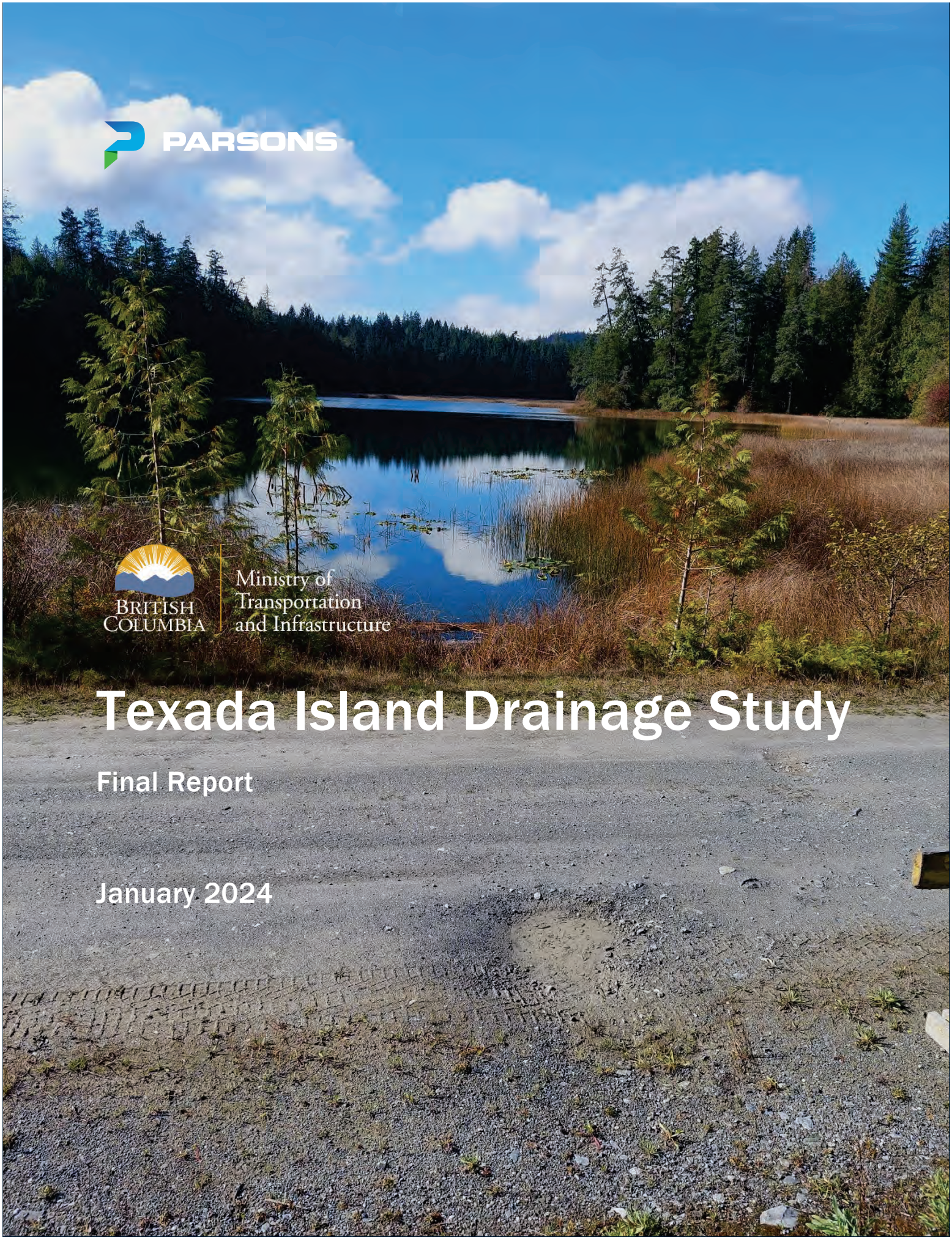

Texada Island Drainage Study

Final Report

January 2024

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1. Introduction

Parsons was retained by the Ministry of Transportation and Infrastructure (MoTI) of British Columbia to undertake engineering services for a drainage study on Texada Island. The purpose of the study was to assess the condition and vulnerability of six priority areas, which cover culvert crossings along major traveling routes.
The primary objectives of the study were as follows:

- Conduct field assessments for each identified priority area, including condition assessment and noticeable problems on site;
- Conduct a hydrologic analysis for the major watersheds and calculate design peak flows for the major streams;
- Conduct a hydraulic analysis using HY-8 for each culvert crossing from the priority areas and additional areas noted from the field assessments;
- Develop new proposed drainage improvement recommendations for each stream crossing with an identified condition or calculated hydraulic efficiency based on current MoTI design criteria; and
- Provide a high-level conceptual cost estimate for the proposed drainage improvements.

In addition to the six priority sites, major arterial roads were included as part of the field condition assessments for major culvert crossings.

This document summarizes the project background, the field assessment, hydrologic and hydraulic assessment, proposed drainage improvement recommendations and cost estimate.

1.1 Project Area

Texada Island is located between the Sunshine Coast of the Mainland and Vancouver Island. Two small communities are situated on the island, Van Anda and Gillies Bay, with an estimated total population of 1,100 permanent residents according to the ***2021 Canadian Census***[1]. The island is accessible from the mainland through the only ferry terminal "Blubber Bay" at the northern tip of the island, that connects with the Blubber Bay Road and other main roads including Gillies Bay Road, Central Road, Airport Road, Bell Road, and other major roads operated by the MoTI. Based on ***iMapBC***[2], the MoTI has over 400 culverts located on Texada Island mostly along major arterial roads.

The MoTI has identified six locations along major traveling routes with drainage issues on Texada Island, shown in Figure 1 below.

[1] 2021 Census of Population Geographic Summary, https://www12.statcan.gc.ca/census-recensement/2021/search-recherche/productresults-resultatsproduits-eng.cfm?LANG=E&GEOCODE=2021A00055927018 (accessed on 27.11.2023)
[2] iMapBC, https://www2.gov.bc.ca/gov/content/data/geographic-data-services/web-based-mapping/imapbc (accessed 27.11.2023) (British Columbia)

FIGURE 1: OVERVIEW MAP OF AREAS OF PRIORITY AREAS

A summary of the background and history for each priority area are listed below:

Priority Area 1: Van Anda Creek at Van Anda Avenue

- Prior high flow events led to a smaller road embankment failure (see Photo 1).
- The culvert crossing has been identified, as being potentially undersized, as it operates frequently at full capacity (see Photo 2).
- The Van Anda Improvement District (VID) noted that a previous maintenance attempt of the culvert had to be abandoned, due to concerns of the failure of the culvert from the maintenance works.

PHOTO 1: AREA 1 - ROAD EMBANKMENT FAILURE (MOTI, MARCH 2022)

PHOTO 2: AREA 1- FULL FLOW (VID, NOVEMBER 2023)

Priority Area 2: Marble Road in Van Anda

- Nuisance flooding due to a lack of drainage along the southside of Marble Road between Gillies Bay Road and Para Street.
- The VID notes that an existing catch basin is plugged, and a new ditch has been installed without showing improvements.

Priority Area 3: Priest Lake at Gillies Bay Road

- The culvert crossing has been identified, as being potentially undersized and impacting fish passage.
- A previous blockage of the culvert had to be removed by a specialized diving team, as the culvert was completely submerged.

Priority Area 4: Airport Road

- A new crossing culvert under Airport Road was installed by the MoTI's maintenance contractor, Capilano Highways, in response to flooding in November 2021 with a noted deficiency of crossing culverts along Airport Road.
- An additional driveway culvert was installed under the driveway to the tennis court at Gillies Bay Road south of the intersection with Airport Road (see Photo 3) in response to the flooding in November 2021.

Priority Area 5: Cranby Creek at Gillies Bay Road

- Culvert crossing and surrounding areas were flooded during the November 2021 event (see Photo 4).
- Gillies Bay is situated in a known floodplain and at risk from riverine flooding and sea level rise.

Priority Area 6: Staaf Creek at Bell Road

- Staaf Creek immediately upstream of the culvert crossing is eroding the parallel road shoulder on a 50 m long section with flooding of the road.

PHOTO 3: AREA 4 - OVERFLOW OF DRIVEWAY CULVERT (MOTI)

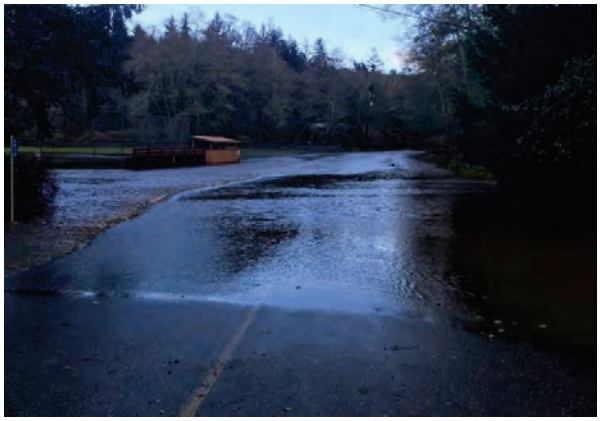

PHOTO 4: AREA 5 - FLOODING OF SCHOOL RD NEAR GILLIES BAY RD (MOTI)

It is understood that the MoTI has no existing record drawings for the culvert crossings in the six priority areas.

1.2 Previous Reports

A number of previous reports covered the drainage study area with additional information which are listed below:

Powell River Regional District Landslide and Fluvial Hazards Study Electoral Area D – Texada Island (Tetra Tech, 2016[3]):

- *"The study area of [Texada Island] is entirely within the Coastal Douglas Fir biogeoclimatic zone and experiences relative warm, dry summers and mild, wet winters."*
- *"Watercourses within the study area will typically experience their annual peak flow between October and February, coinciding with the autumn and winter rain and/or rain-on-snow storm events."*
- Estimated peak flows by the study were as follows:
  - Priest Creek [Van Anda Creek]: 6.6 km^2 drainage area, Q_{100} = 5.0 m^3/s, Q_{200} = 5.4 m^3/s;
  - Cranby Creek: 4.0 km^2 drainage area, Q_{100} = 7.5 m^3/s, Q_{200} = 8.2 m^3/s;
- HEC-RAS 2D Flood depths for Q_{200} at the centreline were as follows:
  - Priest Creek [Van Anda Creek] Downstream of Priest Lake = 0.2 to 2.0 m;
  - Priest Creek [Van Anda Creek] Downstream of Emily Lake = 2.5 to 3.0 m;
  - Cranby Creek = 0.2 to 1.8 m.

Watershed Assessment (CWAP) for Priest Lake, Texada Island, BC – Final Report (EBA Engineering, 2000)[4]:

- The Priest Lake watershed was calculated to be 1,131 ha while the Rational Method calculated an estimated peak flow of 19 m^3/s at the Priest Lake outlet.
- The mean annual discharge for Priest Lake was estimated at around 0.147 m^3/s based on unit discharge estimates.
- *"On Texada Island, the dominant hydrologic process is generated by rain and, less commonly, rain-on-snow. Low flow periods occur in the summer between May and October. Peak flow periods occur in the winter between November and January."*
- *"There are barriers to fish passage below Priest Lake, including the culvert beneath Gillies Bay Road itself. There are resident fish in Priest Lake, which means that resident fish may populate all low gradient (i.e. less than 20% gradient) streams, and lakes, in the watershed. A rare unique species of stickleback, called Vananda Limnetic Stickleback [...] has been recorded in Emily Lake, Priest Lake, and Spectacle Lake."*

Water System Assessment Study Report (McElhanney, 2008)[5]:

- *"The depth of Priest Lake is nominally 10 m at the location of the intake, and the water surface elevation can be expected to fluctuate over a range of 0.7 m during the course of the operating year."*

[3] Powell River Regional Strict – Landslide and Fluvial Hazard Study – Electoral Area D – Texada Island, for Powell River Regional District, Tetra Tech EBA (2014)
[4] Watershed Assessment (CWAP) for Priest Lake, Texada Island, BC – Final Report, for Ministry of Forests, Sunshine Coast Forest District, EBA Engineering Consultants Ltd (2000)
[5] Van Anda Improvement – Water System Assessment Study Report, McElhanney Consulting Services Ltd. (2008)

2. Field Assessment

Parsons conducted a site visit on October 12 and 13, 2023 to visually inspect the condition of the culvert crossings within the identified six priority areas, as well as assessing the overall drainage within the areas. Additionally major culverts with a diameter greater than 900 mm were inspected along the major routes travelled between the priority areas. In total 27 culverts were visually inspected, as well as Marble Road and Airport Road were assessed for potential drainage issues.

Please refer to Appendix A for an overview map of the inspected culverts and their assessed visual condition.

2.1 Field Assessment - Priority Areas

In the following are summaries of the observations and assessments made for the six priority areas identified by the MoTI from October 12 and 13, 2023.

2.1.1 PRIORITY AREA 1: VAN ANDA CREEK @ VAN ANDA AVE

- Twin 900 mm CSP culvert (CHRIS: 2257630 & 2257631, “Culvert 2”) with improvised headwalls and wingwalls at the inlet and outlet from concrete roadside barriers (CRBs).
- Both culvert pipes appeared to be heavily corroded with damaged inlets.
- The lack of a proper headwall led to scour at the inlet between both pipes with the potential for piping.
- The CRBs were placed directly on top of the unprotected pipes creating an uneven load.
- Sediment and vegetation at the outlet blocked about 25% of the overgrown downstream channel.
- Tension cracks are visible on the pavement above along both sides of the culvert crossing indicating settlement and potential piping.
- The culvert pipes appeared to be overall in poor condition and are recommended to be replaced.
- The culvert crossing is signed as fish-bearing.

Refer to Appendix B for the MoTI Culvert Inspection Form and site photos.

2.1.2 PRIORITY AREA 2: MARBLE ROAD

- A big puddle on the southside of 2058 Marble Road extending half into the lane was visible, potentially impacting traffic. An existing 450 mm CSP culvert (CHRIS: 2257259) immediately west conveying a small creek under Marble Road was inspected and found to be in fair condition.
- A circular 600 mm wood stave culvert (CHRIS: 3442931) was inspected crossing Marble Road west of Colburn Street and found in fair condition with significant flow at the time of inspection.
- A 600 mm CSP culvert that has been extended with a 450 mm HDPE pipe next to the Texada Island Boat Yard has been inspected and found to be in fair condition.

Refer to Appendix C for the inspection site photos.

2.1.3 PRIORITY AREA 3: PRIEST LAKE @ GILLIES BAY ROAD

- A single 1200 mm CSP culvert (CHRIS: 3442936, “Culvert 3”) was found connecting Priest Lake with a downstream pond and Van Anda Creek.
- The culvert crossed both the gravel Priest Lake Road and the paved Gillies Bay Road.
- The culvert was completely submerged at the inlet and 75% full at the outlet during the inspection, with no apparent flow through the culvert. The perceived water level difference between inlet and outlet suggests a potential blockage of the culvert. Large woody debris and reeds were present at the upstream and downstream.

- The visible portion of the culvert outlet appeared to be corroded with damaged coating. The overall culvert condition was not assessed due to the limited inspection.
- The downstream water level appeared to be steady and high, indicating that the culvert does not operate under free flow condition but with backwater from the downstream.

Refer to Appendix B for the MoTI Culvert Inspection Form and site photos.

2.1.4 PRIORITY AREA 4: AIRPORT ROAD

- The recently installed 600 mm CSP cross-culvert by Capilano Highway was visually inspected, about a 160 m north of the water storage tank (49.683790°N, 124.494663°W).
  - The culvert was built skewed with a small riprap check dam at the inlet to divert flows into the crossing culvert and convey flows into the forest on the northside of Airport Road.
  - The culvert appeared to have insufficient cover of less than 15 cm and a very poorly constructed pavement restoration with potholes, cracks, and settlement around the pipe.
  - The culvert pipe alignment is bent with minor pipe joint separation visible. The overall culvert condition appeared to be fair.
- A 300 mm CSP culvert (CHRIS: 2258675) was inspected at the water tank driveway with a heavily corroded pipe invert and in poor condition.
- A 450mm DI culvert was inspected south of the water tank with only surficial corrosion and in overall fair condition (49.682369°N, 124.490133°W).
- The western roadside ditch along Airport Road showed multiple locations with visible erosion and scour, likely from the high flows in the ditch due to the high slope between the water tank and Pine Street.
- A 600 mm CSP culvert (CHRIS 2256637) crossing under Pine Street was inspected with visible corrosion of the pipe invert and a damaged inlet but overall, in a fair condition.
- A 300 mm CSP culvert (CHRIS: 2256020) crossing under Airport Road and conveying the roadside ditch flows along the westside of Gillies Bay Road. The culvert showed localized corrosion but appeared to be in fair condition.
- A twin 600 mm CSP culvert was inspected under the driveway for the Tennis Court along Gillies Bay Road between Airport Road and Sanderson Road (49.681761°N, 124.485961°W).
  - The western pipe appeared to be recently installed and in good condition. The pipe appeared not be fully aligned with the ditch.
  - The eastern pipe appeared to be older with significant corrosion and loss of material and in poor condition.
  - Erosion and scour were visible at the inlet and the outlet of the culverts.
- A 525 mm CSP culvert (CHRIS: 2258625) was inspected crossing under Sanderson Road.
  - The culvert had significant corrosion of the pipe invert with complete loss of material. It appeared to be in poor condition.
  - The location of the culvert just downstream of the twin 600 mm CSP appears significant for its compared small conveyance capacity and may indicate that the culvert is undersized.

Refer to Appendix C for the inspection site photos.

2.1.5 PRIORITY AREA 5: CRANBY CREEK @ GILLIES BAY ROAD

- A single 1500 mm CSP culvert transitioning to a 1200 mm CSP culvert (CHRIS: 2256032) was found at the Cranby Creek crossing Gillies Bay Road.
- The transition from the 1500 mm CSP to 1200 mm CSP appeared to be about 3 m upstream of the outlet with a visible skew and joint separation. It appeared that only 2/3 of the pipes were aligned and riprap from the outlet embankment was visible at the joint.

- The culvert invert was visibly corroded with localized significant material loss.
- The culvert appeared to be overall in poor condition and is recommended to be replaced.
- The culvert outlet is next to the confluence of Trout Creek coming from the east and close to the estuary of Cranby Creek.

Refer to Appendix B for the MoTI Culvert Inspection Form and site photos.

2.1.5 PRIORITY AREA 6: STAAF CREEK @ BELL ROAD

- A single 1,800 x 1,000 mm CSP arch-pipe culvert (2254782) was found at the crossing of Staaf Creek and Bell Road.
  - The culvert showed major buckling and significant corrosion of the pipe invert.
  - The small flow present during the inspection did not appear to flow through the inlet or outlet of the culvert but appeared behind the inlet in the middle and disappeared before the outlet, with flow visible underneath the pipe.
  - The outlet road embankment appeared steep and unstable with the road gravel eroding into the channel.
  - The headwall concrete bags had mostly failed, showing cavities around the inlet.
  - The culvert appeared to be overall in poor condition.
- Major erosion and active undermining were visible at the south bank of Staaf Creek next to Bell Road along two sections, estimated together at around 25 m. Signs of recently placed fill, rocks and riprap were visible.

Refer to Appendix B for the MoTI Culvert Inspection Form and site photos.

2.2 Additional Inspections

Additionally, 11 other culverts were inspected along major roads, generally with a pipe diameter of 900 mm or larger during the October 12 and 13, 2023 site visits. A short summary of the visual inspection findings can be found in Table 1 below. Please refer to Appendix C for site photos.

TABLE 1: ADDITIONAL INSPECTIONS SUMMARY TABLE

CULVERT	NOTES
Culvert 1 – Blubber Bay Road (CHRIS ID: 2254949)	• 900mm CSP culvert, appears overall in fair condition. • Inlet damaged, pipe invert corroded and most of pipe coating is lost. • Inlet grate damaged and not attached to the inlet. • Pipe transitions from galvanized heavily corroded CSP at the inlet to coated CSP with minor corrosion.
Culvert 4 – Gillies Bay Road (CHRIS ID: 2256045)	• 1050mm CSP culvert, appears overall in fair condition. • Lower half of the culvert corroded with woody debris in the pipe. • Culvert outlet not inspected as heavily overgrown.
Culvert 5 – Gillies Bay Road (CHRIS ID: 2256047)	• 1200mm CSP culvert, appears overall in fair condition. • Pipe coating mostly intact but starting to fail on both sides. • Minor pipe joint separation and debris within pipe. • Road embankment erosion at the outlet.
Culvert 6 – Gillies Bay Road (CHRIS ID: 2256019)	• 1050mm CSP culvert, appears overall in fair condition. • Pipe joint separation at the middle of the culvert. • Gravel and rock debris present ~15%.
Culvert 7 – Sanderson Road (CHRIS ID: 2258625)	• 525mm CSP culvert, appears overall in poor condition. • Pipe invert completely corroded away, and underlying sediment partly washed out. • Pipe likely undersized, as it drains Airport Rd and Gillies Bay Rd.
Culvert 9 – Shelter Point Road (CHRIS ID: 2256424)	• 1200mm CSP, appears overall in fair condition. • Woody debris at inlet. Pipe coating appears to be mostly intact. • Plunge pool present at the outlet with minor scour.
Culvert 11 – Bell Road (CHRIS ID: 2254788)	• 900mm CSP, appears overall in good condition. • Inlet and outlet bend. • Road embankment at outlet unstable, eroding the gravel road.
Culvert 12 – Central Road (CHRIS ID: 2255061)	• 1200mm CSP, appears overall in poor condition. • Major buckling at 12 o'clock and significant pipe joint separation in the pipe middle. • Pipe coating mostly intact.
Culvert 13 – Central Road (CHRIS ID: 3442926)	• 1050mm CSP, appears overall in good condition. • Active flow present during inspection. • Pipe coating mostly intact with only minor corrosion.
Culvert 14 – Central Road (CHRIS ID: 3442927)	• 1050mm CSP, appears overall in fair condition. • Minor pipe joint separation. • Pipe coating mostly intact
Culvert 15 – Central Road (CHRIS ID: 2255027)	• 2200 x 1350mm CSP arch-pipe, appears overall in fair condition. • Notable corrosion and abrasion of the pipe invert with notable local material loss. • Bank erosion downstream of the culvert. • Gravel potholes present on top of the culvert.

3. Hydrologic & Hydraulic Assessment

A hydrologic and hydraulic assessment was conducted for the priority area culvert crossings to assess if their existing capacity meets the current MoTI design criteria. An overview of the design criteria used in this report is given in Table 2 below.

TABLE 2: DESIGN CRITERIA (SUPPLEMENT TO TAC[6])

CATEGORY	DESIGN CRITERIA
Culvert on Natural Watercourse	• Design Return Period: 200-Year + CC • HW/D ≤ 1.0
Culvert on Drainage Ditch	• Design Return Period: 100-Year + CC • HW/D ≤ 1.0
Stream/ Drainage Ditch (unprotected)	• Flow Velocity ≤ 1.2 m/s

The ArcGIS Pro software was used to delineate the catchment for each culvert crossing for the priority areas based on available Digital Elevation Model (DEM) data, a Regional Flood Frequency Analysis was used to estimate the individual design peak flows and the HY-8 software was used to calculate the culvert hydraulics for each crossing of the existing and new proposed culvert geometry.

3.1 Hydrologic Assessment

Texada Island is located between the Sunshine Coast and Vancouver Island, with the Strait of Georgia to the west and the Malaspina Strait to the east. The island has a substantial height profile with a mix of low-lying flats on the shoreline and higher mountains mostly covered by forest. Some areas along the north of the island have been substantially altered through open pit mining activities. The island has a substantial amount of smaller and larger lakes which vary between natural and human-influenced.

To delineate the catchments for each priority area culvert crossing, the open-source DEM raster data from ***LidarBC***[7] with a resolution of 1 m x 1 m, dated 2019, was used in combination with the ArcGIS Pro (Ver. 2.9.5) software. First the DEM had to be hydrologically conditioned, where artificial dams from culvert crossing had to be adjusted that the correct flow path was calculated. A summary of the delineated catchments can be found in Table 3 below and an overview of the catchments and the topography, as well as the calculated stream flow paths and stream order in Appendix D.

Van Anda Creek is one of the major watercourses of the island and is fed by four major lakes, Emily Lake, Priest Lake, Spectacle Lake, and Kirk Lake and has its estuary in the Van Anda Cove, just 340 m downstream of the culvert crossing at Van Anda Avenue. It has a catchment of more than 15 km^2 with an elevation profile between 300 m and sea level. As mentioned, it is connected with the upstream Priest Lake, which itself is fed by the upstream Spectacle Lake and Kirk Lake. Priest Lake is an active water reservoir for the Van Anda Improvement District (VID) servicing Van Anda residents. The culvert crossing at Gillies Bay Road is acting mostly as a connection of Priest Lake with its downstream pond extension and flow management structure in form of a concrete weir that controls the lake's water level (see Photo 5 and Photo 6). The downstream pond acting as an extension of Priest Lake up to the weir, is a noted sensitive habitat for the painted turtle and stickleback. The weir crest elevation is estimated to be higher than the culvert under Gillies Bay Road, leading to a backwater for the culvert crossing for most time of the year.

[6] Supplement to TAC Geometric Design Guide, Ministry of Transportation and Infrastructure British Columbia (2019)
[7] LidarBC - Open LiDAR Data Portal, Province of British Columbia, https://lidar.gov.bc.ca/pages/download-discovery (accessed October, 2023)

PHOTO 5: PRIEST LAKE WEIR DURING DRY PERIOD (VAN ANDA IMROVEMENT DISTRICT)

PHOTO 6: PRIEST LAKE WEIR DURING WET PERIOD (VAN ANDA IMROVEMENT DISTRICT)

Cranby Creek is another major watercourse of the island with a catchment of more than 9 km^2 and lies northwest from Gillies Bay. It is partially fed by Cranby Lake, which is a water reservoir managed by the Gillies Bay Improvement District with a dam and spillway (see Photo 7). Cranby Creek crosses Gillies Bay Road downstream of the lake, confluences with a smaller arm and crosses Gillies Bay Road again in Gillies Bay before the confluence with Trout Creek and outflowing into the estuary in Gillies Bay. The culvert crossing in Gillies Bay is very low and likely tidally influenced.

PHOTO 7: ORTHOGRAPHIC IMAGE OF CRANBY LAKE DAM AND SPILLWAY (ESRI)

Trout Creek has a catchment size of more than 12 km^2 and is located east of Gillies Bay before confluencing with Cranby Creek in Gillies Bay. Trout Creek's catchment is separated by the catchment of Staaf Creek and Mount Pocahontas. Staaf Creek is another major watercourse and a side stream of Mouat Creek, with a catchment size at the Bell Road culvert crossing of more than 4 km^2. The catchment is separated by the catchment of Russ Creek to the north, Trout Creek to the west and Muoat Creek to the south.

TABLE 3: CALCULATED CATCHMENT AREA SUMMARY

SITE	CATCHMENT AREA (ha)
Priority Area 1: Van Anda Creek @ Van Anda Avenue	1,543.1
Priority Area 2: Unknown Creek @ Marble Road	13.7
Priority Area 3: Priest Lake @ Gillies Bay Road	1,189.9
Priority Area 4-1: Airport Road Crossing Culvert	5.1
Priority Area 4-2: Gillies Bay Road Driveway Culvert	96.6
Priority Area 4-3: Sanderson Road @ Gillies Bay Road	98.6
Priority Area 5-1: Cranby Creek @ Gillies Bay Road	947.9
Priority Area 5-2: Trout Creek @ Gillies Bay Road	1,230.5
Priority Area 6: Staaf Creek @ Bell Road	420.5

3.1.1 REGIONAL FREQUENCY ANALYSIS

As the calculated catchment size for Priority Area 1, 3, 5-1, 5-2 and 6 are close to or larger than 10 km^2, a Regional Frequency Analysis was conducted to estimate the design peak flows for each site, as no long-term flow gauges were available on any of the creeks or in general on Texada Island. Five river gauges with similar catchment characteristics to Texada Island were considered for the Regional Station Frequency Analysis, but only one was chosen for the Generalized Extreme Value Analysis (GEV) based on the annual instantaneous extreme flows. The other river gauges were not used, as they were located too far away with a different rainfall characteristic, or they were located in more urban environments. Refer to Table 4 for an overview over the assessed river gauges and notes of their characteristics in comparison to Texada Island.

TABLE 4: RIVER GAUGE OVERVIEW

RIVER GAUGE #	RIVER GAUGE NAME	CATCHMENT AREA (km²)	DISTANCE (km)	NOTES:
08HB029	Little Qualicum River near Qualicum Beach	237	42	Located relatively close to Texada Island on east Vancouver Island with a long record. Rainfall characteristic is comparable but not equal to Texada Island, as it is the east coast of Vancouver Island. Catchment is substantially larger with a rural residential use downstream and a large lake and mountainous catchments upstream. Catchment characteristic is somewhat comparable but much larger and more mountainous potentially leading to a higher flood-frequency response curve.
08GA061	Mackay Creek at Montroyal Boulevard	3.6	109	Located far away in North Vancouver in a relatively urban catchment. Rainfall characteristics not comparable due to location in North Vancouver. Catchment predominantly urban with some forest and steep slopes without any lakes. River gauge not comparable to Texada Island.
08GB007	Lang Creek near Powell River	128	13	Located close to Texada Island on the Sunshine Coast with a long record of historic flows 1959 to 1995. Similar rainfall characteristic due to proximity. Catchment is a mix of forest and cleared forest with some lakes and mountain catchments upstream. Catchment appears comparable to most of Texada Island.
08MH006	North Alouette River at 232nd Street	37.3	135	Located far away in Maple Ridge in a more urban catchment. Rainfall characteristic not comparable to Texada Island. Catchment is a mix of urban and forest with mountainous catchments and a minimal number of lakes. River gauge not comparable to Texada Island.
08MH018	Mahood Creek near Newton	18.4	136	Located far away in Surrey in a completely urban catchment. Catchment predominantly urban in the centre of Surrey without mountainous catchments and without lakes. River gauge not comparable to Texada Island.

Based on the observations and comparison the river gauge of Lang Creek (08GB007) was chosen to be the most representable River Gauge for Texada Island due to the close proximity on the Sunshine Coast and a very similar catchment with a mix of forested low-lying areas and upstream mountainous areas with some larger upstream lakes.

An Extreme Value Analysis (EVA) was conducted for the river gauge of Lang Creek to analyze and calculate the Flood-Frequency Response Curve of it. The Flood Frequency Response Curve was than transposed to the individual creek in question on Texada Island. A summary of the conducted Extreme Value Analysis (EVA) for the river gauge of Lang Creek can be found in Appendix G. The resulting Flood-Frequency curve is summarized below in Figure 2.

The transposition of flood discharges following the ***Drainage Design Manual***[8] was used in combination with the ***Guide to Bridge Hydraulics***[9] to transpose the historic Flood-Frequency curve from Lang Creek to the various creeks on Texada Island using an exponent n of 0.8. The transposition of flood discharge equation is summarized below, where Q_1 and Q_2 are the discharge flows of the Lang Creek and the various creeks and A_1 and A_2 their respective catchment sizes. The resulting 100-year and 200-year peak design flows for each culvert crossing were calculated and are shown in Table 5 below.

$$Q_2 = Q_1(A_2/A_1)^n$$

[8] Drainage Manual, Section 2.5.4 (Pg. 2.33), Roads and Transportation Association of Canada (1982)
[9] Guide to Bridge Hydraulics, Table 3.3 (Pg. 40), Transportation Association of Canada (2001)

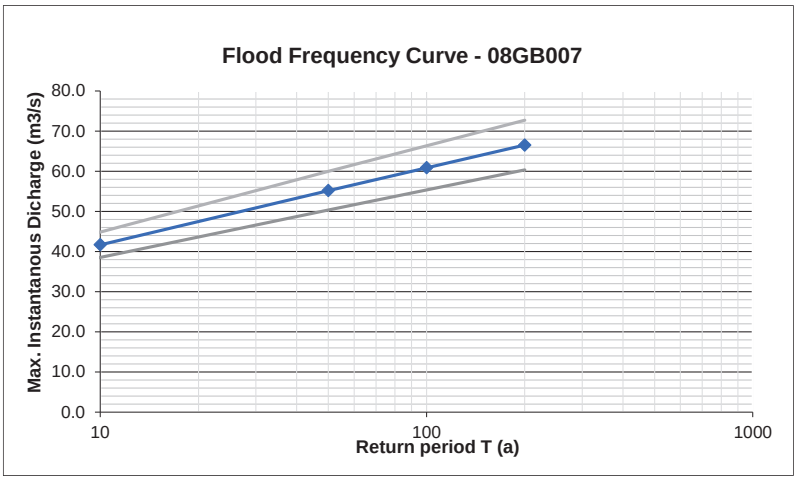

FIGURE 2: 08GB007 - LANG CREEK FLOOD FREQUENCY CURVE

Climate change increase was accounted for by an adaptation factor for the calculated peak design flows. The factor was derived from the comparison of the historic IDF precipitation for Powell River (1046392) for 100-year 24-hour of 80.86 mm and the projection for the bias corrected Coupled Model Intercomparison Project 6 (CMIP 6) and Global Climate Models (GCMs) for the SSP 5.85 scenario from the ***IDF_CC Tool 6.5***[10] of 98.19 mm. The climate change adaption factor was calculated to be +22%, which was added to the peak design flows considered by this study.

TABLE 5: TRANSPOSED PEAK DESIGN FLOWS

CULVERT CROSSING	CATCHMENT SIZE (km^2)	WITHOUT CLIMATE CHANGE		WITH CLIMATE CHANGE (+22%)	
		Q100 PEAK FLOW (m^3/s)	Q200 PEAK FLOW (m^3/s)	Q100 PEAK FLOW (m^3/s)	Q200 PEAK FLOW (m^3/s)
Van Anda Creek @ Van Anda Ave	15.4	11.18	12.23	13.65	14.92
Priest Lake @ Gillies Bay Rd	11.9	9.10	9.95	11.10	12.14
Cranby Creek @ Gillies Bay Rd	9.5	7.60	8.31	9.27	10.14
Trout Creek @ Gillies Bay Rd	12.3	9.35	10.22	11.40	12.47
Staaf Creek @ Bell Rd	4.3	4.03	4.41	4.92	5.38

3.1.2 RATIONAL METHOD

The rational method was used for the Priority Areas with smaller catchments including Priority Area 2, 4-1, 4-2, and 4-3. The land use for the Rational Method was delineated for each catchment between forest, impervious for roads and rural based on the orthographic images for each catchment. The time of concentration for each site was calculated based on the Water Management Method between 0.90 and 3.63 hours. The IDF coefficients were taken from Powell River (1046392) station from the ***IDF_CC Tool 6.5*** including historic and future IDF coefficient with accounting for climate change. Please refer to Appendix E for the calculation spreadsheet of the Rational Method.

[10] Simonovic, S.P., A. Schardong, R. Srivastav, and D. Sandink (2015), IDF_CC Web-based Tool for Updating Intensity-Duration-Frequency Curves to Changing Climate – ver 6.5, Western University Facility for Intelligent Decision Support and Institute for Catastrophic Loss Reduction, https://www.idf-cc-uwo.ca (accessed October, 2023)

An overview of the calculated design peak flows for each culvert crossing of the Priority Areas can be found in Table 6 below.

3.2 Hydraulic Assessment

The hydraulic assessment used the calculated design peak flows from Section 3.1 with the existing culvert geometry from the field assessments. The HY-8 (Ver. 7.60) software was used to calculate the headwater depth to diameter ratio (HW/D) for the existing culverts to assess if the culverts are adequately sized for the new design flows with accounting for climate change. Refer to Appendix H for a summary of the HY-8 calculations.

The stream channel slope, channel geometry and culvert dimensions were based on the field assessment observations, while the pipe inverts and road elevation were based on the LiDAR DEM elevations. A Manning's coefficient of 0.035 was assumed for the natural creek bed. The road elevation was artificially raised in order to calculate the HW/D in HY-8 without using the weir flow over the road crest. A summary of the existing culverts, design peak flow, the existing dimensions and the calculated HW/D can be found in Table 6 below.

TABLE 6: CALCULATED DESIGN PEAK FLOWS

SITE	DESIGN CRITERIA	DESIGN PEAK FLOW (m3/s)	EX. CULVERT	HW/D
Priority Area 1: Van Anda Creek @ Van Anda Avenue	Q200+CC	14.92	2x 900 Ø CSP	2.4
Priority Area 2: Unknown Creek @ Marble Road	Q100+CC	1.17	450 Ø CSP	30.0
Priority Area 3: Priest Lake @ Gillies Bay Road	Q200+CC	12.14	1,200 Ø CSP	18.6
Priority Area 4-1: Airport Road Crossing Culvert	Q100+CC	0.28	600 Ø CSP	1.0
Priority Area 4-2: Gillies Bay Road Driveway Culvert	Q100+CC	2.99	2x 600 Ø CSP	9.2
Priority Area 4-3: Sanderson Road @ Gillies Bay Road	Q100+CC	3.03	525 Ø CSP	50.0
Priority Area 5-1: Cranby Creek @ Gillies Bay Road	Q200+CC	10.14	1,500/1,200 Ø CSP	13.1
Priority Area 5-2: Trout Creek @ Gillies Bay Road	Q200+CC	12.47	1,800 x 1,200 arch-pipe CSP	8.7
Priority Area 6: Staaf Creek @ Bell Road	Q200+CC	5.38	1,800 x 1,200 arch-pipe CSP	2.0

We note that it is possible some of the flows for Priority Areas 2 and 4-3 are diverted from the catchment areas. The catchment areas are delineated based on the DEM and it is unknown whether flow diversions, such as drainage ditches, are present. These calculations should be viewed as conservative results and more detailed hydrologic and hydraulic assessments should be conducted during a later stage of preliminary design.

For the erosion and capacity concerns for Priority Area 6 at the upstream of Staaf Creek with impact on Bell Road, the OpenFlows FlowMaster (Ver. 10.03) software from Bentley was used to assess the creek water levels and velocities during the design peak flows. Staaf Creek appears to have a channel slope of about 6% and was assumed to have a channel bottom width of about 2.0 m width and 1:1 side slopes upstream of the existing culvert. The resulting normal water depth was calculated to be about 0.56 m with an average flow velocity of 3.78 m/s, which is assumed to likely cause erosion along the loose gravel and rocks present in the creek and along the embankment. An overflow of the channel was not calculated, as the existing channel was estimated

to be about 1.0 m deep but due to the very curved shaped flow direction next to Bell Road the actual flow depth might vary greatly especially where the flow condition changes from supercritical to subcritical.

4. Recommendations

The drainage study provides recommendations for identified deficiencies in culvert condition or lack of drainage infrastructure from site assessments, as well as insufficient hydraulic capacity from the hydrologic and hydraulic assessments conducted. The recommendations are listed by priority and sorted into short-term, medium-term and long-term based on the known drainage issues, the history and the severity of condition and capacity insufficiency.

4.1 Recommendations for Priority Area

Most recommendations fall within the identified six priority areas by the MoTI, as this was the main focus of the drainage study. The recommendations are sorted by priority and into short-term recommendations, within next 2 years, and medium-term recommendations, within the next 5 to 10 years. All recommendations for priority areas are generally viewed as medium-term or higher due to the history of known drainage issues and floodings.

Please refer to Table 7 for a summary of the recommendations.

TABLE 7: RECOMENDATION SUMMARY

#	RECOMMENDATION	CHRIS ID	RECOMMENDATION NOTES
	SHORT-TERM RECOMMENDATIONS (within next 2 years)		
1	**Maintenance, Inspection & Blockage Removal at Priest Lake** (Priority Area 3)	344936	• Existing 1,200 mm CSP culvert is likely blocked and has no relief structure with risk of overflowing and flooding of Gillies Bay Road. • Based on observations from site assessment and Van Anda Improvement District comments that the downstream water level is lower than the upstream water level without apparent flow indicating a potential blockage of the culvert. • Similar to previous maintenance, a specialized maintenance crew will be required as the culvert will likely be submerged due to the high downstream water level from the Priest Lake weir downstream of the pond. • Note that Priest Lake is an active water reservoir, and the downstream pond is a sensitive habitat.
2	**Culvert Replacement - Van Anda Creek @ Van Anda Avenue** (Priority Area 1)	2257630, 2257631	• Existing twin 900 mm CSP culvert pipes are in poor condition and undersized for the design storm requiring a replacement. • The critical condition of the culvert is highlighted, as a previous maintenance attempt had to be halted, due to concerns that the culvert could potentially fail during the works. • The replacement culvert was conceptually sized to be a 4,800 x 1,600 mm open-bottom arch culvert with fish gravels for fish passage. The replacement includes headwalls and wingwalls. ▪ The replacement culvert requires a regrading and raise of the Van Anda Avenue crossing.
3	**Erosion Protection of Staaf Creek @ Bell Road** (Priority Area 6)	NA	• Install Class 100kg Riprap along the right bank of Staaf Creek next to Bell Road just upstream of the ex. culvert crossing (2254782) and regrade the creek embankment to 2:1 on a length of 50 metres.
	MEDIUM-TERM RECOMMENDATIONS (within next 5 years)		
4	**Culvert Replacement - Cranby Creek @ Gillies Bay Road** (Priority Area 2)	2256032	• Existing 1,500/1,200 mm CSP culvert is in poor condition and greatly undersized for its large catchment and flows. • The replacement culvert was conceptually sized to be a 2,700 x 2,400 mm box culvert, embedded by 480 mm into fish gravel to improve fish-passage. The replacement includes headwalls and wingwalls. ▪ An alternative culvert was conceptually sized to be a 3,400 x 1,800 mm open-arch culvert. ▪ The conceptual size considered a High-Water Level at the downstream of 1.65 m CGVD13, but future sea level rise should be considered during future design stages as well.
5	**Culvert Replacement - Priest Lake @ Gillies Bay Road** (Priority Area 3)	3442936	• Existing 1,200 mm CSP culvert is greatly undersized without a relief structure and has a history of blockages. • The replacement culvert was conceptually sized to be twin 2,100 x 1,800 mm box culverts with wingwalls and headwalls reducing the likelihood of a blockage. ▪ Priest Lake is an active water reservoir of the Van Anda Improvement District, the downstream pond is a sensitive habitat. ▪ A large diameter gas pipeline is located between Priest Lake Road and Gillies Bay Road and would need to be protected or relocated.
6	**Culvert Replacement - Staaf Creek @ Bell Road** (Priority Area 6)	2254782	• Existing 1,800 x 1,200 mm CSP arch-pipe culvert is in poor condition and undersized with signs of piping at the crossing. • The replacement culvert was conceptually sized to be a 2,800 x 1,500 mm box culvert, embedded by about 300 mm in fish gravel to improve fish passage. The replacement includes headwalls and wingwalls. ▪ Bell Road might be potentially regraded and raised for the culvert replacement.

7	**Culvert Replacement - Trout Creek @ Gillies Bay Road** (Priority Area 5)	2256032	• Existing 1,800 x 1,100 mm CSP arch-pipe culvert is in fair condition but greatly undersized and known for seasonal floodings around Gillies Bay Road. • The replacement culvert was conceptually sized to be a 4,300 x 1,500 mm open bottom arch culvert with headwalls and wingwalls. Note that the culvert for the conceptual size appeared to be outlet controlled and a headloss of 0.3 m has not been achieved. The culvert should be analyzed in detail at a later stage.
8	**Culvert Replacement & Valley Curb Installation – Marble Road**	2257259	• Existing 450 mm CSP culvert is in fair condition but greatly undersized. • The replacement culvert recommended is a 1,200 x 600 mm box culvert. • A new valley curb is recommended to be installed along the southside of Marble Road towards the small creek in the west on an approx. length of 18 metres.
9	**Culvert Replacement – Sanderson Road @ Gillies Bay Road** (Priority Area 3)	2258625	• Existing 525 mm CSP culvert is in poor condition and greatly undersized. • The replacement culvert was conceptually sized to be a 1,800 x 900 mm box culvert with headwalls and wingwalls. • The site assessment did not find another flow route downstream of the ex. twin 600 mm CSP culvert at the Tennis Court, but future design should review the flow path in detail.
10	**Culvert Replacement – Tennis Court @ Gillies Bay Road** (Priority Area 3)	UNK	• Existing twin 600 mm CSP culvert is partially in poor condition and greatly undersized. • The replacement culvert was conceptually sized to be a twin 1,200 x 900 mm box culvert with headwalls and wingwalls.
11	**Culvert Replacement – Airport Road** (Priority Area 3)	UNK	• Existing recently installed 600 mm CSP culvert is poorly installed with insufficient cover and a lack of proper riprap apron at the outlet. • The replacement culvert recommended is a 600 mm HDPE pipe with sufficient min. 450 mm cover with a potential sump at the inlet and a riprap apron at the outlet.
LONG-TERM AND GENERAL RECOMMENDATIONS			
12	**Culvert Replacement – Central Road** (Additional Area)	2255061	• Existing 1200 mm CSP culvert is in poor condition with major pipe joint separation and buckling. • A replacement culvert has not been conceptually sized as part of the study but should be sized in the future.
13	**Regular Culvert Inspections** (-)	NA	• Regular culvert inspections are recommended to be conducted every 5 years to monitor the culvert conditions. • Culverts which were assessed to be in poor condition should be visually assessed every 2 years before being replaced and after every major storm event.

4.3 Cost Estimates

A budgetary cost estimate (AACE class 5 with contingency on the high side of 75%) for the drainage recommendations are presented in Table 8.

TABLE 8: RECOMMENDATION CONSTRUCTION COST ESTIMATES

#	RECOMMENDATION	ESTIMATED CONSTRUCTION COST
	SHORT-TERM RECOMMENDATIONS	
1	Maintenance & Inspection – Priest Lake @ Gillies Bay Road	N/A
2	Culvert Replacement – Van Anda Creek @ Van Anda Avenue	$967,500
3	Erosion Protection of Staaf Creek @ Bell Road	$55,000
	Sub-Total	$1,022,500
	MEDIUM-TERM RECOMENDATIONS	
4	Culvert Replacement – Cranby Creek @ Gillies Bay Road	$401,500
5	Culvert Replacement – Priest Lake @ Gillies Bay Road	$674,000
6	Culvert Replacement – Staaf Creek @ Bell Road	$245,000
7	Culvert Replacement – Trout Creek @ Gillies Bay Road	$876,500
8	Culvert Replacement & Valley Curb Installation – Marble Road	$106,750
9	Culvert Replacement – Sanderson Road @ Gillies Bay Road	$215,000
10	Culvert Replacement – Tennis Court @ Gillies Bay Road	$101,000
11	Culvert Replacement – Airport Road	$53,000
	Sub-Total	$2,672,750
	LONG-TERM AND GENERAL RECOMMENDATIONS	
12	Culvert Replacement – Central Road	N/A
	Sub-Total	$3,695,250
	Contingency (75%)	$2,771,438
	Total (not including GST)	$6,466,688

7. Next Steps

We trust the Texada Island Drainage Study Report provides sufficient details. Should you require any clarification or additional information, please contact the undersigned.

Prepared By:

Bastian Johnen, EIT
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Reviewed By:

2024-01-31

Jenna Lee, P.Eng., LEED AP BD+C
Project Manager

APPENDIX A

Culvert Condition Overview Map

Texada Island Drainage Study - Culvert Condition Map

Coordinate System: NAD 1983 CSRS UTM Zone 10N

Credits: qathet Regional District, Earthstar Geographics

Date Saved: 10/01/2024 11:34

APPENDIX B

MoTI Culvert Inspection Forms

Site Description

Note: Identify the site location on the map.

CHRIS Culvert ID or Site ID (Assign a unique Site ID if CHRIS ID is not available. Label on map)	CHRIS ID: 2257631 (West) & 2257630 (East) Site ID: Culvert 2 – Van Anda Ave @ Van Anda Crk (Priority Area 1)
Road Name	Van Anda Avenue
Inspection Date (YYYY-MM-DD) and Time (HH:MM)	2023-10-12 11:30
Inspected by	BJ, JL

Culvert

Culvert size (diameter or width x height)	Diameter (for circular pipe) 0.9 (west) / 0.9 (east) m				Width x Height (for box/pipe arch) _____ m x _____ m
Culvert material (Choose one from the list)	(CSP)	Concrete Box	Concrete Circular	CSP Pipe Arch	Other _____
General condition of the culvert barrel (percentage of barrel cross section with deterioration)	Abrasion: 50 / 50 % Corrosion: 60 / 80 %				
Signs of roadway overtopping (Y/N)	No				
Is the culvert plugged? (Y/N)	No				
Culvert blockage location (Choose all that apply)	Inlet		Mid-section		Outlet
Percentage of culvert cross section blocked by debris	Woody debris: 0 / 0 % Gravel: 25 / 10 %				
Potential debris removal methodology (Choose one from the list)	Hand Shovel				Excavator
Debris removed? (Choose one from the list)	Y				N
Scour and erosion at the culvert inlet/outlet (E.g. upstream right bank or undermining at the outlet)	Erosion at pipe inlet due to no headwall between twin culvert pipes.				
Sinkhole/depression/tension crack on the pavement surface (Choose one from the list)	(Y)				N
Signs of piping that may indicate flow/seepage from outside the culvert barrel (Choose one from the list)	(Y)				N

Upstream/downstream Channel

Note: Refer channel direction by looking towards the downstream.

Average channel width and depth		Width (m)	Depth (m)
	Upstream	3.5	2.5
	Downstream	2.5	1.8
Signs of channel avulsion/bank erosion (E.g. bank erosion at 20m upstream from culvert inlet)	Bank erosion visible on the right bank 8m upstream from the inlet, probably due to unprotected 1:1 slope.		
Debris accumulation in the adjacent upstream/downstream channel (E.g. Woody debris blocking 50% of the upstream channel, or gravel bar at 10m upstream from the culvert inlet)	Debris accumulation (sediment & vegetation) on the left side of the channel at the outlet, blocking approx. 25% of the channel.		
Potential debris removal methodology (Choose one from the list)	Hand Shovel	(Excavator)	

Road Embankment

Note: Document unit in m.

Location of recent embankment erosion from natural channel or ditch (E.g. 2m of the shoulder was eroded)	NA	
Is the embankment erosion caused by channel avulsion?	Y	(N)

Others

Other issues to be documented	Twin 900 mm CSP pipes cross Van Anda Ave with improvised headwall & wingwalls from CRBs. CRBs sit directly on both pipes. Potential piping between the twin CSP pipes, as they are unprotected, and sediment/material is missing at the inlet. Tension cracks visible on pavement above. Culverts appeared to be in poor condition due to extensive corrosion on the visible portion of the pipes, as well as damaged inlet. About 30cm of water level with minimal flow present during the time of inspection. The creek is signed as fish-bearing.

Rating (1 to 5)

Culvert blockage (1 for 0% plugged, 5 for 100% plugged). Assign 1 if the debris blockage has been removed.	2
Blockage material (1 for no blockage, 3 for woody debris, 5 for gravel/sand/boulder)	5
Roadway flooded (1 for no, 3 for half of the roadway, 5 for completely flooded)	1
Scour/erosion at culvert inlet/outlet (1 for none, 5 for severe)	2
Sinkhole/depression/tension crack on the pavement surface (1 for none, 5 for severe)	3
Signs of piping (1 for none, 5 for severe)	2
Signs of channel avulsion/bank erosion (1 for none, 5 for severe)	2
Debris accumulation in the upstream channel (1 for none, 5 for 100% blockage to the channel)	1
Debris accumulation in the downstream channel (1 for none, 5 for 100% blockage to the channel)	3
Road embankment erosion (1 for none, 3 for half of the travel lanes damaged, 5 for complete lost of embankment)	1

Pictures

Culvert Inlet: Inlet damaged and corroded, CRB headwall & wingwalls

Culvert Outlet: Sediment Accumulation on right bank

Pipe Interior (eastern pipe) facing US: Signs of significant corrosion with loss of material visible, 2 to 11 o'clock

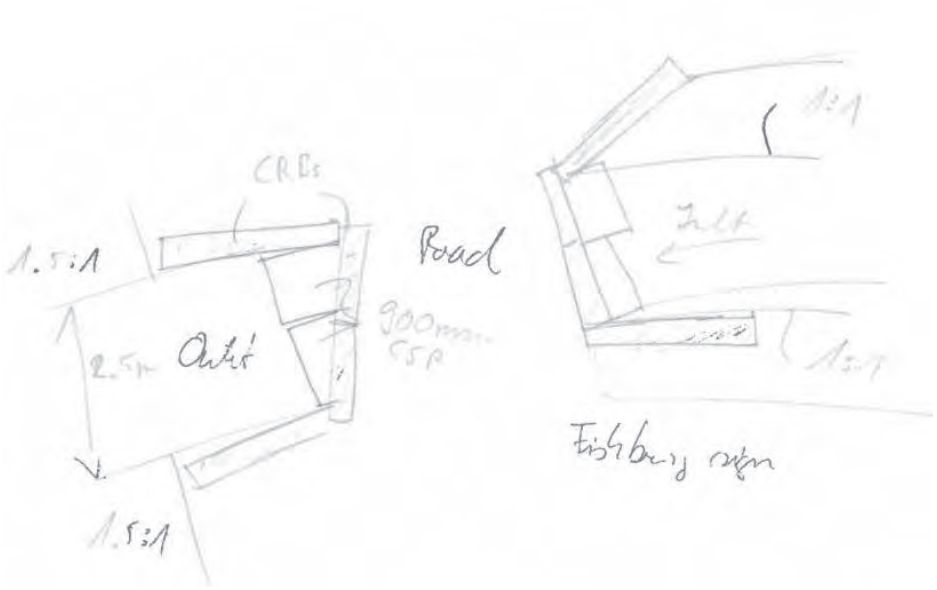
Pipe Interior (western pipe) facing DS: Visible damage of inlet and heavy corrosion of invert

Upstream Channel facing US: Bank erosion visible on the left side

Downstream Channel facing DS: Sediment accumulation and vegetation visible & CRB wingwalls

Culvert Inlet: CRB sitting on culverts, large cavity visible between twin pipes

Pavement Surface: Tension cracks visible on the left and the right from the culvert crossing



Site Sketch of the Culvert Crossing

Site Description

Note: Identify the site location on the map.

CHRIS Culvert ID or Site ID (Assign a unique Site ID if CHRIS ID is not available. Label on map)	CHRIS ID: 3442936 Site ID: Culvert 3 - Gillies Bay Rd @ Van Anda Crk (Priority Area 3)
Road Name	Gillies Bay Road
Inspection Date (YYYY-MM-DD) and Time (HH:MM)	2023-10-12 13:00
Inspected by	BJ, JL

Culvert

Culvert size (diameter or width x height)	Diameter (for circular pipe) _____1.2_ m				Width x Height (for box/pipe arch) _____ m x _____ m
Culvert material (Choose one from the list)	(CSP)	Concrete Box	Concrete Circular	CSP Pipe Arch	Other _____
General condition of the culvert barrel (percentage of barrel cross section with deterioration)	Abrasion: ___?_ % Corrosion: ___?_ %				
Signs of roadway overtopping (Y/N)	No				
Is the culvert plugged? (Y/N)	NA				
Culvert blockage location (Choose all that apply)	Inlet	Mid-section	Outlet		
Percentage of culvert cross section blocked by debris	Woody debris: ___?_ % Gravel: ___?_ %				
Potential debris removal methodology (Choose one from the list)	Hand Shovel	Excavator			
Debris removed? (Choose one from the list)	Y	(N)			
Scour and erosion at the culvert inlet/outlet (E.g. upstream right bank or undermining at the outlet)	Scour or erosion were not visible due to high water level.				
Sinkhole/depression/tension crack on the pavement surface (Choose one from the list)	Y	(N)			
Signs of piping that may indicate flow/seepage from outside the culvert barrel (Choose one from the list)	Y	N			

Upstream/downstream Channel

Note: Refer channel direction by looking towards the downstream.

Average channel width and depth		Width (m)	Depth (m)
	Upstream	NA	2.0
	Downstream	10	3.0
Signs of channel avulsion/bank erosion (E.g. bank erosion at 20m upstream from culvert inlet)	NA		
Debris accumulation in the adjacent upstream/downstream channel (E.g. Woody debris blocking 50% of the upstream channel, or gravel bar at 10m upstream from the culvert inlet)	Debris was visible at the inlet and the downstream ranging from reeds to logs.		
Potential debris removal methodology (Choose one from the list)	Hand Shovel	Excavator	

Road Embankment

Note: Document unit in m.

Location of recent embankment erosion from natural channel or ditch (E.g. 2m of the shoulder was eroded)	Minor road embankment erosion visible above the outlet.	
Is the embankment erosion caused by channel avulsion?	Y	(N)

Others

Other issues to be documented	1200mm CSP culvert crossing Priest Lake Rd & Gillies Bay Rd functioning as the outlet of Priest Lake to Van Anda Creek. At the time of inspection, the inlet was completely submerged, and the outlet was full to ~75%, therefore most of the pipe was not inspected. Water level at the inlet was estimated to be about 1.5 m from pipe invert. Visible portion of the outlet pipe appears to be corroded. The area is indicated as a highly sensitive habitat (painted turtle). High water level at the outlet appeared to be coming from the downstream and water level of Lake appeared higher than downstream without apparent flow, suggesting potential plugging of the culvert. The culvert condition was not assessed.

Rating (1 to 5)

Culvert blockage (1 for 0% plugged, 5 for 100% plugged). Assign 1 if the debris blockage has been removed.	NA
Blockage material (1 for no blockage, 3 for woody debris, 5 for gravel/sand/boulder)	NA
Roadway flooded (1 for no, 3 for half of the roadway, 5 for completely flooded)	1
Scour/erosion at culvert inlet/outlet (1 for none, 5 for severe)	NA
Sinkhole/depression/tension crack on the pavement surface (1 for none, 5 for severe)	1
Signs of piping (1 for none, 5 for severe)	NA
Signs of channel avulsion/bank erosion (1 for none, 5 for severe)	1
Debris accumulation in the upstream channel (1 for none, 5 for 100% blockage to the channel)	2
Debris accumulation in the downstream channel (1 for none, 5 for 100% blockage to the channel)	2
Road embankment erosion (1 for none, 3 for half of the travel lanes damaged, 5 for complete lost of embankment)	2

Pictures

Culvert Inlet: Inlet fully submerged, log and reeds debris present above pipe

Culvert Outlet: Outlet about 75% submerged and visibly corroded on the outside

Pipe Interior facing US: Pipe lining visibly damaged with corrosion visible

Upstream Channel: Culvert acts as outlet of Priest Lake crossing Priest Lake Rd & Gillies Bay Rd

Downstream Channel facing DS: Woody debris and old CSP pipe visible, sensitive habitat for painted turtle

Pavement Surface: Priest Lake Rd (gravel) to the left, Gillies Bay Rd (paved) to the right

Site Description

Note: Identify the site location on the map.

CHRIS Culvert ID or Site ID (Assign a unique Site ID if CHRIS ID is not available. Label on map)	CHRIS ID: 2256032 Site ID: Culvert 8 – Gillies Bay Rd @ Cranby Crk (Priority Area 5)
Road Name	Gillies Bay Road
Inspection Date (YYYY-MM-DD) and Time (HH:MM)	2023-10-12 15:15
Inspected by	BJ, JL

Culvert

Culvert size (diameter or width x height)	Diameter (for circular pipe) 1.5 / 1.2 m			Width x Height (for box/pipe arch) _____ m x _____ m	
Culvert material (Choose one from the list)	(CSP)	Concrete Box	Concrete Circular	CSP Pipe Arch	Other _____
General condition of the culvert barrel (percentage of barrel cross section with deterioration)	Abrasion: 50 % Corrosion: 60 %				
Signs of roadway overtopping (Y/N)	No				
Is the culvert plugged? (Y/N)	No				
Culvert blockage location (Choose all that apply)	Inlet		Mid-section		Outlet
Percentage of culvert cross section blocked by debris	Woody debris: 0 % Gravel: 30 %				
Potential debris removal methodology (Choose one from the list)	Hand Shovel			Excavator	
Debris removed? (Choose one from the list)	Y			N	
Scour and erosion at the culvert inlet/outlet (E.g. upstream right bank or undermining at the outlet)	NA				
Sinkhole/depression/tension crack on the pavement surface (Choose one from the list)	Y			(N)	
Signs of piping that may indicate flow/seepage from outside the culvert barrel (Choose one from the list)	Y			(N)	

Upstream/downstream Channel

Note: Refer channel direction by looking towards the downstream.

Average channel width and depth		Width (m)	Depth (m)
	Upstream	3	2
	Downstream	6	3.5
Signs of channel avulsion/bank erosion (E.g. bank erosion at 20m upstream from culvert inlet)	Bank erosion visible at the right bank 20m upstream from the inlet.		
Debris accumulation in the adjacent upstream/downstream channel (E.g. Woody debris blocking 50% of the upstream channel, or gravel bar at 10m upstream from the culvert inlet)	Upstream channel about 20% blocked by woody debris around 20m upstream from the inlet.		
Potential debris removal methodology (Choose one from the list)	(Hand Shovel)	Excavator	

Road Embankment

Note: Document unit in m.

Location of recent embankment erosion from natural channel or ditch (E.g. 2m of the shoulder was eroded)	NA	
Is the embankment erosion caused by channel avulsion?	Y	N

Others

Other issues to be documented	Culvert pipe size changes from 1500mm CSP at inlet to 1200mm CSP at outlet. Culvert appeared to have a bend approx. 3m upstream of the outlet, where the diameter changes. Visible pipe joint separation at the skew and visible underlying material. Only 2/3 of the culvert appeared to be aligned, blocking about 1/3 of the culvert. Major corrosion visible in the culvert with significant material loss. The culvert is expected to be tidally influenced and fish-bearing. Culvert appears to be overall in poor condition.

Rating (1 to 5)

Culvert blockage (1 for 0% plugged, 5 for 100% plugged). Assign 1 if the debris blockage has been removed.	3
Blockage material (1 for no blockage, 3 for woody debris, 5 for gravel/sand/boulder)	5
Roadway flooded (1 for no, 3 for half of the roadway, 5 for completely flooded)	1
Scour/erosion at culvert inlet/outlet (1 for none, 5 for severe)	1
Sinkhole/depression/tension crack on the pavement surface (1 for none, 5 for severe)	1
Signs of piping (1 for none, 5 for severe)	1
Signs of channel avulsion/bank erosion (1 for none, 5 for severe)	2
Debris accumulation in the upstream channel (1 for none, 5 for 100% blockage to the channel)	2
Debris accumulation in the downstream channel (1 for none, 5 for 100% blockage to the channel)	1
Road embankment erosion (1 for none, 3 for half of the travel lanes damaged, 5 for complete lost of embankment)	1

Pictures

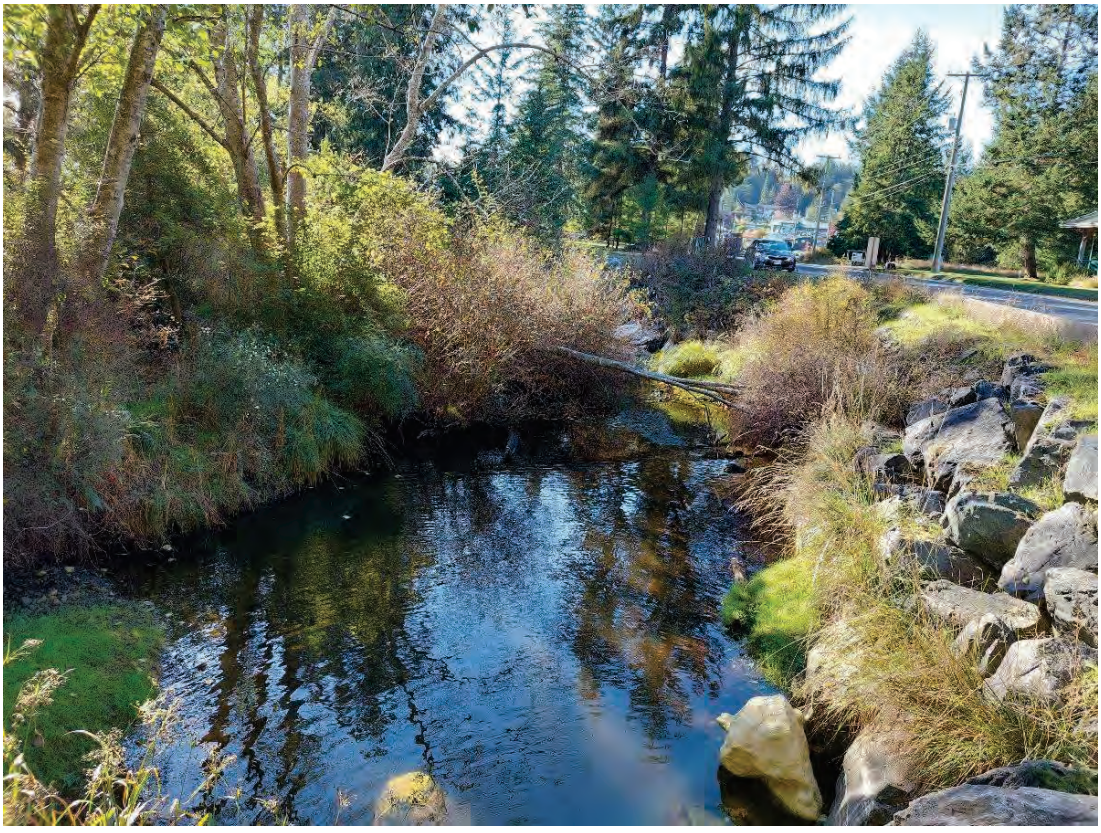
Culvert Inlet: Heavily corrosion at pipe invert with large section of missing material

Culvert Outlet: 1200mm CSP pipe with riprap headwall

Culvert Interior facing US: Visible pipe joint separation with visible rock on the right side

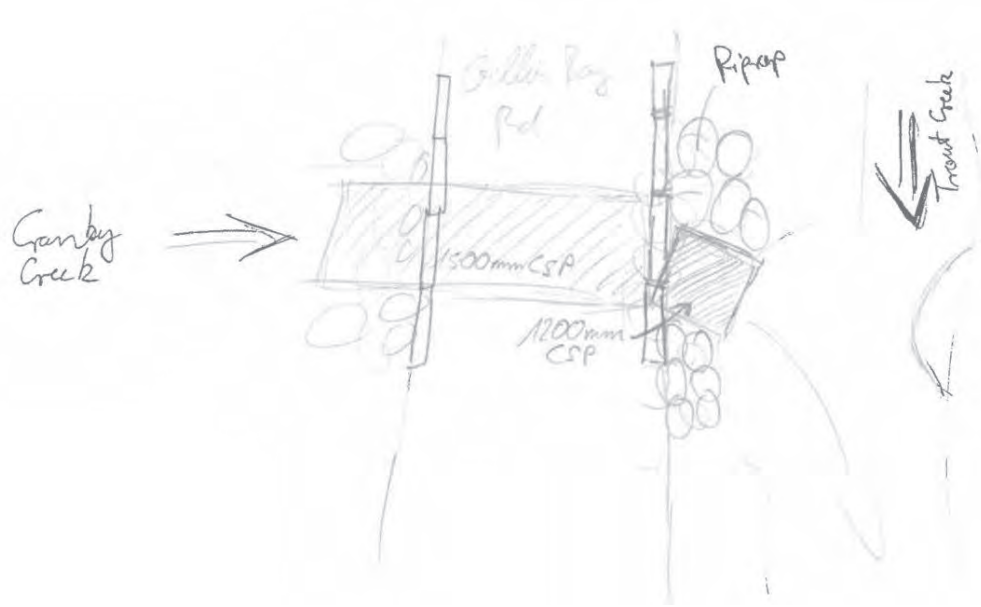
Pipe Interior facing DS: Pipe joint separation visible with skewed outlet pipe and visible rock

Upstream Channel facing US: DI utility service line visible in the upstream channel 3m from inlet



Downstream Channel facing DS: Confluence of Cranby Crk (from right) and Trout Crk (from left)

Pavement Surface: Gillies Bay Road above Cranby Creek Crossing



Site Sketch of Cranby Creek Culvert Crossing at Gillies Bay Road

Site Description

Note: Identify the site location on the map.

CHRIS Culvert ID or Site ID (Assign a unique Site ID if CHRIS ID is not available. Label on map)	CHRIS ID: 2254782 Site ID: Culvert 10 – Bell Rd @ Staaf Crk
Road Name	Bell Road
Inspection Date (YYYY-MM-DD) and Time (HH:MM)	2023-10-13 10:45
Inspected by	BJ, JL

Culvert

Culvert size (diameter or width x height)	Diameter (for circular pipe) _____ m			Width x Height (for box/(pipe arch)) 1.8 m x 1.0 m	
Culvert material (Choose one from the list)	(CSP)	Concrete Box	Concrete Circular	CSP Pipe Arch	Other _____
General condition of the culvert barrel (percentage of barrel cross section with deterioration)	Abrasion: 30 % Corrosion: 40 %				
Signs of roadway overtopping (Y/N)	No				
Is the culvert plugged? (Y/N)	No				
Culvert blockage location (Choose all that apply)	Inlet	Mid-section	Outlet		
Percentage of culvert cross section blocked by debris	Woody debris: 2 % Gravel: 5 %				
Potential debris removal methodology (Choose one from the list)	(Hand Shovel)	Excavator			
Debris removed? (Choose one from the list)	Y	(N)			
Scour and erosion at the culvert inlet/outlet (E.g. upstream right bank or undermining at the outlet)	Undermining at the inlet leading to failing concrete sandbags headwall.				
Sinkhole/depression/tension crack on the pavement surface (Choose one from the list)	Y	(N)			
Signs of piping that may indicate flow/seepage from outside the culvert barrel (Choose one from the list)	(Y)	N			

Upstream/downstream Channel

Note: Refer channel direction by looking towards the downstream.

Average channel width and depth		Width (m)	Depth (m)
	Upstream	5	1.75
	Downstream	4	2.0
Signs of channel avulsion/bank erosion (E.g. bank erosion at 20m upstream from culvert inlet)	Bank erosion on both sides DS from the outlet. Significant erosion on the right bank US from the inlet undermining roadside ditch & road.		
Debris accumulation in the adjacent upstream/downstream channel (E.g. Woody debris blocking 50% of the upstream channel, or gravel bar at 10m upstream from the culvert inlet)	Smaller rocks and woody debris present in the upstream and downstream channel.		
Potential debris removal methodology (Choose one from the list)	Hand Shovel	Excavator	

Road Embankment

Note: Document unit in m.

Location of recent embankment erosion from natural channel or ditch (E.g. 2m of the shoulder was eroded)	The outlet road embankment is unstable on about 5m length at a 90-degree slope. Embankment is actively eroding.	
Is the embankment erosion caused by channel avulsion?	Y	N

Others

Other issues to be documented	Culvert shows major buckling at 2 o'clock position from the inlet. Pipe invert is significantly corroded with major section loss. Observed flow of Staaf Creek was not observed at the inlet or outlet but appeared in the middle of the culvert bottom and disappeared under the culvert, flowing under the culvert outlet, showing major signs of piping. The outlet embankment is unstable and the gravel road eroding. The inlet headwall from concrete bags has mostly failed and cavities around the inlet are visible. The culvert appeared overall in poor condition. Major channel erosion has been observed upstream of the culvert along two alignment that actively erode the existing roadside ditch of the northern side of Bell Rd on a length of ~10m & 14m. Riprap and rocks have been dumped at the furthest location to mitigate the erosion.

Rating (1 to 5)

Culvert blockage (1 for 0% plugged, 5 for 100% plugged). Assign 1 if the debris blockage has been removed.	1
Blockage material (1 for no blockage, 3 for woody debris, 5 for gravel/sand/boulder)	1
Roadway flooded (1 for no, 3 for half of the roadway, 5 for completely flooded)	1
Scour/erosion at culvert inlet/outlet (1 for none, 5 for severe)	3
Sinkhole/depression/tension crack on the pavement surface (1 for none, 5 for severe)	1
Signs of piping (1 for none, 5 for severe)	4
Signs of channel avulsion/bank erosion (1 for none, 5 for severe)	4
Debris accumulation in the upstream channel (1 for none, 5 for 100% blockage to the channel)	1
Debris accumulation in the downstream channel (1 for none, 5 for 100% blockage to the channel)	1
Road embankment erosion (1 for none, 3 for half of the travel lanes damaged, 5 for complete lost of embankment)	3

Pictures

Culvert Inlet: Failed concrete bag headwall, culvert pipe visibly corroded, flow below gravel

Culvert Outlet: Pipe invert heavily corroded, flow visible coming from under the culvert

Culvert Interior facing DS: Buckling visible at 2 o'clock, flowing water visible in the middle of the culvert

Culvert Inlet facing US: Buckling visible at multiple locations, flow disappearing at pipe invert

Culvert Outlet: Visible undermining of culvert pipe with visible stream flowing under pipe

Upstream Channel facing US: Staaf Creek with minimal flow visible

Downstream Channel facing DS: Downstream pool with erosion of banks on both sides

Upstream Channel at Bell Rd: Undermining of roadside ditch along 10m stretch

Upstream Channel at Bell Rd: Undermining of embankment along 14m stretch, dumped riprap visible

Bell Road above Staaf Creek: Gravel Road with eroding road embankment on the left side visible

APPENDIX C

Inspection Photos (October 12/13, 2023)

Texada Island Drainage Study– Inspection Summary

Inspection Photos for Priority Areas (October 12/13, 2023)

AREA 2 MARBLE RD: PUDDLE AT 2058 MARBLE RD SOUTHERN LANE

AREA 2 MARBLE RD: CROSS CULVERT UNDER PAVEMENT CRACK LINES

AREA 2 MARBLE RD: 450MM CSP CROSS CULVERT (2257259) LOOKING DOWNSTREAM

AREA 2 MARBLE RD: NO DRAINAGE ALONG PARTS OF MARBLE RD

AREA 2 MARBLE RD: 600MM WOOD STAVE CULVERT (3442931) INLET

AREA 2 MARBLE RD: WOOD STAVE CULVERT (3442931) INTERIOR

AREA 2 MARBLE RD: 450MM HDPE INLET, EXTENDED FROM CSP

AREA 2 MARBLE RD: 600MM CSP INTERIOR FACING UPSTREAM

AREA 4 AIRPORT RD: NEW CULVERT INLET WITH IMPROVISED CHECK DAM INSIDE ROADSIDE DITCH

AREA 4 AIRPORT RD: NEW CULVERT OUTLET, DRAINS FLOWS INTO THE FOREST

AREA 4 AIRPORT RD: NEW CULVERT INTERIOR FROM OUTLET, VISIBLE PIPE JOINT SEPARATION AND MISALIGNED CULVERT

AREA 4 AIRPORT RD: NEW CULVERT, POOR PAVEMENT INSTALLATION WITH TENSION CRACKS AND SETTLEMENT

AREA 4 AIRPORT RD: 300MM CSP CULVERT (2258675) OUTLET, CORRODED INVERT

AREA 4 AIRPORT RD: 300MM CSP CULVERT (2258675), HEAVILY CORRODED INVERT

AREA 4 AIRPORT RD: EROSION OF ROADSIDE DITCH

AREA 4 AIRPORT RD: 450MM DI CULVERT INLET

AREA 4 AIRPORT RD: 450MM DI CULVERT INTERIOR, SURFICAL CORROSION

AREA 4 AIRPORT RD: 600MM CSP CULVERT (2256637) UNDER PINE ST INTERIOR, PIPE INVERT CORROSION

AREA 4 AIRPORT RD: 600MM CSP CULVERT (2256637) UNDER PINE ST OUTLET

AREA 4 AIRPORT RD: 300MM CSP CROSS CULVERT (2256020) UNDER AIRPORT RD AT GILLIES BAY RD

AREA 4 GILLIES BAY RD: TWIN 600MM CSP CULVERT INLET AT TENNIS COURT

AREA 4 GILLIES BAY RD: OLD EASTERN 600MM CSP CULVERT, MAJOR CORROSION OF PIPE INVERT

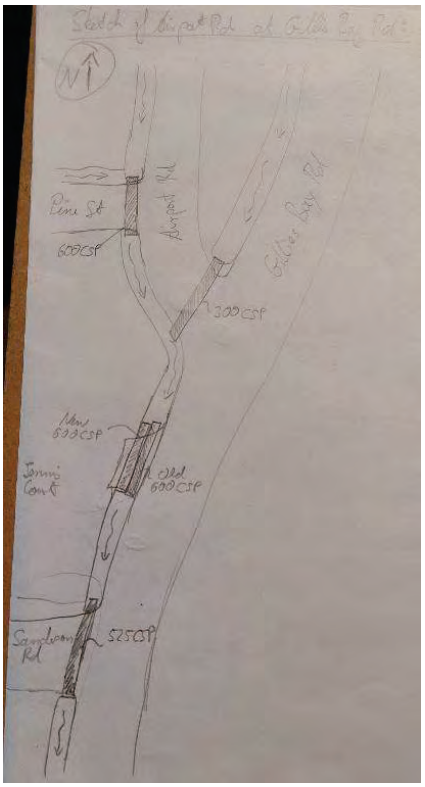
AREA 4 GILLIES BAY RD: NEW WESTERN 600MM CSP CULVERT INTERIOR

AREA 4 GILLIES BAY RD: TWIN 600MM CULVERT OUTLET

AREA 4 SANDERSON RD: OVERGROWN ROADSIDE DITCH

AREA 4 SANDERSON RD: CULVERT (2258625) PIPE INVERT CORRODED AWAY LOOKING DOWNSTREAM

AREA 4 GILLIES BAY RD: BANK EROSION OF ROADSIDE DITCH



AREA 4 SITE SKETCH OF AIRPORT RD ROADSIDE DITCH AT GILLIES BAY RD

AREA 5 GILLIES BAY: ARCH PIPE CULVERT (2256032) INLET OVERGROWN

AREA 5 GILLIES BAY: ARCH PIPE (2256032) WITH LOCAL CORROSION

AREA 5 GILLIES BAY: SIGNS OF BEAVERS UPSTREAM OF CULVERT

AREA 5 GILLIES BAY: SIGNS OF FAILED CONCRETE EMBANKMENT

AREA 5 GILLIES BAY: GILLIES BAY RD

AREA 5 GILLIES BAY: SCHOOL RD AT GILLIES BAY RD

Inspection Photos for major Culverts along Roads of Concern (October 12/13, 2023)

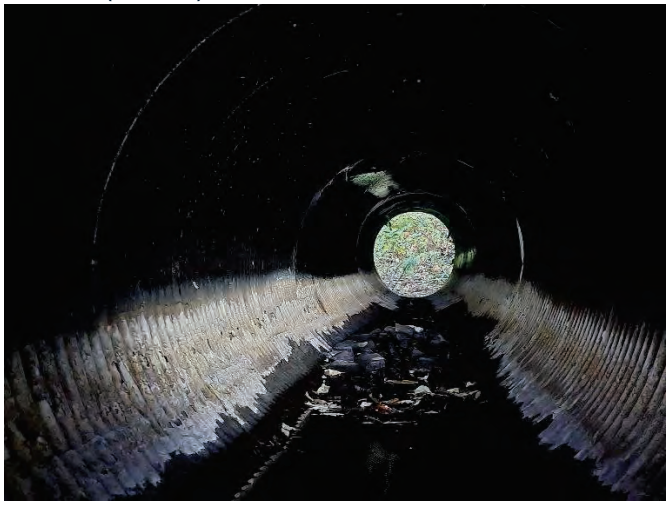
CULVERT 1 (2254949) INLET: DAMAGED INLET AND GRATE

CULVERT 1 (2254949) INTERIOR: MATERIAL CHANGE AND HEAVY CORROSION

CULVERT 4 (2256045) INLET: MINOR WOODY DEBRIS

CULVERT 4 (2256045) INTERIOR: MAJOR CORROSION & MINOR DEBRIS

CULVERT 5 (2256047) INLET: VEGETATION PRESENT AT INLET



CULVERT 5 (2256047) INTERIOR: DAMAGED COATING AND MINOR ROCK

CULVERT 6 (2256019) INLET: OVERGROWN INLET

DEBRIS

CULVERT 6 (2256019) INTERIOR: PIPE JOINT SEPARATION AND ROCK DEBRIS

CULVERT 7 (2258625) OUTLET: OVERGROWN ROADSIDE DITCH

CULVERT 7 (2258625) INTERIOR: PIPE INVERT CORRODED AWAY

CULVERT 9 (2256424) INLET: WOODY DEBRIS AT INLET

CULVERT 9 (2256424) INTERIOR: PIPE COATING MOSTLY INTACT

CULVERT 11 (2254788) OUTLET: ERODING ROAD EMBANKMENT AT OUTLET

CULVERT 11 (2254788) INTERIOR: GOOD PIPE CONDITION

CULVERT 12 (2255061) INLET: INLET BEND

CULVERT 12 (2255061) INTERIOR: BUCKLING AND PIPE JOINT SEPARATION

CULVERT 13 (3442926) ROAD: CENTRAL ROAD ABOVE CULVERT

CULVERT 13 (3442926) INTERIOR: MINOR PIPE JOINT SEPARATION

CULVERT 14 (3442927) INLET: PIPE COATING INTACT

CULVERT 14 (3442927) INTERIOR: MINOR PIPE SEPARATION

CULVERT 15 (2255027) INLET: DEBRIS AND ERODING EMBANKMENT

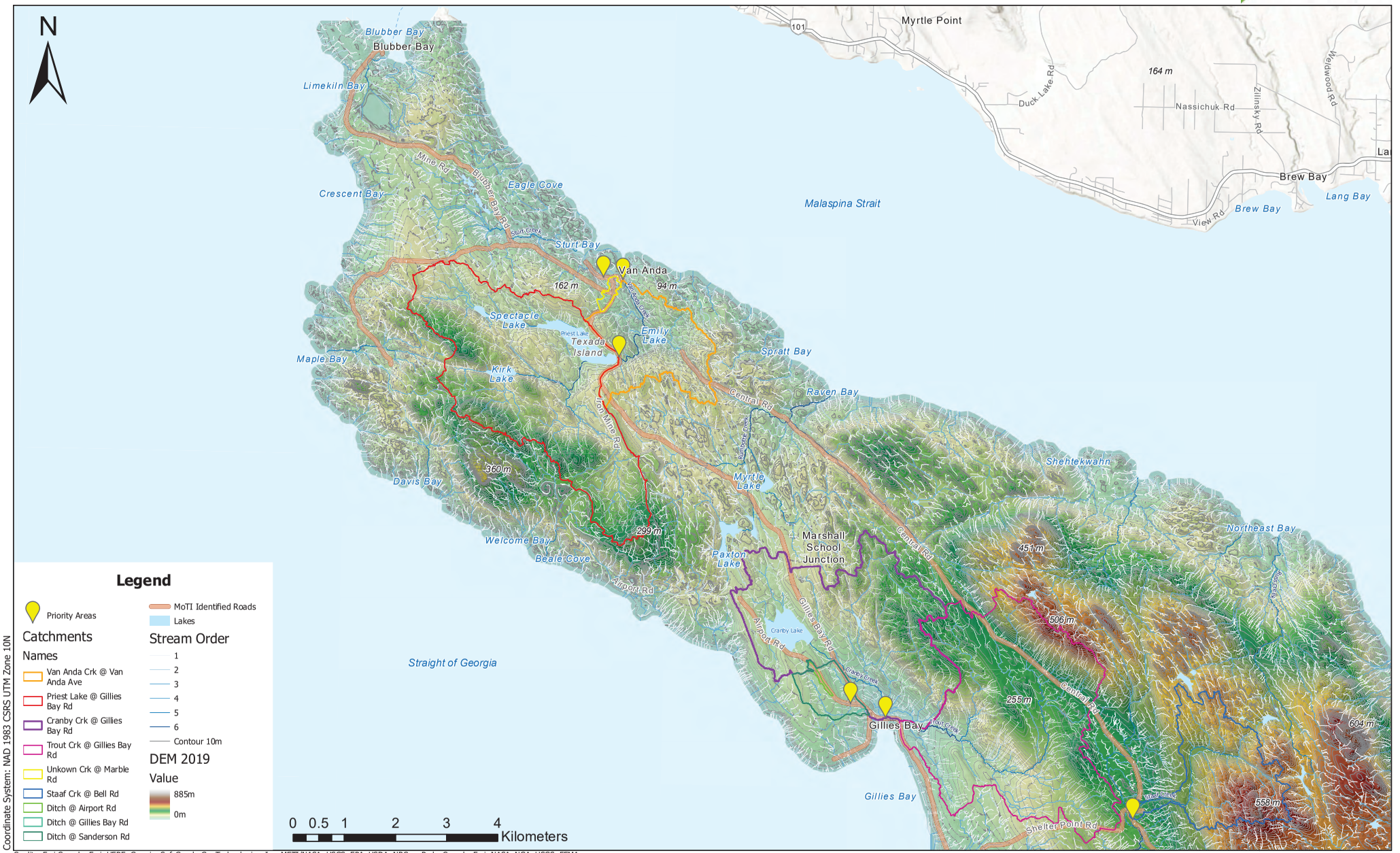
CULVERT 15 (2255027) INTERIOR: SIGNIFICANT CORROSION OF PIPE INVERT

APPENDIX D

Overview Catchment Map

Texada Island Drainage Study - Watershed and Watercourse Map

PARSONS



Coordinate System: NAD 1983 CSRS UTM Zone 10N

Credits: Esri Canada, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, USDA, NRCan, Parks Canada, Esri, NASA, NGA, USGS, FEMA

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APPENDIX E

Rational Method Calculation Spreadsheet

Rational Method Design Flow Calcuation Sheet

Project Name:	Texada Island Drainage Study
Client:	BC MoTI
Calculation Date:	24/11/2023
Calculations by:	BJ
Checked by:	JL
IDF Curve Source Data:	Environmental and Climate Change Canada Powell River (1046392)

Location: Texada Island, BC

Drainage type:	Snowmelt driven	
Decisive Return Rate:	100	a
Add. Snowmelt	0.10	
Add. Return period	0.1	

IDF Coefficients (100 years)		
A	27.20	-
B	-0.657	-
t0	0.051	

Runoff Coefficient (Tab. 1020.A)

Watershed Physiography	Surface Cover				
	Impermeable	Forested	Agricultural	Rural	Urban
mountain (>30%)	1.00	0.90	-	-	-
steep slope (20-30%)	0.95	0.80	-	-	-
moderate slope (10-20%)	0.90	0.65	0.50	0.75	0.85
rolling terrain (5-10%)	0.85	0.50	0.40	0.65	0.80
flat (<5%)	0.80	0.40	0.30	0.55	0.75
return period 10-25 years	0.05	0.02	0.07	0.05	0.05
return period > 25 years	0.10	0.05	0.15	0.10	0.10
snowmelt	0.10	0.10	0.10	0.10	0.10

100-Year Peak Flow Estimate without Climate Change

General Sub-Watershed Data									Water Management Method																
									Surface Cover (ha)					Surface Cover (-)											
Nr.	Catchment	Culvert Size (mm)	Culvert Material	Δ h (m)	Δ l (m)	Slope (%)	Watershed Physiography (Tab. 1020.A)	A_{total} (ha)	Impermeable	Forested	Agricultural	Rural	Urban	Impermeable	Forested	Agricultural	Rural	Urban	Weighted Runoff Coefficient (-)	$A^{0.5}$ (km)	Slope Type (P. 1020.04)	Tc (h)	i (mm/h)	Qp (m3/s)
1	Priority Area 2, Marble Road	450	CSP	62.8	620	10%	moderate slope	13.72	2.19	5.19		6.35		1.10	0.80	0.75	0.95		0.92	0.37	steep	0.895	29.25	1.023
2	Priority Area 4-1, Airport Road	600	CSP	18.5	845	2%	flat	5.11	0.30	4.81		0.00		1.10	0.80	0.75	0.95		0.82	0.23	rolling	1.461	21.21	0.246
3	Priority Area 4-2, Gillies Bay Road	2x600	CSP	78.4	1,565	5%	rolling terrain	96.61	1.33	91.57		3.71		1.10	0.80	0.75	0.95		0.81	0.98	moderate	3.598	11.73	2.549
4	Priority Area 4-3, Sanderson Road	525	CSP	84.9	1,680	5%	rolling terrain	98.59	1.33	93.55		3.71		1.10	0.80	0.75	0.95		0.81	0.99	moderate	3.632	11.66	2.585
		-	-	-	-	-	-							-	-	-	-	-	-	-	-	-	-	

100-Year Peak Flow Estimate with Climate Change

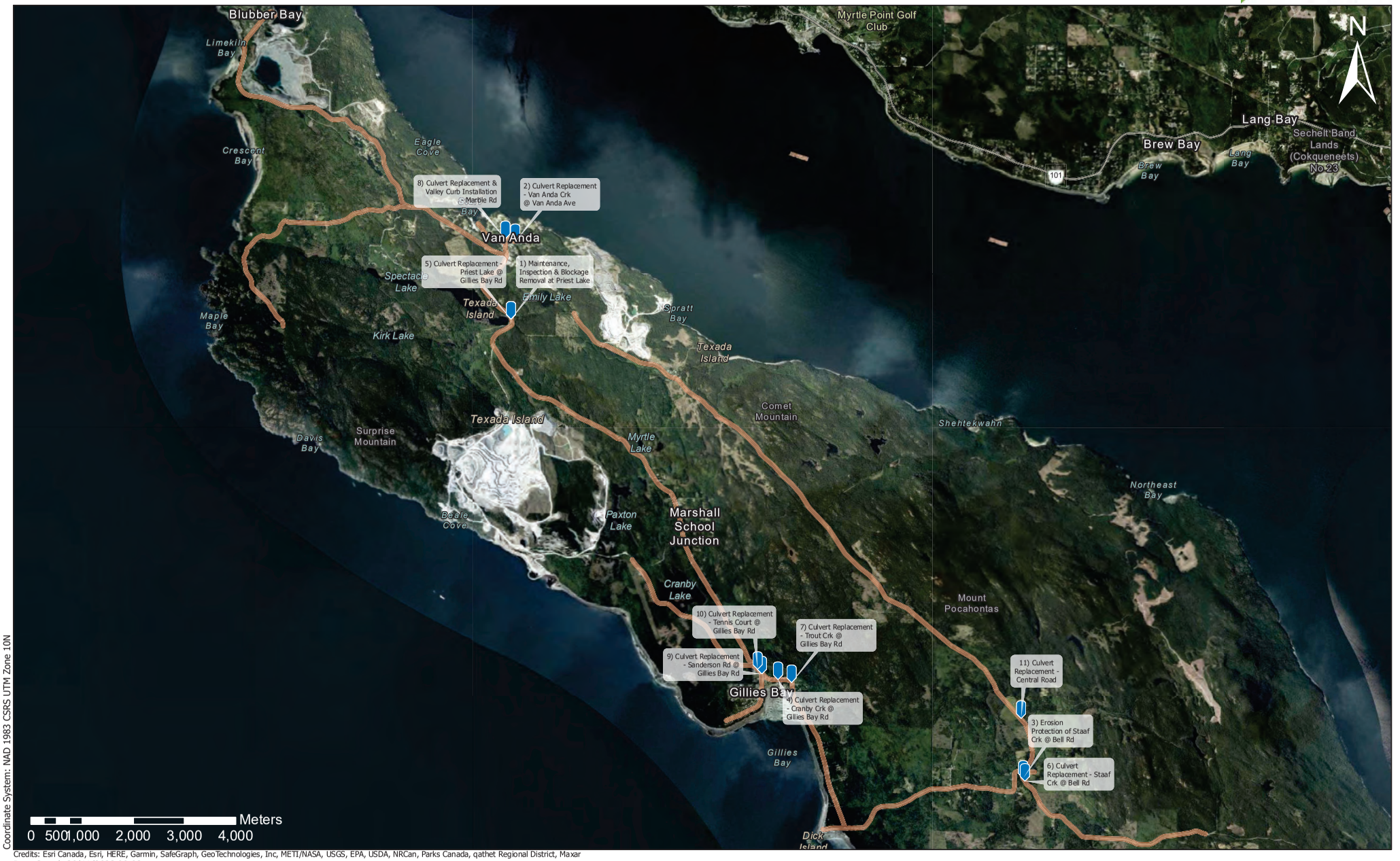
IDF Coefficients (100 years + CC with SSP 5.85)		
A	31.10	
B	-0.637	
t0	0.032	

General Sub-Watershed Data									Water Management Method																
									Surface Cover (ha)					Surface Cover (-)											
Nr.	Catchment	Culvert Size	Culvert Material	Δ h (m)	Δ l (m)	Slope (%)	Watershed Physiography (Tab. 1020.A)	A_{total} (ha)	Impermeable	Forested	Agricultural	Rural	Urban	Impermeable	Forested	Agricultural	Rural	Urban	Weighted Runoff Coefficient (-)	$A^{0.5}$ (km)	Slope Type (P. 1020.04)	Tc (h)	i (mm/h)	Qp (m3/s)
1	Priority Area 2, Marble Road	450	CSP	62.8	620	10%	moderate slope	13.72	2.19	5.19	0	6.35	0	1.10	0.80	0.75	0.95	0	0.92	0.37	steep	0.895	33.37	1.167
2	Priority Area 4-2, Gillies Bay Road	600	CSP	18.5	845	2%	flat	5.11	0.30	4.81	0	0	0	1.10	0.80	0.75	0.95	0	0.82	0.23	rolling	1.461	24.43	0.284
3	Priority Area 4-1, Airport Road	2x600	CSP	78.4	1565	5%	rolling terrain	96.61	1.33	91.57	0	3.71	0	1.10	0.80	0.75	0.95	0	0.81	0.98	moderate	3.598	13.76	2.991
4	Priority Area 4-3, Sanderson Road	525	CSP	84.9	1680	5%	rolling terrain	98.59	1.33	93.55	0	3.71	0	1.10	0.80	0.75	0.95	0	0.81	0.99	moderate	3.632	13.67	3.032
		-	-	-	-	-	-							-	-	-	-	-	-	-	-	-	-	

APPENDIX F

Recommendation Map

Texada Island Drainage Study - Recommendation Map



Coordinate System: NAD 1983 CSRS UTM Zone 10N

Credits: Esri Canada, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, USDA, NRCan, Parks Canada, qathet Regional District, Maxar

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APPENDIX G

Extreme Value Analysis – Lang Creek (08GB007)

Extreme Value Analysis for River Gauge Lang Creek (08GB007)

River Gauge Data: 1960 to 1995

n Number = **36**

max extimate return period (a) = **108** **Shape Parameter k=** **-0.2 (Type III Weibull)**

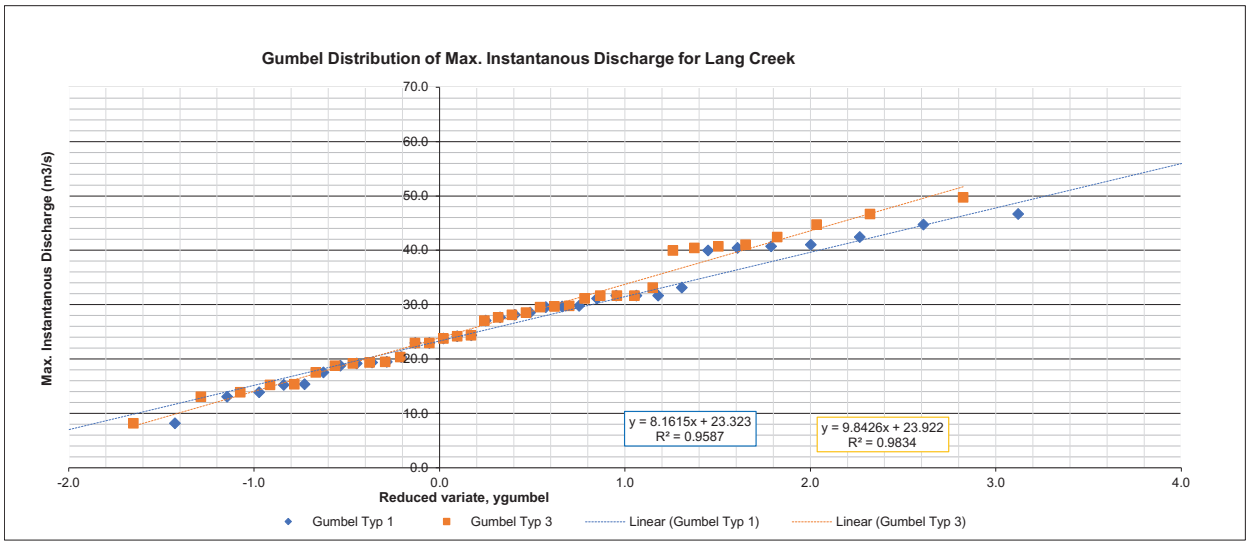
Year	Max. Annual Instantanious Discharge (m3/s)	Rank	Probability (F(x))	Typ 1 y-gumbel	Typ 3 y-gumbel	T (1/a)	z-value (-)	Standard error (Δm3/s)	Lower limit (m3/s)	Upper limit (m3/s)
1985	8.22	1	1.55%	-1.4271	-1.6516	1.02	1.43	1.7280	6.49	9.95
1964	13.10	2	4.32%	-1.1449	-1.2866	1.05	1.14	1.5613	11.54	14.66
1989	13.90	3	7.09%	-0.9734	-1.0746	1.08	0.97	1.4806	12.42	15.38
1965	15.30	4	9.86%	-0.8403	-0.9151	1.11	0.84	1.4308	13.87	16.73
1976	15.40	5	12.62%	-0.7273	-0.7829	1.14	0.73	1.3983	14.00	16.80
1962	17.60	6	15.39%	-0.6266	-0.6676	1.18	0.63	1.3776	16.22	18.98
1970	18.80	7	18.16%	-0.5341	-0.5636	1.22	0.53	1.3656	17.43	20.17
1984	19.20	8	20.93%	-0.4472	-0.4678	1.26	0.45	1.3607	17.84	20.56
1969	19.40	9	23.70%	-0.3645	-0.3781	1.31	0.36	1.3619	18.04	20.76
1967	19.50	10	26.47%	-0.2846	-0.2929	1.36	0.28	1.3684	18.13	20.87
1961	20.40	11	29.24%	-0.2068	-0.2112	1.41	0.21	1.3796	19.02	21.78
1977	23.00	12	32.00%	-0.1304	-0.1321	1.47	0.13	1.3954	21.60	24.40
1982	23.00	13	34.77%	-0.0548	-0.0551	1.53	0.05	1.4154	21.58	24.42
1978	23.80	14	37.54%	0.0205	0.0204	1.60	-0.02	1.4394	22.36	25.24
1988	24.20	15	40.31%	0.0959	0.0950	1.68	-0.10	1.4675	22.73	25.67
1963	24.40	16	43.08%	0.1718	0.1689	1.76	-0.17	1.4995	22.90	25.90
1987	27.10	17	45.85%	0.2486	0.2426	1.85	-0.25	1.5356	25.56	28.64
1979	27.70	18	48.62%	0.3268	0.3164	1.95	-0.33	1.5757	26.12	29.28
1971	28.20	19	51.38%	0.4067	0.3906	2.06	-0.41	1.6201	26.58	29.82
1960	28.60	20	54.15%	0.4888	0.4657	2.18	-0.49	1.6690	26.93	30.27
1995	29.60	21	56.92%	0.5736	0.5419	2.32	-0.57	1.7227	27.88	31.32
1990	29.70	22	59.69%	0.6616	0.6197	2.48	-0.66	1.7815	27.92	31.48
1986	29.80	23	62.46%	0.7536	0.6996	2.66	-0.75	1.8460	27.95	31.65
1981	31.20	24	65.23%	0.8503	0.7819	2.88	-0.85	1.9168	29.28	33.12
1966	31.70	25	68.00%	0.9526	0.8674	3.12	-0.95	1.9947	29.71	33.69
1972	31.70	26	70.76%	1.0618	0.9567	3.42	-1.06	2.0809	29.62	33.78
1980	31.70	27	73.53%	1.1795	1.0507	3.78	-1.18	2.1769	29.52	33.88
1993	33.20	28	76.30%	1.3076	1.1506	4.22	-1.31	2.2845	30.92	35.48
1991	40.00	29	79.07%	1.4489	1.2578	4.78	-1.45	2.4065	37.59	42.41
1994	40.50	30	81.84%	1.6073	1.3746	5.51	-1.61	2.5469	37.95	43.05
1974	40.80	31	84.61%	1.7888	1.5038	6.50	-1.79	2.7117	38.09	43.51
1968	41.10	32	87.38%	2.0028	1.6503	7.92	-2.00	2.9102	38.19	44.01
1975	42.50	33	90.14%	2.2657	1.8218	10.15	-2.27	3.1593	39.34	45.66
1992	44.80	34	92.91%	2.6103	2.0335	14.11	-2.61	3.4928	41.31	48.29
1973	46.70	35	95.68%	3.1202	2.3211	23.15	-3.12	3.9964	42.70	50.70
1983	49.80	36	98.45%	4.1589	2.8236	64.50	-4.16	5.0463	44.75	54.85

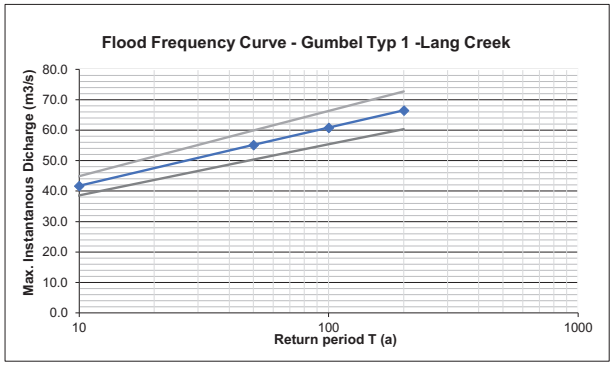
Parameter from the plot
α = 8.1615 β = 23.323
Gumbel Typ 1

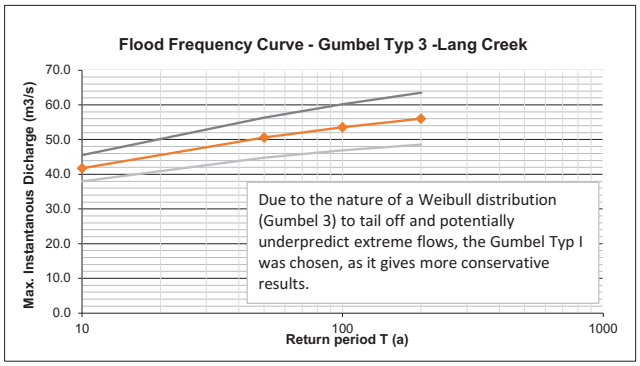
T return period (a)	Max. Inst. Discharge (m3/s)	Z-variable (-)	Standard error (Δm3/s)	Lower limit (m3/s)	Upper limit (m3/s)
2	**26.31**	-0.37	1.60	24.72	27.91
10	**41.69**	-2.25	3.14	38.54	44.83
50	**55.17**	-3.90	4.78	50.38	59.95
100	**60.87**	-4.60	5.50	55.37	66.37
200	**66.54**	-5.30	6.22	60.33	72.76

Parameter from the plot
α = 9.8426 β = 23.922
Gumbel Typ 3

T return period (a)	Max. Inst. Discharge (m3/s)	Z-variable (-)	Standard error (Δm3/s)	Lower limit (m3/s)	Upper limit (m3/s)
2	**27.40**	-0.37	1.93	25.47	29.33
10	**41.76**	-2.25	3.79	37.97	45.55
50	**50.58**	-3.90	5.77	44.81	56.35
100	**53.52**	-4.60	6.63	46.89	60.15
200	**56.07**	-5.30	7.50	48.57	63.57







APPENDIX H

HY-8 Calculations Report

HY-8 Culvert Analysis Report - #1 – Van Anda Creek @ Van Anda Avenue – Existing Culvert

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cms

Design Flow: 13.65 cms

Maximum Flow: 14.92 cms

Table 1 - Summary of Culvert Flows at Crossing: #1 - Van Anda Crk @ Van Anda Ave

Headwater Elevation (m)	Total Discharge (cms)	Ex. Culvert Discharge (cms)	Roadway Discharge (cms)	Iterations
12.82	0.00	0.00	0.00	1
13.65	1.49	1.49	0.00	1
14.34	2.98	2.98	0.00	1
14.64	4.48	3.48	1.00	3
14.74	5.97	3.63	2.33	5
14.82	7.46	3.76	3.70	4
14.90	8.95	3.87	5.08	4
14.97	10.44	3.97	6.47	4
15.04	11.94	4.06	7.87	4
15.11	13.65	4.14	9.51	4
15.16	14.92	4.16	10.75	3
14.50	3.26	3.26	0.00	Overtopping

Table 2 - Culvert Summary Table: Ex. Culvert

****

Straight Culvert

Inlet Elevation (invert): 12.79 m, Outlet Elevation (invert): 12.77 m

Culvert Length: 14.50 m, Culvert Slope: 0.0014

****

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.00	0.00	12.82	0.000	0.030	0-NF	0.000	0.000	0.050	0.000	0.000	0.000
1.49	1.49	13.65	0.751	0.859	2-M2c	0.900	0.508	0.508	0.226	2.017	1.238
2.98	2.98	14.34	1.307	1.546	7-M2c	0.900	0.721	0.721	0.341	2.731	1.590
4.48	3.48	14.64	1.552	1.846	7-M2c	0.900	0.770	0.770	0.433	2.999	1.831
5.97	3.63	14.74	1.637	1.948	7-M2c	0.900	0.784	0.784	0.512	3.091	2.019
7.46	3.76	14.82	1.711	2.033	7-M2c	0.900	0.794	0.794	0.584	3.168	2.176
8.95	3.87	14.90	1.776	2.110	7-M2c	0.900	0.802	0.802	0.649	3.236	2.310
10.44	3.97	14.97	1.837	2.180	7-M2c	0.900	0.809	0.809	0.709	3.299	2.428
11.94	4.06	15.04	1.893	2.245	7-M2t	0.900	0.815	0.816	0.766	3.351	2.534
13.65	4.14	15.11	1.943	2.317	7-M2t	0.900	0.819	0.877	0.827	3.278	2.644
14.92	4.16	15.16	1.958	2.369	4-FFf	0.900	0.821	0.900	0.870	3.273	2.719

Site Data - Ex. Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 m

Inlet Elevation: 12.79 m

Outlet Station: 14.50 m

Outlet Elevation: 12.77 m

Number of Barrels: 2

Culvert Data Summary - Ex. Culvert

Barrel Shape: Circular

Barrel Diameter: 900.00 mm

Barrel Material: Corrugated Steel

Embedment: 0.00 mm

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: #1 - Van Anda Crk @ Van Anda Ave)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
0.00	12.82	0.00	0.00	0.00	0.00
1.49	13.05	0.23	1.24	44.25	0.86
2.98	13.16	0.34	1.59	66.78	0.91
4.48	13.25	0.43	1.83	84.84	0.94
5.97	13.33	0.51	2.02	100.44	0.96
7.46	13.40	0.58	2.18	114.41	0.97
8.95	13.47	0.65	2.31	127.19	0.99
10.44	13.53	0.71	2.43	139.05	1.00
11.94	13.59	0.77	2.53	150.17	1.01
13.65	13.65	0.83	2.64	162.17	1.02
14.92	13.69	0.87	2.72	170.62	1.02

Tailwater Channel Data - #1 - Van Anda Crk @ Van Anda Ave

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 5.00 m

Side Slope (H:V): 1.50 (_:1)

Channel Slope: 0.0200

Channel Manning's n: 0.0400

Channel Invert Elevation: 12.82 m

Roadway Data for Crossing: #1 - Van Anda Crk @ Van Anda Ave

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 12.00 m

Crest Elevation: 14.50 m

Roadway Surface: Paved

Roadway Top Width: 7.00 m

HY-8 Culvert Analysis Report - #1 Van Anda Creek @ Van Anda Avenue – Proposed Culvert

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cms

Design Flow: 13.65 cms

Maximum Flow: 14.92 cms

Table 1 - Summary of Culvert Flows at Crossing: #1 - Van Anda Crk @ Van Anda Ave - Prop

Headwater Elevation (m)	Total Discharge (cms)	Prop. Culvert/Bridge Discharge (cms)	Roadway Discharge (cms)	Iterations
12.85	0.00	0.00	0.00	1
13.20	1.49	1.49	0.00	1
13.41	2.98	2.98	0.00	1
13.59	4.48	4.48	0.00	1
13.75	5.97	5.97	0.00	1
13.89	7.46	7.46	0.00	1
14.03	8.95	8.95	0.00	1
14.16	10.44	10.44	0.00	1
14.29	11.94	11.94	0.00	1
14.43	13.65	13.65	0.00	1
14.53	14.92	14.92	0.00	1
14.75	17.70	17.70	0.00	Overtopping

Table 2 - Culvert Summary Table: Prop. Culvert/Bridge

****

Straight Culvert

Inlet Elevation (invert): 12.79 m, Outlet Elevation (invert): 12.77 m

Culvert Length: 14.50 m, Culvert Slope: 0.0014

****

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.00	0.00	12.85	0.000	0.060	0-NF	0.000	0.000	0.080	0.000	0.000	0.000
1.49	1.49	13.20	0.369	0.415	3-M2t	0.481	0.212	0.288	0.208	1.061	1.347
2.98	2.98	13.41	0.586	0.623	3-M2t	0.737	0.337	0.395	0.315	1.551	1.732
4.48	4.48	13.59	0.769	0.798	3-M2t	0.952	0.441	0.480	0.400	1.913	1.998
5.97	5.97	13.75	0.932	0.955	3-M2t	1.149	0.534	0.554	0.474	2.211	2.206
7.46	7.46	13.89	1.077	1.101	3-M2t	1.349	0.620	0.620	0.540	2.469	2.378
8.95	8.95	14.03	1.209	1.239	2-M2c	1.676	0.698	0.698	0.600	2.633	2.527
10.44	10.44	14.16	1.331	1.370	2-M2c	1.676	0.773	0.773	0.657	2.780	2.658
11.94	11.94	14.29	1.448	1.496	2-M2c	1.676	0.844	0.844	0.709	2.915	2.775
13.65	13.65	14.43	1.579	1.637	2-M2c	1.676	0.922	0.922	0.766	3.058	2.897
14.92	14.92	14.53	1.678	1.739	7-M2c	1.676	0.978	0.978	0.806	3.157	2.980

Site Data - Prop. Culvert/Bridge

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 m

Inlet Elevation: 12.79 m

Outlet Station: 14.50 m

Outlet Elevation: 12.77 m

Number of Barrels: 1

Culvert Data Summary - Prop. Culvert/Bridge

Barrel Shape: Concrete Open-Bottom Arch

Barrel Span: 4876.80 mm

Barrel Rise: 1676.40 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120 (top and sides)

Manning's n: 0.0350 (bottom)

Culvert Type: Straight

Inlet Configuration: 45(deg) wingwall top square edge

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: #1 - Van Anda Crk @ Van Anda Ave -Prop)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
0.00	12.85	0.00	0.00	0.00	0.00
1.49	13.06	0.21	1.35	40.86	0.97
2.98	13.16	0.31	1.73	61.71	1.03
4.48	13.25	0.40	2.00	78.42	1.06
5.97	13.32	0.47	2.21	92.88	1.08
7.46	13.39	0.54	2.38	105.84	1.10
8.95	13.45	0.60	2.53	117.71	1.12
10.44	13.51	0.66	2.66	128.72	1.13
11.94	13.56	0.71	2.78	139.05	1.14
13.65	13.62	0.77	2.90	150.22	1.15
14.92	13.66	0.81	2.98	158.08	1.16

Tailwater Channel Data - #1 - Van Anda Crk @ Van Anda Ave -Prop

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 5.00 m

Side Slope (H:V): 1.50 (_:1)

Channel Slope: 0.0200

Channel Manning's n: 0.0350

Channel Invert Elevation: 12.85 m

Roadway Data for Crossing: #1 - Van Anda Crk @ Van Anda Ave -Prop

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 12.00 m

Crest Elevation: 14.75 m

Roadway Surface: Paved

Roadway Top Width: 7.00 m

HY-8 Culvert Analysis Report - #2 – Marble Rd Crossing – Existing Culvert

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cms

Design Flow: 1.023 cms

Maximum Flow: 1.167 cms

Table 1 - Summary of Culvert Flows at Crossing: #2 - Marble Rd Crossing - Ex.

Headwater Elevation (m)	Total Discharge (cms)	Ex. Culvert Discharge (cms)	Roadway Discharge (cms)	Iterations
13.00	0.00	0.00	0.00	1
13.41	0.12	0.12	0.00	1
13.61	0.23	0.19	0.04	21
13.63	0.35	0.19	0.15	5
13.65	0.47	0.20	0.27	4
13.66	0.58	0.20	0.38	4
13.67	0.70	0.20	0.49	3
13.68	0.82	0.20	0.61	3
13.70	0.93	0.20	0.73	3
13.70	1.02	0.20	0.82	3
13.72	1.17	0.19	0.97	3
13.60	0.19	0.19	0.00	Overtopping

Table 2 - Culvert Summary Table: Ex. Culvert

****

Straight Culvert

Inlet Elevation (invert): 13.00 m, Outlet Elevation (invert): 12.90 m

Culvert Length: 14.00 m, Culvert Slope: 0.0071

****

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.00	0.00	13.00	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
0.12	0.12	13.41	0.377	0.409	2-M2c	0.331	0.238	0.238	0.120	1.366	0.871
0.23	0.19	13.61	0.543	0.615	7-M2c	0.450	0.306	0.306	0.181	1.641	1.095
0.35	0.19	13.63	0.557	0.634	7-M2c	0.450	0.310	0.310	0.229	1.661	1.244
0.47	0.20	13.65	0.567	0.649	7-M2c	0.450	0.313	0.313	0.271	1.675	1.358
0.58	0.20	13.66	0.575	0.662	7-M2c	0.450	0.316	0.316	0.308	1.686	1.451
0.70	0.20	13.67	0.579	0.674	7-M2t	0.450	0.317	0.341	0.341	1.567	1.530
0.82	0.20	13.68	0.581	0.685	7-M2t	0.450	0.318	0.372	0.372	1.447	1.599
0.93	0.20	13.70	0.576	0.695	7-M2t	0.450	0.316	0.401	0.401	1.346	1.660
1.02	0.20	13.70	0.568	0.703	7-M2t	0.450	0.314	0.422	0.422	1.282	1.703
1.17	0.19	13.72	0.554	0.715	4-FFf	0.450	0.310	0.450	0.454	1.215	1.767

Site Data - Ex. Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 m

Inlet Elevation: 13.00 m

Outlet Station: 14.00 m

Outlet Elevation: 12.90 m

Number of Barrels: 1

Culvert Data Summary - Ex. Culvert

Barrel Shape: Circular

Barrel Diameter: 450.00 mm

Barrel Material: Corrugated Steel

Embedment: 0.00 mm

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Thin Edge Projecting

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: #2 - Marble Rd Crossing - Ex.)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
0.00	12.90	0.00	0.00	0.00	0.00
0.12	13.02	0.12	0.87	23.46	0.85
0.23	13.08	0.18	1.10	35.39	0.88
0.35	13.13	0.23	1.24	44.89	0.90
0.47	13.17	0.27	1.36	53.05	0.92
0.58	13.21	0.31	1.45	60.31	0.93
0.70	13.24	0.34	1.53	66.91	0.94
0.82	13.27	0.37	1.60	72.99	0.94
0.93	13.30	0.40	1.66	78.67	0.95
1.02	13.32	0.42	1.70	82.78	0.95
1.17	13.35	0.45	1.77	89.04	0.96

Tailwater Channel Data - #2 - Marble Rd Crossing - Ex.

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 1.00 m

Side Slope (H:V): 1.00 (_:1)

Channel Slope: 0.0200

Channel Manning's n: 0.0350

Channel Invert Elevation: 12.90 m

Roadway Data for Crossing: #2 - Marble Rd Crossing - Ex.

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 15.00 m

Crest Elevation: 13.60 m

Roadway Surface: Paved

Roadway Top Width: 7.50 m

HY-8 Culvert Analysis Report - #2 – Marble Rd Crossing – Proposed Culvert

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cms

Design Flow: 1.023 cms

Maximum Flow: 1.167 cms

Table 1 - Summary of Culvert Flows at Crossing: #5 - Cranby Crk @ Gillies Bay Rd

Headwater Elevation (m)	Total Discharge (cms)	Culvert 1 Discharge (cms)	Roadway Discharge (cms)	Iterations
1.00	0.00	0.00	0.00	1
1.28	1.01	1.01	0.00	1
1.51	2.03	2.03	0.00	1
2.09	3.04	3.04	0.00	1
3.08	4.06	4.06	0.00	1
4.19	5.07	4.28	0.78	10
4.25	6.08	4.20	1.88	6
4.29	7.10	4.12	2.97	5
4.33	8.11	4.04	4.06	4
4.37	9.27	3.96	5.31	4
4.40	10.14	3.90	6.24	4
4.12	4.66	4.66	0.00	Overtopping

Table 2 - Culvert Summary Table: Culvert 1

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Straight Culvert

Inlet Elevation (invert): 0.00 m, Outlet Elevation (invert): 1.00 m

Culvert Length: 13.39 m, Culvert Slope: -0.0749

****

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.00	0.00	1.00	0.000	1.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
1.01	1.01	1.28	0.886	1.278	7-A2c	-0.305	0.546	0.546	0.517	2.027	0.355
2.03	2.03	1.51	1.401	1.511	7-A2c	-0.305	0.784	0.784	0.764	2.592	0.441
3.04	3.04	2.09	2.086	1.901	7-JA2c	-0.305	0.958	0.958	0.954	3.142	0.497
4.06	4.06	3.08	3.083	2.446	7-A2t	-0.305	1.076	1.115	1.115	3.704	0.541
5.07	4.28	4.19	3.353	4.192	4-FFf	-0.305	1.095	1.200	1.255	3.785	0.576
6.08	4.20	4.25	3.256	4.247	4-FFf	-0.305	1.089	1.200	1.381	3.715	0.607
7.10	4.12	4.29	3.160	4.292	4-FFf	-0.305	1.082	1.200	1.496	3.645	0.633
8.11	4.04	4.33	3.069	4.332	4-FFf	-0.305	1.075	1.200	1.603	3.576	0.657
9.27	3.96	4.37	2.973	4.373	4-FFf	-0.305	1.068	1.200	1.716	3.501	0.681
10.14	3.90	4.40	2.904	4.401	4-FFf	-0.305	1.062	1.200	1.795	3.446	0.698

Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 1.15 m

Inlet Elevation: 0.00 m

Outlet Station: 14.50 m

Outlet Elevation: 1.00 m

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Circular

Barrel Diameter: 1200.00 mm

Barrel Material: Corrugated Steel

Embedment: 0.00 mm

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Thin Edge Projecting

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: #5 - Cranby Crk @ Gillies Bay Rd)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
0.00	1.00	0.00	0.00	0.00	0.00
1.01	1.52	0.52	0.35	5.07	0.17
2.03	1.76	0.76	0.44	7.48	0.18
3.04	1.95	0.95	0.50	9.35	0.19
4.06	2.11	1.11	0.54	10.92	0.19
5.07	2.25	1.25	0.58	12.30	0.19
6.08	2.38	1.38	0.61	13.54	0.19
7.10	2.50	1.50	0.63	14.67	0.20
8.11	2.60	1.60	0.66	15.71	0.20
9.27	2.72	1.72	0.68	16.82	0.20
10.14	2.80	1.80	0.70	17.60	0.20

Tailwater Channel Data - #5 - Cranby Crk @ Gillies Bay Rd

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 4.50 m

Side Slope (H:V): 2.00 (_:1)

Channel Slope: 0.0010

Channel Manning's n: 0.0500

Channel Invert Elevation: 1.00 m

Roadway Data for Crossing: #5 - Cranby Crk @ Gillies Bay Rd

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 25.00 m

Crest Elevation: 4.12 m

Roadway Surface: Paved

Roadway Top Width: 8.50 m

HY-8 Culvert Analysis Report - #3 – Priest Lake @ Gillies Bay Rd– Existing Culvert

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cms

Design Flow: 11.10 cms

Maximum Flow: 12.14 cms

Table 1 - Summary of Culvert Flows at Crossing: #3 - Priest Lake @ Gillies Bay Rd

Headwater Elevation (m)	Total Discharge (cms)	Ex. Culvert Discharge (cms)	Roadway Discharge (cms)	Iterations
72.30	0.00	0.00	0.00	1
73.31	1.21	1.21	0.00	1
73.89	2.43	2.43	0.00	1
74.53	3.64	3.19	0.45	11
74.58	4.86	3.23	1.62	6
74.61	6.07	3.27	2.80	5
74.64	7.28	3.29	3.98	4
74.67	8.50	3.31	5.18	4
74.69	9.71	3.34	6.36	3
74.72	11.10	3.37	7.72	3
74.74	12.14	3.39	8.75	3
74.50	3.16	3.16	0.00	Overtopping

Table 2 - Culvert Summary Table: Ex. Culvert

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Straight Culvert

Inlet Elevation (invert): 72.30 m, Outlet Elevation (invert): 72.00 m

Culvert Length: 30.00 m, Culvert Slope: 0.0100

****

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.00	0.00	72.30	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
1.21	1.21	73.31	0.934	1.014	2-M2c	0.652	0.599	0.599	0.146	2.149	0.554
2.43	2.43	73.89	1.589	1.576	7-M2c	1.200	0.859	0.859	0.222	2.803	0.728
3.64	3.19	74.53	2.158	2.233	7-M2c	1.200	0.979	0.979	0.285	3.228	0.853
4.86	3.23	74.58	2.195	2.278	7-M2c	1.200	0.985	0.985	0.339	3.253	0.954
6.07	3.27	74.61	2.225	2.312	7-M2c	1.200	0.989	0.989	0.389	3.274	1.041
7.28	3.29	74.64	2.250	2.341	7-M2c	1.200	0.993	0.993	0.435	3.291	1.117
8.50	3.31	74.67	2.269	2.368	7-M2c	1.200	0.996	0.996	0.478	3.304	1.185
9.71	3.34	74.69	2.293	2.393	7-M2c	1.200	0.999	0.999	0.519	3.320	1.248
11.10	3.37	74.72	2.318	2.419	7-M2c	1.200	1.003	1.003	0.563	3.337	1.313
12.14	3.39	74.74	2.335	2.438	7-M2c	1.200	1.005	1.005	0.596	3.348	1.359

Site Data - Ex. Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 m

Inlet Elevation: 72.30 m

Outlet Station: 30.00 m

Outlet Elevation: 72.00 m

Number of Barrels: 1

Culvert Data Summary - Ex. Culvert

Barrel Shape: Circular

Barrel Diameter: 1200.00 mm

Barrel Material: Corrugated Steel

Embedment: 0.00 mm

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Thin Edge Projecting

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: #3 - Priest Lake @ Gillies Bay Rd)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
0.00	72.00	0.00	0.00	0.00	0.00
1.21	72.15	0.15	0.55	7.17	0.46
2.43	72.22	0.22	0.73	10.90	0.49
3.64	72.28	0.28	0.85	13.95	0.51
4.86	72.34	0.34	0.95	16.63	0.52
6.07	72.39	0.39	1.04	19.06	0.53
7.28	72.43	0.43	1.12	21.31	0.54
8.50	72.48	0.48	1.19	23.43	0.55
9.71	72.52	0.52	1.25	25.43	0.55
11.10	72.56	0.56	1.31	27.61	0.56
12.14	72.60	0.60	1.36	29.19	0.56

Tailwater Channel Data - #3 - Priest Lake @ Gillies Bay Rd

Tailwater Channel Option: Rectangular Channel

Bottom Width: 15.00 m

Channel Slope: 0.0050

Channel Manning's n: 0.0350

Channel Invert Elevation: 72.00 m

Roadway Data for Crossing: #3 - Priest Lake @ Gillies Bay Rd

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 45.00 m

Crest Elevation: 74.50 m

Roadway Surface: Paved

Roadway Top Width: 20.00 m

HY-8 Culvert Analysis Report - #3 – Priest Lake @ Gillies Bay Rd – Proposed Culvert

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cms

Design Flow: 11.10 cms

Maximum Flow: 12.14 cms

Table 1 - Summary of Culvert Flows at Crossing: #3 - Priest Lake @ Gillies Bay Rd -Prop

Headwater Elevation (m)	Total Discharge (cms)	Prop. Culvert Discharge (cms)	Roadway Discharge (cms)	Iterations
72.60	0.00	0.00	0.00	1
72.95	1.21	1.21	0.00	1
73.15	2.43	2.43	0.00	1
73.32	3.64	3.64	0.00	1
73.47	4.86	4.86	0.00	1
73.61	6.07	6.07	0.00	1
73.75	7.28	7.28	0.00	1
73.87	8.50	8.50	0.00	1
73.99	9.71	9.71	0.00	1
74.12	11.10	11.10	0.00	1
74.21	12.14	12.14	0.00	1
74.50	15.33	15.33	0.00	Overtopping

Table 2 - Culvert Summary Table: Prop. Culvert

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Straight Culvert

Inlet Elevation (invert): 72.60 m, Outlet Elevation (invert): 72.30 m

Culvert Length: 30.00 m, Culvert Slope: 0.0100

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Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.00	0.00	72.60	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
1.21	1.21	72.95	0.343	0.350	2-M2c	0.254	0.202	0.202	0.146	1.408	0.554
2.43	2.43	73.15	0.545	0.553	2-M2c	0.390	0.321	0.321	0.222	1.774	0.728
3.64	3.64	73.32	0.714	0.723	2-M2c	0.501	0.420	0.420	0.285	2.031	0.853
4.86	4.86	73.47	0.863	0.875	2-M2c	0.600	0.509	0.509	0.339	2.235	0.954
6.07	6.07	73.61	0.997	1.015	2-M2c	0.690	0.591	0.591	0.389	2.408	1.041
7.28	7.28	73.75	1.123	1.146	2-M2c	0.774	0.667	0.667	0.435	2.559	1.117
8.50	8.50	73.87	1.243	1.270	2-M2c	0.853	0.739	0.739	0.478	2.693	1.185
9.71	9.71	73.99	1.360	1.388	2-M2c	0.929	0.808	0.808	0.519	2.816	1.248
11.10	11.10	74.12	1.490	1.517	2-M2c	1.012	0.883	0.883	0.563	2.944	1.313
12.14	12.14	74.21	1.588	1.610	7-M2c	1.072	0.938	0.938	0.596	3.034	1.359

Site Data - Prop. Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 m

Inlet Elevation: 72.30 m

Outlet Station: 30.00 m

Outlet Elevation: 72.00 m

Number of Barrels: 2

Culvert Data Summary - Prop. Culvert

Barrel Shape: Concrete Box

Barrel Span: 2134.00 mm

Barrel Rise: 1829.00 mm

Barrel Material: Concrete

Embedment: 300.00 mm

Barrel Manning's n: 0.0120 (top and sides)

Manning's n: 0.0350 (bottom)

Culvert Type: Straight

Inlet Configuration: Square Edge (90ï¿½) Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: #3 - Priest Lake @ Gillies Bay Rd -Prop)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
0.00	72.00	0.00	0.00	0.00	0.00
1.21	72.15	0.15	0.55	7.17	0.46
2.43	72.22	0.22	0.73	10.90	0.49
3.64	72.28	0.28	0.85	13.95	0.51
4.86	72.34	0.34	0.95	16.63	0.52
6.07	72.39	0.39	1.04	19.06	0.53
7.28	72.43	0.43	1.12	21.31	0.54
8.50	72.48	0.48	1.19	23.43	0.55
9.71	72.52	0.52	1.25	25.43	0.55
11.10	72.56	0.56	1.31	27.61	0.56
12.14	72.60	0.60	1.36	29.19	0.56

Tailwater Channel Data - #3 - Priest Lake @ Gillies Bay Rd -Prop

Tailwater Channel Option: Rectangular Channel

Bottom Width: 15.00 m

Channel Slope: 0.0050

Channel Manning's n: 0.0350

Channel Invert Elevation: 72.00 m

Roadway Data for Crossing: #3 - Priest Lake @ Gillies Bay Rd -Prop

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 45.00 m

Crest Elevation: 74.50 m

Roadway Surface: Paved

Roadway Top Width: 20.00 m

HY-8 Culvert Analysis Report - #4-1 – Airport Rd – New Crossing Culvert– Existing Culvert

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cms

Design Flow: 0.246 cms

Maximum Flow: 0.284 cms

Table 1 - Summary of Culvert Flows at Crossing: #4-1 - Airport Rd - New Cr Culvert - Ex.

Headwater Elevation (m)	Total Discharge (cms)	Ex. Culvert Discharge (cms)	Roadway Discharge (cms)	Iterations
63.80	0.00	0.00	0.00	1
63.97	0.03	0.03	0.00	1
64.02	0.06	0.06	0.00	1
64.07	0.09	0.09	0.00	1
64.12	0.11	0.11	0.00	1
64.21	0.14	0.14	0.00	1
64.26	0.17	0.17	0.00	1
64.30	0.20	0.20	0.00	1
64.33	0.23	0.23	0.00	1
64.36	0.25	0.25	0.00	1
64.40	0.28	0.28	0.00	18
64.40	0.28	0.28	0.00	Overtopping

Table 2 - Culvert Summary Table: Ex. Culvert

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.00	0.00	63.80	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
0.03	0.03	63.97	0.153	0.174	2-M2c	0.106	0.106	0.106	0.051	0.848	0.527
0.06	0.06	64.02	0.219	0.0*	1-S2n	0.150	0.150	0.150	0.078	1.026	0.678
0.09	0.09	64.07	0.272	0.0*	1-S2n	0.185	0.185	0.185	0.099	1.151	0.782
0.11	0.11	64.12	0.318	0.0*	1-S2n	0.215	0.215	0.215	0.118	1.248	0.863
0.14	0.14	64.21	0.362	0.413	2-M2c	0.242	0.242	0.242	0.135	1.333	0.931
0.17	0.17	64.26	0.403	0.456	2-M2c	0.268	0.266	0.266	0.150	1.410	0.989
0.20	0.20	64.30	0.443	0.496	2-M2c	0.293	0.288	0.288	0.164	1.482	1.040
0.23	0.23	64.33	0.483	0.534	2-M2c	0.317	0.309	0.309	0.178	1.549	1.086
0.25	0.25	64.36	0.509	0.559	2-M2c	0.333	0.322	0.322	0.186	1.592	1.114
0.28	0.28	64.40	0.557	0.601	7-M2c	0.362	0.345	0.345	0.203	1.668	1.166

* Full Flow Headwater elevation is below inlet invert.

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Straight Culvert

Inlet Elevation (invert): 63.80 m, Outlet Elevation (invert): 63.50 m

Culvert Length: 19.50 m, Culvert Slope: 0.0154

****

Site Data - Ex. Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 m

Inlet Elevation: 63.80 m

Outlet Station: 19.50 m

Outlet Elevation: 63.50 m

Number of Barrels: 1

Culvert Data Summary - Ex. Culvert

Barrel Shape: Circular

Barrel Diameter: 600.00 mm

Barrel Material: Corrugated Steel

Embedment: 0.00 mm

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Thin Edge Projecting

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: #4-1 - Airport Rd - New Cr Culvert - Ex.)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
0.00	63.50	0.00	0.00	0.00	0.00
0.03	63.55	0.05	0.53	10.05	0.76
0.06	63.58	0.08	0.68	15.24	0.80
0.09	63.60	0.10	0.78	19.44	0.83
0.11	63.62	0.12	0.86	23.08	0.84
0.14	63.63	0.13	0.93	26.37	0.86
0.17	63.65	0.15	0.99	29.38	0.87
0.20	63.66	0.16	1.04	32.19	0.88
0.23	63.68	0.18	1.09	34.83	0.88
0.25	63.69	0.19	1.11	36.51	0.89
0.28	63.70	0.20	1.17	39.72	0.89

Tailwater Channel Data - #4-1 - Airport Rd - New Cr Culvert - Ex.

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 1.00 m

Side Slope (H:V): 1.00 (_:1)

Channel Slope: 0.0200

Channel Manning's n: 0.0350

Channel Invert Elevation: 63.50 m

Roadway Data for Crossing: #4-1 - Airport Rd - New Cr Culvert - Ex.

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 20.00 m

Crest Elevation: 64.40 m

Roadway Surface: Paved

Roadway Top Width: 12.50 m

HY-8 Culvert Analysis Report- #4-1 – Aiport Rd – New Crossing Culvert– Proposed

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cms

Design Flow: 0.246 cms

Maximum Flow: 0.284 cms

Table 1 - Summary of Culvert Flows at Crossing: #4-1 - Airport Rd - New Cr Culvert - Prop.

Headwater Elevation (m)	Total Discharge (cms)	Prop. Culvert Discharge (cms)	Roadway Discharge (cms)	Iterations
63.75	0.00	0.00	0.00	1
63.89	0.03	0.03	0.00	1
63.95	0.06	0.06	0.00	1
64.00	0.09	0.09	0.00	1
64.04	0.11	0.11	0.00	1
64.09	0.14	0.14	0.00	1
64.13	0.17	0.17	0.00	1
64.17	0.20	0.20	0.00	1
64.20	0.23	0.23	0.00	1
64.23	0.25	0.25	0.00	1
64.27	0.28	0.28	0.00	1
64.40	0.39	0.39	0.00	Overtopping

Table 2 - Culvert Summary Table: Prop. Culvert

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.00	0.00	63.75	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
0.03	0.03	63.89	0.142	0.0*	1-S2n	0.079	0.106	0.079	0.051	1.281	0.527
0.06	0.06	63.95	0.204	0.0*	1-S2n	0.111	0.150	0.111	0.078	1.572	0.678
0.09	0.09	64.00	0.253	0.0*	1-S2n	0.136	0.185	0.136	0.099	1.769	0.782
0.11	0.11	64.04	0.295	0.0*	1-S2n	0.157	0.215	0.159	0.118	1.892	0.863
0.14	0.14	64.09	0.339	0.020	1-S2n	0.176	0.242	0.179	0.135	2.004	0.931
0.17	0.17	64.13	0.380	0.056	1-S2n	0.194	0.266	0.197	0.150	2.105	0.989
0.20	0.20	64.17	0.418	0.093	1-S2n	0.210	0.288	0.215	0.164	2.186	1.040
0.23	0.23	64.20	0.454	0.131	1-S2n	0.226	0.309	0.231	0.178	2.260	1.086
0.25	0.25	64.23	0.477	0.156	1-S2n	0.236	0.322	0.242	0.186	2.303	1.114
0.28	0.28	64.27	0.522	0.210	1-S2n	0.255	0.347	0.263	0.203	2.386	1.166

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 63.75 m, Outlet Elevation (invert): 63.50 m

Culvert Length: 19.50 m, Culvert Slope: 0.0128

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Site Data - Prop. Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 m

Inlet Elevation: 63.75 m

Outlet Station: 19.50 m

Outlet Elevation: 63.50 m

Number of Barrels: 1

Culvert Data Summary - Prop. Culvert

Barrel Shape: Circular

Barrel Diameter: 600.00 mm

Barrel Material: Smooth HDPE

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: #4-1 - Airport Rd - New Cr Culvert - Prop.)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
0.00	63.50	0.00	0.00	0.00	0.00
0.03	63.55	0.05	0.53	10.05	0.76
0.06	63.58	0.08	0.68	15.24	0.80
0.09	63.60	0.10	0.78	19.44	0.83
0.11	63.62	0.12	0.86	23.08	0.84
0.14	63.63	0.13	0.93	26.37	0.86
0.17	63.65	0.15	0.99	29.38	0.87
0.20	63.66	0.16	1.04	32.19	0.88
0.23	63.68	0.18	1.09	34.83	0.88
0.25	63.69	0.19	1.11	36.51	0.89
0.28	63.70	0.20	1.17	39.72	0.89

Tailwater Channel Data - #4-1 - Airport Rd - New Cr Culvert - Prop.

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 1.00 m

Side Slope (H:V): 1.00 (_:1)

Channel Slope: 0.0200

Channel Manning's n: 0.0350

Channel Invert Elevation: 63.50 m

Roadway Data for Crossing: #4-1 - Airport Rd - New Cr Culvert - Prop.

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 20.00 m

Crest Elevation: 64.40 m

Roadway Surface: Paved

Roadway Top Width: 12.50 m

HY-8 Culvert Analysis Report - #4-2 – Airport Rd – Gillies Bay– Existing Culvert

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cms

Design Flow: 2.55 cms

Maximum Flow: 2.99 cms

Table 1 - Summary of Culvert Flows at Crossing: #4-2 - Airport Rd - Gillies Bay - Ex.

Headwater Elevation (m)	Total Discharge (cms)	Ex. Culvert Discharge (cms)	Roadway Discharge (cms)	Iterations
21.40	0.00	0.00	0.00	1
21.76	0.30	0.30	0.00	1
21.97	0.60	0.60	0.00	1
22.14	0.90	0.81	0.09	9
22.19	1.20	0.87	0.33	6
22.23	1.49	0.91	0.58	5
22.27	1.79	0.95	0.84	4
22.30	2.09	0.98	1.11	4
22.33	2.39	1.01	1.38	4
22.35	2.55	1.02	1.52	3
22.39	2.99	1.06	1.93	3
22.10	0.77	0.77	0.00	Overtopping

Table 2 - Culvert Summary Table: Ex. Culvert

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.00	0.00	21.40	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
0.30	0.30	21.76	0.360	0.0*	1-S2n	0.176	0.248	0.177	0.165	2.139	1.088
0.60	0.60	21.97	0.571	0.0*	1-S2n	0.255	0.357	0.255	0.249	2.617	1.371
0.90	0.81	22.14	0.737	0.022	5-S2n	0.303	0.417	0.303	0.316	2.829	1.561
1.20	0.87	22.19	0.789	0.097	5-S2n	0.316	0.432	0.318	0.374	2.849	1.705
1.49	0.91	22.23	0.829	0.155	5-S2n	0.325	0.442	0.328	0.426	2.877	1.824
1.79	0.95	22.27	0.866	0.227	5-S2n	0.333	0.451	0.333	0.473	2.939	1.924
2.09	0.98	22.30	0.899	0.309	5-S2n	0.340	0.458	0.340	0.516	2.962	2.012
2.39	1.01	22.33	0.930	0.386	5-S2n	0.347	0.465	0.347	0.556	2.982	2.091
2.55	1.02	22.35	0.945	0.424	5-S2n	0.350	0.468	0.350	0.577	2.992	2.129
2.99	1.06	22.39	0.987	0.524	5-S2n	0.358	0.476	0.358	0.630	3.016	2.227

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 21.40 m, Outlet Elevation (invert): 20.60 m

Culvert Length: 14.02 m, Culvert Slope: 0.0571

****

Site Data - Ex. Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 m

Inlet Elevation: 21.40 m

Outlet Station: 14.00 m

Outlet Elevation: 20.60 m

Number of Barrels: 2

Culvert Data Summary - Ex. Culvert

Barrel Shape: Circular

Barrel Diameter: 600.00 mm

Barrel Material: Corrugated Steel

Embedment: 0.00 mm

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Thin Edge Projecting

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: #4-2 - Airport Rd - Gillies Bay - Ex.)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
0.00	20.60	0.00	0.00	0.00	0.00
0.30	20.77	0.17	1.09	32.36	0.90
0.60	20.85	0.25	1.37	48.87	0.94
0.90	20.92	0.32	1.56	62.03	0.96
1.20	20.97	0.37	1.71	73.36	0.97
1.49	21.03	0.43	1.82	83.46	0.99
1.79	21.07	0.47	1.92	92.65	0.99
2.09	21.12	0.52	2.01	101.14	1.00
2.39	21.16	0.56	2.09	109.06	1.01
2.55	21.18	0.58	2.13	113.06	1.01
2.99	21.23	0.63	2.23	123.57	1.02

Tailwater Channel Data - #4-2 - Airport Rd - Gillies Bay - Ex.

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 1.50 m

Side Slope (H:V): 1.00 (_:1)

Channel Slope: 0.0200

Channel Manning's n: 0.0350

Channel Invert Elevation: 20.60 m

Roadway Data for Crossing: #4-2 - Airport Rd - Gillies Bay - Ex.

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 7.50 m

Crest Elevation: 22.10 m

Roadway Surface: Paved

Roadway Top Width: 10.00 m

HY-8 Culvert Analysis Report - #4-2 – Airport Rd – Gillies Bay – Proposed Culvert

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cms

Design Flow: 2.55 cms

Maximum Flow: 2.99 cms

Table 1 - Summary of Culvert Flows at Crossing: #4-2 - Airport Rd - Gillies Bay - Prop

Headwater Elevation (m)	Total Discharge (cms)	Prop. Culvert Discharge (cms)	Roadway Discharge (cms)	Iterations
21.40	0.00	0.00	0.00	1
21.59	0.30	0.30	0.00	1
21.70	0.60	0.60	0.00	1
21.79	0.90	0.90	0.00	1
21.88	1.20	1.20	0.00	1
21.95	1.49	1.49	0.00	1
22.03	1.79	1.79	0.00	1
22.10	2.09	2.09	0.00	1
22.16	2.39	2.39	0.00	1
22.20	2.55	2.55	0.00	1
22.29	2.99	2.99	0.00	1
22.30	3.02	3.02	0.00	Overtopping

Table 2 - Culvert Summary Table: Prop. Culvert

* Full Flow Headwater elevation is below inlet invert.

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Straight Culvert

Inlet Elevation (invert): 21.40 m, Outlet Elevation (invert): 20.60 m

Culvert Length: 14.02 m, Culvert Slope: 0.0571

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Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.00	0.00	21.40	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
0.30	0.30	21.59	0.189	0.0*	1-S2n	0.049	0.117	0.049	0.165	2.555	1.088
0.60	0.60	21.70	0.300	0.0*	1-S2n	0.075	0.185	0.078	0.249	3.179	1.371
0.90	0.90	21.79	0.393	0.0*	1-S2n	0.097	0.242	0.097	0.316	3.837	1.561
1.20	1.20	21.88	0.476	0.0*	1-S2n	0.117	0.294	0.132	0.374	3.775	1.705
1.49	1.49	21.95	0.554	0.0*	1-S2n	0.135	0.341	0.156	0.426	3.994	1.824
1.79	1.79	22.03	0.627	0.0*	1-S2n	0.152	0.385	0.180	0.473	4.148	1.924
2.09	2.09	22.10	0.696	0.0*	1-S2n	0.169	0.426	0.203	0.516	4.290	2.012
2.39	2.39	22.16	0.763	0.0*	1-S2n	0.184	0.466	0.226	0.556	4.411	2.091
2.55	2.55	22.20	0.797	0.0*	1-S2n	0.192	0.486	0.238	0.577	4.463	2.129
2.99	2.99	22.29	0.893	0.000	1-S2n	0.214	0.541	0.271	0.630	4.604	2.227

Site Data - Prop. Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 m

Inlet Elevation: 21.40 m

Outlet Station: 14.00 m

Outlet Elevation: 20.60 m

Number of Barrels: 2

Culvert Data Summary - Prop. Culvert

Barrel Shape: Concrete Box

Barrel Span: 1200.00 mm

Barrel Rise: 900.00 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge (90 deg) Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: #4-2 - Airport Rd - Gillies Bay - Prop)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
0.00	20.60	0.00	0.00	0.00	0.00
0.30	20.77	0.17	1.09	32.36	0.90
0.60	20.85	0.25	1.37	48.87	0.94
0.90	20.92	0.32	1.56	62.03	0.96
1.20	20.97	0.37	1.71	73.36	0.97
1.49	21.03	0.43	1.82	83.46	0.99
1.79	21.07	0.47	1.92	92.65	0.99
2.09	21.12	0.52	2.01	101.14	1.00
2.39	21.16	0.56	2.09	109.06	1.01
2.55	21.18	0.58	2.13	113.06	1.01
2.99	21.23	0.63	2.23	123.57	1.02

Tailwater Channel Data - #4-2 - Airport Rd - Gillies Bay - Prop

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 1.50 m

Side Slope (H:V): 1.00 (_:1)

Channel Slope: 0.0200

Channel Manning's n: 0.0350

Channel Invert Elevation: 20.60 m

Roadway Data for Crossing: #4-2 - Airport Rd - Gillies Bay - Prop

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 7.50 m

Crest Elevation: 22.30 m

Roadway Surface: Paved

Roadway Top Width: 10.00 m

HY-8 Culvert Analysis Report - #4-3 – Airport Rd - Sanderson– Existing Culvert

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cms

Design Flow: 2.58 cms

Maximum Flow: 3.03 cms

Table 1 - Summary of Culvert Flows at Crossing: #4-3 - Airport Rd - Sanderson - Ex.

Headwater Elevation (m)	Total Discharge (cms)	Ex. Culvert Discharge (cms)	Roadway Discharge (cms)	Iterations
14.10	0.00	0.00	0.00	1
14.68	0.30	0.30	0.00	1
15.44	0.61	0.61	0.00	1
15.56	0.91	0.64	0.27	8
15.60	1.21	0.65	0.56	5
15.64	1.51	0.66	0.85	4
15.67	1.82	0.67	1.15	4
15.70	2.12	0.68	1.44	4
15.72	2.42	0.68	1.74	3
15.73	2.58	0.69	1.89	3
15.77	3.03	0.70	2.33	3
15.50	0.62	0.62	0.00	Overtopping

Table 2 - Culvert Summary Table: Ex. Culvert

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.00	0.00	14.10	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
0.30	0.30	14.68	0.579	0.0*	5-S2n	0.155	0.373	0.155	0.172	5.693	1.507
0.61	0.61	15.44	1.341	0.0*	5-S2n	0.224	0.493	0.236	0.258	6.437	1.871
0.91	0.64	15.56	1.464	0.0*	5-S2n	0.231	0.499	0.245	0.325	6.477	2.110
1.21	0.65	15.60	1.504	0.0*	5-S2n	0.233	0.500	0.248	0.383	6.491	2.292
1.51	0.66	15.64	1.537	0.0*	5-S2n	0.235	0.501	0.250	0.433	6.503	2.440
1.82	0.67	15.67	1.567	0.0*	5-S2n	0.237	0.495	0.251	0.479	6.564	2.566
2.12	0.68	15.70	1.595	0.0*	5-S2n	0.238	0.488	0.254	0.521	6.531	2.676
2.42	0.68	15.72	1.621	0.0*	5-S2n	0.239	0.484	0.254	0.560	6.579	2.774
2.58	0.69	15.73	1.634	0.0*	5-S2n	0.240	0.482	0.254	0.579	6.614	2.820
3.03	0.70	15.77	1.669	1.318	5-S1f	0.242	0.477	0.525	0.631	3.211	2.943

* Full Flow Headwater elevation is below inlet invert.

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Straight Culvert

Inlet Elevation (invert): 14.10 m, Outlet Elevation (invert): 10.80 m

Culvert Length: 28.19 m, Culvert Slope: 0.1179

****

Site Data - Ex. Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 m

Inlet Elevation: 14.10 m

Outlet Station: 28.00 m

Outlet Elevation: 10.80 m

Number of Barrels: 1

Culvert Data Summary - Ex. Culvert

Barrel Shape: Circular

Barrel Diameter: 525.00 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: #4-3 - Airport Rd - Sanderson - Ex.)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
0.00	10.80	0.00	0.00	0.00	0.00
0.30	10.97	0.17	1.51	67.31	1.24
0.61	11.06	0.26	1.87	100.97	1.29
0.91	11.13	0.33	2.11	127.46	1.32
1.21	11.18	0.38	2.29	149.97	1.34
1.51	11.23	0.43	2.44	169.86	1.35
1.82	11.28	0.48	2.57	187.83	1.36
2.12	11.32	0.52	2.68	204.31	1.37
2.42	11.36	0.56	2.77	219.63	1.38
2.58	11.38	0.58	2.82	227.12	1.38
3.03	11.43	0.63	2.94	247.46	1.39

Tailwater Channel Data - #4-3 - Airport Rd - Sanderson - Ex.

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 1.00 m

Side Slope (H:V): 1.00 (_:1)

Channel Slope: 0.0400

Channel Manning's n: 0.0350

Channel Invert Elevation: 10.80 m

Roadway Data for Crossing: #4-3 - Airport Rd - Sanderson - Ex.

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 10.00 m

Crest Elevation: 15.50 m

Roadway Surface: Paved

Roadway Top Width: 12.50 m

HY-8 Culvert Analysis Report - #4-3 – Airport Rd - Sanderson – Proposed Culvert

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cms

Design Flow: 2.58 cms

Maximum Flow: 3.03 cms

Table 1 - Summary of Culvert Flows at Crossing: #4-3 - Airport Rd - Sanderson - Prop.

Headwater Elevation (m)	Total Discharge (cms)	Prop. Culvert Discharge (cms)	Roadway Discharge (cms)	Iterations
14.10	0.00	0.00	0.00	1
14.32	0.30	0.30	0.00	1
14.45	0.61	0.61	0.00	1
14.55	0.91	0.91	0.00	1
14.66	1.21	1.21	0.00	1
14.75	1.51	1.51	0.00	1
14.84	1.82	1.82	0.00	1
14.93	2.12	2.12	0.00	1
15.02	2.42	2.42	0.00	1
15.07	2.58	2.58	0.00	1
15.20	3.03	3.03	0.00	1
15.50	3.86	3.86	0.00	Overtopping

Table 2 - Culvert Summary Table: Prop. Culvert

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.00	0.00	14.10	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
0.30	0.30	14.32	0.218	0.0*	1-S2n	0.047	0.142	0.047	0.172	3.604	1.507
0.61	0.61	14.45	0.346	0.0*	1-S2n	0.071	0.226	0.071	0.258	4.711	1.871
0.91	0.91	14.55	0.453	0.0*	1-S2n	0.092	0.296	0.092	0.325	5.481	2.110
1.21	1.21	14.66	0.557	0.0*	1-S2n	0.110	0.359	0.110	0.383	6.118	2.292
1.51	1.51	14.75	0.652	0.0*	1-S2n	0.127	0.416	0.136	0.433	6.166	2.440
1.82	1.82	14.84	0.742	0.0*	1-S2n	0.142	0.470	0.153	0.479	6.588	2.566
2.12	2.12	14.93	0.831	0.0*	1-S2n	0.157	0.521	0.171	0.521	6.877	2.676
2.42	2.42	15.02	0.919	0.0*	5-S2n	0.171	0.570	0.190	0.560	7.080	2.774
2.58	2.58	15.07	0.965	0.0*	5-S2n	0.178	0.594	0.200	0.579	7.172	2.820
3.03	3.03	15.20	1.105	0.0*	5-S2n	0.197	0.661	0.228	0.631	7.396	2.943

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 14.10 m, Outlet Elevation (invert): 10.80 m

Culvert Length: 28.19 m, Culvert Slope: 0.1179

****

Site Data - Prop. Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 m

Inlet Elevation: 14.10 m

Outlet Station: 28.00 m

Outlet Elevation: 10.80 m

Number of Barrels: 1

Culvert Data Summary - Prop. Culvert

Barrel Shape: Concrete Box

Barrel Span: 1800.00 mm

Barrel Rise: 900.00 mm

Barrel Material: Concrete

Embedment: 0.00 mm

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge (90deg) Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: #4-3 - Airport Rd - Sanderson - Prop.)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
0.00	10.80	0.00	0.00	0.00	0.00
0.30	10.97	0.17	1.51	67.31	1.24
0.61	11.06	0.26	1.87	100.97	1.29
0.91	11.13	0.33	2.11	127.46	1.32
1.21	11.18	0.38	2.29	149.97	1.34
1.51	11.23	0.43	2.44	169.86	1.35
1.82	11.28	0.48	2.57	187.83	1.36
2.12	11.32	0.52	2.68	204.31	1.37
2.42	11.36	0.56	2.77	219.63	1.38
2.58	11.38	0.58	2.82	227.12	1.38
3.03	11.43	0.63	2.94	247.46	1.39

Tailwater Channel Data - #4-3 - Airport Rd - Sanderson - Prop.

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 1.00 m

Side Slope (H:V): 1.00 (_:1)

Channel Slope: 0.0400

Channel Manning's n: 0.0350

Channel Invert Elevation: 10.80 m

Roadway Data for Crossing: #4-3 - Airport Rd - Sanderson - Prop.

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 10.00 m

Crest Elevation: 15.50 m

Roadway Surface: Paved

Roadway Top Width: 12.50 m

HY-8 Culvert Analysis Report - #5 – Cranby Crk @ Gillies Bay Rd – Existing Culvert

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cms

Design Flow: 9.27 cms

Maximum Flow: 10.14 cms

Table 1 - Summary of Culvert Flows at Crossing: #5 - Cranby Crk @ Gillies Bay Rd - HWL - Ex.

Headwater Elevation (m)	Total Discharge (cms)	Ex. Culvert Discharge (cms)	Roadway Discharge (cms)	Iterations
1.65	0.00	0.00	0.00	1
2.06	1.01	1.01	0.00	1
2.53	2.03	2.03	0.00	1
3.18	3.04	3.04	0.00	1
4.13	4.06	4.01	0.04	21
4.20	5.07	4.08	0.99	7
4.25	6.08	4.12	1.96	5
4.29	7.10	4.15	2.94	5
4.33	8.11	4.18	3.93	4
4.36	9.27	4.21	5.05	4
4.39	10.14	4.24	5.90	3
4.12	4.01	4.01	0.00	Overtopping

Table 2 - Culvert Summary Table: Ex. Culvert

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Straight Culvert

Inlet Elevation (invert): 1.15 m, Outlet Elevation (invert): 1.00 m

Culvert Length: 14.50 m, Culvert Slope: 0.0100

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Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.00	0.00	1.65	0.000	0.505	0-NF	0.000	0.000	0.650	0.650	0.000	0.000
1.01	1.01	2.06	0.835	0.914	3-M1t	0.585	0.546	0.650	0.650	1.621	0.000
2.03	2.03	2.53	1.350	1.381	7-M2c	0.942	0.784	0.784	0.650	2.592	0.000
3.04	3.04	3.18	2.035	1.922	7-M2c	1.200	0.958	0.958	0.650	3.142	0.000
4.06	4.01	4.13	2.984	2.745	7-M2c	1.200	1.073	1.073	0.650	3.763	0.000
5.07	4.08	4.20	3.058	2.799	7-M2c	1.200	1.078	1.078	0.650	3.809	0.000
6.08	4.12	4.25	3.105	2.836	7-M2c	1.200	1.082	1.082	0.650	3.837	0.000
7.10	4.15	4.29	3.145	2.868	7-M2c	1.200	1.085	1.085	0.650	3.861	0.000
8.11	4.18	4.33	3.181	2.896	7-M2c	1.200	1.087	1.087	0.650	3.883	0.000
9.27	4.21	4.36	3.219	2.928	7-M2c	1.200	1.089	1.089	0.650	3.906	0.000
10.14	4.24	4.39	3.246	2.947	7-M2c	1.200	1.091	1.091	0.650	3.922	0.000

Site Data - Ex. Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 m

Inlet Elevation: 1.15 m

Outlet Station: 14.50 m

Outlet Elevation: 1.00 m

Number of Barrels: 1

Culvert Data Summary - Ex. Culvert

Barrel Shape: Circular

Barrel Diameter: 1200.00 mm

Barrel Material: Corrugated Steel

Embedment: 0.00 mm

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Thin Edge Projecting

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: #5 - Cranby Crk @ Gillies Bay Rd - HWL - Ex.)

Flow (cms)	Water Surface Elev (m)	Depth (m)
0.00	1.65	0.65
1.01	1.65	0.65
2.03	1.65	0.65
3.04	1.65	0.65
4.06	1.65	0.65
5.07	1.65	0.65
6.08	1.65	0.65
7.10	1.65	0.65
8.11	1.65	0.65
9.27	1.65	0.65
10.14	1.65	0.65

Tailwater Channel Data - #5 - Cranby Crk @ Gillies Bay Rd - HWL - Ex.

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 1.65 m

Roadway Data for Crossing: #5 - Cranby Crk @ Gillies Bay Rd - HWL - Ex.

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 25.00 m

Crest Elevation: 4.12 m

Roadway Surface: Paved

Roadway Top Width: 8.50 m

HY-8 Culvert Analysis Report - #5 – Cranby Crk @ Gillies Bay Rd – Proposed Culvert

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cms

Design Flow: 9.27 cms

Maximum Flow: 10.14 cms

Table 1 - Summary of Culvert Flows at Crossing: #5 Cranby Crk @ Gillies Bay Rd - HWL - Prop2

Headwater Elevation (m)	Total Discharge (cms)	Alt. Prop. Culvert Discharge (cms)	Roadway Discharge (cms)	Iterations
1.65	0.00	0.00	0.00	1
1.69	1.01	1.01	0.00	1
1.79	2.03	2.03	0.00	1
1.93	3.04	3.04	0.00	1
2.08	4.06	4.06	0.00	1
2.23	5.07	5.07	0.00	1
2.38	6.08	6.08	0.00	1
2.53	7.10	7.10	0.00	1
2.67	8.11	8.11	0.00	1
2.83	9.27	9.27	0.00	1
2.95	10.14	10.14	0.00	1
4.12	17.02	17.02	0.00	Overtopping

Table 2 - Culvert Summary Table: Alt. Prop. Culvert

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Straight Culvert

Inlet Elevation (invert): 1.15 m, Outlet Elevation (invert): 1.00 m

Culvert Length: 14.50 m, Culvert Slope: 0.0100

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Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.00	0.00	1.65	0.000	0.505	0-NF	0.000	0.000	0.650	0.650	0.000	0.000
1.01	1.01	1.69	0.350	0.542	3-M1t	0.277	0.211	0.650	0.650	0.475	0.000
2.03	2.03	1.79	0.557	0.642	3-M1t	0.435	0.334	0.650	0.650	0.950	0.000
3.04	3.04	1.93	0.732	0.783	3-M1t	0.574	0.438	0.650	0.650	1.425	0.000
4.06	4.06	2.08	0.890	0.936	3-M2t	0.705	0.530	0.650	0.650	1.899	0.000
5.07	5.07	2.23	1.031	1.088	3-M2t	0.834	0.615	0.650	0.650	2.374	0.000
6.08	6.08	2.38	1.172	1.236	2-M2c	0.966	0.693	0.693	0.650	2.679	0.000
7.10	7.10	2.53	1.307	1.380	2-M2c	1.106	0.767	0.767	0.650	2.841	0.000
8.11	8.11	2.67	1.428	1.521	2-M2c	1.266	0.838	0.838	0.650	2.992	0.000
9.27	9.27	2.83	1.565	1.681	2-M2c	1.753	0.915	0.915	0.650	3.156	0.000
10.14	10.14	2.95	1.668	1.801	7-M2c	1.753	0.969	0.969	0.650	3.280	0.000

Site Data - Alt. Prop. Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 m

Inlet Elevation: 1.15 m

Outlet Station: 14.50 m

Outlet Elevation: 1.00 m

Number of Barrels: 1

Culvert Data Summary - Alt. Prop. Culvert

Barrel Shape: Arch, Open Bottom

Barrel Span: 3352.80 mm

Barrel Rise: 1752.60 mm

Barrel Material: Corrugated Steel

Embedment: 0.00 mm

Barrel Manning's n: 0.0350 (top and sides)

Manning's n: 0.0350 (bottom)

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: #5 Cranby Crk @ Gillies Bay Rd - HWL -Prop2)

Flow (cms)	Water Surface Elev (m)	Depth (m)
0.00	1.65	0.65
1.01	1.65	0.65
2.03	1.65	0.65
3.04	1.65	0.65
4.06	1.65	0.65
5.07	1.65	0.65
6.08	1.65	0.65
7.10	1.65	0.65
8.11	1.65	0.65
9.27	1.65	0.65
10.14	1.65	0.65

Tailwater Channel Data - #5 Cranby Crk @ Gillies Bay Rd - HWL -Prop2

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 1.65 m

Roadway Data for Crossing: #5 Cranby Crk @ Gillies Bay Rd - HWL -Prop2

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 25.00 m

Crest Elevation: 4.12 m

Roadway Surface: Paved

Roadway Top Width: 8.50 m

HY-8 Culvert Analysis Report - #5-2 – Trout Crk @ Gillies Bay Rd– Existing Culvert

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cms

Design Flow: 10.22 cms

Maximum Flow: 10.47 cms

Table 1 - Summary of Culvert Flows at Crossing: #5-2 Trout Crk @ Gillies Bay Rd - Ex.

Headwater Elevation (m)	Total Discharge (cms)	Ex. Culvert Discharge (cms)	Roadway Discharge (cms)	Iterations
3.72	0.00	0.00	0.00	1
4.47	1.25	1.25	0.00	1
4.89	2.49	2.49	0.00	1
5.22	3.74	3.54	0.19	8
5.30	4.99	3.77	1.21	5
5.36	6.23	3.93	2.30	5
5.41	7.48	4.07	3.41	4
5.45	8.73	4.17	4.56	4
5.51	10.22	4.27	5.94	4
5.54	11.22	4.32	6.90	4
5.58	12.47	4.31	8.16	4
5.19	3.44	3.44	0.00	Overtopping

Table 2 - Culvert Summary Table: Ex. Culvert

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Straight Culvert

Inlet Elevation (invert): 3.72 m, Outlet Elevation (invert): 3.55 m

Culvert Length: 21.00 m, Culvert Slope: 0.0081

****

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.00	0.00	3.72	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
1.25	1.25	4.47	0.696	0.754	2-M2c	0.466	0.430	0.430	0.286	1.897	1.564
2.49	2.49	4.89	1.092	1.168	2-M2c	0.750	0.638	0.638	0.432	2.445	1.969
3.74	3.54	5.22	1.460	1.503	7-M2c	1.194	0.780	0.780	0.548	2.837	2.239
4.99	3.77	5.30	1.554	1.580	7-M2c	1.194	0.808	0.808	0.648	2.920	2.445
6.23	3.93	5.36	1.625	1.638	7-M2c	1.194	0.827	0.827	0.737	2.980	2.614
7.48	4.07	5.41	1.687	1.688	7-M2c	1.194	0.843	0.843	0.818	3.030	2.758
8.73	4.17	5.45	1.735	1.728	3-M2t	1.194	0.855	0.892	0.892	2.954	2.883
10.22	4.27	5.51	1.786	1.781	3-M2t	1.194	0.866	0.975	0.975	2.819	3.015
11.22	4.32	5.54	1.809	1.819	3-M2t	1.194	0.871	1.028	1.028	2.744	3.096
12.47	4.31	5.58	1.805	1.860	7-M2t	1.194	0.871	1.090	1.090	2.640	3.188

Site Data - Ex. Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 m

Inlet Elevation: 3.72 m

Outlet Station: 21.00 m

Outlet Elevation: 3.55 m

Number of Barrels: 1

Culvert Data Summary - Ex. Culvert

Barrel Shape: Pipe Arch

Barrel Span: 1803.40 mm

Barrel Rise: 1193.80 mm

Barrel Material: Steel or Aluminum

Embedment: 0.00 mm

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Projecting

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: #5-2 Trout Crk @ Gillies Bay Rd - Ex.)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
0.00	3.55	0.00	0.00	0.00	0.00
1.25	3.84	0.29	1.56	56.09	0.98
2.49	3.98	0.43	1.97	84.68	1.02
3.74	4.10	0.55	2.24	107.46	1.05
4.99	4.20	0.65	2.45	127.03	1.06
6.23	4.29	0.74	2.61	144.46	1.08
7.48	4.37	0.82	2.76	160.33	1.09
8.73	4.44	0.89	2.88	174.97	1.09
10.22	4.53	0.98	3.02	191.20	1.10
11.22	4.58	1.03	3.10	201.47	1.11
12.47	4.64	1.09	3.19	213.63	1.11

Tailwater Channel Data - #5-2 Trout Crk @ Gillies Bay Rd - Ex.

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 2.50 m

Side Slope (H:V): 1.00 (_:1)

Channel Slope: 0.0200

Channel Manning's n: 0.0350

Channel Invert Elevation: 3.55 m

Roadway Data for Crossing: #5-2 Trout Crk @ Gillies Bay Rd - Ex.

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 20.00 m

Crest Elevation: 5.19 m

Roadway Surface: Paved

Roadway Top Width: 15.00 m

HY-8 Culvert Analysis Report - #5-2 – Trout Crk @ Gillies Bay Rd – Proposed Culvert

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cms

Design Flow: 10.22 cms

Maximum Flow: 12.47 cms

Table 1 - Summary of Culvert Flows at Crossing: #5-2 Trout Crk @ Gillies Bay Rd - Prop.

Headwater Elevation (m)	Total Discharge (cms)	Prop. Culvert Discharge (cms)	Roadway Discharge (cms)	Iterations
3.72	0.00	0.00	0.00	1
4.08	1.25	1.25	0.00	1
4.29	2.49	2.49	0.00	1
4.46	3.74	3.74	0.00	1
4.62	4.99	4.99	0.00	1
4.76	6.23	6.23	0.00	1
4.89	7.48	7.48	0.00	1
5.02	8.73	8.73	0.00	1
5.17	10.22	10.22	0.00	1
5.27	11.22	11.22	0.00	1
5.38	12.47	12.47	0.00	1
5.60	14.77	14.77	0.00	Overtopping

Table 2 - Culvert Summary Table: Prop. Culvert

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Straight Culvert

Inlet Elevation (invert): 3.72 m, Outlet Elevation (invert): 3.55 m

Culvert Length: 21.00 m, Culvert Slope: 0.0081

****

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.00	0.00	3.72	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
1.25	1.25	4.08	0.357	0.361	3-M1t	0.274	0.206	0.286	0.286	1.022	1.564
2.49	2.49	4.29	0.567	0.568	3-M1t	0.417	0.327	0.432	0.432	1.354	1.969
3.74	3.74	4.46	0.743	0.741	3-M1t	0.534	0.428	0.548	0.548	1.600	2.239
4.99	4.99	4.62	0.900	0.896	3-M1t	0.638	0.518	0.648	0.648	1.806	2.445

6.23	6.23	4.76	1.039	1.039	3-M1t	0.733	0.602	0.737	0.737	1.988	2.614
7.48	7.48	4.89	1.165	1.174	3-M2t	0.822	0.677	0.818	0.818	2.155	2.758
8.73	8.73	5.02	1.283	1.302	3-M2t	0.908	0.749	0.892	0.892	2.310	2.883
10.22	10.22	5.17	1.420	1.450	3-M2t	1.006	0.831	0.975	0.975	2.484	3.015
11.22	11.22	5.27	1.512	1.546	3-M2t	1.071	0.883	1.028	1.028	2.596	3.096
12.47	12.47	5.38	1.631	1.663	3-M2t	1.153	0.947	1.090	1.090	2.729	3.188

Site Data - Prop. Culvert

Site Data Option: Culvert Invert Data
Inlet Station: 0.00 m
Inlet Elevation: 3.72 m
Outlet Station: 21.00 m
Outlet Elevation: 3.55 m
Number of Barrels: 1

Culvert Data Summary - Prop. Culvert

Barrel Shape: Concrete Open-Bottom Arch
Barrel Span: 4267.20 mm
Barrel Rise: 1524.00 mm
Barrel Material: Concrete
Embedment: 0.00 mm
Barrel Manning's n: 0.0120 (top and sides)
Manning's n: 0.0350 (bottom)
Culvert Type: Straight
Inlet Configuration: 45 (deg) wingwall top square edge
Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: #5-2 Trout Crk @ Gillies Bay Rd - Prop.)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
0.00	3.55	0.00	0.00	0.00	0.00
1.25	3.84	0.29	1.56	56.09	0.98
2.49	3.98	0.43	1.97	84.68	1.02
3.74	4.10	0.55	2.24	107.46	1.05
4.99	4.20	0.65	2.45	127.03	1.06
6.23	4.29	0.74	2.61	144.46	1.08
7.48	4.37	0.82	2.76	160.33	1.09
8.73	4.44	0.89	2.88	174.97	1.09
10.22	4.53	0.98	3.02	191.20	1.10

11.22	4.58	1.03	3.10	201.47	1.11
12.47	4.64	1.09	3.19	213.63	1.11

Tailwater Channel Data - #5-2 Trout Crk @ Gillies Bay Rd - Prop.

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 2.50 m

Side Slope (H:V): 1.00 (_:1)

Channel Slope: 0.0200

Channel Manning's n: 0.0350

Channel Invert Elevation: 3.55 m

Roadway Data for Crossing: #5-2 Trout Crk @ Gillies Bay Rd - Prop.

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 20.00 m

Crest Elevation: 5.60 m

Roadway Surface: Paved

Roadway Top Width: 15.00 m

HY-8 Culvert Analysis Report - #6 – Staaf Crk @ Bell Rd– Existing Culvert

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cms

Design Flow: 4.92 cms

Maximum Flow: 5.38 cms

Table 1 - Summary of Culvert Flows at Crossing: #6 - Staaf Crk @ Bell Rd

Headwater Elevation (m)	Total Discharge (cms)	Ex. Culvert Discharge (cms)	Roadway Discharge (cms)	Iterations
206.55	0.00	0.00	0.00	1
207.02	0.54	0.54	0.00	1
207.26	1.08	1.08	0.00	1
207.45	1.61	1.61	0.00	1
207.63	2.15	2.15	0.00	1
207.79	2.69	2.69	0.00	1
207.87	3.23	2.94	0.29	6
207.92	3.77	3.10	0.67	5
207.96	4.30	3.24	1.06	4
208.00	4.92	3.38	1.54	4
208.03	5.38	3.48	1.90	4
207.80	2.71	2.71	0.00	Overtopping

Table 2 - Culvert Summary Table: Ex. Culvert

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Straight Culvert

Inlet Elevation (invert): 206.55 m, Outlet Elevation (invert): 206.44 m

Culvert Length: 11.00 m, Culvert Slope: 0.0100

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Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.00	0.00	206.55	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
0.54	0.54	207.02	0.420	0.468	2-M2c	0.274	0.269	0.269	0.159	1.447	0.798
1.08	1.08	207.26	0.633	0.706	2-M2c	0.401	0.396	0.396	0.240	1.803	1.027
1.61	1.61	207.45	0.818	0.902	2-M2c	0.512	0.497	0.497	0.306	2.078	1.185
2.15	2.15	207.63	0.985	1.077	2-M2c	0.620	0.586	0.586	0.362	2.310	1.309
2.69	2.69	207.79	1.153	1.243	7-M2c	0.732	0.666	0.666	0.413	2.520	1.412
3.23	2.94	207.87	1.235	1.318	7-M2c	0.788	0.701	0.701	0.459	2.613	1.500
3.77	3.10	207.92	1.292	1.367	7-M2c	0.826	0.723	0.723	0.502	2.673	1.579
4.30	3.24	207.96	1.342	1.409	7-M2c	0.861	0.741	0.741	0.542	2.724	1.649
4.92	3.38	208.00	1.396	1.454	7-M2c	0.901	0.760	0.760	0.586	2.777	1.721
5.38	3.48	208.03	1.435	1.484	7-M2c	0.932	0.772	0.772	0.617	2.814	1.771

Site Data - Ex. Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 m

Inlet Elevation: 206.55 m

Outlet Station: 11.00 m

Outlet Elevation: 206.44 m

Number of Barrels: 1

Culvert Data Summary - Ex. Culvert

Barrel Shape: Pipe Arch

Barrel Span: 1803.40 mm

Barrel Rise: 1193.80 mm

Barrel Material: Steel or Aluminum

Embedment: 0.00 mm

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Projecting

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: #6 - Staaf Crk @ Bell Rd)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
0.00	206.44	0.00	0.00	0.00	0.00
0.54	206.60	0.16	0.80	15.60	0.66
1.08	206.68	0.24	1.03	23.56	0.70
1.61	206.75	0.31	1.18	29.95	0.72
2.15	206.80	0.36	1.31	35.48	0.73
2.69	206.85	0.41	1.41	40.44	0.75
3.23	206.90	0.46	1.50	44.98	0.76
3.77	206.94	0.50	1.58	49.20	0.77
4.30	206.98	0.54	1.65	53.16	0.77
4.92	207.03	0.59	1.72	57.43	0.78
5.38	207.06	0.62	1.77	60.45	0.78

Tailwater Channel Data - #6 - Staaf Crk @ Bell Rd

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 4.00 m

Side Slope (H:V): 1.50 (_:1)

Channel Slope: 0.0100

Channel Manning's n: 0.0350

Channel Invert Elevation: 206.44 m

Roadway Data for Crossing: #6 - Staaf Crk @ Bell Rd

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 10.00 m

Crest Elevation: 207.80 m

Roadway Surface: Paved

Roadway Top Width: 7.50 m

HY-8 Culvert Analysis Report - #6 – Staaf Crk @ Bell Rd – Proposed Culvert

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cms

Design Flow: 4.92 cms

Maximum Flow: 5.38 cms

Table 1 - Summary of Culvert Flows at Crossing: #6 - Staaf Crk @ Bell Rd -Prop

Headwater Elevation (m)	Total Discharge (cms)	Prop. Culvert Discharge (cms)	Roadway Discharge (cms)	Iterations
206.40	0.00	0.00	0.00	1
206.66	0.54	0.54	0.00	1
206.81	1.08	1.08	0.00	1
206.94	1.61	1.61	0.00	1
207.05	2.15	2.15	0.00	1
207.15	2.69	2.69	0.00	1
207.25	3.23	3.23	0.00	1
207.34	3.77	3.77	0.00	1
207.43	4.30	4.30	0.00	1
207.53	4.92	4.92	0.00	1
207.60	5.38	5.38	0.00	1
208.20	8.71	8.71	0.00	Overtopping

Table 2 - Culvert Summary Table: Prop. Culvert

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.00	0.00	206.40	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
0.54	0.54	206.66	0.257	0.0*	1-S2n	0.135	0.156	0.135	0.159	1.426	0.798
1.08	1.08	206.81	0.409	0.0*	1-S2n	0.206	0.247	0.206	0.240	1.870	1.027
1.61	1.61	206.94	0.535	0.0*	1-S2n	0.263	0.324	0.263	0.306	2.191	1.185
2.15	2.15	207.05	0.649	0.037	1-S2n	0.314	0.392	0.314	0.362	2.450	1.309
2.69	2.69	207.15	0.752	0.126	1-S2n	0.360	0.455	0.360	0.413	2.672	1.412
3.23	3.23	207.25	0.849	0.214	1-S2n	0.402	0.514	0.402	0.459	2.866	1.500
3.77	3.77	207.34	0.942	0.306	1-S2n	0.442	0.569	0.446	0.502	3.013	1.579
4.30	4.30	207.43	1.031	0.400	1-S2n	0.480	0.622	0.480	0.542	3.203	1.649
4.92	4.92	207.53	1.131	0.511	1-S2n	0.521	0.680	0.530	0.586	3.316	1.721
5.38	5.38	207.60	1.205	0.597	5-S2n	0.551	0.722	0.564	0.617	3.409	1.771

* Full Flow Headwater elevation is below inlet invert.

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Straight Culvert

Inlet Elevation (invert): 206.40 m, Outlet Elevation (invert): 206.00 m

Culvert Length: 11.01 m, Culvert Slope: 0.0364

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Site Data - Prop. Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 m

Inlet Elevation: 206.10 m

Outlet Station: 11.00 m

Outlet Elevation: 205.70 m

Number of Barrels: 1

Culvert Data Summary - Prop. Culvert

Barrel Shape: Concrete Box

Barrel Span: 2800.00 mm

Barrel Rise: 1500.00 mm

Barrel Material: Concrete

Embedment: 300.00 mm

Barrel Manning's n: 0.0120 (top and sides)

Manning's n: 0.0350 (bottom)

Culvert Type: Straight

Inlet Configuration: Square Edge (90deg) Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: #6 - Staaf Crk @ Bell Rd -Prop)

Flow (cms)	Water Surface Elev (m)	Depth (m)	Velocity (m/s)	Shear (Pa)	Froude Number
0.00	206.00	0.00	0.00	0.00	0.00
0.54	206.16	0.16	0.80	15.60	0.66
1.08	206.24	0.24	1.03	23.56	0.70
1.61	206.31	0.31	1.18	29.95	0.72
2.15	206.36	0.36	1.31	35.48	0.73
2.69	206.41	0.41	1.41	40.44	0.75
3.23	206.46	0.46	1.50	44.98	0.76
3.77	206.50	0.50	1.58	49.20	0.77
4.30	206.54	0.54	1.65	53.16	0.77
4.92	206.59	0.59	1.72	57.43	0.78
5.38	206.62	0.62	1.77	60.45	0.78

Tailwater Channel Data - #6 - Staaf Crk @ Bell Rd -Prop

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 4.00 m

Side Slope (H:V): 1.50 (_:1)

Channel Slope: 0.0100

Channel Manning's n: 0.0350

Channel Invert Elevation: 206.00 m

Roadway Data for Crossing: #6 - Staaf Crk @ Bell Rd -Prop

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 10.00 m

Crest Elevation: 208.20 m

Roadway Surface: Paved

Roadway Top Width: 7.50 m