Watershed Risk Analysis

for

Tranquille River

Prepared for:

BC Ministry of Environment
1259 Dalhousie Drive
Kamloops, BC
V2C 5Z5

by:

M.J. Milne & Associates Ltd.
2603 23rd Street
Vernon, BC
V1T 4J7

March 10, 2009

1.0 INTRODUCTION

A risk analysis has been completed in the Tranquille River watershed for the BC Ministry of Environment. Funding for the project was received from the Forests for Tomorrow program. The Tranquille River drains an area of approximately 45,000 ha to the north and west of Kamloops, BC. Two basins and one residual area have been delineated for the analysis *[Resource map – Appendix A]*. Two major forest licensees operate within the crown land portion of the watershed; the remaining area is park (35%) or private land (3%).

The watershed was selected for analysis based on extensive mountain pine beetle (MPB) infestation and mortality in upland areas combined with high anadromous fish and fish habitat values on the lower mainstem, and community watershed designation. The analysis is follow-up to the Kamloops Timber Supply Area (KTSA) potential risk rating evaluation[1].

The watershed supports populations of anadromous salmon including chinook, coho, and steelhead trout. Anadromous species are limited to the lower 6 km of the Tranquille mainstem due to a series of falls that restrict passage. Resident rainbow trout are found throughout the system and one or both of Truda and Tranquille lakes have been stocked with Kokanee salmon. Earth fill dams are present on both Truda and Tranquille Lakes; originally designed to augment low flows on the lower Tranquille mainstem for irrigation and/or fish access purposes.

There are 51 water licenses either active or pending in the Tranquille River watershed. Eleven of the active licenses are used for domestic water purposes – three on the Tranquille River mainstem and eight on springs within or near to the Alpine Valley sub-division *[Appendix A]*. The remaining licenses are used primarily for irrigation and storage.

Background, methods and assumptions, analysis, and recommendations are provided in the following sections.

2.0 BACKGROUND

The Tranquille River watershed has been assessed several times over the last 15 years from a water-related perspective. Relevant reports include:

- Continuous Water Quality Monitoring – July 1999. Dean Environmental Services Ltd. for Weyerhaeuser Canada Limited.

[1] A Risk-Based Watershed Screening Procedure for the Kamloops Timber Supply Area, May 2007. Unpublished report completed by Forsite Consulting Ltd. et al for Kamloops TSA Licensees and the BC Ministry of Environment.

- 1999/2000 Tranquille Creek Stream Restoration Project. Arc Environmental Ltd. and BC Rivers Consulting for Weyerhaeuser Canada Limited.
- Completion Report - Tranquille River Watershed Restoration - October 2001. Summit Environmental Consultants Ltd. for Weyerhaeuser Company Ltd. Kamloops, BC.
- Restoration Plan for the Tranquille River Watershed – October 2001. Landmark Forest Management Ltd. for Weyerhaeuser Company Limited. Kamloops, BC.
- Tranquille River Watershed Assessment – Updated 2003. Summit Environmental Consultants Ltd. for Weyerhaeuser Company Ltd. Kamloops, BC.
- A Risk-Based Watershed Screening Procedure for the Kamloops Timber Supply Area – May 2007. Forsite Consulting Ltd. et al for Kamloops TSA Licensees and BC Ministry of Environment, Kamloops, BC.

In 1998 and 1999 water quality was monitored using grab sample techniques at two sites on the Tranquille River for the purpose of developing water quality objectives in the community watershed. The study found that water quality did not meet the Guidelines for Canadian Drinking Water Quality at least some of the time, particularly for turbidity. It was concluded that not enough data had been collected to develop meaningful objectives. No additional work was done and no objectives were developed.

In 1999/2000 prescriptions were prepared to improve resident and anadromous fish and fish habitat values affected by past resource use activities on the lower 4.0 km of the Tranquille River mainstem channel. Proposed treatments included placement of instream structures to create or improve existing habitat, planting of riparian vegetation, removal of an old water intake structure, development of interpretative trails, and installation of set-back fencing to exclude cattle from riparian areas. Maintenance was done on a fish way at an old water intake site and some bank protection prescriptions were implemented along crown land sections of the channel[2]. No other work was done.

In early 2001 restoration prescriptions were prepared for six priority channel sites identified in prior assessment reports. Sites included:

- the Tranquille Meadows Forest Service Recreation Site,
- an abandoned crossing on the Tranquille mainstem approximately 3 km upstream of the Alpine Valley sub-division,

[2] Personal Communication – March 2009. Bill Rublee, Triton Environmental Consultants Ltd., Kamloops, BC.

- a culvert inlet on the O'Connor Lake FSR,
- eroding fillslopes along the upper Watching Creek FSR,
- an infilled ditchline on the Watching Creek FSR immediately south of the O'Connor FSR intersection, and
- an abandoned crossing on Watching Creek northwest of the Watching and Tranquille FSR's intersection.

Work was completed as prescribed within the summer fish window; no follow-up was recommended.

In the fall of 2001 all prior restoration related assessments, prescriptions, and as-built reports were reviewed for future restoration planning purposes. Based on a field examination of priority treatment sites identified in prior reports it was determined that no further restoration related investments were warranted within the crown land portion of the watershed. All priority sites had been adequately addressed.

In 2003 a watershed assessment update was completed to review water related conditions and comment on potential effects of planned forest development, including some MPB salvage. The update indicated a low likelihood of changes in the hydrologic regime as a result of greenwood or MPB salvage development planned at that time. To maintain the low likelihood situation the following recommendations were provided to applicable licensees:

- Inspect all roads not permanently deactivated as part of annual maintenance programs (assumed to mean permitted road only).
- Make the BC Ministry of Transportation (MOT) aware of issues involving the Red Lake road.
- Act on high priority restoration opportunities, as described below.
- Manage riparian areas to reduce sedimentation and maintain both water quality and fish habitat.
- Use updated terrain mapping to identify potential areas of concern to be followed-up on by qualified terrain and forest engineering personnel.
- Employ strategies that minimize risks to water resources and potential for slope failures as part of any development planning with particular attention to "flat over steep" areas and areas close to break in slopes.

Water related conditions were found to be largely unchanged since prior review in 2000, but several new restoration priority sites were identified. Priority ratings and site details were as follows:

- High – A new landslide into Watching Creek from steep terrain below the K2110.00 road. Investigation of drainage upslope of the site recommended landslide rehabilitation and instream restoration where required.
- Moderate - An undersized culvert on road 1100.35 at the Saul Creek crossing, inspection recommended with maintenance as required to prevent failure.
- Moderate - Undersized culverts on the Red Lake road at the Sylvestre Creek crossing. This site was determined to be a MOT responsibility; no recommendations were provided.
- Moderate - A new landslide into the Tranquille mainstem downslope of the Red Lake road immediately south of the middle crossing. The site was also determined to be a MOT responsibility but an investigation of drainage in the area was recommended.
- Moderate – Water pooling in a new cutblock at the end of road 2100.15 downslope of the Watching Creek FSR. Disturbance in this area was preventing drainage into the natural course above steep terrain adjacent to Watching Creek.
- Low - Rutting and a cutbank slump on the S40 road (K1118.00 in this report) near the Gisborne Creek crossing. Re-establishment of the ditchline with grading and re-surfacing recommended.
- Low - Cattle damage to Gisborne Creek at the S40 (K1118.00) road crossing. Riparian planting and placement of large woody debris to prevent access recommended.
- Low - Issues around riparian vegetation removal along the Tranquille mainstem through the Alpine Valley sub-division – recommendations for set-back fencing and planting were provided.
- Low - Cut bank slumps and fine sediment accumulation at culvert inlets on the Watching Creek FSR immediately south of the O'Connor Lake FSR intersection. Re-establishment of the ditchline and culvert maintenance was recommended.

Finally, in 2007 the Tranquille watershed and both the Upper Tranquille and Watching basins were included in a potential risk ranking exercise initiated as a result of MPB infestation in the Kamloops Timber Supply Area (TSA). As part of the process both social and environmental resources at stake, or consequences, were considered along with a series of hazard indicators in the streamflow, sediment source, and riparian function categories. With the extent of likely MPB mortality and salvage activities included the Tranquille watershed and basins were ranked as follows out of a total of 371 units defined:

Unit	Post MPB Rank	
	Environmental	Social
Tranquille watershed	105	59
Upper Tranquille basin	44	157
Watching basin	263	238

The above rankings indicate moderate to high potential risk levels with MPB for the watershed on the social side and upper Tranquille basin on the environmental side.

A comparison of pre and post MPB rank was also done. On the social side the Tranquille watershed moved up 35 positions on the list of 371, more than any other unit in the TSA. The Upper Tranquille basin moved up 26 positions in this regard placing it 13th on the list with regard to change. The Watching basin moved down four positions pre and post MPB.

On the environmental side when comparing pre and post MPB rank the Upper Tranquille residual went up 25 positions with MPB making it 6th on the list in this regard. The Tranquille watershed went up 14 positions making it 24th on the list and the Watching basin went up 2 positions to 103rd on the list.

The changes in relative potential risk outlined above, pre and post MPB, indicate potential concern from a social and environmental consequence perspective in the Tranquille watershed and Upper Tranquille basin in particular. There is less concern in the Watching basin based on these results.

3.0 METHODS AND ASSUMPTIONS

This risk analysis is follow-up to the KTSA relative potential risk ranking exercise and has the following objectives:

- review, define, and map resources at stake in the watershed and basins,
- define water related processes and their effect(s) on resources at stake,
- identify, describe, and rate water related hazards in the streamflow, sediment source, and riparian function categories along with trends expected with MPB,
- determine current risk levels with respect to each resource at stake and the hazards that affect them, and expected trends with MPB,
- provide a discussion of potential management and mitigation opportunities by watershed, basin, and sub-basin, where applicable, and
- prioritize mitigation actions where possible.

3.1 Definitions

The following definitions for terms used in this analysis are adapted from the BC Ministry of Forests - Land Management Handbook 56[3]:

Risk analysis – involves the steps of preliminary analysis and risk estimation. It includes the systematic use of information to identify streamflow, sediment source, and riparian function related hazards and estimate the chance for, and severity of, injury or loss to individuals or populations, property, the environment, or other things of value (resources at stake).

Hazard – a source of potential harm, or a situation with a potential for causing harm, in terms of human injury, damage to property, the environment, and other things of value; or some combination of these. In watershed management increases in the frequency and magnitude of high flow events, sediment input to streams from roads and landslides, and reductions in riparian function are considered hazards.

Hazard rating – the measurement or expression of the likelihood of hazard occurrence, or probability of occurrence.

Consequence – the resource at stake (human well-being, property, the environment, or other things of value) and the change, loss, or damage to the resource(s) that may result from a landslide, road erosion event, high streamflow event, etc…

Risk – the chance of injury or loss as defined as a measure of the probability of hazard occurrence and the consequence of an adverse effect on the resource at stake.

3.2 Data collection

Resources at stake and current hazard ratings were determined through an examination of old and recent aerial photography, calculation of equivalent clearcut and affected MPB stand areas above the snowline, and strategic field analysis.

Alluvial fans and floodplain features were identified on aerial photographs and mapped using Arc/View 3.2. These features are sensitive to changes in streamflow, sediment load, and riparian function. Resources at stake such as

[3] Land Management Handbook 56: Landslide Risk Case Studies in Forest Development Planning and Operations. BC Ministry of Forests, Research Branch, Victoria.

private land, public roads, and high value fish habitat are often associated with these features justifying their identification in this process.

In the field, mainstem channels and both fan and floodplain features were reviewed where accessible; MPB affected stands were reviewed above the snowline, generally; and all roads were reviewed using appropriate means; 4 x 4, ATV, or on foot.

3.3 Assumptions

Assumptions have been made in four key areas to understand current hazard and risk levels, and trends with MPB. They involve:

- road status and road related obligations,
- the snow line concept used to evaluate snow melt related contributions to runoff at the time of peak flow,
- the effect of MPB and incremental effect of salvage harvesting on snow accumulation, snow melt rates, and high flows in affected watersheds, and
- the role of dead pine, non-pine overstory, and understory vegetation in the recovery of MPB affected stands from a snow accumulation and snow melt perspective.

Road status was determined at the outset of the analysis to understand obligations as they relate to the two major forest licensees in the case of permitted roads, Forest Service in the case of FSR's, and Ministry of Transportation in the case of public roads. Roads are a common source of fine sediment to streams and occasionally road related drainage diversion and concentration results in landslides with impacts on channels. Both are important considerations in community watersheds. Non-status roads (NSR's) are not considered to be the responsibility of any of the above entities and as such present complications if and when water related issues are identified. Treatment to address issues on NSR's is eligible for funding under the Forest Investment Account (FIA) program if made a priority by the applicable forest licensee. The assumption in this case is that forest licensees and government agencies have an interest in addressing issues on roads that are under their jurisdiction on a priority basis if such issues are properly identified and are brought to their attention. This assumption also applies to NSR's.

A snow line elevation of 1350 m is used to estimate that portion of the watershed that contributes runoff at the time of peak flow on the lower mainstem channel *[Appendix A]*. Approximately 45% of the Tranquille watershed is located above this elevation. The concept of a snowline location at the time of

peak flow is well known[4] but most often estimated by an H60 elevation in interior watersheds or line above which 60% of the watershed is located[5]. However, it has been shown that snowline location at the time of peak flow can vary with aspect, elevation, and forest cover attributes[6]. Efforts to map the snowline at the time of peak flow in watersheds similar to Tranquille River suggest snowline location may be better estimated by an H40 line[7]. Based on these considerations in conjunction with forest cover, topography, and aspect in the Tranquille watershed the 1350 m snowline elevation is considered reasonable and slightly more conservative than an H40 estimate.

It is assumed that widespread MPB mortality above the snowline will result in a measureable increase in runoff and peak streamflow levels without intervention and that salvage of affected stands can have an incremental effect in this regard. Recent modelling has shown that a shift in a watershed's flood frequency curve can be expected with widespread MPB mortality, exacerbated by salvage[8]. The increase in runoff and streamflow with MPB mortality is attributable to an increase in snow accumulation expected after defoliation. The incremental effect is realized as a result of further increases in snow accumulation after salvage accompanied by increases in snow melt rate resulting from increased exposure to solar radiation and wind.

Where present non-pine overstory species and understory in MPB affected stands can be expected to partly offset both short and longer term MPB effects on snow accumulation, snow melt rates, and ultimately MPB effects on runoff and peak flow over time. Recent surveys of overstory and understory structure have been completed in MPB affected areas, some within the upper Tranquille watershed[9]. The resulting data has been used by others to model the effects of these attributes on snow accumulation and snow melt rates over time using biogeoclimatic zones and the equivalent clearcut area (ECA) concept. Results indicate dead pine trees alone at the grey attack stage in an essentially pure stand can provide up to a 60% reduction in ECA over the salvage situation (assumed to be 100%)[10]. This effect is expected to decrease over time with

[4] U.S. Army Corp of Engineers. 1960. *Runoff from Snowmelt,* U.S. Army EM 1110-2-140, Washington, D.C., 75 p.
[5] Gluns, D.R. 2001. Snowline Pattern During the Melt Season: Evaluation of the H60 Concept, In Watershed Assessment in the Southern Interior of British Columbia. D.A.A. Toews and S. Chatwin (editors). Research Branch, B.C. Ministry of Forests, Victoria B.C. Working Paper 57/2001, 68-80.
[6] Ibid.
[7] Dobson, D. 2007. Chase Creek Watershed Review, 2002 – 2006. Unpublished report prepared for Tolko Industries Inc., Vernon, BC.
[8] BC Forest Practices Board. March 2007. The Effect of Mountain Pine Beetle Attack and Salvage Harvesting on Streamflows. Special Investigation. FPB/SIR/16.
[9] Vyse, A. et al 2007. Regeneration Beneath Stands in the Kamloops TSA. Unpublished report completed for Thompson Rivers University, Kamloops, BC.
[10] Huggard, D. and D. Lewis. 2008. Effects of Salvage Options for Beetle Killed Stands on ECA: February 2008 update. Unpublished report, BC Ministry of Environment, Kamloops, BC.

deadfall unless offset by non-pine overstory or understory vegetation. Non-pine overstory and understory vegetation also has a mitigating effect with regard to ECA, where present. The percentage of non-pine overstory species in an affected stand is directly proportional to its effect on ECA, and understory can be expected to reduce stand level ECA with growth over time. Similar work still underway is also showing that under planting MPB affected stands can result in up to a 20% reduction in maximum ECA over time versus the un-managed situation where applicable[11]. Under planting is expected to be most effective when pine is planted in relatively open pure pine stands with limited understory.

Finally, trends with respect to risk are determined through consideration of MPB effects on streamflow, sediment load, and riparian function. If a resource can be affected by streamflow and MPB is expected to increase runoff and resulting streamflow then the trend with respect to hazard and resulting risk is "increasing." Similarly, if a road crossing structure is currently at capacity with respect to flow and/or mobile sediment and debris any increase in runoff associated with MPB in upstream areas can be expected to place additional stress on the structure increasing risk with respect to failure. In the riparian case, function related to pine can be expected to decrease with mortality. In reality there are very few pine dominated riparian areas in the Tranquille River watershed but pine can contribute debris from adjacent slopes affecting overall riparian function both locally and in downstream areas.

3.4 Presentation

A series of maps and tables are used to support information provided in this report. They include:

- Resource map identifying the location of key resources at stake *[Appendix A]* and:
    - watershed and basin delineation
    - forest tenure, park, and private land boundaries
    - floodplain and alluvial fan features
    - the extent of existing openings and Lodgepole pine leading stands including plantations,
    - terrain class IV and V polygons as defined by Maynard 2002[12], and
    - the expected snowline location at the time of peak flow on the lower Tranquille mainstem channel (1350 m).

[11] Huggard, D. 2008 in progress. Projected Effect of Seedlings Planted Under Mountain Pine Beetle Stands on Equivalent Clearcut Area.

[12] Denny Maynard & Associated Ltd. 2002. Upgrade of Terrain Classification, Terrain Stability, Surface Erosion Potential, and Sediment Delivery Potential of Tranquille-Watching and Peterson-Rosen Community Watersheds. Prepared for Weyerhaeuser Company Limited, Kamloops, BC.

- Summary tables for each basin and the residual *[Appendix B]*. Tables include:
  - overview level statistics – area, area harvested, area above the snowline, area harvested above the snowline, ECA above the snowline, and area above the snow line affected by MPB,
  - a list of resources at stake in each unit,
  - hazard ratings and expected trends in the streamflow, sediment source, and riparian function categories, and
  - risk ratings by resource with trends and mitigation opportunities, where applicable.
- Field photographs to illustrate site-specific or general concerns *[Appendix C]*.
- Road risk map and tables by road status describing water related issues by site or section with an assessment of hazard, resource at stake, likely effect on resource in question, probability of occurrence, and risk *[Appendix D]*.
- Runoff management map with recommendations for forest management within the crown land portion of the watershed *[Appendix E]*.

4.0 ANALYSIS

Three units were delineated for analysis in the Tranquille watershed: lower Tranquille residual, Tranquille basin, and Watching basin *[Appendix A].* The characteristics of each unit are described in the following section along with:

- resources at stake (or consequences),
- water related hazards, hazard ratings, and expected trends with MPB mortality, and
- risk, trends with MPB, and mitigation opportunities where present.

Tranquille River is a plateau type watershed with a snow melt dominated hydrologic regime. The highest flows on the mainstem channel occur between early May and early July. The snow line location at the time of peak flow on the mainstem channel is expected to be approximately 1,350 m, as mentioned previously. Approximately 45% of the watershed is located above this elevation.

Mountain pine beetle (MPB) mortality is significant above the snow line in the Tranquille watershed *[Appendix A]*. Modelling using leading species and percent composition information available on forest cover maps indicates approximately 50% and 40% of the area above the snowline is likely affected in the Tranquille

and Watching basins, respectively. An increase in snow accumulation is expected in affected stands combined with an increase in snow melt rate; the latter occurring with deadfall between 10 and 20 years after death. The combination is expected to produce an earlier and more pronounced runoff and peak flow period; essentially shifting and shortening the hydrograph on the lower mainstem channel. Effects on snow accumulation and snow melt will be realized immediately if salvage occurs. For this reason careful consideration is required to determine where salvage is most appropriate in the Tranquille watershed given resources at stake (see below for details).

4.1 Lower Tranquille residual

The lower Tranquille residual includes that portion of the Tranquille watershed downstream of the Tranquille and Watching basins *[Appendix A]*. The residual is approximately 6,400 ha in size dominated by bunchgrass and Ponderosa pine biogeoclimatic zones. As such, past forest development has been limited to approximately 20% of the unit concentrated along the upper west side *[Appendix B]*. Approximately 70% of the residual is contained within Lac DuBois Provincial Park.

A large fan is present at the mouth of the Tranquille River on Kamloops Lake. Approximately 25% of the fan is active; the remainder is a relic post-glacial feature *[Appendix A].* Floodplains are present along the mainstem upstream of the fan.

Extensive placer mining has taken place within the active portion of the Tranquille fan and along the widest portions of the floodplain upstream of the fan apex. Most of the alluvial material in these areas has been excavated, sluiced, and spoiled leaving irregular berms, piles, and ridges. These features have affected the system's ability to dissipate flow and sediment load related energy during high flow periods resulting in an increase in channel bed and bank scour within confined sections of channel.

Continuous hydrometric data is not available for Tranquille River. Recent flows and flood history can be described using data available from the Deadman River (08LF027) to the west. The highest flow on record (1961-2009) was experienced in the spring of 1990 on the Deadman River with other notable events in the spring of 1999 and 2002[13]. Similar events likely occurred on Tranquille River, although a perfect correlation should not be expected. Flow related disturbance in the form of increased bed load transport, deposition, and lateral channel movement would have occurred on lower Tranquille River during these events *[Photo 1 – Appendix C]*.

[13] http://www.wsc.ec.gc.ca/hydat/H2O/index_e.cfm?cname=WEBfrmPeakReport_e.cfm

The entire Tranquille fan is located within private land along with areas surrounding Lac DuBois. The remains of the Tranquille Institution are located on private land within the relic portion of the fan. New residential/recreational developments are planned in this area; details are unknown at this time.

4.1.1 Resources at stake (consequences):

The following resources are at stake in the lower Tranquille residual:

- public safety and both public and private infrastructure associated with the Canadian Pacific Rail (CPR) and Red Lake road bridges in the active fan area,
- anadromous fish spawning and rearing habitat on the lower reaches, and
- irrigation water quality.

The CPR and Red Lake road bridges can be affected by localized bank erosion and lateral channel movement during high flow periods combined with large woody debris input from riparian areas and debris jam formation. Failure of these structures could result in loss of life, restrictions on access, and measurable input of sediment to the lower mainstem.

Anadromous fish spawning and rearing habitats in the residual can be affected by impaired water quality, impaired riparian function, and increased channel bed and bank scour resulting from berm, levee, and both rail and road crossing related constrictions *[Photo 2]*. Old water intake infrastructure located upstream of the fan is also a likely barrier to fish passage *[Photo 3].* Increases in both fine and coarse sediment load on the lower channel can infill spawning gravels, reduce oxygenation, prevent access, and cause channel avulsions. The old water intake infrastructure may be preventing fish access into several kilometres of suitable habitat.

Water quality in the residual area can be affected by localized erosion during high flow periods, and sediment input from upstream channel and road related sources. Impaired water quality can result in increased water treatment cost, increased frequency of boil water advisories, and effects on human health.

4.1.2 Hazards and hazard ratings

Current water related hazard ratings for the residual are provided in the following table with trends expected with MPB mortality in upstream areas. Hazard ratings for the residual reflect those of the larger watershed as effects on streamflow, sediment load, and to a lesser degree riparian function in this unit are driven by upstream processes and land-use related effects in these areas.

Hazard category	Hazard rating	Trend with MPB
Peak flow	M	Increasing
Sediment source	M	Increasing
Riparian function	H	Increasing

Hazard ratings are moderate at this time in the peak flow and sediment source categories and expected to increase with MPB mortality above the snow line in the Tranquille and Watching basins *[Appendix B]*. Peak flows are driven mainly by snowmelt in the two upstream basins as the residual is located below the snowline.

Sediment input to streams is occurring from moderate and higher risk road sites and sections in the residual and two upstream basins *[Road Risk map and tables – Appendix D]*. Increases in runoff and streamflow that result from MPB mortality are expected to exacerbate road erosion and water management related conditions in the two basins. Sediment input from roads in the residual is occurring and is a water quality related concern, but conditions will not likely be affected by MPB.

The riparian function hazard is high as a result of past land-use disturbance on the fan and floodplain up to the abandoned water intake site, and uncontrolled range and recreational access in this area. The riparian function hazard is expected to increase as a result of increases in peak flow and sediment transport from upstream areas resulting in accelerated channel bed and bank erosion with subsequent damage to riparian vegetation.

4.1.3 Risk and mitigation

Risk to public safety and both public and private infrastructure associated with the CPR and Red Lake road crossings on the fan is high and expected to increase with MPB mortality in upstream areas. Both structures are considered undersized with respect to natural processes and expected increases in streamflow with affects on the channel and riparian areas. Risk in this case can be mitigated by restoring fan and floodplain function in affected areas, improving drainage structure capacity at the CPR crossing, and re-designing the Red Lake road crossing to fail during high flow periods without affecting resources at stake.

Risk to water quality and both fish and fish habitat in the residual is high and also expected to increase with MPB mortality in upstream areas. Risk in these cases can be mitigated by managing runoff from the two upstream basins to minimize MPB effects on peak flow, reducing sediment input from moderate and higher risk roads in the residual and upstream basins, restoring natural fan and floodplain processes, and protecting intact riparian areas.

Increases in peak flow on the Tranquille mainstem expected with MPB mortality in the two upstream basins can be minimized by desynchronizing flows from the Tranquille and Watching basins *[Runoff management map – Appendix E]*: This can be achieved by:

- focussing MPB and other forest health related salvage and affected juvenile stand replacement activity into the Watching basin above the snow line,
- retaining all MPB affected stands above the snowline in the Tranquille basin, including all of Sylvestre Creek, and
- managing outlet controls at the dams on Truda and Tranquille Lakes to maximize storage and minimize outflows during the freshet period.

High flows on Watching Creek occur before those on the Tranquille side as a result of primarily solar aspects and steeper terrain above the snow line. Terrain in the Tranquille basin is low and rolling above the snow line with a higher percentage of non-solar aspects. Management as described above will result in the replacement of MPB affected stands in the Watching basin while allowing deadfall to occur in the Tranquille basin with release of understory vegetation, where present. Where understory vegetation is not considered sufficient in the Tranquille basin under planting could be considered to expedite the recovery process.

Most of the sediment input to channels in the Tranquille watershed occurs in areas upstream of the residual, but some input is occurring or expected from roads in this area. One notable very high risk site is located on the fan downstream of the CPR crossing. In this location the approaches and abutments of an abandoned public or private road crossing constrict the active fan area *[Photo 2].* Washout is expected in this location resulting in significant input of sediment to the lower system. Debris jam formation at the crossing will be the likely trigger for an avulsion at this site. All other road related risks in the residual area are described and illustrated in Appendix D.

A comprehensive program will be required to restore natural fan and floodplain processes in the residual but the benefits to resources at stake will be significant. Key components should include:

- immediate removal of the very high risk road section described above,
- decommissioning and removal of old water intake infrastructure upstream of the fan,
- reworking of historic placer mining spoils to restore overbank flooding and sediment deposition processes, and
- controls on range and recreational access in riparian areas.

4.2 Watching basin

The Watching Creek basin is approximately 14,500 ha in size with elevations ranging from 650 m at the confluence with Tranquille River to over 1800 m along the northern drainage divide *[Appendix A]*. Biogeoclimatic zones include Interior Douglas fir at lower elevation, Montane Spruce at mid-elevation, and Engelmann Spruce - Sub-alpine Fir at upper elevation. The Watching basin is predominantly south aspect; a key factor in the location and upper elevation of the dryer and warmer biogeoclimatic zones (i.e. generally higher than would be expected on more northerly aspects). Approximately 15% of the Watching basin is located within the Lac DuBois and Porcupine Meadows Provincial Parks.

Floodplains are present along much of the mainstem and main tributaries in the Watching basin. Fans are present where Cannell Creek loses confinement near the Cannell Creek road and other main upland tributaries join larger valley bottom watercourses near the Watching Creek and Tranquille East FSR intersection.

Forest development and range are the primary land-use activities in the Watching basin. Unrestricted cattle access to streams occurs throughout the basin. Past forest development has occurred over approximately 33% of the basin; 41% of the area above the snow line (1350 m). The equivalent clearcut area above the snow line is approximately 32% with 40% of the unlogged or juvenile plantation area affected by MPB.

4.2.1 Resources at stake (consequences):

The following resources are at stake in the Watching Creek basin:

- forest road infrastructure and associated public safety and access components at the Sawmill FSR crossing on Watching Creek,
- downstream water quality and anadromous fish and fish habitat,
- other permitted and FSR road crossings on major tributaries, and
- resident fish and fish habitat.

The Sawmill FSR crossing can be affected by debris jam formation at the structure during high flow periods that results from channel bank erosion on the floodplain upstream of the structure. The existing structure is considered undersized in this regard *[Photo 4]*. Failure could result in loss of life, access restrictions, and measurable input of sediment to Watching Creek.

Downstream water quality and anadromous fish and fish habitat, as well as resident fish and fish habitat can be affected by road and landslide related sediment input to channels, and sediment generated through channel bed and bank erosion during high flow periods. Sediment related effects on downstream water quality and anadromous fish and fish habitat are described in the residual area discussion above. Effects on resident fish and fish habitat would be similar.

Other FSR and permitted road crossings on major tributaries can be affected by sediment and debris transport during high flow periods with accumulation at structure inlets. Accumulations that lead to overtopping and/or diversion of runoff will result in erosion, sediment input to channels, and negative effects on water quality and both local and downstream fish and fish habitat.

4.2.2 Hazards and Hazard Ratings

Current water related hazard ratings for the Watching basin are provided in the following table with trends expected with MPB mortality.

Hazard category	Hazard rating	Trend with MPB
Peak flow	M	Increasing
Sediment source	M	Increasing
Riparian function	M	Stable

Hazard ratings are moderate at this time in the peak flow and sediment source categories and expected to increase with MPB mortality in the basin. The riparian function hazard is moderate and should not be significantly affected by MPB.

Sediment input to streams is occurring from moderate and higher risk road sites and sections throughout the basin *[Appendix C]*. Several landslides have occurred on steep slopes adjacent to the channel as a result of drainage diversion and concentration on roads above. Increases in runoff and streamflow

that result from MPB mortality throughout the basin are expected to exacerbate current conditions from a sediment source perspective. Problem sites include:

- Sawmill FSR structure and approaches on the Watching Creek floodplain,
- permitted and non-status roads above steep terrain along Cannell Creek,
- permitted and non-status roads on the Watching floodplain downstream of the Sawmill FSR crossing *[Photo 5]* and on steep slopes to the east,
- FSR, permitted and non-status roads above steep terrain along the south side of Watching Creek and around the confluence of the three main upland tributaries, and
- culvert crossings on streams capable of transporting sediment and woody debris during high flow events.

The riparian function hazard is moderate in the Watching basin and should not be significantly affected by MPB. Riparian vegetation in fan and floodplain areas has been largely protected as a result of difficult access or low timber values, generally. Two key areas have been affected by past harvesting; the first around the upland tributary confluence and the second downstream of the Sawmill FSR crossing in Lac DuBois Provincial Park. Good conifer regeneration is occurring around the upland tributary confluence *[Photo 6]* but portions of the floodplain in the park remain denuded for what appears to be range related reasons. An increase in bank erosion and lateral channel movement may occur in the latter area during high flow periods, particularly with MPB related increases in streamflow, but effects at the basin level are expected to be minor.

4.2.3 Risk and mitigation

Risk to public safety, road infrastructure, and access at the Sawmill FSR crossing on Watching Creek is high and expected to increase with MPB related increases in runoff and streamflow. Risk to these resources can be mitigated by:

- relocating the crossing to a better incised location where floodplain width is less and removing all fill from the floodplain at the existing crossing location, or
- replacing the existing structure with a larger span to reduce or eliminate effects on floodplain processes, or
- installing additional drainage structures (i.e. large diameter culverts) on the approaches to pass flows in the event of debris accumulation at the existing structure inlet or exceedence of existing structure capacity.

Risk to downstream water quality, downstream anadromous fish and fish habitat, and resident fish and fish habitat is moderate in the Watching basin and expected to increase with MPB related increases in runoff and streamflow. Risk to these resources can be mitigated by:

- desynchronizing freshet flows from the Watching and Tranquille basins (as described above),
- managing outlet controls on the dams at Truda and Tranquille Lakes (also described above),
- continuing to protect riparian vegetation in fan and floodplain areas,
- controlling cattle access to water throughout the basin, and
- addressing issues on moderate and higher risk roads.

Risk to road infrastructure at FSR and other permitted road crossings on major tributaries is moderate and expected to increase with MPB related increases in runoff and streamflow. Risk to these resources can be mitigated by:

- replacing existing culverts with larger culverts or open bottom structures capable of passing mobile sediment and debris during high flow periods; narrow floodplains are present at most of these sites, or
- re-designing existing crossings to fail during high flow periods without affecting resources at stake.

4.3 Tranquille basin

The Tranquille basin is approximately 24,000 ha in size with elevations ranging from 650 m at the confluence with Tranquille River to over 1840 m along the northeast drainage divide *[Appendix A]*. Biogeoclimatic zones include Interior Douglas fir at lower to mid-elevation, Montane Spruce around and north of the lakes, and Engelmann Spruce - Sub-alpine Fir north and east of Tranquille Lake. Most of the Tranquille basin above the snowline is low and rolling with gentle north and south aspects.

Floodplains are present along the entire mainstem downstream of Tranquille Lake with the widest feature in this regard located in the Alpine Valley sub-division *[Appendix A]*. Fans are present on most of the tributaries that enter the main valley in the sub-division area as well as:

- the mainstem at and upstream of the upper Red Lake road crossing,
- Sylvestre Creek above the break in the slope,
- along the north side of Tranquille Lake, and
- where other major tributaries lose confinement.

Forest development and range are the primary land-use activities in the Tranquille basin. Unrestricted cattle access to streams and drainage infrastructure occurs throughout *[Photos 7, 8]*. Past forest development has occurred over approximately 36% of the basin; 40% of the area above the snow line (1350 m). The equivalent clearcut area above the snow line is approximately 38% with 49% of the unlogged area affected by MPB. Plantations in the Tranquille basin are younger than those in the Watching basin and as a result have not been affected by MPB to the same extent. Past forest development in the Tranquille basin is more recent, generally.

4.2.1 Resources at stake (consequences):

The following resources are at stake in the Tranquille basin:

- public safety, private property, and public infrastructure on the fan at the upper Red Lake road crossing on the Tranquille mainstem,
- public safety and private property on the ASD 21 fan in the Alpine Valley sub-division,
- public safety and infrastructure at the Red Lake road crossing on the Sylvestre Creek fan,
- private property and both public and private infrastructure on the floodplain and tributary fans in the Alpine Valley sub-division,
- local and downstream water quality,
- downstream anadromous fish habitat,
- the 4020.05 road crossing on the upper Tranquille River,
- Road K1100.35, 4030.25, 4015.60, and 4015.70 crossings on major tributaries, and
- resident fish and fish habitat.

Public safety, private property and public infrastructure on the fan at the upper Red Lake road crossing can be affected by sediment and debris accumulation at the fan apex during high flow periods resulting in channel avulsion *[Photos 9, 10]*. The private residence on the fan in this location has been undermined at least once necessitating evacuation and significant repairs. Future avulsions could result in loss of life, damage to private property, washout of the Red Lake road, and effects on access.

Public safety and private property on the ASD 21 fan can be affected by debris flow or debris flood occurrence during high flow periods that results in channel avulsion and re-direction toward the private residence on this feature *[Photo 11, 12].* Loss of life, damage to private property, and effects on access within the sub-division could occur with an event on this system.

Public safety and infrastructure on the Red Lake road at the Sylvestre Creek crossing can be affected by sediment and debris accumulation at the structure inlet resulting in erosion with sediment input to the channel. The existing culverts are considered undersized with respect to natural fan processes in this area *[Photo 13]* and the channel is scouring its bed and banks as a result of a suspected increase in streamflow from MPB infestation and salvage throughout the sub-basin. Failure of the structure(s) could result in loss of life, damage to public infrastructure, and effects on access.

Private property and both public and private infrastructure on the floodplain and tributary fans in the Alpine Valley sub-division can be affected by bank erosion and lateral channel movement on the floodplain and avulsions on the fans. Erosion and lateral channel movement on the floodplain through the sub-division can result in loss of land and both primary and secondary structures. Avulsions on the fans can affect road infrastructure by blocking existing structures, diverting flows, and eroding both ditchlines and running surfaces. Effects on access could occur.

Local and downstream water quality, and both resident and downstream fish and fish habitat can be affected by sediment input from moderate and higher risk road sites and sections, landslides into tributaries and the mainstem, and accelerated bank erosion on the floodplain where riparian function is lacking. Water quality for drinking, fish, and irrigation can be affected as a result.

The 4020.05, K1100.35, 4030.25, 4015.60, and 4015.70 road crossings can be affected by sediment and debris accumulations at the inlets resulting in washout and/or diversion *[Photos 14, 15, 16, 17]*. Floodplains or fans are present at all of these sites; structures are considered undersized or inappropriate with respect to natural processes.

4.2.2 Hazards and Hazard Ratings

Current water related hazard ratings for the Tranquille basin are provided in the following table with trends expected with MPB mortality.

Hazard category	Hazard rating	Trend with MPB
Peak flow	M	Increasing
Sediment source	M	Increasing
Riparian function	H	Stable

Hazard ratings are moderate at this time in the peak flow and sediment source categories and expected to increase with MPB mortality in the basin. The riparian function hazard is high and will remain so with MPB mortality.

Peak flows are expected to increase on the Tranquille River mainstem and major tributaries with MPB mortality in upstream areas. The situation can be exacerbated over the short term by salvage in areas above the snow line.

Sediment input to streams is occurring from moderate and higher risk road sites and sections throughout the basin *[Appendix D]*. Several landslides or other erosional events have occurred on steep slopes adjacent to the mainstem and major tributaries as a result of drainage diversion and concentration on roads above. Increases in runoff and streamflow that result from MPB mortality throughout the basin are expected to exacerbate current conditions from a sediment source perspective. Problem sites include:

- Red Lake road through fans within the Alpine Valley sub-basin and on climbing grades beyond,
- Red Lake road at the Sylvestre Creek and Upper Tranquille River crossings,
- roads 4015 and 4015D in the upper Sylvestre basin,
- road K1100.35, 4030.25, 4015.60, and 4015.70 crossings on major tributaries, and
- Sawmill FSR crossing on upper Tranquille River.

The riparian function hazard is high in the Tranquille basin as a result of poor riparian management practices on private land through the Alpine Valley sub-division. The mainstem is sensitive to any increases in streamflow, sediment load

or further reductions in riparian function through this area as a result. Increases in streamflow and sediment load are expected with MPB in upstream areas. Regeneration on the floodplain is being prevented by private landowners in this area. Riparian areas elsewhere in the basin are largely intact as a result of difficult access, or have recovered from early mining and logging related disturbance.

4.2.3 Risk and mitigation

Risk to public safety and both public and private infrastructure on the fan at the upper Red Lake road crossing is high and expected to increase with MPB in upstream areas. Risk can be mitigated in this case by minimizing short term forest development and salvage related effects on runoff in upstream areas (i.e. Tranquille basin above the snow line), and enlarging and armouring the channel past the private residence on the fan and possibly through the Red Lake road crossing. Alternatively the Red Lake road could be relocated to a better incised location in the canyon upstream of the site. It is important to note that constraints on development and salvage in upstream areas are designed to minimize effects on streamflow over the short term while measures are taken to mitigate risk at this site. If these measures are not taken while the opportunity presents, resources will be at increased risk over the medium to long term.

Risk to public safety and private property on the ASD 21 fan is high and expected to increase with recent MPB salvage in upstream areas. Risk can be mitigated by minimizing any additional forest development and salvage related effects on runoff in upstream areas and notifying private landowners of the hazards and risk in this location. Preventative measures could be taken to protect the private residence near the apex of the fan, reducing exposure to an event and mitigating risk in this regard.

Risk to public safety and public infrastructure on the Red Lake road at the Sylvestre Creek fan is high and expected to increase with MPB mortality and recent salvage in upstream areas. Risk can be mitigated in this case by minimizing additional salvage related effects on runoff and streamflow within the basin, and either re-locating the public road and FSR or enlarging and armouring the channel through the fan and crossing site with installation of a structure capable of passing expected flows with entrained sediment and woody debris.

Risk to private property and public and private infrastructure on the floodplain and fans through the Alpine Valley sub-division is moderate but expected to increase with MPB effects above the snowline. Risk can be mitigated in this case by minimizing forest development and salvage related effects on runoff in upstream areas (i.e. Tranquille basin above the snow line), and notifying the public in these areas with regard to more appropriate riparian set-back and

management strategies designed to restore and maintain natural fan and floodplain processes. Similar to the fan at the upper Red Lake road crossing, constraints on development and salvage in upstream areas are designed to minimize effects on streamflow over the short term while measures are taken to mitigate risk on the floodplain through the sub-division area. If these measures are not taken while the opportunity presents, resources will be at increased risk over the medium to long term.

Risk to local and downstream water quality and both local and downstream fish and fish habitat is moderate but expected to increase with upstream MPB related effects on runoff, streamflow, and road related issues. Risk to these resources can be mitigated through a combination of minimizing forest development and salvage related effects on runoff in upstream areas, reducing sediment input to streams from roads and road related landslide sites, improving riparian function in denuded or otherwise poorly managed areas, and protecting intact riparian resources in fan and floodplain areas.

Risk to the 4020.05 road crossing on the Upper Tranquille mainstem is moderate but increasing with MPB mortality in upstream areas. The crossing is located on the Tranquille floodplain in this location and considered undersized with respect to sediment and debris transport on the system. Risk in this case can be mitigated by:

- removing the entire crossing, including all approach related materials, and deactivating the road beyond, or
- replacing the structure with a larger span capable of passing expected flows with entrained sediment and debris.

Risk to crossings on roads K1100.35, 4030.25, 4025.60, and 4015.70 is moderate but expected to increase with MPB related effects on flows from upstream areas. Risk in these cases can be mitigated by either:

- replacing existing culverts with larger culverts or open bottom structures capable of passing mobile sediment and debris during high flow periods; narrow floodplains are present at most of these sites,
- re-designing existing crossings to fail during high flow periods without affecting resources at stake, or
- deactivating the crossings and any roads beyond that would be affected by the change in access.

5.0 Recommendations

The following recommendations are provided to the BC Ministry of Environment for their use and distribution to others with resources at stake in the Tranquille River watershed.

5.1 Watershed Stewardship

- Form a management committee for the Tranquille River watershed consisting of representatives from each of the stakeholder groups to communicate the results of this risk analysis and recommendations that follow.
- Notify private landowners and the BC Ministry of Transportation of the current and expected risk of debris jam formation during high flow periods and likely channel avulsion on the Tranquille River fan at and upstream of the upper Red Lake road crossing *[Appendix A]*. Public safety, public infrastructure, and private land are at stake in this location. Review opportunities for flood protection work on private land in this regard and assist where possible.
- Notify the BC Ministry of Transportation regarding the location of the Red Lake road within the active fan area on the lower Tranquille River mainstem channel, and likelihood of structure (bridge) washout or other road prism related damage during high flow periods with subsequent effect on public safety, public infrastructure, and fish habitat.
- Notify owners of private lots on the 100 year floodplain of the Tranquille River through the Alpine Valley sub-division of the hazards and risk associated with improper riparian management and expected increases in peak flow, bank erosion, and lateral channel movement in this area. Provide information as it pertains to improved riparian management within 100 year floodplain areas and assist in the delineation of this feature where possible.
- Notify the BC Ministry of Forests and Range with regard to uncontrolled cattle access to streams and drainage infrastructure throughout the Tranquille River watershed. Make the agency aware of the water quality related resources at stake in this watershed and request improved range management in this regard.

5.2 Forest Management

- Notify those involved in forest management (forest licensees and the BC Ministry of Forests) of current road and streamflow related risks associated with past forest management activity, and trend with mountain pine beetle infestation and other forest health issues throughout the

watershed. Recommend the following road and streamflow related objectives and strategies for ongoing management:

- Address road related risks on FSR, permitted, and non-status roads throughout the Tranquille River watershed to reduce road related effects on water quality, fish and fish habitat, and downstream infrastructure. Address problem sites and sections through a combination of upgrade activity and deactivation in a priority sequence as per road risk maps and tables *[Appendix D]*. Deactivation and environmental maintenance work on non-status roads is eligible for Forest Investment Account funding when identified in overview assessment.
- Minimize expected streamflow related effects on resources at stake in the lower Tranquille residual (fish, CPR mainline and public road crossings, private land) and lower half of the Tranquille basin (public safety, public infrastructure, private land). Manage forest harvesting and stand rehabilitation activities in a way that desynchronizes runoff from the Watching and Tranquille basins *[Appendix E]*. Recommend the following strategies to achieve this objective:
    - The Watching basin has a lower sensitivity to streamflow related effects and fewer resources at stake. The recommended strategy for this basin is to maximize timber recovery and stand rehabilitation. This strategy will result in a short-term increase in ECA and potential streamflow related effects in order to emphasize mid to long term hydrologic recovery. In the Watching basin, focus salvage logging on Lodgepole pine leading stands, regardless of elevation and stand age, and reforest as soon as possible. Pine must make up 60% or more of the stand to be salvaged, as measured by canopy closure. No green wood development in the Watching basin above 1350 m in elevation.
    - In the Watching basin, only conduct salvage above 1350 m in elevation for other forest health reasons where the health related situation will create similar outcome from a snow accumulation and snow melt perspective to that expected under the pine salvage situation described above.
    - In the Tranquille basin, the recommended strategy is to desynchronize runoff with the Watching basin by minimizing short-term increases in snow accumulation and snow melt rates to reduce potential short-term streamflow effects on downstream resources. The emphasis of the strategy is on

retention of existing forest cover, MPB affected or otherwise, in the Sylvestre Creek sub-basin and above the expected snowline (1350 m) in the Tranquille basin. Where possible enhance understory regeneration using techniques that may include under planting and fill planting but no over-story removal.

- No water-related constraints on forest development below 1350 m in either basin.

- Address channel and road related issues on tributaries ASD 17, ASD 21, and ASD 26 in the Alpine Valley sub-division area before conducting any further green wood or salvage related forest development below 1350 m in their respective watersheds. Development above 1350 m is constrained in all sub-basins by recommendations provided above. Issues include:
  - Potential debris flow or debris flood related effects on public safety, private land, and structures on the tributary ASD 21 fan.
  - Potential diversion of tributary ASD 17 down road T003 on the ASD 17 fan with subsequent effects on the Red Lake road and water quality, generally.
  - Diversion of tributary ASD 21 down road H1 on the fan with subsequent effect on fan stability and downstream water quality.

5.3 Infrastructure and Restoration

- Determine who is responsible for the management of earth fill dams on Truda and Tranquille Lakes in the Tranquille basin. Advise the applicable agency or entity of the expected increase in runoff and streamflow within the Tranquille basin and likely effect on downstream resources. Recommend that the systems be drawn down prior to freshet to maximize storage and minimize outflows during the freshet period. There may also be a structure on Saul Lake that can be managed in this regard.
- Develop a comprehensive fan and floodplain restoration program on the lower reaches of the Tranquille River to minimize expected streamflow related effects on channel stability, fish and fish habitat, and both public and private infrastructure. The program should include:
  - Immediate removal (prior to freshet 2009) of a failed bridge crossing on road TI1 and all associated fill material from the active fan area downstream of the CPR mainline. The approaches and failed span structure have increased the likelihood of jam

formation, avulsion, and erosion at and downstream of this location.

- Plans to decommission and remove water intake infrastructure on the floodplain and restore both floodplain processes and fish passage through the site.
- Plans to restore natural fan and floodplain processes affected by historic placer mining activities and dyking efforts from the water intake to the mouth on Kamloops Lake. Other instream and riparian restoration plans to improve fan and floodplain channel stability, and associated fish habitat.

- Notify Canadian Pacific Railway with regard to the location of the mainline crossing within the active portion of the Tranquille River fan. Recommend additional or larger drainage structures within the active fan area to reduce the likelihood of rail prism washout during high flows, and minimize constriction effects on the channel and associated fish habitat.
- Notify the BC Ministry of Transportation of the following other issues involving public roads in the Tranquille River watershed:
  - Low cross drain (culvert) frequencies on the Red Lake road through fans within or near to the Alpine Valley sub-division resulting in drainage diversion, ditch scour, road erosion, and sediment input to streams.
  - Low cross drain frequency on the climbing section of the Red Lake road between the sub-division and upper crossing resulting in drainage diversion, landslides or other fillslope erosion events, ditch scour, and fine sediment delivery to streams.
  - Deposition of road spoil materials on the Tranquille River floodplain downstream of the Alpine Valley sub-division from a recent upgrade at the lower Red Lake road crossing. Erosion of spoiled material has not occurred as yet but is expected as materials are located within the 100 year floodplain area.
  - Presence of undersized and/or inappropriate structures on the Red Lake road at the Sylvestre Creek crossing. Culverts in this location have failed at least once resulting in diversion with subsequent erosion and sediment input to streams. This crossing is located near the toe of the Sylvestre Creek fan. The channel on the fan is unstable; increases in discharge, sediment load, and debris transport to the culverts are expected.

6.0 CLOSURE

This report dated March 10, 2009 has been prepared exclusively for the BC Ministry of Environment and its agents. M.J. Milne & Associates Ltd. accepts no responsibility for use of this document for purposes other than the management of forest and water related resources in the Tranquille River watershed.

This concludes the risk analysis of the Tranquille River watershed. We trust that the information contained herein is complete and consistent with the scope of work assigned to M.J. Milne & Associates Ltd.

Michael J. Milne M.E.S. 06/01/09
Watershed Hydrologist
ABCFP Limited Licensee #0004

BCTS

TFL35
WEYCO

Tranquille

Private land, public infrastructure and public safety on fan at upper Red Lake Road crossing.

BCTS

Public safety and infrastructure at Red Lake road crossing on Sylvestre Creek.

Sylvestre Creek

Watching

A18694
WEYCO

BCTS

ASD 17

Private land, public infrastructure, public safety and multiple irrigation and domestic water licenses on floodplain. Downstream water quality.

Alpine Valley sub-division

FSR crossing on Watching Creek.

ASD 26

Private land and dwelling at the apexof debris flood or debris flow fan - ASD 21

ASD 21

A74910
WEYCO

BCTS

Lower Tranquille residual

Water quality on lower mainstem.

Abandoned water intake site

CP Mainline and Red Lake road in active fan area.

Coho, chinook salmon, steelhead trout spawning and rearing habitat on lower mainstem.

0 2 4 6 8 Kilometers

Tranquille River - Resource Map

- Road - nsr, FSR, RP, Public
- Alluvial fan - active
- Alluvial fan - relic/inactive
- Floodplain
- Existing cutblock
- Pine leading stand affected by MPB - includes plantations
- Terrain Class IV and V - Maynard 2002
- Tenure boundary with license holder
- Expected snow line location at the time of peak flow on Tranquille mainstem
- Provincial Park
- Private land
- Domestic water intake
- Irrigation or other water intake

MJM 02/09

Lower Tranquille residual

Drainage area	6,425 ha		
Area harvested	1,380 ha – 21%		
Area ASL[1]	0		
Area harvested ASL	0		
ECA ASL	0		
Area ASL affected by MPB	0		
Resources at stake (consequences)	Water quality – domestic and irrigation water intakes on mainstem upstream of fan. CP mainline and public road crossings at approximate mid-point of Tranquille fan. Anadromous (chinook and coho salmon, steelhead trout) and resident fish and fish habitat on lower mainstem and fan.		
Hazards			
Category	Rating	Trend with MPB	Description
Streamflow	M	Increasing	Forest cover is limited in the residual area. MPB is not expected to affect local runoff or streamflow levels but increases in flow from upstream basins is expected to increase the frequency and magnitude of high flows on the Tranquille mainstem channel in the residual area. Refer to basin summaries for details.

[1] ASL – Above the snowline. Refers to that portion of the basin or residual that contributes runoff at the time of peak flow on the mainstem channel. Also referred to as the area above the snowline at the time of peak flow. ASL in the Tranquille River watershed is expected to be that area above approximately 1350 m in elevation based on past reports and local experience.

Lower Tranquille residual

Sediment sources	M	Increasing	Sediment input to streams is occurring from moderate and higher risk road sections, isolated channel bank failures, and channel bed and bank erosion during high flow periods. Hazard will increase with increases in streamflow expected as a result of MPB effects in upstream basins. Road related sediment inputs in the residual area are a concern but should remain unchanged with MPB.	
Riparian function	H	Increasing	Critical riparian areas on the Tranquille fan and lower floodplain reaches have been compromised by land-use activity including placer mining, road and rail infrastructure development, institutional development, water intake infrastructure development, and recreational use. New recreational and residential development is proposed on the fan and increases in streamflow from MPB infestation in upstream areas are expected to increase bank erosion, debris loading, debris jam formation, and lateral channel movement.	
Risk				
Resource at stake	Risk rating	Trend with MPB	Affected by	Mitigation
Water quality	H	Increasing	Upstream and localized channel bed and bank erosion during high flow periods, reductions in upstream and localized riparian function, and sediment input from connected road and hillslope related sources.	Desynchronize flows from Tranquille and Watching basins by managing forest cover and outlet controls on Truda and Tranquille Lakes. Restore and protect critical riparian areas including those on the Tranquille fan and lower floodplain reach, and reduce sediment inputs from roads and road related slides as per road risk map and tables.
CP mainline and public road crossings on fan	H	Increasing	Channel bank erosion, large woody debris input, and debris jam formation during high flow periods.	Restore fan and floodplain function in affected areas, improve drainage structure capacity on CP mainline through active fan area, and re-design public road crossing to fail without affecting resources at stake.

Lower Tranquille residual

Anadromous and resident fish and fish habitat	M	Increasing	Upstream and localized channel bed and bank erosion during high flow periods, reductions in upstream and localized riparian function, and sediment input from connected road and hillslope related sources.	Restore and protect critical riparian areas and restore fan and floodplain function on the lower reaches of the Tranquille mainstem. Restoration should include removal of abandoned water intake infrastructure on lower mainstem (likely barrier to fish passage), manipulation of containment berms and levees to restore overbank flooding and lateral channel migration processes, and immediate removal of a failed public or private road crossing downstream of the CP mainline. Reduce sediment inputs from roads and road related slides as per road risk map and tables.

Watching basin

Drainage area	14,417 ha		
Area harvested	4,735 ha - 33%		
Area ASL[1]	7,350 ha		
Area harvested ASL	3,000 ha - 41%		
ECA ASL	2,300 ha - 32%		
Area ASL affected by MPB	2,900 ha - 40%		
Resources at stake (consequences)	Sawmill FSR crossing on Watching Creek floodplain. Downstream water quality and anadromous fish habitat. Other FSR and permitted road crossings on major tributaries. Resident fish and fish habitat.		
Hazards			
Category	Rating	Trend with MPB	Description
Streamflow	M	Increasing	Runoff and peak streamflow levels have likely increased as a result of moderate amounts of past forest development and recent salvage ASL. Advanced pine regeneration in old cutblocks is affected by MPB. Other forest health issues are also affecting forest cover at upper elevation (spruce bark beetle). Significant increase in ECA expected ASL as a result of pine mortality and ongoing salvage. An increase in the frequency and magnitude of high flow events should be expected in the basin.

[1] ASL – Above the snowline. Refers to that portion of the basin or residual that contributes runoff at the time of peak flow on the mainstem channel. Also referred to as the area above the snowline at the time of peak flow. ASL in the Tranquille River watershed is expected to be that area above approximately 1350 m in elevation based on past reports and local experience.

Sediment sources	M	Increasing	Sediment input to streams is occurring from moderate and higher risk road sections and channel bed and bank erosion during high flow periods. Fine sediment content in channel bed materials is considered high. Several road drainage related landslides have occurred on steep coupled slopes along the Watching Creek and Cannell Creek mainstem channels. Several permitted and FSR crossings on major tributaries are undersized and will fail with expected increases in streamflow and sediment transport. The Sawmill FSR crossing on the lower Watching floodplain is undersized with respect to stream discharge and floodplain processes. Washout is expected with input of sediment to fish-bearing waters.	
Riparian function	M	Stable	Critical riparian areas have been largely protected as a result of difficult access or low timber values, generally. Agricultural related clearing on the Watching floodplain downstream of the Sawmill FSR crossing has reduced riparian function locally and will result in increased erosion during high flow periods. One fan/floodplain complex in the area around the Watching Creek and Tranquille East FSR intersection has been logged but is recovering and should not be affected by MPB. Uncontrolled cattle access in riparian areas is affecting vegetation and localized bank stability throughout the basin.	
Risk				
Resource at stake	Risk rating	Trend with MPB	Affected by	Mitigation
Sawmill FSR crossing on Watching Creek	H	Increasing	Flows and floodplain processes on Watching Creek mainstem channel. Flows expected to increase with MPB mortality and other forest health related issues.	Relocate the crossing to a better incised location and remove all fill from active floodplain area, or increase span length to bridge active floodplain feature and remove fill associated with existing approaches.

Watching basin

Downstream water quality and anadromous fish habitat	M	Increasing	Combined flows from the Watching and Tranquille basins resulting in bed and bank erosion in fan and floodplain areas on the Tranquille mainstem channel. Flows expected to increase without forest management intervention. Uncontrolled cattle access to channels throughout the basin.	Desynchronize flows from the Tranquille and Watching basins by managing forest cover and outlet controls on Truda and Tranquille Lakes. Stand replacement recommended in MPB and other forest epidemic affected areas in the Watching Creek basin. Restore and protect critical riparian areas, and reduce sediment inputs from roads and road related slides as per road risk map and tables. Eliminate or control cattle access to water.
FSR and other permitted road crossings (culverts) on major tributaries	M	Increasing	Flows, sediment, and debris transport on tributaries greater than 1.5 m bankfull width.	Replace culverts with structures that span active fan or floodplain features allowing unimpeded sediment and debris transport during high flow periods, or re-design existing crossings to allow failure during high flow events without affecting road prism stability or natural drainage patterns (i.e. no diversion of flows).
Resident fish and fish habitat	L	Increasing	Increase in streamflow levels expected to scour channels and increase bank erosion, generally.	Restore and protect critical riparian areas and reduced sediment input to streams from moderate and higher risk roads and road sections.

Tranquille basin

Drainage area	23,368 ha
Area harvested	8,400 ha - 36%
Area ASL[1]	12,350 ha
Area harvested ASL	4,850 ha - 40%
ECA ASL	4,630 ha - 38%
Area ASL affected by MPB	6,000 ha - 49%
Resources at stake (consequences)	Public safety, private property, and public infrastructure on the fan at the upper Red Lake road crossing on the Tranquille River mainstem. Public safety and private property on the ASD 21 fan. Public safety and infrastructure at the Red Lake Road crossing on the Sylvestre Creek fan. Private property and both public and private infrastructure on the floodplain through the Alpine Valley sub-division and tributary fans. Local and downstream water quality. Downstream anadromous fish habitat. 4020.05 road crossing on upper Tranquille River mainstem. Roads K1100.35, 4030.25, 4015.60, and 4015.70 crossings on major tributaries – ~1.5 m bankfull and larger. Resident fish and fish habitat.

[1] ASL – Above the snowline. Refers to that portion of the basin or residual that contributes runoff at the time of peak flow on the mainstem channel. Also referred to as the area above the snowline at the time of peak flow. ASL in the Tranquille River watershed is expected to be that area above approximately 1350 m in elevation based on past reports and local experience.

Tranquille basin

Hazards			
Category	Rating	Trend with MPB	Description
Streamflow	M	Increasing	Forest development ASL in the Tranquille River has been moderate and mostly recent. High levels of development have occurred in the Sylvestre Creek and ASD 21 and 26 sub-basins. The magnitude and frequency of high flows has likely increased in these sub-basins and the larger Tranquille basin as a result. Extensive MPB mortality ASL in the Tranquille basin will result in high ECA levels, exacerbated by salvage if undertaken. Management of flows using controls in place at the outlets on Truda and Tranquille Lakes can partly offset expected effects on flows but not eliminate them.
Sediment sources	M	Increasing	Sediment input to streams is occurring from moderate and higher risk road sections and channel bed and bank erosion during high flow periods, particularly on the floodplain through the Alpine Valley sub-division. Notable road input sites include the Sawmill FSR crossing on upper Tranquille River and climbing sections of the Red Lake road beyond the Alpine Valley sub-division. Fine sediment content in channel bed materials is considered high in the lower half of the basin. Several landslides and erosional events have also occurred on steep coupled slopes as a result of uncontrolled drainage on the Red Lake road and road K1100.35.
Riparian function	H	Stable	Two of the most critical riparian areas in the basin are located in fan and floodplain areas on private land and have been all or partly denuded. Sensitivity to high flow related disturbance has been increased as a result of this activity resulting in chronic erosion and unwanted lateral channel movement. MPB is not expected to affect local riparian function in these areas but increases in streamflow are expected to increase erosion resulting in loss of land and further reductions in riparian function. Increased debris loading from dead pine in riparian areas is expected to increase debris accumulation and jam formation, where applicable. Uncontrolled cattle access in riparian areas is affecting vegetation and localized bank stability throughout the basin.

Tranquille basin

Risk				
Resource at stake	Risk rating	Trend with MPB	Affected by	Mitigation
Public safety, private property, and public infrastructure on the fan at the upper Red Lake road crossing on the Tranquille River mainstem.	H	Increasing	Flows, sediment transport and deposition, and debris jam formation on the Tranquille River in this location.	Enlarge and armour the mainstem channel on the fan to prevent avulsions resulting from ice or debris jam formation during high flow periods. Minimize forest harvesting related effects on runoff ASL and either replace the existing structure on the Red Lake road in this location with a structure that spans the fan feature, or re-locate to a better incised location.
Public safety and private property on the ASD 21 sub-basin fan.	H	Increasing	Debris flows, debris floods, high flows, sediment transport and deposition, and debris jam formation on tributary ASD 21 in this location.	Minimize forest development related effects on runoff ASL and notify private landowners of the hazards and risk in this location.
Public safety and infrastructure at the Red Lake road crossing on the Sylvestre Creek fan.	H	Increasing	High flows, sediment and debris transport, debris jam formation at the culvert, and avulsions on the fan.	Minimize forest development related effects on runoff in the sub-basin and either re-locate the public road and FSR or enlarge and armour the channel from the apex to a point downstream of the public road and replace culverts with an open bottom structure capable of passing flows with mobile sediment and debris.

Private property and both public and private infrastructure on the floodplain and tributary fans through the Alpine Valley sub-division.	M	Increasing	Flows, sediment, and debris transport on the Tranquille River mainstem channel and tributaries.	Minimize forest development related effects on runoff ASL. Address road related issues on fans and notify the public with regard to more appropriate riparian set-back and management strategies designed to restore and maintain natural fan and floodplain processes.
Local and downstream water quality.	M	Increasing	Road and road related erosion and landslide events. Flows, sediment, and debris transport on the Tranquille River mainstem, and reductions in riparian function particularly in fan and floodplain areas.	Minimize forest development related effects on runoff ASL, reduce sediment input to streams from moderate and higher risk roads and road sections, and improve riparian function in denuded or otherwise poorly managed areas. Protect critical intact riparian areas.
Downstream anadromous fish habitat.	M	Increasing	Road and road related erosion and landslide events. Flows, sediment, and debris transport on the Tranquille River mainstem, and reductions in riparian function particularly in fan and floodplain areas.	Minimize forest harvesting related effects on runoff ASL, reduce sediment input to streams from moderate and higher risk roads and road sections, and improve riparian function in denuded or otherwise poorly managed areas. Protect critical intact riparian areas.
Road 4020.15 crossing on Tranquille mainstem	M	Increasing	Flows, sediment, and debris transport on Tranquille River floodplain.	Remove structure and approaches within active floodplain area or replace with larger structure that spans entire feature with removal of all fill from floodplain area.

K1100.35, 4030.25, 4015.60, and 4015.70 road crossings on major tributaries.	M-H	Increasing	Flows, sediment and debris transport.	Deactivate or upgrade crossings to pass expected flows with mobile sediment and debris. Upgrade options include replacement with oversized culvert, suitable span or other open bottom type structure, or re-design of existing crossing to fail without affecting local or downstream resources.
Resident fish and fish habitat.	M	Increasing	Sediment input from road and slope related sources, and channel scour resulting from increases in streamflow and/or reductions in riparian function.	Minimize forest harvesting related effects on runoff ASL, reduce sediment input to streams from moderate and higher risk roads and road sections, and improve riparian function in denuded or otherwise poorly managed areas. Protect critical intact riparian areas.

Photo 1. Tranquille River fan downstream of CPR and public/private road crossing. Note adventitious root on cottonwood indicating burial during last disturbance event – likely freshet 2002. Approximately 1.5 m of scour has occurred since.

Photo 2. Abandoned public or private road crossing with approaches in active fan area downstream of CPR crossing. Washout likely during high flow periods with sediment input to fish bearing waters.

Old water intake infrastructure on lower Tranquille mainstem. The structure is a likely barrier to fish passage. Some water is still diverted from this site though existing infrastructure.

Photo 4. Sawmill FSR crossing on Watching Creek floodplain. The active floodplain is constricted by the structure – sediment and debris accumulation at the inlet is likely during high flow periods. A washout could affect public safety, public infrastructure, access, and water quality.

Photo 5. Non-status road crossing on Watching Creek downstream of Sawmill FSR. The structure is on the active floodplain and will likely fail during high flow events that mobilize upstream sediment and debris.

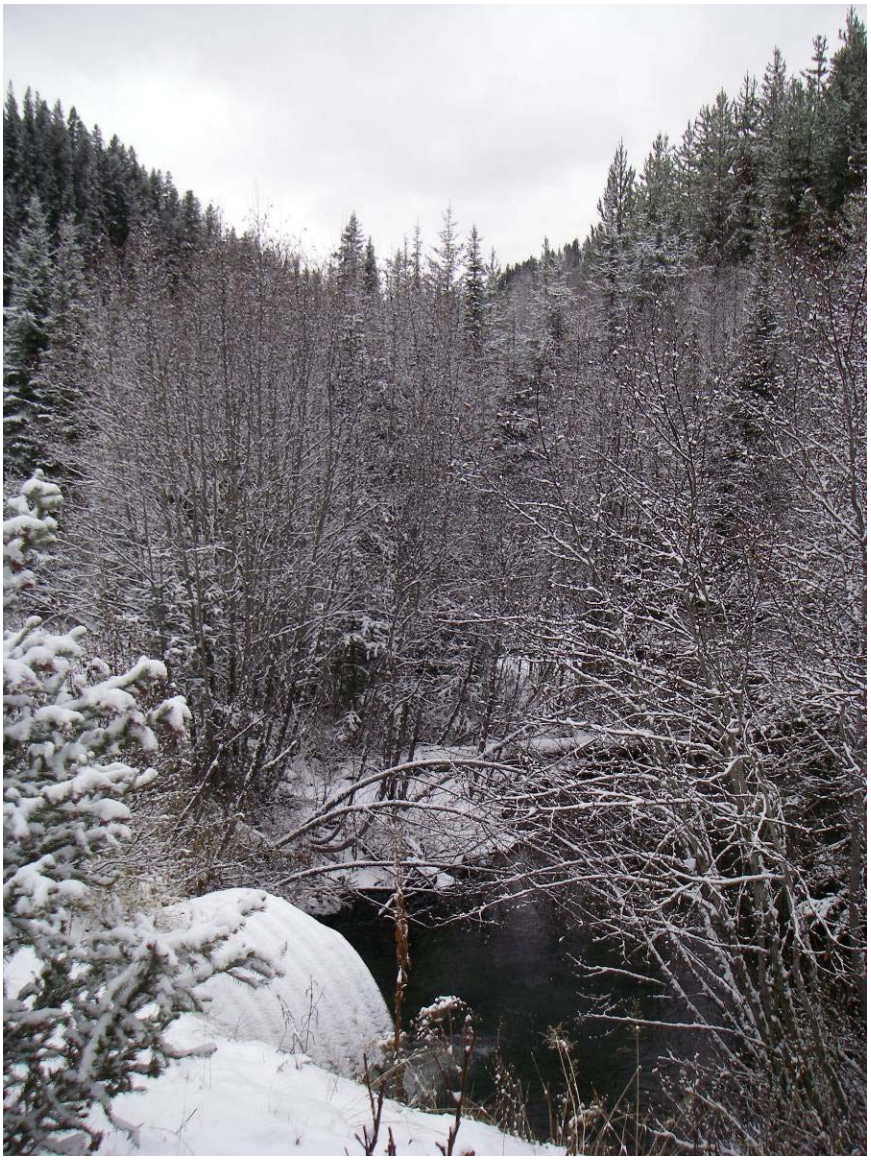

Photo 6. Watching Creek mainstem channel upstream of Tranquille East FSR crossing. Recovery is occurring in riparian areas logged in the 1970's and early 1980's.

Photo 7. Stream and riparian damage by cattle in Sylvestre Creek sub-basin.

Photo 8. Example of cattle related damage to drainage infrastructure in Tranquille basin. Diversion of flow from this site has scoured an erodable ditchline with input to Tranquille River.

Photo 9. Private residence on fan upstream of upper Red Lake road crossing on Tranquille mainstem. Sediment and debris input to the canyon above results in accumulations on the fan during high flow periods with avulsion. The house was undermined in the spring of 1990.

Photo 10. Red Lake road crossing near toe of fan shown in photo above. The structure is undersized and will fail during high flow events that result in sediment and debris accumulation on the upstream side.

Photo 11. ASD 21 fan with residence near apex. Evidence of debris flood activity was noted – an avulsion during such an event could result in loss of life and damage to private property.

Photo 12. Old debris flood, possibly debris flow deposits on ASD 21 fan upstream of private residence shown above.

Photo 13. Undersized culverts on Red Lake road at Sylvestre Creek crossing. The channel is active on the fan; structures have failed at least once already causing diversion down the ditchline with flow over the road. This site was identified as a problem by Summit in 2003.

Photo 14. Road 4020.05 crossing on upper Tranquille River floodplain. The floodplain is constricted by up to 50% by the structure in this location. High flows that mobilize upstream sediment and debris may cause failure in this location.

Photo 15. Mobile sediment and debris accumulation at road 4030.25 crossing on alluvial fan.

Photo 16. Mobile debris (log with rootball) at inlet of structure on Saul Creek at road K1100.35. Flows were overtopping the road in this location, resulting in diversion onto steep coupled slopes and erosion with input to Tranquille River.

Photo 17. Erosion on steep coupled slope downstream of culvert shown above. The site is connected to Tranquille River.

Tranquille River - Road Risk Map

Road status

- Under permit not FSR
- FSR
- Non status
- Public

Road risk

- Very high
- High
- Moderate
- Low

- Alluvial fan - active
- Alluvial fan - relic/inactive
- Terrain Class IV and V - Maynard 2002
- Private land
- Floodplain
- Landslide
- Provincial Park

MJM 02/09

MJM 02/09

0 2 4 6 8 Kilometers

Tranquille FSR Road Risk								
Road	**Basin**	**Length (m)**	**Comments**	**Hazard**	**Resource at stake**	**Probability of hazard occurrence**	**Effect on resource at stake**	**Risk**
4015	Tranquille	199.7	Road on fan, diversion likely onto road or across.	Road erosion, washout, sediment input to Sylvestre Creek	Water quality, fish	H	H	**VH**
Tranquille East FSR	Watching	1119.9	Drainage issues above steep coupled slopes, one slide already.	Landslides into main tributary, road erosion	Water quality	H	H	**VH**
K1100.00 Sawmill Lake FSR	Watching	234.3	Undersized span on floodplain. Approaches constrict flow and process heavy erosion or washout expected with increased runoff, bank erosion and debris accumulation.	Erosion, sediment input to mainstem, road washout	Water quality, public safety	H	H	**VH**
4015	Tranquille	258.2	Road on fan, mobile sediment and debris at culvert, washout likely.	Road damage, sediment delivery to wetland.	Road infrastructure	H	M	**H**
K1100.00 Sawmill Lake FSR	Tranquille	994.6	Significant input of sediment from downhill approaches during wet weather activity. Cattle guard traps in place but not maintained.	Sediment input to Tranquille River	Water quality	H	M	**H**
Tranquille East FSR	Watching	287.1	Culvert on large tributary with mobile debris, will fail and erode prism.	Road erosion, sediment input to channels	Water quality	H	M	**H**
K2100.00 Watching Creek FSR	Watching	2191.6	Portion built on floodplain, armoured but constricts feature and process. Other portion on break above steep coupled slopes, low cross drain frequency, potential for slides with increased runoff.	Road erosion, landslides into mainstem channel.	Water quality	M	H	**H**
K2100.00 Watching Creek FSR	Watching	373.2	Drainage concentrated along this section above steep coupled slopes from diversions on spurs . 1 old slide from diverted drainage.	Landslides or slumps into tributary	Water quality	H	M	**H**
K1100.00 Sawmill Lake FSR	Watching	750.3	Sediment input from steep grade to tributary, culvert 75% blocked, failure imminent with diversion down road.	Sediment input to streams, erosion of road.	Water quality, road infrastructure	H	M	**H**
4015 and 4015A	Tranquille	2051.1	Very low culvert frequency, diversions, erosion, scour.	Road erosion and damage	Road infrastructure	M	M	**M**
4015	Tranquille	1615.4	Rutting and surface erosion with input to streams on grade.	Erosion, sediment delivery to water	Water quality	M	M	**M**
K1121.00 Heller Creek FSR	Tranquille	520.4	Running surface erosion on grade leading down to Tranquille mainstem.	Sediment delivery to streams	Water quality	M	M	**M**
Tranquille East FSR	Watching	1936.9	Low to no culverts on grade, ditch scour, concentration onto steep slopes.	Road erosion, slides in regen.	Water quality, road infrastructure, regeneration	M	M	**M**
Watching Creek FSR	Watching	215.9	Culvert on S3 channel with mobile debris, will fail and erode prism with expected flows, erosion, and debris transport.	Road erosion, sediment input to streams.	Water quality	M	M	**M**
K3100.00 O'Connor Lake FSR	Watching	135.8	Culvert on main tributary with mobile debris. Will fail with debris accumulation at inlet.	Road erosion, sediment input to channel	Water quality	M	M	**M**
K1100.00 Sawmill Lake FSR	Watching	178.7	Downhill approach to Watching Creek mainstem crossing. Running surface input during wet weather.	Erosion, sediment input to mainstem	Water quality	M	M	**M**
K1100.00 Sawmill Lake FSR	Watching	2238.6	Long downhill approach to Watching Creek mainstem, sediment input with active hauling during wet periods	Erosion, sediment input to mainstem	Water quality	M	M	**M**

Tranquille Permitted Road Risk								
Road	**Basin**	**Length (m)**	**Comments**	**Hazard**	**Resource at stake**	**Probability of hazard occurrence**	**Effect on resource at stake**	**Risk**
K2111.00	Watching	661.704	Diversion down ditch to steep coupled slope, one large slide into mainstem already.	Other landslides into mainstem.	Water quality	H	H	**VH**
K2110.00	Watching	1637.999	Drainage issues above steep coupled slope. One slide already.	Diversions causing landslides into mainstem.	Water quality	H	H	**VH**
4417.00	Tranquille	223.299	Failing culvert crossing	Erosion of fill, sediment input to tributary	Water quality	H	M	**H**
4030.25	Tranquille	145.186	Partly blocked oval culvert on fan. Will not pass mobile sediment and debris. Replace or back-up with armoured ford.	Washout, sediment input to streams	Water quality	H	M	**H**
4020.05	Tranquille	278.686	Bridge crossing, abutments constrict floodplain, will erode or hydraulic the channel during high flows.	Erosion of approaches, instream scour, sediment delivery to streams	Water quality	H	M	**H**
4015.70	Tranquille	228.310	Culvert on large S6 channel, mobile debris, will fail and divert.	Erosion, sediment delivery to streams	Water quality	H	M	**H**
K1100.35	Tranquille	309.494	Diversion down ditch and fine textured running surface. Exacerbated by cattle.	Erosion, sediment delivery to streams.	Water quality	H	M	**H**
K2102.01	Watching	1143.724	Failing waterbars, will result in diversion, erosion, rutting.	Sediment delivery to streams and diversion of runoff to steep coupled slope below FSR.	Water quality	M	H	**H**
K1104.01	Watching	1778.002	Diversions above steep coupled slope, one small slide already, more likely.	Landslide, sediment input to tributary.	Water quality	H	M	**H**
K2115.00	Watching	1251.064	Culverts on grade not backed up above steep coupled slope	Culvert failure, diversion, landslides into main tributary.	Water quality	M	H	**H**
K1104.00 - Cannell Creek	Watching	237.971	Culverts on fan crossing, will fail with expectected flows, bank erosion, and debris accumulation.	Erosion of fill around culverts.	Water quality	M	H	**H**
W2	Watching	1483.634	Dry but numerous crossings on draws with no culverts. Could be in Provincial Park.	Landslide onto floodplain or into mainstem.	Water quality	M	H	**H**
K2120.00	Watching	539.511	Culverts on streams with mobile sediment and debris, will fail and erode prism with expected flows.	Erosion, sediment input to tributary.	Water quality, road infrastructure.	H	M	**H**
K2120.00	Watching	434.960	Culverts on tributaries with mobile sediment and debris, will fail and erode prism with expected flows.	Erosion, sediment delivery to tributary.	Water quality, road infrastructure	H	M	**H**
K2100.00 - Watching Creek	Watching	111.628	Culvert on stream with mobile debris, will fail and go down ditch causing significant erosion.	Ditch scour, road erosion, sediment input to streams.	Water quality	H	M	**H**
K2100.00 - Watching Creek	Watching	555.269	Several S4 channels, lots of seepage in ditch on steep grade, high liklihood of diversions.	Diversion, ditch and road scour, sediment input to streams.	Water quality	H	M	**H**
4015.00	Tranquille	1102.362	Failing water bars, erosion, rutting.	Erosion, sediment delivery to Sylvestre Creek	Water quality	M	M	**M**
4000.25	Tranquille	408.005	Waterbars failing on grade, running surface erosion.	Erosion, sediment input to Sylvestre Creek	Water quality	M	M	**M**
4015	Tranquille	491.060	Almost no culverts, diversions and erosion during wet periods.	Road erosion and damage	Road infrastructure	M	M	**M**
4421	Tranquille	5448.878	Rutted on grades, diversions, scour.	Erosion with sediment delivery to streams	Water quality	M	M	**M**
4422	Tranquille	2137.468	Heavy rutting, diversions, cattle effects, undersized structure on main tributary.	Erosion, sediment delivery to streams	Water quality	M	M	**M**
4417.00	Tranquille	352.523	Failing culverts on small S6 channels	Erosion of fill, sediment input to streams	Water quality	M	M	**M**
4400.00	Tranquille	519.820	Erosion on grade, rutting	Sediment delivery to streams	Water quality	M	M	**M**

Tranquille Permitted Road Risk								
Road	**Basin**	**Length (m)**	**Comments**	**Hazard**	**Resource at stake**	**Probability of hazard occurrence**	**Effect on resource at stake**	**Risk**
4421.00	Tranquille	715.779	Rutting, erosion, sediment delivery to tributary	Sediment input to streams	Water quality	M	M	**M**
4030.25	Tranquille	1769.735	Waterbars failing, rutted, diversions likely with erosion	Sediment input to tributary	Water quality	M	M	**M**
4012.00	Tranquille	389.156	Rutting, minor surface erosion, input to mainstem	Sediment input to channel	Water quality	M	M	**M**
4015.00	Tranquille	268.906	Culvert with fill on channel with mobile debris, will fail and erode prism.	Erosion, sediment delivery to streams	Water quality	M	M	**M**
K2125.10	Watching	826.999	Okay now but culverts on steep grade not backed up. Will fail if not maintained.	Erosion, sediment delivery to streams.	Water quality	M	M	**M**
K1104.00 - Cannell Creek	Watching	765.299	Low cross drain frequency, erosion, close to mainstem.	Sediment input to Cannell Creek	Water quality	M	M	**M**
K1105.00	Watching	300.399	Culvert on stream with mobile debris, will fail and erode prism.	Erosion, sediment input to tributary.	Water quality.	M	M	**M**
K1103.00	Watching	61.290	Cattle trample at culvert inlet, will block and fail.	Erosion of crossing, sediment input to tributary.	Water quality	M	M	**M**
K2111.01	Watching	214.553	Culvert on stream with mobile sediment or debris, will fail with expected flows.	Erosion of prism, sediment input to tributary.	Water quality	M	M	**M**
K2111.03	Watching	164.283	Culvert on stream with mobile sediment or debris. Will fail with expected flows.	Erosion of prism, sediment input to tributary.	Water quality	M	M	**M**
K2122.10	Watching	424.401	Diversion above steep slope and slide onto road below.	Ongoing slumps or erosion onto permitted road below.	Road infrastructure, water quality	M	M	**M**
K2130.00	Watching	94.381	Culvert on stream with mobile sediment and small debris, will fail and erode prism with expected flows.	Erosion, sediment input to stream.	Water quality	M	M	**M**
K2120.00	Watching	160.261	Culvert on stream with mobile sediment and debris. Will fail and erode prism with expected flows.	Erosion, sediment input to stream.	Water quality	M	M	**M**
K3300.00 - Rushton Rd.	Watching	150.415	Culvert on stream with mobile debris, will not divert but washout likely.	Erosion of prism, sediment input to stream.	Water quality	M	M	**M**
K2100.00 - Watching Creek	Watching	720.236	Road built on tributary, can divert down road causing erosion.	Erosion, sediment input to tributary.	Water quality	M	M	**M**

Tranquille Public Road Risk								
Road	**Length**	**Basin**	**Comments**	**Hazard**	**Resource at stake**	**Probability of hazard occurrence**	**Effect on resource at stake**	**Risk**
TI1	146.055	Lower Tranquille residual	Failed bridge crossing on mainstem, alternate access to old institution, approaches restrict floodplain and processes.	Erosion of abutments, debris jam formation, sediment input to mainstem.	Water quality, fish habitat	H	H	**VH**
Red Lake Road	247.315	Tranquille	Undersized and inappropriate structures on Sylvestre fan crossing. Relocate road or replace with span and armoured channel.	Road washout, ditch scour, sediment input to Sylvestre Creek	Public safety, road infrastructure, water quality	H	H	**VH**
Red Lake Road	193.790	Tranquille	Undersized span on active fan - uppermost crossing on Tranquille mainstem. Washout inevitable with expected flows and fan process.	Washout, erosion of abutments and approaches, sediment input to streams	Public safety, infrastructure, water quality, fish habitat.	H	H	**VH**
Red Lake Road	493.396	Lower Tranquille residual	Road and undersized span on Tranquille fan, will fail during high flows with expected bank erosion and debris accumulation.	Road washout, sediment input to mainstem	Public safety, infrastructure, water quality, fish habitat	M	H	**H**
TI2	2214.832	Lower Tranquille residual	Road and associated levees restrict fan and floodplain processes.	Increased bed and bank scour during high flow periods, reduced sediment storage, impaired floodplain process.	Channel stability, water quality, fish habitat.	M	H	**H**
Red Lake School Road	255.240	Tranquille	Undersized span on floodplain crossing. Will fail with expected flows, bank erosion, and debris accumulation.	Road washout, sediment input to mainstem	Public safety, infrastructure, water quality	H	M	**H**
Red Lake Road	396.573	Tranquille	Oversteepened fill on steep coupled slopes, slumps and small slides into mainstem.	Sediment input to mainstem	Water quality	H	M	**H**
Red Lake Road	2150.222	Tranquille	Low cross drain frequency on steep grade beyond Alpine sub-division - ditch scour, road erosion, sediment input to tributaries.	Sediment input to streams	Water quality	H	M	**H**
Red Lake Road	2489.044	Tranquille	Low cross drain frequencies through fan areas within and downstream of Alpine sub-division - not designed to manage fan processes.	Erosion, road washout, sediment input to streams.	Public safety, access, water quality	H	M	**H**
Red Lake Road	936.313	Tranquille	Drainage diversions above steep coupled slopes approaching upper Tranquille crossing. Several erosional events already.	Road erosion, sediment input to Sylvestre Creek	Water quality, road infrastructure	H	M	**H**
Red Lake Road	9603.191	Lower Tranquille residual	Surface erosion and ditch scour on steeper grades.	Sediment input to tributaries	Water quality	M	M	**M**
Red Lake Road	2774.547	Tranquille	Surface erosion and ditch scour on steeper grades between residual area and second mainstem crossing.	Sediment input to tributaries	Water quality	M	M	**M**
Red Lake Road	345.204	Tranquille	Downhill approach to second mainstem crossing.	Sediment input to mainstem	Water quality	M	M	**M**

Tranquille Non-status Road Risk								
Road	**Basin**	**Length (m)**	**Comments**	**Hazard**	**Resource at stake**	**Probability of hazard occurrence**	**Effect on resource at stake**	**Risk**
T003	Tranquille	485.7	Climbing trail on fan upslope of Red Lake Road, stream diversion at apex likely, will result is significant erosion and sediment input to Tranquille River.	Erosion, sediment input to tributary and mainstem	Water quality, Red Lake Road	H	H	**VH**
4000.32	Tranquille	4289.5	Streams on road above steep coupled slopes, oversteepened fill above tributaries, slides, landing in draw, unstable fill.	Landslide or bank failure into tributary, erosion into mainstem	Water quality	H	H	**VH**
2120.05	Watching	537.3	Fills in steep draws, uncontrolled drainage.	Landslide into tributary with runout as debris flow to mainstem. Crossings on mainstem at stake.	Water quality	H	H	**VH**
K2100.00	Watching	1181.7	Water management issues above steep coupled slopes. Potential for landslides.	Landslide into mainstem	Water quality	H	H	**VH**
4000.33	Tranquille	1962.3	Culverts with fill and waterbars failing on grade, connected to tributary.	Erosion, sediment input to tributary and mainstem	Water quality	H	M	**H**
T003	Tranquille	875.0	Steep grade, uncontrolled drainage, erosion.	Erosion, sediment input to tributary	Water quality	H	M	**H**
T001a	Tranquille	616.2	Drainage diversion into Red Lake Road ditch. Has caused one slump onto Tranquille floodplain already.	Landslide or bank failure with input to mainstem	Water quality	M	H	**H**
4412.00A	Tranquille	82.1	Undersized culvert on fan crossing. May be private road but likely built to access crown timber.	Washout, sediment input to tributary and mainstem	Water quality	H	M	**H**
H1	Tranquille	340.6	Old road climbs to fan apex, partial diversion now, more likely with increase in flows. Will create new channel on road if not restored.	Erosion, sediment input to mainstem	Water quality	H	M	**H**
4030.20B	Tranquille	2086.3	Uncontrolled drainage above steep coupled slope.	Landslide into mainstem	Water quality	M	H	**H**
T004	Tranquille	3591.9	Old trails through steep mid-slope draws, potential for diversion onto steep coupled slopes.	Erosion, landslide or bank failure, sediment input to tributaries and mainstem	Water quality	H	M	**H**
FB1	Tranquille	101.9	Collapsed foot bridge, approaches constrict floodplain. May result in debris accumulation and washout. Easy to remove.	Erosion during high flow periods	Local water quality	H	M	**H**
4015D	Tranquille	111.8	Road up fan, diversion onto road likely. Will create new channel.	Erosion with sediment input to fish bearing waters.	Road infrastructure, water quality, fish habitat.	H	M	**H**
1100.35A	Tranquille	1723.9	Diversions above steep coupled slopes, undersized culvert on main tributary, slump into mainstem.	Slump or slide into mainstem	Water quality	H	M	**H**
2102.00A	Watching	1373.9	Diversion down to high risk section on FSR. Concentrating runoff above steep coupled slopes.	Erosion, drainage concentration to high risk site, landslide	Water quality	M	H	**H**
1104.00A	Watching	174.5	On the contour, convex slope but drains onto steep coupled slope below, MPB infestation in upstream area - increase in runoff may cause problems in this area.					**H**
1104.00A	Watching	1643.4	Uncontrolled drainage above steep coupled slope, landslides.	Landslides into mainstem	Water quality	H	M	**H**
W1	Watching	401.9	Crossing deactivated but oversteepened fill hanging over floodplain on west side.	Landslide or slump onto floodplain.	Water quality	M	H	**H**
K1104	Watching	2275.1	No culverts in road above steep coupled slope.	Landslide or slumps into mainstem	Water quality	M	H	**H**
W3	Watching	670.2	Road on floodplain with mainstem crossing. Will washout during high flow events with any debris accumulation.	Bridge failure causing jam with erosion of abutments and approaches.	Water quality	H	M	**H**

Tranquille Non-status Road Risk								
Road	**Basin**	**Length (m)**	**Comments**	**Hazard**	**Resource at stake**	**Probability of hazard occurrence**	**Effect on resource at stake**	**Risk**
4000.30	Tranquille	942.5	Steep fill on partly coupled slope, waterbars failing.	Diversion, landslide or slump onto floodplain, private land.	Water quality	M	M	**M**
T001	Tranquille	2736.6	More than one slide from drainage diversion, frequency low but direct impact on mainstem.	Landslide, road erosion	Water quality	M	M	**M**
2101.01A	Watching	805.2	Dry site but no waterbars or cross ditches above steep coupled slope.	Landslide or slump into tributary or mainstem	Water quality	L	H	**M**
2120.074	Watching	1437.8	Diversions above moderate to steep slopes along tributaries.	Slump or slide into tributary	Water quality	M	M	**M**
2100.19	Watching	1126.3	Failing crossings, erosion of fill.	Sediment input to tributaries	Water quality	M	M	**M**
1104.01A	Watching	1572.9	Small S6 on road above steep coupled slope.	Landslide onto floodplain or into mainstem	Water quality, fish habitat	M	M	**M**
1110.00A	Watching	571.9	Snowmobile trail on floodplain. Erosion - direct input of sediment to Cannell Creek.	Erosion, sediment input to Cannell Creek	Water quality	H	L	**M**

Tranquille River - Runoff Management Map

Forest tenure boundaries - license and permittee

Private land

Provincial park

All basins and residual areas

No runoff related constraints on development.

Tranquille basin

Area expected to contribute runoff at the time of peak flow. No salvage or green wood development at this time. Understory enhancement recommended in MPB affected stands.

Area not expected to contribute runoff at the time of peak flow in sub-basins ASD17, ASD21, and ASD26. Constrained for natural process and risk related reasons. Specific conditions required - refer to report for details.

Watching basin

Area expected to contribute runoff at the time of peak flow. Stand replacement recommended for forest health reasons - MPB or otherwise, including affected juvenile stands. Treatment is designed to advance runoff from this basin.

MJM 02/09

BCTS

A18694
WEYCO

Truda Lake

Tranquille River

Saul Creek

Tranquille

BCTS

Tranquille Lake

TFL35
WEYCO

Watching

A18694
WEYCO

Watching Creek

Sylvestre Creek

BCTS

ASD17

Cannell Creek

ASD26

ASD21

A74910
WEYCO

BCTS

Lower Tranquille residual

N

W

E

S

0 2 4 6 8 Kilometers