Regional District of Central Okanagan

Flood Mapping Project:
Peachland and Trepanier Creeks

Draft Report, November 2019

Associated Engineering

Regional District of Central Okanagan

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AE	Associated Engineering (B.C.) Ltd.
CEPF	Community Emergency Preparedness Fund
CGVD1928	Canadian Geodetic Vertical Datum 1928
CGVD2013	Canadian Geodetic Vertical Datum 2013
DEM	Digital Elevation Model
EGBC	Engineers and Geoscientists British Columbia
EGL	Energy Grade Line
EMBC	Emergency Management BC
FPPR	Forest Planning and Practices Regulation
FRPA	Forest and Range Practices Act
GNSS	Global Navigation Satellite System
PGS	Global Positioning System
LiDAR	Light Detection and Ranging
m^3/s	Cubic Metre per Second
m	Metre
MoTI	Ministry of Transportation and Infrastructure
NRC	Natural Resources Canada
OBWB	Okanagan Basin Water Board
PCIC	Pacific Climate Impacts Consortium
PFRR	Preliminary Flood Risk Rating
QP	Qualified Professional
RDCO	Regional District of Central Okanagan
RFMP	Regional Floodplain Management Plan
UBCM	Union of BC Municipalities

1 INTRODUCTION

A flood is a condition where a watercourse overtops its natural or artificial boundaries and covers land not normally occupied by water. When a flood occurs, the result can be hazardous to people, the environment, infrastructure, private property, and cultural and historical resources. Recent flooding events occurred in 2017 and 2018 in areas around the Central Okanagan. These events caused physical damages to stream channels, lake foreshores, property, and infrastructure adjacent to these areas.

Due to the potential for flooding, the **Regional District of Central Okanagan** (RDCO) was interested in completing a flood mapping study of select creeks (the project). The RDCO secured funding from the Union of BC Municipalities (UBCM) for the project. This was under the Community Emergency Preparedness Fund (CEPF) within the Flood Risk Assessment, Mapping and Mitigation Planning Program.

Associated Engineering (B.C.) Ltd. (AE) was engaged to complete the project. The RDCO and AE collaborated prior to beginning the project and reviewed candidate creeks. McDougall, Powers, Peachland, and Trepanier Creeks were considered because these were all identified as critical in the region. It was identified that the City of West Kelowna was already completing flood risk assessment and mitigation plans for McDougall and Powers Creek. Therefore, it was decided that selected channel reaches of Peachland and Trepanier Creeks would be studied.

The three channel reaches selected are shown in Figure 1-1. For the purposes of the project, the selected channel reaches are identified as follows (see Section 2 for further Reach descriptions):

- **Reach 1**: Peachland Creek (approximately 400 m long reach to the mouth at Okanagan Lake);
- **Reach 2**: Trepanier Creek (approximately 900 m long reach to the mouth at Okanagan Lake); and
- **Reach 3**: Trepanier Creek (approximately 600 m long reach adjacent to the District of Peachland water intake).

It is understood that there are currently no flood risk assessments or flood mitigation efforts on Peachland or Trepanier Creeks. Therefore, the RDCO and District of Peachland will benefit from the project to support flood planning. The project can inform floodplain management decisions, or it can be advanced to include flood hazard and flood risk mapping.

AE submitted a proposal on July 5, 2019 with an addendum added on July 16, 2019. The RDCO awarded the project and an Agreement was completed on August 8, 2019. The technical scope of work for the project included the following tasks, which agree with the required stages to complete a flood mapping project (EGBC 2017):

- Field reconnaissance and surveying;
- Hydrological analysis;
- Hydraulic modelling and analysis; and
- Flood mapping.

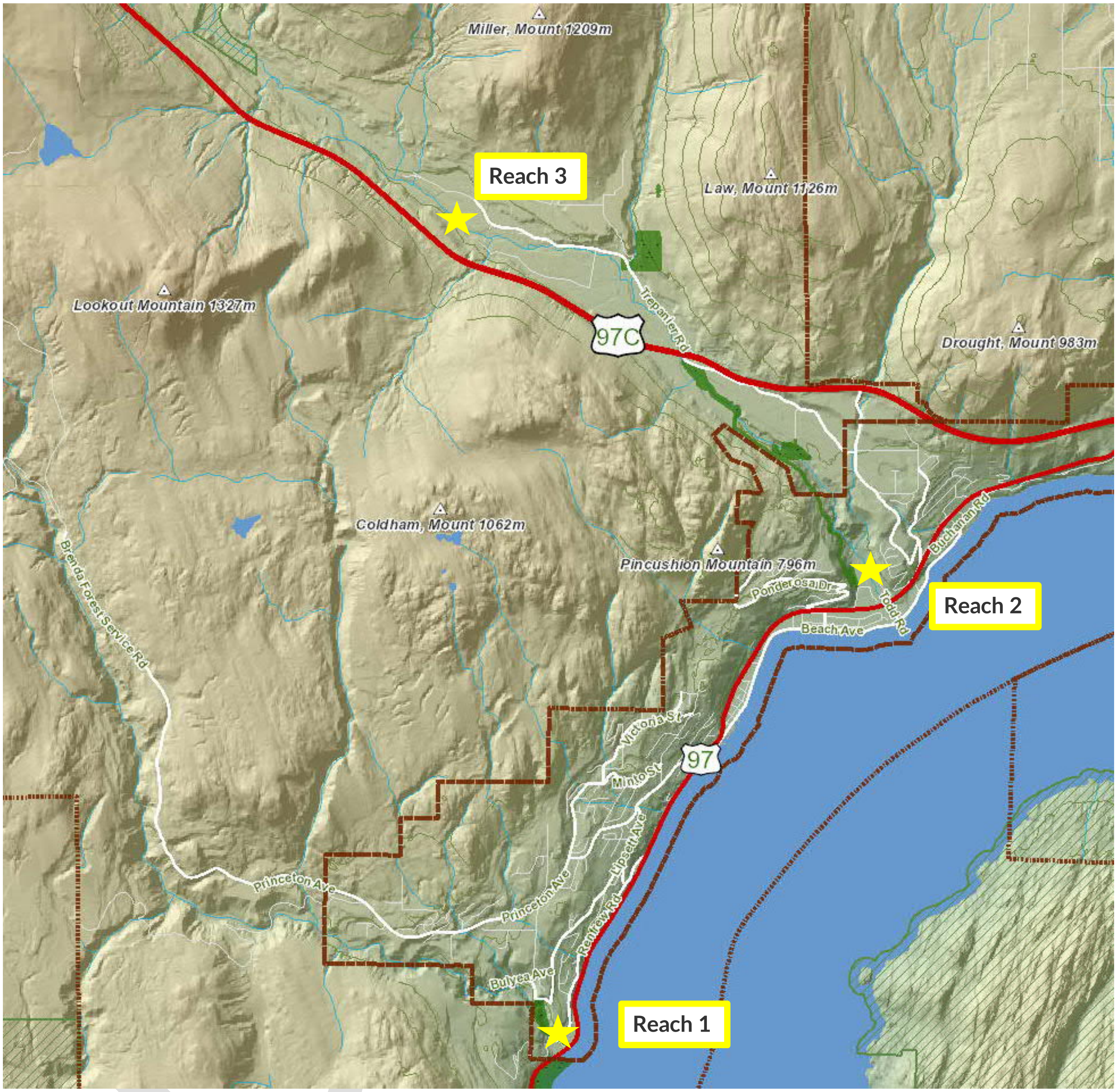


Figure 1-1
Location of Reaches included Within the Project

2 PROJECT CREEKS

2.1 Watershed Descriptions

Peachland and Trepanier Creek are both Community Watersheds[1] located on the west side of the Okanagan Valley. They are tributary systems in the Okanagan Basin and drain in an eastern direction to Okanagan Lake. Both watersheds are considered gently sloping, but they exhibit gentle-over-steep terrain that is common to Southern Interior areas of BC. The creeks are deeply entrenched into the Interior Plateau and form narrow valleys. As they flow closer to Okanagan Lake the channels are incised into the valley wall and terrace above the District of Peachland. In the District of Peachland, the channels flow over alluvial fans into Okanagan Lake.

Peachland and Trepanier Creeks are snowmelt-dominated hydrological systems. This means that annual peak flows are generated during freshet. The watersheds accumulate snow over the winter period; particularly in the higher elevation headwaters. As the spring period advances and temperatures warm, the snowpack begins to melt which results in an increase in runoff. Figure 2-1 provides a chart from the BC River Forecast Centre for the Brenda Mine Station (No. 2F18P, Elevation 1,460 m). This chart shows recent and historical snow water equivalent values that is considered representative of both watersheds. It is evident that the snowpack recedes in April and May, which drives the timing of freshet.

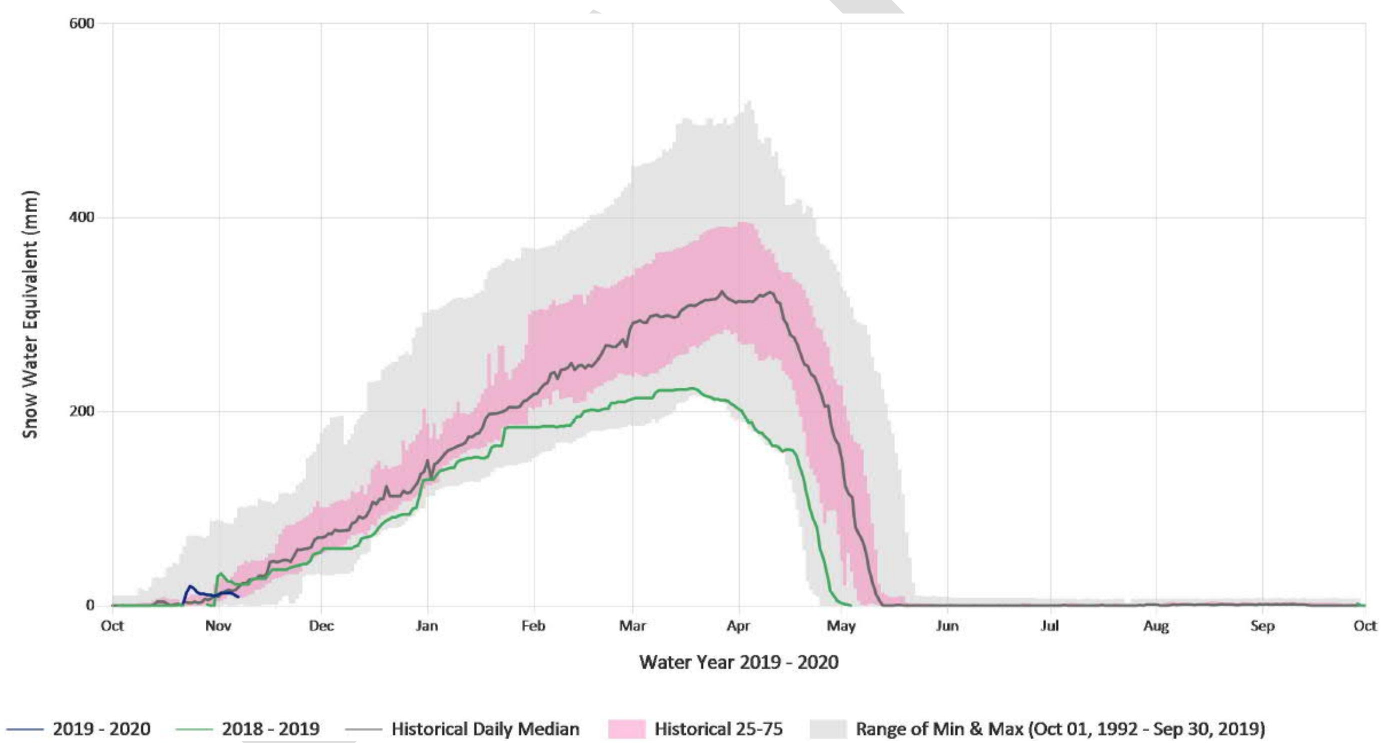


Figure 2-1
Snow Water Equivalent Chart from BC River Forecast Centre for Brenda Mine (Station 2F18P)

[1] Community Watersheds are defined and regulated under the *Forest and Range Practices Act* [SBC 2002] Chapter 69 and the *Forest Planning and Practices Regulation* (BC Reg. 14/2004).

2.1.1 Peachland Creek Watershed

Additional watershed characteristics of Peachland Creek are noted below:

- Peachland Creek watershed is located between Trepanier Creek (to the north) and Trout Creek (to the south).
- The watershed drains an approximate area of 148 km^2.
- The Provincial Freshwater Atlas lists Trepanier Creek as a 4th order system.
- The median elevation is approximately 1,260 m.
- The watershed is primarily forested; there is forest harvesting and resource roads in the watershed.
- Peachland Lake and Peachland Lake Dam are in the watershed.
- The District of Peachland is the major water user and has a water intake.
- There are numerous Water Licences held, including some for storage purposes.
- Greata Creek is the largest tributary system to Peachland Creek.
- Figure 2-2 provides an overview of the watershed.

2.1.2 Trepanier Creek Watershed

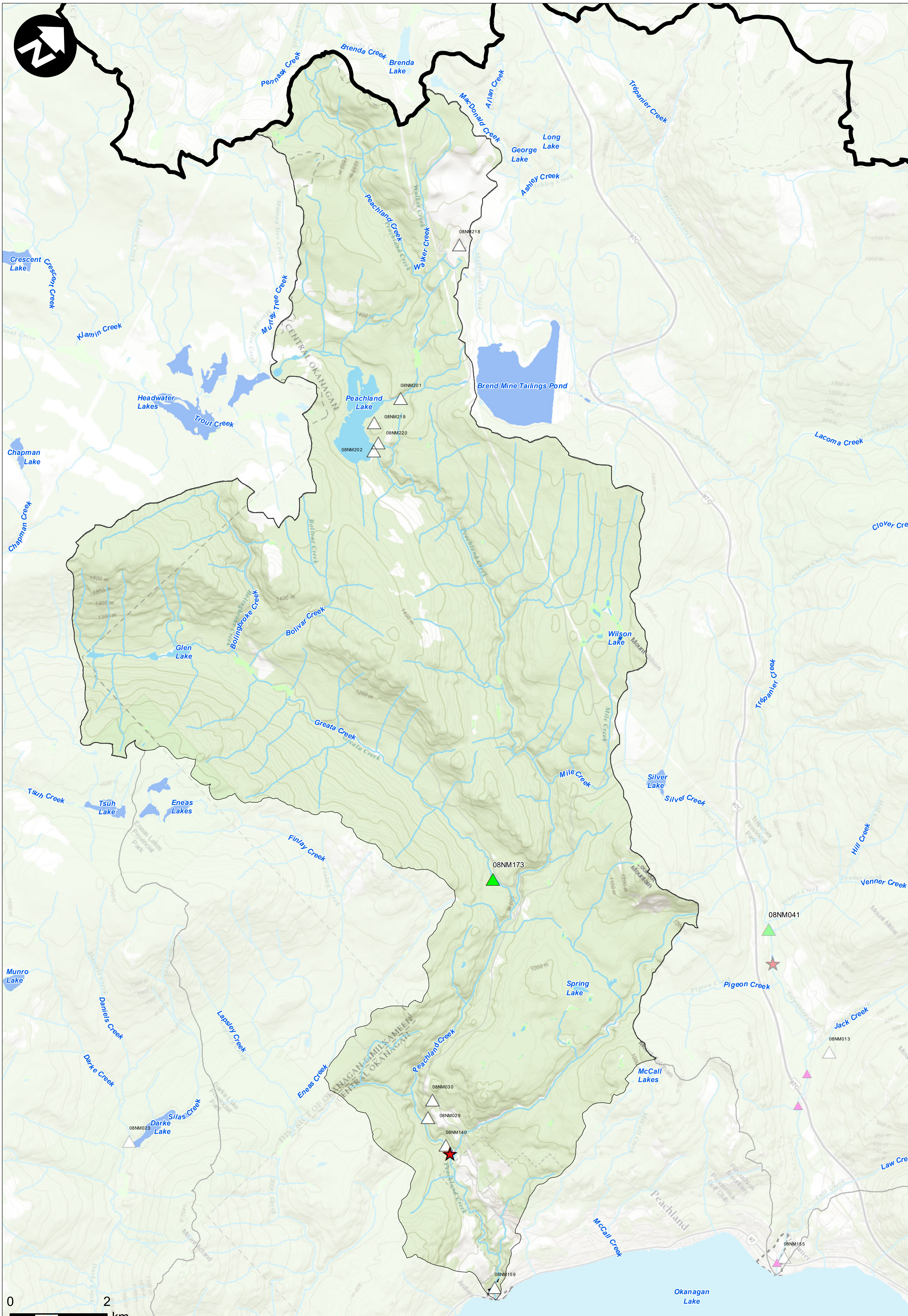
Additional watershed characteristics of Trepanier Creek are noted below:

- Trepanier Creek is located between Powers Creek (to the north) and Peachland Creek (to the south).
- The watershed drains an approximate area of 260 km^2.
- The Provincial Freshwater Atlas lists Trepanier Creek as a 5th order system.
- The median elevation is approximately 1,228 m.
- Highway 97 (Okanagan Connector) bisects the watershed.
- The watershed is primarily forested; there is forest harvesting and resource roads in the watershed.
- Trepanier Provincial Park is in the watershed.
- Brenda Mine is in the watershed.
- The District of Peachland is the major water supplier and has a water intake (located at Reach 3).
- There are numerous Water Licences held, including some for storage purposes.
- MacDonald, Lacoma, and Jack Creeks are the largest tributary systems to Trepanier Creek.
- Figure 2-3 provides an overview of the watershed.

2.2 Flood Mechanism and Timing

As noted above, peak flow rates in Peachland and Trepanier Creeks are generated during freshet. This is influenced by several possible factors that control the magnitude of freshet, such as:

- Groundwater levels, antecedent moisture in the soil layers, and available storage in dam reservoirs.
- The duration of the winter season.
- The depth of snowpack accumulation over the winter season.
- The timing of spring season when temperatures increase, and how rapidly the temperatures rise.
- How much rainfall occurs during the spring season.
- Occurrence of an intense rainfall event on melting snowpack.



Associated Engineering

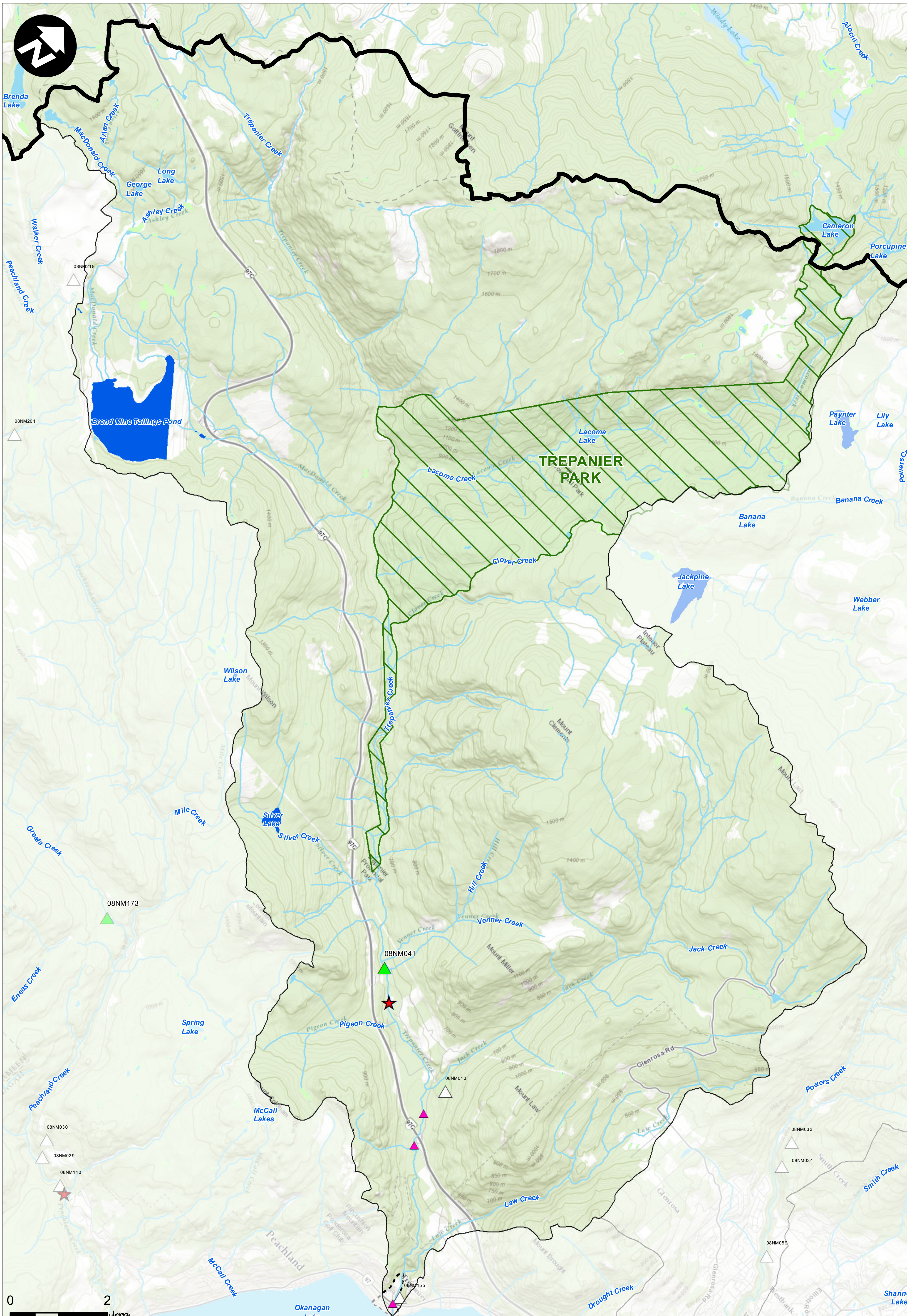
- Active Non-WSC Hydrometric Station
- Discontinued Non-WSC Hydrometric Station
- Active WSC Hydrometric Station
- Discontinued / WSC Hydrometric Station
- Alluvial Fan
- Wetlands
- Reservoirs
- District Water Intake

PROJECT NO.:	2019-2671.000.000
DATE:	Nov. 2019
DRAWN BY:	DA

FIGURE 2-2: PEACHLAND CREEK WATERSHED OVERVIEW

RDCO

Peachland and Trepanier Creek Flood Mapping



Active Non-WSC Hydrometric Station

Discontinued Non-WSC Hydrometric Station

Active WSC Hydrometric Station

Discontinued / WSC Hydrometric Station

Alluvial Fan

Wetlands

Reservoirs

District Water Intake

Associated Engineering

PROJECT NO.:	2019-2671.000.000
DATE:	Nov. 2019
DRAWN BY:	DA

FIGURE 2-3: TREPANIER CREEK WATERSHED OVERVIEW

RDCO

Peachland and Trepanier Creek Flood Mapping

Based on review of the historical Water Survey of Canada (WSC) records, freshet in Trepanier Creek has occurred between late-April to early-June. Flows typically peak during the month of May. The record for Peachland Creek is not as long as Trepanier Creek and it has a smaller watershed area with a lower median elevation. It is expected that freshet timing in Peachland Creek is similar or marginally earlier than Trepanier Creek (i.e., within a few days).

2.3 Reach Descriptions

2.3.1 Reach 1 – Peachland Creek at Okanagan Lake

Peachland Creek flows into Okanagan Lake near the intersection of Highway 97 and Hardy Street. Reach 1 is on the Peachland Creek alluvial fan. Hardy Street is parallel to the channel. Highway 97 extends along the foreshore of the lake across the alluvial.

There are two road crossings along Reach 1: Highway 97 and Renfrew Road. This area is an access point to Hardy Falls Park and within the park there are pedestrian trail bridges crossing the channel. The apex of the alluvial fan is near the first pedestrian trail bridge. It is noted that the area just downstream of this bridge had recent flood-related channel erosion (2017 and 2018 freshet events). Within Hardy Falls Park the channel was enhanced for salmon and trout spawning habitat. Weirs and gravel platforms were installed (date unknown; estimate during in the 1990's).

There are mobile home properties developed on the alluvial fan. Between Renfrew Road and Highway 97 there are mobile home units located in proximity to the left bank of the channel. The channel and right bank floodplain up to Hardy Street are within Hardy Falls Park. South of Hardy Street there are additional mobile home properties.

2.3.2 Reach 2 – Trepanier Creek at Okanagan Lake

Trepanier Creek flows into Okanagan Lake at Beach Avenue in the District of Peachland. Reach 2 is on the Trepanier Creek alluvial fan. Beach Avenue extends along the foreshore of Okanagan Lake. Highway 97 crosses the channel 240 m upstream of Beach Avenue. The highway alignment is elevated, and the bridge structure is substantially higher than the creek.

The Trepanier Creek alluvial fan area is larger than Peachland Creek's. There is mixed land use on the alluvial fan, including: Peachland Elementary School, single family and multi-family properties, mobile homes, park/trail, and a commercial shopping centre. Upstream of Highway 97 there are properties that have developed or landscaped up to the channel banks.

2.3.3 Reach 3 – Trepanier Creek at District of Peachland Water Intake

Reach 3 is located on the Trepanier Bench / Paradise Valley area off Trepanier Road. This Reach is not located within the District of Peachland administrative boundary, but the District operates a water intake system on the creek. This is one of the main water supply sources for the District of Peachland. Highway 97C (Okanagan Connector) is parallel to Reach 3. The highway is cut into the valley hillside south, and upgradient of the channel.

Trepanier Creek has been altered to divert and supply water. The natural channel flows into a wide and deep pool that is approximately 100 m long. The depth of this pool is regulated by adjustable stop logs. Water is diverted into two settling ponds and then into the District of Peachland water system. The residual flow spills over the stop logs and a large concrete weir where it returns to it's natural channel.

3 BASIS FOR THE PROJECT

3.1 Regional Floodplain Management Plan

The RDCO and AE completed a Regional Floodplain Management Plan (RFMP) in 2016 (AE 2016). The RFMP is a tool to assist the RDCO and municipalities in identifying, assessing, and managing flood risks. The RFMP was preceded by a Regional Floodplain Management Framework (Clark Geoscience 2014) that consists of three sequential phases outlined in Figure 3-1. The project fits under Phase 2.

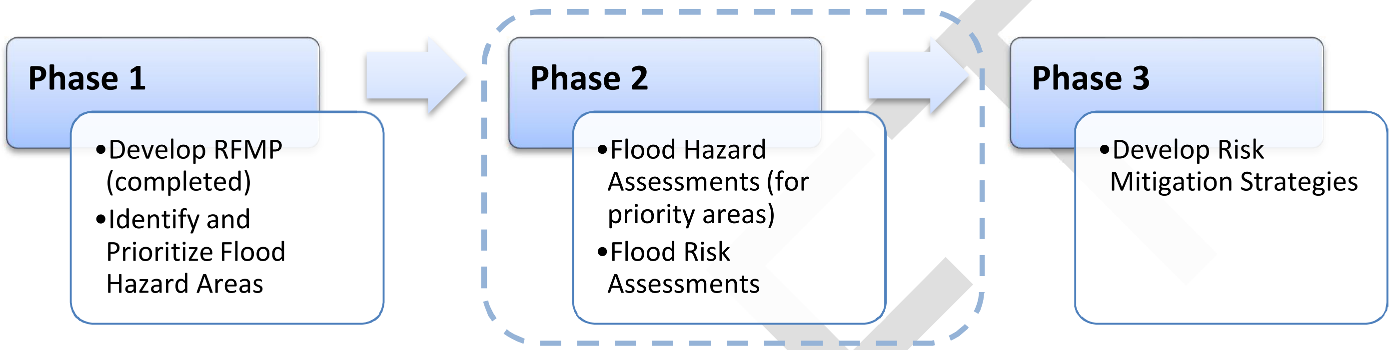


Figure 3-1
Regional Floodplain Management Phases

Peachland and Trepanier Creeks were assigned a Preliminary Flood Risk Rating (PFRR) of High in the RFMP (AE 2016). This PFRR indicates that risk to infrastructure and/or the public is unacceptable and that there is a need for further risk assessment. The project supports an assessment of potential flooding at each Reach.

3.2 Professional Practice Guidelines

In 2017, Engineers and Geoscientists British Columbia (EGBC) published Professional Practice Guidelines for flood mapping projects in BC (EGBC 2017). The guidelines were developed by EGBC and the Ministry of Transportation and Infrastructure (MoTI) – Emergency Management BC (EMBC). The guidelines provide 'best practices' so that professionals completing flood mapping work do so in a consistent manner.

The EGBC (2017) guidelines were reviewed and followed in the project. Accordingly, the guidelines have a *Flood Mapping Assurance Statement* and it is included in Appendix A of this report. The *Flood Mapping Assurance Statement* is to be signed and sealed by a *Qualified Professional* (QP) who has appropriate training and experience to complete the flood mapping work. AE's QP for the project is Geoffrey Cahill, P.Eng.

The EGBC (2017) guidelines describe three categories of flood mapping:

- Inundation Mapping
- Flood Hazard Mapping
- Flood Risk Mapping

Inundation mapping is the first category of a flood mapping project. Flood hazard and flood risk mapping involve more complex study and are built upon results of inundation mapping. This project only includes inundation mapping. If the RDCO or District of Peachland want to do further work, the inundation mapping could be expanded to include analysis of flood hazards and flood risks.

4 METHODS AND ANALYSIS RESULTS

The methods used to complete the project are described below. This includes description of important project steps or assumptions that were necessary in the project. Results of the analyses are also presented below.

4.1 Background Review

Relevant background information was collected and reviewed. This included information from the RDCO, District of Peachland, MoTI, WSC, Okanagan Basin Water Board (OBWB), and online sources. In addition, geospatial data was reviewed from the RDCO and GeoBC.

4.2 Field Reconnaissance and Surveying

Field reconnaissance and channel surveying were completed on September 25, 2019 (Peachland Creek) and September 27, 2019 (Trepanier Creek). This work included:

- Observing the channel at each Reach;
- Observing the floodplain and its connection to the channel at each Reach;
- Photo-documentation; and
- Topographic and bathymetric surveying with GPS/GNSS (Can-Net) and Total Station.

4.3 Survey and Channel Vertical Adjustments

4.3.1 Vertical Reference Systems

The OBWB provided 2018 LiDAR survey data for the project. This data is referenced to Canadian Geodetic Vertical Datum 2013 (CGVD2013), which was released by Natural Resources Canada (NRC) to modernize Canada's vertical reference system. CGVD2013 is a different vertical datum compared to Canadian Geodetic Vertical Datum 1928 (CGVD1928). It is noted that the elevation difference between the two datums is not constant and varies spatially. These vertical reference systems have different methodology to determine their datum:

- CGVD2013 is an equipotential surface for the mean sea level across North America.
- CGVD1928 is a tidal datum defined by mean water elevation at five tidal gauges across Canada.

Data adjustments were required due to the difference in the vertical reference system. These adjustments were identified based on queries from Natural Resources Canada GPS·H online tool[2]. The following adjustments were completed with the GPS/GNSS survey data:

- Reach 1 – site survey data was raised 0.22 m in elevation.
- Reach 2 – site survey data was raised 0.21 m in elevation.
- Reach 3 – no adjustment (Total Station survey only).

4.3.2 LiDAR Data

LiDAR surveys do not typically penetrate through water surfaces. Therefore, LiDAR data may not accurately reflect the channel bed (bathymetry) at every location along each Reach. To rectify this data gap, channel surveying was completed to capture thalweg elevations and representative cross sections along each Reach. This field data was

[2] Accessed October 2019. Available [online]: https://webapp.geod.nrcan.gc.ca/geod/tools-outils/gpsh.php?locale=en

analyzed to support elevation adjustments along the channel beds. LiDAR and survey cross sections were compared and the following elevation adjustments were made to the LiDAR data:

- Reach 1 – channel bed was lowered 0.7 m
- Reach 2 – channel bed was lowered 0.8 m
- Reach 3 – channel bed was lowered:
    - 0.3 m upstream of the water intake area
    - 0.8 m at the water intake area
    - 0.3 m downstream of the water intake area

4.4 Hydrological Analysis

With the lack of active hydrometric stations (and/or stations with sufficient record length) on Peachland and Trepanier Creeks, the Index Flood Method was selected to estimate peak instantaneous and mean daily maximum streamflows (design streamflows). This method is consistent with the estimation procedure recommended by Reksten (1987) for estimating peak streamflows at ungauged locations in BC. The intent of the hydrologic analysis completed herein is to provide reliable and consistent estimates of design streamflows (i.e., 5-, 10-, 20-, 50-, 100-, and 200-year hydrological return periods) for each watercourses at the respective Reach locations.

4.4.1 Climate Change

Changing climate conditions will have an impact on flooding. This will include changes in rainfall, snowpack and temperature, and forest disturbances (e.g., wildfire and insects) (EGBC 2017). These changes will have an influence on watershed processes in Peachland Creek and Trepanier Creek. As such, it is now considered standard engineering practice to include assessment of climate change impacts for flooding projects.

The Pacific Climate Impacts Consortium (PCIC) provides information on climate change and variability. One of the available tools is Plan2Adapt, which generates information to describe future climate conditions over different time periods. As an example of possible impacts, the 2080's time period (2070-2099) was selected for the Central Okanagan region. Results are listed in Table 4-1. These projections indicate that annual temperatures will increase, there will be less snowfall, and more winter rainfall. This could result in a shift in the current hydrological regime for the watersheds. The timing of freshet could be earlier and winter streamflow could be more variable. The frequency and magnitude of flood events could increase.

Table 4-1
PCIC Plan2Adapt Summary of Projected Changes to 2080's from 1961-1990 Baseline Period

Climate Variable	Season	Ensemble Median	10th to 90th Percentiles
Mean Temperature	Annual	+2.9°C	+1.7°C to +4.6°C
Precipitation	Annual Summer Winter	+8% -12% +11%	+2% to +15% -34% to +4% +3% to +27%
Snowfall	Winter Spring	-22% -77%	-44% to -9% -89% to -17%

As per EGBC guidelines for flood assessments (EGBC 2018), In addition, statistical trend analyses (i.e., Mann Kendall test) were completed on mean annual peak daily streamflow values for WSC data. No statistically significant trends were identified; therefore, according to EGBC (2018) guidelines for assessing floods in a changing climate, a 10% upward scaling factor was applied to the design streamflows for each return period. This was applied to account for future climate change conditions in Peachland and Trepanier Creeks.

4.4.2 Index Flood Method

The Index Flood Method is commonly used to estimate peak streamflows at ungauged locations for watersheds larger than 10 km^2 in Canada (National Research Council of Canada 1989; Coulson 1991) and is consistent with the methods presented in the Community Watershed Guidebook (MOF/MELP 1996) that is used in the forest sector for estimating design streamflows for sizing bridges and culverts on forestry roads.

Relevant data from nearby gauged locations are required to derive an appropriate model for calculating the annual maximum daily streamflow (i.e., the index flood). Ratios of higher return periods (e.g., 200-year) annual maximum daily streamflow to the index flood are determined. Finally, an average ratio of the maximum instantaneous to the peak maximum streamflow is determined.

The peak instantaneous streamflow is generally adopted as the basis for the design peak flow. In the present application of the Index Flood Method, one standard deviation (68%) confidence intervals are provided. The confidence interval is based upon the combined standard errors of the index flood, the instantaneous-to-daily streamflow ratio, and the ratios of selected return period streamflows to the index flood.

4.4.3 Selection of Candidate Hydrometric Stations

Historic WSC hydrometric records are available for Peachland and Trepanier Creeks near the respective Reach locations as follows:

- *Peachland Creek at the Mouth* (WSC No. 08NM159; Period of record = 1969-1982);
- *Trepanier Creek near Peachland* (WSC No. 08NM041; Period of record = 1919-2013); and
- *Trepanier Creek at the Mouth* (WSC No. 08NM155; Period of record = 1969-1981).

However, upon further review of the available hydrometric records, it was identified that insufficient records to calculate design streamflows were available for Reach 1 and 2. Alternatively, the available hydrometric records from WSC No. 08NM041 were sufficient for Reach 3.

Following the above, it was decided that for Trepanier Creek, hydrometric records available for WSC No. 08NM041 would be used to support the estimation of the design streamflows for Reach 2 and 3. However, due to water releases by Brenda Mines during peak streamflows into Trepanier Creek and the history of MacDonald Creek (i.e., tributary to Trepanier Creek) diversions into Peachland Creek, WSC No. 08NM041 records were deemed insufficient to use as a surrogate to estimate Peachland Creek streamflows at Reach 1. Therefore, *Camp Creek at the Mouth near Thirsk* (WSC No. 08NM134; Period of record = 1965-2015) was used as the candidate regional hydrometric station to support streamflow estimates for Peachland Creek. WSC No. 08NM134 is in the adjacent watershed (i.e., Trout Creek) to Peachland Creek, has similar watershed characteristics, is located within the same provincial hydrologic zone, and is expected to experience similar climatic patterns.

Data for WSC No. 08NM041 and 08NM134 were used to calculate the mean annual maximum daily unit streamflow for the respective periods of record. The estimates were then adjusted to a long-term mean based on the streamflow records of *Kettle River near Laurier* (WSC No. 08NN012), for which a continuous record extends from 1950-2017. This adjustment reduces the effect of the individual hydrometric station's period of record and the adjusted mean annual maximum daily unit streamflow for WSC No. 08NM041 and 08NM134 are considered the "index floods".

4.4.4 Return Period and Instantaneous-to-Daily Ratios

For WSC No. 08NM041 and 08NM134, the 5-, 10-, 20-, 50-, 100-, and 200-year return period mean daily maximum unit streamflows were calculated. Four different distribution types (Pearson Type III, Log Pearson Type III, Log Normal, and Gumbel) were fitted to the data using the BC Ministry of Environment, Lands, and Parks (MELP) Flood Frequency Analysis Program (Version 1.1). The general procedure for estimating individual return periods from the MELP program involves visually inspecting and assessing the goodness-of-fit for each distribution, with poor fits excluded. Reviews of each distribution concluded that all distributions types fitted the data reasonably well.

Following this, the results from the distributions used were then averaged and used in calculating the average values and 95% confidence limits. These averages were then used to calculate a representative ratio of the respective return period annual maximum daily unit streamflow to the index flood (e.g., 200-year/2-year). For the present application, the average instantaneous/daily (I/D) ratio using all paired observations of instantaneous and daily peak streamflows for each hydrometric station was calculated.

4.4.5 Hydrological Uncertainty

Uncertainty in the design streamflow estimates derives from possible errors in the raw peak streamflow hydrometric data (associated primarily with station location and rating curves), differences in the value of the data from each station due to differences in the length and period of record, and possible errors due to the nature of the hydrometric station (manual or recording). Furthermore, while an attempt was made to account for major differences in location, elevation, and aspect for each Reach, differences between the areas represented by the hydrometric stations exist for these factors and others (such as forested area, degree of land-use development, soils, history of forest fire, and geology).

To account for uncertainty within the design streamflow estimates, a one standard error (68%) confidence interval is provided around the mean streamflow estimate. The true value of the peak instantaneous and mean daily maximum streamflows is estimated to fall within the upper and lower confidence limits 68% of the time. Standard errors in the peak instantaneous and mean daily maximum streamflows estimates are based on combined standard errors in the maximum unit daily streamflow, the I/D ratio, and the ratios of the n-year return period (e.g., n = 200-year) to the mean annual peak daily streamflow.

4.4.6 Design Streamflow Results

The design streamflow estimates for the project Reaches in Peachland and Trepanier Creeks are identified in Table 4-2 (maximum daily) and Table 4-3 (peak instantaneous). Watershed areas were calculated using TRIM and GIS mapping datasets. The design streamflows were calculated for all Reaches and relevant return periods. As noted earlier, the upper confidence interval was adopted as the design value.

For the design streamflow estimates, the following assumptions were included:

- For Trepanier Creek at Reach 3, it was assumed that the history of streamflow releases by Brenda Mines and the diversion of a portion of MacDonald Creek into Peachland Creek did not significantly influence the mean daily maximum streamflow recorded by WSC 08NM041 for the available period of record. In addition, the unit streamflow recorded by WSC No. 08NM041 (watershed area = 177.1 km^2) was assumed consistent at the Reach 3 point-of-interest (watershed area = 179.4 km^2)[3].

- For Trepanier Creek at Reach 2, the same assumptions as for Reach 3 were considered. Similarly, the unit streamflow recorded by WSC 08NM041 was assumed consistent at the Reach 3 point-of-interest (watershed area = 252.7 km^2). In addition, the design streamflows were estimated to the apex of alluvial fan only, as limited additional streamflows occur across the fan.
- For Peachland Creek at Reach 1, it was assumed that the MacDonald Creek diversion into upper Peachland Creek is no longer operational. AE (2019) reported that the District of Peachland stopped using the diversion in 2009. Also, it was assumed that the unit streamflow recorded by WSC No. 08NM134 (drainage area = 34.7 km^2) was consistent at the Reach 1 point-of-interest (drainage area = 147.3 km^2). In addition, the design streamflows were estimated to the apex of alluvial fan only, as limited additional streamflows occur across the fan. Lastly, it was assumed that during design streamflows there is limited reservoir attenuation by Glen and Peachland Reservoirs.

Table 4-2
Maximum Daily Flow Estimates

Flow Rate	Hydrological Return Period (Years)	Annual Exceedance Probability (AEP)	Peachland Creek Reach 1 (m^3/s)	Trepanier Creek Reach 2 (m^3/s)	Trepanier Creek Reach 3 (m^3/s)
Q_{5}	5	20%	12.2	20.5	14.5
Q_{10}	10	10%	14.5	24.2	17.2
Q_{20}	20	5%	16.6	27.5	19.5
Q_{50}	50	2%	19.2	32.0	22.7
Q_{100}	100	1%	21.1	35.1	24.9
Q_{200}	200	0.5%	22.9	38.1	27.1

Table 4-3
Peak Instantaneous Flow Estimates

Flow Rate	Hydrological Return Period (Years)	Annual Exceedance Probability (AEP)	Peachland Creek Reach 1 (m^3/s)	Trepanier Creek Reach 2 (m^3/s)	Trepanier Creek Reach 3 (m^3/s)
Q_{5}	5	20%	13.8	23.1	16.4
Q_{10}	10	10%	16.4	27.3	19.4
Q_{20}	20	5%	18.8	30.9	21.9
Q_{50}	50	2%	21.8	35.9	25.5
Q_{100}	100	1%	23.9	39.4	28.0
Q_{200}	200	0.5%	25.9	42.8	30.4

[3] The drainage areas for Trepanier Creek do not consider the portion of Brenda Mines within the watershed (i.e., 6.8 km^2). Brenda Mines captures all water on site and releases at designated times; therefore, a portion of the natural watershed has been removed.

4.4.7 Okanagan Lake Elevation

Okanagan Lake is the receiving water body for Peachland and Trepanier Creeks. The lake elevation is the downstream boundary condition for the hydraulic models at Reach 1 and Reach 2. Statistical analysis was completed to estimate various lake elevations at WSC No. 08NM083 (Okanagan Lake at Kelowna, Table 4-4). Various statistical distributions were analyzed using HEC-SSP software (US ACE 2019).

Table 4-4
WSC Hydrometric Station on Okanagan Lake

Station	Name	Period of Record	No. Years	Area (km^2)
08NM083	Okanagan Lake at Kelowna	1943-2019	77	5,980

It is noted that there is an ongoing OBWB project for Okanagan Mainstem Flood Mapping. One of the anticipated outcomes of the OBWB project is a detailed analysis of Okanagan Lake water elevations and flood mapping along foreshore areas. At the time of writing this report the OBWB project is not complete. Therefore, statistical analysis of historical lake elevations completed herein was considered suitable for the project. The same statistical return periods as the design streamflows were applied in the project for lake elevations (i.e., 5-, 10-, 20-, 50-, 100-, and 200-year).

Okanagan Lake water elevations have been recorded for 77 years at WSC 08NM083. This is considered a long record compared to most gauges in the Okanagan Basin. The historical daily data is presented in Figure 4-1 as an elevation duration curve. This shows that the lake elevation has fluctuated by 1.87 m over this period. It is noted that the lake level and outflows are regulated at the Okanagan Lake Dam in Penticton. The minimum and maximum lake elevations are 341.37 m and 343.25 m, respectively (CGVD1928). The median lake elevation is 341.8 m (CGVD1928).

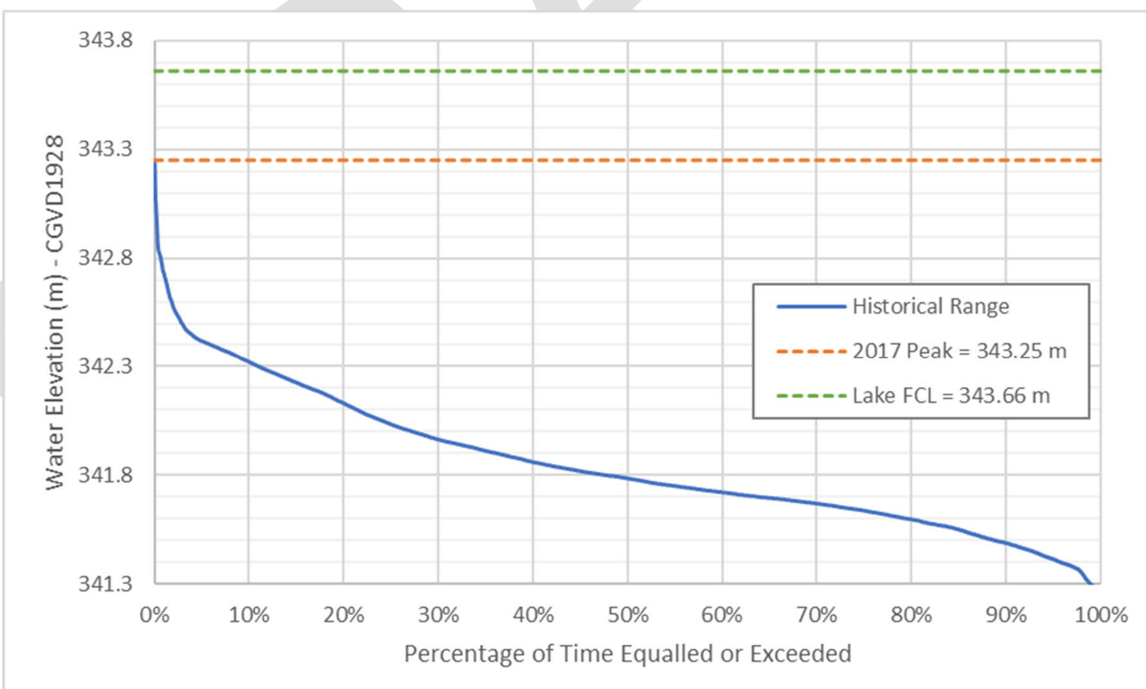


Figure 4-1
Elevation Duration Curve for Okanagan Lake (WSC 08NM083)

The maximum recorded lake elevation (343.25 m, CGVD1928) occurred between June 7-9, 2017. This was a high flood year in the Okanagan Basin and there were extensive flooding issues around the lake (AE 2017). It is noted that the current Flood Construction Level (FCL) for Okanagan Lake is 343.66 m (CGVD1928), although this elevation includes freeboard. The 2017 peak and the FCL are overlaid on the elevation duration curve (Figure 4-1).

The statistical frequency analysis chart is shown in Figure 4-2 for the PearsonIII distribution. It is noted that the analysis identified the 2017 peak elevation as a statistical high outlier. The results are listed in Table 4-5, which are the 95% confidence limit values that were selected from the analysis.

Table 4-5
Summary of Lake Elevations Estimated in the Project for Reach 1 and Reach 2

Lake Elevation	Hydrological Return Period (Years)	Annual Exceedance Probability (AEP)	Estimated Value (m) – CGVD1928
E_5	5	20%	342.66
E_{10}	10	10%	342.80
E_{20}	20	5%	342.92
E_{50}	50	2%	343.06
E_{100}	100	1%	343.16
E_{200}	200	0.5%	343.25

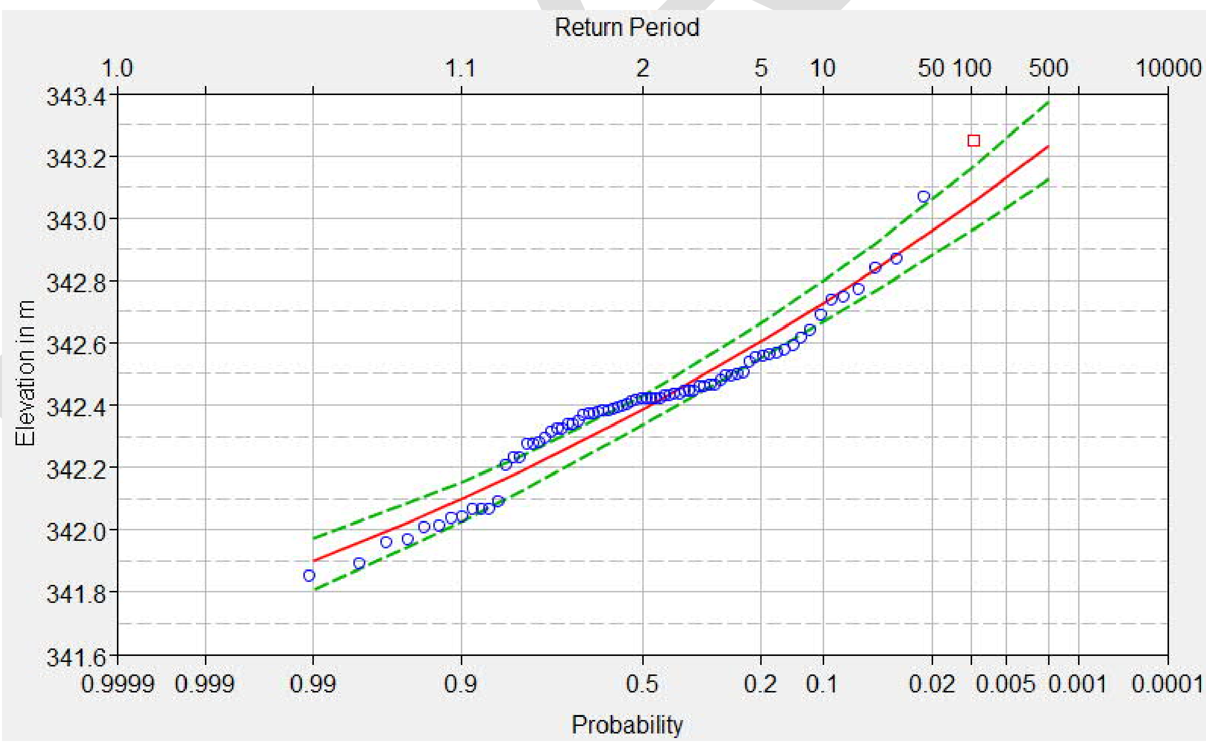


Figure 4-2
Frequency Analysis Chart for Okanagan Lake WSC 08NM083 (CGVD1928)

4.5 Hydraulic Analysis

4.5.1 Model Build

Hydraulic analysis was completed using GeoHEC-RAS software from CivilGeo and HEC-RAS software from the US Army Corps of Engineers. Model project files are compatible with both software packages. The hydraulic models were built using:

- 2018 LiDAR digital elevation model (DEM) (Section 4.3).
- Site surveys (and vertical adjustments noted in Section 4.3).
- Bridge crossing information:
    - Highway 97 at Peachland Creek (single span steel bridge)
    - Highway 97 at Trepanier Creek (multi-span concrete bridge)
    - Renfrew Road (metal arch culvert)
    - Beach Avenue (single span concrete bridge)
- Weir information for Trepanier Creek Reach 3.
    - The adjustable stop logs were set at the elevation observed on September 27, 2019.
- Design streamflows from hydrological analysis (Section 4.4)
    - Maximum daily streamflows
    - Peak instantaneous streamflows
- Surface roughness (Manning's n)
    - n = 0.05 for main channels
    - n = 0.10 for floodplains
- Upstream and downstream boundary conditions
    - Upstream: Normal depth associated with design streamflow and slope of energy grade line (EGL)
    - Downstream Reach 1 and Reach 2: Okanagan Lake water elevations
    - Downstream Reach 3: Normal depth

Model schematic images are presented in Figures 4-3 to 4-5. These show the LiDAR data with hillshading topography and the model elements (e.g., channel and cross sections). The alluvial fans on Peachland and Trepanier Creek are visible in the hilshading topography (Reach 1 and 2, respectively).

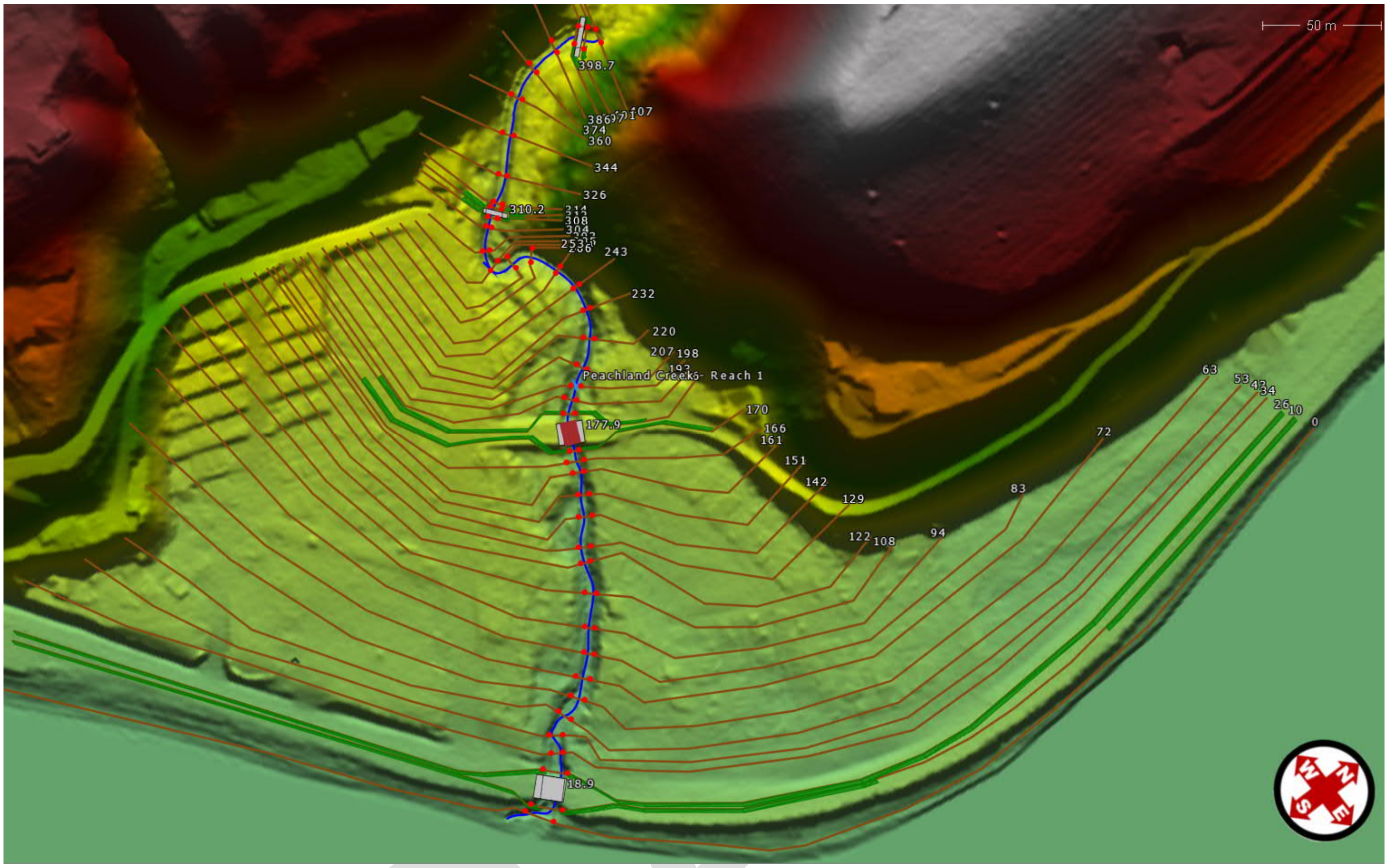


Figure 4-3
GeoHEC-RAS Model Schematic for Peachland Creek Reach 1

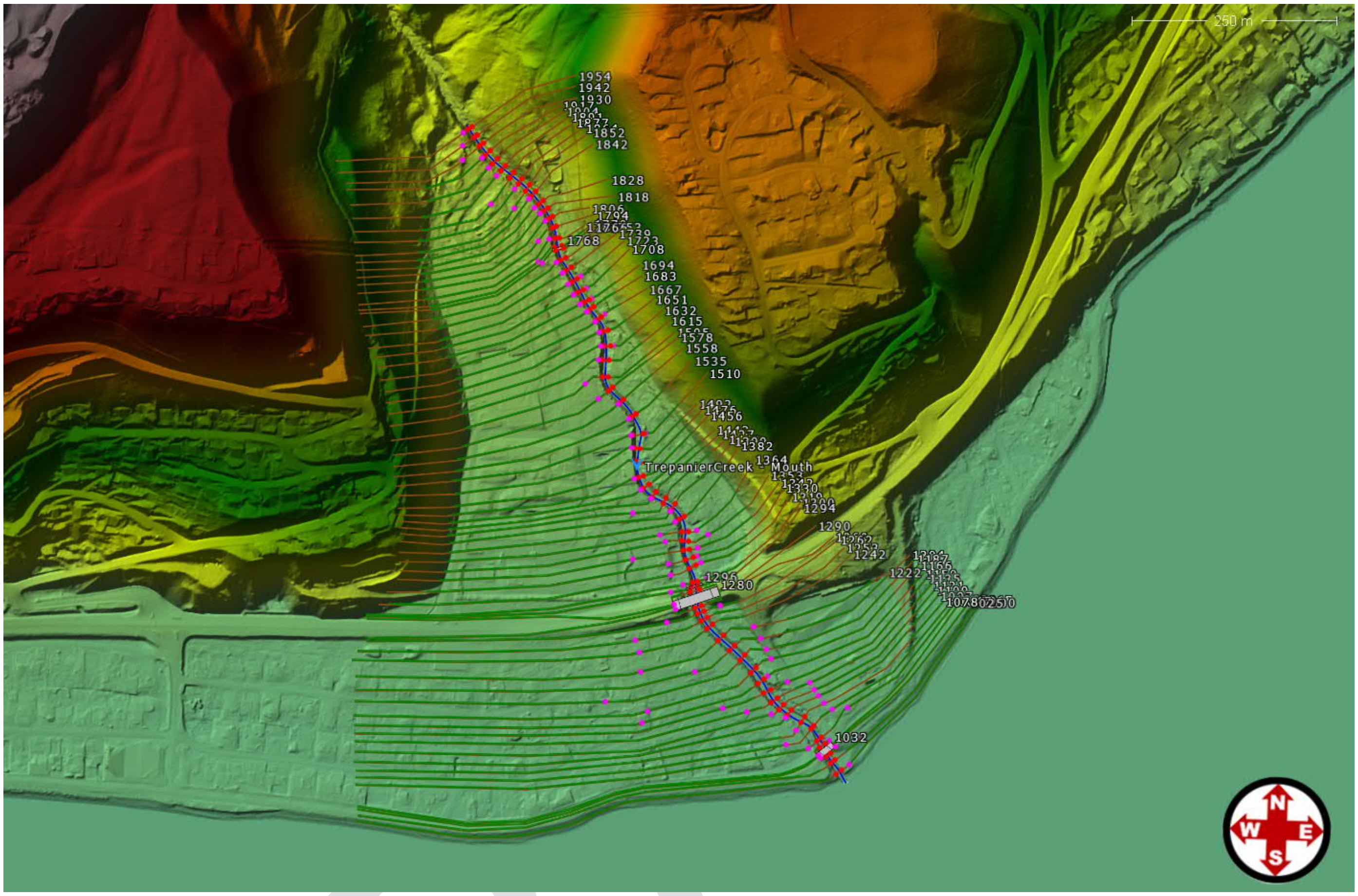


Figure 4-4
GeoHEC-RAS Model Schematic for Trepanier Creek Reach 2

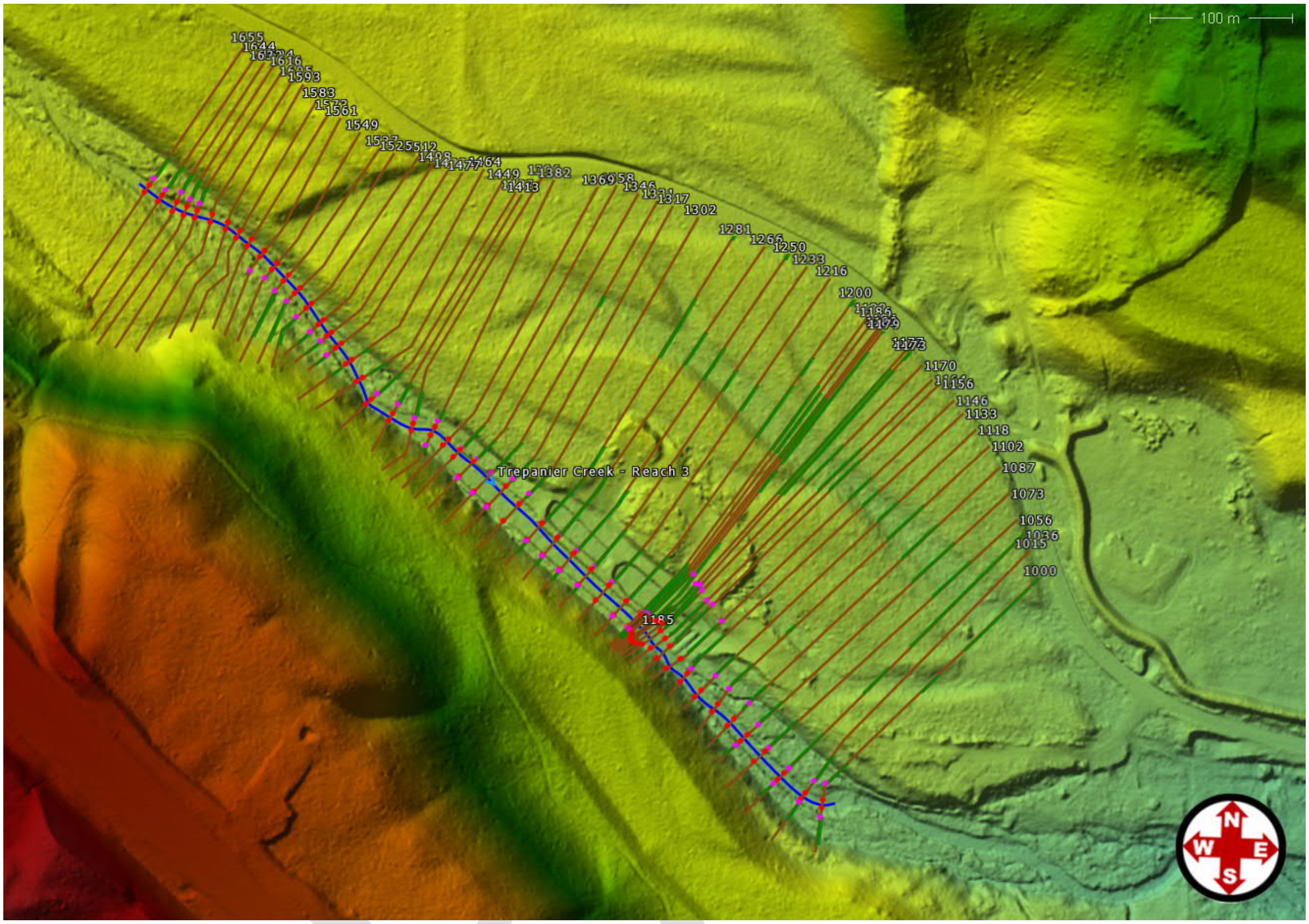


Figure 4-5
GeoHEC-RAS Model Schematic for Trepanier Creek Reach 3

4.5.2 Model Scenarios

The hydraulic simulations were performed using steady-state flow rates under sub-critical flow conditions. For the purposes of the project, 11 hydraulic model scenarios were analyzed for Reach 1 and Reach 2. Furthermore, each scenario was modelled under design streamflow conditions (peak instantaneous and maximum daily). These scenarios are listed in Table 4-6.

Scenarios 1 to 6 include a 5-year lake elevation as the downstream boundary condition with the full range of design streamflows. The 5-year return period lake elevation was selected as a reasonable boundary condition for the range of design streamflows. Okanagan Lake outflows and elevations are regulated, and the maximum lake elevations have typically occurred later than peak freshet in Peachland and Trepanier Creeks.

Scenarios 7 to 11 include a 5-year design streamflow with the full range of lake elevations. The objective of running multiple scenarios is to identify the critical factor for flood conditions.

Table 4-6
Summary of Hydraulic Model Scenarios for Reach 1 and Reach 2

Scenario No.	Design Streamflow and Lake Elevation	Scenario No.	Design Streamflow and Lake Elevation
1	Q_{200} – E_5	7	E_{200} – Q_5
2	Q_{100} – E_5	8	E_{100} – Q_5
3	Q_{50} – E_5	9	E_{50} – Q_5
4	Q_{20} – E_5	10	E_{20} – Q_5
5	Q_{10} – E_5	11	E_{10} – Q_5
6	Q_5 – E_5		

Reach 3 does not include Okanagan Lake. Therefore, only six model scenarios were completed on Reach 3, which correspond to the design streamflows. These scenarios are listed in Table 4-7.

Table 4-7
Summary of Hydraulic Model Scenarios for Trepanier Creek Reach 3

Scenario No.	Flow Rate
12	Q_{200}
13	Q_{100}
14	Q_{50}
15	Q_{20}
16	Q_{10}
17	Q_5

4.5.3 Model Validation

In the absence of site-specific streamflow and water level data, model calibrations were not possible. The models were validated by analyzing water surface profiles and other hydraulic characteristics at each site. Model parameters (e.g., Manning's n and boundary conditions) were increased and decreased to observe the sensitivity of adjustment. Final model parameters were selected based on this analysis, experience with similar sites, and with comparison to available hydraulic literature.

4.5.4 Flood and Channel Conditions

Peachland and Trepanier Creeks are mountainous streams and there are dam structures in each watershed. They are also mobile bed systems that have naturally occurring sediment transport processes, as evidenced by the formation of alluvial fans at the outlet of Reaches 1 and 2. Thus, there are conditions that could affect flood events and these are discussed below.

One of these conditions is the potential for debris floods or debris flows. An assessment of these hazards was outside the scope of work for the project. However, it must be noted that these types of events have an influence on flood magnitude. When a debris flood or debris flow event occurs, water entrains debris and the result is a greater volumetric flow rate that is highly erosive. These events typically cause significant channel alterations and deposit a large volume of material on the alluvial fan. The project only modelled 'clear flood' conditions without any blockages or debris in the channels.

Another condition is related to the presence of upland storage dams in the watersheds. There is potential for dam failures that could lead to unnaturally high streamflows. The impacts from dam failures and the degree of flood inundation is typically far greater compared to 'clear flood' conditions. Dam breach analysis and resulting flood inundation were not considered in the project; however, it is noted that the District of Peachland is currently completing this work with Urban Systems Ltd.

The last condition is related to the channel bed stability. Peachland and Trepanier Creeks are alluvial channels with mobile beds. Sediment moves and stream systems make adjustments as new sediment is replenished from the watershed. This is a complex geomorphological process and these types of streams are continually changing. Sediment yield studies were not completed in the project and stable channels were assumed in the hydraulic models.

4.5.5 Freeboard

Each model scenario listed in Section 4.5.2 was analyzed with the design streamflows. The purpose of this is to confirm which flood profile (i.e., hydraulic grade line) is higher when a freeboard height is added to the flood profile. Freeboard is a vertical distance that accounts for hydrotechnical uncertainties, and flood and channel conditions such as those described above in Section 3.7. Freeboard is added to hydraulic model results for the purposes of inundation mapping. Flood maps were prepared for the governing condition for the 20-year and 200-year hydrological return periods. The remaining events were provided to the RDCO as GIS shapefiles. The following freeboard was considered:

- No freeboard – estimate of flood profiles and inundation extents
- Maximum Daily Streamflow
  - 0.6 m freeboard – minimum amount for uncertainties
  - 0.9 m freeboard – additional amount for sedimentation and channel conditions
- Peak Instantaneous streamflow
  - 0.3 m freeboard – minimum amount for uncertainties
  - 0.6 m freeboard – additional amount for sedimentation and channel conditions

4.5.6 Reach 1 Hydraulic Results

The model results show that the Peachland Creek channel along the alluvial fan generally has adequate hydraulic capacity for the 20-year and 200-year design streamflows. However, the following results are important to consider for Reach 1:

- The Highway 97 bridge crossing passes the design streamflows, but the bridge freeboard (0.69 m and 0.49 m, respectively) is less than MoTI design standards for highways (typically 1.5 m).
- The Renfrew Road arch culvert passes the design streamflows. The 200-year design streamflow is backwatering upstream of the road embankment.
- The first trail bridge in Hardy Falls Park does not have capacity for the design streamflows. It is expected that the bridge crossing would be adversely impacted by these flood conditions. As noted above, this area was impacted by recent flooding.

4.5.7 Reach 2 Hydraulic Results

The model results show that the Trepanier Creek channel along the alluvial fan has out-of-channel flooding, which extends onto the following floodplain areas:

- Peachland Elementary School.
- Mobile home properties at 5432 Chidely Road.
- 5481 Clements Crescent.
- 5407/5409 and 5415 Clements Crescent.
- 5501 Todd Road.
- Multiple properties on the Butler Creek cul-de-sac.
- Portions of the roadway areas on Clements Crescent, Todd Road, and Beach Avenue.

In addition to the above, it is noted that the Beach Avenue bridge crossing does not have adequate capacity to pass the 200-year design streamflow. It is expected that the bridge crossing would be adversely impacted by these flood conditions. The bridge crossing has marginal capacity to pass the 20-year design streamflow (with almost zero freeboard).

4.5.8 Reach 3 Hydraulic Results

The model results show that the Trepanier Creek channel along the District of Peachland water intake site has out-of-channel flooding. The settling ponds would be inundated for the 20-year and 200-year design streamflows. These results are specific to the elevation of the weir observed on September 27, 2019.

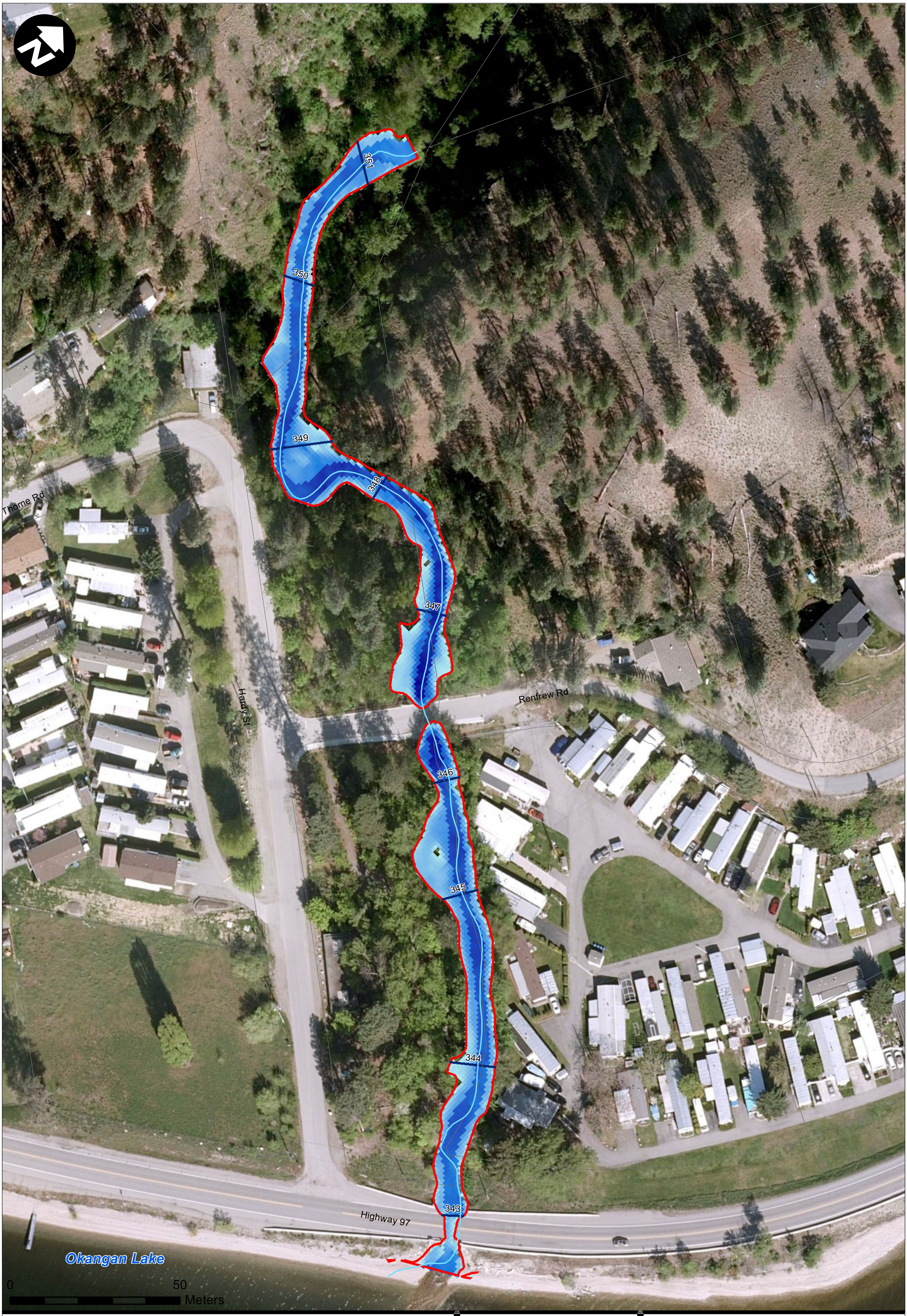
It is noted that the adjustable stop logs at the weir govern the water elevation in the channel adjacent to the settling ponds. The District of Peachland can raise or lower the stop logs. This provides operational control, so staff could remove stop logs prior to freshet. This would increase the hydraulic capacity in the channel.

5 FLOOD MAPPING

Flood inundation maps are presented in the following set of figures (Table 5-1). These maps show the estimate of maximum inundation extents for the 20-year and 200-year hydrological return periods.

Table 5-1
List of Flood Maps

Figure No.	Flood Map
	Peachland Creek Reach 1
5-1	20-Year Flood Extents
5-2	200-Year Flood Extents
	Trepanier Creek Reach 2
5-3	20-Year Flood Extents
5-4	200-Year Flood Extents
	Trepanier Creek Reach 3
5-5	20-Year Flood Extents
5-6	200-Year Flood Extents



Peachland Creek
Water Surface Elevation
Cadastral boundaries
Inundation Extent

Water Depth (m)
High : 2.34
Low : 0

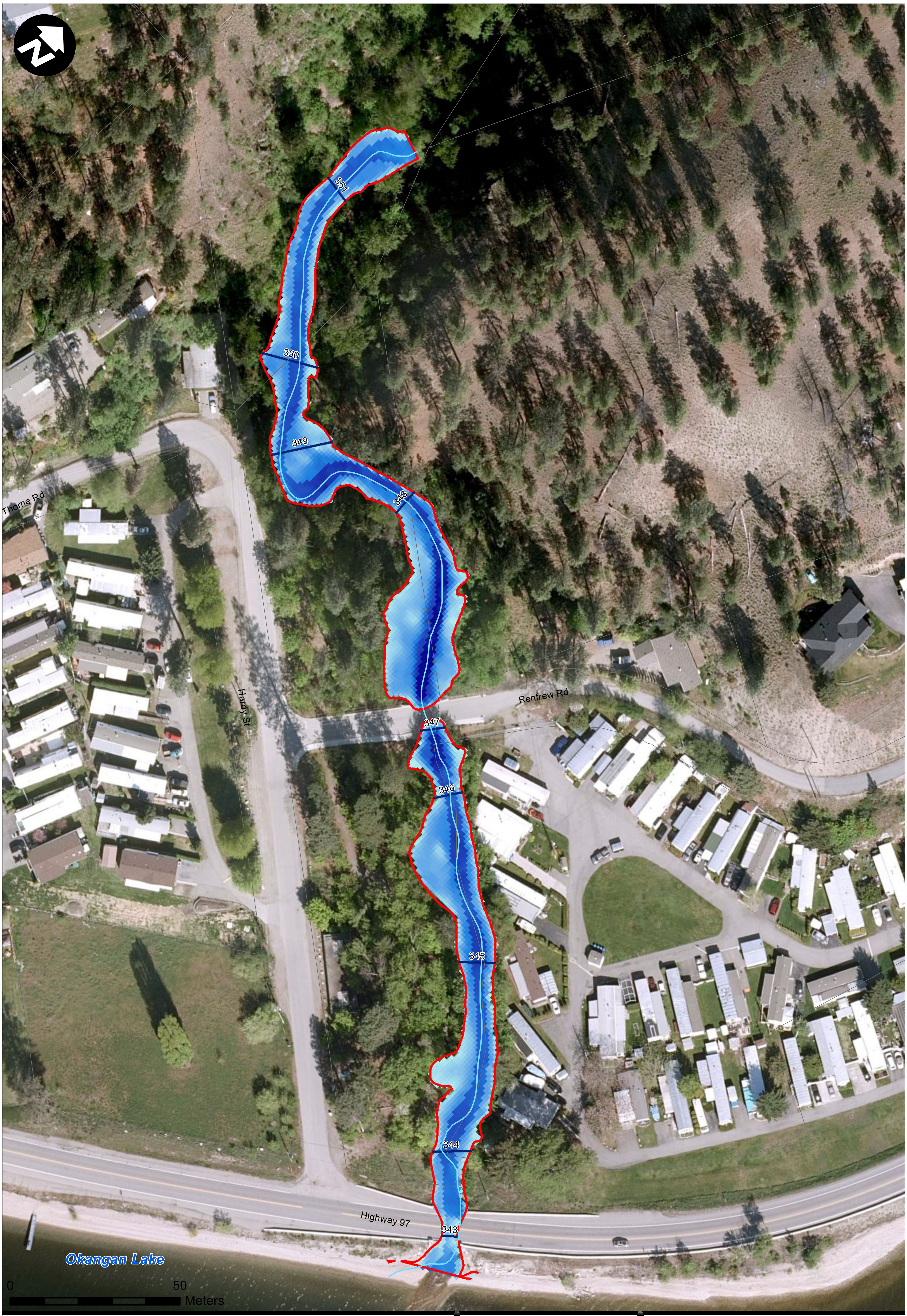
Associated Engineering

PROJECT NO.:	2019-2671.000.000
DATE:	Nov. 2019
DRAWN BY:	DA

FIGURE 5-1: PEACHLAND CREEK REACH 1, 20-YEAR FLOOD EXTENTS

RDCO

Peachland and Trepanier Creek Flood Mapping

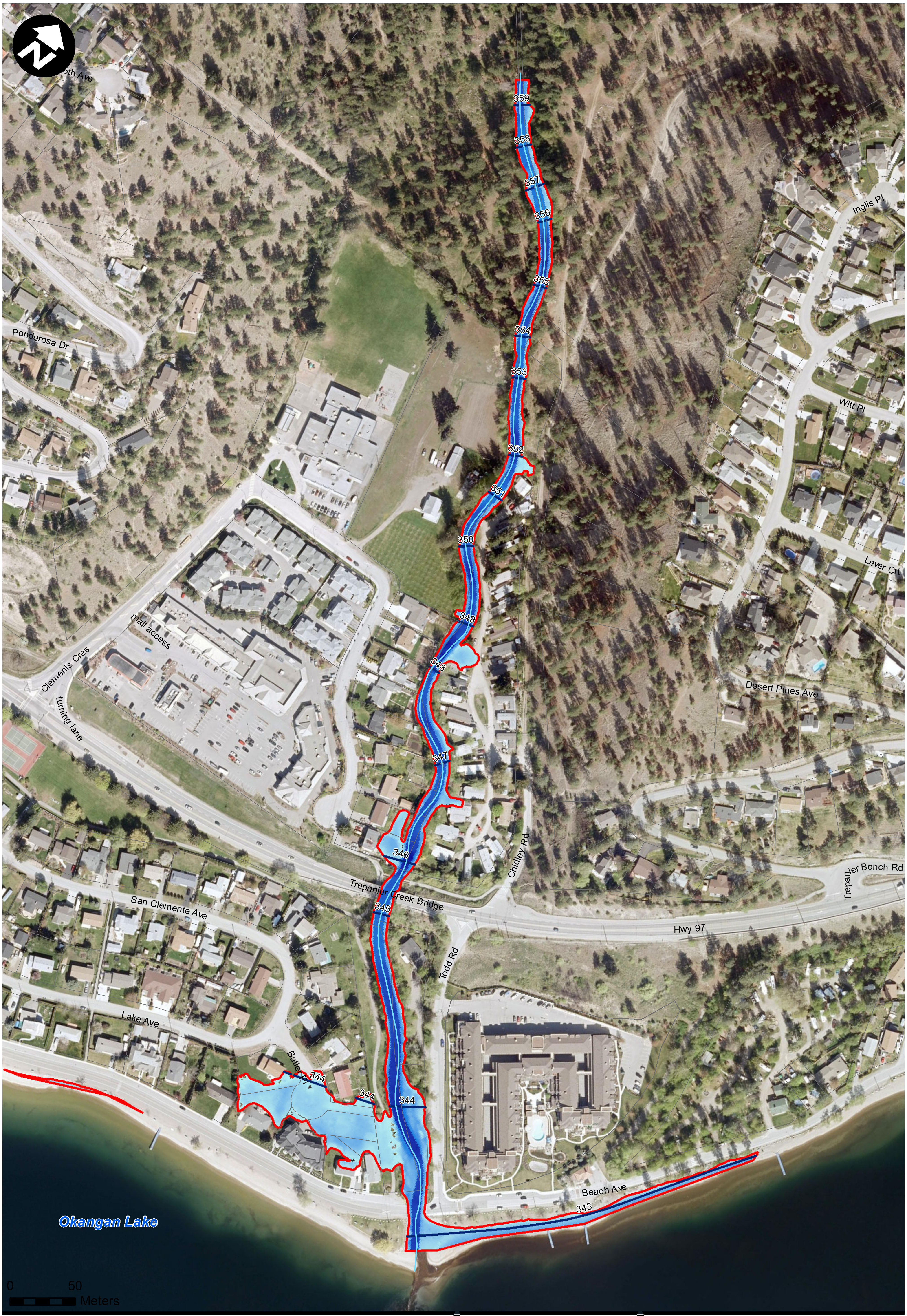


Peachland Creek
Water Surface Elevation
Cadastral boundaries
Inundation Extent

Water Depth (m)
High : 3.01
Low : 0

PROJECT NO.: 2019-2671.000.000
DATE: Nov. 2019
DRAWN BY: DA

FIGURE 5-2: PEACHLAND CREEK REACH 1, 200-YEAR FLOOD EXTENTS
RDCO
Peachland and Trepanier Creek Flood Mapping



Associated Engineering

- Trepanier Creek
- Water Surface Elevation
- Cadastral boundaries
- Inundation Extent

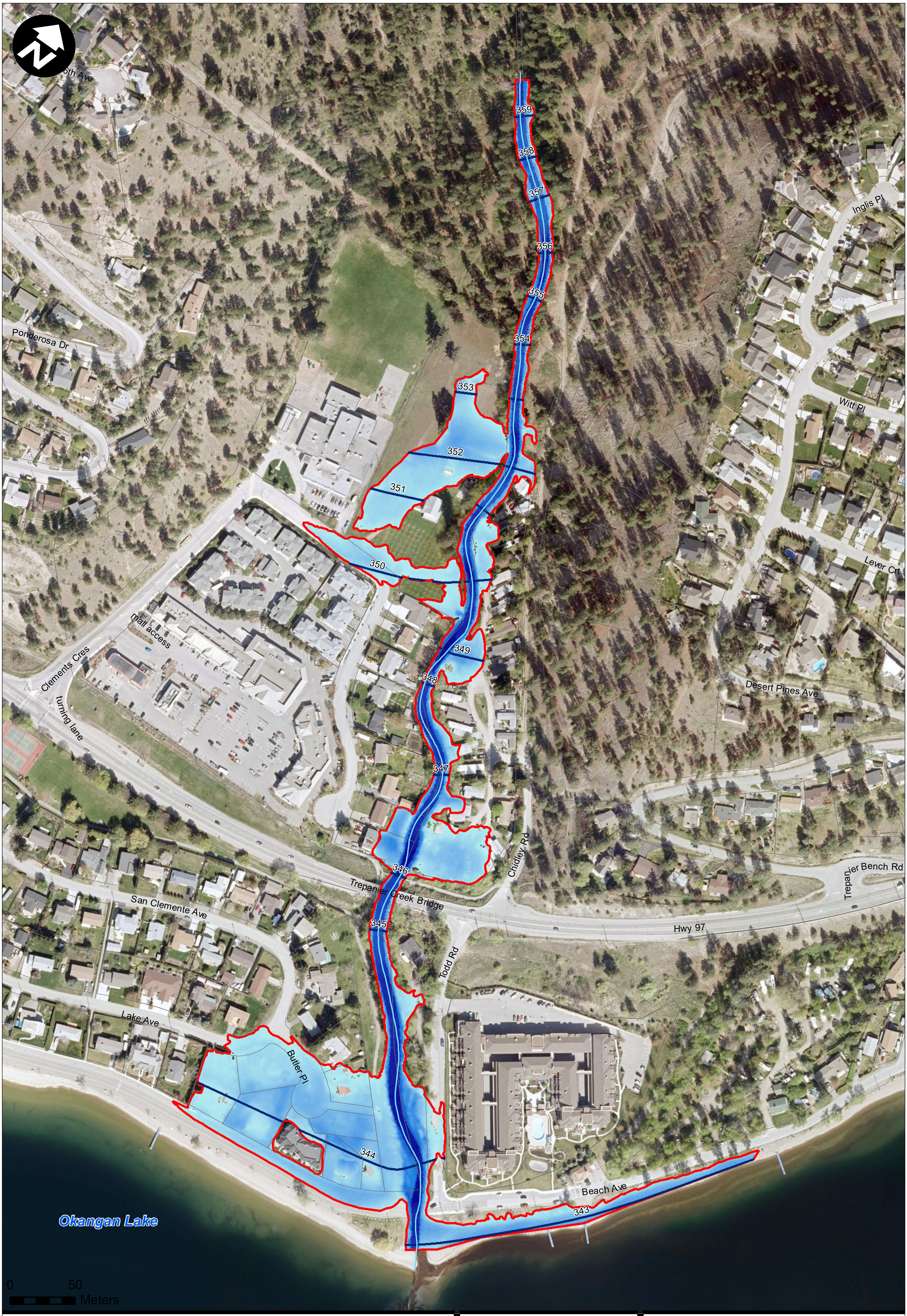
Water Depth (m)
High : 2.35
Low : 0

PROJECT NO.:	2019-2671.000.000
DATE:	Nov. 2019
DRAWN BY:	DA

FIGURE 5-3: TREPANIER CREEK REACH 2, 20-YEAR FLOOD EXTENTS

RDCO

Peachland and Trepanier Creek Flood Mapping



Associated Engineering

Trepanier Creek

Water Surface Elevation

Cadastral boundaries

Inundation Extent

Water Depth (m)

High : 2.81

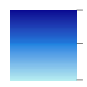
Low : 0

PROJECT NO.:	2019-2671.000.000
DATE:	Nov. 2019
DRAWN BY:	DA

FIGURE 5-4: TREPANIER CREEK REACH 2, 200-YEAR FLOOD EXTENTS

RDCO

Peachland and Trepanier Creek Flood Mapping



Trepanier Creek

Water Surface Elevation

Inundation Extent

Water Depth (m)

High : 2.55707

Low : 0.0

PROJECT NO.: 2019-2671.000.000

DATE: Nov. 2019

DRAWN BY: DA

FIGURE 5-5: TREPANIER CREEK REACH 3, 20-YEAR FLOOD EXTENTS

RDCO

Peachland and Trepanier Creek Flood Mapping

Associated Engineering

Trepanier Creek

Water Surface Elevation

Inundation Extent

Water Depth (m)

High : 2.82025

Low : 0.0

PROJECT NO.: 2019-2671.000.000

DATE: Nov. 2019

DRAWN BY: DA

FIGURE 5-6: TREPANIER CREEK REACH 3, 200-YEAR FLOOD EXTENTS

RDCO

Peachland and Trepanier Creek Flood Mapping

6 CONCLUSIONS

Three stream channel Reaches on Peachland and Trepanier Creeks were assessed, and inundation maps were prepared as follows:

- Reach 1: Peachland Creek (approximately 400 m long reach to the mouth at Okanagan Lake);
- Reach 2: Trepanier Creek (approximately 900 m long reach to the mouth at Okanagan Lake); and
- Reach 3: Trepanier Creek (approximately 600 m long reach adjacent to the District of Peachland water intake).

Field assessments and surveying were completed to supplement available data and information. Hydrological and hydraulic analyses were completed for the project. Some of the main project conclusions are highlighted below:

- Peachland and Trepanier Creek are both Community Watersheds draining portions of the western side of the Okanagan Lake valley.
- These watersheds are snowmelt dominated hydrological systems and are expected to have peak streamflows in April or May.
- Reach 1 and Reach 2 are on alluvial fans of Peachland and Trepanier Creek, respectively.
- Based on the hydraulic model results, all three project Reaches are subject to flooding.
  - Peachland Creek Reach 1 generally has adequate hydraulic capacity for the design streamflows; however, the bridge crossings could be subject to flood-related damage.
  - Trepanier Creek Reach 2 has out-of-channel flooding. The 200-year design streamflow could inundate at least 7 locations adjacent to the channel.
  - Trepanier Creek Reach 2 also has out-of-channel flooding; however, the District of Peachland has operational control of the weir structure and this can influence the results.
- Flood inundation maps were prepared for the 20-year and 200-year design streamflows at each Reach (Figures 5-1 to 5-6).
- The *Flood Mapping Assurance Statement* is included in Appendix A.

CLOSURE

This report was prepared for the Regional District of Central Okanagan to prepare flood mapping for selected Reaches of Peachland and Trepanier Creeks.

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.

Jacob Tetreault, M.A.Sc., EIT
Project Engineer

Geoffrey Cahill, P.Eng.
Water Resources Engineer

Drew Lejbak, M.Sc.
Senior Hydrologist

John van der Eerden, M.Eng., P.Eng.
Vice President, Water Resources

REFERENCES

AE (Associated Environmental Consultants Inc.). 2017. *Review of 2017 Flood Response: Okanagan Lake Regulation System and Nicola Dam*. File 2017-8178. Ministry of Forests, Lands, Natural Resources Operations & Rural Development.

AE. 2016. *Regional Floodplain Management Plan: Phase 1*. Final Report. File 2015-8202.000. Regional District of Central Okanagan.

AE. 2019. *Streamflow Datasets to Support the Application of the Okanagan Tennant Method in Priority Okanagan Streams*. Prepared for the Okanagan Basin Water Board, September 2019.

BC Ministry of Forests and Ministry of Environment, Lands, and Parks (MOF/MELP). 1996. *Community Watershed Guidebook*. October 1996.

Clarke Geoscience Ltd. 2014. *Terms of Reference for a Regional Floodplain Management Framework for the Regional District of Central Okanagan*.

Coulson, CH. 1991. *Manual of Operational Hydrology in British Columbia*. Second Edition. Ministry of Environment, Water Management Division, Hydrology Section.

EGBC (Engineers and Geoscientists British Columbia). 2017. *Flood Mapping in BC – APEGBC Professional Practice Guidelines*. V1.0.

EGBC. 2018. *Legislated Flood Assessment in a Changing Climate in BC*. Version 2.1. Professional Practice Guidelines.

National Research Council of Canada. 1989. *Hydrology of Floods in Canada: A Guide to Planning and Design*. W.E. Watt (ed.). Ottawa, Canada.

Reksten, DE. 1987. *A Procedure for Regionalization of Peak Flows in BC*. Ministry of Environment and Parks, Water Management Branch, Hydrology Section.

US ACE (US Army Corps of Engineers). 2019. *Statistical Software Package (HEC-SSP)*. Version 2.2. Institute for Water Resources, Hydrologic Engineering Centre, Davis, CA.

APPENDIX A - FLOOD MAPPING ASSURANCE STATEMENT

(To Be Submitted with Final Report)

1450 KLO Road
Kelowna, BC, V1W 3Z4
rdco.com

Regional District of Central Okanagan