



COUNCIL REPORT

Date: October 10, 2017 File No. 1220-20-201705

From: Bernie Serné, ASCT, Superintendent of Public Works

Subject: **Windermere Creek – Hydrotechnical Assessment, Drainage Study**

Recommendation

That Council receive the Hydrotechnical Assessment of Windermere Creek report, dated September 15, 2017 from Kerr Wood Leidel Consulting Engineers (KWL), for information purposes;

And that Village staff contact Metro Vancouver to inform them of the concerns presented in the report;

And that Village staff contact the seven identified property owners to inform them of the concerns presented in the report;

And that Village staff include in the budget removal of the old logging bridge upstream of Senkler Road Bridge;

And that Village staff monitor the Creek and bridges during and after major flows to confirm their structural integrity;

And that Village staff contact Metro Vancouver, Port Moody and the Imperial Oil Company to assess the Sasamat Lake catchment and Weir to evaluate possible high flow scenarios.

Background

At the November 5, 2012, Council Meeting it was noted that further dialogue was required regarding the need to update drainage corridors on road allowances. It was suggested that the necessity to update the drainage study, previously completed in the 1980's.

In February 15, 2015, the Village of Belcarra (Village) Corporate Plan 2015 – 2018 included a Drainage Study as one of its priorities.

On December 12, 2016, HY Engineering contacted Engineering firms versed in hydraulic studies for an initial study of the Creek between the Sasamat Lake outlet and Bedwell Bay. The scope of work would essentially be to walk the creek, review available information and recommend any further study required. The recommendation would also include an estimate of the cost to carry out the further recommended study work.

On January 16, 2017, KWL was contracted with to perform a review of a portion of Windermere Creek. The review consisted of a site inspection followed by a comments and recommendation on further work.

Two additional deliverables were requested;

- An assessment of the vegetation debris “dams” upstream of Senkler Bridge to determine the potential for flooding and recommended remedial works; and
- An assessment of a drainage water course that flows into Sasamat Creek in support of facilitating a new pedestrian foot path crossing. There is evidence of Windermere Creek top of bank erosion that may require remedial work at the same time as the new pedestrian crossing is undertaken.

March 3, 2017: KWL personnel and Larry Scott reviewed and discussed key locations for assessment and recommendations, and conducted preliminary assessments.

June 29, 2017: KWL personnel assessed Windermere Creek from Sasamat Lake to Bedwell Bay and met with Bernie Serné to discuss plans for the proposed pedestrian crossing of Avalon Creek.

In support of a drainage study the Village plans to complete, KWL was retained to complete a field assessment of Windermere Creek relative to flooding, erosion, sediment, and debris.

Windermere Creek (aka Sasamat Creek), is fish bearing and flows from Sasamat Lake through the village before discharging into Bedwell Bay on the Indian Arm. The creek outlets from Sasamat Lake outside of the Village boundaries, and is controlled by a weir structure owned by Imperial Oil (Esso) at the northwest end of Sasamat Lake.

Avalon Creek is a small tributary that enters Windermere Creek immediately upstream of the mouth of Windermere Creek at Bedwell Bay. In addition, the Village requested KWL review existing erosion concerns at the downstream end of Avalon Creek where the village is planning to construct a new pedestrian crossing as part of the development of a new trail.

Findings

- Log Debris Blockage Downstream of Sasamat Lake
 - Staff are monitoring the erosion and log debris in this location. This matter will be reassessed after 5 years or after a significant flood event.
 - Staff will remove the Large Woody Debris if the blockage or bank erosion worsens, limiting creek capacity or endangering the road.

Seven Identified Property Owners to be contacted

- High Eroded Right Bank (at Block 37 Lots 14 & 4)
 - A geotechnical engineer should be engaged to conduct an assessment of the failed right bank to determine if adjacent properties are at risk.
- Left Bank Slope Failure Adjacent to Block 5 Lot 3
 - A geotechnical engineer should be engaged to conduct an assessment of the failed left bank to determine if adjacent property is at risk.

- **Undercut Trees Across from Block 37 Lot 1**
 - An arborist should be retained to assess the two undercut trees on the left bank. Due to the proximity to the house on the right side of the creek, it is likely that the trees will require removal.
 - A flood hazard assessment should be considered, given the relative low elevation of the property, the narrowing of the creek at that location, and the potential for debris accumulation. This location should be monitored during significant flood events.

Avalon Creek near Proposed Pedestrian Crossing

- Staff will obtain design peak discharges for Avalon Creek and the small drainage proposed to be diverted to it. This would be required to assess whether the existing culvert on Avalon Creek upstream of the pedestrian bridge has sufficient capacity, as well as provide information for the design of the proposed pedestrian crossing (culvert or bridge) for the new trail.
- Given the degree of creek erosion and the slope failure on the Village property, Staff will monitor and consider retaining a geotechnical engineer to assess the long-term stability of the slope near the eroding creek banks at the existing private pedestrian bridge.
- Staff will contact the owner of the existing private pedestrian bridge and inform them of the concerns presented in the report.

Conclusion

In general, Windermere Creek does not have substantial hydrotechnical concerns, though several items are noted that are recommended for additional action; however, it does not appear to be a debris flow or a debris flood prone creek downstream of the outlet at Sasamat Lake.

The lower reach of Avalon Creek near the proposed pedestrian crossing requires further consideration of hydrotechnical, and geotechnical, concerns, due to erosion and slope stability concerns.

Attachment A: KWL Windermere Creek Report



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Technical Memorandum

DATE: September 15, 2017

TO: Bernie Serne, Village of Belcarra

CC: Ron Beesley, H.Y. Engineering Ltd.

FROM: Stefan Joyce, P.Eng

RE: **WINDERMERE CREEK**
Hydrotechnical Assessment of Windermere Creek
Our File 2272.003-300

This report provides documentation of the 2017 flood and erosion overview assessment of Windermere Creek and a limited assessment of the downstream reach of Avalon Creek in the Village of Belcarra.

1. Introduction

1.1 Background

Windermere Creek (also known as Sasamat Creek), flows from the northwest end of Sasamat Lake through the Village of Belcarra ("the Village") before discharging into Bedwell Bay on Indian Arm. Windermere Creek is a fish-bearing creek. The creek outlet from Sasamat Lake (herein referred to as the "Sasamat Lake outlet") is outside of the Village of Belcarra boundaries, and is controlled by a dam with a weir structure and low-level outlet owned by Imperial Oil (Esso) at the northwest end of Sasamat Lake. It is understood that there is a water supply intake owned by Esso at the south end of Sasamat Lake. Avalon Creek is a small tributary that enters Windermere Creek immediately upstream of the mouth of Windermere Creek at Bedwell Bay. In support of a drainage study the Village plans to complete, Kerr Wood Leidal Associates Ltd. (KWL) was retained to complete a field assessment of Windermere Creek relative to flooding, erosion, sediment, and debris. In addition, the Village requested KWL review existing erosion concerns at the downstream end of Avalon Creek where the Village is planning to construct a new pedestrian crossing as part of the development of a new trail.

1.2 Scope

The scope for this project included:

- review available background material;
- conduct site visit for hydrotechnical engineer and geomorphologist to assess Windermere Creek relative to flooding, erosion, sediment and debris in the reach between Sasamat Lake and Bedwell Bay; and
- prepare a memorandum documenting field observations with recommendations for next steps and order of magnitude costs.



Two locations were identified by the Village for specific assessment and comment:

- an existing debris blockage upstream of the Senkler Road Bridge and related potential for flooding and the need for remedial work recommendations, and
- the downstream portion a tributary stream to Windermere Creek with existing erosion concerns (Avalon Creek), where the Village plans to construct a new pedestrian crossing and trail.

The additional assessment of Avalon Creek was limited to the reach of the Creek from the confluence with Windermere Creek up to the culvert under a driveway at the end of Tatlow Trail.

2. Hydrotechnical Assessment

2.1 Background Information

Background documents provided for review included: Senkler Road Bridge record drawings, history of Belcarra Water Supply System, and the Village of Belcarra Water System Overall Plan. The catchment area was not provided for Windermere or Avalon Creek, and there were no available discharge records. LiDAR elevation contours and cadastral were provided by H.Y. Engineering. This elevation data provides the following general information about the creek geomorphology:

- Windermere Creek slope ranges from 1.5% up to 15%, with an overall average slope of approximately 5% and a total length of 850 m.
- The steepest section of the creek is downstream of the Senkler Road bridge, while the shallowest section is the upper reach near the lake.

It is understood that the Sasamat Lake outlet structure at the northwest end of the lake (which controls flow from the Sasamat Lake to Windermere Creek) is considered a dam as defined by the Dam Safety Regulation (DSR) and that Imperial Oil (Esso) owns and operates the dam. The hydrotechnical assessment did not include a review of the dam and related risks. Sasamat Lake outlet drawings and available flow data were requested from Esso but no information was provided. In addition, it is understood that Imperial Oil (Esso) also owns and operates a water intake for its operations at the south end of Sasamat Lake, which is not a part of this assessment.

There are four active domestic water licenses on Windermere Creek, and two active domestic water licenses on Avalon Creek, each for 2.273 m³/day (600 US gallons/day). No discharge data for the creek was provided or is readily available; however, the City of Port Moody or Imperial Oil (Esso) may have flow records for Windermere Creek given that the Sasamat Lake outlet is controlled by the Imperial Oil dam and located on Port Moody land.

Four bridges cross Windermere Creek (from upstream to downstream): a pedestrian bridge to Sasamat Outdoor Centre, the Senkler Road Bridge, a private foot bridge, and a private driveway bridge.

In the lower portion of Avalon Creek (just upstream of the confluence with Windermere Creek), there is a culvert underneath an existing driveway, several concrete step structures in the creek, and a private pedestrian bridge. Avalon Creek above the driveway culvert at the end of Tatlow Trail was not assessed.

The lower reaches of Windermere Creek (Senkler Bridge downstream to Bedwell Bay) cross a number of private properties that could potentially be affected by creek related hazards. It was noted by the Village that Windermere Creek has a history of flooding in the past 30 to 40 years that has resulted in property damage (anecdotal evidence).



2.2 Field Investigation

The Windermere Creek assessment was conducted on two separate days due to poor weather conditions which made the creek unsafe for personnel to access on the first day. The site visits included:

- March 3, 2017: KWL personnel and Larry Scott reviewed and discussed key locations for assessment and recommendations, documented high flow conditions at the weir outflow, and conducted preliminary assessments.
- June 29, 2017: KWL personnel assessed Windermere Creek from Sasamat Lake to Bedwell Bay and met with Bernie Serne to discuss plans for the proposed pedestrian crossing of Avalon Creek.

Data collected during the field assessment included: georeferenced photos, GPS locations and observations for areas of note, and creek measurements.

Section 2.3 provides field observations for Windermere Creek, and Section 2.4 provides field observations for the Avalon Creek tributary, both organized upstream to downstream. Figure 1 contains a map with of the study area and locations of note identified by section numbers below, and site photos are included in the attached photo appendix. The left and right sides of the creeks are looking downstream. Block and Lot numbers refer to the cadastral provided by H.Y. Engineering, which is shown on Figure 1.

2.3 Site Observations – Windermere Creek

Sasamat Lake Outlet

Windermere Creek flows are controlled by a dam with a weir structure and low-level outlet at the northwest end of Sasamat Lake. This structure is referred to in this memorandum as the “Sasamat Lake outlet”. This area is outside of the Village’s jurisdiction. Below are general observations of the Sasamat Lake outlet.

- Depth of flow over weir on March 3 was 11-11.5 cm (33.5 cm below the existing top of concrete which chain link fence sits on). The weir narrows from approximately 19 m to 10-12 m.
- On June 29, the weir had no flow over it, with the only flow from the low-level pipe.
- Windermere Creek is wide and meandering near the Sasamat Lake outlet with a gentle slope.

Pedestrian Bridge to Sasamat Outdoor Centre

- The bridge has 2.9 m of clearance from the creek bed to the steel girders, and based on visual inspection this appears to be adequate to convey most large flows, though a hydraulic assessment of peak flows has not been completed.
- No material accumulation, erosion, or other issues are apparent at the bridge.
- The creek in this reach is meandering with riffles, pools, and a shallow slope.

Log Debris Blockage

There is a large log debris blockage approximately 100 m downstream of the pedestrian bridge to Sasamat Outdoor Centre, described further below.

- A fallen tree appears to have pulled away part of the right bank.



- 1.5-2 m (height) of large woody debris (LWD) has accumulated in this location, which spans two-thirds of the creek width. The creek is flowing under the LWD, which was not causing any backwater during the site visits.
- Minor erosion is present along the right bank, which may be caused by the LWD moving with changing creek water levels.
- The LWD blockage and erosion are adjacent to a trail on the left bank and a high steep slope on the right bank that is not close to infrastructure. Based on its location, the erosion and LWD blockage are not significant concerns.

Senkler Road Bridge

The Senkler Road Bridge is a new bridge owned by the Village, which was retrofitted in 2012. Below are the key observations in this location and for the creek reach downstream of the bridge.

- An old wooden bridge is partially collapsed upstream of the new bridge, with debris accumulating behind and on top of it. Accumulated material could pose a future risk for blockage at the Senkler Road Bridge.
- Two pipes are supported by the bridge and cross the creek below the bridge deck. The bridge has 2.5 m of clearance from the creek bed to the lowest pipe underneath the bridge, and based on visual inspection this appears to be adequate to convey most large flows (provided there isn't a blockage), though a hydraulic assessment of peak flows has not been completed.
- No debris accumulation or erosion issues are apparent at the bridge.
- Downstream of the Senkler Road Bridge, the creek is steeper with cascading pools and large boulders.

Water Intakes Along Creek

- Multiple small water intakes with pumps, piping, and small sheds are located along the creek from Senkler Road downstream to Bedwell Bay.
- This infrastructure is often in the floodplain, and in some instances the flexible piping crosses the creek and rests on debris in the creek. Low-lying piping and attached equipment could be at risk during a large discharge event.

Private Foot Bridge

- A small private aluminum foot bridge crosses the creek approximately 100 m downstream of Senkler Road.
- The bridge has 1.4 m of clearance and there is no debris accumulation. Based on visual observations, this bridge has limited capacity, though a hydraulic assessment of peak flows has not been completed.
- Upstream of the bridge, the right bank has some grouted riprap in place.



High Eroded Right Bank (at Block 37 Lots 14 & 4)

- A short distance downstream of the private bridge described in 2.2.6, the right bank has a high, near-vertical face from a past slope failure (on Block 37 Lots 14 and 4). Most of the toe of the failed slope has vegetation growth and does not have evidence of active erosion. This could pose a risk to existing buildings and infrastructure on nearby properties (Block 37 Lots 5 and 13).
- The total bank height is approximately 8-10 m. The bottom 4-5 m has a 1H:1V slope, and the bank above is vertical with a slight overhang near the top.
- There is erosion at the downstream end of the high cut bank with an undercut tree. There is no obvious nearby building or infrastructure that could be damaged if the tree were to fall.

Private Driveway Bridge

- The driveway bridge has a steel I-beam deck with timber supports that are braced against the creek bed. These timber supports occupy some of the clearance beneath the bridge, which could result in woody debris accumulation.
- Apart from the timber supports, the bridge has 1.9 m of clearance from the creek bed to the underside of the bridge. It is unclear if there is adequate capacity based on visual observations, primarily due to the timber supports within the conveyance channel; however, a hydraulic assessment of peak flows was not completed.
- Some minor erosion is occurring at the downstream left abutment, but it is not significant enough to cause concern for the footings of the abutment at this time.

Left Bank Slope Failure adjacent to Block 5 Lot 3

- 20-30 m upstream of the Avalon Creek confluence with Windermere Creek, the left bank has failed and has a vertical face. Along the bank failure, no evidence of recent toe erosion was observed. A house (Block 5 Lot 3) is located close to the top of bank.

Undercut Trees Across from Block 37 Lot 1

- Downstream of the left bank slope failure, there is erosion at the toe, which has undercut two trees. The undercut trees are directly across from a concrete retaining wall and a property (Block 37 Lot 1) with a house near the creek on the right bank. If the trees were to fall, the house could be damaged.
- The right bank concrete retaining wall along the house (Block 37 Lot 1) appears to be in good condition, but the house is close to the creek and relatively low in elevation. The creek narrows here, suggesting that this reach could be vulnerable to debris blockage. If a blockage were to occur during a flood event, then it may result in floodwaters reaching the house.

Mouth of Windermere Creek

- Minor erosion and undercutting has occurred at the base of a tree at the mouth of Windermere Creek to Bedwell Bay; however, it is not a concern given the location of the tree on the creek and lack of nearby buildings.



2.4 Site Observations – Avalon Creek

The assessment of Avalon Creek was limited to the reach from the confluence with Windermere Creek up to the culvert under a driveway ("driveway culvert") at the end of Tatlow Trail (access to Block 5 Lot 3). The Village requested review of this limited section as it plans to construct a new pedestrian crossing between the existing driveway culvert and private pedestrian bridge. As a result, erosion, flood, or other creek hazards upstream of this location have not been assessed.

Driveway Culvert

- There is an existing 450 mm (internal diameter) concrete culvert under a driveway entrance (Block 5 Lot 3) at the end of Tatlow Trail. It is reported that the culvert has only overflowed over the road when debris has blocked the culvert.
- Upstream of the culvert, the channel dimensions range from 1.5-1.8 m wide at top of bank, 0.5-0.7 m deep, and approximately 0.9 m wide at the base of the creek with a slope of approximately 14%.

Step Structures

- Concrete step structures were installed in the creek several decades ago from the culvert outlet to the existing pedestrian bridge (possibly installed by the property owner). The works are failing due to significant erosion of the fine bank material on Avalon Creek, which is very steep from the culvert to Windermere Creek.
- The ground on the left side of the creek along the concrete step structures is low and slopes to the north.

Private Pedestrian Bridge

- The concrete step structure beneath the private pedestrian bridge is undercut, and directs the creek flow to the right bank (comprised of fine erodible material), which shows evidence of significant erosion. Some minor undercutting was also noted at the concrete step structure immediately upstream of the bridge.

3. Proposed Avalon Creek Pedestrian Crossing

The Village plans to install a new pedestrian crossing over Avalon Creek to replace the existing private pedestrian bridge that is failing. The initial concept proposed by the Village is described below.

- Install an 1800 mm diameter culvert, 2.5 m long, buried 0.3 to 0.9 m below the creek bed for a pedestrian crossing as part of the new trail. The proposed culvert capacity would be greater than what currently exists in the channel immediately upstream of the private pedestrian bridge and driveway culvert; however, the culvert size should be confirmed against peak design flows, which have not been developed.
- The proposed culvert is planned to be located upstream of the private pedestrian bridge and area of most significant creek erosion.

Some preliminary comments on this proposed concept are provided below.

- The crossing would still be susceptible to long-term erosion issues on Avalon Creek if creek stabilization works are not completed.



- A bridge supported on piles set back from the creek banks would be less susceptible to creek erosion and would simplify environmental approvals (discussed further below).

In addition to the above engineering comments, the environmental considerations of the culvert option versus a bridge option are described below.

For a crossing (bridge or culvert) to be installed under a Water Sustainability Act (WSA) Notification (45 calendar day waiting period) rather than an Approval (140 calendar days or greater) the proposed design must be completed for a 200-year return period maximum daily flow. This would require a flood frequency assessment for Avalon Creek. The general requirements for environmental permitting for each option are described below.

Culvert Option:

- WSA Notification possible (45 day waiting period) but Change Approval could be required (estimated 140-day review period) if any one of the 15 conditions in Section 39(1)(a) of Water Sustainability Regulation cannot be met.
- DFO project review required for new culverts.
- Aquatic Effects Assessment (impact assessment) required in support of DFO submission.
- Environmental monitoring required during construction.
- Fish salvage required.

Clear-Span Bridge Option:

- WSA Notification required only (45 day waiting period) provided all 5 conditions in Section 39(1)(a) of Water Sustainability Regulation can be met – conditions are easier to meet for clear-span bridges.
- No DFO review of clear-span bridges required – falls in self-assessment category.
- *Aquatic Effects Assessment not required because of lower impacts of bridge options.*
- Environmental monitoring required during construction.
- *Fish salvage not required if no footings below the high water mark.*

In summary, the permitting requirements for a clear span bridge would require significantly less effort and time.

The Village is also considering diverting additional drainage to the creek channel upstream of the existing culvert. Diversion of the drainage may require an approval from the Province if it is considered a watercourse pursuant to the Water Sustainability Act.

4. Summary and Recommendations

4.1 Summary of Findings

In general, Windermere Creek does not have substantial hydrotechnical concerns, though several items are noted that are recommended for additional action, as described in Section 4.2. Slope failures could introduce sediment and debris into Windermere Creek; however, it does not appear to be a debris flow or debris flood prone creek downstream of the outlet at Sasamat Lake. As previously noted, the lower



reaches of Windermere Creek cross several private properties that could potentially be affected by creek related hazards.

The lower reach of Avalon Creek near the proposed pedestrian crossing requires further consideration of hydrotechnical, geotechnical, and biological concerns, as outlined in Section 4.2, due to erosion and slope stability concerns. Avalon Creek was not assessed above the driveway culvert, and as a result creek hazards cannot be fully assessed without further investigation.

4.2 Comments and Recommendations

Windermere Creek

The following are comments and recommendations based on the site assessment of Windermere Creek.

- **Sasamat Lake Outlet**
 - It is understood that the Sasamat Lake outlet structure is considered a dam as defined by the Dam Safety Regulation (DSR) and that Imperial Oil (Esso) owns and operates the dam.
 - The Village should be informed of potential downstream flood and erosion risks posed by the dam, which Imperial Oil should be able to provide documentation on, if they have not already done so.
- **Windermere Creek Discharge**
 - Discharge data and design discharges for Windermere Creek may be available from Imperial Oil (Esso) or the City of Port Moody, as the Sasamat Lake Outlet is controlled by Imperial Oil and located on Port Moody land.
 - If data is not available from the above sources a hydrologist should be retained to develop design discharges for Windermere Creek to enable more detailed capacity assessments of the creek and bridges. This work could be done as a part of a drainage study the Village is planning to commission this year.
- **Windermere Creek Flood Capacity**
 - Given the anecdotal evidence of flooding along the lower reaches of Windermere Creek, a detailed review of flood history and hydraulic assessment of the flood capacity of the creek (from just upstream of Senkler Road Bridge to Bedwell Bay) should be considered.
- **All Bridges**
 - The bridges should be inspected during and after large creek flow events to determine if blockages, sediment deposition, or erosion have occurred.
 - The bridge hydraulic capacities should be evaluated upon completion of the development of design flows for Windermere Creek (as recommended above).
- **Log Debris Blockage Downstream of Sasamat Lake**
 - Erosion and log debris should be monitored in this location. It should be reassessed after 5 years or after a significant flood event.
 - Removal of the LWD may be considered if the blockage or bank erosion worsens, limiting creek capacity or endangering the road, which is set back from the top of the right bank.



- If removal is completed, it may be beneficial to leave some LWD for habitat and because it creates a natural location for debris accumulation, rather than LWD blocking one of the downstream bridges.
- **Senkler Road Bridge**
 - The old bridge and accumulated debris upstream of the Senkler Road Bridge should be removed.
- **Water Intakes Along Creek**
 - The water infrastructure along the creek is vulnerable to disruption during creek events. While not likely a direct responsibility of the Village, this should be recognized.
- **High Eroded Right Bank (at Block 37 Lots 14 & 4)**
 - A geotechnical engineer should be retained to conduct an assessment of the failed right bank to determine if adjacent properties are at risk (Block 37 Lots 5 and 13).
 - The undercut tree likely does not require removal as there are no clear nearby targets. However, an arborist could review the tree if on site to inspect the danger trees in the lower reach of the creek.
- **Left Bank Slope Failure Adjacent to Block 5 Lot 3**
 - If not already completed, a geotechnical engineer should be engaged to conduct an assessment of the failed left bank to determine if adjacent property (Block 5 Lot 3) is at risk.
- **Undercut Trees Across from Block 37 Lot 1**
 - An arborist should be retained to assess the two undercut trees on the left bank across from Block 37 Lot 1. Due to the proximity to the house on the right side of the creek, it is likely that the trees will require removal.
 - A flood hazard assessment should be considered for the house on Block 37 Lot 1, given the relative low elevation of the property, the narrowing of the creek at that location, and the potential for debris accumulation. This location should be monitored during significant flood events.

Avalon Creek near Proposed Pedestrian Crossing

The following are comments and recommendations based on the site assessment of Avalon Creek near the proposed pedestrian crossing.

- A hydrologist should be retained to develop design peak discharges for Avalon Creek and the small drainage proposed to be diverted to it. This would be required to assess whether the existing culvert on Avalon Creek upstream of the pedestrian bridge has sufficient capacity, as well as provide information for the design of the proposed pedestrian crossing (culvert or bridge) for the new trail. This work could be done as a part of a drainage study the Village is planning to commission this year.
- Given the degree of creek erosion and the slope failure on the adjacent property, a geotechnical engineer should be retained to assess the long-term stability of the slope near the eroding creek banks at the existing private pedestrian bridge and provide geotechnical guidance and recommendations for the new pedestrian crossing.



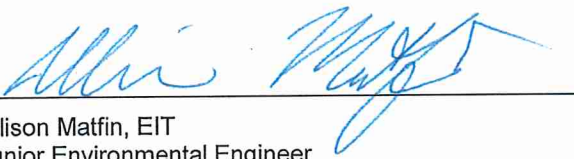
- The advantages and disadvantages of a culvert or bridge crossing should be evaluated relative to long term stability, permitting and other considerations during the planning and design of the proposed pedestrian crossing.
- An engineer should be retained to design the proposed pedestrian crossing (bridge or culvert) and confirm that it has sufficient capacity and will be stable for the intended design life given the existing creek erosion and slope failure in the area.
- On the left bank of the proposed pedestrian crossing where the bank appears to be low, an assessment should be conducted to confirm that there is sufficient freeboard to prevent flood flows from bypassing the crossing and flowing overland downslope.
- In conjunction with the proposed pedestrian crossing and as a short-term measure to reduce the rate of erosion at the concrete step structures upstream of the pedestrian bridge, buttressing the base of the existing concrete step structures with angular rock should be considered.
- In the long term, removal of the failing creek works (concrete step structures) should be considered to avoid debris accumulation in Windermere creek downstream and development of creek stabilization design options, as the exposed banks and bed would be susceptible to accelerated erosion following structure removal.

5. Closing

We trust this memorandum meets your present requirements. If you have any questions or comments, please contact the undersigned.

KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:

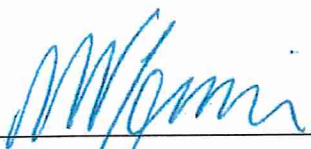

Allison Matfin, EIT
Junior Environmental Engineer

Prepared by:

This document is a copy of the sealed and signed hard copy original retained on file. The content of the electronically transmitted document can be confirmed by referring to the filed original.


Stefan Joyce, P.Eng.
Senior Hydrotechnical Engineer

Reviewed by:


Mike V. Currie, M.Eng., P.Eng., FEC
Principal, Senior Water Resources Engineer

KERR WOOD LEIDAL ASSOCIATES LTD.
consulting engineers



Encl.: Figure 1 – Key Observations for Windermere Creek
Photo Appendix

Statement of Limitations

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This document represents KWL's best professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practising under similar conditions. No warranty, express or implied, is made.

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Revision History

Revision #	Date	Status	Revision Description	Author
1	September 15, 2017	FINAL	Final memorandum issued.	ARM/SFJ
A	August 3, 2017	DRAFT	Draft for Client Review.	ARM/SFJ



Village of Belcarra
Hydrotechnical Assessment of Windermere Creek

KWL KERR WOOD LEIDAL
consulting engineers



Project No. 2272.003
Date September 2017
Scale 1:2,500

Key Observations for Windermere Creek

Figure 1



Site Photographs



Photo 1: Sasamat Lake outlet March 3



Photo 2: Sasamat Lake outlet June 29



Photo 3: Windermere Creek between Sasamat Lake and pedestrian bridge on March 3



Photo 4: Trail along Windermere Creek downstream of Sasamat Lake June 29



Site Photographs



Photo 5: Pedestrian bridge to Sasamat Outdoor Centre
June 29



Photo 6: Pedestrian bridge to Sasamat Outdoor Centre
June 29

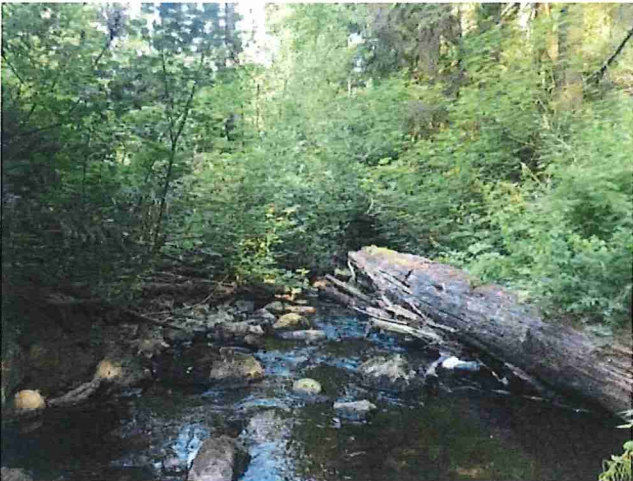


Photo 7: Meandering riffle-pool reach between
pedestrian bridge and LWD blockage



Photo 8: Log debris blockage with fallen tree from right
bank March 3



Site Photographs



Photo 9: Log debris blockage, looking from right bank to left bank June 29



Photo 10: Erosion at toe of right bank adjacent to log debris blockage June 29

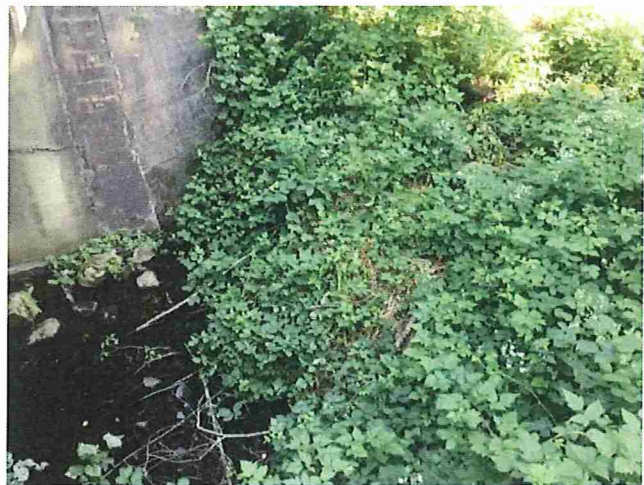


Photo 11: Old wooden bridge covered with debris immediately upstream of the Senkler bridge June 29



Site Photographs



Photo 12: Looking upstream under the Senkler Bridge
June 29



Photo 13: Looking downstream under the Senkler Bridge
March 3



Photo 14: Water intake lines across creek and shed in floodplain (looking upstream) June 29



Site Photographs



Photo 15: Private pedestrian footbridge (looking downstream) June 29

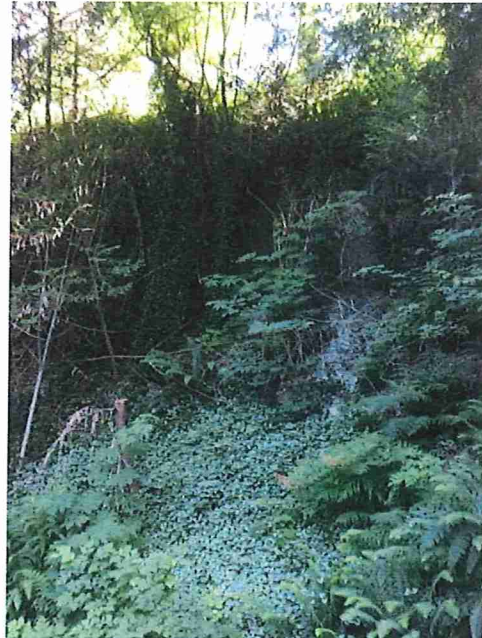


Photo 16: High failed right bank June 29



Photo 17: Erosion at downstream toe of failed high right bank June 29

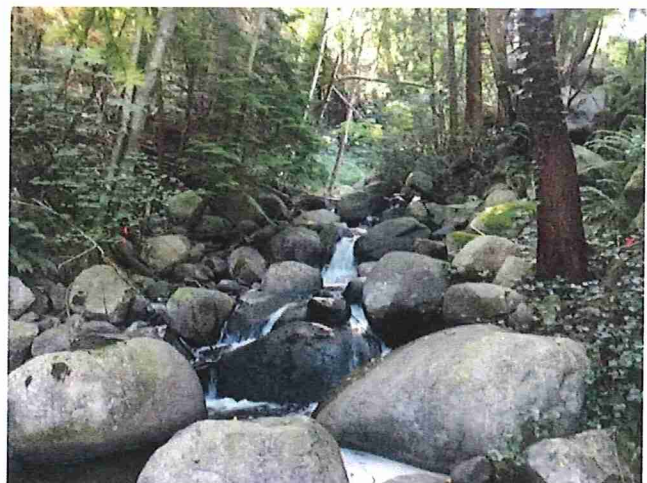


Photo 18: Typical photo of cascade-pool reach between private footbridge and driveway bridge June 29



Site Photographs



Photo 19: Private driveway bridge with timber supports (looking downstream) June 29



Photo 20: Private driveway bridge with timber supports (looking downstream) March 3



Photo 21: Left bank slope failure upstream of Avalon Creek confluence



Photo 22: Erosion and undercut trees on left bank (looking downstream) June 29



Site Photographs



Photo 23: Undercut trees on left bank across from retaining wall and home on right bank (looking downstream)
June 29

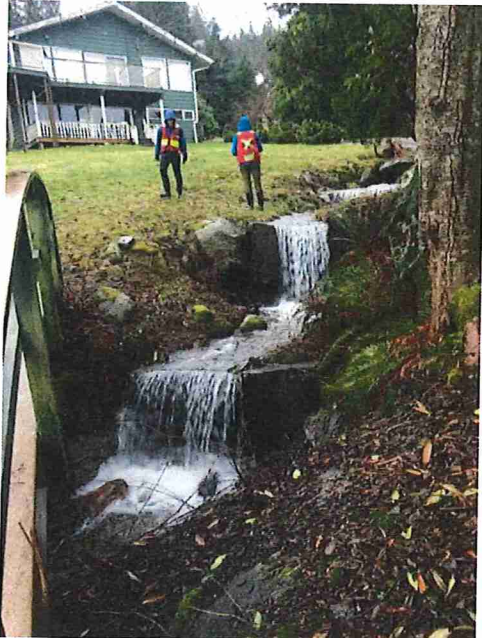


Photo 24: Concrete step weirs on Avalon Creek
upstream of private footbridge March 3



Photo 25: Eroded right bank on Avalon Creek
downstream of private footbridge March 3



Site Photographs



Photo 26: Downstream end of eroded right bank on Avalon Creek above confluence March 3



Photo 27: Undercut concrete weir downstream of private footbridge with hanging cables March 3



Photo 28: Slight undercutting at concrete step weir immediately upstream of private footbridge on Avalon Creek



Site Photographs



Photo 29: Undercut concrete weir downstream of private footbridge (looking down from bridge) March 3



Photo 30: Avalon Creek upstream of existing 450 mm culvert March 3

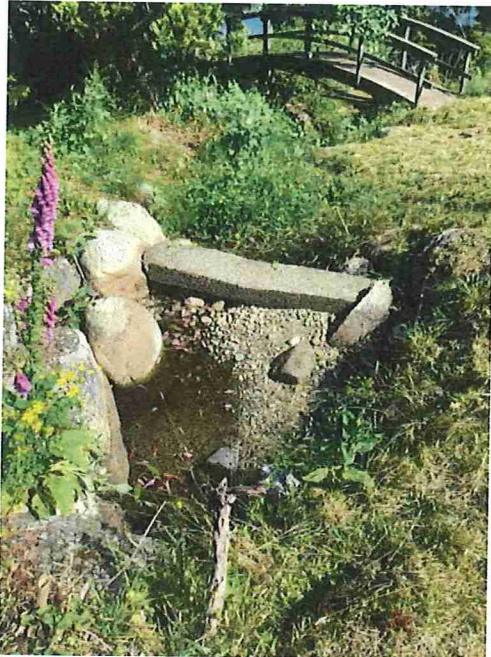


Photo 31: Avalon Creek looking downstream from June 29