FINAL REPORT: City of Vernon: Detailed Flood Mapping, Risk Analysis, and Mitigation

Part 2 – B.X. Creek below Swan Lake and Vernon Creek below Kalamalka Lake

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- Chris Long — Hydraulic Model Review
- Daniel Arnold — Surveying
- Pablo Rodriguez — Surveying

EXECUTIVE SUMMARY

Flooding in the City of Vernon (Vernon) in 2017, 2018, and 2020 has resulted in an increased focus on the hazards of flooding to the community, and an interest in understanding how these hazards may change in the future. As a result, Vernon hired Northwest Hydraulic Consultants Ltd. to update the floodplain inundation and hazard mapping in two parts. Part 1, completed in 2020, covered flooding on B.X. Creek above Swan Lake. Part 2, this report, covers flooding on B.X. Creek from Swan Lake to its confluence with Vernon Creek, and Vernon Creek from Kalamalka Lake to Okanagan Lake.

This report and the associated floodplain maps provide a basis for evaluating and mitigating flood hazards within the study area and for assessing and guiding future development with respect to flood extents. It is recommended that this report and attachments be read in entirety prior to applying any of the findings.

The purpose of this project was to prepare detailed floodplain and hazard maps for the study reaches within the Vernon city boundary; assess the associated flood risk; evaluate mitigation options; and document and communicate the findings. The information developed is intended to be used for:

- Flood risk management (prevention and mitigation);
- Land use planning and land management;
- Emergency management; and
- Public awareness.

The flood maps and risk assessment provide the basis for the identification and implementation of mitigation measures to reduce flood risk.

Design flows for lower B.X. and lower Vernon Creek were determined through a combination of hydrologic modelling and analysis of gauge data within Vernon. Modelling of releases from Kalamalka Lake in a future climate resulted in an estimated 200-year return period release of 12.6 m^3/s from Kalamalka Lake into Vernon Creek. As in Part 1, the 1996 flood of record (5.8 m^3/s) from upper B.X. Creek was estimated to be larger than the 200-year flow on lower B.X. Creek and was used as the design event after an increase for climate change impacts (to 6.5 m^3/s). This flow was used as the design outflow from Swan Lake into B.X. Creek. Additionally, a combination of hydrologic modelling and gauge data analysis estimated a climate change adjusted 200-year local inflow within the city limits to B.X. and Vernon Creek of 7.1 m^3/s. This local inflow was distributed between B.X. and Vernon Creek based on contributing watershed areas.

The flood extents, levels and depths associated with the design flows were simulated with a hydraulic model. The model was developed in HEC-RAS software (the US Army Corps of Engineers Hydraulic Engineering Centre's River Analysis System) based on LiDAR and bathymetric survey data collected as part of this project. The model results were compared with past observations from the 2020 flood to verify the model prior to simulation of the design flood. A 0.6 m freeboard was added to the modeled water surface profile to account for local water level variations and uncertainty in the analysis. This design water surface was mapped by extending flood levels across the floodplain as represented by the LiDAR data, to approximate the extents of inundation. Isolines were added to the map at a uniform interval to provide recommended minimum flood construction levels (FCL).

The survey and all maps were prepared in the recently adopted CGVD2013 vertical datum. This should ensure ease of use, as the datum allows consistent survey with modern GPS survey techniques. Data in CGVD2013 is roughly 0.3 m greater in elevation than data in the previously used datum, CGVD28 (1928) HT2.0.

Stream setbacks are recommended at 15 m, according to EGBC guidelines. However, there are sections in the results with overbank flow that is further from the bank than 15m, and obstruction at culverts or bridges can further increase these areas. Setbacks are therefore recommended as 30 m in these locations to ensure flow remains unconstricted (indicated on the maps, Appendix C).

The flood risk assessment in this report presents a qualitative understanding of the impact of both the 20-year flood and the design flood event. Risk classification is based on ratings provided in the Risk Assessment Information Template (RAIT) and an example flood risk matrix provided by Engineers and Geoscientists of British Columbia (EGBC, 2018). The 20-year flood is classified as 'likely' by the example EGBC flood risk matrix and given a relatively high likelihood of 4/5 in the RAIT. The design flood event has a return period between 200 and 500 years, classifying it as 'unlikely' by the example EGBC flood risk matrix and giving it a relatively low likelihood of 2/5 in the RAIT.

An important finding from the flood risk assessment is that the fermenter building in the Vernon Water Reclamation Centre (wastewater treatment plant) is exposed to both the design flood and 20-year flood events. Cascading infrastructure failure due to flooding such as lack of electricity at the centre should be considered. The risk assessment also found that groundwater saturation or non-connected ponding could affect the stability of runway surfaces at Vernon's airports. Site specific studies of these facilities are outside the scope of this work, but may warrant consideration for emergency planning.

Additionally, though outside the boundary of the City of Vernon, the flood risk assessment found that the residents of Priest's Valley First Nation are anticipated to be affected by both the 20-year and design flood events.

There is a variety of both structural and non-structural flood risk reduction options, which have been selected and discussed based on the results of the analysis in this area. Non-structural mitigation options include:

- Land use planning; including setbacks, limiting housing densities in flood prone areas, requiring site specific flood hazard assessments and requiring buildings to be built to the provided FCL.
- Development of emergency response plans.
- Flood risk education for the public.
- Recovery pre-planning through the development of recovery plans and resources in advance of a flood or other hazard event.

Structural mitigation is considered as any specific engineering works that reduce flooding impacts. Several undersized crossing structures (overtopping / backwatering) have been identified in the study area and are summarized. Site specific structural mitigation measures to reduce flood risk within the community have been developed and modelled for the Part 2 study area:

- 43rd Street crossing upgrades
- Okanagan Landing Road crossing upgrades
- Lakeshore Road crossing upgrades

These mitigation options have also been ranked in combination with the recommendations in the Part 1 report to provide a comprehensive list of most significant mitigation options for the City of Vernon.

GLOSSARY

Definitions of technical terms used specifically in this report.

Crossing capacity:	The maximum discharge that can be conveyed through a crossing (bridge or culvert).
Debris:	Loose material that has the potential to be transported and deposited by streamflow processes. Can include sediment as well as vegetation, including wood and logs, rubble, litter, etc.
Digital elevation model (DEM):	A 3-D representation of earth's terrain in the form of a raster (grid-type) dataset, where each raster cell corresponds to a horizontal geographic location on the surface of the earth, and the value assigned to the raster cell is the elevation at that location.
Design flood:	A flood event selected for establishing design criteria and defined by some form of magnitude (generally including flow or water level) and often an associated probability of occurrence.
Flood construction level (FCL):	The sum of freeboard and the design flood level.
Flood fringe:	An area at risk from flood events that is not expected to experience high velocity, large depth, or substantially contribute to flow conveyance during flood.
Flood map:	A map that illustrates the design flood event as the inundation extent, flood level, flood depth, flood velocity, and/or flood timing.
Floodplain:	The land adjacent to a river or lake that may be submerged by floodwaters, in this case during the design event.
Flood Hazard Assessment	A report written by a Qualified Professional to characterize the flood processes, identify the existing and future elements at risk, and determine the flood intensity characteristics that may damaged the proposed development. It will determine whether the proposed development is subject to flood, debris flood, debris flow or other hazards. It does not address other potential natural hazards such as landslides, soil erosion, subsidence, or avalanches except as related to flooding.
Flood risk:	The product of the probability of floods occurring that have the potential to result in hazardous consequences and expected consequences of the floods.

Floodway:	An area at risk from a flood event that is expected to substantially contribute to flow conveyance and or experience high velocity or large depth of inundation during a flood. The floodway generally encompasses all active channels plus overbank areas and relic channels where velocities are estimated to be greater than 1 m/s and/or depths greater than 1 m.
Freeboard:	A vertical offset from the water surface calculated for the design flood event to account for local variations in water level and uncertainty in the underlying data and analysis.
Hazard map:	A map that highlights areas that are affected by or are vulnerable to a particular hazard.
Light detection and ranging (LiDAR):	A remote sensing technology used to create DEMs that employs a laser to measure distances from known elevations to the surface of the earth.
Natural boundary:	The visible high watermark of a lake, stream, river, or other body of water where the presence and action of the water is so common, usual, and long continued as to mark upon the soil a character distinct from that of the banks.
Peak daily flow (QPD):	The maximum of all daily-averaged streamflow that occurs in a given period (usually a year).
Peak instantaneous flow (QPI):	The maximum instantaneous streamflow that occurs in a given period (usually a year).
Qualified Professional:	A person with experience and training in the pertinent discipline, and who is a qualified expert with expertise appropriate for the relevant critical area
Return period (RP):	Also called average recurrence interval (ARI). The average time until an event (in this case a peak flow) re-occurs. Usually expressed in years.
Sediment infilling:	The process through which sediment transported by a stream is deposited in such a way that it reduces the cross-sectional flow area of a channel or crossing, often resulting in reduced flow capacity.
Setback:	Refers to the distance from the top of bank of a water body or existing dike in which development should be prohibited or restricted to limit local flood risk, limit transfer of risk to upstream properties, and provide sufficient space for future flood protection (e.g. dikes).
Structural mitigation:	Reduces flood risk through the establishment of new or modification of existing physical features that alter the hydrology or hydraulics of a flood.

Examples include dams, dikes, training berms, floodwalls, seawalls, bank protection works, flood retention basins, sediment basins, river diversions, floodways, channel modifications, sediment management, debris barriers, pump stations, and flood boxes.

Top of bank: The upper edge of a watercourse.

1D flow modelling: Modelling flow in one dimension, with simulations assuming all flow is parallel to the primary flow path.

2D flow modelling: Modelling flow in two dimensions, with simulations assuming all flow is planar to the water surface. Vertical flow components are not simulated.

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APPENDICES

1 INTRODUCTION

The City of Vernon (Vernon) is located on the northern end of Kalamalka Lake in British Columbia's North Okanagan. A number of streams run through the city, including Vernon Creek, which flows from Kalamalka Lake into Okanagan Lake, and B.X. Creek, which has its headwaters northwest of Vernon and runs through Swan Lake before joining Vernon Creek. These water bodies and creeks can impose flood hazard on the community. In order to define the flood hazard to the community, the City of Vernon retained NHC to develop floodplain maps for B.X. Creek and Vernon Creek within Vernon's city limits.

The project was split into two phases. Part 1 (NHC, 2020b) focused on upper B.X. Creek, upstream of Swan Lake. In this report (Part 2), the work focuses specifically on flood mapping and risk analysis on lower B.X. Creek, between Swan Lake and Vernon Creek, and Vernon Creek, from the outlet of Kalamalka Lake to Okanagan Lake. Information from Part 1, as well as NHC's recent work mapping the Okanagan Mainstem Lakes (NHC, 2020d) have supported the work described in this report. This report is intended as a complement to the Part 1 report; we avoid repetition of information from the Part 1 report when possible. Thus, review of both reports is recommended for full understanding of Vernon's updated floodplain mapping work.

1.1 Project Objectives

Building upon Part 1, the purpose of this project is to prepare detailed floodplain and hazard maps for lower B.X. Creek and Vernon Creek within the Vernon city boundary, assess the associated flood risk, and document and communicate the findings. The information developed is intended to be used for flood risk management (prevention and mitigation), land use planning, emergency preparedness, and public awareness.

As the underlying goal is the assessment and mitigation of flood risk to the community, the mapping and associated hydrology, survey, modelling, and hazard analysis is aimed to be of sufficiently high quality to avoid misrepresentation of the hazards. The flood maps and risk assessment provide the basis for the identification and implementation of mitigation measures to reduce flood risk.

1.2 Study Area

Part 2 of the Vernon floodplain mapping focuses on flood inundation along approximately 4.5 km of lower B.X. Creek, from the outlet of Swan Lake to the confluence with Vernon Creek, and along the approximately 11 km reach of Vernon Creek, from the outlet of Kalamalka Lake to Okanagan Lake. The model reaches are shown in Figure 1.1.

Boundary conditions are dictated by lake levels in Swan, Kalamalka, and Okanagan Lake. Modelling extends beyond the Vernon city boundary to sufficiently limit sensitivity to the model boundary conditions. Results are presented only within the City of Vernon boundary.

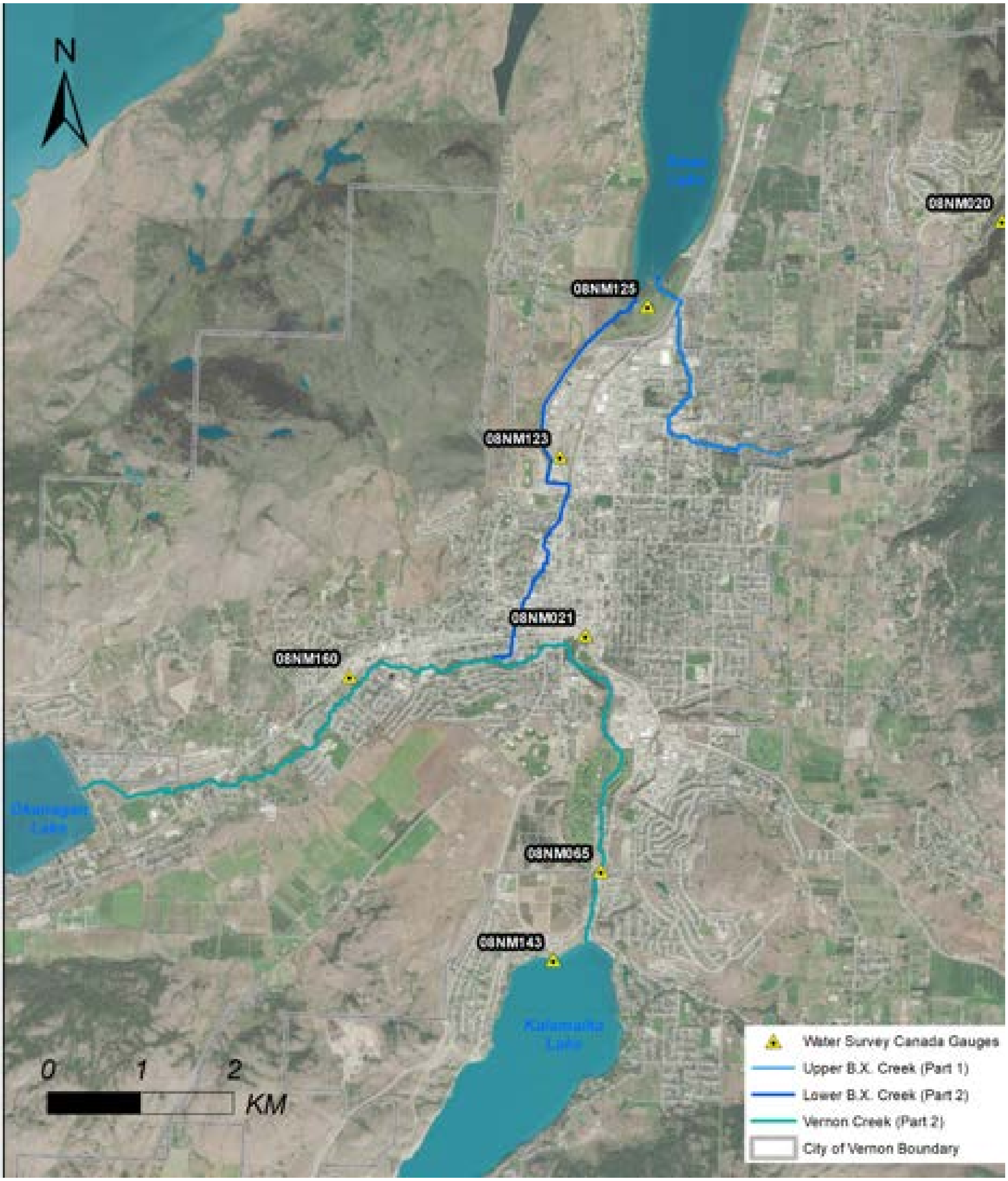


Figure 1.1 Project location for Parts 1 and 2.

1.3 Scope of Work

This report presents the main tasks completed for the City of Vernon's overarching "Detailed Flood Mapping, Risk Analysis and Mitigation Project" for Part 2: lower B.X. Creek and Vernon Creek. The tasks specific to Part 2 described in this report include:

- Data acquisition and background data review (Section 3)
- Geometrical survey of creek cross sections and crossings (Section 3.2)
- Hydrologic analysis (Section 4)
- Hydraulic analysis through the application of a coupled 1D/2D model (Section 5)
- Flood mapping of inundation limits, flood construction levels and hazards (Section 6)
- Flood risk assessment (Section 7)
- Flood risk reduction planning (Section 8)

Public engagement is being carried out via a web-based flood story map (in development as of August 2021).

1.3.1 Flood Mapping, Risk Analysis, and Mitigation

Flood risk reduction can be understood in the three steps depicted in Figure 1.2. While the steps are depicted in a linear fashion, they are a cycle which must be revisited and updated as actions are taken, new information becomes available, and a community evolves.

Flood risk reduction starts with understanding the hazard. The first step involves mapping the inundation extents, which is achieved by analysing and determining the design flood event. The maps are prepared to be readily understood by the public, engineering and design professionals, local government staff, and elected officials.

The next phase of flood risk reduction is a risk assessment to identify areas where valued community receptors are exposed to the modelled flood hazard. The risk assessment for this project is based on the flood hazard mapping and available receptor data. With the understanding of the hazard and risk presented by this project, local community members and decision makers have the information to begin the final phase of flood risk reduction: taking action.

Taking action for flood risk reduction can include structural and non-structural mitigation measures. Potential mitigation measures are identified as a part of this project; however, further analysis and community input is needed to develop a comprehensive flood risk reduction plan. In other words, this report represents one phase in the ongoing cycle of flood risk reduction.

Figure 1.2 Flood risk reduction process (NRCan).

1.4 Applicable Guidelines and Regulations

The following guidelines and regulatory documents are applicable to the flood and hazard mapping components of this project:

- Flood Mapping in BC, EGBC Professional Practice Guidelines, V1.0, 2017 (APEGBC, 2017)
- Flood Hazard Area Land Use Management Guidelines, Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD), Amended 2018 (MFLNRORD, 2018)
- Federal Airborne LiDAR Data Acquisition Guideline, V2.0, 2018 (Natural Resources Canada and Public Safety Canada, 2018)
- Federal Geomatics Guidelines for Flood Mapping, V1.0, 2019 (NRCan and Public Safety Canada, 2019)

Flood risk assessment is a non-standardized process, particularly in BC, where there are a wide range of potentially interacting flood hazards and inconsistencies in data and interpretation of receptors and associated vulnerability. Guidance for this project was attained from:

- Past flood risk assessments
- Legislated Flood Assessments in a Changing Climate in BC Professional Practice Guidelines (EGBC, 2018)
- Risk Assessment Information Template (RAIT) as part of the National Disaster Mitigation Program (NDMP) (Public Safety Canada, 2017)
- In-progress Flood Risk Assessment Procedures developed by NHC for Natural Resources Canada (NRCan).

1.5 Limitations

Floodplain hazard mapping, assessment of flood risks, and hydrologic and hydraulic modelling to support such work are core services for NHC. This study has been completed with ongoing review from Vernon and NHC's internal review team to assure the quality of services and deliverables. However, the study and its deliverables are still subject to the general limitations outlined below. Further detail on the assumptions, uncertainties, and limitations of each component of the study are provided in each section:

- The models developed and used in this study are based on current land-use conditions and historic data. Changes to land-use or new information or data may require analysis and the produced maps to be updated.
- There may be errors in the data and software used in this study that have not been identified.
- Streamflow values estimated for design are based on extrapolation of frequency analyses and model simulations to less frequent events. The impact of regulation operations on the outlets of Kalamalka Lake and Swan Lake are simulated versions of actual human operation during major flooding. Thus, the resulting design values have an inherent uncertainty.
- Model simulations for future conditions use plausible climate conditions that could occur in the future, given current projections on increases in greenhouse gas concentrations in our planet's atmosphere. The climate conditions that will actually exist in the future are not known.
- The floodplain mapping is based on a bare-earth representation of topography with further generalizing assumptions made for some of the mapped areas. New development or re-development may alter that surface used in the simulation and mapping, potentially altering the hydraulics from those simulated. Site-specific flood hazard assessments may be required to assess a specific proposed development.
- Occurrence of flood events larger than the flood-of-record for any areas included in the study should trigger re-evaluation of the design flood hydrology.
- Residual risk, greater than that shown in this report, exists; that is, a more extreme event (larger average recurrence interval) or sequence of events could result in higher flood levels and greater flood inundation than that mapped.
- Prior to engaging the public on the development of the flood maps, the City of Vernon pursued development of both structural and non-structural mitigation measures. The City shared the flooding mapping information while still in draft format with OKIB, OBWB and directly impacted key community facilities identified in Section 7 of this report. The Risk Assessment presented in this report is expected to evolve as a better understanding of the receptors and their vulnerability are better understood.
- Ground truthing (e.g. on-the-ground confirmation of data from GIS and satellite layers) was not applied in the development of this study to identify or assess vulnerability of flood risk receptors. Risk assessment results may vary as the understanding of receptors and their vulnerability are refined.
- The impact to people is calculated based on direct exposure (i.e. dwellings located within the mapped floodplain). Vulnerability and consequences extend beyond the exposed residents, as others would be impacted by a flood through transportation or service disruptions. However, these additional receptors were not incorporated in this flood risk analysis.
- Building damage estimates are based on damage curves developed for the United States as comparable Canadian curves were not available at the time of analysis. Construction standards differ in Canada so these damage estimates may not be entirely representative.

This document should be read and understood in its entirety before applying the maps, models, or other findings from this study. The reader is advised to seek the advice of a Qualified Professional to understand the study, its results, and the implications of any assumptions, uncertainties, and limitations.

2 BACKGROUND

2.1 Study Area Description

Both the watershed characteristics and the flood generating processes for lower B.X. Creek and Vernon Creek (Part 2 of the study) are notably different than those of upper B.X. Creek (Part 1). While upper B.X. Creek is driven by a relatively steep, natural, mountainous stream, lower B.X. Creek and Vernon Creek are dominated by regulated outflows from two lakes, and the local watershed area is primarily lower elevation terrain which does not see substantial winter snowfall.

Inflows to lower B.X. Creek are dominated by release from Swan Lake, which is regulated by a small dam at its southern end. Upper B.X. Creek flows into Swan Lake, with the lake's storage attenuating peak flows before flow continues downstream through the Swan Lake dam. Flow past the dam is regulated through the manual addition and removal of stoplogs by the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD). A full description of the dam and its operational strategy is available from Ecora (2019).

Similarly, flows on Vernon Creek within the study area are dictated by releases from Kalamalka Lake via the Kalamalka Lake dam at the northern end of Kalamalka Lake, near the corner of Westkal Road and Kalamalka Road. BC FLNRORD operates the gates of the Kalamalka Lake dam to balance multiple operational goals including:

- Avoiding flooding on Kalamalka and Wood Lake
- Maintaining high enough lake levels for recreational use and water supply
- Maintaining minimum environmental flows on Vernon Creek
- Minimizing exposure to damaging high flows on Vernon Creek or flooding within the City of Vernon.

In years when large inflows to Kalamalka Lake are expected, based on measurements of high elevation snow, Kalamalka Lake is drawn down in late winter in anticipation of a large spring freshet. A full description of the Kalamalka Lake operational strategy is available from AE (2017).

For the Kalamalka Lake dam, flows are generally dictated by operational decisions. However, during extreme high flow (or high lake level) situations, water has the potential to flow around the structure. During the 2017 freshet season, sandbagging was required around the Kalamalka Lake dam to maintain regulatory control and limit flooding downstream. Because floodplain mapping requires simulation of extreme high flow situations, our modelling focuses on these situations where regulation may no longer be effective; we developed an "open gates" scenario for the Kalamalka Lake dam, following the methods from NHC (2020d) used for the Okanagan River. This scenario uses a combination of empirical rating curve and hydraulic modelling to determine flows into Vernon Creek during extreme conditions. It is described further in NHC (2020a).

Along with the high flows that can occur due to high lake levels upstream of the study reaches, flooding on lower B.X. and Vernon Creek has the potential for two further exacerbating factors. The first is local inflows generated within the City of Vernon along the study reaches. Whereas the releases from Swan Lake and Kalamalka Lake are likely to be driven by spikes in inflow when lake levels are already high, local inflows can be caused by shorter, high intensity, rainstorms

Second, the downstream boundary condition of Okanagan Lake influences flooding at the lower end of the study area. High lake levels prevent water from draining quickly from lower Vernon Creek. This scenario is quite likely; high lake levels on Kalamalka and Swan Lake occur at the same time as high lake levels on Okanagan Lake. Our design flood events assume a scenario in which all these events occur at the same time.

2.2 Flood History

Various cases of local flood inundation have occurred within Vernon in the past 30 years. Notable events are summarized below. For a history of flooding in the entire Okanagan system, see the Okanagan Flood Story[1].

- Extreme lake levels on Okanagan and Kalamalka lakes in 1990 resulted in sandbagging in the City of Vernon (see Okanagan Flood Story).
- Extreme flows on upper B.X. Creek May 1996, led to high lake levels on Swan Lake (Summit, 1996).
- The highest flow release from Kalamalka Lake on record occurred in June 1997, due to extreme snow depth in the Okanagan watershed and high inflows to Kalamalka Lake (See Appendix A).
- Flow went over and around the Swan Lake Dam in 2012 (Vernon, pers. comm. 2020).
- Extreme lake levels were experienced on Okanagan and Kalamalka lake in 2017 due to high spring rainfall and rapid snowmelt in the spring of 2017 (AE, 2017; NHC, 2020d)
- Flooding near 48th Avenue in Vernon occurred May 2018 due to heavy rainfall (Vernon, pers. comm. 2020).
- Flooding near Polson Park in Vernon occurred 2020 due to heavy rainfall and apparently saturated ground (Vernon, pers. comm. 2020).
- Flow over and around the Swan Lake dam occurred during the 2020 freshet (Vernon, pers. comm. 2020).

[1] https://okanagan-basin-flood-portal-rdco.hub.arcgis.com/

2.3 Available Data

In addition to the data sources described in NHC (2020b), the following references and data sources were used:

- Vernon provided 2019 orthophotos for the lower B.X. and Vernon creek study area.
- Vernon provided utility infrastructure spatial data layers including BC Hydro, FortisBC gas, Shaw telecom, and Telus telecom infrastructure.
- Spatial data layers were obtained from the BC Data Catalogue for species and ecosystems at risk, critical habitat for federally-listed species at risk, and sensitive ecosystems (Government of British Columbia, 2021).

3 DATA ACQUISITION AND DEM DEVELOPMENT

3.1 Coordinate Systems and Datums

All elevation data and geographic information presented in this report use the following coordinate system and datums:

- Horizontal coordinate system: Universal Transverse Mercator (UTM) Zone 11. Coordinates are in metres.
- Horizontal datum: North American Datum of 1983 (NAD83) CSRS.
- Vertical Datum: Canadian Geodetic Vertical Datum of 2013 (CGVD2013)

The CGVD2013 vertical datum was used for modelling and mapping for this project as Canada has adopted CGVD2013 as the official datum, and the Province of BC is in the process of migrating to this new datum. In a recent study completed May 2021, which aimed to assess the current level of awareness of flood risks among the communities in BC, 42 of the 109 local governments that responded reported having created or updated floodplain maps. Of the 42 communities, 85% of those who knew which vertical datum was used reported using CGVD2013 (BCREA & UBCO, 2021).

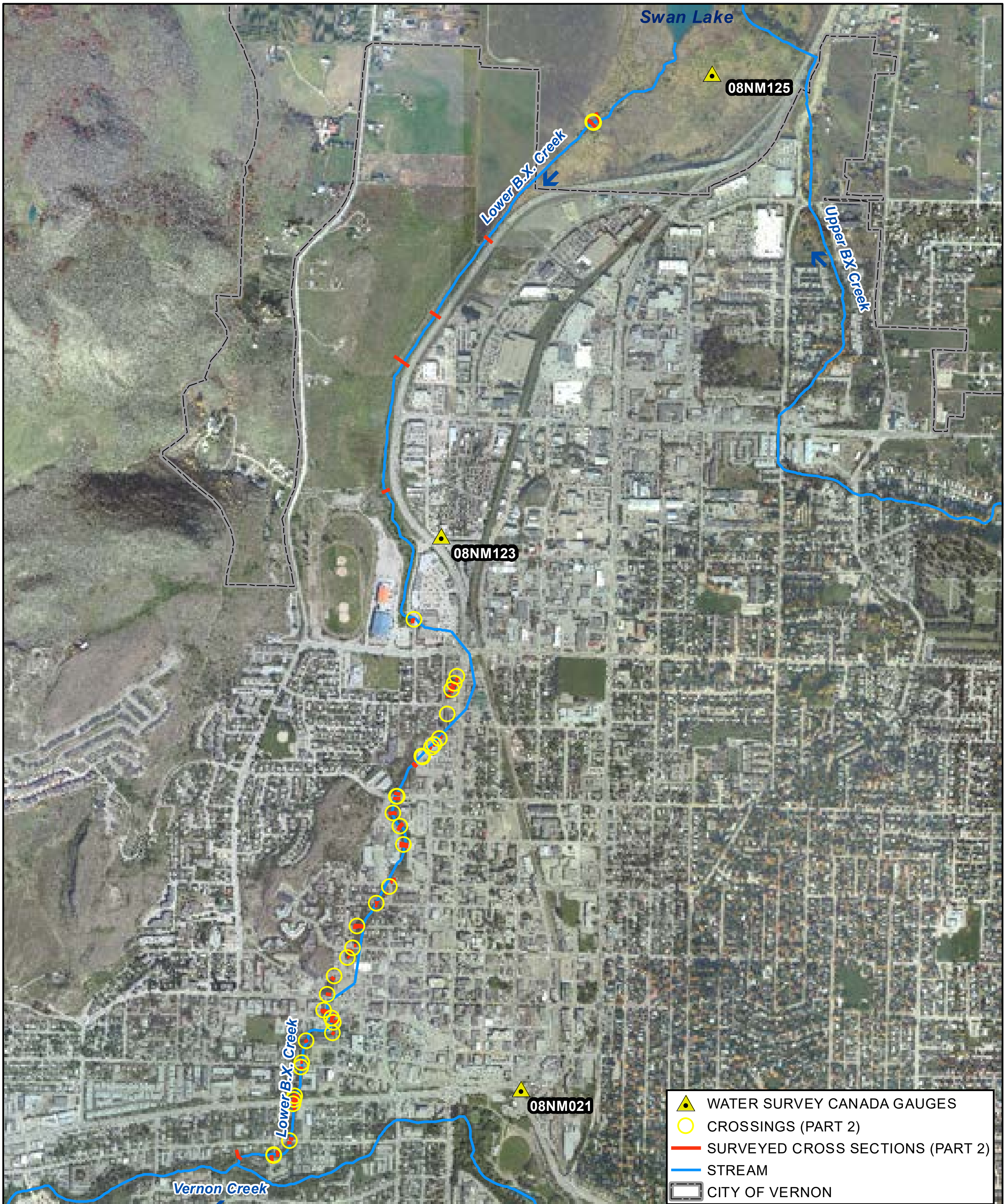
3.2 Survey

Over the span of 3.5 weeks (Sept 28th to October 25th, 2019), survey data concentrating on channel bathymetry was collected for both Part 1: upper B.X. Creek to Swan Lake and Part 2: Swan Lake along lower B.X. Creek to the confluence of Vernon Creek, and Kalamalka Lake along Vernon Creek to the inlet of Okanagan Lake. Survey equipment, data collection and data quality control details can be found in NHC (2020b). For the purposes of mapping and reporting, Vernon Creek has been split into upper Vernon Creek and lower Vernon Creek, divided by the lower B.X. confluence.

A total of 65 cross sections were surveyed along the 5.1 km reach of lower B.X. Creek, 62 cross sections along the 4.7 km reach of upper Vernon Creek, and 54 along the 6.3 km reach of lower Vernon Creek.

Cross sections were collected primarily upstream and downstream of each crossing structure (bridge, culvert, or pipe crossing) and at specific locations between crossings that were found pertinent to the model development. Project data collected includes bridge and culvert details for 110 structures within the project extent, 86 of which are along lower B.X. Creek and Vernon Creek. Detailed photographs of each crossing were taken during the survey and provided to Vernon with the collected survey data during Part 1.

Figure 3.1 and Figure 3.2 show the surveyed cross sections and crossing locations along each reach. A crossing inventory outlining observed and surveyed crossing information can be found in Appendix B.



CITY OF Vernon

nhc northwest hydraulic consultants

SCALE - 1:18,000

0 0.15 0.3 0.6 KM

N

Coordinate System: NAD 1983 UTM ZONE 11N
Units: METRES

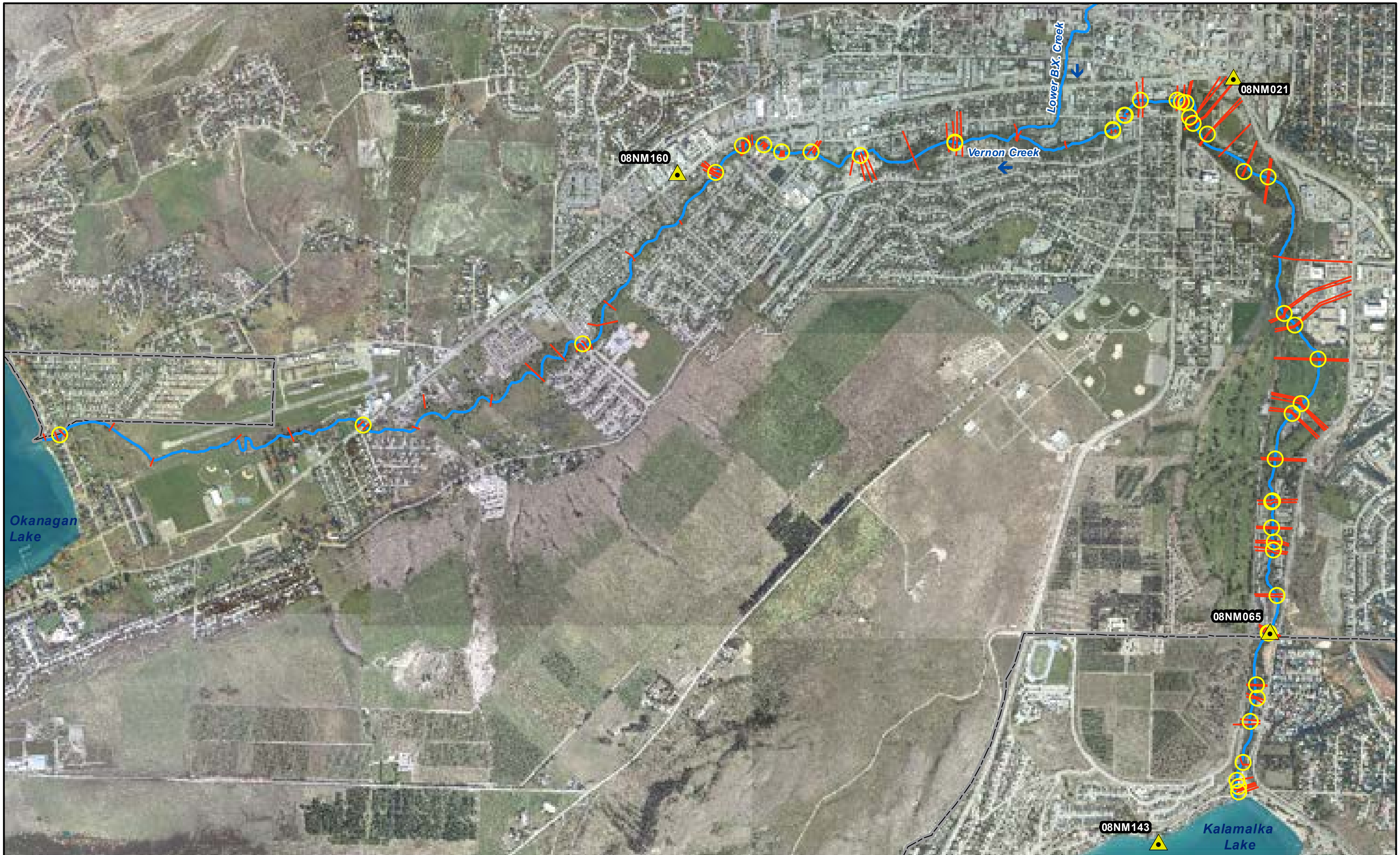
Job: 3005032 | 18-AUG-2021

CITY OF VERNON
FLOODPLAIN MAPPING

LOWER B.X. CREEK
SURVEYED CROSS SECTIONS
PART II

FIGURE 3.1

RLM, \\mainfile-van\Projects\Active\3005032 Vernon Flood Mapping\95 GIS\3005032_RLM_Fig_SurveyXS_Part2_US.mxd



CITY OF Vernon

nhc northwest hydraulic consultants

WATER SURVEY CANADA GAUGES
CROSSINGS (PART 2)
SURVEYED CROSS SECTIONS (PART 2)
STREAM
CITY OF VERNON

SCALE - 1:24,000

0 0.2 0.4 0.8 KM

N

Coordinate System: NAD 1983 UTM ZONE 11N
Units: METRES

Job: 3005032 | 18-AUG-2021

CITY OF VERNON
FLOODPLAIN MAPPING
VERNON CREEK
SUVEYED CROSS SECTION
LOCATIONS - PART II

FIGURE 3.2

RLM, \\mainfile-van\Projects\Active\3005032 Vernon Flood Mapping\95 GIS\3005032_RLM_Fig_SurveyXS_Part2_DS.mxd

3.3 Digital Elevation Model (DEM) Development

DEM development methodologies described in Part 1 covered the complete project area for both Part 1 and Part 2. Details describing LiDAR collection, point density, and accuracy can be found in NHC (2020b).

Bridges are typically removed from the LiDAR-derived bare earth DEM, so that the DEM approximately represents the channel under the bridge, whereas culverts are typically not removed from the DEM. Although this was the case with most of the DEM data supplied for the City of Vernon, some of the smaller structures were either missed or mistakenly identified by the LiDAR provider. One culvert was removed after LiDAR collection. A total of 11 structures were edited by NHC in the bare earth DEM. The locations are listed in the Table 3.1 below:

Table 3.1 DEM editing of bridge and culverts for the hydraulic model.

Location	NHC Crossing ID	Purpose of Edit
Downstream (8 m) of Swan Lake Weir	XING - 51	Triple barrel culvert removed by MoTI, 2020
32 St. and 42 Ave. – Blue Stream Motel	XING - 54	Bridge not removed – small pedestrian bridge
Kalamalka Rd. and College Way – Dutch's Campground	XING - 102	Bridge not removed – small wooden car bridge
Kalamalka Lake Rd. – Uncle Dave's Pizzeria and Alpine Center	XING - 104	Triple barrel culvert removed, mistaken as bridge – NHC patched in
Browne Rd. – Kalloway Greens	XING - 109.1	Bridge not removed – concrete vehicle bridge
Browne Rd. – Private Drive 409A and 409B	XING - 110	Bridge not removed – concrete vehicle bridge
Polson Drive – Vernon Golf and Country Club	XING - 122	Bridge not removed – concrete vehicle bridge
Polson Park near 32 St.	XING - 132	Bridge not removed – small steel walking bridge
34 St. south of 25 Ave.	XING - 136	Bridge not removed – large multilane vehicle bridge
24 Ave. – Private drive at back of Elephant Storage	XING - 144	Bridge not removed – large vehicle bridge

Where cross sections were needed in the hydraulic model, elevation data extracted from the DEM data was combined with the bathymetric cross section survey data. An additional 223 cross sections were added to the model based on the LiDAR and adjacent survey data. These additional sections were added to represent features in the channel not sufficiently captured in the survey data, such as channel widening or embankment elevation changes. The DEM was used to represent the overbank areas in the hydraulic model. Quality control and accuracy checks were completed for the LiDAR and survey data collected, and can be found in NHC (2020b).

Colour orthophotos collected by EMBC in 2018-2019 were provided by Vernon. Orthophotos were used to interpret features on the floodplain, help assess channel and floodplain roughness, supplement field survey information, and provide context in the interpretation of model results. They were also used to create the base image for floodplain mapping.

4 HYDROLOGY

This section summarizes the design flows developed for lower B.X. Creek and Vernon Creek. Development of the design flows are described in greater detail in NHC (2020a), attached as Appendix A to this report.

Flow in both lower B.X. Creek and Vernon Creek come from upstream, regulated lakes, thus standard flood frequency analysis on these creeks is inappropriate. NHC expanded upon the hydrologic and reservoir operations model developed for the Okanagan mainstem floodplain mapping project (NHC, 2020d) to model lake outflows to present and projected future (end of century) design conditions. As with Part 1, the 1996 peak flow on upper B.X. Creek (the flood of record, estimated as roughly a 500-year event) was used as the design event input to Swan Lake and lower B.X. Creek. According to model output from NHC's Okanagan mainstem model, this corresponds to a flow equivalent of a future 500-year event at the outlet of Swan Lake as well. For Vernon Creek, the 200-year return period outflow from Kalamalka Lake from the Okanagan mainstem hydrologic model was used as the design event, assuming dam gates were fully open.

Additionally, local inflows (assumed to occur during the design events) along each reach of the hydraulic model (Section 5) were estimated using a combination of hydrologic model output and observational data. Relevant design flows, used in the hydraulic modelling for the three input locations, are summarized in Table 4.1. The 20-year event is considered the 'likely' flood event used in the flood risk assessment and thus included in the Table 4.1. Note that future flows for the 20-year return period represent mid-century conditions (2041-2070) whereas design flows (200-year or flood of record) represent end of century (2071-2100) conditions. Mid-century conditions are considered to have a slightly lower uncertainty than end of century conditions.

Table 4.1 Design flow summary. Flows shown in m^3/s. * indicates primary design event flows.

Return Period (yr)	Vernon Creek from Kalamalka Lake		Lower B.X. Creek from Swan Lake		Local inflows to B.X. and Vernon Creek	
	Present	Future	Present	Future	Present	Future
20	6.1	8.5	3.6	4.1	5.1	5.5
200	8.4	12.6*	N/A	N/A	6.1	7.1*
1996 Event	N/A	N/A	5.8	6.5*	N/A	N/A

An elevation of 343.86 m (CGVD2013), the same design level for Okanagan Lake used in NHC (2020d) was used for the downstream boundary condition on Okanagan Lake during the design event. 342.89 m was used for the 20-year event.

5 HYDRAULIC MODELING

The hydraulic analysis of Part 2 is comprised of constructing and calibrating a numerical hydraulic model to calculate hydraulic conditions along lower B.X. Creek and Vernon Creek during the design flood event. This section discusses model development and calibration results. The resulting hydraulics (flood extent, depth and velocity) from simulation of the design flows are discussed in Section 6.

5.1 Model Development

The Hydrologic Engineering Center's River Analysis System (HEC-RAS), a freely available hydraulic modelling software program developed by the US Army Corp of Engineers (USACE) (Version 5.0.7, 2019), has been utilized for the hydraulic analysis of lower B.X. Creek and Vernon Creek. A 1D/2D coupled model was used to simulate flood flows in the channel. Where flow is predominantly in one direction, either in the channel or floodplain, 1D modelling was used. The 1D model reaches are based on cross sectional data of the channel. Where flow in multiple directions, such as across an overbank route not parallel to the main channel, 2D modelling was used. The 2D model simulates hydrodynamic flow routing over a surface represented by a mesh of interconnected elements. This modelling approach combines the advantages of 1D and 2D modelling, such as the inclusion of established bridge and culvert crossing representation in the 1D model and detailed representation of converging and diverging flow over the floodplain in the 2D model. This modelling method does present certain disadvantages, as a coupled 1D/2D model can often be more complex to develop and can exhibit numerical stability problems at the 1D/2D interfaces.

The hydraulic model covers a reach length of approximately 4.5 km on lower B.X. Creek from Swan Lake to the confluence with Vernon Creek, and 11 km on Vernon Creek from Kalamalka Lake to Okanagan Lake. The 1D model is based on digitization of the 2016 orthophoto, 181 cross sections derived from NHC in-channel surveys (2019), overbank LiDAR data, and a total of 67 crossings (38 bridges and 29 culverts) surveyed by NHC (2019). Where culverts size was unclear due to variable levels of sediment infilling, full culvert dimensions were extracted from available record drawings and the 2015 Stantec inspection (Stantec, 2016). Moreover, two crossings with variable geometries along their length were modelled using the most restrictive cross section dimensions (including the infilling noted during survey). Specifically, the crossing at 34th St north of 43rd Avenue – composed a box culvert followed by two differently sized circular culverts – and the crossing at 32nd St south of 25th Avenue – composed of an arch culvert followed by an ellipse culvert recessed under a bridge with an arch outlet – were both modelled to represent the smallest culverts. Details on all crossings are presented in Appendix B.

Long bending culverts and culvert size changes are not within HEC-RAS's capability to simulate. HEC-RAS cannot simulate head loss from pipe constrictions, expansions, or bends. Lower B.X Creek contains a large number of crossings that are either very long, bend, change size, or have some kind of obstruction within the culvert/bridge which makes them difficult to accurately simulate in the HEC-RAS model. A

PCSWMM model was therefore developed for lower B.X. Creek to verify the HEC-RAS simulation of these structures. PCSWMM is a

and watershed systems model developed by Computational Hydraulics International (CHI) which is designed to simulate pipe flow. Water surface profiles calculated using the two models were compared for a range of flows. This comparison was used to refine the simulation parameters for the HEC-RAS model.

The 2D floodplain model is comprised of 3 sections: 1) the confluence of lower B.X. Creek and Vernon Creek; 2) near the Vernon Water Reclamation Centre; and 3) at the outlet of Vernon Creek into Okanagan Lake (Figure 5.1). The 2D model is composed of a 5 m by 5 m mesh for the first two locations (the confluence and near the water reclamation facility), and a variably spaced mesh down to 5 m by 5 m near the Vernon Creek outlet. The topography is derived from the DEM described in Section 3.3. The 2D component does not include any municipal stormwater systems. Therefore, water can only flow along the terrain. This assumes that the design event would include high intensity rainfall within the city and storm sewers would be flowing at capacity. The 2D mesh assumes there are no temporary berms, dikes, or sandbags along the creek banks.

The design flow events and corresponding Okanagan Lake water levels defined in Section 0 were applied as fixed upstream and downstream boundary conditions, respectively. Local B.X. and Vernon Creek inflows were distributed based on the watershed area of the three main stream reaches within Vernon. For the design event (7.1 m^3/s) this resulted in:

- 1.1 m^3/s along lower B.X. Creek from Swan Lake to Vernon Creek (9.8 km^2 watershed area). This was applied at the upstream boundary at Swan Lake.
- 3.0 m^3/s for upper Vernon Creek from Kalamalka Lake to the confluence with B.X. Creek (25.2 km^2 watershed area). This was applied at the upstream boundary at Kalamalka Lake.
- 3.0 m^3/s for lower Vernon Creek from the confluence with B.X. Creek to Okanagan Lake (25.1 km^2 watershed area). As a conservative assumption, this was applied at the confluence of Vernon Creek and B.X. Creek.

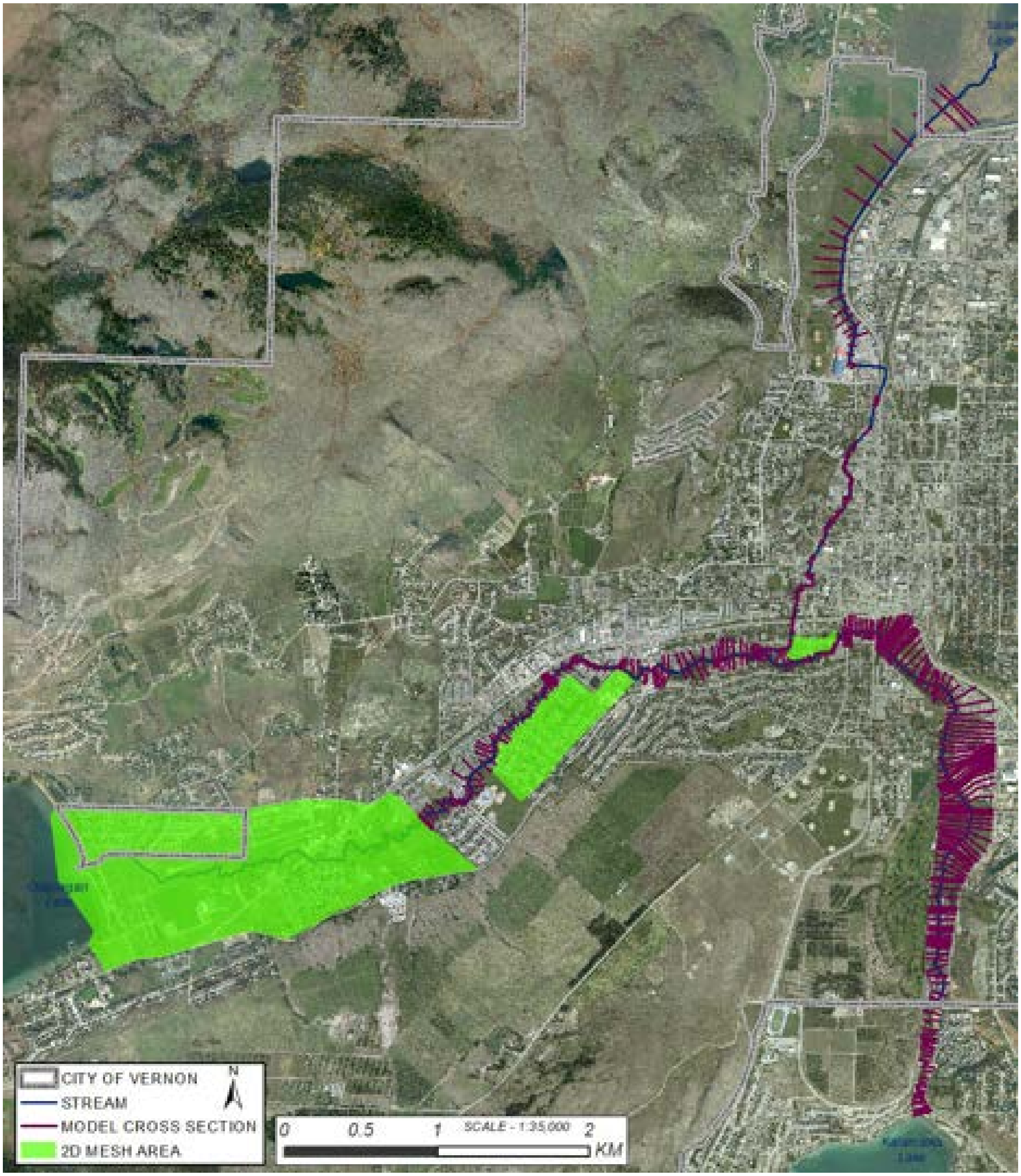


Figure 5.1 Hydraulic model layout map

5.2 Model Calibration

Evaluation of model parameters during calibration showed that, other than geometry (including blockage of culverts) and flow, channel roughness has the most influence overall on the simulated water surface elevation for Vernon and lower B.X. Creek. Entrance and exit losses for culverts also impacted the simulated water surface elevation locally. In contrast, overbank roughness has little effect due to most of the flow being conveyed within the channels except for near the outlet of Vernon Creek. The Manning's n value used to define channel roughness, following calibration, varied between 0.06 and 0.04; 0.06 was used in the more heavily vegetated portions of the reach and 0.04 in the less constricted sections. The roughness coefficients in the floodplain were defined based on the land use type according to the National Land Cover Database naming convention developed in 2011 by the Multi-Resolution Land Characteristics Consortium presented in Table 5.1 (MRLC, 2011).

Table 5.1 Roughness coefficient with respect to land use type.

Land use type	Manning's n
Barren land	0.04
Road	0.013
Cultivated crops	0.06
Developed high intensity	0.15
Developed low intensity	0.08
Developed medium intensity	0.10
Developed open space	0.04
Grassland / herbaceous	0.045
Mixed forest	0.08
Pasture / hay	0.06

Despite recent flooding in 2020, there is no survey record of flood levels or extents. The 1D model was calibrated using limited information consisting mainly of anecdotal accounts, news reports and photographic evidence of the 2020 flood provided by the City of Vernon. A sample of the photo record is illustrated in Figure 5.2. Water surface elevations and flood extents were deduced from such information and compared to model results for calibration purposes. The main calibration parameter was channel roughness as described above.

Figure 5.2 Photographic evidence of 2020 flood used for calibration purposes (provided by City of Vernon).

The spring 2020 discharge for Vernon Creek was collected from the WSC gauge - *Vernon Creek at Outlet of Kalamalka Lake* and the downstream lake level was collected from WSC gauge - *Okanagan Lake at Kelowna*. An accurate estimate of the 2020 discharge was not available for lower B.X. Creek.

Figure 5.3 shows the modelled profiles for the three observed flood events in spring 2020 compared to observed water elevations. Overall, there is good agreement between the calibration and the modelled water surface for the reach where calibration data is available. Upstream of the 32nd Street crossing on Vernon Creek, the modelled water surface elevation is about 40 cm higher than observed. This discrepancy could be caused by the changing size of the culvert. The inlet is an arch culvert but was modelled as an ellipse culvert because it is the smallest of the three culvert types in this specific crossing, and consequently the limiting factor. There was no photo data available for lower B.X. Creek and lower Vernon Creek and numerical calibration was not possible.

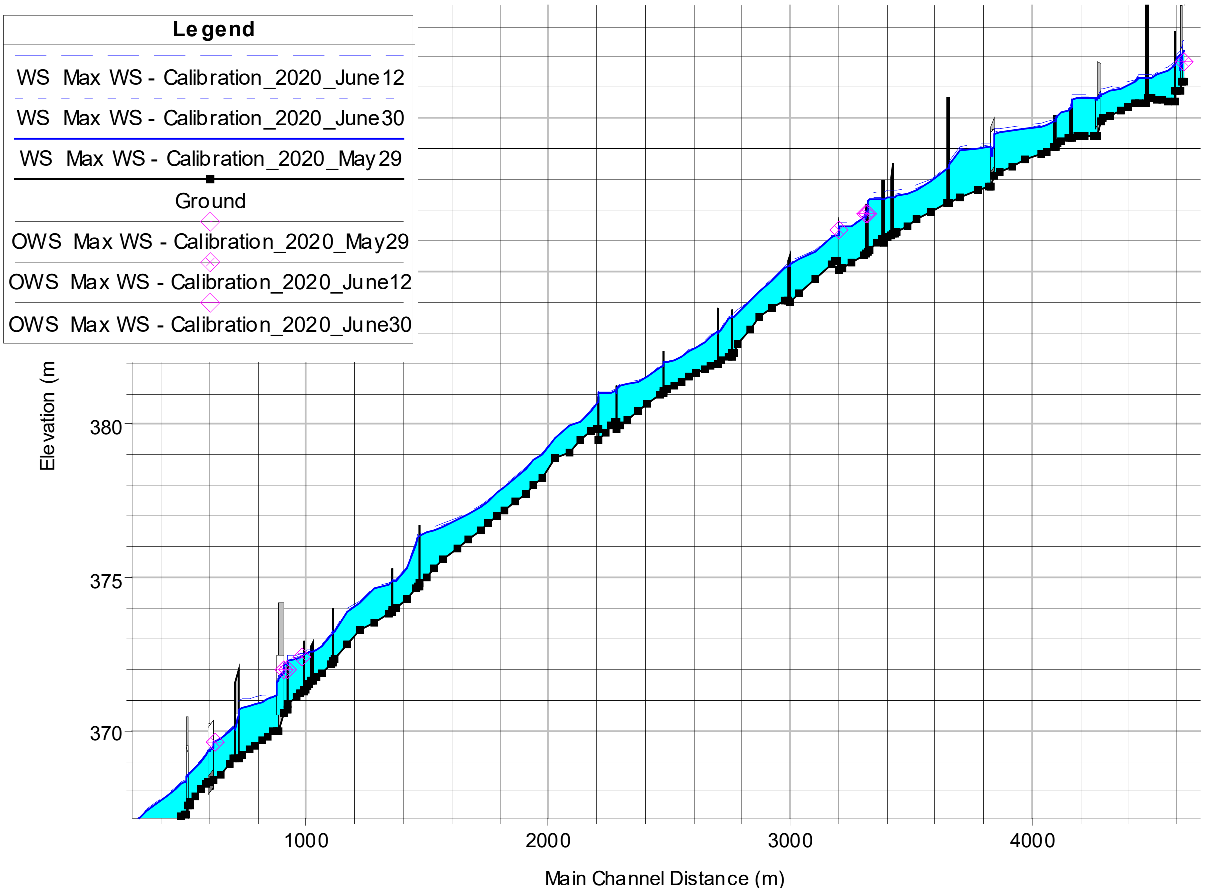


Figure 5.3 Calibration results for the 2020 spring flood, upper Vernon Creek (3 separate dates).

Given the sparsity of observed high water data and no available flow data for lower B.X. Creek or lower Vernon Creek during the 2020 flood event, no further calibration was carried out. This lack of calibration data limits confidence in the model results. Further model calibration should be conducted when water level and flow data from future high flow events is collected.

Model representation of the observed water surface is affected by the assumption that the channel geometry, particularly the bed, is fixed. During a flood event, the channel may degrade, widen, or become obstructed with sediment deposition or debris blockage.

5.3 Modelling Approach

The calibrated 1D model defined the following main areas of overbank flooding:

- Overbank flow on the right bank of Vernon Creek just upstream of 24th Avenue
- Overbank flow on the left bank of Vernon Creek at 43rd Street
- Overbank flow upstream and downstream of the Okanagan Landing Road
- Overbank flow upstream of Lakeshore Road

As a coupled 1D/2D model, the overbank flow in the above four areas were modelled using a 2D floodplain mesh. This allowed the simulation of overbank flow through town and around buildings. The 1D component of the model was linked to the 2D mesh either through a series of lateral weirs representing the high terrain along the banks which allowed water in and out of the channel or through a 1D to 2D connection in the channel. Flow overtopping at crossings (bridge decks) stays within the 1D component of the model. This limitation is considered acceptable as overtopping flow would likely flow over the road and into the channel downstream of the crossing.

A hydrograph with a prolonged peak was used in the simulation to mimic steady flow conditions. Simulations were run sufficiently long (24 hours) to ensure stable water surface elevations across the flood extents, indicative that equilibrium was reached.

5.4 Modelling Results

For the design flood event, flooding occurs in the following locations.

From Vernon Creek:

- Vernon Golf and Country Club and in Polson Park.
- 25th Avenue between 32nd Street (Hwy 97) and 34th Street
- Intersection at 24th Avenue and 34th Street; flow continues along 24th Avenue towards B.X Creek and along 34th Street back into Vernon Creek
- 24th Avenue further downstream, near 39th Street.
- 43rd Street and the subdivision south of the Vernon Water Reclamation facility
- Creekside Drive in two separate locations
- Okanagan Landing Road and several nearby streets and subdivisions
- Lakeshore Road and nearby neighborhoods to both sides of the creek

From lower B.X. Creek:

- Agricultural land near Swan Lake and Kal Tire Place
- Schell Motel (South of 30 Avenue)
- 36th Street near the confluence

Water mostly stays in the channel through the rest of Vernon Creek and lower B.X Creek. While the flow may be mostly confined to the channel, many of the culvert and bridge crossings along lower B.X. Creek are either at capacity or being overtopped. Obstruction at any of the crossings, from sediment deposition or debris, could result if greater flooding. Further discussion on the structure capacity can be found in Section 8.2 and Appendix E.

5.4.1 Sensitivity Testing

Due to the large number of crossings within Vernon, the model is sensitive to several parameters. Variations in flow (for example a 25% increase) can increase the water level roughly 0.1 m – 0.15 m throughout the channel. However, the local flooding at a structure can increase upwards of 0.5 m. This can cause a structure that was close to, or at capacity, to overtop a road or flood nearby properties. The crossings are also sensitive to blockages. If a blockage were to occur in a channel or at the crossing during the flood, it would change the water level in the channel, possibly sending it overbank and over the roads. The model is also sensitive to the entrance and exit losses of the culverts locally, which affect the head and tailwater elevations. The model is not very sensitivity to roughness coefficient in the overbanks.

5.5 Limitations

The following is a sample of assumptions and limitations of this study. Despite these limitations, the flood maps produced are expected to sufficiently represent design flood levels and extents to be used for flood mitigation planning.

- The channel bed and banks are fixed.
- The current study does not investigate probability or impact of structural failure of the dams at Swan Lake and Kalamalka Lake.
- Flood extent boundaries have not been verified in the field.
- The design flood events have been selected based on typically accepted level of probability of exceedance. Events less likely to occur (longer average return period) can occur and result in increased flooding.

Uncertainties in the model geometry are:

- Uncertainties in survey data (0.05-0.10 m for topographic data and ~0.05 m for gauge station data) and fluctuations between the cross sections that were surveyed (can be much larger than the stated survey error).
- Uncertainty in the LiDAR data: the LiDAR data has a reported density of 30 points per m^2 and a non-vegetated vertical accuracy root mean square error (95 % [1.96*RMSEz]) of 0.092 m. These are within NRCan's recommended LiDAR accuracy and density values for flood mapping (Natural Resources Canada and Public Safety Canada, 2019).
- Although specified to contain bare-earth data, the LiDAR used for developing the DEM may contain some artificially high points, especially in areas where the vegetation is dense, creating unrealistic "dry spots" for some floodplain model runs. Additionally, the DEM may contain low points or under predict the crest height on structures that are porous by natures (large rock constructs such as breakwaters or riprap structures).
- Culverts, ditches, and other drainage features located on the floodplain instead of the creek channels were not incorporated in the model.

6 FLOOD AND HAZARD MAPPING

The hydraulic model results for the design flood events were mapped. Two types of maps were produced:

1. Floodplain maps: maps of flood inundation limits and flood construction levels, including freeboard.
2. Flood hazard maps: maps of flood depth and velocity, excluding freeboard.

Maps are displayed on a set of six 22" x 34" map sheets at a 1:4,000 scale. The coordinate system used is UTM Zone 11 metres NAD 83 (CSRS) and CGVD2013 vertical datum. The floodplain maps are accompanied by a 1:25,000 scale index map which includes detailed map notes. Index, floodplain, and hazard maps are included in Appendix C. Geographic information system (GIS) layers produced for flood mapping are summarized in Table 6.1.

Table 6.1 Floodplain mapping GIS layers.

Description	Includes Climate Change	Includes Freeboard	Includes FCL	Polygon, Line, or Point	Depth Raster	Velocity Point
FLOODPLAIN INUNDATION AND HAZARD (1D & 2D MERGED MODEL RESULTS)						
Mapping limit	n/a	n/a	n/a	Y-on map	n/a	n/a
Flood construction levels (FCL) isolines	Y	Y	Y-on map	N	N	N
Design flood event extent (with freeboard)	Y	Y	Y-on map	Y-on map	N	N
Design flood event extent (without freeboard)	Y	N	N	Y	Y	Y
20-year flood event extent (without freeboard)	Y	N	N	Y	Y	N
MODEL REFERENCE LAYERS						
Surveyed river cross sections	Y	Y-depending on event	n/a	n/a	n/a	n/a
Model 1D/2D area boundaries	n/a	n/a	n/a	Y	n/a	n/a
Bridges and culverts	n/a	n/a	n/a	Y-on map	n/a	n/a

6.1 Flood Inundation Limits and Flood Construction Levels

A floodplain map has been provided for the design flood event showing inundation limits and FCLs based on hydraulic model results for the 1996 event on lower B.X. Creek and 200-year event on Vernon Creek (Section 5.4).

Freeboard is added to the simulated water level to provide a minimum level for construction within the floodplain, referred to as the flood construction level (FCL). The freeboard accounts for local variations in water level (i.e., super elevation, turbulence, surging) as well as for the confidence in the data and assessment. APEGBC (2017) suggests that a minimum freeboard of 0.3 m should be applied to the annual peak instantaneous (QPI) flows and 0.6 m to the annual max daily (QPD) flows. For lower B.X. Creek and Vernon Creek, a 0.6 m freeboard has been applied to the design flood event (QPI flow). This freeboard is considered appropriate given the sparse data available for model calibration and potential for local increases in water level associated with partial obstruction of any of the many culverts and bridges within this study.

The FCLs are based on model results plus freeboard. For the 1D model area, the freeboard is added to the cross sections and projected out along the cross section. For areas modelled in 2D, flood extents and FCLs were defined based on the water surface elevation calculated by the model with the addition of freeboard. All FCLs have been clipped to the flood extents and the City of Vernon administrative boundary.

6.1.1 Use of FCLs

FCLs are documented on the floodplain maps with labelled isolines. The FCL for a specific building or space is to be taken as the highest FCL applicable for that location, which is considered the FCL at the upstream extent of the building or space. Where the building or space is located between isolines, two options exist for determining the applicable FCL:

- Approach 1: the FCL is taken as the value represented by the next upstream isoline, or
- Approach 2: the FCL is calculated through linear interpolation between the two isolines in which the upstream face of the building or space is located.

An example is presented below based on the building and mapped isolines shown in Figure 6.2:

- The highlighted FCL line has an elevation of 403 m, with the downstream FCL (shown as a black line) having an elevation of 402 m. The distance between these lines is 45 m, and the upstream side of the building is 39 m upstream from the 402 m FCL isoline.
- The FCL for the labelled building can be calculated as follows:
  - Approach 1: $403.0\ \text{m}$
  - Approach 2: $402.0 + (403.0 - 402.0)\left(\frac{39}{45}\right) = 402.6\ \text{m}$

If Approach 2 is to be used, the user is recommended to extract distances from the Vernon GIS mapping program to avoid scaling issues from floodplain maps.

Figure 6.1 Example of FCL line calculation.

6.1.2 Mapping Boundaries and Filtering

The standard approach of projecting the FCL perpendicular across the floodplain is not possible for all locations mapped. At some locations the FCL projects across a dropping slope instead of a rising slope, suggesting an ever-increasing flood depth. Where such a condition exists and the flood level without freeboard is above the banks, 2D modelling was used to determine an expected flow path and depth. The results of the 2D model were then used to define the overbank FCL. Where only the freeboard extended overbank, a boundary was defined. Beyond this boundary, any overbank flow is expected to be low enough to be blocked (such as with sandbags or a flood barrier) or thinned out enough (sheets of water in the gutters of the roads) to be intercepted by existing stormwater infrastructure under the design event. As further precaution, an FCL for these unmapped areas can be defined as 0.3 m above the surrounding dominate grade to account for the potential water that might flow to these areas.

Filtering was used to remove isolated inundated areas and isolated elevated areas smaller than 100 m^2. This is typically done to improve the readability of the maps and to limit the reliance on slight variations in floodplain topography, which may change with time. Isolated inundation areas smaller than 100 m^2 were removed, except for those within 40 m of direct inundation; these were mapped as inundated to account for culverts or seepage that may be connected to these isolated wet areas.

6.1.3 Setbacks

Setbacks from waterbodies are defined to maintain the floodway and limit the risk of future development becoming impacted by channel migration and bank erosion. Additionally, setbacks may be increased in areas where structural mitigation is recommended to ensure such areas are not taken for development. Setbacks have been defined on the floodplain maps.

FLNRORD (2018) defined setbacks on small streams as 15 m from the natural boundary of the channel, given that the channel is not obstructed. For Vernon Creek and B.X. Creek, the natural boundary is either at or within the top of banks for the creeks. The setback has been established from the top of bank for the floodplain maps to further address future slumping or failure of the banks due to scour and erosion. However, there are sections with overbank flow that is further from the bank than 15 m, and obstruction at culverts or bridges can further increase these areas. Setbacks are therefore recommended to be increased to 30 m in such locations. The prescribed increase in setback is to ensure the flow is not constricted (potentially increasing upstream flood hazard), future development is not at excessive threat to high velocity flow or erosion, and to provide space for future construction of structural mitigations (such as dikes).

6.2 Flood Hazard

The flood hazard map depicts the design flood event. Simulated water depths are shown for each inundated cell in the 2D mesh and calculated velocities were filtered down to a 20 m grid to clearly represent overland flow and in-channel velocities at the 1:4,000 mapping scale. Within the river channel in 1D locations, flood depths are based on 1D model results and velocities are based on 1D model velocities at cross section locations. 1D velocity arrows within the channel that overlap at a 1:4,000 scale were filtered from the hazard map. Freeboard was not included in mapped depths or extents on the hazard map.

The colour shading used to represent depth listed in Table 6.2 references the Okanagan Flood Mapping Standards (NHC, 2020e), which were adapted from the European Exchange Circle on Flood Mapping (EXCIMAP, 2007) and the national standard in Japan (MLIT, 2005). Full bathymetric survey data was not collected for the entirety of the reaches, only at cross section locations. As such, the deepest depths (purple) are not representative of accurate in-channel depths and have been labeled as "> 2.0; River". The description of potential consequences stated in Table 6.2 are based on those presented from the original references. These consequences are expected to be relevant but are generic and not verified against the specific buildings, electrical system, and roads present in the study area.

Table 6.2 Flood depth description.

Depth (m)	Description of potential consequence	Colour (RGB)	Example
< 0.1	Most buildings expected to be dry; underground infrastructure and basements may be flooded.	Yellow (255/255/0)	
0.1 – 0.3	Water may enter buildings at grade, but most expected to be dry; walking in moving water or driving is potentially dangerous; underground infrastructure and basements may be flooded.	Green (8/255/0)	
0.3 – 0.5	Water may enter ground floor of buildings; walking in moving or still water or driving is dangerous; underground infrastructure and basements may be flooded.	Light Blue (115/178/255)	
0.5 – 1.0	Water on ground floor; underground infrastructure and basements flooded; electricity failed; vehicles are commonly carried off roadways.	Medium Blue (0/112/255)	
1.0 – 2.0	Ground floor flooded; residents and workers evacuate.	Dark Blue (0/38/115)	
> 2.0; River	First floor and often higher levels covered by water; residents and workers evacuate.	Purple (76/0/115)	

7 FLOOD RISK ASSESSMENT

A flood risk assessment has been completed for the Part 2 study area, evaluating the impacts of the 20-year and design flood scenarios. The following sub-sections discuss the risk assessment approach, data sources, findings, conclusions, and limitations.

7.1 Approach

For this project, a flood risk assessment is the process by which the consequence and likelihood of flooding is assessed. Best practices for a risk assessment includes a spatial analysis using available flood hazard information and mapping of receptors (people, economy, culture, and environment) that are affected by flooding. Figure 7.1 provides an outline of the components of a risk assessment; detailed definitions of the presented terms are in Section 7.2.

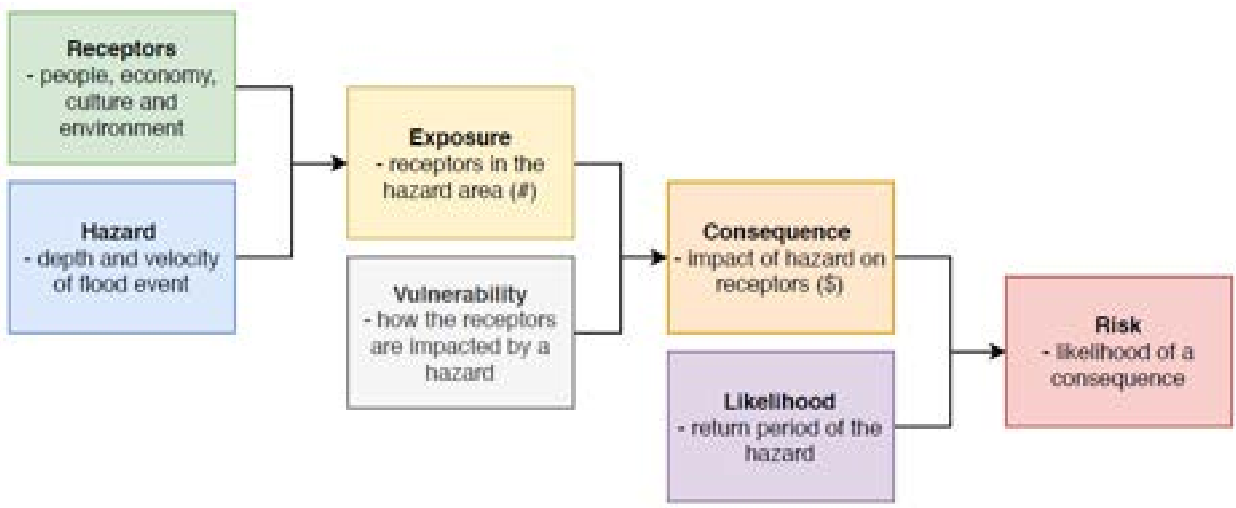


Figure 7.1 Risk assessment terminology and concept diagram.

7.2 Terminology Definitions

Receptors

Within flood risk assessments, "receptors" is a term commonly used[2] for the entities that may be harmed (a person, property, habitat, etc.) by a flood hazard (FLOODsite, 2005).

In this project, receptors are categorized as *people, economy, environment*, and *culture* as shown below in Figure 7.2. This figure includes the associated icons from the United Nations Office for the Coordination of Humanitarian affairs (OCHA) for each category. For this project, both locally and

[2] Valued asset is an alternative phrase used for receptor

provincially available datasets were used, however, the project was completed without direct ground truthing (e.g. field investigations) of receptors. It is expected that future work should include this step.

Figure 7.2 Receptor categories including icons (UN OCHA, 2018).

Additionally, as the City of Vernon is pursuing both structural and non-structural mitigation options, this project was completed prior to extensive community input on flood receptors. Public engagement and community input may be planned for a later time to validate and refine this risk assessment.

Hazard

A hazard is "a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation" as defined by the UN report on terminology relating to disaster risk reduction (United Nations, 2016). A flood hazard may refer to flood water characteristics including depth, velocity, debris, duration, and onset speed of the event. For this study both flood depth and velocity were modelled, however flood depth forms the basis for much of the risk assessment.

Exposure

Exposure is "the [location] of people, infrastructure, housing, production capacities and other tangible human receptors in hazard-prone areas" (United Nations, 2016). Exposure is assessed by identifying the receptors located within the delineated hazard areas; that is, within the inundation extents. For example, buildings which are in the flood hazard area are identified and considered in the calculation of exposure.

Vulnerability

Vulnerability is the measure of how susceptible a receptor is to a specific hazard. To illustrate the concept of flood vulnerability, a house constructed to an elevation lower than the local FCL would have a higher vulnerability compared to house built to an elevation higher than its respective FCL, even if both houses are on the floodplain. Vulnerability is determined by “physical, social, economic and environmental factors or processes which increase the susceptibility of a receptor to the [consequence] of hazard” (United Nations, 2016).

Vulnerability of buildings can be analyzed through depth-damage curves, which estimate the percent damage for a given flood depth based on building type and elevation. Vulnerability for other receptors are generally more challenging to quantify, and due to the level of detail of this assessment, have not been considered. Vulnerability could be added at a later phase for other receptors, such as social vulnerability (for people), environmental vulnerability (for habitat), flood resistance of particular crops (for agricultural lands); through local assessment of receptors; and through engagement with local stakeholders.

Consequence

When considering risk analysis, the concept of consequence is understood in the same way as impact. The UN defines disaster impact as “the total effect, including negative effects (e.g., economic losses) and positive effects (e.g., economic gains), of a hazardous event or a disaster. The term includes economic, human and environmental impacts, and may include death, injuries, disease and other negative effects on human physical, mental and social well-being” (United Nations, 2016).

To determine the consequence of a flood event, exposure to a hazard and vulnerability are combined. For example, a depth-damage curve for a structure with a given construction type (vulnerability) is applied to the value of a building with that construction type that is flooded to a depth of two metres (exposure). This combination of exposure and vulnerability gives the consequence of the flood event. This is used to calculate risk in combination with likelihood. The consequences of floods are often framed as net negative, however some benefits can also be realized, such as redevelopment or soil nutrient replenishment.

Likelihood

Likelihood is the probability of an event occurring. The probability is often presented with respect to the design life or as an annual probability, stated as the annual exceedance probability (AEP). The AEP is also expressed as its inverse, that is the average return period for an event; e.g. a 1 in 100 year flood has a return period of 100-years and 1 % AEP, and a 1 in 200 year flood has a return period of 200-years and 0.5 % AEP.

Risk

In engineering, risk is typically analyzed as “the combination of the likelihood of an event and its consequence” (California Natural Resources Agency, 2018). Put mathematically:

$$Risk = Consequence \times Likelihood$$

7.3 Methods and Results

The following sections discuss the specific receptors considered within the categories of people, economy, environment, and culture. For both the 20-yr and design flood events, the modelled flood extent and depth (without freeboard) have been overlaid with spatial datasets using GIS analysis to determine which receptors will be exposed to flood hazard. Vulnerability of the exposed receptors to the flood hazard has also been assessed, where possible. This has been completed for Vernon and, where applicable, the community of Priest's Valley 6, which is located southwest of Vernon at the downstream extent of Vernon Creek.

7.3.1 People

To determine flood impacts to people, an assessment was conducted to estimate the number of Vernon residents likely to be displaced from their homes. It has been assumed that such displacement from a residential building will occur if the building is exposed to flooding. The building is considered exposed if:

- The building is within the flooded area; or
- Roadway flooding prevents access to the building.

Population information was sourced from Canadian Census data (most recently available from 2016). As census data are reported by aggregated areas, the smallest of which is a census block, there is substantial error associated with using census results to study the populations of small areas. As such, the census data was used solely to calculate the average population per Vernon dwelling, which is 2.2 people.

A building analysis was then conducted to estimate the number of exposed dwellings. Vernon provided NHC with spatial data layers containing:

- Building footprints;
- Vernon Official Community Plan (OCP) land use plan; and
- Vernon zoning districts.

OCP land use designations were used to identify which of the flood exposed buildings are classified as residential. Multi-unit residential buildings were identified from the Vernon zoning districts and the number of dwellings per multi-unit building was estimated based on satellite imagery and Google Street View.

The assumed residential density of 2.2 people per dwelling located within Vernon was applied to the total estimated number of dwellings in exposed residential buildings to approximate the exposed population. The estimated number of dwellings (residential units in residential buildings) and people exposed to flooding are summarized in Table 7.1.

Table 7.1 Estimated Vernon population displaced by flooding based on number of exposed dwellings.

Factor	20-year Flood Event	Design Flood Event
Exposed Dwellings	580	1320
Displaced Population (number[1])	1,276	2,904
Displaced Population (percent[2])	3%	6%

Notes:
1. Assumes 2.2 people per Vernon dwelling based on 2016 census data.
2. Based on total Vernon population of 48,073 from 2016 census data.

7.3.1.1 Priest's Valley

Priest's Valley 6 is an Indigenous reserve of the Syilx Okanagan People, located on the shores of Okanagan Lake directly southwest of Vernon, along the downstream extent of Vernon Creek. The extent of flooding through this area is notable for both the 20-year and design flood events.

Though Priest's Valley is located outside of the Vernon city limits, the urbanization of B.X. Creek and Vernon Creek within Vernon could influence flood effects on the downstream community. Furthermore, in the event of a hazardous flood, Priest's Valley residents are likely to be displaced into Vernon and use resources available to them there.

The same methodology introduced in Section 7.3.1 was employed to estimate the number of Priest's Valley residents exposed to the 20-year and design floods. Based on 2016 Canadian Census data, the average population per Priest's Valley dwelling is 2.1 people. The estimated number of dwellings and people exposed to flooding are summarized in Table 7.2.

Table 7.2 Estimated Priest's Valley population displaced by flooding based on number of exposed dwellings.

Factor	20-year Flood Event	Design Flood Event
Exposed Dwellings	60	138
Displaced Population (number[1])	126	290
Displaced Population (percent[2])	20%	46%

Notes:
1. Assumes 2.1 people per Priest's Valley dwelling based on 2016 census data.
2. Based on total Priest's Valley population of 628 from 2016 census data.

7.3.2 Economy

Key economic receptors include agricultural land, infrastructure, and buildings. The receptors exposed to the 20-year and design floods were identified within the following spatial datasets, which were provided to NHC by Vernon unless otherwise cited:

- Vernon OCP land use plan;
- Vernon zoning districts;
- Stormwater mains (City of Vernon, 2021);
- BC Hydro infrastructure including underground hydro distribution (primary and secondary lines), overhead hydro distribution (primary and secondary lines), hydro poles, hydro junction boxes, underground transformers, manholes, and transmission structures;
- Fortis BC gas infrastructure including distribution valves, distribution pipes, distribution stations, transmission pipes, transmission valves, and transmission pipe facilities;
- Shaw and Telus telecom infrastructure including telecom facilities, telecom poles, underground lines, cable wires, and manholes;
- Transportation infrastructure including roads (City of Vernon, 2021) and railways (Natural Resources Canada, 2013); and
- Building footprints.

7.3.2.1 Agricultural Land

There are several rural properties near the upstream extent of lower B.X. Creek that are classified as ALR (Agricultural Land Reserve) by the Vernon OCP. The Vernon zoning districts classify these properties as country residential rather than agricultural, and from a desktop study using Google Maps and Google Street View it has been assumed that these properties are not currently used for agricultural purposes. However, given their ALR classification, there is potential that they will be used for agriculture in the future, in which case there would be some economic risk for exposure to flooding. During the 20-year event 1.4 ha of ALR land will be inundated from flooding on B.X. Creek, and during the design flood event, 12.4 ha of ALR land will be inundated.

Based on the assumption that these ALR properties are not currently used for agriculture, there is no present flood risk to agricultural land within the study area. This may change if the land is developed for agriculture in the future, or if ground truthing can confirm that any of the properties are presently used for agricultural practices. Additionally, flooding is not necessarily a detriment to agricultural land, if infrastructure is undamaged. Flooding can help replenish nutrients to soils and thus increase future productivity.

7.3.2.2 Utility Infrastructure

Utility infrastructure found within the modelled flood extents of the 20-year and design events are summarized in Table 7.3. More specific details of the exposed infrastructure components are provided in Appendix D.

As infrastructure ranges from below grade to above grade, the relationship between flood depth and consequence is not consistent. Therefore, flood depth was not considered for this assessment of consequence. The results shown should be used to understand exposure and potential disruption to utility infrastructure, rather than damage. To determine potential damage to infrastructure, utility companies should be involved in identifying the impacts of inundation. Impacts can include water damage, short-circuiting, undermining poles and structure foundations, flooding underground hydro or transmission infrastructure, storm sewer backups, and increased uplift forces for inundated buoyant infrastructure (i.e. pipelines and closed chambers).

Table 7.3 Exposed utility infrastructure.

Infrastructure Category	Infrastructure Type	Quantity[1]	20-year Flood Event	Design Flood Event
Stormwater	Mains	Count	75	115
		Length (m)	3,442	5,441
BC Hydro	Primary underground distribution lines	Count	6	20
		Length (m)	356	957
	Secondary underground distribution lines	Count	19	33
		Length (m)	448	734
	Primary overhead distribution lines	Count	56	129
		Length (m)	3,214	6,034
	Secondary overhead distribution lines	Count	140	328
		Length (m)	3,766	7,923
	Poles	Count	54	118
	Junction boxes	Count	0	1
	Underground transformers	Count	0	2
	Manholes	Count	0	0
	Transmission structures	Count	0	1
FortisBC Gas	Distribution valves	Count	0	1
	Distribution pipes	Count	47	91
		Length (m)	5,830	10,115
	Distribution stations	Count	0	0
	Transmission valves	Count	0	0
	Transmission pipes	Count	8	9
		Length (m)	325	420
	Transmission pipeline facility	Count	0	0
Shaw Telecom	Telecom facility	Count	12	30
	Poles	Count	78	152
	Manholes	Count	0	0
	Underground lines	Count	32	78
		Length (m)	1,928	3,775
Telus Telecom	Telecom facility	Count	0	0
	Poles	Count	32	79
	Manholes	Count	0	3
	Cable wire	Count	53	102
		Length (m)	5,836	7,981

Notes:
1. For linear features such as mains, lines, pipes, and wires, "Count" refers to the number of segments within the flood affected area and "Length" refers to the total length of the exposed segments.

7.3.2.3 Transportation Infrastructure

Road infrastructure in Vernon and Priest's Valley has been assessed for exposure to flooding based on the provided road widths, or an assumed width of 5 m if no width data was available. A detailed inventory of road segments exposed to flooding is provided in Appendix D; Table 7.4 provides a summary based on road type. Note that private roads such as those within apartment building strata or mobile home parks were not included in this analysis as no spatial data was available for them.

Table 7.4 Flooded road infrastructure.

Road Type	Quantity[1]	20-year Flood Event	Design Flood Event
Vernon			
Arterial	Count	5	8
	Length (m)	1,623	2,486
Collector	Count	3	10
	Length (m)	1,151	2,480
Local	Count	20	36
	Length (m)	4,423	7,421
Lane	Count	0	2
	Length (m)	0	282
Street right of way	Count	8	20
	Length (m)	2,921	10,680
Priest's Valley 6			
Local	Count	4	17
	Length (m)	565	2,189

Notes:
1. "Count" refers to the number of road segments within the flood affected area and "Length" refers to the total length of the exposed segments.

One minor section of railway track, located west of Polson Drive upstream of Polson Park, is overtopped during both flood events. During the 20-year flood, 5 m of the track is overtopped with a maximum depth of 9 cm. During the 200-year flood, 7 m of the track is overtopped with a maximum depth of 21 cm.

The Vernon Regional Airport property is subject to some flooding during both events, including flood extents around the western end of the runway. However, there is no flooding modelled on the runway itself or any other airport facilities for either event, and as such direct flooding is not anticipated to affect flights or airport activity. However, it is possible that groundwater saturation or non-connected ponding could affect the stability of runway surfaces or connecting roads to to/from the airport. Study of such impacts is outside the scope of this work, but may warrant consideration for emergency planning.

7.3.2.4 Building Infrastructure

To evaluate flood impact to buildings, the building dataset was overlaid with the modelled flood depth results. The DEM used to develop the flood depth raster datasets included raised building footprints, so to account for this, the building footprints were buffered by 2 m to overlap them with surrounding floodwaters. The maximum flood depth for each building within this buffer was identified.

The ER2 Rapid Risk Evaluation Tool (Version 2.05) developed by the University of New Brunswick was used to estimate flood damage to the exposed buildings and their contents (University of New Brunswick, 2016). The depth-damage curves built into the ER2 Rapid Risk Evaluation tool were used to estimate the consequence of the maximum flood depth experienced by each building, based on building type. Without a comprehensive building database, several assumptions were made about all structures, including that they are of average quality and built in 1995. As the elevations used to calculate the flood depths are for the first floor elevation, foundation type was set to ‘0’. Parameters in the tool not relevant to percent damage calculations such as presence or absence of a garage were not used. Further assumptions, which varied by building type, are identified in Table 7.5.

There were numerous sheds and parking structures found within the flood extents. Damage to these smaller structures was not estimated using the ER2 tool.

The results of the flood damage assessment are summarized in Table 7.6 for Vernon and Table 7.7 for Priest’s Valley. Full damage results are provided in Appendix D.

An important finding from the building infrastructure analysis is that one of the buildings in the Vernon Water Reclamation Centre (wastewater treatment plant) is exposed to both flood events. Further, road access to the primary and secondary treatment areas of the plant is blocked by flooding on 43rd Street during the design event, which may or may not impact the continued operation of the plant. Damage to the exposed building or a prolonged lack of personnel access to part of the facility could result in a contaminant breach due to damage or a backed-up sanitary sewer system from loss of use. This could have environmental consequences and human health concerns, in addition to the potential costs required for local and/or regional clean-up, as well as facility repairs.

Table 7.5 Building type assumptions for ER2 Rapid Risk Evaluation tool.

Building Type	Parameter	Value Assumed	Reasoning
Single Family Dwelling	Stories	2 stories	2 stories assumed based on typical configuration observed from air photos.
	Basement	Yes	Majority of homes assumed to have basements.
Duplex Triplex/Quad Multi-Dwellings, 5-9 Multi-Dwellings, 20-49 Multi-Dwellings, 50+	Stories	2 stories	2 or multi-story buildings based on likely configurations; flooding does not exceed first floor depth so exact number of stories does not affect calculation.
	Basement	No	Basement not compatible with ER2 tool for these building types.
Manufactured Housing	Stories	1 story	Assumed value based on likely configuration.
	Basement	No	Assumed value based on likely configuration.
Nursing Home	Stories	2 stories	Multi-story based on air photos; flooding does not exceed first floor depth so exact number of stories does not affect calculation.
	Basement	No	Basement not compatible with ER2 tool for this building type.
Temporary Lodging	Stories	2 stories	2 or multi-story buildings based on likely configurations; flooding does not exceed first floor depth so exact number of stories does not affect calculation.
	Basement	No	Basement not compatible with ER2 tool for this building type.
Retail Trade	Stories	1 story	1 story assumed based on typical configuration observed from air photos.
	Basement	No	Assumed value based on likely configuration.
Light Industry	Stories	1 story	1 story assumed based on typical configuration observed from air photos.
	Basement	No	Assumed value based on likely configuration.
Institutional	Stories	2-stories	2 stories selected based on specific buildings.
	Basement	No	Assumed value based on likely configuration.
General Services (Gov)	Stories	1 or 2 stories	1 or 2 stories selected based on specific buildings.
	Basement	No	Assumed value based on likely configuration.
Medical Office	Stories	2-stories	2 stories selected based on specific building.
	Basement	No	Assumed value based on likely configuration.
Churches	Stories	2 Story	1 story selected based on specific building.
	Basement	No	Assumed value based on likely configuration.

Table 7.6 Vernon building damage estimate summary. Structure and content damage values represent the estimated percent of replacement cost.

Building Type	Parameter	20-year Flood Event	Design Flood Event
Single Family Dwelling	Count	43	88
	Average Estimated Structure Damage	22%	27%
	Average Estimated Content Damage	20%	25%
Duplex	Count	3	10
	Average Estimated Structure Damage	23%	25%
	Average Estimated Content Damage	28%	27%
Triplex/Quad	Count	6	65
	Average Estimated Structure Damage	29%	23%
	Average Estimated Content Damage	34%	27%
Multi-Dwellings, 5-9	Count	0	3
	Average Estimated Structure Damage	N/A	15%
	Average Estimated Content Damage	N/A	15%
Multi-Dwellings, 20-49	Count	0	1
	Average Estimated Structure Damage	N/A	37%
	Average Estimated Content Damage	N/A	45%
Multi-Dwellings, 50+	Count	1	1
	Average Estimated Structure Damage	34%	34%
	Average Estimated Content Damage	42%	48%
Manufactured Housing	Count	71	82
	Average Estimated Structure Damage	50%	61%
	Average Estimated Content Damage	40%	52%
Nursing Home	Count	3	3
	Average Estimated Structure Damage	2%	2%
	Average Estimated Content Damage	9%	14%
Temporary Lodging	Count	3	7
	Average Estimated Structure Damage	3%	9%
	Average Estimated Content Damage	12%	32%
Retail Trade	Count	3	9
	Average Estimated Structure Damage	2%	13%
	Average Estimated Content Damage	6%	47%
Light Industry	Count	3	5
	Average Estimated Structure Damage	8%	15%
	Average Estimated Content Damage	14%	33%
Institutional	Count	2	2
	Average Estimated Structure Damage	9%	21%
	Average Estimated Content Damage	58%	100%
General Services (Gov)	Count	3	4
	Average Estimated Structure Damage	13%	25%
	Average Estimated Content Damage	100%	100%
Medical Office	Count	0	1
	Average Estimated Structure Damage	N/A	13%
	Average Estimated Content Damage	N/A	79%
Churches	Count	1	1
	Average Estimated Structure Damage	6%	8%
	Average Estimated Content Damage	48%	63%
All Buildings	**Count**	**142**	**282**

Table 7.7 Priest's Valley 6 building damage estimate summary.

Building Type	Parameter	20-year Flood Event	Design Flood Event
Manufactured Housing	Count	60	118
	Average Estimated Structure Damage	45%	63%
	Average Estimated Content Damage	35%	54%

Datasets of key community facilities were also examined for exposure to flooding, including datasets provided to NHC from Vernon showing emergency services (fire stations, police stations), healthcare facilities, schools, daycares, and community centres. These datasets were confirmed and expanded upon through a desktop study with Google Maps and Google Street View, however the datasets were not augmented or confirmed in the field (ground-truthing). Key facilities identified through this process, and the reason for their potential sensitivity to flooding, are listed in Table 7.8.

Table 7.8 Key community facilities.

Facility Name	Flood Event	Reason for Sensitivity
Vernon Restholm Retirement Home (2808 35th St)	Design flood event	Residents may have limited mobility and face difficulties in a potential evacuation, requiring extra time and assistance.
Silver Springs Seniors Community (3309 39th Ave)	20-year and design flood events	
Creekside Landing Retirement Home (6190 Okanagan Landing Rd)	20-year and design flood events	
Creekside Village Retirement Home (3502 27th Ave)	20-year and design flood events	
Pharmacy in Safeway (3417 30th Ave)	20-year and design flood events	As a component of the healthcare resources in the area, flooding eliminating access to or function of the pharmacy may disrupt people's access to medication.
Stirling Centre (3210 25th Ave)	Design flood event	Includes several healthcare facilities including the Stirling Centre, Centreville Clinic, RX Pharmacy, Lakeshore Medical Supplies, Interior Health Authority Lab, and several doctors' offices. If flooding eliminates access to or function of the Stirling Centre, people's access to healthcare and medication may be disrupted.
Turning Points Collaborative Society (social services organization; 3301 24th Ave)	Design flood event	These organizations support at-risk populations through providing access to safe housing, health care, and education and employment opportunities. Loss of function of these facilities may put the people dependent on them at increased risk.
John Howard Society (social services organization; 2307 43rd St)	20-year and design flood events	

7.3.3 Environment

Potential environmental impacts can be characterized by contamination sources, areas sensitive to contaminants, and habitat or ecosystem impacts.

Contamination sources can include fuel supplies, household or industrial chemicals, sewage, and agricultural chemicals or wastes. Some local governments maintain a record of potential contamination sources based on land use or an on-the-ground survey. No household or industrial contamination source datasets were available for this project, so those sources were not characterized.

At the northern extent of the study area, in the upstream section of lower B.X. Creek, the 20-year and design floods inundate ALR lands. These lands do not appear to be currently used for agriculture, but if they ever are, they will be potential sources of contaminants such as pesticides, fertilizer, manure, or fuel.

The Vernon Water Reclamation Centre is located approximately 1 km downstream of the confluence of lower B.X. Creek and Vernon Creek. The fermenter building is exposed to both the 20-year and design flood extents, and it is possible that damage to the building could negatively impact the viability of the wastewater treatment process or, in the case of a breach, could cause contamination of floodwaters. Further, road access to the primary and secondary wastewater treatment areas is blocked during the design event by flooding on 43 Street. It is unknown whether lack of personnel access to this section of the wastewater treatment plant could delay plant operations, but if that is the case such lack of access may result in backups of the sanitary sewer network, which could have both environmental and human health impacts. Cascading infrastructure failure due to flooding such as lack of electricity at the centre should be considered. A facility-specific risk assessment to flooding is recommended to identify resiliency improvements.

There is sanitary sewer collection in most of Vernon and some septic systems toward the west side of town near Okanagan lake and in neighborhoods located further from the city centre. The only area with septic systems at risk from Vernon Creek is within the Dallas neighbourhood south of Okanagan Landing Road, around Myriad Road and Dallas Road, which is exposed to flooding during both the 20-year and design flood events. Flooding of septic fields carries a risk for contamination. The contaminated water can spread in the flood waters and be carried downstream to impact a larger area.

NHC has confirmed with Vernon that the stormwater and sanitary sewer systems are not combined, and as a result if flooding overwhelms storm sewers it should not affect the sanitary sewer system or cause any resulting contamination[3]. However, flooding can cause sewage backups at individual residences or through breakage of a municipal sewer pipe. This can cause the contamination of floodwaters with sewage, leading to difficult cleanups as well as health and environmental impacts.

[3] Conversations with the Vernon Utilities Manager confirmed that though the storm and sanitary sewer systems are separate, there may be minor anomalies where private services (i.e., non Vernon infrastructure) have been tied into the system, however these are estimated to be a very small percentage of the overall networks and are corrected if found.

Environmental impact can also be characterized by identifying areas most sensitive to contaminants including wells, water intakes, and sensitive ecosystems. Drinking water in Vernon is provided by the Greater Vernon Water utility, which draws water from Kalamalka Lake and Duteau Creek, both of which are outside of the flood affected area. Wells are not considered as a sensitive receptor; while there may be some wells within the study area, they are not likely used for drinking water since there is municipally supplied water.

The following datasets from the BC Data Catalogue (Government of British Columbia, 2021) were reviewed to identify sensitive ecosystems, critical habitat, and species at risk that could be exposed to flood impacts. The results are summarized in Table 7.9:

- Species and Ecosystems at Risk;
- Critical Habitat for Federally-Listed Species at Risk; and
- Sensitive Ecosystems Inventory.

Table 7.9 Exposed Species and Ecosystems at Risk, Critical Habitat, and Sensitive Ecosystems.

Species and Ecosystems at Risk	Flood-Affected Area (ha)	
	20-year Flood Event	Design Flood Event
Species and Ecosystems at Risk		
American Badger	58	101
Black Cottonwood / Common Snowberry - Roses	32	41
Common Cattail Marsh	0.1	0.3
Dark Lamb's-quarters	0.0	0.02
Dark Saltflat Tiger Beetle	4.1	7.3
Gopher Snake, Deserticola Subspecies	0.2	0.3
Great Basin Spadefoot	1.6	2.2
Hard-stemmed Bulrush Deep Marsh	4.6	7.4
Mexican Mosquito Fern	0.7	0.8
Painted Turtle - Intermountain - Rocky Mountain Population	0.3	0.4
Rocky Mountain Ridged Mussel	1.3	1.3
Vivid Dancer	0.5	0.8
Western Harvest Mouse	33	47
Western Screech-owl, Macfarlanei Subspecies	20	29
Critical Habitat for Federally-Listed Species at Risk		
Great Basin Gophersnake	72	117
Great Basin Spadefoot	59	84
Mexican Mosquito-fern	2.8	3.3
Western Rattlesnake	72	117
Sensitive Ecosystems[1]		
BW:ac - Broadleaf Woodland, aspen copse	0.1	0.1
FS - Seasonally Flooded Fields	1.1	1.6
GR:dg - Grasslands, disturbed	0.1	0.1
RI:be - Riparian, beach	0.001	0.002
RI:ff - Riparian, fringe	0.1	0.2
RI:fp - Riparian, fluvial plain	23	27
WN:ms - Wetland, marsh	3.6	6.1

Notes:
1. Refers to the Sensitive Ecosystem Inventory first component, which is the dominant sensitive ecosystem in the given area (Iverson, 2008).

7.3.4 Culture

Potential cultural impacts were identified through looking at Indigenous lands or known heritage sites in the area as well as recreational, spiritual, and community areas. Potential cultural receptors include trails, recreation facilities, community halls, and places of worship. A desktop study was completed using Google Maps and Google Street View to identify cultural receptors in the inundation zones for the 20-year and design flood events.

Vernon and the extent of the flood affected area located within the traditional lands of the Syilx Okanagan and Secwépemc peoples, and as such it is possible that cultural receptors of importance to these Indigenous communities may be located within anticipated flood extents. The large-scale Okanagan Nation Alliance t̓ik̓t (flood) Adaptation Project[4], which covers the entire Okanagan Basin, identifies several cultural amenities within the predicted flood area. Additional cultural receptors of importance could be identified through future consultation with local First Nations, including but not limited to the residents of Priest's Valley, who are anticipated to be affected by both the 20-year and design flood events.

The remaining cultural receptors identified within Vernon from the desktop study are summarized in Table 7.10. Additional receptors may exist, which could be identified by members of the Vernon community through consultation.

Table 7.10 Exposed cultural receptors.

Receptor Name	Flood Event
Vernon Golf & Country Club	20-year and design flood events
Polson Park and Polson Park Trail	20-year and design flood events
Living Word Lutheran Church	20-year and design flood events
Marshall Field Park and Marshall Fields Trail	20-year and design flood events
Lakers Park	20-year and design flood events
Lakers Clubhouse	20-year and design flood events
Lakeshore Park and Beach	Design flood event
Sandy Beach Campground	Design flood event

[4] https://www.syilx.org/projects/t%cc%93ik%cc%93t-flood-adaptation-project/

7.4 Classification and Findings

The findings presented above provide a quantitative understanding of the impact of both the 20-year and design flood events. This section discusses the results and provides a risk classification for each of the four receptor categories. Note that the results for Priest's Valley have been incorporated into this overall risk assessment for Vernon, based on the assumption that there is substantial community overlap.

The risk classifications for this project have been developed based on risk ratings provided in the National Disaster and Mitigation Program Risk Assessment Information Template (RAIT; Public Safety Canada, 2016) and an example flood risk matrix in the EGBC professional practice guidelines *Legislated Flood Assessments in a Changing Climate in BC* (EGBC, 2018). The risk matrix developed as a synthesis of these two resources is presented in Table 7.11, and classifications are discussed in the preceding sub-sections. Note that these classifications are not based on stakeholder consultation and as they are designed for a wider context, they may not reflect the impact to the local community.

Table 7.11 Suggested project risk matrix.

Likelihood	Return Period (years)	Risk Level				
Likely	<30	M	H	H	VH	VH
Moderate	30-50	L	M	H	H	VH
Unlikely	50-500	VL	L	M	H	VH
Very Unlikely	500-5000	VL	L	L	M	H
Extremely Unlikely	>5000	VL	VL	L	L	M
	Consequence:	**1 -Negligible**	**2-Minor**	**3-Moderate**	**4-High**	**5-Severe**

Notes:
The Risk Level letters represent the following characterization of risk as defined by the example EBGC flood risk matrix (EGBC, 2018). These descriptions are provided as an example only; risk tolerability should be established based on community input.

- **VH – Very High risk** is unacceptable; short-term (before next flood season) risk reduction is required.
- **H – High risk** is unacceptable; medium-term risk reduction plan must be developed and implemented within a reasonable time frame (2 to 5 years); planning should begin as soon as possible.
- **M – Moderate risk** may be tolerable or mitigated with short to long-term planning.
- **L – Low risk** is tolerable; continue to monitor if resources allow.
- **VL – Very Low risk** is broadly acceptable; no further review or risk reduction required.

Both a relatively high likelihood event and a relatively low likelihood event were analyzed as part of the risk assessment. The 20-year flood has a relatively high likelihood; it is classified as "likely" in the EGBC example flood risk matrix and assigned a likelihood rating of 5/5 in the RAIT based on a return period of less than 30 years. The design flood event has a return period of 200-years or greater, classifying it as "unlikely" by the example EGBC flood risk matrix and giving it a relatively low likelihood of 2/5 in the RAIT based on a return period between 50-500 years. With reference to the suggested risk matrix in Table 7.11, the 20-year flood and design flood have been assigned likelihoods of "likely" and "unlikely", respectively.

7.4.1 People

The impact to people from these flood events is primarily displacement, damage experienced, and disruption of daily activities, such as transportation and commercial activities. For assigning a risk classification to people, it is appropriate to consider the entire flood-affected area, including the area assessed in Part 1 of this project (NHC, 2020b). Table 7.12 summarizes the estimated number of people displaced from their homes, including results from Part 1 and Part 2.

Table 7.12 Summary of displaced people from Part 1 and Part 2 study areas.

Displaced People	20-year Flood Event	Design Flood Event
Part 1[1]	95	232
Part 2	1,402	3,194
Total	1,497	3,426
Percentage of Total Population[2]	3%	7%

Notes:
1. Results are from *City of Vernon Detailed Flood Mapping, Risk Analysis and Mitigation: Part 1 - Upper B.X. Creek* (NHC, 2020b)
2. Based on total Vernon population of 48,073 and total Priest's Valley population of 628 from 2016 census data.

Due to the presence of lakes at the upstream extents of lower B.X. Creek and Vernon Creek, flooding of either stream is relatively predictable and is not expected to be a rapid onset event such as a debris flow or a dike breach; as such, flooding is unlikely to cause death or serious injury. With effective evacuation, it is likely possible to remove all residents from the path of the floodwater. There is potential for injury amongst emergency responders and locals who remain in the area. In addition to those directly affected, it is likely that thousands more people will be affected through loss of business, damage to properties, and interruption to routine.

As both 20-year and design floods are not likely to cause fatalities and any injuries will likely be within local response capacity, both floods are classified to be of "negligible" consequence in the respect of human safety as per the EGBC example flood risk matrix (EGBC, 2018).

The RAIT classifies people related impacts in terms of fatalities, injuries, percentage of displaced individuals, and duration of displacement (Public Safety Canada, 2016). For both flood events, fatalities and injuries receive a RAIT classification of 1/5. Percentage of displaced individuals receives a RAIT classification of 2/5 for the 20-year flood and 3/5 for the design flood. Duration of displacement for either flood is likely to be around one to two weeks, which classifies as a 2/5 to 3/5 on the RAIT (Public Safety Canada, 2016).

Overall, based on the above ratings, the consequence classifications for people for the current project are "2-Minor" for the 20-year flood and "3-Moderate" for the design flood.

In considering impacts to people, it is essential to understand that not all people are affected equally by the same circumstances. Social vulnerability can lead to differential impacts which typically cause more significant impacts to those who are more vulnerable as identified by metrics such as first language, income, health, etc. Socially vulnerable individuals should be considered as more at-risk and this should be factored into flood risk reduction decisions and other emergency planning and preparedness programs.

7.4.2 Economy

The economic impact has been examined through affected utility and transportation infrastructure, buildings, and community facilities. The stormwater system is likely sensitive to flooding and there is potential for it to be overwhelmed, leading to prolonged occurrence of overland flooding. Other underground utilities may also be at risk from floodwater, especially the underground hydro transformer identified and other junction or distribution facilities which are below the waterline. The wastewater treatment plant is exposed to flooding during both events, could be costly to repair and may lead to contamination. Enhancing infrastructure resiliency helps reduce flood risk, especially by reducing recovery duration. The RAIT characterizes impact to utilities in terms of impacts to a percentage of the area's population; however, this study only examines the utilities that are considered exposed within the flood affected area. As noted in Section 7.3.2.2, the relationship between flood depth and consequence is not known and requires input from utility companies to accurately quantify.

The impact on transportation is likely to be one of the most substantial risks associated with these potential floods. Transportation throughout the flooded areas of Vernon will be difficult as much of the floodwater flows along the roads. This hampers emergency response, property protection, and evacuation. Loss of access while road repairs are made could increase the duration of disruption. The disruption to arterial roads as well as the railway in both flood events would be substantial disruptions to access in the area and the wider community. The RAIT classifies impact to transportation partially in terms of affected population, but determining the affected population will require a detailed analysis that is not within the scope of this assessment. The most appropriate RAIT classification in terms of transportation is likely a 2/5, with local activity stopped for 13-24 hours and minor reduction in access to local area and/or delivery of crucial services or products (Public Safety Canada, 2016).

The 20-year flood is expected to damage 202 buildings, compared to the 400 buildings anticipated to be flooded in the design event. For some areas where flood depths are low and much of the flow happens along roads, it is possible that sandbagging and other temporary flood defense mechanisms may reduce potential damage. Of note are the key community facilities identified in Table 7.8. The four retirement homes which are exposed to flooding have increased flood risk as evacuation from these facilities will require extra time and resources. The two pharmacies and several healthcare facilities are exposed to flooding, so specific plans should be developed to ensure a flood-resilient supply of medication and access to health care treatment, especially to those who may have lower mobility.

Based on the discussed economic impacts, both floods are estimated to have "severe" to "catastrophic" economic consequence as per the example EGBC flood risk matrix, including severe receptor loss, several months business interruption, and greater than $1 million dollars of damage (EGBC, 2018). For the current project, both flood events have been assigned an economic consequence of "5-Severe".

7.4.3 Environment

The environmental impact of the flooding is based on the consideration of potential contamination sources and receptors, and habitat. As characterized by the example EGBC matrix, the environmental impact is most likely recoverable within months, depending on potential contamination risk from the wastewater treatment plant and septic fields in the Dallas neighbourhood. The 20-year and design floods have both been assigned a "4-High" consequence classification for environmental impacts.

7.4.4 Culture

The cultural impact presented in the report is expected to evolve as a better understanding of the receptors and their vulnerability are better understood through further consultation with the public. Based on the descriptions provided in the example EGBC flood risk matrix and the documented impact of the flood, the social and cultural impact is likely best characterized as moderate ("recoverable within weeks") for a 20-year event and as high ("recoverable within months") for the design flood event. This corresponds with ratings of "3-Moderate" and "4-High" for the 20-year and design flood events, respectively, using the suggested project risk matrix in Table 7.11. Community input is needed to refine rating for use in decision-making.

7.4.5 Risk Assessment Findings

The ratings discussed above are shown for each event on the flood risk matrices in Table 7.13 and Table 7.14. An overall rating combining different consequence categories was not developed as community input on consequence classifications, relative importance, or risk tolerance was not included in this project.

Table 7.13 Risk matrix for 20-year flood event.

Risk for "likely" 20-year flood event[1]	M	H	H	VH	VH
Consequence	**1-Negligible**	**2-Minor**	**3-Moderate**	**4-High**	**5-Severe**
People		X			
Economy					X
Environment				X	
Culture			X		

Notes:
1. As defined based on consequence and likelihood in Table 7.11.

Table 7.14 Risk matrix for design flood event.

Risk for "unlikely" design flood event[1]	VL	L	L	M	H
Consequence	**1-Negligible**	**2-Minor**	**3-Moderate**	**4-High**	**5-Severe**
People			X		
Economy					X
Environment				X	
Culture				X	

Notes:
1. As defined based on consequence and likelihood in Table 7.11.

7.5 Limitations

Limitations of the flood risk assessment include the following:

- The Vernon and Priest's Valley communities were not engaged in the process at the time of writing this report to provide input on receptors or risk rating;
- The receptors were based on a desktop study of data and were not ground-truthed;
- Population is based on 2016 Canadian census data (the latest available), but changes may have occurred since then;
- Impact to people has been calculated based on dwelling location to reflect potential evacuation requirements. In reality, more people use the flood impacted area than just residents, and would be impacted by the flood through aspects such as transportation or business disruption;
- Only direct impacts are estimated. Impacts due to disruption of business through a flood event and rebuilding process are not estimated;
- Building damage estimates are based on damage curves developed for the United States as comparable Canadian curves are not yet available. Construction standards differ in Canada so these damage estimates may not be entirely representative;
- First floor ground elevation of buildings is not known, leading to significant potential for under or over-estimation of flood damage to buildings;
- Building characteristics were assumed for a selection of damage curves. An accurate building inventory could improve building damage estimates.
- Social vulnerability is not considered in this assessment. For decision-making based on this assessment, social vulnerability should be considered, and equity-based analysis of risk reduction plans implemented; and
- Cultural impacts were estimated based on exposed community facilities identified through a desktop study using mainly Google Maps. Community consultation is required to determine a

more complete assessment of cultural risk, particularly with respect to the local First Nations community in Priest's Valley and the surrounding region.

8 FLOOD RISK REDUCTION PLANNING

Flood risk reduction planning is an ongoing, iterative process which requires careful consideration and community input. As presented in Figure 1.2, flood risk reduction is based on information from both a flood hazard and flood risk assessment. Flood risk reduction planning builds on the available information about hazards and valued community receptors to develop a plan to minimize impacts. Table 8.1 outlines examples of structural and non-structural mitigation options that are commonly used in British Columbia.

Table 8.1 Examples of mitigation measures.

Non-Structural ***Reducing Exposure & Vulnerability***	**Structural** ***Reducing Flood Hazard***
• Hazard and risk assessment • Land use planning ○ Zoning ○ Bylaws ○ Relocation or retreat • Public awareness and education • Emergency routing and safe zone delineation • Emergency preparation and planning ○ Community flood response plan ○ Community preparedness ○ Home and business response plan ○ Individual preparedness • Monitoring and warning systems • Maintenance	• Barrier to the hazard ○ Dikes (new or improved) ○ Flood gates • Armouring against hazard ○ Riprap banks/dikes ○ Spurs and groynes • Conveyance improvements ○ Dredging ○ Dike set back ○ Removing constrictions (culverts, bridges) ○ Reducing channel roughness ○ Pumps • Flood flow ○ Diversion of flow ○ Upstream storage ○ Infiltration

There is a variety of both structural and non-structural flood risk reduction options presented in the following sections. The risk reduction options presented have been selected and discussed based on the results of the analysis in this area. This discussion is preliminary and does not constitute a comprehensive mitigation plan or recommended options. To plan for and implement the options presented, consideration should be given to the following:

- Community preferences, values, and equity;
- Risk-based prioritization;
- Lifecycle costs of both building and maintaining any measures;
- Return on investment;

- Annualized protection provided, including potential benefits to mitigating high frequency, low magnitude events;
- Potential ecosystem enhancement or negative impacts;
- Other potential co-benefits such as recreation, stormwater attenuation;
- Local groundwater impacts (not examined through this project);
- Climate change and anticipated future land use conditions; and
- Design life of infrastructure to be protected (see Table 8.2 for encounter probabilities based on a range of return periods and design lives).

Table 8.2 Encounter probabilities for a range of flood return periods and design life durations.

Return Period (years)	Design Life			
	25 years	50 years	75 years	100 years
1-in-10	93 %	99 %	100 %	100 %
1-in-33	53 %	78 %	90 %	95 %
1-in-50	40 %	64 %	78 %	87 %
1-in-100	22 %	39 %	53 %	63 %
1-in-200	12 %	22 %	31 %	39 %
1-in-500	5 %	10 %	14 %	18 %
1-in-1000	2 %	5 %	7 %	10 %

8.1 Non-Structural Mitigation

Non-structural mitigation is considered flood protection that does not rely on the use of a dedicated flood protection structure (structural mitigation). The following are non-structural measures that can be considered by Vernon.

8.1.1 Land Use Planning

Land use planning can be used to reduce flood risk. A variety of land use planning tools are authorized for flood risk reduction by provincial acts and can be used, including zoning, development permit areas, and bylaws indicating setbacks. Some policies which these measures can be used to implement include:

- Where dikes may be considered in the future, maintaining setbacks of at least 30 m for future dike alignment to preserve right-of-way;
- Limiting density increases through rezoning or developing no-build zones in the highest hazard areas;
- Requiring site-specific flood hazard assessments in the floodplain or identified high hazard areas; and

- Requiring building to the FCL elevation for all developments which require a building permit (e.g. new construction or major renovations) within the floodplain or a designated area. Vernon should consider reviewing existing by-laws to include the FCL requirements for suitable developments.

The floodplain mapping provides the FCL and setback criteria typically applicable to watercourses within BC. During flood bylaw preparation the application of the results of this project may vary based on proposed land use to best reflect the risk tolerance of the local community. For example:

i. renovations and replacement of single-family homes may be required to follow the FCL and setback, whereas
ii. new homes and subdivisions may require site specific flood hazard assessments, and
iii. hospitals, schools, long term care homes, and storage of deleterious substances may require further mitigation (i.e. more extreme event, increased freeboard, or increased setback).

8.1.2 Emergency Response Planning

Pre-planning a response to potential flooding can help ensure an efficient, safe, and effective response. The following are suggestions for Vernon for further emergency response planning.

- Identify key locations to monitor flows / water levels to trigger emergency plan actions;
- Pre-plan locations for temporary community flood barriers and culvert blockage clearing during high-water events; and
- Refine evacuation routes and an evacuation plan based on updated flood hazard mapping.

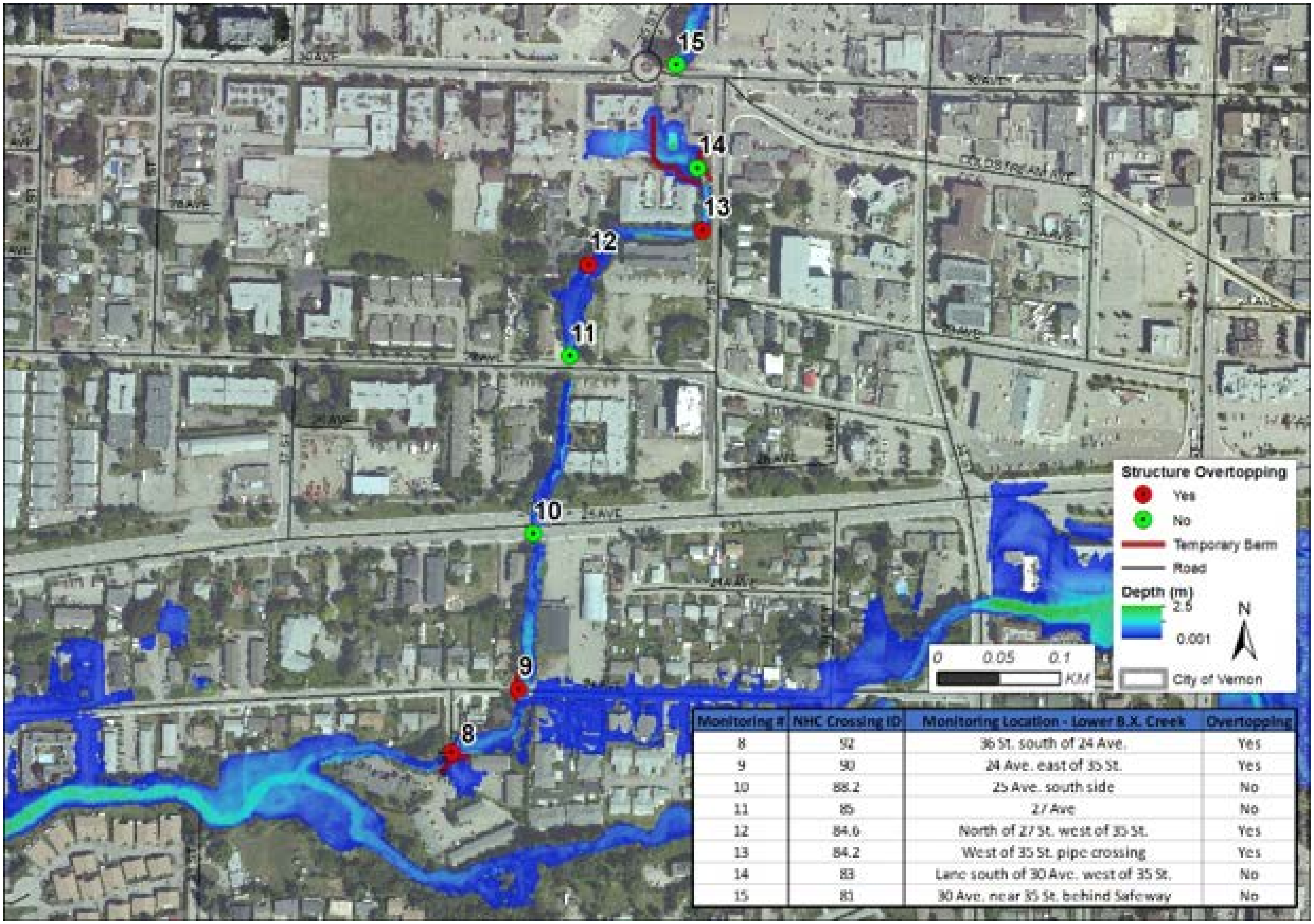
Figure 8.1 through Figure 8.8 are an examples of recommended monitoring locations and temporary flood barriers based on flooding or overtopping structures. Vernon should create a formal plan and accompanying map that describes what actions should be carried out at what stage of flooding, along with defined evacuation routes based on the hazard map results. Locations of temporary barriers should be selected by Vernon to best protect their receptors. The provided example locations are based on modeling and mapping results and do not consider the protection of specific infrastructure, but rather where flow is observed leaving the channel, overtopping the structure, or backwatering the structure.

Monitoring #	NHC Crossing ID	Monitoring Location - Lower B.X. Creek	Overtopping
23	61	Below Blue Stream Motel, 32 St. Hwy 97	No
24	59	32 St. south of 43 Ave.	Yes
25	57	34 St. north of 43 Ave.	No

Figure 8.1 Suggested emergency response planning measures for lower B.X. Creek (1/3).

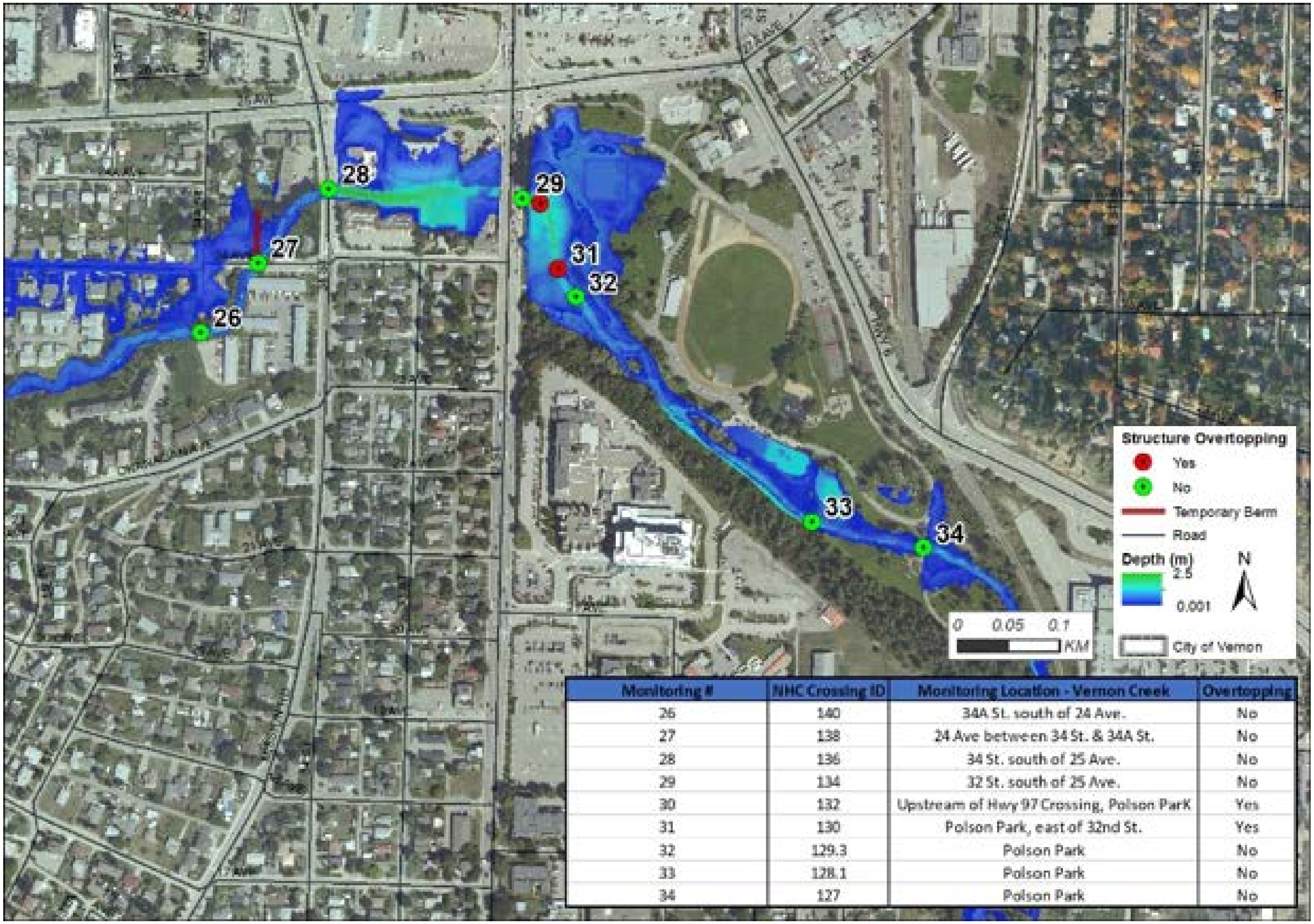
Monitoring #	NHC Crossing ID	Monitoring Location - Lower B.X. Creek	Overtopping
16	77	32 Ave. between 34 St. & 35 St.	Yes
17	75	33 Ave. off of 35 St.	No
18	73	34 Ave. between 34 St. & 35 St.	No
19	71	35 Ave. & 34 St.	Yes
20	63.6	Under Vernon Lodge parking	No
21	63.5	Inside Vernon Lodge	No
22	63.25	Inside Vernon Lodge	No

Figure 8.2 Suggested emergency response planning measures for lower B.X. Creek (2/3).



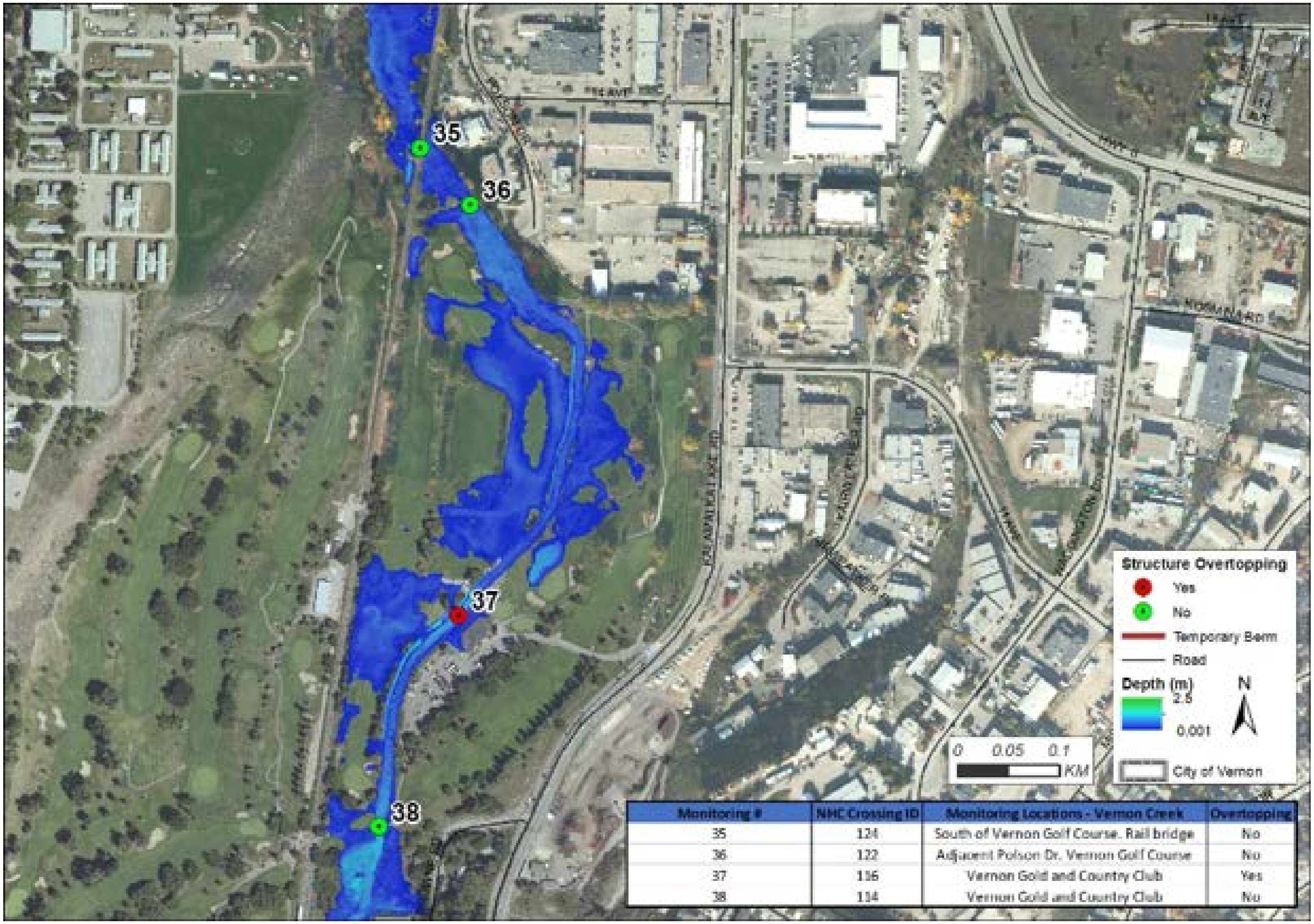
Monitoring #	NHC Crossing ID	Monitoring Location - Lower B.X. Creek	Overtopping
8	92	36 St. south of 24 Ave.	Yes
9	90	24 Ave. east of 35 St.	Yes
10	88.2	25 Ave. south side	No
11	85	27 Ave	No
12	84.6	North of 27 St. west of 35 St.	Yes
13	84.2	West of 35 St. pipe crossing	Yes
14	83	Lane south of 30 Ave. west of 35 St.	No
15	81	30 Ave. near 35 St. behind Safeway	No

Figure 8.3 Suggested emergency response planning measures for lower B.X. Creek (3/3).



Monitoring #	NHC Crossing ID	Monitoring Location - Vernon Creek	Overtopping
26	140	34A St. south of 24 Ave.	No
27	138	24 Ave between 34 St. & 34A St.	No
28	136	34 St. south of 25 Ave.	No
29	134	32 St. south of 25 Ave.	No
30	132	Upstream of Hwy 97 Crossing, Polson Park	Yes
31	130	Polson Park, east of 32nd St.	Yes
32	129.3	Polson Park	No
33	128.1	Polson Park	No
34	127	Polson Park	No

Figure 8.4 Suggested emergency response planning measures for upper Vernon Creek (1/3).

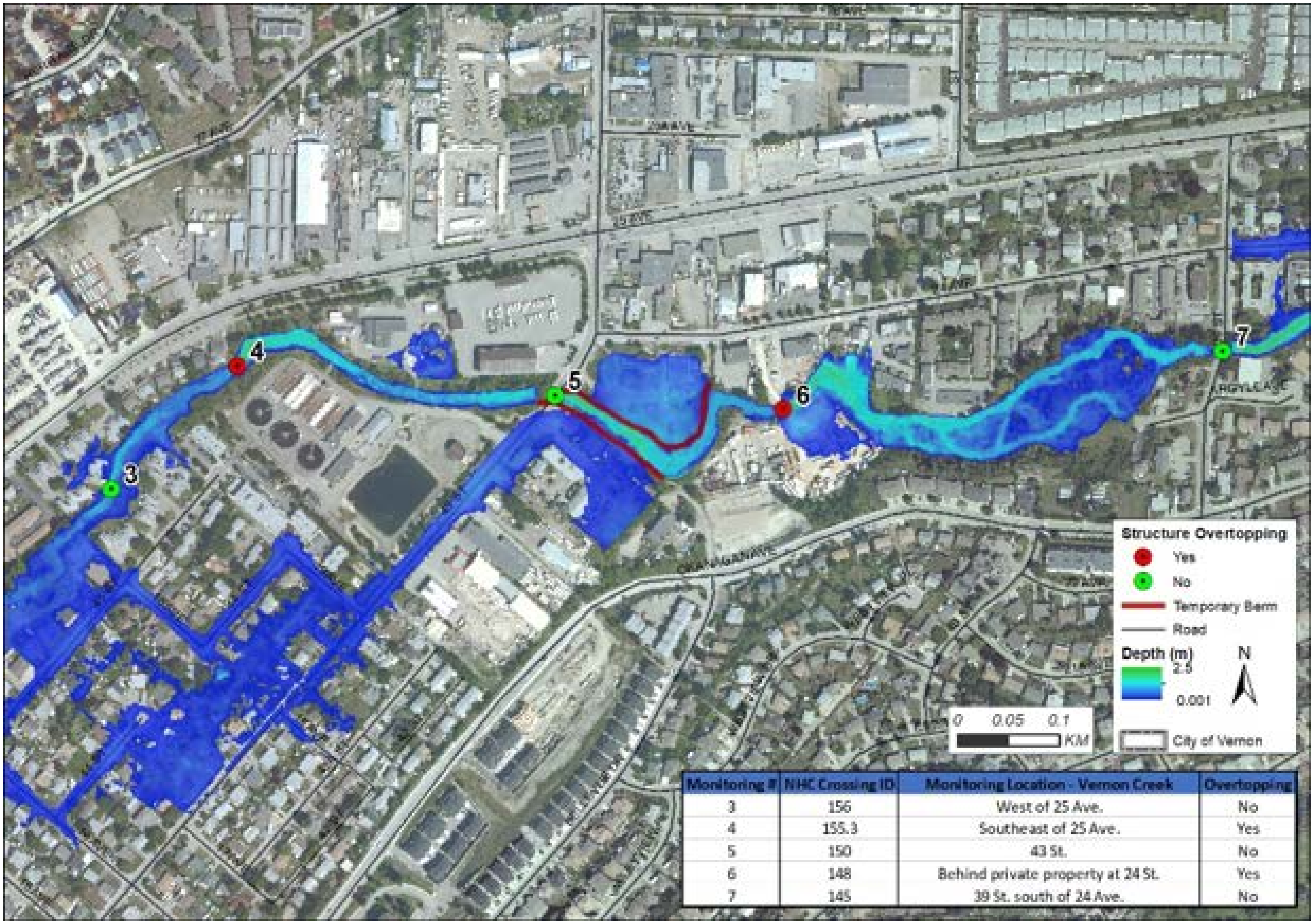


Monitoring #	NHC Crossing ID	Monitoring Locations - Vernon Creek	Overtopping
35	124	South of Vernon Golf Course. Rail bridge	No
36	122	Adjacent Polson Dr. Vernon Golf Course	No
37	116	Vernon Gold and Country Club	Yes
38	114	Vernon Gold and Country Club	No

Figure 8.5 Suggested emergency response planning measures for upper Vernon Creek (2/3).

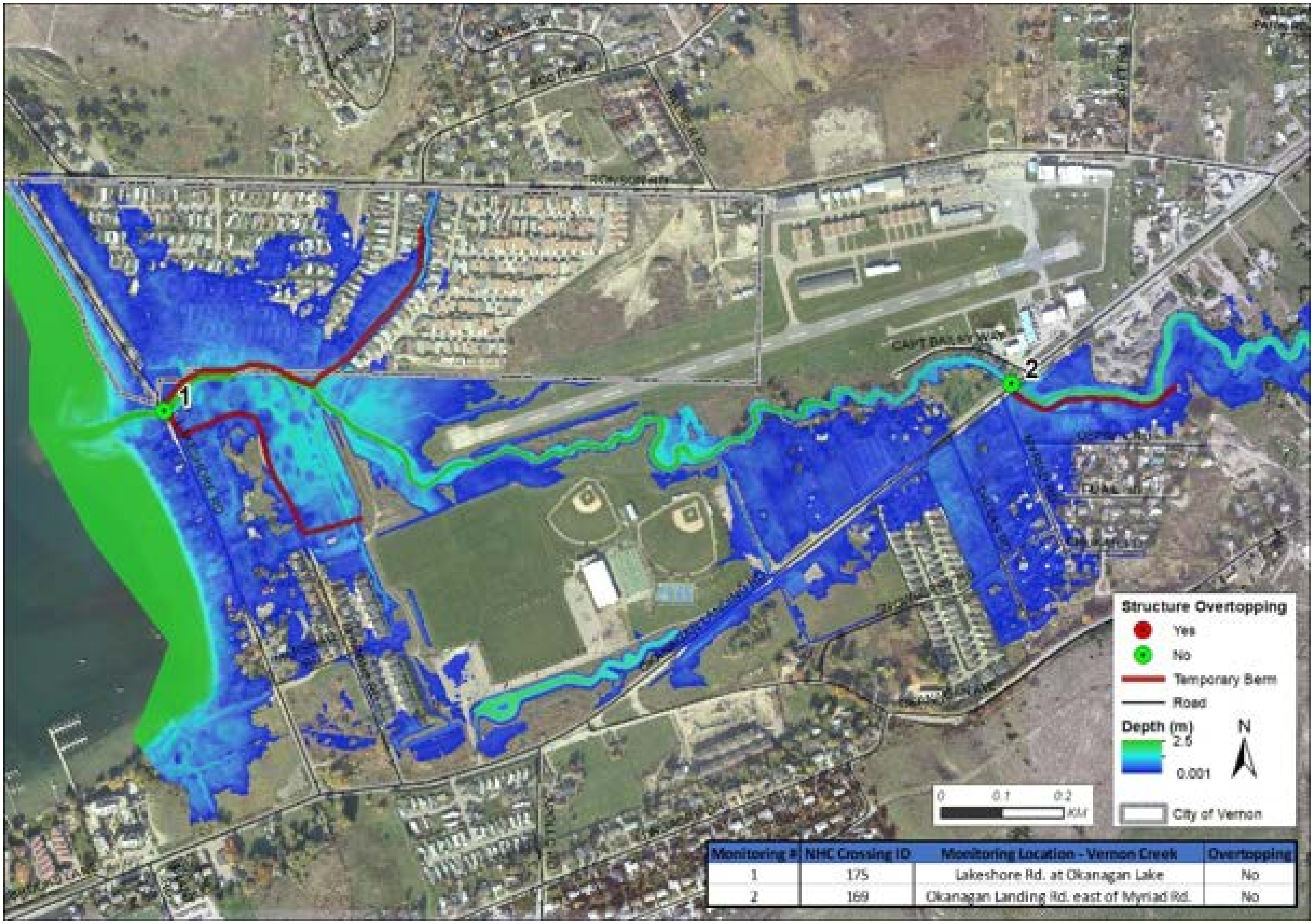
Monitoring #	NHC Crossing ID	Monitoring Locations - Vernon Creek	Overtopping
39	112	Browne Rd.	Yes
40	110	Adjacent Browne Rd. Cul-de-sack	Yes
41	109.1	Adjacent Browne Rd. Housing subdivision	No
42	108	Adjacent Browne Rd. Housing subdivision	No
43	104	Kalamalka Lake Rd. North of lake	No

Figure 8.6 Suggested emergency response planning measures for upper Vernon Creek (3/3).



Monitoring #	NHC Crossing ID	Monitoring Location - Vernon Creek	Overtopping
3	156	West of 25 Ave.	No
4	155.3	Southeast of 25 Ave.	Yes
5	150	43 St.	No
6	148	Behind private property at 24 St.	Yes
7	145	39 St. south of 24 Ave.	No

Figure 8.7 Suggested emergency response planning measures for lower Vernon Creek (1/2).



Monitoring #	NHC Crossing ID	Monitoring Location - Vernon Creek	Overtopping
1	175	Lakeshore Rd. at Okanagan Lake	No
2	169	Okanagan Landing Rd. east of Myriad Rd.	No

Figure 8.8 Suggested emergency response planning measures for lower Vernon Creek (2/2). Note that the eastern berm is intended to protect from high water levels on lower Vernon Creek, not from high levels on Okanagan Lake.

8.1.3 Flood Risk Education

Ensuring that the local community, including individuals and businesses, are aware of the flood risk helps to empower local community members to become flood prepared with respect to their home, family, and business. The development of a flood story map to digitally share the flood hazard information with the Vernon community has been undertaken. This will be a helpful medium to share information, and should be used alongside other outreach methods including highlights in community media (social and traditional), public meetings, and seasonal reminders. As these outreach methods are undertaken, key aspects to share with the community include:

- What areas are exposed to flood risk, including the potential for flooding;
- The likelihood of various floods in easy to understand language (i.e. what is the chance of a 1-in-20 year flood happening this year or in the next five years);
- What aspects of flood risk reduction are an individual's responsibility and/or governmental responsibility;
- Publicly accessible flood forecasting information sources for Vernon;
- What individuals can do to reduce flood risk, such as flood proofing or raising homes, and installing sewer backflow valves;
- What individuals can do to prepare for imminent floods, including sand bagging and preparing for potential evacuation; and
- What Vernon is doing to reduce community flood risk, including next steps for flood mitigation consultation.

Disaster financial assistance is generally only available for uninsurable assets. Ensuring the community is aware of their responsibility to acquire flood insurance where available is a critical step to improving the post disaster recovery.

8.1.4 Recovery Pre-Planning

BC is modernizing their emergency management legislation and practices to include a focus on recovery as a key pillar for emergency management alongside mitigation, preparedness, and response. Consideration of recovery plans and resources in advance of a flood or other hazard event is recommended. Recovery plans can include the identification of:

- Pre-determined roles for city personnel and community volunteers;
- Plans to access designated financial resources;
- Assistance agreements with neighbouring communities;
- Pre-prepared designs of structural mitigation to apply for funding, when available;
- Disposal plans for debris; and
- Identification of contractors to support engineering and construction needs.

Vernon may want to consider pre-planning for recovery from floods and possibly incorporate this with recovery planning for a range of potential hazards (such as wildfires).

8.2 Structural Mitigation

Structural mitigation are engineering works that reduce flooding impacts. This can include dams, dikes, training berms, floodwalls, seawalls, bank protection works, flood retention basins, sediment basins, river diversions, floodways, channel modifications, sediment management, debris barriers, pump stations, and flood boxes (EGBC, 2018).

For the Part 2 study area and flood events reviewed, the primary structural flood mitigation measures are upstream storage and improved conveyance. Upstream storage is currently provided by Swan, Wood, and Kalamalka Lakes. These reservoirs have been assessed for their ability to provide additional flood mitigation (Section 8.2.1). The large number of crossings (64) on lower B.X. Creek and Vernon Creek provide the greatest impediment to conveyance. Improvements to or replacements of the crossings have been investigated to improve conveyance (Sections 8.2.2 to 0).

Other structural mitigations, such as dikes, diversions, and pumping appear not be feasible in the Part 2 study area based on the current land use and design flow conditions. Locations where dikes or diversions could be useful are currently developed and the benefit of such measurers are not expected to warrant the cost, particularly in comparison to improving the most restrictive crossings.

For any mitigation options taken forward to detailed design, note that structural mitigation shall be designed to the applicable local standards and provincial guidelines, and include consideration for operation and maintenance, as they will become the responsibility of Vernon once constructed. For any considered option, land tenure or acquisition should also be considered, as there is currently limited space along lower Vernon Creek.

8.2.1 Upstream Storage

Each model reaches in this study is bounded on the upstream end by a dammed lake. These lakes already provide an attenuating effect on the inflows from upstream. For example, the 1996 flood flow on upper B.X. Creek was estimated as 19.5 m^3/s, and this inflow resulted in a peak outflow from Swan Lake of 6.5 m^3/s. Similarly, in Kalamalka Lake, flows are typically managed with the intent of keeping flow into Vernon Creek below 6 m^3/s, even as peak (calculated, mean daily) inflows have often exceeded 15 m^3/s and are modelled to increase in the future (NHC, 2020d).

In the future, there may be flood mitigation opportunities for both B.X. Creek and Vernon Creek through an increase in live storage and upgrades in management methods of these lakes. However, each of these options currently have significant challenges associated with them and are likely not feasible at this time. Both of these options would require long term collaboration between Vernon and the province of B.C., the managers of both dams, and an extensive study of potential ecological effects (particularly for Swan Lake) and effects on citizens both inside outside of Vernon (particularly for Kalamalka Lake).

For Swan Lake, an increase in storage could be accomplished through raising of the Swan Lake dam. Due to the flat terrain, this would also require substantial widening of the dam through the wetland at the south end of the lake and an assessment of impacts of increased levels on the lakeshore. For Kalamalka Lake, any mitigation of downstream flooding would likely come through water level management updates (e.g., lowering of summer water levels) and lowering of the sill level of the dam into Vernon Creek. These changes would cause an impact on water supply during drought years, and have recreation impacts for residents that surround Kalamalka and Wood Lake.

8.2.2 Crossing Upgrades

NHC has closely examined the design flood modeling results at all 64 creek crossings within the Part 2 study area. Many of the crossings were identified as undersized and unable to effectively pass the design flood. The model results indicated water levels would be higher upstream due to the crossing constriction (backwatered), upstream banks would be overtopped, and in some cases, flow would overtop the crossing. The crossings with the greatest restriction to flow are culvert crossings. A detailed summary of the undersized crossings and relevant capacity issues is provided in Appendix E. The location of the undersized crossings is marked in Figure 8.1 through Figure 8.8. These crossings should be considered for future upgrades. Until upgraded, they should be monitored for obstruction and overbank inundation during flood flows.

Three crossing have been identified that would provide significant mitigative improvements if upgraded. They are all culvert crossings located on lower Vernon Creek (Figure 8.9 and Figure 8.10):

- 43rd Street culvert
- Okanagan Landing Road culvert
- Lakeshore Road culvert

These crossings are undersized and cause significant backwatering and raised upstream water levels that result in extensive flooding of roads and residential neighbourhoods. Crossing upgrades to reduce flood risk at these sites have been investigated to support Vernon on future risk reduction efforts. The type and size of replacement crossing is not part of the current study. However, for this evaluation, comparison was made between the current culvert crossings and replacement clear span bridges. This investigation included modeling the proposed mitigation measures and assessing the improvements, as well as identifying any transfer of risk to other locations. The assessment for each of the three crossing upgrades is presented in the following subsections.

An options assessment of the three crossing upgrades has also been completed to help Vernon prioritize which options should be considered (Sections 8.2.3 and 0).

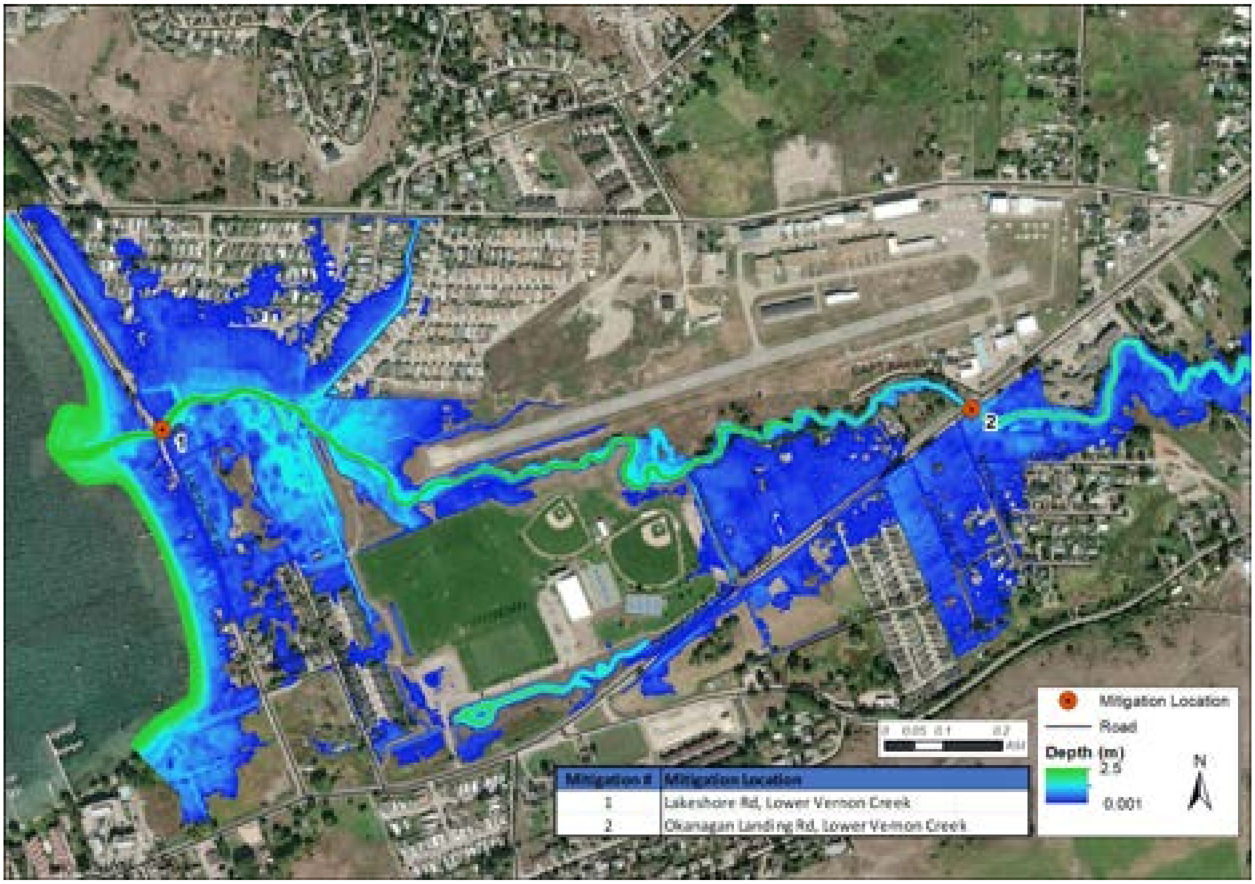


Figure 8.9 Recommended crossing upgrade locations for lower Vernon Creek (1/2).

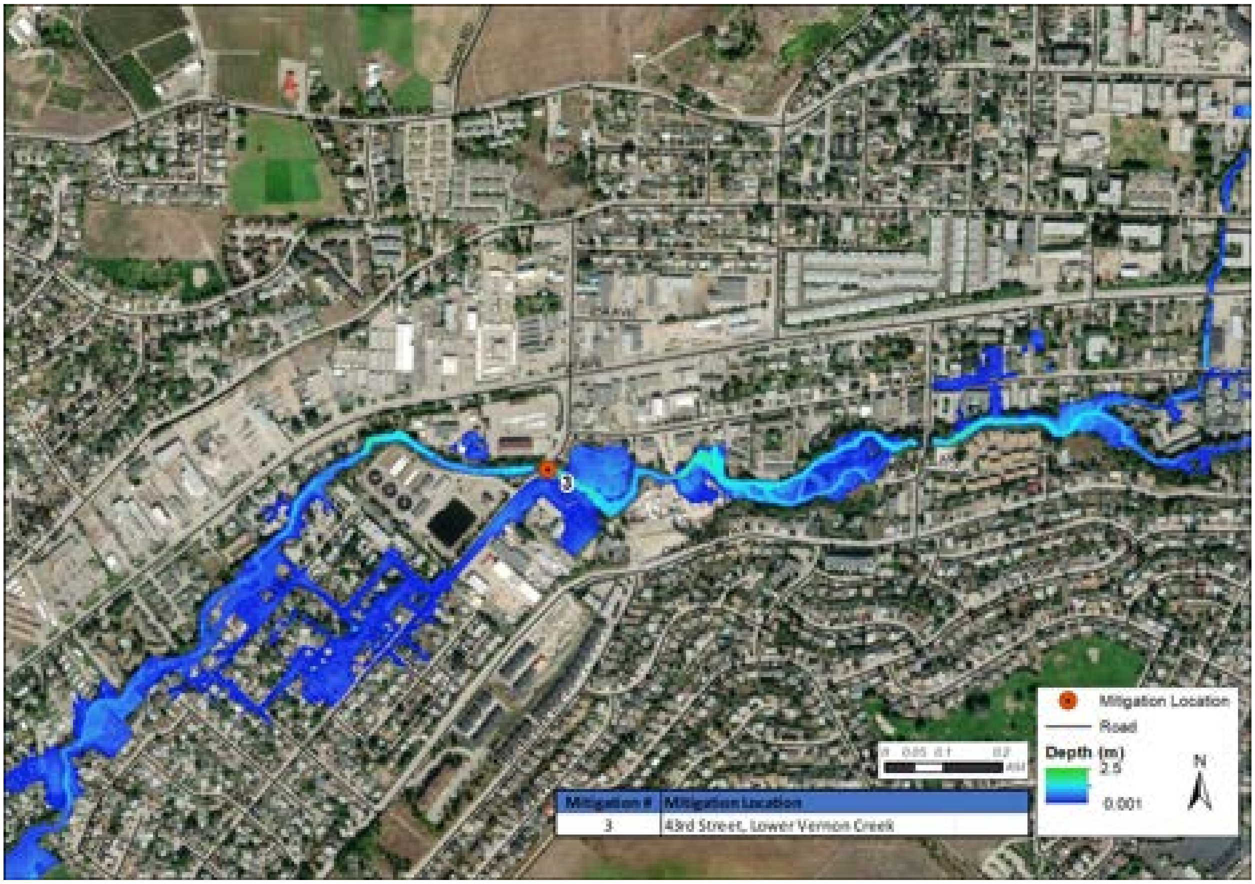


Figure 8.10 Recommended crossing upgrade locations for lower Vernon Creek (2/2).

8.2.2.1 43rd Street

The existing crossing at 43rd Street is a 5.09 m by 2.06 m open bottom arch culvert with concrete headwalls (Figure 8.11). The crossing is undersized and backwaters the upstream channel. Under design flood conditions, this results in overbank flooding on both sides of the channel. On the right side (facing downstream), a large corner property and social services buildings are inundated. On the left side, overbank flooding extends onto 43rd Street, inundating the road southwest of the crossing as well as an industrial property. Flow on 43rd Street is conveyed further southwest and flooding directly affects approximately 50 houses in a residential neighbourhood. Flooding further affects six residential roads in the neighbourhood, blocking access to additional homes, before flows rejoin lower Vernon Creek around 16th Avenue (Figure 8.12).

Figure 8.11 Lower Vernon Creek at 43rd Street culvert crossing, facing downstream.

The recommended crossing improvements include replacing the culvert with an 18 m clear span bridge and widening the channel starting approximately 100 m upstream of the crossing. The channel would need to be widened to roughly the natural channel width of 5m. From modeling, these changes are shown to prevent overtopping of 43rd Street, protecting the currently affected houses and roads downstream. The industrial property and social services buildings remain impacted, but temporary berms are recommended at these locations, as shown in Figure 8.7. The impact on expected flood extent and depth of the proposed mitigation is illustrated in Figure 8.12.

Figure 8.12 Flood extents at 43rd Street crossing under current (top) and proposed improved (bottom) conditions based on model results for the design flood event. Blue gradient indicates depth of water (without freeboard) in meters.

8.2.2.2 Okanagan Landing Road

The existing Okanagan Landing Road crossing is a 4.15 m wide by 2.55 m high elliptical corrugated metal pipe (CMP) culvert (Figure 8.13). The CMP projects from the mechanically stabilised earth (MSE) headwalls.

Figure 8.13 Lower Vernon Creek at Okanagan Landing Road culvert crossing, facing upstream.

This crossing is undersized and backwaters the upstream channel, causing overbank flooding on both banks under the modeled design flood conditions. The left overbank flooding directly impacts approximately 70 homes in a residential neighbourhood, as well as five residential roads, before overtopping Okanagan Landing Road. From there, the overland flow continues to flood eight additional properties before rejoining lower Vernon Creek. A portion of the overbank flow continues southwest down Okanagan Landing Road, flooding parkland and minor roads and properties near Okanagan Lake.

The proposed crossing upgrade consists of replacing the culvert with a 19 m clear span bridge. With the increased capacity, left overbank flooding is almost entirely avoided. Approximately 10 houses and properties remain impacted, but the remaining level of inundation can likely be addressed through as-needed protection measures such as sandbagging (Figure 8.8). The effectiveness of the proposed mitigation is exemplified in Figure 8.14.

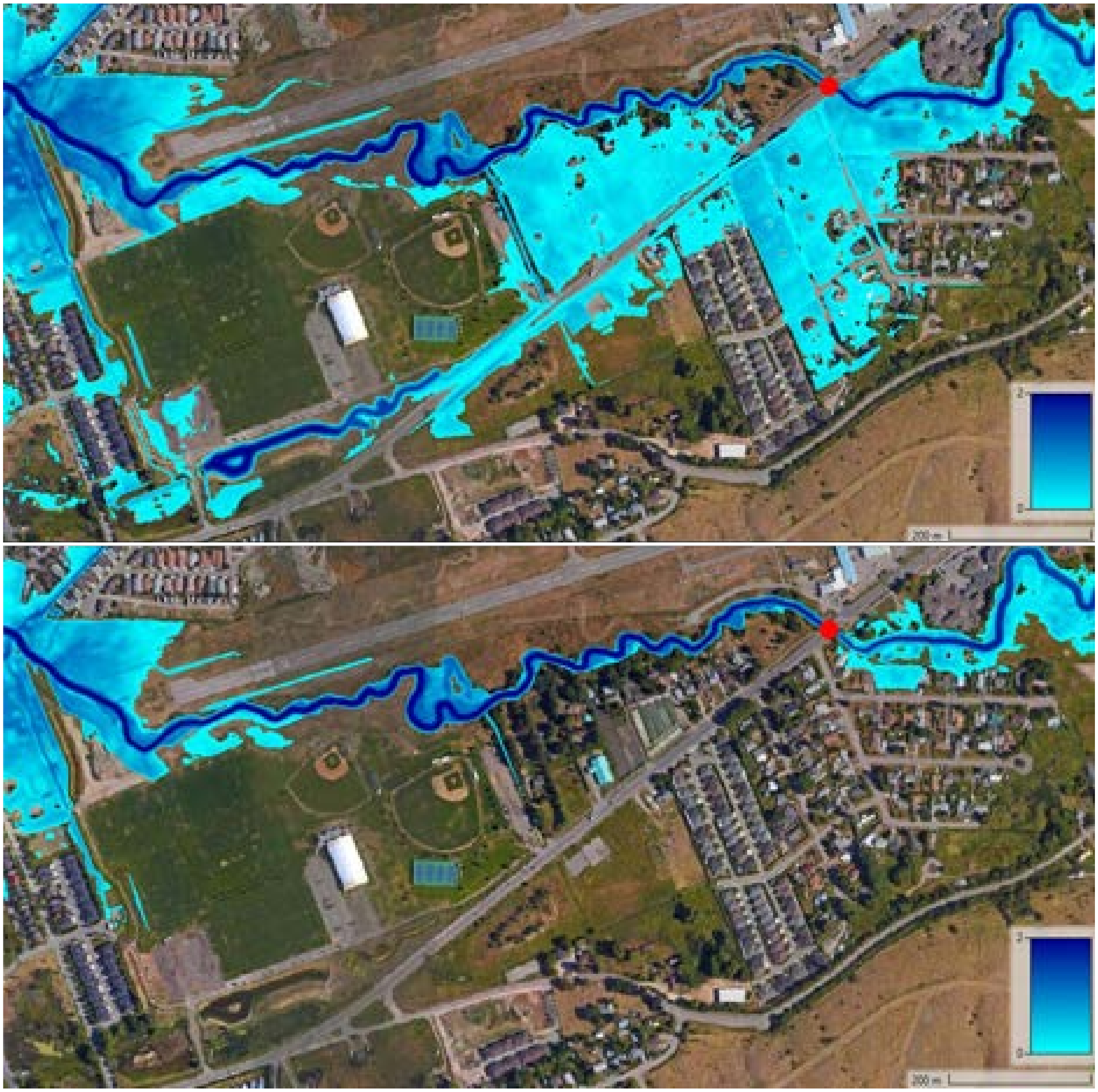


Figure 8.14 Flood extents at Okanagan Landing Road under current (top) and proposed improved (bottom) conditions based on model results of the design flood. Crossing location indicated by red points. Blue gradient indicates depth of water (without freeboard) in meters.

8.2.2.3 Lakeshore Road

The existing Lakeshore Road crossing is a 4.3 m wide by 2.7 m high CMP arch culvert that projects from earth fill headwalls (Figure 8.15).

Figure 8.15 Lower Vernon Creek at Lakeshore Road culvert crossing, facing downstream.

This crossing located close to the outlet of Vernon Creek and is undersized. When the culvert is not backwatered by high levels on Okanagan Lake, creek flow is inlet controlled and the head loss as flood flows enter the pipe is sufficient to result in overbank flooding upstream. This also leads to the overtopping of Lakeshore Road and further flooding of properties adjacent to the crossing. Under design flood conditions, for which the downstream lake level is 343.9 m, flow through the culvert is downstream controlled, resulting in further overbank creek flooding in addition to lakeshore flooding.

The proposed crossing upgrade consists of replacing the existing culvert with a 15 m clear span bridge. To better understand the impacts resulting from Okanagan Lake shoreline flooding and backwatering versus overbank creek flooding from the undersized crossing, the crossing was modeled under four conditions for the design flow on lower Vernon Creek (25.6 m^3/s). The existing and proposed crossings were modeled under the design water level in Okanagan Lake (343.9 m) as well as at a reduced water level to indicate no shoreline flooding (341.9 m; comparable to the lowest lake level likely to occur during the freshet period, near the end of April). Table 8.3 summarizes the modeling condition parameters as well as the number of flooded houses under each condition. The modeling results are illustrated in Figure 8.16.

Table 8.3 Model conditions for Lakeshore Road crossing under design flow on lower Vernon Creek.

Condition	Crossing Description	Okanagan Lake Water Level	Approx. Number of Flooded Homes
Condition 1	Existing culvert	343.9 m (design condition)	140
Condition 2	Proposed clear span bridge	343.9 m (design condition)	90
Condition 3	Existing culvert	341.9 m (2 m below design condition)	105
Condition 4	Proposed clear span bridge	341.9 m (2 m below design condition)	10

For both the design lake level and lowered lake level, the proposed bridge provides improvements compared to the existing culvert, as exemplified by the number of flooded homes summarized in the above table. Approximately 50 fewer homes are flooded with the improved crossing under the design lake level, and 95 fewer homes are flooded with the improved crossing under the lower lake level. This supports the decision to upgrade the crossing, as it indicates that the flooding in the Lakeshore Road area is largely a result of the existing undersized crossing, despite the additional influence of high lake levels.

The flood impacts from high levels on Okanagan Lake are still very significant, indicated by the 90 homes impacted under Condition 2 when the crossing is improved but lake levels still are high. Lakeshore flooding is less straightforward to mitigate; temporary as-needed flood protection measures such as sandbagging are recommended to protect houses and properties when lake levels are high.

Figure 8.16 Flood extents at Okanagan Landing Road for design Okanagan Lake water levels (left) and lowered lake levels (right) under current (top) and proposed (bottom) crossing conditions. Crossing location is indicated by red points. Blue gradient indicates depth of water (without freeboard) in meters.

8.2.3 Mitigation Options Assessment - Approach

The above structural mitigation measures have been evaluated using a qualitative risk and feasibility assessment. The risk component of the assessment assigns a score of the severity of risk avoided by the proposed mitigation. The feasibility component of the assessment assigns a score to represent the ease of implementation of the proposed mitigation. These two scores are then combined into a risk/feasibility ratio. A high risk avoided score and low feasibility score indicates the best scenario under this rating system. This information is provided to help inform decisions on the identified mitigations. Other factors (such as road improvements, age of crossing, condition of crossing, available funding, etc.) will further inform the decision on the mitigation option.

8.2.3.1 Scoring of Risk Avoidance

To identify the level of risk avoided through each mitigation option, a risk score was assigned based on the likelihood of the flood event overwhelming existing defences and the consequence of the flood event. For this component of the project, risk is determined through the matrix shown in Table 8.4.

Table 8.4 Scoring matrix for risk avoidance.

Likelihood of Reducing Hazard	Rating:	Risk Score		
Very likely to be highly effective	High – 3	**3**	**4**	**5**
Likely to be highly effective	Medium – 2	**2**	**3**	**4**
Likely to be moderately effective	Low – 1	**1**	**2**	**3**
Estimated Consequence without Proposed Mitigation		Minimal exposure of people, economic sociocultural, & ecological receptors/areas	Some exposure of people, economic sociocultural, & ecological receptors/areas	High exposure of people, economic sociocultural, & ecological receptors/areas
	Rating:	Low – 1	Medium – 2	High – 3

The likelihood of the adverse effect is evaluated based on the probability that a flood event will overwhelm existing defences and impact an area. The consequence is described for the area that would be defended by the mitigation. Consequence is estimated by an assessment of the people, receptors directly exposed to the flood hazard, and the potential extent of damage associated with the flood hazard which would be eliminated by the mitigation measure. Assessment of consequence aligns with the approach used in the flood risk assessment documented in Section 7.

The estimated, approximate protected area for each structural mitigation measure has been identified, based on flood mapping results. The impact to people, economy, environment, and cultural receptors was qualitatively categorized within the protected area. This matrix does not capture the importance to the community of the consequences estimated. Community consultation could further refine this matrix, through adjustment of the estimated consequence axis to better represent community values.

Based on the risk assessment, each feature is assigned a risk score between 1 to 5, based on the matrix shown in Table 8.4. A score of 5 indicates highest risk avoided or greatest benefit of the mitigation measure.

8.2.3.2 Scoring of Feasibility

The feasibility score quantifies the feasibility of each mitigation option. A low feasibility score represents a project which is easy to implement. The feasibility score has been estimated by applying the matrix in Table 8.5 to the two feasibility factors: ease of execution and cost of implementation.

Ease of execution includes considerations regarding design complexity, environmental constraints, land acquisition or easements, and impacts on property-owners or other stakeholders. The cost of implementation factor considers the estimated costs of the proposed works. Category descriptions are provided in the following table. Factors applied and the values assigned to the factors can be refined through stakeholder or community discussion and progressing the design and costing.

Table 8.5 Scoring matrix for feasibility factor.

Cost of Implementation	Rating:	Feasibility Score		
>$1,500,000	High – 3	**3**	**4**	**5**
$750,000 to $1,500,000	Medium – 2	**2**	**3**	**4**
<$750,000	Low – 1	**1**	**2**	**3**
Ease of Execution		Straightforward design and implementation. Minimal environmental impact. Does not require changes in land ownership. Minimal impact to stakeholders.	Somewhat complex design and implementation. May include moderate environmental impact. May require minor changes in land ownership. May have moderate impact on other stakeholders.	Complex design. May include substantial environmental impact. May require changes in land ownership. May substantially impact other stakeholders.
	Rating:	Low – 1	Medium – 2	High – 3

8.2.3.3 Approach for Cost Estimation

Cost estimation for structural mitigation measures has been carried out at a 'planning' level of estimating which is defined by BC Ministry of Transportation and Infrastructure (MoTI) (2013b) as being "based on sufficient knowledge of site conditions adequate to identify high level risk". The expected accuracy range for this level of estimating is +/- 40%. Unit prices for construction items were obtained from recent NHC projects in the region.

Soft costs are typically 15% to 35% of construction costs. This is supported by provincial documentation by MoTI which suggests 25% (2013a). For this project we have adopted soft costs at the middle of this range, assuming some service costs are incorporated with the contractor's scope, such as environmental monitoring, surveying, and material testing. The distribution of this is as follows:

- Project management and planning: 3%
- Design: 15%
- Construction supervision and inspection: 7%

Costs were inflated to reflect the uncertainty of the estimate by a contingency rate of 40% of construction cost. This contingency rate is commensurate with the accuracy range of this project as per MoTI (2013b). The presented cost estimates only include design and construction costs. On-going monitoring and maintenance have not been included but should be budgeted for.

An additional 6% cost inflation for the COVID-19 pandemic has also been added to reflect pricing increases observed during the pandemic due to material shortages. This inflation cost is an estimate based on construction price increases for residential and commercial towers in Ontario (based on materials) (Cameron, 2021). This may not be reflective of the cost increase for infrastructure in BC but no credible sources have yet been published. This inflation may not impact the cost of the project at the time of construction if shortages and backlogs caused by the pandemic are resumed to normal levels.

8.2.3.4 Limitations

This assessment is based on the hydraulic model results of the existing conditions and assumed conditions of the structures along lower B.X. and Vernon Creek. Changes in bed conditions from those simulated will have an impact on the flood levels and extents. Based on the preliminary investigation of the identified mitigation measures, there is expected to be low transfer of flooding risk to other properties. However, this should be confirmed at the design phase for any structural work within a floodplain.

Cost estimates are based on results from the existing hydraulic model and coarse geometric generalizations. This level of uncertainty is reflected by the 40% contingency added to the total project costs. Survey and design of the mitigation measures are required to refine the estimate of quantities and costs. Costs and unit rates used in the estimates are based on other similar projects in the region and may differ from unit rates used in the detailed design and construction phase.

8.2.4 Mitigation Options Assessment - Results

Risk Avoidance Assessment

Likelihood

Enlarging the crossings would have a positive effect on flow conveyance through this reach of Vernon Creek. The likelihood of effectiveness at mitigating flooding in Vernon is a '3' or 'high' described as 'very likely to be highly effective' for all 3 crossings. Improving the conveyance at these sites may result in a local increase in velocity and sediment transport which will need to be considered in the design. However, it is not expected that these factors will affect the effectiveness or suitability for reducing flood levels.

Consequence

Implementing crossing upgrades would reduce flooding in several areas, as shown in Figure 8.12, Figure 8.14 and Figure 8.16. The receptors protected through this measure are characterized as '3' or 'high' and described as 'high exposure of people, economic, sociocultural, & ecological receptors/areas'. The consequence avoided through this measure is high as protection covers entire neighborhoods and avoids consequence for several commercial buildings and roads.

Risk Avoidance Score

Based on the matrices shown in Table 8.6 to Table 8.8, the overall risk avoidance score is a 5 for all three crossings.

Table 8.6 Risk avoidance score for 43rd Street crossing upgrades.

Proposed Measure	Risk Avoided Score			
	Factor	Factor Score	Factor Description	Overall Score
43 Street Crossing Upgrade	Likelihood	3	Very likely to be highly effective	5
	Consequence	3	High exposure of people, economic sociocultural, & ecological receptors/areas	

Table 8.7 Risk avoidance score for Okanagan Landing Road crossing upgrades.

Proposed Measure	Risk Avoided Score			
	Factor	Factor Score	Factor Description	Overall Score
Okanagan Landing Road Crossing Upgrade	Likelihood	3	Very likely to be highly effective	5
	Consequence	3	High exposure of people, economic sociocultural, & ecological receptors/areas	

Table 8.8 Risk avoidance score for Lakeshore Road crossing upgrades.

Proposed Measure	Risk Avoided Score			
	Factor	Factor Score	Factor Description	Overall Score
Lakeshore Road Crossing Upgrade	Likelihood	3	Very likely to be highly effective	5
	Consequence	3	High exposure of people, economic sociocultural, & ecological receptors/areas	

Feasibility Assessment

Ease of Execution

The ease of execution of the crossing upgrades along Vernon Creek is low, as they will require engineering design with challenges associated to working in and around watercourses as well as limiting impacts to adjacent roads, utilities, and buildings. The ease of execution is ranked as '3' or 'low' and described as 'Complex design. May include substantial environmental impact. May require significant changes in land ownership. May impact other stakeholders significantly'.

Cost Estimate

For this assessment it has been assumed that the crossings would be upgraded to clear-span bridges. The need for bridges versus culverts has not been included in the current scope of this project and the type of replacement structures should be considered at the detailed design phase. The use of culverts may be suitable and result in reduced cost, however a newer, larger culvert may cost just as much as a bridge when all factors are considered (fish passage, debris blockage, ease of access, and equipment required for installation). The crossing structures should be designed with capacity and clearance suitable to pass the design flow plus the expected sediment and debris.

It is expected that the replacement of the 43rd Street crossing would require 43rd Street to be raised for approximately 170 m from the crossing heading south-west. The cost estimate for all structures has been created using a bridge construction cost (by deck area) estimate based on previous MoTI bridge replacement projects in the last 3 years.

It has been assumed that crossing upgrades would all be completed separately (no cost sharing). However, it was assumed that the road raising (for 43rd Street only) will be done with the crossing upgrade and therefore share in costs such as mobilization, demobilization, and traffic management. Costs are developed from other projects that had similar design constraints. However, it should be noted that these project costs are based on MoTI projects. Table 8.9 through Table 8.11 summarize the estimated cost of upgrading all three crossings.

Table 8.9 Cost estimate for crossing upgrades at 43rd Street.

Item	Quantity	Unit Rate	Cost
Mobilization and demobilization	1	$50,000	$50,000
Traffic management	1	$100,000	$100,000
Demolition of existing crossing	1	$100,000	$100,000
Bridge Construction (by deck area) (m^2)	151	$6,000	$908,280
Road Grading (m)	170	$3,500	$595,000
Channel Riprap (m^3)	208	$185	$38,480
Supplementary construction	1	$250,000	$250,000
Soft costs	25%	-	$510,440
Possible COVID-19 cost inflation	6%	-	$122,506
Contingency	40%	-	$816,704
		Total	$3,490,000

Table 8.10 Cost estimate for crossing upgrades at Okanagan Landing Road.

Item	Quantity	Unit Rate	Cost
Mobilization and demobilization	1	$50,000	$50,000
Traffic management	1	$100,000	$100,000
Demolition of existing crossing	1	$100,000	$100,000
Bridge Construction (by deck area) (m^2)	133	$6,000	$798,000
Road Grading (m)	0	$3,500	$0
Channel Riprap (m^3)	208	$185	$38,480
Supplementary construction	1	$250,000	$250,000
Soft costs	25%	-	$334,120
Possible COVID-19 cost inflation	6%	-	$80,189
Contingency	40%	-	$534,592
		Total	$2,290,000

Table 8.11 Cost estimate for crossing upgrades at Lakeshore Road.

Item	Quantity	Unit Rate	Cost
Mobilization and demobilization	1	$50,000	$50,000
Traffic management	1	$100,000	$100,000
Demolition of existing crossing	1	$100,000	$100,000
Bridge Construction (by deck area) (m^2)	105	$6,000	$630,000
Road Grading (m)	0	$3,500	$0
Channel Riprap (m^3)	208	$185	$38,480
Supplementary construction	1	$250,000	$250,000
Soft costs	25%	-	$292,120
Possible COVID-19 cost inflation	6%	-	$70,109
Contingency	40%	-	$467,392
		Total	$2,000,000

Feasibility Score

Based on the matrices shown in Table 8.12,

Table 8.13 and Table 8.14 the overall feasibility score for all crossings is a 5.

Table 8.12 Feasibility score for 43rd Street crossing upgrades.

Proposed Measure	Feasibility Score			
	Factor	Factor Score	Factor Description	Overall Score
43 Street Crossing Upgrade	Ease of execution	3	Complex design. May include substantial environmental impact. May require significant changes in land ownership. May impact other stakeholders significantly	5
	Cost of implementation	3	>$1,500,000	

Table 8.13 Feasibility score for Okanagan Landing Road crossing upgrades.

Proposed Measure	Feasibility Score			
	Factor	Factor Score	Factor Description	Overall Score
Okanagan Landing Road Crossing Upgrade	Ease of execution	3	Complex design. May include substantial environmental impact. May require significant changes in land ownership. May impact other stakeholders significantly	5
	Cost of implementation	3	>$1,500,000	

Table 8.14 Feasibility score for Lakeshore Road crossing upgrades.

Proposed Measure	Feasibility Score			
	Factor	Factor Score	Factor Description	Overall Score
Lakeshore Road Crossing Upgrade	Ease of execution	3	Complex design. May include substantial environmental impact. May require significant changes in land ownership. May impact other stakeholders significantly	5
	Cost of implementation	3	>$1,500,000	

Overall Ratio Score

Table 8.15, Table 8.16, and Table 8.17 presents the risk to feasibility ratios for upgrading the 43rd Street, Okanagan Landing Road, and Lakeshore Road crossings on Vernon Creek. A high risk avoided score and a low feasibility score would indicate the best scenario. This project received a high risk avoidance score and a high feasibility score, resulting in a 5:5 Risk/Feasibility ratio for all crossings.

Table 8.15 Risk/Feasibility ratio for 43rd Street crossing upgrades.

Proposed Measure	Risk Avoided Score			Feasibility Score			Risk/ Feasibility Ratio
	Factor	Factor Score	Overall Score	Factor	Factor Score	Overall Score	
43 Street Crossing Upgrade	Likelihood	3	5	Ease of execution	3	5	5:5
	Consequence	3		Cost of implementation	3		

Table 8.16 Risk/Feasibility ratio for Okanagan Landing Road crossing upgrades.

Proposed Measure	Risk Avoided Score			Feasibility Score			Risk/ Feasibility Ratio
	Factor	Factor Score	Overall Score	Factor	Factor Score	Overall Score	
Okanagan Landing Road Crossing Upgrade	Likelihood	3	5	Ease of execution	3	5	5:5
	Consequence	3		Cost of implementation	3		

Table 8.17 Risk/Feasibility ratio for Lakeshore Road crossing upgrades.

Proposed Measure	Risk Avoided Score			Feasibility Score			Risk/ Feasibility Ratio
	Factor	Factor Score	Overall Score	Factor	Factor Score	Overall Score	
Lakeshore Road Crossing Upgrade	Likelihood	3	5	Ease of execution	3	5	5:5
	Consequence	3		Cost of implementation	3		

8.2.5 Summary of Part 1 and 2 Structural Mitigation Options

The Part 2 options assessment introduced in Section 8.2.3 was previously applied to the structural mitigation options explored for the Part 1 study area. Five mitigation options were considered for the Part 1 study area on upper B.X. Creek:

- Sediment and debris management plan
- Diking near Pleasant Valley Road
- Crossing upgrades on 20th Street and 48th Avenue
- Diking between 20th Street and Deleenheer Road
- Highway 97 crossing upgrade

Details of the recommended structural mitigation options for upper B.X. Creek are provided in the Part 1 project report (NHC, 2020b). The full structural mitigation options assessment for Part 1 is provided in the *City of Vernon Flood Mapping, Risk Analysis and Mitigation Project, Part 1 Mitigation Evaluation* report (NHC, 2020c), submitted to Vernon on November 26, 2020.

Table 8.18 summarizes the final Risk/Feasibility ratios and estimated costs of the structural mitigation options assessed in both Parts 1 and 2 of this study.

Table 8.18 Summary of Structural Mitigation Options Assessment (Parts 1 and 2)

Creek	Structural Mitigation Measure	Risk/Feasibility Ratio	Cost
Upper B.X. Creek (Part 1 Study Area)	Sediment and debris management plan	3:3	$1,150,000
	Diking near Pleasant Valley Road	2:5	$1,510,000
	Crossing upgrades on 20th Street and 48th Avenue	4:5	$12,460,000
	Diking between 20th Street and Deleenheer Road	5:5	$2,570,000
	Highway 97 crossing upgrade	4:5	>$1,500,000
Lower Vernon Creek (Part 2 Study Area)	43rd Street crossing upgrade	5:5	$3,490,000
	Okanagan Landing Road crossing upgrade	5:5	$2,290,000
	Lakeshore Road crossing upgrade	5:5	$2,000,000

Of the above structural mitigation measures, the greatest risk avoidance is expected to be achieved by diking upper B.X. Creek between 20th Street and Deleenheer Road and upgrading the lower Vernon Creek crossings at 43rd Street, Okanagan Landing Road, and Lakeshore Road. However, these measures can be anticipated to be complicated to design and expensive to construct. Upper B.X. Creek crossing upgrades on 20th Street, 48th Avenue, and Highway 97 are anticipated to be the next most effective for risk avoidance, but also exhibit high costs and difficult feasibility. The sediment and debris management plan has moderate scores for both risk avoidance and feasibility. Diking near Pleasant Valley Road is anticipated to be somewhat helpful in flood mitigation, but will likely be very difficult and expensive to construct.

8.3 Prioritization of Mitigation

The prioritization of flood mitigation within a community should be developed based on the flood hazard, understanding of flood risk, community priorities, and implementation constraints. An understanding of flood hazard as developed in this project is key to planning mitigations effectively through identifying impactful mitigations and evaluating potential effects on flood depths or erosion upstream or downstream from the mitigation. Risk assessments help prioritization as communities may choose to prioritize high-risk areas to minimize the impact to vulnerable buildings or populations. Mitigation measures should be selected to align with community priorities, which can include protection of cultural sites and community landmarks, or selecting mitigation designs which complement recreation or habitat uses in an area. Implementation constraints can include lifecycle project costs, co-benefits, potential negative impacts, available land, permitting requirements, and available funding.

Of the structural and non-structural mitigation options identified for Part 1 and Part 2 of this project, the six that are anticipated to have the largest benefits are listed below.

1. Emergency Flood Response Plan (entire city)

The recommended first priority is the development of an Emergency Flood Response Plan that will guide Vernon through the response stage to a potential future flood event. This is a low-cost mitigation measure that can be prepared quickly and would provide large benefits to the community. An effective Emergency Flood Response Plan ensures efficient use of resources to minimize flooding.

2. OCP and Zoning By-law update

The second non-structural mitigation, which is of equal priority to the first, is to establish flood by-laws that prevent development within the floodway and limit development within the floodplain. The limits to development should be dependent on the risk, that is the proposed land use and identified hazard.

3. Sediment and Debris Management Plan (upper B.X. Creek)

The development of a sediment and debris management plan is recommended prior to the design and construction of other structural mitigation options on upper B.X. Creek, as it can be used as a tool in the design of other mitigation options. Sediment transport to the fan is identified as a flood hazard for upper B.X. Creek and the design of structural mitigation should include a detailed understanding of how existing infrastructure (sediment traps/basins) along with their maintenance and operation will impact proposed structural mitigation.

4. Diking between 20th Street and Deleenheer Road (upper B.X. Creek)

Two structural mitigation options discussed in the Part 1 project report for flood risk reduction on upper B.X. Creek were (1) crossing upgrades on 20th Street and 48th Avenue and (2) diking of the downstream channel between 20th Street and Deleenheer Road. Both options are large capital projects that will include property acquisition and construction of sizeable infrastructure; however, diking of the downstream channel is anticipated to have a lower capital cost and a higher reduction of flood risk. The design of this mitigation option should assume that the upstream crossing upgrades will be completed in the future, increasing flow and sediment transport to the downstream channel where the dike is proposed.

5. Crossing upgrades on 43rd Street, Okanagan Landing Road, and Lakeshore Road (lower Vernon Creek)

The three crossing upgrades recommended for lower Vernon Creek (Section 8.2) are all considered large capital projects that will likely require raising roads (and associated utilities), construction of large clear span structures that do not constrict the waterway, and possible property acquisitions. Despite the high costs, the improved crossings are anticipated to greatly reduce flood risk at all locations.

6. Crossing upgrades on 20th Street and 48th Avenue (upper B.X. Creek)

Like the lower Vernon Creek crossing upgrades, the upper B.X. Creek crossing upgrades at 20th Street and 48th Avenue are considered large capital projects that will have very high costs. The cost of this mitigation option is anticipated to be much greater than the downstream diking between 20th Street and

Deleenheer Road, and to have a similar reduction in flood risk. Design of this option should consider sediment transport, suitable clearance at crossings, existing channel constrictions, and channel improvements between crossings.

In making implementation decisions regarding the recommended mitigation measures, conversations about priorities for mitigation should include public consultation and the priorities of Vernon.

9 REFERENCES

AE (2017). Review of 2017 Flood Response: Okanagan Lake Regulation System and Nicola Dam, prepared for Ministry of Forests, Lands, Natural Resource Operations & Rural Development. Associated Environmental Consultants Ltd.

APEGBC (2017). Flood Mapping in BC, APEGBC Professional Practice Guidelines, V1.0. The Association of Professional Engineers and Geoscientists of British Columbia, Burnaby, BC. 54 pp. [online] Available from: https://www.egbc.ca/app/Practice-Resources/Individual-Practice/Guidelines-Advisories/Document/01525AMW6CMLNYZOJFZ5AY4MD3UNNDZQWW/Flood%20Mapping%20in%20BC (Accessed 9 March 2021).

California Natural Resources Agency (2018). State of California Sea-level Rise Guidance.

Cameron, G. (2021, 31 May). Industry Perspectives Op-Ed: COVID-19 impact on material prices creating storm clouds for construction. Daily Commercial News by ConstructConnect Canada. [online] Available from: https://canada.constructconnect.com/dcn/news/resource/2021/05/industry-perspectives-op-ed-covid-19-impact-on-material-prices-creating-storm-clouds-for-construction (Accessed 29 July 2021).

City of Vernon (2021). Open Data Catalogue. City of Vernon. [online] Available from: https://cov-open-data-vernon.hub.arcgis.com/.

Ecora (2019). Swan Lake Dam Operations Plan (GK-18-729-MOF). BC Ministry of Forests and Lands, Natural Resource Operations and Rural Development. 124 pp.

EGBC (2018). Legislated Flood Assessments in a Changing Climate in BC, Version 2.1. Engineers & Geoscientists British Columbia, Burnaby, BC. 192 pp.

EXCIMAP (2007). Flood mapping: a core component of flood risk management - Atlas of Flood Maps: Examples from 19 Countries, USA and Japan. European Commission - Environment. [online] Available from: http://ec.europa.eu/environment/water/flood_risk/flood_atlas/ (Accessed 13 August 2018).

FLOODsite (2005). Language of Risk. [online] Available from: http://www.floodsite.net/html/partner_area/project_docs/FLOODsite_Language_of_Risk_v4_0_P1.pdf.

Government of British Columbia (2021). BC Data Catalogue. British Columbia. [online] Available from: https://catalogue.data.gov.bc.ca/dataset?download_audience=Public.

Iverson, K. (2008). Sensitive Ecosystems Inventory: Coldstream - Vernon, 2007. Volume 1: Methods, Ecological Descriptions, Results, Conservation Analysis, and Management Recommendations.

MFLNRORD (2018). Flood Hazard Area Land Use Management Guidelines, originally Ministry of Water, Land and Air Protection, Province of British Columbia, May 2004, amended January 2018 by the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD). Ministry of Forests, Lands, Natural Resource Operations and Rural Development.

MLIT (2005). Flood Hazard Mapping Manual in Japan. Flood Control Division, River Bureau, Ministry of Land, Infrastructure and Transport (MLIT). 87 pp. [online] Available from: http://www.icharm.pwri.go.jp/publication/pdf/2005/flood_hazard_mapping_manual.pdf (Accessed 20 February 2021).

MOTI (2013a). Highway Planning Cost Estimating System: User Manual.

MOTI (2013b). Project Cost Estimating Guidelines Version 01.02.

MRLC (2011). National Land Cover Database 2011 (NLCD2011) Legend. Multi-Resolution Land Characteristics Consortium. [online] Available from: https://www.mrlc.gov/data/legends/national-land-cover-database-2011-nlcd2011-legend.

Natural Resources Canada (2013). National Railway Network - NRWN - GeoBase Series. Government of Canada. [online] Available from: https://open.canada.ca/data/en/dataset/ac26807e-a1e8-49fa-87bf-451175a859b8.

Natural Resources Canada, and Public Safety Canada (2018). Federal airborne LiDAR data acquisition guideline, Version 2.0 (General Information Product 117e). Government of Canada. 64 pp. [online] Available from: http://publications.gc.ca/collections/collection_2019/rncan-nrcan/M113-3-4-2018-eng.pdf (Accessed 10 September 2019).

NHC (2020a). City of Vernon: Detailed Flood Mapping, Risk Analysis and Mitigation Design Flow Estimation - Part 2: Lower B.X. and Vernon Creek. Prepared by Northwest Hydraulic Consultants Ltd. for the City of Vernon. 15 pp.

NHC (2020b). City of Vernon Detailed Flood Mapping, Risk Analysis and Mitigation: Part 1 - Upper B.X. Creek (3005032). Prepared by Northwest Hydraulic Consultants Ltd. for City of Vernon. 88 + Appendices pp.

NHC (2020c). City of Vernon Flood Mapping, Risk Analysis and Mitigation Project, Part 1 Mitigation Evaluation. Draft. Prepared by Northwest Hydraulic Consultants Ltd. for City of Vernon.

NHC (2020d). Okanagan Mainstem Floodplain Mapping Project (NHC PN3004430). Report prepared by Northwest Hydraulic Consultants Ltd. (NHC) for the Okanagan Basin Water Board (OBWB), 31 March 2020.

NHC (2020e). Okanagan Valley Flood Mapping Standards (NHC PN3004430). Report prepared by Northwest Hydraulic Consultants Ltd. (NHC) for the Okanagan Basin Water Board (OBWB). 34 pp. [online] Available from: https://www.obwb.ca/docs/2020-okanagan-floodplain-mapping-standards-nhc.pdf (Accessed 1 August 2020).

NRCan, and Public Safety Canada (2019). Federal Geomatics Guidelines for Flood Mapping, Version 1.0 (Natural Resources Canada, Public Safety Canada) (General Information Product 114e). Government of Canada. 59 pp. [online] Available from:

http://ftp.geogratis.gc.ca/pub/nrcan_rncan/publications/ess_sst/299/299810/gip_114_en.pdf (Accessed 10 September 2019).

Public Safety Canada (2016). Risk Assessment Information Template. [online] Available from: https://www.publicsafety.gc.ca/cnt/mrgnc-mngmnt/dsstr-prvntn-mtgtn/ndmp/_fls/ndmp-rait-en.pdf.

Public Safety Canada (2017). NDMP Program Guidelines. Public Safety Canada. [online] Available from: https://www.publicsafety.gc.ca/cnt/mrgnc-mngmnt/dsstr-prvntn-mtgtn/ndmp/prgrm-gdlns-en.aspx#a01.

Stantec (2016). City of Vernon 2015 Inspection & Maintenance Program Report. Prepared for City of Vernon by Stantec Consulting Ltd., Burnaby, BC.

Summit (1996). B.X. Creek Peak Flow Analysis - Final Report. Prepared for the Corporation of the City of Vernon by Summit Environmental Consultants Ltd., Vernon, BC.

UN OCHA (2018). OCHA launches 500 free humanitarian symbols. [online] Available from: https://www.unocha.org/story/ocha-launches-500-free-humanitarian-symbols.

United Nations (2016). Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction. [online] Available from: https://www.preventionweb.net/files/50683_oiewgreportenglish.pdf.

University of New Brunswick (2016). Rapid Risk Evaluator (ER2-flood). University of New Brunswick.

APPENDIX A

DESIGN FLOW ESTIMATION TECHNICAL MEMO

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8 April 2021

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Attention: **Mathew Keast, PEng**
Project Manager, Water Resource Engineer

Via email: mkeast@vernon.ca

Re: **City of Vernon: Detailed Flood Mapping, Risk Analysis and Mitigation Design Flow Estimation - Part 2: Lower B.X. and Vernon Creek**

Dear Mr. Keast:

This memo contains our hydrologic analysis methods and results for the City of Vernon – Part 2: Lower B.X. and Vernon Creek floodplain study. The following describes how the design flow estimates for Lower B.X. Creek and Vernon Creek (between Kalamalka and Okanagan Lake) were developed. Lower B.X. Creek and Vernon Creek are a part of the heavily regulated Okanagan Basin. Because of this, alternative methods (to traditional flood frequency analysis) for estimating design flows on this system had to be used.

1 INTRODUCTION

In July 2020, NHC completed part 1 of the City of Vernon's detailed floodplain mapping, risk analysis and mitigation study. Part 1 focused on Upper B.X. Creek, from the city limits to the point where B.X. Creek flows into Swan Lake (NHC, 2020a). Part 2 began directly after completion of part 1 and focuses on Lower B.X. Creek, from Swan Lake to the confluence of Vernon Creek, and Vernon Creek, from Kalamalka Lake to Okanagan Lake.

This report details the methods for estimating design flows (including climate change impacts) for input to the 2-dimensional hydraulic model of Lower B.X. and Vernon Creek within the City of Vernon. Design flows were estimated in three parts: 1) outflows from Kalamalka Lake into Vernon Creek; 2) outflows from Swan Lake into Lower B.X. Creek; and, 3) local flows generated within the City of Vernon. The stream layout is shown in Figure 1, and details on the Water Survey of Canada (WSC) gauges used in the analysis are shown in Table 1.

In part 1, the observed flood event from June 1996 on B.X. Creek was used as the design event, as it was estimated to have a return period greater than 500 years. The flood of 1996 on Upper B.X. Creek was caused by intense rainfall (~45 mm in at most two days in the City of Vernon, and likely more within upper B.X. Creek) on top of a melting snowpack in the upper reaches of B.X. Creek. In part 2, the 1996 flood event was again used as the inflow to Swan Lake which was then routed through the lake and into Lower B.X. Creek.

Kalamalka Lake levels respond much more slowly than B.X. Creek, as the total watershed area is much larger, and the storage of Ellison, Wood, and Kalamalka Lake slow the hydrograph response. The highest lake levels (and thus largest outflows into Vernon Creek) are likely to occur when a synoptic scale (e.g. covering the entire watershed) rainstorm occurs on top of melt from a very large snowpack, such as the peak lake outflows that occurred in the Spring of 1997, one of the highest snowpack years on record.

Though the 1996 B.X. Creek event was shorter and more intense than what would cause maximum outflow from Kalamalka Lake, it occurred on June 1, which is within the time of year for maximum Kalamalka Lake levels. Thus, we use a more traditional 200-year flow on Vernon Creek (from Kalamalka Lake) as a design flow that occurs at the same time as the 1996 routing on Lower B.X. Creek.

Table 1 WSC Gauge Summary

ID	Name	Watershed area (km^2)	Variables	Time range
08NM020	B.X. Creek above Vernon intake	53.2 (NHC Est.)	Flow, Level	1921-1927 1959-1999
08NM065	Vernon Creek at outlet of Kalamalka Lake	572 (NHC Est.)	Flow, Level	1927-1930 1959-Present
08NM123	B.X. Creek below Swan Lake control dam	120 (WSC Est.)	Flow, Level	1959-1978
08NM143	Kalamalka Lake at Vernon pumphouse	571 (NHC Est.)	Level	1967-Present
08NM160	Vernon Creek near the mouth	751 (WSC Est.)	Flow, Level	1969-1999

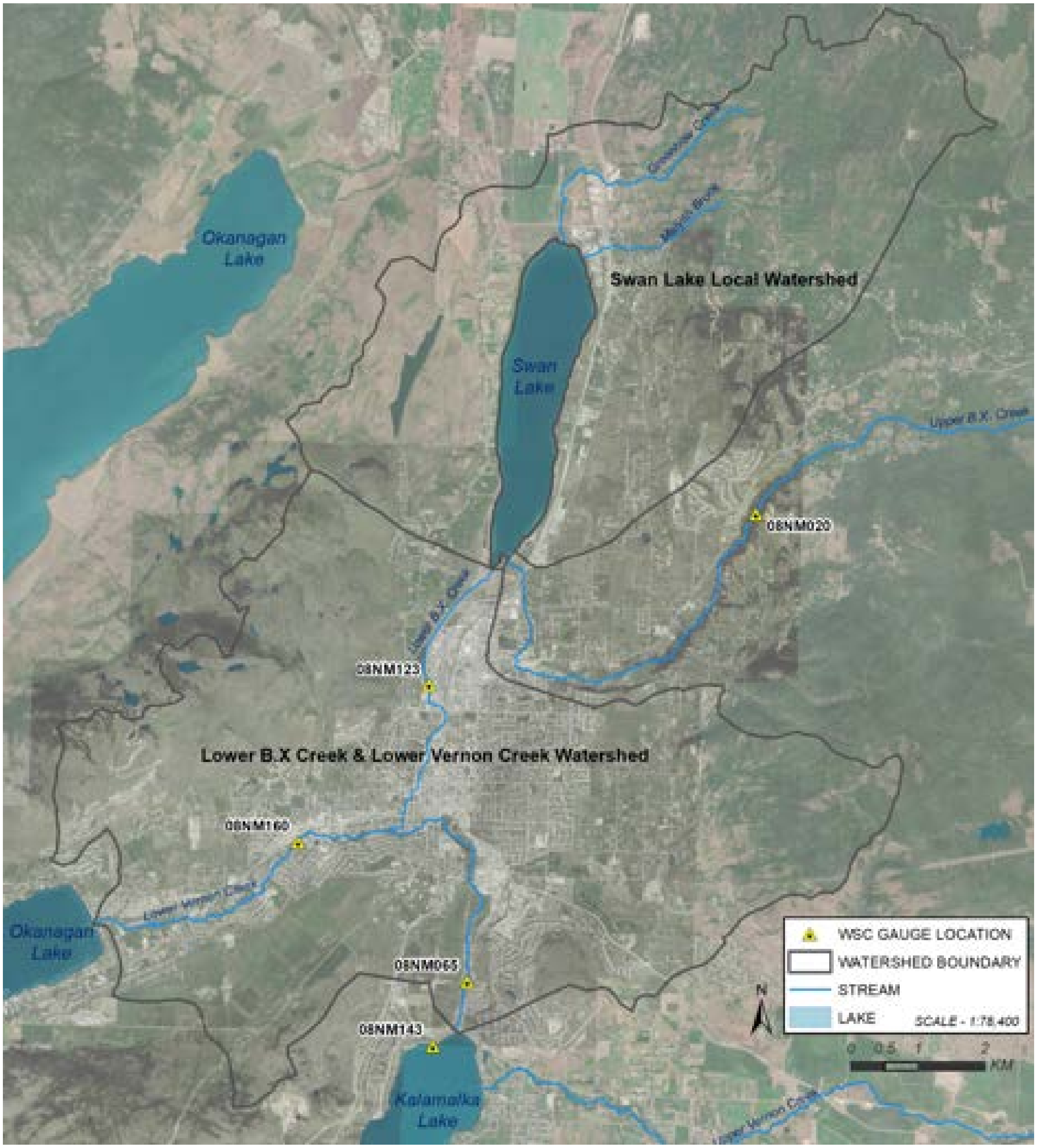


Figure 1 Location Map.

2 KALAMALKA LAKE INTO VERNON CREEK

As described in the part 1 report, NHC developed a hydrologic and reservoir operations model for the entire Okanagan River mainstem, from Ellison Lake to Osoyoos Lake (NHC, 2020b). This hydrologic model, developed in the Raven platform (Craig et al., 2020), uses an ensemble of 50 synthetically generated weather timeseries, from 1950-2100, to simulate the combination of natural hydrology and corresponding reservoir operation responses to these conditions in order to model reservoir levels.

As in part 1, this model was modified for direct application to the City of Vernon and used for estimating outflows from Kalamalka Lake into Vernon Creek. Kalamalka Lake outflows are regulated by a set of three 5-foot (1.52 m) wide sluice gates at the outlet of the lake. The operation of these gates is controlled by the BC FLNRORD Okanagan reservoir manager in order to meet a combination of lake level and streamflow targets throughout the year. Lake level targets are determined based on forecasts of total spring freshet inflows into Kalamalka Lake; freshet inflows are forecast by the BC River Forecast Centre and supplied to the reservoir manager on a monthly basis from January – May. The full operations guidelines of Kalamalka Lake are detailed in AE (2017). The most significant portion of the operations guidelines applies to late winter target levels. When the freshet inflows are forecast to be large (primarily due to buildup of a large winter snowpack), the reservoir manager aims to bring the lake levels down to lower pre-melt levels than if the inflow forecast is small. This allows for a balance between preventing lake flooding and keeping enough water in the lake for summer demand and environmental flow needs.

Target release flow rates are only capped at the lower end in the Kalamalka Lake operations guidelines, in order to meet environmental flow needs. However, discussions with the reservoir manager indicated that the maximum release from Kalamalka Lake should not exceed approximately 6 m^3/s; higher flows are likely to cause infrastructure damage along Vernon Creek at present (Shaun Reimer, BC FLNRORD, pers. comm. Jan. 2020). Due to the higher risk of damage from moving water than high lake levels, this maximum flow release cap is given a higher priority than reaching target lake levels.

Though there is no intent to allow releases higher than 6 m^3/s into Vernon Creek from Kalamalka Lake, NHC has followed the approach adopted for the Okanagan mainstem flood mapping work to simulate a more conservative ‘open gates’ scenario for Kalamalka Lake releases. In NHC (2020b), design flows on Okanagan River were determined by allowing free flowing water out of Okanagan Lake for the ensemble hydrologic model simulation. We have followed this approach for flows into Vernon Creek, assuming the Kalamalka Lake outlet gates are left fully open for the entire spring freshet.

The open gate scenario is a more conservative assumption[1] than capping all releases into Vernon Creek at 6 m^3/s and maintains continuity with design flow estimates along the Okanagan River. While there is no intent to exceed 6 m^3/s, it is possible that normal operations could be compromised. Potential operations malfunctions at the outlet of Kalamalka Lake could make closing gates impossible, or extreme lake levels could risk damaging the dam itself if water is not released as quickly as possible. Thus, the

[1] The open gates scenario is more conservative for Vernon Creek flows (producing higher flows) but likely less conservative for estimating Kalamalka Lake design levels. Hence, the regulation rules were used when simulating design lake levels in NHC (2020b).

open gates scenario can help to account for these potential operations outside of normal conditions on Vernon Creek.

In order to use an open gates simulation in the Raven model, it was necessary to develop a rating curve for the Kalamalka Lake release structure. NHC constructed this rating curve through a combination of two methods: 1) an empirical rating curve based on data from the 1997 freshet, when gates were left fully open for the duration of the freshet, and 2) an inline structure hydraulic model for extreme levels if lake levels reached the top of the open gates.

The empirical rating curve was developed through a comparison of flow at the Water Survey of Canada (WSC) gauge 08NM065 – Vernon Creek at outlet of Kalamalka Lake and stage at 08NM143 – Kalamalka Lake at Vernon pumphouse. The empirical rating curve is likely to provide a more realistic stage-discharge relationship for the range of observed flows as it implicitly accounts for obstructions and flow influences aside from the dam structure alone. For example, it was indicated by the reservoir manager (Shaun Reimer, BC FLNRORD, pers. comm., Sep 2020) that sediment has built up in front of the release structure and is likely slowing releases from the lake; additionally, flows may be controlled in the channel downstream of Kalamalka lake, underneath the train tracks (approximately 50 m downstream). A comparison of stage-discharge in 1997 and 2020 indicated evidence of sedimentation buildup that is slowing outflow from the lake. In other words, the same lake stage would result in a lower flow in 2020 than it would have in 1997. However, this issue is under investigation by FLNRORD and dredging around the release structure in Kalamalka is likely. Thus, the 1997 rating curve is more appropriate for use over the long term than the 2020 relationship. The fitted empirical curve is shown in black in Figure 2 up to a stage of approximately 392.4 (the highest stage reached in 1997).

The most extreme lake levels and discharges, where the gates become completely submerged and water flows round the structure, have thankfully not been reached since the structure was built, so the empirical curve does not cover these situations. Thus, we estimated the upper end of the rating curve, which could potentially be needed in the ensemble simulations of 50 members from 1945-2100, using an inline structure in HEC-RAS (Brunner, 2016). We created a rating curve via incrementally increasing lake levels to simulate flow through and over the submerged dam gates above the observed conditions. The HEC-RAS rating curve begins in Figure 2 (in black) at the flat spot; this flat section, where stage increases with little effect on flows, indicates the submerged gate orifice flow. Eventually, the stage rises high enough to simulate flow over the top of the gates (when the flat area ends and flows again begin to increase). Weir flow over the gates in a flood situation assumed that Kalamalka Lake was confined and could not spill around the gates, only overtop. This scenario is likely; in most extreme lake level situations (e.g. 2017) sandbags would be placed around the dam to route lake water through, rather than around, the release structure.

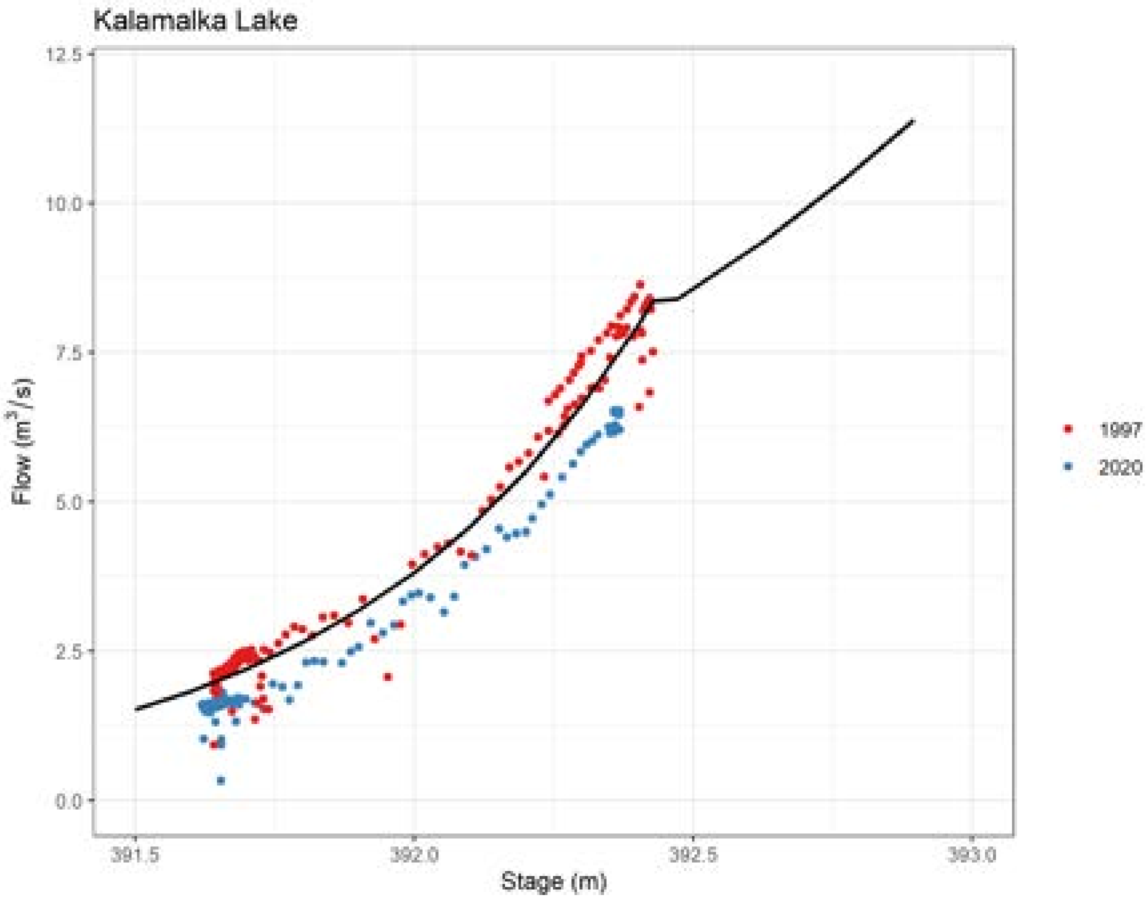


Figure 2 Empirical rating curve (in black) fit for Kalamalka Lake outflow from 1997 up to 392.4 m, and developed in HEC-RAS above.

After building the combined empirical/simulated rating curve, this curve was integrated into NHC's full Okanagan reservoir model, and the full ensemble set of 50 members from 1950-2100 was run. In order to conservatively simulate the gates being opened once the lake was already at target levels, we restricted minimum lake levels to the monthly target levels for a high inflow year from the operations plan (AE, 2017). Above this level, free flow from the open gates was allowed.

As in part 1 (for both B.X. Creek and Swan Lake), the annual maximum outflow from Kalamalka Lake was extracted for each year and ensemble member, resulting in 7500 total annual maximum outflows into Vernon Creek. Also as in part 1, we divided these outflows into 30-year blocks of pseudo-stationary outflow datasets, with each block containing 1500 simulated years of outflow. Each time block was analyzed using empirical flood frequency analysis to determine design flows for the present day (defined as 2020 +/- 15 years and two future time periods. An example empirical frequency analysis is shown in Figure 3, and design flow results are shown in Table 2. NHC recommends that the end of century model flows are used to best account for potential climate change impacts.

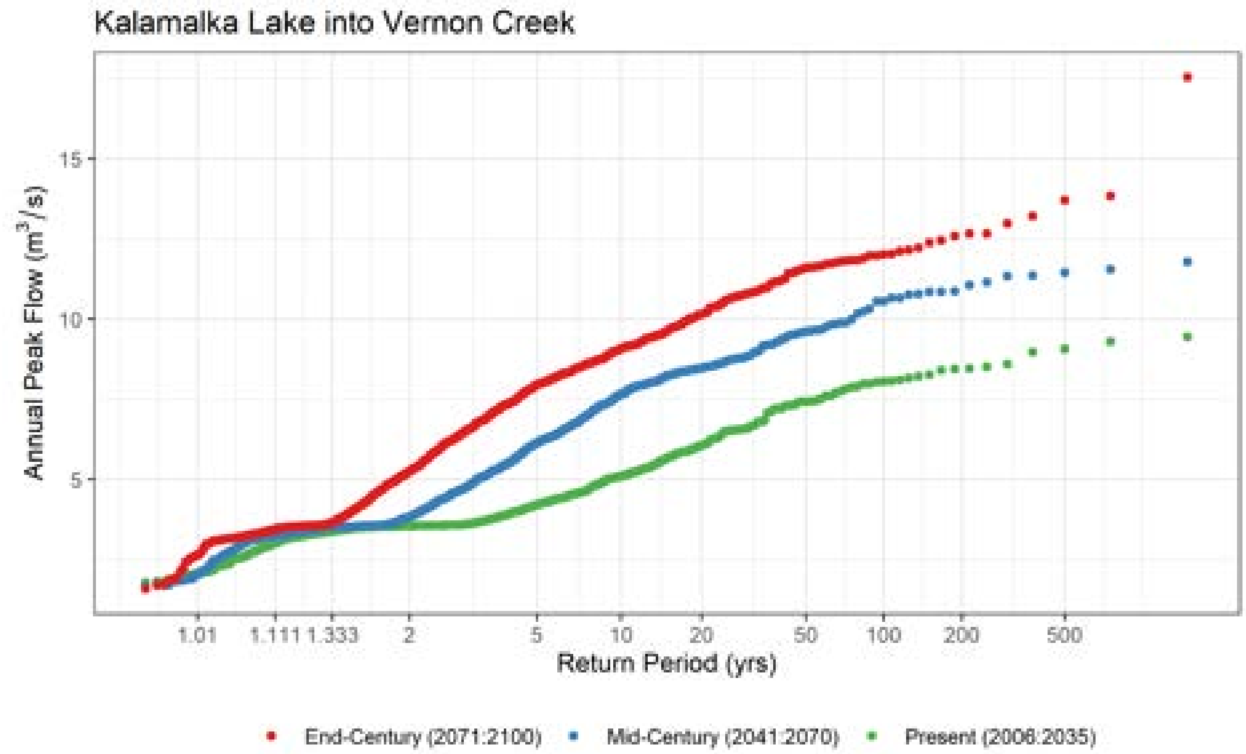


Figure 3 **Empirical frequency analysis of annual maximum releases from Kalamalka Lake into Vernon Creek for the three analysis periods in the NHC Okanagan Mainstem model.**

Table 2 **Mean daily peak Kalamalka Lake releases (m^3/s) into Vernon Creek from NHC Okanagan Mainstem Raven model using the open gates scenario. Recommended hydraulic model inputs is shown in bold.**

Return Period (yr)	Present (2006-2035)	Future (2041-2070)	Future (2071-2100)
10	5.1	7.7	9.1
20	6.1	8.5	10.1
100	8.0	10.5	12.0
200	8.4	10.9	**12.6**

The Raven Okanagan mainstem model runs on a daily timestep, and as such these peak outflows are mean daily outflows. However, Kalamalka Lake and its corresponding outflows are a relatively slow responding system. The highest observed flows on the WSC gauge 08NM065: Vernon Creek at outlet of Kalamalka Lake are 8.71 m^3/s (instantaneous) and 8.63 m^3/s (daily), both on June 12, 1997.

Additionally, there is no correlation between the difference between instantaneous and daily Kalamalka Lake levels and the maximum annual level in the WSC record. The average difference between instantaneous and annual maximum level on Kalamalka Lake is 1.5 cm, corresponding to a difference in peak outflow of less than 0.2 m^3/s. Thus, we recommend the mean daily flows as the design input from Kalamalka Lake into Vernon Creek.

3 SWAN LAKE INTO LOWER B.X. CREEK

The City of Vernon part 1 report for Upper B.X. Creek (NHC, 2020a) used the instantaneous maximum peak flow from the June 1, 1996 event on Upper B.X. Creek (WSC gauge 08NM020). The observed instantaneous maximum was 13.2 m^3/s, which was above the 500-year flow estimate (12.9). As such, NHC recommended the use of this value as a design flow instead of the typical 200-year calculated flow. The value was scaled up (via area-based scaling) to the top of the model reach (for the part 1, Upper B.X. Creek hydraulic model) for a flow of 17.7 m^3/s for the present day and 19.5 m^3/s with an additional 10% safety factor due to climate change.

For part 2, we routed the 17.7 and 19.5 m^3/s flows through Swan Lake within NHC's Okanagan Mainstem Raven model to determine the maximum outflow from Swan Lake into Lower B.X. Creek. In addition to these B.X. Creek design flows, local inflows generated within the Raven model were included in the Swan Lake inflows.

The Raven model was run for the May 15 – June 15, 1996 period at a one-hour timestep. The model inflows to Swan Lake were overridden by a hydrograph based on interpolation of the instantaneous maximum and mean daily observations on B.X. Creek, upscaled to the same size as flows used in part 1 (for the upper end of the part 1 model reach). All other inflows to Swan Lake were modelled directly within Raven using weather observations from the May 15 - June 15, 1996 period, however the inflows from B.X. Creek were the dominant input to the lake. A sample inflow/outflow routing result is shown in Figure 4 using the present day 1996 inflow estimate and the Swan Lake local inflows.

Routing the 1996 event through Swan Lake required further investigation into the rating curves for the outlet of Swan Lake. Ecora (2019) provided rating curves for the different stoplog configurations on the weir (from 0 to 6 logs). However, these rating curves were developed (via hydraulic modelling) prior to the removal of the three culverts downstream of the Swan Lake weir. These culverts had previously provided a backwater effect during high flows and thus were likely to lower the outflow rate while increasing lake levels.

As a sensitivity test, NHC compared model routing results of the June 1996 peak flows between the Ecora calculated stage-discharge rating curve and a broad crested weir equation, which is likely to better simulate unconstrained outflow from Swan Lake (C = 0.6, crest length = 3.6 m). Both methods used a conservative assumption of 5 stoplogs in place on the Swan Lake dam. The number of stoplogs in place did not effect the peak outflow, but did affect the peak lake level reached within the event. Results are shown in Table 3. As the results are from an instantaneous peak inflow to the model, run with an hourly timestep, they should be considered instantaneous peaks. As expected, the Ecora rating curves, which assume downstream flow constriction, result in lower peak flows but higher maximum lake levels. NHC recommends using the weir equation results as design flows from Swan Lake into Lower B.X. Creek.

Comparatively, the highest observed outflow from Swan Lake (WSC Gauge 08NM123: B.X. Creek below Swan Lake Control Dam) was a mean daily flow of 2.94 m^3/s on April 26, 1973. However, no instantaneous peak flows have been reported; additionally, the period of record is quite short (~1960-1975) and occurred prior to installation of the current outflow structure in 1975 (Ecora, 2019).

As a final check, we empirically calculated maximum outflows from Swan Lake directly from Raven (using the ensemble simulation as in Vernon Creek/Kalamalka Lake). Results showed an end of century 200-year peak flow of 5.2 m^3/s, indicating that the 1996 event is still the most conservative design event for inflows to Lower B.X. Creek.

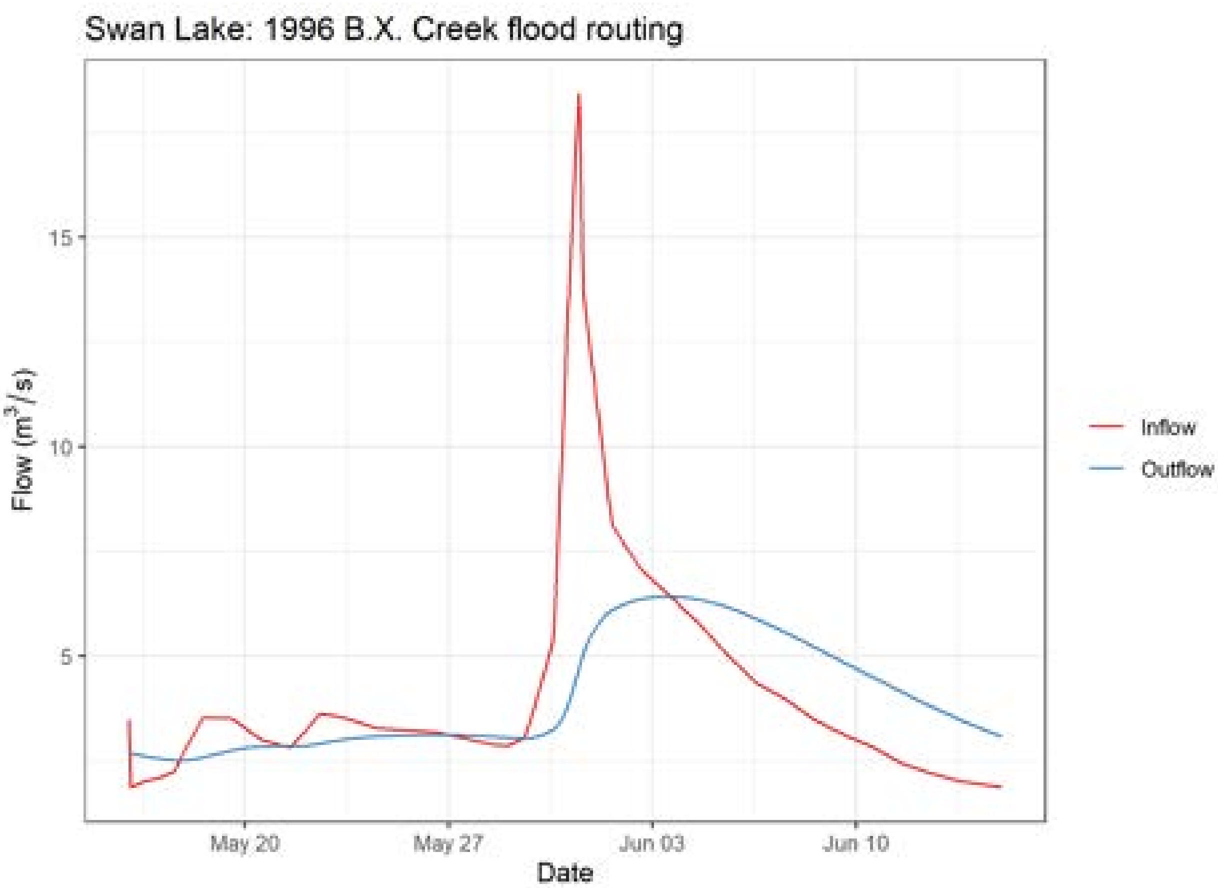


Figure 4 **Routing of the 1996 B.X. Creek flood through Swan Lake in the NHC Okanagan Mainstem Raven model. Inflows include both design flow input from Upper B.X. Creek and modelled local Swan Lake inflows.**

Table 3 **Routing results for the 1996 flood through Swan Lake. RC = rating curve. Recommended hydraulic model input is shown in bold. Future inflows are based on the climate change adjustment for the 1996 B.X. Creek flow described in NHC (2020a).**

Maximum	Ecora (2019) RC, present day inflow	Ecora (2019) RC, future inflow	Weir EQ (5 logs), present inflow	Weir EQ, (5 logs), future inflow
Flow (m^3/s)	5.8	5.8	6.4	**6.5**
Level (m)	390.62	390.63	390.26	390.27

4 LOCAL INFLOWS

Local inflows to B.X. and Vernon Creek were simulated for present and future conditions for the primarily urban local watershed area from Swan and Kalamalka Lake into Okanagan Lake (60.3 km^2, labelled as Lower B.X. and Lower Vernon in Figure 1). This watershed area is substantially flatter and lower elevation than the watershed areas draining into Kalamalka and Swan Lakes, and hence the hydrologic drivers are quite different.

We investigated peak flows in this area by two methods. First, we used streamflow observations in the overlapping time period from approximately 1970 to 1979, where observations on WSC Gauges:

- 08NM160 – Vernon Creek near the mouth
- 08NM065 – Vernon Creek at outlet of Kalamalka Lake
- 08NM123 – B.X. Creek below Swan Lake Control Dam

were all available. We subtracted the flows on 08NM065 and 08NM123 from 08NM160 to estimate local inflows within this area. The maximum estimated mean daily local inflow was 2.6 m^3/s on October 12, 1976 at the 08NM160 gauge. While this record is quite short, not recent, and only based on daily data, it illustrated that peak inflows in the local areas of B.X. Creek have occurred throughout the year, and are not necessarily coordinated with peak flows on the mountain snowmelt and rainfall driven upper reaches of B.X. Creek and Vernon Creek.

As a second step, we extracted local flows for the area between Swan, Kalamalka and Okanagan Lake from the NHC Okanagan Mainstem Raven model. Results also indicated that peak flows along this reach can occur at many different times of the year and are not necessarily synchronized with the maximum (and larger) outflows from either Swan or Kalamalka Lake.

As the gauge record was too short for frequency analysis of observed data, we instead extracted the annual maximum peak daily inflows from the local watershed along B.X. and Vernon Creek from the Okanagan Raven. We empirically calculated design flows from the annual inflows as was done with the Kalamalka Lake outlets to Vernon Creek

We then estimated an increase to move from the daily timestep Raven model to instantaneous flows using gauge data from the deactivated 08NM160 WSC gauge. Since both upstream tributaries come from slow responding lakes (Swan and Kalamalka), it is likely that the majority of instantaneous increases at the 08NM160 gauge are due to local stormflow within Vernon. The largest difference between annual maximum daily and maximum instantaneous flow during the freshet season was 3.2 m3/s on the 08NM160 gauge in 1980. We applied this increase directly to the design flow results from Raven for the present day (2006-2035 period).

To estimate potential local stormflow increases due to climate change, we investigated 24-hour duration IDF storm data for the City of Vernon using Western University's IDF-CC tool[2]. Ensemble median results were less than 10% increases in 24-hour 100 year peak rainfall (the highest return period supplied) for both the RCP 4.5 and 8.5 (moderate and high emissions scenarios) and for both the mid century and end of century periods. Thus, we increased the 3.2 m3/s instantaneous offset by a 10% factor of safety for both future periods (3.5 m3/s).

Local design flow results are shown in Table 4. It must be emphasized that these local inflows are only intended for use in conjunction with the design flows on B.X. and Vernon Creek stated above. Additionally, estimates of future increases in instantaneous peak flows do not take into account urban expansion of the City of Vernon. For assessment specific to an event within the City of Vernon, stormwater drainage, urban development, and shorter duration storms should be assessed.

Table 4 Mean daily peak local inflows (m^3/s) within the City of Vernon in the NHC Okanagan Mainstem Raven model. Present estimates include an instantaneous increase factor of 3.2 m^3/s. Future periods include an instantaneous increase factor of 3.5 m^3/s. Recommended hydraulic model input is shown in bold.

Return Period (yr)	Present (2006-2035)	Future (2041-2070)	Future (2071-2100)
10	4.8	5.2	5.5
20	5.1	5.5	5.9
100	5.8	6.3	6.8
200	6.1	6.6	**7.1**

As a final check on the total design flows within the city, we compared the total flows estimated for each reach with a standard flood frequency analysis of the WSC gauge 08NM160. The heavy influence of regulation on this gauge mean that it is not appropriate for design flow calculation; however, it can be used as a secondary reality check of other methods. A frequency analysis (using the Gumbel distribution, fitted via l-moments) to this gauge gave an instantaneous 200-year flow estimate of 16.5 m^3/s. This result lends credibility to our total estimate (combining the three methods above) of 20.9 m^3/s for the design flow into Okanagan Lake for the present day.

[2] https://www.idf-cc-uwo.ca/

5 REFERENCES

AE (2017). Review of 2017 Flood Response: Okanagan Lake Regulation System and Nicola Dam, prepared for Ministry of Forests, Lands, Natural Resource Operations & Rural Development. Associated Environmental Consultants Ltd.

Brunner, G. W. (2016). HEC-RAS River Analysis System User's Manual. Version 5.0. Manual. US Army Corps of Engineers.

Craig, J. R., Brown, G., Chlumsky, R., Jenkinson, W., Jost, G., Lee, K., Mai, J., Serrer, M., Snowdon, A. P., Sgro, N., Snowdon, A., and Tolson, B. A. (2020). Flexible watershed simulation with the Raven hydrological modelling framework. Environmental Modelling & Software, 104728. doi:10.1016/j.envsoft.2020.104728.

Ecora (2019). Swan Lake Dam Operations Plan (GK-18-729-MOF). BC Ministry of Forests and Lands, Natural Resource Operations and Rural Development. 124 pp.

NHC (2020a). City of Vernon Detailed Flood Mapping, Risk Analysis and Mitigation: Part 1 - Upper B.X. Creek (3005032). 73 pp.

NHC (2020b). Okanagan Mainstem Floodplain Mapping Project (NHC PN3004430). Report prepared by Northwest Hydraulic Consultants Ltd. (NHC) for the Okanagan Basin Water Board (OBWB).

6 CLOSURE

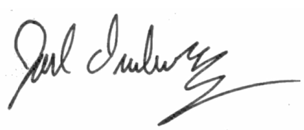
The purpose of this report is to provide a summary of the hydrologic analysis completed for Part 2: Lower B.X. and Vernon Creek flood mapping. The design flows described here are intended for use as hydraulic inputs to the 2-d hydraulic model of Lower B.X. and Vernon Creek.

Feel free to contact the undersigned by telephone (250.851.9262) or email (jtrubilowicz@nhcweb.com) with any questions.

Sincerely,

Northwest Hydraulic Consultants Ltd.

Prepared by:



Joel Trubilowicz, PhD, PEng
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Reviewed by:

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Principal Hydrologist

cc: Dale Muir, P.Eng. – Principal (dmuir@nhcweb.com)

DISCLAIMER

This document has been prepared by Northwest Hydraulic Consultants Ltd. for the benefit of the City of Vernon for specific application to floodplain mapping of Lower B.X. Creek and Vernon Creek. The information and data contained herein represent Northwest Hydraulic Consultants Ltd. best professional judgment in light of the knowledge and information available to Northwest Hydraulic Consultants Ltd. at the time of preparation, and was prepared in accordance with generally accepted engineering practices.

Except as required by law, this report and the information and data contained herein are to be treated as confidential and may be used and relied upon only by the City of Vernon, its officers and employees. Northwest Hydraulic Consultants Ltd. denies any liability whatsoever to other parties who may obtain access to this report for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this report or any of its contents.

APPENDIX B

CROSSING INVENTORY

CROSSING INVENTORY

Structure	Station	NHC Xing - ID	Location	Description	Width (m)*	Height (m)**
Culvert	4616.856	XING 95	Westkal Rd. Kalamalka Lake Outlet	Concrete arch with debris rack	4.19	2.45
Bridge	4578.317	XING 96.4	Cafe, N of Westkal Rd	Wooden building platform	3.80	1.46
Bridge	4475.247	XING 97	Trestle Train Bridge, Kalamalka Lake Rd.	Wooden trestle train bridge	N/A	3.56
Culvert	4273.147	XING 100	College Way Rd.	Open bottom arch culvert.	8.80	1.17
Bridge	4158.332	XING 102	Campground, Kalamalka Lk Rd.	Wood vehicle bridge in Campground.	4.76	0.75
Bridge	4094.027	XING 103.1	Campground, Kalamalka Lk Rd.	Wood vehicle bridge in Campground.	4.76	0.93
Culvert	3836.261	XING 104	Kalamalka Lake Rd north of lake	Triple Concrete Culverts	1.40	1.40
Bridge	3654.377	XING 106	Adjacent Okanagan Skate Shop and Kalamalka Lk Rd.	Concrete bridge	5.62	0.51
Bridge	3423.115	XING 108	Adjacent Browne Rd. housing subdivision	Concrete laneway bridge	6.20	1.61
Bridge	3384.414	XING 109.1	Adjacent Browne Rd. housing subdivision	Concrete laneway bridge	8.40	1.36
Bridge	3315.935	XING 110	Adjacent Browne Rd. cul-de-sac	Concrete bridge with 16" Diam CSP pipe	3.68	1.03
Culvert	3195.824	XING 112	Browne Rd.	Triple barrel riveted CSP arch	1.78	1.12
Bridge	2994.117	XING 114	Vernon Golf and Country Club	Mason and stone bridge	3.58	0.43
Bridge	2761.935	XING 116	Vernon Golf and Country Club	Small concrete arch pedestrian bridge	2.25	1.13
Bridge	2700.969	XING 118	Vernon Golf and Country Club	Concrete arched pedestrian bridge	3.43	1.61
Bridge	2475.642	XING 120	Vernon Golf and Country Club	Small wooden golf cart crossing	2.18	1.25
Bridge	2280.252	XING 122	Adjacent Polson Dr. on Vernon Golf and Country Club	Concrete vehicle bridge	4.16	1.47
Bridge	2205.388	XING 124	South of Golf Course, rail bridge	Wooden Rail Bridge	3.60	1.43
Bridge	1466.079	XING 127	Polson Park	Wooden pedestrian walking bridge	4.79	1.51
Bridge	1353.909	XING 128.1	Polson Park	Pedestrian bridge, small concrete slab	1.72	1.39
Bridge	1108.269	XING 129.1	Polson Park	Pedestrian Bridge, wooden, arched.	1.15	1.51
Bridge	1022.389	XING 129.3	Polson Park	Pedestrian Bridge, concrete	1.73	1.15

Structure	Station	NHC Xing - ID	Location	Description	Width (m)*	Height (m)**
Bridge	989.642	XS 130	Polson Park, east of 32 St.	Small concrete pedestrian bridge	1.63	1.58
Bridge	920.9241	XS 132	Upstream of Hwy 97 Crossing, Polson Park	Wooden with concrete deck	3.68	0.79
Culvert	894.2007	XING 134	32 St. south of 25 Ave.	Single barrel arch bridge inlet, elliptical culvert	2.84	1.91
Bridge	710.7551	XS 136	34 St. south of 25 Ave.	Bridge with CSP pipes mounted below	17.90	2.19
Culvert	604.8765	XING 138	24 Ave. between 34 St. and 34A St.	Double barrel CSP arch	2.38	2.20
Culvert	506.6482	XING 140	34A St. south 24 Ave.	Double barrel CSP	2.20	2.20
Culvert	5979.23	XING 145	39 St, South of 24 Ave.	Double Barrel CSP Culvert	2.10	2.05
Bridge	5476.521	XING 148	Behind storage yard at 24 St.	Concrete bridge with lock blocks, private	8.84	1.60
Culvert	5186.983	XING 150	43 St.	Single barrel open bottom arch	5.09	2.06
Bridge	5053.388	XING 152	Vernon Water Reclamation Centre, west of 43 St.	Steel walking bridge with pipe below	1.79	2.26
Bridge	4965.482	XING 154	Vernon Water Reclamation Centre, west of 43 St.	Sewage pipe cage crossing the creek	3.91	3.32
Bridge	4849.412	XING 155.3	Southeast of 25 Ave.	Concrete Pedestrian footbridge pipe centered below (LC)	1.10	1.23
Bridge	4668.692	XING 156	West of 25 Ave.	Concrete Pedestrian Bridge	1.11	1.54
Bridge	3522.726	XING 162	Fulton Rd.	Bridge, two lanes, concrete	9.34	1.80
Culvert	1928.232	XING 169	Okanagan Landing Rd.	Single barrel arch	4.15	2.55
Culvert	84.574	XING 175	Lakeshore Rd.	Single barrel pipe arch	4.30	2.70
Culvert	2288.473	XING 57	34 St north and south of 43 Ave.	Concrete box culvert	2.30	2.30
Bridge	2158.991	XING 59	Parking entrance bridge - 32 St., south of 43 Ave.	Bridge at parking entrance	3.60	1.04
Bridge	2138.277	XING 61	Below Blue Stream Motel, 32 St. Hwy 97	Box culvert, wall platform, concrete channel	3.59	0.97
Culvert	2039.897	XING 63	42 Ave. west of 32 St.	Concrete culvert	2.20	2.20
Culvert	1950.997	XING 63.25	Upstream entrance below Vernon Lodge	Concrete box culvert	1.85	0.90
Bridge	1918.011	XING 63.5	Vernon Lodge restaurant platform	Restaurant bridge platform	16.50	1.92
Culvert	1864.705	XING 63.6	Under Vernon Lodge parking	Twin CIP concrete box culvert	1.85	0.90
Culvert	1697.572	XING 65	39 Ave.	Culvert double barrel pipe	1.83	1.83

Structure	Station	NHC Xing - ID	Location	Description	Width (m)*	Height (m)**
Bridge	1633.76	XING 67	Curling rink lot	Pedestrian bridge, concrete	1.73	0.89
Bridge	1576.884	XING 68	Performing Arts Centre	Pedestrian bridge	1.66	1.39
Bridge	1503.537	XING 69	Performing Arts Centre	Concrete pedestrian bridge	4.14	2.08
Culvert	1322.1	XING 71.1	35 Ave. and 34 St.	Single barrel arch culvert	2.50	1.50
Culvert	1247.662	XING 73.1	34 Ave. between 34 St. and 35 St.	Single barrel arch culvert	2.61	1.79
Bridge	1128.901	XING 75	33 Ave. off 35 St.	Concrete pedestrian bridge	1.14	1.17
Culvert	1045.117	XING 77	32 Ave. between 34 St. and 35 St.	Single barrel arch culvert, concrete	2.70	1.59
Culvert	966.8643	XING 79	31 Ave. and 35 St.	Single barrel arch culvert (2.45m)	2.40	1.60
Culvert	829.7076	XING 81	30 Ave. near 35 St. behind Safeway	CIP Concrete arch, CSP pipe outlet	3.80	1.63
Culvert	739.0903	XING 83	Lane south 30 Ave., west 35 St.	Single barrel CSP culvert. KWL 2016	1.80	1.80
Bridge	692.5181	XING 84.2	Along 35 St.	Sheet metal box with plastic pipe, metal grate	1.00	1.04
Bridge	585.0482	XING 84.6	North of 27 St., west of 35 St.	Wooden Pedestrian footbridge	1.15	1.28
Culvert	496.6529	XING 85	27 Ave.	Box Culvert, low pipe inside	1.73	1.40
Bridge	382.5153	XING 87	25 Ave.	Pedestrian/cycle bridge, steel.	2.60	1.58
Bridge	370.3364	XING 88	25 Ave. (north side)	Bridge, concrete, highway (two lane)	10.59	1.22
Culvert	354.9673	XING 88.2	25 Ave. (south side)	Single barrel arch culvert	2.58	1.14
Culvert	227.6941	XING 90	24 Ave., east 35 St.	Single barrel CSP pipe culvert	2.10	2.10
Culvert	140.1855	XING 92	36 St., south of 24 Ave.	Double barrel riveted CSP pipe arch	1.65	1.20

* Height for bridges measured from channel thalweg to bottom of deck at upstream face.

** Width of bridges measured at bottom of deck at upstream face.

APPENDIX C

FLOOD MAPS

Notes to Users:

1. Please refer to **Disclaimer** below.
2. Please review the associated project report before using the floodplain and hazard maps:
   a. Northwest Hydraulic Consultants Ltd. (NHC). 2020. 'City of Vernon Detailed Flood Mapping, Risk Analysis and Mitigation Part 1 - Upper B.X. Creek'. Report prepared for the City of Vernon (CoV). 2020 August 25. NHC project number 3005032.
   b. Northwest Hydraulic Consultants Ltd. (NHC). 2021. 'City of Vernon Detailed Flood Mapping, Risk Analysis and Mitigation Part 2 - Lower B.X. Creek and Vernon Creek'. Report prepared for the City of Vernon (CoV). 2021 August 06. NHC project number 3005032.
3. Map sheet layout shown on this map applies to both floodplain and hazard maps.
4. Floodplain maps delineate flood construction level (FCL) extents under the design flood event.
   a. The mapped FCLs include a freeboard allowance of 0.6 m added to the calculated flood water elevation. It has been added to account for local variations in water level, debris risk, and uncertainty in channel conditions, data, and analysis.
   b. FCL is shown on the map as smoothed isolines to create a user-friendly interpretation of FCL. The upstream most face or point of any structure should be used to determine the structure's FCL. If an FCL isoline runs along this location its value can be taken as the FCL for the structure. If the structure is located between two isolines, the FCL can be either the next upstream isoline (next greatest) or calculated through interpolation by distance between the isoline upstream and downstream of the upstream face or point of the structure.
5. Floodplain maps include the floodway, flood fringe, and setbacks. Floodway is considered the primary flow path during a flood event. Flood fringe is considered part of the floodplain that does not contribute substantially to conveyance and where depth and velocity are generally low (< 1 m and < 1 m/s). Setbacks are provided as a recommended no-build zones to maintain flood conveyance and limit risk to development from channel hazards (e.g., high velocity flow, erosion, scour, channel migration, etc.).
6. Hazard maps depict the simulated flood depths and velocities during the design event. No freeboard has been added to flood depths. Hazard maps show modelled flood depths and velocities for both 1D and 2D areas. Low velocity zones are indicted on the hazard maps with the smallest arrow. Areas where velocity arrows are not shown, are indicative of areas where velocity has not been calculated (i.e., overbank areas simulated using 1D model).
   a. Flood depths include a generalized description of the potential consequence. These descriptions are not based on assessment of exposure or vulnerability within the study area, and therefore may not be accurate.
7. Underlying hydraulic analysis assumes channel geometry is stationary. Erosion, deposition, degradation, and aggradation are expected to occur and may alter actual observed flood levels and extents. An increased or decreased level of obstruction will result in different flood extents and elevations for the same flow event. Local storm water inflows, temporary diking, drainage, and groundwater may further alter flood extents and elevations from those indicated on the maps.
8. The calculated water level has been extended perpendicular to flow across the floodplain, thus mapping inundation of isolated areas regardless of likelihood of inundation. Isolated areas may become inundated due to dike failure, seepage, or local inflows. Site specific judgement by a Qualified Professional is required to determine validity of isolated inundation.
9. Filtering was used to remove isolated inundation areas smaller than 100 m^2 as well as isolated "islands" in the inundation extent less than 100 m^2. Isolated inundation areas larger than 100 m^2 within 40 m of adjacent inundation are mapped as inundated areas.
10. The accuracy of simulated flood levels is limited by the reliability and extent of water level, flow, and climate data. The accuracy of the floodplain extents is limited by the accuracy of the design flood flow, the hydraulic model, and the digital surface representation of local topography. Localized areas above or below the FCL may be generalized by the inundation mapping. Therefore, floodplain maps should be considered an administrative tool that indicates flood elevations and floodplain boundaries for a designated flood. A Qualified Professional is to be consulted for site-specific engineering analysis. Accuracy of the maps may deteriorate with time as hydrology, channel and crossing geometry, and land use changes differ from that assessed.
11. Industry best practices have been followed to generate the floodplain maps. However, actual flood levels and extents may vary from those shown. Residual flood risk beyond that mapped exists for flood events more extreme than the design event. CoV and NHC do not assume any liability for variations of flood levels and extents from that shown.

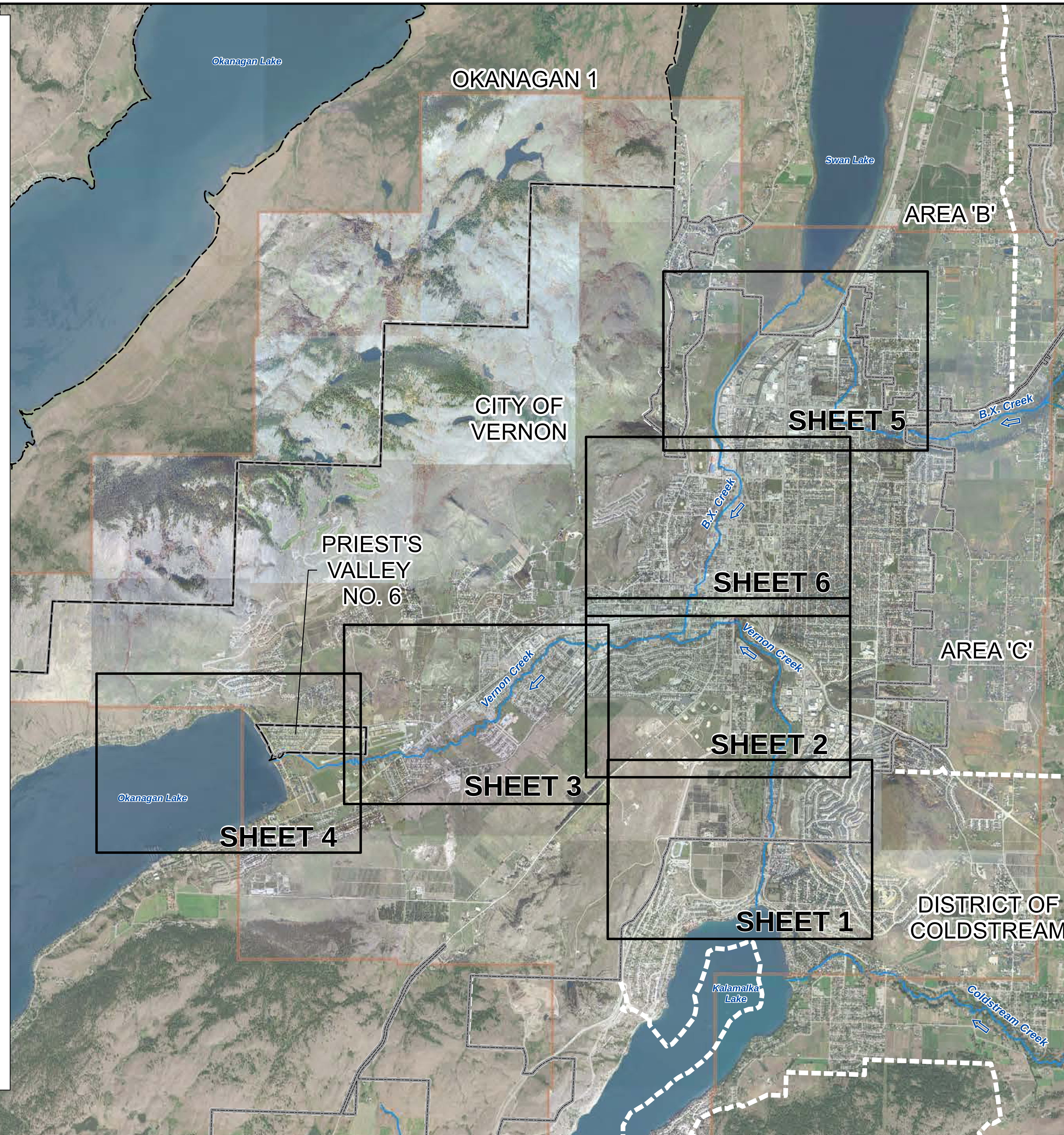
Data Sources and References:

1. The design flood event is based on hydrologic modelling of the Upper B.X. Creek, Lower B.X. Creek and Vernon Creek watersheds. The design flood event for B.X. Creek is the instantaneous 1996 flood of record adjusted for end of century (2070-2100, including climate change), which is comparable to an instantaneous 500-year end of century flood event. The design flood event for Vernon Creek is the instantaneous 200-year end of century flood event. The two downstream boundary conditions include, the Swan Lake 500-year flood elevation of 390.08 m, and the Okanagan Lake 2017 flood of record event adjusted for mid-century climate change (comparable to an instantaneous 500-year mid-century flood event).
2. The hydraulic response is based on a coupled 1D/2D numerical model developed by NHC using HEC-RAS software, and ArcGIS software for pre and post processing. The hydraulic model was calibrated to the 2020 flood event.
3. The digital elevation model (DEM) used to develop the model and mapping is based on mosaiced, bare-earth (no buildings or structures) LiDAR (2018 & 2019, Emergency Management BC (EMBC)), channel survey (2019, NHC), and additional survey data (2019, SEL Survey). Contour lines are derived from the DEM.
4. Orthophoto imagery is from CoV (2016 & 2019) and Esri (along with other base mapping), National Railway Network railway lines are from Natural Resources Canada, and highways, arterial roads, collector centerlines, and administrative boundaries are from CoV (2019).

Disclaimer:

This study has been prepared by **Northwest Hydraulic Consultants Ltd.** for the benefit of **City of Vernon** for specific application to the **B.X. Creek and Vernon Creek Detailed Flood Mapping, Risk Analysis and Mitigation**. The information and data contained herein represent **Northwest Hydraulic Consultants Ltd.** best professional judgment in light of the knowledge and information available to Northwest Hydraulic Consultants Ltd. at the time of preparation and was prepared in accordance with generally accepted engineering practices.

Except as required by law, this document and the information and data contained herein are to be treated as confidential and may be used and relied upon only by **City of Vernon**, its officers and employees. **Northwest Hydraulic Consultants Ltd.** denies any liability whatsoever to other parties who may obtain access to this document for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this report or any of its contents.



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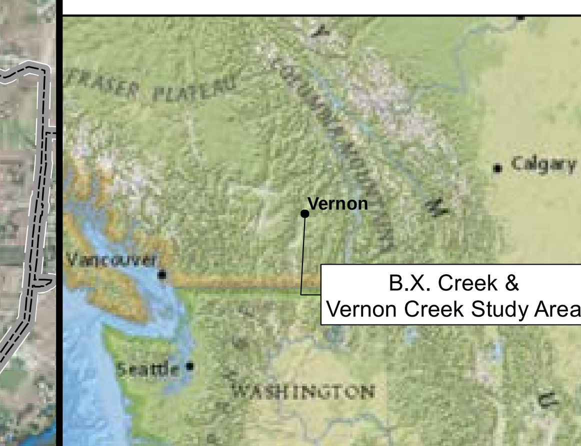


- CITY OF VERNON
- FIRST NATIONS RESERVE
- REGIONAL DISTRICT OF NORTH OKANAGAN SUB-AREA BOUNDARY
- 2019 ORTHOPHOTO EXTENT
- FLOW DIRECTION
- STREAM

SCALE - 1:25,000
0 0.5 1 1.5 KM
N

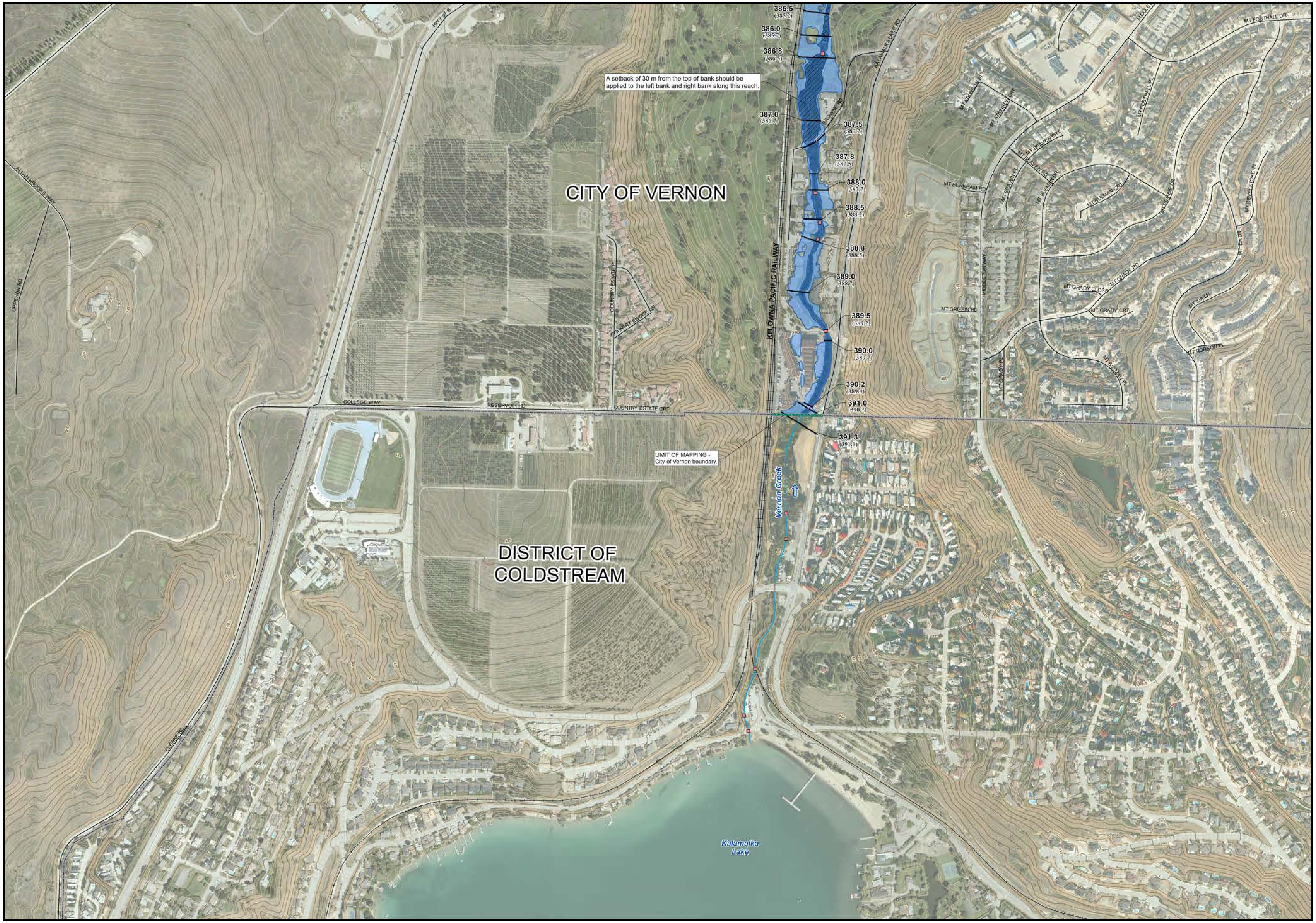
Coordinate System: NAD 1983 CSRS UTM ZONE 11N
Units: METRES; Vertical Datum: CGVD2013

Engineer	GIS	Reviewer
VCCM	RLM	JWT/DPM

Job Number	Date
3005032	13-Oct-2021

CITY OF VERNON FLOOD MAPPING B.X. CREEK & VERNON CREEK SHEET INDEX

SHEET 2 ↑



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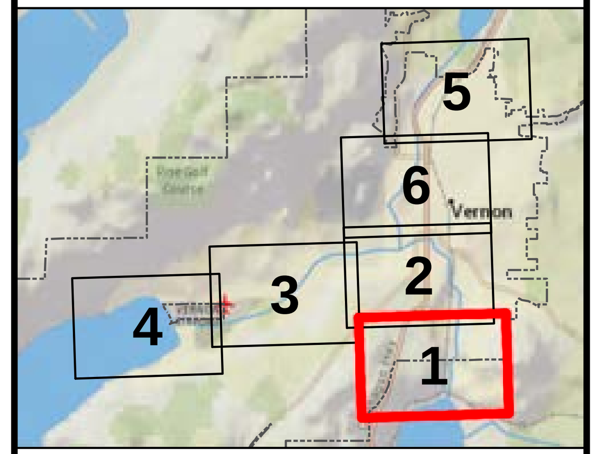


- FLOW DIRECTION
- CITY OF VERNON
- FIRST NATIONS RESERVE
- BRIDGE
- CULVERT
- MAJOR CONTOUR AT 5 METRE INTERVAL *Labelled with elevation in metres*
- MINOR CONTOUR AT 1 METRE
- 2019 ORTHOPHOTO EXTENT
- RAILWAY LINE
- ROAD
- STREAM
- 123.4 (123.4) FLOOD CONSTRUCTION LEVEL (FCL) *Labelled with FCL in metres CGVD2013 (FCL in CGVD28)*
- LIMIT OF MAPPING

INUNDATION EXTENT - DESIGN EVENT WITH FREEBOARD

- FLOODWAY *15 m top of bank setback*
- FLOODWAY *30 m left bank and 15 m right bank top of bank setback*
- FLOODWAY *30 m top of bank setback*
- FLOOD FRINGE
- OKANAGAN LAKE SHORELINE ZONE *Due to wave effects an FCL of 345.5 m CGVD2013(or 345.2 m CGVD28) should be applied to this area*

PLEASE REFER TO NOTES ON SHEET INDEX

SCALE - 1:4,000
0 100 200 M
N

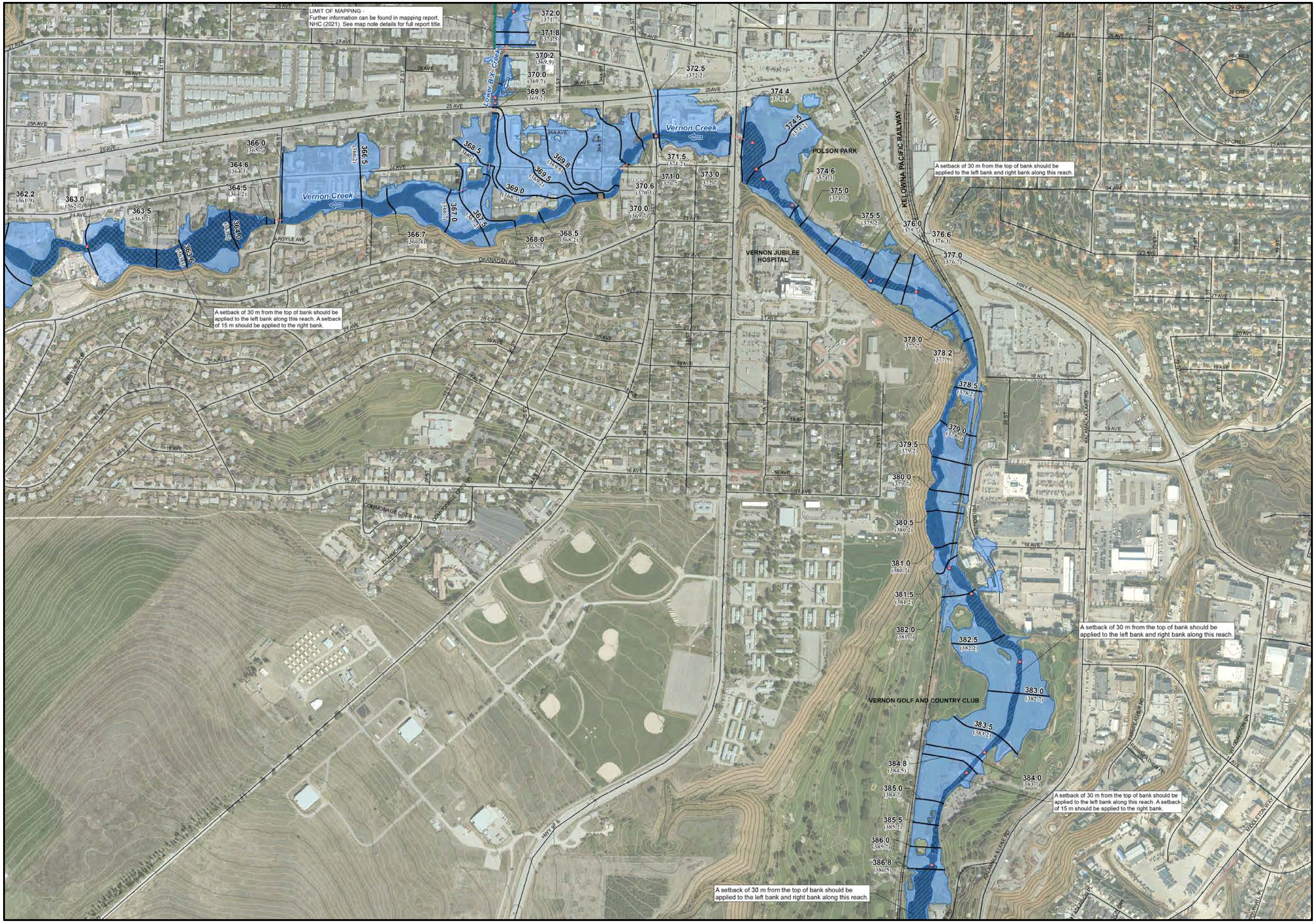
Coordinate System: NAD 1983 CSRS UTM ZONE 11N
Units: METRES; Vertical Datum: CGVD2013

Engineer	GIS	Reviewer
VCCM	RLM	JWT/DPM

Job Number	Date
3005032	13-OCT-2021

CITY OF VERNON
FLOOD MAPPING
B.X. CREEK &
VERNON CREEK
FLOODPLAIN
SHEET 1 OF 6

SHEET 6 ↑



SHEET 3 ↑

SHEET 1 ↓

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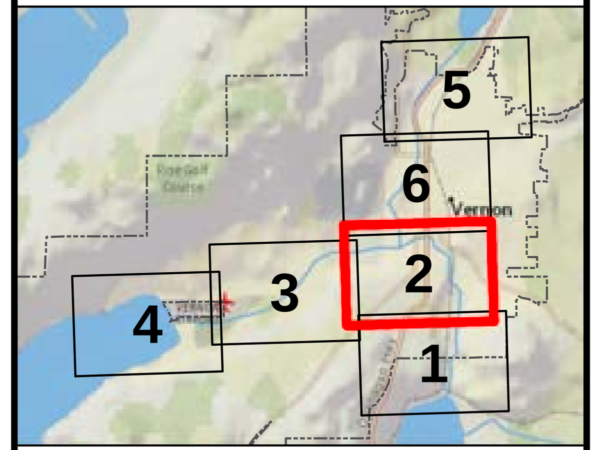

FLOW DIRECTION
CITY OF VERNON
FIRST NATIONS RESERVE
BRIDGE
CULVERT
MAJOR CONTOUR AT 5 METRE INTERVAL *Labelled with elevation in metres*
MINOR CONTOUR AT 1 METRE
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ROAD
STREAM
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PLEASE REFER TO NOTES ON SHEET INDEX

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N

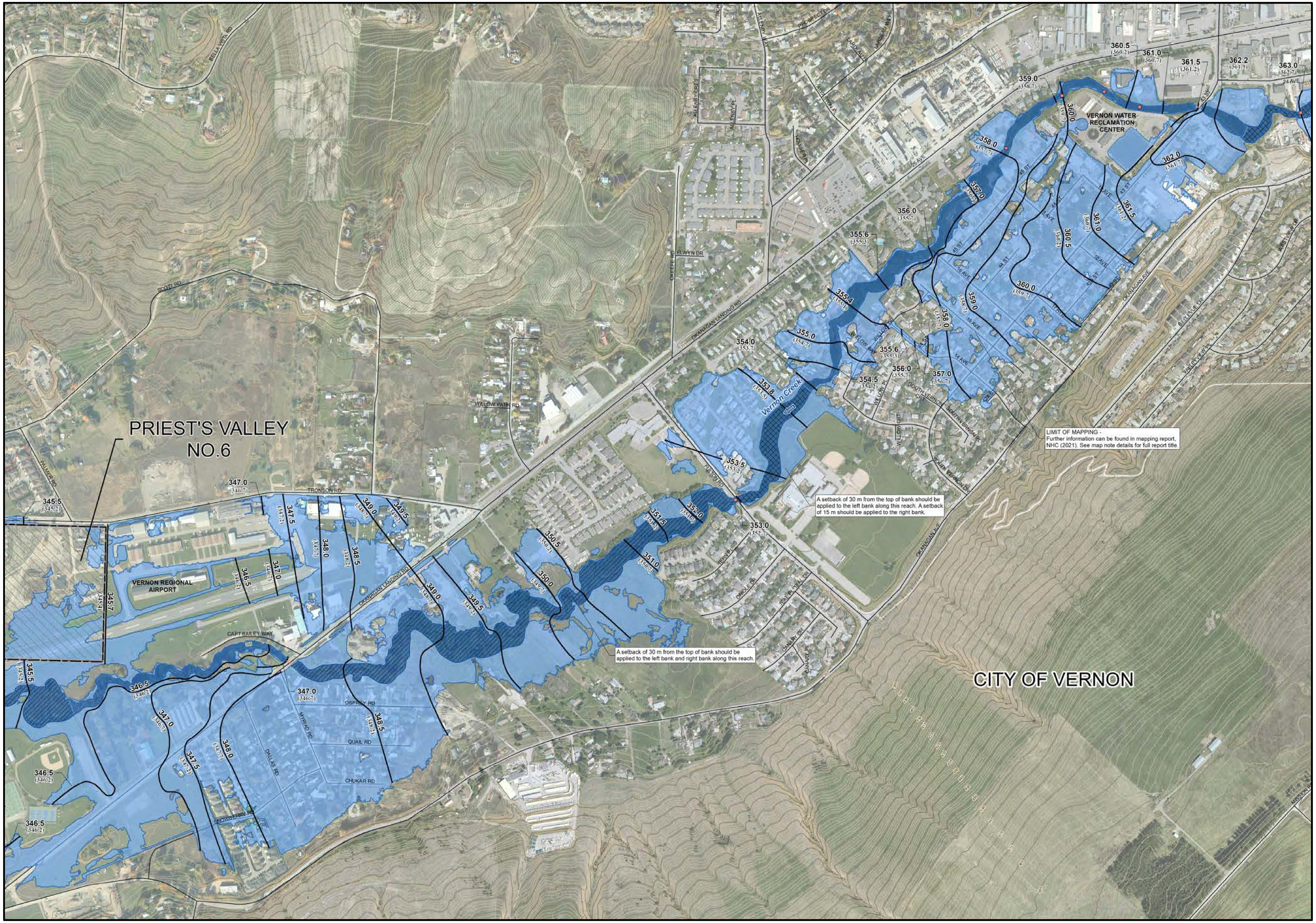
Coordinate System: NAD 1983 CSRS UTM ZONE 11N
Units: METRES; Vertical Datum: CGVD2013

Engineer	GIS	Reviewer
VCCM	RLM	JWT/DPM

Job Number	Date
3005032	18-AUG-2021

CITY OF VERNON
FLOOD MAPPING
B.X. CREEK &
VERNON CREEK
FLOODPLAIN
SHEET 2 OF 6

SHEET 4 ↑



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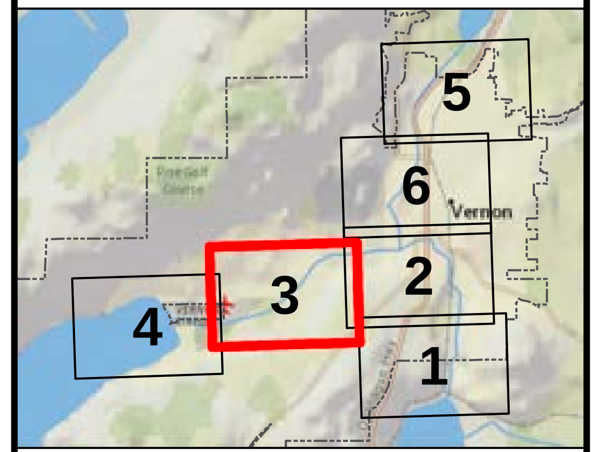

- FLOW DIRECTION
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- CULVERT
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DESIGN EVENT WITH FREEBOARD

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PLEASE REFER TO NOTES ON SHEET INDEX

SCALE - 1:4,000

0 100 200 M

N

Coordinate System: NAD 1983 CSRS UTM ZONE 11N
Units: METRES; Vertical Datum: CGVD2013

Engineer	GIS	Reviewer
VCCM	RLM	JWT/DPM

Job Number	Date
3005032	18-AUG-2021

CITY OF VERNON
FLOOD MAPPING
B.X. CREEK &
VERNON CREEK
FLOODPLAIN
SHEET 3 OF 6

\\mainfile-van\Projects\Active\3005032 Vernon Flood Mapping\04 Flood Mapping\Part 2 Deliverables\Updated Final Deliverables (October)\3005032_Map_FloodMap_Combined_ReMap.mxd

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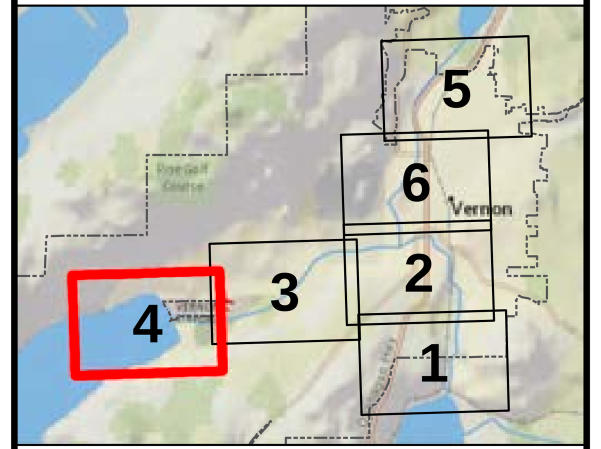

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PLEASE REFER TO NOTES ON SHEET INDEX

SCALE - 1:4,000

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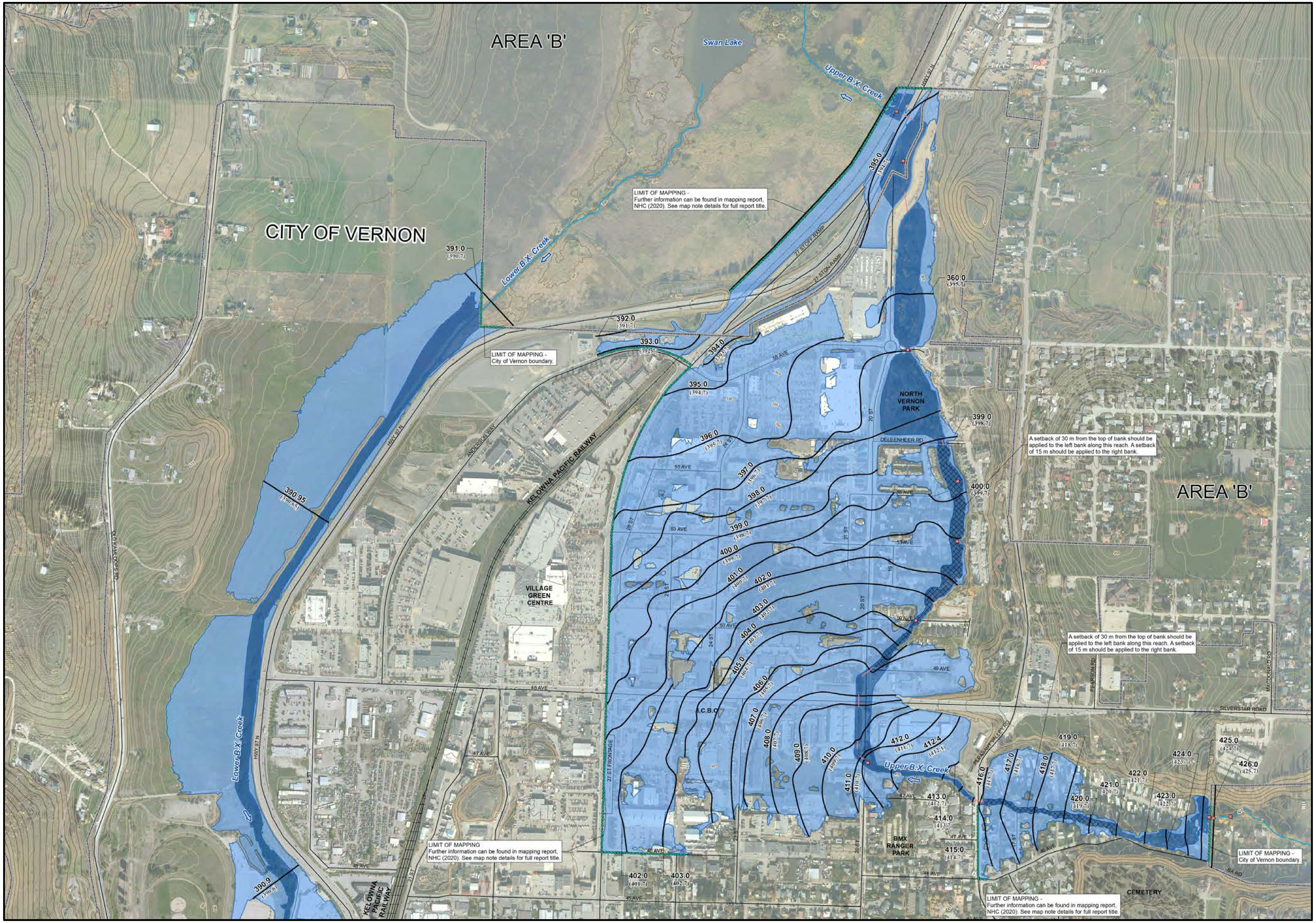
Coordinate System: NAD 1983 CSRS UTM ZONE 11N
Units: METRES; Vertical Datum: CGVD2013

Engineer	GIS	Reviewer
VCCM	RLM	JWT/DPM

Job Number	Date
3005032	18-AUG-2021

CITY OF VERNON
FLOOD MAPPING
B.X. CREEK &
VERNON CREEK
FLOODPLAIN
SHEET 4 OF 6



SHEET 6 ↓

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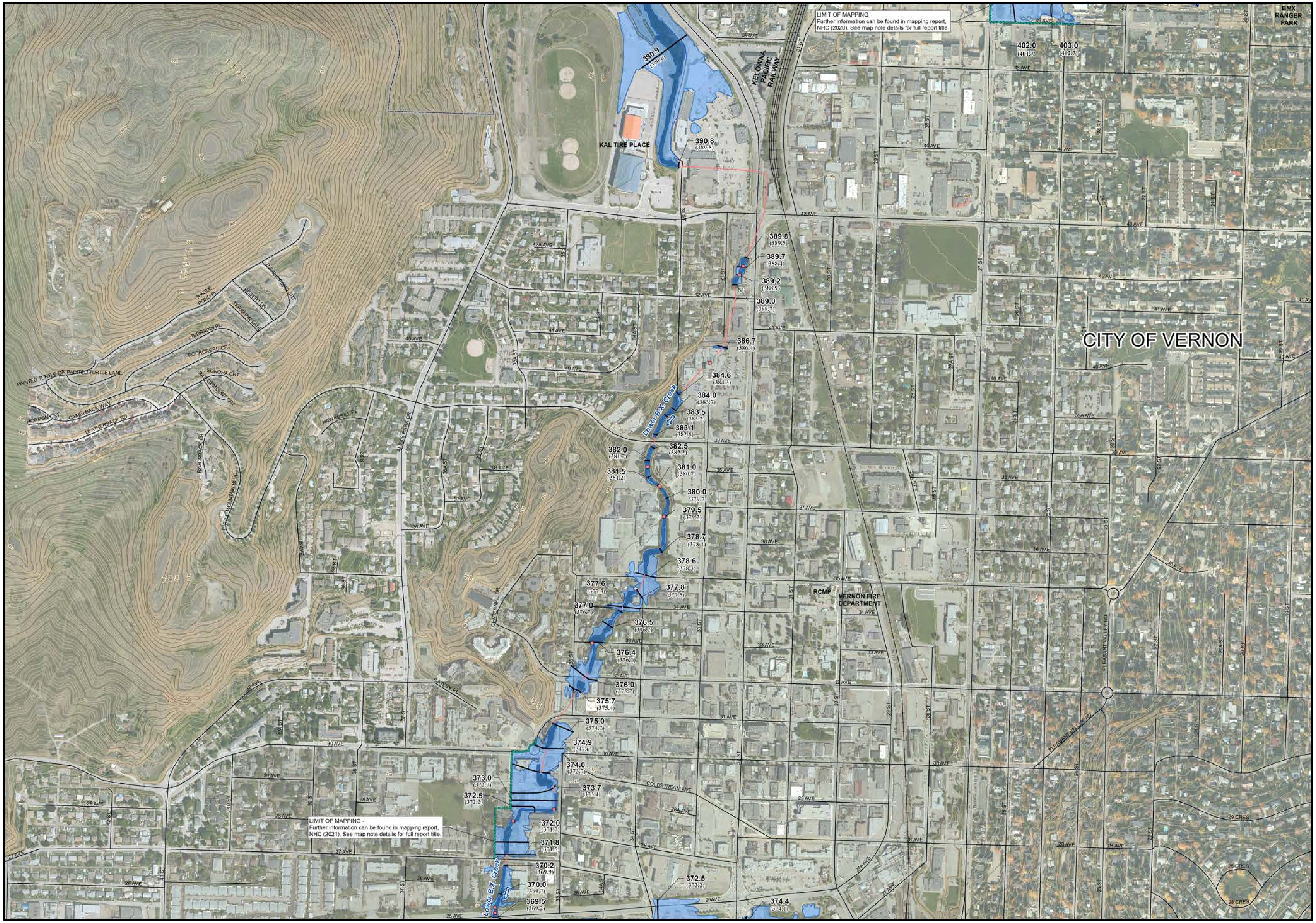
Engineer	GIS	Reviewer
VCCM	RLM	JWT/DPM

Job Number	Date
3005032	18-AUG-2021

CITY OF VERNON
FLOOD MAPPING
B.X. CREEK &
VERNON CREEK
FLOODPLAIN
SHEET 5 OF 6

SHEET 5 ↑



SHEET 2 ↓

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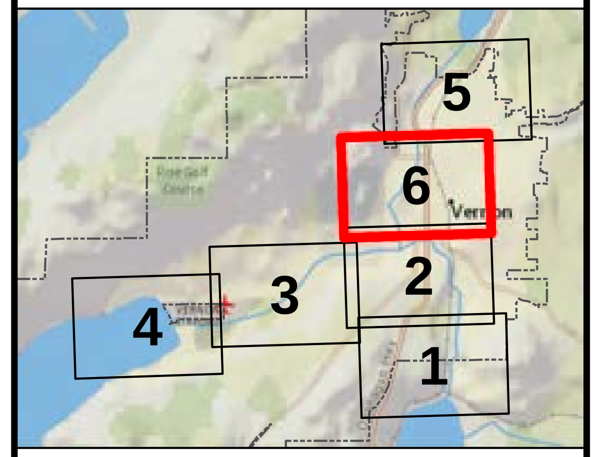

- FLOW DIRECTION
- CITY OF VERNON
- FIRST NATIONS RESERVE
- BRIDGE
- CULVERT
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PLEASE REFER TO NOTES ON SHEET INDEX

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0 100 200 M
N

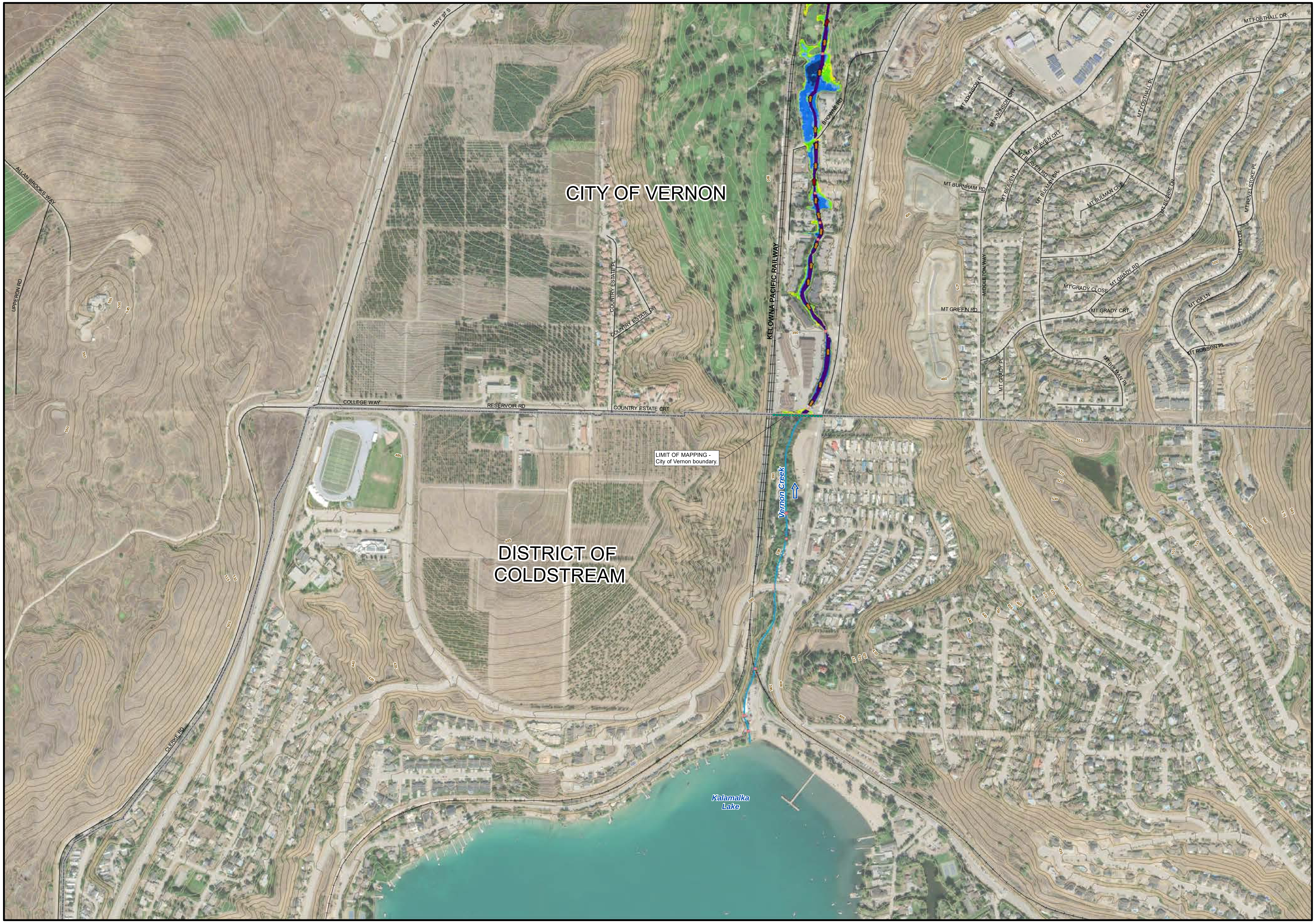
Coordinate System: NAD 1983 CSRS UTM ZONE 11N
Units: METRES; Vertical Datum: CGVD2013

Engineer	GIS	Reviewer
VCCM	RLM	JWT/DPM

Job Number	Date
3005032	12-OCT-2021

CITY OF VERNON
FLOOD MAPPING
B.X. CREEK &
VERNON CREEK
FLOODPLAIN
SHEET 6 OF 6

SHEET 2 ↑



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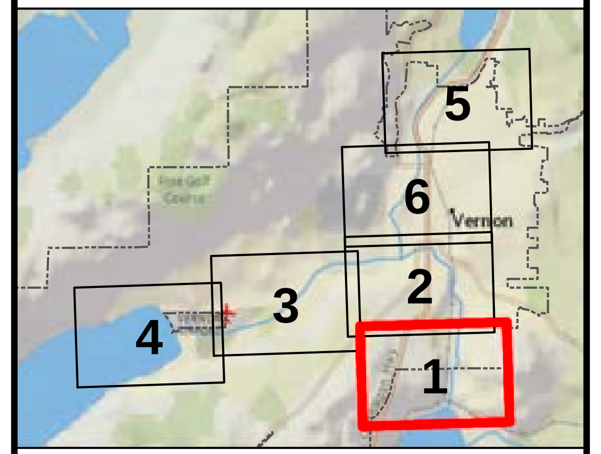


FLOW DIRECTION
CITY OF VERNON
FIRST NATIONS RESERVE
BRIDGE
CULVERT
MAJOR CONTOUR AT 5 METRE INTERVAL *Labelled with elevation in metres*
MINOR CONTOUR AT 1 METRE INTERVAL
2019 ORTHOPHOTO EXTENT
RAILWAY LINE
ROAD
STREAM
LIMIT OF MAPPING

VELOCITY AND DEPTH - DESIGN EVENT WITHOUT FREEBOARD

VELOCITY (m/s)

< 0.1	*Areas where velocity arrows are not shown are indicative of areas where velocity has not been calculated.*
0.1 - 0.5	
0.5 - 1.5	
1.5 - 2.5	

DEPTH (m)

< 0.1	*most buildings expected to be dry; underground infrastructure and basements may be flooded*
0.1 - 0.3	*water may enter buildings at grade, but most expected to be dry; walking in moving water or driving is potentially dangerous; underground infrastructure and basements may be flooded*
0.3 - 0.5	*water may enter ground floor of buildings; walking in moving or still water or driving is dangerous; underground infrastructure and basements may be flooded*
0.5 - 1.0	*water on ground floor; underground infrastructure and basements flooded; electricity failed; vehicles are commonly carried off roadways*
1.0 - 2.0	*ground floor flooded; residents and workers evacuate*
> 2.0; River	*first floor and often higher levels covered by water; residents and workers evacuate*

PLEASE REFER TO NOTES ON SHEET INDEX

SCALE - 1:4,000
0 100 200 M
N

Coordinate System: NAD 1983 CSRS UTM ZONE 11N
Units: METRES; Vertical Datum: CGVD2013

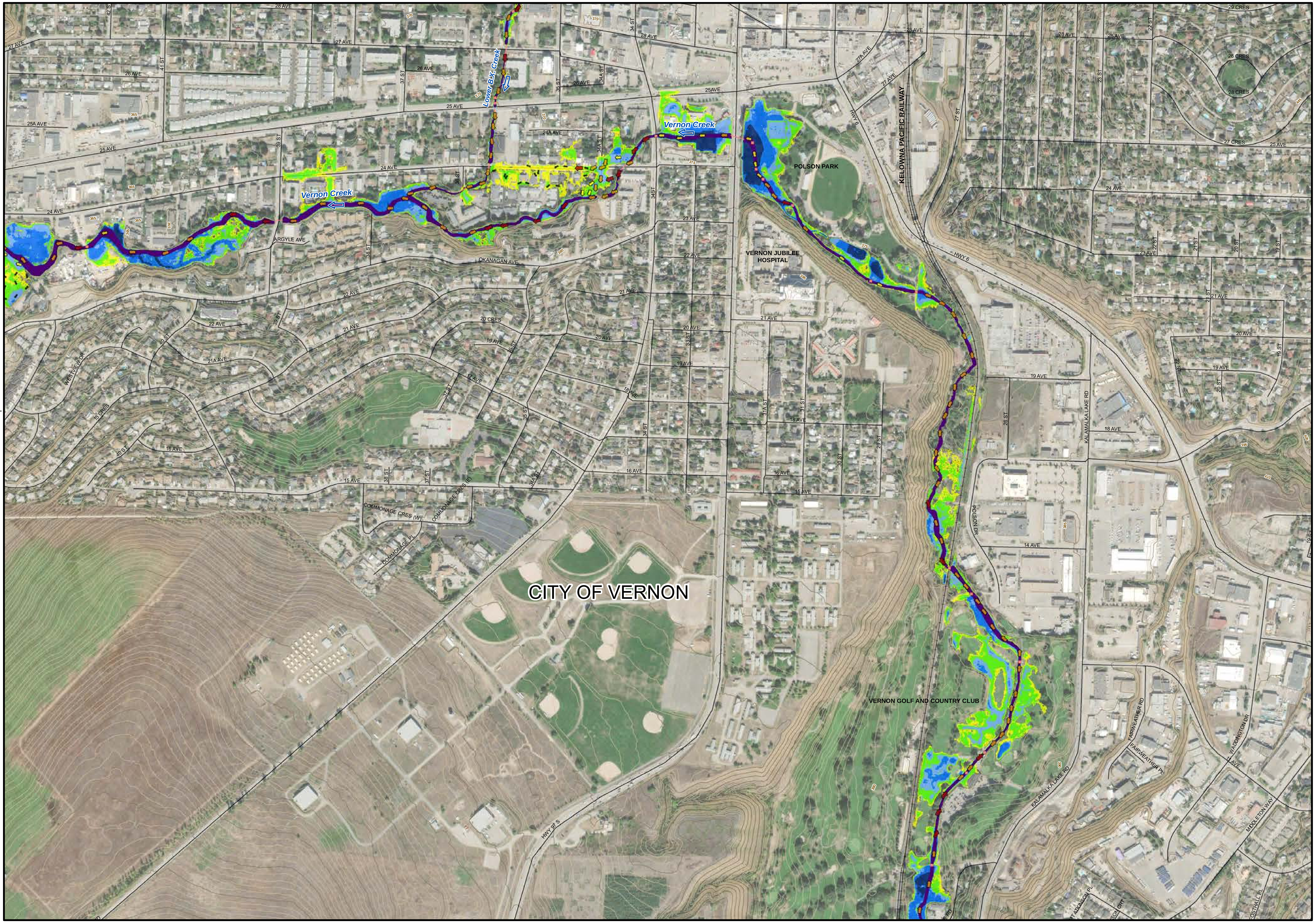
Engineer	*GIS*	*Reviewer*
VCCM	*RLM*	*JWT/DPM*

Job Number	*Date*
3005032	*13-OCT-2021*

CITY OF VERNON
FLOOD MAPPING
B.X. CREEK &
VERNON CREEK

HAZARD MAP
SHEET 1 OF 6

SHEET 6 ↑



SHEET 3 ↑

SHEET 1 ↓

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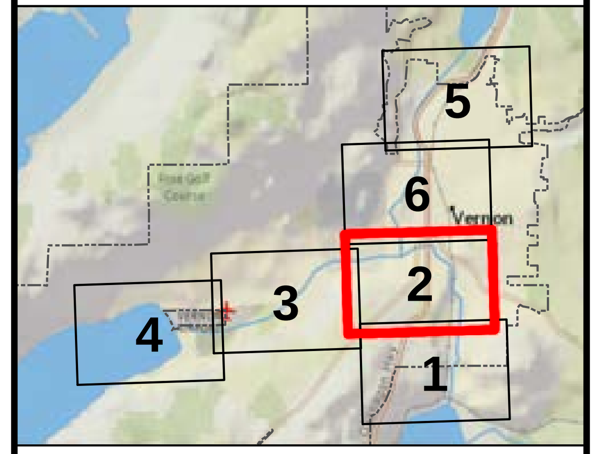
Fax: 604.980.9264
www.nhcweb.com



FLOW DIRECTION
CITY OF VERNON
FIRST NATIONS RESERVE
BRIDGE
CULVERT
MAJOR CONTOUR AT 5 METRE INTERVAL
Labelled with elevation in metres
MINOR CONTOUR AT 1 METRE INTERVAL
2019 ORTHOPHOTO EXTENT
RAILWAY LINE
ROAD
STREAM
LIMIT OF MAPPING

VELOCITY AND DEPTH - DESIGN EVENT WITHOUT FREEBOARD

VELOCITY (m/s)

- < 0.1
- 0.1 - 0.5
- 0.5 - 1.5
- 1.5 - 2.5

Areas where velocity arrows are not shown are indicative of areas where velocity has not been calculated.

DEPTH (m)

< 0.1	*most buildings expected to be dry; underground infrastructure and basements may be flooded*
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1.0 - 2.0	*ground floor flooded; residents and workers evacuate*
> 2.0; River	*first floor and often higher levels covered by water; residents and workers evacuate*

PLEASE REFER TO NOTES ON SHEET INDEX

SCALE - 1:4,000

0 100 200 M

N

Coordinate System: NAD 1983 CSRS UTM ZONE 11N
Units: METRES; Vertical Datum: CGVD2013

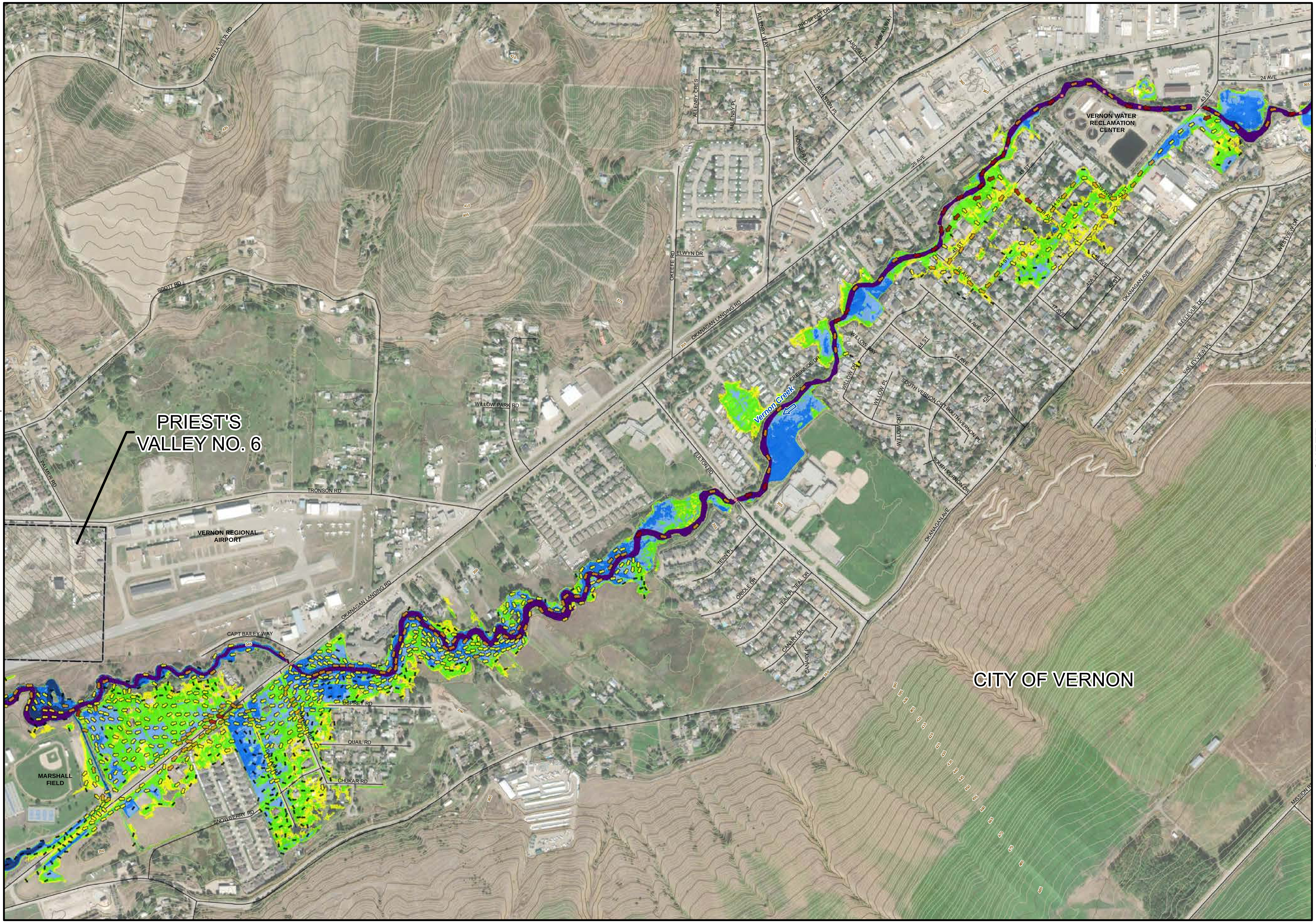
Engineer	*GIS*	*Reviewer*
VCCM	*RLM*	*JWT/DPM*

Job Number	*Date*
3005032	*18-AUG-2021*

CITY OF VERNON
FLOOD MAPPING
B.X. CREEK &
VERNON CREEK

HAZARD MAP
SHEET 2 OF 6

Deliverables\Updated Final Deliverables (October)\3005032_Map_HazardMap_Combined_ReMap.mxd



CITY OF Vernon

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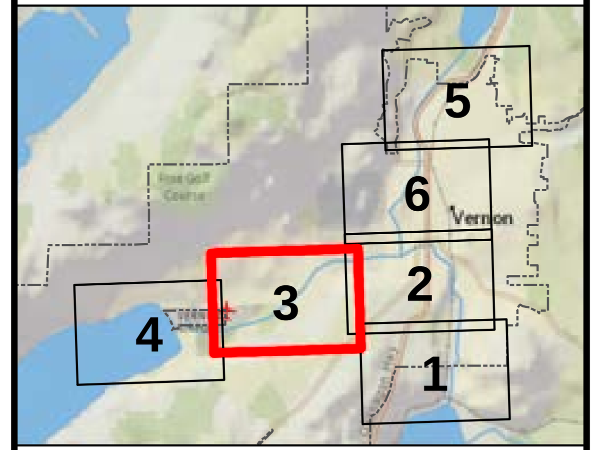

FLOW DIRECTION
CITY OF VERNON
FIRST NATIONS RESERVE
BRIDGE
CULVERT
MAJOR CONTOUR AT 5 METRE INTERVAL
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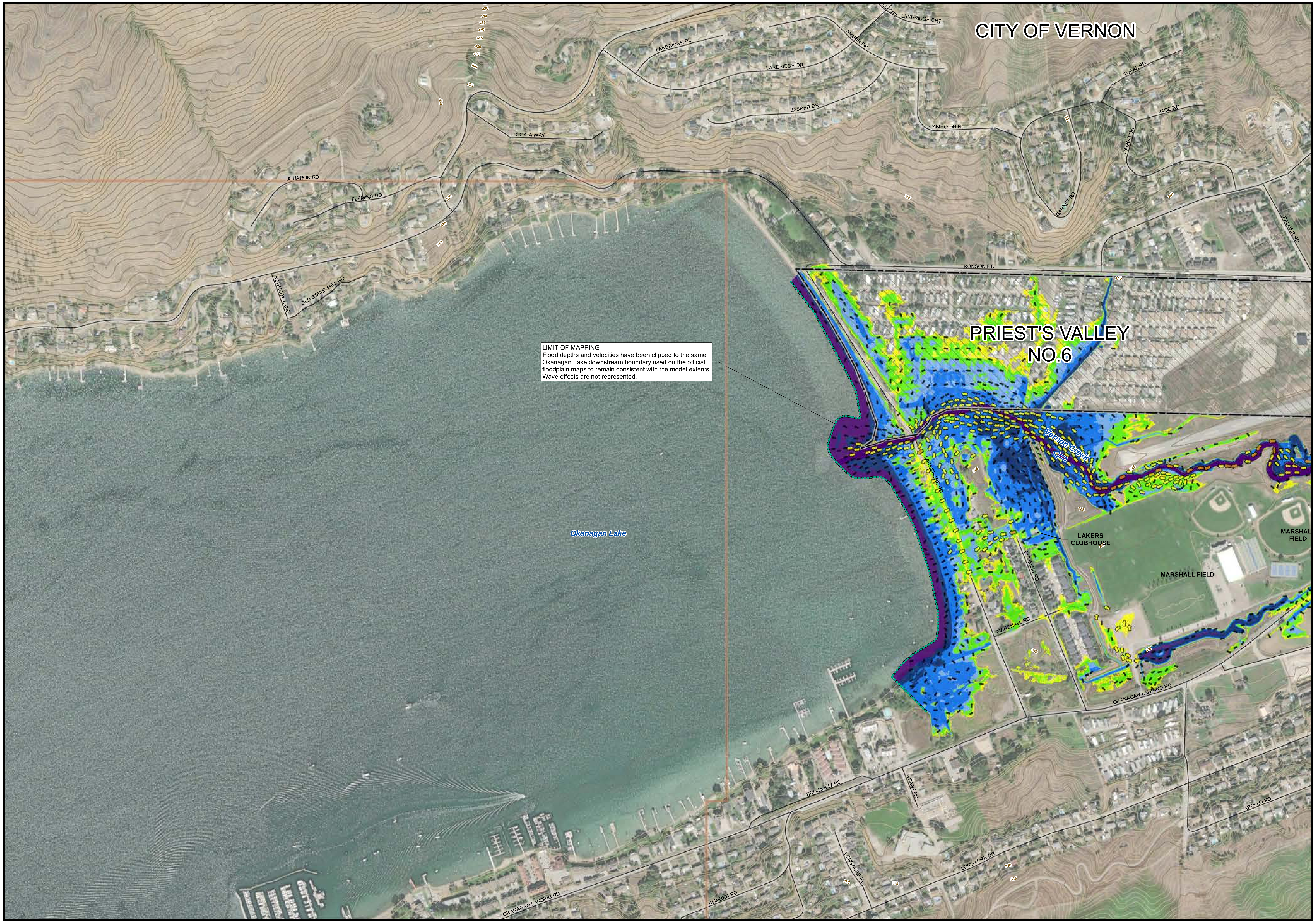
Engineer	*GIS*	*Reviewer*
VCCM	*RLM*	*JWT/DPM*

Job Number	*Date*
3005032	*18-AUG-2021*

CITY OF VERNON
FLOOD MAPPING
B.X. CREEK &
VERNON CREEK

HAZARD MAP
SHEET 3 OF 6

\\mainfile-van\Projects\Active\3005032 Vernon Flood Mapping\04 Flood Mapping\Part 2 Deliverables\Updated Final Deliverables (October)\3005032_Map_HazardMap_Combined_ReMap.mxd



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- FLOW DIRECTION
- CITY OF VERNON
- FIRST NATIONS RESERVE
- BRIDGE
- CULVERT
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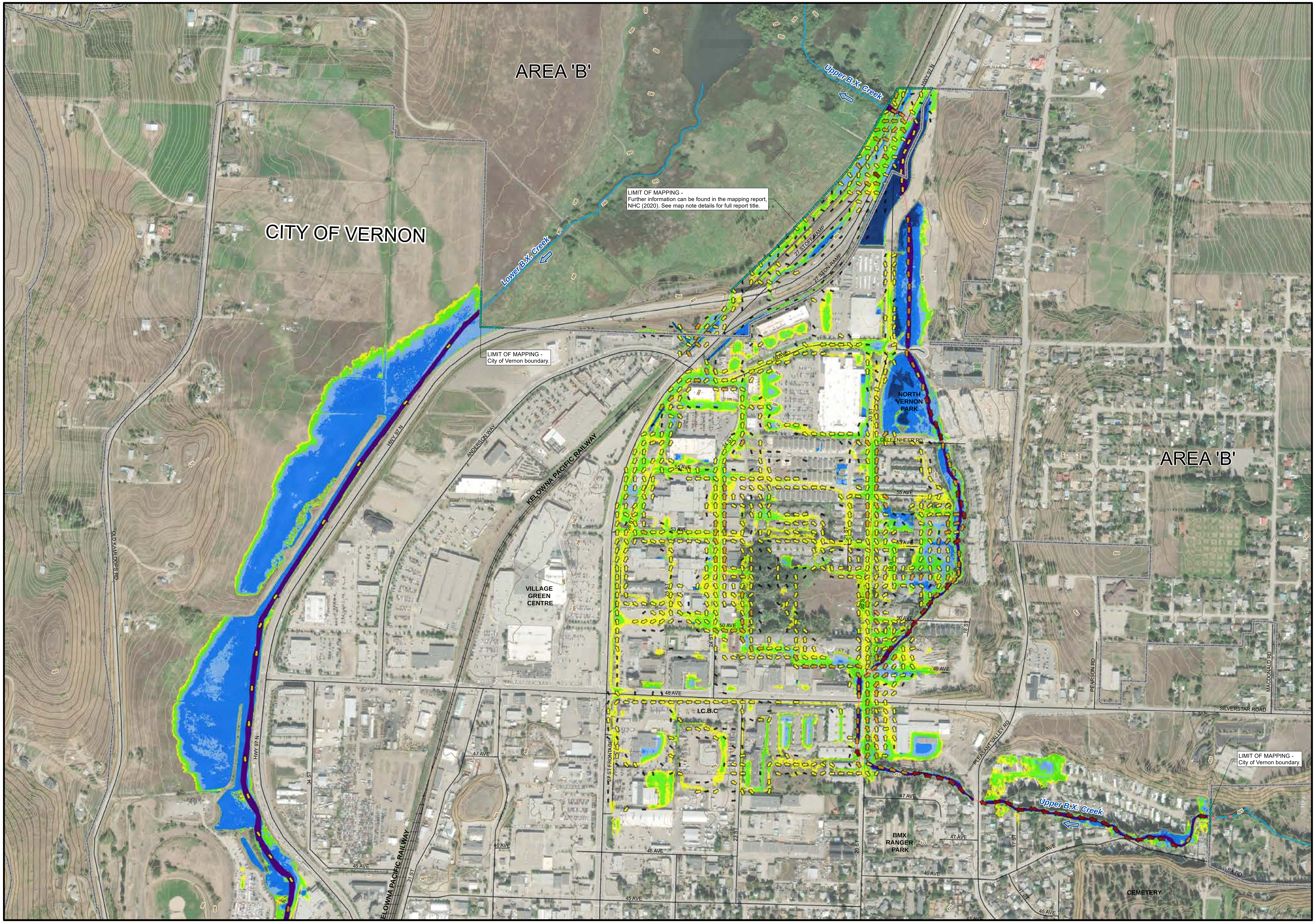
Engineer	GIS	Reviewer
VCCM	RLM	JWT/DPM

Job Number	Date
3005032	18-AUG-2021

CITY OF VERNON
FLOOD MAPPING
B.X. CREEK &
VERNON CREEK

HAZARD MAP
SHEET 4 OF 6



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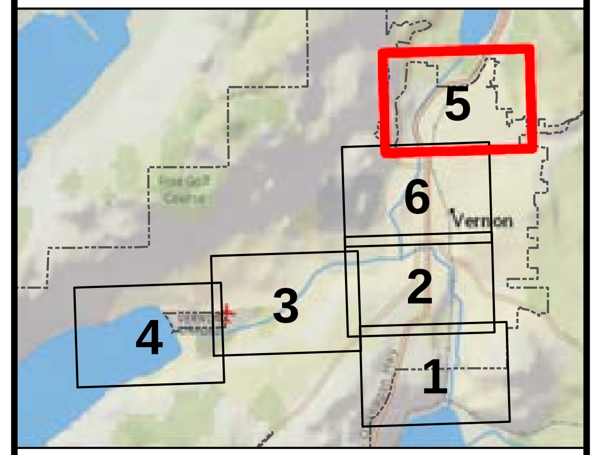

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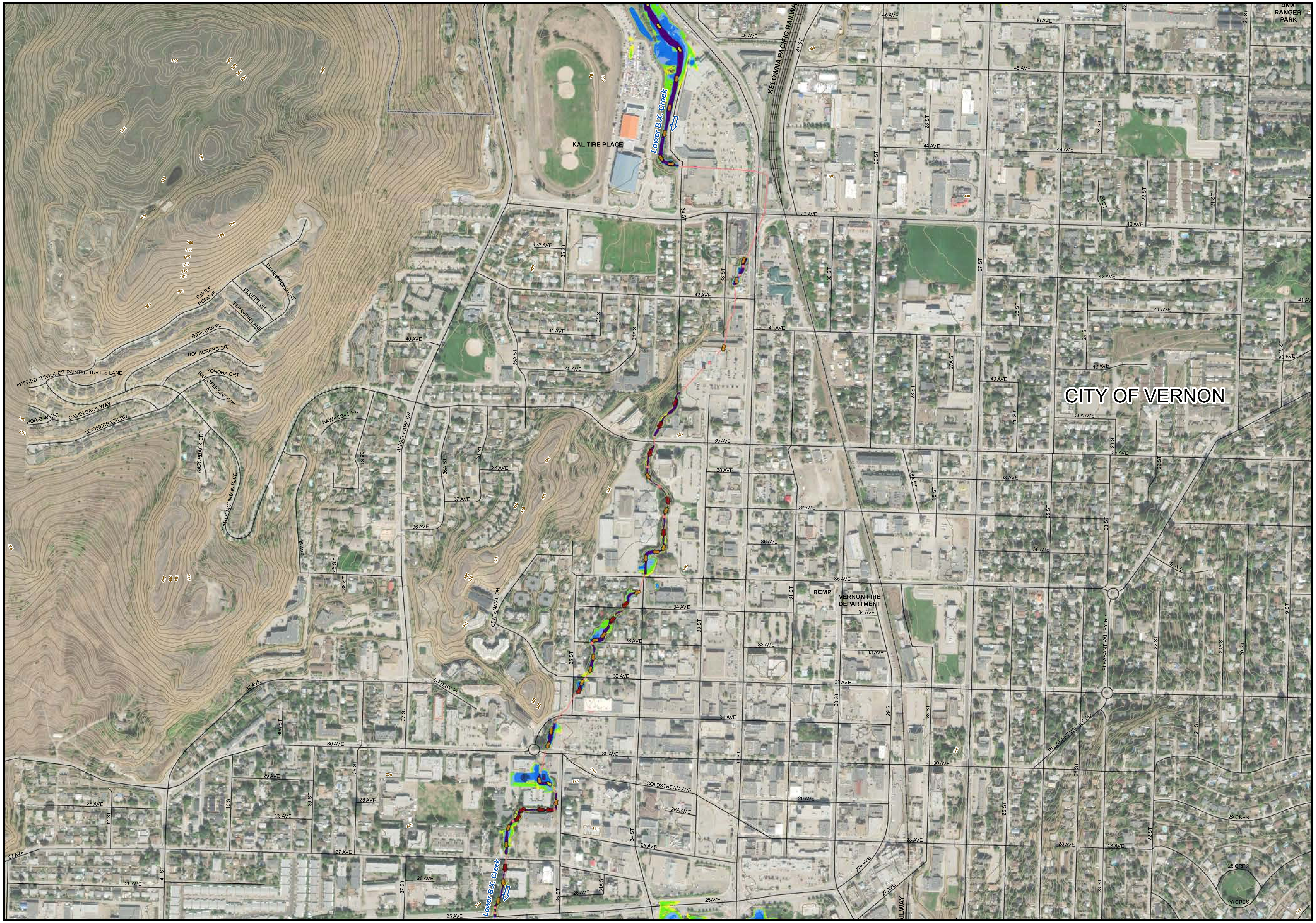
3005032	18-AUG-2021

CITY OF VERNON
FLOOD MAPPING
B.X. CREEK &
VERNON CREEK

HAZARD MAP
SHEET 5 OF 6

\\mainfile-van\Projects\Active\3005032 Vernon Flood Mapping\04 Flood Mapping\Part 2 Deliverables\Updated Final Deliverables (October)\3005032_Map_HazardMap_Combined_ReMap.mxd

SHEET 5 ↑



SHEET 2 ↓

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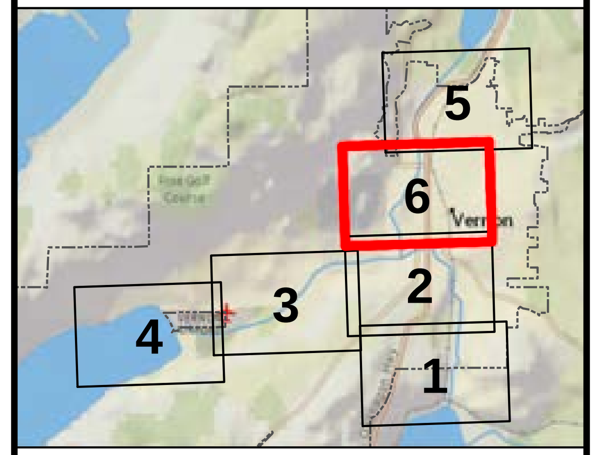

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Job Number	*Date*
3005032	*12-OCT-2021*

CITY OF VERNON
FLOOD MAPPING
B.X. CREEK &
VERNON CREEK

HAZARD MAP
SHEET 6 OF 6

\\mainfile-van\Projects\Active\3005032 Vernon Flood Mapping\04 Flood Mapping\Part 2 Deliverables\Updated Final Deliverables (October)\3005032_Map_HazardMap_Combined_ReMap.mxd

APPENDIX D

FLOOD RISK ASSESSMENT DETAILED RESULTS

FLOOD RISK ASSESSMENT DETAILED RESULTS

The tables in the following sections outline the stormwater, road, and building infrastructure components affected by the 20-year flood and the design flood.

- Stormwater pipe infrastructure (Tables D1 and D2) was obtained from the CoV Open Data Catalogue (City of Vernon, 2021).
- Road segment data (Tables D3 and D4) was provided to NHC by CoV.
- Building data (Tables D5 and D6) was provided to NHC by CoV.

Stormwater

Table D1 Stormwater Pipes Inundated by 20-year Flood.

Stormwater Pipes Inundated by 20-year Flood					
Pipe ID	**Diameter (mm)**	**Material**	**Facility ID**	**Location**	**Length (m)**
1037	900	CONC	STMM008202		208.4
1527	300	CONC	STMM001527	2424 32 St	62.8
1872	250	AC	STMM001872	3465 34 Ave	96.9
1985	350	AC	STMM001985		20.9
2002	200	HAND FRMD CONC	STMM002002	4502 15 AVE	74.7
2003	600	CONC	STMM002003	1600 45 St	40.9
2017	400	AC	STMM002017		72.5
2201	750	PVC-RIB	STMM008852	2336 39 St	13.7
3808	600	CONC	STMM003808	2413 Fulton Rd	10.9
4383	600	CONC	STMM004383	2428 Fulton Rd	7.9
4468	450	CONC	STMM004468		53.0
4624	2500	CSP	STMM004624	4284 32 St	142.1
4742	300	PVC	STMM004742	6328 Captain Bailey Pl	23.7
4748	300	PVC	STMM004748	6302 Captain Bailey Pl	21.5
4752	600	CONC	STMM004752	6293 Okanagan Landing Rd	15.2
4753	600	PVC	STMM004753	2491 Myriad Rd	100.8
4754	600	CONC	STMM004754	2451 Myriad Rd	94.6
4755	600	CONC	STMM004755	2411 Myriad Rd	57.6
4756	400	PERF-PVC	STMM004756	2349 Myriad Rd	25.5
4757	400	PERF-PVC	STMM004757	6273 Chukar Rd	59.8
4762	450	CONC	STMM004762	1723 Snowberry Rd	116.0
4763	375	CONC	STMM004763	2344 Dallas Rd	87.0
4766	300	CONC	STMM004766	6298 Osprey Rd	4.5
4767	300	CONC	STMM004767	6298 Osprey Rd	4.3
4768	300	CONC	STMM004768	2425 Myriad Rd	4.5
4769	300	CONC	STMM004769	2425 Myriad Rd	4.3
4770	300	CONC	STMM004770	2383 Myriad Rd	2.2
4772	375	CONC	STMM004772	2404 Dallas Rd	4.5
5359	600	CSP	STMM005359	6579 Okanagan Landing Rd	24.8

Stormwater Pipes Inundated by 20-year Flood					
Pipe ID	**Diameter (mm)**	**Material**	**Facility ID**	**Location**	**Length (m)**
5400	450	PVC	STMM005400	6496 Okanagan Landing Rd	105.2
5446	450	PVC	STMM005446	6548 Okanagan Landing Rd	120.3
5487	2300	CONC	STMM008912	4391 34 St	20.4
5493	450	PVC	STMM005493	6470 Okanagan Landing Rd	14.2
5510	300	PVC-RIB	STMM005510	3543 25 Ave	119.9
5569	300	PVC	STMM005569	6448 Okanagan Landing Rd	85.4
6198	900	CONC	STMM008229		63.7
6205	450	CSP	STMM008217	2370 39 St	91.4
6296	375	PVC-RIB	STMM006296	6900 MARSHALL RD	37.8
6367	250	PVC	STMM006367	2437 34 St	8.9
6492	600	PVC	STMM006492		22.9
6989	300	CONC	STMM006989	2447 34 St	9.9
8478	300	PVC-RIB	STMM008478	6450 OKANAGAN LANDING RD	81.4
8540	1050	CONC	STMM008540	6723 Okanagan Landing Rd	28.8
8543	900	PVC	STMM008543		177.4
8821	600	CSP	STMM008821	4504 Hwy 97	49.7
8825	3000	CSP	STMM008825		280.9
8830	1850	CSP	STMM008830	3352 39 Ave	16.1
8831	1850	CSP	STMM008831	3354 39 Ave	15.8
8832	2500	CONC	STMM008832	3481 34 St	49.1
8833	3000	CONC	STMM008833	3428 34 Ave	7.7
8834	2600	CONC	STMM008834	3483 32 Ave	26.2
8835	1800	CSP	STMM008835		56.8
8836	1800	CSP	STMM008836	2928 35 St	16.8
8838	2000	CONC	STMM008838	3569 27 Ave	22.1
8839	2600	CONC	STMM008839	3582 25 Ave	11.4
8844	1800	CSP	STMM008844	469 Browne Rd	11.5
8845	1800	CSP	STMM008845	467 Browne Rd	11.6
8846	1800	CSP	STMM008846	467 Browne Rd	10.7
8847	3100	CMP	STMM008847	2451 32 St	29.7
8848	2100	CSP	STMM008848	3404 24 Ave	18.0
8849	2150	CSP	STMM008849	2332 34A St	12.2
8850	2200	CSP	STMM008850	2337 39 St	19.2
8851	2200	CSP	STMM008851	2339 39 St	19.2
8853	2400	CSP	STMM008853	6287 Okanagan Landing Rd	12.4
8854	4000	CSP	STMM008854	2701 Lakeshore Rd	16.7
8897	250	PVC	STMM008897	3565 27 Ave	10.2
8913	300	CSP	STMM008913	6578 Okanagan Landing Rd	5.4
9035	250	CMP	STMM009035	2404 34A St	78.1
9036	250	CMP	STMM009036	2367 34A St	63.4

Stormwater Pipes Inundated by 20-year Flood					
Pipe ID	Diameter (mm)	Material	Facility ID	Location	Length (m)
9073	300	PVC	STMM009073		18.2
9169	600	PVC	STMM009169	2453 32 St	4.7
9180	1800	CONC	STMM009180		31.0
9185	1800	CONC	STMM009185		39.3
9209	600	AC	STMM009209	2453 32 St	7.6
9331	250	PVC	STMM009331		26.8

Table D2 Stormwater Pipes Inundated by Design Flood.

Stormwater Pipes Inundated by Design Flood					
Pipe ID	Diameter (mm)	Material	Facility ID	Location	Length (m)
1037	900	CONC	STMM008202		208.4
1468	200	VIT	STMM001468		86.3
1476	450	AC	STMM009024	2469 32 St	9.0
1527	300	CONC	STMM001527	2424 32 St	62.8
1589	200	VIT	STMM009039	3554 24 Ave	31.4
1589	200	VIT	STMM009038	3532 24 Ave	34.8
1593	200	VIT	STMM001593	3504 24 Ave	58.4
1645	250	AC	STMM001645	3802 24 Ave	95.2
1646	250	AC	STMM008214	3874 24 Ave	93.0
1872	250	AC	STMM001872	3465 34 Ave	96.9
1920	200	TILE	STMM001920	1651 43 St	220.9
1927	200	TILE	STMM001927	1626 43 St	34.5
1981	250	AC	STMM001981	1842 44 St	106.7
1982	250	AC	STMM001982	4450 18 Ave	99.4
1983	350	AC	STMM001983	1768 45 St	76.3
1984	350	AC	STMM001984	1614 45 ST	47.1
1985	350	AC	STMM001985		20.9
1992	200	AC	STMM008317	1654 44 St	79.2
2002	200	HAND FRMD CONC	STMM002002	4502 15 AVE	74.7
2003	600	CONC	STMM002003	1600 45 St	40.9
2017	400	AC	STMM002017		72.5
2149	200	TILE	STMM002149	2218 43 St	106.7
2150	300	AC	STMM008942	2320 43 St	26.9
3808	600	CONC	STMM003808	2413 Fulton Rd	10.9
4383	600	CONC	STMM004383	2428 Fulton Rd	7.9
4468	450	CONC	STMM004468		53.0
4499	500	CSP	STMM004499	3463 48 Ave	123.9
4500	500	CSP	STMM004500	3461 48 Ave	124.7
4624	2500	CSP	STMM004624	4284 32 St	142.1
4742	300	PVC	STMM004742	6328 Captain Bailey Pl	23.7
4748	300	PVC	STMM004748	6302 Captain Bailey Pl	21.5
4752	600	CONC	STMM004752	6293 Okanagan Landing Rd	15.2
4753	600	PVC	STMM004753	2491 Myriad Rd	100.8
4754	600	CONC	STMM004754	2451 Myriad Rd	94.6

Stormwater Pipes Inundated by Design Flood					
Pipe ID	Diameter (mm)	Material	Facility ID	Location	Length (m)
4755	600	CONC	STMM004755	2411 Myriad Rd	57.6
4756	400	PERF-PVC	STMM004756	2349 Myriad Rd	25.5
4757	400	PERF-PVC	STMM004757	6273 Chukar Rd	59.8
4762	450	CONC	STMM004762	1723 Snowberry Rd	116.0
4763	375	CONC	STMM004763	2344 Dallas Rd	87.0
4764	300	CONC	STMM004764		33.0
4766	300	CONC	STMM004766	6298 Osprey Rd	4.5
4767	300	CONC	STMM004767	6298 Osprey Rd	4.3
4768	300	CONC	STMM004768	2425 Myriad Rd	4.5
4769	300	CONC	STMM004769	2425 Myriad Rd	4.3
4770	300	CONC	STMM004770	2383 Myriad Rd	2.2
4772	375	CONC	STMM004772	2404 Dallas Rd	4.5
4811	250	PVC-RIB	STMM004811	6993 Cummins Rd	79.4
4812	375	PVC-RIB	STMM004812	6984 Cummins Rd	47.7
4814	250	PVC-RIB	STMM004814	6949 Cummins Rd	81.7
4816	200	PVC-RIB	STMM004816	6936 Cummins Rd	13.6
4817	250	PVC-RIB	STMM004817	6999 Cummins Rd	9.4
4818	250	PVC-RIB	STMM004818	6999 Cummins Rd	13.8
5359	600	CSP	STMM005359	6579 Okanagan Landing Rd	24.8
5400	450	PVC	STMM005400	6496 Okanagan Landing Rd	105.2
5446	450	PVC	STMM005446	6548 Okanagan Landing Rd	120.3
5487	2300	CONC	STMM008912	4391 34 St	20.4
5493	450	PVC	STMM005493	6470 Okanagan Landing Rd	14.2
5510	300	PVC-RIB	STMM005510	3543 25 Ave	119.9
5569	300	PVC	STMM005569	6448 Okanagan Landing Rd	85.4
6053	250	PVC	STMM006053	6944 Marshall Rd	5.0
6054	250	PVC	STMM006054	6945 Marshall Rd	14.4
6055	250	PVC	STMM006055	6900 MARSHALL RD	96.9
6056	250	PVC	STMM006056	6900 MARSHALL RD	9.0
6198	900	CONC	STMM008229		63.7
6296	375	PVC-RIB	STMM006296	6900 MARSHALL RD	37.8
6367	250	PVC	STMM006367	2437 34 St	8.9
6380	250	PVC	STMM006380	1902 44 St	22.7
6381	250	PVC	STMM006381	4389 19 Ave	26.4
6492	600	PVC	STMM006492		22.9
6989	300	CONC	STMM006989	2447 34 St	9.9
8478	300	PVC-RIB	STMM008478	6450 OKANAGAN LANDING RD	81.4
8540	1050	CONC	STMM008540	6723 Okanagan Landing Rd	28.8
8543	900	PVC	STMM008543		177.4
8603	600	CONC	STMM008603		3.1
8607	250	PVC	STMM008607		42.1

Stormwater Pipes Inundated by Design Flood					
Pipe ID	Diameter (mm)	Material	Facility ID	Location	Length (m)
8608	250	PVC	STMM008608		3.0
8628	450	PVC	STMM008628		7.1
8635	375	PVC	STMM008635		7.5
8636	375	PVC	STMM008636		23.0
8821	600	CSP	STMM008821	4504 Hwy 97	49.7
8825	3000	CSP	STMM008825		280.9
8829	350	PVC	STMM008829	3359 39 Ave	13.2
8830	1850	CSP	STMM008830	3352 39 Ave	16.1
8831	1850	CSP	STMM008831	3354 39 Ave	15.8
8832	2500	CONC	STMM008832	3481 34 St	49.1
8833	3000	CONC	STMM008833	3428 34 Ave	7.7
8834	2600	CONC	STMM008834	3483 32 Ave	26.2
8835	1800	CSP	STMM008835		56.8
8836	1800	CSP	STMM008836	2928 35 St	16.8
8838	2000	CONC	STMM008838	3569 27 Ave	22.1
8839	2600	CONC	STMM008839	3582 25 Ave	11.4
8844	1800	CSP	STMM008844	469 Browne Rd	11.5
8845	1800	CSP	STMM008845	467 Browne Rd	11.6
8846	1800	CSP	STMM008846	467 Browne Rd	10.7
8847	3100	CMP	STMM008847	2451 32 St	29.7
8848	2100	CSP	STMM008848	3404 24 Ave	18.0
8849	2150	CSP	STMM008849	2332 34A St	12.2
8850	2200	CSP	STMM008850	2337 39 St	19.2
8851	2200	CSP	STMM008851	2339 39 St	19.2
8853	2400	CSP	STMM008853	6287 Okanagan Landing Rd	12.4
8854	4000	CSP	STMM008854	2701 Lakeshore Rd	16.7
8911	600	CSP	STMM008911	4579 Hwy 97	34.4
8913	300	CSP	STMM008913	6578 Okanagan Landing Rd	5.4
9035	250	CMP	STMM009035	2404 34A St	78.1
9036	250	CMP	STMM009036	2367 34A St	63.4
9072	250	PVC	STMM009072		53.7
9073	300	PVC	STMM009073		18.2
9074	250	PVC	STMM009074		4.1
9171	600	PVC	STMM009171	2471 32 St	4.5
9172	600	PVC	STMM009172	2467 32 St	6.2
9177	600	PVC	STMM009177	2461 32 St	11.1
9180	1800	CONC	STMM009180		31.0
9185	1800	CONC	STMM009185		39.3
9209	600	AC	STMM009209	2453 32 St	7.6
9331	250	PVC	STMM009331		26.8
1037	900	CONC	STMM008202		208.4
1468	200	VIT	STMM001468		86.3
1476	450	AC	STMM009024	2469 32 St	9.0
1527	300	CONC	STMM001527	2424 32 St	62.8
1589	200	VIT	STMM009039	3554 24 Ave	31.4
1589	200	VIT	STMM009038	3532 24 Ave	34.8

Stormwater Pipes Inundated by Design Flood					
Pipe ID	Diameter (mm)	Material	Facility ID	Location	Length (m)
1593	200	VIT	STMM001593	3504 24 Ave	58.4
1645	250	AC	STMM001645	3802 24 Ave	95.2
1646	250	AC	STMM008214	3874 24 Ave	93.0
1872	250	AC	STMM001872	3465 34 Ave	96.9
1920	200	TILE	STMM001920	1651 43 St	220.9
1927	200	TILE	STMM001927	1626 43 St	34.5
1981	250	AC	STMM001981	1842 44 St	106.7
1982	250	AC	STMM001982	4450 18 Ave	99.4
1983	350	AC	STMM001983	1768 45 St	76.3
1984	350	AC	STMM001984	1614 45 ST	47.1
1985	350	AC	STMM001985		20.9
1992	200	AC	STMM008317	1654 44 St	79.2
2002	200	HAND FRMD CONC	STMM002002	4502 15 AVE	74.7
2003	600	CONC	STMM002003	1600 45 St	40.9
2017	400	AC	STMM002017		72.5
2149	200	TILE	STMM002149	2218 43 St	106.7
2150	300	AC	STMM008942	2320 43 St	26.9
3808	600	CONC	STMM003808	2413 Fulton Rd	10.9
4383	600	CONC	STMM004383	2428 Fulton Rd	7.9
4468	450	CONC	STMM004468		53.0
4499	500	CSP	STMM004499	3463 48 Ave	123.9
4500	500	CSP	STMM004500	3461 48 Ave	124.7
4624	2500	CSP	STMM004624	4284 32 St	142.1
4742	300	PVC	STMM004742	6328 Captain Bailey Pl	23.7
4748	300	PVC	STMM004748	6302 Captain Bailey Pl	21.5
4752	600	CONC	STMM004752	6293 Okanagan Landing Rd	15.2
4753	600	PVC	STMM004753	2491 Myriad Rd	100.8
4754	600	CONC	STMM004754	2451 Myriad Rd	94.6
4755	600	CONC	STMM004755	2411 Myriad Rd	57.6

Roads

Table D3 Road Segments Inundated by 20-year Flood.

Object ID	Section ID	Road Name	From Street	To Street	Road Function Class	Bus Route	Number of Lanes	Facility ID	Road Width (m)	Max Flood Depth (m)	Mean Flood Depth (m)	Road Segment Length (m)
Vernon Roads												
1	10410	CHUKAR RD	MYRIAD RD	EOP	LOCAL	<Null>	2	TRDS010410	7.0	0.1	0.1	147.8
2	10420	QUAIL RD	MYRIAD RD	CUL DE SAC	LOCAL	<Null>	2	TRDS010420	8.5	0.4	0.1	250.3
3	10430	OSPREY RD	MYRIAD RD	EOP	LOCAL	<Null>	2	TRDS010430	6.0	0.9	0.1	324.6
4	50070	ROW NE OF WILLOW BAY	WILLOW DR	VERNON CREEK	SROW	<Null>	0	TRDS050070	5.0	0.6	0.2	94.4
5	4390	33 AVE	35 ST	34 ST	LOCAL	<Null>	2	TRDS004390	9.5	0.1	0.0	181.0
6	1950	24 AVE	34A ST	34 ST	LOCAL	BUS	2	TRDS001950	10.1	0.6	0.1	154.8
7	4880	34A ST	EOP (S)	24 AVE	LOCAL	<Null>	2	TRDS004880	8.0	0.3	0.1	68.8
8	4890	34A ST	24 AVE	24A AVE	LOCAL	<Null>	2	TRDS004890	8.5	0.2	0.1	105.9
9	51440	ROW (SEWER) CNR	POLSON PARK	BROWNE RD	SROW	<Null>	0	TRDS051440	5.0	0.4	0.1	1363.4
10	51920	ROW 307 BROWNE RD	BROWNE RD	CREEK	SROW	<Null>	0	TRDS051920	5.0	0.6	0.4	73.0
11	51940	ROW AT 307 KAL LAKE RD	KAL LAKE RD	<Null>	SROW	<Null>	0	TRDS051940	5.0	0.8	0.5	124.2
12	51950	ROW @ 407 BROWNE RD	BROWNE RD	<Null>	SROW	<Null>	0	TRDS051950	5.0	1.0	0.3	93.5
13	51960	ROW @ 112 KAL LAKE RD	<Null>	<Null>	SROW	<Null>	0	TRDS051960	5.0	0.4	0.1	106.0
14	10390	SNOWBERRY RD	OKANAGAN AVE	DALLAS RD	LOCAL	<Null>	2	TRDS010390	8.8	0.5	0.1	410.5
15	10395	SNOWBERRY RD	DALLAS RD	MYRIAD RD	LOCAL	<Null>	2	TRDS010395	7.0	0.5	0.2	125.7
16	10380	DALLAS RD	SNOWBERRY RD	OKANAGAN LANDING RD	LOCAL	<Null>	2	TRDS010380	6.0	0.7	0.2	243.8

Road Segments Inundated by 20-year Flood												
Object ID	Section ID	Road Name	From Street	To Street	Road Function Class	Bus Route	Number of Lanes	Facility ID	Road Width (m)	Max Flood Depth (m)	Mean Flood Depth (m)	Road Segment Length (m)
17	10385	DALLAS RD	CUL DE SAC	SNOWBERRY RD	LOCAL	<Null>	2	TRDS010385	8.1	0.4	0.2	110.6
18	10405	MYRIAD RD	SNOWBERRY RD	CHUKAR RD	LOCAL	<Null>	2	TRDS010405	7.0	0.3	0.1	57.9
19	10400	MYRIAD RD	OKANAGAN LANDING RD	OSPREY RD	LOCAL	<Null>	2	TRDS010400	7.0	0.6	0.2	105.1
20	10401	MYRIAD RD	OSPREY RD	QUAIL RD	LOCAL	<Null>	2	TRDS010401	7.0	0.7	0.2	117.2
21	10403	MYRIAD RD	QUAIL RD	SNOWBERRY RD	LOCAL	<Null>	2	TRDS010403	7.0	0.3	0.1	81.2
22	9657	OKANAGAN LANDING RD	CAPTAIN BAILEY WAY	TRONSON RD	ARTERIAL	BUS	2	TRDS009657	13.8	0.6	0.4	562.5
23	9653	OKANAGAN LANDING RD	DALLAS RD	MYRIAD RD	ARTERIAL	BUS	2	TRDS009653	11.0	0.2	0.1	140.0
24	9655	OKANAGAN LANDING RD	MYRIAD RD	CAPTAIN BAILEY WAY	ARTERIAL	BUS	2	TRDS009655	10.0	2.6	1.2	89.4
25	9820	TRONSON RD	PALMER RD	SCOTT RD (W)	COLLECTOR	<Null>	2	TRDS009820	9.0	0.8	0.3	506.5
26	10360	LAKESHORE RD	CUMMINS RD (N)	TRONSON RD	LOCAL	BUS	2	TRDS010360	6.5	3.1	1.7	607.0
27	9690	CUMMINS RD	OKANAGAN LANDING RD	MARSHALL RD	LOCAL	<Null>	2	TRDS009690	11.0	0.2	0.1	265.1
28	9695	CUMMINS RD	MARSHALL RD	EOP (N)	LOCAL	<Null>	2	TRDS009695	10.5	0.4	0.1	226.9
29	53390	SROW NW OF 15 AVE	15 AVE	<Null>	SROW	<Null>	0	TRDS053390	5.0	0.5	0.2	93.2
30	9645	OKANAGAN LANDING RD	CUMMINS RD	APOLLO RD	COLLECTOR	BUS	2	TRDS009645	11.5	0.1	0.1	269.7
31	54230	WESTKAL RD	EOP	EOP	SROW	<Null>	0	TRDS054230	5.0	1.0	0.3	973.1
32	7150	BROWNE RD	CNR CROSSING	KALAMALKA LAKE RD	LOCAL	<Null>	2	TRDS007150	6.0	0.8	0.3	360.0

Road Segments Inundated by 20-year Flood												
Object ID	Section ID	Road Name	From Street	To Street	Road Function Class	Bus Route	Number of Lanes	Facility ID	Road Width (m)	Max Flood Depth (m)	Mean Flood Depth (m)	Road Segment Length (m)
33	54725	OKANAGAN LANDING RD	OKANAGAN AVE	6545 OKANAGAN LANDING RD	ARTERIAL	BUS	2	TRDS054725	12.0	1.0	0.2	414.2
34	54750	TRONSON RD	6800 BLK TRONSON RD	SCOTT RD	COLLECTOR	BUS	2	TRDS054750	9.0	0.3	0.1	375.2
35	10365	LAKESHORE RD	MARHSHALL RD	CUMMINS RD (N)	LOCAL	BUS	2	TRDS010365	7.5	0.5	0.1	478.7
36	54730	OKANAGAN LANDING RD	6545 OKANAGAN LANDING RD	DALLAS RD	ARTERIAL	BUS	2	TRDS054730	12.8	0.8	0.1	416.7
Priest’s Valley 6 Roads												
2	389470	Lakeshore Rd	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.10	0.04	30.6
3	389471	Lakeshore Rd	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.52	0.18	195.0
4	389472	Lakeshore Rd	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.13	0.06	73.9
5	389473	Lakeshore Rd	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.31	0.09	265.6

Table D4 Road Segments Inundated by Design Flood.

Road Segments Inundated by Design Flood												
Object ID	**Section ID**	**Road Name**	**From Street**	**To Street**	**Road Function Class**	**Bus Route**	**Number of Lanes**	**Facility ID**	**Road Width (m)**	**Max Flood Depth (m)**	**Mean Flood Depth (m)**	**Road Segment Length (m)**
Vernon Roads												
1	10800	MARSHALL RD	CUMMINS RD	EOP (E)	LOCAL	<Null>	2	TRDS010800	8.1	0.3	0.1	108.7
2	10410	CHUKAR RD	MYRIAD RD	EOP	LOCAL	<Null>	2	TRDS010410	7.0	0.2	0.1	147.8
3	10420	QUAIL RD	MYRIAD RD	CUL DE SAC	LOCAL	<Null>	2	TRDS010420	8.5	0.5	0.1	250.3
4	10430	OSPREY RD	MYRIAD RD	EOP	LOCAL	<Null>	2	TRDS010430	6.0	1.0	0.2	324.6
5	50320	ROW ACROSS VGCC NOT REGISTERED	COUNTRY CLUB ESTATES	BROWNE RD	SROW	<Null>	0	TRDS050320	5.0	1.2	0.3	651.5
6	50270	ROW NE OF 18 AVE	45 ST	25 AVE	SROW	<Null>	0	TRDS050270	5.0	0.8	0.2	188.1
7	50240	ROW SW OF 18 AVE	45 ST	72M NORTH WEST	SROW	<Null>	0	TRDS050240	5.0	0.7	0.3	88.0
8	50070	ROW NE OF WILLOW BAY	WILLOW DR	VERNON CREEK	SROW	<Null>	0	TRDS050070	5.0	0.8	0.3	94.4
9	4390	33 AVE	35 ST	34 ST	LOCAL	<Null>	2	TRDS004390	9.5	0.4	0.3	181.0
10	4960	35 AVE	34 ST	33 ST	COLLECTOR	BUS	2	TRDS004960	10.5	0.1	0.1	165.8
12	4840	34 ST	34 AVE	35 AVE	COLLECTOR	<Null>	2	TRDS004840	11.5	0.4	0.1	106.7
13	950	18 AVE	43 ST	42A ST	LOCAL	<Null>	2	TRDS000950	8.5	0.2	0.1	102.3
14	940	18 AVE	44 ST	45 ST	LOCAL	<Null>	2	TRDS000940	8.8	0.5	0.2	127.0
15	6710	44 ST	18 AVE	19 AVE	LOCAL	<Null>	2	TRDS006710	9.2	0.4	0.1	155.0
16	6700	44 ST	16 AVE	CUL DE SAC	LOCAL	<Null>	2	TRDS006700	10.5	0.4	0.1	163.6
17	5700	38 ST	OKANAGAN AVE	END OF GRAVEL (N)	LOCAL	<Null>	2	TRDS005700	2.6	1.5	1.0	132.6
18	5980	39 ST	24 AVE	25 AVE	COLLECTOR	<Null>	2	TRDS005980	12.0	0.2	0.1	148.3
19	5370	36 ST	CUL DE SAC	24 AVE	LOCAL	<Null>	2	TRDS005370	12.9	0.8	0.2	119.5
20	2150	25 AVE	37 ST	35 ST	ARTERIAL	<Null>	4	TRDS002150	21.3	0.8	0.3	415.8
21	10810	MARSHALL RD	LAKESHORE RD	CUMMINS RD	LOCAL	<Null>	2	TRDS010810	7.5	0.4	0.2	152.9

Road Segments Inundated by Design Flood												
Object ID	**Section ID**	**Road Name**	**From Street**	**To Street**	**Road Function Class**	**Bus Route**	**Number of Lanes**	**Facility ID**	**Road Width (m)**	**Max Flood Depth (m)**	**Mean Flood Depth (m)**	**Road Segment Length (m)**
22	2290	25 AVE	34 ST	HWY 97 (32 ST)	ARTERIAL	<Null>	4	TRDS002290	20.1	0.4	0.1	254.3
23	1950	24 AVE	34A ST	34 ST	LOCAL	BUS	2	TRDS001950	10.1	0.8	0.2	154.8
24	4880	34A ST	EOP (S)	24 AVE	LOCAL	<Null>	2	TRDS004880	8.0	0.4	0.2	68.8
25	4890	34A ST	24 AVE	24A AVE	LOCAL	<Null>	2	TRDS004890	8.5	0.3	0.1	105.9
27	52420	ROW E OF 34 ST (25 AVE TO S)	25 AVE	CREEK	SROW	<Null>	0	TRDS052420	5.0	2.1	0.6	111.9
28	1940	24 AVE	39 ST	36 ST	LOCAL	TBAN	2	TRDS001940	8.0	0.4	0.1	435.9
29	1945	24 AVE	36 ST	34A ST	LOCAL	TBAN	2	TRDS001945	8.5	0.8	0.1	338.8
30	5970	39 ST	ARGYLE AVE	24 AVE	COLLECTOR	<Null>	2	TRDS005970	12.5	1.9	0.6	193.7
31	51350	POLSON PARK LANE 2	<Null>	<Null>	PRIVATE	<Null>	1	TRDS051350	5.0	0.3	0.1	115.2
32	51360	POLSON PARK LANE 4	<Null>	<Null>	PRIVATE	<Null>	1	TRDS051360	5.0	0.5	0.1	254.9
33	51440	ROW (SEWER) CNR	POLSON PARK	BROWNE RD	SROW	<Null>	0	TRDS051440	5.0	0.6	0.2	1363.4
34	51820	EASEMENT W OF KAL LAKE RD	KAL LAKE RD	CITY LIMITS	SROW	<Null>	0	TRDS051820	5.0	1.3	1.0	106.8
35	51920	ROW 307 BROWNE RD	BROWNE RD	CREEK	SROW	<Null>	0	TRDS051920	5.0	0.7	0.5	73.0
36	51940	ROW AT 307 KAL LAKE RD	KAL LAKE RD	<Null>	SROW	<Null>	0	TRDS051940	5.0	0.9	0.5	124.2
37	51950	ROW @ 407 BROWNE RD	BROWNE RD	<Null>	SROW	<Null>	0	TRDS051950	5.0	1.1	0.3	93.5
38	51960	ROW @ 112 KAL LAKE RD	<Null>	<Null>	SROW	<Null>	0	TRDS051960	5.0	0.6	0.2	106.0
39	51990	EASEMENT COUNTRY ESTATES N	COUNTRY ESTATES PL	<Null>	SROW	<Null>	0	TRDS051990	5.0	0.7	0.4	1333.4

Road Segments Inundated by Design Flood												
Object ID	Section ID	Road Name	From Street	To Street	Road Function Class	Bus Route	Number of Lanes	Facility ID	Road Width (m)	Max Flood Depth (m)	Mean Flood Depth (m)	Road Segment Length (m)
40	52100	REC CENTRE ROW	35 AVE	REC CENTRE	SROW	<Null>	0	TRDS052100	5.0	0.7	0.3	121.0
41	52140	OFFSHORE SEWER INT ROW	<Null>	<Null>	SROW	<Null>	0	TRDS052140	5.0	0.3	0.1	2938.7
42	10390	SNOWBERRY RD	OKANAGAN AVE	DALLAS RD	LOCAL	<Null>	2	TRDS010390	8.8	0.6	0.2	410.5
43	10395	SNOWBERRY RD	DALLAS RD	MYRIAD RD	LOCAL	<Null>	2	TRDS010395	7.0	0.5	0.2	125.7
44	10380	DALLAS RD	SNOWBERRY RD	OKANAGAN LANDING RD	LOCAL	<Null>	2	TRDS010380	6.0	0.8	0.2	243.8
45	10385	DALLAS RD	CUL DE SAC	SNOWBERRY RD	LOCAL	<Null>	2	TRDS010385	8.1	0.5	0.2	110.6
46	10405	MYRIAD RD	SNOWBERRY RD	CHUKAR RD	LOCAL	<Null>	2	TRDS010405	7.0	0.4	0.1	57.9
47	10400	MYRIAD RD	OKANAGAN LANDING RD	OSPREY RD	LOCAL	<Null>	2	TRDS010400	7.0	0.7	0.2	105.1
48	10401	MYRIAD RD	OSPREY RD	QUAIL RD	LOCAL	<Null>	2	TRDS010401	7.0	0.7	0.2	117.2
49	10403	MYRIAD RD	QUAIL RD	SNOWBERRY RD	LOCAL	<Null>	2	TRDS010403	7.0	0.4	0.2	81.2
50	9657	OKANAGAN LANDING RD	CAPTAIN BAILEY WAY	TRONSON RD	ARTERIAL	BUS	2	TRDS009657	13.8	0.7	0.4	562.5
51	9653	OKANAGAN LANDING RD	DALLAS RD	MYRIAD RD	ARTERIAL	BUS	2	TRDS009653	11.0	0.2	0.1	140.0
52	9655	OKANAGAN LANDING RD	MYRIAD RD	CAPTAIN BAILEY WAY	ARTERIAL	BUS	2	TRDS009655	10.0	2.6	0.8	89.4
53	9820	TRONSON RD	PALMER RD	SCOTT RD (W)	COLLECTOR	<Null>	2	TRDS009820	9.0	1.0	0.5	506.5
54	10360	LAKESHORE RD	CUMMINS RD (N)	TRONSON RD	LOCAL	BUS	2	TRDS010360	6.5	3.4	0.5	607.0

Road Segments Inundated by Design Flood												
Object ID	Section ID	Road Name	From Street	To Street	Road Function Class	Bus Route	Number of Lanes	Facility ID	Road Width (m)	Max Flood Depth (m)	Mean Flood Depth (m)	Road Segment Length (m)
55	9690	CUMMINS RD	OKANAGAN LANDING RD	MARSHALL RD	LOCAL	<Null>	2	TRDS009690	11.0	0.3	0.1	265.1
56	9695	CUMMINS RD	MARSHALL RD	EOP (N)	LOCAL	<Null>	2	TRDS009695	10.5	0.7	0.2	226.9
57	650	16 AVE	44 ST	43 ST	LOCAL	<Null>	2	TRDS000650	8.5	0.1	0.0	125.8
58	653	16 AVE	45 ST	44 ST	LOCAL	<Null>	2	TRDS000653	8.5	0.2	0.1	126.7
59	655	16 AVE	EOP (N)	45 ST	LOCAL	<Null>	2	TRDS000655	8.5	0.6	0.3	69.5
60	6595	43 ST	17 AVE	18 AVE	COLLECTOR	BUS	2	TRDS006595	8.5	0.3	0.1	173.2
61	6600	43 ST	19 AVE	24 AVE	COLLECTOR	BUS	2	TRDS006600	9.7	1.8	0.3	389.9
62	6605	43 ST	18 AVE	19 AVE	COLLECTOR	BUS	2	TRDS006605	8.5	0.1	0.0	151.2
63	6800	45 ST	16 AVE	18 AVE	LOCAL	<Null>	2	TRDS006800	9.0	0.4	0.1	249.8
64	53330	EASEMENT 43 ST AND OK AVE	43 ST	OKANAGAN AVE	SROW	<Null>	0	TRDS053330	5.0	0.4	0.2	178.6
65	53390	SROW NW OF 15 AVE	15 AVE	<Null>	SROW	<Null>	0	TRDS053390	5.0	0.7	0.2	93.2
66	53410	SROW SW OF WILLOW BAY	WILLOW DR	<Null>	SROW	<Null>	0	TRDS053410	5.0	0.6	0.4	60.4
67	7070	34 ST	43 AVE	45 AVE	LOCAL	<Null>	2	TRDS007070	10.9	0.7	0.2	463.0
68	9645	OKANAGAN LANDING RD	CUMMINS RD	APOLLO RD	COLLECTOR	BUS	2	TRDS009645	11.5	0.1	0.0	269.7
70	54230	WESTKAL RD	EOP	EOP	SROW	<Null>	0	TRDS054230	5.0	1.2	0.5	973.1
71	7150	BROWNE RD	CNR CROSSING	KALAMALKA LAKE RD	LOCAL	<Null>	2	TRDS007150	6.0	1.1	0.2	360.0
72	51810	ROW W OF KAL LAKE RD	CITY LIMITS	RAILWAY	SROW	<Null>	0	TRDS051810	5.0	1.1	0.8	242.7
73	54725	OKANAGAN LANDING RD	OKANAGAN AVE	6545 OKANAGAN LANDING RD	ARTERIAL	BUS	2	TRDS054725	12.0	1.0	0.2	414.2

Road Segments Inundated by Design Flood												
Object ID	**Section ID**	**Road Name**	**From Street**	**To Street**	**Road Function Class**	**Bus Route**	**Number of Lanes**	**Facility ID**	**Road Width (m)**	**Max Flood Depth (m)**	**Mean Flood Depth (m)**	**Road Segment Length (m)**
74	54750	TRONSON RD	6800 BLK TRONSON RD	SCOTT RD	COLLECTOR	BUS	2	TRDS054750	9.0	0.6	0.3	375.2
75	55412	34 ST	24 AVE	25 AVE	ARTERIAL	BUS	2	TRDS055412	11.0	2.1	0.9	193.2
76	55606	LANE S OF 19 AVE (W OF 43 ST)	EOP (S)	19 AVE	LANE	<Null>	1	TRDS055606	4.0	0.5	0.2	92.6
77	1150	19 AVE	44 ST	43 ST	LOCAL	<Null>	2	TRDS001150	9.2	0.3	0.1	127.6
78	51240	LANE S OF 30 AVE	35 ST	EOP	LANE	<Null>	1	TRDS051240	5.0	0.4	0.1	189.7
79	10365	LAKESHORE RD	MARHSHALL RD	CUMMINS RD (N)	LOCAL	BUS	2	TRDS010365	7.5	0.7	0.1	478.7
80	55963	SRW BLUE JAY MAIN	<Null>	<Null>	SROW	<Null>	<Null>	TRDS055963	5.0	0.4	0.2	1738.2
81	54730	OKANAGAN LANDING RD	6545 OKANAGAN LANDING RD	DALLAS RD	ARTERIAL	BUS	2	TRDS054730	12.8	0.9	0.1	416.7
Priest's Valley 6 Roads												
1	526371	TRONSON RD	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.2	0.1	5.9
2	333002	TRONSON RD	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.2	0.1	72.5
3	333006	TRONSON RD	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.3	0.1	70.1
4	389466	LAKESHORE RD	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.5	0.2	47.4
5	389469	LAKESHORE RD	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.4	0.3	147.6
6	389470	LAKESHORE RD	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.8	0.4	30.6
7	389471	LAKESHORE RD	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.4	0.2	195.0
8	389472	LAKESHORE RD	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.6	0.2	73.9

Road Segments Inundated by Design Flood												
Object ID	Section ID	Road Name	From Street	To Street	Road Function Class	Bus Route	Number of Lanes	Facility ID	Road Width (m)	Max Flood Depth (m)	Mean Flood Depth (m)	Road Segment Length (m)
9	389473	LAKESHORE RD	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.2	0.1	265.6
10	389477	TRONSON RD	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.5	0.2	184.2
11	389478	TRONSON RD	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.3	0.1	204.9
12	389482	TRONSON RD	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.1	0.0	59.1
13	389485	TRONSON RD	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.1	0.1	242.7
14	389486	TRONSON RD	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.5	0.2	191.2
15	389489	TRONSON RD	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.6	0.3	80.4
16	389490	TRONSON RD	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.4	0.1	36.7
17	1630205	TRONSON RD	N/A	N/A	LOCAL	N/A	2	N/A	N/A	0.1	0.1	280.9

Buildings

Table D5 Buildings Inundated by 20-year Flood.

Buildings Inundated by 20-year Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
Vernon							
1	0.050	386.79	PARKS & OPEN SPACE	TEMPORARY LODGING	0	0.5%	1.8%
2	0.003	384.99	COMMUNITY COMMERCIAL	NURSING HOME	121	0.1%	0.4%
3	0.174	348.77	RESIDENTIAL - LOW DENSITY	NURSING HOME	70	1.1%	6.2%
6	0.121	359.99	PUBLIC & INSTITUTIONAL	INSTITUTIONAL	0	2.8%	15.1%
7	0.481	361.16	LIGHT INDUSTRIAL / SERVICE COMMERCIAL	GENERAL SERVICES (GOV)	0	12.7%	104.8%
8	0.441	361.28	LIGHT INDUSTRIAL / SERVICE COMMERCIAL	GENERAL SERVICES (GOV)	0	12.3%	101.0%
9	0.005	361.43	LIGHT INDUSTRIAL / SERVICE COMMERCIAL	LIGHT INDUSTRY	0	1.1%	0.1%
10	0.408	370.46	PARKS & OPEN SPACE	DUPLEX	2	37.0%	45.0%
11	0.193	369.13	RESIDENTIAL - MEDIUM DENSITY	DUPLEX	2	15.6%	19.6%
14	0.050	369.08	RESIDENTIAL - MEDIUM DENSITY	RETAIL TRADE	0	2.3%	5.9%
15	0.050	370.38	RESIDENTIAL - MEDIUM DENSITY	SINGLE FAMILY DWELLING	1	19.3%	16.3%
16	0.285	369.81	RESIDENTIAL - MEDIUM DENSITY	SINGLE FAMILY DWELLING	1	20.9%	17.9%
17	0.398	369.57	RESIDENTIAL - MEDIUM DENSITY	SINGLE FAMILY DWELLING	1	32.5%	34.1%
18	0.180	369.58	RESIDENTIAL - MEDIUM DENSITY	SINGLE FAMILY DWELLING	1	20.2%	17.2%
19	0.050	370.55	RESIDENTIAL - HIGH DENSITY	NURSING HOME	75	4.0%	21.6%
22	0.523	385.83	RESIDENTIAL - MEDIUM DENSITY	SINGLE FAMILY DWELLING	1	34.6%	37.0%
23	0.214	387.79	RESIDENTIAL - MEDIUM DENSITY	DUPLEX	2	15.7%	20.4%
24	0.497	387.69	PARKS & OPEN SPACE	TEMPORARY LODGING	0	8.3%	32.1%
26	0.050	387.90	PARKS & OPEN SPACE	TEMPORARY LODGING	0	0.5%	1.8%
27	0.050	377.53	PARKS & OPEN SPACE	RETAIL TRADE	0	2.3%	5.9%
28	0.072	344.45	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	19.5%	16.5%
29	0.048	343.82	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	19.3%	16.3%

Buildings Inundated by 20-year Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
30	0.071	343.87	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	19.5%	16.5%
32	0.361	343.85	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	31.9%	33.3%
34	0.212	343.62	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	20.4%	17.4%
35	0.251	343.81	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	20.6%	17.6%
36	0.447	343.62	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	33.3%	35.3%
37	0.243	343.98	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	20.6%	17.6%
39	0.157	343.75	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.0%	17.0%
69	0.230	347.35	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.5%	17.5%
72	0.183	347.47	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	30.8%	17.4%
73	0.213	347.59	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.4%	17.4%
74	0.166	347.38	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	29.0%	16.1%
76	0.166	347.64	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	29.0%	16.1%
77	0.017	347.61	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	12.9%	4.4%
78	0.072	347.52	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	18.8%	8.7%
79	0.083	347.62	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	19.9%	9.5%
86	0.031	347.94	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	14.3%	5.4%
93	0.175	347.96	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	30.0%	16.8%
94	0.152	347.74	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	27.4%	15.0%
95	0.082	347.81	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	19.8%	9.4%
100	0.137	347.81	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	25.8%	13.8%
102	0.395	347.62	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	87.6%	77.5%
103	0.686	347.26	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	105.5%	112.7%
104	0.801	347.17	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	109.3%	118.4%
105	0.462	347.79	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	91.8%	82.4%
106	0.546	347.53	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	97.0%	88.4%
107	0.803	347.41	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	109.3%	118.5%
108	0.080	347.71	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	19.7%	9.3%

Buildings Inundated by 20-year Flood							
Object ID	**Maximum Flood Depth (m)**	**Ground Floor Elevation (m)**	**OCP Designation**	**Damage Curve**	**Dwelling Units (#)**	**Structure Damage (%)**	**Contents Damage (%)**
109	0.236	347.49	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	36.6%	21.6%
110	0.063	347.82	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	17.8%	7.9%
111	0.105	347.67	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	22.3%	11.2%
112	0.220	347.57	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	34.8%	20.3%
113	0.238	347.44	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	36.8%	21.8%
114	0.315	347.44	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	82.7%	71.8%
115	0.317	347.47	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	82.8%	71.9%
117	0.272	347.57	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	40.4%	24.4%
118	0.264	347.63	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	39.6%	23.8%
119	0.432	347.56	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	89.9%	80.2%
120	0.305	347.35	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	82.0%	71.0%
122	0.344	347.46	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	84.5%	73.8%
124	0.452	347.88	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	91.1%	81.6%
126	0.214	347.42	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	34.2%	19.9%
127	0.361	347.34	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	85.5%	75.1%
128	0.244	347.39	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	37.4%	22.2%
129	0.620	346.88	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	103.3%	109.5%
130	0.548	347.04	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	97.2%	88.6%
131	0.587	346.92	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	99.6%	91.4%
132	0.572	347.22	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	98.7%	90.3%
133	0.565	347.60	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	98.2%	89.8%
134	0.565	347.04	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	98.2%	89.8%
136	0.479	347.22	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	92.9%	83.6%
139	0.284	347.27	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	41.7%	25.4%
140	0.363	347.25	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	85.6%	75.2%
143	0.071	346.92	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.5%	16.5%
145	0.159	347.08	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.0%	17.0%
146	0.168	346.98	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.1%	17.1%
148	0.200	346.66	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.3%	17.3%
155	0.049	346.88	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.3%	16.3%
157	0.053	346.49	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.3%	16.3%
160	0.214	346.17	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.4%	17.4%

Buildings Inundated by 20-year Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
162	0.180	346.16	RESIDENTIAL - LOW DENSITY	CHURCHES	0	5.9%	48.4%
164	0.218	345.85	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.4%	17.4%
165	0.109	346.01	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.7%	16.7%
166	0.162	346.01	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.1%	17.1%
175	0.164	347.25	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.1%	17.1%
176	0.168	347.12	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.1%	17.1%
177	0.135	347.21	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.9%	16.9%
178	0.099	347.19	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.6%	16.6%
179	0.206	347.00	RESIDENTIAL - MEDIUM DENSITY	SINGLE FAMILY DWELLING	1	20.3%	17.3%
188	0.125	347.29	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.8%	16.8%
189	0.228	347.15	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.5%	17.5%
190	0.216	347.10	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.4%	17.4%
199	0.033	347.59	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.2%	16.2%
200	0.185	347.40	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.2%	17.2%
201	0.176	347.34	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.2%	17.2%
202	0.147	347.36	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.0%	17.0%
203	0.041	347.36	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.3%	16.3%
204	0.584	347.49	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	99.4%	91.2%
205	0.365	347.72	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	85.8%	75.4%
209	0.006	348.07	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	11.7%	3.5%
212	0.002	348.26	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	11.2%	3.2%
219	0.435	347.54	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	33.1%	35.0%
221	0.223	353.09	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	35.1%	20.5%
222	0.205	352.89	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	33.2%	19.2%
223	0.222	352.94	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	35.0%	20.5%
224	0.230	352.95	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	35.9%	21.1%
225	0.095	353.07	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	21.3%	10.5%
226	0.114	353.19	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	23.3%	11.9%
227	0.181	352.93	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	30.6%	17.2%
228	0.224	352.91	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	35.2%	20.6%
229	0.236	352.88	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	36.5%	21.6%
230	0.330	352.96	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	83.6%	72.8%

Buildings Inundated by 20-year Flood							
Object ID	**Maximum Flood Depth (m)**	**Ground Floor Elevation (m)**	**OCP Designation**	**Damage Curve**	**Dwelling Units (#)**	**Structure Damage (%)**	**Contents Damage (%)**
231	0.206	352.91	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	33.3%	19.2%
232	0.054	353.32	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	16.8%	7.2%
233	0.084	353.24	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	20.1%	9.6%
234	0.122	353.20	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	24.2%	12.6%
235	0.122	353.19	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	24.2%	12.6%
236	0.111	353.07	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	23.0%	11.7%
237	0.545	352.29	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	34.9%	37.5%
238	0.088	354.91	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	20.5%	9.9%
240	0.138	355.02	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	26.0%	13.9%
241	0.122	354.88	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	24.2%	12.6%
242	0.050	357.32	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.2%	14.0%
243	0.193	355.89	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.6%	19.6%
244	0.356	354.99	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	35.5%	43.5%
245	0.348	354.54	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	35.3%	43.3%
246	0.350	354.51	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	35.3%	43.3%
247	0.043	354.26	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	15.6%	6.4%
248	0.499	354.14	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	94.1%	85.0%
249	0.029	354.51	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	14.2%	5.3%
250	0.401	369.11	RESIDENTIAL - MEDIUM DENSITY	SINGLE FAMILY DWELLING	1	32.6%	34.2%
253	0.327	362.35	LIGHT INDUSTRIAL / SERVICE COMMERCIAL	LIGHT INDUSTRY	0	19.4%	38.0%
254	0.328	362.64	LIGHT INDUSTRIAL / SERVICE COMMERCIAL	TRIPLEX/QUAD	4	34.7%	42.7%
255	0.050	375.61	PARKS & OPEN SPACE	RETAIL TRADE	0	2.3%	5.9%
256	0.050	377.06	PARKS & OPEN SPACE	SINGLE FAMILY DWELLING	1	19.3%	16.3%
257	0.318	373.97	RESIDENTIAL - HIGH DENSITY	MULTI-DWELLINGS, 50 +	56	34.4%	42.4%
260	0.552	361.08	LIGHT INDUSTRIAL / SERVICE COMMERCIAL	GENERAL SERVICES (GOV)	0	13.4%	111.5%
261	0.083	361.67	LIGHT INDUSTRIAL / SERVICE COMMERCIAL	LIGHT INDUSTRY	0	3.2%	2.5%
262	0.210	347.84	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	33.7%	19.5%
263	0.136	347.38	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	25.7%	13.7%
265	0.560	360.14	PUBLIC & INSTITUTIONAL	INSTITUTIONAL	0	15.5%	100.4%

Buildings Inundated by 20-year Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
Priest's Valley 6							
266	0.081	344.11	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	19.8%	9.4%
267	0.081	344.08	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	19.8%	9.4%
268	0.190	343.95	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	31.6%	18.0%
269	0.190	343.90	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	31.6%	18.0%
270	0.112	344.08	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	23.1%	11.8%
271	0.292	343.91	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	42.6%	26.0%
272	0.183	343.90	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	30.8%	17.4%
273	0.136	343.93	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	25.7%	13.7%
274	0.159	343.95	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	28.2%	15.5%
275	0.042	344.08	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	15.5%	6.3%
276	0.058	344.17	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	17.2%	7.5%
277	0.026	344.23	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	13.9%	5.1%
278	0.086	344.10	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	20.3%	9.7%
279	0.088	344.13	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	20.5%	9.9%
280	0.281	343.92	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	41.5%	25.2%
281	0.194	343.90	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	32.0%	18.3%
282	0.476	343.76	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	92.6%	83.3%
283	0.225	343.91	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	35.3%	20.7%
284	0.203	343.91	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	33.0%	19.0%
286	0.598	343.56	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	100.3%	92.2%
288	0.104	344.12	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	22.2%	11.2%
289	0.915	343.49	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	103.0%	100.0%
290	0.274	343.92	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	40.6%	24.6%
291	0.115	343.88	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	23.4%	12.0%
292	0.110	343.91	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	23.0%	11.7%
293	0.105	344.07	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	22.4%	11.3%
294	0.153	344.00	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	27.6%	15.1%
295	0.187	343.88	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	31.2%	17.7%
296	0.139	343.82	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	26.0%	13.9%
297	0.237	343.82	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	36.6%	21.6%
298	0.141	343.89	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	26.2%	14.1%

Buildings Inundated by 20-year Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
299	0.090	343.92	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	20.8%	10.1%
300	0.111	343.92	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	23.0%	11.7%
301	0.286	343.76	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	42.0%	25.6%
302	0.180	343.85	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	30.5%	17.2%
303	0.209	344.00	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	33.6%	19.4%
304	0.321	343.70	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	83.0%	72.2%
305	0.154	343.89	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	27.6%	15.1%
306	0.192	343.89	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	31.8%	18.1%
307	0.311	343.72	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	82.4%	71.4%
308	0.341	343.71	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	84.2%	73.6%
309	0.356	343.73	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	85.2%	74.7%
310	0.254	343.73	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	38.5%	23.0%
311	0.113	343.92	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	23.2%	11.9%
312	0.238	343.84	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	36.8%	21.8%
313	0.796	343.42	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	109.1%	118.2%
314	0.683	343.37	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	105.4%	112.6%
315	0.819	343.48	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	109.9%	119.3%
316	0.807	343.42	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	109.5%	118.7%
317	0.681	343.43	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	105.4%	112.5%
318	0.578	343.73	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	99.0%	90.7%
319	0.434	343.82	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	90.1%	80.3%
320	0.145	343.94	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	26.7%	14.4%
321	0.692	343.72	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	105.7%	113.0%
322	0.229	343.94	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	35.8%	21.1%
323	0.260	344.07	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	39.1%	23.5%
324	0.167	343.97	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	29.0%	16.1%
325	0.213	344.07	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	34.1%	19.8%
326	0.010	344.10	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	12.1%	3.8%
327	0.033	344.26	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	14.6%	5.6%

Table D6 Buildings Inundated by Design Flood.

Buildings Inundated by Design Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
Vernon							
2	0.314	390.47	COMMUNITY COMMERCIAL	RETAIL TRADE	0	19.2%	58.5%
3	0.084	386.79	PARKS & OPEN SPACE	TEMPORARY LODGING	0	0.8%	3.0%
4	0.042	384.99	COMMUNITY COMMERCIAL	NURSING HOME	121	1.0%	5.2%
9	0.234	348.77	RESIDENTIAL - LOW DENSITY	NURSING HOME	70	5.4%	29.2%
18	0.126	361.12	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.4%	17.0%
19	0.016	360.82	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.1%	12.6%
21	0.115	360.47	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.4%	16.5%
24	0.021	359.84	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.1%	12.8%
25	0.258	359.52	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.8%	22.2%
26	0.399	359.26	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	36.8%	44.8%
27	0.416	359.20	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	37.3%	45.3%
28	0.385	359.27	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	36.4%	44.4%
29	0.161	359.82	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.5%	18.3%
31	0.064	359.98	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.2%	14.5%
32	0.166	360.07	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.5%	18.6%
33	0.168	360.13	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.5%	18.6%
34	0.254	360.29	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.8%	22.0%
36	0.056	360.69	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.2%	14.2%
37	0.228	360.58	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.7%	21.0%
38	0.313	360.27	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	34.2%	42.2%
42	0.049	359.91	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.2%	13.9%
43	0.337	359.28	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	35.0%	43.0%
44	0.184	359.42	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.6%	19.3%
47	0.400	359.27	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	36.8%	44.8%
50	0.146	359.61	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.0%	17.0%
51	0.247	359.49	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.8%	21.7%
52	0.271	359.35	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.9%	22.7%
55	0.184	359.70	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.6%	19.2%
56	0.276	359.41	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.8%	17.8%

Buildings Inundated by Design Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
57	0.353	359.42	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	31.8%	33.1%
58	0.179	359.67	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.2%	17.2%
64	0.030	359.13	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.2%	16.2%
65	0.022	359.14	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.1%	16.1%
81	1.122	359.26	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	34.7%	48.4%
82	0.200	360.06	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.7%	19.9%
84	0.129	360.35	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.4%	17.1%
85	0.091	360.42	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.3%	15.6%
86	0.113	360.60	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.4%	16.5%
87	0.443	360.22	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	38.1%	46.1%
89	0.094	361.86	LIGHT INDUSTRIAL / SERVICE COMMERCIAL	LIGHT INDUSTRY	0	3.5%	2.8%
96	0.330	359.99	PUBLIC & INSTITUTIONAL	INSTITUTIONAL	0	13.2%	83.8%
114	0.167	357.16	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.5%	18.6%
115	0.340	356.96	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	35.0%	43.0%
117	0.097	357.36	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.3%	15.8%
118	0.340	357.24	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	35.0%	43.0%
119	0.272	356.68	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.9%	22.7%
120	0.306	356.70	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	34.0%	42.0%
122	0.340	356.92	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	35.0%	43.0%
123	0.340	356.81	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	35.0%	43.0%
124	0.340	357.27	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	35.0%	43.0%
127	0.143	358.14	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.5%	17.6%
129	0.092	357.52	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.3%	15.6%
131	0.156	357.81	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.5%	18.1%
134	0.298	359.39	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	16.0%	23.7%
135	0.234	359.97	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.8%	21.2%
138	0.692	361.16	LIGHT INDUSTRIAL / SERVICE COMMERCIAL	GENERAL SERVICES (GOV)	0	29.4%	123.1%
139	0.655	361.28	LIGHT INDUSTRIAL / SERVICE COMMERCIAL	GENERAL SERVICES (GOV)	0	28.7%	121.2%
141	0.348	361.43	LIGHT INDUSTRIAL / SERVICE COMMERCIAL	LIGHT INDUSTRY	0	19.7%	39.0%

Buildings Inundated by Design Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
142	0.216	361.87	LIGHT INDUSTRIAL / SERVICE COMMERCIAL	LIGHT INDUSTRY	0	6.7%	6.4%
144	0.365	372.45	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	MEDICAL OFFICE	0	13.2%	78.5%
145	0.050	372.59	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	RETAIL TRADE	0	2.3%	5.9%
146	0.120	372.46	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	RETAIL TRADE	0	4.1%	11.4%
149	0.565	370.46	PARKS & OPEN SPACE	DUPLEX	2	41.7%	49.7%
150	0.382	372.75	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	GENERAL SERVICES (GOV)	0	11.8%	95.4%
151	0.570	371.98	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	TEMPORARY LODGING	0	8.7%	34.0%
152	0.395	372.03	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	TEMPORARY LODGING	0	7.6%	29.4%
153	0.450	372.44	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	TEMPORARY LODGING	0	8.0%	30.8%
155	0.055	369.73	RESIDENTIAL - MEDIUM DENSITY	DUPLEX	2	15.2%	14.1%
163	0.038	369.16	RESIDENTIAL - MEDIUM DENSITY	DUPLEX	2	15.1%	13.5%
165	0.366	369.13	RESIDENTIAL - MEDIUM DENSITY	DUPLEX	2	35.8%	43.8%
172	0.053	367.61	RESIDENTIAL - MEDIUM DENSITY	MULTI-DWELLINGS, 5-9	6	15.2%	14.1%
179	0.134	368.19	RESIDENTIAL - MEDIUM DENSITY	DUPLEX	2	15.4%	17.3%
180	0.009	368.49	RESIDENTIAL - MEDIUM DENSITY	TRIPLEX/QUAD	4	15.0%	12.3%
182	0.053	368.47	RESIDENTIAL - MEDIUM DENSITY	TRIPLEX/QUAD	4	15.2%	14.1%
185	0.154	368.64	RESIDENTIAL - MEDIUM DENSITY	DUPLEX	2	15.5%	18.1%
186	0.053	368.98	RESIDENTIAL - MEDIUM DENSITY	DUPLEX	2	15.2%	14.1%
188	0.752	366.09	RESIDENTIAL - MEDIUM DENSITY	DUPLEX	2	38.4%	41.9%
189	0.140	369.08	RESIDENTIAL - MEDIUM DENSITY	RETAIL TRADE	0	4.7%	13.0%
190	0.207	370.38	RESIDENTIAL - MEDIUM DENSITY	SINGLE FAMILY DWELLING	1	20.4%	17.4%
191	0.441	369.81	RESIDENTIAL - MEDIUM DENSITY	SINGLE FAMILY DWELLING	1	33.2%	35.1%
192	0.460	369.57	RESIDENTIAL - MEDIUM DENSITY	SINGLE FAMILY DWELLING	1	33.5%	35.6%
195	0.326	369.58	RESIDENTIAL - MEDIUM DENSITY	SINGLE FAMILY DWELLING	1	31.3%	32.5%
196	0.041	369.40	RESIDENTIAL - MEDIUM DENSITY	SINGLE FAMILY DWELLING	1	19.3%	16.3%

Buildings Inundated by Design Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
197	0.050	370.55	RESIDENTIAL - HIGH DENSITY	NURSING HOME	75	1.1%	6.2%
198	0.100	385.31	PARKS & OPEN SPACE	RETAIL TRADE	0	3.6%	9.8%
201	0.639	385.83	RESIDENTIAL - MEDIUM DENSITY	SINGLE FAMILY DWELLING	1	38.3%	41.4%
205	0.494	387.79	RESIDENTIAL - MEDIUM DENSITY	DUPLEX	2	39.6%	47.6%
206	1.243	387.69	PARKS & OPEN SPACE	TEMPORARY LODGING	0	23.2%	69.4%
208	0.230	387.90	PARKS & OPEN SPACE	TEMPORARY LODGING	0	2.3%	8.3%
209	0.650	377.53	PARKS & OPEN SPACE	RETAIL TRADE	0	22.3%	99.8%
210	0.335	344.45	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	31.5%	32.7%
211	0.145	344.08	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	TRIPLEX/QUAD	4	15.5%	17.7%
212	0.324	343.82	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	31.3%	32.4%
214	0.415	343.87	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	32.8%	34.5%
215	0.708	343.45	PARKS & OPEN SPACE	SINGLE FAMILY DWELLING	1	39.0%	42.3%
216	0.684	343.52	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	38.7%	42.0%
219	0.325	344.10	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	31.3%	32.5%
222	0.393	343.84	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	32.4%	34.0%
223	0.604	343.64	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	35.9%	38.9%
226	0.321	343.81	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	31.3%	32.4%
227	0.464	343.71	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	33.6%	35.7%
228	0.411	343.89	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	32.7%	34.4%
229	0.210	344.04	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	20.4%	17.4%

Buildings Inundated by Design Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
230	0.671	343.69	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	38.6%	41.8%
231	0.697	343.52	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	38.9%	42.1%
234	0.669	343.54	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	38.6%	41.8%
235	0.600	343.66	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	35.8%	38.8%
239	0.723	343.61	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	39.1%	42.5%
240	0.942	342.97	PARKS & OPEN SPACE	SINGLE FAMILY DWELLING	1	59.4%	53.4%
242	1.004	343.08	PARKS & OPEN SPACE	SINGLE FAMILY DWELLING	1	60.5%	54.2%
247	0.600	343.85	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	35.8%	38.8%
250	0.508	343.62	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	34.3%	36.7%
252	0.521	343.81	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	34.6%	37.0%
253	0.776	343.62	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	39.6%	43.2%
257	0.183	344.54	PARKS & OPEN SPACE	SINGLE FAMILY DWELLING	1	20.2%	17.2%
258	0.504	343.84	PARKS & OPEN SPACE	SINGLE FAMILY DWELLING	1	34.3%	36.6%
259	0.301	344.03	PARKS & OPEN SPACE	SINGLE FAMILY DWELLING	1	21.0%	18.0%
260	0.436	343.98	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	33.1%	35.0%
261	0.054	344.33	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	19.4%	16.4%
263	0.077	344.38	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	19.5%	16.5%
265	0.113	344.36	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	19.7%	16.7%
266	0.041	344.11	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.1%	13.6%
267	0.055	345.06	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.2%	14.2%

Buildings Inundated by Design Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
268	0.583	343.75	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	35.6%	38.4%
269	0.531	343.75	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	40.7%	48.7%
272	0.120	344.17	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.4%	16.7%
273	0.146	344.05	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.5%	17.7%
274	0.194	343.97	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.6%	19.6%
275	0.239	343.84	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.8%	21.4%
314	0.367	347.35	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	32.0%	33.4%
318	0.250	347.47	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	38.0%	22.7%
319	0.023	347.80	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	13.5%	4.8%
320	0.245	347.59	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.6%	17.6%
321	0.198	347.38	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	32.4%	18.6%
323	0.198	347.64	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	32.5%	18.6%
324	0.050	347.61	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	16.4%	6.9%
326	0.106	347.52	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	22.5%	11.4%
327	0.102	347.62	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	22.0%	11.0%
334	0.070	347.94	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	18.6%	8.5%
341	0.207	347.96	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	33.4%	19.3%
342	0.184	347.74	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	30.9%	17.5%
343	0.113	347.81	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	23.2%	11.9%
349	0.174	347.81	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	29.9%	16.7%
352	0.429	347.62	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	89.7%	80.0%
353	0.737	347.26	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	107.2%	115.3%
354	0.851	347.17	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	110.9%	120.9%
355	0.512	347.79	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	94.9%	85.9%
357	0.595	347.53	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	100.1%	92.0%
360	0.853	347.41	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	111.0%	121.0%
361	0.113	347.71	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	23.2%	11.9%
362	0.269	347.49	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	40.1%	24.2%
363	0.097	347.82	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	21.5%	10.6%
365	0.158	347.67	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	28.1%	15.4%
366	0.295	347.57	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	43.0%	26.3%
367	0.318	347.44	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	82.8%	71.9%

Buildings Inundated by Design Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
368	0.392	347.44	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	87.4%	77.3%
373	0.397	347.47	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	87.7%	77.6%
375	0.352	347.57	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	85.0%	74.4%
378	0.313	347.63	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	82.5%	71.6%
380	0.498	347.56	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	94.1%	85.0%
382	0.365	347.35	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	85.8%	75.3%
384	0.396	347.46	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	87.7%	77.6%
387	0.498	347.88	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	94.1%	85.0%
391	0.251	347.42	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	38.2%	22.8%
392	0.394	347.34	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	87.5%	77.4%
395	0.276	347.39	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	40.9%	24.8%
396	0.680	346.88	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	105.3%	112.4%
397	0.607	347.04	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	100.8%	92.8%
398	0.649	346.92	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	104.3%	110.9%
401	0.636	347.22	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	103.9%	110.3%
402	0.630	347.60	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	103.7%	110.0%
403	0.631	347.04	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	103.7%	110.1%
406	0.546	347.22	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	97.0%	88.4%
411	0.351	347.27	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	84.9%	74.4%
412	0.430	347.25	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	89.8%	80.0%
413	0.023	347.04	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.2%	16.2%
414	0.110	347.24	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.7%	16.7%
416	0.080	347.05	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.5%	16.5%
419	0.151	346.92	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.0%	17.0%
422	0.237	347.08	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.6%	17.6%
423	0.248	346.98	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.6%	17.6%
427	0.279	346.66	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.8%	17.8%
435	0.116	346.88	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.8%	16.8%
437	0.108	346.49	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.7%	16.7%
443	0.263	346.17	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.7%	17.7%
445	0.249	346.16	RESIDENTIAL - LOW DENSITY	CHURCH	0	8.2%	63.1%
447	0.304	345.85	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	21.0%	18.0%

Buildings Inundated by Design Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
448	0.167	346.01	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.1%	17.1%
449	0.237	346.01	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.6%	17.6%
458	0.202	347.25	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.3%	17.3%
459	0.206	347.12	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.4%	17.4%
460	0.169	347.21	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.1%	17.1%
461	0.136	347.19	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.9%	16.9%
462	0.220	347.00	RESIDENTIAL - MEDIUM DENSITY	SINGLE FAMILY DWELLING	1	20.4%	17.4%
470	0.047	347.40	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.3%	16.3%
471	0.167	347.29	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.1%	17.1%
472	0.273	347.15	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.8%	17.8%
473	0.258	347.10	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.7%	17.7%
482	0.097	347.59	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.6%	16.6%
483	0.234	347.40	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.5%	17.5%
484	0.235	347.34	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.5%	17.5%
485	0.198	347.36	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.3%	17.3%
486	0.099	347.36	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.6%	16.6%
488	0.635	347.49	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	103.8%	110.3%
491	0.429	347.72	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	89.7%	79.9%
495	0.084	348.07	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	20.1%	9.6%
499	0.082	348.26	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	19.9%	9.5%
510	0.487	347.54	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	34.0%	36.2%
512	0.134	353.41	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	25.5%	13.5%
513	0.387	353.09	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	87.1%	77.0%
514	0.372	352.89	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	86.2%	75.8%
515	0.392	352.94	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	87.4%	77.3%
516	0.404	352.95	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	88.2%	78.1%
517	0.273	353.07	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	40.5%	24.5%
518	0.281	353.19	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	41.4%	25.1%
519	0.349	352.93	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	84.7%	74.2%
521	0.397	352.91	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	87.7%	77.6%
522	0.413	352.88	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	88.8%	78.8%
523	0.512	352.96	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	94.9%	86.0%

Buildings Inundated by Design Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
524	0.392	352.91	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	87.4%	77.3%
525	0.229	353.32	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	35.8%	21.0%
526	0.262	353.24	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	39.3%	23.6%
527	0.303	353.20	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	43.8%	26.9%
529	0.306	353.19	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	82.1%	71.1%
530	0.298	353.07	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	43.2%	26.5%
531	0.172	353.24	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	29.6%	16.5%
532	0.735	352.29	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	39.2%	42.6%
533	0.300	354.91	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	43.5%	26.6%
534	0.206	355.21	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	33.3%	19.2%
535	0.349	355.02	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	84.8%	74.2%
536	0.311	354.88	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	82.4%	71.5%
538	0.678	357.32	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	37.7%	41.5%
539	0.039	358.44	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.3%	16.3%
546	0.040	358.68	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.3%	16.3%
547	0.040	358.50	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.3%	16.3%
548	0.099	358.36	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.6%	16.6%
549	0.041	358.21	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.3%	16.3%
550	0.279	357.56	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.8%	17.8%
551	0.340	357.05	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	35.0%	43.0%
555	0.074	356.85	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.2%	14.9%
556	0.060	356.79	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.2%	14.3%
557	0.402	355.89	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	36.9%	44.9%
558	0.573	354.99	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	41.9%	49.9%
559	0.559	354.54	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	41.5%	49.5%
561	0.574	354.51	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	42.0%	50.0%
566	0.010	354.81	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.1%	16.1%
567	0.058	355.25	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	19.4%	16.4%
568	0.213	355.31	RESIDENTIAL - LOW DENSITY	SINGLE FAMILY DWELLING	1	20.4%	17.4%
588	0.147	353.32	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	26.9%	14.6%
589	0.122	353.34	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	24.2%	12.6%
597	0.126	354.25	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	24.7%	12.9%

Buildings Inundated by Design Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
599	0.251	354.23	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	38.1%	22.7%
600	0.301	354.32	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	43.5%	26.7%
602	0.279	354.26	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	41.2%	24.9%
604	0.733	354.14	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	107.0%	115.1%
605	0.289	354.51	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	42.3%	25.8%
606	0.050	354.48	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	16.5%	7.0%
614	0.025	355.50	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	13.7%	5.0%
617	0.518	369.11	RESIDENTIAL - MEDIUM DENSITY	SINGLE FAMILY DWELLING	1	34.5%	36.9%
619	0.090	366.07	RESIDENTIAL - MEDIUM DENSITY	MULTI-DWELLINGS, 5-9	6	15.3%	15.6%
620	0.070	366.10	RESIDENTIAL - MEDIUM DENSITY	MULTI-DWELLINGS, 5-9	6	15.2%	14.7%
626	0.019	367.06	RESIDENTIAL - MEDIUM DENSITY	DUPLEX	2	15.1%	12.8%
630	0.839	362.35	LIGHT INDUSTRIAL / SERVICE COMMERCIAL	LIGHT INDUSTRY	0	28.3%	80.0%
633	0.794	362.64	LIGHT INDUSTRIAL / SERVICE COMMERCIAL	TRIPLEX/QUAD	4	38.8%	42.2%
637	0.462	375.61	PARKS & OPEN SPACE	RETAIL TRADE	0	21.6%	66.2%
638	0.221	377.06	PARKS & OPEN SPACE	SINGLE FAMILY DWELLING	1	20.4%	17.4%
639	0.076	377.11	RESIDENTIAL SMALL LOT - SINGLE & TWO FAMILY DWELLING	SINGLE FAMILY DWELLING	1	19.5%	16.5%
641	0.337	374.94	MIXED USE - HIGH DENSITY COMMERCIAL AND RESIDENTIAL	RETAIL TRADE	0	19.5%	59.7%
642	0.780	374.04	RESIDENTIAL - HIGH DENSITY	TEMPORARY LODGING	0	9.6%	46.4%
643	1.050	373.97	RESIDENTIAL - HIGH DENSITY	MULTI-DWELLINGS, 50 +	56	34.4%	47.9%
646	0.344	365.63	RESIDENTIAL - MEDIUM DENSITY	TRIPLEX/QUAD	4	35.2%	43.2%
647	0.209	365.86	RESIDENTIAL - MEDIUM DENSITY	TRIPLEX/QUAD	4	15.7%	20.2%
650	0.420	366.06	RESIDENTIAL - MEDIUM DENSITY	MULTI-DWELLINGS, 20 - 49	27	37.4%	45.4%
654	0.251	367.16	RESIDENTIAL - MEDIUM DENSITY	SINGLE FAMILY DWELLING	1	20.6%	17.6%
656	0.681	373.96	MIXED USE - HIGH DENSITY COMMERCIAL AND RESIDENTIAL	RETAIL TRADE	0	22.5%	101.3%
658	0.853	361.08	LIGHT INDUSTRIAL / SERVICE COMMERCIAL	GENERAL SERVICES (GOV)	0	32.0%	131.0%

Buildings Inundated by Design Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
660	0.318	361.67	LIGHT INDUSTRIAL / SERVICE COMMERCIAL	LIGHT INDUSTRY	0	19.2%	37.6%
666	0.071	358.18	RESIDENTIAL - LOW DENSITY	TRIPLEX/QUAD	4	15.2%	14.8%
670	0.267	347.84	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	39.9%	24.0%
672	0.203	347.38	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	32.9%	19.0%
677	0.572	343.81	MIXED USE - MEDIUM DENSITY COMMERCIAL AND RESIDENTIAL	SINGLE FAMILY DWELLING	1	35.4%	38.1%
678	0.760	360.14	PUBLIC & INSTITUTIONAL	INSTITUTIONAL	0	28.0%	118.4%
Priest's Valley 6							
685	0.04071	344.63	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	15%	6%
687	0.022095	344.59	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	13%	5%
688	0.345367	344.11	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	85%	74%
689	0.196899	344.21	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	32%	19%
690	0.345398	344.08	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	85%	74%
691	0.454742	343.95	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	91%	82%
692	0.454742	343.90	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	91%	82%
693	0.37735	344.08	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	87%	76%
694	0.556305	343.91	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	98%	89%
695	0.44696	343.90	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	91%	81%
696	0.392242	343.93	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	87%	77%
697	0.423462	343.95	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	89%	80%
698	0.306335	344.08	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	82%	71%
699	0.321899	344.17	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	83%	72%
700	0.29071	344.23	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	42%	26%
701	0.056305	344.40	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	17%	7%
705	0.071838	344.32	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	19%	9%
706	0.126373	344.30	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	25%	13%
707	0.001404	344.38	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	11%	3%
711	0.350342	344.10	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	85%	74%
712	0.352997	344.13	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	85%	74%
713	0.546967	343.92	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	97%	88%
714	0.145477	344.33	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	27%	14%

Buildings Inundated by Design Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
715	0.209351	344.29	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	34%	19%
717	0.458618	343.90	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	92%	82%
718	0.740173	343.76	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	107%	115%
719	0.489624	343.91	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	94%	84%
720	0.478271	343.91	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	93%	84%
722	0.875824	343.56	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	112%	122%
725	0.375977	344.12	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	86%	76%
726	1.19519	343.49	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	108%	106%
727	0.547211	343.92	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	97%	88%
728	0.389954	343.88	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	87%	77%
729	0.388916	343.91	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	87%	77%
730	0.388	344.07	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	87%	77%
731	0.441467	344.00	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	91%	81%
732	0.479248	343.88	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	93%	84%
733	0.408203	343.82	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	88%	78%
734	0.508759	343.82	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	95%	86%
735	0.414551	343.89	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	89%	79%
736	0.36676	343.92	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	86%	75%
737	0.389465	343.92	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	87%	77%
738	0.57428	343.76	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	99%	90%
739	0.465698	343.85	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	92%	83%
740	0.502075	344.00	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	94%	85%
741	0.612152	343.70	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	103%	109%
742	0.447266	343.89	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	91%	81%
743	0.485779	343.89	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	93%	84%
744	0.603607	343.72	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	101%	93%
745	0.63443	343.71	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	104%	110%
746	0.649597	343.73	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	104%	111%
747	0.547699	343.73	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	97%	89%
748	0.407074	343.92	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	88%	78%
749	0.532166	343.84	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	96%	87%
750	1.082611	343.42	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	106%	103%

Buildings Inundated by Design Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
751	0.966553	343.37	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	104%	101%
752	1.111145	343.48	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	106%	104%
753	1.101837	343.42	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	106%	104%
754	0.976685	343.43	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	104%	101%
755	0.874268	343.73	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	112%	122%
756	0.732849	343.82	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	107%	115%
757	0.443787	343.94	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	91%	81%
758	0.990479	343.72	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	104%	101%
759	0.523712	343.94	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	96%	87%
760	0.202576	344.09	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	33%	19%
761	0.288391	344.13	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	42%	26%
762	0.40567	344.12	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	88%	78%
763	0.555115	344.07	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	98%	89%
764	0.461365	343.97	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	92%	82%
765	0.514984	343.93	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	95%	86%
766	0.492615	344.07	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	94%	85%
767	0.312988	344.10	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	83%	72%
768	0.305298	344.01	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	82%	71%
769	0.297546	344.05	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	43%	26%
770	0.165405	344.13	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	29%	16%
771	0.220947	344.18	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	35%	20%
772	0.205383	344.10	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	33%	19%
773	0.175354	344.15	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	30%	17%
774	0.161224	344.15	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	28%	16%
775	0.107056	344.20	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	23%	11%
778	0.16864	344.12	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	29%	16%
779	0.296356	344.17	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	43%	26%
780	0.062714	344.33	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	18%	8%
781	0.106445	344.30	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	23%	11%
785	0.187927	344.19	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	31%	18%
786	0.031677	344.33	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	14%	5%
789	0.109741	344.29	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	23%	12%

Buildings Inundated by Design Flood							
Object ID	Maximum Flood Depth (m)	Ground Floor Elevation (m)	OCP Designation	Damage Curve	Dwelling Units (#)	Structure Damage (%)	Contents Damage (%)
790	0.141022	344.31	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	26%	14%
793	0.207703	344.17	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	33%	19%
794	0.207672	344.20	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	33%	19%
795	0.04425	344.29	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	16%	6%
796	0.309326	344.08	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	82%	71%
797	0.246857	344.17	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	38%	22%
798	0.152832	344.26	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	28%	15%
799	0.043427	344.21	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	16%	6%
800	0.098206	344.22	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	22%	11%
802	0.002106	344.37	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	11%	3%
803	0.056152	344.44	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	17%	7%
804	0.125702	344.42	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	25%	13%
805	0.187958	344.31	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	31%	18%
806	0.047302	344.44	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	16%	7%
807	0.19574	344.14	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	32%	18%
808	0.35199	344.26	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	85%	74%
813	0.19574	344.24	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	32%	18%
814	0.203552	344.29	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	33%	19%
818	0.054047	344.36	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	17%	7%
821	0.164459	344.22	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	29%	16%
822	0.148865	344.21	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	27%	15%
823	0.32074	344.34	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	83%	72%
825	0.086304	344.25	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	20%	10%
827	0.148865	344.32	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	27%	15%
828	0.25824	344.14	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	39%	23%
829	0.203552	344.08	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	33%	19%
830	0.203552	344.11	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	33%	19%
831	0.016052	344.28	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	13%	4%
832	0.054077	344.41	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	17%	7%
833	0.210297	344.21	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	34%	20%
834	0.055115	344.35	RESIDENTIAL - LOW DENSITY	MANUFACTURED HOUSING	1	17%	7%

APPENDIX E

DETAILED SUMMARY OF UNDERSIZED CROSSINGS

Crossing ID	Station	Reach	Type	Location	Undersized	Overtopping	Causing Overbank Flooding Upstream
57	2288	Lower BX Creek	CULV	34 st north of 43 Ave	Yes	No	No
59	2159	Lower BX Creek	BRIDGE	32 St south of 43 Ave	Yes	Yes, partial	Yes, minor.
61	2138	Lower BX Creek	CULV	Below Blue Stream Motel, 32 St. Hwy 97	Yes	No	Yes, impacts buildings.
63.25	1951	Lower BX Creek	CULV	Below Vernon Lodge	Yes	No	No
63.6	1865	Lower BX Creek	CULV	Under Vernon Lodge parking	Yes	No	No
71	1322	Lower BX Creek	CULV	35 Ave / 34 St	Yes	Yes	Yes, impacts buildings.
73	1248	Lower BX Creek	CULV	34 Ave btwn 34 St & 35 St	Yes	No	Yes, impacts buildings.
75	1129	Lower BX Creek	BRIDGE	33rd Ave off of 35th Street	Yes	No	Yes
77	1045	Lower BX Creek	CULV	32 Ave btwn 34 St & 35 St	Yes	Yes	Yes
81	830	Lower BX Creek	CULV	30 Ave near 35 St - Behind Safeway	Yes	No	Yes
83	739	Lower BX Creek	CULV	Lane south 30 Ave west 35 St	Yes	No	Yes, impacts buildings and laneway.
84.2	693	Lower BX Creek	CULV	Along 35 St	Yes	Yes	Yes, minor.
84.6	585	Lower BX Creek	BRIDGE	N of 27 St, West of 35 St	Yes	Yes	Yes.
85	497	Lower BX Creek	CULV	27 Ave	Yes	No	Yes, impacts building and property.
88.199997	355	Lower BX Creek	CULV	25 Ave (South side)	Yes	No	No
90	228	Lower BX Creek	CULV	24 Ave East 35 St	Yes	Yes	Yes
92	140	Lower BX Creek	CULV	36 St South 24 Ave	Yes	Yes	Yes, impacts bulidings, property and 36 St.
95	4617	Upper Vernon Creek	CULV	Westkal Rd. Kalamalka Lake Outlet	Yes	No	No
96.400002	4578	Upper Vernon Creek	BRIDGE	Cafe, N of Westkal Rd	Yes	No	No
100	4273	Upper Vernon Creek	CULV	College Way, DSCF3828	Yes	No	Yes.
102	4158	Upper Vernon Creek	BRIDGE	Campground, Kalamalka Lk Rd.	Yes	Yes, At Crest	Yes, impacts buildings, property and parking.
103.1	4094	Upper Vernon Creek	BRIDGE	Campground, Kalamalka Lk Rd.	Yes	Yes	Yes, impacts buildings, property and parking.
104	3836	Upper Vernon Creek	CULV	Kalamalka Lake Rd north of lake	Yes	No	Yes, impacts buildings and property.
108	3423	Upper Vernon Creek	BRIDGE	Adjacent Browne Rd. Housing Subdivision	Yes	No	No
109.1	3384	Upper Vernon Creek	BRIDGE	Adjacent Browne Rd. Housing subdivision	Yes	No	No
110	3316	Upper Vernon Creek	BRIDGE	Adjacent Browne Rd. Cul-de-sack	Yes	Yes	Yes, impacts property.
112	3196	Upper Vernon Creek	CULV	Browne Rd	Yes	Yes	Yes, impacts buildings and property.
114	2994	Upper Vernon Creek	BRIDGE	Vernon Golf and Country Club	Yes	No	Yes, impacts buildings and property.
116	2762	Upper Vernon Creek	BRIDGE	Vernon Golf and Country Club	Yes	Yes	Yes, impacts golf course and building.
122	2280	Upper Vernon Creek	BRIDGE	Adjacent Polson Dr. on Vernon Golf Club	Yes	No	Yes, impacts golf course.
124	2205	Upper Vernon Creek	BRIDGE	South of Golf Course, Rail bridge	Yes	No	Yes
127	1466	Upper Vernon Creek	BRIDGE	Polson Park	Yes	No	Yes, impacts Polson Park.
128.1	1354	Upper Vernon Creek	BRIDGE	Polson Park	Yes	No	Yes, impacts Polson Park.
129.3	1022	Upper Vernon Creek	BRIDGE	Polson Park	Yes	No	Yes, impacts Polson Park.
130	990	Upper Vernon Creek	BRIDGE	Polson Park, east of 32nd St	Yes	Yes	Yes, impacts Polson Park.
132	921	Upper Vernon Creek	BRIDGE	Upstream of Hwy 97 Crossing, Polson Park	Yes	Yes	Yes, impacts Polson Park.
134	894	Upper Vernon Creek	CULV	32 St south of 25 Ave	Yes	No	Yes, impacts Polson Park.
136	711	Upper Vernon Creek	BRIDGE	34 St south of 25 Ave	Yes	No	Yes, impacts buildings, parking lots, 25 Ave.
138	605	Upper Vernon Creek	CULV	24 Ave btwn 34 St & 34A St	Yes	No	Yes, impacts buildings, property , 34a St. and 25 Ave.
145	5979	Lower Vernon Creek	CULV	39 St, South of 24th Ave	Yes	No	Yes, impacts buildings and 24 Ave.
148	5477	Lower Vernon Creek	BRIDGE	Behind storage yard at 24th St	Yes	Yes	Yes
150	5187	Lower Vernon Creek	CULV	43 St	Yes	No	Yes, impacts industrial buildings, parking areas, 43 St, large residential area
155.3	4849	Lower Vernon Creek	BRIDGE	Southest of 25 Ave	Yes	Yes	No
156	4669	Lower Vernon Creek	BRIDGE	West of 25th Ave	Yes	No	Yes, impacts buildings, parking areas, 44 St
169	2D Model	Lower Vernon Creek	CULV	Okanagan Landing Rd	Yes	No	Yes, impacts large residential areas, Okanagan Landing Rd.
175	2D Model	Lower Vernon Creek	CULV	Lakeshore Rd	Yes	No	Yes, impacts large residential areas, Lakeshore Rd.