ROCKWELL DRIVE RECOVERY PROJECT DF4 ENVIRONMENTAL OVERVIEW ASSESSMENT

January 2023

Prepared for:

BC Ministry of Transportation and Infrastructure

Coquitlam, British Columbia

Hatfield Consultants LLP

#200 - 850 Harbourside Drive
North Vancouver, British Columbia, Canada V7P 0A3
Tel: 1.604.926.3261 • Fax: 1.604.926.5389
www.hatfieldgroup.com

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Prepared for:

BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE
310 – 1500 WOOLRIDGE STREET
COQUITLAM, BC
CANADA V3K 0B6

Prepared by:

HATFIELD CONSULTANTS LLP
#200 - 850 HARBOURSIDE DRIVE
NORTH VANCOUVER, BC
CANADA V7P 0A3
TEL: 1.604.926.3261 • WWW.HATFIELDGROUP.COM

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AMENDMENT RECORD

This report has been issued and amended as follows:

Issue	Description	Date	Approved by	
1	First version of Rockwell Drive Recovery Project DF4 Environmental Overview Assessment	20221014	Garth Taylor Project Director	Tim Poulton Project Manager
2	Final version of Rockwell Drive Recovery Project DF4 Environmental Overview Assessment	20230103	Garth Taylor Project Director	Tim Poulton Tim Poulton Project Manager

1.0 INTRODUCTION

Hatfield Consultants (Hatfield) was retained by the Ministry of Transportation and Infrastructure (MOTI) to provide environmental support for the Rockwell Drive Recovery Project (the Project). The Project is comprised of four sites (DF1, DF2, DF3, and DF4). This environmental overview assessment (EOA) report summarizes key environmental features, environmental permit implications, and preliminary design and construction mitigation strategies for site DF4. Sites DF1 to 3 are discussed in a separate EOA (Hatfield 2022a). This EOA has been developed to inform the site DF4 design options analysis and subsequent detailed design.

1.1 PROJECT DESCRIPTION

Damage to the Trout Lake Creek crossing of Hicks Lake Road (referred to as site DF4) occurred as a result of flooding associated with the November 2021 "atmospheric river" flood event. Site DF4 is located at the southern extent of Hicks Lake Road (just north of the intersection with Rockwell Drive) where the MOTI right-of-way bisects Sasquatch Provincial Park at the southeast extent of Harrison Lake near Harrison Hot Springs (Figure 1).

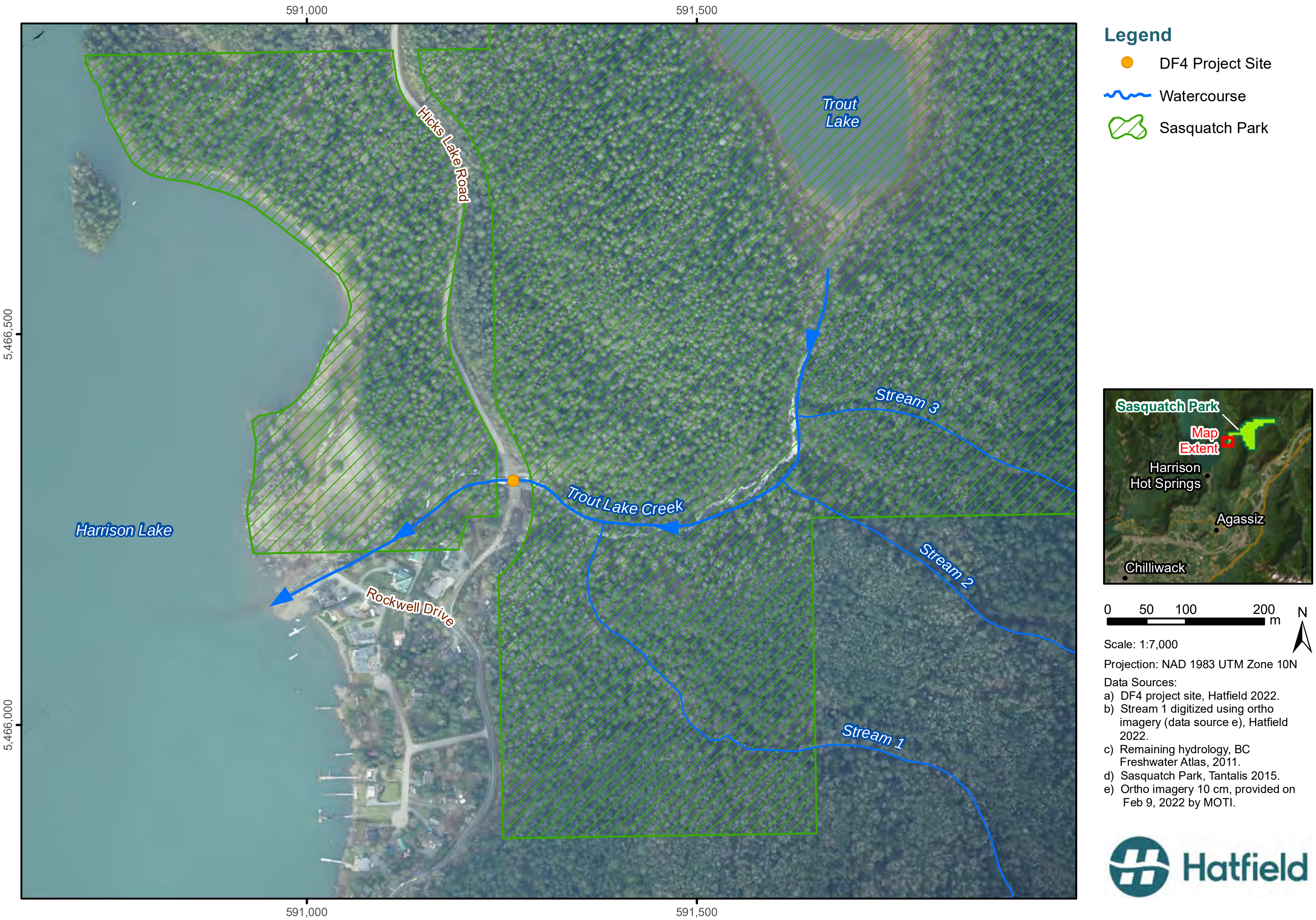
Emergency repair works associated with the 2021 flood were conducted at site DF4 and MOTI has retained Associated Engineering (AE) to conduct an options analysis to support the design of a new permanent crossing.

The November 2021 flood event was the most recent of multiple washouts at site DF4 (AE 2022). The 2021 flood resulted in channel embankment erosion and caused Trout Lake Creek to top its banks and wash out a temporary railcar bridge (installed following a previous flood event in 2020). Emergency works included the removal of flood debris and the washed-out bridge, installation of four 1500 mm diameter High-Density Polyethylene (HDPE) culverts under the reconstructed Hicks Lake Road, and associated riprap erosion protection (AE 2022 and Figure 2). The options analysis (Appendix A1) includes four (4) potential permanent design solutions:

- Option 1: Maintain existing 4 HDPE culverts;
- Option 2: New Corrugated Steel Pipe (CSP) Arch Culvert with Upstream Debris Mitigation;
- Option 3: New Bridge with Upstream Debris Mitigation; and
- Option 4: New Bridge Sized to Convey Debris floods.

Given the hydraulic capacity and the ability to convey the design debris flood, Option 4 is the preferred option (AE 2022).

Figure 1 Site DF4 Project Location.



Scale: 1:7,000

Projection: NAD 1983 UTM Zone 10N

Data Sources:

a) DF4 project site, Hatfield 2022.
b) Stream 1 digitized using ortho imagery (data source e), Hatfield 2022.
c) Remaining hydrology, BC Freshwater Atlas, 2011.
d) Sasquatch Park, Tantalis 2015.
e) Ortho imagery 10 cm, provided on Feb 9, 2022 by MOTI.

Hatfield

Trout Lake Creek Request for Review

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Figure 2 Photographs of site DF4 (March 30, 2022).

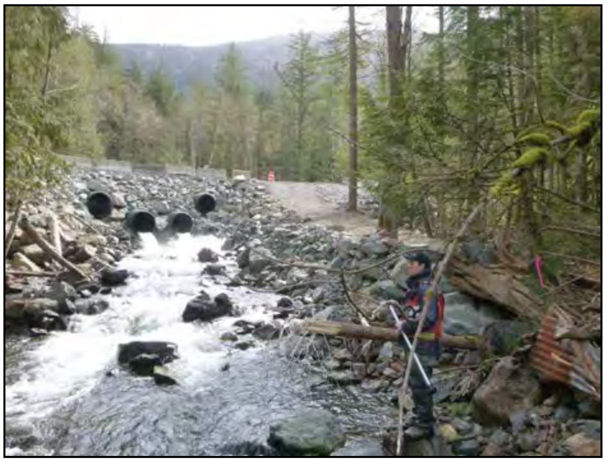


Photo 1 Trout Lake Creek looking upstream to Hicks Lake Road.

Photo 2 Trout Lake Creek looking downstream to Hicks Lake Road.

2.0 METHODS

2.1 LITERATURE REVIEW

This EOA was supported by:

- A desktop literature review of information specific to the study area (i.e., site DF4 which includes Trout Lake Creek and the surronding riparian area within 30 m of the creek, downstream to Harrison Lake and upstream to Trout Lake unless otherwise specified) using online databases; and
- A field assessment to update aquatic and terrestrial baseline conditions.

2.1.1 Fish and Fish Habitat

Hatfield conducted a desktop review of aquatic resources within the study area using the following data sources;

- Habitat Wizard (BC Ministry of Environment (MOE 2022a);
- BC Conservation Data Centre (CDC);
  - BC Species and Ecosystems Explorer (BC MOE 2022b);
  - Conservation Data Center (CDC) iMap (BC MOE 2022c);
- Species Inventory Web Explorer (SIWE) (BC MOE 2022d);
- Ecological Reports Catalogue (ECOCat) (BC MOE 2022e);
- BC Fish Inventories Dara Queries (FIDQ) (BC MOE 2022f); and
- Historical Assessments conducted by Hatfield from 2017 to 2020 (Appendix A2).

2.1.2 Terrestrial Resources

A review of existing information was also completed for terrestrial resources in the study area and within an approximate 1 km radius surrounding site DF4. Data sources included:

Wildlife

- BC Conservation Data Centre (CDC) Species and Ecosystems Explorer (BC MOE 2022b);
- Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (COSEWIC 2022);
- *Species at Risk Act* (SARA) Registry (Govt Canada 2002);
- Conservation Data Center (CDC) iMap (BC MOE 2022c);
- iNaturalist Canada (Canadian Wildlife Federation et al 2022); and
- eBird Canada (eBird 2022).

Plants

- CDC iMap (BC MOE 2022c) and BC Species and Ecosystems Explorer (BC MOE 2022b);
- e-Flora BC (Klinkenberg B 2021);
- BC *Weed Control Act (*Government of Canada 1996*)*;
- BC Invasive Species Council of BC (ISCBC) (ISCBC 2022);
- Invasive Alien Plan Program (IAPP) database and map display (BC MOE 2022g); and
- ECOCat and DataBC Data Catalogue, in addition to the District of Kent online mapping tools (DOK. 2022).

2.1.3 Species at Risk

A preliminary list of federally and provincially listed species was generated by querying the CDC Species and Ecosystem Explorer database for occurrences within the Fraser Valley Regional District, and within the Coastal Western Hemlock (CWH) zone, in which the study area is located. The list was refined by obtaining habitat information from species-specific summary reports and determining habitat suitability in supporting critical life-history functions for each species. Such requisites include breeding, foraging, migration for bird species, flowering, and seed dispersal for plants.

2.2 FIELD DATA COLLECTION

Hatfield conducted field baseline studies on March 30, 2022, including the following activities:

- Characterization of fish habitat features upstream and downstream of site DF4 including updating habitat transects completed in 2018 (Appendix A2);
- General reconnaissance of wildlife and wildlife habitat features upstream and downstream of the crossing; and
- Drone survey from Hicks Lake Road downstream to Harrison Lake.

2.2.1 Fish Habitat

Characterization of fish habitat in Trout Lake Creek included re-establishing eleven (11) of the twelve (12) habitat transects previously conducted in 2018 to assess habitat changes caused by past flood events. The most upstream transect (i.e., Transect 12) was not impacted by the recent flood events so was not updated. We performed transect assessments as per Resource Inventory Standards Committee (RISC) methods and included the following measurements:

- Average channel width;
- Average wetted width;
- Depth and velocity measurements (3 per transect);
- Substrate composition;

- Channel morphology (e.g., percent riffle, pool, run, cascade) and gradient;
- In situ water quality including dissolved oxygen (mg/L), pH, conductivity (µs/cm), and water temperature (°C); and
- An assessment of fish passage.

Fish sampling was not conducted in 2022 (see previous fish sampling reports from 2017 and 2018; Appendix A2).

2.2.2 Terrestrial Resources

Avian Species

Given the time of year and the small area associated with each site, we did not perform detailed surveys for nesting birds; however, we did document incidental observations.

Technicians also surveyed the forest surrounding each site and scanned the canopies for any stick nests including the nests of hawks, ospreys, bald eagles, and great blue herons. Technicians also examined trees within the forested areas for whitewash (excrements) and the bases of the trees for pellets, to look for evidence of owl foraging, nesting, or young.

Wildlife and Wildlife Habitat Features

Technicians walked 5 to 10 m apart in the forested areas on either side of each fish habitat survey reach and looked for different wildlife habitat features, including:

- Cover availability (e.g., micro-terrain features, understory plants, coarse woody debris);
- Game trails and dens; and
- Wildlife trees and snags.

Technicians also turned over cobble-sized rocks during the fish habitat surveys looking for evidence of coastal tailed frog (*Ascaphus truei*) tadpoles.

3.0 RESULTS

3.1 FISH

A summary of fish species documented to occur in Trout Lake Creek during previous desktop and field surveys (Appendix A2) is presented in Table 1. The Creek is used by both spring and fall spawning salmonids. Spawning chum salmon (*Oncorhynchus keta*) were previously observed by Hatfield during a survey in November 2017, between the mouth of the Creek and Hicks lake Road. Coastal cutthroat trout (*Oncorhynchus clarkii clarkii*) and rainbow trout (*Oncorhynchus mykiss*) were captured during the 2017 survey upstream and downstream of Hicks Lake Road, respectively. Hicks Lake Road presents a barrier to upstream migration, therefore it is assumed that cutthroat trout captured upstream of the road are either moving downstream from Trout Lake or represent a small isolated population.

Table 1 Documented fish species in Trout Lake Creek (Hatfield 2018).

Common Name	Scientific Name	[1]Capture Location	Common Name	Scientific Name	Capture Location
Chum salmon	*Oncorhynchus keta*	Downstream	Sockeye salmon	*Oncorhynchus nerka*	Unknown
Coho salmon	*Oncorhynchus kisutch*	Downstream	Stickleback	*Gasterosteus sp.*	Unknown
Coastal cutthroat trout	*Oncorhynchus clarkii clarkii*	Upstream			
Kokanee	*Oncorhynchus nerka*	Unknown			
Longnose dace	*Rhinichtys cataractae*	Upstream			
Pink salmon	*Oncorhynchus gorbuscha*	Unkown			
Rainbow trout	*Oncorhynchus mykiss*	Downstream			
Sculpin	*Cottus sp.*	Downstream			

[1]Capture location in relation to Hicks Lake Road.

3.2 FISH HABITAT

Hatfield previously conducted fish habitat baseline studies at site DF4 in 2017 and 2018 (Appendix A2); however, these studies have been updated due to extensive erosion and bedload movement which occurred during the 2020 and 2021 floods.

Trout Lake Creek originates in Trout Lake, about 670 m upstream of site DF4 (Westrek, 2020) and the creek receives streamflow from Hicks Lake and other unnamed watercourses upstream of Trout Lake and within the watershed. Site DF4 is located approximately 300 m upstream of Harrison Lake and surrounded by Sasquatch Provincial Park, and several private lots located on the fan west of Hicks Lake Road (Westrek 2020). The reaches of Trout Lake Creek conveyed over the fan are ephemeral, drying out and/or flowing subsurface during the late summer/early fall (i.e., August/September) as observed during the recent debris removal works at Green Point Bridge; the crossing of Trout Lake Creek at Rockwell Drive. Trout Lake Creek upstream of Hicks Lake Road appears to flow year-round (Hatfield 2022b). Water temperature, pH, dissolved oxygen, and conductivity within a pool upstream of Hicks Lake Road were 8.7°C, 6.36, 11.86 mg/L, and 39.2 us/cm, respectively, during the March 30, 2022, field assessment.

A substantial amount of bedload and road fill material was deposited downstream of site DF4 during the 2020 and 2021 flood events (Hatfield 2022b), resulting in morphological changes to Trout Lake Creek (e.g., raising the streambed profile, infilling of pools, accumulation of wood debris, and changes in substrate composition). Emergency works to remove accumulated debris upstream and downstream of the Green Point Bridge located further downstream at Rockwell Drive were conducted during the 2022 least-risk fisheries window to reinstate the freeboard under the bridge (Hatfield 2022b and Figure 3). The previous floods and associated emergency works have also resulted in changes to Trout Lake Creek upstream of site DF4. The approximate 100 m reach upstream of Hicks Lake Road previously characterized by riffle-run-pool morphology has shifted to primarily cascade-pool morphology and a considerable amount of riparian vegetation has been replaced with riprap erosion protection (Figure 3).

Fish habitat within the study area has been heavily disturbed by the floods and provides limited opportunity for salmonid rearing or spawning given the change in channel morphology and substrate composition, infilling of pools, and displacement of riparian vegetation with riprap scour protection; however, this habitat is likely suitable for longnose dace (*Rhinichtys cataractae*) and sculpin (*Cottus* sp.) previously captured further upstream in 2017 (Appendix A2). Chum salmon (*Oncorhynchus keta*) were observed spawning within Trout Lake Creek during previous surveys in November 2017 downstream of Hicks Lake Road; however, much of the suitable gravel spawning substrate has been displaced downstream to the lower reaches of Trout Lake Creek at Harrison Lake. Similar to the previously perched culvert at site DF4 (Figure 3), the current crossing structure is a barrier to fish passage. A summary of fish habitat measurements from the 2022 habitat transects (Figure 4) is provided in Table 1.

Figure 3 **2018 to 2022 photographic comparison of the site DF4 study area.**

Photo 1 **Downstream (west) view showing the pre-flood clearance under Green Point Bridge. (March 26, 2018).**

Photo 2 **Downstream (west) view showing post-flood clearance under Green Point Bridge. (March 30, 2022).**

Photo 3 Trout Lake Creek upstream of Hicks Lake Road. (upstream view; March 26, 2018).

Photo 4 Trout Lake Creek upstream of Hicks Lake Road. (upstream view; March 30, 2022).

Photo 5 Trout Lake Creek downstream of Hicks Lake Road. (upstream view; March 26, 2018).

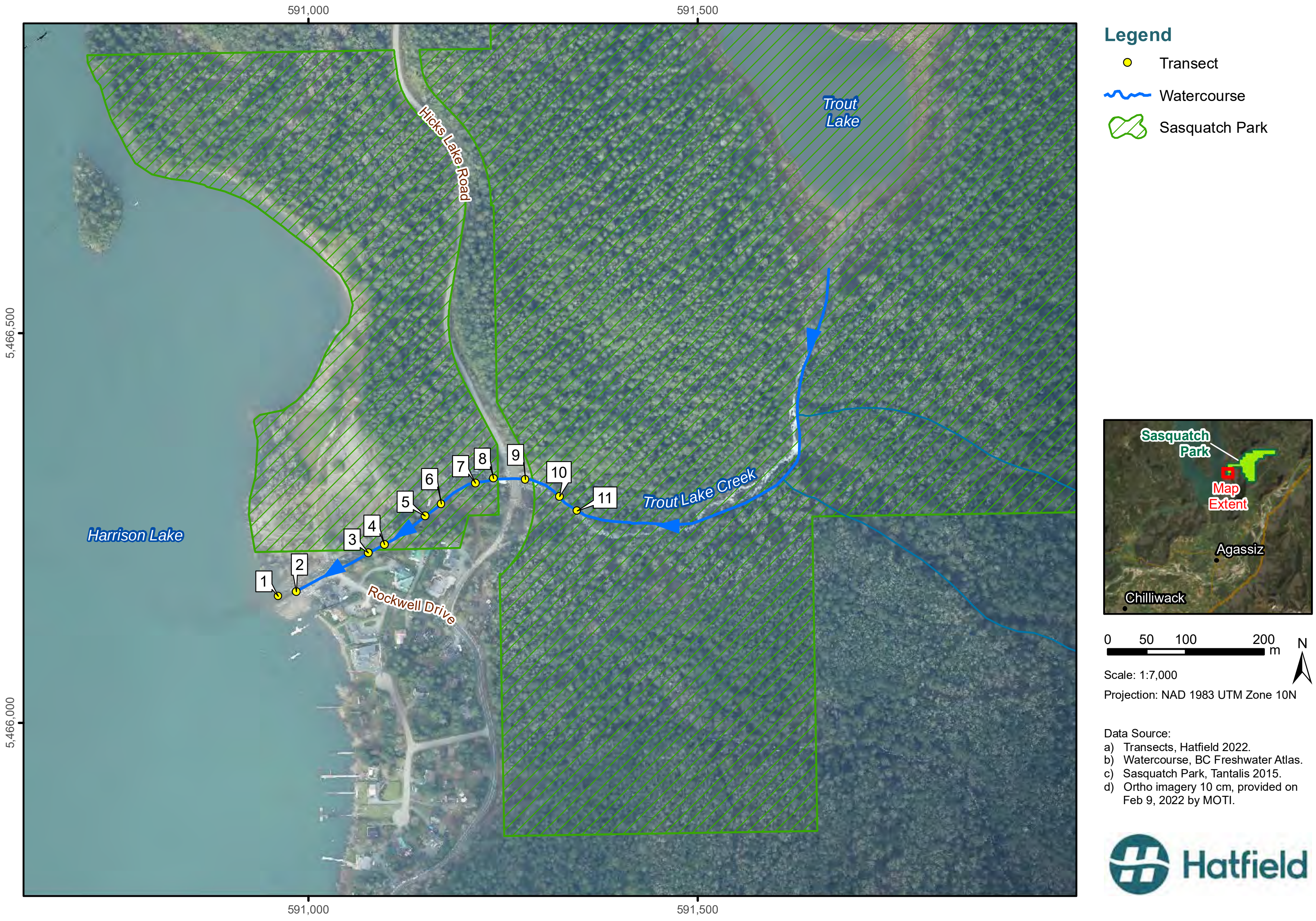
Photo 6 Trout Lake Creek downstream of Hicks Lake Road. (upstream view; March 30, 2022).

Table 2 Trout Lake Creek fish habitat transects from downstream to upstream.

Transect ID	Gradient (%)	Channel Width (m)	Wetted Width (m)	Substrate		Depth (cm) Across Channel			Velocity (m/s) Across Channel		
				Dominant	Subdominant	25%	50%	75%	25%	50%	75%
1	2.0	20.7	6.3	Cb	Gr	19	28	28	0.3	0.6	1.0
2	2.5	5.5	3.9	Cb	Gr	36	47	35	0.6	0.7	0.2
3	3.5	13.2	6.7	Cb	Bd	35	36	21	0.9	0.8	0.4
4	2.0	18.8	8.5	Cb	Gr	25	38	20	0.8	0.5	0.6
5	3.0	22.6	8.5	Cb	Bd	39	22	28	1.1	0.1	0.9
6	4.0	25.0	5.2	Cb	Gr	56	56	36	0.2	0.9	0.3
7	3.0	28.5	7.5	Cb	Bd	24	44	13	0.1	0.5	0.1
8	3.5	10.8	8.8	Cb	Bd	16	29	23	0.9	1.2	1.0
9	8.0	28.3	7.3	Cb	Bd	32	22	16	0.3	0.2	1.5
10	4.5	10.4	6.8	Cb	Gr	39	62	26	0.1	0.2	0.3
11	8.0	9.3	7.7	Bd	Gr	25	56	39	0.2	0.7	0.4

GR= Gravel; Cb = Cobble; Bd = Boulder

Figure 4 **Location of Habitat Transects along Trout Lake Creek (March 30, 2022).**



Data Source:
a) Transects, Hatfield 2022.
b) Watercourse, BC Freshwater Atlas.
c) Sasquatch Park, Tantalis 2015.
d) Ortho imagery 10 cm, provided on Feb 9, 2022 by MOTI.

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3.3 TERRESTRIAL RESOURCES

The study area is located in the dry maritime subzone within the Coastal Western Hemlock biogeoclimatic zone (CWHdm) and transitions to very wet maritime (CWHvm2) at an elevation of approximately 650 m – 1000 m.

3.3.1 Wildlife and Wildlife Habitat

The study area does not occur within a provincially designated management area. The nearest designated management area is the Harrison-Chehalis Wildlife Management Area located approximately 10 km to the southwest near Harrison Mills. Given that site DF4 occurs primarily within the MOTI road right-of-way, which is subject to routine maintenance, and there has been significant disturbance from the 2021 flood event, wildlife habitat features such as riparian vegetation, coarse woody debris, and snags (i.e., standing dead trees) were largely absent. Bird nests (including stick nests and cavity nests) were not observed.

3.3.2 Species at Risk

Species at risk are identified by both provincial and national ranking systems. Federally, the COSEWIC assesses and recommends species ranks. The Government in Council uses COSEWIC information to decide which species to include on Schedule 1 of SARA. Provincially, species are assessed by the CDC based on the systematic collection and analysis of information on their extent, distribution, and vulnerability to disturbance. Species are red- or blue-listed depending on the urgency of their conservation needs.

Listed wildlife species with the potential to occur within and/or in proximity to the study area (as determined using methods described in Sections 2.1.2 and 2.1.3) are provided in Table 3 along with the status of each species, per the CDC and SARA databases. There is a known occurrence of Oregon forestsnail south of the study area near Agassiz and draft habitat mapping suggests that suitable habitat extends into the study area (Personal communication with BC Parks and MOTI staff, May 2022). This species has a specific habitat association with mature bigleaf maple, stinging nettle and sword fern forest types, which were not observed within the study area during the site assessment. Additionally, there is a masked occurrence (ID 52866) 2.5 km from site DF4 (BC MOE 2022h); however, after further discussion with CDC staff (email: Katrina Stipec. June 30, 2022), it was determined that this species will not be impacted by the Project.

Listed plant species with the potential to occur within the study area (as determined using methods described in Sections 2.1.2 and 2.1.3) are provided in Table 4 along with the status of each species, per the CDC and SARA databases.

3.3.3 Invasive Species

There have been several invasive plant species identified close to the study area (<1 km) including tansy ragwort (*Senecio jacobaea),* common tansy (*Tanacetum vulgare*), butterfly bush (*Buddleja*), English ivy (*Hedera helix*), bull thistle (*Cirsium vulgare*), Himalayan blackberry (*Rubus armeniacus*), and cutleaf blackberry (*Rubus laciniatus*) (BC MOE 2022c). Invasive animal species that have been documented in the area include the American bullfrog (*Rana catesbeiana*) and green frog (*Lithobates clamitans*) (BC MOE 2022c). Invasive species and/or noxious weeds as regulated by the BC *Weed Control Act* and regulation were not identified during the site assessment.

Table 3 Listed animal species with the potential to occur within the study area.

Common Name	Scientific Name	SARA Schedule 1	Provincial Status	Habitat Requirements	Habitat Requisites to Support Critical Life Functions within the study area
Birds					
Band-tailed pigeon	*Patagioenas fasciata*	Special Concern	Blue	Found around forests, riparian habitats and springs	Yes
Barn swallow	*Hirundo rustica*	Threatened	Blue	Found around forests, wetlands, riparian habitats as well as agricultural and anthropogenic environments	Yes
Northern goshawk	*Accipiter gentilis laingi*	Threatened	Red	Found around forests and riparian habitats	Yes
Olive-sided flycatcher	*Contopus cooperi*	Threatened	Blue	Found around forests, lakes and riparian habitats	Yes
Western screech-owl	*Megascops kennicottii kennicottii*	Threatened	Blue	Found around forests and riparian habitats	Yes
Amphibians					
Coastal tailed frog	*Ascaphus truei*	Special Concern	Yellow	Found in and around cold, clear, fast-moving streams associated with mature forested habitat	Yes
Northern red-legged frog	*Rana aurora*	Special Concern	Blue	Found around riparian habitats, streams, lakes and grassland	Yes
Oregon spotted frog	*Rana pretiosa*	Endangered	Red	Found around riparian habitats, streams, and lakes	Yes
Mammals					
Pacific water shrew	*Sorex bendirii*	Endangered	Red	Found in riparian and wetland habitats	Yes
Trowbridge's shrew	*Sorex trowbridgii*	N/A	Blue	Found in forests and riparian habitats	Yes

Limited to vertebrate species that are either provincially red or blue listed, and/or on SARA schedule 1 as Endangered or Threatened. (BC MOE. 2022a and BC MOE. 2022c)

Table 4 Listed plant species with the potential to occur within the study area.

Common Name	Scientific Name	SARA Schedule 1	Provincial Status	Habitat Requirements	Habitat Requisites to Support Critical Life Functions within study area
Plants					
Tall bugbane	*Actaea elata var. elata*	Endangered	Red	Found around forest habitats	Yes
Cut-leaved water-parsnip	*Berula incisa*	Not listed	Blue	Found around lakes, springs, riparian habitat and lakes	Yes
Angled bittercress	*Cardamine angulate*	Not listed	Blue	Found around forests, riparian habitats and streams/rivers	Yes
Phantom orchid	*Cephalanthera austiniae*	Threatened	Red	Found around foresthabitats	Yes

Limited to plant species that are either provincially red or blue listed, and/or on SARA schedule 1 as Endangered or Threatened. (BC MOE. 2022a and BC MOE. 2022c)

4.0 PRELIMINARY ASSESSMENT OF IMPACTS

4.1 DESIGN

Based on the options analysis report (AE 2022), Option 4 is the preferred long-term design option for site DF4 and is comprised of a new clearspan bridge to convey the design debris flood. Option 4 would have the largest hydraulic opening of the options, and would be least susceptible to debris blockage. A temporary detour would be required during construction.

It is expected that replacing the culverts with a bridge of current design standards that considers climate change and debris flood events will reduce erosion to Hicks Lake Road and subsequent flooding of downstream environments, infrastructure, and property. Despite this overall net benefit, there will be minor losses of riparian habitat and permanent modifications to aquatic habitat associated with the placement of riprap scour protection.

4.2 CONSTRUCTION

The following changes in and about a stream as defined by the Water Sustainability Regulation Section 39(1), are anticipated with Option 4:

- The removal of a culvert for crossing a stream for the purposes of a road;
- The construction of a clear-span bridge;
- The restoration or maintenance of a stream channel by the government;
- The construction of a temporary diversion around or through a worksite for the purposes of constructing bridge abutments;
- The repair or maintenance of existing dikes or existing erosion protection works to their original state; and
- The restoration or maintenance of fish habitat by the Crown in right of either Canada or British Columbia.

Potential temporary adverse impacts to the aquatic environment during construction are primarily related to water quality, including but not limited to:

- Erosion of exposed soils and resultant sediment release; and
- Use of heavy machinery and potential accidental release of hydrocarbons.

Potential temporary direct adverse impacts to the terrestrial environment during construction include:

- Temporary loss of localized riparian wildlife habitat;
- Habitat degradation associated with construction (e.g hydrocarbon spill); and
- Mortality of small vertebrates breeding in microhabitats within the construction footprint.

Potential indirect adverse impacts include habitat avoidance and reduced reproductive success as a result of sensory (visual and auditory) disturbance to wildlife species nesting/denning in the study area.

5.0 IMPACT MITIGATION STRATEGIES

Residual impacts (i.e., predicted to remain after all mitigation is considered) to environmental resources are not expected as long as conventional design and construction best management practices (BMPs) are followed. The Project will be undertaken in a small area already heavily affected by anthropogenic disturbances. Habitat within the Project footprint is highly disturbed as a result of previous flood events, routine road maintenance, and traffic noise resulting in limited fish and wildlife usage of the area.

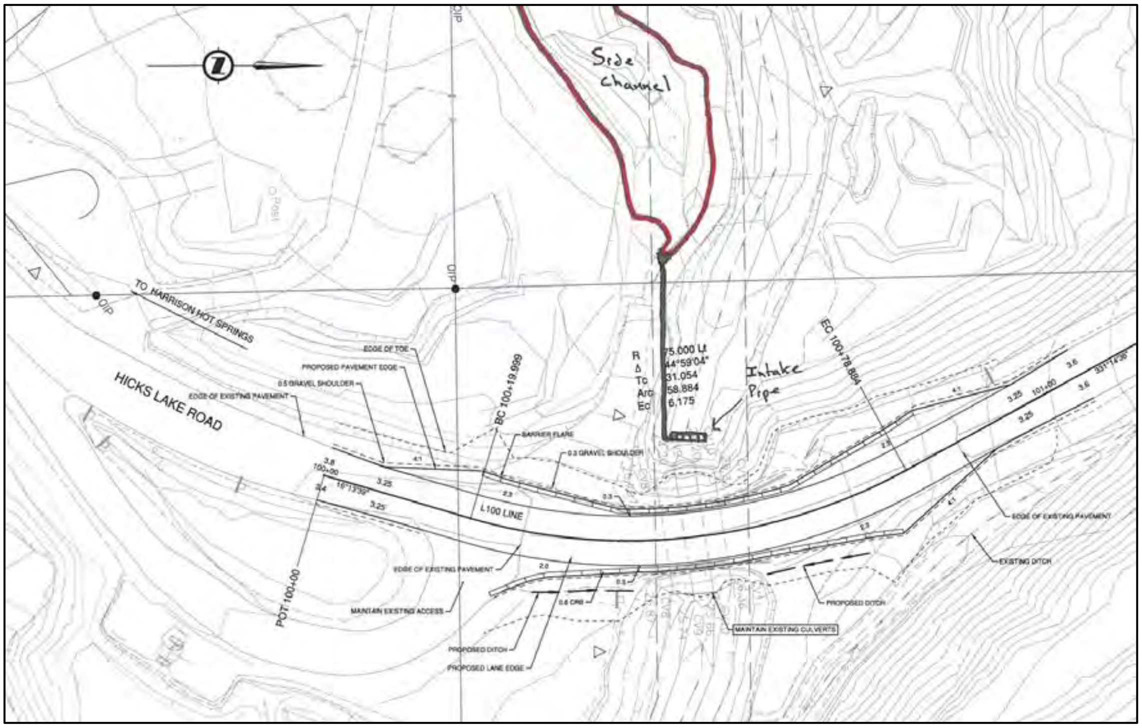
5.1 DESIGN

Generally, the footprint of the new bridge and associated riprap should be minimized to the extent feasible while maintaining current design standards. Minimizing the footprint to within the existing footprint will reduce the permanent loss of aquatic and terrestrial resources. Top-dressing riprap below the high watermark with native stream substrates salvaged during excavation, and maintaining the natural channel shape are design impact mitigation strategies that should be employed where possible. Riparian areas disturbed during construction should be revegetated with native shrub and tree species suited to site conditions.

Providing fish passage through the new design structure has been extensively reviewed and discussed with the Project team during the options analysis as the current and previous structures do not facilitate fish passage. Based on the previous baseline studies conducted in 2017 and 2018 (Appendix A2), which documented suitable fish habitat in the form of potential rearing and spawning areas within an approximate 100 m reach upstream of Hicks Lake Road, it was originally determined that designing for fish passage was warranted; however, due to shifting baseline conditions as a result of the 2020 and 2021 flood events and associated emergency works, the previously identified suitable habitat has been downgraded to marginal habitat (see Section 3.1). Given the marginal habitat for fish upstream of Hicks Lake Road and engineering challenges associated with steep channel gradients and the large size of riprap required, we are no longer recommending this design mitigation strategy. Alternatively, we have identified a fish habitat restoration opportunity downstream of site DF4 that would provide greater benefits to fish in Trout Lake Creek. As opposed to providing upstream access for fish to approximately 100 m of marginal habitat not previously accessible, we are considering a concept to reinstate an abandoned side channel within Sasquatch Provincial Park approximately 50 m downstream of Hicks Lake Road (Figure 5). The side channel is blind-ended (i.e., only connected to the mainstem at the downstream extent). The concept includes rewatering the abandoned side channel via a pipe from the approximate new bridge location (Figure 6), and recontouring the side channel complete with cover features (e.g., anchored large woody debris) to maximize overwintering and summer rearing habitat for salmonids, habitat features that are currently limited in the lower reaches of Trout Lake Creek. The blind-ended side channel would also provide high-flow refuge for fish during future flood events. Hatfield has received preliminary support from BC Parks (Daris LaPointe personal communication, August 2022) and will work with the design team to formalize this conceptual plan during the detailed design and permitting stage of the Project.

Figure 5 **Abandoned side channel downstream of Hicks Lake Road (March 30, 2022).**

Figure 6 **Intake pipe concept to rewater the abandoned side channel downstream of Hicks Lake Road.**



5.2 CONSTRUCTION

The successful Contractor(s) will be required to submit a detailed Construction Environmental Management Plan (CEMP) with work procedures prior to commencing construction. The CEMP shall be prepared in compliance with MOTI's Standard Specifications for Highway Construction (MOTI 2020a) Section 165 Protection of the Environment (SS 165) and align with the Requirements and Best Management Practices for Making Changes in and About a Stream in British Columbia (Gov. BC 2022), and the Measures to Protect Fish and Fish Habitat (DFO 2019a). The CEMP will be submitted to MOTI for review and approval prior to the start of works. Special provisions (SPs) contained in the Project tender package will identify any expectations that differ from MOTI SS 165 and will also include conditions of any environmental approvals. SPs may also refer to mitigation measures outlined in this, or any other environmental assessment reports prepared for the Project that form part of regulatory application submissions. Mitigation measures and BMPs detailed in the CEMP will include but not be limited to the following management plans:

- Fish and fish habitat protection plan (including fish salvages where required);
- Spill prevention and emergency response plan;
- Erosion and sediment control plan;
- Vegetation management plan (including management of invasive and noxious weeds);
- Wildlife protection plan; and
- Waste management plan.

5.2.1 Least Risk Windows

Fish

Instream works should be conducted during the regional least risk work window of August 1 to September 15 to protect against potential effects on trout and salmon species (BC MOE 2006). It should be noted that the least risk window for fish does not apply if the watercourse is naturally dry. Instream works outside the least risk window may be allowed with compelling rationale and appropriate mitigation measures.

Birds

Vegetation is limited at this previously disturbed site but, if vegetation clearing is required, particularly for site preparation works, mitigation during construction should include work restrictions during the breeding bird window, March 15 to August 30 (ECCC 2018). Bird nesting surveys, as per MOTI protocol, and measures to protect active nests are required for vegetation removal and disturbance activities during the active nesting period (MOTI 2020b). If clearing cannot be conducted during this time due to the Project schedule, pre-clearing bird nesting surveys by an Appropriately Qualified Professional (AQP as defined in MOTI SS 165) will be required to ensure compliance with the federal *Migratory Birds Convention Act*, which prohibits the removal or destruction of birds or bird habitat during the breeding season. Surveys should be conducted so that no-disturbance buffers can be established around active nest sites. Raptor nests were not observed during the field assessments; regardless, raptor nest surveys should be completed immediately prior to construction to ensure conditions have not changed.

6.0 REGULATORY CONSIDERATIONS

Based on a review of the options analysis (AE 2022) and existing environmental resources identified in this EOA, Hatfield has identified the following environmental legislation and permits that may apply to the Project (Table 5).

Table 5 Summary of legislation applicable to the Project.

Legislation	Agency	Area of Regulation	Possible Permits/Action
Federal			
Species at Risk Act	Environment and Climate Change Canada (ECCC)	Protects threatened or endangered species	No endangered or threatened species listed under Schedule 1 have been identified in the study area.
Migratory Birds Convention Act and Regulations	ECCC	Prohibits injury, molestations, and destruction of migratory birds and their nests.	Bird nesting surveys and measures to protect active nests are required for vegetation removal during the active nesting period (March 15 to August 30).
Fisheries Act	Fisheries and Oceans Canada (DFO)	No person shall carry on any work, undertaking or activity that results in the death of fish or the harmful alteration, disruption or destruction (HADD) of fish habitat.	A request for project review will be required to confirm DFO agrees no HADD or death of fish will occur. An avoid and mitigate letter (aka Letter of Advice) is expected to be issued from DFO.
Provincial			
Water Sustainability Act and Regulation	BC Ministry of Forests (MOF)	Regulates activities being carried out in and about a stream.	The bridge and restoration works will require either a Change Approval or a Water Licence.
Wildlife Act	MOF	Regulates works that impact raptors. Bald eagle, golden eagle, peregrine falcon, gyrfalcon, osprey and burrowing owl nests are protected year-round.	Raptors or their nests have not been identified within the study area. A pre-construction survey should be conducted to confirm that conditions have not changed.
		Regulates works that impact vertebrate species, other than birds	A general wildlife permit is required to salvage and relocate vertebrate species.
Weed Control Act and Regulation	BC Ministry of Agriculture and Lands	The Weed Control Regulation prohibits the spread of provincial and/or regional noxious weeds throughout the province. This includes vectors such as soils, machinery or vehicles, and seed mixes.	Noxious weeds have not been identified within the study area; however, a pre-construction survey should be conducted to assess if conditions have changed. Requires all land occupiers to control the spread of provincial and/or regional noxious weeds on their land and premises.
Park Act	Ministry of Environment and Climate Change Strategy	-	A letter of Authorization is likely required to conduct restoration works within Sasquatch Provincial Park.

6.1 *SPECIES AT RISK ACT*

SARA-listed birds and aquatic species are protected where their critical habitat has been identified, in all lands regardless of jurisdictions. Management Plans and Recovery Strategies are federal stewardship initiatives that involve collaboration with provincial governments, and as such it is expected that these protocols are adhered to on provincial lands as a matter of due diligence. It is expected that SARA permits will not be required for this Project.

6.2 *MIGRATORY BIRDS CONVENTION ACT*

ECCC's Canadian Wildlife Service (CWS) has jurisdiction over birds listed under the federal *Migratory Birds Convention Act* (MBCA 1994). In the general area of the Project, species include insectivorous birds (i.e., warblers, flycatchers, hummingbirds, wrens, thrushes, vireos, nightjars, swallows, tanagers, woodpeckers, chickadees, and their allies), seed eaters (i.e., sparrows, finches, grosbeaks, tanagers), and water birds (i.e., shorebirds, gulls, waterfowl, and their allies). Some of these species are listed under SARA. MBCA prohibits injury, molestations, and destruction of migratory birds and their nests. Generally accepted work windows revolve around the breeding bird nesting periods defined by ECCC. The nesting window is between March 15 and August 30 for birds in the Fraser Valley (ECCC 2018). If works cannot be conducted outside of these windows, measures to protect active nests are required.

6.3 *FISHERIES ACT*

The *Fisheries Act* requires that project works, undertakings or activities avoid causing:

- The death of fish by means other than fishing; and
- Harmful alteration, disruption, or destruction (HADD) unless authorized by the minister of fisheries and Oceans Canada.

In accordance with the Fish and Fish Habitat Protection Policy Statement (DFO. 2019b), DFO interprets HADD as any temporary or permanent change to fish habitat that directly or indirectly impairs the habitat's capacity to support one or more life processes of fish.

Hatfield has evaluated the proposed Project works, undertakings, and activities to confirm if all Measures to Protect Fish and Fish Habitat (DFO. 2019a) can be implemented. A Request for Review application to DFO will be required given the Project is unable to avoid "disturbing or removing materials from the banks, shoreline or waterbody bed" (DFO 2019a). It is expected that DFO will issue a, avoid and mitigate letter (aka Letter of Advice, or LoA) for the Project to proceed within 60 days of submitting the Request for Review application.

6.4 *WATER SUSTAINABILITY ACT*

To make changes in and about a stream requires a license, use approval or change approval or compliance with an order, or Part 3 of the Water Sustainability Regulation (the Regulation), which includes submitting a Notification to a Habitat Officer. The BC *Water Sustainability Act* defines changes in and about a stream as "any modification to the nature of a stream, including any modification to the land, vegetation and natural environment of a stream or the flow of water in a stream, or any activity or construction within a stream channel that has or may have an impact on a stream or a stream channel" (WSA 2016). A stream channel includes the bed and banks of the stream and includes side channels.

Based on the preferred option of a new clearspan bridge complete with channel reconstruction and bank erosion protection (AE 2022), and consideration of proposed habitat restoration works, it is anticipated that a Change Approval pursuant to Section 11 of the *Water Sustainability Act* will be required. MOF may advise that a Water Licence is more appropriate, given the proposed habitat restoration works downstream of Hicks Lake Road include restoring an isolated side channel via a diversion pipe (i.e., water diversion) that will likely require future maintenance activities that would be authorized under a Water Licence, but not under a one-time Change Approval.

6.5 *BC WILDLIFE ACT*

Wildlife in BC are protected from harm under the *Wildlife Act*, except as allowed by regulation for such activities as hunting and trapping. The *Wildlife Act* falls under the jurisdiction of MOF and extends to vertebrate animals including bird species not listed under the *Migratory Birds Convention Act*. A *Wildlife Act* permit is required to relocate vertebrates from the construction footprint to avoid disturbance and/or mortality. Although there is no timeline for the review of the permit, there is a general 60-day review period following the submission of a permit application. A permit application includes a detailed salvage plan (including contingency measures and effectiveness monitoring), and First Nations consultation, which can be a lengthy process. A permit application review may be expedited through payment to Front Counter BC.

Based on the habitat conditions and nature of work at site DF4 it is recommended that a pre-construction salvage for Pacific water shrew occur before commencing works, with consideration for the provincial BMPs (Craig et al. 2010). This would mitigate potential mortality of Pacific water shrew, demonstrating due diligence towards species protection and support for the provincial and federal goal for recovery (Environment Canada 2014). It will be the contractor's AQP's responsibility to obtain a permit and define appropriate salvage methods for Pacific water shrew.

6.6 *WEED CONTROL ACT*

Pursuant to the *Weed Control Act* (WCA 1996), the spread of all regionally and provincially designated noxious weeds must be controlled. The aim of the *Weed Control Act* is to protect the province's economy, natural resources, and society from the negative impacts that noxious weeds have on native ecosystems and infrastructure. Noxious weeds are to be managed throughout the construction phase of the Project per the contractor's CEMP.

7.0 CLOSURE

MOTI proposes upgrades to the Trout Lake Creek crossing at Hicks Lake Road, which was damaged during the November 2021 atmospheric river. Project works include changes in and about a stream and as such will require regulatory review in accordance with the federal *Fisheries Act* and provincial *Water Sustainability Act*. Based on a review of the draft options analysis (AE 2022) and contingent upon recommended design and construction mitigation strategies provided in this EOA, it is Hatfield's opinion that residual impacts on environmental resources will not occur as a result of the Project. A more detailed quantification of Project-related impacts in support of environmental permit applications will be provided as Project design drawings are advanced.

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APPENDICES

Appendix A1

Associated Engineering, Draft Options Analysis and Conceptual Design Report

Associated Engineering
GLOBAL PERSPECTIVE.
LOCAL FOCUS.

TECHNICAL MEMORANDUM

Issue Date: August 19, 2022
File No.: 2020-2904-00
To: Dan Cossette, MSc, P.Eng.
Previous Issue Date: N/A
From: Eric Finney, P.Eng.
Project No.: 2020-2904
Client: Ministry of Transportation and Infrastructure
Project Name: Trout Lake Creek Culvert Replacement
Subject: Draft Options Analysis and Conceptual Design Report

1 BACKGROUND

In 2017, the **Ministry of Transportation and Infrastructure (MoTI)** retained **Associated Engineering (AE)** to complete an assessment on the existing Trout Lake Creek culvert under Hick's Lake Road, northeast of Harrison, BC.

AE completed a hydrotechnical analysis of the existing crossing. The 2018 Hydrotechnical Analysis is included in **Appendix A**. The 100-year peak flow rate based on historical data was estimated at 28.7 m3/s. A climate change allowance of 20% was also included, resulting in an estimated design 100-year peak flow rate of 34.5 m3/s. The initial culvert sizing indicated a closed bottom pipe arch with a 6200 mm span and a 3900 mm rise, with an assumed embedment of 850 mm, would be required.

As part of that assignment, AE also completed a Conceptual Bridge Design. The 2018 Conceptual Bridge Design is provided in **Appendix B**. The bridge concept had ten 700 mm deep precast concrete box girders, with a span length of 17 m. For completeness, we have also included the Geotechnical Memorandum provided by MoTI in 2018 which was used to support the conceptual bridge design; this memo is provided in **Appendix C**.

Following the completion of the 2018 assessments, no immediate upgrades were implemented.

On January 31, 2020, MoTI experienced a washout event of the existing culvert under Hick's Lake Road. MoTI completed emergency work to install a temporary bridge at the site. Following the emergency response, MoTI retained AE to review additional culvert concepts for the crossing and provide a summary of the life-cycle-cost analysis for the culvert and bridge options. As part of this assignment, Westrek Geotechnical completed a Preliminary Hydrogeomorphic Assessment, which is provided herein as **Appendix D**. AE completed additional hydraulic analyses of alternative culverts and summarized our findings and recommendations in the Trout Lake Creek Culvert Replacement Culvert Concept Design; this technical memorandum and the concept design drawings are provided as **Appendix E**.

In November 2021, MoTI experienced another major rainfall event. As a result of this rainfall event and the ensuing peak flows, the temporary rail car bridge that MoTI installed in early 2020 was washed out. MoTI completed emergency works to install four 1500 mm diameter HDPE culverts under Hick's Lake Road.

2 CURRENT ASSESSMENT

Following the November 2021 washout, the Trout Lake Creek crossing was identified as being eligible for Disaster Financial Assistance Arrangement (DFAA) funding. In order to support the DFAA funding process, MoTI requested AE to complete an Options Analysis of four potential alternative design solutions for the crossing:

- Option 1 – Maintain the existing four 1500 mm HDPE culverts.

- Option 2 – Construct a new CSP arch culvert to convey the clearwater design flow, with an upstream debris mitigation net.
- Option 3 – Construct a new bridge to convey the clearwater design flow, with an upstream debris mitigation net.
- Option 4 – Construct a new bridge to convey the design debris flood.

To support the options analysis of these four alternatives, our team completed additional hydrotechnical, roadway, and structural concept designs. We also received additional hydrogeomorphic analysis from Westrek Geotechnical. Design considerations for each of these disciplines are discussed briefly below. We note that environmental input for the assignment is being provided by Hatfield Consultants directly to MoTI.

2.1 Hydrogeomorphic Assessment

Westrek Geotechnical is currently completing a hydrogeomorphic assessment to: characterize the November 2021 washout event; review the stability of upslope logging roads within the catchment; assess options for an upstream debris catchment fence; complete a change-detection analysis from multiple LiDAR sets to identify areas of depletion and accumulation within the watershed; and estimate the annual sediment yield on the system. The hydrogeomorphic assessment is still underway, and reporting is not yet available. However, Westrek has provided the following key inputs at this time:

- The November 2021 event within the Trout Lake Creek channel was likely to be a debris flood. We would classify it as a “damaging debris flood”, i.e., one where some lateral changes to the channel bedload were observed and some bank erosion occurred.
- The contribution from the channel within the un-named gullied creek to the south is probably very similar, although not as much sediment appeared to have been mobilised and moved down to Trout Lake Creek.
- While historic debris flows have occurred in the two gullied streams that are tributaries to Trout Lake Creek (immediately downstream from the lake outlet), these hazards did not occur as a result of the rainfall that occurred in November 2021. The debris from these historic events generally arrested in the mainstem channel of Trout Lake Creek, within about 70 m downstream from the confluence.
- The dam that was located at the outlet of Trout Lake, no longer exists; it appears to have been removed /decommissioned some time ago.
- As a result of the above observations, we consider that the reaches of Trout Lake Creek upstream from the crossing to be prone to Type 1 debris floods (from Church & Jakob, 2020).
- For the design of the crossing, we recommend a bulking factor of 1.1 or 10% would be appropriate to pass the design debris flood.

Based on a review of the field conditions on site, Westrek has noted that the initial concept of installing a debris catchment net upstream of the crossing does not appear feasible; while the channel is contained by the hillside immediately north of the creek, the topography to the south of the creek is not suitable to anchor a debris catchment net.

Westrek has noted that an alternative debris mitigation measure, such as a grizzly-type debris rack, could be considered. The potential benefit of a grizzly-type debris rack would be to capture large woody debris before it reaches the crossing.

Westrek has noted that such a structure would need to be located approximately 50 m to 60 m upstream of Hick's Lake Road. The upstream distance is necessary to provide flows an opportunity to enter back into the creek channel prior to reaching Hick's Lake Road; if the grizzly-type debris rack were located immediately upstream of the crossing, there is a risk the flows could be diverted out of the channel bank and spill over the road. Further, given the topography of the site, the grizzly-type debris rack would need to extend over the full width of the floodplain at this location, spanning from valley-wall-to-valley-wall. The grizzly-type debris rack would be approximately 40 m to 50 m long. Westrek has noted that if the hydraulic structure at Hick's Lake Road can be sized to provide adequate hydraulic capacity for the design debris flood, then an upstream mitigation measure would not be required from a hydrotechnical perspective.

2.2 Diversion Berm

Westrek has also noted that there is a serious public safety concern related to the unregulated berm which forms part of a diversion of flows from a historic channel to the north into Trout Lake Creek. This issue was also identified by Westrek as part of the 2020 Preliminary Hydrogeomorphic Assessment.

While this issue is independent from the Trout Lake Creek Options Analysis, Westrek has noted that it needs to be addressed. Recognizing the importance of this issue, we have included the following excerpt from the 2020 Preliminary Hydrogeomorphic Assessment:
"The February 2020 breach of the (likely) unregulated berm that was previously diverting flow at the Stream 1 apex revealed a serious public safety concern at this site that will have to be immediately addressed and managed by the local government. A future berm failure could threaten infrastructure downstream, the provincial park, private property, and human life. The restoration of the berm completed in February (2020) should be considered temporary, and the berm should be assessed and upgraded as necessary to a permanent structure that meets a modern standard and takes into account the effect of climate change. Such structures are regulated in the Province, and an agency (likely the local government or another designated authority) will have to take responsibility for this structure so that it can be inspected and repaired as needed. It is recommended that this report be forwarded to the responsible agency so that they can proceed with this."

2.3 Hydrotechnical Assessment

2.3.1 Design Flow Rate

As noted above, a hydrologic assessment was completed previously to estimate the design 100-year return period flow. The design flow rate is estimated at 34.5 m^3/s, which includes a 20% allowance for future climate change.

Based on the initial input provided by Westrek, we have allowed for a 10% bulking factor for the purposes of assessing the hydraulic openings under the design debris flood. The resulting flow rate used for the debris flood analyses is 38.0 m^3/s.

2.3.2 January-February 2020 and November 2021 Rainfall Events

To support Westrek's analysis and characterization of past events on Trout Lake Creek, AE reviewed the observed rainfall data from both the January-February 2020 event and the November 2021 event, and estimated the corresponding return periods for each event.

Our rainfall analysis was based on 15-minute interval data provided by Environment Canada for both the Hope Airport (ID#1113540) and Agassiz RCS (ID#1100119) rainfall stations.

Table 2-1
Rainfall Analysis for Hope Airport (Environment Canada Gauge 1113540)

Published Rainfall Intensity (mm/hr)							November 2021 Event		January - February 2020 Event	
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	Observed Rainfall Intensity (mm/hr)	Approximate Return Period	Observed Rainfall Intensity (mm/hr)	Approximate Return Period
15 min	23.1	29.9	34.3	40	44.2	48.3	16.8	<2yr	11.2	<2yr
30 min	17.3	21.6	24.4	28	30.7	33.3	15.6	<2yr	10.6	<2yr
1 hr	13.1	16.2	18.3	20.9	22.8	24.8	14.7	2yr-5yr	9.6	<2yr
2 hr	10.2	12.5	14	15.9	17.3	18.7	13.1	5yr-10yr	8.9	<2yr
6 hr	6.8	8	8.8	9.7	10.5	11.2	10.6	50yr-100yr	7.8	2yr-5yr
12 hr	5.1	6.3	7.1	8.1	8.8	9.6	9.7	>100yr	7.0	5yr-10yr
24 hr	3.5	4.8	5.7	6.8	7.6	8.4	8.0	50yr-100yr	5.4	5yr-10yr

Table 2-2
Rainfall Analysis for Agassiz RCS (Environment Canada Gauge 1100119)

Published Rainfall Intensity (mm/hr)							November 2021 Event		January - February 2020 Event	
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	Observed Rainfall Intensity (mm/hr)	Approximate Return Period	Observed Rainfall Intensity (mm/hr)	Approximate Return Period
15 min	20.6	25	27.9	31.6	34.3	37	16.0	<2yr	7.6	<2yr
30 min	14.6	17.6	19.6	22.2	24.1	25.9	15.0	2yr-5yr	7.4	<2yr
1 hr	10.9	13.2	14.7	16.6	18.1	19.5	13.5	5yr-10yr	7.2	<2yr
2 hr	8.3	9.6	10.4	11.5	12.2	13	12.2	25yr-50yr	7.0	<2yr
6 hr	5.5	6.2	6.8	7.4	7.9	8.4	9.5	>100yr	5.5	<2yr
12 hr	4.2	4.9	5.4	6	6.5	6.9	7.8	>100yr	4.7	2yr-5yr
24 hr	3.1	3.8	4.3	4.9	5.3	5.8	6.5	>100yr	3.6	2yr-5yr

The observed rainfall intensities from both events are also plotted on top of the IDF curves for each rain gauge, as shown on **Figure 2-1** and **Figure 2-2.**

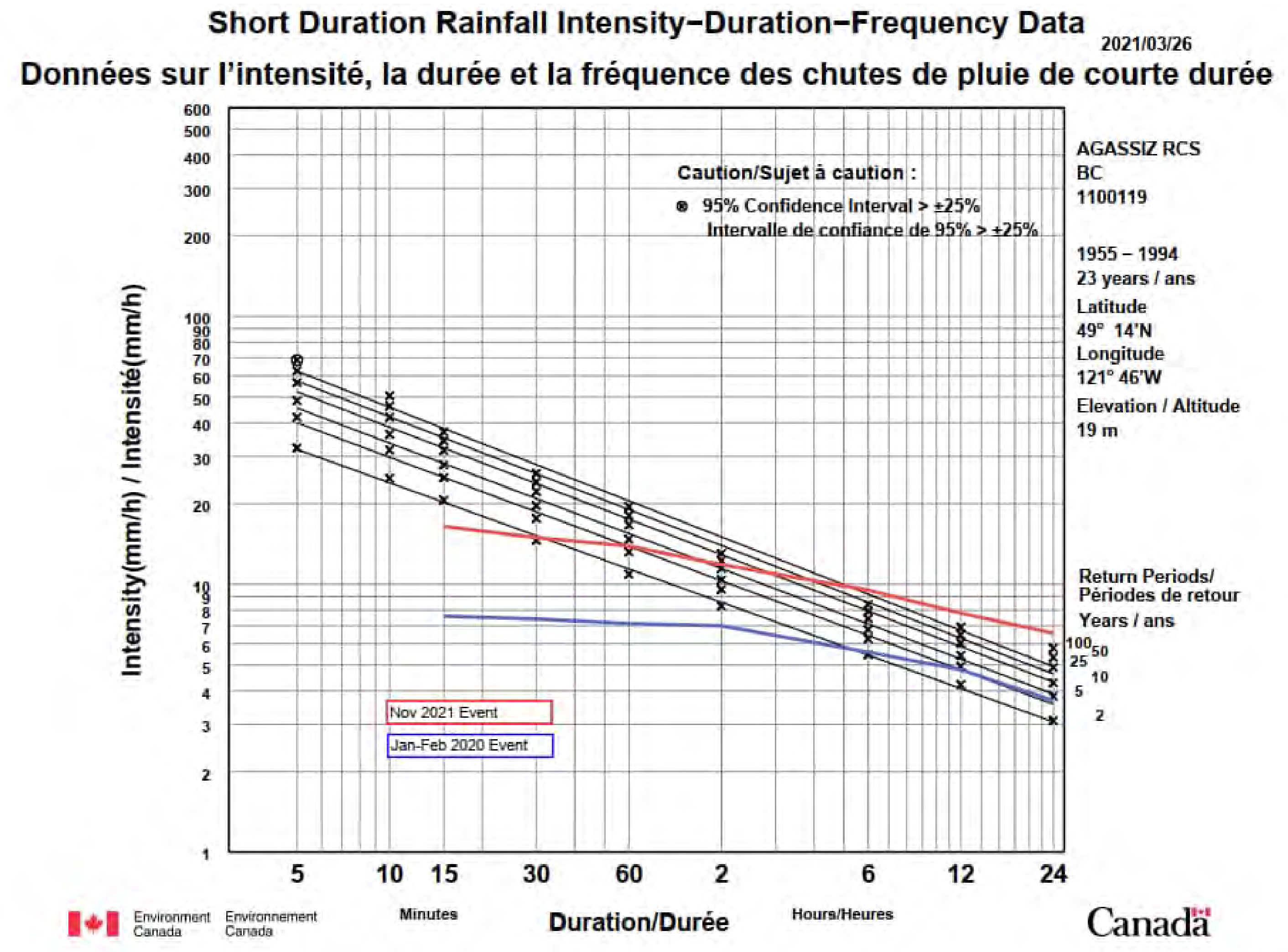


Figure 2-1
Agassiz RCS IDF Curve annotated with recent storms

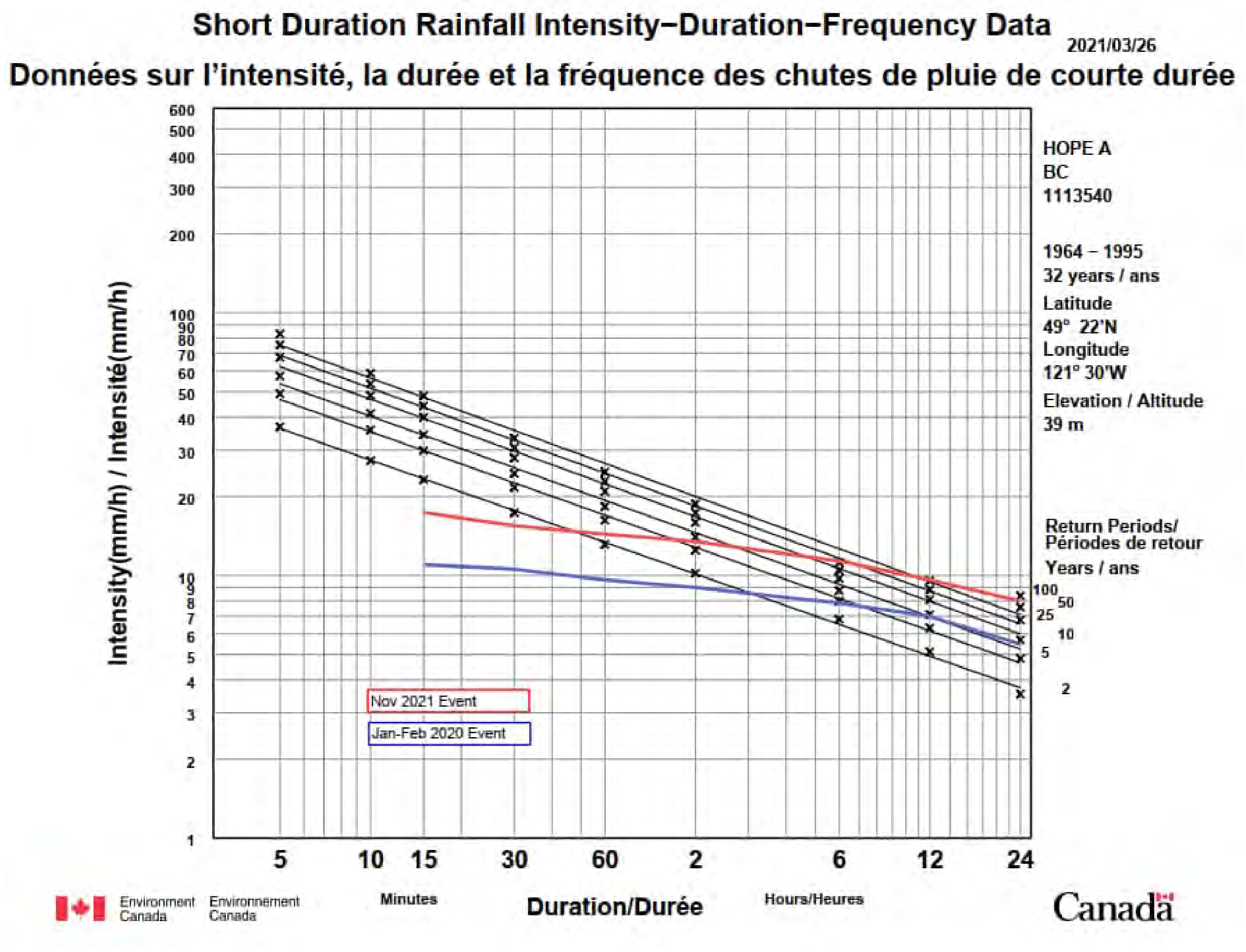


Figure 2-2
Hope A IDF Curve annotated with recent storms

As indicated by the results of this analysis, the November 2021 event had a return period of approximately 2-years to 10-years for the peak of 15 minutes to 1 hour. However, for durations between 6 hours and 24 hours, the observed rainfall is estimated to be in excess of a 100-year return period.

2.3.3 Updated Hydraulic Modelling

As part of the current assignment, our team was provided with a topographic survey of the creek from approximately 150 m upstream of Hick's Lake Road out to Harrison Lake.

2.3.4 Bridge Opening

We used this recent topographic survey to develop a new HEC-RAS model of the creek system and analyzed the bridge opening under the design flow rate for both the clearwater flow and debris flood (i.e. with 10% bulking factor applied).

Our review of the longitudinal profile along the creek centerline noted that there is a steep drop at the outlet of the existing HDPE culverts. To mitigate this vertical drop, we have proposed that the channel invert be regraded through the crossing to provide a consistent slope.

Figure 2-3 below shows the design water surface elevation through the bridge opening for both the clearwater flow and debris flood scenarios:

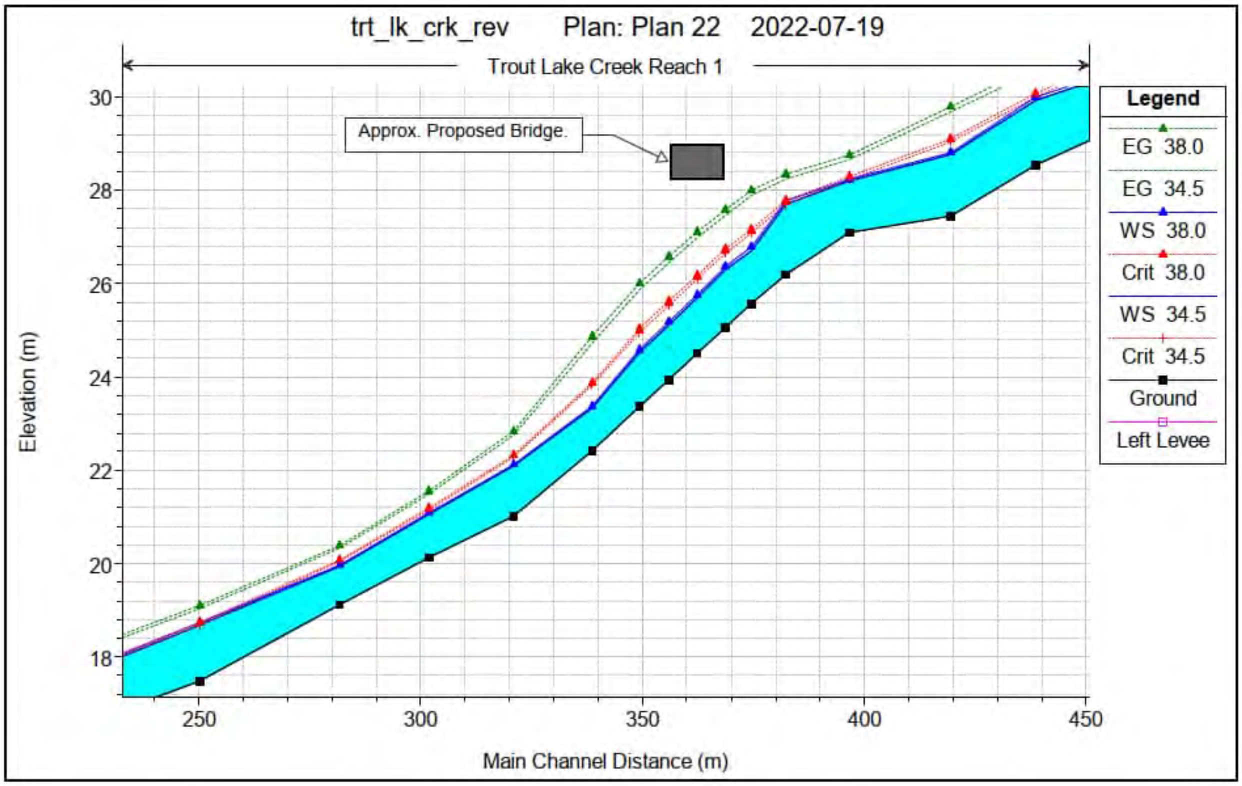


Figure 2-3
Profile of Proposed Bridge Channel

Based on this updated HEC-RAS modelling, the water surface elevation at the upstream face of the bridge for the 100-year return period is estimated at 26.29 m for the clearwater flow scenario (Q = 34.5 m^3/s). When we include the 10% bulking factor to account for the debris flood (Q = 38.0 m^3/s), the water surface elevation at the upstream face of the bridge is estimated at 26.37 m.

As indicated on the conceptual bridge design drawing (refer to **Section 2.4**), the minimum soffit elevation of the new bridge is approximately 28.65 m.

This results in a design freeboard of approximately 2.36 m for the clearwater peak instantaneous 100-year event. The freeboard is only nominally reduced to 2.28 m when the 10% bulking factor is applied to account for the debris flood.

2.3.4.1 Existing Culverts

Based on the survey data provided, we also developed an existing condition HEC-RAS model of the 4 HDPE culverts. The modelling results indicate that Hick's Lake Road would overtop during the design flow event under existing conditions.

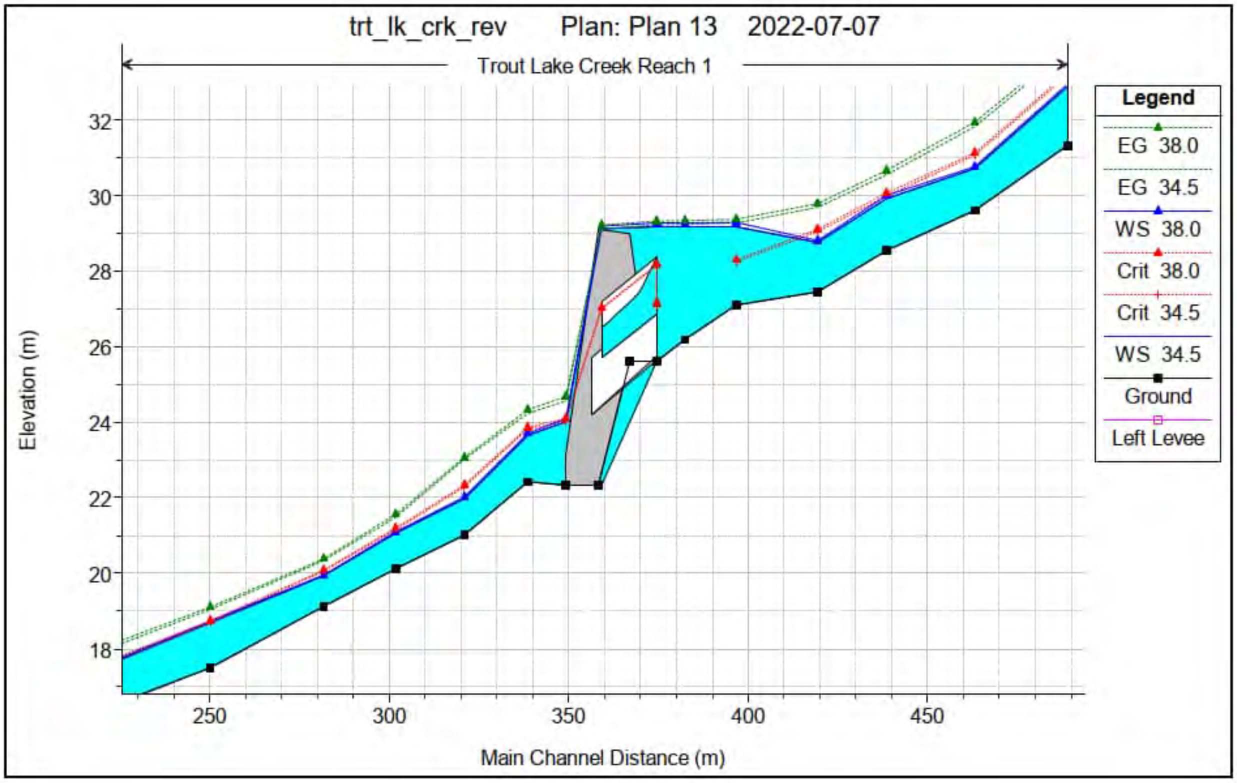


Figure 2-4
Existing Culvert Profile Showing Overtopping of Hick's Lake Road

2.3.4.2 CSP Arch Culvert

As part of the 2021 Culvert Conceptual Design, we estimated that a 7670 mm x 2570 mm CSP Arch Culvert would be required to convey the design flow rate of 34.5 m3/s. Based on the modelled water surface elevation at the culvert inlet, the proposed arch culvert would provide approximately 540 mm of freeboard for the clearwater flow scenario. No additional hydraulic modelling was completed for this scenario as part of the current assessment.

Recognizing that the initially proposed concept of installing a debris catchment net upstream of the crossing may not be feasible, we analyzed the proposed CSP Arch Culvert under a design flow rate of 38.0 m3/s, to reflect the potential debris flood scenario. Under this scenario, the proposed culvert would have approximately 310 mm of freeboard.

2.4 Conceptual Road Design

Based on communications with MoTI, the classification for Hick's Lake Road has been confirmed as a Low Volume Road. The highway design criteria are presented in **Appendix G**.

We have developed conceptual road designs to accommodate the four options being considered as part of the overall assessment.

Under Option 1, the existing 4 HDPE culverts would be maintained. Under this scenario, only nominal road upgrades would be completed to address safety concerns. These upgrades include remediation of the pavement structure and the addition of a concrete roadside barrier for the length of the creek crossing, complete with barrier flares. We note that the vertical road profile for Option 1 has been developed to tie into the existing road grades and minimize grading impacts; the resulting vertical sag curve is substandard and does not achieve the highway design criteria presented herein.

For Options 2, 3, and 4, the conceptual road design is very similar. The proposed road geometry includes raising the grade of Hick's Lake Road at the crossing to achieve a vertical sag curve that is in accordance with modern design standards presented in the highway design criteria. The horizontal curve radius at the creek crossing has been increased due to the steep grades on the north approach. This flatter curve also improves vehicle tracking and sight lines.

The conceptual options assume a pavement structure of 100 mm asphalt, 300 mm well graded base course, and 300 mm select granular sub-base.

Conceptual road design drawings are presented in **Figure 2-5** through **Figure 2-13** found in **Appendix I**.

2.5 Conceptual Bridge Design

The bridge option developed during this assessment has largely been based on the bridge concept developed in 2018, described in the previous report included as **Appendix B**. The new hydrotechnical and roadway designs forming the base of all the options explored in this report, however, prompted several changes to the bridge concept to accommodate. The two primary changes in bridge requirements include:

- Span length has increased from 17 m to 19 m, based on more detailed channel grading.
- Structure width has been reduced from 12.114 m to 9.552 m, based on current roadway design section.

The structural design criteria for the new bridge have been updated to reflect these changes and is included in **Appendix H**.

The change in bridge requirements from the original 2018 conceptual design are relatively minor, such that they do not change the rationale behind choosing precast concrete box girders. For the 19 m span, precast concrete box girder bridges are typically the efficient and economical option when compared against a steel girder bridge or a precast concrete I-girder bridge. They also provide greater freeboard than the other options, with similar abutments. Precast concrete box girders are well suited to the bridge requirements.

The revised conceptual bridge design is presented in **Figure 2-14** and **Figure 2-15**. The significant changes include increasing the precast concrete box girder depth from 700 mm to 800 mm and decreasing the bridge width from ten box girders to only eight.

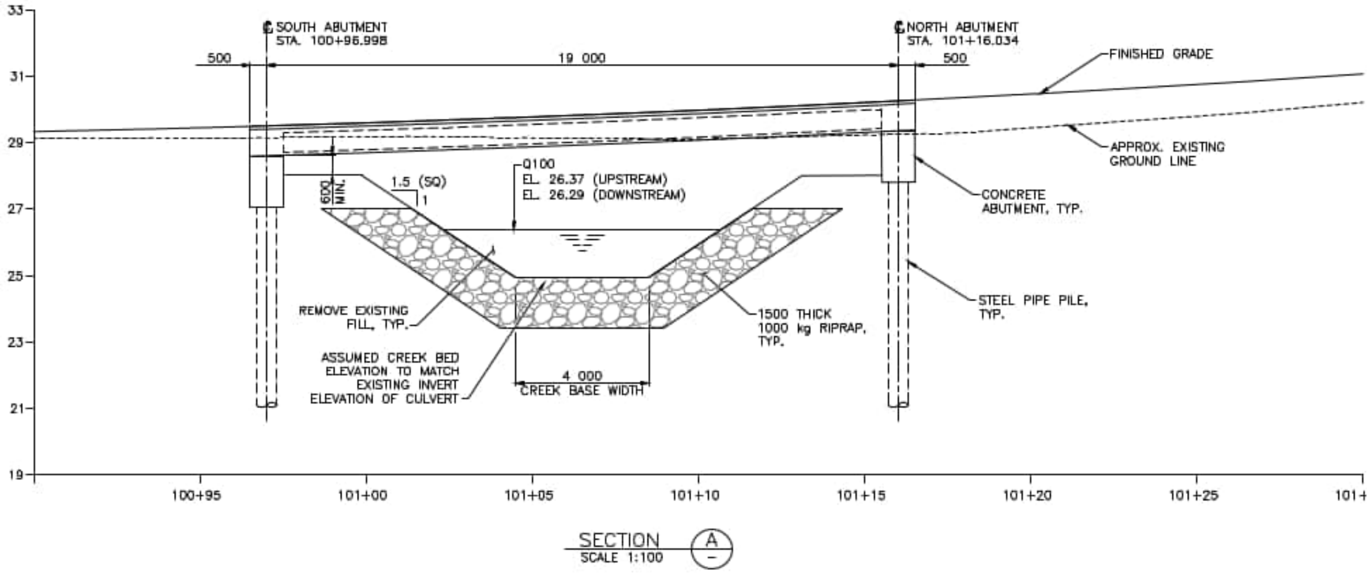


Figure 2-14
Bridge Concept Section Along Road Centreline

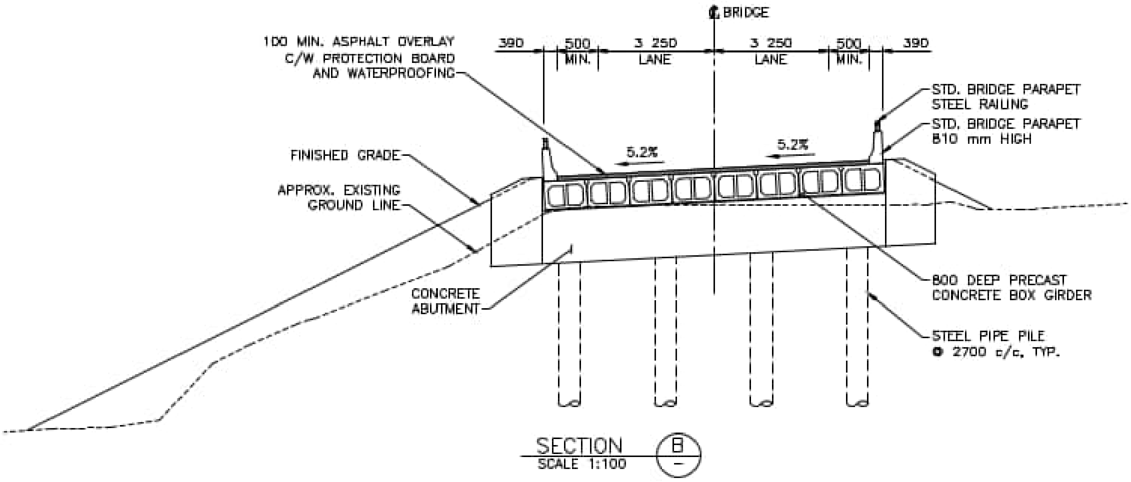


Figure 2-15
Bridge Concept Cross Section

The full bridge conceptual drawing is included as **Appendix J**. Key components of the bridge concept include:

- 100 mm asphalt overlay with protection board and waterproofing underneath.
- 8 x 800 mm deep precast prestressed concrete box girders, without a reinforced concrete overlay to minimize construction duration.
- BC MOTI standard bridge parapets with steel bicycle railings.
- Semi-integral reinforced concrete abutments to eliminate deck end joints, and wing walls parallel abutments.
- Four steel piles at each abutment with an assumed 610 mm diameter and 15.9 mm thick plate (to be confirmed by a geotechnical engineer during detailed design).

Approach slabs have not been included in the bridge concept as a consequence of the road being classified a Low Volume Road. Approach slabs may be added during the detailed design phase if warranted.

3 OPTIONS ANALYSIS

We have reviewed each of the four options based on the following considerations:

- Structural.
- Roadway.
- Hydrotechnical.
- Hydrogeomorphic.
- Environmental.
- Geotechnical.
- Cost.
- Risk.
- Property.
- Maintenance
- Constructability

The Options Analysis assessment is presented in **Table 3-1**.

Table 3-1

	Option	Structural Considerations	Roadway Considerations	Hydrotechnical Considerations	Hydrogeomorphic Considerations	Environmental Considerations	Geotechnical Considerations	Cost Considerations	Risks	Property Requirements	Maintenance	Constructability
1	Maintain Existing 4 HDPE Culverts Minimal Road Improvements	● n/a	● Minimal road improvements to address safety concerns (addition of barriers, c/w barrier flares). ● Geometry to tie-in to ambient conditions. ● Vertical sag curve used to suit existing grades is sub-standard.	● Culverts do not have capacity for clear water design flow event. ● Road overtops during the design flood event. ● Situation is further exacerbated when considering debris and corresponding bulking factor.	● Smallest hydraulic opening of the four options. ● Most susceptible to future debris and sediment blockages.	● The existing culverts are a barrier to fish passage.	● No piles required.	● Roadway / earthworks = $186,000 ● Bridge = n/a ● Culvert = n/a ● Total Cost = $390,000 (with 30% contigency and other costs)	● Culverts are undersized for the design flow; the road is expected to overtop during design flood event. ● This option is the most susceptible to debris blockage.	● n/a - none required; already constructed.	● Most susceptible to debris blockage and sediment accumulation at the inlet. ● Maintenance activities will need to be focussed primarily at the culvert inlet.	● Already constructed.
2	Construct a New CSP Arch to Convey Peak 100-yr Flow Construct Upstream Debris Mitigation	● Multi-plate 7670 mm x 2570 mm CSP Arch Culvert ● Reinforced concrete footing and vertical stems required to support culvert on each side. ● Refer to AE March 2021 Tech Memo.	● Geometry improved to meet Low Volume Road design standards as per Highway Design Criteria.	● Culvert is sized to convey peak 100-year clearwater flow, with minimum 500 mm freeboard ● Freeboard achieved for clear water flow (34.5 m3/s) = 540 mm. ● Freeboard achieved for debris flow (38.0 m3/s) = 310 mm.	● As noted by Westrek, the site conditions are not conducive to a debris catchment net. ● As a result, ***the netting option is not feasible*** . ● An alternative mitigation measure, such as a grizzly-type debris rack could be considered. However, it would need to be located approximately 50 m to 60 m upstream of the crossing, and would need to extend a length of 40 m to 50 m to span the width of the floodplain at that location. ● If no debris mitigation is provided, the opening would be subjected to the debris flood. ● The Arch Culvert option would be better than Option 1 with respect to debris and sediment, but not as good as Options 3 or 4.	● Riprap could be constructed in step pools through the crossing, to facilitate fish passage. ● In theory, low flow periods would be most conducive to fish passage, based on estimated flow velocities. ● However, subsurface flows would likley occur due to large riprap classification (1000 kg). ● Based on on arbitrary low-flow rate of 0.5 m3/s, the lowest step-pool velocity is estimated at 0.5 m/s (compared to 1.3 m/s for constant graded channel). ● Refer to AE March 2021 Tech Memo. ● If an alternative debris mitigation is implemented, then maintenance activities would be focussed more upstream of the crossing.	● The previous concept design noted that piles are not required, as the spread footings are sufficient to resist the loads. ● However, piles could be considered, to provide a more robust footing system with respect to scour.	● Roadway / earthworks = $238,000 ● Bridge = n/a ● Culvert = $ 1,450,000 ● Piles = $ ● Total Cost = $3,630,000 (with 30% contigency and other costs)	● Upstream debris net is not feasible. ● The Arch Culvert is more susceptible to debris blockage than a bridge option. ● There is potential for the footings to be undermined, which would be problematic if they are not founded on piles.	● No private property constraints. ● Coordination required with BC Parks.	● Arch culvert would have a larger hydraulic opening than the existing 4 HDPE culverts, so it would be less susceptible to debris blockages and sediment accumulation. ● Difficult to access the interior of culvert to remove debris, or address potential issues with riprap. ● If alternative debris mitigation is implemented, then maintenance activities would be focussed more upstream of the crossing.	● Temporary detour and bridge likely required to provide construction access for the new culvert. ● Based on site grades, the temporary detour and bridge would likely be located upstream of Hick's Lake Road. ● CSP Arch Culvert would extend further upstream than a new bridge, due to the embankment fill slope. As a result, the temporary bridge and detour would need to be located further upstream than for the bridge option.
3	Construct Clear Span Bridge to Convey the Peak 100-yr Flow Construct Upstream Debris Mitigation	● New bridge as per revised Concept Design. ● Structure length has increased to 19 m (previously estimated at 17 m) based on a more detailed assessment of the channel grading requirements.	● Geometry improved to meet Low Volume Road design standards as per Highway Design Criteria.	● Bridge opening is sized to convey peak 100-year clearwater flow, with minimum 500 mm freeboard ● Soffit Elev ~28.65 m ● 100-year W.S.El. = 26.29 m ● Freeboard achieved = 2360 mm	● As noted by Westrek, the site conditions are not conducive to a debris catchment net. ● As a result, ***this netting option is not feasible*** . ● An alternative mitigation measure, such as a grizzly-type debris rack could be considered. However, it would need to be located approximately 50 m to 60 m upstream of the crossing, and would need to extend a length of 40 m to 50 m to span the width of the floodplain at that location. ● If no debris mitigation is provided, the bridge opening would be subjected to the debris flood (which is the basis for Option 4 below). ● The bridge option has the largest hydraulic opening of the options.	● Riprap could be constructed in step pools through the crossing, to facilitate fish passage. ● In theory, low flow periods would be most conducive to fish passage, based on estimated flow velocities. ● However, subsurface flows would likley occur due to large riprap classification (1000 kg). ● Based on on arbitrary low-flow rate of 0.5 m3/s, the lowest step-pool velocity is estimated at 0.5 m/s (compared to 1.3 m/s for constant graded channel). ● Refer to AE March 2021 Tech Memo. ● If an alternative debris mitigation is implemented, then maintenance activities would be focussed more upstream of the crossing.	● Piles required.	● Roadway / earthworks = $264,000 ● Structural = $1,360,000 ● Culvert = n/a ● Piles = $ ● Total Cost = $4,110,000	● Upstream debris net is not feasible. ● The bridge option is a more robust solution than either culvert option; it has the least risk of future failure due to debris blockage or sediment accumulation.	● No private property constraints. ● Coordination required with BC Parks.	● Bridge opening provides best access for future maintenance of the creek invert itself (debris removal, riprap adjustments, etc). ● If alternative debris mitigation is implemented, then maintenance activities would be focussed more upstream of the crossing. ● If alternative debris mitigation is not implemented, then debris and sediment would be more likely to be conveyed through the bridge opening and deposited downstream; maintenance activities would likely need to occur downstream of the crossing.	● Temporary detour and bridge likely required to provide construction access for the new bridge. ● Based on site grades, the temporary detour and bridge would likely be located upstream of Hick's Lake Road. ● The bridge option does not extend as far upstream as the CSP Arch Culvert. As a result, the temporary bridge and detour would not need to be located as far upstream (compared to the CSP Arch Culvert option).
4	Construct Clear Span Bridge to Convey Peak 100-yr Flow with Bulking Factor to Account for Debris	● New bridge as per revised Concept Design. ● Structure length has increased to 19 m (previously estimated at 17 m) based on a more detailed assessment of the channel grading requirements. ● Same bridge design as Option 3, since it already meets the freeboard requirements (i.e. bulking factor does not impact bridge design, it just nominally reduces the freeboard).	● Geometry improved to meet Low Volume Road design standards as per Highway Design Criteria.	● Sized to convey peak 100-year flow with bulking factor applied, with minimum 500 mm freeboard ● Soffit Elev ~28.65 m ● 100-year W.S.El. = 26.37 m ● Freeboard achieved = 2280 mm	● The hydraulic opening has been sized to convey the design flow rate with a bulking factor applied to account for the debris and sediment. ● During a major debris flood event, it is expected that material could be conveyed through the opening and likely deposited downstream of Hick's Lake Road where the channel grade flattens. ● The bridge option has the largest hydraulic opening of the options.	● Riprap could be constructed in step pools through the crossing, to facilitate fish passage. ● In theory, low flow periods would be most conducive to fish passage, based on estimated flow velocities. ● However, subsurface flows would likley occur due to large riprap classification (1000 kg). ● Based on on arbitrary low-flow rate of 0.5 m3/s, the lowest step-pool velocity is estimated at 0.5 m/s (compared to 1.3 m/s for constant graded channel). ● Refer to AE March 2021 Tech Memo. ● Sediment and debris would be deposited downstream of the bridge crossing; future maintenance activities would need to occur in this area.	● Piles required.	● Roadway / earthworks = $264,000 ● Structural = $1,360,000 ● Culvert = n/a ● Piles = $ ● Total Cost = $3,810,000	● The bridge option is a more robust solution than either culvert option; it has the least risk of future failure due to debris blockage or sediment accumulation.	● No private property constraints. ● Coordination required with BC Parks.	● Bridge opening provides best access for future maintenance of the creek invert itself (debris removal, riprap adjustments, etc). ● Debris and sediment more likely to be conveyed through the bridge opening and deposited downstream; maintenance activities would likley need to occur downstream of the crossing.	● Temporary detour and bridge likely required to provide construction access for the new bridge. ● Based on site grades, the temporary detour and bridge would likely be located upstream of Hick's Lake Road. ● The bridge option does not extend as far upstream as the CSP Arch Culvert. As a result, the temporary bridge and detour would not need to be located as far upstream (compared to the CSP Arch Culvert option).

3.1 Summary

Option 1 – Maintain existing 4 HDPE culverts

- The estimated cost is approximately $390,000.
- The achieved vertical sag curve for the road is substandard with a k factor of 3.8, while the guideline criteria is 9.The existing culverts do not have sufficient capacity to convey the design flow rate, and Hick's Lake Road is expected to overtop during the design event.
- The existing culverts are a barrier to fish passage.
- This option is most-susceptible to debris blockage and sediment accumulation.
- This option requires the highest frequency of maintenance activities, to keep the inlets clear.

Option 2 – New CSP Arch Culvert with Upstream Debris Mitigation

- As noted, the original concept for a debris catchment net is not feasible. An alternative mitigation measure, such as a grizzly-type debris rack, could be considered.
- The estimated cost is approximately $3,630,000.
- The roadway geometry is improved and achieves the design criteria.
- The hydraulic capacity of the culvert is adequate to convey the peak instantaneous 100-year clearwater flow, with approximately 540 mm of freeboard.
- If subjected to a debris flood (based on a bulking factor of 10%), the estimated freeboard would be reduced to approximately 310 mm.
- The CSP Arch Culvert would be less susceptible to debris blockage than the existing culverts, but more susceptible to debris blockage than a bridge opening.
- There is potential to construct riprap in a step-pool arrangement through the crossing to help facilitate upstream fish passage.
- Maintenance access to the channel itself (through the crossing) is more restricted than a bridge opening.
- Given the footprint of the proposed culvert, this option would require the largest temporary detour during construction.

Option 3 – New Bridge with Upstream Debris Mitigation

- As noted, the original concept for a debris catchment net is not feasible. An alternative mitigation measure, such as a grizzly-type debris rack, could be considered.
- The estimated cost is approximately $4,110,000
- The roadway geometry is improved and achieves the design criteria.
- The hydraulic capacity of the bridge opening is adequate to convey the peak instantaneous 100-year clearwater flow, with approximately 2.36 m of freeboard.
- The proposed bridge would have the largest hydraulic opening of the various options and would be the least susceptible to debris blockage.
- There is potential to construct riprap in a step-pool arrangement through the crossing to help facilitate upstream fish passage.
- Maintenance access to the channel itself (through the crossing) is less restricted than the CSP Arch Culvert.
- A temporary detour would be required during construction.

Option 4 – New Bridge Sized to Convey Debris Flood

- The estimated cost is approximately $3,810,000
- The roadway geometry is improved and achieves the design criteria.
- The hydraulic capacity of the bridge opening is adequate to convey the design debris flood flow rate of 38 m3/s (i.e. 100-year clearwater flow rate plus 10% bulking factor), with approximately 2.28 m of freeboard.
- As with Option 3, the proposed bridge would have the largest hydraulic opening of the various options and would be the least susceptible to debris blockage.
- There is potential to construct riprap in a step-pool arrangement through the crossing to help facilitate upstream fish passage.
- Maintenance access to the channel itself (through the crossing) is less restricted than the CSP Arch Culvert.
- A temporary detour would be required during construction.

A conceptual level cost estimate is provided in **Appendix K**.

3.2 Recommendation

Recognizing that the existing 4 HDPE culverts do not have sufficient hydraulic capacity to convey the design event, and that the vertical curve to match existing road grades is substandard, we recommend that Option 1 be dismissed.

The high-level cost estimates for the CSP Arch Culvert (Option 2) and the new bridge (Options 3 and 4) indicate that the costs are comparable between these options. Given the amount of freeboard that would be achieved by the bridge (2.36 m under a clearwater flow; 2.28 m under a debris flood with a 10% bulking factor applied), it would clearly provide a higher level of service than the proposed CSP Arch Culvert from a hydrotechnical perspective.

The bridge solution would also provide better access to the creek itself (through the crossing) for future maintenance.

Based on these considerations, we recommend that the Ministry proceed with a new bridge. Given the hydraulic capacity of the proposed opening and its ability to convey the design debris flood, an upstream debris mitigation measure does not appear to be critical to the crossing. However, if an upstream debris mitigation measure were implemented, it would tend to focus maintenance activities (i.e. debris removal) upstream of Hick's Lake Road rather than downstream of Hick's Lake Road.

Prepared by:	**Reviewed by:**
Eric Finney, P.Eng. Water Resources Engineer	Josh Thiessen, P.Eng. Senior Water Resources Engineer

EF/JT/sn

APPENDIX A – 2018 PRELIMINARY HYDROTECHNICAL ANALYSIS (FINAL TECH MEMO).

Associated Engineering
GLOBAL PERSPECTIVE. LOCAL FOCUS.

Issue Date:	June 1, 2018	**File:**	2017-2915.02.E.04.00
Previous Issue Date	February 28, 2018		
To:	Dickson Chung, P.Eng.		
From:	Jenna Lee, P.Eng., LEED AP BD+C		
Client:	Ministry of Transportation and Infrastructure		
Project Name	Trout Lake Creek Culvert Replacement		
Project No.	2017-2915		
Subject:	Preliminary Hydrotechnical Analysis (Final)		

TECHNICAL MEMORANDUM

1 BACKGROUND

The Ministry of Transportation and Infrastructure (the "Ministry") retained Associated Engineering to complete a hydrotechnical analysis for the replacement of the Trout Lake Creek Culvert. The culvert conveys Trout Lake Creek across Rockwell Drive (Hick's Lake Road) downstream of Trout Lake in Harrison, BC. The culvert is located a short distance upstream of Harrison Lake. Rockwell Drive is the only access to Sasquatch Provincial Park and is also used by local logging operations for hauling harvested timber.

The Ministry identified this culvert to be structurally deficient due to the loss of the invert section of the culvert. The culvert is perched by over 3 m with a large plunge pool at its outlet and is an obstacle to fish passage. The culvert invert is structurally suspect, with damage and corrosion of the invert.

Associated Engineering conducted a field review on November 1, 2017 with the Ministry Representatives and collected field data such as Manning's roughness and approximate culvert size. We completed a topographic survey on November 30, 2017 and developed a topographic surface for development of a hydraulic model.

The existing culvert is a 23 m long, 2400 mm wide by 1800 mm high pipe arch culvert on an approximately 8.6% gradient.

2 DESIGN CRITERIA

We used the following design criteria for the hydrotechnical analysis for the Trout Lake Creek Culvert Replacement.

- Size the culvert for the 100-year return period flood event. Note the culvert is under a low volume road.
- Apply a 20% increase to the flow estimates to account for climate change (Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate BC). Note IDF CC tool indicates approximately 15% to 25% increase in rainfall intensities in the project area (Agassiz IDF station) for Scenario RCP 8.5.
- Design the culvert for fish passage with the maximum culvert grade of 5% (BC MoTI Culvert and Fish Passage Fact Sheet). Notably, using the reduced gradient will increase the height of the plunge at the culvert outlet.

3 FLOW ESTIMATES

The catchment area of the Trout Lake Creek culvert drains westwards to Harrison Lake and has a high level of attenuation due to Trout Lake, approximately 700 m upstream of the culvert crossing, and Hicks Lake, approximately

2.5 km upstream of the culvert crossing. The total catchment area is approximately 22.2 km^2. The catchment boundary is shown in Figure 3-1.

Figure 3-1
Study Watershed

No flow records are available for Trout Lake Creek. Therefore, we reviewed Water Survey Canada hydrometric stations in BC to select watersheds with similar hydrological characteristics for estimating the design flow. Based on proximity, drainage area, hydrological regime, amount of attenuation, general exposure and topography, we selected three WSC gauges and completed a regional frequency analysis as summarized in Table 3-1. As mentioned, the Trout Lake Creek watershed has a significant amount of attenuation due to Trout Lake and Hicks Lake within the watershed. Therefore, we eliminated watersheds with low attenuation during our selection process.

Table 3-1
Regional Frequency Analysis

Station ID	Station Name	Drainage Area (km^2)	Years of Record	100-Year Flow Estimate (m^3/s)	Flow Per Unit Area (m^3/s/km^2)
08GA023	Rubble Creek near Garibaldi	74.1	10	74.8	1.0
08MF048	Elk Creek at Prairie Central Road	11.9	13	13.2	1.1
08MF006	Wahleach Creek near Laidlaw (upper)	64.8	14	58.5	0.9

The frequency analysis was completed in EasyFit, a statistical analysis tool, using maximum daily discharge data for the three gauges as instantaneous peak data was not available at these locations. We used a regression method to estimate the 100-year flow at the Trout Lake Creek crossing as shown in Figure 3-2. We estimated a peaking factor for the Trout Lake Creek watershed based on the estimated maximum daily 100-year flow and instantaneous peak 100-year flow for the WSC Jacobs Creek Above Jacobs Lake (08MH108) gauge. Note this gauge has relatively similar hydrologic characteristics to the Trout Lake Creek watershed, but was not used in the regression method as it results in a skewed result. The estimated peaking factor is 1.2. Note the Generalized Extreme Value (GEV) distribution was used for the frequency analysis, and the peak flow for the study watershed was scaled based on the ratio of the watershed areas for each of the three WSC gauges for the regression method. As suggested in TAC Guide to Bridge Hydraulics, a scaling exponent of 0.8 for small drainage areas in the range of 10 to 100 km^2, in which peak flows are highly dependant on area, was applied to the study watershed.

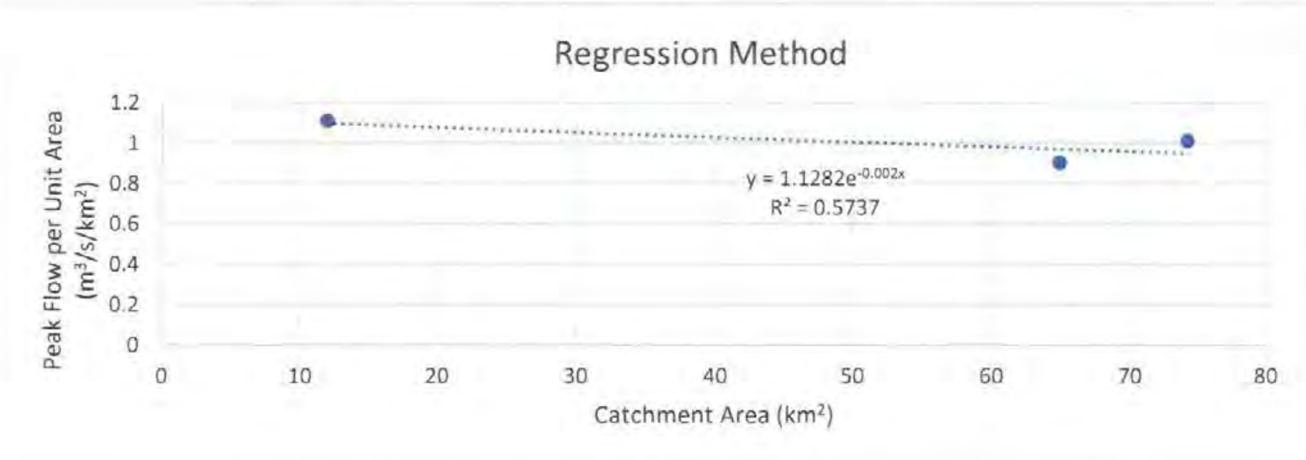


Figure 3-2
Regression Method

The results of the 100-year return period flow estimate for the Trout Lake Creek crossing are summarized in Table 3-2.

Table 3-2
Trout Lake Creek Flow Estimates

100-Year Max Daily Flow Estimate* (m^3/s)	100-Year Instantaneous Peak Estimate** (m^3/s)	100-Year Design Flow*** (m^3/s)
24.0	28.7	34.5

* Based on the regression method

Flow Per Unit Area = $1.1282e^{-0.002A}$ = 1.1 $m^3/s/km^2$, where A is the drainage area (22.2 km^2)

** With a peaking factor of 1.2

*** With climate change

4 HYDRAULIC ANALYSIS

We used HEC-RAS to develop a hydraulic model of the stream crossing. The hydraulic model parameters used for the model are summarized in Table 4-1. Note the model parameters are based on literature and were not calibrated as no flow data is available for the study area.

Table 4-1
Hydraulic Model Parameters

Model Parameter	Value
Manning's roughness, channel	0.1
Manning's roughness, over banks	0.05
Manning's roughness, CSP culvert	0.024
Manning's roughness, concrete culvert	0.013
Expansion coefficient	0.1
Contraction coefficients	0.3
Entrance loss coefficient	0.5
Exit Loss coefficient	1
Weir coefficient for roadway	2.6

The model results indicate that 100-year peak water level overtops the road by approximately 800 mm at the culvert inlet as shown in Figure 4-1. Note that the existing pipe culvert has a hydraulic capacity of approximately 8.0 m^3/s, which approximately corresponds to the 2-year return period flow.

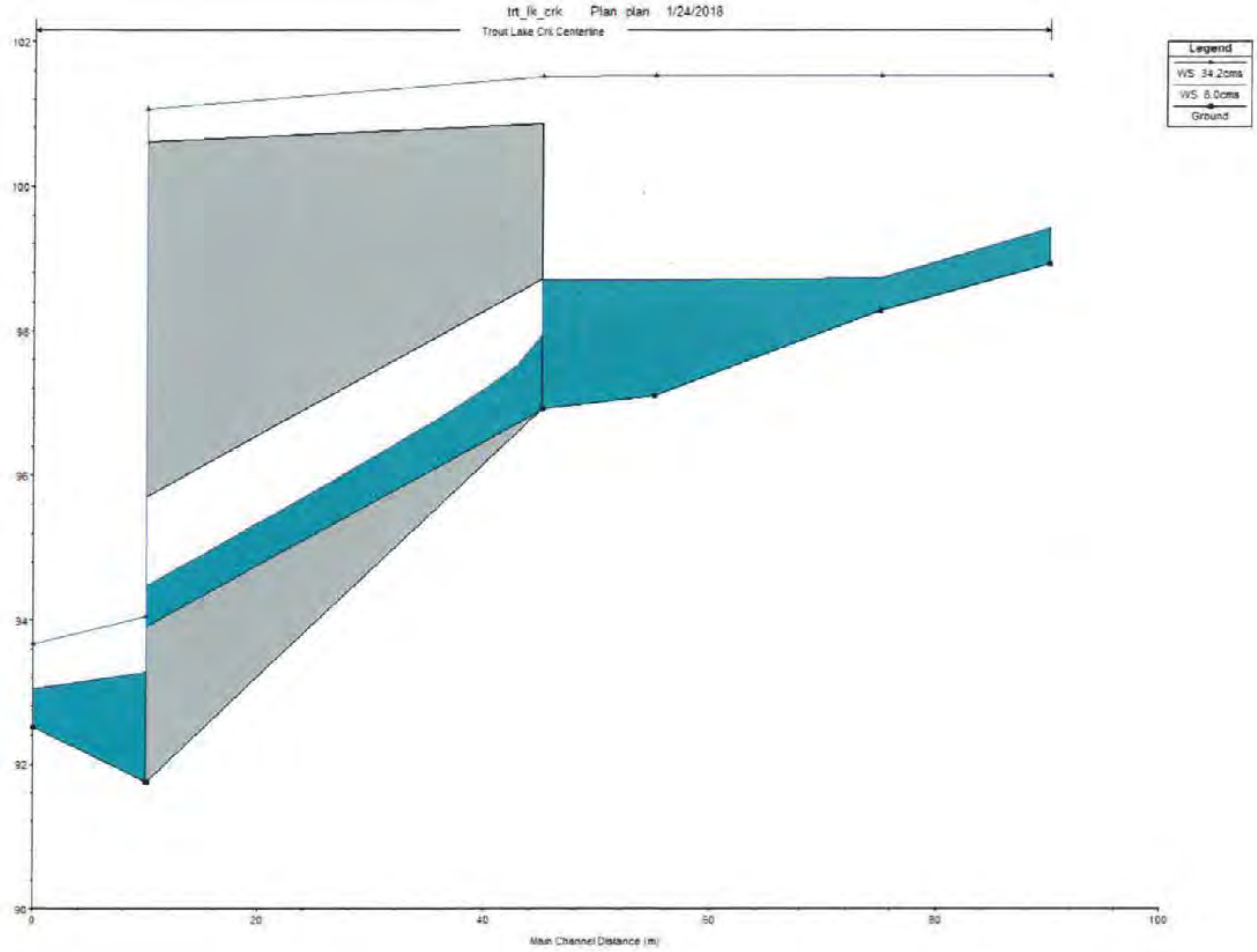


Figure 4-1
100-Year Peak HGL Profile – Existing Culvert

An open bottom arch culvert with 5 m span and approximately 3.2 m rise hydraulic opening (i.e. not including depth of embedment of footings etc.), is required to convey the 100-year design peak flow with approximately 0.4 m freeboard to allow passage of debris at the inlet. The Canadian Highway Bridge Design Code (CHBDC) specifies freeboard requirements to be no less than 1.0 m for bridges on freeways, arterials, and collector roads, and not less than 0.3 m on other roads (i.e. low volume). Given that the culvert is on a low volume road and freeboard requirements are not specifically applied at culvert, we feel that a minimum of 0.3 m freeboard is adequate for the proposed culvert. Figure 4-2 shows the hydraulic model results. The culvert is at approximately a 9% grade. For bottom stability, step pools will likely be required.

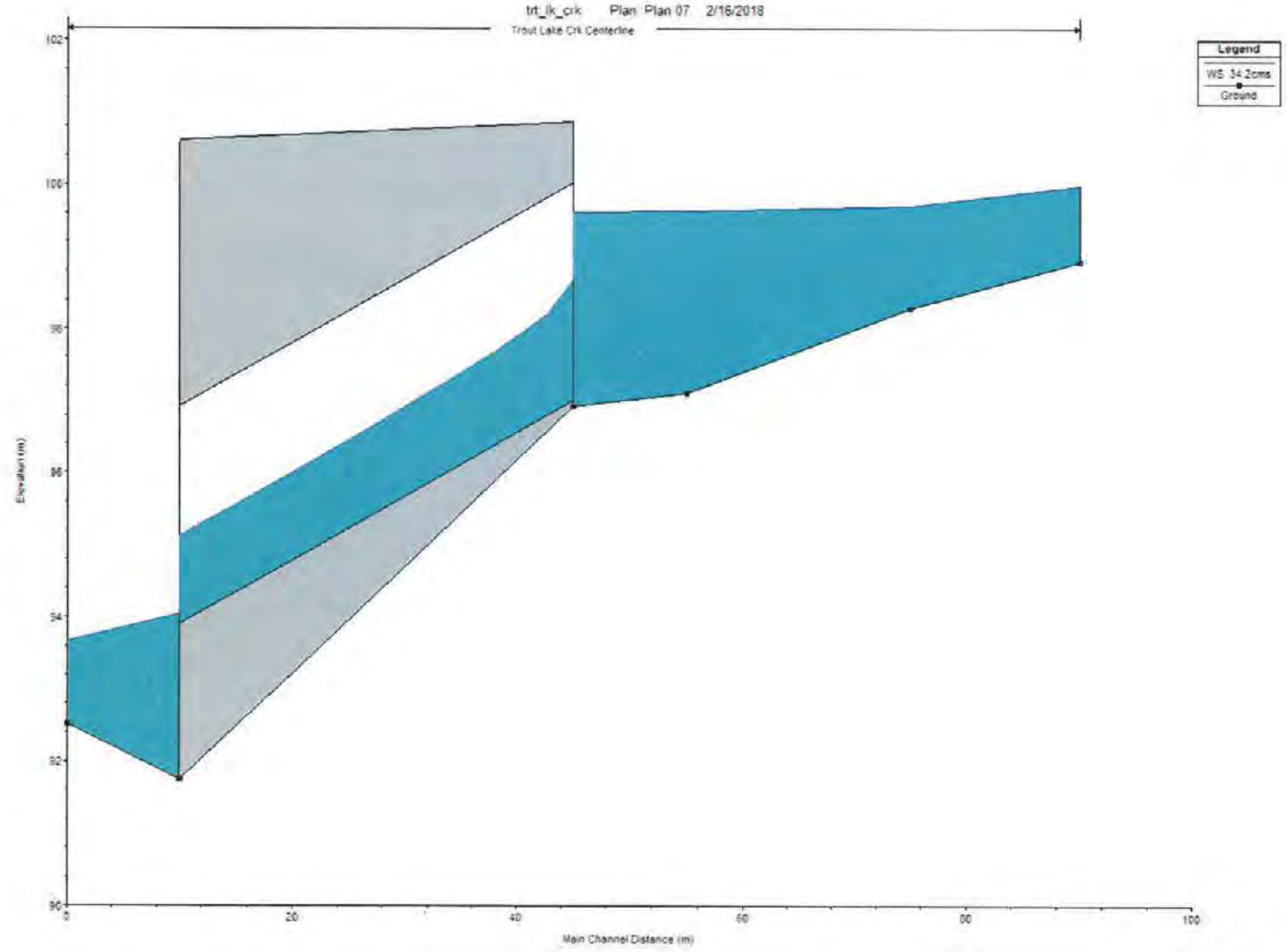


Figure 4-2
100-Year Peak HGL Profile – Proposed Culvert

We estimate that 1000 kg riprap will be required for a step pool arrangement in the culvert, and the channel upstream and downstream. If a continuously sloped channel is employed, which is not conducive to fish passage, then heavier riprap will be required. Lessening the culvert grade to accommodate fish passage will produce a larger drop at the outlet that will need to be overcome with additional channel works.

A closed bottom pipe arch of approximately 6.2 m span by 3.9 m rise, and 0.85 m embedment, would be approximately equivalent to the open bottom pipe arch in terms of hydraulic performance. Notably, provision of internal step pools in either culvert option may be problematic in terms of construction.

We are concerned with the vulnerability of the proposed open bottom arch culvert footings to scour in the context of the steep channel gradient and high energy of this stream system. We recommend pile supported footings. However, pile supported footings will not mitigate the potential loss of stability of the pipe arch itself in the event that fill material is washed out by seepage through the road embankment, or undercutting of the footings.

Alternatively, the culvert can be replaced with a bridge structure. AE developed a bridge concept with a conceptual cost estimate that was presented to the Ministry in a separate memo.

Our hydraulic assessment of the bridge concept indicated the creek channel would have a 4 m base width, with 1.5H:1V side slopes. As with the open bottom arch option, the channel under the bridge would need to be configured with step pools to facilitate fish passage, and provide energy dissipation.

5 CLOSURE

Atlantic Industries will be providing a cost estimate for the open bottom arch option, for comparison with the bridge concept.

Prepared by:

J. LEE

June 4, 2018

Jenna Lee, P.Eng. LEED AP BC+C
Water Resources Engineer

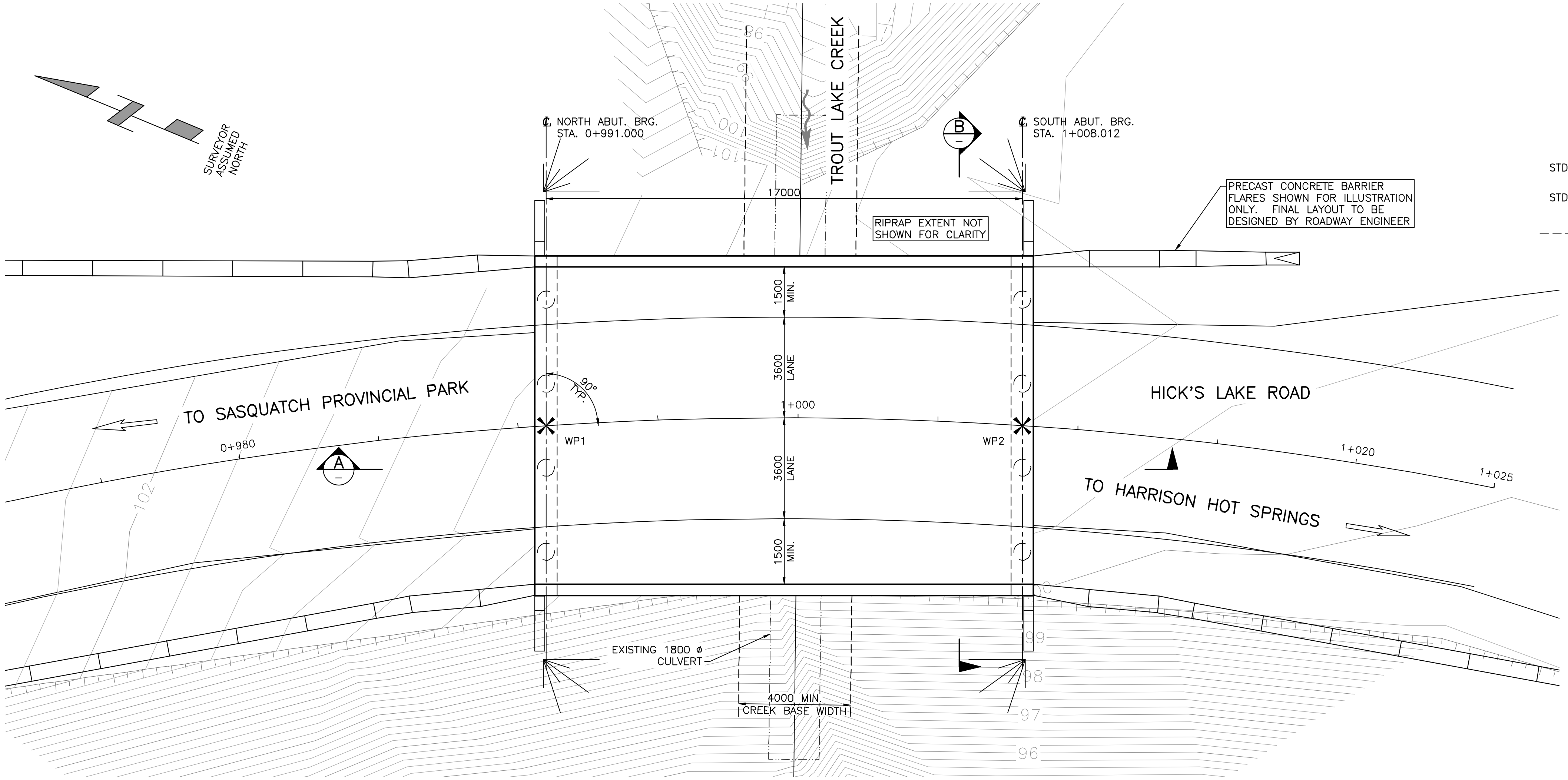
Reviewed by:

Michael MacLatchy, Ph.D., P.Eng.
Specialist – Watershed Management

JL/MM/lp

ASSOCIATED ENGINEERING
QUALITY MANAGEMENT SIGN-OFF
Signature
Date 04/06/2018
#04-18-062

APPENDIX B – 2018 TROUT LAKE CREEK CULVERT REPLACEMENT BRIDGE CONCEPTUAL DESIGN.



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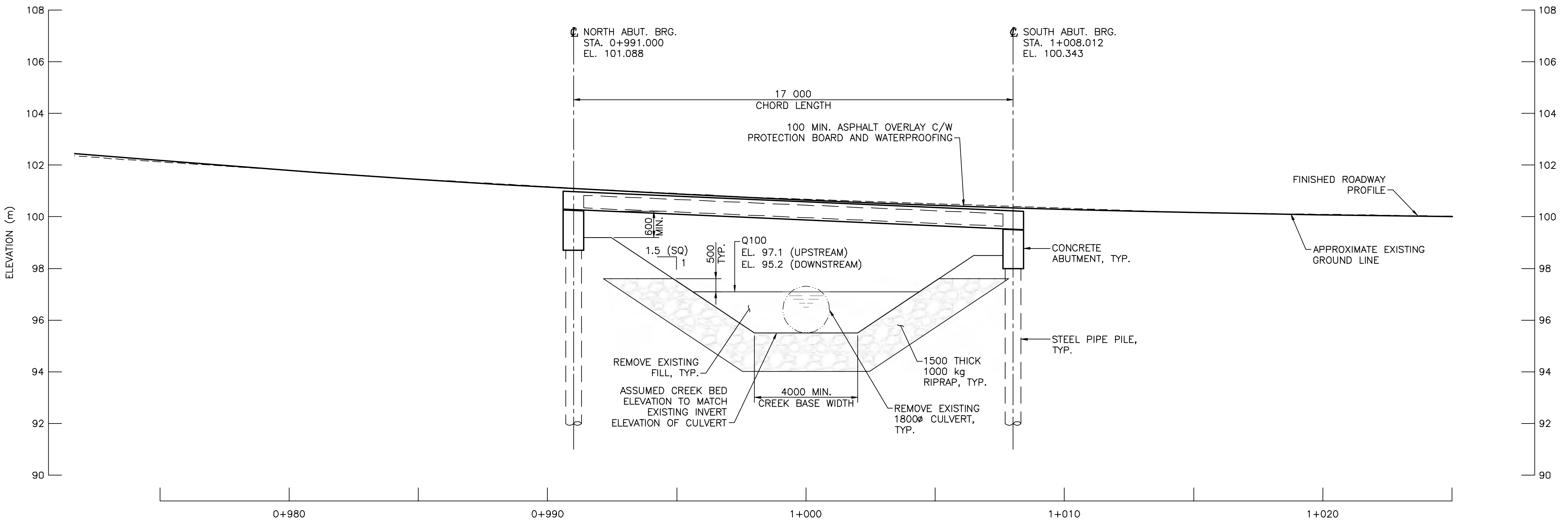

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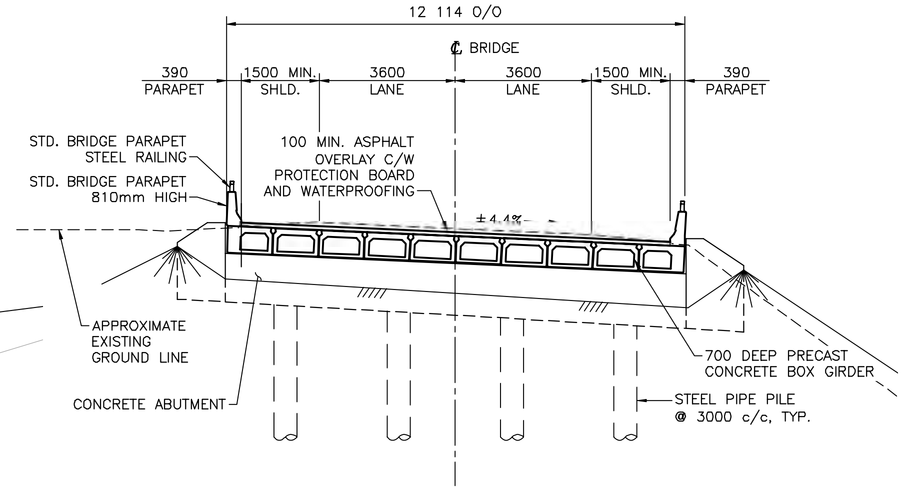

SECTION B
SCALE: 1:100

WORKPOINT	NORTHING	EASTING	STATION	OFFSET
WP1	5 065.955	2 967.603	0+991.000	0.000
WP2	5 050.250	2 974.111	1+008.012	0.000

NOTES:

1. DESIGN SPECIFICATION:
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   b. BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE BRIDGE STANDARDS AND PROCEDURES MANUAL (BSM) VOL. 1 SUPPLEMENT TO CHBDC S6–14 (OCTOBER 2016)
2. LIVE LOAD:
   a. LIVE LOAD: BCL–625 (IN ACCORDANCE WITH BSM)
3. CLIMATIC DATA:

a.	MAXIMUM DAILY MEAN TEMPERATURE	28°C
b.	MINIMUM DAILY MEAN TEMPERATURE	–20°C
c.	RAINFALL	8 mm / 15 MINUTES
d.	WIND LOAD: 1/50 YEAR REFERENCE	0.755 kPa

4. ASSUMED DESIGN SPEED: 40 km/hr. (TO BE CONFIRMED BY MoTI)
5. HIGHWAY DESIGN: MATCH EXISTING ROADWAY ALIGNMENT AND PROFILE.
6. CO–ORDINATE AND DATUM ARE ARBITRARY AND FOR REFERENCE PURPOSE ONLY.
7. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE.
8. ALL ELEVATION AND STATIONS ARE IN METRES.

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Associated Engineering

Rev	Date	Description	Init
A	2018-02-28	ISSUED FOR DISCUSSION	RS

REVISIONS

BRITISH COLUMBIA

Ministry of Transportation & Infrastructure
South Coast Region

LOWER MAINLAND DISTRICT
HICK'S LAKE ROAD

TROUT LAKE CREEK BRIDGE
CONCEPTUAL GENERAL ARRANGEMENT

PREPARED UNDER THE DIRECTION OF

ENGINEER OF RECORD

DATE

DESIGNED R. SAIEDI DATE 2018-02-08
CHECKED DATE
DRAWN V. LAM DATE 2018-02-08
SCALE
NEGATIVE No.

FILE No.	PROJECT No.	REG.	DRAWING No.	
		1	2915-02-SK-101	A

H–308k–r–cs(03–16)

CANCEL PRINTS BEARING PREVIOUS LETTER

FOR DISCUSSION ONLY

PRELIMINARY/ FOR DISCUSSION
NOT FOR CONSTRUCTION

FILE: P:\20172915\02_TRT_LK_CRK_CULVRT\WORKING_DWGS\300_STRUCTURAL\2915-02-SK-101.DWG
PLOTTED : February-28-18

Associated Engineering | GLOBAL PERSPECTIVE. LOCAL FOCUS.

DOCUMENT TRANSMITTAL

To: Ministry of Transportation and Infrastructure – Bridge Engineering
310 – 1500 Woolridge Street
Coquitlam, BC V3K 0B8

Attention: Maziar Kazemi, P.Eng.

Subject: **Trout Lake Creek Culvert Replacement - Bridge Conceptual Design Technical Memorandum**

Transmittal No: 1

Page: 1 of 1

Date: February 28, 2018

File: 20172915.00.E.04.00

Project No: 2017-2915

CODES:

A Reviewed
B Reviewed as Modified
C For Correction
D Not Reviewed
E For Approval
F As Requested
G For Your Comments
H For Your Information
I Issued for Construction

OTHER

Document	Issue Date	No. of Copies	Description or Drawing Title	Code
Tech. Memo	Feb. 28/18	pdf	Trout Lake Creek Culvert Replacement - Bridge Conceptual Design	F

Forwarded by:
Tijana Vulic

Associated Engineering (B.C.) Ltd.
Suite 500 – 2889 East 12th Avenue
Vancouver, B.C., Canada V5M 4T5

Associated Engineering

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TECHNICAL MEMORANDUM

Ministry of Transportation and Infrastructure

Trout Lake Creek Culvert Replacement
Bridge Conceptual Design

February 2018

ASSOCIATED ENGINEERING
QUALITY MANAGEMENT SIGN-OFF
Signature……………………………………
Date…………………………………………

Table of Contents

TECHNICAL MEMORANDUM

Ministry of Transportation and Infrastructure

Trout Lake Creek Culvert Replacement
Bridge Conceptual Design

Issued: February 28, 2018
Previous Issue: None

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1 Introduction

Associated Engineering was retained by the **Ministry of Transportation and Infrastructure** (Ministry), under General Hydrotechnical Engineering Services Contract 830 CS 0899, to provide engineering services for the Trout Lake Creek Culvert Replacement project. The culvert carries the flow of Trout Lake Creek downstream of Trout Lake in Sasquatch Provincial Park, BC and crosses Rockwell Drive (Hick's Lake Road). The Ministry identified this existing culvert to be hydraulically deficient as it is significantly perched with a large plunge pool at its outlet and is an obstacle to fish passage.

The Ministry could replace the existing culvert with a larger culvert or a clear span bridge along the existing highway alignment. We have carried out a preliminary hydrotechnical analysis to develop the conceptual design of a new culvert, presented in a separate hydrotechnical memorandum titled "Preliminary Hydrotechnical Analysis". Among the possible options for a clear span bridge, we have identified a precast concrete box girder bridge as the most economical solution for this site and bridge geometry. This technical memorandum describes the requirements, design criteria, and conceptual design of the proposed bridge.

2 Bridge Requirements

2.1 GENERAL

The new bridge must conform to Ministry design and safety standards and provide value to the Ministry with respect to economy, constructability, and future maintenance requirements.

2.2 HYDROTECHNICAL REQUIREMENTS

The Ministry have indicated the bridge is a Low Volume Road structure. Thus, the bridge opening must accommodate the estimated Q_{100} water level, including 0.5 m free board and an allowance for climate change, as per the BC MoTI Supplement to CHBDC S6-14 and the hydrotechnical memorandum, respectively.

The hydrotechnical memo recommends a channel grade of 8.6% (matching that of the existing culvert), a channel width of 4 m, and side slopes of 1.5(H):1(V). The side slopes will require confirmation by the geotechnical engineer. For bottom stability, step pools will be required. The channel bed and side slopes are to be protected by a 1.5 m thick layer of Class 1,000 kg riprap, extending a minimum of 0.5 m above the Q_{100} water elevation. The riprap protection is to wrap around the abutment embankments both upstream and downstream of the bridge.

2.3 HIGHWAY DESIGN

Ideally, the new bridge would minimize profile changes to the existing highway while achieving minimum free board. Fortunately, the existing highway is sufficiently high relative to the channel bed not to require raising of the highway profile or use of a shallow superstructure type. The longitudinal grade of the roadway is approximately 4.4%, sloping down from north to south, which will be maintained.

This crossing is on a curved section of the highway with a radius of 130 m. The existing super-elevation is 4.4% sloping in the same direction as the channel, which can accommodate a design speed of 40 km/hr. This matches the posted speed limit of 40 km/hr. A higher design speed would require an increase in super-elevation.

2.4 DRAINAGE

Runoff approaching the bridge from the north and runoff from the bridge deck will be accounted for during detailed design. Drainage barriers and riprap spillways can be installed at the lower bridge side (northwest and southwest corners of the structure) if necessary. Due to the short structure length and longitudinal grades, deck drains will not be required on the structure itself.

2.5 GEOTECHNICAL CONSIDERATIONS

The geotechnical site investigation was completed by the Ministry, and preliminary geotechnical recommendations were provided in a draft memo dated October 31, 2017. This memo identifies the soil as sandy gravel fill underlain by a natural deposit of sandy gravel. The memo does not comment on pile type, size, driveability or capacity; however, we expect 610 mm diameter steel pipe piles can be driven into the soil, and can resist the applied loads with reasonable depths. The load transfer mechanism between the driven piles and surrounding soil would be by a combination of end bearing and shaft friction. Pile design parameters will be confirmed with the geotechnical engineer during detailed design. The memo indicates the soil has low liquefaction potential during a seismic event.

2.6 CONSTRUCTION STAGING AND DURATION

Sasquatch Provincial Park is a popular destination in the summer months, and Rockwell Drive is the only access road into it. As such, traffic volumes in the summer months are significant. To prevent full road closures, the removal of the existing culvert and construction of the new bridge are to be done in stages, with traffic reduced to single-lane alternating traffic in each stage. To minimize traffic disruption, one key consideration is to minimize the number of construction stages and duration of construction.

3 Bridge Design Criteria

The bridge design criteria are given in the table below.

Design Codes and Standards:	• CAN/CSA-S6-14 Canadian Highway Bridge Design Code (CHBDC) • BC Ministry of Transportation and Infrastructure Bridge Standards and Procedures Manual October 2016 Edition (BSM) Supplement to CHBDC S6-14
Design Life:	• 75 years • 100 years for time-dependent calculations
Class of Highway:	• Class "C" (TBC)
Seismic Design Classification:	• Structure: “Other Bridges”
Bridge Deck Width:	• 12 m overall consisting of two 3.6 m lanes, two 1.5 m shoulders, and two bridge parapets
Clearances:	• Minimum soffit elevation: El. 98.6 m upstream, El. 96.7 m downstream (recommended in hydrotechnical memo) • Creek channel width – 4 m minimum with 1.5H:1V slopes. (recommended in hydrotechnical memo)
Utilities:	• None
Longitudinal Grade:	• 4.4% (TBC)
Drainage:	• Deck runoff will be discharged into catch basins (TBC) • Bridge end-slopes will be protected by rip-rap scour erosion blankets (1000 kg riprap recommended in hydrotechnical memo)
Barriers:	• TL-4 compliant Standard Concrete Bridge Parapet 810 mm high (Drawing 2784-1) with Steel Bicycle Railing
Live Load:	• BCL-625
Dead Load:	• Self-weight of all bridge components

Environmental Loads (Agassiz, BC):	• Wind Pressure (50-year return): 0.755 kPa • Maximum Mean Daily Temperature: 28ºC • Minimum Mean Daily Temperature: -20ºC • Rainfall: 8 mm in 15 minutes • Ice Accretion: 31 mm
Site Seismicity:	• Peak Ground Acceleration – 2475-year return period: 0.190g (2015 NBCC) • Seismic Performance Category 3 (TBC, Table 4.10 of CHBDC) • Site Class C • Liquefaction: not anticipated
Structural Steelwork:	• CSA G40.21 Grade 350 AT Category 3
Miscellaneous Steelwork:	• CSA G40.21 Grade 300W • Galvanizing: SS422.36, ASTM A153M-09, and ASTM B695-04 (2009)
Reinforcing Steel:	• CSA G30.18 Grade 400R U.N.O. • Top mat of deck and parapet reinforcing to be stainless steel. All other reinforcing steel to be plain black (uncoated) • Stirrups protruding into deck from precast concrete girders to be stainless steel
Concrete Cover:	• Concrete deck top cover to reinforcing steel to be 60 mm • All other concrete covers: CAN/CSA-S6-14
Pre-stressing Steel:	• ASTM A416 Grade 1,860 MPa low-relaxation • Pre-tensioning strand to be 15.2 mm or 12.7 mm nominal diameter, low relaxation, seven-wire strand
Cast in Place Concrete:	• Deck Slabs and Parapets: 35 MPa • Substructure: 30 MPa • Other Concrete: 30 MPa
Precast Concrete:	• Precast Concrete Superstructure: 35 MPa at release, 45 MPa at 28 days (TBC)
Bearing Piles:	• Steel Pipe Piling: ASTM A252 Grade 3

* TBC: To be confirmed

4 Bridge Conceptual Design

We recommend a precast concrete box girder bridge with semi-integral abutments founded on steel pipe piles. Appendix B contains the General Arrangement Drawing of the proposed bridge.

4.1 GIRDER TYPE

Precast concrete box girders are ideal for this crossing configuration. At approximately 17.0 m, the span is well within the range where precast concrete box girders are efficient and economical. The advantages of precast concrete box girders include:

- Girders are readily available from local precast fabricators due to the standard form.
- Girder weight and length allows for standard transportation and erection methods.
- Construction methods are standard and straightforward.
- Future maintenance required is minimal.
- No debris can accumulate on or between girders, and the structure is robust in case of future extreme flood events and debris flows.

A steel girder bridge with an suitable depth would be deeper than the proposed box girder bridge, which would reduce the available free board. While a steel girder bridge would be lighter than a precast concrete box girder bridge, the foundation design would be similar for both options. The reduced superstructure weight would not notably reduce the cost of the foundation piles.

4.2 SUPERSTRUCTURE

The superstructure is comprised of 10 x 700 mm deep precast concrete box girders. The bridge is straight and provides wider shoulders than the minimum required to accommodate the curved highway alignment at the crossing.

The precast concrete box girders are topped with an asphalt overlay, including protection board and waterproofing. A cast-in-place concrete deck is omitted to minimize construction duration and traffic disruption. The top flange of the box girders will be designed to support the wheel load of the design truck.

The proposed bridge barriers are the BC MoTI standard bridge parapets with steel railing. Read-mix concrete for the cast-in-place barriers can be readily sourced, as the nearest concrete batching plant (Agassiz Ready Mix Concrete) is a 20-minute drive from the site. The two exterior box girders have thicker outside webs to anchor the bridge barriers.

4.3 ABUTMENTS

Semi-integral abutments are proposed to eliminate deck joints and associated maintenance issues throughout the life of the bridge. Wing walls parallel to the abutments will retain the fill behind them.

Bridge end fill behind the abutments will be limited to the excavation required to construct the abutments. The existing soils at the site are expected to have good drainage properties, so replacing them with bridge end fill would have limited value.

No approach slab is required, because:

- Settlement of fill behind abutments is expected to be negligible, as the approaches are not being raised;
- Design speeds are low, so soil settlement behind abutments is of little consequence to ride quality;
- Liquefaction potential during a seismic event is low;
- The bridge is expected to perform well during a seismic event;
- The bridge is not on a critical connection (seismic importance category is “other bridges”).

4.4 PILES

Based on the soils at the site, we assume the bridge can be founded on steel pipe piles at each abutment. We have assumed 610 mm diameter, 15.9 mm thick steel pipe piles. These assumptions should be confirmed by the geotechnical engineer. The use of piles minimizes bridge construction work required below the high-water level of the creek. Each abutment is supported on four piles, with two piles supporting each half-abutment cast in each of the two construction stages.

4.5 CONSTRUCTION

The length of the existing culvert (23 m) and width of the existing embankment allow for the removal of the existing culvert and construction of the new bridge in two construction stages. Traffic will be reduced to single-lane alternating traffic in each stage. The construction sequence could be as follows:

Stage 1:

1. Erect temporary retaining wall at the east (upstream) end of the existing culvert.
2. Place compacted fill behind the retaining wall.
3. Place pavement over the new fill and connect it to existing roadway to create a temporary detour.
4. Shift traffic onto this detour as single-lane alternating traffic (SLAT).
5. Excavate the embankment west (downstream) of this detour at 1.5H:1V slope.
6. Build western half of the bridge: five concrete box girders with asphalt topping, with the half-abutments supported on two piles each.
7. Shift traffic onto this completed half of bridge in a SLAT configuration.

Stage 2:

1. Excavate the embankment supporting the detour and remove the retaining wall.
2. Build eastern half of the bridge: five concrete box girders with asphalt topping, with the new half-abutments supported on two new piles each.
3. Open the bridge to two-way traffic.

The contractor should also remove the exposed culvert and construct riprap channel. This should be done during the fisheries window, which is generally mid-August to mid-September. This is also usually the lowest flow period, so performing these tasks during this period minimizes the effects on the creek.

The contractor may be able to use excavated material as fill to minimize the import and disposal of material. The pull-out (rest area) south of the bridge site could be used as a construction laydown area, with permission from BC Parks. We anticipate construction will take four to six months.

4.6 COST ESTIMATE

Our estimate for the conceptual net construction cost of this bridge is $1.2M, with a total bridge cost of $1.5M including 25% contingency. This estimate includes the mainline bridge construction only. Details of our cost estimate are presented in Appendix A.

Closure

This report was prepared for the Ministry of Transportation and Infrastructure to present our conceptual design considerations for the Trout Lake Creek Culvert Replacement.

The services provided by Associated Engineering (B.C.) Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering (B.C.) Ltd.

Prepared by:	Reviewed by:
Reza Saiedi, M.A.Sc., P.Eng. Bridge Engineer	David Harvey, M.Sc., P.Eng., Struct.Eng., FEC Bridge Specialist

RS/DH/mc

Appendix A - Cost Estimate

Client: Ministry of Transportation

Project: Trout Lake Creek Culvert Replacement

Details: Bridge Conceputal Design - Cost Estimate

File: 2017-2915.00.E.04.00

Prepared by: RS

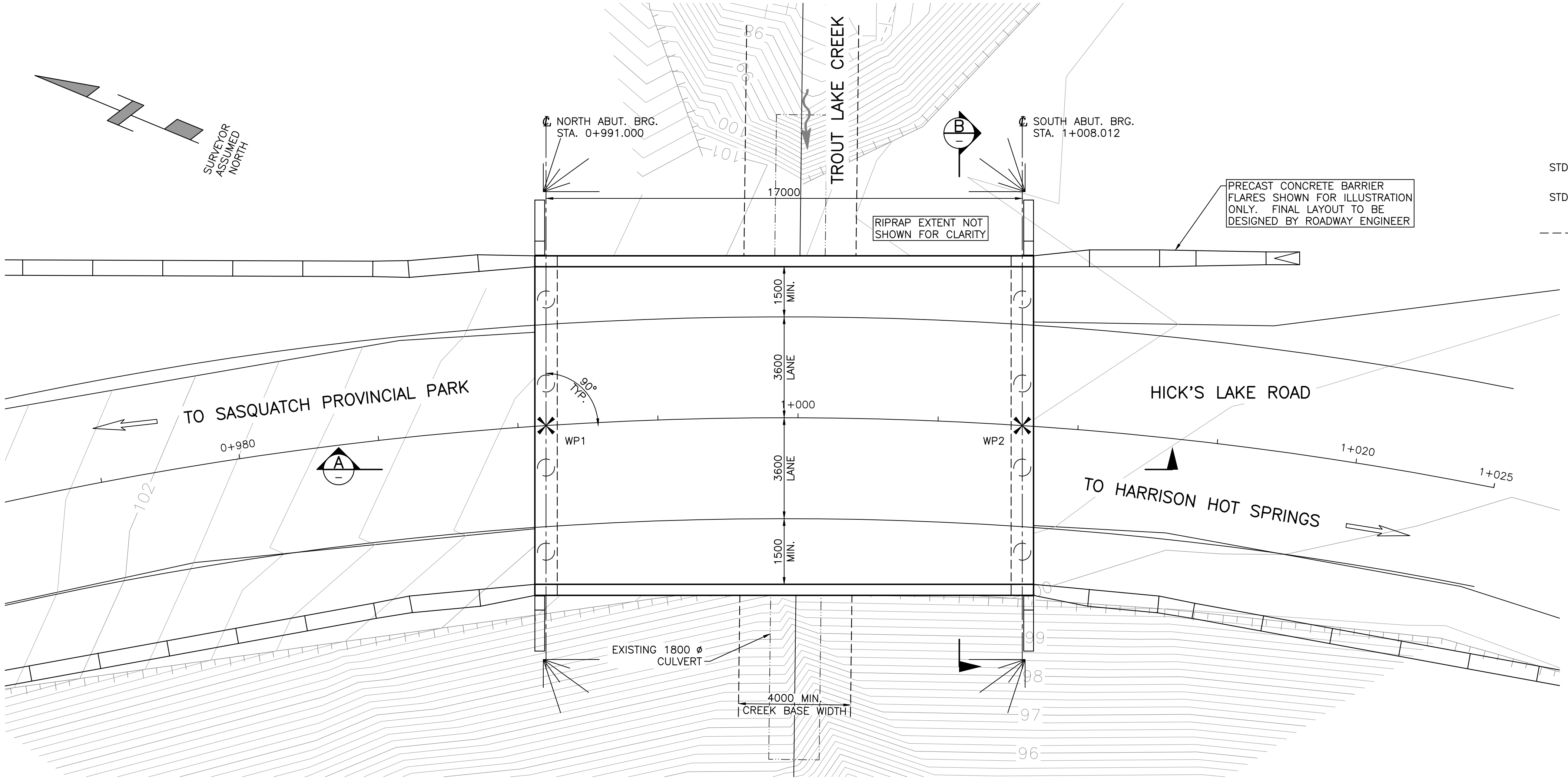
Reviewed by: DH

Date: 2018-02-28

Submission: Conceptual Design

Item No.	Item	Unit	Approx. Quantity	Unit Cost	Extended Amount
1.0	**General**				
1.1	Mobilization and Demobilization (5%)	L.S.	1	$52,000	$52,000
1.2	Quality Management (2%)	L.S.	1	$21,000	$21,000
1.3	Traffic Management and Construction Staging	L.S.	1	$100,000	$100,000
1.4	Environmental Management & Monitoring	L.S.	1	L.S.	$20,000
1.5	Working Office	L.S.	1	L.S.	$10,000
				Sub-Total	**$203,000**
2.0	**Excavation & Backfill**				
2.1	Excavation & Backfill	L.S.	1	LS	$60,000
				Sub-Total	**$60,000**
3.0	**Steel Pipe Piles**				
3.1	Mobilization and Fixed Costs for Pile Installation	L.S.	1	$30,000	$30,000
3.2	Supply & Installation of 610 mm ϕ x 15.9 mm Steel Pipe Piles, assumed 18 m deep	m	144	$1,100	$158,000
3.3	Pile Reinforced Concrete (Top 5 m)	m3	11	$800	$9,000
				Sub-Total	**$197,000**
4.0	**CIP Concrete**				
4.1	Superstructure Concrete (Parapets)	m^3	12	$2,500	$30,000
4.2	Substructure Concrete (Abutments and Wing Walls)	m^3	44	$1,800	$79,000
				Sub-Total	**$109,000**
5.0	**Precast Box Girder**				
5.1	Supply and Fabrication of Precast Concrete Box Girders	Each	10	$27,000	$270,000
5.2	Shipping and Erection of Precast Concrete Box Girders	L.S.	1	$81,000	$81,000
				Sub-Total	**$351,000**
6.0	**Other Items**				
6.1	Parapet Steel Bicycle Railings	m	46	$450	$21,000
6.2	Waterproofing Membrane on Bridge	m^2	204	$80	$17,000
6.3	Asphalt Pavement on Bridge	tonne	47	$200	$10,000
6.4	Asphalt Pavement on Approaches	tonne	49	$200	$10,000
6.5	Precast Concrete Barriers on Approaches	L.S.	1	L.S.	$26,600
6.6	Precast Concrete Catch Basins	Each	2	$2,500	$5,000
6.8	Clearing and Grubbing	L.S.	1	L.S.	$5,000
6.9	Remove and Dispose of Existing CSP Culvert	L.S.	1	L.S.	$10,000
7.0	Riprap Protection (1000 kg Class)	m^3	1344	$150.00	$202,000
				Sub-Total	**$306,600**
	NET CONSTRUCTION COST				**$ 1,226,600**
	Contingency (25%)				**$ 307,000**
	TOTAL PROJECT COST (Excluding taxes)				**$ 1,533,600**

Appendix B - General Arrangement Drawing



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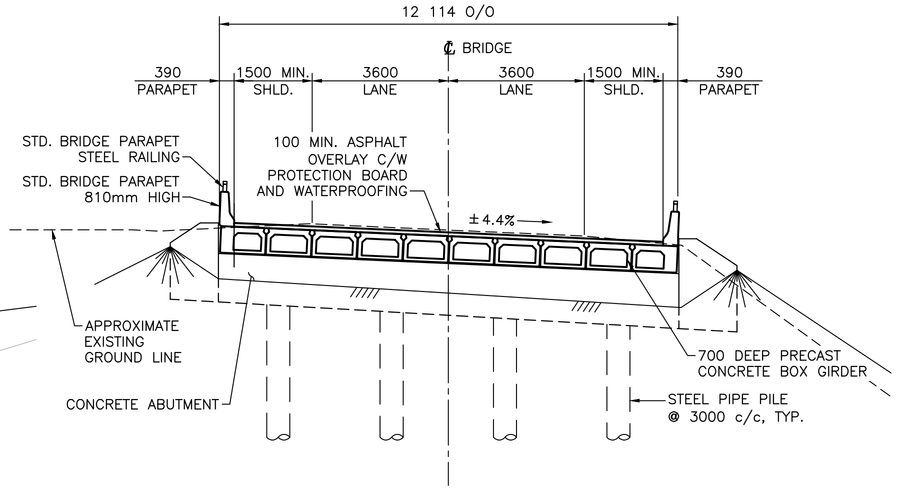

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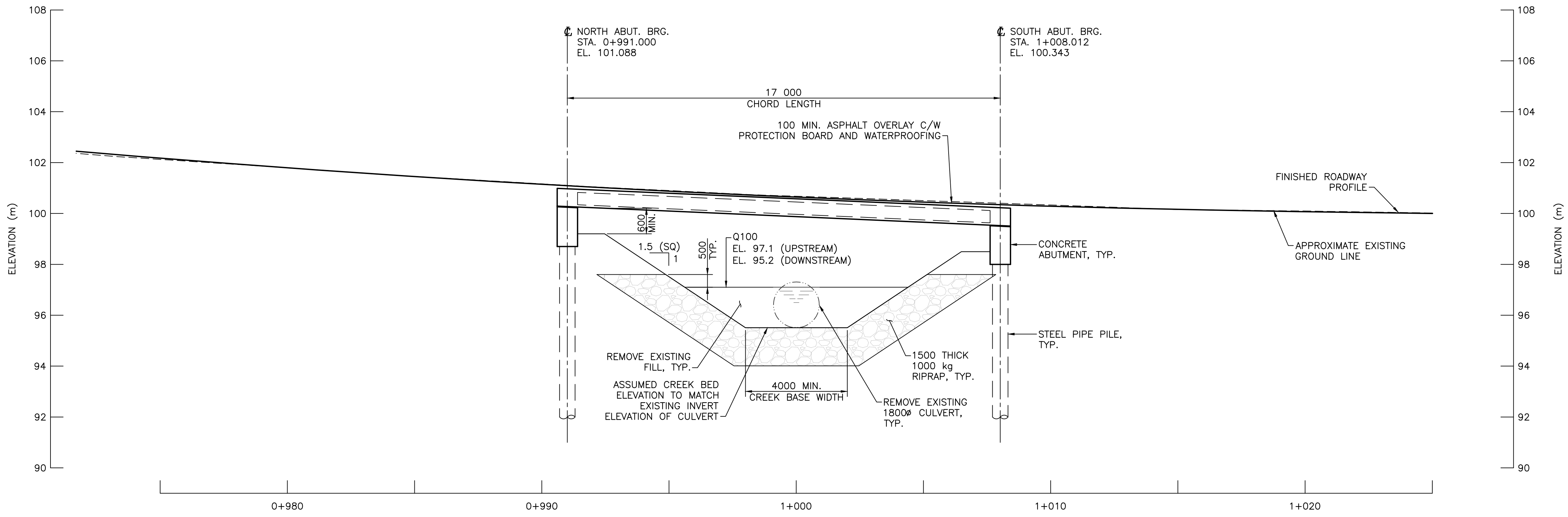

SECTION A
SCALE: 1:100

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PRELIMINARY/ FOR DISCUSSION
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Associated Engineering

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A	2018–02–28	ISSUED FOR DISCUSSION	RS

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BRITISH COLUMBIA
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TROUT LAKE CREEK BRIDGE
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CANCEL PRINTS BEARING PREVIOUS LETTER

H–308k–r–cs(03–16)

FILE: P:\20172915\02_TRT_LK_CRK_CULVRT\WORKING_DWGS\300_STRUCTURAL\2915–02–SK–101.DWG
PLOTTED : February–28–18

APPENDIX C – 2018 MOTI GEOTECHNICAL MEMO.

BRITISH COLUMBIA

Ministry of Transportation and Infrastructure

South Coast Region
310 1500 Woolridge St.
Coquitlam BC V3K 0B8

MEMORANDUM

October 31, 2017

To: Dickson Chung, Hydrotechnical Engineer, MoTI
Cc: Maziar Kazemi, Area Manager, MoTI

Re: Geotechnical Drilling Investigation – Trout Lake Creek Culvert Replacement, Harrison Hot Springs, BC (N49°20'34" W121°44'37")

1.0 Introduction

The existing Trout Lake Creek Culvert is located under Hick’s Lake Road, approximately 200 m north of the intersection with Rockwell Drive at the east shore of Harrison Lake. See the Site Location Plan attached. This memorandum provides a brief summary of the geotechnical background review results, the drilling investigation results and also provides geotechnical recommendations on the proposed culvert replacement. A draft memorandum was sent to you on October 25, 2017 for your review and comments. This is a final version of the memorandum.

2.0 Background

Local surficial geological mapping indicates that the natural surficial deposit at this site consists of sandy materials but with an unknown thickness. Western Geotechnical Consultants Ltd. (WGCL) completed a geotechnical assessment for a residential property at 7552 Hick’s Lake Road which is approximately 50 m to 100 m away from the site. Refer to the report “Geotechnical Assessment, Proposed Single Family Development, 7552 Hick’s Lake Road, Harrison Hot Springs, BC” prepared by WGCL and dated August 24, 2016. The report indicates that the site is situated on a colluvium fan that is downstream of three (3) creeks (Trout Lake Creek, and two other creeks). WGCL also completed a total of three (3) test pits at depths of 1.0 m to 1.6 m below grade. The soils found in the test pits were described as angular gravel and coarse to fine sand with cobbles and boulders.

Soil information for the culvert site was not found and the abovementioned background soil information is considered to be too limited for design and construction of the culvert replacement. A drilling investigation was recommended and then completed on October 18, 2017. A summary of the investigation results is provided below.

3.0 Testhole Drilling and Sampling

On October 18, 2017, Sea to Sky Drilling Ltd. was retained by Associated Engineering Ltd. on behalf of the MoTI and completed the drilling of two (2) testholes (TH17-01 to TH17-02) on the gravel shoulders setback approximately 2.5 m at each side of the existing culvert. See the testhole location plan attached to this memorandum.

A Mobile B-53 truck-mounted drill rig was used for the drilling. The testholes were advanced using an open faced bit with bentonite drilling fluid used to return cuttings to the surface, or a tricone drill bit when suspected cobbles or boulders were encountered. Standard Penetration Tests (SPT) with a 0.61 m-long (24”) split spoon sampler were conducted in the granular layers at 1.5 m (5 ft) intervals to determine the relative density of the granular soils. Representative soil samples were collected at 1.5 m (5 ft) intervals or at any change in soil strata from the split spoon sampler. All samples were visually inspected on site and classified in accordance with the Ministry Modified Unified Soil Classification System (USCS, ASTM D2487). Individual testholes were drilled to depths ranging from 10.5 m (34.5 ft) for DH17-02 and 11.0 m (36 ft) for DH17-01. All testholes were then backfilled in accordance with Groundwater Protection Regulation (B.C. Reg. 152/2016). Detailed summary logs including all the field observations are attached to this memorandum.

4.0 Drilling Investigaiton Results

4.1 Site Stratigraphy

In general, the stratigraphy at the culvert site consists of a layer of sandy gravel fill underlain by a natural deposit of sandy gravel.

A layer of poorly graded sandy gravel (GP) fill with a thickness ranging approximately from 5.2 m at TH17-02 (southwest of the culvert) to 5.3 m at TH12-01 (northeast of the culvert) was encountered. The sandy gravel fill was brown, damp, poorly graded, some cobbles, and compact to loose in relative density with an uncorrected SPT N-value of 6 to 15 blows per 305 mm (per foot) and averaged at 9 blows per 305 mm.

Beneath the sandy gravel fill, a natural deposit of poorly graded sandy gravel (GP) was encountered to the end depth of each testhole. The sandy gravel deposit was generally brown to grey in colour, damp to wet, poorly graded, dense to very dense, some cobbles or boulders. The uncorrected SPT N-values in the sandy gravel deposit ranged from 20 to 65 blows per 305 mm and averaged at 46 blows per 305 mm.

4.2 Groundwater Conditions

Since water was used for mud rotary drilling, groundwater infiltration could not be observed in the testholes during the drilling. Because both the roadway fill and the natural deposits are highly permeable materials, it is expected that the groundwater table at the site could fluctuate seasonally and in response to the creek water level. It is concluded therefore that the groundwater level will likely be within or above the foundation elevation of the existing or proposed culvert.

5.0 Discussions and Recommendations

Based on the drilling investigation results at the site and a review of the background soil information in the vicinity of the site, I provide the following geotechnical recommendations for design and construction of the proposed culvert replacement.

- The loose fill or materials should be removed and replaced with well compacted granular fill for the culvert foundation in accordance with the Ministry Standard Specifications for Highway Construction (2016 or the latest version). Assuming a culvert (concrete) foundation of minimum 1.0 m wide and buried at minimum 0.5 m deep below grade at the culvert bottom, the factored Ultimate Limit State (ULS) bearing capacity of the dense natural sandy gravel deposit or the well compacted granular fill is estimated to be 250 kPa when a geotechnical resistance factor of 0.50 is applied as per Table 6.2 of Canadian Highway Bridge Design Code S6-14 (2014) for the Limit State Design (LSD).

- The natural deposit at the site is dense to very dense sandy gravel and is interpreted as Site Class C for seismic site response based on Canadian Highway Bridge Design Code (CHBDC) S6-14 Table 4.1. The 2015 National Build Code (NBC) Seismic Hazard Calculation for Site Class C is attached for seismic designs. The dense to very dense sandy gravel deposit is considered to be low liquefaction potential during a seismic event.

- It is recommended to replace the culvert during dry season when the creek level is low to minimize the efforts on the creek or groundwater water management in the vicinity of the foundations.

- All the earthwork construction should be conducted in accordance with the Ministry Standard Specifications for Highway Construction (2016 or the latest version), which may include but may not be limited to excavation, foundation preparation, backfill materials, fill placement and compaction, culvert installation, and pavement.

- Temporary excavation side slopes of 1.5H:1V can be used within the sandy gravel materials (i.e. the roadway fill) above the groundwater table, provided the slopes are inspected during excavation and prior to any other construction activities. Below the water table slopes will have to be flattened and may require pumping in order to maintain safe and stable excavation side slopes. Excavation side slopes below the water table, should they occur, will have to be assessed and designed by a qualified professional geotechnical engineer. In the event of rainfall events, temporary slopes should be covered with poly sheeting to prevent water infiltration, erosion and potential localized sloughing. Stockpiling of fill or parking of heavy equipment at or within 10 m of the crest of the excavation slopes is not allowed.

- Geotechnical inspections by a qualified professional geotechnical engineer are highly recommended to be performed for the entire foundation subgrade areas and all the roadway excavated slopes once they are exposed.

Please let me or the undersigned know if any questions regarding the enclosed information.

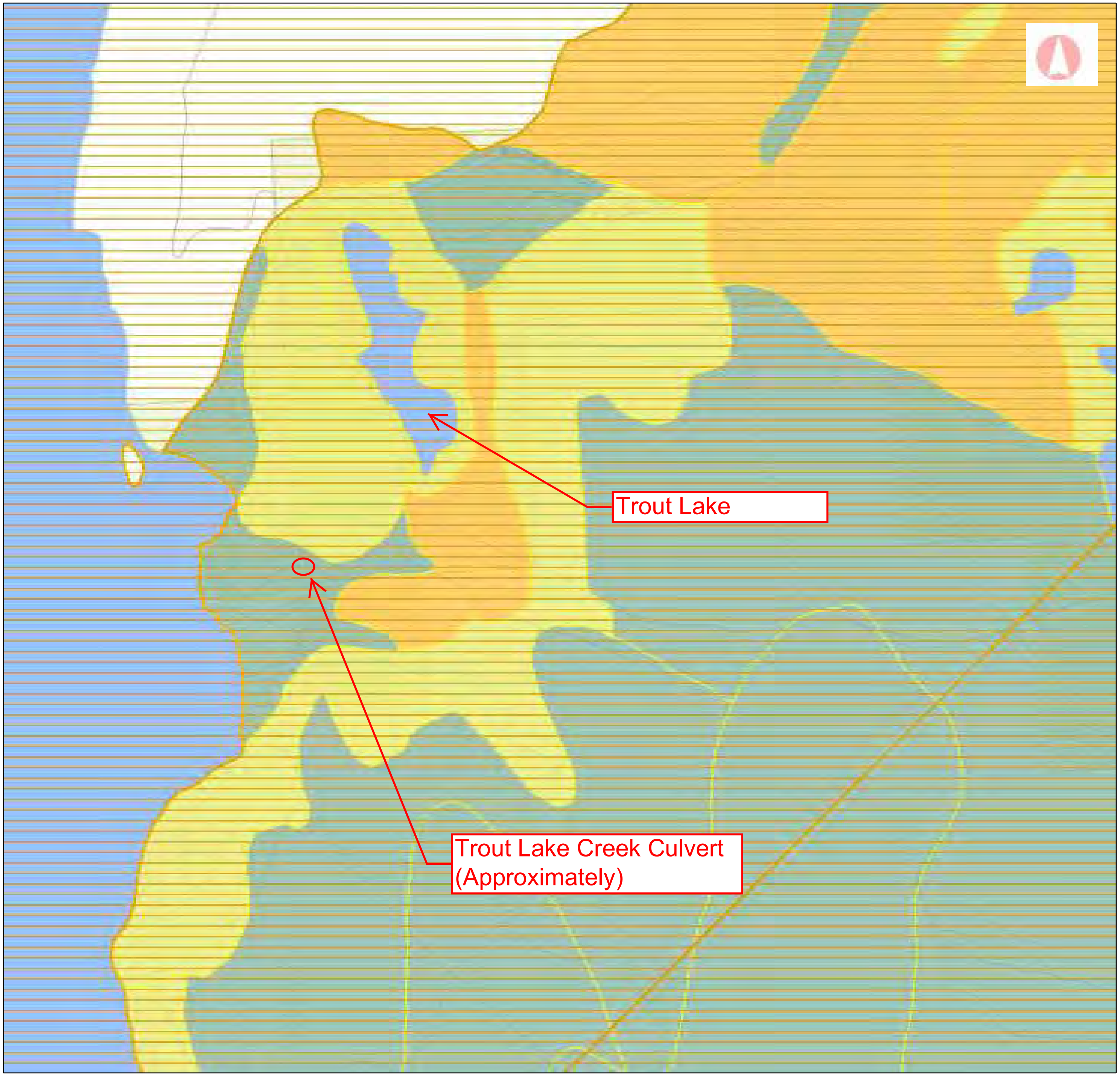
Prepared by	Reviewed by
Dr. K. YE # 44597	
Kevin Ye, Ph.D., P.Eng. Geotechnical Engineer Ministry of Transportation and Infrastructure	Scott Cosman, P.Eng. Lead Geotechnical Engineer Ministry of Transportation and Infrastructure

Attachments:

- Site Location Plan (1 page)
- Testhole Location Plan (1 page),
- Site Surficial Geology from iMapBC (1 page),
- Soil Logs (2 pages), and
- 2015 NBC Seismic Hazard Calculation (1 page).

Site Location Plan (Not To Scale)
– Existing Trout Lake Creek Culvert at Approximately 200m North of Intersection with Rockwell Drive, Harrison Hot Springs, BC

Testhole Location Plan (Approximately)



BRITISH COLUMBIA

iMapBC Mapping

Legend

- ▨ Soil Project Boundaries - Cr
- ☐ Soil Survey Polygons
- Soil Survey Polygons - Textu
  - TEXTURE_1
  - Not Applicable
  - 🟦 Sand
  - 🟦 Loamy Sand
  - 🟩 Sandy Loam
  - 🟩 Fine Sandy Loam
  - 🟩 Sandy Clay Loam
  - 🟩 Silt
  - 🟨 Silty Loam
  - 🟨 Silty Clay
  - 🟨 Silty Clay Loam

0 0.37 0.75 km

1: 18,455

Copyright/Disclaimer

Datum: NAD83
Projection: NAD_1983_BC_Environment_Albers

Key Map of British Columbia

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

Prepared by:
Ministry of Transportation & Infrastructure
Logged by: MS Reviewed by: KJY

SUMMARY LOG

Drill Hole #: TH17-01

Project: **Trout Lake Creek Culvert Replacement Project**
Location: NE of Culvert at Hick's Lake Rd north of Intersection with Rockwell Dr
Datum: UTM NAD83 Zone 10N
Alignment: N/A
Northing/Easting: 5466322 , 591269
Station/Offset: N/A
Elevation:

Date(s) Drilled: October 18, 2017
Drilling Company: Sea to Sky Drilling Ltd.
Driller: Chad Brown
Drill Make/Model: Mobile B-53 Truck
Drilling Method: Mud Rotary

✕ Pocket Penetrometer ✕ Shear Strength (kPa) 100 200 300 400
✳ DYNAMIC CONE (BLOWS/300 mm) ✳
+ Natural Vane (KPa) ⊕ Remold Vane (KPa)
▲ SPT "N" (BLOWS/300 mm) ▲
W_P% W% W_L% 20 40 60 80

DEPTH (m)	DRILLING DETAILS	SPT	SPT "N"	SAMPLE NO	RECOVERY (%)	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING Drillers Estimate {G % S % F %}
0	Mud Rotary (0 – 11 m)					sandy GRAVEL, brown, damp, loose to compact, poorly graded (FILL) some cobbles between 0.3 m and 1.1 m	GP	
1		3 5 5 4	10	1	8			{G:80 S:20 F:0}
3		4 4 6 6	10	2	0			
4.5		1 3 2 7	5	3	8			{G:65 S:30 F:5}
5.33m						sandy GRAVEL, some cobbles up to 0.25 m diameter between 5.3 m and 7.3 m, brown, damp to wet, dense to very dense, poorly graded	GP	
6.4		50	50/3"	4	0			
7.5		7 10 10 11	20	5	21			{G:70 S:25 F:5}
9		8 11 50	61	6	17	some cobbles from 9.1m		{G:60 S:35 F:5}
10.5		31 37 28 8	65	7	38			
10.97m						Target Depth Achieved. Test Hole Terminated at 10.97 m		1) Coordinates were approximated based on the field measurements and Google Earth. 2) Groundwater conditions could not be observed during drilling because water was used for the mud rotary drilling. 3) The testhole was advanced using an open faced bit, but switched to a tricone drill bit when suspected cobbles or boulders were encountered at depths between 5.5 m to 7.3 m. 4) Drill hole was backfilled in accordance with Groundwater Protection Regulation.

Legend
Sample Type:
A-Auger
C-Core
G-Grab
V-Vane
● L#-Lab Sample
S-Split Spoon
O-Odex (air rotary)
W-Wash (mud return)
T-Shelby Tube

Final Depth of Hole: 11.0 m
Depth to Top of Rock:

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

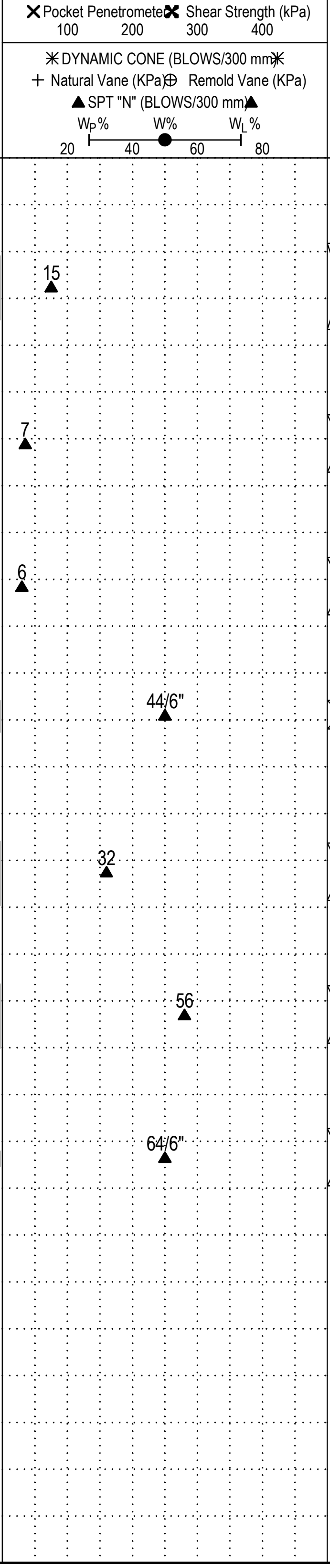
SUMMARY LOG

Drill Hole #: **TH17-02**

Project: **Trout Lake Creek Culvert Replacement Project**
Location: SW of Culvert at Hick's Lake Rd north of Intersection with Rockwell Dr
Datum: UTM NAD83 Zone 10N
Alignment: N/A
Northing/Easting: 5466308 , 591254
Station/Offset: N/A
Elevation:

Prepared by:
Ministry of Transportation & Infrastructure
Logged by: MS Reviewed by: KJY

Date(s) Drilled: October 18, 2017
Drilling Company: Sea to Sky Drilling Ltd.
Driller: Chad Brown
Drill Make/Model: Mobile B-53 Truck
Drilling Method: Mud Rotary



Drilling details: Mud Rotary (0 to 10.52 m)

DEPTH (m)	SPT	SPT "N"	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	COMMENTS TESTING Drillers Estimate {G % S % F %}
~1.4	8 8 7 10	15	S-Split Spoon	1	12	{G:85 S:15 F:0}
~3.0	6 4 3 3	7	S-Split Spoon	2	21	{G:65 S:30 F:5}
~4.5	3 3 3 3	6	S-Split Spoon	3	33	{G:50 S:50 F:0}
~5.9	41 44	44/6"	S-Split Spoon	4	21	{G:60 S:35 F:5}
~7.6	28 18 14 9	32	S-Split Spoon	5	17	{G:65 S:30 F:5}
~9.1	16 24 32 22	56	S-Split Spoon	6	38	{G:65 S:30 F:5}
~10.6	64	64/6"	S-Split Spoon	7	0	

Depth	SOIL DESCRIPTION	CLASSIFICATION
0 – 5.18m	sandy GRAVEL, brown to brown grey, damp, loose to compact, poorly graded (FILL) some cobbles from 0.3 m	GP
5.18m – 10.52m	sandy GRAVEL, some cobbles between 5.2 m and 7.6 m, brown, damp to wet, dense to very dense, poorly graded large boulder encountered at 9.6 m	GP
10.52m	Target Depth Achieved. Test Hole Terminated at 10.52 m	

1) Coordinates were approximated based on the field measurements and Google Earth.
2) Groundwater conditions could not be observed during drilling because water was used for the mud rotary drilling.
3) The testhole was advanced using an open faced bit, but switched to a tricone drill bit when suspected cobbles or boulders were encountered from 9.6 m deep below grade.
4) Drill hole was backfilled in accordance with Groundwater Protection Regulation.

Legend
Sample Type:
A-Auger
C-Core
G-Grab
V-Vane
S-Split Spoon
O-Odex (air rotary)
W-Wash (mud return)
T-Shelby Tube
● L#-Lab Sample

Final Depth of Hole: 10.5 m
Depth to Top of Rock:

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

October 27, 2017

Site: 49.3427 N, 121.7435 W User File Reference: Trout Creek Lake Culvert, Harrison Hot Springs, BC

Requested by: Kevin Ye, MoTI

National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.05)	Sa(0.1)	**Sa(0.2)**	Sa(0.3)	**Sa(0.5)**	**Sa(1.0)**	**Sa(2.0)**	**Sa(5.0)**	**Sa(10.0)**	**PGA (g)**	**PGV (m/s)**
0.223	0.332	**0.419**	0.405	**0.354**	**0.229**	**0.148**	**0.055**	**0.019**	**0.190**	**0.287**

Notes. Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. ***These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.***

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.046	0.106	0.150
Sa(0.1)	0.070	0.160	0.224
Sa(0.2)	0.095	0.211	0.291
Sa(0.3)	0.096	0.210	0.287
Sa(0.5)	0.081	0.181	0.250
Sa(1.0)	0.045	0.109	0.155
Sa(2.0)	0.026	0.066	0.097
Sa(5.0)	0.0064	0.019	0.032
Sa(10.0)	0.0025	0.0069	0.011
PGA	0.040	0.093	0.130
PGV	0.050	0.128	0.189

References

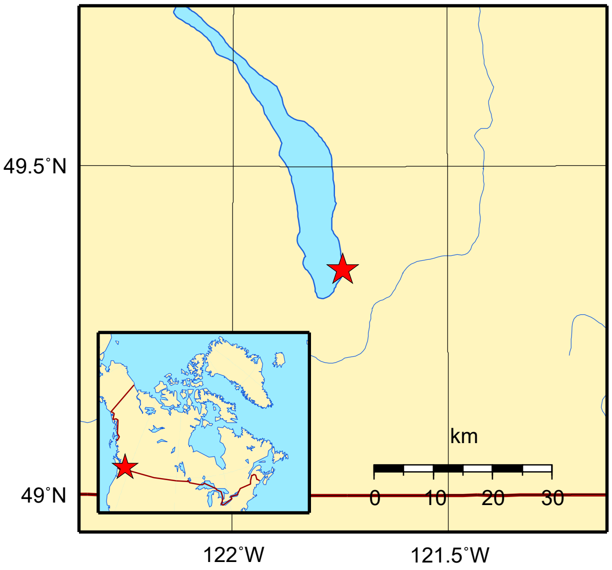
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

User's Guide - NBC 2015, Structural Commentaries NRCC no. xxxxxx (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites *www.EarthquakesCanada.ca* and *www.nationalcodes.ca* for more information

Aussi disponible en français



APPENDIX D – 2020 PRELIMINARY HYDROGEOMORPHIC ASSESSMENT.

Preliminary Hydrogeomorphic Assessment

Trout Lake Creek Crossing, North of Harrison Hot Springs, BC

Prepared for:

Associated Engineering (B.C.) Ltd.
500 – 2889 East 12th Avenue
Vancouver, BC V5M 4T5

Prepared by:

Westrek Geotechnical Services Ltd.
100 - 1383 McGill Road
Kamloops, BC V2C 6K7
www.westrekgeotech.com

October 13, 2020
File No. 020-030

1 Introduction and Scope

As requested by Associated Engineering (B.C.) Ltd. (AE), Westrek Geotechnical Services Ltd. (Westrek) carried out a preliminary hydrogeomorphic assessment for the Trout Lake Creek crossing (the "Crossing") at Rockwell Drive, about 5 km north of Harrison Hot Springs, BC. The assessment is part of a workplan for the Ministry of Transportation and Infrastructure (MoTI) to address improvements to the existing culvert in the crossing. A flood hazard assessment was not part of our scope.

The work was completed in accordance with our proposal dated March 22, 2020, and the agreement between AE and Westrek dated May 19, 2020.

2 References and Methodology

The following historic air photographs were reviewed:

- BCD16416 #563-566, 658-662, 809-814 (2016)
- SRS6929 #273, 274 (2004)
- 30BCC96081 #38, 39 (1996)
- 30BCB93032 #44, 45 (1993)
- 30BCC90014 #158, 159 (1990)
- 30BC86029 #204, 205 (1986)
- 30BC83012 #131, 132 (1983)
- 30BC79103 #48-50 (1979)
- 30BC79069 #20-22 (1979)
- BC7476 #235, 236 (1973)
- BC5322 #3-5 (1969)
- BC5064 #258-260 (1963)
- BC1623 #36, 37 (1952)
- BC717 #99-101 (1949)
- BC140 #33-35, 83, 84 (1939)

The following information was also reviewed:

- Monger, J.W.H. 1989 *Geology, Hope*, British Columbia; Geological Survey of Canada, Map 41-1989, sheet 1, scale 1:250,000.
- Associated Engineering Ltd. 2018a *Trout Lake Creek Culvert Replacement, Preliminary Hydrotechnical Analysis (Final)*, Technical Memorandum, dated June 1, 2018.
- Associated Engineering Ltd. 2018b *Trout Lake Creek Culvert Replacement, Bridge Conceptual Design*, Technical Memorandum, dated February 28, 2018.
- iMapBC water well record database, wildfire history, logging history; retrieved on September 24, 2020.
- Google Earth Professional™ imagery dated 2004, including relevant applications provided by DataBC (TRIM elevation data, Freshwater Atlas, cadastral information).

- LiDAR imagery acquired in 2020 (hillshade and 1m-contours), provided by MoTI / AE in September 2020.

Following review of the available background information, Simon Gautschi MSc PGeo of Westrek conducted the fieldwork on May 21 and 22, 2020. Information recorded included observations of relevant terrain features and surficial soil conditions. The approximate locations of site features were recorded using a hand-held GPS unit, which is typically accurate to 5 to 10 m for planimetric coordinates. Other measurements were made using a clinometer and laser range finder. No subsurface investigation or laboratory testing was completed except for shallow excavations dug with a hand shovel.

LiDAR imagery provided subsequent to the field work was utilized in the completion of the analysis.

3 Setting and Background Information

An overview map is provided in Figure 1.

The Crossing is located above the gently sloped, west-facing Trout Lake Creek fan, about 350 m upstream from the shore of Harrison Lake, and conveys Trout Lake Creek underneath Rockwell Drive. The area up- and downstream of the Crossing is occupied by Sasquatch Provincial Park, and several private lots are located on the fan to the south of Trout Lake Creek.

Trout Lake Creek flows from Trout Lake, which is about 670 m upstream of the Crossing at elevation 85 m. Based on Google Earth imagery, Trout Lake receives streamflow from a much larger watershed above it. Two gullies (Stream 2 and 3) drain into Trout Lake Creek below the lake outlet and their watersheds extend to about 760 m elevation.

An unnamed creek (Stream 1) joins Trout Lake Creek about 130 m upstream of the Crossing. Its watershed extends southeast to the height of land at about elevation 1000 m. Stream 1 has a large, superimposed fan at the southeast of the Trout Lake Creek fan.

On the available regional scale mapping, the bedrock is identified as sandstone and conglomerate of the Jurassic and Cretaceous Peninsula Formation. Surficial geological mapping of the study area was not available. Two water well logs from the area about 200 m south of the Crossing listed mostly sand and angular gravel with variable fines to about 30 m depth. Below that, possible till layers to about 39 m depth were found in one drill hole, underlain by bedrock.

According to local resident John Allen (see also the attached District of Kent’s press release dated February 4, 2020), heavy rainfall and runoff on the Stream 1 fan on February 1, 2020 caused major erosion and damage on Rockwell Drive and the developments below it, about 200 m south of the Crossing. Mr. Allen reported that Stream 1 had avulsed on the upper fan by breaching through an old, man-made berm, which had been built during the early logging operations and used to convey Stream 1 across the upper fan toward Trout Lake Creek.

Over the following hours and days, the Trout Lake Creek culvert at the Crossing became blocked with gravelly-cobbly bedload and woody debris. While Stream 1 was still flowing, MoTI work crews repaired the berm breach to redirect Stream 1 back into its previous diversion channel. They also installed an emergency bridge at the Crossing.

According to Mr. Allen, Trout Lake Creek delivers woody debris on a regular basis during flooding events, but typically without gravel and cobbles. This had required periodic cleaning of the culvert inlet.

3.1 Historical Air Photo Review

The 1939 air photos showed a railway trestle at the Crossing location. It was unclear, due to low photo resolution, whether the dam at the Trout Lake outlet was in place. Houses and a possible logging camp were visible on the lower Trout Lake Creek and Stream 1 fans. The Stream 1 fan was logged and/or burnt by a wildfire in 1938. It showed multiple channels, but the active stream bed was not clearly visible. The Stream 1 and 3 gullies had signs of erosional scour, and a side slope failure was visible along Stream 1, but no signs of debris flows or debris floods were visible.

A dam at the Trout Lake outlet was visible on the 1949 photos. The penstock leading down toward the fan was located on the north side of Trout Lake Creek. The railway trestle had collapsed and the crossing had been shifted somewhat toward the lake. The lower Trout Creek fan was occupied by some buildings, including a logging camp. The Stream 1 channel location on its fan was unclear. No signs of debris flows or debris floods were visible in Streams 1 to 3.

The 1952 photos revealed that the Trout Lake dam had disappeared and the water level had dropped. The creek channel below seemed cleared of vegetation, indicative of a dam breach. This was corroborated by John Allen, but written documentation was not available. A berm was visible along Trout Lake Creek above the Crossing. The Stream 1 fan was re-forested, and no debris flows or debris floods were visible in Streams 1 to 3.

Widespread logging in the upper watersheds of Streams 1 to 3 was visible on the 1963 photos, as well as the impact of a wildfire that occurred in 1957. Signs of possible erosion were visible along some gully slopes, but no major landslides or debris flows were triggered. The railway grade may have been converted into a road.

The 1969 photos showed Stream 1 in its current location, likely by means of the man-made berm that still exists today. The berm diverts Stream 1 across the upper fan toward Trout Lake Creek. An access trail to the berm was also visible, indicating that it was constructed (or re-constructed) around that time. No landslides or debris flows were visible in Streams 1 to 3.

Erosion and/or slope failures visible on the 1973 photos in two locations along both Trout Lake Creek and Stream 1 were possibly associated with the historic flood year in 1972. No debris flows or debris floods were triggered.

The 1983, 1986, 1990 and 1993 photos showed debris avalanche or debris flow paths and some erosion on the side slopes of the upper Stream 1 gully, but they did not trigger any larger events reaching the fan. A possible old log jam was visible in the Trout Lake Creek gully between

Streams 2 and 3 in 1993, which may have been remnant debris from the dam failure farther upstream.

The 2016 photos revealed possible debris flow or debris flood deposits within Stream 2, which did not reach the lower slopes or Trout Lake Creek. No major changes were visible on the fan and the Crossing.

4 Morphometric Analysis

A morphometric analysis was undertaken on Streams 1 to 3 to estimate their susceptibility to the three main hydrogeomorphic processes (i.e. debris flow, debris flood, or flood). The Trout Lake Creek watershed was not considered in the analysis due its size and complexity, and the fact that there is a lake upstream from the fan which buffers the effects of flooding. It has to be noted that this analysis is intended for screening purposes, and that the actual susceptibility to floods, debris floods or debris flows depends on many local factors that are not considered in the analysis, such as precipitation, the amount of loose debris in the stream bed, and the channel geometry among others.

The analysis followed the methodology presented in Millard *et al*. (2006)[1], based on empirical thresholds of the Melton ratio[2] as follows:

Floods	**Debris Floods**	**Debris Flows**
Melton < 0.3	Melton 0.3 to 0.6	Melton > 0.6

This was adjusted according to new research presented in Church and Jakob 2020[3]. Watersheds were based on the Freshwater Atlas, with adjustments according to the LiDAR mapping. The results are presented in Table 1.

Table 1: *Results of the morphometric analysis of the selected watersheds.*

Name	**Area [km^2]**	**Relief [km]**	**Melton Ratio**	**Hydrogeomorphic Process**
Stream 1	1.26	0.93	0.82	Debris flow, debris flood
Stream 2	0.39	0.70	1.13	Debris flow
Stream 3	0.36	0.67	1.11	Debris flow

---

[1] Millard T.H., Wilford D.J. and Oden M.E. 2006, Coastal Fan Destabilization and Forest Management, TR-034 Geomorphology, Forest Service British Columbia.

[2] Melton ratio is defined as the watershed relief divided by the square root of the watershed area.

[3] Church M. and Jakob M. 2020, Water Resources Research, What is a Debris Flood?, Research Article 10.1029/2020WR027144, American Geophysical Union.

5 Site Observations

The approximate locations of our key field observations are identified as waypoints (Wpts) on Figure 2. Selected photographs are provided in Figure 3.

5.1 Trout Lake Creek

A 15 m long rail car steel structure served as a temporary bridge at the time of our site visit (Wpt 001; Photo 1). It had roughly 3.5 m of clearance above the stream and was supported on both sides by 1 m high ramps. The existing culvert outlet was about 2.5 m wide and 2 m high and was visible from below the Crossing; the culvert inlet was buried in debris and not visible.

Trout Lake Creek below the Crossing has an overall gradient of 4°. Debris from the February event was visible in the stream bed and in in the forest next to it. An old abandoned channel reach about 5 m wide and 1.5 m deep was found downstream at Wpt 069, otherwise the original terrain surface in this area had been modified by the man-made developments, as mentioned in Section 3.

Upstream of the Crossing, recently deposited gravelly-cobbly debris, partly man-made from the emergency bridge installation, along with natural debris flood deposits were visible. Old bouldery berms up to 3 m high were found along the stream, which also appeared at least partly man-made (Photo 2). The overall terrain surface slope above the Crossing is 3° to 5°.

Stream 1 joins Trout Lake Creek at Wpt 006. Cobbly to bouldery bedload was visible in the stream bed (Photo 3). The Trout Lake Creek gully near the confluence is about 30 to 50 m wide, has a 4° gradient and is infilled with blocky, lobate debris that has created 2 to 3 creek branches. The Trout Creek stream bed above showed signs of recent flooding with flow marks up to 1 m high and some erosional scour, but recent debris flow or debris flood deposits were not visible.

An old log jam about 20 m wide and 35 m long is present at Wpt 008, where the gully bottom is 20 m wide at a gradient of 7°. More jammed logs are present up to Wpt 011, where the V-shaped, 10 m wide Stream 2 gully with some stream flow joins in from the southeast. A relatively recent (2 to 5 years old) deposit of gravelly-cobbly debris about 10 m wide was visible at the gully outlet (Photo 4).

Another draw feature joins Trout Lake Creek from the southeast at Wpt 012. It was vegetated and had minor flow, and no notable debris deposits were visible at the outlet.

Stream 3 extends southeast from Wpt 013 in a 25 m wide, 15 m deep, V-shaped gully. It had some stream flow, without notable debris deposits at the outlet. Trout Lake Creek flows mainly on bedrock at this location, with some cobbly bedload and minor logs. The stream gradient toward the Trout Lake outlet is around 3°.

5.2 Stream 1

The Stream 1 fan below the apex (Wpt 035) has overall gradients around 13°. The location where the channel avulsion occurred during the February runoff event was clearly visible at that location (Photo 5). The flow must have breached the (presumed) existing, man-made berm about 1.5 m high, and the repaired section was also visible. Significant channel erosion had started about 40 m farther upstream but above that, the stream bed appeared largely intact. Below the avulsion, the flow path was 4 to 8 m wide and probably followed a pre-existing channel (Photo 6). Recent significant scour depth was up to 1.5 m. A 10 m wide debris flood deposit was found at Wpt 055. The flood path continued down to Rockwell Drive, where signs of the recent road repairs were noted.

The Stream 1 channel partly contained by the berm leads from Wpt 035 across the upper fan toward Trout Lake Creek at Wpt 006. It is 4 to 8 m wide and 1 to 3 m deep and had signs of significant runoff, but only minor erosion. A 15 m wide, cobbly-bouldery debris deposit was found above Wpt 006.

Several abandoned, dry channels up to 6 m wide and 1 m deep were found on the lower Stream 1 fan above Rockwell Drive, at a fan gradient around 10°.

Stream 1 upstream of the fan apex has a gradient around 15°, flows on bouldery debris and had flow marks from occasional runoff up to about 0.6 m high. Minor debris and wood jams were noted, but no signs of recent debris flows or debris floods were present. Old, vegetated levees may be present in places, but this could not be confirmed due to abundant wood debris covering the ground. The stream channel at the bend (Wpt 025) seems to be well confined to the north by a berm-like feature at least 8 m high.

5.3 Stream 2

Recent debris deposits and wood debris up to 8 m wide, with signs of high runoff, are present at the Stream 2 gully bottom between Wpts 022 and 024, which corresponds to the observations on the 2016 air photos. Gradients in this gully segment are up to 15°. Debris deposits extend to Wpt 021, where the gully splits up in two reaches and the flow marks are up to 1.5 m high.

5.4 Stream 3

The Stream 3 gully between Trout Lake Creek and Wpt 017 has a gradient ranging from 8° to 17° and has a gravelly-cobbly bedload in the channel. Gradients steepen to 30° farther upstream, where the stream flows on bedrock. Signs of recent debris flows or debris floods were not visible.

6 Assessment

The Trout Lake Creek fan and the Crossing location have been significantly modified by human activity and development, and most original landforms have disappeared. The Trout Lake dam breach in the early 1950s likely disturbed or removed many of the natural terrain features in the stream bed below. No major debris floods or debris flows reaching the Crossing were observed on the historic air photos, but small debris floods may not have been visible and there may have been on-going annual sediment transport.

However, the February 2020 event demonstrated that the Crossing is susceptible to debris floods. The frequency / magnitude relationship has not been investigated, but it seems to depend on the debris flow / debris flood occurrence in Streams 2, 3 and especially Stream 1.

Based on the watershed morphometrics and field evidence, Streams 2 and 3 seem to be prone to debris flows. Major deposits were not visible at the outlet; they may have been removed by periodic flooding or by the Trout Lake dam breach. It is assumed that any large future events from these streams would probably arrest above the Crossing, due to the relatively wide gully bottom below the outlets, occupied by uneven, bouldery debris and log deposits. Nonetheless, events in one or both of these streams could supply sediment that will likely affect the Crossing.

Stream 1 seems to be prone to debris floods and debris flows, based on the recent event and on the morphometric analysis. The Crossing is located about 300 m northwest of the Stream 1 fan apex, and although unlikely to be in the direct runout path of a debris flow, it is likely to be affected by future events in that watershed. The fan is complex with numerous channels and the berm at the fan apex that was recently re-established after the emergency.

The estimation of the frequency and magnitude of future debris floods at the Crossing will require further investigation.

7 Recommendations

As woody debris in Trout Lake Creek already blocked the existing culvert on a regular basis in the past, it is recommended that the space upstream of the Crossing be considered for the installation of a debris catchment structure, which should be designed to accommodate both the wooden debris and any future debris floods.

An option for the catchment structure may be the installation of a flexible (ring net) barrier to retain the solids (gravel, boulders, wood), while allowing the water to pass and flow through the Crossing and toward the lake.

The establishment of the design debris flood, i.e. the event size that the Crossing will be protected against, should be based on a combination of the following:

- available information from the MoTI and the residents about past blockages and experiences with the culvert maintenance;
- a refined hydrological analysis of the Trout Lake Creek flow regime, with a focus on the tributary Streams 1, 2 and 3, including an estimation of the sediment potential; and
- the available space for the structure and other constraints within Provincial Park land.

Westrek would be pleased to assist with the design of the structure.

The February 2020 breach of the (likely) unregulated berm that was previously diverting flow at the Stream 1 apex revealed a serious public safety concern at this site that will have to be immediately addressed and managed by the local government. A future berm failure could threaten infrastructure downstream, the provincial park, private property, and human life. The restoration of the berm completed in February should be considered temporary and the berm should be assessed and upgraded as necessary to a permanent structure that meets a modern standard and takes into account the effect of climate change. Such structures are regulated in the Province, and an agency (likely the local government or another designated authority) will have to take responsibility for this structure so that it can be inspected and repaired as needed. It is recommended that this report be forwarded to the responsible agency so that they can proceed with this.

8 Closure

If there are any questions or you require additional details, please contact the undersigned.

Westrek Geotechnical Services Ltd.

S. GAUTSCHI
38042

Oct 13, 2020

S. Gaut

Per:

Simon Gautschi MSc PGeo
Senior Engineering Geologist

This is an electronic replica of the original signed and sealed report and has been provided for convenience. Westrek has retained the original signed / sealed report on file and can provide an authenticated document if required.

Reviewed:

Kevin Turner PEng
Senior Geotechnical Engineer

Attachments:	Figure 1	Area Overview Map
	Figure 2	Site Observation Map
	Figure 3	Selected Site Photographs
	District of Kent press release dated February 4, 2020	
	Appendix A	*Interpretation and Use of Study and Report and Limitations of Liability*

APPENDIX A

INTERPRETATION AND USE OF STUDY AND REPORT AND LIMITATIONS

1. STANDARD OF CARE.

This study and Report have been prepared in accordance with generally accepted engineering and geoscience practices. No other warranty, express or implied, is made. Geological and geotechnical studies and reports do not include environmental consulting unless specifically stated in the report.

2. COMPLETE REPORT.

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report which is of a summary nature and is not intended to stand alone without reference to the instructions given to us by the Client, communications between us and the Client, and to any other reports, writings, proposals or documents prepared by us for the Client relative to the specific site described herein, all of which constitute the Report.

IN ORDER TO UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. WE CANNOT BE RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF THE REPORT.

The Report has been prepared for the specific site, development, design objectives and purpose that were described to us by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the document are only valid to the extent that there has been no material alteration to or variation from any of the said descriptions provided to us unless we are specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT.

The information and opinions expressed in the Report, or any document forming the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT OUR WRITTEN CONSENT. WE WILL CONSENT TO ANY REASONABLE REQUEST BY THE CLIENT TO APPROVE THE USE OF THIS REPORT BY OTHER PARTIES AS “APPROVED USERS”. The contents of the Report remain our copyright property and we authorise only the Client and Approved Users to make copies of the Report only in such quantities as are reasonably necessary for the use of the Report by those parties. The Client and Approved Users may not give, lend, sell or otherwise make the Report or any portion thereof, available to any party without our written permission. Any uses, which a third party makes of the Report, or any portion of the Report, are the sole responsibility of such third parties. Westrek accepts no responsibility for damages suffered by any third party resulting from unauthorised use of the Report.

5. INTERPRETATION OF THE REPORT.

(i) Nature and Exactness of Soil and Description: Classification and identification of soils, rocks, geological units, and engineering estimates have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature and even comprehensive sampling and testing programs, implemented with the appropriate equipment by experienced personnel, may fail to locate some conditions. All investigations utilising the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarising such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and all persons making use of such documents or records should be aware of, and accept, this risk. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

(ii) Reliance on Provided information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to us. We have relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, we cannot accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations or fraudulent acts of any persons providing representations, information and instructions.

(iii) To avoid misunderstandings, Westrek should be retained to work with the other design professionals to explain relevant geotechnical findings and to review the adequacy of their plans and specifications relative to engineering issues. Further, Westrek should be retained to provide field reviews during the construction, consistent with generally accepted practices.

6. LIMITATIONS OF LIABILITY.

Westrek’s liability will be limited as follows:

(a) In recognition of the relative risks and benefits of the Services to be provided to the Client by Westrek, the risks have been allocated such that the Client agrees, to the fullest extent permitted by law, to limit the liability of Westrek, its officers, directors, partners, employees, shareholders, owners, subconsultants and principals for any and all claims, losses, costs, damages of any nature whatsoever or claims expenses from any cause or causes, whether arising in contract or tort including negligence, including legal fees and costs and disbursements (the “Claim”), so that the total aggregate liability of Westrek, its officers, directors, partners, employees, shareholders, owners, subconsultants and principals:

  i. if the Claim is satisfied by the re-performance of the Services proven to be in error, shall not exceed and shall be limited to the cost to Westrek in re-performing such Services; or

  ii. if the Claim cannot be satisfied by the re-performance of the Services and:

    1. if Westrek’s professional liability insurance does not apply to the Claim, shall not exceed and shall be limited to Westrek’s total fee for services rendered for this matter, whichever is the lesser amount. The Client will indemnify and hold harmless Westrek from third party Claims that exceed such amount; or

    2. if Westrek’s professional liability insurance applies to the Claim, shall be limited to $25,000 or to the total fee including expenses invoiced for the project, whichever is less. The Client will indemnify and hold harmless Westrek from third party Claims that exceed such coverage amount. Westrek shall maintain professional liability insurance in this stated amount for a period of two (2) years from the date of substantial performance of the Services or earlier termination of this Agreement. If the Client wishes to increase the amount of such insurance coverage or duration of such policy or obtain other special or increased insurance coverage, Westrek will cooperate with the Client to obtain such coverage at the Client’s expense.

    It is intended that this limitation will apply to any and all liability or cause of action however alleged or arising, including negligence, unless otherwise prohibited by law. Notwithstanding the foregoing, it is expressly agreed that there shall be no claim whatsoever against Westrek, its officers, directors, partners, employees, shareholders, owners, subconsultants and principals for loss of income, profit or other consequential damages howsoever arising, including negligence, liability being limited to direct damages.

(b) Westrek is not responsible for any errors, omissions, mistakes or inaccuracies contained in information provided by the Client, including but not limited to the location of underground or buried services, and with respect to such information, Westrek may rely on it without having to verify or test that information. Further, Westrek is not responsible for any errors or omissions committed by persons, consultants or specialists retained directly by the Client and with respect to any information, documents or opinions provided by such persons, consultants or specialists, Westrek may rely on such information, documents or opinions without having to verify or test the same.

(c) Notwithstanding the provisions of the Limitation Act, R.S.B.C. 2012 c. 13, amendments thereto, or new legislation enacted in its place, Westrek’s liability for any and all claims, including a Claim as defined herein, of the Client or any third party shall absolutely cease to exist after a period of two (2) years following the date of:

  i. Substantial performance of the Services,

  ii. Suspension or abandonment of the Services provided under this agreement, or

  iii. Termination of Westrek’s Services under the agreement,

whichever shall occur first, and following such period, the Client shall have no claim, including a Claim as defined herein, whatsoever against Westrek.

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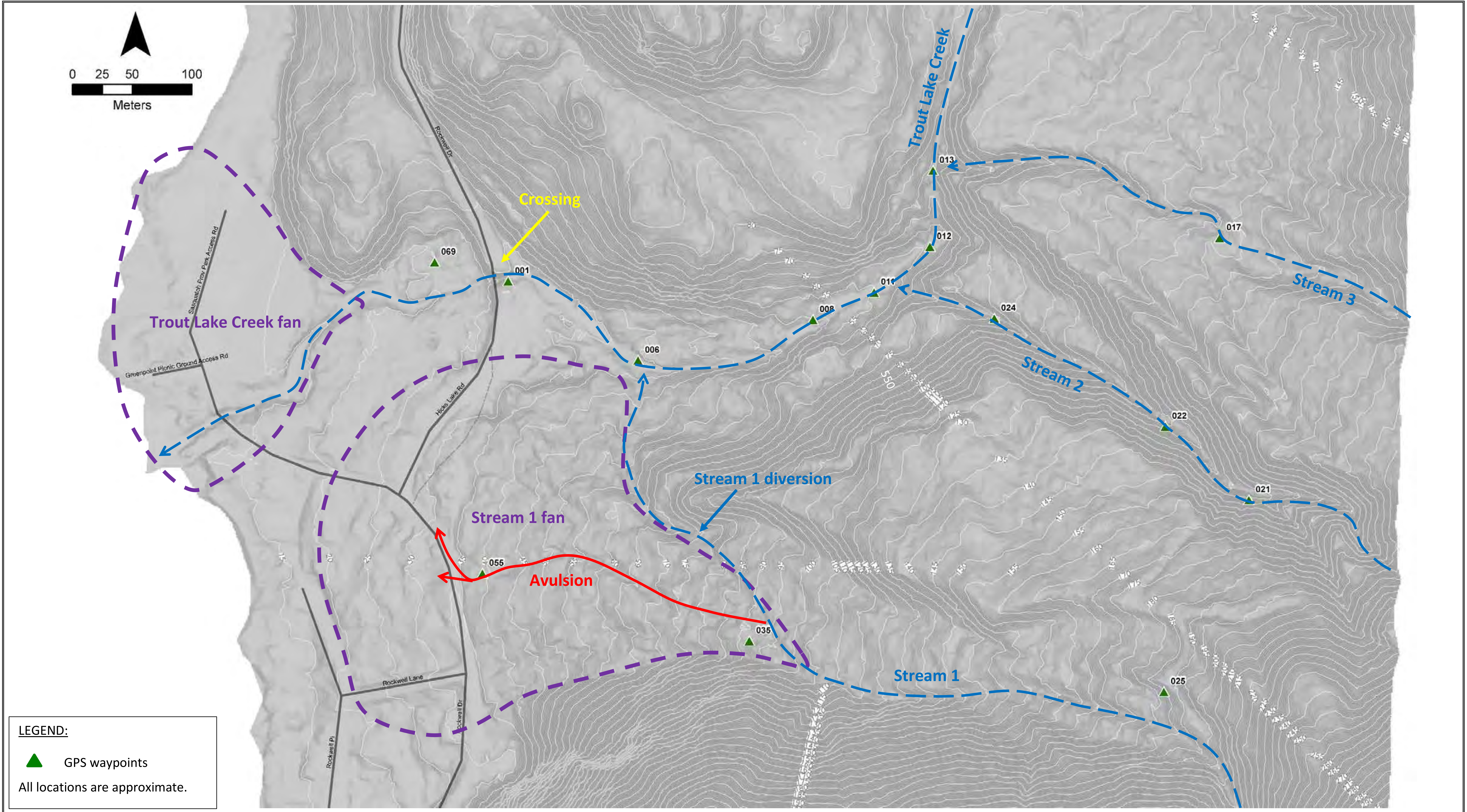
OVERVIEW MAP
TROUT LAKE CREEK CROSSING
NORTH OF HARRISON HOT SPRINGS, BC

Scale: As Shown

Date: October 13, 2020

Project No.: 020-030

FIGURE 1



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Scale: 1: 3,000

Date: October 13, 2020

Project No.: 020-030

SITE MAP

TROUT LAKE CREEK CROSSING - NORTH OF HARRISON HOT SPRINGS, BC

LiDAR imagery: Ministry of Transportation and Infrastructure, acquired 2020

FIGURE 2

***Photo 1** – View of the temporary crossing at Wpt 001.*

***Photo 2** – Looking downstream Trout Lake Creek toward the Crossing. The man-made berm is visible in the foreground.*

***Photo 3** –Cobbly-bouldery bedload in the Stream 1 channel, just above Wpt 006.*

***Photo 4** – Recent debris deposit at the Stream 2 outlet by Wpt 011.*

***Photo 5** – Looking downstream (north) at the avulsion in Stream 1 near Wpt 035. The berm to the left has been repaired after the breach in February 2020.*

***Photo 6** – Along the flow path of the avulsed debris flood, about 40 m below Wpt 035. Note the scoured trees.*

westrek geotechnical services ltd.	Project No: 020-030 Date: October 13, 2020	**CLIENT: ASSOCIATED ENGINEERING LTD.**	**TROUT LAKE CREEK CROSSING** **NORTH OF HARRISON HOT SPRINGS, BC**	**FIGURE 3**

DISTRICT OF KENT
125 YEARS
CIVIC PRIDE

PRESS RELEASE

State of Local Emergency

February 4, 2020

Agassiz, British Columbia – A State of Local Emergency (SoLE) was declared by Mayor Sylvia Pranger on February 1, 2020 due to heavy rainfall damaging roads and potable water infrastructure.

Evacuation orders were issued on February 1, 2020 at 4:00 p.m. requesting all residents affected to immediately leave the area due to the damaged road infrastructure, no potable water and rapid water flows across the highway. Kent-Harrison Search and Rescue along with the RCMP delivered notices to residents.

On February 4, 2020 the same affected properties were issued a revised evacuation order by the District of Kent encouraging remaining residents to evacuate the area primarily for their safety and to allow work crews a safe environment to continue to reconstruct the road and restore potable water service.

Since the SoLE was declared, the District of Kent has been working with the Ministry of Transportation and Infrastructure (MOTI) and Emil Anderson Construction to coordinate efforts to provide single lane temporary access throughout the evacuated area.

The flood waters that originated from Trout Lake Creek when it breached its bank has been successfully restored to its intended channel. The MOTI intends to restore the road to its original design.

The District of Kent Engineering Department is working with Emil Anderson to restore potable water service to the area residents.

The MOTI in conjunction with its contractor, Emil Anderson, are currently developing a plan to restore access for local traffic to the area residents as soon as possible. Currently access to Rockwell Drive is restricted to local traffic and construction vehicles. Traffic control personnel will be requesting documentation for proof of local residency and all vehicles accessing the area will be recorded.

There is no access beyond the intersection of Rockwell Drive and Hicks Lake Road. At this time there is no road access to Sasquatch Provincial Park or the Harrison East Forest Service Road.

Security and police will continue to be present in the affected area.

APPENDIX E – 2021 TROUT LAKE CREEK CULVERT REPLACEMENT CULVERT CONCEPTUAL DESIGN.

TECHNICAL MEMORANDUM

Ministry of Transportation & Infrastructure

Trout Lake Creek Culvert Replacement
Culvert Conceptual Design

MARCH 2021

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TABLE OF CONTENTS

1 BACKGROUND

The Ministry of Transportation and Infrastructure (MoTI) experienced a washout at the existing Trout Lake Creek Culvert located under Hicks Lake Road near Harrison. The washout occurred following a significant rainfall event on January 31, 2020. MoTI has already completed emergency works on site to provide a temporary solution to maintain access across the watercourse.

This technical memorandum provides a summary of the hydraulic modelling results for the Trout Lake Creek Culvert Replacement, conceptual design of the proposed culvert and channel improvements, and a summary of the life-cycle-cost analysis comparing the culvert conceptual design and the bridge conceptual design, which was developed in the technical memorandum titled Trout Lake Creek Culvert Replacement – Bridge Conceptual Design (AE, 2018).

2 DESIGN FLOW RATES

The hydrologic analysis for the Trout Lake Creek Culvert was completed as part of a previous study from 2018. We are using the results from that previous hydrologic analysis for the assignment.

Measured flow data is not available for Trout Lake Creek. As a result, the previous hydrologic assessment required a regional analysis, based on the results of a frequency analysis for the following three nearby stations:

- 08GA023 – Rubble Creek near Garibaldi
- 08MF048 – Elk Creek at Prairie Central Road
- 08MF006 – Wahleach Creek near Laidlaw (upper)

Based on this previous analysis, the 100-year peak instantaneous flow rate was estimated as 34.5 m^3/s. The estimated peak instantaneous 2-year flow rate is 5.6 m^3/s. Both of these estimates include an allowance for climate change.

For our current hydraulic analysis, we have sized the culverts to convey the 100-year flow rate, with a minimum freeboard of 0.5 m. For the purposes of evaluating fish passage at the crossing, we are using 50% of the 2-year flow rate.

3 CULVERT SIZING

As outlined in our workplan, we completed HEC-RAS hydraulic modelling and sized culverts for the following five scenarios:

- Open Bottom CSP Arch, with a slope to suit the upstream and downstream channel elevations.
- Closed Bottom CSP Arch
  - "Steep" arrangement to suit upstream and downstream channel elevations
  - "Flat" arrangement to try to minimize velocity within the culvert barrel
- Concrete Box Culvert
  - "Steep" arrangement to suit upstream and downstream channel elevations
  - "Flat" arrangement to try to minimize velocity within the culvert barrel

For the Closed Bottom CSP Arch and the Concrete Box Culvert, the bottom of the culverts where infilled with riprap to limit velocities within the culvert, in an effort to accommodate upstream fish passage as best as possible.

Recognizing that the thickness of the riprap is a function of the classification, and that the riprap classification is a function of velocity, the culvert sizing for both the Closed Bottom Arch and Concrete Box Culvert was an iterative process, as the culvert size had to be increased to accommodate the riprap infill.

As noted above, we sized the culverts to achieve a minimum of 500 mm freeboard for the 100-year flow rate. The resulting culvert sizes are summarized **Table 2-1** below.

Table 2-1
Culvert Sizing for 100-year Event

		Slope	Span	Rise	100-year Velocity[1]	Riprap Class	Riprap Thickness	Clear Height	Water Depth at Inlet	Freeboard
		[%]	[mm]	[mm]	[m/s]	[kg]	[mm]	[mm]	[m]	[mm]
Open Bottom Arch	Steep	13.9	7670	2570	6.38	1000	1500	2570	2.03	540
Closed Bottom Arch	Steep	14.4	6800	4350	6.16	1000	1500	2850	2.31	540
Closed Bottom Arch	Flat	0	5980	3850	4.04	50	550	3300	2.76	540
Concrete Box	Steep	14.4	6000	4500	6.69	1000	1500	3000	2.47	530
Concrete Box	Flat	0	6500	3450	3.73	50	550	2900	2.34	560

1. We reviewed both the upstream and downstream culvert velocities reported by the model. In all cases, the downstream culvert velocity was higher than the upstream culvert velocity for the 100-year flow rate. Accordingly, the values reported here are based on the downstream velocities.

4 FISH PASSAGE CONSIDERATIONS

After we had sized the culverts for the 100-year flow rate, we simulated the 50% of 2-year flow rate, to assess the velocities under the lower flow conditions, for the purposes of evaluating fish passage.

Based on the input provided to us by Hatfield, at a minimum, the culvert velocities should be limited to achieve the following:

- Accommodate prolonged swimming speeds of all species and all life stages during mean annual discharge, and
- Accommodate sustained swimming speeds for adults during spring and fall spawning migrations (higher flows).

Recognizing that we do not have measured flow data from Trout Lake Creek, we cannot directly quantify the mean annual discharge. Rather, we have used the 50% of 2-year flow as a low-flow values for assessing fish passage.

The image below is taken from the reporting provided to us by Hatfield, and shows the maximum swimming speeds and jump heights for various salmonid species on Trout Lake Creek.

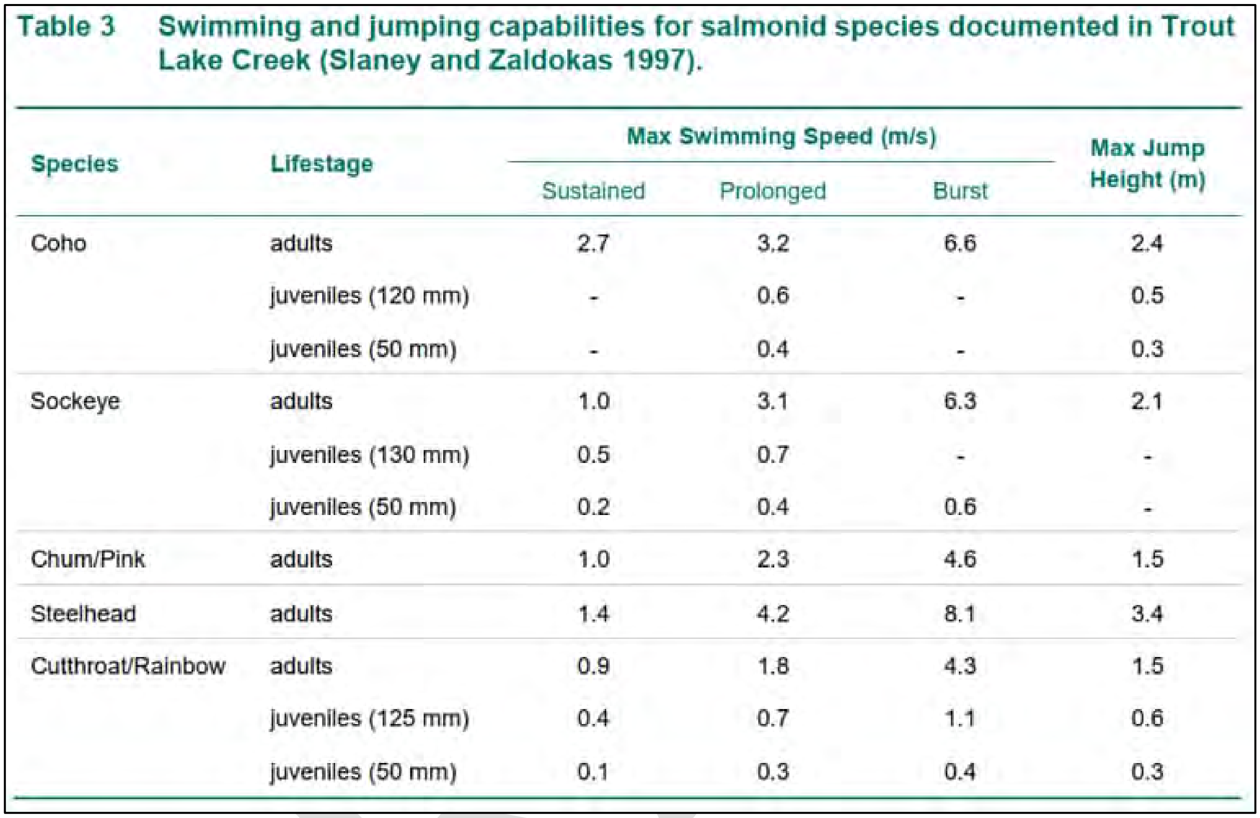

Table 3 Swimming and jumping capabilities for salmonid species documented in Trout Lake Creek (Slaney and Zaldokas 1997).

Species	Lifestage	Max Swimming Speed (m/s)			Max Jump Height (m)
		Sustained	Prolonged	Burst	
Coho	adults	2.7	3.2	6.6	2.4
	juveniles (120 mm)	-	0.6	-	0.5
	juveniles (50 mm)	-	0.4	-	0.3
Sockeye	adults	1.0	3.1	6.3	2.1
	juveniles (130 mm)	0.5	0.7	-	-
	juveniles (50 mm)	0.2	0.4	0.6	-
Chum/Pink	adults	1.0	2.3	4.6	1.5
Steelhead	adults	1.4	4.2	8.1	3.4
Cutthroat/Rainbow	adults	0.9	1.8	4.3	1.5
	juveniles (125 mm)	0.4	0.7	1.1	0.6
	juveniles (50 mm)	0.1	0.3	0.4	0.3

The modelling results for the 50% of the 2-year Flow Rate are summarized in **Table 3-1** below.

Table 3-1
50% of 2-year Velocities

		Span	Rise	50% of 2-year Velocity[1]
		[mm]	[mm]	[m/s]
Open Bottom Arch	Steep	7670	2570	2.65
Closed Bottom Arch	Steep	6800	4350	2.84
Closed Bottom Arch	Flat	5980	3850	1.66
Concrete Box	Steep	6000	4500	1.66
Concrete Box	Flat	6500	3450	1.62

[1] We reviewed both the upstream and downstream culvert velocities reported by the model. For the flat culvert scenarios, the downstream velocity was higher than the upstream velocity for this event. Conversely, for the steep culvert scenarios, the upstream velocities were higher. The values reported here are based on the higher of the two values for each scenario.

The HGL plots of the five culvert scenarios for the 50% of 2-year event are included in **Figures 3-1** to **3.5** below.

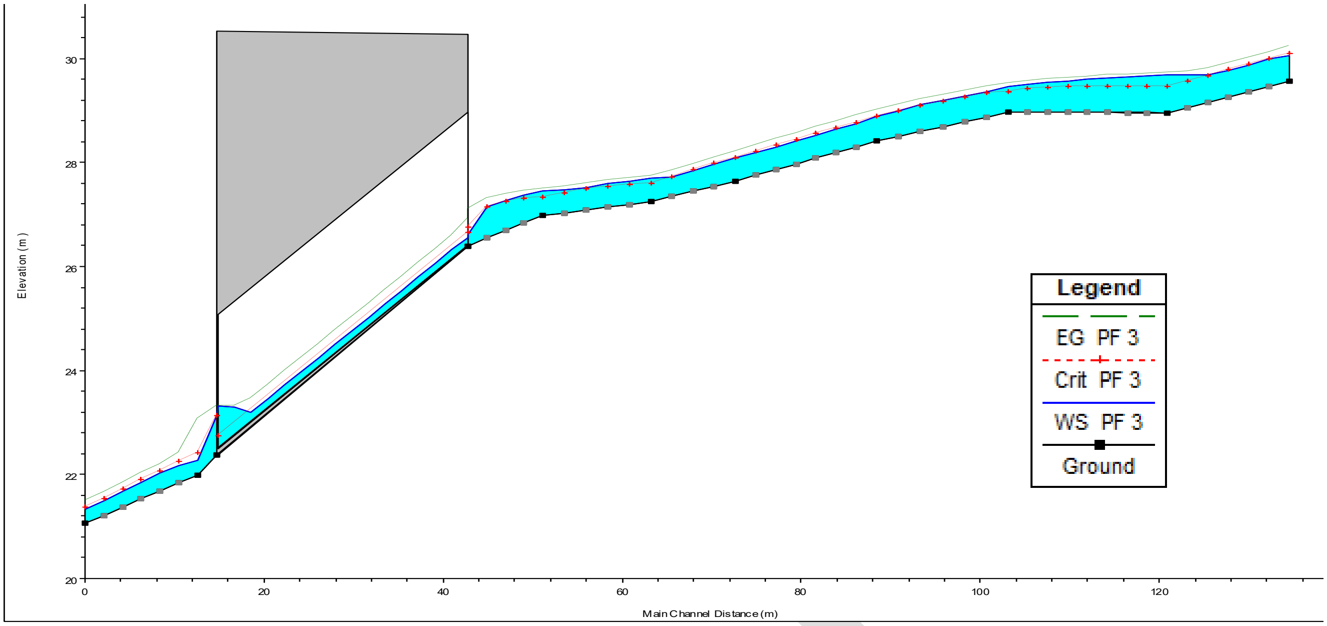

Figure 4-1 Open Bottom Arch - Steep

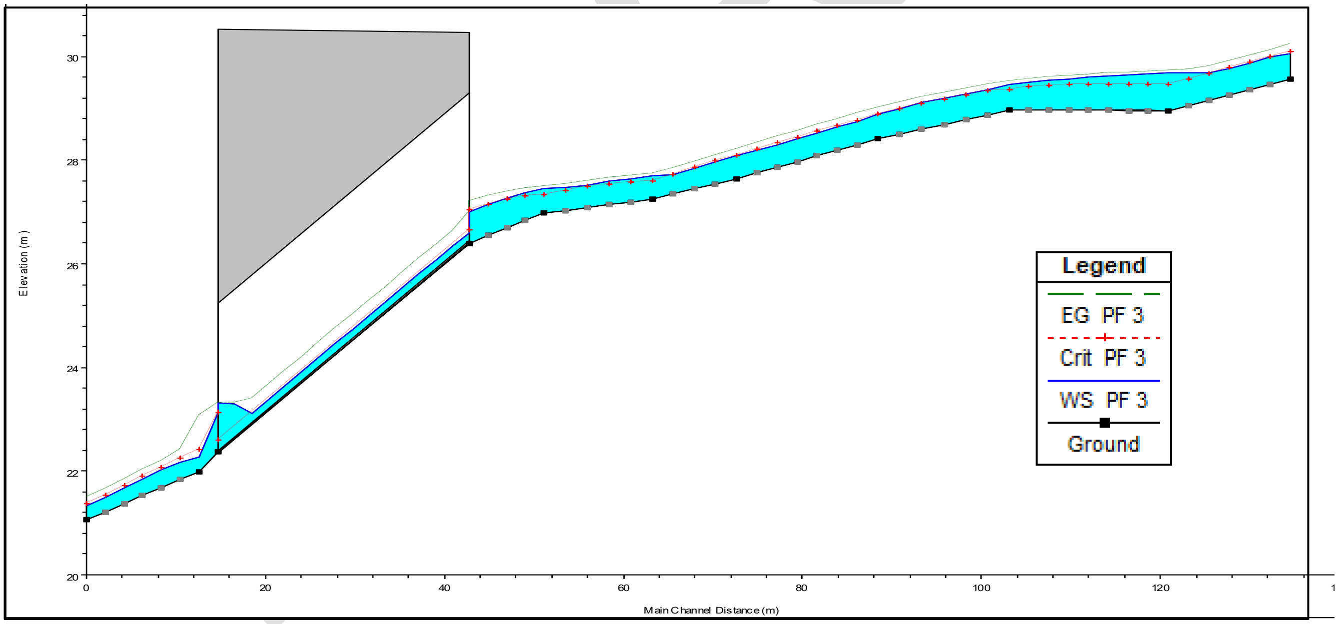

Figure 4-2 Closed Bottom Arch - Steep

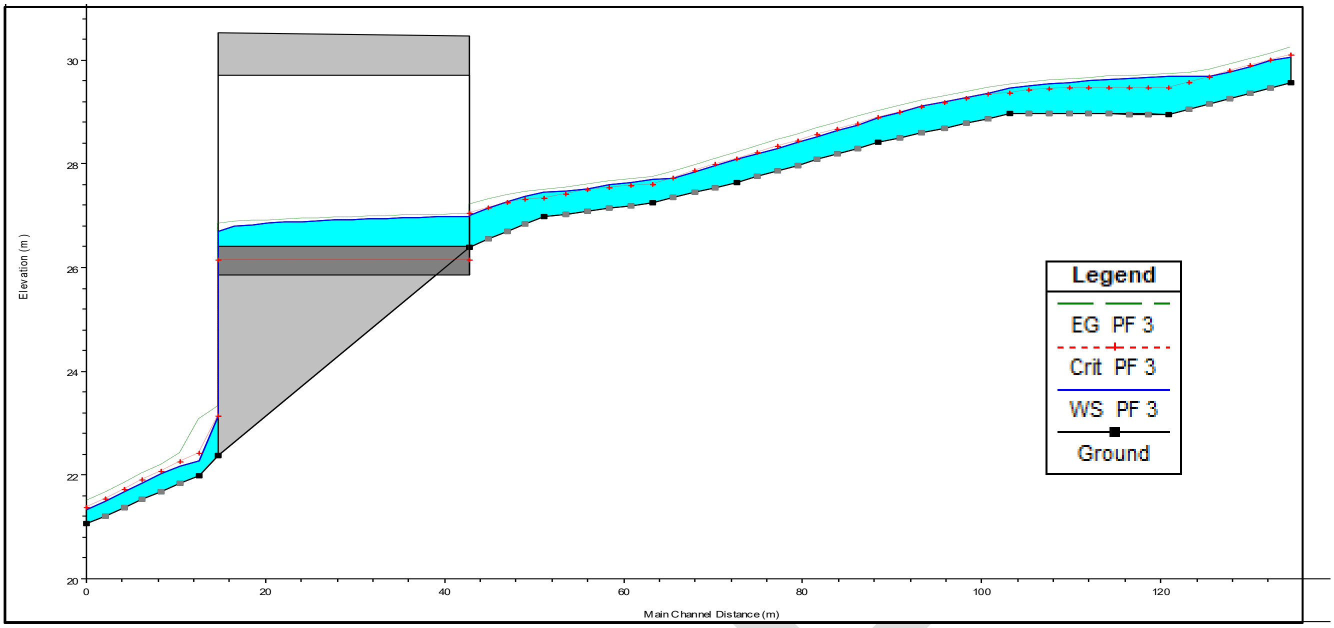

Figure 4-3 Closed Bottom Arch - Flat

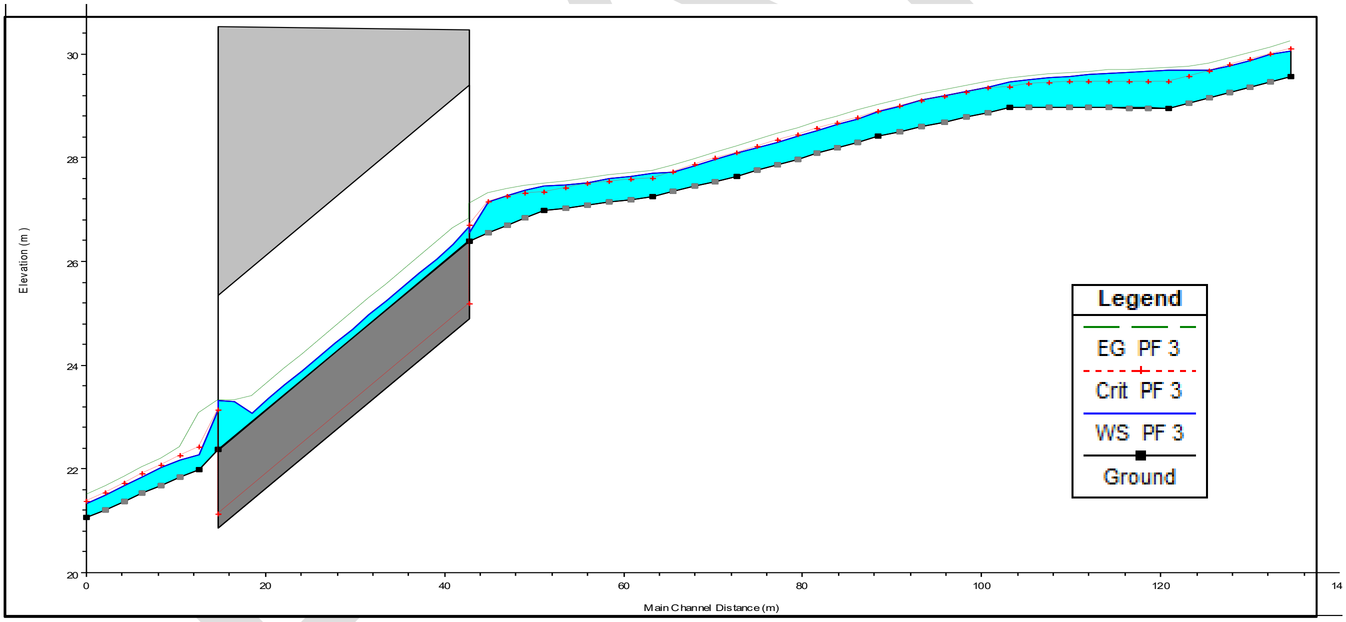

Figure 4-4 Concrete Box - Steep

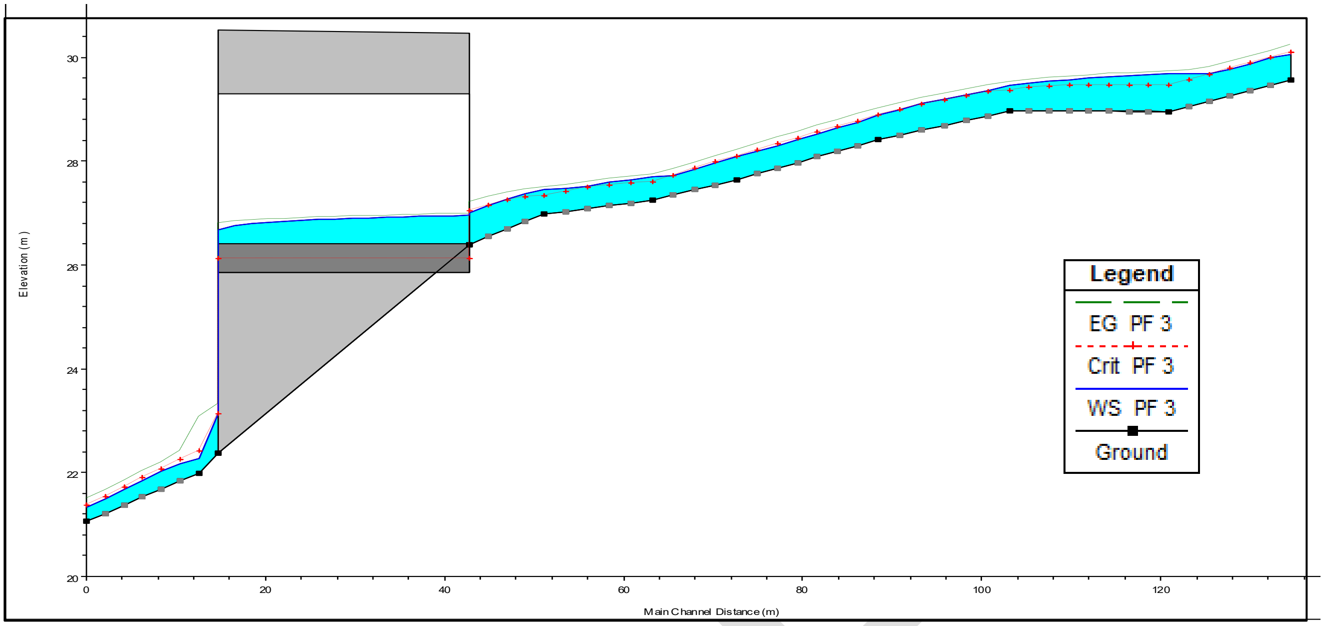

Figure 4-5 Concrete Box - Flat

5 FISH PASSAGE OBSERVATIONS

Flat Culvert Scenarios

For the two flat culvert scenarios, the Closed Bottom CSP Arch had a peak 50% of 2-year velocity of 1.66 m/s, while the Concrete Box had peak 50% of 2-year velocity of 1.62 m/s.

These velocities exceed the prolonged swim speeds for juveniles for all species. They also exceed the sustained swim speeds for adults for all species except Coho.

As such, installing the culverts on a flat gradient does not appear to provide a significant benefit in terms of accommodating upstream fish passage through the crossing.

In addition, in order to achieve a flat gradient through the crossing, the culvert outlet would be perched approximately 4.0 m above the creek invert. Under this scenario, a major additional fish passage structure would be required to get the fish from the creek up to the culvert outlet.

On this basis, neither of the flat culvert options appears to provide a reasonable solution.

Steep Culvert Scenarios

For the three steep culvert options, the peak velocities from the 50% of the 2-year flow are as follows:

- Concrete Box = 1.66 m/s
- Open Bottom Arch = 2.65 m/s
- Closed Bottom Arch = 2.84 m/s

The steep Concrete Box culvert velocity is similar to the results from the two flat culvert options discussed above, with similar limitations on the upstream fish passage as noted above. Namely, the velocity exceeds the prolonged swim speeds for juveniles for all species, and also exceeds the sustained swim speeds for adults for all species, except Coho.

For the steep Open Bottom Arch and the steep Closed Bottom Arch scenarios, the velocities again exceed the swim speeds for all juveniles of all species. They also exceed the sustained swimming speeds for the adults for all species (with the exception of Coho, for which the design velocities approximately match the sustained swimming speed).

Additional Fish Passage Considerations

Given the relatively large flows on the system, and the 14.5% gradient at this crossing, a step-pool arrangement within the bottom of the creek would likely be necessary to facilitate any meaningful limitation in velocity, from a fish passage perspective.

It is not feasible to construct steep pools within an enclosed culvert (either a Closed Bottom Arch or a Concrete Box). However, it would likely be feasible to construct step pools in concert with an Open Bottom Arch, which would be seated on concrete strip footings supported by spread footings Based on our structural analysis, piles are not required as the spread footing is sufficient to resist the loads.

Alternatively, step-pools could be constructed in the channel through a bridge opening.

6 RIPRAP STABILITY CONSIDERATIONS

While we have sized riprap for the steep culvert scenarios to accommodate the high velocities, there are practical limitations to placing riprap within culverts on a 14.5% grade.

The bottom of the riprap would be seated on the smooth surface of the culvert invert, which could potentially act as a slip plane. This presents a serious risk that the riprap could become unstable under extreme flows, in spite of the large riprap classification.

As such, we dismissed both of the flat culvert options, as well as the two closed-bottom steep culvert options and carried forward the open-bottom arch for conceptual design development.

7 STEP POOL ARRANGEMENT

We modified the channel bed geometry of the Open Bottom Arch scenario within the culvert to include a step-pool arrangement and simulated three low flows, 2.8 m^3/s (i.e. 50% of Q2), 1.0 m^3/s, and 0.5 m^3/s, to evaluate the benefits of the step pools in term of velocities. We limited the maximum height of the step geometry to 0.3 m to accommodate fish jumping heights. Based on channel slope of 14.5%, this gives a step length of approximately 2.0 m.

Table 6-1 compares the minimum velocities of the three low flow scenarios with a step-pool arrangement and without a step-pool arrangement. The results indicate that the step-pool arrangement lowers the velocities by approximately 30% for the 50% of Q2 event, and approximately 50% for both lower flows (i.e. 1.0 m^3/s and 0.5 m^3/s). This is a significant improvement for fish passage.

Table 6-1
Culvert Velocities

Flow Scenario	Minimum Velocity without Step-Pools	Minimum Velocity with Step-Pools
	[m/s]	[m/s]
Q = 2.8 m^3/s (50% of Q2)	1.9	1.1
Q = 1.0 m^3/s	1.5	0.7
Q = 0.3 m^3/s	1.3	0.5

While the HEC-RAS results indicate that the step-pool arrangement provides a benefit in terms of reducing velocities, we note that the detailed hydraulics within a step pool arrangement are complex. The HEC-RAS model does not fully capture the complex nature of the three dimension plunge pools, eddies, and flow conditions; rather, it is intended to simply illustrate that the pools provide a general benefit in terms of reducing velocities.

The culvert requires 1000kg riprap on the channel bed, and the step pools constructed with 1000kg would have large voids. Much of the water would be conveyed through the rocks, as opposed to on top of the rocks, at the low flows. While there are potential design options to address this, they come with challenges. Gravels could be placed to infill the voids. This would help facilitate that natural infilling that would occur over time, but there is uncertainty regarding how stable these gravels would be. An alternative design approach that has been used elsewhere would be to grout the riprap. However, that is difficult to properly construct, particularly at this site. It is also subject to cracking as the riprap particles shift. It is also a less natural solution. Based on these general concerns, we would not recommend grouting the riprap.

8 CONCEPT DESIGN

We have developed concept drawings for the Open-Bottom Arch Culvert and channel improvements as shown in Drawings R1-XXX-701SK, 721SK, 722SK, 751SK and 761SK (Appendix A). The channel improvements include an upstream sediment basin and an extension of the existing berm upstream of the culvert.

The culvert concept includes a step pool arrangement which consists of 14 steps of 2.0 m length and 0.3 m height per step constructed with 1000 kg riprap.

The sediment basin provides an additional volume of approximately 120 m^3 within the channel, for debris.

The berm extension is approximately 45 m long from the road to the existing berm, with 0.5 m crest width and 2H:1V side slopes.

9 LIFE CYCLE COSTS

We estimated the life-cycle costs for the culvert concept and bridge concept (previously developed) for comparison. The life-cycle-cost estimates for the culvert concept and bridge concept are $1.7M and $1.6M, respectively. We estimated the life-cycle cost for the sediment basin and berm extension separate from the culvert and the bridge concepts as they can be completed independently from the culvert replacement, and therefor should not impact the decision between a culvert or bridge solution. Note we assumed 5% mobilization and demobilization and 2% quality management in the capital cost estimates and included 25% contingency. The breakdowns of the estimates for both concepts are summarized in **Table 9-1**. The details of the life-cycle cost estimates can be found in **Appendix B**.

Table 9-1
Life-Cycle-Costs

Item	Culvert Concept	Bridge Concept	Sediment Basin & Berm Extension
Total Capital Cost	$1.7 M	$1.5M	$122 K
Total Maintenance Cost	$35 K	$48 K	$20 K
Total Life-Cycle Cost	$1.7 M	$1.6 M	$142 K

The maintenance costs were estimated based on the Net Present Value (NPV) with a discount rate of 6% to account for the future inflation. Although the design service life for the culvert and the bridge is 75 years, we accounted only the first 50 years as the values in the remaining years are insignificant in NPV. We assumed $10,000 spent every 5 years for general maintenance such as patching and filling of holes and debris removal for the culvert and the bridge. The bridge requires additional maintenance for deck surfacing and membrane replacement and resurfacing. We assumed $20,000 at Year 20 for deck surfacing and $40,000 at Year 40 for membrane replacement and deck surfacing. Similarly, we assumed $1,000 for annual maintenance cost for the sediment basin and the berm extension, which includes efforts to remove sediment from the sediment basin.

10 RECOMMENDATIONS

Based on the results of the hydraulic modelling and the life-cycle cost analysis, we recommend the bridge option.

The estimated life-cycle costs of the Open Bottom Arch Culvert concept and the bridge concept are comparable. In fact, our estimates indicate the bridge option is slightly more economical. Furthermore, the bridge has a much larger opening, approximately three times larger than the culvert. Thus, the bridge has a hydraulic advantage and has a lower risk with blockage.

CLOSURE

This report was prepared for the Ministry of Transportation and Infrastructure to present our conceptual design considerations for the Trout Lake Creek Culvert Replacement.

Respectfully submitted,
Associated Engineering (B.C.) Ltd.

Prepared by:	Reviewed by:
Jenna Lee, P.Eng., LEED AP Water Resource Engineer	Josh Thiessen, P.Eng. Senior Water Resources Engineer

JL/JT/fd

APPENDIX A – CONCEPTUAL DRAWINGS

NOTES:

1. TOPOGRAPHIC SURVEY COMPLETED ON JUNE 16, 2020 AND PROVIDED BY MOTI
2. DESIGN FLOW $Q_{100} = 34.5m^3/s$
3. MAXIMUM DESIGN VELOCITY = $6.4m^3/s$
4. SEDIMENT BASIN VOLUME = $120m^3$

PLAN
SCALE 1:200

Consultant Logo

Associated Engineering

Rev	Date	Description	Init
A	2021-02-26	ISSUED FOR DISCUSSION	JL

REVISIONS

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure
South Coast Region

LOWER MAINLAND DISTRICT
ROCKWELL DRIVE

TROUT LAKE CREEK CULVERT REPLACEMENT AND CHANNEL IMPROVEMENTS PLAN

PREPARED UNDER THE DIRECTION OF

J. LEE, P.ENG
ENGINEER OF RECORD
DATE 2021-02-26

DESIGNED J. LEE DATE 2021-02-26
CHECKED J. THIESSEN DATE 2021-02-26
DRAWN H. LEE DATE 2021-02-26
SCALE AS NOTED
NEGATIVE No.

FILE No.	PROJECT No.	REG.	DRAWING No.	
	----	1	R1-XXX-701SK	A

CANCEL PRINTS BEARING PREVIOUS LETTER

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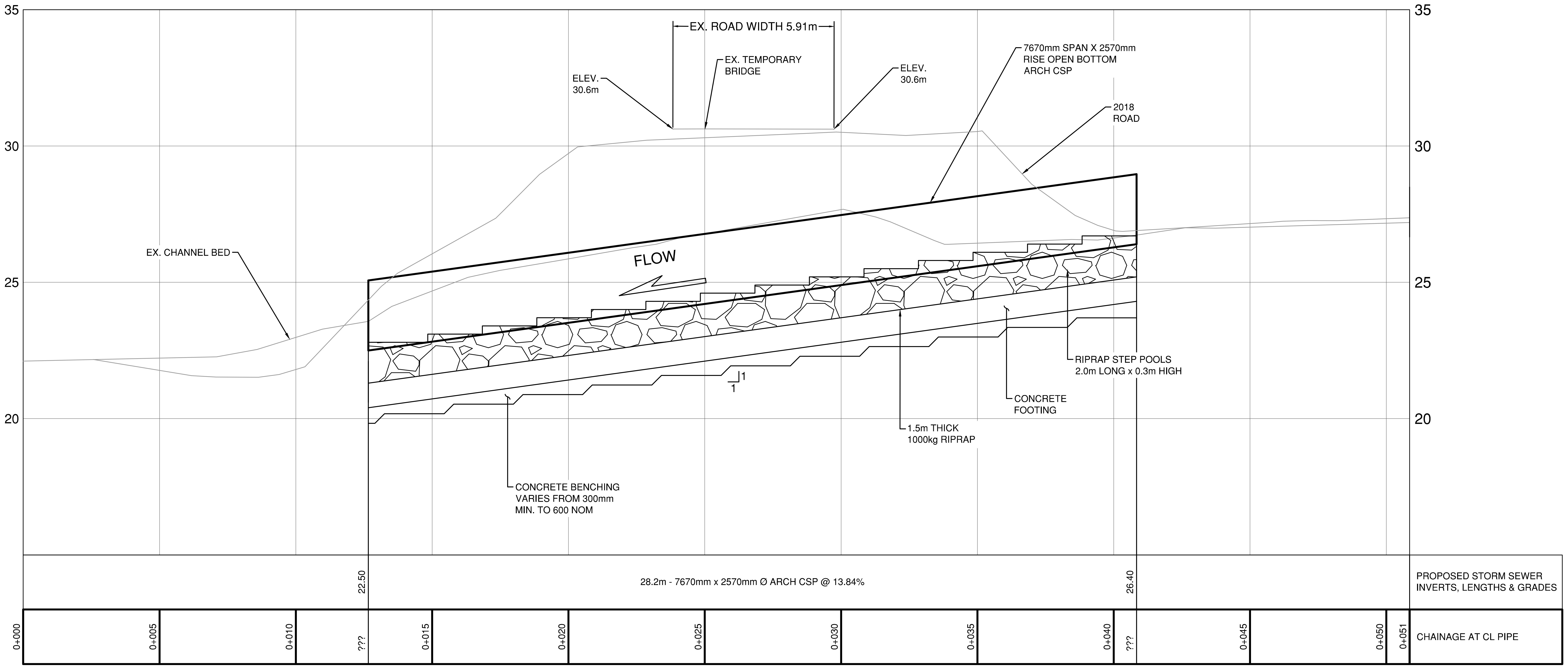

PROFILE
SCALE 1:100

Consultant Logo

Associated Engineering

Rev	Date	Description	Init
A	2021-02-26	ISSUED FOR DISCUSSION	JL

REVISIONS

BRITISH COLUMBIA

Ministry of Transportation
and Infrastructure
South Coast Region

LOWER MAINLAND DISTRICT
ROCKWELL DRIVE

TROUT LAKE CREEK CULVERT REPLACEMENT AND CHANNEL IMPROVEMENTS CULVERT PLAN AND PROFILE

PREPARED UNDER THE DIRECTION OF

J. LEE, P.ENG
ENGINEER OF RECORD
DATE 2021-02-26

DESIGNED J. LEE DATE 2021-02-26
CHECKED J. THIESSEN DATE 2021-02-26
DRAWN H. LEE DATE 2021-02-26
SCALE AS NOTED
NEGATIVE No.

FILE No.
PROJECT No. ----
REG. 1
DRAWING No. R1-XXX-721SK A

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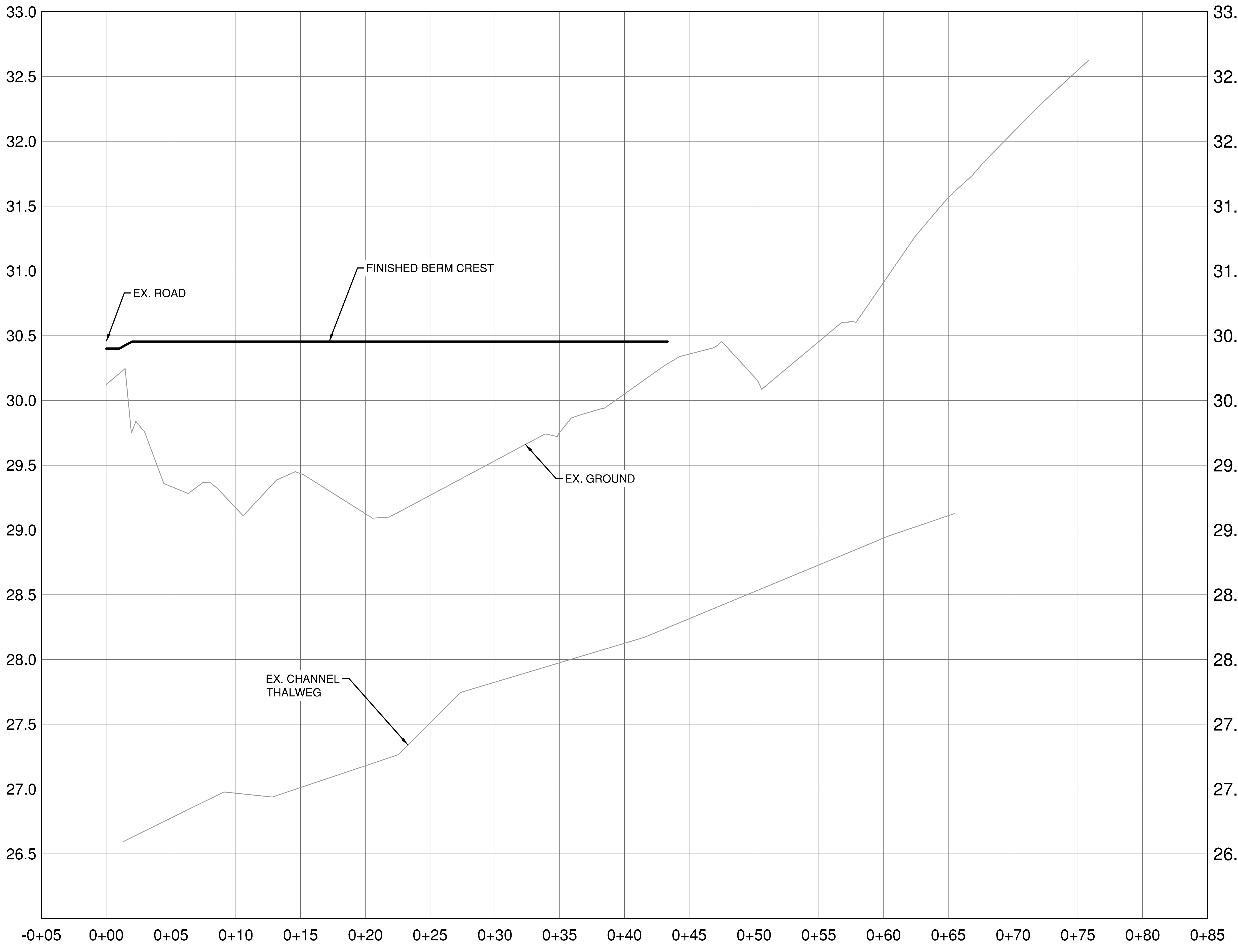

PROFILE L200
SCALE 1:250

Consultant Logo

Associated Engineering

Rev	Date	Description	Init
A	2020-11-25	ISSUED FOR XXX DESIGN	JL

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BRITISH COLUMBIA

Ministry of Transportation and Infrastructure
South Coast Region

LOWER MAINLAND DISTRICT
ROCKWELL DRIVE

TROUT LAKE CREEK CULVERT REPLACEMENT AND CHANNEL IMPROVEMENTS BERM PLAN AND PROFILE

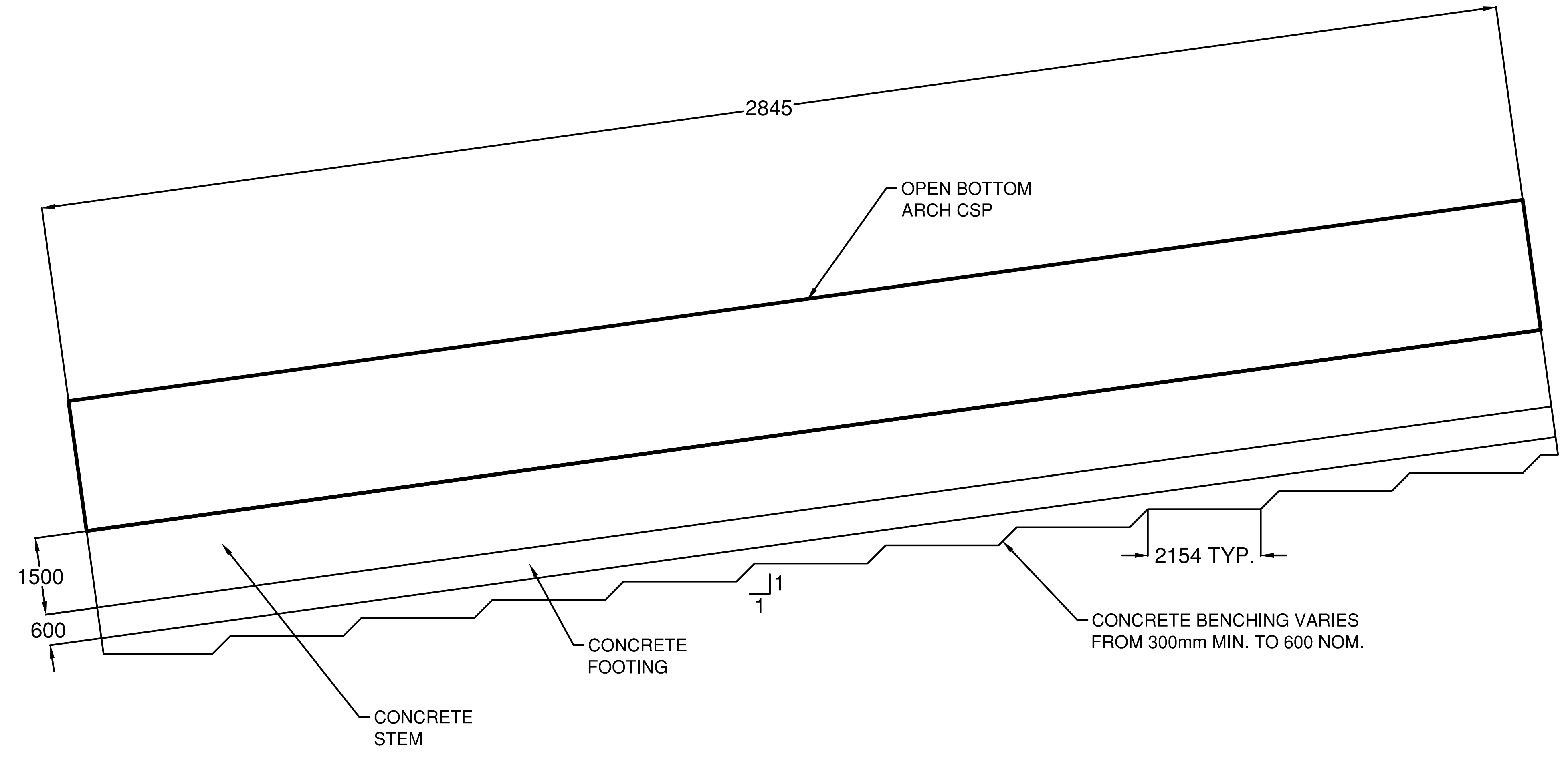
PREPARED UNDER THE DIRECTION OF

J. LEE, P.ENG
ENGINEER OF RECORD
DATE 2021-02-26

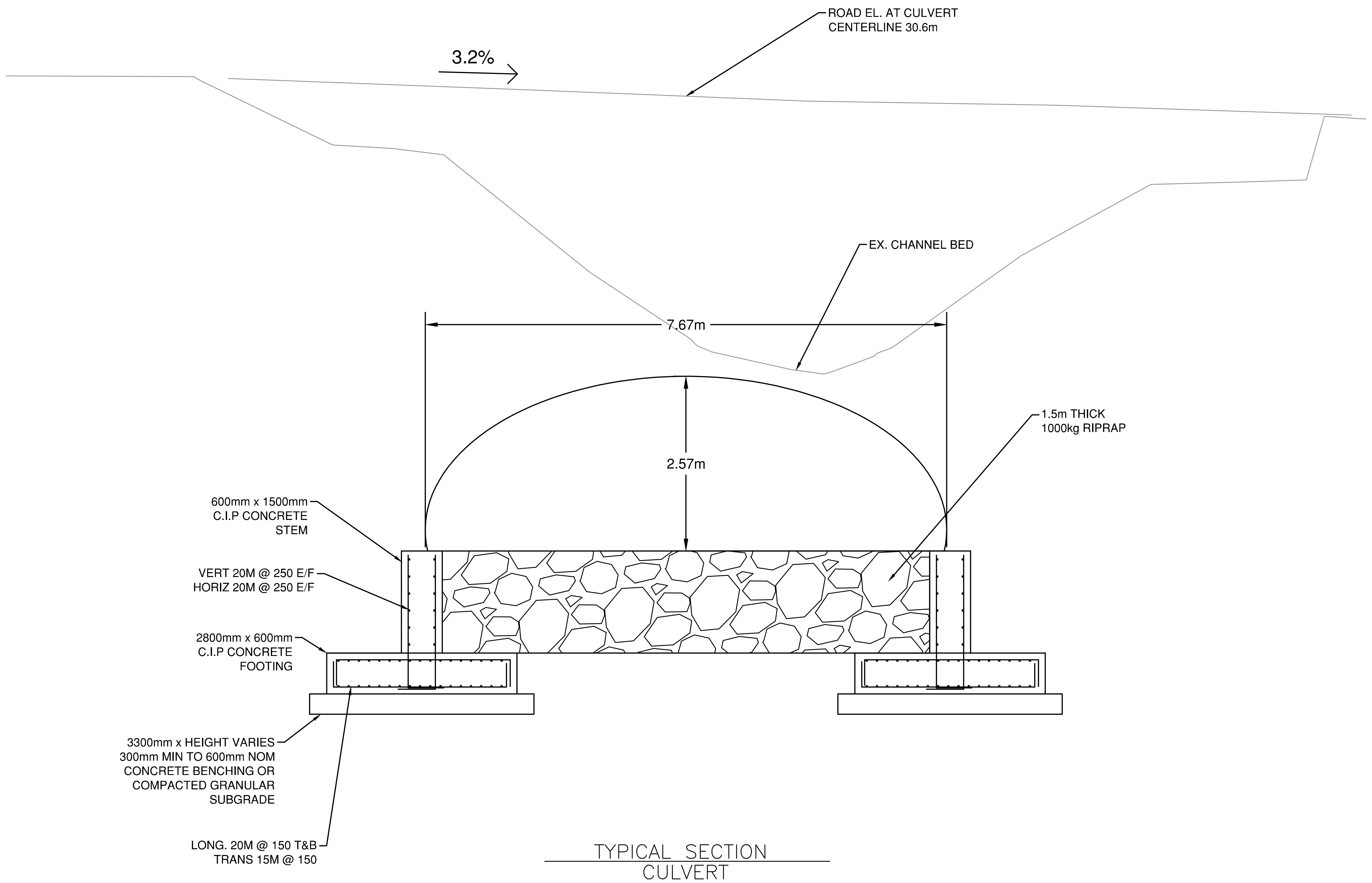
DESIGNED J. LEE DATE 2021-02-26
CHECKED J. THIESSEN DATE 2021-02-26
DRAWN H. LEE DATE 2021-02-26
SCALE AS NOTED
NEGATIVE No.

FILE No.	PROJECT No.	REG.	DRAWING No.
	----	1	R1-XXX-722SK A

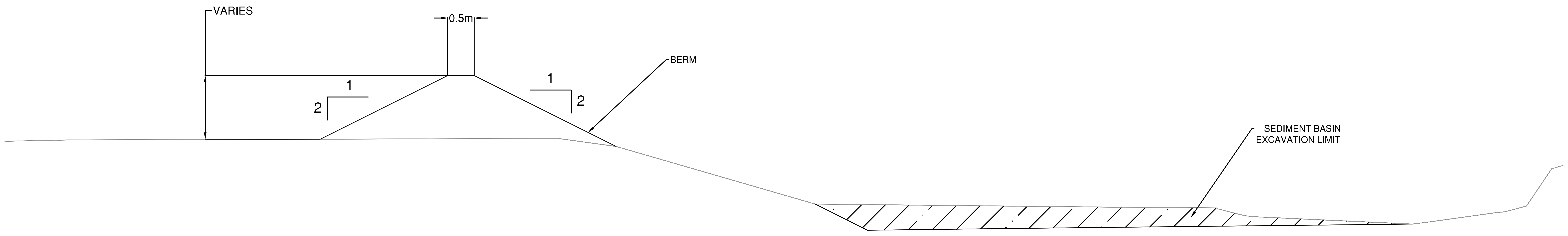
CANCEL PRINTS BEARING PREVIOUS LETTER



ELEVATION OF CULVERT FOOTING
SCALE 1:100



TYPICAL SECTION
CULVERT
SCALE 1:50



TYPICAL SECTION
SEDIMENT BASIN AND BERM
SCALE 1:50

Consultant Logo

Associated Engineering

Rev	Date	Description	Init
A	2021–02–26	ISSUED FOR DISCUSSION	JL

REVISIONS

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure
South Coast Region

LOWER MAINLAND DISTRICT
ROCKWELL DRIVE

TROUT LAKE CREEK CULVERT REPLACEMENT AND CHANNEL IMPROVEMENTS
TYPICAL SECTIONS

PREPARED UNDER THE DIRECTION OF
J. LEE, P.ENG
ENGINEER OF RECORD
DATE 2021–02–26

DESIGNED J. LEE DATE 2021–02–26
CHECKED J. THIESSEN DATE 2021–02–26
DRAWN H. LEE DATE 2021–02–26
SCALE AS NOTED
NEGATIVE No.

FILE No.	PROJECT No.	REG.	DRAWING No.
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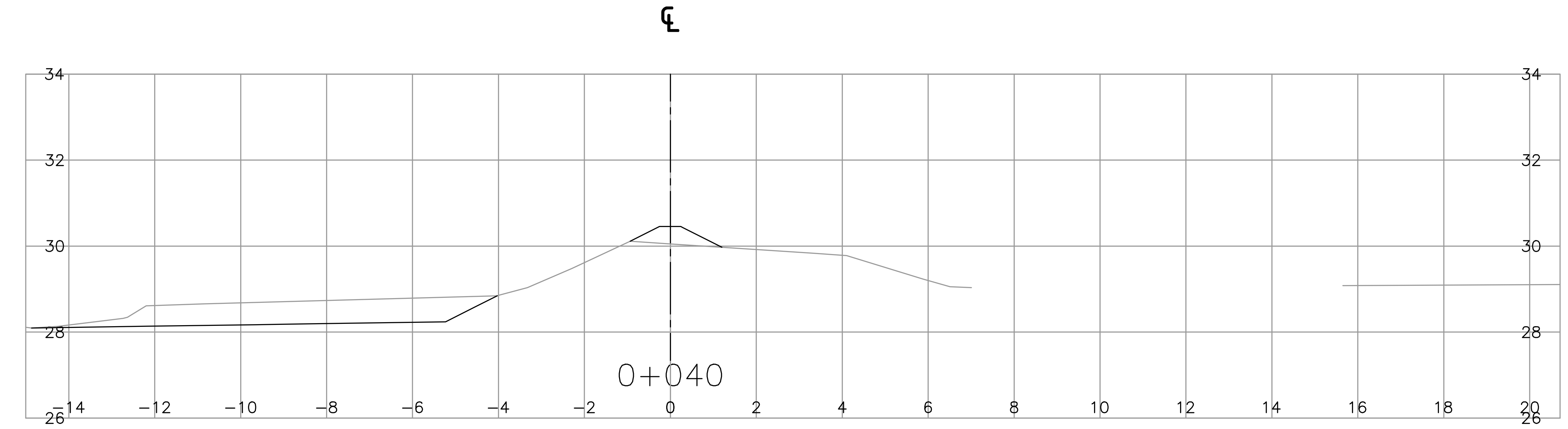

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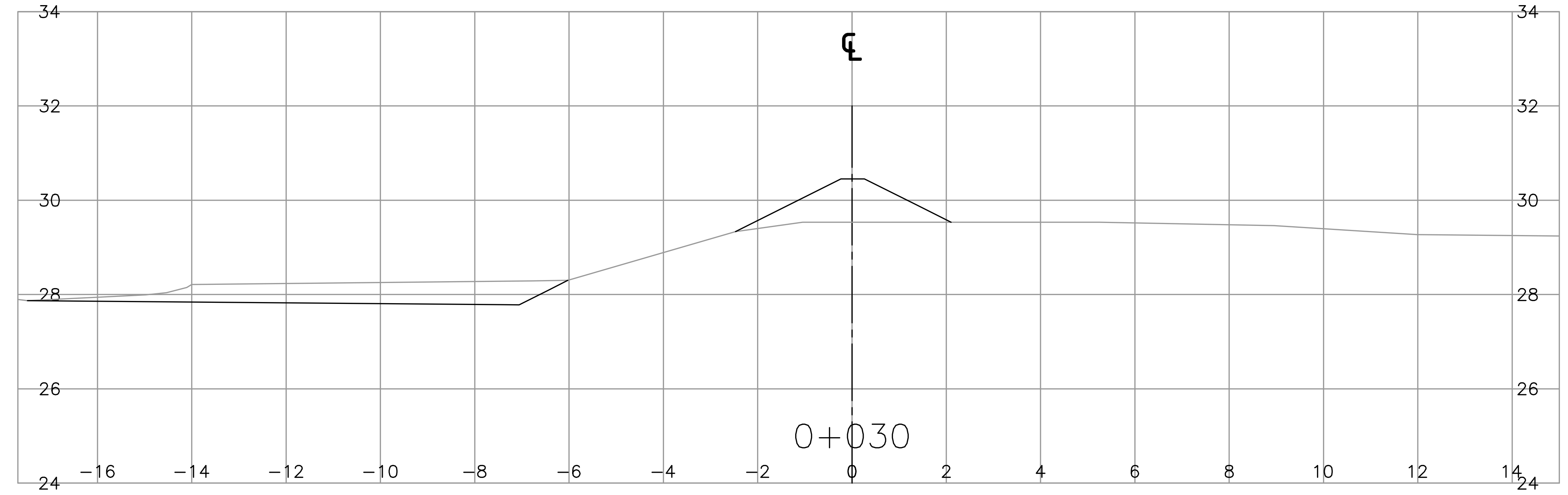

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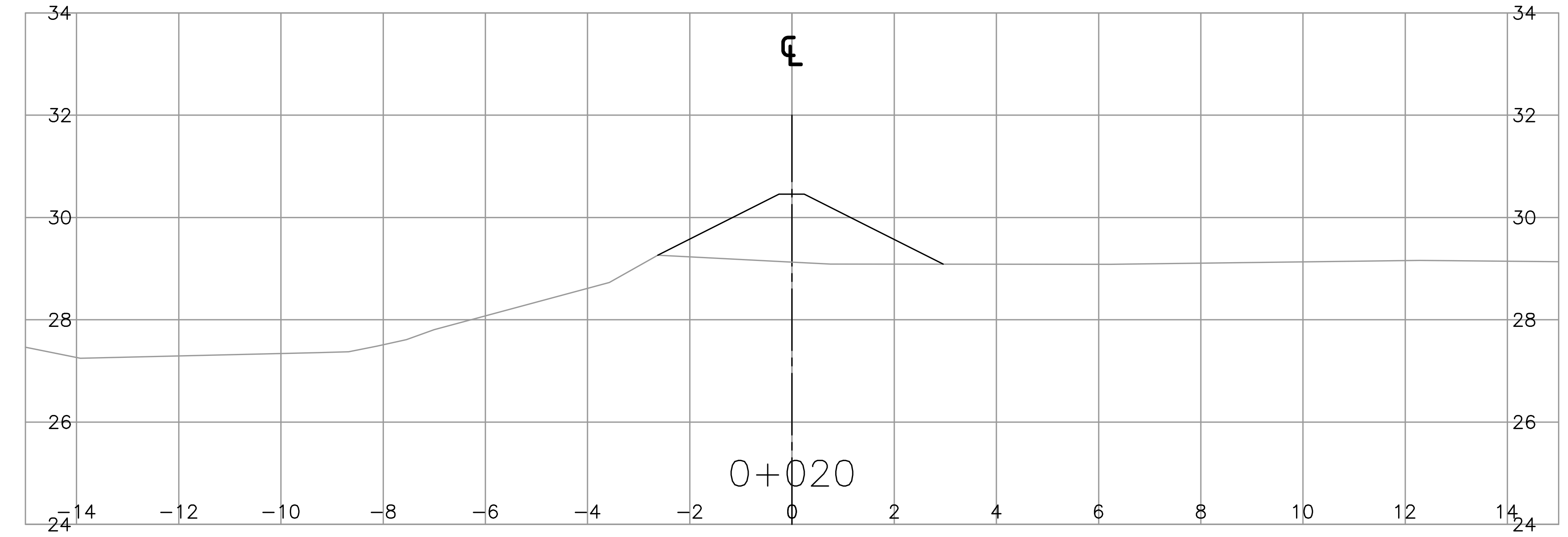

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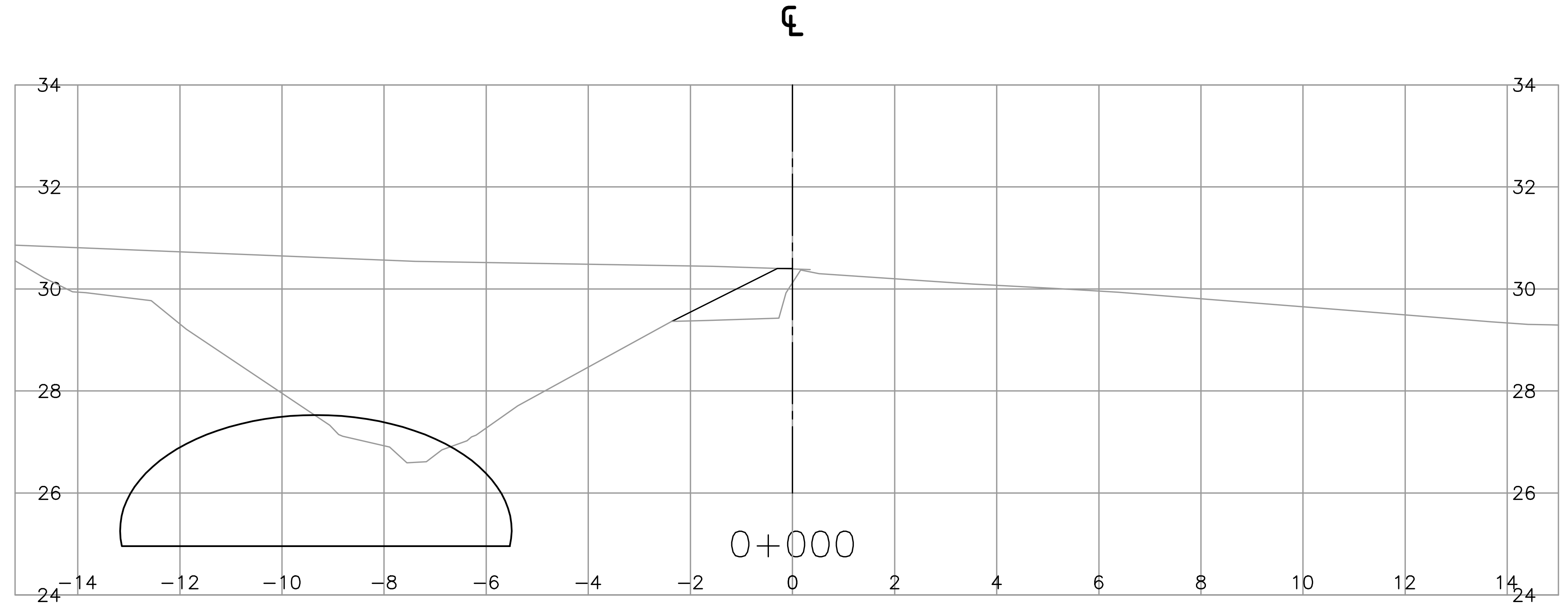

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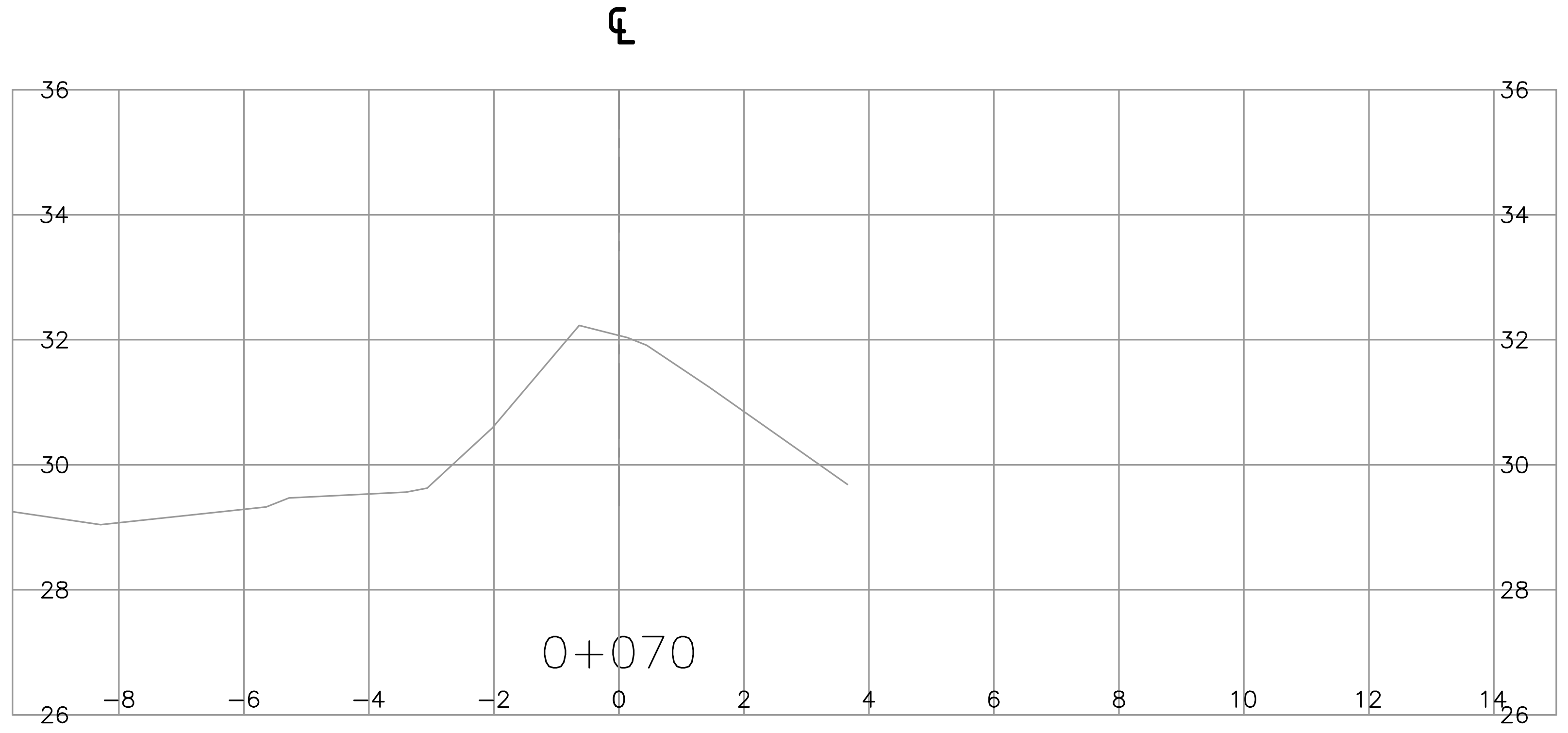

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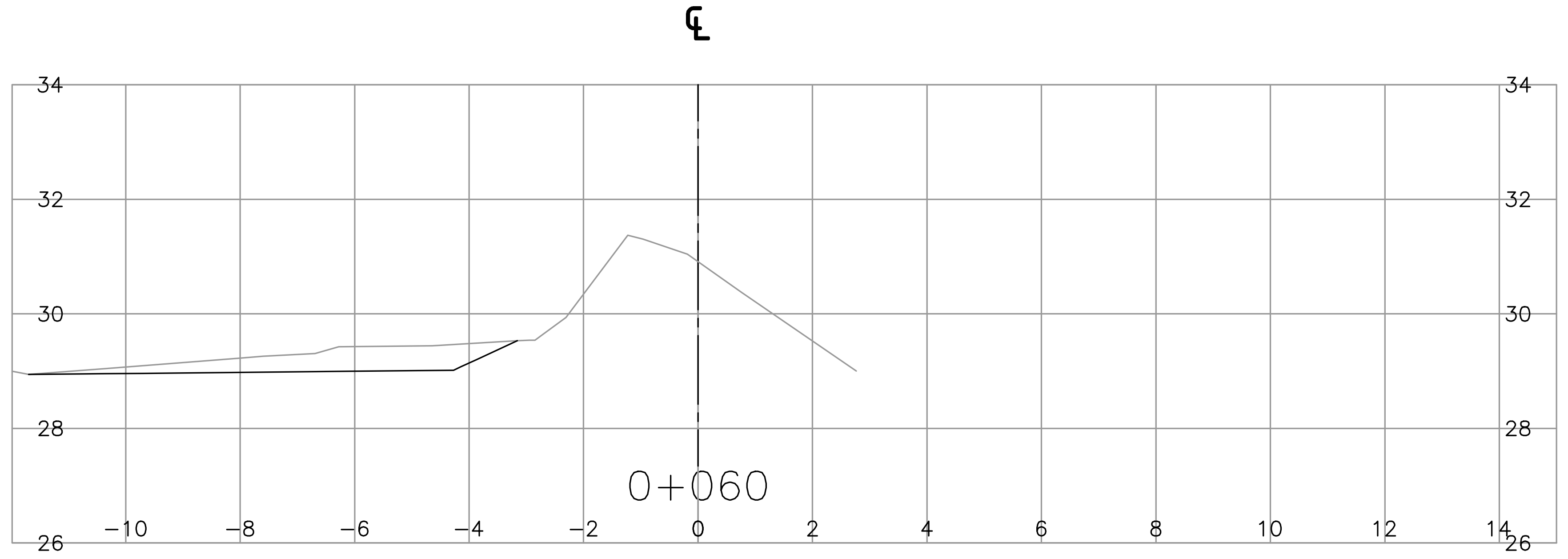

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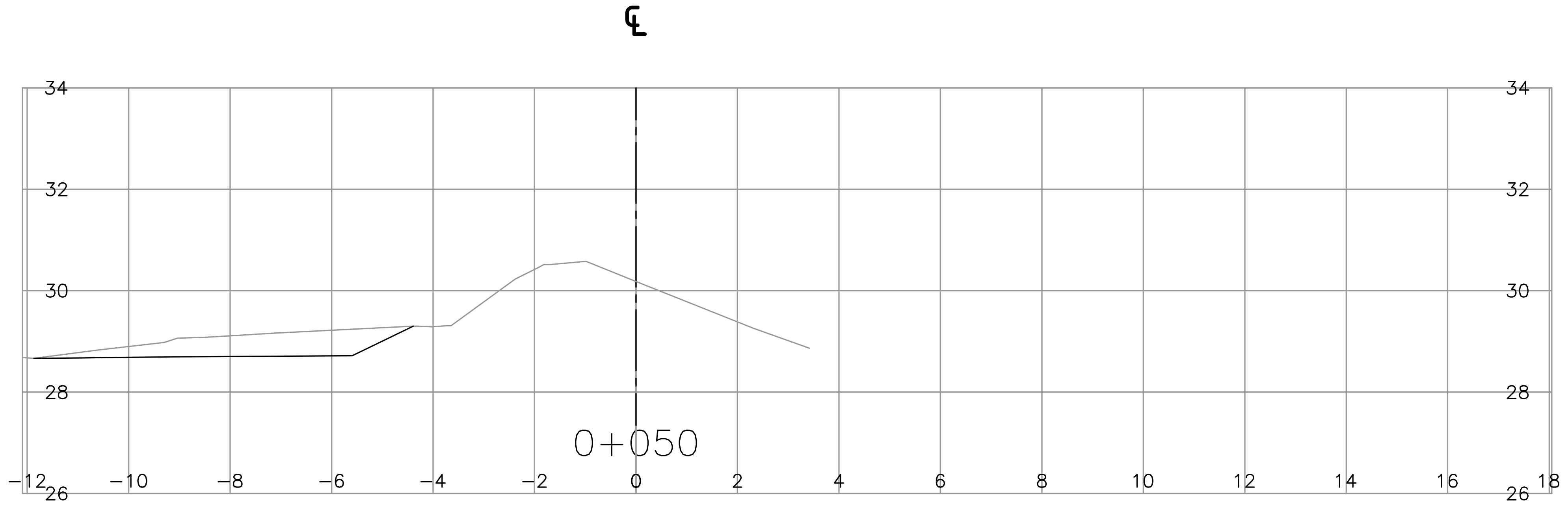

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SECTION
SCALE 1:100

PRELIMINARY/
FOR DISCUSSION
NOT FOR CONSTRUCTION

Consultant Logo

Associated Engineering

Rev	Date	Description	Init
A	2021-02-26	ISSUED FOR DISCUSSION	JL

REVISIONS

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure
South Coast Region

LOWER MAINLAND DISTRICT
ROCKWELL DRIVE

TROUT LAKE CREEK CULVERT REPLACEMENT AND CHANNEL IMPROVEMENTS
L200 SECTIONS

PREPARED UNDER THE DIRECTION OF
J. LEE, P.ENG
ENGINEER OF RECORD
DATE 2021-02-26

DESIGNED J. LEE DATE 2021-02-26
CHECKED J. THIESSEN DATE 2021-02-26
DRAWN H. LEE DATE 2021-02-26
SCALE AS NOTED
NEGATIVE No.

FILE No.	PROJECT No.	REG.	DRAWING No.	
	----	1	R1-XXX-761SK	A

CANCEL PRINTS BEARING PREVIOUS LETTER

APPENDIX B – LIFE-CYCLE-COST ESTIMATES

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Client: **Ministry of Transportation and Infrastructure**

Project: **Trout Lake Creek Culvert Replacement & Channel Improvments - Conceptual Design**

Subject: Life Cycle Cost Estimate for Culvert Concept

File: 2020-2904.00.E.04.00

Item No.	Item	Unit	Approx. Quantity	Unit Cost	Extended Amount
1.0	**CAPITAL COST ESTIMATES**				
1.1	**General**				
1.1.1	Mobilization and Demobilization (5%)	L.S.	1	$57,000	$57,000
1.1.2	Quality Management (2%)	L.S.	1	$23,000	$23,000
1.1.3	Traffic Management and Construction Staging	L.S.	1	$100,000	$100,000
1.1.4	Environmental Management & Monitoring	L.S.	1	$20,000	$20,000
1.1.5	Working Office	L.S.	1	$10,000	$10,000
1.2	**Excavation & Backfill**				
1.2.1	Excavation & Backfill	L.S.	1	$190,000	$190,000
1.3	**Culvert**				
1.3.1	Supply of 7670 mm x 2570 mm arch	L.S.	1	$300,000	$300,000
1.3.1	Installation of 7670 mm x 2570 mm arch	L.S.	1	$150,000	$150,000
1.3.2	Supply & Installation of Concrete Footings	m^3	155	$2,000	$310,000
1.3.2	Supply & Installation of Concrete Benching	m^3	82	$1,200	$98,400
1.3.3	1000 kg Riprap (Step-Pool Arrangement)	m^3	400	$150	$60,000
1.4	**Other Items**				
1.4.1	Clearing and Grubbing	L.S.	1	$5,000	$5,000
1.4.2	Revegetation Seeding	L.S.	1	$500	$500
1.4.3	Remove and Dispose of Existing Structure	L.S.	1	$10,000	$10,000
				Net Capital Cost:	**$1,333,900**
				Contingency (25%):	**$334,000**
				Total Capital Cost (A):	**$1,667,900**
2.0	**MAINTENANCE COST ESTIMATES**				
	General Maintenance (75 Year Design Service Life)	L.S.	1	$28,000	$28,000
				Net Maintenance Cost:	**$28,000**
				Contingency (25%):	**$7,000**
				Total Maintenance Cost (B):	**$35,000**
				TOTAL LIFE-CYCLE-COST (A+B):	**$1,702,900**

Client: **Ministry of Transportation and Infrastructure**

Project: **Trout Lake Creek Culvert Replacement & Channel Improvments - Conceptual Design**

Subject: Life Cycle Cost Estimate for Bridge Concept

File: 2020-2904.00.E.04.00

Item No.	Item	Unit	Approx. Quantity	Unit Cost	Extended Amount
1.1	**CAPITAL COST ESTIMATES**				
1.0	**General**				
1.1	Mobilization and Demobilization (5%)	L.S.	1	$51,000	$51,000
1.2	Quality Management (2%)	L.S.	1	$21,000	$21,000
1.3	Traffic Management and Construction Staging	L.S.	1	$100,000	$100,000
1.4	Environmental Management & Monitoring	L.S.	1	$20,000	$20,000
1.5	Working Office	L.S.	1	$10,000	$10,000
1.2	**Excavation & Backfill**				
1.2.1	Excavation & Backfill	L.S.	1	$190,000	$190,000
1.3	**Steel Pipe Piles**				
1.3.1	Mobilization and Fixed Costs for Pile Installation	L.S.	1	$30,000	$30,000
1.3.2	Supply & Installation of 610 mm dia. x 15.9 mm Steel Pipe Piles, assumed 18 m deep	m	144	$1,100	$158,000
1.3.3	Pile Reinforced Concrete (Top 5 m)	m3	11	$800	$9,000
1.4	**CIP Concrete**				
1.4.1	Superstructure Concrete (Parapets)	m^3	12	$2,500	$30,000
1.4.2	Substructure Concrete (Abutments and Wing Walls)	m^3	44	$1,800	$79,000
1.5	**Precast Box Girder**				
1.5.1	Supply and Fabrication of Precast Concrete Box Girders	Each	10	$27,000	$270,000
1.5.2	Shipping and Erection of Precast Concrete Box Girders	L.S.	1	$81,000	$81,000
1.6	**Other Items**				
1.6.1	Parapet Steel Bicycle Railings	m	46	$450	$21,000
1.6.2	Waterproofing Membrane on Bridge	m^2	204	$80	$17,000
1.6.3	Asphalt Pavement on Bridge	tonne	47	$200	$10,000
1.6.4	Asphalt Pavement on Approaches	tonne	49	$200	$10,000
1.6.5	Precast Concrete Barriers on Approaches	L.S.	1	$26,600	$26,600
1.6.6	Precast Concrete Catch Basins	Each	2	$2,500	$5,000
1.6.7	Clearing and Grubbing	L.S.	1	$5,000	$5,000
1.6.8	Revegetation Seeding	L.S.	1	$500	$500
1.6.9	Remove and Dispose of Existing Structure	L.S.	1	$10,000	$10,000
1.6.10	Riprap Protection (1000 kg Class)	m^3	400	$150.00	$60,000
				Net Capital Cost:	**$1,214,100**
				Contingency (25%):	**$304,000**
				Total Capital Cost (A):	**$1,518,100**
2.0	**MAINTENANCE COST ESTIMATES**				
2.1	General Maintenance (75 Year Design Service Life)	L.S.	1	$28,000	$28,000
2.1.2	Deck Resurfacing (at Year 20)	L.S.	1	$6,300	$6,300
2.1.2	Membrane Replacement and Resurfacing (at Year 40)	L.S.	1	$3,900	$3,900
				Net Maintenance Cost:	**$38,200**
				Contingency (25%):	**$10,000**
				Total Maintenance Cost (B):	**$48,200**
				TOTAL LIFE-CYCLE-COST (A+B):	**$1,566,300**

Client: **Ministry of Transportation and Infrastructure**

Project: **Trout Lake Creek Culvert Replacement & Channel Improvments - Conceptual Design**

Subject: Life Cycle Cost Estimate for Sediment Basin and Berm Extension

File: 2020-2904.00.E.04.00

Item No.	Item	Unit	Approx. Quantity	Unit Cost	Extended Amount
1.0	**CAPITAL COST ESTIMATES**				
1.1	**General**				
1.1.1	Mobilization and Demobilization (5%)	L.S.	1	$5,000	$5,000
1.1.2	Quality Management (2%)	L.S.	1	$2,000	$2,000
1.2	**Sediment Basin**				
1.2.1	Excavation to Off-site Disposal	m^3	120	$60	$7,200
1.3	**Berm Extension**				
1.3.1	Borrow	m^3	110	$60	$6,600
1.4	**Other Items**				
1.4.1	Clearing and Grubbing	L.S.	1	$75,000	$75,000
1.4.2	Revegetation Seeding	L.S.	1	$1,000	$1,000
				Net Capital Cost:	**$96,800**
				Contingency (25%):	**$25,000**
				Total Capital Cost (A):	**$121,800**
2.0	**MAINTENANCE COST ESTIMATES**				
2.1	General Maintenance (75 Year Design Service Life)	L.S.	1	$16,000	$16,000
				Net Maintenance Cost:	**$16,000**
				Contingency (25%):	**$4,000**
				Total Maintenance Cost (B):	**$20,000**
				TOTAL LIFE-CYCLE-COST (A+B):	**$141,800**

APPENDIX F – 2022 HYDROGEOMORPHIC ASSESSMENT.

To be included in the Final Memorandum

APPENDIX G – HIGHWAY DESIGN CRITERIA.

Project Design Criteria

Highway Engineering
Ministry of Transportation and Infrastructure

Project: *Trout Lake Creek Culvert Replacement*
Type of work: *Options Analysis and Conceptual Design*
Location: *Hicks Lake Road crossing Trout Lake Creek, District of Kent, BC*
Length: Approximately *0.2 km*

• all Projects involving highway geometrics	**ACCEPTED BY:** Senior Highway Design Engineer	Date
• minor exceptions to standards • ambient standards or context sensitive guidleines	**ACCEPTED BY:** Senior Engineering Manager, Highway Design Services	Date
• Major Projects • Partnership Projects • highway corridor standards	**ACCEPTED BY:** Director, Highway Design and Survey Engineering	Date
• major exceptions to standards	**ACCEPTED BY:** Chief Engineer	Date

Notes:

1) All projects require acceptance at the Senior Highway Design Engineer level. Where minor exceptions to standards are proposed for a project, or where Ambient Standards or Context Sensitive Guidelines are proposed, the Senior Engineering Manager, Highway Design Services must accept. For Major Projects or Partnership Projects, and for corridor-wide standards, the Director, Highway Design and Survey Engineering must accept. Where there are major exceptions to prevailing standards, the Chief Engineer's acceptance will be required.
2) The following page(s) set out more detailed design criteria for this project.

Project Design Criteria

Highway Engineering
Ministry of Transportation and Infrastructure

Project:	*Trout Lake Creek Culvert Replacement*
Type of work:	*Options Analysis and Conceptual Design*
Location:	*Hicks Lake Road crossing Trout Lake Creek, District of Kent, BC*
Length:	Approximately *0.2 km*

Hicks Lake Road (L100)

Design Element	Present Conditions	Adjacent Project Conditions	MoTI/TAC Guidelines Criteria	Proposed Project Criteria	Achieved Project Criteria	Comments/Notes (c)
Functional Classification	Minor Road	Minor Road	Minor Road	Minor Road	Minor Road	
Design Classification	LVR	LVR	LVR	LVR	LVR	See Note 1
Posted Speed	40 km/h	40 km/h	40 km/h	40 km/h	40 km/h	See Note 2
Design Speed	-	-	40 km/h	40 km/h	40 km/h	
Basic # of Lanes	2	2	2	2	2	
Minimum Horizontal Radius	75 m	11.5 m	55 m	75 m	90 m	
Min. “K” factor…… Sag V.C.	2.3	2.5	9	3.8 / 9	9	See Note 3
Min. “K” factor…… Crest V.C.	7.2	2.6	7	7.2	N/A	See Note 4
Max. Grade	13.4 %	16.3 %	14 %	13.4 %	13.4 %	See Note 5
Max. Superelevation	6.8 %	7.1 %	6 %	6 %	5.2 %	
Minimum S.S.D.	95 m	25 m	50 m	50 m	50 m	See Note 6
Lane Width	3.2 - 3.6 m	3.2 – 4.0 m	3.25 m	3.25 m	3.25 m	
Shoulder Width Outside	0.5 – 2.1 m	0.3 – 1.6m	0.5 m	0.5 m	0.5 m	
Clear Zone - Offset Width Recovery Slope (X:1)	N/A	N/A	N/A			See Note 7
Current Traffic Volume: AADT	< 200 AADT	< 200 AADT				See Note 8
Design AADT / Design Hourly Vol.			< 200 AADT			See Note 8
Level of Service (to year 20xx)						
Design Vehicle			I-BUS / LG5	I-BUS / LG5	I-BUS / LG5	

Project Design Criteria

Highway Engineering
Ministry of Transportation and Infrastructure

Project:	*Trout Lake Creek Culvert Replacement*
Type of work:	*Options Analysis and Conceptual Design*
Location:	*Hicks Lake Road crossing Trout Lake Creek, District of Kent, BC*
Length:	Approximately *0.2 km*

Scope of Work:
The temporary rail car bridge on Hicks Lake Road was washed out in November 2021 during a major rainfall event. This project involves options analysis for replacing the Hicks Lake Road crossing with permanent alternatives for crossing Trout Lake Creek.

The four conceptual designs being developed are:
- Option 1. Do Nothing – Leave existing culverts in place.
- Option 2. Construct a new CSP Arch Culvert.
- Option 3. Construct a clear span bridge.
- Option 4. Construct a longer clear span bridge to convey the debris flood.

Explanatory Notes / Discussion:

1. Confirmation has been provided by MoTI that this section of road has a Class 5C rating and based on operational observations is a Low Volume Road (LVR).

2. The existing posted speed limit on Hicks Lake Road through the project area is 40 km/h.

3. Sag curve minimum k factors are based on BC Supplement table 510.I for Vertical Curves on LVR's and are based on headlight control to achieve Stopping Sight Distance. The existing sag curve located at the creek crossing is substandard. The sag curve k factor proposed for Option 1 is 3.8 to limit grading, while the proposed sag curve k factor to meet the guideline criteria is 9 for Options 2/3/4.

4. Crest curve minimum k factors are based on BC Supplement table 510.I for Vertical Curves on LVR's and are based on fixed object visibility to achieve Stopping Sight Distance.

5. Maximum grade is based on BC Supplement table 510.J Maximum Grades for LVR's with mountainous topography.

6. Adequate sightlines are provided for vehicles turning left from the existing pull-out. It is worth noting that due to the grade of the road, vehicles approaching from the north would have improved visibility of the left turning vehicles. Left turning vehicles from the pull-out would also have improved visibility of the approaching southbound vehicles.

7. Clear zone is not required on LVR's with regards to slope treatment according to 510.08 of the BC Supplement to TAC.

8. Based on information provided by MoTI, the existing traffic volume is less than 200 AADT due to the location and amenities in the area.

RECOMMENDED BY: Engineer of Record: Matthew du Toit, P. Eng Date: 2022-08-05
(Print Name / Provide Seal & Signature)

Engineering Firm: Associated Engineering (B.C.) Ltd

APPENDIX H – STRUCTURAL DESIGN CRITERIA.

MEMO

Date: June 17, 2022 **File:** 2020-2904.215

To: British Columbia Ministry of Transportation and Infrastructure **Page:** Page 1 of 2

From: Mike Lumb, P.Eng.

Project: 2020-2904

Subject: Trout Lake Creek Culvert Replacement - Bridge Structural Design Criteria

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Design Codes and Standards:	• CAN/CSA-S6-14 Canadian Highway Bridge Design Code (CHBDC) • BC Ministry of Transportation and Infrastructure Bridge Standards and Procedures Manual October 2016 Edition Supplement to CHBDC S6-14 (BSM)
Design Life:	• 75 years • 100 years for time-dependent calculations
Class of Highway:	• Class "C" (TBC)
Seismic Design Classification:	• Structure: “Other Bridges”
Bridge Deck Width:	• Approximately 12 m overall consisting of two 3.6 m lanes on a curve, two 1.5 m minimum shoulders, and two bridge parapets
Clearances:	• Minimum soffit elevation, creek channel width: TBC by hydrotechnical investigation.
Utilities:	• None
Longitudinal Grade:	• TBC by highway design
Drainage:	• Deck runoff will be discharged into catch basins (TBC) • Bridge end-slopes will be protected by rip-rap scour erosion blankets (TBC by hydrotechnical investigation)
Barriers:	• TL-4 compliant Standard Concrete Bridge Parapet 810 mm high (Drawing 2784-1) with Steel Bicycle Railing
Live Load:	• BCL-625 • Design speed: 40 kmph (TBC)
Dead Load:	• Self-weight of all bridge components • An allowance for an additional 50 mm concrete overlay over full area of bridge deck to account for future deck rehabilitation • Unit material weights as specified by BSM and CHBDC

Environmental Loads: (Agassiz, BC)	• Reference Wind Pressure: 0.755 kPa (50 year return period) • Maximum Mean Daily Temperature: 30°C • Minimum Mean Daily Temperature: -25°C • Annual average relative humidity: 75% • Ice Accretion: 31 mm • Rainfall: 8 mm in 15 minutes
Site Seismicity:	• Peak Ground Acceleration – 2475-year return period: 0.254g (2020 NBCC) • Seismic Performance Category (by CHBDC): 3 • Site Class: C • Liquefaction: not anticipated • Based on "Geotechnical Drilling Investigation – Trout Lake Creek Culvert Replacement, Harrison Hot Springs, BC" prepared by BC MoTI dated October 31, 2017
Structural Steelwork:	• CSA G40.21 Grade 350 AT Category 3
Miscellaneous Steelwork:	• CSA G40.21 Grade 300W • Galvanizing: SS422.36, ASTM A153M, and ASTM B695
Reinforcing Steel:	• CSA G30.18 Grade 400W • Top mat of deck and parapet reinforcing to be stainless steel. All other reinforcing steel to be plain black (uncoated) • Stirrups protruding into deck from precast concrete girders to be stainless steel
Concrete Cover and Tolerances:	• Concrete deck top cover to reinforcing steel to be 60 mm, tolerance from +6 mm to -0 mm • All other concrete covers and tolerances to BSM and CHBDC
Pre-stressing Steel:	• ASTM A416 Grade 1,860 MPa low-relaxation • Pre-tensioning strand to be 15.2 mm or 12.7 mm nominal diameter, low relaxation, seven-wire strand
Cast in Place Concrete:	• Deck Slabs and Parapets: 35 MPa • Substructure: 30 MPa • Other Concrete: 30 MPa
Precast Concrete:	• Precast Concrete Superstructure: 35 MPa at release, 45 MPa at 28 days (TBC)
Bearing Piles:	• Steel Pipe Piling: ASTM A252 Grade 3

TBC: To be confirmed

Associated Engineering 75 YEARS

MEMO

Date: August 19, 2022
File: 2020-2904.215
To: British Columbia Ministry of Transportation and Infrastructure
Page: Page 1 of 2
From: Mike Lumb, P.Eng.
Project: 2020-2904
Subject: Trout Lake Creek Culvert Replacement - Bridge Structural Design Criteria

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Design Codes and Standards:	• CAN/CSA-S6-14 Canadian Highway Bridge Design Code (CHBDC) • BC Ministry of Transportation and Infrastructure Bridge Standards and Procedures Manual October 2016 Edition Supplement to CHBDC S6-14 (BSM)
Design Life:	• 75 years • 100 years for time-dependent calculations
Class of Highway:	• Class "C"
Seismic Design Classification:	• Structure: “Other Bridges”
Bridge Deck Width:	• Approximately 10 m overall consisting of two 3.25 m lanes on a curve, two 0.5 m minimum shoulders, and two bridge parapets
Clearances:	• Minimum soffit elevation: 28.2 m • Channel width at bridge: 18m
Utilities:	• None
Longitudinal Grade:	• Approximately 4%
Drainage:	• Deck runoff will be discharged into catch basins (TBC) • Bridge end-slopes will be protected by rip-rap scour erosion blankets
Barriers:	• TL-4 compliant Standard Concrete Bridge Parapet 810 mm high (Drawing 2784-1) with Steel Bicycle Railing
Live Load:	• BCL-625 • Design speed: 40 kmph
Dead Load:	• Self-weight of all bridge components • An allowance for an additional 50 mm concrete overlay over full area of bridge deck to account for future deck rehabilitation • Unit material weights as specified by BSM and CHBDC

Environmental Loads: (Agassiz, BC)	• Reference Wind Pressure: 0.755 kPa (50 year return period) • Maximum Mean Daily Temperature: 30°C • Minimum Mean Daily Temperature: -25°C • Annual average relative humidity: 75% • Ice Accretion: 31 mm • Rainfall: 8 mm in 15 minutes
Site Seismicity:	• Peak Ground Acceleration – 2475-year return period: 0.254g (2020 NBCC) • Seismic Performance Category (by CHBDC): 3 • Site Class: C • Liquefaction: not anticipated • Based on “Geotechnical Drilling Investigation – Trout Lake Creek Culvert Replacement, Harrison Hot Springs, BC” prepared by BC MoTI dated October 31, 2017
Structural Steelwork:	• CSA G40.21 Grade 350 AT Category 3
Miscellaneous Steelwork:	• CSA G40.21 Grade 300W • Galvanizing: SS422.36, ASTM A153M, and ASTM B695
Reinforcing Steel:	• CSA G30.18 Grade 400W • Top mat of deck and parapet reinforcing to be stainless steel. All other reinforcing steel to be plain black (uncoated) • Stirrups protruding into deck from precast concrete girders to be stainless steel
Concrete Cover and Tolerances:	• Concrete deck top cover to reinforcing steel to be 60 mm, tolerance from +6 mm to -0 mm • All other concrete covers and tolerances to BSM and CHBDC
Pre-stressing Steel:	• ASTM A416 Grade 1,860 MPa low-relaxation • Pre-tensioning strand to be 15.2 mm or 12.7 mm nominal diameter, low relaxation, seven-wire strand
Cast in Place Concrete:	• Deck Slabs and Parapets: 35 MPa • Substructure: 30 MPa • Other Concrete: 30 MPa
Precast Concrete:	• Precast Concrete Superstructure: 35 MPa at release, 45 MPa at 28 days (TBC)
Bearing Piles:	• Steel Pipe Piling: ASTM A252 Grade 3

TBC: To be confirmed

APPENDIX I – 2022 TROUT LAKE CREEK CULVERT REPLACEMENT ROAD CONCEPTUAL DESIGN.

DATE: AUGUST 16, 2022

TROUT LAKE CREEK CULVERT REPLACEMENT
PLAN
OPTION 1

FIGURE 2-5

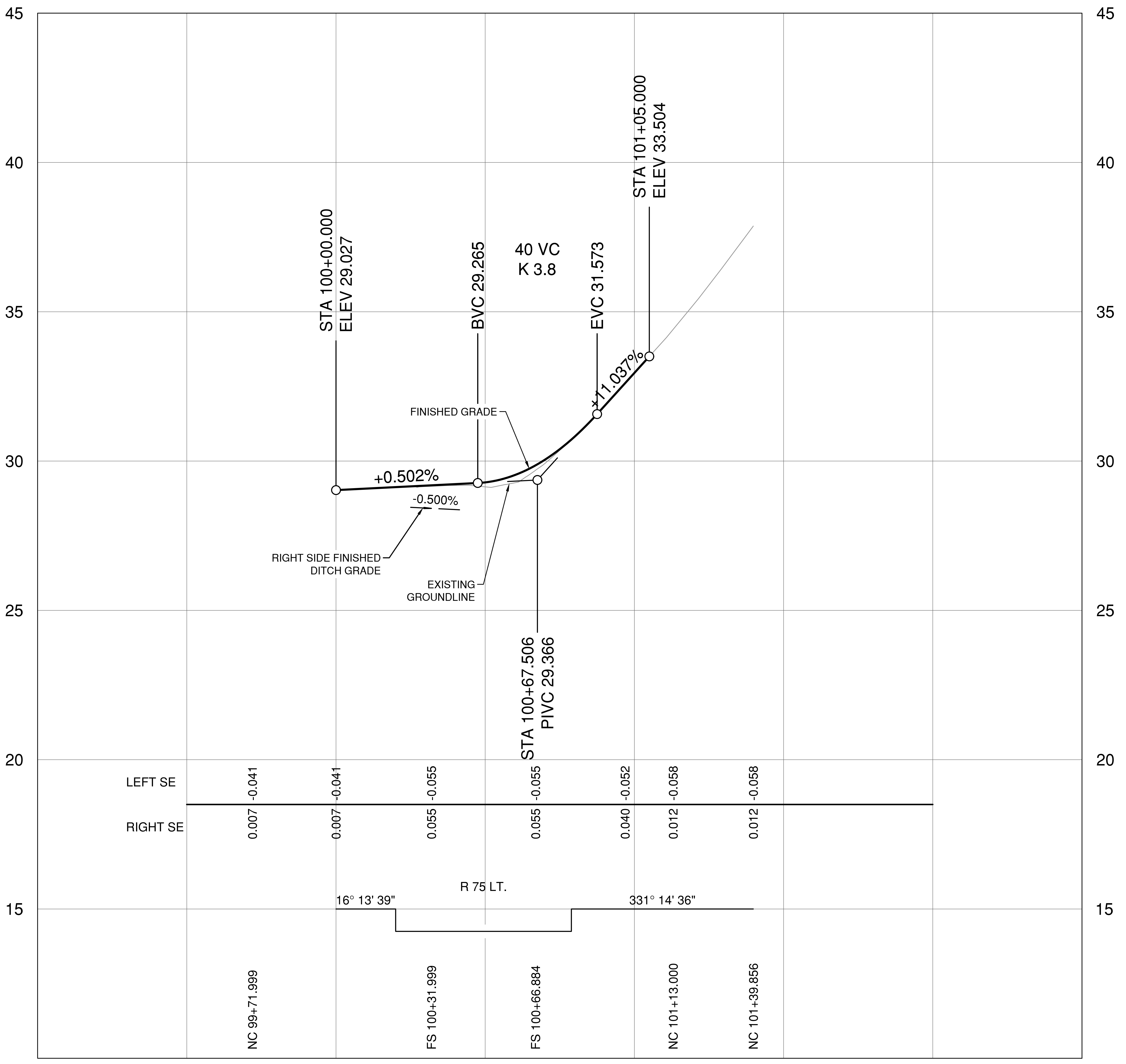
PLOT DATE: 2022/08/19 Q:\2020-2904-00\civ\model\MoTI_Working_Drawings_Rockwell\DrawingProduction\2300_SketchDrawings\2904-00-c-7101_Plan_Option1.dwg

DATE: AUGUST 5, 2022

TROUT LAKE CREEK CULVERT REPLACEMENT
PLAN
OPTION 1

FIGURE 2-6

PLOT DATE: 2022/08/19 Q:\2020-2904-00\civil\model\MoTI_Working_Drawings_Rockwell\DrawingProduction\2300_SketchDrawings\2904-00-c-7101_Plan_Option1.dwg



SCALE 0 10 H 1:1000 50m
0 1 V 1:100 5m

DATE: AUGUST 16, 2022

TROUT LAKE CREEK CULVERT REPLACEMENT
PROFILE
OPTION 1

FIGURE 2-7

PLOT DATE: 2022/08/19 Q:\2020-2904-00\civil\model\MoTI_Working_Drawings_Rockwell\DrawingProduction\2300_SketchDrawings\2904-00-c-7105_Profile_Option1.dwg

SCALE 0 2 1:250 12m

DATE:AUGUST 16, 2022

TROUT LAKE CREEK CULVERT REPLACEMENT
PLAN
OPTION 2

FIGURE 2-8

PLOT DATE: 2022/08/19 Q:\2020-2904-00\civil\model\MoTI_Working_Drawings_Rockwell\DrawingProduction\2300_SketchDrawings\2904-00-c-7111_Plan_Option2.dwg

SCALE 0 2 1:250 12m

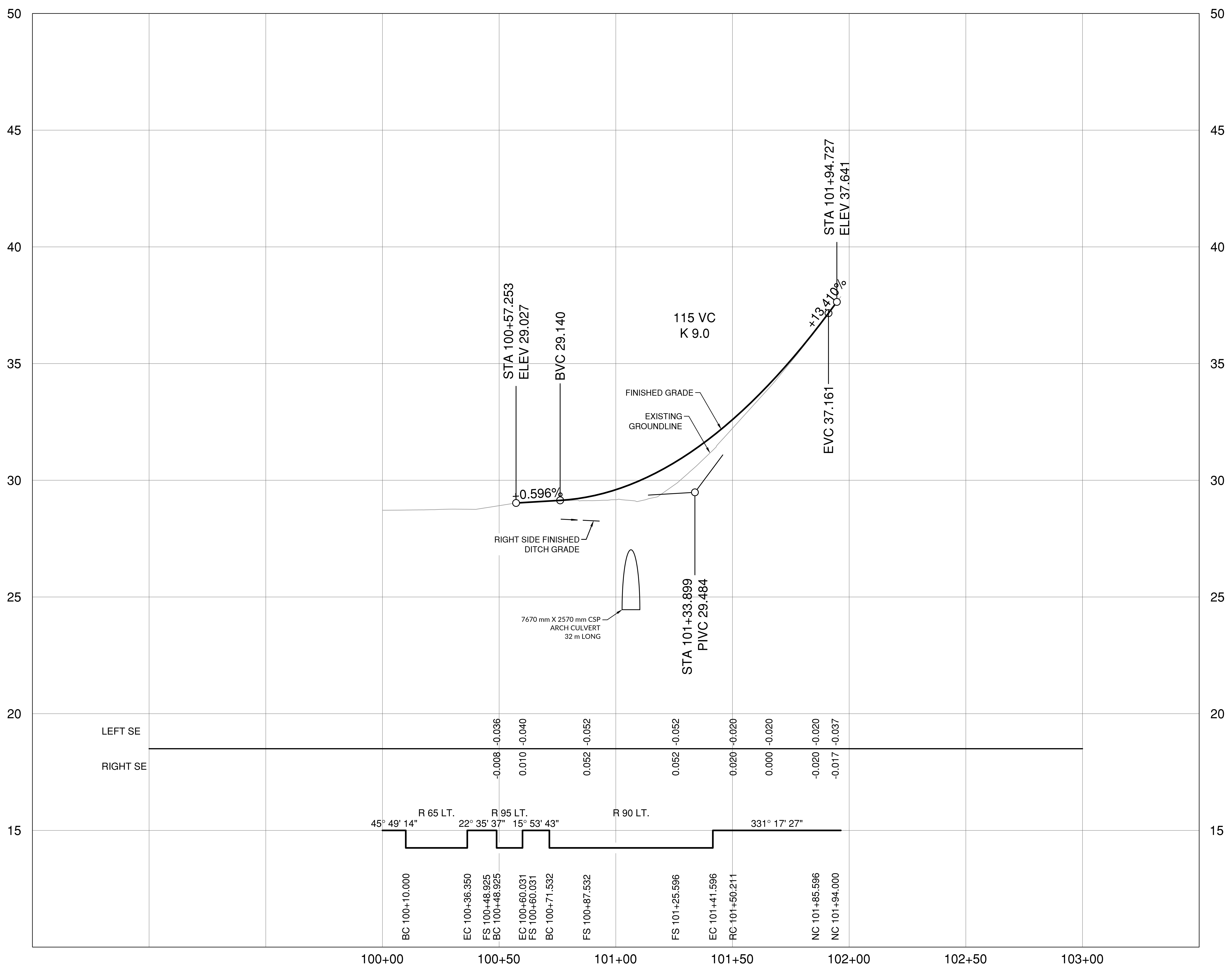
DATE:AUGUST 16, 2022

TROUT LAKE CREEK CULVERT REPLACEMENT
PLAN
OPTION 2

PLOT DATE: 2022/08/19 Q:\2020-2904-00\civl\model\MoTI_Working_Drawings_Rockwell\DrawingProduction\2300_SketchDrawings\2904-00-c-7111_Plan_Option2.dwg

FIGURE 2-9

PLOT DATE: 2022/08/19 Q:\2020-2904-00\civ\model\MoTI_Working_Drawings_Rockwell\DrawingProduction\2300_SketchDrawings\2904-00-c-7112_Profile_Option2.dwg



SCALE 0 10 H 1:1000 50m
0 1 V 1:100 5m

DATE: AUGUST 16, 2022

TROUT LAKE CREEK CULVERT REPLACEMENT
PROFILE
OPTIONS 2

FIGURE 2-10

SCALE 0 2 1:250 12m

DATE: AUGUST 16, 2022

TROUT LAKE CREEK CULVERT REPLACEMENT
PLAN
OPTIONS 3 & 4

FIGURE 2-11

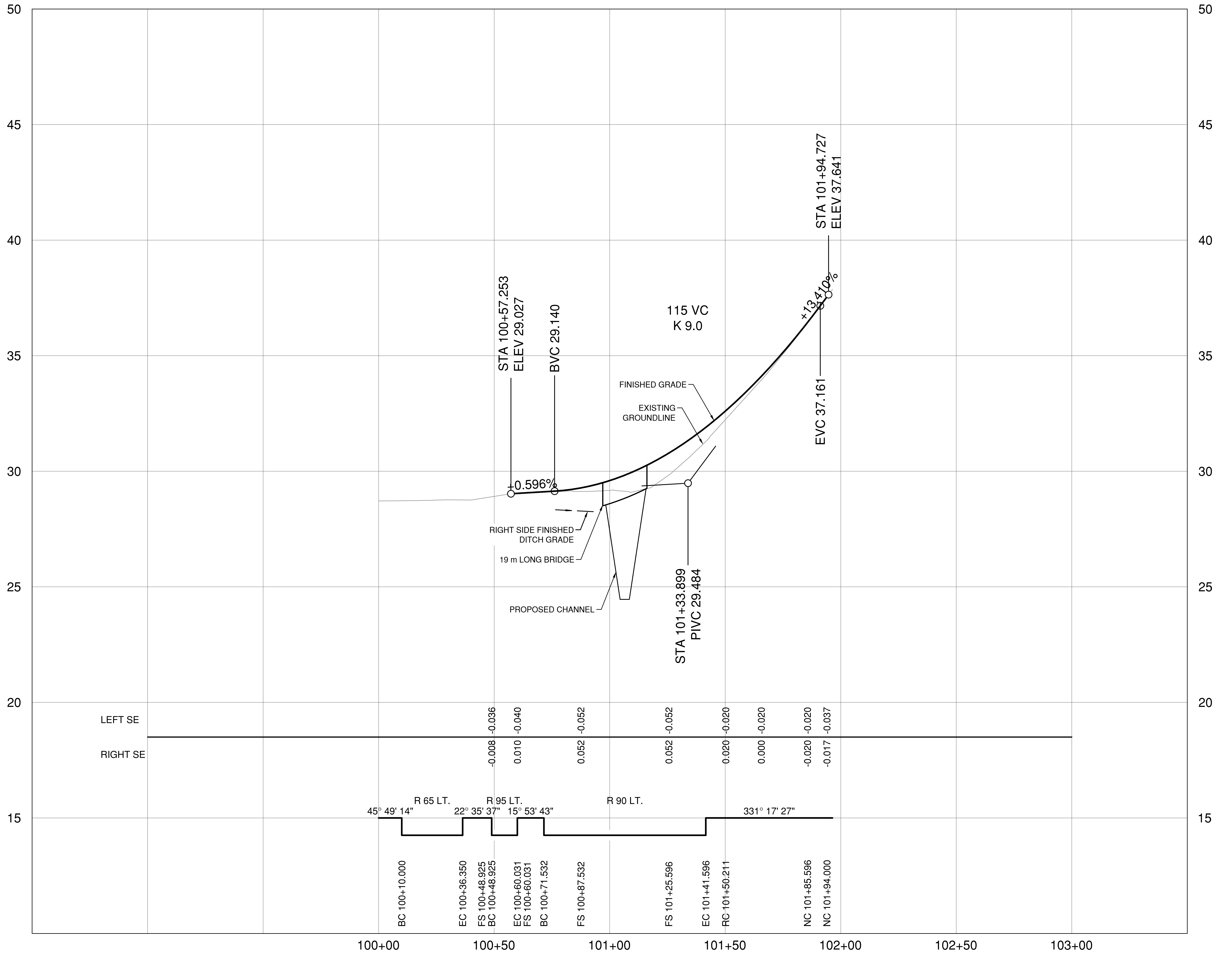
PLOT DATE: 2022/08/19 Q:\2020-2904-00\civil\model\MoTI_Working_Drawings_Rockwell\DrawingProduction\2300_SketchDrawings\2904-00-c-7114_Plan_Option3.dwg

DATE: AUGUST 16, 2022

TROUT LAKE CREEK CULVERT REPLACEMENT
PLAN
OPTIONS 3 & 4

FIGURE 2-12

PLOT DATE: 2022/08/19 Q:\2020-2904-00\civ\model\MoTI_Working_Drawings_Rockwell\DrawingProduction\2300_SketchDrawings\2904-00-c-7114_Plan_Option3.dwg



SCALE 0 10 H 1:1000 50m
0 1 V 1:100 5m

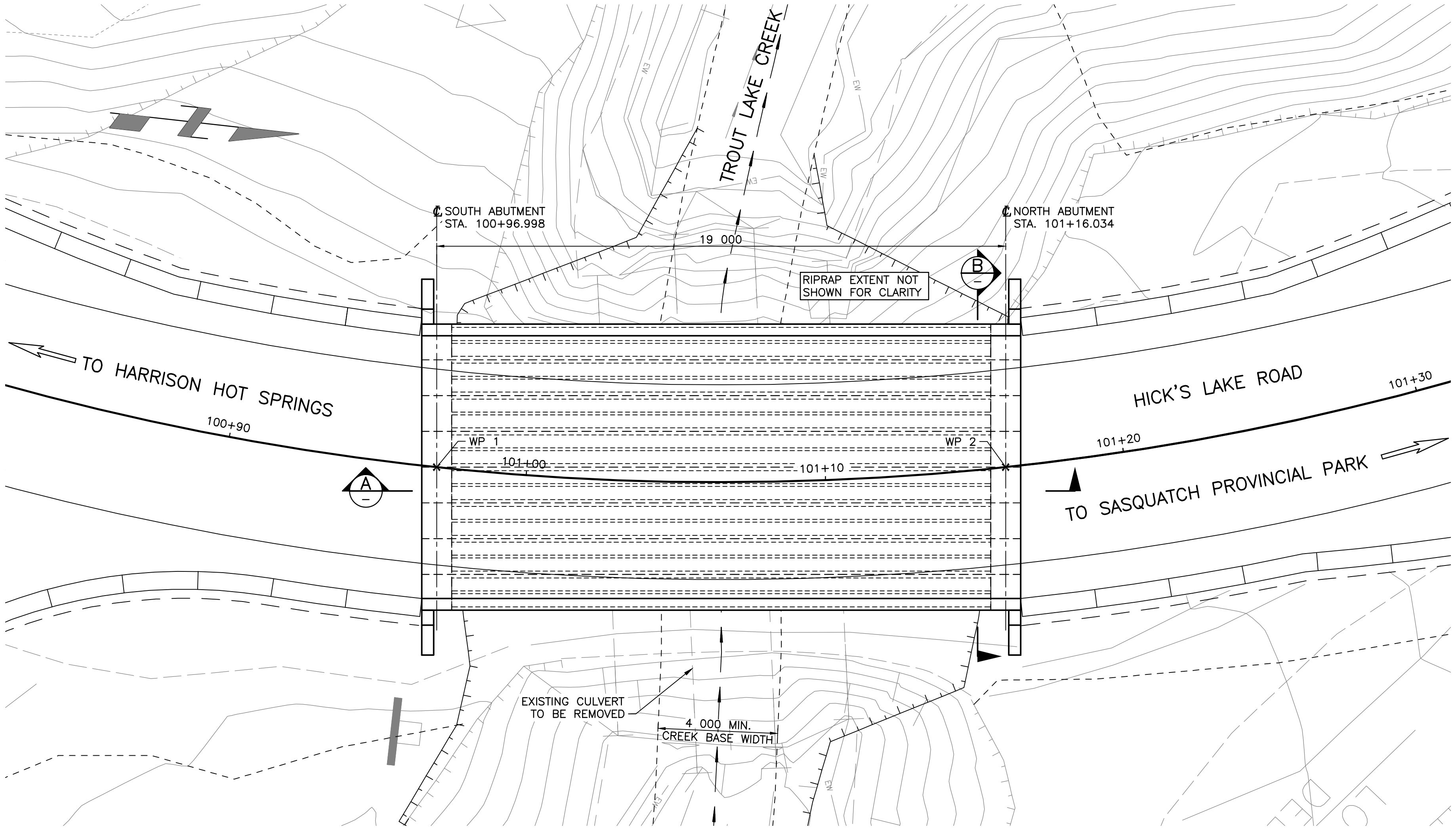
DATE: AUGUST 16, 2022

TROUT LAKE CREEK CULVERT REPLACEMENT
PROFILE
OPTIONS 3 & 4

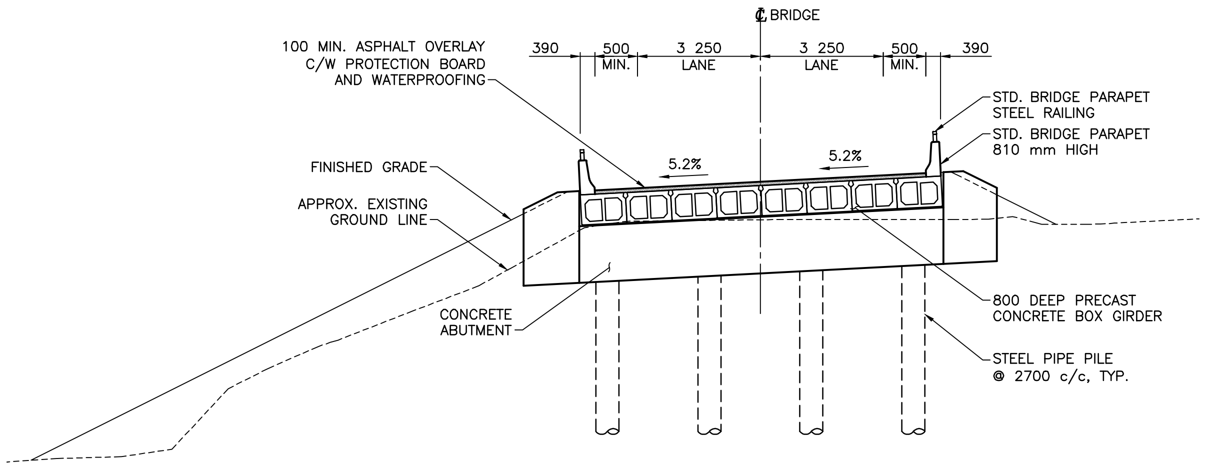
FIGURE 2-13

PLOT DATE: 2022/08/19 Q:\2020-2904-00\civ\model\MoTI_Working_Drawings_Rockwell\DrawingProduction\2300_SketchDrawings\2904-00-c-7116_Profile_Option34.dwg

APPENDIX J – 2022 TROUT LAKE CREEK CULVERT REPLACEMENT BRIDGE CONCEPTUAL DESIGN.



PLAN
SCALE 1:100

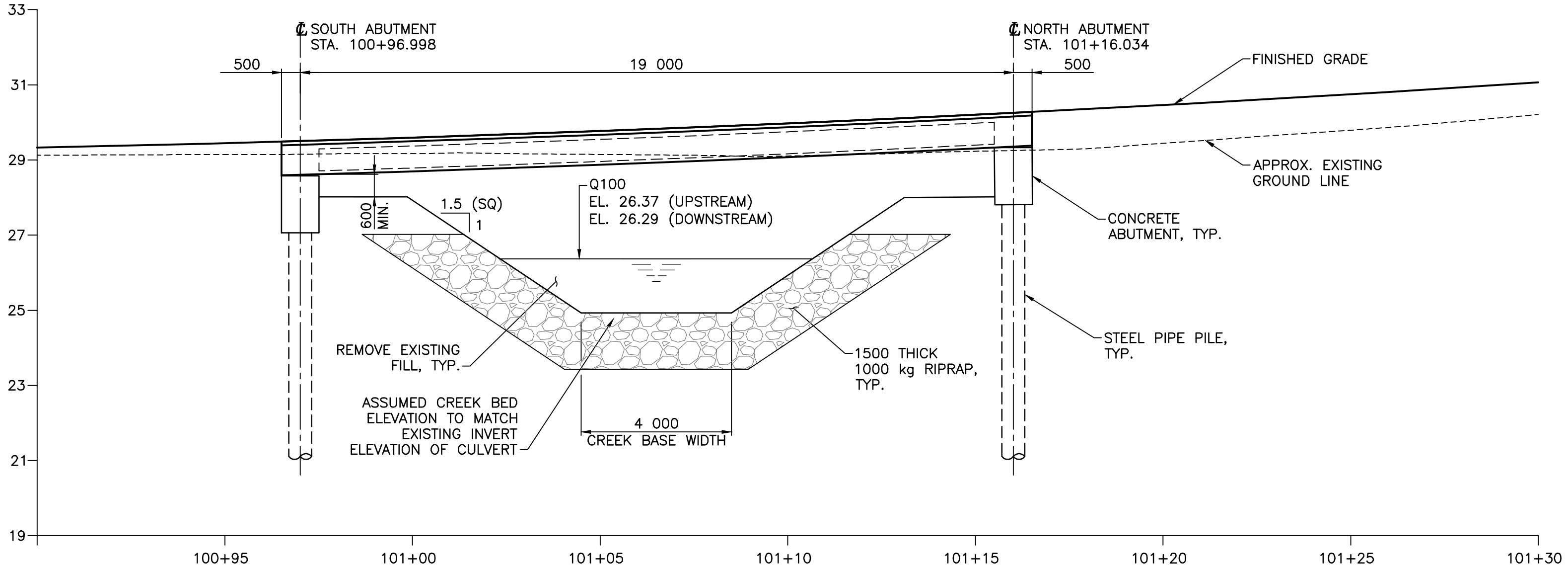


SECTION B
SCALE 1:100

WORKPOINT	NORTHING	EASTING	STATION	OFFSET
WP 1	466303.068	591264.793	100+96.998	0.000
WP 2	466321.951	591262.683	101+16.034	0.000

NOTES:

1. DESIGN SPECIFICATION:
   - a. CSA S6–14 CANADIAN HIGHWAY BRIDGE DESIGN CODE (CHBDC)
   - b. BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE BRIDGE STANDARDS AND PROCEDURES MANUAL (BSM) VOL. 1 SUPPLEMENT TO CHBDC S6–14 (OCTOBER 2016)
2. LIVE LOAD:
   - a. LIVE LOAD: BCL–625 (IN ACCORDANCE WITH BSM)
3. CLIMATIC DATA:
   - a. MAXIMUM DAILY MEAN TEMPERATURE 30°C
   - b. MINIMUM DAILY MEAN TEMPERATURE –25°C
   - c. RAINFALL 8 mm / 15 MINUTES
   - d. WIND LOAD: 1/50 YEAR REFERENCE 0.755 kPa
4. DESIGN SPEED: 40 km/hr
5. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE.
6. ALL ELEVATION AND STATIONS ARE IN METRES.



SECTION A
SCALE 1:100

FOR DISCUSSION ONLY

PRELIMINARY/ FOR DISCUSSION
NOT FOR CONSTRUCTION

Consultant Logo
Associated Engineering

Rev	Date	Description	Init
A	2022–08–19	ISSUED FOR DISCUSSION	ML

REVISIONS

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure
South Coast Region

LOWER MAINLAND DISTRICT
HICK'S LAKE ROAD

TROUT LAKE CREEK BRIDGE CONCEPTUAL GENERAL ARRANGEMENT

PREPARED UNDER THE DIRECTION OF
ENGINEER OF RECORD
DATE

DESIGNED ____ DATE ____
CHECKED ____ DATE ____
DRAWN ____ DATE ____
SCALE
NEGATIVE No.

FILE No.	PROJECT No.	REG.	DRAWING No.	
		1	2904–00–SK–101	A

CANCEL PRINTS BEARING PREVIOUS LETTER

APPENDIX K – CONCEPTUAL LEVEL COST ESTIMATE.

Trout Lake Creek Culvert Replacement Options
Draft Opinion of Probable Cost Summary
Revision 0
19-Aug-22

				Option 1		**Option 2**		**Option 3**		**Option 4**	
				Maintain Existing Culverts		**Arch Culvert**		**New Bridge with Debris Mitigation Net**		**New Bridge that conveys Debris Flood**	
Item#	**Description of Work**	**Unit of Measure**	**Unit Price**	**Approx. Quantity**	**Extended Amount**	**Approx. Quantity**	**Extended Amount**	**Approx. Quantity**	**Extended Amount**	**Approx. Quantity**	**Extended Amount**
01	**SECTION 1 - GENERAL**										
01.01	Mobilization (6%)	L.S.	100%	L.S.	$ 11,100.00	L.S.	$ 103,700.00	L.S.	$ 117,000.00	L.S.	$ 108,000.00
01.02	Traffic Management (8%)	L.S.	100%	L.S.	$ 14,900.00	L.S.	$ 138,300.00	L.S.	$ 155,900.00	L.S.	$ 143,900.00
01.03	Quality Management (4%)	L.S.	100%	L.S.	$ 7,400.00	L.S.	$ 69,100.00	L.S.	$ 78,000.00	L.S.	$ 72,000.00
01.04	Site Modifications (6%)	L.S.	100%	L.S.	$ 11,100.00	L.S.	$ 103,700.00	L.S.	$ 117,000.00	L.S.	$ 108,000.00
02	**SECTION 2 - GRADING**										
02.01	**Removal and Adjustment of Existing Works**										
02.01.01	Clearing and Grubbing	Hectare	$ 30,000.00	0.12	$ 3,600.00	0.2	$ 6,000.00	0.2	$ 6,000.00	0.2	$ 6,000.00
02.01.02	Remove Existing Culverts	Each	$ 10,000.00	0	$ -	4	$ 40,000.00	4	$ 40,000.00	4	$ 40,000.00
02.01.03	Remove Existing Concrete Barriers	L.S.	100%	L.S.	$ 4,000.00	L.S.	$ 4,000.00	L.S.	$ 4,000.00	L.S.	$ 4,000.00
02.02	**Pavement Cutting, Cold Milling and Removal**			0							
02.02.01	Pavement Cutting	Metre	$ 20.00	30	$ 600.00	30	$ 600.00	30	$ 600.00	30	$ 600.00
02.02.02	Cold Milling and Pavement Removal	Square Metre	$ 15.00	400	$ 6,000.00	650	$ 9,750.00	650	$ 9,750.00	650	$ 9,750.00
02.03	**Roadway and Drainage Excavation**			0							
02.03.01	Organic Stripping (0.3 m deep)	Cubic Metre	$ 20.00	300	$ 6,000.00	400	$ 8,000.00	400	$ 8,000.00	400	$ 8,000.00
02.03.02	Type D Excavation for On-Site Use (Fill)	Cubic Metre	$ 40.00	50	$ 2,000.00	600	$ 24,000.00	500	$ 20,000.00	500	$ 20,000.00
02.03.03	Type D Excavation for Off-Site Disposal	Cubic Metre	$ 50.00	600	$ 30,000.00	350	$ 17,500.00	500	$ 25,000.00	500	$ 25,000.00
02.04	**Granular Materials**										
02.04.01	Select Granular Sub-Base (SGSB)	Cubic Metre	$ 60.00	340	$ 20,400.00	440	$ 26,400.00	360	$ 21,600.00	360	$ 21,600.00
02.04.02	25 mm Well Graded Base (WGB)	Cubic Metre	$ 80.00	300	$ 24,000.00	400	$ 32,000.00	330	$ 26,400.00	330	$ 26,400.00
02.04.03	Shouldering	Cubic Metre	$ 120.00	4	$ 480.00	5	$ 600.00	4	$ 480.00	4	$ 480.00
03	**SECTION 3 - DRAINAGE**										
03.01	Open Bottom CSP Arch Culvert (7670x2570mm)	L.S.	$ 1,100,000.00	0	$ -	1	$ 1,100,000.00	0	$ -	0	$ -
03.02	Rip Rap (1000kg Class)	Cubic Metre	$ 250.00	0	$ -	800	$ 200,000.00	700	$ 175,000.00	700	$ 175,000.00
03.03	Debris Mitigation Structure	Each	$ 150,000.00	0	$ -	1	$ 150,000.00	1	$ 150,000.00	0	$ -
04	**SECTION 4 - STRUCTURES**										
04.01	Roadside Barrier (CRB)	Metre	$ 180.00	116	$ 20,880.00	134	$ 24,120.00	95	$ 17,100.00	95	$ 17,100.00
04.02	Bridge	Square Metre	$ 6,800.00	0	$ -	0	$ -	200	$ 1,360,000.00	200	$ 1,360,000.00
05	**SECTION 5 - PAVING**										
05.01	Asphalt Aggregate	Tonne	$ 30.00	240	$ 7,200.00	310	$ 9,300.00	310	$ 9,300.00	310	$ 9,300.00
05.02	Asphalt Pavement	Tonne	$ 200.00	240	$ 48,000.00	310	$ 62,000.00	310	$ 62,000.00	310	$ 62,000.00
06	**SECTION 6 - SIGNING AND PAVEMENT MARKINGS**										
06.01	Supply and Install Signs	Each	$ 600.00	10	$ 6,000.00	10	$ 6,000.00	10	$ 6,000.00	10	$ 6,000.00
06.02	Pavement Markings	L.S.	100%	L.S.	$ 5,000.00	L.S.	$ 5,000.00	L.S.	$ 5,000.00	L.S.	$ 5,000.00
07	**SECTION 7 - TOPSOIL AND REVEGATATION**										
07.01	Revegetation Seeding	Hectare	$ 15,000.00	0.1	$ 1,500.00	0.2	$ 3,000.00	0.2	$ 3,000.00	0.2	$ 3,000.00
	PRICE ESTIMATE				**$ 230,000.00**		**$ 2,143,000.00**		**$ 2,417,000.00**		**$ 2,231,000.00**
	Contingency (30%)				**$ 69,000.00**		**$ 643,000.00**		**$ 726,000.00**		**$ 670,000.00**
	PRICE ESTIMATE Including Contingencies				**$ 300,000.00**		**$ 2,790,000.00**		**$ 3,150,000.00**		**$ 2,910,000.00**
Other costs:	Engineering, Planning and Design (10% of construction cost)				$ 30,000		$ 280,000		$ 320,000		$ 300,000
	Project Management and Construction Services (10% of construction cost)				$ 30,000		$ 280,000		$ 320,000		$ 300,000
	Contingency for other ancillary costs (10% of construction cost)				$ 30,000		$ 280,000		$ 320,000		$ 300,000
	Total Other Costs:				**$ 90,000**		**$ 840,000**		**$ 960,000**		**$ 900,000**
	Total Project Costs				**$ 390,000**		**$ 3,630,000**		**$ 4,110,000**		**$ 3,810,000**

Note: Total project cost estimate has been rounded up to the nearest $10,000.
Debris Mitigation Structure pricing is highly uncertain. More analysis is required.
Temporary detour costs have not been included.
Environmental mitigation costs have not been included.

Associated Engineering

Appendix A2

Historical Baseline Studies

MEMO

Date: May 20, 2020
Hatfield Ref No.: MOTI9530
From: Hannah Nieman
To: Krista Englund, BC Ministry of Transportation and Infrastructure
Subject: **Trout Lake Creek Spring Culvert Assessment**

Dear Ms. Englund:

The following correspondence provides a summary of observations from a reconnaissance survey conducted at Trout Lake Creek at Rockwell Drive in the District of Kent on May 5, 2020.

1.0 PROJECT BACKGROUND

Hatfield Consultants (Hatfield) previously conducted two fish and fish habitat studies within Trout Lake Creek in support of the Trout Lake Creek Culvert Replacement Project (the Project; Hatfield 2017 and Hatfield 2018). It is Hatfield's understanding that the Project remained in the conceptual design phase following these previous studies. A significant rainfall event occurred on January 31, 2020, in the District of Kent resulting in high flows, flooding and landslides. The Rockwell Drive culvert was subsequently washed out during this event. A local state of emergency was declared, and actions were taken to repair Rockwell Drive including a temporary clear-span bridge over Trout Lake Creek.

2.0 METHODS

Hatfield conducted an assessment of fish habitat on May 5, 2020. Two habitat transects, (transect 8 and transect 9; Attachment A1), established in March 2018 were used to reassess fish habitat upstream and downstream the Rockwell Drive crossing. General observations of habitat suitability for salmonid species and disturbances as a result of the culvert washout were documented during the reconnaissance. The following measurements were collected:

- Channel width;
- Wetted width;
- Channel depth and velocity at 25, 50, and 75% of the channel width;
- Substrate composition;
- Channel gradient and morphology (e.g., percent riffle, pool, run, cascade);
- In situ water quality; and
- An assessment of fish passage.

3.0 PRE-FLOOD CONDITIONS

From the mouth of the creek to the Rockwell Drive culvert the creek is characterized by riffle-pool morphology with short sections of steeper riffles/cascades. Trout Lake Creek immediately downstream of Rockwell Drive was characterized by a large plunge pool (max. depth of approximately 2 m) as a result of the perched culvert. With the exception of the Rockwell Drive culvert no barriers to fish migration were observed downstream to Harrison Lake. The Rockwell Drive culvert was characterized by a 1.5 m drop at the outlet, shallow in-culvert water depth, high water velocities relative to the creek and approximately an 8% grade (Hatfield 2018). All of these factors combined likely precluded fish passage despite the large plunge pool (max depth of approximately 2 m) downstream of the culvert (Hatfield 2018).

Upstream of the culvert the creek was characterized by an approximate 15 m section of steeper cascade morphology (approximate 10% grade). Upstream of this cascade the creek was characterized by riffle-pool morphology with short sections of cascades for approximately 150 m. Substrates were comprised predominately of gravels and cobbles and boulders occurred less frequently. Cover for fish was provided primarily by boulders, deep pools and occasional large woody debris.

4.0 RESULTS

Upstream Rockwell Drive

Our observations indicate that the January flood event likely scoured out an existing rock-filled berm along the left bank. Material from the berm appears to have been deposited in previously classified high-quality fish habitat (i.e., riffle-pool) upstream of Rockwell Drive (Figure 1). The resulting gravel deposition has constricted the channel, increased water velocity and shifted the channel alignment to the right bank (Figure 1).

Results from habitat transect 9 located 13 m upstream of Rockwell Drive (Appendix A1) confirmed changes to channel morphology from pre-flood conditions (Figure 1 and Table 1). Channel width has increased, channel depth and gradient have decreased, and substrates have shifted from being cobble dominated to primarily gravel. It is likely that these habitat changes occurred as a result of the recent flood and deposition of material, and subsequent emergency works upstream of Rockwell Drive.

The flood-disturbed area extends to approximately 80 m upstream of Rockwell Drive and is currently characterized by shallow fast-flowing riffles which provide little opportunity for salmonid rearing or spawning; however, this habitat is suitable for longnose dace (*Rhinichtys cataractae*) and prickly sculpin (*Cottus asper*) previously documented further upstream in 2017 (Appendix A2). Habitat provisions for salmonid species within the flood-disturbed area are limited to migratory habitat to higher quality rearing and overwintering habitat (i.e. deep pools) and limited spawning habitat upstream the flood disturbance.

Figure 1 Photographs of Trout Lake Creek upstream of Rockwell Drive during pre-flood and post-flood conditions.

Pre-flood conditions (2017) **Post-flood conditions (2020)**

Riffle-pool habitat and berm upstream of Rockwell Drive (upstream view).

Channel constriction and gravel deposition located upstream of Rockwell Drive (upstream view).

Riffle habitat upstream of Rockwell (looking downstream).

Riffle habitat located upstream of Rockwell Drive (looking downstream).

Rockwell Drive Crossing

The culvert inlet was partially buried with substrate and damaged during the flood event whereby approximately two-thirds of flow is currently conveyed through the culvert with the remaining flow conveyed overtop of the culvert. Emergency works included the installation of a temporary clear span bridge and riprap protection at Rockwell Drive (Figure 2).

Figure 2 Photographs of Rockwell Drive culvert during pre-flood and post-flood conditions.

Pre-flood conditions (2017) **Post-flood conditions (2020)**

Plunge-pool downstream of Rockwell Drive (upstream view).

Riffle and cascade downstream of Rockwell Drive (upstream view).

Cascade habitat upstream of Rockwell Drive (looking downstream).

Riffle habitat located upstream of Rockwell Drive (looking downstream).

Downstream Rockwell Drive

The large plunge-pool previously located downstream of the culvert outlet has been infilled with flood debris and washed out road material (Figure 2). Evidence of flood debris was observed to approximately 50 m downstream of the culvert (Figure 3). An off-channel pool along the left bank (likely scoured during the flood) was identified as a possible location for habitat restoration/offsetting if required (Figure 3). Connectivity improvements to the main channel and instream complexing would be beneficial design features to improve off-channel rearing for juvenile salmonids.

Results from habitat transect 8 showed significant changes to stream morphology downstream of the culvert (Table 1). Morphology has shifted from pool to riffle and cascade habitat (Figure 2). Similar to upstream of Rockwell Drive, habitat provisions for salmonid species in the flood-disturbed area is limited to migratory habitat to higher quality rearing and spawning habitat located further downstream. In situ water quality from Trout Lake Creek and the off-channel pool are summarized in Table 2.

Figure 3 Photographs of Trout Lake Creek downstream Rockwell Drive (May 5, 2020).

Substrate deposition downstream of Rockwell Drive (downstream view).

Substrate deposition downstream of Rockwell Drive (downstream view).

Off-channel scour pool (arrow; looking cross-stream).

Off-channel scour pool.

Table 1 Trout Lake creek habitat transect information downstream and upstream Rockwell Drive (2018 and 2020).

Transect ID	Year	Gradient (%)	Morphology	X_UTM	Y_UTM	Channel Width (m)	Wetted Width (m)	[1]Substrate		Depth (m)			Velocity (m/s)		
								Dominant	Sub dominant	25%	50%	75%	25%	50%	75%
8	2018	<1	Pool	591225	5466283	11.9	9.0	Cb	Gr	0.32	0.49	0.33	-	-	-
8	2020	7	Riffle	591225	5466283	17.9	9.4	Gr	Bd	0.19	0.31	0.19	0.8	0.3	0.9
9	2018	3	Riffle	591281	5466313	10.0	6.5	Cb	Gr	0.59	0.37	0.23	-	-	-
9	2020	2	Riffle	591281	5466313	11.1	8.6	Gr	Cb	0.24	0.16	0.12	0.6	0.7	0.8

[1] Gr=Gravel; Cb=Cobble; Bd=Boulder

Table 2 Trout Lake Creek in situ water quality data (May 5, 2020).

Location	Temperature (°C)	DO (mg/L)	pH	Conductivity (µs/cm)	Turbidity (NTU)
Off-channel pool d/s of Rockwell Drive culvert	12.8	10.1	7.53	74	0.64
Main channel d/s of Rockwell Drive culvert	12.8	10.5	7.58	42	0.34

5.0 CLOSURE

Hatfield will work with the design team to provide recommendations regarding fish-passage for a new permanent crossing structure. A number of design recommendations including swimming capabilities of documented fish species in Trout Lake Creek were previously provided in an environmental summary report (Hatfield 2017; Appendix A2).

If you have any questions or comments, please contact the undersigned.

Sincerely,

Hannah Nieman, RBTech
Fisheries Technician
HATFIELD CONSULTANTS LLP

Reviewed by

Tim Poulton

Tim Poulton, RPBio, PBiol
Senior Environmental Specialist and Manager
HATFIELD CONSULTANTS LLP

6.0 REFERENCES

Hatfield Consultants. 2017. Trout Lake Culvert Assessment – Environmental Summary Report. Prepared for: BC Ministry of Transportation and Infrastructure. November 28, 2017

Hatfield Consultants. 2018. Trout Lake Creek Winter Fish Assessment – Summary Report. Prepared for: BC Ministry of Transportation and Infrastructure. July 4, 2018

APPENDICES

Appendix A1

Trout Lake Creek Winter Fish Assessment – Summary Report 2018

Hatfield
CONSULTANTS

HCP Ref #: MOTI8444

July 4, 2018

Krista Englund
BC Ministry of Transportation and Infrastructure
310 – 1500 Woolridge St., Coquitlam, BC
V3K 0B8

Re: Trout Lake Creek Winter Fish Assessment – Summary Report

Dear Ms. Englund:

The following correspondence provides a summary of overwintering fisheries resource values upstream and downstream of the Trout Lake Creek culvert at Rockwell Drive in the District of Kent. Recommendations regarding the design and construction of a replacement crossing are also provided.

METHODS

Fish Habitat

Hatfield Consultants (Hatfield) conducted an assessment of fish habitat on March 26 and 27, 2018. A reconnaissance survey to assess overwintering fish habitat was conducted from the mouth of the creek to a large waterfall located approximately 400 m upstream of the Rockwell Drive culvert. General observations of habitat suitability for salmonid species were documented during the reconnaissance. For further habitat information refer to *Trout Lake Creek Culvert Assessment – Environmental Summary Report* from November 28, 2017.

A detailed survey was conducted from the mouth of Trout Lake Creek at Harrison Lake to approximately 150 m upstream of the Rockwell Drive culvert. Upstream of this point the creek becomes steeper and is characterized as steeper cascade morphology less suitable for fish. The following measurements were collected:

- Average channel width;
- Average wetted width;
- Channel depth at 25, 50, and 75% of the channel width;
- Substrate composition;
- Channel gradient and morphology (e.g., percent riffle, pool, run, cascade);
- In situ water quality; and
- An assessment of fish passage.

Fish Distribution

Fish distribution was assessed from the mouth of the creek to approximately 150 m upstream of the Rockwell Drive culvert. A total of twenty baited gee-type minnow traps were deployed in deeper water habitats and allowed to soak for 24-hours. Five minnow traps were set in pools in the 150 m stretch of creek upstream of the Rockwell Drive culvert. Two minnow traps were set in the large pool downstream of the culvert and six minnow traps were deployed in smaller pools located downstream of the culvert and upstream of parks yard access bridge. Three minnow traps were placed between the parks yard access bridge and Green Point day use area access bridge, and the remaining two minnow traps were set in pools below the Green Point day use access bridge in the final reach before outflow into Harrison Lake. Single-pass backpack electrofishing (Smith Root LR-24 electrofisher) was conducted from the mouth of the creek upstream to approximately 150 m upstream of the Rockwell Drive culvert.

Electrofishing effort was 1,394 seconds at 225V for all areas downstream of the Rockwell Drive culvert, and 251 seconds above the culvert at 225V. High flow conditions at the time of the survey limited electrofishing capture success in the main channel; as such, electrofishing effort was focused on pools and areas of lower flow velocity (e.g., margins of the creek and deeper runs).

Captured fish were enumerated by species, weighed with a digital scale (±0.1 g), and measured for fork length (±1 mm). All captured fish were released unharmed to their point of capture. Photographs of each fish species were taken to confirm species identification.

RESULTS

Fish Distribution

A total of 40 fish were captured during the winter survey of Trout Lake Creek. All fish were captured below the Rockwell Drive culvert, with 26 fish captured by electrofishing and a further 13 captured in minnow traps. Similar to the November 2017 survey, longnose dace (*Rhinichtys cataractae*), cutthroat trout (*Oncorhynchus clarki clarki*), rainbow trout (*Oncorhynchus mykiss*), and prickly sculpin (*Cottus asper*) were the only species captured (Figure 1). A total of one cutthroat trout, four rainbow trout, thirty-four prickly sculpin, and one longnose dace were captured downstream of the Rockwell Drive culvert to the creek mouth at Harrison lake. No fish were captured upstream of the Rockwell Drive culvert during this survey.

Average fork-length and weight per species is summarized in Table 1. Raw data per gear type is presented in Table 2 and Table 3. A length-frequency distribution for sculpin captured in Trout Lake Creek is provided in Figure 2. Inadequate sample sizes for other species prevented the development of length-frequency distributions for these species. Sculpin appear to have multiple age classes with immature (<41 mm) and adult/subadult ($\geq$ 41 mm) fish present.

Figure 1 Fish captured by minnow trap and backpack electrofisher downstream of the Rockwell Drive culvert (March 26, 2018).

Cutthroat trout captured downstream of the Rockwell Drive culvert.

Rainbow trout captured downstream of the Rockwell Drive culvert.

Prickly sculpin captured downstream of the Rockwell Drive culvert.

Longnose dace captured downstream of the Rockwell Drive culvert

Table 1 Average fork-length and weight per species captured in Trout Lake Creek March, 2018.

Species	Number Caught	Average Fork-Length (mm)	Standard Deviation (Fork-Length)	Average Weight (g)	Standard Deviation (Weight)
Prickly sculpin	34	53.8	12.1	1.7	1.4
Rainbow trout	4	90.5	13.1	6.4	1.7
Cutthroat trout	1	113.0	-	12.1	-
Longnose dace	1	109.0	-	8.9	-

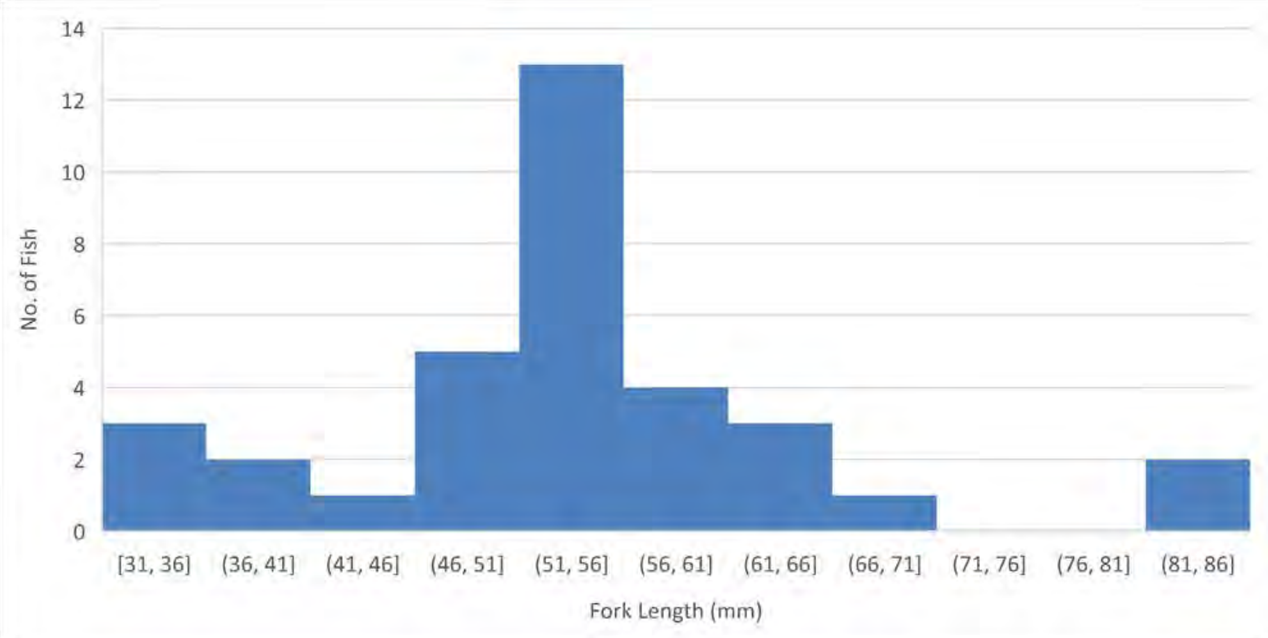
Table 2 Fish data collected for Trout Lake Creek by minnow trap downstream of Rockwell Drive (March 27, 2018).

Species	Length (mm)	Weight (g)
Prickly sculpin	50	1.2
Prickly sculpin	86	6.6
Prickly sculpin	86	6.5
Prickly sculpin	65	2.8
Prickly sculpin	48	0.8
Prickly sculpin	52	1.1
Prickly sculpin	53	1.1
Prickly sculpin	52	1.1
Prickly sculpin	51	1.5
Cutthroat trout	113	12.1
Rainbow trout	105	6.8
Rainbow trout	78	4.6
Rainbow trout	98	8.5
Rainbow trout	81	5.8

Table 3 Fish data collected for Trout Lake Creek by backpack electrofisher downstream of Rockwell Drive (March 26, 2018).

Species	Length (mm)	Weight (g)
Prickly sculpin	52	1.3
Prickly sculpin	53	1.4
Prickly sculpin	55	1.3
Prickly sculpin	53	1.0
Prickly sculpin	41	0.4
Prickly sculpin	38	0.4
Prickly sculpin	62	2.5
Prickly sculpin	58	1.5
Prickly sculpin	53	1.3
Prickly sculpin	54	1.2
Prickly sculpin	55	1.3
Prickly sculpin	53	1.2
Prickly sculpin	44	0.7
Prickly sculpin	33	0.3
Prickly sculpin	31	0.4
Prickly sculpin	32	0.3
Prickly sculpin	55	1.9
Prickly sculpin	60	1.6
Prickly sculpin	60	2.3
Prickly sculpin	64	2.4
Prickly sculpin	70	3.4
Prickly sculpin	52	1.1
Prickly sculpin	61	1.9
Prickly sculpin	50	1.2
Prickly sculpin	48	1.1
Longnose dace	109	8.9

Figure 2 Length-frequency histogram for prickly sculpin captured in Trout Lake Creek, March, 2018.



Fish Habitat

From the mouth of the creek to the Rockwell Drive culvert the creek is characterized by riffle-pool morphology with short sections of steeper riffles/cascades (Figure 3). Barriers to fish migration were not observed downstream, of Rockwell Drive. The Rockwell Drive culvert is characterized by a 1.5 m drop at the outlet, shallow in culvert water depth, high water velocities relative to the creek and an approximate 8% grade (Figure 4). All of these factors combined likely preclude fish passage despite the large plunge pool (max depth of approximately 2 m) downstream of the culvert.

Figure 3 Photographs of Trout Lake Creek downstream of the Rockwell Drive culvert (March 27, 2018).

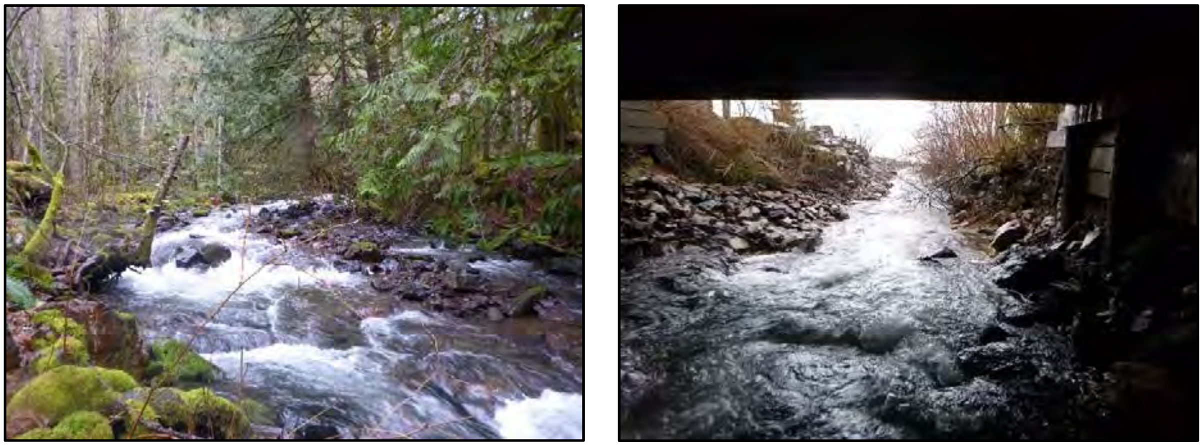


Figure 4 Rockwell Drive culvert outlet (March 27, 2018).

Upstream of the culvert the creek is characterized by an approximate 15 m section of steeper cascade morphology (approximate 10% grade). Upstream of this cascade the creek is characterized by riffle-pool morphology with short sections of cascades for approximately 150 m (Figure 5). Substrates are comprised predominately of gravels and cobbles. Boulders occur less frequently. Cover for fish is primarily provided by boulders, deep pools and occasional large woody debris.

Figure 5 Photographs of Trout Lake Creek upstream of Rockwell Drive to approximately 150 m upstream Rockwell Drive (March 27, 2018).

High flow velocity observed at the Rockwell Drive culvert inlet.

Riffle-pool habitat located upstream of Rockwell Drive.

In situ water quality parameters and creek habitat transect measurements were collected along the surveyed reach of Trout Lake creek. In situ water quality results are within the approved water quality guidelines for the protection of freshwater life (MOE 2018; Table 4). Creek transect measurements can be found in Table 5, with the corresponding transect locations on Figure 6.

Table 4 Trout Lake Creek In Situ water quality data.

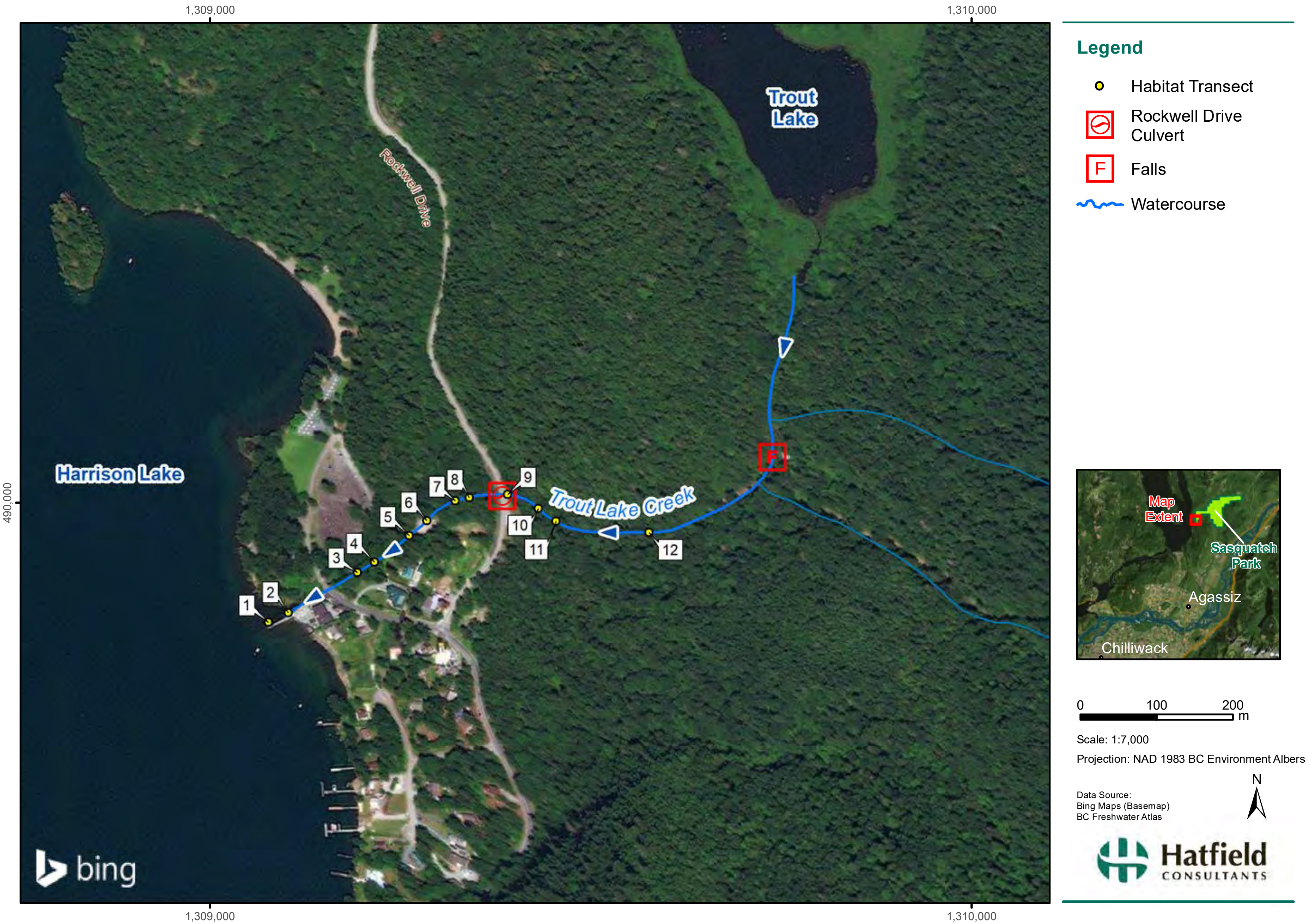
Location	Temperature (°C)	DO (mg/L)	pH	Conductivity (µs/cm)	Turbidity (NTU)
Mouth at Harrison Lake	6.2	12.3	8.1	40.3	2.0
Pool d/s of Rockwell Drive culvert	6.2	12.1	8.1	39.8	1.9
Pool u/s of Rockwell Drive culvert	6.2	12.1	8.0	40.4	0.3

Table 5 Trout Lake creek fish habitat transects from downstream to upstream.

Transect ID	Gradient (%)	Morphology	X_UTMZone10N	Y_UTMZone10N	Channel Width (m)	Wetted Width (m)	[1]Substrate		Depth (cm)		
							Dominant	Sub dominant	25%	50%	75%
1	-	Riffle	590957	5466167	6.7	6.0	Gr	Cb	37	30	31
2	-	Riffle	590985	5466172	6.3	5.0	Cb	Gr	28	29	41
3	4	Riffle	591076	5466222	8.7	6.9	Cb	Gr	48	31	10
4	4	Riffle	591091	5466245	8.3	7.2	Cb	Gr	34	61	31
5	4	Riffle	591129	5466299	8.0	6.4	Cb	Bd	25	28	31
6	2	Riffle	591155	5466302	12.6	11.4	Gr	Cb	40	29	11
7	7	Cascade	591210	5466312	12.3	10.4	Cb	Gr	12	22	34
8	-	Pool	591225	5466283	11.9	9.0	Cb	Gr	32	49	33
9	3	Riffle	591281	5466313	10.0	6.5	Cb	Gr	59	37	23
10	3	Riffle	591318	5466287	12.2	9.4	Gr	Cb	19	29	36
11	7	Cascade	591335	5466262	10.6	8.2	Gr	Bd	48	66	42
12	8	Cascade	591464	5466269	8.7	6.7	Cb	Bd	38	41	18

[1] Gr=Gravel; Cb=Cobble; Bd=Boulder

Figure 6 Locations of Trout Lake Creek habitat transects, March 2018.



Scale: 1:7,000

Projection: NAD 1983 BC Environment Albers

Data Source:
Bing Maps (Basemap)
BC Freshwater Atlas

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Please contact me should you have any questions regarding this correspondence.

Sincerely,

Tim Poulton

Tim Poulton, RPBio, PBiol
Senior Environmental Specialist and Manager
HATFIELD CONSULTANTS

REFRENCES

[BC MOE] BC Ministry of Environment & Climate Change Strategy. 2018. British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture. Summary Report. March 2018.

Appendix A2

Trout Lake Creek Culvert Assessment – Summary Report 2017

Hatfield
CONSULTANTS

HCP Ref #: MOTI8902

November 28, 2017

Krista Englund
BC Ministry of Transportation and Infrastructure
310 – 1500 Woolridge St., Coquitlam, BC
V3K 0B8

Re: Trout Lake Creek Culvert Assessment – Environmental Summary Report

Dear Ms. Englund:

The following correspondence provides a summary of fisheries resource values and a cursory assessment of species at risk upstream and downstream of the Trout Lake Creek culvert at Rockwell Drive in the District of Kent. Recommendations regarding the design and construction of a replacement crossing are also provided.

METHODS

Fish Habitat

Hatfield Consultants (Hatfield) conducted an assessment of fish habitat on November 8, 2017. A reconnaissance survey to assess fish passage was conducted from the mouth of the creek to a large waterfall located approximately 400 m upstream of the Rockwell Drive culvert. General observations of habitat suitability for salmonid species were documented during the reconnaissance.

A more detailed survey was conducted from the Rockwell Drive culvert to approximately 150 m upstream in a section of creek that was identified as higher value habitat for salmonid species during the reconnaissance survey. The following measurements were collected in this reach:

- Average channel width;
- Average wetted width;
- Max pool depth;
- Substrate composition;
- Channel gradient and morphology (e.g., percent riffle, pool, run, cascade);
- Type and percent overhead and instream cover;
- Characterization of the riparian area;
- In situ water quality; and
- An assessment of fish passage.

Fish Distribution

Fish distribution was assessed from the mouth of the creek to the large waterfall located approximately 400 m upstream of the Rockwell Drive culvert. A visual assessment for spawning salmon was conducted from the mouth of the creek to the Rockwell Drive culvert. Baited gee-type minnow traps were deployed in deeper water habitats and allowed to soak for 24-hours. Two minnow traps were set in the large pool downstream of the Rockwell Drive culvert. Two more minnow traps were deployed in smaller pools located approximately 15 m to 30 m downstream of the culvert. Single-pass (full coverage) backpack electrofishing (Smith Root LR-24 electrofisher) was conducted upstream of the Rockwell Drive culvert to the large waterfall for 1751 seconds. Electrofishing was not conducted downstream of the Rockwell Drive culvert due to the presence of spawning salmon.

Captured fish were enumerated by species, weighed with a digital scale (±0.1 g), and measured for fork length (±1 mm). All captured fish were released unharmed to their point of capture. Photographs of each fish species were taken to confirm species identification.

Species at Risk

On November 8, 2017, Hatfield conducted a reconnaissance survey of wildlife habitat within the riparian zone of Trout Lake Creek upstream and downstream of the Rockwell Drive culvert. The survey focused on assessing broad wildlife values, as well as specific habitat suitability for species of concern. The crew walked straight-line transects approximately 5 m – 10 m apart from the mouth of the creek to the waterfall approximately 400 m upstream.

The riparian areas were also assessed for Pacific water shrew (*Sorex bendirii*) habitat conditions based on forest structure and habitat connectivity in both the stream and terrestrial environments. Particular attention was paid to critical habitat features that are important for this species, such as:

- Forest structure and age;
- Understory attributes such as shrub cover and composition along creek banks and upland of creek edges;
- Coarse woody debris (CWD) amounts, cover and decay stage;
- Stream attributes such as channel width and depth, bank height and gradient, and channel morphology; and
- Presence of wet areas (permanent or ephemeral).

Trout Lake Creek was also specifically assessed for coastal tailed frog (*Ascaphus truei*) suitability. In addition to measuring the wetted and channel width and depth of the surveyed reaches, stream structure was documented by collecting the following information:

- Basic geology of the substrate in terms of rock durability (i.e., the presence of competent or friable rock, or both);
- Channel morphology (the presence and level of development of step-pools);
- Bank stability;

- Evidence and extent of bedload movement (frequency of disturbances such as aggradations and levees, and the size of the material within them); and
- Vegetation characteristics.

A time constrained search (TCS) was conducted from the existing culvert to the waterfall.

A desktop review of potential species at risk that may occur in the study area was conducted using species listings and information at the British Columbia Conservation Data Centre (BCCDC 2017).

RESULTS

Fish Distribution

Spawning chum salmon (*Oncorhynchus keta*) were observed from the mouth of Trout Lake Creek to just below the large pool located at the Rockwell Drive Culvert outlet (Figure 1). The majority of adult chum were observed from the mouth of the creek to the downstream clear span bridge. Upstream of this point chum were more occasional likely due to the steeper gradient and coarser substrate composition (i.e., more boulder and cobble with less gravel).

Figure 1 Spawning chum salmon observed below the Rockwell Drive culvert to the mouth of Trout Lake Creek (November 8, 2017).

A total of 24 rainbow trout parr (*Oncorhynchus mykiss*) were captured in the large pool at the outlet of the Rockwell Drive culvert (Figure 2). Three more rainbow trout were captured in two small pools located downstream of the culvert plunge pool. Fork length and weight per species and gear type are summarized in Table 1 and Table 2.

Figure 2 Fish captured by minnow trap downstream of the Rockwell Drive Culvert (November 9, 2017).

A total of four cutthroat trout (*Oncorhynchus clarki clarki*), eight prickly sculpin (*Cottus asper*), and one longnose dace (*Rhinichtys cataractae*) were captured upstream of the Rockwell Drive culvert to approximately 250 m upstream (Figure 3). No fish were captured upstream of this point as the creek became steeper and was characterized as steeper cascade morphology less suitable for fish.

Figure 3 Fish captured by minnow trap and backpack electrofisher upstream of the Rockwell Drive culvert (November 9, 2017).

Cutthroat trout captured upstream of the Rockwell Drive culvert.

Longnose dace captured upstream of the Rockwell Drive culvert.

Table 1 Fish data collected for Trout Lake Creek by minnow trap and location (November 9, 2017).

Species	Length (mm)	Weight (g)	Location
Rainbow trout	93	6.3	Pool Downstream Rockwell Drive Culvert
Rainbow trout	92	6.6	Pool Downstream Rockwell Drive Culvert
Rainbow trout	76	4.5	Pool Downstream Rockwell Drive Culvert
Rainbow trout	92	7.5	Pool Downstream Rockwell Drive Culvert
Rainbow trout	76	4.6	Pool Downstream Rockwell Drive Culvert
Rainbow trout	73	3.6	Pool Downstream Rockwell Drive Culvert
Rainbow trout	82	5.0	Pool Downstream Rockwell Drive Culvert
Rainbow trout	80	5.4	Pool Downstream Rockwell Drive Culvert
Rainbow trout	81	5.0	Pool Downstream Rockwell Drive Culvert
Rainbow trout	87	6.7	Pool Downstream Rockwell Drive Culvert
Rainbow trout	76	3.8	Pool Downstream Rockwell Drive Culvert
Rainbow trout	80	4.8	Pool Downstream Rockwell Drive Culvert
Rainbow trout	89	7.0	Pool Downstream Rockwell Drive Culvert
Rainbow trout	75	4.4	Pool Downstream Rockwell Drive Culvert
Rainbow trout	88	6.6	Pool Downstream Rockwell Drive Culvert
Rainbow trout	82	5.1	Pool Downstream Rockwell Drive Culvert
Rainbow trout	79	5.3	Pool Downstream Rockwell Drive Culvert
Rainbow trout	81	4.7	Pool Downstream Rockwell Drive Culvert
Rainbow trout	77	4.8	Pool Downstream Rockwell Drive Culvert
Rainbow trout	78	4.6	Pool Downstream Rockwell Drive Culvert
Rainbow trout	83	5.6	Pool Downstream Rockwell Drive Culvert
Rainbow trout	75	3.4	Pool Downstream Rockwell Drive Culvert
Rainbow trout	77	3.8	Pool Downstream Rockwell Drive Culvert
Rainbow trout	82	4.8	Pool Downstream Rockwell Drive Culvert
Rainbow trout	84	5.6	Downstream of Plunge Pool
Rainbow trout	96	9.0	Downstream of Plunge Pool
Rainbow trout	78	4.4	Downstream of Plunge Pool
Cutthroat trout	144	27.2	Pool Upstream Rockwell Drive

Table 2 Fish data collected for Trout Lake Creek by backpack electrofisher upstream of Rockwell Drive (November 9, 2017).

Species	Length (mm)	Weight (g)
Prickly sculpin	82	8.2
Prickly sculpin	61	3.3
Prickly sculpin	87	9.1
Cutthroat trout	76	4.4
Prickly sculpin	55	2.0
Prickly sculpin	62	2.7
Prickly sculpin	70	4.0
Prickly sculpin	61	2.4
Cutthroat trout	94	8.0
Longnose Dace	94	8.6
Prickly sculpin	93	10.9
Cutthroat trout	85	5.6

Fish Habitat

From the mouth of the creek to the Rockwell Drive culvert the creek is characterized by riffle-pool morphology with short sections of steeper riffles/cascades (Figure 4). With the exception of the Rockwell Drive culvert no barriers to fish migration were observed downstream to Harrison Lake. The Rockwell Drive culvert is characterized by a 1.5 m drop at the outlet, shallow in culvert water depth, high water velocities relative to the creek and approximately an 8% grade (Figure 5). All of these factors combined likely preclude fish passage despite the large plunge pool (max depth of approximately 2 m) downstream of the culvert.

Figure 4 Photographs of Trout Lake Creek downstream of the Rockwell Drive culvert (November 8, 2017).

Figure 5 Rockwell Drive culvert outlet (November 8, 2017).

Upstream of the culvert the creek is characterized by an approximate 15 m section of steeper cascade morphology (approximate 10% grade). Upstream of this cascade the creek is characterized by riffle-pool morphology with short sections of cascades for approximately 150 m (Figure 6). Substrates are comprised predominately of gravels and cobbles. Boulders occur less frequently. Cover for fish is provided primarily by boulders, deep pools and occasional large woody debris. A fish habitat site card is appended to this report.

Figure 6 Photographs of Trout Lake Creek upstream of Rockwell Drive to approximately 150 m upstream Rockwell Drive (November 8, 2017).

Cascade located at the Rockwell Drive culvert inlet.

Riffle-pool habitat located upstream of Rockwell Drive.

From 150 m upstream of Rockwell Drive to the waterfall the creek is characterized by steeper gradient (15% to 25% grade) cascades comprised primarily of boulders (Figure 7). Moss covered boulders and cobbles throughout the riparian environment and a large log jam provided evidence of a historical debris flow. The 8-m waterfall located 400 m upstream of Rockwell Drive is a barrier to upstream fish migration.

Figure 7 Photographs of Trout Lake Creek from 150 m upstream Rockwell Drive to 400 m upstream (November 8, 2017).

Steeper cascade habitat located approximately 250 m upstream Rockwell Drive.

Waterfall located approximately 400 m upstream Rockwell Drive.

Wildlife and Species of Concern

There were no sightings or evidence of any mammal or terrestrial invertebrate species during the surveys. Five species of birds were identified: American dipper (*Cinclus mexicanus*), bald eagle (*Haliaeetus leucocephalus*), common raven (Corvus corax), golden-crowned kinglet (*Regulus satrapa*) and pacific wren (*Troglodytes pacificus*). Because most song birds begin breeding in early to mid-April, all observed songbird species were assumed to be transitory or year-round residents.

The riparian forest habitat is composed of a young deciduous forest immediately adjacent to the creek channel and is dominated by big leaf maple (*Acer macrophyllum*) and red alder (Alnus rubra). This quickly transitions into a mature mixed forest comprised of western hemlock (*Tsuga heterophylla*), Douglas-fir (*Pseudotsuga menziesii*), western redcedar (Thuja plicata), big leaf maple and red alder with occasional remnant old-growth trees (Douglas-fir and western redcedar) interspersed. This forest type is characteristic of the Coastal Western Hemlock (CWH) biogeoclimatic zone. It is composed of a complex understory consisting of shrubs and saplings and moderate amounts of coarse woody debris (CWD) cover.

No species of concern were documented during the reconnaissance survey. TCS for coastal-tailed frog tadpoles and/or adults yielded no results, however; the riffle-pool morphology with occasional step-pool formations and the cobble and gravel substrates represent suitable habitat for this species. The presence of shallow riffle-pool habitat along the margins of the creek and unobstructed access to mature forest and associated shrub and CWD cover represents high quality Pacific water shrew habitat (Craig 2006).

No critical habitat features such as wildlife trees, mineral licks, song bird nests, stick nests, or animal dens were documented within the immediate vicinity of the creek during the reconnaissance survey. No bat hibernation or breeding potential was found.

RECOMMENDATIONS

Design

When choosing a new crossing structure, the design team should refer to the Fish-stream Crossing Guidebook (MFLNRO and DFO 2012) and swimming and jumping capabilities (Slaney and Zaldokas 1997) of salmonid species observed during this survey and documented within Trout Lake Creek (Pearson and Chiavaroli 2010). Swimming and jumping capabilities of salmonids documented in Trout Lake Creek are summarized in Table 3.

Table 3 Swimming and jumping capabilities for salmonid species documented in Trout Lake Creek (Slaney and Zaldokas 1997).

Species	Lifestage	Max Swimming Speed (m/s)			Max Jump Height (m)
		Sustained	Prolonged	Burst	
Coho	adults	2.7	3.2	6.6	2.4
	juveniles (120 mm)	-	0.6	-	0.5
	juveniles (50 mm)	-	0.4	-	0.3
Sockeye	adults	1.0	3.1	6.3	2.1
	juveniles (130 mm)	0.5	0.7	-	-
	juveniles (50 mm)	0.2	0.4	0.6	-
Chum/Pink	adults	1.0	2.3	4.6	1.5
Steelhead	adults	1.4	4.2	8.1	3.4
Cutthroat/Rainbow	adults	0.9	1.8	4.3	1.5
	juveniles (125 mm)	0.4	0.7	1.1	0.6
	juveniles (50 mm)	0.1	0.3	0.4	0.3

Weather the replacement structure is closed bottom, open bottom or clear span it is likely that step-pools will need to be constructed to address fish passage and stream gradient. The preferred pool-depth to jump-height ratio for salmonids is 1.25 or greater (Adams and Whyte 1990), whereby the depth of the downstream pool is 1.25 times the height of the upstream step (from surface of the water to crest of upstream step).

An option to consider for maintaining the high value plunge pool downstream of the culvert is to construct a Newbury style riffle at the outlet of the pool. The crest of the riffle would be designed to maintain existing depth of the pool once the invert elevation of the current culvert is lowered by the replacement structure. This style of riffle will maintain fish passage and create additional spawning habitat on the downstream side of the riffle (Newbury 2011).

Construction

It is recommended that a Construction Environmental Management Plan (CEMP) be developed to address items such as, but not limited to:

- Sediment and erosion control;
- Instream work window and fish salvage;
- Breeding bird windows and breeding bird surveys if required;
- Salvages for species at risk (i.e., Pacific tailed frog and Pacific water shrew);
- Spill management; and
- Environmental monitoring and reporting requirements.

Given the species documented to occur in Trout Lake Creek an instream least risk work window of August 1 to September 15 would be required (MOE 2006). The general breeding bird window for this region is from March 15 to August 15 (Environment Canada 2017). It is recommended that breeding bird surveys be conducted prior to construction if works are to proceed during this period. Although raptors were not observed during the survey it should be noted that these species have specific nesting periods not covered by the general breeding bird window. As such, a follow up survey to inspect for raptor nests should be conducted prior to construction.

Please contact me should you have any questions regarding this correspondence.

Sincerely,

Tim Poulton

Tim Poulton, RPBio, PBiol
Senior Environmental Specialist
HATFIELD CONSULTANTS

Encl. (1)

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Fish Habitat Inventory Site Card

Hatfield CONSULTANTS

Data Collectors Tim P. / Jason VR	**Date** NOV. 8, 2017	**Time (24h)** 1323	**Project** MOTI 8902	**Stream Name (Gazetted)** Trout Lake Crk.
Site Name US Rockwell Drive Culvert to 150m US	**Stream Name (Local)**		**Watershed Code**	
Reach #	**Site Length (m)** 150 m	**Fish Form** [✓ Yes] / No	**Field UTM Zone** 10	**Easting** 591364 · **Northing** 5466256
Cloud Cover (5%) 10	**Air Temp (°C)** 7	**Access/Safety Concerns** Slippery Rocks Deep Pools		

Flow Data	**Transect 1**			**Transect 2**			**Transect 3**		
Section Width	25%	50%	75%	25%	50%	75%	25%	50%	75%
Depth (m)									
Velocity (m/s)									
Section Length (m)	Wetted Width (m)	Depth at bankfull (m)		Wetted Width (m)	Depth at bankfull (m)		Wetted Width (m)	Depth at bankfull (m)	
Dom. Morph. (riffle/pool/run)	Cascade - Pool								

Flow Meter Type: — **Equip. No.:** — **Dom. Channel. Morph.** Riffle-Pool [✓ Cascade-Pool] Step-Pool Lg Channel

Morphology	**Transect** 1 (u/s)	2	3	4	5	6 (d/s)
Channel Width (m)	9.6	11.2	8.1	10.6	8.0	8.5
Wetted Width (m)	5.8	8.3	5.5	7.3	5.0	4.8
Max Pool Depth (m)	0.18	0.82	0.40	0.25	0.55	0.32
Bankfull Channel Depth						

Equipment type: Eslon Tape **Equipment No.:**

Slope (%)	
centre to 50 m u/s	5
centre to 50 m d/s	4
Left bank	60
Right bank	80
Equipment type:	Clino
Equipment No.:	

Stage: Low / [✓ Mod] / High No Vis. Ch. ☐ Dry/Int. ☐ Dewatering ☐ Tribs ☐

Cover[1] (Total 100%) Total	**SWD**	**LWD**	**Boulder**	**Under-cut Bank**	**Deep Pool**	**O/h Veg. (<1 m fr water)**	**Instr. Veg.**
Cover (%) 65	5	5	50	10	20	10	0
Loc. (P, S, O)	P	P	P	P	P	P	P

P=Primary, S=Secondary, O=Off-channel **Instr. Veg. :** None [✓ Algae] Mosses Vascular

~~[1]See back of sheet for visual reference~~

Flood Signs? [✓ Yes] / No Recent [✓ Old]

Crown Closure (%) 0 1-20 [✓ 21-40] 41-70 71-90 >90

Functional LWD (circle) None [✓ <1 per Bankfull Width] >1 per Bankfull Width

Bed Material	
Dominant	Gravel
Subdominant	Cobble
D_{95} (~~cm~~) m	0.4

Channel Composition Riffle (%)	Pool (%)	Run (%)	Cascade (%)
5	40	5	50

Right Bank Circle - 1 for Shape, up to 2 for Texture
Shape Undercut [✓ Vertical/Steep] Gradual Overhanging
Texture Fines Gravel [✓ Cobble] Boulder Bedrock Anthro

Left Bank Circle - 1 for Shape, up to 2 for Texture
Shape Undercut [✓ Vertical/Steep] Gradual Overhanging
Texture Fines Gravel Cobble [✓ Boulder] Bedrock Anthro

Riparian Zone (30 m) buffer (circle)
Airport (noise) Fence Dump Logging
Mining Road (1 / 2 / 4 lanes) Railway
Urban Power Lines Gas Line Cultivated Field
Forest: Old / [✓ Mature] / Young / Comm. Thinned
Coniferous Deciduous [✓ Mixed]
Clearcut Herbaceous Clearcut Shrubby
[✓ Shrubs] Grasses Sedges Flooded
Other:

Landscape (beyond 30 m buffer) (circle)
Airport (noise) Fence Dump Logging
Mining Road (1 / [✓ 2] / 4 lanes) Railway
[✓ Urban] Power Lines Gas Line Cultivated Field
Forest: Old / [✓ Mature] / Young / Comm. Thinned
[✓ Coniferous] Deciduous Mixed
Clearcut Herbaceous Clearcut Shrubby
[✓ Shrubs] Grasses Sedges Flooded
Other:

Disturbance Indicators (circle)
Aband. Ch. [✓ Eroding Bks] Avulsions
SWD LWD Dist. Stone Lines Invasives[1]
Homo. Bd. Txt. Sed. Fingers Sed. Wedges
Ext. Bars Ext. Scour Beaver Dams
Min. Pool Area Mult./Braided Ch. LWD Jams
Ext. Riffles/Cascades Elev. Mid-Ch. Bars

[1] Describe on Back

Confinement (circle): Entrenched Confined [✓ Freq. Confined] Occ. Confined Unconfined N/A

~~**Islands**~~ (circle): None [✓ Occasional] Frequent, Irreg. Frequent, Reg. Split Anastom.

Channel Pattern (circle): Irreg. Meand. Reg. Meand. Tort. Meand. Straight [✓ Sinuous] Irreg. Wand.

Coupling: [✓ Decoupled] Partially Coupled Coupled

***In Situ* Water Parameters**		**Equipment No.**	**Calibration Date**
Sample Depth (m)	0.3		
Dissolved O_2 (%)			
Dissolved O_2 (mg/L)	12.2	Titration	
Temp (°C)	5	Hanna	Pen
pH	6.8	Hanna Pen	
Cond. (µS/cm)	55		
Turbidity (NTU)			
Sample Time:		Requisition? Yes / [✓ No] Requisition No.:	

Barriers Description	**Zone**	**Easting**	**Northing**
8 m Water Fall	10	591633	5466352

Recorded by: Tim Poulton Signature: TLP

Adapted from RISC Standards