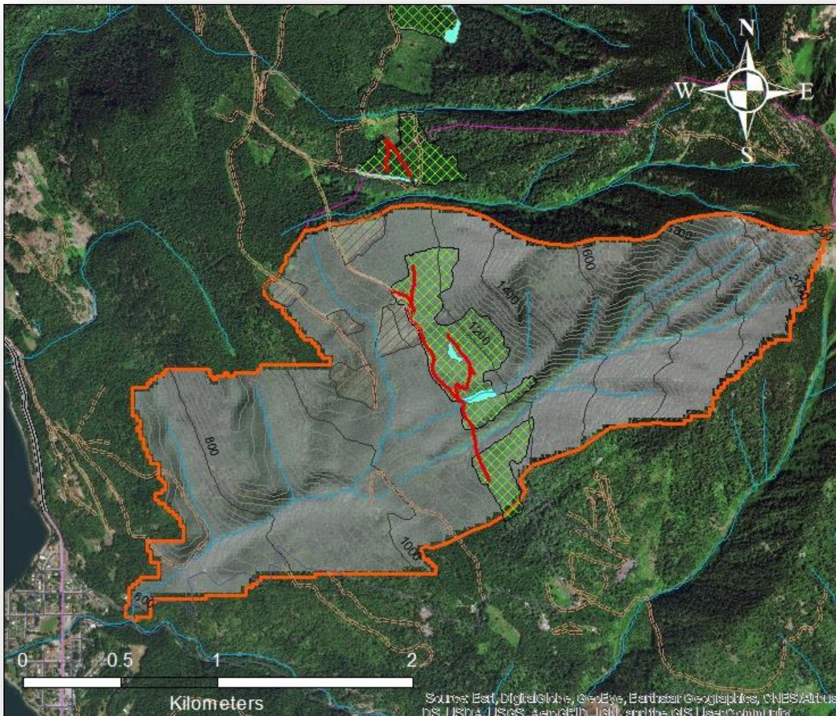

BARTLETT CREEK HYDROGEOMORPHIC ASSESSMENT

APEX FILE (HA-18-PR-01)

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July 13, 2018

This report was prepared by Apex Geoscience Consultants Ltd. for the account of the Village of Silverton. The information in this report is based on analysis of geospatial data, historical hydrometric data and observations of geomorphologic processes visible on orthophotographs and in the field. Any use of this report by a third party, or any reliance on or decisions made based on it, are the sole responsibility of such third parties.

Executive Summary

Apex Geoscience Consultants Ltd (Apex) has undertaken a hydrogeomorphic assessment of Bartlett Creek. The objective of this investigation is to identify any obvious concerns with respect to hydrogeomorphic processes that could potentially stem from the planned forest development.

Bartlett Creek is a 4.2 km^2 watershed drains southwest towards Silverton Creek. A previous watershed delineation showed the headwater of Harris Creek (to the north) flowing southward into Bartlett Creek at an elevation of approximately 1100 metres. Fieldwork during this assessment has confirmed that Harris Creek flows westward and does not turn southwards to feed into Bartlett Creek as previously delineated. Bartlett Creek includes two main tributaries. The steep headwater channel that flows from Idaho Peak, referred to in this report as the east fork, is an ephemeral stream (seasonal) that ceases to flow by late May or early June. The tributary that flows from Hartney flats, referred to as the north fork, is a perennial groundwater-sourced stream that flows all year. Flows in the north fork are seasonally elevated with snowmelt runoff.

The slopes of Bartlett Creek have primarily southwest and west aspects which results in the majority of Bartlett receiving substantial amounts of solar radiation starting early in the freshet period resulting in very little desynchronization of snowmelt across slopes in this watershed. The geology underlying most of the watershed is fine grained sedimentary rocks which is erodible and breaks down into sand and gravel relatively quickly so that much of the bedload moving through Bartlett Creek is fine textured gravel to sand-sized sediment.

Five small cut blocks in the Hartney Flats area and a small area of natural disturbance total 19.2 hectares account 5% equivalent clearcut area (ECA) of the 420 ha watershed area (4.5%). Yucwmenlucwu planned cut blocks 4 and 4c of CP 122 account for an additional 34.9 hectares within Bartlett Creek watershed. The existing and planned blocks will increase the total ECA to 54 hectares or about 13% of the watershed area. Block 4 of CP 122 represents approximately 26% of the 83 hectare face area that feeds into the north fork of Bartlett Creek on Hartney Flats.

Field observations indicate that Bartlett Creek is not a typical snowmelt watershed. The east fork headwater tributary carries runoff for a very short period of time during the freshet period which is likely a result of the steep, predominantly west aspect slopes. In addition, there are numerous groundwater springs that supply the north fork tributary.

Planned block 4 is located directly upslope from the spring-fed north fork of Bartlett Creek and accounts for a level of cut of about 25% (21.3 ha of the 83ha area). The uniform aspect and elevation of block 4 will result in the synchronized delivery of increased snowmelt to the north fork tributary over a short period of time. As a result, peak flows in the north fork are likely to increase and result in increased frequency of sediment transport, channel erosion and turbidity during the early spring melt period. In addition, a number of culvert flags were noted on the planned road above steep slopes along the east side of Hartney Flats. Harvesting of block 4 upslope from this road will increase snowmelt runoff substantially so it is important that the slopes below these proposed culvert locations be investigated for the potential for instability or erosion associated with increased, concentrated discharge from the culverts.

Table of Contents

List of Figures

List of Tables

List of Photographs

1. Introduction

Apex Geoscience Consultants Ltd (Apex) has been retained under contract by the Village of Silverton to undertake a hydrogeomorphic assessment of Bartlett Creek. The Village of Silverton holds the consumptive-use water licence for Bartlett Creek and maintains a dam and water intake on the channel as a back-up water supply. Forest development is planned within the catchment by Splatsin Development Corporation and the Village would like information regarding how this development and any future development could affect water quality and quantity in Bartlett Creek. In addition, bull trout spawning occurs in Silverton Creek at the point of confluence with Bartlett Creek so additional concerns exist for changes to water quality in Bartlett Creek that could impact spawning habitat in Silverton Creek.

The objective of this investigation is to identify any obvious red-flag with respect to hydrogeomorphic processes that could potentially stem from the planned forest development. This assessment includes a geospatial analysis of the watersheds within the area of interest (AOI), an equivalent clear-cut area (ECA) estimate for the watershed as it is now and with the planned development, an investigation of hydrometric and climate data and a field survey of sections of the Bartlett Creek channel. The field survey of the watershed was undertaken on June 18th, 2018 by Kim Green, P.Geo with the assistance of Laurel Halleran. A follow-up visit was undertaken on June 27th 2018, to investigate the source of Bartlett North-fork tributary. During the field investigation data on channel geometry, sediment mobility, channel disturbance history and riparian-channel processes were recorded. In addition, observations were made by Will Halleran., P.Geo., L.Eng., along the proposed road and Block 4 and 4c of CP 122 on issues concerning the potential for sediment delivery and slope instability.

2. Methods

The hydrogeomorpic investigation of the Bartlett Creek watershed includes a GIS-based geospatial analysis of physical watershed characteristics and a field-based investigation of channel and watershed morphological processes and disturbance history. Data for the geospatial analysis including the 20 metre resolution digital elevation model (DEM) was downloaded from the Provincial data warehouse (https://data.gov.bc.ca/, accessed June 2018) and the Environment Canada website (https://wateroffice.ec.gc.ca/mainmenu/historical_data_index_e.html, accessed June, 2018). The review includes a GIS-based geospatial analysis of watershed physical characteristics including elevation and aspect distribution, slope gradient distribution and channel profile. The geospatial, geological and hydrological analysis was undertaken by Kim Green, PGeo., PhD. The equivalent clearcut area (ECA) analysis is based on the 2016 VRI forest stand characteristics, existing and proposed development shapefiles and google earth imagery.

3. Physiography

Bartlett Creek is an approximately 4.2 km^2 watershed located in the Selkirk Mountains directly northeast of Silverton BC. Bartlett Creek flows southwest towards Silverton Creek. Idaho Peak at 2267 meters is the highest point in the watershed.

The catchment boundaries for Bartlett Creek are delineated in orange on the Google Earth image shown in Figure 1. A previous watershed delineation showed the headwater of Harris Creek (to the north) flowing southward into Bartlett Creek at an elevation of approximately 1100 metres. This previous watershed boundary is defined with the fine pink line that extends north from the current orange boundary. Fieldwork during this assessment has confirmed that Harris Creek flows westward and does not turn southwards to feed into Bartlett Creek as previously delineated. Some uncertainty remains regarding the exact location of the catchment boundaries through the central topographic ‘flats’. The source area for the north-fork of Bartlett Creek which flow from Hartney Flats was field verified as part of this study however, the southern catchment boundary at similar elevations has not been field verified. Maps provided by Brad Sindlinger, RPF (forester for Yucwmenlucwu, Splatsin Development Corporation) indicate this segment of the catchment boundary is shifted northward by roughly 100 metres but field observations made during this study were not able to confirm if this was the case.

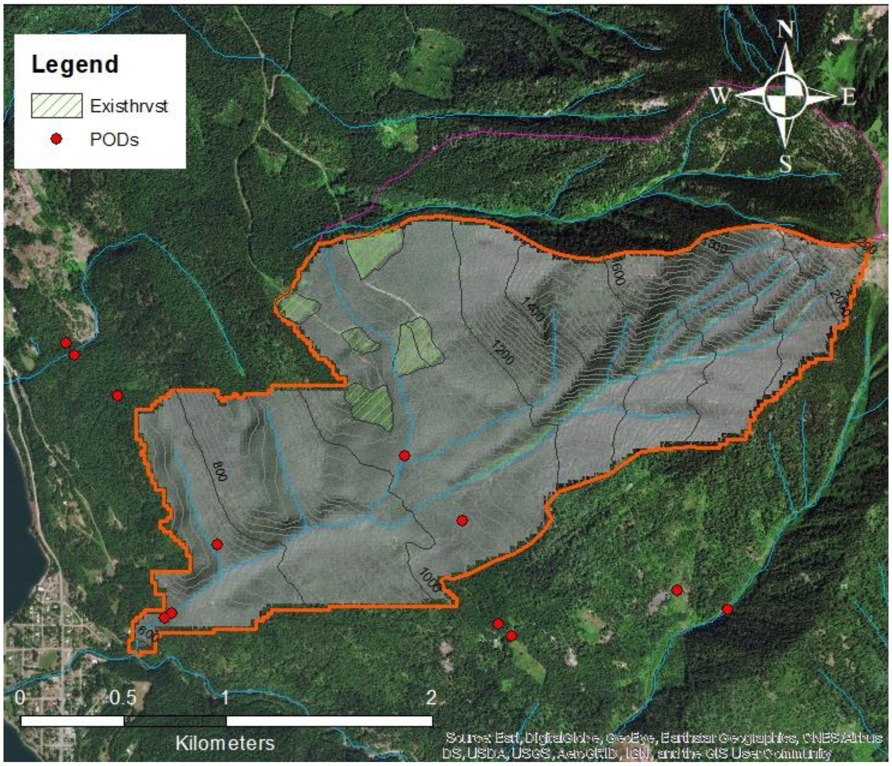

FIGURE 1. BARTLETT CREEK (POSSIBLE) WATERSHED OUTLINED IN ORANGE.

The actual catchment boundary of Bartlett Creek is uncertain for two reasons. Firstly, subtle, complex terrain features between the elevations of 1000 metres and 1200 metres on both the north and south sides of Bartlett Creek make delineation of the surface catchment area difficult given the low resolution of the available digital elevation model (DEM) and, secondly, the source of Bartlett Creek includes groundwater springs that occur at an elevation of around 1100 metres. The source area of these groundwater springs is uncertain. Observations of topography, geology and physical features of the springs suggest they are controlled to some degree by geological structures in the underlying bedrock. The geomorphic features of these springs are discussed in the Field Observations section of this report.

4. Watershed Physical Characteristics

An analysis of elevation, aspect and slope gradient distribution can assist in determining how the watershed is likely to respond hydrologically to changes in forest cover (Green and Alila, 2012). The 20m DEM has been used to describe the physical characteristics of Bartlett Creek watershed.

Channel Profile

The channel profile of Bartlett Creek (blue line and left vertical axis, Figure 2) is plotted together with channel gradient (orange line and right vertical axis, Figure 2). The channel profile is constructed from the 20 metre DEM. Channel gradient is calculated as a 100-metre moving average using the channel profile (X,Y) data. This figure shows that the channel through the headwater reaches (1800 to 2200 metres) is characterized by gradients of over 70% (see right-side vertical axis). Between 1800 metres and 1200 metres the channel gradient drops to below 60% (35% to 60%). The channel gradient average less than 20% between 1200 and 1000 metres in the low gradient bench area referred to as Hartney Flats and then increases to between 15% to 45% through the lower reach of Bartlett Creek between 1000m and 600m elevation.

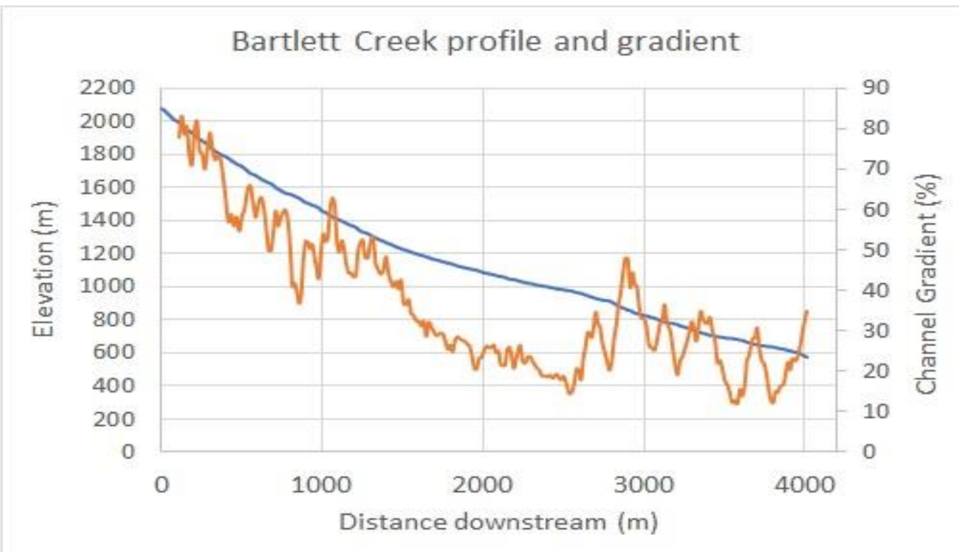

FIGURE 2. CHANNEL PROFILE (BLUE) AND THE AVERAGE GRADIENT OVER 100 METRES (ORANGE) OF BARTLETT CREEK.

Elevation Distribution

The hypsometric curve (Figure 3) shows the elevation distribution of slopes within the catchment area. The hypsometric curve for Bartlett Creek shows that 40% of the catchment spans the region between 1200m and 2200 m elevation. An additional 30% of the catchment area lies between 1200 and 1000m elevation. The lower 30% of the watershed area ranges from 1000 to 600m elevation. The hypsometric curve highlights the three physiographic regions of the watershed; the steep upper headwaters, the central Hartney Flats and the lower Bartlett Creek canyon. The H60 elevation (i.e. 60% of the watershed lies above this elevation) of Bartlett

Creek is 1044 meters. In some snowmelt watersheds the H60 elevation band corresponds to the region where freshet peak flows are generated.

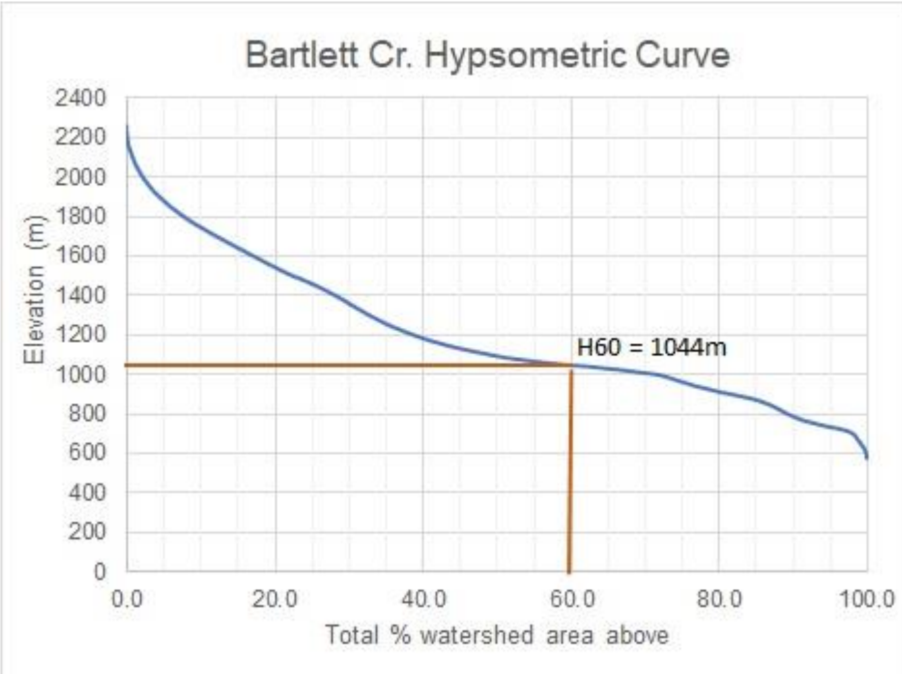

FIGURE 3. HYPSOMETRIC CURVE FOR BARTLETT CREEK. H60 ELEVATION IS 1044M

Slope Aspect distribution

The distribution of slope aspects plays a role in hydrographic response in mountainous snowmelt dominated watersheds. Watersheds that contain a substantial amount of south and western aspects tend to have quick flow response to short-term warm periods compared to watersheds with a wider ranges of slope aspects. In addition, watersheds with a substantial component of northern aspect slopes tend to have slower return to base flows on the recession limb of the hydrograph due to the slower snowmelt from shaded, north aspect slopes.

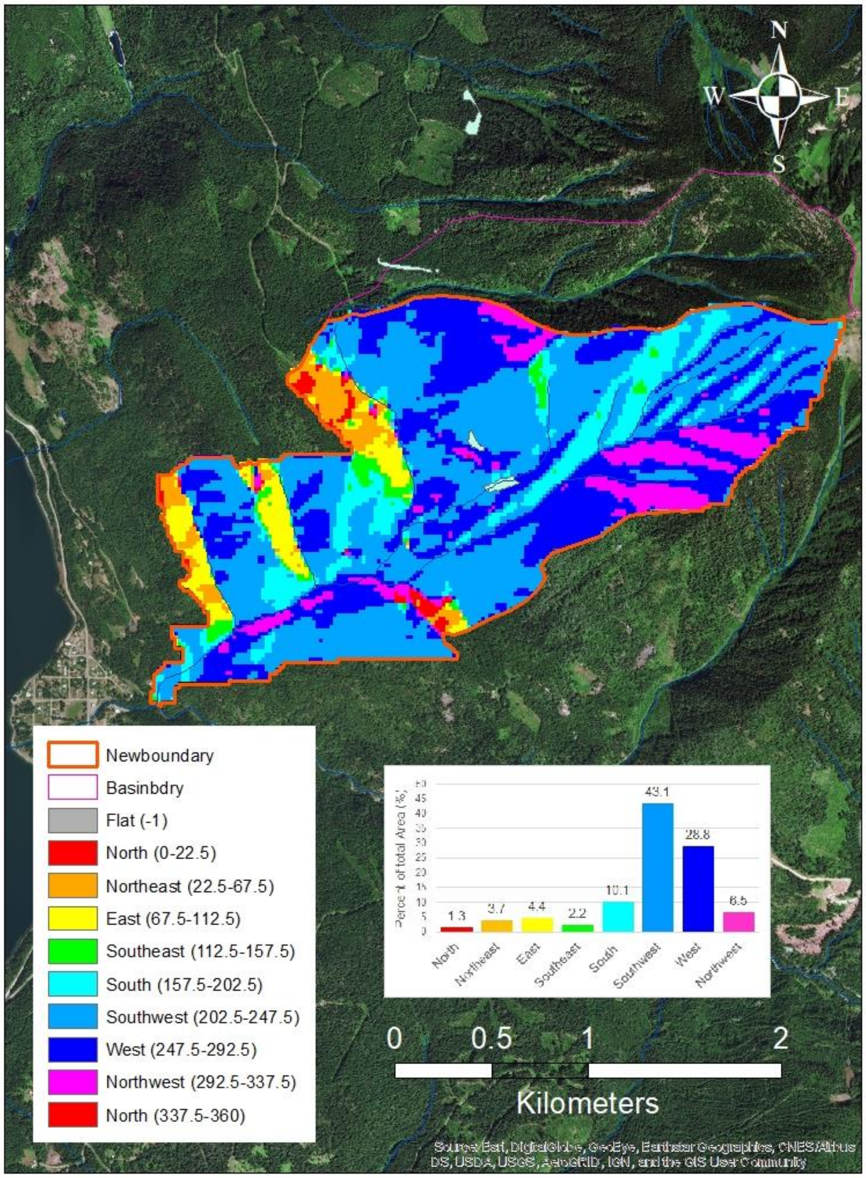

FIGURE 4. ASPECT DISTRIBUTION OF BARTLETT CREEK.

The slopes in Bartlett Creek are primarily southwest and west aspect (Figure 4). These two aspects account for over 70% of the catchment. South aspect slopes account for 10%. North and east aspects together account for less than 20% of the watershed area.

This distribution of aspects results in the majority of Bartlett receiving substantial amounts of solar radiation starting early in the freshet period and suggests there is very little desynchronization of melt across aspects in this watershed.

Slope gradient

Slope gradient, in part, affects the responsiveness of runoff in a snowmelt watershed to short-duration melt events associated with solar radiation and precipitation. Steeper slopes tend to have quicker flow response than low-gradient slopes.

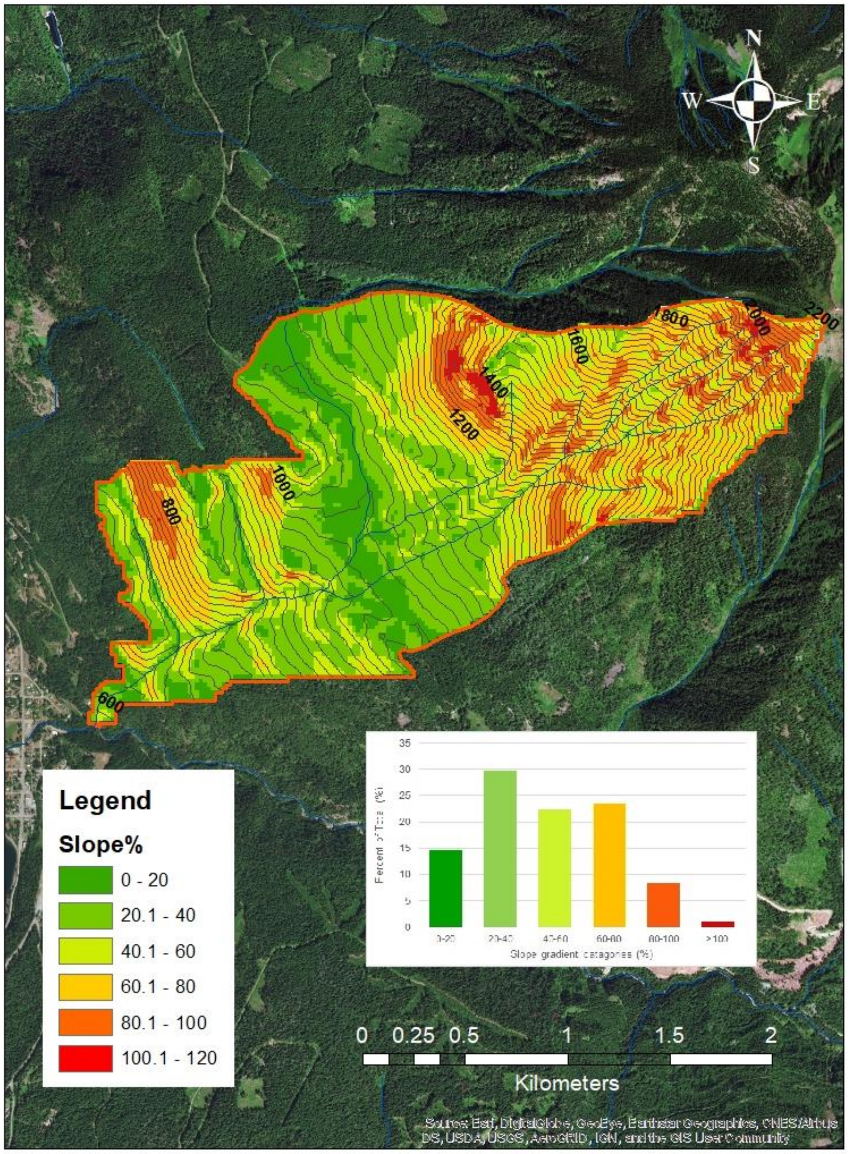

FIGURE 5. SLOPE GRADIENT DISTRIBUTION IN BARTLETT CREEK. THE CENTRAL LOW GRADIENT HARTNEY FLATS SEPARATES THE STEEP HEADWATER REGIONS FROM MODERATELY STEEP LOWER CANYON REGION.

Bartlett Creek is characterized by a steep headwater region where slopes range from 60% to over 100%, a central, low gradient ‘flats’ with gradients below 40% and a lower moderate to steep gradient canyon (Figure 5).

This slope gradient distribution suggest that the headwaters region is rapidly drained and capable of carrying avalanches and debris flows. The flatter, central region allows for deposition of sediment and debris from mass wasting events to occur before flows enter the lower canyon region. This figure also highlights that sediment entering Bartlett Creek through the lower reaches is primarily coming from the steep canyon sides in this lower elevation portion of the watershed.

5. Geology

Geology plays a role in determining the morphology of stream channels and the sensitivity of the streams to changes in flow regimes. Watersheds underlain by coarse, intrusive and metamorphic rocks such as granite and gneiss are likely to have more resilient stream channels than those underlain by more erodible sedimentary and metamorphic rocks including siltstones and argillites due to the coarser bed load.

Geology information from ImapBC indicates that Bartlett Creek is underlain primarily by fine grained sedimentary rocks of the Slocan Group (Figure 6). Most of the bedload observed in the stream consists of fine grained black argillaceous siltstones. This material is erodible and breaks down into finer sediment relatively quickly so that much of the bedload moving through Bartlett Creek is fine textured gravel to sand-sized sediment. The highly erodible nature of this sediment also results in few exposures of bedrock. The upper half of the watershed is covered by a veneer of colluvium. Glacial deposits blanket the central flats. Till and colluvium covered bedrock occurs on the ridges adjacent to the lower Bartlett canyon.

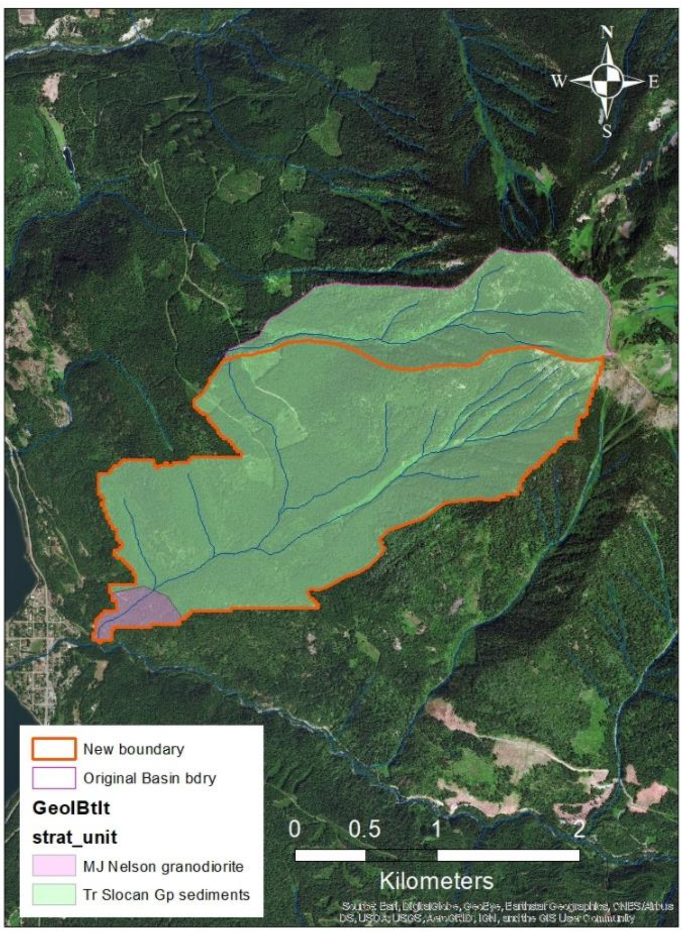

FIGURE 6. GEOLOGY OF BARTLETT CREEK. THE GREEN-COLOURED AREA IS UNDERLAIN BY BEDDED ARGILLACEOUS SILTSTONES. THE PINK UNIT AT THE BOTTOM OF BARTLETT CREEK IS MAPPED AS INTRUSIVE GRANITIC ROCKS OF THE NELSON BATHOLITH.

6. Hydrology

There is no recorded discharge data for Bartlett Creek. Vevey Creek a 6.2Km^2 watershed approximately 5 km south of Silverton is the closest small stream with hydrometric data. Daily discharge was recorded on Vevey Creek over a 4 year period from 1917 to 1920. The hydrometric data for Vevey Creek shows that for the period of gauging peak flows averaged just under 0.2m^3/s.

The average (bankfull) discharge for Bartlett Creek was estimated at 0.36 m^3/s for site B7 using Mannings' equation and measurements of channel hydraulic geometry;

$$Q = \frac{A * R^{2/3} * S^{1/2}}{n}$$

In this equation Q is discharge (m^3/s), A is channel cross-sectional area (m^2), R is channel wetted perimeter (m), S is channel gradient (m/m) and n is Mannings' roughness coefficient which was estimated at 0.15 for the channel at site B7. This value is based on measured values of 'n' from my own published research in forested mountain stream as well as other published studies. Further downstream at site B8 above the dam the average (bankfull) discharge estimated using Manning's equation drops to 0.22 m^3/s. This decrease in discharge results from water being lost to the subsurface as the width of the valley bottom and depth of alluvial deposits increases. Discharge divided by drainage area results in unit discharges of 0.05 m^3/s/Km^2 for the Bartlett Creek at the dam and 0.03 m^3/s/Km^2 for Vevey Creek which are generally similar.

Field observations made during this study suggest that, other than similarities in the magnitude of average annual peak discharge, the hydrograph for Bartlett Creek likely does not resemble that for Vevey Creek which rises rapidly in April or May and remains elevated into July. Field observations made during this study indicate that snowmelt runoff in both Bartlett Creek and neighbouring Harris Creek is short duration and at the time of the field investigation (June 18th) the headwater reaches of both streams were dry. This lack of an extended runoff relates to the predominantly west to southwest aspect of Bartlett Creek (and Harris Creek) which acts to limit total snow accumulation through the winter months and contributes to quick runoff response starting early in the freshet period.

Perennial flow in Bartlett Creek is associated with several springs that emerge on Hartney Flats and in the small, linear draws that occur downslope and west of the flats. At the time of the field investigation the two upper springs (Sites B4 and B5) were both flowing at a rate of approximately 0.04 m^3/s (Manning's estimate with n = 0.1). Both springs show indicators of seasonally higher flows. These bankfull discharges are estimated using Mannings' equation at 0.11m^3/s for the spring at site B4 and 0.13m^3/s for the spring at site B5. Similar springs supply perennial flows to Harris Creek to the north.

7. Forest Disturbance

As of June 2018 five small cutblocks are present in the Hartney Flats portion of Bartlett Creek watershed (light green, Figure 7). According to the VRI database these existing cutblocks, were harvested in 1998 and 2000.

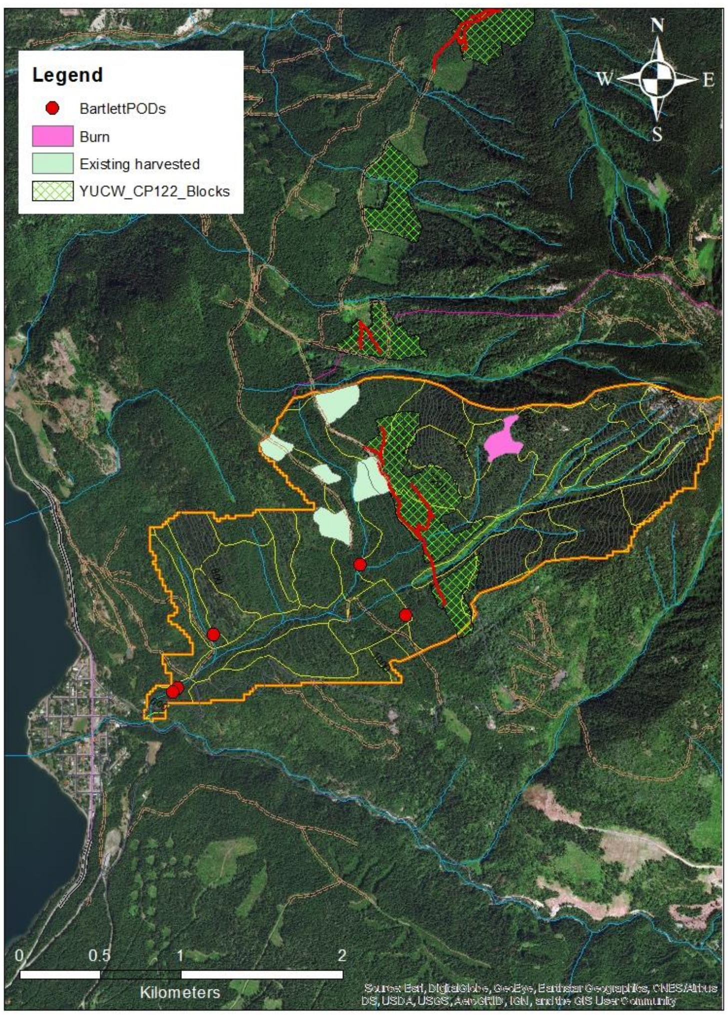

FIGURE 7. EXISTING AND PLANNED DEVELOPMENT IN BARTLETT CREEK.

A small area of disturbance due to forest fire is also indicated by the Vegetation Resource Inventory (VRI) database which shows one small polygon (pink, Figure 7) that appears to have burnt sometime in the last century.

The planned blocks of Yucwmenlucwu are show in green haching and proposed roads are indicated in red. Only blocks 4 and 4c of CP 122 are located within the catchment of Bartlett Creek. Block 4 is north of Bartlett Creek and 4c is south of Bartlett Creek.

Equivalent Clearcut Area

The removal of forests in snowmelt regions either through logging or by natural disturbance results in changes to the surface hydrological processes. Compared to the forested condition, openings accumulate more snow and melt off quicker in the spring. At the watershed-scale these changes in snow accumulation and melt at the stand level can result in changes in the frequency and magnitude of peak flows as well as changes in the timing and duration of low flows. Equivalent clear cut area calculations are undertaken to account for hydrological recovery in previously harvested stands which have had some amount of forest regeneration. To date there have been no studies of hydrological recovery of disturbed stands in Kootenay region forest types on which to base a Kootenay forest 'recovery curve'.

An estimate of the current level of equivalent clear-cut area (ECA) in Bartlett Creek was undertaken using the most current information regarding stand level hydrological recovery from studies undertaken in the Thompson-Okanagan region in stands consisting of lodgepole pine, Englemann spruce and Subalpine fir (Winkler and Boon, 2015). Recovery values in Table 1 are conservative but are based to some degree on the Winkler and Boon curve as well as an investigation of the forest stand attributes for regenerating and fully mature stands in the Bartlett Creek area as provided in the 2016 VRI database.

TABLE 1. BARTLETT CR. ESTIMATED HYDROLOGICAL RECOVERY

Recovery %	Height m	Canopy Closure %*
0	≤ 5	0
10	> 5 to ≤ 8	20
30	>8 to ≤ 10	>20
50	> 10 to ≤12	>30
70	>12 to ≤15	>40
80	>15 to ≤20	>40
90	>20 to ≤25	>50
100	>25	60

* For cc% less than threshold recovery drops to lower %value.

Mature stands through the middle elevations (ICH biogeoclimatic zone) are characterized as (age >=139 yrs), Douglas fir, hemlock and cedar mixed coniferous forest with crown closure averaging 65% and tree heights averaging 29 meters. For the ECA assessment regenerating stands with these characteristics (CC~60% and Ht>25m) are considered fully hydrologically recovered. A regenerating stand is also considered hydrologically recovered within the ICH zone if it has a height of equal or greater than 20 meters and a canopy closure of 65 percent or more. It is estimated that stands to not start to have any hydrological recovery applied until the regenerating stand exceeds 5 metres and has a crown closure of at least 20%.

Based on the recovery values given in Table 1, none of the regenerating stands in the five small blocks has any measurable hydrological recovery. These existing blocks (including the burned area) total 19.2 hectares in size which is less than 5% of the 420 ha watershed area (4.5%).

Yucwmenlucwu planned cut blocks 4 and 4c (aka block 5 depending on the map) of CP 122 account for an additional 34.9 hectares within Bartlett Creek watershed. The existing and planned blocks will increase the total ECA to 54 hectares or about 13% of the watershed area. This total ECA could change to some degree based on the actual location of the southern catchment boundaries. All of the existing and planned harvesting is concentrated in and directly above the Hartney flats portion of the watershed. Block 4 of CP 122 represents approximately 26% of the 83 hectare face area that feeds into the north fork of Bartlett Creek on Hartney Flats.

8. Field Observations

The main Bartlett Creek channel and the north fork channels were observed in the field (Figure 8). Information collected during the field survey included channel geometry and geomorphology, disturbance history, riparian function and maximum mobile bed material. This information is used to assess the channel's sensitivity to land cover disturbance as well as the likely hydrological response to disturbance. Observations regarding slope stability and erosion issues were made within proposed block 4 and 4c (aka blk 5) and along the proposed road (Figure 9). Observations are presented firstly for the channel observations.

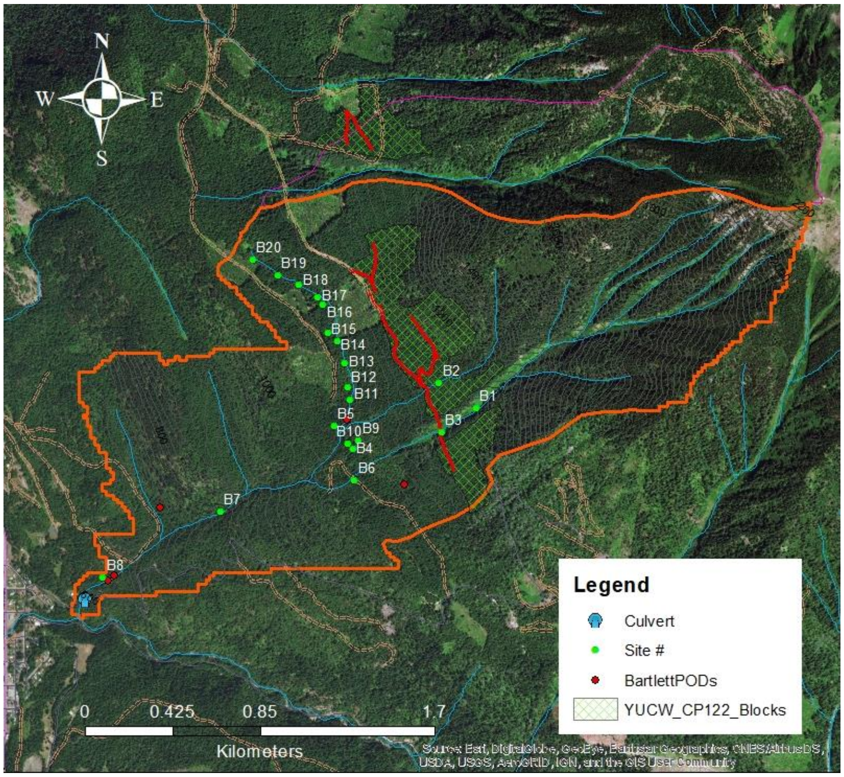

FIGURE 8. LOCATION OF STREAM FIELD SITES.

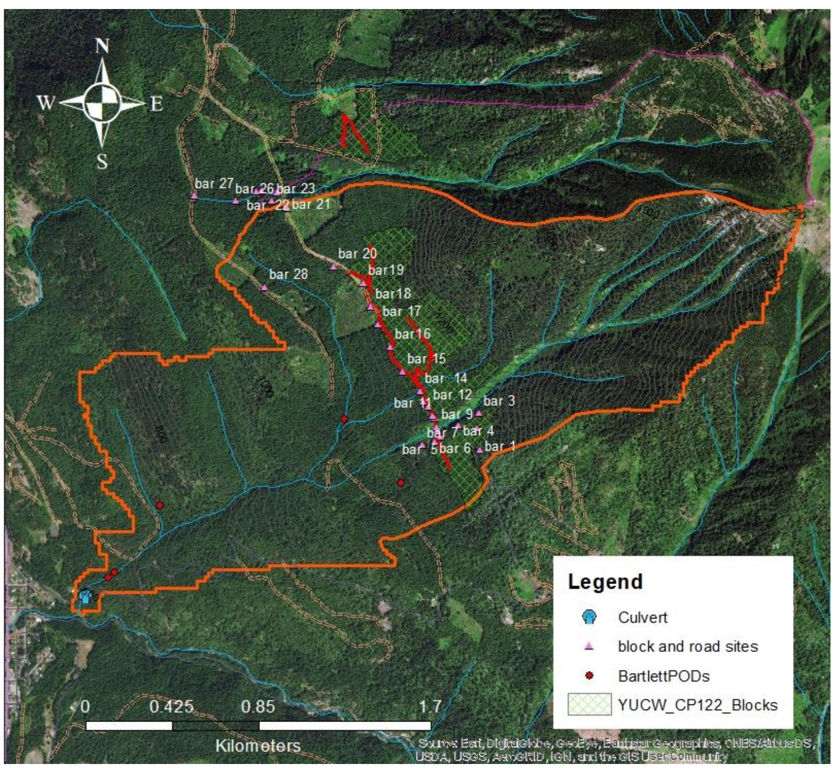

FIGURE 9. LOCATION OF ROAD AND BLOCK OBSERVATION SITES

Bartlett Creek

The headwater of Bartlett Creek and the small tributary directly north of Bartlett were investigated in the field (Sites B1-B3, Figure 8). Above 1100 metres the gully containing the main headwater channel Bartlett Creek is thickly vegetated in deciduous shrubs including alder, dogwood, maple and thimbleberry and, based on the age of the deciduous vegetation appears to carry snow avalanches with a frequency of roughly once every 20 to 50 years.

PHOTO 1. LOOKING UPSTREAM AT COLLUVIAL CHANNEL AT B1.

At the time of the field inspection (June 18th, 2018) the headwater channel was dry. At sites B1 and B3 the Bartlett Creek headwater is a single-thread channel that is confined in a v-shaped gully. Evidence was noted of relatively high flows this past spring that created some scour of channel banks.

At sites B1 and B3 Bartlett Creek is a woody-debris step to colluvial channel with an average bankfull width of about 2 metres and an average bankfull depth of 0.16 metres. Angular bedload sediment consisting of primarily sedimentary rock has an average D90 (i.e. 90% of the bedload is smaller than this diameter) of 17 cm. Channel gradient above B1 is over 30% but drops to less than 20% at B3 which corresponds to the proposed road crossing location. Despite the steep channel recent debris levees were not evident indicating this headwater reach does not carry debris flows with any frequency.

PHOTO 2. ANGULAR COBBLE SIZED SEDIMENT UP TO ABOUT 17 CM IS MOBILE THROUGH THE HEADWATER OF BARTLETT CREEK.

Below 1100 metres the gradient of the main eastern headwater tributary drops to less than 20%. A broad fan associated with successive deposits of avalanche debris over past centuries is evident between 1000 and 1040 metre elevation on the hillshade image constructed from the low resolution DEM.

A channel observation site at station B6 (Figure 8) indicates that even at this low elevation on the downslope portion of the depositional fan the eastern headwater tributary was fully dry with no evidence of seepage.

PHOTO 3. THE APPEARANCE OF THE DRY CHANNEL AT THE BOTTOM OF THE EASTERN TRIBUTARY AT SITE B6

The eastern tributary at an elevation of 1000 metres has a similar small woody-debris step morphology that was observed at site B1 and B3. The maximum mobile bed material at site B6 is also similar in size to the bed load noted further upstream although at this point there is more fine gravel being transported. Site B6 also displayed bank scour and recent erosion associated with high flows that occurred this past spring (Photo 3). Immediately upstream from site B6 the channel gradient is approximately 10% to 15%.

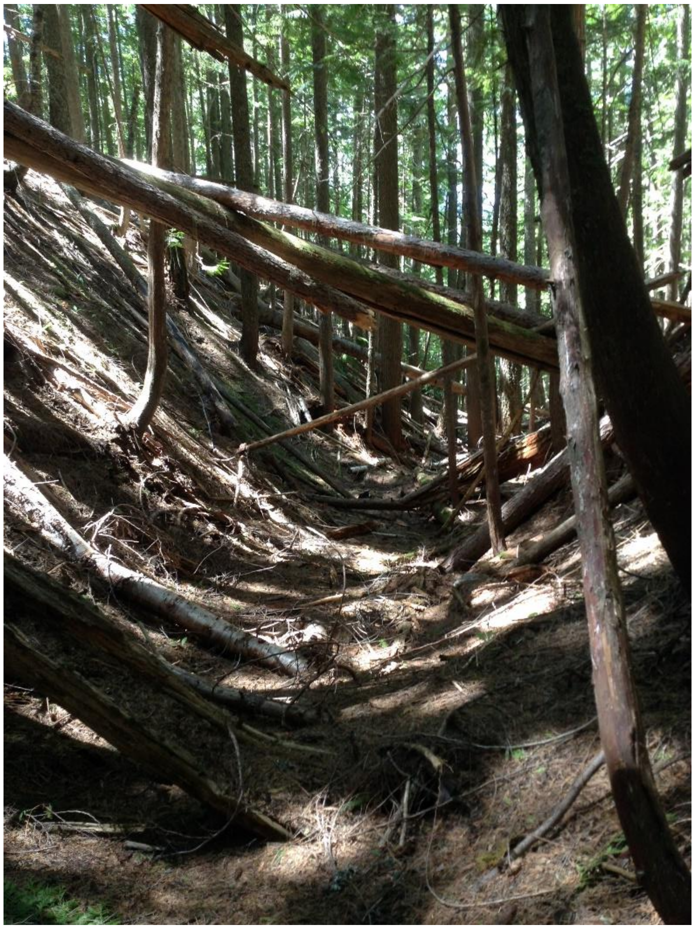

PHOTO 4. LOOKING UPSTREAM AT B2. VEGETATION AND THE ACCUMULATION OF DEBRIS INDICATES THAT THIS GULLY DOES NOT CARRY SURFACE FLOW AT ANY TIME DURING THE YEAR.

The smaller headwater tributary of Bartlett Creek directly north and parallel to the main eastern headwater tributary was observed at sites B2 and B9. At site B2 this well defined gully displays no indicators of carrying surface flow. A very decomposed accumulation of woody debris indicates that this gully carried a debris flow or debris avalanche at least 75 years ago and likely over 100 years ago. At site B9 where a branch of this gully ends at Hartney Flats the base of the gully shows some evidence of surface flow that mobilized small organic debris including coniferous needles and very small branches.

A number of springs occur at the elevation of Hartney Flats. At site B4 (Figure 8) and a second site (B10) about 30 metres north of B4 springs emerge from the forest floor. These springs are topographically higher than the base of the gully at site B9 suggesting that they are not sourced by runoff in the gully. The spring at site B4 has mossy banks and channel bed and appears to have constant flow with limited seasonal flow variability. The spring at B10 is smaller and emerges from the ground on an old mining road.

PHOTO 5. SPRING AT B4 EMERGING FROM FOREST FLOOR.

A larger spring flows south along Hartney Flats and is referred to in this assessment as the north fork headwater of Bartlett Creek. The confluence of the north fork with B4 spring occurs at an elevation of about 1000 metres elevation. A second field session was undertaken to determine the source area of the north fork of Bartlett Creek. Sites B11 to B20 on Figure 8 trace the location of this perennial spring. At several locations along the course of the main channel including sites B13, B16 and B18 additional springs enter the main channel from the eastern slopes of Hartney flats. Upstream from site B16 the north fork channel becomes intermittent and flows subsurface for some stretches (Photo 6).

PHOTO 6. NORTH FORK CHANNEL AT SITE B16. CHANNEL IS INTERMITTENT (FLOWING BENEATH THE FOREST FLOOR) UPSTREAM FROM THIS POINT.

About 30 metres northwest of site B20 the north fork flows from a 40 metre diameter pond/wetland that appears to be the main source area for the north fork channel.

PHOTO 7. LOOKING UPSTREAM AT SITE B14 ON BARTLETT NORTH FORK.

For most of the length of the north fork of Bartlett Creek, the channel is a low gradient (<2%) riffle-pool channel with a bedload limited to fine gravel, sand and organic muck. Channel banks are overhanging and vegetated with mosses. Some recent bank scour above the current flow stage noted in locations along the length of this channel indicates that there is some seasonal flow variation associated with the spring freshet. The scour appears to be from the 2018 freshet. Channel bankfull width and depth is generally invariant along the length of the north fork channel ranging from 1.7 metres to 1.85 metres as the surface catchment area increases from 45 hectares to 99 hectares.

PHOTO 8. LOOKING UPSTREAM AT BARTLETT CREEK AT SITE B7.

Below Hartney flats Bartlett Creek is contained in a steep-sided (~80%) valley underlain by glacial sediments. The channel has a gradient of 28% and a forced step morphology with single pieces of large woody debris distributed along the channel forming steps. Channel banks are vegetated and overhanging. The bedload sediment is relatively fine grained and consists primarily of subrounded small cobble to gravel. The D90 through this section are subrounded cobbles with a diameter of about 15 cm.

Woody debris forming steps in the channel and spanning the channel appears to have been in place for at least 50 years or more. This observation along with well vegetated flood deposits noted along the channel margins downstream from B7 suggest that the last major channel forming flood in this portion of Barrett Creek occurred at least 50 to 75 years ago. Some recent scour along upper channel banks indicates that the 2018 flood was a larger than average flood event. Small woody debris including the branches less than about 1cm diameter were mobilized in the 2018 flood but none of the larger elements in the channel appear to have been disturbed.

PHOTO 9. THE DAM ON BARTLETT CREEK AT B8. THE LARGER THAN AVERAGE PEAK FLOW IN 2018 HAS DEPOSITED A WEDGE OF SMALL COBBLE TO ORGANIC MUD WHICH IS TRAPPED BEHIND THE DAM.

PHOTO 10.LOOKING UPSTREAM ABOVE THE DAM AT BARTLETT CREEK. BEDROCK EXPOSED AT THE DAM IS INTRUSIVE GRANODIORITE.

Bartlett Creek upstream from the dam has a cobble and woody debris step pool morphology. Abundant old woody debris spanning the channel suggests that the last channel forming flood occurred at least 50 years ago. Channel banks are generally overhanging and vegetated. There has been a substantial amount of disturbance to the riparian area along this section of Bartlett Creek which makes it difficult to asses the disturbance history.

At the Standard Road crossing Bartlett Creek is carried in two culverts with diametres of 850mm and a 600mm (Photo 11). The culvert inlet and road ditchline display no obvious indicators of erosion which suggests they are sufficiently sized.

PHOTO 11. BARTLETT CREEK AT STANDARD ROAD. TWO CULVERTS (850MM AND 600MM) APPEAR TO HAVE MANAGED FLOWS ON BARTLETT CREEK WITHOUT INCIDENT FOR AT LEAST SEVERAL DECADES .

Observations of proposed road and blocks

Block 4c and the proposed road that extends through Block 4 from Harris Creek to Bartlett Creek were reviewed in the field for 'red flag' issues that could potentially impact water quality and quantity in Bartlett Creek. No major issues were identified, however, the proposed road between sites bar 15 and bar 20 (Figure 9) has flags identifying proposed culverts that are upslope from steep terrain. Increased slope runoff following harvesting and the location of these culverts could result in debris slides on the slope above the north fork of Bartlett Creek. There is also a question of the potential for blow down of the reserve strips along the eastern headwater of Bartlett Creek. Finally, the snow avalanche hazard will need to be considered in the design of the road crossing of the main eastern headwater of Bartlett Creek. Ideally, there should be the requirement for the road fill to be removed from the gully following harvesting or there should be design considerations to limit the impact of this road fill with respect to avalanche processes in the gully.

Hydraulic Geometery

Hydraulic geometry relates channel physical characteristics (width, depth and sediment calibre) to upstream catchment area. This relationship reveals information about runoff processes and channel responsiveness in a watershed. Data for Bartlett Creek was collected at 20 field sites in both the eastern and northern tributaries and the lower mainstem channel. Catchment boundaries were defined using the 20m DEM and likely have uncertainties of at least ± 10%. Figure 10 includes four graphs that show watershed area (hectares) versus channel bankfull width, bankfull depth, bankfull cross-sectional area (product of width and depth), and maximum mobile bedload (D90).

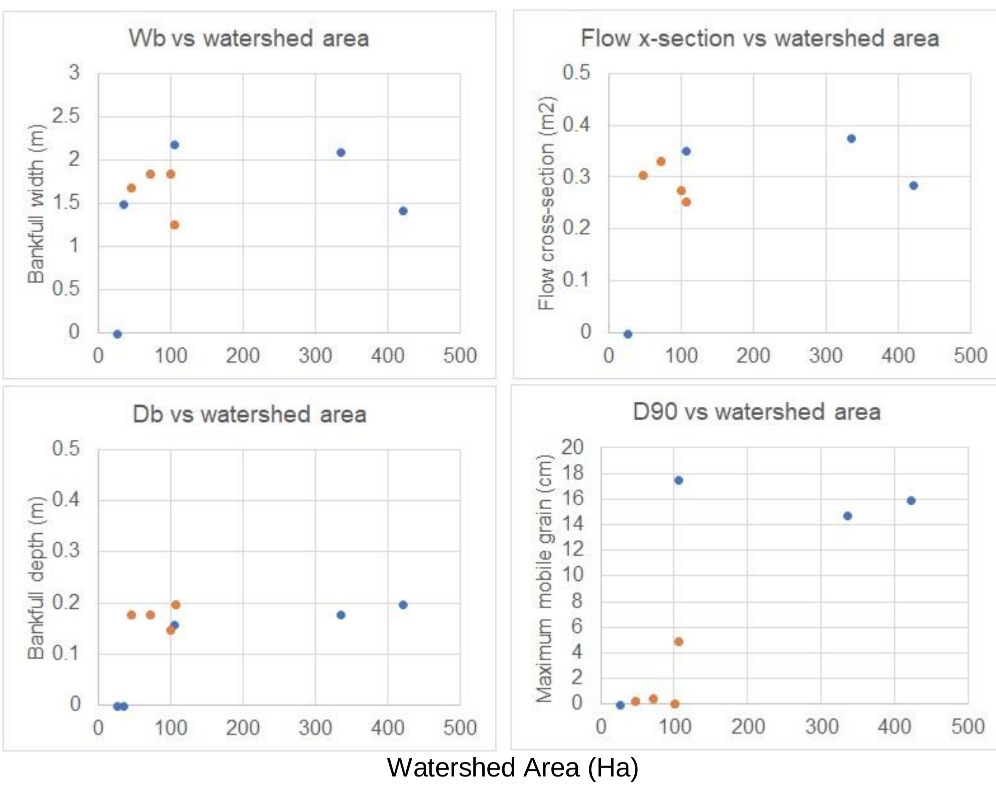

FIGURE 10. BARTLETT CREEK HYDRAULIC GEOMETRY RELATIONSHIPS.

Figure 10 shows a lack of an obvious trend between watershed area and bankfull width, depth, flow cross-sectional area or D90. A lack of a downstream trend in these physical characteristics indicates that Bartlett Creek is not a typical alluvial or semi-alluvial channel in which increasing discharge with increasing channel area imparts controls on channel form or processes of bedload transport.

9. Discussion

Current conditions

Bartlett Creek is an unusual watershed in that it does not display commonly-observed relationships between catchment area and channel form or processes. It is interesting that at the time of the field investigation in mid-June, the snowmelt-related discharge had finished. This is particularly surprising considering the high elevation of the headwater region and the exceptional snowpack of 2018. The analysis of aspect distribution highlights the fact that the upper headwater area has predominantly west to southwest aspects that receive high levels of shortwave radiation. For this reason, the headwater basin likely experiences snowmelt throughout the late winter and early spring period when temperatures are above freezing. Consequently, less snow is available for sustaining the melt runoff during the spring freshet. Another possibility is that surface runoff from the headwater regions above 1200m elevation is entering bedrock structures rather than flowing overland or as shallow soil water to the stream system.

An additional unusual feature of Bartlett Creek is the numerous springs in the Hartney Flats area. Observations that the springs are perennial with relatively constant flows indicate that these springs are not directly connected to surface runoff. Hartney Flats is a linear feature that parallels the Slocan Lake Fault, a regional-scale, normal fault that has down-dropped rocks to the east by over 10km. This suggests that the flow of water from these springs is potentially related to water travelling up related bedrock fault systems rather than flowing directly down from upslope areas. An investigation of water conductivity could provide some clues as to the source of the springs. The north fork of Bartlett Creek carries elevated flows associated with snowmelt for a short time. These elevated flows result in some movement of bed material and, this year, created some local scour of the channel banks in the north fork tributary.

In general, the low gradient Hartney Flats region separates and buffers steep headwater processes of sediment and debris transport, mostly due to snow avalanches, from the lower reaches of Bartlett Creek. Elevated discharge during the 2018 freshet through the lower canyon of Bartlett Creek resulted in elevated rates of bedload transport and some scour of the channel banks. Field observations indicate that large channel forming floods occur infrequently in the lower reaches of Bartlett Creek. This likely reflects the low volume of surface runoff from headwater regions.

Implications for harvesting and road construction for CP 122 Blocks 4 and 4c

The planned blocks 4 and 4c of CP 122 results in an increase in the total level of cut to 54 hectares or about 13% of the watershed area. Although this is generally a small level of cut when considered as a percentage of the total watershed area, block 4 is located directly upslope from the north fork of Bartlett Creek and accounts for a level of cut of 25% (21.3 ha of the 83ha area). The uniform aspect and elevation of Block 4 will result in snow from this area melting off at the same time. As a result, the snowmelt runoff in the north fork is likely to increase and result in increased sediment transport, channel erosion and turbidity during the early spring melt period.

Field observations along the proposed road alignment did not identify any major concerns regarding areas of instability. A number of culvert flags were noted above steep slopes along the side of Hartney Flats. Harvesting upslope from this road will increase snowmelt runoff substantially so it is important that the slopes below these proposed culvert locations be investigated for the potential for instability associated with increased, concentrated discharge from the culverts.

10. Conclusion

Bartlett Creek is not a typical snowmelt dominated watershed. The perennial base flows of Bartlett Creek are the result of groundwater springs rather than snowmelt runoff. This feature means that Bartlett Creek is less susceptible to alterations in water quantity during much of the year. However, the north fork of Bartlett Creek, which is fed from multiple springs on Hartney Flats also includes a component of snowmelt runoff during the freshet period. Block 4, which is located directly upslope from the north fork channel will result in increased snowmelt runoff delivered to this stream. This higher snowmelt runoff will likely result in higher freshet peaks in this tributary. The north fork channel has a low gradient, riffle pool morphology with a fine textured bed load. Increases in peak discharge in this channel from additional runoff following the harvest of block 4 will result in some increased bedload transport and channel erosion. This will likely create increases in turbidity in Bartlett Creek early in the spring freshet period. These impacts will persist for at least 40 years until the forest has regenerated sufficiently to reduce the increased rate of snowmelt runoff from the harvested block.

The proposed road has some culverts situated above steeper slopes along Hartney Flats. An investigation of areas downslope from these proposed culverts will be needed to ensure the increased runoff will not contribute to debris slides or erosion that could potentially enter the north fork of Bartlett Creek.

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11. Literature cited/referenced

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Winkler R. and S. Boon. 2015. Revised snow recovery estimates for pine-dominated forests in interior British Columbia. Prov. B.C., Victoria, B.C. Exten. Note 116. www.for.gov.bc.ca/hfd/pubs/Docs/En/En116.htm

12. Current Water Licenses on Bartlett Creek

TABLE 2. TABLE OF CURRENT WATER LICENSE HOLDERS.

LIC_STATUS	*CURRENT*	*CURRENT*	*CURRENT*	*CURRENT*	*CURRENT*	*CURRENT*	*CURRENT*	*CURRENT*	*CURRENT*
LCPPLFLG	L	L	L	L	L	L	L	L	L
LICENSEE	PETERSON CHRISTINE MARIE	PETERSON CHRISTINE MARIE	VILLAGE OF SILVERTON	HICKS JAMES A ET AL	PETERSON CHRISTINE MARIE	VILLAGE OF SILVERTON	ANKENMAN JEFFREY A ET AL	VILLAGE OF SILVERTON	ANKENMAN JEFFREY A ET AL
STATUS	L	L	L	L	L	L	L	L	L
STRMNM	Bartlett Creek	Bartlett Creek	Bartlett Creek	Hicks Spring	Bartlett Creek	Bartlett Creek	Bartlett Creek	Levar Spring	Levar Spring
PCL_NO	22562	22562	03662	13291	22562		23973		
MPSHTPD	5502 Z3 (PD69070)	5502 Z3 (PD69070)	5502 H (PD27968)	5502 H3 (PD27959)	5502 Z3 (PD69070)	5502 H (PD27968)	5502 B4 (PD75928)	5502 KK (PD27978)	5502 KK (PD27978)
LICENCE_NO	C107846	C107846	F014680	C057570	C107846	C052762	C116068	C052762	C052761
OBJECTID	5777	17758	21552	28341	31291	38240	42746	54014	63556
REDIV_FLAG	N	N	N	N	N	Y	N	N	N
UNITS	MD	MS	MY	MD	MY		MS	MY	MD
XPRDT	0	0	0	0	0	0	0	0	0
DDRSSLN2	CALGARY AB	CALGARY AB	SILVERTON BC	NEW DENVER BC	CALGARY AB	SILVERTON BC	SILVERTON BC	SILVERTON BC	SILVERTON BC
LCSTTDT	19971117	19971117	19900329	19900329	19971117	19900329	20020418	19900329	19900329
FILE_NO	4002957	4002957	0242228	0368416	4002957	0342109	4004232	0342109	0342217
DDRSSLN1	4927 VANGUARD ROAD NW	4927 VANGUARD ROAD NW	BOX 14	BOX 42	4927 VANGUARD ROAD NW	BOX 14	BOX 141	BOX 14	BOX 141
FTRCD	EA83010000	EA83010000	EA83010000	EA83010000	EA83010000	EA83010000	EA83010000	EA83010000	EA83010000
FLAG_DESC	Total demand one POD	Total demand one POD	Total demand one POD	Total demand one POD	Total demand one POD		Total demand one POD	Total demand one POD	Total demand one POD
TPOD_TAG	PD69070	PD69070	PD27968	PD27959	PD69070	PD27968	PD75928	PD27978	PD27978
QUANTITY	6.819	0.018	165932.285	2.273	7709.25	0	0.014	82966.143	2.273
QTY_FLAG	T	T	T	T	T		T	T	T
PURPOSE	DOMESTIC	POWER: RESIDENTIAL	WATERWORKS: LOCAL PROVIDE	DOMESTIC	IRRIGATION: PRIVATE		POWER: RESIDENTIAL	WATERWORKS: LOCAL PROVIDE	DOMESTIC
PRRTDT	19940314	19940314	19011025	19810415	19940314	19770927	20010312	19770927	19771018