

# **MARK CREEK HYDROLOGIC REVIEW**

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*Prepared for:*

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## **1.0 INTRODUCTION & OBJECTIVES**

Streamworks Consulting Inc. (Streamworks) was retained by BC Timber Sales, Kootenay Business Area (BCTS) to review currently proposed development and conduct an update of hydrologic conditions in the Mark Creek watershed. Mark Creek is a community watershed supplying most of the fresh water needs for the City of Kimberley (population ~6,500) in southeastern BC. This study is only concerned with those areas draining into Mark Creek upstream of the community intake and reservoir. An updated Equivalent Clearcut Area (ECA) Map (2020) superimposed on an orthophoto base has been attached to this report to provide an overview of the watershed, including existing, permitted and proposed forest development.

The main purpose of this assessment was to review possible hydrologic implications or impacts which may result from the currently proposed forest development, including the Sullivan Hill portion of the Residual Area. Field inspections of the proposed blocks and environs were made in the company of BCTS personnel in July 2020. Selected photos from the field assessments along with GPS locations (UTM coordinates) are provided as appendices.

In addition to the field assessments, this report includes an update of current and projected ECA levels in the watershed according to BCTS development plans. The ECA analysis was conducted by GIS specialists at Landmark Solutions at the direction of Streamworks.

Streamworks has been following BCTS forest development in Mark Creek since it completed a full watershed assessment in 2005 (Streamworks 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2014, 2016, 2017, 2018). This document should be considered an extension to these previous discussions and reports.

### **1.1 Report Use and Limitations of this Study**

This report has been prepared in accordance with generally accepted professional practices as applied to the forest industry in British Columbia. Recommendations are the professional opinion of Streamworks Consulting Inc. Findings are based on limited field investigation and inferences from surficial features. Interpretation of field conditions and predicted impacts of future development are judgmental in nature and based on the aforesaid limited investigation, experience and professional opinion. Natural variability in surface and subsurface conditions may create unforeseen situations. Additionally, extreme environmental conditions could cause unpredictable events and/or outcomes. By using this report, the client acknowledges the limitations of the data and recommendations and assumes full responsibility for its use.

## **2.0 BACKGROUND**

### **2.1. Study Area**

Mark Creek drains southeast then south from the eastern edge of the Purcell Mountains, through the City of Kimberley, continuing further south to join the St. Mary River near Marysville. The City of Kimberley has used the creek as a community water source since 1920. In 1995, a dam and new reservoir were constructed to serve as an improved storage and intake site for the city. The study area of concern assessed in this report consists of approximately 95 km<sup>2</sup> of mostly forested terrain upstream of the community intake site. The area of interest is covered by TRIM maps 82F080, 82F090, 82G071 and 82G081. The attached ECA map provides an overview of the study area, including watershed and sub-basin boundaries, stream networks, roads and other forest development features. Existing roads in the watershed have been constructed to service the community reservoir, as well as access forest and mineral resources.

The Mark Creek watershed upstream of the community intake is a fifth order basin, with an approximate main channel length of 13km. Elevations range from 1350m at the reservoir to over 2600m on the high alpine ridges to the northwest. The main tributaries that form Mark Creek descend steeply from these high elevation areas dotted with alpine lakes. A lower gradient tributary draining the eastern portions of the watershed flows through a series of lakes and wetlands (Sub-basin 5).

### **2.1.1 Climate & Hydrology**

The Mark Creek watershed is in a transitional zone between the eastern edge of the Columbia Mountains (Purcell Ranges) and the Rocky Mountain Trench physiographic regions. It falls within the Montane Cordillera ecozone and the Southern Rocky Mountain Trench ecoregion. Biogeoclimatic zones found within the watershed are Montane Spruce (MSdk) in the valley bottoms, and Engelmann Spruce, Sub-Alpine Fir (ESSFdk, ESSFdkp and ESSdkw) at higher elevations. Alpine areas (AT) can be found on some of the higher ridges.

Patterns of temperature and precipitation variation in the Mark Creek region are assumed to be typical for mountainous terrain, with rainfall and snow accumulation increasing with elevation, and mean temperatures decreasing with elevation. Precipitation also likely decreases from west to east, due to the rain shadow effect of the Purcell Mountains. Average total precipitation at the nearest weather station (at elevation 899m) is approximately 431 mm/year, comprised of 283 mm of rain and 148 cm of snow [Environment Canada–Kimberley PCC Station 1981-2010]. Precipitation in the upper watershed is likely to be higher.

Flows have been gauged in Mark Creek continuously (except 1996 and 1997) since 1989 by the City of Kimberley. Other sporadic gauging records exist. Estimated annual instantaneous peak flows are 24.3 m<sup>3</sup>/s (10 year return period) and 31.1 m<sup>3</sup>/s (100 year return period) [Green 2001]. Peak flows typically occur in May or June and begin to decline in July. Archival records indicate that significant flood flows occurred in Mark Creek in 1916, 1948, 1956, 1957(?), 1976, 1991, 2002, 2011, 2013, 2017 and 2018. The highest and most damaging of these floods likely occurred in 1948 (Columbia Basin Institute).

Local snow pack data is available from a snow course near Sullivan Mine (Elev. 1550m) dating back to 1954. Information from the snow course site indicates that snow pack typically reaches a maximum in late March, early April, and the area in the vicinity of the gauge is usually snow free by the end of May.

Water quality at the intake on Mark Creek has been monitored since 1985 by the City of Kimberley.

### **2.1.2 Physiography**

Bedrock underlying Mark Creek has been identified as Middle and Upper Aldridge Formation (quartzite, quartz wacke, rusty-weathering argillite and siltstone). The Lower Creston Formation (argillite and siltstone) lies stratigraphically above the Aldridge Formation and is found at higher elevations. Bedrock of the Aldridge Formation is relatively resistant to erosion. Colluvium derived from this type of rock typically consists of large blocky boulders. Soils and tills derived from these rocks are generally coarse textured (and/or sandy) and well-drained.

Most of the landforms and soils within the Mark Creek watershed were formed during Fraser Glaciation (~10,000 years ago). Thick glaciofluvial sands and gravels fill the

Mark Creek valley bottom and the lower slopes of the tributaries. At mid-elevations, sandy, silty and/or gravelly glacial till blankets and veneers cover the slopes through the eastern and central portions of the watershed. Colluvium and rock are exposed in many of the steep areas at higher elevation (Green 2001).

## **2.2. Natural Resources**

Key elements of available and/or developed resources that may be of importance to this hydrologic assessment are summarized below. For more detailed information, refer to the Mark Creek Integrated Watershed Management Plan (1999).

### **2.2.1 Forest Resources**

Mark Creek is located within the Cranbrook Management Unit of the BC Ministry of Forests Rocky Mountain Forest District. Forest resources in Mark Creek are managed by BCTS according to the 1999 Mark Creek Integrated Watershed Management Plan (MCIWMP). An assessment of timber values in the watershed was conducted by the Ministry of Forests in 1992. Approximately 77% of the watershed has commercial forest potential. When netdowns such as inoperable areas, environmentally sensitive zones, non-merchantable timber types were applied, the Crown forested land base that is suitable and available for harvesting was found to be 5,193 ha, or 60% of the watershed area (MCIWMP 1999).

Forest development by BCTS in the watershed has been relatively recent (mostly within the last 20 years) and carefully considered to protect resources. Commercial softwood species available in the watershed are predominantly lodgepole pine, Douglas-fir, western larch, Engelmann spruce, balsam, sub-alpine fir and whitebark pine.

Tree mortality related to mountain pine beetle has been identified in the study area. Lodgepole pine dominates (is the leading species) in approximately 77% of the available crown forest (MCIWMP 1999). Mountain pine beetle infestation could potentially affect a large portion of the watershed.

Forest fires are a natural recurring disturbance process in Mark Creek and at any given time (in history), significantly portions of the watershed were likely burned. A large wildfire in 1919 affected approximately 57% of the low elevation forest in the watershed (Green 2001). Although evidence of the fire remains, and sections of the forest may not be considered fully recovered in terms of seral stage (mature >100 years), the forest canopy is considered 'hydrologically' recovered in these areas (see Section 3.1).

### **2.2.2 Water Resources**

The City of Kimberley intake and reservoir is located at the downstream end of the study watershed. No other domestic licensed water intakes exist upstream of the reservoir. The total licensed capacity for the City of Kimberley is approximately 12.65 million cubic metres per year (representing a steady flow rate of about 0.4 m<sup>3</sup>/s).

### **2.2.3 Mineral Resources**

Mining and mineral exploration have been active in the watershed since the late 1800's (Green 2001). A significant portion of the study area is covered by active mineral tenures or crown grants. The Sullivan Mine (Cominco), which has been in operation since the early 1900's, is located just outside the southeastern boundary of the study area. Some land-clearing has occurred in association with the mining operation.

Most of the existing roads and trails in the study area, older than 20 years, are the result of mineral exploration. Several drill sites have been more recently active in the

watershed.

#### **2.2.4 Fisheries Resources**

Lower gradient sections of Mark Creek and its tributaries may provide habitat for Westslope (Yellowstone) cutthroat trout (*Oncorhynchus clarki lewisi*) [MCIWMP 1999]. The reservoir likely provides over-wintering habitat for the trout as they can no longer migrate down to the St. Mary River (the dam is a barrier). The small lakes and wetlands in the eastern portion of the watershed may provide important rearing areas for cutthroat trout (MCIWMP 1999). It is important to note that Westslope cutthroat trout are currently included on the BC Blue list of endangered species (B.C. Conservation Data Centre).

### **3.0 METHODOLOGY**

#### **3.1. Equivalent Clearcut Area**

Equivalent Clearcut Area (ECA) is a measure of the extent of deforestation at a given time in a watershed, including forest openings related to harvesting, mining operations, private land clearing and/or natural disturbances such as wildfires. Deforestation affects natural processes such as rainfall interception, evapo-transpiration, snow accumulation and snowmelt on a local scale. When deforestation becomes extensive, these local effects may compound (cumulate) to cause broader, watershed scale impacts. Evaluating ECA is useful in assessing the likelihood of cumulative changes to stream flow regimes in a watershed.

Hydrologic recovery is a term used to describe the return of hydrological functions to a forest opening as it regenerates following disturbance. As trees grow and the forest re-establishes, the opening behaves less like a clearcut. ECA calculations need to be updated periodically to account for tree growth, recent disturbance and updated silviculture information. Current snapshots or future hydrologic recovery can be calculated and projected using standard forest/tree growth models for plantations and/or natural regeneration.

Tree heights may be converted into percentage hydrologic recovery values for use in ECA calculations to account for older blocks. Percentage recovery relationships have been developed for BC forests, typically based on tree height, although stand density and crown closure may also be considered where data are available. In this analysis, we used revised snow recovery estimates developed by Winkler & Boom (2015) for pine dominated forests in the Thompson Okanagan region. While these recovery curves may imperfectly represent the forest-types found in the study area, they are the best available information and likely underestimate recovery (giving a conservative result).

##### **3.1.1 Watershed, POI and Sub-basins**

ECA was evaluated for Mark Creek in the 2001 IWAP (Green 2001) using the methodology set out by the revised 1999 IWAP (Anonymous 1999b). The watershed and sub-basins were delineated and the 'Point of Interest' (POI) was set at the community intake. The same delineations and locations were used in the 2005 watershed assessment (Streamworks 2005) and continue to be used in all assessments to date, including this update. That said, improved mapping and GIS techniques have resulted in slight changes to the watershed and sub-basin boundaries in some areas, especially along the eastern limit. This is reflected in some small adjustments to the sub-basin areas but this has not changed the intent of the delineations.

##### **3.1.2 Existing Openings and Approved Blocks**

Existing openings in the watershed are shown on the attached ECA map. Forest

harvesting in Mark Creek did not start in earnest until the early 2000s, so hydrologic recovery is fairly limited in most blocks. All 'approved' and/or 'OP Plan Complete' blocks are assumed to have been logged in the ECA calculations.

Openings created by land clearing in association with the Sullivan Mine are included in the Residual sub-basin. Areas were obtained from Forest Cover mapping polygons. These openings are considered non-productive (NSR) and no hydrologic recovery was calculated. Small openings created by past and existing drill sites were considered minor and not included in the ECA calculations. As they are unnatural openings, cleared right-of-ways for forestry roads have been added to the ECA totals.

### **3.1.3 Proposed Harvesting**

The areas currently being considered for harvesting are shown on the attached ECA map. Specific harvest dates have not yet been assigned to the proposed blocks depicted. An evaluation of the ECA represented by the total area of the proposed plans is included in the analysis.

Proposed roads are assessed for ECA as future 20m wide strip cuts using the same method applied to existing roads as described in the previous section.

### **3.1.4 H60 Line and Weighting Factor**

Research in the Interior of British Columbia has shown that snow typically covers the upper 60% of a watershed when streamflow levels begin to rise in the spring. To assess the effects of harvesting at higher elevations, hypsometric curves are used to determine the elevation at which 60 percent of the watershed area is above. This elevation was assessed to be 1700m in the previous IWAP (Green 2001). The contour corresponding to that elevation has been highlighted on the map as an H60 line on the ECA map.

Forest cover removal in areas above the H60 line is generally considered to more significantly affect snowmelt peak flows in a watershed than those below the H60. ECA above and below the H60 was therefore calculated separately to permit separate evaluation and assessment.

### **3.1.5 Climate Change**

Potential changes in climate may pose risks to geomorphic processes and watershed resource values in the future, regardless of development and/or possibly compounded by development. The potential for anthropogenic climate change affecting runoff in the Mark Creek watershed was evaluated using the online Pacific Climates Impacts Consortium *Climate Explorer* (PCEX) tool. The online tool uses a broad range of available climate modeling data sets to predict a range of future climates for a geographical polygon, allowing for averaging and extrapolation.

For the purposes of our assessment of Mark Creek, the Canadian General Circulation Model (CanESM2) was selected as the best model. Future estimations of two key parameters ('5 year annual maximum one day precipitation amount', and 'precipitation as snow') were plotted using the tool, allowing for a comparison of historical values up to the year 2100.

An online tool for the development of Intensity-Duration-Frequency Curves under Climate Change (IDF-CC, Version 4.5) maintained by Western University and the Institute for Catastrophic Loss Reduction was also used to assess climate change in the Mark Creek region. Projected future rainfall IDF curves were produced for the watershed location and compared to historic values based on existing data.

Representative Concentration Pathways (RCPs) are used in climate models to represent different emission scenarios. For the purposes and projections of this investigation, an intermediate emission scenario was selected (RCP 4.5 - Radiative Forcing reaching 4.5 watts/m<sup>2</sup> by the year 2100). This emission scenario falls somewhere between worst-case and best-case scenarios represented by RCP 8.5 and RCP 2.6 respectively.

### 3.2. Field Reconnaissance

An inspection tour of the Mark Creek watershed was made by Alan Bates, P.Eng. of Streamworks on July 7 and 8, 2020. Inspections focused on new or newly proposed harvesting areas in Sub-basins 1, 5 and the Residual Area. Select photographs from the assessments have been reproduced and provided in Appendix B. Inspection sites and traverse locations throughout the assessments were recorded using hand-held Global Positioning System (GPS) receivers. Recorded GPS waypoints have been listed along with coordinates in Appendix A. Accuracy of the recorded waypoints were typically within 10m.

## 4.0 OBSERVATIONS & RESULTS

The results of the ECA analyses and the field reconnaissance are summarized in the following sections. Refer to the ECA map for watershed and development features referred to in the text.

### 4.1. Results of Equivalent Clearcut Area Analyses

The following table summarizes the existing and proposed ECA for each sub-basin and the watershed as a whole.

**Table 1: Equivalent Clearcut Area\* (ECA) Summary for the Mark Creek Watershed**

| Sub-basin              |      | 1            | 2           | 3           | 4           | 5            | Residual     | Watershed Total |
|------------------------|------|--------------|-------------|-------------|-------------|--------------|--------------|-----------------|
| Sub-basin Area         | Ha   | 1185.7       | 1674.5      | 2601.2      | 645.7       | 1679.9       | 1582.1       | <b>9368.9</b>   |
| Existing Openings      | (ha) | 116.7        | 41.8        | 75.4        | 27.5        | 314.7        | 298.8        | <b>874.9</b>    |
|                        | %    | 9.8%         | 2.5%        | 2.9%        | 4.3%        | 18.7%        | 18.9%        | <b>9.3%</b>     |
| Proposed Blocks        | (ha) | 22.2         | 0.0         | 0.0         | 0.0         | 41.9         | 75.5         | <b>139.6</b>    |
|                        | %    | 1.9          | 0.0         | 0.0         | 0.0         | 2.5          | 4.8          | <b>1.5</b>      |
| Total ECA Post-Harvest | (ha) | 138.9        | 41.8        | 75.4        | 27.5        | 356.5        | 374.4        | <b>1014.5</b>   |
|                        | %    | <b>11.7%</b> | <b>2.5%</b> | <b>2.9%</b> | <b>4.3%</b> | <b>21.2%</b> | <b>23.7%</b> | <b>10.8%</b>    |

*\* No weighting has been applied to these values for portions above the H60 elevation.*

Although not shown in Table 1, areas above and below the H60 elevation of 1700m were tracked. The distribution of the ECA is close to even, with approximately 5% of the 10% total ECA occurring above the designated H60 line elevation.

Results of this analysis and the potential for peak flow alteration in the watershed are discussed in Section 5.1.

## **4.2. General Observations from Field Reconnaissance**

### **Field Inspections**

Field tours of the Mark Creek watershed were made on July 7 and 8, 2020 in the company of BCTS personnel. A general tour of the watershed was made along existing roads, looking for any indications of watershed changes and/or emerging issues. Proposed blocks (under preliminary layout) were inspected to assess forest types, drainage conditions and possible sensitivities. GPS points of specific sites visited during the field inspection are listed in Appendix A. A detailed map of the proposed harvesting in the Sullivan Hill area is shown as Figure 1.

### **Sullivan Hill - Proposed Blocks G71-1376, G71-1377, G71-1378, G71-1382, G71-1383, G71-1384, G71-1385, G71-1386 (GPS 075 to 090)**

Based on preliminary layout boundaries flagged in the field, areas of proposed harvest and new road construction were inspected on Sullivan Hill (see Figure 1). The forest types in the area were dominated by mature pine, with some veteran larch and a mostly deciduous understory. Some juvenile fir, balsam, and spruce were also noted (Photo A).

Terrain in the area to be developed is low to moderately sloping and the aspect is generally northwest. Exposed soils appeared to be well-drained with a high coarse fragment. Surface runoff on the hillside was generally dispersed, with a few poorly-defined, intermittent channels in shallow draws (Photo B). Mapped NCDs within the proposed blocks have been added to the layout shown in Figure 1. These identified channels and defined draws should be protected by no-machine zones, wildlife tree patches and/or excluded from the final block layout.

Two new roads are proposed to access the proposed blocks (see Figure 1). The upper road crosses two NCDs that combine to form an S4 channel downstream of the crossing (GPS 077 – Photo B). A minimum 750mm culvert should be installed at the crossing (on the larger of the two NCDs). Additional culverts should be installed wherever surface water drainage routes, discernable draws and significant exposed seepage areas intersect the new road. Drainage routes may become more obvious when the road grade is cut. Due to the dispersed nature of drainage on the hillside, frequent cross drainage should be provided during road construction to ensure any intercepted surface drainage remains dispersed and not concentrated into fewer crossings. A post-construction inspection during a heavy rainfall event and/or spring runoff is recommended to identify any inadequacies in the drainage structures provided. Any identified insufficiencies should be addressed in a timely manner.

Some wet areas were identified along the proposed lower road near where it connects to the Mark Creek Main (CR0252.20). The intersection is also close to where the S4 channel crosses beneath the Mark Creek Main. Some adjustment to the road alignment is recommended to ensure the road is located on drier ground and sufficiently away from the S4 channel.

No other specific hydrologic concerns were identified in association with these proposed blocks on Sullivan Hill.

### **Proposed Block G71-1359 (GPS 091 to 094)**

Proposed harvest area G71-1359 was partly traversed by Streamworks in 2017 and briefly described in the Sept 15, 2017 letter to Steve Knowles. As shown in the proposed harvest plan, a mapped channel and defined draw running through the middle of the block will be protected by a Riparian Management Area (RMA). Other areas within the block were found to be well-drained, with little evidence of surface flow. Terrain is low to moderately sloping

and block aspect is northwest. The forests were predominately mature pine with little understorey (Photo C and D).

Approximately 200m of new road from the switchback to the south (Mark Creek Main Spur 8000 - CR0252.23) had been constructed at the time of inspection. No culvert had been installed yet at an NCD crossing a short distance in from the switchback (GPS 091). Although flow is intermittent, it is recommended a minimum 400mm diameter culvert is installed at this location.

The mapped stream (S4) flowing through the middle of the proposed block was noted to be a flowing, gravel-bed riffle-pool stream with large woody debris inputs contributing to its morphology (Photo E). This suggests the preservation of riparian forests as currently planned is important to maintain channel stability. Although there are no fish present, a low impact crossing of this channel would require a bridge or a possibly large culvert (minimum 1800mm). It is also confined in a broad but steep-sided draw. After some discussion in the field, it was suggested that it may be easier to access the north half of the block from an existing old road to the north (Photo F), rather than trying to cross the creek and associated steep slopes. This would eliminate the need for a crossing on the creek, but require a longer access route, and reactivation of the old road (brushing and some upgrades). The ECA map was updated to reflect the access from either side (eliminating the need for a stream crossing).

No other specific hydrologic concerns were identified in association with this proposed block assuming riparian buffers are maintained.

**Other Proposed Blocks shown on the ECA Map: F80-1343, G71-1357, A0166-1 and A0166-2**

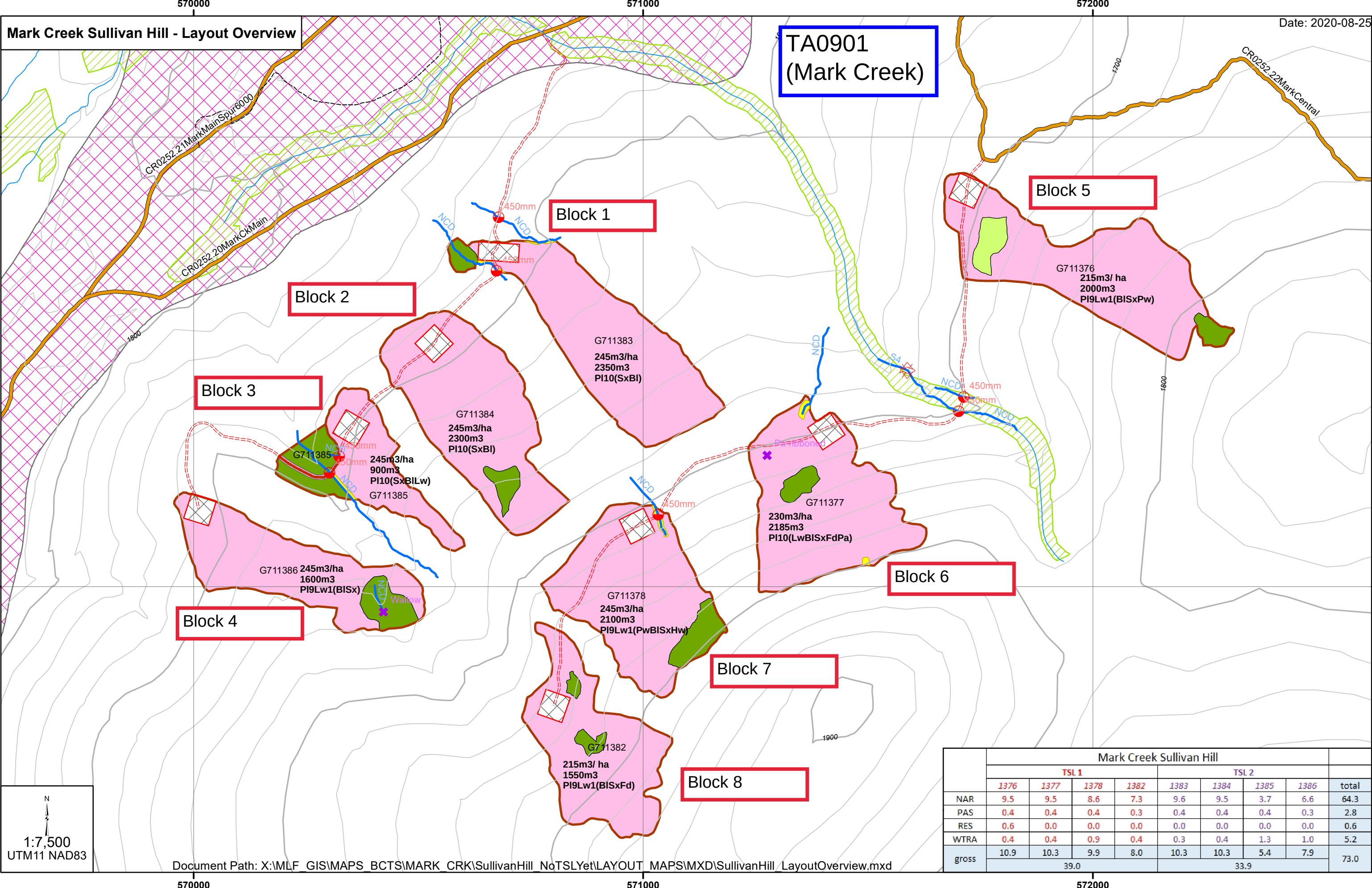
Proposed harvest areas in Sub-basin 1 were inspected by stream works in 2017. F80-1343 and G71-1357 were described in the Sept 15, 2017 letter to Steve Knowles. No specific hydrologic concerns were identified.

Proposed harvest areas A0166-1 and A0166-2 were also briefly inspected in 2017. No watercourses were identified or drainage issues anticipated as the proposed harvest areas are relatively high on a moderately sloping ridge. Preliminary layout had not yet occurred and the block designs were in the early stages of development/consideration. As a general recommendation, all channels and/or defined draws identified in these proposed areas should be protected by no-machine zones, wildlife tree patches and/or excluded from the final block layout.

**Mark Creek Bank Failure Site (GPS 038)**

A previously identified slumping bank failure directly into Mark Creek just upstream of the second mainstem creek crossing was re-inspected. As noted in earlier assessments, erosion along the toe of the slope by the creek may have been the prime factor in the failure. The site may be a source of fine sediment (turbidity) into the creek during high water. This site has been assessed by a terrain stability professional and it was reported the failure was likely a natural occurrence.

Although there may be some continued raveling on the upper slope face since the last inspection, there were no new fallen trees. The toe (creek edge) appears to be mostly stable and 'greening-up' (Photo G). Despite minor seeps in the slope face, no dirty water appeared to be entering the creek at the time of inspection.



Mark Creek Sullivan Hill - Layout Overview

TA0901  
(Mark Creek)

Date: 2020-08-25

Block 1

Block 2

Block 3

Block 4

Block 5

Block 6

Block 7

Block 8

N

1:7,500  
UTM11 NAD83

Document Path: X:\MLF\_GIS\MAPS\_BCT\MARK\_CRK\SullivanHill\_NoTSLYet\LAYOUT\_MAPS\MXD\SullivanHill\_LayoutOverview.mxd

|       | Mark Creek Sullivan Hill |      |      |      |       |      |      |      |      |
|-------|--------------------------|------|------|------|-------|------|------|------|------|
|       | TSL 1                    |      |      |      | TSL 2 |      |      |      |      |
|       | 1376                     | 1377 | 1378 | 1382 | 1383  | 1384 | 1385 | 1386 |      |
| NAR   | 9.5                      | 9.5  | 8.6  | 7.3  | 9.6   | 9.5  | 3.7  | 6.6  | 64.3 |
| PAS   | 0.4                      | 0.4  | 0.4  | 0.3  | 0.4   | 0.4  | 0.4  | 0.3  | 2.8  |
| RES   | 0.6                      | 0.0  | 0.0  | 0.0  | 0.0   | 0.0  | 0.0  | 0.0  | 0.6  |
| WTRA  | 0.4                      | 0.4  | 0.9  | 0.4  | 0.3   | 0.4  | 1.3  | 1.0  | 5.2  |
| gross | 10.9                     | 10.3 | 9.9  | 8.0  | 10.3  | 10.3 | 5.4  | 7.9  | 73.0 |
|       | 39.0                     |      |      |      | 33.9  |      |      |      |      |

## 5.0 DISCUSSION & RECOMMENDATIONS

### 5.1. Potential Changes to Watershed Condition

#### 5.1.1 Hydrologic Regime (Peak & Low Flows)

##### Peak Discharge

Existing and proposed ECA for Mark Creek, prepared by the Landmark Solutions GIS Team is summarized in Table 1 (Section 4.1). ECA levels in the Mark Creek watershed are presently low at approximately 9.3% for the total watershed. Harvesting to date has been concentrated mostly in Sub-basins 1 (9.8% ECA) and 5 (18.7% ECA), and the Residual Area (18.9% ECA – note that the Residual Area is not a drainage basin so the percent ECA is somewhat meaningless until it is accounted for in the watershed as a whole).

These relatively low levels of canopy loss or disturbance (all but Sub-basin 5 are less than 10%) are considered a low risk for hydrologic regime change and are not likely to affect peak or low flows in the sub-basins or in the watershed as a whole. As mentioned in previous assessments, a key point in the Mark Creek watershed is avoiding disturbance in the upper portions of Sub-basins 2 and 3. In the 2001 IWAP, Green stated *“In Mark Creek, peak flows are controlled primarily by snow melt from the alpine areas in Sub-basins 2 and 3, and to a lesser extent from alpine areas in Sub-basin 5.”* Most of the existing harvest in Sub-basin 5 is within the lower half of that sub-basin. Leaving these higher elevation, higher snowpack areas intact will ensure relatively stable (natural) summer peak and low flows in the watershed.

Sub-basin 5 currently has the highest ECA level at 18.7%. Flow regime change typically results from disturbance levels above 30% ECA. Staying closer to 20% provides a ‘reserve’ in case of wildfire, tree mortality through disease or pests, or other uncontrollable changes in natural forest cover. The wetland areas found in the lower portion of Sub-basin 5 will serve to attenuate peak flows leaving the sub-basin. Any increased runoff or sediment from the forest operations in that sub-basin will be moderated and absorbed and not passed downstream.

Approximately 140 hectares are currently proposed for harvest in the watershed, again, mostly in Sub-basins 1 and 5, and the Residual area. These sub-basins were suggested as being the least risk by previous assessments. ECA levels in Sub-basin 5 will increase to 21.2% following the proposed harvest, entering the lower end of a moderate hazard range. As mentioned above, Mark Creek in Sub-basin 5 is well-buffered from peak flow and/or sediment generation effects by the slow draining wetlands along the main channel. Peak flows dissipate as they discharge into the broad floodplain areas, also allowing for the settlement of suspended sediment. Proposed harvest levels are therefore still considered a low risk and development related flow regime change and/or sediment impacts are unlikely.

ECA levels in Sub-basin 1 would increase to 11.7%, remaining at low risk for flow regime change. ECA in the watershed as a whole would increase to 10.8% following the proposed harvest. These ECA levels are unlikely to initiate any significant flow regime change in the watershed related to loss of forest cover. The proposed harvesting represents a low hydrologic risk and maintains watershed management goals.

In addition to the extent and elevation of the canopy reduction, cutblock aspect can also play a role in the rate in which snow melts in the spring time. South and west facing blocks tend to melt faster due to sun exposure during the warmest time of day (late

afternoon). Proposed blocks on Sullivan Hill and Sub-basin 5 generally have a northwest aspect on moderate slopes, providing for some shading and reduction in the rate of snowmelt. Proposed block F80-1343 in Sub-basin 1 has a northwest aspect as well. Proposed blocks A0166-1 and -2 have slight southeast aspects. These blocks are relatively long and narrow, and close to the gentle ridge top, providing for some shading in the blocks.

The harvest areas contributing to ECA with respect to the H60 elevation were found to be evenly distributed. Those harvest areas that are above the H60 elevation were still considered to be relatively low compared to the high snowpack areas near the northern boundary. Harvesting tends to advance snowmelt slightly due to exposure to sun and wind. These lower areas, although above the H60 elevation, would be desynchronized from snow melt in the upper basins, and therefore not significantly contribute to peak flows. The risk of the existing or proposed harvesting causing hydrologic regime change with respect to elevation was considered low.

### **5.1.2 Sediment Sources**

Existing roads and road cuts in the study area were inspected for potential sediment and drainage issues. Soils in roaded areas were predominantly well-drained with a high coarse fragment, resulting in reduced surface runoff and generally well-armoured ditchlines. Roads in the watershed were noted to be constructed to a very high standard as evidenced by frequent cross-drainage, downslope protection on culvert outlets and/or seeded cutslopes and shoulders. Evidence of sustained flow in ditchlines was infrequently observed. Lower standard trails (e.g. disused mineral exploration trails) were frequently deactivated and overgrown.

The most likely source of sediment to significantly affect water quality at the intake (and long-term channel stability) would be potential landslides/bank failures along the lower mainstem of Mark Creek. None of the proposed harvesting is near or directly above the main channel. Several hundred metres of relatively flat, forested land exists between the proposed harvest on Sullivan Hill and the mainstem of Mark Creek. The risk of the proposed harvesting causing a landslide into Mark Creek was considered very low.

New road construction also increases the risk of sediment generation and delivery to the water resource. Approximately 5km of new road is required to access the currently proposed development. For the most part, these roads are well-away from the mainstem channel or larger creeks that could deliver turbid water to the community intake. Well-drained, high coarse fragment soils also reduce the potential of accumulating ditch flows and scour during runoff events. Maintaining high standards for construction and taking appropriate care when crossing existing drainage routes will minimize the potential for increased sediment generation and delivery. Inspections should be made during runoff events to ensure adequate cross-drainage has been provided, natural drainage routes are maintained and any new drainage structures function as planned.

An existing (naturally eroding and raveling glaciofluvial terrace) bank failure has been identified as a chronic point source of sediment to the Mark Creek mainstem (Photo G). Field inspections suggest this bank failure area is recovering and currently producing minimal sediment. Continued monitoring of the site is recommended, especially following flood events.

### **5.1.3 Riparian Condition**

Planned harvesting appears to have made adequate provision for riparian protection in

the Mark Creek watershed. During block layout, any permanent or ephemeral defined channel should be identified, classified and mapped so that it can be appropriately protected with buffers and/or 'no machine zones'. Maintaining riparian condition is key for channel stability, controlling sediment movement and improving channel resilience to potential changes in flow and sediment regimes. In streams where falling trees influence channel morphology, block boundaries should remain at least one tree length away from the top of bank, with consideration given to wind-firmness. It is also a 'good practice' and makes operational sense to keep harvesting beyond any steeper slope breaks above a creek draw. The direct disturbance of steep slopes above a creek should be avoided.

#### 5.1.4 Climate Change

Potential changes in climate may alter long term geomorphic processes and ultimately pose risks to channel stability and watershed resource values in the future, regardless of development and/or compounded by development. The potential for climate change affecting hydrology and runoff in the Mark Creek watershed was evaluated using the online Pacific Climates Impacts Consortium Climate Explorer (PCEX) tool. For the purposes of our assessment of Mark Creek, the Canadian General Circulation Model (CanESM2) was selected as the best available model for the region. A moderate emission scenario was used (RCP 4.5), as opposed to a 'worst-case' scenario (RCP 8.5).

Future estimations of the 1 in 5-year return period, annual maximum one day precipitation amount was plotted using the tool, allowing for a comparison of historical values up to the year 2085. The resultant graph is shown below as Figure 2:

**Figure 2: Change in 1:5 Year Return Period Maximum Daily Precipitation Using the CanESM2 Model**

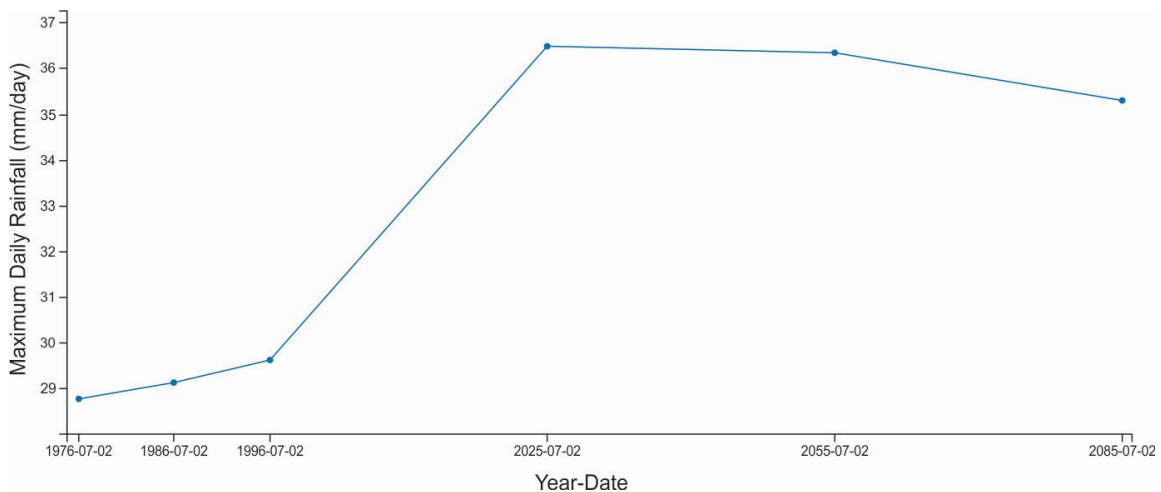
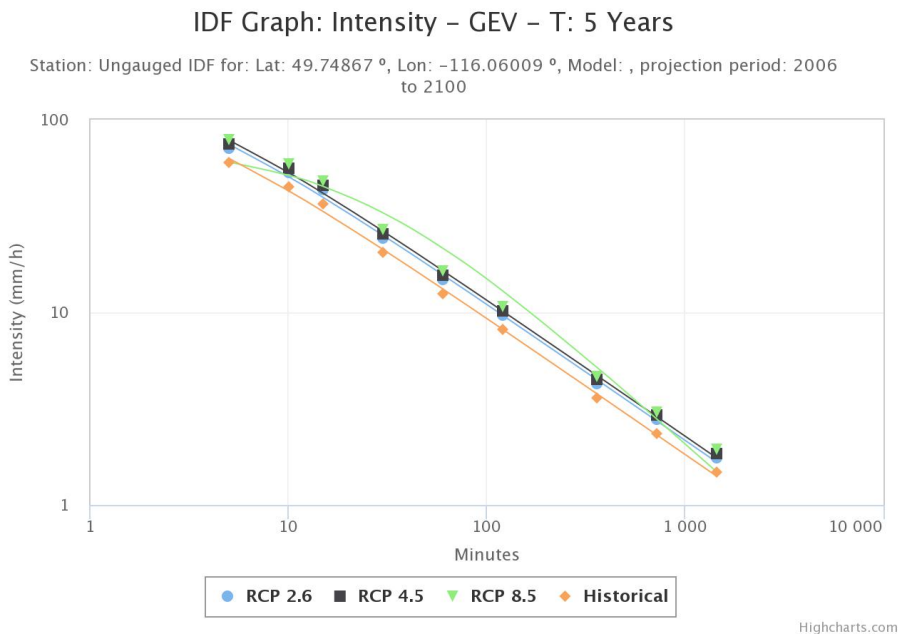


Figure 2 depicts a potential increase of the maximum daily rainfall from less than 30mm in the 1970s to about 36mm per day by 2025. From 2025 to 2085, it declines slightly but remains high. Assuming a 5-year return period is a representative fairly frequent but severe event, this 20% increase in precipitation may translate into significantly more runoff during a summer storm. This magnitude of change will likely dwarf any changes in runoff related to changes in forest cover as described in Section 5.1.1. That said, the

interception and the ground protection provided by forest cover will play an important role in protecting the landscape and making it more resilient to future climate variation. For these reasons, it is important to manage and maintain ECA levels in the low range, and ensure riparian zones are preserved to assist in sustaining robust channel systems.

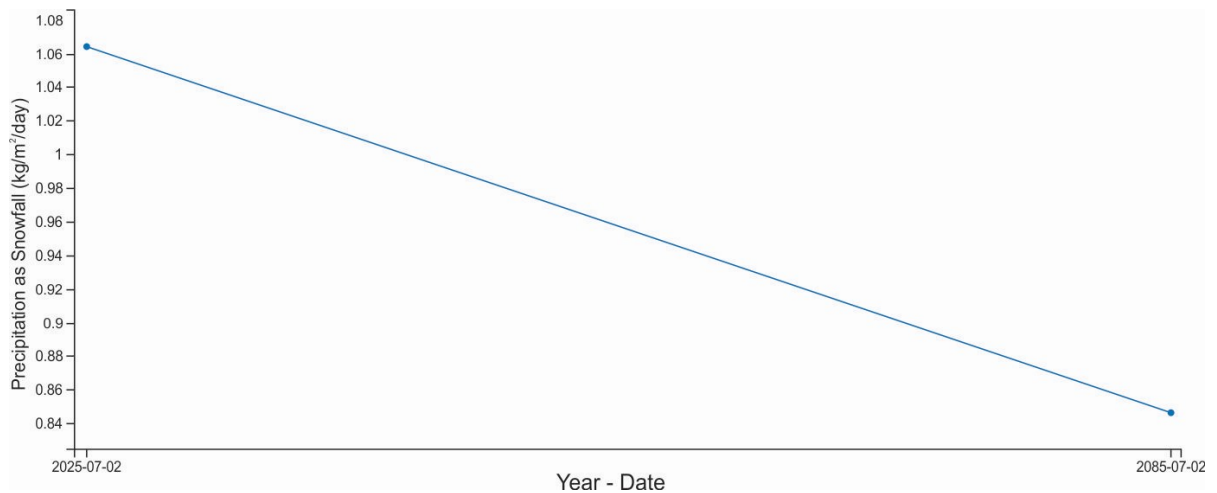
An upward shift in the Rainfall Intensity-Duration-Frequency Curves for the watershed was confirmed using the Climate Change (IDF-CC, Version 4.5) model (which also uses CanESM2) as shown in Figure 3 below. Based on this shift, higher intensity rain storms can be expected to occur with more frequency (Note the three RCP values shown on the graph represent increasingly unfavourable emission scenarios). According to the model, a 60-minute duration rainstorm with a historical intensity of 13.2 mm/hr would increase to 14.1 mm/hr by the year 2100 (under RCP 4.5). Running a rough runoff model based on the graphed shift of the IDF relationship, peak flows in Mark Creek following a rainfall event of similar frequencies could increase between 5 and 10%. Or, conversely stated, peak flows of a similar magnitude would occur with increased frequency. Higher peak flows would do more 'channel work', potentially affecting morphological processes and forcing physical adaptation of the channel to an altered and/or increased flow regime.

**Figure 3: Modeled Changes in Intensity-Duration-Frequency Relationship For Three Climate Change/Emission Scenarios**



It is important to note that summer rainfall events are not usually the driver of annual peak flow and/or sustained channel-forming events in the Mark Creek watershed. Rapid spring snowmelt or possibly rain-on-snow events typically generate the highest and longest lasting flood levels in the watershed. Figure 4 below depicts projected snowfall amounts in a future changing climate using the same models as above.

**Figure 4: Change in Daily Precipitation Falling as Snow Using the CanESM2 Model**



Daily average snowfall amounts are expected to decrease with climate change as warmer temperatures will result in a shorter cold season. This will likely result in reduced annual peak flows in the lower channel. Canopy removal typically results in an increased snowpack with more rapid melting in the spring, however; a smaller snowpack will be less sensitive to changes in forest cover. Lower seasonal snowpacks may lead to diminished late season flows in Mark Creek as snowmelt runs out sooner. The preservation of the high snowpack, higher elevation areas is therefore once again justified as a late season source of streamflow.

## **5.2. Summary and Recommendations**

The currently proposed harvesting in the Mark Creek watershed is consistent with the recommendations of previous hydrologic assessments. ECA levels in Sub-basin 5 are at moderate hazard levels, however given the slow routing and peak flow dissipating effect of wetlands in the sub-basin, risks remain low. Changes to flow regimes are not expected to occur as a result of the currently proposed development in other areas.

With the exception of road crossings, larger channels in the watershed are well-buffered from forest development. Well-drained soils help to prevent the accumulation of ditch flow and/or runoff diversion. Localized impacts at stream crossings do not appear to have any significant effects. Assuming continued good construction practices, planned road development is also not anticipated to affect water quality in the Mark Creek community watershed.

The following list summarizes recommendations developed through this and previous assessments aimed at mitigating the level of hydrologic risk and protecting water resources in the Mark Creek watershed:

1. Ensure that all road construction and forest harvest operations maintain natural surface and near-surface drainage patterns, and avoid concentrating and/or diverting surface runoff, especially when working above areas mapped as potentially unstable. In areas of dispersed natural drainage, frequent cross drainage should be provided to ensure any intercepted surface drainage remains dispersed and not concentrated into too few crossings.

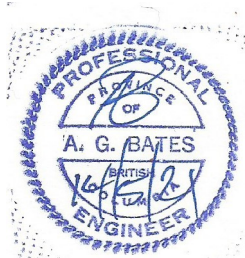
2. Institute routine annual and/or post-runoff event inspections of roads and drainage structures to ensure proper and continued function. Any identified insufficiencies should be addressed in a timely manner.
3. During block layout, identify, classify and map any permanent or ephemeral defined and apply 'no machine zones' and/or appropriate riparian buffers (maintain a width of at least one tree length and/or keep blocks boundaries beyond any steep slope breaks above a creek draw).
4. A minimum 750mm culvert should be installed on the larger of the two NCDs at the crossing in between proposed Blocks G71-1376 and G71-1377 (See Figure 1). The 450mm diameter culverts specified at the other NCD crossings are likely adequate.
5. The natural bank/slope failure into Mark Creek above the second creek crossing appears to be recovering/revegetating. Continued monitoring of the site is recommended, especially following flood events.
6. The originally proposed road crossing in Block G71-1359 has been eliminated and harvesting should be kept back from steeper slopes adjacent to the watercourse.
7. Maintaining riparian condition is key for channel stability, controlling sediment movement and improving channel resilience to potential changes in flow and sediment regimes. In streams where falling trees influence channel morphology, block boundaries should remain at least one tree length away from the top of bank, with consideration given to wind-firmness. It is also a 'good practice' and makes operational sense to keep harvesting beyond any steeper slope breaks above a creek draw. The direct disturbance of steep slopes above a creek should be avoided.
8. Climate change in the Mark Creek region may increase rainfall frequency and intensity, and decrease snowpacks in the future. Preserving the higher elevation, high snowpack areas will help sustain late-season low flows. Maintaining effective riparian buffers and other best-management practices associated with forest development will help support the resiliency of the watershed in response to climate change.

The analysis and recommendations in this report assume normal good harvesting and road building practices, and makes some specific recommendations regarding development, which, if followed, should result in minimized hydrological impacts. However, the recommendations in this report will only be effective in they are implemented properly. It is therefore recommended that BCTS ensure that there are proper planning and operational procedures in place, including adequate supervision of on-site activities, to ensure that the intent of the recommendations in this report are met during operations.

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**Appendix A - UTM Coordinates (NAD 83) for recorded GPS Points:**

| GPS Reference Point | Latitude      | Longitude      |
|---------------------|---------------|----------------|
| 75                  | 49°44'39.67"N | 116° 0'16.51"W |
| 76                  | 49°44'31.00"N | 49°44'31.00"N  |
| 77                  | 49°44'30.02"N | 116° 0'14.63"W |
| 78                  | 49°44'28.66"N | 116° 0'33.16"W |
| 79                  | 49°44'24.25"N | 116° 0'52.08"W |
| 80                  | 49°44'8.96"N  | 116° 1'5.03"W  |
| 81                  | 49°44'16.59"N | 116° 1'21.62"W |
| 82                  | 49°44'22.48"N | 116° 1'23.63"W |
| 83                  | 49°44'24.75"N | 116° 1'25.98"W |
| 84                  | 49°44'25.42"N | 116° 1'27.57"W |
| 85                  | 49°44'25.70"N | 116° 1'27.60"W |
| 86                  | 49°44'29.03"N | 116° 1'25.42"W |
| 87                  | 49°44'40.79"N | 116° 1'8.78"W  |
| 88                  | 49°44'41.81"N | 116° 1'8.58"W  |
| 89                  | 49°44'44.79"N | 116° 1'8.32"W  |
| 90                  | 49°44'56.16"N | 116° 0'58.72"W |
| 91                  | 49°45'48.35"N | 115°58'37.64"W |
| 92                  | 49°45'52.44"N | 115°58'34.40"W |
| 93                  | 49°45'52.33"N | 115°58'18.82"W |
| 94                  | 49°45'57.47"N | 115°58'21.50"W |
| 95                  | 49°44'6.39"N  | 116° 2'32.93"W |

## **APPENDIX B**

### **Selected Photographs**



Photo A – Mostly pine stand with little understorey and some juveniles of other species in G71-1376 (GPS 075).



Photo B – A shallow draw with an intermittent channel. This is the mapped watercourse between proposed blocks G71-1376 and G71-1377 on Sullivan Hill (GPS 077).



Photo C – Pure pine stand with low deciduous understorey in the southern portion of G71-1359 (GPS 092).



Photo D – Pure pine stand with little understorey in the northern portion of G71-1359 (GPS 094).



Photo E – Stream channel through the middle of G71-1359. A Wildlife Tree Patch (WTP) is proposed as a riparian buffer (GPS 093).



Photo F – Old road on the northern half of G71-1359 (GPS 094).



Photo G – Natural, existing bank failure upstream of the second crossing of the Mark Creek mainstem (GPS 095). Note the green-up along the toe.