REPORT

Peers Flood Study

Main Report

Submitted to:

Alberta Environment and Protected Areas

11th Floor Oxbridge Place
9820 - 106 St NW
Edmonton, Alberta

Submitted by:

WSP Canada Inc.

237 - 4 Avenue SW, Calgary, AB
T2P 4K3 Canada

(403) 243-8380

CA0041746.1954

February 2026

Distribution List

1 Digital Copy - Alberta Environment and Protected Areas
1 Digital Copy - WSP Canada Inc.

Executive Summary

Alberta Environment and Protected Areas (EPA) commissioned WSP Canada Inc. (WSP) in Sept 2024 to conduct the Peers Flood Study. The purpose of the study is to assess and identify flood hazards along the January Creek through the Hamlet of Peers (Peers), Alberta. 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 flood hazards. Project stakeholders include the Government of Alberta, the Hamlet of Peers, Yellowhead County and the public. There are no previous provincial flood studies for this area.

This report documents the methodology and results for all major study components listed below:

- Survey and Base Data Collection
- Open Water Hydrology Assessment
- Open Water Hydraulic Modelling
- Flood Inundation Mapping
- Design Flood Hazard Identification and Flood Hazard Mapping

The total length of the January Creek study reach is approximately 10 km reach through Peers. The survey was completed in October 2024 and supplemental data was collected in June 2025. The hydraulic features in this study are summarized in Table i. There are no flood control structures or weirs identified in the study area.

Table i: Summary of Survey Features

Feature	Total Number
Cross Sections	152
Bridges	3
Culverts	2

A hydrology assessment was completed to provide the flood peak discharge estimates at key locations in the study area as inputs to the HEC-RAS models.

A two-dimensional HEC-RAS model was setup for the study reach. The model was calibrated based on high flow condition (i.e., high water marks identified based on aerial flood imagery) associated with the 2023 flood event on the January Creek.

The calibrated channel Manning’s n value was 0.05 near Peers, and 0.07 for upstream and downstream of Peers, where more instream woody debris is present. 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 along the study area.

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

Flood inundation and hazard maps were prepared for the study reaches of the January Creek using ArcGIS. The simulated flood water levels were used to create a continuous water surface. The edge of inundation was delineated by subtracting the LiDAR DTM from the water surface. Direct inundation areas were mapped where there is a direct connection between the main channel and inundated areas on the floodplain. This includes areas where inundation is caused by single or multiple topographic or structural overtopping points or backwater flooding.

Hydraulic modelling indicates that minimal residential, commercial, and/or critical infrastructure within Peers are affected by direct inundation from January Creek under the modelled flood events. The area that appears to experience the greatest impacts is the RV storage lot situated north of the railway and east of Highway 32. Highway 32 is overtopped approximately 1 km north of the Highway 32 crossing for flood events equal to and greater than 1:35-year flood. The full set of open water flood inundation maps was prepared in this study.

The boundary between the floodway and flood fringe is determined based on the adopted criteria using the calibrated HEC-RAS model. 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.

The flood hazard mapping confirms that all residential and commercial areas lie outside the floodway, and the flood fringe does not encroach upon developed community lands within Peers, with the exception of an RV storage lot east of the community and Highway 32, which is overtopped approximately 1 km north of the Highway 32 crossing. The full sets of floodway criteria maps and flood hazard maps are provided in this report.

Acknowledgements

The study was completed by the Government of Alberta under the provincial Flood Hazard Identification Program, the goals of which include enhancement of public safety and reduction of future flood damages through the identification of river and flood hazards. The study was co-funded by the Government of Canada through the federal Flood Hazard Identification and Mapping Program

WSP Canada Inc. (WSP) acknowledges the contributions of the following staff of Alberta Environment and Protected Areas (EPA):

- Mr. Jim Choles, EPA's project manager for the study, coordinated the participation from EPA, and provided technical advice and review of this report.

The contributions of the following staff from WSP are acknowledged:

- Mr. Liv Hundal, WSP's project director, was responsible for providing corporate oversight, senior technical guidance and review, and ensuring overall quality and successful delivery of the project.
- Mr. Gaven Tang, WSP's project manager, lead project engineer, and river survey specialist was responsible for regular communications with EPA, leading the river survey and providing technical direction for the overall project.
- Mr. Martin Lacroix, supporting project manager and hydrology specialist, was responsible for providing project support and leading the climate change assessment.
- Dr. Getu Biftu, senior hydrologist, was responsible for review of the open water hydrology assessment.
- Ms. Amber Liu, hydraulic modelling support and supporting project manager working under direction of Mr. Gaven Tang and Mr. Liv Hundal in preparing the hydraulic model, flood maps, and reporting.
- Mr. Peter Thiede, a GIS specialist, was responsible for preparation of the flood hazard maps and provided inputs to this report.

Table of Contents

TABLES

FIGURES

APPENDICES

APPENDIX A
Locations of Cross Sections Hydraulic Structures and Flood Control Structures

APPENDIX B
Hydraulic Structure Datasheets

APPENDIX C
Technical Memorandum on Flood Control Structures

APPENDIX D
Technical Memorandum on Open Water Hydrology Assessment

APPENDIX E
Open Water Flood Profiles

APPENDIX F
Open Water Sensitivity Analysis

APPENDIX G
Open Water Inundation Maps

APPENDIX H
Floodway Criteria Maps and Flood Hazard Maps

APPENDIX I
Climate Change Flood Profiles

1 INTRODUCTION

1.1 Study Background

Alberta Environment and Protected Areas (EPA) retained WSP Canada Inc. (WSP) in Sept 2024 to conduct the Peers Flood Study. The study is part of the provincial Flood Hazard Identification Program (FHIP), and the purpose of the study is to assess and identify river and flood hazards along the 10 km reach of the January Creek through the Hamlet of Peers (Peers). The study reach extends from the southern boundary of SE 15-54-14-W5M downstream to the northern boundary of NE 20-54-14-W5M.

The study is conducted under 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 flood hazards. Project stakeholders are the Government of Alberta, the Hamlet of Peers, Yellowhead County and the public.

There were no previous provincial flood hazard studies for this area.

The study is comprised of multiple components and deliverables. This report documents the methodology and results of all major study components listed below:

1) Survey and Base Data Collection

2) Open Water Hydrology Assessment

3) Open Water Hydraulic Modelling

4) Flood Inundation Mapping

5) Design Flood Hazard Identification and Flood Hazard Mapping

1.2 Study Objectives

The overall goal of the study is to enhance public safety and support the assessment and identification of flood hazards in the study area. The primary focus of the study was open water hydraulic modelling and flood mapping. The study results are intended to reduce potential future flood damages and associated disaster assistance costs, to mitigate flood impacts by informing land use planning decisions, and for emergency preparation.

This report summarizes the work of all five major study components. The primary tasks, services, and deliverables associated with this report are:

- River cross section surveys
- Hydraulic structure data collection
- Survey and digital terrain model (DTM) data integration
- Documentation of flood history
- Flood hydrology assessment
- Creation and calibration of a HEC-RAS hydraulic model
- Flood simulation of 13 flood events (ranging from 2- to 1,000-year return periods) and creation of water surface profiles along the study area.

- Sensitivity analysis of the model inputs
- Production of flood inundation maps
- Determination of floodway criteria and creation of design flood water surface profiles throughout the study reach
- Production of floodway criteria maps and flood hazard maps

1.3 Study Area

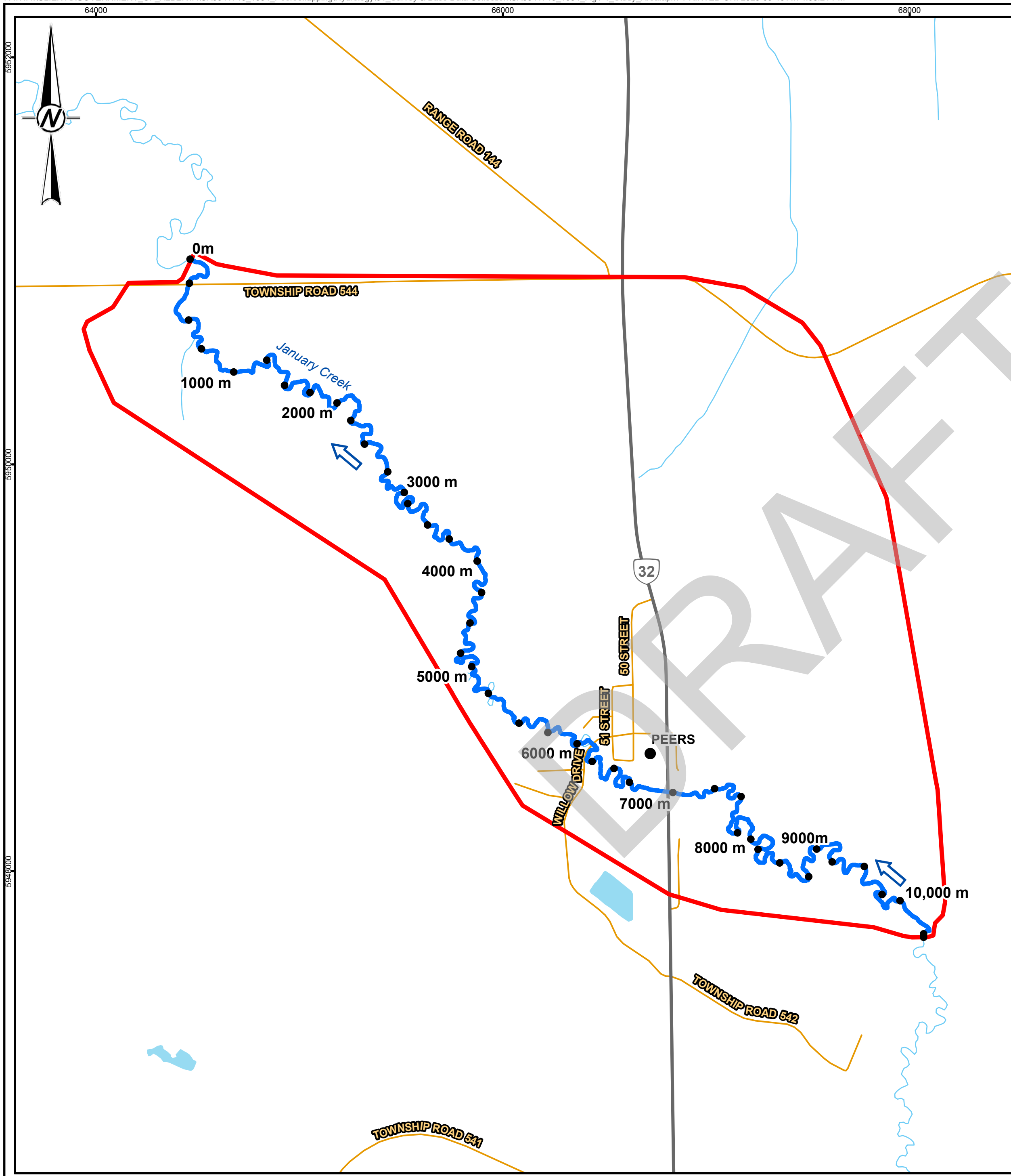
Peers is located in west-central Alberta within Yellowhead County. It is situated along Highway 32, approximately 35 km northeast of the Town of Edson and about 200 km west of Edmonton.

Peers is located along January Creek, a watercourse that flows through Yellowhead County, and is surrounded by predominantly forested land.

Peers encompasses a land area of approximately 0.9 km². According to the 2021 Census, Peers had a population of 98 residents living in 47 of its 60 private dwellings (Statistics Canada, 2022) . The surrounding area supports agriculture, forestry, and other resource-based activities. Local infrastructure in Peers includes a community hall and a fire station, while schools and other essential services are in nearby communities such as Edson.

Figure 1-1 provides an overview of the study area. Field surveys, hydraulic modelling, and flood mapping were carried out within and around Peers to support this study.

PATH: I:\CLIENTS\GOVERNMENT_OF_ALBERTA\CA0041746_1954_Peers\Mapping\Hydrology\01_Survey & Base Data Collection\CA0041746_1954_Fig1-1_Study_Area.aprx PRINTED ON: 2025-09-19 AT: 4:08:21 PM



LEGEND

- FLOW DIRECTION
- PROFILE STATION (EVERY 250 m)
- SETTLEMENT
- LOCAL ROAD
- PRIMARY HIGHWAY
- SURVEY REACH
- WATERCOURSE
- FLOOD STUDY AREA
- WATERBODY

0 1 2

1:30,000 KILOMETRES

REFERENCE(S)

POPULATED PLACES, ROADS AND HYDROGRAPHY OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
DATUM: NAD 1983 CSRS 3TM 117

CLIENT
ALBERTA ENVIRONMENT AND PROTECTED AREAS

Alberta Canada

PROJECT
PEERS FLOOD STUDY

TITLE
LOCATION MAP OF THE STUDY AREA

CONSULTANT

wsp

YYYY-MM-DD	2025-09-19
DESIGNED	AL
PREPARED	MV
REVIEWED	GT
APPROVED	LH

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	1001	0	1-1

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

25mm

0

Classification: Public

2 SURVEY AND BASE DATA COLLECTION

2.1 General

WSP conducted a topographic survey of the January Creek within the study area on October 23 to 30, 2024 and returned to collect supplemental hydraulic structure measurements on June 23, 2025. The survey scope included a survey of channel cross sections and hydraulic structures. No flood control structures were identified in the study area.

In addition, three (3) common benchmarks were surveyed upon the request of EPA in support of Light Detection and Ranging (LiDAR) remote sensing data collection (by others) to confirm that the LiDAR based digital terrain model (DTM) meets FHIP accuracy standards and that there is consistency between the LiDAR and ground surveys.

Site reconnaissance was conducted by representatives from Yellowhead County, EPA and WSP on September 18, 2024. The field visit included the following activities:

- Reviewing and confirming the preliminary survey plan
- Confirming the locations and number of channel cross sections and hydraulic structures to be surveyed
- Confirming there are no flood control structures in the study area
- Familiarizing the project team with January Creek channel and floodplain along the study area

2.2 Procedures and Methodology

2.2.1 Survey Equipment and Control

The survey equipment used in the collection of the topographic, bathymetric, and structure data for this study included the following:

- Real-time Kinematic (RTK) Global Positioning System (GPS): A Trimble® R8 RTK base station and Trimble® R10 RTK rover units, the latter of which were paired to Trimble® TSC3 hand-held data collectors running Trimble Access® survey software, and used to survey ground features, water levels, and river/creek bed levels in areas where hydraulic conditions allowed the surveyors to wade the channel and walk on the banks. Some reaches of January Creek were accessed using an inflatable kayak. The RTK system was also used to survey the following:
  - Control points and benchmarks that were identified or placed within the study area
  - Bridge structures

The proposed cross section locations were identified in a digital georeferenced vector format, which the survey crew utilized on their data collectors to guide the survey. Uploading a georeferenced survey plan into the data collector aided the surveyor in maintaining precise spacing and alignment of cross sections.

All surveyed points were acquired by wading the channel or walking on the banks. Each survey data point collected was attributed a specific code. A schematic of survey point codes and corresponding descriptions is shown in Figure 2-1, which includes a complete list of survey codes for the RTK.

The data collected using above methods and equipment was referenced to the ASCM benchmark situated within or close to the study area (i.e., ASCM 286864). No calibration of the collected survey data was performed as the Can-Net network covered the area and the collected data was accurate in comparison to the ASCM benchmark. The calibration process involved having the field crew check the survey equipment readings against the ASCM. Survey crew obtained a secondary check on data accuracy by having the static (temporary) RTK base station log data continuously at the start and end of each survey day.

All survey data was collected in the 3TM 117° W coordinate system and referenced to NAD83 (CSRS) horizontal and CGVD28 vertical datums. The RTK survey data outputs provided an orthometric elevation with correct northing and easting coordinates. The survey data were acquired by pre-loading geoid files into the survey equipment. Ellipsoidal heights were transformed to CGVD28 orthometric heights using the HTv2.0 geoid model.

2.2.2 Channel Cross Sections and Longitudinal Profiles

The locations of representative cross sections were selected to capture the variations in the physical characteristics of the channel and floodplains that could affect flood levels along the study reaches. Considerations of changes to the channel width, cross section area, channel bed and bank materials, and the presence of any confluences or islands, bridges, and other channel features contributed to the selection of the cross section locations.

The alignment of each cross section was established so that it would be orientated perpendicular to the direction of river/creek flow, as anticipated under high flow conditions. A shapefile showing the alignment of each cross section was provided to the survey crew at the outset of the field work and uploaded to the data collectors to provide guidance on where along the study reach to acquire data.

Each survey point collected with the RTK utilized a schematic of survey point codes and corresponding locations as shown in Figure 2-1, which also includes a complete list of survey codes for the RTK.

The quality and accuracy of all survey data were 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.

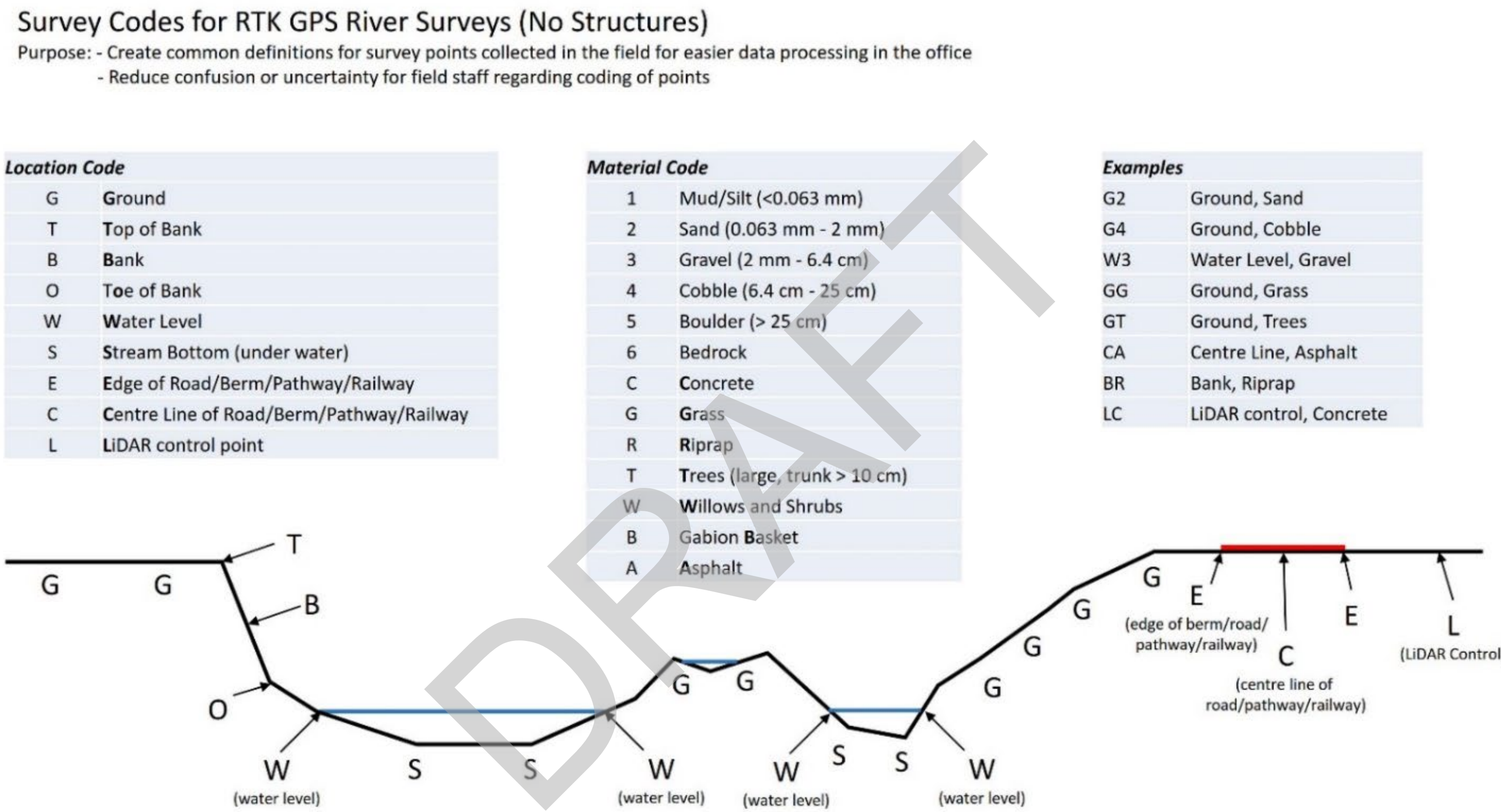


Figure 2-1: Schematic of Survey Point Locations and Code Descriptions

The main objective of the cross section surveys was to capture the characteristics of the main channel. However, limited overbank floodplain areas were also surveyed to overlap with the LiDAR survey (provided by EPA). The cross sections were extended into the overbank areas during the hydraulic model development using the topographic (LiDAR) data provided by EPA. A breakline survey technique was utilized to capture variances in the bank geometry (i.e., slope breaks), with enough data points collected along each cross section to properly define the channel geometry and the near-bank floodplain.

Each recorded survey data point included Northing and Easting coordinate positions, water surface, and/or ground elevation and was attributed with a survey code that denotes its location (e.g., bank, stream bottom, edge of water, water level, top of bank, etc.).

The following procedures were adhered to in conducting bathymetric survey by wading:

- RTK rover units were used to collect cross section information from a location approximately 2 to 5 m beyond top of bank on one side of the river/creek channel, to a location approximately 2 to 5 m beyond top of bank on the other side. A minimum of 15 survey data points were obtained 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.
- Each of the surveyed data points was attributed with field codes that described substrate and vegetation types (see Figure 2-1).

The water surface elevation was surveyed at all points along the cross section where the water had contact with the bank.

Reach-representative photographs were taken at key locations within the study area during the site reconnaissance and field survey. The photographs, which include salient details and features at surveyed cross sections, are georeferenced with appropriate metadata.

Discharge measurements were not undertaken during the survey as there was little to no-flow in the channel.

2.2.3 Hydraulic Structures

All hydraulic structures within the study area were surveyed. These structures included bridges and culverts.

The features of each bridge/culvert structure surveyed included 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 left abutment
- Type of piers (e.g., concrete, pile bent, steel column)
- Shape of pier (e.g., round nose, wedge, circular)

- Top of road surface profile

2.3 Survey Standards and Accuracy

Quality control and quality assurance (QA/QC) of collected data were conducted in the field at the time of data collection and in the office during data processing. QA/QC of field data was conducted as described below.

- Position and elevation from the RTK rover unit were checked for accuracy each day, based on the ASCM benchmark mentioned previously. All survey data collected during the field program were tied to the ASCM benchmark. Temporary benchmarks were established by the field crew along the watercourses as required to maintain data accuracy.
- The field crew was provided with a shapefile showing cross section alignment for the purpose of guiding the survey along the selected cross sections.
- The RTK data collectors were set up to provide a warning when calculated maximum error exceeded 0.05 m for a manually recorded point. When notified, the surveyor either adjusted their location or waited for a better solution before surveying a point.

The RTK control network is considered accurate to within ±2 cm at 95 percent confidence in both horizontal and vertical directions. A high level of accuracy was maintained throughout the field program by calibrating the spatial position and elevation of each RTK rover unit to an ASCM benchmark daily. Furthermore, the daily protocol required that the survey crew calibrate to, and then open and close on, an ASCM benchmark to maintain absolute positional accuracy.

The collected survey data were imported into a Geographic Information System (GIS) to allow for validation and further processing. In addition to the QA/QC procedures for field data collection, the technical lead for the field program reviewed the survey data within 24 hours of it being collected to check for outliers (including erroneous or missing data) and to ensure appropriate coverage along each cross section and on the hydraulic structures.

2.4 Cross Sections and Longitudinal Profiles

The surveyed length of the January Creek was approximately 10.3 km. A total of 152 channel cross sections were surveyed. Table 2-1 provides a summary of surveyed cross sections by reach and APPENDIX A shows the locations of cross sections and Hydraulic Structures.

Table 2-1: Surveyed Cross Sections within the Study Area

Waterbody	Reach Description	Reach Length (m)	No. of Cross Sections	Average Cross Section Spacing (m)
January Creek	1.6 km reach extending from 2.7 km upstream of Railway Bridge to 1.1 km upstream of Railway Bridge	1571	26	62.8
January Creek	4.2 km reach extending from 1.1 km upstream of railway Bridge to 1.6 km downstream of Willow Drive Bridge	4181	81	52.3
January Creek	4.5 km reach extending from 1.6 km downstream of Willow Drive Bridge to 0.3 km downstream of Township Road 544 Culvert	4514	45	102.6

An overview of the surveyed channel thalweg, bridges/culverts and surface water profile is provided in Figure 2-2.

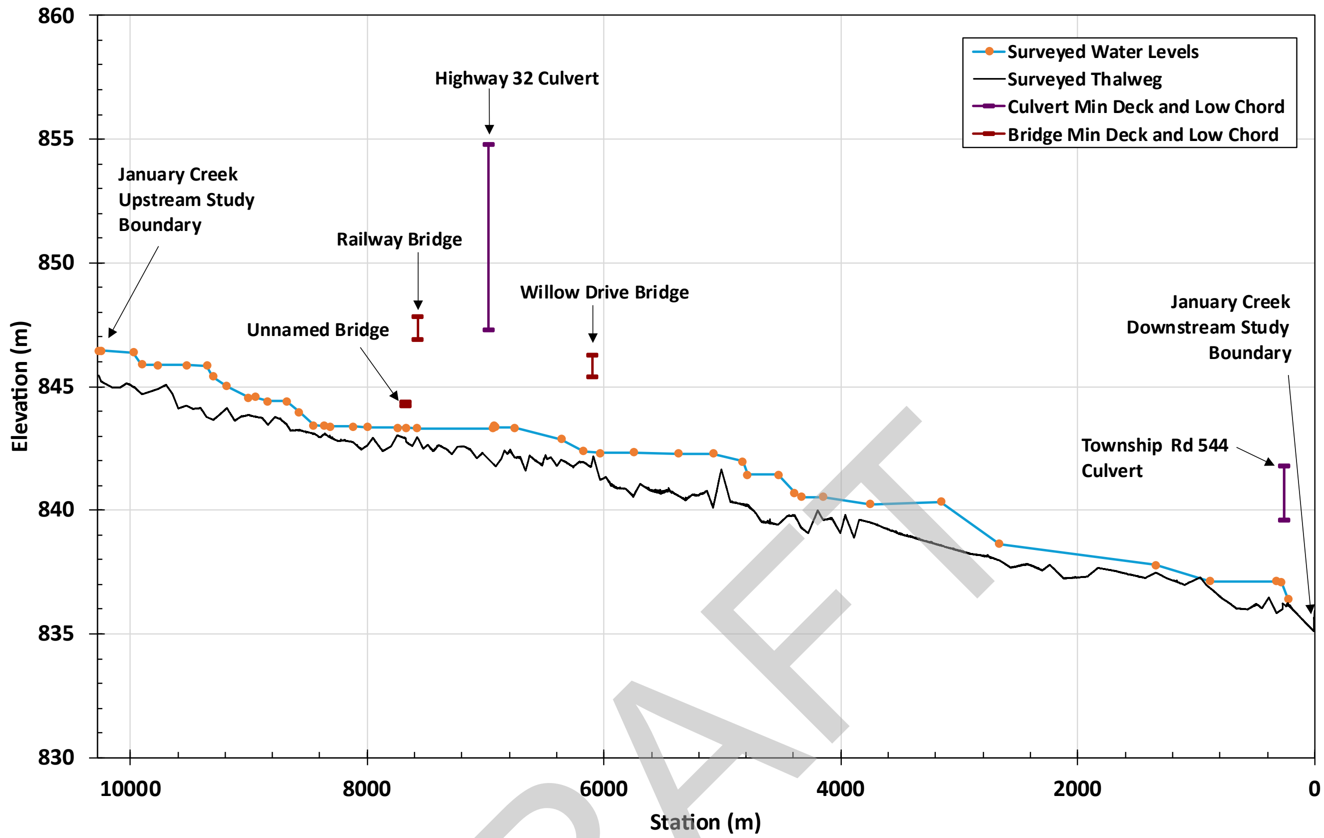


Figure 2-2: Channel Thalweg and surveyed Surface Water Profile along January Creek

2.5 Discharge and Water Level Measurements

No discharge measurement was conducted on the January Creek as there was little to no flow in the channel during the survey. Standing water was present in the channel due to beaver dams and the relatively flat channel gradient. Water levels were recorded during cross section surveys.

2.6 Hydraulic Structures

There are five hydraulic structures (i.e., three bridges and two culvert crossings) in the study area. A summary of the general characteristics of the surveyed bridges is provided in Table 2-2. APPENDIX B shows the hydraulic structure datasheets.

Table 2-2: Characteristics of Bridge and Culvert Structures

Bridge ID	Bridge Name	River Station (m)	Type	No. of Bridge Spans/Culvert Barrels
HS-01	Unnamed Bridge	7+672	Private	1
HS-02	Railway Bridge	7+571	Rail	3
HS-03	Highway 32 Culvert	6+976	Traffic	1
HS-04	Willow Dr. Bridge	6+098	Traffic	1
HS-05	Township Rd 544 Culvert	0+258	Traffic	2

2.7 Flood Control Structures

As documented in Appendix C, there are no flood control structures located in the January Creek study area.

2.8 Additional Base Data

Additional base data collected in support of hydraulic modelling and mapping included the following:

- LiDAR topographic data collected in Jan 2024 and provided by EPA
- Project imagery captured in 2023 and provided by the Provincial Geospatial Centre via EPA
- Aerial flood imagery for the June 2023 flood event, provided by EPA

3 OPEN WATER HYDROLOGY ASSESSMENT

3.1 Overview

A comprehensive open water hydrology assessment for the January Creek in the study area is provided in Appendix D. The sections below are a summary of the assessment.

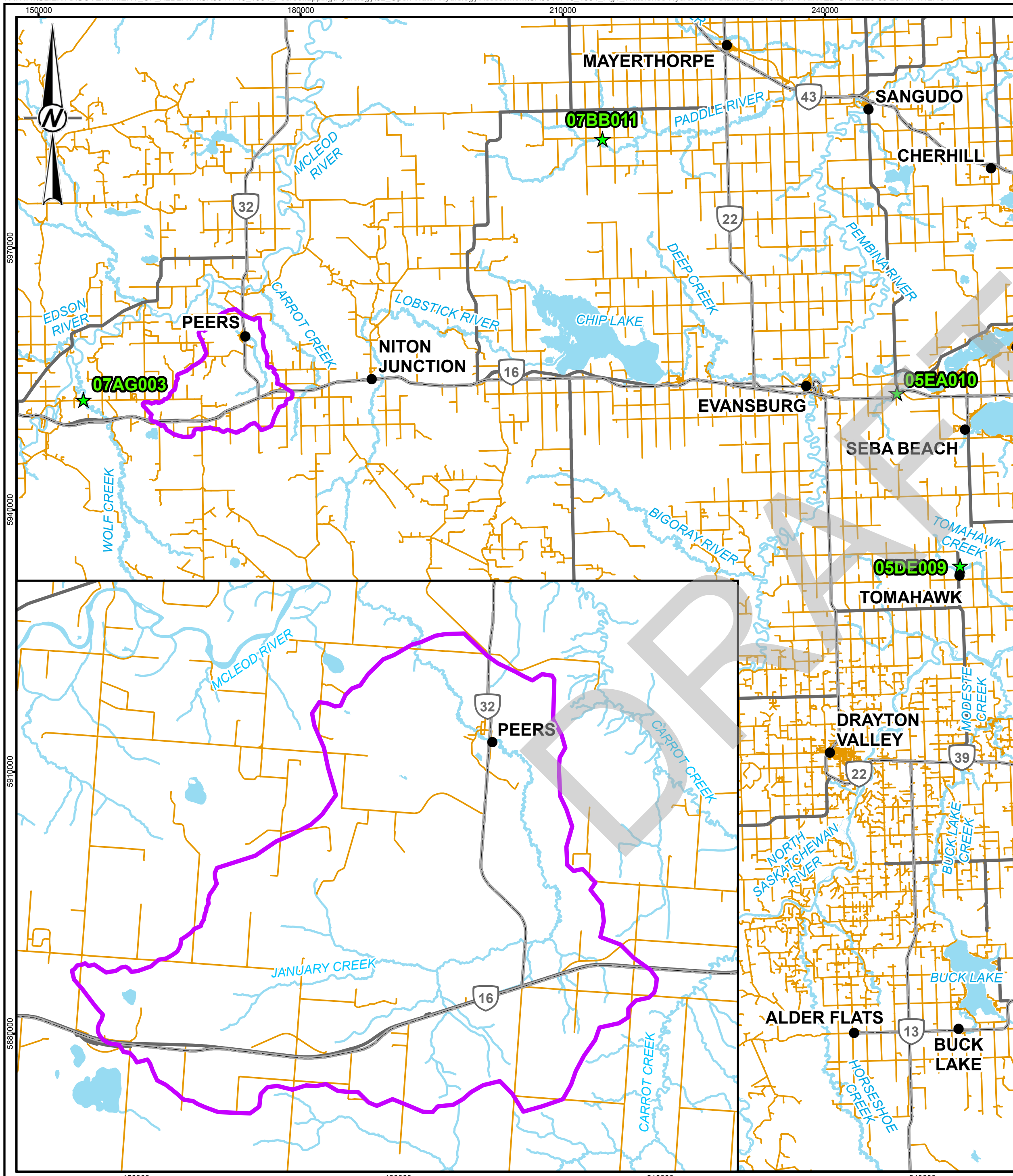
3.2 Flooding History

3.2.1 General Information

The watershed of January Creek is shown in Figure 3-1. January Creek drains into the McLeod River approximately 8 km downstream of Peers. The January Creek drainage area is approximately 136 km^2 at Peers (i.e., at the downstream end of the study reach) and 143 km^2 at the McLeod River. January Creek is a fourth-order watercourse with a total length of 26 km from its headwaters to the McLeod River. The main drainage area land type is flat agricultural land.

3.2.2 Open Water Flood History

January Creek has no historical flow records or systematic monitoring by Water Survey of Canada (WSC). HWMs recorded during the 1980 and 2023 flood events were used to support flood flow estimates through regional analysis. To estimate flood frequencies for January Creek, empirical relationships were developed between drainage areas and flood frequency estimates using data from regional WSC hydrometric stations. These relationships were applied to derive flood frequency estimates for January Creek through Peers and Yellowhead County. The process involved compiling drainage areas, annual maximum daily discharges, and annual maximum instantaneous discharges for the selected WSC stations. Graphical regressions were developed to estimate missing instantaneous discharges based on event-based daily and instantaneous values.



LEGEND

- HYDROMETRIC GAUGING STATION
- SETTLEMENT
- PRIMARY HIGHWAY
- LOCAL ROAD
- PRIMARY HIGHWAY
- WATERCOURSE
- WATERBODY
- JANUARY RIVER WATERSHED

0 20 40

1:700,000 KILOMETRES

REFERENCE(S)

HYDROMETRIC STATIONS OBTAINED FROM WATER SURVEY OF CANADA (WSC).
POPULATED PLACES, ROADS AND HYDROGRAPHY OBTAINED FROM GEOGRATIS,

DATUM: NAD 1983 CSRS 3TM 117

CLIENT
ALBERTA ENVIRONMENT AND PROTECTED AREAS

PROJECT
PEERS FLOOD STUDY

TITLE
JANUARY CREEK WATERSHED AT PEERS AND REGIONAL GAUGING STATIONS

CONSULTANT

wsp

YYYY-MM-DD	2025-05-26
DESIGNED	TT
PREPARED	PT
REVIEWED	TT
APPROVED	ML

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	2000	0	3-1

3.3 Open Water Flood Frequency Analysis

Regional flood frequency analyses of annual maximum instantaneous discharges was conducted to estimate the flood frequency discharges for various return periods (i.e., 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1,000-year floods) at the study area. The flood frequency estimates for January Creek were derived based on the regional analysis detailed in Appendix D.

Table 3-1 summarizes the flood peak discharge estimates and the associated upper and lower 95% confidence intervals. The annual maximum instantaneous discharge 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 D.

Table 3-1: Flood Peak Discharge Estimates and their 95% Confidence Intervals

Return Periods (Years)	Annual Probability Of Exceedance (%)	Flood Frequency Analysis (m^3/s)		
		Lower 95% Limit	Value	Upper 95% Limit
2	50	5.77	8.47	12.4
5	20	12.2	17.2	22.8
10	10	17.4	24.4	31.4
20	5.0	22.7	32.5	41.7
35	2.9	27.3	40.0	52.1
50	2.0	30.1	45.3	59.8
75	1.3	33.1	51.7	70.1
100	1.0	35.2	56.7	79
200	0.5	40.1	70.1	103
350	0.29	43.7	82.5	129
500	0.20	46.1	91.2	147
750	0.13	48.7	102	171
1,000	0.10	50.4	110	190

4 OPEN WATER HYDRAULIC MODELLING

4.1 Overview

The following sections describe the methodology and results of the open water hydraulic modelling component. The scope of this component includes summary of available data, description of the flooding history and stream/valley features in the study area, hydraulic model setup, hydraulic model calibration, sensitivity analysis, and generation of open water flood frequency profiles. The results of this component are used in the flood inundation mapping, flood hazard identification, and governing design flood hazard mapping components.

4.2 Available Data

4.2.1 Digital Terrain Model

Digital Terrain Model (DTM) data was provided by EPA for this study. The DTM was derived from survey-verified high-accuracy Light Detection and Ranging (LiDAR) remote sensing data set acquired during May 2024.

4.2.2 Aerial Flood Photography

Aerial flood photography from the 2023 flood event was supplied by EPA for this study. High-resolution SPOT satellite imagery was obtained, with a spatial resolution of 1.5 metres in the RGB bands. This imagery provides a clear visual reference of the potential maximum flood inundation extents during peak flow conditions of the 2023 flood event, particularly on agricultural land. The aerial imagery was reviewed in conjunction with LiDAR data to support hydraulic model calibration and identify inundation patterns across the study area.

4.2.3 High Water Marks

Several high water marks (HWMs) from the 2023 flood were identified through a comparison of LiDAR data against flood aerial imagery and were used to support model calibration. The flood extent was delineated by interpreting mudlines and sediment deposition in the aerial imagery. These features, typically visible as color or texture changes on the ground, were used to trace the flood edge. Elevation values were extracted from the LiDAR surface at representative locations along this flood edge and used as point-based HWMs. The identified HWMs were compared with nearby surveyed HWMs and demonstrated good agreement. Selection of points considered clarity of the mudline, topography, and spatial coverage across the floodplain.

The HWM used for this study are listed in Table 4-1. Locations of HWMs are shown in Figure 4-1. Figure 4-2 (a) to Figure 4-2 (e) illustrate examples of how HWMs were identified from mudlines visible in the flood imagery.

Table 4-1: 2023 HWMs Identified from Flood Aerial Imagery

No.	Approximate River Stations	Description	Elevation (m)	Adjacent Structure	3TM Coordinates		Figures
					Easting	Northing	
1	7+653	Mudline observed in the field southwest of the Railway Bridge	846.71	Railway Bridge	66998.392	5948241.861	Figure 4-2(a)
2	7+031	Mudline overbank northeast of the Highway 32 Culvert	846.29	Highway 32 Culvert	66864.676	5948450.914	Figure 4-2 (b)
3	6+133	Mudline southeast of the Willow Drive Bridge	844.92	Willow Dr. Bridge	66476.836	5948604.957	Figure 4-2 (c)
4	5+343	Mudline north of the dugout	843.54	-	66163.278	5948944.174	Figure 4-2 (d)
5	0+333	Mudline southwest of the Township Road 544 Culvert	840.98	Township Rd 544 Culvert	64390.934	5950838.651	Figure 4-2 (e)

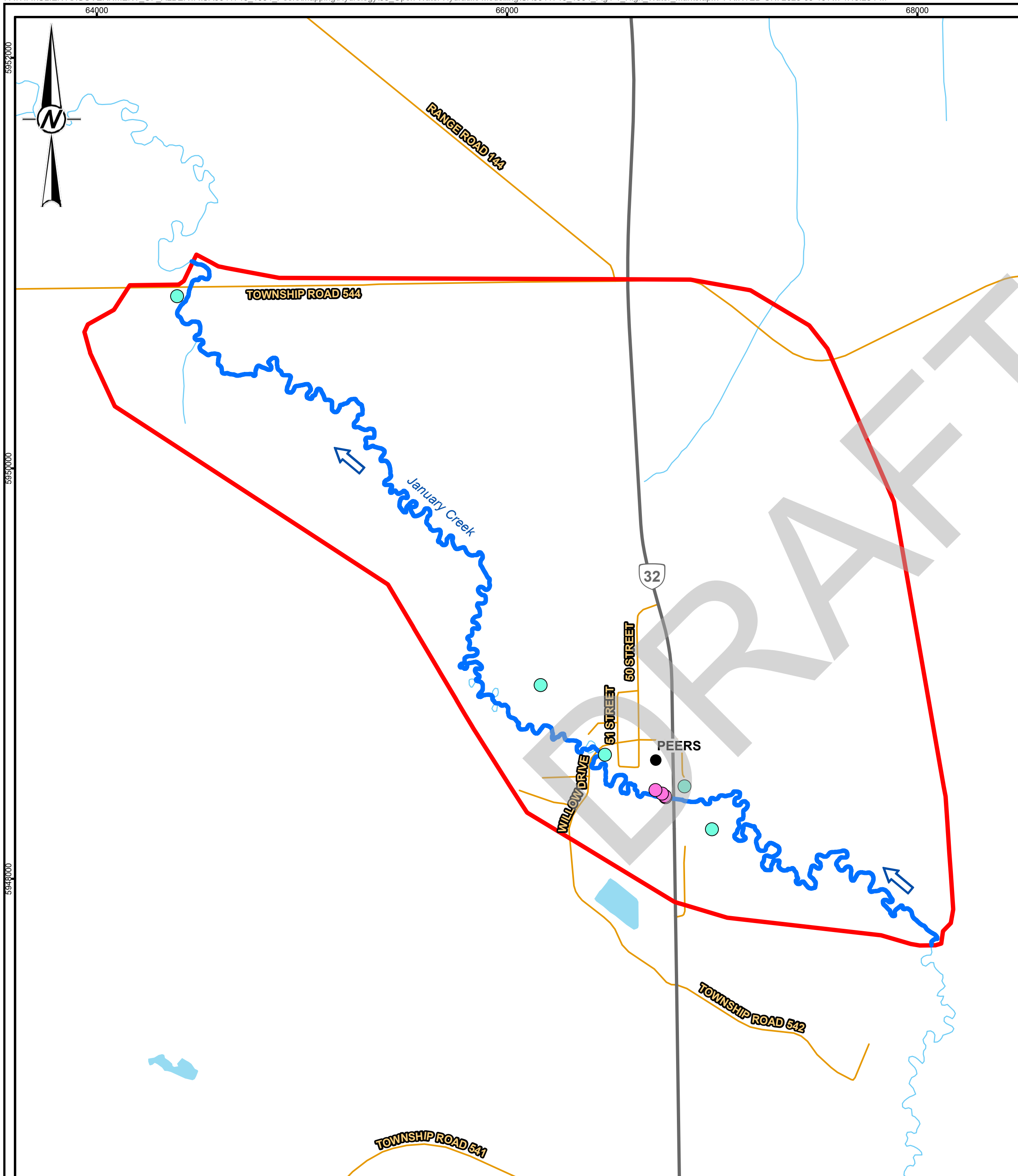
In addition to the flood aerial imagery, EPA provided a supplementary set of HWMs collected following the 2023 flood event, including four (4) field-surveyed local datum points and photographs, all located near the downstream side of the Highway 32 culvert. These surveyed HWMs were tied to geodetic elevation by WSP during the field survey. The HWMs identified from aerial imagery were used as the primary dataset for model calibration due to their spatial coverage. The surveyed HWMs were used to support and corroborate the flood extent interpretation. This additional HWM information is summarized in Table 4-2.

Another historical HWM was measured in 1980 at the Highway 32 crossing, was used in previous studies (AMEC, 2016) for flow estimation. However, as it constitutes a single isolated data point, it was not incorporated into the model calibration for this study.

Table 4-2: Surveyed HWMs from the 2023 Flood Event

No.	Approximate River Stations	Description	Elevation (m)	Adjacent Structure	3TM Coordinates	
					Easting	Northing
1	6+935	Right bank, approximately 3 m downstream of the Highway 32 culvert	844.12	Highway 32 Culvert	66771.884	5948397.969 ~~4~~
2	6+932	Right bank, approximately 6 m downstream of the Highway 32 culvert	845.44	Highway 32 Culvert	66769.161	5948403.496~~3~~
3	6+916	Right bank, approximately 22 m downstream of the Highway 32 culvert	845.63	Highway 32 Culvert	66755.108	5948415.54 ~~2~~
4	6+875	Right bank, approximately 37 m downstream of the Highway 32 culvert	845.27	Highway 32 Culvert	66723.13	5948432.894

PATH: I:\CLIENTS\GOVERNMENT_OF_ALBERTA\CA0041746_1954_Peers\Mapping\Hydrology\03_Open Water Hydraulic Modelling\CA0041746_1954_Fig4-1_High_Water_Marks.aprx PRINTED ON: 2025-09-19 AT: 4:19:25 PM



LEGEND

- FLOW DIRECTION
- HIGH WATER MARK INDENTIFIED FROM AERIAL IMAGERY
- SURVEYED HIGH WATER MARK
- SETTLEMENT
- LOCAL ROAD
- PRIMARY HIGHWAY
- SURVEY REACH
- WATERCOURSE
- WATERBODY
- FLOOD STUDY AREA

0 1 2

1:30,000 KILOMETRES

REFERENCE(S)

POPULATED PLACES, ROADS AND HYDROGRAPHY OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
DATUM: NAD 1983 CSRS 3TM 117

CLIENT
ALBERTA ENVIRONMENT AND PROTECTED AREAS

Alberta Canada

PROJECT
PEERS FLOOD STUDY

TITLE
HIGH WATER MARKS

CONSULTANT

wsp

YYYY-MM-DD	2025-09-19
DESIGNED	AL
PREPARED	MV
REVIEWED	GT
APPROVED	LH

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	3001	0	4-1

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

25mm

0

Classification: Public

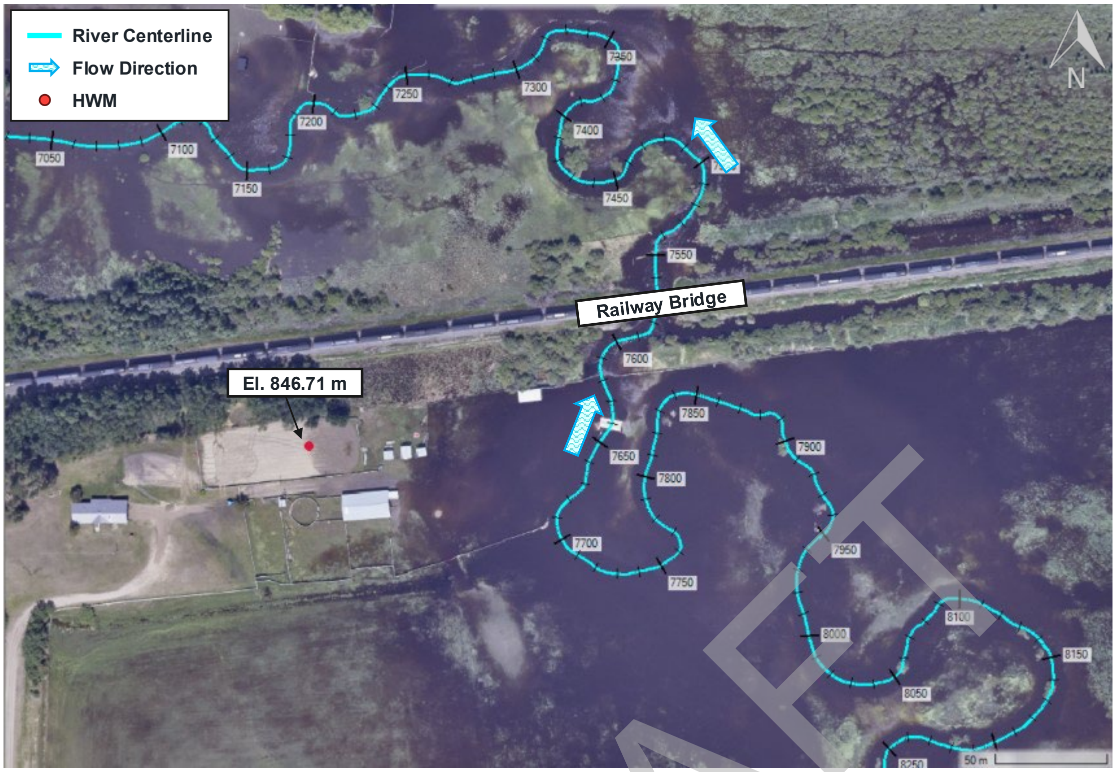


Figure 4-2 (a): HWMs Identified from Mudlines in 2023 Flood Aerial Imagery Located Southwest of the Railway Bridge

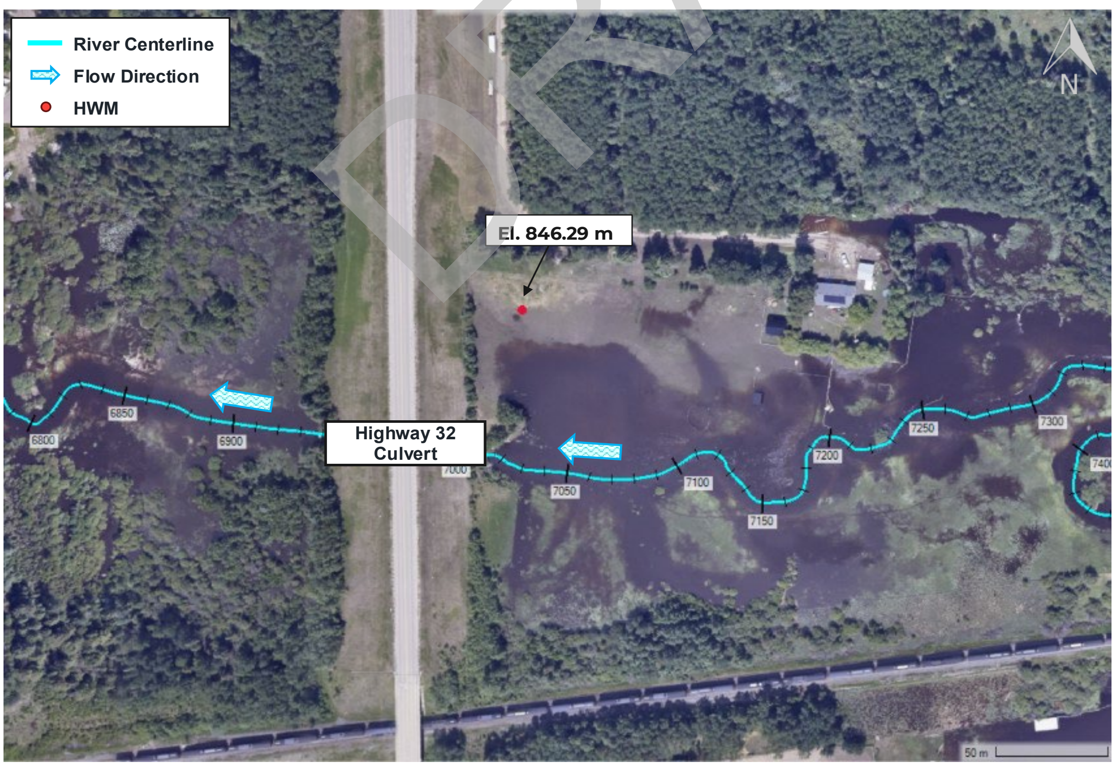


Figure 4-2 (b): HWMs Identified from Mudlines in 2023 Flood Aerial Imagery Located Northeast of the Highway 32 Culvert

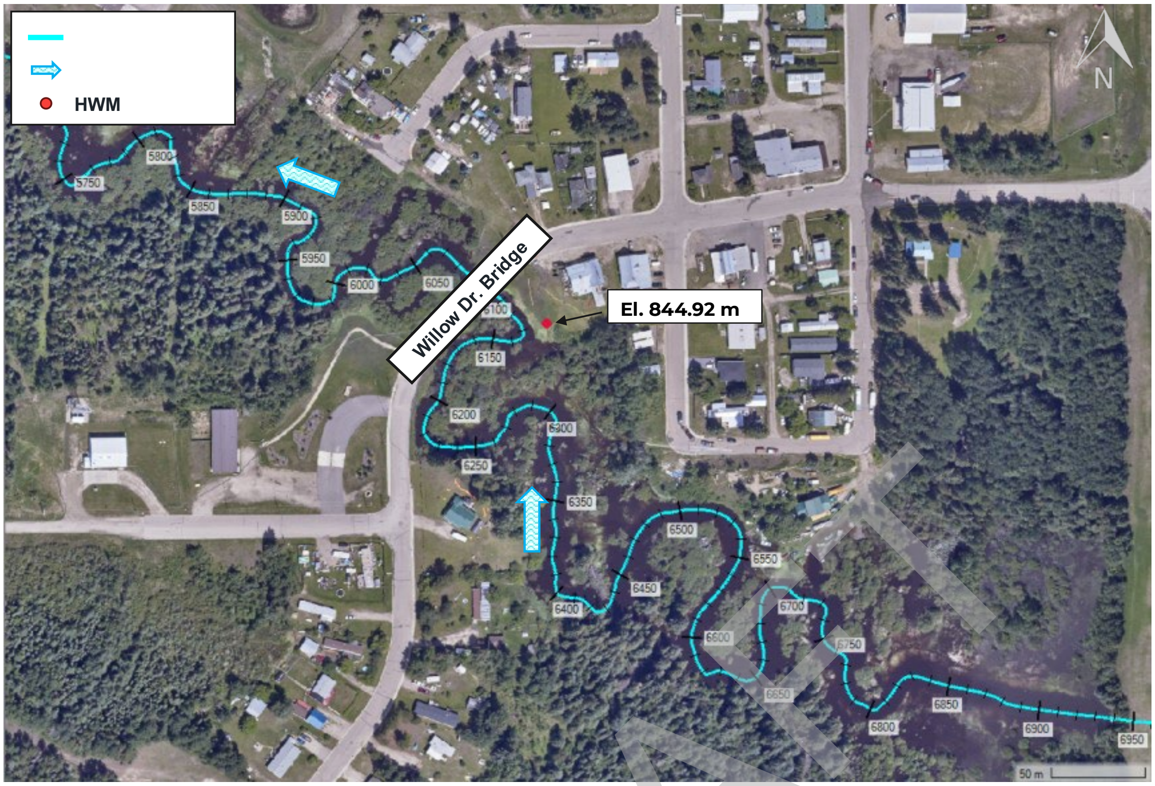


Figure 4-2 (c): HWMs Identified from Mudlines in 2023 Flood Aerial Imagery Located Southeast of the Willow Drive Bridge

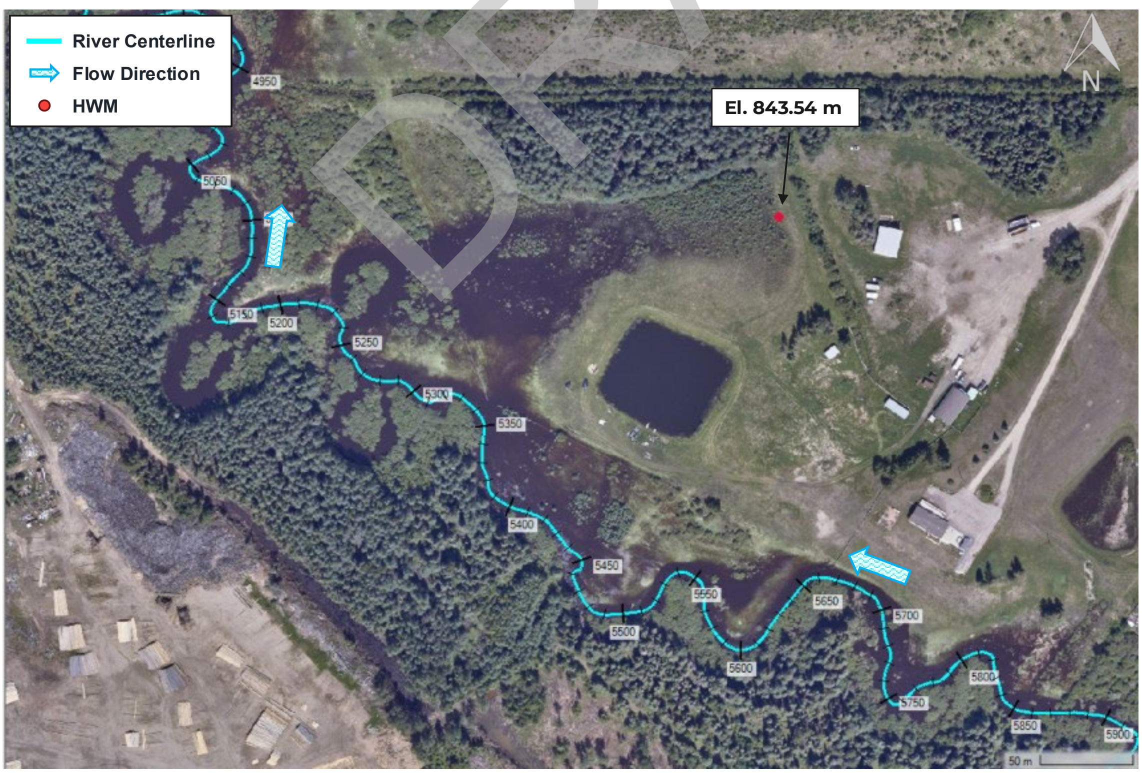


Figure 4-2 (d): HWMs Identified from Mudlines in 2023 Flood Aerial Imagery Located North of the Dugout

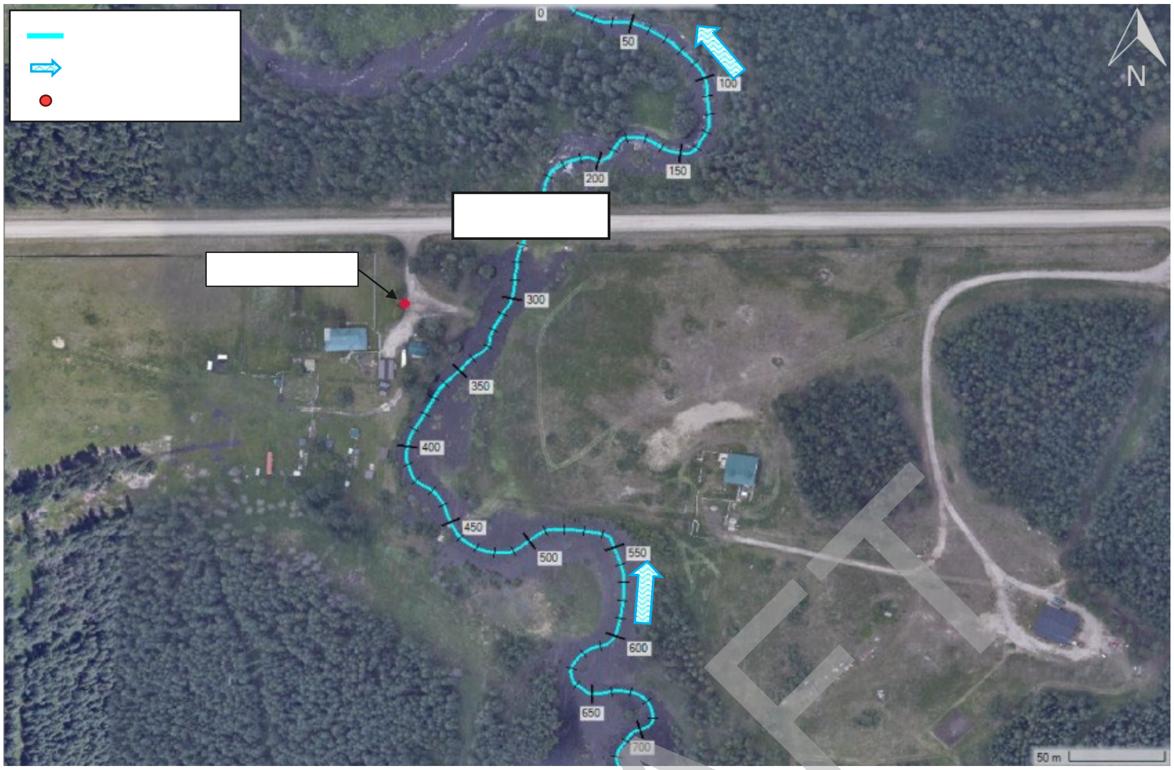


Figure 4-2 (e): HWMs Identified from Mudlines in 2023 Flood Aerial Imagery Located Southwest of the Township Road 544 Culvert

4.2.4 Existing AMEC 1D Hydraulic Model

AMEC Foster Wheeler Environment and Infrastructure (AMEC now WSP) completed a flood risk assessment for January Creek in 2016, covering approximately 8 km downstream of Peers, from Highway 32 to just downstream of Willow Drive Road (AMEC, 2016). The assessment used GeoHECRAS, an extension of the HEC-RAS hydraulic modeling software developed by the U.S. Army Corps of Engineers, to build a 1D hydraulic model of the creek. The model parameters and results were reviewed as part of this study. The model was used to an initial estimate of the 2023 flood flow which is discussed in Section .4.4.6.2.

4.3 Stream and Valley Features

4.3.1 General Description

The January Creek study reach is located in Yellowhead County, approximately 20 km northwest of the Town of Edson and includes Peers. The study reach covers about 10 km of January Creek, extending from the southern boundary of SE 15-54-14-W5M downstream to the northern boundary of NE 20-54-14-W5M. January Creek drains a watershed area of approximately 106 km² at Peers, increasing to about 123 km² at its confluence with the McLeod River approximately 8 km downstream of the study area. January Creek is classified as a fourth-order stream with a total length of approximately 26 km from its headwaters to the McLeod River confluence.

4.3.2 Channel and Floodplain Characteristics

The typical bankfull channel width of the January Creek ranges from 8 to 10 m, with depths between 2.5 and 3.0 m. The creek bed and banks are predominantly composed of fine-textured sediments, and the banks are well-vegetated with tall grasses, willows, and shrubs. Numerous beaver dams are located throughout the study reach, influencing local hydraulic conditions and the surrounding floodplain dynamics.

January Creek has a relatively flat gradient of approximately 0.0007 m/m (0.07%) and exhibits a meandering pattern with a channel sinuosity of 2.1. Numerous beaver dams and woody debris is present along the study reach. The meander belt width varies from approximately 20 to 50 meters and is densely vegetated with brush and trees.

The lands adjacent to the meander belt primarily consist of grass, shrubs, and forest. At Peers, the land use rural residential and commercial that is located on a terrace that is approximately 2.0 to 3.7 m higher than the January Creek floodplain. The channel and floodplain are generally constrained by terrace and man-made features such as roads and crossings.

The channel is prone to overbank flooding during discharges equal to or exceeding the 5-year flood. A significant spill location is just upstream of the Highway 32 crossing, where the overbank flow spreads across the broad, flat terrain north of Peers, eventually overtopping Highway 32 approximately 1 km north of the road crossing, and following natural drainage paths that reconnect with the January Creek channel. Depending on the magnitude of flooding, these paths can become extensive, with portions of the overbank flow decouple from the main channel for long distances. Further analysis of this process is provided in the modelling and mapping section of the report.

4.3.3 Bridges and Culverts

The three bridge crossings and two culvert crossing in the study area are described in APPENDIX B and summarized in Table 4-3.

Table 4-3: List of Bridges and Culverts within the Study Area

Bridge ID	Bridge Name	River Station (Approx.)	Type	No. of Bridge Spans/Culvert Barrels
HS-01	Unnamed Bridge	7+672	Private	1
HS-02	Railway Bridge	7+571	Rail	3
HS-03	Highway 32 Culvert	6+976	Traffic	1
HS-04	Willow Dr. Bridge	6+098	Traffic	1
HS-05	Township Rd 544 Culvert	0+258	Traffic	2

4.3.4 Weir, Dam and Flood Control Structure

There are no weirs, dams or flood control structures along the study reach of January Creek.

4.4 Model Construction

4.4.1 Methodology

The latest HEC-RAS program (Version 6.6, Sep 2024) was used to develop a two-dimensional (2D) hydraulic model for the study area.

4.4.2 HEC-RAS Program

The HEC-RAS program was developed by the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers (USACE). The software has a graphical user interface, separate hydraulic analysis components, data storage and management capabilities, and graphics and reporting facilities. HEC-RAS is a commonly-used program in North America and around the world.

The HEC-RAS program was designed to perform one-dimensional (1D), two dimensional (2D) or combined 1D and 2D hydraulic calculations for a full network of natural and constructed channels. The program supports steady-state and unsteady-state hydraulic simulation. HEC-RAS can be used to calculate water surface profiles for gradually varied flow. In this study, the program was used for 2D unsteady-state simulation.

The program can be used to simulate the effects of various obstructions such as bridges, culverts, weirs, levees and other structures. The program can simulate the water surface profiles associated with subcritical, supercritical and mixed flow regimes.

4.4.3 Modelling Approach

In this study, a full 2D HEC-RAS model was set up for entire study area. The rationale for selecting the full 2D HEC-RAS modelling approach is provided below:

- January Creek consists of many tortuous meanders and relatively flat floodplain on naturally vegetated, forested and agricultural lands. It would be challenging to define cross section alignments using a 1D modelling approach in this area. Significant manual edit efforts and professional judgment would be required to define the cross sections.
- Multiple oxbows, wetlands, and ponds are situated within the study reach. Many ineffective areas would be required to represent the effective flow area per cross section. More effort would be required for a 1D model to capture the bathymetric details for these ponds and wetlands.

- There are several key structures within the floodplains, including Highway 32, CN Rail Crossing, Range Road 143A (Willow Drive), and Township Road 544. Our past modelling experience indicate that in the event of overtopping of these linear infrastructures away from the main channel, limitations of a 1D model approach may lead to inaccuracies and would not adequately capture these key structure features.
- The study area was modelled fully in 2D to avoid internal boundary conditions that would be required in a 1D model or coupled 1D/2D model and to account for the complex interactions between multiple flow paths on the same floodplain.
- The mesh along the main channel of January Creek and its floodplains can be further refined to represent the channel characteristics in 2D domain.

The 2D HEC-RAS model offers the following benefits:

- A 2D model allows the highwater marks at their specific locations to be compared with the simulated water levels for model calibration.
- A 2D model reduces the uncertainty in defining the alignment of cross section and the selection of appropriate ineffective flow areas for large floodplains in the model domain.
- A 2D model lowers the risk of profiles crossing at the locations where ineffective area would be activated when flood control structures, levees or roads would be overtopped.
- A 2D model allows for direct detailed inundation mapping without interpolating water levels between cross sections, which significantly reduces efforts in flood mapping and increases the accuracy of flood mapping.
- A 2D model drastically reduces efforts for model setup comparing to coupled 1D/2D model. Significant effort is required to set up the lateral structures required for connecting 1D component and 2D component in a coupled 1D/2D model.

4.4.4 General Model Setup

4.4.4.1 Model Domain

It is generally preferable to use a single geometry file to simulate flood events across multiple return periods. To support this approach, the model domain was defined to encompass the full extent of inundation associated with the 1,000-year flood event, which is the largest simulated flood. Flow continuity was preserved throughout the domain, and there was no flow leakage at the lateral boundaries.

Figure 4-3 presents the model domain for this study.

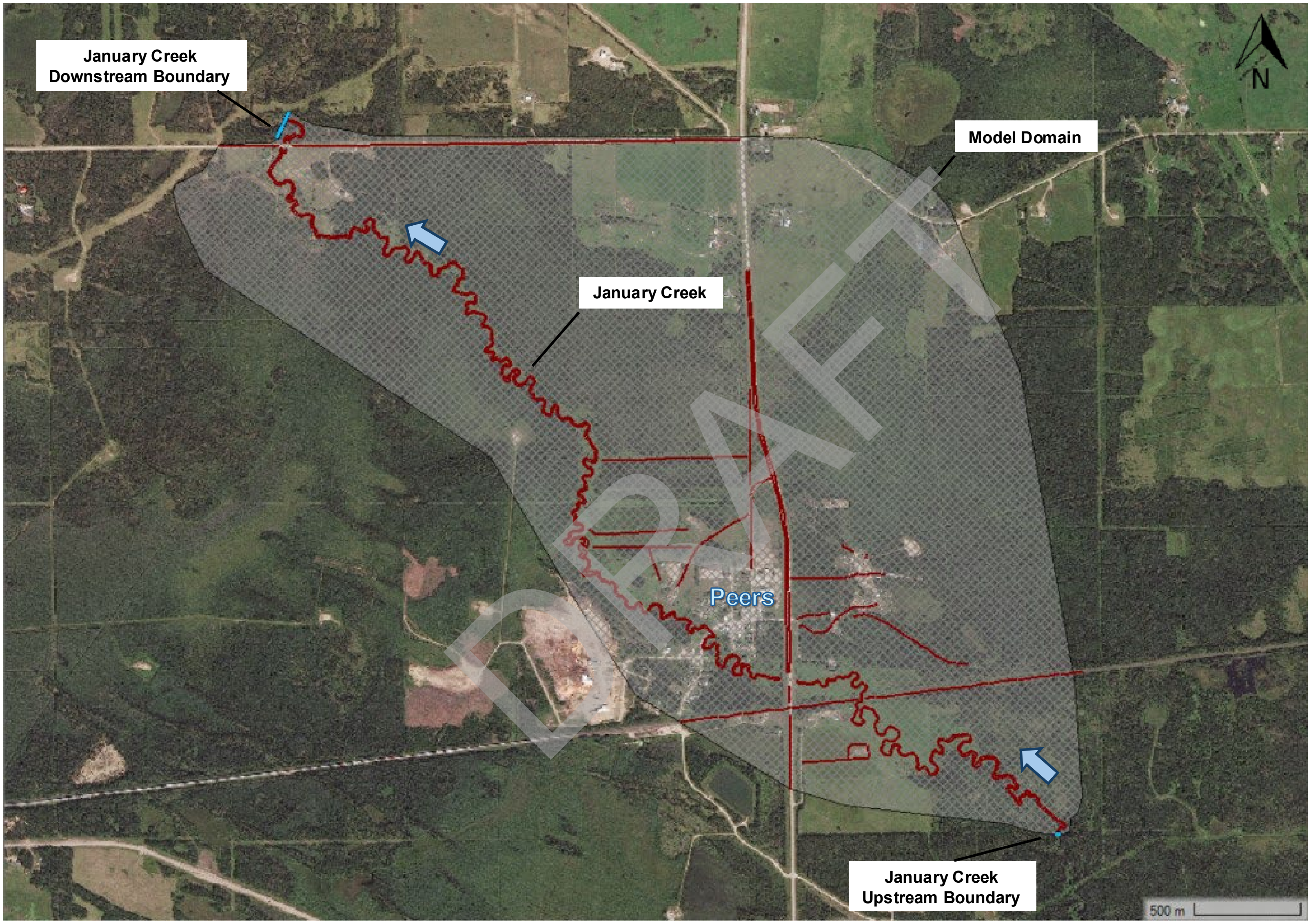


Figure 4-3: Model Domain

4.4.4.2 Model Mesh

The model mesh includes the following:

- The mesh along the main channel of January Creek, was further refined to 1 to 3 m to represent the channel characteristics. Breaklines were defined along both banks and channel centre line.
- Floodplains were defined with an average mesh size of 10 x 10 m, with small elements used in areas where topographic details were important to adequately simulate the local hydraulic conditions. Local refinements were performed along key structures and side channels.
- The mesh along Highway 32, the CN railway, and several local roads was refined to 2 m resolution to better capture their physical features and accurately represent their influence on flow passing conditions.
- Several spill points on the floodplain north of the railway and east of Highway 32 were identified. Any overtopping of these spill points lead to widespread flooding to the north. Mesh refinements were applied to these spill points with break lines to ensure flood simulations correctly captured overtopping of these features.

Figure 4-4 illustrates final model mesh and the mesh refinement near Highway 32 and CN Railway.

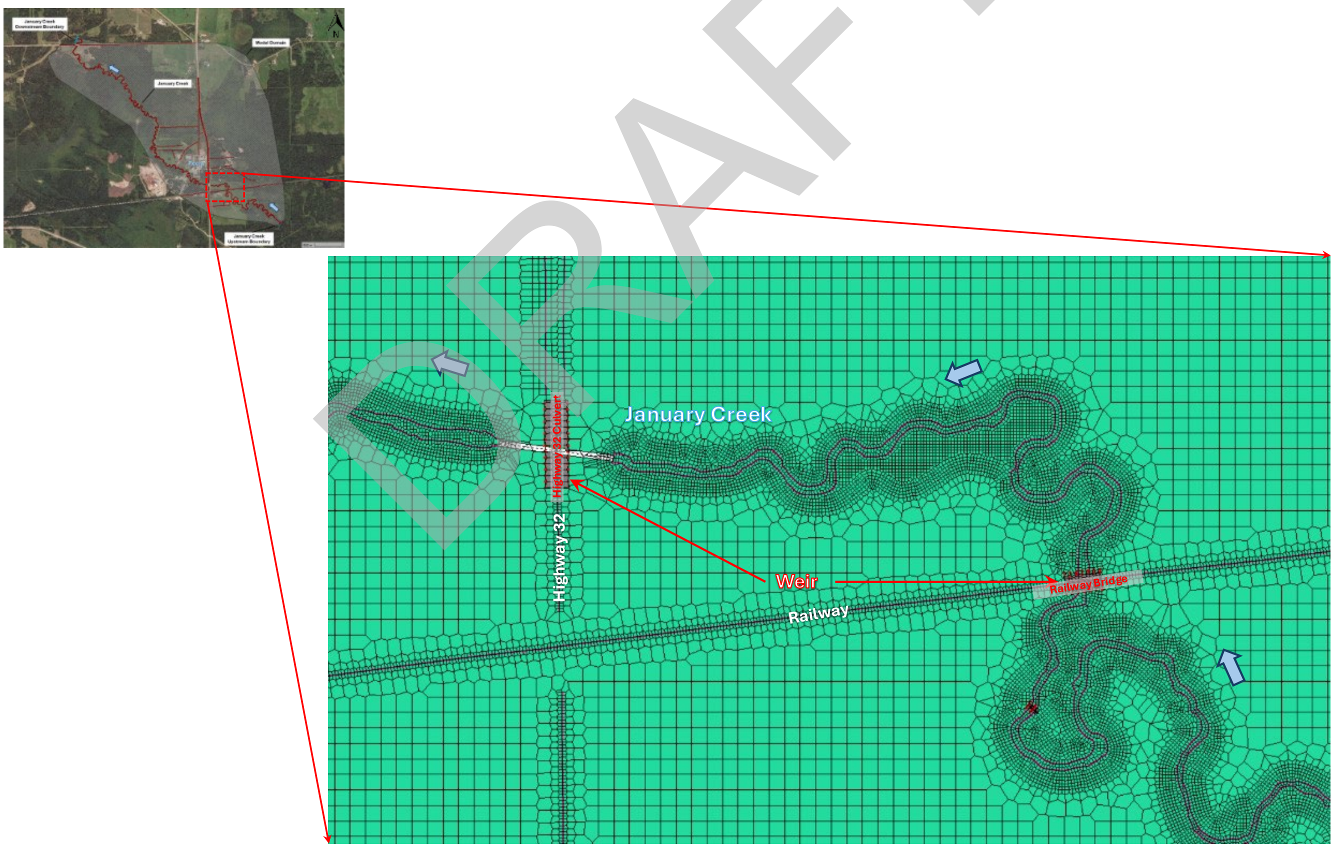


Figure 4-4: Example of Local Mesh Refinement

4.4.4.3 Boundary Conditions

The 2D HEC-RAS model requires specification of boundary conditions at all open boundaries. The open boundaries of the hydraulic model (see Figure 4-3) are listed below:

- Discharges at the upstream model boundary of January Creek
- Normal flow condition (with an estimated energy slope of 0.1%) at downstream boundary of January Creek

4.4.5 Geometric Data Base

4.4.5.1 Integrated DEM

The LiDAR data provided for this study did not include the channel bathymetry. Therefore, the surveyed cross section data was combined with the LiDAR surface to produce an integrated DEM that represents both floodplain topography and channel bathymetry.

The surveyed cross section data along January Creek was imported to HEC-RAS. The left and right edges of water were delineated based on LiDAR and imagery comparison. Using RAS Mapper, a bathymetric terrain surface within the water edge lines was generated by linear interpolation using the surveyed cross section data. The interpolated bathymetric surfaces replaced the topography within the water edges of the LiDAR to create an integrated DEM that included channel bathymetry. This integrated DEM was used for HEC-RAS model development. Figure 4-5 contains an example cross section comparing the terrain surface with and without channel bathymetry. The comparison illustrates that channel bathymetry was included in the integrated DEM.

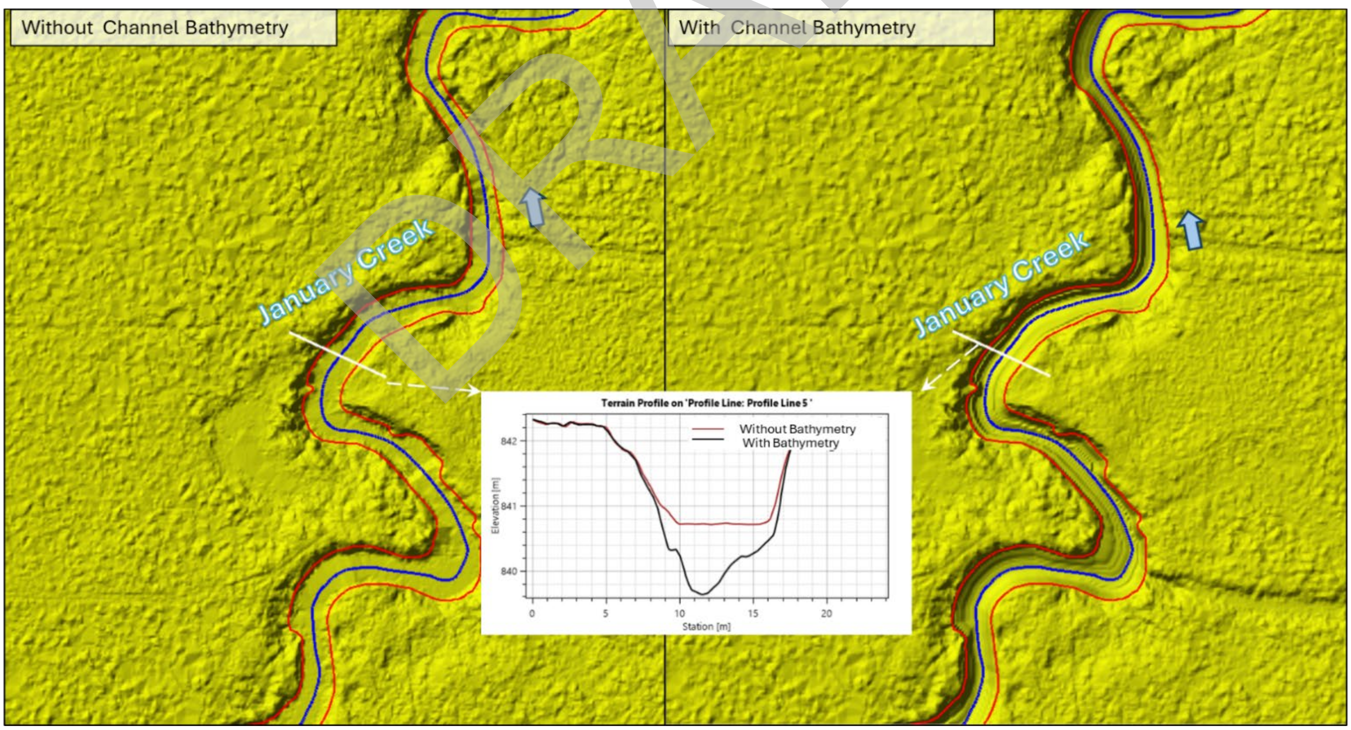


Figure 4-5: Example of Channel Bathymetry in the Integrated DEM

4.4.5.2 Roughness Coefficients

The left and right bank stations defining the main channel were digitized in RAS Mapper based on the LiDAR data, aerial imagery and survey data. The initial roughness distribution was specified based on the following data:

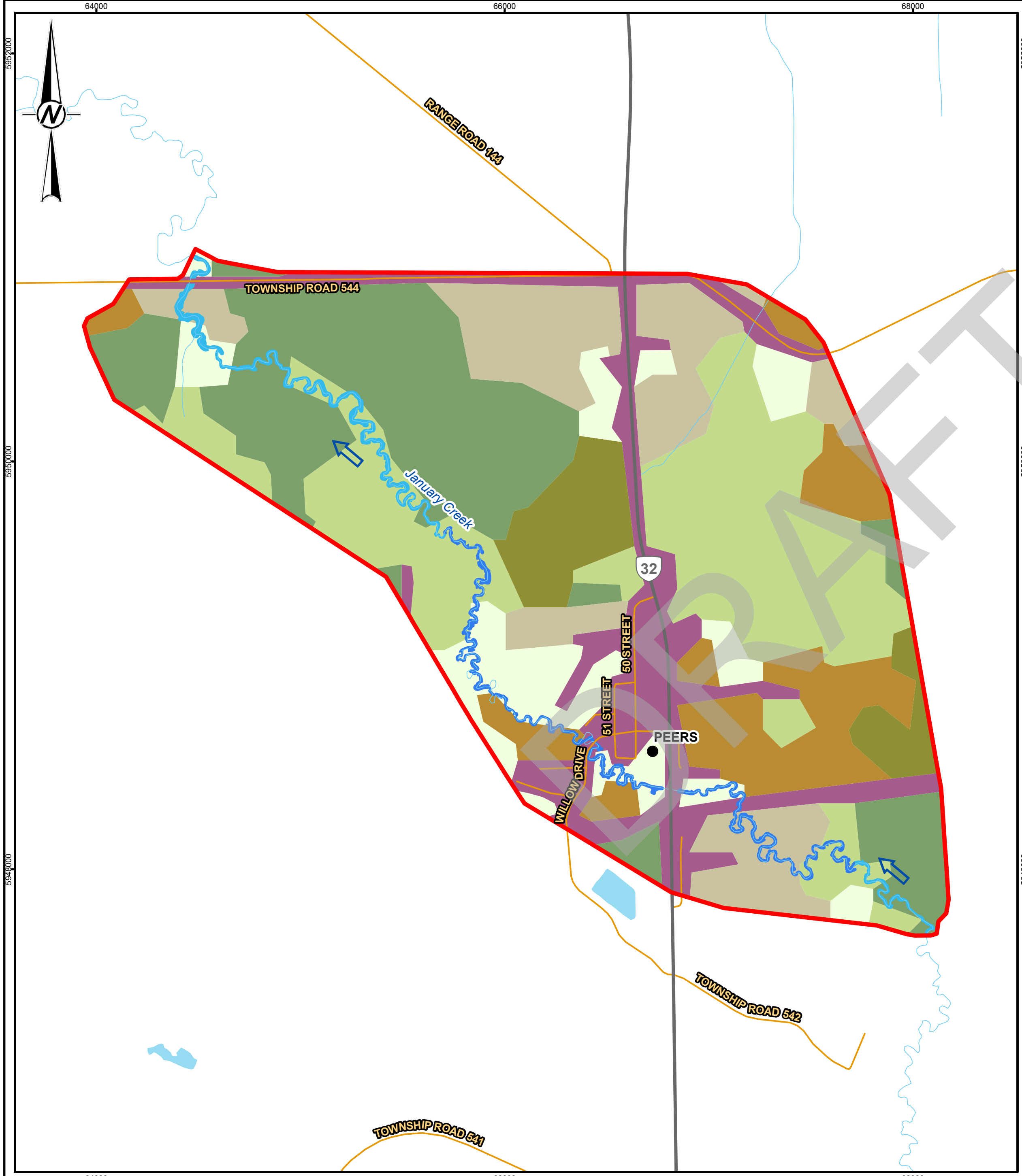
- Bank lines established from the LiDAR data, aerial imagery and surveys to identify the main channels
- Land use information from Government of Alberta

Eight roughness classes were used for the model setup. The initial Manning's *n* values assigned to the classes are listed in Table 4-4. These initial values were selected based on channel bed materials, vegetation types, etc. (Chow 1959; USACE 2025). These roughness values were modified at some locations during the model calibration process. The roughness values were specified in the cross sections using RAS Mapper. Figure 4-6 shows the distribution of the roughness classes.

Table 4-4: Roughness Classes and Initial Manning's n Values

Number	Description	Initial Manning's *n*
1	Developed	0.05
2	Shrubland	0.08
3	Grassland	0.05
4	Agriculture	0.05
5	Coniferous forest	0.12
6	Broadleaf forest	0.18
7	Mixed forest	0.15
8	January Creek Channel	0.05

PATH: I:\CLIENTS\GOVERNMENT_OF_ALBERTA\CA0041746_1954_Peers\Mapping\Hydrology\03_Open Water Hydraulic Modelling\CA0041746_1954_Fig4-6_Roughness_Class_Distribution.aprx PRINTED ON: 2025-09-19 AT: 4:20:08 PM



LEGEND

- FLOW DIRECTION
- SETTLEMENT
- LOCAL ROAD
- PRIMARY HIGHWAY
- SURVEY REACH
- WATERCOURSE
- WATERBODY
- FLOOD STUDY AREA

ROUGHNESS CLASS

- AGRICULTURE
- BROADLEAF FOREST
- CHANNEL WITHIN HAMLET OF PEERS
- CHANNEL UPSTREAM/DOWNSTREAM OF PEERS
- CONIFEROUS FOREST
- DEVELOPED
- GRASSLAND
- MIXED FOREST
- SHRUBLAND

0 1 2

1:30,000 KILOMETRES

REFERENCE(S)

ROUGHNESS CREATED AND MODIFIED FROM ABMI HUMAN FOOTPRINT INDEX 2021.
POPULATED PLACES, ROADS AND HYDROGRAPHY OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
DATUM: NAD 1983 CSRS 3TM 117

CLIENT
ALBERTA ENVIRONMENT AND PROTECTED AREAS

PROJECT
PEERS FLOOD STUDY

TITLE
DISTRIBUTION OF ROUGHNESS CLASSES

CONSULTANT

YYYY-MM-DD	2025-09-19
DESIGNED	AL
PREPARED	MV
REVIEWED	GT
APPROVED	LH

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	3001	0	4-6

25mm 0
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET HAS BEEN MODIFIED FROM: ANSI A

4.4.5.3 Bridges and Culverts

4.4.5.3.1 Bridges

The bridge geometries used in the HEC-RAS model were defined based on the hydraulic structure surveys conducted in 2024 (see Section 2). The three bridges (see Section 2.6) were represented in the HEC-RAS model. The bridge deck, pier and abutment information were programmed into the model. Losses through bridges were calculated using the energy equation (i.e., standard step method). Flow over the bridge and approach embankment were calculated using the standard weir equation.

4.4.5.3.2 Culverts

There are two culvert crossings (see Section 2.6) in the study area. They were represented in the HEC-RAS model based on the hydraulic structure survey data. The pertinent culvert information, including size, length, and upstream and downstream invert elevations, was specified in the model. For the culverts in the 2D domain, entrance and exit loss coefficients were selected based on the configuration of culvert inlet and outlet.

4.4.5.3.3 Weir, Dam and Flood Control Structure

There are no weir, dam or flood control structures in the study area. Therefore, these features were not represented in the HEC-RAS model.

4.4.6 Model Calibration

4.4.6.1 Methodology

The Manning's *n* and contraction/expansion coefficients are the primary model parameters that were adjusted, if necessary, in calibrating the HEC-RAS model. Selection of the initial Manning's *n* values before model calibration included consideration of stream bed/bank materials, vegetation cover, site information collected during the field inspection, and WSP's experience from previous hydraulic modelling studies.

Manning's *n* value may reduce with increased stage. High flow model calibration was conducted to determine appropriate Manning's *n* values based on the 2023 flood. A low flow calibration was not conducted since there was little to no flow in January Creek during the survey. Available flood photographs and HWMs from the 2023 flood event on January Creek were used for high-flow calibration. This event was the largest recent flood documented in terms of peak flow estimates and the availability of reliable HWMs.

The model calibration process involved multiple iterations to adjust the model parameter values, conduct simulations, and compare the simulated water levels to the HWMs for the high flow calibration. The objective of the model calibration was to achieve good matches between the simulated water levels and the HWMs.

4.4.6.2 High Flow Calibration

The HEC-RAS model for January Creek was calibrated using the HWM data from 2023 flood event, which had an estimated discharge of 33 m^3/s. Discharges at the Highway 32 culvert are inlet controlled, which means that there is a good relationship between water levels upstream of the culvert and discharge. A discharge of 33 m^3/s was estimated based on the culvert geometry, slope, roughness coefficient and the HWMs upstream of the culvert. The model calibration was primarily achieved by adjusting the channel Manning's *n* values to ensure the simulated water levels aligned well with the observed HWMs. Blockage heights at hydraulic structures were also included in the model to account for debris observed by Yellowhead County staff during the 2023 event, and as reported by the Peers community. This blockage was identified as a key factor affecting water levels and was represented by introducing a blockage height at select hydraulic structures as an additional calibration parameter.

These blockages were removed for the flood frequency simulations discussed in Section 4.4.8. Floodplain roughness values were found to have minimal impact on the calibration.

Table 4-5 presents the comparison between LiDAR-derived HWM elevations and simulated water surface elevations at the reported HWM locations along January Creek. The simulation is based on calibrated channel Manning's n values of 0.05 for within Peers and 0.07 for the reaches upstream and downstream of Peers. To reflect flow blockage during the event, block depths of 3.55 m, 1.4 m and 1.3 m were introduced at the Railway Bridge, Township Road 544 culvert 1 (West) and culvert 2 (East), respectively.

Figure 4-7 shows the simulated water surface profile along January Creek with the five (5) HWM data points. For the 2023 flood event, the average difference between the simulated water level and identified HWMs is approximately 15 cm, with a range from -32 cm (simulated lower than observed) to +9 cm (simulated higher than observed).

Table 4-5: Comparison of Simulated Water Surface Elevations and Reported LiDAR-derived HWM Elevations for the 2023 Flood Event

No.	Approximate River Stations (m)	HWM Location	HWM Elevation (m)	Simulated Water Surface Elevation (m)	Difference[a] (m)
1	7+653	Southwest of the Railway Bridge	846.71	846.57	-0.14
2	7+031	Northeast of the Highway 32 Culvert	846.29	846.17	-0.12
3	6+133	Southeast of the Willow Drive Bridge	844.92	844.60	-0.32
4	5+343	North of the dugout	843.54	843.33	-0.21
5	0+333	Southwest of the Township Road 544 Culvert	840.98	841.07	0.09

Note:

(a) Difference = Simulated water surface elevation - LiDAR-derived HWM Elevation

4.4.6.3 Summary of Calibration Results

The HEC-RAS model for the study reaches of January Creek was calibrated. The results are summarized below:

- The high flow calibration results show that the simulated water levels compare well to the available HWMs for January Creek. The channel Manning's *n* value was calibrated based on the 2023 flood HWMs.
- Manning's n values of 0.05 for the main channel of January Creek near Peers, and 0.07 for the upstream and downstream reaches, can be reliably used for simulating flood levels.
- Debris blockages were introduced to the following hydraulic structures as blockage heights. These blockages were removed for flood simulation.
  - Railway Bridge – 3.55 m
- Township Road 544 Culvert 1 (West) – 1.4 m
  - Township Road 544 Culvert 2 (East) – 1.3 m

The calibrated channel Manning's *n* values summarized above are within the typical range of roughness values for similar streams (Chow 1959), and the calibrated values were subsequently used for generating the simulated flood profiles for all 13 flood events.

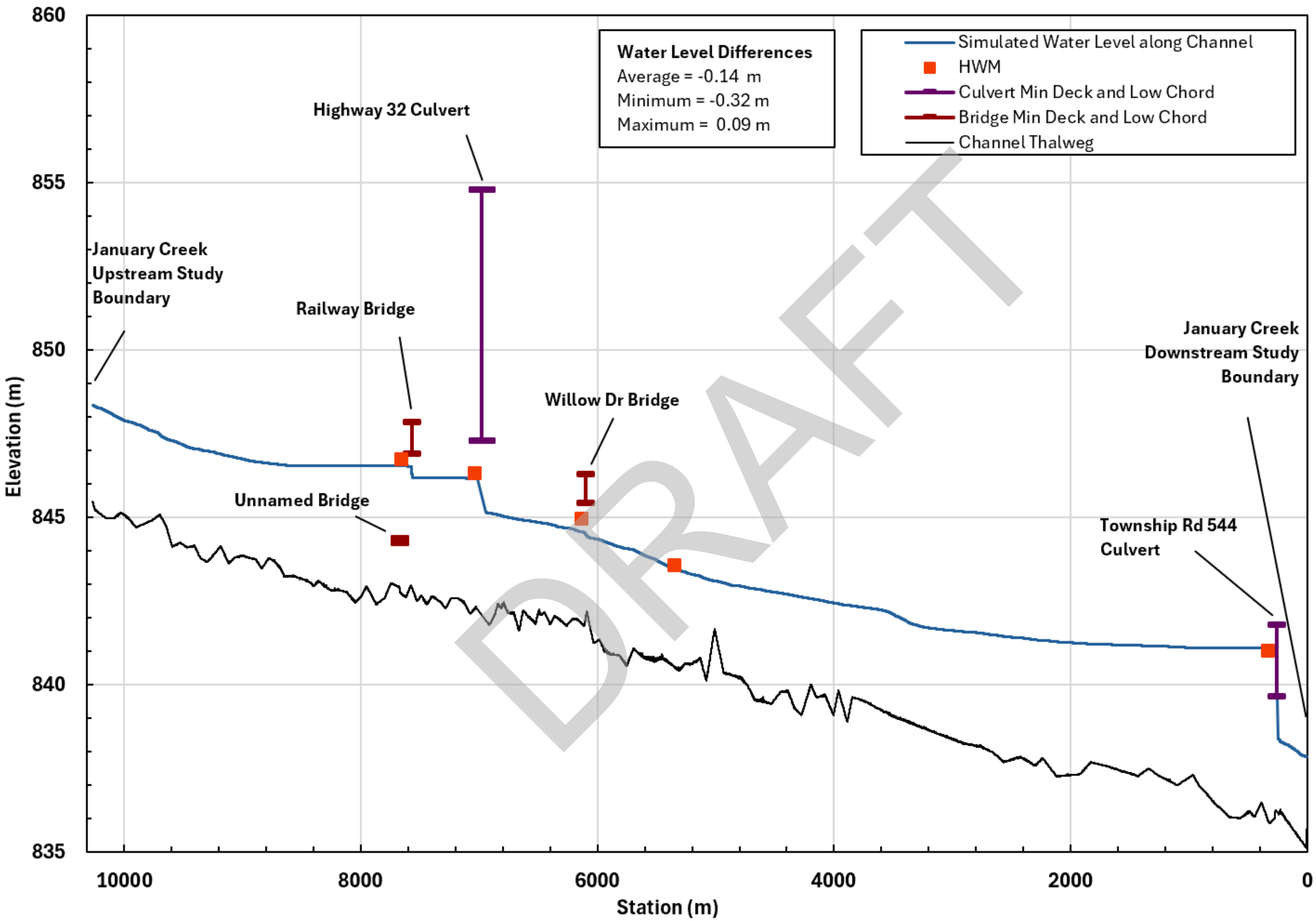


Figure 4-7: Comparison of Simulated January Creek Water Surface Profile and Reported High Water Marks for the 2023 Flood Event

4.4.7 Model Parameters and Options

4.4.7.1 Manning's Roughness Coefficient

Channel Roughness

For the final model runs, a calibrated Manning's n value of 0.05 was chosen for January Creek within Peers where is less instream vegetation and woody debris, and 0.07 for upstream and downstream sections with more woody debris. These selections were based on model calibration results (see Section 4.4.6), literature values, and professional judgment. The selected Manning's n values are within the reasonable range when compared to typical values of similar streams (Chow 1959).

Overbank Roughness

Table 4-6 presents the selected overbank Manning's *n* values based on the various land uses on the floodplains.

Table 4-6: Manning's *n* Values for Various Land Uses on the Floodplains

Description	Initial Manning's *n*	Selected Manning's n Value
Developed	0.05	0.05
Shrubland	0.08	0.08
Grassland	0.05	0.05
Agriculture	0.05	0.05
Coniferous forest	0.12	0.12
Broadleaf forest	0.18	0.18
Mixed forest	0.15	0.15
January Creek Channel within Peers	0.05	0.05
January Creek Channel upstream/downstream of Peers	0.05	0.07

4.4.7.2 Expansion and Contraction Coefficients

The contraction and expansion coefficient values for bridges were selected to be 0.3 and 0.5.

4.4.8 Open Water Flood Frequency Profiles

4.4.8.1 Production Model

The HEC-RAS model was developed based on the calibrated and estimated Manning's *n* values. The flood peak flows used in the HEC-RAS model for flood simulation were estimated based on the hydrology assessment results (see Section 3). Surface water profiles were simulated for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750- and 1,000-year flood events.

The simulation period was set to 84 hours for most of the runs. For the 35- to 50-year events, it was extended beyond 84 hours to ensure the model reached steady-state conditions throughout the entire domain.

4.4.8.2 Flow Change Locations

There is no flow change location within the model boundaries of the study reach.

4.4.8.3 Flood Peak Flows

The estimates of flood peak flows at the upstream model boundary (based on Section 3) in the HEC-RAS production model are summarized in Table 4-7.

Table 4-7: Summary of Flood Peak Flows Used in the HEC-RAS Production Model

Discharges of Various Return Periods (m³/s)												
2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1,000-year
8.47	17.2	24.4	32.5	40	45.3	51.7	56.7	70.1	82.5	91.2	102	110

4.4.8.4 Model Boundary Conditions

The boundary conditions of the HEC-RAS production model (see Figure 4-3) are listed below:

- The discharges specified for the upstream model boundary as shown in Table 4-7.
- Normal flow condition (with an estimated energy slope of 0.1%) at downstream boundary of January Creek

4.4.8.5 Open Water Flood Frequency Profiles

Since there are no cross sections within the 2D model domain, water levels were extracted from the 2D model results along the main channel in regular intervals. The channel stations are presented in the inundation maps. The simulated open water flood profiles along the study reach of January Creek are presented in Figure E-1 in Appendix E. The simulated open water flood water levels at individual cross sections along the study reach of January Creek are listed in Table E-1 in Appendix E.

4.4.9 Model Sensitivity

A model sensitivity analysis was conducted to evaluate the effects of changing model roughness values and downstream boundary conditions on the simulated water levels. The discharges used for the model sensitivity analysis were the 100-year flood peak flows. The results of the sensitivity analysis were used to quantify the level of uncertainty associated with the simulated flood levels along the study reach of January Creek.

The analysis of model sensitivity to Manning's *n* involves the following two sets of Manning's *n* values for the river channels and floodplains and one set of downstream boundary condition:

- ±10% changes of the base channel Manning's *n* values only
- ±10% changes of the base floodplain Manning's *n* values only
- ±20% changes of the specified energy slope for the downstream boundary.

Figures F-1 to F-3 in Appendix F graphically present the differences between the simulated water levels for the 100-year flood along the study reach of January Creek. The results of the sensitivity analysis indicate the following:

- The uncertainty in the simulated flood levels, on average, is within a range of -0.025 m to 0.022 m (with standard deviation of 0.015 m) along the entire study reach, based on the differences in the simulated flood levels for the ±10% changes to the base channel Manning's *n* values only.
- The uncertainty in the simulated flood levels, on average, is within a range of -0.021 m to 0.019 m (with standard deviation of 0.007 m) along the entire study reach, based on the differences in the simulated flood levels for the ±10% changes to the base floodplain Manning's *n* values only.

- A ±20% change to the energy slope at the downstream boundary of January Creek influences the simulated flood levels by a range of ±0.001 m for approximately 0.24 km upstream of the downstream boundary.

5 FLOOD INUNDATION MAPS

5.1 Methodology

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
- Topography from the 2024 LiDAR survey
- Aerial imagery of the study area collected in 2023

Direct flood inundation areas are identified either as being part of the river channel and directly connected overbank areas. The following general procedure was used in ArcGIS to develop the inundation extent of the 13 open water flood events:

- Flood inundation boundaries, water level grids and depth grids are exported from the 2D HEC-RAS model. The results from the last time step were exported from HEC-RAS to ensure that the model reached a steady state.
- Areas that are not directly connected to the main river channel 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.

5.2 Inundation Polygon Modifications

5.2.1 Open Water Inundation Mapping

One set of open water flood inundation maps was prepared for each of the 13 flood events. The study area is covered by a total of three 11 inch x 17 inch map sheets at a scale of 1:500. The maps were prepared using the local 3-Degree Transverse Mercator (3TM) zone and the Canadian Spatial Reference System North American Datum of 1983 (NAD83 CSRS) coordinate system and datum.

The maps include the 2023 aerial imagery and other base data (roads and railways) provided by EPA. The resulting inundation maps for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750- and 1,000-year flood events are presented in a separate document (i.e., Appendix G: Open Water Flood Inundation Map Library).

The flood inundation maps were prepared in a geographical information system. The maps including all layers were provided to EPA as digital files in the ESRI ArcGIS file format.

5.2.2 Manual Edits

Flood inundation mapping at some locations required manual edits to produce reasonable inundation extents. These manual edits are summarized in Table 5-1.

Table 5-1: Locations of Manual Edits for Flood Inundation Polygon

Floodplain	Closest River Station (m)	Description	Flood Events
North side of Highway 32 near the intersection with Range Road 143	4+250	Added road overtopping as it was not correctly represented in model outputs.	35- to 50-year
Township Road 544 at the Culvert	0+258	Added road overtopping as it was not correctly represented in model outputs.	350- to 500-year

After applying the manual edits, the flood inundation polygons underwent automated smoothing and filtering to create more simplified inundation extents. All dry areas fully enclosed by inundation polygons ("islands") smaller than 25 m^2 were filled and added to the inundated areas. The flood inundation polygons were also smoothed using the PEAK (Polynomial Approximation with Exponential Kernel) algorithm with a smoothing tolerance of 15 m. This smoothing tolerance generally results in changes to the inundation boundary well below 1 m in most areas.

5.3 Areas Affected by Floods

5.3.1 Residential and Commercial Areas Affected by Floods

Hydraulic modelling indicates that minimal residential, and/or commercial infrastructure within Peers are affected by direct inundation from January Creek under the modelled flood events. The area that appears to experience the greatest impacts is the RV storage lot situated north of the railway and east of Highway 32. Highway 32 is overtopped approximately 1 km north of the Highway 32 crossing for flood events equal to and greater than 1:35-year flood. Aside from this, the areas predicted to be inundated are limited to agricultural and forested land with no critical infrastructure (other than the previously noted Highway 32 overtopping) or buildings present. Detailed inundation maps are provided in Appendix G.

5.3.2 Flooding of Bridges and Culverts

A bridge is considered affected by flooding when flood waters reach its low chord. A culvert is considered affected by flooding when the flood waters reach the road surface. Two (2) bridges along January Creek would be affected during the 100-year flood event. No culvert would be affected during the 100-year flood event.

The simulated water levels at the bridges and culverts along January Creek for the various flood events, as well as the flow velocities and clearances for the 100-year flood event are summarized in Table 5-2.

5.4 Flood Depth Grids

5.4.1 GIS Data Specifications

The following GIS data is provided to EPA for each of the 13 flood events:

- Inundation polygons
- Water surface elevation raster
- Flood depth raster

All GIS data was created in ArcGIS 10.7.1 or ArcGIS Pro 3 compatible format in the native study coordinate system (Canadian Spatial Reference System, North American Datum of 1983 [CSRS NAD83], Epoch 2002 and 3-Degree Transverse Mercator projection with the Central Meridian of 117° [3TM 117]). All raster files have a spatial resolution of 0.5 m.

The inundation polygons and raster files were stored in ArcGIS file geodatabases, Version 10.8.

5.4.2 General Comments

The flood water level data, provided as rasters, cover all areas within the study area including dry areas. The flood water depth rasters only include the areas with a water depth of more than 0.01 m.

Table 5-2: Flooding at the Bridges and Culverts along the Study Reaches of January Creek

Bridge Station (m)	Name	Minimum Deck/Road Surface Elevation (m)	Minimum Low Chord Elevation (m)	Simulated Water Level at the Bridges and Culvert Inlets for the Various Flood Events (m)													Average Flow Velocity for the 100-year Flood Event (m/s)	Clearance for 100-year Flood Event[a] (m)	Flood Event Causing Pressure Flow or Overtopping Road Surface (Return Period)
				2-Year	5-Year	10-Year	20-Year	35-Year	50-Year	75-Year	100-Year	200-Year	350-Year	500-Year	750-Year	1,000-Year			
7+672	Unnamed Bridge	844.35	844.21	844.95	845.53	845.81	846.21	846.59	846.74	846.87	846.97	847.16	847.30	847.40	847.50	847.57	0.17	-2.76	≥2 year
7+571	Railway Bridge	847.82	846.89	844.85	845.48	845.76	846.17	846.56	846.72	846.85	846.93	847.10	847.23	847.30	847.39	847.44	1.29	-0.04	≥100 year
6+976	Highway 32 Culvert	854.77	847.28	844.45	845.23	845.65	846.12	846.52	846.68	846.80	846.88	847.03	847.12	847.18	847.24	847.28	0.43	0.39	>1000 year
6+098	Willow Dr. Bridge	846.28	845.40	843.39	844.01	844.28	844.47	844.60	844.65	844.68	844.71	844.74	844.77	844.78	844.80	844.81	1.85	0.69	>1000 year
0+258	Township Rd 544 Culvert	841.77	839.62	838.09	838.71	839.15	839.60	839.98	840.26	840.59	840.87	841.65	841.81	841.83	841.81	841.86	0.24	0.91	≥35 year

Note:

(a) For bridges, the clearance for the 100-year flood event is defined as the elevation difference between the bridge's low chord and the simulated water surface. For culverts, clearance refers to the elevation difference between the top of culvert and the simulated water level. A negative clearance indicates that water overtops the bridge low chord or top of culvert.

6 DESIGN FLOOD HAZARD MAPPING

6.1 Flood Hazard Mapping Approach

The flood hazard mapping approach is described in detail in the Flood Hazard Identification Program (FHIP) – Flood Study Technical Guidelines (AEP 2022). The major technical changes compared to previous mapping are listed below. The second, third and fourth items listed below are not applicable to this study.

- Encroachment analysis will no longer be used to define floodway limits or determine 100-year design flood levels. The 0.3 m water level rise criterion is no longer used to define the floodway limit.
- Existing floodways from previous flood studies will not typically get larger when flood hazard maps are updated. For areas with previously defined floodways, the initial new floodway location will typically correspond to the existing floodway. The floodway can only get larger or smaller if it is deemed necessary with new modelling results based on consultation with local authorities.
- A new high hazard flood fringe zone will highlight parts of the flood fringe with deeper or faster moving water than the rest of the flood fringe outside of the floodway. The new high hazard flood fringe zone will be defined where the water is 1 m deep or greater or local velocities are 1 m/s or faster within the flood fringe zone.
- The protection provided by dedicated flood berms will be reflected in new flood hazard maps. 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.
- Flood hazard maps will show areas at risk of more severe flooding than just the 100-year design flood. Areas of incremental flood risk outside of the 100-year flood hazard area will be highlighted, including the 200-year and 500-year flood extents.

6.2 Design Flood

The 100-year open water flood was selected as the design flood in accordance with the Flood Hazard Identification Program (FHIP) Flood Study Technical Guidelines (AEP 2022). The 100-year flood water levels simulated in open water flood frequency profiles (Section 4) were selected as the final design flood levels. The design flood levels at 500 m stationing intervals along January Creek are provided in Appendix E.

6.3 Floodway and Flood Fringe Terminology

The flood hazard area is the area of land that will be flooded during the design flood event. 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 part 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 becomes larger or design flood levels become higher. New development is discouraged in the floodway and may not be permitted in some communities.

- **Flood Fringe**: The flood fringe is the part 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. New development in the flood fringe may be permitted in some communities.

6.4 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 (AEP 2022), 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

When a flood hazard map is updated, an existing floodway will not change in most circumstances. Exceptions to this would be: (1) a floodway could become larger if the main channel has shifted outside of a previously-defined floodway, or (2) a floodway could become smaller if an area of previously-defined floodway is no longer flooded by the design flood. Furthermore, the existing floodway near it ends may be revised to allow for smoother transitions between the existing floodway and extended area of the updated floodway when the updated floodway extends beyond the existing floodway limits.

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 January Creek were based on the depth and velocity criteria as presented on the Floodway Criteria Maps in Appendix H.

6.5 Floodway Criteria Maps

Floodway criteria maps show the basis for determining the floodway, high hazard flood fringe zone, protected flood fringe areas and flood fringe zone for the design flood and documenting the results of water levels, depths, and flow velocities. The floodway criteria maps include the following information:

- Inundation extents of the 100-year design flood

- Areas meeting or exceeding the 1 m depth floodway criterion for the design flood
- Areas meeting or exceeding the 1 m/s velocity floodway criterion for the design flood
- Proposed floodway boundary for the design flood
- Background aerial imagery collected in 2023
- Roads, bridges, culverts and flood control structures as applicable

The open water design flood water surface elevations and flow velocities were generated from the 2D HEC-RAS model. The model was run until it reached steady state conditions. The last simulation time step was then used to extract the flood water surface elevations and flow velocities directly from the RAS Mapper tool of the HEC-RAS model.

The floodway boundary was delineated in a way that is considered hydraulically smooth. Therefore, most of the side channels and oxbow channels were not included in the floodway.

The floodway criteria maps were produced using the same template as the inundation maps. The maps are provided in Appendix H.

6.5.1 Flood Hazard Maps

The flood hazard maps display the areas in the floodway and flood fringe zones. The floodway was determined as part of the floodway criteria mapping. 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, like the 200-year and 500-year floods. Flood hazard mapping is typically used for long-term flood hazard area management and land-use planning. 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 H.

Areas in the Floodway

The January Creek floodway is mainly confined to the creek channel and the immediate overbank areas through most of the study area. Exceptions are in areas upstream of the both the Highway 32 and the railway bridge, where the floodway extends farther into the floodplain due to backwater effects. A farmyard, including a residence, is located within the floodway between Highway 32 and the railroad bridge, and there are several outbuildings in the floodway upstream of the railroad bridge. There are no other residences or businesses located in the floodway within the study area.

Areas in the Flood Fringe

The flood fringe within the study area does not extend into the residential or commercial portions of the Peers community. The only developed area potentially subject to partial inundation is an RV storage lot situated east of Peers, beyond Highway 32 and north of the railway corridor. The flood fringe does not encroach upon developed community lands within Peers, with the exception of an RV storage lot east of the community and Highway 32, which is overtopped approximately 1 km north of the Highway 32 crossing. The full sets of floodway criteria maps and flood hazard maps are provided in this report.

6.6 Design Flood Grids

6.6.1 Water Surface Elevation Grids

The water surface elevation grid was output directly from the RAS Mapper tool of the HEC-RAS model. Where manual edits were applied to the flood inundation extents, these edits are reflected in the grids as well. Generally, the water surface elevations provided by RAS Mapper were replaced with higher elevations and slightly extended where required. The water surface elevation grid has the same resolution (0.5 m) and alignment as the DTM. The water surface elevation raster was then clipped to the directly-inundated areas. The results from the last time step of the simulation were used, when the model had reached steady state conditions.

6.6.2 Flood Depth Grids

The flood depth grid was created by subtracting the water surface elevation grid from the DTM. The flood depth grid has the same resolution (0.5 m) and alignment as the DTM. The extent of the depth grid is limited to the directly-inundated areas.

6.6.3 General Comments

All GIS data were created in ArcGIS Version 10.7.1 and ArcGIS Pro 3 compatible format in the native study coordinate system [Canadian Spatial Reference System, North American Datum of 1983 (CSRS NAD83), Epoch 2002 and 3-Degree Transverse Mercator projection with the Central Meridian of 117° (3TM 117)].

7 POTENTIAL CLIMATE CHANGE IMPACTS

A cursory examination of potential increases in 100-year design water levels associated with climate change were performed to understand the possible impacts of climate change on flood levels. The effect of the 100-year flood conditions more severe than the baseline was assessed under the following two open water flow scenarios:

- 100-year open water discharge +10%
- 100-year open water discharge +20%

No hydraulic modelling parameters were varied other than discharges under the open water conditions. Water level profiles were produced along the study reaches for the two additional flow scenarios. The water level differences compared to the baseline 100-year open water discharge were calculated and average values are summarized below. These water level differences were identified as potential “freeboards” that could be applied to the design water levels to account for flow changes that could result from climate change.

- For January Creek, the average increases in open water flood levels are 0.097 m for a 10 percent increase in flow, and 0.199 m for a 20 percent increase in flow.

The above analyses are not based on a regional climate change impact assessment but on a simplified assumption that climate change will result in increased flood peak flows. The presented values can be viewed as a general range of potential climate change “freeboard” that could be considered in addition to the computed design flood water levels.

The difference between the simulated water levels difference between 100-year flood event and climate-affected flood along the study reaches, are presented in Figure I-1 in Appendix I. The simulated climate-affected open water flood water levels at individual river stations are compared to the baseline 100-year open water discharge in Table I-1 in Appendix I.

8 CONCLUSIONS

8.1 Survey and Base Data Collection

Topographic, bathymetric, and supporting base data required for this study were collected in accordance with EPA requirements, as noted below:

- *Cross Section Surveys* – Cross section survey data collected in Oct 2024 meets the current study requirements with regard to cross section spacing and alignment, extents of cross sections on the floodplains, labeling of survey points, and data accuracy.
- *Hydraulic and Flood Control Structure Surveys* – Hydraulic structure survey data collected in Oct 2024 and Jun 2025 meet the study requirements and include the necessary details for the hydraulic modelling.
- *Digital Terrain Model* – The differences in elevation between the selected survey points and the DTM data are considered to be within an acceptable range. Therefore, the DTM is considered suitable for overbank cross section data extraction and flood mapping.

8.2 Open Water Hydrology Assessment

The results of the open water hydrology assessment completed in this study support the following conclusions:

- 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 inputs to the other components of the study (e.g., hydraulic modelling). Estimates of flood peak discharges were obtained for various return periods ranging from 2 to 1,000 years, including the 95% upper and lower confidence intervals.

8.3 Open Water Hydraulic Modelling

8.3.1 Model Calibration

The 2D HEC-RAS model, set up for the study reach of January Creek was calibrated based on the available high flow data. The calibrated HEC-RAS model can be reliably used in this study for simulating various flood events with return periods ranging from 2 to 1,000 years.

The calibrated channel Manning's *n* value for high flow conditions is 0.05 near Peers, and 0.07 for the upstream and downstream reaches. Block depths of 3.55 m at the Railway Bridge, 1.4 m of the Township Rd 544 Culvert 1 (West), and 1.3 m at the Township Road 544 culvert 2 (East) were incorporated to represent debris and blockage conditions observed during the 2023 flood event.

8.3.2 Model Sensitivity

The model sensitivity analysis was conducted for the 100-year flood event to evaluate the effects of changing model roughness values and downstream boundary conditions on the simulated water levels. The results of the sensitivity analysis indicate the following:

- The uncertainty in the simulated flood levels for changing roughness values of the channel, on average, is within a range of -0.025 to 0.022 m along January Creek.
- The uncertainty in the simulated flood levels for changing roughness values of the floodplain, on average, is within a range of -0.021 to 0.019 m along January Creek.

- A ±20% change to the energy slope at the downstream boundary of January Creek influences the simulated flood levels by a range of ±0.001 m for approximately 0.24 km upstream of the downstream boundary.

8.3.3 Flood Profiles

The HEC-RAS model is considered 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 HEC-RAS model results and the LiDAR DTM were used for preparing inundation maps for the 13 open water flood events (i.e., 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1,000-year open water floods), including direct flood inundation areas and other indirect flood inundation areas.

Based on the simulation results, the main areas to be affected by open water flooding have been identified, including two (2) bridges crossings along January Creek that would be affected during the 100-year flood event or higher. No residential and commercial areas were affected along January Creek by direct inundation based on the simulation results.

8.5 Design Flood Hazard Mapping

The 100-year open water flood is selected as the design flood for the study area in accordance with the Flood Hazard Identification Program (FHIP) Guidelines (AEP 2022). The floodway was determined as part of the floodway criteria mapping.

Areas in the Floodway

The floodway extends farther into the floodplain upstream of the both the Highway 32 and the railway bridge due to backwater effects. A farmyard, including a residence, is located within the floodway between Highway 32 and the railroad bridge, and there are several outbuildings in the floodway upstream of the railroad bridge. There are no other residences or businesses located in the floodway within the study area.

Areas in the Flood Fringe

The flood fringe does not extend into the residential or commercial zones of the Peers community. Key community infrastructures are located outside the flood fringe and is therefore not at risk of inundation under the modeled flood events. The only developed area within the flood fringe that may experience partial inundation is an RV storage lot situated east of Peers, on the east side of Highway 32 and north of the railway corridor.

8.6 Quantitative Climate Change Assessments

Potential effects of climate change on open water floods were assessed through a sensitivity analysis of flood water level differences due to 10- and 20-percent increases in the 100-year flood peak flows. These water level differences were identified as potential “freeboards” that could be applied to the design water levels to account for flow changes that could result from climate change. The results of the climate change effects assessment are summarized below:

- For January Creek, the average increases in the open water flood levels are 0.097 m for a 10% increase in flow, and 0.199 m for a 20% increase in flow

The analysis in this study was not based on a regional climate change impact assessment but on a simplified assumption of increased flood peak flows that could result from climate change.

9 REFERENCES

AEP (Alberta Environment and Parks). 2022. Flood Hazard Identification Program Flood Study Technical Guidelines. June 2022

AMEC (AMEC Foster Wheeler Environment & Infrastructure). 2016. January Creek Flood Risk Assessment EW1086

Chow, V.T. 1959. Open-channel Hydraulics. McGraw-Hill, New York, 680 p.

Statistics Canada. (2022). Census Profile, 2021 Census of Population.

USACE (U.S. Army Corps of Engineers). 2025. HEC-RAS River Analysis System, User's Manual. Version 6.4.

Third Party Disclaimer

This report has been prepared by WSP Canada Inc. (WSP) for the benefit of the client to whom it is addressed. The information and data contained herein represent WSP's best professional judgment in light of the knowledge and information available to WSP at the time of preparation. Except as required by law, this report and the information and data contained herein area to be treated as confidential and may be used and relied upon only by the client, its officers and employees. WSP denies any liability whatsoever to other parties who may obtain access to this report for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this report or any of its contents without the express written consent of WSP and the client.

Signature Page

WSP Canada Inc.

Amber Liu, M.Sc., E.I.T.
Water Resources Engineer-in-Training

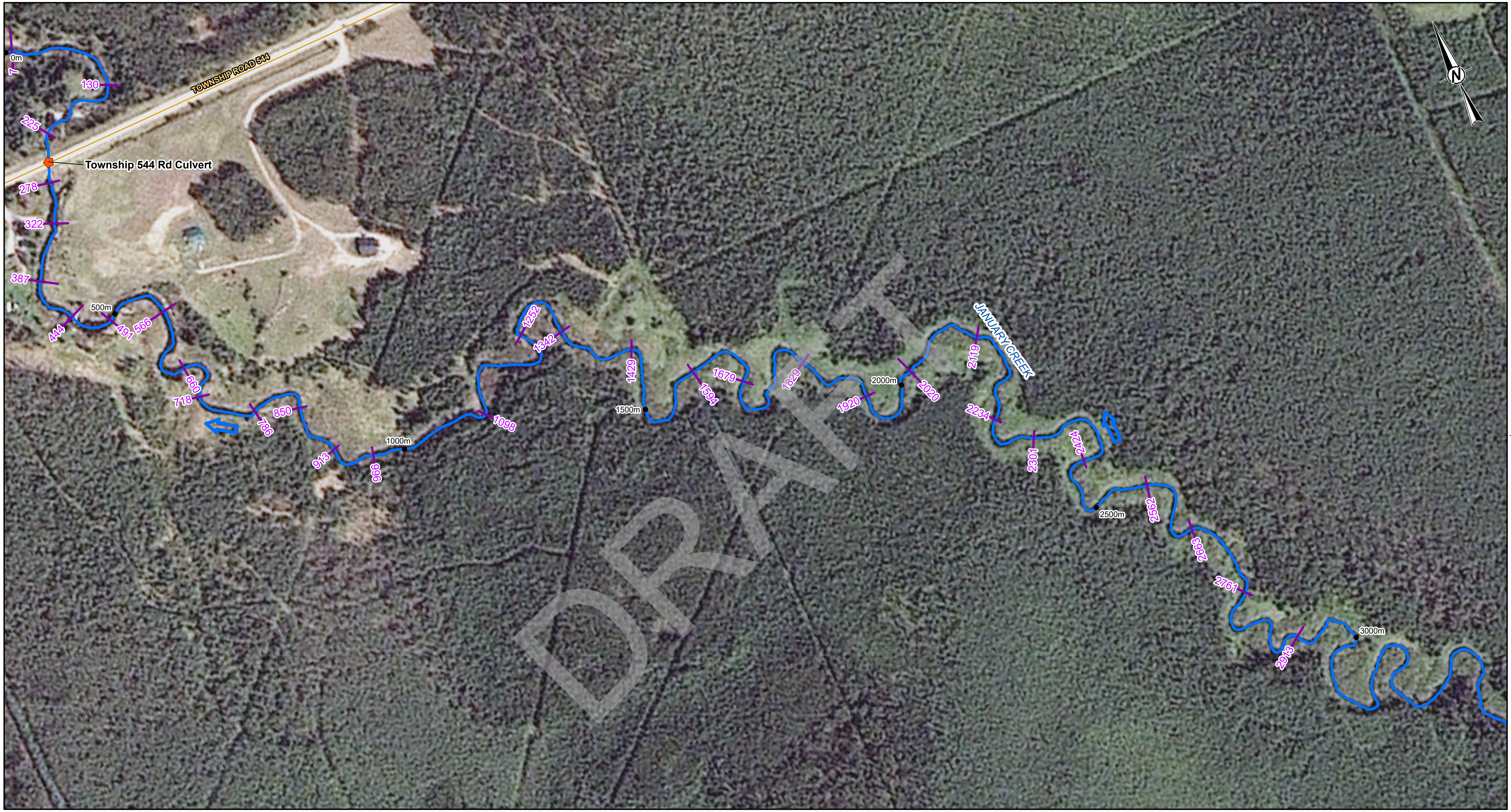
L.S. Hundal, M.Eng., P.Eng.
Senior Principal Water Resources Engineer

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

https://wsponlinecan.sharepoint.com/sites/ca-ca0041746.1954/shared documents/05. technical/06_reporting & documentation/03_study summary report/02_final/ca0041746.1954_final report_rev0.docx

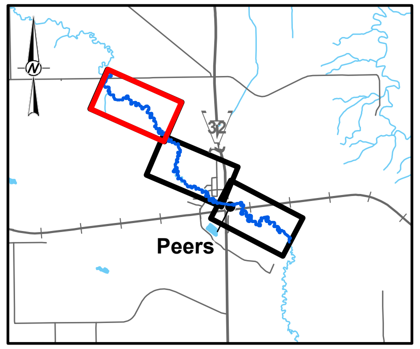
APPENDIX A

Locations of Cross Sections Hydraulic Structures and Flood Control Structures



LEGEND

- PROFILE STATION
- FLOW DIRECTION
- LOCAL ROAD
- PRIMARY HIGHWAY
- RAILROAD
- BRIDGE
- CULVERT
- SURVEY REACH
- SURVEYED CROSS SECTION (STATIONING, m)



0 100 200
1:4,000 METRES

CLIENT
ALBERTA ENVIRONMENT AND PROTECTED AREAS

Alberta Canada

CONSULTANT

wsp

YYYY-MM-DD	2025-09-19
DESIGNED	AL
PREPARED	MV
REVIEWED	GT
APPROVED	LH

REFERENCE(S)
ROADS AND WATERBODIES OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED OR ALTALIS LTD.© GOVERNMENT OF ALBERTA 2025. ALL RIGHTS RESERVED. PROJECT IMAGERY CAPTURED AUGUST 2023 BY PLANET LABS GEOMATICS CORP. FOR THE GOVERNMENT OF ALBERTA.
DATUM: NAD 83 CSRS PROJECTION: 3TM 117

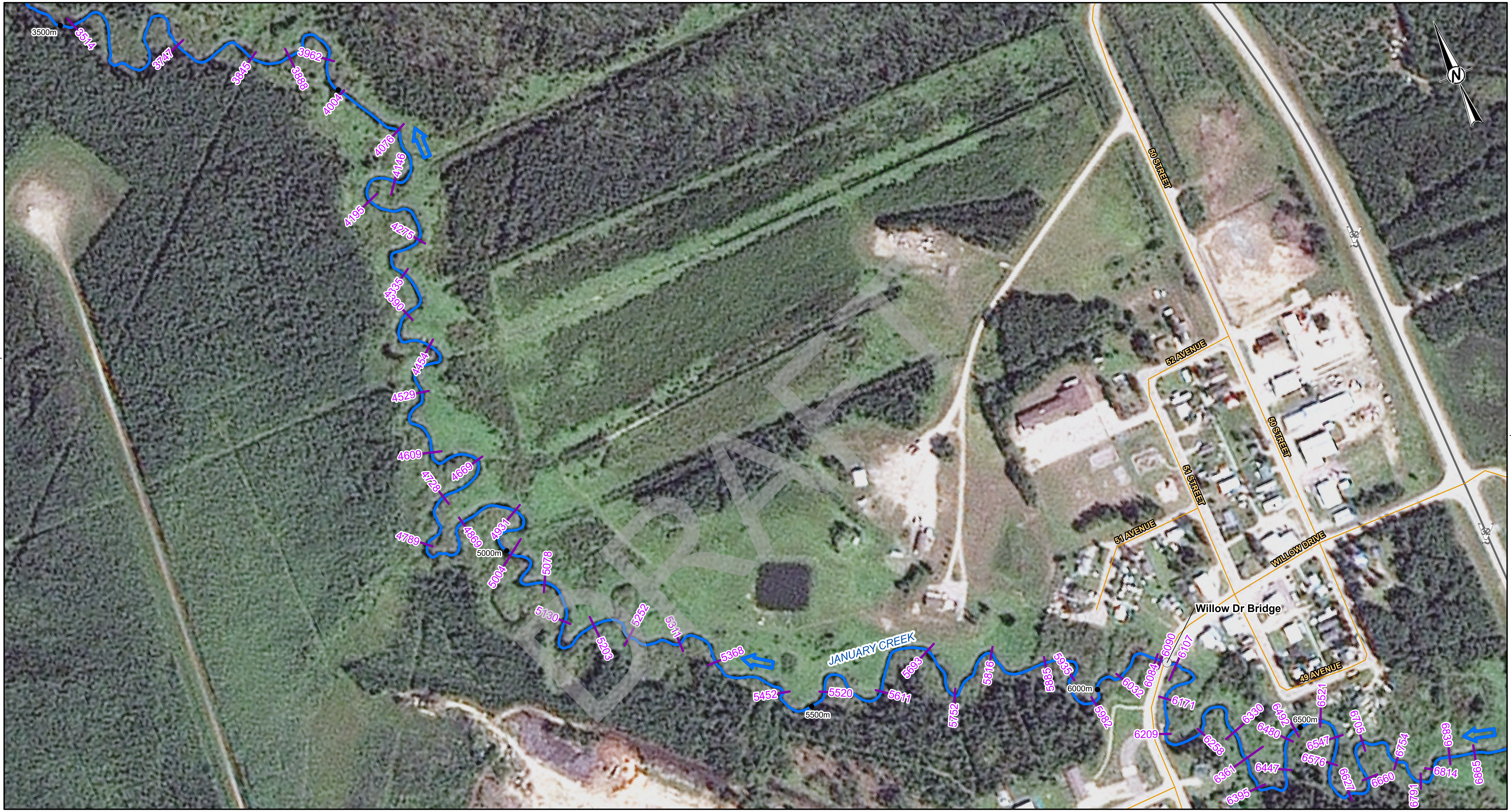
PROJECT
PEERS FLOOD STUDY

TITLE
LOCATIONS OF CROSS SECTIONS AND HYDRAULIC STRUCTURES

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	1001	0	SHEET 1 OF 3

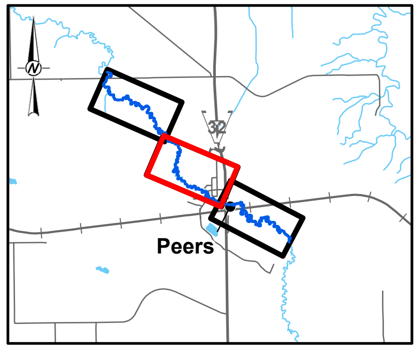
25mm IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI B

Classification: Public



LEGEND

- PROFILE STATION
- FLOW DIRECTION
- LOCAL ROAD
- PRIMARY HIGHWAY
- RAILROAD
- BRIDGE
- CULVERT
- SURVEY REACH
- SURVEYED CROSS SECTION (STATIONING, m)



0 100 200
1:4,000 METRES

REFERENCE(S)
ROADS AND WATERBODIES OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED OR ALTALIS LTD.© GOVERNMENT OF ALBERTA 2025. ALL RIGHTS RESERVED. PROJECT IMAGERY CAPTURED AUGUST 2023 BY PLANET LABS GEOMATICS CORP. FOR THE GOVERNMENT OF ALBERTA.
DATUM: NAD 83 CSRS PROJECTION: 3TM 117

CLIENT
ALBERTA ENVIRONMENT AND PROTECTED AREAS

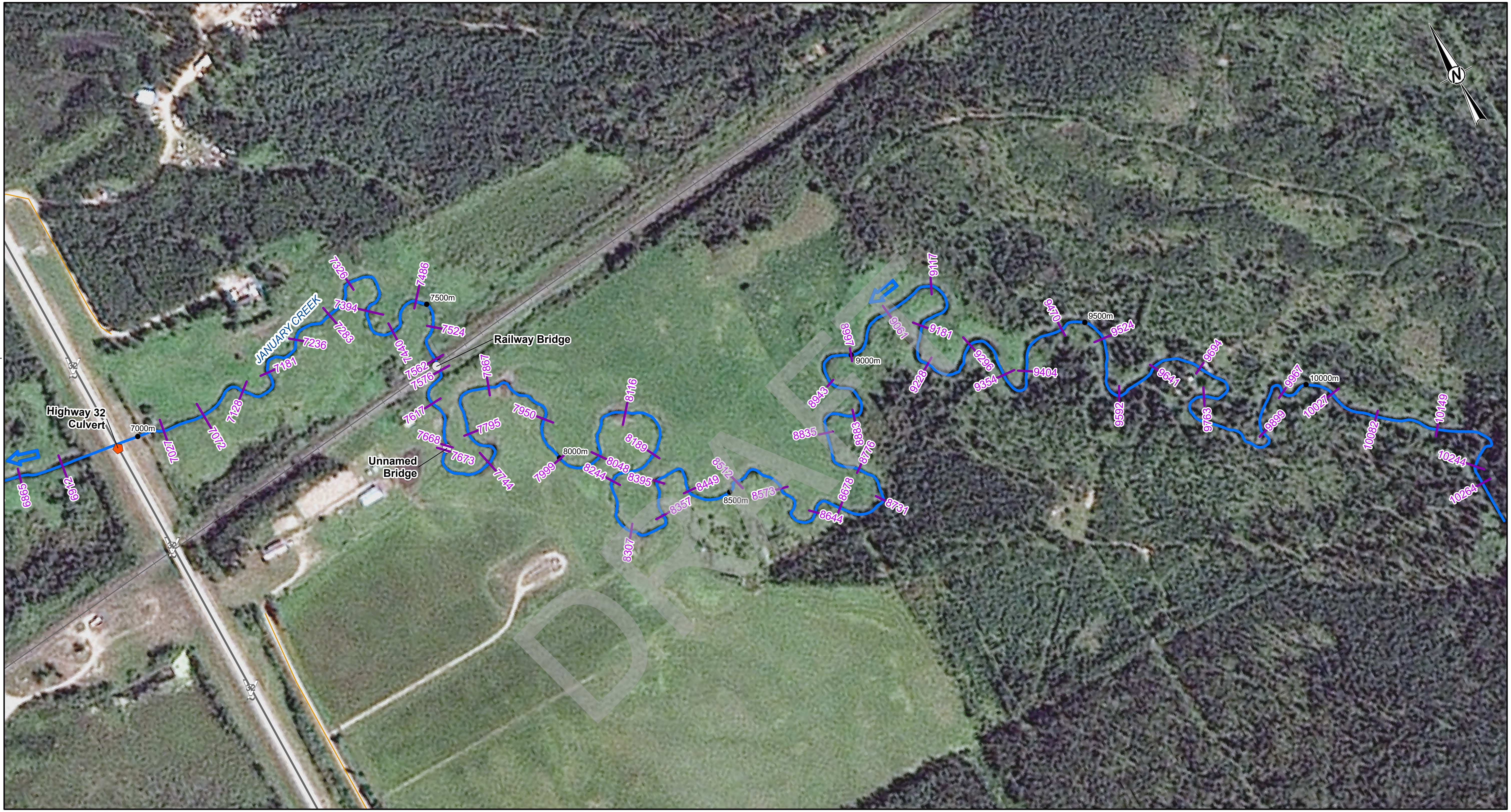
PROJECT
PEERS FLOOD STUDY

CONSULTANT

YYYY-MM-DD	2025-09-19
DESIGNED	AL
PREPARED	MV
REVIEWED	GT
APPROVED	LH

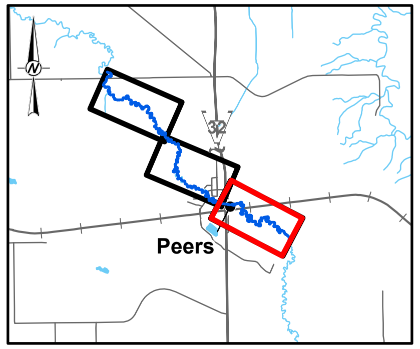
TITLE
LOCATIONS OF CROSS SECTIONS AND HYDRAULIC STRUCTURES

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	1001	0	SHEET 2 OF 3



LEGEND

- • PROFILE STATION
- FLOW DIRECTION
- LOCAL ROAD
- PRIMARY HIGHWAY
- RAILROAD
- BRIDGE
- CULVERT
- SURVEY REACH
- SURVEYED CROSS SECTION (STATIONING, m)



0 100 200
1:4,000 METRES

CLIENT
ALBERTA ENVIRONMENT AND PROTECTED AREAS

Alberta Canada

CONSULTANT

wsp

YYYY-MM-DD	2025-09-19
DESIGNED	AL
PREPARED	MV
REVIEWED	GT
APPROVED	LH

REFERENCE(S)
ROADS AND WATERBODIES OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED OR ALTALIS LTD.© GOVERNMENT OF ALBERTA 2025. ALL RIGHTS RESERVED. PROJECT IMAGERY CAPTURED AUGUST 2023 BY PLANET LABS GEOMATICS CORP. FOR THE GOVERNMENT OF ALBERTA.
DATUM: NAD 83 CSRS PROJECTION: 3TM 117

PROJECT
PEERS FLOOD STUDY

TITLE
LOCATIONS OF CROSS SECTIONS AND HYDRAULIC STRUCTURES

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	1001	0	SHEET 3 OF 3

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

Classification: Public

APPENDIX B

Hydraulic Structure Datasheets

0 50 100

1:1,500 METRES

PHOTO 1 LEFT BANK, LOOKING UPSTREAM

PHOTO 2 RIGHT BANK, LOOKING DOWNSTREAM

TITLE

HS-01 HYDRAULIC STRUCTURE DATASHEET - UNNAMED BRIDGE

LOCATION	JANUARY CREEK
DESCRIPTION	UNNAMED BRIDGE
BRIDGE FILE NUMBER	
TOTAL LENGTH OF SPAN (m)	5.51
DECK WIDTH OF BRIDGE (m)	2.91
AVERAGE TOP OF CURB OR SOLID GUARD RAIL ELEVATION (m)	844.38
AVERAGE LOW CHORD ELEVATION (m)	844.2
BRIDGE OBSTRUCTION HEIGHT (m)	0.18
NUMBER OF PIERS	0

PIER	CENTRE STATION (m)	WIDTH (m)	TYPE	SHAPE
NONE				

LEGEND

- BRIDGE SURVEY POINT
- FLOW DIRECTION
- RAILROAD
- LOCAL ROAD
- PRIMARY HIGHWAY

NOTE(S)

BRIDGE SURVEY DETAILS WERE USED FOR HYDRAULIC MODELLING.

REFERENCE(S)

BRIDGE SURVEY AND BRIDGE PHOTOS BY WSP CANADA INC. OCT 2024.
ROADS OBTAINED FROM ALTALIS © GOVERNMENT OF ALBERTA 2023. ALL RIGHTS RESERVED.
IMAGERY CAPTURED 2023 BY PROVINCIAL GEOSPATIAL CENTRE FOR THE GOVERNMENT OF ALBERTA.
DATUM: NAD 83 CSRS PROJECTION: 3TM 117

CLIENT

ALBERTA ENVIRONMENT AND PROTECTED AREAS

Alberta Canada

PROJECT

PEERS FLOOD STUDY

CONSULTANT

wsp

YYYY-MM-DD	2025-09-19
DESIGNED	AL
PREPARED	MV
REVIEWED	GT
APPROVED	LH

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	1001	0	B-1

0 50 100

1:1,500 METRES

PHOTO 1 LEFT BANK, LOOKING UPSTREAM

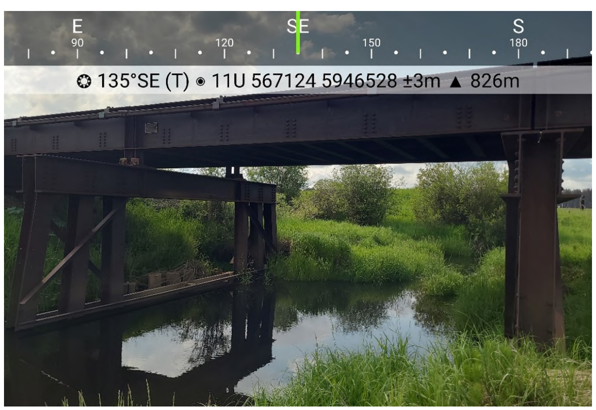


PHOTO 2 LEFT BANK, LOOKING DOWNSTREAM

TITLE

HS-02 HYDRAULIC STRUCTURE DATASHEET - RAILWAY BRIDGE

LOCATION	JANUARY CREEK
DESCRIPTION	RAILWAY BRIDGE
BRIDGE FILE NUMBER	
TOTAL LENGTH OF SPAN (m)	21.95
DECK WIDTH OF BRIDGE (m)	8.88
AVERAGE TOP OF CURB OR SOLID GUARD RAIL ELEVATION (m)	847.93
AVERAGE LOW CHORD ELEVATION (m)	846.91
BRIDGE OBSTRUCTION HEIGHT (m)	1.02
NUMBER OF PIERS	2

PIER	CENTRE STATION (m)	WIDTH (m)	TYPE	SHAPE
1	7.75	0.3	STEEL	H-SHAPE
2	15	0.3	STEEL	H-SHAPE

LEGEND

- BRIDGE SURVEY POINT
- FLOW DIRECTION
- RAILROAD
- LOCAL ROAD
- PRIMARY HIGHWAY

NOTE(S)

BRIDGE SURVEY DETAILS WERE USED FOR HYDRAULIC MODELLING.

REFERENCE(S)

BRIDGE SURVEY AND BRIDGE PHOTOS BY WSP CANADA INC. OCT 2024,
ROADS OBTAINED FROM ALTALIS © GOVERNMENT OF ALBERTA 2023. ALL RIGHTS RESERVED.
IMAGERY CAPTURED 2023 BY PROVINCIAL GEOSPATIAL CENTRE FOR THE GOVERNMENT OF ALBERTA.
DATUM: NAD 83 CSRS PROJECTION: 3TM 117

CLIENT

ALBERTA ENVIRONMENT AND PROTECTED AREAS

Alberta Canada

PROJECT

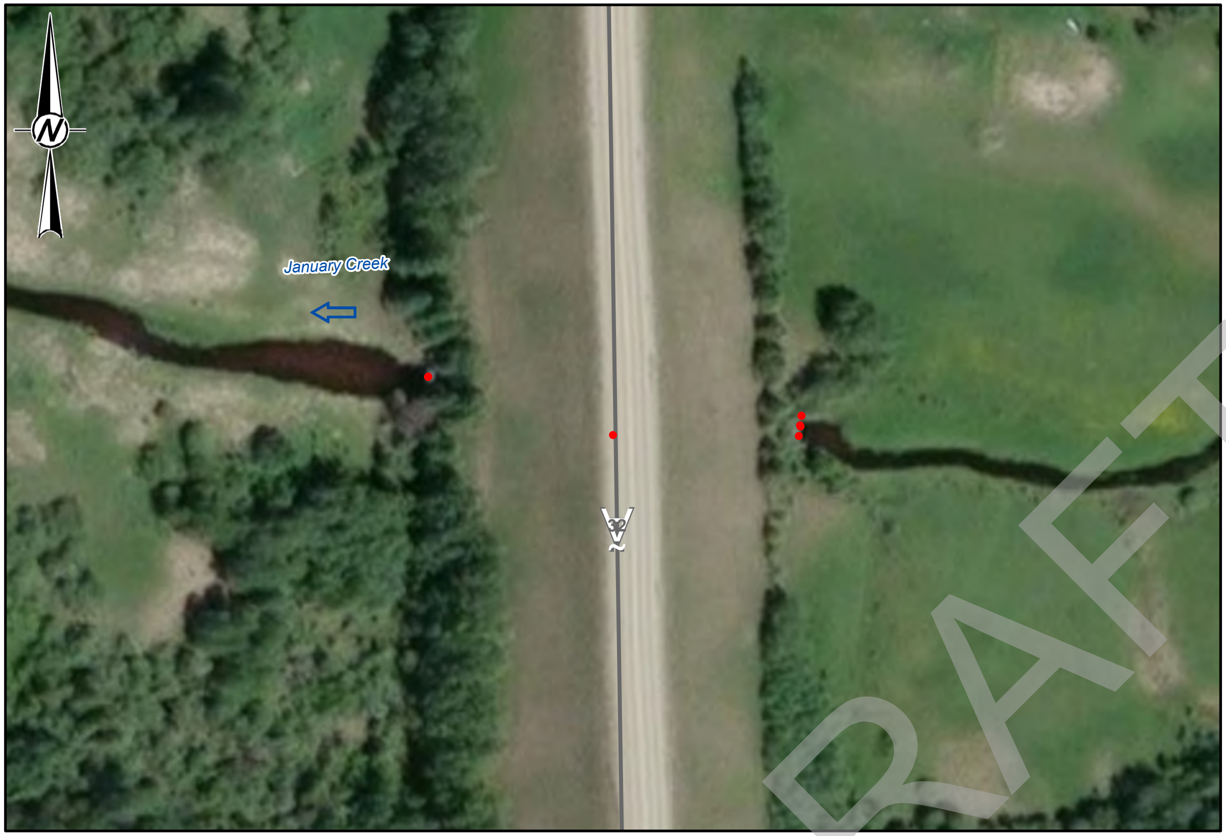
PEERS FLOOD STUDY

CONSULTANT

wsp

YYYY-MM-DD	2025-09-19
DESIGNED	AL
PREPARED	MV
REVIEWED	GT
APPROVED	LH

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	1001	0	B-2



0 50 100

1:1,500 METRES

DRAFT

PHOTO 1 LEFT BANK, LOOKING UPSTREAM

PHOTO 2 LEFT BANK, LOOKING DOWNSTREAM

TITLE

HS-03 HYDRAULIC STRUCTURE DATASHEET - HIGHWAY 32 CULVERT

LOCATION	JANUARY CREEK
DESCRIPTION	HIGHWAY 32 CULVERT
NUMBER OF CULVERTS	1
CULVERT TYPE	CORRUGATED STEEL PIPE
CULVERT SHAPE	ELLIPSE

CULVERT	LENGTH (m)	RISE (m)	SPAN (m)	UPSTREAM INVERT ELEVATION (m)	DOWNSTREAM INVERT ELEVATION (m)
1	90	6.18	4.05	841.1	840.83

LEGEND

- CULVERT SURVEY POINT
- FLOW DIRECTION
- LOCAL ROAD
- PRIMARY HIGHWAY

NOTE(S)

CULVERT SURVEY DETAILS WERE USED FOR HYDRAULIC MODELLING.

REFERENCE(S)

CULVERT SURVEY AND CULVERT PHOTOS BY WSP CANADA INC. OCT 2024,
ROADS OBTAINED FROM ALTALIS © GOVERNMENT OF ALBERTA 2023. ALL RIGHTS RESERVED.
IMAGERY CAPTURED 2023 BY PROVINCIAL GEOSPATIAL CENTRE FOR THE GOVERNMENT OF ALBERTA.
DATUM: NAD 83 CSRS PROJECTION: 3TM 117

CLIENT

ALBERTA ENVIRONMENT AND PROTECTED AREAS

PROJECT

PEERS FLOOD STUDY

CONSULTANT

YYYY-MM-DD	2025-09-19
DESIGNED	AL
PREPARED	MV
REVIEWED	GT
APPROVED	LH

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	1001	0	B-3

TITLE

HS-04 HYDRAULIC STRUCTURE DATASHEET - WILLOW DR. BRIDGE

0 50 100

1:1,500 METRES

LOCATION	JANUARY CREEK
DESCRIPTION	WILLOW DR. BRIDGE
BRIDGE FILE NUMBER	08060
TOTAL LENGTH OF SPAN (m)	10.67
DECK WIDTH OF BRIDGE (m)	9.3
AVERAGE TOP OF CURB OR SOLID GUARD RAIL ELEVATION (m)	846.8
AVERAGE LOW CHORD ELEVATION (m)	845.43
BRIDGE OBSTRUCTION HEIGHT (m)	1.37
NUMBER OF PIERS	0

PIER	CENTRE STATION (m)	WIDTH (m)	TYPE	SHAPE
NONE				

LEGEND

- BRIDGE SURVEY POINT
- FLOW DIRECTION
- LOCAL ROAD
- PRIMARY HIGHWAY

NOTE(S)

BRIDGE SURVEY DETAILS WERE USED FOR HYDRAULIC MODELLING.

REFERENCE(S)

BRIDGE SURVEY AND BRIDGE PHOTOS BY WSP CANADA INC. OCT 2024.
ROADS OBTAINED FROM ALTALIS © GOVERNMENT OF ALBERTA 2023. ALL RIGHTS RESERVED.
IMAGERY CAPTURED 2023 BY PROVINCIAL GEOSPATIAL CENTRE FOR THE GOVERNMENT OF ALBERTA.
DATUM: NAD 83 CSRS PROJECTION: 3TM 117

PHOTO 1 RIGHT BANK, LOOKING UPSTREAM

PHOTO 2 RIGHT BANK, LOOKING DOWNSTREAM

CLIENT

ALBERTA ENVIRONMENT AND PROTECTED AREAS

Alberta Canada

PROJECT

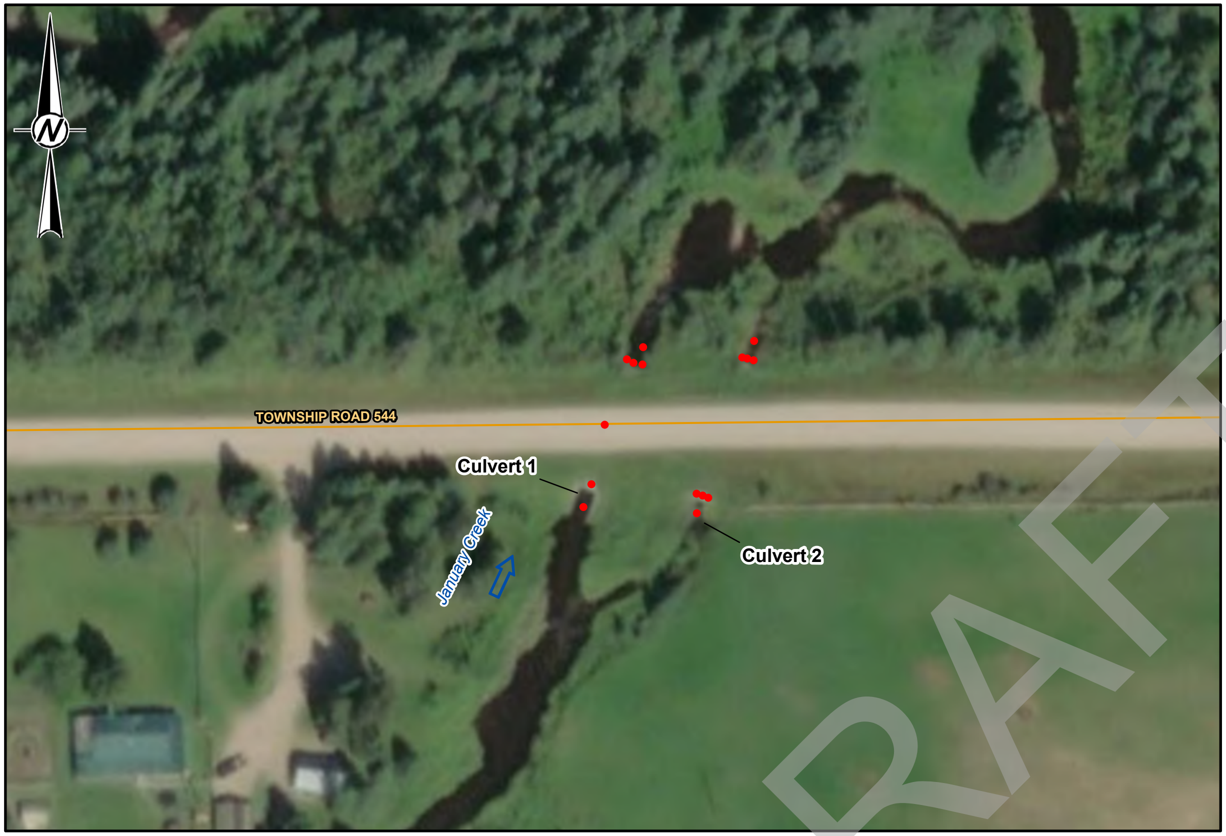
PEERS FLOOD STUDY

CONSULTANT

wsp

YYYY-MM-DD	2025-09-19
DESIGNED	AL
PREPARED	MV
REVIEWED	GT
APPROVED	LH

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	1001	0	B-4



0 50 100

1:1,500 METRES

PHOTO 1 CULVERT 1, LOOKING DOWNSTREAM

PHOTO 2 CULVERT 2, LOOKING DOWNSTREAM

TITLE

HS-05 HYDRAULIC STRUCTURE DATASHEET - TOWNSHIP ROAD 544 CULVERT

LOCATION	JANUARY CREEK
DESCRIPTION	TOWNSHIP 544 RD CULVERT
NUMBER OF CULVERTS	2
CULVERT TYPE	CORRUGATED STEEL PIPE
CULVERT SHAPE	ELLIPSE

CULVERT	LENGTH (m)	RISE (m)	SPAN (m)	UPSTREAM INVERT ELEVATION (m)	DOWNSTREAM INVERT ELEVATION (m)
1	4.5	4.01	3.26	836.45	836.03
2	15.1	2.82	2.4	836.84	836.43

LEGEND

- CULVERT SURVEY POINT
- FLOW DIRECTION
- LOCAL ROAD
- PRIMARY HIGHWAY

NOTE(S)

CULVERT SURVEY DETAILS WERE USED FOR HYDRAULIC MODELLING.

REFERENCE(S)

CULVERT SURVEY AND CULVERT PHOTOS BY WSP CANADA INC. OCT 2024,
ROADS OBTAINED FROM ALTALIS © GOVERNMENT OF ALBERTA 2023. ALL RIGHTS RESERVED.
IMAGERY CAPTURED 2023 BY PROVINCIAL GEOSPATIAL CENTRE FOR THE GOVERNMENT OF ALBERTA.
DATUM: NAD 83 CSRS PROJECTION: 3TM 117

CLIENT

ALBERTA ENVIRONMENT AND PROTECTED AREAS

PROJECT

PEERS FLOOD STUDY

CONSULTANT

YYYY-MM-DD	2025-09-19
DESIGNED	AL
PREPARED	MV
REVIEWED	GT
APPROVED	LH

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	1001	0	B-5

APPENDIX C

Technical Memorandum on Flood Control Structures

MEMO

TO:	Jim Choles, P.Eng.
COMPANY:	Alberta Environment and Protected Areas (EPA)
FROM:	Martin Lacroix
DATE:	October 29, 2024
CC:	Gaven Tang; Liv Hundal
WSP PROJECT:	CA0041746.1954
EPA Contract:	25RSD911
SUBJECT:	TECHNICAL MEMORANDUM ON FLOOD CONTROL STRUCTURES FOR THE PEERS FLOOD STUDY

1 INTRODUCTION

Alberta Environment and Protected Areas (EPA) retained WSP Canada Inc. (WSP) to conduct the Peers Flood Study. The study is part of the provincial Flood Hazard Identification Program (FHIP), and the purpose of the study is to assess and identify river and flood hazards along the approximately 10 km reach of January Creek within Yellowhead County, including Hamlet of Peers Alberta. The study reach for January Creek extends downstream from its south boundary at SE 15-54-14-W5M to its north boundary at SE 29-54-14-W5M (just north of Township Road 544).

This memorandum documents there is no flood control structures within the above noted study reach.

2 CLOSURE

WSP Canada Inc. (WSP) prepared this report solely for the use of the intended recipient, Alberta Environment and Protected Areas (EPA), in accordance with the professional services agreement. The intended recipient is solely responsible for the disclosure of any information contained in this report. The content and opinions contained in the present report are based on the observations and/or information available to WSP at the time of preparation. If a third party makes use of, relies on, or makes decisions in accordance with this report, said third party is solely responsible for such use, reliance or decisions. WSP does not accept responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken by said third party based on this report. This limitations statement is considered an integral part of this report.

Yours sincerely,

Prepared by:

Martin Lacroix, M.Sc., P.Geo.
Supporting Project Manager, Water Resources

Reviewed by:

Gaven Tang, M.A.Sc., P.Eng
Project Manager, Water Resources

Liv Hundal, M.Eng., P.Eng.
Senior Principal Engineer, Water Resources

WSP Canada Inc.
3300, 237 – 4th Avenue SW
Calgary, AB T2P 4K3

wsp.com

APPENDIX D

Technical Memorandum on Open Water Hydrology Assessment

TECHNICAL MEMORANDUM

DATE June 5, 2025 **Project No.** CA0041746.1954

TO Jim Choles
Alberta Environment and Protected Areas (EPA)

FROM Tebikachew Tariku and Martin Lacroix

CC Getu Biftu and Liv Hundal

OPEN WATER HYDROLOGY ASSESSMENT – PEERS FLOOD STUDY

1.0 INTRODUCTION

1.1 Study Area and Scope

Alberta Environment and Protected Areas (EPA) retained WSP to conduct the Peers Flood Study. The study is part of the provincial Flood Hazard Identification Program (AEP, 2022), and the purpose of the study is to assess and identify river and flood hazards along the 10 km reach of January Creek through Yellowhead County, including the Hamlet of Peers. The study reach extends from the south boundary of SE 15-54-14-W5M downstream to the north boundary of NE 20-54-14-W5M. The open water hydrology assessment results contained in this memorandum will be used as the flood discharges for the hydraulic modeling and open water hydraulic flood mapping. The scope of this memorandum includes data series preparation, regional flood flow regression, flood frequency analysis and climate change commentary.

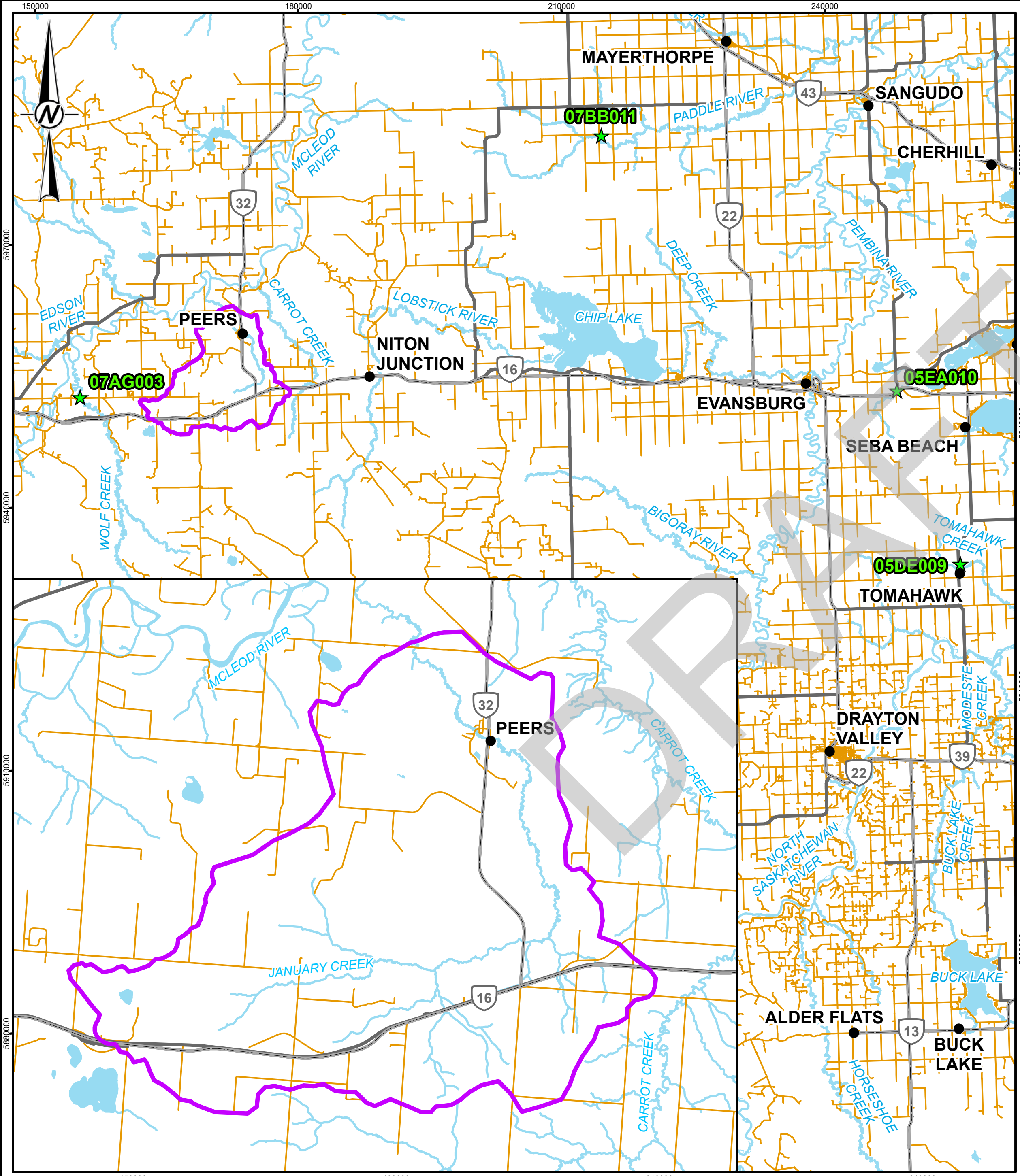
1.2 Study Objectives and Results

The objective of open water hydrology assessment is to determine flood peak discharge estimates at the study reach of January Creek. The assessment included frequency flows of 2-, 5-, 10-, 20-, 25-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1000-year return period for open water flood peak discharges.

1.3 Watershed Setting and Historical Floods

January Creek drains into the McLeod River approximately 8 km downstream of Peers. The January Creek drainage area is approximately 136 km^2 at Peers (i.e., at the downstream end of the study reach) and 143 km^2 at the McLeod River. January Creek is a fourth-order watercourse with a total length of 26 km from its headwaters to the McLeod River. The main drainage area land types are flat agricultural lands. An overall map of the study area and the regional hydrometric stations used for flood analysis are presented in Figure 1.

PATH: I:\CLIENTS\GOVERNMENT_OF_ALBERTA\CA0041746_1954_Peers\Mapping\Hydrology\02_Open Water Hydrology Assessment\CA0041746_1954_Fig1_Watershed-Hydrometric-Stations_Rev0.aprx PRINTED ON: 2025-05-26 AT: 1:12:43 PM



LEGEND

- HYDROMETRIC GAUGING STATION
- SETTLEMENT
- PRIMARY HIGHWAY
- LOCAL ROAD
- PRIMARY HIGHWAY
- WATERCOURSE
- WATERBODY
- JANUARY RIVER WATERSHED

0 20 40

1:700,000 KILOMETRES

REFERENCE(S)

HYDROMETRIC STATIONS OBTAINED FROM WATER SURVEY OF CANADA (WSC).
POPULATED PLACES, ROADS AND HYDROGRAPHY OBTAINED FROM GEOGRATIS,

DATUM: NAD 1983 CSRS 3TM 117

CLIENT
ALBERTA ENVIRONMENT AND PROTECTED AREAS

PROJECT
PEERS FLOOD STUDY

TITLE
JANUARY CREEK WATERSHED AT PEERS AND REGIONAL GAUGING STATIONS

CONSULTANT

wsp

YYYY-MM-DD	2025-05-26
DESIGNED	TT
PREPARED	PT
REVIEWED	TT
APPROVED	ML

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	2000	0	1

January Creek is an ungauged stream. The Wolf Creek at Highway No. 16A (WSC Station No. 07AG003) is the closest gauging station and is located approximately 20 km southeast of Peers. The Wolf Creek gauging station has a drainage area of 826 km^2 and recorded data from 1954 to 2023. The largest recorded flood in Wolf Creek occurred on July 18, 1986, with an instantaneous discharge of 570 m^3/s. Other large floods in Wolf Creek occurred on June 20, 2023, and June 26, 1972. The 2023 flood in Wolf Creek, with an instantaneous discharge of 344 m^3/s, exceeded the 50-year return period, based on the flood frequency analysis presented later in this document.

The majority of the floods for Wolf Creek were recorded in June and July. This shows that floods were mostly dominated by summer rainstorms. Hence, the January Creek flood mechanism is likely be similar to that of Wolf Creek.

2.0 AVAILABLE FLOW DATA

2.1 Record Data

The regional hydrometric stations that were used in the regional analysis (see Table 1) were selected based on their proximity to the study area, similar size in drainage areas and similar hydrologic characteristics. The Groat Creek near Whitecourt (07AG008) and Sundance Creek near Bickerdike (07AF010) were initially included in the regional analysis but were later excluded because they showed a different flood response than the other regional hydrometric stations. The Groat Creek has a quick and small duration flood peak than the other because of its small drainage area and steep gradient, whereas the Sundance Creek was slow and steady flood duration, most likely due to the watershed characteristics such as forest dominance, waterbodies along the stream, and watershed orientation.

Table 1: Summary of Gauged Stations Considered in the Regional Study

WSC Station Number	WSC Station Name	Latitude (degrees)	Longitude (degrees)	Approximate Distance from the Study Area (km)	Gross Drainage Area (km^2)	Effective Drainage Area (km^2)	Period of Record	Length of Record (years)
07AG003	Wolf Creek at Highway No. 16A	53.60	-116.27	20	826	807	1955-2023	68
07BB011	Paddle River near Anselmo	53.86	-115.36	45	253	253	1980-2024	44
05EA010	Sturgeon River near Magnolia Bridge	53.59	-114.86	75	121	121	1981-2022	41
05DE009	Tomahawk Creek near Tomahawk	53.41	-114.76	86	94.2	94.2	1984-2024	40

2.2 Historic Data

There are no additional historic flow data available for the study area before systematic gauging and monitoring by the WSC stations. However, high water marks (HWM) were measured along the January Creek during the 1980 and 2023 flood events. These HWMs were used to evaluate the flood flow estimate for January Creek through regional analysis.

2.3 Previous Studies

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

- The 2016 January Creek Flood Risk Assessment that was incorporated into the Hamlet of Peers Area Structure Plan, September 2017 (AMEC 2016).
- Assessment of climate change effects on water yield from the North Saskatchewan River (NSR) Basin for North Saskatchewan Watershed Alliance (Golder 2008).

The review involved documentation of the assumptions, limitations, and understanding of the hydrologic techniques applied in 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 a large number of 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 Ungauged Locations

Empirical relationships were developed between the drainage areas and flood frequency estimates for the regional WSC hydrometric stations listed in Table 1. The relationships were then used to derive the flood frequency estimates for the January Creek through Hamlet of Peers and Yellowhead County in the study area.

The best-fit power functions were used, and the following steps were undertaken to complete the flood frequency estimates:

- The drainage areas, annual maximum daily discharges, and annual maximum instantaneous discharges for WSC hydrometric stations were compiled.
- Graphical regressions between event-based annual maximum daily discharges and annual maximum instantaneous discharges (same flood event for both values) were developed for each WSC hydrometric station to derive missing annual maximum instantaneous discharges (graphs are provided in Appendix A).
- The complete sets of annual maximum instantaneous discharges were used to estimate flood frequency flows for a range of return periods from 2- to 1000-year (frequency analyses for different stations are provided in Appendix B).

- The flood frequency estimates and corresponding drainage areas for each station were plotted, and graphical regressions were developed for each return period, as shown in Figure 2. Although the R-square value for the curves is good, as shown on the figure, for moderate to large floods (e.g., 20-year return period and greater), Tomahawk Creek and Wolf Creek plot below the regression curve and Sturgeon River and Paddle River plot above the regression curve. For example, the best fit 100-year return period regression line plots at the 500-year return period estimate for Tomahawk Creek. The individual physiographic and land use characteristics of each watershed account for this difference. Table 2 below lists select physiographic and land use characteristics of the gauged watershed and January Creek. The Tomahawk Creek was selected to best represent the January Creek watershed, based on a comparison of these characteristics. In particular, Tomahawk Creek best represents January Creek with respect to: (1) the average watershed elevation; (2) average watershed slope (defined as the average slope of the land that makes up a watershed is calculated as mean of slope of each grid of land within the watershed) and the land use characteristics (i.e., proportion of watershed that is agricultural and forested). The average channel slope of Tomahawk Creek and January Creek are 0.28% and 0.11%, respectively. This may result in a degree of conservativeness in the January Creek flood discharge estimates (i.e., a steeper channel slope usually results in a higher unit discharge).
- The flood peak discharges for January Creek for various return periods were estimated from the flood frequency analysis of Tomahawk Creek near Tomahawk (Station No. 05DE009), which has similar watershed characteristics such as land use, watershed slope, and channel slope close to January Creek using a linear area transfer relationship as shown in the equation below:

$$Q_{\text{January Creek,n return period}} = Q_{Tomahawk\ Creek,n\ return\ period} \left(\frac{Drainage\ Area_{\ January\ Creek}}{Drainae\ Area_{\ Tomahawk\ Creek}} \right)^{C,n\ return\ period}$$

Where, Q is peak discharge, n return periods from 2- to 1000-year, and C is the power coefficient from the regional relationship shown in Figure 2.

Table 2: Physiographic and Land Use Characteristics of the Gauged Watershed and January Creek

	Wolf Creek at Highway No. 16A (07AG003)	Tomahawk Creek near Tomahawk (05DE009)	Sundance Creek near Bickerdike (07DF010)	January Creek
Drainage Area (km^2)	807	94.2	178	136
Channel Length (km)	123	20.0	54.0	33.0
Average Channel Slope (%)	0.18	0.28	1.21	0.11
Average Watershed Slope (%)	3.95	2.49	8.16	2.14
Average Watershed Elevation (m)	1014	802	1082	880
Land Use Fraction[(a)]				
Agriculture	1%	35%	0%	24%
Broadleaf forest	8%	26%	17%	16%
Coniferous forest	56%	12%	62%	22%
Developed	5%	5%	4%	9%
Exposed land	0%	0%	0%	0%
Grassland	6%	14%	7%	8%
Mixed forest	3%	4%	3%	5%
Rock/Rubble	0%	0%	0%	0%
Shrubland	18%	5%	4%	16%
Snow/Ice	0%	0%	0%	0%
Water	3%	0%	2%	0%

Note(s):
(a) Based on the ABMI land cover data.

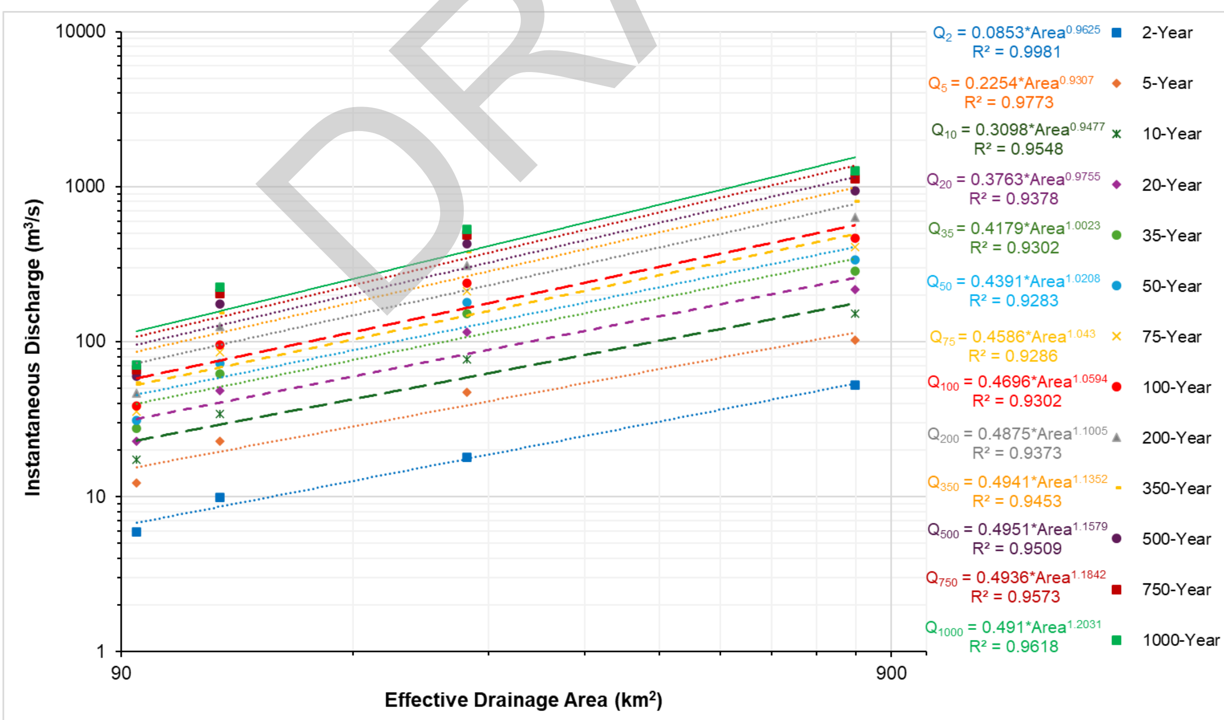


Figure 2: Empirical Relationships between Flood Peak Flows and Drainage Areas for the Regional Stations

4.0 FLOOD FREQUENCY ANALYSIS

4.1 Statistical Tests

4.1.1 Methodology

Prior to fitting the appropriate frequency distribution to the flood flow data, a number of statistical tests were performed to determine the quality of the developed annual maximum instantaneous discharge series. Software developed by WSP that is similar to Environment Canada's Consolidated Frequency Analysis (CFA), but with enhanced methodology, was used for flood frequency analyses and statistical analysis for independence (not serially correlated), trend, randomness, and homogeneity tests. WSP's software includes a 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)
- Weibull distribution (Moment)

Best fit distributions were selected based on the non-parametric Anderson-Darling test.

4.1.2 Results

The results of statistical analysis for the regional stations are provided in Table A-2 in Appendix A. The results show that the annual maximum instantaneous discharge series are independent, random, homogeneous, and do not display any significant trends at both the 5% and 1% levels of significance.

4.2 Flood Frequency Estimates

Flood frequency analyses of the annual maximum instantaneous discharge series for regional WSC Hydrometric Stations were conducted to estimate the flood peak discharges of various return periods of floods (i.e., 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1000-year floods). The annual maximum instantaneous discharge 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 B.

The flood frequency estimates for January Creek were estimated using the regional relationships described in Section 3.2. The resulting flood frequency estimates and the associated upper and lower 95% confidence intervals are summarized in Table 3. The Tomahawk Creek near Tomahawk, which has a watershed characteristic close to the January Creek is used to estimate the upper and lower 95% estimates for January Creek.

Table 3: Flood Frequency Estimates for January Creek at Peers using Regional Analysis

Return Periods (years)	Annual Probability of Exceedance (%)	Flood Frequency Estimates (m^3/s)		
		Lower 90% Limit[(a)]	Value	Upper 90% Limit[(a)]
2	50	5.77	8.47	12.4
5	20	12.2	17.2	22.8
10	10	17.4	24.4	31.4
20	5.0	22.7	32.5	41.7
35	2.9	27.3	40.0	52.1
50	2.0	30.1	45.3	59.8
75	1.3	33.1	51.7	70.1
100	1.0	35.2	56.7	79.0
200	0.50	40.1	70.1	103
350	0.29	43.7	82.5	129
500	0.20	46.1	91.2	147
750	0.13	48.7	102	171
1000	0.10	50.4	110	190

Note(s):

(a) Values calculated based on values for Tomahawk Creek near Tomahawk (i.e., the ratio of the best flood frequency estimates to lower/upper confidence limits for each return period were used as factors).

4.3 Comparison of Previous Studies

A comparison of the flood frequency estimates obtained in this study for January Creek with estimates previously completed by AMEC (2010, 2016), is provided in Table 4.

In the AMEC (2010, 2016) studies, flood frequency estimates for January Creek were based on high water marks (HWM) from June 5, 1980, as well as flood frequency estimates for Wolf Creek and Sundance Creek. The discharge of January Creek for the 1980 flood was estimated to be 18.0 m^3/s using culvert hydraulic modelling, based on the known culvert/channel geometry and gradient, as well as HWM's. Based on the flood frequency estimates for the Sundance Creek and Wolf Creek gauges, the 1980 flood has a return period of 10- to 20-year. Hence, AMEC (2010, 2016) studies assumed that the discharge of 18 m^3/s estimated for the 1980 January Creek flood has a return period of 20-year. The ratio of 100-year to 20-year discharge for Sundance Creek and Wolf Creek were estimated to range from 1.6 to 2.3. Therefore, the ratio of 1.67 was used to estimate the 100-year flood for January Creek, which is 30 m^3/s. The AMEC (2016) study used recorded data from Wolf Creek up to 2015 to update the flood frequency estimate and the ratio of 100-year to 20-year discharge (i.e., the ratio of 1.78 was used for January Creek). Filling of missing data was considered a similar approach as in this study.
The average of the three distributions (i.e., 3-Parameter Log-normal, EV, and Gumbel) was used for the data in the AMEC (2016) study, while the Extreme Value 2 distribution is selected as the best distribution fit to the data in this study.

The resulting flood frequency estimates for this study are higher than those in AMEC (2010, 2016) estimates. The comparison in Table 4 shows that the main differences in the flood frequency estimates are due to the different approaches used to estimate flood flows and lengths of the recorded data used in the flood frequency analyses as well as the selections of different frequency curve distributions.

Table 4: Comparison of the Flood Frequency Estimates of Various Studies

Return Period (years)	AMEC (2010)[(a)]	AMEC (2016)[(b)]	This Study (2024)
2	4.90	-	8.47
5	10.2	-	17.2
10	14.3	-	24.4
20	18.0	18.0	32.5
50	25.0	-	45.3
100	30.0	32.0	56.7

Note(s):

(a) The AMEC (2010) study involved use of the recorded 1980 HWM's at the Highway 32 crossing and culvert hydraulic modelling, as well as Sundance Creek and Wolf Creek flood frequency estimate using recorded data from 1955 to 2010 and use of an index flood approach.

(b) The AMEC (2016) study updated the AMEC (2010) flood frequency estimate for Wolf Creek, including five additional annual peak flow records (from 2010 to 2015), and updated the ratio of 100-year to 20-year flood discharge.

5.0 POTENTIAL EFECTS OF CLIMATE CHANGE ON FLOOD PEAK DISCHARGES AND FLOOD FREQUENCY ESTIMATES

In recent years, flooding has been identified as the most frequent and costliest natural disaster in Canada, with thousands of homeowners experiencing property damage and loss of personal belongings (Moudrak and Feltmate 2017). Recent studies on the effect of climate change on surface water supplies in the North Saskatchewan River (NSR) basin above Edmonton (Anis and Sauchyn 2021) indicate that climate change could result in increased air temperature, precipitation, and runoff, and increased flooding. As a result of climate change and variability, the NSR Basin could experience warmer air temperatures and changes in streamflow magnitude and timing (e.g., higher winter streamflows and lower summer streamflows). Stadnyk and Déry (2021) predict the following for the Mackenzie River basin (i.e., January Creek is part of this basin): (1) virtually certain increase in temperature (+4.0°C); (2) medium confidence in increasing precipitation (+10%); (3) very likely decline in SWE (-2.5 to 0% per decade); (4) highly likely increase in streamflow; and (5) medium confidence in decreasing headwater runoff.

Bush and Lemmen (2019) note the following effects of climate change on Canada: (1) the frequency of temperature and precipitation extremes will change, leading to more frequent droughts and floods with stronger warming in the winter, as well as daily extreme precipitation increases along with decreases in summer precipitation; (2) decline in snow cover extent, including portions of the year with snow cover decreases and later snow onset and earlier spring melt, but that decreases/increases in snow accumulation vary from area to area; and (3) annual flows have varied with increases in annual and winter runoff and declines in summer flow, as well as with the earlier onset of spring freshet there has also been, and is predicted to be, more rain on snow events. As Bush and Lemmen (2019) unambiguously state: "*Canada's climate has warmed and will warm further in the future, driven by human influence*".

Dibike et al. (2019) comments that changes in the frequency and magnitude of peak flow events for the Athabasca River result from a temperature-induced shift in precipitation from snowfall towards rain with corresponding changes in precipitation intensity and snowmelt timing. Dibike et al. (2019) also note an overall projected increase in peak flows, especially low-frequency events, and that projected changes in the 100-year peak flow events for points along the Athabasca River could range between 4% and 33% under high emission scenarios.

Appendix C contains more detailed information from both Bush and Lemmen (2019) and Dibike et al. (2019) studies.

Golder (2008) completed an assessment of the effect of climate change using four selected representative GCMs (i.e., CGCM3T47, ECHAM50M, GFDLC21, and NCARCCSM3) and three scenarios (i.e., SR-A1B, SR-A2, and SR-B1) outputs for the NSR. The projected climate change was 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 2021 to 2050) as represented by its 30-year average. The results indicated that the changes in mean annual flow for the NSR watershed could vary from decreasing projections ranging from 3% to 23% to increasing projections range from 5% to 15%. Therefore, the changes in the mean annual discharges for NSR were expected to be small for the median climate change projections. This study did not provide results for flood peaks analyses.

Kienzle et al. (2012) analyzed the impact of climate change using four GCMs and three scenario outputs for the NSR. The projected climate change was between the modelled baseline period (1961 to 1990) and three modelled future periods (2010-2039 [2020s], 2040-2069 [2050s], and 2070-2099 [2080s]). The five selected scenarios representing climate conditions in this study were BCM 20 (A2), MIROC32 (A1B), CCSM30 (B1), CCSM30 (A1B), and CGCM3 (B1). The results from this study indicated that the flood peaks for the NSR watershed would increase for all climate scenarios and future periods.

Using the predictions from the Canadian Regional Climate Model, Valeo et al. (2007) showed that May precipitation could increase by more than 35 percent under a 2xCO_2 scenario. The resulting increases in precipitation in May could nearly double spring peak flows.

Droppo et al.'s (2018) 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.

The International Panel on Climate Change (IPCC) is the United Nations body that assesses the science related to climate change. Since it was created in 1988, it has produced a series of synthesis reports (i.e., 1990; 1995; 2001; 2007; 2014; 2023). These reports use data from the most up-to-date General Climate Models (GCMs) which in turn help guide policymakers around the world toward mitigation and adaptation strategies with respect to climate change (IPCC, 2023).

The previous GCM model outputs used in the IPCC assessments were based on Representative Concentration Pathways (RCPs) describing different levels of greenhouse gases and radiative forcings (i.e., RCP2.6, RCPR4.5, RCP6.0, and RCP8.5 expressed in watts per meter squared). The IPCC's sixth assessment report (AR6) uses the most recent generation of climate model outputs based on the Scenario Model Intercomparison Project (ScenarioMIP) Phase 6 of the Coupled Model Intercomparison Project (CMIP6) from the World Climate Research Programme (WCRP).

The current emission scenarios are called Shared Socioeconomic Pathways (SSPs) and there are five families of SSP-based scenarios that can be categorized along two broad axes, i.e., challenges to mitigation and challenges to adaptation (see Appendix D for broader detail on SSPs).

For the current Peers study, WSP completed an assessment using Wang et al. (2016) which uses an ensemble of 13 GCMs for SSP126, SSP245, and SSP585. Appendix D shows selected figures from these SSPs along with the baseline of 1991-2020 for the location of Peers AB (i.e., 53° 40’ 14” N; 116° 00’ 00” W) at an elevation of 848 m asl. Relevant results are summarized below:

- **Mean annual temperature** is expected to increase between 3.9°C to 4.0°C (2020s), 4.7°C to 5.9°C (2050s) and 4.9°C to 8.2°C (2080s) under the different emissions scenarios of SSP126, SSP245, and SSP585, respectively, compared to the baseline of 3.0°C for 1991-2020 (see Figure D-4 in Appendix D).
- **Mean annual precipitation** is expected to increase between 598 to 601 mm(2020s), 618 to 624 mm (2050s) and 616 to 637 mm (2080s) under the different emissions scenarios of SSP126, SSP245, and SSP585, respectively, compared to the baseline of 518 mm for 1991-2020 (see Figure D-5 in Appendix D).
- **May to September mean precipitation** is expected to increase between 428 to 431 mm (2020s), 438 to 444 mm (2050s), and 425 to 450 mm (2080s) under the different emissions scenarios of SSP126, SSP245, and SSP585, respectively, compared to the baseline of 363 mm for 1991-2020 (see Figure D-6 in Appendix D).
- **Mean precipitation as snow** is expected to increase between 118 to 119 mm (2020s), 110 to 116 mm (2050s), and 89 to 114 mm (2080s) under the different emissions scenarios of SSP126, SSP245, and SSP585, respectively, compared to the baseline of 108 mm for 1991-2020 (see Figure D-7 in Appendix D). However, it is worth noting that amounts are slowly decreasing as we progress into the future.
- **Winter mean temperatures** (December; January; February (DJF)) are expected to vary slightly higher (colder) between -9.6°C to -9.7°C (2020s) compared to the baseline of -9.3°C for 1991-2000, and are expected to decrease (warm) to between -7.6°C to -8.7°C (2050s) and -5.3°C to -8.5°C (2080s) under the different emissions scenarios of SSP126, SSP245, and SSP585, respectively (see Figure D-8 in Appendix D).
- **Spring mean temperatures** (March; April; May (MAM)) are expected to increase between 4.4°C to 4.5°C (2020s), 5.2°C to 6.1°C (2050s), and 5.3°C to 8.1°C (2080s) under the different emissions scenarios of SSP126, SSP245, and SSP585, respectively, compared to the baseline of 3.5°C for 1991-2020 (see Figure D-9 in Appendix D).
- **Winter mean precipitation** (DJF) is expected to increase to 77 mm (2020s), between 80 to 83 mm (2050s) and 79 to 88 mm (2080s) under the different emissions scenarios of SSP126, SSP245, and SSP585, respectively, compared to the baseline of 59 mm for 1991-2020 (see Figure D-10 in Appendix D).
- **Spring mean precipitation** (MAM) is expected to increase from the baseline of 105 mm for 1991-2020 to 116 to 119 mm (i.e., 11.4% to 13.3% increase) for the 2020s, 127 to 132 mm (i.e., 21.0% to 25.7% increase) for the 2050s and 125 to 145 mm (i.e., 19.0% to 38.1% increase) for the 2080s under the different emissions scenarios of SSP126, SSP245, and SSP585 (see Figure D-11 in Appendix D).
- **Summer mean precipitation** (June; July; August (JJA)) is expected to increase between 304 to 306 mm (2020s), 302 to 312 mm (2050s), and 283 to 313 mm (2080s) under the different emissions scenarios of SSP126, SSP245, and SSP585, respectively, compared to the baseline of 258 mm for 1991-2020 (see Figure D-12 in Appendix D).

- **Autumn mean precipitation** (September; October; November (SON)) is expected to increase between 100 to 101 mm (2020s), 100 to 107 mm (2050s), and 101 to 112 mm (2080s) under the different emissions scenarios of SSP126, SSP245, and SSP585, respectively, compared to the baseline of 95 mm for 1991-2020 (see Figure D-13 in Appendix D).

Prediction of future scenarios depends on the climate model used for the prediction. In the January Creek basin, precipitation is projected to increase, with a shift toward less precipitation falling as snow and more rainfall-on-snow events (Martz et al. 2007; Valeo et al. 2007). These changes in precipitation patterns could increase the frequency and intensity of extreme events (i.e., floods, droughts, hails, and windstorms). It is also predicted that the flood events for the January Creek basin 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.

Approximately 57 percent of the recorded annual peak flows in Wolf Creek (1954 to 2023) occurred in June and July (Figure 3). The frequency of annual peak flows occurring outside this time window (earlier or later) does not appear to be changing with time. The recent patterns in the timing of these peak flows are similar to what were observed at the beginning of the 21st century. There is no clear evidence that the patterns in magnitude or timing of annual peak flows have changed significantly over the past seventy years.

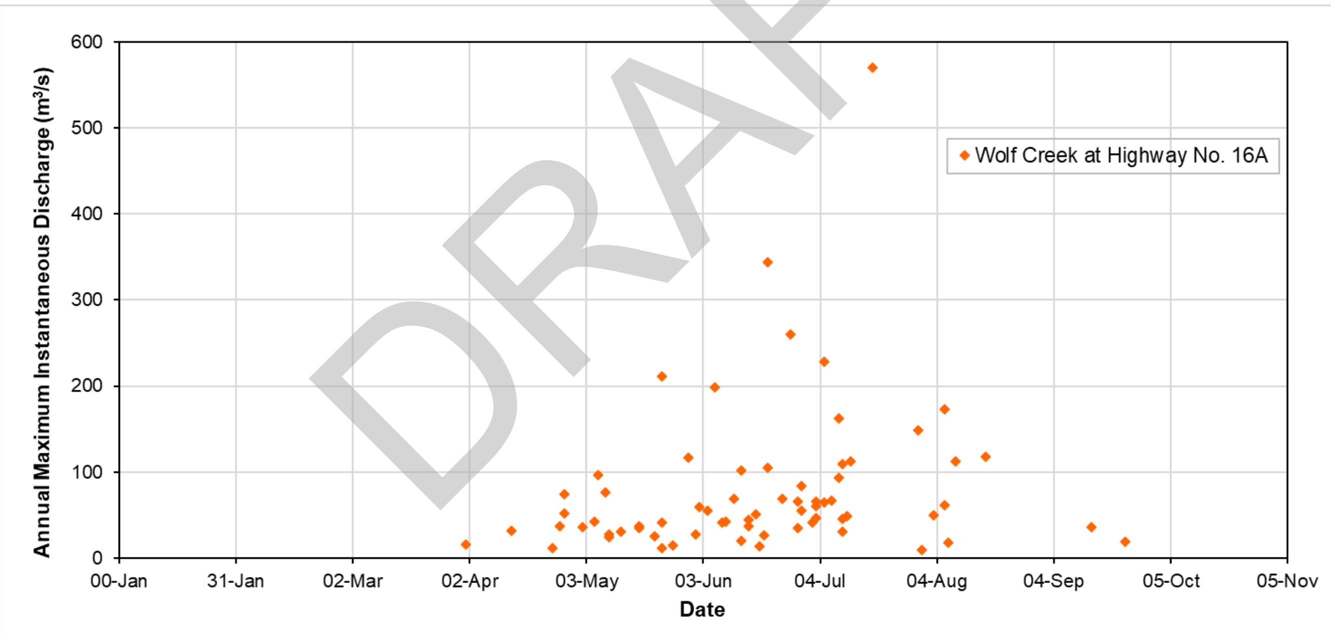


Figure 3: Timing of Wolf Creek Flood Peak Occurrences

6.0 CONCLUSIONS

The flood frequency estimates completed in this study provide the most up-to-date flood hydrology information for the flood mapping component of the study to assess and identify river and flood hazards along the 10 km reach of January Creek through Yellowhead County, including the Hamlet of Peers. Results of the estimates are summarized for various return periods from 2- to 1,000 years with the 95% upper and lower confidence intervals in Table 3.

The length of record data used to derived flood flow series used in the flood frequency analysis is approximately 40 to 68 years. As a result, there are large uncertainties (greater range between the lower and upper confidence intervals) with the flood frequency estimates for return periods greater than 50 years. The open water hydrology assessment results stated in this memorandum will be used as the flood discharges for the hydraulic modeling and open water hydraulic flood mapping task.

7.0 CLOSURE

WSP Canada Inc. (WSP) prepared this report solely for the use of the intended recipient, Alberta Environment and Protected Areas (EPA), in accordance with the professional services agreement. The intended recipient is solely responsible for the disclosure of any information contained in this report. The content and opinions contained in the present report are based on the observations and/or information available to WSP at the time of preparation. If a third party makes use of, relies on, or makes decisions in accordance with this report, said third party is solely responsible for such use, reliance or decisions. WSP does not accept responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken by said third party based on this report. This limitations statement is considered an integral part of this report.

The original of this digital file will be conserved by WSP for a period of not less than 10 years. As the digital file transmitted to the intended recipient is no longer under the control of WSP, its integrity cannot be assured. As such, WSP does not guarantee any modifications made to this digital file subsequent to its transmission to the intended recipient.

This memorandum was prepared and reviewed by the undersigned.

WSP Canada Inc.

Prepared by:

PROFESSIONAL ENGINEER ALBERTA
TEBIKACHEW TARIKU
ID 261659
2025-06-05

Tebikachew Tariku, Ph.D., P.Eng.
Water Resources Engineer

Reviewed by:

PROFESSIONAL ENGINEER ALBERTA
GETU FANA BIFTU
ID 65191
Jun. 6 2025

Getu Biftu, Ph.D., P.Eng.
Fellow, Senior Water Resources Engineer

Martin Lacroix, M.Sc., P.Geo.
Principal Hydrologist & Geoscientist

PROFESSIONAL ENGINEER ALBERTA
LIVLEEN HUNDAL
51344
2025-06-06

Liv Hundal, M.Sc., P.Eng.
Senior Principal Engineer

PERMIT TO PRACTICE
WSP CANADA INC.
RM SIGNATURE:
RM APEGA ID #: 65191
DATE: Jun. 6 2025
PERMIT NUMBER: P007641
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

TT/ML/GB/LH

Attachments: Appendix A – Graphical and Tabulated Summaries of Flood Flow Series at Gauged Stations
Appendix B – Frequency Analysis – Graphs and Tables
Appendix C – Climate Change Quotes from Recent Publications
Appendix D – Selected Future Climate Change Model Figures for Peers

8.0 REFERENCES

AEP (Alberta Environment and Parks). 2022. Flood Hazard Identification Program (FHIP) - Flood Study Technical Guidelines. June 2022.

AMEC. 2010. Hamlet of Peers – Preliminary January Creek Flood Assessment for Proposed Stormwater Pond – NE 16 – 54 – 14 – W5M. April 2010.

AMEC. 2016. Flood Risk Assessment – January Creek (Hamlet of Peers). Submitted to Yellowhead County. August 2016.

Anis, M.R.; Sauchyn, D.J. 2021. Ensemble Projection of Future Climate and Surface Water Supplies in the North Saskatchewan River Basin above Edmonton, Alberta, Canada. Water 2021, 13, 2425. https://doi.org/10.3390/w13172425.

Bush, E. and Lemmen, D.S., editors. 2019. Canada's Changing Climate Report; Government of Canada, Ottawa, ON, 444 p.

Dibike, Y., Eum, H-I, Coulibaly, P. and Hartmann, J. 2019. Projected Changes in the Frequency of Peak Flows along the Athabasca River: Sensitivity of Results to Statistical Methods of Analysis. Climate, 2019, 7, 88; doi.org/10.3390/cli7070088

Droppo, I. G., T. Prowse, B. Bonsal, Y. Dibike, S. Beltaos, B. Krishnappan, H-I. Eum, S. Kashyap, A. Shakibaeinia and A. Gupta. 2018. Regional hydro-climatic and sediment modelling. Oil Sands Monitoring Program Technical Series No. 1.6. 89 p.

Golder. 2008. Assessment of Climate Change Effects on Water Yield from the North Saskatchewan River Basin. Submitted to North Saskatchewan Watershed Alliance. July 2008.

IPCC, 2023. Intergovernmental Panel on Climate Change, Synthesis Report. https://www.ipcc.ch/ar6-syr/, accessed May 2023.

Kienzle, S. W. Michael W. Nemeth, James M. Byrne, Ryan J. MacDonald. 2012. Simulating the hydrological impacts of climate change in the upper North Saskatchewan River basin, Alberta, Canada, Journal of Hydrology, Volumes 412–413. doi.org/10.1016/j.jhydrol.2011.01.058.

Lee, J. Y. et al. (2021) Future Global Climate: Scenario-Based Projections and Near-Term Information. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V. et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 553–672, doi:10.1017/9781009157896.006.

Martz, L., B. Joel and J.T. Rolfe. 2007. Climate Change and Water: SSRB (South Saskatchewan River Basin) Final Technical Report.

Meinshausen et al. (2020). The shared socio-economic pathway (SSP) greenhouse gas concentrations and their extensions to 2500. Geoscientific Model Development, 13(8), 3571–3605. https://doi.org/10.5194/gmd-13-3571-2020.

Moudrak, N. and Feltmate, B. 2017. Preventing Disaster Before It Strikes: Developing a Canadian Standard for New Flood-Resilient Residential Communities. Prepared for Standards Council of Canada. Intact Centre on Climate Adaptation, University of Waterloo. Available at: http://www.intactcentreclimateadaptation.ca/wp-content/uploads/2017/09/Preventing-Disaster-Before-It-Strikes.pdf.

O'Neill et al. 2016: The Scenario Model Intercomparison Project (ScenarioMIP) for CMIP6, Geosci. Model Dev., 9, 3461–3482, 2016, doi:10.5194/gmd-9-3461-2016

Stadnyk, T.A.; Déry, S.J. 2021. Canadian Continental-Scale Hydrology under a Changing Climate: A Review. Water 2021, 13, 906. https://doi.org/10.3390/w13070906.

Valeo, C., Z. Xiang, F.J.C. Bouchart, P. Yeung and M.C. Ryan. 2007. Climate Change Impacts in the Elbow River Watershed. Canadian Water Resources Association Journal. Vol. 32(4): 285-302.

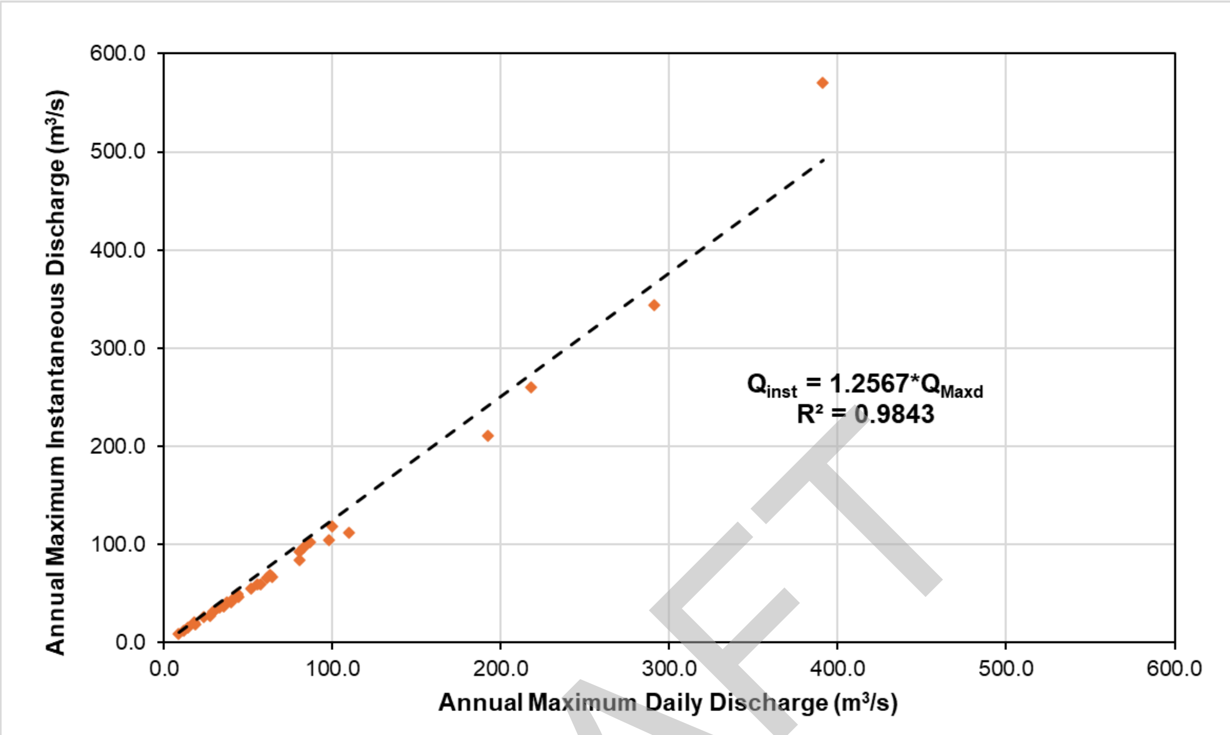
Wang T, Hamann A, Spittlehouse D, Carroll C (2016) Locally Downscaled and Spatially Customizable Climate Data for Historical and Future Periods for North America. PLoS ONE 11(6): e0156720. doi:10.1371/journal.pone.0156720.

WSP. 2023. 2023 Spring Flooding Event Assessment. Submitted to Alberta Emergency Management Agency (AEMA). 10 August 2023.

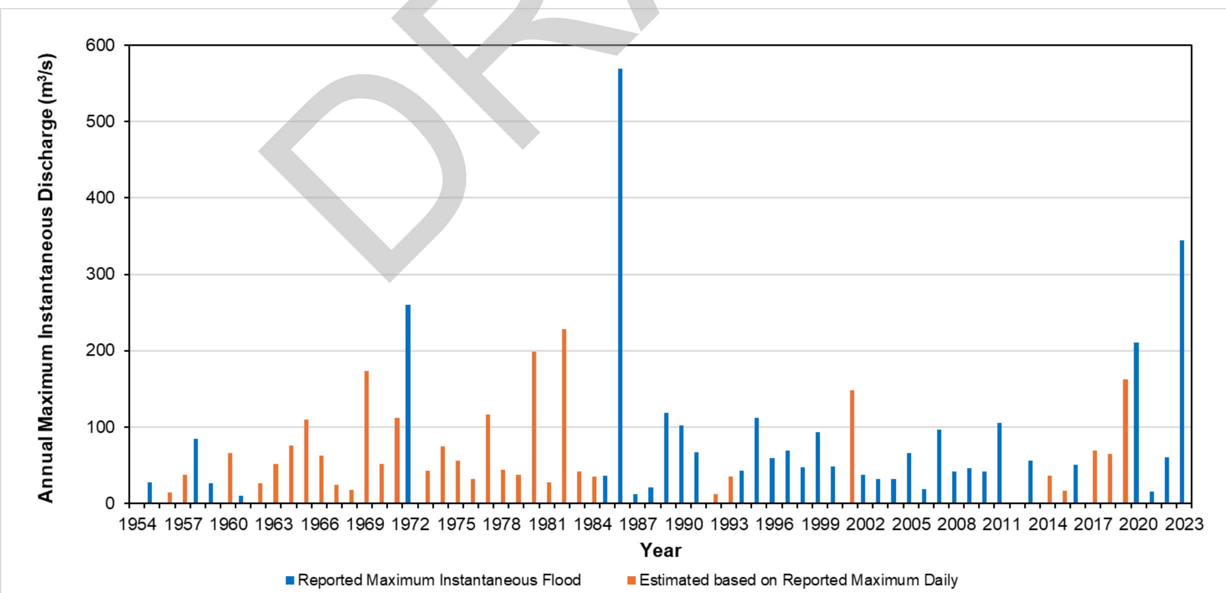
APPENDIX A

Graphical and Tabulated Summaries of Flood Flow Series at Gauged Stations

Figure A-1: WSC Station No. 07AG003, Wolf Creek at Highway No. 16A

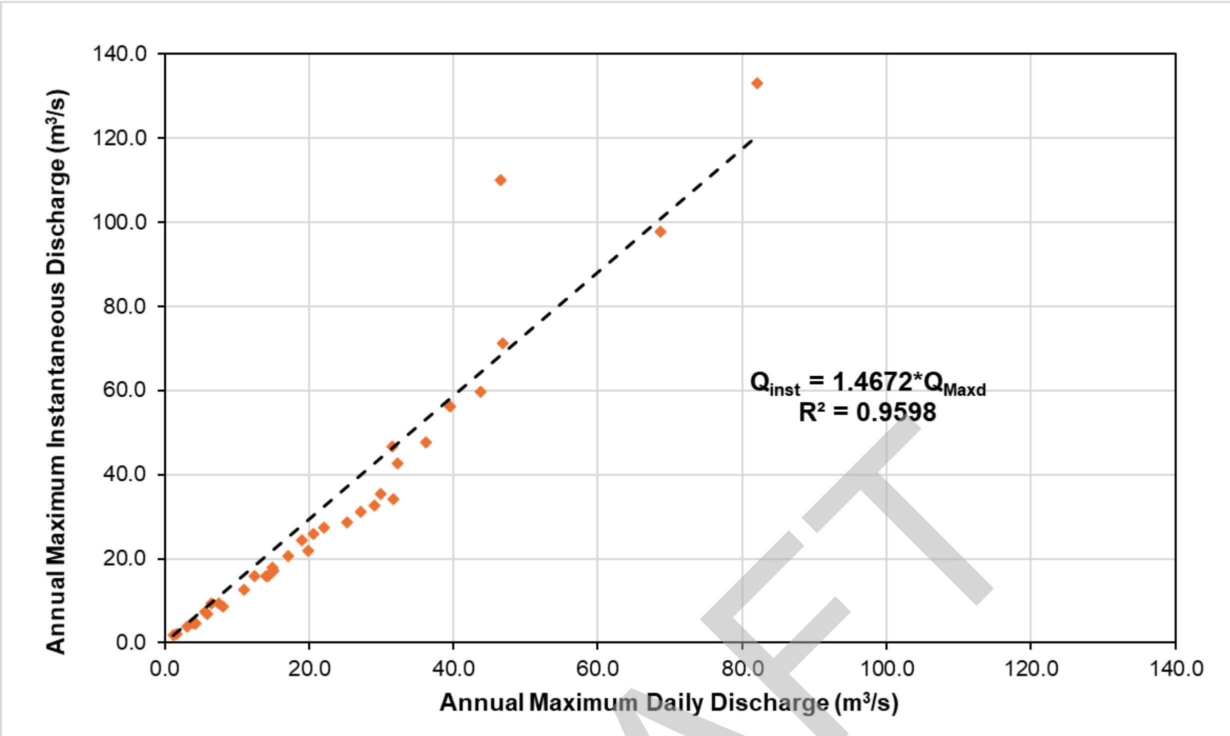


Relationship between Annual Maximum Daily and Annual Maximum Instantaneous Discharge for Wolf Creek at Highway No. 16A (WSC Station No. 07AG003)

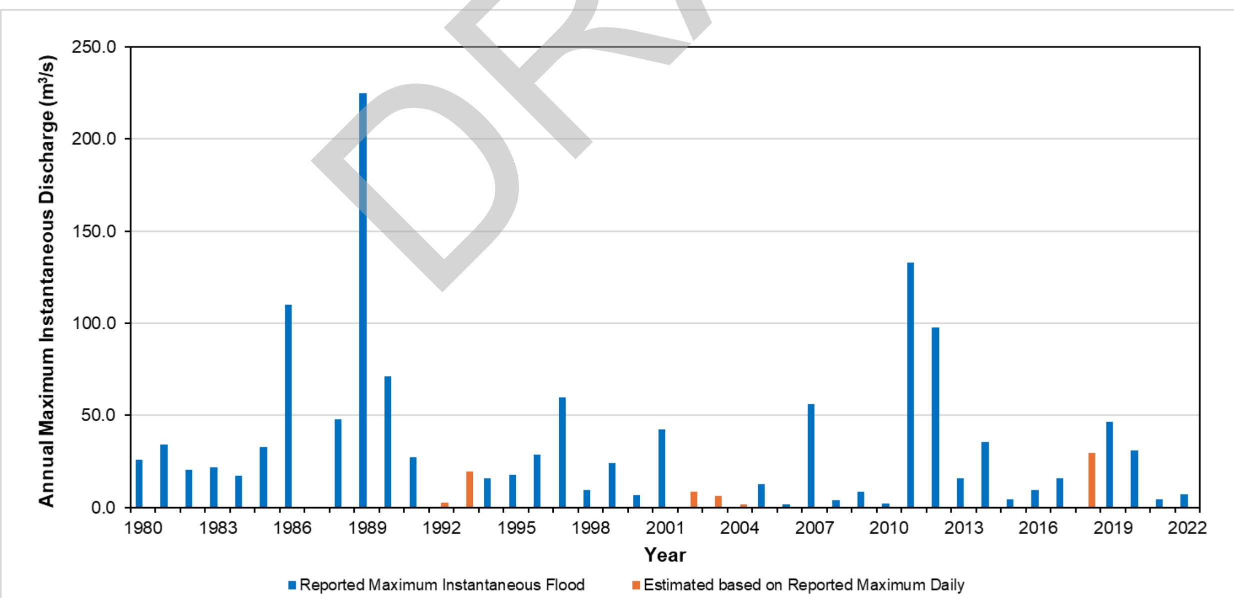


Annual Maximum Instantaneous Flood Flow Series for Wolf Creek at Highway No. 16A (WSC Station No. 07AG003)

Figure A-2: WSC Station No. 07BB011, Paddle River near Anselmo

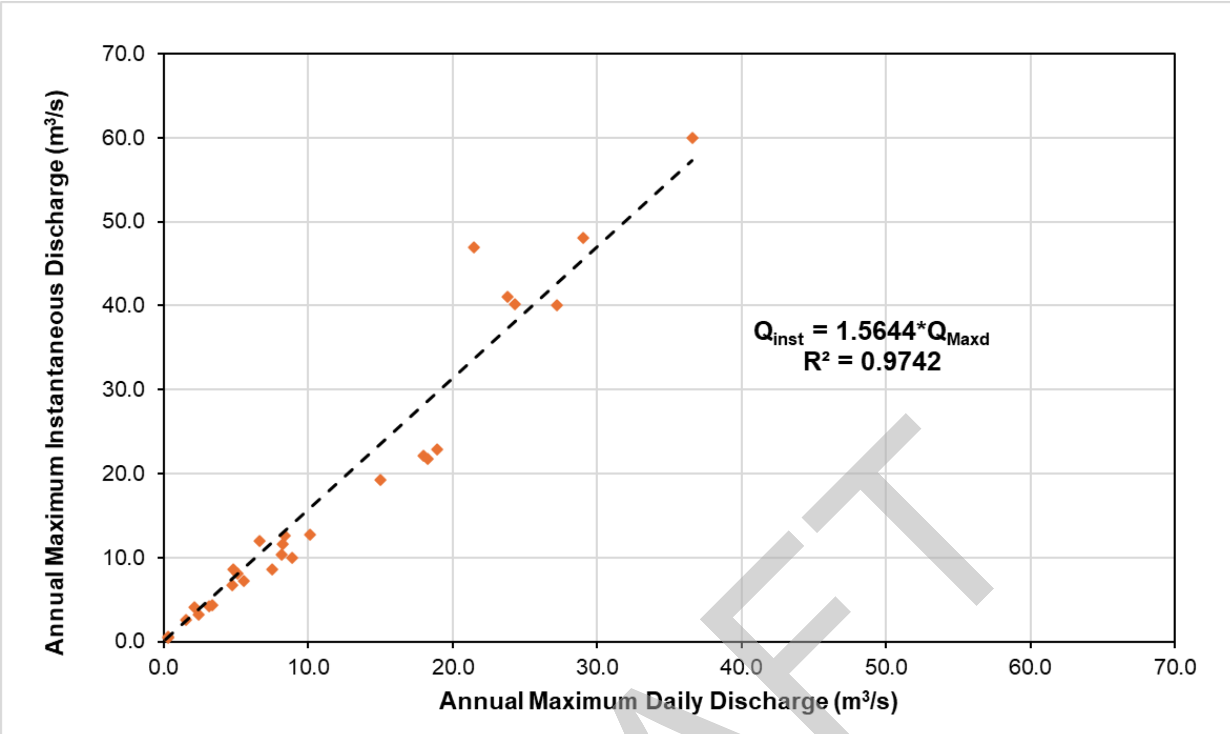


Relationship between Annual Maximum Daily and Annual Maximum Instantaneous Discharge for Paddle River near Anselmo (WSC Station No. 07BB011)

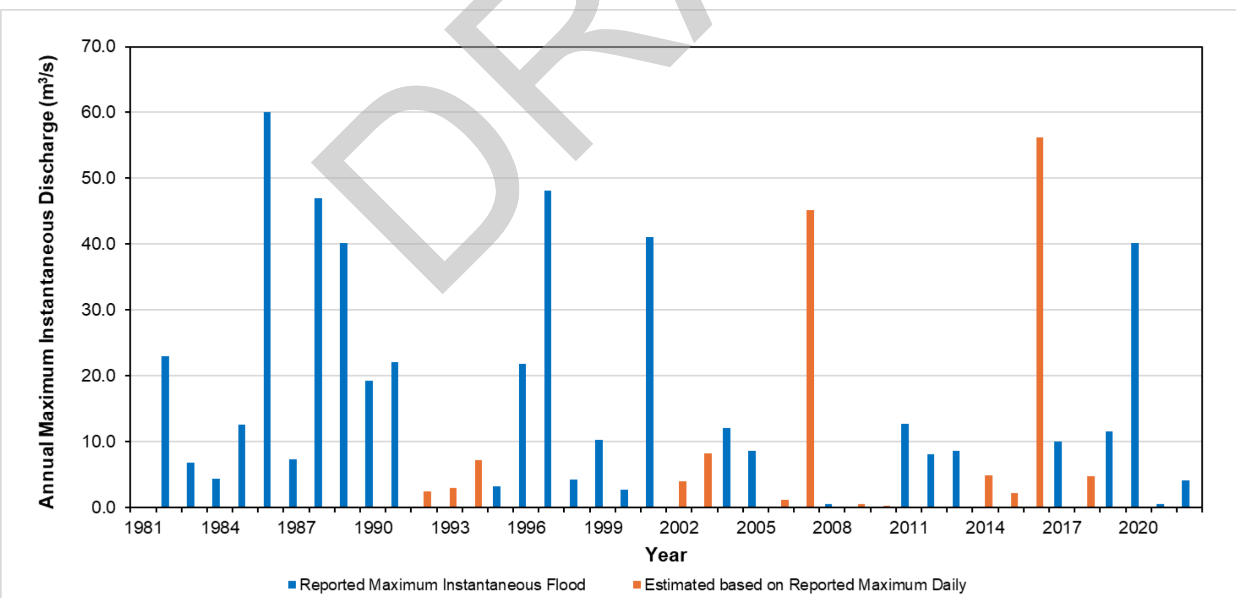


Annual Maximum Instantaneous Flood Flow Series for Paddle River near Anselmo (WSC Station No. 07BB011)

Figure A-3: WSC Station No. 05EA010, Sturgeon River near Magnolia

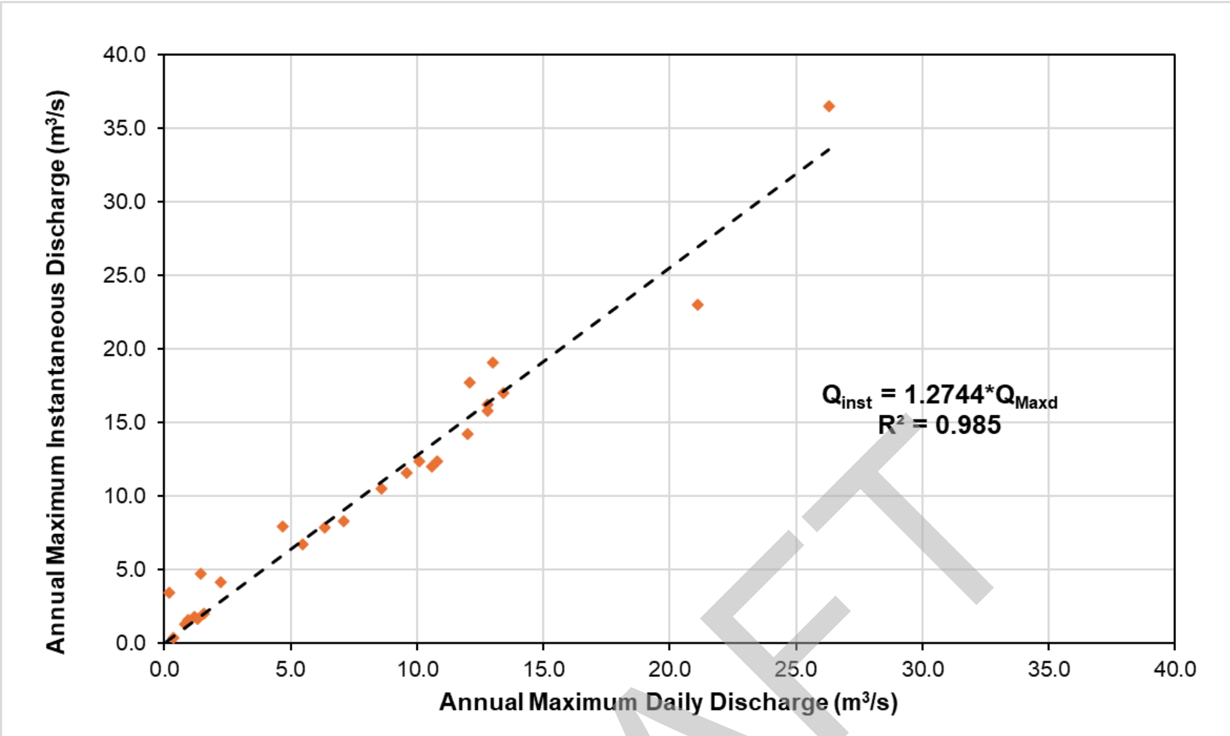


Relationship between Annual Maximum Daily and Annual Maximum Instantaneous Discharge for Sturgeon River near Magnolia (WSC Station No. 05EA010)

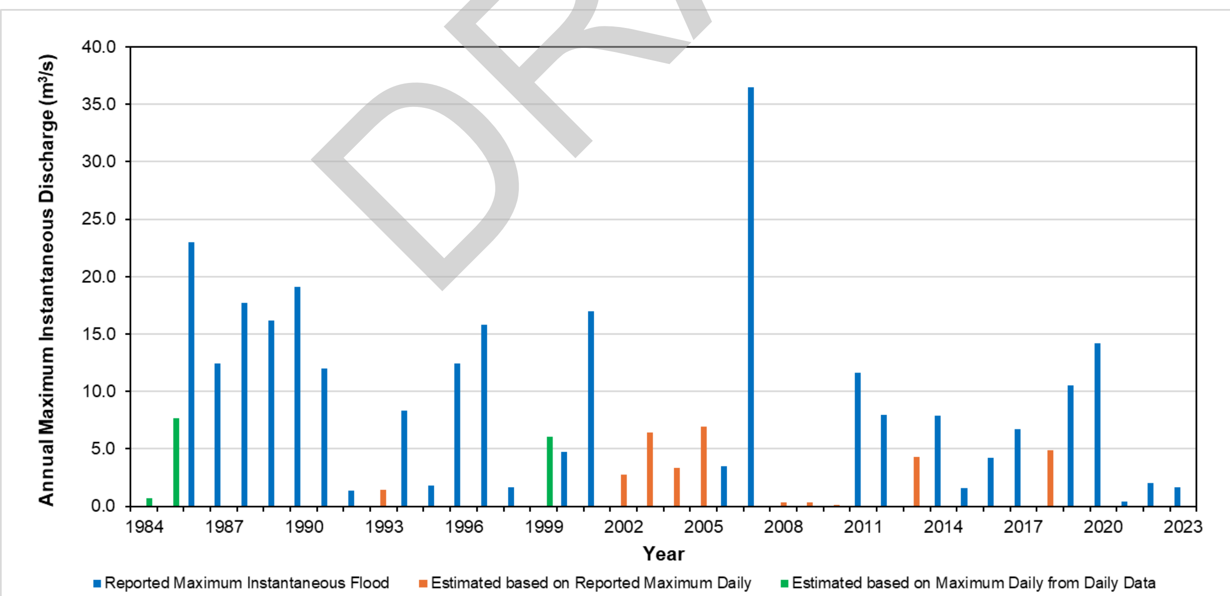


Annual Maximum Instantaneous Flood Flow Series for Sturgeon River near Magnolia (WSC Station No. 05EA010)

Figure A-4: WSC Station No. 05DE009, Tomahawk Creek near Tomahawk



Relationship between Annual Maximum Daily and Annual Maximum Instantaneous Discharge for Tomahawk Creek near Tomahawk (WSC Station No. 05DE009)



Annual Maximum Instantaneous Flood Flow Series for Tomahawk Creek near Tomahawk (WSC Station No. 05DE009

Table A-1: Annual Maximum Instantaneous Flood Data Used for Flood Frequency Analysis

Year	WSC Station No. 07AG003, Wolf Creek at Highway No. 16A	WSC Station No. 07BB011, Paddle River near Anselmo	WSC Station No. 05EA010, Sturgeon River near Magnolia Bridge	WSC Station No. 07DE009, Tomahawk Creek near Tomahawk
1954	-	-	-	-
1955	27.4	-	-	-
1956	14.1	-	-	-
1957	36.9	-	-	-
1958	84.1	-	-	-
1959	26.6	-	-	-
1960	66.2	-	-	-
1961	9.40	-	-	-
1962	25.8	-	-	-
1963	51.7	-	-	-
1964	76.2	-	-	-
1965	109	-	-	-
1966	62.0	-	-	-
1967	24.1	-	-	-
1968	17.7	-	-	-
1969	173	-	-	-
1970	51.3	-	-	-
1971	112	-	-	-
1972	260	-	-	-
1973	42.4	-	-	-
1974	74.0	-	-	-
1975	55.5	-	-	-
1976	31.5	-	-	-
1977	117	-	-	-
1978	44.1	-	-	-
1979	37.2	-	-	-
1980	199	25.8	-	-
1981	27.9	34.2	-	-
1982	229	20.6	22.9	-
1983	41.1	22.0	6.76	-
1984	34.7	17.1	4.29	0.700
1985	35.6	32.7	12.6	7.65
1986	570	110	60.0	23.0
1987	11.8	4.87	7.28	12.4
1988	20.5	47.7	47.0	17.7
1989	118	225	40.2	16.2
1990	102	71.2	19.3	19.1
1991	66.9	27.3	22.1	12.0
1992	12.1	2.49	2.39	1.34

Table A-1: Annual Maximum Instantaneous Flood Data Used for Flood Frequency Analysis

Year	WSC Station No. 07AG003, Wolf Creek at Highway No. 16A	WSC Station No. 07BB011, Paddle River near Anselmo	WSC Station No. 05EA010, Sturgeon River near Magnolia Bridge	WSC Station No. 07DE009, Tomahawk Creek near Tomahawk
1993	34.8	19.4	2.96	1.44
1994	42.8	15.8	7.15	8.32
1995	112	17.9	3.18	1.83
1996	59.6	28.6	21.8	12.4
1997	69.5	59.7	48.1	15.8
1998	46.7	9.33	4.22	1.64
1999	93.2	24.3	10.3	6.05
2000	48.4	6.96	2.62	4.75
2001	148	42.6	41.1	17.0
2002	37.4	8.74	3.96	2.75
2003	31.2	6.49	8.15	6.38
2004	31.2	1.82	12.0	3.36
2005	65.9	12.6	8.56	6.96
2006	18.9	1.84	1.18	3.48
2007	96.9	56.2	45.2	36.5
2008	41.7	3.91	0.544	0.343
2009	45.8	8.67	0.527	0.306
2010	41.4	2.13	0.235	0.097
2011	105	133	12.7	11.6
2012	-	97.7	8.06	7.98
2013	55.4	15.8	8.56	4.29
2014	35.7	35.4	4.88	7.91
2015	16.3	4.63	2.14	1.58
2016	49.9	9.37	56.2	4.19
2017	69.5	15.8	9.94	6.73
2018	64.7	29.5	4.74	4.86
2019	162	46.7	11.6	10.5
2020	211	31.1	40.1	14.2
2021	15.1	4.70	0.441	0.382
2022	60.0	7.33	4.10	2.03
2023	344	-	-	1.68

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

WSC Station ID, Station Name	WSC Station No. 07AG003, Wolf Creek at Highway No. 16A	WSC Station No. 07BB011, Paddle River near Anselmo	WSC Station No. 05EA010, Sturgeon River near Magnolia Bridge	WSC Station No. 07DE009, Tomahawk Creek near Tomahawk
Anderson-Darling statistic, $A^2 = -N-S$				
3 Parameter Log-normal	0.237	0.293	0.394	0.461
Extreme Value	0.159	0.269	0.938	0.448
Log_Pearson III	0.187	0.175	0.398	0.182
Weilbull	4.951	0.841	1.875	0.264
Serial correlation coefficient test for independence				
S_1	-0.051	0.081	-0.039	0.159
t	-0.408	0.512	-0.238	0.982
t(a=0.05)	-1.669	1.684	-1.686	1.687
t(a=0.01)	-2.385	2.423	-2.429	2.431
Spearman rank order correlation coefficient test for no-trend				
r_s	-0.132	0.227	0.245	0.289
t	-1.083	1.495	1.577	1.864
t(a=0.05)	-1.997	2.020	2.023	2.024
t(a=0.01)	-2.652	2.701	2.708	2.712
Mann-Whitney split sample test for homogeneity				
Size of earlier sample	48	48	48	30
z	-0.067			-0.875
z(a=0.05)	-1.645			-1.645
z(a=0.01)	-2.326			-2.326
Test of general randomness (Runs for above or below the median)				
Median	51	19	8.2	6.2
N1(for Q>=Median)	34	22	21	20
N2(for Q<Median)	34	21	20	20
Run_ab	36	22	24	23
z	0.244	0.151	0.795	0.641
z(a=0.05)	1.960	1.960	1.960	1.960
z(a=0.01)	2.576	2.576	2.576	2.576

Notes:
1. Selected distribution based on best statistical fit.

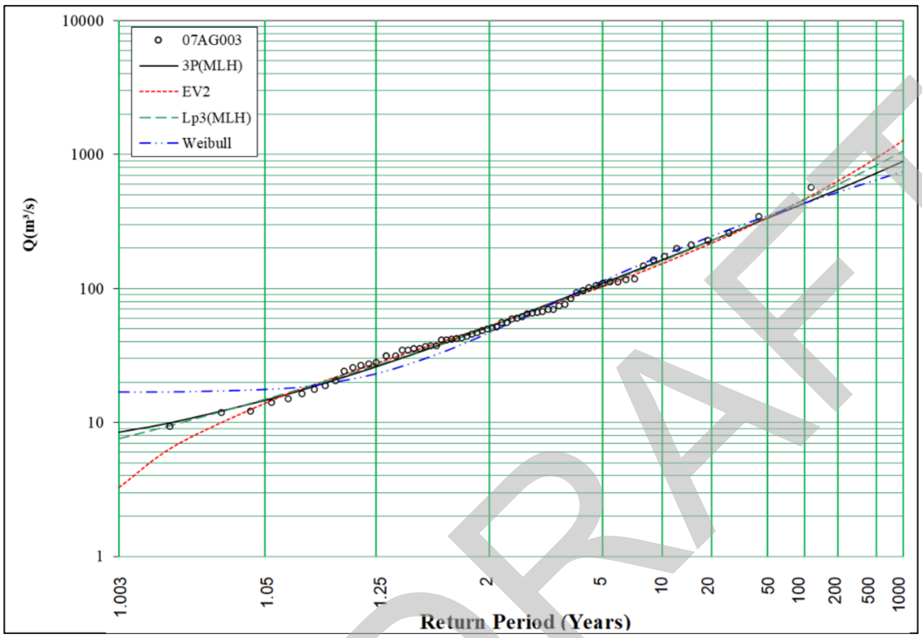
APPENDIX B

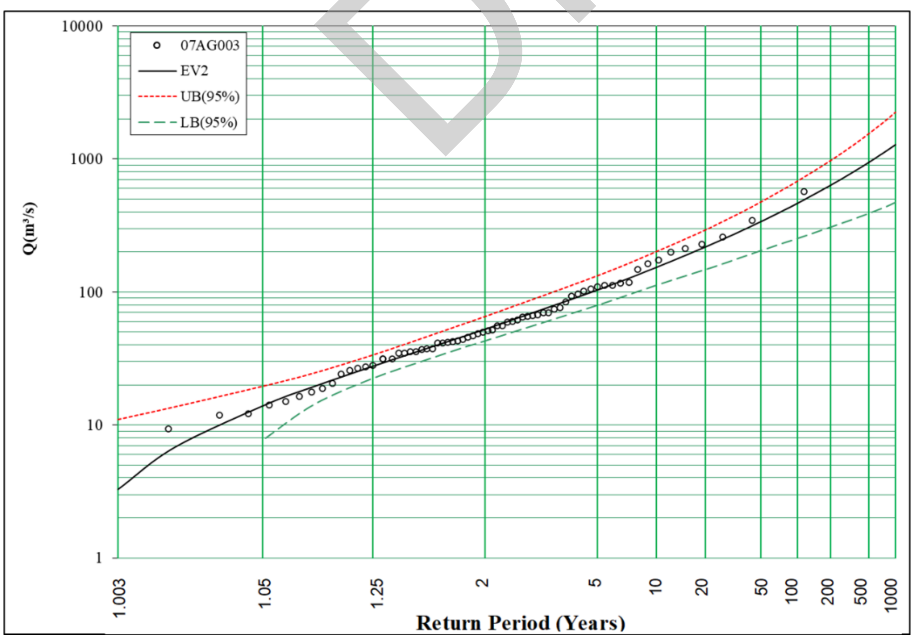
Frequency Analysis - Graphs and Tables

This appendix includes the graphs and results from the frequency analysis of the compiled/derived maximum instantaneous flood flow series at the gauged stations. 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

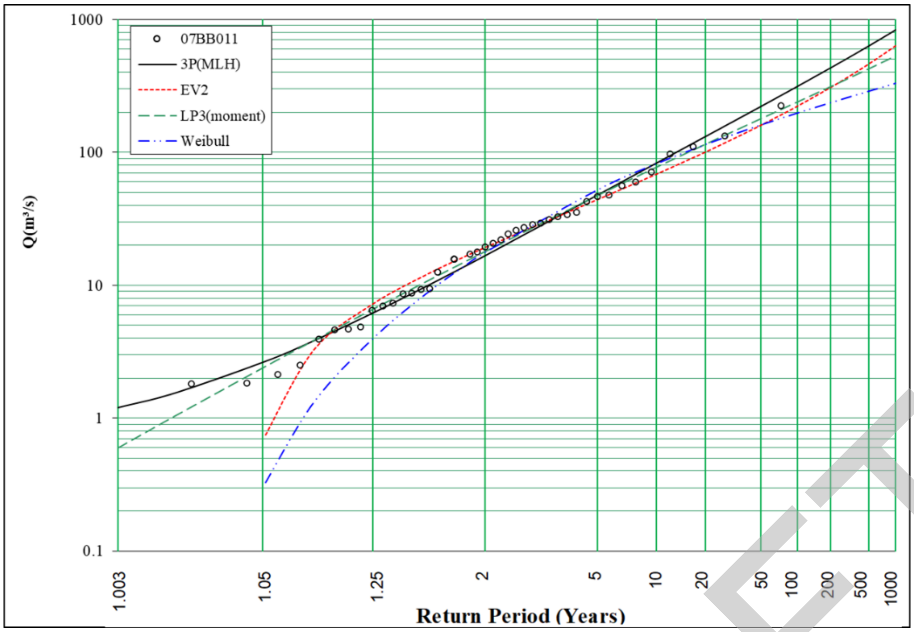
Figure B-1: WSC Station No. 07AG003, Wolf Creek at Highway No. 16A

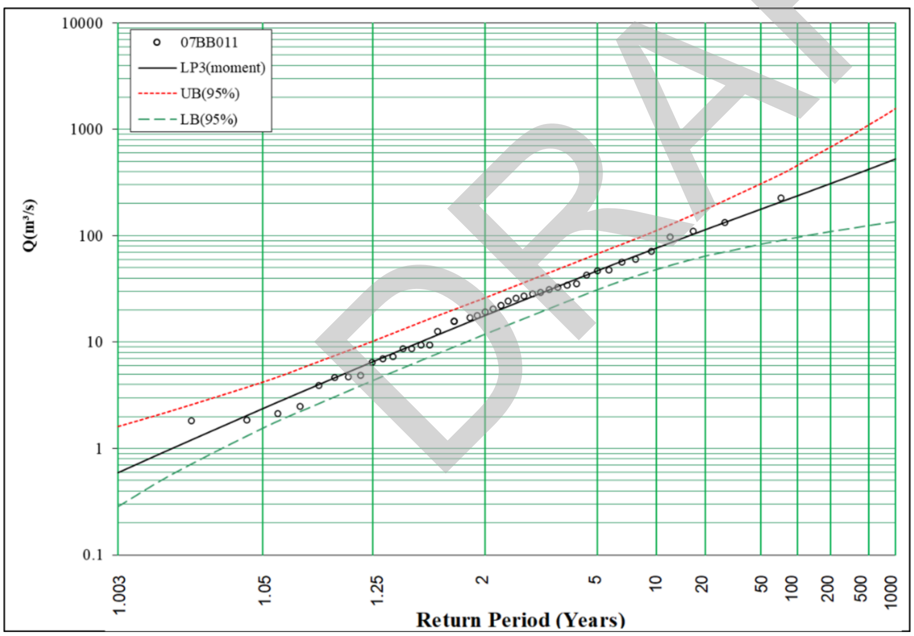




Return Period	3P (Moment)	EV2	LP3 (Moment)	Weibull
2	52.0	52.2	51.7	47.0
5	110	103	107	114
10	164	153	161	177
20	230	217	228	247
35	292	285	295	309
50	337	337	344	350
75	393	406	408	399
100	435	462	458	435
200	551	630	598	525
350	658	806	735	601
500	733	942	834	651
750	826	1124	961	709
1000	896	1273	1060	751

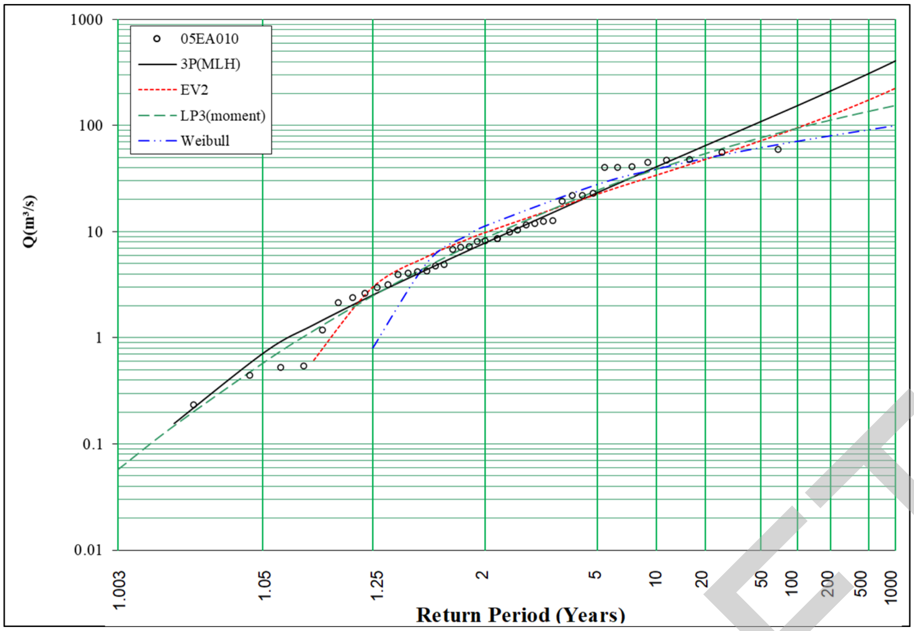
Figure B-2: WSC Station No. 07BB011, Paddle River near Anselmo

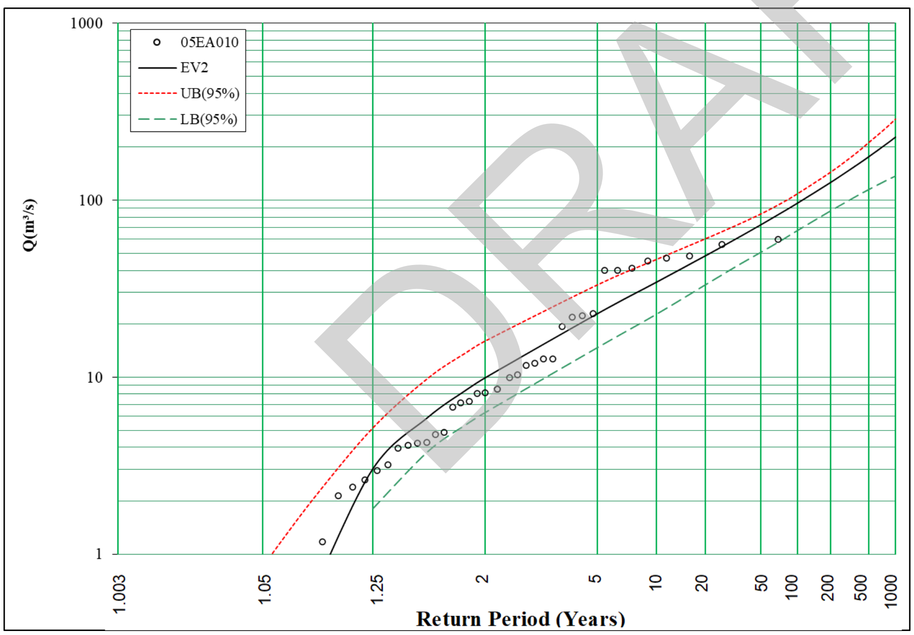




Return Period	3P (Moment)	EV2	LP3 (Moment)	Weibull
2	16.7	19.3	17.9	17.7
5	47.6	44.2	47.2	52.2
10	82.8	68.8	77.2	82.3
20	131	101	115	115
35	182	135	152	143
50	221	161	179	161
75	272	195	213	183
100	312	224	239	198
200	429	308	311	237
350	546	398	379	269
500	631	467	426	290
750	741	559	485	314
1000	827	635	530	331

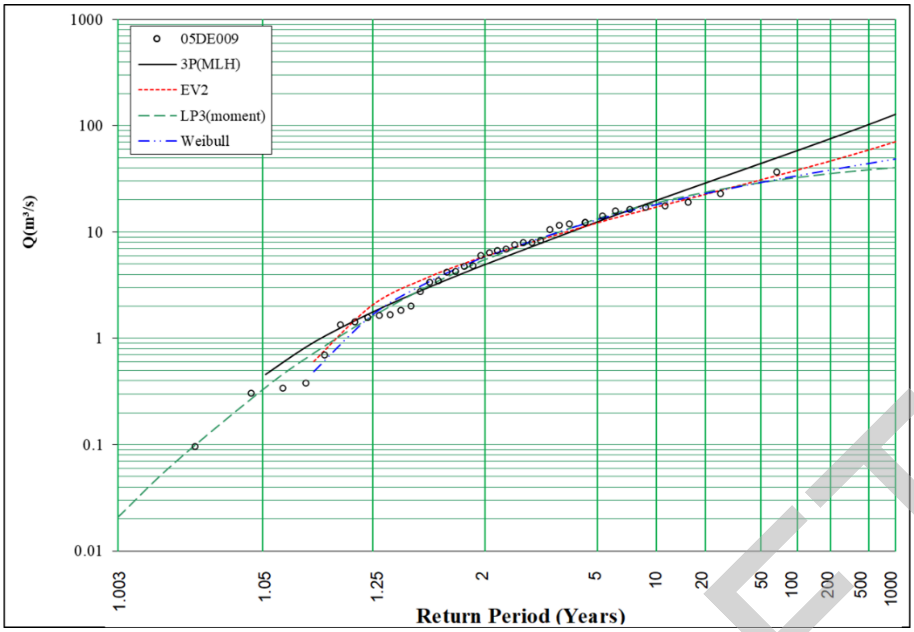
Figure B-3: WSC Station No. 05EA010, Sturgeon River near Magnolia

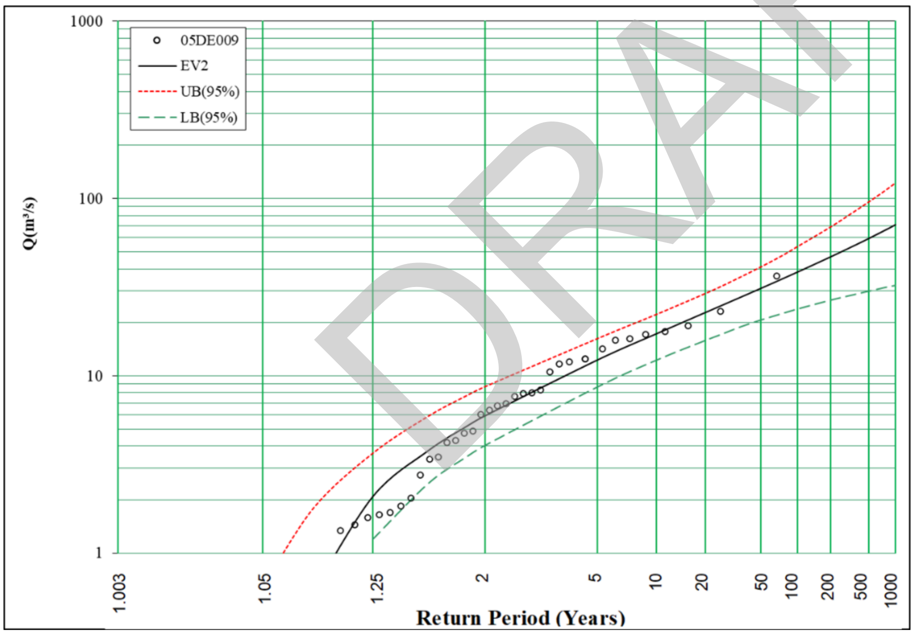




Return Period	3P (Moment)	EV2	LP3 (Moment)	Weibull
2	7.86	9.87	8.70	11.29
5	23.4	22.7	24.5	27.8
10	41.0	34.2	38.7	38.8
20	65.1	48.3	54.5	49.0
35	90.3	62.1	68.0	56.9
50	110	72.3	76.8	61.7
75	135	85.4	87.1	67.1
100	155	95.8	94.5	70.9
200	212	125	112	79.8
350	270	154	127	86.7
500	312	176	136	91.1
750	366	204	147	96.0
1000	408	226	154	99.4

Figure B-4: WSC Station No. 05DE009, Tomahawk Creek near Tomahawk





Return Period	3P (Moment)	EV2	LP3 (Moment)	Weibull
2	4.97	5.95	5.54	5.86
5	12.5	12.2	13.4	13.1
10	19.8	17.2	18.9	18.2
20	28.9	22.7	23.8	23.1
35	37.7	27.7	27.3	26.9
50	44.1	31.1	29.3	29.4
75	52.1	35.3	31.3	32.1
100	58.3	38.4	32.7	34.0
200	75.3	46.8	35.6	38.5
350	91.2	54.4	37.5	42.1
500	103	59.6	38.6	44.4
750	117	66.1	39.7	46.9
1000	127	71.0	40.4	48.7

APPENDIX C

Climate Change Quotes from Recent Publications

The literature on climate change is quite vast and continuously being updated, but the key takeaways highlighted in Bush and Lemmen (2019) study are:

Changes in Temperature and Precipitation Across Canada

- The changing frequency of temperature and precipitation extremes can be expected to lead to a change in the likelihood of events such as wildfires, droughts, and floods. (p.119)
- To date, warming has been stronger in winter than in other seasons. Widespread changes in temperature indices and extremes associated with warming have been observed. (p. 154)
- The increase in Canadian mean temperature is about twice the rate of global mean temperature. This is the case in the historical record and also applies to future change, regardless of the emissions pathway that the earth will follow. (p. 154)
- In addition, regional climate model projections show a general increase in rain-on-snow events over the coming century. (p. 167)
- In the future, daily extreme precipitation is projected to increase (high confidence). (p. 155)
- There is medium confidence that annual mean precipitation has increased, on average, in Canada, with larger percentage increases in northern Canada. (p. 173)
- Annual and winter precipitation is projected to increase everywhere in Canada over the 21st century, with larger percentage changes in northern Canada. Summer precipitation is projected to decrease over southern Canada under a high emission scenario toward the end of the 21st century, but only small changes are projected under a low emission scenario. (p. 173)

Changes in Snow, Ice, and Permafrost Across Canada

- There is also very high confidence that snow cover extent has declined in the northern hemisphere. (p.37)
- The duration of seasonal lake ice cover has declined across Canada over the past five decades due to later ice formation in fall and earlier spring breakup (high confidence). (p.199)
- The portion of the year with snow cover decreased across most of Canada (very high confidence) as did the seasonal snow accumulation (medium confidence). Snow cover fraction decreased between 5% and 10% per decade since 1981 due to later snow onset and earlier spring melt. (p. 203)
- It is very likely that snow cover duration will decline to mid-century across Canada due to increases in surface air temperature under all emissions scenarios. Scenario-based differences in projected spring snow cover emerge by the end of the century, with stabilized snow loss for a medium emission scenario but continued snow loss under a high emission scenario (high confidence). (p.203)
- Seasonal snow accumulation decreased by a rate of 5% to 10% per decade across most of Canada (1981–2015), except of southern Saskatchewan, Alberta, and British Columbia (increases of 2% to 5% per decade), driven by both temperature and precipitation changes. (p. 210)

- A reduction of 5% to 10% per decade in seasonal snow accumulation (through 2050) is projected across much of southern Canada; only small changes in snow accumulation are projected across northern regions of Canada because increases in winter precipitation are expected to offset a shorter snow accumulation period. (p. 210)

Changes in Freshwater Availability Across Canada

- Annual flows over western Canada have varied from one region to another, with both increasing and decreasing trends since approximately the 1960s and 1970s. Most declines were observed in rivers draining the eastern slopes of the central/southern Rocky Mountains, including the Athabasca, Peace, Red Deer, Elbow, and Oldman rivers. (p. 274)
- Several flows were associated with naturally occurring internal climate variability (mainly El Niño–Southern Oscillation, Pacific Decadal Oscillation [PDO], and Arctic Oscillation [AO]; particularly for western Canada during winter...). (p.278)
- In general, for the mid-21st century, watersheds in British Columbia and northern Alberta are projected to have increases in annual and winter runoff, whereas some watersheds in Alberta, southwest British Columbia, and southern Ontario are projected to have declines in summer flow. (p.281)
- Athabasca River watershed (AB): projected increases in spring and winter flows, increases in minimum and maximum flows, with summer flows projected to decrease in the 2050s and 2080s; overall increase in annual runoff reaching the river mouth. (p.282)
- Several regional studies in western Canada… have also found an earlier onset of spring freshet over the past several decades. (p. 286)
- There are few studies of future streamflow timing in Canada. An earlier snowmelt peak and resulting spring freshet are projected for mid-century (2041–2070) over western Canada, particularly for northern basins, using a high emission scenario. For the majority of western Canada basins, this earlier shift was also projected for the end-of-winter low-flow events. Earlier spring freshet flows for the mid-century period (2041–2070) are also projected using several CMIP5 models under a medium (RCP4.5) and a high (RCP8.5) emission scenario. (p. 287)
- Depletion of the snowpack by mid-winter melt events is projected to lead to a major reduction in the frequency of spring ice jam flooding, but could increase the potential for mid-winter ice jam flooding in the Peace–Athabasca delta in northern Alberta. (p.291)
- The most significant observed changes in freshwater availability are in the seasonal distribution of streamflow in many snow-fed catchments: winter flows have become higher, the timing of spring peak flows has become earlier, and there has been an overall reduction in summer flows (high confidence). (p. 432)

Dibike et al. (2019) noted the following projected changes in the frequency of peak flows along the Athabasca River:

- Flows originating from alpine-dominated cold region watersheds typically experience extended winter low flows followed by spring snowmelt and summer rainfall-driven high flows. In a warmer climate, there will be a temperature-induced shift in precipitation from snowfall towards rain along with changes in precipitation intensity and snowmelt timing, resulting in alterations in the frequency and magnitude of peak flow events.
- Hydrological model projections show an overall increase in mean annual streamflow in the watershed and a corresponding shift in the freshet timing to an earlier period. The river flow is projected to experience increases during the winter and spring seasons and decreases during the summer and early fall seasons, with an overall projected increase in peak flow, especially for low frequency events.
- Both stationary and non-stationary methods of peak flow analysis, performed at multiple points along the Athabasca River, show that projected changes in the 100-year peak flow event for the high emissions scenario by the 2080s range between 4% and 33% depending on the driving climate models and the statistical method of analysis. A closer examination of the results also reveals that the sensitivity of projected changes in peak flows to the statistical method of frequency analysis is relatively small compared to that resulting from inter-climate model variability.

APPENDIX D

Selected Future Climate Change Model Figures for Paddle Prairie

SSPs are scenarios (Figure D-1) of projected socioeconomic global changes up to the year 2100 and are used to derive greenhouse gas emissions scenarios with different climate policies (Lee et al., 2021; Meinshausen et al., 2020), where they can be described simply as:

- **SSP1** Sustainability (Taking the Green Road)
- **SSP2** Middle of the Road
- **SSP3** Regional Rivalry (A Rocky Road)
- **SSP4** Inequality (A Road Divided)
- **SSP5** Fossil-Fueled Development (Taking the Highway)

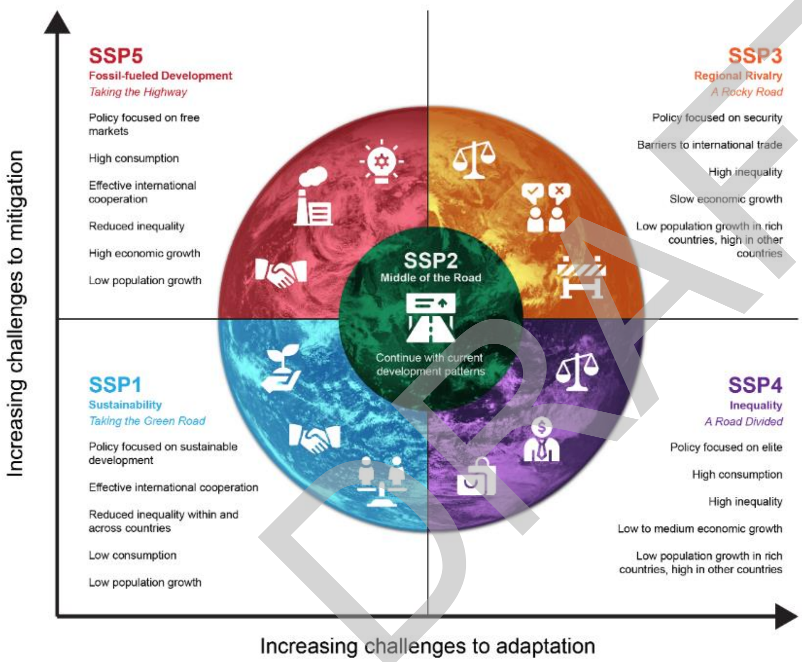


Figure D-1 The Five Families of SSP-Based Scenarios used in CMIP6

Source: https://climatedata.ca/resource/understanding-shared-socio-economic-pathways-ssps/

From these five families, four individual emission scenarios for families 1, 2, 3 and 5 based on radiative forcing (in units of tenths of watts) are used and defined as:

- **SSP126**: this scenario mimics the RCP2.6 scenario with an anticipated radiative forcing change of 2.6 W/m^2 by the year 2100 using a 2°C target for development that assumes climate measures are taken.
- **SSP245**: this is an update to the RCP4.5 emission scenario that uses a radiative forcing of 4.5 W/m^2 by the year 2100 that represents the medium pathway of future greenhouse gas emissions that assumes climate protection measures are taken.
- **SSP370**: this is a newly introduced family that came after the RCP scenarios with the intent to close the gap between RCP6.0 and RCP8.5 and has a radiative forcing of 7 W/m^2 by 2100.
- **SSP585**: this scenario represents the upper bound of the GCM outputs with a radiative forcing of 8.5 W/m^2 by the year 2100 and is an update to the RCP8.5 from CMIP5 that now encapsulates socioeconomic conditions.

The figures below show the shared socioeconomic pathways (Figure D-2) and anthropogenic radiative forcing in W/m^2 (Figure D-3) from the CMIP6 scenarios (O'Neill et al., 2016). Figures D-4 to D-13 show temperature and precipitation under different shared socioeconomic pathways (SSPs) for various time periods.

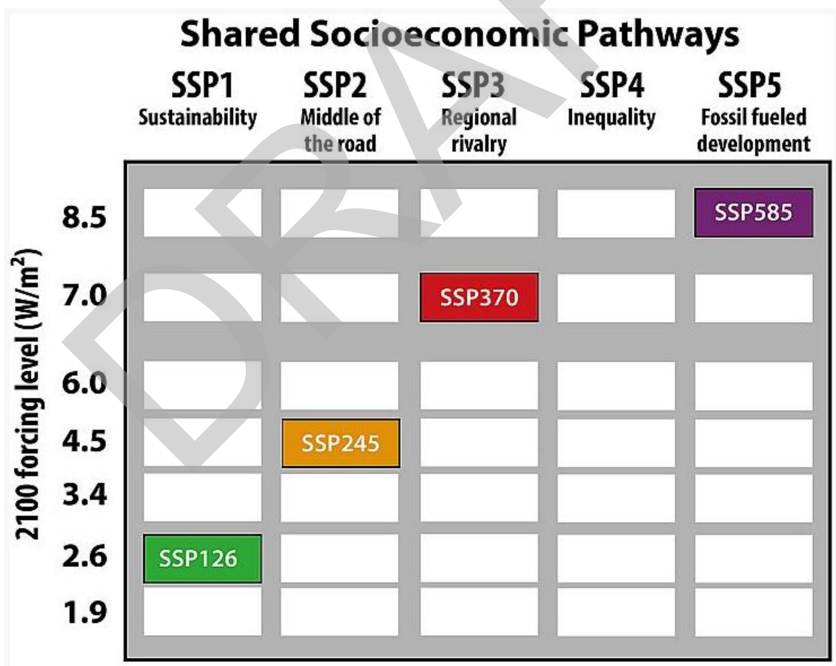


Figure D-2 Shared Socioeconomic Pathways by Year 2100 Forcing Level (W/m^2)

Source: O'Neill et al., 2016.

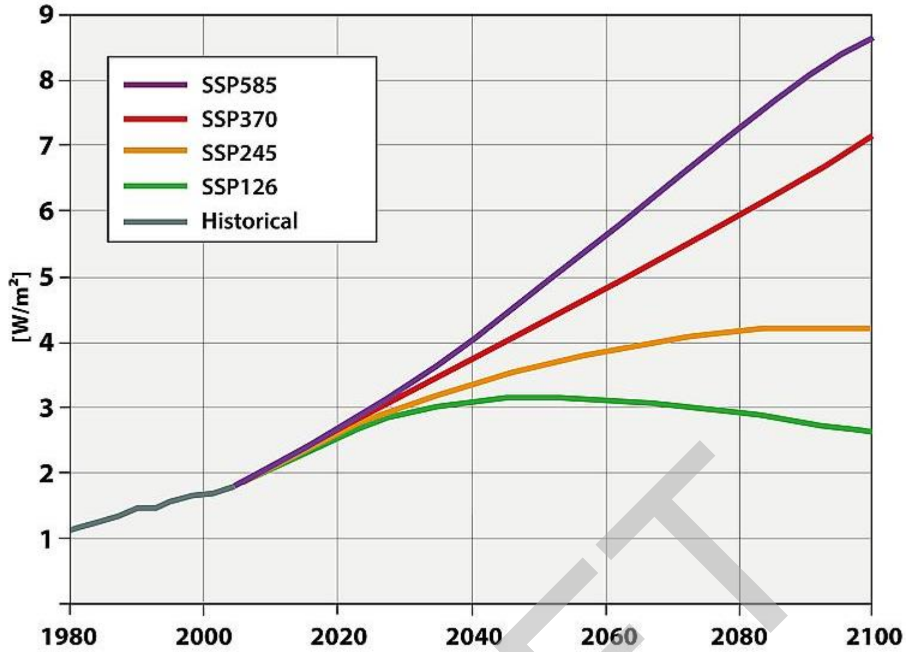


Figure D-3 CMIP6 Scenarios – Anthropogenic Radiative Forcing (W/m²)

Source: O'Neill et al., 2016.

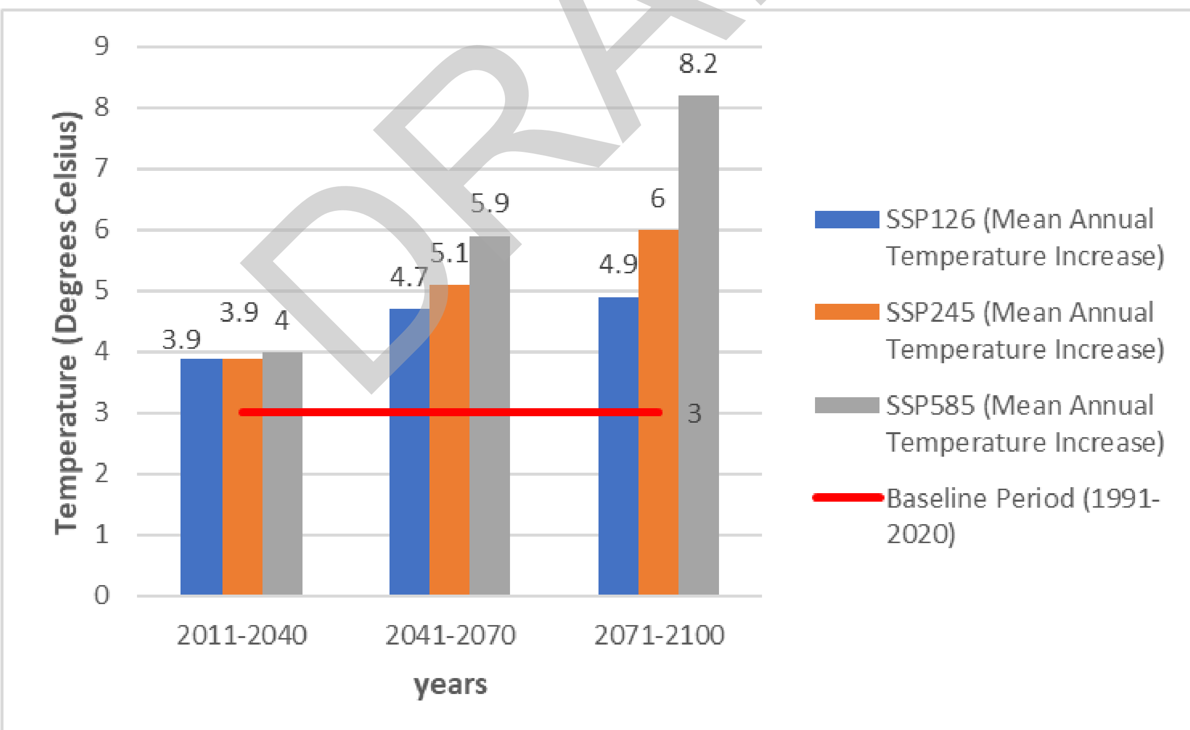


Figure D-4: Mean Annual Temperature Increase Under Different Shared Socioeconomic Pathways (SSPs) for Various Time Periods

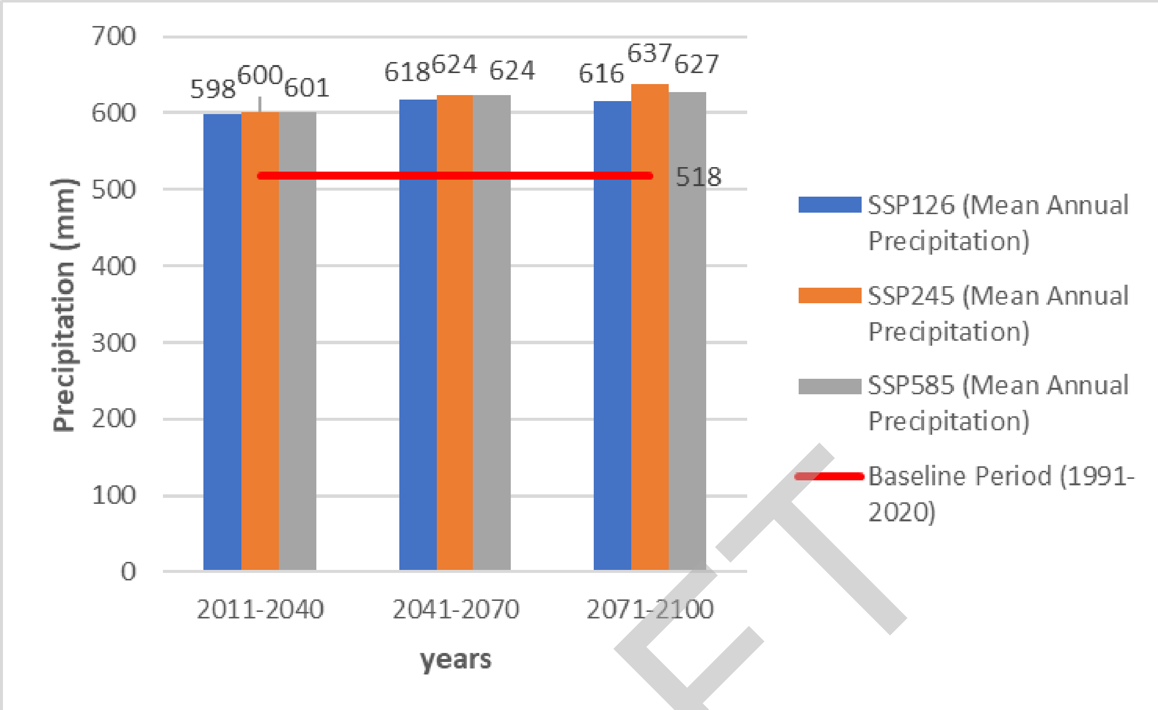


Figure D-5 **Mean Annual Precipitation Under Different Shared Socioeconomic Pathways (SSPs) for Various Time Periods**

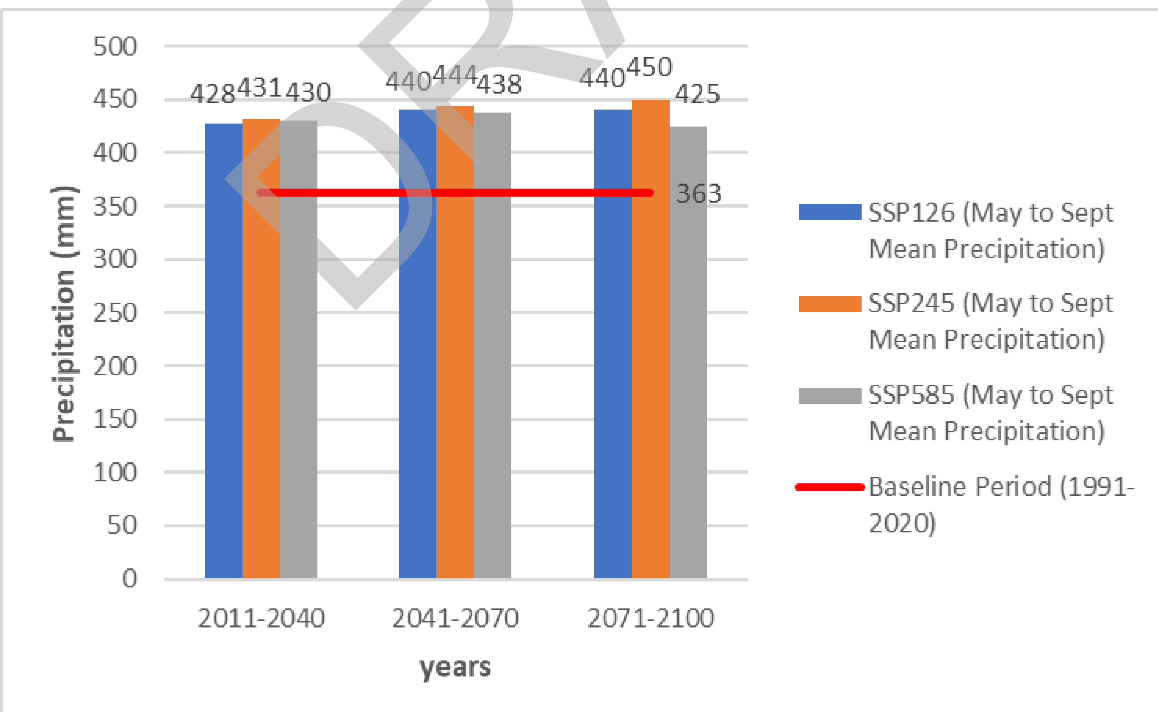


Figure D-6: **May to September Mean Precipitation Under Different Shared Socioeconomic Pathways (SSPs) for Various Time Periods**

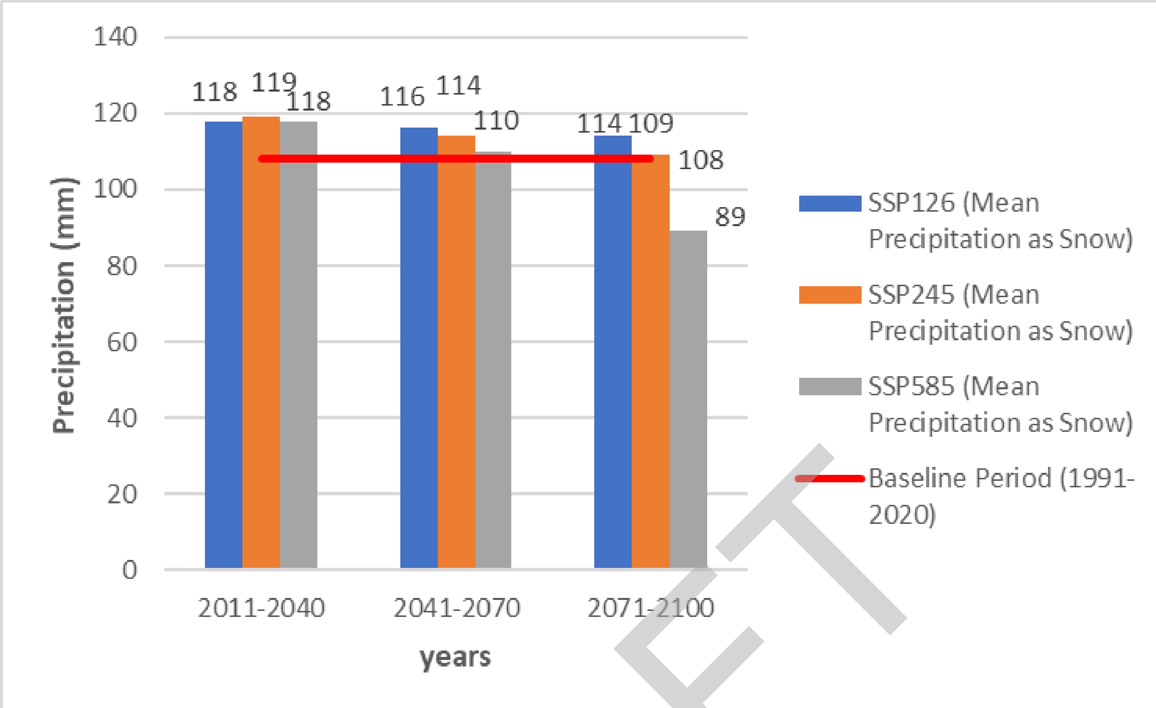


Figure D-7 **Mean Precipitation as Snow Under Different Shared Socioeconomic Pathways (SSPs) for Various Time Periods**

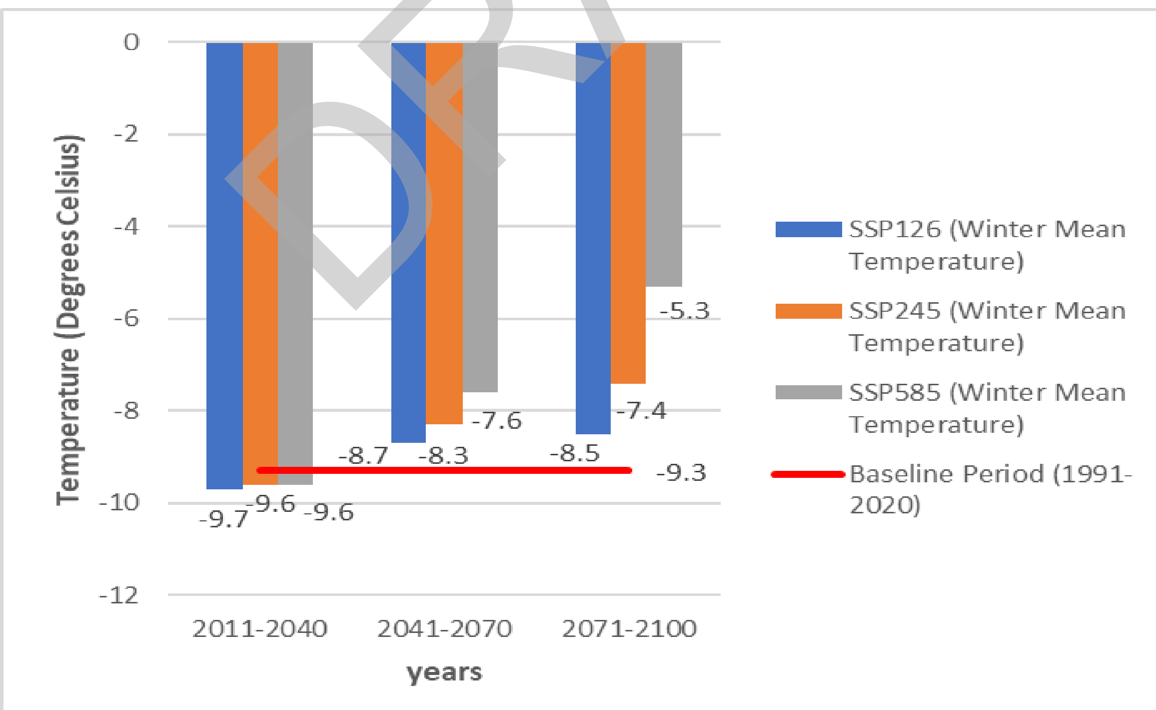


Figure D-8 **Winter Mean Temperature (DJF) Under Different Shared Socioeconomic Pathways (SSPs) for Various Time Periods**

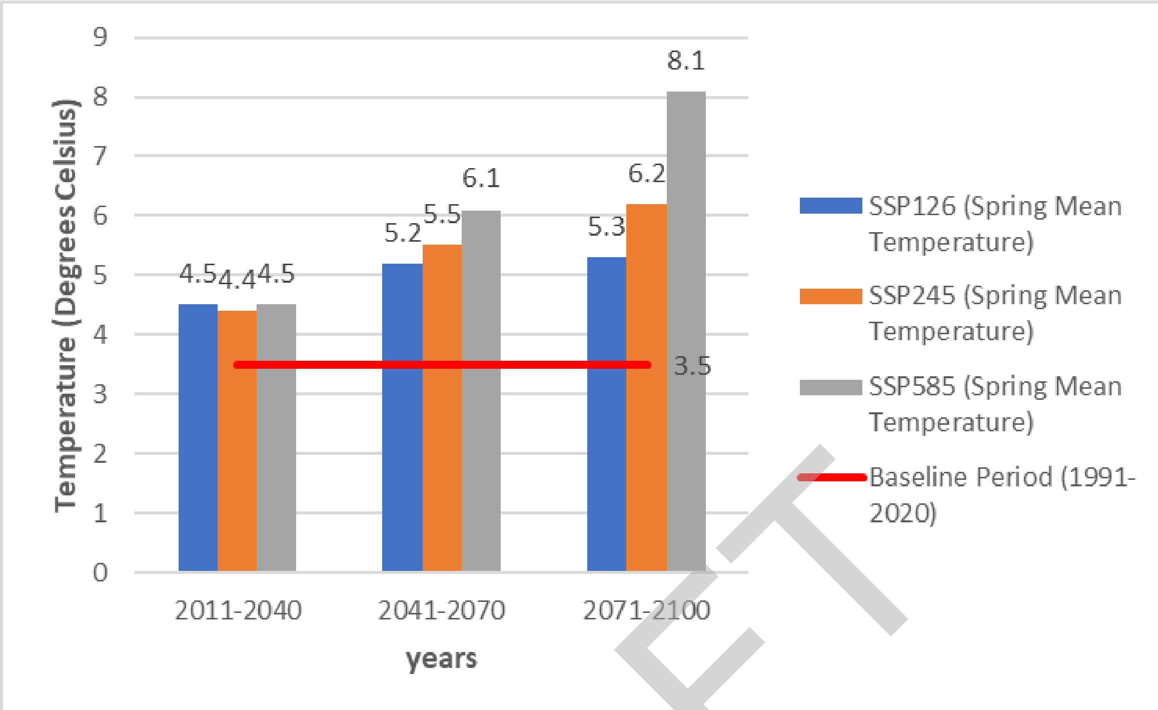


Figure D-9: Spring Mean Temperature (MAM) Under Different Shared Socioeconomic Pathways (SSPs) for Various Time Periods

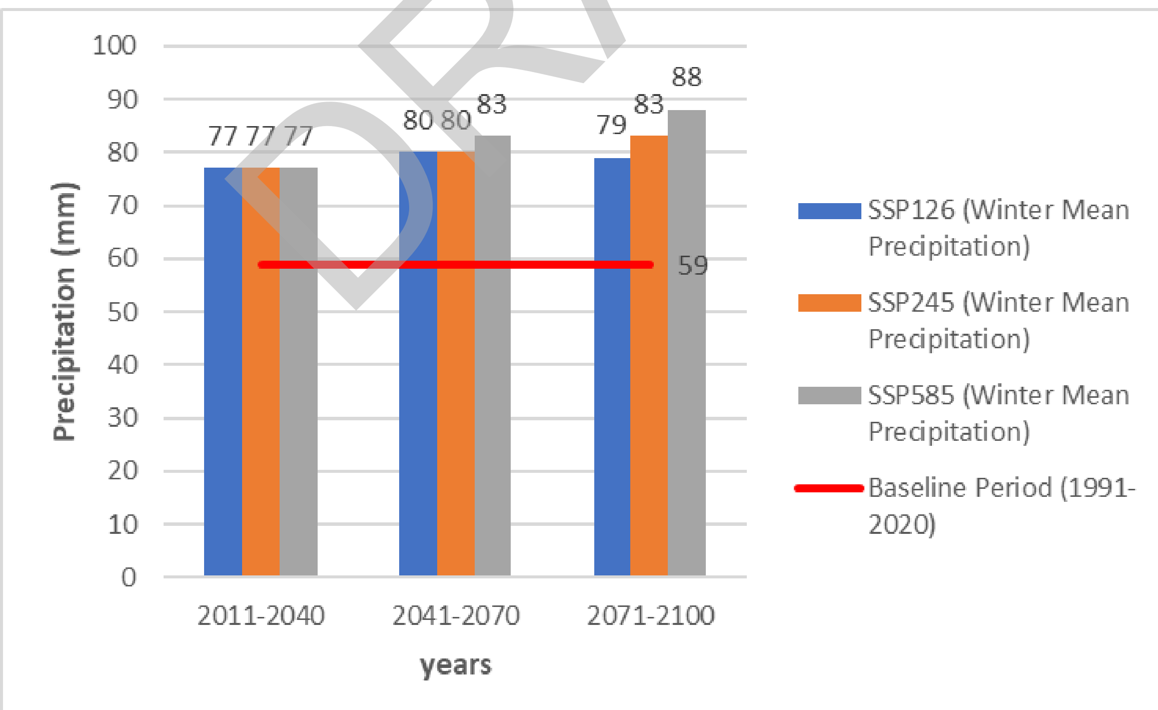


Figure D-10 Winter Mean Precipitation (DJF) Under Different Shared Socioeconomic Pathways (SSPs) for Various Time Periods

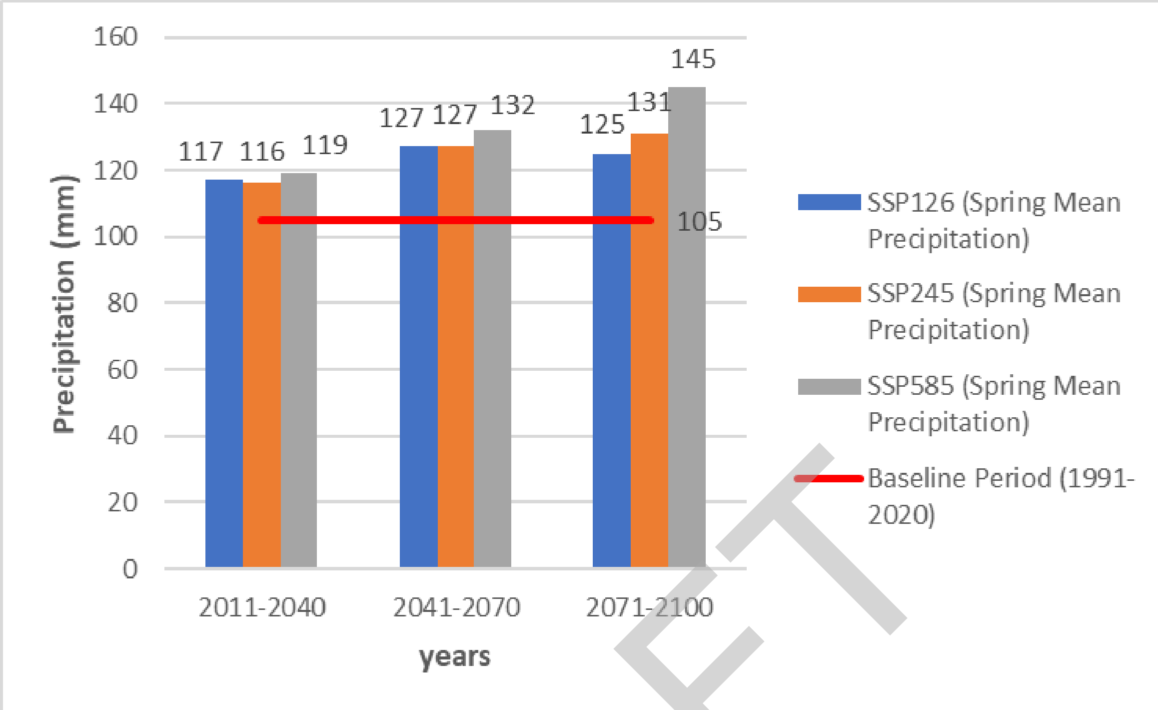


Figure D-11 **Spring Mean Precipitation (MAM) Under Different Shared Socioeconomic Pathways (SSPs) for Various Time Periods**

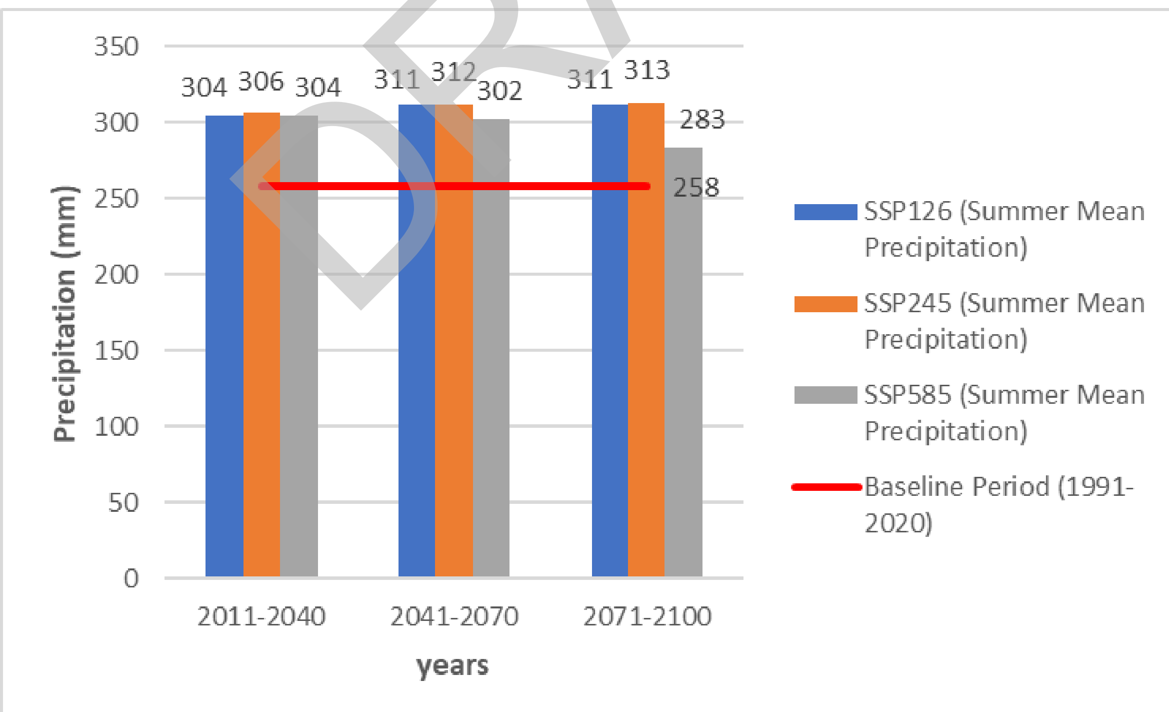


Figure D-12 **Summer Mean Precipitation (JJA) Under Different Shared Socioeconomic Pathways (SSPs) for Various Time Periods**

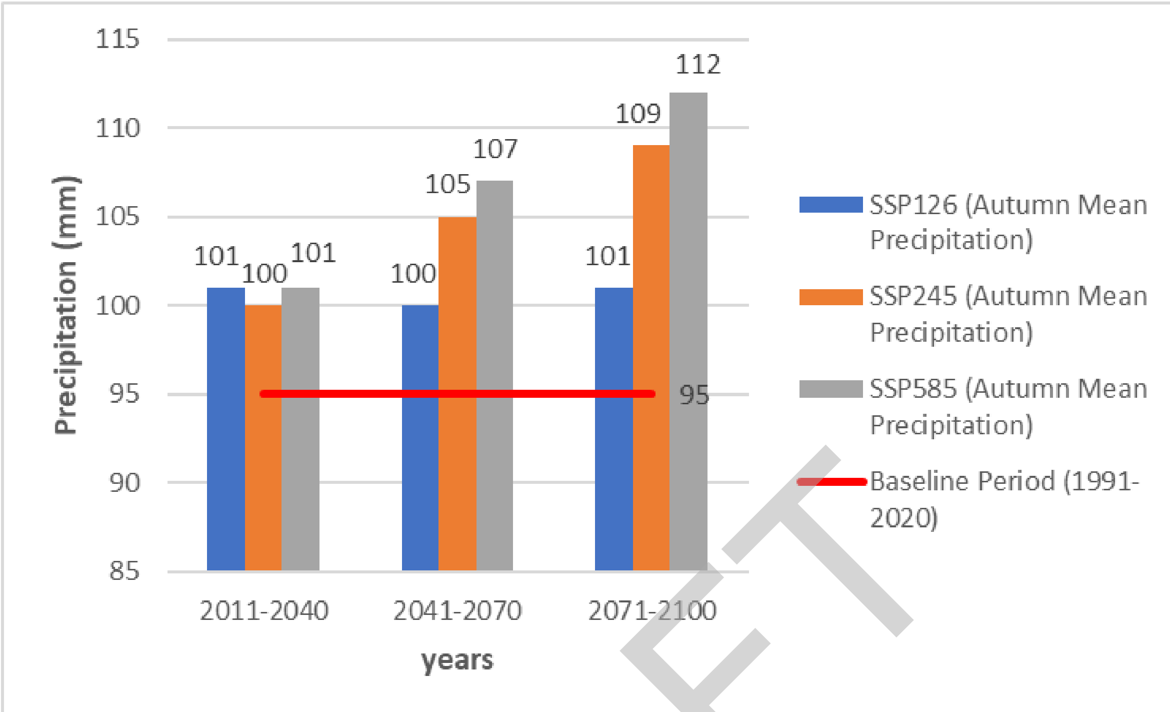


Figure D-13 Autumn Mean Precipitation (SON) Under Different Shared Socioeconomic Pathways (SSPs) for Various Time Periods

APPENDIX E

Open Water Flood Profiles

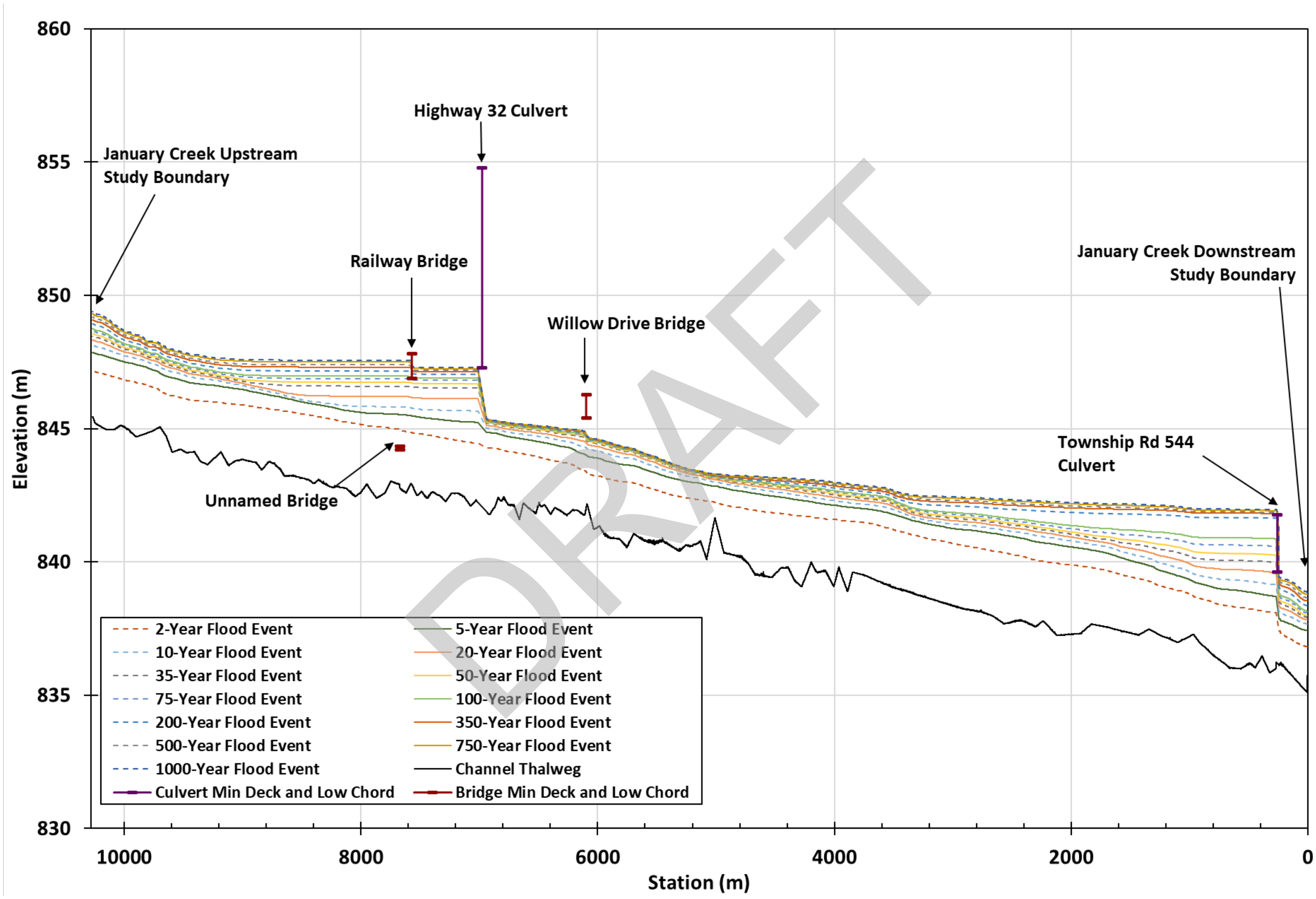


Figure E-1: Simulated Water Surface Profile along the January Creek Study Reach

Table E-1: January Creek Flood Profiles

River Station (m)	Channel Thalweg (m)	Simulated Water Level (m)												
		2-Year Flood Event	5-Year Flood Event	10-Year Flood Event	20-Year Flood Event	35-Year Flood Event	50-Year Flood Event	75-Year Flood Event	100-Year Flood Event	200-Year Flood Event	350-Year Flood Event	500-Year Flood Event	750-Year Flood Event	1000-Year Flood Event
10+250	845.24	847.14	847.83	848.10	848.30	848.44	848.54	848.64	848.72	848.90	849.05	849.14	849.26	849.34
10+000	845.07	846.82	847.50	847.73	847.88	847.98	848.05	848.13	848.18	848.32	848.44	848.52	848.61	848.68
9+750	844.94	846.53	847.19	847.42	847.55	847.65	847.71	847.78	847.83	847.95	848.06	848.13	848.22	848.28
9+500	844.17	846.14	846.79	847.02	847.14	847.22	847.28	847.35	847.40	847.53	847.64	847.72	847.81	847.86
9+250	843.85	846.01	846.63	846.83	846.93	847.00	847.05	847.12	847.17	847.31	847.43	847.51	847.61	847.66
9+000	843.84	845.89	846.47	846.62	846.70	846.78	846.85	846.94	847.02	847.20	847.33	847.42	847.53	847.59
8+750	843.71	845.72	846.24	846.36	846.46	846.65	846.77	846.89	846.98	847.17	847.31	847.41	847.51	847.58
8+500	843.15	845.55	846.00	846.09	846.26	846.60	846.75	846.88	846.97	847.17	847.31	847.40	847.51	847.57
8+250	842.81	845.36	845.81	845.93	846.22	846.59	846.74	846.88	846.97	847.16	847.31	847.40	847.51	847.57
8+000	842.61	845.16	845.61	845.83	846.21	846.59	846.74	846.88	846.97	847.16	847.31	847.40	847.51	847.57
7+750	843.00	845.02	845.55	845.82	846.21	846.59	846.74	846.87	846.97	847.16	847.30	847.40	847.50	847.57
7+500	842.60	844.81	845.43	845.72	846.14	846.54	846.69	846.82	846.90	847.04	847.14	847.19	847.26	847.30
7+250	842.49	844.61	845.30	845.68	846.13	846.54	846.69	846.82	846.90	847.04	847.13	847.19	847.25	847.29
7+000	842.30	844.45	845.23	845.65	846.12	846.52	846.68	846.80	846.88	847.03	847.12	847.18	847.24	847.28
6+750	842.13	844.14	844.70	844.86	844.98	845.06	845.10	845.12	845.14	845.17	845.19	845.20	845.21	845.22
6+500	842.14	843.93	844.51	844.71	844.83	844.93	844.96	844.99	845.01	845.05	845.07	845.08	845.10	845.11
6+250	841.80	843.70	844.29	844.51	844.66	844.77	844.82	844.86	844.88	844.92	844.94	844.96	844.98	844.99
6+000	841.30	843.22	843.89	844.16	844.33	844.43	844.47	844.50	844.52	844.55	844.57	844.58	844.59	844.60
5+750	840.60	842.99	843.63	843.89	844.04	844.14	844.18	844.20	844.22	844.25	844.26	844.27	844.28	844.29
5+500	840.74	842.69	843.32	843.56	843.70	843.79	843.82	843.84	843.85	843.88	843.89	843.90	843.91	843.92
5+250	840.63	842.40	843.02	843.23	843.33	843.39	843.41	843.43	843.44	843.46	843.48	843.49	843.50	843.51
5+000	841.49	842.24	842.84	843.00	843.08	843.14	843.16	843.17	843.19	843.21	843.24	843.26	843.28	843.30
4+750	840.03	841.99	842.63	842.80	842.90	842.97	843.00	843.03	843.04	843.09	843.14	843.17	843.20	843.23
4+500	839.55	841.84	842.45	842.63	842.74	842.82	842.86	842.90	842.93	842.99	843.05	843.09	843.14	843.17
4+250	839.37	841.71	842.29	842.46	842.58	842.67	842.72	842.77	842.81	842.89	842.96	843.01	843.06	843.10
4+000	839.16	841.59	842.13	842.30	842.42	842.51	842.57	842.63	842.67	842.77	842.85	842.90	842.95	842.99
3+750	839.50	841.47	841.99	842.16	842.29	842.38	842.43	842.49	842.53	842.64	842.72	842.76	842.82	842.86
3+500	839.05	841.21	841.78	841.96	842.08	842.17	842.22	842.27	842.32	842.43	842.52	842.58	842.64	842.68
3+250	838.70	840.93	841.46	841.59	841.69	841.77	841.82	841.89	841.94	842.15	842.28	842.35	842.42	842.48

3+000	838.35	840.70	841.26	841.42	841.55	841.65	841.72	841.79	841.86	842.11	842.24	842.31	842.39	842.45
2+750	838.12	840.49	841.13	841.31	841.45	841.55	841.62	841.70	841.77	842.05	842.20	842.27	842.35	842.40
2+500	837.75	840.29	840.96	841.15	841.28	841.38	841.45	841.54	841.62	841.97	842.12	842.20	842.28	842.33
2+250	837.75	840.03	840.73	840.96	841.10	841.21	841.29	841.39	841.49	841.91	842.07	842.14	842.22	842.28
2+000	837.29	839.88	840.56	840.79	840.93	841.04	841.13	841.24	841.37	841.86	842.03	842.10	842.18	842.23
1+750	837.60	839.72	840.38	840.61	840.75	840.87	840.97	841.11	841.26	841.82	841.99	842.06	842.14	842.19
1+500	837.34	839.44	840.05	840.31	840.51	840.68	840.82	841.01	841.19	841.80	841.97	842.04	842.11	842.17
1+250	837.25	839.10	839.68	839.97	840.24	840.47	840.66	840.90	841.11	841.76	841.94	842.00	842.07	842.13
1+000	837.21	838.80	839.34	839.63	839.94	840.22	840.44	840.72	840.96	841.69	841.85	841.91	841.97	842.02
0+750	836.34	838.41	839.00	839.35	839.73	840.07	840.33	840.64	840.90	841.66	841.83	841.88	841.94	841.98
0+500	836.16	838.24	838.87	839.27	839.69	840.04	840.31	840.63	840.90	841.66	841.83	841.88	841.94	841.98
0+250	836.13	837.41	837.87	838.13	838.34	838.49	838.60	838.72	838.81	839.03	839.17	839.28	839.36	839.43
0+000	835.94	836.83	837.43	837.68	837.83	837.92	837.99	838.09	838.16	838.36	838.54	838.65	838.78	838.87

APPENDIX F

Open Water Sensitivity Analysis

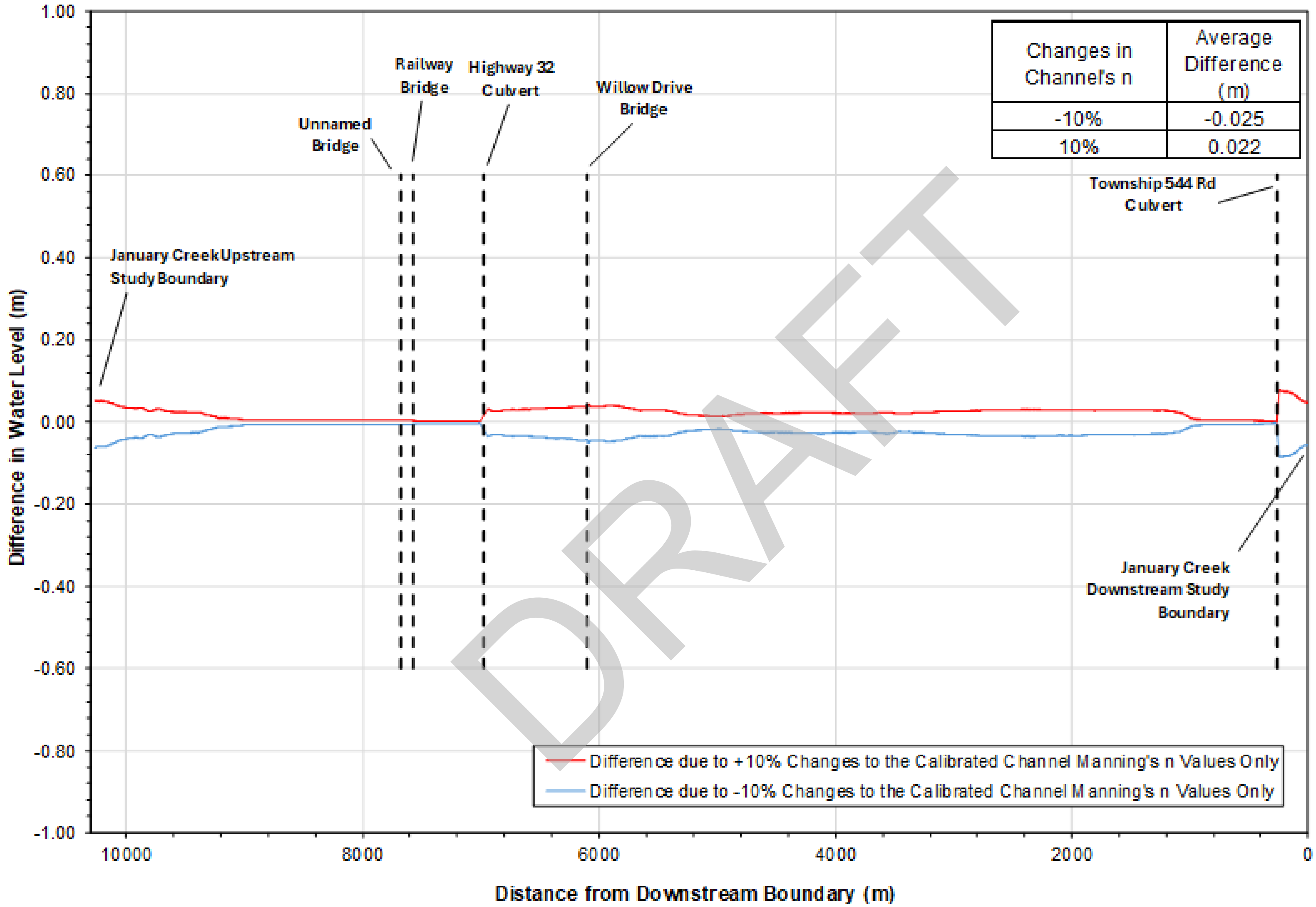


Figure F-1: Sensitivity of Simulated Water Level along the January Creek Study Reach for the 100-Year Flood Event (Channel Manning's n Only)

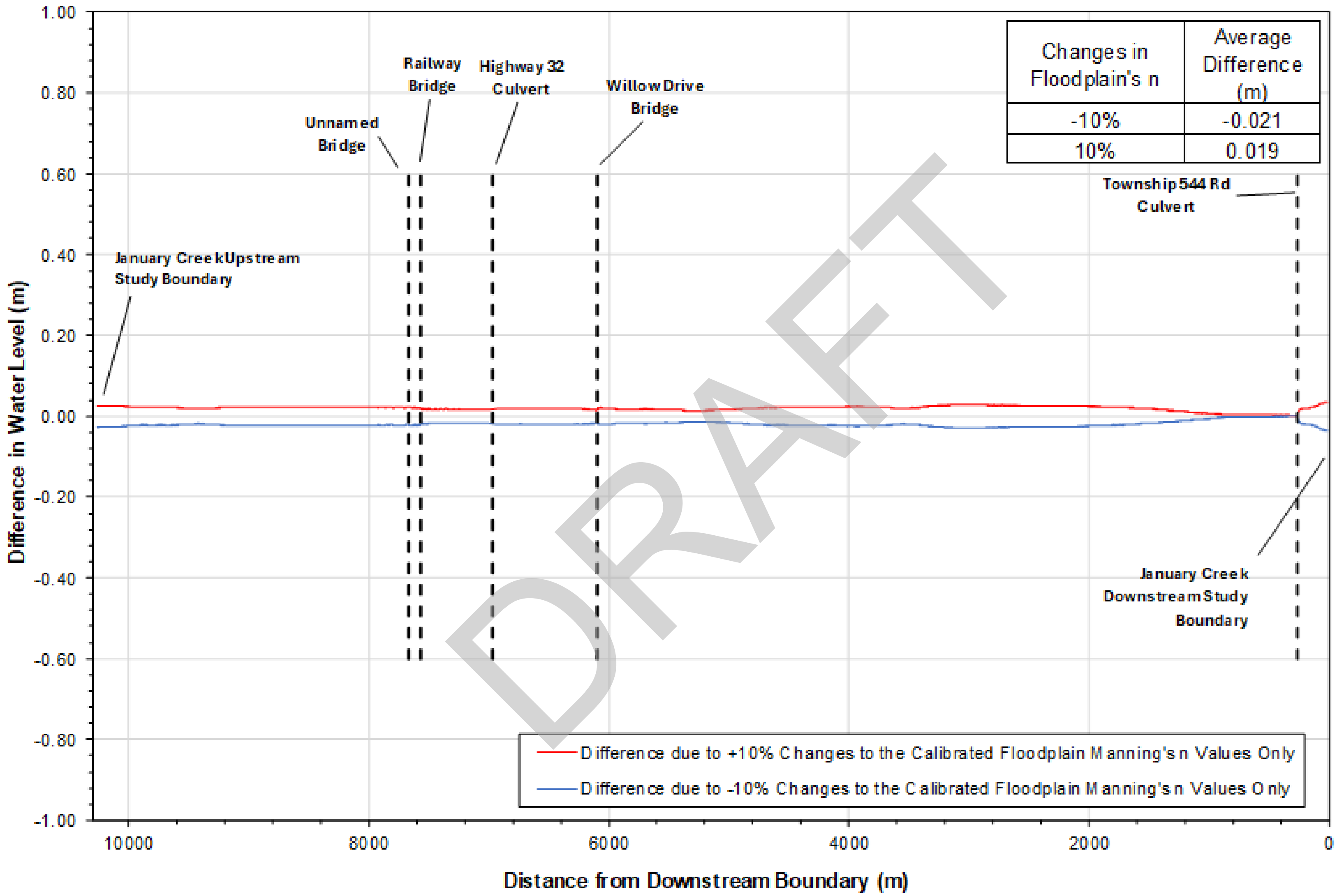


Figure F-2: Sensitivity of Simulated Water Level along the January Creek Study Reach for the 100-Year Flood Event (Floodplain Manning's n Only)

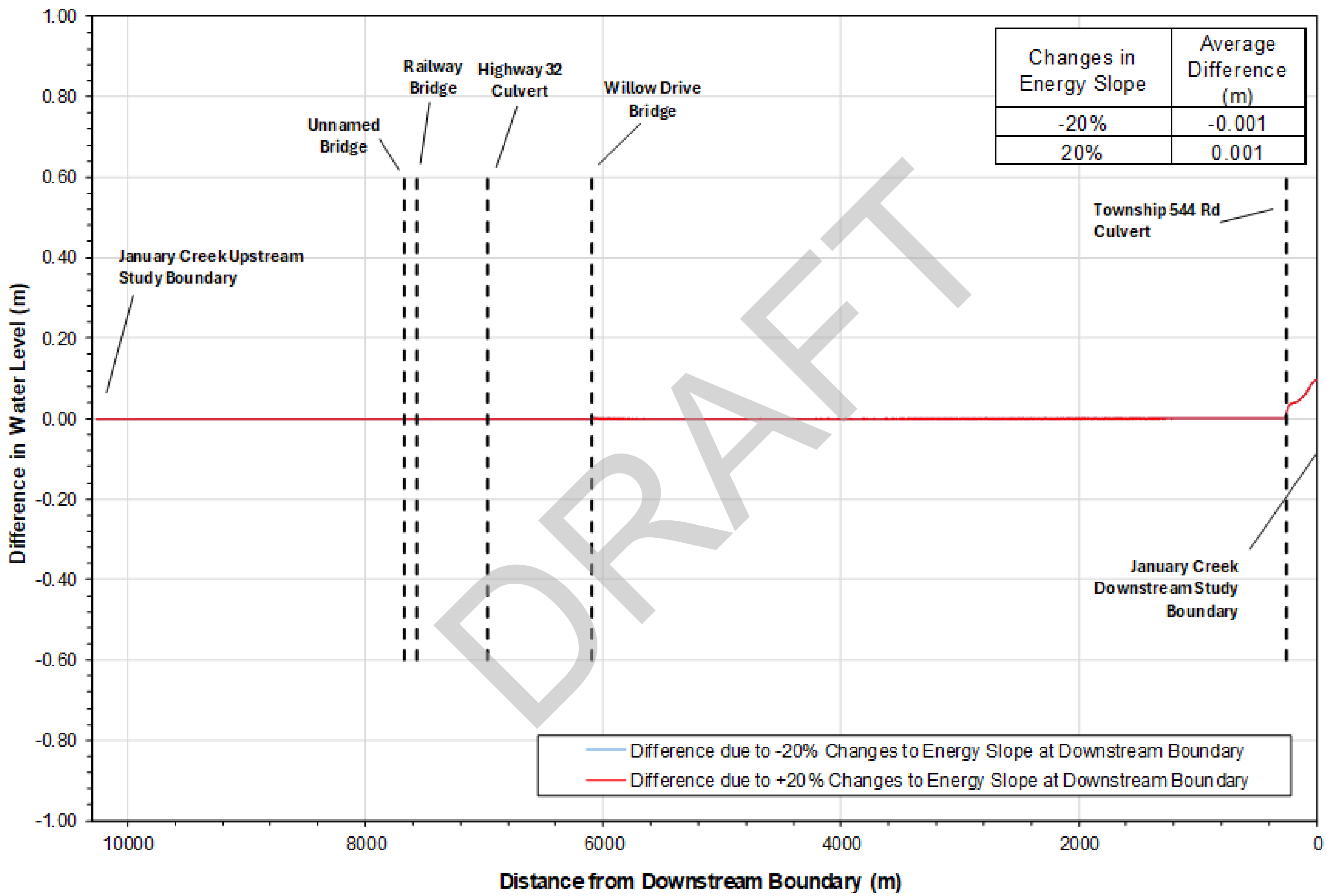


Figure F-3: Sensitivity of Simulated Water Level along the January Creek Study Reach for the 100-Year Flood Event (Downstream Boundary)

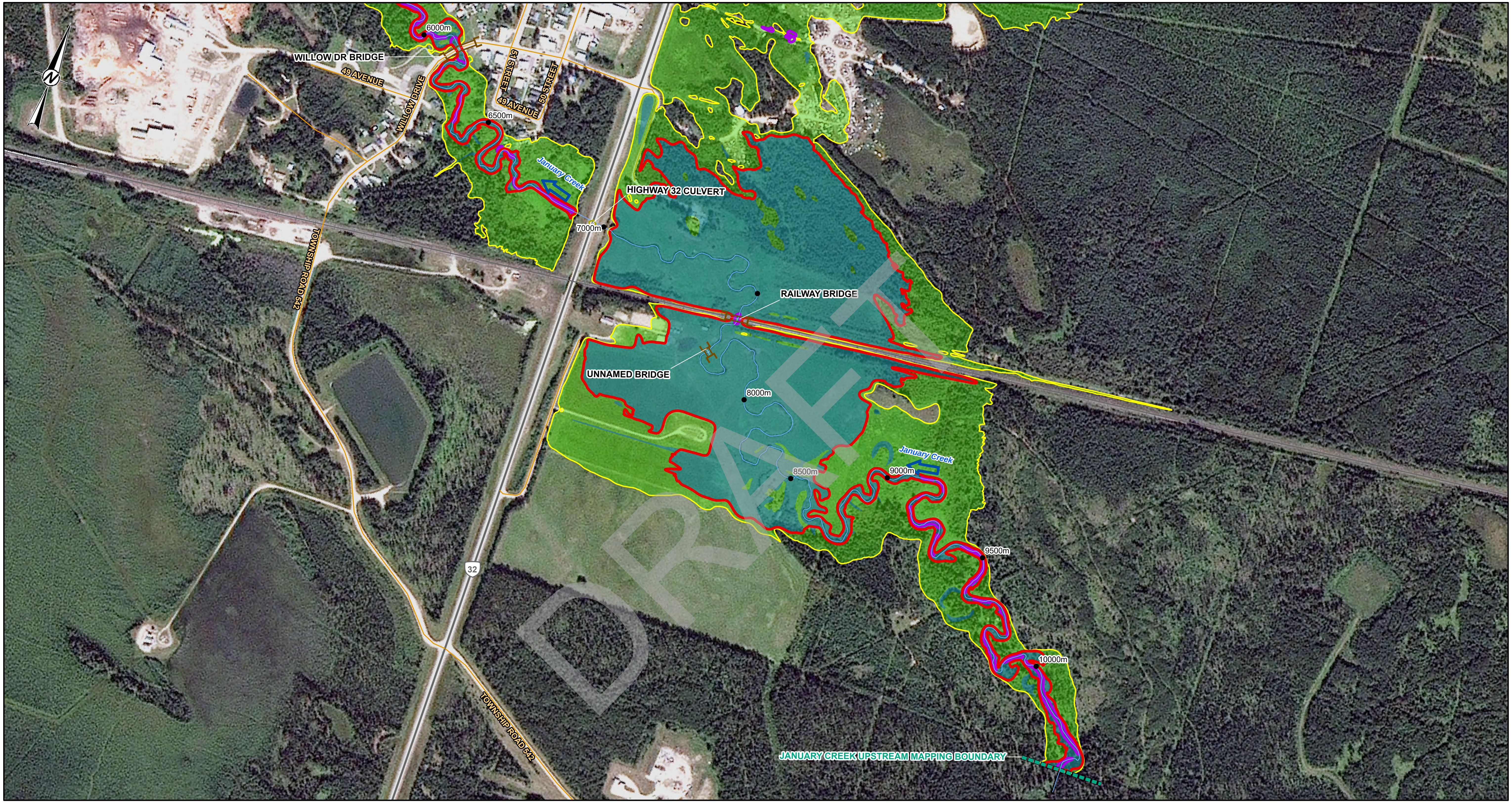
APPENDIX G

Open Water Inundation Maps

TO BE PROVIDED SEPARATELY IN THE MAP LIBRARY

APPENDIX H

Floodway Criteria Maps and Flood Hazard Maps



LEGEND

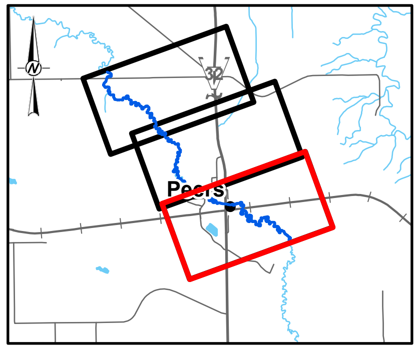
- PROFILE STATION
- MAPPING BOUNDARY
- FLOW DIRECTION
- LOCAL ROAD
- PRIMARY HIGHWAY
- RAILROAD
- CHANNEL CENTRELINE

HYDRAULIC STRUCTURES

- BRIDGE
- CULVERT

- PROPOSED FLOODWAY BOUNDARY
- DEPTH ≥ 1 m
- 100-YEAR DESIGN FLOOD EXTENT
- VELOCITY ≥ 1 m/s

DISCHARGE
JANUARY CREEK = 56.7 m^3/s



0 250 500
1:7,500 METRES

REFERENCE(S)
ROADS AND WATERBODIES OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED OR ALTALIS LTD.© GOVERNMENT OF ALBERTA 2025. ALL RIGHTS RESERVED. PROJECT IMAGERY CAPTURED AUGUST 2023 BY PLANET LABS GEOMATICS CORP. FOR THE GOVERNMENT OF ALBERTA.
DATUM: NAD 83 CSRS PROJECTION: 3TM 117

CLIENT
ALBERTA ENVIRONMENT AND PROTECTED AREAS

Alberta Canada

CONSULTANT
wsp

YYYY-MM-DD	2025-09-22
DESIGNED	AL
PREPARED	MV
REVIEWED	GT
APPROVED	LH

PROJECT
PEERS FLOOD STUDY

TITLE
FLOODWAY CRITERIA MAP

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	5000	0	SHEET 1 OF 3

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

Classification: Public

LEGEND

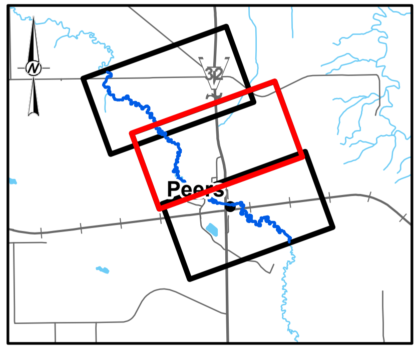
- ● PROFILE STATION
- MAPPING BOUNDARY
- FLOW DIRECTION
- LOCAL ROAD
- PRIMARY HIGHWAY
- RAILROAD
- CHANNEL CENTRELINE

HYDRAULIC STRUCTURES

- BRIDGE
- CULVERT

- PROPOSED FLOODWAY BOUNDARY
- DEPTH ≥ 1 m
- 100-YEAR DESIGN FLOOD EXTENT
- VELOCITY ≥ 1 m/s

DISCHARGE
JANUARY CREEK = 56.7 m^3/s



0 250 500
1:7,500 METRES

CLIENT
ALBERTA ENVIRONMENT AND PROTECTED AREAS

CONSULTANT

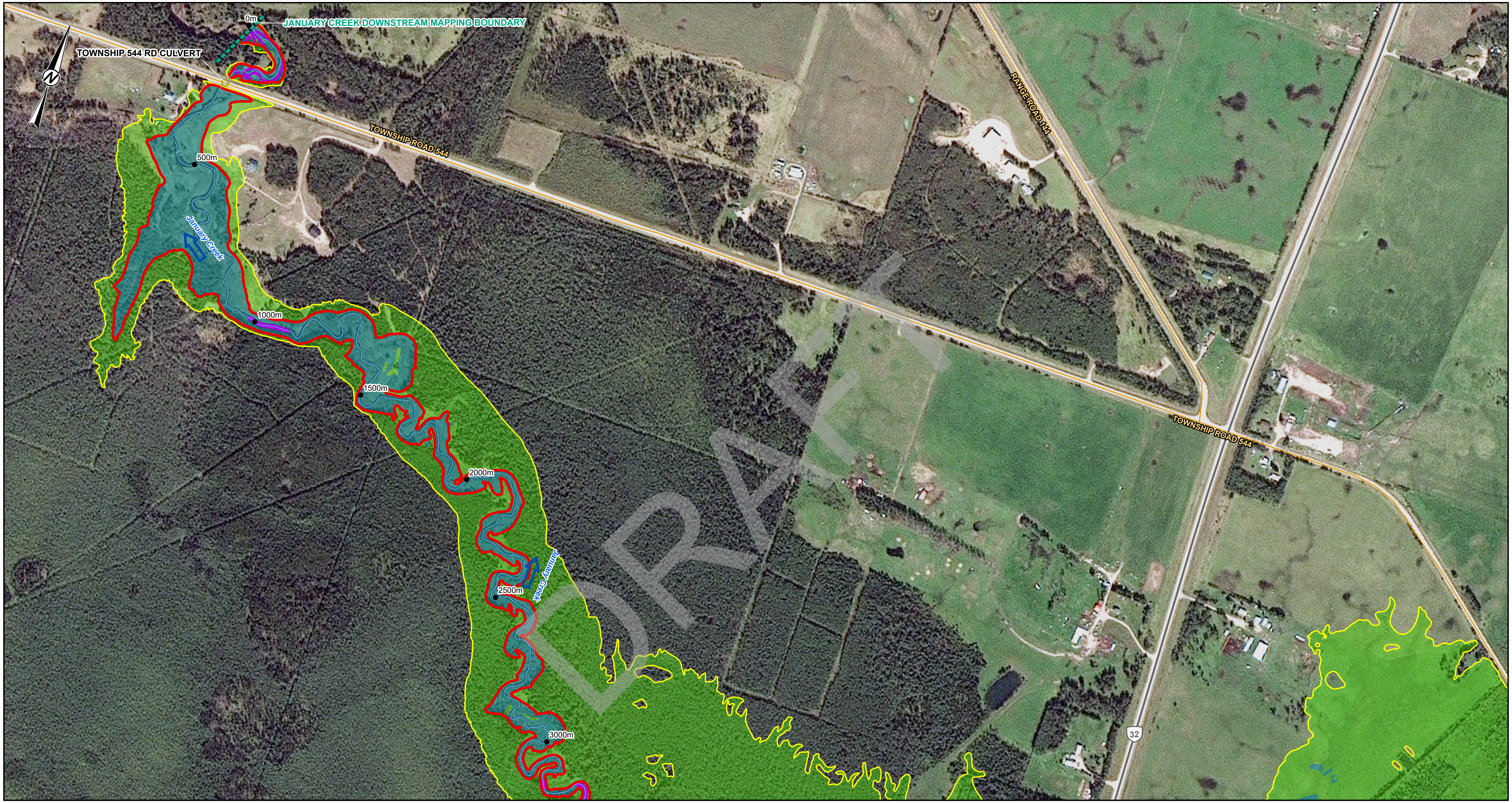
YYYY-MM-DD	2025-09-22
DESIGNED	AL
PREPARED	MV
REVIEWED	GT
APPROVED	LH

REFERENCE(S)
ROADS AND WATERBODIES OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED OR ALTALIS LTD.© GOVERNMENT OF ALBERTA 2025. ALL RIGHTS RESERVED. PROJECT IMAGERY CAPTURED AUGUST 2023 BY PLANET LABS GEOMATICS CORP. FOR THE GOVERNMENT OF ALBERTA.
DATUM: NAD 83 CSRS PROJECTION: 3TM 117

PROJECT
PEERS FLOOD STUDY

TITLE
FLOODWAY CRITERIA MAP

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	5000	0	SHEET 2 OF 3



LEGEND

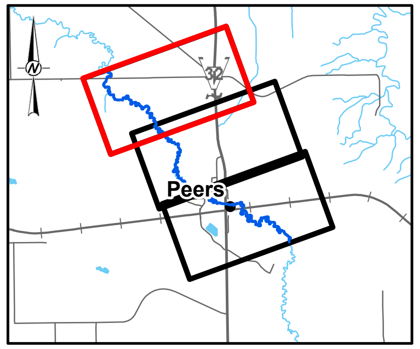
- PROFILE STATION
- MAPPING BOUNDARY
- FLOW DIRECTION
- LOCAL ROAD
- PRIMARY HIGHWAY
- RAILROAD
- CHANNEL CENTRELINE

HYDRAULIC STRUCTURES

- BRIDGE
- CULVERT

- PROPOSED FLOODWAY BOUNDARY
- DEPTH ≥ 1 m
- 100-YEAR DESIGN FLOOD EXTENT
- VELOCITY ≥ 1 m/s

DISCHARGE
JANUARY CREEK = 56.7 m^3/s



0 250 500
1:7,500 METRES

CLIENT
ALBERTA ENVIRONMENT AND PROTECTED AREAS

CONSULTANT

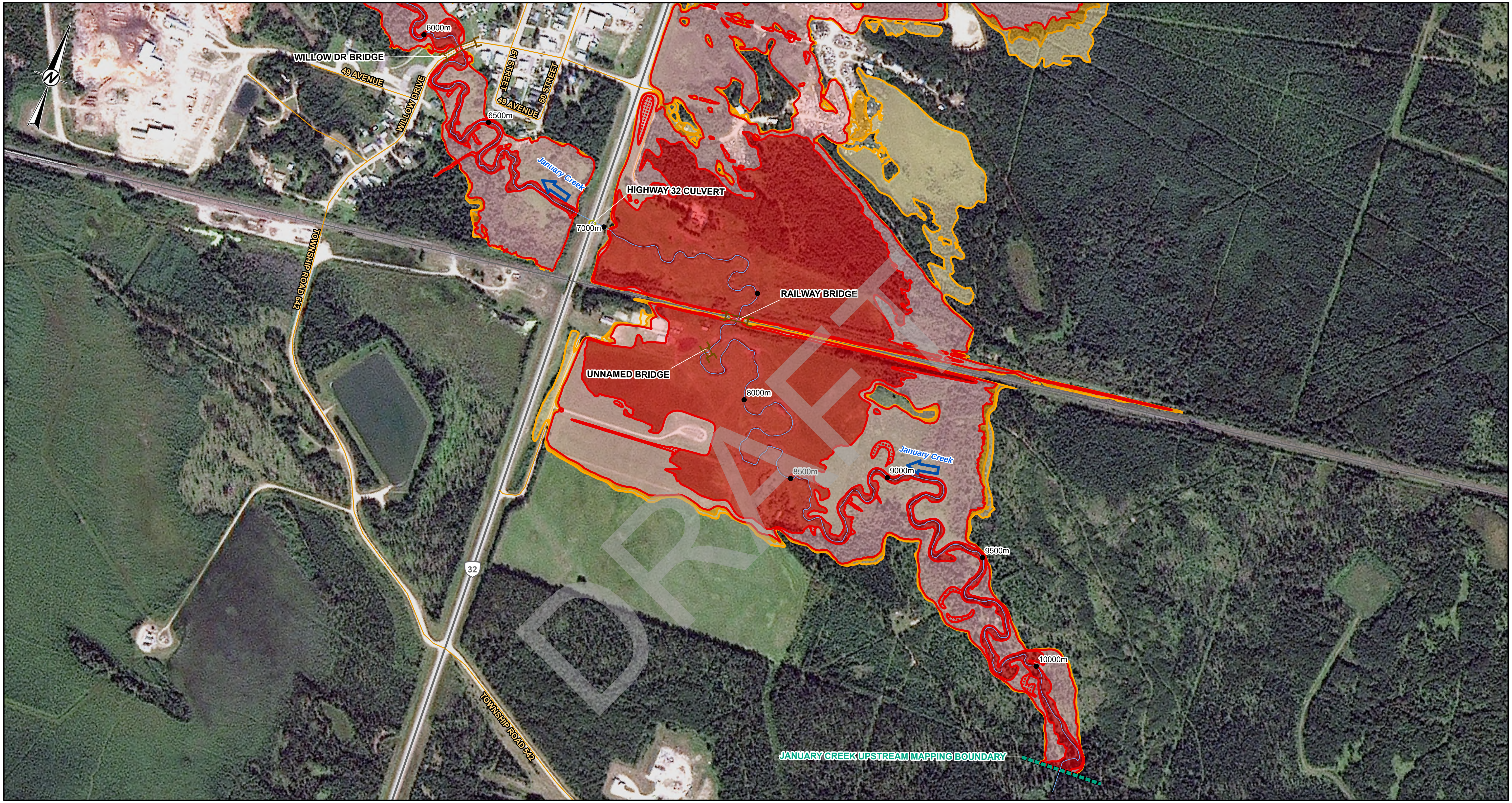
YYYY-MM-DD	2025-09-22
DESIGNED	AL
PREPARED	MV
REVIEWED	GT
APPROVED	LH

REFERENCE(S)
ROADS AND WATERBODIES OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED OR ALTALIS LTD.© GOVERNMENT OF ALBERTA 2025. ALL RIGHTS RESERVED. PROJECT IMAGERY CAPTURED AUGUST 2023 BY PLANET LABS GEOMATICS CORP. FOR THE GOVERNMENT OF ALBERTA.
DATUM: NAD 83 CSRS PROJECTION: 3TM 117

PROJECT
PEERS FLOOD STUDY

TITLE
FLOODWAY CRITERIA MAP

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	5000	0	SHEET 3 OF 3



LEGEND

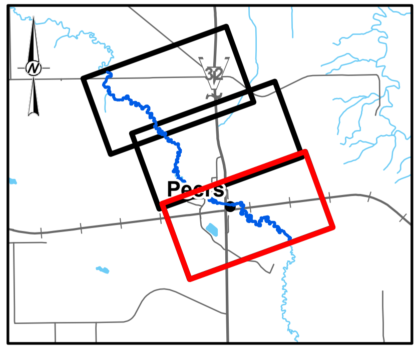
- PROFILE STATION
- MAPPING BOUNDARY
- FLOW DIRECTION
- LOCAL ROAD
- PRIMARY HIGHWAY
- RAILROAD
- CHANNEL CENTRELINE

HYDRAULIC STRUCTURES

- BRIDGE
- CULVERT

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

DISCHARGE
JANUARY CREEK = 56.7 m^3/s



0 250 500
1:7,500 METRES

CLIENT
ALBERTA ENVIRONMENT AND PROTECTED AREAS

CONSULTANT

YYYY-MM-DD	2025-09-22
DESIGNED	AL
PREPARED	MV
REVIEWED	GT
APPROVED	LH

REFERENCE(S)

DATUM: NAD 83 CSRS PROJECTION: 3TM 117

PROJECT
PEERS FLOOD STUDY

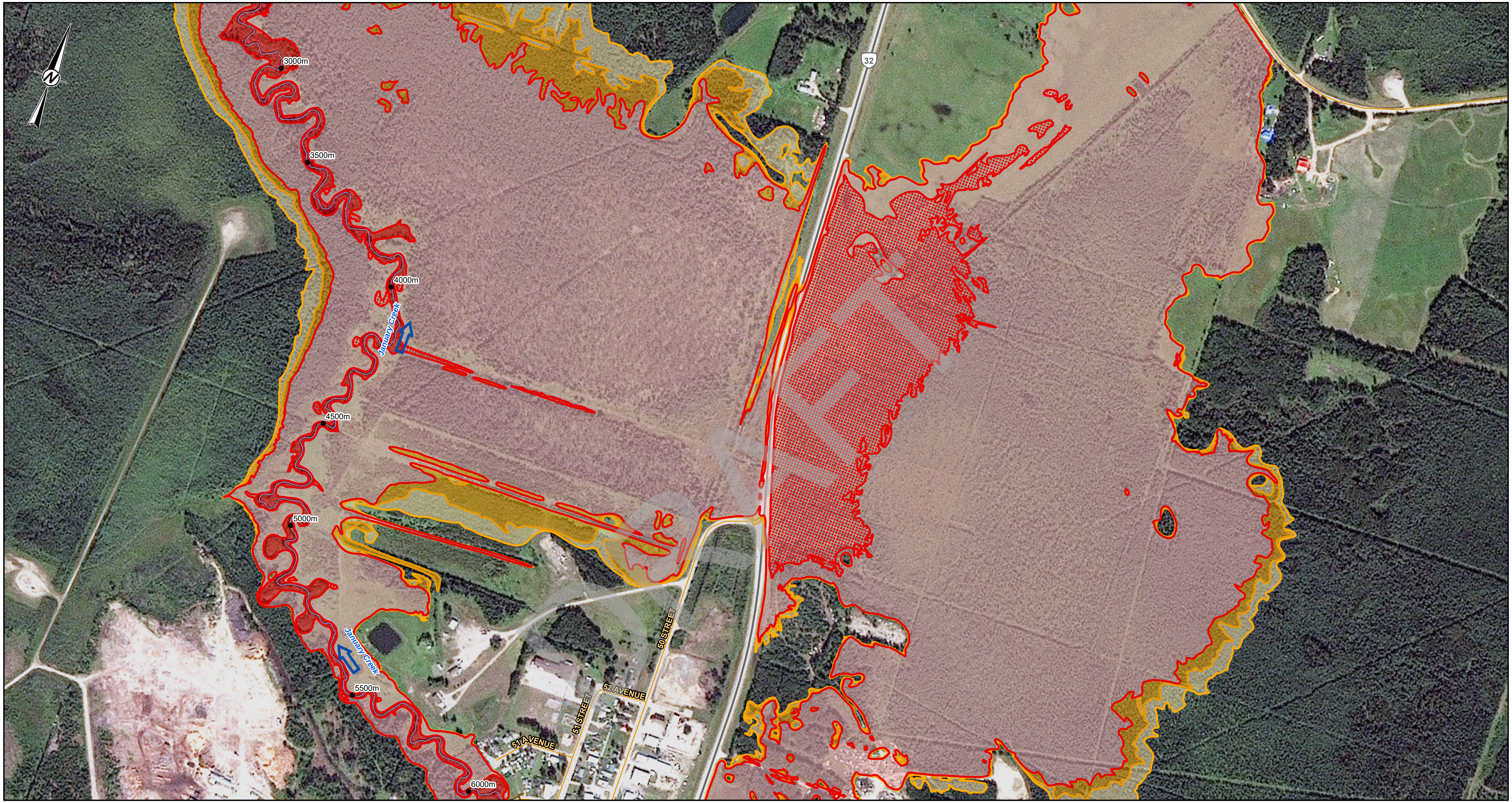
TITLE
FLOOD HAZARD MAP

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	5000	0	SHEET 1 OF 3

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

25mm

Classification: Public



LEGEND

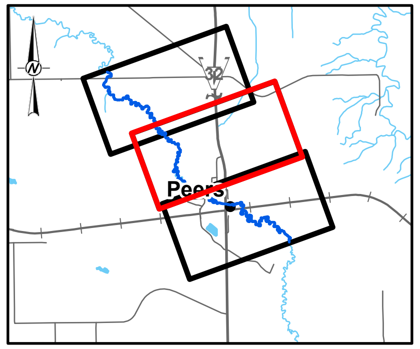
- ● PROFILE STATION
- MAPPING BOUNDARY
- FLOW DIRECTION
- LOCAL ROAD
- PRIMARY HIGHWAY
- RAILROAD
- CHANNEL CENTRELINE

HYDRAULIC STRUCTURES

- BRIDGE
- CULVERT

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

DISCHARGE
JANUARY CREEK = 56.7 m^3/s



0 250 500
1:7,500 METRES

CLIENT
ALBERTA ENVIRONMENT AND PROTECTED AREAS

CONSULTANT

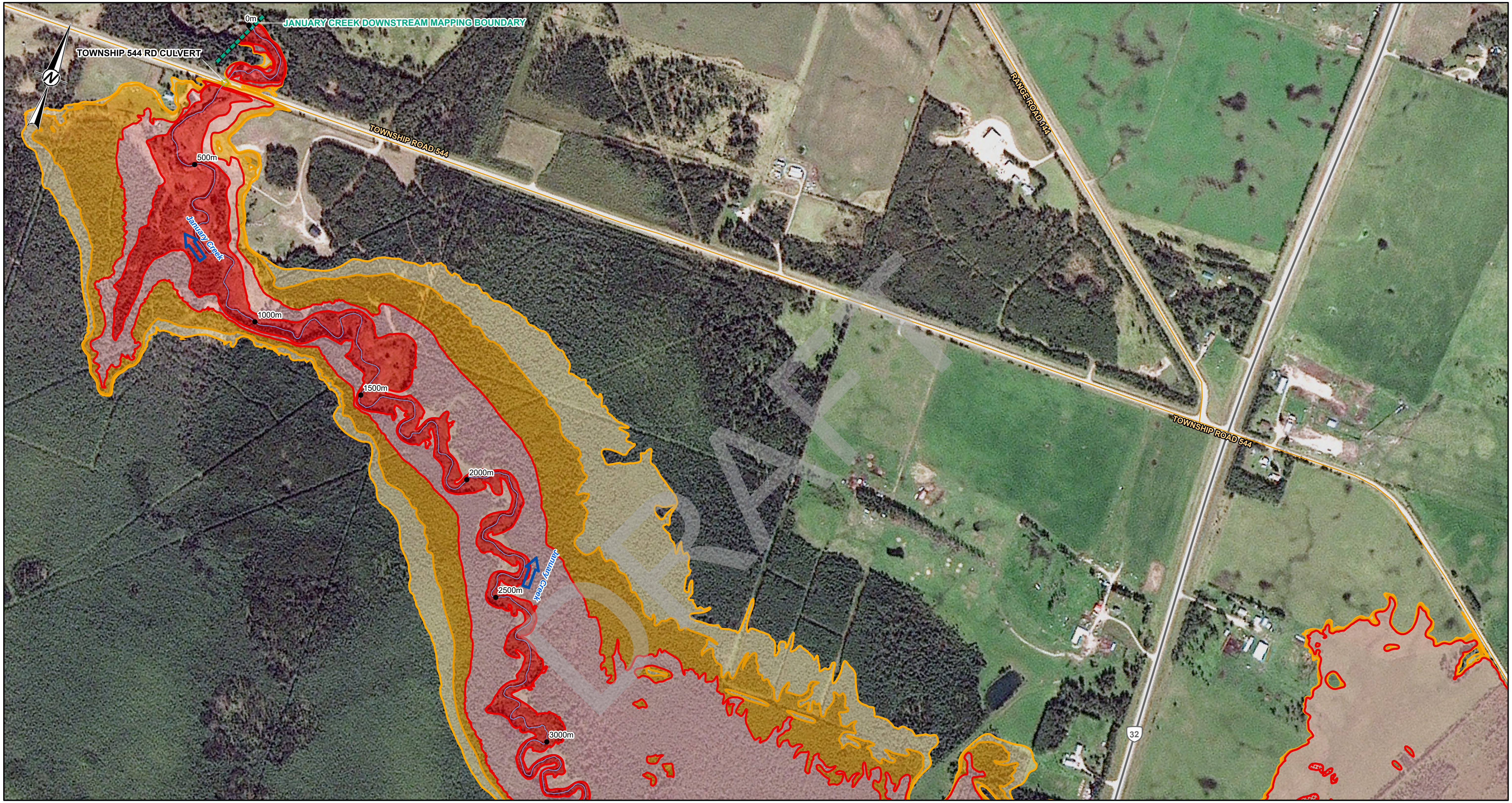
YYYY-MM-DD	2025-09-22
DESIGNED	AL
PREPARED	MV
REVIEWED	GT
APPROVED	LH

DATUM: NAD 83 CSRS PROJECTION: 3TM 117

PROJECT
PEERS FLOOD STUDY

TITLE
FLOOD HAZARD MAP

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	5000	0	SHEET 2 OF 3



LEGEND

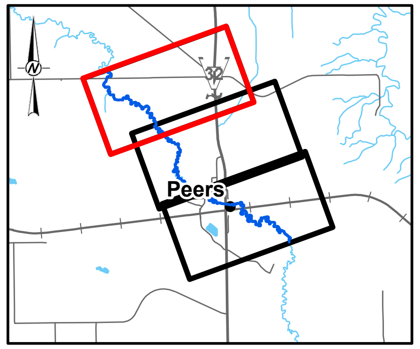
- PROFILE STATION
- MAPPING BOUNDARY
- FLOW DIRECTION
- LOCAL ROAD
- PRIMARY HIGHWAY
- RAILROAD
- CHANNEL CENTRELINE

HYDRAULIC STRUCTURES

- BRIDGE
- CULVERT

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

DISCHARGE
JANUARY CREEK = 56.7 m^3/s



0 250 500
1:7,500 METRES

CLIENT
ALBERTA ENVIRONMENT AND PROTECTED AREAS

CONSULTANT

YYYY-MM-DD	2025-09-22
DESIGNED	AL
PREPARED	MV
REVIEWED	GT
APPROVED	LH

REFERENCE(S)

DATUM: NAD 83 CSRS PROJECTION: 3TM 117

PROJECT
PEERS FLOOD STUDY

TITLE
FLOOD HAZARD MAP

PROJECT NO.	CONTROL	REV.	FIGURE
CA0041746.1954	5000	0	SHEET 3 OF 3

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

APPENDIX I

Climate Change Flood Profiles

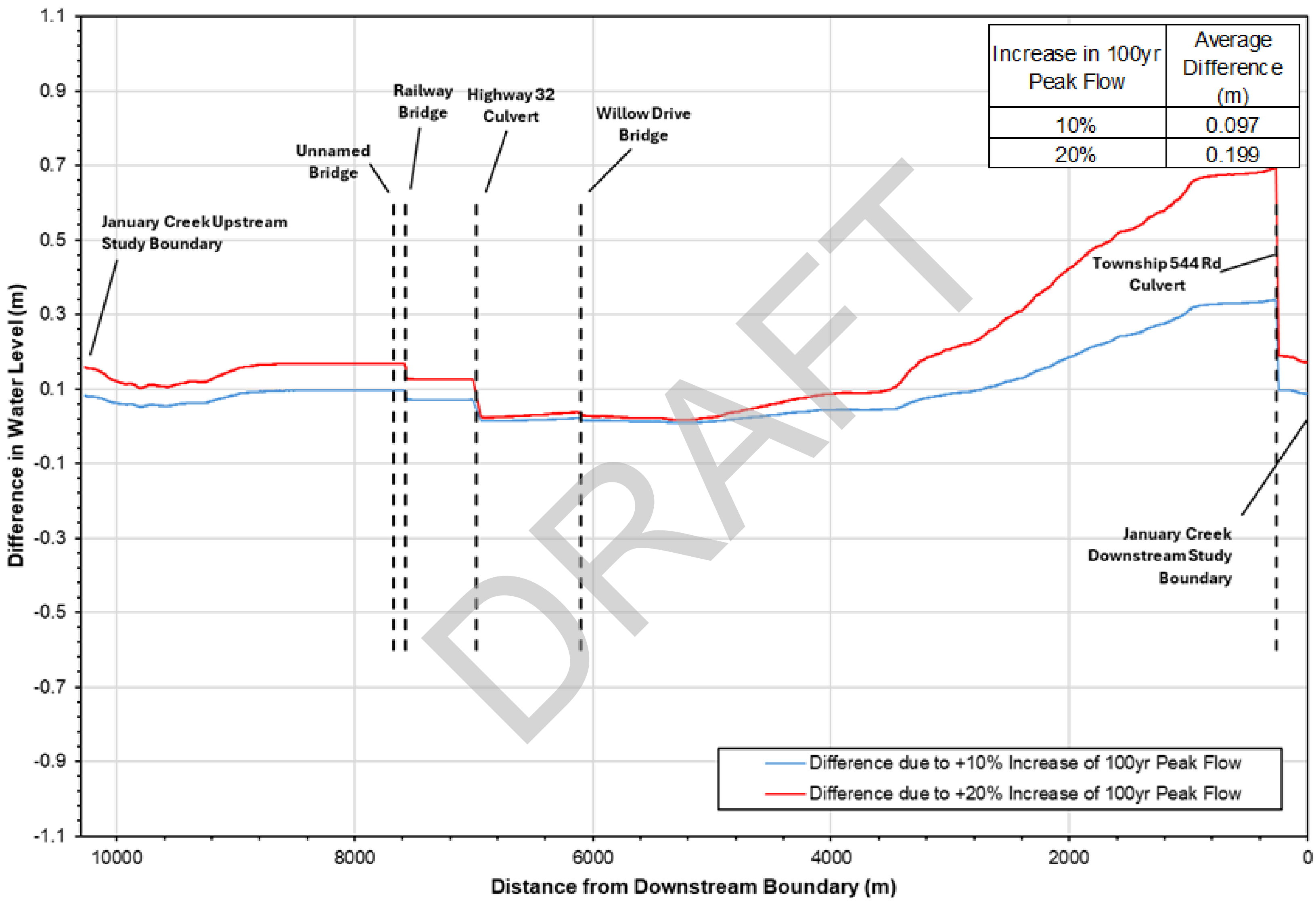


Figure I-1: Simulated Water Surface Profile along the January Creek Study Reach Due to Climate Change

Table I-1: Water Level Difference along the January Creek Study Reach due to Climate Change

River	River Station (m)	Water Level for 100-Year Peak Flow (Base Case) (m)	Water Level for 10% Increase in Peak Flow (m)	Water Level for 20% Increase in Peak Flow (m)	Difference due to 10% increase in Peak Flow (m)	Difference due to 20% increase in Peak Flow (m)
January Creek	10+250	848.72	848.80	848.87	0.08	0.15
January Creek	10+000	848.18	848.24	848.30	0.06	0.12
January Creek	9+750	847.83	847.88	847.94	0.05	0.11
January Creek	9+500	847.40	847.46	847.51	0.06	0.11
January Creek	9+250	847.17	847.23	847.29	0.06	0.12
January Creek	9+000	847.02	847.10	847.17	0.08	0.15
January Creek	8+750	846.98	847.08	847.15	0.09	0.17
January Creek	8+500	846.97	847.07	847.14	0.10	0.17
January Creek	8+250	846.97	847.07	847.14	0.10	0.17
January Creek	8+000	846.97	847.07	847.14	0.10	0.17
January Creek	7+750	846.97	847.06	847.14	0.09	0.17
January Creek	7+500	846.90	846.97	847.03	0.07	0.13
January Creek	7+250	846.90	846.97	847.02	0.07	0.13
January Creek	7+000	846.88	846.96	847.01	0.07	0.13
January Creek	6+750	845.14	845.16	845.17	0.01	0.03
January Creek	6+500	845.01	845.03	845.04	0.02	0.03
January Creek	6+250	844.88	844.90	844.91	0.02	0.03
January Creek	6+000	844.52	844.53	844.54	0.01	0.03
January Creek	5+750	844.22	844.23	844.24	0.01	0.02
January Creek	5+500	843.85	843.87	843.88	0.01	0.02
January Creek	5+250	843.44	843.45	843.46	0.01	0.02
January Creek	5+000	843.19	843.20	843.21	0.01	0.02
January Creek	4+750	843.04	843.07	843.09	0.02	0.04
January Creek	4+500	842.93	842.96	842.98	0.03	0.06
January Creek	4+250	842.81	842.84	842.88	0.04	0.08
January Creek	4+000	842.67	842.71	842.76	0.04	0.08
January Creek	3+750	842.53	842.57	842.62	0.04	0.09
January Creek	3+500	842.32	842.36	842.41	0.04	0.10
January Creek	3+250	841.94	842.01	842.11	0.07	0.17
January Creek	3+000	841.86	841.94	842.06	0.09	0.21
January Creek	2+750	841.77	841.87	842.01	0.10	0.24
January Creek	2+500	841.62	841.74	841.91	0.12	0.29
January Creek	2+250	841.49	841.64	841.85	0.15	0.36
January Creek	2+000	841.37	841.55	841.79	0.18	0.42
January Creek	1+750	841.26	841.48	841.75	0.22	0.48
January Creek	1+500	841.19	841.44	841.72	0.24	0.53
January Creek	1+250	841.11	841.38	841.68	0.27	0.57
January Creek	1+000	840.96	841.27	841.60	0.31	0.64
January Creek	0+750	840.90	841.23	841.58	0.33	0.67
January Creek	0+500	840.90	841.23	841.57	0.33	0.68
January Creek	0+250	838.81	838.91	839.00	0.10	0.19
January Creek	0+000	838.16	838.25	838.33	0.09	0.17

wsp.com