CARIBOO ROAD RECOVERY PROJECTS

KERSLEY-DALE LANDING ROAD

CARIBOO ROAD RECOVERY PROJECT (26250)

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SUBJECT :	Kersley Creek – Hydrotechnical Memo
DATE :	July 02, 2024

The following versions of this document have been submitted.

Version	Date Issued	Revision Description
A	July 7, 2023	Draft memo submitted for comments
B	August 4, 2023	Draft memo updates with OE comments addressed
C	September 28, 2023	Draft memo updates with OE comments addressed
D	December 5, 2023	Added Section 11, 'Kersley-Dale Landing Road Culvert Drainage Considerations' with updates to Section 6 'Hydrology' and Section 12, 'Summary and Recommendations
0	December 12, 2023	Final memo
1	May 9, 2024	Updated for riprap footprint and quantities in Section 11, 'Kersley-Dale Landing Road Culvert Drainage Considerations' and Section 12, 'Summary and Recommendations
2	May 31, 2024	Updated Final Memo with OE comment addressed
3	July 02, 2024	Updated Final Memo with new OE comments addressed

1.0 INTRODUCTION

WSP Canada Inc (WSP) is a member of the Multidisciplinary Design Team (MDT) led by Urban Systems Ltd (USL) for the Kersley-Dale Landing Road project. This project is one of ten under the Cariboo Road Recovery Projects (CRRP) managed by the Ministry of Transportation and Infrastructure (MOTI).

Kersley Creek, where Kersley-Dale Landing Road is located, has steep slopes that have experienced significant slope failures over the years. This has raised concerns about public safety and infrastructure integrity. This memo includes a desktop hydrologic analysis of the project area, an initial hydrotechnical analysis of the existing channel, and conceptual considerations for erosion protection to repair and upgrade Kersley-Dale Landing Road.

The purpose and objective of this memo is to provide hydrotechnical information for potential work on Kersley Creek, specifically to inform the conceptual engineering of slope stabilizations below Kersley-Dale Landing Road. It will also help the team determine the feasibility and costs associated with the road alignment and provide a basis for further hydrotechnical analysis and design on Kersley Creek.

This memo is based on a desktop study and relies on limited information from field personnel.

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2.0 BASIS OF DESIGN

This section describes the Basis of Design for the hydrological and hydraulic analyses. The purpose of this section is to give a concise summary of the key relevant aspects of the methodologies and assumptions.

REVIEW OF AVAILABLE DATA

Background Information:

- Westrek's geotechnical assessment "Geotechnical Assessment (18-SS-1294), Kersley-Dale Landing Road"
- Historical hydrotechnical reports (NHC Sept 2015, March 2016)
- LiDAR data from 2019 to 2023
- Water Survey of Canada (WSC) station data
- BC Streamflow Inventory Data
- BC Extreme Flood Data
- IDF_CC (version 6.5) Climate Change projections
- PCIC regional Climate Change projections
- PCIC Extreme Streamflow projections

DESIGN CRITERIA

In accordance with the Canadian Highway Bridge Design Code (CHBDC; CSA, 2109) the minimum requirement for the design flood is a 50-year return period. MOTI's supplement to S6 specifies a 100-year return period for culverts less than 3 m in diameter. Similarly, the Supplement to Transportation Association of Canada (TAC) guideline suggests the use of a 100-year return period for culverts less than 3 m in diameter and located on low volume roads. The Supplement to TAC Geometric Design Guide (April 2019) suggests the use of 100-year return period for River Training and Channel Control Works on Low Volume Roads.

Design Flow Return Period: 100-year return period including climate change adjustment.

DESIGN FLOW ESTIMATION

To determine the design flow, local stream gauge data was analyzed and compared to other sources, namely the BC Streamflow Inventory as well as the BC Extreme Flood data.

The design flow will be based on the drainage area associated with the twin culvert location at the end of the creek to be representative for the entire length of Kersley Creek.

RIPRAP SIZING

Riprap sizing is computed from the United States Army Corps of Engineers (USACE) relationship recommended by TAC Guide to Bridge Hydraulics.

Manning's equation hydraulic model is used to determine the local velocity and local flow depth for the channel.

Riprap layer thickness is in accordance with the Design Build Standard Specifications for Highway Construction (Volume 1; MOTI, 2020).

3.0 LOCATION AND STUDY AREA

Highway 97 crosses Kersley Creek roughly 25 km south of Quesnel, BC with Kersley-Dale Landing Road leading to the west. The study area for this memo is focused on an approximately 2.5 km length of Kersley Creek extending from the outlet into the Fraser River to the crossing with Highway 97.

The study area is shown in Figure 1.

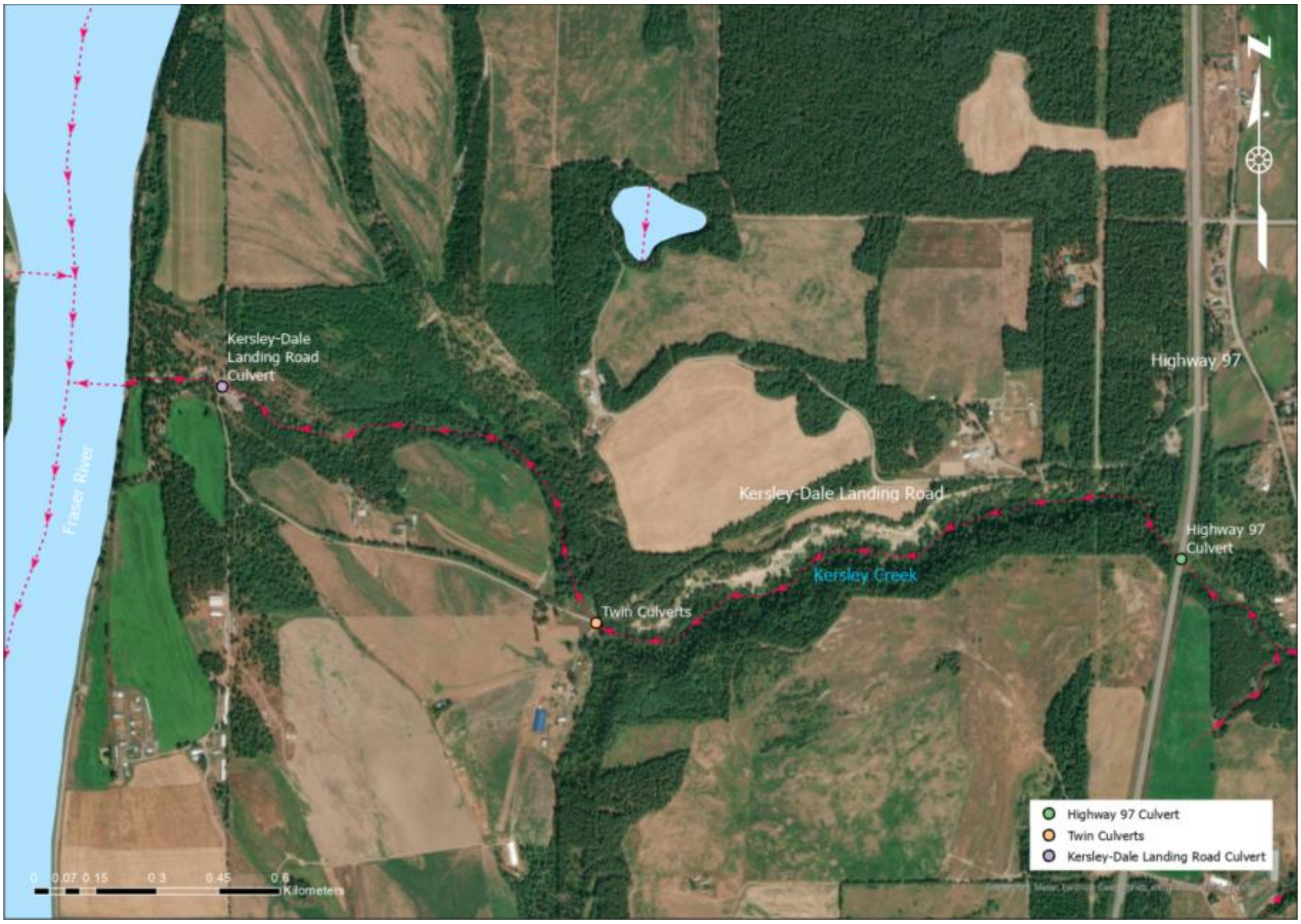

Figure 1 – Kersley Creek Study Area

4.0 DATA REVIEW

INITIAL FIELD INVESTIGATION

The Cariboo team and WSP personnel were on site on November 4, 2022. Site visit photos taken from Kersley-Dale Landing Road are shown in Figure 2.

Figure 2 – Site visit photos

GEOTECHNICAL REPORT SUMMARY

Westrek completed a geotechnical assessment of the site. The report is called, "Geotechnical Assessment (18-SS-1294), Kersley-Dale Landing Road" dated June 6, 2021. The report included a review of failures along Kersley-Dale Landing Road and the development of high-level Geotech recommendations to remediate those failures. A summary of the report related to hydrotechnical components is provided below:

- "Erosional scour causing loss of toe support in areas along the steep valley bottom slopes, next to Kersley Creek" is probably a contributing factor to the existing slope stability issues, but the report seems to focus more on groundwater fluctuations, significant seepage zones in the fill slope, and over-steepened fill slopes as the primary causes of instability.
- The assessment of the creek bank's condition was hindered by the snow conditions on-site, making it impossible to determine the presence and extent of the toe erosion caused by the creek channel. As a result, the need for bank armouring remains unknown.
- "Between 1982 and 1985, three fill slope failures were noted on the images, at least one of which reached the creek below." Five naturally occurring landslides were observed. Three of the landslides initiated about mid-way up the slope and may be related to loss of toe support due to undercutting by Kersley Creek."
- Areas of high reflectance were observed in the channel near the lower section of the gully, potentially indicating downstream movement of debris from these failures. Surficial geology mapping identified meltwater or outwash channels, as well as riverbanks and terraces.
- Prolonged erosional scouring at the base of the slopes may result in loss of support, potentially triggering shallow or deep-seated failures on these slopes.
- When considering redesign options, it is important to assess the overall impact of erosional scour and determine the necessity and location of riprap armouring.

- The layer of sandy gravel/gravelly sand extends below the road shoulder towards the creek, with a thickness of at least 10 meters and in some areas reaching up to 15 meters below the road. Significant seepage zones were identified within this layer along several recent fill slope failure paths, indicating the potential presence of a perched groundwater table.
- Considering the fishery sensitivity of Kersley Creek, earthworks on the steep slopes above the channel would necessitate the development and implementation of a comprehensive erosion and sediment control plan to mitigate environmental risks effectively. There is a licensed point of diversion near the valley bottom, about 150 m upstream from where the road crosses Kersley Creek.

SECONDARY FIELD INVESTIGATION

Urban Systems and Stantec personnel were on-site during the week of May 8-12, 2023. The teams observed a significant drop in water flow rates between locations ‘A’ and ‘B’ as shown in Figure 3. Location ‘B’ is downstream of location ‘A’, which is close to the Fraser River. The left image shows the flow path from the National Hydro Network (NHN). The right image shows the LiDAR data.

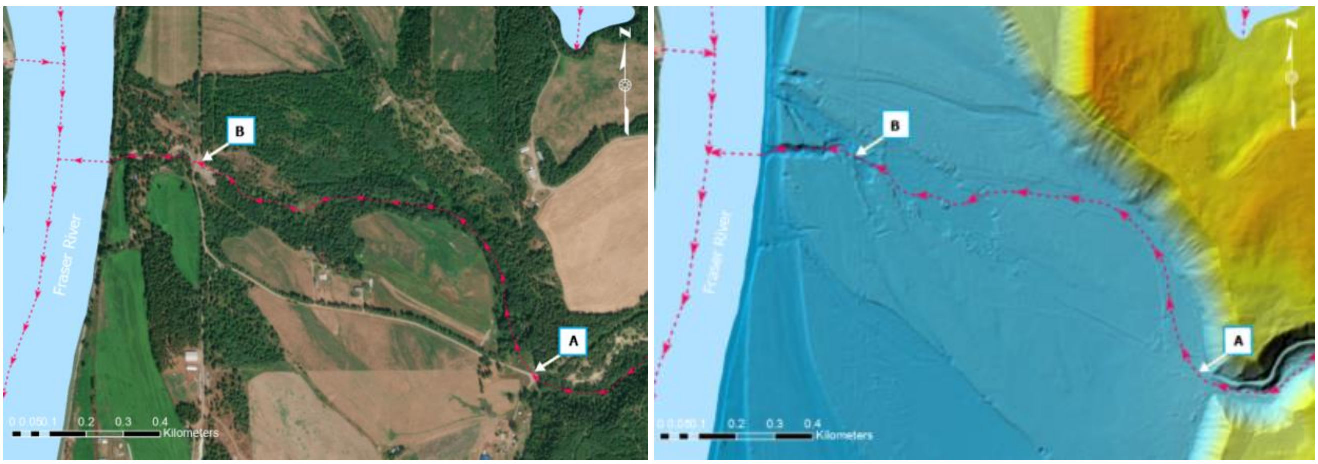

Figure 3 – Flow paths from location ‘A’ to location ‘B’. Left image: National Hydro Network (NHN). Right image: BC Open Lidar data.

WSP completed additional desktop research into potential causes for the drop in water flow rates. WSP also discussed these possibilities with Urban Systems and Stantec during a subsequent team update meeting. We have included potential causes with comments provided:

- Water Use Diversion Potential: The Westrek Geotechnical Assessment (18-SS-1294) mentions “a licensed point of diversion near the valley bottom, about 150 m upstream from where the road crosses Kersley Creek. The diverted water is used for irrigation and domestic purposes.” Based on discussions during the Kersley-Dale team meeting on May 24, 2023, the water diversion is likely coming from a diversion device installed by the landowner to irrigate the land. It was estimated that 2/3 of the flow was going into the diversion. This is likely to be the reason for the missing flow.
- Subsurface flow potential: The WSP Geotechnical team provided some comments regarding the subsurface flow potential. There isn’t any borehole drilling in the immediate area of the creek, but the boreholes that were drilled along the proposed L500 road alignment, located north of the 2900 mm diameter CSP culvert crossing, typically encountered fluvial sands and gravels near the ground surface which are likely to be relatively permeable. Upstream of this culvert crossing, the geotechnical team did see some exposed sands and gravels in a cut bank which appeared to be relatively coarse-grained which is consistent with what was encountered in boreholes to the north of the crossing. Based on the type of surficial deposits generally anticipated to be encountered on this lower terrace, it seems possible that stream flow could be going into the surrounding soils around and below the creek as it flows to the west towards the Fraser River. There is potential for subsurface flow to be a secondary reason for the missing flow.

- Historical Hydrotechnical Reports: The historical hydrotechnical reports (NHC Sept 2015, March 2016) for the 2900 mm dia. culvert replacement do not mention a diversion for the upstream flow at this site.

If a future design phase will be completed, additional field investigation could be completed to better understand the water diversion channel and subsurface flow potential. In addition, the landowner of the potential water diversion device could be consulted during a field visit to further estimate the diversion flow potential and timing.

Although not part of Kersley Creek, a small culvert crossing was identified at location 'C', shown in Figure 4, which was dry during the inspection. This crossing accommodated local flow only from a small catchment where the flow paths are not mapped. Specifics can be investigated further with the Arnoldus Road design.

Figure 4 – Location 'C' crossing of an unnamed drainage course was dry during the inspection. Left image: Site location. Right image: Site photo during the inspection

LIDAR DATA REVIEW

The LiDAR datasets available for the study area are shown in Table 4-1. The LiDAR data from July 2019 and May 2023 are similar. This memo used the May 2023 data for the analysis and figures provided in this memo.

Table 4-1 – LiDAR Datasets

DATA SET	LIDAR POINT SPACING (M)	COMMENTS
May 2023 (MOTI)	0.32 – 0.46	High-resolution point density; recent data
November 2020 (MOTI)	~ 3.5	Lowest point density
July 2019 (BC Open LiDAR)	0.27 – 0.35	Highest resolution point density; older data

Note: We also investigated the May / October 2021 LiDAR and July 2022 LiDAR datasets (MOTI). Upon initial review, the 2021 LiDAR point cloud elevations appear to be erroneous as they are -500 m to -600 m in elevation. The 2022 LiDAR does not have elevation information in Kersley Creek, however, there is information for the surrounding areas. As there is good information for the 2023 and 2019 LiDAR datasets, no further investigation into the LiDAR mentioned above was completed.

5.0 EXISTING CONDITIONS

DESKTOP INFORMATION REVIEW

Kersley Creek within the study area flows from east to west and is a tributary to Fraser River, roughly 2.5 km west of Highway 97. The creek runs within a valley that is up to 60 m deep and 200 m wide. The longitudinal section and profile of Kersley Creek through the study area, streambed slopes and culvert locations are shown in Figure 5. There are culverts in place on Kersley Creek, Highway 97 and Kersley-Dale landing road as shown in orange (Kersley Creek crossings), and blue (roadway drainage culverts). The streambed profile is shown in yellow with average slopes for each reach indicated in red.

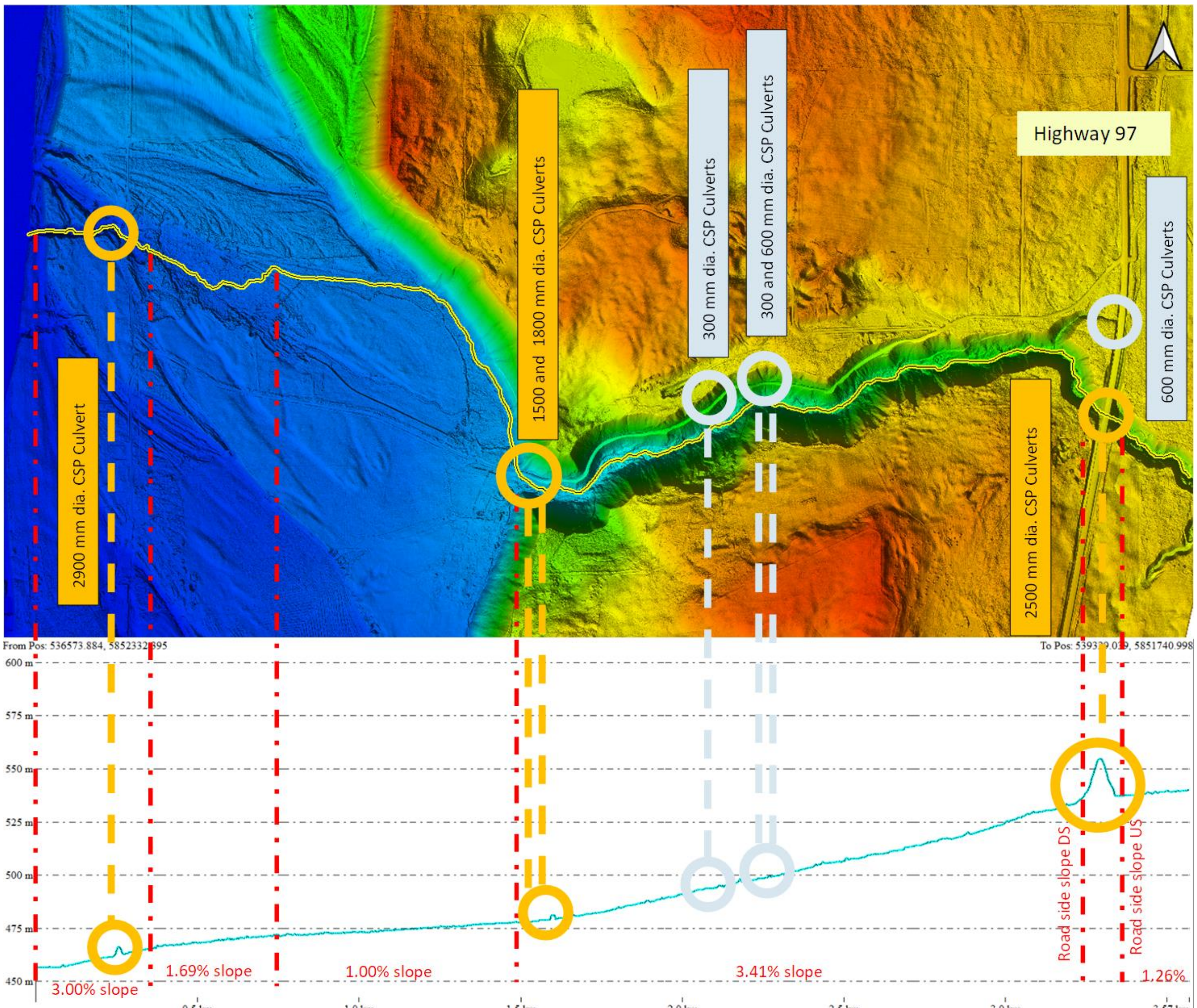

Figure 5 – Kersley Creek longitudinal section and profile

There are two culverts under Highway 97 on Kersley Creek (2500 mm dia. SPCSP and a 600 mm dia. CSP). Additionally, three culverts are located along Kersley-Dale Landing Road on Kersley Creek (600, 300, and 300 mm dia.) based on the BC Web Map Library.

There are twin culverts (1500 and 1800 mm dia. CSPs) located further downstream on Kersley-Dale Landing Road, near the end of the Kersley Creek Valley. These culverts are mentioned in the Culvert Replacement Project, Preliminary Hydrotechnical Design (NHC Draft Report dated September 15, 2015).

A 2900 mm dia. CSP culvert is located downstream of Kersley Creek approx. 250 m upstream of the confluence with Fraser River.

6.0 HYDROLOGY

Kersley Creek is located on the border of BC's Streamflow Inventory Hydrologic Zone 15 – Fraser Plateau, adjacent to Zone 14 – Northern Columbia Mountains (Ahmed, 2020). Figure 6 below illustrates the hydrologic zone boundaries in the province, with the Project site denoted by a red star.

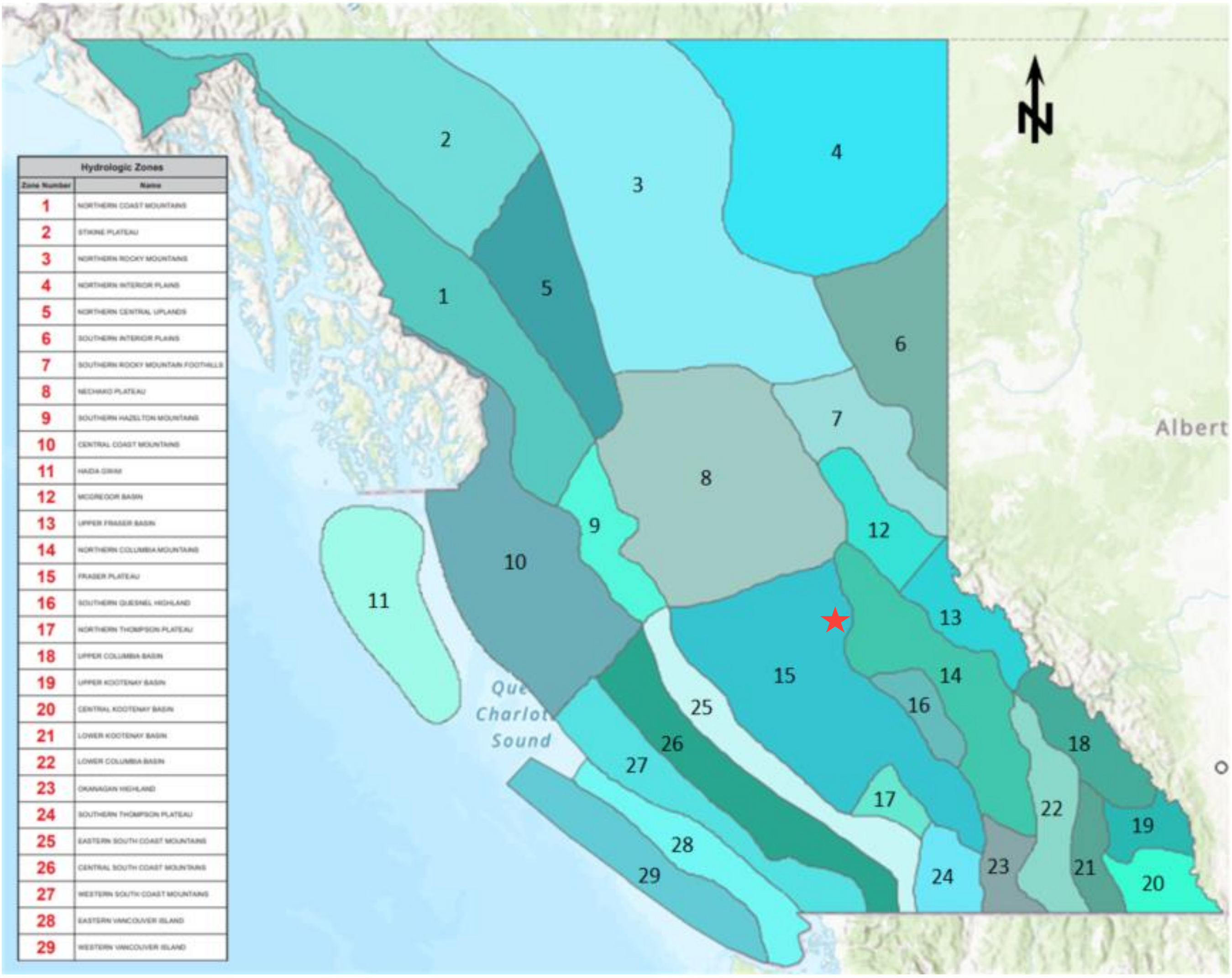

Figure 6 – Hydrologic Zones and Project Location (Ahmed, 2020)

KERSLEY CREEK DRAINAGE AREA

A hydrologic desktop study was conducted for the crossings, which included the delineation of the drainage areas upstream of the project, a review of nearby Water Survey of Canada (WSC) gauging stations and their published discharge records, as well as an estimation of the design discharge. Drainage areas were delineated using the Freshwater Atlas stream network lines as well as 1:20,000 scale topographic data published by the Government of British Columbia. Basins corresponding to the three culverts in Kersley Creek are presented in Figure 7 and cumulative drainage areas are summarized in Table 6-1.

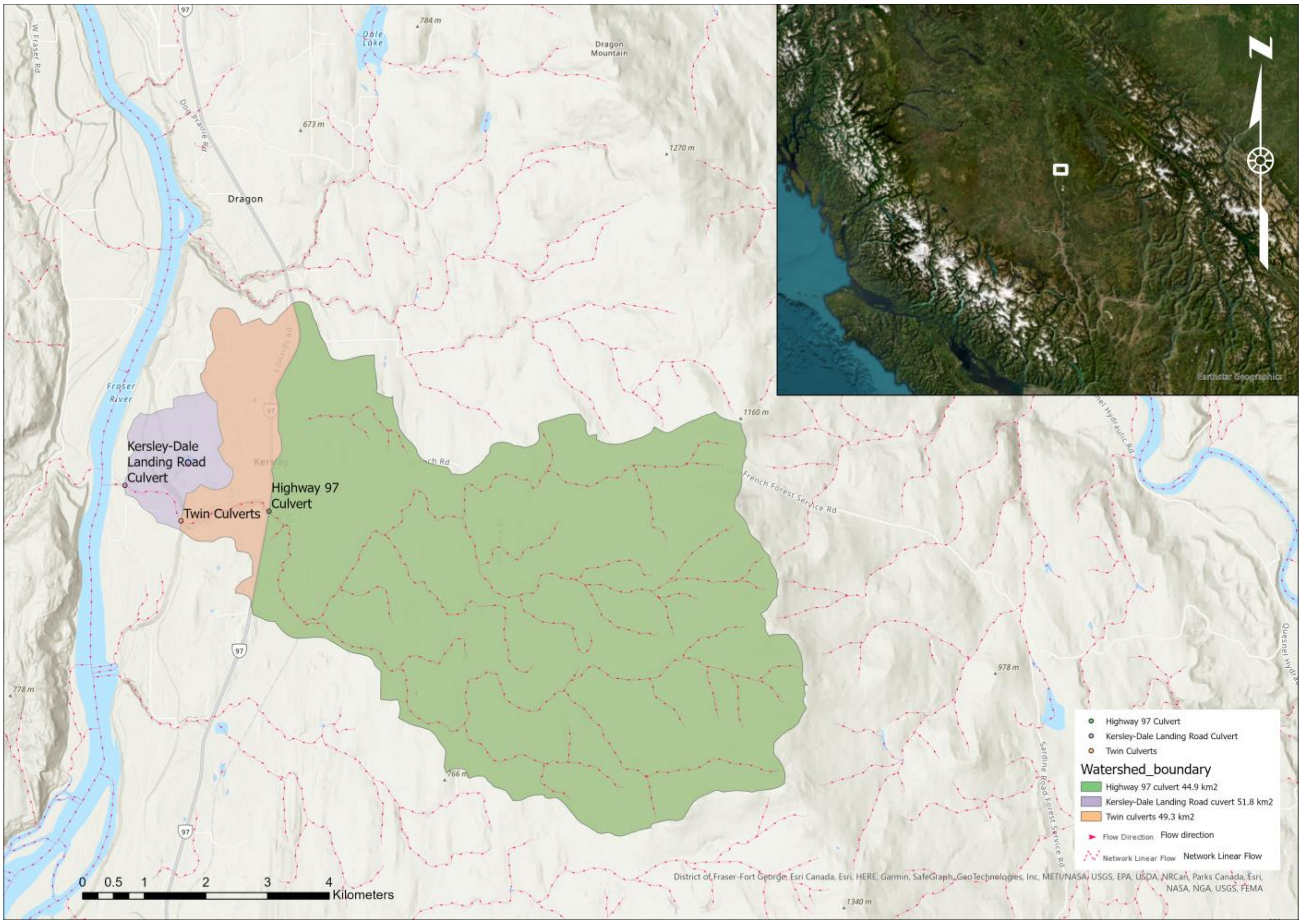

Figure 7 – Study area and culvert location map

Table 6-1 – Kersley Creek Drainage Areas

LOCATION	DRAINAGE AREA (KM^2)
Highway 97 culvert	44.9
Twin culverts at end of Kersley Creek Valley	49.3
Kersley-Dale landing road culvert	51.8

LOCAL STREAM GAUGE DATA AND ANALYSIS

Water Survey of Canada (WSC) stations were compared in terms of location/proximity to the study area, years of record, hydrologic zone, and terrain considerations.

One station and associated watershed being of comparable size to the study area was chosen for analysis. The basin of station 08MC045 – Sheridan Creek above McLeese Lake is located approx. 45 km south of Kersley Creek. It has similar topography and size and lies within the same hydrological Zone 15. It provides 23 years of records (instantaneous and mean daily extremes, 2000 – 2023).

A flood frequency analysis was completed to determine the peak instantaneous design discharges and unit flows for specified return periods, based on a statistical analysis of historical annual peak flow data. The Sheridan Creek gauge data was assessed, and the data passed the tests for independence, stationarity, and homogeneity. A distribution analysis was then completed, and the Weibull distribution was selected as the best fit for the frequency analysis.

The stations' location is shown in Figure 8. The gauge data is shown in Table 6-2.

It is notable that peak flow events typically occur between April, with some events occurring as early as mid-March and as late as May, suggesting that most peak flows may be rain-on-snow driven or heavy rain-driven events.

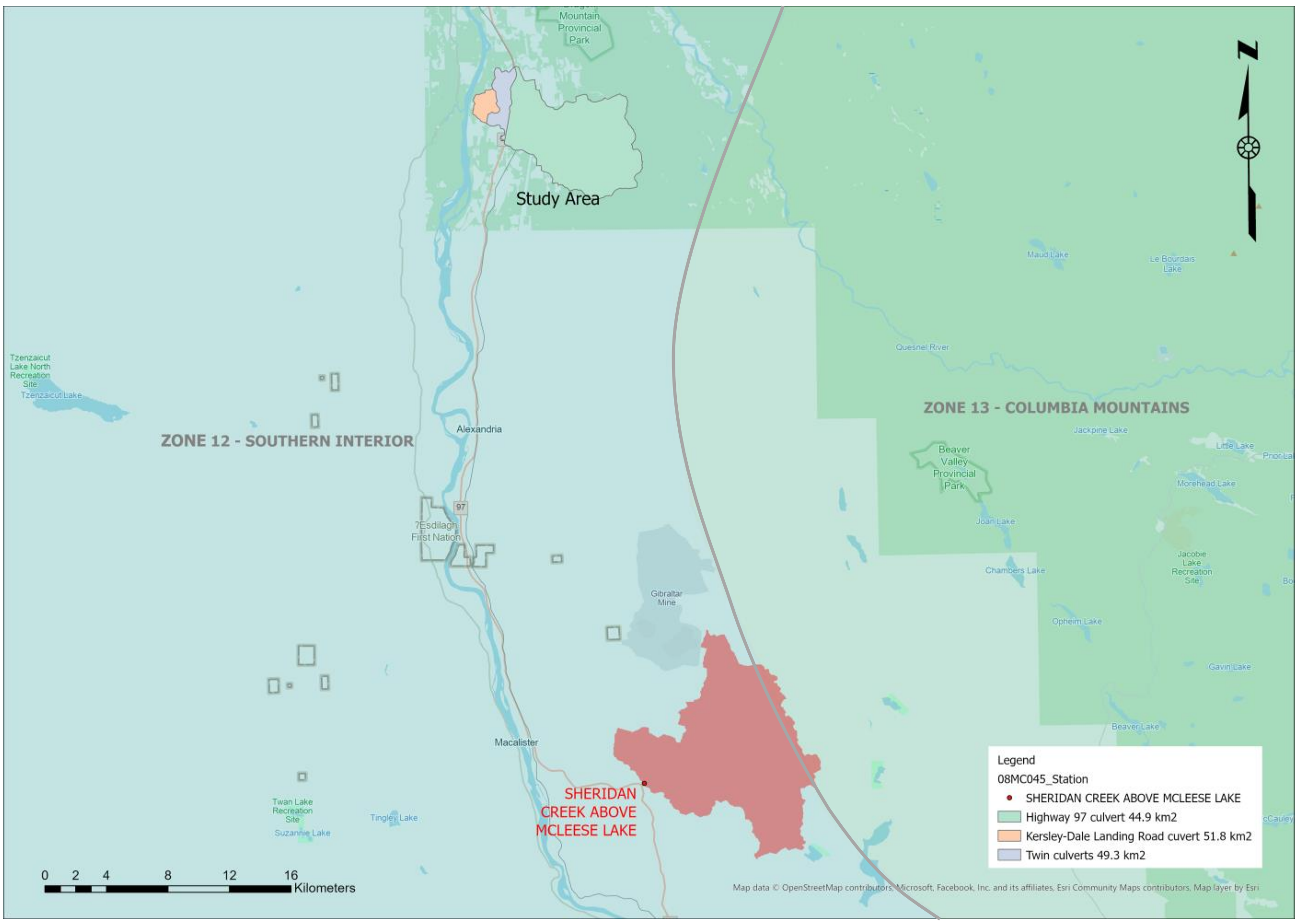

Figure 8 – Study area and WSC station with associated drainage areas

Table 6-2 – WSC Gauge Data

WSC STATION	ID NUMBER	NUMBER OF RECORDS	DRAINAGE AREA (KM^2)
Sheridan Creek Above McLeese Lake	08MC045	23	99

The Sheridan Creek gauge data was assessed and the data passed the tests for independence, stationarity, and homogeneity. A distribution analysis was then completed and the Weibull distribution was selected as the best fit for the frequency analysis.

To transfer the Sheridan Creek gauge 200-year flow to the project sites at Kersley Creek, the drainage area scaling method was used with the following formula:

$$Q_{ungauged} = Q_{gauged} \times \left(\frac{Area_{ungauged}}{Area_{gauged}}\right)^{b}$$

At Kersley Creek the basin transfer coefficient (b), based on published data from the BC Extreme Flood Project, is 0.85 (corresponding to ecozone/province 14.2), the drainage area for the Sheridan Creek gauge is 99 km^2 and the 100-year and 200-year flows for the gauge are 13.2 m^3/s and 14.5 m^3/s respectively. Flows from the WSC gauge Sheridan Creek have been transferred to the three Kersley Creek crossing locations. A summary of the flows established is presented in Section 8.0, Table 8-1.

The design discharge (Q100 + 15% Climate Change) that was used to estimate riprap sizes is 8.4 m^3/s based on the drainage area associated with the twin culvert location at the end of the creek.

COMPARISON OF WSC GAUGE DISTRIBUTIONS

Figure 9 is a distribution comparison for WSC Gauge 08MC045 – Sheridan Creek Above McLeese Lake. Return periods corresponding to non-exceedance probabilities can be calculated using the equation:

$$Return\ Period\ (years) = \frac{1}{(1 - Non\ exceedance\ probability)}$$

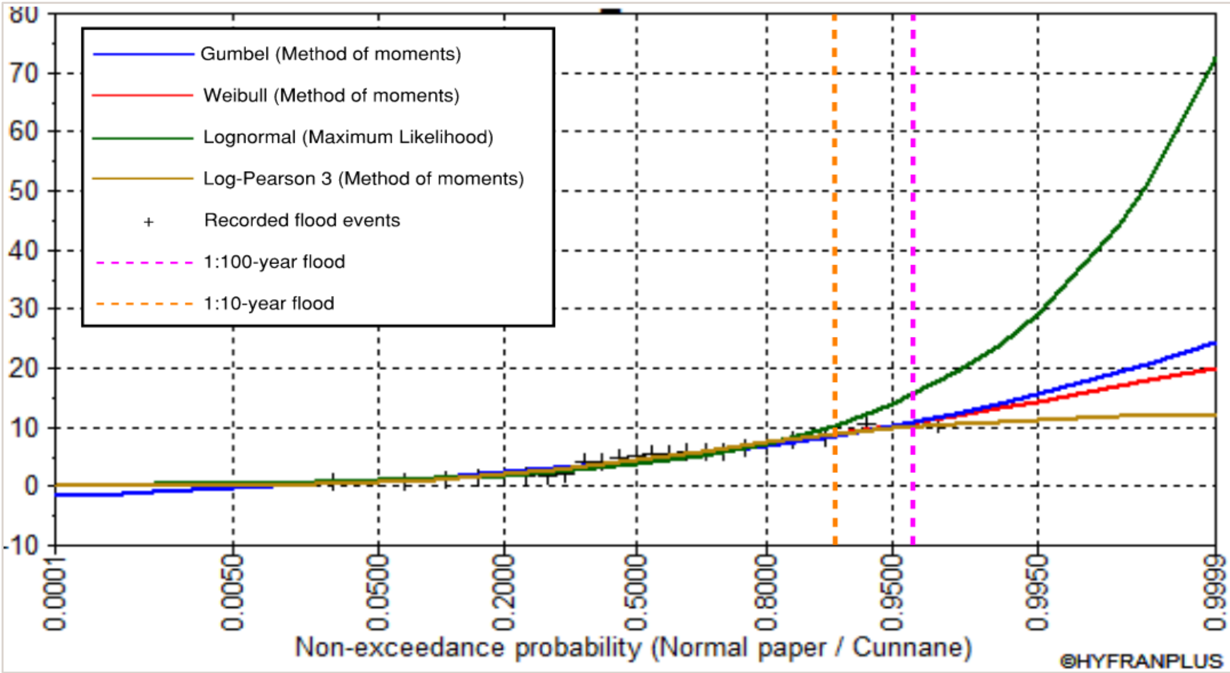

Figure 9 – Distribution Comparisons WSC Gauge 08MC045, 10-year and 100-year flood indication

Through visual comparison, high-flow events such as the 1:100-year flood, are predicted to be much higher based on the Lognormal distributions than the other 3 distributions, which show fairly similar results.

For low peak flow events, all distributions give similar results, although the Lognormal distribution gives slightly higher values. It is further noticeable that the Log-Pearson 3 distribution predicts only slight increases in discharges between high-flow events (non-exceedance probability over 0.95). The Weibull distribution is recommended. A comparison of the Bayesian information criterion and Akaike information criterion of different distributions is presented below.

Table 6-3 – Comparison of the Bayesian information criterion and Akaike information criterion of different distributions

DISTRIBUTION MODEL	1:100-YEAR FLOOD DISCHARGE	BAYESIAN INFORMATION CRITERION	AKAIKE INFORMATION CRITERION	COMMENTS
Weibull (Method of moments)	13.2	117	114	This is the best-fitted distribution with the lowest Bayesian information criterion and Akaike information criterion, which fits well for high flow events (non-exceedance probability over 0.95) as well as lower peak flow events such as 1:10-year flood (non-exceedance probability = 0.9).
Log-Pearson type 3 (Method of moments (BOB), base = 10)	11.1	118	115	Distribution may underestimate discharge for high-flow events.
Gumbel (Method of moments)	13.9	119	117	Bayesian and Akaike criteria are higher than for Weibull.
Lognormal (Maximum Likelihood)	23.8	121	118	Distribution may overestimate discharge for high-flow events and does not fit well for floods with a non-exceedance probability over 0.9 (1:10-year flood and higher). This distribution has the highest Bayesian and Akaike criterion, which indicates that the distribution does not fit well.

GAUGE ANALYSIS COMPARISON TO OTHER SOURCES

BC STREAMFLOW INVENTORY DATA

The design discharge 8.4 m^3/s as determined in the previous section, has been compared to the results from the BC Streamflow Inventory. The report titled “Inventory of Streamflow in the Cariboo Region” (Ahmed, 2017) evaluates WSC hydrometric station data up to and including 2012 and was reviewed to expand the regional analysis data to apply to Kersley Creek.

Results from the gauge analysis for the WSC Sheridan Creek gauge, which included all current data, were compared to the Inventory of Streamflow Data results as shown in Table 6-4. The frequency analysis results for our analysis of the 100-year flow using the Weibull distribution appear to be a better fit for this site than the results from the Extreme Flood Project using a Log Pearson III distribution. The Weibull distribution gives the lowest Bayesian information criterion and Akaike information criterion, while the Log Pearson III distribution might underestimate discharge for high-flow events (refer to Figure 9 and Table 6-3 for comparison of the goodness of fit).

Table 6-4 – Flow (200-year) comparison for Sheridan Creek Gauge

WSC STATION	ID NUMBER	CURRENT STUDY WEIBULL (M^3/S)	STREAMFLOW INVENTORY LOG PEARSON III (M^3/S)
Sheridan Creek Above McLeese Lake	08MC045	13.2	16.1

Results from the local stream gauge analysis and Inventory of Streamflow in the Cariboo Region are comparable, however, the Streamflow inventory only includes data until 2012, while the frequency analysis conducted as part of this study includes instantaneous and mean daily extremes until May 2023 (inclusive).

BC EXTREME FLOOD DATA

Results from the local stream gauge data analysis have further been compared to the British Columbia Extreme Flood Project, Regional Flood Frequency Analysis – Technical development report and manual (NHC, 2020).

Analysis and results for the Sheridan Creek gauge published in the Extreme Flood Project study (NHC, 2020) were compared to the local stream gauge analysis above. The published 1-day 100-year flow is 21.9 m^3/s based on a Log-normal distribution. This was scaled up to the peak instantaneous flow using a factor of 1.164 (NHC, 2020), resulting in a 100-year peak flow of 25.5 m^3/s. Based on the distribution analysis completed for Sheridan Creek, the Log-normal distribution is not a good fit for this gauge specifically and it results in a flow nearly two times the predicted flow established in this study using the Weibull distribution. The variance between resulting flows for Sheridan Creek potentially points to inaccurate results for this specific area.

The Extreme Flood Project used distributions selected based on generic criteria applied province-wide, which may not be representative of this specific location. Consequently, results from the BC extreme flood project (NHC, 2020) have been omitted from further analysis in this study.

7.0 CLIMATE CHANGE PROJECTIONS

GENERAL CLIMATE CHANGE PROJECTIONS

IDF_CC (version 6.5), a tool developed by Western University (https://www.idf-cc-uwo.ca/idfstation) generates historical and projected rainfall IDF summaries from Environmental Canada meteorological stations. Using the Kersley station IDF data (ID 1094125), the 100-year, 24-hour rainfall was used. The corresponding 200-year rainfall for the historical and projected scenarios was then estimated using the Gumbel distribution, which resulted in a projected increase of 24%. The tabulated summary is included in Table 7-1:

Table 7-1 – IDF CC Short-Duration Rainfall Projections

STATION NAME	STATION ID	YEARS OF DATA	100-YEAR, 24-HOUR RAINFALL (MM)	200-YEAR, 24-HOUR RAINFALL (MM)	PROJECTED 200 YEAR*, 24-HOUR RAINFALL (MM)	% INCREASE
Kersley	1094125	11 (1981 – 1992)	43.4	46.3	57.4	24

*200-year rainfall depth projected from 50- and 100-year rainfall data using Gumbel distribution

Pacific Climate Impacts Consortium (PCIC) have developed regional projections on a seasonal basis, available through their Plan2Adapt tool (https://www.pacificclimate.org/analysis-tools/plan2adapt), which are presented in Table 7-2 below.

Climate change projections were summarized from 2070 through 2100, or 50-80 years from the present. Projections were targeted for the 2080s (2070-2100). PCIC projections suggest that for the Cariboo Region, winter precipitation may increase by 11% for the median, and 17% for the 90th percentile, with an annual median increase in precipitation of 9.2% (21% for the 90th percentile). There is also expected to be less precipitation as snow; a median of -38% or -46% at the 10th percentile on an annual basis. Since these are annual and seasonal projections, variation on a daily time-scale is not accounted for and these numbers may differ from trends in extreme rainfall events.

Table 7-2 – PCIC Plan to Adapt Tool for the Cariboo Region, Climate Parameters Projected for the 2080s

CLIMATE VARIABLE	**SEASON**	PROJECTED CHANGE FROM 1961 – 1990 BASELINE	
		Ensemble Median	**Range (10th to 90th percentile)**
Temperature (°C)	Annual	+5.0 °C	+3.7 °C to +6.6 °C
Precipitation (%)	Annual	+9.2%	+2.7% to +21%
	Summer	-5.0%	-29% to +18%
	Winter	+11%	+1.9% to +17%
Precipitation as Snow* (%)	Annual	-38%	-46% to -35%

CAUTION: This variable may have a low baseline. See note 2 below.	Winter	-25%	-35% to -20%
	Spring	-60%	-72% to -51%

IDF CC and PCIC projections suggest that climate change in the Cariboo Region is anticipated to increase the frequency and intensity of rainfall events. The shoulder seasons of spring and fall may see more rain on snow events, with a dramatic, short freshet. There may be a long-term reduction in snowpack with warmer winters, however, it is not likely that snowpack will be eliminated.

CLIMATE CHANGE EXTREME PROJECTIONS

PCIC has developed the Climate Explorer – Extreme Streamflow web application, containing climate model-derived data and hydrologic model analysis for watersheds within the region of the Fraser River basin. The climate model used by PCIC for the tool is CanESM2 [Canadian Centre for Climate Modelling and Analysis ESM2 (Earth System Model ver. 2)] with an RCP 8.5 emissions scenario.

Figure 10 depicts the selected watershed area from the PCIC tool with the Kersley Creek watershed area shown for comparison. Figure 11 shows streamflow projections for the 200-year return period from 1951 to 2071 for the PCIC area. The output graph shows predicted trends in peak annual 1-day streamflow for the 200-year return period event, showing the mean as well as the 2.5 and 97.5 percentiles. The label rXi1P1 is an indication of the GCM scenario used (rX is meant to convey that the data derives from pooling together of multiple ensemble members for each period, r stands for realization, i stands for initialization, and p stands for physics, followed by an integer).

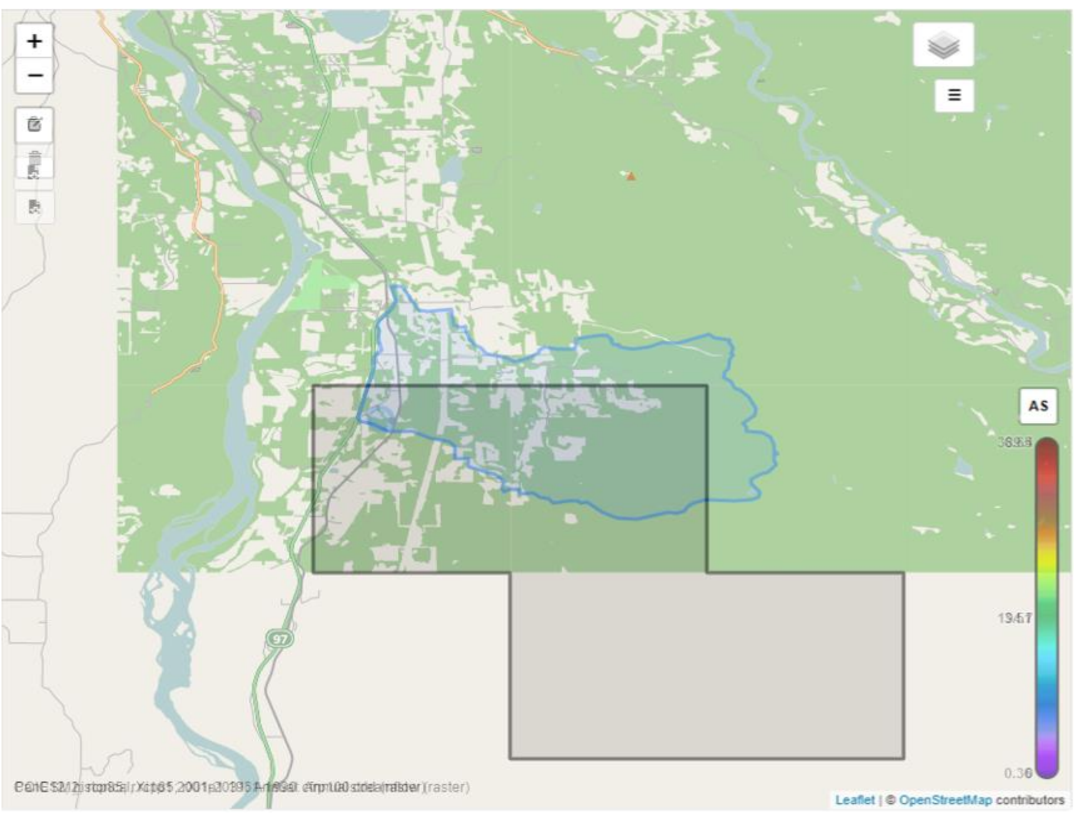

Figure 10 – PCIC Extreme Streamflow tool, selected polygon in black, delineated study area in blue

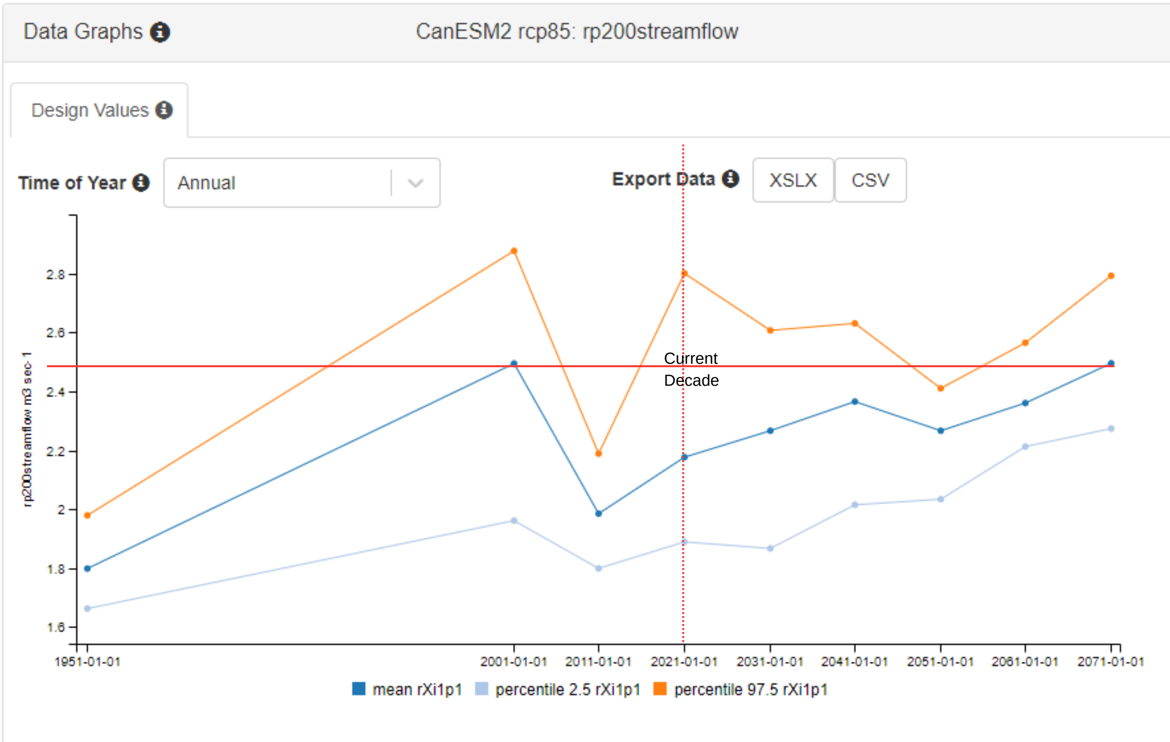

Figure 11 – PCIC Extreme Streamflow projections from 1951 to 2071, the 200-year return period for the assumed drainage area (April 2023).

The 200-year flows can not be used directly for Kersley Creek because the drainage areas are different, however, the data can be applied for an indication of climate change trends over time. The results do provide a relative indication of how climate change might impact the design flows at this location and can inform the determination of the climate change adjustment factor. Based on the trendline of mean data projections, there is anticipated to be an increase of 15% from current conditions to the end of the projected timeseries.

CLIMATE CHANGE SUMMARY

Data captured in the PCIC Climate Explorer suggests an increase of 15% in streamflow for the study area between the 2021 and 2071 projected periods using the mean data points. This aligns with the annual median and 90th percentile increase in precipitation of 9.2% and 21% respectively determined for the Cariboo Region. An increase in design flows of 15% is therefore recommended for the climate change adjustment.

8.0 DESIGN FLOW

The design discharges at Kersley Creek are summarized in Table 8-1.

Table 8-1 – Design discharge summary at Kersley Creek

CROSSING	DRAINAGE AREA km^2	Q100 m^3/s	Q100 + CC m^3/s	Q200 m^3/s	Q200 + CC m^3/s
Highway 97 Culvert	44.9	6.7	7.8	7.4	8.5
Twin Culverts at end of Kersley Creek Valley	49.3	7.3	8.4	8.0	9.2
Kersley-Dale Landing Road Culvert	51.8	7.6	8.8	8.4	9.6

9.0 HYDRAULICS

Manning's equation was used to provide estimated velocities and design flow depths in Kersley Creek for the Q100 flow plus 15% climate change. The LiDAR data appears to capture the channel definition in Figure 12, however, survey data should be used in a future design phase, if required. Our hydraulic analysis and recommendations for this memo consider the level of detail expected with the data available with relevant comments provided on accuracy and where additional data may be required.

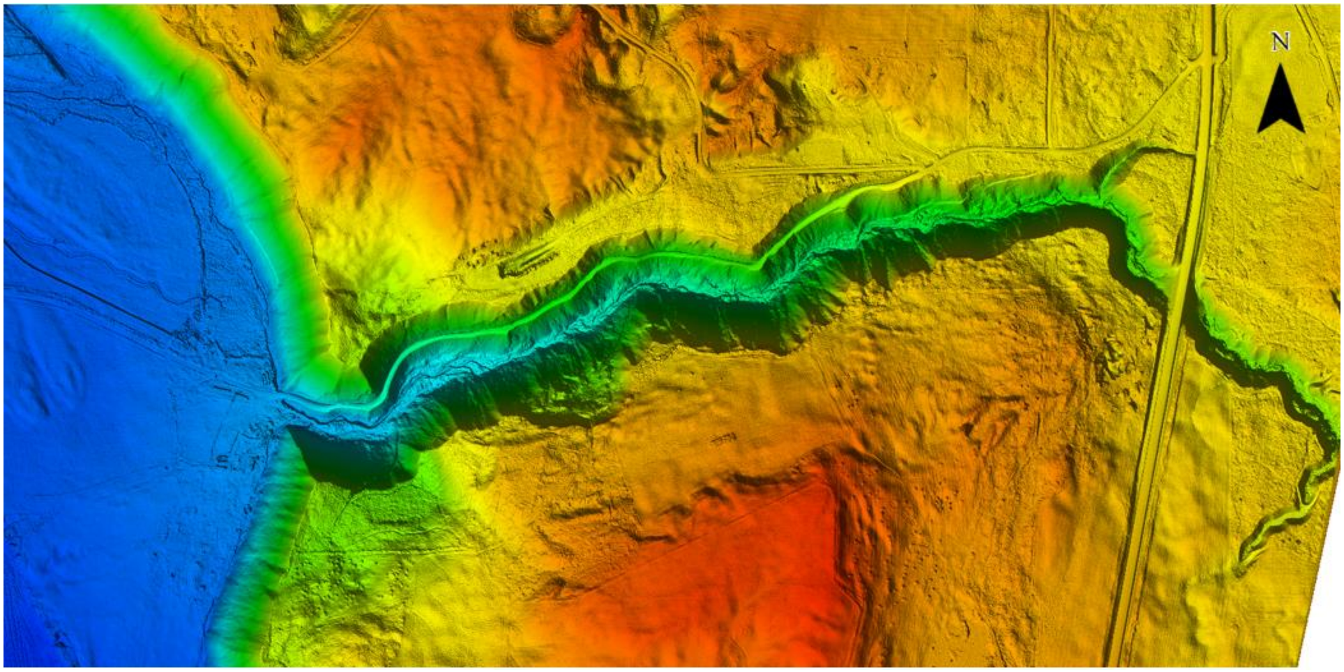

Figure 12 – Kersley Creek LiDAR (MOTI, May 2023)

A general trapezoidal shape was estimated, and channel slope information is based on the available lidar data.

We estimated the design discharge to be the same for all of Kersley Creek by using the design discharge of 8.4 m^3/s (including 15% climate change) at the twin culverts at the end of Kersley Creek valley. The estimated channel parameters are provided in Table 9-1.

Table 9-1 – Estimated Channel Parameters

	STREAMBED WIDTH (M)	CHANNEL SLOPE (M/M)	BANK SLOPE (H:1)	BED ROUGHNESS	VELOCITY (M/S)	FLOW DEPTH (M)
Straight River	3	0.034	2	0.037	3.1	0.6
Curved River	3	0.034	2	0.043	2.7	0.7

10.0 CONCEPTUAL DESIGN CONSIDERATIONS-KERSLEY CREEK VALLEY

STREAMBED AGGRADATION / DEGRADATION

There is a potential that Kersley Creek within the study area could be subject to aggradation or degradation over time. In the relatively steep section of channel within the valley degradation could be a risk, and in the flatter section downstream of the valley there could be a risk of aggradation. The 2900 mm dia. CSP culvert design report (NHC Draft Report dated September 15, 2015) discussed the potential degradation of the streambed in the vicinity of the Kersley Land Road culvert crossing. As stated in this report, channel degradation was observed to extend approximately 60 m upstream of the Kersley-Dale landing road following the culvert washout in 2015. It was noted that the culvert was plugged during the spring 2015 event as noted by MOTI staff. The blockage may have resulted in backwatering upstream until the road overtopped, causing failure of the road fill. The large backwater related to the road failure could have resulted in significant degradation in the proximity of this crossing, especially upstream. The sequence of events was unconfirmed but deemed likely in the report. The washout in 2015 caused degradation along the channel for approximately 60 m upstream, at which point there is a small step that transitions to a narrower, more stable channel. Armouring the nick point with riprap was considered to help prevent degradation from affecting the channel further upstream. This erosion protection was mentioned as it could be added upstream. It was recommended that the site be monitored for degradation and that a mitigation plan be developed as needed.

Aggradation and/or degradation cannot be ruled out based on the available information. Further investigation into sediment transport and channel bed elevation changes should be completed by a geomorphologist in the design phase if required.

EROSION PROTECTION AND TOE EROSION

The presence and extent of existing toe erosion of the valley banks caused by the creek channel are unknown (Westrek, 2021) and the need for armouring the channel as part of potential roadway upgrades was considered at a conceptual level. For this purpose, riprap was considered for erosion protection along the length of Kersley Creek from the Highway 97 culvert to the twin culverts near the bottom of the valley. Turf reinforcement was also considered as an option; however, it requires an established grass and root system to hold the turf reinforcement in place during flow events. Due to the shaded valley and tree cover, vegetation growth may be difficult to rely on. The use of this type of matting in a channel is also a risk to fish and fish habitat if it were to fail and be transported downstream during an event.

Conceptual riprap sizing was based on channel flow velocities and flow depths estimated from the culvert hydraulics. Two gradation types of rock riprap are proposed. Class 25 kg riprap is recommended for straight channel stretches. Class 250 kg riprap is recommended for the curved channel stretches and protection of the culvert. The rock is assumed to be placed in a trapezoidal channel shape with a bottom width of 3 m, and 2H:1V side slopes. The nominal thickness of the riprap is 0.45 m for Class 25 kg riprap and 1.0 m thickness for Class 250 kg riprap. For conceptual purposes at this stage in the project we recommend lining both sides and the bottom of the channel with riprap to prevent degradation and impacts to either side of the valley due to erosion.

In addition to placing rocks, adding spawning gravel could enhance the habitat. A layer of gravel could be placed over the riprap to improve the habitat. Further investigation with additional environmental input, such as a habitat assessment, could be conducted during a future design phase if necessary.

RIPRAP SIZING

Preliminary riprap sizing for erosion protection in the open channel was assessed. Riprap sizing is computed from the USACE relationship recommended by TAC Guide to Bridge Hydraulics. The equation is:

$$\frac{D}{y} = S_f C_s C_v C_T \left[\frac{V^2}{(s-1)k_t g y}\right]^{1.25}$$

Where S_f is the safety factor, here a typical value of 1.1 is chosen. C_s = 0.375 is the stability coefficient for rounded rock, C_T = 1 is the thickness coefficient, s = 2.5 is the dry rock density relative to water. For a side slope of 2H:1V, the side slope factor k_t is 0.9. The local velocity, V, and the local flow depth, y, are based on the results of the Manning's equation hydraulic model for the channel. For Kersley Creek the typical channel is assumed relatively straight compared to the width and C_v=1, for stretches of curved channel C_v=1.16.

For the proposed opening, the minimum rock size was computed as shown in Table 10-1 below.

Table 10-1 – Riprap sizing summary table

FLOW SCENARIO	LOCAL VELOCITY [M/S]	LOCAL FLOW DEPTH [M]	MINIMUM MASS (M50) [KG]	RIPRAP CLASS [KG]
Straight channel – Q100 + CC design flows	2.4	0.6	13	25
Curved channel – Q100 + CC design flows	3.4	0.7	216	250

EROSION PROTECTION QUANTITIES

Based on the concerns in relation to the current Kersley-Dale Landing Road alignment on top of Kersley Creek erosion protection in the form of riprap is proposed to protect the channel bed from sediment migration, degradation and aggradation, as well as to help stabilise the roadside slopes.

Lining Kersley Creek from the Highway 97 culvert to the twin culverts near the bottom of the valley two types of rock riprap gradations are proposed to mitigate degradation, aggradation and protect the road slopes. For straight channel sections (1,450 m in length) a Class 25 Riprap is being proposed, and Class 250 Riprap for curved sections along the channel as well as to protect the culverts (200 m in length). These lengths are estimated based on the current horizontal alignment of the channel, with the assumption that some straightening of the channel would be done as a result of the channel work. Riprap sizing at curved sections is conservatively applied to account for unknowns in the final channel geometry and layout.

Conceptual riprap sizing and related quantities are summarized in Table 10-2.

Table 10-2 – Riprap sizing and quantities

	CLASS (KG)	HEIGHT (M)	THICKNESS (M)	LENGTH (M)	QUANTITY (M3)
Straight Channel	25	0.91	0.45	1,450	5,000
Curved Channel	250	0.97	1.00	200	1,500

11.0 KERSLEY-DALE LANDING ROAD CULVERT DRAINAGE CONSIDERATIONS

The proposed roadway design includes a drainage ditch with an outlet into Kersley Creek at the inlet of the existing culvert, which is a 2900 mm CSP, partially filled with substrate. The capacity of the existing culvert has been reviewed to determine if the additional ditch flow can be accommodated.

CULVERT DATA AND DESIGN PARAMETERS

The design parameters of the existing culvert based on the original design and current model data sources are summarised in Table 11-1. The Kersley-Dale landing road culvert drawing is included in Appendix A.

Table 11-1 – HY-8 Design Parameters

	VALUE	COMMENT
Culvert Dimensions	2900 mm dia. round CSP	As per historical hydrotechnical design brief, Drawing No. 0003-176-2, Profile (NHC, 2016)
Culvert Inlet Invert	461.61 m	As per historical hydrotechnical design brief, Drawing No. 0003-176-2, Table 1 – WP2 Elevation (NHC, 2016)
Culvert Outlet Invert	460.85 m	As per historical hydrotechnical design brief, Drawing No. 0003-176-2, Table 1 – WP3 Elevation (NHC, 2016)
Embedment	1.19 m	As per historical hydrotechnical design brief, Drawing No. 0003-176-2, Profile (NHC, 2016): El. 462.41 m [Top of streambed] – El. 461.22 m [Steel Invert Elevation] = 1.19 m [Embedment] Note: The culvert fill material is defined as streambed material as noted in the drawing legend.
Manning's n	0.024 (Top/Sides)	Typical CSP culvert roughness.
	0.05 (Channel and Culvert Bottom)	Within range of historical hydrotechnical design report draft, Table 4 – Base value range 0.04 to 0.065 (NHC, 2015)
Channel Dimensions	Bottom width = 3.0 m Side Slope = 1.5:1 (H:V)	As per historical hydrotechnical design brief, Drawing No. 0003-176-2, Section B (NHC, 2016)
Channel Slope	0.036 m/m	As per historical hydrotechnical design brief, Drawing No. 0003-176-2, Note 3.4 (NHC, 2016)
Channel Invert Elevation Downstream	462.04 m	As per historical hydrotechnical design brief, Drawing No. 0003-176-2, Table 1 (NHC, 2016): El. 460.85 m [WP3] + El. 1.19 m [Embedment] = El. 462.04 m [Channel Invert Elevation]

MODEL CALIBRATION

A hydraulic model of the existing culvert was developed using HY-8 software (software version 7.80.0), and the results have been compared to the 2016 design HEC-RAS model. See Appendix B for model result details. The HY-8 model results were validated by comparing the water surface elevation with the 2016 HEC-RAS model results. The water surface elevation from the HY-8 model was consistent with the 2016 model within 0.1 m elevation (Table 11-2 shows the comparison). The results are within reasonable matching accuracy and are considered equivalent for the purpose of this analysis.

Table 11-2 – Model Results Comparison

	HEC-RAS MODEL (2016)	HY-8 MODEL (2023)
LOCATION	WATER SURFACE ELEVATION	WATER SURFACE ELEVATION
Upstream	464.5 m	464.4 m
Downstream	462.8 m	462.9 m

COMBINED FLOWS AND CULVERT MODEL RESULTS

The increased 100-year design flow for Kersley Creek resulting from the additional ditch flow has been assessed, and the resulting freeboard at the existing culvert has been calculated with the new model. The increased design flow, combining the original design flow for the culvert, and the added ditch flow was assessed using two methods as described below.

Combined Flows Method 1 - Sum of Flows

1) The 2023 100-year design flow, including climate change, is 8.8 m^3/s. Adding the new 100-year return period storm design flow from the ditch, including climate change, of 1.74 m^3/s increases the overall design flow to 10.5 m^3/s. This flow results in a negative freeboard of -0.29 m as shown in Table 11-4. During a flood event, the predicted flow velocities through the culvert are expected to mobilize and remove the existing streambed fill material inside the culvert. The removal of 0.22 m of material would result in +0.02 m of freeboard.

2) During a design event, it's improbable that the culvert and ditch flow peaks will coincide. The coincidental occurrence of the peak flows was considered given the difference in the contributing drainage area's size and characteristics, which was done to refine the design flow from Step 1 above. The Hydraulic Engineering Circular 22 (HEC-22) by the Federal Highway Administration outlines frequencies of coincidental occurrence for a main stream and a tributary based on the drainage area ratio as shown in Table 11-3. The drainage ratio in this case is 274:1 since the original drainage area is 51.8 km^2 and the new ditch drainage area is 0.19 km^2 (19.1 ha). This area ratio is closest to the 100 to 1 shown in the table. Based on the table for the 100-year design, Kersley Creek and the ditch flows have frequency combinations of 100-year and 25-year, or 25-year and 100-year.

Table 11-3 – Frequencies for coincidental occurrence from HEC-22

Table 7-3. Frequencies for Coincidental Occurrence.

Area Ratio	Frequencies for Coincidental Occurrence			
	10-Year Design		100-Year Design	
	Main Stream	Tributary	Main Stream	Tributary
10,000 to 1	1 10	10 1	2 100	100 2
1,000 to 1	2 10	10 2	10 100	100 10
100 to 1	5 10	10 5	25 100	100 25
10 to 1	10 10	10 10	50 100	100 50
1 to 1	10 10	10 10	100 100	100 100

For a design scenario, a 100-year event for Kersley Creek combined with a 25-year flow event in the ditch was considered, which represents a reasonable design scenario. The ditch 25-year return period storm design flow, including climate change, is 0.91 m^3/s, resulting in an overall design flow of 9.7 m^3/s. This flow results in a freeboard of -0.15 m as shown in Table 11-4. During a flood event, a loss of streambed fill material inside the culvert can be assumed. The removal of only 0.15 m of material would result in +0.05 m of freeboard, which is consistent with design the design criteria.

Combined Flows Method 2 - Additional Drainage Area

1) The original drainage area established in Section 6 was 51.8 km^2. Adding the new ditch drainage area of 0.19 km^2 (19.1 ha) increases the drainage area to 52.0 km^2. As the increase in the drainage area is insignificant, the design flow would remain the same at 8.8 m^3/s. This flow results in a small negative freeboard of -0.1 m as shown in Table 11-4.

Combined Design Flow Summary

A summary of the various flow scenarios and the resulting freeboard at the existing culvert inlet is provided in Table 11-4.

The recommended design flow established in Section 6 is based on drainage area and Regional Frequency analysis, which does not account for individual streams, ditches, or tributaries. Therefore, the "Additional Drainage Area" method is consistent with the design methodology used in the report and is considered to be an appropriate design flow for the culvert for the proposed ditch upgrade conditions. The higher flows are possible when considering the "Sum of Flows" method is more conservative and could be considered as a 'check' flow, with the riprap design for that scenario.

Table 11-4 – HY-8 Model Results

FLOW SCENARIO	FLOW (M^3/S)	FREEBOARD (M)
Flow (2016)	8.2	0.09
Flow (2023) with Climate Change (Report Section 6)	8.8	-0.01
Flow (2023) with Climate Change and 25-Year Ditch Flow (Sum of Flows)*	9.7	-0.15
Design 'Check' Flow (2023) with Climate Change and 100-Year Ditch Flow (Sum of Flows)**	10.5	-0.29
Design Flow (2023) with Climate Change and Ditch Flow Area (Add. Drainage Area)***	8.8	-0.01

Notes:
*Original flow = 8.8 m^3/s, plus adjusted increased flow (0.91 m^3/s) = 9.7 m^3/s for the updated flow.
**Original flow = 8.8 m^3/s, plus adjusted increased flow (1.74 m^3/s) = 10.5 m^3/s for the updated flow.
***Original Drainage Area = 51.8 km^2, plus adjusted drainage area of 0.19 km^2 (191 ha) = 52.0 km^2. The flow is unchanged 8.8 m^3/s.

Culvert Capacity Conclusion

The existing Kersley Creek culvert can reasonably accommodate the increased ditch flow. Further, this analysis does not consider the potential reduction in design flows as a result of suspected subsurface flows upstream, which could reduce the risk of flows exceeding the culvert capacity. And, during a flood event, it's likely that the streambed material in the culvert would partially wash out and provide additional capacity. The potential negative freeboard at the 'check' flow scenario presents a minor risk, which can be mitigation with adequate erosion protection above the culvert.

EROSION PROTECTION REVIEW

Site photos between October 2021 and May 2023 have been compared to determine the potential loss of riprap erosion protection both upstream and downstream of the culvert, indicating vulnerable areas that may require repairs (see Figure 13 and Figure 14).

Figure 13 – View upstream; left photo October 2021, center photo March 2022, right photo May 2023

Figure 14 – View downstream; left photo March 2022, right photo May 2023

No major movement of the riprap was observed, and the culvert remains protected in place. Based on the photos, there is no need to extend the erosion control at the culvert upstream or downstream.

CULVERT SUMMARY AND RECOMMENDATIONS

Channel Erosion Protection

Erosion protection appears to be stable both upstream and downstream of the crossing. The hydrotechnical design brief, Drawing No. 0003-176-2 (NHC, 2016) recommended the site be monitored for degradation and that a mitigation plan be developed if required. The upstream and downstream channel erosion protection is not recommended to be extended at this time.

Upstream Erosion Protection

Extending the existing Class 100 kg riprap to tie in with the ditch drainage riprap is recommended, with details to be determined after the ditch design has been completed.

Riprap erosion protection should also be raised above the culvert invert to protect against the design ‘check’ flow of 10.5 m^3/s. Adding 0.3 m freeboard above the design ‘check’ flow elevation results in a height of 0.6 m above the inlet of the culvert.

Downstream Erosion Protection

The preliminary hydrotechnical design report (NHC, draft 2015) stated that MoTl staff have noted that the original 1200 mm dia. culvert was plugged during the spring 2015 flood event. The blockage resulted in backwatering upstream until the road overtopped, causing failure of the road fill. The culvert is in a sag in the road and to address the risk of an extreme event overtopping the road the original design, Drawing No. 0003-176-2 (NHC, 2016), recommended placing riprap on the downstream end to the top of the road elevation to mitigate risk of culvert washout if the culvert is blocked with large woody derbis (LWD). The riprap was originally placed lower than the design and it is recommended to raise the outlet riprap to the road shoulder to increase the resiliency of the crossing. Further investigation identified right of way restrictions that will require work within the existing right of way. The additional riprap has been modified to fit inside the existing right of way.

Riprap Volumes

The following riprap quantities are recommended.

Table 11-5 – Riprap Quantities for Culvert Drainage Considerations

LOCATION	CLASS (KG)	QUANTITY (M^3)
Culvert Inlet	100	19
Culvert Outlet	100	31

12.0 SUMMARY AND RECOMMENDATIONS

The purpose of this memo is to provide hydrotechnical information for potential work on Kersley Creek, specifically to inform the conceptual engineering of slope stabilizations below the Kersley-Dale Landing Road. Kersley Creek has steep slopes that have experienced significant slope failures over the years. A desktop hydrologic analysis of the project area, an initial hydrotechnical analysis of the existing channel as well as conceptual considerations for erosion protection of the channel to repair and upgrade Kersley-Dale Landing Road were considered to help the team determine the feasibility and costs and provide a basis for further hydrotechnical analysis and design on Kersley Creek. This memo is based on a desktop study and relies on limited information from field personnel.

The hydrological analysis included the delineation of the Kersley Creek drainage area and a basin transfer to determine the 100-year design flow discharge to the creek. A design discharge (Q100 + 15% Climate Change) of 8.4 m^3/s has been established.

The climate change analysis detailed in this memo utilized the PCIC Climate Explorer data. The data captured suggests an increase of 15% in streamflow for the study area between the 2021 and 2071 projected periods using the mean data points. This aligns with the annual median and 90th percentile increase in precipitation of 9.2% and 21% respectively determined for the Cariboo Region. An increase in design flows of 15% is therefore recommended for the climate change adjustment.

Streambed degradation within the Kersley Creek Valley cannot be ruled out based on the available information. At a conceptual level, it is recommended to protect the Kersley Creek with rock riprap to reduce the risk of degradation and erosion of the channel banks which could destabilize the Kersley-Dale Road embankment. Quantities for lining the creek from the Highway 97 culvert to the twin culverts near the bottom of the valley are proposed as follows (Table 12-1). The Class 25 kg riprap for 'straight channel sections' is based on assumed typical geometry. The Class 250 kg riprap for 'curved channel sections' is conservatively sized to account for unknown channel layout details.

Table 12-1 Design channel dimensions, riprap class and quantities

CHANNEL GEOMETRY	CHANNEL BOTTOM WIDTH (M)	CHANNEL SLOPES (H:V)	CLASS (KG)	QUANTITY (M3)
Straight Channel	3	2:1	25	5,000
Curved Channel			250	1,500

If upgrades to the length of Kersley-Dale Landing Road alongside Kersley Creek is pursued, additional information and analysis will be required to refine the erosion protection details. These steps should include the following:

- Survey data and detailed site inspection will be required to verify the presence and extent of existing erosional scour along the channel. The most up to date LiDAR should be used in combination with the survey.
- Additional field investigation could be completed to better understand the water diversion channel and subsurface flow potential downstream of the valley. In addition, the landowner of the water diversion device could be consulted during a field visit to further estimate the diversion flow potential and timing.
- Habitat impact sensitivity is a key component that requires further understanding. Environmental coordination will be required for riprap placement and environmental permitting. Additional design options like riffles or steps should be considered in the detailed design phase, if required, for fish habitat and to limit the use of riprap. Further input from the environmental and geotechnical teams will be critical to refine the conceptual details of the options presented in this report. Multidisciplinary discussions should be conducted during a future design phase to assess possibilities of optimizing the use of riprap and minimizing associated costs.
- Investigation into the potential ongoing degradation and/or sedimentation of Kersley Creek within the project area should be completed, which should include input from a geomorphologist.

- Analysis of the existing culvert crossing of Kersley Dale Landing Road under the proposed road upgrade conditions concluded that the culvert capacity is adequate. For increased resilience, it is recommended to add additional Class 100 kg riprap to the upstream and downstream ends. The riprap has been modified to fit inside the existing right of way. The following riprap quantities are recommended.

Table 12-2 – Riprap Quantities for Culvert Drainage Considerations

LOCATION	CLASS (KG)	QUANTITY (M^3)
Culvert Inlet	100	19
Culvert Outlet	100	31

13.0 CLOSURE

We trust this memorandum meets your current needs. If you require additional information or have any questions, please contact our office.

ACRONYMS AND ABREVIATIONS

BC	British Columbia
CanESM2	Canadian Centre for Climate Modelling and Analysis ESM2 (Earth System Model ver. 2)
CC	Climate change
CHBDC	Canadian Highway Bridge Design Code
CSA	Canadian Standards Association
CRRP	Cariboo Road Recovery Projects
CSP	Corrugated Steel Pipe
GCM	Global Climate Model
HEC-RAS	Hydraulic Engineering Center – River Analysis System
IDF	Intensity-duration-frequency
LiDAR	Light Detection and Ranging
MDT	Multidisciplinary Design Team
MOTI	Ministry of Transportation and Infrastructure
NHC	Northwest Hydraulic Consultants
NHN	National Hydro Network
PCIC	Pacific Climate Impacts Consortium
RCP	Representative Concentration Pathway
rXi1P1	rX is meant to convey that the data derives from pooling together of multiple ensemble members for each period, r stands for realization, i stands for initialization, and p stands for physics, followed by an integer
SPCSP	Structural Plate Corrugated Steel Pipe
TAC	Transportation Association of Canada
USACE	United States Army Corps of Engineers
USL	Urban Systems Ltd
WSC	Water Survey of Canada

Approx.	Approximately
Dia.	Diameter
El.	Elevation
H:V	Horizontal:Vertical
No.	Number

SIGNATURES

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2024-07-02

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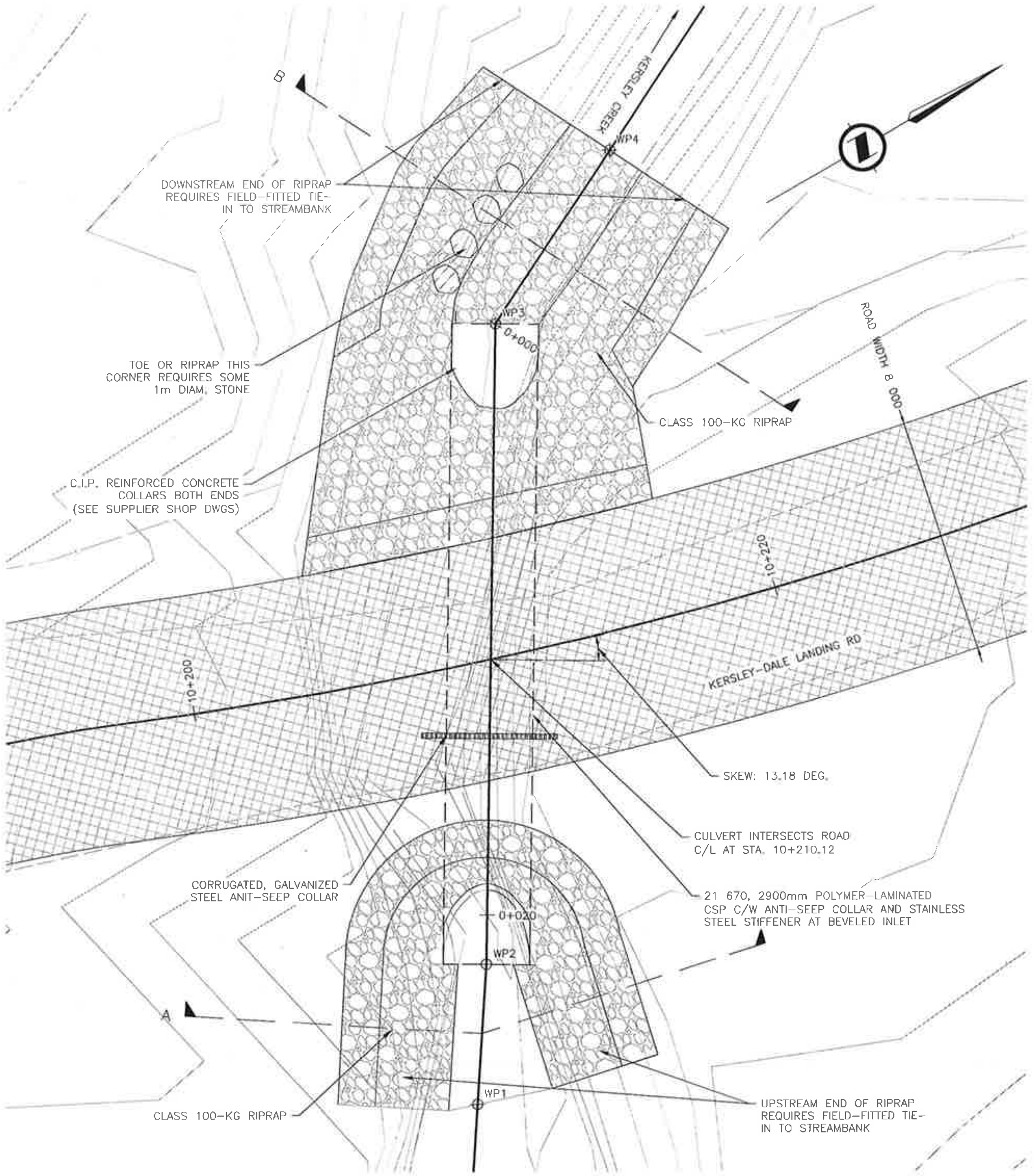
APPENDIX

A

KERSLEY-DALE LANDING ROAD CULVERT DRAWING



PLAN
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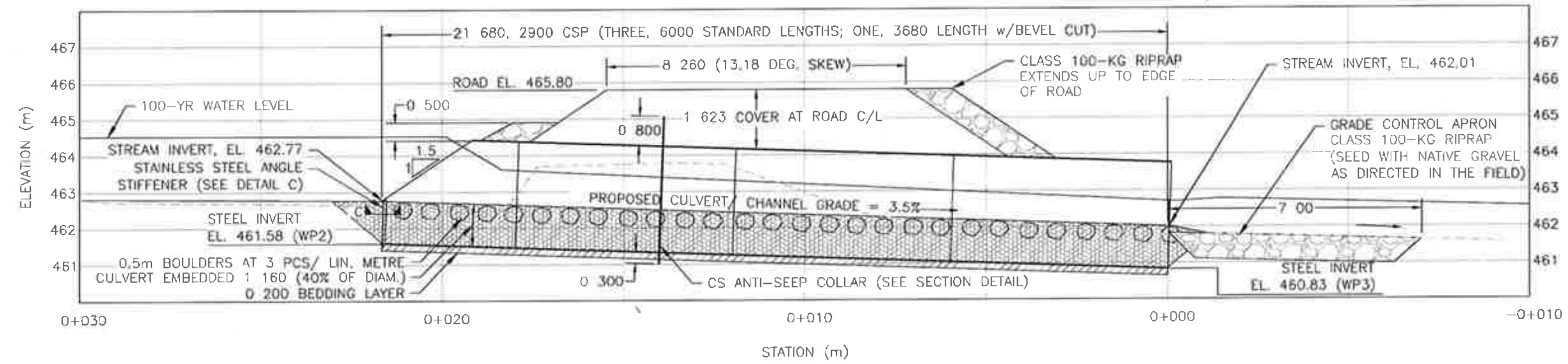

PROFILE - PROFILE ALONG CENTRELINE OF STREAM AND CULVERT
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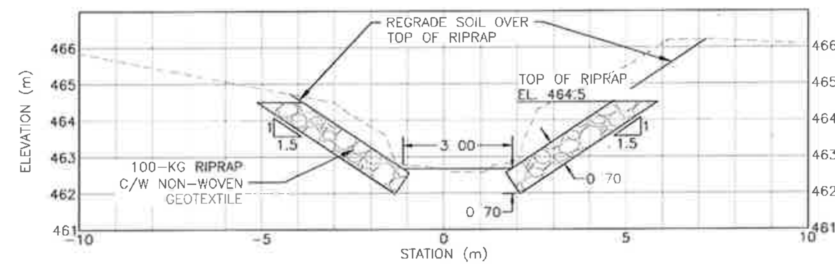

SECTION A
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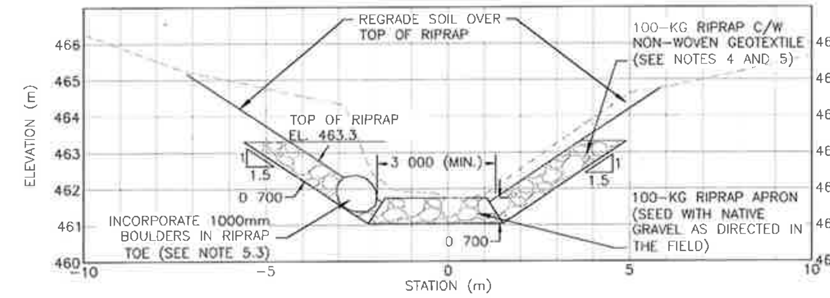


SECTION B
SCALE = 1:100

1. DESIGN STANDARDS AND GUIDELINES

1.1. CANADIAN HIGHWAY BRIDGE DESIGN CODE, (CAN/CSA-S6-06)
1.2. CANADIAN STANDARDS ASSOCIATION (CAN/CSA G401-01)
1.3. AMERICAN SOCIETY OF TESTING AND MATERIALS (ASTM)
1.4. BC MINISTRY OF TRANSPORTATION - MANUAL OF STANDARDS AND PROCEDURES VOLUME I AND II

2. DESIGN PARAMETERS

2.1. DESIGN LIVE LOAD IS BCL-625 AS PER REFERENCE 1.4 ABOVE
2.2. DESIGN HEIGHT OF COVER = 1480mm to 1770mm.
2.3. DESIGN SERVICE LIFE = 50 YEARS
2.4. DESIGN (100-YEAR) STREAMFLOW = 8.2 m^3/s
2.5. 100-YEAR WL. AND VELOCITY AT INLET = El. 464.5, 0.8 m/s
2.6. 100-YEAR WL. AND VELOCITY AT OUTLET = El. 462.8, 2.4 m/s
2.7. 100-YEAR SCOUR = 700 mm BELOW STREAMBED

3. STREAM DATA

3.1. MEAN ANNUAL FLOW = 0.06 m^3/s
3.2. 2-YEAR FLOOD = 1.9 m^3/s
3.3. NATURAL CHANNEL BOTTOM WIDTH = 3.0m
3.4. AVERAGE CHANNEL GRADIENT = 3.6%
3.5. D50 BED MATERIAL = 75mm

4. CULVERT AND ACCESSORIES

4.1. 2900mm POLYMER-LAMINATED CORRUGATED STEEL PIPE (CSP) SUPPLIED IN THREE (3) STANDARD 6m LENGTHS AND ONE (1) 3.68m LENGTH WITH BEVEL AS SHOWN. CSP SHALL HAVE 125mm X 25mm CORRUGATIONS AND 2.8mm STEEL THICKNESS. BE
4.2. BOLT HOLES SHALL BE PROVIDED AT THE END OF THE BEVEL CUT SECTION TO ACCOMODATE FASTENING OF THE STAINLESS STEEL ANGLE STIFFENER.
4.3. CULVERT SUPPLIER SHALL PROVIDE HARDWARE AND DRAWINGS FOR THE CORRUGATED, GALVANIZED STEEL ANTI-SEEP COLLAR

5. CULVERT INSTALLATION (BEDDING, BACKFILL AND COMPACTION)

5.1. REFER TO DRAWING 4099-D1 BY GEONORTH ENGINEERING LTD.

6. GEOTEXTILE

6.1. GEOTEXTILE SHALL BE PLACED BENEATH ALL SLOPING RIPRAP AND SHALL MEET OR EXCEED THE FOLLOWING SPECIFCATIONS:
GRAB STRENGTH (N) ASTM D4632 > 1kN
TEAR STRENGTH (N) ASTM D4533 > 400N
PUNCTURE STRENGTH (N) ASTM D6241 > 2.7kN
PERMITTIVITY (SEC-1) ASTM D4491 > 1.0 /s
APPARENT OPENING SIZE (mm) ASTM D451 0.150mm
6.2 GEOTEXTILE SHALL BE KEYED INTO THE SLOPE JUST ABOVE THE TOP ELEVATION OF THE RIPRAP THEN LAID ALONG THE ENTIRE SLOPE DOWN TO THE TOE OF THE RIPRAP WITH APPROPRIATE SLACK TO ENSURE IT DOES NOT TEAR UPON PLACEMENT OF THE RIPRAP.
6.3 GEOTEXTILE SHALL BE PLACED SUCH THAT THERE IS A MINIMUM OVERLAP OF 0.5m AT EACH JOINT.
6.4 SECURING PINS SHALL BE INSTALLED ALONG A LINE THROUGH THE MIDPOINT OF EACH JOINT OVERLAP, AT MAX. 1.5m SPACING.
6.5 SECURING PINS SHALL BE 5mm DIAMETER STEEL PINS, 300mm IN LENGTH C/W 75mm DIAMETER STEEL WASHERS, AND SHALL SUPPLIED BY THE CONTRACTOR.

7. RIPRAP

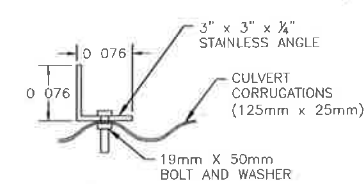
7.1. RIPRAP SHALL BE PLACED AS INDICATED ON THE DRAWINGS AND PER STANDARD SPECIFICATION SS205 AND THE RIPRAP INSTALLATION GUIDE.
7.2. RIPRAP SHALL BE CLASS 100-KG PLACED TO A NOMINAL THICKNESS OF 700mm. THE APPROXIMATE AVERAGE DIMENSION OF STONES SHALL BE AS FOLLOWS:
- 15% SMALLER THAN 195mm
- 50% GREATER THAN 415mm
- 85% GREATER THAN 600mm
- NONE GREATER THAN 700mm
7.3. THE TOE OF THE DOWNSTREAM OUTSIDE STREAM BANK WILL REQUIRE SOME RIPRAP PIECES 1000mm IN DIAMETER.

8. SURVEY

8.1. SURVEY COMPLETED BY CMS CONSTRUCTION MANAGEMENT SERVICES ON MAY 8th, 2015.
8.2. INFORMATION ON EXISTING UTILITIES MAY NOT BE COMPLETE OR ACCURATE. PRIOR TO CONSTRUCTION THE CONTRACTOR SHALL EXPOSE LOCATIONS OF ALL EXISTING UTILITIES AND ADVISE THE OWNER OF POTENTIAL CONFLICTS.
8.3. THE PROPERTY BOUNDARIES SHOWN ARE COMPILED FROM LTO PLANS AND ARE APPROXIMATE ONLY, THEY ARE NOT FIELD TIED. THEY SHOULD BE USED ACCORDINGLY.

9. QUANTITIES

9.1. CLASS 100-KG RIPRAP: 150 CUBIC METRES
9.2. 500mm BOULDERS (FOR BARREL): APPROX. 60 PCS
9.3. 1000mm BOULDERS: APPROX. 4 PCS



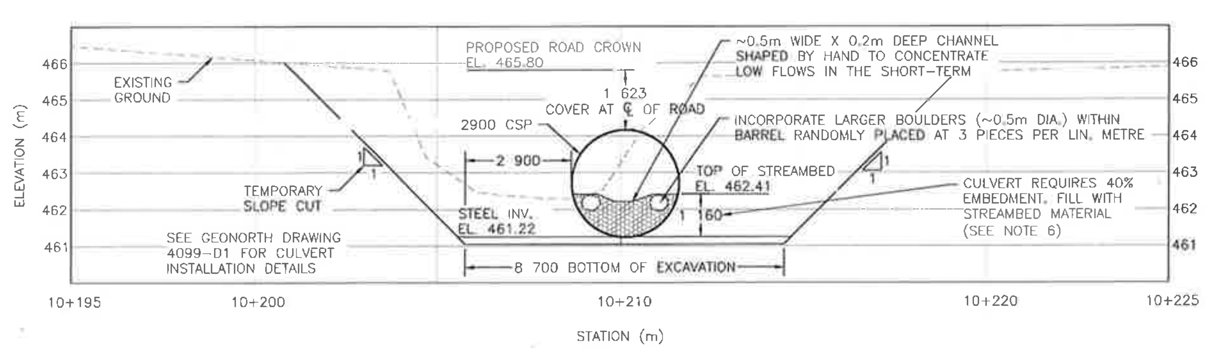
DETAIL C - STAINLESS ANGLE STIFFENER
SCALE = 1:5

TABLE 1 - WORKPOINTS

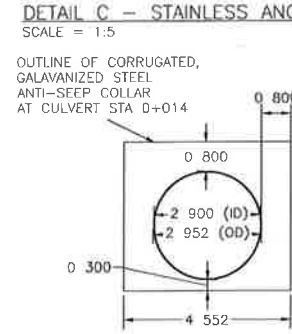
WORKPOINT	EASTING	NORTHING	ELEVATION
WP1	537041.00	854774.95	N/A
WP2	537037.05	854777.56	461.61
WP3	537018.42	854788.62	460.85
WP4	537015.26	854794.87	N/A

2016/03/08
PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA D. J. GOOLD # 28281

LEGEND:
CLASS 100 KG RIPRAP
STREAMBED MATERIAL(SEE NOTE 6)
EDGE OF WIDENED ROAD
PROPOSED TOP OF STREAMBANK
FENCE
EDGE OF WATER
EDGE OF EXISTING GRAVEL ROAD
PROPOSED GROUND



PROFILE - CULVERT ELEVATION AND EXCAVATION ENVELOPE ALONG ROAD CENTRELINE
SCALE = 1:100



SECTION DETAIL - ANTI-SEEP COLLAR
SCALE = 1:100

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BRITISH COLUMBIA
Ministry of Transportation & Infrastructure
Southern Interior Region

QUESNEL DISTRICT
KERSLEY DALE LANDING ROAD CULVERT

GENERAL ARRANGEMENT

SCALE

Rev	Date	Description	Init

REVISIONS

PREPARED UNDER THE DIRECTION OF
DES GOOLD, P.ENG.
ENGINEER OF RECORD
DATE 2016-03-08

DESIGNED DJG DATE 15-10-13
CHECKED DJG DATE 16-03-08
DRAWN CGC/ KEH DATE 16-03-08
SCALE AS SHOWN
NEGATIVE No.

FILE No.	PROJECT No	REG.	DRAWING No.
		2	0003-176-2

CANCEL PRINTS BEARING PREVIOUS LETTER

APPENDIX

B

HY-8 CULVERT HYDRAULICS

KERSLEY DALE LANDING ROAD CULVERT – CAPACITY ANALYSIS

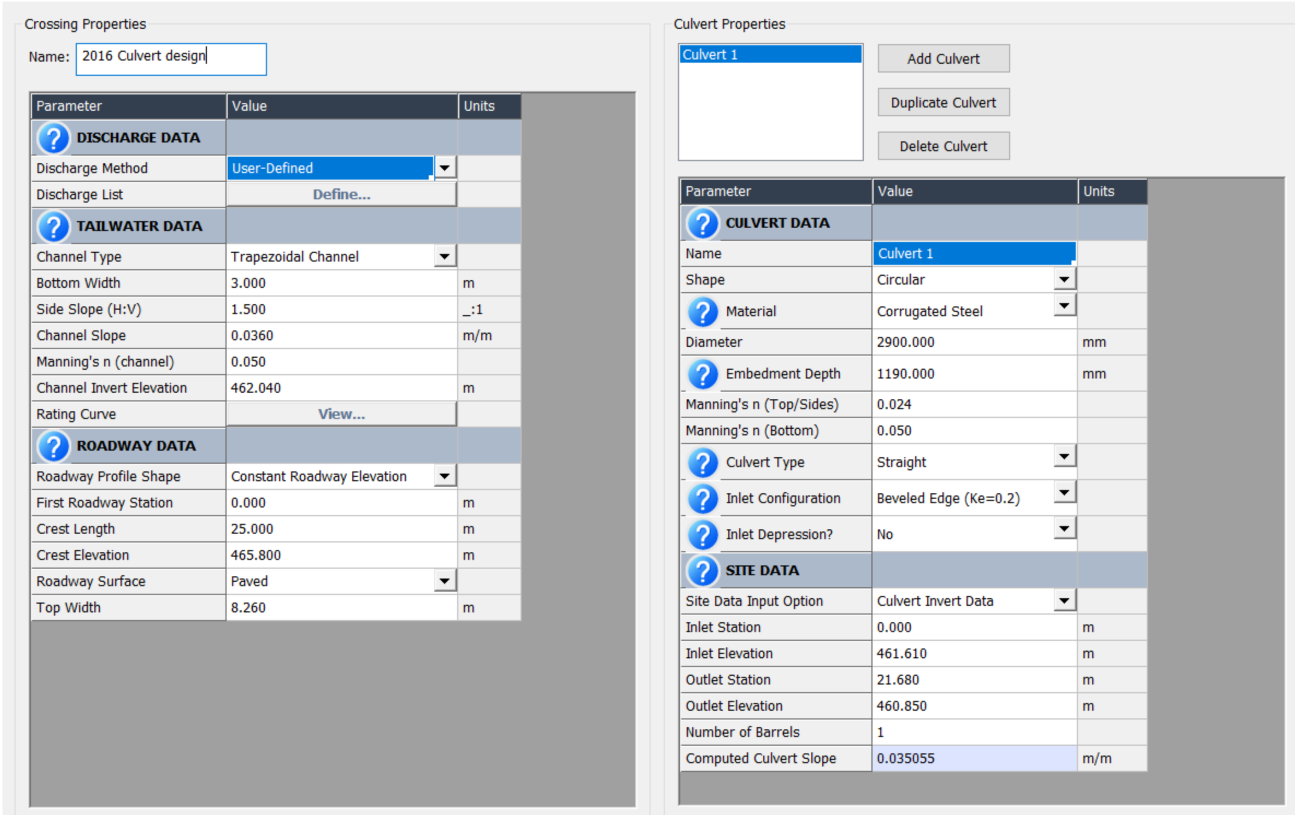

Figure 15 – HY-8 Model Input, Culvert design.

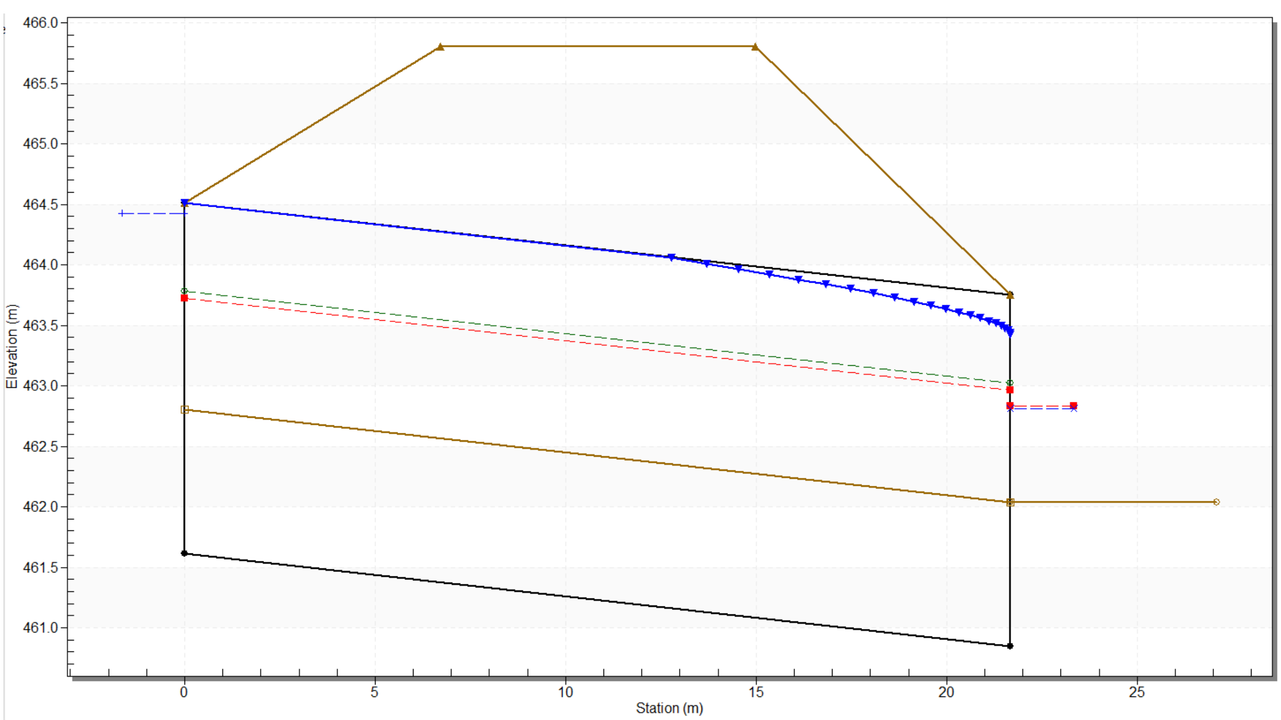

Figure 16 – HY-8 Model Output, Culvert design at a 8.2 m³/s discharge as per Historical Hydrotechnical Design Brief, Drawing No. 0003-176-2, Note 2.4 (NHC, 2016).

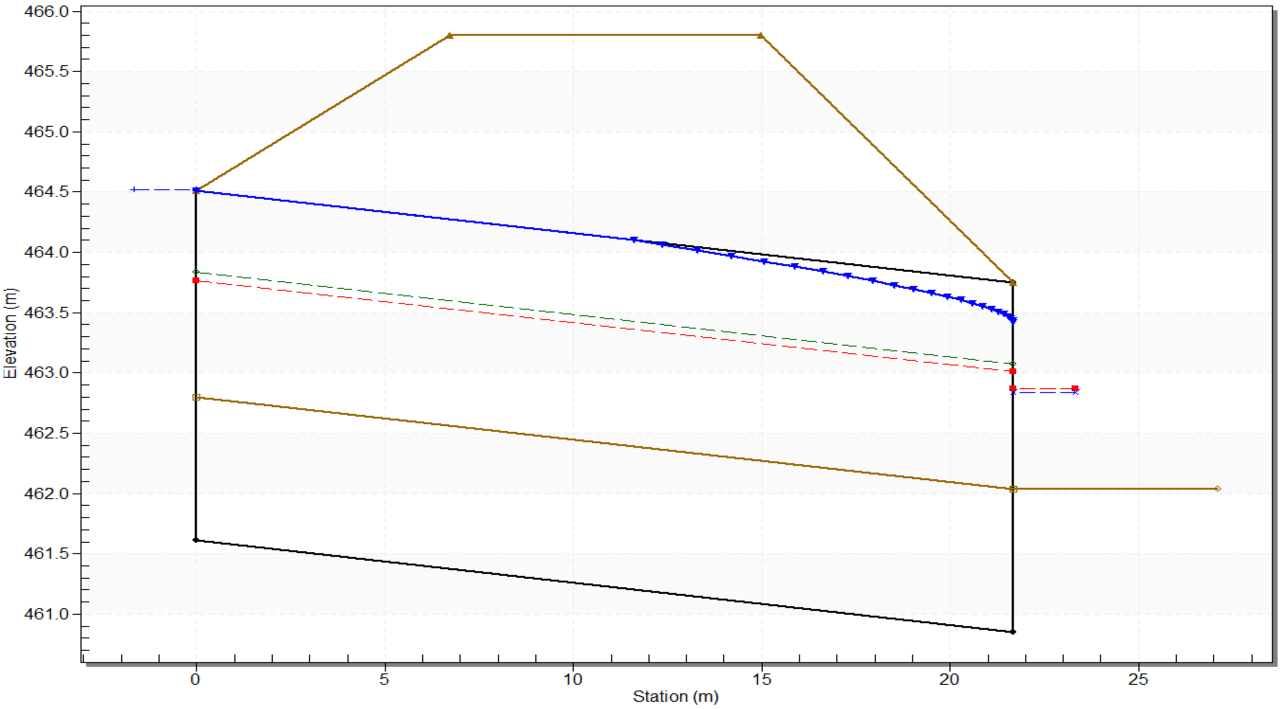

Figure 17 – HY-8 Model Output, Culvert design at a 8.8 m^3/s discharge (Q100 plus CC).

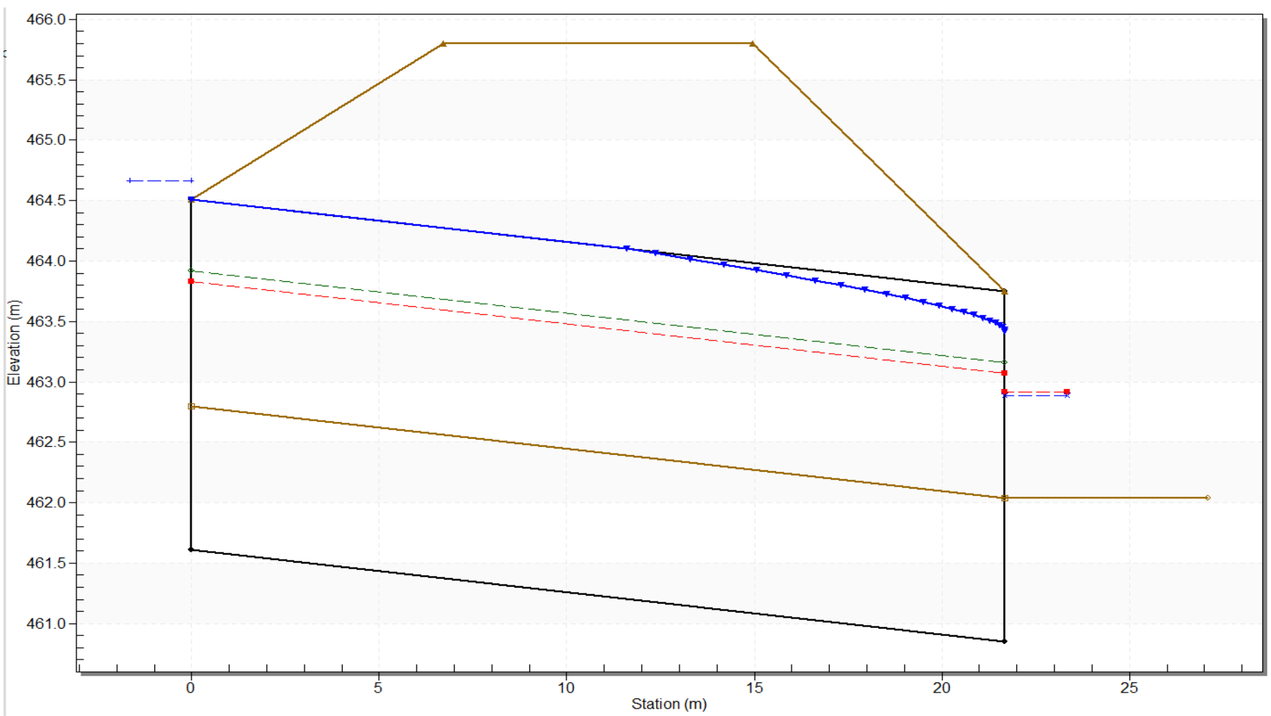

Figure 18 – HY-8 Model Output, Culvert design at a 9.7 m^3/s discharge (Q100 plus CC, Q25 ditch flows plus CC).

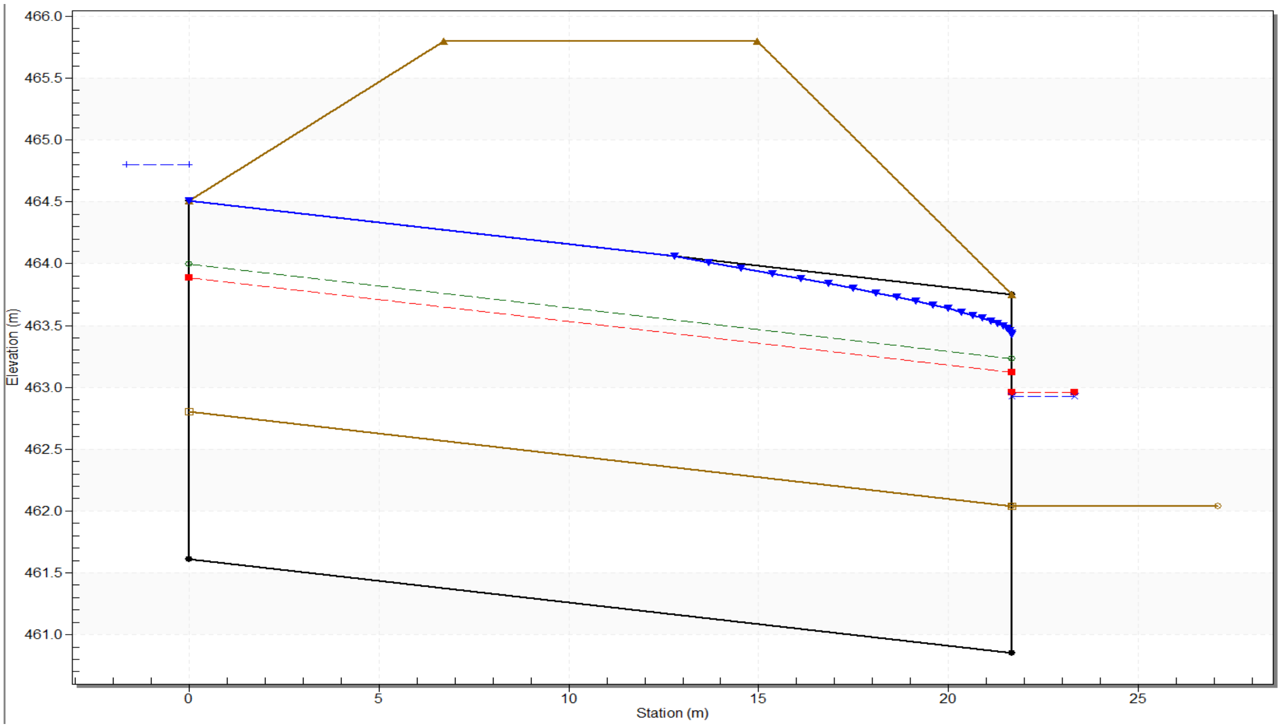

Figure 19 – HY-8 Model Output, Culvert design at a 10.5 m^3/s discharge (Q100 plus CC, Q100 ditch flows plus CC).