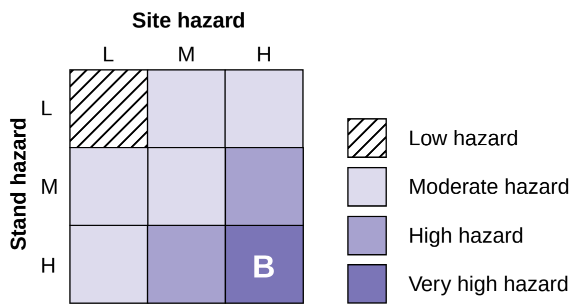
Step 4: Integrate Biophysical Hazard components

A Biophysical Hazard grid (Figure 6) is used to integrate site and stand hazard components. There are four classes of biophysical hazard noted by degree of shading: low, medium, high, and very high. Biophysical hazard estimates the stability of a stand in its pre-treatment condition.

The Biophysical Hazard for Stand B is rated very high because it has both high site hazard and high stand hazard.

Site and stand hazards determine Biophysical Hazard

Figure 6 Biophysical Hazard grid



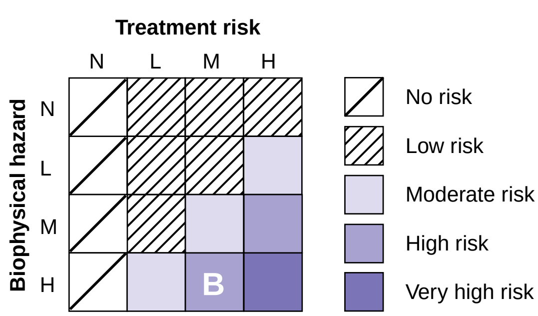
Step 5: Integrate Biophysical Hazard and Treatment Risk

A Windthrow Risk grid (Figure 7) is used to integrate biophysical hazard and treatment risk. The five classes of windthrow risk (none, low, moderate, high, very high), are indicated by levels of shading ranging from no shading to black. To predict the windthrow risk of a particular treatment, biophysical hazard is integrated with treatment risk.

Treatment Risk for the proposed partial cut in Stand B is moderate (from Step 2). Biophysical Hazard for Stand B is very high (from Step 4). Therefore, Windthrow Risk for Stand B is high, implying substantial loss of stems due to windthrow in the years immediately following treatment.

Biophysical hazard and treatment risk determine Windthrow Risk

Figure 7 Windthrow Risk grid



Step 6: Calibrate the assessment

Check biophysical hazard and treatment risk assessments against local wind damage

The estimates of the biophysical and treatment components of windthrow risk are preliminary, and should be checked against local wind damage experience. The pre-treatment position of wind-damaged stands can be plotted on the SDMD to refine the boundaries of the stand hazard zones. Remember that wind damage reflects the combination of stand, topographic, and soil factors—and only the stand factors are represented on the SDMD.

If the occurrence of wind damage is lower than that predicted by the windthrow risk estimate, consider which components (soils, topographic exposure, stand, treatment) might have been overestimated and adjust them downwards until your windthrow risk estimate conforms with your observations. This is the best way to locally calibrate the thresholds for the component hazard classes.

Using Windthrow Risk Estimates

Designing Treatments for High Stand Hazard Zones

The high and moderate Stand Hazard zones on the SDMD identify stands vulnerable to wind damage when they occur in combination with high site hazard (soil conditions, topographical exposure).

The following recommendations on treatment design are most relevant for high stand hazard sites. Recognizing that a stand is currently in a high-hazard zone, or will grow into one without intervention, signals the need to consider windthrow risk in designing stand treatment.

Designing stand treatments begins with considering the consequences of potential wind damage. Some wind damage may be acceptable, in which case mitigative actions may not be warranted. As biophysical hazard increases, and acceptability of damage decreases, more conservative stand treatments should be considered (e.g., those that maintain mutual support and the most windfirm individuals within a stand).

Consider impacts and acceptable levels of wind damage in designing stand treatments

Silvicultural Actions

Crop planning

On sites known to have high hazard soils or topographic exposure there are three basic long-term treatment strategies or “crop plans” (Figure 8):

T1 Grow stands at low densities so that individual trees will grow windfirm. In locations with high prevailing winds, these trees will have more limbs, may have suppressed height, and may grow with asymmetric boles and crowns. This practice is sometimes referred to as “oceanic forestry,” because of its use in windy coastal locations in the United Kingdom.

T2 Grow stands at moderately high densities with very limited or no thinning, relying on mutual shelter and support to maintain stand windfirmness as long as possible. Harvest stands when they reach a height at which endemic windthrow begins. This is the primary strategy used in the United Kingdom for Sitka Spruce on upland sites.

T3 Maintain moderate stand densities by repeated light thinnings through the juvenile and early pole stage. This enables individual trees to develop moderate windfirmness. Once a height of 15–20 m is reached, no further thinning is done; mutual shelter and support maintain stand stability as height growth continues.

Juvenile spacing and commercial thinning

T4 For thinning in tall, dense, previously unmanaged stands, mutual support can be preserved through light thinning if an angle of no more than 10 degrees is maintained between the base of one tree and the tops of its neighbours. Thinning from below (maintaining dominants) is recommended over non-selective or strip thinning because it results in less damage. These principles apply also to commercial thinning and uniform shelterwoods.

Fertilizing

Delay fertilizing for at least 3 years after thinning high hazard stands or sites

Nitrogen-fertilized trees expand their crowns and upper stems. Higher damage has been observed in stands in the years immediately following combined thinning and fertilization. In high-hazard stands, or in moderate-hazard stands on high-hazard sites, it is recommended that fertilizing be delayed for at least three years after thinning to allow time for trees to stabilize.

Pruning

Pruning will reduce the sail area of the crown. If excessive, it may reduce the vigour of the tree and its ability to add more wood and develop windfirmness. While pruning lower branches is less effective at reducing windloads than pruning upper branches, it also reduces tree vigour less.

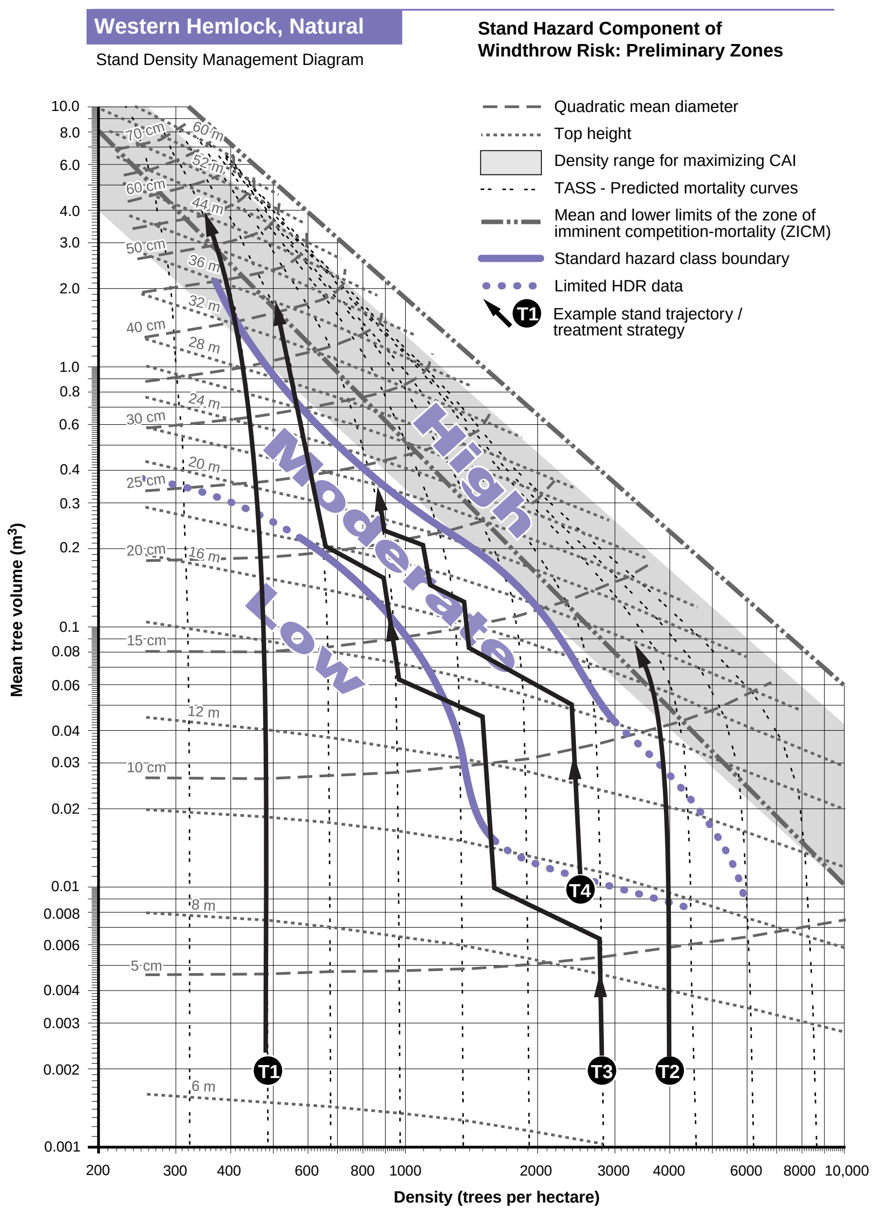
Group/patch/retention systems

In high density stands, removing groups of trees may be a better strategy than uniform thinning

Cutting out groups of trees may be a better strategy than uniform thinning in high density stands that depend on mutual support. Trees along the edges of openings can lay back into their neighbours. In high-hazard stands without mutual support, openings should be kept under four tree lengths wide to reduce wind penetration into the canopy. Observe road right-of-ways, corners of cutblocks, and naturally created gaps (e.g., by slides) to get a sense of critical opening size.

The Windthrow Handbook for British Columbia Forests contains a broader discussion of layout strategies for sites with high soil and topographic hazards.

Figure 8 Long-term treatment strategies (crop plans) on high-hazard sites



Three long-term strategies for high hazard sites:

- **T1** *grow at low densities for windfirm trees*
- **T2** *grow at moderately high densities with no thinning*
- **T3** *maintain moderate densities by repeated thinnings*

Monitoring and Feedback

Try new treatments

Use the principle of adaptive management. Look for existing patterns of wind damage to determine whether some treatments result in more damage. If things are working well, there is no need to change treatment approach. In trying new treatments, be more cautious on sites with higher biophysical hazard. Try a range of treatment intensities covering smaller portions of a range of sites. Look for signs of damage in natural situations that resemble the proposed treatments (e.g., stands that have grown at different densities naturally, natural gaps, and old edges).

Monitor treatments

Use a system of operational trials with periodic observation or remeasurement, or a formal permanent sample plot system to monitor treatment outcomes and compare results with controls. Add stand points to SDMDs (e.g., Figure A1-2) and update opening records and overview maps with instances of wind damage.

Closing Remarks

SDMDs can be used to estimate the stand hazard component of windthrow risk. Locating current stands on the SDMD and projecting their future growth can give advance warning of future risk and indicate the potential benefits of early thinning treatments. Density-reducing treatments increase windthrow risk in the short term, but enable stands to become more windfirm in the long term. Initial estimates of windthrow risk should be checked and calibrated against local experience.

Glossary

Biophysical Hazard: an estimate of the intrinsic stability of the stand on a particular site prior to treatment; reflects tree, stand, soil, and topographic characteristics which determine the wind loading and wind resistance of trees.

Catastrophic damage: damage caused by infrequently occurring very high-speed winds; may occur when soils are dry; typically has a high proportion of broken trees.

Damping: reduction in tree sway due to contact with neighbouring stems or crowns.

Endemic damage: damage caused by high speed winds that occur frequently (e.g., every 1–3 years); usually occurs during seasons when soils are wet; typically has a high proportion of uprooted trees.

Hazard: a condition where there is the potential for an undesirable effect without reference to the probability of the potential actually occurring.

Height-diameter ratio (HDR): total tree height divided by stem diameter at breast height.

Live crown ratio (LCR): the percentage of stem length within the live crown.

Lorey's mean height (Hq): an adjusted mean height for the stand.
Hq= Σ [tree height*(BAtree/BAha)].

Mean-tree height: the average height of all trees in the stand that are bigger than a specified minimum diameter.

Quadratic mean diameter (Dq): an adjusted mean diameter for the stand.
Dq = ((BA*40000)/(SPH*3.14))0.5 for BA= stand basal area/hectare, SPH=stems/hectare.

Resisting moment: the ability of a tree to resist overturning or breakage.

Risk: the probability that an undesirable event will occur.

Top height: height of the largest diameter tree on a 0.01 ha plot, providing the tree is suitable (i.e., the tree is healthy, does not have a broken or damaged top, and its height growth is not affected by a competitor).

Treatment Risk: an estimate of the change in wind loading on residual trees expected because of treatment.

Turning moment: force multiplied by the length of the lever arm; in windthrow the applied moment is drag force multiplied by distance from crown center of gravity; the resisting moment is proportional to stem strength or strength of anchorage.

Windsnap: tree breakage that results when the applied turning moment exceeds the resisting moment within the stem.

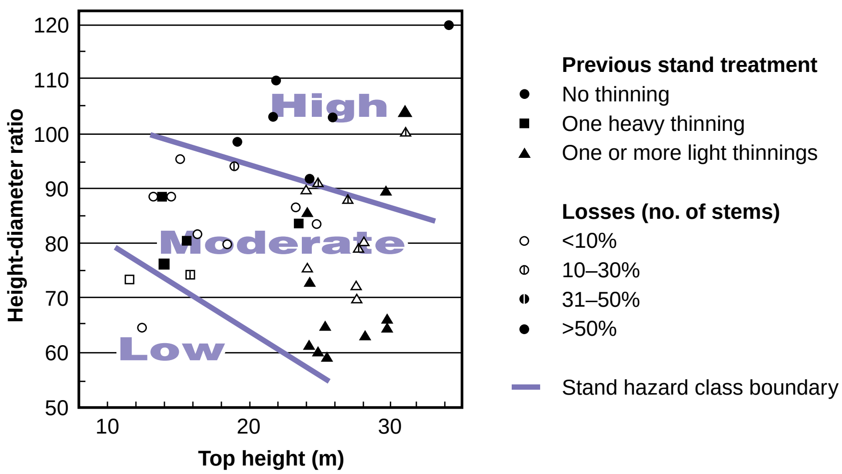
Windthrow: tree uprooting which results when applied turning moments exceed resisting moments of the root–soil anchorage; also used generally to describe both uprooting and stem breakage resulting from strong winds; also called blowdown.

Windthrow Risk: intensity of damage expected to result from endemic peak winds; in a given location it is determined by the combination of environmental factors (“biophysical hazard”) and management factors (“treatment risk”).

Appendix 1
Identifying Preliminary Stand Hazard Zones for SDMDs

In a review of wind damage in French conifer plantations, Becquey and Riou-Nivert (1987) identified three zones of stand vulnerability to wind damage when stands were plotted on a graph of HDR (mean) versus H (top) (Figure A1-1). The consistency of these results with findings of other authors in the international windthrow literature suggests that general zones of stability exist for uniform stands of temperate zone conifers.

Figure A1-1 Zones of wind damage vulnerability given stand top height and mean tree stem form (after Becquey and Riou-Nivert 1987)

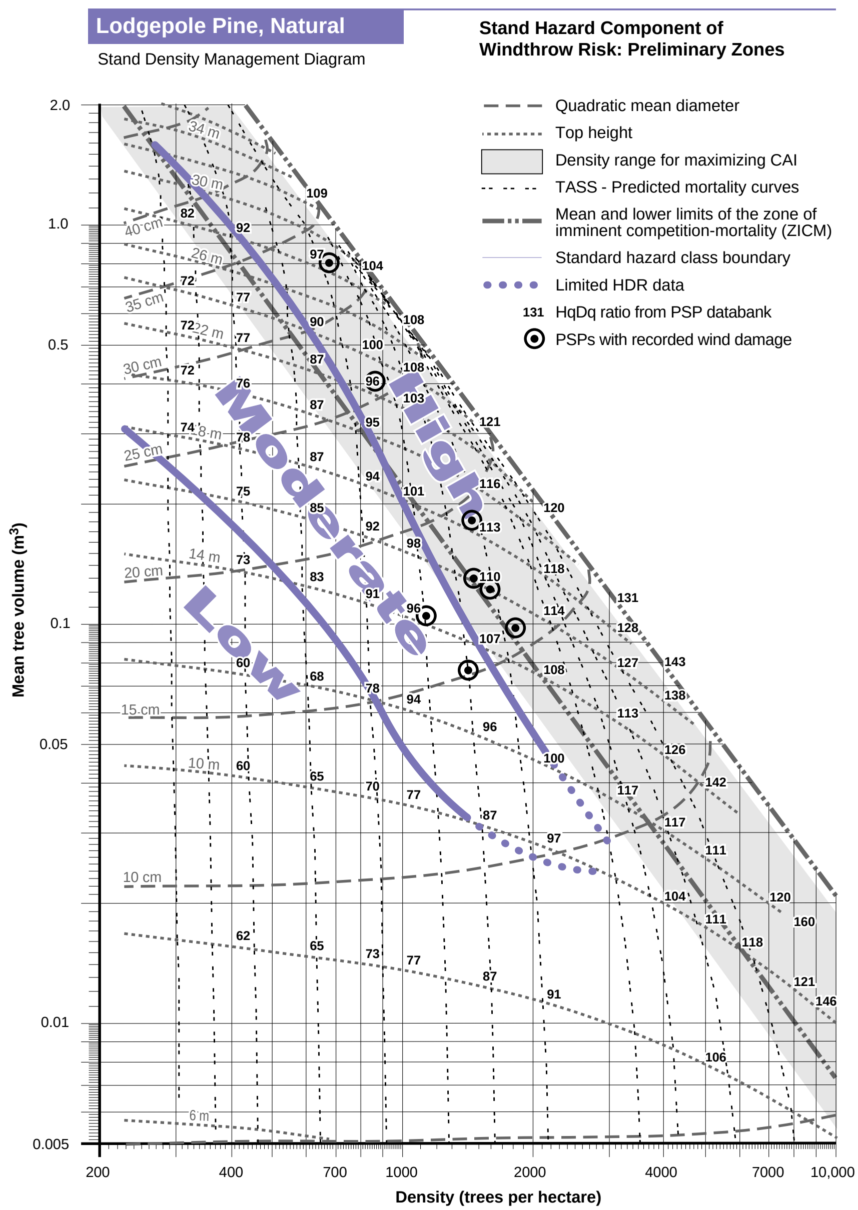


The HDR (mean) and H (top) values given by Becquey and Riou-Nivert have been used in this paper to identify preliminary low, moderate, and high stand hazard zones on the SDMDs for common B.C. species (Appendix 2). Because HDR (mean) can not be read directly off the SDMD, an overlay was developed from permanent sample plot (PSP) data for each species (Figure A1-2).

The PSP datasets contained top height, Lorey's mean height (Hq), quadratic diameter (Dq) and stems/ha. HDRmean (HqDq) was obtained by dividing Hq by Dq. From the PSP data for each species, plots were classified by top height and HqDq was plotted against stems/ha for each top height class. The average value of HDRmean for a given top height, stems/ha combination was obtained from these plots and was transferred to the SDMD. The boundaries between Low and Moderate, and Moderate and High stand hazards were then located as shown in Figure A1-2.

Wind damage is not always accurately recorded in the PSP dataset and has not been relied upon to produce the zones in this paper. Points have been added to the SDMD in Figure A1-2 showing the location of stands where damage was reported. Addition of more points from records of damaged stands would assist in refining the hazard zones.

Figure A1-2 Stand hazard zones for permanent sample plots in which windthrow damage was recorded



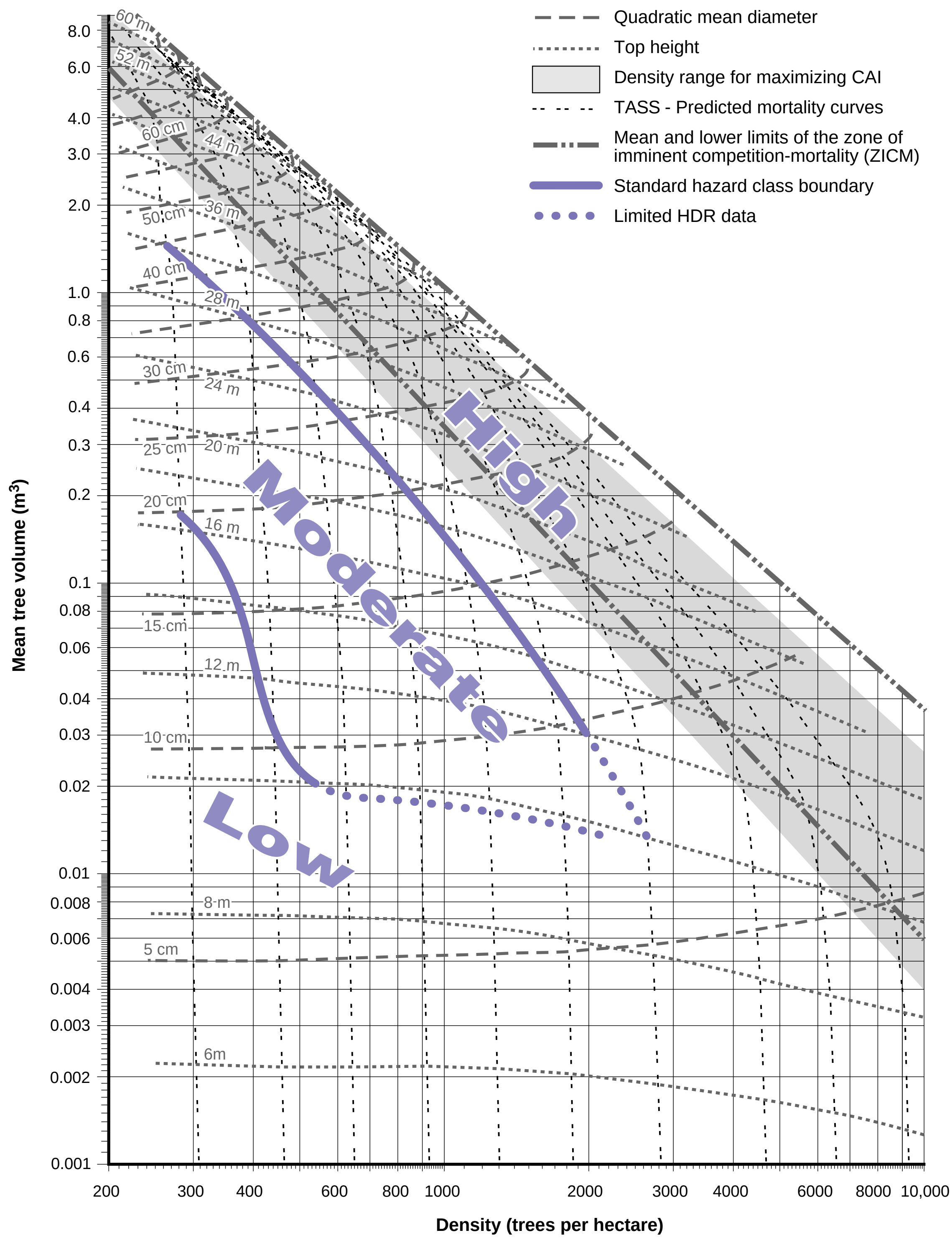
Appendix 2
Stand Density Management Diagrams with Preliminary Stand Hazard Zones

The SDMDs used in this document are based on data produced using the BC Ministry of Forests model WinTIPSY to represent natural regeneration.

Coastal Douglas-fir, Natural

Stand Density Management Diagram

Stand Hazard Component of Windthrow Risk: Preliminary Zones

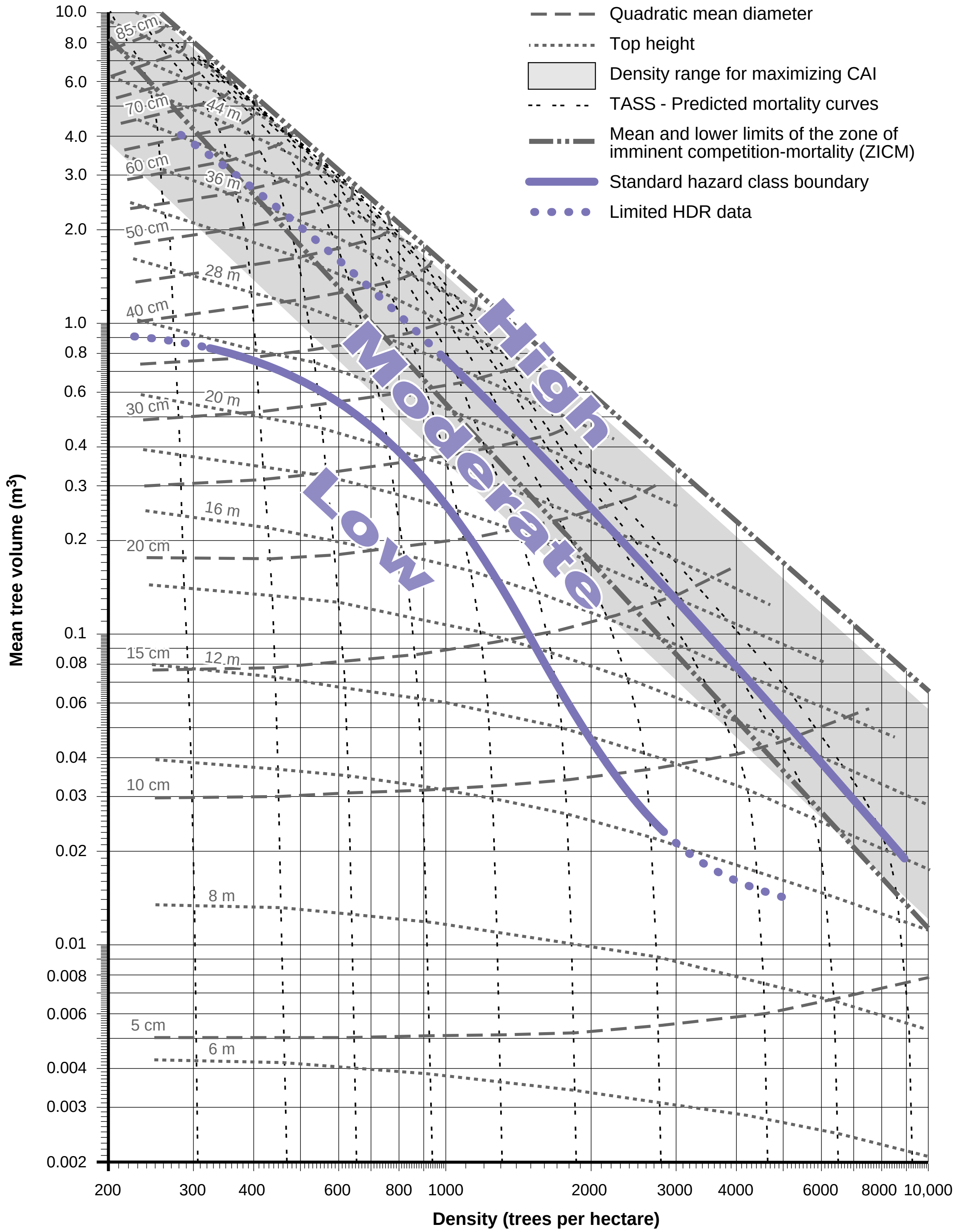


Stand Hazard Zones: Steve Mitchell, PhD, RPF for BC Ministry of Forests, Forest Practices Branch with funding from Forest Renewal BC; 2000
Base SDMD: Craig Farnden, RPF for BC Ministry of Forests, Forest Practices Branch with funding from Forest Renewal BC; data source WinTIPSY 1.3, 1996
Layout: Rich Rawling, Cortex Consultants Inc. with funding from Forest Renewal BC

Sitka Spruce, Natural

Stand Density Management Diagram

Stand Hazard Component of Windthrow Risk: Preliminary Zones



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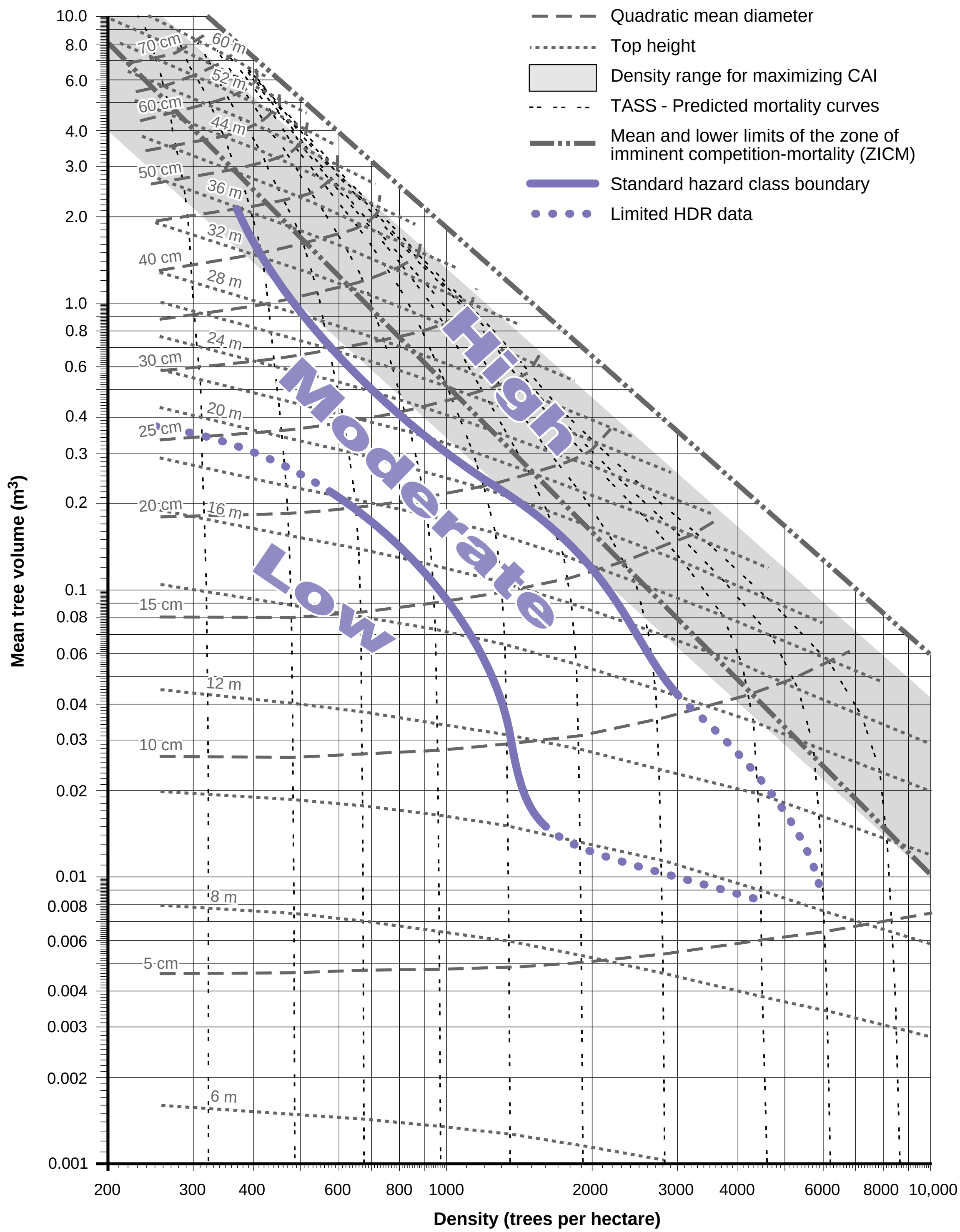
Layout: Rich Rawling, Cortex Consultants Inc. with funding from Forest Renewal BC

Western Hemlock, Natural

Stand Density Management Diagram

Stand Hazard Component of Windthrow Risk: Preliminary Zones



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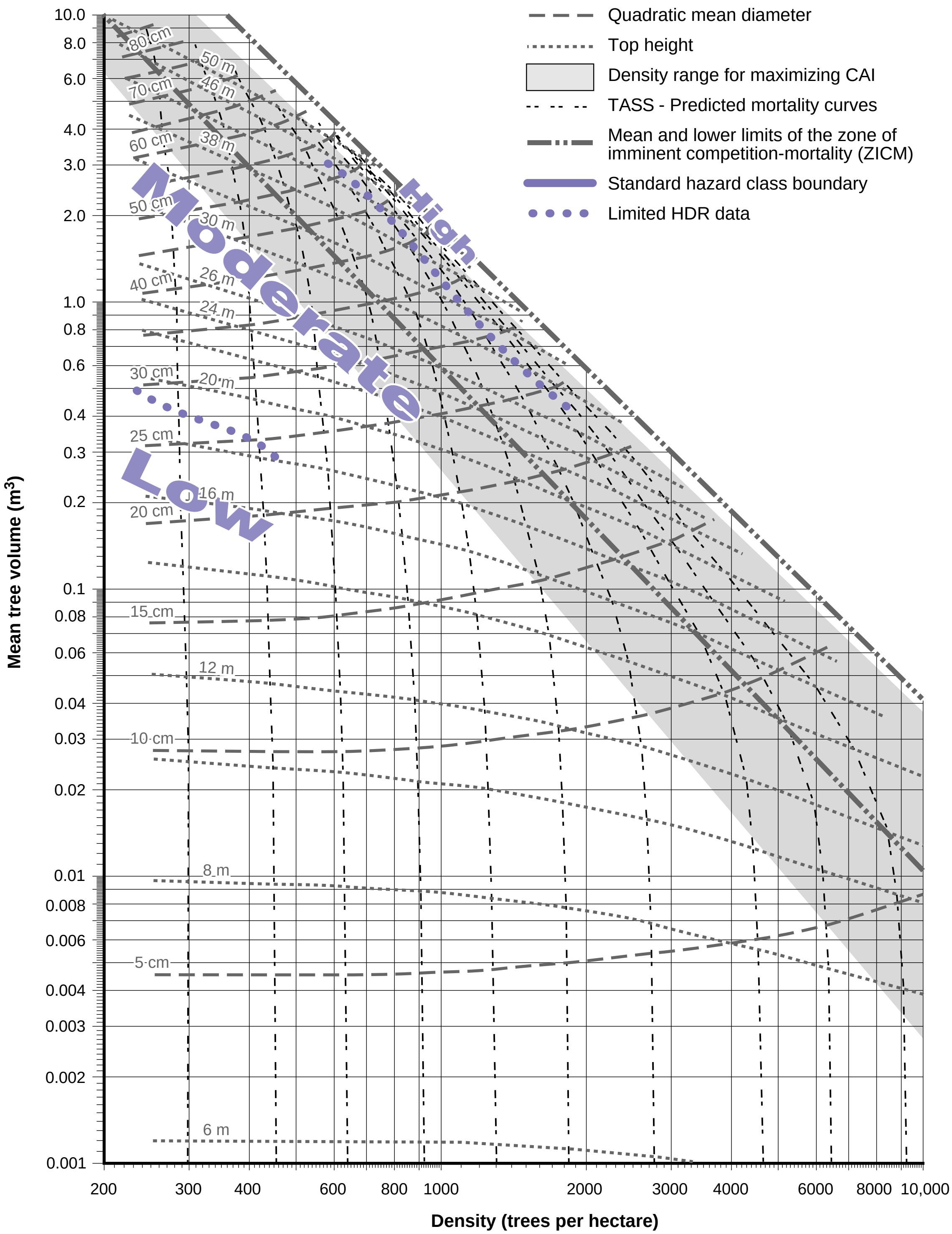
Western Redcedar, Natural

Stand Density Management Diagram

Stand Hazard Component of Windthrow Risk: Preliminary Zones

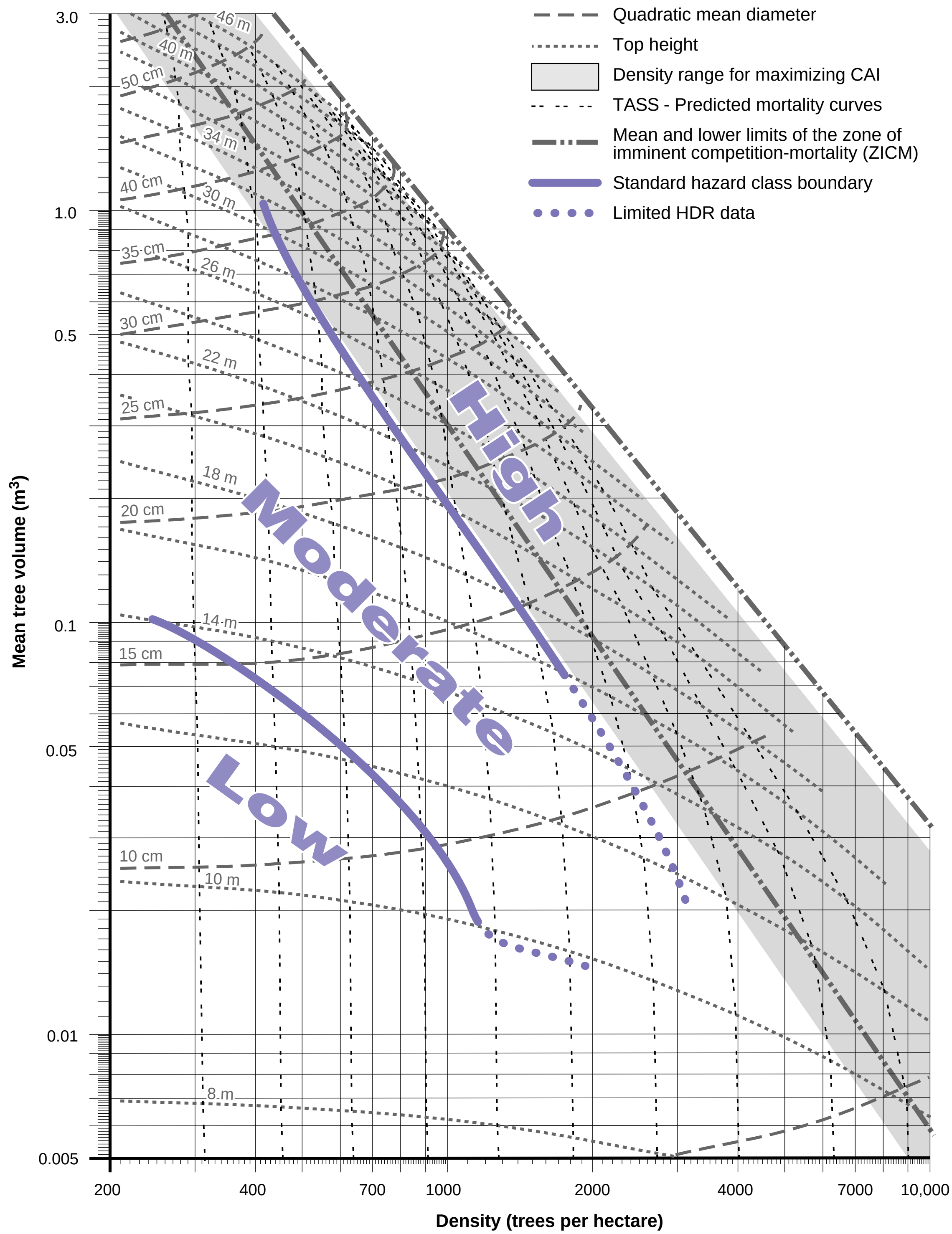


Stand Hazard Zones: Steve Mitchell, PhD, RPF for BC Ministry of Forests, Forest Practices Branch with funding from Forest Renewal BC; 2000
Base SDMD: Craig Farnden, RPF for BC Ministry of Forests, Forest Practices Branch with funding from Forest Renewal BC; data source WinTIPSY 1.3, 1996
Layout: Rich Rawling, Cortex Consultants Inc. with funding from Forest Renewal BC

Interior Douglas-fir, Natural

Stand Density Management Diagram

Stand Hazard Component of Windthrow Risk: Preliminary Zones

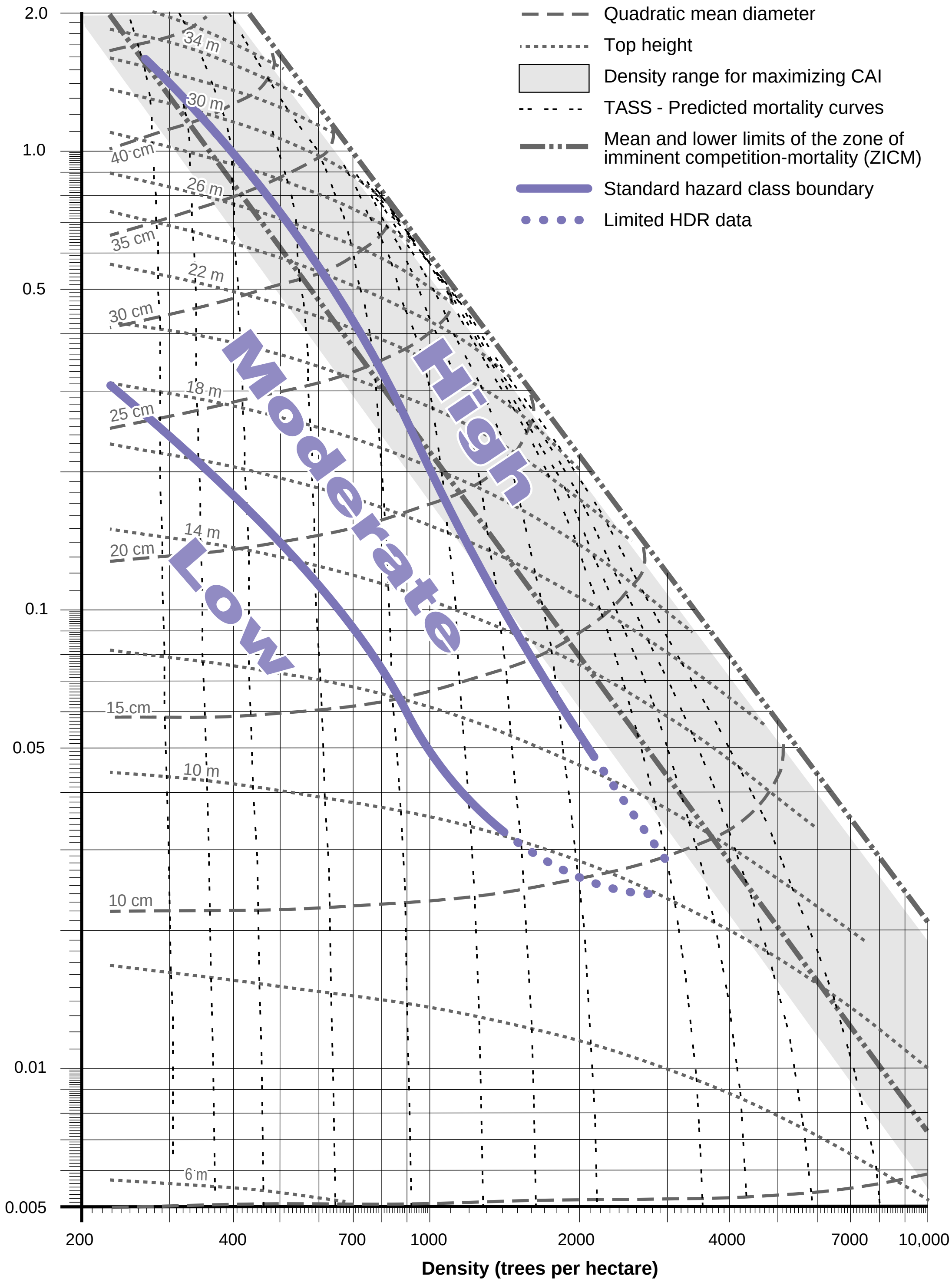


Stand Hazard Zones: Steve Mitchell, PhD, RPF for BC Ministry of Forests, Forest Practices Branch with funding from Forest Renewal BC; 2000
Base SDMD: Canadian Forest Service; data source WinTIPSY 1.0, 1996
Layout: Rich Rawling, Cortex Consultants Inc. with funding from Forest Renewal BC

Lodgepole Pine, Natural

Stand Density Management Diagram

Stand Hazard Component of Windthrow Risk: Preliminary Zones

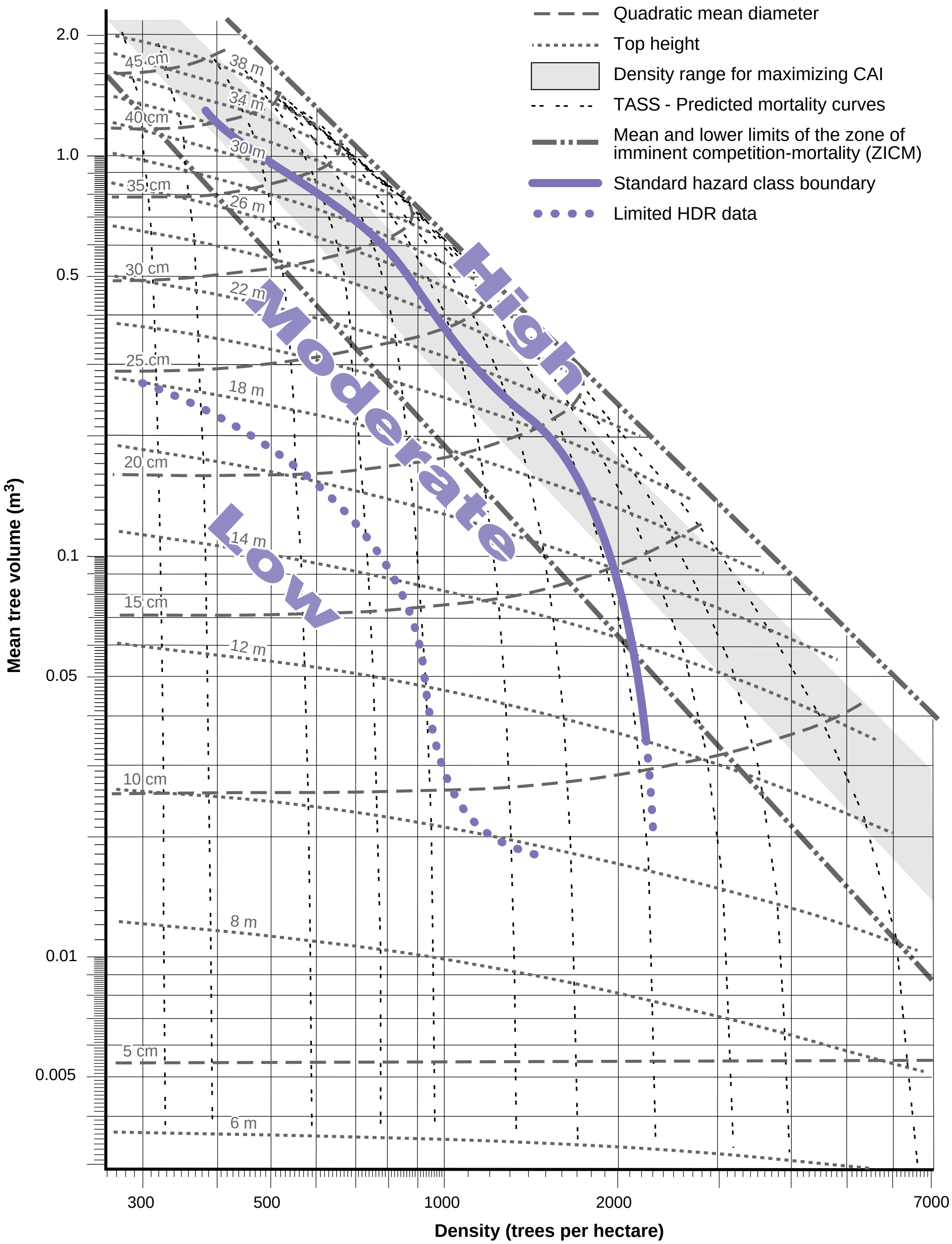


Stand Hazard Zones: Steve Mitchell, PhD, RPF for BC Ministry of Forests, Forest Practices Branch with funding from Forest Renewal BC; 2000
Base SDMD: Canadian Forest Service; data source WinTIPSY 1.0, 1996
Layout: Rich Rawling, Cortex Consultants Inc. with funding from Forest Renewal BC

White Spruce, Natural

Stand Density Management Diagram

Stand Hazard Component of Windthrow Risk: Preliminary Zones



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Base SDMD: Canadian Forest Service; data source WinTIPSY 1.0, 1996
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References and Sources of More Information

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Extension material on UBC wind tunnel and field studies of wind flow over forests with interpretations of topographic hazard and treatment risk are being developed.