IDF Strategy for Williams Lake and 100 Mile TSAs

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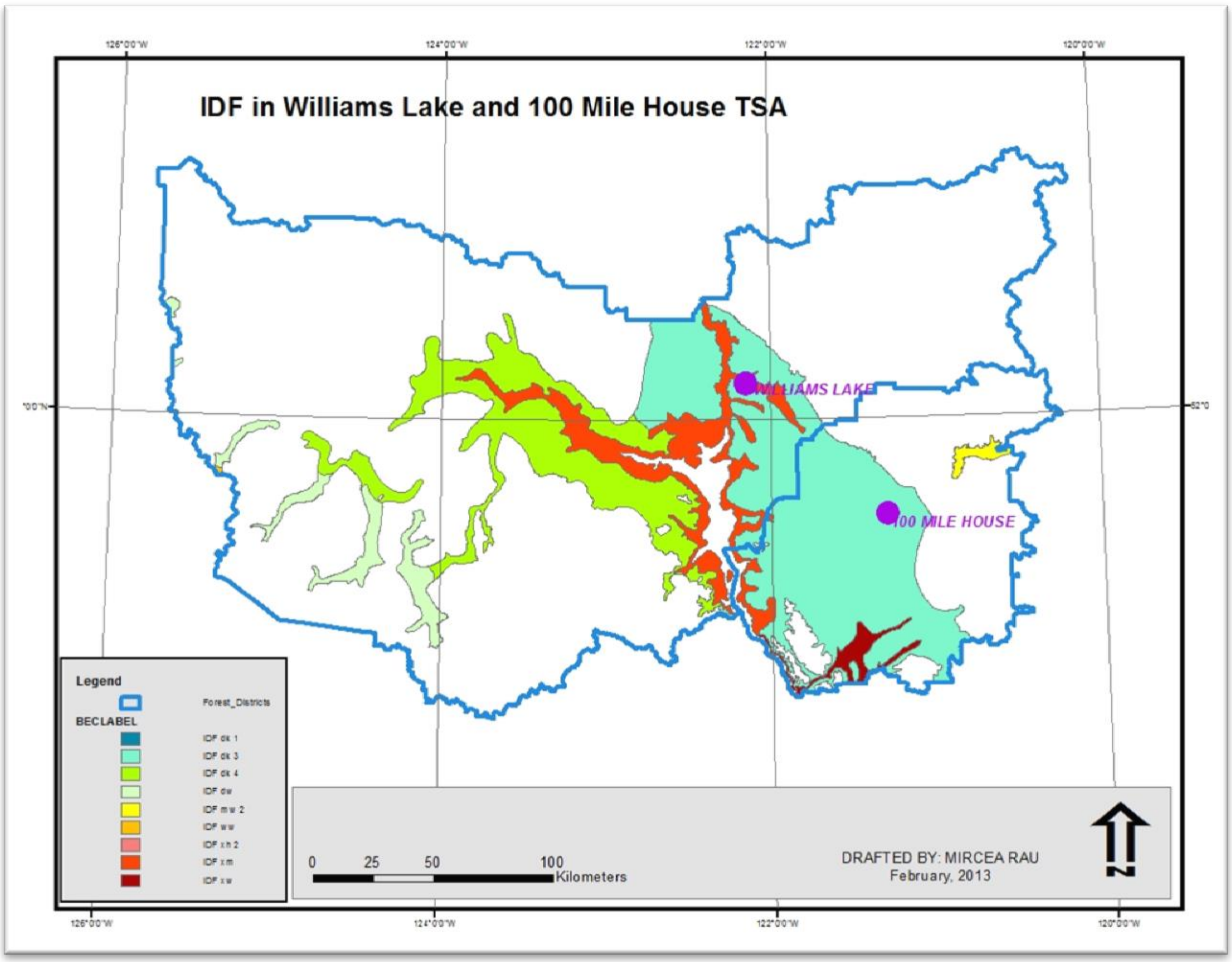

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Summary of Recommendations

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1. Compile existing growth and yield plot results and identify information and research gaps in support of TSR. 4
2. Ensure RESULTS (tabular and spatial) is up to date with PCT treatments. 4
3. Silvicultural approaches in the IDF must recognize the social/ecological values and the ecological/silvicultural challenges. 5
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5. Establish lodgepole pine regeneration at >2500 stems per hectare to allow for high levels of juvenile mortality. Consider mechanisms to recognize increased cost and share risk. 11
6. Devise a new approach to forest inventory and growth and yield in uneven-aged stands. As part of this process, assess the cost/benefits of implementing the stand-structure classification developed under the Tolko (IFPA) to the Williams Lake and/or 100 Mile House TSAs. 12
7. Work with Forest Practices Branch to develop/adjust policy to allow implementation and funding of Forestry Licences To Cut for combined overstory removal and understory thinning in stands with low potential for near term harvest. 12
8. Conduct and monitor fertilization experiments in thinned relatively even aged pole sapling to young forest IDFdk3 Douglas-fir. 13
9. Conduct silviculture systems trials to assess different management approaches. 13

10. Stand-level modelling question – for existing young pine-leading stands is it more productive to continue to manage for pine or convert to Douglas-fir over time? Temper conclusion with climate change concerns. 14
11. Pursue research in facilitated migration of western larch with FLNRO. 14
12. Stand-level modelling question -- fine tuning of a commercial thinning strategy for lodgepole pine and Douglas-fir in the IDF. 14
13. Stand-level modelling question – which of the three silvicultural strategies for the Douglas-fir group provide the best growth and yield results? 15
14. These three silvicultural approaches are untested and unproven. Operational trials should be established to demonstrate each system and gain experience in their implementation. A phased implementation is necessary. 15
15. Stand-level modelling question – which stands benefit most from Pre-Commercial Thinning (PCT)? 15
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Introduction

The Interior Douglas-fir (IDF) biogeoclimatic subzone comprises about 25% of the Timber Harvesting Land Base (THLB) in the Williams Lake TSA. In proportion of area the IDF is second only to the SBPS biogeoclimatic zone in this TSA. In the 100 Mile House TSA, the IDF comprises about 50% of the THLB. This means that the IDF is a critical component of the timber supply for both TSAs. By contrast, however, the IDF only comprises about 4% of the provincial landbase.

The IDF is dominated by multi-aged Douglas-fir forests that have significant variability. Much of the THLB has been previously harvested. For example, 70% of the Knife Creek Block of the Alex Fraser Research Forest had been harvested before 1987. Diameter-limit cutting in the 1960s and 1970s figured strongly in that harvest history, with two-thirds of the logging at Knife Creek occurring in that era. This form of harvesting removed merchantable Douglas-fir and left stands stocked or over-stocked with advanced regeneration and various levels of moderate to poor-quality residual Douglas-fir. Stands harvested before 1966 also have a component of lodgepole pine in the overstory. Fifty years on, many of those stands are grossly overstocked with significant portions of the growing stock stagnated. There exists a cohort of these young, mostly even-sized Douglas-fir stands that are appropriately stocked. These stands illustrate the excellent growth capacity, and suggest opportunities for even-aged management (e.g. through shelterwood silvicultural systems) of Douglas-fir in a portion of the IDF.

The Dry Cool subzones of the IDF (dk3, dk4) contained significant components of mature pine, particularly on flat terrain. Virtually all of that pine was killed by the recent mountain pine beetle outbreak, and many of these stands have been salvaged by clearcutting with reserves.

Problem Statements

Management of the IDF has been a low priority provincially, and suffers from several gaps in information:

- Little emphasis in the provincial research program
    - No trials to establish the impact of fertilization
    - Poorly served by the dominant managed-stand GY model TASS/TIPSY. PROGNOSIS^{BC} is an alternative growth model available for use but it requires detailed inventory data
- Inventory poorly represents stand structure and may underestimate site quality
- Timber supply reviews (TSR) have traditionally used conservative assumptions due to the uncertainties associated with the inventory and growth and yield, which some foresters feel has under estimated potential yields
    - TSR 2 applied a blanket 1 m^3/ha/year to Douglas-fir-leading stands in the IDF
    - Case-study growth plots at Knife Creek (projects 88-03[1] and 88-11[2]) document growth rates (total tree volume less mortality) ranging from 0.5 to 7.6 m3/ha/year over a15 year measurement history
    - Total growth net of mortality is relatively insensitive to stand structure
- Despite the completion of substantial pre-commercial thinning area through various programs, treatment records in RESULTS may be incomplete (especially the spatial component)
- Recent Pli salvage logging has been predominantly using clearcut with reserves with reforestation with mostly Pli. There are concerns that Pli-dominated stands established to the current stocking standards may not be resilient over the long term due to poor form and frequent damage by insects and diseases. However there is a lack of monitoring with which to definitively assess this situation.

Recommendation 1: Compile existing growth and yield plot results and identify information and research gaps in support of TSR.

Recommendation 2: Ensure RESULTS (tabular and spatial) is up to date with PCT treatments.

In addition, silviculture in the IDF is complex due to the multi-cohort stand structures, complex stand establishment and development pathways and some key site limiting factors:

- Frequent drought stress and shade limits growth of all trees
    - Due to frequent growing-season frost and lethal daytime high temperatures, shelter is necessary for successful regeneration of Douglas-fir
    - Open conditions become dominated by pine grass, hindering regeneration
    - Once established, growth performance of regeneration can be significantly negatively impacted by a relatively low density of overstory trees

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[1] Marshall, P.L., T. Lee, K. Day, and C. Koot. 2005. Summary of 16 Years of Growth of Uneven-Aged Interior Douglas-fir with Different Stand Structures in the Alex Fraser Research Forest, Williams Lake, British Columbia (Project 88-3). Final Report. FSP Project Y05-1131. 10 pp..

[2] Marshall, P.L, T. Lee, K. Day and C. Koot. 2005. Summary of the 13-Year Results of an Interior Douglas-fir Precommercial Thinning Experiment in the Alex Fraser Research Forest, Williams Lake, British Columbia (Project 88-11). Final Report. FSP Project Y05-1131. 12 pp.

- Low stand crown closure, combined with drought stress, produce high levels of understory light. Douglas-fir trees seldom die of drought stress. Increasing understory density without mortality means that understory trees eventually stagnate.
    - Inefficient allocation of scarce precipitation to stagnant understory
- Reduction in disturbance frequency mean that many stands have achieved maximum leaf area, and disturbance is necessary to reallocate growing space and leaf area to fewer trees
- High-density stands suffer from low vigour and are therefore at risk
    - Overstory trees have limited defence against bark beetles
    - Understory structure, distribution and vigour is conducive to spruce budworm outbreaks and limits recovery of defoliated trees
- Accumulation of live and dead biomass creates heavy fuel loading and low crown base height, increasing the potential for extreme fire behaviour and high fire intensity
    - Threat to life and limb, and values
    - Potential change of forest land to non-forest due to severe fire effects and difficulty of regeneration.
- Our communities and infrastructure are predominantly located in the IDF
    - Haul costs for timber harvesting are low, but complex silvicultural systems can add costs relative to typical clearcutting operations.
    - Multiple values held by the public – recreation, visual quality and aesthetics, cultural values, range, wildlife habitat, water quality and supply.
- Low elevation and dry climate means these forests receive relatively little snowfall, and are therefore important winter habitat for ungulates, particularly mule deer.
- Proximity to grasslands means many species at risk need IDF forest in their habitat.
- Understory and overstory trees can respond well to release of growing space.

Recommendation 3: Silvicultural approaches in the IDF must recognize the social/ecological values and the ecological/silvicultural challenges.

History of Management in the IDF

Harvesting in the IDF of the Cariboo has gone through multiple phases where significantly different approaches were used (see Table 1). A large part of the IDF forest has been harvested at some time since the 1940s, with significant areas of unrecorded harvesting before that time. As an example, the Knife Creek Block was approximately 70% harvested before the creation of the UBC Alex Fraser Research Forest in 1987.

Particularly notable in the harvest history is the period of diameter-limit cutting. This extensive harvest practice removed the majority of the merchantable overstory trees and retained the advanced regeneration for re-stocking. Sometimes euphemistically called a “natural shelterwood”, this approach was used to accomplish over half of the harvesting of the Knife Creek block (Table 1), and the contemporary pattern of roads and skid trails remains evident over wide swaths of the IDF. As shown in Table 1, the result was often a stand of over-dense thickets interspersed with un-regenerated gaps.

Diameter-limit cutting was found wanting in the late 1970s – the thickets and gaps grew poorly and often with low quality, and the harvest removed a lot of small trees. There was a general move to faller's selection methods that directed loggers to remove about 40-50% of the volume from a stand and protect the advanced regeneration. Often non-commercial veteran trees were left in the overstory.

Extensive diameter-limit cutting also led to a conflict over harvesting on mule deer winter range in the 1970s. Subsequently Harold Armleder and others began a 20-year research program to investigate mule deer habitat ecology and the integration of those values into a silvicultural approach more appropriate for mule deer habitat requirements. In aggregate their research findings (Armleder et al. 1994)[3] became incorporated into the Cariboo Chilcotin Land Use Plan (CCLUP) and General Wildlife Measures put forward under the Government Actions Regulation.

The Biodiversity Strategy under the CCLUP recognized two different stand types in the IDF:

- The Fir group was comprised of stands with more than 40% of their volume as Douglas-fir, managed for uneven-aged stand conditions and older conditions
- The Pine group is comprised of stands with less than 40% of their volume as Douglas-fir and are managed in an even-aged condition

Mountain pine beetle has affected virtually all the pine over about 40 years of age, and resulted in substantial harvesting in the IDF. Harvesting methods have included retention of Douglas-fir and aspen, but more recently the harvesting has moved to clearcutting with reserves, often leaving insufficient shelter for Douglas-fir regeneration. Regeneration after pine salvage logging has been predominantly by natural regeneration with fill-planting of pine.

There has been little harvesting in the fir group in the IDF since the early 1990s, and virtually no harvesting of fir-leading stands in mule deer winter range since the early 1990s. Twenty years of inaction suggests that the status quo is very limited logging. The practical results of this inaction mean the loss of forest management and operational experience.

Starting in the 1980s, substantial areas of the IDF have been pre-commercially thinned to improve the density, structure and growth of stands, particularly those that have been diameter-limit cut. Projects were carried out under a variety of programs. Unfortunately not all of the treatment records have been introduced into RESULTS (especially the spatial data) (see Recommendation 2 above).

[3] Armleder, H.M., Waterhouse, M.J., Keisker, D.G., and Dawson, R.J. 1994. Winter habitat use by mule deer in the central interior of British Columbia. Can. J. Zool. 72: 1721 - 1725.

Table 1: Historical harvest practices by period on the Knife Creek block, with descriptions of resulting stands. Copied from Day (1998)[4].

Period	Harvest Type	Resulting Stand Structure	Harvest Area (ha)
1942-1952	Bush Mill and horse logging targeted narrow diameter range	Good Residual Structure	495 [20.5%]
1955-1969	Low Diameter Limit	Poor diameter distribution, very little vertical structure, voids and over-dense thickets	1,308 [54%]
1970-1980	High Diameter Limit	Poor diameter distribution, little vertical structure, voids and over-dense thickets.	286 [12%]
1980-1983	Faller's Selection	Fair diameter distribution, fair vertical structure, dense thickets, few voids.	29 [1%]
1980-1983	Clearcut with reserves	Poor diameter distribution, poor vertical structure, largely regenerated to Pl and At, little Fd regeneration.	152 [6%]
1983-1984	Mule deer winter range Handbook logging – low volume selection cutting	Good diameter distribution, good vertical structure, dense thickets, regenerated gaps.	139 [6%]
	Total		2,409 [100%]

Silviculture Strategy for the IDF: Going Forward

In an unpublished extension note, Day and Swift (2011)[5] summarized best management practices for the IDF zone.

- Management of Douglas-fir forests requires a partial-cutting silvicultural system to provide shelter during regeneration.
- Water deficit is expected each year on mesic sites.
- Stand structure is a primary determinant of stand productivity and risk of loss.
- Partial cutting remains dominant.
- A large portion of total stand volume is not merchantable because it is contained in very small trees or poor-quality veterans.
- Thinning reduces the slenderness of residual trees, making them more resistant to snow breakage.

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[4] Day, J.K. 1998. Selection management of interior Douglas-fir for mule deer winter range. MF Thesis, UBC Faculty of Forestry.

[5] Day, K. and K. Swift. (2011). Silviculture in the Interior Douglas-fir biogeoclimatic zone. Unpublished extension note.

- In general IDF sites under shelter regenerate freely unless there is a lack of seed source due to spruce budworm.
- Plantation and natural regeneration after clearcutting can be risky.

Day and Swift (2011) proposed best management practices for IDF Silviculture, which follow in Table 2. In general, we seek to regenerate Douglas-fir or lodgepole pine in the IDF subzones of the Williams Lake and 100 Mile House TSAs. Aspen, Rocky Mountain juniper, and white birch also form an important component of the regenerating and mature stands, providing habitat and cultural values across the landscape. Hybrid spruce is an important stand component in moisture-receiving sites. The reproduction method or silvicultural system depends upon the species of choice and the existing structure of the stand being managed.

Both lodgepole pine and Douglas-fir are ecologically suitable and can form resilient stands with desirable timber attributes if grown at appropriate densities in the IDF subzones of the Williams Lake and 100 Mile House TSAs. TIPSY 4.2 allows a theoretical comparison of the two species on a zonal site. While we recognize that this approach will likely only be feasible for Douglas-fir if the plantations are established under the influence of an overstory (e.g.: shelterwood), the comparison is instructive in considering which species can be more productive for timber. Assuming planting with 1200 stems/ha for both species, with 5% genetic improved stock and standard OAFs (OAF1=85% and OAF2=95%), we find the following results:

- Lodgepole pine culminates at age 60 on zonal sites (SI_{50}=20m)[6]
  - Net merch volume at culmination = 276 m^3/ha
  - MAI = 4.60 m^3/ha/year
  - At age 110 pine has about 425 m^3/ha
- Douglas-fir culminates at age 110 on the zonal site (SI_{50}=19) [7][8]
  - net merch volume at culmination = 378 m^3/ha
  - MAI at culmination = 3.44 m^3/ha/year
  - However, at age 60 Douglas-fir offers only 159 m^3/ha

Based on this theoretical review of model results, lodgepole pine is a clear winner in the even-aged model environment, if logging occurs before about age 130 years. However, recent Central Cariboo Forest District sampling for Stand Development Monitoring surveys showed that up to 34% of the total pine stems are affected or killed by one of many forest health factors, in young stands sampled in the IDF. Similar results have been found in adjacent forest management units. Apparently lodgepole pine has a tendency to live fast and die young.

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[6] SIBEC estimates from Klinka et al. 2004. Site units of the University of British Columbia Alex Fraser Research Forest. FII contract report.
[7] SIBEC; Second Approximation, June,2011 show Douglas-fir SI of 17m for ss01 for the IDF dk3.
[8] SIBEC estimates from Klinka et al. 2004. Site units of the University of British Columbia Alex Fraser Research Forest. FII contract report.

Table 2: Summary of best management practices by absolute soil moisture regime (AMSR) and silvicultural system (clearcut and partial cut). Copied with permission from Day and Swift (2011).

		Partial Cut			Clear Cut			
ASMR	Key Risks	Regen-eration	Early Veg Mngmt	Density Mngmt	Reforestation	Early Veg Mngmt	Density Mngmt	Longer Term Forest Health
Gen-eral	Subtle variation in edaphic situation result in significant changes in site limitations. Drought and heat injury are significant limitations. Growing season frost is significant limitation on flat and receiving sites. Dwarf mistletoes limit regeneration species choices. Unsalvaged stand damage leads to bark beetle infestation in Fd and Sx.	Retain and protect advanced regeneration from logging damage. Py, Lw and Pl limited to group selection or group shelterwood due to low tolerance to shade.	Maintain overstory to reduce grass vigour. Retain a component of aspen and birch in stands to provide diversity and cavity-nesting habitat.	Thin in all size classes to maintain vigour and improve mechanical stability. Thin overstory to maintain sufficient exposure for regen species. PCT in layer 2 and 3 to improve quality and vigour. Remove overstory when shelter is no longer required if management objectives allow.	Retain and protect advanced regeneration from logging damage. Fd and Sx significantly limited for regeneration of clearcuts – cold shedding sites only. Natural regeneration of Pl from cones successful if cones are seed-bearing. Plant against obstacles to avoid cattle trampling. Stump to reduce root disease inoculum load in moist and wet subzones, and plant species with greater resistance.	Site preparation to limit grass competition at establishment phase. Woody shrubs are significant competition in Fresh and Moist conditions only. Grazing is beneficial but trampling can be problematic. Ungulate winter browsing can be locally problematic.	Expect substantial mortality and variable stocking. Establish at high initial density to develop good form and hasten self-pruning. Consider commercial thinning to maintain appropriate height-to-diameter ratios (<0.80).	Defoliators and bark beetles are principle health factors. Dwarf mistletoe is potentially controlled by species selection and avoiding infection in the overstory. Pine needle cast is a frequent problem as are stem rusts of pines. Root diseases are frequent problems; isolated in dry subzones but widespread in moist and wet subzones. Manage fuel accumulation to limit fire severity. Snow and ice damage is prevalent in stands with slender form, giving rise to bark beetle outbreaks.

		Partial Cut			Clear Cut			
Very Dry	Driest sites (e.g. shallow to bedrock) are protection forest.	Favour Py and Fd. Monitor cone crops and defoliators		Stand will be variable density – retain overstory to provide shade.	Plant Py in very dry subzones, or Pl in dry subzones, in shade from stumps or logs. Expect high mortality.	Screef or rip/plow to reduce grass competition and growing season frost.		High probability of lethal drought conditions causing conversion to grassland. Spruce budworm will be an episodic or ongoing problem.
Dry	Identify small protection sites in low-slope terrain, e.g. bedrock or small wetlands.	Favour Py Fd and Lw	Maintain overstory to shelter regen, either small clumps or uniform.	Thin in thickets at each entry to maintain vigour and improve mechanical stability.	Plant Py, Lw, and Pl in shade from stumps and logs. Expect significant mortality. Natural regeneration of Pl from seed in cones can be patchy	Screef or plow to reduce grass competition and growing season frost.	Moderate site quality suggests later commercial thinning.	Spruce budworm will be an episodic or ongoing problem. Presence of downed wood is critical to soil moisture and germination success.
Fresh	Significant number of growing season frost events in receiving sites. Root diseases are prevalent in moist and wet subzones.	Favour Sx, Fd, Pl, Lw, Py, Cw	Overstory will impede significant competing vegetation. Maintain overstory to shelter regen, either larger gaps or uniform.	Thin overstory to maintain sufficient exposure for regen species. PCT in layer 2 and 3 to improve quality and vigour. Remove overstory when shelter no longer required, if land use objectives allow.	Plant Py, Lw, and Pl. Fd on cold-shedding locations only. Natural regeneration of Pl from cones can be patchy. Stumping is necessary to reduce root disease inoculum. Plant with tolerant or resistant tree species according to pathogen/host species interactions.	Monitor vegetation development and growing season frost. Brushing treatments will increase frost frequency.	High site quality suggests commercial thinning should be early.	Spruce budworm will be an occasional problem. Presence of downed wood is important to soil moisture and germination success. Root disease is a feature of site, and will be a dominant issue through time.

The impact of damaging agents on managed lodgepole pine yields and quality is not yet definitively known. However, the following preliminary risk analysis provides a frame of reference:

- Assumed mortality in lodgepole pine only needs to be increased by 6% (at 60 years)(OAF 2=75%) before the expected merchantable yield drops below that of Douglas-fir at and beyond 110 years (Douglas-fir culmination age).
- Assumed mortality in lodgepole pine only needs to be increased by 20% (at 60 years)(OAF 2=63%) before the expected merchantable yield drops to 220 m^3/ha at 60 years (Pli culmination age). With this assumption Douglas fir yields exceed those of lodgepole pine above about 82 years and at age 100 years Douglas fir is expected to yield about 44% more than lodgepole pine.

In addition to the current forest health and damage situation, climate change is expected to put lodgepole pine at further risk. Modelling in the San Jose watershed using the TACA model has indicated that lodgepole pine will be negatively impacted on all sites, whereas Douglas-fir could be positively impacted on good and medium sites and negatively impacted on poor sites. Recent work by Craig DeLong for the Williams Lake TSA Silviculture Subcommittee shows that lodgepole pine is currently at moderate risk of drought, and climate change will put pine at high risk of drought. Douglas-fir is considered by DeLong to be at low risk of drought currently and in the future given climate change assumptions. Finally some entomologists suggest the next significant MPB outbreak could hit the interior of B.C. in as few as 40 to 60 years [9]. This adds further risk to management for lodgepole pine.

Incorporating the risks to lodgepole pine, picking a winner between managed even-aged pine versus even-aged Douglas-fir is un-clear. However in the short term, to minimize the risks associated with management of lodgepole pine, we recommend that establishment densities should be at least 1600 stems/ha and preferably >2500 stems/ha to allow for high levels of juvenile mortality. In addition to producing more resilient stands, past studies show that improved product values will result from this regime[10]. Current trials by Dr. Bill Chapman (FLNRO) investigating direct seeding may help to efficiently increase establishment density. However, due to the significantly higher costs associated with higher establishment densities of lodgepole pine, management for Douglas-fir by natural regeneration may be even more desirable.

Recommendation 4: Conduct more modelling of pine vs. fir performance in TIPSY incorporating forest health factors and in PROGNOSIS^{BC} to determine the relative growth rates of the two species and their admixtures and structures.

Recommendation 5: Establish lodgepole pine regeneration at >2500 stems per hectare to allow for high levels of juvenile mortality. Consider mechanisms to recognize increased cost and share risk.

DWB, Tesera and Blackwell (2009) used a system of stand structure classification, growth and yield modelling (using PROGNOSIS^{BC}), and financial analysis to assess and develop silviculture regimes and

[9] MacLauchlin, L. (2012). Presentation to SISCO Conference
[10] Middleton, et al. (1995?). Fornitek Canada Technical Report on Lodgepole Pine Product Yields Related to Differences in Stand Density

apply these to a pilot project area of about 7000 hectares in the Chimney Lake operating area near the borders of the Williams Lake and 100 Mile House Timber Supply Areas (TSA). The key findings from this project were:

1. The stand structure classification developed under the Tolko Innovative Forest Practices Agreement (IFPA) and the data from a set of 103 permanent sample plots provided a reasonable platform for developing and assessing silviculture regimes that are linked to stand structure. For the pilot project area six regimes were developed.
2. Many stands have more than 10 m2/ha of basal area in Layer 1 which are not expected to provide a viable harvest in the foreseeable future. Many of these stands have low vigour to stagnant understories, in part suppressed by the overstory. It was determined that the preferred treatment regime was to remove most of the overstory, followed by thinning of the understory where densities exceed 2,000 stems/ha).
3. Another common stand type with potential for viable treatment (with a 2% ROI) to benefit mid-term timber supply was stands with low overstory stocking and moderately dense to dense stockings of juvenile stems.

Recommendation 6: Devise a new approach to forest inventory and growth and yield in uneven-aged stands. As part of this process, assess the cost/benefits of implementing the stand-structure classification developed under the Tolko (IFPA) to the Williams Lake and/or 100 Mile House TSAs.

Recommendation 7: Work with Forest Practices Branch to develop/adjust policy to allow implementation and funding of Forestry Licences To Cut for combined overstory removal and understory thinning in stands with low potential for near term harvest.

According to Brockley[11] there has not been any fertilization research with Douglas-fir in the IDF and there are no area-based fertilizer response estimates for this portion of the BC interior. The reasons are twofold:

- it always ranked as a lower priority when allocating limited research $ for nutrition/fertilization research; and
- designing and implementing fertilizer research trials is very difficult in the IDF, due to variable site/stand conditions, which means that detecting and quantifying a fertilizer response in these stands is extremely difficult using conventional area-based trial methodology.

Having results from area-based research plots that show an adequate response is necessary to justify operational fertilization in dry-belt Fir stands. While it is un-likely that research plots in variable uneven-aged Fir stands will give reliable growth response estimates (Brockley, 2012) and there is un-certainty whether the responses would be large enough to justify treatment, some foresters wonder about the response potential for immature, even-aged stands of Fir in the IDFdk3.

[11] Email to Louise de Montigny, October 18, 2012

Recommendation 8: Conduct and monitor fertilization experiments in thinned relatively even aged pole sapling to young forest IDFdk3 Douglas-fir.

Recommendation 9: Conduct silviculture systems trials to assess different management approaches.

Type IV Silviculture Strategy Assumptions for the IDF

The IDF is broken into three working groups, as discussed below. The following discussion assumes that all important attributes of stand-level biodiversity, including standing dead trees, coarse woody debris, species diversity and habitat elements are retained in every stand.

Lodgepole Pine Working Group

- All THLB stands with <40% Douglas-fir outside MDWR
- Stands in the lodgepole pine working group remain in that working group or convert to the Fir group
    - Consider conversion to Douglas-fir to reduce risk from climate change
- Pine leading stands >30 years
    - Salvage where a commercial opportunity exists
    - Protect live non-pine if converting to Douglas-fir
    - Reforest with Douglas-fir or pine with densities of >2500sph,
    - If fir is second species and there are reasonable prospects for a future harvest, no treatment, and convert to the Fir group with reduced yields.
- Pine leading stands <30 years
    - Low density and or poor health and quality stands convert to Douglas-fir (by cleaning to remove the Pli and favour the Douglas-fir and/or fill planting with Douglas-fir; convert to the Fir group
    - Moderate to high density, healthy Pli (>2500sph) (these stands are not common); no treatment or schedule for future commercial thinning.
- Reproduction is by patch cut or clearcut with retention, by natural regeneration with fill planting
- Target density at regeneration is 2500 to 4000 stems/ha
- Consider deployment of larch in mixture with lodgepole pine
- Grow pine at high density to age 20 or later before thinning
- For even-aged stands of pine and fir, commercial thinning regimes may provide mid-term volume and contribute to enhanced future timber values and yields. Fertilization could potentially enhance these regimes.
- Example crop plan from stand density management diagrams for discussion purposes (based on Scandanavian thinning regimes for lodgepole and Scots pine):
    - Brushing/Cleaning/PCT
        - age 12
        - if necessary to adjust species composition and espacement
        - target density 2500 stems/ha
    - First commercial thinning
        - at 14 m height (age 30 on SI_{50}=20m)

        - thin to 1000 stems/ha cutting 75 m^3/ha gross volume (0.075 m^3 gross volume piece size)
        - Remove defective and damaged trees
        - Investment required from crown because piece size and low volume/ha render this entry uneconomic on sawlog volume alone; expect primarily biomass or pulpwood recovery.
    - Second thinning
        - At 20 m height (age 50 on SI_{50}=20m)
        - Thin to 600 stems/ha cutting 75 m^3/ha gross volume (0.3 m^3 gross volume piece size)
        - No investment required from crown
    - Final Harvest
        - At 24 m height (age 70 on SI_{50}=20m)
        - 316 m^3/ha gross volume (0.55 m^3 gross volume piece size)

Recommendation 10: Stand-level modelling question – for existing young pine-leading stands is it more productive to continue to manage for pine or convert to Douglas-fir over time? Temper conclusion with climate change concerns.

Recommendation 11: Pursue research in facilitated migration of western larch with FLNRO.

Recommendation 12: Stand-level modelling question -- fine tuning of a commercial thinning strategy for lodgepole pine and Douglas-fir in the IDF.

Douglas-fir Working Group

- All THLB stands outside MDWR with >40% Douglas-fir
- Stands in the Douglas-fir working group remain in that working group
- Conversion of multi-aged structures to even-aged structures is discouraged because it has negative impact on yield due to waste of non-merch volume
- Reproduction is by natural regeneration in the shelter of an overstory through uniform or small group shelterwood, or through single tree or group selection,
    - Shelterwood
        - Retain 50-60% of pre-harvest basal area
        - Natural regeneration or plant with Douglas-fir
        - Thin from below to improve residual stand vigour
        - Minimize logging damage
        - Maximum gap size one tree-length in diameter
        - Remove overstory trees at year 20 when regeneration is 2 m tall
        - Re-use trails if summer logging in first entry
        - Slash damaged advanced regeneration after final harvest
        - These stands could be candidates for fertilization between 10 and 30 years prior to the next prepatory cut
    - Group selection systems should also include thinning in the matrix

        - Remove 1/6th of the stand in groups less than one tree-length in diameter
        - Thin the matrix of the stand from below to improve quality, health and vigour of residual stand
        - Retain 67% of the basal area in the thinned matrix
        - 20 year re-entry period
        - Slash damaged advanced regeneration after each entry
    - Single-tree selection can follow BDq regulation
        - B=16-22 m^2/ha (about 50% of pre-harvest BA), D=60, q=1.25
        - Cutting cycle = 20 years
        - At each harvest entry there should be regeneration gaps cut, up to 1 tree length in diameter
        - At each harvest entry there should be thinning from below throughout the stand matrix to release growing space to residual trees
        - Slash damaged advanced regeneration and space in Layer 2 and 3 after each entry
- Improvement cutting in stands with no prospects for commercial harvest
    - Pre-commercial thinning of stands with poor to moderate differentiation of juvenile stems, L2 to 3 densities of >2000sph and overstory basal areas of <10m2/ha. Will require funding.
    - Overstory removal for stands with L1 stems with poor form and vigour making up >10m2/ha. In these stands analysis shows that, to achieve enough of the benefits of density management of the understory to justify this treatment, that the removal of at least some of the overstory is also required. This regime is expected to generate some merchantable volume, but not enough to cover the cost of the treatments (overstory and understory thinning), so implementation will utilize a Forestry Licence To Cut (FLTC) and will require funding.
- Thinning entries should target low-vigour and high risk trees
- Target diameters should not exceed 60 cm DBH except to recruit snags and CWD
- Advanced regeneration of Douglas-fir and spruce is suitable and amenable to release cutting and should be protected during harvest operations

Recommendation 13: Stand-level modelling question – which of the three silvicultural strategies for the Douglas-fir group provide the best growth and yield results?

Recommendation 14: These three silvicultural approaches are untested and unproven. Operational trials should be established to demonstrate each system and gain experience in their implementation. A phased implementation is necessary.

Recommendation 15: Stand-level modelling question – which stands benefit most from Pre-Commercial Thinning (PCT)?

Lodgepole pine MDWR Working Group

- All THLB stands within MDWR with <40% Douglas-fir
- Stands in the Lodgepole pine MDWR working group move over time into the Douglas-fir MDWR working group
- Reproduction is through clearcutting with reserves and protection of advanced regeneration to augment the Douglas-fir stocking at each harvest entry

Douglas-fir MDWR Working Group

- All THLB stands within MDWR with >40% Douglas-fir
- Stands in the Douglas-fir MDWR working group remain in that working group
- Reproduction is through single tree selection with three classes of habitat – High, Medium, and Low
  - Single-tree selection can follow BDq regulation
    - High habitat B=29 m^2/ha, D=60, q=1.25
    - Moderate habitat B=22, D=55, q=1.25
    - Low habitat B=16, D=50, q=1.3
    - Cutting cycle = 30 years
    - At each harvest entry there should be regeneration gaps cut, up to 1 tree length in diameter at a rate of 4 gaps/ha
    - At each harvest entry there should be thinning from below throughout the stand matrix to release growing space to residual trees
    - Slash damaged advanced regeneration and space in Layer 2 and 3 after each entry
    - Production is constrained until 2026 to 20% or 25% of the pre-harvest basal area at each entry
- Lack of management is resulting in declining vigour and increasing mortality, particularly in large old trees and regeneration
  - Consider development of a disturbance regime for Old Growth Management Areas
  - Consider that the long re-entry period implies stands will go through a period of competition-induced mortality, particularly in moderate and high habitat objectives.
  - High-habitat objective is severely constraining on timber access and is unlikely to be managed by normal commercial timber harvesting

Recommendation 16: Operational research and adaptive management is necessary to adapt harvest methods to achieve the direction resulting from 20 years of research in mule deer habitat ecology and silviculture. Methods to achieve objectives across the whole landbase should be considered

Type IV Silviculture Strategy Analysis Units Summary

Working Group	Sub group	Aanlysis Unit	Discussion
Lodgepole Pine	>30 years old	Dead Pl	Convert to species 2 Fd or At Low-volume stand
Lodgepole Pine	<30 years old	Pine stand with commercial thinning	
Douglas-fir	Uniform shelterwood	Fd Two entries over 20 years	Currently 100 m^3/ha @ 27.5+
Douglas-fir	Group selection	Fd 6 entries over 120 years	Currently 100 m^3/ha @ 27.5+. Multi-aged stand by area
Douglas-fir	Commercial thin	Prep cut	Currently 100 m^3/ha @ 12.5+.
Douglas-fir	No commercial volume	Fd PCT	Difficult to find in inventory
Douglas-fir MDWR	High Habitat	MDWR High	Salvage only – no block harvest opportunity due to high residual stand requirements
Douglas-fir MDWR	Moderate Habitat	MDWR Moderate	30 yr cycle, 20% of volume
Douglas-fir MDWR	Low Habitat	MDWR Low	30 yr cycle, 25% of volume
Douglas-fir	Commercial thin	Prep cut	Currently 100 m^3/ha @ 12.5+.
Douglas-fir MDWR	No commercial volume	Fd PCT	Difficult to find in inventory