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Chad
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Mountain Pine Beetle Epidemic and Flood Risk in the Fraser River Basin

Dr. Younes Alila, P.Eng.
Associate Professor
Faculty of Forestry
University of British Columbia
Tel: (604) 822-6058 Fax: (604) 822-9106
Email: alila@interchange.ubc.ca

Preface

The BC Forest Practice Board (FPB) recently released a report on a modelling study[1] which concluded that the pine-beetle epidemic and clearcut salvage logging will increase substantially the flood risk within the tributaries of the Fraser River Basin. Since then, many local scientists and professionals have asked for more detail regarding the model and its underlying assumptions, the mechanisms causing the increase in flood risk and the extent to which we have enough understanding of the hydrologic processes that enable us to quantify the relation between MPB and floods. This document provides answers to a number of repeated requests for clarification and elaboration.

Question A) How much do we know about the effects of large scale MPB-kill and salvage logging on flood hydrology from the historic literature?

Very few studies have reported the effects of MPB in larger watersheds on flood hydrology (Bethlahmy 1975 Colorado, Potts 1984 Montana, Cheng 1989 BC Southern Interior). These rather opportunistic studies reported up to 27% increase in the average peak flow for 27-35% salvage logging or beetle kill depending on watershed size, aspect and topography. No studies have been done that look at the effects of MPB impacts on flooding in areas with plateau-like topography.

From stand level studies we know that MPB affects hydrologic processes such as interception, transpiration and snow melt rates. These stand level alterations of hydrologic processes from the various aspects and elevations within the same drainage induce more complex changes of operationally important watershed scale functions such as water yield and peak flow regimes. There is a lot published at the stand level for green and clear-cut stands but very little on beetle infested grey stands that lost their needles and branches (Uunilla et al. 2006) and this is the subject of ongoing research by BC university and government scientists.

At the watershed scale, the substantial body of literature on the relation between flood and forest is based mostly on conventional harvesting in experimental small-paired catchments, generally less than few square km. There is limited empirical evidence about the extent to which the results from these small catchment studies can be extrapolated to larger watersheds in snow environment (Troendle et al. 2001). In light of the urgency of the matter, our only hope of shedding some light into this complex topic is through the use of hydrologic watershed scale models. All along, we need to keep in mind that models are only an approximation of reality and, at least in the foreseeable terms, their predictions will always be associated with uncertainties (Oreskes et al. 1994).

Question B) What is the cause of the increased flood risk? What is the origin of the increased risk- snowmelt? Rain?

Pure rain induced floods are rare in interior BC watersheds larger than a few ten's of square kilometers in area. The origin of the increased risk relates mostly to the energy-induced snowmelt floods that dominate in most interior watersheds. Snow accumulation in a grey stand was modeled to be halfway between a

[1] http://www.fpb.gov.bc.ca/news/releases/2007/03.16.07.htm

Designed for 200yr now @ only 50yr ←
60% of shed in most heavily affected area
· Threats by prov: consultants and premier to not release information
not necessarily saying that development the issue but sig. enough to at least look @ it.
– check hydrographs in last couple of years
· Sealevel
· Sediment ↑
· MPB

clear cut and a healthy green stand, based on recent measurements near Prince George (Beaudry 2006). Radiation / energy transmitted to the snow pack under grey stand was modeled using published detailed energy stand level work on deciduous stands (Federer 1971, Hardy et al. 1998). How much radiation is being transmitted to the snow pack under a grey stand was assumed to be comparable to what occurs under a deciduous (leafless) stand. These calculations were bounded by the snowmelt measurements in stands conducted by Pierre Beaudry (Beaudry 2006). At this stage, this may be just an approximation but no other information pertinent to energy acting on the snow pack under a grey stand is available. New information from the various ongoing scientific investigations will be incorporated into the model as it becomes available.

Question C) **What are the mechanisms and factors that make you sounding the alarm bells on increased flood risk in MPB infested and / or salvage logged watersheds?**

The mechanisms causing an increased flood risk involve not only what is changing at the stand-level but also how do these stand level changes translate to the larger scales, watersheds of sufficient size to potentially affect public safety, infrastructure and property. In addition, and equally important, how slow is the hydrologic peak flow regime recovery to pre-disturbance levels. In the watersheds within the most heavily affected areas of BC (Upper Fraser, Nechako, and the Fraser Plateau areas), here are the mechanisms involved in increasing the flood risk at the watershed scale:

1. ***Increased accumulation of snow in grey and salvaged logged stands in comparison to a green stand:*** Recent studies have indicated that relative to a green stand the increase in snow accumulation is less in a grey stand than in salvage logged opening (Beaudry 2006).

2. ***Substantial reduction of shading in grey stands, and no shading in salvage logged stands:*** Reduced shade during the snow melt period results in increased radiant energy at the snow surface which contributes to increased melt rates.

3. **Increased wind speed at the snowpack surface in salvaged logged stands**: This may result in increased energy transfer of sensible and latent heat therefore increases in snow melt rates (Bernier 1990).

4. ***Synchronization of runoff from all parts of subdued, low relief plateau-like watersheds:*** In these types of terrains, melt and runoff contributing to peak flows are occurring simultaneously from many parts of the watershed. There is not enough variation in aspect or gradient that can help desynchronize the melt/runoff. The influence of salvage harvesting will be amplified in flatter topographies due to lack of desynchronization of runoff.

5. ***Very slow hydrologic recovery in the snow dominated watersheds:*** Recovery is defined as the time period required for the peak flow or flood regime to come back to its pre-disturbance conditions. Available literature suggests it takes 50 to 60 years for the peak flow regime to come back to its pre-logging conditions (Troendle and King 1985, Elder et al. 2006). It is important to remember that hydrologic recovery must be considered as the time period required not for the stand level processes of snow melt, transpiration or snow accumulation one at a time, but their combined interactive effects on stream runoff and peak flow regimes to begin to approximate those of pre-disturbance conditions. Such a long period will increase the risk of flooding (risk of flooding is defined as the likelihood of a flood event, such as 2-, 5-, 10-, 20-year etc., being exceeded within the time span of the recovery).

6. ***Past Logging history:*** Past logging in most of the watersheds affected by MPB adds to the effects of MPB related mortality and salvage logging.

7. ***Current MPB salvage logging:*** The rate of current logging is relatively high as a result of the short window of opportunity for salvage harvesting in relation to wood merchantability.

In light of the above seven points, professionals need to ask themselves the following questions (my answer to these questions is given in parenthesis at the end of each question):

Are these factors enough to justify sounding the alarm bells (absolutely yes)? In the conditions described above, particularly the plateau topographies, large scale disturbances and very slow recovery of the peak flow regime, do we really need a hydrologic model to realize the great potentials for increased snow melt induced flood risks (yes)? Should we wait another 5 years until more detailed process based stand level information or more reliable watershed scale models are available while these watersheds are being aggressively salvaged logged without even a watershed assessment (definitely not)?

Since the most heavily MPB affected areas constitutes 60% of the areas draining the Fraser River, should we raise the question whether the MPB and its treatment by salvage logging has any downstream effects of flooding whether in the Fraser River or many of its tributaries (absolutely yes, because we are bound by our Professional code of ethics to do so)?

Further details in support of my personal answers to the above questions are provided in the subsequent sections of this document.

Question D) How much snow do dead pines intercept compared to a clearcut or a green pine stand?

New stand level measurements on the difference in peak snow water equivalent (pswe) between a green stand, a clear cut stand and a grey stand near Prince George and Vanderhoof indicate that a grey stand is half way between a clear cut and the green stand (Beaudry 2006). This means that at the time of the winter's peak snow accumulation, clearcuts contain significantly more swe than green stands, and that grey stands are intermediate (around 50% that of a clear cut). The difference depends on the year, stand structure and the proportion of pine in the profile.

Even though there may be an over emphasis on the post attack stage being referred to as "grey" in this document, work funded by CFS MPBI have shown that the physical traits of a dead stand is much more complex in space and evolve over time (Teti, 2007). This indicates that the stages that dead stands go through from the time of needle drop until the time when recovery substantially exceeds deterioration are all important.

Question E) How could one or two years of swe measurements at few stands be used to make sweeping generalization when interception processes changes with stand structure and proportion of pine?

The difference in swe between green stands and clearcuts has generally been well established in the literature (Winkler 2001 and references therein). The main additional factor being investigated by stand level snow researchers is related to quantifying the intermediate effects of grey stands. Different researchers working independently in different parts of the BC Interior are generating similar results. Although the periods of field measurements are short, the similarity of results among researchers clearly and strongly suggests the intermediate nature of grey stands with respect to snow accumulation. It is clear that grey stands are not equivalent to clearcuts. Snow water equivalent before the start of the melt season is a measure of winter snow accumulation and is only one of three stand level changes caused by beetle kill or salvage logging; the other two stand level changes are melt rates and transpiration.

Snow accumulation measurements should not be used to define hydrologic recovery or decide how much to log from any drainage. Changes in peak flow regimes are caused not only by changes in the amount of water stored as snow but most importantly changes to the energy acting on the snow pack (i.e. melt rates).

In terms of changes to seasonal water yield as a result of tree mortality and salvage logging, alterations to transpiration are as important if not more important than alteration to snow accumulation. For instance, paired watershed studies in the snow environment of the Colorado have shown that up to two thirds of the total increase in water yield as a result of logging could be attributed to the suppression of transpiration (e.g. Troendle and King 1985 p.1922). This same study have also demonstrated that the return of the peak flow regime to its pre-logging condition is very slow and takes up to 50-60 years and this can only be attributed dominantly to changes in melt rates and their slow recovery as opposed to changes in snow accumulation alone.

Work is ongoing by our group and several colleagues in the province (government scientists and academics such as Rita Winkler, Pat Teti, Darryl Carlyle-Moses, and David Spittlehouse) to better understand the differences in these stand level processes between a grey stand, green stand and a clear cut stand (snow accumulation, melt and soil moisture). These stand level processes are affected by elevation and aspect among other factors within the same watershed. This is one of the reasons why up-scaling any stand level information to larger watersheds adds another dimension to the challenge of predicting the effects of disturbance on a watershed scale function like streamflow.

Question F) I know that there is a real concern about increased soil moisture when transpiration and winter snow interception are curtailed. I am just wondering what are the mechanisms that led to the conclusions in your report?

Curtailed transpiration will have an effect on the water yield (total runoff). Most of the onsite effects (i.e. within the watershed of interest and not downstream) on peak flows are caused by increases in radiant energy, snow accumulation and wind. These processes are happening simultaneously and in synchronized ways from all parts of the watershed in the low relief terrains.

Hewlett and Helvey (1970) have warned that downstream flooding may not necessarily be the results of an increase in peak flows (caused by logging the headwaters). Rather, downstream flooding may be caused by the downstream cumulative effects of an increase in runoff volumes caused by logging the headwaters. Therefore, we may not be able to say that the suppression of transpiration may not be contributing to a potential increase in flood risk.

The Baker Creek modelling in the BC FPB study suggests that it is the change in energy first and snow accumulation second that cause an increase in flood risk. Downstream of Baker, however, flooding may be caused by the superposition of increased runoff volumes. For instance, a spring or early summer rain storm falling on a wide snowmelt hydrograph (that can be made wider by logging the headwaters) could create downstream flooding! In this case, it is not just the rain alone that may have caused the flooding but the flood risk may be exacerbated by the increase in runoff volumes in the disturbed headwaters. If rain is invoked in the increase of downstream flood risk then it speaks to the need to begin factoring-in what the global climate change could be doing to the frequency of these early summer rain storms (one of the facets of the complexity of the problem at hand).

Question G) Have you been accused of being an ill-informed fear monger when you linked downstream flooding of the Lower Fraser River to MPB?

Considering that there are no studies that describe the flood dynamics of the Fraser River basin we are pretty much all ill-informed. It's important to recognize the need for a clearer understanding of this issue in the very near future so we can better understand the impacts of the beetle in the Fraser Basin. One of the questions is how does the plateau area contribute to the flood peak at different points along the Fraser River? There is a huge part of the Fraser River basin upstream from Prince George that drains from Clearwater and McBride that are far to the East in the Caribou Mountains. If you consider surface area and total runoff of the contributing slopes rather than just area alone it may be in fact that the area upstream from PG is controlling peak flows more than the Plateau area – but we don't know this because nobody has done this sort of analysis with and without the compounding influence of MPB infestation and salvage logging on the landscape.

Unfortunately, we have all mostly been trained to see things as a series of unconnected issues as opposed to seeing things as a system. If we recognize the potential linkages between upstream causes and downstream consequences it is possible for the MPB epidemic and related management policies to contribute to increases in flood risk in the Lower Fraser River. The factors that I use to support the possible linkages between MPB and flooding in the Lower Fraser River are:

1. Sixty percent of the areas drained by the Fraser River are heavily affected by the mountain pine beetle infestation. The suppression of transpiration and the very slow recovery of the new forest (after beetle infestation) will increase runoff volumes within the Fraser River. Historically, a May rain storm event falling on a wide snowmelt hydrograph (that can be made wider and with a higher baseflow by logging the uplands) has caused flooding in the Lower Fraser Valley. In the current context, it is not just the rain alone that may cause the flooding but the flood risk may be exacerbated by the cumulative increase in runoff volumes, and not necessarily peak flows, in the MPB disturbed headwaters of the Fraser River.

2. Current rush for salvage logging the MPB affected watersheds, justified by the short "shelf-life" of beetle-killed timber, can and likely will make the effects on increased downstream runoff volumes more dramatic. Furthermore, there is a perceived possible rush into the use of beetle-killed wood for power production, and harvesting will continue to feed oriented strandboard and fuel pellet plants.

3. It has been documented by the local media over the last several weeks to few months that sections of the dikes of the Lower Fraser River do not have adequate capacity because of silt and sediment build up over the years (Fraser River Basin Council 2006). Even though these dikes were originally designed to handle the 200-yr flood level of 1894, they are likely to be overtopped with more frequent flood events. Current MPB situation needs to be considered in the context of the dikes not having adequate capacity.

4. A warmer, wetter climate related to global warming increasing the likelihood of rising sea level and storm surges on the capacity of these dikes have also been in the news (Spencer 2007) and continues to be a major source of worries for coastal cities around the world.

5. Flooding in sections of the Lower Fraser River had traditionally been caused by May warm rain storms falling on a wide snowmelt hydrograph. The frequency and magnitude of these May storms could be changing as a result of global warming. Therefore, global warming is likely to exacerbate the flood risk in the Lower Fraser River (Factors 1, 4 and 5).

The largest flood of record on the Fraser was in 1894 and estimated to be a 200-year flood event. For the area of the Fraser Basin currently dominated by second growth lodgepole pine (say, 60+% of the total Fraser Basin area), what was the age distribution of pine stands in 1894? Might there have been a role in the 1894 flood related to landscape level fire and vegetation change? While these might be thought of as scary conjectures they are legitimate questions that need to be investigated.

The CBC News of Monday April 2, 2007, covered climate change and adaptation in British Columbia by airing two interesting pieces: first piece on the hypothetical scenario of the dikes of the City of Delta being overtopped by a storm surge and potential sea rise, and the second piece on the devastating mountain pine beetle MPB but with no reference to flooding (CBC The National 2006). Even though the two pieces were aired back-to-back in the same context of climate change and adaptation, the CBC reporters made no connections between MPB and downstream flooding in the Lower Fraser River. One could not possibly blame the reporters or the public for not making the connections between these factors, when even scientists at times have difficulties making these connections. My take is that when covering a complex topic such as the effects of climate change and adaptations, it would help the public, politicians, bureaucrats and policy makers to paint a full picture and not present one or few aspects of the problem in a disconnected way, especially when the whole could be much larger than the sum of its parts.

Due diligence necessitate that we should not rule out a possible connection between the "little beetles demolishing BC forest" and the "safety of 350,000 people 1000 km away". Conjecture and unsupported guesses are clearly insufficient in this regard, with such a significantly potential negative outcome at stake – increase risk to public safety and infrastructure associated with catastrophic flooding.

Question H) And why have you labeled this a clear cutting issue. How would partial salvage harvest be different?

In the most heavily affected areas of BC with characteristics described in points 1 to 7 above anyone flying over many drainages would see nothing but large clear-cut areas. When I talked to the media I decided not play the game of semantics and loose track of what is at stake (namely what I think is potentially a serious problem). Most of these stands are clearcut with reserves, where reserves are about 15% of the stand. These areas provide biodiversity value, but it is unlikely they provide hydrological value.

Where there is a pure even-age pine with high percentage kill over large scale subdued topographies, there may not be too many options between leaving it alone and salvage logging it via large scale clearcut operations. In these conditions, salvage logging by leaving scattered patches of dead trees across the landscape may be good enough for biodiversity, for instance, but not enough for reducing the risk of flooding and protecting other soil and water related values. How much to log and where to log in such drainage are best determined through detailed watershed specific assessments. However, professionals conducting the assessments currently do not have sufficient quantitative, scientifically defensible information by which to make informed assessment conclusions. There is a strong need to fast track hydrologic modelling efforts to provide sound and defensible information.

Industry and professionals need to also be reminded that large scale clearcutting everywhere in the name of MPB infestation when there is a significant portion of other species alive in the stand can not be justified.

Question I) What % of a watershed could be salvage harvested without changing the risk of flooding posed by complete beetle kill? How would this % affect the risk if it were dispersed – partial salvage – vs. concentrated – patch of clear cutting if the same % of the trees were removed from the watershed?

These questions are legitimate but were not part of the terms of reference of our contract for the BC FPB. The key message, that we need to remind ourselves with, is that in plateau-like topography such as that of Baker Creek, dead trees over large areas are likely to increase the flood risk (even without any salvage logging). However, in these types of watersheds, additional salvage logging could make the situation significantly worse, especially if there are viable spruce or fir saplings beneath the pine. The over riding objective of all management prescriptions in these plateau areas should be the rapid re-establishment of a coniferous stand but management activities should be approached with caution and limited over space and time – until we have a clearer understanding of the linkages between the impacts of MPB and downstream consequences such as large magnitude flooding and channel response.

This may not be as much of a concern in other areas of the Province such as the southern interior where watersheds may have steeper gradients and, as a result, heterogeneous aspects that are likely to mitigate the effects on peak flows and where the stand may not be 100% pine and with some under story. But, there is insufficient information currently available to make that conclusion definitively. There is a strong need to apply distributed hydrologic models to watersheds typical of the sizes and characteristics of the southern interior, to determine as best we can what MPB and harvest effects can be anticipated, and to evaluate the types and extents of harvest that can be applied.

Since the forest hydrology literature is dominated by stand level knowledge and small paired watershed studies, often less than few square km in size. Such small scale knowledge, on its own, can not be used to guide the management in much larger watersheds affected by MPB.

Even if some sort of a watershed assessment is mandated by the BC Government to help guide management activities, professionals will face a major challenge of not having the right tools or the scientifically defensible management guidelines that help them decide how much or where to salvage log in such large watersheds.

There is a desperate need for studies similar to the one commissioned by the BC FPB on large watersheds with physiographic, forest cover and climatic characteristics different from the Baker Creek watershed. Baker Creek may be a worst case scenario because of its plateau-like topography and pine dominated stands. Similar modelling studies on several other watersheds of varying characteristics will be instrumental in guiding the management of MPB drainages over the next several years. Notwithstanding uncertainties in model predictions, distributed modelling remains our only viable option for investigating the effects of disturbances over larger watersheds.

Question J) Why have you decided to make headline news with your report for the BC FPB?

The FPB made the decision to hold a news conference because of the importance of the report findings to mountain pine beetle management and to try and ensure that the media interpreted the report accurately. The news conference contained a PowerPoint presentation that went through the steps of the model and its interpretation. The FPB was pleased that, for the most part, the press writing was accurate.

I maintain that you don't need a model to figure this out. Not having a comprehensive understanding of processes cannot be used to justify possibly inappropriate policy decisions, professional recommendations and forest company actions that can compromise public safety and downstream ecosystem integrity.

During the Forest Practice Code, licensees were required to do watershed assessments in community watersheds and high value fish streams. Currently, however, fewer watershed assessments are done by the licensees.

As it came clear in the press conference, the BC FPB is sounding the alarms that excessive salvage logging, particularly without a professionally conducted watershed assessment for each drainage, could be a recipe for problems not just in terms of flooding but lots of other aspects associated with the flood regime, such as channel condition, habitat for fish, etc.

I happen to agree - not necessarily in defense of my model predictions but common sense. In situations like this it is more prudent to lean on the safer side (be more conservative) and be moderate in the application of management activities.

The messages of the BC FPB are targeted at the BC Government, Forest Industry, and professionals working for the licensees. Our report has generated a lot of discussion within government agencies and between these agencies and the BC FPB over the last few months, which in my mind is positive.

Question K) Should the existing state of technology in distributed modelling, which may reflect the lack of understanding of hydrologic processes, be used to influence land management policies?

One of the reasons why anyone resorts to risk analysis and therefore invoke probability concepts is because of our lack of understanding of systems. Why should this important topic on the effects of MPB on floods in BC be an exception when there could be so much at stake!?

We have used the hydroclimate data available to us to develop the application of the distributed hydrology model for Baker Creek. No doubt we have used simplifying assumptions in this model because of the lack of hydro-climate data on the internal tributaries of the watershed and because of the lack of detailed process information at the stand level particularly in a grey stand.

A reminder that no matter how much data we have available there always be uncertainties associated with the predictions of current modelling technologies. It is well known in the science community that the more data we have the more likely we will be able to invalidate a model (Beven 1993). We have applied the model in this study in a heuristic mode for exploring "what-if" questions, bounding the problem and identifying areas that are in most need of further study and areas where more empirical data are mostly needed (Oreskes et al. 1994). Our model results are alarming and strongly suggest the need to address hydrology issues more diligently.

The urgent need to answer MPB related operational questions, most of which are at the larger watershed scales, necessitates immediate actions from government agencies, industry partners and other stakeholders. Waiting until we have fine-tuned our understanding of processes is not an option (particularly when the bulk of process understanding is and continues to be done on the smallest scales). Ironically, it is also well acknowledged in the science community that a better understanding of processes at the small scales has not been necessarily translating into a better ability of predictions of watershed responses at the larger scales (Sivapalan 2003).

Much of the scientific "common-sense" described in this document can lead to the same conclusion as a reliable distributed hydrologic model, albeit in qualitative ways. If enough hydroclimate data measured in a nested fashion within a mesoscale watershed (100s and 1000s of square km) become available more confidence could be built in the prediction of distributed hydrologic models. It is only then that the explicit representation of our understanding of hydrologic processes across larger spatial scales via the use of such models will provide the quantitative substantiation of this "common sense".

We have launched a new campaign of collecting hydroclimate data in a nested fashion at the Baker Creek watershed near Quesnel (http://www.forestry.ubc.ca/bakercreek/Home/tabid/1480/Default.aspx). This project is funded by the CFS MPB Initiative and BC Environment. Data from this new larger watershed initiative, along with data from the well established longer term Upper Penticton and Cotton Creek experimental watersheds, will be instrumental in building more confidence in existing distributed hydrological models and testing new distributed modelling concepts over a wide range of watershed scales, climates and physiographic characteristics.

Recommendations

1. Anyone involved in advising decision makers in the government or industry should avoid seeing things as a series of unconnected issues and start considering land management activities as part of a system. An example of how crucial it could be to see things as a system is the possible connection between MPB and an increase in flood risk in the Fraser River, as illustrated above. A second example would be the relation between forest and the streamflow regime and how it can only be fully understood by considering the combined effects of forest canopy on melt rates and transpiration processes and not just the snow accumulation process.

2. Current snapshot assessments of the visual, hydrological and wildlife effects of beetle should be viewed in the context of the fact that the same landscape has experienced large scale stand replacing disturbance for millennia, albeit with no roads and with dead stems left on site. The ultimate goal is to balance the longer term objectives of the pathways and speed of succession that are needed to re-establish the ecosystem processes of nutrient cycling, biomass accumulation, hydrological regulation and habitat redevelopment with the more immediate worries about the visual, hydrological and wildlife values.

3. There remains significant knowledge gaps on the hydrological impacts from large scale pine-beetle kill and salvage logging. However, these impacts will be larger than the effects of any recent historic conventional logging of a healthy forest. It is obvious that we can not wait until the results of all desirable research are available. In a situation like this, expert knowledge and consensus among scientists and professionals should be used as guidance for decision making. Everyone who is involved in guiding government authorities or the forest industry on how to manage MPB affected watersheds should err on the side of caution, particularly when public safety may be at a stake.

4. The management of MPB watersheds that results into large scale disturbances should not be conducted without detailed watershed assessments that guide forest industry and stakeholders on how much, and where within the drainage, salvage logging is likely to keep to a minimum the effects on soil and water values.

5. The streamflow regime is the most operationally relevant in understanding the functioning of watersheds and associated ecosystems because it supplies the primary medium and source of energy for the movement of water, sediment, organic material, nutrients and thermal energy. Hydrologic recovery and traditional ECA calculations should be conducted in relation to the integrative watershed scale streamflow metrics (such as peak flow or water yield), and not in relation to a single stand level hydrologic process such as snow accumulation. Snow accumulation alone can not be used to define hydrologic recovery or decide how much to log from any drainage. Snow accumulation is only one of three hydrologic processes that interact to affect the streamflow regime. Changes in the streamflow regime, and particularly peak flows, are caused more by changes to the energy acting on the snow pack (i.e. melt rates) and less by changes to winter snow losses by interception and other means (i.e. pswe).

6. If a watershed assessment is mandated by the government, professionals will face a major challenge of not having the right tools that can help them decide how much or where to salvage log in these large watersheds. Baker Creek may be a worst-case scenario because of its plateau-like topography and pine dominated stands. Similar modelling studies on several other watersheds of varying characteristics, if undertaken immediately, would help guide the management of MPB drainages over the next several years. Notwithstanding uncertainties in model predictions, distributed hydrological models, guided by expert knowledge, remain our only viably option for investigating the effects of disturbances over larger watersheds. These models will be updated as new process based knowledge becomes available over the next few years.

7. Large scale clearcutting everywhere in the name of MPB infestation, when there is a significant portion of other species alive in the stand, may not be justified. If selective salvage logging is not cost effective or feasible, dead pine in such mixed stands should not be salvage logged, which could help sustain future timber supply while minimizing deleterious effects on soil and hydrology.

In summary, because of the lack of knowledge in the literature on the effects of large scale beetle disturbance we have laid out some of our arguments more based on soft "expert knowledge" as opposed to the traditional hard quantitative scientific facts. Therefore, some of our arguments are only as strong as they stand to challenges and questions. We encourage the readers of this memo to share with us their thoughts and particularly disagreements with any of the arguments put forward in this document.

Acknowledgments

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Winkler, R.D. 2001. The effects of forest structure on snow accumulation and melt in south-central British Columbia. Ph.D. Dissertation, Faculty of Forestry, University of British Columbia, Vancouver, Canada.

Protection of farming: Farms along the reserve and across from ALR require special protection sec. 9.0 development permit guideline.

OCP: 7.6 Flood protection

→ piecemeal inadequate

→ needs to ensure ongoing maintenance.

no mention of particulars/spec. examples.

7.2: - Obj. 2 policy limit increase in impervious surfaces to decrease runoff

- strategies must achieve cost effectiveness and net env. benefit.

ESA guidelines

9.6.1 All nat'l areas

look @ again/print

(d) Dev. should not unduly increase storm water runoff and should not alter the natural drainage pattern of adjacent properties

9.6.2

(a) all applicants must provide a veg. survey.

8.3.13 West Cambie plan

City may ask proponents but are under no obligation to undertake their own impact assesments