Watershed Assessment of Proposed Forest Development within the Peachland Creek Community Watershed

Prepared for

Tolko Industries Ltd.

BC Timber Sales (Okanagan-Columbia Business Area)

Ntityix Resources LP

Revised Final Report

November 5, 2018

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LETTER OF TRANSMITTAL

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November 5, 2018

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VIA EMAIL: Jamie.Skinner@tolko.ocm

Attention: Jamie Skinner, RPF

RE: Watershed Assessment of Proposed Forest Development within the Peachland Creek Community Watershed – REVISED FINAL REPORT

Enclosed is the revised final report assessing the cumulative hydrological impacts of proposed forest development activities within the Peachland Creek community watershed. s.13
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Please contact me if you have questions or comments.

Sincerely,

Robert A Scherer

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Cc: Tony Zanotto, RPF - BC Timber Sales – Okanagan Columbia
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TABLE OF CONTENTS

LETTER OF TRANSMITTAL .... **I**

1.0 INTRODUCTION **1**

1.1 PROJECT BACKGROUND 1

1.2 ASSESSMENT METHODS 4

1.3 HYDROLOGIC INDICATORS AND CONSEQUENCES 6

2.0 BACKGROUND INFORMATION **8**

2.1 PEACHLAND CREEK WATERSHED - GENERAL WATERSHED CHARACTERISTICS 8

2.2 WATERSHED CHARACTERISTICS AND SENSITIVITY TO FOREST DEVELOPMENT 8

2.3 PEACHLAND CREEK WATER SYSTEM – WATER SUPPLY INFRASTRUCTURE 13

2.4 FISH VALUES 15

2.5 KEY RESOURCES AT STAKE (ELEMENTS AT RISK) 15

2.6 KEY REFERENCE DOCUMENTS 16

3.0 WATERSED ASSESSMENT - CURRENT CONDITION **16**

3.1 WATERSHED EQUIVALENT CLEARCUT AREA (ECA) AND STREAMFLOW 16

3.2 FIELD REVIEW 21

4.0 ASSESSMENT OF PROPOSED FOREST DEVELOPMENT **33**

4.1 PROPOSED DEVELOPMENT 33

4.2 PEAK FLOWS AND CHANNEL SENSITIVITY 34

4.3 SURFACE EROSION AND WATER QUALITY 36

4.4 MASS WASTING 41

4.5 RIPARIAN FUNCTION 42

4.6 OTHER LAND USE CONSIDERATIONS 42

5.0 RISK ANALYSIS **43**

6.0 SUMMARY AND RECOMMENDATIONS **47**

6.1 KEY ISSUES AND ELEMENTS AT RISK 47

6.2 CURRENT WATERSHED CONDITION AND PAST FOREST DEVELOPMENT 47

6.3 PROPOSED FOREST DEVELOPMENT SUMMARY 49

6.4 RECOMMENDATIONS 51

7.0 USE AND LIMITATIONS **54**

8.0 REFERENCES **55**

LIST OF FIGURES

Figure 1.1. Location map of the Peachland Creek community watershed showing its sub-basins, drainage units and residual areas. The operating area boundaries of the forest licensees in the watershed and the District of Peachland community water intake are also shown in the map. 3

Figure 2.1. Settling ponds at the District of Peachland water intake (image copied from the RDCO GIS Mapping website, URL: http://www.peachland.ca/gis accessed February 15, 2018). 14

LIST OF TABLES

Table 1.1. Summary of hydrologic indicators, potential hydrologic responses and potential consequences. 7

Table 2.1. Summary of spill start date and end date over the Peachland Lake reservoir spillway (S. Grundy, personal communication, November 30, 2017) 12

Table 2.2. Summary of elements at risk and the consequence of each element. 15

Table 3.1. Summary of current ECA's for the Peachland Creek watershed to the end of December 31, 2017 19

Table 3.2. Four classes of observed surface erosion potential. 25

Table 3.3. Three classes of surface erosion delivery. 25

Table 3.4. Watershed sensitivity to the current level of forest development at the watershed and sub-basin scale. 33

Table 4.1. Summary of proposed ECA's for the Peachland Creek watershed assuming all proposed blocks are harvested before the end of 2017. 34

Table 4.2. Watershed sensitivity to proposed forest development at the watershed and sub-basin scale. 36

Table 4.3. Summary of length of proposed roads in each of the sub-basins, drainage units and residual area in the Peachland Creek watershed. 37

Table 4.4. Summary of the length of proposed roads situated on terrain stability Class IV or V polygons and moderate to very high surface erosion potential polygons as identified by Maynard (2001). 38

Table 5.1. Summary risk ratings associated with proposed development on water quality, water supply infrastructure, water quantity/supply, fish and fish habitat and downstream infrastructure. 46

APPENDICES

Appendix A – Watershed Condition Maps

Appendix B – Summary of Field Inspection Locations

Appendix C – Photographs

Appendix D – Review of streamflow, snow survey data and rainfall data for the Peachland Creek watershed

Appendix E – Office-based review of the surface erosion potential associated with proposed development

Appendix F – Equivalent Clearcut Area Analysis Peachland Creek Watershed (Project 41-258). Report includes long-term ECA projections. Report completed by Forsite Consultants Ltd. (October 29, 2018)

1.0 INTRODUCTION

1.1 Project Background

This watershed assessment has been completed for Tolko Industries Ltd., BC Timber Sales and Ntityix Resources LP (the Licensees) to provide guidance with regards to the hydrologic sensitivity and risk of further forest development in the Peachland Creek community watershed (Figure 1.1). The watershed area upstream of the District of Peachland's intake is approximately 126 km^2 above the confluence of Peachland Creek and 145 km^2 above the confluence with Okanagan Lake. The District of Peachland's water intake, situated on Peachland Creek approximately 3.5 km upstream from Okanagan Lake, was considered the primary point of interest for this assessment.

For purposes of this assessment the watershed was divided into two sub-basins (Peachland Creek sub-basin and Greata Creek sub-basin) with one residual area (Figure 1.1). The Peachland Creek sub-basin was also broken into two drainage units (Mid-Peachland Creek and Upper Peachland Creek) in order to identify the ECAs above and below Peachland Lake.

Scope of Work

The scope of this project was to complete an overview watershed assessment in the Peachland Creek community watershed that is consistent to the requirements identified in the licensees' forest stewardship plans and in accordance with the objectives set by government for community watersheds. The ultimate goal of this assessment was to identify cumulative hydrological effects from forest development activities that could cause material adverse impacts on water quantity, water quality or timing of flows in the watershed, and to provide recommendations to mitigate any identified impacts.

Specific objectives of this work included the following:

- Assessment of the potential cumulative hydrologic effects of existing and proposed forest development on the watershed; rates of hydrologic recovery within the watershed and its sub-basins; watershed characteristics; watershed processes (water quantity, water quality and timing of flows); and waterworks infrastructure.
- Identification of the potential for primary forest activities to result in:
    - a material adverse impact on the quantity of water or the timing of the flow of the water from the waterworks; and
    - the water from the waterworks having a material adverse impact on human health that cannot be addressed by water treatment required under an enactment or the licence pertaining to the waterworks.

- Assessment of the risk of past forest development and the licensees' proposed forest development in not conserving the B.C. government objectives for community watersheds. The assessment of risk also included an evaluation of potential material adverse impacts to other elements at risk such as fish and fish habitat, private property and infrastructure and human safety.
- Identification of potential hydrologic risks associated with past forest development and the proposed forest development. This included an overview assessment of stream channel morphology, mass wasting and sediment erosion/delivery, riparian condition and the quality, quantity and timing of water flows.
- Provided guidance with regards to proposed development in the watershed based on the current watershed conditions, potential hydrologic risks in the watershed and projected ECAs that could result a material adverse effect at the District's water intake, fish and fish habitat or private property.
- Developed recommendations regarding alternatives to mitigate and/or minimize any potential material adverse impacts on water quantity, water quality or timing of flows.

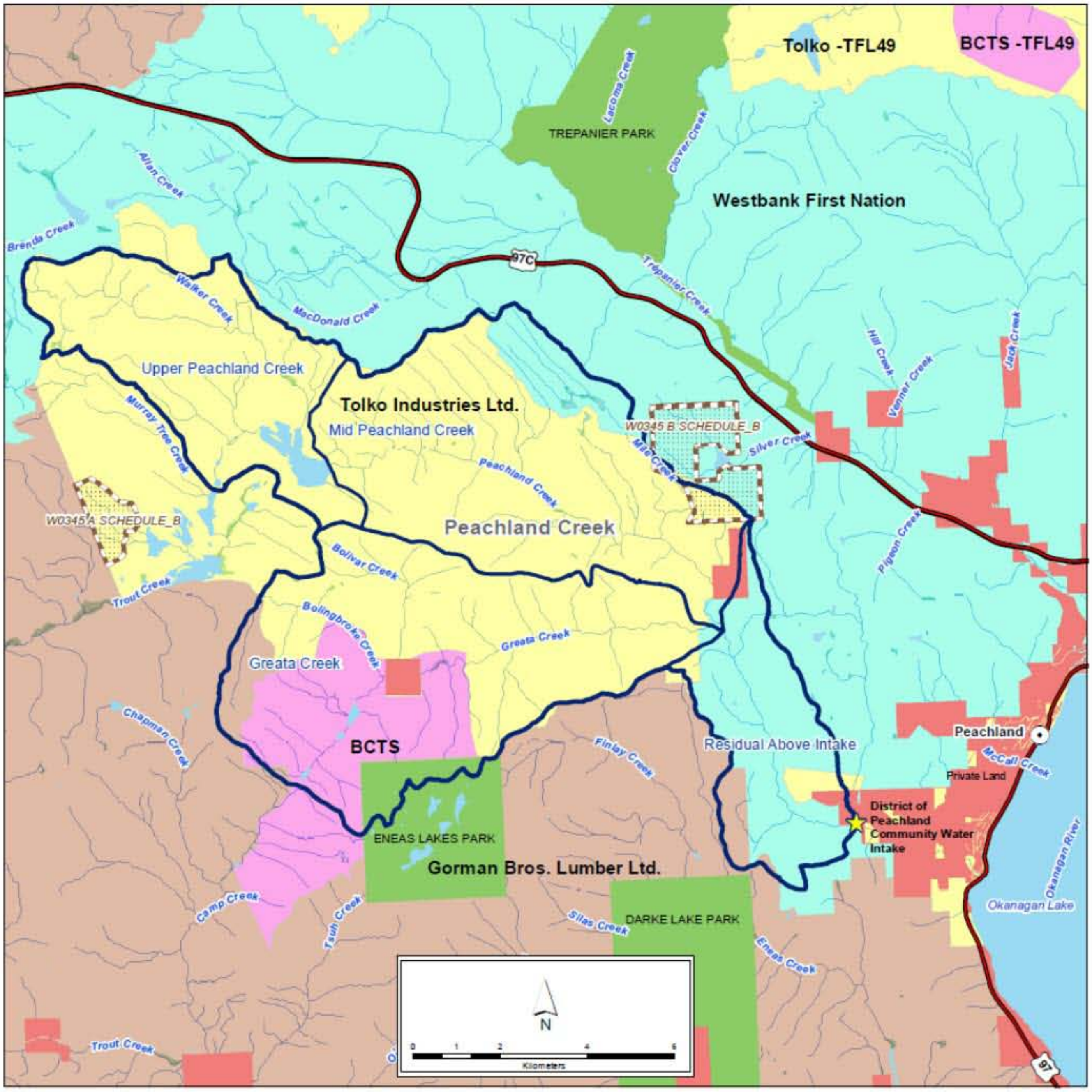

Figure 1.1. Location map of the Peachland Creek community watershed showing its sub-basins, drainage units and residual area. The operating area boundaries of the forest licensees in the watershed and the District of Peachland community water intake are shown on the map. Private land and park boundaries are also shown.

1.2 Assessment Methods

This assessment was completed to be consistent with the requirements that are currently outlined in the licensees' Forest Stewardship Plans by completing the following tasks:

Task 1 – Review of Existing Information
Reviewed relevant and applicable reports and information, ortho/aerial photographs, Google Earth images, bare-earth maps generated from LiDAR data for the entire watershed, proposed and existing forest development plans.

Task 2 – GIS Mapping and ECA Calculations
Using available topographic and terrain information, as well as all relevant forestry spatial information (i.e. planned and existing cutblocks and roads and forest inventories) supplied by the licensees, the following calculations and mapping were completed for the watershed:

- Determined the current ECAs for the watershed to the end of December 31, 2017 including the ECA above the snow sensitive zone (H_{40} line of 1340 m asl.) based on revised snow recovery estimates for pine dominated forests in the interior British Columbia using the methodology suggested in Extension Note 116 (Winkler and Boon 2015).
- Determined current rates of hydrologic recovery based on tree height data that was generated from LiDAR data for the entire watershed;
- Determined proposed ECAs based on current rates of hydrologic recovery;
- Projected ECA recovery over the next 20 years assuming no additional proposed development occurs further than what was included in this report; and,
- Prepared a current watershed map that included the proposed development, existing cutblocks and roads, identification of pine leading stands that have been effected by mountain pine beetle, zones of hydrologic sensitivity to future forest development, hydrologic recovery rates, snow sensitive zone elevation (H_{40} elevation), community watershed waterworks infrastructure, and any issues (e.g. field stop locations) noted within the watershed.

All GIS mapping and ECA calculations were completed by Forsite Consultants Ltd. Details regarding the ECA analysis are not summarized in this report but can be found in Forsite's (2018) report titled: Equivalent Clearcut Area Analysis Peachland Creek Watershed (refer to Appendix F).

Task 3 – Field Assessment

A reconnaissance field assessment was conducted (August 18, 19, 22 and September 10, 2017) to confirm the current condition of the watershed and to identify potential hydrologic risks associated with past and proposed development. The field assessment included the following:

- Confirmed the current condition of the watershed (i.e. peak flow impacts, channel conditions, riparian condition and sediment delivery to streams). This included an overview assessment of roads, channels, riparian areas, respective waterworks infrastructure and existing cutblocks;
- Assessed sediment erosion and delivery from point sources, existing and proposed roads and cutblocks and other landuses;
- Reviewed proposed development within the watershed and identified potential hydrologic or water quality concerns;
- Reviewed other landuse activities within the watershed and identified potential hydrologic or water quality concerns;
- Identified sensitive areas or zones in the watershed, that may have hydrologic and water quality concerns for further forest development; and,
- Identified specific sites of concern (e.g. road crossings, surface erosion issues and impacted channels) and assigned a field stop site number to accommodate further review or remediation.

Task 4 - District of Peachland Meeting

Met with the District of Peachland to understand their drinking water related issues/challenges and process for water management. An initial meeting was held November 7, 2017 with J. Mitchell, P.Eng., Director of Operations, District of Peachland; Don Dobson P.Eng., Dobson Engineering Ltd.; Sue Lapp, P.Geo., Climaterra Consulting Ltd.; and, Jamie Skinner, RPF, Tolko Industries Ltd. This meeting was used to obtain existing information regarding forest development concerns in the watershed. A second meeting was held February 26, 2018 with the District of Peachland, FLNR and the forest licensees (Tolko Industries Ltd., BC Timber Sales, Ntityix Resources LP and Gorman Bros. Lumber Ltd.) to discuss the watershed and to develop a list of preliminary options for mitigating issues identified in the watershed. At the meeting a framework for communicating and addressing watershed issues was discussed.

Task 5 – Reporting

Completed a watershed assessment report consistent with the strategies identified in licensees' Forest Stewardship Plans and assessed the risk of whether the *Forest Planning and Practices Regulation* (Section 8.2) objectives will be conserved as a result of the proposed forest development and provided recommendations for the proposed and past development to minimize or mitigate potential hydrologic hazards. Information included the following:

- The current watershed condition and the future hydrologic and water quality conditions from proposed development on the District of Peachland's water intake/water supply,

- Identification of hydrologic sensitive areas that are at risk to future forest development,
- Current and future ECAs for the watershed based on revised snow recovery estimates for pine dominated forests in the interior British Columbia (Extension Note 116, Winkler and Boon 2015),
- A risk analysis and recommendations to minimize potential hydrologic effects associated with the proposed and past development within the watershed,
- Tabular summary of issues identified from the field review (e.g. channel condition/stability, riparian area condition, and sediment erosion/delivery issues); and,
- Long-term ECA projections over the next 20 years based on the licensees' current level of proposed forest development (refer to Appendix F).

The underlying methodology for the assessment of this watershed was based upon the assessment components (i.e. peak flows and hydrological recovery, sediment source survey, reconnaissance level channel assessment procedure and a riparian assessment) that are outlined in the Watershed Assessment Procedure, Guidebook (1999). Assessment of the condition of stream channels was based on the Channel Assessment Procedure Field Guidebook (1996). Although the *Forest and Ranges Practices Act* has superseded the use of these guidebooks, these procedures are still considered relevant guidance for overview assessments of watersheds. Riparian function is based on criteria used to determine properly functioning condition as described by Tschaplinski and Pike (2010). The primary focus of this assessment was to qualitatively assess potential land-use effects on the physical hydrologic processes of the watershed.

1.3 Hydrologic Indicators and Consequences

The hydrologic indicators and the potential hydrologic responses associated with forest development were evaluated using a partial risk assessment framework similar to Wise et al. (2004). This report was also based on Tolko's Watershed Risk Management Framework that is currently being finalized.

Table 1.1 summarizes the hydrologic indicators that were used in this assessment to evaluate the current condition of the watershed and whether proposed forest development would cause material adverse impacts on the quantity, quality or timing of flows at the District of Peachland's water intake. These hydrologic indicators were also used to evaluate potential material adverse effects to other elements at risk (e.g. fish and fish habitat, private property and infrastructure and human safety).

Table 1.1. Summary of hydrologic indicators, potential hydrologic responses and potential consequences.

Hydrologic Indicators	Potential Hydrologic Response (Hazard Type)	Consequence
Watershed Characteristics - Elevation range - Aspect - Size - Drainage density - Water storage (lakes, wetlands) - Soil drainage - Terrain stability - Terrain connectivity to streams - Soil erosion potential	Runoff generation response - Increases in peak flows - Changes in water yield Surface erosion potential and sediment loading leading to reduced water quality	Sensitivity of the watershed to forest development that could affect water quality, cause damage to infrastructure or human safety
Peak Flows - ECA - Drainage density and soil drainage - Potential for synchronization of flows - Attenuation of peak flows (e.g. presence of lakes and reservoirs)	Increases in peak flows resulting in reduced channel stability or water quality	Flooding, damage to fish habitat, damage to water intakes, damage to infrastructure and human safety
Water Yield and Low Flows - ECA - Reservoir storage capacity - Ability to fill reservoirs on an annual basis	Increases in water yield resulting in reduced channel stability or water quality	Flooding, damage to fish habitat, damage to infrastructure and human safety
	Decreases in water yield (i.e. reduced low flows) reducing flows for fish or water supply	Impacts to fish and fish habitat and reduced water supply
Timing of Runoff - ECA - Amount of forest development on southern and southwesterly aspects - Reservoir storage capacity	Shifts in timing of runoff (e.g. earlier peak flows) that could have implications for stream water supply or fish	Impacts to water supply and fish (e.g. water purveyor must rely on reservoir storage earlier in the drier summer months during the irrigation season that increases the risk of water shortages)
Channel Disturbance/Sensitivity - Channel type - Channel disturbance indicators	Stability of channels that could have implications on water quality or fish	Impacts to water quality, fish, fish habitat and infrastructure
Surface Erosion and Delivery of Sediment to Streams - Evidence of surface erosion - Connectivity of surface erosion to stream channels partially based on bare-earth mapping with 5 m contours	Surface erosion and delivery of sediment from roads, cutblocks and other watershed disturbances (e.g. grazing, recreation) that result in reduced water quality	Impacts to water quality, fish, fish habitat, infrastructure or human safety
Mass Wasting - Number of landslides - Cause/initiation of landslides - Connectivity of hillslopes and landslides to stream channels	Landslides and debris flows delivering sediment and debris to stream channels that could have implications on water quality, property or water intake infrastructure	Impacts to water quality, fish, fish habitat, infrastructure and human safety
Riparian Function and Condition - Channel stability, channel bank stability, in-stream wood characteristics, channel morphology, fish cover diversity, riparian soil disturbance, shade and microclimate, vegetation form and structure, windthrow frequency	Riparian area function (e.g. properly functioning condition has been altered) resulting in reduced water quality or channel stability	Impacts to water quality, fish, fish habitat, infrastructure and human safety.

2.0 BACKGROUND INFORMATION

2.1 Peachland Creek Watershed - General Watershed Characteristics

Peachland Creek is a community watershed for the District of Peachland. The watershed drains from the Thompson Plateau on the west side of Okanagan Lake near the District of Peachland, BC (Figure 1.1). The watershed area upstream of the District of Peachland's intake is approximately 126 km^2 and 145 km^2 above the confluence of Peachland Creek and Okanagan Lake. Elevations in the watershed range from 587 m at the District intake to ~1820 m near Brenda Mines. Major tributaries that drain into Peachland Creek include Greata Creek and Mile Creek. Tributaries to Greata Creek include Bolivar Creek and Bolingbroke Creek. Licensed storage within the watershed include the Peachland Lake reservoir and Glen Lake reservoir.

2.2 Watershed Characteristics and Sensitivity to Forest Development

The inherent physical characteristics of a watershed determine a watershed's sensitivity to forest development, independent of the development activities themselves. The physical characteristics (e.g. slope gradient, aspect, size of watershed, elevation range, drainage density) of a watershed have been shown to play a role in amplifying or mitigating snowmelt generated peak flow responses associated with forest development (Green and Alila 2012). For example, Green and Alila (2012) suggested that peak flow response to disturbance and watershed characteristics should have the greatest effects in small watersheds with steep slopes, uniform aspect, dense forest cover and high drainage density. Also terrain attributes (e.g. steepness of watershed, upslope connectivity to streams, soil erodibility, amount of Class IV and V terrain) play a role in determining the response to potential disturbances associated with forest development that can affect channel geomorphology and sediment loading.

Based on the physical characteristics of the watershed, Peachland Creek is considered moderately sensitive to forest development. This statement is based on the following description of watershed characteristics.

Watershed Size – The Peachland Creek watershed is considered a medium sized watershed; therefore, the effects of forest development in upland and headwater areas on streamflow and water quality do not necessarily cause direct impacts to the water supply since medium to larger sized watersheds have increased opportunities for surface and subsurface detention and retention of water, desynchronization of snowmelt and attenuation of streamflow and sediment within the stream channels, lakes and wetlands.

Elevation Range - Elevations range from approximately 850 m to 1820 m in the Peachland Creek sub-basin and range from approximately 850 m to 1725 m in the Greata Creek sub-basin. Forty percent of the watershed is situated above 1340 m (H_{40} elevation). This H_{40} elevation is considered to be relatively low in elevation; therefore, this watershed is considered to have only moderate snow accumulation and is not considered to have the potential for relatively large magnitude and high powered spring freshet, snowmelt events. The moderate snow accumulation is also reflected in the predominant biogeoclimatic zones situated in the watershed. The main BEC zones in the watershed include the MSdm2 zone situated roughly above the H_{40} elevation and the IDFdk2 zone situated in the lower half of the watershed. A small portion of ESSFdc2 is present in the upper ~10% of the watershed in the northwest and the PPxh1 zone is present in the lower watershed below the District of Peachland water intake (Golder 2010, Grainger 2010).

Slope Aspect - Peachland Creek flows in a southeastern to southerly direction with the Peachland Creek sub-basin predominately having a southeasterly to south aspect. South-facing aspects are considered to be the most sensitive to forest disturbance and changes in peak flows since removal of the forest canopy can increase the net radiation associated with the conversion from longwave-dominated snowmelt beneath the forest canopy to shortwave-dominated snowmelt in harvested areas (Green and Alila 2012). For this reason the Peachland Creek sub-basin is considered to have a high potential for changes in streamflow (i.e. peak flows, timing of flows) in relation to its slope aspect. Greata Creek flows almost due east with the slopes of the Greata Creek sub-basin being approximately equally split between southern and northern aspects. North-facing aspects tend to be less sensitive to changes in forest canopy since the potential for increased shortwave radiation to increase snowmelt is lower due to shading of the incoming solar radiation by the hillslopes. For this reason the Greata Creek sub-basin is considered to have a moderate potential for change in streamflow.

Slope Gradient, Terrain Stability and Hillslope Connectivity - The majority of the upper portions (i.e. above elevation ~1000 m) of the Peachland Creek community watershed are located on the southeastern edge of the Thompson Plateau that is generally benign, gently rolling plateau terrain (slope gradients <30%) with limited to no evidence of slope instability. Small headwaters streams situated in these upper areas tend to be weakly incised and relatively low gradient (< 10% gradient). As noted by Golder (1998) the terrain on the plateau is considered to be relatively stable characterized by Class I or Class II terrain stability classes that indicate a low potential for landslides.

Lower portions of the watershed are characterized by low gradient (slope gradients <30%) to moderately steep terrain (slope gradients ranging between 30 to 60%). The upper reaches of the mainstem of Peachland Creek situated above Peachland Lake is incised into a moderately steep valley (gradient ranging from 50% to 70%). The Peachland Creek mainstem situated below Peachland Lake is confined by a relatively narrow, steep sided valley consisting of post glacial terraces and bedrock canyons. The upper to mid reaches of Greata Creek are moderately confined by glacial tills and terraces with the lower stream reaches confined by bedrock. Steep sidewall slopes situated along Peachland Creek and Greata Creek have been classified Class IV terrain with a small percentage of Class V terrain situated along the lower mainstem of Peachland Creek (refer to Appendix A, Watershed Condition Map). These terrain classes typically indicate a high potential for landslides. Overall the watershed is considered generally stable however steep slopes situated adjacent to Peachland Creek and, to a lesser extent, along Greata Creek are considered susceptible to erosion and/or mass wasting.

For the most part the upland plateau terrain is disconnected from the stream network; therefore, the efficiency of water and sediment transport are somewhat buffered and not directly connected to the stream network. However, the steeper valley slopes that extend along the mainstem of Peachland Creek and Greata Creek tend to be more sensitive to potential changes in water and sediment inputs given that the transport of water and sediment to the stream channels is more directly connected to the hillslopes. These steeper areas tend to be the most sensitive to forest development in regards to potential impacts on water quality and quantity.

Soil Drainage and Drainage Density – Drainage basin characteristics such as soil drainage and drainage density affect the sensitivity of a watershed to runoff. For example, watersheds with steep terrain, shallow/poorly draining soils with high drainage densities are likely more sensitive to changes in peak flows than watersheds with relatively flat terrain, deep soils and low drainage densities. Soils in the Peachland Creek watershed are typically well drained, moderately coarse to coarse textured morainal material with some steep slopes and infrequent poorly draining, glaciofluvial sediments. The drainage density of streams in the watershed is low due to the presence of predominantly well-drained soils and gentle, plateau terrain situated throughout the majority of the watershed (Golder 2010, Grainger 2010).

Streamflow description **-** Peachland Creek is a snow dominated hydrologic system; however, in the spring of 2017 peak flows exceeding a 1 in 50 year event were associated with rain and snowmelt (Appendix D). Total annual precipitation ranges from 400 mm at an elevation of 345 m near Okanagan Lake to 650 mm near Brenda Mines at an elevation of 1520 m. At higher elevations approximately 75% of the annual precipitation falls as snow and is largely stored until the spring freshet snowmelt. It is estimated that roughly 75% of annual runoff occurs between April and July in response to snowmelt.

Streamflow has been recorded at a number of hydrometric stations in the watershed in the seventies and early eighties (Golder 2010). Based on streamflow data collected on Peachland Creek at the mouth (hydrometric station #08NM159) from 1969 to 1982 the mean annual discharge was 0.384 m^3/s (Golder 2010) with a maximum daily discharge of 9.26 m^3/s occurring in 1972. Naturalized mean annul discharges (i.e. natural flows are flows that would exist if storage reservoirs didn't capture any water and water intakes did not operate) were estimated to be 0.570 m^3/s (Summit 2004). The mean annual discharge is lower than the naturalized mean annual discharge; therefore, it appears that storage of streamflow runoff during spring snowmelt has attenuated peak flows at the District of Peachland water intake (see below for further discussion).

An active hydrometric station (Greata Creek near the Mouth, Stn #08NM173) is situated on Greata Creek approximately 600 m upstream from the confluence with Peachland Creek. Streamflow data has been collected at this station from 1970 to present. The Greata Creek hydrometric station and the nearby Camp Creek hydrometric station (Camp Creek at Mouth near Thirsk, Stn #08NM134) have been used as a paired-catchment study to investigate the effects of harvesting on streamflow for Camp Creek (Cheng 1989, Moore and Scott 2005, Green and Alila 2012). The three largest instantaneous peak discharges recorded on Greata Creek were 2.67 m^3/s in 2017, 2.53 m^3/s in 1997 and 2.37 m^3/s in 1972 (refer to Appendix D). Based on this information Greata Creek exceeded a 1 in 50 year peak flow event in 2017 which is consistent with the wide-spread flooding that occurred throughout the Thompson/Okanagan region in 2017. This event was related to high snowmelt in the mid-elevation range (~900 m to 1300 m) of the watershed in conjunction with high rainfall (Appendix D).

Presence of Lakes and Wetlands - Very few lakes or wetlands are present within the watershed. The two largest lakes in the watershed include Peachland Lake and Glen Lake. Both of these lakes are regulated by the District of Peachland for water storage.

Storage of streamflow runoff during spring snowmelt can potentially attenuate downstream peak flows. Although only about 20% of the watershed area is upstream of Peachland Lake approximately 75% of the mean annual runoff flows into Peachland Lake and the much smaller Glen Lake reservoirs (Dobson 2006). As described by Grainger (2010) stream discharge peaks on Peachland Creek are "somewhat moderated" by the storage volume of the Peachland Lake reservoir but approximately 60% of the high elevation snow zone situated above the H_{40} elevation is uncontrolled and does not pass through the Peachland Lake reservoir.

Attenuation of peak flows in Peachland Creek below Peachland Lake due to storage of streamflow during spring snowmelt is also consistent with information provided by the District of Peachland (S. Grundy and J. Mitchell, personal communication, November 30, 2017). The District of Peachland manages the Peachland Lake reservoir so that full pool is 2 feet below the spill elevation to allow for some freeboard to prevent spilling that could possibly effect water quality and to attenuate large flows down Peachland Creek (S. Grundy, personal communication, November 30, 2017). In the past eleven years the reservoir has spilled six times (~50%) (Table 2.1).

It should also be noted that during the spring of 2017 streamflows on Greata Creek peaked approximately 6-9 days prior to filling of the Peachland Lake reservoir (refer to Appendix D). This indicates that in the spring of 2017 the large peak flow generated from mid-elevation snowmelt and rainfall was most likely not synchronized with snowmelt from the higher elevations (>1600 m) in the watershed.

Table 2.1. Summary of spill start date and end date over the Peachland Lake reservoir spillway (S. Grundy, personal communication, November 30, 2017). Also shown is the annual peak flow date recorded on Greata Creek.

Year	Spill start	Spill end	Greata Creek Peak Flow Date
2017	May-30	Jun-07	May-12 and May-23
2016	Jun-05 Jul-13	Jun-15 Jul-22	Apr-21
2015	No spill	-	May-1
2014	No spill	-	May-17
2013	No spill	-	May-8
2012	No spill	-	May-17
2011	No spill	-	May-26
2010	Jun-04	Jun-15	May-20
2009	No spill	-	May-19
2008	Jun-11	Jun-27	May-19
2007	Jun-06	Jul-10	May-14

Low flows in the summer and winter are also moderated in the watershed through the release of stored water from Peachland Lake to provide water for irrigation and fish conservation flows. BC Environment has a conservation license of 3084 ML on the Peachland Lake reservoir. This license is used to manage low flows through the release of water from the Peachland Lake reservoir (Dobson 2006; Urban Systems 2015b).

***Soil Erosion Potential and Delivery* -** The majority of soils within the watershed tend to have low to moderate soil erosion potential (Maynard 2001). The majority of soil textures are characterized by coarse-grained gravel or sand tills that are well-drained. Even though the majority of the watershed is characterized by soils with low to moderate soil erosion potential, portions of the watershed are characterized as having high surface erosion potentials (refer to Appendix A, Current Condition Map showing Surface Erosion Potential). These areas with high surface erosion potential tend to be located along the moderately steep to steep valley sidewalls along the mainstem of Peachland Creek and Greata Creek.

Generally surface erosion is not a major concern in undisturbed or clearcut areas with intact ground vegetation (e.g. grasses and debris) throughout the watershed; however, roads that are situated on erodible landforms (e.g. glacio-fluvial or glacio-lucustrine landforms) and directly adjacent and/or connected to perennial streams have been identified as high erosion concerns (refer to Urban Systems 2015c, Golder 2010, Grainger 2010).

2.3 Peachland Creek Water System – Water Supply Infrastructure

The District of Peachland currently relies on three surface water sources: Peachland Creek, Trepanier Creek, and Okanagan Lake (District of Peachland 2016) that supplies water to a population just exceeding 5000 people. The Peachland Creek distribution network supplies approximately two-thirds of the water to the west and south end of the District. It also supplies water to the properties in the Ponderosa area and a portion of the downtown area. The Trepanier Creek distribution network supplies the remaining one-third of the water to the remainder northern portion of the District. Okanagan Lake can be utilized as a standby as an emergency source of water for the Trepanier distribution network. For example, during spring freshet water is pumped from Okanagan Lake to the Trepanier Creek distribution network since the water from the lake is less turbid than water from Trepanier Creek. All the distribution systems currently use chlorine gas as its primary disinfectant to inactivate bacteria, viruses and giardia cysts (Dobson 2006, Urban Systems 2007 and 2015a).

Currently the District is in the process of "eventual abandonment of the Trepanier Creek water source (Urban Systems 2015a, page 2)." through the installation of a water treatment plant facility at the Peachland Creek water intake to improve water quality treatment and to meet water quality standards and objectives set by the BC Ministry of Health (Urban Systems 2007, Urban Systems 2015a, District of Peachland 2016). The water treatment plant is projected to be completed in 2020 and once completed all of the District's water will be obtained from the Peachland Creek watershed (J. Mitchell, personal communication, November 7, 2017). It should be noted that in order for the District to supply enough water to meet the entire demands from the Peachland Creek watershed current water licenses on Trepanier Creek would remain in place. Water from the Trepanier Creek watershed would either be diverted to the Peachland Reservoir from the MacDonald Creek or from the Brenda Mine water treatment plant (Urban Systems 2015b).

Currently water from Peachland Creek at the District intake is diverted into a series of two settling ponds that serve to settle suspended solids carried in water from upstream (Figure 2.1). A chlorine contact tank is situated immediately downstream of the settling ponds. The chlorine contact tank provides sufficient chlorine contact time to treat pathogenic organisms such as *giardia lamblia* which is responsible for beaver fever. From the chlorine contact tank, water enters the distribution system (Urban Systems 2007). In the near future the District will also utilize a conventional filtration system to provide barriers against micro-organisms such as Giardia and Cryptosporidium (Urban Systems 2015a).

As stated by Urban Systems (2015b) the District of Peachland currently holds irrigation and domestic licenses on Peachland Creek at the intake totaling 7,237 ML. This is supported by upstream storage licenses on Peachland Reservoir (4,070 ML) and Glen Lake Reservoir (308 ML). The District also holds a diversion license in MacDonald Creek to divert 617 ML of water to Peachland Lake reservoir. There is presently no access to MacDonald Creek for water under this license. For further details regarding the availability of water, future plans for water supply and the current diversion of water refer to the Urban Systems reports (2015a and 2015b).

It should be highlighted that the main concern identified by the District of Peachland in relation to the Peachland Creek watershed and drinking water quality is sediment transport that results in degraded drinking water quality due to increased turbidity and microbial organisms that has implications for human health and operational costs (Golder 2010; Urban Systems 2015c). Reduced water quality as result of increased sediment and turbidity have been an ongoing issue for the District and have resulted in the District issuing water quality advisories and, at times, boil water notices each year for water users on the Peachland Creek water system during these high turbidity events (Urban Systems 2015c). These high turbidity events are associated with spring freshet and heavy rainfall events and appear to be getting worse (i.e. higher turbidity levels) over the past few years (J. Mitchell, personal communication, November 30, 2017; Urban Systems 2015c).

Figure 2.1. Settling ponds at the District of Peachland water intake (image copied from the RDCO GIS Mapping website, URL: http://www.peachland.ca/gis accessed February 15, 2018).

2.4 Fish Values

Peachland Creek is also considered to have high fisheries values. Fish species identified in the watershed include kokanee, rainbow trout, brook trout and sucker. It should be noted that the lower 1.2 km of Peachland Creek situated below Hardy Falls and above Okanagan Lake are considered important spawning habitat for kokanee (Grainger 2010; Urban Systems 2015c). More detailed information regarding fish status in the watershed is provided in Grainger (2010) and Urban Systems (2015c).

2.5 Key Resources at Stake (Elements at risk)

Key resources at stake (elements at risk) in the watershed are summarized below (Table 2.2). This information was used to evaluate the vulnerability (i.e. the robustness of the value and its exposure to a source of risk) of key resources (i.e. domestic water and public safety) in the watershed and its sub-basins from hydrologic hazards that may be associated with forest development. These vulnerability ratings are consistent with the ratings utilized by Grainger (2010).

Table 2.2. Summary of elements at risk and the consequence of each element.

Element at Risk	Vulnerability
Water quality at the District of Peachland water intake (primarily turbidity and human-introduced pathogens)	**H** (Decreased water quality results in higher treatment costs and issuing of water quality advisories and, at times, boil water notices)
Potential damage to the District of Peachland's water intake infrastructure as result of landslides or disturbance to stream channels	**M** (Water intake is considered moderately robust to the majority of channel disturbances)
Changes to water quantity or timing of flows that could have implications for stream water supply, channel stability or fish	**M** (Current reservoir storage, capacity and availability of water is adequate to minimize moderate changes in water quantity or timing of flows).
Fish populations and habitat (primary focus is kokanee salmon habitat situated in the lower 1.2 km of Peachland Creek)	**H** (High value spawning habitat is situated in the lower 1.2 km of the watershed which is currently unstable and is susceptible to changes in streamflows)
Infrastructure not related to municipal water supply (e.g. Highway 97 bridge crossing, residential homes situated directly adjacent to Peachland Creek below Renfrew Road and other road/stream crossing infrastructure).	**M** (Residential homes are directly adjacent to the unstable, lower reach of Peachland Creek and the Highway 97 bridge has low clearance to accommodate debris and high flows)

This watershed can be divided into two hydrologic zones. The first zone is the unbuffered area immediately upstream of the intake and downstream of all reservoirs (e.g. Peachland Lake and Glen Lake reservoirs). In this zone any impacts to water quality (i.e. sediment inputs) and quantity are a higher risk since it has a higher likelihood of effecting water quality or quantity at the intake. The second, upper zone, includes those areas upstream of a reservoir (e.g. Peachland Lake reservoir and Glen Lake reservoir). Runoff from the upper zone is stored before being released to the intake. Impacts to water quantity and quality in the buffered areas are considered a lower risk as measured at the intake due the benefits of water storage.

The majority of the landbase in the Peachland Creek watershed is considered multiple use which includes recreation use (e.g. off-road vehicle use), camping, hunting, fishing, range use and forestry. For detailed information regarding other land uses other than forestry and their potential effects on water quantity and quality in the watershed refer to the Watershed Assessment Report for Drinking Water Source Protection (Golder 2010).

2.6 Key Reference Documents

Numerous past assessments have been completed in this watershed (refer to references for a detailed list of the most relevant reports to this assessment). Although not summarized here these reports were reviewed to better understand the past and current issues and conditions of the watershed. Where relevant issues identified in these reports have been included in this report.

3.0 WATERSED ASSESSMENT - CURRENT CONDITION

The current condition of the watershed was evaluated using five primary hydrologic areas of focus: streamflows (i.e. peak flows, water yield, low flows and timing of flows), channel disturbance/sensitivity, surface erosion, mass wasting and riparian condition. These hydrologic areas of focus were evaluated in conjunction with the overall inherent physical characteristics of the watershed. These evaluations included both an office and field reconnaissance review completed on August 18, 19, 22 and September 10, 2017 to confirm the current condition of the watershed and to identify potential hydrologic risks associated with past and proposed development.

3.1 Watershed Equivalent Clearcut Area (ECA) and Streamflow

3.1.1 ECA and Potential for Increased Peak Flows

For purposes of this assessment the watershed was divided into two sub-basins (Peachland Creek sub-basin and Greata Creek sub-basin) with one residual area (refer to Figure 1.1). The Peachland Creek sub-basin was also broken into two drainage units (Mid Peachland Creek and Upper

Peachland Creek) in order to identify the ECAs above and below Peachland Lake. The primary point of interest (POI) used for the assessment was the District of Peachland water intake. This POI was used as the lowest most point in the watershed for all ECA calculations.

The general consensus from both paired catchment studies and computer simulations is that peak flows and water yield associated with spring snowmelt in small to moderate sized watersheds (<100 km^2) can increase in magnitude and frequency after forest harvesting (MacDonald et al. 1997, Austin 1999, Scherer and Pike 2003, MacDonald and Stednick 2003, Schnorbus et al. 2004, Moore and Scott 2005, Grant et al. 2008, Green and Alila 2012, Zhang and Wei 2014). As noted by Winkler et al. (2010) risks of potential peak flow increases associated with forest harvesting in snow dominated hydrologic regimes are considered low when up to 20% of a catchment is harvested but risks increase as harvest levels exceed 30%. Statistically significant increases in annual daily peak flow magnitudes for various return periods (e.g. 2 year, 10 year and 50 year) have also been shown after a watershed has been harvested (Schnorbus et al. 2004; Green and Alila 2012, Winkler and Boon 2017). The hydrological or ecological importance of these changes in peak flow magnitude and frequency are dependent upon stream channel morphology (Schnorbus et al. 2004).

The likelihood of a significant peak flow increase (increased frequency and/or magnitude) in the watershed, sub-basins and residuals areas was assigned a rating based upon the above information and the ECA above the H_{40} line. These ratings are based on research that has estimated the relation between percent increase in daily peak flow with the ECA (percent of a watershed harvested) (Schnorbus et al. 2004; Green and Alila 2011; Winkler and Boon 2017) For reference, the following ECAs above the H_{40} line were categorized as having a low, moderate or high likelihood of increased peak flows for the watershed, sub-basins and residual areas:

- <30% ECA above H_{40} = low likelihood of peak flow increases
- 30 to 40% ECA above H_{40} = moderate likelihood of peak flow increases
- >40% ECA above H_{40} = high likelihood of peak flow increases

The low rating for the likelihood of peak flow increases indicates that although the frequency and magnitude of peak flows may increase, the increases are likely not measureable or are not expected to have significant material adverse effects on channel stability or watershed conditions. A moderate rating for the likelihood of peak flow increases indicates that increases in the frequency and magnitude of peak flows are possible but the effects are not expected to be large or have detrimental effects to the channel stability or watershed conditions. A high rating for the likelihood of peak flow increases indicates that significant increases in peak flow magnitude or frequency are likely and that there is an increased potential for detrimental effects to channel stability or watershed conditions.

It should be noted that these ratings based on ECA are just one indicator used to evaluate the potential for hydrologic change within the watershed (Winkler and Boon 2017). As highlighted by Winkler and Boon (2017) overall affects to the watershed condition (e.g. channel stability, water quantity and quality) were further evaluated using a combination of watershed attributes such as the watershed size, aspect, elevation, distribution of cutblocks, observed effects of road drainage and sensitivity of channels to altered peak flows.

The H_{40} elevation (snow sensitive zone) assumes that the upper 40% of the watershed is snow-covered during spring freshet and contributes meltwater during the time of peak flow. Changes to peak streamflow are assumed to be more sensitive to forest development above this contour elevation. As already mentioned forty percent of the watershed is situated above 1340 m (H_{40} elevation).

The current ECA's for the watershed are provided in Table 3.1. The overall ECA and the ECA above the H_{40} elevation for the entire Peachland Creek watershed are 20% and 25%, respectively. At the sub-basin level the current ECA and the ECA above the H_{40} elevation are 30% and 34% for the Peachland Creek sub-basin and 14% and 15% for the Greata Creek sub-basin. The current ECA and the ECA above the H_{40} elevation above Peachland Lake (Upper Peachland Creek drainage unit) are 33% and 36%. The current ECA and ECA above the H_{40} elevation for the Mid Peachland drainage unit are 26% and 26%. At the watershed level the ECAs are considered a low likelihood for increased peak flows. At the sub-basin level, the current ECAs are considered to have a moderate likelihood for increased peak flows in the entire Peachland Creek sub-basin and the Upper Peachland Creek drainage unit. Current ECA's in the Greata Creek sub-basin and Mid Peachland Creek drainage unit are considered to have a low likelihood for increased peak flows.

The mortality due to mountain pine beetle in unlogged pine stands (e.g. pine stands with greater than 30% mortality) has also been included in the summary of ECAs. This mortality information is based on current forest cover information that describes the percentage of stand mortality and years since attack (Forsite 2018). As shown in Table 3.1 the ECA contribution from current estimates of MPB mortality in unlogged pine stands are in the 0 to 2% range; therefore, the peak flows hazards associated with MPB mortality are considered small and are currently not considered a major issue in regards to potential increases in peak flow. This statement is also consistent with findings that unlogged pine stands that experience mortality due to mountain pine beetle are considered to have lower likelihood of increasing snowmelt generated peak flows as compared to clearcut harvesting due to factors such as shading from standing dead trees, presence of non-pine species within the forest stand and growth of understory vegetation (Lewis and Huggard 2010, Winkler et al 2015).

Table 3.1. Summary of current ECA's for the Peachland Creek watershed to the end of December 31 2017. Note: ECAs were based on revised snow recovery estimates for pine dominated forests in the interior British Columbia using the methodology suggested in Extension Note 116 (Winkler and Boon 2015).

Sub-basin (or Drainage Unit)	Area (ha)	Total ECA		Area Above H_{40}	ECA Above H_{40}		ECA Above H_{40} without a Forest Health Factor (e.g. No Mature Pine Mortality)	
		(ha)	(%)	(ha)	(ha)	(%)	(ha)	(%)
Upper Peachland Creek Drainage Unit	2416	793	33	1860	662	36	626	34
Mid Peachland Creek Drainage Unit	4057	1067	26	892	235	26	233	26
Entire Peachland Creek sub-basin (includes Upper and Mid Peachland Creek)	6473	1860	29	2752	897	33	859	31
Greata Creek Sub-basin	4496	641	14	2029	301	15	300	15
Watershed	12553	2526	20	4780	1198	25	1160	24

Note: H_{40} elevation for the snow sensitive zone was calculated to be 1340 m based upon the entire watershed area situated above the District of Peachland water intake.

3.1.2 Water Yield, Low flows and Timing of Flows

Detrimental or material changes to the other components of streamflow such as annual water yield, low flows and timing flows associated with the existing level of forest development are considered to have a low likelihood of having a negative impact to downstream water users and supply.

Annual Water Yield – Reductions in annual water yield associated with forest development are often identified as a concern for water supply; however, the general consensus is that forest development has no effect or increases annual water yield. For example, Stednick (1996) showed that measureable water yield increases are undetectable below harvest levels of 15% or could increase in direct proportion with harvest levels (ECA levels) in snow dominated hydrologic regimes similar to the Peachland Creek watershed; therefore, changes in annual water yield are expected to be unchanged or at elevated levels due to increased snow accumulation and reduced evapotranspiration and interception as result of past forest harvesting. Decreases in water yield are unlikely and do not typically occur in snow dominated hydrologic regimes (Stednick 1996, Scherer and Pike 2003). This previous information is also consistent with research completed in two paired watershed studies. In the first study, Moore and Scott (2005) analyzed hydrometric data collected from Camp Creek and Greata Creek in which harvesting of 27% of the area of Camp Creek resulted in annual water yields increasing up to 60 mm higher than predicted values but the differences were found not be statistically significant. In the second study, Winkler et al. (2016) found that logging 47% of 241 Creek (situated directly east of Penticton, B.C.) resulted in a small effect (5% increase) on annual water yield in comparison to the control watershed (240 Creek).

It should be noted that as forest stands regenerate water yield increases will most likely return to undisturbed forest stand conditions or become reduced as result higher water demand by juvenile forest stands.

Low Flows - Low flows are also not expected to decrease due to forest development (Scherer and Pike 2003) since forest harvesting reduces interception losses and evapotranspiration especially during the summer, growing season. Based upon the research, changes in low flows have been shown to be either undetectable or increase subsequent to forest harvesting; therefore, even if low flows increase the amount of increase is typically small (< 2mm) given the relatively low discharges that occur during the summer to winter low flow period. Adverse effects associated with the current level of forest harvesting on low flows and water supply are therefore considered a low hazard to water supply, fish or fish habitat.

An important consideration in Peachland Creek is the maintenance of low flows for fish in the summer to winter months especially for kokanee salmon that spawn and rear in the lower 1.2 km of Peachland Creek situated below Hardy Falls. As mentioned earlier low flows in the summer and winter are moderated in the watershed through the release of stored water from Peachland Lake to provide water for irrigation and fish conservation flows. BC Environment has a conservation license of 3084 ML on the Peachland Lake reservoir. This license is used to manage low flows through the release of water from the Peachland Lake reservoir (Dobson 2006; Urban Systems 2015b). Therefore, based on the controlled release of fish conservation flows it is unlikely that the current level of forest development has had a significant effect on low flows.

Timing of Flows - In watersheds that are snowmelt dominated shifts in peak flows and monthly water yields during the spring can occur as a result of changes in snow accumulation and snowmelt. Removal of the forest canopy can result in a faster rate of snowmelt and earlier melt of the snow pack (Winkler 2001, Winkler et al. 2005, Winkler et al. 2015). Shifts in the timing of peak flows or in the seasonal volume of water can have implications for summer low flows, reservoir storage and fish life cycles (e.g. migration patterns, rearing habitat quality and timing of migration).
In the literature the average date of peak flows that occurred subsequent to forest harvesting was quite variable. In a summary of nine paired watershed studies the date of peak ranged from an advancement of 18 days to no change compared to control watersheds (Scherer and Pike 2003). These findings are similar to Moore and Scott's (2005) analysis of data from Camp Creek and Greata Creek in which 27% of Camp Creek was logged in response to a mountain pine beetle infestation. In their analysis significant increases in April flows as well as significant advances in

the timing of peak flows relative to the control stream (Greata Creek) were observed. For example April flows were consistently higher in Camp Creek compared to Greata Creek following forest harvesting. Also peak flows occurred between 0 to almost 40 days later at Camp Creek as compared to Greata Creek prior to forest harvesting; however, following harvesting Camp Creek peak flows occurred on the same date as or one day earlier than those at Greata Creek (Moore and Scott 2005).

Recent research completed by Winkler et al. (2015) also observed a shift in the timing of monthly water yields from two relatively high elevation, spring snowmelt dominated sub-basins (~ 5 km^2) situated in the upper Penticton Creek watershed compared to an unlogged sub-basin. Fifty percent of both sub-basins were clearcut logged. In the first sub-basin (241 Creek), May water yields increased by 36% with water yields decreasing by 28% in June over predicted values. In the second sub-basin (242 Creek) April water yields increased by >100% and decreased by 16% in June and 22% in July over predicted values. Differences between observed and predicted monthly water yields in the remaining months were found to be not significant. Shifts in spring freshet peak flows and monthly water yield to earlier in the spring could prolong the low flow period once snowmelt has finished. This shift in spring freshet peak flows will likely also be exacerbated by global warming given warmer air temperatures and early spring snowmelt (Leith and Whitfield 1998).

Therefore, advancement in peak flows and water yield have likely occurred in the Peachland Creek watershed and its sub-basins in comparison to the available research; however, based upon the current level of harvest and the amount of available storage it is unlikely that the overall volume of water available for storage has been adversely affected. Based on this information there is a low likelihood that forest development has had an adverse or material effect on water supply as result of changes to the timing of peak flows. This conclusion is also based on the amount of storage available in the Peachland Creek watershed to capture and store spring freshet flows and to maintain low flows for fish conservation as required by District of Peachland.

3.2 Field Review

The following is a summary of the field inspections of the watershed. Detailed information regarding the field inspections are included in the enclosed maps referenced with field stop site numbers (Appendix A) and in the field inspection summaries (Appendix B). Field photos are also included in Appendix C.

3.2.1 Channel Disturbance/Sensitivity

In comparison to past assessment work (Grainger 2010; Urban Systems 2015) the following channel sections were considered disturbed:

- Field Stop #1 (Photos 1 to 3) - The lower reach of Peachland Creek directly above Okanagan Lake was actively eroded in the 2017 spring freshet event. Channel disturbance observed in this area included stream bank erosion, active bedload movement, downcutting of the streambed below several artificial weirs (riffles) that were constructed to improve spawning fish habitat and erosion of the abutments of two footbridges (Bridge #2 and #8) situated within Hardy Falls Regional Park. The majority of the bank erosion is likely attributed to the blockage and damming of debris and water behind several of the foot bridges that are present in the Hardy Falls Regional Park. As result water was diverted around the foot bridges causing significant channel and bank erosion.

- Field Stop #3 (Photo 4 to 8) – Peachland Creek situated adjacent to the Munro FSR and downstream to the District of Peachland water intake were impacted by a landslide that occurred below the Munro FSR on April 28, 2017. The landslide event resulted in a large pulse of sediment moving down the channel into the District of Peachland's settling ponds. In May 2017 approximately 120 m of channel was relocated to the eastern side of the channel valley to avoid further undercutting by Peachland Creek at the toe of the unstable slope and to minimize sediment deposition from upslope into the creek (D. Dobson, personal communication, November 7, 2017).

- Field Stop #55 (Photo 47) – The channel and the toe of the fill slope at the Bolivar Creek crossing at Peachland Main was eroded at the outlet of the culvert crossing (~1500 mm round culvert). Two proposed blocks (KP1146 and KP1147) are situated above this location; therefore, this crossing should be reviewed prior to upslope harvesting to ensure the culvert is adequately sized to accommodate peak discharges and to ensure further channel erosion is minimized.

- Field Stop #38 (Photo 38) – The north end of spillway from Peachland Lake drains onto a steep valley slope (>75%). Diversion of water over the steep valley slope has caused excessive channel down cutting and has created a large gully (~5 m wide x 6 m deep x 50 m long) in the glacial terrace at this location.

- Field Stop #58 (Photo 50) – Bolingbroke Creek situated in the ditchline of Peachland Main had eroded approximately 50 m section of Peachland Main. In May 2017 the channel was subsequently excavated to prevent further erosion along the road (personal communication, J. Hatch, Gorman Bros. Lumber Ltd., August 28, 2017).

- Field Stop #41 and 42 (Photo 40) – Two wood culverts situated at two tributaries to Peachland Lake have failed

Peachland Creek Sub-basin, Mainstem and Residual Area (Photo 8, 17, 18, 23, 27, 37) – Other than the channel reaches mentioned above the majority of mainstem reaches of Peachland Creek were considered to be similar to the condition of channels that were observed in past assessment work (Grainger 2010; Urban Systems 2015). The mainstem channel reaches of Peachland Creek (e.g. Field Stops 4, 8, 9, 15, 27, 28, 37, 40) from the Peachland Lake to the approximately 500 m above the District of Peachland water intake were considered stable cascade-pool and riffle-pool channels with limited evidence of channel disturbance (e.g. eroded channel banks, active bedload movement). Tributary channels were also considered to be generally stable with limited evidence of channel disturbance; however, there was evidence of localized channel disturbance at a few tributary crossings (e.g. Field Stops 22, 41 and 42). Channels above these tributary crossings were stable.

Based on these field observations and past assessment work the majority of the mainstem of Peachland Creek and its major tributaries are considered to have a moderate sensitivity to changes in peak flows or sediment delivery. The moderate channel sensitivity is associated to the cascade-pool and riffle-pool channel morphologies that contain medium sized textured beds and banks (e.g. cobble and gravels) that are susceptible to channel adjustment during significant peak flow or sediment delivery events. This moderate channel sensitivity rating is consistent with Grainger's (2010) assessment of the watershed.

It should be noted that although the spring freshet peak flow events in Greata Creek exceeded a one in fifty year return period, stream channels in the Peachland Creek sub-basin and along the majority of the Peachland Creek mainstem were not observed to be disturbed as result of the 2017 spring freshet events. The 2017 spring freshet events were primarily driven by higher than normal rainfall and mid-elevation (~1000 m to 1400 m) snowmelt that resulted in numerous mid elevation watersheds being flooded or disturbed throughout the Okanagan and Thompson regions. Hydrometric data is not available for the mainstem of Peachland Creek therefore it is difficult to determine how significant peak flows were on the mainstem of Peachland Creek but it is very likely that peak flows were not as significant as flows observed in Greata Creek due the relatively high elevation of the Peachland Creek sub-basin in comparison to the Greata Creek sub-basin and due to attenuation and storage of streamflows at Peachland Lake (refer to Table 2.1).

Lower Peachland Creek (Photo 1 to 3) - One exception to the moderate channel sensitivity is the lower reach of Peachland Creek situated below Hardy Falls. This lower reach is considered to have a high sensitivity to changes in peak flows. The high sensitivity of this lower reach is associated with the fact that this channel experienced active channel bed movement and bank erosion in the spring of 2017. This channel reach is also contains important kokanee spawning habitat and is directly adjacent to several residential homes situated directly along Peachland Creek between Renfrew Road and Highway 97. Channel morphology consists of riffle-pool channels with eroded channel banks that are considered to be the most sensitive to increases in peak flow.

Greata Creek Sub-basin (Photo 41, 43, 45, 48) - The majority of channel reaches along Greata Creek were observed to be partially aggraded to stable, cascade-pool and riffle pool channels with the lower 500 m of Greata Creek being characterized as a partially aggraded, step-pool channel. These channel reaches were similar to the condition of channels observed in previous assessment work (i.e. Urban Systems 2015); however, there was evidence of overtopping of channel banks, movement of the channel bed and elevated sediment bars as result of the 2017 spring freshet. As already mentioned, Greata Creek experienced relatively large spring freshet peak flows with a return interval exceeding a one in fifty year event. As result of this event mainstem channels remained relatively intact with only moderate levels of channel changes (e.g. moderately elevated sediment bars and limited bank erosion). Within this sub-basin tributary channels were also considered to be stable except for the localized channel disturbances that occurred on Bolivar Creek crossing on Peachland Main (Field Stop #55, Photo 47) and on Bolingbroke Creek directly adjacent to Peachland Main (Field Stop #58, Photo 50).

3.2.2 Surface Erosion and Sediment Delivery

An overview sediment source survey was conducted by reviewing a high proportion of roads and trails within the watershed. The sediment source survey was conducted to assess the surface erosion potential and sediment delivery potential from existing roads, trails and cutblocks. The overall potential of surface erosion and sediment delivery from existing roads and cutblocks were considered low in the majority of the watershed. A few high erosion concerns were identified (refer to the list below and Appendix B), that are considered to have a high likelihood of effecting water quality at the District of Peachland's water intake (i.e. elevated turbidity and suspended sediment levels).

Suspended sediment and elevated turbidity levels associated with the spring freshet and/or during high intensity rain storms have been an ongoing issue for the District of Peachland (Urban Systems 2015b). The main concerns of elevated suspended sediment in relation to drinking water are increased turbidity and micorganisms degrading water quality that increase health risks and increase treatment and operation costs (Golder 2010; Urban Systems 2015b). As result of elevated turbidity levels during spring freshet and/or high intensity rain storms the District of Peachland has had to issue water quality advisories and, at times, boil water notices for water users on the Peachland Creek water system for the past several years (Urban Systems 2015b, J. Mitchell, personal communication, November 7, 2017). Based on past information the elevated suspended sediment and turbidity issues appear to be mainly generated within the lower 7 km of the mainstem of Peachland Creek above the District of Peachland's water intake. Surface erosion issues in this area are associated legacy road issues (e.g. Brenda Mines Road, Munro FSR and Peachland Main between 6 to 8 km), stream bank erosion and presence of fine textured (glacio-lacustrine) deposits.

A qualitative rating of surface erosion potential was used in this assessment based upon visual estimates of the surface erosion potential and surface erosion delivery following the approach utilized by Maynard (2001) and B.C. Ministry of Forests (1999). Four classes of surface erosion potential (Table 3.2) and three classes of sediment delivery (Table 3.3) were used to determine the overall surface erosion potential.

Table 3.2. Four classes of observed surface erosion potential.

Surface Erosion Potential Rating	Description
Low - No significant problem with erosion observed	Limited to no evidence of erosion of fines from exposed mineral soils, road ditchlines or road surfaces. Also limited to no evidence of rill erosion or evidence of light erosion (typical of well armoured low-use roads)
Moderate - Some problems with erosion observed	Minor to moderate evidence of erosion of fines from exposed mineral soils, road ditchlines or road surfaces. Some evidence of rill erosion or small gullies.
High - Significant problems with erosion observed	Significant evidence of erosion of fines along road ditchlines or road ditchlines. Exposed mineral soils show significant rill erosion and/or gulling.
Very High - Severe problems with erosion observed	Severe surface and gully erosion exist. Large amounts of sediment have been eroded.

Table 3.3. Three classes of surface erosion delivery.

Surface Erosion Delivery Rating	Description
Low	No or minimal delivery of sediment from roads to any stream system. Sediment commonly delivered to forest floor with a very low to low likelihood of the eroded sediment entering a permanent stream or lake. Also no surface runoff evident or expected during snowmelt or high rainfall. Low likelihood that eroded sediment will reach a permanent stream or lake.
Moderate	Moderate level of sediment delivery. Sediment delivery is partially connected to the stream network. Disconnected by flat terrain and/or discontinuous drainage routes. Low gradients and discontinuous nature of the connecting drainage routes lead to deposition of most of the sediment originating on the roads. Moderate likelihood that eroded sediment will reach a permanent stream or lake.
High	High to very high level of sediment delivery. Sediment delivered directly or intermittently to the stream network via either or both ditch drainage or surface runoff routes. High or very high likelihood that eroded sediment will reach a permanent stream or lake.

The following sites were identified as surface erosion concerns:

- **Munro FSR** (Field Stop #2 and 4, Photo 6, 7, 9 to 14) – Approximately 200 m of the Munro FSR situated west of Peachland Creek considered the most significant contributor of fine sediment into Peachland creek that effects water quality at the District of Peachland Creek water intake. The water intake is situated only 250 m downstream. Also in the spring of 2017 a landslide (~1000 m^2) that entered Peachland Creek was initiated below the Munro FSR. This section of road is currently experiencing heavy industrial and recreation traffic (e.g. logging trucks and quad tours).
  - **High surface erosion potential** (high erosion potential and high sediment delivery)
  - **Recommendation:** Ongoing maintenance of existing sediment control measures are required. For example culvert inlets and sediment fences are infilled, sediment bumber strips along the bridge require maintenance and rubber belting is infilled and frayed by vehicle traffic. Additional erosion control measures should also be considered on the road such as road surfacing, hydro-seeding and cutbank stabilization to minimize surface erosion. This recommendation is particularly important if the road remains to be used by industrial and recreational traffic.
  - Ultimately the road (i.e. west of Peachland Creek that drains toward the creek) should be deactivated once forest development in the area is completed. However, if the road is intended to be used for continued industrial and recreational traffic (e.g. ATV quad tours) additional erosion control measures (as opposed to sediment control) should be utilized since erosion control is the most effective long-term solution to minimizing erosion and associated water quality issues. This last point is particularly important since the majority of erosion is associated with fine sediment (silts) that are very hard to contain once mobile.

    For purposes of clarification erosion control is the practice that inhibits erosion processes from occurring whereas sediment control is the practice of capturing sediment once it is displaced by erosion. Erosion control and sediment control when used in combination provide the greatest protection to reduced water quality.

- **Peachland Creek Channel Relocation** (Field Stop #3, Photo 5) – In 2017 a 120 m portion of Peachland Creek was relocated to the east of the valley bottom to prevent further undercutting of unstable slope situated below the Munro FSR. The banks of the relocated section of channel are currently exposed and are a source of sediment to Peachland Creek. The channel banks will likely stabilize with vegetation over time but are currently considered a high surface erosion hazard since mineral soil is currently exposed that is directly connected to the stream channel.

- **High surface erosion potential** (high erosion potential and high sediment delivery)
- **Recommendation:** Channel banks should be stabilized with grass seed, vegetation and additional riprap.

- **Brenda Mines Road ~2 km** (Field Stop #7, Photo 16) – Overland flow of water along the road combined with surface erosion is directly connected to Peachland Creek.
  - **High surface erosion potential** (moderate erosion potential and high sediment delivery)
  - **Recommendation:** Additional review of this portion of road is required to determine potential alternatives for sediment and erosion control.

- **Peachland FSR ~6km** (Field Stop #10-11, #16-21, Photo 19 to 22) – The switchback on Peachland Main ~6 km is a chronic sediment source to Peachland Creek. Evidence of surface erosion at this location includes rill erosion along the edges of the road fill, cutbank erosion and a recent landslide failure connected directly to Peachland Creek that occurred in the last few years.
  - **High surface erosion potential** (high erosion potential and high sediment delivery)
  - **Recommendation:** Additional review of this road section is required in order to develop appropriate erosion and sediment control measures. In development of measures to reduce sediment delivery the focus should be on erosion control (e.g. bank stabilization, road surfacing) as opposed to sediment control since the majority of erosion is associated with fine sediment (silts) that are very hard to contain once mobile. However, sediment control measures should also be used as a secondary barrier to the delivery of sediment to Peachland Creek.

- **Old Trail east of Peachland Creek** (Field Stop #22-26 and 32, Photo 24 to 29) – Numerous recent fill slope failures and road/channel erosion were present along an old trail that extends along the northeast side of Peachland Creek. These failures are likely related to the 2017 spring freshet, poor drainage on the old trails and, in some cases, upslope harvesting that occurred since 2015.
  - **High and Moderate surface erosion potential** (high/moderate erosion potential and high/moderate sediment delivery)
  - **Recommendation:** Permanent or semi-permanent deactivation of the road and connected trails is required.

- **Brenda Mines Road at Mile Creek** (Field Stop #33-36, Photo 30) – Excessive ditchline erosion was observed along the Brenda Mines Road as result of a plugged culvert at the Brenda Mines Road crossing at Mile Creek. A pond situated behind the plugged culvert was diverted along the road eroding the ditchline for ~400 m down the Brenda Mines Road. The diverted channel also overtopped and eroded a crossing on the Silver Lake Resort Road. In September 2017 the majority of the ditchline along the Brenda Mines Road was repaired however it is not known if the plugged and the undersized culvert at the Brenda Mines Road and Mile Creek has been repaired. If this crossing has not been repaired to accommodate higher flows there is still a high likelihood that further surface erosion will occur in association with high streamflow events.
    - **High surface erosion potential** (high erosion potential and high sediment delivery)
    - **Recommendation:** The culvert at the stream crossing should be replaced to accommodate higher streamflows. Also a ditch block should be placed at the culvert inlet to prevent water from flowing down the ditchline.

- **Peachland Lake Spillway** (Field Stop #38, Photo 38) – The east end of the Peachland Lake spillway channel that drains onto a steep valley slope was highly eroded (i.e. gully erosion). It is assumed this sediment source is directly connected to Peachland Creek.
    - **High surface erosion potential** (high erosion potential and high sediment delivery)
    - **Recommendation:** Additional review of the erosion at the end of the spillway channel is required in order to develop appropriate erosion and sediment control measures.

- **Ester Road south of Greata Creek** (Field Stop #50, Photo 44) – Fine sediment is being delivered to Greata Creek at a small tributary that crosses Ester Road. The cutbank and fillslope of the road has failed as result of highly erodible soils (silty sand) and overland flow of water. Fine sediment from the failure is being delivered to Greata Creek at this location.
    - **High surface erosion potential** (high erosion potential and high sediment delivery)
    - **Recommendation:** Additional review of this road section is required in order to develop appropriate erosion and sediment control measures.

- **Ester Creek Road** (Field Stop #49) – A small non-classified drainage crosses the Ester Creek Road. Soils are highly erodible and fine sediment is being delivered to Greata Creek.
    - **Moderate surface erosion potential** (moderate erosion potential and moderate sediment delivery)

- **Recommendation:** Additional review of this road section is required in order to develop appropriate erosion and sediment control measures.

- **Peachland Main ~16.5 km** (Field Stop #56, Photo 47) – Surface flow over Peachland Main is entering Bolivar Creek on the uphill side of the road. A relatively large wedge of fine sediment was observed above the culvert inlet directly adjacent to the stream channel. Also excessive erosion and channel downcutting has occurred at the outlet of the 1500 mm culvert. The toe of the road fill is also eroded at this location.
  - **High surface erosion potential** (high erosion potential and high sediment delivery)
  - **Recommendation:** Additional review of this road section is required in order to develop measures to prevent surface erosion off of Peachland Main from entering Bolivar Creek. It should be noted that this culvert is located below two proposed blocks (KP1146 and KP1147); therefore, the crossing should be reviewed prior to logging the blocks to ensure the culvert is properly sized and to prevent further channel erosion at the culvert outlet. Bolivar creek also crosses the Glen Lake FSR so the crossing at Glen Lake FSR should also be reviewed since it was not reviewed as part of this assessment.

- **Peachland Main at Bolingbroke Creek** (Field Stop #58, Photo 50) – Bolingbroke Creek eroded Peachland Main in the spring of 2017. Peachland Creek is directly adjacent to Bolingbroke Creek in this location. The channel was excavated and a berm was placed along the channel to maintain flow down the creek during the spring freshet of 2017 (J. Hatch, personnel comm. August 29, 2017).
  - **High surface erosion potential** (high erosion potential and high sediment delivery)
  - **Recommendation:** The berm that was constructed along Bolingbroke Creek in the spring of 2017 to prevent erosion of the road prism should be reviewed to ensure it is adequate to accommodate high flows in Bolingbroke Creek and to determine if it is adequate to minimize surface erosion on Peachland Main from entering Bolingbroke Creek.

It should be noted that Urban Systems (2015b), Grainger (2010) and Golder (2010) also completed a sediment source assessment in the Peachland Creek watershed. In all these cases the Munro FSR and Peachland Main at 6 km was identified as a high surface erosion concern for potential water quality impacts at the District of Peachland's water intake. Surface erosion concerns were also identified at the Peachland Main crossing over Bolivar Creek and along Peachland Main situated directly along Bolingbroke Creek by Grainger (2010) and Golder (2010). Additional surface erosion issues were also identified in these reports. In development of a plan to mitigate erosion and sediment delivery hazards these reports should also be reviewed. This recommendation was also suggested during the February 26, 2018 meeting with the District of Peachland that a complete list of surface erosion issues should be created to allow for planning and mitigation.

3.2.3 Mass Wasting – Sediment Point Sources

In addition to the sediment sources that were identified above (e.g. Munro FSR and Munro FSR landslide, Peachland Main ~6 km and the old trail east of Peachland Creek) no additional point sources of sediment (e.g. landslides) were identified that were related to forest development. However, it should be noted that Grainger (2010) identified one "large slope failure" in the Upper Peachland Creek drainage area that was related to an earlier stream diversion (e.g. old Brenda Mines MacDonald Creek diversion) from the Trepanier Creek watershed. This slope failure does not appear to be a surface erosion concern based on a review of 2013 Google earth images since it currently is well vegetated. Several shallow bank failures are also situated along Peachland Creek within the vicinity of Peachland Main (~6 km), these bank failures are considered natural and periodically contribute sediment to the channel (Photo 20).

In regards to mass wasting the Peachland Creek watershed is considered to have a low mass wasting potential based on the relatively benign and stable terrain in the majority of the watershed. However, the steep sidewall slopes situated along Peachland Creek and Greata Creek have been classified as Class IV terrain with a small percentage of Class V terrain situated along the lower mainstem of Peachland Creek (refer to Appendix A, watershed condition map).

3.2.4 Riparian Function and Condition

Riparian function and condition were assessed within the watershed utilizing the riparian, stream and aquatic indicators mentioned in Table 1.0. These indicators were used to classify the riparian areas in the watershed into one of four categories based on the approach summarized by Tschaplinski and Pike (2010). The four categories are:

- Properly functioning condition
- Properly functioning condition, limited impacts
- Properly functioning condition with impacts
- Not properly functioning

Applying this approach riparian areas were observed to be properly functioning or properly functioning with limited impacts throughout the majority of the Peachland Creek watershed. The amount of riparian area logged along mainstem channels in the watershed is low; therefore, a very high proportion of mainstem channels have intact, properly functioning riparian areas. No channel instabilities associated with the removal of riparian vegetation were identified in the watershed. Although not directly observed in this assessment cattle grazing was identified to be impacting channel stability and riparian conditions in the Greata Creek sub-basin and along portions of Peachland Creek (e.g. Peachland Main ~6 km and Munro FSR stream crossings) (Urban Systems

2015). Based on the above information and orthophoto images, overall riparian areas are in a properly functioning condition within the Peachland Creek watershed and its sub-basins.

3.2.5 Watershed Sensitivity (Peak Flows, Sediment Supply and Channel Sensitivity)

The current sensitivity (i.e. potential for hydrologic disturbances that could affect the intake or water supply infrastructure) of the watershed and its sub-basins to the current level of forest development was evaluated based on the likelihood for increased peak flows, likelihood of adverse stream channel changes (i.e. susceptibility of stream channels to change as result of increased peak flows), potential for increased sediment to stream channels and the current condition of riparian areas. The overall sensitivity of the watershed was used to describe the potential cumulative hydrologic effects of sediment sources, sediment delivery, riparian conditions and potential peak flow increases associated with the current level of forest development in the watershed and at the District of Peachland's water intake.

Peachland Creek sub-basin:

The current sensitivity of the Peachland Creek sub-basin to the current level of forest development is considered moderate. Rationale for this rating is based on the combination of the following:

- The current ECA and the ECA above the H_{40} line are at a level in which there is a moderate likelihood for increased peak flows.
- Stream channels are considered to have a moderate sensitivity to increased peak flows or sediment delivery. The moderate channel sensitivity is associated to the cascade-pool and riffle-pool channel morphologies that contain medium sized textured beds and banks (e.g. cobble and gravels) that are susceptible to channel adjustment during significant peak flow or sediment delivery events.
- Surface erosion from Peachland Main (~6 km) and along the old trail that is situated north of Peachland Creek are currently chronic sediment sources that are likely affecting water quality at the District of Peachland water intake.

Factors that reduce the sensitivity of the Peachland Creek sub-basin to potential hydrologic disturbances include the following:

- There is strong evidence to suggest that peak flows have been attenuated due to storage in the Peachland Lake reservoir. Attenuation peak flows most likely reduces peak flows from the upper Peachland Creek drainage; however, approximately 70% of the Peachland Creek sub-basin is situated below Peachland Lake and is not buffered by Peachland Lake.
- Riparian areas adjacent to mainstem channels are properly functioning with no evidence of bank instability or widening.

Greata Creek Sub-basin:

The current sensitivity of the Greata Creek sub-basin associated with the current level of forest development is considered low. Rationale for this rating is based on the combination of the following:

- Stream channels are considered to have a moderate sensitivity to increased peak flows due to changes in peak flows or sediment delivery. The moderate channel sensitivity is associated to mainstem channels that are characterized as having riffle-pool channel morphologies that contain medium sized textured beds and banks (e.g. cobble and gravels) that are susceptible to channel adjustment during significant peak flow or sediment delivery events.

- There is no potential for attenuation of peak flows since there are no major storage reservoirs in this sub-basin. No storage reservoirs are situated in the lower portions of the sub-basin; therefore, the majority of this sub-basin is unbuffered from the water intake.

Factors that reduce the sensitivity of the Greata Creek sub-basin to potential hydrologic disturbances include the following:

- The current ECA and the ECA above the H_{40} line that are at a level in which there is a low likelihood for increased peak flows that could significantly affect channel stability.

- Riparian areas adjacent to mainstem channels are properly functioning with limited evidence of bank instability or widening.

Peachland Creek Watershed:

The overall sensitivity of the Peachland Creek watershed to potential hydrologic disturbance based on the current level of forest development is considered moderate at the District of Peachland water intake. This rating is based on the current ECAs for the watershed, the moderate sensitivity of channels to increased peak flows and the moderate attenuation of peak flows at the watershed level associated with the Peachland Lake reservoir.

However it should be noted that the lower mainstem of Peachland Creek situated below Hardy Falls was actively eroded in the spring of 2017 and is considered highly sensitive to peak flows or sediment inputs. Although this channel is considered highly sensitive to peak flows it is unlikely that the current forest development exacerbated the current channel condition. As mentioned above channel disturbance in this area resulted from a unusual spring freshet event that was primarily driven by higher than normal rainfall and mid-elevation (~1000 m to 1400 m) snowmelt that resulted in wide spread disturbance in mid elevation watersheds being flooded or disturbed throughout the Okanagan and Thompson regions. Also the majority of the channel bank erosion was likely attributed to the blockage and damming of debris and water behind several of the foot bridges that are present in the Hardy Falls Regional Park. As result water was diverted around the foot bridges causing significant channel and bank erosion.

Table 3.4. Watershed sensitivity to the current level of forest development at the watershed and sub-basin scale.

Watershed, Sub-Basin or Drainage Unit	Peak Flow Attenuation Potential	Likelihood of Peak Flow Increases	Channel Sensitivity Rating	Watershed Sensitivity (Potential for hydrologic disturbances)
Upper Peachland Creek Drainage Unit	Good	M	M	M
Mid Peachland Creek Drainage Unit	Poor	L	M	L
Peachland Creek Sub-basin	Good	M	M	M
Greata Creek Sub-basin	Poor	L	M	L
Peachland Creek Watershed	Moderate	L	M/H*	M

* The lower mainstem of Peachland Creek situated below hardy falls was actively eroded in the spring of 2017 and is considered highly sensitive to peak flows or sediment inputs.

4.0 ASSESSMENT OF PROPOSED FOREST DEVELOPMENT

This section provides guidance with regards to proposed development in the watershed based on the current watershed conditions, potential hydrologic hazards/risks in the watershed and projected ECAs.

4.1 Proposed Development

The proposed forest development within the Peachland Creek watershed is approximately 1043 ha which would increase the overall ECA for the watershed from 20% to 28% and the ECA above the H_{40} elevation from 25% to 35% (Table 4.1). The proposed ECA level above the H_{40} line will therefore increase the likelihood of increased peak flows from low to moderate.

At the sub-basin level overall ECA would increase from 29% to 35% in the Peachland Creek sub-basin and from 14% to 28% in the Greata Creek sub-basin. ECA above the H_{40} elevation would increase from 33% to 40% in the Peachland Creek sub-basin and increase from 15% to 28% in the Greata Creek sub-basin. Current ECAs above Peachland Lake would increase by no more than 1% given limited proposed forest development situated above Peachland Lake. In the Mid Peachland drainage unit, current ECA would increase from 26% to 36% and ECA above the H_{40} elevation would increase from 26% to 47%. Proposed ECA's in the Mid Peachland Creek drainage unit are considered to have a high likelihood for increased peak flows. Proposed ECA's are considered to have moderate likelihood for increased peak flows in the entire Peachland Creek sub-basin and the Upper Peachland Creek drainage unit. Proposed ECA's in the Greata Creek sub-basin are consider to have a low likelihood for increased peak flows.

Table 4.1. Summary of proposed ECA's for the Peachland Creek watershed assuming all proposed blocks are harvested before the end of 2017. Note: ECAs were based on revised snow recovery estimates for pine dominated forests in the interior British Columbia using the methodology suggested in Extension Note 116 (Winkler and Boon 2015).

Sub-basin	Area (ha)	Total ECA		Area Above H_{40}	ECA Above H_{40}		ECA Above H_{40} without Forest Health Factor (e.g. Mature Pine Mortality)	
		(ha)	(%)	(ha)	(ha)	(%)		
Upper Peachland Creek Drainage Unit	2416	805	33	1860	674	36	639	34
Mid Peachland Creek Drainage Unit	4057	1442	36	892	416	47	415	47
Entire Peachland Creek sub-basin (included Upper and Mid Peachland Creek)	6473	2247	35	2752	1090	40	1053	38
Greata Creek Sub-basin	4496	1237	28	2029	574	28	573	28
Watershed	12553	3539	28	4780	1664	35	1626	34

Note: H_{40} elevation for the snow sensitive zone was calculated to be 1340 m based upon the entire watershed area situated above the District of Peachland intake.

Even though the likelihood for increased peak flows is considered low to moderate at the sub-basin level it is critical that careful consideration be given to ensure all existing and proposed road crossings and road drainage systems are adequate to accommodate large peak flows, prevent excessive erosion and concentration of surface drainage. This recommendation is primarily based on the fact that the majority of stream channel or surface erosion issues that were identified in the watershed were associated with upslope diversion or concentration of surface drainage as result of road drainage or due to the combination of rapid snowmelt from recently harvested upslope cutblocks and concentration of stream flows due to road drainage. This recommendation is particularly important in light of climate change that has been projected to cause a higher frequency of extreme events (e.g. higher frequency of intense rainfall events, higher frequency of rain-on-snow events that can generate larger than average streamflow events).

4.2 Peak Flows and Channel Sensitivity

Peak flows in the watershed and sub-basin mainstem channels are typically generated by snowmelt from the snow sensitive zone (above the H_{40} elevation). Removal of forest stands through forest harvesting leads to increased rates of snowmelt and runoff and may result in increased peak flows. As flow volumes increase, so do water depths and shear stresses exerted on channel bed and banks. Increased shear stresses can lead to greater rates of bank erosion, sediment transport and reduced water quality.

As described above, the sensitivity of the watershed to potential hydrologic disturbances that could affect the water intake or water supply infrastructure are currently considered moderate for the majority watershed due to the combination of a moderate likelihood for increased peak flows and stream channels that are moderately sensitive to potential peak flow increases (Table 4.2). The two exemptions or areas of particular concern include the Mid Peachland Creek drainage unit and the lower 1.2 km of Peachland Creek situated below Hardy Falls.

Based on the proposed ECAs within the Mid Peachland Creek drainage unit and the observed channel disturbance (e.g. Mile Creek) observed within this drainage unit a high watershed sensitivity rating has been assigned to the proposed level of development within this drainage unit (Table 4.2)

The lower 1.2 km of Peachland Creek situated below Hardy Falls is considered to be highly sensitive to peak flows as result of recent channel instability associated with the 2017 spring freshet, important spawning habitat for kokanee salmon and the direct proximity of residential buildings adjacent to Peachland Creek. Therefore, a high potential hydrologic disturbance rating in association with the proposed development has been assigned to the lower Peachland Creek channel reach (Table 4.2). Currently the Regional District of Central Okanagan is in the process of developing plans to remediate the impacts from the 2017 spring freshet on the lower reach of Peachland Creek that are situated within the Hardy Falls Regional Park (W. Darlington, September 6, 2017). Ideally these remediation plans should be developed to minimize future channel instability.

It is also important to note that there is little evidence to link channel disturbance with ECA alone (BC Ministry of Forests 1999; Grant et al. 2008), in isolation from other affects such as riparian disturbance and increases in sediment supply. As stated by Grant et al. (2008) "...no field studies explicitly link changes in peak flows to changes in channel morphology". The interplay of many additional factors can cause changes in channel morphology. These factors include increased sediment loads to stream channels from landslides, poor riparian conditions that result in loss of channel bank stability and channel morphologies (e.g. forced riffle-pool or riffle-pool channels) that are sensitive to increases in peak flows (Grant et al. 2008). Hogan and Luzi (2010) also provided a hierarchy of the potential of forest practices activities to influence channel conditions. This hierarchy highlights how channel impacts are likely greater in watersheds with high levels of mass wasting and high proportion of vegetation removal directly along mainstem channels as compared to watersheds that may have high proportion of the watershed area logged but with limited mass wasting and riparian logging. **The above information highlights the importance of ensuring all road structures, road ditchlines, cross-drain culverts and stream crossings situated below proposed development are sufficient to maintain natural drainage patterns to accommodate stream flows associated with the potential increased peak flows. Also maintenance of properly functioning riparian areas to maintain channel and bank stability is important.**

Table 4.2. Watershed sensitivity to proposed forest development at the watershed and sub-basin scale.

Watershed or Sub-Basin	Peak Flow Attenuation Potential	Likelihood of Peak Flow Increases	Channel Sensitivity Rating	Watershed Sensitivity (Potential for hydrologic disturbances)
Upper Peachland Creek Drainage Unit	Good	M	M	M
Mid Peachland Creek Drainage Unit	Poor	H	M	H
Peachland Creek Sub-basin	Good	M	M	M
Greata Creek Sub-basin	Poor	L	M	M
Peachland Creek Watershed	Moderate	M	M/H*	M/H*

*A high potential for hydrologic disturbance rating has been assigned to the lower 1.2 km of Peachland Creek situated directly above Okanagan Lake due to its current channel sensitivity.

4.3 Surface Erosion and Water Quality

As already mentioned a key element at risk is water quality at the District of Peachland water intake; therefore, it is important that all proposed forest development is carried out in manner that will avoid potential erosion and sediment delivery issues that could affect water quality at the District of Peachland water intake. The primary sediment source related to forest development is forest roads either from events originating from roads or from erosion of exposed soils within the road prism (Maynard 2001, Gillie 2007); therefore, proposed roads were the main focus of this portion of the assessment even though an overview of proposed cutblocks was also completed. As stated by Maynard (2001) surface is usually not a major concern from undisturbed clearcut areas, except for roads and bladed trails, recent landslide and gully scour, sensitive landforms and sites with extensive surface disturbance.

In this assessment the potential for increased surface erosion and sediment delivery as result of proposed forest development were assessed based on the following:

- Inventory of proposed roads and number of stream crossings by drainage unit
- Inventory of proposed roads situated on Class IV or V terrain stability polygons
- Inventory of proposed roads situated on moderate to very high surface erosion polygons
- Office review of individual proposed cutblocks and road locations within the watershed using a bare-earth hillslope map with 5 m contours (refer to Appendix A for bare-earth map).

It should be noted that the potential for increased surface erosion and the effects on water quality were based on an office based assessment using the above mentioned information. This information is suitable to assist in forest planning; however, this assessment was not detailed enough to substitute for site-specific, operational recommendations and decisions. The terrain and surface erosion mapping used in this assessment was completed by Maynard (2001).

Inventory of Proposed Roads and Stream Crossings

A total of 51.9 km of new road is planned to access the proposed development with 23.4 km of the proposed road situated above the H_{40} line (Table 4.3). As shown in Table 4.3 the majority of the proposed roads are situated in the Mid-Peachland and Greata Creek drainage areas. The majority of proposed development in these drainage areas are situated below Peachland Lake and Glen Lake reservoirs in the unbuffered area (i.e. no reservoirs are present downstream) of the watershed upstream of the intake. In this area if surface erosion/sediment delivery to stream channels occur it has a higher likelihood of effecting water quality at the intake.

Table 4.3. Summary of length of proposed roads in each of the sub-basins, drainage units and residual area in the Peachland Creek watershed.

Basin	Length of Proposed Roads (km)			Number of New Stream Crossings
	Above H_{40} Line	Below H_{40} Line	Basin Total	
Upper Peachland Creek	0.7	0.0	0.7	0
Mid Peachland Creek	12.3	12.6	24.9	6
Greata Creek Sub-basin	10.4	14.2	24.6	17
Residual above Intake	0.0	1.7	1.7	1
Watershed Total	**23.4**	**28.5**	**51.9**	**24**

Terrain Stability and Surface Erosion Potential Mapping

Terrain stability and surface erosion potential mapping was completed by Maynard (2001). As stated by Maynard (2001) Terrain Survey Intensity Level C mapping at a scale of 1:20,000 was carried out in the Peachland Creek watershed to provide interpretations of terrain stability and surface erosion potential to indicate an expected response of terrain to conventional forest development operations (road construction and clearcut harvesting). The surface erosion potential mapping was used to determine the likelihood of proposed roads effecting water quality from each of the sub-basins (Table 4.4). As summarized in Table 4.4 in the Greata Creek sub-basin there are approximately 2.5 km of proposed road situated on Class IV terrain. Also within the Mid-Peachland drainage unit and in the Greata Creek sub-basin sections of road are situated on moderate to very high surface erosion potential (refer to Table 4.4). As identified by Maynard

(2001) ratings for surface erosion are a qualitative assessment of the likelihood for generating sediment by overland water flow during and after forest development and presume the mineral soil is exposed. Thus areas of main concern related to the proposed development are roads and bladed trails situated on or above terrain Class IV and V polygons and moderate to very high surface erosion polygons. Details regarding the rating of surface erosion potential polygons and sediment delivery polygons are provided in Appendix II and III in Maynard (2001).

Table 4.4. Summary of the length of proposed roads situated on terrain stability Class IV or V polygons and moderate to very high surface erosion potential polygons as identified by Maynard (2001). Length of proposed roads on Class I to III terrain are not shown.

Drainage Unit	Terrain Stability (Proposed Road Length)		Surface Erosion Potential (Proposed Road Length)			
	Class IV terrain (km)	Class V terrain (km)	Low Surface Erosion Potential (km)	Moderate Surface Erosion (km)	High Surface Erosion (km)	Very High Surface Erosion (km))
Upper Peachland Creek	0	0	0.7	0	0	0
Mid Peachland Creek	0	0	14.3	8.0	2.2	1.3
Greata Creek Sub-basin	2.5	0	7.8	9.1	5.0	2.8
Residual above Intake	0	0	0	1.7	0	0
Watershed Total	2.5	0	0	1.9	0.7	0

Review of Individual Proposed Cutblocks and Road Locations

An office review of individual proposed roads and cutblocks using ArcGIS was completed to assess the likelihood for increased surface erosion and delivery as result of proposed forest development to the District of Peachland water intake (refer to Appendix E for details). Factors that were considered in the review included the proximity of the proposed development to moderate to very high surface erosion polygons, proximity of the proposed development to Class IV or V terrain, road-stream connectivity to streams, location of wetlands or lakes that may buffer sediment transport, field review information, topographic factors such as the slope gradient, slope shape and slope length, and presence of terrain features that may indicate areas susceptible to generating surface erosion as result of forest development (e.g. excessive gullied terrain, old landslide scars) based on a bare-earth hillslope map with 5 m contours of the entire watershed. The bare-earth map was generated from LiDAR data that was used to generate rasters having a 1 m by 1 m pixel size for the entire watershed (refer to Appendix A for bare-earth map).

Based on this office review the majority of proposed roads and cutblocks are considered to have a low potential to increase surface erosion and affect water quality at the District of Peachland water intake (refer to Appendix E). The following cutblocks and associated access roads were highlighted as requiring further on the ground assessment or planning to ensure increased surface erosion and delivery of sediment are minimized:

- **KP1094 K23** – This proposed block is situated adjacent to Mile Creek and a tributary channel to Peachland Creek. Also moderate and high surface erosion polygons and Class IV terrain are situated below the proposed block. Both stream channels were eroded at the old trail situated below this block (Field Stop #22 and #23). The proposed spur road for this block does not appear to be a surface erosion concern since it is situated on relatively flat terrain and is not in close proximity to any stream channels. An existing spur road located on the south end of the block has the potential to divert and concentrate flows that could cause surface erosion downslope into Peachland Creek.

  Recommendation:
  - It is critical that natural drainage patterns be reviewed and maintained both within the block and below the block. This recommendation is particularly important at the lower end of an existing spur road situated on the south end of the block. Drainage along the existing spur road may concentrate surface flows down the road ditchline onto Class IV terrain; therefore, the spur road should be deactivated to ensure natural drainage patterns are maintained. Consideration should also be given to deactivating the road crossings at the old trail to avoid further erosion.

- **KP1128 556** – This proposed block is situated on moderate surface erosion potential polygon with the northwest portion of the block situated on Class IV terrain. Also the existing access roads situated on the northern portion of the block cross a relatively deep gully.

  Recommendation:
  - It is suggested that the northwest portion of block should be reviewed by terrain/surface erosion specialist to ensure surface erosion potential is not increased after development of the proposed block. Also the two stream crossings on the existing access roads on the lower (northern) portion of the block should reviewed to ensure surface erosion and sediment delivery is not an issue.

- **KP1129 556** – The west portion of the proposed block is situated slightly on or above a high surface erosion potential and above Class IV/V terrain.

  Recommendation:
  - Ensure terrain instability associated with Class V and IV is not increased below the proposed block. Ensure natural drainage patterns are maintained.

- **KP1149 K20** – This proposed block and access road is located on moderate surface erosion potential polygon with a high sediment delivery potential. Also the north end of the block is situated above Class IV terrain. The upper access road crosses three gullies visible on the bare-earth map that may be susceptible to surface erosion in association with road construction.

  Recommendation:
  - The gullies situated along the upper access road should be reviewed to ensure surface erosion is not increased.

- **KP1167 K23** – This proposed road and block are situated on a moderate surface erosion potential polygon and above gullied terrain that was observed to have eroded fine sands/silts (situated above Field Stop #49) with sediment delivery to Greata Creek. The proposed block could increase stream flow along the Ester Road further increasing erosion and sediment delivery to Greata Creek.

  Recommendation:
  - The stability of the gullies and road drainage along Ester Road should be reviewed and upgraded prior to development of the proposed block to minimize potential surface erosion to Greata Creek.

- **KP1168** - The west portion of this proposed block is situated on and above Very High and High surface erosion potential polygons and Class V/IV terrain. Also an existing road and switchback are situated in relatively close proximity to the Class V/IV terrain.

  Recommendation:
  - Road drainage below the switchback on an existing road on the west edge of the block should be reviewed to ensure surface runoff will not be concentrated onto Class V and IV terrain and Very High and High surface erosion polygons. Ensure natural drainage patterns are maintained along all existing and proposed access roads. Ensure slope instability or surface erosion potential are not increased downslope at the west end of the block.

- **BCTS K7GS** – This proposed block and access road is situated on moderate surface erosion potential polygon and Class IV terrain with two stream crossings proposed to access the block.

Recommendation:

- The moderate surface erosion potential and Class IV terrain should be included in road and block forest development planning considerations to ensure surface erosion delivery to Glen Lake is avoided.

- **BCTS K7J3 and K7J4** – The access road that passes through K7J4 includes four crossings that traverses relatively steep terrain. This access road also includes one major switchback and crosses gullied terrain on the northern end of the K7J3. Portions of the proposed road and block are also situated on moderate and high surface erosion polygons.

  Recommendation:

  - Ensure natural drainage patterns are maintained along the access road. Ensure all downslope road crossings are adequately sized to accommodate potential increased peak flows. Gullied terrain is present at the northern end of the proposed block; therefore, ensure the road location (i.e. road cutbanks and road prism) does not increase surface erosion into the tributary channel (e.g. if necessary, consider relocation of this access road)

- **BCTS K7J2** - This proposed block and the lower access road are situated on a moderate surface erosion potential polygon and Class IV terrain.

  Recommendation:

  - The moderate surface erosion potential should be included in road and block forest development planning considerations to ensure surface erosion delivery to Glen Lake is avoided.

- **BCTS K7HJ** - A portion of this proposed block is situated on a high surface erosion potential polygon and Class IV terrain with four proposed stream crossings. Two of these proposed stream crossings are situated within the proposed block.

  Recommendation:

  - Ensure surface erosion from block is not increased given high surface erosion potential. Avoid localized erosion from block. Also any proposed roads should be developed in a manner that does not increase surface erosion potential.

4.4 Mass Wasting

It should be recognized that this watershed assessment is an overview level watershed assessment and is not sufficient to address specific development (cutblock or road) related terrain stability concerns. Terrain stability assessments should be completed by a qualified professional for proposed harvest and road construction where deemed necessary during the forest development planning and layout process. Based on current practices it is understood that appropriate terrain stability assessments will be carried out where required in this watershed and based on these assessments the potential for mass wasting to impact watercourses or water quality will not be increased. Avoidance of slope instability into stream channels is viewed as critical to the maintenance of stream channel stability and water quality throughout the watershed since changes in instream sediment supply can have detrimental effects on channel conditions, fish habitat and water quality.

As shown on the watershed condition map (Appendix A) and as described in Section 4.3 a small proportion of proposed development is situated on or above Class IV terrain; therefore, it is critical that careful consideration be given to developing these areas so that the likelihood of mass wasting and sediment delivery is not increased to stream channels.

4.5 Riparian Function

There is no forest development proposed directly adjacent to the mainstem channels. Also it is assumed that appropriate riparian management practices that are consistent with forest licensees' forest stewardship plans for all proposed cutblocks that are in close proximity to unclassified or small streams will be adequate to minimize riparian disturbances that could have detrimental effects at the District of Peachland's water intake. This assumption is based upon the fact that no evidence was found that current riparian management strategies were inadequate to protect water quality at the District's water intake. Therefore, there is a low likelihood that the proposed forest development will impact riparian functions and associated water quality or quantity provided appropriate riparian management practices are implemented to maintain channel stability. It should be noted that an important component to maintain the stream channel stability can be achieved through maintenance of properly functioning riparian areas.

4.6 Other Land use Considerations

Past reports (e.g. Forest Practices Board 2012) have identified that other land uses (e.g. recreation and cattle grazing) in conjunction with forest development can affect water quality. Therefore, it is essential that not only the potential direct effects on water from forest harvesting/roads be considered in the forest development planning process but the unintended consequences of forest development be considered. For example, forest harvesting can result in the natural loss of barriers that normally would limit access to watercourses by cattle or recreational users (Forest Practices Board 2012). In addition forest development can increase access of drainage areas/water courses to recreational users.

In terms of risk to water quality, the most vulnerable portions of the watershed are the mainstem channels situated between the main storage reservoirs and the water intake. To further safeguard against potential water quality effects in these areas extra consideration should be given to the maintenance of healthy riparian areas that adequately buffer these water courses from potential effects of forest development and other land uses. Also deactivation of roads when no longer required for forest development will also help to minimize potential water quality effects from other land uses.

5.0 RISK ANALYSIS

A partial risk analysis was used to evaluate the potential effects of proposed development (Wise 2004). Definitions of the specific risk analysis terms can be found in Tolko's Watershed Risk Management Framework (2018). The risk analysis was grouped into five main categories based on the primary elements at risk (Table 5.1).

Water Quality - A primary concern of the District of Peachland is the potential effects that forest development may have on water quality at the District's intake. Currently numerous issues have been identified in the watershed that are considered ongoing chronic water quality issues at the water intake. Mitigation of current surface erosion issues would most likely help to minimize water quality issues at the intake. Initial discussion regarding these issues occurred at the forest licensees' meeting with the District of Peachland on February 26, 2018.

A significant amount of forest development is proposed within the unbuffered area immediately upstream of the intake and downstream of all reservoirs (e.g. Peachland Lake and Glen Lake reservoirs) (refer to Appendix A, watershed condition maps). In this zone any impacts to water quality (i.e. sediment inputs) and quantity have a higher likelihood of affecting the District's water intake. The second, upper zone, includes those areas upstream of a reservoir (e.g. Peachland Lake reservoir and Glen Lake reservoir). Runoff from the upper zone is stored before being released to the intake. Impacts to water quantity and quality in the buffered areas are considered a lower risk as measured at the intake due to the benefits of water storage.

In recognition of the above mentioned water quality concerns an office based review of the proposed roads and blocks was completed. As described in Section 4.3 the majority of proposed roads and cutblocks are considered to have a low potential to increase surface erosion and affect water quality at the District of Peachland water intake (refer to Appendix E). A list of cutblocks and associated access roads were highlighted as requiring further on the ground assessment or planning to ensure increased surface erosion or delivery of sediment is minimized. Based on this information the risk to water quality and the potential likelihood of whether water quality will be affected is site specific and depends on how well erosion and sediment control measures are applied in all phases of forest development (e.g. forest development planning, construction, and post-harvesting) to ensure potential erosion/sediment delivery issues are avoided.

Water Supply Infrastructure – Proposed forest development is considered to have low risk to cause damage of the District of Peachland's water intake infrastructure as result of landslides or disturbance to stream channels since the proposed forest development is situated well away from the intake and is situated on relatively stable terrain. It should be noted that there still is the potential for further slope instability below the Munro FSR; however, recent relocation of the Peachland Creek should have minimized the potential for the movement of debris into the water intake infrastructure.

Water Quantity/Supply – Overall changes to water quantity/supply associated with the proposed forest development that could have implications for stream channel stability, reservoir storage, low flows or fish are considered to be a moderate risk. This risk rating is based on the proposed moderate to low ECA levels for the watershed that could result in moderate increases in the frequency and magnitude of streamflows. However, it is important to note that proposed ECAs above the snow sensitive zone in the entire Peachland Creek sub-basin and Mid Peachland drainage unit will likely result in the advancement in the timing of spring freshet runoff which could result in earlier and longer use of reservoir storage. However, the relatively large reservoir storage capacity in Peachland Lake will help to mitigate advancements in the timing of spring freshet runoff associated with the proposed ECA in this sub-basin.

Also proposed ECAs within the Mid Peachland Creek drainage unit are in the high range for potential changes in peak flows. At this level of development peak flow changes become highly uncertain.

Fish and Fish Habitat – Fish and fish habitat is situated throughout the mainstem channels of the watershed; however, the primary habitat of concern is situated in the lower 1.2 km of Peachland Creek below Hardy Falls. Proposed forest development is considered to have a high risk rating for potential effects on the lower reach of Peachland Creek. This risk rating is based on the combination of high channel sensitivity, moderate likelihood for peak flow increases and the high vulnerability rating of the disturbed mainstem channel situated below Hardy Falls. Although direct impacts from proposed forest development are very unlikely the potential indirect, cumulative effects from changes in flood frequency are a concern. Improvements to the currently disturbed lower channel reach would help to minimize the potential risks.

Fish and fish habitat situated within the remainder of the watershed are considered to have a moderate risk rating. This lower risk rating is mainly associated with the fact that fish species such as brook trout and rainbow trout that are present in the remainder of the watershed are more robust and less sensitive to water quality or channel disturbance issues. Also the majority of channels situated above the District of Peachland intake were considered relatively stable with properly functioning riparian areas and intact fish habitat.

Infrastructure – The potential effects of the proposed forest development is considered to have a moderate risk rating for infrastructure not related to the municipal water supply. Infrastructure of concern includes the Highway 97 bridge crossing near Okanagan Lake and residences situated on the alluvial fan near Okanagan Lake. The primary factors that contributed to this risk rating is the moderate potential for increased peak flows, channel sensitivity on the lower fan and the vulnerability of these structures. Similar to above, improvements to the currently disturbed lower reach of Peachland Creek would help to minimize potential risks associated with the proposed development.

Additional infrastructure (other than the specific issues mentioned above) associated with roads (status and non-status roads) and stream crossings situated within the watershed are considered to have a low risk for potential effects from forest development. This is based upon the general observation that the majority of road structures were adequately designed to accommodate relatively large stream flow events. However, all road structures, road ditchlines, cross-drain culverts and stream crossings situated below proposed forest development should be evaluated to ensure these structures are adequate to maintain surface drainage patterns and to accommodate increased stream flows associated with upslope development and potential climate change effects. This recommendation also pertains to non-status roads and trails.

Table 5.1. Summary risk ratings associated with proposed development on water quality, water supply infrastructure, water quantity/supply, fish and fish habitat and downstream infrastructure.

Elements at Risk	Vulnerability Rating	Watershed Sensitivity (Potential for Hydrologic Disturbances)	Likelihood of Occurrence	Surface Erosion and Delivery Potential	Risk
Water Quality Water quality at the District of Peachland water intake (primarily turbidity and human-introduced pathogens)	**H**	**M**	**M**	**L to H***	**L to H*** (see text for rationale)
Water Supply Infrastructure Potential damage to the District of Peachland's water intake infrastructure as result of landslides or disturbance to stream channels	**M**	**M**	**L**	**L (low likelihood of large mass wasting events)**	**L**
Water Quantity/Supply Changes to water quantity or timing of flows that could have implications for water supply, stream channel stability or fish	**M**	**M**	**L**	**N/A**	**M**
Fish and Fish Habitat Fish and fish habitat (primary focus is kokanee salmon habitat situated in the lower 1.2 km of Peachland Creek)	**M/H**	**H**	**M**	**M**	**M/H**
Infrastructure Infrastructure not related to municipal water supply (e.g. Highway 97 bridge crossing and residential homes situated directly adjacent to Peachland Creek below Renfrew Road).	**M**	**M**	**L**	**N/A**	**M**

*Surface erosion potential and delivery are site specific and range from low to very high (details regarding surface erosion concerns are described in Section 3.2.2 and Section 4.3).

6.0 SUMMARY AND RECOMMENDATIONS

6.1 Key Issues and Elements at Risk

Key resources at stake (elements at risk) in the watershed include the following:

- Water quality at the District of Peachland water intake (primarily turbidity and human-introduced pathogens);
- Potential damage to the District of Peachland's water intake infrastructure as result of landslides or disturbance to stream channels;
- Changes to water quantity or timing of flows that could have implications for stream water supply, channel stability or fish;
- Fish populations and habitat (primary focus is kokanee salmon habitat situated in the lower 1.2 km of Peachland Creek); and,
- Infrastructure not related to the municipal water supply (e.g. Highway 97 bridge crossing, residential homes situated directly adjacent to Peachland Creek below Renfrew Road and other road/stream crossing infrastructure).

Currently the District is in the process of "eventual abandonment of the Trepanier Creek water source" through the installation of a water treatment plant facility at the Peachland Creek water intake to improve water quality treatment and to meet water quality standards and objectives set by the BC Ministry of Health (Urban Systems 2007, Urban Systems 2015a, District of Peachland 2016). The water treatment plant is projected to be completed in 2020. Once completed all of the District's water will be obtained through the Peachland Creek watershed, highlighting the importance of this watershed as a stable and clean source of water for the District of Peachland. It should be noted that in order for the District to supply enough water to meet the entire demands from the Peachland Creek watershed current water licenses on Trepanier Creek would remain in place. Water from the Trepanier Creek watershed would either be diverted to the Peachland Reservoir from the MacDonald Creek or from the Brenda Mine water treatment plant (Urban Systems 2015b).

6.2 Current Watershed Condition and Past Forest Development

- The overall ECA and the ECA within the snow sensitive zone (i.e. above the H_{40} elevation) for the entire Peachland Creek watershed are 20% and 25%, respectively (refer to Table 4.1). These ECAs for the watershed are considered to have a low likelihood for increased peak flows. At the sub-basin level, the current ECAs are considered to have a moderate likelihood for increased peak flows in the entire Peachland Creek sub-basin and the Upper Peachland Creek drainage unit. Current ECA's in the Greata Creek sub-basin and Mid

Peachland Creek drainage unit are considered to have a low likelihood for increased peak flows.

- Detrimental or material changes to the other components of streamflow such as annual water yield, low flows and timing of flows associated with the existing level of development are considered to have a low likelihood of having a negative impact to downstream water users and supply. This statement is partly based on the storage and moderation of streamflows associated with the release of water from Peachland Lake to provide water for irrigation and fish conservation flows.

- The majority of stream channels situated within the watershed were observed to be relatively robust with limited to no evidence of instability associated with past forest development. The majority of stream channels in the watershed were considered to have a moderate sensitivity to changes in peak flows or sediment delivery based on the main channel morphologies (riffle-pool and cascade-pool channels with gravel/cobble beds) present within the watershed. The lower reach (~1.2 km) of Peachland Creek situated below Hardy Falls was actively eroded in the 2017 spring freshet event. This stream reach was considered to have a high channel sensitivity. Channel sensitivity was also observed on Mile Creek partly as result of upstream diversion of flows along the Brenda Mines Road.

- The current sensitivity of the watershed to potential hydrologic disturbances associated with the current level of forest development are considered low to moderate for the majority of mainstem channels situated throughout watershed; however, the lower mainstem of Peachland Creek situated below Hardy Falls is considered to be highly sensitive to potential peak flow increases.

- Suspended sediment and elevated turbidity levels associated with the spring freshet and during high intensity rain storms have been an ongoing issue for the District of Peachland. Surface erosion and sediment delivery from existing roads and cutblocks was considered low in the majority of the watershed based upon limited observed evidence of erosion concerns. However, several chronic ongoing surface erosion issues exist with the watershed. The main issues include the lower end of the Munro FSR, and Peachland Main (~6km). Additional road related surface erosion issues were also identified and the reader is encouraged to review Section 3.2.2 of this report.

- The majority of the Peachland Creek watershed is characterized by a plateau with generally benign, rolling terrain with relatively gentle slopes; therefore, and as identified in past assessments, mass wasting/landslides are considered a low concern in the watershed and its sub-basins. However localized surface erosion and terrain issues (e.g. Munro FSR and Peachland Main (~6 km) and an old trail situated northeast of Peachland Creek have contributed sediment into Peachland Creek and are a water quality concern.

- In the majority of the watershed riparian areas are considered to be properly functioning or properly functioning with limited impacts. No stream bank instability associated with harvesting of riparian areas on Crown land was identified.

6.3 Proposed Forest Development Summary

- Within the next 5 years Tolko Industries Ltd., BC Timber Sales and Ntityix Resources LP propose to harvest approximately 1043 ha within the watershed with approximately 466 ha of this development proposed above the H_{40} line. This would result in proposed ECAs to increase into the 28% to 47% range for the watershed, its sub-basins and drainage units (Table 4.2). At the watershed level the proposed ECA above the snow sensitive zone is considered to have a moderate likelihood for increased peak flows. At the sub-basin and drainage unit level, proposed ECA's are considered to have moderate likelihood for increased peak flows in the entire Peachland Creek sub-basin and the Upper Peachland Creek drainage unit. Proposed ECA's in the Mid Peachland Creek drainage unit are considered to have a high likelihood for increased peak flows; however, peak flows increases at the larger sub-basin level will be moderated by the attenuation of peak flows at Peachland Lake. Proposed ECA's in the Greata Creek sub-basin are consider to have a low likelihood for increased peak flows.

- On the whole, detrimental or material changes to the other components of streamflow such as annual water yield and low flows associated with the proposed level of development are considered to have a low likelihood of having a negative impact to downstream water users and supply. This statement is partly based on the storage capacity and moderation of streamflows associated with the release of water from Peachland Lake to provide water for irrigation and fish conservation flows.

- It is important to note that proposed ECAs above the snow sensitive zone in the entire Peachland Creek sub-basin and Mid Peachland drainage unit will likely result in the advancement in the timing of spring freshet runoff which could result in earlier and longer use of reservoir storage. However, the relatively large reservoir storage capacity in Peachland Lake will help to mitigate advancements in the timing of spring freshet runoff associated with the proposed ECA in these sub-basins.

- Approximately 51.9 km of road will be required to access the proposed development in the watershed. Soils range from low to very high surface erosion potential within the watershed. Based on an a office review of individual proposed roads and cutblocks the majority of proposed roads and cutblocks are considered to have a low potential to increase surface erosion and affect water quality at the District of Peachland water intake. However, several access roads and proposed blocks were highlighted as requiring further on the ground assessment or planning to ensure increased surface erosion and delivery of sediment are minimized (refer to Section 4.3 for further details).

- Provided that appropriate terrain stability assessments will be carried out in this watershed to evaluate and avoid slope instability it is assumed that it is unlikely the proposed forest development will increase mass wasting into stream channels that could have detrimental effects on channel conditions, fish habitat and water quality.

- There is no forest development proposed directly adjacent to the mainstem channels. Also it is assumed that appropriate riparian management practices that are consistent with the forest licensees' forest stewardship plans for all proposed cutblocks that are in close proximity to unclassified or small streams will be adequate to minimize riparian disturbances that could have detrimental effects at the District of Peachland's water intake. This assumption is based upon the fact that no evidence was found that current riparian management strategies were inadequate to protect water quality at the District's water intake. Therefore, based upon this assumption it is unlikely that the proposed forest development will adversely affect the condition of riparian areas.

- A qualitative risk analysis was used to evaluate the potential effects of proposed development. The following three items were highlighted as the main risk concerns:

    - A primary concern are the potential effects that forest development may have on water quality at the District of Peachland's water intake. Based on an office review of proposed development the majority of proposed roads and cutblocks are considered to have a low potential to increase surface erosion and affect water quality at the District of Peachland's water intake. However a list (refer to Section 4.3) of cutblocks and associated access roads were highlighted as requiring further on the ground assessment or planning to ensure increased surface erosion or delivery of sediment is minimized. Based on this information the risk to water quality and the potential likelihood of whether water quality will be affected is site specific and depends on how well erosion and sediment control measures are applied in all phases of forest development (e.g. forest development planning, construction, and post-harvesting) to ensure potential erosion/sediment delivery issues are avoided.

    - The potential indirect, cumulative effects from changes in flood frequency and magnitude associated with proposed forest development are considered a high risk for fish and fish habitat situated in the lower 1.2 km of Peachland Creek below Hardy Falls. This risk rating is based on the combination of high channel sensitivity, moderate likelihood for increased peak flows and the high vulnerability of this section of channel. Improvements to the currently disturbed lower channel reach would help to minimize the potential risk to fish and fish habitat along the 1.2 km of Peachland Creek.

- Proposed ECAs within the Mid Peachland Creek drainage unit are in the high range for potential changes in peak flows. At this level of development peak flow changes become highly uncertain. Also at this level of development an advancement in the timing of spring freshet would likely occur requiring earlier and long use of reservoir storage that could result in water shortages later in the low flow season.

6.4 Recommendations

Based on the review of the current watershed condition and the proposed forest development in the Peachland Creek watershed the following are recommended:

- A meeting should be convened with the District of Peachland to allow the District to provide input in regards to the current condition of the watershed and proposed forest development.

- Numerous legacy issues associated with erosion and sediment delivery to Greata Creek and Peachland Creek were identified in this watershed. A plan to mitigate these issues should be developed. It should be acknowledged that this planning process would require the involvement of various organizations (e.g. forest licensees', District of Peachland and the Ministry of Forests, Lands, Natural Resource Operations & Rural Development) given the complexity of responsibility and funding availability.

- Water quality is a primary concern in this watershed; therefore, it is essential that prior to road construction all proposed roads should be evaluated to determine their potential surface erosion and sediment delivery. It is essential that appropriate erosion and sediment control measures (e.g. Carson and Younie 2003; Gillies 2007; B.C. MFLNRO et al. 2012; Carson and Maloney 2013) be implemented in all phases of forest development (e.g. forest development planning, construction, and post-harvesting) to ensure potential erosion issues are avoided along road sections and proposed stream crossings. This includes that care and attention be taken in re-activating old roads and in the design and layout of new roads and skid trails to minimize disturbance to the natural drainage patterns and sediment erosion/transport. This statement particularly applies to any proposed stream crossings.

- It should be highlighted that the majority of proposed development is situated below the Peachland Lake and Glen Lake reservoirs and are situated in the unbuffered area (i.e. no reservoirs are present downstream) of the watershed upstream of the intake. In this area any surface erosion/sediment delivery to stream channels are more likely to impact water quality at the intake. Therefore, to safeguard against potential water quality effects in these areas extra consideration should be given to planning and constructing roads to prevent additional surface erosion and sediment delivery to stream channels. Also careful consideration should be given to the maintenance of healthy riparian areas that adequately buffer water courses from potential effects of forest development and other land uses.

- In addition to the surface erosion recommendations provided in Section 3.2.2 and 4.3 the following is recommended for new road construction:
    - where practical temporary roads should be used to help reduce the "unintended" and long term consequences of roads over the longer term,
    - plan road locations to avoid problems near or along stream channels,
    - design roads to divert water flow into the forest rather than directly into streams,
    - ensure cross-drains (and cross-ditches) are adequately spaced to prevent concentration of surface water along road surfaces and ditchlines,
    - plan vertical alignments of roads at stream crossings to ensure that surface runoff from the road surface is not directed towards stream channels,
    - revegetate bare ground (e.g. native grass mixes) as soon as possible following construction,
    - conduct ongoing and timely road maintenance; and
    - use good quality road fill and surfacing materials for any roads that have a moderate or higher potential for sediment delivery to stream channels.

- Recreation use (e.g. quad traffic/trails) and cattle use are present in this watershed; therefore, it is not only important to address the direct effects (e.g. surface erosion) on water from forest harvesting/roads in the forest stewardship planning process but the unintended consequences of forest development be considered. For example, forest harvesting can result in the loss of natural barriers that normally would limit access to watercourses by cattle or recreational users. As a result, increased access to streams by recreational users or cattle should be avoided.

- As suggested at the February 26, 2018 forest licensee meeting with the District of Peachland an integrated list of water quality concerns should be developed by a watershed technical working group that can be used to develop surface erosion mitigation strategies to minimize water quality issues at the District of Peachland water intake. The integrated list could aid in identifying funding, responsibility and timelines for mitigation.

- For all proposed forest development it is critical that careful consideration be given to ensuring all existing and proposed road crossings and road drainage systems are adequate to accommodate large peak flows, prevent excessive erosion and concentration of surface drainage patterns. This recommendation is primarily based on the fact that the few stream channel or surface erosion issues that were identified in the watershed (refer to Section 3.2.2 of this report) were associated with upslope diversion or concentration of surface drainage as result of diversion of surface flows by road drainage or due to the combination of rapid snowmelt from recently harvested upslope cutblocks and road drainage. This recommendation is particularly important in light of climate change that has been projected to cause a higher frequency of extreme events (e.g. higher frequency of intense rainfall events, higher frequency of rain-on-snow events that can generate larger than average streamflow events).

- Ongoing development of harvest blocks in the watershed is increasing the road density in the watershed and increasing the potential for surface and interruption of natural drainage patterns. As a result, a program that strategically deactivates portions of moderate to high risk roads (including non-status roads) within the watershed should be implemented.

- The Regional District of Central Okanagan and FLNR (Fish and Wildlife) should be consulted in regards to their plans for remediating the lower 1.2 km of Peachland Creek situated below Hardy Falls. Ideally this lower section of Peachland Creek should be designed to accommodate large peak flow events (i.e. peak flow return period of greater than 100 years).

- Given the level of past forest development in this watershed consideration should be given to updating the assessment of the watershed every five years or at a frequency that is consistent with any significant new proposed forest development that wasn't included in this assessment.

- Consideration should be given to completing predictive stream mapping based on the available LiDAR data for the watershed. This information could be used to refine erosion and sediment control management and to better identify the connectivity of stream channels to proposed roads and cutblocks.

7.0 USE AND LIMITATIONS

This assessment has been undertaken in accordance with generally accepted methods of watershed assessment for forested watersheds within the southern interior of British Columbia. No other undertaking is given. No portion of this report may be extracted and used independently; it is meant to be read and used in its entirety.

This report is for the sole use of Tolko Industries Ltd., BC Timber Sales and Ntityix Resources LP for the purpose of forest development planning within the Peachland Creek community watershed. It is not for use by any other party or for any other purpose.

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Peer reviewed by Suzan Lapp, Ph.D., P.Geo., June 27, 2018.

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APPENDIX A

Watershed Condition Maps

Appendix A-1 – Watershed Condition Map with Class IV and V Terrain Polygons

Appendix A-2 – Watershed Condition Map with Moderate, High and Very High Surface Erosion Potential Polygons

Appendix A-3 - Bare-earth Hillslope Map with 5 m Contours of the Entire Watershed

APPENDIX B

Summary of Field Inspection Sites

Field Assessment completed on August 18, 19, 22 and September 10, 2017

Appendix B - Field Inspection Summary

Field Review #	Location	Channel Description	Slope (%)	Bank-full Width (m)	Bank-full Depth (cm)	Largest Particle Diam. (cm)	Channel Disturbance Indicators	Riparian Function	Surface Erosion and Delivery	Crossing Description (with Approximate Dimensions)	Comments
1	**Peachland Creek below Hardy Falls (~100 m above confluence with Okanagan Lake)**	Riffle-Pool (Cobble) Stable to Partially Degraded High Sensitivity	3	5	50	20	None (moss covered boulders)	Properly Functioning	Low	Numerous crossings including Hwy 97, Renfrew Road and Hardy Falls Park foot bridges	Channel was actively eroded in the 2017 spring freshet. The abutment/streambank of approximately two of the foot bridges were washed out within Hardy Falls Regional Park. Also approximately five of the forced riffles were undermined.
2	**Peachland Creek at Munro FSR**	Cascade-Pool (Boulder/ Cobble) Stable Moderate Sensitivity	5	5	70	25	Moderate level of bank erosion as result of 2017 spring freshet	Properly Functioning (mature conifers)	High (High Surface Erosion x High Sediment Delivery)	Bridge	Channel was moderately disturbed as result of high streamflows and a landslide that occurred approximately 250 m upstream. Munro FSR is a significant contributor of fine sediment into Peachland Creek. The District of Peachland water intake is only located ~ 250 m downstream.
3	**Peachland Creek – relocated channel section (~ 120 metres long)**	Cascade-Pool (Boulder/ Cobble) Stable Moderate Sensitivity	5	5	70	25	In 2017 channel was relocated approximately 30 metres to east of original location of channel as result of landslide below the Munro FSR that occurred on April 28, 2017	Currently functioning at risk since riparian vegetation directly adjacent to channel has not yet been established due to relocation of channel	High due to exposed banks that have not yet vegetated as result of relocation of channel	N/A	Relocation of Peachland Creek to the east has moved the channel further away from the base of the slope below Munro FSR; therefore, direct sediment inputs from the Munro FSR from the first switch back to approximately 100 m down the road should have been reduced. Installation of riprap along the relocated channel section would help to minimize bank erosion along the exposed channel banks
4	**Peachland Creek directly above relocated channel**	Cascade-Pool (Boulder) Stable Low Sensitivity	5	5	70	25	None	Properly Functioning (mature deciduous/conifers)	Low	N/A	-
5	**Munro FSR southwest of Peachland Creek (500 m section of road from Peachland Creek to first switchback)**	N/A	-	-	-	-	N/A	N/A	High (High Surface Erosion x High Sediment Delivery)	N/A	Munro FSR is a significant contributor of fine sediment into Peachland Creek. The District of Peachland water intake is only located ~ 250 m downstream. Significant surface erosion and delivery of fine sediment into District of Peachland water intake (further remediation is required of this road section is required to minimize surface erosion and delivery)

Field Review #	Location	Channel Description	Slope (%)	Bank-full Width (m)	Bank-full Depth (cm)	Largest Particle Diam. (cm)	Channel Disturbance Indicators	Riparian Function	Surface Erosion and Delivery	Crossing Description (with Approximate Dimensions)	Comments
6	**Small intermittent tributary to Peachland Creek (Munro FSR crossing)**	Very small alluvial channel Low Sensitivity	8	0.5	50	<5	None	Properly Functioning (mature conifers)	Low (Note: 0.5 m wide by 0.5 m deep rill is present on upslope side of road)	400 mm CMP with 1 m deep sump	
7	**Brenda Mines Road (~ 1 km section of road)**	-	-	-	-	-	-	-	High	N/A	Overland flow along road surface and associated surface erosion from Brenda Mines Road is directly connected to Peachland Creek as evidenced by rill erosion. Rill erosion is visible on Google Earth images.
8	**Peachland Creek directly below Greata Creek**	Cascade-Pool (Boulder/Cobble) Stable Low Sensitivity	4	7	50	40	Slightly elevated channel bars of cobbles along channel edge No bank erosion evidence however channel banks have been overtopped in the Spring of 2017 (fine roots exposed along channel banks)	Properly Functioning (mature deciduous and conifers)	Low	N/A	
9	**Peachland Creek between Peachland Main and confluence with Greata Creek**	Riffle-Pool (Cobble/gravel) Partially Aggraded Low Sensitivity	2.5	7	30	20	Partially to Moderately aggraded	Properly Functioning (mature deciduous and conifers)	Low	N/A	
10	**Landslide off of Peachland Main from west side of valley** **(~50 long by 4 m wide x 1.5 m deep)**	-	-	-	-	-	-	-	High	N/A	Toe of slide is directly adjacent (~20 m) to Peachland Creek. Landslide toe has been stabilized with sediment fence however fines likely entered creek during event.
11	**Natural bank failure along Peachland Creek** **(~20 m long x 6 m high 1.5 m deep)**	-	-	-	-	-	-	-	High	N/A	Bank failure along creek is very similar to what was observed in 2014 channel assessment completed by Urban Systems. Bank failure appears to be natural as result of the slope being undercut by Peachland Creek

Field Review #	Location	Channel Description	Slope (%)	Bank-full Width (m)	Bank-full Depth (cm)	Largest Particle Diam. (cm)	Channel Disturbance Indicators	Riparian Function	Surface Erosion and Delivery	Crossing Description (with Approximate Dimensions)	Comments
12	**Peachland Creek approximately 50 m below Peachland Main**	Cascade-Pool (Cobble) Partially Aggraded	3	5-6	40	15	Slightly elevated gravel/cobble bars along channel edge	Properly Functioning (mature deciduous and conifers)	Low	N/A	
13 -14	**Peachland Creek at Peachland Main**	-	-	-	-	-	-	Road Crossing (no riparian area for ~30 m)	High (High Surface Erosion x High Sediment Delivery	3 x 1800 CMPs (CMP inlet on one of the culverts is not visible and is buried in fill)	Peachland Main from 6 km to 8 km is a chronic sediment source of fine sediment to Peachland Creek
15	**Peachland Creek directly above Peachland Main**	Cascade-Pool (Cobble) Stable	3	5-6	40	15	Slightly elevated gravel/cobble bars along channel edge	Properly Functioning (mature conifers)	Low	N/A	No evidence of major bank erosion from the 2017 spring freshet however flows appear to have overtopped the channel banks in the Spring of 2017
16 -21	**Peachland Main switchback** **(~ 1 km in length)**	-	-	-	-	-	-	-	High (Moderate to High Surface Erosion x High Sediment Delivery)	N/A	Overland flow along road surface and associated surface erosion along Peachland Main is directly connected to Peachland Creek as evidenced by rill erosion along the fill slope of the road
22	**Mile Creek at old trail crossing**	Step-Pool (Boulder/Cobble) Partially Degraded	12	2.5	60	20	Old trail has been overtopped and Mile Creek has eroded the trail	Properly Functioning (mainly deciduous)	Moderate (Moderate Surface Erosion x Moderate Sediment Delivery)	No evidence of crossing structure	Old trail crossing has been overtopped and trail is eroded.
23	**Small tributary at old trail**	-	-	-	-	-	Old trail has been overtopped and gully has been created (0.7 m wide x 4 m long x 0.5 mdeep)	-	Moderate (Moderate Surface Erosion x Moderate Sediment Delivery)	No evidence of crossing structure	Old trail has been overtopped and trail and channel is eroded. Erosion and concentrated flows are likely associate with diversion of flows from the road that is ~ 70 m upslope.
24	**Small tributary at old trail**	-	-	-	-	-	Old trail has been overtopped and gully has been created (1 m wide x 4 m long x 0.5 m deep)	-	Moderate (Moderate Surface Erosion x Moderate Sediment Delivery)	No evidence of crossing structure	Recent harvesting from 2015 (KP1089) is situated directly upslope approximately 60 m.
25	**Cross-ditch on old trail**	-	-	-	-	-	-	-	Low	-	Evidence that old trail has diverted flows from upslope since ditchline shows some minor sediment movement
26	**Landslide (debris flow) that crossed old trail**	-	-	-	-	-	-	-	High (High Surface Erosion x High Sediment Delivery)		Debris flow track is partially vegetated and sediment fence has been used to contain sand/gravel. Debris flow tracks extends to Peachland Creek

Field Review #	Location	Channel Description	Slope (%)	Bank-full Width (m)	Bank-full Depth (cm)	Largest Particle Diam. (cm)	Channel Disturbance Indicators	Riparian Function	Surface Erosion and Delivery	Crossing Description (with Approximate Dimensions)	Comments
											Recent harvesting from 2015 (KP1089) is situated directly upslope approximately 150 m
27	**Peachland Creek (low gradient section)**	Riffle-Pool (Gravel) Stable Sequence of beaver ponds and meadows	1	10	100	5	None	Properly Functioning	Low	N/A	
28	**Peachland Creek**	Riffle-Pool (Gravel) Stable	2-3	3.5	50	10	None	Properly Functioning	Low	N/A	
29	**Small cutbank failure on old trail**	-	-	-	-	-	None	-	Low	N/A	Cutbank failure on old trail (5 m long x 3 m high x 0.5 m deep)
30	**Small tributary crossing on old trail (cross-ditch is intact)**	-	-	-	-	-	None	-	Low	Cross-ditch across old trail is function properly	
31	**Old trail fill slope is slumping**	-	-	-	-	-	None	-	Low	N/A	Fill slope on lower edge of road is slumping (~20 m long). Evidence of tension cracks on fill slope. Road will likely fail further with potential to introduce sediment into a small tributary.
32	**Small tributary at old road**	Step-Pool (Cobble/Gravel)	8	0.5	30	10	Old trail has been overtopped and gully has been created (1.5 m wide x 4 m long x 2.5 m deep)	Properly Functioning	High (High Surface Erosion x High Sediment Delivery)	Cross-ditch has been eroded	Two fill slope failures are located in this area. A small tributary has overtopped the old trail and has created a gully. Recent harvesting in 2015 (KP1032) is located directly upslope ~30 – 50 m Water was diverted down a dichline off of a trail that connects with the lower trail. Fine sediment entered Peachland Creek.
33	**Mile Creek at Brenda Mines Road**	Pond situated above road and a small alluvial channel situated below road	6	0.5	-	-	Excessive ditchline erosion (repaired in summer of 2017)	N/A	High (High Surface Erosion x High Sediment Delivery)	600 CMP with plugged inlet	Culvert inlet is plugged at Brenda Mines Road. A pond above the road overtopped and eroded the ditchline for ~400 m down Brenda Mines Road.

Field Review #	Location	Channel Description	Slope (%)	Bank-full Width (m)	Bank-full Depth (cm)	Largest Particle Diam. (cm)	Channel Disturbance Indicators	Riparian Function	Surface Erosion and Delivery	Crossing Description (with Approximate Dimensions)	Comments
34	**Brenda Mines Road**	-	-	-	-	-	-	-	High (High Surface Erosion x High Sediment Delivery)	-	Ditchline erosion along Brenda Mines Road as result of plugged culvert at Mile Creek and the Brenda Mines Road
35	**Brenda Mines Road**	-	-	-	-	-	-	-	High (High Surface Erosion x High Sediment Delivery)	-	Ditchline erosion along Brenda Mines Road as result of plugged culvert at Mile Creek and the Brenda Mines Road
36	**Silver Lake Resort Road**	-	-	-	-	-	-	-	High (High Surface Erosion x High Sediment Delivery)	-	Ditchline erosion along Brenda Mines Road as result of plugged culvert at Mile Creek and the Brenda Mines Road
37	**Peachland Creek directly below Peachland Lake outlet**	Step-Pool (Boulder) Stable	9	3	0.5	10	None	Properly Functioning	None	-	Moss covered bed and stable banks
38	**Outlet of Peachland Lake diversion ditch**	Steep channel Severely degraded	>60	5	-	-	Excessive channel degradation	N/A	High	-	West end of diversion ditch from Peachland Lake drains onto steep valley slope. A large gully has been eroded in the valley slope as result of increased flow from diversion ditch.
39	**Upper Peachland Creek at confluence with Peachland Lake**	Cascade-Pool (Boulder) Partially Degraded	5	3.5	40	30	Channel degradation	Not Properly Functioning	Moderate however sediment delivery is buffered by Peachland Lake	4 CMPS: 2 x 400 mm 2 x 700 mm	Peachland Creek periodically is diverted down access road and flows through the rec. site into Peachland Lake.
40	**Upper Peachland Creek directly above reservoir by-pass**	Riffle-Pool (Cobble) Stable	2.5	5.5	30	10	None	Properly Functioning with Impacts	Low	N/A	Riparian area logged ~40 years ago
41 - 42	**Small tributaries to Peachland Lake**	Cascade-Pool (Cobble) Partially Degraded	5	1	30	<10	Wood culvert has failed at each tributary	Properly Functioning with Impacts Logged riparian area	Low	Wood Culvert (0.5m x 0.3m) at each tributary	1990's logging. Wood culverts have failed.
43	**Tributary #1 on west side of Peachland Creek (Bolivar Main)**	Step-Pool (Boulder/Cobble) Stable	16	0.8	40	10	None	Properly Functioning ~10 m riparian buffer left along creek	Low (low level of rill erosion near outlet of culvert)	1400 CMP	

Field Review #	Location	Channel Description	Slope (%)	Bank-full Width (m)	Bank-full Depth (cm)	Largest Particle Diam. (cm)	Channel Disturbance Indicators	Riparian Function	Surface Erosion and Delivery	Crossing Description (with Approximate Dimensions)	Comments
44	**Tributary #2 on west side of Peachland Creek (Bolivar Main)**	Small Alluvial Channel	6	0.5	30	5	None	Properly Functioning	Low (low level of erosion on downstream side of crossing)	Wood culver (span ~1 m)	
45	**Bolivar Main**	-	-	-	-	-	-	-	Low	-	Roads in the Bolivar main area have minimal evidence of sediment erosion or production. Most roads are partially to fully vegetated with grasses.
46	**Greate Creek ~50 m above confluence with Peachland Creek**	Step-Pool (Boulder/Cobble) Partially Aggraded	10	3	90	25	Moderate to low bank erosion. Exposed fine roots along banks.	Properly Functioning (mature conifers)	None	N/A	Small alluvial fan at confluence with Peachland Creek. Channel overtopped bankful in the spring of 2017.
47	**Greata Creek ~700 m upstream from Peachland Creek**	Cascade-Pool (Cobble) Stable	4	3	50	10	Minor evidence of bank erosion	Properly Functioning (mature conifers/deciduous)	None	N/A	
48	**Greata Creek at Ester Road crossing**	Cascade-Pool (Cobble) Partially Aggraded	4	4-4.5	70	20	Numerous elevated channel bars with sand and gravel along edges of channel. (~2m x 3m x 0.4m deep) Minor bank erosion.	Properly Functioning (mature conifers/deciduous)	Low (Low Sediment Erosion x Moderate Sediment Delivery)	Bridge (log timber)	
49	**Small Tributary crossing Ester Road**	-	-	-	-	-	-	-	Moderate (Moderate Sediment Erosion x Moderate Sediment Delivery)	~600 mm CMP (Big O)	Soils highly erodible (glacial fluvial sandy silt) Fine sediment delivery is directly connected to Greata Creek
50	**Small Tributary crossing Ester Road**	-	-	-	-	-	-	-	High (High Sediment Erosion x Moderate Sediment Delivery)	600 CMP	Small failure above and below crossing. Highly erodible sandy silts. Evidence of soil pipes at interface between relatively impervious sandy silt layer and sandy soil. Fine sediment delivery is directly connected to Greata Creek
51	**Greata Creek mid-reach**	Riffle-Pool (Cobble) Stable	2.5	3.5	70	20	None	Properly Functioning	None	N/A	No evidence of sediment bars as observed at Field Site #48

Field Review #	Location	Channel Description	Slope (%)	Bank-full Width (m)	Bank-full Depth (cm)	Largest Particle Diam. (cm)	Channel Disturbance Indicators	Riparian Function	Surface Erosion and Delivery	Crossing Description (with Approximate Dimensions)	Comments
52	**Recent harvesting in BC Timber Sales operating area**	-	-	-	-	-	-	-	Low	N/A	Surface erosion and ground disturbance in the cutblock was minimal.
53	**Greata Creek at East Fir Road crossing**	Cascade-Pool (cobble) Stable	4	2.5	60	10	None	Properly Functioning	Low	1500 mm CMP	Road surface at the crossing is slightly lower than road surfaces that approach the road therefore there is a potential for the delivery of sediment to the Greata Creek however limited to no surface erosion was observed.
54	**Glen Lake spillway and outlet to Greata Creek**	Cascade-Pool (cobble) Stable	4	2.5	60	10	None (except immediately below spillway due to construction of spillway)	Properly Functioning	Low	N/A	No evidence of excessive channel erosion as result of the 2017 spring freshet event.
55	**Bolivar Creek crossing at Peachland Main**	Riffle-Pool (gravel) Moderately Aggraded Above Road Crossing Cascade-Pool (Boulder/Cobble) Moderately Degraded Below Road Crossing	2-8	2	20	10	Excessive erosion of channel below culvert (gun barrel culvert protruding from road fill)	Properly Functioning	High (High Sediment Erosion x High Sediment Delivery)	1500 mm CMP	Surface flow over Peachland Main is entering Bolivar Creek on the uphill side of the road. A relatively large wedge of find sediment was observed above the culvert inlet. Excessive erosion has occurred at the outlet of the culvert. The culvert is protruding from the road fill.
56	**Bolivar Creek ~ 300 m above Peachland Main**	Cascade-Pool (Cobble) Stable	4	2	30	20	None	Properly Functioning (Mature Conifers)	None	N/A	30 m reserve left along creek with limited evidence of bank erosion from the 2017 spring freshet
57	**Recent harvesting within the Bolivar Creek sub-drainage**	-	-	-	-	-	-	-	Low	N/A	Surface erosion and ground disturbance in cutblock was minimal.
58	**Bolingbroke Creek situated adjacent to Peachland Main**	Step-Pool (Boulder/Cobble) Moderately Aggraded	>6	1.5	50	30	Creek flows along ditchline of Peachland Main	Not Properly Functioning	High	N/A	Bolingbroke Creek eroded Peachland Main in the spring of 2017. The channel was subsequently excavated to maintain flow down creek.

Note: [1]Riparian function is based on criteria used to determine properly functioning condition as described by Tschaplinski, P.J and R.G. Pik

APPENDIX C

Photographs

Photo #1 (Field Stop 1):

Location:
Peachland Creek below Hardy Falls

Notes:
Lower reach of Peachland Creek below Hardy Falls was actively eroded in the 2017 spring freshet. The abutment/streambank of approximately two of the foot bridges were washed out within Hardy Falls Regional Park.

Photo #2 (Field Stop 1):

Location:
Peachland Creek below Hardy Falls

Notes:
Lower reach of Peachland Creek below Hardy Falls was actively eroded in the 2017 spring freshet. Forced riffles placed to create fish habitat were undermined.

Photo #3 (Field Stop 1):

Location:
Peachland Creek below Hardy Falls

Notes:
Peachland Creek is directly adjacent to homes situated below Renfrew Road. Channel bank below homes is highly erodible.

Photo #4 (Field Stop 2): **Location:** Peachland Creek at Munro FSR **Notes:** Stable, Cascade-Pool (Boulder/Cobble) channel. Channel was moderately disturbed as result of high streamflows and a landslide that occurred approximately 250 m upstream. Munro FSR is a significant contributor of fine sediment into Peachland Creek. The District of Peachland water intake is only located ~ 250 m downstream.	
Photo #5 (Field Stop #3): **Location:** Peachland Creek at relocated channel section **Notes:** In 2017 channel was relocated approximately 30 metres to east of original location of channel as result of landslide below the Munro FSR that occurred on April 28, 2017. Channel banks are unvegetated and likely stabilize over next few spring freshets.	
Photo #6 (Field Stop #3): **Location:** Landslide below Munro FSR on west side of Peachland Creek **Notes:** Landslide directly impacted Peachland Creek subsequent to this event ~120 m of Peachland Creek was relocated to the eastside of the partially confined channel valley.	

Photo #7 (Field Stop #3): **Location:** Landslide below Munro FSR on west side of Peachland Creek **Notes:** Overview of Munro FSR landslide (red arrow) situated above the District of Peachland water intake. **Photo Source:** Gorman Bros. Lumber Ltd., Licensee presentation to the Peachland District Mayor and Council (June 13, 2017).	
Photo #8 (Field Stop #4): **Location:** Peachland Creek directly above relocated channel **Notes:** Stable, Cascade-Pool (Boulder) channel	
Photo #9 (Field Stop #2): **Location:** Munro FSR bridge over Peachland Creek **Notes:** Bridge deck and road approaches are major delivery points for sediment. District of Peachland intake is approximately 250 m downstream.	

Photo #10 (Field Stop #2): **Location:** Munro FSR bridge over Peachland Creek **Notes:** Barrier used to minimize delivery of sediment off of the bridge deck into Peachland Creek requires maintenance.	
Photo #11 (Field Stop #5): **Location:** Munro FSR southwest of Peachland Creek **Notes:** Rubber belting used to divert surface flow of water and sediment along surface of Munro FSR needs to be replaced.	
Photo #12 (Field Stop #5): **Location:** Munro FSR southwest of Peachland Creek (within 20 m of Peachland Creek) **Notes:** Sediment fence installed below cross-drain culvert require maintenance.	

Photo #13 (Field Stop #5):

Location:
Munro FSR southwest of Peachland Creek (within 20 m of Peachland Creek)

Notes:
Cross-drain culvert has been filled by fine sediment. This photo highlights the mobility of fine sediments along this portion of the Munro FSR.

Photo #14 (Field Stop #5):

Location:
Munro FSR southwest of Peachland Creek (situated at first switchback southwest of Peachland Creek)

Notes:
Mineral soil is exposed along cutbank. Extensive rill erosion was present along cutbanks.

Photo #15:

Location:
Wildfire (August 4, 2017) approximately 400 m above the District of Peachland water intake (directly northeast of Peachland Creek and the Munro FSR)

Notes:
No direct sediment erosion or delivery hazards were observed below lower end of fire however the lower end of an access trail/fire guard located along the south edge of fire should be deactivated.

Photo #16 (Field Stop #7): **Location:** Brenda Mines Road (Princeton Avenue ~4 km from Peachland) **Notes:** Overland flow along road surface and associated surface erosion from Brenda Mines Road directly connected to Peachland Creek as evidenced by rill erosion (Relatively large rill shown in centre of photo). Note: Rill erosion is also visible on Google Earth images.	
Photo #17 (Field Stop #8): **Location:** Peachland Creek directly below Greata Creek **Notes:** Stable, Cascade-Pool (Boulder/Cobble) channel	
Photo #18 (Field Stop #9): **Location:** Peachland Creek situated between Peachland Main and confluence with Greata Creek **Notes:** Partially Aggraded, Riffle-Pool (Cobble/Gravel)	

Photo #19 (Field Stop #10):

Location:
Toe of landslide off of Peachland Main (~6.5 km) from west side of valley.

Notes:
Toe of landslide is directly adjacent (~20 m) to Peachland Creek. Landslide toe has been stabilized with sediment fence however fine sediment likely entered creek during event.

Sediment fence appears to require maintenance to ensure sediment is does not enter Peachland Creek.

Photo #20 (Field Stop #11):

Location:
Natural bank failure along Peachland Creek (~20 m long x 6 m high 1.5 m deep)

Notes:
Bank failure along creek is very similar to what was observed in the 2014 channel assessment completed by Urban Systems (2015a).

Bank failure appears to be natural as result of the slope being undercut by Peachland Creek

Photo #21 (Field Stop #16-21):

Location:
Peachland Main Switchback at ~6 km

Notes:
Overland flow along road surface and associated surface erosion along Peachland Main is directly connected to Peachland Creek as evidenced by rill erosion along the fill slope of the road

Photo #22 (Field Stop #20-21): **Location:** Peachland Main Switchback at ~6 km **Notes:** Cutbank along west of Peachland Creek is a chronic sediment source to Peachland Creek.	
Photo #23 (Field Stop #15): **Location:** Peachland Creek directly above Peachland Main **Notes:** Stable, Cascade-Pool (Cobble) channel. No evidence of major bank erosion from the 2017 spring freshet however flows appear to have overtopped the channel banks in the Spring of 2017.	
Photo #24 (Field Stop #22): **Location:** Mile Creek at old trail crossing **Notes:** Partially Degraded, Step-Pool (Boulder/Cobble) channel. Old trail has been overtopped and Mile Creek has eroded the trail	

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Photo #25 (Field Stop #24):

Location:
Small Tributary at old trail

Notes:
Old trail has been overtopped and gully has been created (1 m wide x 4 m long x 0.5 m deep)

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Photo #26 (Field Stop #26):

Location:
Landslide (debris flow) that crossed old trail.

Notes:
Debris flow track is partially vegetated and sediment fence has been used to contain sand/gravel.

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Photo #27 (Field Stop #28):

Location:
Peachland Creek mainstem

Notes:
Stable, Riffle-Pool (Gravel) channel.

Photo #28 (Field Stop #32):

Location:
Small Tributary at old trail (1st failure)

Notes:
Two fill slope failures are located in this area. A small tributary has overtopped the old trail and has created a gully. Recent harvesting in 2015 (KP1032) is located directly upslope ~30 – 50 m. Water was diverted down a dichline off of a trail that connects with the lower trail. Slope failure is directly connected to Peachland Creek. Gully in photo is approximately 2 m deep.

Photo #29 (Field Stop #32):

Location:
Small Tributary at old trail (2nd failure)

Notes:
Two fill slope failures are located in this area. A small tributary has overtopped the old trail and has created a gully. Recent harvesting in 2015 (KP1032) is located directly upslope ~30 – 50 m. Water was diverted down a dichline off of a trail that connects with the lower trail. Slope failure is directly connected to Peachland Creek

Photo #30 (Field Stop #33 to 36):

Location:
Mile Creek crossing on Brenda Mines Road

Notes:
Culvert inlet is plugged at the Brenda Mines Road crossing over Mile Creek. A pond above the road overtopped and eroded the ditchline for >400 m down Brenda Mines Road. Road ditchline was repaired in the summer of 2017 after this photo was taken.

Photo #37 (Field Stop #37):

Location:
Peachland Creek directly below Peachland Lake outlet

Notes:
Stable, Step-Pool (Boulder) channel. Moss covered bed and stable banks.

Photo #38 (Field Stop #38):

Location:
Outlet of Peachland Lake diversion ditch

Notes:
East end of diversion ditch from Peachland Lake drains onto steep valley slope. A large gully has been eroded in the steep valley slope as result of flow from diversion ditch.

Photo #39 (Field Stop #40):

Location:
Upper Peachland Creek directly above Peachland Lake reservoir by-pass

Notes:
Stable, Riffle-Pool (Cobble) channel.

Photo #40 (Field Stop #41-42):

Location:
Small tributary to Peachland Lake.

Notes:
Partially Degraded, Cascade-Pool (Cobble) channel.
1990's logging. Wood culvert has failed.

Photo #41 (Field Stop #46):

Location:
Greata Creek ~50 m above confluence with Peachland Creek

Notes:
Partially Degraded, Step-Pool (Cobble) channel. Moderate to low bank erosion. Exposed fine roots along banks. Channel overtopped bankfull in the spring of 2017.

Photo #42 (Field Stop #47):

Location:
Greata Creek ~700 m above confluence with Peachland Creek

Notes:
Stable, Cascade-Pool (Cobble) channel. Moderate to low bank erosion. Minor evidence of bank erosion.

Photo #43 (Field Stop #48):

Location:
Greata Creek at Ester Road Crossing

Notes:
Partially aggraded, Cascade-Pool (Cobble) channel. Numerous elevated channel bars with sand and gravel along edges of channel. Minor bank erosion.

Photo #44 (Field Stop #50):

Location:

Small Tributary crossing Ester Road

Notes:
Small failure above and below crossing. Highly erodible sandy silts. Fine sediment delivery is directly connected to Greata Creek.

Photo #45 (Field Stop #51):

Location:
Mid-reach of Greata Creek

Notes:
Stable, Riffle-Pool (Cobble) channel.

Photo #46 (Field Stop #52):

Location:
Recent harvesting in BC Timber Sales operating area

Notes:
Surface erosion and ground disturbance within the cutblock was minimal.

Photo #47 (Field Stop #55): **Location:** Bolivar Creek crossing at Peachland Main **Notes:** Moderately Aggraded, Riffle-Pool (Gravel) channel above road crossing. Moderately Degraded, Cascade-Pool (Boulder/Cobble) below road crossing. Excessive erosion of channel below culvert (gun barrel culvert protruding from road fill). Surface flow over Peachland Main is entering Bolivar Creek on the uphill side of the road. A relatively large wedge of find sediment was observed above the culvert inlet.	
Photo #48 (Field Stop #56): **Location:** Bolivar Creek ~ 300 m above Peachland Main **Notes:** Stable, Cascade-Pool (Cobble) channel. 30 m reserve left along creek with limited evidence of bank erosion from the 2017 spring freshet	
Photo #49 (Field Stop #57): **Location:** Recent harvesting (KP1133) within the Bolivar Creek sub-drainage **Notes:** Surface erosion and ground disturbance in cutblock was minimal.	

Photo #50 (Field Stop #58): **Location:** Bolingbroke Creek situated directly adjacent to Peachland Main **Notes:** Moderately Degraded, Step-Pool (Boulder/Cobble) channel. Bolingbroke Creek eroded Peachland Main in the spring of 2017. The channel was subsequently excavated to maintain flow down ditchline.	

APPENDIX D

Review of streamflow, snow survey data and rainfall data for the Peachland Creek watershed

Appendix D – Review of streamflow, snow survey data and rainfall data for the Peachland Creek watershed

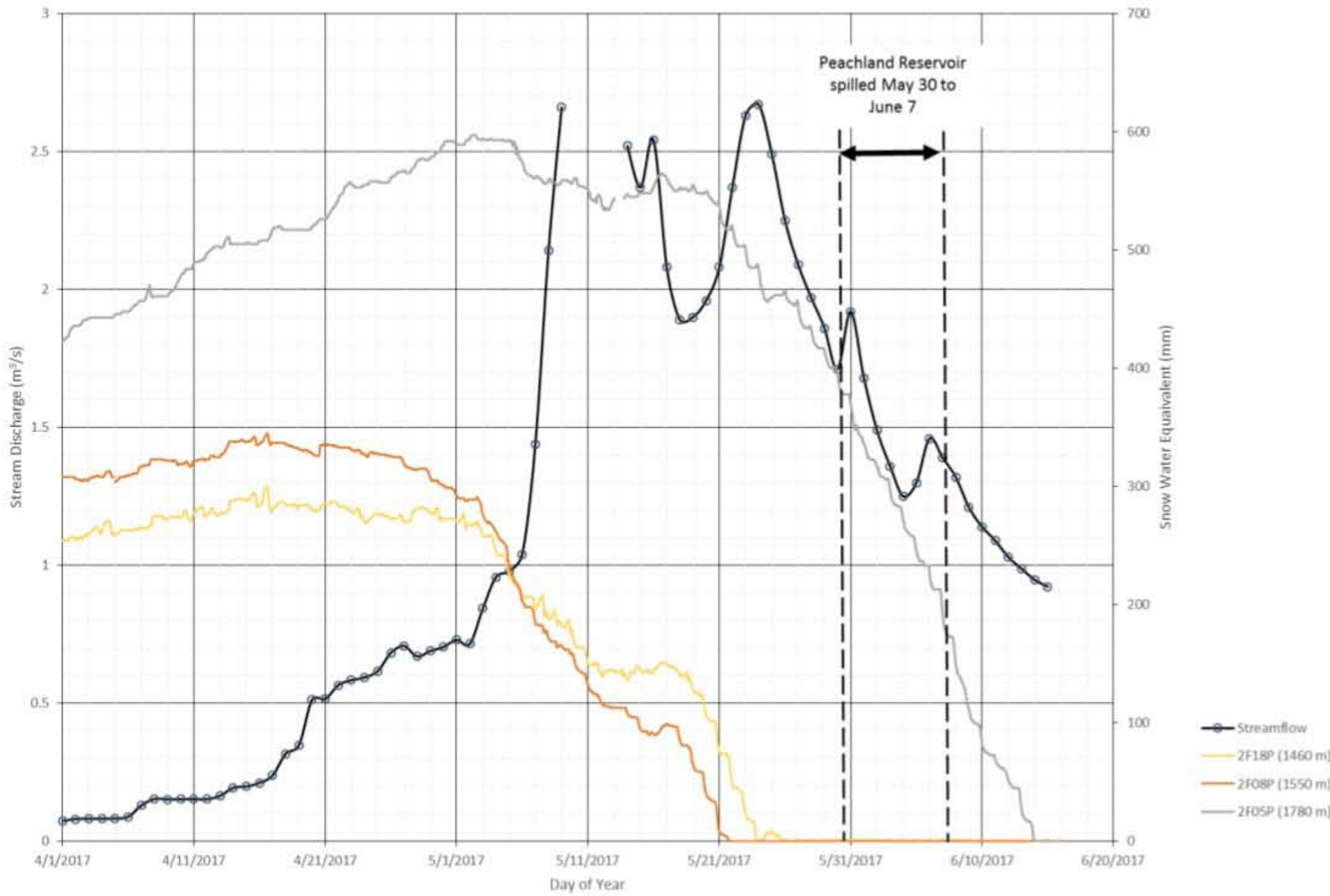

Figure D.1. Greata Creek streamflow data (Stn #08NM173) from April 1, 2017 to June 20, 2017. Peak flow on May 12, 2017 and on May 24, 2017 exceeded a one in 50 year event. Also shown is automated snow survey data from various elevations within the Okanagan Basin (Brenda Mines (2F18P), Greyback Reservoir (2F08P), Mission Creek (2F05P)). The dates at which the Peachland Lake reservoir spilled are also shown. Note: In 2017 stream discharge data is missing for May 10 to May 13, 2017 therefore the annual maximum peak flow in 2017 likely exceeded the actual recorded maximum peak of 2.67 m^3/s.

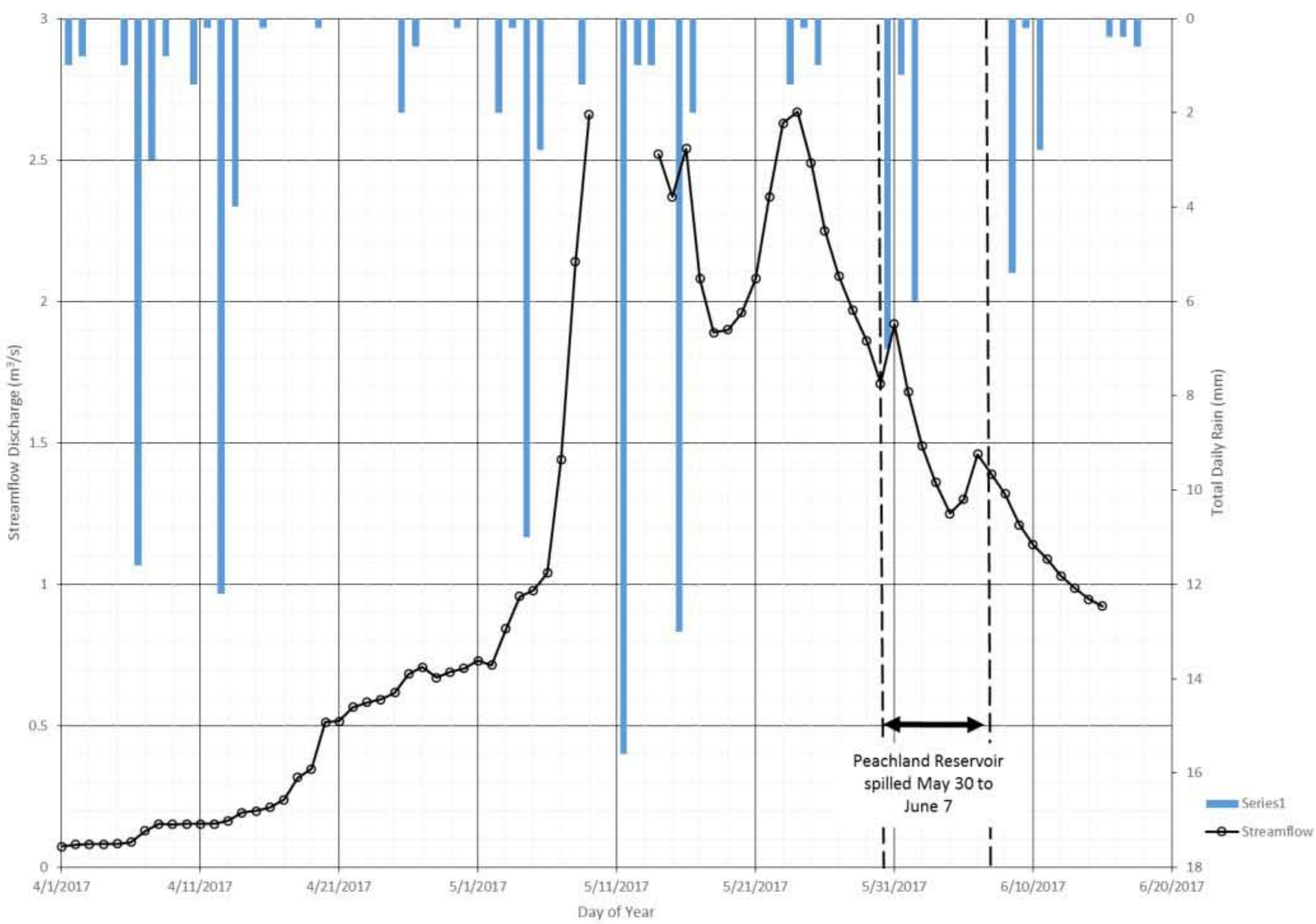

Figure D.2. Greata Creek streamflow data (Stn #08NM173) from April 1, 2017 to June 20, 2017. Peak flow on May 12, 2017 and on May 24, 2017 exceeded a one in 50 year event. Also shown is rainfall data from the Peachland Environment Canada weather station (Climate ID #1126070). The dates at which the Peachland Lake reservoir spilled are also shown. Peak flows in Greata Creek were primarily related to mid-elevation (1300 m to 1500 m) snowmelt and rainfall.

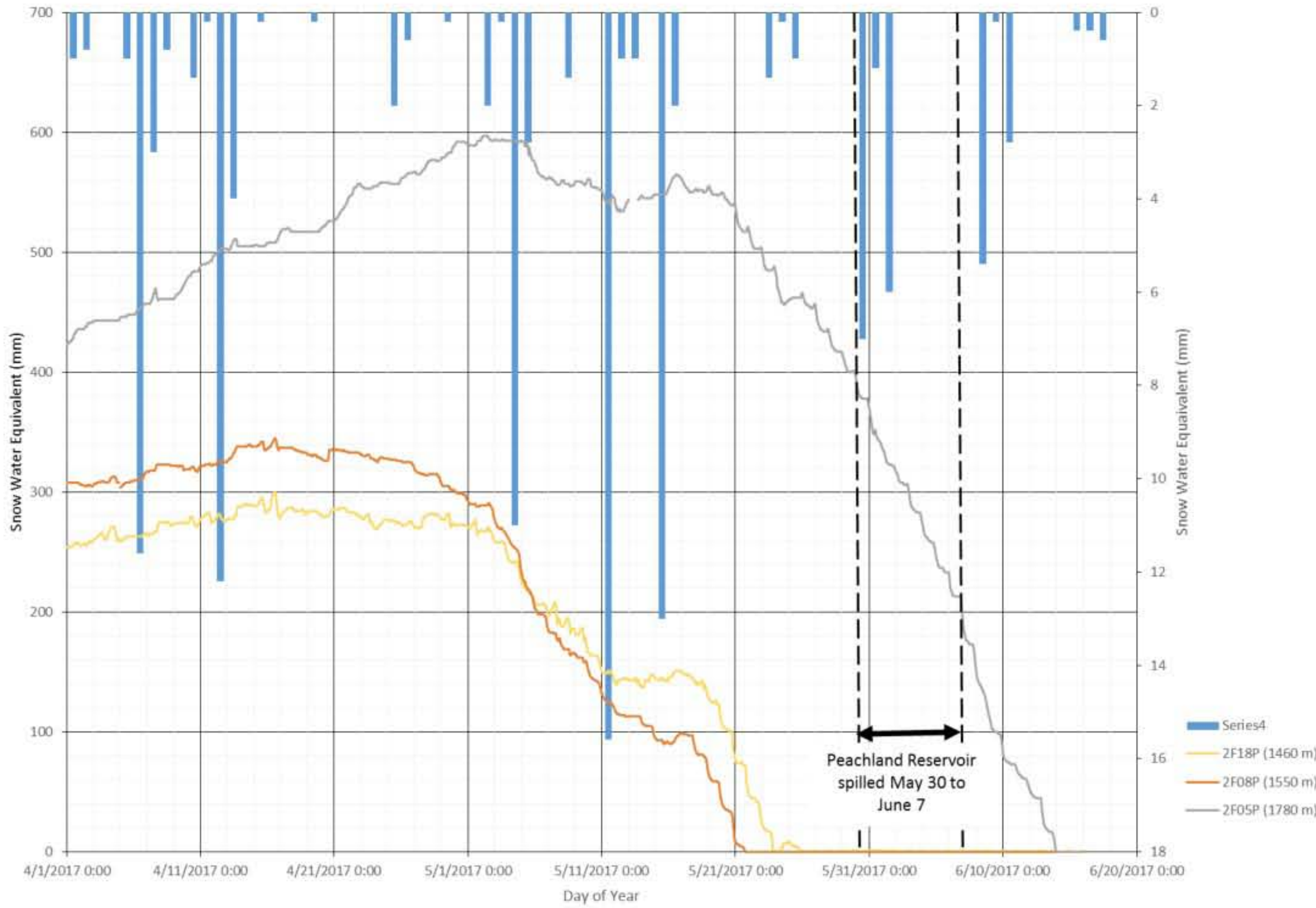

Figure D.3. Automated snow survey data from various elevations within the Okanagan Basin (Brenda Mines (2F18P), Greyback Reservoir (2F08P), Mission Creek (2F05P)) are shown. Also shown is rainfall data from the Peachland Environment Canada weather station (Climate ID #1126070). The dates at which the Peachland Lake reservoir spilled are also shown. Peak flows in Greata Creek were primarily related to mid-elevation (1300 m to 1500 m) snowmelt and rainfall.

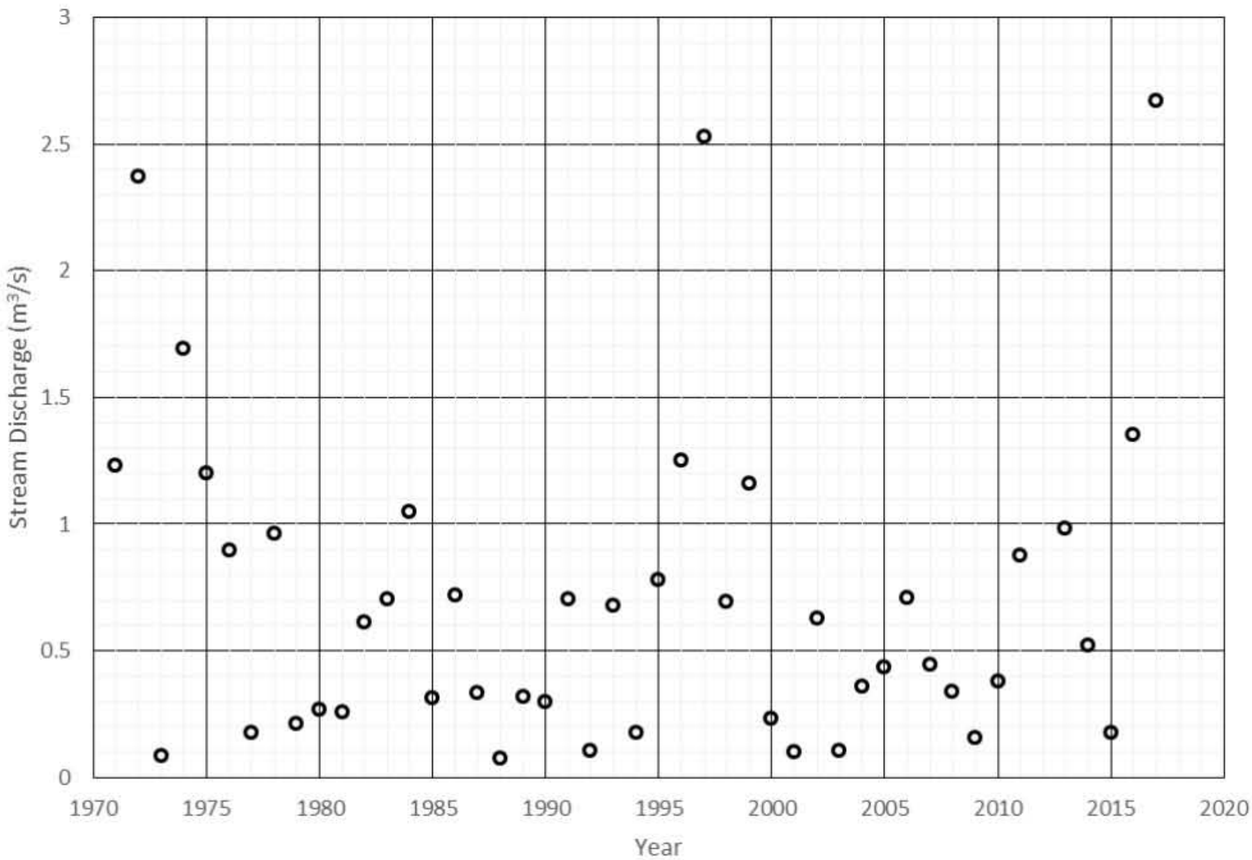

Figure D.4. Annual peak stream discharge for Greata Creek (Stn #08NM173) from 1971 to 2017. Note the three largest annual peak flows on record occurred in 2017, 1997 and 1972. Note: In 2017 stream discharge data is missing for May 10 to May 13, 2017 therefore the annual maximum peak flow in 2017 likely exceeded the actual recorded maximum peak of 2.67 m^3/s.

APPENDIX E

Office-based review of the surface erosion potential

associated with proposed development

(*Note: the portions of the following table that are highlighted in yellow indicate proposed development that requires additional consideration to ensure potential surface erosion issues are minimized)

Block	CP	Drainage Basin	Area (ha)	Road or Block Proximity to Moderate to Very High Surface Erosion Polygon	Road or Block Proximity to Class IV or V Terrain	Surface Erosion Potential (Maynard SFCERO_POT)	Sediment Delivery Potential (Maynard SESED_CLS)	Number of proposed road stream crossings to access block	Road-Stream Connectivity	Overall Potential Surface Erosion	Overall Potential Delivery of Sediment to Water Intake	Comment	Recommendation
KP1003	K20	Mid-Peachland	25.2	None	None	Low	Low to Mod.	None	Low	Low	Low	No direct connectivity to DOP water intake	Ensure downslope road crossings are adequately sized to accommodate potential increased peak flows. Ensure natural drainage patterns are maintained along access roads.
KP1027	K23	Mid-Peachland	39.8	Upper road is situated on Mod. Surface Erosion Polygon	Approx. 250 m of southeast edge of block is situated above Class IV terrain	Low to Mod	Low to Mod. w/ **southern portion of block and road situated on High**	One	Low (except at stream crossing)	Low (except at stream crossings)	Low (except at stream crossings)	No direct connectivity to DOP water intake provided surface drainage patterns are maintained. Stream within in block ~ 350 m long according to Trim data however stream may be outside block boundary based on bare earth image . Stream width <1 m wide based on field site #44. Stream also situated southeast of block bndy (<1 m in width)	Ensure downslope road crossings are adequately sized to accommodate potential increased peak flows. Ensure natural drainage patterns are maintained along access roads. Ensure road crossings are designed to avoid surface erosion and delivery. Ensure slope stability is not increased for the small portion of Class IV terrain situated below southeast edge of block.
KP1021	N66	Upper Peachland	7.2	Block situated on and above Mod. Surface Erosion Polygon	Class IV terrain situated >25 m below the proposed block	Block situated on Mod.	Moderate	None	Low	Low	Low	Situated upstream from Peachland Lake ~4 km and also buffered by wetland situated ~1.5 km downstream of proposed block and road. No new road to be constructed however it appears that an old trail will be upgraded.	Ensure slope stability is not increased below proposed block. Ensure natural drainage patterns are maintained along access road.
KP1058	K23	Mid-Peachland	14.0	None	None	Low	Low to Mod.	None	Low	Low	Low	Proposed block is situated on both sides of Mile Creek along relatively steep gully	Ensure downslope road crossings are adequately sized to accommodate potential increased peak flows. Ensure adequate riparian buffer is maintained to minimize surface erosion and delivery to Mile Creek. Avoid bladed skids trails adjacent to Mile Creek within the steep gully present within the block.
KP1166	K23	Mid-Peachland	31.7	None	None	Low	Low to Mod.	One	Low	Low	Low	Situated adjacent to small headwater tributary to Peachland Creek mainstem	Ensure downslope road crossings are adequately sized to accommodate potential increased peak flows. Ensure natural drainage patterns are maintained along access roads.
KP1094	K23	Mid-Peachland	14.4	Moderate and high surface potential polygon situated below the proposed block	Class IV terrain situated below the proposed block	Low	Moderate	None	Low for proposed road and **High for existing spur road situated on south end of block**	Low from proposed road. **High from existing spur road on south end of block**	Low from proposed road. **High from existing spur road on south end of block**	Mile Creek and a tributary channel are situated east and west of the proposed block, respectively. Tributary crossings at the old trail were eroded (Field Stop #22 and #23).	Two old roads are situated at the lower (south) end of the block. It is critical that natural drainage patterns be reviewed and maintained both within the block and below the block. This recommendation is particularly important at the lower end of the existing spur road situated on the south end of the block. The spur road may concentrate surface flows down road ditchline onto Class IV terrain. Consideration should also be given to deactivating the road crossings at the old trail to avoid further erosion.
KP1147	K20	Greata Creek	46.9	**High surface erosion potential polygon situated below block on west side**	None	Low to Mod with **High surface erosion polygon below block on west side**	Moderate	Two	Low (existing road is 60 m upslope. In block roads will be greater than 60 m from Bolivar Creek.	Low	Low		Outlet of culvert at Peachland Main crossing Bolivar Creek needs to be stabilized to prevent further erosion. Ensure natural drainage patterns are maintained along access roads.
KP1161	K23	Mid-Peachland	40.9	Block situated on moderate	None	Moderate	Low	None	Very Low	Low	Low	No direct connectivity to DOP water intake	Ensure natural drainage patterns are maintained along access roads.
KP1114	K20	Greata Creek	51.0	Block and road situated on low	None	Low	Low to High	Two	Low	Low	Low	High elevation block situated well away from mainstem stream channels	Ensure downslope road crossings are adequately sized to accommodate potential increased peak flows. Ensure natural drainage patterns are maintained along access roads.

Block	CP	Drainage Basin	Area (ha)	Road or Block Proximity to Moderate to Very High Surface Erosion Polygon	Road or Block Proximity to Class IV or V Terrain	Surface Erosion Potential (Maynard SFCERO_POT)	Sediment Delivery Potential (Maynard SESED_CLS)	Number of proposed road stream crossings to access block	Road-Stream Connectivity	Overall Potential Surface Erosion	Overall Potential Delivery of Sediment to Water Intake	Comment	Recommendation
KP1123	K20	Upper Peachland	7.2	Situated above High surface erosion potential polygons	Situated above Class V and IV terrain	Low	Low	None	Low	Low	Low	Situated above a wetland and Peachland Lake; therefore, no direct connectivity to DOP water intake	Ensure terrain instability associated with Class V and IV is not increased below the proposed block. Drainage of the existing road situated below the proposed block should be reviewed to ensure upslope runoff does not erode the road.
KP1128	556	Mid-Peachland	40.2	Block is situated on a moderate surface erosion potential polygon.	Northwest portion of block is situated on a Class IV terrain. Also northeast side of block is situated above Class IV terrain.	Low to Mod.	Low to Mod.	3 existing crossings	Low	Low with moderate surface erosion potential along northwest portion of the proposed block needs to be reviewed to ensure surface erosion or terrain instability are not increased.	Low with moderate delivery potential on northwest portion of the proposed block.		Northwest portion of block needs to reviewed by terrain/surface erosion specialist to ensure surface erosion potential is not increased. Based on the office assessment road access at northwest portion of block should be reviewed to ensure surface erosion or sediment delivery is not increased at stream crossings that are tributary to Peachland Creek.
KP1129	556	Mid-Peachland	9.9	West portion of block is situated slightly on and above high surface erosion potential polygons	West portion of bock is situated slightly on and above Class V and IV terrain	Low, Mod and small portion of high	Mod. to high	None	Low	Low except for northwest portion of block	Low except for northwest portion of block		Ensure terrain instability associated with Class V and IV is not increased below the proposed block. Ensure natural drainage patterns are maintained.
KP1130	K20	Mid-Peachland	9.8	Proposed Roads and block are situated on moderate	None	Moderate	Low to High	None	Low	Low	Low	Upper elevation block situated away from major tributaries	Ensure downslope road crossings are adequately sized to accommodate potential increased peak flows.
KP1134	556	Mid-Peachland and Greata Creek	4.4	None	Southern portion of block is situated above IV terrain - however stream connectivity is very low	Low	Low to Very Low	None	Low	Low	Low	Upper elevation block situated away from major tributaries	
KP1138	558	Greata Creek	2.6	None	None	Low	Very Low	One	Low	Low	Low	Upper elevation block situated away from major tributaries	Small tributary crossing to access block
KP1139	558	Greata Creek	3.1	None	None	Low	Low to Very Low	None	Low	Low	Low	Upper elevation block situated away from major tributaries	
KP1141	K20	Greata Creek	3.5	None	None	Low	Low to Very Low	None	Low	Low	Low	Upper elevation block situated away from major tributaries	
KP1142	K20	Mid-Peachland Creek	114.5	None	None	Low	Low	Two	Low	Low	Low		Ensure all downslope road crossings are adequately sized to accommodate potential increased peak flows.

Block	CP	Drainage Basin	Area (ha)	Road or Block Proximity to Moderate to Very High Surface Erosion Polygon	Road or Block Proximity to Class IV or V Terrain	Surface Erosion Potential (Maynard SFCERO_POT)	Sediment Delivery Potential (Maynard SESED_CLS)	Number of proposed road stream crossings to access block	Road-Stream Connectivity	Overall Potential Surface Erosion	Overall Potential Delivery of Sediment to Water Intake	Comment	Recommendation
KP1145	K20	Greata Creek	9.0	None	None	Low	Low	None	Low	Low	Low	Existing road on east edge of block is adverse grade that may concentrate flows however it doesn't appear to be connected to any streams since it appears to be on a dry south facing hillslope.	
KP1146	K20	Greata Creek	40.4	Small portion of road and block on Moderate	None	Mostly Low with some Moderate	Very Low to Moderate	None	Low	Low	Low		Outlet of culvert at Peachland Main crossing Bolivar Creek needs to be stabilized to prevent further erosion.
KP1149	K20	Mid-Peachland	9.9	Proposed Road and block is situated on Moderate	North end of block and access road is situated above Class IV terrain	Moderate	High	One	Low	Moderate	High	Upper access road crosses three gullies visible on bare earth map.	Review gullies before road construction to ensure surface erosion will not be increased. Ensure downslope road crossings are adequately sized to accommodate potential increased peak flows. Ensure natural drainage patterns are maintained along access roads.
KP1151	K20	Mid-Peachland	8.1	None	None	Low	Moderate	None	Low	Low	Low	Brenda Mines road situated downslope of block, hillside above Brenda Mines Road appears dry and unlikely to have surface runoff.	
KP1160	K23	Mid-Peachland	11.2	None directly however situated above Field Site #23	None directly	Low with small portion of proposed road and block on Moderate	Moderate	One	Low	Low	Low		Situated above Field Stop #23. Ensure natural drainage patterns are maintained and ensure downslope road drainage is adequate to accommodate potential increased flows from proposed cutblock (e.g. it is suggested the old trail situated below the proposed block should be deactivated).
KP1157	K23	Mid-Peachland and Greata Creek	10.0	None	None	Low	Very Low	None	Low	Low	Low	Upper elevation block situated away from major tributaries	
KP1158	K20	Mid-Peachland	14.1	Proposed Road and block is situated on Moderate	None	Low to Moderate	Very Low and High	None	Low	Low	Low	Up slope of Class IV and moderate surface erosion polygon; however, provided natural drainage patterns are maintained affects on these polygons should be insignificant	Ensure downslope road crossings are adequately sized to accommodate potential increased peak flows. Ensure natural drainage patterns are maintained along access roads.
KP1159	K23	Mid-Peachland	9.6	Situated above High surface erosion polygon	Situated above Class IV terrain	Very Low to Low	Moderate	None	Low	Low	Low	Proposed access roads are generally low gradient and don't appear connected to downslope the high surface erosion polygon or Class IV terrain. Access road at western edge of block crosses relatively deeply incised gully.	Ensure natural drainage patterns are maintained along access roads. Ensure access road crossing gully at western edge of block increases surface erosion.
KP1162	K23	Mid-Peachland	7.5	None	None	Low	Moderate	None	Low	Low	Low	No apparent concerns	
KP1156	K23	Greata Creek	13.8	None	None	Low	Low	None	Low	Low	Low	Block adjacent to Peachland Main and approx. 64 m to Greata Creek on relatively flat terrain. No access roads proposed.	
KP1154	K23	Greata Creek	20.5	Portion of block and road is located on Moderate	None	Low to Moderate	Very Low and Moderate	None	Low	Low	Low	High elevation road and block situated well away from mainstem stream channels	
KP1167	K23	Greata Creek	18.0	Proposed road and block is situated on Moderate	None	Moderate	High	One	Low	Moderate	High	Proposed road and block are situated above gullied terrain that was observed to have erodible fine sands/silts. Situated above Field Site #49.	Proposed block could increase stream flow along Ester Road. Gully stability and road drainage should be reviewed and upgraded (if necessary) to minimize potential surface erosion to Greata Creek.

Block	CP	Drainage Basin	Area (ha)	Road or Block Proximity to Moderate to Very High Surface Erosion Polygon	Road or Block Proximity to Class IV or V Terrain	Surface Erosion Potential (Maynard SFCERO_POT)	Sediment Delivery Potential (Maynard SESED_CLS)	Number of proposed road stream crossings to access block	Road-Stream Connectivity	Overall Potential Surface Erosion	Overall Potential Delivery of Sediment to Water Intake	Comment	Recommendation
KP1168		Mid-Peachland	14.7	West portion of block is situated on and above Very High and High surface erosion potential polygons	West portion of block is situated on and above Class V and IV terrain	Mainly Low	Mainly Moderate	None	Moderate	Moderate	Moderate	Road drainage below the switchback on an existing road on the west edge of the block should be reviewed to ensure surface runoff will not be concentrated onto Class V and IV terrain and Very High and High surface erosion polygons.	Ensure natural drainage patterns are maintained along access roads. Ensure slope instability or surface erosion potential are not increased downslope at the west end of the block.
KP1169		Mid-Peachland	5.3	None	None	Low	Low	None	Low	Low	Low	No apparent concerns however several gullies are present downslope but do not appear to be connected to surface drainage.	
BCTS	K7GS	Greata Creek	51.85	Situated on Moderate surface erosion potential polygon	Situated on Class IV terrain	Moderate	High	Two	Low	Moderate	Moderate	Glen Lake and swamp complexes situated below blocks therefore potential surface erosion is likely buffered; however, careful erosion/sediment control planning should be implemented.	Moderate surface erosion potential should be included in road and block forest development planning considerations to ensure surface erosion delivery to Glen Lake is avoided.
BCTS	K7J3	Greata Creek	108.39	Portions of proposed road and block are situated on Moderate and High	Small polygon of Class V terrain (appears to be a rock talus slope)	Low to High	Very Low, Low and Very High	Three	Moderate	Moderate	Moderate	Access road on northern edge includes four crossings on relatively steep terrain. Also includes one major switchback. Lower access road also crosses gullied terrain at northern end of the proposed block.	Ensure natural drainage patterns are maintained along access road. A drainage management plan should be developed to ensure natural drainage patterns are maintained. Ensure all downslope road crossings are adequately sized to accommodate potential increased peak flows. Gullied terrain is present at the northern end of the proposed block; therefore, ensure road location does not increase surface erosion adjacent to tributary channel (e.g. if necessary, consider relocation of access road)
BCTS	K7J4	Greata Creek	94.95	Proposed road and block are situated on Moderate	None	Low to Moderate	Low, Moderate and High	Three	Moderate	Moderate	Moderate	(see comments regarding K7J3)	(see comments regarding K7J3)
BCTS	K7J2	Greata Creek	57.44	Proposed road and block are situated on Moderate surface erosion potential polygon	Proposed block situated on Class IV	Low to Moderate	Low and High	None (one existing crossings that should be reviewed for surface erosion)	Low	Moderate	Moderate	Glen Lake and swamp complexes situated below blocks therefore potential surface erosion is likely buffered; however, careful erosion/sediment control planning should be implemented.	Moderate surface erosion potential should be included in road and block forest development planning considerations to ensure surface erosion delivery to Glen Lake is avoided.
BCTS	K7J5	Greata Creek	41.76	None	None	Low	Very Low and Moderate	None	Low	Low	Low	Hummocky features along lower end of the block shown in bare earth image	Avoid bladed skid trails that could expose mineral soil along the lower end of the cutblock
BCTS	K7HJ	Greata Creek	43.77	Portion of proposed access road and block are situated on High (~45%) and Moderate surface erosion potential polygon	Portion of block is located on Class IV terrain	Moderate and High	Low, Moderate and High	4 (includes 2 situated past block bndy	Two streams situated within the cutblock	High	Moderate	Glen Lake and swamp complexes situated below blocks therefore potential surface erosion is likely buffered; however, careful erosion/sediment control planning should be implemented.	Ensure surface erosion from block is not increased given high surface erosion potential. Avoid localized erosion from block. Also any proposed roads should be developed in a manner that does not increase surface erosion potential.

Block	CP	Drainage Basin	Area (ha)	Road or Block Proximity to Moderate to Very High Surface Erosion Polygon	Road or Block Proximity to Class IV or V Terrain	Surface Erosion Potential (Maynard SFCERO_POT)	Sediment Delivery Potential (Maynard SESED_CLS)	Number of proposed road stream crossings to access block	Road-Stream Connectivity	Overall Potential Surface Erosion	Overall Potential Delivery of Sediment to Water Intake	Comment	Recommendation
WBFN	K1P CP	Mid-Peachland and Residual Area	17.7	No road planned, Block is situated above Moderate surface erosion potential polygon	Block situated above Class IV terrain	Low	Low	No access road required	Low	Low	Low	Proposed block is situated directly above Peachland Main at 6 km. Harvest method appears to be partial cut.	Make sure block does not affect downslope surface erosion at the Peachland Main crossings
WBFN	K1P CP	Residual Area	9.6	None	None	Low	Very Low	No access road information provided.	Low situated along ridge top on watershed boundary	Low	Low	Harvest method appears to be partial cut	
WBFN	K1P CP	Not in watershed	1									Not in watershed	
WBFN	K1P	Residual Area	8.9	Situated above Very High and Moderate surface erosion potential polygons	Situated above Class IV terrain	Low and Moderate	Moderate	One	Low	Low	Low	Harvest method clearcut	Potential downslope surface erosion and terrain issues that could effect water quality at the DOP intake. Ensure forest development planning takes this into consideration to avoid surface erosion of terrain issues associated with any road construction or block development.
WBFN	K1P	Residual Area	13.9	None	None	Low	Very Low and Moderate	One	Assumed low since the block is situated away from Peachland Creek canyon and slope	Low	Low	Harvest method clearcut	Although block appears to be situated away from the steep canyon of Peachland Creek ensure road or block development does not effect surface erosion or slope stability at tributary channel to Peachland Creek

APPENDIX F

Equivalent Clearcut Area Analysis Peachland Creek Watershed

(includes long-term ECA projections)

Refer to attached report

Forsite. 2018. Equivalent Clearcut Area Analysis Peachland Creek Watershed (Project 41-258). Report prepared for Tolko Industries Ltd., Okanagan Woodlands, Kelowna, BC. (October 29, 2018)

Equivalent Clearcut Area Analysis
Peachland Creek Watershed

- ***Upper Peachland Creek***
- ***Mid Peachland Creek***
- ***Greata Creek***

October 29, 2018

Project 41-258

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Table of Contents

Table of Contents ... 1
List of Figures ... 1
List of Tables ... 1
1 Introduction ... 2
1.1 Project Objectives ... 2
2 Approach ... 3
2.1 Data Gathering and Preparation ... 3
2.2 Data Processing and Analysis ... 4
3 Results ... 7

List of Figures

Figure 1 Watershed Unit Boundaries ... 2
Figure 2 Sub Unit Boundaries ... 3
Figure 3 Snowline (1340m). ... 4
Figure 4 LiDAR Canopy Height Model ... 5
Figure 5 Winkler Curve graphed – ECA% by Stand Height ... 6
Figure 6 Current ECA (Winkler& Boon) with Forest Health Stand Mortality ... 9
Figure 7 Proposed ECA (Winkler& Boon) with Forest Health Stand Mortality ... 10
Figure 8 5 year Recovery (Winkler& Boon) with Forest Health Stand Mortality. ... 11
Figure 9 10 Year Recovery (Winkler& Boon) with Forest Health Stand Mortality ... 12
Figure 10 20 Year Recovery (Winkler& Boon) with Forest Health Stand Mortality ... 13

List of Tables

Table 1 Forest Health Stand Mortality ECA values based on a combination of years since attack, percentage of pine within the stand, and the stand percentage dead* ... 7
Table 2 ECA Summary (Current/Proposed/Future) - (Winkler) ... 8
Table 3 ECA Above Snowline (Current/Proposed/Future) - (Winkler) ... 8

1 Introduction

This project provides Equivalent Clearcut Area (ECA) calculations for the Peachland Creek watershed and four defined sub units; Upper Peachland Creek, Mid Peachland Creek, Greata Creek and Residual above Intake (Figure 1 & Figure 2). ECA calculations provide a measure of hydrologic impact from forest cover removal and are expressed as a percentage of the total watershed area - both above and below the snowline. The snowline for this project was adopted from previous Land Based Reporting work completed for Tolko and defined as 1340m.

Figure 1 ***Watershed boundary and location***

1.1 Project Objectives

The purpose of this project is to:

1. Complete a 'Current Condition' ECA analysis for the watershed's total area as well as a separate ECA analysis for the area above and below the snow sensitive line using the 2005 Rita Winkler curve. Where sub units exist, they will have the same calculations completed.
2. Complete a 'Proposed Condition' ECA analysis that includes proposed harvest blocks as well as planned roads.

3. Complete a series of 'Future Condition' scenarios (20 year annual increments) to show recovery over time.

2 Approach

2.1 Data Gathering and Preparation

Define Spatial Units

1. Spatial boundaries and snow sensitive zones for the Peachland Creek Watershed and respective basins were supplied by Rob Scherer (Figures 1/2/3). The snow sensitive line was adopted from previous land based reporting work completed for Tolko.
   Note: *For the purpose of this analysis, the Mid Peachland Creek reporting unit does not include the portion of Upper Peachland Creek that flows into it.*

Update the Forest Inventory to September 2017

1. Ensured logged and CP approved blocks were reflected as logged in the inventory using RESULTs and FTA data available through Data BC. Proposed blocks were supplied by three separate Licensee stakeholder groups (Tolko, BC Timber Sales and Stityix).
2. Ensured fires were appropriately reflected in the inventory (polygons and approximate heights)
   Note: Active fires and recent (2017) have not been incorporated into this analysis.
3. Visually confirmed accuracy of forest cover disturbances / depletions, and anthropogenic disturbed areas using Spot 5 imagery subscription.

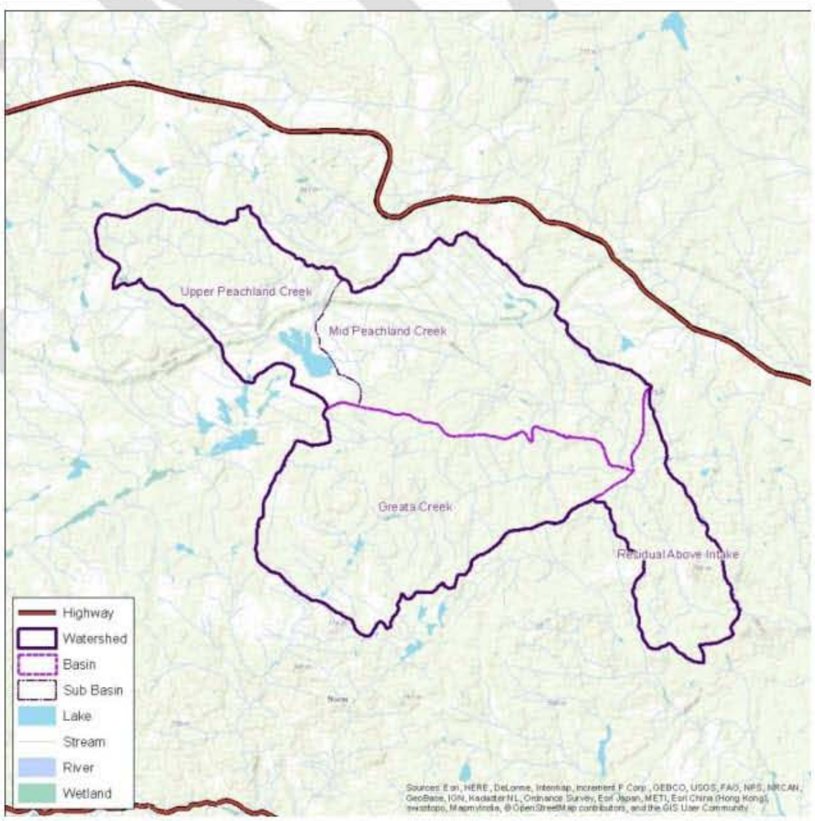

Figure 2 ***Watershed boundary and sub units***

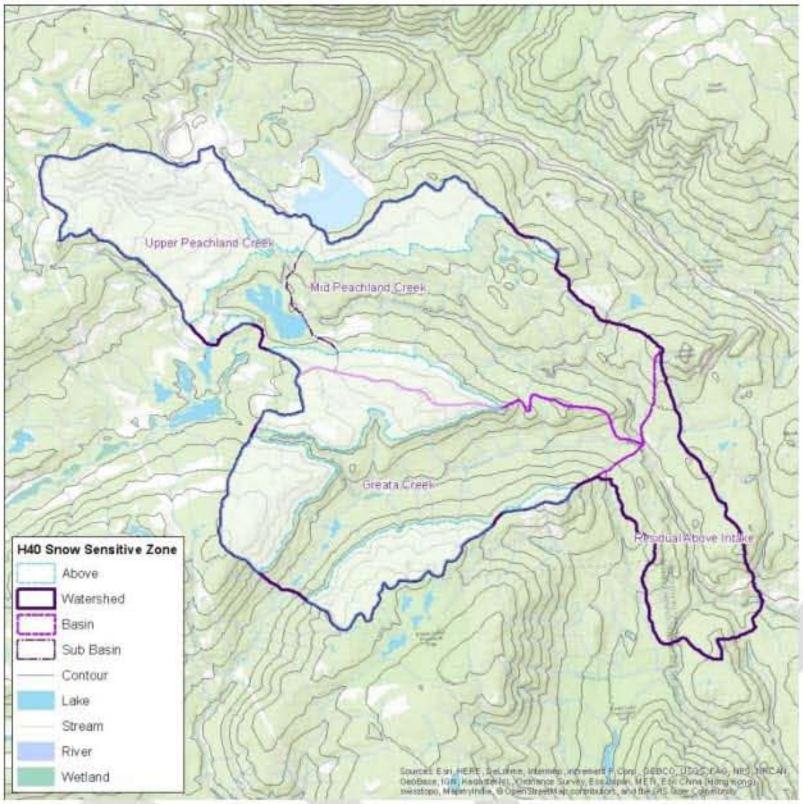

Figure 3 ***Location of snow sensitive line (1340m)***

2.2 Data Processing and Analysis

Identify polygons that contribute to ECA

1. Using the Forest Cover Inventory, polygons with a BC Land Classification System (BCLCS) polygons were selected and given an ECA value of 0% if they are naturally non-forest (rock, water, brush) or a value of 100% if they are likely to have once been forested (agricultural land, gravel pit, etc.). An additional manual QC of the area was performed using the Spot 5 Imagery and the Forest Cover Ownership layer to pull out anthropogenic disturbed private land that may have been missed in the Inventory coding.
2. Forested polygons with a disturbance indicator (logged, burned, IBM/IBS) were selected for ECA assignment. A Forest Health Stand Mortality was adopted for assigning an ECA value to insect affected stands. This approach uses a years-since –attack component that reflects recovery over time. In the Forest Health Stand Mortality scenario, only IBM/IBS impacted stands with a stand mortality >30% were considered disturbed. Only burned stands less than 20 years old, and available within the VRI typing were included.
3. Roads were included in in the Current ECA in one of two ways:
    - Where VRI typing indicated
    - Active permitted roads taken from the BC Government FTEN Roads layer were applied a buffer of 15m (total) and assigned an ECA value of 100% for perpetuity.

Planned roads, provided by licensees were included in the Proposed and Future scenarios. All planned roads were buffered to a 15m width and maintain 100% ECA for perpetuity.

Determine tree heights for ECA calculations

1. The individual stand heights were calculated from the generalized LiDAR data. The LiDAR Canopy Height Model (CHM) raster was generalized into 5m by 5m pixels, retaining the maximum tree height within each cell.
2. Within each stand polygon, the 5x5 meter pixels were summed starting with the tallest class and working downwards in a sequential manner until at least 50% of the total polygon area was accounted for. This method ensures that the majority of a block is to be at least as tall as the height assigned. The depletions layer (a combination of RESULTs, FTA, VRI and Licensee provided block data), were compared against the SPOT imagery and edited where needed to ensure that visible retention trees are assigned a unique height value versus their depleted neighbour.
3. Future growth (20 Year increments) were calculated through programmatically accessing the BC Government's Site Tools software. Using a managed site index (generated from the BC Site Productivity Points), leading species code, and the age of the disturbed stand. The annual growth increment is then added to the initial LiDAR derived height to account for stand recovery over a 20 year period.

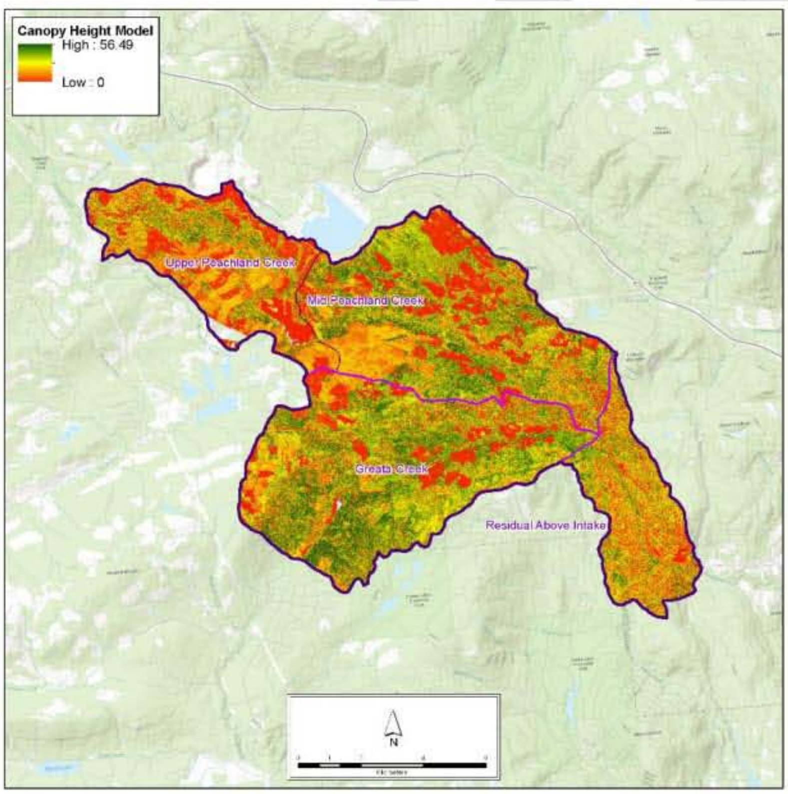

Figure 4 ***LiDAR derived Canopy Height model***

Assign an ECA value to all disturbed polygons

1. An ECA value was assigned to all polygons flagged as disturbed.

- Harvested polygons, as well as fire disturbed polygons were assigned values based on the Winkler and Boon recovery curve (Figure).

  Note: All current, approved and planned blocks are assumed to be clear-cut. The Stityix planned blocks have tentative harvest dates of 2020, and 2025 and therefore will only contribute to the overall ECA percentage in the recovery scenarios.

- Where an IBM flag is present and stand mortality is greater than 30%, a MPB ECA value was generated based on the stand percentage dead, and years since attack (Table). The use of the Years-Since-Attack typing allows for recovery over time within affected stands. Where an MPB ECA value and a Harvest ECA value (Winkler and Boon) both exist the MPB was added to the Harvest ECA value (to a maximum of 100). Where an MPB ECA exists but no historical harvesting is recorded, only the MPB ECA value was retained.

2. If no typing is available within the inventory an ECA value of 100% was assumed (e.g. some private land).
3. Disturbed polygons were assigned an ECA value by referencing the polygon's height (generated from Site Tools) and appropriate value on the Winkler and Boon curve. The Winkler and Boon curve assumes a mature stand height of 25m and has been factored to reflect shorter mature stands (i.e. 20m mature heights at 100 years of age).

<12m SI stands = 20m Mature Stand ECA curve,

> 12m SI stands = 25m Mature Stand ECA curve,

Curves are not factored for taller stands.

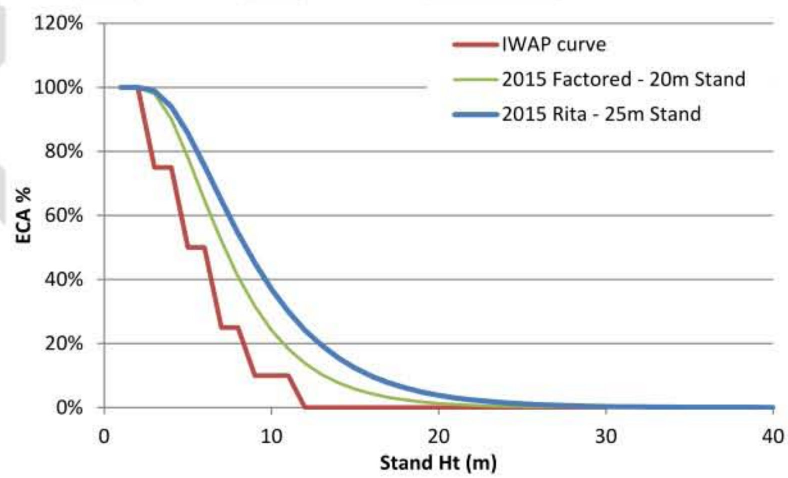

Figure 5 IWAP and Winkler Curve graphed – ECA% by Stand Height

The ECA is calculated as a percentage of the watershed as a whole, and as a percentage of each portion of the watershed above and below the snowline. To do this, the area of each polygon is multiplied by its respective ECA %, and the resulting ECA summed and calculated as a percent of the gross area of the entire watershed or portion thereof.

Table 1 Forest Health Stand Mortality ECA values based on a combination of years since attack, percentage of pine within the stand, and the stand percentage dead*

Years Since Attack	Pine Content Dead Class (30 – 50%)	Pine Content Dead Class (50 – 70%)	Pine Content Dead Class (> 70%)
0-5	5	5	10
6-10	10	15	30
11-15	15	20	40
16-20	20	30	45
21-25	20	30	45
26-30	15	20	40
31-35	10	15	30
36-40	5	10	25
41-45	0	5	20
46-50	0	0	15
51-55	0	0	10
56-60	0	0	5
61+	0	0	0

** Breaks and values adopted directly from BC Government recommendations (Equivalent Clearcut Area Determination for Proposed FSWs – Omenica Region – Nov. 2nd 2016)*

Determine the stand growth (ECA Recovery) over time

1. Stand growth is calculated using Site Tools. The calculated Managed Site Index, VRI leading species and the current stand ages (from the depletions within the proposed scenario).

2. The ECA values (Rita and Boon) are recalculated using these updated 'future' stand heights to indicate stand recovery over time.

Results

The calculated ECA values for the Peachland Creek Watershed and sub basins are provided in Tables 2 and. ECA values were calculated using the Winkler and Boon curve and summarized for the total watershed area and the portions above the snowline.

Mapping of the ECAs assigned to polygons in the current, approved and future scenarios are provided in Figures 6 through 10.

Table 2 Current ECA – Total Watershed and Above/Below the Snow Sensitive Line (2017 to 2037)

Note: *The values representing Mid Peachland Creek in the table below do not include the portion of Upper Peachland Creek that flows into it.*

Current ECA

Peachland Creek

Curve	Year	Total Harvested Area ha	Total Harvested Area %	Total Area ha	Snowline (Above) ha	Snowline (Above) %	Snowline (Below) ha	Snowline (Below) %	ECA ha	ECA %	ECA (above Snowline) ha	ECA (above Snowline) %	ECA (below Snowline) ha	ECA (below Snowline) %
IWAP	2017								2245.9	17.9%	1035.9	21.7%	1210.1	15.6%
	2017								2526.8	20.1%	1198.2	25.1%	1328.5	17.1%
	2018								2492.4	19.9%	1177.1	24.6%	1315.3	16.9%
	2019								2460.1	19.6%	1157.2	24.2%	1303.0	16.8%
	2020								2426.1	19.3%	1137.5	23.8%	1288.7	16.6%
	2021								2395.0	19.1%	1122.2	23.5%	1272.8	16.4%
	2022								2361.4	18.8%	1102.1	23.1%	1259.4	16.2%
	2023								2314.8	18.4%	1067.8	22.3%	1247.0	16.0%
	2024								2281.7	18.2%	1047.1	21.9%	1234.6	15.9%
	2025								2211.1	17.6%	1002.0	21.0%	1209.1	15.6%
Winkler & Boone (2015)	2026	2891.5	23.0%	12552.5	4780.4	38.1%	7772.2	61.9%	2147.7	17.1%	978.1	20.5%	1169.7	15.0%
	2027								2101.3	16.7%	953.5	19.9%	1147.8	14.8%
	2028								2052.7	16.4%	928.3	19.4%	1124.4	14.5%
	2029								1983.4	15.8%	886.2	18.5%	1097.1	14.1%
	2030								1923.8	15.3%	857.2	17.9%	1066.6	13.7%
	2031								1821.1	14.5%	800.7	16.7%	1020.4	13.1%
	2032								1733.9	13.8%	771.7	16.1%	962.2	12.4%
	2033								1649.2	13.1%	727.5	15.2%	921.7	11.9%
	2034								1579.2	12.6%	698.3	14.6%	880.9	11.3%
	2035								1478.0	11.8%	647.3	13.5%	830.8	10.7%
	2036								1384.4	11.0%	614.5	12.9%	769.9	9.9%
	2037								1311.9	10.5%	579.8	12.1%	732.1	9.4%

Mid Peachland Creek (not including Upper Peachland Creek)

Curve	Year	Total Area ha	Snowline (Above) ha	Snowline (Above) %	Snowline (Below) ha	Snowline (Below) %	ECA ha	ECA %	ECA (above Snowline) ha	ECA (above Snowline) %	ECA (below Snowline) ha	ECA (below Snowline) %
IWAP	2017						953.7	23.5%	196.2	22.0%	757.5	23.9%
	2017						1067.0	26.3%	235.7	26.4%	831.3	26.3%
	2018						1054.7	26.0%	231.0	25.9%	823.7	26.0%
	2019						1042.4	25.7%	226.2	25.4%	816.2	25.8%
	2020						1028.0	25.3%	221.3	24.8%	806.7	25.5%
	2021						1014.2	25.0%	216.5	24.3%	797.7	25.2%
	2022						1000.1	24.7%	212.0	23.8%	788.1	24.9%
	2023						988.5	24.4%	207.8	23.3%	780.6	24.7%
	2024						975.6	24.0%	203.0	22.8%	772.6	24.4%
	2025						954.1	23.5%	196.4	22.0%	757.7	23.9%
Winkler & Boone (2015)	2026	4056.6	891.3	22.0%	3165.3	78.0%	923.5	22.8%	190.1	21.3%	733.4	23.2%
	2027						903.3	22.3%	183.2	20.6%	720.1	22.7%
	2028						879.9	21.7%	175.8	19.7%	704.1	22.2%
	2029						853.5	21.0%	167.8	18.8%	685.7	21.7%
	2030						824.5	20.3%	159.4	17.9%	665.1	21.0%
	2031						787.9	19.4%	149.9	16.8%	637.9	20.2%
	2032						742.6	18.3%	141.2	15.8%	601.4	19.0%
	2033						705.1	17.4%	132.1	14.8%	573.0	18.1%
	2034						668.9	16.5%	123.8	13.9%	545.1	17.2%
	2035						630.2	15.5%	115.4	13.0%	514.8	16.3%
	2036						584.6	14.4%	108.2	12.1%	476.4	15.0%
	2037						552.6	13.6%	101.2	11.4%	451.4	14.3%

Upper Peachland Creek

Curve	Year	Total Area ha	Snowline (Above) ha	Snowline (Above) %	Snowline (Below) ha	Snowline (Below) %	ECA ha	ECA %	ECA (above Snowline) ha	ECA (above Snowline) %	ECA (below Snowline) ha	ECA (below Snowline) %
IWAP	2017						663.8	27.5%	568.3	30.6%	95.5	17.2%
	2017						792.6	32.8%	661.7	35.6%	130.9	23.6%
	2018						775.8	32.1%	649.5	34.9%	126.3	22.7%
	2019						760.4	31.5%	638.3	34.3%	122.1	22.0%
	2020						746.1	30.9%	627.9	33.8%	118.3	21.3%
	2021						733.8	30.4%	621.7	33.4%	112.1	20.2%
	2022						719.1	29.8%	610.5	32.8%	108.6	19.5%
	2023						689.7	28.5%	585.0	31.4%	104.7	18.8%
	2024						674.9	27.9%	573.7	30.8%	101.2	18.2%
	2025						637.8	26.4%	540.2	29.0%	97.7	17.6%
Winkler & Boone (2015)	2026	2416.1	1860.2	77.2%	555.9	23.0%	622.7	25.8%	528.3	28.4%	94.3	17.0%
	2027						604.8	25.0%	516.2	27.7%	88.7	15.9%
	2028						589.7	24.4%	504.4	27.1%	85.3	15.3%
	2029						558.3	23.1%	476.5	25.6%	81.9	14.7%
	2030						540.7	22.4%	462.4	24.9%	78.3	14.1%
	2031						494.7	20.5%	422.0	22.7%	72.7	13.1%
	2032						478.8	19.8%	409.2	22.0%	69.6	12.5%
	2033						447.6	18.5%	381.1	20.5%	66.5	12.0%
	2034						430.9	17.8%	367.3	19.7%	63.6	11.4%
	2035						390.6	16.2%	331.7	17.8%	59.0	10.6%
	2036						369.7	15.3%	313.5	16.9%	56.2	10.1%
	2037						346.0	14.3%	292.7	15.7%	53.3	9.6%

Greata Creek

Curve	Year	Total Area ha	Snowline (Above) ha	Snowline (Above) %	Snowline (Below) ha	Snowline (Below) %	ECA ha	ECA %	ECA (above Snowline) ha	ECA (above Snowline) %	ECA (below Snowline) ha	ECA (below Snowline) %
IWAP	2017						602.7	13.4%	271.4	13.4%	331.3	13.4%
	2017						641.4	14.3%	300.9	14.8%	340.5	13.8%
	2018						636.1	14.1%	296.7	14.6%	339.5	13.8%
	2019						631.3	14.0%	292.7	14.4%	338.7	13.7%
	2020						626.1	13.9%	288.3	14.2%	337.7	13.7%
	2021						621.1	13.8%	284.0	14.0%	337.1	13.7%
	2022						616.3	13.7%	279.6	13.8%	336.7	13.6%
	2023						610.7	13.6%	275.0	13.6%	335.7	13.6%
	2024						605.1	13.5%	270.5	13.3%	334.6	13.6%
	2025						593.1	13.2%	265.4	13.1%	327.6	13.3%
Winkler & Boone (2015)	2026	4495.7	2028.8	45.1%	2466.9	54.9%	575.4	12.8%	259.7	12.8%	315.8	12.8%
	2027						566.9	12.6%	254.1	12.5%	312.8	12.7%
	2028						557.0	12.4%	248.2	12.2%	308.8	12.5%
	2029						545.4	12.1%	241.9	11.9%	303.4	12.3%
	2030						532.4	11.8%	235.4	11.6%	297.0	12.0%
	2031						512.4	11.4%	228.7	11.3%	283.7	11.5%
	2032						486.4	10.8%	221.3	10.9%	265.1	10.7%
	2033						470.4	10.5%	214.3	10.6%	256.0	10.4%
	2034						453.4	10.1%	207.1	10.2%	246.3	10.0%
	2035						431.3	9.6%	200.2	9.9%	231.1	9.4%
	2036						404.2	9.0%	192.8	9.5%	211.4	8.6%
	2037						387.4	8.6%	185.9	9.2%	201.5	8.2%

Table 3 Approved and Planned ECA - Total Watershed and Above/Below the Snow Sensitive Line (2017 to 2037).

Note: *The values representing Mid Peachland Creek in the table below do not include the portion of Upper Peachland Creek that flows into it.*

Approved + Planned ECA

Peachland Creek

Curve	Year	Total Harvested Area ha	Total Harvested Area %	Total Area ha	Snowline (Above) ha	Snowline (Above) %	Snowline (Below) ha	Snowline (Below) %	ECA ha	ECA %	ECA (above Snowline) ha	ECA (above Snowline) %	ECA (below Snowline) ha	ECA (below Snowline) %
IWAP	2017								3258.5	26.0%	1501.4	31.4%	1757.1	22.6%
	2017	4034.5	32.1%						3539.3	28.2%	1663.7	34.8%	1875.6	24.1%
	2018								3504.6	27.9%	1642.5	34.4%	1862.1	24.0%
	2019								3472.2	27.7%	1622.4	33.9%	1849.8	23.8%
	2020								3465.1	27.6%	1602.8	33.5%	1862.4	24.0%
	2021	4061.3	32.4%						3433.7	27.4%	1587.3	33.2%	1846.3	23.8%
	2022								3400.0	27.1%	1567.1	32.8%	1832.9	23.6%
	2023								3353.2	26.7%	1532.8	32.1%	1820.4	23.4%
	2024								3319.9	26.4%	1512.0	31.6%	1807.9	23.3%
	2025								3271.7	26.1%	1466.7	30.7%	1805.0	23.2%
Winkler & Boone (2015)	2026			12552.5	4780.4	38.1%	7772.2	61.9%	3208.1	25.6%	1442.6	30.2%	1765.4	22.7%
	2027								3160.9	25.2%	1417.7	29.7%	1743.2	22.4%
	2028								3110.0	24.8%	1391.4	29.1%	1718.6	22.1%
	2029								3035.2	24.2%	1346.7	28.2%	1688.6	21.7%
	2030	4083.9	32.5%						2965.8	23.6%	1313.0	27.5%	1652.8	21.3%
	2031								2847.7	22.7%	1249.3	26.1%	1598.4	20.6%
	2032								2738.4	21.8%	1210.4	25.3%	1528.1	19.7%
	2033								2626.1	20.9%	1153.9	24.1%	1472.2	18.9%
	2034								2523.2	20.1%	1110.3	23.2%	1412.9	18.2%
	2035								2384.8	19.0%	1042.9	21.8%	1341.9	17.3%
	2036								2251.0	17.9%	992.6	20.8%	1258.4	16.2%
	2037								2136.6	17.0%	939.7	19.7%	1196.9	15.4%

Mid Peachland Creek (not including Upper Peachland Creek)

Curve	Year	Total Area ha	Snowline (Above) ha	Snowline (Above) %	Snowline (Below) ha	Snowline (Below) %	ECA ha	ECA %	ECA (above Snowline) ha	ECA (above Snowline) %	ECA (below Snowline) ha	ECA (below Snowline) %
IWAP	2017						1328.9	32.8%	377.1	42.3%	951.8	30.1%
	2017						1442.1	35.5%	416.5	46.7%	1156.6	36.5%
	2018						1429.6	35.2%	411.8	46.2%	1144.2	36.1%
	2019						1417.2	34.9%	406.8	45.6%	1132.5	35.8%
	2020						1412.3	34.8%	401.9	45.1%	1128.7	35.7%
	2021						1398.6	34.5%	397.2	44.6%	1113.5	35.2%
	2022						1384.4	34.1%	392.6	44.0%	1100.4	34.8%
	2023						1372.6	33.8%	388.4	43.6%	1088.9	34.4%
	2024						1359.5	33.5%	383.4	43.0%	1077.4	34.0%
	2025						1338.0	33.0%	376.8	42.3%	1058.9	33.5%
Winkler & Boone (2015)	2026	4056.6	891.3	22.0%	3165.3	78.0%	1307.4	32.2%	370.5	41.6%	1031.3	32.6%
	2027						1287.0	31.7%	363.5	40.8%	1012.2	32.0%
	2028						1262.7	31.1%	355.6	39.9%	992.4	31.4%
	2029						1234.1	30.4%	346.5	38.9%	969.5	30.6%
	2030						1201.1	29.6%	336.1	37.7%	943.3	29.8%
	2031						1158.3	28.6%	323.6	36.3%	907.3	28.7%
	2032						1104.6	27.2%	310.9	34.9%	863.3	27.3%
	2033						1057.0	26.1%	297.0	33.3%	826.6	26.1%
	2034						1008.8	24.9%	283.1	31.8%	789.3	24.9%
	2035						956.7	23.6%	268.5	30.1%	747.2	23.6%
	2036						896.7	22.1%	254.7	28.6%	698.2	22.1%
	2037						850.0	21.0%	240.9	27.0%	662.4	20.9%

Upper Peachland Creek

Curve	Year	Total Area ha	Snowline (Above) ha	Snowline (Above) %	Snowline (Below) ha	Snowline (Below) %	ECA ha	ECA %	ECA (above Snowline) ha	ECA (above Snowline) %	ECA (below Snowline) ha	ECA (below Snowline) %
IWAP	2017						675.9	28.0%	580.3	31.2%	95.5	17.2%
	2017						804.7	33.3%	673.7	36.2%	130.9	23.6%
	2018						787.8	32.6%	661.5	35.6%	126.3	22.7%
	2019						772.5	32.0%	650.4	35.0%	122.1	22.0%
	2020						758.2	31.4%	639.9	34.4%	118.3	21.3%
	2021						745.6	30.9%	633.5	34.1%	112.1	20.2%
	2022						731.0	30.3%	622.3	33.5%	108.6	19.5%
	2023						701.5	29.0%	596.8	32.1%	104.7	18.8%
	2024						686.7	28.4%	585.5	31.5%	101.2	18.2%
	2025						649.6	26.9%	552.0	29.7%	97.7	17.6%
Winkler & Boone (2015)	2026	2416.1	1860.2	77.2%	555.9	23.0%	634.5	26.3%	540.2	29.0%	94.3	17.0%
	2027						616.7	25.5%	528.0	28.4%	88.7	15.9%
	2028						601.5	24.9%	516.2	27.8%	85.3	15.3%
	2029						570.2	23.6%	488.3	26.2%	81.9	14.7%
	2030						552.5	22.9%	474.2	25.5%	78.3	14.1%
	2031						506.8	21.0%	434.1	23.3%	72.7	13.1%
	2032						490.8	20.3%	421.2	22.6%	69.6	12.5%
	2033						459.7	19.0%	393.2	21.1%	66.5	12.0%
	2034						443.0	18.3%	379.4	20.4%	63.6	11.4%
	2035						402.4	16.7%	343.5	18.5%	59.0	10.6%
	2036						381.0	15.8%	324.8	17.5%	56.2	10.1%
	2037						356.8	14.8%	303.5	16.3%	53.3	9.6%

Greata Creek

Curve	Year	Total Area ha	Snowline (Above) ha	Snowline (Above) %	Snowline (Below) ha	Snowline (Below) %	ECA ha	ECA %	ECA (above Snowline) ha	ECA (above Snowline) %	ECA (below Snowline) ha	ECA (below Snowline) %
IWAP	2017						1198.2	26.7%	544.0	26.8%	654.2	26.5%
	2017						1236.9	27.5%	573.5	28.3%	663.4	26.9%
	2018						1231.6	27.4%	569.3	28.1%	662.3	26.8%
	2019						1226.8	27.3%	565.2	27.9%	661.5	26.8%
	2020						1221.5	27.2%	560.9	27.6%	660.6	26.8%
	2021						1216.4	27.1%	556.6	27.4%	659.8	26.7%
	2022						1211.6	26.9%	552.2	27.2%	659.4	26.7%
	2023						1206.0	26.8%	547.6	27.0%	658.4	26.7%
	2024						1200.3	26.7%	543.0	26.8%	657.3	26.6%
	2025						1188.2	26.4%	537.9	26.5%	650.3	26.4%
Winkler & Boone (2015)	2026	4495.7	2028.8	45.1%	2466.9	54.9%	1170.3	26.0%	532.0	26.2%	638.3	25.9%
	2027						1161.3	25.8%	526.2	25.9%	635.1	25.7%
	2028						1149.9	25.6%	519.6	25.6%	630.3	25.6%
	2029						1135.1	25.2%	511.9	25.2%	623.3	25.3%
	2030						1116.4	24.8%	502.7	24.8%	613.8	24.9%
	2031						1087.1	24.2%	491.6	24.2%	595.5	24.1%
	2032						1047.9	23.3%	478.3	23.6%	569.7	23.1%
	2033						1015.1	22.6%	463.8	22.9%	551.3	22.3%
	2034						978.3	21.8%	447.7	22.1%	530.5	21.5%
	2035						934.0	20.8%	431.0	21.2%	503.0	20.4%
	2036						883.2	19.6%	413.1	20.4%	470.1	19.1%
	2037						841.6	18.7%	395.3	19.5%	446.4	18.1%

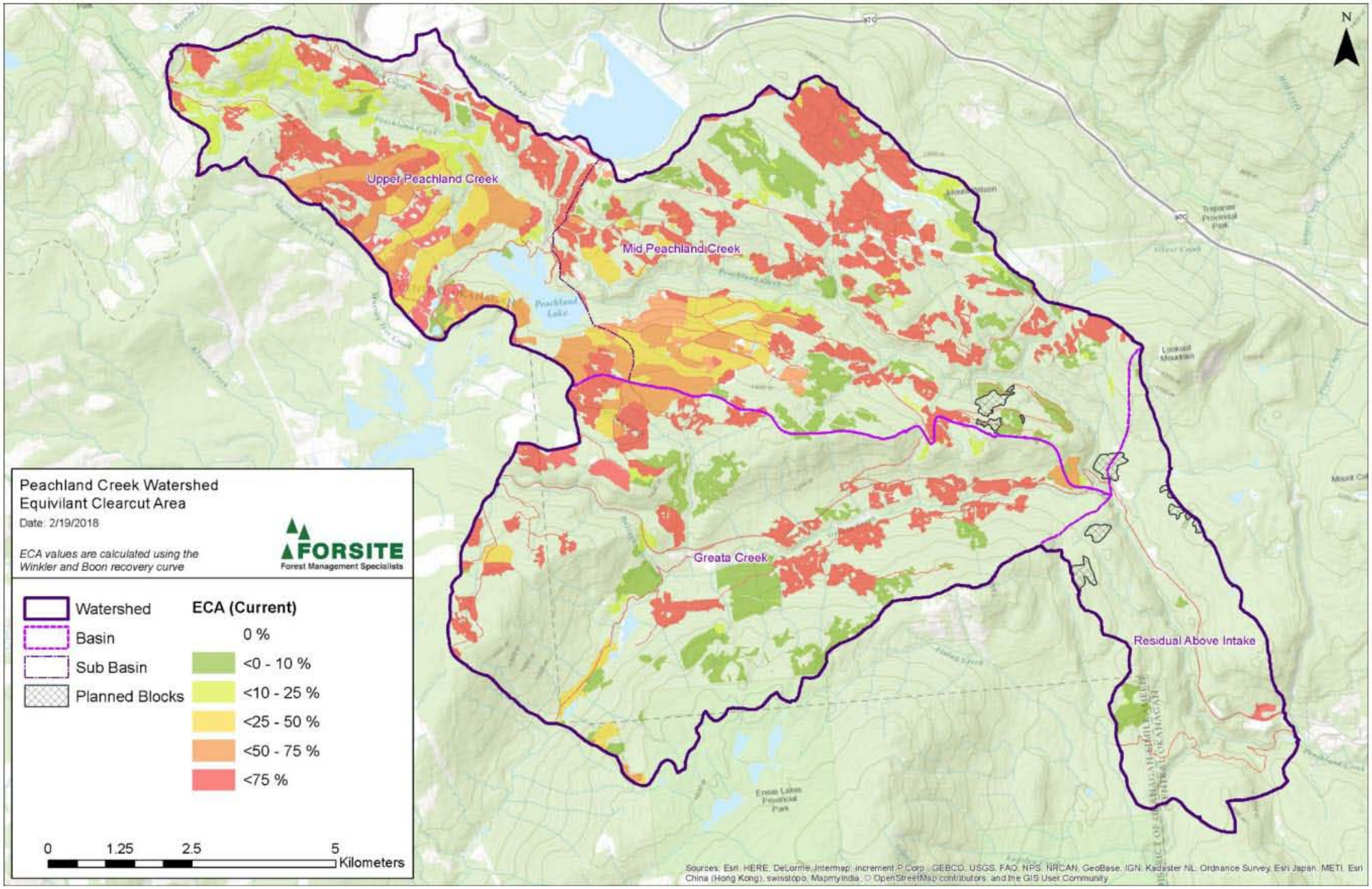

Figure 6 Current ECA (Winkler and Boon – with Omenica Forest Health applied).

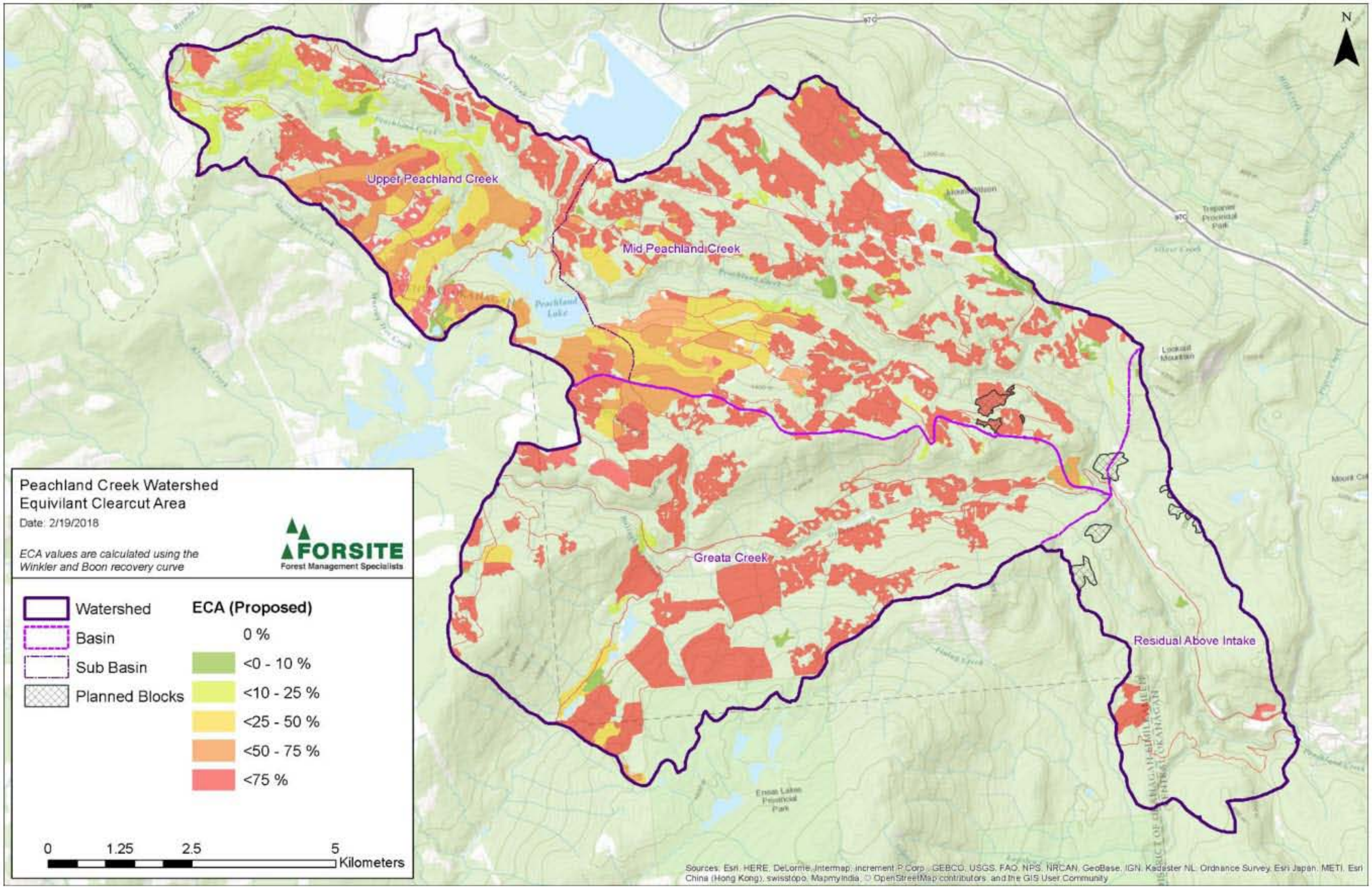

Figure 7 Proposed ECA (Winkler and Boon – Omenica FHF with proposed blocks (Tolko, BCTS, and Stityix).

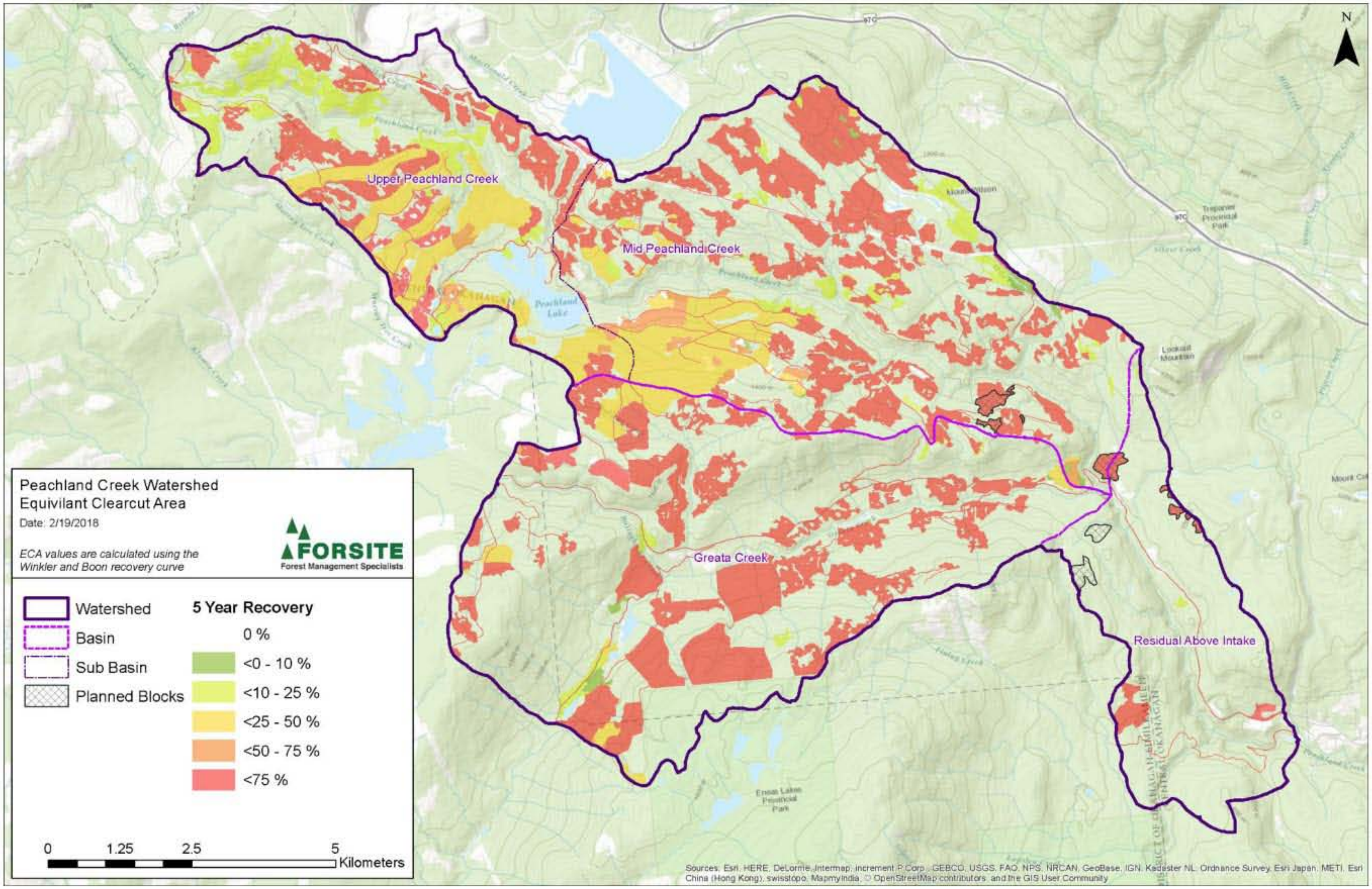

Figure 8 5 Year Recovery ECA (Winkler and Boon – Omenica FHF with proposed blocks (Tolko, BCTS, and Stityix).

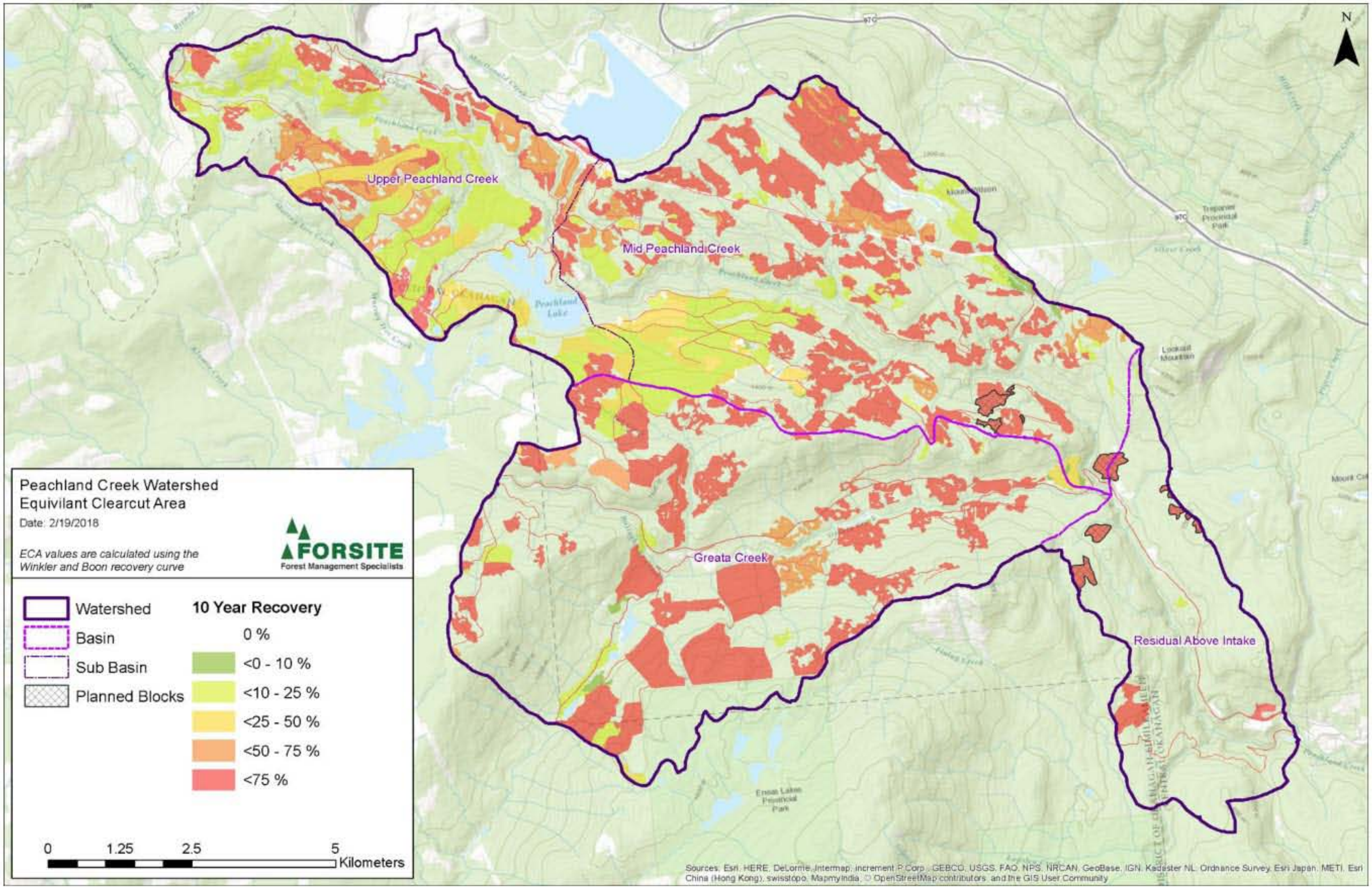

Figure 9 10 Year Recovery ECA (Winkler and Boon – Omenica FHF with proposed blocks (Tolko, BCTS, and Stityix).

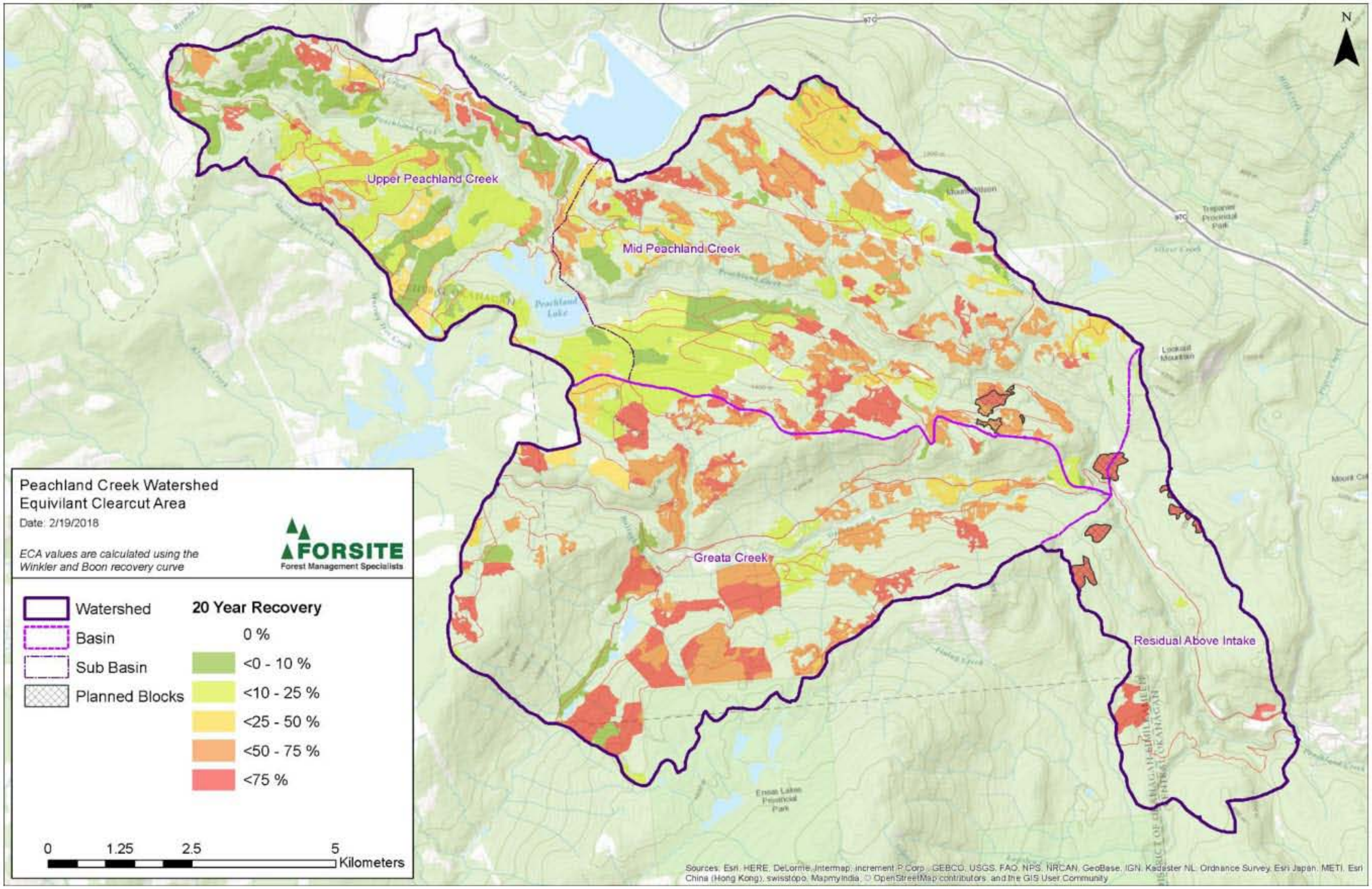

Figure 10 20 Year Recovery ECA (Winkler and Boon – Omenica FHF with proposed blocks (Tolko, BCTS, and Stityix)