FLOOD HAZARD RISK ASSESSMENT

MIDDLE VERNON CREEK

May 30, 2023

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EXECUTIVE SUMMARY

The District of Lake Country (District) proactively works to identify and address flood hazards throughout the community. As part of this ongoing flood mitigation effort, the District has identified a need to better understand flood risks along the Middle Vernon Creek (MVC) corridor within the District boundary.

The District engaged Urban Systems to conduct a Flood Hazard Risk Assessment (FHRA) of MVC through the Community Emergency Preparedness Fund (CEPF) program.

The CEPF program is a suite of funding streams intended to enhance the resiliency of local governments and communities in responding to emergencies. Funding is provided by the Province of BC and is administered by the Union of BC Municipalities (UBCM).

The scope of this study includes the segment of MVC within the District boundary starting at Beaver Lake Road and extending to Wood Lake. MVC travels through highly developed areas of the community with parks, schools, residential, agricultural, and other properties directly adjacent to the channel. The District's road network also crosses the creek at several critical locations.

Communications and Engagement

Throughout the summer of 2022, the District undertook a series of engagement opportunities to collect input from the local community. Community members were asked to share their flood stories, experiences, and photos to help identify current and future flood risks in the area.

Establish Climactic Conditions

Design flows for both existing and future conditions based on available data and projected climate were developed. For the purposes of the current study, the 2-year peak rainfall runoff from the 5 identified catchments was added to the each of the 20-year and 200-year Ellison Lake outflow scenarios. The 2-year runoff is considered to approximate the average runoff rate and is therefore deemed appropriate to use in conjunction with the 20-year and 200-year freshet flow rate driven by Ellison Lake levels.

Develop Hydraulic Model

A computer model of the river channel was constructed using the hydraulic modelling program GeoHEC-RAS. This program was selected because it uses the industry standard HEC-RAS river modelling engine developed by the US Army Corps of Engineers. Model development began with a field survey of river cross-sections, which was completed as part of this project. The field survey provided accurate main channel and bridge/culvert cross-sections to ensure a reliable model.

Complete Flood Risk Assessment

Identify flood risks, considering likelihood of a failure and the severity of its potential impacts. Determining the level of risk corresponding to flood hazards helps focus improvement efforts on high priority infrastructure where investments pay the greatest returns in terms of public safety property protection.

The process of risk assessment involves identifying flood hazards and estimating the consequences for each hazard and combining the results to obtain an overall estimate of the expected risk. The following figure outlines the process utilized for the MVC flood risk assessment.

Flood Risk Assessment Process

Flood Hazards

- Develop an Understanding of the Flood Hazards in the Study Area
  - Insufficient hydraulic capacity
  - Conveyance system blocked by debris
  - Debris blockage within channel
  - Flood wave due to crossing failure or debris blockage failure
  - Watershed Flood Risks Outside District Boundary

Impact Receptors

- Consider the Flood Hazards in Terms of the Following Impact Receptors
  - People
  - Infrastructure
  - Economy
  - Culture
  - Environment

Consequence Assessment

- Complete Consequence Assessment
  - Determine the impact receptors at risk to flood hazards
  - Determine how vulnerable each impact receptor is to the flood hazards
  - Assign a consequence score

Likelihood Assessment

- Consider the Likelihood of a Flood Hazard Occuring to an Impact Receptor
  - Review return period of hazard
  - Define likelihood of flood risks that are difficult to predict (ie. debris blockage)

Risk Assessment

- Complete Risk Assessment
  - Combine the results of the consequnce and likelihood assessments
  - Determine the overall flood hazard risk

Flood Risk Assessment Results

The FHRA identifies the types of flood hazards that exist in the District and describes the vulnerabilities (or elements at risk) present. The result of the risk assessment based on the identified impact receptor categories is summarized in the following table.

Category	Overall Flood Hazard Risk
People	Low
Infrastructure	Moderate to High
Economy	Low
Culture	Low
Environment	Low

Flood Risk to Infrastructure

An important step for the District to mitigate flood risk through the corridor is work towards upgrading all locations that MVC crosses with District owned road and utility infrastructure. The District has made good progress on this initiative over the past years, and should continue with this effort, as it directly reduces or eliminates risks associated with insufficient hydraulic capacity, conveyance structures blocked by debris and the potential flood wave and overland flow that can come as a result of poorly sized and configured road crossings.

The older style 2 m x 3 m pipe arch culverts are undersized to convey both the 200 year and 20 year design flow. The following crossings are considered high flood risks and should be considered a high priority for replacement include, Beaver Lake Road, Bottom Wood Lake Road (near Mayrus), and Woodsdale Road.

Long Term Flood Risks

In addition to the more tangible infrastructure upgrades to be considered along MVC, the District should also continue to collaborate with various regulatory agencies and stakeholders as it relates to long term planning for the MVC watershed. The FHRA indicates that there are several identified and ongoing flood risks associated with MVC, which are summarized below.

Overall Debris in Channel – a healthy natural creek system requires large woody debris and sediment to move through the system. In MVC case, they watershed is highly modified and urbanized both upstream and within the District boundary. This is leading to significant debris jams that are not representative of a healthy system and pose a significant flood risk to the community. Managing debris in MVC is not the responsibility of the District as it is largely regulated by MoF and DFO, however, the District often becomes involved when road crossings are blocked or flooding of adjacent properties occurs and remedial action is required. The District has successfully worked with regulatory agencies and qualified professionals to identify and address some of the more significant debris jams in recent years, and when appropriate should advocate for mitigating against debris jam flood risk.

Upstream Inputs to MVC – the District should continue to play a role in understanding the long term plans for the following upstream watershed inputs. Each of these significantly impacts flood risk through the MVC corridor.

- Watershed dam / reservoir long term operation plan and dam breach risk
- Upper Vernon Creek Flow Path to Ellison Lake
- Ellison Lake Water Level
- MVC Upstream of District in Duck Lake 7

Next Steps for Flood Risk Mitigation

Prioritize and implement ***structural flood mitigation initiatives.*** This includes replacing higher risk road crossing structures and flood proofing at risk infrastructure such as sanitary manholes in infiltration areas or erosion protection of at-risk infrastructure.

Continual Improvement **on non-structural flood mitigation initiatives**. This includes the ongoing effort related to land use planning (OCP, Zoning, Development Permits), flood prediction, monitoring and maintenance, emergency response planning, flood risk education, recovery pre-planning, flood flow reduction. These includes coordination efforts on debris jam management and long term watershed planning initiatives.

1.0 INTRODUCTION

The District of Lake Country (District) proactively works to identify and address flood hazards throughout the community. As part of this ongoing flood mitigation effort, the District has identified a need to better understand flood risks along the Middle Vernon Creek (MVC) corridor within the District boundary.

The District engaged Urban Systems to conduct a Flood Hazard Risk Assessment (FHRA) of MVC through the Community Emergency Preparedness Fund (CEPF) program.

The CEPF program is a suite of funding streams intended to enhance the resiliency of local governments and communities in responding to emergencies. Funding is provided by the Province of BC and is administered by the Union of BC Municipalities (UBCM).

1.1 PROJECT OBJECTIVES

Specific issues that are addressed in the development of this FHRA study include:

- The need to better understand existing flood hazards and risks to existing development and property;
- The need for an assessment of future development plans and land use intensification near MVC to reduce flood hazards and avoid creating new hazards and/or issues;
- The need to understand how non-District owned and maintained assets may affect flooding potentials in the area (i.e. upstream reservoirs, upstream FN, landuse);
- Identify non-structural mitigation plans, such as a bylaw aimed at flood hazard protection through municipal regulations.

1.2 STUDY AREA

The District is situated in the Central Okanagan Region of British Columbia, with Okanagan Lake along the western boundary, Wood Lake within the boundary, and the southern part of Kalamalka Lake within the boundary. MVC connects Ellison Lake to Wood Lake and includes several tributaries within that reach.

The scope of this study includes the segment of MVC within the District boundary starting at Beaver Lake Road and extending to Wood Lake. MVC travels through highly developed areas of the community with parks, schools, residential, agricultural, and other properties directly adjacent to the channel. The District's road network also crosses the creek at several critical locations.

The section of MVC upstream of the District boundary (south of Beaver Lake Road to Ellison Lake) falls within the Okanagan Indian Band lands.

1.3 SCOPE OF WORK – FLOOD HAZARD RISK ASESSMENT

The purpose of this project is to complete a FHRA on MVC within the District's boundary. The study will identify hazards along the MVC corridor. We will base this plan on demonstrated performance of best practices, with the aim of learning and adapting to the region.

The approach successfully used in other FHRA studies was applied to this study and includes the following steps:

- Review background documents to establish existing conditions, highlight existing challenges, and identify findings that can be modified or applied to this study.
- Establish climactic conditions throughout the study area, focusing on existing conditions as recorded by weather stations, and projected future conditions under climate change. Establishing climactic conditions helps validify the assumptions made to determine the design flows.
- Develop design flows for both existing and future conditions based on available data and projected climate.
- Identify flood hazards, locations and infrastructure that may be at risk during a flood event.
- Identify flood risks, considering likelihood of a failure and the severity of its potential impacts. Determining the level of risk corresponding to flood hazards helps focus improvement efforts on high priority infrastructure where investments pay the greatest returns in terms of public safety property protection.

1.4 APPLICABLE GUIDELINES AND REGULATIONS

The following guidelines and regulations were utilized for the MVC FHRA.

- Legislated Flood Assessments in a Changing Climate in BC Professional practice Guidelines (EGBC, 2018)
- Flood Hazard Area Land Use Management Guidelines, Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FNRORD), Amended 2018 (MOF, 2018)
- Flood Mapping in BC, EGBC Professional Practice Guidelines, Engineers and Geoscientists British Columbia (EGBC, 2017)

Figure 1.1: Applicable Guidelines and Regulations

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2.0 BACKGROUND

2.1 FLOOD HISTORY OF MIDDLE VERNON CREEK

Lake Country has been hit hard by extreme weather events in recent years. In May 2017 freshet, a rainfall event during snow melt caused significant flooding along the MVC corridor. The increased runoff caused a great deal of damage when streamflow overtopped banks and flooded property, overwhelmed culverts and bridges, deposited significant quantities of woody debris and sediment in the channel, and in other locations caused avulsion of channel banks.

In May 2017, property owners along MVC dug trenches and built sandbag barriers to deal with the high flows. Residents were also placed on evacuation alerts along Bottom Wood Lake Road, Deldor Road, Seymor Road, Reimche Road, and Woodsdale Road. Evacuation orders were given for properties near Wood Lake.

The higher-than-average snowpacks from 2017 / 2018 winter also resulted in significant runoff flows, but limited rainfall during the 2018 freshet and good reservoir level management allowed the District to avoid significant flooding for a second consecutive year. MVC remains extremely vulnerable and susceptible to erosion, debris blockage and flooding onto private and public property. This will be a continual risk that requires assessment, planning, mitigation, and response.

High density development is concentrated along some reaches of MVC. As a result, significant infrastructure is built on the floodplain. Much of this development has encroached on the natural boundaries of MVC and significant modifications have been made along this corridor. In many areas, MVC has very little physical space for natural avulsion and deposition processes to occur without causing damage to property and infrastructure. This is illustrated on the Flood Hazard Maps and is reflected in the Lake Country Official Community Plan (OCP). Land uses in the floodplain include:

- High Density Residential
- Mixed Use Commercial
- Institutional
- Park
- Agricultural
- Valuable Transportation Corridors
- Tourist
- Commercial

Significant flooding in any of these areas could result in negative impacts to many residential property owners, business owners, farmers, and park users, in addition to causing closures to critical transportation corridors. These impacts will have negative consequences on the community.

2.2 PREVIOUS STUDIES

Phase 1 of a Regional Floodplain Management Plan, prepared by Associated Engineering for The Regional District of Central Okanagan, June 2016.

- The scope of this project included a preliminary flood risk screening assessment to assign a preliminary flood risk rating to watercourses within the RDCO. This risk analysis indicated a high risk for MVC and that the risk is unacceptable and that it should be a high priority for further risk assessment in subsequent phases.

Okanagan Hydrologic Models for Long-term Water Planning & Management, prepared by Associated Environmental (AE) for the Okanagan Basin Water Board, February, 2020.

- This report describes the development and first application of Okanagan Hydrologic Modelling Environment (OHME) Version 1 (OHME V1), an open source hydrologic modelling framework for the Okanagan Basin based on the Raven Hydrological Modelling Framework (Raven).

Okanagan Mainstem Floodplain Mapping, prepared by Northwest Hydraulic Consultants for the Okanagan Basin Water Board, March, 2020.

- In 2020, the Okanagan Basin Water Board released its Okanagan Mainstem Floodplain Mapping report, produced floodplain mapping for the Okanagan River and the Okanagan River's mainstem lakes. This included Ellison and Wood Lakes, which bound this project's study area.

Swalwell and Crooked Lakes Dam Breach Inundation Analysis Technical Memorandum was prepared by Urban Systems for the District of Lake Country, June 2018.

- In 2018, DLC completed a Dam Breach Inundation review for Swalwell and Crooked Lakes. The analysis was completed using HEC-RAS v.5.0.3. and the memo summarizes the assumptions, methodology and results of the analysis.

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3.0 RELEVANT LEGISLATION

3.1 FEDERAL LEGISLATION

Fisheries Act

The Fisheries Act provides a framework to manage and control Canada's fisheries, as well as to conserve and protect fish and fish habitat, including pollution prevention. The Act was amended on June 21, 2019, with changes coming into force August 28, 2019.

Projects with the potential to adversely impact fish and/or fish habitat and with a project scope that is not covered under the standards and codes of practice[1] should be reviewed by Fisheries and Oceans Canada (DFO) through the Request for Review process.

This applies to work in or near water bodies that are frequented by fish and any other areas which fish depend on directly or indirectly to carry out their life processes, including spawning grounds, nursery, rearing, food supply and migration areas, including any waterbody that is connected to fish-bearing waters at any time of the year. The review will determine if the project requires an authorization under the Fisheries Act.

DFO will review the proposed works to determine if the project is likely to result in:

- the death of fish by means other than fishing and the harmful alteration, disruption or destruction of fish habitat which are prohibited under subsections 34.4(1) and 35(1) of the Fisheries Act; and
- effects to listed aquatic species at risk, any part of their critical habitat or the residences of their individuals in a manner which is prohibited under sections 32, 33 and subsection 58(1) of the Species at Risk Act.

Works may require an Authorization under Section 35 of the federal Fisheries Act. Authorizations typically require the implementation of a habitat off-setting plan. It is expected that the Fisheries Act Authorization will take 6 to 12 months to receive upon submission to Fisheries and Oceans Canada.

Migratory Birds Convention Act

The majority of migrating birds in Canada are protected under the Migratory Birds Convention Act. The Canadian government has the authority to pass and enforce regulations to protect those species of migratory birds and their nests which are included in the Convention.

[1] A code of practice specifies procedures, practices or standards for avoiding the death of fish or the harmful alteration, disruption or destruction of fish habitat for routine or maintenance work, including beaver dam removal, culvert maintenance, small water intake screens, temporary diversion channels, and temporary stream crossings.

Compliance under this Act can be maintained by conducting land clearing activities outside of the nesting season for birds. If clearing must be conducted within this period, a qualified avian specialist must first assess the area to ensure that birds and their nests will not be adversely impacted by land clearing activities.

Species at Risk Act

The federal Species at Risk Act (SARA) provides protection to endangered or threatened organisms and their habitats. This legislation applies to all federal land. Although SARA prohibitions are automatically imposed on federal lands including First Nations lands, the intent of SARA also applies to provincial crown and private lands. SARA encourages provincial and First Nations governments to cooperate to protect wildlife in Canada.

SARA also provides protection to aquatic species (administered by DFO) and migratory birds (covered by the Migratory Birds Convention Act).

3.2 PROVINCIAL LEGISLATION

BC Water Sustainability Act

The Water Sustainability Act (WSA) establishes the broad legal framework for managing the diversion and use of water resources in British Columbia. Much of the detail of how the principles of the Act are applied is provided in regulations. The Water Sustainability Regulation addresses the requirements for the allocation of both ground and surface water (e.g., application requirements) and identifies the requirements for using water or making changes to a stream.

BC Wildlife Act

The BC Wildlife Act protects indigenous wildlife and fish across the province. Similar to the Migratory Birds Convention Act, the BC Wildlife Act protects bird nests, bird eggs and nesting birds. Species that are not protected under the Migratory Birds Convention Act, such as raptors, herons, and owls, are protected under the BC Wildlife Act. Compliance under this Act can be maintained by conducting land clearing activities outside of the nesting season for birds. If clearing must be conducted within this period, a qualified avian specialist must first assess the area to ensure that birds and their nests will not be adversely impacted by land clearing activities.

An Angling and Scientific Fish Collection Regulation may be required to salvage fish from any instream work areas.

BC Heritage Conservation Act

The purpose of this Act is to encourage and facilitate the protection and conservation of heritage property in British Columbia. A professional archaeologist can be contacted to provide recommendations with respect to archaeological and heritage resources.

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BC Riparian Areas Protection Act

The Riparian Areas Protection Regulation (RAPR) of the Riparian Areas Protection Act calls on local governments to protect riparian areas during residential, commercial, and industrial development by ensuring that a Qualified Environmental Professional (QEP) conducts a science-based assessment of proposed activities.

The purpose of the regulation is to protect the many and varied features, functions and conditions that are vital for maintaining stream health and productivity, including:

- Sources of large organic debris, such as fallen trees and tree roots;
- Areas for stream channel migration;
- Vegetative cover to help moderate water temperature;
- Provision of food, nutrients and organic matter to the stream;
- Stream bank stabilization; and
- Buffers for streams from excessive silt and surface run-off pollution.

3.3 LOCAL GOVERNMENT LEGISLATION

District of Lake Country Zoning Bylaw Zoning Bylaw 561, 2007 Consolidated Version

Natural Boundary means the visible high water mark of any lake, river, stream or other body of water where the presence and action of the water are so common and usual, and so long continued in all ordinary years, as to mark the soil of the bed of the body of water a character distinct from that of its banks, in vegetation, as well as in the nature of the soil itself.

Watercourse means any natural depression with visible banks, that contains water at some time, and includes any lake, river, stream, creek, spring, ravine, swamp, gulch, coulee, wetland, or surface source of water, whether containing fish or not, including intermittent streams, and drainage works that contain fish.

Zone Boundaries where a zone boundary is shown as approximately following the edge, shoreline, or high water mark of a river, lake, or other water body, it follows the natural boundary. In the event of change, it moves with the natural boundary;

District Of Lake Country Official Community Plan (OCP) Bylaw 1065, 2018 Consolidated Version

Riparian area - areas of vegetation, habitats, or ecosystems that are associated with bodies of water or are dependent on the existence of perennial, intermittent, or ephemeral surface or subsurface water.

Riparian Assessment Area

- For a stream, the 30 m strip on both sides of the stream, measured from the high water mark;
- For a ravine less than 60 m wide, a strip on both sides of the stream measured from the high water mark to a point that is 30 m beyond the top of the ravine bank, and
- For a ravine 60 m wide or greater, a strip on both sides of the stream measured from the high water mark to a point that is 10 m beyond the top of the ravine bank.

Development within Riparian Areas

Any of the following associated with or resulting from the local government regulation or approval of development activities or ancillary activities to the extent that they are subject to local government powers under Part 14 of the Local Government Act:

- Removal, alteration, disruption or destruction of vegetation;
- Disturbance of soils;
- Construction of non-structural impervious or semiimpervious surfaces;
- Flood protection works;
- Construction of roads, trails, docks, wharves and bridges;
- Provision and maintenance of sewer and water services;
- Development of drainage systems;
- Development of utility corridors;
- Subdivision.

Natural Environment DP Area Guidelines

Natural Environment Development Permit Areas have been designated to lessen the potential negative effects that development can have on sensitive environmental features.

For areas identified as Riparian Areas on Map 15 a Natural Environment Development Permit is required for any subdivision or development. A Natural Environment Development Permit shall not be issued until the District has been provided with a copy of an assessment report, prepared by a Qualified Environmental Professional who has carried out an assessment, that:

- Certifies that the Qualified Environmental Professional is qualified to carry out the assessment.
- Certifies that the assessment methods have been followed.
- Provides the professional opinion of the Qualified Environmental Professional that:
    - if the development is implemented as proposed there will be no harmful alteration, disruption or destruction of natural features, functions and conditions that support fish life processes in the riparian assessment area; or
    - if the width of the streamside protection and enhancement area identified in the report is protected from the development, and the measures identified in the report as necessary to protect the integrity of those areas from the effects of the development are implemented by the developer, there will be no harmful alteration, disruption or destruction of natural features, functions and conditions that support fish life processes in the Riparian Assessment Area.

The District may include, as conditions of approval of a Development Permit application, the measures identified by a Qualified Environmental Professional in the environmental assessment report necessary to protect streamside protection and enhancement areas.

4.0 COMMUNICATIONS AND ENGAGEMENT

Throughout the summer of 2022, the District undertook a series of engagement opportunities to collect input from the local community. Community members were asked to share their flood stories, experiences, and photos to help identify current and future flood risks in the area.

The following section provides a summary of what we heard throughout the engagement process.

4.1 HOW WE CONNECTED

Let's Talk Lake Country Web Content

118 total visitors

14 informed visitors (clicked through content)

82 aware visitors (viewed the project page)

Online Survey

4 respondents

Pop-Up Event

Held at Live! In Lake Country event

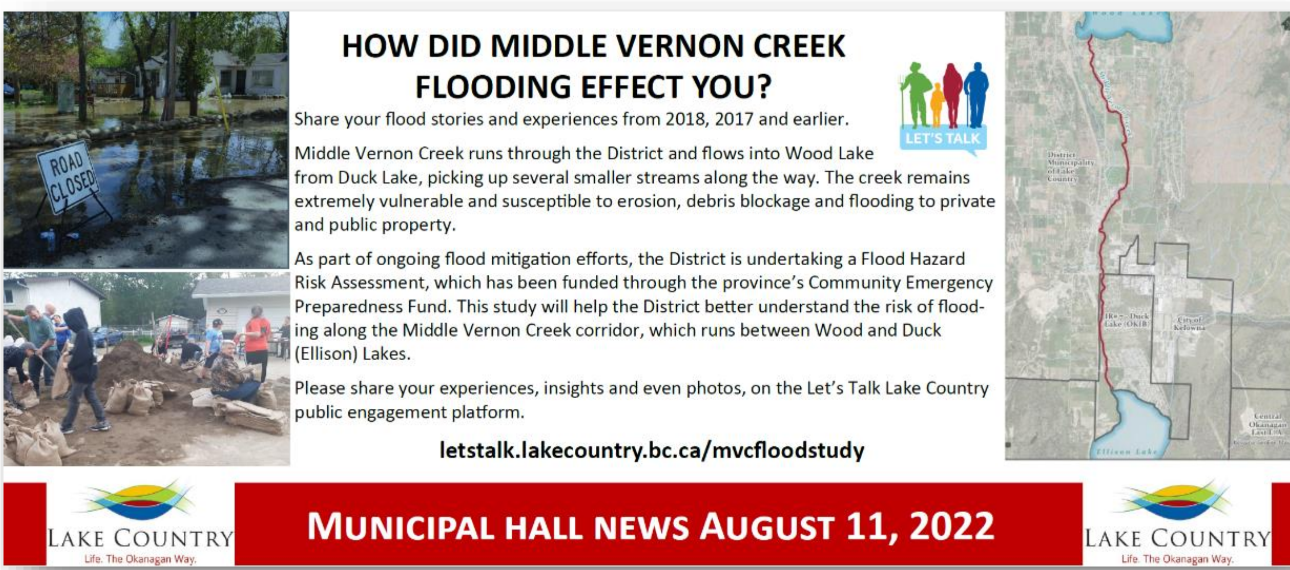

Figure 4.1 - Project Information Bulletin

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4.2 ENGAGEMENT OPPORTUNITIES

Pop-Up Event

(August 25, 2022 from 3pm to 8 pm)

The project team hosted an in-person pop-up event at Live! in Lake Country's Swalwell Park to provide community members with an opportunity to learn more about the project and share their flood stories. Participants were encouraged to share their flood stories by leaving comments on a map or by filling out the online survey.

Online Survey

(August 2022 to September 16, 2022)

An online survey was available through the District's website for community members to submit their flood stories and photos.

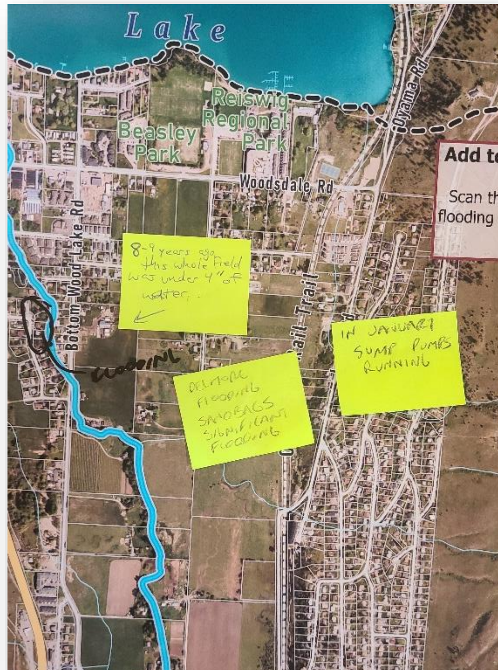

Figure 4.2 – Pop – Up Event Feedback

Figure 4.3 - Project team at Live! in Lake Country

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4.3 WHAT WE HEARD

Key themes that emerged through the in-person pop-up event and the online survey are summarized in the following section. Detailed findings from the online survey are also provided.

Key Themes

Many shared stories of the significant flooding they have observed along the MVC area and the efforts they have seen, or taken themselves, to mitigate damage to surrounding properties, such as sandbags, dikes and using sump pumps.

Along MVC, the most common evidence of flooding observed by respondents was debris, flooding/overland water flow and breached creek bend.

Top 3 Flooding Evidence Observations

- Debris
- Flooding/overland water flow
- Breached creek bend

It was noted that creek flooding is not the only challenge in the area. Flooding from Ellison Lake in 2017 impacted many surrounding properties and caused significant damage, particularly to Holiday Park Resort, where the golf course was completely destroyed. The high-water table caused long-term challenges and has taken several years of recovery efforts.

Respondents called for improved maintenance to control the build up of debris in the creek and to mitigate flooding, noting that most of the issues have been observed upstream from the Beaver Lake Road culvert.

Figure 4.4. Flooded property along Middle Vernon Creek

5.0 DATA ACQUISITION AND DEM DEVELOPMENT

5.1 COORDINATE SYSTEM

The geographic data for this assignment used the following coordinate systems.

- Projected Coordinate System - Universal Transverse Mercator (UTM) Zone 11
- North American Datum (NAD) 83
- Canadian Geodetic Vertical Datum 2013 (CGVD2013)

5.2 SURVEY DATA

Andres Surveys completed topographic survey of the main channel and banks of MVC. The survey included approximately 160 cross sections along the 7 km MVC reach, between Ellison (Duck) Lake, and Wood Lake. In November 2021 survey data from Beaver Lake Road to Wood Lake was collected and in April 2022 data was collected between Ellison Lake and Beaver Lake Road.

Cross sections were taken approximately every 50m along the channel. The coordinates of preferred cross section locations were provided by the engineering team, and then refined with the survey team based on access, safety, and professional judgement.

Cross sections upstream and downstream of culverts and bridges to be modelled were collected as per open channel modelling best practices:

- Cross section 1 – start of channel contraction
- Cross section 2 – immediately upstream of bridge/culvert
- Cross section 3 – immediately downstream of bridge/culvert
- Cross section 4 – start of channel expansion

Cross sections were taken from top of bank to top of bank, perpendicular to the channel. Most cross sections were 30m or less in width.

Culvert and bridge surveys included:

- Photos looking upstream and downstream of crossing
- Abutments, deck, low chord, piers, railings, and road centerline
- Culvert invert at upstream and downstream locations
- Culvert obvert at upstream and downstream locations
- Culvert diameter, or width and length if box culvert
- Road centreline elevation
- Measurements of crest height, width, and any other noticeable features.

5.3 DIGITAL ELEVATION MODEL DEVELOPMENT

Steps to develop the Digital Elevation Model (DEM) for the MVC corridor are outlined below.

- 2018 LiDAR was provided by OBWB, with a vertical datum of CGVD2013. LiDAR was used to build a DEM with 1m resolution which was clipped to the study limits.
- Survey data was converted to points in GIS, then brought into the GeoHECRAS model.
- Channel centreline and banks were drawn along MVC based on thalweg and top of bank points picked up in survey as well as what was shown in the LiDAR.
- A DEM was built from the ground survey points to represent MVC from bank to bank.
- The DEM of the channel was overlaid on the DEM built from LiDAR. This created a continuous surface of the study are that included bathymetric data of the channel. The channel was checked for inconsistencies and some locations were smoothed individually using the Stamp Geometry tool in GeoHECRAS.

6.0 CLIMATE CONDITIONS

As part of the FHRA process, background climatic information was reviewed to establish climate conditions in the District. Projected climate changes were also obtained to inform potential impacts of climate change.

6.1 PLAN2ADAPT TOOL

The Plan2Adapt tool was developed to serve the needs of those involved in local and regional community planning. The Plan2Adapt tool generates maps, plots, and data describing projected future climate conditions for regions throughout BC. It relies on 12 different Global Climate Models (GCMs) each using one run of the selected RCP 8.5 high emissions scenario. Projections for the Central Okanagan Region were obtained for the time period of 2070-2099. The table below summarizes projected trends for temperature, precipitation, and snowfall.

Table 6.1 - Projected Changes to Climate for the Central Okanagan Region of BC

Climate Variable	Season	Ensemble Median	Range (10th to 90th Percentile)
Temperature (°C)	Annual	+5.0	+3.8 to +6.7
Precipitation	Annual	+5.1%	+2.3% to +13%
	Summer	-14%	-45% to +6.5%
	Winter	+10%	+1.7% to +18%
Snowfall	Annual	-48%	-55% to -42%
	Winter	-40%	-46% to -31%
	Spring	-75%	-86% to -57%

This table is elaborated graphically in the figures following. The light grey bar shading shows the range of the central 80% of projections in the set, which is the same as the 10th to 90th percentiles. The central black line shows the median of the set. The purple shading separates the data into 30-year intervals commonly used in presenting the results of climate change impacts.

Figure 6.1 below shows the change in annual temperature is projected to increase into the future. This graph is similar when restricted to Winter, Spring, Summer, and Fall. Higher temperatures may possibly translate into increased flows from snowmelt in the spring.

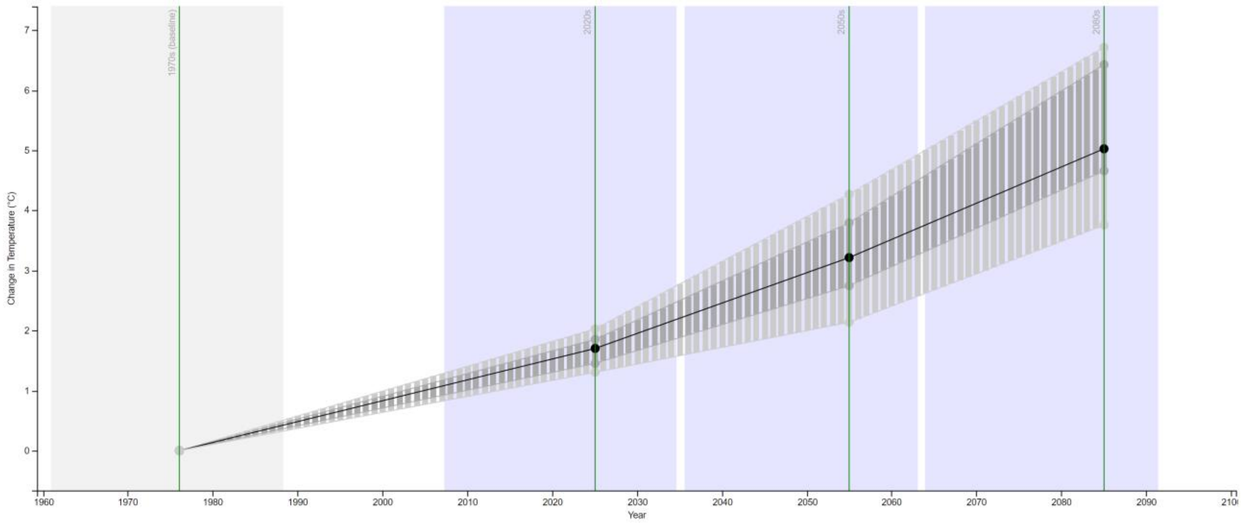


Figure 6.1 - Percent Change in Annual Average Temperature

Figures 6.2 through 6.6 show the change in precipitation annually, and through the four different seasons. Summer precipitation is the only one which shows a stationary or downwards trend, the other seasons show an increase in precipitation. This may translate into more frequent rain-on-snow events and thus higher flows.

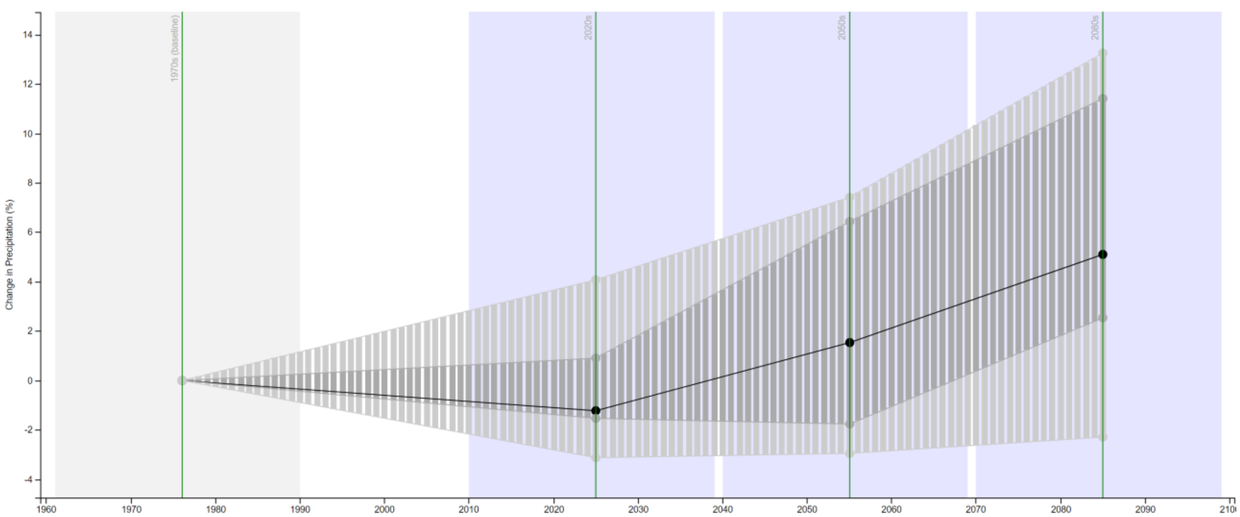


Figure 6.2 - Percent Change in Annual Precipitation

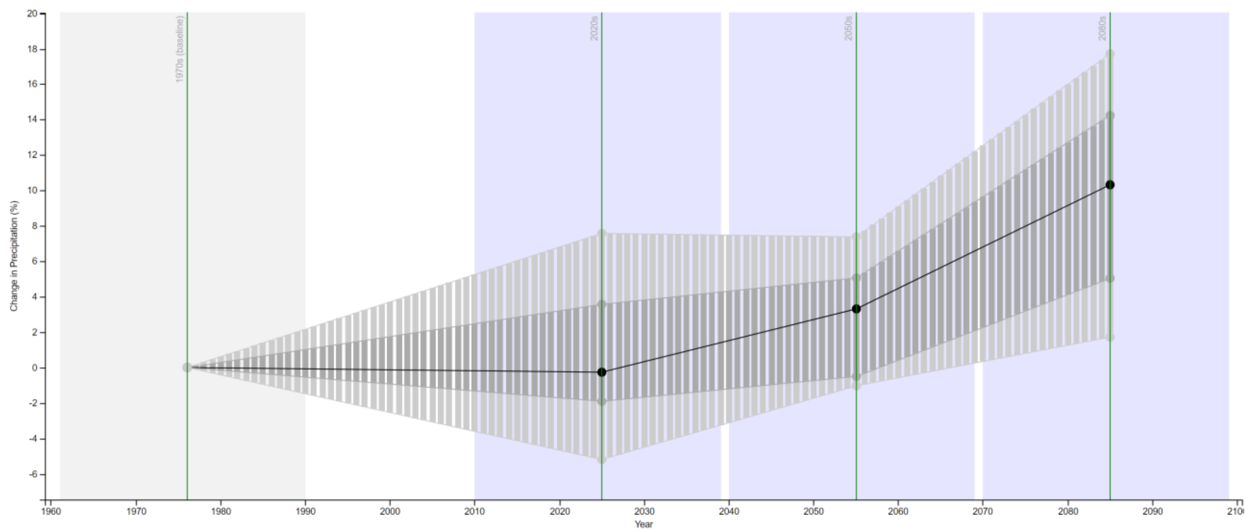


Figure 6.3 - Percent Change in Winter Precipitation

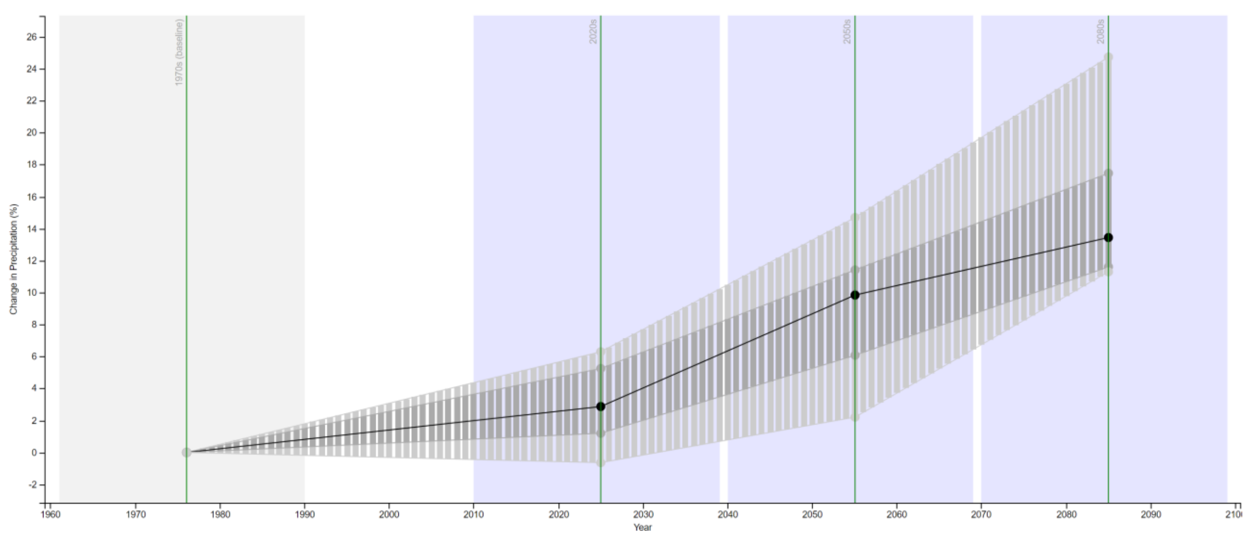


Figure 6.4 - Percent Change in Spring Precipitation

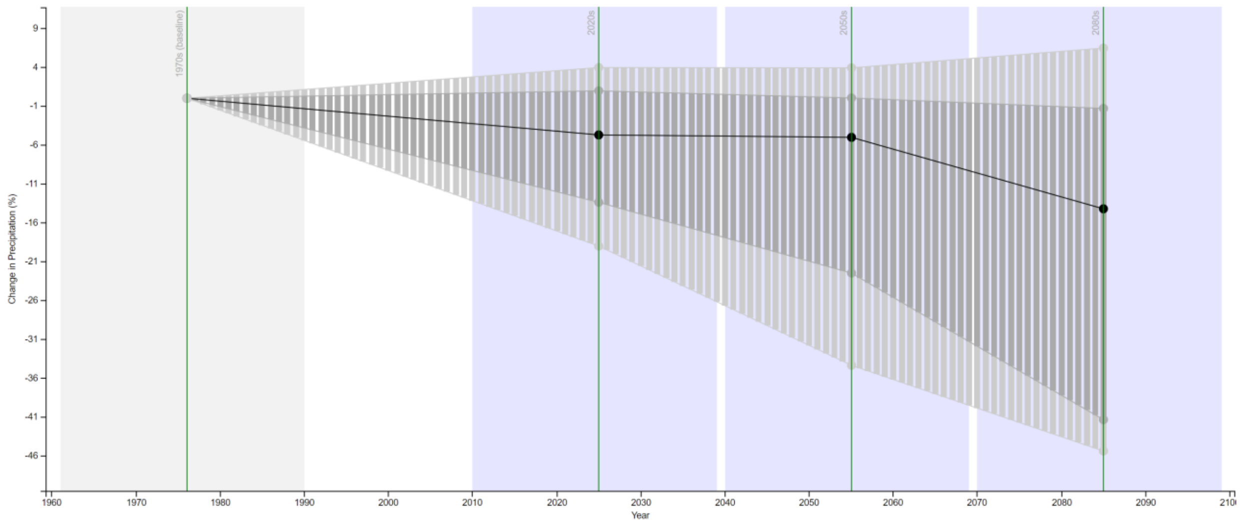


Figure 6.5 - Percent Change in Summer Precipitation

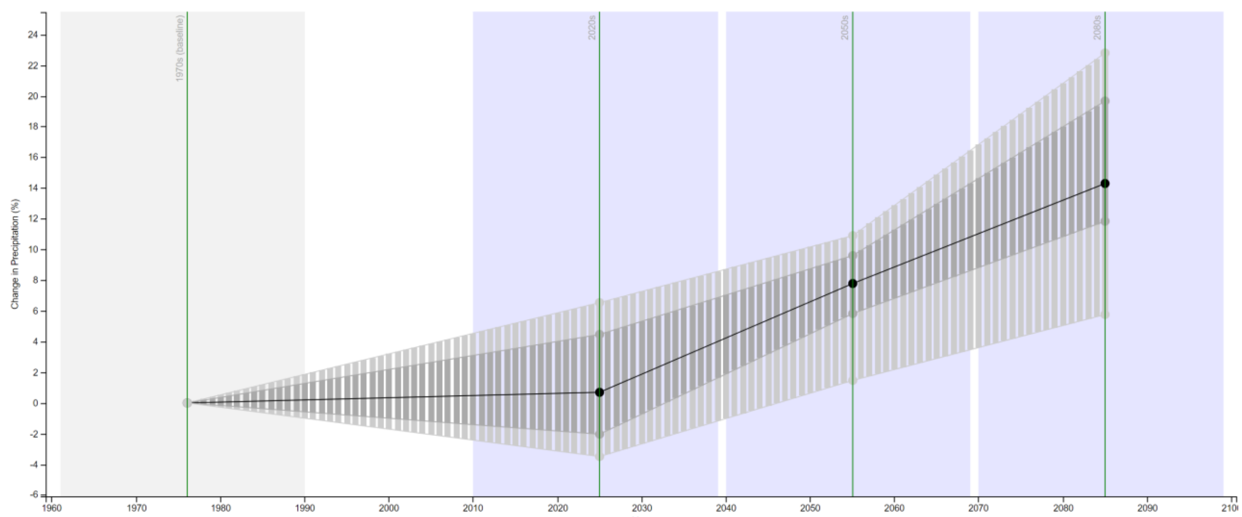


Figure 6.6 - Percent Change in Fall Precipitation

Figure 6.7 below shows the change in the amount of annual precipitation falling as snow. The plot shows a clear decreasing trend in the amount of precipitation falling as snow, which could have the effect of decreasing snowpack. It also means the precipitation falling during colder seasons is more likely to manifest as rain than snow, possibly leading to an increase in precipitation-driven flow events. However, it is cautioned that this variable may have a low initial baseline, resulting in deceptively large percent change values. This is because the region naturally has a low snowpack historically.

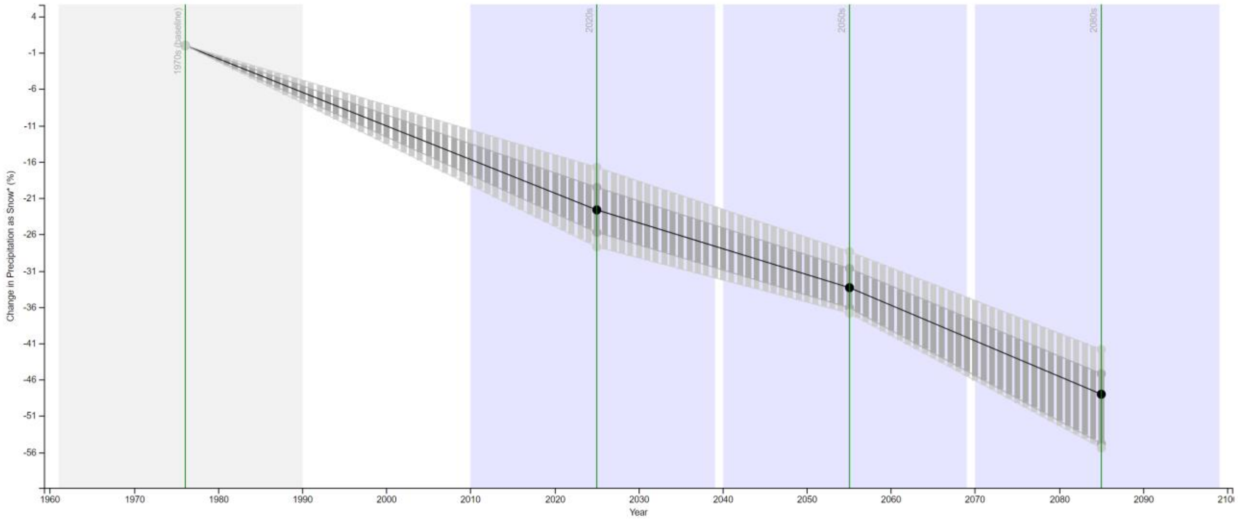


Figure 6.7 - Percent Change in Annual Proportion of Precipitation as Snow

6.2 IDF_CC TOOL

An Intensity-Duration-Frequency curve (IDF curve) describes the relationship between rainfall intensity, rainfall duration, and return period (or probability of exceedance). The IDF_CC tool, which was developed by the University of Western Ontario, is a web-based tool that provides updated IDF curves using historical additional precipitation data when available.

It also provides IDF curves based on climate change projections. Future climate projections are developed using global climate/circulation models (GCMs), which emulate physical processes in the atmosphere, ocean, cryosphere, and land surface.

Shared Socioeconomic Pathways (SSP) are trajectories of greenhouse gas concentrations adopted by the Intergovernmental Panel on Climate Change (IPCC) for its sixth Assessment Report and the associated Coupled Model Intercomparison Project 6 (CMIP6). There are multiple SSPs which describe possible climate futures, depending on how much greenhouse gas is emitted in the years to come. This is an evolution from the previous RCP method of predicting greenhouse gas change, as SSPs also take into account socioeconomic factors over the next century. These include things such as population, economic growth, education, urbanization and the rate of technological development

The IDF_CC tool allows the user to select from any combination of CMIP5 and CMIP6 climate models, including four (4) CMIP6 SSPs (SSP 1.26, SSP 2.45, SSP 3.70 and SSP 5.85), three (3) of which are bias corrected (SSP 1.26, SSP 2.45, and SSP 5.85). These various SSP scenarios provide a wide range of updated IDF curves.

The SSP 5.85 was chosen for analysis. This value was selected as it is considered to represent the "business as usual" case for climate change. The median output from the bias corrected GCMs, and the upper and lower confidence intervals, are shown in the table for both the 2 year, and 100 year return periods.

Running the IDF_CC tool for the Kelowna Airport station yields the following output:

Table 6.2 - Summary of IDF CC Tool Output for 2 and 100 Year 24 Hour Events for KELOWNA A (1123970) from 2015 to 2100

Parameter	2-year 24-hour intensity (mm/hr)	100-year 24-hour intensity (mm/hr)	2-year 24-hour increase over historical	100-year 24-hour increase over historical
Intensity, Historical GEV (mm/hr)	0.97	1.70	-	-
Intensity, SSP 5.85 (mm/hr)	1.08	2.15	11%	27%

Thus, the climate change scenarios are anticipated to increase the 2-year 24 hour intensity by 11%, and the 100-year 24 hour intensity by 27%, assuming fossil fuel resources are still widely used to support economic and population growth in the future.

The social, economic, and environmental effects of climate change represent a significant research challenge in recent times. Although analytical tools such as the IDF CC Tool can provide valuable information on the predicted impacts of climate change, output from these tools must be taken in hand while simultaneously acknowledging the uncertainty associated with any future climate predictions.

In the context of the District FHRA, the output from the IDF CC tool aids in understanding the potential heightened flooding risks and hazards but does not provide a direct quantitative estimate of climate change impacts to flooding.

7.0 HYDROLOGIC ANALYSIS

This section outlines the methodology and justifications for the design flow estimates for the MVC FHRA. It includes a review of the contributing watersheds, impacts of dams / reservoirs, and water elevations for Ellison Lake and Wood Lake used as boundary conditions in the hydraulic model.

7.1 MIDDLE VERNON CREEK WATERSHED

The District is located in the southern interior of B.C., and is characterized by hot, dry summers, and cold, dry winters. Lying in the rain shadow of the Coast and Cascade mountains, the region is relatively arid due to low rates of precipitation and high rates of evaporation. Winter snowpack accumulation and subsequent snowmelt significantly influences spring streamflow's within MVC.

The MVC watershed can be broken into the following catchment areas, as illustrated on Figure 7.1.

- Clark Creek Watershed
- Direct to Ellison Lake Watershed
- Direct to MVC Watershed
- Upper Vernon Creek Watershed

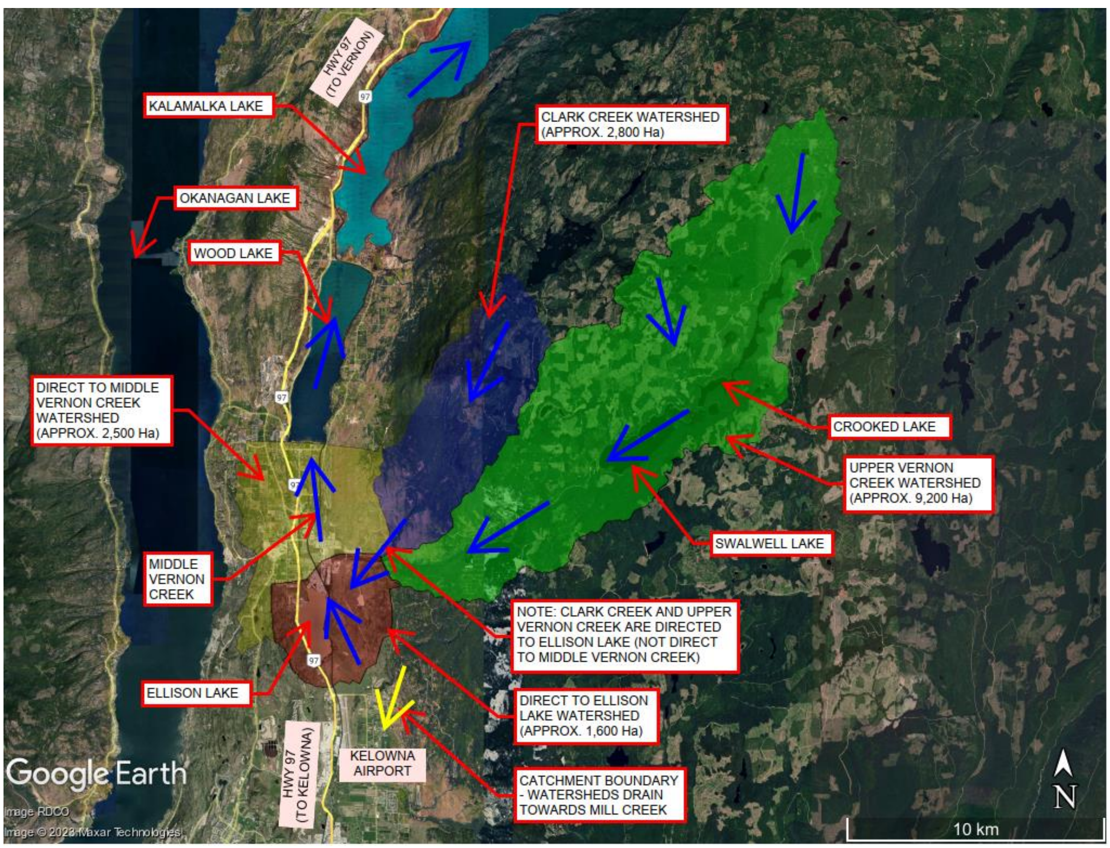


Figure 7.1 – Middle Vernon Creek Watershed

Clark Creek

The Clark Creek watershed is approximately 2,800 hectares and area and joins with Upper Vernon Creek approximately 3.3 km upstream of the confluence with Ellison Lake. There are no reservoirs or dam structures within the Clark Creek watershed.

Ellison Lake

The flow in MVC is largely controlled by the level of Ellison Lake. There are no registered dams located that control the level of Ellison Lake, however flow is significantly impacted by the presence / absence of obstructions like beaver dams in the low gradient reach that extends for approximately 1 km downstream of Ellison Lake. A sandbag dam has been in use in the past to raise Ellison Lake level in the summer and then release water in the fall for Kokanee. The location of this intermittent structure can be seen on the maps in Appendix A.

Lower Catchments – Direct to Ellison Lake

Ellison Lake also receives a small amount of surface runoff from the sub-catchments that surround and directly discharge to the lake.

Lower Catchments – Direct to Middle Vernon Creek

In addition to the Ellison Lake input to MVC, there are several overland and underground drainage systems that discharge to MVC within the District boundary. These catchments include the west and east valley sides and the urbanized areas on either side of MVC.

Upper Vernon Creek

The major inlet to Ellison Lake is Upper Vernon Creek. Upper Vernon Creek has historically shifted north and south on its alluvial fan, often having several channels and likely not flowing into Ellison Lake. Current BC Watershed Atlas available on iMapBC shows two paths, one towards Ellison Lake and the other north discharging to MVC near the south end of Meadows Road upstream of the Lodge Road crossing. This is also reinforced by the dam breach analysis (Urban, 2018) that shows overland flow branching out in different places on the alluvial fan. To ensure that Upper Vernon Creek flows reach Ellison Lake rather than spill over into the industrial area and on to the north, a canal was constructed from the railway tracks near Ellison Lake to approximately 1.3 km upstream.

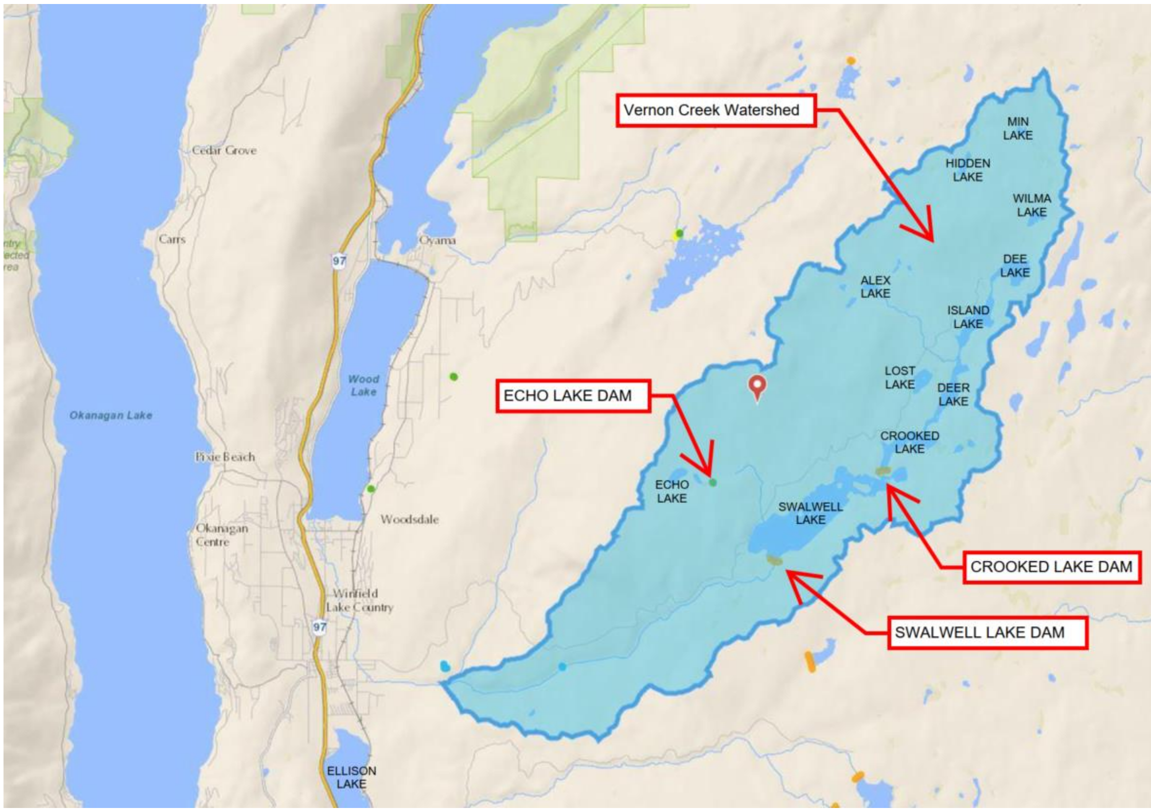
In the watersheds current configuration, Upper Vernon Creek is strongly influenced by developed storage throughout the watershed. The storage reservoirs capture snowmelt runoff and water is released into Vernon Creek to augment natural low summer, fall, and winter flows. Crooked and Swalwell Lake are connected and operate together to control stream flows within Upper Vernon Creek.

The District operates a number of dams within the Upper Vernon Creek watershed. Information from the BC Provincial iMapBC for each of the registered dams is outlined in Table 7.1 and shown on Figure 7.2.

Table 7.1 – iMapBC Registered Dams in Middle Vernon Creek Watershed

Dam Name	Dam Height	Dam Length	Dam Type
Swalwell Lake Dam	7.1 m	187 m	Earthfill
Crooked Lake Dam	5.2 m	226.5 m	Earthfill
Echo Lake Dam	1.9 m	N / A	Earthfill

Figure 7.2 – Upper Vernon Creek Registered Dam Locations



7.2 FLOW REGULATION

As indicated in Section 6.1, the water level in Ellison Lake drives the base flow within MVC. Discharges from Swalwell Lake significantly impact Ellison Lake levels. Flow adjustments at Swalwell Lake are well managed and documented by District Staff. This is not the case with the sandbag flow control structure at the outlet of Ellison Lake. The opening geometry varies from year to year – usually because of intentional adjustment by members of the MVC Action Plan (MVCAP) - but also due to impacts of flow and other natural causes such as ice movement. Adjustments to the sandbag control structure are made several times per year by MVCAP members. The primary purpose is to store water for autumn release during spawning season. However, the water level is also sometimes dropped to encourage optimal growth of shoreline vegetation.

Water Survey of Canada (WSC) operated several hydrometric stations within the study area during the 1960's and 1970's. This included locations on Upper Vernon Creek, Ellison Lake, and MVC. While interesting, these data sets are not useful for developing reliable peak flow estimates – much has changed since they were decommissioned, there are gaps in the records, and given that climate is not stationary, the data are less relevant than current records.

Over the last 10 years, the Okanagan Basin Water Board (OBWB) and the MVCAP committee have installed several hydrometric stations. Unfortunately, there have been challenges and only sporadic water level data has been collected on Upper Vernon Creek, Ellison Lake, and MVC (Epp et al, 2016). Locations include:

- just downstream of the Swalwell Lake outfall
- just upstream of Ellison Lake
- on Ellison Lake, near the north shore
- on MVC (at Reimche Road and near Beaver Lake Road)

Converting water levels to flows has proven challenging because of continuing changes to the natural channel geometry, backwater impacts of beaver dams and/or other channel obstructions in MVC, and occasional equipment malfunctions. Despite these challenges, the work indicates the following typical values:

- Peak discharges from Swalwell Lake, including through the spillway during freshet, range between 3.0 to 5.2 m^3/s.
- Peak flows entering Ellison Lake from Upper Vernon Creek range between 3.0 to 6.3 m^3/s.
- Peak flows within MVC, near Beaver Lake Road, range between 3.5 to 6.3 m^3/s.
- Peak flows within MVC, near Reimche Road, range between 3.2 to 6.2 m^3/s.
- Water levels within Ellison Lake range between 425.0 and 426.5 m (1.5 m fluctuation). Note that the highest water level recorded on Ellison Lake was approximately 427.3 m (1970-05-29). This value is approximate because it is based on a conversion from an older Water Survey of Canada geodetic system (GSCD) to the current one (CGVD13).

It is interesting to note that discharge from Wood-Kalamalka Lake into Vernon Creek at its north end is recommended to be no greater than 6.0 m^3/s (AE, 2020). While this will have no material impact on flows within MVC, it could have an impact on Wood Lake water levels should runoff into the system increase due to climate change.

7.3 CLIMATE CHANGE ANALYSIS

The Okanagan Mainstream Mapping Study (NHC, 2020) included modeling scenarios that were driven by future climate projections. NHC used the Canadian Large Ensembles Adjusted Dataset version 1 (CanLEADv1) for RCP 8.5 from 1950 to 2100, downscaled for the Okanagan basin. In general, the data reflects the following changes over the remainder of this century:

- increased average daily temperatures,
- higher freezing levels,
- increased precipitation during fall, winter, and spring
- reduced precipitation during the summer,
- earlier freshet season (2-3 weeks earlier)

The impacts of these changes on runoff, and ultimately on the peak water levels in Ellison Lake, are not intuitive. Some climate changes will drive higher runoff peaks and volumes while others will result in less runoff. The modeling, however, indicated that annual peak water levels in Ellison Lake are likely to increase until mid-century (2050 or so), then start to level-off toward the end of the century.

The study developed recommended quantile water levels for Ellison Lake for each of four periods – Historical (1950-2019), Near-Term (2006-2035), Mid-Century (2041-2070), and End of Century (2071-2100). These recommendations reflect both current and recommended (modified) regulation protocols that were developed in consultation with the Province. Figure 7.2 illustrates these peak water levels for the 2-year, 20-year and 200-year return periods. It also compares peak water levels to recorded (WSC) "average" and "high" water levels, which were used in lieu of a frequency analysis due to the short record length.

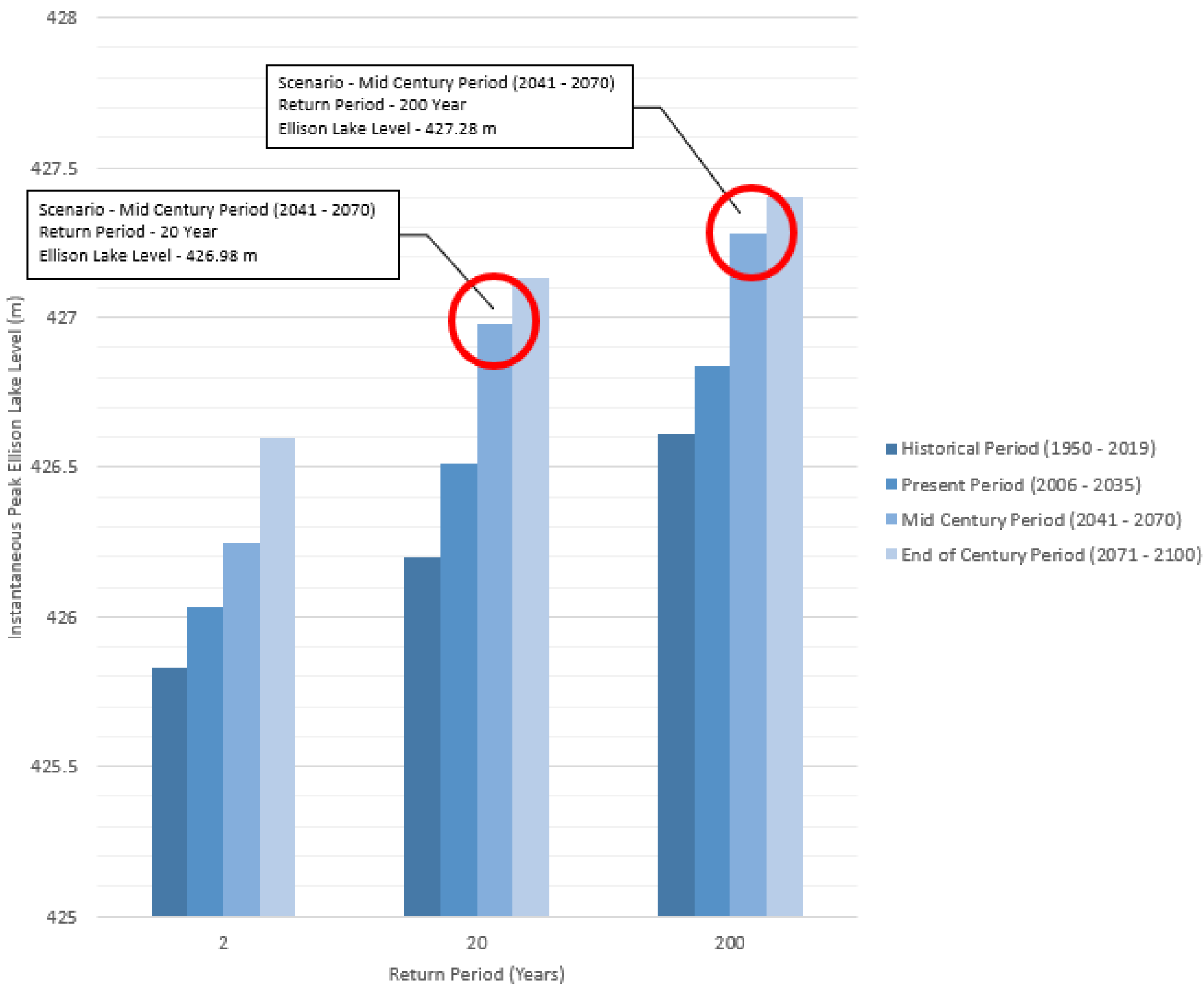


Figure 7.2 - Ellison Lake – Recommended Design Water Levels

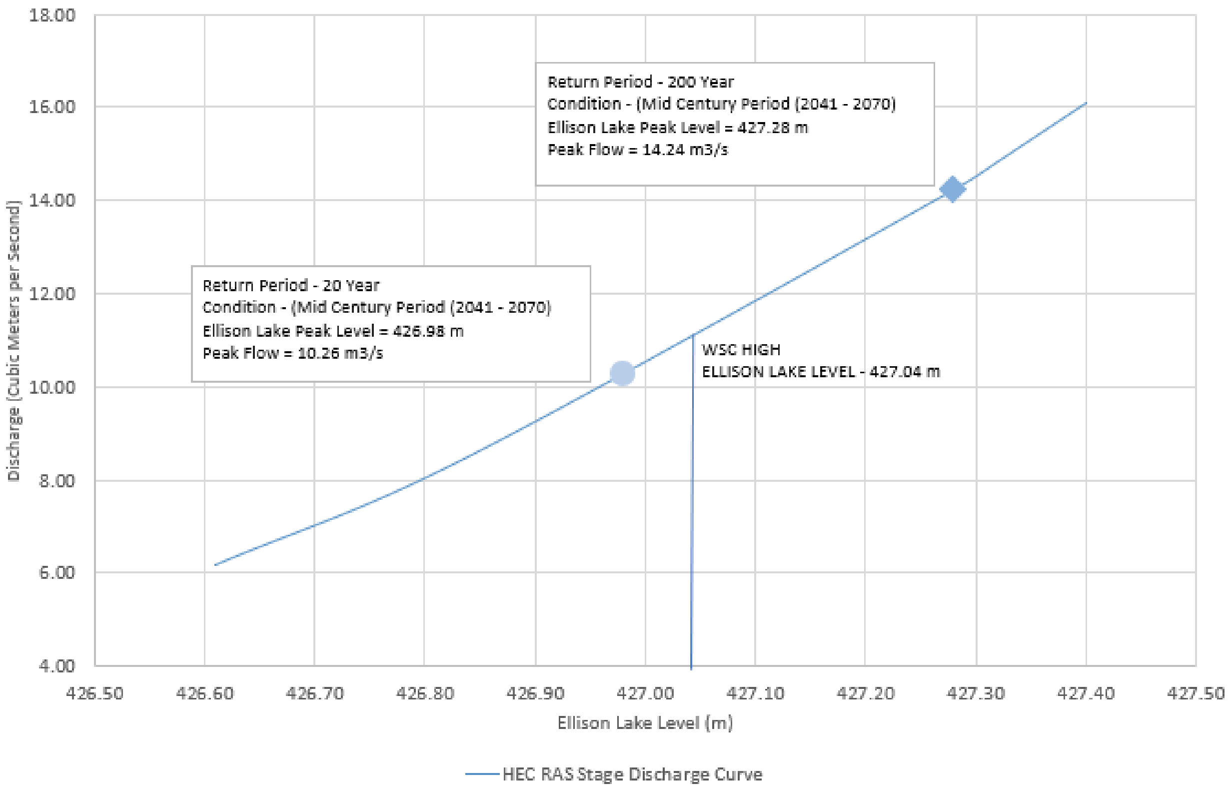
To provide firm direction to the District regarding climate change preparedness, a more detailed study should be completed. This subsequent study should account for the uncertainty in the projected climate impacts; the risks associated with the changing climate; the infrastructure costs associated with updated design standards; as well as consideration for potential capital upgrades to help mitigate the changes in climate. The study should aim to assist the District in finding a balance between the impacts of climate change and the costs associated with mitigation.

7.4 DESIGN FLOWS AT MIDDLE VERNON CREEK

A stage/discharge curve was developed from the HEC-RAS model using topographic and bathymetric survey data. Based on this, we have used the discharges developed from the HEC-RAS model for the stated lake elevations outlined above. The HEC-RAS model assumes that the sandbag control structure does not exist and therefore relies on the channel cross-section and general reach slope between Ellison Lake and Commonwealth Road.

Figure 7.3 summarizes the recommended 20-year and 200-year design water levels in Ellison Lake and the corresponding discharge rates into MVC as determined by the stage/discharge curves.

Figure 7.3 - Ellison Lake Stage/Discharge Curve



In addition to the outflows from Ellison Lake, rainfall runoff also discharges into MVC at several locations along its length between Ellison Lake and Wood Lake. Table 7-3 outlines the outfall locations for the 5 catchments that drain to MVC.

Table 7.3 - Tributary Middle Vernon Creek Catchments – Peak Runoff

Catchment	2-Yr Peak Runoff (m^3/s)
Location 1 - Between Commonwealth Road and Beaver Lake Road	0.066
Location 2 - Upstream of Beaver Lake Road	0.103
Location 3 - Upstream of Bottom Wood Lake Road Near Swalwell Park	0.014
Location 4 - George Elliot Secondary	0.255
Location 5 - Upstream of Lodge Road	0.241
Total	0.678

For the purposes of the current study, the 2-year peak rainfall runoff from the 5 identified catchments was added to the each of the 20-year and 200-year Ellison Lake outflow scenarios. The 2-year runoff is considered to approximate the average runoff rate and is therefore deemed appropriate to use in conjunction with the 20-year and 200-year freshet flow rate driven by Ellison Lake levels.

Based on the above analysis, design flows at and along Middle Vernon Creek are summarized as follows:

20-Year Return Period – Used for Likelihood Assessment

- Condition – Mid Century (2041 to 2070)
- 20-Year Peak Discharge Rate – 10.26 m^3/s at exit from Ellison Lake
- Add 2-Year Peak Runoff Rates from direct MVC catchments – additional 0.678 m^3/s

200-Year Return Period – Design Event

- Condition – Mid Century (2041 to 2070)
- 200-Year Peak Discharge Rate – 14.24 m^3/s at exit from Ellison Lake
- Add 2-Year Peak Runoff Rates from direct MVC catchments – additional 0.678 m^3/s

An additional scenario was considered that reviewed an average freshet (2-year) coupled with a 200-year rainfall event in the directly connected MVC catchments. The total combined flow into MVC in this scenario is in line with the 200-Year Return Period Design Event described earlier. However, the 200-year rainfall event would be distributed along MVC, at the locations described in Table 7.3, thereby spreading out the impact in the channel; in the case of the 200-year freshet flow, the full flow rate enters MVC at the start of the channel, causing a chance for flooding along the entire reach. Therefore, for flood hazard modelling in this study, we have chosen to use the Design Event composed of the 200-year freshet flow from Ellison Lake and the 2-year peak rainfall runoff from the directly connected MVC catchments.

8.0 HYDRAULIC ANALYSIS

A computer model of the river channel was constructed using the hydraulic modelling program GeoHEC-RAS. This program was selected because it uses the industry standard HEC-RAS river modelling engine developed by the US Army Corps of Engineers. HEC-RAS is robust at performing 1D and 2D hydraulic calculations for open water channels. GeoHEC-RAS provides an interface that integrate GIS and HEC-RAS, and allows for more efficient modelling than simply using standalone HEC-RAS. MVC was modelled as a 1D channel from Ellison Lake to Wood Lake, with cross sections and road crossings along the way, representing channel geometry and structures.

8.1 MODEL DEVELOPMENT

Model development began with a field survey of river cross-sections, which was carried out as described in Section 4.2. The field survey provided accurate main channel and bridge/culvert cross-sections to ensure a reliable model. A few wooden footbridge crossings exist across the creek, but these were modelled in less detail. The DEM described in Section 4.2 was used as the basis to extract cross sections along the channel. The LiDAR was used to expand the detailed cross-section information in the overbank areas. Standard expansion and contraction coefficients were used for cross sections around the bridges:

- Gradual Transitions: Contraction/Expansion = 0.1/0.3
- Typical Bridge Sections: Contraction/Expansion =0.6/0.8

8.1.1 MANNING'S ROUGHNESS COEFFICIENTS

Manning's roughness values were populated in the model for both the main channel and overbank areas. For the main channel, Manning's roughness coefficients (Manning's n) were determined using the Modified Channel Method as outlined in the Guide for Selecting Manning's Roughness for Natural Channels and Floodplains – USGS (1989). Manning's n for the channel was based on photographs taken of the channel, from previous modeling experience, and site visits to MVC.

For the overbank areas, a Manning's roughness landcover layer was manually created by classifying the orthophoto from 2021. Manning's n values for each land use type were assigned. The table below shows the Manning's n value used for each land use type:

Table 8.1 – Manning's n Values

Land Cover Type	Manning's n
Building	100.250
Agricultural	0.063
Grassy/Lawn/Open Space	0.029
Pavement/Road/Gravel	0.015
Forest/Treed	0.105
Water	0.07

8.1.2 CHANNEL CROSSINGS

The road crossings were modelled between Ellison Lake and Wood Lake. In this reach, MVC has 14 crossing structures. Refer to Appendix B for a summary of crossing information at each intersection of MVC and the District's road network. The following table provides a brief summary of the various MVC crossings and includes crossing type, material, endwall treatment, size and condition.

Table 8.2 – Summary of Channel Crossings

Beaver Lake Road

- Closed bottom arch
- Corrugated steel pipe (CSP)
- 3.0 m wide x 2.0 m high
- Nearing end of life poor condition

Bottom Woodlake Road (near Swalwell Park)

- Open bottom arch culvert
- Bolted steel with reinforced concrete headwalls
- D/S – 8.0 m wide x 2.8 m high
- U/S - 8.0 m wide X 2.0 m high
- New installation good condition

Lodge Road

- Clear span bridge
- Reinforced concrete bridge abutments
- 12.5 m wide span approximately 2.1 m high

Bottom Wood Lake Road (near Mayrus)

- Closed bottom arch
- Corrugated steel pipe without headwalls
- 3.0 m wide x 2.0 m high
- Nearing end of life but in fair condition

Reimche Road

- Open bottom arch
- Bolted steel plate with reinforced concrete headwalls
- Size at inlet 1.89 m high x 5.34 m wide
- Size at outlet 1.59 m high x 5.29 m wide
- New installation good condition

Woodsdale Road

- Closed bottom arch
- Corrugated steel pipe with lock blocks and riprap at inlet/outlet
- 3.0 m wide by 2.1 m high
- Nearing end of life but in fair condition

Turtle Bay Court (Private)

- Closed bottom arch
- Corrugated steel pipe with no headwalls
- 3.5 m wide by 2.0 m high
- Nearing end of life but in fair condition

Small Foot Bridges

- There are 7 small foot bridges along the corridor, all of these small bridges are privately owned with the exception of the District owned bridge near Swalwell Park

9.0 FLOOD AND HAZARD MAPPING

The hydraulic modelling calculated the extent and depth of flooding at each cross section for each defined flood event. The results were used to develop flood and hazard mapping for MVC. These maps were then used to assess potential impacts on buildings and infrastructure within the Study area.

As indicated in Section 6, there is a very strong correlation between the Ellison Lake level and flows in MVC. Flood inundation and hazard maps were developed for the 20-year and 200-year event under the Mid-Century (2041-2070) scenario as outlined in Section 6 – Hydrologic Analysis. For both the 20-year and 200-year return period, 2-year peak flows have been added at the catchment locations that directly contribute along MVC.

Limitations

- The design flows identified from Ellison Lake are based on the Mid Century (2041 to 2070) scenario outlined in the Okanagan Mainstem Floodplain Mapping results (NHC, 2020). Flows and lake levels are projected to increase over time because of climate change. If the operational regime of the dams controlling flows from the watersheds change, flood levels could be greater than those illustrated on the maps.
- The mapping includes a hatch indicating flood Inundation extent for the design events.
- The mapping includes an additional flood risk extent that reflects a freeboard allowance of 0.3 m. This is to illustrate anticipated inundation extents, as well as freeboard to account for local variations in water level due to uncertainty in design event estimates, and to allow impacts of debris blockages along the MVC corridor.
- In general, the analysis assumes that the channel and crossing geometry is stationary. Erosion, aggradation, and local debris blockages may occur during a flood event, which can significantly alter the conveyance performance of MVC and can cause flood levels to exceed those indicated on the maps.
- The purposed of the MVC FHRA is to provide floodplain level results for the identified hydrologic and hydraulic conditions. Localized areas above or below the inundation level or freeboard level may be generalized. The FHRA maps should be considered an administrative tool that indicates inundation areas. A qualified professional should be engaged to complete site specific engineering analysis.

The Flood Hazard Maps are included in Appendix A. The Flood Hazard Maps are plotted on 4 sheets at 1:1,500 scale for both the 20 Year and 200 Year return periods.

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10.0 FLOOD RISK ASSESSMENT

10.1 RISK ASSESSMENT APPROACH

The EGBC Professional Practice Guideline Flood Mapping in BC defines flood risk as the combination of the probability of a flood event and the potential adverse consequences to human health, the environment and economic activity associated with a flood event. The process of risk assessment involves identifying flood hazards and estimating the consequences for each hazard and combining the results to obtain an overall estimate of the expected risk. The following figure outlines the process utilized for the MVC flood risk assessment.

Flood Hazards

- Develop an Understanding of the Flood Hazards in the Study Area
  - Insufficient hydraulic capacity
  - Conveyance system blocked by debris
  - Debris blockage within channel
  - Flood wave due to crossing failure or debris blockage failure
  - Watershed Flood Risks Outside District Boundary

Impact Receptors

- Consider the Flood Hazards in Terms of the Following Impact Receptors
  - People
  - Infrastructure
  - Economy
  - Culture
  - Environment

Consequence Assessment

- Complete Consequence Assessment
  - Determine the impact receptors at risk to flood hazards
  - Determine how vulnerable each impact receptor is to the flood hazards
  - Assign a consequence score

Likelihood Assessment

- Consider the Likelihood of a Flood Hazard Occuring to an Impact Receptor
  - Review return period of hazard
  - Define likelihood of flood risks that are difficult to predict (ie. debris blockage)

Risk Assessment

- Complete Risk Assessment
  - Combine the results of the consequnce and likelihood assessments
  - Determine the overall flood hazard risk

10.2 RISK TOLERANCE

Risk tolerance can be defined as the amount and type of risk that an organization is willing to accept to meet their strategic objectives. An important step of a flood risk assessment is to compare determined risk values against accepted risk tolerance. At this time, however, there have been no formal flood risk tolerance criteria defined locally, provincially, or federally. Per EGBC Legislated Flood Assessment (2018), tolerable risks may vary from country to country, and within countries, depending on historic exposure to natural hazards, the intrinsic value that is placed on the life of an ordinary citizen, and the system of ownership and control of floodplains and other natural hazards areas.

The question of risk tolerance is specific to the District and cannot be addressed by an outside party. However, this section discusses the results and provides a risk classification for each category. The classification is based on ratings provided in the RAIT and an example flood risk matrix provided by EGBC. These classifications are suitable for use in a wide context report such as a flood hazard assessment. They are not based on stakeholder consultation and therefore may not reflect the impact to specific areas of the community. The following is a suggested project risk matrix.

Likelihood		**Consequence**				
Description	Return Period (years)	Negligible	Minor	Moderate	High	Severe
Very Likely	< 5	M	H	H	VH	VH
Likely	5 - 20	L	M	H	H	VH
Moderate	20 - 100	VL	L	M	H	VH
Unlikely	100 - 200	VL	L	L	M	H
Very Unlikely	>200	VL	VL	L	L	M

Very High

Risk is unacceptable short-term (before next flood). Risk reduction required, long-term risk reduction plan must be developed and implemented.

High

Risk is unacceptable - a medium-term risk reduction plan must be developed and implemented in a reasonable (5 years) time frame. Planning should begin as soon as feasible.

Moderate

Risk may be tolerable - more detailed review required. Reduce risk to low where reasonably practical.

Low

Risk is tolerable - continue to monitor if resources allow.

Very Low

Risk is broadly acceptable - no further review or risk reduction required.

10.3 TYPES OF HAZARDS

This section of the report provides information on the types of flood hazards that exist in the District and describes the vulnerabilities (or elements at risk) present.

The major types of flood hazards identified along MVC that have the potential to put people and property at risk include the following.

- Insufficient hydraulic capacity of drainage infrastructure
- Conveyance structures blocked by debris and/or sediment
- Debris blockage within channel
- Flood wave due to crossing failure or debris jam
- Erosion and avulsion
- Overland flow along unpredictable paths (caused by any of the above flood hazards)

Each hazard type is discussed in further detail below.

10.3.1 INSUFFICIENT HYDRAULIC CAPACITY

Culverts and bridges may suffer from insufficient hydraulic capacity due to under sizing, inefficient orientation, incorrect installation, collapse, corrosion, or other forms of disrepair. Inundation at the structure's inlet may cause water to spill in an undesirable location, or a piping failure of the structure due to flows travelling through the surrounding soils causing erosion and potential failure. Both modes of failure result in flows circumventing the conveyance structure in uncontrolled locations, putting people and infrastructure at risk.

Aggradation from sedimentation and vegetation can reduce the capacity of a channel by reducing its cross-sectional area and increasing its friction losses. Aggradation is the accumulation of gravel and sediment in an active creek bed as part of natural sediment transport and deposition. Vegetation growth is the result of warm water, slow flows, and nutrients from adjacent development. Both these causes can impair the capacity of a natural or anthropogenic channel and put it at risk of failure.

10.3.2 CONVEYANCE STRUCTURES BLOCKED BY DEBRIS AND/OR SEDIMENTS

There is increased potential for conveyance structures to suddenly get blocked by woody debris and sediments moved during peak flows, causing the hydraulic capacity to be reduced, sometimes to the point of effectively blocking the conveyance structures completely. When conveyance structures are blocked, it can cause water to back-up at the inlet before overtopping the road embankment or flowing to another location. It can also cause piping failure by forcing flows through the soil around the culvert or bridge footings and eroding it.

The extent of the upstream flooded area is referred to as the conveyance structure's inundation area. Inundation areas for all conveyance structures in the District were reviewed to identify those with the potential to cause damage to buildings and other infrastructure. Spill from these inundation areas may cause flows to travel in uncontrolled and undesirable ways.

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10.3.3 DEBRIS BLOCKAGE WITHIN CHANNEL

Similar to blockages at conveyance structures, there is increased potential for the channel itself to gradually or suddenly become blocked by woody debris and sediments moved during peak flows. This can significantly reduce the hydraulic capacity of the overall system. It can cause water to back-up behind the debris blockage, overtopping channel banks, and directing flow in unpredictable directions. It can also lead to channel bank erosion as the water looks for paths around the blockage, carrying the sediments downstream to potentially create other blockages.

10.3.4 FLOOD WAVE DUE TO CROSSING OR DEBRIS JAM FAILURE

In some cases, the blockage of conveyance structures has the potential to lead to catastrophic loss of the embankment through overtopping and erosion, similar to a dam failure. The loss of embankment leads to the release of the stored water and the creation of a flood wave several times greater than the peak flow of the extreme event reaching the culvert. To complicate matters, when some of these conveyance structures are overtopped, the flows do not return to the main channel, but follow an unexpected path.

10.3.5 EROSION AND AVULSION

Channel avulsion refers to the rapid abandonment of a channel and the flooding and erosion of a new channel. This can be caused by high peak flows or a channel blockage such as sediment or debris. The new channel is often a former channel that was previously abandoned. However, sometimes the stream is relocated completely outside its recent former channels.

Erosion protection is typically the armouring of banks with angular rock riprap. Erosion protection on its own does not provide protection from high water levels but can limit erosion and channel migration which can threaten dikes, homes, and other infrastructure located near the fast-flowing water.

Erosion protection has challenges related to cost of land acquisition, construction, monitoring and maintenance, impact to riparian vegetation, installation of a barrier between terrestrial and aquatic habitat, and potentially constricting the natural width and migration of the river resulting in local scour and increased probability of lateral migration on the opposite bank. Some of the adverse aspects of erosion protection can be reduced if the armouring is set back from the active channel or by incorporating planting of shrubs in benches, pockets, or riprap voids. A healthy riparian zone on both sides of the active stream channel can also reduce erosion and avulsion.

10.3.6 OVERLAND FLOW ALONG UNPREDICTABLE PATHS

All the flood hazards identified above can cause water to flow out of the established MVC channel in different directions towards Wood Lake. Because the areas adjacent to MVC are highly developed and urbanized in some locations, the overland flow path through the floodplain can be unpredictable and often results in significant damage to private and public property. It can lead to widespread impacts to people and infrastructure.

10.3.7 WATERSHED FLOOD RISKS – OUTSIDE OF DISTRICT BOUNDARY

Ellison Lake Levels

The level in Ellison Lake is the most significant and direct impact on the flow entering the Middle Vernon Creek system. It is important for many reasons including low flow scenarios where downstream fish habitat can be negatively impacted when environmental flow needs are not met, to high flow scenarios where too much water is exiting Wood Lake leading to downstream flooding. The District should continue to coordinate with regional stakeholders to better understand the short and long term plans for managing Ellison Lake Levels.

Upper Vernon Creek

Upper Vernon Creek currently flows directly to Ellison Lake. There is potential for Upper Vernon Creek to take a more direct path towards MVC by spilling into the industrial area and heading north towards Wood Lake via MVC. A channel was constructed from the railway tracks near Ellison Lake to approximately 1.3 km upstream. If this channel was to fail, flows could be sent directly towards MVC without Ellison Lake acting as a buffer causing flooding along the MVC corridor.

Middle Vernon Creek – Duck Lake 7

The same risks identified within the District boundary are also present along the Okanagan Indian Band Duck Lake 7 section of MVC. That includes issues with hydraulic capacity, debris blockages, conveyance structure blockages, flood waves, erosion, avulsion, and flow along unpredictable overland flow paths. This is also the section of MVC that largely controls the outflow from Ellison Lake. Blockages within the channel (whether man made or natural) can impound significant volumes of water and the sudden release of that water can result in significant downstream flooding.

Dam Breach Risk

The Crooked and Swalwell Lake Dam Breach Inundation Analysis indicates that Middle Vernon Creek would be significantly impacted by dam failures in the watershed. Dam risk is not studied in detail in the MVC FHRA, however it is important not note, that flood inundation mapping indicates significant flooding of Upper Vernon Creek prior to Ellison Lake and sent more directly north causing flooding along the Middle Vernon Creek corridor.

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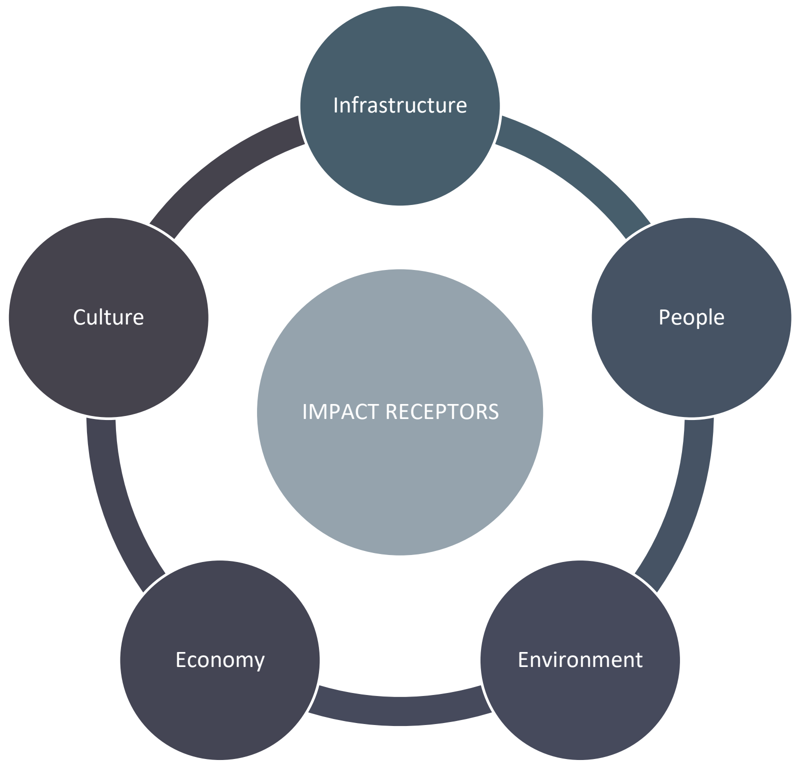
10.4 IMPACT RECEPTORS

Vulnerabilities refer to elements at risk from flood hazards. Estimating consequences of flooding can be challenging since extensive spatial databases are often needed to characterize the elements at risk, including infrastructure, people, the environment, the economy, and areas of cultural value.

Some resources are available to help estimate consequences using damage functions, which relate consequences such as amount of property damage to variables like water depth and velocity. However, engineers must use their professional judgment to determine whether these functions are accurate for the specific application and elements at risk. Understanding the potential consequence of flooding for each element at risk (or vulnerability) is a critical input to estimating overall risk.

The report provides information on the vulnerabilities present in the District by exploring impacts to these receptors.



11.0 FLOOD RISKS ASSESSMENT RESULTS

Having understood the hazards impacting vulnerabilities in the District, the risks were then quantified to provide a relative ranking of various flood hazards. This was done to allow the District to identify priorities and inform its efforts in flood risk mitigation.

11.1 IMPACTS TO PEOPLE

The impact to people and society from flooding can be significant. Some form of human suffering is almost always associated with damaging floods, through displacement, loss of assets, and/or loss of life. These impacts can be very difficult to quantify.

Loss of Life

The magnitude of the risk of loss of life depends largely on whether the flood was predicted and if appropriate warning and evacuation takes place. In the District, the main hazards that have the potential to cause loss of life are flood waves. Flood waves in the District are most likely to occur through the breach of an embankment (such as a road with a plugged culvert) once a significant amount of water has been stored upstream of the crossing. Therefore, it is unlikely that a flood wave would occur with no warning, though the possibility still exists. The District should develop a flood notification procedure to ensure that residents at risk of flooding are notified in a timely manner to allow for evacuation if needed. This warning greatly reduces the risk of loss of life.

Although the worst-case scenarios assessed in this study indicate very low potential for loss of life, the District should define what is a reasonable level of risk for potential loss of life.

Table 11.1 – Impacts to People Risk Assessment Results

	Consequence				
Likelihood	Negligible	Minor	Moderate	High	Severe
Very Likely					
Likely					
Moderate	Hydraulic Capacity				
Unlikely		Debris Blockages			
Very Unlikely		Overland Flow	Flood Wave		

Results - Flood Risk Impacts to People – Low

11.2 IMPACTS TO ENVIRONMENT

Potential environmental risks due to flooding include spills of hazardous materials, oil and fuel spills, and flooding of farms that lead to uncontrolled release of manure and fertilizer. Economic impacts from these types of releases are very difficult to quantify.

For the purposes of this study, high risk locations for potential pollutants were identified, including wastewater treatment and equipment yards. These locations were overlaid with the identified flood hazard locations to identify risks. The District may wish to take action to ensure that future developments do not create a pollution risk in flood-prone areas, such as the implementation of bylaws to require storage of hazardous materials safely away from major flood paths.

As identified in the impacts to infrastructure section, the sanitary sewer collection system and treatment system can be overwhelmed during flooding events. This can result in negative impacts to the environment if the sewer system is overwhelmed causing direct discharge to the environment.

Table 11.2 – Impacts to the Environment Risk Assessment Results

	Consequence				
Likelihood	Negligible	Minor	Moderate	High	Severe
Very Likely					
Likely	Hydraulic Capacity				
Moderate	Debris Blockages				
Unlikely		Overland Flow			
Very Unlikely			Flood Wave		

Results: Flood Risk Impacts to Environment – Low

11.3 IMPACTS TO ECONOMY

Economic impacts of flooding broadly fall into the categories of loss of assets and losses to the local/regional economy. Loss of assets can be estimated as direct damages to infrastructure including buildings. Losses to the local/regional economy are much more difficult to estimate. This could include unemployment, loss of business, and impacts to economic opportunities.

Table 11.3 – Impacts to Economy Risk Assessment Results

	Consequence				
Likelihood	Negligible	Minor	Moderate	High	Severe
Very Likely					
Likely					
Moderate	Hydraulic Capacity				
Unlikely	Debris Blockages	Overland Flow			
Very Unlikely			Flood Wave		

Results: Flood Risk Impacts to Economy - Low

11.4 IMPACTS TO AREAS OF CULTURAL VALUE

Areas of cultural value cannot be quantified monetarily. However, it is important to assess the potential impact to these areas as part of the FHRA. Cultural or historic losses could include flooding of graveyards, buildings of historic value, and cultural grounds.

Table 11.4 – Impacts to Cultural Value Risk Assessment Results

	Consequence				
Likelihood	Negligible	Minor	Moderate	High	Severe
Very Likely					
Likely					
Moderate	Hydraulic Capacity				
Unlikely	Debris Blockages	Overland Flow			
Very Unlikely		Flood Wave			

Results: Flood Risk Impacts to Cultural Value – Low

11.5 IMPACTS TO INFRASTRUCTURE – ROAD CROSSINGS

The District owns and maintains 6 major road network crossings of Middle Vernon Creek. Over the years, the District has improved a number of these crossings.

To better under the likelihood of flood risk impacting each location, crossing capacity was calculated using HEC RAS based on inlet-controlled conditions and maintaining a headwater (HW) upstream of the crossing below the top of the crossing structure (ie. HW/d <1). In reality, each of the road crossings have some additional capacity when headwater at the inlet rises above the top of the crossing prior to spilling over the road, however that comes with an increase risk of debris blockages, overland flow and flood waves.

To calculate the crossing capacity, the model was utilized to determine the highest flow at which the water surface level at the nearest upstream cross section below the top of the crossing inlet. The crossing capacity does not include an allowance for embedment, freeboard or debris blockage which will further limit the effectiveness and capacity of each crossing.

Table 11.5 – Capacity Assessment of Road Crossings

Crossing	Size and Type	Crossing Capacity (m^3/s)	Design Flow Q200 (m^3/s)	Ratio of Design Flow to Capacity Q200/q	Design Flow Q20 (m^3/s)	Ratio of Design Flow to Capacity Q20/q
Beaver Lake Road	3m x 2m Pipe Arch	9.21	14.3	156%	10.43	113%
Bottom Wood Lake Road (near Swalwell)	8m Span Open Bottom Arch	28.11	14.38	51%	10.44	37%
Lodge Road	12.5 m Clear Span Bridge	22.85	14.88	73%	10.94	53%
Bottom Wood Lake Road (near Mayrus)	3m x 2m Pipe Arch	7.55	14.88	197%	10.94	145%
Reimche Road	5.3 m x 1.6 m Open Bottom Arch	8.05	14.88	185%	10.94	136%
Woodsdale Road	3m x 2m Pipe Arch	9.99	14.88	10.94%	10.94	110%

Table 11.6 – Impacts to Infrastructure – Road Crossings - Risk Assessment Results

	Consequence				
Likelihood	Negligible	Minor	Moderate	High	Severe
Very Likely		Hydraulic Capacity			
Likely			Debris Blockages		
Moderate			Overland Flow		
Unlikely				Flood Wave	
Very Unlikely					

Results: Flood Risk Impacts to Road Crossings – Moderate to High

The overall flood risk for road crossings in the District is moderate, however, based on the results of the culvert capacity assessment, the older style 2 m x 3 m pipe arch culverts are undersized to convey both the 200 year and 20 year design flow. The following crossings are considered high flood risks and should be considered a high priority for replacement.

- Beaver Lake Road
- Bottom Wood Lake Road (near Mayrus)
- Woodsdale Road

To further assist with summarizing the crossing information, Appendix B Crossing Summary Sheets which summarize each structures properties and configuration used in the development of the model as well as the capacity results outlined in the above table.

11.6 IMPACTS TO INFRASTRUCTURE - UTILITIES

Impacts to infrastructure through flooding can have a significant impact on a community, including inconvenience from loss of service and economic impacts of recovery. The following types of infrastructure were included in the vulnerability assessment:

- Potable water system
- Sanitary sewer system
- Electrical power
- Telecommunications
- Natural gas

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Utility infrastructure that was identified within the extents of the flood event is summarized in the following table. Most of this infrastructure is located at major road crossings or adjacent to MVC or a potential overland flow path.

Table 11.7 - Infrastructure Along Middle Vernon Creek

Location	Road	Sanitary	Water	Other
Beaver Lake Road	2 Lane Arterial	300 mm PVC sanitary main	800mm PVC watermain	Overhead power and telecom Natural gas
Bottom Wood Lake Road (near Swalwell)	2 Lane Collector	200 mm PVC sanitary	250 mm AC watermain	Underground power and telecom Natural gas
Lodge Road	2 Lane Collector	300 mm PVC sanitary main	none	Overhead power and telecom Natural gas
Bottom Wood Lake Road	2 Lane Local	200 mm PVC sanitary main and 150 mm HDPE forcemain	300 mm PVC watermain	Overhead power and telecom Natural gas
Bottom Wood Lake Road – North Overland Flow Path	2 Lane Local	200 mm PVC sanitary main and 150 mm HDPE forcemain	none	Overhead power and telecom Natural gas
Adjacent to Alexis Road (near Reimche Road)	2 Lane Local	200 mm PVC sanitary	none	Overhead power and telecom
Reimche Road	2 Lane Collector	none	200 mm HDPE watermain	Overhead power and telecom
Woodsdale Road	2 Lane Local	100 mm and 150 mm HDPE sanitary forcemain and 200 mm sanitary main	none	Overhead power and telecom Natural gas

Underground utilities could be at risk depending on the severity of flooding. Most potable water and sanitary pipe networks are buried underneath roadways. If roadway washout occurs, and the underlying subsurface soil erodes, buried infrastructure could be exposed and damaged. If a channel avulsion were to occur, the new channel could expose and damage the buried infrastructure.

Sanitary sewer systems are particularly at risk to flooding, as inflow and infiltration whether to gravity systems (manholes and gravity mains) or pressurized systems (sewer lift stations and forcemains) can cause significant increases in flow resulting in challenges in the collection systems ability to convey the flow as well as the ability of the treatment plant to treat the increased flows.

When considering flood waves, the potential for higher flows and velocities results in a much higher potential for damage. As such, all buried, surface and elevated infrastructure is vulnerable to damage through flood wave.

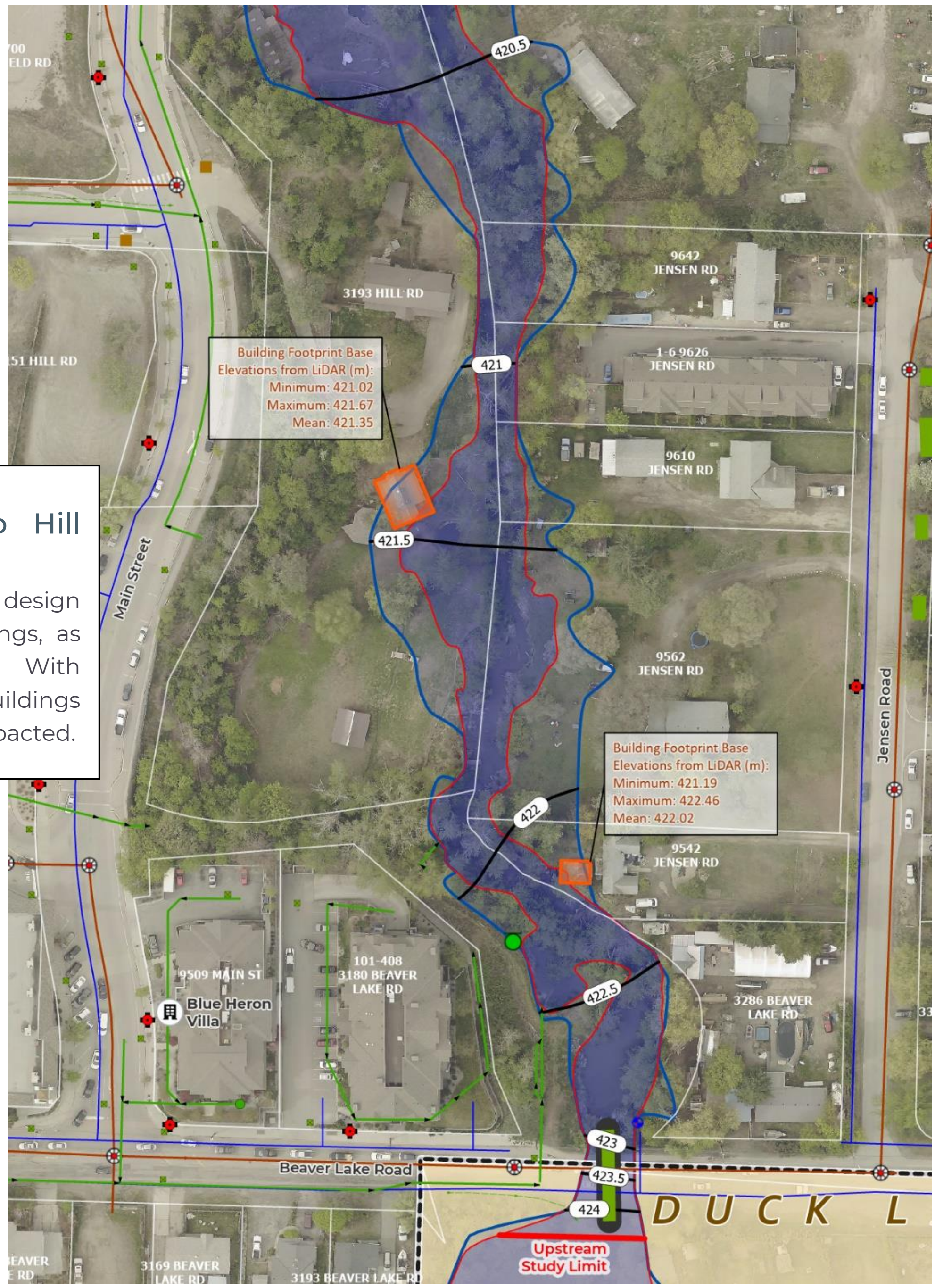
Table 11.8 – Impacts to Infrastructure - Utilities - Risk Assessment Results

	Consequence				
Likelihood	Negligible	Minor	Moderate	High	Severe
Very Likely					
Likely		Hydraulic Capacity			
Moderate			Debris Blockages		
Unlikely			Overland Flow		
Very Unlikely			Flood Wave		

Results: Flood Risk Impacts to Infrastructure Utilities - Moderate

11.7 IMPACTS TO INFRASTRUCTURE - BUILDINGS

In addition to road and utility infrastructure, there are several buildings potentially effected by flooding in MVC. The following provides a summary of buildings potentially impacted. Buildings that are within the design event flood extents prior to the addition of freeboard are shown on the subsequent mapping. Mapping shows the extent of the design event (red outline) as well as the design event with 30cm of freeboard added (blue line). Isolines shown in black represent the water surface elevation *with* freeboard added. Building footprint elevations are taken directly from the LiDAR data and have not been surveyed.



Beaver Lake Road to Hill Road

The water elevation during the design event approaches two buildings, as highlighted on the map. With freeboard added, the buildings become more significantly impacted.

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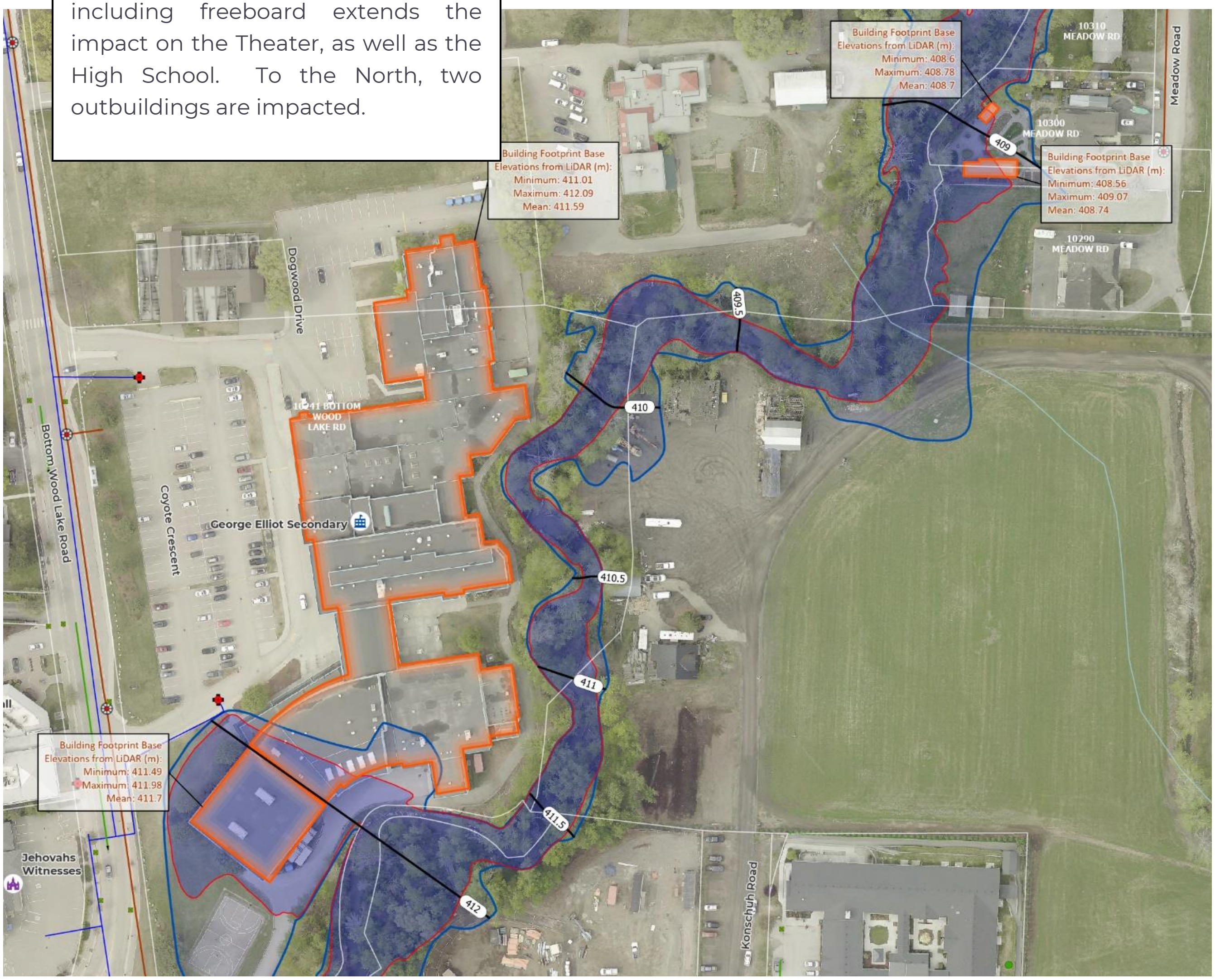
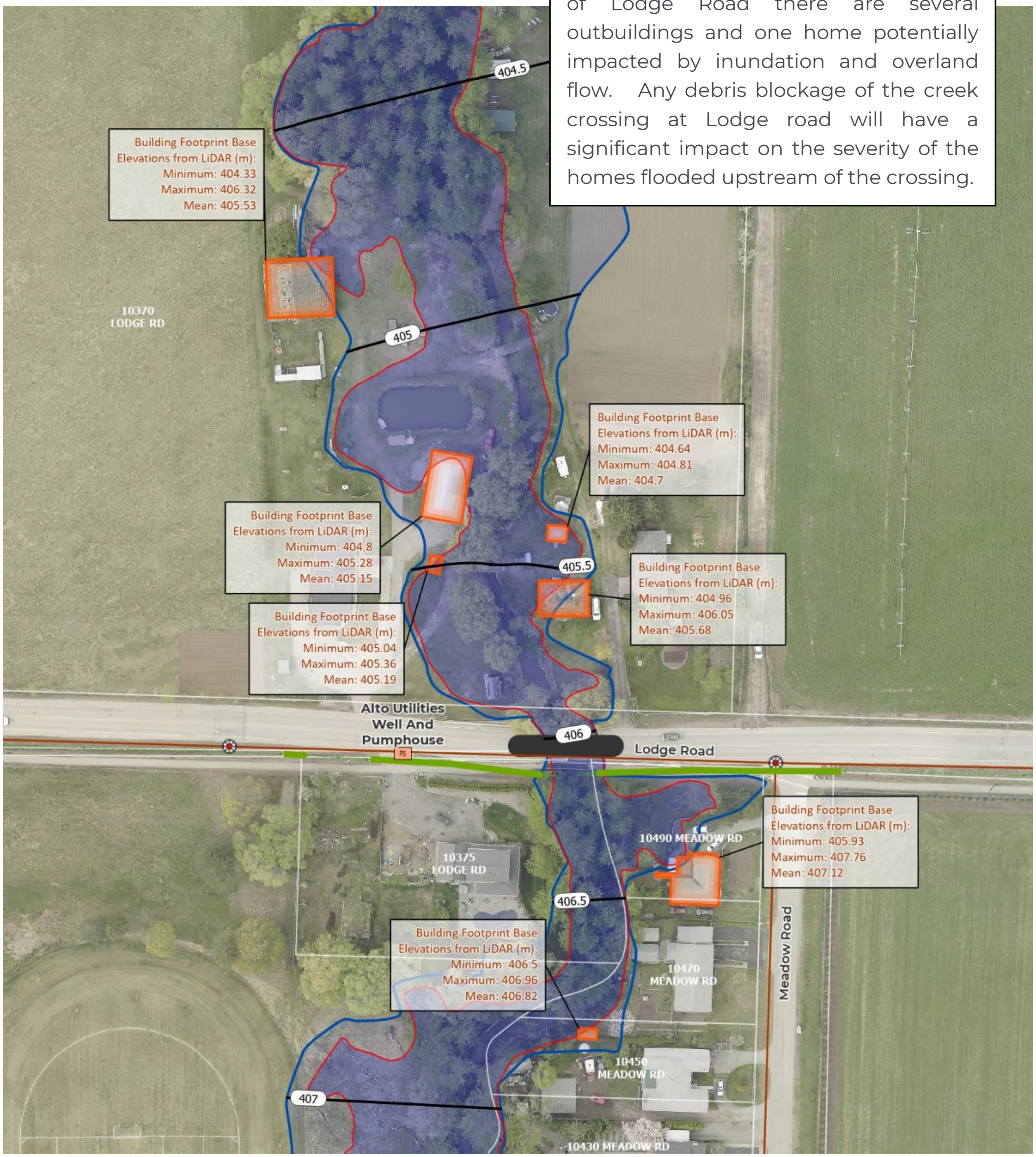
Bottom Wood Lake Road / Meadow Road

The water elevation during the design event has potential to impact Creekside Theater. The design event including freeboard extends the impact on the Theater, as well as the High School. To the North, two outbuildings are impacted.



Lodge Road

Immediately upstream and downstream of Lodge Road there are several outbuildings and one home potentially impacted by inundation and overland flow. Any debris blockage of the creek crossing at Lodge road will have a significant impact on the severity of the homes flooded upstream of the crossing.



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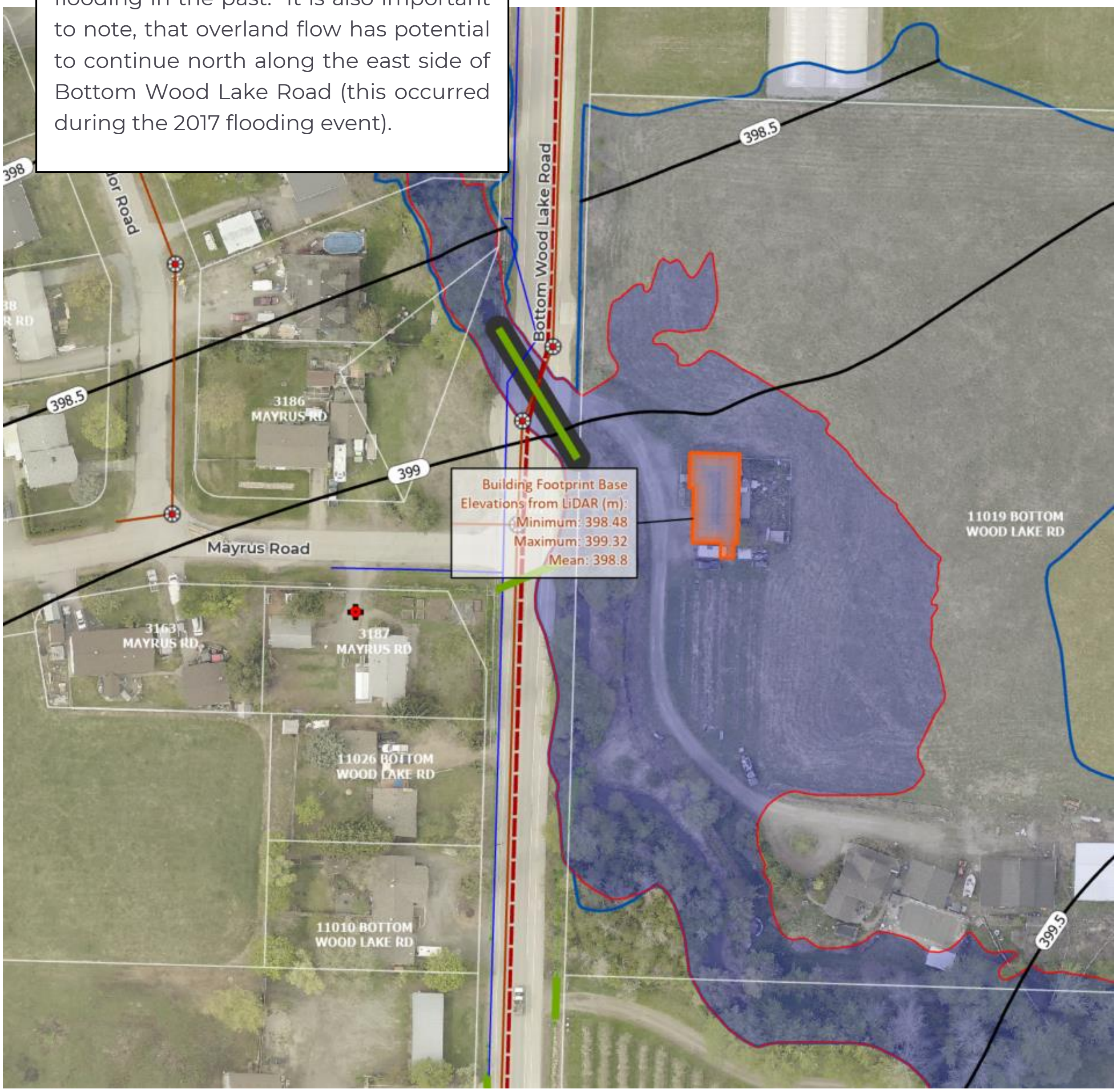
11019 Bottom Wood Lake Road

The property located adjacent to the Bottom Wood Lake Road crossing is impacted by inundation and overland flow. This location has experienced flooding in the past. It is also important to note, that overland flow has potential to continue north along the east side of Bottom Wood Lake Road (this occurred during the 2017 flooding event).



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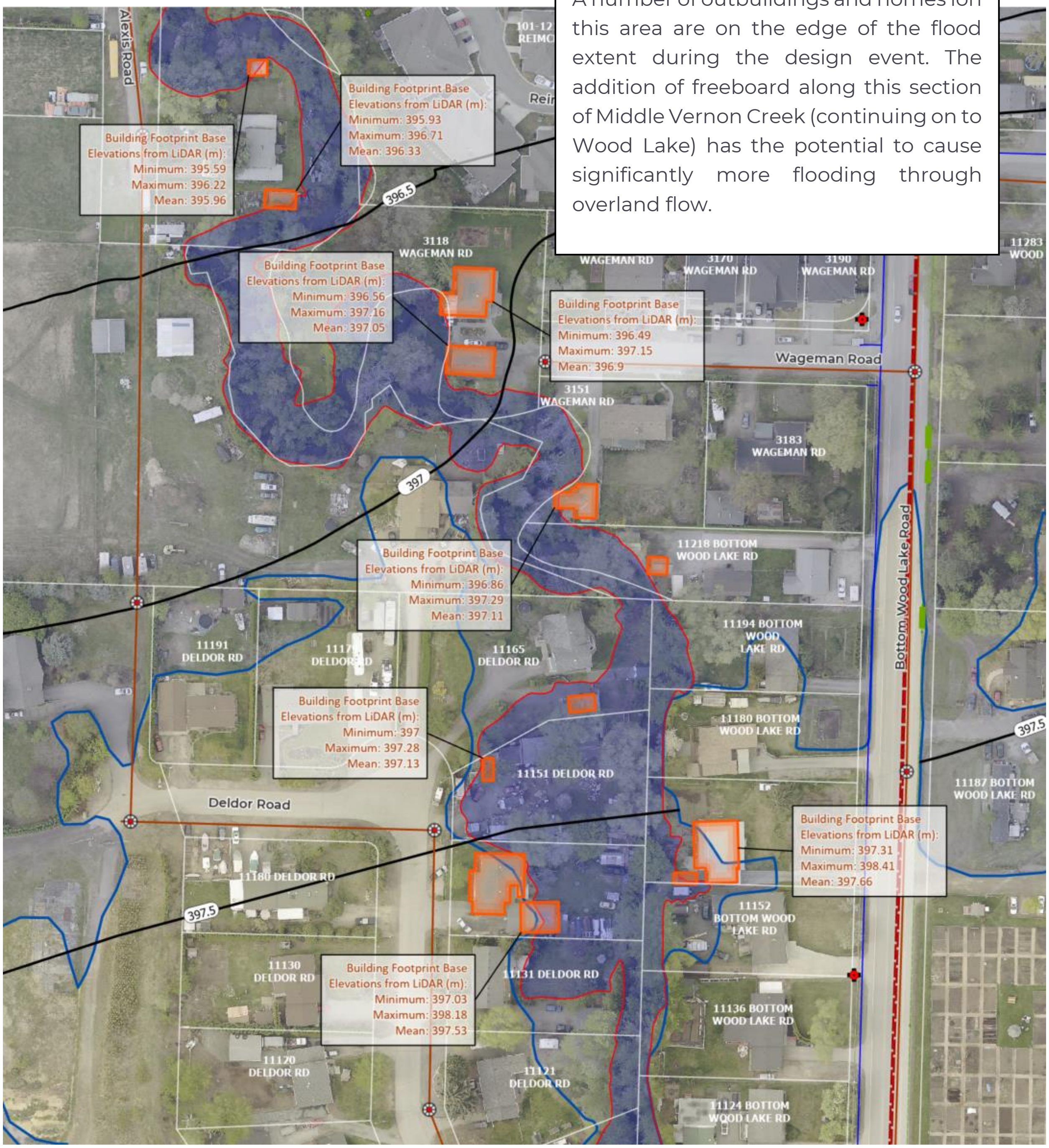
Bottom Wood Lake Road (Deldor Rd to Reimche Rd)

A number of outbuildings and homes ion this area are on the edge of the flood extent during the design event. The addition of freeboard along this section of Middle Vernon Creek (continuing on to Wood Lake) has the potential to cause significantly more flooding through overland flow.



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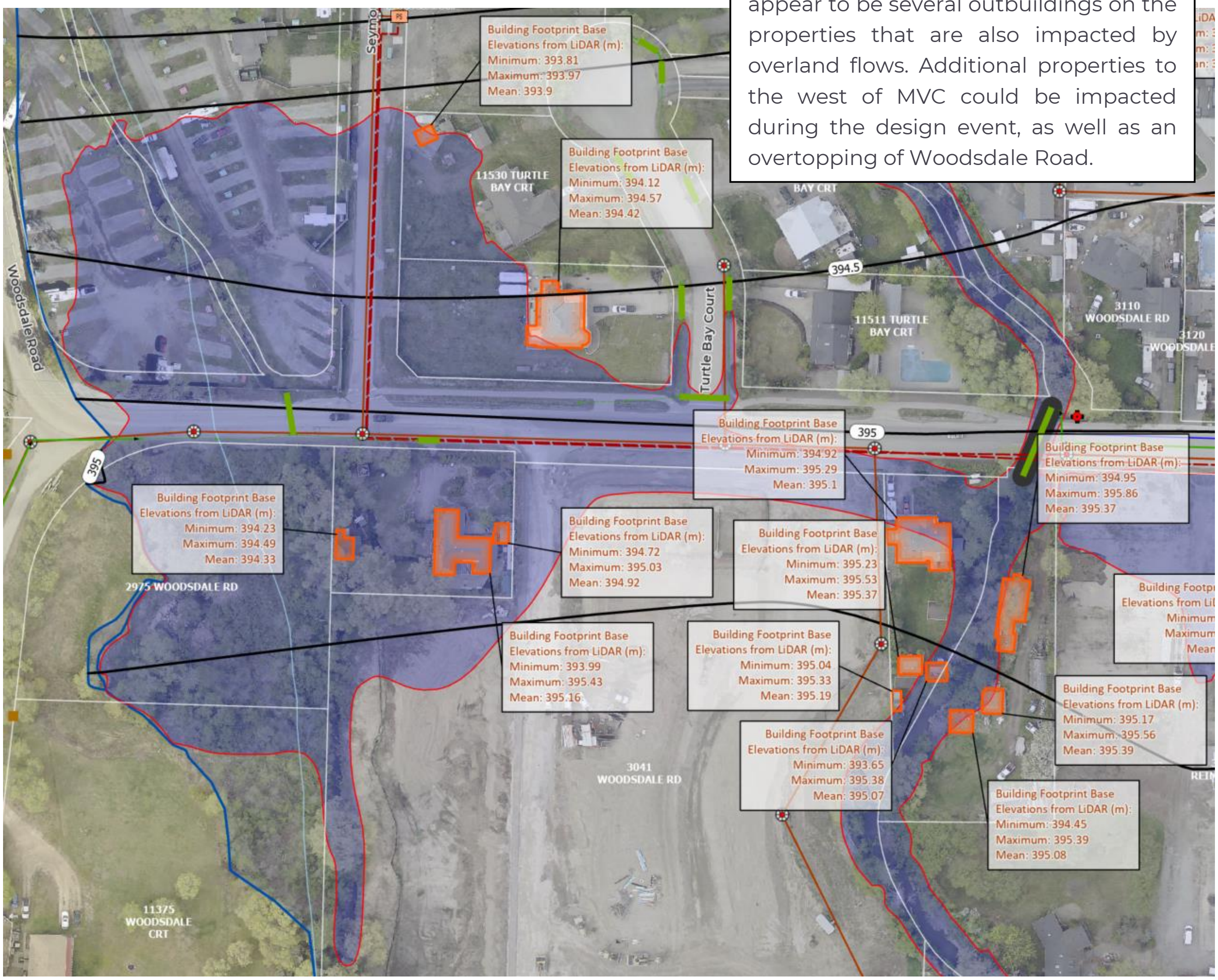
Woodsdale Road, West of MVC

The two properties on either side of MVC on the upstream side of the Woodsdale Road crossing are impacted by inundation and overland flow. There appear to be several outbuildings on the properties that are also impacted by overland flows. Additional properties to the west of MVC could be impacted during the design event, as well as an overtopping of Woodsdale Road.



URBAN SYSTEMS

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Woodsdale Road, East of MVC

Under the design flow event, the east bank of Middle Vernon Creek shows a potential for overtopping, within centimeters of the existing top of bank. Should this occur, a significant number of homes could be impacted as flow travels east, overtops Woodsdale Road, and flows towards Wood Lake. The addition of freeboard in this area greatly increases the number of homes impacted.

Table 11.9 – Impacts to Infrastructure – Buildings - Risk Assessment Results

	Consequence				
Likelihood	Negligible	Minor	Moderate	High	Severe
Very Likely					
Likely		Hydraulic Capacity			
Moderate		Overland Flow	Debris Blockages		
Unlikely			Flood Wave		
Very Unlikely					

Results: Flood Risk Impacts to Infrastructure – Buildings -- Moderate

12.0 NON-STRUCTURAL MITIGATION

Flood risk reduction planning is an ongoing, iterative process which requires careful consideration and community input. Flood risk reduction planning builds on the available information about hazards and valued assets to develop a plan to minimize impact to valued community assets. The following table outlines examples of structural and non-structural mitigation options that are commonly used in BC.

Table 10.5 – Non-Structural vs Structural Mitigation

Non-Structural	Structural

• 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
	  ○ Flood gates
	• Armoring against hazard
	  ○ Riprap banks/dikes
	  ○ Spurs and groynes
	• Conveyance improvements
	  ○ Dredging
	  ○ Dike set-back
	  ○ Removing constrictions (culverts, bridges)
	  ○ Reducing channel roughness
	  ○ Pumps
	• Flood Flows
	  ○ Diversion of flow
	  ○ Upstream Storage
	• Infiltration

12.1 LAND USE PLANNING

The province provides guidelines to help local governments develop and implement land-use management plans and make development decisions for flood hazard areas (MFO, 201*). Development decisions may include limiting land use and density within certain hazard zones and or requiring site specific hazard assessment and mitigation measures for development within hazard zones (i.e. EGBC, 2018). Part 14 of the Local Government Act (Land Title Act 1996) provides local governments with several land-use management tools to promote flood safety. For example, the Act empowers local authorities to establish development permit areas, designate certain lands as floodplains through bylaws, enact zones to promote safety developments in floodplains, and implement measures such as setbacks from the rivers edge preventing disturbance of riparian vegetation.

Any development within the floodplain should only be done following a site-specific flood hazard assessment conducted by a registered professional following the EGBC guidelines for such assessments (EGBC, 2018). Assessments may be waived by regulators if the flood risk and any mitigation measures are well known, for example, development within an existing community behind a regulated dike, with current floodplain mapping. Specific land-use management measures include zoning, development permit areas, setbacks and relocation or managed retreat. There is some overlap in implementation of these measures, and they can be implemented in conjunction with each other.

Development Permit Areas

Development permit areas are another land use management tool to ensure that specific requirements are met within hazard areas. They can specify conditions such as flood construction levels and requirement for a property-specific hazard assessment. These can be used in conjunction with zoning.

Zoning

Some communities have allowed limited development within the floodplain for specific land uses (i.e. agricultural and recreation) or on pre-existing lots that otherwise would not be eligible for development. Such allowances should be reviewed and approved only if deemed safe for use and flood risk is not transferred to other properties. Covenants and occasionally other communications (such as signage or warnings in lease agreements) are typically a condition of such developments to ensure future landowners and users are aware of the risk. Evacuation planning for humans, animals, and potentially goods of value should be considered prior to development.

Setbacks from Waterways

Typically, mitigation measures include setbacks from the top of back, water's edge or dike by a defined amount. Setbacks as a mitigation measure should also consider remnant side channels that may reactivate during high flow events.

12.2 FLOOD PREDICTION

Accurate and timely flood prediction and warning has a significant impact on short-term community preparedness. Adequate flood prediction and warning enables relocation of sensitive assets and vulnerable people, effective evacuation if required, and implementation of any temporary flood barriers. Flood prediction requires robust scientific understanding, accurate, detailed measurements of snowfall and precipitation, robust weather forecasting and clear dam operation rules. Flood warning must be clear, consistent, and informative.

12.3 MONITORING AND MAINTENANCE

Many of the tributary flood conditions may be exacerbated by blockages of crossings. Monitoring and subsequent removal of debris and sediment from these culverts and their entrances should be done routinely throughout the high flow season to ensure flow is not further restricted at these locations. The impact of culvert blockages on Middle Vernon Creek is well known and documented. Referring to the mapping in Section 10, the impact of a blocked culvert at Woodsdale Road, for example, could have significant consequences. In addition, any dikes or other flood protection infrastructure should be inspected annually and maintained as needed. Operation, maintenance, and surveillance documents should exist, be readily available, and reviewed periodically for key flood mitigation infrastructure.

12.4 EMERGENCY RESPONSE PLANNING

Emergency Response Planning is critical to identify what actions need to occur during an emergency to ensure public safety. This includes specific personal, roles, and implementation sequencing (timing of the actions). The flood risk mapping can help guide the emergency response plan in identifying areas at risk of flooding and high ground safe areas. Of particular interest should be access routes, emergency center locations, and large social spaces such as schools and libraries. The hazard mapping may be used to identify likely high velocity and depth areas to avoid.

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

- Identify key locations to monitor flows and corresponding thresholds to trigger emergency plan actions.
- Pre-plan locations for temporary community flood barriers.
- Pre-plan locations to monitor for culvert and bridge blockages and have plan to remove debris when required.
- Define evacuation routes and develop an evacuation plan based on updated flood hazard mapping.

12.5 FLOOD RISK EDUCATION

A provincial review of floods and wildfires (BCFWR, 2018) identified dissemination of awareness and education as the one of the of the key pillars of a complete flood mitigation plan. Flood mapping is identified as the first step of awareness of the hazard (NRC/PCS, 2018). Despite preparation of the floodplain map, distribution and education should shortly follow.

Education about flood risk can help inform property owners to help them be more prepared. Flood risk education can include the following:

- Present the new flood mapping and updated understanding of the current and future flood hazard (i.e. floodplain FCL, depth, velocity, or hazard maps) to residents.
- Identify aspects of flood risk reduction that are an individual's responsibility and/or governmental responsibilities.
- List actions that individuals can take to reduce flood risk, such as flood proofing or raising homes, and installing sewer backflow valves.
- List what individuals can do to prepare for imminent floods, including sand bagging and preparing for potential evacuation.
- Describe how to prepare for and be aware of the timing and seasonality of floods.
- Provide guidance / links on where to find sources for information on floods and flood preparedness.
- Be familiar with community resources with respect to flooding (such as information from Okanagan Basin Water Board, BC Flood Forecast Center and District website).
- Provide guidance / links on where to find real time forecasts of water levels, water flows, and what they mean.

- Share local evacuation routes, notifications, procedures, and high ground locations.
- Communicate what the District is doing to reduce community flood risk.

Community outreach can take the form of websites, handouts, news articles, community meetings, and poster and booth presentations at community events. Some communities hold spring sandbag competitions to build awareness of the upcoming flood season).

12.6 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 key DLC personnel and community volunteers
- Plans to access designated financial resources
- Strategy and tools to track expenditures for cost recovery
- Assistance agreements with neighboring communities
- Pre-prepared designs of structural mitigation to apply for funding
- Disposal plans for debris
- Identification of consultants and contractors to support engineering and construction needs

12.7 FLOOD FLOW REDUCTION

Upstream storage can be used to attenuate flood flows. There are numerous dams within the study area with sizeable reservoirs (lakes) which are operated for the purposes of flood reduction as well as many other priorities. Dam operation can mitigate downstream flooding by prolonging and subsequently reducing the peak flow downstream. In order to also reduce upstream flooding (i.e. lake shoreline flooding) the operator may need to lower lake levels in anticipation of high inflows. Operation of the dams will continue to change as the understanding of climate change evolves and other agreements related to the operation of the dam are updated. Due to the uncertainty regarding timing and magnitude of future flows under a changed climate, dam operators will be increasingly challenged to determine when to lower upstream lake levels, which may reduce their effectiveness for flood mitigation in the future.

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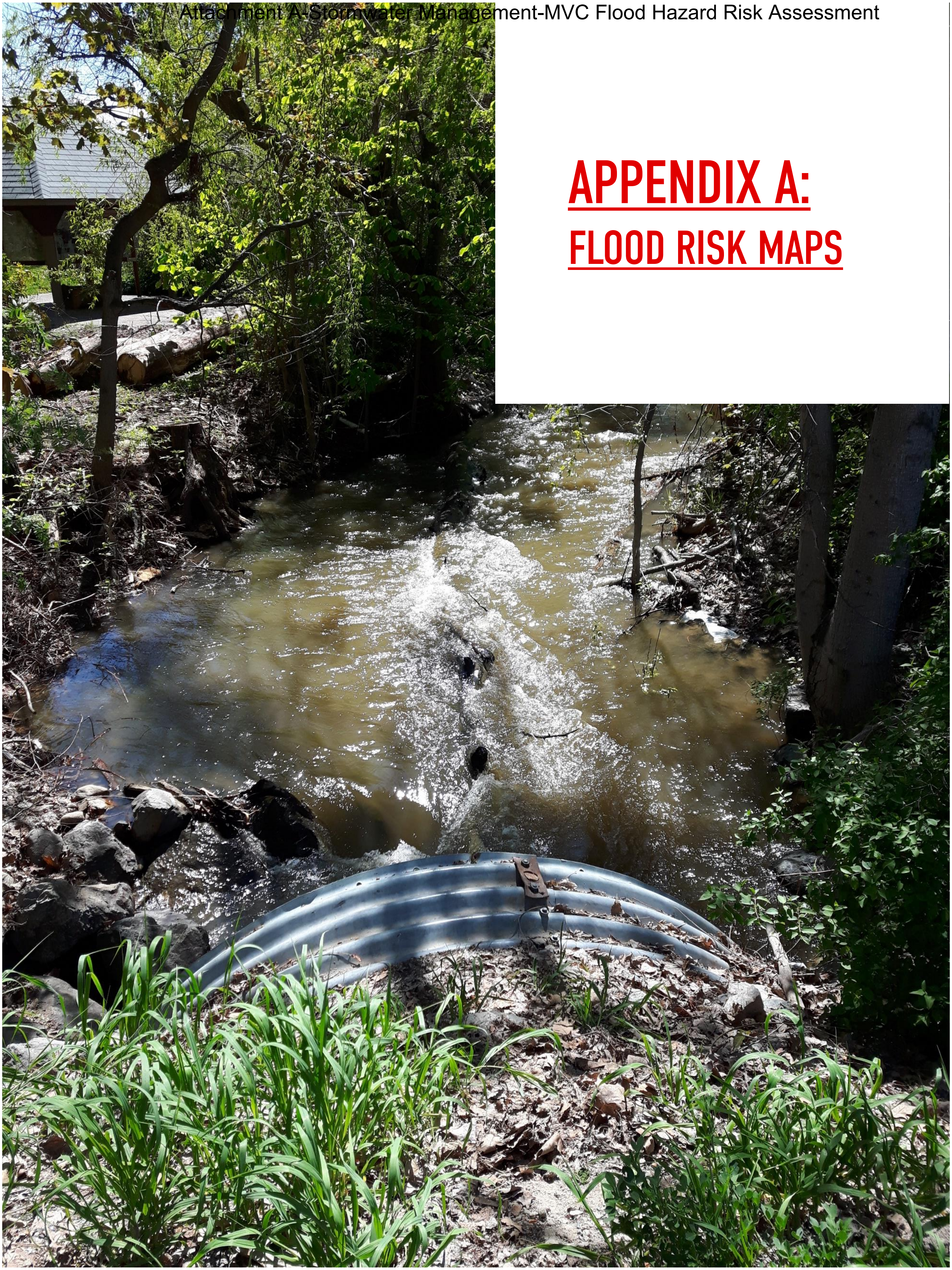
Province of British Columbia, BC Map Services, iMapBC. https://maps.gov.bc.ca/ess/hm/imap4m

APPENDIX A:

FLOOD RISK MAPS



LIMITATIONS OF FLOODPLAIN MAPS:

1. The flood hazard maps are based on river surveys conducted in 2021 and 2022, and LiDAR surveys from 2018. The maps depict flood conditions at the time of the surveys. Changes to the channel, floodplain, or climate will affect the flood levels and render the site-specific map information obsolete.
2. Flood hazard maps are administrative tools that show the minimum designated flood elevation and floodplain boundaries. Flooding may occur outside the designated boundaries. Urban Systems Ltd. (USL) do not assume any liability by reason of the designation or failure to designate areas on the map.
3. Flood hazard maps do not provide information on site-specific hazards such as land erosion, channel avulsion, or other sudden shifts in the water course.
4. Other sources of water, roads, railways or other barriers can restrict water flow and affect flood levels locally. Channel obstructions, local storm water inflows, groundwater or other land drainage can cause flood levels to exceed those indicated on the map. Land adjacent to a floodplain may be subjected to flooding from tributary streams that are not indicated on the maps.
5. The accuracy of the location of a floodplain boundary as shown on this map is limited by the accuracy of the LiDAR data used for generating base contour mapping.
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NOTES TO USERS:

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b) 2-year storm for contributing low elevation catchments and storm infrastructure inflow.
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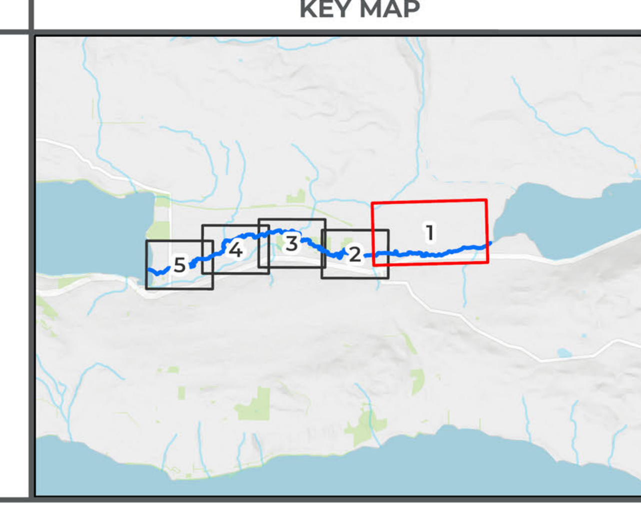
3. Freshet flood levels were computed using a 1D hydraulic model in GeoHEC-RAS, version 4.1.0.2425.
4. Flood inundation boundaries are delineated based on the Designated Flood with 0.3m of freeboard added.
5. The flood boundaries are not established on the ground by legal survey and are not delineated for side streams, local drainage or storm water runoff.
6. The required setback of the buildings from natural boundaries or water courses is not shown.

LEGEND

- Administrative Boundary
- Parcel Boundary
- Park
- Building
- Flood Limit
- Flood Limit +0.3m freeboard
- Water Surface Elevation Isoline (Including freeboard)
- Administrative Boundary
- Study Limits
- 1D Modeled Cross Sections
- Modeled Roadway Crossings

KEY MAP



The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

Data Sources:

- Data provided by District of Lake Country, DataBC and Urban Systems Ltd.
- Base map provided by ESRI

Project #:	1577.0119.01
Date:	2023 / 5 / 25

Coordinate System:
NAD 1983 UTM Zone 11N
Vertical Datum CGVD2013
All elevations shown in meters

Author:	AK
Checked:	BP
Status:	DRAFT
Revision:	A

Middle Vernon Creek Flood Hazard Study

MAP 1 of 5

Scale: 1:2,000

0 70 140 210 Meters

(When plotted at 24"x36")

LAKE COUNTRY
Life. The Okanagan Way.

URBAN SYSTEMS

LIMITATIONS OF FLOODPLAIN MAPS:
1. The flood hazard maps are based on river surveys conducted in 2021 and 2022, and LiDAR surveys from 2018. The maps depict flood conditions at the time of the surveys. Changes to the channel, floodplain, or climate will affect the flood levels and render the site-specific map information obsolete. 2. Flood hazard maps are administrative tools that show the minimum designated flood elevation and floodplain boundaries. Flooding may occur outside the designated boundaries. Urban Systems Ltd. (USL) do not assume any liability by reason of the designation or failure to designate areas on the map. 3. Flood hazard maps do not provide information on site-specific hazards such as land erosion, channel avulsion, or other sudden shifts in the water course. 4. Other sources of water, roads, railways or other barriers can restrict water flow and affect flood levels locally. Channel obstructions, local storm water inflows, groundwater or other land drainage can cause flood levels to exceed those indicated on the map. Land adjacent to a floodplain may be subjected to flooding from tributary streams that are not indicated on the maps. 5. The accuracy of the location of a floodplain boundary as shown on this map is limited by the accuracy of the LiDAR data used for generating base contour mapping. 6. Professional assistance and detailed site-specific engineering analysis are required to address any of the above issues.

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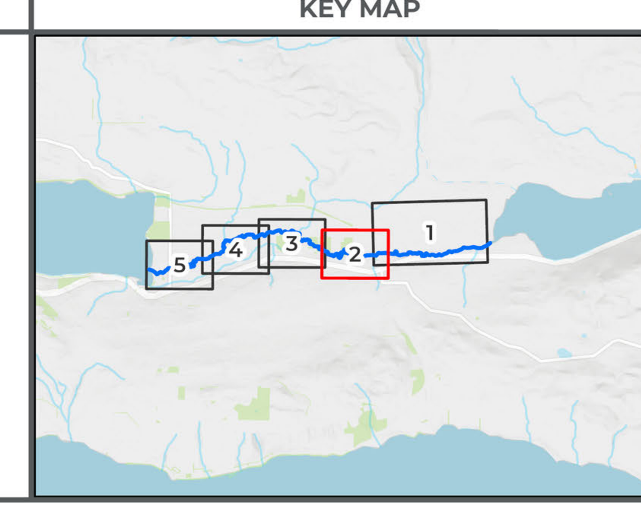
5. The flood boundaries are not established on the ground by legal survey and are not delineated for side streams, local drainage or storm water runoff.
6. The required setback of the buildings from natural boundaries or water courses is not shown.

LEGEND

- Administrative Boundary
- Parcel Boundary
- Park
- Building
- Flood Limit
- Flood Limit +0.3m freeboard
- Water Surface Elevation Isoline (Including freeboard)
- Administrative Boundary
- Study Limits
- 1D Modeled Cross Sections
- Modeled Roadway Crossings

KEY MAP



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Data Sources:

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- Base map provided by ESRI

Project #: 1577.0119.01
Date: 2023 / 5 / 25
Coordinate System:
NAD 1983 UTM Zone 11N
Vertical Datum CGVD2013
All elevations shown in meters

Author: AK
Checked: BP
Status: DRAFT
Revision: A

Middle Vernon Creek Flood Hazard Study

MAP 2 of 5

Scale: 1:1,500

0 50 100 150
Meters

(When plotted at 24"x36")

LAKE COUNTRY
Life. The Okanagan Way.

URBAN SYSTEMS

LIMITATIONS OF FLOODPLAIN MAPS:

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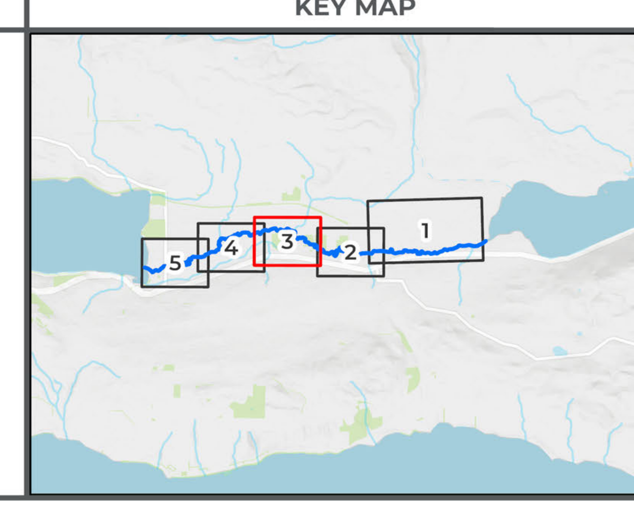
LEGEND

- Administrative Boundary
- Parcel Boundary
- Park
- Building
- Flood Limit
- Flood Limit +0.3m freeboard
- Water Surface Elevation Isoline (Including freeboard)
- 1D Modeled Cross Sections
- Modeled Roadway Crossings

KEY MAP



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Data Sources:

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- Base map provided by ESRI

Project #: 1577.0119.01
Date: 2023 / 5 / 24

Coordinate System:
NAD 1983 UTM Zone 11N
Vertical Datum CGVD2013
All elevations shown in meters

Author: AK
Checked: BP
Status: DRAFT
Revision: A

Middle Vernon Creek Flood Hazard Study

MAP 3 of 5

Scale: 1:1,500

0 50 100 150
Meters

(When plotted at 24"x36")

LAKE COUNTRY
Life. The Okanagan Way.

URBAN SYSTEMS

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Last updated by akhliestkova on May 24, 2023 at 4:08 PM
Last exported by akhliestkova on May 24, 2023 4:06 PM

LIMITATIONS OF FLOODPLAIN MAPS:

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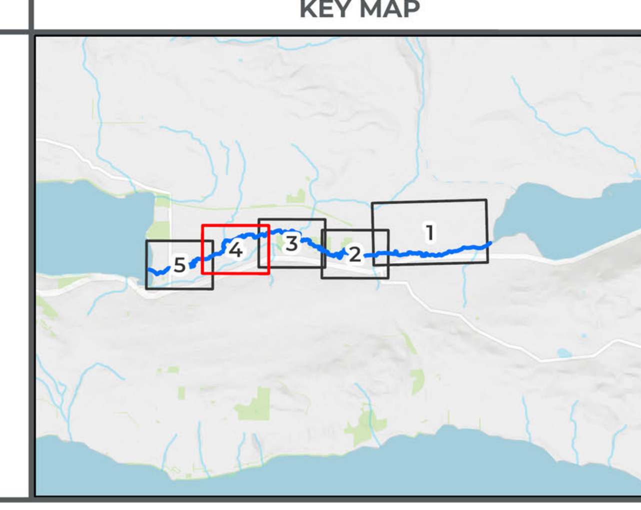
LEGEND

- Administrative Boundary
- Parcel Boundary
- Park
- Building
- Flood Limit
- Flood Limit +0.3m freeboard (Including freeboard)
- Water Surface Elevation Isoline (Including freeboard)
- 1D Modeled Cross Sections
- Modeled Roadway Crossings

KEY MAP



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- Base map provided by ESRI

Project #: 1577.0119.01
Date: 2023 / 5 / 24
Coordinate System:
NAD 1983 UTM Zone 11N
Vertical Datum CGVD2013
All elevations shown in meters

Author: AK
Checked: BP
Status: DRAFT
Revision: A

Middle Vernon Creek
Flood Hazard Study

MAP 4 of 5

N E S W

Scale: 1:1,500

0 50 100 150
Meters

(When plotted at 24"x36")

LAKE COUNTRY
Life. The Okanagan Way.

URBAN SYSTEMS

U:\Projects_KEL\1577\0119\01\D-Design\GIS\Projects\Pro_Projects\FloodplainMapping_1577.0119.01 RevB.aprx\Middle Vernon Creek Official Floodplain Mapping Figures

Last updated by akhliestkova on May 24, 2023 at 3:37 PM
Last exported by akhliestkova on May 24, 2023 3:36 PM

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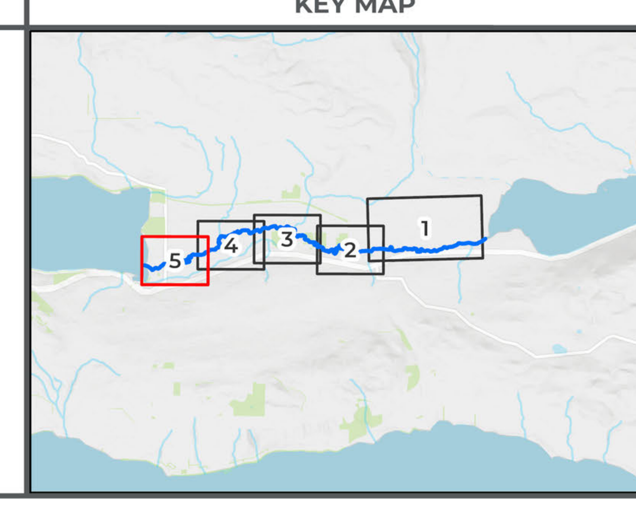
LEGEND
Administrative Boundary
Parcel Boundary
Park
Building
Flood Limit
Flood Limit +0.3m freeboard
Lake Flood Construction Level (FCL) Zone (Inundation Extent)
Water Surface Elevation Isoline (Including freeboard)
Study Limits
1D Modeled Cross Sections
Modeled Roadway Crossings

KEY MAP



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Project #:	1577.0119.01
Date:	2023 / 5 / 24
Coordinate System:	NAD 1983 UTM Zone 11N Vertical Datum CGVD2013 All elevations shown in meters
Author:	AK
Checked:	BP
Status:	DRAFT
Revision:	A

Middle Vernon Creek
Flood Hazard Study

MAP 5 of 5

Scale: 1:1,500

0 50 100 150
Meters

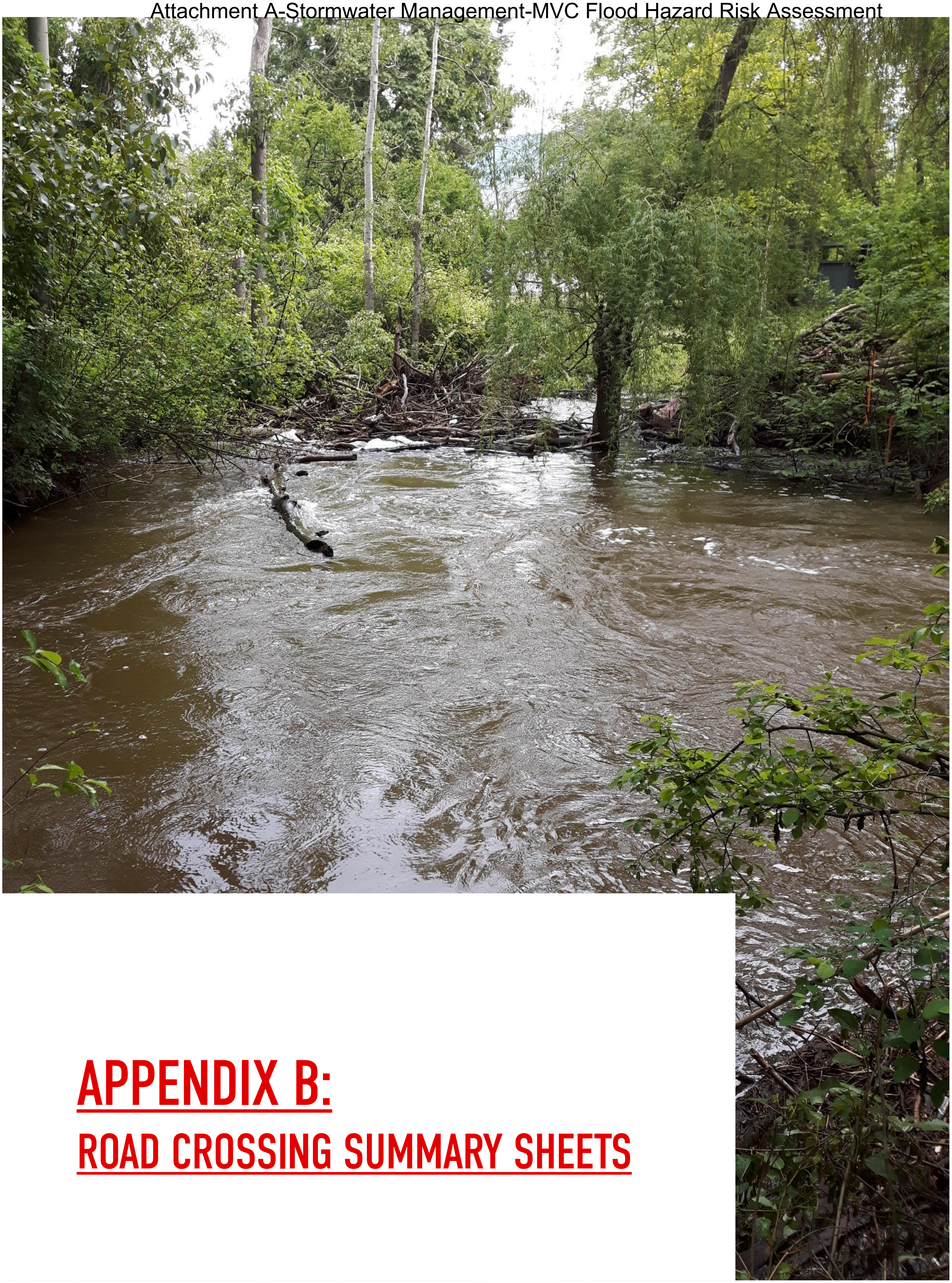
(When plotted at 24"x36")

LAKE COUNTRY
Life. The Okanagan Way.

URBAN SYSTEMS

U:\Projects_KEL\1577\0119\01\D-Design\GIS\Projects\Pro_Projects\FloodplainMapping_1577.0119.01 RevB.aprx\Middle Vernon Creek Official Floodplain Mapping Figures

Last updated by akhliestkova on May 24, 2023 at 3:16 PM
Last exported by akhliestkova on May 24, 2023 3:15 PM

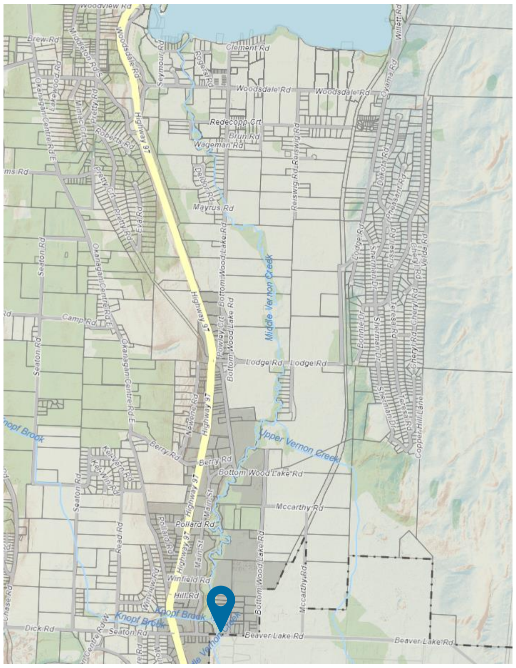


APPENDIX B:

ROAD CROSSING SUMMARY SHEETS

LAKE COUNTRY
Life. The Okanagan Way.

MIDDLE VERNON CREEK
BEAVER LAKE ROAD



CULVERT TYPE	• CLOSED BOTTOM ARCH
MATERIAL	• CORRUGATED STEEL PIPE (CSP)
INLET/OUTLET TREATMENT	• RIPRAP
EROSION PROTECTION	• RIPRAP
SIZE	• 3.0 m WIDE X 2.0 m HIGH
UPSTREAM INVERT	• 421.34 m
DOWNSTREAM INVERT	• 421.14 m
MAXIMUM CAPACITY (q)	• 9.21 m^3/s
Q200 UPSTREAM WSE	• 423.20 m
Q200 DOWNSTREAM WSE	• 422.64 m
Q200 FLOW (Q)	• 14.37 m^3/s
Q200 Q/q	• 156%
Q20 UPSTREAM WSE	• 422.83 m
Q20 DOWNSTREAM WSE	• 422.41 m
Q20 (Q)	• 10.43 m^3/s
Q20 Q/q	• 113%
FLOOD RISK SCORE	LOW - MODERATE - **HIGH**


Beaver Lake Road Outlet

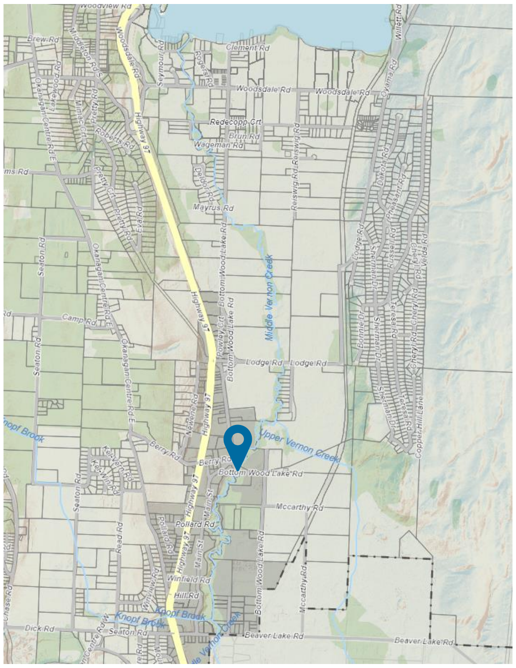

Beaver Lake Road Inlet


Beaver Lake Road Downstream


Beaver Lake Road Upstream

Attachment A - Stormwater Management-MVC Flood Hazard Risk Assessment

MIDDLE VERNON CREEK
SWALWELL CULVERT



CULVERT TYPE	• OPEN BOTTOM ARCH CULVERT
MATERIAL	• BOLTED STEEL
INLET/OUTLET TREATMENT	• REINFORCED CONCRETE HEADWALLS
EROSION PROTECTION	• RIPRAP EROSION PROTECTION
DOWNSTREAM SIZE	• D/S – 8.0 m WIDE X 2.8 m HIGH
UPSTREAM SIZE	• U/S - 8.0 m WIDE X 2.0 m HIGH
UPSTREAM INVERT	• 410.88 m
DOWNSTREAM INVERT	• 410.22 m
MAXIMUM CAPACITY (q)	• 28.11 m^3/s
Q200 UPSTREAM WSE	• 412.30 m
Q200 DOWNSTREAM WSE	• 412.22 m
Q200 FLOW (Q)	• 14.38 m^3/s
Q200 Q/q	• 51%
Q20 UPSTREAM WSE	• 412.12 m
Q20 DOWNSTREAM WSE	• 412.13 m
Q20 (Q)	• 10.44 m^3/s
Q20 Q/q	• 37%
FLOOD RISK SCORE	LOW - MODERATE - HIGH

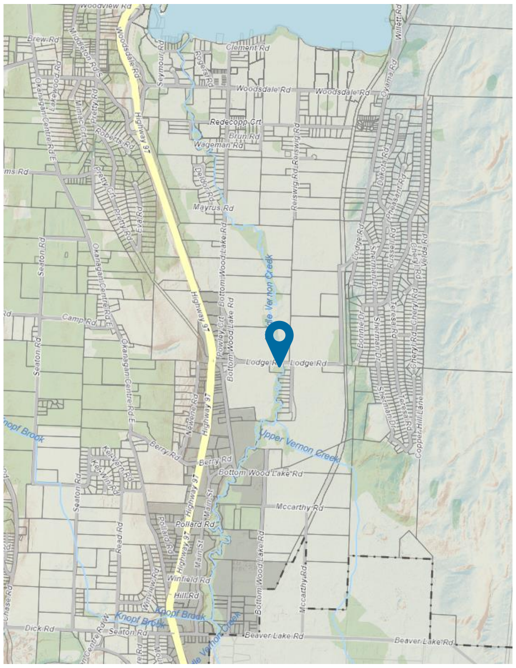

Bottom Wood Lake Road Outlet


Bottom Wood Lake Road Inlet


Bottom Wood Lake Road Downstream


Bottom Wood Lake Road Upstream

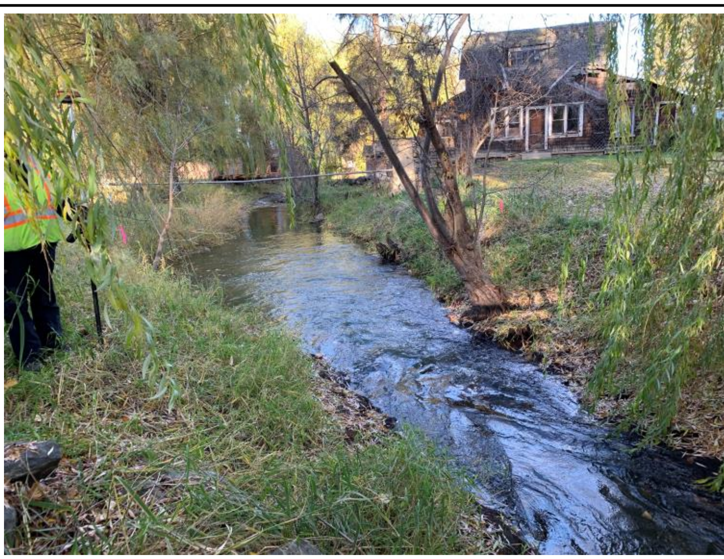
MIDDLE VERNON CREEK
LODGE ROAD CROSSING



CULVERT TYPE	• CLEAR SPAN BRIDGE
MATERIAL	• REINFORCED CONCRETE
INLET/OUTLET TREATMENT	• BRIDGE ABUTMENTS
EROSION PROTECTION	• RIPRAP
BOTTOM OF BRIDGE DECK ELEV.	• 406.33 m
BRIDGE SPAN	• 12.5 m
UPSTREAM INVERT	• 404.33 m
DOWNSTREAM INVERT	• 404.09 m
MAXIMUM CAPACITY (q)	• 22.85 m^3/s
Q200 UPSTREAM WSE	• 406.05 m
Q200 DOWNSTREAM WSE	• 405.88 m
Q200 REMAINING FREEBOARD	• 0.28 m (measured from upstream WSE to bridge low chord)
Q200 FLOW (Q)	• 14.88 m^3/s
Q200 Q/q	• 73%
Q20 UPSTREAM WSE	• 405.86 m
Q20 DOWNSTREAM WSE	• 405.73 m
Q20 REMAINING FREEBOARD	• 0.47 m (measured from upstream WSE to bridge low chord)
Q20 FLOW (Q)	• 10.94 m^3/s
Q20 Q/q	• 53%
FLOOD RISK SCORE	**LOW** - MODERATE - HIGH

Lodge Road Outlet

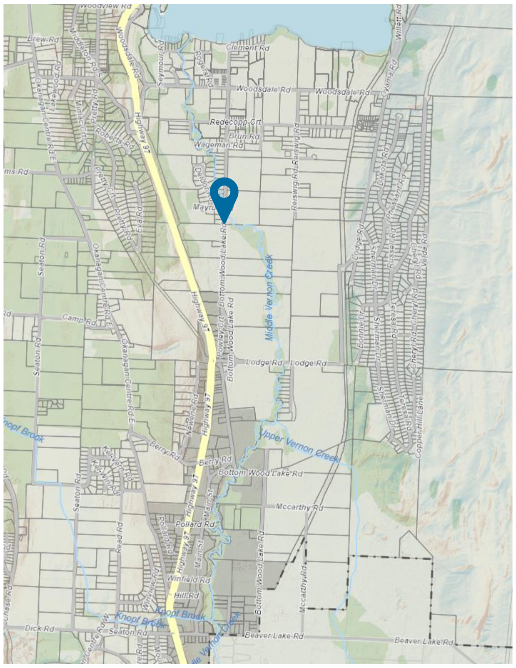
Lodge Road Inlet



Lodge Road Downstream

Lodge Road Upstream

MIDDLE VERNON CREEK
BOTTOM WOOD LAKE ROAD

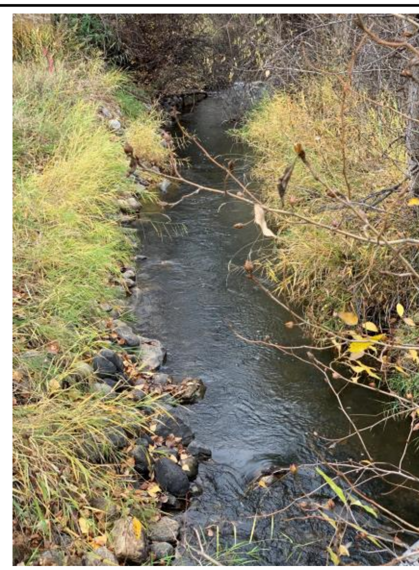


CULVERT TYPE	CLOSED BOTTOM ARCH
MATERIAL	CORREGATED STEEL PIPE
INLET/OUTLET TREATMENT	RIPRAP
EROSION PROTECTION	RIPRAP
SIZE	3.0 m WIDE x 2.0 m HIGH
UPSTREAM INVERT	396.16 m
DOWNSTREAM INVERT	396.10 m
MAXIMUM CAPACITY (q)	7.55 m^3/s
Q200 UPSTREAM WSE	398.08 m
Q200 DOWNSTREAM WSE	398.02 m
Q200 FLOW (Q)	14.88m^3/s
Q200 Q/q	197%
Q20 UPSTREAM WSE	398.08 m
Q20 DOWNSTREAM WSE	398.02 m
Q20 (Q)	10.94m^3/s
Q20 Q/q	145%
FLOOD RISK SCORE	LOW - MODERATE - HIGH

Bottom Wood Lake Road Outlet

Bottom Wood Lake Road Inlet

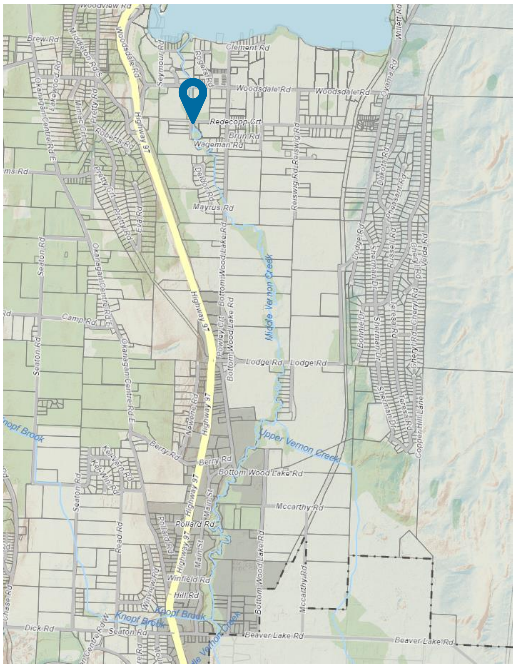
Bottom Wood Lake Road Downstream



Bottom Wood Lake Road Upstream

LAKE COUNTRY
Life. The Okanagan Way.

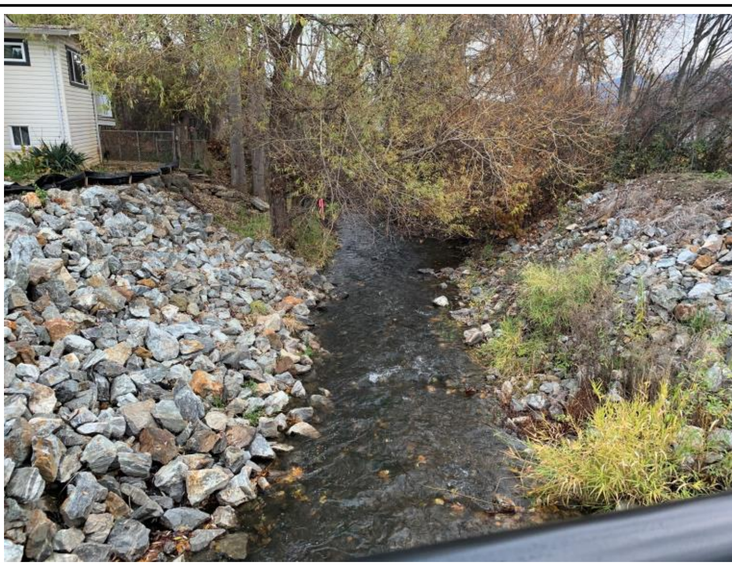
MIDDLE VERNON CREEK
REIMCHE ROAD CROSSING



CULVERT TYPE	• OPEN BOTTOM ARCH
MATERIAL	• BOLTED STEEL PLATE
INLET/OUTLET TREATMENT	• REINFORCED CONCRETE
EROSION PROTECTION	• RIPRAP
DOWNSTREAM SIZE	• 1.89 m HIGH X 5.34 m WIDE
UPSTREAM SIZE	• 1.59 m HIGH X 5.29 m WIDE
UPSTREAM INVERT	• 393.55 m
DOWNSTREAM INVERT	• 393.43 m
MAXIMUM CAPACITY (q)	• 8.05 m^3/s
Q200 UPSTREAM WSE	• 395.14 m
Q200 DOWNSTREAM WSE	• 395.02 m
Q200 FLOW (Q)	• 14.88 m^3/s
Q200 Q/q	• 185%
Q20 UPSTREAM WSE	• 395.14 m
Q20 DOWNSTREAM WSE	• 395.02 m
Q20 (Q)	• 10.94 m^3/s
Q20 Q/q	• 136%
FLOOD RISK SCORE	LOW - MODERATE - HIGH

Reimche Road Outlet

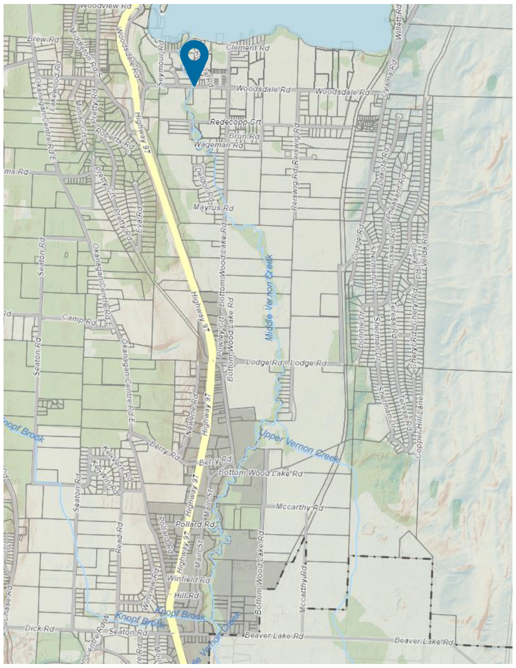
Reimche Road Inlet



Reimche Road Downstream

Reimche Road Upstream

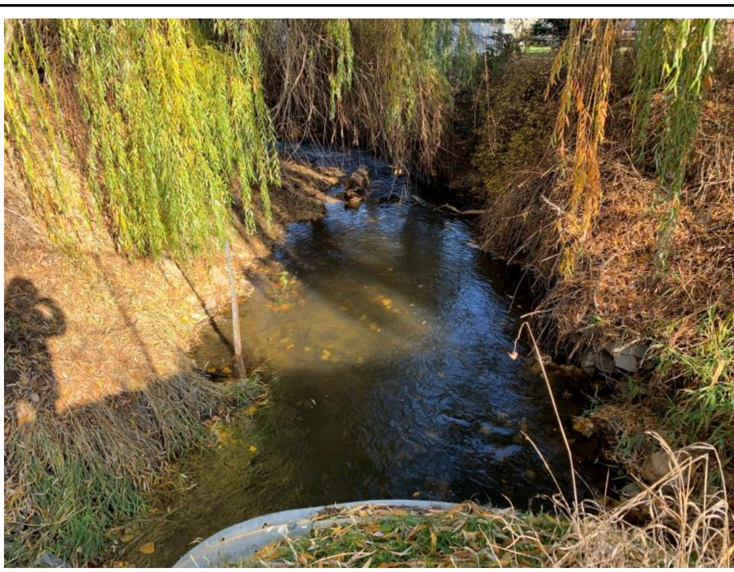
MIDDLE VERNON CREEK
WOODSDALE CROSSING



CULVERT TYPE	CLOSED BOTTOM ARCH
MATERIAL	CORRUGATED STEEL PIPE
INLET/OUTLET TREATMENT	LOCK BLOCK AND RIPRAP
EROSION PROTECTION	RIPRAP
SIZE	3.0 m WIDE BY 2.1 m HIGH
UPSTREAM INVERT	392.55 m
DOWNSTREAM INVERT	392.21 m
MAXIMUM CAPACITY (q)	9.99 m^3/s
Q200 UPSTREAM WSE	394.53 m
Q200 DOWNSTREAM WSE	394.26 m
Q200 FLOW (Q)	14.88 m^3/s
Q200 Q/q	149%
Q20 UPSTREAM WSE	394.02 m
Q20 DOWNSTREAM WSE	393.96 m
Q20 (Q)	10.94 m^3/s
Q20 Q/q	110%
FLOOD RISK SCORE	LOW - MODERATE - **HIGH**

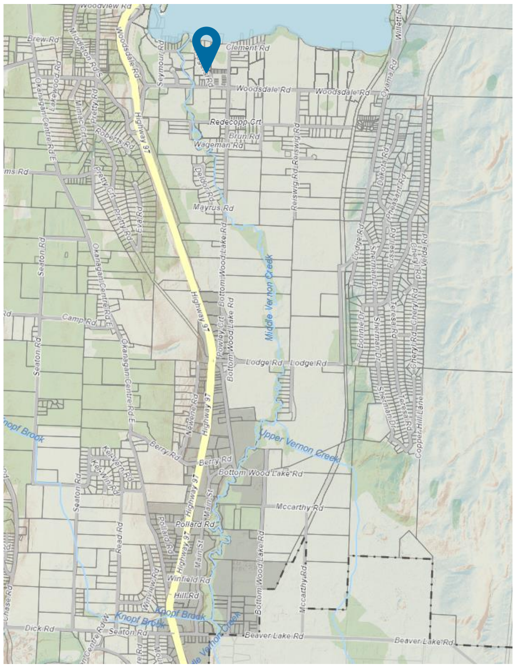

Woodsdale Road Outlet


Woodsdale Road Inlet


Woodsdale Road Downstream


Woodsdale Road Upstream

MIDDLE VERNON CREEK
TURTLE BAY COURT

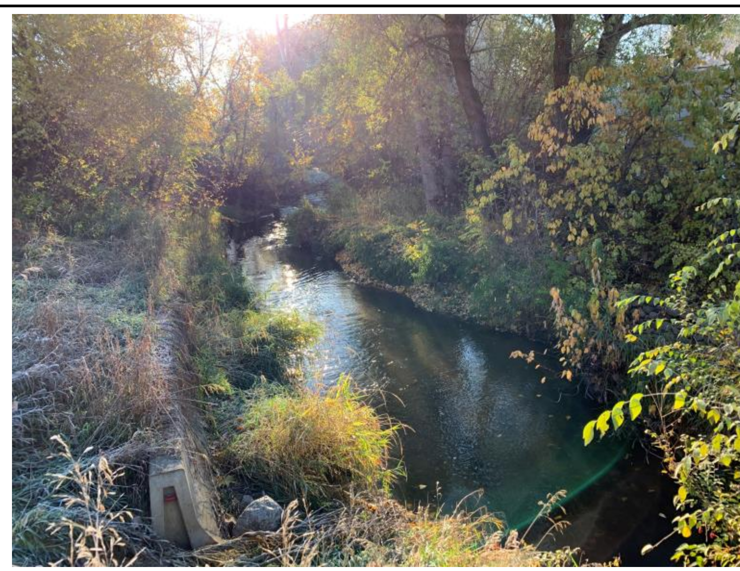


CULVERT TYPE	CLOSED BOTTOM ARCH
MATERIAL	CORRUGATED STEEL PIPE
INLET/OUTLET TREATMENT	LOCK BLOCK AND RIPRAP
EROSION PROTECTION	RIPRAP
SIZE	3.5 m WIDE BY 2.0 m HIGH
UPSTREAM INVERT	391.45 m
DOWNSTREAM INVERT	391.40 m
MAXIMUM CAPACITY (q)	9.24 m^3/s
Q200 UPSTREAM WSE	393.45 m
Q200 DOWNSTREAM WSE	393.29 m
Q200 FLOW (Q)	14.88 m^3/s
Q200 Q/q	161%
Q20 UPSTREAM WSE	393.30 m
Q20 DOWNSTREAM WSE	393.16 m
Q20 (Q)	10.94 m^3/s
Q20 Q/q	118%
FLOOD RISK SCORE	LOW - MODERATE - **HIGH**

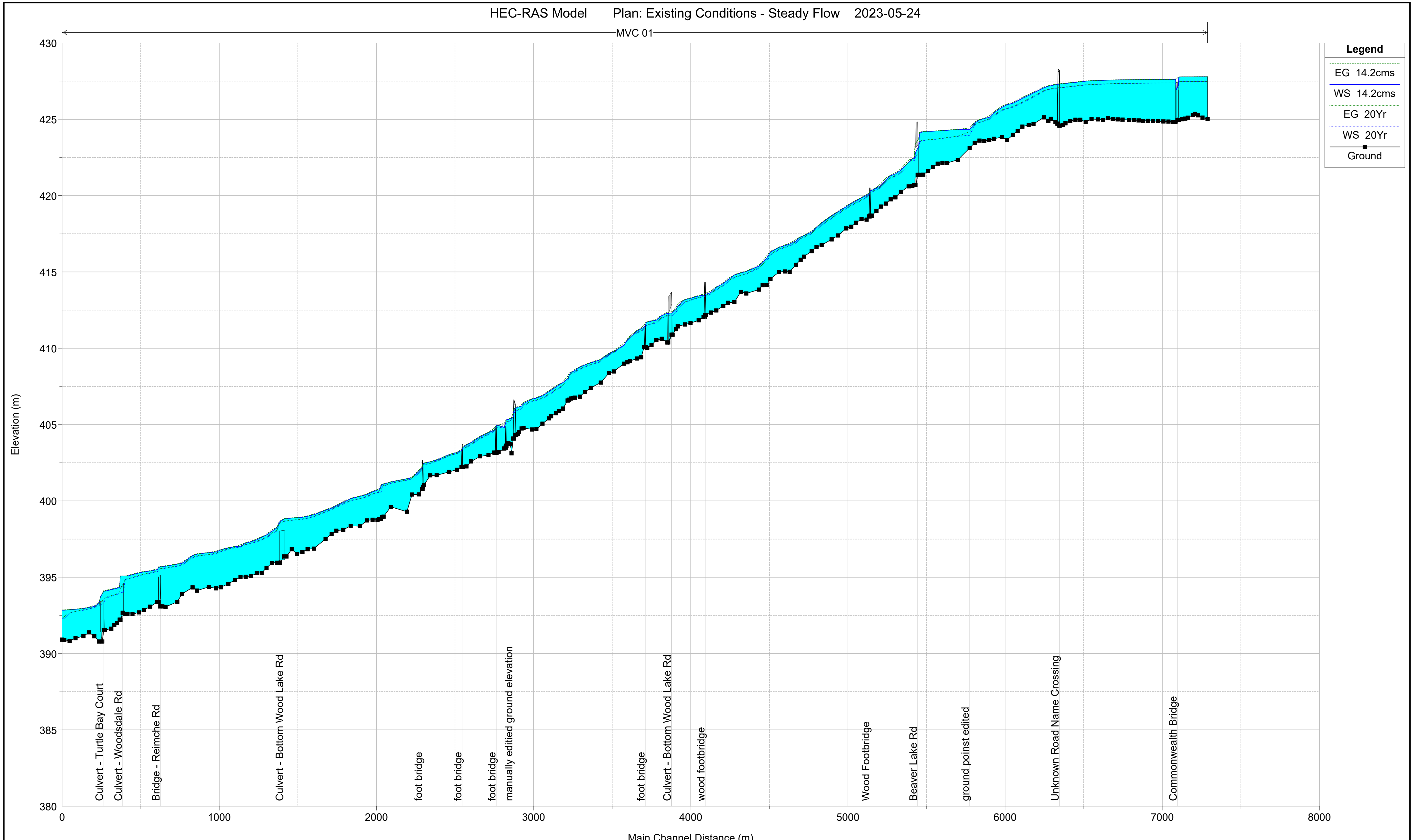
Turtle Bay Court Outlet

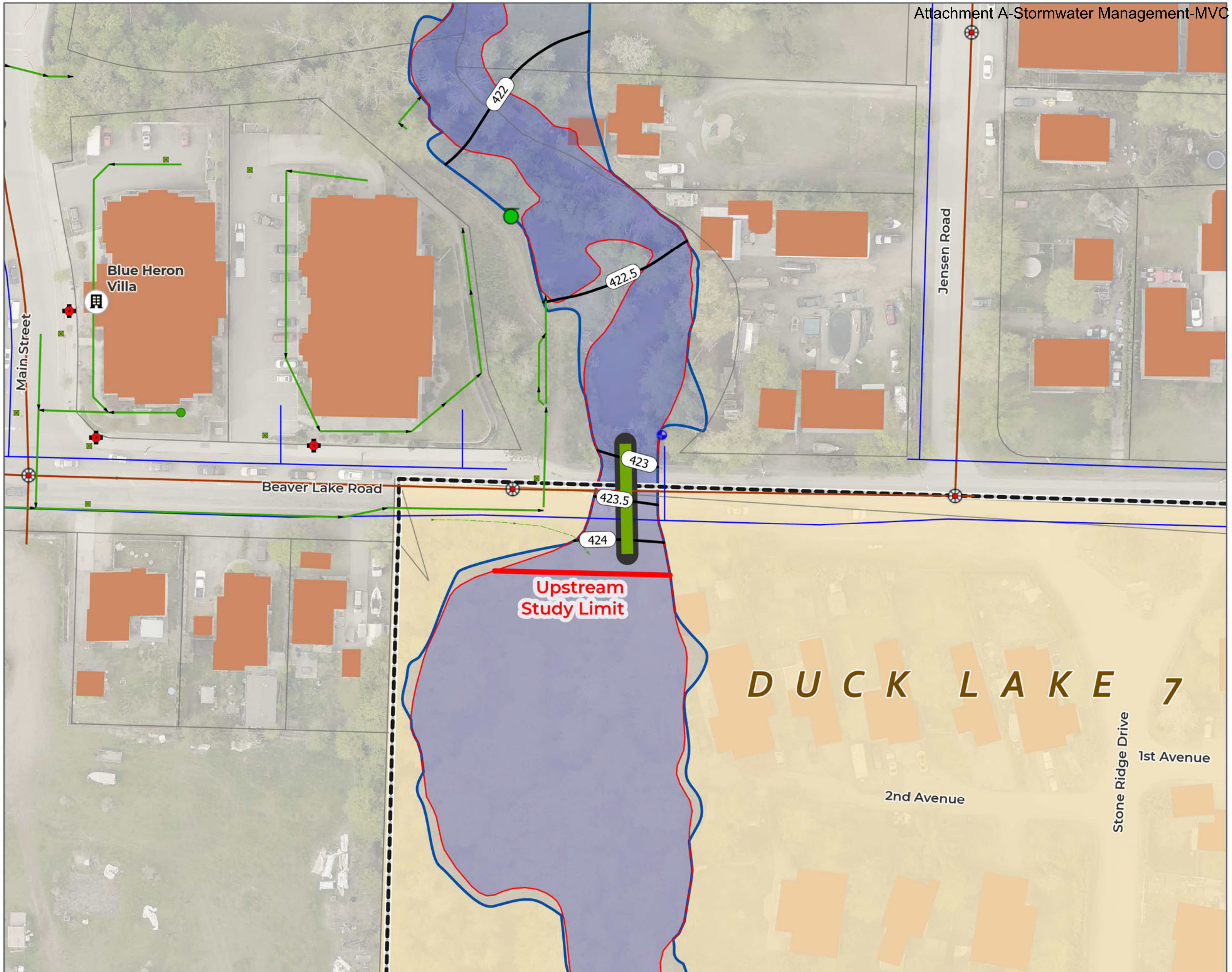
Turtle Bay Court Inlet

Turtle Bay Court Downstream



Turtle Bay Court Upstream


HEC-RAS Model Plan: Existing Conditions - Steady Flow 2023-05-24
MVC 01
Legend
EG 14.2cms
WS 14.2cms
EG 20Yr
WS 20Yr
Ground
Elevation (m)
Main Channel Distance (m)
430
425
420
415
410
405
400
395
390
385
380
0
1000
2000
3000
4000
5000
6000
7000
8000
Culvert - Turtle Bay Court
Culvert - Woodsdale Rd
Bridge - Reimche Rd
Culvert - Bottom Wood Lake Rd
foot bridge
foot bridge
foot bridge
manually editied ground elevation
foot bridge
Culvert - Bottom Wood Lake Rd
wood footbridge
Wood Footbridge
Beaver Lake Rd
ground poinst edited
Unknown Road Name Crossing
Commonwealth Bridge



LAKE COUNTRY
Life. The Okanagan Way.

Middle Vernon Creek Flood Hazard Study

Beaver Lake Road Culvert

Legend

- Modelled Crossings
- Flood Limit
- Flood Limit +0.3m freeboard
- Study Limits
- Water Surface Elevation Isoline (Including freeboard)
- Drainage Catchbasins
- Drainage Cleanouts
- Pond
- Drainage Culverts
- Drainage Gravity Main
- Ditch
- Hydrants
- Blowoff Station
- Existing Water Main
- Sanitary Manhole
- Sanitary Gravity Main

0 10 20 30 40
Meters

Coordinate System: NAD 1983 UTM Zone 11N

Scale: 1:750 (When plotted at 11"x17")

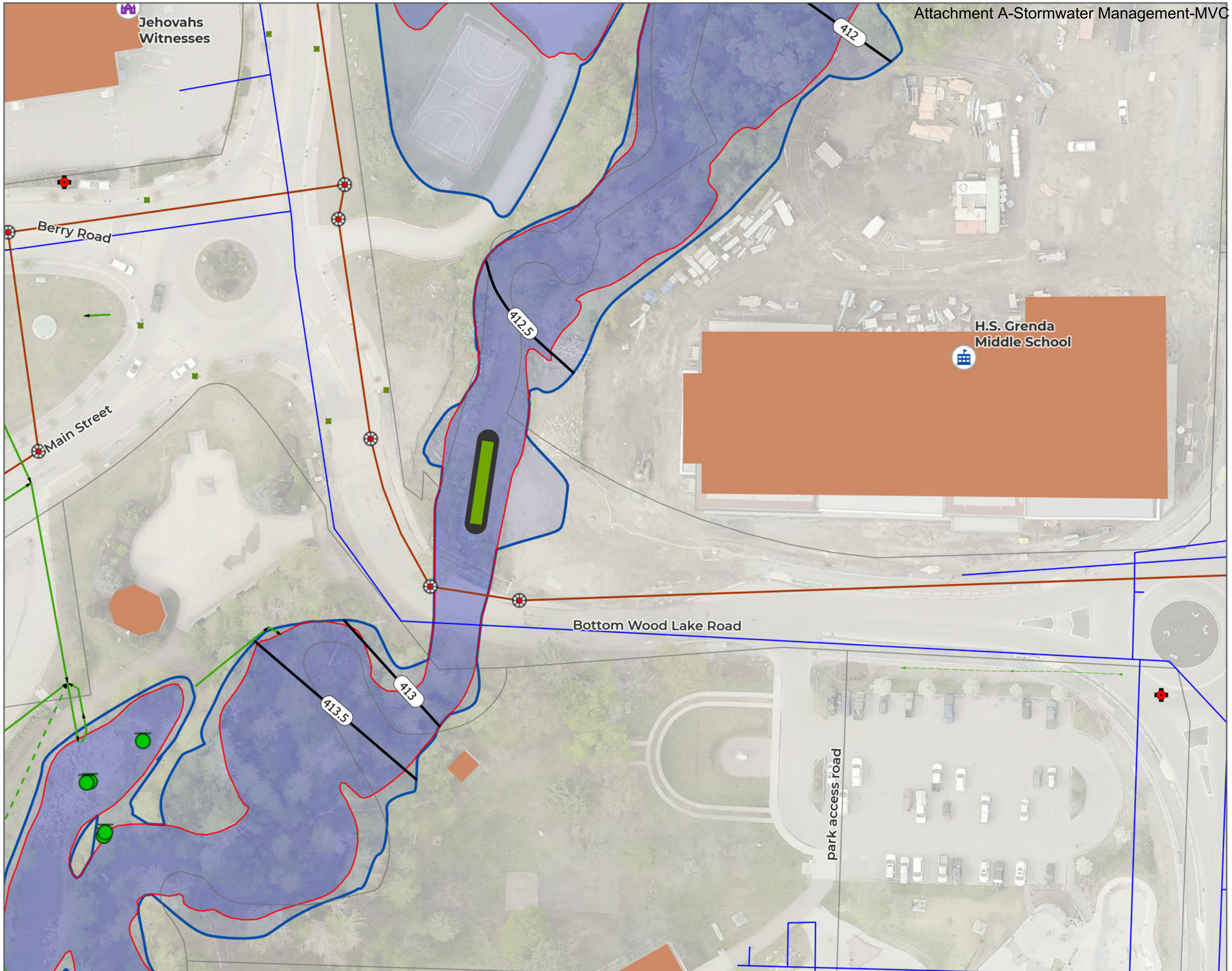
Data Sources:

- Data provided by District of Lake Country

Project #: 1577.0119.01
Author: AK
Checked: BP
Status: Draft
Revision: A
Date: 2023 / 5 / 17

URBAN SYSTEMS

CROSSING 1



LAKE COUNTRY
Life. The Okanagan Way.

Middle Vernon Creek Flood Hazard Study

Bottom Wood Lake Road Culvert

Legend

- Modelled Crossings
- Flood Limit
- Flood Limit +0.3m freeboard
- Water Surface Elevation Isoline (Including freeboard)
- Drainage Catchbasins
- Pond
- Drainage Culverts
- Drainage Gravity Main
- Darinage Gravity Main (proposed)
- Ditch
- Hydrants
- Existing Water Main
- Sanitary Manhole
- Sanitary Gravity Main

0 10 20 30 40
Meters

Coordinate System: NAD 1983 UTM Zone 11N

Scale: 1:750 (When plotted at 11"x17")

Data Sources:

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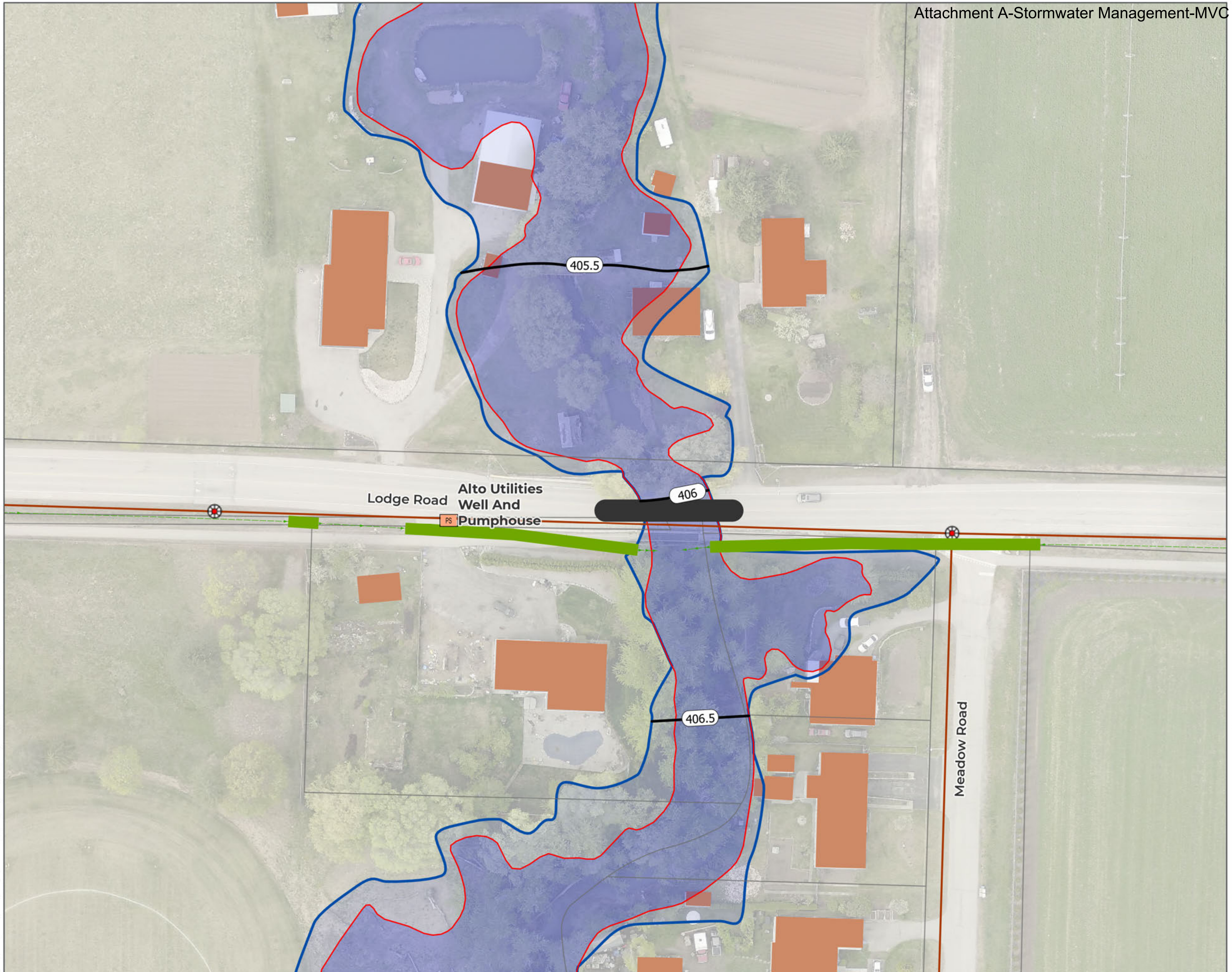
URBAN SYSTEMS

CROSSING 2



LAKE COUNTRY
Life. The Okanagan Way.

Middle Vernon Creek Flood Hazard Study

Lodge Road Bridge

Legend

- Modelled Crossings
- Flood Limit
- Flood Limit +0.3m freeboard
- Water Surface Elevation Isoline (Including freeboard)
- Drainage Culverts
- Ditch
- Sanitary Manhole
- Sanitary Gravity Main

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 10 20 30 40
Meters

Coordinate System: NAD 1983 UTM Zone 11N

Scale: 1:750 (When plotted at 11"x17")

Data Sources:

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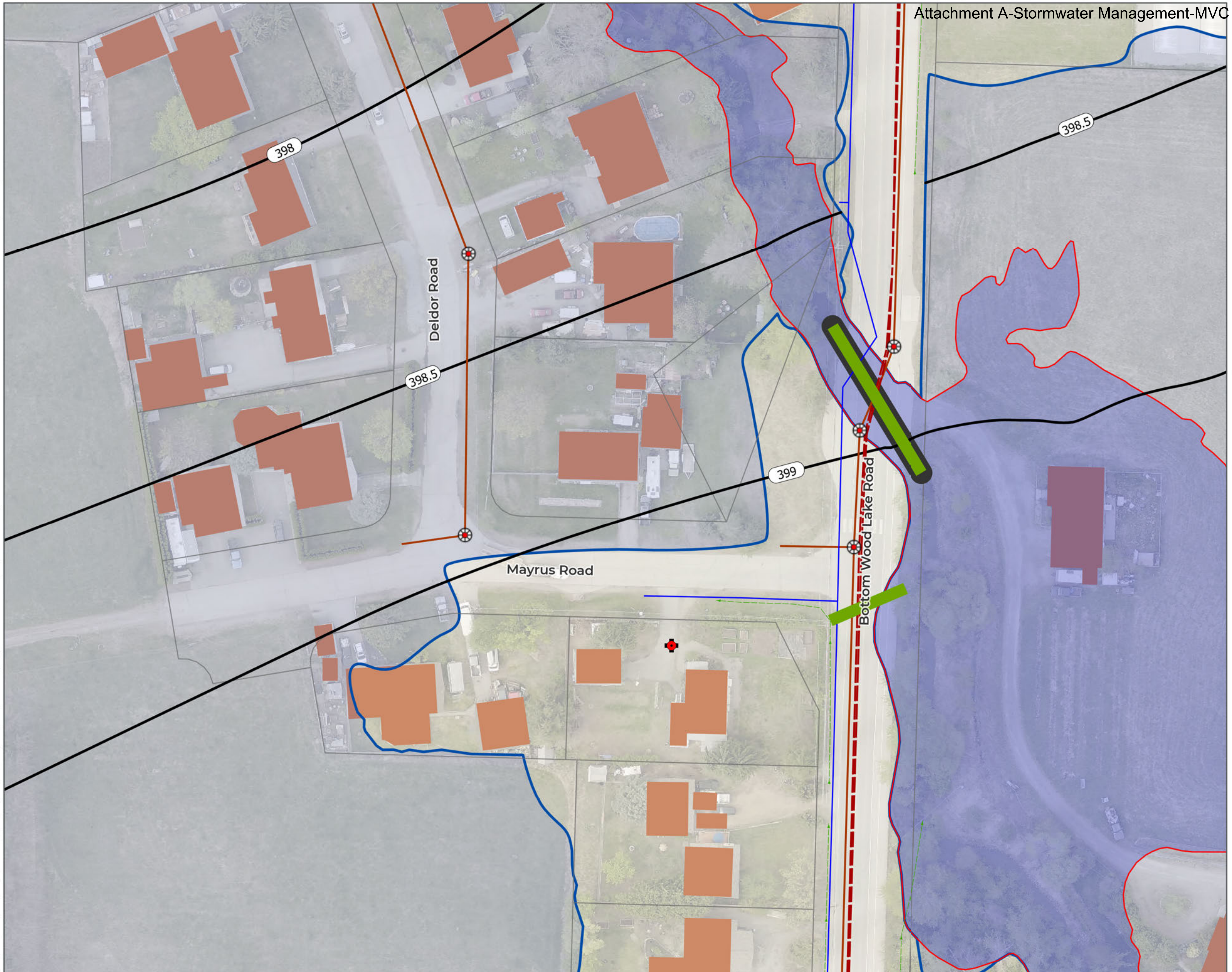
URBAN SYSTEMS

CROSSING 3



LAKE COUNTRY
Life. The Okanagan Way.

Middle Vernon Creek Flood Hazard Study

Bottom Wood Lake Road Culvert

Legend

- Modelled Crossings
- Flood Limit
- Flood Limit +0.3m freeboard
- Water Surface Elevation Isoline (Including freeboard)
- Drainage Culverts
- Ditch
- Hydrants
- Existing Water Main
- Sanitary Manhole
- Sanitary Forcemain
- Sanitary Gravity Main

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0 10 20 30 40
Meters

N

Coordinate System: NAD 1983 UTM Zone 11N

Scale: 1:750 (When plotted at 11"x17")

Data Sources:

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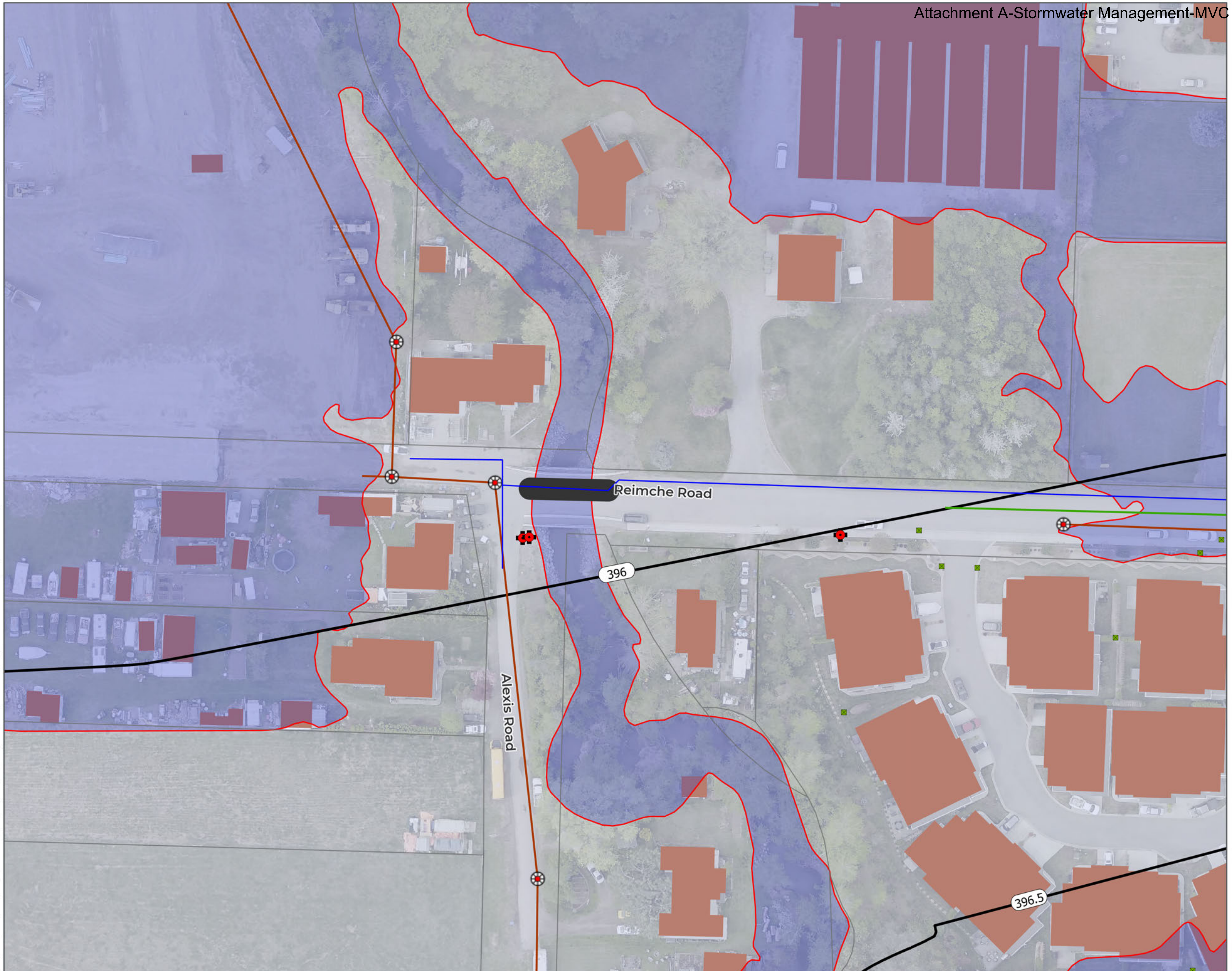
Date:	2023 / 5 / 17

URBAN SYSTEMS

CROSSING 4

Last updated by akhliestkova on May 17, 2023 at 10:23 AM
Last exported by akhliestkova on May 17, 2023 10:21 AM
Last printed by akhliestkova on September 25, 2017 11:46 AM

U:\Projects_KEL\1577\0119\01\D-Design\GIS\Projects\Pro_Projects\FloodplainMapping_1577.0119.01 RevB.aprx\Road Crossings



LAKE COUNTRY
Life. The Okanagan Way.

Middle Vernon Creek Flood Hazard Study

Reimche Road Bridge

Legend

- Modelled Crossings
- Flood Limit
- Flood Limit +0.3m freeboard
- Water Surface Elevation Isoline (Including freeboard)
- Drainage Catchbasins
- Drainage Gravity Main
- Hydrants
- Existing Water Main
- Sanitary Manhole
- Sanitary Gravity Main

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0 10 20 30 40
Meters

Coordinate System: NAD 1983 UTM Zone 11N

Scale: 1:750 (When plotted at 11"x17")

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Checked: BP
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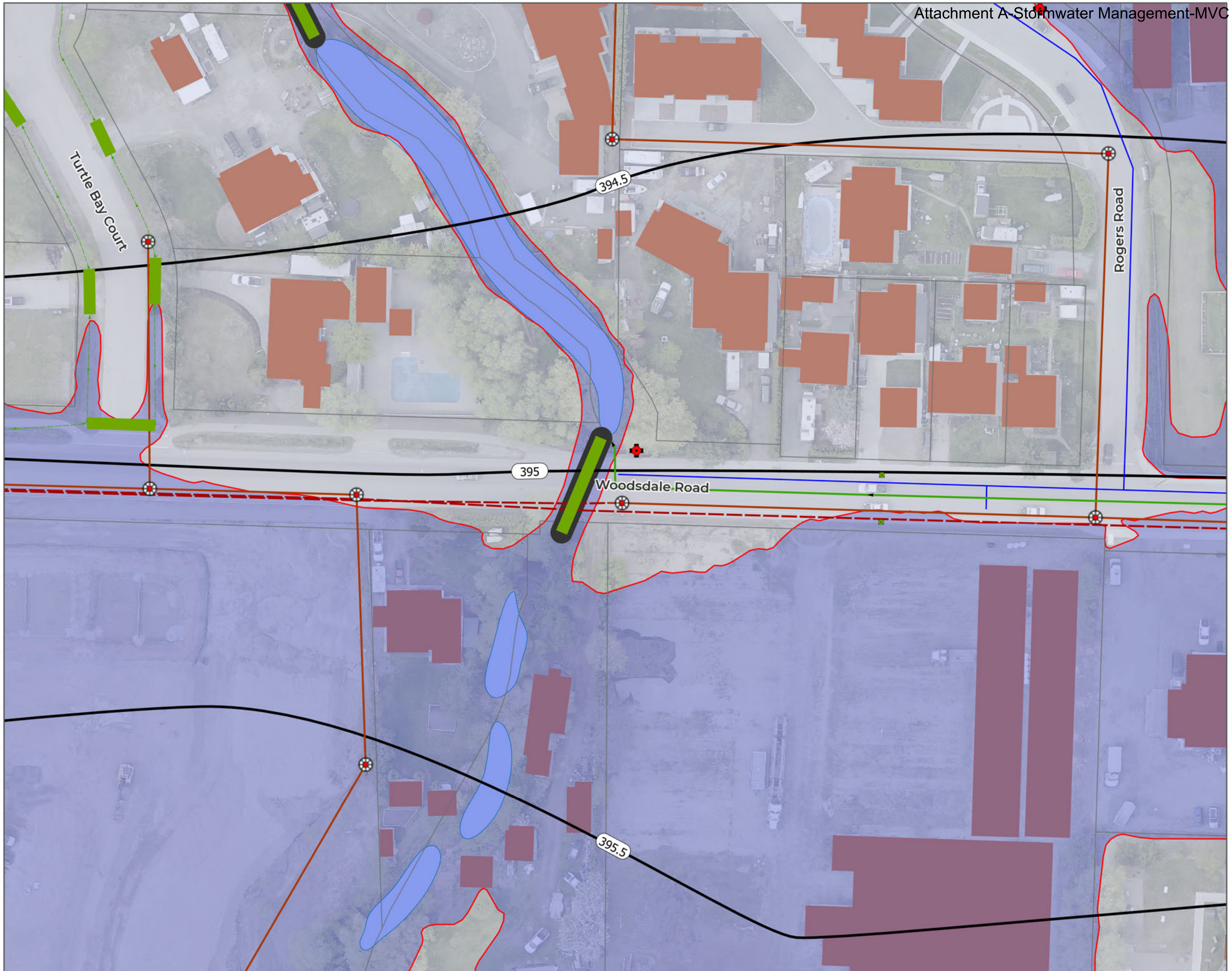
URBAN SYSTEMS

CROSSING 5



LAKE COUNTRY
Life. The Okanagan Way.

Middle Vernon Creek Flood Hazard Study

Woodsdale Road Culvert

Legend

- Modelled Crossings
- Flood Limit
- Flood Limit +0.3m freeboard
- Lake Flood Construction Level (FCL) Zone (Inundation Extent)
- Water Surface Elevation Isoline (Including freeboard)
- Drainage Catchbasins
- Drainage Culverts
- Drainage Gravity Main
- Ditch
- Hydrants
- Existing Water Main
- Sanitary Manhole
- Sanitary Forcemain
- Sanitary Gravity Main

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0 10 20 30 40
Meters

Coordinate System: NAD 1983 UTM Zone 11N

Scale: 1:750 (When plotted at 11"x17")

Data Sources:

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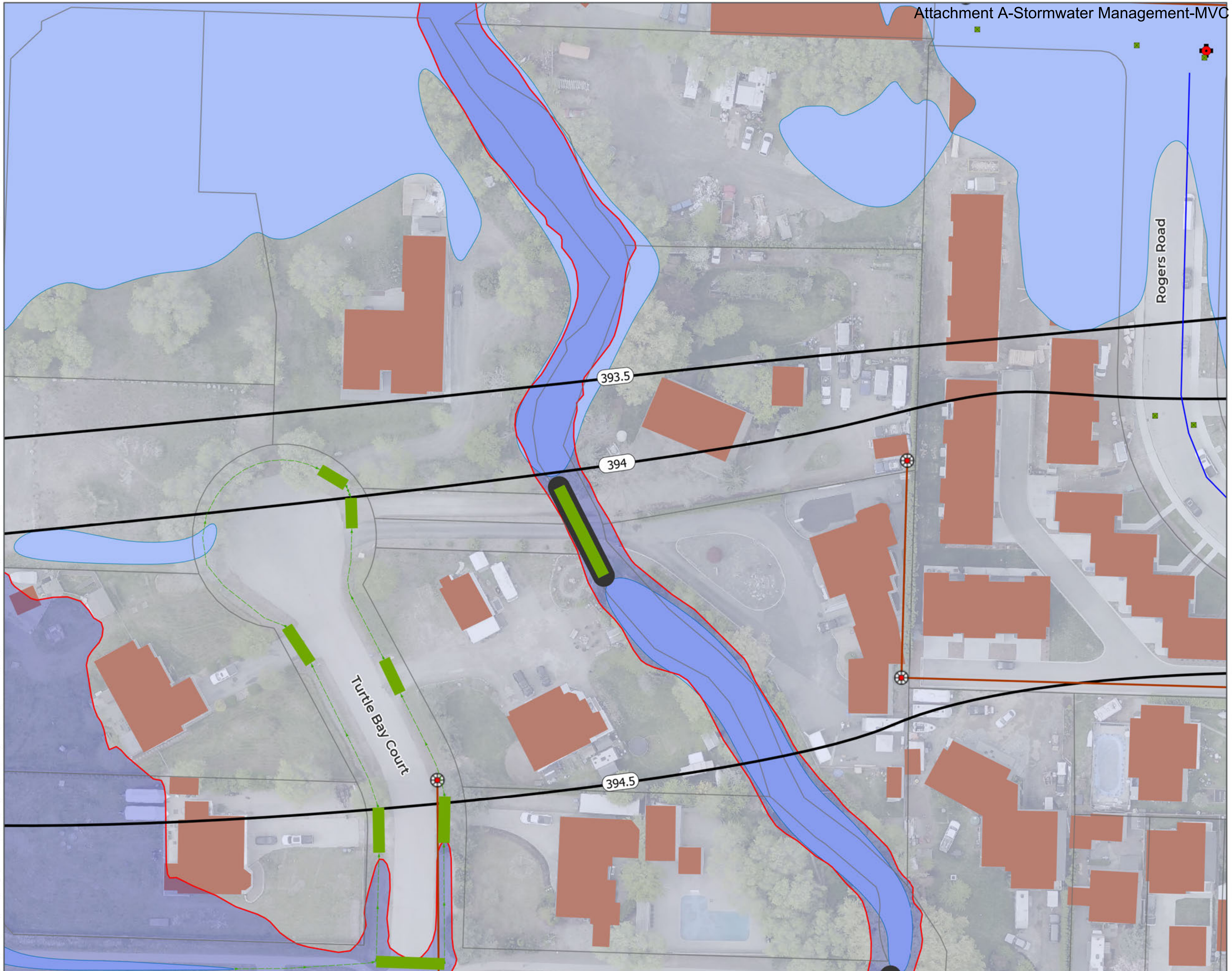
Checked:	BP
Status:	Draft
Revision:	A
Date:	2023 / 5 / 17

URBAN SYSTEMS

CROSSING 6



LAKE COUNTRY
Life. The Okanagan Way.

Middle Vernon Creek Flood Hazard Study

Turtle Bay Court Culvert

Legend

- Modelled Crossings
- Flood Limit
- Flood Limit +0.3m freeboard
- Lake Flood Construction Level (FCL) Zone (Inundation Extent)
- Water Surface Elevation Isoline (Including freeboard)
- Drainage Catchbasins
- Drainage Culverts
- Drainage Gravity Main
- Ditch
- Hydrants
- Existing Water Main
- Sanitary Manhole
- Sanitary Gravity Main

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0 10 20 30 40
Meters

Coordinate System: NAD 1983 UTM Zone 11N

Scale: 1:750 (When plotted at 11"x17")

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URBAN SYSTEMS

CROSSING 7