REPORT

BC Ministry of Transportation and Infrastructure

Maple Falls Road Drainage Assessment

FEBRUARY 2021

A Carbon Neutral Company

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Date Feb. 12, 2021

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1 INTRODUCTION

For many years, drainage issues have been reported in the vicinity of Maple Falls Road, in the community of Lindell Beach, south of the City of Chilliwack. An unnamed watercourse, west of Frost Creek, currently drains into a wetlands area, referred to by locals and the BC Ministry of Transportation and Infrastructure (the Ministry) as the 'Kettle'. There is no known outlet point for the Kettle and anecdotal records state that the ground below the Kettle is deep gravel that allows for a significant amount of infiltration. However, flooding from the Kettle has impacted Ministry infrastructure and local properties including roads, homes, and agricultural fields. The watercourse feeding the Kettle is reportedly intermittent, typically dry in the summer and flowing in the winter. Not surprisingly, flooding in and around the Kettle is linked to large storm events during the winter months.

On January 31st, 2020 a major rainfall event occurred within the Fraser Valley. During this event the Kettle was flooded. Nearby land and infrastructure were impacted by this flooding and a local state of emergency was declared on February 1st, 2020.

Associated Engineering (B.C.) Ltd. (AE) has been retained by the **BC Ministry of Transportation and Infrastructure** to complete an assessment of the flooding that occurs at the Kettle and Maple Falls Road and develop conceptual upgrade options that can alleviate the flooding. We have completed a hydrologic and hydraulic assessment of the Kettle, the unnamed watercourse that directs flow into the Kettle and the surrounding area. From our assessment, we have developed a set of potential solutions that are proposed to mitigate the flooding along Maple Falls Road.

2 BACKGROUND REVIEW

The Kettle is a large gravel basin located immediately north of Maple Falls Road. The Kettle is not located within a MoTI right-of-way (ROW). Anecdotal records indicate that the Kettle is not a natural drainage feature of the area, rather it is said to have been constructed for farming purposes circa 1900. There are no existing records available that confirm this information, however the Ministry has indicated that the surrounding farm lands have changed significantly over the years, making it difficult to determine the historic flow path downstream of the Kettle, if in fact there was such an outlet. Anecdotally, the area is said to have a significant sub-surface gravel layer which allows for infiltration. The Ministry informed AE that the Kettle has historically been cleared of debris and sediment every two years during the summer months. It has been reported by the Ministry that the Kettle was last cleared in the summer of 2017. It has been anecdotally stated by the Ministry that an approximate 10 m (35 feet) depth of silt can be removed from the Kettle before encountering the subsurface geology. The composition of the subsurface geology is unknown and is thought to be bedrock or a granular material.

The watershed that feeds the Kettle is largely comprised of steep, higher elevation, forested lands that extend south of the Canada/US Border. The majority of the forested catchments appears to be untouched, however forest harvesting on the US side of the watershed may be altering the hydrology of the upper watershed. At the time of this project we have not investigated the extent of any forestry activities or whether the area has current logging activity. The lower portion of the watershed consists of flat agricultural land, used for berry farming. **Map 2-1** shows the study area and the watershed of the Kettle.

A single unnamed creek discharges into the Kettle. Local residents and the Ministry have stated that the creek is typically completely dry in the summer, but floods during the winter months every year. The Ministry Area Manager and local residents have reported that flooding has occurred at the Kettle every year since 1995. It is reported that flooding comes both from the creek that flows into the Kettle as well as from the agricultural blueberry farms to the north of the Kettle.

There are two culverts along the unnamed creek, upstream of the Kettle. The first is a 2100 mm diameter CSP culvert located at Kosikar Road. The second is a 1200 mm diameter CSP culvert located at Maple Falls Road which functions as the inlet to the Kettle.

2.1 January 31st Storm Event

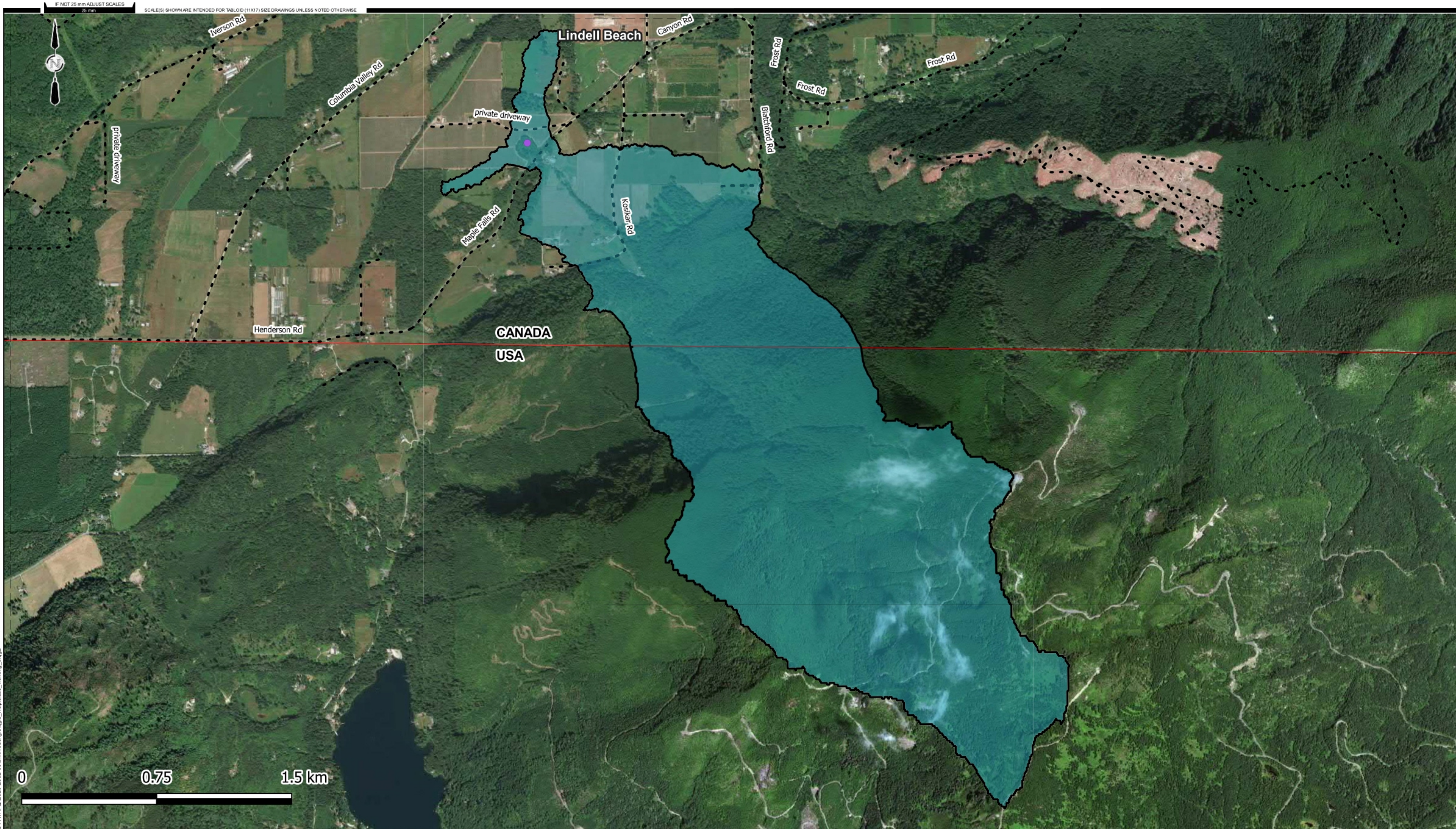
A major rainfall event occurred throughout the Fraser Valley region between January 31st, 2020 and February 1st, 2020. During this event, the Kettle flooded across Maple Falls Road and around local properties.

At the time of the event, the Kettle was filled with water that had been retained within the Kettle since the rainy season in late 2019, with the consequence that there was little storage volume available and indicating that the Kettle was not draining effectively during this period. During the event, the Kettle overflowed with water coming from the southern sub-catchments. Local residents reported that more debris was seen within the channel this year, compared to previous years. Over the course of the storm, the Kettle flooded overland covering Maple Falls Road and blocking access to the two properties located directly across from the Kettle. Sand bags had been placed along the channel and residents' properties to protect the properties and homes from flooding.

In the days following the event, the water that had flooded overland around the Kettle gradually infiltrated into the ground. The channel just upstream of the Kettle was filled with approximately 450 mm of sediment. The water

IF NOT 25 mm ADJUST SCALES

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE



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Associated Engineering

BEST MANAGED COMPANIES Platinum member

Legend

- WATERSHED AREA
- CANADA BORDER
- ROAD
- KETTLE

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

AE PROJECT No.	2020-2882
SCALE	AS SHOWN
APPROVED	M. MACLATCHY
DATE	20210119
REV	1
DESCRIPTION	ISSUED FOR STUDY

MAP 2-1

BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

MAPLE FALLS ROAD DRAINAGE ASSESSMENT STUDY AREA remained in the Kettle until the summer of 2020, at which point a maintenance contractor removed the built-up silt and mud from the Kettle.

2.2 Field Reconnaissance

AE (Nicola Van Der Mark) completed a site reconnaissance of the Maple Falls Road study area on February 12th, 2020. The sites visited included the Kettle, the unnamed creek that feeds into the Kettle, Frost Creek at Blatchford Road, and the surrounding area in Lindell Beach. She was accompanied by Ian Mandrusiak, the Ministry's Area Manager of the Lower Mainland District. The purpose of the site visit was to investigate the Kettle and the surrounding area that had been recently flooded to inform this assessment.

At the time of the site visit there was no visible flooding along Maple Falls Road. However, sediment and debris were visible alongside the road and extended several metres into the shoulder of the road on the north side of the road, and the private properties on the south side of the road. See in **Figure 2-1**. Remains of mud, sediment, and debris were also seen along Maple Falls Road towards the south-west for approximately 490 m along the roadside until reaching what appeared to be a subtle low point in the road.

Figure 2-1
Sediment along Maple Falls Road

At the time of the visit, the Kettle could be described similar to a small lake or a marshland. The ponding within the Kettle bordered the agricultural fields on the north, east, and west sides. The approximate footprint of the Kettle at the time of the site visit was estimated to be just over one hectare in area at the surface. The Kettle was covered with vegetation including grass, brush, and numerous trees. **Figure 2-2** shows the flooding extents of the Kettle towards the north. The red bushes in the agricultural fields can be seen just past the extents of visible flooding. The water elevation in the Kettle was noted to be close to its maximum contained depth with approximately 300 mm of freeboard between the water surface in the Kettle and the surface of Maple Falls Road, as shown in **Figure 2-3**.

The 1200 mm diameter culvert that discharges into the Kettle was visibly crushed at both the inlet and outlet at the time of the site visit. Due to high water elevations at the time of the visit only approximately 300 mm at the inlet was visible, and the outlet was almost surcharged due to the high water elevations in the Kettle. The surface area of the culvert that could be seen at both the inlet and outlet was rusted, indicating that the culvert may be frequently surcharged. **Figure 2-3** and **Figure 2-4** show the culvert inlet and outlet, respectively.

Figure 2-2
The Kettle looking North

Figure 2-3
Maple Falls Road Culvert outlet at the Kettle

Figure 2-4
Maple Falls Road Culvert Inlet

In addition to visiting the Kettle, AE walked along the unnamed creek upstream of the Kettle within the agricultural lands and at Kosikar Road. At the time of the visit, the channel immediately upstream of the Kettle, located between the two private properties, was approximately 1 m wide and 1 m deep, as shown in **Figure 2-5**.

At the time of the site visit, the channel appeared to be covered in sediment and mud with vegetation uprooted or broken and loose throughout the length of the channel. Tall grasses and brush are present along the channel banks as you traverse from the Kettle through the properties and into the agricultural area. A small wooden bridge crosses the creek between the properties. This may not have been representative of the maximum width or depth of the channel as it was reported by the local residents to be filled with more sediment and debris than normal. Further upstream into the agricultural lands the channel widens and maintains a shallow depth. At the time of the site visit the creek appeared to be 2-3 m wide, with some untouched high points covered in cobbles and small boulders. However, local homeowners said that during large storm events the water will span over the rocks to cover the full extents of the channel. **Figure 2-6** provides a snapshot of the channel within the agricultural lands approximately 200 m upstream of the Maple Falls Road crossing.

At Kosikar Road, the furthest upstream point of the creek that AE visited, the channel is wide and deep, as shown in **Figure 2-7**. The channel was over 2 m deep at the Kosikar Road crossing. Small boulders were visible within the channel. There is a 2100 mm CSP culvert that conveys the channel at Kosikar Road. The culvert appeared to be in good condition at the time of the visit. Visible high water marks could be seen between one third to one half of the diameter of the culvert. Below that level the culvert was rusted. There was no visible damage at either the culvert inlet or outlet. The inverts of both the culvert inlet and outlet could not be seen at the time of the visit. **Figure 2-8** shows the Kosikar Road culvert.

Figure 2-5
Unnamed Creek Channel at properties upstream of Maple Falls Road

Figure 2-6
Unnamed Creek at Agricultural Lands Approximately 200 m Upstream of Maple Falls Road

Figure 2-7
Unnamed Creek at Kosikar Road Culvert Outlet

Figure 2-8
Kosikar Road 2100 mm Diameter Culvert Inlet

In addition to visiting the area surrounding the Kettle and its catchment, AE visited Frost Creek at two locations to review potential improvement alignment options for this assignment. The first location along Frost Creek was at the intersection of Blatchford Road and Canyon Road. At this location the invert of Frost Creek is located within a steep ravine that is approximately 50 m deep. The side slopes of the ravine were covered with trees and vegetation. The surficial soils were not visible. The second site visited was the bridge crossing Frost Creek along Columbia Valley Road. At this location the channel of Frost Creek was no longer in a deep ravine and could be easily seen. The channel was approximately 15 m wide. The channel bed was composed of boulders and the side banks had vegetation and tree growth.

2.3 Background Data Collection

We collected available background information from a variety of sources to support the modelling and analysis of this project. We downloaded infrastructure data, streamlines, and soils mapping from iMapBC. As the area of Lindell Beach is a small unincorporated agricultural community there is not a significant amount of infrastructure within the area, however there were a series of culverts shown in the MoT database. The Ministry provided a LiDAR surface that extended from the Canadian-US border to Cultus Lake. Additionally, the Ministry provided a KMZ file outlining a high level estimate of the extents of flooding around the Kettle from years of recent flooding.

As the watershed extends into the United States we also downloaded available LiDAR data from USGS that covers the southern US extent of the watershed.

3 HYDROLOGICAL ASSESSMENT

3.1 Rain Gauge Selection

To select a rain gauge for this assignment, we reviewed and compared IDF curves from Environment Canada (EC) and Metro Vancouver (MV) stations located within Abbotsford and Chilliwack as they are the closest gauged regions to the study area. We reviewed the following gauges, Abbotsford A (EC-1100030), Huntingdon VYE Road (EC-1103636), Chilliwack Microwave (EC-1101562), Central Abbotsford (MV-AB76), Chilliwack Airport (MV-CK74). We reviewed the stations for the period of record used to develop the IDF data, how recently the data was recorded, and compared the rainfall intensity for long-duration events (>6 hr) between IDF curves. The Chilliwack Airport rain gauge has a recent record of data, ending in 2001, and was developed upon 13 years of data, similar to other stations within the area. Relative to other stations in the vicinity of the study area with similar periods of record, Chilliwack Airport station has more conservative (higher) IDF data for storms at 6-hour duration or longer. Therefore, we have used rainfall data from the Chilliwack Airport gauge to support this assignment.

3.2 Design Rainfall

As discussed in **Section 2**, it has been reported that the flooding of the Kettle only occurs during winter months, as the creek that feeds into the Kettle is dry in the summer. Winter and summer storm events within the southern coastal region of BC can be characterized by different rainfall distributions. Summer storm events are typically of a shorter duration with a higher peak intensity. Winter storm events in the southern coastal region of BC are more often characterized by sustained lower intensity rainfall.

To consider both summer and winter storm conditions we assessed the Kettle with two different rainfall distributions, a 24-hour SCS Type IA distribution and a 24-hour AES distribution. Both storm events reflect the same 24-hour volume of rainfall, which is based on the total rainfall volumes presented for the 5-, 10-, 25-, 50-, and 100-year return periods in the Chilliwack Airport IDF curve, however the temporal distribution of rainfall within the two storm events is different. Although the flooding of the Kettle is dependant on the volume which it can hold, the rate and duration of flooding may vary depending on the storm distribution, as the AES storm has a lower peak intensity, and therefore lower peak flow rate, than the SCS Type IA storm.

In addition to a 24-hour SCS Type IA storm, we have developed a 72-hour SCS Type IA storm. We have used this storm to assess the Kettle with a greater volume of rainfall than a 24-hour storm. This may, in a way, also reflect the conditions of the Kettle if it is partially full of water before a 24-hour storm event.

3.2.1 SCS Storm Distribution

The US Soil Conservation Service (SCS) design rainfall distributions can be used for estimating peak design flows for small watersheds. Peak flow estimates can differ drastically between the different SCS storm types; therefore, to determine the most representative SCS storm distribution for the area we referenced the SCS storm distributions outlined in the paper “SCS Storm Type Selection for Estimating Design Flows in British Columbia” (Millar, 2017).

We graphed and compared cumulative rainfall depths from the Chilliwack Airport IDF to known cumulative rainfall distributions for Type I, Type IA, and Type II storms. We determined through a visual assessment that a SCS Type IA storm best represents the distribution represented by recorded rainfall data at the Chilliwack Airport. **Figure 3-1** shows a graphical comparison of recorded cumulative rainfall data from the Chilliwack Airport IDF for the 10-year return period event to the typical rainfall distributions for SCS storm presented by Millar. This aligns with the assessment completed by Millar, which states that "within BC, the distribution suggests that Type IA storm would be most appropriate for the south coastal and adjacent south-west interior" (Millar, 2017).

Using the SCS IA distribution we developed storm events for the 5-, 10-, 25-, 50-, and 100-year 24-hour return periods.

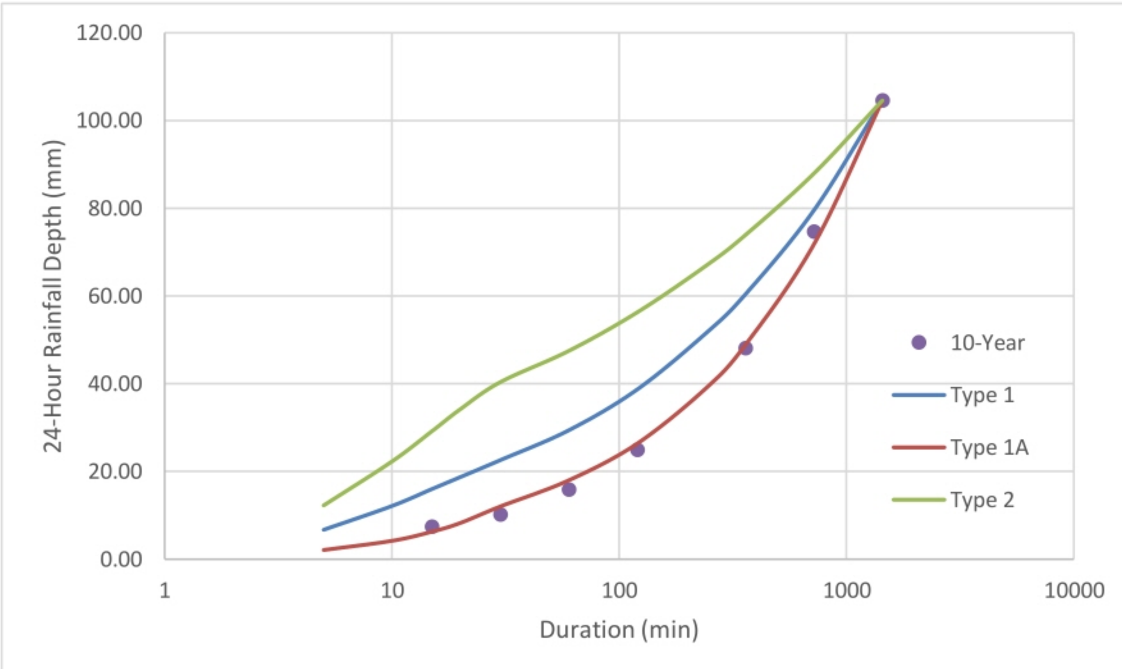


Figure 3-1
10-year SCS Storm Distributions

3.2.2 Long-Duration Storm Event Development

As the Kettle is a volume dominated system, we also developed a long-duration storm to review the systems response to a storm duration greater than 24 hours. We developed a synthetic 72-hour storm with a peak intensity equivalent to that of a 24-hour SCS Type IA storm of the same return period in the centre 24 hours of the storm. We have bounded the 24-hour SCS Type IA distribution on either side with a low intensity rainfall that has a total precipitation volume equivalent to the difference in total precipitation volume for a 72-hour storm and a 24-hour storm distributed evenly across 48 hours. Figure 3-2 compares the rainfall distributions of the 10-year return period event for 24-hour and 72-hour storm durations.

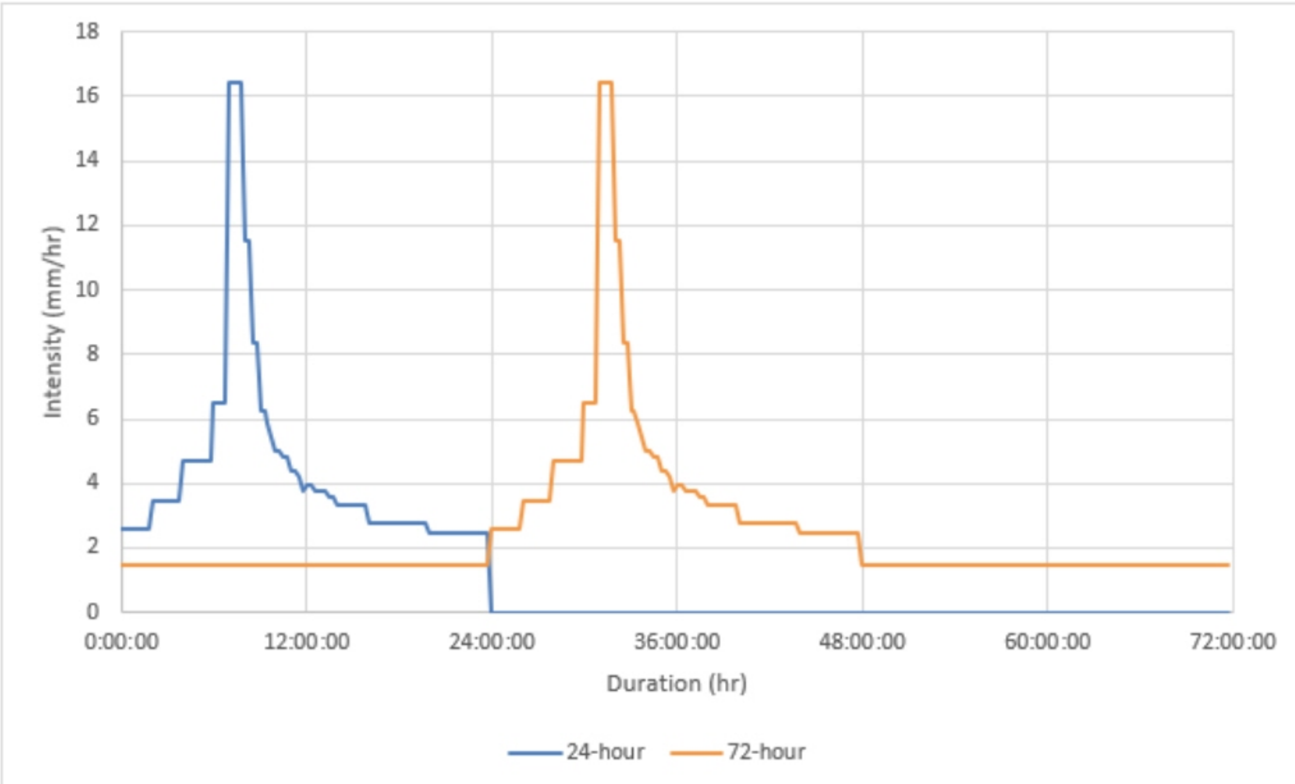


Figure 3-2
SCS Type IA Rainfall Duration Comparison

3.2.3 AES Storm Distribution

We have also developed a rainfall event using a 50% Time Probability AES Storm Distribution, as developed by W.D. Hogg for comparison to the SCS Type 1A distribution. This distribution was specifically developed to represent "convective shower events and synoptic scale cyclonic circulation events" for the B.C. Coast (Hogg, 1980). We note that the rainfall data used to derive the AES distributions is now over 40 years old and would not reflect any changes in rainfall patterns since that time, e.g. due to climate change impacts.

Using the AES distribution, we developed storm events for the 5-, 10-, 25-, 50-, and 100-year 24-hour return periods.

The AES 24-h storms have the same total rainfall volume as the SCS IA 24-h storms, however, the peak intensity of the AES event is approximately 38% of the peak intensity of the SCS IA event. Figure 3-3 compares the distributions of the 10-year 24-hour AES and SCS IA storms.

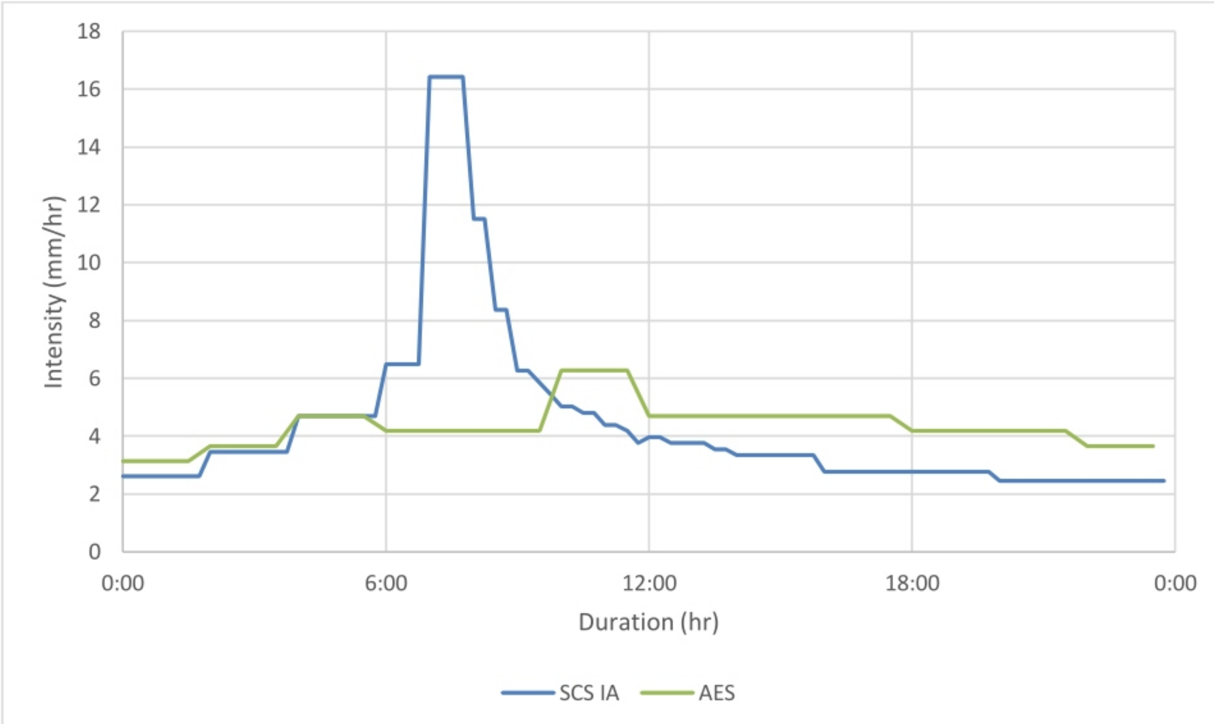


Figure 3-3
AES and SCS Type IA Hyetograph Comparison

3.3 Climate Change

As outlined in BC MoTI Technical Circular T-04/19, the impacts of future climate change are required to be considered on all Ministry projects. Future climate change is anticipated to increase peak rainfall intensities, which will result in an increase to flow volume and peak flow rates for drainage designs.

The BC MoTI Supplement to TAC Geometric Design Guide does not explicitly state the design life of enclosed drainage infrastructure, such as storm sewer systems. However, it identifies the structural design life of culverts to be 75 years. As such, we have assumed a 75-year design life for the proposed systems associated with the Kettle. We have estimated the increase to rainfall due to climate change to the year 2095.

We used Western University's online IDF-CC tool to derive estimates for the impact of climate change on the local rainfall characteristics. The tool uses 24 Global Climate Models and 9 downscaled Global Climate Models to simulate various climate conditions, modify historic IDF data, and derive new IDF curves for future conditions. The tool estimates IDF curves to a target year centered within a 30- or 50-year range. We reviewed data from the Environment Canada Abbotsford A station under the highest greenhouse gas emissions scenario (RCP 8.5) over 50-year spans between the years 2020-2100. We estimated increases to rainfall intensity by plotting estimated IDF curves outputted by the IDF-CC tool, at 25-year intervals, and extrapolated an IDF curve for the year 2095.

As Metro Vancouver's IDF database is not included within the IDF-CC tool we could not directly estimate future increase in precipitation using our selected project rain gauge (MV-CK74). Therefore, we have estimated the %

increase in precipitation using Abbotsford A (EC-1100030). We selected Abbotsford A based on its proximity to site, its 24 year record ending in 2001, and its conservative historic IDF intensities.

Using this data, we estimate an average increase in precipitation from the IDF-CC tool of 25% for all storms greater than 6 hours. We applied this increase to the total precipitation values of the 24-hour storm durations from Metro Vancouver's Chilliwack Airport gauge (MV-CK74). **Table 3-1** shows the estimated increase in total rainfall of the 5-, 10-, 25-, 50-, and 100-year 24-hour events between historic conditions and conditions in the year 2095. **Figure 3-4** presents a comparison of the 10-year 24-hour SCS Type IA rainfall event with and without adjustments for climate change.

Additionally, we reviewed projected changes to annual precipitation in the Fraser Valley using PCIC's Plan2Adapt tool. We reviewed the 90th percentile changes in precipitation to the 2080 time horizon and found that estimated percent change in precipitation ranges from 14% to 20% in Spring/Fall and Winter seasons.

Given the watershed size and corresponding time of concentration, combined with the previously determined focus on long-duration events we selected a 25% increase in intensity for all storm events. We note that this value is similar to the 20% increase found in Engineers & Geoscientists British Columbia's "Guidelines for Legislated Flood Assessments in a Changing Climate" for application to flood magnitudes.

Table 3-1
24-Hour Total Precipitation Increase

	5-Year	10-Year	25-Year	50-Year	100-Year
Historic Precipitation (mm)	91.89	104.61	120.69	132.62	144.46
Future Precipitation (mm)	114.86	130.77	150.87	165.78	180.58

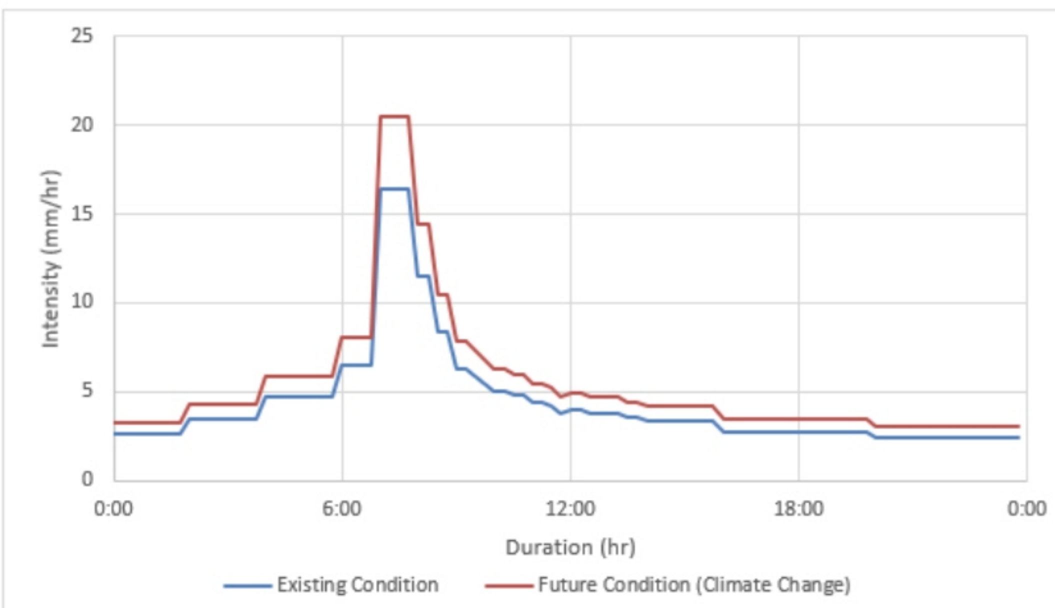


Figure 3-4
10-Year 24-hr Existing and Future Hyetograph Comparison

4 HYDROLOGIC AND HYDRAULIC MODELLING

We built a hydrologic and 1D hydraulic model in PCSWMM of the study area, from the forested upslope extents of the watershed, to the downslope agricultural areas surrounding the Kettle. Within the model we developed infrastructure layers to represent the Kettle, contributing sub-catchments, and unnamed creek. The model was built to assess the drainage conditions within the study area in their existing state and assess the magnitude of flooding around the Kettle.

4.1 Sub-Catchment Delineation and Characteristics

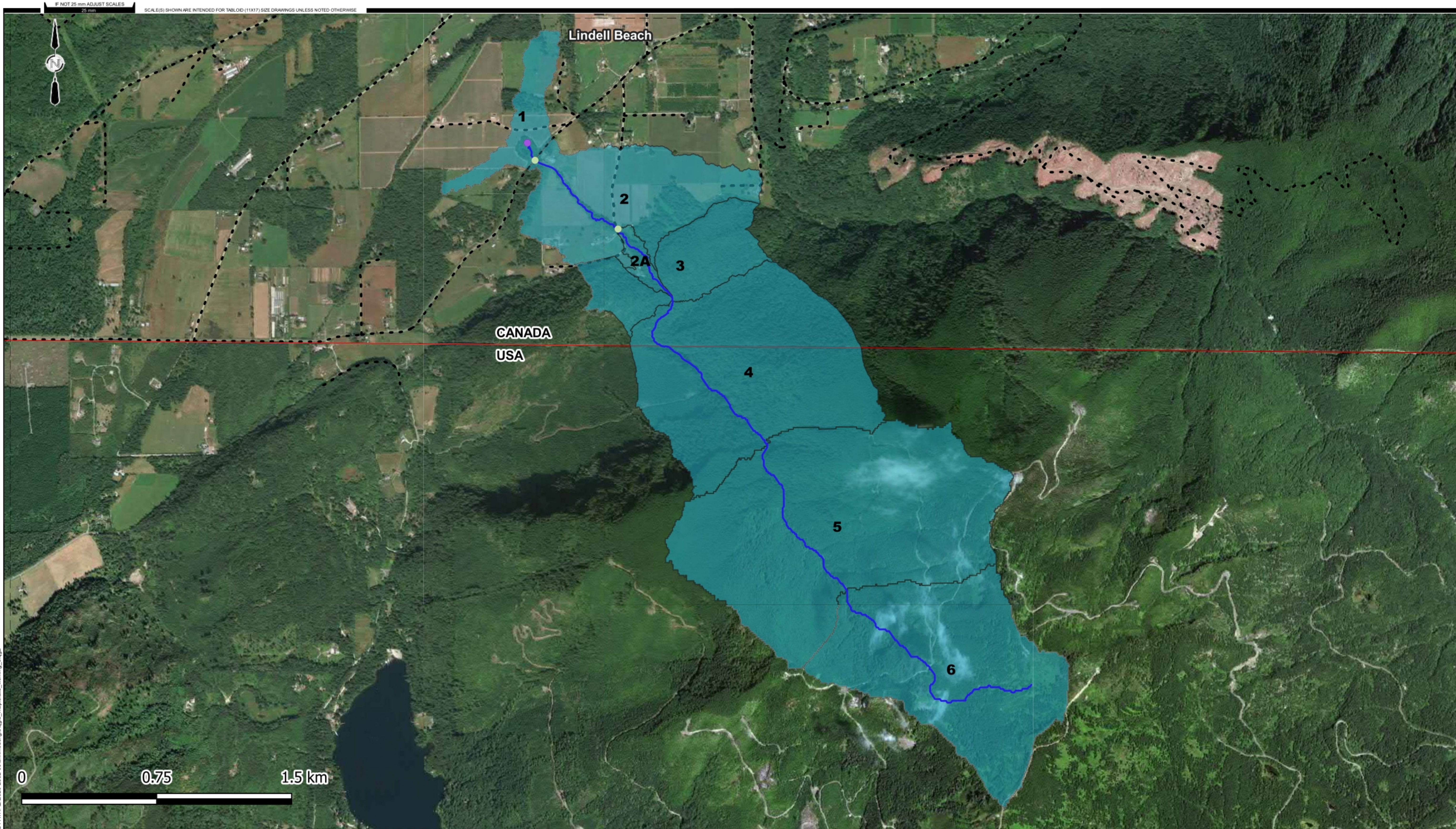
Assessment of the drainage patterns within the study area was completed to a sufficient level of detail using the Ministry's LiDAR surface and the USGS LiDAR surface. We applied an automated GIS technique to the LiDAR surfaces data to delineate the sub-catchments that contribute to the Kettle. The LiDAR surfaces were also used to estimate the average slope of each sub-catchment. We observed generated stream lines and delineated catchments developed from the surface. Using the LiDAR it appears that the majority of flow to the Kettle comes from the south but that additional area from agricultural lands lying north of the Kettle contribute runoff to the Kettle. We divided the southern sub-catchment into 6 individual sub-catchments. Runoff from the 6 sub-catchments are each routed into various points along the stream that are then routed to the Kettle as stream flow. The northern agricultural sub-catchment is routed directly into the Kettle as runoff. The total catchment area of the Kettle is 483.3 ha. Table 4-1 shows the area of each sub-catchment that contributes to the Kettle. Map 4-1 shows the delineated sub-catchments.

Table 4-1
Sub-Catchment Area

Sub-catchment	Area (ha)
1	17.0
2	58.0
2A	4.1
3	33.8
4	110.6
5	158.6
6	101.2

We assumed at this time that there will be no significant future developments within the sub-catchment, therefore the hydraulic modelling has been completed to represent existing land conditions. Sub-catchment parameters have been assigned to account for the forested and agricultural lands that make up the catchment. There are limited impervious areas within the sub-catchments, mainly found along the existing roadways. Sub-catchment parameters including Manning's Roughness coefficients for overland flow, depression storage, and Horton infiltration rates were estimated based on our interpretation of aerial imagery, open data sources from MoTI and USGS, and site visits. Table 4-2 shows the hydrologic parameters applied in the hydraulic model.

IF NOT 25 mm ADJUST SCALES
SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE



Legend

- SUB-CATCHMENTS
- EXISTING CULVERT
- KETTLE
- CREEK CHANNEL
- CANADA BORDER
- ROAD

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BEST MANAGED COMPANIES Platinum member

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

AE PROJECT No.	2020-2882
SCALE	AS SHOWN
APPROVED	M. MACLATCHY
DATE	20201215
REV	N/A
DESCRIPTION	ISSUED FOR STUDY

MAP 4-1

BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

MAPLE FALLS ROAD
DRAINAGE ASSESSMENT
SUB-CATCHMENTS AND DRAINAGE AREA

Table 4-2
Sub-Catchment Hydrologic Parameters

Hydrologic Model Parameters	
Manning's Roughness Coefficient for Overland Flow	
Impervious Surface	0.011
Pervious Surface	0.4 (Forested) 0.1 (Agricultural Lands)
Depression Storage	
Impervious Surface (mm)	1.27
Pervious Surface (mm)	7.6 (Forested) 5.1 (Agricultural Lands)
Horton's Infiltration Parameters	
Maximum Infiltration Rate (mm/hr)	5.08
Minimum Infiltration Rate (mm/hr)	1.6
Decay Constant (h^{-1})	4
Drying Time (days)	7

We note that for the purpose of this study we have used the Horton Infiltration Method as it is appropriate for watershed scale analyses. However, the Horton Infiltration Method has limitations in that it does not consider changing hydraulic gradients and boundary conditions (such as ground water mounding) that may impact realized infiltration rates. Therefore, it is not intended for the design of infiltration systems nor is it intended for diagnosing infiltration problems.

4.2 Stormwater Features

4.2.1 Creek Channels

To estimate the dimensions of stormwater features, including natural channels and storage within the model, we derived contours and cross-sections from the two LiDAR surfaces.

Cross-sections were drawn through the channel identified in the Ministry's LiDAR surface at 200 m intervals along 2 km of the stream. Cross-sections were also taken at key points modelled within PCSWMM, such as the inlet of the culvert at Maple Falls Road. We did not review the channel in the USGS LiDAR. The channel width, heights, and slopes at each cross-section were used to inform the channel dimensions in the model. We have assumed that the channel maintains the same dimensions in the US portion of the watershed as it does in the upper portions of the Canadian side of the watershed. The dimensions shown in the cross-sections were more prominent in the upslope areas, showing a deep and wide channel, which both reduced in height and width as the channel progressed through the agricultural lands to the Kettle, which is representative of what was observed on site. Table 4-3 shows the modelled channel dimensions within the stream length of each modelled sub-catchment.

Table 4-3
Channel Dimensions within the Kettle Catchment

Subcatchment	Channel Height (m)	Channel Width (m)	Right Channel Slope	Left Channel Slope
1	-	-	-	-
2 (between properties) 2 (in agricultural lands)	2 2	1 5	1:2.5 1:2.5	1:2.5 1:2.5
2A	2	5	1:2.5	1:2.5
3	2.5	5	1:2	1:2.5
4	2.5	5	1:1.5	1:4.0
5	1.5	5	1:1.5	1:1.5
6	1.5	5	1:1.5	1:1.5

4.2.2 Storage at the Kettle

We derived contours at 0.2 m intervals from the Ministry's LiDAR. We used the contours to estimate the depth of storage available within the Kettle as well as the depth of storage available within the overland area surrounding the Kettle. To estimate the available storage volume within the Kettle and the overland areas we developed a depth-area relationship curve based on the surface area delineated for each contour at a 0.2 m interval. We have assumed that the Kettle has a maximum elevation of 204.0 m, higher elevations are considered to be overland. This elevation is approximately 3.1 m from the invert of the Kettle based on the LiDAR surface. Using the contours delineated from the LiDAR surface we have estimated the maximum storage volume of the Kettle to be 16,600 m^3. We estimated overland storage to a maximum depth of 1 m with a maximum overland flooding volume of 16,680 m^3. The combined storage volume modelled at the Kettle is 33,280 m^3.

We recognize that the Ministry has stated that the Kettle, when cleared of sediment, is approximately 10 m deep. As we do not have LiDAR data available to support this stated depth, we are unable to estimate the volume associated with this anecdotal depth. Further, the Ministry has stated that the Kettle can be left for multiple seasons, or even years, without clearing, therefore the depth and volume of the Kettle used in our analysis may be most representative of the uncleared conditions. Prior to a detailed design, further surveying of the Kettle may provide a refined estimate of the full depth and volume of the Kettle.

Two outlets have been modelled connected to the Kettle. In reality, there is the gradual infiltration of water into the underlying soil stratum and the potential for spilling of water overland once the Kettle has filled to a certain elevation. We have modelled the high level overland outlet from the kettle as a spillway at the high point that exists along Maple Falls Road to the south-east that would become active when the flooding depth reaches approximately 3.7 m, or an elevation of approximately 204.6 m. As stated in Section 2.2, this location has been seen to act as a spillway for the system in real flooding conditions. A low flow orifice is used to model the gradual infiltration based drainage of the Kettle. The rate of drainage by infiltration is unmeasured in reality but our model allows for a slow release over the 6-day simulation period used for modelling.

5 EXISTING CONDITIONS HYDRAULIC ANALYSIS RESULTS

Using the existing condition model, we evaluated the study area drainage system and the associated flooding of the Kettle during the 5-, 10-, 25-, 50-, and 100-year return periods with the 24-hour SCS Type IA event, 72-hour SCS Type IA event, and 24-hour AES storm events.

We reviewed flooding depths and peak flow to the storage nodes which represent the Kettle. To evaluate the flooding extents in each scenario, we reviewed the depth of overland flooding. For the existing condition model, we have defined overland flooding as anything that spills over the top of the Kettle, the boundary of which we have defined to be at 204.0 m elevation. Based on this definition, the Kettle floods in all modelled scenarios. The following sub-sections summarize the flooding results from the model for the 24-hour SCS Type IA Storm, 72-hour SCS Type IA Storm, and 24-hour AES Storm. For the purpose of this assessment we have not considered the impacts of climate change on rainfall as we presume that the existing situation would only be exacerbated with climate change.

5.1 24-hour SCS Type IA Storm

In existing conditions with a 24-hour SCS Type IA storm, the Kettle floods in each of the return periods that we reviewed. The model results indicate that the Kettle floods within just a few hours of the peak of the SCS Type IA storm event. The duration of flooding at the Kettle in the model lasts for approximately 40 to 44 hours, depending on the storm's return period. Based on anecdotal information provided by the Ministry, this has been seen to occur following actual flooding events at the Kettle over the last 20 years.

Table 5-1 outlines the peak flow into the Kettle for each return period reviewed.

Table 5-1
24-hour SCS Type IA - Peak Flow into Kettle

Return Period	Peak Flow (m^3/s)
5	8.8
10	11.1
25	13.9
50	16.4
100	18.5

Maximum overland flooding depths range from 0.83 m to 0.96 m above the top of the Kettle. **Table 5-2** shows the maximum overland flooding depths for each return period and the combined volume contained in the Kettle and overland storage. **Map 5-1** shows the extent of flooding for the 5-year and 100-year return period events based on the associated overland flooding depths. It is seen in the map that these flooding extents extends quite close to one of the properties along Maple Falls Road.

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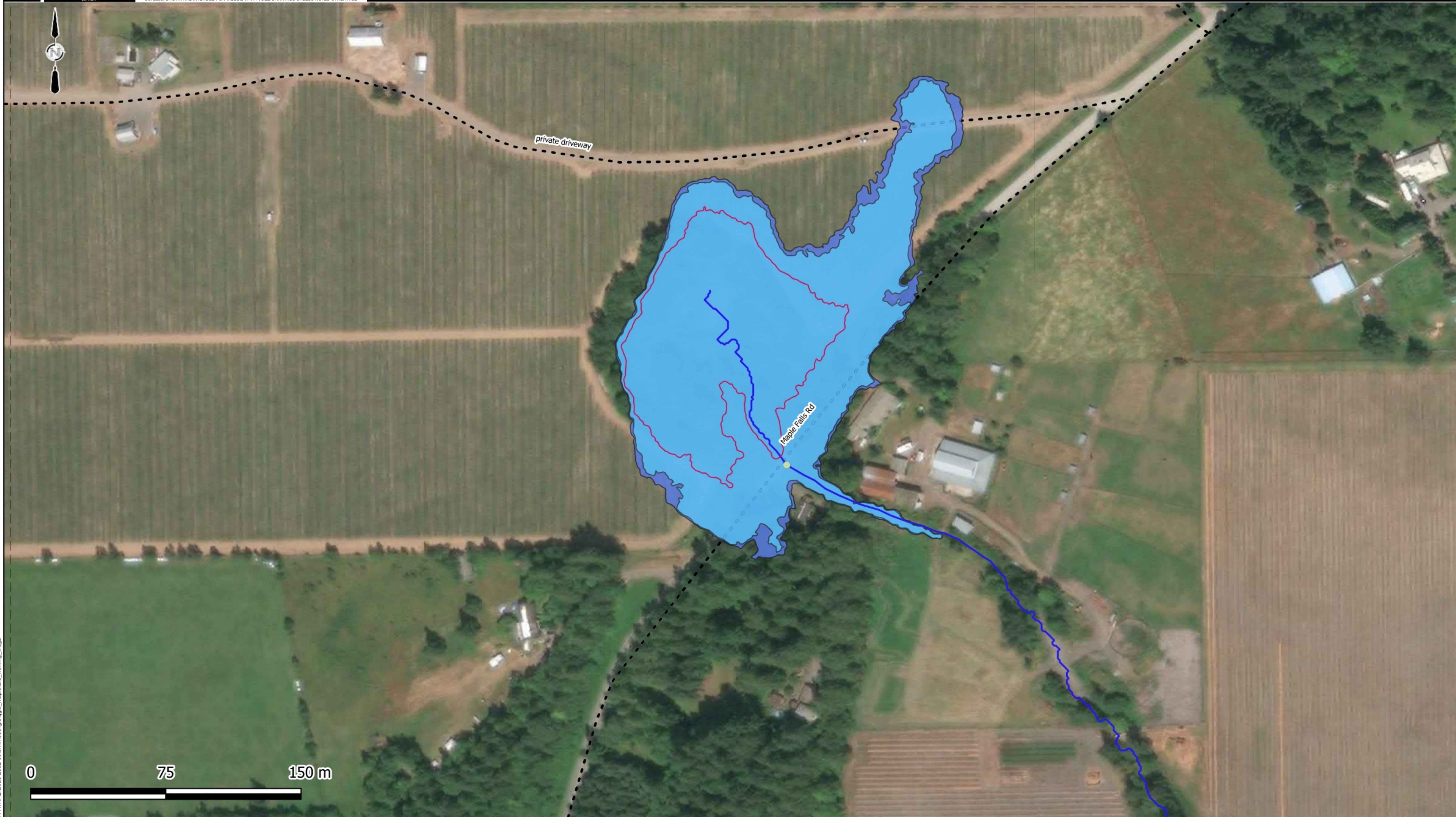

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Legend

- ESTIMATED 5-YEAR FLOOD EXTENTS
- ESTIMATED 100-YEAR FLOOD EXTENTS
- EXISTING CULVERT
- CREEK CHANNEL
- ROAD
- TOP OF KETTLE

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

AE PROJECT No.	2020-2882
SCALE	AS SHOWN
APPROVED	M. MACLATCHY
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MAP 5-1

BC MINISTRY OF TRANSPORTATION
AND INFRASTRUCTURE

MAPLE FALLS ROAD
DRAINAGE ASSESSMENT
FLOODING EXTENTS:
24-HOUR SCS TYPE 1A STORM

Table 5-2
24-hour SCS Type IA - Overland Flooding Depths and Stored Volume

Return Period	Depth of Overland Flooding (m)	Stored Volume (m^3)
5	0.83	29,600
10	0.87	30,500
25	0.91	31,500
50	0.93	32,100
100	0.96	32,700

For a period of time, the overland flooding is contained within a local depression along Maple Falls Road, however once the overland flooding reaches 204.6 m elevation, the water begins to overflow along Maple Falls Road towards the south-west in the direction which the road elevation decreases. Overland flow from this location occurs for approximately 18 to 20 hours, depending on the return period of the storm event. This corresponds well to observation of sediment accumulation at this location, and remnants of overland flooding and overflow, in the form of debris and sediment, were observed along the side of Maple Falls Road towards the south-west during the site visit completed by AE in February of 2020. It is expected that the overflow would progress towards the south-west and eventually pass over the border or otherwise infiltrate. Table 5-3 shows the peak overflow from the Kettle and Maple Falls Road toward the south-west.

Table 5-3
24-hour SCS Type IA – Peak Overflow from Kettle

Return Period	Peak Overflow (m^3/s)
5	7.6
10	10.4
25	13.7
50	16.0
100	18.3

5.2 72-hour SCS Type IA Storm

The modelled results for the 72-hour SCS Type IA storm show flooding of the Kettle within an hour of the peak of the SCS Type IA storm event. The duration of flooding at the Kettle in the model lasts for approximately 44 hours for the 5-year return period and increases to just over 72 hours for the 100-year return period. As discussed in Section 5.1, this corresponds with anecdotal records of events provided by the Ministry. Table 5-4 shows the resulting peak flows into the Kettle for the 5-, 10-, 25-, 50-, and 100-year return periods.

Table 5-4
72-hour SCS Type IA - Peak Flow Estimates

Return Period	Peak Flow (m^3/s)
5	8.6
10	11.2
25	14.8
50	17.1
100	19.2

The modelled results for the 72-hour SCS Type IA storm shows maximum overland flooding depths ranging from 0.83 m to 0.96 m. Table 5-5 shows the maximum overland flooding depths and stored volume within the Kettle and overland area associated with the 72-hour SCS IA storm for the 5-, 10-, 25-, 50-, and 100-year return periods. Although the overland flooding depths presented appear to be identical to values seen during the 24-hour SCS Type IA event, they are in fact slightly higher in the 72-hour event. For the purpose of reporting we have rounded the values to 0.01 m precision. It is for that reason that the stored volume for the 72-hour event is larger than the stored volumes from the 24-hour event. Map 5-2 shows the extent of flooding for the 5-year and 100-year return period events based on the associated overland flooding depths.

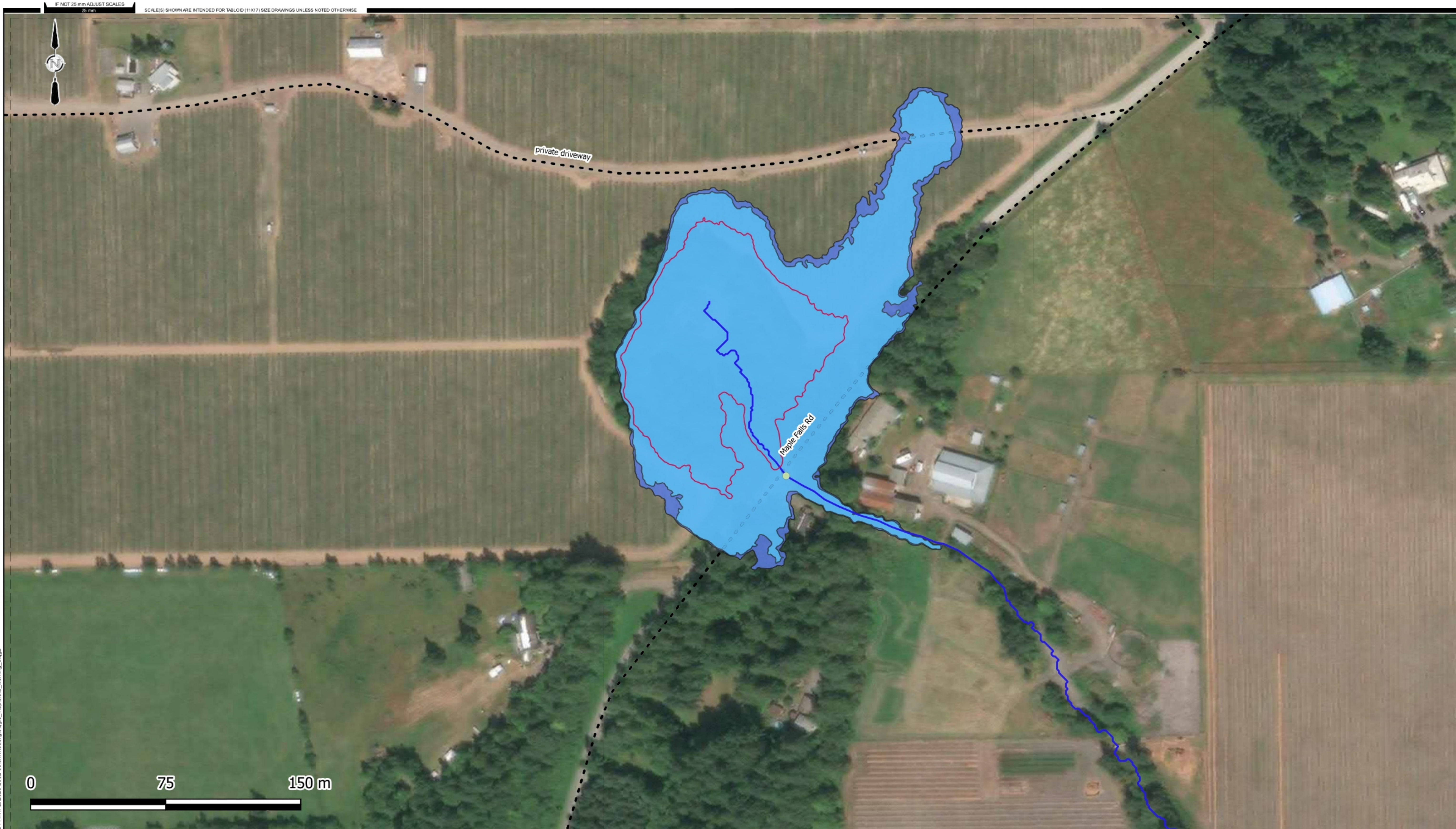
Table 5-5
72-hour SCS Type IA - Overland Flooding Depths and Stored Volume

Return Period	Depth of Overland Flooding (m)	Stored Volume (m^3)
5	0.83	29,700
10	0.87	30,600
25	0.92	31,700
50	0.94	32,400
100	0.96	32,900

During the 72-hour event, the model results indicate that overland flooding along Maple Falls Road towards the south-west would occur for approximately 22 hours following a 5-year return period event. This overflow is shown to last just over two times longer, for approximately 48 hours, following a 100-year return period event. Table 5-6 summarizes the peak overflow rates from the Kettle towards the south-west along Maple Falls Road.

Table 5-6
72-hour SCS Type IA - Peak Overflow from Kettle

Return Period	Peak Overflow Rate (m^3/s)
5	7.8
10	10.6
25	14.5
50	16.9
100	19.0



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Legend

- ESTIMATED 5-YEAR FLOOD EXTENTS
- ESTIMATED 100-YEAR FLOOD EXTENTS
- EXISTING CULVERT
- CREEK CHANNEL
- ROAD
- TOP OF KETTLE

British Columbia — Ministry of Transportation and Infrastructure

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DESCRIPTION	ISSUED FOR STUDY

MAP 5-2

BC MINISTRY OF TRANSPORTATION
AND INFRASTRUCTURE

MAPLE FALLS ROAD
DRAINAGE ASSESSMENT
FLOODING EXTENTS:
72-HOUR SCS TYPE 1A STORM

5.3 24-hour AES Storm

Due to the difference in rainfall distribution and peak rainfall intensity between the SCS Type IA storms and the AES storms a significant difference is seen in peak flow rates into the Kettle. Flow rates resulting from the 24-hour AES storms are approximately 2.3 times lower than those resulting from the 24-hour SCS Type 1A event. Table 5-7 shows the peak flow rates into the Kettle for the 24-hour AES storm.

Table 5-7
24-hour AES - Peak Flow Estimates

Return Period	Peak Flow (m^3/s)
5	4.0
10	5.1
25	6.4
50	7.3
100	8.2

Maximum overland flooding results from the AES storm range from 0.75 m to 0.83 m. Table 5-8 shows the maximum overland flooding depths resulting from the 24-hour AES storm for the 5-, 10-, 25-, 50-, and 100-year return periods. Map 5-3 shows the extent of flooding for the 5-year and 100-year return period events based on the associated modelled overland flooding depths. Despite the difference in rainfall distribution between the SCS Type IA storm and the AES storm, the total volume of rainfall remains the same. It is for this reason that the overland flooding depths are within the same range for the two events. The slightly lower depths seen from the AES storm results is due to the more sustained and less concentrated pattern of inflow to the Kettle than compared with the SCS storm event, which allows for the outflow to the south to better keep pace with the inflow.

Table 5-8
24-hour AES - Overland Flooding Depths and Stored Volume

Return Period	Depth of Overland Flooding (m)	Stored Volume (m^3)
5	0.75	28,000
10	0.78	28,500
25	0.80	29,000
50	0.82	29,400
100	0.83	29,700

Flooding above the top elevation of the Kettle is shown to occur for 40 to 45 hours during the AES storm event and occurs between the two peak intensities of the AES distribution. Again, as stated in Section 5.1, this corresponds with anecdotal records of events provided by the Ministry.

Following the second peak of the storm event the flooding is shown to spill towards the south-west along Maple Falls Road for a duration ranging between 18 and 24 hours, depending on the return period of the event. Table 5-9 shows the peak overflow rates from the Kettle towards the south-west along Maple Falls Road.

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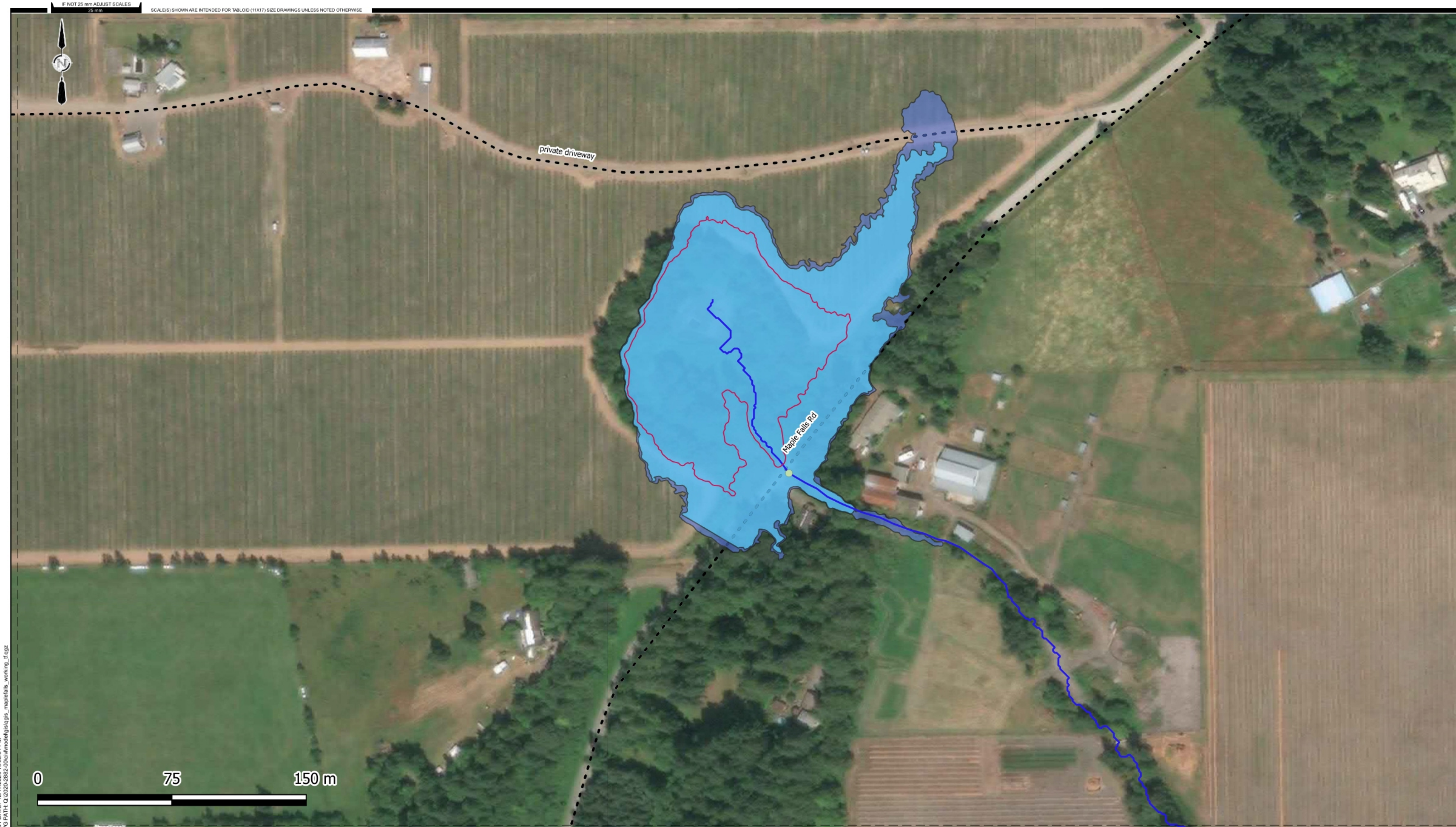

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Legend

- 100-YEAR FLOOD EXTENTS
- 5-YEAR FLOOD EXTENTS
- EXISTING CULVERT
- CREEK CHANNEL
- ROAD
- TOP OF KETTLE

British Columbia Ministry of Transportation and Infrastructure

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MAP 5-3

BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

MAPLE FALLS ROAD DRAINAGE ASSESSMENT FLOODING EXTENTS: 24-HOUR AES STORM

Table 5-9
24-hour AES - Peak Overflow from Kettle

Return Period	Peak Overflow Rate (m^3/s)
5	3.6
10	4.8
25	6.1
50	7.1
100	8.0

5.4 Calibration

The models that have been developed for this study have not been quantifiably calibrated, and only compared to anecdotal observations. While model calibration is preferred, it is dependant on the availability of detailed hydrologic data, including site specific rainfall and gauged runoff responses, to reliably fit parameters within the models. As there are no available records within the area for runoff, groundwater flow, or local meteorological data, we were unable to calibrate these aspects of the models.

In lieu of calibration, we have proceeded with selecting model parameters based on literature review, sensitivity analysis, and professional experience of similar work.

Additionally, during the project the Ministry provided AE with a high-level estimate of the flooding extents seen at the Kettle. Comparing the extents drawn by the Ministry to the extents derived from the modelled overland flooding depths of each storm event, we believe that the flood extents modelled generally reflect those seen by the Ministry and local residents. Map 5-4 shows the flooding extents delineated by the Ministry and compares it to the 5-year AES return period flooding extents from the modelling results.

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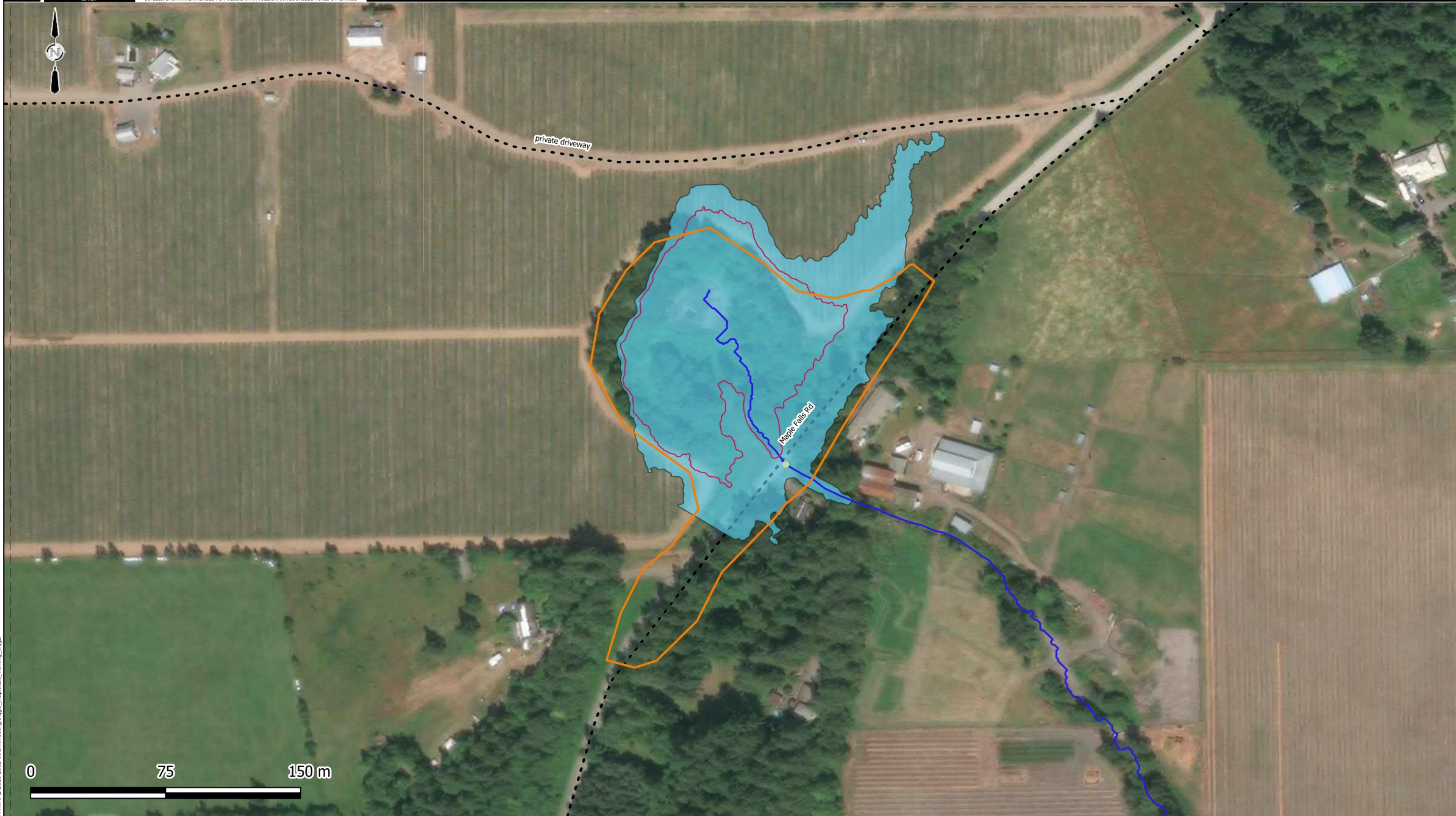

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Legend

- ESTIMATED 24HR 5-YEAR AES FLOOD EXTENTS
- MOTI 2020 ANECDOTAL FLOOD EXTENTS
- EXISTING CULVERT
- CREEK CHANNEL
- ROAD
- TOP OF KETTLE

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

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MAP 5-4

BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

MAPLE FALLS ROAD
DRAINAGE ASSESSMENT
FLOODING EXTENTS:
ANECDOTAL COMPARISON

6 CONCEPTUAL UPGRADE OPTIONS

Based on our understanding of the constraints of the existing drainage system at Maple Falls Road, providing a positive outlet for the Kettle is critical to mitigate the flooding of the Kettle onto Maple Falls road and the surrounding properties. To provide an outlet for the Kettle, we have considered the feasibility and implementation of a diversion pipe, along three possible alignments, that will outlet into Frost Creek. The following sections outlines the three alignment alternatives that were reviewed as part of the conceptual upgrade options and recommended strategies that may aid in mitigating the flooding issues in the area. Each alternative is intended to mitigate the severity and frequency of flooding problems and impacts to Maple Falls Road and private property, reduce the liability to the responsible agency, and improve public safety within the area.

We have evaluated three separate models that were built upon the existing conditions model and each has a piped hydraulic connection and outlet point for the Kettle. The diversion is intended only as an outlet for the Kettle and its catchments, not as a general stormwater collection system for the area. Therefore, there are no additional downstream inlet points to the diversion (i.e. from other catchments along its route).

For the purpose of the upgrade modelling, we have adjusted the model parameters to reflect future climate conditions. We have evaluated the diversion pipe connection to the Kettle for the 10-year and 100-year return periods with the 24-hour SCS Type IA event and the 24-hour AES event, considering the impacts of climate change on rainfall.

Significant development is not anticipated within the area of Maple Falls Road, therefore land and development conditions in the model have remained the same as those in the existing condition hydraulic assessment, discussed in **Section 4**.

At this time, we have not modelled these alternatives as open ditches based on assumed spatial constraints. The space needed for a ditch and associated maintenance easements, could magnify the potential impact to private properties adjacent to, or through which, the improvement alignment passes. Therefore, we have not considered a ditch as an optimal improvement option and have exclusively modelled the improvements and downstream system as an enclosed pipe. A combination of open ditches and pipes could be considered for each alternative in later design phases. **Map 6-1** shows the three proposed alignments.

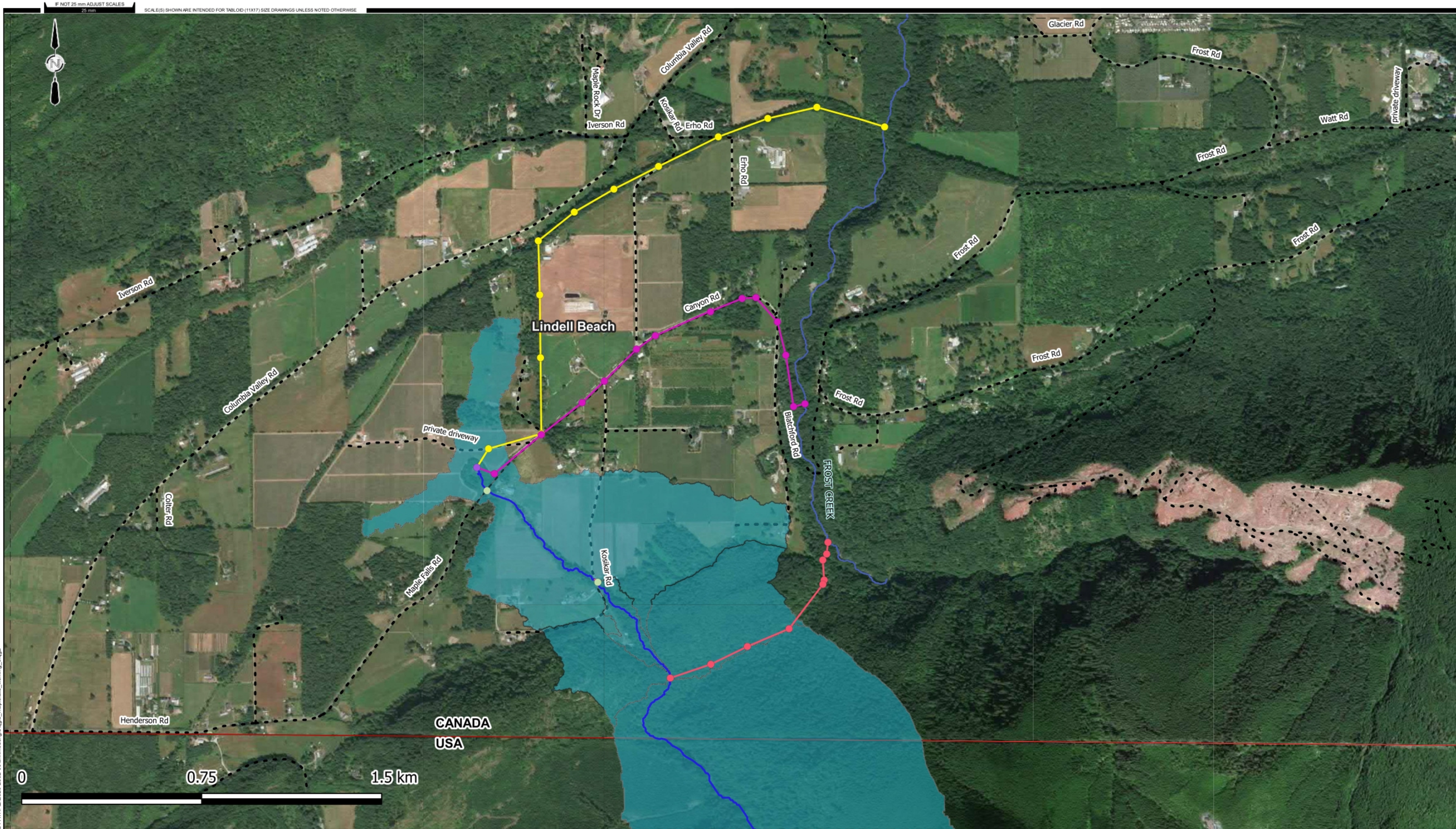
6.1 Assessment Criteria

The BC MoTI Supplement to TAC Geometric Design Guide – 1000 Hydraulics Chapter does not define design criteria for diversion pipes, therefore we have used the following criteria when assessing the diversion pipes:

- Pipes should be designed to carry the 10-year return period storm.
- Flooding should not occur above 204.0 m elevation, the assumed top elevation of the Kettle, during the 10-year return period 24-hour storm event.

6.2 Option 1: Alignment Along Maple Falls Road

The first alignment option between the Kettle and Frost Creek traverses north-east below Maple Falls Road until it becomes Kosikar Road, as shown on **Map 6-1**. At the intersection of Kosikar Road and Canyon Road the diversion pipe continues east below Canyon Road until the road reaches the invert of Frost Creek where the pipe would outlet.



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SUB-CATCHMENTS	CREEK CHANNEL
EXISTING CULVERTS	CANADA BORDER
KETTLE	ROAD
DIVERSION OPTION 1	
DIVERSION OPTION 2	
DIVERSION OPTION 3	

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MAP 6-1

BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

MAPLE FALLS ROAD DRAINAGE ASSESSMENT DRAINAGE UPGRADE OPTIONS

We recognize that Frost Creek is susceptible to erosion and that erosion is an ongoing concern at the creek, further discussion on opportunities to reduce the potential for further erosion are discussed in **Section 6.5.1**.

The proposed alignment is located within the Ministry's ROW for the entire length of the diversion pipe. Construction of this alignment may require coordination between the responsible agency and the Ministry and/or owners of private property within the area should the required excavation extents extend into private property or the Ministry's ROW.

The length of the diversion pipe system along this alignment is approximately 2000 m. In this option the invert of the diversion pipe has been modelled just above the invert of the Kettle at 201.0 m elevation. The diversion pipe has been modelled as a concrete pipe. The diameter of the diversion pipe is dependant on the storm event and the peak flows that impact the storage in the Kettle. Specific pipe diameters for alignment Option 1 are discussed further in the following sections. As the topography and roads within the area are quite flat, most of the pipe has been modelled with a minimum slope of 0.5%. The maximum depth of the pipe invert below the ground surface is approximately 15 m. A pumped system could be considered; however, we believe this approach would be cost prohibitive when compared to other options, such as a gravity fed pipe along the same alignment.

In addition to the diversion pipe, we have evaluated the culvert capacity and size of culvert that would be required below Maple Falls Road to convey the 10-year and 100-year storm events.

To compare the alignment options, we have assessed two main features of the system, the depth of water within the Kettle, and the peak flows that can be conveyed through the diversion pipe.

6.2.1 SCS IA Storm

We evaluated the Option 1 diversion pipe with the 10-year and 100-year future storms using an SCS Type IA distribution. We began our assessment by reviewing the conditions that would prevent flooding from the Kettle during the 10-year return period event. To convey the 10-year peak flow of the SCS Type IA storm, the crossing below Maple Falls Road requires eight 1200 mm diameter CSP culverts to prevent flooding across the roadway. The diversion pipe required to prevent overtopping of the Kettle is 2400 mm diameter. A diversion pipe of this size does not prevent flooding of the roadway during the 100-year event. **Table 6-1** shows the water elevation within the Kettle, the depth of overland flooding, peak flows into the Kettle, and peak flow out of the Kettle through the diversion pipe during the 10-year and 100-year events. Although flooding of the Kettle is not mitigated during the 100-year event, the duration of flooding and peak overflow rate from the Kettle is significantly reduced when compared to existing conditions. **Table 6-2** compares the overland flooding duration, overflow duration, and peak overflow of the 100-year return period event for existing conditions and future conditions with a diversion sized to accommodate the 10-year return period in place. **Appendix A** contains graphs comparing the existing and future condition flood elevations and overflow. **Map 6-2** shows the estimated flooding extents of the 100-year SCS Type IA return period event with the Option 1 diversion pipe in place.

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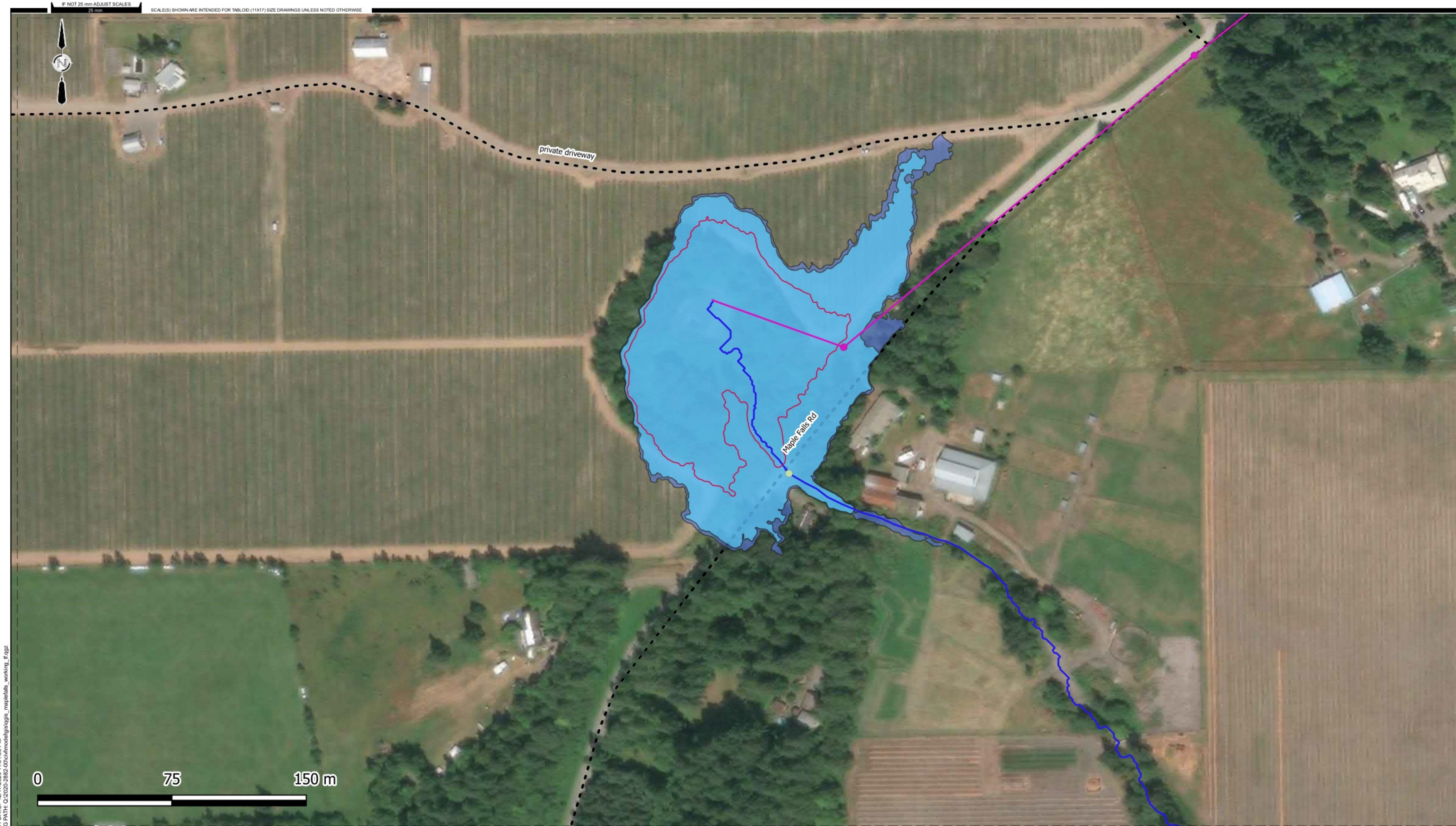

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AES 100-YEAR FLOOD EXTENTS	CREEK CHANNEL
SCS 1A 100-YEAR FLOOD EXTENTS	ROAD
EXISTING CULVERT	TOP OF KETTLE
OPTION 1 MANHOLE	OPTION 1 DIVERSION PIPE

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MAP 6-2

BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

MAPLE FALLS ROAD DRAINAGE ASSESSMENT FLOODING EXTENTS: DIVERSION OPTION 1

Table 6-1
Option 1 –SCS IA Elevations and Peak Flows

	10-year RP	100-year RP
Elevation Water at the Kettle (m)	203.3	204.8
Depth of Overland Flooding (m)	0	0.8
Peak Inflow to Kettle (m^3/s)	15.8	24.7
Peak Outflow through Diversion (m^3/s)	14.7	15.7

Table 6-2
Option 1 –SCS IA Flooding Summary

	Existing 100-year RP	Option 1 100-year RP with CC
Duration of Flooding (hr)	43.5	3.5
Duration of Overflow (hr)	43.5	2
Peak Overflow (m^3/s)	18.3	6.7

To prevent flooding of Maple Falls Road during the 100-year event both the diversion pipe and the culvert below Maple Falls Road requires upsizing. The diversion pipe required to prevent overtopping of the Kettle during the 100-year event is 3050 mm diameter. To convey the 100-year peak flow of the SCS Type IA storm without flooding the roadway, the crossing below Maple Falls Road requires seventeen 1200 mm diameter CSP culverts. We recognize that a crossing with the identified culvert configuration would be impractical. Our assessment of the Maple Falls Road culvert crossing has been completed for comparative purposes only and other configurations could be considered to provide the same hydraulic capacity. An alternative configuration is shown in Table 6-3. Table 6-3 summarizes the infrastructure that would be required to prevent flooding along Maple Falls Road during the 10-year and 100-year SCS IA storm events.

Table 6-3
Option 1 – 10-year and 100-year SCS IA Upgrade Comparison

	10-year RP	100-year RP
Diversion Pipe Diameter (mm)	2400	3050
Maple Falls Road Culvert No. of Barrels / Diameter (mm)	8 / 1200	17 / 1200
Equivalent Culvert Diameter No. of Barrels / Diameter (mm)	2 / 2400	3 / 3050

6.2.2 AES Storm

We also evaluated the Option 1 diversion pipe with the 10-year and 100-year future storms using an AES storm distribution. We began our assessment by reviewing the conditions that would mitigate flooding during the 10-year return period event. To convey the 10-year peak flow of the AES storm, the crossing below Maple Falls Road requires four 1200 mm diameter CSP culverts. The diversion pipe required to prevent flooding from the Kettle is 1800 mm diameter. Like the SCS Type IA storm event, this infrastructure does not prevent flooding of the roadway during the 100-year AES storm event. Table 6-4 shows the water elevation within the Kettle, the depth of overland flooding, peak flows into the Kettle, and peak flow out of the Kettle through the diversion pipe for the 10-year and 100-year events with a diversion pipe sized for the 10-year event in place. Although flooding of the Kettle is not mitigated during the 100-year event, the duration of flooding and peak overflow rate from the Kettle is significantly reduced when compared to existing conditions. Table 6-5 compares the flooding duration, overflow duration, and peak overflow for the 100-year return period events in existing conditions and future conditions with a diversion pipe. Map 6-2 shows the estimated flooding extents of the 100-year AES return period event with the Option 1 diversion pipe in place.

Table 6-4
Option 1 –AES Elevations and Peak Flows

	10-year RP	100-year RP
Elevation Water at the Kettle (m)	202.6	204.7
Depth of Overland Flooding (m)	0	0.7
Peak Inflow to Kettle (m^3/s)	7.2	10.6
Peak Outflow from Kettle (m^3/s)	6.8	7.9

Table 6-5
Option 1 –AES Flooding Summary

	Existing 100-year RP	Option 1 100-year RP with CC
Duration of Flooding (hr)	45.0	13.0
Duration of Overflow (hr)	22.5	8.0
Peak Overflow (m^3/s)	8.0	1.3

To prevent flooding of Maple Falls Road during the 100-year event both the diversion pipe and the culvert below Maple Falls Road requires upsizing. To convey the 100-year peak flow of the SCS Type IA storm, the crossing below Maple Falls Road requires five 1200 mm diameter CSP culverts to prevent flooding across the roadway. The diversion pipe required to prevent overtopping of the Kettle is 2100 mm diameter. Table 6-6 summarizes the infrastructure that would be required to prevent flooding along Maple Falls Road during the 10-year and 100-year SCS IA storm events.

Table 6-6
Option 1 – 10-year and 100-year AES Upgrade Comparison

	10-year RP	100-year RP
Diversion Pipe Diameter (mm)	1800	3050
Maple Falls Road Culvert No. of Barrels / Diameter (mm)	4 / 1200	5 / 1200
Equivalent Culvert Diameter Size No. of Barrels / Diameter (mm)	1 / 2400	1 / 2700

6.3 Option 2: Alignment Along Fraser Valley Regional District ROW

The second alignment option that we reviewed traverses through private property and extends along what is assumed to be a Fraser Valley Regional District (FVRD) ROW. The alignment traverses north from the Kettle to a private driveway. From there it extends east towards Maple Falls Road. From Maple Falls Road it will extend north along what appears to be a property line. The pipe will progress down a steeper slope immediately south of Columbia Valley Road. At the base of the slope the pipe will turn to the north-east, just south of Columbia Valley Road, and progress along what may be a FVRD ROW. The pipe will continue to the north-east, parallel to Columbia Valley Road, pass below Kosikar Road, and continue north-east until the pipe outlets into Frost Creek. Like Option 1, this alignment may exacerbate erosion issues within Frost Creek without additional protective measures in place.

As this proposed alignment is located in proximity of private properties as well as a possible FVRD ROW, coordination would be required between all impacted parties. Additionally, it is unknown what other utilities might already exist within the assumed FVRD ROW. An existing utility review should be completed early on as part of the preliminary design should this alignment be the preferred upgrade option.

The length of the diversion pipe system along this alignment is approximately 2700 m. The invert of the pipe has been modelled just above the invert of the Kettle at 201.0 m elevation. The diversion pipe has been modelled as a concrete pipe. The diameter of the diversion pipe is dependant on the storm event and the peak flows that impact the storage in the Kettle. Specific pipe diameter estimates for alignment Option 2 are discussed further in the following sections. Like Option 1, most of the pipe in this option has been modelled with a minimum slope of 0.5%. The pipe is steeper as it traverses north along a hillside to reach the assumed FVRD ROW. The topography along this alignment is more varied than that in Option 1. The maximum depth of the pipe invert below the ground surface is approximately 16 m.

In addition to the diversion pipe, we have evaluated the culvert capacity and size that would be required below Maple Falls Road to convey the 10-year and 100-year storm events.

To compare the alignment options, we have assessed two main features of the system, the depth of water within the Kettle, and the peak flows that can be conveyed through the diversion pipe.

6.3.1 SCS 1A Storm

We evaluated the Option 2 diversion pipe with the 10-year and 100-year future storms using an SCS Type IA distribution. We began our assessment by reviewing the conditions that would mitigate flooding during the 10-year return period event. To convey the 10-year peak flow of the SCS Type IA storm, the crossing below Maple Falls Road requires eight 1200 mm diameter CSP culverts to prevent flooding across the roadway. The diversion pipe required to prevent overtopping of the Kettle is 2400 mm diameter. However, this infrastructure does not prevent flooding of the roadway during the 100-year event. Table 6-7 shows the water elevation within the Kettle, the depth of overland flooding, peak flows into the Kettle, and peak flow out of the Kettle through the diversion pipe. Although flooding of the Kettle is not prevented during the 100-year event, the duration of flooding and peak overflow rate from the Kettle is significantly reduced when compared to existing conditions. Table 6-8 compares the flooding duration, overflow duration, and peak overflow for existing and future conditions. Map 6-3 shows the estimated flooding extents of the 100-year SCS Type IA return period event with the Option 2 diversion pipe in place.

Table 6-7
Option 2 – SCS IA Elevations and Peak Flows

	10-year RP	100-year RP
Elevation Water at the Kettle (m)	203.3	204.8
Depth of Overland Flooding (m)	0	0.8
Peak Inflow to Kettle (m^3/s)	16.0	24.8
Peak Outflow from Kettle (m^3/s)	14.8	18.3

Table 6-8
Option 2 –SCS IA Flooding Summary

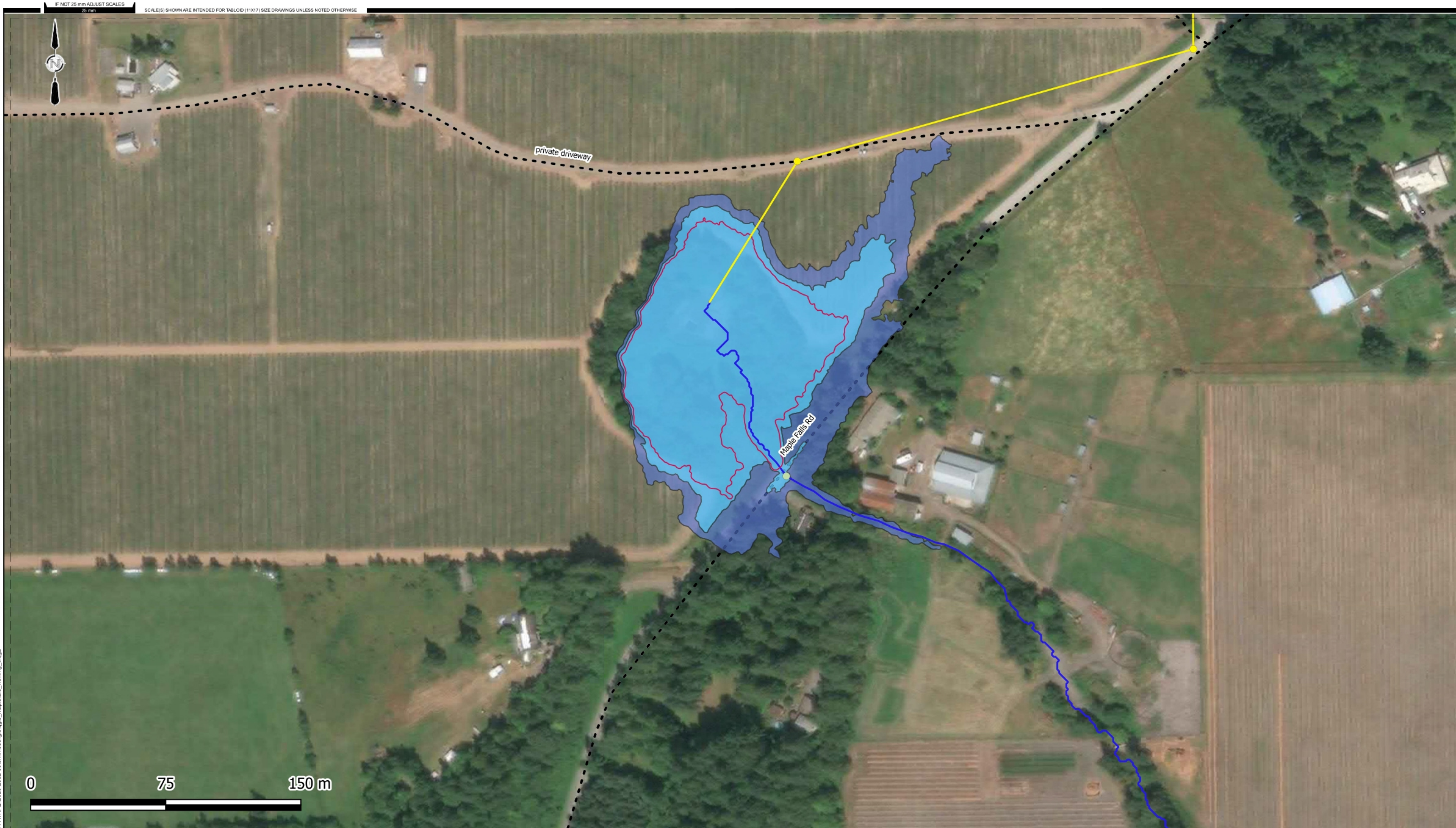
	Existing 100-year RP	Option 2 100-year RP with CC
Duration of Flooding (hr)	43.5	3.0
Duration of Overflow (hr)	43.5	1.5
Peak Overflow (m^3/s)	18.3	3.9

To prevent flooding of Maple Falls Road during the 100-year event both the diversion pipe and the culvert below Maple Falls Road requires upsizing. To convey the 100-year peak flow of the SCS Type IA storm, the crossing below Maple Falls Road requires seventeen 1200 mm diameter CSP culverts to prevent flooding across the roadway. The diversion pipe required to prevent overtopping of the Kettle is 3050 mm diameter. Table 6-9 shows the water elevation within the Kettle, the depth of overland flooding, peak flows into the Kettle, and peak flow out of the Kettle through the diversion pipe.

Table 6-9
Option 2 – 10-year and 100-year SCS IA Upgrade Comparison

	10-year RP	100-year RP
Diversion Pipe Diameter (mm)	2400	3050
Maple Falls Road Culvert No. of Barrels / Diameter (mm)	8 / 1200	17 / 1200
Equivalent Culvert Diameter Size No. of Barrels / Diameter (mm)	2 / 2400	3 / 3050

IF NOT 25 mm ADJUST SCALES
SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE



PLOT DATE: 12/17/2020 10:59:32 PM
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Associated Engineering

BEST MANAGED COMPANIES
Platinum member

Legend

AES 100-YEAR FLOOD EXTENTS	CREEK CHANNEL
SCS 1A 100-YEAR FLOOD EXTENTS	ROAD
EXISTING CULVERT	TOP OF KETTLE
OPTION 2 MANHOLE	OPTION 2 DIVERSION PIPE

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

AE PROJECT No.	2020-2882
SCALE	AS SHOWN
APPROVED	M. MACLATCHY
DATE	20201215
REV	N/A
DESCRIPTION	ISSUED FOR STUDY

MAP 6-3

BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

MAPLE FALLS ROAD
DRAINAGE ASSESSMENT
FLOODING EXTENTS:
DIVERSION OPTION 2

6.3.2 AES Storm

We also evaluated the Option 2 diversion pipe with the 10-year and 100-year future storms using an AES storm distribution. We began our assessment by reviewing the conditions that would mitigate flooding during the 10-year return period event. Like Option 1, to convey the 10-year peak flow of the AES storm, the crossing below Maple Falls Road requires four 1200 mm diameter CSP culverts to prevent flooding across the roadway. The diversion pipe required to prevent overtopping of the Kettle is 1800 mm diameter. This infrastructure does not prevent flooding of the roadway during the 100-year AES storm event. **Table 6-10** shows the water elevation within the Kettle, the depth of overland flooding, peak flows into the Kettle, and peak flow out of the Kettle through the diversion pipe for the 10-year and 100-year return periods. Although flooding of the Kettle is not mitigated during the 100-year event, the duration of flooding from the Kettle is significantly reduced when compared to existing conditions and the resulting flooding is not shown to overtop the high point along Maple Falls Road, therefore the water would be contained around the Kettle and would not spill towards the south-west along Maple Falls Road. **Table 6-11** compares the flooding duration, overflow duration, and peak overflow for existing and future conditions. **Map 6-3** shows the estimated flooding extents of the 100-year SCS Type IA return period event with the Option 2 diversion pipe in place.

Table 6-10
Option 2 – AES Elevations and Peak Flows

	10-year RP	100-year RP
Elevation Water at the Kettle (m)	202.6	204.4
Depth of Overland Flooding (m)	0	0.4
Peak Inflow to Kettle (m^3/s)	7.2	10.7
Peak Outflow from Kettle (m^3/s)	6.9	8.8

Table 6-11
Option 2 –AES Flooding Summary

	Existing 100-year RP	Option 1 100-year RP with CC
Duration of Flooding (hr)	45.0	8.5
Duration of Overflow (hr)	22.5	0
Peak Overflow (m^3/s)	8.0	0

To prevent flooding of Maple Falls Road during the 100-year event both the diversion pipe and the culvert below Maple Falls Road requires upsizing. To convey the 100-year peak flow of the SCS Type IA storm, the crossing below Maple Falls Road requires five 1200 mm diameter CSP culverts to prevent flooding across the roadway. The diversion pipe required to prevent overtopping of the Kettle is 2100 mm diameter. **Table 6-12** shows the water elevation within the Kettle, the depth of overland flooding, peak flows into the Kettle, and peak flow out of the Kettle through the diversion pipe.

Table 6-12
Option 2 – 10-year and 100-year AES Upgrade Comparison

	10-year RP	100-year RP
Diversion Pipe Diameter (mm)	1800	3050
Maple Falls Road Culvert No. of Barrels / Diameter (mm)	4 / 1200	5 / 1200
Equivalent Culvert Diameter Size No. of Barrels / Diameter (mm)	1 / 2400	1 / 2700

6.4 Option 3: Diversion Upstream of the Kettle

A third option that we undertook a cursory assessment of was a diversion located upstream of the Kettle. This diversion is modelled upstream of the Kosikar Road culvert near the base of the mountain slope. This alignment is connected such that it would divert runoff from 370.4 ha of forested land that currently flows into the Kettle.

The length of the diversion pipe system along this alignment is approximately 960 m. As this option would divert the entire stream, upstream of Kosikar Road, we have modelled the diversion pipe as a 3050 mm diameter concrete pipe to allow for complete diversion of all return periods up to the 100-year return period. The pipe is modelled with a minimum slope of 0.5%. The pipe traverses below the mountainside for a portion of the alignment and the pipe reaches a maximum depth of 18 m below the ground surface.

We ran the model with 24-hour SCS Type IA and AES storm events for the 10-year and 100-year return periods with consideration for climate change. Despite the upstream diversion, in all modelled scenarios the Kettle is seen to flood. As such, we did not consider this alignment further.

Environmental impacts associated with this alignment were not assessed. However, the reduction in water volume regularly entering the Kettle from high frequency storm events may lead to environmental impacts in the downstream reaches of the unnamed creek and the Kettle. Additionally, increased flow volumes and flow rates entering Frost Creek may lead to greater environmental impacts and instabilities downstream such as erosion concerns and bank instabilities.

6.5 Recommendations

Based on the results from the upgrade options assessments, a diversion system is required to provide the Kettle with a defined outlet which should reduce the flooding within the vicinity of the Kettle. Events with return periods greater than 10 years will still flood the roadway, however the flooding would be at a reduced magnitude compared to the flooding that would be incurred without an outlet for the Kettle. Based on the pipe diameters required to mitigate flooding during the 100-year return period event, we believe that sizing for the 100-year return period would not be a cost-effective solution. As shown in Map 6-2 and Map 6-3 the anticipated flooding extents of the Kettle during a 100-year return period storm event with a diversion system in place ranges from 204.4 m to 204.8 m. These flood elevations and extents are similar to existing condition flood elevations and flood extents but are anticipated to last for a shorter duration.

Further discussion and consideration should be given to what storm distribution is used to design the diversion pipe. As seen in the results of the upgrade options, the AES storm distribution requires a smaller pipe to maintain storage depths below the top elevation of the Kettle, resulting in a more economical solution. However, should a pipe be sized for an AES distribution it should be understood that there would be residual risk of flooding should a more aggressive storm occur.

Additionally, regular maintenance of the diversion pipe and the Kettle will be necessary to ensure both features are clear of debris and functioning as designed. We recommend that further analysis be completed during detailed design to assess the potential benefits of increasing the active storage volume of the Kettle which would allow a reduction in the required pipe sizes for the diversion options. These design features and recommendations are discussed further in the following sections.

6.5.1 Energy Dissipation System

The Ministry has informed AE that Frost Creek is susceptible to erosion and that ongoing erosion issues have been identified at Frost Creek. Should a diversion pipe be constructed to outlet into Frost Creek the increased flow into Frost Creek may cause instabilities, impacts to sensitive areas within the creek, and increased erosion.

An outfall structure with energy dissipation measures will be required as part of any diversion to Frost Creek. Additional erosion control measures may also be needed to address the impact of the additional flows introduced to Frost Creek by any such diversion system. At this time, we have not assessed the increase in peak flows within Frost Creek.

6.5.2 Maintenance

Regular maintenance of the Kettle and the diversion pipe system will be required. Maintenance of the diversion pipe will be required to ensure that the pipe is free of debris and damage. In addition to this, we note that the Kettle will continue to act as a sink for sediment and debris. Therefore, clearing of debris and sediment at the Kettle will continue to be required on an ongoing basis to maintain the active storage volume.

6.5.3 Increased Storage

The upgrade options proposed as part of this assignment have not considered adding storage capacity to the Kettle. However, alternative configurations that incorporate additional storage within the system could be reviewed during detailed design. Increasing available storage at the Kettle may aid in reducing the pipe diameter required for the diversion system, but the required volume to achieve a worthwhile decrease in pipe diameter is likely very large.

We recognize that the Kettle is not on land owned by the Ministry, therefore should this alternative solution be considered it would require coordination and cooperation with the Ministry, the local property owners, and FVRD. Further, increasing the storage alone would not be a practical solution to completely eliminate the flooding at the Kettle. A diversion pipe would still be required to provide an outlet for the system, even in the presence of additional storage.

Should adding storage to the Kettle be considered, we recommend a cost benefit analysis be completed to compare the relative costs of a diversion pipe alone, versus a diversion pipe with additional storage. Property acquisition costs would likely be incurred in significantly increasing the Kettle's active storage volume and should be accounted for in weighing the various options.

6.6 Cost Estimate

We have developed Class D cost estimates for the four alternatives. These being, Option 1 and Option 2 diversion pipe alignments, both sized for the 10-year AES and 10-year SCS Type IA return periods. These estimates may be used to compare the proposed strategies and select a preferred option. The cost estimate considers the associated costs of implementation of the diversion pipe system; however, it does not account for upgrades to the Maple Falls Road culvert, nor does the cost estimate consider the costs of the required outfall structure and erosion protection works that may be required in Frost Creek. The cost estimate does not consider costs associated with land acquisition. The cost estimate is shown in **Appendix B**.

A summary of overall estimated costs for each option is shown in **Table 6-13**.

Table 6-13
Cost Estimate Summary

	Total Estimated Cost
Option 1 – SCS Type IA	$13,792,500
Option 1 – AES	$10,012,500
Option 2 – SCS Type IA	$18,255,000
Option 2 - AES	$13,162,500

6.6.1 Multi-Jurisdictional Coordination

The flooding problem in the vicinity of Maple Falls Road and the Kettle has several aspects:

1. The majority of the unnamed creek watershed is located south of Maple Falls Road and includes forested lands south of the Canada/US Border, and forested and agricultural lands north of the Border. The forested lands are largely mountainous in nature.
2. The watershed drains to a topographic low or sink, which includes the Kettle and immediately surrounding lands, with no positive outlet.
3. Except when the Kettle fills to an elevation where spilling to the southwest can occur, all current drainage of the area is by infiltration into unconfirmed subsurface soils.
4. While historical anecdotal information indicate the Kettle is a result of human activity, this is not certain. There is no evidence of other outlets or routing for the unnamed creek apparent in aerial imagery or mapping that would provide confirmation that the Kettle is artificial.
5. Significant cleaning efforts are required on a regular basis to maintain the Kettle's infiltration and storage capacity.
6. The Ministry's sole infrastructure in the impacted area is Maple Falls Road, including the culvert on the unnamed creek.
7. Maple Falls Road is not the source of the recurring flooding, but Maple Falls Road and thus the Ministry are impacted by it.
8. Only one private property is known to be directly affected by the flooding.

Given the multiple factors contributing to the issue, mitigation of the flooding issues on Maple Falls Road will require coordination between the Ministry and other parties, which includes the FVRD or private property owners.

CLOSURE

This report was prepared for the BC Ministry of Transportation and Infrastructure to summarize our assessment of ongoing drainage issues and flooding along Maple Falls Road and at the Kettle in Lindell Beach, BC. The report discusses our initial assessment of flood elevations, flow routes, and flood impacts within the area of Maple Falls Road. We have assessed and outlined conceptual drainage system upgrades which can be considered to mitigate the flooding of the Kettle.

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

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

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Project Engineer

Reviewed by:

Feb. 12 2021

Michael Ma[illegible]itchy, Ph.D., P.Eng.
Project Manager

NV/MM/fd

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Hogg, W.D., 1982. *Distribution of Rainfall With Time: Design Considerations* Proceedings, Chapman Conference on Rainfall Rates, American Geophysical Union, Urbana, Illinois. April 1982.

Millar, R., 2017. *SCS STORM TYPE SELECTION FOR ESTIMATING DESIGN FLOWS IN BRITISH COLUMBIA.* Technical Paper, May 31-June 3, 2017.

APPENDIX A - EXISTING AND UPGRADE FLOODING COMPARISON GRAPHS

Flooding Elevation Graphs

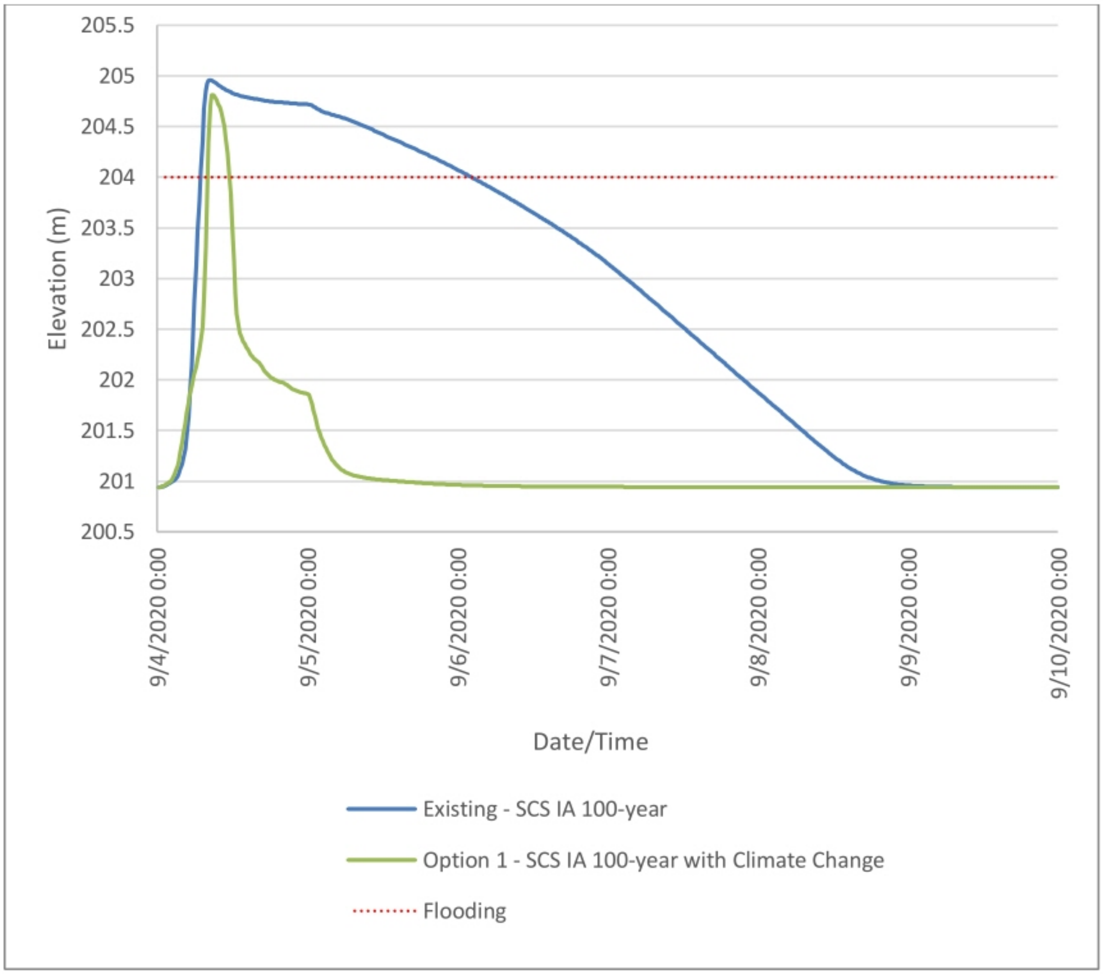

Figure A-1
Option 1 - SCS Type IA Flooding Elevation Comparison

Existing Conditions / Future Conditions with Diversion Pipe

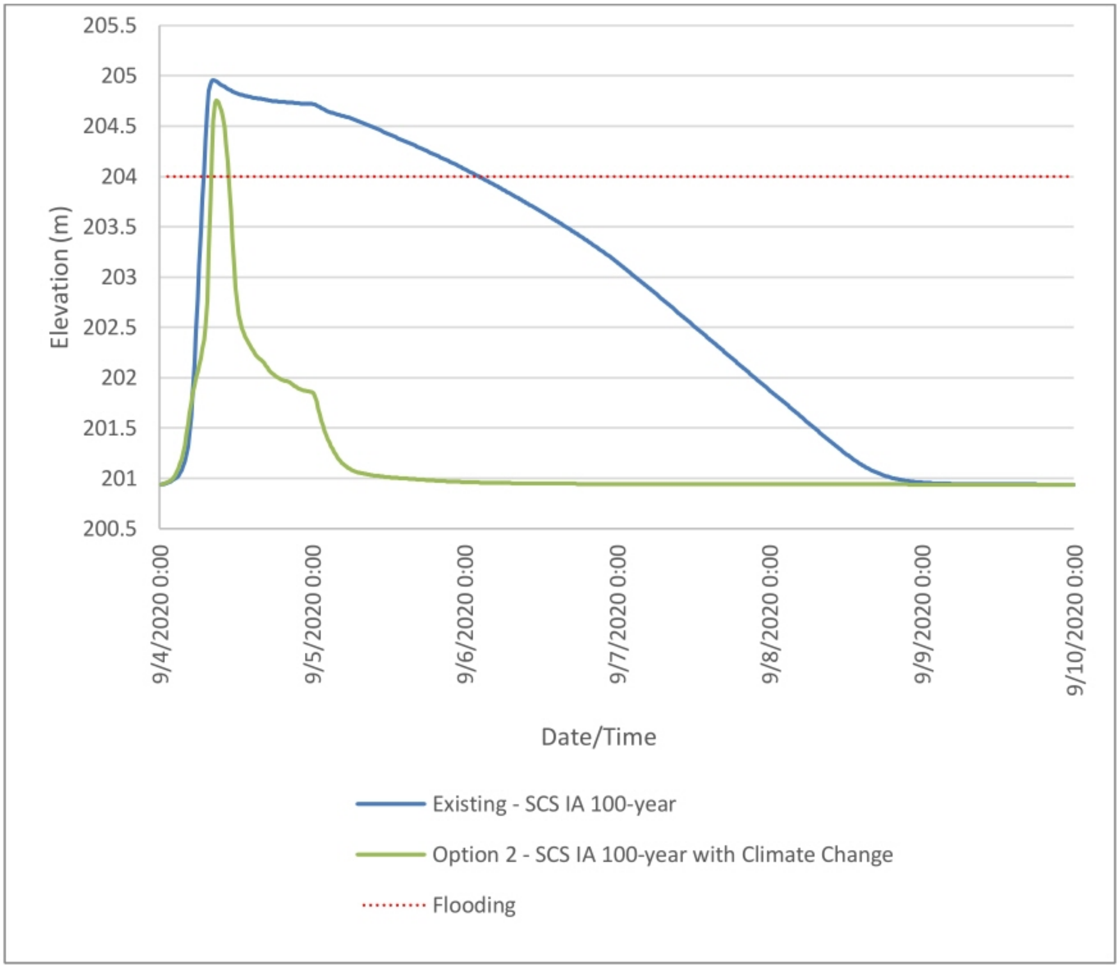

Figure A-2
Option 2 - SCS Type IA Flooding Elevation Comparison

Existing Conditions / Future Conditions with Diversion Pipe

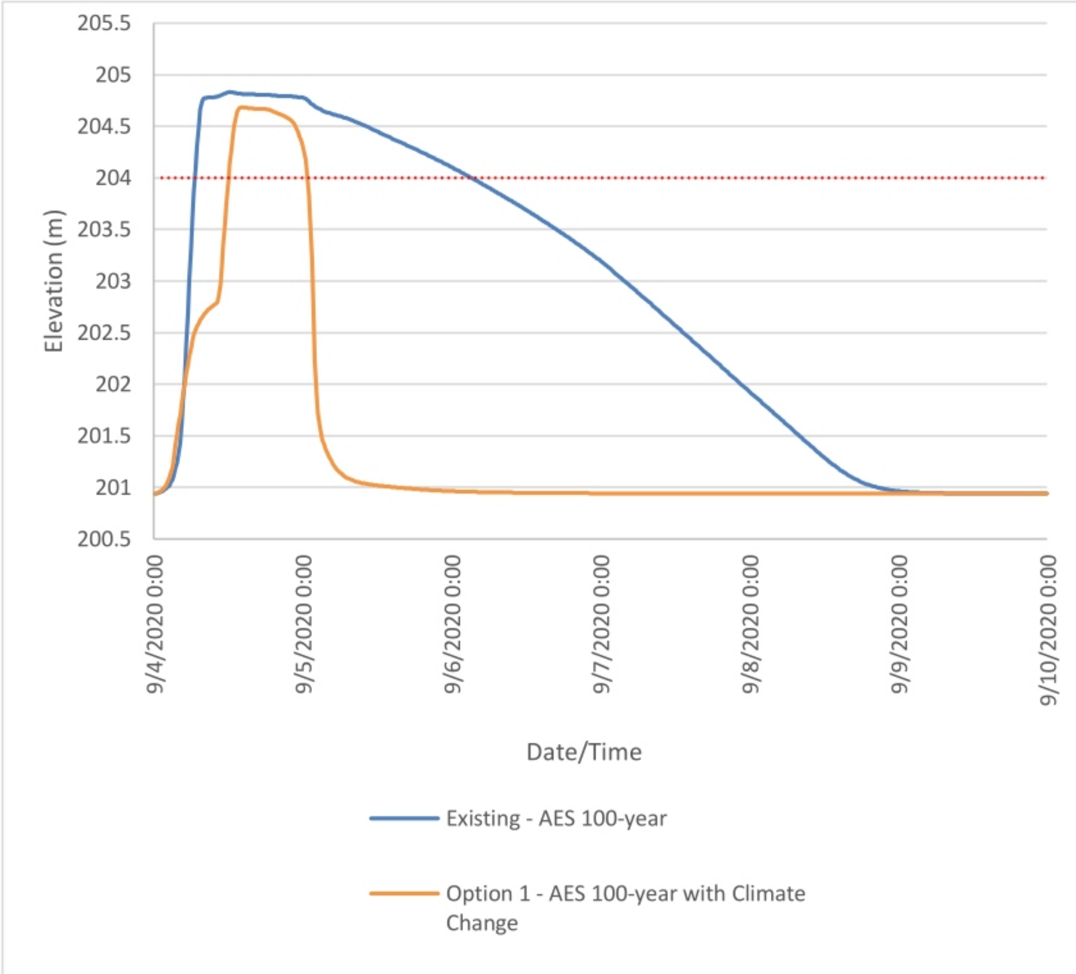

Figure A-3
Option 1 - AES Flooding Elevation Comparison

Existing Conditions / Future Conditions with Diversion Pipe

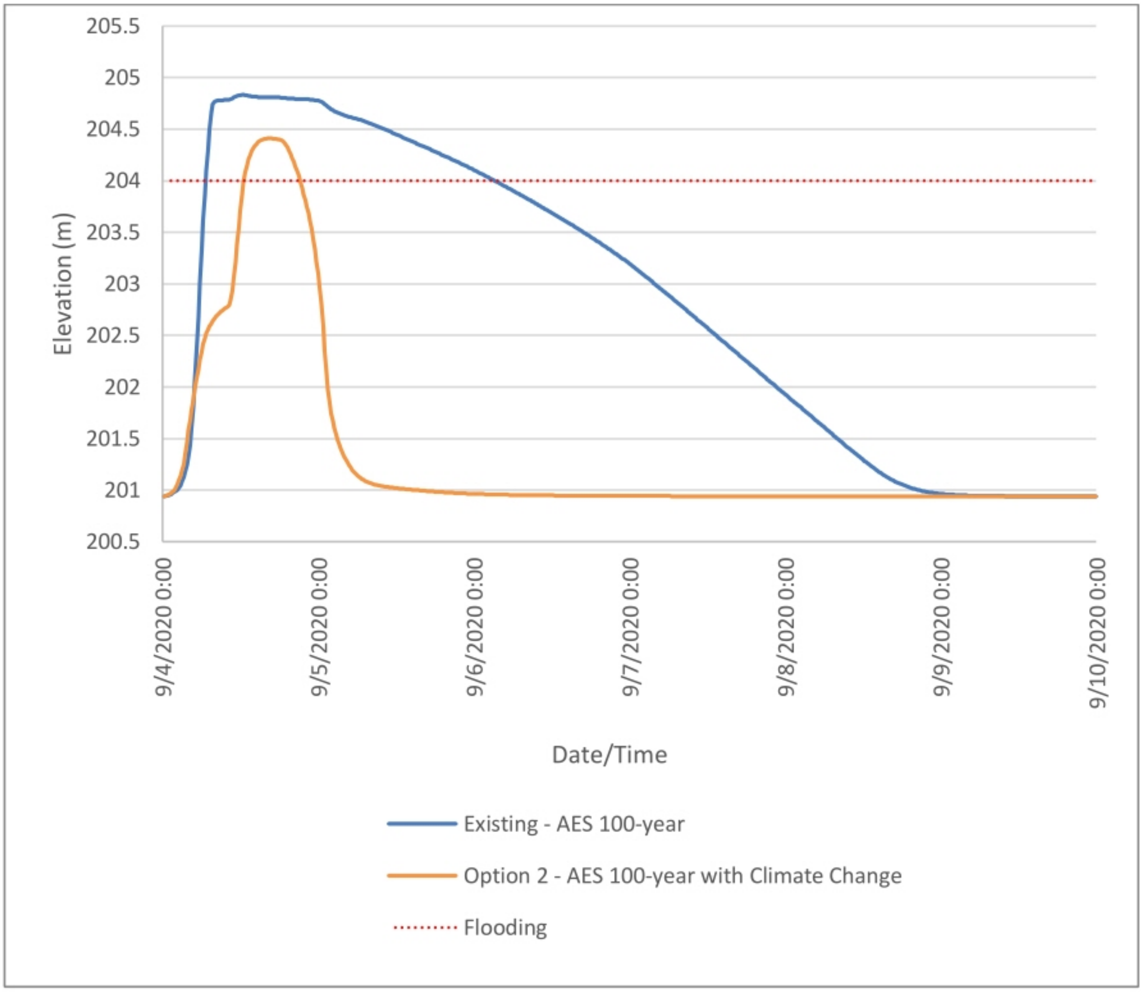

Figure A-4
Option 2 - AES Flooding Elevation Comparison

Existing Conditions / Future Conditions with Diversion Pipe

Overflow Graphs

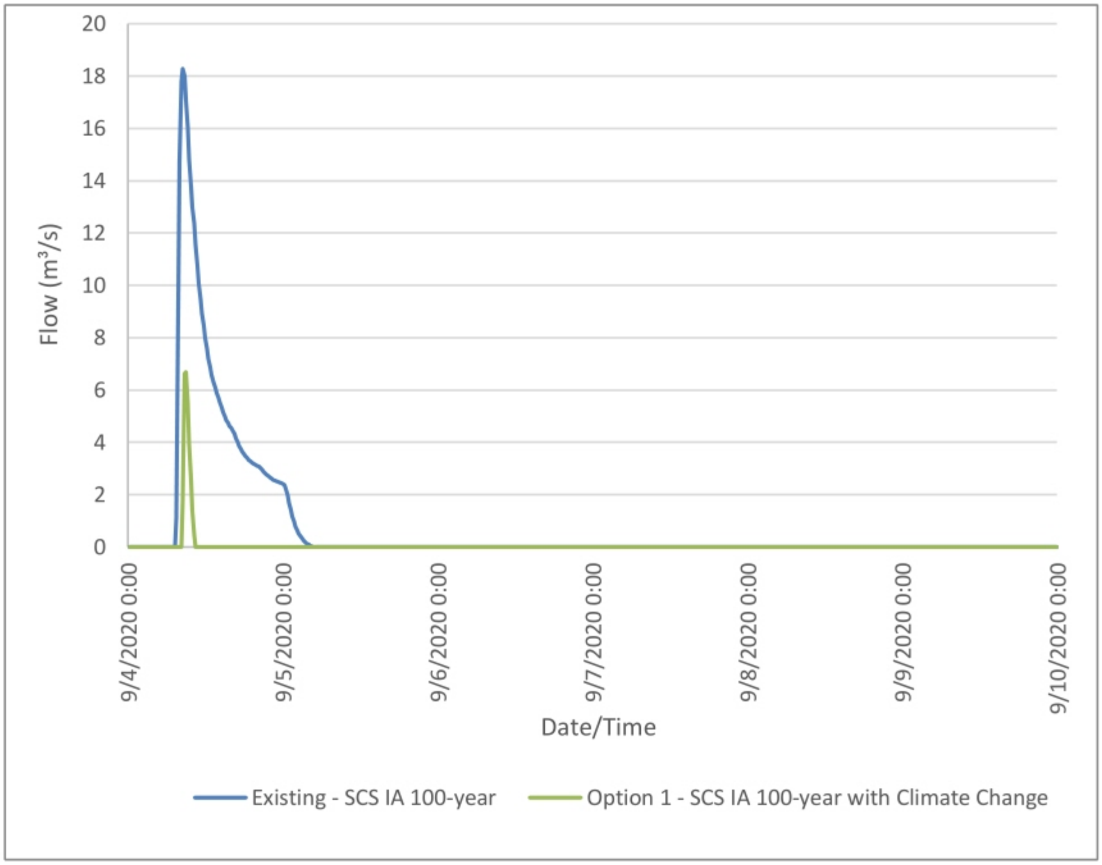

Figure A-5
Option 1 – SCS Type IA Peak Overflow Comparison

Existing Conditions / Future Conditions with Diversion Pipe

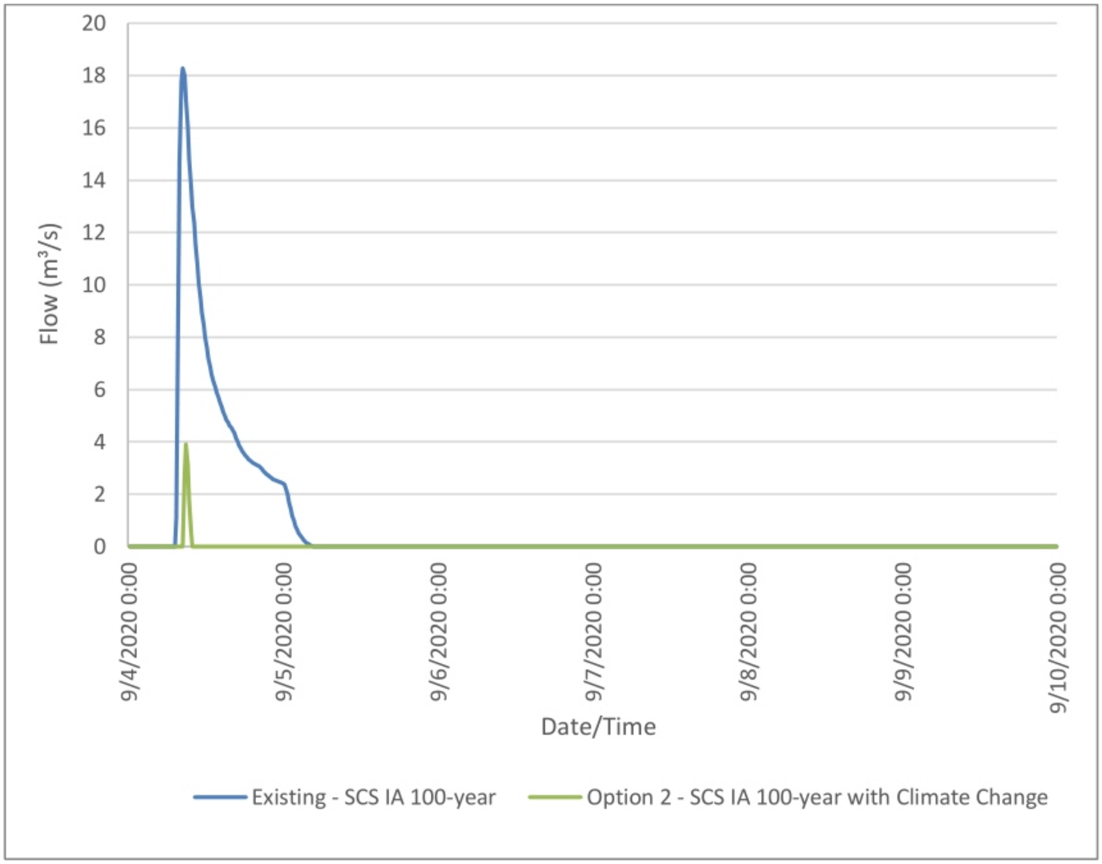

Figure A-6
Option 2 – SCS Type IA Peak Overflow Comparison

Existing Conditions / Future Conditions with Diversion Pipe

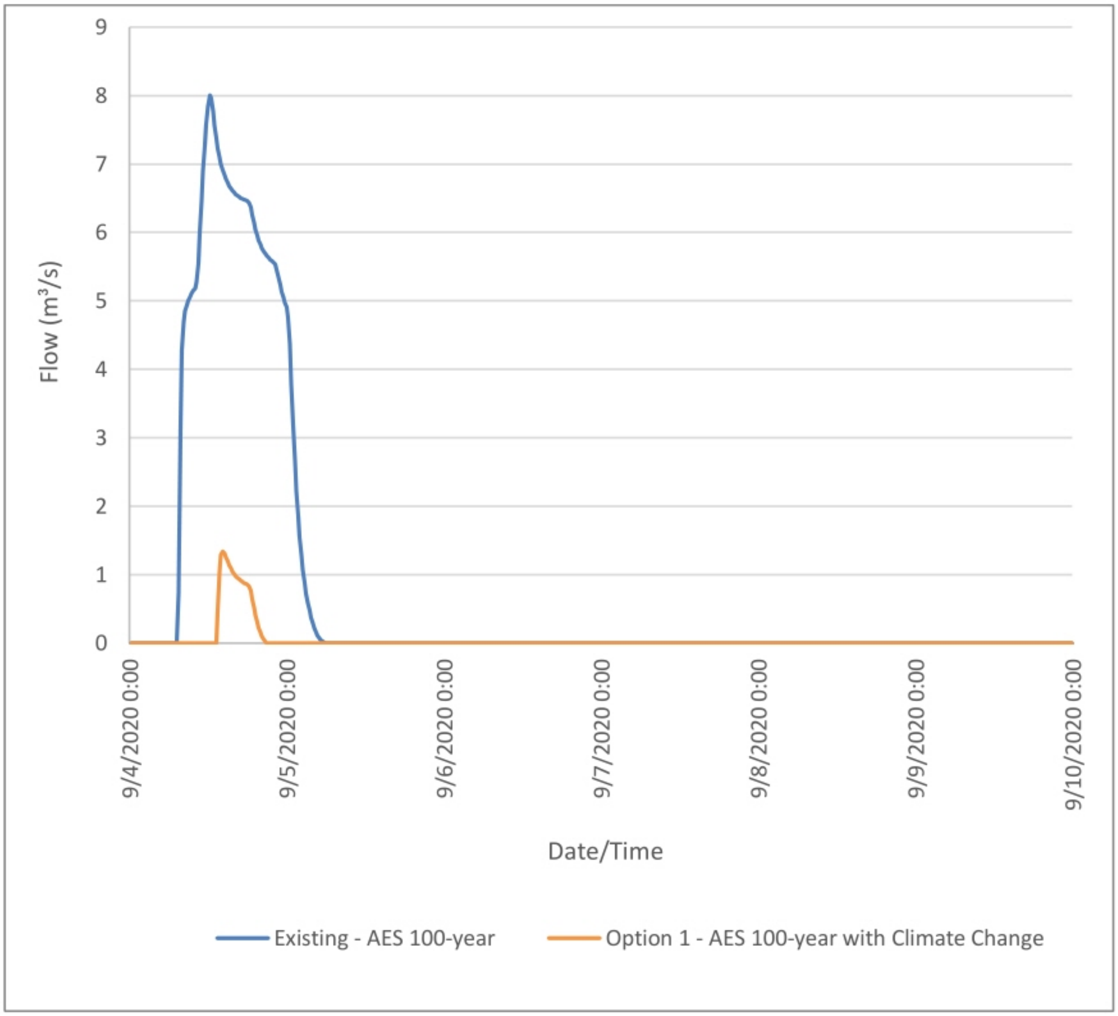

Figure A-7
Option 1 – AES Peak Overflow Comparison

Existing Conditions / Future Conditions with Diversion Pipe

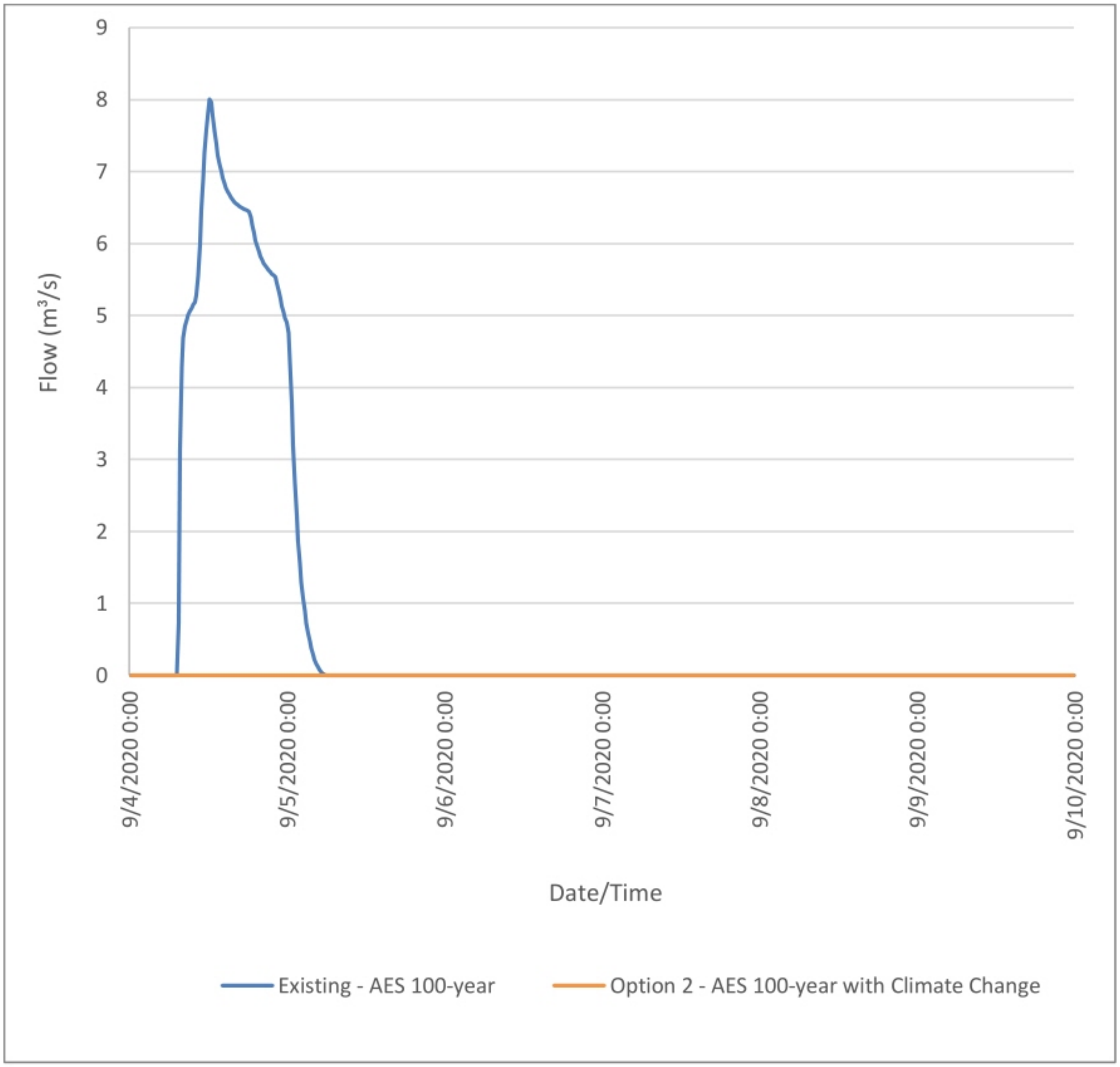

Figure A-8
Option 2 – AES Peak Overflow Comparison

Existing Conditions / Future Conditions with Diversion Pipe

APPENDIX B - COST ESTIMATE

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CONCEPTUAL DESIGN - CLASS 'D' COST ESTIMATE
OPTION 1 - SCS TYPE IA

Schedule of Approximate Quantities and Unit Prices

Project No: 2020-2882

Project Name: Maple Falls Road Drainage Assessment

TOTAL TENDER AND ASSOCIATED MINISTRY COST ESTIMATE

Item#	Description of Work	Unit of Measure	Approx. Quantity	Unit Price	Extended Amount
01	**SECTION 1 - GENERAL**				
01.01	Mobilization/Demobilization (Provisional)	LS	s.17; s.21		
01.02	Environmental Assessment and Monitoring (Provisional)	LS			
01.03	Traffic Control (Provisional)	LS			
03	**SECTION 3 - DRAINAGE**				
03.01	**Precast Concrete Catch Basins and Manholes**				
03.01.01	Precast Riser Manhole 2400 mm	Each			
03.02	**Storm Pipe**				
03.02.01	2400 mm Diameter Concrete	Metre			
03.03	**Inlet Structures**				
03.03.01	Precast Concrete Headwall 2400 mm Pipe	Each			
Part A	**CLASS 'D' COST ESTIMATE**				
901.00	Contingencies	40%			
902.00	Engineering	10%			
	ASSOCIATED MINISTRY CLASS 'D' COST ESTIMATES				
	TOTAL CLASS 'D' AND ASSOCIATED MINISTRY COST ESTIMATES				**$13,792,500.00**

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CONCEPTUAL DESIGN - CLASS 'D' COST ESTIMATE

OPTION 1 - AES

Schedule of Approximate Quantities and Unit Prices

Project No: 2020-2882

Project Name: Maple Falls Road Drainage Assessment

TOTAL TENDER AND ASSOCIATED MINISTRY COST ESTIMATE

Item#	Description of Work	Unit of Measure	Approx. Quantity	Unit Price	Extended Amount
01	**SECTION 1 - GENERAL**				
01.01	Mobilization/Demobilization (Provisional)	LS	s.17; s.21		
01.02	Environmental Assessment and Monitoring (Provisional)	LS			
01.03	Traffic Control (Provisional)	LS			
03	**SECTION 3 - DRAINAGE**				
03.01	**Precast Concrete Catch Basins and Manholes**				
03.01.01	Precast Riser Manhole 1800 mm	Each			
03.02	**Storm Pipe**				
03.02.01	1800 mm Diameter Concrete	Metre			
03.03	**Inlet Structures**				
03.03.01	Precast Concrete Headwall 1800 mm Pipe	Each			
Part A	**CLASS 'D' COST ESTIMATE**				
901.00	Contingencies	40%			
902.00	Engineering	10%			
	ASSOCIATED MINISTRY CLASS 'D' COST ESTIMATES				
	TOTAL CLASS 'D' AND ASSOCIATED MINISTRY COST ESTIMATES				**$10,012,500.00**

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CONCEPTUAL DESIGN - CLASS 'D' COST ESTIMATE

OPTION 2 - SCS TYPE IA

Schedule of Approximate Quantities and Unit Prices

Project No: 2020-2882

Project Name: Maple Falls Road Drainage Assessment

TOTAL TENDER AND ASSOCIATED MINISTRY COST ESTIMATE

Item#	Description of Work	Unit of Measure	Approx. Quantity	Unit Price	Extended Amount
01	**SECTION 1 - GENERAL**				
01.01	Mobilization/Demobilization (Provisional)	LS	s.17; s.21		
01.02	Environmental Assessment and Monitoring (Provisional)	LS			
01.03	Traffic Control (Provisional)	LS			
03	**SECTION 3 - DRAINAGE**				
03.01	**Precast Concrete Catch Basins and Manholes**				
03.01.01	2400 mm Diameter Concrete	Each			
03.02	**Storm Pipe**				
03.02.01	2400 mm Diameter Concrete	Metre			
03.03	**Inlet Structures**				
03.03.01	Precast Concrete Headwall 2400 mm Pipe	Each			
Part A	**CLASS 'D' COST ESTIMATE**				
901.00	Contingencies	40%			
902.00	Engineering	10%			
	ASSOCIATED MINISTRY CLASS 'D' COST ESTIMATES				
	TOTAL CLASS 'D' AND ASSOCIATED MINISTRY COST ESTIMATES				**$18,255,000.00**

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Province of British Columbia

CONCEPTUAL DESIGN - CLASS 'D' COST ESTIMATE
OPTION 2 - AES

Schedule of Approximate Quantities and Unit Prices

Project No: 2020-2882

Project Name: Maple Falls Road Drainage Assessment

TOTAL TENDER AND ASSOCIATED MINISTRY COST ESTIMATE

Item#	Description of Work	Unit of Measure	Approx. Quantity	Unit Price	Extended Amount
01	**SECTION 1 - GENERAL**				
01.01	Mobilization/Demobilization (Provisional)	LS	s.17; s.21		
01.02	Environmental Assessment and Monitoring (Provisional)	LS			
01.03	Traffic Control (Provisional)	LS			
03	**SECTION 3 - DRAINAGE**				
03.01	**Precast Concrete Catch Basins and Manholes**				
03.01.01	Precast Riser Manhole 1800 mm	Each			
03.02	**Storm Pipe**				
03.02.01	1800 mm Diameter Concrete	Metre			
03.03	**Inlet Structures**				
03.03.01	Precast Concrete Headwall 1800 mm Pipe	Each			
Part A	**CLASS 'D' COST ESTIMATE**				
901.00	Contingencies	40%			
902.00	Engineering	10%			
	ASSOCIATED MINISTRY CLASS 'D' COST ESTIMATES				
	TOTAL CLASS 'D' AND ASSOCIATED MINISTRY COST ESTIMATES				**$13,162,500.00**