WATERSHED ASSESSMENT

Haslam Lang Community Watershed

Haslam Lake and Lang Creek

Project Number: 17-183

May 19, 2020

Client:

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SUMMARY

The Haslam Lang Community Watershed encompasses Haslam Lake, Lang Creek, and their tributary streams. The community watershed supplies drinking water to Powell River and Brew Bay, and Lang Creek is home to salmon runs and a hatchery. Several forest licensees operate in the watershed, including the Powell River Community Forest (PRCF), which encompasses about 48% of the total watershed area.

PRCF, Thichum Forest Products, and BC Timber Sales retained Statlu Environmental Consulting Ltd. to assess the Haslam Lang Community Watershed. The effectiveness of past watershed assessment recommendations was reviewed. The cumulative hydrologic effects of past and proposed future harvesting in the watershed were evaluated, and the present condition of the watershed was described.

Previous watershed assessments determined that forestry roads presented the greatest potential to cause adverse effects on the watershed. Consequently, recommendations focused on managing forest harvesting and road construction and reconstruction. Implementation of these recommendations have been effective, and should continue in future.

Past, present, and proposed future forest harvesting and road building will result in low hydrologic hazard and low hydrologic risk, if development proceeds as planned and remains consistent with past practices.

Two sources of hydrologic risk in the watershed were not previously discussed in detail. Firstly, in lower Lang Creek, several large, old woody debris jams control local stream channel morphology. These debris jams are beginning to break down and release the sediment that they retain, while maturing second-growth coniferous riparian forests are not yet contributing enough woody debris to replace or supplement the decaying wood that forms the jams. If the jams fully break down, the channel morphology of Lang Creek will change, with consequent effects on sediment in the channel, stream channel pattern, riparian habitat, water quality, and

stream temperature. It may be necessary to supplement woody debris in the channel of Lang Creek until such time as the maturing riparian forest can supply the required woody debris on its own.

Secondly, climate change is already affecting the watershed, and these changes will intensify in future, according to models that use current greenhouse gas emission scenarios to predict temperature and precipitation. Forest land managers and water users should both evaluate their ability to increase climate resiliency and should implement adaptive management practices that recognize and anticipate the expected changes to watershed hydrology and climate. Changes in water availability, including longer and lower low summer flows, increased peak flows, and increased summer stream temperature are expected.

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1.0 INTRODUCTION

Results Based Forest Management (RBFM), acting for the Powell River Community Forest (PRCF), BC Timber Sales (BCTS), and Thichum Forest Products (Thichum), retained Statlu Environmental Consulting Ltd. (Statlu) to complete a watershed assessment of the Haslam Lang Community Watershed. The drainage area of Haslam Lake and Lang Creek forms the Haslam Lang Community Watershed near Powell River. Haslam Lake is the primary water source to Powell River, and the Brew Bay Improvement District uses water from Lang Creek. The Powell River Salmon Society maintains a hatchery on Lang Creek. The Powell River Community Forest, BC Timber Sales, and Thichum Forest Products (the forest company of Tla'amin First Nation) are the major forest tenure holders and forest land managers within the watershed. Western Forest Products and Island Timberlands manage small areas within the watershed.

The watershed assessment is a cumulative effects assessment of past, present, and planned future watershed conditions and is intended to guide future forestry activity on Crown land. The results of the assessment will help forest and land managers plan for development so that it is hydrologically sustainable and maintains a low level of hydrologic hazard with respect to channel stability, sedimentation, timing of flows, and effects on peak and low flows in the watershed.

2.0 OVERVIEW AND BACKGROUND

The Haslam Lang Community Watershed, with an area of 13,125 ha, is located east of Powell River (Figure 1) in the Pacific Ranges of the Coast Mountains and on the northern edge of the Georgia Lowlands. Haslam Lake is a large (1200 ha) lake in the northern part of the watershed, and it drains south via Lang Creek through Duck Lake and thence to the Salish Sea at Brew Bay.

2.1 Physiography and Geology

The northern part of the watershed, around Haslam Lake, is bordered by steep terrain. To the west, the Haslam Lake/Island Lake divide has low-gradient upland surface on the ridge crest and steeper slopes with gullies draining down to Haslam Lake. To the northeast, steep slopes drain down to Haslam Lake from Tin Hat Mountain. These two steeper areas are separated by a low-gradient pass through from the north end of Haslam Lake to Powell Lake via Giovanno Lake.

Haslam Lake is a natural lake that was scoured by glaciers during the last ice age, so it is deep. Its water level has been artificially raised by a small weir at its outlet that controls water level in the lake and flow in the stream during the summer months. Water flows a short distance downstream from this weir via Lang Creek to Duck Lake, which is broad and shallow, and from the outlet of Duck Lake continues down Lang Creek to the ocean. The lower part of Lang Creek watershed, downstream of Haslam Lake, has highlands along the eastern watershed divide. Several tributary streams, including Anderson Creek and Blackwater Creek, flow from these highlands and into Lang Creek. The lower reaches of Lang Creek have incised through thick deposits of Quaternary sediment to expose bedrock in some places. The central and western part of the lower watershed and the southwestern watershed divide have subdued topography and are underlain by the same Quaternary sediments. These sediments include sandy to bouldery glaciofluvial deposits and silty to clayey glaciolacustrine and glaciomarine deposits.

Most of the watershed is underlain by intrusive bedrock, including granodiorite and diorite, of the Coast Plutonic Complex (iMapBC, 2019). A small portion of the southwestern part of the watershed is underlain by sedimentary rocks (claystone, mudstone, siltstone, sandstone, and conglomerate, with coal seams) of the Nanaimo Formation (MINFILE, 2019).

2.2 Climate

Climate in the watershed is generally well-represented by historic climatic data from Powell River. Precipitation in the watershed increases with elevation, with a greater proportion falling as snow at higher elevations. I used the ClimateBC program (Wang *et al*, 2016) to predict climatic variables for four locations in the watershed (Table 1):

1. the sorting station at the mouth of the watershed near Brew Bay,
2. the outlet of Haslam Lake near the weir,
3. the headwaters of Blackwater Creek, and the
4. the summit of Tin Hat Mountain.

I have also reported the expected notional runoff (the difference between precipitation and modelled evapotranspiration) for each location to illustrate the way in which higher elevations generate an increased amount of runoff. The notional runoff is typically less than the actual runoff because of seasonal water shortages which reduce evapotranspiration below the modelled reference ET value, but because of the lakes in the Haslam/Lang watershed, the notional runoff values may more closely approximate actual runoff for the lower elevation locations.

Table 1: Representative Climatic Variables from ClimateBC by Watershed (Wang et al., 2016)

Location	Elevation (m a.s.l.)	Mean Annual PPT (mm)	Rainfall (mm)	Snowfall (cm)	% Total Autumn Winter PPT	Reference ET (mm)	Notional Runoff (PPT - ET) (mm)
Sorting Station near mouth of Lang Creek at Brew Bay	13	1079	1046	33	67%	637	442
Outlet of Haslam Lake at Weir	175	1346	1286	60	66%	633	713
Headwaters of Blackwater Creek	675	2282	2017	265	66%	605	1677
Summit of Tin Hat Mountain	1185	2770	2050	720	64%	556	2214

2.3 Hydrology and Water Quality

The Powell River Salmon Society (PRSS) maintains a stream gauge on Lang Creek. Peak flows in the watershed typically occur in the fall and winter months and are caused by heavy rainfall and rain-on-snow events. Figure 2 shows 2018 and 2019 records of maximum and minimum daily discharge plotted against daily measured precipitation from Powell River airport. The effects of fall and winter storms on peak flows in the creek are evident. From late spring until fall, there is a disconnect between precipitation and stream response caused by the Haslam Lake weir; when water level falls below the weir, changes in inflows into Haslam Lake do not produce increased flow in Lang Creek until the water level rises significantly enough to again overtop the weir. In 2018, for instance, water levels dropped below the weir in May, remained below it until late September, rose over it, then dropped again in late October, and rose over it again in November.

PRSS, the Brew Bay Improvement District (BBID), and City of Powell River all monitor aspects of water quality. Powell River and BBID monitor raw water quality in cooperation with the BC Ministry of Health to ensure it meets drinking water standards, while PRSS has an extensive sampling program throughout the watershed to monitor water quality for their hatchery operation.

Water quality in the Haslam Lang system is strongly affected by the presence of Haslam Lake in the headwaters. Haslam Lake is large and deep, and provides effective buffering of water temperature and quality for inflows to the lake. Transient elevated turbidity levels were measured near the Powell River water intake, particularly in 2017 and 2018 (PRSS, 2018). The increased turbidity may have resulted from construction during an upgrade of the intake, which disturbed soil near the shore of the lake. Wave action on the lakeshore can also contribute to elevated turbidity when water levels are low. There was also an issue with beaver dams near the weir in 2018 which resulted in temporary and localized sedimentation in the slough (Powell River Peak, 2018). Fewer incidences of elevated turbidity were measured in 2019 than 2018.

The outlet of Haslam Lake near the weir is shallow, warming the water flowing over the weir, despite water in the lake itself being cold. When the water level in the lake falls below the weir, inflow to Lang Creek is also warm and is made warmer by the shallow Duck Lake. Temperature modulation along lower Lang Creek is provided by inflows from side tributaries such as Anderson and Coho Creeks and by groundwater inflows, so the stream typically cools slightly as it flows from Duck Lake to Brew Bay (PRSS, 2018). Anderson Creek was provincially designated as a temperature sensitive stream under the Forest Practices Code, but is not under the Forest and Range Practices Act, although it is still managed with consideration for temperature sensitivity.

Bank erosion events along lower Lang Creek during winter storms can and have caused elevated turbidity in Lang Creek (Carson, 2015; PRSS, 2018). The thick deposits of glaciogenic, fine-textured sediment along the lower watershed are more susceptible to such erosion and sediment generation than are reaches with bedrock channels.

2.4 Land Use and History

Haslam Lake and Lang Creek are located within the traditional territory of the Tla'amin Nation who have inhabited the area for thousands of years (IWMP 1999, Tla'amin, 2019). The Haslam-Lang Integrated Watershed Management Plan (IWMP) (1999) also identified the watershed as part of the traditional territory of the shíshálh (Sechelt) Nation, while the shíshálh Strategic Land Use Plan (shíshálh, 2019) identified shíshálh territory as bordering the eastern edge of the watershed.

The 1999 IWMP provided an overview, summarized from earlier documents, of Tla'amin traditional uses and land management practices within the watershed, which included hunting and fishing camps, and a trail network. Fish weirs were likely located on Lang Creek, where salmon, cutthroat, and rainbow trout were fished. Plants within the watershed supplied timber, food, fuel, tools and implements, and medicine. Game animals including deer, elk, bear, cougar, and mountain goats were hunted within the watershed. Tla'amin use of the watershed continues today, with varied uses including hunting, fishing, plant gathering, and timber harvesting.

Industrial-scale forestry in the watershed began in the early 1890s, and included railway logging as well as skidding timber directly into Haslam Lake. A railhead was established at Haslam Lake in 1918. Large volumes of logging debris were left behind in the lake and accumulated near the lake outlet and the present weir location. A very large forest fire burned the area in 1922, and post-fire salvage logging ended near 1926. After a hiatus, a second phase of small-scale harvesting occurred from the 1960s through the 1980s along the eastern watershed divide, followed by more intensive harvesting beginning in 1985.

Integrated watershed management planning began in 1993, community watershed designation was granted in 1995, and the IWMP was completed in 1999. Since then, the IWMP, supplemented by watershed and other assessments, has guided development in the Haslam-Lang Community Watershed. The original IWMP document has been superseded over the last two decades through improvements in science, changes in forest tenure, and alterations in the branches of government that were signatory to the original plan. As a result, watershed assessments and their recommendations have become the primary documents that guide forest management in the watershed.

The IWMP document and previous watershed assessments have effectively summarized the past history of forestry and other developments in the watershed up to the early 2000s. Accordingly, I did not re-review historic aerial photography for this assessment.

2.5 Previous Assessments

Previous watershed, hydrologic, or other assessments of the Haslam Lang Community Watershed include:

- Annual water quality reports. Powell River Salmon Society. Most recent report on 2019 water year published March 2020.
- Haslam Lang Community Watershed Assessment Procedure (CWAP) Update. Carson Land Resources Management, 2015
- Community Watersheds: From Objectives to Results on the Ground. Forest Practices Board, 2014.

- Audit of Forest Planning and Practices, Sechelt Community Projects Inc., Powell River Community Forest Ltd., Sliammon First Nation, Klahoose First Nation. Forest Practices Board, 2012.
- Water Quality Effectiveness Evaluation, Powell River Community Forest Road Network. Carson Land Resources Management, 2010.
- Long Term Water Supply, Corporation of the District of Powell River. Dayton and Knight, 2005.
- Haslam Lang Community Watershed Assessment Procedure (CWAP) Update. Carson Land Resources Management 2003
- Haslam Lang Community Watershed Assessment Procedure (CWAP). Carson Land Resources Management, 2000.
- Haslam Lake and Lang Creek, Integrated Watershed Management Plan. BC Ministry of Forests and BC Ministry of Environment, Lands and Parks, 1999.

2.6 Water Use

Haslam Lake is the primary water source for Powell River, and supplies water to about 13,000 people in over 5,000 households (City of Powell River, 2019). Water is taken from the lake via a submerged intake offshore and treated at the lake shore. The water intake and treatment infrastructure were upgraded in 2017-2018. The city is licensed to divert or store about 22.3 million cubic meters per year of water.

Lang Creek supplies drinking water to the Brew Bay Improvement District (BCMoE Water Licenses Report, 2019). The Brew Bay Improvement District holds seven separate waterworks licenses on Lang Creek, for a total licensed diversion volume of about 66,000 m^3/year, the equivalent of about 75 to 80 individual domestic licenses. In addition to these waterworks water licenses there are fourteen individual domestic water licences, one irrigation license, one work camp license, and three conservation water licenses (held by Powell River Salmon Society) on Lang Creek, for a total permitted diversion from all licenses on Lang Creek, summed, of about

16.1 million cubic meters per year, which corresponds to an average extraction rate of about 0.5 m^3/s. This may overestimate the actual extraction because some licenses are for storage or other non-consumptive use.

Additional details on Haslam Lake and Lang Creek water licenses are presented in Appendix 4.

2.7 Fish

Lang Creek supports runs of pink, chum, coho, and chinook salmon as well as winter-run steelhead and kokanee. Cutthroat trout, rainbow trout, prickly sculpin, and coastrange sculpin are also present (Habitat Wizard, 2019).

Powell River Salmon Society maintains a hatchery operation. Fish are taken from returns to Lang Creek, hatched in the hatchery, reared at the hatchery, in net pens in Duck Lake and at the Catalyst pulp mill, and released to the system at multiple locations. Runs of pink, chum, coho, and chinook are counted annually as they return, but only chum, coho and chinook are presently hatched and reared (PRSS, 2019).

3.0 ASSESSMENT METHODS

3.1 Rationale for Assessment

I assessed the potential for forest harvesting and road building to affect watershed hydrology using the rationale originally established by the Watershed Assessment Procedure Guidebook (second edition, version 2.1, 1999), and the Community Watershed Guidebook (1996), and most recently described by EGBC/ABCFP (2020) guidelines for watershed assessment. I used revised methods of estimating hydrologic recovery for rainfall, rain-on-snow and snowmelt zones in coastal watersheds as described by Hudson and Horel (2007) and defined through practice since. I followed the EGBC/ABCFP recommendations for hydrologic and watershed assessments in defining hydrologic risk and elements at risk.

This assessment method examines the cumulative effects of past harvesting, and evaluates the partial risk of future logging and its effects on hydrologic regimes. The assessment considers cumulative hydrologic effects of changes in forest cover, forest stand age, and, to some extent, forest species composition through the mechanism of equivalent clearcut area (ECA). It also considers hydrologic risk from roads, sedimentation hazards posed by road networks and landslides, changes to riparian forest, and changes in channel patterns. A detailed description of the rationale for assessment, the assessment methods used, and definitions of hazard and risk are presented in Appendices 2 and 3.

3.2 Identification of Hydrologic Risks

Watershed assessment of the risks posed by forest disturbance identifies and characterizes potential sources of disturbances (either natural or human-caused) that can potentially affect hydrologic parameters of value. These risks result from the presence of the parameters of value and the likelihood (hazard) that natural and human-caused disturbances can affect those parameters of value. Risk assessment requires identification of risks, determination of the level of risk, evaluation of means to alter or reduce the risk, and evaluation of the acceptability of the unmodified and modified levels of risk. Ultimately, determination of the acceptability of a particular level of risk is the responsibility of land managers and statutory decision-makers.

With respect to Haslam Lake and Lang Creek, identified parameters of value and risks have been well-defined by previous assessment reports. Identified parameters of value in general are fish, drinking water, and infrastructure. Specific parameters of value follow from those general parameters and are interrelated. For instance, an increase in suspended sediment transport might adversely affect both fish and drinking water quality, as might an increase in water temperature. More frequent or larger floods could damage fish habitat and infrastructure; longer-lasting or lower low flows would affect fish and water availability for water users.

Identified risks include:

- Changes in the timing, duration, magnitude, or frequency of stream flows, including larger or more frequent peak flows (floods), longer-lasting or lower low flows, and adverse changes to the magnitude of mean (monthly or annual) flows.
- Decreases in channel stability which could arise from changes in woody debris dynamics, or increased coarse sedimentation, or channel avulsion, or increases in bank erosion due to increased flooding;
- Changes in water quality, either including or as a result of increased suspended sedimentation or changes in stream temperature, which might in turn arise from changes in riparian vegetation, woody debris abundance, or timing, magnitude and duration of high or low flows;
- Changes in channel pattern or riparian function, which might result from changes in woody debris abundance, increased or decreased sedimentation, or changes to the abundance or species composition of riparian vegetation.

These risks are also interrelated. For instance, changes in channel pattern and riparian function can result in decreases in channel stability, and vice versa. The general format of the watershed assessment recognizes this by subdividing the assessment into assessments of cumulative effects (equivalent clearcut area and road density) and description of site-specific sources of hydrologic risk such as landslides, eroding stream banks, and other point sources.

3.3 Peak Flow Generating Hydrologic Processes

Information about forest cover, including tree age and height, species, canopy closure, etc., was obtained from GIS databases, including the provincial Vegetation Resources Inventory, and LIDAR-derived canopy height models that had been interpolated to VRI-like polygons. PRCF, BCTS, and Thichum provided data on the watershed. Some areas of the watershed, including the WFP TFL land along the eastern edge of the watershed, and private land in lower Lang Creek, were not included in the forest cover databases. I used Sentinel™ and Google™ Earth imagery from September and October 2019, supplemented by observations made during helicopter overflights in 2019, to check forest cover status and infer hydrologic recovery of the areas for which no geographic data was available.

Hydrologic recovery was calculated using the method presented in Hudson and Horel (2007) with the generalized storm model, rather than trying to evaluate effects on storms of different return periods.

The CWAP guidebook (1995, 1999) recommends using three elevation bands (sea level to 300 m, 300 m to 800 m, and 800 m and up) for evaluating hydrologic recovery, corresponding to the rainfall, rain-on-snow, and snowmelt-dominated portions of the watershed. Hudson and Horel (2007) discriminate between warm rain-on-snow and cold rain-on-snow: warm rain liberates more water from a snowpack than cold rain does. Millard (2012) questioned whether, for Vancouver Island, it was even appropriate to use a snowmelt zone or whether rain-on-snow should be considered the dominant peak flow generating process throughout watersheds, given what events typically cause the largest floods there.

Accordingly, I designated three separate elevation zones to evaluate hydrologic recovery within the Haslam-Lang Community Watershed. I assumed that elevations below 300 m a.s.l. would experience purely rainfall-driven peak flow generation during a typical warm Pineapple Express type storm. I used two rain-on-snow zones: I assumed that events between 300 m and 800 m would be warm rain-on-snow and that elevations above 800 m would be cold rain-on-snow. In theory, purely snowmelt-driven peak flow processes should predominate above 1200 m elevation, but because the highest elevations in the watershed are just under 1200 m elevation, I didn't use a pure snowmelt zone in modelling hydrologic recovery.

All of the watershed is within Snowpack Accumulation Zone 4 (Hudson, 2000; Hudson and Horel, 2007). I calculated expected peak snowpack depths for each elevation band within the watershed above 300 m based on the midpoint elevation of the band, so that, the expected peak snowpack depth of 1.3 m for the 300 m to 800 m elevation band is based on a midpoint elevation of 550 m, and the expected peak snowpack depth of 2.0 m for the 800 m to 1200 m band is based on a midpoint elevation of 1000 m.

3.3.1 Age and Height of Full Recovery

I used an age of 119 years to assume full hydrologic recovery for any stand. The Hudson and Horel (2007) hydrologic recovery equations are inverse exponential functions such that as trees age and grow in height, they approach full recovery (90%, 99%, 99.9%, 99.99%) without ever reaching full (100%) recovery. By designating an age of full recovery, it is not necessary to consider tiny fractions of recovery for stands that were disturbed before the forest fire and advent of widespread logging in the early 20th Century.

In addition to an age of full recovery, I used a height of full recovery. Hudson and Horel (2007) found that under some conditions, dense second growth forests actually intercept more rainfall than reference old-growth stands. They proposed a hydrologic over-recovery factor (essentially a negative ECA) to account for this process, but there are logistic and practical complications with implementing it, and corresponding streamflow studies have not verified their suggestion. Recent research on rain-on-snow floods (Floyd, 2012) suggested that using a height of full recovery might provide better accuracy than implementing an over-recovery factor. Accordingly, I designated 25 m as the height of full recovery for stands in the Haslam-Lang Community Watershed.

3.4 Field Inspections

I made several field inspections of the watershed during the course of this assessment. On November 28, 2017, I toured the Powell River water intake on Haslam Lake, the weir on Haslam Lake, Duck Lake, the Duck Lake FSR, and the PRSS sorting station at the mouth of Lang Creek as part of an IWMP management meeting accompanied by a group of professionals from MFNRORD, City of Powell River, Results Based, BCTS, PRSS, and Brian Carson. On May 24 and 25, 2018, I toured the remainder of the watershed, accompanied by Chris Laing of Results Based. We made a traverse of sections of the main channel of Lang Creek from north of the Duck Lake Hatchery to just south of the boundary of the private land in the lower watershed, downstream of Coho Creek, on May 24, 2018. On May 25, 2018 we reviewed blocks, roads, and stream channels in the Haslam Lake watershed and the eastern part of Lang Creek watershed, from the northern boundary near the divide with Giovanno Lake to the Granite Main.

I made several additional observations of parts of the watershed while conducting helicopter overflights from Powell River airport *en route* to other work areas outside the watershed. On November 16, 2018, I flew over Haslam Lake's western watershed divide. On July 7, 15 and 22, 2019, I flew various routes over the southern portion of the Lang Creek watershed on flight lines between Powell River airport and Saltery Bay and between the northern end of Lois Lake and the airport, from which I observed ongoing harvesting and road building in the Tla'amin and PRCF chart areas. All of these assessments took place under dry conditions. I also made a few stops at the PRSS sorting station off Highway 101 during 2018 and 2019, while driving to or from Powell River, in order to observe a range of flow and water levels in lower Lang Creek.

3.5 Climate Change

Ongoing climate change is expected to change hydrologic processes across British Columbia. Land managers and decision makers can develop adaptive management strategies by understanding and anticipating these changes. Consequently, in addition to assessing the cumulative effects of past forest development on the watershed, it is necessary to evaluate potential future changes to the watershed, which may be of greater magnitude than the effects of past development.

The same four locations used to characterize the present climate in the watershed were used to model the effects of climate change for the whole watershed. The model downscales and applies results from three separate global climate models (GCM) (the CanESM2, CNRM-CM5, and HADGM ES-2 models) to create potential future climate scenarios. The worst case scenario, one in which carbon emissions continue to increase between the present and 2085, was used because it models the greatest potential change in climate. If less carbon and other greenhouse gases are emitted than modelled under this worst case scenario, it is probable that the effects will be less severe than what is described here. We can compare the historic past climate to the present climate. We can determine how the climate has changed in the past by evaluating climate date from about 65 years in the past (1955) and comparing it to current climatic condition, and those predicted for 2085, about 65 years from now.

Historic data for past climate normal periods is available to the model and can be used to describe historic conditions. Climate normal periods cover thirty-year intervals. We presently use data collected from 1981 to 2010 to estimate the current climate, although that climate interval is now nine years past. (In the early 2020s, it will be possible to use the 1991 to 2020 climate normal period for a different, and probably slightly more accurate, take on the present 2019 climate.) When considering past climate, in 1955, there are three overlapping climate normal intervals which it would be possible to use: 1931-1960, 1941-1970, or 1951-1980. Since we want to compare the climate about 65 years ago to the predicted climate 65 years from now, it is appropriate to use the oldest of those three intervals (1931-1960) to evaluate the expected average 1955 climate.

The intent of predicting climate change in the watershed is to evaluate the direction and possible magnitude of trends in climate factors that affect streamflow in order to predict changes in streamflow. The climate is changing, and this has had, and will have, an effect on watershed hydrology. Understanding these changes is necessary in order to separate and distinguish their effects from the effects of forest management on hydrologic conditions in the Haslam-Lang community watershed.

4.0 RESULTS AND OBSERVATIONS

4.1 Equivalent Clearcut Area

Table 2 describes the present (2019) ECA levels, expressed as area in hectares and as percentage of total area, for each individual sub-basin in the watershed, for the larger Haslam Lake and Lang Creek areas, and for the entire watershed. I have also evaluated what the effects of ongoing recovery would be and the resultant ECA in 2022 and 2025 if no further logging were to take place. These values illustrate the baseline conditions of the watershed now and over the next six years. Future development that will modify these baseline conditions is presented in Section 5 and discussed in Section 6.

Table 2: Equivalent Clearcut Area, Present and Future, No Additional Development

Sub-basin or Watershed	Area (ha)	2019 ECA		2022 ECA		2025 ECA	
		ha	%	ha	%	ha	%
Haslam Lake (H1+H2)	5091	648	12.7%	603	11.8%	566	11.1%
Haslam 4	625	138	22.1%	121	19.4%	97	15.5%
Boulder (Haslam 5)	705	59	8.4%	53	7.5%	46	6.5%
Slough/Duck Lake (Lang 3)	863	117	13.6%	112	12.9%	106	12.2%
Sweetwater (Lang 6)	1297	120	9.2%	112	8.7%	99	7.6%
Washout (Lang 7)	660	84	12.7%	79	12.0%	75	11.3%
Lower Lang/Coho (Lang 8)	1746	391	22.4%	368	21.0%	334	19.1%
Blackwater (Lang 9)	630	66	10.4%	59	9.4%	56	8.9%
Anderson/Suicide (Lang 10)	1509	221	14.7%	191	12.6%	164	10.8%
All Haslam (H1, H2, H4, H5)	6421	845	13.2%	777	12.1%	708	11.0%
All Lang below Haslam Lake (L3, L6, L7, L8, L9, L10)	6704	999	14.9%	921	13.7%	833	12.4%
Entire Community Watershed	13124	1844	14.0%	1698	12.9%	1541	11.7%

4.2 Road Density

Table 3 presents the existing road length and road density (km of road per km² of drainage area) values for the sub-basins and for the watershed as a whole. These figures include only built roads as of 2019 and do not include either old roads that have previously been permanently deactivated, trails, or planned roads.

Table 3: Road Length and Density by Subbasin

Subbasin or Watershed	Area (km²)	Road Length (km)	Road Density (km/km²)
Haslam Lake (H1+H2)	50.9	52.5	1.03
Haslam 4	6.3	5.0	0.79
Boulder (Haslam 5)	7.1	13.2	1.86
Slough/Duck Lake (Lang 3)	8.6	13.6	1.58
Sweetwater (Lang 6)	13.0	17.9	1.38
Washout (Lang 7)	6.6	9.2	1.39
Lower Lang/Coho (Lang 8)	17.5	40.4	2.31
Blackwater (Lang 9)	6.3	9.7	1.54
Anderson/Suicide (Lang 10)	15.1	30.5	2.02
All Haslam (H1, H2, H4, H5)	64.2	70.7	1.10
All Lang below Haslam Lake (L3, L6, L7, L8, L9, L10)	67.0	121.3	1.81
Entire Community Watershed	131.2	192	1.46

4.3 Sediment Source Survey

Past CWAP reports have highlighted three specific sources of sediment that result in adverse effects on water quality for water users and fish: bank erosion along Lang Creek, sediment derived from the road network, and sediment derived from the shoreline on Haslam Lake near the City of Powell River water intake. Landslides, which make up a significant sediment source in some other watersheds, are generally not a significant sediment source in the Haslam Lang watershed.

All of these sediment sources have created short-lived episodes of increased turbidity as measured at monitoring stations throughout the watershed. Increased turbidity at the Haslam Lake intake observed in 2017 and 2018 was associated with the construction work taking place during the upgrade of the City intake. The upgrade work is finished and revegetation of disturbed ground is taking place, so sedimentation from this source should decrease in future.

Sedimentation from bank erosion is characteristic of all stream systems. In an incised stream like Lang Creek, bank erosion can result in not only sedimentation as bank material is eroded, but instability on the steep slopes above the banks, which then causes additional sedimentation in the channel. Bank erosion in Lang Creek has two direct causes: erosion due to streamflow impinging on the bank, and erosion due to trees growing on the bank falling over and bringing the sediment from their roots into the channel. It can sometimes be difficult to determine if a tree has fallen as a result of erosion, such as if its roots were undermined and it then fell over, or if the tree fell over due to some other factor such as blowdown and the crater that it left has then suffered additional erosion.

The riparian forest treatments carried out along lower Lang Creek in the early 2000s to reduce deciduous forest canopy dominance and to promote conifer regeneration have clearly been successful, and these measures have probably reduced the amount of senescent alders along the banks of Lang Creek, thus reducing sedimentation to the stream somewhat.

The forest road network is potentially the largest source of sedimentation in the watershed, and has been recognized for the past twenty years. Erosion and sediment control measures have been successively implemented, as recommended in past CWAPs, so that sediment production from new and existing roads is minimized and sediment sources are disconnected from streams that could transport sediment downstream to fish habitat or water intakes. Therefore, most existing and newly constructed roads are not acting as significant sources of sediment to streams.

Some old roads in the watershed, particularly those ones that have not been used for industrial purposes for many years but that still see recreational vehicle traffic, are sediment sources. Damage to the road surface, caused by rutting from recreational traffic, has diverted drainage. As forest development reuses or deactivates these old roads, their sediment output is reduced or eliminated accordingly. Several kilometers of these old roads have been upgraded to modern standards within the last few years.

4.4 Riparian Assessment and Channel Conditions

4.4.1 Lang Creek

I spent most of my field time within the watershed assessing the mainstem channel of Lang Creek between Duck Lake and the boundary of private property near the mouth of the creek. Between the Haslam Lake weir and Duck Lake, Lang Creek is not incised. From Duck Lake downstream, Lang Creek becomes progressively incised into the surrounding surficial materials and bedrock. Where bedrock is exposed in Lang Creek's bed and banks, it is plutonic rock (granite) that ranges from competent but fractured, to deeply weathered and crumbly (grus). Surficial materials present along the channel include till, coarse-textured glaciofluvial sediments, and fine-textured glaciolacustrine and glaciomarine sediments. Previous watershed assessments have described these sediments. The few outcrops of grus-forming bedrock along the channel may have previously been overlooked, but behave similarly to compacted glaciofluvial sediment, although they are more resistant to erosion.

The channel of Lang Creek exhibits several morphologies. The three most common morphologies are:

- low-gradient coarse-bedded reaches with substrate composed of cobbles and boulders
- low-gradient fine-bedded reaches with sand and gravel, and some cobbles
- bedrock reaches with small waterfalls or rapids and exposed bedrock in the channel.

These three morphologies typically occur in a characteristic sequence, and are influenced by woody debris. Specifically, the reaches with fine-textured bed sediments occur upstream of large coarse woody debris logjams. The bedrock reaches tend to occur closely downstream of woody debris jams, and the coarse-textured reaches with boulders and cobbles forming the predominant bed sediments are located between the bedrock reaches and the fine-textured reaches. Other factors can interrupt this simplified sequence, such as tributary streams entering Lang Creek and depositing their bedload at the confluence.

Several large log jams composed of coarse woody debris are present in Lang Creek. The old logs that comprise the jams are predominantly charred, indicating that they date back to the forest fire that burned the watershed in the 1920s. Therefore, the logs composing the jams, and in some cases the jams themselves, may be about 100 years old. The jams trap sediment, reducing the upstream channel gradient, and creating the reaches dominated by the finer-grained sediment. Conversely, by trapping sediment, the jams have also restricted the supply of sediment to the reaches which are located immediately downstream, causing local degradation or coarsening of the bed and resulting in depletion of finer textured sediment leaving either channel segments dominated by coarse sediment or bedrock-dominated reaches. Some of these large jams dominated by old wood appear to be beginning to fall apart as the wood making them up decays in place, releasing some of the trapped sediment to downstream reaches. A hundred years is often presented in scientific literature on in-stream woody debris (e.g. Scherer 2004, Naiman 2002) as at or near the upper range of potential ages for jams.

Wood reaches stream channels by two typical processes. The first is trees that fall into the stream from the streambanks and the second is when floods, debris flows, and landslides in tributary streams bring wood to the main stream. In the reaches of Lang Creek between the woody debris jams, coarse woody debris is composed of trees that have fallen into the stream from the streambanks. Because Lang Creek and its tributaries are low-gradient and located in predominantly stable terrain, with Haslam and Duck Lakes upstream, contributions of wood from landslides and floods from steep tributaries contribute only minimally to the total amount of wood reaching Lang Creek's channel. Wood falling in from the banks of Lang Creek is the dominant wood recruitment process.

Historic forest harvesting in the watershed included harvest of riparian forest along the banks of Lang Creek. These areas were not replanted at the time and consequently regrew as deciduous-dominated stands with a high component of red alder. Watershed assessments in the early 2000s identified these alder-dominated stands as reducing the quality of the riparian forest. Firstly, alder decays rapidly in water (only lasting a few years) so when alder fall into the stream they do not contribute to long-lived woody debris. Secondly, deciduous vegetation, and particularly alder, cause higher seasonal cycling of dissolved organic carbon (DOC) in the water as fallen leaves decay when compared to coniferous stands, and DOC can form trihalomethanes (THM) when water is chlorinated for treatment. THM are a potential carcinogen. Thirdly, alder stands become senescent and fall over at 60 to 80 years of age, and the alder stands along Lang Creek were reaching that age. Accordingly, a pilot project was carried out in the early 2000s to treat riparian alder stands along Lang Creek. Some alders were logged and removed, while others were girdled and left to die in place and form snags. The coniferous understory present under the alder canopy was released by these treatments with the goal of speeding up the deciduous-to-coniferous transition time and improve the quality of the riparian forest. Fifteen years later, these treatments appear to have been successful. Some of the girdled alder snags are still in place, and the released conifers have greatly increased in size and now form the dominant trees of the canopy, while potential bank erosion from senescent alder blowdown appears to have been largely averted.

4.4.2 Streams around Haslam Lake

The small streams around Haslam Lake are generally steep and only two sub-basins, the Haslam 4 and Boulder Creek (Haslam 5), have significant short alluvial reaches near their mouths, where they flow into Haslam Lake. These alluvial reaches are located on fans that provide spawning habitat for the lake kokanee (Carson, 2003). Both of these streams are steep enough that they have experienced periodic debris floods or debris flows, but neither stream has experienced such a flow at least since the 1980s. The fan of Boulder Creek at Misty Beach is forested with mature deciduous trees, including bigleaf maple and red alder, which probably date back to the last such event on the fan. This fan has experienced a flood within the last five years which moved large woody debris and scoured moss from immobile boulders on the fan.

4.4.3 Streams in the Lang Creek Catchment Flowing into Duck Lake

Sweetwater Creek (Lang 6), Washout Creek (Lang 7), and Blackwater Creek (Lang 9) all flow into Lang Creek via Duck Lake. Thus, Duck Lake provides buffering of flood flows and sediment transport in these streams before they reach the Lang Creek mainstem. Mud Lake is also in the system, but is too small to provide effective buffering of inflows.

Second growth riparian forest along these streams is mature and dominated by conifers. Although the original riparian forest was harvested, and mature and maturing coniferous trees do not become senescent and contribute woody debris to stream channels at the same rate that old or over mature forests do, this is offset by the presence of woody debris left over from the first pass of harvesting. Enough of that woody debris is still present that remedial removal of woody debris from streams was considered in the 1990s (Carson, 2003). Therefore, there is still enough woody debris in these streams to form jams and trap sediment.

We only observed one location in these streams where localized sedimentation has occurred. On Blackwater Creek, near and downstream of the FSR crossing, where Blackwater Creek flows off the slightly steeper hillside and onto the low-gradient valley bottom as it approaches the Duck Lake Protected Area boundary, sandy sediment has aggraded, raising the bed of the channel and depositing on the banks to either side. It is likely that this sandy sediment comes at least partially from erosion of old and unmaintained road networks upstream, as discussed in Section 4.3. Some of the sediment also appears to be coming from the ditch of the Duck Lake FSR Br-1 near 10.5 km, as previously identified by Brian Carson (Site 75).

4.4.4 Streams Flowing Directly into Lang Creek

Anderson Creek is the largest stream that flows directly into Lang Creek within the watershed. Coho Creek and another smaller stream flow into Lang Creek downstream of Anderson Creek. Because these streams flow directly into Lang Creek without first flowing through Haslam or Duck Lake, they provide sediment directly to the channel of Lang Creek. They contribute cold water to Lang Creek during the summer low flow period that both modulates temperatures in Lang Creek and provides sidechannel respite for juvenile fish. As with the other tributary streams in the Lang catchment, their riparian stands were previously logged, and under present conditions have mature stands of coniferous-dominated riparian forest as well as woody debris that is partly derived from old logging debris.

These streams transport bedload sediment that is sandy to cobbly-textured, and flow over beds that contain some lag sediment consisting of immobile boulders. Their channels steepen as they approach Lang Creek because Lang Creek is incised. Where they flow into Lang Creek, they have constructed small fans of cobbly to bouldery sediment and these fans have pushed Lang Creek's channel to flow against the opposite bank, creating localized bank erosion on the opposite banks. There are woody debris jams just downstream of both confluences, and unlike the woody debris jams further upstream that contain mostly old wood derived from the 1922 forest fire and subsequent riparian logging, the woody debris jams near Coho Creek, Anderson Creek, and the unnamed creek contain a significant fraction of smaller and younger wood derived from the second-growth riparian canopy.

4.5 Other Potential Affronts to Water Quality

Past watershed assessments have identified the recreational use of the watershed as a source of potential contamination of the water supply. Specifically, camping and burning pallets and garbage, littering, and erosion caused by off-road vehicle use have been highlighted as having the potential to degrade water quality, either by introducing contaminants, starting forest fires, or generating sediment.

Measures to discourage and control these uses of the watershed have been implemented in the past, and may have somewhat curbed the undesired outcomes, but they have not eliminated them. Discarded oil bottles, garbage, fire pits, and off-road vehicle tire tracks on eroded trails were all visible in the watershed during the 2017 and 2018 field work.

Although these undesirable watershed uses and pollutants remain a concern, they have not resulted in detectable decreases in water quality to date, in that the sampled water quality throughout the watershed almost always remains within the desirable range of values.

4.6 Climate Change

Table 4 presents the past observed and range of future predicted climate at the four locations in the watershed previously described in Table 1. For ease of comparison, the differences are presented as percentages rather than absolute differences, i.e. if the present annual precipitation is 1500 mm, and it was, or is expected to, decrease to 1400 mm, this would be a 7% decrease, so it would be listed as -7%. If it was 1650 mm in the past or if it were expected to increase to 1650 mm, this would be a 10% increase so it would be listed as +10% relative to the present. For future conditions, different models give different predictions so I have presented the range of the model outcomes (e.g. -3% to +12%) rather than the individual predictions. The exception is for the proportion of autumn and winter precipitation, which is already expressed as a percentage. Here the percentage difference is just the difference between those two values, i.e. 69% is 2% more than 67% and would be expressed as +2%.

Table 4: Past and Predicted Future Climate, Haslam-Lang Community Watershed

	Sorting Station at Mouth of Lang Creek		**Weir at Outlet of Haslam Lake**		**Headwaters of Blackwater Creek**		**Summit of Tin Hat Mountain**	
	1955 Relative to Present	2085 Relative to Present	1955 Relative to Present	2085 Relative to Present	1955 Relative to Present	2085 Relative to Present	1955 Relative to Present	2085 Relative to Present
Precipitation	**-8%**	**+4% to +10%**	**-9%**	**+3% to +15%**	**-6%**	**+6% to +17%**	**-9%**	**+3% to +15%**
Rainfall	**-8%**	**+6% to +17%**	**-9%**	**+7% to +19%**	**-8%**	**+16% to +29%**	**-12%**	**+30% to +45%**
Snowfall	**+10%**	**-73% to - 91%**	**+8%**	**-73% to -85%**	**+8%**	**-68% to -85%**	**+1%**	**-70% to -83%**
% PPT Autumn Winter	**+2%**	**+6% to +12%**	**+2%**	**+7% to +13%**	**+1%**	**+7% to +12%**	**+2%**	**+6% to +12%**
Reference ET	**+3%**	**+15% to +31%**	**+3%**	**+15% to +32%**	**0%**	**+15% to +32%**	**-3%**	**+24% to +42%**
Nominal Runoff	**-23%**	**-36% to +14%**	**-20%**	**-22% to +14%**	**-8%**	**-4% to +18%**	**-10%**	**-6% to +13%**

5.0 PLANNED FOREST DEVELOPMENT

PRCF, Thichum, and BCTS provided details on their planned forest development. Specifically, BCTS provided details on their planned forest development through 2025. Thichum only provided details on forest development planned through 2022, and indicated that they had not yet developed any plans for development over a 3 year to 6 year time frame.

Chris Laing of Results Based provided detailed block and road planning information for the PRCF, but with a caveat that the area of planned blocks was significantly larger than what would actually be developed over the six year time frame. He noted that PRCF's Annual Allowable Cut is 35,000 m^3, of which about 5,000 m^3 is road right-of-way volume, so that about 30,000 m^3/year of their cut is from block development. If the average volume per area is about 800 m^3/ha, this AAC equates to about 37.5 ha/year of harvested area. The total area of all planned blocks in the PRCF data is about 363 ha, so this represents the equivalent of about 10 years of planned harvesting. Planned block timing information was included, but only as either engineered or future, not with specific dates. Chris Laing indicated that some engineered blocks would be harvested over several passes using a phased approach, rather than all at once.

I requested, but did not receive, planned harvest information from WFP for the TFL portion within the community watershed.

Table 5 includes all of the information on planned harvesting that I received from PRCF, Thichum, and BCTS, divided by sub-basin.

Table 5: Forest Harvesting Plans by Licensee and Sub-Basin

Subbasin or Watershed	PRCF Engineered Blocks (ha)	PRCF Future Blocks (ha)	Thichum Planned Blocks 2019-2022	BCTS Planned Blocks 2019-2022	BCTS Planned Blocks 2022-2025
Haslam Lake (H1+H2)	35.2	90.6	16	10.3	37.5
Haslam 4	0	0	0	0	0
Boulder (Haslam 5)	17.2	0	0	0	0
Slough/Duck Lake (Lang 3)	0	0.3	0	24.8	0
Sweetwater (Lang 6)	0	0	0	0	0
Washout (Lang 7)	0	18.7	0	0	0
Lower Lang/Coho (Lang 8)	55.8	20	50.3	0	0
Blackwater (Lang 9)	26.8	45.8	0	0	0
Anderson/Suicide (Lang 10)	32.2	20.1	25.1	0	0
All Haslam (H1, H2, H4, H5)	52.4	90.6	16	10.3	37.5
All Lang below Haslam Lake (L3, L6, L7, L8, L9, L10)	114.8	104.9	75.4	24.8	0
Entire Community Watershed	167.2	195.5	91.4	35.1	37.5

Table 6 presents the resultant ECA values, in hectares and % area, for the sub-basins and for the watershed as a whole, in 2022 and 2025, if all blocks are developed as planned.

Table 6: Equivalent Clearcut Area, Present and Future, Including Planned Development

Subbasin or Watershed	Area (ha)	2022 ECA		2025 ECA	
		ha	%	ha	%
Haslam Lake (H1+H2)	5091	665	13.1%	755	14.8%
Haslam 4	625	121	19.4%	97	15.5%
Boulder (Haslam 5)	705	70	10.0%	63	8.9%
Slough/Duck Lake (Lang 3)	863	137	15.8%	131	15.1%
Sweetwater (Lang 6)	1297	112	8.7%	99	7.6%
Washout (Lang 7)	660	79	12.0%	93	14.2%
Lower Lang/Coho (Lang 8)	1746	474	27.1%	460	26.4%
Blackwater (Lang 9)	630	86	13.7%	129	20.4%
Anderson/Suicide (Lang 10)	1509	248	16.4%	241	16.0%
All Haslam (H1, H2, H4, H5)	6421	856	13.3%	915	14.2%
All Lang below Haslam Lake (L3, L6, L7, L8, L9, L10)	6704	1136	16.9%	1153	17.2%
Entire Community Watershed	13124	1992	15.2%	2068	15.8%

It is likely that the numbers in Table 6 generally overestimate what sub-basin and watershed ECA will be in 2022 and 2025 because the PRCF block plan information contained roughly ten years' worth of cut and Table 6 presumes that it would all be developed by 2025. Additionally, some block plan shapes from all licensees are only based on preliminary information and will be reduced during the layout process, either by excluding area from the block or through designation of reserves. It is also possible that ECA in some specific sub-basins may be higher than estimated here, either because Thichum identifies areas for harvest over the period 2022 to 2025, or because WFP harvests in the TFL. I expect that the cumulative effects of these factors would only amount to a difference of at most two to three percentage points of ECA at the subbasin level and less than 1% at the watershed level.

Few new roads are planned for construction in the watershed over the interval, probably because so many existing roads are present as part of the existing road network that few new roads are needed for forest development.

Table 7 summarizes the planned new roads by sub-basin and presents their effects on road density in 2025 if all are built as planned and no existing roads are deactivated.

Table 7: Planned Road Construction, 2025 Road Length, and Density by Subbasin, 2025

Subbasin or Watershed	Area (km²)	2019 Road Length (km)	Planned Road Construction (2019-2025) km	2025 Road Length (km)	2025 Road Density (km/km²)
Haslam Lake (H1+H2)	50.9	52.5	1.3	53.8	1.06
Haslam 4	6.3	5.0	0	5	0.79
Boulder (Haslam 5)	7.1	13.2	1.7	14.9	2.10
Slough/Duck Lake (Lang 3)	8.6	13.6	0.3	13.9	1.62
Sweetwater (Lang 6)	13.0	17.9	0	17.9	1.38
Washout (Lang 7)	6.6	9.2	0	9.2	1.39
Lower Lang/Coho (Lang 8)	17.5	40.4	3.2	43.6	2.49
Blackwater (Lang 9)	6.3	9.7	1.1	10.8	1.71
Anderson/Suicide (Lang 10)	15.1	30.5	3.0	33.5	2.22
All Haslam (H1, H2, H4, H5)	64.2	70.7	3.0	73.7	1.15
All Lang below Haslam Lake (L3, L6, L7, L8, L9, L10)	67.0	121.3	7.6	128.9	1.92
Entire Community Watershed	131.2	192	10.6	202.6	1.54

6.0 DISCUSSION

Present and future harvesting are unlikely to result in adverse cumulative effects to watershed hydrology. Past watershed assessments recommended an ECA threshold of 30% for hydrologically relevant sub-basins within the watershed. As indicated in Table 6, none of the sub-basins in the watershed will reach this threshold, and it is likely that, because planned harvesting has been overestimated, none of the sub-basins within the watershed will even reach a 25% ECA level. At the larger scale, Haslam Lake, Lang Creek below Haslam Lake, and the entire Haslam-Lang Community Watershed will maintain ECA levels below 20%. This indicates a low to very low level of hydrologic risk from the cumulative effects of harvesting.

The road length and road density values presented in Table 3 and Table 7 provide only a general estimate of road length and road density in the watershed because they do not take into account the status of the roads beyond whether they are either presently built or planned for future construction. They also do not account for the slope gradients across which they are built. Slope gradients do matter when considering the hydrologic effects of roads because roads that are built with overland construction methods across gently sloping or flat terrain do not have cutslopes and so do not intercept subsurface water, bring it to the surface, or channel it down road ditches the way that conventionally constructed cut-and-fill roads on steeper slopes do. Many of the roads in the watershed, particularly those in the Lang Creek subbasins, are built with overland construction across gentle slopes and therefore have less hydrologic effects than do the roads built across steeper terrain in the rest of the watershed. Therefore, although the road density values in Table 7 indicate values that might indicate a moderate hydrologic hazard from roads in some sub-basins, I expect that the actual hydrologic hazard from roads in the watershed is low, based on my knowledge of the terrain and my observations of the road network. More detailed information on road status (active conventional, temporarily deactivated conventional, active overland construction across low-gradient slopes, permanently deactivated, etc.) could be used to refine the estimates of total road density in Tables 3 and 7.

Past assessments have focused on potential sediment production from roads and have recommended measures to control and prevent such sedimentation. These measures appear to have been effective in controlling road-related sedimentation. New roads and reconstructed roads within the watershed are constructed to a high standard and are not significant sediment sources. Some old roads that have not yet been reconstructed are sediment sources, particularly those with high levels of recreational ORV use. As these roads are either reactivated or deactivated, sediment production from them will decrease. I observed some local sedimentation upstream of Duck Lake and Mud Lake, which I inferred was related to these old roads upslope, but I did not observe any evidence of sedimentation further downstream along the main stem of Lang Creek..

Along Lang Creek, from Duck Lake to the mouth, it appears that woody debris abundance in the channel has decreased over time. Several large woody debris jams are very old and contain wood that was burnt in fires in the early 20th Century. These old woody debris jams are starting to break down and to release the sediment that they have retained. These changes are likely to result in changes to the stream channel pattern, reach gradient, sediment caliber, and texture, and other features of the channel of Lang Creek over the coming decades, and may influence summer stream temperature (Arrigoni et al., 2008).

Ongoing climate change is also resulting in changes to the watershed. Compared to 1955, as modeled by the 1931 to 1960 climate interval, the watershed is already somewhat wetter, with less snowfall and more rainfall. It is likely that over the next few decades, unless significant progress to limit production of atmospheric greenhouse gasses is implemented, the watershed will see radically decreased snowfall, increased temperatures, and increased seasonality of precipitation. These changes will result in higher peak flows in fall and winter, and a longer and lower low-flow period in summer with increased stream temperatures. These changes are likely to adversely affect water availability and water quality for both human consumption and for fish.

7.0 RECOMMENDATIONS

Firstly, past recommendations for forest management in the Haslam Lang Community Watershed have been successful in protecting water availability and water quality for fish and for human use. The recommendations contained in past watershed assessments and implemented by forest licensees in their practices for harvesting and road construction should continue to be used.

Secondly, functional (large, coniferous) woody debris in Lang Creek is mostly old and is beginning to break down, while recruitment of new woody debris to replace the old debris has been delayed by past riparian harvesting and by replacement of coniferous riparian stands with deciduous riparian stands. Second-growth riparian coniferous forests are nearing maturity, have been improved by deciduous removal in recent decades, and will likely begin to result in increased coniferous woody debris recruitment over the next few decades. In the interim, any measures which could result in increased large coniferous woody debris recruitment to the channel of Lang Creek should be explored. Increased recruitment of woody debris to the channel of lower Lang Creek will result in increased sediment retention in-channel, which should both improve the quality of in-channel fish habitat, increase groundwater recharge, and lag and buffer high temperature summer streamflow (Arrigoni *et al.*, 2008).

Thirdly, climate change is already affecting the watershed, and the effects of these changes will become more pronounced in future. Any forest management or water use measures which can be effectively implemented to mitigate the effects of climate change on the watershed should be implemented. On the forestry side, reforesting for expected future climate conditions rather than present conditions, upgrading infrastructure to handle larger and more frequent storms, and implementing stand management practices to reduce wildfire risk, are examples of practices that can mitigate some of the predicted outcomes of present climate change scenarios. On the water management side, planning for increased variability of source water quantity, implementing water conservation measures to reduce demand, and ensuring that water infrastructure is resilient against water volumes and lake levels that will exceed previously observed ranges are all measures that can be taken.

8.0 SUMMARY AND CONCLUSIONS

The Haslam Lang Community Watershed encompasses Haslam Lake, Lang Creek, and their tributary streams. The community watershed supplies drinking water to Powell River and Brew Bay, and Lang Creek is home to salmon runs and a hatchery. Several forest licensees operate in the watershed, including the Powell River Community Forest (PRCF), which encompasses about 48% of the total watershed area.

Previous watershed assessments determined that forestry roads presented the greatest potential to cause adverse effects on the watershed. Consequently, recommendations focused on managing forest harvesting and road construction and reconstruction. Implementation of these recommendations have been effective, and should continue in future.

Past, present, and proposed future forest harvesting and road building will result in low hydrologic hazard and low hydrologic risk, if development proceeds as planned and remains consistent with past practices.

Two sources of hydrologic risk in the watershed were not previously discussed in detail. Firstly, in lower Lang Creek, several large, old woody debris jams control local stream channel morphology. These debris jams are beginning to break down and release the sediment that they retain, while maturing second-growth coniferous riparian forests are not yet contributing enough woody debris to replace or supplement the decaying wood that forms the jams. If the jams fully break down, the channel morphology of Lang Creek will change, with consequent effects on sediment in the channel, stream channel pattern, riparian habitat, water quality and stream temperature. It may be necessary to supplement woody debris in the channel of Lang Creek until such time as the maturing riparian forest can supply the required woody debris on its own.

Secondly, climate change is already affecting the watershed, and these changes will intensify in future, according to models that use current greenhouse gas emission scenarios to predict temperature and precipitation. Forest land managers and water users should both evaluate their ability to increase climate resiliency and should implement adaptive management practices that recognize and anticipate the expected changes to watershed hydrology and climate. Changes in water availability, including longer and lower low summer flows, increased peak flows, and increased summer stream temperature are expected.

9.0 LIMITATIONS

The recommendations provided in this report are based on observations made by Statlu and are supported by information Statlu gathered. Observations are inherently imprecise. Conditions other than those indicated above may exist on the site. If such conditions are observed or if additional information becomes available, Statlu should be contacted so that this report may be reviewed and amended accordingly.

This report was prepared considering circumstances applying specifically to the client. It is intended only for internal use by the client for the purposes for which it was commissioned and for use by government agencies regulating the specific activities to which it pertains. It is not reasonable for other parties to rely on the observations or conclusions contained herein.

Statlu prepared the report in a manner consistent with current provincial standards and on par or better than the level of care normally exercised by Professional Geoscientists currently practicing in the area under similar conditions and budgetary constraints. Statlu offers no other warranties, either expressed or implied.

10.0 CLOSURE

Please contact me should you have any questions or if you require further clarification.

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APPENDIX 2: RATIONALE FOR WATERSHED ASSESSMENT

Forest harvesting can affect hydrology in many ways. The assessment of hydrologic impacts in a watershed assessment focuses on the potential for:

- Changes to frequency, magnitude and duration of peak (and low, median etc.) stream flows,
- Accelerated surface soil erosion,
- Accelerated landslide activity,
- Changes to riparian zones; and,
- Changes to channel morphology.

The following section describes the potential effects of changes to these five hazard indicators resulting from forestry and forestry-related activities.

Changes to Peak Stream Flow

Peak flow is the maximum flow rate that occurs within a specified period, usually on an annual or event basis. Generally, melting of the snowpack in spring and/or heavy rainstorms or rain-on-snow events generate peak flows. Tree removal and road building by forestry can affect peak flow timing and volumes. By removing trees, not only is more precipitation able to reach the ground and infiltrate the soil, but the timing of the delivery may be altered. Timber harvesting reduces interception and evapotranspiration, and increases the winter snowpack. This can result in an earlier and more rapid snowmelt, and higher flow resulting from the deeper snowpack. It can also result directly in higher runoff during rainfall events and/or higher groundwater levels. Changes in insolation and radiation balance can affect the timing of snowmelt, resulting in synchronization or desynchronization of melt from different areas of the watershed.

Construction of logging roads can affect the pathway and the timing in which precipitation reaches the stream channel. Subsurface flow may be intercepted and directed down ditchlines as surface flow, reaching stream channels at an accelerated rate. Compacted surfaces of roads reduce infiltration, transferring surface flow to ditches, which also means that surface water reaches stream channels at an accelerated rate.

Accelerated Surface Soil Erosion

Surface soil erosion is defined as the detachment, entrainment, and transport of individual sediment particles due to falling or running water, or wind. It is a function of surface cover, mineral soil type, slope gradient, slope length and shape, and rainfall intensity.

The principal effect of forest practices on surface soil erosion results from road building. Sediment generated from ditches, cut and fill slopes, and road surfaces is introduced to stream channels through ditches and at stream crossings. Higher road densities indicate higher potential for sediment delivery to streams. High quantities of sediment can clog ditches and stream channels, accelerate stream bank erosion, deposit fine sediments in reservoirs, cover fish spawning grounds, and reduce downstream water quality. Timber harvesting can also cause accelerated surface soil erosion due to exposing soil as a byproduct of removal of vegetation. However, roads, particularly old pre-*Forest Practices Code* roads that have not been deactivated, pipeline and powerline access roads, and other similar roads, are a far greater potential source of sediment than conventional harvesting done to current *Forest and Range Practices Act* (FRPA) standards.

Landslide Activity

Landslides are a natural process on steep terrain, and occur over time at a natural rate. Forest practices can accelerate this natural rate through road construction and logging on unstable or potentially unstable terrain.

The alteration of natural drainage patterns through road building can lead to unusual concentrations of water on hillslopes, road fillslopes, and road beds, leading to a higher likelihood of landsliding. Timber harvesting can alter slope hydrology. Removal of forest cover results in a reduction of transpiration and interception losses, leading to increased soil saturation, subsurface flow, and surface runoff. In addition, when trees are harvested, the roots of the stumps decay and begin to lose their soil binding strength, reducing their reinforcing capacity. This makes slopes more susceptible to landsliding until new growth re-establishes deep root systems.

The harvesting method can also lead to slope instability. Log yarding can disrupt natural pathways for water drainage, and create new pathways. Yarding logs across slopes and using heavy machinery can damage the soil surface and the roots that help hold the soil.

FRPA requires that logging not cause landslides, adverse gully processes, or fan destabilization, or alter natural drainage patterns. The frequency of landsliding from logged terrain has been reduced by identifying and avoiding harvesting on unstable slopes, and by applying mitigation measures that promote stability on harvested slopes.

Changes to Riparian Zone

The riparian area, or land adjacent to the high water line in watercourses and standing bodies of water, is important to stream ecosystems and stream morphology. Riparian areas help maintain water quality by controlling sedimentation, supplying nutrients and large woody debris, and maintaining stream channel morphology. Excessive harvesting within riparian areas can destabilize stream banks, increase bank erosion and stream sedimentation, diminish the supply of woody debris to the channel, and increase the size of sediment wedges of some stream reaches.

Changes to Stream Channel Pattern

Analysis of stream channel patterns can indicate that changes to sediment supply, riparian vegetation, or peak flow indices may have influenced a watershed because these variables influence changes to stream channel pattern. For instance, increased flooding can lead to increased bank erosion or overbank deposition as well as changes in bed material texture. Increased sediment supply can result in increased sediment deposition in-channel and a consequent widening of the channel or changes in the texture and composition of channel bedforms. Changes to riparian vegetation can change coarse woody debris inputs to the channel, altering the frequency and size of logjams as well as the bed texture.

GIS Analysis and Hydrologic Calculations

I estimated the level of probability that forest harvesting could have adversely impacted peak flows in the study area watersheds by calculating road density (km of road per km^2 of watershed area) and effective clearcut area (ECA).

ECA is determined by adjusting area of a clearcut by a recovery term based on the height of new tree growth, which accounts for the new growth. For instance, an area of 10 ha, originally clearcut, fully restocked, and with vigorous new growth 20 years old, might be calculated to have recovered 30% of the original hydrological effectiveness of the previous forest in terms of rainfall and snowfall interception and ground shading. The ECA is calculated as clearcut area times the recovery factor (percent clearcut minus percent recovered). In this example, the ECA is 10 ha * (100%-30%) = 7 ha. Therefore the 10 ha, 20-year-old block would be determined to be hydrologically equivalent to a 7 ha fresh clearcut. For the watershed as a whole, ECA can be expressed both as a figure (number of hectares) and, more commonly, as a percentage of the area of the watershed or sub-basin. This facilitates comparison of ECA levels between different watersheds or sub-basins.

I used the method of calculating ECA outlined in Hudson and Horel (2007), with modifications as discussed in Section 3; this is considered a more rigorous and accurate method than previous methods, and evaluates snowpack recovery and snow water equivalent changes under Interior harvested stands.

Unforested polygons can occur for many reasons, not all directly related to forestry. Some should be counted towards effective clearcut area while others should not. I separated out treeless or mostly treeless (>50% non-vegetated area) polygons with lakes, exposed bedrock or talus patches and considered them as fully recovered. Conversely, unvegetated landslide paths, or unvegetated gravel bars in rivers resulting from stream aggradation, are areas that might revegetate in future and to which forestry activity may have contributed. These polygons are included in the area considered as unrecovered.

APPENDIX 3: HYDROLOGIC HAZARD AND RISK ASSESSMENT METHODOLOGY

Peak flow is the maximum flow rate that occurs within a specified period, usually on an annual or event basis. Generally, melting of the snowpack in spring and/or heavy rainstorms or rain-on-snow events generate peak flows. Tree removal and road building by forestry can affect peak flow timing and volumes. By removing trees, not only is more precipitation able to reach the ground and infiltrate the soil, but the timing of the delivery may be altered. Timber harvesting reduces interception and evapotranspiration, and increases the winter snowpack. This can result in an earlier and more rapid snowmelt, and higher flow resulting from the deeper snowpack. It can also result directly in higher runoff during rainfall events and/or higher groundwater levels. By changing the longwave and shortwave radiative balance, logging can also change the timing of snowmelt, although this depends on aspect and other shading as well as forest canopy removal.

Construction of logging roads can affect the pathway and the timing in which precipitation or snowmelt reaches the stream channel. Subsurface flow may be intercepted and directed down ditches as surface flow, reaching stream channels at an accelerated rate. Compacted surfaces of roads reduce infiltration, transferring surface flow to ditches, which also means that surface water reaches stream channels at an accelerated rate.

Cumulative hydrologic hazard is commonly expressed as the likelihood that logging will result in increases to peak flow magnitude or frequency. Cumulative hydrologic hazard is evaluated by considering the net area logged over time and determining the equivalent clearcut area (ECA) for each logged area, which consists of the initially clearcut area modified by a recovery term that accounts for the restoration of forest canopy, root structures, transpiration and interception as new trees grow. For instance, an area of 10 ha, originally clearcut, fully restocked, and with vigorous new growth 20 years old, might be calculated to have recovered 30% of the original hydrological effectiveness of the previous forest in terms of rainfall and snowfall interception and ground shading. The ECA is calculated as clearcut area times the recovery factor (percent clearcut minus percent recovered). In this example, the ECA is 10 ha * (100%-30%) = 7 ha. Therefore the 10 ha, 20-year-old block would be determined to be hydrologically equivalent to a 7 ha fresh clearcut. ECA is summed for each past block harvested in a watershed to determine cumulative hydrologic hazard. Intermediate categories of hazard (such as very low to low) are included in the table to indicate the range of watershed sensitivities, which depend on woody debris abundance, channel substrate, geology, hydrograph type (snowmelt or rainfall dominated) and other factors.

In addition to peak flow changes, cumulative hydrologic hazard can result in changes to mean annual or low flow, and to changes in the timing and duration of flow. Flow might become more or less variable if melt from different aspects and elevations is synchronized or altered. The timing of low flow might be altered, and its duration lengthened, if snowmelt occurs earlier in the year. Conversely, by reducing transpiration, forest harvesting might increase low flow levels or decrease the duration of summer low flows.

ECA Range (percent of total watershed area)	Hydrologic Hazard	Qualitative Interpretation
0% to 15%	Very low.	Detectable changes to peak, mean and low flow will not occur
15% to 20%	Very low to low	
20% to 25%	Low	Detectable changes to peak or flow are unlikely to occur. Small variations might be detectable using statistical analysis.
25% to 30%	Low to moderate	
30% to 35%	Moderate	Detectable changes to peak flow might occur for some flow magnitudes and return periods. Flow durations might be altered.
35% to 40%	Moderate to high	
40% to 45%	High	Detectable changes to peak flow frequency and magnitude will occur. Floods will become larger and more frequent. Low flows might increase or decrease. Mean annual flow might change.
45% to 50%	High to very high	
50% or higher	Very high	Watershed hydrology will be significantly changed. Peak flow frequency and magnitude will undergo large changes. Floods will be much larger and much more frequent. Low flow and mean annual flow frequency and duration will change.

Risk is a function of hazard (the likelihood of an event) as well as the exposure of downslope or downstream resources to the event, and vulnerability of the downslope resources to the hazard, which together determine the consequences should the hazard occur. Land Management Handbook 56 (Wise et al. 2004) and the BC Ministry of Forests Forest Road Engineering Guidebook (2002) define risk as the product of the probability of hazard and consequence. Consequence further depends on the nature of the element(s) at risk, the exposure of those elements to the hazard, and the vulnerability of those elements to the hazard.

Statlu recognizes that the evaluation of the exposure and vulnerability of elements at risk to the identified hazards is difficult and may require specialized skills or additional information not available to professional geoscientists. Since the information is available or potentially available to land managers and statutory decision makers, we have concentrated on identifying and describing the geomorphic components of the consequence of hydrologic hazard, specifically their likelihood of reaching downstream identified elements and resources at risk. This is a partial risk analysis since it identifies the geomorphic components of a risk analysis without addressing the vulnerability of the elements at risk to the hazard.

As an example, consider a theoretical watershed of 1000 ha. The existing ECA is 150 ha, and another 100 ha are planned for logging, with associated road construction, which will raise the watershed ECA to 25%. The main stream in the watershed flows into a lake and has built a fan at its mouth; there are cabins on the lake, with a community water license intake near the head of the fan, and fish present in stream reaches on and near the fan, while higher stream reaches are too steep for fish habitat. Statlu estimates that the post-harvest hazard of peak flow changes is low, and that if changes to peak flow regimes do occur, they are likely to be transient and persist for less than five years. Small changes to the timing of flow are likely: spring snowmelt may occur up to a week earlier, and the summer low flow period may be extended by a similar length of time, but summer low flows may be slightly higher for up to ten years due to reduced evapotranspiration. Changes to channel pattern in the stream and on the fan are unlikely and changes to water quality are unlikely if all roads are built as planned and incorporate site-specific erosion and sediment control measures, and if old roads are deactivated.

To extend this hydrogeomorphic analysis to a full evaluation of the consequence of the potential harvesting and road building and the resultant risk, requires information on the frequency of use, and designated flood construction level and flood control measures incorporated into the design of the cabins on the fan, the nature and frequency of use of the forest service roads by industrial and recreational traffic, the quality of riparian habitat, species present and seasonality of use of the fish stream by those species, the water diversion and treatment methods used at the water intake, and other information beyond the purview of geoscience but available or potentially available to land managers and statutory decision makers.

Broadly speaking, the qualitative estimations of probability determined by Statlu correspond to the following classes of consequence from the Forest Road Engineering Guidebook (Table A2). These correspondences are approximate and are provided only to help with decision-making.

Qualitative Probability of Consequence	Range of Quantitative Probabilities of Occurrence	Approximate Qualitative Consequence Class
Certain; Will Occur	>50%	Very High
Likely to Occur	25-50%	High
Probable; Could Occur	10-25%	Moderate
Unlikely to Occur	1-10%	Low
Remote or Will not Occur	<1%	Very Low

APPENDIX 4: HASLAM LAKE AND LANG CREEK WATER LICENSES

License Number	Map Reference and Points Code	Stream	Use	Permitted Volume (m^3/yr)
C024035	92.F.088.4.3 A (PD44847)	Haslam Lake	Waterworks: Local Provide	22337804
C024036	92.F.088.4.1 A (PD44844)	Haslam Lake	Stream Storage: Non-Power	17762112
C024665	92.F.079.3.3 C (PD44642)	Lang Creek	Waterworks: Local Provide	49780
C033938	92.F.079.3.3 C (PD44642)	Lang Creek	Waterworks: Local Provide	830
C033939	92.F.079.3.3 C (PD44642)	Lang Creek	Waterworks: Local Provide	1659
C033944	92.F.079.3.3 C (PD44642)	Lang Creek	Waterworks: Local Provide	830
C033947	92.F.079.3.3 C (PD44642)	Lang Creek	Waterworks: Local Provide	830
C033949	92.F.079.3.3 C (PD44642)	Lang Creek	Waterworks: Local Provide	830
C048989	92.F.079.3.3 U (PD44640)	Lang Creek	Domestic	830
"	"	Lang Creek	Irrigation: Private	8634
C053506	92.F.079.3.3 C (PD44642)	Lang Creek	Waterworks: Local Provide	830
C055988	92.F.079.3.3 B (PD44634)	Lang Creek	Domestic	1162
C058577	92F/16d A (PD45352)	Lang Creek	Domestic	830
C059751	92.F.079.3.3 V (PD44635)	Lang Creek	Domestic	830
C061723	92.F.079.3.3 X (PD44637)	Lang Creek	Domestic	830
C061724	92.F.079.3.3 W (PD44638)	Lang Creek	Domestic	830
C062365	92.F.079.3.3 S (PD44639)	Lang Creek	Domestic	830
C065324	92.F.079.3.3 AA (PD44643)	Lang Creek	Conservation: Use Of Water	14295593
C067912	92.F.079.3.3 C (PD44642)	Lang Creek	Waterworks: Local Provide	9956
C070078	92.F.079.3.3 C (PD44642)	Lang Creek	Camps & Pub Facil: Work Camp	830
C072782	92F/16d B (PD45351)	Lang Creek	Conservation: Use Of Water	883613
"	92F/16d E (PD65297)	Lang Creek	Conservation: Use Of Water	883613
C108360	92.F.079.3.3 CC (PD69715)	Lang Creek	Domestic	830
C111319	92.F.079.3.3 BB (PD44641)	Lang Creek	Domestic	830
C111320	92.F.079.3.3 EE (PD72433)	Lang Creek	Domestic	830
C120934	92.F.079.3.3 (PD79225)	Lang Creek	Domestic	830
C122062	92.F.079.3.3 (PD79968)	Lang Creek	Domestic	830
C133046	PD187564 - 92.F.079.3.3	Lang Creek	Domestic (Wsa01)	731
C133696	92.F.079.3.3 BB (PD44641)	Lang Creek	Domestic (Wsa01)	731