REPORT

Marten Beach Flood Hazard Study

Submitted to:

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Executive Summary

Alberta Environment and Protected Areas (EPA) commissioned WSP Canda Inc. (WSP) in September 2020 to conduct the Marten Beach Flood Hazard Study (the study). The purpose of the study is to assess and identify river and flood hazards along Marten Creek and Unnamed Tributary through the Marten Beach and adjacent areas. The study is part of the provincial Flood Hazard Identification Program (FHIP), the goals of which include enhancement of public safety and reduction of future flood damages through the identification of river and flood hazards. Project stakeholders include the Government of Alberta, the Municipal District of Lesser Slave River No. 124 (MDLSR) and the general public.

This report documents the methodology and results of all components of the study. The study tasks include the following:

- field survey
- hydrology assessment
- flood history documentation
- HEC-RAS 2D model creation, calibration, and validation
- open water flood frequency modelling and profile creation
- model sensitivity analysis
- flood inundation mapping
- flood hazard mapping

The total length of Marten Creek study reach is approximately 3.2 km, extending upstream from its mouth at Lesser Slave Lake. An Unnamed Tributary to Marten Creek was also included, with a reach length of approximately 1.3 km within the study area. A small portion of Lesser Slave Lake was included in the model to enable definition of a reasonable downstream boundary condition and to account for backwater effects from Lesser Slave Lake into Marten Creek. The survey was completed in October 2020. There is one bridge in the study area, and no designated flood control structures.

A hydrology assessment was completed to provide a) flood peak flow estimates at key locations in the study area and b) Lesser Slave Lake water levels as boundary conditions inputs to the hydraulic model.

A HEC-RAS 2D model was constructed using surveyed river cross-sections data, surveyed hydraulic structure data and topographic LiDAR data. The selected Manning's *n* values for the channel, roadways, and floodplain are 0.025, 0.03, and 0.07, respectively. The calibrated model was used to simulate the water surface profiles for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750- and 1,000-year flood events in the study area. The model was validated by comparing the various flood simulations against highwater mark data collected by EPA for the 2011, 2018, and 2019 flood events.

The model sensitivity was evaluated using the 100-year flood simulation results. The results of the sensitivity analysis show that variation of the main channel roughness values has a higher influence on the simulated water levels than variation of the floodplain roughness values along Marten Creek and the Unnamed Tributary.

Flood inundation and hazard maps were prepared for the study reaches of Marten Creek and the Unnamed Tributary using ArcGIS. The HEC-RAS 2D model produced a continuous water surface of directly inundated areas for each simulated flood event. Direct inundation areas refer to where there is a direct connection between the main river channels and inundated areas on the floodplains. This includes areas where inundation is caused by single or multiple topographic or structural overtopping points or backwater flooding.

Based on the simulation results, the main residential and/or commercial development areas that would be flooded within the study area have been identified as follows:

- Residential areas south of Poplar Crescent along Pine Drive, Marten Drive, and connected roads on the north side of Marten Creek.
- Residential areas south of Marten Creek north of Lesser Slave Lake Provincial Park.

The floodway was defined based on the 1 m depth and 1 m/s velocity criteria. The results of the design flood hazard mapping are the delineation of the floodway and flood fringe zones including high hazard flood fringe areas.

Acknowledgements

The Marten Beach Flood Study was managed by Mr. Gaven Tang and Ms. Nancy Guo. Overall direction and senior review were provided by Dr. Wolf Ploeger. The hydraulic modelling, flood inundation mapping and flood hazard mapping was conducted by Dr. Parnian Hosseini, Mx. Richard Cunningham, Ms. Sujata Budhathoki and Mr. Peter Thiede.

The authors express their special thanks to Mr. Jim Choles, Project Manager for Alberta Environment and Protected Areas (EPA) who provided overall study management, background data, and technical guidance.

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1.0 INTRODUCTION

1.1 Study Objectives

Alberta Environment and Protected Areas (EPA) commissioned WSP Canada Inc. (WSP) in September 2020 to conduct the Marten Beach Flood Hazard Study (the study). The purpose of the study is to assess and identify river and flood hazards along Marten Creek and Unnamed Tributary through the Marten Beach and adjacent areas (Figure 1). The study is part of the provincial Flood Hazard Identification Program (FHIP), the goals of which include enhancement of public safety and reduction of future flood damages through the identification of river and flood hazards. Project stakeholders include the Government of Alberta, the Municipal District of Lesser Slave River No. 124 (MDLSR) and the general public.

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1.2 Study Area

The study area includes a 3.2 km reach of Marten Creek and a 1.3 km reach of an Unnamed Tributary (see Figure 1). The study reaches are summarized in Table 1.

Table 1: River Reaches in the Study Area

River	Description	Length
Marten Creek	From the study area boundary to the confluence of Marten Creek with Lesser Slave Lake	3.2 km
Unnamed Tributary	From the study are boundary to the confluence of the Unnamed Tributary with Marten Creek	1.3 km

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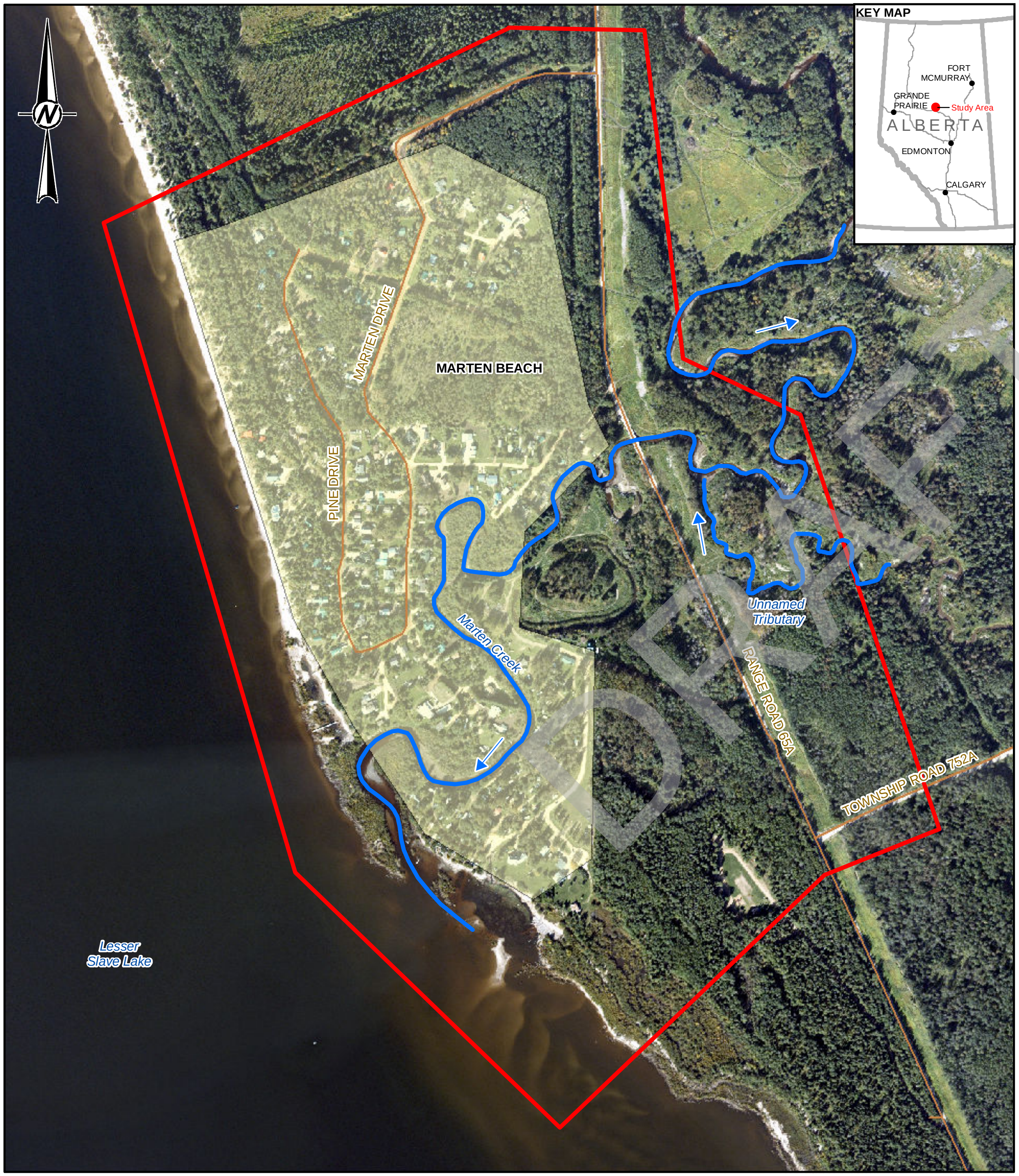

LEGEND

- FLOW DIRECTION
- LOCAL ROAD
- SURVEY REACH
- POPULATED AREA
- STUDY AREA

0 250 500

1:10,000 METRES

REFERENCE(S)

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CLIENT
ALBERTA ENVIRONMENT AND PARKS

PROJECT
MARTEN BEACH FLOOD HAZARD STUDY

TITLE
LOCATION MAP OF THE STUDY AREA

CONSULTANT

YYYY-MM-DD	2022-04-01
DESIGNED	WP
PREPARED	RC
REVIEWED	GT
APPROVED	WP

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1.3 Work Scope

The scope of the study includes the following:

- documentation of flooding history
- summary of available data
- documentation of river and valley features
- model setup
- model calibration and validation
- generation of open-water flood frequency profiles
- model sensitivity analysis
- open water flood inundation mapping
- open water flood hazard mapping

2.0 FLOODING HISTORY

2.1 General Information

Marten Creek originates at the Marten Lakes and flows for approximately 23 km in a south-westerly direction to its confluence into Lesser Slave Lake at Marten Beach. The hamlet of Marten Beach is situated on the Marten Creek alluvial fan. The creek's watershed is primarily forested, with a drainage area of 235 km^2 and a mean elevation of 828 m above sea level.

Marten Creek at Marten Beach is fed by a catchment upstream of Highway 88 and the Unnamed Tributary (locally known as Brady Creek) with a drainage area of 31.3 km^2 that joins Marten Creek immediately upstream of Range Road 65A. The Marten Creek headwaters are at Marten Lakes located approximately 23 km upstream of Marten Beach.

2.2 Open Water Floods

Marten Beach has historically been subject to flooding from Marten Creek due to extreme rainfall events. Significant floods were recorded in 1978, 1987, 1988, 1996, 2011, 2018, and most recently in July 2019 (Golder 2019). The largest flood event, according to accounts by the Municipal District of Lesser Slave River No. 124 (the MD), was the July 2019 flood event.

2.3 Ice Jam Floods

Based on a review of available documents, ice jams are not a significant source of flooding within the study area.

3.0 AVAILABLE DOCUMENTS AND DATA

3.1 Hydrology Summary

The flood frequency estimates of peak flows for Marten Creek and the flood frequency estimates of water levels in Lesser Slave Lake are documented in Appendix A. These estimates are summarized in Table 2 and Table 3.

Table 2: Recommended Flood Frequency Estimates and their 95% Confidence Interval

Return Period (Years)	Marten Creek at Marten Beach			Marten Creek upstream of the confluence with the Unnamed Tributary Creek		
	Peak Flow (m^3/s)	95% Lower Bound (m^3/s)	95% Upper Bound (m^3/s)	Peak Flow (m^3/s)	95% Lower Bound (m^3/s)	95% Upper Bound (m^3/s)
2	42.7	34.3	53.1	37.3	29.9	46.3
5	87.3	70.9	110	77.7	63.0	97.6
10	123	99.1	165	111	89.2	149
20	161	126	234	147	114	213
35	193	145	301	177	133	276
50	214	155	349	197	143	322
75	239	167	410	222	154	380
100	257	174	457	239	162	426
200	302	190	590	284	178	554
350	339	201	717	321	190	678
500	363	207	810	345	197	769
750	391	214	928	373	204	885
1,000	411	218	1,020	393	209	976

Table 3: Estimated Flood Peak Water Levels for Lesser Slave Lake and their 95% Confidence Interval

Return Period (Years)	Peak Level (m)	95% Lower Bound (m)	95% Upper Bound (m)
2	577.01	576.88	577.19
5	577.47	577.23	577.72
10	577.77	577.43	578.06
20	578.05	577.63	578.37
35	578.27	577.78	578.62
50	578.41	577.87	578.77
75	578.57	577.97	578.94
100	578.69	578.03	579.06
200	578.96	578.19	579.35
350	579.18	578.31	579.60
500	579.32	578.39	579.76
750	579.48	578.47	579.94
1,000	579.60	578.52	580.08

3.2 DTM Data

The detailed Digital Terrain Model (DTM) for the study area was provided by EPA. It was developed from a 2020 LiDAR survey and is available as a gridded raster with 0.5 m resolution as well as ESRI Terrain and LAS files. The DTM was delivered in the local study area coordinate system and datum (3TM 114˚, NAD83 CSRS).

3.3 Survey Data

The survey of stream cross sections, hydraulic structures, and flood control structures within the study area was conducted between October 12, 2020 and October 15, 2020. Water levels and flow were measured along Marten Creek; however, it is not expected that this information will be suitable to support hydraulic model calibration as the water levels and flow were very low.

3.4 Procedures and Methodology

3.4.1 Topographic, Bathymetric, and Structure Surveys

The following survey equipment were used to collect the topographic, bathymetric, and structure data for this study:

a) **Real-time Kinematic (RTK) GPS** – Trimble R8® and R10® RTK units were used to survey ground features and stream bed levels in the areas where hydraulic conditions allowed the surveyors to wade the channel. The RTK units were also used to survey the control points and benchmarks found within the study area.

b) **Remotely Operated Vehicle (ROV) with SonarMite Echo Sounder** – A Seafloor SonarMite echo sounder was used on a Seafloor Hydrone remotely operated vehicle in combination with an RTK unit to survey the stream bed in the areas where water was too deep or too fast flowing to wade.

All survey data collected in this study was referenced to the Alberta Survey Control Network using Alberta Survey Control Markers (ASCMs). An RTK base station was set up over temporary benchmarks at various locations and calibrated to an ASCM that was close to the study reach or a WSP-established temporary benchmark that had been tied to an ASCM.

The survey data was acquired by RTK rover units with pre-loaded geoid files. The RTK data output for this study provides orthometric elevations with correct northing and easting coordinates. All survey data was collected in the 3TM coordinate system with the Meridian at 114° W and referenced to NAD83 (CSRS) horizontal and CGVD28 vertical datum. Ellipsoidal heights are transformed to CGVD28 orthometric heights using the HTv2.0 geoid model.

Each survey point collected using the RTK utilized a schematic of survey point codes and corresponding locations as shown in Figure 2, which also includes a complete list of survey codes for the RTK.

The quality and accuracy of all survey data was checked by using a Trimble data extraction and processing tool. All survey data was imported into ArcGIS to allow for validation and further processing. Data with horizontal or vertical accuracies of greater than ±0.05 m was rejected. Daily quality and accuracy checks were conducted in the office. In cases where multiple points with low accuracy were detected at a cross section, the survey crew repeated that survey the next day.

A map of all collected survey points are summarized in Figure 3.

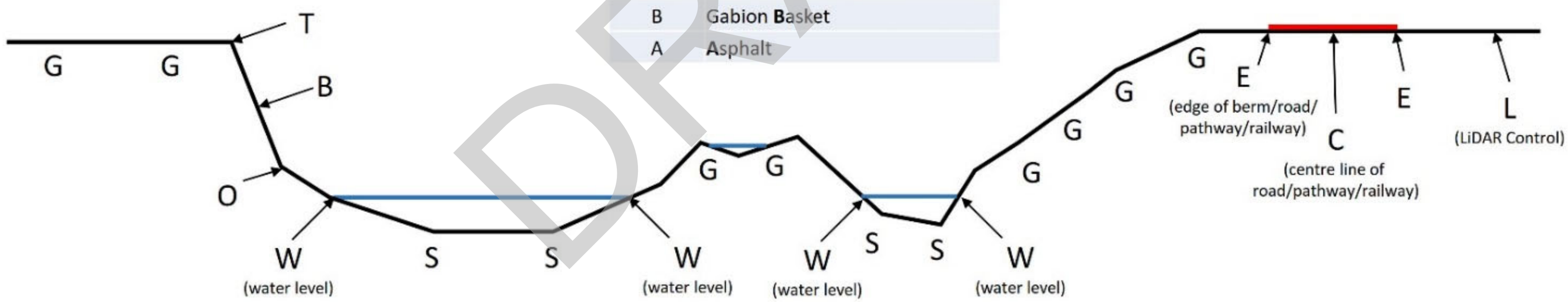
Survey Codes for RTK GPS River Surveys (No Structures)

Purpose: - Create common definitions for survey points collected in the field for easier data processing in the office
- Reduce confusion or uncertainty for field staff regarding coding of points

Location Code	
G	**G**round
T	**T**op of Bank
B	**B**ank
O	T**o**e of Bank
W	**W**ater Level
S	**S**tream Bottom (under water)
E	**E**dge of Road/Berm/Pathway/Railway
C	**C**entre Line of Road/Berm/Pathway/Railway
L	**L**iDAR control point

Material Code	
1	Mud/Silt (<0.063 mm)
2	Sand (0.063 mm - 2 mm)
3	Gravel (2 mm - 6.4 cm)
4	Cobble (6.4 cm - 25 cm)
5	Boulder (> 25 cm)
6	Bedrock
C	**C**oncrete
G	**G**rass
R	**R**iprap
T	**T**rees (large, trunk > 10 cm)
W	**W**illows and Shrubs
B	Gabion **B**asket
A	**A**sphalt

Examples	
G2	Ground, Sand
G4	Ground, Cobble
W3	Water Level, Gravel
GG	Ground, Grass
GT	Ground, Trees
CA	Centre Line, Asphalt
BR	Bank, Riprap
LC	LiDAR control, Concrete



Version 0, August 25, 2017 Golder Associates Ltd. Wolf Ploeger

Figure 2: Schematic of Survey Point Locations and Code Descriptions

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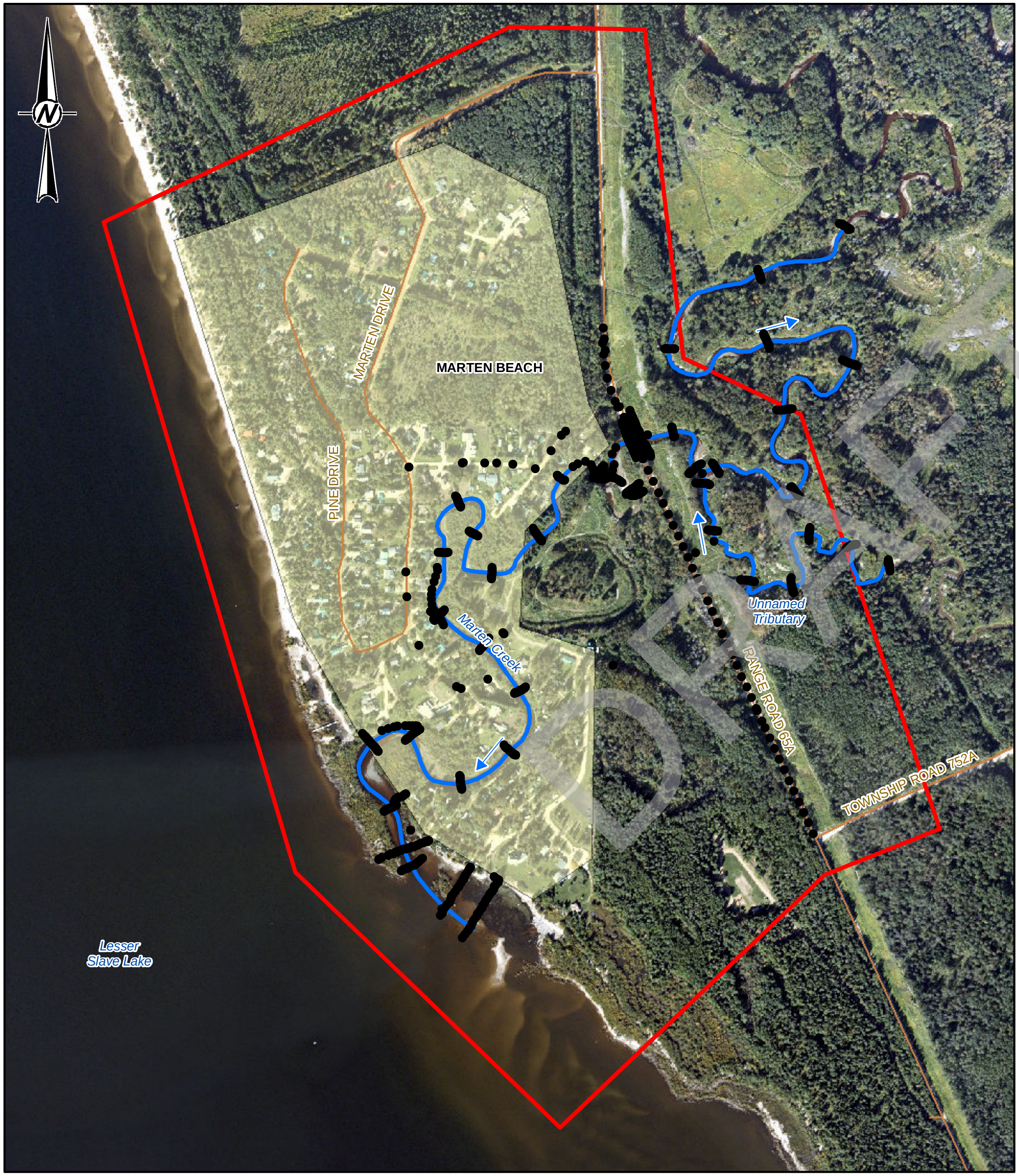

LEGEND

- SURVEY POINT
- FLOW DIRECTION
- LOCAL ROAD
- SURVEY REACH
- POPULATED AREA
- STUDY AREA

0 250 500

1:10,000 METRES

REFERENCE(S)

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CLIENT
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PROJECT
MARTEN BEACH FLOOD HAZARD STUDY

TITLE
SURVEY LOCATIONS

CONSULTANT

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REVIEWED	GT
APPROVED	WP

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Channel Cross Section Surveys

The field data was collected by surveying channel cross sections approximately perpendicular to the direction of the flow. The study reaches within Marten Creek and the Unnamed Tributary were surveyed by wading. For some cross sections where the water was too deep to wade, a remotely operated vehicle (ROV) was used.

The following procedures were applied when carrying out a bathymetric survey by wading:

- Set up the RTK-GPS base station since Can-net coverage was not available for the study area or did not provide sufficient accuracy.
- RTK rover units were used to collect cross-sectional information from a location approximately 2 to 5 m beyond the top of bank on one side of the channel to a location approximately 2 to 5 m beyond the top of bank on the other side. A minimum of 20 points were established across the channel and care was taken to reference points where the transverse bed slope changed significantly.
- Special attention was paid to surveying topographic slope breaks along the banks.
- All surveyed data points were attributed with field codes that described substrate and vegetation types.
- The water surface elevation was surveyed where the water had contact with the banks.

The following procedures were applied when carrying out a bathymetric survey by ROV:

- Set up the RTK-GPS base station since Can-net coverage was not available for the study area or did not provide sufficient accuracy.
- Mount the SonarMite onto the frame on the Hydrone ROV.
- Place the RTK-GPS unit on top of the SonarMite mount and measure the offset to the water surface.
- Connect both SonarMite and RTK-GPS units to a data collector with Bluetooth transmission capability and use a field laptop or Trimble data collector for data collection.

For each day when the ROV was used, a calibration was performed to correct the water depth measurements. This was conducted by placing the ROV over a relatively flat riverbed, measuring the water depth and surveying the same point with the RTK unit. The elevation correction was then applied in the office.

Hydraulic Structures

There is one hydraulic structure within the study area that could affect channel conveyance and water levels, a bridge at Range Road 65A. The surveyed features of the bridge include the following:

- length of span (corner points, abutment-to-abutment)
- width of bridge (corner points, outside-to-outside)
- top of curb or solid guard rail elevations
- low chord elevations
- number and width of piers
- location of piers and the distance of each pier relative to the abutment

- type of piers (e.g., concrete, pile bent)
- shape of pier (e.g., round nose, wedge-shaped, circular)
- top of roadway (or path) profile

The hydraulic structure was surveyed using RTK-GPS and measuring tape. Geo-located photos of the structure were taken during the survey.

Flood Control Structures

There were no dedicated flood control structures identified within the Marten Beach study area during the site inspection in October 2020. A letter confirming the absence of flood control structures within the Marten Beach study area is provided in Appendix B.

3.4.2 Flow and Water Level Measurements

Water levels along the Marten Beach study reach were measured during the survey to support the low-flow hydraulic model calibration.

One flow measurement was completed along Marten Creek downstream of the Unnamed Tributary confluence. A flow was not measured along the Unnamed Tributary due to insufficient flow depth.

The flow measurement was performed by wading the Marten Creek channel with a handheld Acoustic Doppler Velocimeter (*Sontek FlowTracker2® ADV)* and top-set wading rod in accordance with standard Water Survey of Canada protocols. This includes: (i) selecting a suitable measurement location; (ii) choosing an even number of transects with equal left bank to right transects and right bank to left transects; and (iii) ensuring that the data set of each transect is within a maximum standard deviation of five percent. The measurement procedure involved the following:

- Survey points were selected to result in a minimum of 20 panels (flow segments across the stream thus requiring a minimum of 21 velocity measurement points).
- Velocity readings were taken at 0.6 of the total depth at measurement locations since flow depth was less than 1.0 m in all cases.
- Survey points were selected such that no panel flow exceeded 10 percent of the total flow.

A flow measurement was conducted along Marten Creek downstream of the Unnamed Tributary on October 14, 2020 and yielded 0.65 m^3/s. Upstream of the Marten Creek and Unnamed Tributary Confluence, it was assumed that 80% of the flow originates from Marten Creek and 20% of the flow originates from the Unnamed Tributary.

3.5 Cross Sections

The survey of Marten Creek included an approximately 3.2 km reach along Marten Creek starting at Lesser Slave Lake and an approximately 1.3 km reach along the Unnamed Tributary starting at the confluence with Marten Creek. A summary of the surveyed channel cross sections is provided in Table 4.

Table 4: Surveyed Channel Cross Sections within the Study Area

Waterbody	Reach Description	Number of Cross Sections	Average Spacing Between Cross Sections	Year of Survey
Marten Creek	1.7 km upstream of Range Road 65A bridge to confluence with Lesser Slave Lake	32	101 m	2020
Unnamed Tributary	1.3 km upstream of confluence with Marten Creek	7	182 m	2020

3.6 Existing Models

The existing hydraulic model for the study area is listed in Table 5.

Table 5: Existing Hydraulic Model for the Study Area

No.	Report	Program Used	Date	Author
1	Marten River Flood Mitigation Engineering Preliminary Design Report	HEC-RAS 2D	September 30, 2019	Golder Associates Ltd.

3.7 Highwater Marks

Highwater marks for open-water flooding are available as outlined in Table 6.

Table 6: Flood Events for which Highwater Marks have been Recorded

Flood Event	Number of Highwater Marks	Contributing Agency
2011	17	Government of Alberta
2018	13	Government of Alberta
2019	23	Government of Alberta

3.8 Gauging Station Data and Rating Curves

There are no Water Survey of Canada gauging stations located along Marten Creek or the Unnamed Tributary. There is a Water Survey of Canada gauging station located on Lesser Slave Lake (Station No. 07BJ006, Lesser Slave Lake at Slave Lake).

3.9 Flood Photography

The MDLSR collected flood photography during some of the more recent flood events. Photographs are available from the MDLSR for the flood events in Table 7.

Table 7: Available Flood Photography of Open Water Flooding in the Study Area

No.	Description	Flood Event	Source
1	Photographs of Marten Beach taken during the 2011 flood	2011	MDLSR
2	Photographs of Marten Beach taken during the 2018 flood	2018	MDLSR
3	Photographs of Marten Beach taken during the 2019 flood	2019	MDLSR

3.10 Aerial Imagery

EPA provided the recent aerial imagery (obtained in September 2020) for the Marten Beach Flood Study that was used for preparing the flood inundation as well as flood criteria and hazard maps.

4.0 RIVER AND VALLEY FEATURES

4.1 General Description

Terrain throughout the Marten Creek watershed is primarily coniferous forest, including active logging areas. The source of flow for Marten Creek includes a catchment upstream of Highway 88 and the Unnamed Tributary sub-catchment, which joins Marten Creek immediately upstream of Range Road 65A.

4.2 Channel and Floodplain Characteristics

Channel Characteristics

The channels of Marten Creek and the Unnamed Tributary are characterized by high sinuosity throughout the study area. The Marten River gradient decreases on the alluvial fan downstream of the Range Road 65A bridge, on which the hamlet of Marten Beach is situated. There is historic and recent evidence of avulsion along Marten Creek in Marten Beach, indicated by the presence of abandoned oxbows and recent cut-offs. Alluvium deposits from Marten Creek can be observed forming sandbars at stream bends.

Floodplain Characteristics

In the study area, much of the Marten Creek floodplain consists of residential properties. Overtopping of Marten Creek results in the development of drainage paths on streets and in ditches for less severe floods, and wide-spread inundation for more severe floods. High flows in the Unnamed Tributary have been observed to cause overtopping of Range Road 65A south of the bridge. Flooding in Marten Beach is also influenced by backwater effects from water levels in Lesser Slave Lake.

4.3 Bridges, Culverts, and Weirs

There is one bridge within the study area, where Range Road 65A crosses Marten Creek. It is supported with two sets of piers.

4.4 Flood Control Structures

There are no flood control structures within the study area.

5.0 HYDRAULIC MODELLING

5.1 HEC-RAS 2D Program

5.1.1 Description

The HEC-RAS 2D program (Version 6.4.1) was used as the software platform for developing the two-dimensional hydraulic models in the study area. The HEC-RAS 2D program was developed by the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers (USACE). The River Analysis System (RAS) software has a graphical user interface, separate hydraulic analysis components, data storage and management capabilities, and graphics and reporting facilities. HEC-RAS 2D is a commonly used program in North America and around the world (USACE 2021).

The HEC-RAS 2D program can perform unsteady two-dimensional hydrodynamic routing using Diffusion Wave Equations or Shallow Water Equations by solving an implicit finite volume solution algorithm, producing detailed hydraulic property tables for computational cells and cell faces.

5.1.2 General Model Setup

Reaches

The entirety of the study area is included in the model setup, including Marten Creek, the Unnamed Tributary, and approximately 2.3 km of shoreline along Lesser Slave Lake. The reaches are specified in Table 8 and shown in Figure 4.

Table 8: Reaches in the Hydraulic Model

River	Reach	Length
Marten Creek	Marten Creek	3.2 km
Unnamed Tributary	Unnamed Tributary	1.3 km

Integrated DEM

The collected survey data along Marten Creek and the Unnamed Tributary were used to create an integrated DEM that included both topographic and interpolated bathymetric surfaces using a WSP-developed interpolation tool. The tool uses an anisotropic interpolation method which considers the curvature of the thalweg, the left and right edges of the water along the banks, and integrates with bare-earth LiDAR to form an integrated DEM. Survey data collected along the beaches of Lesser Slave Lake were used to create an approximate lake shore surface, which was also integrated into the DEM.

Boundary Conditions

The HEC-RAS 2D model requires specification of boundary condition at all open and internal boundaries. The open boundaries specified in the hydraulic models are as follows:

- Channel bed slope and inflow at the upstream end of the Marten Creek study reach.
- Channel bed slope and inflow at the upstream end of the Unnamed Tributary reach.
- Water level at the downstream end of the study area in Lesser Slave Lake.

A schematic showing the model setup is shown in Figure 4.

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LEGEND

- FLOW DIRECTION
- LOCAL ROAD
- CHANNEL CENTRE LINE
- MODELLING EXTENT

0 250 500

1:12,500 METRES

REFERENCE(S)

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TITLE
MODEL EXTENT

CONSULTANT

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DESIGNED	WP
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REVIEWED	GT
APPROVED	WP

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Classification: Public

5.2 Geometric Data Base

5.2.1 Integrated DEM

The integrated DEM includes coverage of the full study reaches of Marten Creek and the Unnamed Tributary at a 0.5 m resolution. It was generated based on survey data collected in 2021 and LiDAR data collected in 2020. The HEC-RAS 2D model was created by directly importing the integrated DEM.

5.2.2 Roughness Distribution

Three roughness classes were defined for the study area: channel, roadway, and floodplain. The left and right banks defining the main channel were based on the 2020 LiDAR data, 2020 aerial imagery and survey data. Roadways were delineated based on aerial imagery. The roughness distribution is shown in Figure 5.

The initial roughness values assigned to the classes are provided in Table 9. These initial values were selected based on literature and professional judgement. The roughness values were implemented into the HEC-RAS 2D model and adjusted during model calibration (see Section 5.3.3).

Table 9: Initial Roughness Estimates (from Golder 2019)

Element	Roughness
Channel	0.035
Floodplain (including roadways)	0.100

5.2.3 Bridges

The bridge geometry implemented in the HEC-RAS model was defined based on the following data:

- River and bridge survey completed in 2020
- As-built drawings provided by Alberta Transportation (AT)

Only one bridge exists within the study area, the Range Road 65A bridge, and is represented in the HEC-RAS 2D model. Losses through bridges are calculated in the model using the energy equation (i.e., standard step method). The 2D flow modelling capabilities within HEC-RAS 2D allows the bridge deck and pier geometry to be positionally defined relative to the bridge centreline.

5.2.4 Flood Control Structures

There are no dedicated flood control structures within the Marten Beach study area.

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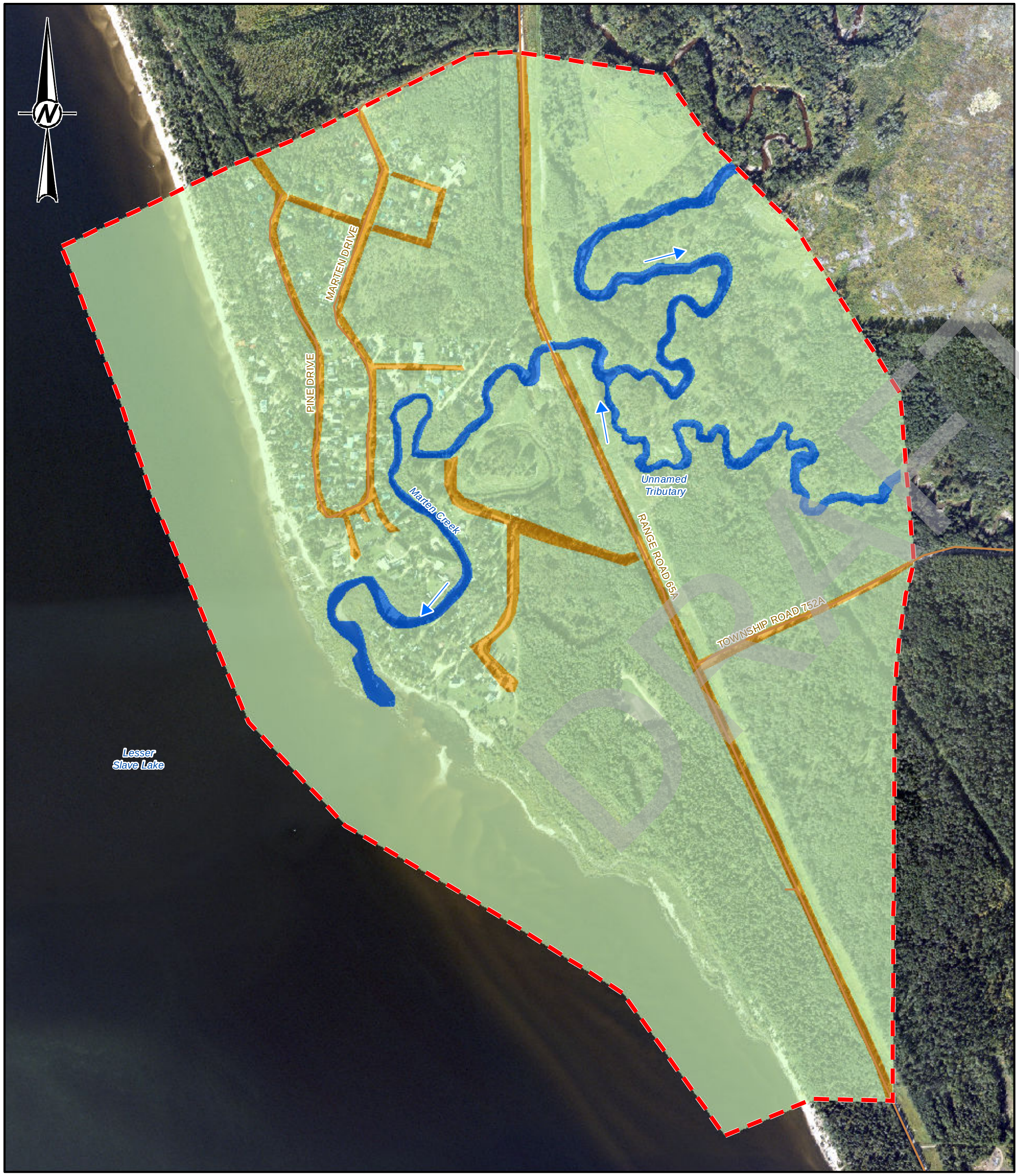

LEGEND

FLOW DIRECTION
LOCAL ROAD
MODELLING EXTENT

ROUGHNESS CLASS DISTRIBUTION

FLOODPLAIN
MAIN CHANNEL
ROADWAYS

0 250 500
1:12,500 METRES

REFERENCE(S)

POPULATED PLACES AND HYDROGRAPHY OBTAINED FROM ALTALIS, © GOVERNMENT OF ALBERTA 2021. ALL RIGHTS RESERVED.
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DATUM: NAD 83 CSRS PROJECTION: 3TM 114

CLIENT
ALBERTA ENVIRONMENT AND PARKS

PROJECT
MARTEN BEACH FLOOD HAZARD STUDY

TITLE
ROUGHNESS CLASS DISTRIBUTION

CONSULTANT

YYYY-MM-DD	2022-04-01
DESIGNED	WP
PREPARED	RC
REVIEWED	GT
APPROVED	WP

PROJECT NO.	CONTROL	REV.	FIGURE
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5.3 Model Calibration and Validation

5.3.1 Methodology

Manning's *n* values for the channel, roadways, and floodplain are the parameters used in calibrating the HEC-RAS 2D model. The Manning's *n* value is a composite empirical parameter which may decrease with increased water depth. Selection of initial Manning's *n* values included consideration of stream bed and bank materials, vegetation cover, site information collected during the field inspection, aerial imagery, and WSP's experience with previous hydraulic modelling studies. Model calibration was conducted based on pertinent highwater mark elevations from recent flood events and associated water level data for Lesser Slave Lake. Highwater mark elevations were provided by EPA for the 2011, 2018, and 2019 flood events. The associated water levels in Lesser Slave Lake for these flood events were 577.51 m, 577.25 m, and 577.12 m, respectively. Water levels in the lake were acquired from the Water Survey of Canada hydrometric station, Lesser Slave Lake at Lesser Slave Lake (07BJ006). It was assumed that there was no difference in lake water levels between the gauge location and the study area.

Since there is no hydrometric data available for Marten Creek during the past flood events, the following calibration methodology was adopted:

1) The HEC-RAS 2D model was run for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, and 100-year flood events using lake water level data associated with each of the 2011, 2018, and 2019 flood events.

2) The available highwater marks were compared to modelled water levels to select the nearest applicable modelled flood event.

3) Manning's *n* was changed and the models re-run to improve the alignment of the model with the highwater mark data. Roughness values were kept within a reasonable range suitable for the observed land cover.

5.3.2 Low Flow Calibration

A measurement of flow in Marten Creek was conducted on October 14, 2020. The model was calibrated to the measured flow (0.65 m^3/s), split between Marten Creek (80% of flow) and the Unnamed Tributary (20% of flow) (Section 3.4.2). Water level at Lesser Slave Lake was measured during the survey as 577.22 m. Calibration was conducted using average water surface elevations for cross-sections measured on October 14, 2020.

The resulting channel roughness value (n=0.06) resulted in an average difference between the modelled and measured water surface elevations of less than 1 cm. This channel roughness was however judged to be too high to be used during high flow simulations. A comparison of the simulated and surveyed water levels for the low-flow calibration is shown in Figure 6.

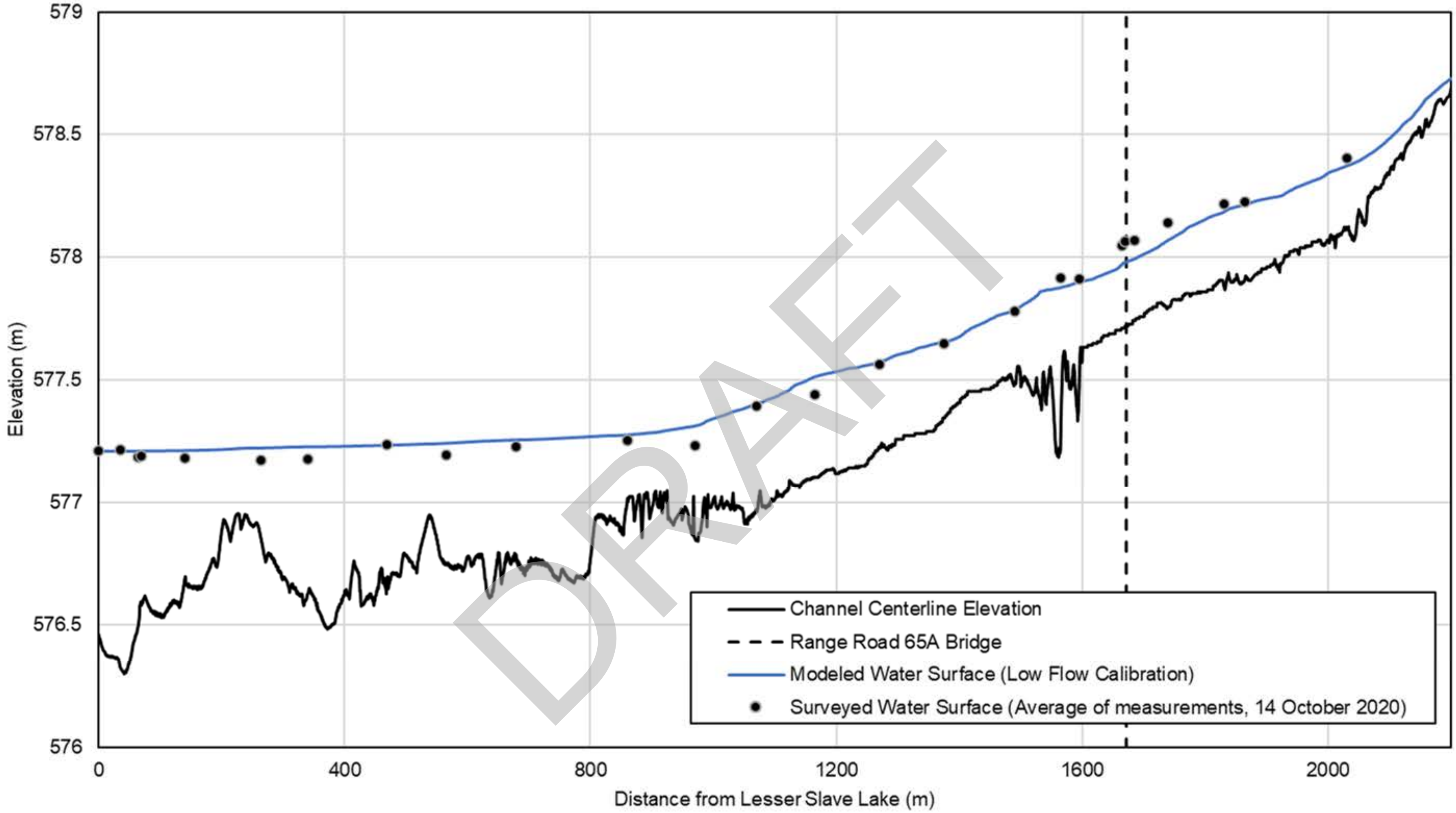

Figure 6: Comparison of Simulated Water Surface Profiles with Surveyed Water Levels for the Low Flow Condition (Calibrated to Low Flow conditions)

5.3.3 High Flow Calibration

Initial roughness values were used to simulate the 2- to 1000-year flood events. Those flood water level surfaces were then compared against the 2011, 2018, and 2018 highwater mark sets. It was determined that the initial roughness values were too high and overly conservative, as the comparisons suggested that all three flood events corresponded with a 2-year or more frequent flood event. Based on professional judgement, the roughness values were adjusted (lowered) for the main channel, roadway and overbank areas to 0.025, 0.03, and 0.07, respectively. This adjusted calibration yielded highwater mark and simulated flood water level surface comparisons that are summarized in Table 10. The available highwater marks are presented in a map in Appendix C. A comparison of highwater mark and simulated water levels is listed in detail in a table in Appendix C. Data pertaining to the 2011 flood were found to be unreliable and, as such, were not considered for calibration.

Table 10: Calibration Summary

Observed Flood	Comparative Flood Event	Average Difference (m)	Maximum Difference (m)
2011	1:2-year flood	0.71	1.05
2018	1:5-year flood	0.32	0.55
2019	1:5-year flood	0.00	-0.29

While the adjusted calibration suggests that the 2011, 2018 and 2019 flood events are fairly frequent (2- to 5-year recurrence intervals), it is unlikely that roughness values should be reduced further as they would fall outside the bounds of applicability for the site conditions within the Marten Beach study area.

5.3.4 Gauge Data and Rating Curves

No Water Survey of Canada gauges exist along Marten Creek or the Unnamed Tributary.

5.4 Model Parameters

5.4.1 Selected Roughness Values

The calibrated Manning's *n* values are summarized in Table 11.

Table 11: Calibrated Channel Roughness Values for High Flow Conditions

Region	Calibrated Manning's *n* Value
Channel	0.025
Roadways	0.03
Floodplain	0.07

5.4.2 Expansion and Contraction Coefficients

The contraction and expansion coefficients used in modelling the Range Road 65A bridge were 0.1 and 0.3, respectively, which are the standard values for bridge crossings.

5.4.3 Boundary Conditions

Upstream boundary conditions for the model include flow rate and river channel slope. Flow rate at the upstream boundary of Marten Creek is the flood peak flow at Marten Creek upstream of the confluence with the Unnamed Tributary Creek; and flow rate at the upstream boundary of Unnamed Tributary is the flow difference between Marten Creek at Marten Beach and upstream of the confluence with the Unnamed Tributary Creek (Table 2). The river channel slope assumed for Marten Creek and the Unnamed Tributary are 0.8% and 0.02%, respectively.

The downstream boundary for the model is the water level in Lesser Slave Lake associated with the corresponding recurrence interval (Table 3).

5.5 Open Water Flood Frequency Profiles

5.5.1 Flood Profiles

The calibrated HEC-RAS 2D model provides a reliable tool for simulating the flood profiles of the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750- and 1,000-year flood events in the study area. Flood profiles are shown in Figure 7 and Figure 8 and are provided in tabular form in Appendix D.

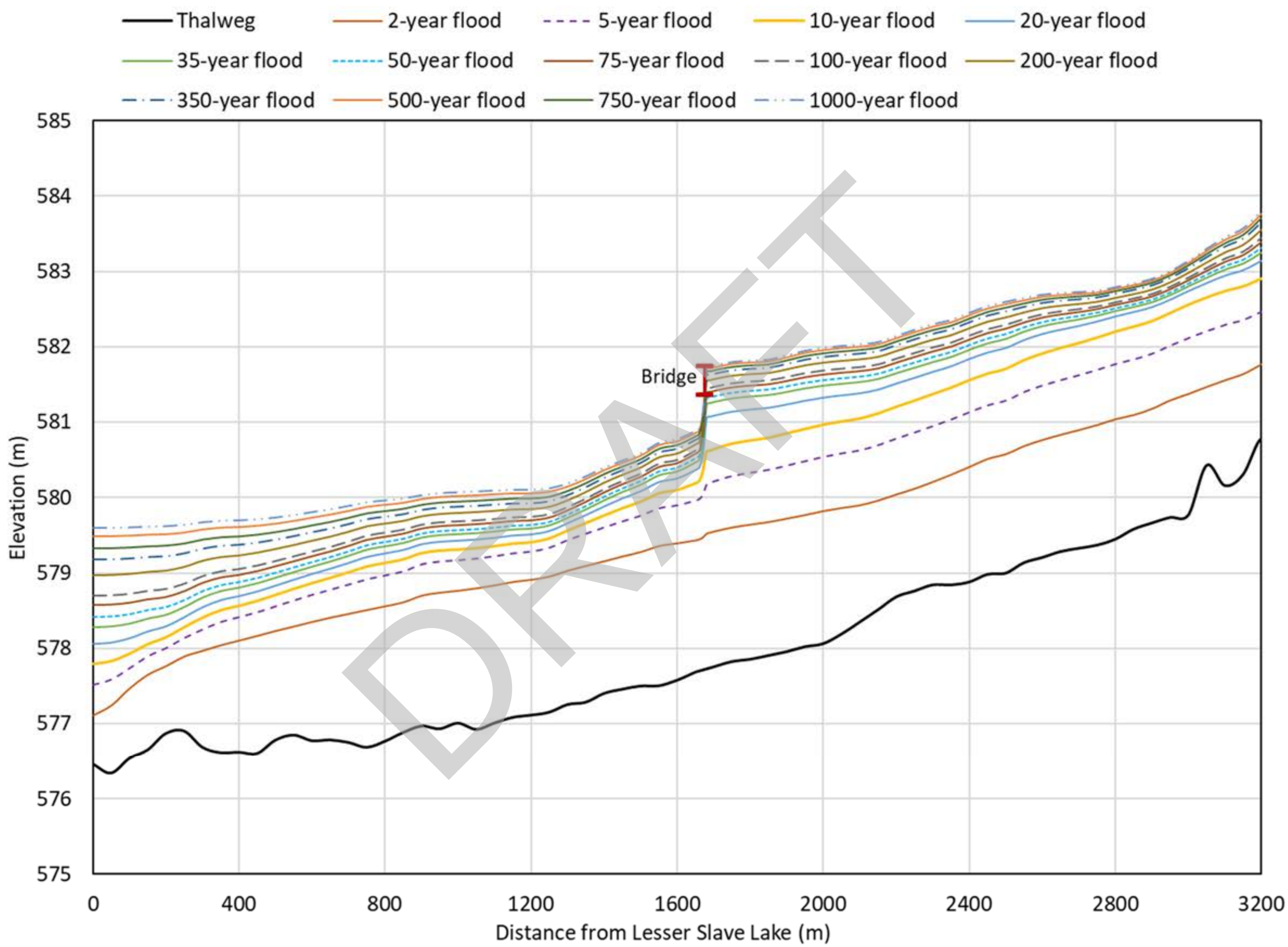

Figure 7: Marten Creek Flood Profiles

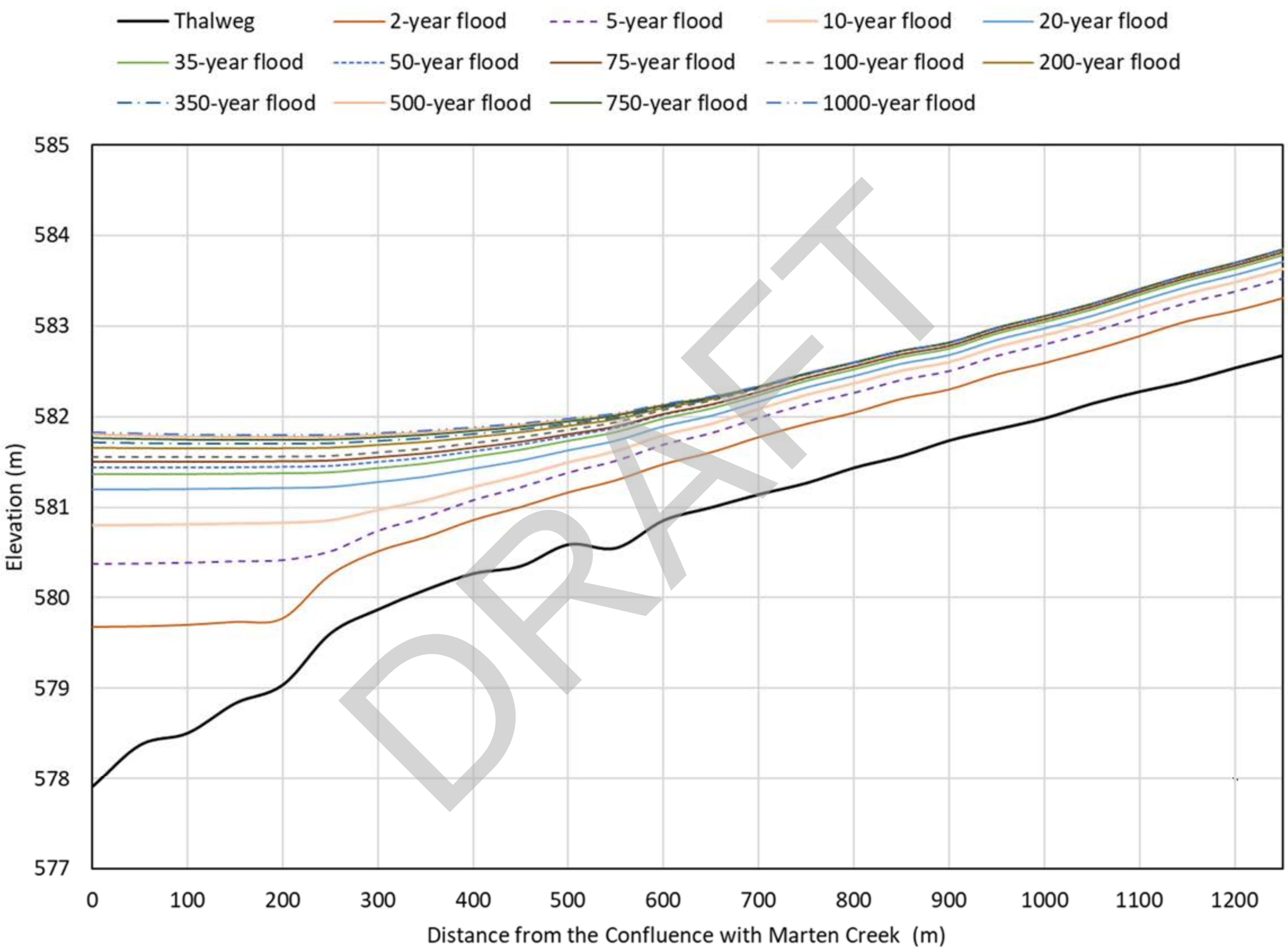

Figure 8: Unnamed Tributary Flood Profiles

5.5.2 Flow Over Range Road 65A

During previous flood events, a portion of flow from the Unnamed Tributary has been observed spill over Range Road 65A south of the bridge. The amount of total flow spilling over Range Road 65A south of the bridge from the Unnamed Tributary is summarized in Table 12.

Table 12: Flow over Range Road 65A

Return Period	Total Flow (Marten Creek and Unnamed Tributary) (m^3/s)	Flow Under Range Road 65A Bridge (m^3/s)	Flow Spilling over Range Road 65A (m^3/s)	Percent of Flow Spilling over Range Road 65A South of Bridge
2	42.7	42.7	0	0%
5	87.3	87.3	0	0%
10	123	122.9	0.1	0%
20	161	157.4	3.6	2%
35	193	177.1	15.9	8%
50	214	187.4	26.6	12%
75	239	196.8	42.2	18%
100	257	202.2	54.8	21%
200	302	213.1	88.9	29%
350	339	221.2	117.8	35%
500	363	225.6	137.4	38%
750	391	231.8	159.2	41%
1,000	411	235.2	175.8	43%

5.6 Model Sensitivity

5.6.1 Purpose

Sensitivity analyses were conducted to evaluate the effects of changing model parameters on the simulated 100-year flood water levels. The model parameters included in the sensitivity analyses were the downstream boundary condition and Manning's *n* values for channels and floodplains (including roadway). The results of the sensitivity analyses were used to quantify the level of uncertainty associated with the simulated 100-year flood levels.

In addition to water levels, inundated area has been used as a sensitivity metric. Approximately 0.44 km^2 of the modelled area is permanently inundated (i.e., part of Lesser Slave Lake), approximated from aerial imagery. This area has been excluded from percentage increase/decrease in inundated area.

5.6.2 Manning's Roughness

Channel Roughness

The main channel Manning's *n* values were increased and decreased by 10% for the sensitivity analysis. The results of the sensitivity analysis of the channel Manning's *n* values are presented in Figures E.1a and E.1b in Appendix E. The average water level differences for increasing and decreasing the channel roughness compared to the base case are +0.02 m and -0.02 m along Marten Creek and +0.04 m and -0.04 m along the Unnamed Tributary, respectively. Increasing and decreasing the channel roughness also resulted in an increase and decrease of the total inundated area of +0.6% and -0.8%, respectively.

Floodplain Roughness

The floodplain and roadway Manning's *n* values were increased and decreased by 10% for the sensitivity analysis. The results of the sensitivity analysis of the channel Manning's *n* values are presented in Figures E.2a and E.2b in Appendix E. The average water level differences for increasing and decreasing the floodplain and roadway roughnesses compared to the base case are +0.02 m and -0.02 m along Marten Creek and +0.01 m and -0.01 m along the Unnamed Tributary, respectively. Increasing and decreasing the floodplain and roadway roughnesses also resulted in an increase and decrease of the total inundated area of +0.9% and -0.9%, respectively.

Channel and Floodplain Roughness

All Manning's *n* values were increased and decreased by 10% for the sensitivity analysis. The results of the sensitivity analysis of the channel Manning's *n* values are presented in Figures E.3a and E.3b in Appendix E. The average water level differences for increasing and decreasing all roughnesses compared to the base case are +0.04 m and -0.05 m along Marten Creek and +0.04 m and -0.05 m along the Unnamed Tributary, respectively. Increasing and decreasing all roughnesses also resulted in an increase and decrease of the total inundated area of +1.4% and -1.5%, respectively.

5.6.3 Boundary Conditions

The downstream boundary condition (i.e., the water level in Lesser Slave Lake) was increased and decreased by 20 cm for the sensitivity analysis. The results of the sensitivity analysis of the lake water level are presented in Figures E.4a and E.4b in Appendix E. The average water level differences compared to the base case are +0.03 and -0.02 m in Marten Creek for lake water level increases and decreases, respectively. Increasing and decreasing the lake water level also resulted in an increase and decrease of the total inundated area of +1.7% and -1.3%, respectively. There was no change in water levels along the Unnamed Tributary due to variation in water level in the lake.

5.6.4 Summary

The sensitivity analysis results are summarized in Table 13.

Table 13: Summary of Sensitivity Analysis Results

Sensitivity Metric		Manning's n						Lesser Slave Lake Water Surface Elevation	
		Channel		Floodplain		Channel and Floodplain			
		+10%	-10%	+10%	-10%	+10%	-10%	+0.2 m	-0.2 m
Inundation Area (%)		+0.6%	-0.8%	+0.9%	-0.9%	+1.4%	-1.5%	+1.7%	-1.3%
Water Depth along Marten Creek (m)	Maximum	+0.06	+0.01	+0.04	-	+0.08	-	+0.20	-
	Minimum	-0.01	-0.07	-	-0.04	-	-0.09	-	-0.20
	Average	+0.02	-0.02	+0.02	-0.02	+0.04	-0.05	+0.03	-0.02
Water Depth along the Unnamed Tributary (m)	Maximum	+0.06	-0.01	+0.01	-	+0.06	-0.02	-	-
	Minimum	+0.01	-0.06	-	-0.02	+0.02	-0.06	-	-
	Average	+0.04	-0.04	+0.01	-0.01	+0.04	-0.05	-	-

6.0 FLOOD INUNDATION MAPPING

6.1 Methodology

6.1.1 Map Preparation

The flood inundation maps were prepared based on the following information:

- the simulated water levels for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750- and 1,000-year flood events
- the LiDAR DTM

There are no dedicated flood control structures within the study area, so no protected areas were identified. The inundation maps show the areas throughout the study area, including applicable segments of Marten Creek, the Unnamed Tributary, and Lesser Slave Lake.

The general purpose of flood inundation maps is to show both direct flood inundation areas and areas at risk of flooding due to potential flood control structure failure, while the later is not applicable in this study area.

The full set of open water flood inundation maps is provided in a separate document (Appendix F).

6.1.2 Direct Flood Inundation Areas

Direct flood inundation areas are identified either as being part of the actively-flowing creek channel or flooded overbank areas directly connected to the actively-flowing creek channel. The following general procedure was used in ArcGIS to develop the inundation extent for the 13 open water flood events:

1) Flood inundation boundaries are exported from HEC-RAS 2D based on modelled water surface elevation and terrain data.
2) Areas that are not directly connected to the main river channels are manually removed. Areas where there is no direct overland connection but a hydraulic connection through culverts or other features, may be included in the inundation extent.

6.2 Flood Impacts

The residential and commercial areas affected by direct inundation are described below. Detailed inundation maps are provided in a separate inundation map library document.

- Residential areas south of Poplar Crescent along Pine Drive, Marten Drive, and connected roads on the north side of Marten Creek.
- Residential areas south of Marten Creek north of Lesser Slave Lake Provincial Park.

7.0 FLOODWAY DETERMINATION

7.1 Design Flood

The 100-year flood was selected as the open water design flood in accordance with the Flood Hazard Identification Program (FHIP) Guidelines (AENV, 2011). Flood Hazard Maps were prepared for the study area inclusive of Marten Creek and the Unnamed Tributary study reaches and the shoreline of Lesser Slave Lake. The design flood levels defined at 50 m stationing intervals, as shown in Figure D1 in Appendix D, are provided in Appendix G.

7.2 Floodway and Flood Fringe Terminology

The flood hazard area is the area of land that will be flooded during the design flood event (i.e., 100-year flood). The flood hazard area is typically divided into two zones: floodway and flood fringe. Flood hazard maps can also show additional flood hazard information, including areas of high hazard within the flood fringe and incremental areas at risk for more severe floods such as the 200-year and 500-year floods. Flood hazard mapping is typically used for long-term flood hazard area management and land-use planning. The floodway and flood fringe zones are defined as follows:

- Floodway: When a floodway is first defined on a flood hazard map, it typically represents the area of highest flood hazard where flows are deepest, fastest, and most destructive during the 100-year design flood. The floodway generally includes areas where the water is 1 m deep or greater and the local velocities are 1 m/s or faster. The floodway typically includes the main channel of a stream and a portion of the adjacent overbank area. Previously mapped floodways do not typically become larger when a flood hazard map is updated, even if the flood hazard area gets larger or design flood levels get higher.
- Flood Fringe: The flood fringe is the portion of the flood hazard area outside of the floodway. The flood fringe typically represents areas with shallower (less than 1 m deep), slower (less than 1 m/s velocity), and less destructive flooding during the 100-year design flood. However, areas with deep or fast moving water may also be identified as high hazard flood fringe within the flood fringe. Areas at risk behind flood berms may also be mapped as protected flood fringe areas.

7.3 Floodway Determination Criteria

In areas being mapped for the first time, the floodway typically represents the area of highest hazard where flows are deepest, fastest, and most destructive during the design flood. The following criteria, based on those described in current FHIP guidelines, are used to delineate the floodway in such cases:

- Areas in which the depth of water exceeds 1 m or the flow velocities are greater than 1 m/s shall be part of the floodway.
- Exceptions may be made for small backwater areas, ineffective flow areas, and to support creation of a hydraulically smooth floodway.
- For reaches of supercritical flow, the floodway boundary should correspond to the edge of inundation or the main channel, whichever is larger.

Areas of deeper or faster moving water outside of the floodway are identified as high hazard flood fringe. These high hazard flood fringe zones are identified in all areas, whether they are newly-mapped or have an existing floodway.

- The depth and velocity criteria used to define high hazard flood fringe zones will be aligned with the 1 m depth and 1 m/s velocity floodway determination criteria for newly-mapped areas.
- All areas protected by dedicated flood berms that are not overtopped during the design flood are excluded from the floodway. Areas behind flood berms will still be mapped as flooded if they are overtopped, but areas at risk of flooding behind dedicated flood berms that are not overtopped will be mapped as a protected flood fringe zone.

The governing criteria for Marten Creek and the Unnamed Tributary were based on the depth and velocity criteria as presented on the Floodway Criteria Maps in Appendix H. As modelling was conducted using a 2D hydraulic approach, the flow velocity information was deemed to be reliable when compared against the standard 1D approach.

7.4 Floodway Criteria Maps

Floodway criteria maps are a tool for determining floodway and flood fringe extents for the design flood, including boundaries of high hazard flood fringe and protected flood fringe areas. The Open Water Floodway Criteria Maps provided in the Maps and Drawings section of this report show:

- the extent of the 100-year design flood
- areas meeting or exceeding the 1 m depth floodway determination criterion for the design flood
- areas meeting or exceeding the 1 m/s velocity floodway determination criterion for the design flood
- the floodway boundary for the open water design flood
- background aerial imagery
- roads, bridges, and flood control structures

The open water design flood water surface elevations and flow velocities were generated from the calibrated HEC-RAS 2D model.

Flood depth and flow velocities are output directly from the RAS Mapper tool of the HEC-RAS 2D model.

The floodway boundary was delineated such that a hydraulically smooth floodway boundary was produced. The floodway criteria maps were produced using the same template as the inundation maps. The maps are provided in Appendix H.

7.5 Flood Hazard Maps

The flood hazard maps show the floodway and flood fringe for the design flood event. These maps have been developed in accordance with applicable provincial standards. The floodway was determined based on the floodway criteria. The extent of the flood fringe, beyond the floodway, corresponds to the extent of the design flood, including inundation due to potential flood control structure failure. All areas within the floodway boundary are shown as part of the floodway, even if the water levels of the design flood would not indicate a location as inundated (i.e., “islands” of dry ground within the floodway shown on the floodway criteria maps are not present on the flood hazard maps).

The flood hazard maps were produced using the same template as the inundation maps. The maps are provided in Appendix I.

7.6 Quantitative Climate Change Discussion

A simplified climate change assessment was completed to quantify the effects on the 100-year flood water levels for both 10% and 20% peak flow increases for Marten Creek. Table 14 summarizes the average water level increases in Marten Creek and the Unnamed Tributary under the assumed climate change conditions.

It is acknowledged that this simplified analysis is not based on a regional climate change impacts assessment but are based on a basic assumption that climate change may result in increased flood peak flows. The presented values can be viewed as a general range of potential climate change “freeboard” values that could be considered in addition to the computed design flood water levels. The 10% and 20% flow increase scenarios would respectively result in 1.9% and 3.4% increases in inundated area for the 100-year flood scenario, excluding the roughly 0.44 km^2 modelled area which is permanently inundated by Lesser Slave Lake.

Table 14: Effect of Increased Flows on Average Water Levels

Watercourse	Average Water Level Change for 10% Increase in 100-year Flood Peak Flow (m)	Average Water Level Change for 20% Increase in 100-year Flood Peak Flow (m)
Marten Creek	0.05	0.09
Unnamed Tributary	0.02	0.07

8.0 CONCLUSIONS

8.1 Model Calibration

The HEC-RAS 2D model for the study reach was calibrated based on the available highwater marks and lake level data. The calibrated HEC-RAS 2D model can be reliably used in this study for simulating various flood events with return periods ranging from 2 to 1,000 years.

The channel Manning’s *n* roughness coefficient is the main model parameter used in calibrating the HEC-RAS 2D model. The calibrated Manning’s *n* values for the channel, roadways, and floodplain are 0.025, 0.03, and 0.07, respectively. These Manning’s *n* values are on the low end of typical ranges of roughness values but considered reasonable based on the model calibration (Chow 1959).

8.2 Model Sensitivity

Model sensitivity was evaluated using the 100-year flood simulation results. The results of the sensitivity analysis show that variation of the main channel roughness value has a higher influence on the simulated water levels than variation of the floodplain roughness values along Marten Creek and the Unnamed Tributary. A variation of the main channel and floodplain Manning’s n values by ±10% resulted in changes of the simulated water levels within 0.09 m along Marten Creek and 0.06 m along the Unnamed Tributary. A variation of the water surface elevation in Lesser Slave Lake by ±0.20 m resulted in changes to inundated area within 1.7%.

8.3 Flood Profiles

The calibrated HEC-RAS 2D model provides a reliable tool for simulating the flood profiles of the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1,000-year flood events in the study area.

8.4 Flood Inundation Mapping

The simulated flood water levels were used to prepare flood inundation maps for the study area using ArcGIS. Based on the simulation results, the main residential and/or commercial development areas that would be flooded within the study area have been identified as follows:

- Residential areas south of Poplar Crescent along Pine Drive, Marten Drive, and connected roads on the north side of Marten Creek.

- Residential areas south of Marten Creek north of Lesser Slave Lake Provincial Park.

8.5 Flood Hazard Determination and Mapping

The boundary between the floodway and flood fringe is determined using the calibrated HEC-RAS 2D model and in accordance with the current FHIP Guidelines. The results of the design flood hazard mapping are the delineation of the floodway and flood fringe zones and determination of the design flood water levels.

9.0 CLOSURE

Thie report was prepared and reviewed by the undersigned.

WSP Canada Inc.

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SB/NG/RC/WP

10.0 REFERENCES

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Chow, Ven Te. 1959. *Open Channel Hydraulics*.

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USACE (US Army Corps of Engineers). 2021. *HEC-RAS 2D River Analysis System.* Hydrologic Engineering Center. Version 6.4.1.

THIRD PARTY DISCLAIMER

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APPENDIX A

Open Water Hydrology Assessment

DATE September 29, 2023 **Project No.** CA0010400

TO Jim Choles
Environment and Protected Areas

CC Wolf Ploeger and Dejiang Long

FROM Mesgana Gizaw and Getu Biftu **EMAIL** mesgana.gizaw@wsp.com

OPEN WATER HYDROLOGY ASSESSMENT – MARTEN BEACH FLOOD STUDY

1.0 INTRODUCTION

1.1 Study Area and Scope

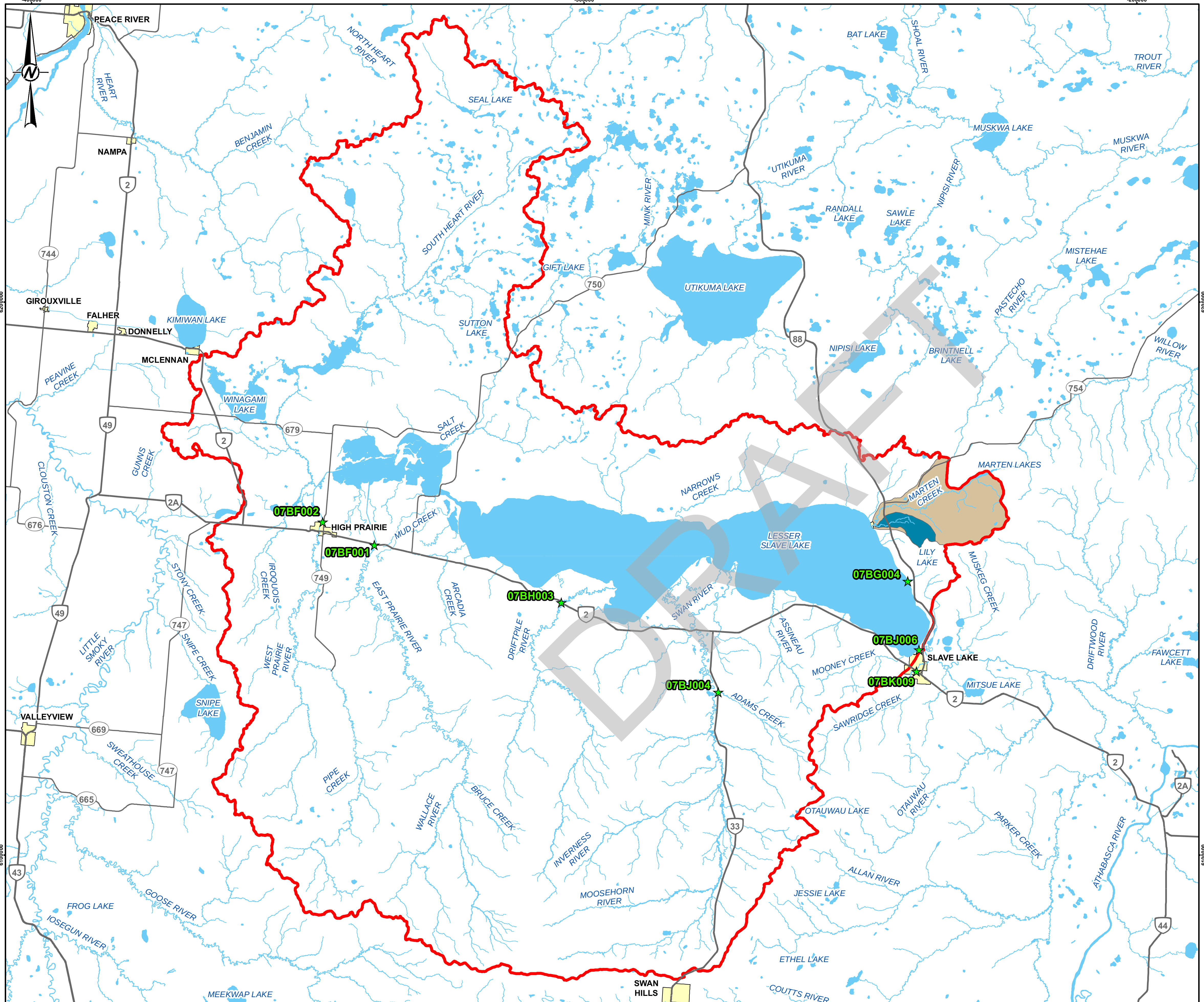
Alberta Environment and Protected Areas (EPA), formerly called Alberta Environment and Parks (AEP), commissioned the then Golder Associates Ltd. (Golder), now amalgamated into WSP Canada Inc. (WSP), in October 2020 to conduct the Marten Beach Flood Study (the study). The purpose of the study is to assess and identify river and flood hazards along a 3.2 km reach of Marten Creek through the Hamlet of Marten Beach (Figure 1).

The study is part of the provincial Flood Hazard Identification Program (FHIP), the goals of which include enhancement of public safety and reduction of future flood damages through the identification of river and flood hazards. Project stakeholders include the Government of Alberta, the Municipal District of Lesser Slave River, the residents of the Hamlet of Marten Beach, and the public.

The study comprises multiple components and deliverables. This memorandum documents the methodology and results of the open water hydrology assessment that will support the hydraulic modelling and open water flood mapping. The individual tasks associated with this hydrology assessment component include the following:

- Data Series Preparation: Compile peak flow information available for the gauged locations and prepare flood flow data series.
- Flood Frequency Analysis: Conduct frequency analyses to estimate flood flows and water levels for return periods ranging from 2 to 1,000 years using the recorded and derived flood peak flow and water level data for the available periods of record up to 2020.
- Climate Change Commentary: Provide comments and insight into how climate change processes may impact the flood peak flows and flood frequency estimates.

The flood frequency estimates obtained in this study are the most up to date for the study area. These estimates provide the updated flood hydrology information as flow inputs to hydraulic modelling in this study.



LEGEND

- PRIMARY HIGHWAY
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- POPULATED PLACE
- WATER SURVEY OF CANADA GAUGING STATION

WATERSHED

- MARTEN CREEK
- UNNAMED TRIBUTARY CREEK
- LESSER SLAVE LAKE

0 20 40

1:700,000 KILOMETRES

NOTE(S)

SUB-BASINS WERE OBTAINED FROM HUC8 WATERSHEDS (GOVERNMENT OF ALBERTA 2015) WHERE POSSIBLE. OUTSIDE OF ALBERTA, SUB-BASINS WERE OBTAINED FROM AAFC WATERSHED DATA.

REFERENCE(S)

HYDROMETRIC STATIONS OBTAINED FROM AGRICULTURE AND AGRI-FOOD CANADA (AAFC). BASIN AND SUB-BASIN DATA OBTAINED FROM AGRICULTURE AND AGRI-FOOD CANADA (AAFC) AND THE GOVERNMENT OF ALBERTA 2015.
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DATUM: NAD 83 CSRS PROJECTION: 3TM 111

CLIENT
ALBERTA ENVIRONMENT AND PARKS

PROJECT
MARTEN BEACH FLOOD HAZARD STUDY

TITLE
MARTEN CREEK AND UNNAMED TRIBUTARY CREEK WATERSHEDS AT MARTEN BEACH

CONSULTANT

YYYY-MM-DD	2023-08-25
DESIGNED	GT
PREPARED	PT
REVIEWED	GT
APPROVED	GB

PROJECT NO.	REV.	FIGURE
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1.2 Study Objectives and Results

The primary objective of this study is to identify and assess river-related hazards. The objective of the open water hydrology assessment is to generate flood peak flow estimates along the study reaches of Marten Creek, and to determine flood peak water levels at Lesser Slave Lake. The results of the frequency analysis include estimates of the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1,000-year open water flood peak flows and water levels.

This study includes the use of some preliminary estimates of annual peak flow and water levels for the period from 2015 to 2020 for the gauged regional watersheds, which were provided by Environment and Climate Change Canada, Water Survey of Canada (WSC), and EPA. Including these provisional data increases the sample sizes for the flood frequency analyses and reliability of the resulting flood frequency estimates.

It is important to note that some of the annual maximum instantaneous flow and water levels for the period 2015 to 2020 are provisional and preliminary, and may be subject to change when reviewed and corrected by the WSC. Therefore, the flood frequency statistics presented in this memorandum should be used with caution and reviewed when the finalized flow values are available.

1.3 Watershed Setting and Historical Floods

Marten Creek is a tributary stream to Lesser Slave Lake and has a drainage area of 235 km^2 and a mean watershed elevation of 828 masl (metres above sea level). The drainage areas and boundaries were estimated based on Agriculture and Agri-Food Canada's (AAFC) Watersheds Project (AAFC 2013) watershed boundaries within the 1:20,000 ALTALIS provincial Digital Elevation Model (DEM).

Marten Beach is situated on the Marten Creek alluvial fan along the shoreline of Lesser Slave Lake. Marten Creek at Marten Beach is fed by a catchment upstream of Highway 88 and an unnamed tributary creek, locally known as Brady Creek, with a drainage area of 31.3 km^2 that joins Marten Creek immediately upstream of Range Road 65A. The Marten Creek headwaters are at Marten Lakes located approximately 23 km upstream of Marten Beach.

Marten Beach has historically been subject to flooding from Marten Creek due to extreme rainfall events. Significant floods were recorded in 1978, 1987, 1988, 1996, 2011, 2018, and most recently in July 2019 (Golder 2019a). The largest flood event, according to accounts by the Municipal District of Lesser Slave River No. 124 (the MD) was the July 2019 flood event. Preliminary analysis in Golder study (2019a) anecdotally suggested that the July 2019 flood event may have been close to a five-year flood event.

2.0 AVAILABLE FLOW DATA

2.1 Recorded Data

The flood frequency estimates for Marten Creek were derived based on the results of a regional analysis of flood peak flows. The recorded water level data from the WSC website is available for the Lesser Slave Lake adjacent to the study area. The preliminary annual maximum instantaneous flow data for the period from 2015 to 2020 were obtained from WSC and EPA.

A summary of the basic hydrologic information used to derive the flood frequency estimates for the study area is provided in Table 1. The data details are provided in Appendix A. The regional hydrometric stations were selected based on their proximity (i.e., relatively close to the study area), size (i.e., reasonable range of gross and effective drainage area that can be used to establish the regional relationships), and physiographic characteristics (e.g., similar drainage characteristics).

Table 1: Summary of Gauged Stations Considered in the Study

WSC Station Number	WSC Station Name	Measured Hydrometric Variable	Latitude	Longitude	Approximate Distance from the Study Area (km)	Gross Drainage Area (km^2)	Effective Drainage Area (km^2)	Length of Record (years)	Period of Record
07BF001	East Prairie River Near Enilda	Flow and Water Level	55°25'03" N	116°20'24" W	90	1,470	1,470	100	1921-2020
07BF002	West Prairie River Near High Prairie	Flow and Water Level	55°26'53" N	116°29'33" W	100	1,150	1,150	100	1921-2020
07BG004	Lily Creek Near Slave Lake	Flow and Water Level	55°24'57" N	114°48'51" W	12	23.7	23.7	34	1987-2020
07BH003	Driftpile River Near Driftpile	Flow and Water Level	55°20'47" N	115°47'47" W	58	835	835	49	1972-2020
07BJ004	Adams Creek Near Kinuso	Flow	55°13'05" N	115°20'04" W	41	138	138	19	1977-1995
07BK009	Sawridge Creek Near Slave Lake	Flow and Water Level	55°16'14" N	114°46'30" W	28	230	230	45	1976-2020
07BJ006	Lesser Slave Lake at Slave Lake	Water Level	55°18'20" N	114°46'17" W	24	13,600	13,400	42	1979-2020

Note: For comparison, the study reach of Marten Creek is located at latitude of approximately 55°30'00" N and longitude of approximately 114°55'20" W, and has a gross drainage area of approximately 235 km^2 and effective drainage area of approximately 235 km^2.

2.2 Historic Data

The earliest recorded and well documented flooding around the Lesser Slave Lake area was for Sawridge Creek at Slave Lake. The earliest historical flood event noted for Sawridge Creek before systematic gauging and monitoring, occurred on July 1, 1961 due to an intense rainstorm. That flood event came close but did not overflow the banks of the Creek (Topham and Stevenson 1973). Another flood event, which occurred in 1968, was the last flood of significance on Sawridge Creek prior to construction of the Diversion Canal in 1971.

The flood of June 18, 1972 of Sawridge Creek was well documented (Topham and Stevenson 1973) and provided the first test of the completed flood protection works. According to local newspaper accounts, flows of notable magnitude occurred in 1974 and 1975, but these floods did not cause large damage.

EPA operated a staff gauge on Sawridge Creek from 1962 to 1975. The estimates of the 1974 and 1975 flood peak flows were made based on the water level measurements of that staff gauge. However, a report by EPA (then Alberta Environment Protection [AEP]) in 1993 indicates that the estimated 1974 and 1975 flows should be regarded as a relative indication of the flow magnitude due to a limited amount of data used to estimate the flow values (AEP, 1993).

No historic hydrometric data are available for Marten Creek.

2.3 Previous Studies

This study included a review of several background documents, including previous hydrology and flood studies. Several hydrology studies were completed over the last two decades. Some of these studies included assessments of open water hydrology. These studies include the following:

- Sawridge Creek Hydrology for the Town of Slave Lake Floodplain Study by Alberta Environment (Taggart 1992)
- Slave Lake Flood Risk Mapping Study, Alberta Environmental Protection (AEP 1993)
- Climate Change Assessment for Athabasca River Basin (Golder 2013)
- Hydro-Climate Model Selection and Application on the Athabasca and Beaver River Basins (Golder 2009)
- Athabasca River Basin - Feasibility Study (IBI and Golder 2014)
- Quantifying the effects of Climate Change and Land Use on Streamflow and Lake Levels in the Lesser Slave Watershed (Sturgess 2017)
- Regional Hydro-Climatic and Sediment Modeling (Droppo et al. 2019)
- Marten River Flood Mitigation Engineering Preliminary Design Report (Golder 2019a).
- Open Water Hydrology Assessment for the Slave Lake Flood Hazard Study (Golder 2019b)

The review involved documentation of the assumptions, limitations, and understanding of the hydrologic techniques applied in the past studies. The results of these past studies provided a frame of reference for interpretation of the results and comparison to this study. The review helped identify data gaps and apparent discrepancies in the data that may affect their use in subsequent analyses.

3.0 PREPARATION OF FLOOD FLOW DATA SERIES

3.1 Introduction

Preparation of the flood flow series involved consideration of many factors, including unequal and non-overlapping record lengths, and incomplete flow records. The methods used to compile the flood flow series and to address the data gaps are described in the following sections.

3.2 Flood Flow Series for the Gauged Location

The flood frequency estimates for the gauged locations were derived based on the recorded annual maximum instantaneous flow and water level series, and where there are missing data, the annual maximum daily flows and water levels that were used to estimate the instantaneous flood flows and water levels.

The following method was used for estimating the annual maximum instantaneous flows and water levels based on the annual maximum daily flows and water levels to fill the data gaps in the record:

- Annual maximum daily flow and water level series were developed using the recorded daily flow and water level series.

- Relationships were established between event-based annual maximum daily and annual maximum instantaneous flows and water levels in the record. If the reported annual maximum daily and annual maximum instantaneous flows and water levels for the same year were not coincident (i.e., from the same flood event), the former values were replaced by the daily flow and water level values for the events corresponding to the annual maximum instantaneous flows and water levels. This relationship was used to estimate the annual maximum instantaneous flows and water levels based on the recorded annual maximum daily flows and water levels.

3.2.1 Consideration of Historical Flood Information

In this study, historical floods at gauged locations are defined as documented floods which occurred prior to the start of systematic flow monitoring. From the list of gauged locations assessed in this study, well documented historical flood information of Sawridge Creek are available and, therefore, further investigated because it has comparable drainage area and is near Marten Creek. Discussion of documented and anecdotal evidence of the historical floods for Sawridge Creek are provided in Section 2.2. A summary of the notable historical flood events on the Sawridge Creek at the Town of Slave Lake, is provided in Table 2.

Table 2: Notable Historical Floods on Sawridge Creek at the Town of Slave Lake (AEP 1993)

Year	Estimated Flood Flows (m^3/s)	Comment
1961	122	Consideration of available Highwater Mark data
1968	103	Consideration of available Highwater Mark data
1972	66	Consideration of available Highwater Mark data
1974	52	Estimated based on the water level measurements using the staff gauge
1975	70.5	Estimated based on the water level measurements using the staff gauge

There is some uncertainty with the estimated magnitudes of the historical floods. However, the United States Geological Survey Bulletin 17C (England et al. 2018) methodology allows for inclusion of historical flood events with uncertain flows using observation thresholds and estimated flow intervals over an ungauged period in which a flood has been documented to have occurred.

Bulletin 17C follows the Bulletin 17B analytical framework but makes several improvements related to the treatment of historical floods, the identification of low outliers, and the calculation of confidence limits. Bulletin 17C also provides the use of regional skew coefficients, if they are available, and updates the Bureau's understanding of climate variability and climate change.

The most relevant changes between Bulletins 17B and 17C are related to (i) the use of the expected moments algorithm to define the statistical characteristics of a given flood series and (ii) the ability to include more than one threshold level. Bulletin 17C relies principally on regional skew coefficients, but when they are not available it defaults to the station skew. While these features are positive, Bulletin 17C is very much a "black box" with very little user input beyond, for example, inserting the flood data and setting the threshold levels associated with each event. One significant short coming is that only the log-Pearson III distribution is available.

Using the Bulletin 17C methodology, frequency analysis was performed using the Sawridge Creek flood peak data series, with and without inclusion of the pre-systematic period of 1961 to 1975. Appropriate perception thresholds and flow intervals were assigned for ten “non-flood” years, using a flood magnitude of 52 m^3/s threshold value.

3.3 Flood Flow Series for the Ungauged Locations

There are no hydrometric gauges at Marten Creek. Therefore, flood flow series were not developed at Marten Creek, and flood frequency estimates were based on the methodology discussed below.

Empirical relationships between drainage areas and flood peak flows were established based on the available regional flow records and for the return periods ranging from 2 to 1,000 years. The relationships were then used to derive the flood frequency estimates for Marten Creek in the study area.

The flood peak flows of Marten Creek were obtained from the flood peak flows at Sawridge Creek that were derived with consideration of historical flood information (see Section 3.2.1) as follows:

- The drainage areas at the WSC stations were compiled. The gross drainage areas at the ungauged locations of Marten Creek (i.e., Marten Creek at Marten Beach [drainage area of 235 km^2] and Marten Creek upstream of the confluence with the unnamed tributary creek [drainage area of 200 km^2]) were estimated in a GIS analysis. Downstream of the confluence of Marten Creek with the unnamed tributary creek, additional runoff joins Marten Creek from local drainage area of 3.7 km^2.
- The flood frequency estimates for the WSC stations with flow data (Table 1) were obtained based on the systematic recorded or derived annual maximum instantaneous flow series as described in Section 3.2.
- For the purpose of developing the regional relationships, the flood frequency estimates for Sawridge Creek were developed based on systematic record floods (i.e., without correction for historical floods) to be consistent with data used for the other regional stations (i.e., systematic recorded floods only).
- Regional relationships between drainage area and peak flows for a range of return periods (i.e., 2 to 1,000 years) were developed, as shown in Figure 2 to come up with the regional area power factors.
- The flood frequency estimates for Marten Creek for the various return periods were derived from the flood peak flows of Sawridge Creek that were derived with consideration of historical flood information (see Section 3.2.1 and area power factors from the regional analysis (Figure 2).

Sawridge Creek was selected for estimating the peak flows of Marten Creek because it has almost the same drainage area (230 km^2) as Marten Creek (235 km^2) and because the available period of record for Sawridge Creek (45 years) is longer than the other two smaller gauged watersheds (i.e., 19 years only for Adams Creek near Kinuso, and 34 years for Lily Creek near Slave Lake).

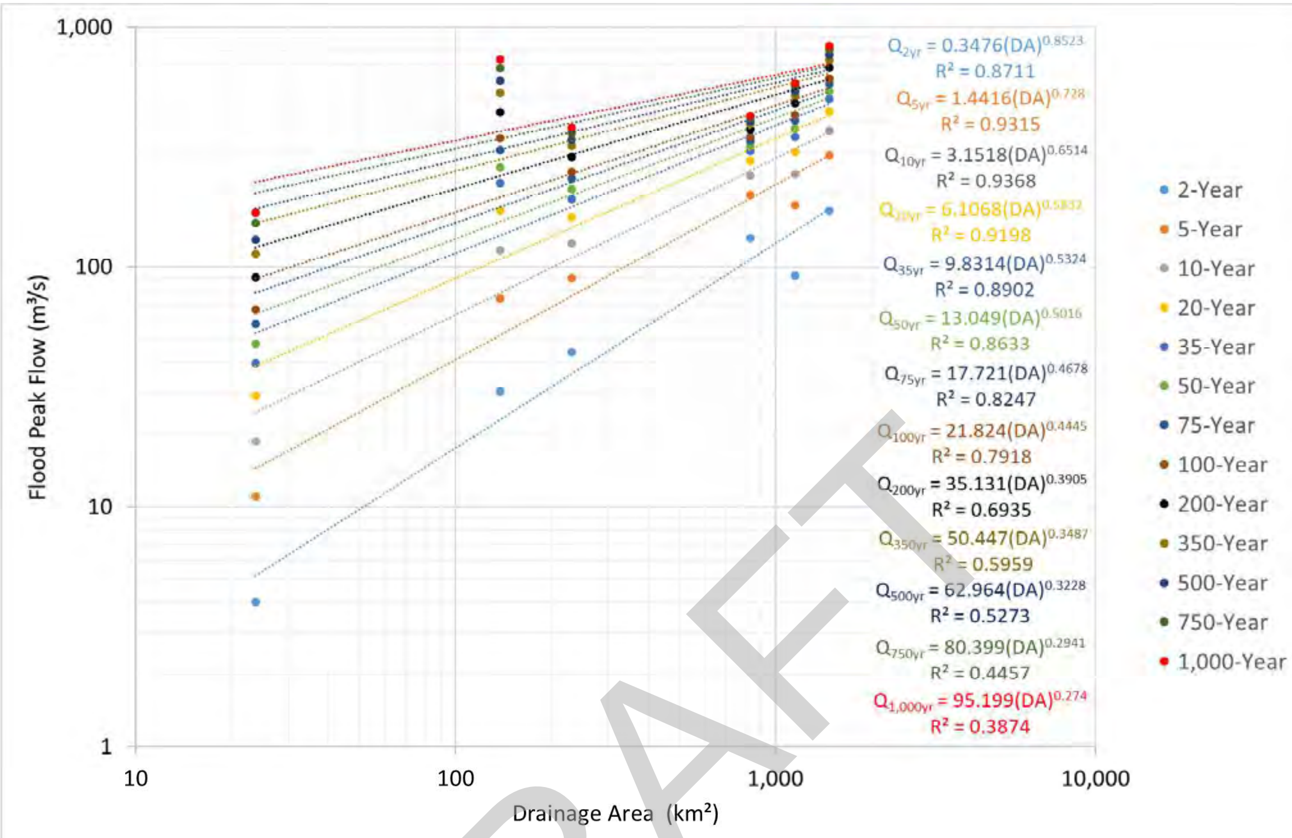

Figure 2: Empirical Relationships between Flood Peak Flows and Drainage Areas for the Regional Stations

4.0 FLOOD FREQUENCY ANALYSIS

4.1 Statistical Tests

4.1.1 Methodology

Prior to fitting the appropriate frequency distribution to the flood flow and water level data, several statistical tests were performed to determine the quality of the developed annual maximum instantaneous flow and water level series. Software developed by Golder (now WSP) that is similar to Environment and Climate Change Canada's Consolidated Frequency Analysis (CFA), but with enhanced methodology, was used for: (i) flood frequency analyses and statistical tests for independence (not serially correlated); and (ii) trend, randomness, and homogeneity tests. Golder's software includes modern boot-strapping method and estimation of confidence intervals.

The following probability distributions were analyzed with select parameter estimation methods (i.e., method of moments [Moment], maximum likelihood estimation [MLH], and Method of L-moments [MLM]):

- Three-parameter Log Normal distribution (3P, Moment and MLH)
- Generalized Extreme Value distribution, which includes Extreme Value 1, 2, and 3 distributions (EV, MLM)
- Log-Pearson Type III distribution (LP3, Moment, and MLH); and

- Weibull distribution (Moment).

Numerical goodness-of-fit tests were performed using the non-parametric Anderson-Darling test (Stephens 1974).

4.1.2 Results

The results of statistical analysis for the regional stations are provided in Table A-2, Appendix A. The results show that most of the annual maximum instantaneous flow series and water level series are independent, random, homogeneous, and do not display any significant trends.

The annual maximum instantaneous flow series for West Prairie River near High Prairie displays non-randomness at the 5% level of significance but not at 1% level of significance. Obtaining data that is perfectly random is almost impossible since factors, such as data length and record period can affect the outcome of the statistical tests.

4.2 Flood Frequency Estimates

Flood frequency analyses of the annual maximum instantaneous flow (that includes the preliminary estimates of the 2015 to 2020 flood flows) of regional hydrometric stations with flow data (Table 1) were conducted to estimate peak flows of various return periods (i.e., 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1,000-year floods). These peak flows were used to develop the regional relationships shown in Figure 2. Flood frequency analysis was also performed for Sawridge Creek near Slave Lake (WSC Station #07BK009) considering historical and censored data using the methodology of Bulletin 17C. Frequency analysis was also performed on the annual maximum instantaneous water levels for Lesser Slave Lake at Slave Lake (WSC Station #07BJ006).

4.2.1 Results

The flood frequency estimates for Sawridge Creek and the 95% confidence intervals that are derived with consideration of historical floods and censored data are provided in Table 3.

Table 3: Sawridge Creek Flood Frequency Estimates Considering Historical Floods and Censored Data.

Return Period (years)	Annual Probability of Exceedance (%)	Value (m^3/s)	Lower 95% Limit (m^3/s)	Upper 95% limit (m^3/s)
2	50	41.9	33.6	52.1
5	20	85.9	69.7	108
10	10	121	97.6	163
20	5.0	159	124	231
35	2.9	191	143	297
50	2.0	212	154	345
75	1.3	237	165	405
100	1.0	254	172	453
200	0.50	299	188	584
350	0.29	336	199	712
500	0.20	360	206	804
750	0.13	389	212	922
1,000	0.10	409	217	1013

The flood frequency estimates along with their 95% confidence intervals for Marten Creek at Marten Beach and Marten Creek just upstream of the confluence with the unnamed tributary creek were prorated from the flood frequency estimates for Sawridge Creek near Slave Lake (Table 3), and the area power factor developed based on the regional relationship presented in Figure 2. The flood flow estimates and the associated upper and lower 95% confidence intervals for Marten Creek at these two locations are summarized in Table 4 and Table 5.

Adams Creek near Kinuso has a relatively short period of data record (i.e., 19 years), and the corresponding flood peak flows appear to be overestimated when comparing against the regional relationships in Figure 2. The effect of Adams Creek in the regional flood analysis was evaluated by excluding this creek from the regional analysis. Excluding Adams Creek from the list of regional stations used for regional analysis will have no effect on the flood frequency estimates for Marten Creek at Marten Beach and Marten Creek just upstream of the confluence with the unnamed tributary creek. Hence, the regional relationships developed by including Adams Creek are retained to derive the area power factor used to estimate flood flow estimates for Marten Beach at these two locations.

Table 4: Recommended Flood Frequency Estimates for Marten Creek at Marten Beach

Return Period (years)	Annual Probability of Exceedance (%)	Value (m^3/s)	Lower 95% Limit (m^3/s)	Upper 95% limit (m^3/s)
2	50	42.7	34.3	53.1
5	20	87.3	70.9	110
10	10	123	99.1	165
20	5.0	161	126	234
35	2.9	193	145	301
50	2.0	214	155	349
75	1.3	239	167	410
100	1.0	257	174	457
200	0.50	302	190	590
350	0.29	339	201	717
500	0.20	363	207	810
750	0.13	391	214	928
1,000	0.10	411	218	1,020

Table 5: Recommended Flood Frequency Estimates for Marten Creek upstream of the Confluence with the Unnamed Tributary Creek.

Return Period (years)	Annual Probability of Exceedance (%)	Value (m^3/s)	Lower 95% Limit (m^3/s)	Upper 95% limit (m^3/s)
2	50	37.3	29.9	46.3
5	20	77.7	63.0	97.6
10	10	111	89.2	149
20	5.0	147	114	213
35	2.9	177	133	276
50	2.0	197	143	322
75	1.3	222	154	380
100	1.0	239	162	426
200	0.50	284	178	554
350	0.29	321	190	678
500	0.20	345	197	769
750	0.13	373	204	885
1,000	0.10	393	209	976

The flood water level estimates for Lesser Slave Lake at Slave Lake and the associated upper and lower 95% confidence intervals are summarized in Table 6. The frequency estimates of the water level at Slave Lake are used to approximate and represent those at Marten Beach because Slave Lake is in close proximity to Marten Beach, and there is no lake water level record at Marten Beach. Although such approximation is reasonable, it is recognized that winds affect areal variation in the lake level, and such effects may affect the accuracy of the lake water level frequency estimates at Marten Beach.

The annual maximum instantaneous flow and water level series used in the flood frequency analyses, the various frequency distributions, and the best-fit distributions along with their 95% confidence intervals are provided in Appendix A and B.

Table 6: Recommended Flood Frequency Estimates for the Lesser Slave Lake at Slave Lake

Return Period (years)	Annual Probability of Exceedance (%)	Value (m)	Lower 95% Limit (m)	Upper 95% limit (m)
2	50	577.01	576.88	577.19
5	20	577.47	577.23	577.72
10	10	577.77	577.43	578.06
20	5.0	578.05	577.63	578.37
35	2.9	578.27	577.78	578.62
50	2.0	578.41	577.87	578.77
75	1.3	578.57	577.97	578.94
100	1.0	578.69	578.03	579.06
200	0.50	578.96	578.19	579.35
350	0.29	579.18	578.31	579.60
500	0.20	579.32	578.39	579.76

Table 6: Recommended Flood Frequency Estimates for the Lesser Slave Lake at Slave Lake

Return Period (years)	Annual Probability of Exceedance (%)	Value (m)	Lower 95% Limit (m)	Upper 95% limit (m)
750	0.13	579.48	578.47	579.94
1,000	0.10	579.60	578.52	580.08

4.3 Comparison to Previous Studies

A comparison of the flood frequency estimates obtained in this study for Marten Creek at Marten Beach and Lesser Slave Lake at Slave Lake, with the previously completed studies, are provided in Table 7 and Table 8.

The current study is based on the provisional and published regional gauging station flow and water level data up to 2020. In addition, this study includes analyses to update the relationships between annual maximum daily and annual maximum instantaneous flows for regional stations.

The comparison in Table 7 and Table 8 shows that the main differences in the flood frequency estimates are due to the different lengths of the recorded data used in the flood frequency analyses and the selections of different frequency curve distributions.

Table 7: Comparison of the Marten Creek at Marten Beach Flood Frequency Estimate to Previous Studies

Return Period (years)	Flood Peak Flow of Marten Creek at Marten Beach (m^3/s)	
	Golder (2019b)	This Study
2	40.3	42.7
5	82.8	87.3
10	120	123
20	161	161
50	227	214
100	284	257

Note:
The Golder (2019b) study involved the use of the recorded data spanning between 1921 to 2015.

Table 8: Comparison of the Lesser Slave Lake at Slave Lake Flood Frequency Estimate to Previous Studies

Return Period (years)	Flood Peak Water Level of Lesser Slave Lake at Slave Lake (m)				
	AEP (1993)	IBI and Golder (2014)	Golder (2019a)	Golder (2019b)	This Study
2	576.73	576.85	576.97	577.0	577.01
5	577.14	577	577.39	577.4	577.47
10	577.38	578	577.67	577.7	577.77
20	577.60	578	577.94	577.9	578.05
25	577.66	578	-	-	-
50	577.86	578.24	578.29	578.3	578.41
100	578.05	579	578.55	578.5	578.69
500	-	579	579.18	-	579.32

Notes:

The AEP (1993) study involved the use of the recorded data from 1975 to 1989 for Sawridge Creek near Slave Lake.

The IBI and Golder (2014) study involved the use of the recorded data from 1976 to 2011 for Sawridge Creek near Slave Lake, from 1988 to 2011 for Lesser Slave River at Slave Lake, and from 1984 to 2011 for Lesser Slave Lake at Slave Lake.

The Golder (2019a) study involved the use of recorded and provisional data spanning between 1979 and 2018.

The Golder (2019b) study involved the use of the recorded data spanning between 1979 to 2015.

Distribution used to estimate water level frequency estimates is not provided in the AEP (1993) report.

5.0 POTENTIAL EFFECTS OF CLIMATE CHANGE ON FLOOD PEAK FLOWS AND FLOOD FREQUENCY ESTIMATES

Recent studies on the effect of climate change (e.g., Martz et al. 2007; Sturgess 2017; Droppo et al. 2019) indicate that climate change could result in increased air temperature, more frequent drought and water shortages, increased precipitation in some areas, and increased flooding. As a result of the expected change in both the systematic climate and its variability, many regions of Canada, including the Prairies, could experience warmer air temperatures and changes in stream flow magnitude and timing (e.g., higher winter stream flows, early spring peak streamflow, and lower summer stream flows).

Droppo et al. (2019) review of several studies indicates with high confidence that projected increases in extreme precipitation are expected to increase the potential for future urban flooding. There is medium confidence that projected higher temperatures will result in a shift toward earlier floods associated with spring snowmelt, ice jams, and rain-on-snow events. However, it is uncertain how projected higher temperatures and reductions in snow cover will affect the frequency and magnitude of future snowmelt-related flooding.

Assessment of future climate scenarios depends on the climate model used for the prediction. Regardless, precipitation is projected to increase in Alberta, with less precipitation falling as snow and more rainfall-on-snow precipitation events (Valeo et al. 2007). Therefore, it is anticipated that such changes in precipitation patterns could increase the frequency and intensity of extreme events (i.e., flood, drought, hail, and windstorms). It is also predicted that the flood events for the Marten Creek watershed could occur earlier in the spring than in the past if rain-on-snow events occur more frequently and the snowpack begins to melt earlier.

Golder (2013) completed an assessment of the effect of climate change using five selected representative GCMs and scenarios outputs from the IPCC Fourth Assessment Report (AR4) (IPCC 2007) for the Athabasca River basin, which includes Marten Creek. The five selected scenarios represent climate conditions that were cooler and drier (BCM2.0 SR-B1), cooler and wetter (INMCM3.0 SR-A2), warmer and wetter (MIROC3.2 hires SR-A1B), and warmer and drier (CNRMCM3 SR-A2) than median conditions (CGCM3T47 SR-B1).

The forecasted total climate change between the modelled baseline period (1961 to 1990) as represented by its 30-year average and the modelled future period (i.e., the period of 2051 to 2080 called the 2060s) as represented by its 30-year average. The results indicate that the changes in flood peaks for the Athabasca River watershed that include Marten Creek will vary from slight decrease for the 2-year flood (i.e., less than 5%) to slight increase (i.e., less than 10%) for the 100-year flood for the median climate change conditions. Therefore, changes in the flood peak flows for Marten Creek are expected to be small for the median climate change projections.

Sturgess (2017) used six future climate change scenarios derived from the CanESM2 general circulation model for three 30-year periods (i.e., 2010-2040, 2040-2070, and 2070-2100) to evaluate changes in the hydrological response of the Lesser Slave River Watershed that include Marten Creek. Each climate scenario was simulated under the following two "Representative Concentration Pathways" (RCP):

- RCP 4.5, a moderate scenario where greenhouse gas emissions stabilize and radiative forcing is stabilized by the year 2100.
- RCP 8.5, a severe scenario where greenhouse gas emissions continue to increase indefinitely.

The results of the analysis indicated the following:

- In general, climate in the Lesser Slave River watershed that include Marten Creek is projected to be warmer and wetter under all future climate change scenarios.
- Under future climate change scenarios, maximum daily flow for Lesser Salve River at Slave Lake was projected to largely increase (i.e., by more than 50%).
- Under all future climate change scenarios, Lesser Slave Lake water levels were projected to increase substantially throughout the year. The increase is projected to be the largest during the spring runoff period, and the projection involved increased peak lake water levels during the spring, coinciding with snowmelts. For the period of 2070 to 2100, the average lake level was projected to increase by approximately 0.8 m. Even under a conservative climate change scenario (i.e., RCP 4.5), the lake levels were projected to reach 577.0 m at least in one of every five springs, which is approximately 0.5 m greater than the level for the range of historical 30-years average seasonal variability.

Analysis of trend in historical annual peak flows in Marten Creek is indirectly completed using the recorded flow from neighbouring Sawridge Creek. The 1988 flood on the Sawridge Creek has been the largest flood since 1961, as illustrated in Figure 3. Based on the recorded flow data for the past 60 years (i.e., 1961 to 2020), the annual peak flows on Sawridge Creek do not appear to be trending upward or downward. Any upward or downward trend shown in Figure 3 is not statistically significant. Therefore, a similar trend is expected for Marten Creek.

Approximately 62% of the recorded annual maximum flows on Sawridge Creek occurred between the beginning of May and the end of July (see Table 9 and Figure 4). There is no clear evidence that the patterns in magnitude or timing of annual maximum flows have changed significantly over the past 50 years. However, the frequency of annual maximum flows occurring in late April and May has increased since the 1990's from that for the period 1975 to 1990.

Table 9: Timings of Annual Maximum Instantaneous Flows on the Sawridge Creek (1976 – 2020)

Month	Number	%
March	3	7
April	6	13
May	9	20
June	9	20
July	10	22
August	6	13
September	2	4

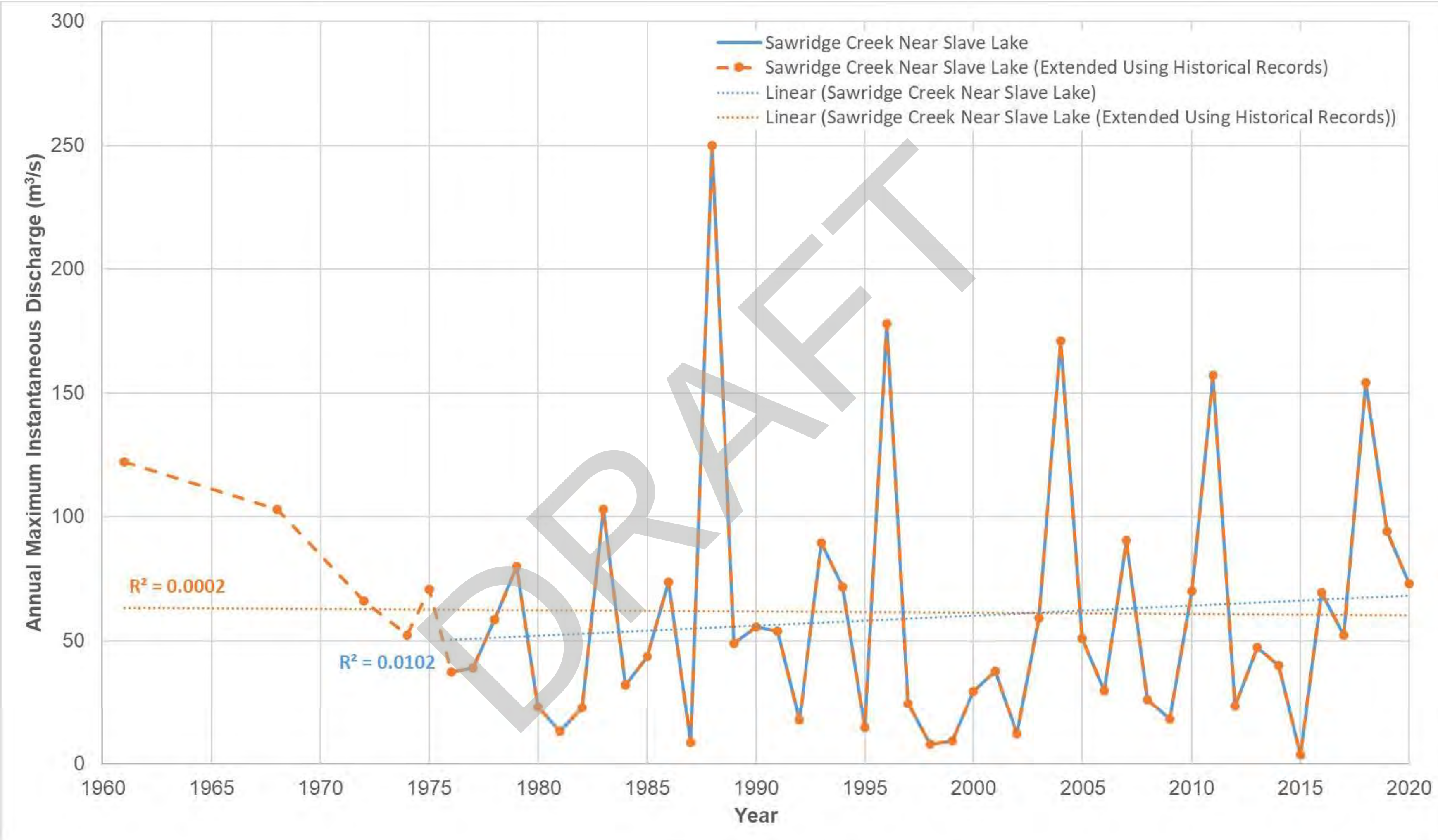

Figure 3: Annual Flood Peak Flows on the Sawridge Creek near Slave Lake

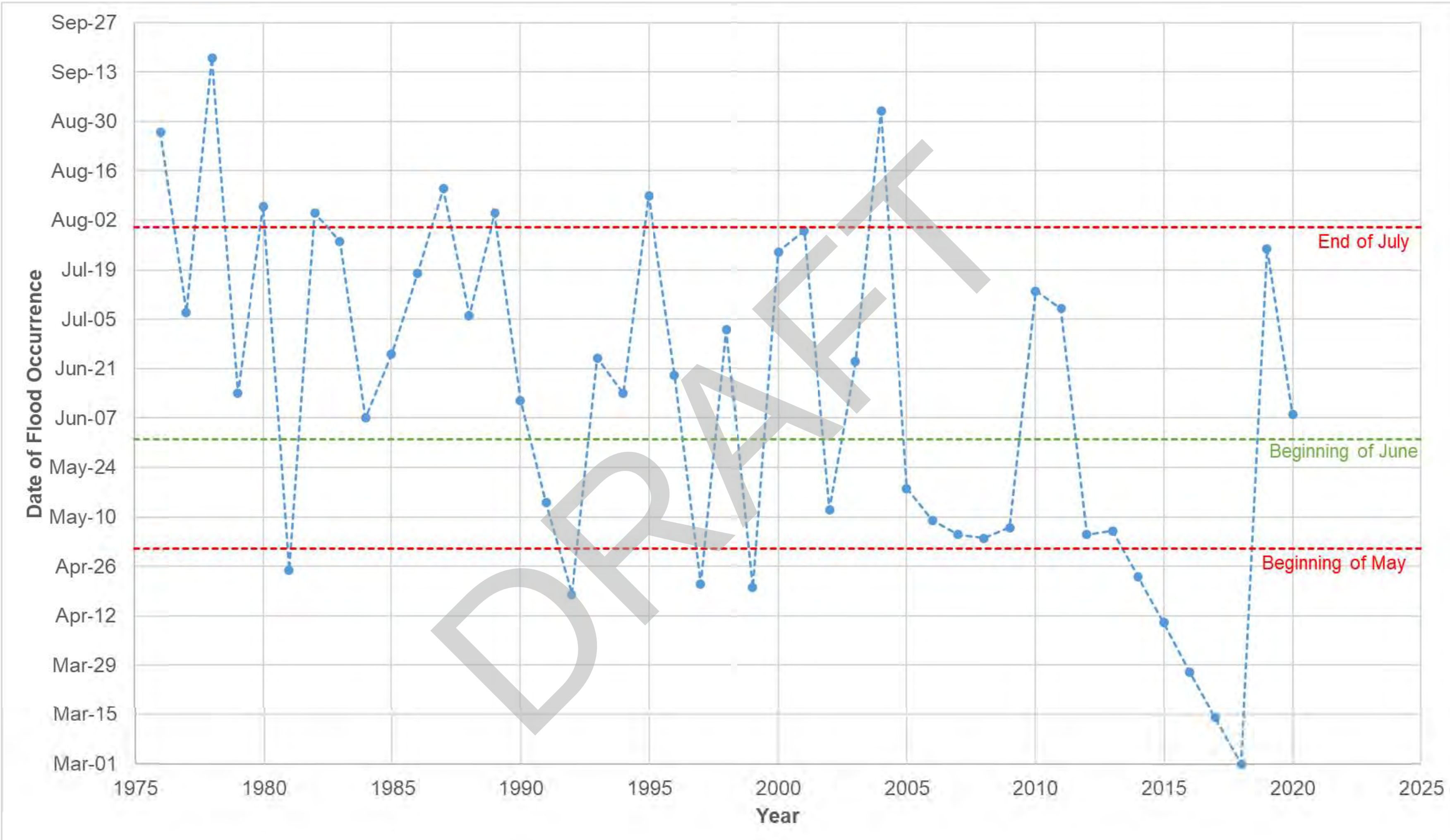

Figure 4: Timings of Past Annual Maximum Flows on the Sawridge Creek

6.0 CONCLUSIONS

The results of this hydrology assessment support the following conclusions:

- The flood frequency estimates obtained in this study are the most up-to-date for Marten Creek at Marten Beach, Marten Creek upstream of the confluence with the unnamed tributary creek, and Lesser Slave Lake at Slave Lake (and Marten Beach). These estimates provide the updated flood hydrology information as inputs to the other components of the study (e.g., hydraulic modelling). A summary of the estimates of flood peak flows and water levels for various return periods ranging from 2 to 1,000 years and the 95% upper and lower confidence intervals is provided in Table 4 and Table 5.
- This study includes preliminary estimates of the annual maximum instantaneous flows and water levels for the period from 2015 to 2020. Inclusion of the additional flow information increases the sample size for the flood frequency analyses and reliability of the resulting flood frequency estimates.
- Consideration of historical floods and censored information using the methodology outlined in Bulletin 17C for updating the flood frequency estimates for Sawridge Creek increases the reliability of the estimated results for Marten Creek.
- The lengths of time period of the recorded flood flow data available and used in the regional flood frequency analyses are no more than 100 years. Therefore, there are large uncertainties (i.e., the confidence intervals are very large) with flood frequency estimates for return periods greater than 100 years.

7.0 CLOSURE

This memorandum was prepared and reviewed by the undersigned.

WSP Canada Inc.

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Appendices: Appendix A: Graphical and Tabulated Summaries of Flood Flow and Water Level Series at Gauged Stations
Appendix B: Frequency Analyses - Graphs and Tables

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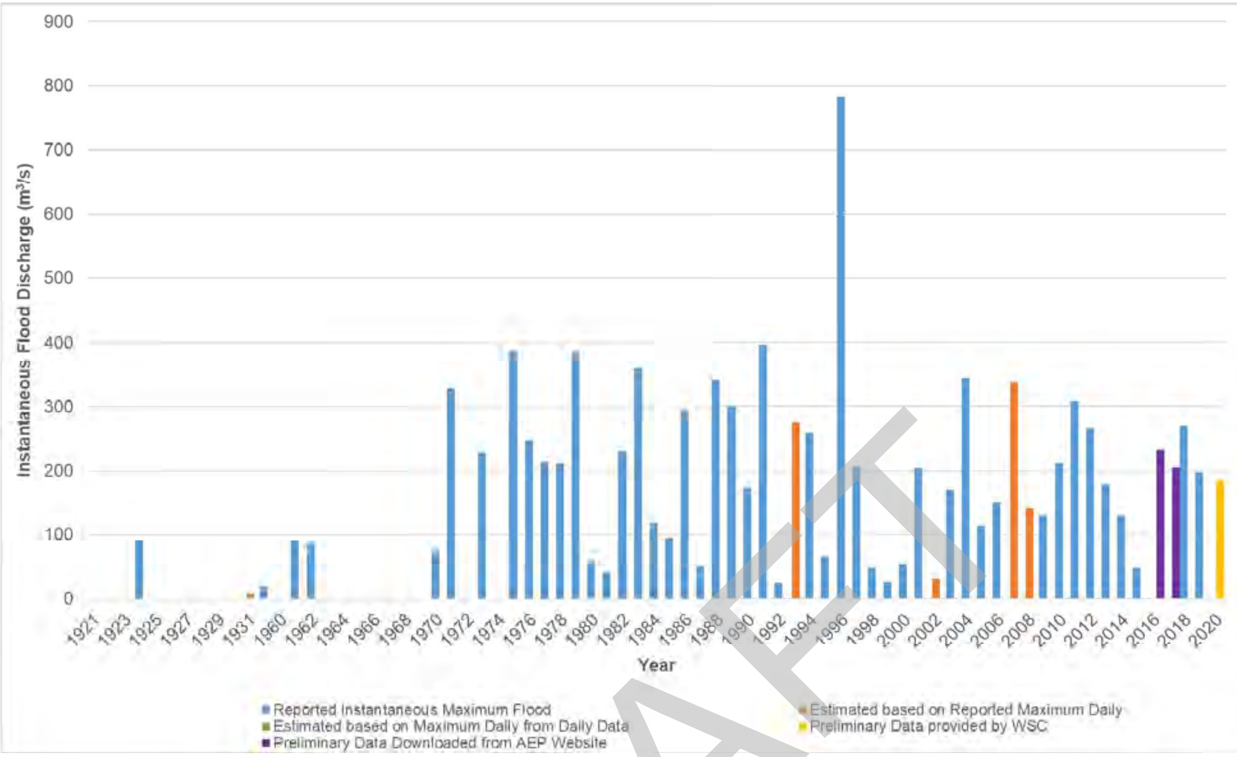
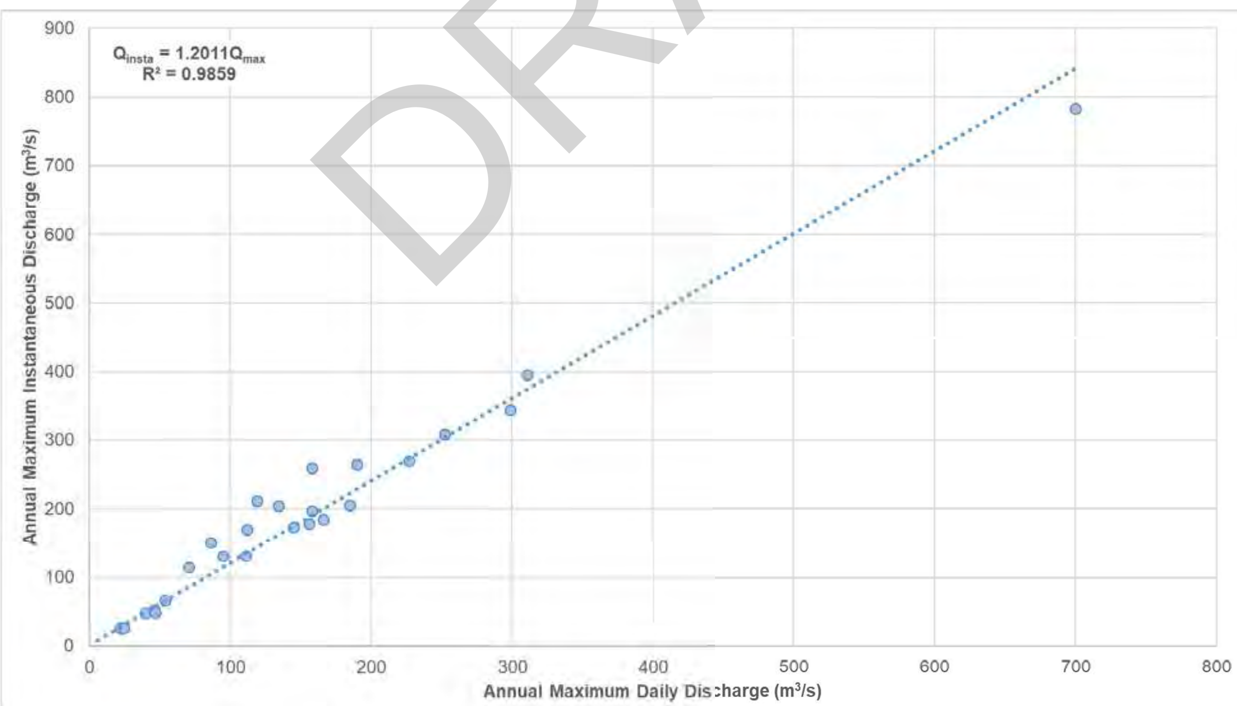
APPENDIX A

Graphical and Tabulated Summaries of Flood Flow and Water Level Series at Gauged Stations

Figure A-1: WSC Station No. 07BF001, East Prairie River Near Enilda

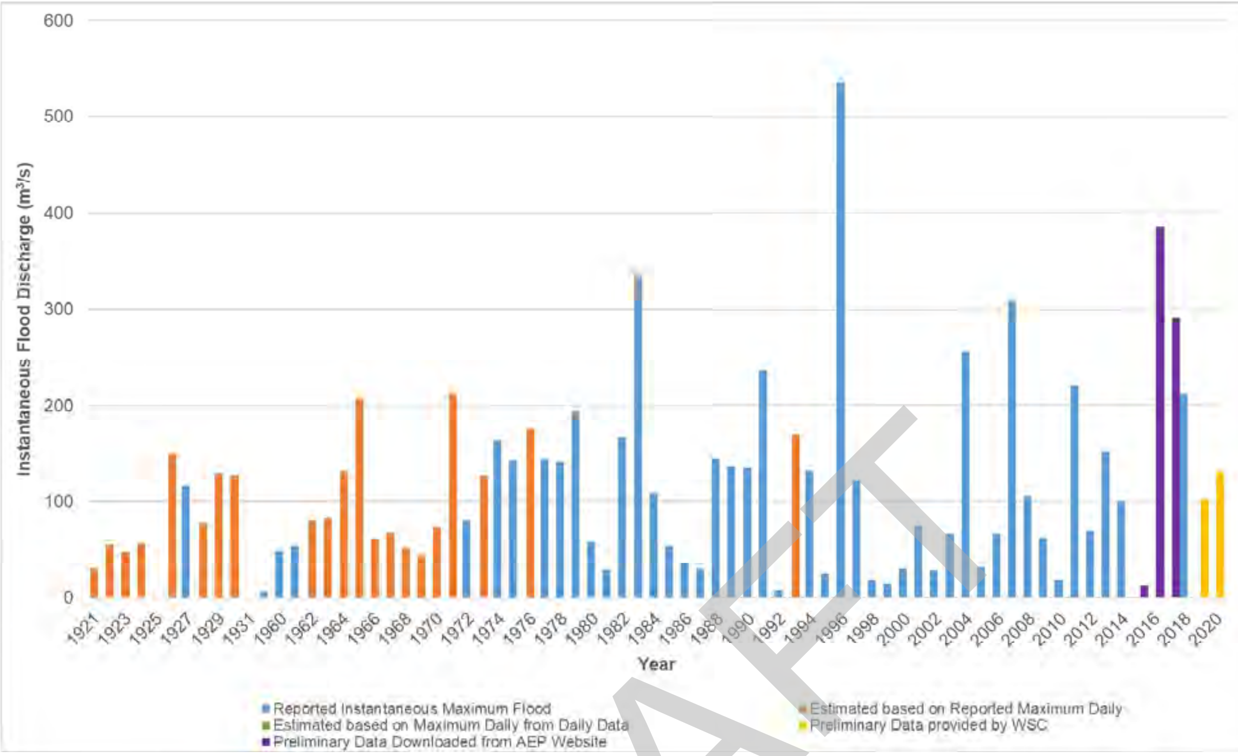


Relationship between Annual Maximum Daily and Annual Maximum Instantaneous Discharges at East Prairie River Near Enilda (WSC Station No. 07BF001)

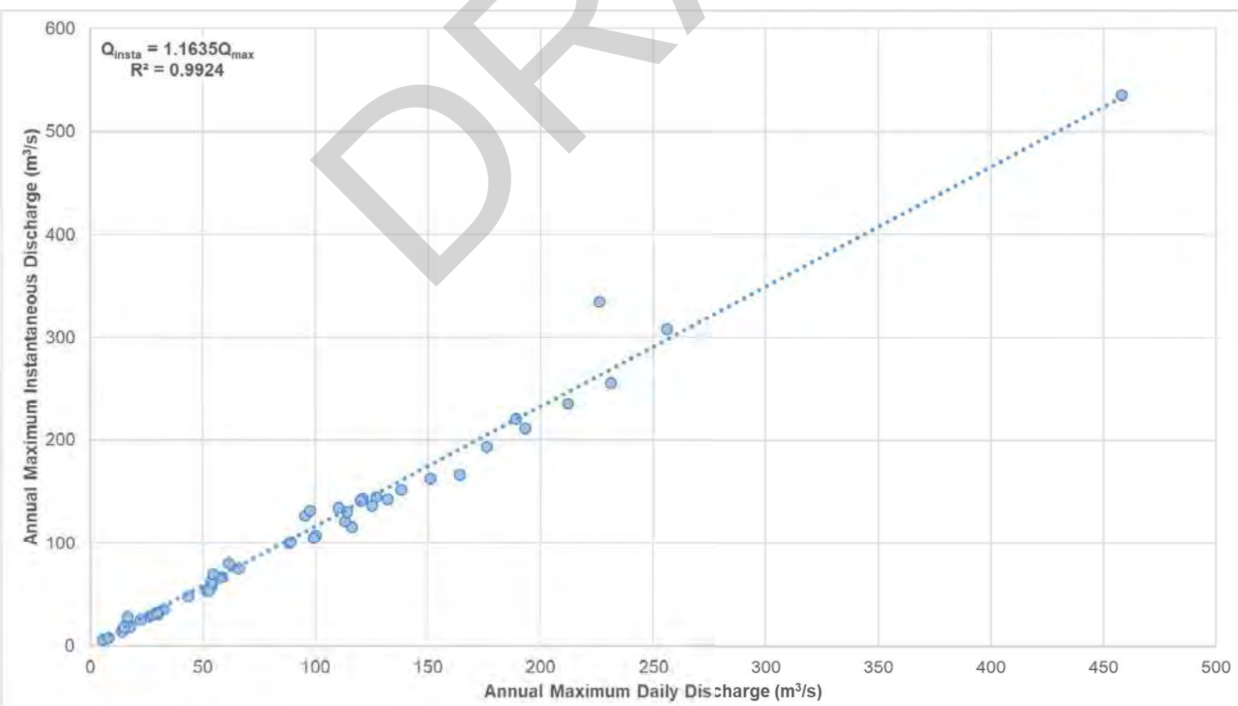


Maximum Instantaneous Flood Flow Series at East Prairie River Near Enilda (WSC Station No. 07BF001)

Figure A-2: WSC Station No. 07BF002, West Prairie River Near High Prairie

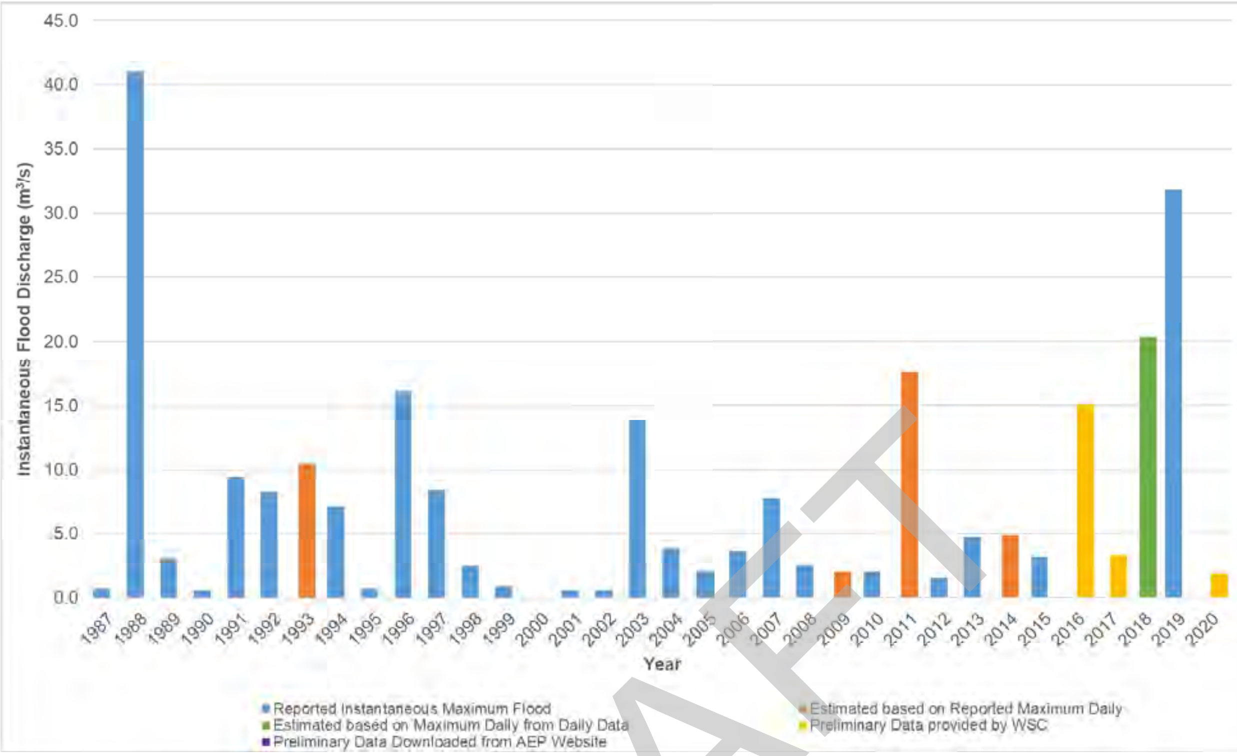


Relationship between Annual Maximum Daily and Annual Maximum Instantaneous Discharges at West Prairie River Near High Prairie (WSC Station No. 07BF002)

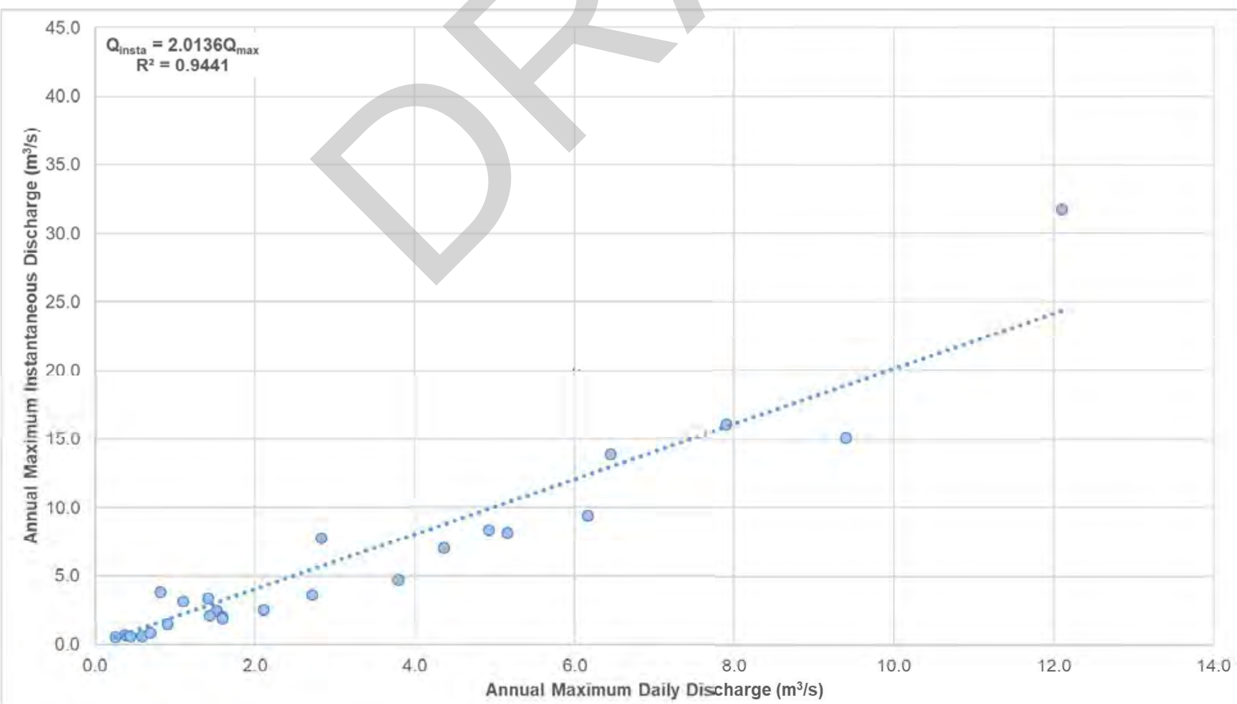


Maximum Instantaneous Flood Flow Series at West Prairie River Near High Prairie (WSC Station No. 07BF002)

Figure A-3: WSC Station No. 07BG004, Lily Creek Near Slave Lake

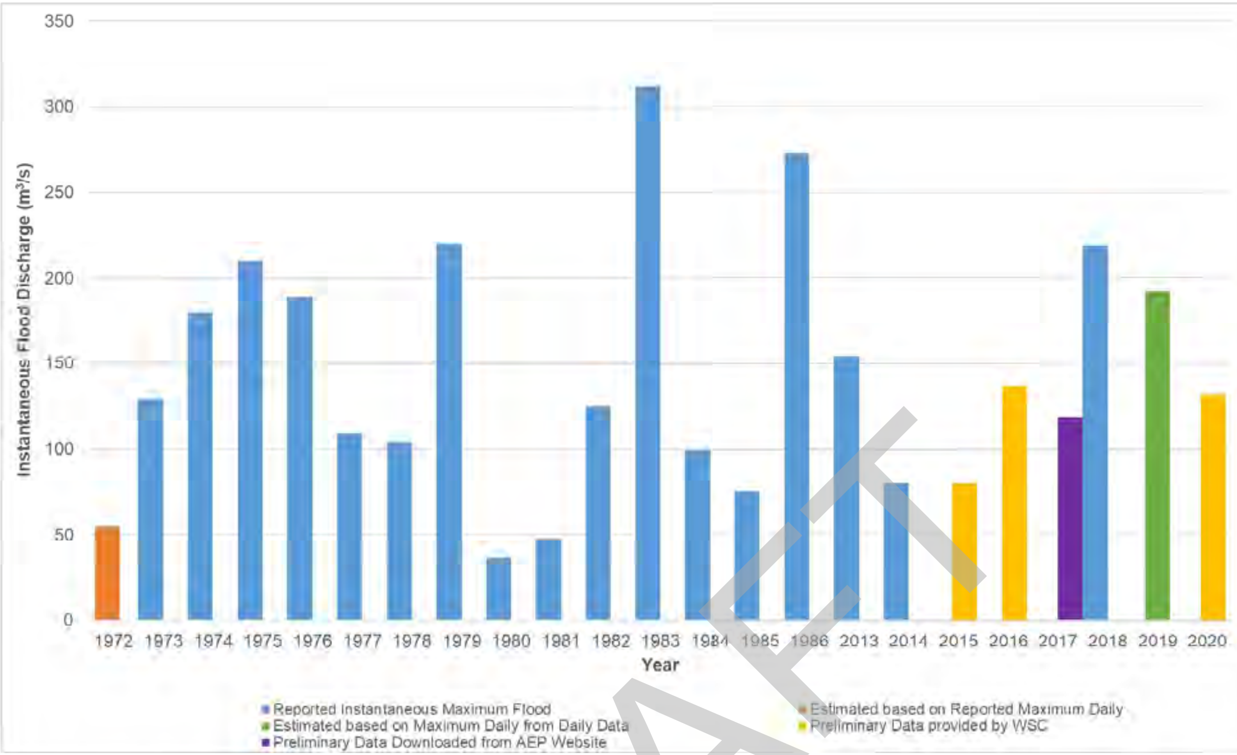


Relationship between Annual Maximum Daily and Annual Maximum Instantaneous Discharges at Lily Creek Near Slave Lake (WSC Station No. 07BG004)

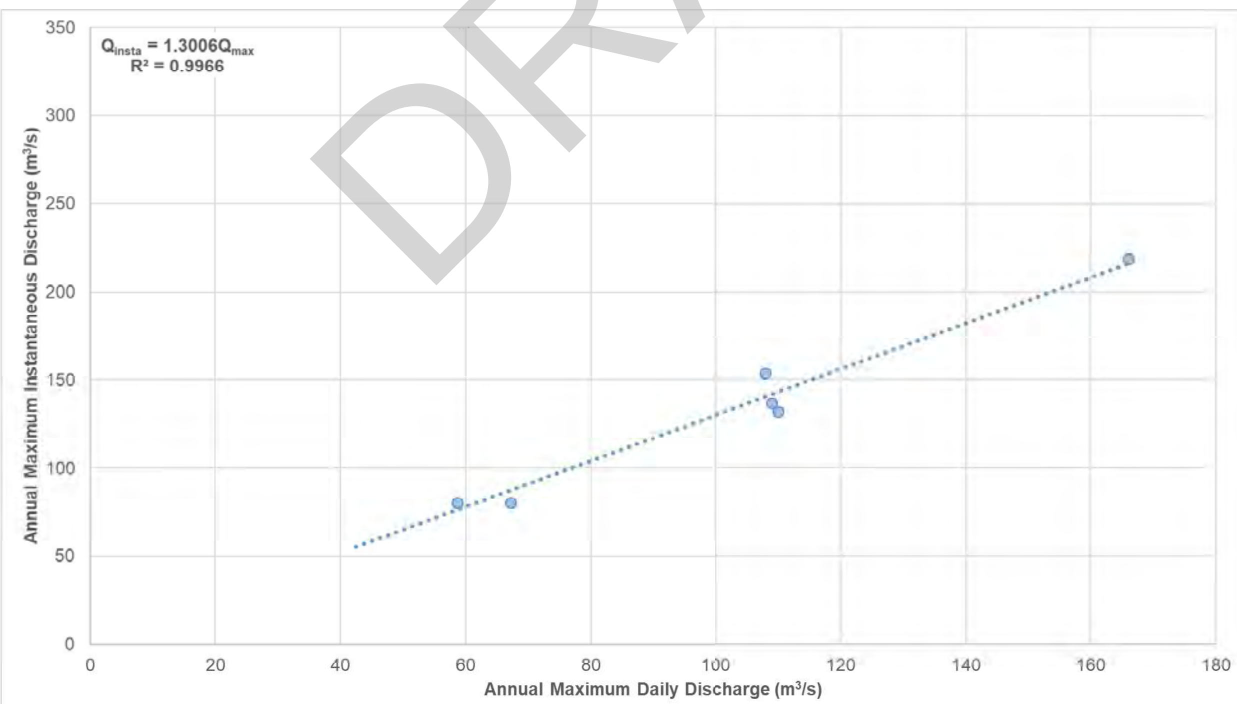


Maximum Instantaneous Flood Flow Series at Lily Creek Near Slave Lake (WSC Station No. 07BG004)

Figure A-4: WSC Station No. 07BH003, Driftpile River Near Driftpile

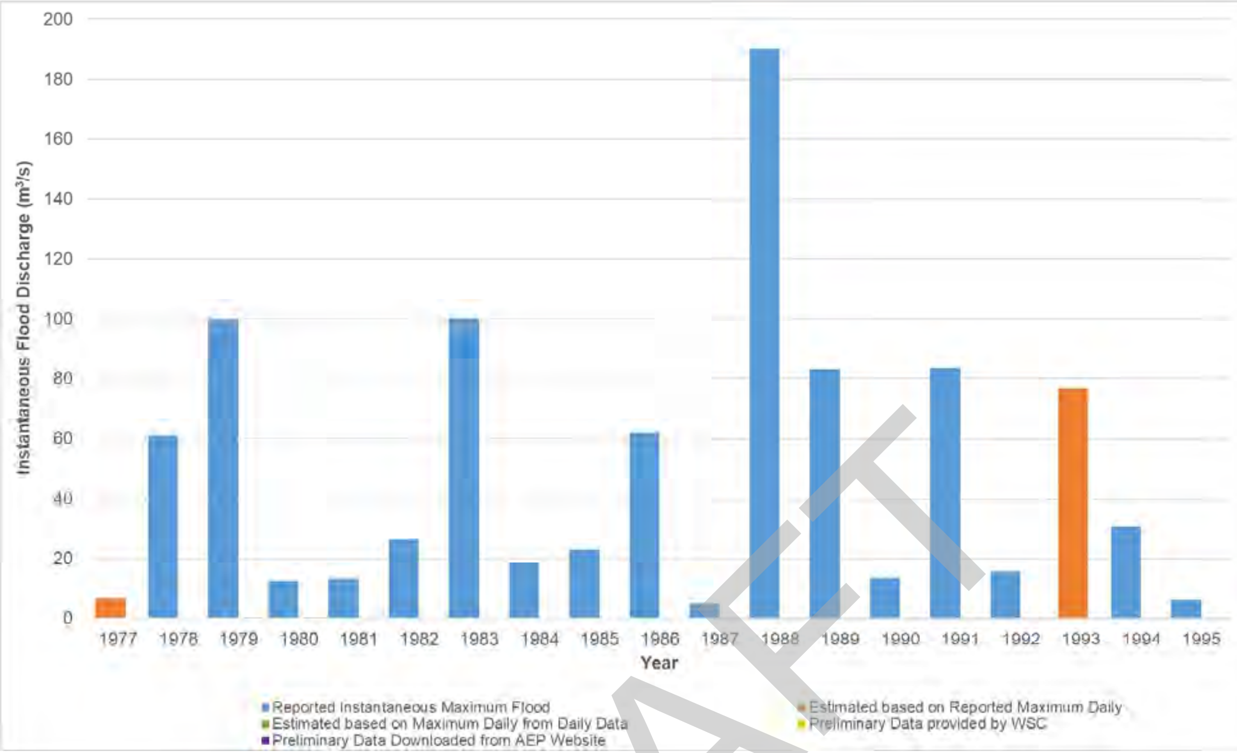


Relationship between Annual Maximum Daily and Annual Maximum Instantaneous Discharges at Driftpile River Near Driftpile (WSC Station No. 07BH003)

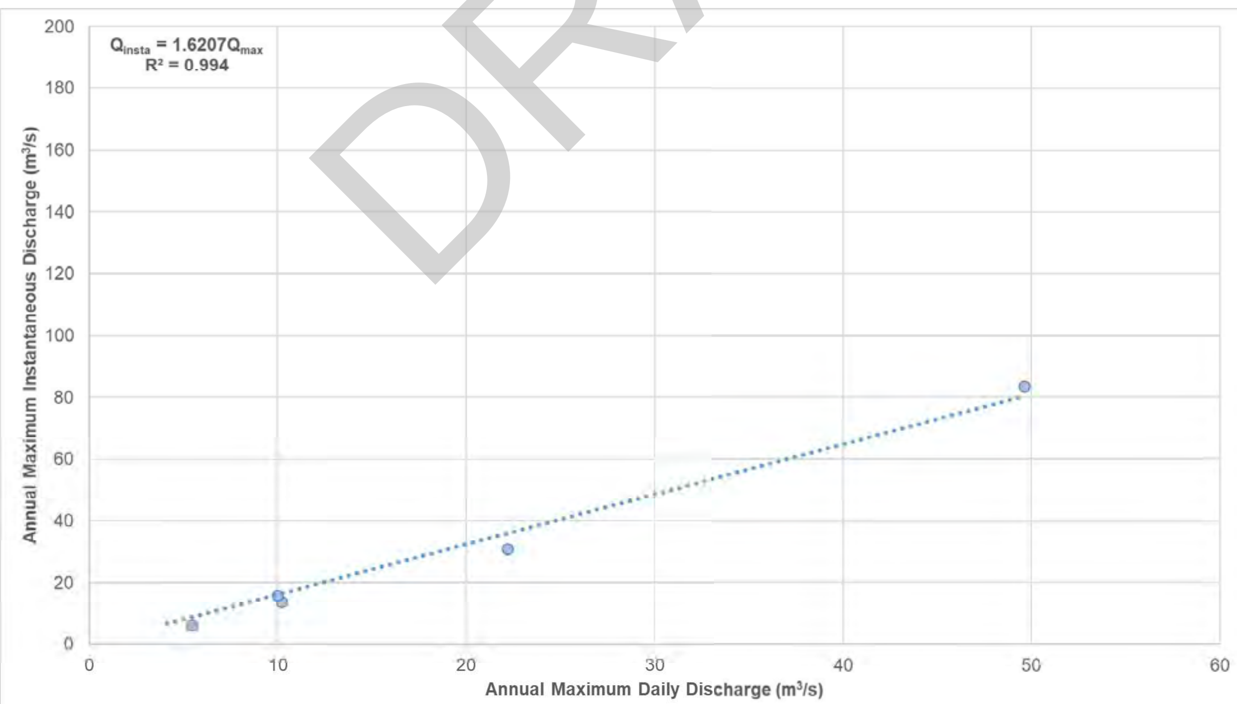


Maximum Instantaneous Flood Flow Series at Driftpile River Near Driftpile (WSC Station No. 07BH003)

Figure A-5: WSC Station No. 07BJ004, Adams Creek Near Kinuso

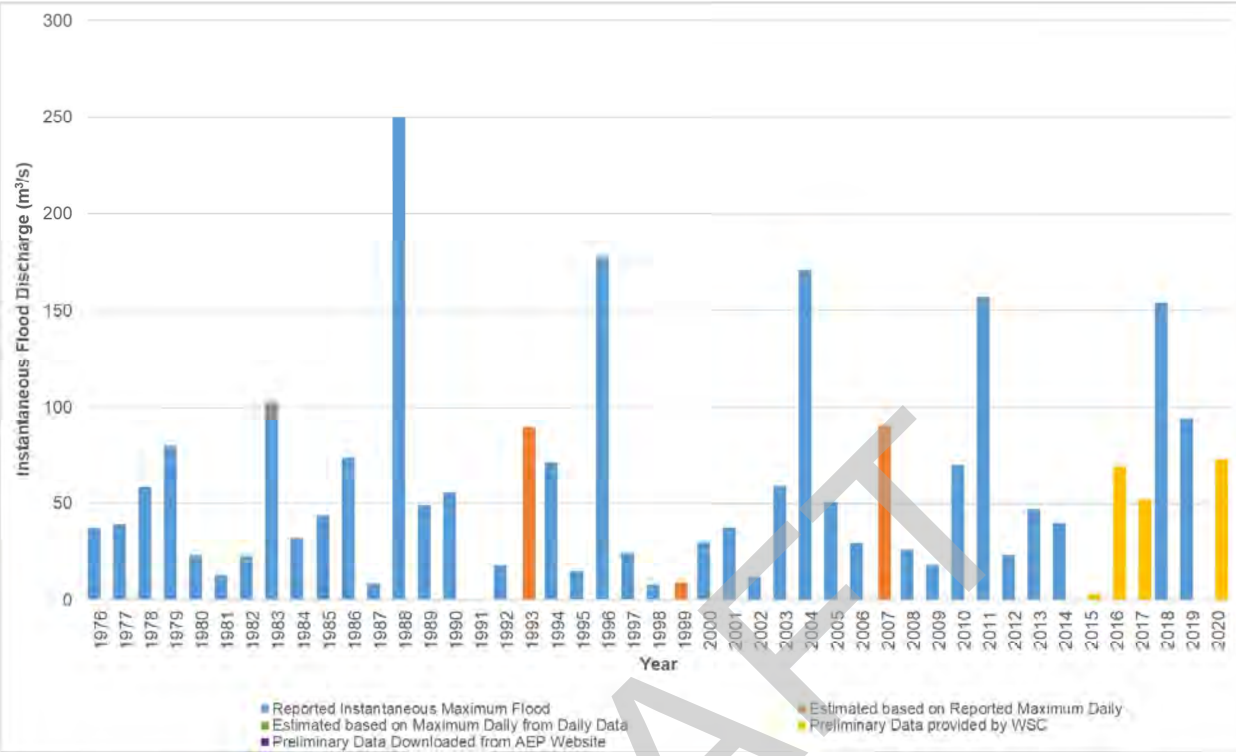


Relationship between Annual Maximum Daily and Annual Maximum Instantaneous Discharges at Adams Creek Near Kinuso (WSC Station No. 07BJ004)

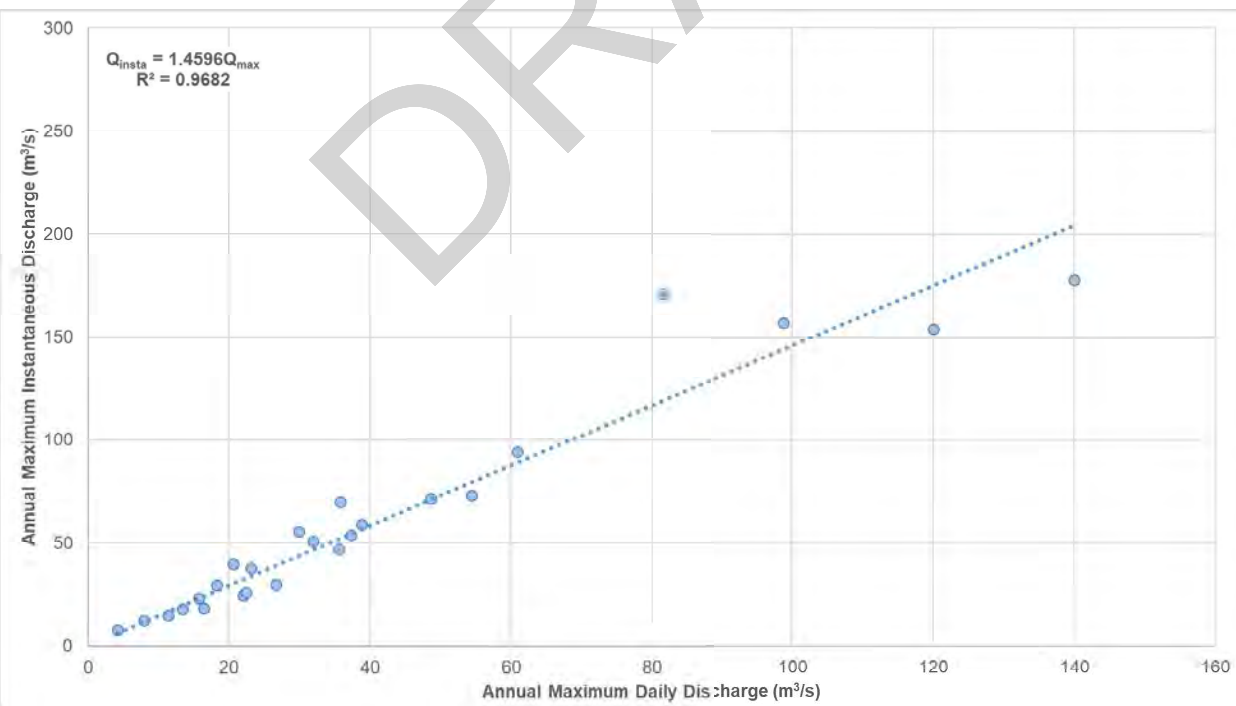


Maximum Instantaneous Flood Flow Series at Adams Creek Near Kinuso (WSC Station No. 07BJ004)

Figure A-6: WSC Station No. 07BK009, Sawridge Creek Near Slave Lake

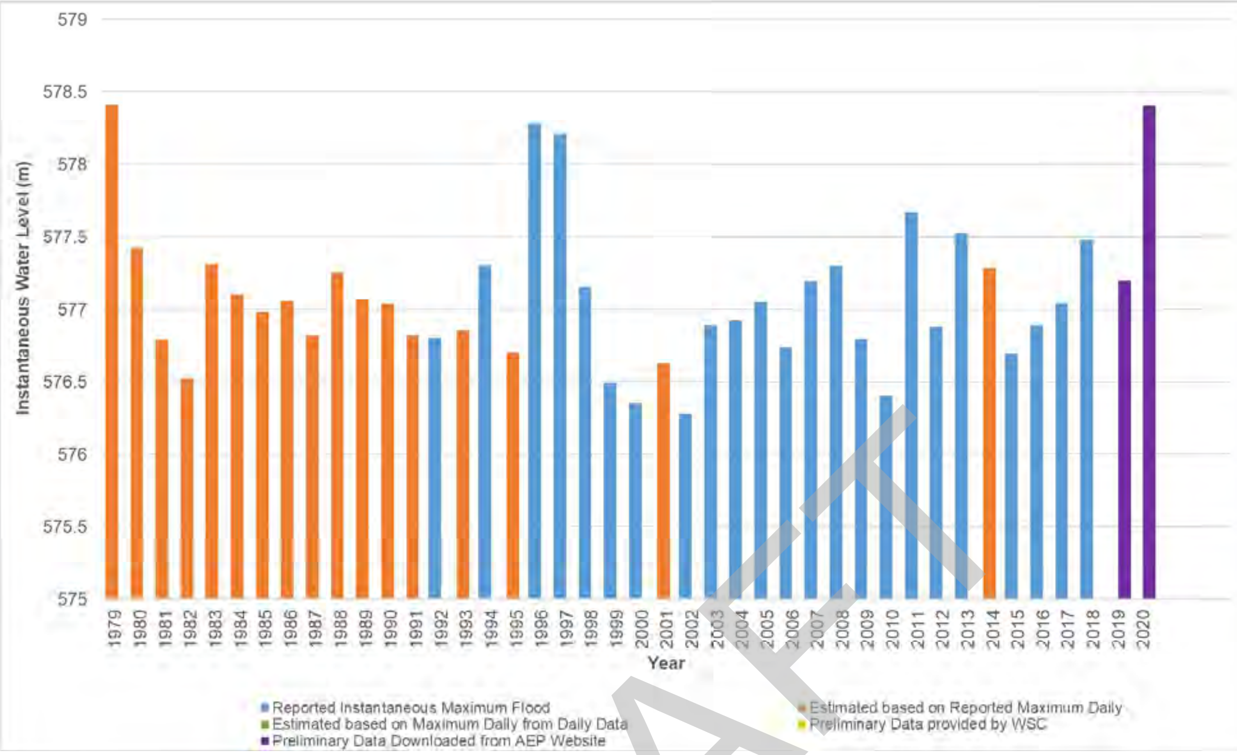


Relationship between Annual Maximum Daily and Annual Maximum Instantaneous Discharges at Sawridge Creek Near Slave Lake (WSC Station No. 07BK009)

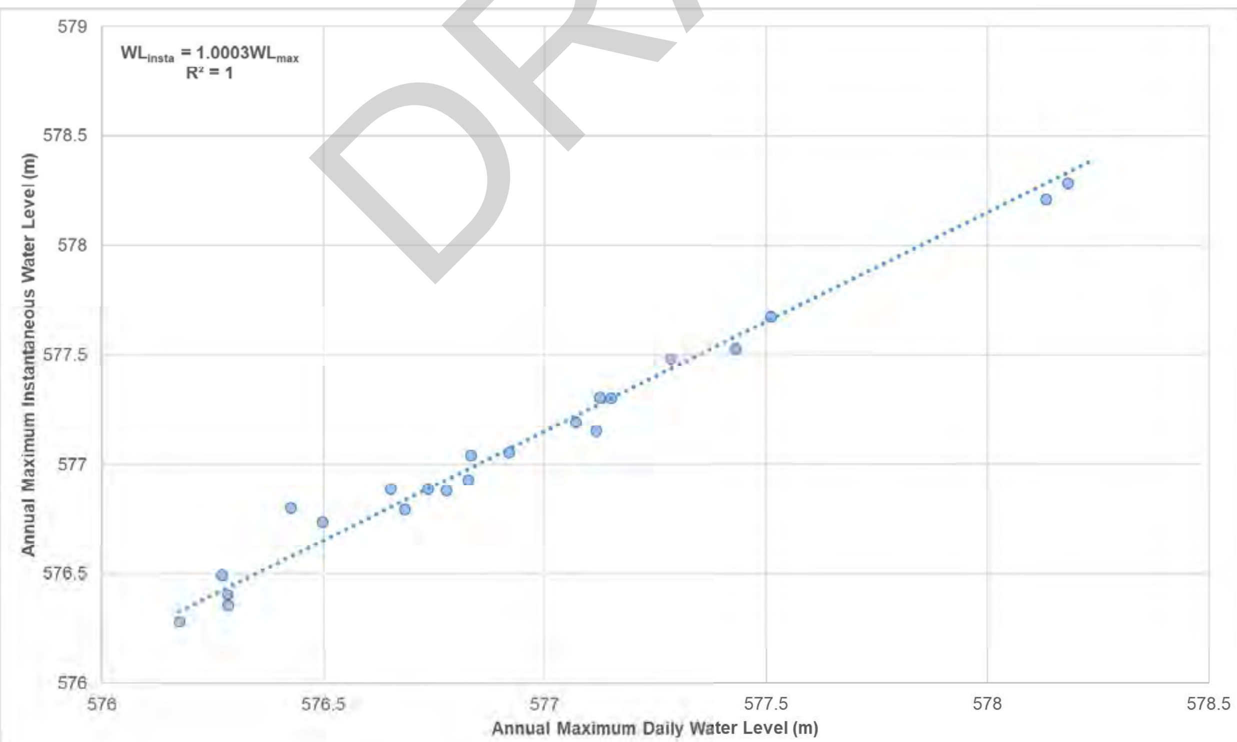


Maximum Instantaneous Flood Flow Series at Sawridge Creek Near Slave Lake (WSC Station No. 07BK009)

Figure A-7: WSC Station No. 07BJ006, Lesser Slave Lake at Slave Lake



Relationship between Annual Maximum Daily and Annual Maximum Instantaneous Water Levels at Lesser Slave Lake at Slave Lake (WSC Station No. 07BJ006)



Maximum Instantaneous Water Level Series at Lesser Slave Lake at Slave Lake (WSC Station No. 07BJ006)

Table A-1: Data used for Frequency Analysis

Year	WSC Station No. 07BF001, East Prairie River Near Enilda (m^3/s)	WSC Station No. 07BF002, West Prairie River Near High Prairie (m^3/s)	WSC Station No. 07BG004, Lily Creek Near Slave Lake (m^3/s)	WSC Station No. 07BH003, Driftpile River Near Driftpile (m^3/s)	WSC Station No. 07BJ004, Adams Creek Near Kinuso (m^3/s)	WSC Station No. 07BK009, Sawridge Creek Near Slave Lake (m^3/s)	WSC Station No. 07BJ006, Lesser Slave Lake at Slave Lake (masl)
1921	-	30.6	-	-	-	-	-
1922	-	55.4	-	-	-	-	-
1923	-	47.8	-	-	-	-	-
1924	90.6	56.3	-	-	-	-	-
1925	-	-	-	-	-	-	-
1926	-	150	-	-	-	-	-
1927	-	116	-	-	-	-	-
1928	-	77.7	-	-	-	-	-
1929	-	130	-	-	-	-	-
1930	-	128	-	-	-	-	-
1931	7.69	-	-	-	-	-	-
1932	-	-	-	-	-	-	-
1933	-	-	-	-	-	-	-
1934	-	-	-	-	-	-	-
1935	-	-	-	-	-	-	-
1936	-	-	-	-	-	-	-
1937	-	-	-	-	-	-	-
1938	-	-	-	-	-	-	-
1939	-	-	-	-	-	-	-
1940	-	-	-	-	-	-	-
1941	-	-	-	-	-	-	-
1942	-	-	-	-	-	-	-
1943	-	-	-	-	-	-	-
1944	-	-	-	-	-	-	-
1945	-	-	-	-	-	-	-
1946	-	-	-	-	-	-	-
1947	-	-	-	-	-	-	-
1948	-	-	-	-	-	-	-
1949	-	-	-	-	-	-	-
1950	-	-	-	-	-	-	-
1951	-	-	-	-	-	-	-
1952	-	-	-	-	-	-	-
1953	-	-	-	-	-	-	-
1954	-	-	-	-	-	-	-
1955	-	-	-	-	-	-	-
1956	-	-	-	-	-	-	-

Table A-1: Data used for Frequency Analysis

Year	WSC Station No. 07BF001, East Prairie River Near Enilda (m^3/s)	WSC Station No. 07BF002, West Prairie River Near High Prairie (m^3/s)	WSC Station No. 07BG004, Lily Creek Near Slave Lake (m^3/s)	WSC Station No. 07BH003, Driftpile River Near Driftpile (m^3/s)	WSC Station No. 07BJ004, Adams Creek Near Kinuso (m^3/s)	WSC Station No. 07BK009, Sawridge Creek Near Slave Lake (m^3/s)	WSC Station No. 07BJ006, Lesser Slave Lake at Slave Lake (masl)
1957	-	-	-	-	-	-	-
1958	-	-	-	-	-	-	-
1959	20.2	5.78	-	-	-	-	-
1960	-	48.7	-	-	-	-	-
1961	90.3	53.8	-	-	-	-	-
1962	85.0	80.7	-	-	-	-	-
1963	-	82.4	-	-	-	-	-
1964	-	131	-	-	-	-	-
1965	-	207	-	-	-	-	-
1966	-	61.7	-	-	-	-	-
1967	-	67.8	-	-	-	-	-
1968	-	51.1	-	-	-	-	-
1969	-	43.5	-	-	-	-	-
1970	74.5	72.8	-	-	-	-	-
1971	328	213	-	-	-	-	-
1972	-	80.1	-	55.3	-	-	-
1973	228	127	-	129	-	-	-
1974	-	163	-	180	-	-	-
1975	388	143	-	210	-	-	-
1976	247	176	-	189	-	37.4	-
1977	214	144	-	109	6.68	39.1	-
1978	212	142	-	104	61.2	58.3	-
1979	385	194	-	220	100	79.8	578.41
1980	59.1	57.9	-	36.6	12.5	23.0	577.42
1981	40.6	29.1	-	47.6	13.2	13.1	576.79
1982	230	167	-	125	26.4	22.8	576.52
1983	360	335	-	312	100	103	577.31
1984	118	108	-	100	18.7	32.1	577.11
1985	94.4	53.8	-	75.5	23.0	43.7	576.98
1986	295	35.9	-	273	61.8	73.7	577.06
1987	50.5	31.0	0.704	-	4.90	8.49	576.82
1988	341	145	41.0	-	190	250	577.26
1989	300	137	3.14	-	83.1	49.0	577.07
1990	173	135	0.620	-	13.7	55.6	577.04
1991	396	236	9.43	-	83.6	53.9	576.82
1992	25.4	8.32	8.20	-	15.8	18.0	576.80
1993	275	170	10.5	-	76.8	89.5	576.86

Table A-1: Data used for Frequency Analysis

Year	WSC Station No. 07BF001, East Prairie River Near Enilda (m^3/s)	WSC Station No. 07BF002, West Prairie River Near High Prairie (m^3/s)	WSC Station No. 07BG004, Lily Creek Near Slave Lake (m^3/s)	WSC Station No. 07BH003, Driftpile River Near Driftpile (m^3/s)	WSC Station No. 07BJ004, Adams Creek Near Kinuso (m^3/s)	WSC Station No. 07BK009, Sawridge Creek Near Slave Lake (m^3/s)	WSC Station No. 07BJ006, Lesser Slave Lake at Slave Lake (masl)
1994	259	132	7.08	-	30.9	71.6	577.31
1995	66.1	25.5	0.695	-	6.27	15.0	576.71
1996	783	536	16.1	-	-	178	578.29
1997	206	122	8.39	-	-	24.5	578.21
1998	48.1	18.8	2.47	-	-	8.00	577.16
1999	26.2	14.5	0.872	-	-	9.18	576.49
2000	53.3	30.5	-	-	-	29.5	576.36
2001	204	75.6	0.602	-	-	37.7	576.63
2002	31.0	28.6	0.576	-	-	12.3	576.28
2003	170	66.9	13.9	-	-	59.1	576.89
2004	344	256	3.85	-	-	171	576.93
2005	114	32.4	2.11	-	-	50.9	577.06
2006	150	66.4	3.64	-	-	29.7	576.74
2007	338	309	7.76	-	-	90.5	577.19
2008	142	105	2.56	-	-	26.0	577.30
2009	131	62.1	2.01	-	-	18.3	576.80
2010	212	18.9	2.04	-	-	69.9	576.40
2011	308	221	17.6	-	-	157	577.67
2012	265	69.8	1.52	-	-	23.3	576.88
2013	179	152	4.73	154	-	47.1	577.53
2014	131	100	4.89	80.3	-	39.9	577.29
2015	48.7	12.2	3.16	80.3	-	3.51	576.70
2016	233	386	15.1	137	-	69.3	576.89
2017	205	291	3.35	119	-	52.2	577.04
2018	270	212	20.3	219	-	154	577.48
2019	197	102	31.8	192	-	94.2	577.20
2020	185	131	1.93	132	-	72.9	578.41

Note: masl = meters above sea level

Table A-2: Results of Statistical Tests of Annual Maximum Instantaneous Discharges and Goodness-of-Fit of Probability Distribution Functions

WSC Station ID	07BF001	07BF002	07BG004	07BH003	07BJ004	07BK009	07BJ006
WSC Station Name or Location of Interest	East Prairie River Near Enilda	West Prairie River Near High Prairie	Lily Creek Near Slave Lake	Driftpile River Near Driftpile	Adams Creek Near Kinuso	Sawridge Creek Near Slave Lake	Lesser Slave Lake at Slave Lake
Anderson-Darling statistic, A^2 = - N -S							
3 Parameter Log-normal	0.632	0.311	0.722	0.151	0.416	0.159	0.396
Extreme Value	0.488	0.335	0.540	0.146	0.672	0.176	14.100
Log-Pearson III	0.826	0.225	0.299	0.138	0.423	0.155	0.964
Weibull	2.341	1.943	1.067	0.145	0.591	0.275	1.008
Serial correlation coefficient test for independence							
S_1	0.0634	0.1178	-0.0682	0.0234	-0.3333	-0.0514	0.1717
t	0.4537	0.9780	-0.3743	0.1049	-1.4142	-0.3338	1.0885
t(α=0.05)	1.6753	1.6676	-1.6973	1.7247	-1.7459	-1.6820	1.6849
t(α=0.01)	2.4017	2.3824	-2.4573	2.5280	-2.5835	-2.4185	2.4258
Spearman rank order correlation coefficient test for no-trend							
r_s	-0.0933	-0.1313	-0.1156	-0.1171	-0.0421	-0.1258	-0.0412
t	-0.6758	-1.0998	-0.6482	-0.5404	-0.1738	-0.8317	-0.2606
t(α=0.05)	-2.0066	-1.9949	-2.0395	-2.0796	-2.1098	-2.0167	-2.0211
t(α=0.01)	-2.6737	-2.6490	-2.7440	-2.8314	-2.8982	-2.6951	-2.7045
Mann-Whitney split sample test for homogeneity							
Size of earlier sample	27	36	17	12	10	23	21
z	-0.2249	-0.0230	-0.5764	-0.1231	-0.0816	-0.3179	-0.6163
z(a=0.05)	-1.6449	-1.6449				-1.6449	-1.6449
z(a=0.01)	-2.3263	-2.3263				-2.3263	-2.3263
Test of general randomness (Runs for above or below the median)							
Median	191.0	100.0	3.6	129.0	26.4	47.1	577.0
N1(for Q>=Median)	27	36	17	12	10	23	21
N2(for Q<Median)	27	35	16	11	9	22	21
Run_ab	25	28	19	12	13	22	21
z	0.8243	2.0308	0.5365	0.2045	1.1963	0.4493	0.3124
z(a=0.05)	1.9600	1.9600				1.9600	1.9600
z(a=0.01)	2.5758	2.5758				2.5758	2.5758

Notes:
1. Selected distribution based on best statistical fit 0.488
2. Criteria for the respective statistical tests were not met 1.9600

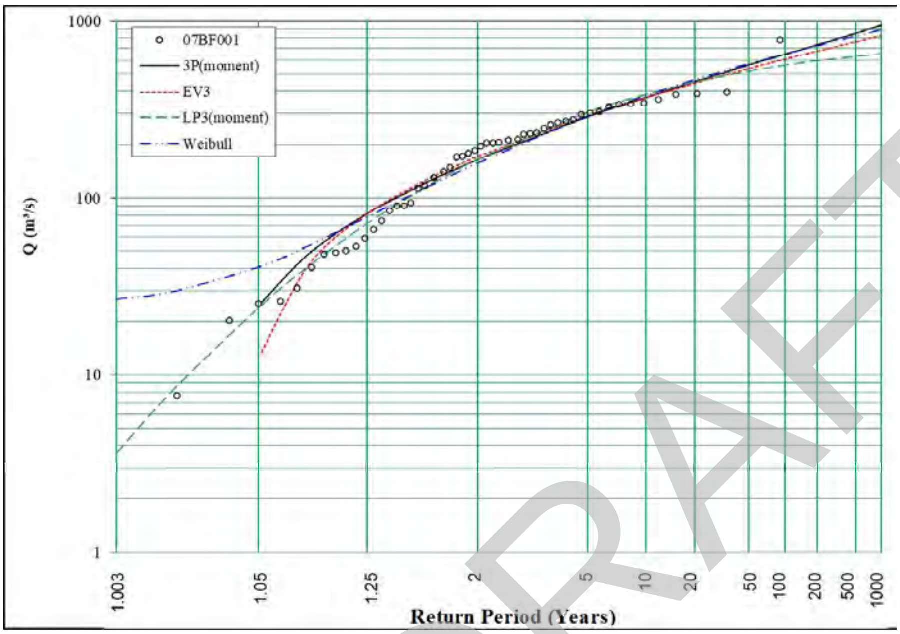
APPENDIX B

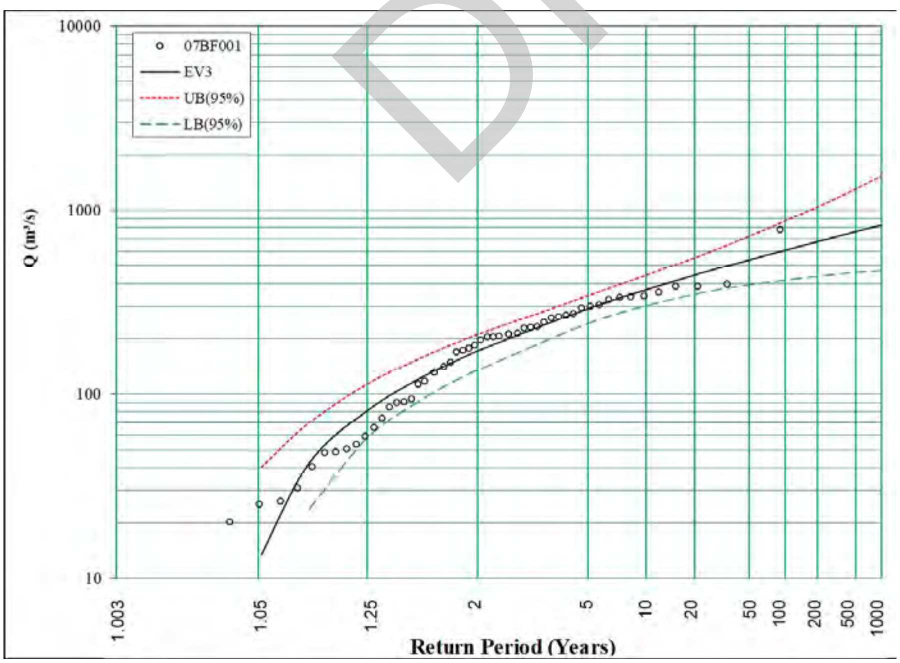
Frequency Analyses - Graphs and Tables

This appendix includes the graphs and results from the frequency analysis of the compiled/derived maximum instantaneous flood flow series at either the gauged stations or locations of interest within the study area. For each flood flow series, the following information is presented:

- Frequency distribution graph – all distributions;
- Frequency distribution graph – best fit graph with confidence interval; and
- Flood flow estimates – all distributions.

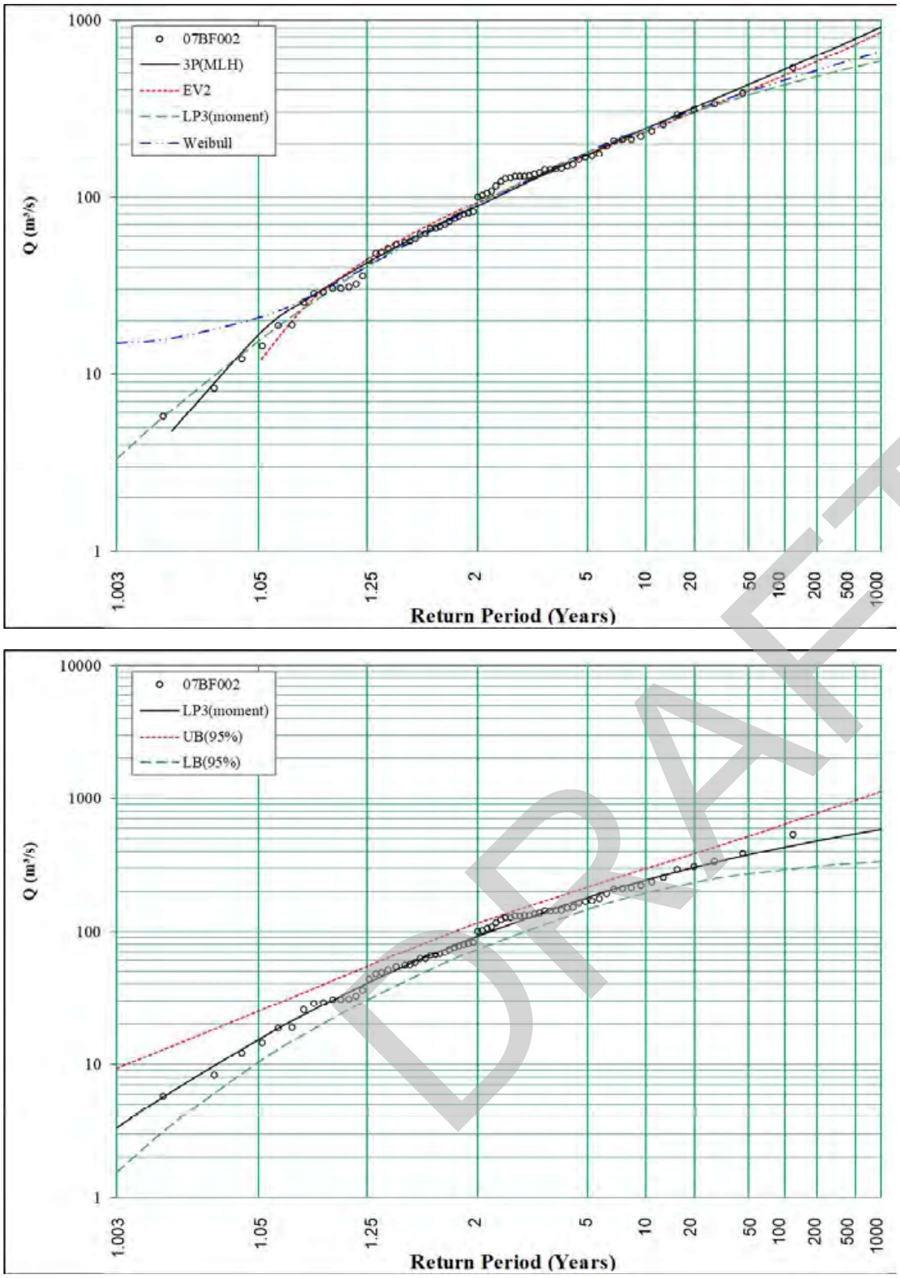
Figure B-1: WSC Station No. 07BF001, East Prairie River Near Enilda





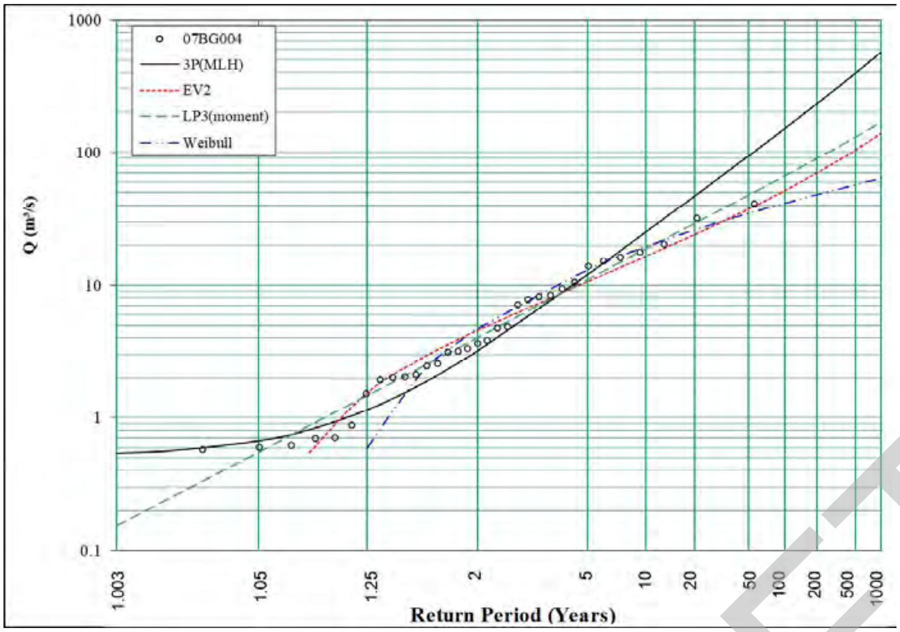
Return Period	3P(MLH)	EV3	LP3 (moment)	Weibull
2	166	172	166	158
5	287	292	305	290
10	371	370	386	380
20	453	444	452	465
35	520	502	496	531
50	563	538	521	572
75	613	579	546	618
100	648	608	562	650
200	736	676	595	726
350	808	731	617	786
500	855	765	629	824
750	909	804	641	866
1,000	949	831	649	896

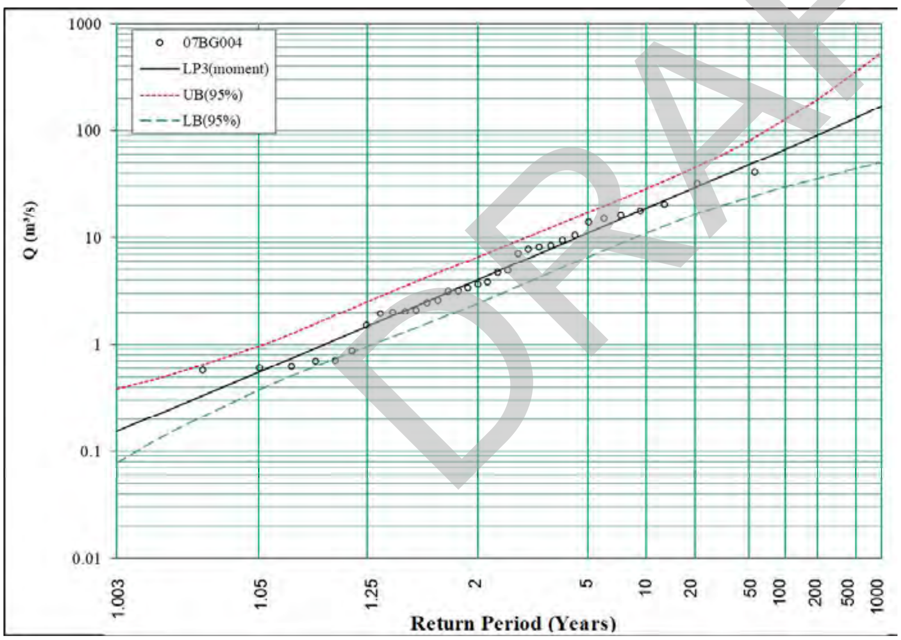
Figure B-2: WSC Station No. 07BF002, West Prairie River Near High Prairie



Return Period	3P(MLH)	EV3	LP3 (moment)	Weibull
2	89.2	93.4	92.3	89.1
5	174	172	181	179
10	243	233	243	244
20	319	299	303	308
35	385	358	348	359
50	431	398	377	392
75	485	447	408	428
100	525	483	429	454
200	629	579	479	516
350	721	664	518	565
500	783	723	541	596
750	857	795	567	632
1,000	912	849	585	657

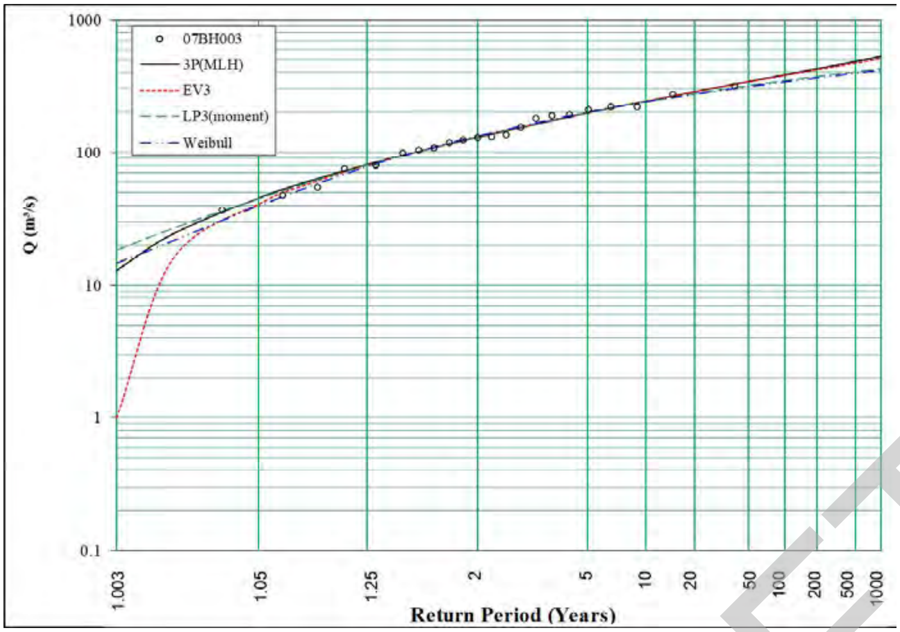
Figure B-3: WSC Station No. 07BG004, Lily Creek Near Slave Lake

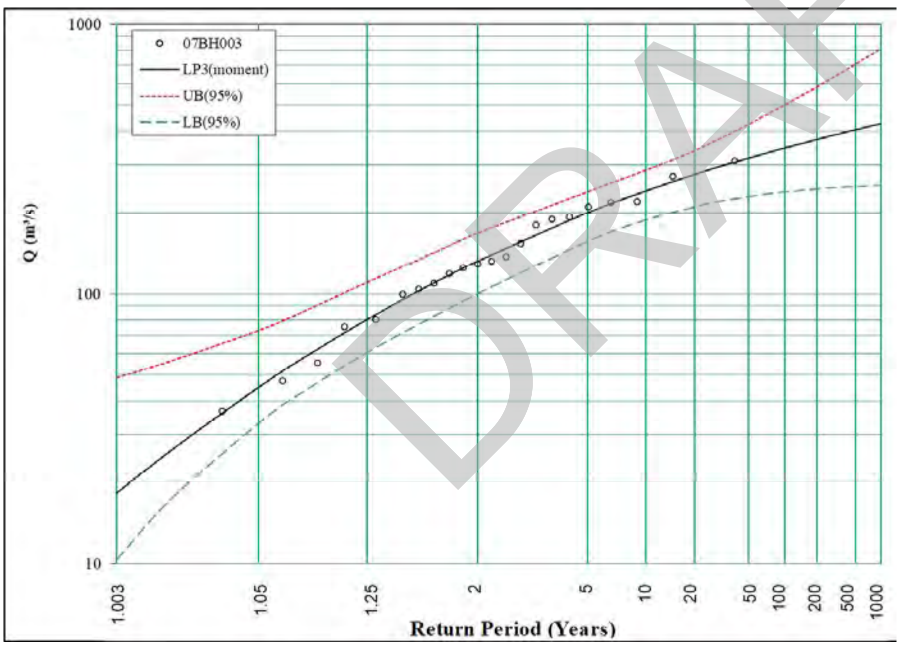




Return Period	3P(MLH)	EV3	LP3 (moment)	Weibull
2	3.20	4.60	4.01	4.72
5	12.0	10.7	11.0	13.1
10	25.2	16.6	18.8	19.6
20	46.8	24.1	29.1	26.1
35	72.8	31.9	39.8	31.5
50	94.5	37.8	47.8	34.9
75	125	45.6	58.2	38.8
100	151	52.0	66.5	41.6
200	233	70.7	90.1	48.4
350	322	90.1	113	53.9
500	392	105	130	57.4
750	487	125	152	61.3
1,000	566	141	169	64.2

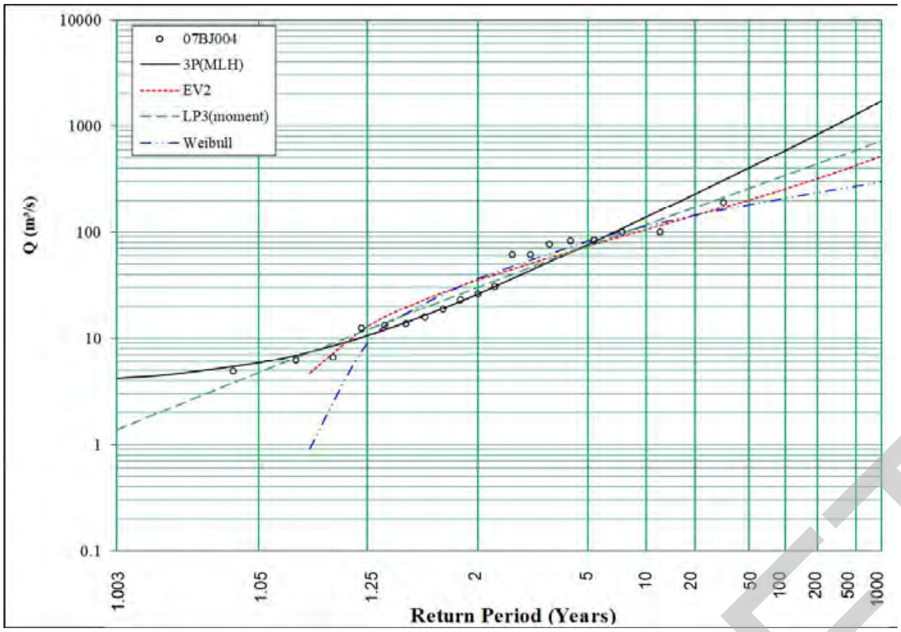
Figure B-4: WSC Station No. 07BH003, Driftpile River Near Driftpile

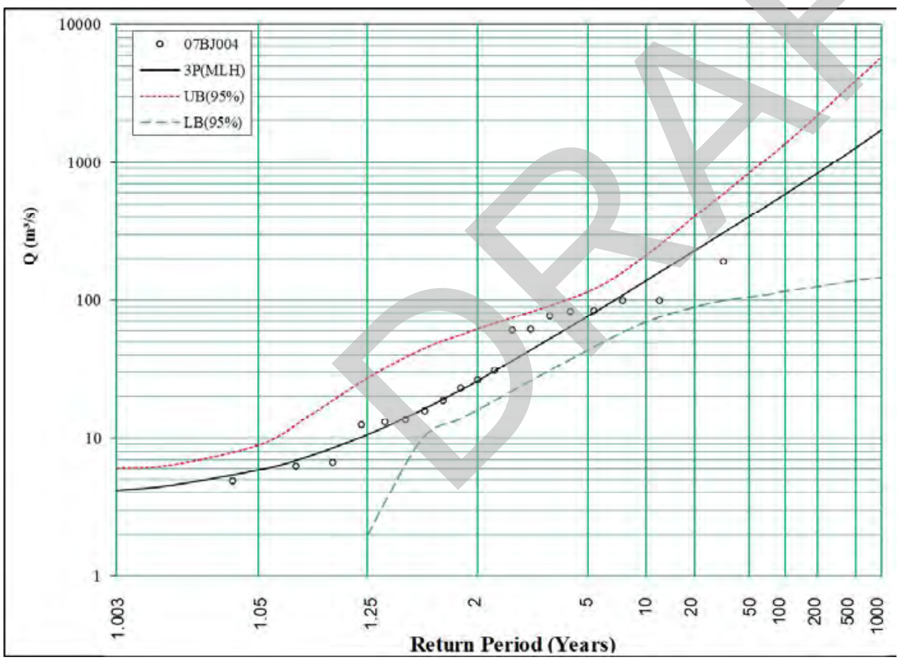




Return Period	3P(MLH)	EV3	LP3 (moment)	Weibull
2	130	131	132	134
5	198	198	200	202
10	242	242	241	241
20	285	284	277	274
35	319	317	303	298
50	340	337	319	313
75	365	361	336	329
100	382	377	348	339
200	424	416	374	364
350	459	447	393	383
500	481	467	405	394
750	507	489	418	407
1,000	525	505	427	415

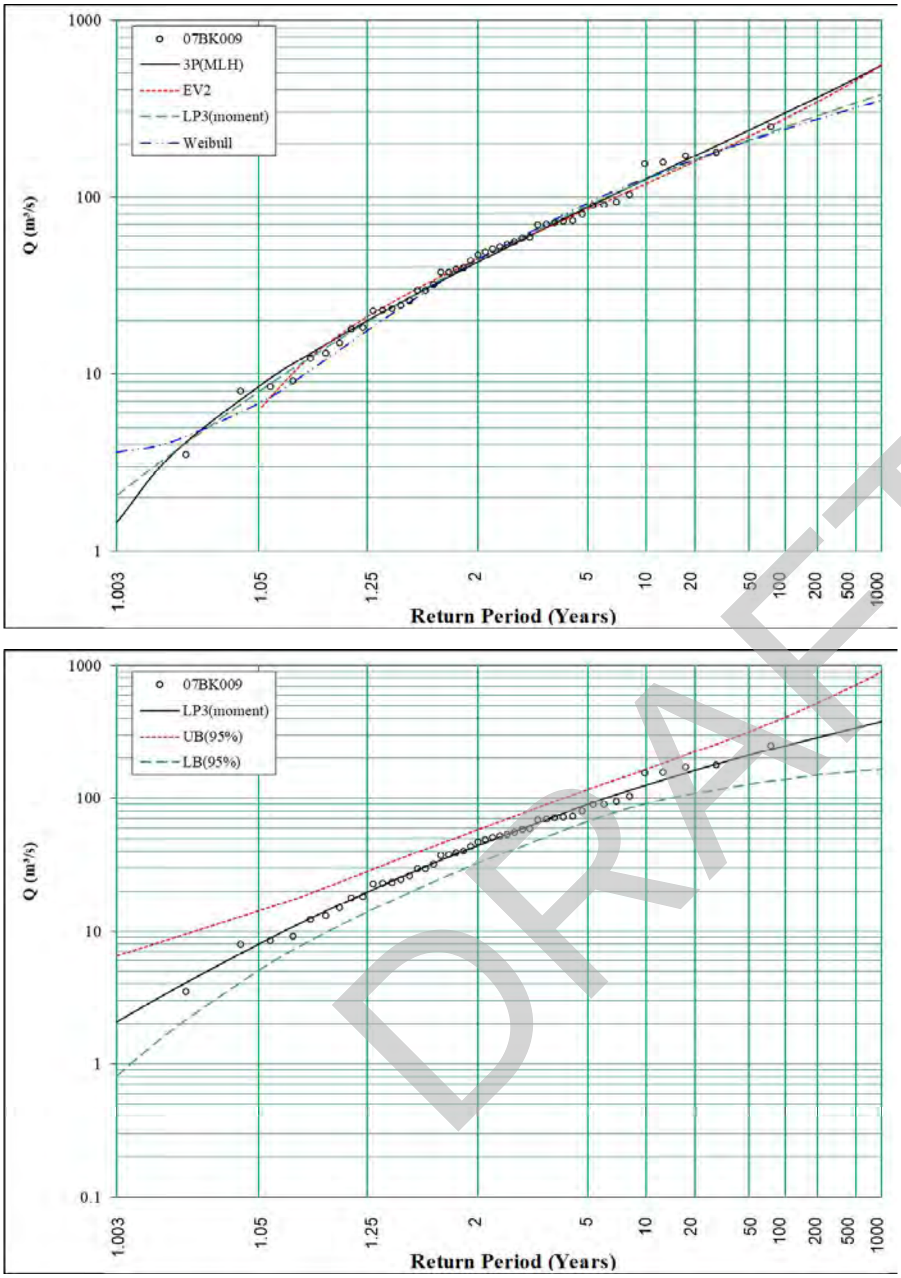
Figure B-5: WSC Station No. 07BJ004, Adams Creek Near Kinuso





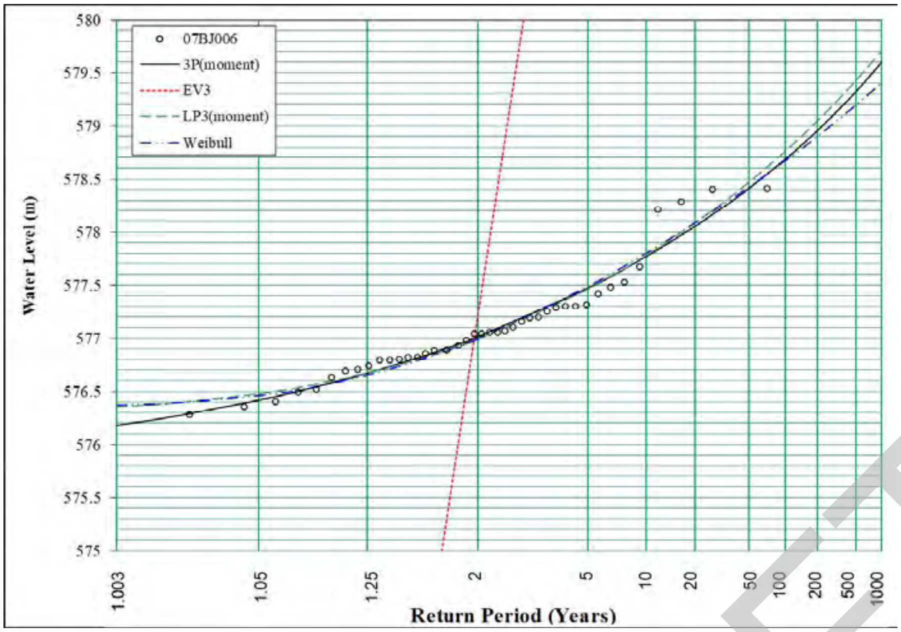
Return Period	3P(MLH)	EV3	LP3 (moment)	Weibull
2	26.0	35.1	30.2	36.4
5	76.5	73.4	74.2	82.1
10	139	105	118	114
20	229	142	171	144
35	327	176	223	167
50	403	201	260	182
75	506	231	307	198
100	590	254	343	209
200	835	318	441	236
350	1087	378	532	258
500	1276	420	596	271
750	1521	474	675	286
1,000	1717	515	735	297

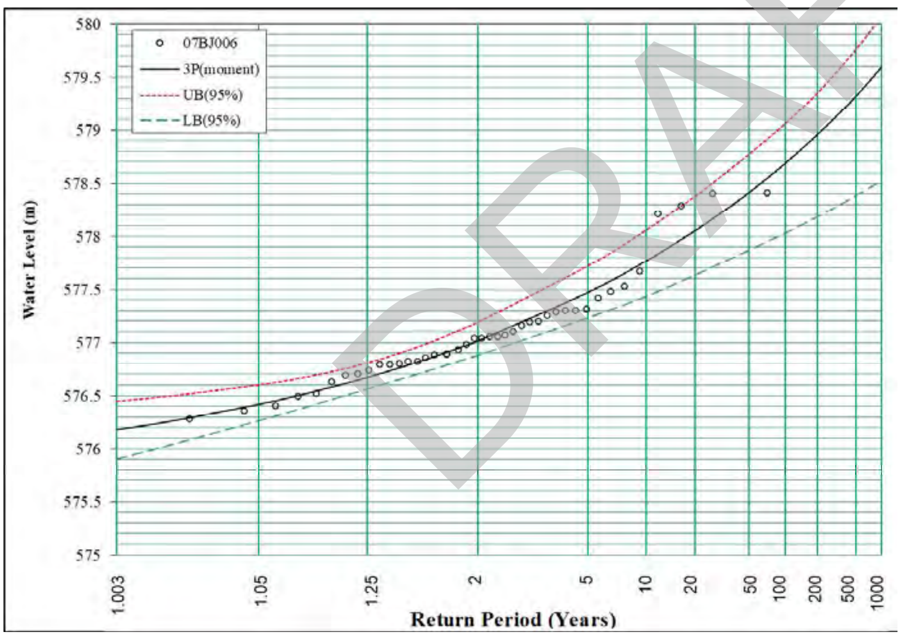
Figure B-6: WSC Station No. 07BK009, Sawridge Creek Near Slave Lake



Return Period	3P(MLH)	EV3	LP3 (moment)	Weibull
2	42.9	44.6	44.4	44.2
5	87.9	85.3	90.1	92.8
10	127	119	125	128
20	171	158	162	163
35	211	195	192	191
50	238	220	211	208
75	272	252	233	228
100	297	277	249	242
200	364	344	288	275
350	424	408	319	301
500	465	453	340	318
750	514	509	363	337
1,000	552	553	379	351

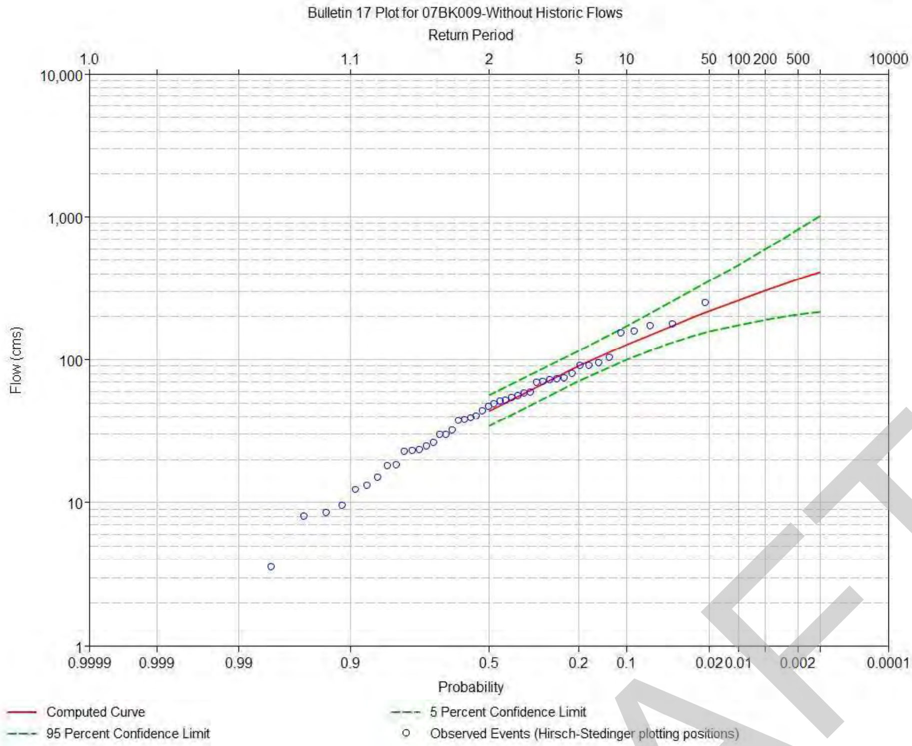
Figure B-7: WSC Station No. 07BJ006, Lesser Slave Lake at Slave Lake

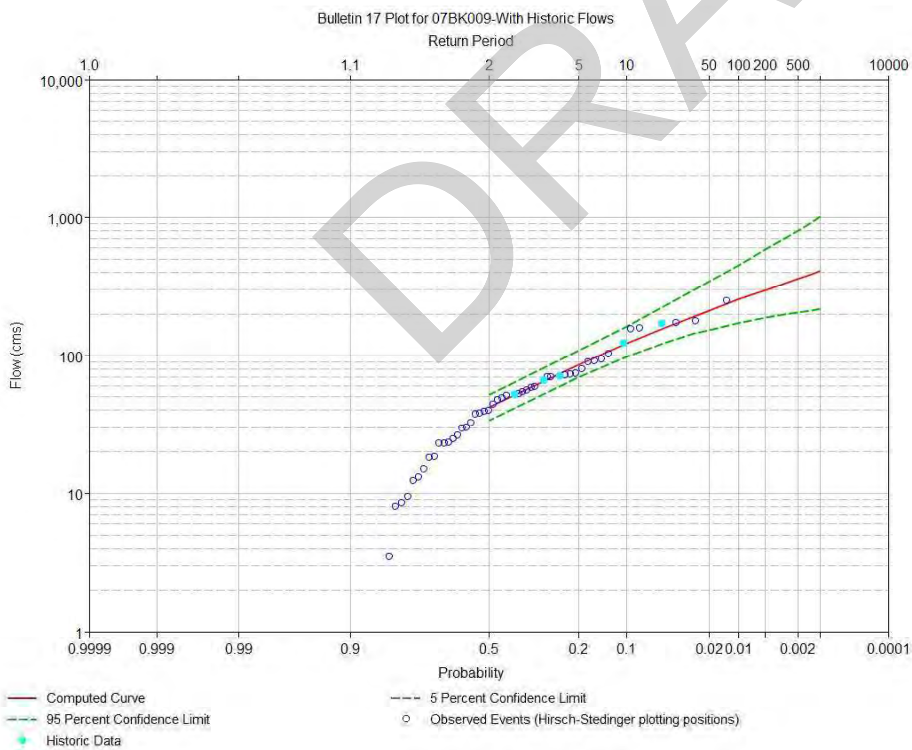




Return Period	3P(MLH)	EV3	LP3 (moment)	Weibull
2	577.01	577.23	576.99	577.00
5	577.47	583.90	577.46	577.49
10	577.77	587.16	577.78	577.80
20	578.05	589.64	578.08	578.08
35	578.27	591.23	578.32	578.30
50	578.41	592.09	578.47	578.43
75	578.57	592.96	578.64	578.57
100	578.69	593.51	578.76	578.67
200	578.96	594.64	579.04	578.90
350	579.18	595.39	579.27	579.08
500	579.32	595.80	579.42	579.19
750	579.48	596.21	579.59	579.32
1,000	579.60	596.47	579.70	579.40

Figure B-8: WSC Station No. 07BK009, Sawridge Creek Near Slave Lake – Using Bulletin 17C Method





Return Period	Without Historical and Censored Data	With Historic and Censored Data
2	43.9	41.9
5	90.1	85.9
10	127	121
20	166	159
35	198	191
50	219	212
75	244	237
100	262	254
200	306	299
350	343	336
500	367	360
750	394	389
1,000	414	409

APPENDIX B

Flood Control Structures

19 November 2020 Project No. 20368087

James Choles
Alberta Environment and Parks
River Engineering and Technical Services Section
Environmental and Prediction Branch
11th floor Oxbridge Place
9820 - 106 St. N.W.
Edmonton, AB T5K 2J6

MARTEN BEACH FLOOD STUDY – FLOOD CONTROL STRUCTURES

Dear Jim,

Further to our discussion during the project kickoff meeting on November 12th, 2020, we are issuing this letter to confirm that no official Flood Control Structures were identified within the Marten Beach study area during the site inspection conducted on October 14th, 2020 and during the field survey in October 2020.

Best Regards,

Golder Associates Ltd.

Gaven Tang, M.A.Sc., P.Eng.
River Engineer

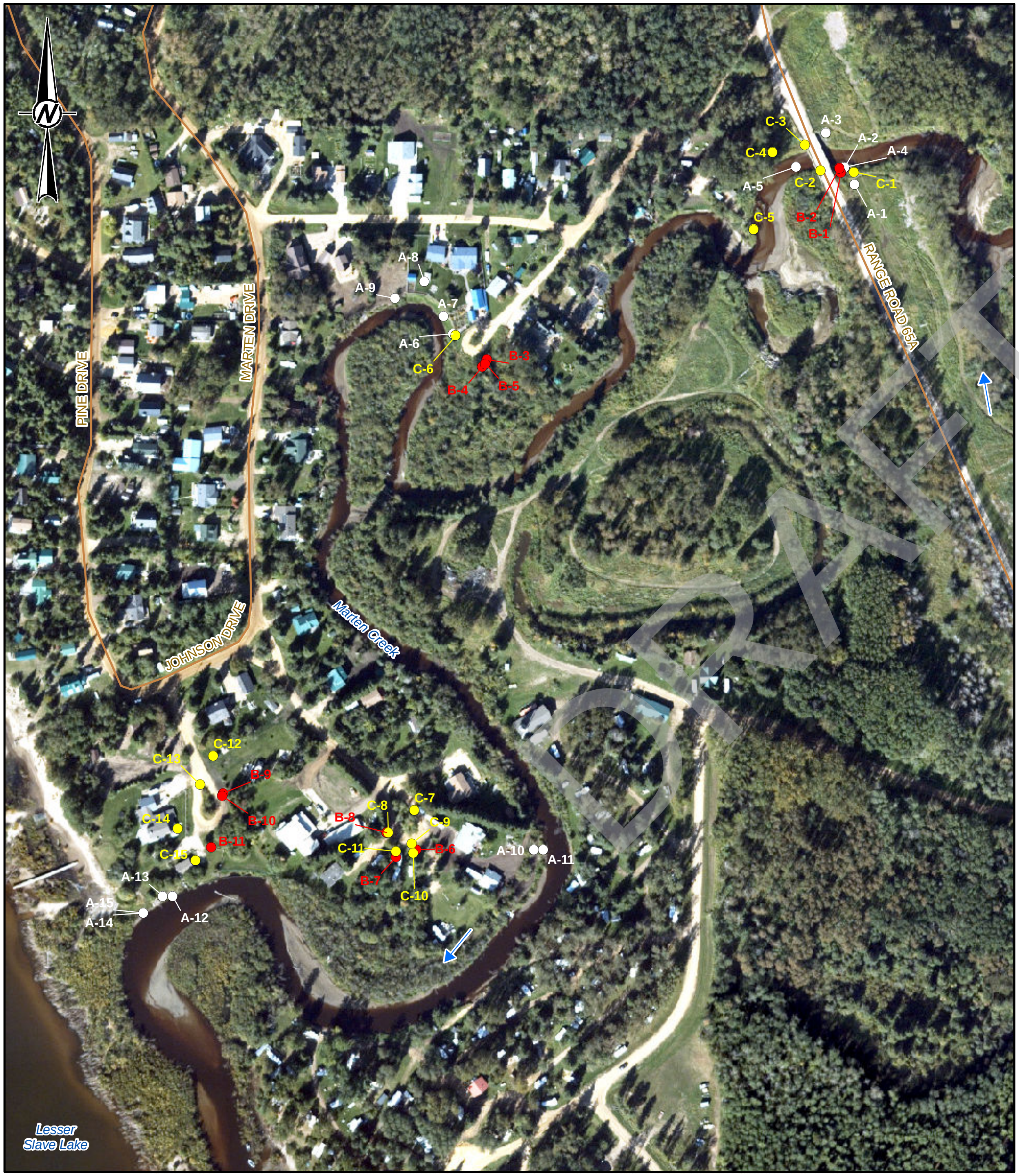
Wolf Ploeger, Dr.-Ing., P.Eng.
Associate, Senior River Engineer

GT/WP

APPENDIX C

Model Calibration Results

PATH: I:\CLIENTS\AEP\20368087\Mapping\Products\Hydrology\03_Hydraulic_Modelling\Rev0\20368087_FigC1_High-Water-Marks-Calibration_Rev0.mxd PRINTED ON: 2022-04-01 AT: 2:23:46 PM



LEGEND

FLOW DIRECTION

LOCAL ROAD

HIGH WATER MARK LOCATION

2011

2018

2019

0 100 200

1:4,000 METRES

REFERENCE(S)

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DATUM: NAD 83 CSRS PROJECTION: 3TM 114

CLIENT
ALBERTA ENVIRONMENT AND PARKS

Alberta

PROJECT
MARTEN BEACH FLOOD HAZARD STUDY

TITLE
HIGH WATER MARKS

CONSULTANT

wsp

YYYY-MM-DD	2022-04-01
DESIGNED	WP
PREPARED	NB
REVIEWED	GT
APPROVED	WP

PROJECT NO.	CONTROL	REV.	FIGURE
20368087		0	C1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET HAS BEEN MODIFIED FROM: ANSI A

25mm

0

Classification: Public

Table C.1: Comparison of Simulated Water Levels and Selected Surveyed Highwater Marks for the 2011 Flood Event

Highwater Mark		Simulated Water Level (m)			Water Level Difference (m) (Simulated Water Level minus Highwater Mark Elevation)		
ID	Water Level (m)	2-Year Flood	5-Year Flood	10-Year Flood	2-Year Flood	5-Year Flood	10-Year Flood
A-1	579.72	-	580.44	580.94	-	0.72	1.22
A-2	579.06	579.68	580.41	580.91	0.62	1.35	1.85
A-3	578.92	-	580.39	580.89	-	1.47	1.98
A-4	579.10	579.69	580.42	580.92	0.58	1.32	1.82
A-5	579.07	579.58	580.12	580.38	0.51	1.05	1.31
A-6	578.13	578.97	579.32	579.47	0.84	1.19	1.34
A-7	578.18	578.96	579.31	579.46	0.78	1.13	1.28
A-8	578.76	-	579.29	579.46	-	0.54	0.70
A-9	578.72	-	579.29	579.45	-	0.58	0.73
A-10	577.92	578.50	578.86	579.03	0.58	0.94	1.11
A-11	577.45	578.50	578.86	579.03	1.05	1.41	1.58
A-12	577.47	578.11	578.38	578.51	0.65	0.92	1.05
A-13	577.15	578.00	578.29	578.44	0.85	1.14	1.29
A-14	577.14	577.98	578.26	578.41	0.84	1.12	1.27
A-15	577.52	577.98	578.25	578.40	0.46	0.73	0.88
Average Difference:					**0.71**	**1.04**	**1.29**

Note: 1) White columns indicate the most comparable flood event for model calibration
2) Absent values indicate locations which were not inundated for that particular flood simulation
3) Only relevant highwater marks used for calibration are included in the above table

Table C.2: Comparison of Simulated Water Levels and Selected Surveyed Highwater Marks for the 2018 Flood Event

Highwater Mark		Simulated Water Level (m)			Water Level Difference (m) (Simulated Water Level minus Highwater Mark Elevation)		
ID	Water Level (m)	2-Year Flood	5-Year Flood	10-Year Flood	2-Year Flood	5-Year Flood	10-Year Flood
B-1	579.87	-	580.41	580.91	-	0.54	1.04
B-2	579.86	579.68	580.41	580.91	-0.18	0.55	1.05
B-3	579.38	-	-	579.53	-	-	0.15
B-4	579.37	-	579.35	579.53	-	-0.02	0.16
B-5	579.32	-	579.35	579.53	-	0.03	0.21
B-6	578.48	-	578.81	578.97	-	0.32	0.49
B-7	578.46	-	578.78	578.94	-	0.32	0.48
B-8	578.48	-	578.83	578.99	-	0.35	0.51
B-9	578.24	578.32	578.75	578.90	0.08	0.52	0.66
B-10	578.44	578.32	578.75	578.90	-0.12	0.31	0.46
B-11	578.43	-	578.69	578.79	-	0.26	0.36
				Average Difference:	**-0.07**	**0.32**	**0.51**

Note: 1) White columns indicate the most comparable flood event for model calibration
2) Absent values indicate locations which were not inundated for that particular flood simulation
3) Only relevant highwater marks used for calibration are included in the above table

Table C.3: Comparison of Simulated Water Levels and Selected Surveyed Highwater Marks for the 2019 Flood Event

Highwater Mark		Simulated Water Level (m)			Water Level Difference (m) (Simulated Water Level minus Highwater Mark Elevation)		
ID	Water Level (m)	2-Year Flood	5-Year Flood	10-Year Flood	2-Year Flood	5-Year Flood	10-Year Flood
C-1	580.72	-	580.43	580.93	-	-0.29	0.21
C-2	580.52	579.64	580.30	580.72	-0.88	-0.22	0.20
C-3	580.58	-	-	580.55	-	-	-0.03
C-4	580.50	-	-	580.37	-	-	-0.12
C-5	580.10	579.53	580.03	580.26	-0.57	-0.07	0.16
C-6	579.49	-	579.32	579.47	-	-0.17	-0.01
C-7	578.75	-	578.88	579.04	-	0.13	0.29
C-8	578.68	-	578.83	578.99	-	0.15	0.31
C-9	578.73	-	578.82	578.98	-	0.08	0.25
C-10	578.74	-	578.80	578.96	-	0.06	0.22
C-11	578.68	-	578.79	578.95	-	0.10	0.27
C-12	578.74	578.32	578.76	578.91	-0.42	0.02	0.18
C-13	578.72	578.32	578.75	578.90	-0.40	0.03	0.18
C-14	578.66	-	578.73	578.86	-	0.07	0.20
C-15	578.58	-	578.69	578.76	-	0.10	0.18
				Average Difference:	**-0.57**	**0.00**	**0.17**

Note: 1) White columns indicate the most comparable flood event for model calibration
2) Absent values indicate locations which were not inundated for that particular flood simulation
3) Only relevant highwater marks used for calibration are included in the above table

APPENDIX D

Flood Profiles

LEGEND

- FLOW DIRECTION
- LOCAL ROAD
- MARTEN CREEK STATION (50m)
- UNNAMED TRIBUTARY STATION (50m)
- MARTEN CREEK
- UNNAMED TRIBUTARY
- STUDY AREA

0 250 500

1:10,000 METRES

REFERENCE(S)

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DATUM: NAD 83 CSRS PROJECTION: 3TM 114

CLIENT
ALBERTA ENVIRONMENT AND PARKS

PROJECT
MARTEN BEACH FLOOD HAZARD STUDY

TITLE
FLOOD PROFILE STATIONING

CONSULTANT

YYYY-MM-DD	2022-04-01
DESIGNED	WP
PREPARED	RC
REVIEWED	GT
APPROVED	WP

PROJECT NO.	CONTROL	REV.	FIGURE
20368087		0	D1

Table D.1: Marten Creek Flood Profiles

Station	Channel Centerline Bed Elevation	2-year flood	5-year flood	10-year flood	20-year flood	35-year flood	50-year flood	75-year flood	100-year flood	200-year flood	350-year flood	750-year flood	500-year flood	1000-year flood
0+000	576.46	577.11	577.52	577.80	578.06	578.28	578.42	578.58	578.69	578.96	579.18	579.32	579.48	579.60
0+050	576.34	577.25	577.59	577.83	578.08	578.29	578.43	578.58	578.70	578.97	579.19	579.33	579.48	579.60
0+100	576.54	577.47	577.74	577.93	578.14	578.33	578.45	578.61	578.72	578.98	579.20	579.33	579.49	579.61
0+150	576.65	577.65	577.90	578.06	578.23	578.39	578.51	578.65	578.76	579.01	579.22	579.35	579.50	579.62
0+200	576.87	577.77	578.01	578.15	578.30	578.44	578.55	578.68	578.79	579.03	579.23	579.36	579.51	579.63
0+250	576.91	577.90	578.14	578.28	578.42	578.55	578.64	578.76	578.85	579.08	579.27	579.39	579.53	579.64
0+300	576.69	577.97	578.25	578.41	578.55	578.67	578.76	578.87	578.95	579.16	579.33	579.44	579.57	579.68
0+350	576.62	578.04	578.35	578.51	578.64	578.76	578.84	578.94	579.02	579.21	579.36	579.47	579.60	579.70
0+400	576.62	578.11	578.42	578.57	578.70	578.81	578.88	578.98	579.05	579.23	579.38	579.48	579.61	579.70
0+450	576.61	578.17	578.48	578.63	578.76	578.86	578.94	579.03	579.10	579.27	579.41	579.50	579.62	579.72
0+500	576.79	578.23	578.56	578.71	578.84	578.94	579.01	579.09	579.16	579.31	579.45	579.54	579.65	579.74
0+550	576.85	578.29	578.64	578.79	578.92	579.01	579.08	579.16	579.22	579.37	579.49	579.58	579.69	579.77
0+600	576.78	578.35	578.71	578.87	578.99	579.08	579.15	579.22	579.28	579.42	579.55	579.63	579.73	579.81
0+650	576.79	578.41	578.78	578.94	579.06	579.15	579.21	579.29	579.34	579.48	579.59	579.67	579.77	579.85
0+700	576.75	578.46	578.85	579.01	579.14	579.23	579.29	579.36	579.41	579.54	579.65	579.73	579.82	579.89
0+750	576.69	578.51	578.92	579.09	579.22	579.31	579.37	579.44	579.49	579.62	579.72	579.79	579.87	579.94
0+800	576.77	578.56	578.97	579.14	579.26	579.35	579.41	579.48	579.53	579.65	579.75	579.82	579.90	579.97
0+850	576.89	578.61	579.02	579.18	579.31	579.40	579.46	579.52	579.57	579.69	579.78	579.85	579.93	579.99
0+900	576.97	578.70	579.12	579.27	579.39	579.47	579.53	579.59	579.64	579.75	579.84	579.90	579.98	580.04
0+950	576.94	578.74	579.15	579.30	579.42	579.50	579.56	579.62	579.67	579.78	579.87	579.93	580.01	580.06
1+000	577.01	578.77	579.17	579.31	579.43	579.51	579.57	579.64	579.68	579.79	579.88	579.94	580.02	580.08
1+050	576.93	578.80	579.19	579.33	579.45	579.53	579.58	579.65	579.69	579.80	579.89	579.95	580.03	580.09
1+100	577.01	578.84	579.23	579.36	579.47	579.55	579.60	579.67	579.71	579.82	579.91	579.97	580.04	580.10
1+150	577.09	578.88	579.26	579.39	579.50	579.58	579.63	579.69	579.73	579.84	579.92	579.98	580.05	580.11
1+200	577.12	578.91	579.29	579.41	579.51	579.59	579.64	579.70	579.74	579.84	579.93	579.98	580.05	580.11
1+250	577.16	578.96	579.34	579.46	579.56	579.63	579.68	579.74	579.78	579.88	579.96	580.01	580.08	580.13
1+300	577.26	579.03	579.44	579.57	579.67	579.73	579.78	579.83	579.87	579.96	580.04	580.09	580.15	580.19
1+350	577.29	579.10	579.53	579.67	579.77	579.85	579.89	579.95	579.99	580.07	580.14	580.19	580.25	580.29
1+400	577.41	579.16	579.61	579.77	579.89	579.97	580.02	580.07	580.11	580.20	580.27	580.31	580.36	580.40

Table D.1: Marten Creek Flood Profiles

Station	Channel Centerline Bed Elevation	2-year flood	5-year flood	10-year flood	20-year flood	35-year flood	50-year flood	75-year flood	100-year flood	200-year flood	350-year flood	750-year flood	500-year flood	1000-year flood
1+450	577.46	579.22	579.69	579.86	579.99	580.08	580.13	580.18	580.22	580.30	580.37	580.41	580.46	580.50
1+500	577.50	579.28	579.76	579.95	580.09	580.17	580.22	580.28	580.32	580.40	580.47	580.51	580.56	580.59
1+550	577.51	579.36	579.86	580.06	580.21	580.30	580.35	580.41	580.45	580.53	580.60	580.65	580.70	580.73
1+600	577.58	579.40	579.90	580.11	580.26	580.35	580.40	580.46	580.50	580.58	580.65	580.70	580.75	580.78
1+650	577.69	579.44	579.96	580.19	580.37	580.47	580.53	580.59	580.62	580.71	580.77	580.81	580.86	580.89
1+660	577.70	579.45	579.98	580.22	580.41	580.51	580.57	580.63	580.66	580.75	580.81	580.85	580.90	580.93
1+670	577.72	579.48	580.05	580.34	580.60	580.73	580.79	580.85	580.89	580.98	581.05	581.09	581.13	581.16
1+680	577.73	579.52	580.18	580.61	581.06	581.24	581.32	581.39	581.44	581.55	581.62	581.66	581.70	581.73
1+690	577.74	579.54	580.20	580.63	581.07	581.26	581.33	581.40	581.45	581.56	581.63	581.67	581.71	581.74
1+700	577.76	579.55	580.22	580.65	581.09	581.27	581.35	581.42	581.47	581.57	581.64	581.68	581.73	581.76
1+750	577.83	579.61	580.29	580.72	581.14	581.32	581.40	581.47	581.51	581.62	581.69	581.73	581.77	581.80
1+800	577.86	579.64	580.33	580.76	581.17	581.34	581.42	581.49	581.54	581.64	581.71	581.75	581.79	581.82
1+850	577.91	579.68	580.37	580.80	581.19	581.36	581.44	581.51	581.55	581.66	581.72	581.76	581.81	581.84
1+900	577.96	579.72	580.43	580.86	581.24	581.40	581.48	581.55	581.60	581.70	581.77	581.82	581.86	581.89
1+950	578.03	579.77	580.49	580.92	581.29	581.45	581.53	581.60	581.65	581.76	581.83	581.87	581.92	581.95
2+000	578.07	579.82	580.54	580.97	581.33	581.49	581.56	581.64	581.68	581.79	581.87	581.91	581.96	581.99
2+050	578.19	579.87	580.59	581.02	581.36	581.51	581.59	581.66	581.71	581.82	581.89	581.94	581.98	582.02
2+100	578.35	579.90	580.63	581.05	581.38	581.54	581.61	581.68	581.73	581.84	581.91	581.96	582.00	582.04
2+150	578.52	579.96	580.70	581.12	581.43	581.58	581.65	581.72	581.76	581.87	581.94	581.99	582.04	582.07
2+200	578.69	580.05	580.79	581.21	581.51	581.65	581.72	581.79	581.84	581.95	582.02	582.07	582.12	582.15
2+250	578.76	580.12	580.87	581.29	581.59	581.73	581.80	581.87	581.92	582.02	582.10	582.15	582.20	582.23
2+300	578.85	580.21	580.95	581.38	581.67	581.80	581.87	581.94	581.99	582.10	582.17	582.22	582.27	582.31
2+350	578.85	580.31	581.04	581.46	581.74	581.87	581.94	582.01	582.05	582.16	582.23	582.28	582.33	582.36
2+400	578.88	580.41	581.14	581.56	581.84	581.97	582.03	582.10	582.15	582.25	582.33	582.37	582.42	582.46
2+450	578.99	580.52	581.23	581.65	581.92	582.05	582.12	582.19	582.23	582.34	582.41	582.46	582.51	582.55
2+500	579.00	580.58	581.29	581.71	581.99	582.11	582.18	582.25	582.29	582.40	582.47	582.52	582.57	582.60
2+550	579.14	580.69	581.40	581.83	582.09	582.21	582.26	582.33	582.37	582.46	582.53	582.57	582.62	582.65
2+600	579.21	580.77	581.49	581.92	582.17	582.28	582.33	582.39	582.43	582.52	582.58	582.62	582.67	582.70
2+650	579.29	580.84	581.56	581.99	582.23	582.33	582.38	582.43	582.47	582.55	582.61	582.65	582.69	582.72

Table D.1: Marten Creek Flood Profiles

Station	Channel Centerline Bed Elevation	2-year flood	5-year flood	10-year flood	20-year flood	35-year flood	50-year flood	75-year flood	100-year flood	200-year flood	350-year flood	750-year flood	500-year flood	1000-year flood
2+700	579.33	580.90	581.63	582.06	582.28	582.37	582.41	582.47	582.50	582.57	582.63	582.67	582.70	582.73
2+750	579.37	580.97	581.70	582.13	582.34	582.42	582.46	582.50	582.53	582.60	582.65	582.69	582.72	582.75
2+800	579.45	581.04	581.77	582.21	582.40	582.48	582.52	582.56	582.59	582.65	582.70	582.74	582.77	582.80
2+850	579.59	581.10	581.84	582.27	582.46	582.53	582.57	582.61	582.64	582.70	582.75	582.79	582.82	582.85
2+900	579.67	581.18	581.91	582.35	582.53	582.60	582.63	582.67	582.70	582.76	582.81	582.85	582.88	582.91
2+950	579.74	581.29	582.02	582.45	582.63	582.69	582.73	582.77	582.80	582.86	582.91	582.95	582.98	583.01
3+000	579.77	581.38	582.12	582.56	582.74	582.81	582.85	582.89	582.92	582.99	583.04	583.08	583.12	583.15
3+050	580.43	581.47	582.21	582.66	582.85	582.92	582.97	583.01	583.05	583.13	583.19	583.23	583.28	583.31
3+100	580.17	581.56	582.29	582.75	582.94	583.03	583.08	583.13	583.17	583.26	583.33	583.37	583.42	583.46
3+150	580.31	581.64	582.36	582.81	583.02	583.11	583.16	583.22	583.26	583.36	583.44	583.49	583.54	583.58
3+200	580.78	581.77	582.47	582.91	583.14	583.26	583.32	583.40	583.44	583.56	583.65	583.71	583.77	583.81
3+234	580.43	581.85	582.54	582.98	583.23	583.36	583.43	583.52	583.57	583.70	583.80	583.87	583.94	583.98

Table D.2: Unnamed Tributary Flood Profiles

Station	Channel Centerline Bed Elevation	2-year flood	5-year flood	10-year flood	20-year flood	35-year flood	50-year flood	75-year flood	100-year flood	200-year flood	350-year flood	750-year flood	500-year flood	1000-year flood
0+000	577.91	579.68	580.37	580.80	581.19	581.36	581.44	581.51	581.55	581.65	581.72	581.76	581.81	581.83
0+050	578.37	579.68	580.37	580.80	581.19	581.36	581.44	581.50	581.55	581.65	581.71	581.75	581.79	581.82
0+100	578.50	579.70	580.38	580.81	581.20	581.36	581.44	581.50	581.55	581.65	581.71	581.75	581.78	581.81
0+150	578.83	579.73	580.40	580.82	581.20	581.37	581.44	581.51	581.55	581.65	581.71	581.74	581.78	581.80
0+200	579.04	579.77	580.41	580.83	581.21	581.37	581.45	581.51	581.56	581.65	581.71	581.74	581.78	581.80
0+250	579.61	580.25	580.51	580.85	581.22	581.38	581.45	581.52	581.56	581.65	581.71	581.75	581.78	581.81
0+300	579.87	580.51	580.74	580.97	581.27	581.43	581.50	581.56	581.60	581.69	581.74	581.77	581.80	581.83
0+350	580.09	580.67	580.89	581.07	581.33	581.48	581.55	581.60	581.64	581.72	581.77	581.80	581.83	581.85
0+400	580.27	580.86	581.07	581.22	581.42	581.56	581.62	581.66	581.70	581.77	581.82	581.84	581.87	581.89
0+450	580.35	581.00	581.22	581.35	581.51	581.63	581.69	581.73	581.77	581.83	581.86	581.89	581.91	581.93
0+500	580.59	581.16	581.38	581.49	581.62	581.73	581.78	581.81	581.85	581.90	581.93	581.95	581.97	581.98
0+550	580.55	581.30	581.51	581.62	581.73	581.83	581.88	581.90	581.94	581.97	582.00	582.01	582.03	582.04
0+600	580.86	581.47	581.69	581.79	581.89	581.98	582.02	582.03	582.07	582.10	582.11	582.12	582.14	582.15
0+650	581.00	581.60	581.82	581.92	582.01	582.09	582.13	582.14	582.17	582.19	582.20	582.21	582.22	582.23
0+700	581.15	581.77	581.99	582.08	582.16	582.24	582.27	582.28	582.31	582.32	582.33	582.33	582.34	582.34
0+750	581.27	581.92	582.14	582.24	582.32	582.39	582.43	582.43	582.46	582.47	582.47	582.48	582.48	582.48
0+800	581.44	582.04	582.26	582.37	582.45	582.52	582.56	582.56	582.59	582.59	582.60	582.60	582.60	582.60
0+850	581.57	582.19	582.41	582.51	582.58	582.65	582.69	582.69	582.72	582.72	582.73	582.73	582.73	582.73
0+900	581.74	582.30	582.50	582.60	582.68	582.75	582.78	582.78	582.82	582.82	582.82	582.82	582.82	582.82
0+950	581.87	582.46	582.67	582.77	582.84	582.92	582.95	582.95	582.98	582.98	582.98	582.98	582.98	582.98
1+000	581.99	582.59	582.80	582.90	582.97	583.04	583.08	583.08	583.11	583.11	583.11	583.11	583.11	583.11
1+050	582.15	582.73	582.94	583.04	583.11	583.18	583.21	583.22	583.25	583.25	583.25	583.25	583.25	583.25
1+100	582.28	582.89	583.10	583.20	583.28	583.35	583.38	583.38	583.41	583.41	583.41	583.41	583.41	583.41
1+150	582.40	583.05	583.26	583.36	583.43	583.50	583.54	583.54	583.57	583.57	583.57	583.57	583.57	583.57
1+200	582.54	583.16	583.38	583.48	583.56	583.63	583.67	583.67	583.70	583.70	583.70	583.70	583.70	583.70
1+250	582.68	583.30	583.53	583.63	583.71	583.78	583.82	583.82	583.85	583.85	583.85	583.85	583.85	583.85
1+276	582.77	583.40	583.61	583.72	583.80	583.87	583.91	583.91	583.94	583.94	583.94	583.94	583.94	583.94

APPENDIX E

Model Sensitivity Analysis

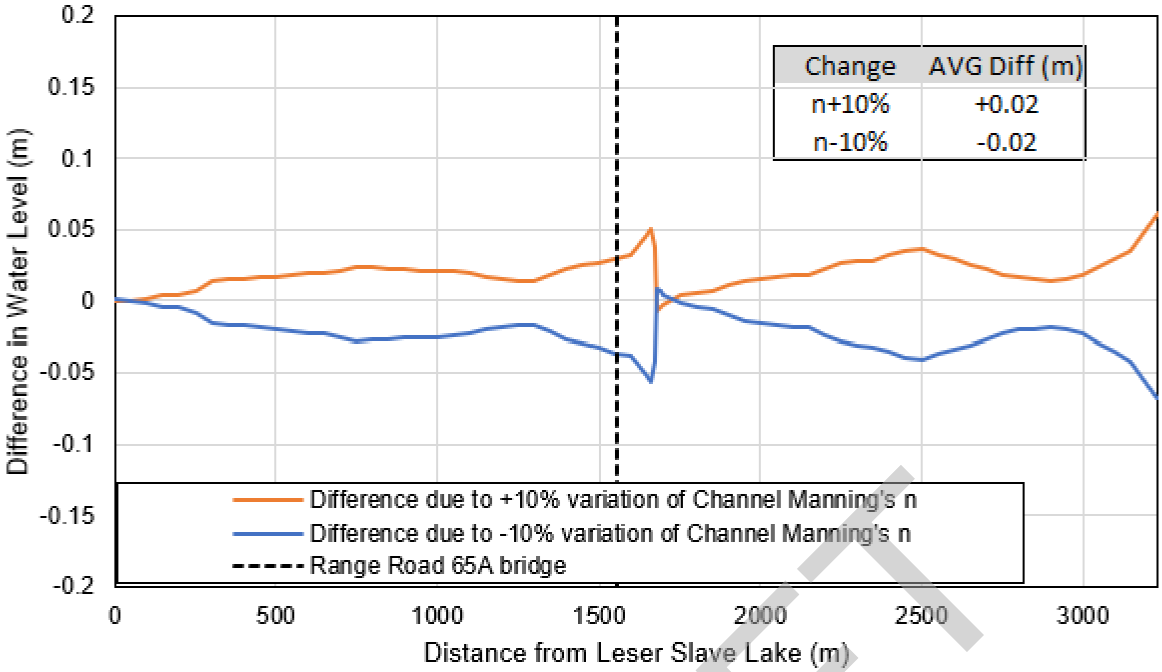


Figure E.1a: Channel Roughness Sensitivity Analysis for Marten Creek

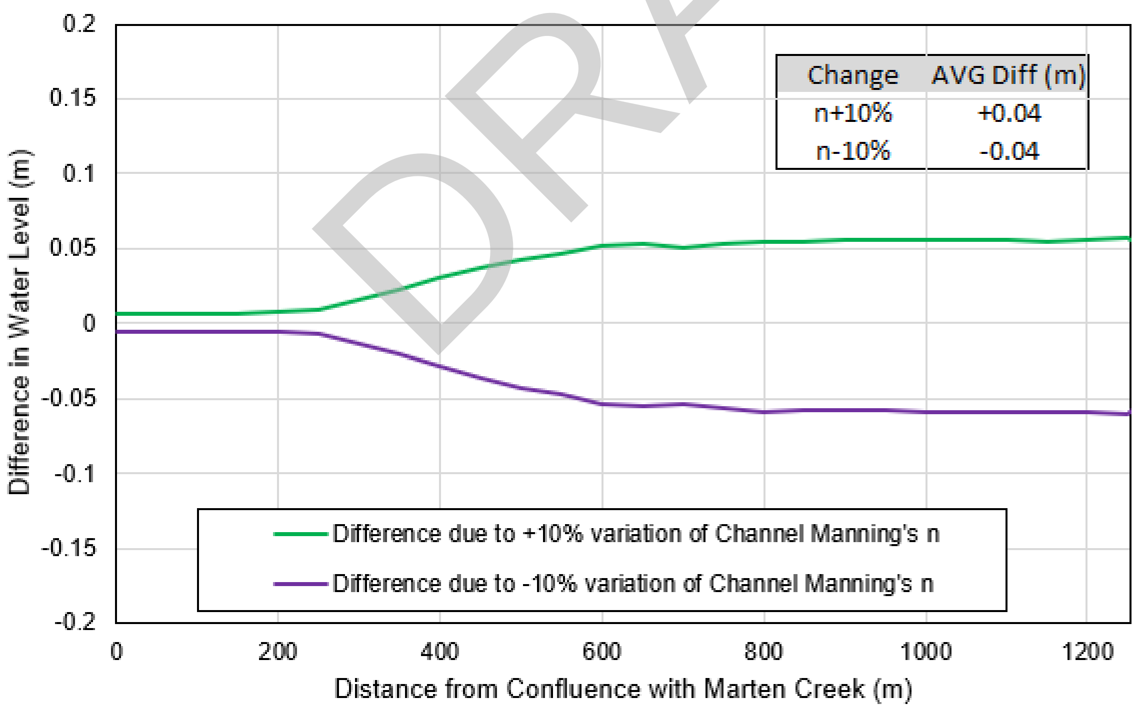


Figure E.1b: Channel Roughness Sensitivity Analysis for Unnamed Tributary

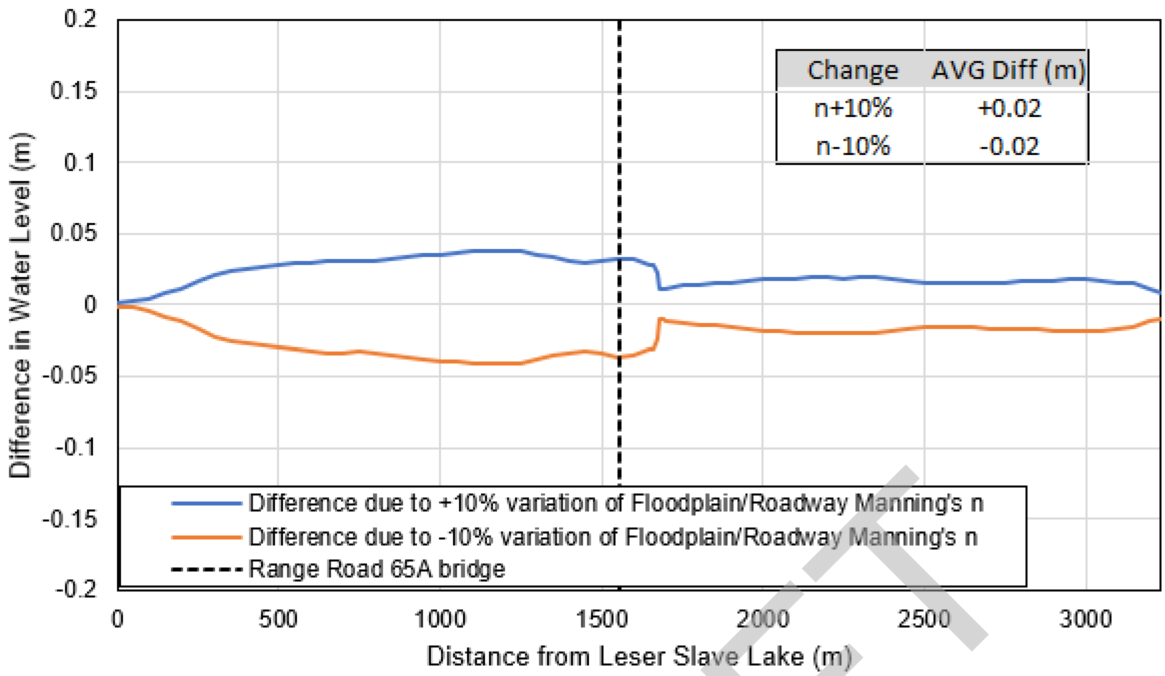


Figure E.2a: Floodplain and Roadway Roughness Sensitivity Analysis for Marten Creek

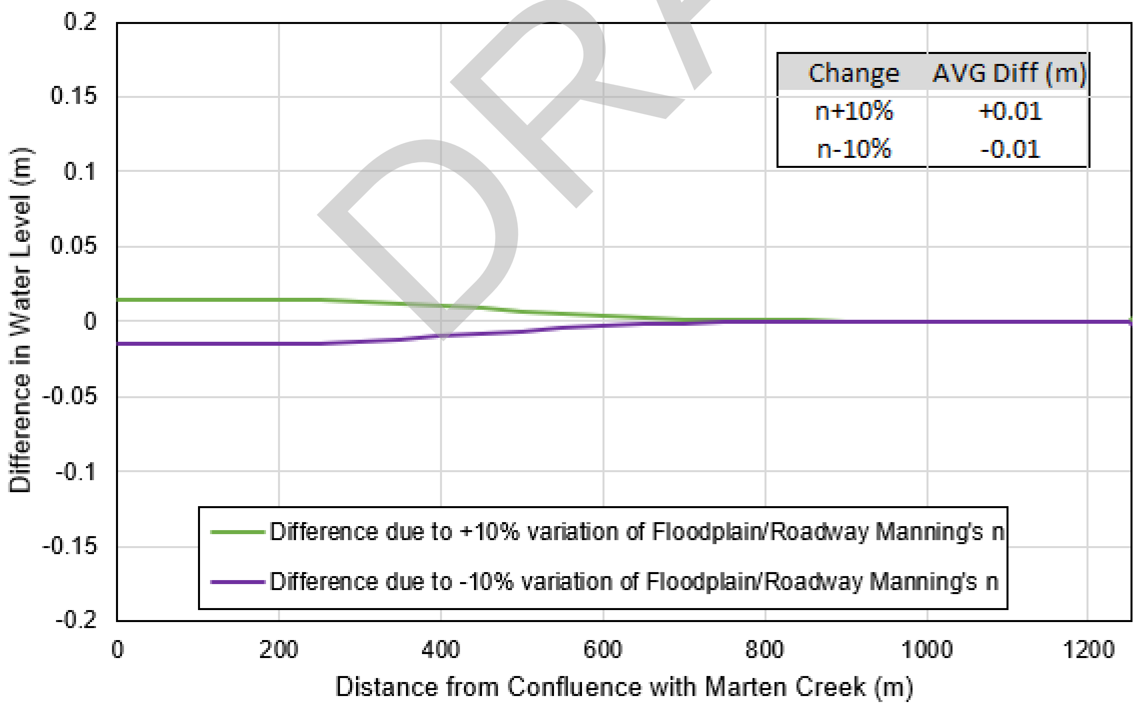


Figure E.2b: Floodplain and Roadway Roughness Sensitivity Analysis for Unnamed Tributary

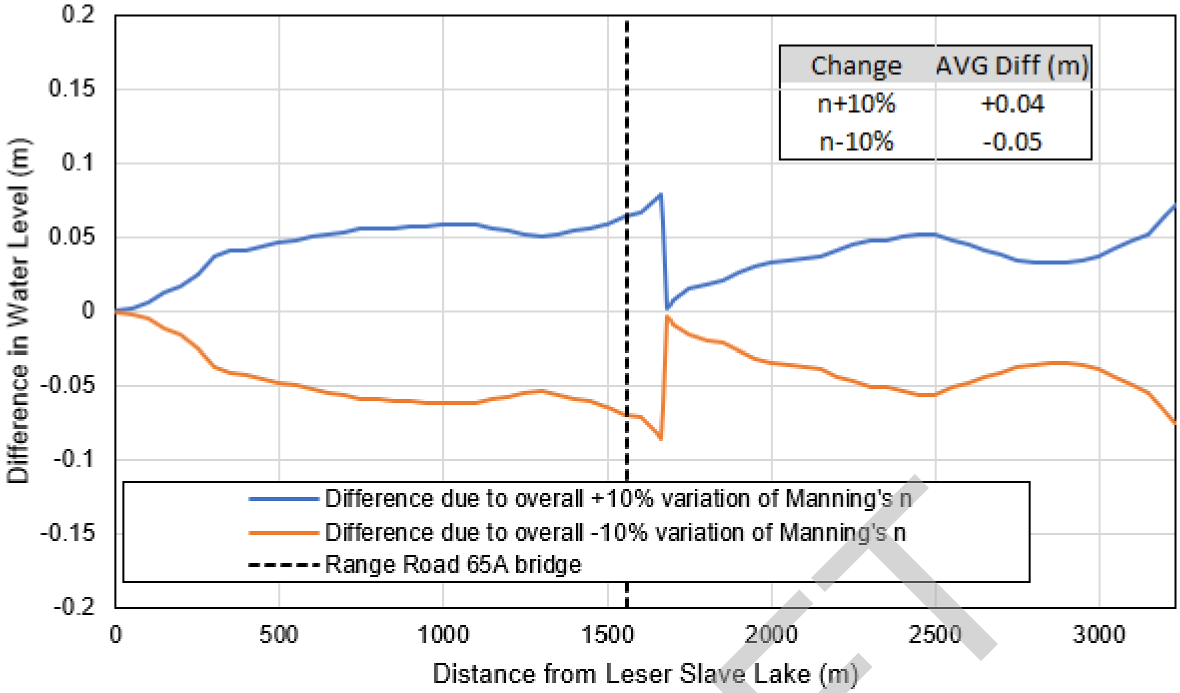


Figure E.3a: General Roughness Sensitivity Analysis for Marten Creek

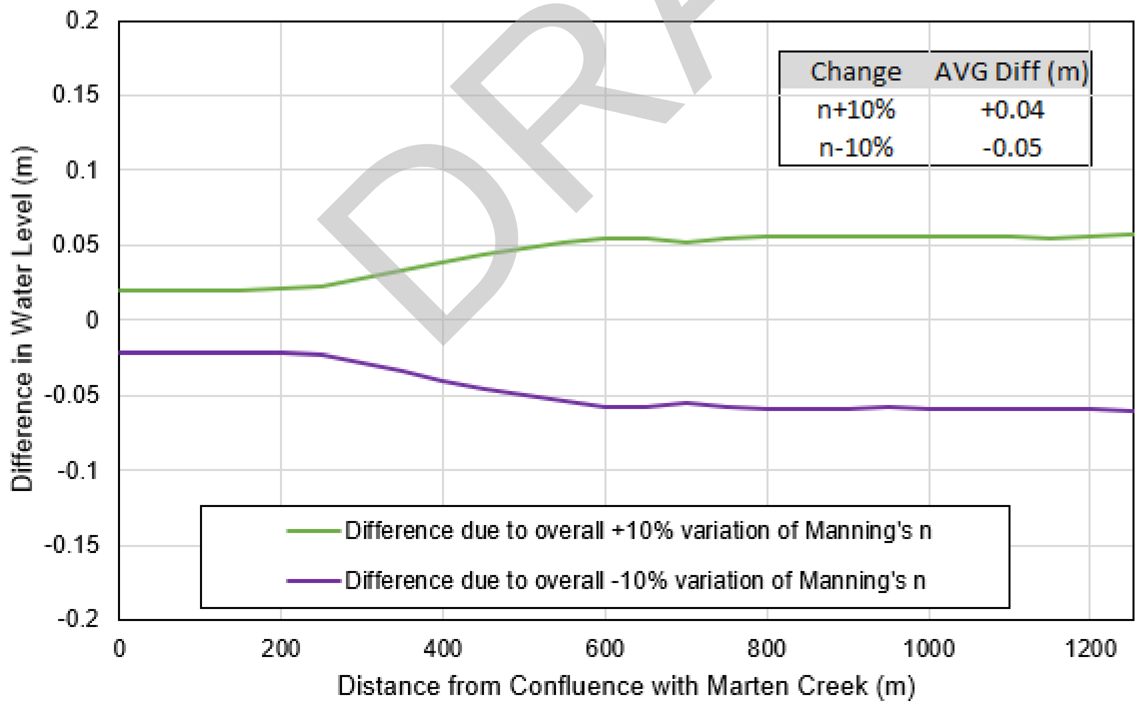


Figure E.3b: General Roughness Sensitivity Analysis for Unnamed Tributary

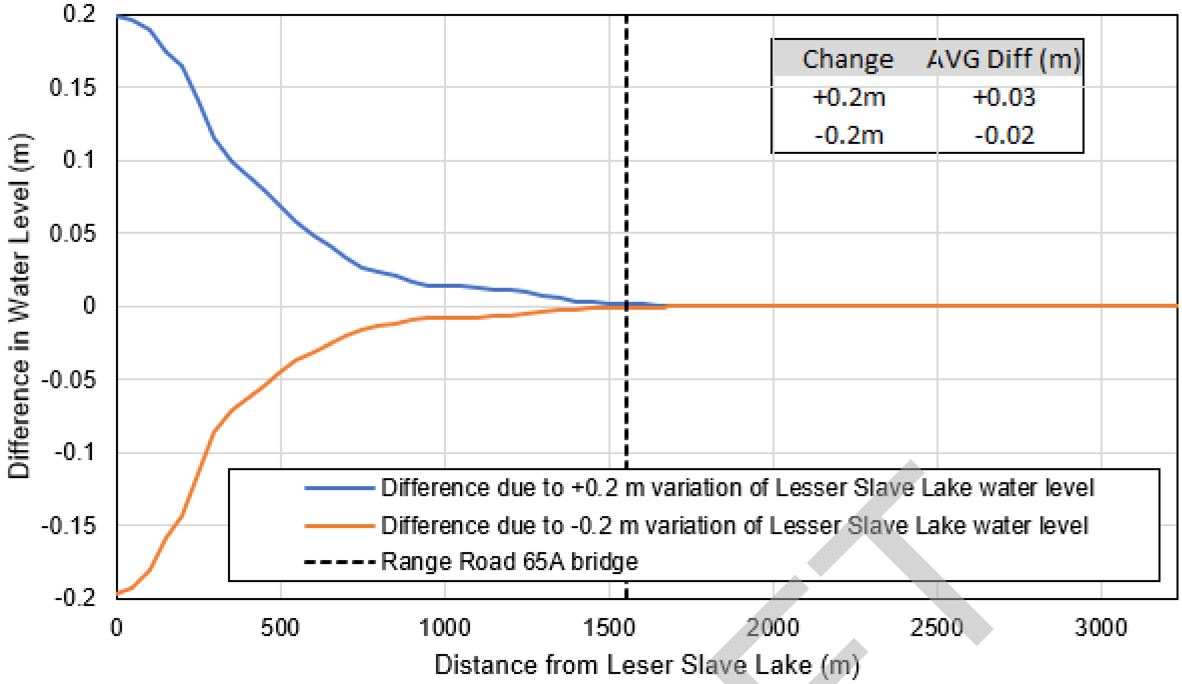


Figure E.4a: Downstream Boundary (Lesser Slave Lake Water Level) Sensitivity Analysis for Marten Creek

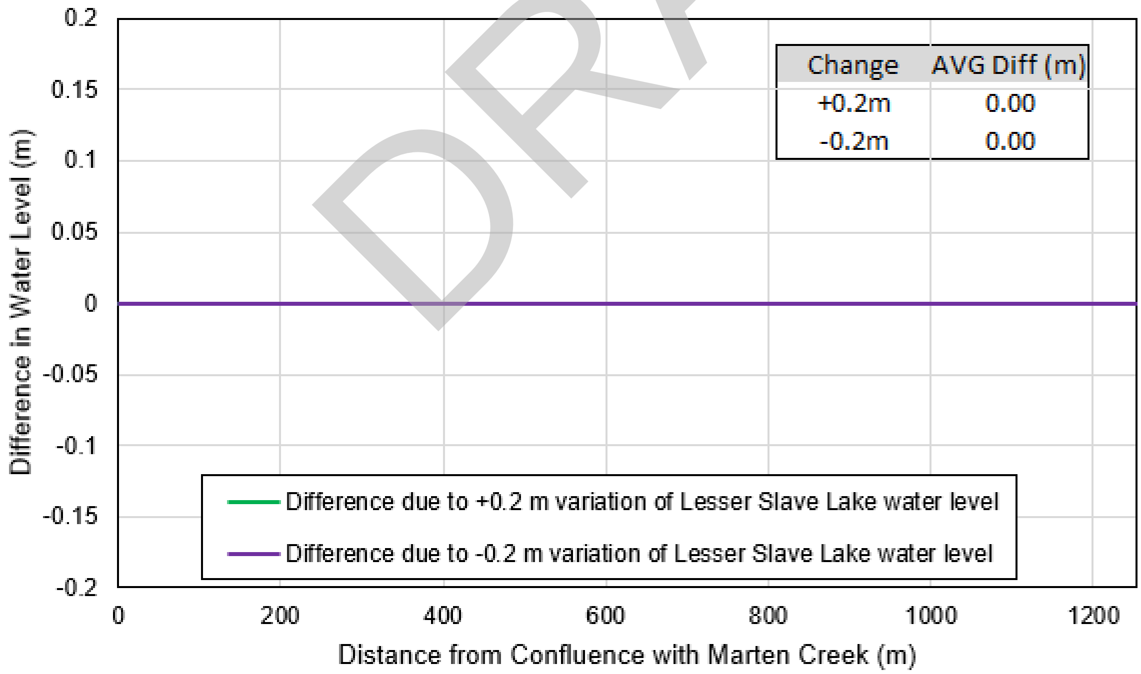


Figure E.4b: Downstream Boundary (Lesser Slave Lake Water Level) Sensitivity Analysis for Unnamed Tributary

APPENDIX F

Open Water Flood Inundation Map Library (Provided under Separate Cover)

APPENDIX G

Floodway Criteria and Design Flood Water Levels

Table G.1: Marten Creek Floodway Criteria and Design Flood Water Levels

River	Reach	Station	1:100-year Design Flood
Marten Creek	Marten Creek	0+000	578.69
Marten Creek	Marten Creek	0+050	578.70
Marten Creek	Marten Creek	0+100	578.72
Marten Creek	Marten Creek	0+150	578.76
Marten Creek	Marten Creek	0+200	578.79
Marten Creek	Marten Creek	0+250	578.85
Marten Creek	Marten Creek	0+300	578.95
Marten Creek	Marten Creek	0+350	579.02
Marten Creek	Marten Creek	0+400	579.05
Marten Creek	Marten Creek	0+450	579.10
Marten Creek	Marten Creek	0+500	579.16
Marten Creek	Marten Creek	0+550	579.22
Marten Creek	Marten Creek	0+600	579.28
Marten Creek	Marten Creek	0+650	579.34
Marten Creek	Marten Creek	0+700	579.41
Marten Creek	Marten Creek	0+750	579.49
Marten Creek	Marten Creek	0+800	579.53
Marten Creek	Marten Creek	0+850	579.57
Marten Creek	Marten Creek	0+900	579.64
Marten Creek	Marten Creek	0+950	579.67
Marten Creek	Marten Creek	1+000	579.68
Marten Creek	Marten Creek	1+050	579.69
Marten Creek	Marten Creek	1+100	579.71
Marten Creek	Marten Creek	1+150	579.73
Marten Creek	Marten Creek	1+200	579.74
Marten Creek	Marten Creek	1+250	579.78
Marten Creek	Marten Creek	1+300	579.87
Marten Creek	Marten Creek	1+350	579.99
Marten Creek	Marten Creek	1+400	580.11
Marten Creek	Marten Creek	1+450	580.22
Marten Creek	Marten Creek	1+500	580.32
Marten Creek	Marten Creek	1+550	580.45
Marten Creek	Marten Creek	1+600	580.50
Marten Creek	Marten Creek	1+650	580.62
Marten Creek	Marten Creek	1+660	580.66
Marten Creek	Marten Creek	1+670	580.89
Marten Creek	Marten Creek	1+680	581.44
Marten Creek	Marten Creek	1+690	581.45
Marten Creek	Marten Creek	1+700	581.47
Marten Creek	Marten Creek	1+750	581.51
Marten Creek	Marten Creek	1+800	581.54

Table G.1: Marten Creek Floodway Criteria and Design Flood Water Levels

River	Reach	Station	1:100-year Design Flood
Marten Creek	Marten Creek	1+850	581.55
Marten Creek	Marten Creek	1+900	581.60
Marten Creek	Marten Creek	1+950	581.65
Marten Creek	Marten Creek	2+000	581.68
Marten Creek	Marten Creek	2+050	581.71
Marten Creek	Marten Creek	2+100	581.73
Marten Creek	Marten Creek	2+150	581.76
Marten Creek	Marten Creek	2+200	581.84
Marten Creek	Marten Creek	2+250	581.92
Marten Creek	Marten Creek	2+300	581.99
Marten Creek	Marten Creek	2+350	582.05
Marten Creek	Marten Creek	2+400	582.15
Marten Creek	Marten Creek	2+450	582.23
Marten Creek	Marten Creek	2+500	582.29
Marten Creek	Marten Creek	2+550	582.37
Marten Creek	Marten Creek	2+600	582.43
Marten Creek	Marten Creek	2+650	582.47
Marten Creek	Marten Creek	2+700	582.50
Marten Creek	Marten Creek	2+750	582.53
Marten Creek	Marten Creek	2+800	582.59
Marten Creek	Marten Creek	2+850	582.64
Marten Creek	Marten Creek	2+900	582.70
Marten Creek	Marten Creek	2+950	582.80
Marten Creek	Marten Creek	3+000	582.92
Marten Creek	Marten Creek	3+050	583.05
Marten Creek	Marten Creek	3+100	583.17
Marten Creek	Marten Creek	3+150	583.26
Marten Creek	Marten Creek	3+200	583.44
Marten Creek	Marten Creek	3+234	583.57

Table G.2: Unnamed Tributary Floodway Criteria and Design Flood Water Levels

River	Reach	Station	1:100-year Design Flood
Unnamed Tributary	Unnamed Tributary	0+000	581.55
Unnamed Tributary	Unnamed Tributary	0+050	581.55
Unnamed Tributary	Unnamed Tributary	0+100	581.55
Unnamed Tributary	Unnamed Tributary	0+150	581.55
Unnamed Tributary	Unnamed Tributary	0+200	581.56
Unnamed Tributary	Unnamed Tributary	0+250	581.56
Unnamed Tributary	Unnamed Tributary	0+300	581.60
Unnamed Tributary	Unnamed Tributary	0+350	581.64
Unnamed Tributary	Unnamed Tributary	0+400	581.70
Unnamed Tributary	Unnamed Tributary	0+450	581.77
Unnamed Tributary	Unnamed Tributary	0+500	581.85
Unnamed Tributary	Unnamed Tributary	0+550	581.94
Unnamed Tributary	Unnamed Tributary	0+600	582.07
Unnamed Tributary	Unnamed Tributary	0+650	582.17
Unnamed Tributary	Unnamed Tributary	0+700	582.31
Unnamed Tributary	Unnamed Tributary	0+750	582.46
Unnamed Tributary	Unnamed Tributary	0+800	582.59
Unnamed Tributary	Unnamed Tributary	0+850	582.72
Unnamed Tributary	Unnamed Tributary	0+900	582.82
Unnamed Tributary	Unnamed Tributary	0+950	582.98
Unnamed Tributary	Unnamed Tributary	1+000	583.11
Unnamed Tributary	Unnamed Tributary	1+050	583.25
Unnamed Tributary	Unnamed Tributary	1+100	583.41
Unnamed Tributary	Unnamed Tributary	1+150	583.57
Unnamed Tributary	Unnamed Tributary	1+200	583.70
Unnamed Tributary	Unnamed Tributary	1+250	583.85
Unnamed Tributary	Unnamed Tributary	1+276	583.94

APPENDIX H

Floodway Criteria Maps

LEGEND

- STUDY BOUNDARY
- FLOW DIRECTION
- LOCAL ROAD

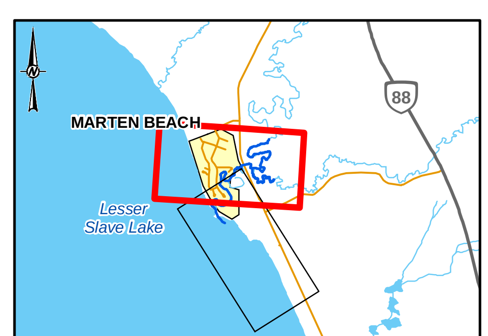
HYDRAULIC STRUCTURES

- BRIDGE

- PROPOSED FLOODWAY BOUNDARY
- VELOCITY ≥ 1 M/S
- DEPTH ≥ 1 M
- 100-YEAR DESIGN FLOOD EXTENT

DISCHARGE AND WATER LEVEL INFORMATION

MARTEN CREEK UPSTREAM OF UNNAMED TRIBUTARY DISCHARGE = 239 M^3/S
UNNAMED TRIBUTARY CREEK INFLOW = 18 M^3/S
MARTEN CREEK AT MARTEN BEACH DISCHARGE = 257 M^3/S
LESSER SLAVE LAKE WATER LEVEL = 578.69 M



0 100 200
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REFERENCE(S)

DATUM: NAD 83 CSRS PROJECTION: 3TM 114

CLIENT
ALBERTA ENVIRONMENT AND PROTECTED AREAS

CONSULTANT

YYYY-MM-DD	2023-09-29
DESIGNED	SB
PREPARED	PT
REVIEWED	WP
APPROVED	WP

PROJECT
MARTEN BEACH FLOOD HAZARD STUDY

TITLE
OPEN WATER FLOODWAY CRITERIA MAP

PROJECT NO.	CONTROL	REV.	FIGURE
20368087	4000	1	SHEET 1 OF 2

25mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

LEGEND

- STUDY BOUNDARY
- FLOW DIRECTION
- LOCAL ROAD

HYDRAULIC STRUCTURES

- BRIDGE

- PROPOSED FLOODWAY BOUNDARY
- VELOCITY ≥ 1 M/S
- DEPTH ≥ 1 M
- 100-YEAR DESIGN FLOOD EXTENT

DISCHARGE AND WATER LEVEL INFORMATION

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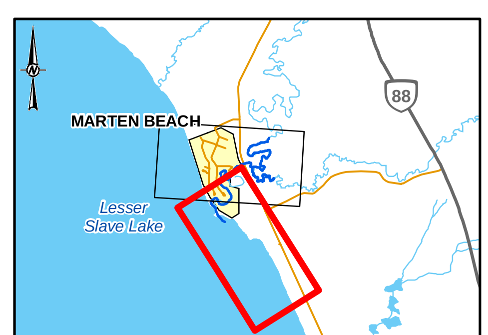

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1:5,000 METRES

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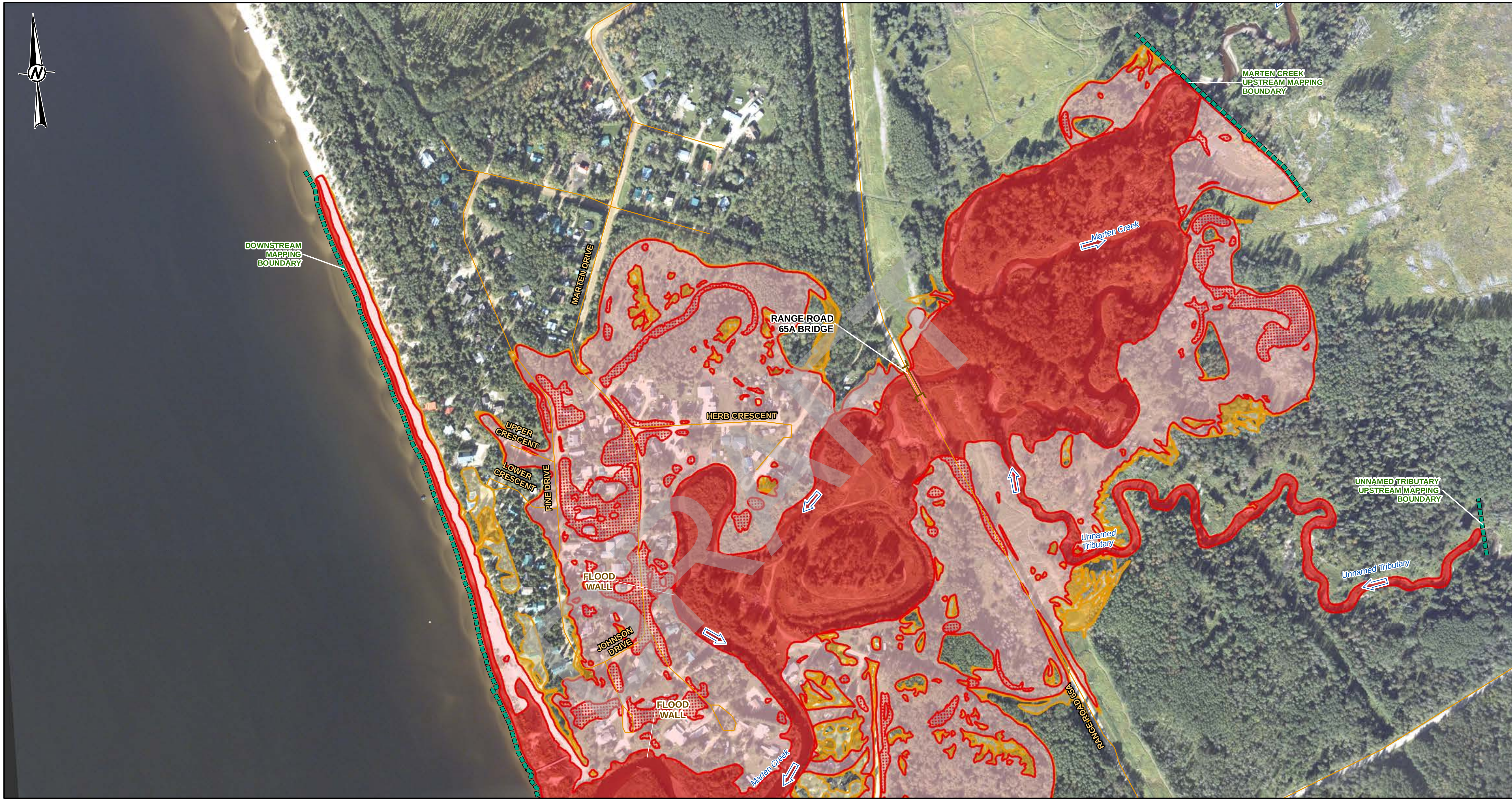
20368087	4000	1	SHEET 2 OF 2

APPENDIX I

Flood Hazard Maps



LEGEND

- STUDY BOUNDARY
- FLOW DIRECTION
- LOCAL ROAD

HYDRAULIC STRUCTURES

- BRIDGE
- FLOODWAY
- HIGH HAZARD FLOOD FRINGE
- FLOOD FRINGE
- 200-YEAR FLOOD EXTENT
- 500-YEAR FLOOD EXTENT

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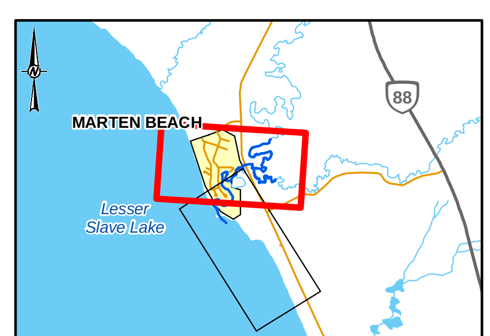

0 100 200
1:5,000 METRES

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PROJECT
MARTEN BEACH FLOOD HAZARD STUDY

TITLE
GOVERNING DESIGN FLOOD HAZARD MAP

PROJECT NO.	CONTROL	REV.	FIGURE
20368087	4000	1	SHEET 1 OF 2

25mm

LEGEND

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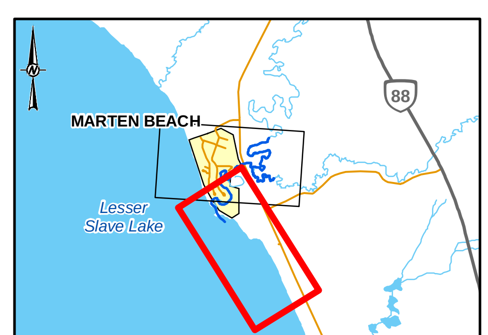

0 100 200
1:5,000 METRES

REFERENCE(S)

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PROJECT NO.	CONTROL	REV.	FIGURE
20368087	4000	1	SHEET 2 OF 2

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