Ponoka Flood Study

Main Report

Prepared by:

Northwest Hydraulic Consultants Ltd.
9819 – 12 Avenue SW
Edmonton, AB T6X 0E3
Tel: 780.436.5868
www.nhcwater.com

Prepared for:

Alberta Environment and Protected Areas
11th floor, Oxbridge Place
9820-106 Street NW
Edmonton, AB T5K 2J6

March 1, 2025
Main Report

NHC Reference No. 1008017

Report prepared by:

Dan Healy, PhD, PEng
Principal

Ken Zhao, PhD, PEng
Principal
Hydrology

Report reviewed by:

Robyn Andrishak, MSc, PEng
Principal

DISCLAIMER

This report has been prepared by Northwest Hydraulic Consultants Ltd. for the benefit of Alberta Environment and Protected Areas for specific application to the Ponoka Flood Study. The information and data contained herein represent **Northwest Hydraulic Consultants Ltd.'s** professional judgment in light of the knowledge and information available to **Northwest Hydraulic Consultants Ltd.** at the time of preparation and were prepared in accordance with generally accepted engineering and geoscience practices.

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

CREDITS AND ACKNOWLEDGEMENTS

The authors would like to thank Alberta Environment and Protected Areas for initiating this study, making background information available, and providing technical input throughout the project.

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.

The efforts of the following project representatives from Environment and Protected Areas, River Engineering and Technical Services are greatly appreciated:

- Jane Eaket — Water Resources Engineer, Project Manager
- Tachara Larocque — River Hazard Technologist, Project Advisor
- Peter Onyshko — Flood Hazard Specialist, Project Advisor

NHC personnel that participated in this study and their roles are:

- Robyn Andrishak — Review
- Dan Healy — Project Manager and Lead Project Engineer
- Ken Zhao — Lead Hydrology Specialist
- Makamum Mahmood — Hydrology Specialist
- Kevin Emmelkamp — Engineering Technical Support
- Jerry Yan — GIS Specialist
- Gary Van Der Vinne — Senior Advisor

EXECUTIVE SUMMARY

The Ponoka Flood Study was initiated by Alberta Environment and Protected Areas (EPA) to identify and assess flood hazards along the Battle River and an unnamed tributary through the Town of Ponoka and Ponoka County. This study is being undertaken as part of the Flood Hazard Identification Program (FHIP) with the intent of enhancing public safety and reducing future flood damages within the Province of Alberta.

The Ponoka Flood Study is comprised of five major components: Survey and Base Data Collection, Flood Hydrology, Hydraulic Modelling, Flood Inundation Mapping, Design Flood Hazard Mapping, and Documentation and Reporting. This report summarizes the work of all five components.

Open water flood frequency estimates were developed for each watercourse for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1000-year flood scenarios. The current estimates are notably smaller than those available from previous studies. This difference is largely attributed to (1) a 30 year increase in the hydrologic data record and (2) the separation of spring and summer flood events and application of a combined-population frequency analysis approach.

A detailed fully 2D hydraulic model was developed to compute flood levels for all 13 flood scenarios. The computed flood levels were then used to determine the extent of inundation for each of the respective flood scenarios and are presented as a set of flood inundation maps for each scenario (the flood inundation map library). This library is intended primarily for stakeholders to use in emergency response planning and preparation.

The open water floodway criteria maps and design flood hazard maps are key deliverables for this project and are provided as appendices to this report. Flood hazard identification involves defining the flood hazard area, which is comprised of floodway and flood fringe zones. Areas of deeper or faster moving water outside of the floodway (within the flood fringe) are identified as high hazard flood fringe areas. The design flood hazard map depicts the floodway and flood fringe based on the information resulting from the floodway criteria map. The methods summarized in this report follow the provincial FHIP Flood Study Technical Guidelines (June 2022), incorporating technical changes implemented in 2021 regarding how floodways are mapped in Alberta.

Due to the notable changes in the 100-year design floodway, the current floodway was redetermined according to the normal floodway criteria based on the results of the 2D modelling. The current floodway is smaller than the previous floodway, owing to the reduction of the 100-year design flood magnitude.

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1 INTRODUCTION

1.1 Study Background

In March 2023, Alberta Environment and Protected Areas (EPA) retained Northwest Hydraulic Consultants Ltd. (NHC) to complete a flood study for approximately 19 km of the Battle River and approximately 5 km of an unnamed tributary through the Town of Ponoka and Ponoka County. This study was facilitated under the Province's Flood Hazard Identification Program (FHIP) with the intent to enhance public safety and reduce future flood damages in Alberta. Results from this study are also intended to inform local land use planning decisions, flood mitigation projects, and emergency response planning.

This study replaces a prior provincial study completed in 1994; it provides updated hydrology and expands on the prior hydraulic modelling and flood mapping coverage.

The study is comprised of the following five major study components:

1. Survey and Base Data Collection
2. Flood Hydrology
3. Hydraulic Modelling
4. Flood Inundation Mapping
5. Design Flood Hazard Mapping

The open water hydrology assessment was completed in the early stages of the project and was issued as a separate report to EPA on 20 November 2023. The full open water hydrology assessment is reproduced in this report as **Appendix A**. All other study components are summarized within the main body of this report.

1.2 Study Objectives

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
- Flood history documentation
- Open water hydrology assessment to provide flood frequency estimates

- Development of a calibrated open water hydraulic model and simulation of flood levels over a range of return periods
- Sensitivity analysis of simulated flood levels to variation in key modelling parameters
- Production of flood inundation maps for selected return periods
- Production of floodway criteria and flood hazard maps for the selected design flood

1.3 Study Area and Reach

Figure 1 depicts the study area illustrating the extent of the study reach and boundaries of the mapping domain, which includes:

- A 19 km long reach of the Battle River extending upstream from the Highway 2 bridge downstream to the Township Road 434 bridge.
- The lower 5 km segment of an unnamed tributary extending from Highway 2A to its confluence with the Battle River in the Town of Ponoka, just upstream of the Highway 53 crossing.

The study reach was extended to include river cross section data some distance above and below the mapping domain to improve hydraulic modelling and mapping – primarily to limit the potential effects of model boundary conditions on the accuracy of results within the mapping domain.

2 SURVEY AND BASE DATA COLLECTION

This section details the survey procedure and methodology, including the coordinate system and datum. It summarizes the control network points and discusses survey accuracy and comparisons with the published benchmarks. Additionally, it describes the collected project base data, such as DTM, aerial imagery, surveyed cross sections, hydraulic structures, flood control structures, site photographs, hydrometric gauging station information, and other base mapping features.

2.1 Digital Terrain Model

Fully-processed and non-hydro-flattened, 0.5 m resolution, bare earth DTM and hill shade raster products were provided by EPA. The LiDAR data were acquired on 10 September 2023 by Lidar Services International Inc. The horizontal spatial reference system is 3TM 114, NAD83 (CSRS), epoch 2002. The vertical datum is CGVD28. The LiDAR derived DTM was verified by EPA to meet or exceed a vertical accuracy of ±15 cm at 95%, on hard, flat, open (non-vegetated) surfaces, using independently collected survey data. A comparison between the survey data elevations and DTM elevations is provided in a Section 2.7.

2.2 Aerial Imagery

Aerial imagery of the study area was provided by EPA. The imagery was acquired in the Fall of 2023. This imagery was used as the image background for all flood mapping products. It was also used as a visual reference for alignment of various geometry features used to construct the hydraulic model. The imagery was orthorectified in the same coordinate system as the DTM, that is: 3TM 114, NAD83 (CSRS).

2.3 Survey Procedures and Methodology

The main survey program was completed between 5 and 9 June 2023, and 21 and 22 August 2023. The objective of the survey program was to survey channel cross sections along the study reaches to support development of a hydraulic model. Before commencement of the work, a survey plan was submitted to and approved by EPA. A site visit was conducted on 1 May 2023 to inspect the study reaches and assess the overall condition of the channel and floodplain.

Ground positioning for the survey was measured using Global Navigation Satellite Systems (GNSS) and Trimble R10 and R12 Real Time Kinematic (RTK) GNSS receivers. The channel bed, bank, and floodplain elevations were all measured with the RTK GNSS receiver attached to a survey rod. The surveyed cross sections included the riverbanks and were extended into the floodplain to overlap with the DTM provided by EPA.

The Trimble RTK GNSS receivers used for the survey can provide an accuracy of ±0.02 m under optimal operating conditions when the receiver is mounted to a tripod with a clear view of the sky and sufficient satellites to accurately establish the receiver position. Additional errors may be introduced when the receiver is off level, obstructed by nearby trees or vegetation, or the receiver height is incorrectly recorded. The expected accuracy of ground-based survey points is ±0.05 m, except in rare cases where points are surveyed in tree cover or near large vertical banks resulting in poor satellite coverage.

2.3.1 Coordinate System and Datum

Horizontal positions were referenced to the three-degree Transverse Mercator (3TM) projection with a central meridian of 114°W. The 3TM projection is part of the Canadian Spatial Reference System (CSRS) North American Datum of 1983 (NAD83), which is a three-dimensional grid on which the position of an object or feature can be precisely pinpointed. Orthometric heights are based on the Canadian Geodetic Vertical Datum of 1928 (CGVD28) and HTv2.0 hybrid geoid model.

2.3.2 Control Network

A control point network was established from local Alberta Survey Control Monuments (ASCMs), WSC Benchmarks, and GNSS surveying to provide a spatial reference for the survey program. Five ASCMs, one WSC Benchmark (BM), and four NHC project survey control points were tied into the survey. The survey control points are listed in **Table 1**.

Table 1 Control point summary

Point Name	Type	Easting (m)	Northing (m)	Elevation (m)
ASCM 835 28.18	ASCM	26840.239	5835782.827	809.861
ASCM 835 28.19	ASCM	26893.602	5836530.594	812.944
ASCM 835 32.19	ASCM	28854.816	5836754.451	806.608
ASCM 838 32.26	ASCM	29807.278	5839666.072	804.194
ASCM 383 32.34	ASCM	28957.929	5838861.171	809.072
NHC 1	Project Control Point	25555.022	5835849.510	807.926
NHC 2	Project Control Point	28693.464	5837473.050	803.002
NHC 3	Project Control Point	30455.768	5840550.833	803.974
NHC 4	Project Control Point	31380.655	5843687.519	799.924
A2022-42	WSC BM	28325.008	5836650.397	804.360

The coordinates for the four NHC project control points tabulated above were determined by running the GNSS receivers simultaneously in static mode for more than four hours to obtain CSRS precise point positions (PPP) results. The baselines between control points were then post-processed using Trimble Business Center software to carry out a network adjustment. The adopted coordinates were obtained by constraining the survey to the NHC 1 control point, which had the longest occupation time and most accurate CSRS-PPP result. The horizontal and vertical errors in the three NHC control points after post-processing are summarized in **Table 2** The largest horizontal error was 0.0111 m, and the largest vertical error was 0.0376 m.

Table 2 Control network errors

Point Name	Easting (m)	Northing (m)	Elevation (m)
NHC 1	N/A	N/A	N/A
NHC 2	0.011	0.011	0.037
NHC 3	0.011	0.011	0.037
NHC 4	0.011	0.011	0.038

A comparison between the survey elevations (after post-processing and adjustment) and published ASCM elevations is provided in **Table 3**. The mean of the elevation residuals is −0.016 m, which indicates good vertical agreement between the control network and local benchmarks.

Table 3 Comparison between surveyed coordinates and published ASCM coordinates

Point Name	Residuals (Survey minus Published)		
	Easting (m)	Northing (m)	Elevation (m)
ASCM 835 28.18	N/A	N/A	-0.009
ASCM 835 28.19	0.101	-0.096	-0.039
ASCM 835 32.19	0.116	-0.115	-0.041
ASCM 838 32.26	0.134	-0.090	0.006
ASCM 383 32.34	0.118	-0.106	-0.008
A2022-42	0.121	-0.112	-0.006

2.4 Cross Sections and Bathymetry

Cross section locations were selected to ensure adequate representation of the channel geometry in the hydraulic model. Cross section alignments were determined ahead of the field program. Cross sections were positioned along the study reach to capture changes in channel pattern, widths, and slopes. Additional cross sections were placed at the upstream and downstream faces of bridges, inlet and outlet of culverts, and a few river widths upstream and downstream of the structures. The additional sections at hydraulic structures followed the geometry requirements for modelling bridges and culverts as recommended in the HEC-RAS documentation. Cross sections were surveyed over two separate field visits in June and August of 2023. The cross section locations are indicated in the survey overview maps provided as **Appendix B**. A summary of the surveyed cross sections is listed in **Table 4**. The survey was extended approximately 1 km below the downstream study limit of the Battle River (Township Road 434) to reduce the boundary affects at the limits of the mapping domain. The survey point data were assembled in the survey geodatabase and are provided separately with the digital study file.

Table 4 Surveyed cross section summary

Reach	Reach Length (m)	Number of Cross sections	Average Spacing (m)	Minimum Spacing (m)	Maximum Spacing (m)
Battle River	20300	115	178	6	654
unnamed tributary	4900	49	105	3	280

2.5 Hydraulic Structures

The hydraulic structures measured as part of the survey program include twelve bridges and two culvert crossings as listed in **Table 5**. The table also includes the corresponding Alberta Transportation and Economic Corridors (TEC) Bridge File (BF) numbers when available. It was later determined that the culvert crossing Highway 2A on the small drainage path to Unnamed Tributary was not required in the model; although, it is included in the table for information. An additional culvert crossing on the unnamed tributary was submerged in the backwater of a beaver dam and was not able to be found during the field program. The Town confirmed the existence of a culvert crossing with two 600 mm culverts. The approximate location, length, and invert elevations for these culverts were estimated by inspection of historic imagery and DTM.

Table 5 Hydraulic structure summary

Stream	River Station (m)	Crossing Description	Structure Type	TEC Bridge File Number
Battle River	19187.70	Highway 2 (South Bound Lane)	Bridge	75535
	19155.11	Highway 2 (North Bound Lane)	Bridge	75535
	13023.15	Highway 2A	Bridge	00278
	11430.63	CP Rail	Bridge	
	10682.48	Highway 53	Bridge	78896
	10362.71	Pedestrian	Bridge	00348
	8882.84	50th Avenue	Bridge	01972
	7766.42	Pedestrian	Bridge	
	0.02	Township Road 434	Bridge	
unnamed tributary	4843.31	Highway 2A	Culvert	09746
	3211.96	CP Rail	Bridge	3212
	1575.37	Unfound Culvert[1]	Culvert	
	1063.26	Pedestrian	Bridge	
	31.38	Pedestrian	Bridge	
Tributary of unnamed tributary	none	Highway 2A	Culvert	07270

1. The unfound culvert could not be located and surveyed as it was submerged in the backwater of a beaver dam. Its existence and size (2 x 600m) were later confirmed by the Town.

The locations of these structures are shown in the survey overview maps provided in **Appendix B**. Survey data collected for each bridge includes span length, deck width, low chord elevation, top of curb or solid guardrail elevation, and pier details. Information collected for each culvert includes culvert type, shape (dimensions and length), entrance condition, upstream and downstream invert elevation, crest elevation. In addition, available bridge and culvert design drawings were obtained to complement the survey data. Details on each structure and field photographs are provided in **Appendix C**.

2.6 Flood Control Structures

Flood control structures, also commonly referred to as flood berms, are defined by the provincial Flood Hazard Identification Program (AEP, 2022) as a *permanent barrier or engineered system that keeps water from entering and flooding an area*. These structures typically require regulatory approval prior to construction, receive routine inspection and maintenance, and are officially recognized by local authorities as flood management infrastructure. As per the study terms of reference, the geometric details for the flood berms identified by local authorities in this study were surveyed. Three separate flood berms were located and surveyed and were denoted sequentially, upstream to downstream, as Berm 1, Berm 2, and Berm 3. Information for these berms is listed in **Table 6**. More detailed information on the flood berms was provided in a separate technical memorandum, included as **Appendix D.** The survey data (and locations) of these flood berms are also indicated in the survey overview in **Appendix B.**

Table 6 Flood control structure summary

Name	Owner	Stream	Approximate River Station (m)	Crest Length (m)
Berm 1	Town of Ponoka	Battle River	10200 – 10300	65
Berm 2			10300 – 10400	100
Berm 3			7800 – 7900	90

2.7 DTM Comparison to Survey Data

2.7.1 Control Point Comparison

NHC completed a comparative analysis between the LiDAR-based DTM and survey data collected by NHC. The first comparison was made between the surveyed control points and elevation values extracted from the DTM at these locations. The results of the comparison are listed in **Table 7**. The ASCM control points could be buried below the surrounding ground elevation and are not necessarily representative of the ground surface elevation, while the NHC control points are representative of the actual ground elevation. Accordingly, the surveyed elevations of the ASCM control points are expected to differ more from DTM elevations than NHC control point elevations, which is seen in **Table 7**.

Table 7 Comparison between DTM and surveyed control point elevations

Point Name	Surveyed Elevation (m)	DTM Elevation (m)	DTM Elevation – Surveyed Elevation (m)
ASCM 835 28.18	809.86	809.92	0.06
ASCM 835 28.19	812.94	813.15	0.21
ASCM 835 32.19	806.61	806.60	-0.01
ASCM 838 32.26	804.19	804.20	0.01
ASCM 383 32.34	809.07	809.28	0.21
NHC 1	807.93	807.89	-0.04
NHC 2	803.00	802.95	-0.05
NHC 3	803.97	803.99	0.02
NHC 4	799.92	799.99	0.07

2.7.2 DTM Comparison to Channel Cross Section Survey

Standard GIS processing tools were used to extract DTM elevation values at each surveyed point location. The method for comparison was to assess the difference in elevation between the values extracted from the DTM to the values from the NHC survey. The differences were found through subtraction of the surveyed values from the DTM values (DTM elevation – survey elevation) and were calculated for surveyed data points located in overbank areas. Points surveyed on steep banks or beneath the water surface were excluded from the comparison.

Figure 2 depicts the results of the comparison as a histogram for the two different classes of survey point data. The first class includes points surveyed on dry ground areas in the overbank away from stream banks, flood berm points, and road points; the second class includes just flood berm and road points. The range of expected accuracy of the DTM (±15 cm) is provided for comparison. The comparative assessment indicates good agreement between surveyed overbank elevation data and the DTM; the DTM was found to be suitable for overbank cross section data extraction and flood mapping purposes.

2.8 Additional Data

2.8.1 Discharge Measurements

No direct discharge measurements were conducted as part of this study. The WSC gauge is located within the study reach and was operation during the field program. Reported flows were very low during the survey - less than 0.05 m^3/s during the 5 – 9 June 2023 visit, and less than

0.08 m^3/s during 21 – 22 August 2023 visit. These flows were far too low to be suitable for model calibration, so discharge measurements were not conducted.

2.8.2 Hydraulic Structure Design Drawings

NHC requested design drawings for all bridge structures through EPA, TEC, and the Town of Ponoka. Information was obtained from these sources for the 50th Avenue Bridge (TEC file number 01972) and for the Highway 53 Bridge (provided by the Town of Ponoka).

2.8.3 Base Mapping Features

In addition to the data listed above, other base mapping data were obtained to support modelling and mapping for the study, including road network, hydrography, administrative boundaries, topographic maps, and Alberta Township System (ATS) grids within the study area.

2.8.4 Field Photographs

Appendix E provides annotated reach representative field photographs that were obtained during the site inspection and survey program. The location, time, and other metadata information are embedded in the electronic images included as part of the digital file submission.

3 FLOOD HYDROLOGY

3.1 Flood History

A description of local flood history provides context for the model calibration and the flood frequency magnitudes used as model inputs to develop the mapping. A brief description of documented floods experienced at the Town of Ponoka follows. Photographs depicting flood waters for some of the major floods referenced in this section are provided in **Appendix F**.

3.1.1 Recent and Recorded Open Water Floods

Recent and recorded floods are those floods associated with the systematic recording of water levels and discharge. The systematic record for the Battle River near Ponoka spans from 1913 to 1930 and 1967 to present day. For the purpose of this study, floods occurring during these periods are denoted as recorded floods. Dates and brief remarks for these floods are listed in **Table 8**.

Table 8 Recent and recorded open water floods

Year	Date	Remarks
1917	Unknown	*"highwater eroded part of the bank of an approach road" noted in a letter by Government of Alberta Department of Public Works, dated April 20, 1917, indicates highwater eroded part of the bank of an approach road (Bridge File 01972, 1917)*[1]
1920	9 May	No remarks available[1]
1927	Unknown	*"high spring ice flow required dynamite… ice jam threatens the structure"*[1]
1974	19 April	No remarks available[1]
1982	24 April	highwater marks collected by Alberta Environment (1982)[1]
1990	4 July	highwater marks collected by Alberta Environment (1990)[1] HIS File History report 00278 notes highwater elevations

[1] Floods documented in the previous flood study (Hydrotech Consulting and B.K. Hydrology Service, 1994).

3.1.2 Historic Open Water Floods

Historic floods refer to major floods that occurred prior to the period of hydrometric data collection and systematic recording of water level and discharge. The magnitude of historic floods can be estimated based on observations or anecdotal information. A list of historic floods is provided in **Table 9**.

Table 9 Historic open water floods

Year	Month/Date	Remarks
1902	June	The flood peak discharge was estimated by modelling based on available highwater mark (HWM) data provided by Alberta Environment (1992). The month of the flood event was estimated by NHC based on a local account by W.M. James, a resident of Ponoka, who mentioned an extraordinarily long duration of rain in June 1902.
1904	Unknown	AT bridge file #00278 (Alberta Transportation, HIS) noted that the estimated highwater level of this event was about 2.7 m above the south bank of the Battle River at the Highway 2A bridge.
1908	Unknown	AT bridge file #00278 (Alberta Transportation, HIS) noted that the Highway 2A bridge was washed out and subsequently replaced.
1948	May	The flood peak discharge was estimated by modelling based on available HWM data according to Alberta Environment (1992). AT bridge file #00278 noted that the highwater level was 0.74 m (29 inches) above the Highway 2A bridge deck.
1954	Unknown	AT bridge file #00278 (Alberta Transportation, HIS) noted that the highwater level was near the elevation of the south abutment bridge footing for the Highway 2A bridge.

3.2 Ice Jam Floods

As noted in the remarks of the preceding tables, the highwater flood event of 1927 was attributed to an ice jam flood. Since that time, there have been no major flood accounts describing ice jam floods. Within the systematic record, open water flooding is found to produce the highest flood levels. The previous study reviewed ice affected water levels at this location and found that ice jam floods did not exceed the 5-year open water flood (Hydrotech Consulting and B.K. Hydrology Service, 1994). Open water flooding is the dominant flood mechanism and ice jam flooding was not within the scope of this study.

3.3 Flood Frequency Analysis

A key outcome of the open water hydrology assessment (attached as **Appendix A**) was the estimation of the open water flood frequency magnitudes for the Battle River and unnamed tributary study reaches. The results of the flood frequency analysis are reproduced here as **Table** 10 and **Table 11**, for the Battle River and the unnamed tributary, respectively.

Table 10 Flood frequency estimates for Battle River near Ponoka

Return Period (Years)	Annual Probability of Exceedance (%)	Peak Instantaneous Discharge (m^3/s)
1000	0.10	796
750	0.13	706
500	0.20	593
350	0.29	505
200	0.50	389
100	1.0	275
75	1.3	236
50	2.0	191
35	2.9	158
20	5.0	120
10	10	86.6
5	20	60.2
2	50	29.5

Table 11 Flood frequency estimates for unnamed tributary at the mouth

Return Period (Years)	Annual Probability of Exceedance (%)	Peak Instantaneous Discharge (m^3/s)
1000	0.10	8.17
750	0.13	7.79
500	0.20	7.24
350	0.29	6.78
200	0.50	6.02
100	1.0	5.11
75	1.3	4.75
50	2.0	4.23
35	2.9	3.78
20	5.0	3.07
10	10	2.24
5	20	1.45
2	50	0.55

4 HYDRAULIC MODELLING

4.1 Available Data

The hydraulic modelling relied on the available data that existed prior to this study, as well as data collected during this study; a description of these data follows.

4.1.1 Survey & Base Data

Development of the model geometry relied primarily on the survey and base data. Survey data was comprised of the surveyed channel data and field verification data on hydraulic structure geometry. The base data used to develop the model geometry included hydraulic structure design information, the DTM, aerial imagery, and base mapping information. Channel survey data was used to define the in-channel geometry that was incorporated into the DTM to create a modified terrain for the 2D model that is representative of both the main channel and floodplain areas. The methods used to develop the modified terrain are detailed in Section 4.3. Hydraulic structure data collected during the survey combined with TEC information was used to code the bridge and culvert geometry into the hydraulic model. Base mapping data, aerial imagery, and the DTM were referenced during model creation to align hydraulic structures and digitize breaklines during creation of the 2D model domain. Aerial imagery was referenced when delineating various land use classification areas for estimation of model Manning's roughness values in both the channel and overbank areas.

4.1.2 Existing Models

The following two prior flood studies were completed for portions of the current study reach.

- Ponoka Floodplain Study. Alberta Environment (1979)
- Ponoka Flood Risk Mapping Study. Hydrotech Consulting Ltd. and B.K. Hydrology Service (1994)

Both the 1979 and 1994 studies relied on early generations of the HEC hydraulic models (HEC-2) to compute flood profiles. The 1979 study model is not available. The 1994 study model was provided by EPA.

The domain of the 1994 model extends along the Battle River from Highway 2A to Township Road 432 (near the wastewater treatment lagoons). While the model did not include the unnamed tributary, the flood mapping included backwater from the Battle River a short distance up the unnamed tributary.

4.1.3 Highwater Marks

A highwater mark (HWM) survey documents the highest water levels experienced along the river during the passage of a flood event. Typically, the observations are taken shortly after the passage of the flood while evidence of the highest water level experienced at the HWM location remains apparent. The HWM survey data collected from the 1982 and 1990 floods were examined for this study.

Table 12 and **Table 13** list the HWM elevations values reported for the 1982 and 1990 floods, respectively. The location of the HWMs is presented with the survey overview data provided in **Appendix B**. The spatial information was provided in ESRI shapefile format by EPA. The HWM IDs and descriptions provided in the table were transcribed from the shapefile features provided by EPA.

Table 12 1982 HWM summary

HWM ID	Description	Elevation (m)
1982-BAT-015-h	25 m u/s of rock	803.28
1982-BAT-015-g	culvert, road crossing	802.99
1982-BAT-017-d	dam site near cross section 12, u/s of bridge	802.15
1982-BAT-017-c	u/s side of left approach road to North bridge	802.23
1982-BAT-017-b	d/s side of left approach road to North bridge	802.08

Table 12 1982 HWM summary (continued)

HWM ID	Description	Elevation (m)
1982-BAT-019-b	in line with Lift Station A left bank	801.86
1982-BAT-018-b	cross-section #4	801.65
1982-BAT-020-b	at junction of east west road and river road, left bank	801.32

Table 13 1990 HWM summary

HWM ID	Description	Elevation (m)
1990-BAT-021-a	HWM upstream right bank	807.42
1990-BAT-021-b	HWM downstream right bank	807.37
1990-BAT-013-a	HWM 1 m upstream left bank	806.09
1990-BAT-013-b	HWM 1 m downstream left bank	805.75
1990-BAT-013-c	HWM downstream 50 m north along F/L	805.78
1990-BAT-015-a	HWM upstream 25 m south of bridge	804.66
1990-BAT-015-b	HWM downstream 30 m south of bridge	804.40
1990-BAT-014-a	HWM 2 m upstream	803.71
1990-BAT-014-b	HWM 3 m downstream	803.72
1990-BAT-017-a	HWM downstream road left bank	803.45
1990-BAT-019-a	HWM on station wall	803.17
1990-BAT-018-a	HWM on lawn	802.93
1990-BAT-020-a	HWM *[no description in source documentation]*	802.20
1990-BAT-016-a	HWM upstream road, west of bridge	798.55
1990-BAT-016-b	HWM downstream road, west of bridge	798.34

4.1.4 Gauge Data & Rating Curves

The 05FA001 Battle River at Ponoka Gauge was originally established in 1913 and has been moved several times prior to its current location (which was established a few months after the 1990 food in October 1990). A summary of gauge movements over the years was documented in the 1994 flood study (Hydrotech Consulting Ltd. and B.K. Hydrology Service). The rating curve relationship with direct measurement data (corresponding to its current location) is presented in Section 4.3.

4.1.5 Flood Photography

Aerial photography was acquired several hours in advance of the 1990 flood peak and was provided by EPA as digital scans of 1:5000 scale stereo photos. The photos were acquired around 9:50 AM on July 4, 1990. The timing of the photos in relation to the observed flood peak was documented in the 1994 flood study (Hydrotech Consulting Ltd. and B.K. Hydrology Service) as follows:

> *Based on flow records from the WSC gauge 05FA001, the flow on July 4, 1990 at 9:54 AM was about 200 m^3/s. On July 4, 1990 at 11:00 AM, the flow was about 220 m^3/s. The July 4, 1990 flood peak occurred around 6:20 PM with a flow of 287 m^3/s.*

These aerial photos were referenced during model development and model calibration. The extent of inundation depicted in the flood photography was visually compared to preliminary model results. There was good agreement between the flood extents depicted in the photos and flood extents estimated by the hydraulic model.

4.2 River & Valley Features

The 1994 flood study (Hydrotech Consulting Ltd. and B.K. Hydrology Service) provides a good general description of the river valley and features and most of the previous study description was adapted for the descriptions below.

4.2.1 General Description

The Battle River originates at Battle Lake and flows southeast toward Ponoka. At Ponoka, the river drains about 1830 km^2 of mainly agricultural land. At the upstream end of the study reach the valley is wider (about 300 m). Downstream of the Highway 2A bridge the river straightens somewhat and the valley narrows to about 30 m above the CPR bridge, after which it widens back to about 300 m. The river meanders along developed urban areas through town between relatively high valley slopes to the east and west. Downstream of the urban developments and wastewater treatment lagoons the valley widens slightly, extending to the limits of the study area at Township Road 434.

4.2.2 Channel Characteristics

The Battle River has a well-defined channel throughout the study reach. The river planform carries an irregular meander pattern that is confined by valley walls and high terraces throughout. There are few straight segments along the study reach where the channel follows the valley walls, is confined in reaches with a narrow floodplain or passing through developed areas. Channel widths are near-constant throughout at about 25 m to 30 m wide.

4.2.3 Floodplain Characteristics

The floodplain limits are contained by terraces and valley walls. It is vegetated with a mixture of pasture, brush, shrub, and occasional stands of trees. There is some limited development along the edges of the floodplain. During the 1990 flood, the floodplain widths depicted in the aerial imagery ranged from 350 m to 400 m along the Town of Ponoka. Downstream of the wastewater treatment lagoons the extent of flooding widened up to about 600 m. Upstream of the town, between Highway 2A and CPR bridge the floodplain is narrow (about 100 m to 180 m). The floodplain width varies considerably in the upper reaches of the study area between Highway 2, where widths are about 250 m, to Highway 2A, where widths are about 400 m. Mid-way, between these highways, the floodplain bulges dramatically to nearly 2 km wide.

4.2.4 Anthropogenic Features

The Town of Ponoka and related development present the dominant anthropogenic features along the study reach. Below is a summary of the primary features, generally listed from upstream to downstream.

- 12 bridge crossings and two culvert crossings (as listed in **Table 5**)
- Various low density residential and rural development outside the Town limits
- Ponoka Industrial Airport (Labrie Field).
- Recreational area including Diamond Willow Trail at the confluence of the unnamed tributary
- Town of Ponoka residential, commercial, and industrial areas alongside the limits of the floodplain
- Various parks, baseball diamonds, trails, and recreation areas in the floodplain throughout the Town of Ponoka
- Wastewater treatment lagoons alongside the right bank of the Battle River, just downstream of the Town
- Various mixed agriculture downstream of the Town to the study limit

4.3 Model Construction

The U.S. Army Corps of Engineers Hydrologic Engineering Center-River Analysis System (HEC-RAS) computer program (Version 6.5 February 2024) was used to calculate the flood levels along the study reaches. HEC-RAS can perform one-dimensional (1D), two-dimensional (2D), or combined 1D and 2D hydraulic calculations for a network of channels, hydraulic structures, and overbank areas. This study relied on the results of a full 2D HEC-RAS model with some limited 1D modelling used to support preliminary model scoping and terrain modification. The resulting model calibrated well to the observed HWMs and the flood extents represented in the 1990 flood photography. Further, the resulting mapping outperforms that achieved with a 1D model or a coupled 1D / 2D model.

The resulting model was comprised of a single 2D area and included the following features:

- A 2D computational mesh comprised of approximately 190,000 cells with an average computational point spacing of about 10 m.
- Two separate inflow boundaries: one for the Battle River (upstream of Highway 2) and one for the unnamed tributary (upstream of Highway 2A).
- A single outflow boundary on the Battle River (downstream of Township Road 434).
- 11 bridge crossings and 2 culvert crossings (as listed in **Table 5**).

The geometry of the computation mesh was derived from a digital terrain model. Bridge and culvert geometry was entered into the HEC-RAS geometry editor. **Figure 3** provides a schematic of the various model elements. The methods used to develop the various model components are detailed below.

4.3.1 Methodology

Terrain Modifications

Three separate terrain models were created during the model construction – all of which were created with tools available in the HEC-RAS Mapper environment (RAS Mapper). **Figure 4** provides an illustrative comparison of the three terrains created for modelling purposes, as described below. The comparison is provided for a reach that is representative of the changes.

The first, a **bare-earth-terrain**, was created from the LiDAR-based bare-earth DTM provided by EPA. The bare-earth DTM provides a land surface that excludes all features projecting above grade such as trees, buildings, and bridge decks. However, no corrections are made to capture land surfaces below water (streams and water bodies). And so, the elevations over the main channel portions of the Battle River, the unnamed tributary, and lagoons are indicative of the elevation of the water surface covering these hydrographic features as they existed during LiDAR acquisition program.

The second terrain, denoted as the **2D-model-terrain**, was based on the bare-earth-terrain modified to account for the geometry within the main channel portions of the Battle River and unnamed tributary study reaches. It did not include modifications for any other water bodies, such as the lagoons. The first step was to create a terrain within the extents of the main channel geometry. This *main channel geometry* terrain was then merged into the bare-earth-terrain to replace those portions, below the water surface, that were not captured under the LiDAR survey program. The processes outlined in the HEC-RAS Mapper User's Manual were used to create the channel terrain from surveyed cross sections. Then, the channel terrain was merged into the bare-earth-terrain to create the final 2D-model-terrain. The portion of the terrain within the main channel was synthesized by interpolation of the main channel between surveyed cross sections. The resulting 2D channel geometry provides an analogue that is hydraulically similar to the real 2D channel geometry. That is, flood profiles computed along the synthesized 2D channel geometry are consistent with those computed by a 1D model created from the surveyed cross sections. The 2D-model-terrain is well-suited for computation of flood level profiles along the channel; however, it should not be relied on to resolve the two-dimensional hydrodynamics within the main channel domain. Along the Battle River, the extent of the main channel is visible in the orthophotos and bare-earth-terrain. Along the unnamed tributary, portions of the main channel were obscured by backwater behind beaver dams. Consequently, the alignment of the stream could only be estimated through these areas, and thus, the channel portion of the 2D-model-terrain does not necessarily follow the actual channel alignment.

During preliminary calibration efforts it was discovered that one of the wastewater treatment lagoons had been removed from the floodplain following the 1990 flood. This lagoon created a notable backwater along the Battle River during the flood (as is evident in the 1990 highwater mark elevation data). This was problematic to model calibration since the computed profiles, based on the 2D-model-terrain that reflects the current lagoon geometry, significantly underpredicted the observed highwater marks within the backwater of the lagoon. To facilitate model calibration through this backwater zone, the 2D-model-terrain was further modified to include an approximation of the old lagoon geometry present during the 1990 flood. This was achieved by adding a prismatic three-dimensional feature in the terrain. The old lagoon was created by tracing what appeared to be the remnants of the toe of the old lagoon and a visual comparison of aerial images in the previous study. The elevation of the top of the old lagoon was based on the overbank elevations reported in the previous study cross section intersecting the old lagoon. The resulting terrain ,denoted as the **2D-calibration-terrain**, was used to calibrate the model to the 1982 and 1990 flood highwater marks.

2D Flow Area

The 2D flow area is comprised of a computational mesh with polygonal cells of varying shapes and sizes. The meshes were developed in an iterative manner beginning with a coarse mesh and flows commensurate with the estimated 1000-year flood overflows. The domain of the mesh was reduced to limit dry areas and the mesh size was ultimately reduced to a nominal 10 m by 10 m grid. The cells along streams were conditioned to follow the channel flow paths by introducing breaklines coincident to the stream centrelines. Cell spacing remained at 10 m along the Battle River but was reduced to 5 m along the unnamed tributary. The stream breaklines ensured that the computational faces were aligned perpendicular to flow in the main channel and over the banks into the floodplain areas. Breaklines were also added at hydraulic structures, along road and railway embankments, as well as ridges and other high points throughout the model domain to prevent flows passing through these highpoints.

Channel and Overbank Roughness

Manning's roughness values were varied spatially according to the land cover values listed **Table 14**. The spatial variation is depicted by land use areas in Figure 5. A single roughness value was assigned to each land cover category. Channel roughness was calibrated to the 1990 flood highwater marks and rating curve data at the gauge. The roughness values for the overbank varied somewhat, compared to those assigned in the previous flood study (Hydrotech Consulting Ltd. and B.K. Hydrology Service, 1994).

Table 14 Land cover and Manning's roughness values

Land Cover	Manning's Roughness (current study, 2D)	Manning's Roughness (previous study, 1D)
Channel	0.040	0.045
Pasture and grass	0.060	0.055
Scattered brush	0.085	0.085
Trees and heavy brush	0.115	0.115
Developed – low density	0.065	none
Developed – moderate density	0.080	none
Developed – high density	0.100	none

Bridges and Culverts

The model included 11 bridge crossings and 2 culvert crossings. Positioning of the hydraulic structures was based on the survey data and available design drawings. The exception was a low elevation private double culvert crossing on the unnamed tributary. These culverts were submerged during the cross section survey and could not be safely located to measure or survey. It was later determined that two, 24" diameter, corrugated steel pipe culverts were installed at this location[1]. Their locations were approximated by inspection of available imagery and the terrain.

Bridges were coded directly into the 2D model domain using *2D Area Connections*. The connections were aligned along the centreline of the crossings. The extent of the crossing is defined by the connection line which was limited to the opening through the road embankment for bridges, and a nominal distance (about three creek widths) at the two culvert crossings on

[1] EPA personal communication with Town of Ponoka staff (June 2024).

the unnamed tributary. The structure geometry was then entered within the HEC-RAS geometry editor in the usual manner for bridges and culverts in a 1D model.

4.3.2 Geometric Data Base

All the HEC-RAS model geometry components are assembled into a geometric database and provided with the study electronic deliverables. These components include point and vector features for: survey data, extents of the model domain, channel centreline, flow paths, bank lines, breaklines, river stationing bank stations, and bridge locations. Model components were developed using standard ArcGIS geospatial tools and the built-in HEC-RAS geometry tools found in the RAS Mapper utility. The key hydraulic model elements included in the geometric data base are depicted in **Figure 3**.

4.3.3 Model Calibration

Model calibration involves the selection and adjustment of model parameters such that calculated flood levels agree well with observed flood levels. For this study, channel roughness was the chief calibration parameter. The basic approach was to adjust roughness until computed flood levels agreed well to both the 1982 and 1990 highwater marks. For the calibration simulations, the floodplain geometry was based on the terrain modified to include the lagoon that had been removed following the 1990 flood (denoted previously as the **2D-calibration-terrain**).

The model was calibrated to match highwater marks for the 1982 and 1990 floods which experienced flood discharges of 90.7 m^3/s and 291m^3/s, respectively. For comparison, the 10-year flood is 86.6 m^3/s and the 100-year design flood is 275 m^3/s. This calibration corresponds to a high flow calibration which ensures that the model presents as a good analogue under high flow conditions. A low flow calibration was not possible as there was no low flow calibration data available. The calibrated model was used to compute a rating curve at the WSC Gauge location. This computed rating curve was compared to the published rating curve data.

There is no calibration data available for the unnamed tributary. The channel bed material for the unnamed tributary was comparable to that for the Battle River and so the calibrated values for the Battle River were adopted as roughness values for the unnamed tributary.

Calibration to 1982 and 1990 HWM data

The resulting calibration profiles are depicted in **Figure 6**. The profiles provide a comparison of the computed water surface profile along the centreline of the Battle River. River stations are referenced to the downstream mapping boundary, coincident with the Township Road 434 crossing. River stations increase from zero at the Township Road 434 crossing in a streamwise direction along the channel centreline. The locations of highwater marks, relative to the stream centeline, were visually estimated. **Table 15** provides a comparison between the computed flood elevations and the observed highwater mark elevations. Computed elevations in the table differ slightly from those plotted in the figure as they were extracted from the flood surface nearest the reported location of each highwater mark location. Values with absolute difference greater than 0.15 m are indicated with bold text. For the 1982 calibration, differences between the computed and observed values were on average 0.09 m, ranging from -0.13 to +0.15 m. For the 1990 calibration, differences were on average 0.11 m, ranging from -0.21 to +0.25 m. The values with the greatest difference appear to be within the backwater area of the old lagoon. It is plausible that the modified terrain did not adequately represent the true geometry at the time of the 1990 flood.

Table 15 Calibration results

HWM ID	HWM Elevation (m)	Computed Elevation (m)	Difference (m)
Comparison to 1982 HWMs			
1982-BAT-015-h	803.28	803.15	-0.13
1982-BAT-015-g	802.99	803.14	0.15
1982-BAT-017-d	802.15	802.18	0.03
1982-BAT-017-c	802.23	802.11	-0.12
1982-BAT-017-b	802.08	802.07	-0.01
1982-BAT-019-b	801.86	801.76	-0.10
1982-BAT-018-b	801.65	801.57	-0.08
1982-BAT-020-b	801.32	801.24	-0.08
Comparison to 1990 HWMs			
1990-BAT-021-a	807.42	807.43	0.01
1990-BAT-021-b	807.37	807.23	-0.14
1990-BAT-013-a	806.09	806.15	0.06
1990-BAT-013-b	805.75	805.78	0.03
1990-BAT-013-c	805.78	805.73	-0.05
1990-BAT-015-a	804.66	804.66	0.00
1990-BAT-015-b	804.10	804.55	0.15
1990-BAT-014-a	803.71	803.96	**0.25**
1990-BAT-014-b	803.72	803.88	**0.16**
1990-BAT-017-a	803.45	803.34	-0.11
1990-BAT-019-a	803.17	802.96	**-0.21**
1990-BAT-018-a	802.93	802.77	**-0.16**

Table 15 Calibration results (continued)

HWM ID	HWM Elevation (m)	Computed Elevation (m)	Difference (m)
Comparison to 1990 HWMs			
1990-BAT-020-a	802.20	802.29	0.09
1990-BAT-016-a	798.55	798.74	**0.19**
1990-BAT-016-b	798.34	798.30	-0.04

Comparison to WSC Gauge 05FA001 Battle River at Ponoka

Figure 7 provides the most recent rating curve relationship along with the available direct measurement data collected at the gauge since establishment at its current location in October of 1990. The data includes an additional value for the 7 July 1990 flood when the gauge was located upstream of the CP Bridge. It is not known how this value was estimated for the current gauge location. The recent rating curve relationship published by WSC (ERT 13) is provided for comparison. The model rating curve falls within the range of data and agrees well with the published rating curve, up to about the 10-year flood level. The computed curve is well below the published rating curve and the 1990 WSC estimated peak.

Nearby HWMs (collected 113 m upstream of the gauge) for the 1982 and 1990 floods, are plotted for additional comparison. Both 1982 and 1990 HWM elevations are slightly higher than the values computed at the gauge site – as would be expected. It appears as though the computed rating curve is consistent with these upstream HWMs.

4.3.4 Model Parameters & Options

The following lists the most salient model parameters and options. Unless otherwise stated, HEC-RAS default values were adopted for all model input and run parameters.

Solver: The Diffusion Wave Solver was adopted for this study for robust model performance and practical simulation times (about an hour). The objective of the 2D model application was not to resolve the 2D dynamic flow hydraulics in the main channel, nor resolve details on momentum transfer between the main channel and floodplain. Rather, it was to create a suitable flood model analogue that well represented the flood extents across the floodplain.

Quasi-steady flow assumption: The 2D simulations represent a quasi-steady flow condition by applying a constant inflow time series over a long simulation period (about four days). The downstream boundary condition was set to a normal depth approximation that assumed a constant level profile across the entire outflow boundary.

Simulation time and time steps: The model simulation time was set to four days with a time step of 10 seconds. Hydrograph and mapping outputs were set to 30 minutes. The four day simulation time was necessary to ensure a steady condition (constant flood level) was attained throughout the entire model domain. Stable solutions were found with the adopted time step. At the end of the full simulation time, total inflows matched total outflows within a fraction of a percent.

4.3.5 Open Water Flood Frequency Profiles

The calibrated hydraulic model was used to generate flood frequency profiles for the thirteen open water floods of varying magnitude listed in **Table 10** and **Table 11**. The computed flood frequency water levels are listed in **Appendix G** and depicted graphically on **Figure 8** and **Figure 9** for the Battle River and unnamed tributary, respectively.

4.3.6 Model Sensitivity

A sensitivity analysis was undertaken to determine the effects of changing model parameters on water levels, flow depths, and inundation widths. The 100-year design flood was selected as a baseline for testing the sensitivity of model results to a variation in discharge, the downstream boundary condition, and Manning's roughness. These variations were evaluated to gain an indication of the range of error associated with model inputs.

Unlike a 1D model, there are no model elements available to extract the width of flood extents. It was not practical to attempt to measure floodplain widths along the study reach for the 2D model. Alternatively, the changes in width were estimated by two different length parameters that are indicative of floodplain width, as defined below. Incremental changes in these parameters, as compared to the 100-year baseline condition, are representative of the average incremental change in the width of the flood extent.

1. $\mathbf{W_{RECTILINEAR}}$ – the calculated total area of inundation extent divided by the combined reach lengths of the Battle River and unnamed tributary. This relationship approximates the inundation extent as a long rectilinear shape.
2. $\mathbf{W_{RADIAL}}$ – the square root of the calculated total area of inundation extent divided by π (3.1416). This relationship approximates the inundation extent as a circular shape.

Visual comparison of the mapped inundation extents for the baseline and sensitivity tests found these values to be a reasonable approximation of the incremental change in inundation width.

The incremental change in flow depths is the same as that for changes in water levels. For this summary, the changes in water levels were chosen for presentation since the changes can be visualized through comparison of computed water surface profiles (in addition to tabulated summaries).

Sensitivity to Variation in Flood Frequency Estimates

The lower and upper limits of the 95% confidence interval (4.43 m^3/s and 6.08 m^3/s) for the 100-year instantaneous peak discharge (5.11 m^3/s) were tested for the unnamed tributary (refer to **Table 10**). It was not practical to determine confidence intervals for the Battle River which was based on a combined-population flood frequency curve. The available methods to estimate confidence limits are not accurate for longer return periods as described in the attached hydrology memo (refer to **Appendix A**). And so, the range of discharges tested for the Battle River were based on the same percent differences tested for the unnamed tributary which were +19% and -13%, corresponding to 238 m^3/s and 327 m^3/s.

Table 16 and **Table 17** list the variations in water levels and inundation widths, respectively, from the 100-year baseline for the range of test values. The statistics provided are based on values extracted along the channel centrelines, at 100 m intervals. The variation of the sensitivity test profiles from the baseline are depicted in **Figure 10** and **Figure 11** for the Battle River and unnamed tributary, respectively.

Table 16 Sensitivity of water levels to variation in 100-year flood frequency estimates

Stream	Difference from baseline (100-year) profile (m)			
	Lower flood frequency estimates		Higher flood frequency estimates	
	Mean	Maximum	Mean	Maximum
Battle River	-0.19	-0.35	0.24	0.46
unnamed tributary	-0.10	-0.19	0.11	0.25

Table 17 Sensitivity of inundation width to variation in 100-year flood frequency estimates

Stream	Difference from baseline (100-year) (m)			
	Lower flood frequency estimates		Higher flood frequency estimates	
	$W_{RECTILINEAR}$	W_{RADIAL}	$W_{RECTILINEAR}$	W_{RADIAL}
Battle River and unnamed tributary	-17	-88	21	108

Sensitivity to Variation in the Downstream Boundary Condition

The adopted downstream boundary condition was based on a normal depth approximation, where the starting water level was calculated by Manning's equation with a specified energy slope equal to 0.00040 m/m. This slope was based on inspection of the bed slope of the Battle River near the downstream boundary. A plausible range of uncertainty in estimating the energy grade line slope is approximately ±20%, which resulted in a low value of 0.00032 m/m and a high value of 0.00048 m/m. The changes in computed water surface elevations from the baseline condition were local to the downstream boundary and difference between the baseline and test conditions were negligible by the time they reached the downstream mapping limit at Township Road 434 (station 0 km), about 1.1 km upstream of the downstream model boundary. The variation of the sensitivity test profiles from the baseline are depicted in **Figure 12** and **Figure** 13 for the Battle River and unnamed tributary, respectively.

Sensitivity to Variation in Channel Roughness

The main channel Manning's roughness value of *n* = 0.040 (for both the Battle River and unnamed tributary) was adjusted by ±20%. This incremental adjustment provided variations in water levels that were indicative of the range of errors expected for a typical calibration (0.15 to 0.20 m). This equated to a lower value of Manning's roughness, *n* = 0.032, and higher value of *n* = 0.048.

Table 18 and **Table 19** list the variations in water levels and inundation widths, respectively, from the 100-year baseline for the range of test values. The statistics provided are based on values extracted along the channel centrelines, at 100 m intervals. The variation of the sensitivity test profiles from the baseline are depicted in **Figure 14** and **Figure 15** for the Battle River and unnamed tributary, respectively.

Table 18 Sensitivity of water levels to variation in channel roughness values

Stream	Difference from baseline (100-year) profile (m)			
	Lower roughness values		Higher roughness values	
	Mean	Maximum	Mean	Maximum
Battle River	-0.15	-0.31	0.12	0.25
unnamed tributary	-0.08	-0.19	0.06	0.12

Table 19 Sensitivity of inundation widths to variation in channel roughness values

Stream	Difference from baseline (100-year) (m)			
	Lower roughness values		Higher roughness values	
	$W_{RECTILINEAR}$	W_{RADIAL}	$W_{RECTILINEAR}$	W_{RADIAL}
Battle River and unnamed tributary	-15	-74	9	45

Sensitivity to Variation in Overbank Roughness

The sensitivity tests for overbank roughness were applied to all land cover conditions in a single test. The adopted overbank roughness values were adjusted by ±20%, as listed in **Table 20**, for testing an overall increase and overall decrease in overbank roughness values. The mean and maximum changes in calculated water levels and inundation widths corresponding to the range of tested channel roughness values are listed in **Table 21** and **Table 22**, respectively. The statistics provided are based on values extracted along the channel centrelines, at 100 m intervals. The variation of the sensitivity test profiles from the baseline are depicted in **Figure 16** and **Figure 17** for the Battle River and unnamed tributary, respectively.

Table 20 Sensitivity test values for an increase and decrease in overbank roughness

Land Cover	Baseline (Calibrated)	Decrease of 20%	Increase of 20%
Pasture and grass	0.060	0.048	0.072
Scattered brush	0.085	0.068	0.102
Trees and heavy brush	0.115	0.092	0.138
Developed – low density	0.065	0.052	0.078
Developed – moderate density	0.080	0.064	0.096
Developed – high density	0.100	0.080	0.120

Table 21 Sensitivity of water levels to variation in overbank roughness values

River	Difference from baseline (100-year) profile (m)			
	Lower roughness values		Higher roughness values	
	Mean	Maximum	Mean	Maximum
Battle River	-0.12	-0.18	0.10	0.15
unnamed tributary	-0.06	-0.15	0.04	0.12

Table 22 Sensitivity of inundation widths to variation in overbank roughness values

River	Difference from baseline (100-year) (m)			
	Lower roughness values		Higher roughness values	
	$W_{RECTILINEAR}$	W_{RADIAL}	$W_{RECTILINEAR}$	W_{RADIAL}
Battle River and unnamed tributary	-11	-54	7	36

4.4 Modelled Flows

The flood frequency estimates for the Battle River and unnamed tributary (**Table 10** and **Table 11**, respectively) were set as the modelled inflows at the upstream boundary of the Battle River and unnamed tributary. These inflows are combined within the 2D model at the confluence of these streams and so, downstream of the confluence, the flows in the Battle River are slightly higher than those upstream. The slight increase in flows on the Battle River have a negligible effect on the model and mapping results. **Table 24** lists the flows simulated by the model along these reaches.

Table 23 Model flows

Return Period (Years)	Battle River upstream of the unnamed tributary (m^3/s)	Unnamed tributary (m^3/s)	Battle River downstream of the unnamed tributary (m^3/s)
1000	796	8.17	804
750	706	7.79	714
500	593	7.24	600
350	505	6.78	512
200	389	6.02	395
100	275	5.11	280
75	236	4.75	241
50	191	4.23	195
35	158	3.78	162
20	120	3.07	123
10	86.6	2.24	88.8
5	60.2	1.45	61.7
2	29.5	0.55	30.1

5 FLOOD INUNDATION MAPS

Flood inundation mapping provides a visual display of the extent of inundation for a given design flood scenario. A separate flood inundation map was created for each of the 13 flood frequency flow estimates corresponding to return periods ranging from 2 to 1000 years. **Appendix H** provides flood inundation maps for all scenarios. The following describes the process followed to produce the flood inundation maps.

5.1 Methodology

The methodology used to create the flood inundation maps followed these steps, details of which are provided in the subsequent sections.

1. Create a water surface elevation (WSE) triangular irregular network (TIN) that is representative of a contiguous flood surface throughout the modelled reaches and floodplain, and overland flow areas.
3. Create a WSE grid with elevation values based on the WSE TIN.
4. Create a depth grid based on the difference between the WSE grid and underlying DTM.
5. Create inundation polygons based on the depth grid such that the polygon extents delineate positive depth areas, with polygon edges following zero depth contours.
6. Adjust the inundation polygons manually for areas where depths and hydraulic connectivity cannot be adequately resolved by the preceding steps.
7. Finalize inundation extents to include manual edits and smoothing.

5.1.1 Water Surface Elevation TIN

The TIN inputs were based on calculated water levels for all the 2D computational cell centres (point water surface elevation values centred at each 2D computational cell). The interpolation of the TIN surface was informed by the breaklines used in the model. The extent of the TIN domain was clipped to the extent of the model 2D flow area.

Additional features used to modify the TIN included polygons around areas of constant water surface elevation to inform manual edits for backwater and level pools (e.g. areas behind beaver dams) and areas mapped withing the lagoons.

These geometry inputs were then combined to create a WSE TIN with standard GIS TIN creation tools.

5.1.2 WSE and Depth Grids

The WSE grid was created directly from the WSE TIN using ArcGIS Pro tools. The WSE grid provides a raster data set with water surface elevation values at the same cell resolution and is congruent with the underlying digital terrain model (DTM). The depth grid was created by subtracting the underlying DTM elevation values from the WSE grid values.

5.1.3 Inundation Polygons

Inundation polygons were created through a series of steps, described as follows.

Filtered Depth Mask: The first step was to create an inundation mask of wetted areas found within the depth grids. This step is based solely on positive depth values with no filtering. Negative depth values indicate dry cells and are assigned a NoData value. Positive depth values denote wet cells and were assigned a value of 1. This mask was denoted as the positive depth mask. The positive depth mask was further processed and filtered to aggregate contiguous areas of wet cells and remove patchy dry areas. This also minimizes the creation of small self-intersecting loops and knots in the resulting inundation polygon. This final mask was denoted as the filtered depth mask.

Initial Inundation Polygons: Initial inundation polygons are created through a series of steps, beginning with conversion of the filtered depth mask into polygons. These initial inundation polygons were further processed by ensuring there are no multipart polygons and dissolving contiguous polygon features; removing small, isolated polygon areas (less than 50 m^2); and, filling small holes inside polygons (less than 50 m^2).

Manual Polygon Edits: The initial inundation polygons were manually edited in areas where the hydraulic connectivity could not be adequately resolved by the normal workflow in the following instances.

- Very steep and/or shallow 2D flow areas where small patchy wetted areas were filtered out during the creation of the filtered depth mask. Manual polygons were created to ensure hydraulic connectivity across these areas. Examples include areas near the crest of steep road embankments and across the crest of small beaver dams along the unnamed tributary.
- For lower flow scenarios, the calculated water surface can lie below the DTM surface where elevated water surfaces were captured during LiDAR data acquisition. These areas were typically found behind beaver dams along the unnamed tributary. Manual polygons were added to account for these areas.

The manual polygons were merged with the initial inundation polygons to update the polygon extents depicting all areas of inundation.

Inundation Areas Classification: The initial inundation polygons (updated with manual edits) were then examined and visually classified as direct inundation areas (including areas connected by culverts), areas behind flood control structures, and isolated areas within the lagoons. The final polygon areas (classified as direct inundation areas) were then used to mask the WSE and depth gridded datasets.

Final Inundation Extents: The final polygon areas were then smoothed to create the final inundation extents. The Polynomial Approximation with Exponential Kernel method and a smoothing tolerance of 3 m was applied. Further visual checks were conducted to ensure proper nesting of flood extent limits across the range of flood frequency estimates. In some instances, the smoothing process resulted in very small overlaps (fractions of a metre) between flood frequencies, particularly where the edges of inundation followed steep banks. In these instances, the lower flood frequency extents were constrained by higher frequency events.

5.2 Flood Inundation Areas

The extent of flood inundation is evident in the flood inundation maps (**Appendix H**). The following provides context for areas exposed to direct flooding and areas behind flood control structures (i.e. flood berms and the lagoon dikes). **Table 24** and **Table 25** provide a streamwise summary of developed areas and infrastructure impacted by flooding over the range of flood frequencies for the Battle River and the unnamed tributary, respectively. The table is divided into areas impacted by flooding on the left and right floodplains with the location indicated by river station(s) listed down the centre of the table.

Table 24 Flood inundation areas along the Battle River

Impacted Areas along Left Floodplain													River Station (m)	Impacted Areas along Right Floodplain												
2-YR	5-YR	10-YR	20-YR	35-YR	50-YR	75-YR	100-YR	200-YR	350-YR	500-YR	750-YR	1000-YR		2-YR	5-YR	10-YR	20-YR	35-YR	50-YR	75-YR	100-YR	200-YR	350-YR	500-YR	750-YR	1000-YR
Township Road 434 bridge approach													0 - 2800	Township Road 434 bridge approach												
								200	350	500	750	1K							50	75	100	200	350	500	750	1K
Range Road 252A														Tire recycling yard (0 - 600 m)												
									350	500	750	1K			5	10	20	35	50	75	100	200	350	500	750	1K
Dugout (0 - 200 m)																										
			20	35	50	75	100	200	350	500	750	1K														
Pond and access road (1000 - 2500 m)																										
	5	10	20	35	50	75	100	200	350	500	750	1K														
Range Road 252A													2800 - 4200													
			20	35	50	75	100	200	350	500	750	1K														
Rural residence (2800 - 3000 m)																										
						75	100	200	350	500	750	1K														
Rural residences west of Range Road 252A (3300 - 4200 m)																										
								200	350	500	750	1K														
Rural residences (4200 - 5500 m)													4200 - 6900	Wastewater treatment lagoons (4400 - 6200 m)[1]												
				35	50	75	100	200	350	500	750	1K										200	350	500	750	1K
Rural residence (5500 - 5600 m)																										
					50	75	100	200	350	500	750	1K														
Range Road 252A (5600 - 6200 m)																										
												1K														
Rural residences (6400 -6900 m)																										
					50	75	100	200	350	500	750	1K														

[1] Impacted areas are protected by wastewater treatment lagoon berms at flood frequencies indicated.

Table 24 Flood inundation areas along the Battle River (continued)

Impacted Areas along Left Floodplain	2-YR	5-YR	10-YR	20-YR	35-YR	50-YR	75-YR	100-YR	200-YR	350-YR	500-YR	750-YR	1000-YR	River Station (m)
														6900 - 7700
Pedestrian bridge approach									200	350	500	750	1K	7770
Paved path and park areas (8000 - 8500 m)		5	10	20	35	50	75	100	200	350	500	750	1K	7700 - 8900
Residences (8800 8900 m)								100	200	350	500	750	1K	7700 - 8900
Industry west of 49 Street (8800 8900 m)												750	1K	7700 - 8900
50 Avenue bridge approach												750	1K	8880
49 Street (8900 - 9300 m)					35	50	75	100	200	350	500	750	1K	8900 - 10400
Residence (8900 - 9000 m)											500	750	1K	8900 - 10400
Residence (9300 - 9400 m)										350	500	750	1K	8900 - 10400

River Station (m)	Impacted Areas along Left Floodplain	2-YR	5-YR	10-YR	20-YR	35-YR	50-YR	75-YR	100-YR	200-YR	350-YR	500-YR	750-YR	1000-YR
6900 - 7700	Commercial businesses (6900 - 7200 m)											500	750	1K
6900 - 7700	Rural residences (7200 -7300 m)										350	500	750	1K
6900 - 7700	Paved path and park areas (7000 - 7900 m)		5	10	20	35	50	75	100	200	350	500	750	1K
7770	Pedestrian bridge approach		5	10	20	35	50	75	100	200	350	500	750	1K
7700 - 8900	Paved path and park areas		5	10	20	35	50	75	100	200	350	500	750	1K
7700 - 8900	Residence (8700 m)													1K
8880	50 Avenue bridge approach											500	750	1K
8900 - 10400	Abandoned road/ bridge approach				20	35	50	75	100	200	350	500	750	1K
8900 - 10400	Residences (9600 - 10000 m)										350	500	750	1K
8900 - 10400	Ball diamonds (9600 - 10400 m)		5	10	20	35	50	75	100	200	350	500	750	1K
8900 - 10400	Residences (10100 - 10300 m)					35	50	75	100	200	350	500	750	1K

Table 24 Flood inundation areas along the Battle River (continued)

Impacted Areas along Left Floodplain													River Station (m)	Impacted Areas along Left Floodplain												
2-YR	5-YR	10-YR	20-YR	35-YR	50-YR	75-YR	100-YR	200-YR	350-YR	500-YR	750-YR	1000-YR		2-YR	5-YR	10-YR	20-YR	35-YR	50-YR	75-YR	100-YR	200-YR	350-YR	500-YR	750-YR	1000-YR
Pedestrian bridge approach													10350	Pedestrian bridge approach												
								200	350	500	750	1K						35	50	75	100	200	350	500	750	1K
CP Railway (10400 - 10700 m)													10400 - 10700	Residences (10400 - 10700)												
										500	750	1K										200	350	500	750	1K
														Adventure Centre (10500)												
																			50	75	100	200	350	500	750	1K
Highway 53 Bridge approach													10350	Highway 53 Bridge approach												
																								500	750	1K
CP Railway (10700 - 11400 m)													10700 - 11400	Residences (10700 - 11400)												
									350	500	750	1K								75	100	200	350	500	750	1K
														Community gardens (11200)												
																	20	35	50	75	100	200	350	500	750	1K
														Park trails (10700 - 11400)												
																10	20	35	50	75	100	200	350	500	750	1K
CP Rail Bridge approach													11430	CP Rail Bridge approach												
									350	500	750	1K													750	1K
Rural out buildings (11400 -11600)													11400 - 13000	Rural residential (12700 -13000)												
								200	350	500	750	1K													750	1K
Highway 2A Bridge approach													13030	Highway 2A Bridge approach												
								200	350	500	750	1K									100	200	350	500	750	1K

Table 24 Flood inundation areas along the Battle River (continued)

Impacted Areas along Left Floodplain													River Station (m)	Impacted Areas along Left Floodplain												
2-YR	5-YR	10-YR	20-YR	35-YR	50-YR	75-YR	100-YR	200-YR	350-YR	500-YR	750-YR	1000-YR		2-YR	5-YR	10-YR	20-YR	35-YR	50-YR	75-YR	100-YR	200-YR	350-YR	500-YR	750-YR	1000-YR
Rural development (13200)													13000 - 19100	Township Road 425A (13000 - 15000)												
												1K											350	500	750	1K
Rural development (14000)														Rural development (13800)												
									350	500	750	1K												500	750	1K
Open pit (15200)														Rural residences (14600 -14800)												
			20	35	50	75	100	200	350	500	750	1K									100	200	350	500	750	1K
Township Road 430 (14400 -15800)														Well site (18800)												
							100	200	350	500	750	1K											350	500	750	1K
Rural residences (15700 -15800)																										
			20	35	50	75	100	200	350	500	750	1K														
Highway 2 Bridge approach													19200	Highway 2 Bridge approach												
												1K										200	350	500	750	1K

Table 25 Flood inundation areas along the unnamed tributary

Impacted Areas along Left Floodplain													River Station (m)	Impacted Areas along Right Floodplain												
2-YR	5-YR	10-YR	20-YR	35-YR	50-YR	75-YR	100-YR	200-YR	350-YR	500-YR	750-YR	1000-YR		2-YR	5-YR	10-YR	20-YR	35-YR	50-YR	75-YR	100-YR	200-YR	350-YR	500-YR	750-YR	1000-YR
Pedestrian bridge approach													0	Pedestrian bridge approach												
	5	10	20	35	50	75	100	200	350	500	750	1K			5	10	20	35	50	75	100	200	350	500	750	1K
													0 - 1100	Highway 53 Bridge approach (100 m)												
																								500	750	1K
														Residences (200 - 1100)												
																				75	100	200	350	500	750	1K
														Community gardens (800 - 900)												
																	20	35	50	75	100	200	350	500	750	1K
Pedestrian bridge approach													1050	Pedestrian bridge approach												
			20	35	50	75	100	200	350	500	750	1K				10	20	35	50	75	100	200	350	500	750	1K
Park trails (1100 - 1400 m)													1100 - 3200													
			20	35	50	75	100	200	350	500	750	1K														
CP Railway (1100 - 3200 m)																										
											750	1K														
CP Railway bridge approach													3210	CP Railway bridge approach												
Private drive (4250)													3200 - 4800													
									350	500	750	1K														
Highway 2A Bridge approach													4840	Highway 2A Bridge approach												

6 FLOODWAY DETERMINATION

Flood hazard identification involves the delineation of floodway and flood fringe zones for a specified design flood. A description of key terms from the FHIP Flood Study Technical Guidelines (Alberta Environment and Parks, 2022) is provided in the following sections. The resulting floodway criteria maps and flood hazard maps are provided as **Appendix I** and **Appendix J**, respectively.

6.1 Design Flood Selection

The design flood for open water flood hazard identification in Alberta is typically associated with a natural (non-regulated) peak instantaneous discharge that has a one percent chance of being equaled or exceeded in any given year – an annual exceedance probability, AEP = 1%. This is a flood with a statistical 100-year return period, also commonly referred to as the "one in on e hundred year flood".

The 100-year open water flood was selected as the design flood for the study area. Corresponding design flood discharge values for each stream are summarized in **Table 26**. The simulated design flows were assumed to be concurrent, with 100-year discharge values ascribed to the inflow boundaries of the Battle River and unnamed tributary. The values correspond to those determined by the open water hydrology (**Table 10**). The design flow downstream of the confluence of the Battle River and unnamed tributary increases incrementally by the 100-year open water flood of the unnamed tributary. The incremental increase is small; further, it was impractical to abstract the unnamed tributary inflows from the 2D model, downstream of the confluence.

Table 26 Design flood discharges

Reach	Discharge (m^3/s)
Battle River (above unnamed tributary)	275
unnamed tributary	5.11
Battle River (below unnamed tributary)	280

6.2 Floodway and Flood Fringe Terminology

Flood Hazard Map

A flood hazard map is a specific type of flood map that identifies the area flooded or at risk of flooding for the 100-year design flood and divides that flood hazard area into floodway and flood fringe zones. It also includes flood fringe sub-zones: high hazard flood fringe and protected flood fringe. Flood hazard maps can also illustrate additional flood hazard information, including incremental areas at risk for more severe floods than the design flood, including the 200- and 500-year floods.

Floodway

When a floodway is first defined on a flood hazard map, it typically represents the area of highest flood hazard for the 100-year design flood, where flows are deepest, fastest, and most destructive. When a flood hazard map is updated, the floodway may no longer represent the area of highest hazard based on new information.

Flood Fringe

The flood fringe is the area outside of the floodway that is flooded or could be flooded during the 100-year design flood. The flood fringe typically represents areas with shallower, slower, and less destructive flooding, but it may also include high hazard flood fringe areas. Areas at risk of flooding behind flood berms may also be mapped as protected flood fringe areas.

High Hazard Flood Fringe

The high hazard flood fringe identifies areas within the flood fringe with deeper or faster moving water than the rest of the flood fringe. High hazard flood fringe areas are likely to be more significant in flood maps that are being updated, but t hey may also be included in new flood maps.

Protected Flood Fringe

The protected flood fringe identifies areas that could be flooded if dedicated flood berms fail or do not work as designed during the 100-year design flood, even if they are not overtopped. Protected flood fringe areas illustrate residual flood risk and do not differentiate between areas with deeper and faster moving water and shallower or slower moving water. Protected flood fringe areas were found behind the sewage lagoons located in the floodplain.

6.3 Flood Hazard Identification

6.3.1 Design Flood Levels and Profiles

The open water design flood levels for the Battle River and unnamed tributary are listed in **Table 27** and **Table 28**, respectively. The values are reported at 500 m increments for the Battle River and 200 m increments for the unnamed tributary, along the channel centerelines. Station markers depicting the incremental distance along the channel centerelines are indicated in the mapping. The design flood levels are the same as those calculated for the 100-year flood frequency which are listed in **Appendix G** at 100 m station intervals. The design flood profiles are plotted in **Figure 18** and **Figure 19** for the Battle River and unnamed tributary, respectively.

Table 27 Design flood levels – Battle River

River Station (m)	Design Flood Level (m)	River Station (m)	Design Flood Level (m)	River Station (m)	Design Flood Level (m)
0	798.58	6500	802.41	13000	805.67
500	798.92	7000	802.50	13500	806.13
1000	799.38	7500	802.63	14000	806.22
1500	799.64	8000	802.76	14500	806.33
2000	800.11	8500	802.85	15000	806.37
2500	800.61	9000	803.16	15500	806.49
3000	801.36	9500	803.31	16000	806.58
3500	801.58	10000	803.40	16500	806.64
4000	801.73	10500	803.71	17000	806.79
4500	801.92	11000	803.92	17500	806.81
5000	802.08	11500	804.59	18000	806.96
5500	802.25	12000	805.03	18500	807.04
6000	802.35	12500	805.39	19000	807.08

Table 28 Design flood levels – unnamed tributary

River Station (m)	Design Flood Level (m)	River Station (m)	Design Flood Level (m)	River Station (m)	Design Flood Level (m)
200	803.87	1800	804.41	3400	806.21
400	803.88	2000	804.44	3600	806.44
600	803.88	2200	804.54	3800	806.66
800	803.88	2400	804.74	4000	806.95
1000	803.88	2600	804.94	4200	807.15
1200	803.89	2800	805.19	4400	807.77
1400	803.91	3000	805.51	4600	808.07
1600	804.38	3200	805.95	4800	808.47

6.3.2 Floodway Determination Criteria

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

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

When a flood hazard map is updated, an existing floodway typically remains. Exceptions were made for this study since there was a notable decrease in the design flood magnitude of the previous study (452 m^3/s) to the current study (275 m^3/s). Due to this reduction, a significant area of previously-defined floodway is no longer flooded by the design flood. As such, the floodway was determined based on the criteria for areas being mapped for the first time, with consideration of the extents of the previously defined floodway to guide the alignment of the floodway in areas governed by a hydraulically-smooth path.

Areas of deeper or faster moving water outside of the floodway are identified as high hazard flood fringe. In some reaches, there is a departure from the aforementioned criteria to provide a hydraulically-smooth path; these areas are denoted as such in the table.

The floodway limits and determining criteria are listed in **Table 29** and **Table 30** according to the streamwise distance along the centreline path of the channel (denoted as river station) for the Battle River and unnamed tributary reaches, respectively.

Table 29 Floodway limit criteria by river station (RS) – Battle River

<table>
<thead>
<tr><th>Left Floodway Limit Criteria</th><th>RS (m)</th><th>Right Floodway Limit Criteria</th></tr>
</thead>
<tbody>
<tr><td>mixed: 1 m depth, 1 m/s velocity (bridge)</td><td>0</td><td>mixed: 1 m depth, 1 m/s velocity (bridge)</td></tr>
<tr><td rowspan="3">1 m depth</td><td>200</td><td rowspan="7">mixed: 1 m depth, hydraulically smooth</td></tr>
<tr><td>400</td></tr>
<tr><td>600</td></tr>
<tr><td rowspan="2">mixed: 1 m depth, 1 m/s velocity, hydraulically smooth</td><td>800</td></tr>
<tr><td>1000</td></tr>
<tr><td rowspan="6">1 m depth</td><td>1200</td></tr>
<tr><td>1400</td></tr>
<tr><td>1600</td><td rowspan="3">mixed: 1 m depth, 1 m/s velocity, hydraulically smooth</td></tr>
<tr><td>1800</td></tr>
<tr><td>2000</td></tr>
<tr><td>2200</td><td rowspan="24">1 m depth</td></tr>
<tr><td rowspan="3">mixed: 1 m depth, 1 m/s velocity, hydraulically smooth</td><td>2400</td></tr>
<tr><td>2600</td></tr>
<tr><td>2800</td></tr>
<tr><td rowspan="20">1 m depth</td><td>3000</td></tr>
<tr><td>3200</td></tr>
<tr><td>3400</td></tr>
<tr><td>3600</td></tr>
<tr><td>3800</td></tr>
<tr><td>4000</td></tr>
<tr><td>4200</td></tr>
<tr><td>4400</td></tr>
<tr><td>4600</td></tr>
<tr><td>4800</td></tr>
<tr><td>5000</td></tr>
<tr><td>5200</td></tr>
<tr><td>5400</td></tr>
<tr><td>5600</td></tr>
<tr><td>5800</td></tr>
<tr><td>6000</td></tr>
<tr><td>6200</td></tr>
<tr><td>6400</td></tr>
<tr><td>6600</td></tr>
<tr><td>6800</td></tr>
</tbody>
</table>

Table 29 Floodway limit criteria by river station (RS) – Battle River (continued)

<table>
<tr><th>Left Floodway Limit Criteria</th><th>RS (m)</th><th>Right Floodway Limit Criteria</th></tr>
<tr><td rowspan="10">1 m depth</td><td>7000</td><td rowspan="8">1 m depth</td></tr>
<tr><td>7200</td></tr>
<tr><td>7400</td></tr>
<tr><td>7600</td></tr>
<tr><td>7800</td></tr>
<tr><td>8000</td></tr>
<tr><td>8200</td></tr>
<tr><td>8400</td></tr>
<tr><td>8600</td><td>hydraulically smooth</td></tr>
<tr><td>8800</td><td>1 m depth</td></tr>
<tr><td rowspan="2">mixed: 1 m depth, 1 m/s velocity (bridge)</td><td>9000</td><td rowspan="2">mixed: 1 m depth, 1 m/s velocity (bridge)</td></tr>
<tr><td>9200</td></tr>
<tr><td rowspan="7">1 m depth</td><td>9400</td><td rowspan="3">1 m depth</td></tr>
<tr><td>9600</td></tr>
<tr><td>9800</td></tr>
<tr><td>10000</td><td rowspan="2">hydraulically smooth</td></tr>
<tr><td>10200</td></tr>
<tr><td>10400</td><td rowspan="3">1 m depth</td></tr>
<tr><td>10600</td></tr>
<tr><td rowspan="2">mixed: 1 m depth, hydraulically smooth</td><td>10800</td></tr>
<tr><td>11000</td><td rowspan="2">mixed: 1 m depth, previous floodway</td></tr>
<tr><td rowspan="3">mixed: 1 m depth, hydraulically smooth, previous floodway (approximate)</td><td>11200</td></tr>
<tr><td>11400</td><td rowspan="8">1 m depth</td></tr>
<tr><td>11600</td></tr>
<tr><td rowspan="6">1m depth</td><td>11800</td></tr>
<tr><td>12000</td></tr>
<tr><td>12200</td></tr>
<tr><td>12400</td></tr>
<tr><td>12600</td></tr>
<tr><td>12800</td></tr>
<tr><td>mixed: 1 m depth, 1 m/s velocity (bridge)</td><td>13000</td><td>mixed: 1 m depth, 1 m/s velocity (bridge)</td></tr>
<tr><td rowspan="4">1 m depth</td><td>13200</td><td rowspan="4">1 m depth</td></tr>
<tr><td>13400</td></tr>
<tr><td>13600</td></tr>
<tr><td>13800</td></tr>
</table>

Table 29 Floodway limit criteria by river station (RS) – Battle River (continued)

<table>
<tr><th>Left Floodway Limit Criteria</th><th>RS (m)</th><th>Right Floodway Limit Criteria</th></tr>
<tr><td rowspan="5">1 m depth</td><td>14000</td><td rowspan="4">1 m depth</td></tr>
<tr><td>14200</td></tr>
<tr><td>14400</td></tr>
<tr><td>14600</td></tr>
<tr><td>14800</td><td rowspan="3">hydraulically smooth</td></tr>
<tr><td rowspan="3">hydraulically smooth</td><td>15000</td></tr>
<tr><td>15200</td></tr>
<tr><td>15400</td><td rowspan="20">1 m depth</td></tr>
<tr><td rowspan="2">mixed: 1 m depth, hydraulically smooth</td><td>15600</td></tr>
<tr><td>15800</td></tr>
<tr><td rowspan="17">1 m depth</td><td>16000</td></tr>
<tr><td>16200</td></tr>
<tr><td>16400</td></tr>
<tr><td>16600</td></tr>
<tr><td>16800</td></tr>
<tr><td>17000</td></tr>
<tr><td>17200</td></tr>
<tr><td>17400</td></tr>
<tr><td>17600</td></tr>
<tr><td>17800</td></tr>
<tr><td>18000</td></tr>
<tr><td>18200</td></tr>
<tr><td>18400</td></tr>
<tr><td>18600</td></tr>
<tr><td>18800</td></tr>
<tr><td>19000</td></tr>
<tr><td>19200</td></tr>
</table>

Table 30 Floodway limit criteria by river station (RS) – unnamed tributary

<table>
<tr><th>Left Floodway Limit Criteria</th><th>RS (m)</th><th>Right Floodway Limit Criteria</th></tr>
<tr><td rowspan="5">1 m depth</td><td>0</td><td rowspan="3">1 m depth</td></tr>
<tr><td>200</td></tr>
<tr><td>400</td></tr>
<tr><td>600</td><td rowspan="2">mixed: 1 m depth, previous floodway</td></tr>
<tr><td>800</td></tr>
<tr><td>mixed: 1 m depth, hydraulically smooth</td><td>1000</td><td rowspan="3">mixed: 1 m depth, channel extent</td></tr>
<tr><td>mixed: 1 m depth, channel extent</td><td>1200</td></tr>
<tr><td rowspan="14">channel extent</td><td>1400</td></tr>
<tr><td>1600</td><td rowspan="13">channel extent</td></tr>
<tr><td>1800</td></tr>
<tr><td>2000</td></tr>
<tr><td>2200</td></tr>
<tr><td>2400</td></tr>
<tr><td>2600</td></tr>
<tr><td>2800</td></tr>
<tr><td>3000</td></tr>
<tr><td>3200</td></tr>
<tr><td>3400</td></tr>
<tr><td>3600</td></tr>
<tr><td>3800</td></tr>
<tr><td>4000</td></tr>
<tr><td rowspan="2">mixed: 1 m depth, channel extent</td><td>4200</td><td rowspan="2">mixed: 1 m depth, channel extent</td></tr>
<tr><td>4400</td></tr>
<tr><td rowspan="2">channel extent</td><td>4600</td><td rowspan="2">channel extent</td></tr>
<tr><td>4800</td></tr>
</table>

6.4 Flood Hazard Inundation Areas

The flood fringe areas include mostly parkland, undeveloped areas, with only a few residential areas. The floodway includes only parkland, undeveloped areas, and some park infrastructure (e.g. trails and two ball diamonds). There are no major developments or infrastructure within the floodway.

7 POTENTIAL CLIMATE CHANGE IMPACTS

To address the potential impacts of climate change on flood levels, more severe open water flood scenarios were compared to the current design flood estimates to obtain a measure of “freeboard” that may be generally appropriate for long-term planning purposes. To obtain information appropriate for other applications, the simplified approach taken herein could be supplemented in the future by a more rigorous regional climate analysis and site-specific impact assessment.

7.1 Comparative Studies

For the open water flood hazard, the current 100-year design flood water levels were compared to those associated with discharges that are 10% and 20% higher than the current 100-year flood estimates. This approach is consistent with guidelines prepared by Engineers and Geoscientists British Columbia (EGBC, 2018), which recommends that for basins where no historical trend is detectable in local or regional streamflow magnitude frequency relations, a 10% increase in design discharge be applied to account for likely future changes in water input from precipitation. On the other hand, if a statistically significant trend is detected, a 20% increase may be appropriate, particularly for smaller basins.

7.2 Results

NHC found the magnitude of the increases to be fairly uniform along the study reaches. Along the Battle River reach, the average increases in water levels due to a 10 and 20% increase in the 100-year flood discharge were 0.13 m and 0.26 m, respectively. Along the unnamed tributary reach, the average increases in water levels due to a 10 and 20% increase in the 100-year flood discharge were 0.06 m and 0.11 m, respectively.

8 CONCLUSIONS

The objectives of this study were to assess river flood-related hazards along approximately 19 km of the Battle River and approximately 5 km of an unnamed tributary through the Town of Ponoka and Ponoka County. This study replaces a prior provincial study completed in 1994; it provides updated hydrology and expands on the prior hydraulic modelling and flood mapping coverage.

The study was divided into five major project components: Survey and Base Data Collection, Flood Hydrology, Hydraulic Modelling, Flood Inundation Mapping, and Design Flood Hazard Mapping. This report summarizes the work of all five components.

A total of 115 cross sections were surveyed on the Battle River and 49 on the unnamed tributary. These data were used to develop channel geometry, which was combined with the DTM to create a terrain suitable for a fully 2D model. In addition, geometric details were collected for 11 bridges and two culvert crossings in the study reach. A third culvert crossing on the unnamed tributary was submerged in the backwater of a beaver dam at the time of the survey and could not be found. The Town later confirmed its existence and culvert size (length and location were estimated from aerial imagery and the DTM). Three flood control structures were identified in the study area, and crest and toe details were surveyed during the field program.

The primary purpose of the flood hydrology was to develop flood frequency estimates to support the hydraulic modelling and flood mapping tasks. The current estimates are notably smaller than those available from previous studies. This difference is largely attributed to (1) a 30 year increase in the hydrologic data record and (2) the separation of spring and summer flood events and application of a combined-population frequency analysis approach.

A fully 2D hydraulic model of the study reach was developed using the HEC-RAS computer program from the U.S. Army Corps of Engineers. Channel bathymetry was combined with the LiDAR DTM to develop a fully 2D terrain model for the entire mapping domain. Inflow discharges were assigned at the upstream boundaries of the Battle River and the unnamed tributary. The discharges were those estimated by the flood frequency analysis. Discharges below the confluence of the Battle River and the unnamed tributary were the combined flow inputs at the upstream extent of these streams. The channel roughness Manning's n values were initially set to values used in the previous study and then calibrated to the observed HWMs for the 1982 and 1990 floods.

Water surface profiles were prepared for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1000-year open water flood frequency return period discharges. A sensitivity analysis was performed on several model parameters including boundary conditions (upstream and downstream) and the Manning's roughness coefficient (channel and overbanks).

Flood inundation maps have been generated for the 13 different open water flood frequency return periods, ranging from 2- to 1000-year, based on water surface profiles derived from hydraulic modeling. Floodway criteria maps were created for the 100-year design flood, depicting the criteria used to delineate both the floodway and flood fringe. Due to the notable changes in the 100-year design floodway, the current floodway was re-delineated according to the normal floodway criteria based on the modelling results. The current floodway is smaller than the previous floodway, owing to the reduction of the 100-year design flood magnitude.

9 REFERENCES

Alberta Environment. 1979. Ponoka Floodplain Study, May 1979, for Environmental Engineering, Support Services, Technical Services Division.

Alberta Environment. 1982. Battle River 1982 flood highwater mark report. Unpublished document provided by EPA in April 2023.

Alberta Environment. 1990. Battle River 1990 flood highwater mark report. Unpublished document provided by EPA in April 2023.

Alberta Environment. 1992. Flood frequency analysis – Ponoka floodplain study. Water Resources Managements Services, Technical Services Division, Hydrology Branch.

Alberta Transportation. HIS system. Various Bridge Files.

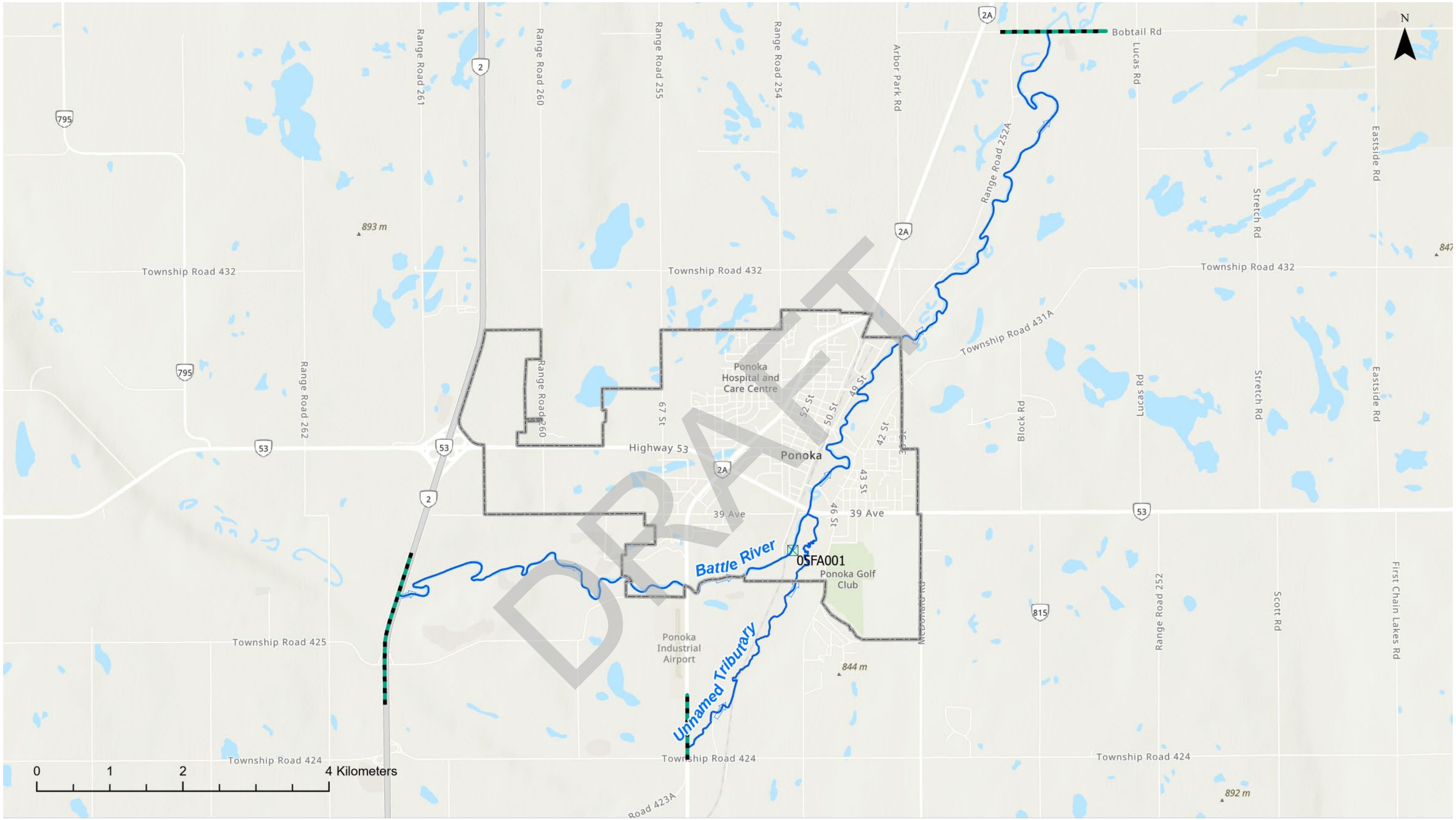
Alberta Environment and Parks (2022). Flood Hazard Identification Program Flood Study Technical Guidelines, River Engineering and Technical Services, Alberta Environment and Parks, June 2022.

Environment and Protection Alberta. 1982 & 1990 HWMs Database – *"Export 04-17-2023.xlsx"*. Unpublished electronic data provided by EPA in April 2023.

Engineers and Geoscientists British Columbia (EGBC), 2018. Legislated Flood Assessments in a Changing Climate in BC. Version 2.1. Available at https://www.egbc.ca/getmedia/f5c2d7e9-26ad-4cb3-b528-940b3aaa9069/Legislated-Flood-Assessments-in-BC.pdf

Hydrotech Consulting Ltd. and B.K. Hydrology Service. 1994. Ponoka Flood Risk Mapping Study. Submitted to Alberta Environmental Protection, October 1994, 67 pp.

FIGURES

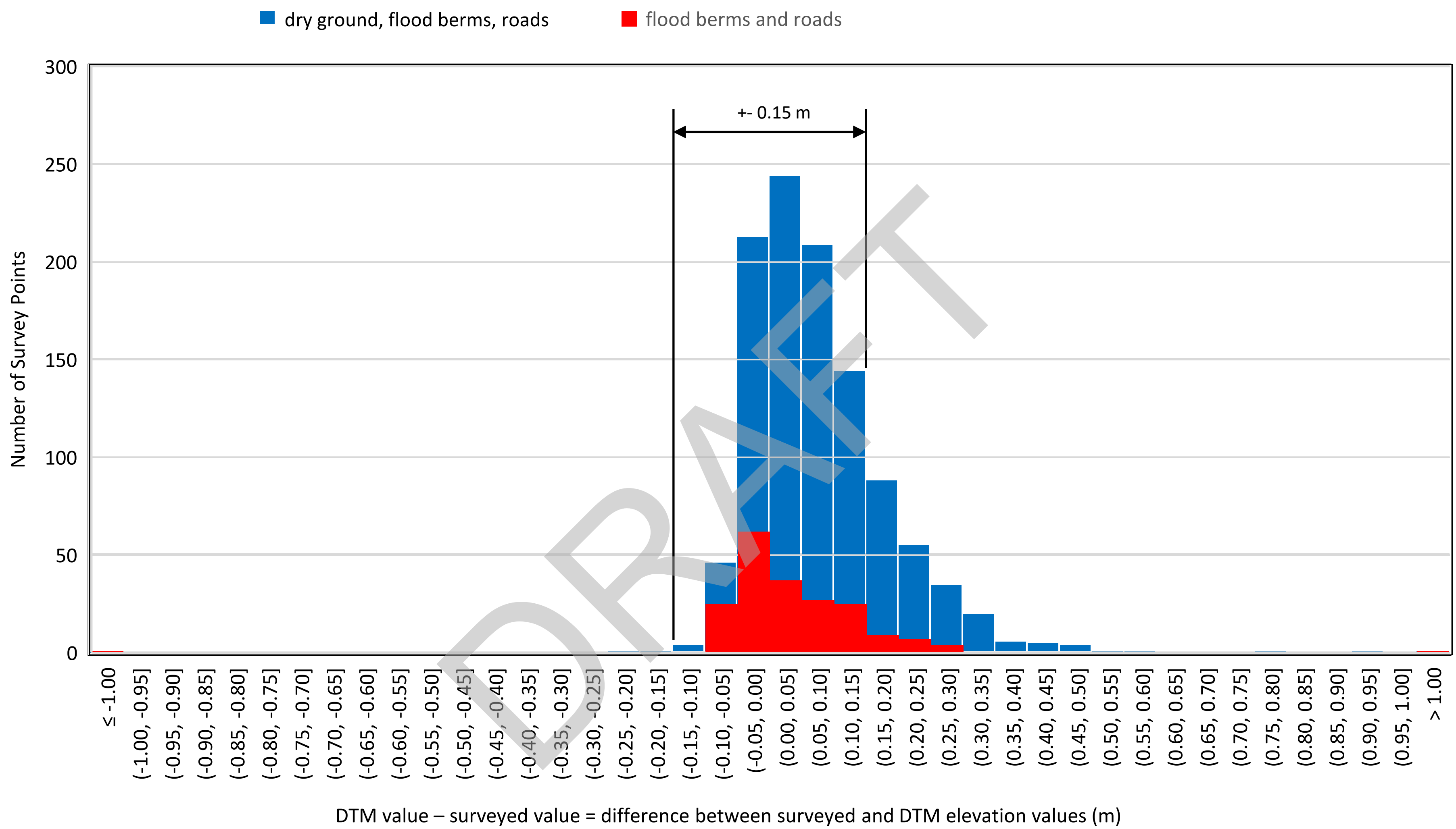


TOWN OF PONOKA
STUDY BOUNDARY
RIVER CENTRE LINE
WSC GAUGE

PONOKA FLOOD STUDY

STUDY AREA

Job: 1008017 | *Date: Mar-2025* | *FIGURE 1*



Alberta
Canada
nhc

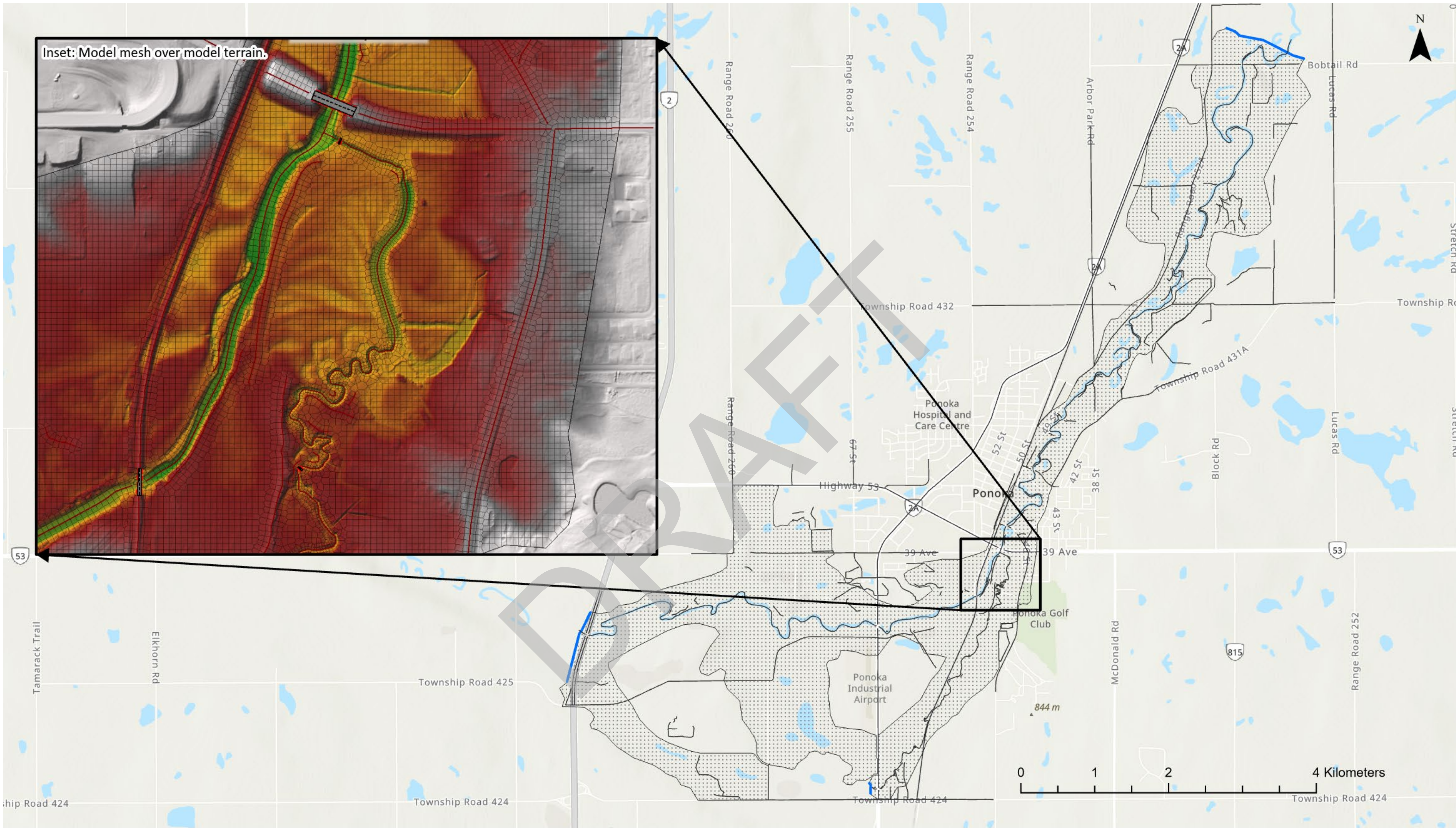
PONOKA FLOOD STUDY

DIFFERENCES BETWEEN SURVEYED AND DTM ELEVATION VALUES

Job: 1008017 | *Date: Jan-2025*

FIGURE 2

Classification: Public



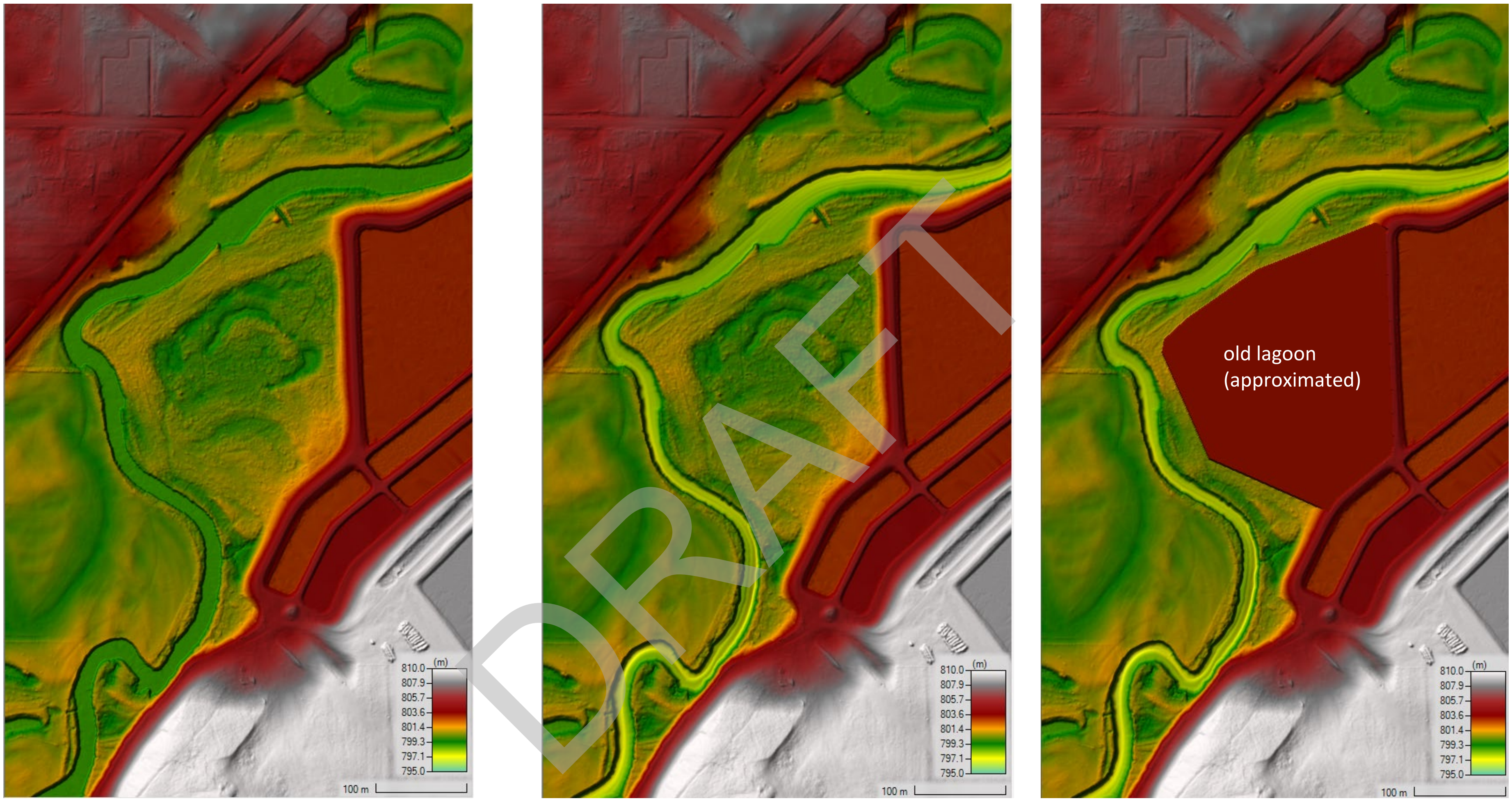
- Model 2D Breaklines
- Model 2D Boundaries
- Model 2D Areas

Alberta
Canada
nhc

PONOKA FLOOD STUDY

HYDRAULIC MODEL ELEMENTS

Job: 1008017 | *Date: Mar-2025* | *FIGURE 3*



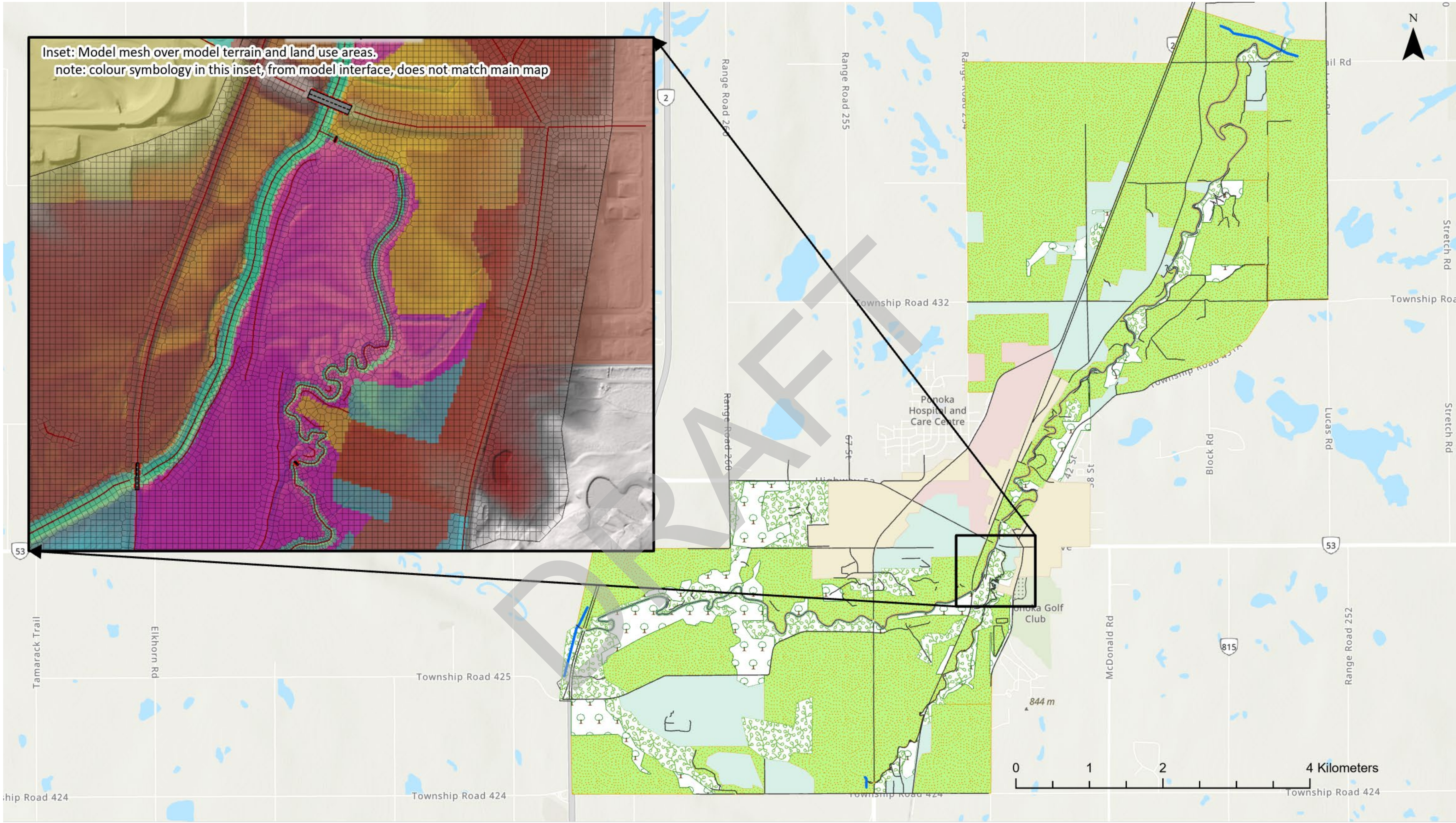
(a) bare-earth-terrain **(b) 2D-model-terrain** **(c) 2D-calibration-terrain**

PONOKA FLOOD STUDY

ILLUSTRATIVE COMPARISON OF TERRAIN MODIFICATIONS

Job: 1008017 *Date: Jan-2025*

FIGURE 4



Channel

Pasture and grass

Scattered brush

Trees and heavy brush

Developed - low density

Developed - moderate density

Developed - high density

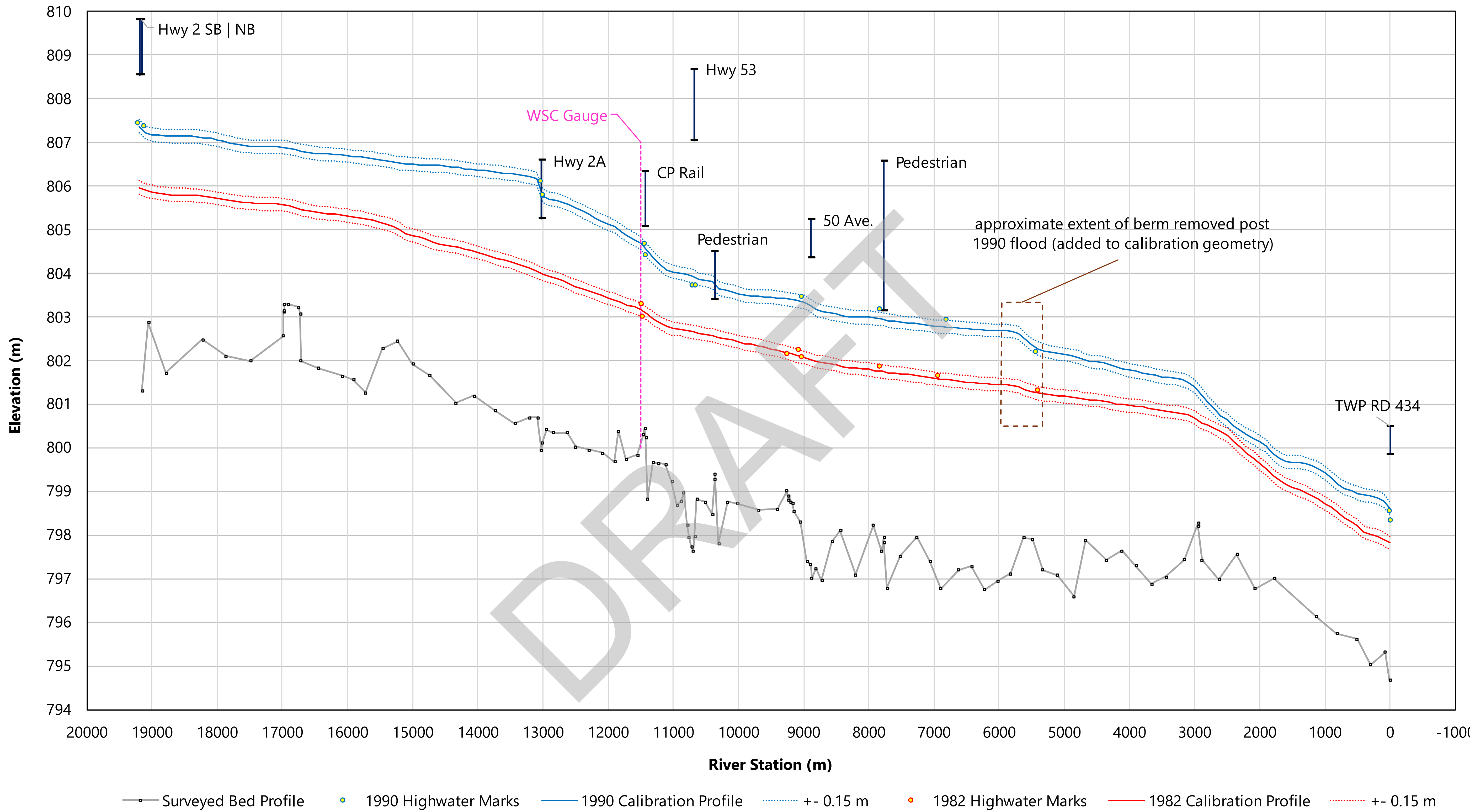
PONOKA FLOOD STUDY

LAND USE AREAS FOR MANNING'S ROUGHNESS

Job: 1008017 | *Date: Mar-2025*

FIGURE 5

Alberta Canada nhc



Bridges

high chord

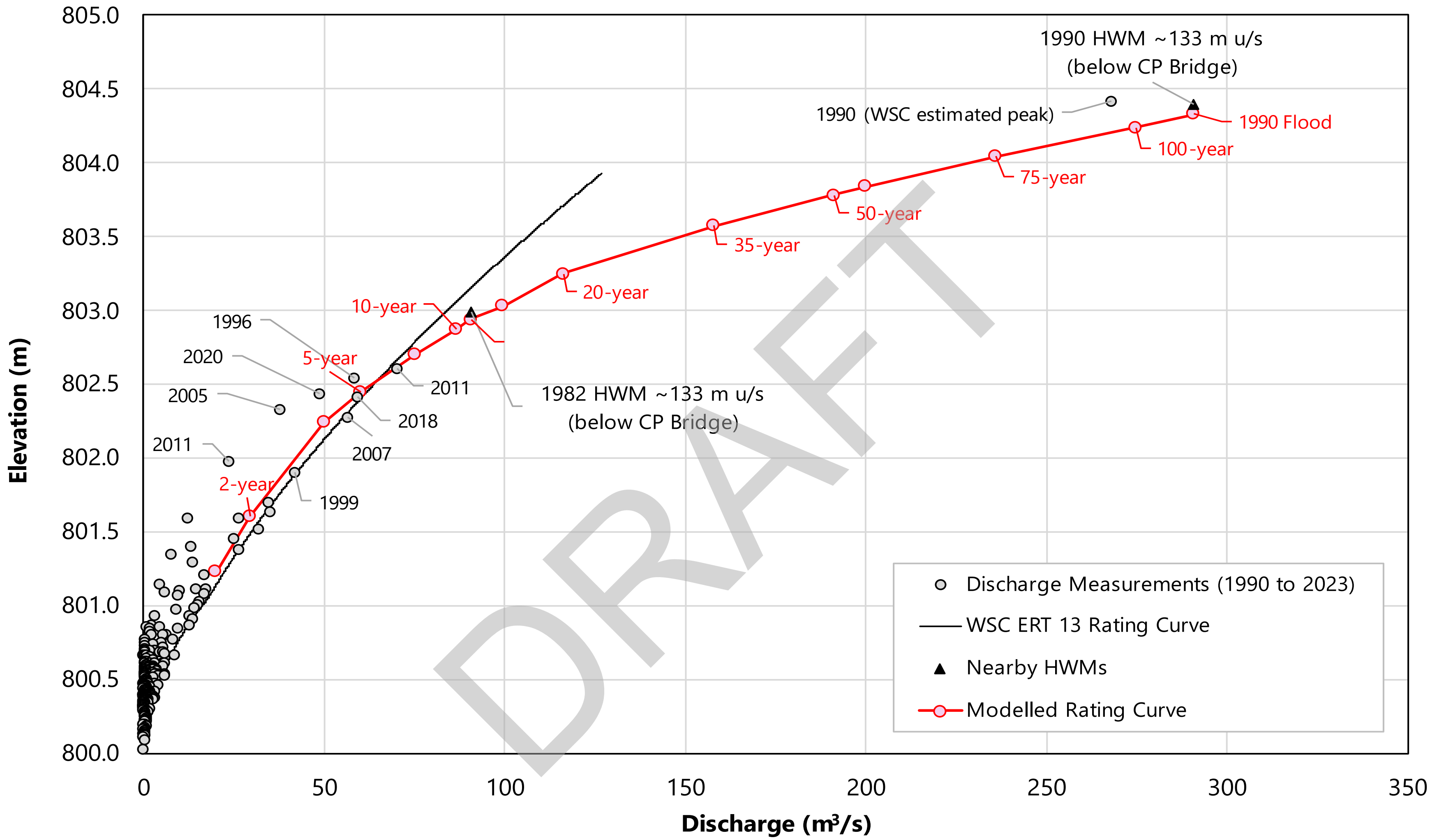
low chord

PONOKA FLOOD STUDY

CALIBRATION PROFILES
BATTLE RIVER

Job: 1008017 | *Date: Mar-2025*

FIGURE 6

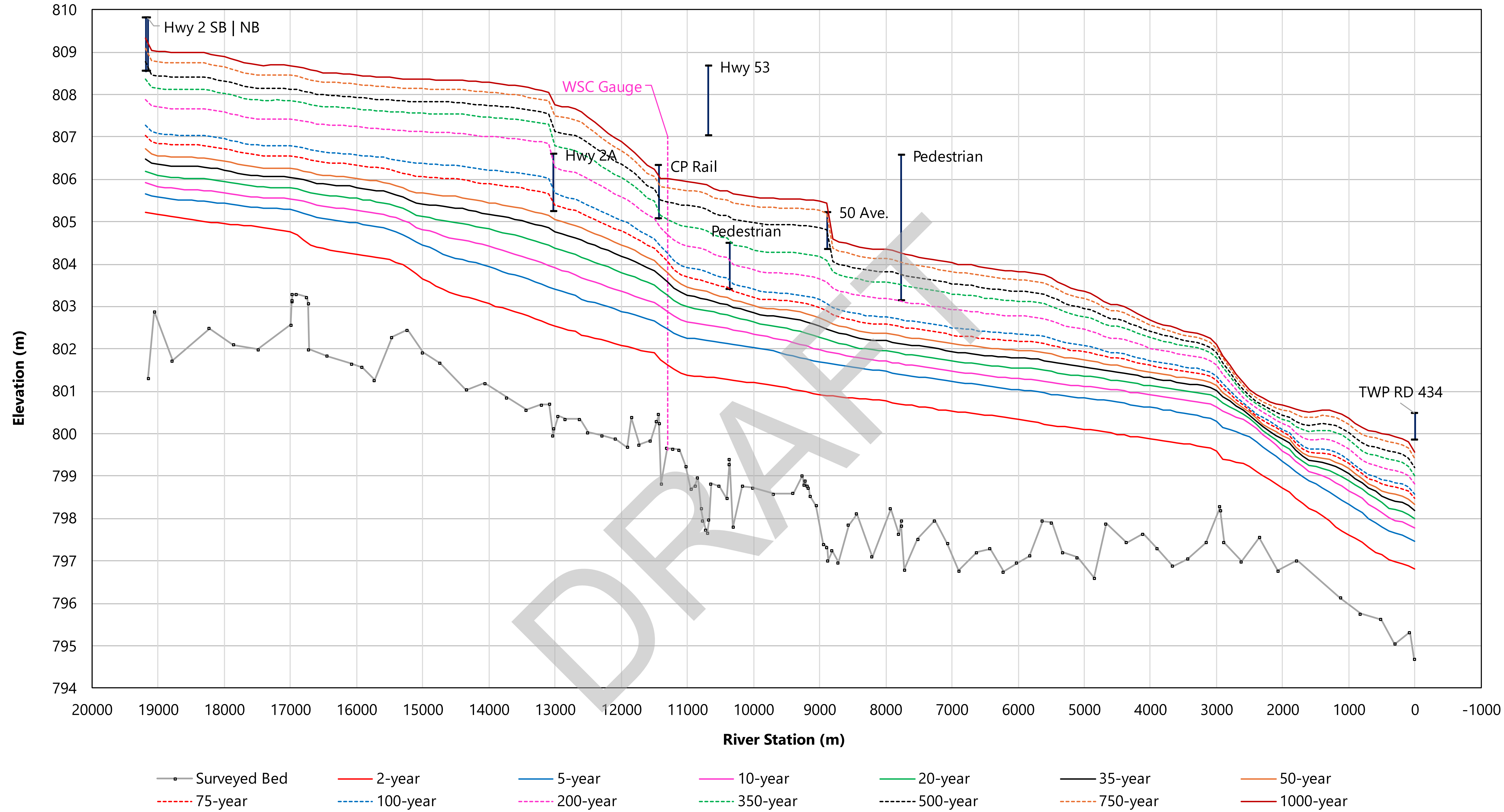


PONOKA FLOOD STUDY

RATING CURVE CALIBRATION
05FA001 BATTLE RIVER AT PONOKA

Job: 1008017 | *Date: Jan-2025*

FIGURE 7

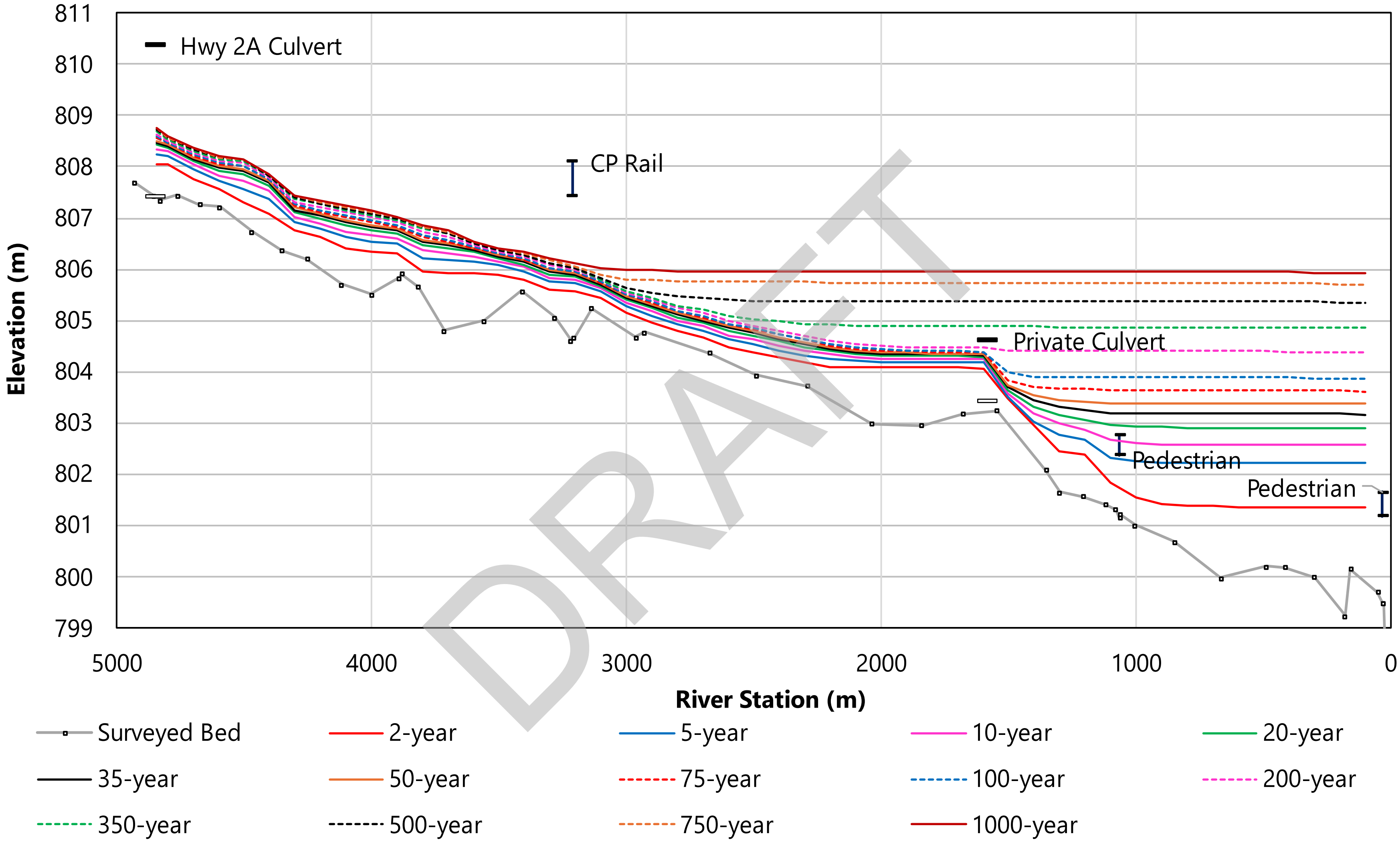


Bridges

high chord

low chord

		PONOKA FLOOD STUDY
		FLOOD FREQUENCY PROFILES BATTLE RIVER
Job: 1008017	*Date: Mar-2025*	*FIGURE 8*



Bridges

high chord

low chord

Culverts

top of road

culvert invert (approx.)

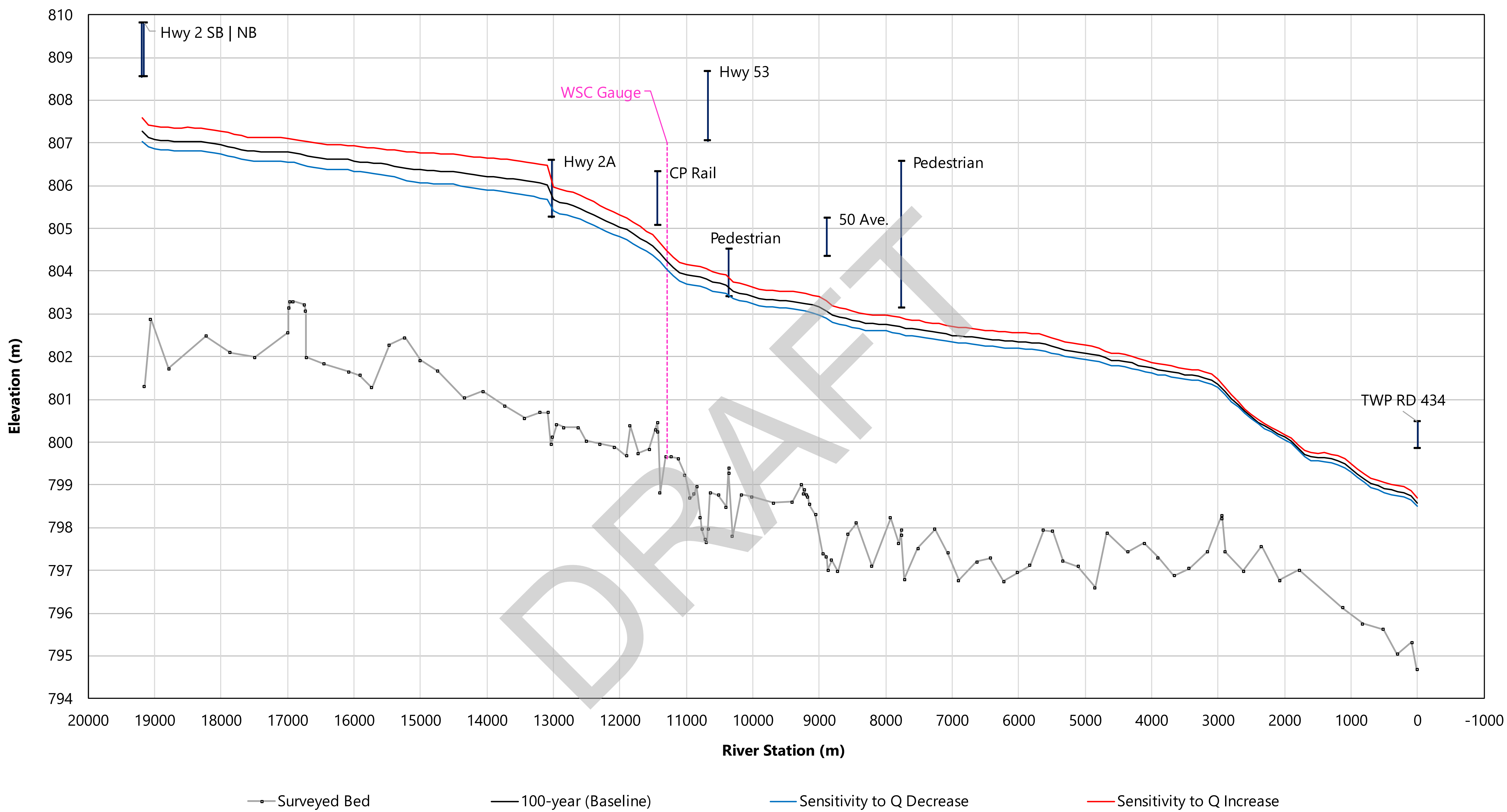
Job: 1008017

Date: Jan-2025

PONOKA FLOOD STUDY

FLOOD FREQUENCY PROFILES
UNNAMED TRIBUTARY

FIGURE 9

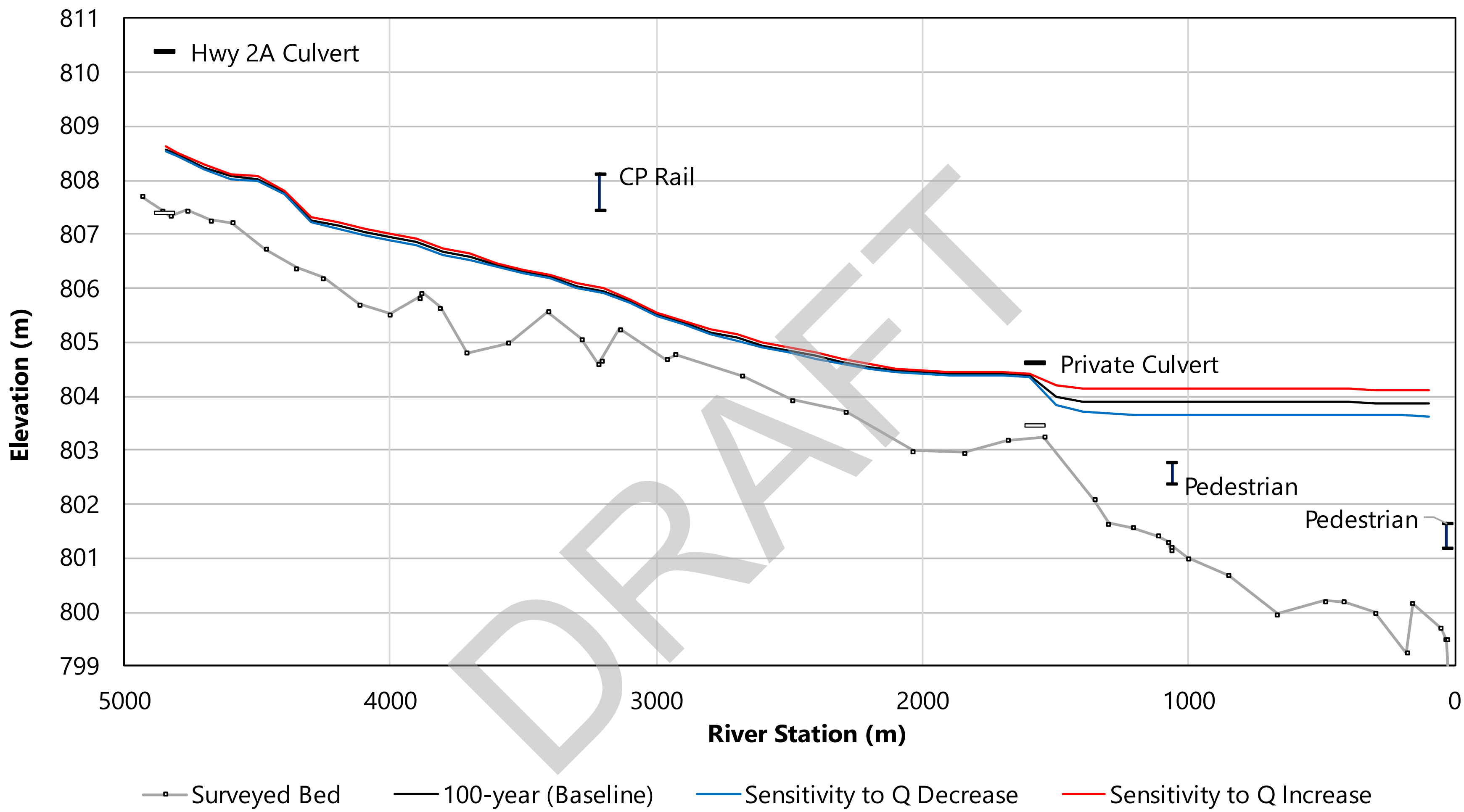


Bridges

high chord

low chord

		PONOKA FLOOD STUDY
		SENSITIVITY TO VARIATION IN FLOOD FREQUENCY ESTIMATES: BATTLE RIVER
Job: 1008017	*Date: Mar-2025*	*FIGURE 10*



Bridges

high chord

low chord

Culverts

top of road

culvert invert (approx.)

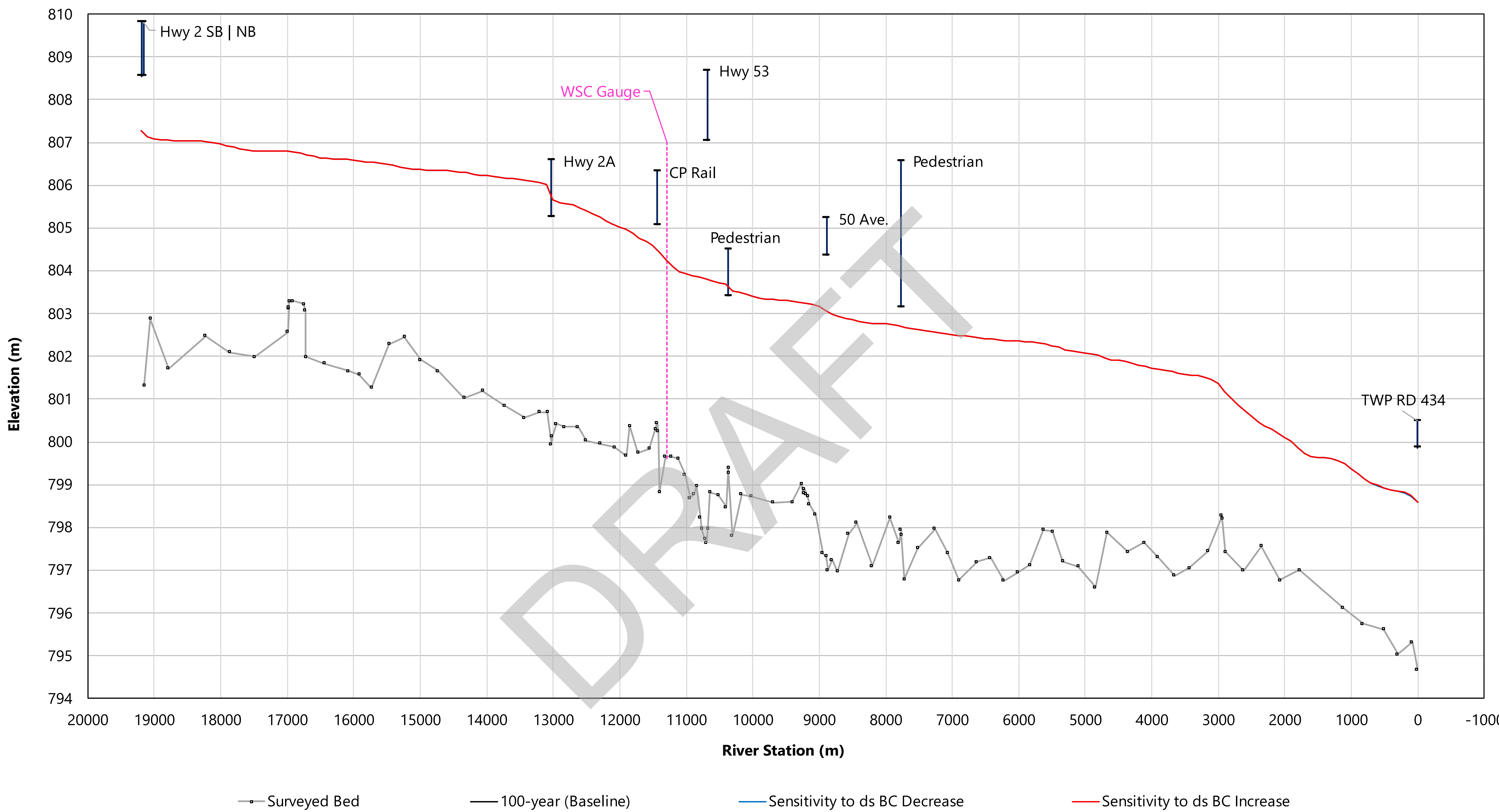
PONOKA FLOOD STUDY

SENSITIVITY TO VARIATION IN FLOOD FREQUENCY ESTIMATES: UNNAMED TRIBUTARY

Job: 1008017

Date: Jan-2025

FIGURE 11

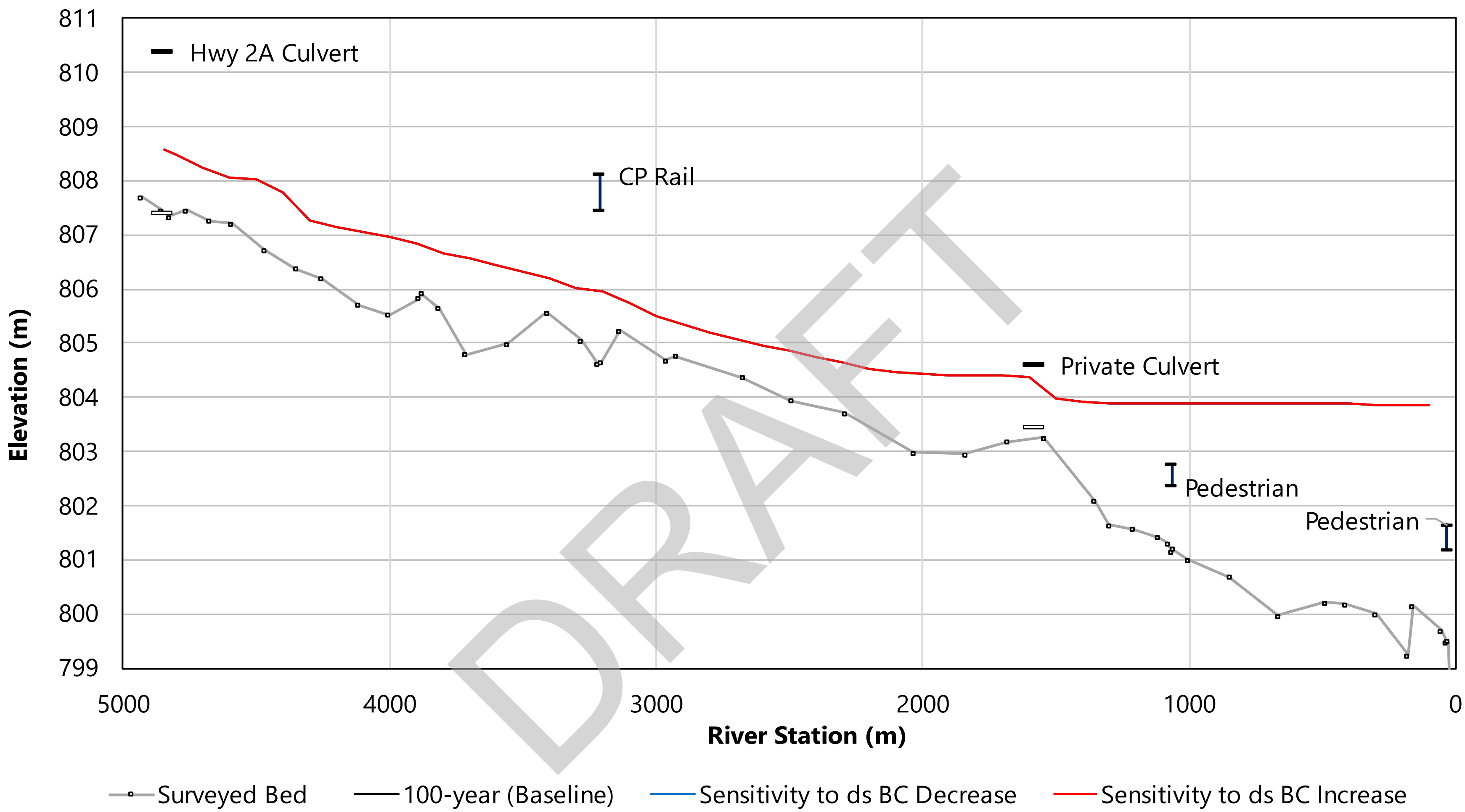


Bridges

high chord

low chord

		PONOKA FLOOD STUDY ***SENSITIVITY TO VARIATION IN DOWNSTREAM BOUNDARY CONDITION: BATTLE RIVER***
Job: 1008017	*Date: Mar-2025*	*FIGURE 12*



Alberta
Canada
nhc

Bridges

high chord

low chord

Culverts

top of road

culvert invert (approx.)

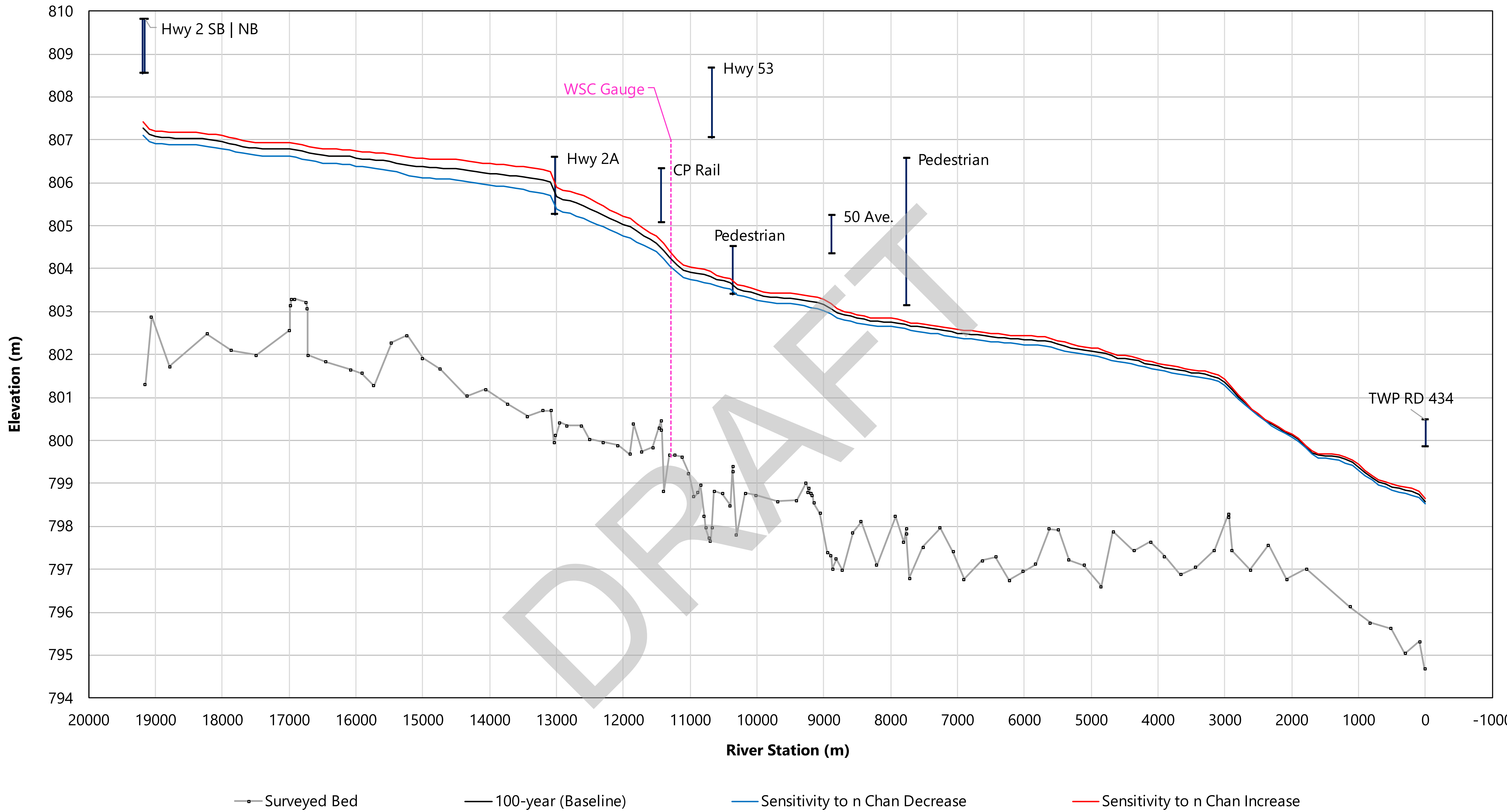
Job: 1008017

Date: Jan-2025

PONOKA FLOOD STUDY

SENSITIVITY TO VARIATION IN DOWNSTREAM BOUNDARY CONDITION: UNNAMED TRIBUTARY

FIGURE 13



Bridges

high chord

low chord

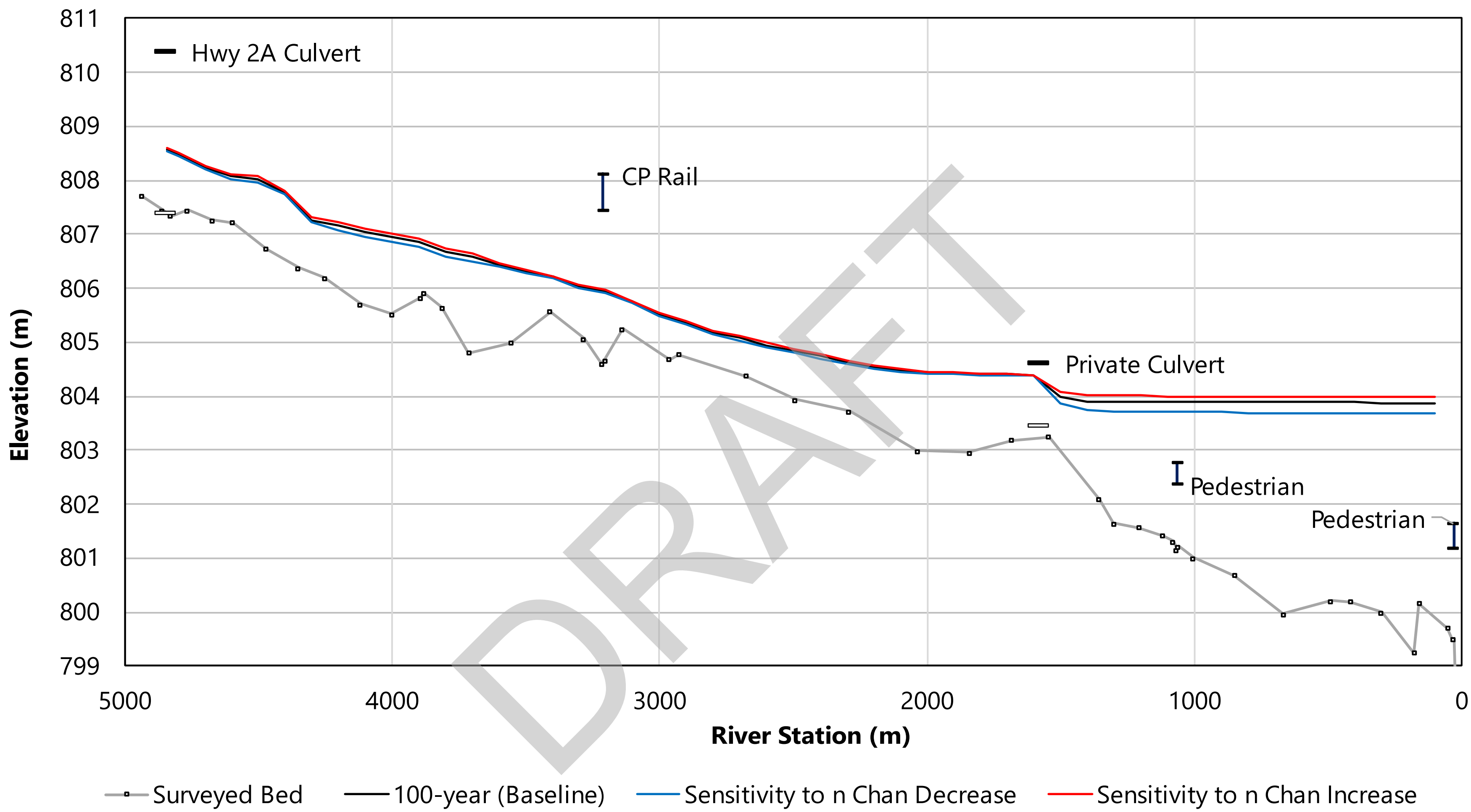
PONOKA FLOOD STUDY

SENSITIVITY TO VARIATION IN CHANNEL ROUGHNESS: BATTLE RIVER

Job: 1008017 | *Date: Mar-2025*

FIGURE 14

Classification: Public



Alberta
Canada
nhc

Bridges
high chord
low chord

Culverts
top of road
culvert invert (approx.)

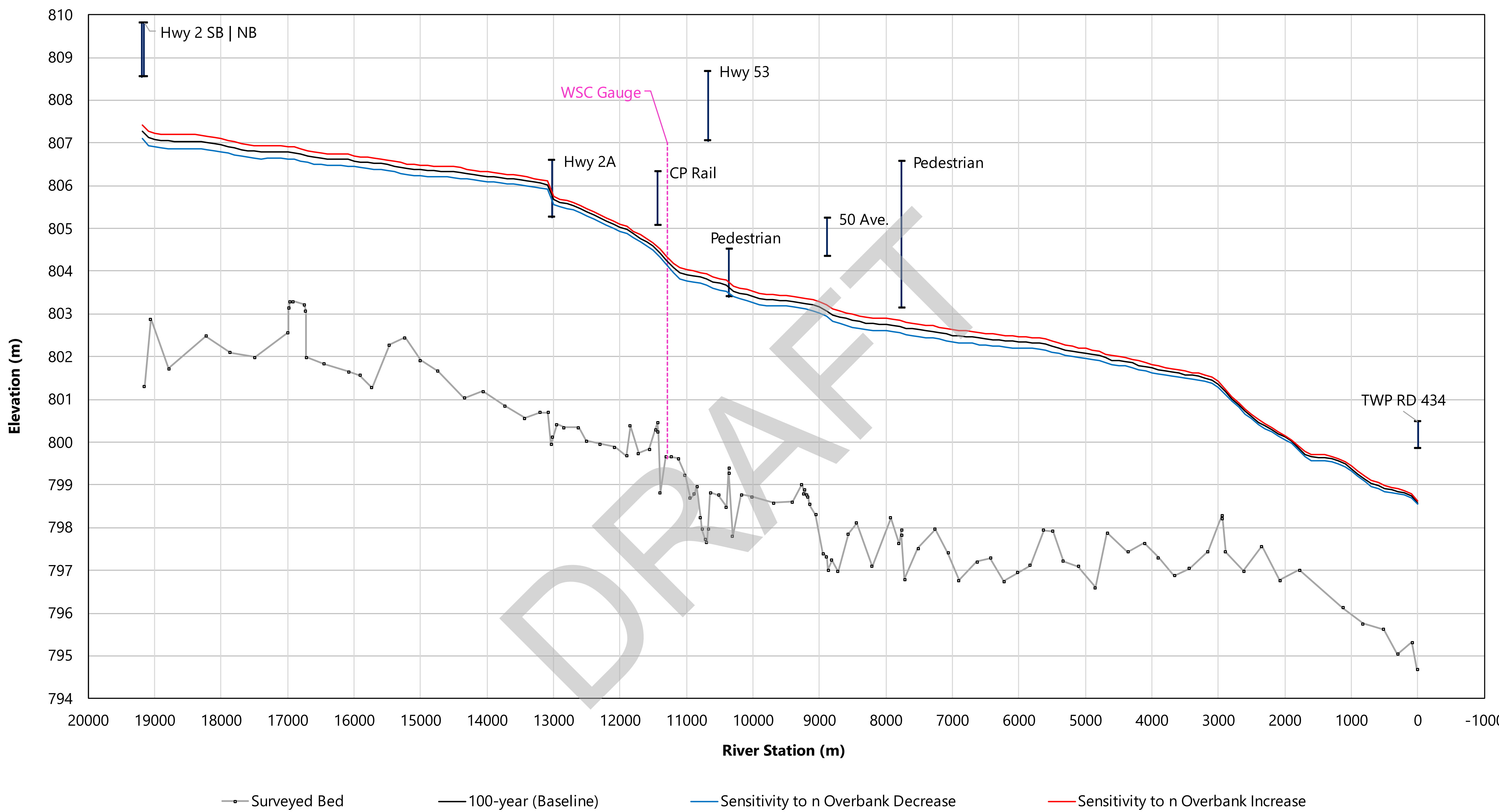
Job: 1008017

Date: Jan-2025

PONOKA FLOOD STUDY

SENSITIVITY TO VARIATION IN CHANNEL ROUGHNESS: UNNAMED TRIBUTARY

FIGURE 15



Bridges

high chord

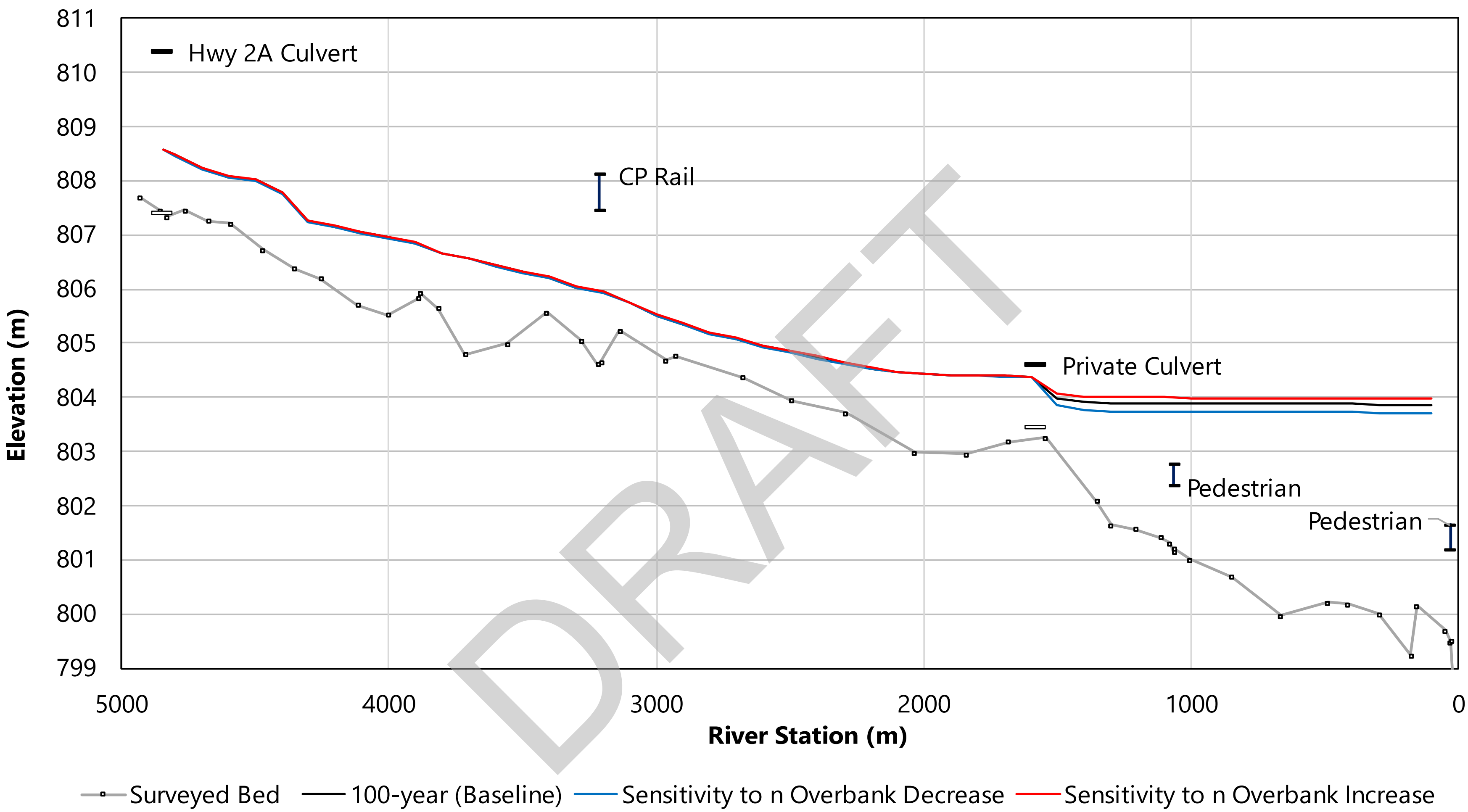
low chord

PONOKA FLOOD STUDY

SENSITIVITY TO VARIATION IN OVERBANK ROUGHNESS: BATTLE RIVER

Job: 1008017 | *Date: Mar-2025*

FIGURE 16



Bridges

high chord

low chord

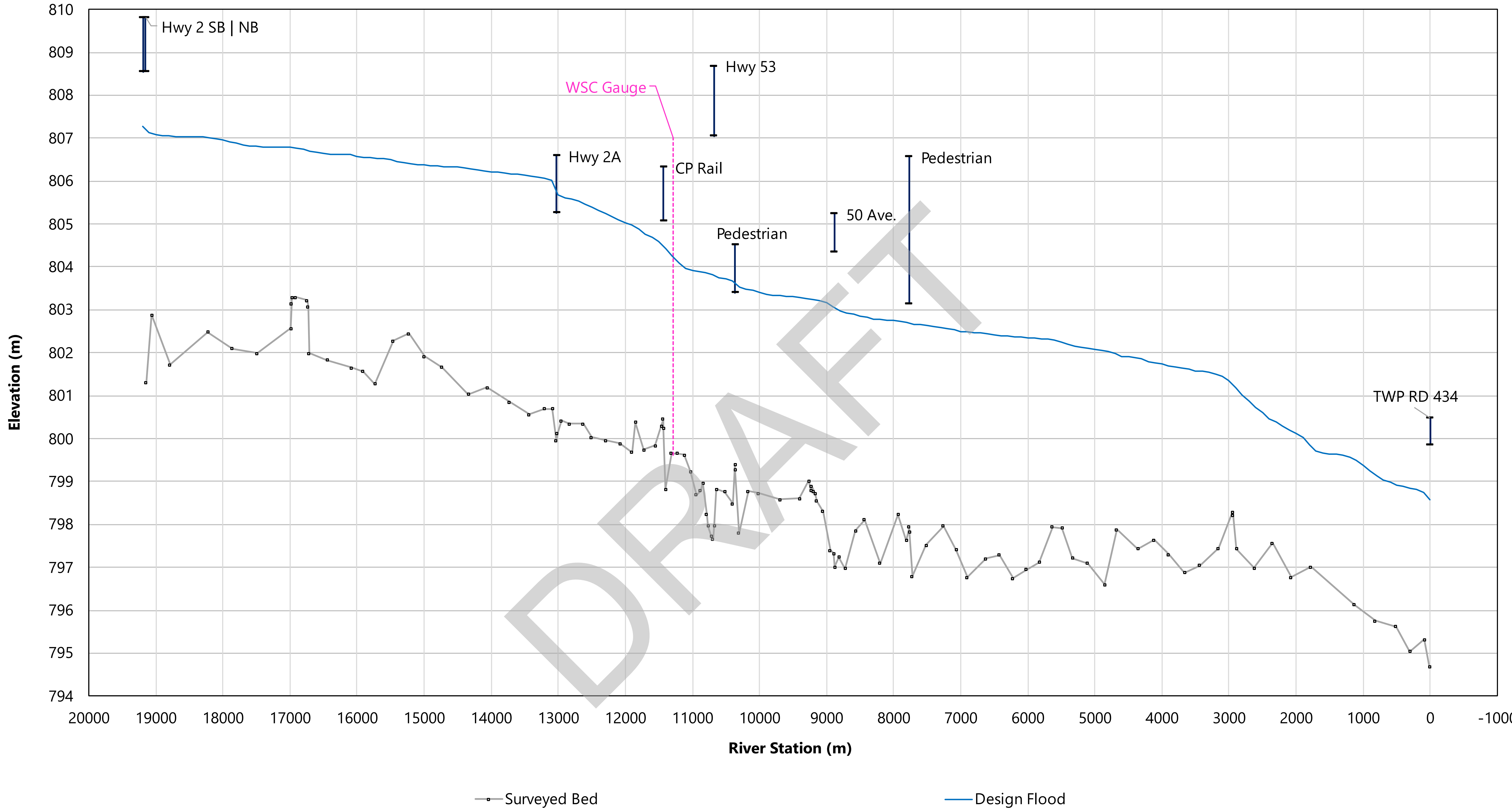
Job: 1008017

Date: Jan-2025

PONOKA FLOOD STUDY

SENSITIVITY TO VARIATION IN OVERBANK ROUGHNESS: UNNAMED TRIBUTARY

FIGURE 17

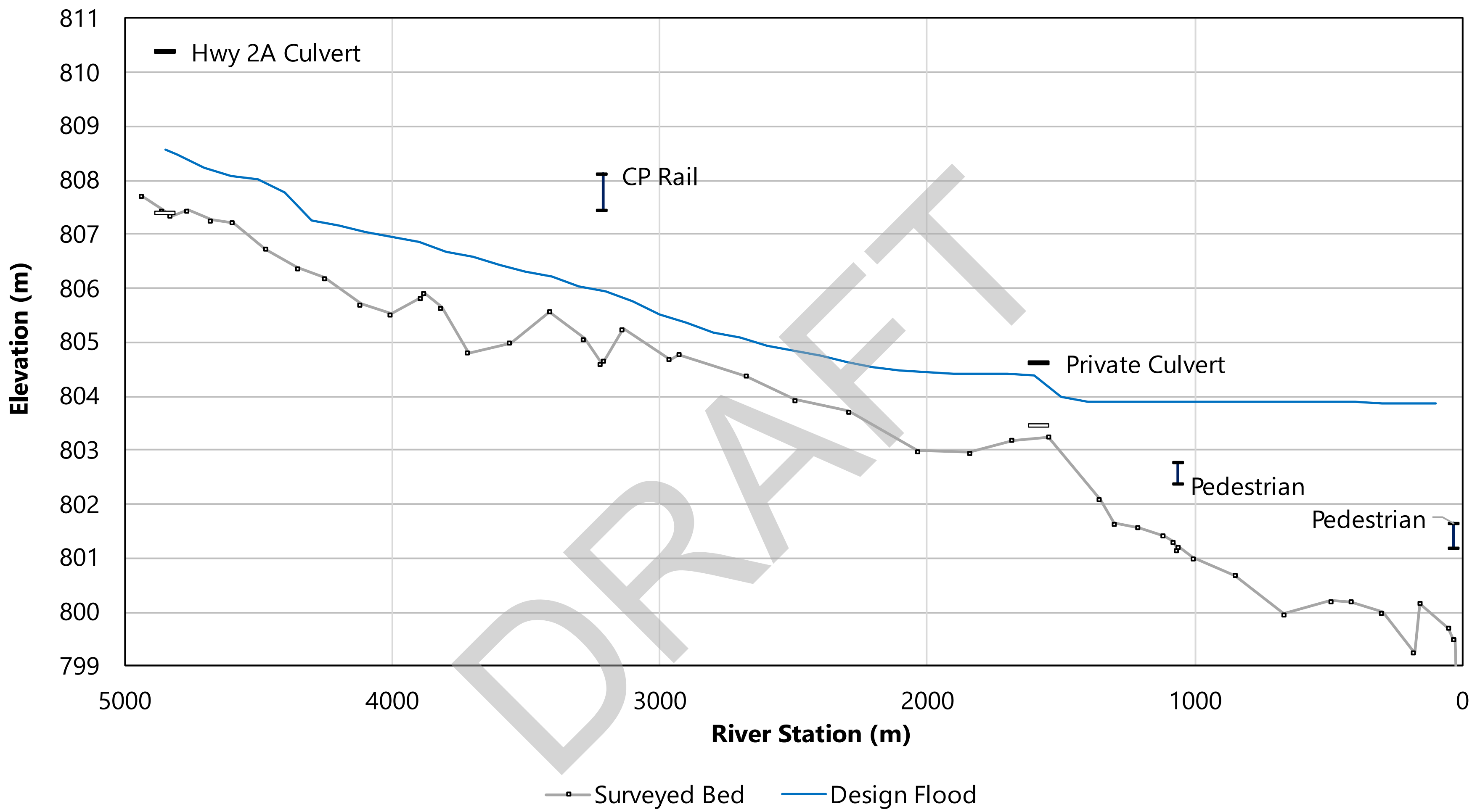


Bridges

high chord

low chord

		PONOKA FLOOD STUDY
		DESIGN FLOOD PROFILE BATTLE RIVER
Job: 1008017	*Date: Mar-2025*	*FIGURE 18*



Bridges

high chord

low chord

Culverts

top of road

culvert invert (approx.)

Job: 1008017

Date: Jan-2025

PONOKA FLOOD STUDY

DESIGN FLOOD PROFILE
UNNAMED TRIBUTARY

FIGURE 19

Classification: Public

APPENDIX A

OPEN WATER HYDROLOGY

Northwest Hydraulic Consultants Ltd.
9819 - 12 Avenue SW
Edmonton, AB T6X 0E3
Tel: (780) 436-5868
www.nhcweb.com

NHC Reference 01008017
March 3, 2025

Alberta Environment and Protected Areas
River Engineering and Technical Services Section
11th floor, Oxbridge Place
9820-106th Street NW
Edmonton, AB T5K 2J6

Attention: Jane Eaket
Email: Jane.Eaket@gov.ab.ca

Re: **Ponoka Flood Study – Open Water Hydrology Assessment**
Final Report (Revision 1)

1 Introduction

In March 2023, Alberta Environment and Protected Areas (EPA) retained Northwest Hydraulic Consultants Ltd. (NHC) to complete a flood study for approximately 19 km of the Battle River and approximately 5 km of an unnamed tributary through the town of Ponoka and Ponoka County. This study was facilitated under the Province's Flood Hazard Identification Program (FHIP) with the intent to enhance public safety and reduce future flood damages in Alberta. Results from this study are also intended to inform local land use planning decisions, flood mitigation projects, and emergency response planning.

The scope of work for this study includes the following major components:

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

This letter report presents the ***open water hydrology assessment***, the primary objective of which is to develop flood frequency estimates for the Battle River and unnamed tributary within the study area, in support of the hydraulic modelling and flood mapping tasks of the Ponoka Flood Study.

2 Study Area

Figure 1 shows the location and boundaries of the study area, which includes:

- 19 km of the Battle River extending from the Highway 2 bridge to the Township Road 434 bridge
- 5 km of the unnamed tributary extending from Highway 2A near Township Road 424 to its confluence with the Battle River in the town of Ponoka

The Water Survey of Canada (WSC) gauging station 05FA001 – Battle River near Ponoka is located within the study reach.

The Battle River is prairie-fed. Much of the river flow is generated from Battle Lake and Pigeon Lake outflows plus runoff from the prairie rural land upstream (northwest) of Ponoka. The upper portion of the basin generally receives slightly more precipitation and tends to produce more surface runoff than the lower portion. From the upstream to downstream boundary of the study reach, the Battle River drainage area increases about 8%. The local drainage area contributing to the study reach consists mostly of developed urban areas. Snowmelt in this area generally starts and finishes earlier than in upstream rural areas, and the runoff response of the urban area is generally faster during both snowmelt and rainfall events. So, as the Battle River flows through the study area, contribution of this local area to the flood peak would be relatively small.

The unnamed tributary is a relatively small stream that joins the Battle River downstream of WSC Station 05FA001. Hereinafter, this tributary is referred to as Unnamed Tributary in this report.

Two locations are identified in **Figure 1** as the sites where flood frequency estimates are required for the Ponoka flood study:

- Battle River near Ponoka (WSC Station 05FA001)
- Unnamed Tributary at the mouth

3 Hydrologic Characteristics

3.1 Basin Sizes and Settings

The Battle River is a major tributary of the North Saskatchewan River. It originates at Battle Lake and Pigeon Lake in central Alberta. From Battle Lake, the Battle River flows in a south-easterly direction for about 70 km to Ponoka. It flows north-easterly through the town of Ponoka. After passing the confluence with Pipestone Creek near Wetaskiwin, it flows generally towards the east border of Alberta and eventually joins the North Saskatchewan River at Battleford, Saskatchewan.

As shown in **Figure 2**, the Battle River basin area upstream of Ponoka is approximately 1820 km^2 based on the information from the WSC. The land classification system adopted by Alberta divides the province into six natural regions composed of 21 subregions. These regions and subregions are defined geographically based on landscape patterns, notably vegetation, soils and physiographic features, which reflect the combined influence of climate, hydrology, topography and geology. The upper half of the Battle River basin above Ponoka lies in the Dry Mixedwood Natural Subregion, while the lower half near Ponoka lies in the Central Parkland Subregion. Generally, the Central Parkland Subregion is slightly warmer and receives slightly less precipitation than the Dry Mixedwood Subregion. Additionally, the Central Parkland Subregion is more cultivated than the Dry Mixedwood Subregion.

Unnamed Tributary is a small, ungauged prairie stream which joins the Battle River immediately upstream of the Highway 53 bridge. Its drainage area was estimated to be 23 km^2. **Figure 2** shows the boundary of this drainage area, which was delineated based on a 1-m LiDAR digital elevation model (DEM) provided by EPA and Alberta Flow Estimation Tool for Ungauged Watershed (AFETUW).

3.2 Historic Flood Events and Flood Characteristics

Historic floods refer to major floods that occurred prior to the period of systematic hydrometric data collection. If the magnitude of a historic flood can be estimated based on available information, the estimate could be used to improve the flood frequency estimates.

Systematic flow monitoring data on the Battle River near Ponoka (WSC Station 05FA001) are available from 1913 to 1930 and from 1967 to 2021. The largest event over the periods of the gauge record is the July 1990 event with a reported peak instantaneous discharge of 291 m^3/s. The 1974 spring flood that occurred on April 19 is the second largest event on the gauge record. The published peak instantaneous discharge for this event is 108 m^3/s.

It has been known that large floods occurred at Ponoka in some years outside the periods of record. Information of these historic events are summarized in **Table 1**. Based on Alberta Transportation (AT) bridge file #00278, which includes the history of and observed flood levels at the Highway 2A bridge, the 1902 flood was likely the largest known event, and the July 1990 flood was the second largest, followed by the 1948 event. The peak discharges of these three events are two to three times as high as the April 1974 flood peak (108 m^3/s).

As noted in the previous study (AEP, 1992), both rainfall and snowmelt runoff events contribute to the annual peak flows on the Battle River near Ponoka. While most annual events were dominated by snowmelt runoff; however, floods due to summer rainstorms are not uncommon for the Battle River.

Ice jams have not typically been a problem along the Battle River near Ponoka, except for the spring of 1927 when an ice jam threatened the Highway 2A bridge and dynamite was used to clear it according to the AT bridge file #00278.

Table 1: Summary of historic flood events at Ponoka

Year	Month/Date	Peak Discharge (m^3/s)	Remarks
1902	June	324	The flood peak discharge was estimated by modelling based on available highwater mark (HWM) data according to AEP (1992). The month of the flood event was estimated by NHC based on the story of W.M. James, a resident of Ponoka (https://www.wikitree.com/), which mentioned an extraordinarily long duration of rain in June 1902.
1904	Unknown	Not available	AT bridge file #00278 noted that the estimated highwater level of this event was about 2.7 m above the south bank of the Battle River at the Highway 2A bridge.
1908	Unknown	Not available	AT bridge file #00278 noted that the Highway 2A bridge was washed out and subsequently replaced.
1948	May	232	The flood peak discharge was estimated by modelling based on available HWM data according to AEP (1992). AT bridge file #00278 noted that the highwater level was 0.74 m (29 inches) above the Highway 2A bridge deck.
1954	Unknown	Not available	AT bridge file #00278 noted that the highwater level was near the elevation of the south abutment bridge footing for the Highway 2A bridge.

4 Data Series Preparation

4.1 Flow Data for Battle River near Ponoka

Annual peak discharges reported by the WSC for Station 05FA001 and two estimated peak discharges for the two historic floods (1902 and 1948) discussed in Section 3.2 are listed in **Table 2**. While the gauge data series for WSC Station 05FA001 spans from 1913 to 1930 and 1967 to 2021 instantaneous peaks were not reported in many of the years, and where missing, they were calculated based on the relationship between the instantaneous peak (Q_i) and daily discharges (Q_d) for years when both were measured at WSC Station 05FA001. This relationship ($Q_i = 1.04Q_d$) is illustrated in **Figure 3**. When developing this relationship, the data point representing the July 1990 event (the largest measured flood peak) was deemed an outlier and ignored. So, the relationship is based on the data points with the maximum daily discharges ranging from 2.13 m^3/s to 104 m^3/s, which adequately covers the range of discharges for the years where peak instantaneous discharges need to be estimated.

Table 2: Annual peak discharges for Battle River near Ponoka

Year	Peak Instantaneous Discharge (m^3/s)	Date	Maximum Daily Discharge (m^3/s)	Date	Daily Discharge on the Same Event of Peak Instantaneous Discharge (m^3/s)
1902	324[1]	Jun	-	-	
1913	17.7[2]	-	17.0	Jul-16	
1914	57.7[2]	-	55.5	Jun-10	
1915	58.0[2]	-	55.8	Jun-6	

Year	Peak Instantaneous Discharge (m^3/s)	Date	Maximum Daily Discharge (m^3/s)	Date	Daily Discharge on the Same Event of Peak Instantaneous Discharge (m^3/s)
1916	61.3[2]	-	58.9	Sep-8	
1917	61.9[2]	-	59.5	Apr-14	
1918	7.36[2]	-	7.08	Apr-14	
1919	29.4[2]	-	28.3	Apr-14	
1920	94.5[2]	-	90.9	May-9	
1921	33.6[2]	-	32.3	Apr-16	
1922	2.51[2]	-	2.41	Jun-6	
1923	6.56[2]	-	6.31	Jul-11	
1924	4.12[2]	-	3.96	Apr-28	
1925	57.4[2]	-	55.2	Apr-10	
1926	46.4	Jun-23	46.2	Jun-23	
1927	78.4	Jul-10	75.6	Jul-11	
1928	55.1[2]	-	53.0	Mar-26	
1929	9.02[2]	-	8.67	Apr-18	
1930	1.59[2]	-	1.53	Apr-2	
1931-1947	No data				
1948	232[1]	May			
1949-1969	No data				
1967	18.1[2]	-	17.4	Apr-26	
1968	No data				
1969	68.6[2]	-	66.0	Apr-10	
1970	33.0[2]	-	31.7	Apr-12	
1971	55.5	Apr-16	53.5	Apr-16	
1972	18.5[2]	-	17.8	Apr-9	
1973	29.2	Jul-4	27.8	Jul-5	
1974	108	Apr-19	104	Apr-19	
1975	20.8[2]	-	20.0	Apr-22	
1976	11.5[2]	-	11.1	Apr-10	
1977	11.0	May-31	9.88	Jun-1	
1978	13.8	Apr-1	12.7	Apr-1	
1979	15.6	Apr-22	15.2	Apr-22	
1980	17.3	Jul-4	14.4	Jul-4	
1981	65.3	Aug-2	63.7	Aug-2	
1982	90.7	Apr-24	89.3	Apr-24	
1983	22.2[2]	-	21.3	Apr-4	
1984	11.1	Sep-25	9.76	Jun-11	6.14[3]
1985	56.7[2]	-	54.5	Apr-4	
1986	47.5	Jul-21	45.7	Jul-21	
1987	28.4[2]	-	27.3	Apr-6	

Year	Peak Instantaneous Discharge (m^3/s)	Date	Maximum Daily Discharge (m^3/s)	Date	Daily Discharge on the Same Event of Peak Instantaneous Discharge (m^3/s)
1988	52.0[2]	-	50.0	Jul-9	
1989	34.7[2]	-	33.4	Apr-15	
1990	291	Jul-4	202	Jul-4	
1991	37.8[2]	-	36.3	Apr-5	
1992	14.6[2]	-	14.0	Mar-16	
1993	23.9[2]	-	23.0	Mar-26	
1994	10.4[2]	-	9.99	Apr-1	
1995	6.61[2]	-	6.36	Mar-19	
1996	58.4[2]	-	56.2	Apr-11	
1997	27.5[2]	-	26.4	Apr-18	
1998	14.9	Jul-3	14.7	Jul-3	
1999	52.5	Apr-14	51.4	Apr-14	
2000	28.3	Jul-13	26.9	Jul-13	
2001	17.2	Aug-1	14.9	Aug-1	
2002	30.8	Apr-24	25.4	Apr-23	
2003	90.8[2]	-	87.3	Apr-11	
2004	3.38	Aug-4	2.13	Aug-4	
2005	60.9[2]	-	58.6	Apr-5	
2006	17.0[2]	-	16.3	Apr-6	
2007	70.5	May-7	64.2	May-7	
2008	5.12	May-6	4.85	May-6	
2009	2.86[2]	-	2.75	Apr-17	
2010	21.3	Jul-20	20.2	Jul-20	
2011	71.0	Jul-29	69.6	Jul-29	
2012	12.1[2]	-	11.6	Apr-2	
2013	14.4[2]	-	13.8	Apr-21	
2014	47.2[2]	-	45.4	Apr-16	
2015	20.0[2]	-	19.2	Mar-30	
2016	3.39[2]	-	3.26	Oct-7	
2017	48.9[2]	-	47.0	Apr-2	
2018	67.1	Apr-22	64.9	Apr-22	
2019	37.4[2]	-	36.0	Apr-1	
2020	55.0[2]	-	52.9	Apr-20	
2021	4.64	May-20	4.43	May-20	

Notes:

1. Peak discharge for historic floods were estimated from highwater mark data (AEP, 1992).
2. Peak instantaneous discharges were estimated from daily values based on the relationship Q_i=1.04Q_d established in **Figure 3**.
3. Daily discharge for the event of peak instantaneous discharge is reported in the table where the WSC reported annual peak instantaneous and daily discharges do not correspond to the same event.

As shown in **Table 2**, there are still gaps in this data series (1903-1912, 1931-1947, 1949-1969 and 1968). Unfortunately, no regional data or other information is available to fill these gaps.

In central Alberta, spring snowmelt runoff typically occurs before May. Runoff in summer (May through September) is usually dominated by rainfall associated with cold lows, convective storms or occasional thunderstorms. About 60% of the Battle River annual peak discharges (45 out of 74 events) listed in **Table 2** occurred in March and April, primarily due to snowmelt. The remainder 40% (or 29 events) were summer events that occurred between May and October. The three largest events (June 1902, July 1990 and May 1948) were summer events, and the fourth largest event (April 1974) was the largest spring event of the record. As mentioned in Section 3.2, the peak discharges of the three largest summer events were two to three times as high as the April 1974 flood peak. **Figure 4** illustrates the magnitudes of the annual instantaneous peak discharges listed in **Table 2** with spring and summer events shown in different colors.

Clearly the annual flood peak data series for Battle River near Ponoka belongs to a mixed population consisting of snowmelt and rainfall events. As discussed later, separate analyses for spring (snowmelt governing) and summer (rainfall governing) events would provide more reliable flood frequency estimates for this site. As such, the annual peak discharges dataset was segregated into spring and summer populations as shown in **Table 3**. A second peak daily discharge was determined for each year corresponding to either a spring (if the annual peak event was in summer) or summer high-flow event (if the annual peak event was in spring) from the daily flow gauge data. Instantaneous peak discharges for these second events were estimated from the daily discharges based on the peak-to-daily discharge relationship shown in **Figure 3**. As described in Section 5.2, these data sets were used later to develop a combined-population frequency curve.

Table 3: Maximum spring and summer discharges for Battle River near Ponoka

Year	Spring Event				Summer Event			
	Q_i (m^3/s)	Date	Q_d (m^3/s)	Date	Q_i (m^3/s)	Date	Q_d (m^3/s)	Date
1902	No data				324[1]	June	-	-
1903-1912	No data							
1913	No data				17.7[2]	-	17.0	Jul-16
1914	5.14[2]	-	4.93	Apr-25	57.8[2]	-	55.5	Jun-10
1915	5.88[2]	-	5.64	Apr-9	58.1[2]	-	55.8	Jun-6
1916	15.0[2]	-	14.4	Mar-26	61.4[2]	-	58.9	Sep-8
1917	62.0[2]	-	59.5	Apr-14	61.1[2]	-	58.6	May-20
1918	7.38[2]	-	7.08	Apr-14	3.66[2]	-	3.51	Jun-2
1919	29.5[2]	-	28.3	Apr-14	18.1[2]	-	17.4	May-11
1920	1.77[2]	-	1.70	Mar-31	94.7[2]	-	90.9	May-9
1921	33.7[2]	-	32.3	Apr-16	4.11[2]	-	3.94	May-13
1922	1.77[2]	-	1.70	Apr-23	2.51[2]	-	2.41	Jun-6
1923	5.25[2]	-	5.04	Apr-26	6.58[2]	-	6.31	Jul-11
1924	4.13[2]	-	3.96	Apr-28	2.33[2]	-	2.24	May-31
1925	57.5[2]	-	55.2	Apr-10	4.66[2]	-	4.47	Jun-6
1926	25.4[2]	-	24.4	Apr-13	46.4	Jun-23	46.2	Jun-23

Year	Spring Event				Summer Event			
	Q_i (m³/s)	Date	Q_d (m³/s)	Date	Q_i (m³/s)	Date	Q_d (m³/s)	Date
1927	77.9[2]	-	74.8	Apr-18	78.4	Jul-10	75.6	Jul-11
1928	55.2[2]	-	53.0	Mar-26	24.8[2]	-	23.8	Jun-20
1929	9.03[2]	-	8.67	Apr-18	3.83[2]	-	3.68	May-18
1930	1.59[2]	-	1.53	Apr-2	1.50[2]	-	1.44	Jun-30
1931-1947	No data							
1948	No data				232[1]	May	-	-
1949-1966	No data							
1967	18.1[2]	-	17.4	Apr-26	3.72	-	3.57	Jun-19
1968	No data							
1969	68.8[2]	-	66.0	Apr-10	2.13[2]	-	2.04	May-14
1970	33.0[2]	-	31.7	Apr-12	9.47[2]	-	9.09	Jul-3
1971	55.5	Apr-16	53.5	Apr-16	15.9[2]	-	15.3	Jul-13
1972	18.5[2]	-	17.8	Apr-9	3.45[2]	-	3.31	Jun-27
1973	13.9[2]	-	13.3	Apr-4	29.2	Jul-4	27.8	Jul-5
1974	108	Apr-19	104	Apr-19	16.3[2]	-	15.6	Jul-15
1975	20.8[2]	-	20.0	Apr-22	1.87[2]	-	1.79	Jul-9
1976	11.6[2]	-	11.1	Apr-10	2.57[2]	-	2.47	Aug-20
1977	4.16[2]	-	3.99	Apr-8	11.0	May-31	9.88	Jun-1
1978	13.8	Apr-1	12.7	Apr-1	3.54[2]	-	3.40	Jun-2
1979	15.6	Apr-22	15.2	Apr-22	3.92[2]	-	3.76	May-19
1980	12.6[2]	-	12.1	Apr-11	17.3	Jul-4	14.4	Jul-4
1981	12.3[2]	-	11.8	Mar-18	65.3	Aug-2	63.7	Aug-2
1982	90.7	Apr-24	89.3	Apr-24	61.0[2]	-	58.5	Jul-7
1983	22.2[2]	-	21.3	Apr-4	12.5[2]	-	12.0	Jul-10
1984	7.55[2]	-	7.25	Mar-27	11.1	Sep-25	6.14	Sep-25
1985	56.8[2]	-	54.5	Apr-4	2.10[2]	-	2.02	May-30
1986	13.5[2]	-	13.0	Mar-4	47.5	Jul-21	45.7	Jul-21
1987	28.4[2]	-	27.3	Apr-6	6.36[2]	-	6.10	May-23
1988	2.76[2]	-	2.65	Apr-7	52.1[2]	-	50.0	Jul-9
1989	34.8[2]	-	33.4	Apr-15	12.8[2]	-	12.3	May-22
1990	40.5[2]	-	38.9	Apr-2	291	Jul-4	202	Jul-4
1991	37.8[2]	-	36.3	Apr-5	30.2[2]	-	29.0	May-16
1992	14.6[2]	-	14.0	Mar-16	8.30[2]	-	7.97	Jun-1
1993	24.0[2]	-	23.0	Mar-26	3.50[2]	-	3.36	May-10
1994	10.4[2]	-	9.99	Apr-1	3.18[2]	-	3.05	May-23
1995	6.63[2]	-	6.36	Mar-19	1.55[2]	-	1.49	Jul-13
1996	58.6[2]	-	56.2	Apr-11	8.69[2]	-	8.34	Aug-7
1997	27.5[2]	-	26.4	Apr-18	18.7[2]	-	17.9	Jun-24
1998	5.21[2]	-	5.00	Mar-22	14.9	Jul-3	14.7	Jul-3

Year	Spring Event				Summer Event			
	Q_i (m^3/s)	Date	Q_d (m^3/s)	Date	Q_i (m^3/s)	Date	Q_d (m^3/s)	Date
1999	52.5	Apr-14	51.4	Apr-14	41.8	-	40.1	Jul-19
2000	13.5[2]	-	13.0	Mar-31	28.3	Jul-13	26.9	Jul-13
2001	1.26[2]	-	1.21	Apr-19	17.2	Aug-1	14.9	Aug-1
2002	30.8	Apr-24	25.4	Apr-23	2.90[2]	-	2.79	May-16
2003	91.0[2]	-	87.3	Apr-11	8.65[2]	-	8.30	May-11
2004	2.12[2]	-	2.03	Apr-2	3.38	Aug-4	2.13	Aug-4
2005	61.1[2]	-	58.6	Apr-5	5.01[2]	-	4.81	Jun-25
2006	17.0[2]	-	16.3	Apr-6	1.19[2]	-	1.14	Sep-19
2007	18.5[2]	-	17.8	Apr-21	70.5	May-7	64.2	May-7
2008	1.47[2]	-	1.41	Apr-13	5.12	May-6	4.85	May-6
2009	2.87[2]	-	2.75	Apr-17	2.23[2]	-	2.14	Jul-11
2010	0.210[2]	-	0.204	Mar-19	21.3	Jul-20	20.2	Jul-20
2011	57.2[2]	-	54.9	Apr-27	71.0	Jul-29	69.6	Jul-29
2012	12.1[2]	-	11.6	Apr-2	9.45[2]	-	9.07	Jun-16
2013	14.4[2]	-	13.8	Apr-21	6.98[2]	-	6.70	Jun-1
2014	47.3[2]	-	45.4	Apr-16	5.80[2]	-	5.57	May-31
2015	20.0[2]	-	19.2	Mar-30	1.51[2]	-	1.45	May-8
2016	2.43[2]	-	2.33	Mar-13	3.40[2]	-	3.26	Oct-7
2017	49.0[2]	-	47.0	Apr-2	6.89[2]	-	6.61	May-26
2018	67.1	Apr-22	64.9	Apr-22	0.700[2]	-	0.657	Oct-1
2019	37.5[2]	-	36.0	Apr-1	3.86[2]	-	3.70	Jul-21
2020	55.1[2]	-	52.9	Apr-20	14.8[2]	-	14.2	May-24
2021	1.92[2]	-	1.84	Mar-18	4.64	May-20	4.43	May-20

Notes:

1. Peak discharge for historic floods were estimated from highwater mark data.
2. Peak instantaneous discharges were estimated from daily values based on the relationship $Q_i=1.04Q_d$ established in **Figure 3**.

4.2 Regional Flow Data

A regional analysis is required to develop flood frequency estimates for Unnamed Tributary because it is ungauged. Selection of regional stations for the regional flood frequency analysis involves evaluation of various factors, including their proximity to the study area, climate conditions, basin size, length and period of record, and topography.

For this study, nine WSC gauge stations were initially selected as candidate regional stations for the regional analysis. These gauge stations are summarized in **Table 4,** and their locations are shown in **Figure 2**.

Table 4: List of candidate hydrometric stations initially selected for regional analysis

WSC Station ID	Station Name	Gross Drainage Area (km²)	Effective Drainage Area (km²)	Period of Record	Length of Record (years)
05FA012/ 05FA022	**Pipestone Creek near Wetaskiwin**[1,2]	1,030	733	1972-1988, 1990-2014, 2016-2021	48
05FA014	Maskwa Creek No. 1 above Bearhills Lake	79	61.2	1972-1993, 1995-1997, 1991-2021	48
05FA024	**Weiller Creek near Wetaskiwin**[1]	236	90.1	1985-1999, 2001-2022	37
05CD006	**Haynes Creek near Haynes**[1]	165	165	1978-2022	42
05CD913	Haynes Creek near Joffre	24.4	24.4	1991-2001	11
05CD007	Parlby Creek at Alix	511	452	1983-2022	40
05CD902	Parlby Creek near Mirror	866	620	1981-2021	41
05CC008	Blindman River near Bluffton	353	353	1965-2014, 2016-2022	57
05CC009	Lloyd Creek near Bluffton	239	239	1965-2014, 2017-2022	56

Notes:

1. Finally selected gauge station for regional analysis.
2. Data for WSC Station 05FA012 – Pipestone Creek near Wetaskiwin (period of record: 1972-1979 and 1991-2021) and 05FA022 – Pipestone Creek below Bigstone Creek (period of record: 1980-1990) are combined given the proximity of these two gauging stations and their similar drainage areas.

Flow data for these regional gauge stations were collected and analyzed, and their basin conditions were further reviewed. Following the review, some of them were excluded:

- Maskwa Creek No. 1 above Bearhills Lake (WSC Station 05FA014) was eliminated because flood peaks at this gauge were relatively low and likely affected by two wetlands located a few kilometers upstream of the gauge.

- Haynes Creek near Joffre (WSC Station 05CD913) was eliminated due to its short record length.

- Parlby Creek at Alix (WSC Station 05CD007) and Parlby Creek near Mirror (WSC Station 05CD902) were eliminated because flood peaks at these two gauges were likely affected by Chain Lakes and Magee Lake on Parlby Creek.

- Blindman River near Bluffton (WSC Station 05CC008) and Lloyd Creek near Bluffton (WSC Station 05CC009) were eliminated because these basins have significantly higher runoff potential than the other regional basins. They lie over the Lower Foothills and Dry Mixedwood Natural Subregions, while the Unnamed Tributary and the other regional basins are in the Central Parkland Subregion which typically receives slightly less precipitation. The Alberta runoff depth map (AT, 2006) also indicates that these two basins are in a higher runoff zone.

The finally selected WSC stations for the regional analysis are noted in **Table 4** and listed as follows:

- 05FA012/05FA022 – Pipestone Creek near Wetaskiwin

- 05FA024 – Weiller Creek near Wetaskiwin
- 05CD006 – Haynes Creek near Haynes

All data series used for the regional analysis are presented in **Appendix A**.

5 Flood Frequency Analysis

The objective of this task is to provide instantaneous peak discharge estimates for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750- and 1000-year open water floods, for the Battle River and Unnamed Tributary near Ponoka.

5.1 Methodology

The analysis was conducted using the USACE HEC-SSP (version 2.3) flood frequency program and a spreadsheet model developed by NHC. In accordance with the Hydrologic and Hydraulic Guidelines for Flood Hazard Area Delineation by AENV (2008), Guidelines on Flood Frequency Analysis by Alberta Transportation (AT, 2001), and Guidelines for Determining Flood Frequency by USGS (2018), various theoretical probability distributions were tested, including the normal (N), log-normal (LN), three parameter log-normal (LN3), Pearson type III (P3), log-Pearson type III (LP3), Gumbel (G), generalized extreme value (GEV), and Weibull (W) distributions. In accordance with AT (2001), the method of moments was used in the calculation of means, variances, and skew coefficients with theoretical limits being considered. The Cunnane plotting position formula was used to plot data points for visualization purposes. An analysis following the Guidelines for Determining Flood Frequency – Bulletin 17C (USGS, 2018) was also performed in this study.

The goodness of fit of each of the distributions, as applied to a flood series, was compared through the Kolmogorov–Smirnov test (K-S test). The K-S test can be used to compare a sample with a reference probability distribution. It quantifies a distance between the empirical probability of the sample and the cumulative distribution function of the reference distribution. The maximum distance (referenced to as D-statistic value, D_n) can be used to describe the goodness of fit, where a smaller D_n value would indicate a better fit between the empirical distribution and the theoretical one.

The goodness of fit was also evaluated with a least square method (Kite, 1977) is based on the sum of squared errors (*SSE*) calculated by:

$$SSE = \sqrt{\frac{1}{n-m}\sum_{i=1}^{n}(x_i - y_i)^2} \qquad \textbf{(Equation 1)}$$

where n is the number of recorded events, m is the number of parameters used by a frequency distribution, x_i is the i^{th} recorded peak discharge, and y_i is the discharge computed from the frequency distribution at the probability equal to the empirical probability of discharge x_i.

The *SSE* values of the tested probability distributions were then normalized by the mean peak discharge (Q_{pm}, the average of the annual peak discharges for each station) to provide a dimensionless

SSE. In this approach a lower dimensionless *SSE* would indicate a better fit between the empirical distribution and the theoretical one.

Each of these methods has their own advantages and disadvantages. The D_n value from the K-S test is defined as the maximum discrepancy between the predicted probabilities (for given flood peaks) by the frequency curve and empirical probabilities from the data sample, while the SSE value represents the average deviation of predicted flood peaks from the measured or estimated discharges.

In this study, the applied frequency distributions were ranked first by D_n and *SSE* values separately, and the sums of the rankings were then compared to derive the final combined ranking. Note, however, that using these statistical methods tends not to provide a foolproof assessment of the goodness of fit along the tails of the distributions, which are especially important in defining the return periods of the severe floods. Therefore, the selection of the best representative distribution is based as much on judgement and visual assessment as it is on the statistical ranking result.

5.2 Single Station Analysis for Battle River near Ponoka

A flood frequency analysis was first performed on the annual instantaneous peak discharges for Battle Rive near Ponoka shown in **Table 2**. As discussed in Section 4.1, the dataset consists of spring (snowmelt governing) and summer (rainfall governing) events. So, the derived flood frequency curve is a mixed-population frequency curve. A second flood frequency curve, combined-population frequency curve was also derived from two separate frequency curves, each developed from the spring or summer flood peak datasets listed in **Table 3**.

5.2.1 Mixed-population Flood Frequency Curve

Table 5 shows the ranking of the probability distributions based on D_n and *SSE* values for the annual instantaneous peak discharges for Battle River near Ponoka. Based on these statistical values, the LN and LP3 distributions are ranked the best in the combined ranking, followed by the LN3 and W distributions (which resulted in similar frequency curves as for LP3). The LN and LP3 distributions are compared in **Figure 5**. The other evaluated distributions are shown graphically in **Appendix B**.

Table 5: Mixed-population flood frequency curve goodness-of-fit comparison for Battle River near Ponoka

Distribution	D_n	Normalized *SSE* ($Q_{pm} = 45.1\ m^3/s$)	Rank by D_n	Rank by *SSE*	Combined Ranking
Normal(N)	0.219	0.823	9	9	9
Log-normal(LN)	0.102	0.342	2	1	1
Three parameter log-normal (LN3)	0.122	0.400	4	3	3
Pearson III (P3)	0.139	0.421	6	5	5
Log-Pearson III (LP3)	0.087	0.386	1	2	1
Gumbel (G)	0.219	0.604	8	8	8
Generalized extreme value (GEV)	0.154	0.437	7	6	7
Weibull (W)	0.122	0.405	3	4	3
Bulletin 17C	0.122	0.516	5	7	6

As shown in **Figure 5**, both the LN and LP3 curves fit the low-flow data points well, but they do not perform as well for return periods longer than 10 years. The LN curve fits the three largest events (1902, 1990 and 1948) better the LP3 curve and result in 100-year and 1000-year peak discharges 32% and 68% greater than those from the LP3 curve, respectively. However, the comparison is subject to the plotting positions for these events, which were determined from the total number of years (74) with available data. As discussed in Section 3.2, based on the available information from the AT bridge file #00278, these three events are likely the largest events over the 120-year period from 1902 to 2021. **Figure 5** shows the plotting positions for these three events based on the 120-year span of the record. Based on the adjusted plotting position, the return period for the 1902 flood event would be about 200 years, which appears more reasonable and in favor of selecting the LP3 curve over the LN curve. However, the LN curve is still better in fitting the second and third largest events. While the LN curve should probably be selected to represent the data series, it is difficult to determine which curve would provide more reasonable flood peak estimates for longer return periods. Another issue is that neither curve provides a good fit for mid-range floods. The April 1974 event was a large widespread spring flood that impacted a large portion of central Alberta. For many areas, this event was considered being close to a 100-year snowmelt flood. For the Battle River, the plotting position for this event corresponds to a 20-year return period in **Figure 5**. However, both the LN and LP3 curves would predict a return period of about 10 years for the 1974 flood peak discharge, which appears to be too short. These issues are likely due to that the annual flood peak data series is a mixed population with the three largest events being rainfall-governing (summer) events and the remainder consisting of more spring snowmelt events. As such, the combined-population frequency analysis approach from USACE (1982) was undertaken as described in the following section to check how segregation of the data series into spring and summer events would impact flood frequency estimates.

5.2.2 Combined-population Flood Frequency Curve

The combined frequency analysis approach from USACE (1982) involves development of separate flood frequency curves for spring (snowmelt governing) and summer (rainfall governing) floods and the resulting frequency curves are then used to compute a combined frequency curve based on the following equation (where *P* is the exceedance probability of a given discharge):

$$\boldsymbol{P_{combined} = P_{spring} + P_{summer} - P_{spring}P_{summer}} \qquad \textbf{(Equation 2)}$$

Separate food frequency analyses were performed on the spring and summer peak instantaneous discharge datasets for Battle River near Ponoka shown in **Table 3**.

For the spring floods, the P3 and Weibull curves were ranked the best based on the goodness-of-fit assessment described above, and they are nearly identical. So, the P3 curve was adopted for the spring floods for Battle River near Ponoka. As shown in **Figure 6**, the curve fits the data well. It suggests that the return period for the largest spring flood (1974) would be about 70 years.

For the summer floods, the LN and Weibull curves were ranked the best based on the goodness-of-fit assessment. The two curves are shown in **Figure 7**. The LN curve visually fit the data better. The Weibull curve appears to fit better the three largest events with the adjusted plotting positions that account for the span of the record (120 years); but overall, the LN curve fit all data points reasonably well. Note that both curves predict similar 100-year flood peak discharges, while the LN curve results in conservatively high discharges for longer return periods. As such, the LN curve was adopted for the summer floods.

Finally, a combined flood frequency curve was computed from the adopted P3 and LN frequency curves for the spring and summer floods based on Equation 2. The combined frequency curve is shown in **Figure 8** along with the annual flood peak data series (mixed population). The two top-ranked mixed-population frequency curves (LN and LP3) presented in the previous section are also shown in the figure for a comparison. The combined-population frequency curve provides an overall better fit for the annual flood peak data series. The process to develop this frequency curve is also more rigorous. As such, this combined-population frequency curve is recommended for Battle River near Ponoka.

The adopted flood frequency curve is shown in **Figure 9**. This combined-population flood frequency curve was computed from two separate frequency curves. Some of the currently available computational tools (e.g., HEC-SSP) could compute the 95% confidence limits for the combined population frequency curve using the order statistics method discussed by USACE (1997). This method cannot provide an acceptable accuracy for confidence limits at longer return periods. Some advanced methods such as bootstrapping could potentially provide better estimates; however, computational tools with these methods are not readily available. Therefore, the confidence limits for the adopted combined-population flood frequency curve are not provided in this study.

5.3 Regional Analysis for Unnamed Tributary

As discussed in Section 4.2, the regional flood frequency analysis for Unnamed Tributary in this study was based on the following gauge stations:

- 05FA012/05FA022 – Pipestone Creek near Wetaskiwin
- 05FA024 – Weiller Creek near Wetaskiwin
- 05CD006 – Haynes Creek near Haynes

Information for these regional stations is summarized in **Table 4,** and their locations are shown in **Figure 2**.

The annual peak instantaneous discharges (Q_p) for each of the selected regional stations were normalized by their mean value (Q_{pm}) and are plotted in **Figure 10** against their empirical return periods (or plotting positions) based on the Cunnane formula. The P3 distribution were found to provide the best fit for each individual regional station. As such, a normalized P3 curve was used to fit the normalized regional flow data. The normalized P3 curve shown in **Figure 10** was computed by varying the standard deviation and coefficient of skewness within the respective ranges of the values for the selected gauge stations until the sum of the *SSE* values (**Equation 1**) for the regional stations reached the minimum. As shown in the figure, the curve fits all data points reasonably well. **Figure 10** also shows the 95% confidence limits for the normalized P3 curve, which were estimated based on the average length of the regional flood data series (43 years).

Figure 11 shows the relationship between the mean annual peak discharges (Q_{pm}) and drainage areas for the selected regional stations. It shows that the peak discharge is proportional to drainage area to the power of 0.91. Using the normalized P3 curve from **Figure 10** and the relationship of mean peak discharge versus drainage area from **Figure 11**, flood frequency estimates was developed for Unnamed Tributary with its drainage area (23 km^2) as the input. The resulting flood frequency curve is shown in **Figure 12**.

6 Flood Frequency Estimates

Flood frequency estimates were provided for the 2-, 5-, 10-, 20-, 35, 50-, 75-, 100-, 200-, 350-, 500-, 750- and 1000-year open water floods, for Battle River near Ponoka and Unnamed Tributary at the mouth.

6.1 Battle River near Ponoka

The flood frequency estimates for Battle River near Ponoka (WSC Station 05FAD001) are presented in **Table 6**. They are based on the combined-population flood frequency curve derived from two separate frequency curves, each developed from the annual spring or summer peak discharge data for the period between 1902 and 2021.

Table 6: Flood frequency estimates for Battle River near Ponoka

Return Period (Years)	Annual Probability of Exceedance (%)	Peak Instantaneous Discharge (m^3/s)
1000	0.1	796
750	0.13	706
500	0.2	593
350	0.29	505
200	0.5	389
100	1	275
75	1.3	236
50	2	191
35	2.9	158
20	5	120
10	10	86.6
5	20	60.2
2	50	29.5

6.2 Unnamed Tributary

Table 7 shows the flood frequency estimates for Unnamed Tributary at the mouth. They were derived from the normalized P3 regional frequency curve based on an estimated mean annual peak discharge of 0.95 m^3/s for this 23 km^2 basin.

Table 7: Flood frequency estimates for Unnamed Tributary at the mouth

Return Period (Years)	Annual Probability of Exceedance (%)	Peak Instantaneous Discharge (m^3/s)	
		Value	95% Confidence Limit
1000	0.1	8.17	7.04 - 9.77
750	0.13	7.79	6.72 - 9.31
500	0.2	7.24	6.25 - 8.64
350	0.29	6.78	5.86 - 8.08
200	0.5	6.02	5.21 - 7.17
100	1	5.11	4.43 - 6.08
75	1.3	4.75	4.13 - 5.64
50	2	4.23	3.67 - 5.00
35	2.9	3.78	3.28 - 4.46
20	5	3.07	2.67 - 3.62
10	10	2.24	1.92 - 2.65
5	20	1.45	1.18 - 1.75
2	50	0.55	0.65 - 1.19

6.3 Comparison With Previous Studies

The flood frequency estimates for Battle River near Ponoka are compared with the estimates from the previous study (AEP, 1992) in **Table 8**. The estimated peak discharges from this study are significantly smaller than those from AEP (1992) except the 2-year values which are similar. The AEP (1992) estimates were from a LN frequency curve developed based on a flood discharge data series up to 1990, which is 30 years shorter than that used for this study. The shorter data series contained the same four largest food events as for the data series used in this study (1902, 1990, 1948 and 1974), and the return periods for these events were inherently underestimated. As such, the flood frequency estimates from AEP (1992) are too high and not representative of the current flood data series. Also, the previous study did not consider separating the spring and summer flood data and applying the combined-population frequency analysis approach.

Table 8: Comparison with previous flood frequency estimates for Battle River near Ponoka

Return Period (Years)	Peak Instantaneous Discharge (m^3/s)	
	This Study	AEP (1992)
100	275	452
50	191	331
20	120	207
10	86.6	137
5	60.2	83
2	29.5	31

7 Climate Change Commentary

This section provides a summary of a qualitative interpretation of climate and hydrologic projections obtained from the scientific literature that would be pertinent to evaluating future changes in flood hazards in the study area.

Current global climate models indicate that temperature will increase due to projected increases in CO_2 concentrations in the atmosphere. Increased temperatures in the winter months will likely result in smaller snowpacks, earlier snowmelt runoff, higher winter flows as more winter precipitation falls as rain instead of snow, and lower spring flows due to reduced snow storage.

While there are no investigations on potential impacts of climate change on flood hydrology specifically for the Battle River, some assessments the North Saskatchewan River basin are pertinent and summarized as follows.

Golder (2008) assessed potential changes in the water yield from the North Saskatchewan River basin in Alberta under forecasted future climatic conditions. Trend analyses across the basin suggested that there was an increasing trend in air temperature but the trends in monthly, seasonal and annual precipitation data were not statistically significant. The study forecasted air temperature, precipitation and water yield for the 2021 – 2050 period for twelve combinations of Global Climate Models (GCMs) and future development scenarios, and the results were compared to the conditions for the 1961 – 1990 baseline period. The forecasted air temperature was higher than the baseline by 0.3 – 2.2 °C while changes in mean annual precipitation ranged from an 8% decrease to an 19% increase, depending on the GCM-scenario combination. The predicted changes in annual yield varied from a 23% decrease to 15% increase. Increases in monthly yield tended to occur during the spring months. Most of the GCM-scenario combinations resulted in increases in yield for May, averaging 11% while varying from -3% to +28%; however, the changes in June varied from -26% to +31% with an average of -1.3%. The study did not evaluate changes in daily flows or flood peaks.

Poitras et al. (2011) investigated projected changes in average and extreme streamflows of ten major river basins across western Canada. The streamflows were derived from climate simulations performed with the fourth generation of the CRCM forced with the A2 emission scenario (an upper-mid range emission scenario representing a very heterogeneous world where economic development is regionally-oriented and economic growth and technological change are relatively slow). The comparisons were made between the 1961 – 1990 period and 2041 – 2070 period. Mean annual flows were projected to increase in all basins, with a 17% increase in the North Saskatchewan River basin. In future climate, snowmelt events in the basin were predicted to occur earlier and peak discharges were likely to increase by up to 20%.

According to DFO (2013), annual temperatures in the Prairies will increase for all seasons in the range of 0.8 – 5.4 °C, and winter temperatures will increase more than summer temperatures. Annual precipitation over large basins is projected to generally increase; however, projections are more uncertain for the Saskatchewan River basin as both an increase and a decrease have been predicted by different models. Higher precipitation is expected in winter compared to summer and the type of precipitation will change (e.g. more winter rain vs. snow). It is expected that there will be fewer precipitation events, but they will occur at higher intensity or as more extreme weather events. During the summer months, streamflow volumes in the Saskatchewan River basin could decrease by up to 50%.

While increases in spring flows are expected, the forecast becomes more complicated and inconclusive in some recent studies that considers ENSO effects such as Islam and Gan (2015). Moreover, while temperature has been generally increasing over the last 100 years, the trend of changes in annual peak discharge of many Canadian rivers to be different than the forecasted. Yue and Pilon (2003) performed trend analyses on annual minimum, mean, and maximum daily flows of streams with 30 to 50 years of gauge records in Canada, using the Mann-Kendall statistical test with a trend-free pre-whitening procedure. They noted that the annual maximum daily flow decreased across Canada south of latitude 60°N, however, a bootstrap test at the significance level of 0.05 showed this trend was insignificant. **Figure 13** illustrates a downward trend of the flood peak discharges for Battle River near Ponoka from 1902 to 2021, which is consistent with the assessment of Yue and Pilon (2003).

Overall, there is insufficient information to be able to identify all the linkages between precipitation and runoff to make any forecasts about how climate change might affect flood peaks for Battle River near Ponoka. Hydrologic modelling for the Battle River basin would be necessary to evaluate potential impacts of climate change on the flood risk in the study area, which is beyond the scope of this study.

8 REFERENCES

AENV (2008). Hydrologic and Hydraulic Guidelines for Flood Hazard Area Delineation. Alberta Environment, March 2008.

AEP (1992). Flood Frequency Analysis – Ponoka Floodplain Study. Alberta Environmental Protection, March 1992.

AT (2001). Guidelines on Flood Frequency Analysis. Alberta Transportation, April 2001.

Alberta Transportation (2006). Development of Runoff Depth Map for Alberta. September 2006.

DFO (2013). Risk-based Assessment of Climate Change Impacts and Risks on the Biological Systems and Infrastructure within Fisheries and Ocean Canada's mandate – Freshwater Large Aquatic Basin. DFO Canada, Science Advisory Secretariat, Science Response 2013/011, July 2013.

Golder (2008). Assessment of Climate Change Effects on Water Yield from the North Saskatchewan River Basin. Report submitted to North Saskatchewan Watershed Alliance, July 2008.

Islam, Z. and Gan, T.Y. (2015). Potential Combined Hydrologic Impacts of Climate Change and El Niño Southern Oscillation to South Saskatchewan River Basin. Journal of Hydrology, 523(2015), 34-48.

Kite, G.W. (1977). Frequency and Risk Analyses in Hydrology, Water Resources Publications, Colorado.

Poitras, V., Sushama, L., Seglenieks, F., Khaliq, M.N., and Soulis, E. (2011). Projected Changes to Streamflow Characteristics over Wester Canada as Simulated by the Canadian RCM. Journal of Hydrometeorology, 12, 1395-1413.

Yue, S. and Pilon, P. (2003). Canadian streamflow trend detection: impacts of serial and cross-correlation. *Hydrological Sciences Journal*, 48(1). February 2003.

USACE (1982). Mixed-population Frequency Analysis. US Army Corps of Engineers, Institute for Water Resources Hydrologic Engineering Center, Davis, CA, April 1982.

USACE (1997). Uncertainty Estimates for Nonanalytic Frequency Curves. US Army Corps of Engineers Technical Letter No. 1110-2-537, Washington, DC, October 1997.

USGS (2018). Guidelines for Determining Flood Flow Frequency – Bulletin 17C, U.S. Geological Survey, Reston, Virginia, 2018.

9 Closure

We trust that the information provided is sufficient for your current needs. Please feel free to contact the undersigned at (780) 436-5868 should you have any questions or require additional information.

DISCLAIMER

This document has been prepared by Northwest Hydraulic Consultants Ltd. in accordance with generally accepted engineering practices and is intended for the exclusive use and benefit of Alberta Environment and Protected Areas and their authorized representatives for specific application to the Alberta Environment and Protected Areas. The contents of this document are not to be relied upon or used, in whole or in part, by or for the benefit of others without specific written authorization from Northwest Hydraulic Consultants Ltd. No other warranty, expressed or implied, is made. Northwest Hydraulic Consultants Ltd. and its officers, directors, employees, and agents assume no responsibility for the reliance upon this document or any of its contents by any parties other than Alberta Environment and Protected Areas.

Sincerely,

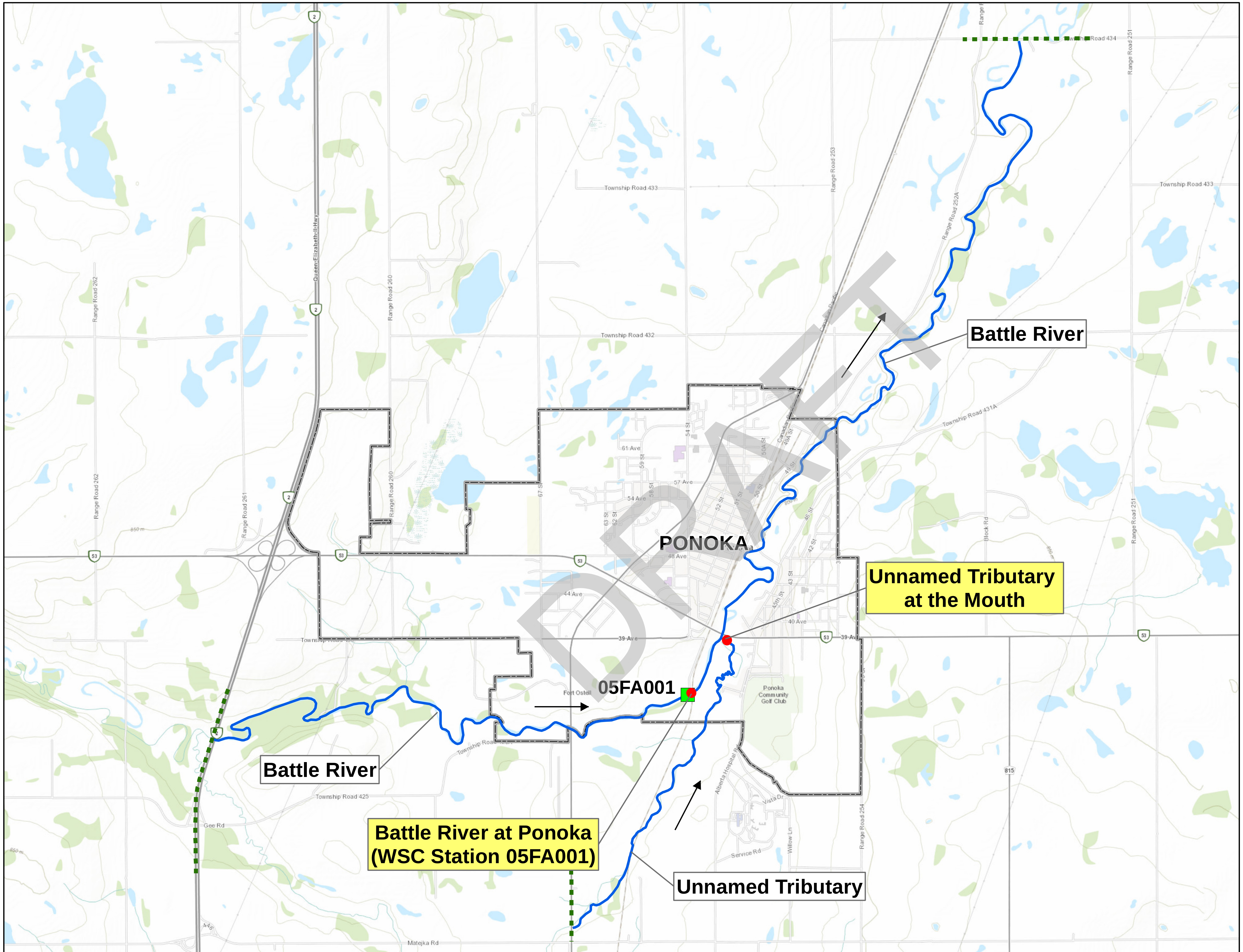
Northwest Hydraulic Consultants Ltd.

C.H. (Ken) Zhao, PhD, PEng
Principal

Reviewed by:

Dan Healy, PhD, PEng
Principal

Figures



Alberta Canada

nhc

FLOOD FREQUENCY ESTIMATE LOCATION
WSC STATION
STUDY LIMITS
STUDY REACH
TOWN

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:40,000
0 1 KM
N

Coordinate System: NAD 1983 CSRS 3TM 114
Units: METRES

Engineer	GIS	Reviewer
AMH	JY	KZ

Job Number	Date
1008017	24-MAR-2025

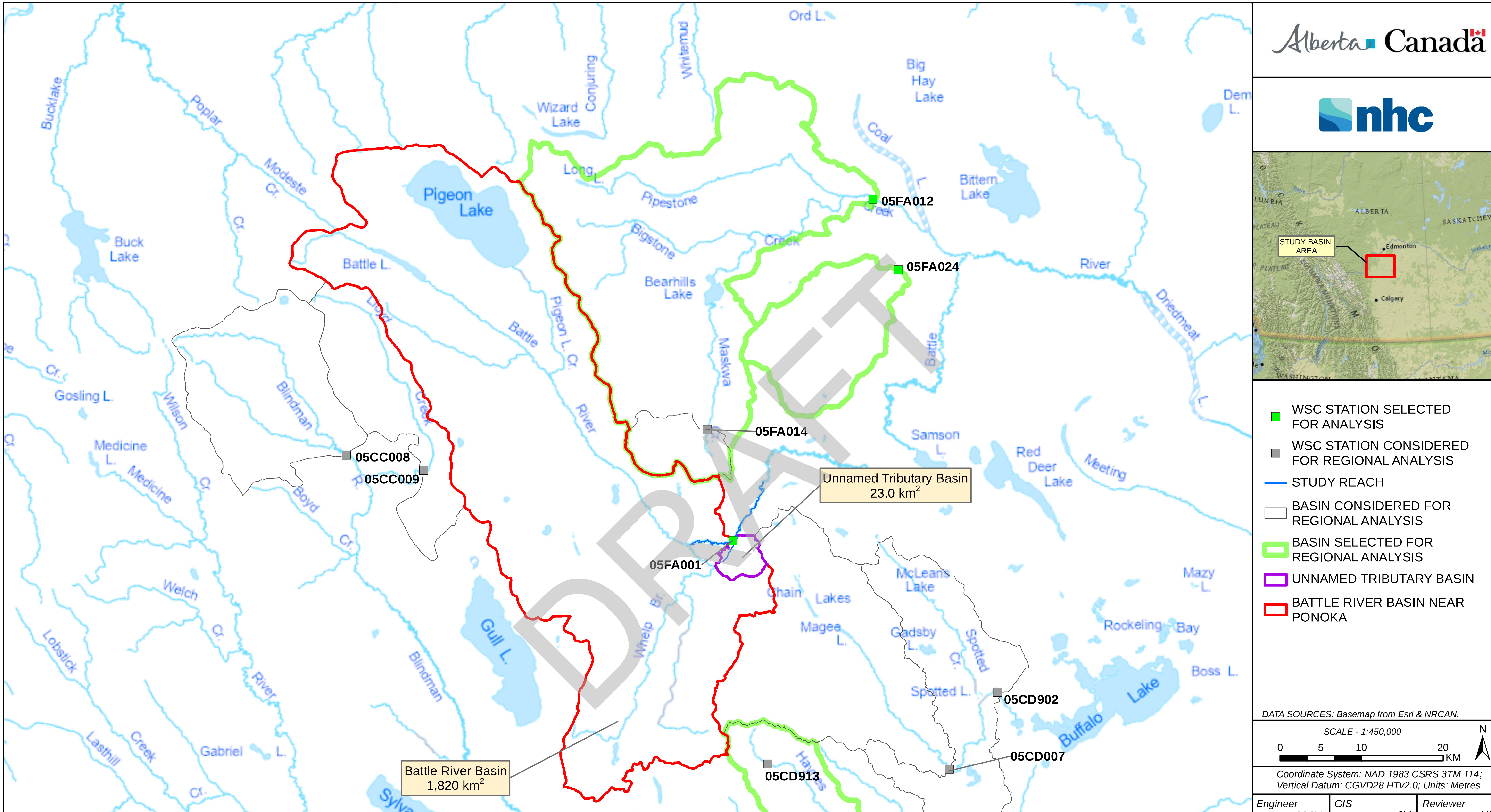
PONOKA FLOOD STUDY

FLOOD STUDY AREA AND FLOOD FREQUENCY ESTIMATE LOCATIONS

FIGURE 1

JY, P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\1008017 JY OWH FIG 01 Study Area and FF Estimate Locations.mxd

Classification: Public



WSC Station ID	Station Name	Gross Drainage Area (km^2)	Effective Drainage Area (km^2)	Period of Record	Length of Record (years)
05FA001	**Battle River near Ponoka**	1,820	1,550	1913-1930, 1967-2021	71
05FA012/05FA022	**Pipestone Creek near Wetaskiwin**	1,030	733	1972-1988, 1990-2014, 2016-2021	48
05FA014	Maskwa Creek No. 1 above Bearhills Lake	79	61.2	1972-1993, 1995-1997, 1991-2021	48
05FA024	**Weiller Creek near Wetaskinwin**	236	90.1	1985-1999, 2001-2022	37
05CD006	**Haynes Creek near Haynes**	165	165	1978-2022	42
05CD913	Haynes Creek near Joffre	24.4	24.4	1991-2001	11
05CD007	Parlby Creek at Alix	511	452	1983-2022	40
05CD902	Parlby Creek near Mirror	866	620	1981-2021	41
05CC008	Blindman River near Bluffton	353	353	1965-2014, 2016-2022	57
05CC009	Lloyd Creek near Bluffton	239	239	1965-2014, 2017-2022	56

Alberta Canada

nhc

WSC STATION SELECTED FOR ANALYSIS
WSC STATION CONSIDERED FOR REGIONAL ANALYSIS
STUDY REACH
BASIN CONSIDERED FOR REGIONAL ANALYSIS
BASIN SELECTED FOR REGIONAL ANALYSIS
UNNAMED TRIBUTARY BASIN
BATTLE RIVER BASIN NEAR PONOKA

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:450,000
0 5 10 20 KM
N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
AMH	JY	KZ

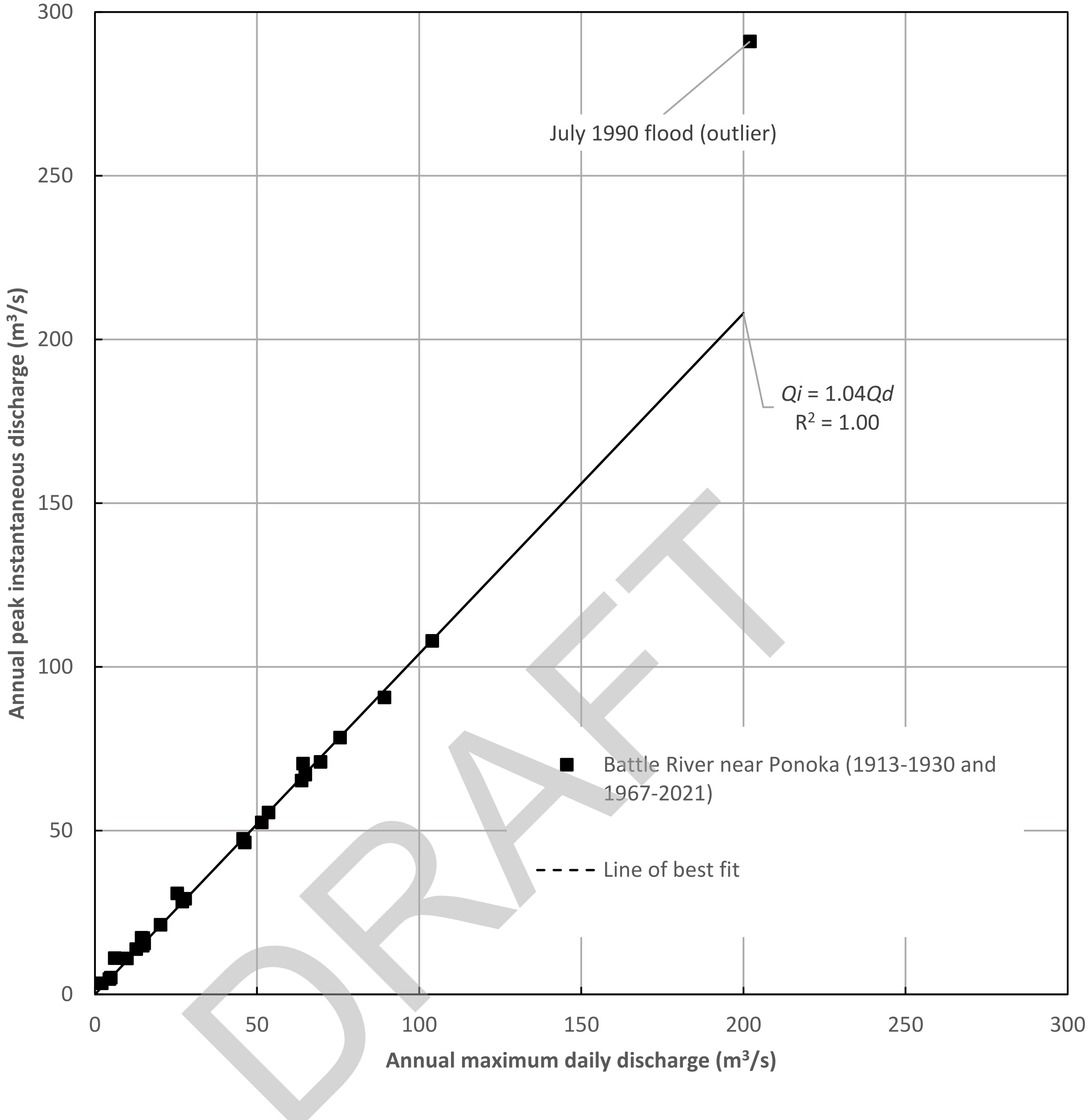
Job: 1008017 *Date: 24-MAR-2025*

PONOKA FLOOD STUDY

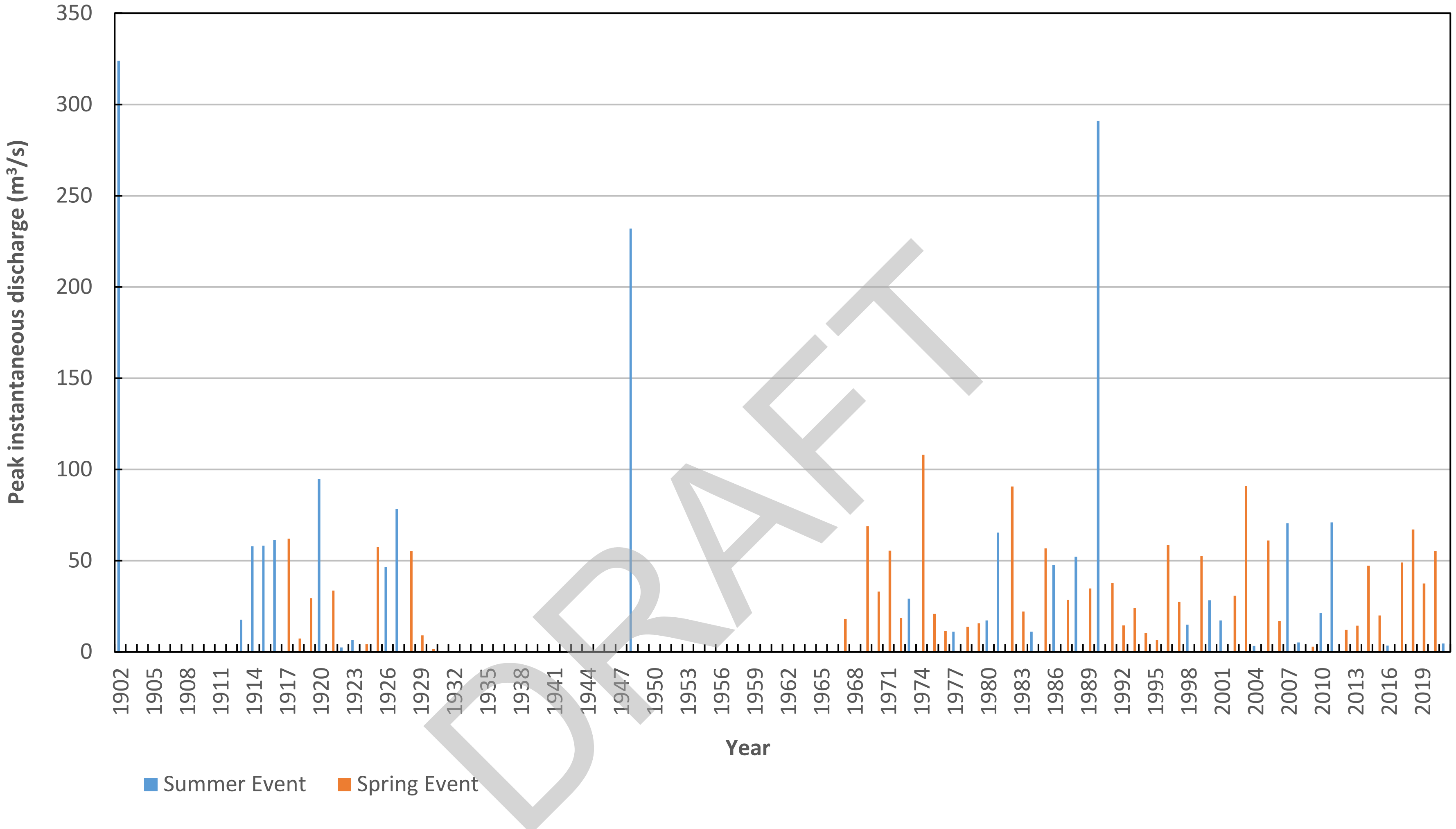
BASIN OVERVIEW

FIGURE 2

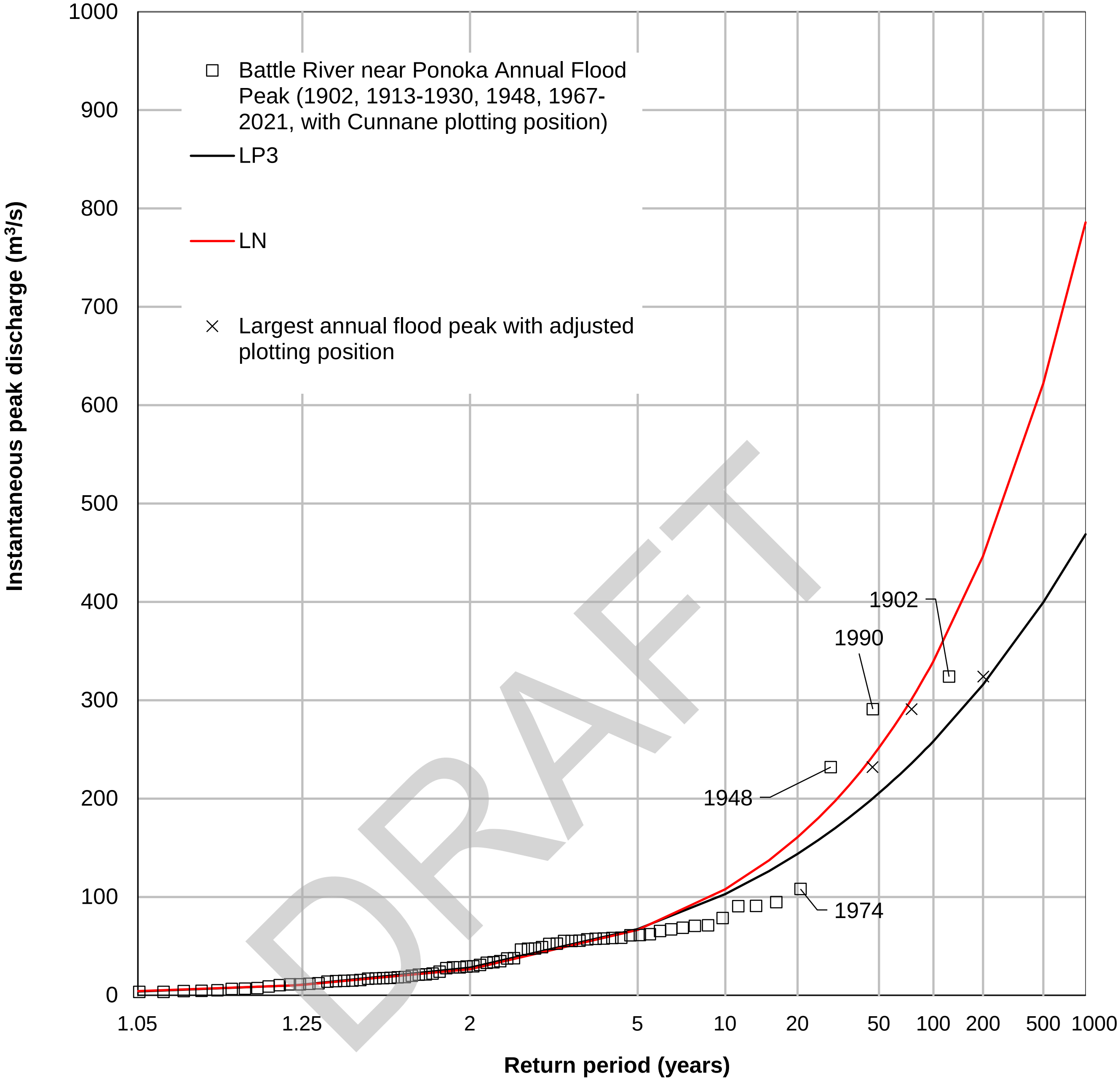
JY_P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\1008017_JY_OWH_FIG 02 Regional Analysis Basin Overview.mxd



Alberta / Canada / nhc	SCALE – AS SHOWN	PONOKA FLOOD STUDY OPEN WATER HYDROLOGY ASSESSMENT
	Coordinate System: Units: As Shown	***CORRELATION BETWEEN ANNUAL MAXIMUM DAILY AND INSTANTANEOUS DISCHARGES***
	Job: 1008017	*Date: 12-Aug-2022*
		FIGURE 3



Alberta / Canada / nhc	SCALE – AS SHOWN	PONOKA FLOOD STUDY OPEN WATER HYDROLOGY ASSESSMENT ***ANNUAL PEAK INSTANTANEOUS DISCHARGES FOR BATTLE RIVER NEAR PONOKA***
	Coordinate System: Units: As Shown	
	Job: 1008017 | *Date: 12-Aug-2023*	FIGURE 4



SCALE – AS SHOWN

Coordinate System:
Units: As Shown

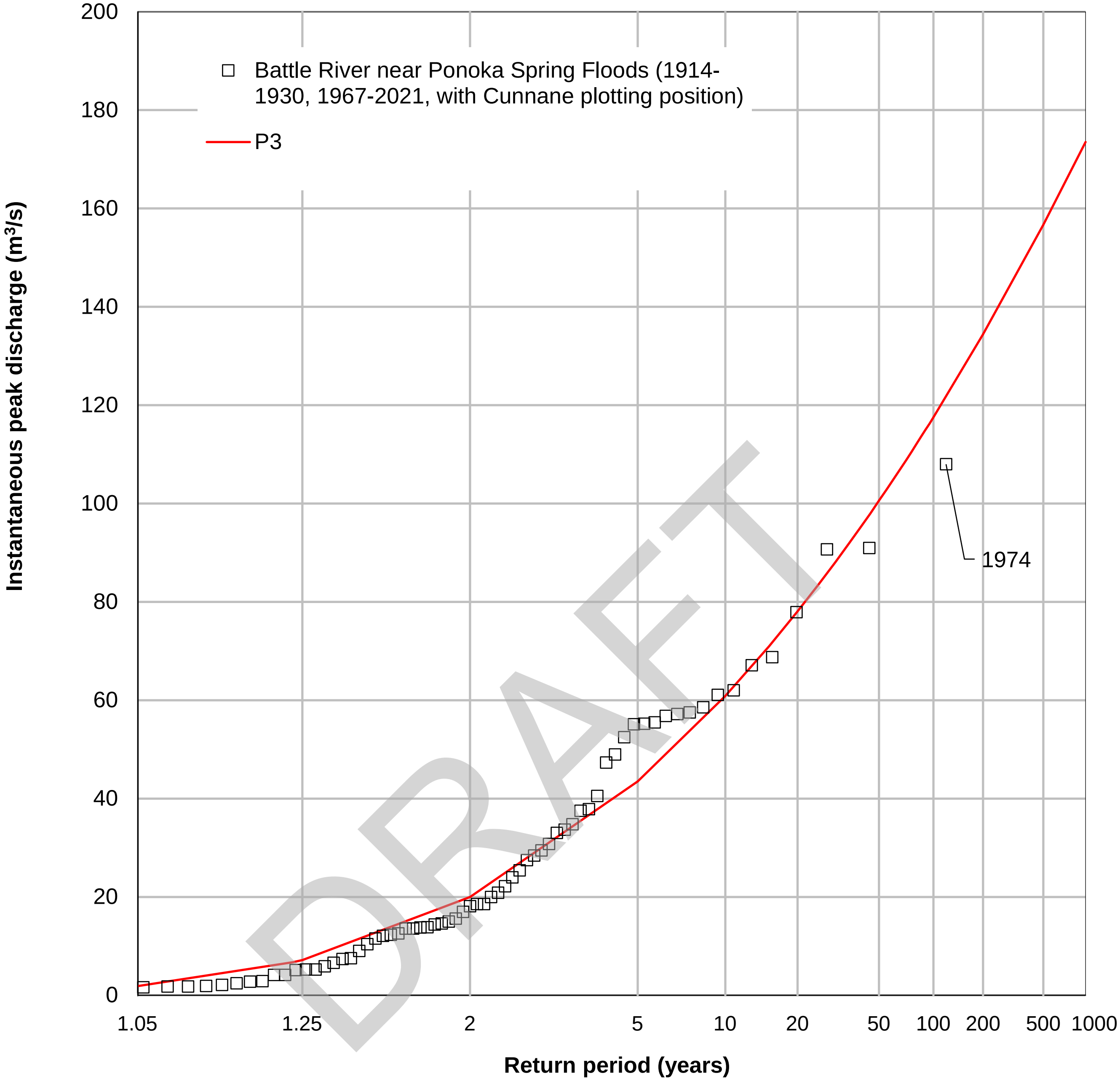
Job: 1008017

Date: 12-Aug-2022

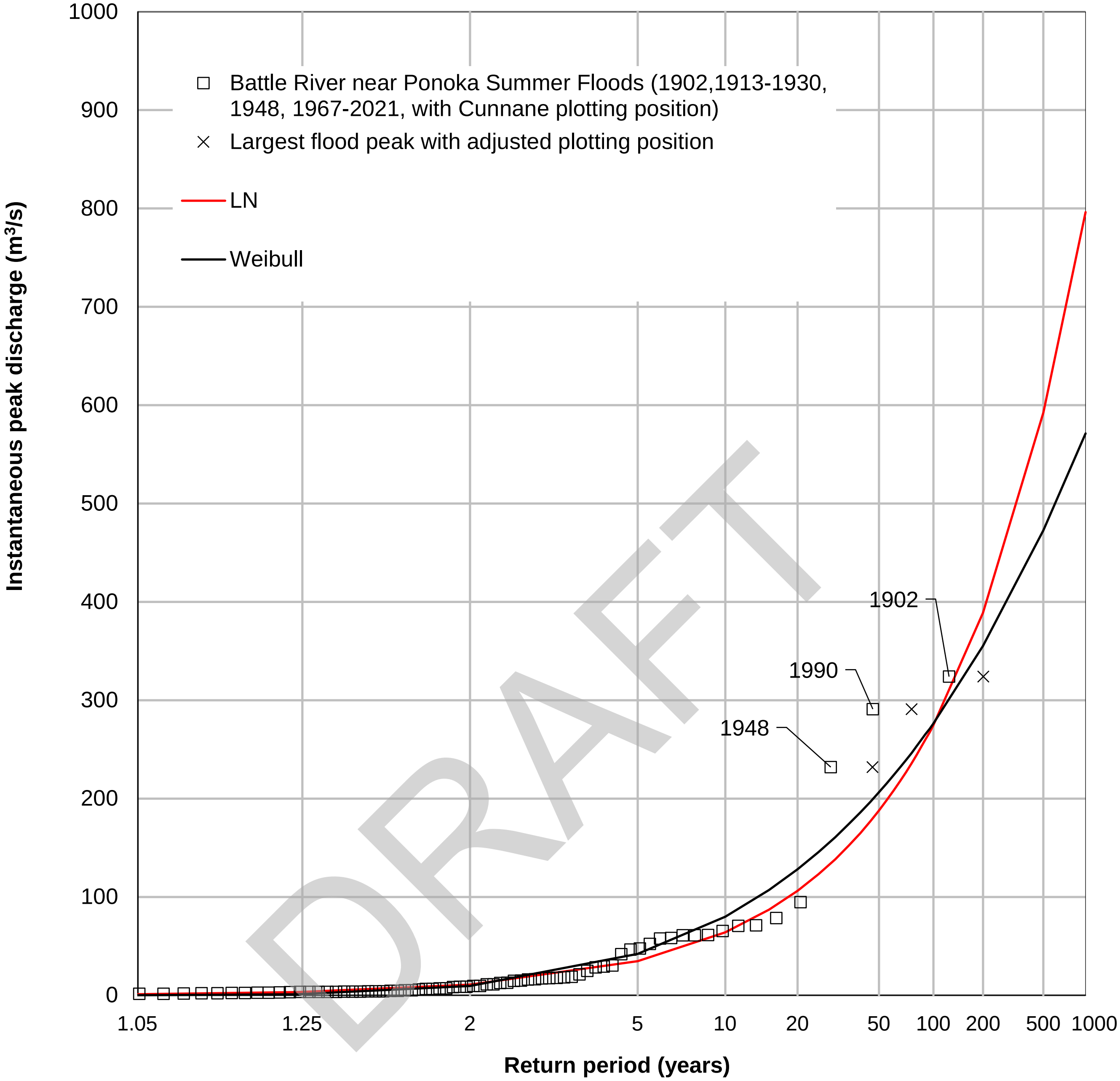
PONOKA FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

COMPARISON OF MIXED-POPULATION FLOOD FREQUENCY CURVES FOR BATTLE RIVER NEAR PONOKA

FIGURE 5



SCALE – AS SHOWN		PONOKA FLOOD STUDY OPEN WATER HYDROLOGY ASSESSMENT
Coordinate System: Units: As Shown		***ADOPTED SPRING FLOOD FREQUENCY CURVE FOR BATTLE RIVER NEAR PONOKA***
Job: 1008017	*Date: 12-Aug-2022*	FIGURE 6



SCALE – AS SHOWN

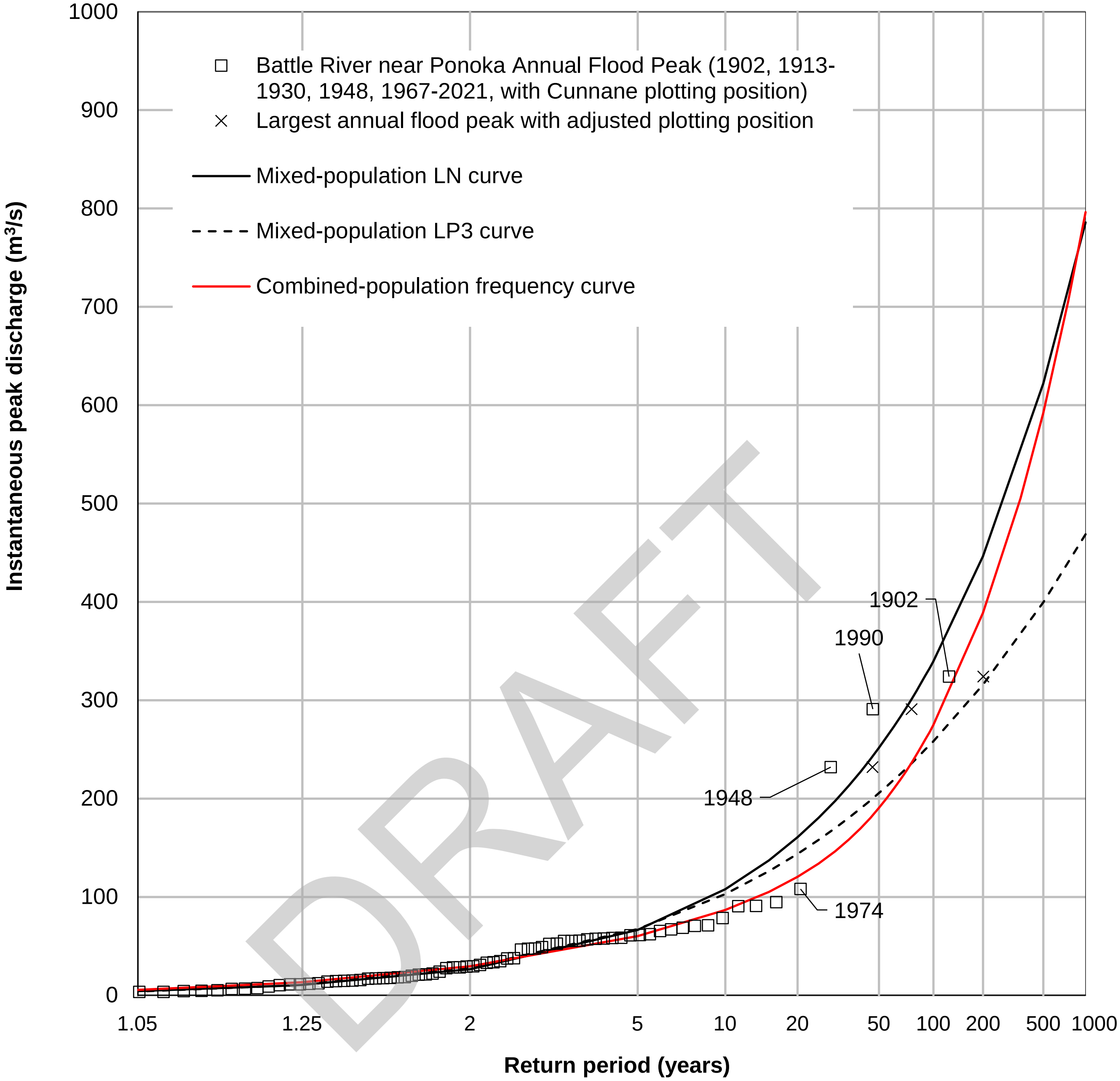
Coordinate System:
Units: As Shown

Job: 1008017 | *Date: 12-Aug-2022*

PONOKA FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

COMPARISON OF SUMMER FLOOD FREQUENCY CURVES FOR BATTLE RIVER NEAR PONOKA

FIGURE 7



SCALE – AS SHOWN

Coordinate System:
Units: As Shown

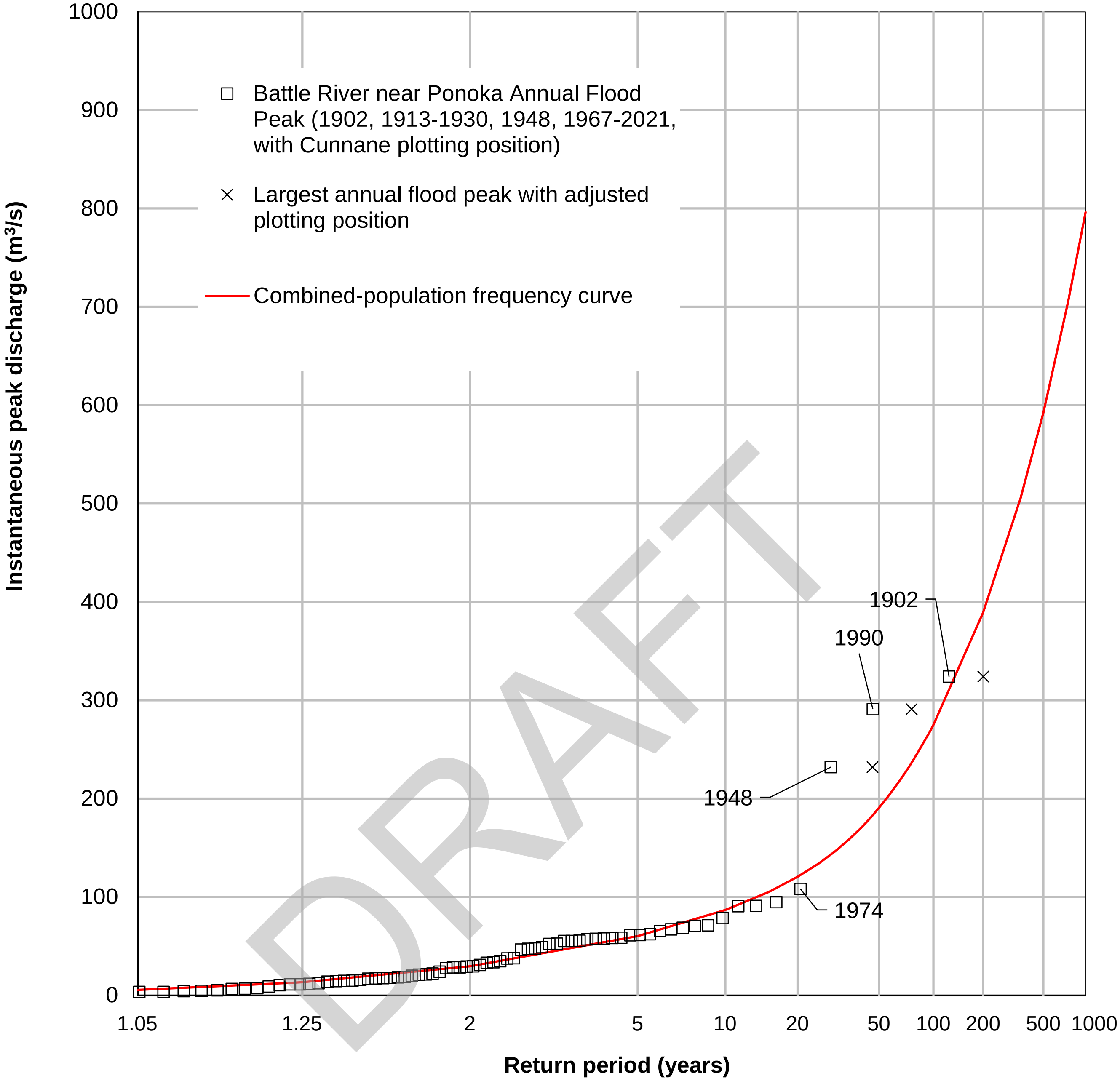
Job: 1008017

Date: 12-Aug-2022

PONOKA FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

COMPARISON OF COMBINED-POPULATION AND MIXED-POPULATION FLOOD FREQUENCY CURVES FOR BATTLE RIVER NEAR PONOKA

FIGURE 8



SCALE – AS SHOWN

Coordinate System:
Units: As Shown

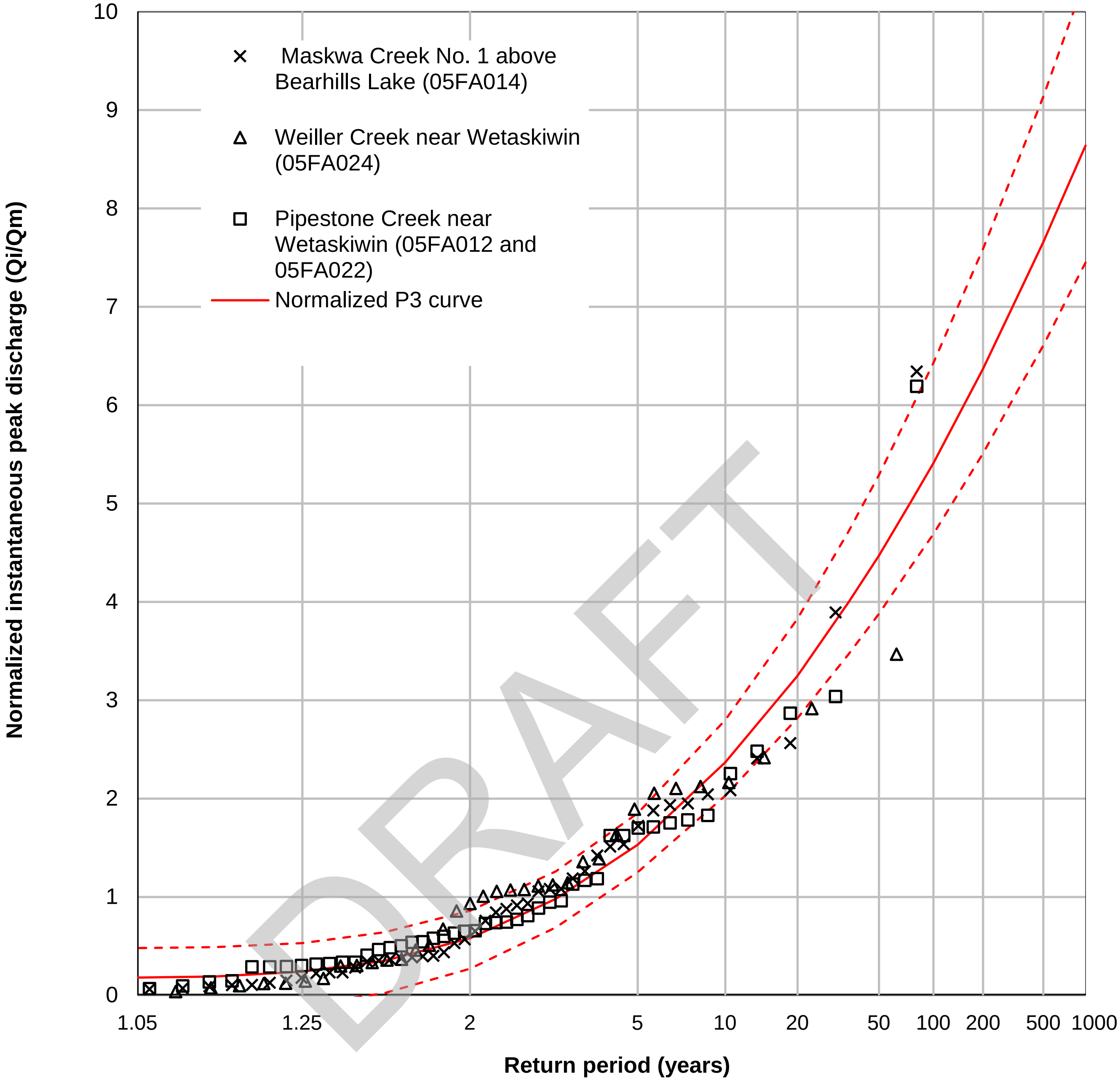
Job: 1008017

Date: 12-Aug-2022

PONOKA FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

ADOPTED FLOOD FREQUENCY CURVE FOR BATTLE RIVER NEAR PONOKA

FIGURE 9



SCALE – AS SHOWN

Coordinate System:
Units: As Shown

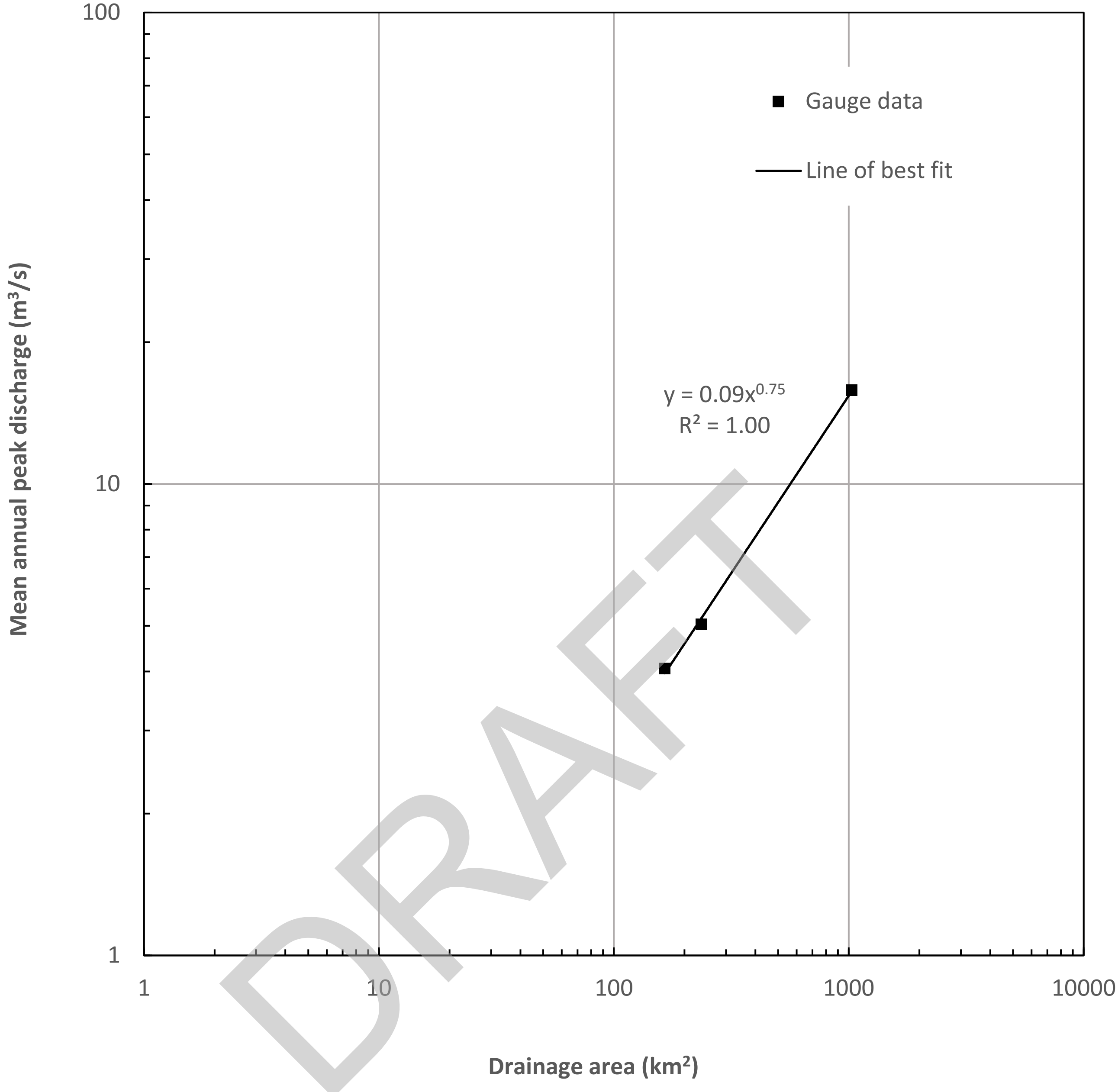
Job: 1008017

Date: 12-Aug-2022

PONOKA FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

NORMALIZED REGIONAL FLOOD FREQUENCY CURVE

FIGURE 10



SCALE – AS SHOWN

PONOKA FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

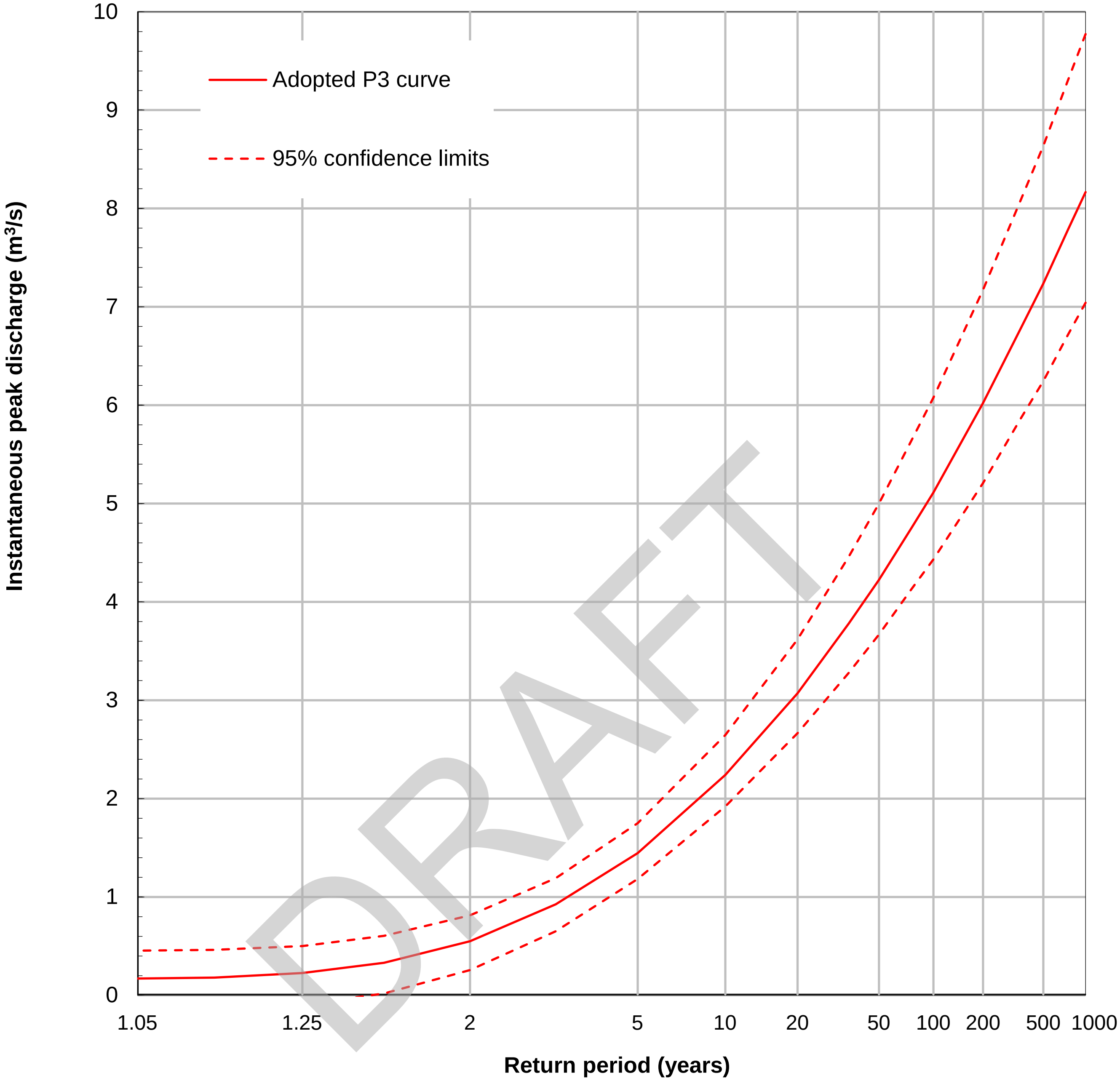
Coordinate System:
Units: As Shown

RELATIONSHIP BETWEEN MEAN ANNUAL PEAK DISCHARGE AND DRAINAGE AREA

Job: 1008017

Date: 12-Aug-2022

FIGURE 11



SCALE – AS SHOWN

Coordinate System:
Units: As Shown

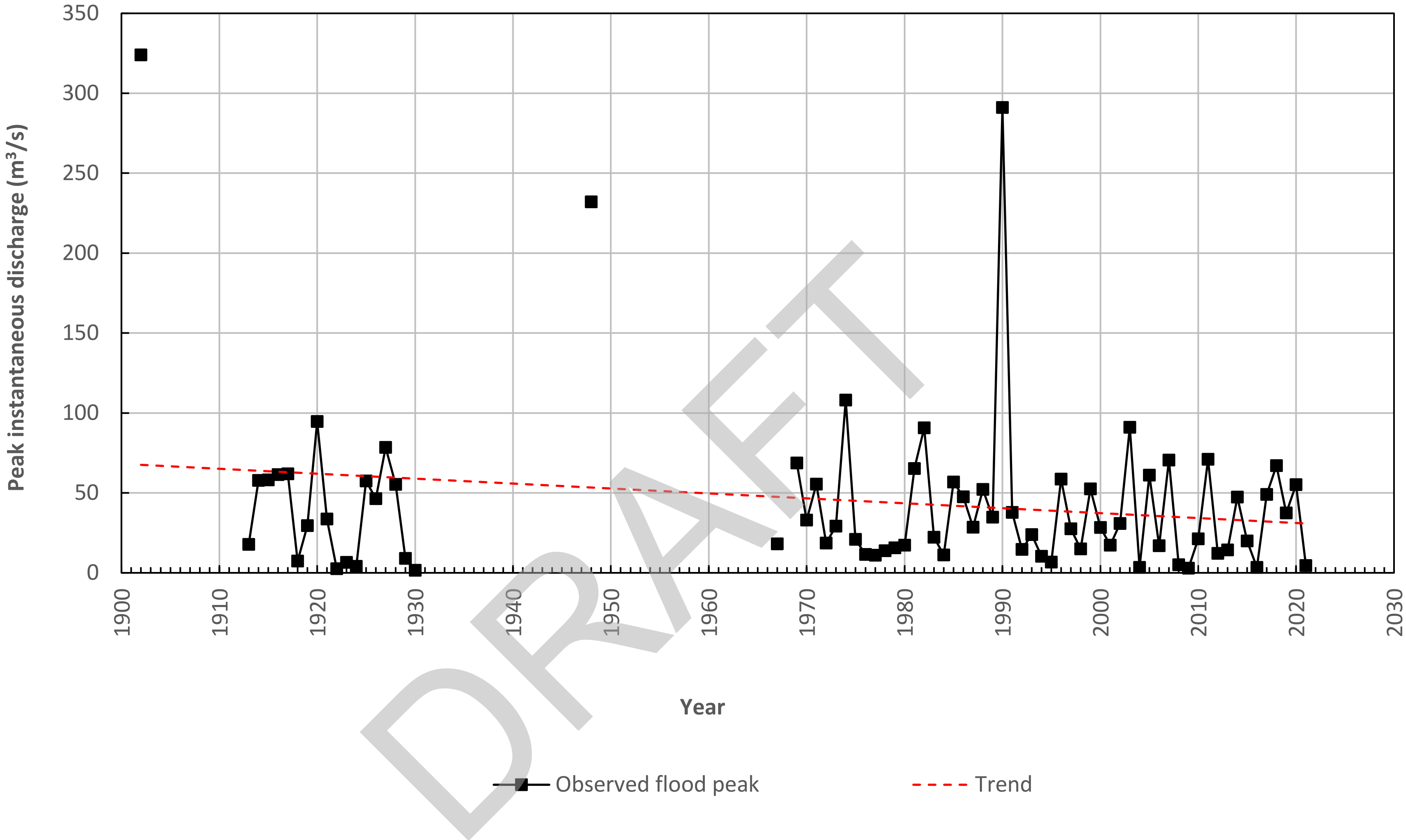
Job: 1008017

Date: 12-Aug-2022

PONOKA FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

ADOPTED FLOOD FREQUENCY CURVE FOR UNNAMED TRIBUTARY

FIGURE 12



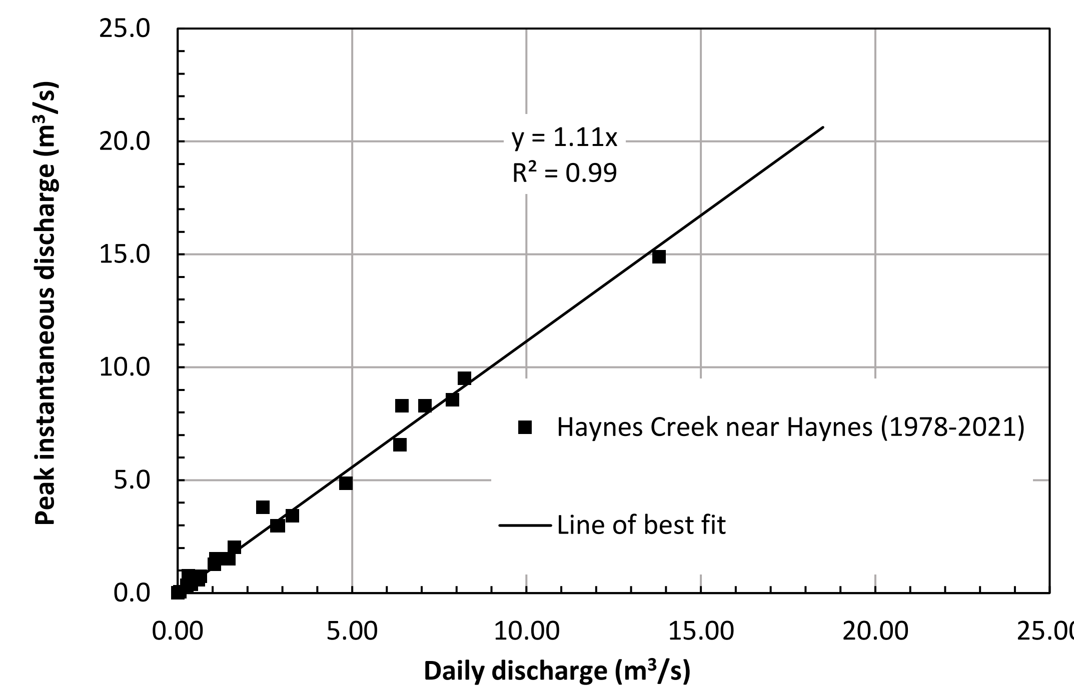
Alberta / Canada / nhc	SCALE – AS SHOWN	PONOKA FLOOD STUDY OPEN WATER HYDROLOGY ASSESSMENT ***TREND OF FLOOD PEAKS FOR BATTLE RIVER NEAR PONOKA***
	Coordinate System: Units: As Shown	
	Job: 1008017 / *Date: 12-Aug-2023*	FIGURE 13

Appendix A

Flow Data Used for Regional Analysis

Year	Peak Instantaneous Discharge (m^3/s)	Date	Peak Daily Discharge (m^3/s)	Date	Daily Discharge on Date of Peak Instantaneous Discharge (m^3/s)
1978	**0.03**		0.025	14-Sep	
1979	1.51	19-Mar	1.130	18-Mar	1.11
1980	**1.49**		1.340	08-Apr	
1981	0.75	17-Mar	0.650	17-Mar	
1982	6.56	18-Apr	6.370	18-Apr	
1983	1.27	07-Jul	1.050	07-Jul	
1984	0.76	02-May	0.316	03-May	0.28
1985	2.99	03-Apr	2.890	03-Apr	
1986	**1.40**		1.260	03-Mar	
1987	**4.91**		4.400	05-Apr	
1988	**0.13**		0.119	29-Jul	
1989	3.80	09-Apr	2.440	09-Apr	
1990	1.53	15-Jun	1.470	15-Jun	
1991	0.60	05-Apr	0.590	05-Apr	
1992	**2.33**		2.090	08-Mar	
1993	**1.61**		1.440	26-Mar	
1994	**1.56**		1.400	19-Mar	
1995	0.44	20-Mar	0.333	20-Mar	
1996	**20.63**		18.500	09-Apr	
1997	**4.60**		4.130	02-Apr	
1998	0.07	13-Jul	0.069	13-Jul	
1999	4.87	09-Apr	4.820	09-Apr	
2000	**1.57**		1.410	01-Apr	
2001	0.02	21-May	0.015	21-Jun	0.01
2002	2.02	23-Apr	1.630	24-Apr	1.63
2003	8.29	10-Apr	7.090	10-Apr	
2004	**0.01**		0.005	09-Jul	
2005	**3.90**		3.500	01-Apr	
2006	**4.31**		3.870	04-Apr	
2007	8.57	06-May	7.880	06-May	
2008	1.52	03-May	1.090	03-May	
2009	0.40	12-Apr	0.386	12-Apr	
2010	8.30	15-Jul	6.430	15-Jul	
2011	**15.16**		13.600	13-Apr	
2012	2.98	31-Mar	2.850	31-Mar	
2013	3.42	21-Apr	3.290	21-Apr	
2014	**9.53**		8.550	11-Apr	
2015	**0.81**		0.730	30-Mar	
2016	**0.38**		0.345	26-May	
2017	**6.20**		5.561	28-Mar	
2018	14.90	21-Apr	13.800	21-Apr	
2019	**4.76**		4.270	30-Mar	
2020	9.50	19-Apr	8.230	20-Apr	7.46
2021	0.36	24-May	0.267	24-May	

05CD006 – Haynes Creek near Haynes



Notes: 1. The bolded and underlined values are based on Qi=1.11Qd.
2. Data for 2017 are preliminary from WSC.

SCALE – AS SHOWN

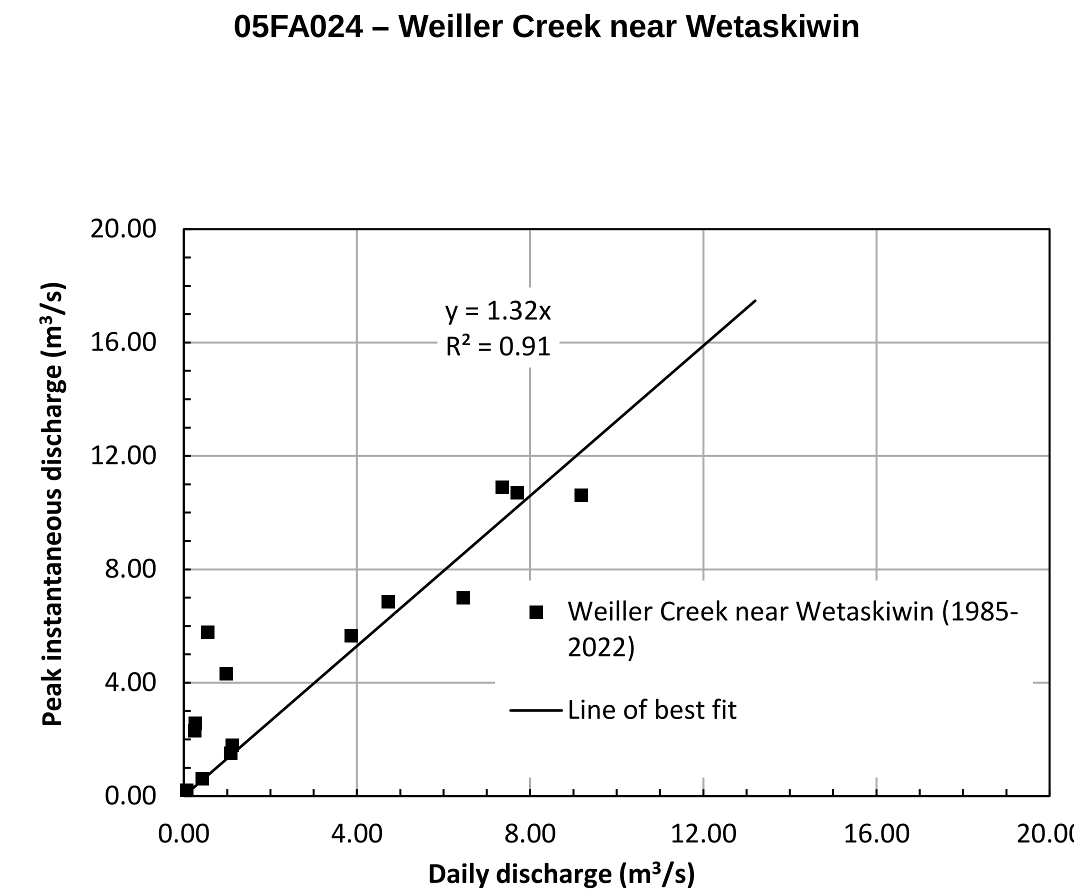
Coordinate System:
Units: As Shown

Job: 1008017 | Date: 20-OCT-2023

PONOKA FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT
Haynes Creek near Haynes
MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

Figure A-1

Year	Peak Instantaneous Discharge (m^3/s)	Date	Peak Daily Discharge (m^3/s)	Date	Daily Discharge on Date of Peak Instantaneous Discharge (m^3/s)
1985	6.99	20-Mar	6.46	19-Mar	3.93
1986	**4.70**		3.55	02-Mar	
1987	**0.62**		0.47	31-Mar	
1988	2.31	24-Oct	0.25	24-Oct	
1989	2.56	27-Oct	0.26	27-Oct	
1990	4.32	04-Jul	2.3	29-Mar	0.98
1991	**1.68**		1.27	30-Mar	
1992	**3.39**		2.56	21-Mar	
1993	**0.87**		0.66	27-Mar	
1994	**0.72**		0.54	21-Mar	
1995	0.60	19-Aug	0.43	19-Aug	
1996	**1.84**		1.39	08-Apr	
1997	**5.07**		3.83	13-Apr	
1998	1.52	06-Jul	1.11	29-Jun	1.09
1999	**9.53**		7.2	11-Apr	
2001	0.19	29-Jul	0.08	29-Jul	
2002	**1.50**		1.13	19-Apr	
2003	**5.60**		4.23	10-Apr	
2004	5.77	05-Jul	0.55	05-Jul	
2005	10.90	11-Mar	8.13	02-Apr	7.36
2006	**8.25**		6.23	06-Apr	
2007	10.70	05-May	7.71	05-May	
2008	**0.15**		0.11	30-Apr	
2009	**0.09**		0.07	09-Apr	
2010	6.85	23-Jul	4.72	23-Jul	
2011	10.60	16-Apr	9.19	16-Apr	
2012	1.80	16-Jul	1.12	16-Jul	
2013	5.65	25-Apr	3.87	25-Apr	
2014	**5.43**		4.10	11-Apr	
2015	**5.39**		4.07	28-Mar	
2016	**0.49**		0.37	16-Mar	
2017	**12.17**		9.19	28-Mar	
2018	**14.69**		11.10	19-Apr	
2019	**5.32**		4.02	29-Mar	
2020	**17.47**		13.20	18-Apr	
2021	**0.37**		0.28	19-May	
2022	**10.36**		7.83	24-Jun	



Notes: 1. The bolded and underlined values are based on Qi=1.32Qd.
2. Data for 2015, 2016, 2017, 2021, and 2022 are preliminary from WSC.

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

Job: 1008017 | Date: 20-OCT-2023

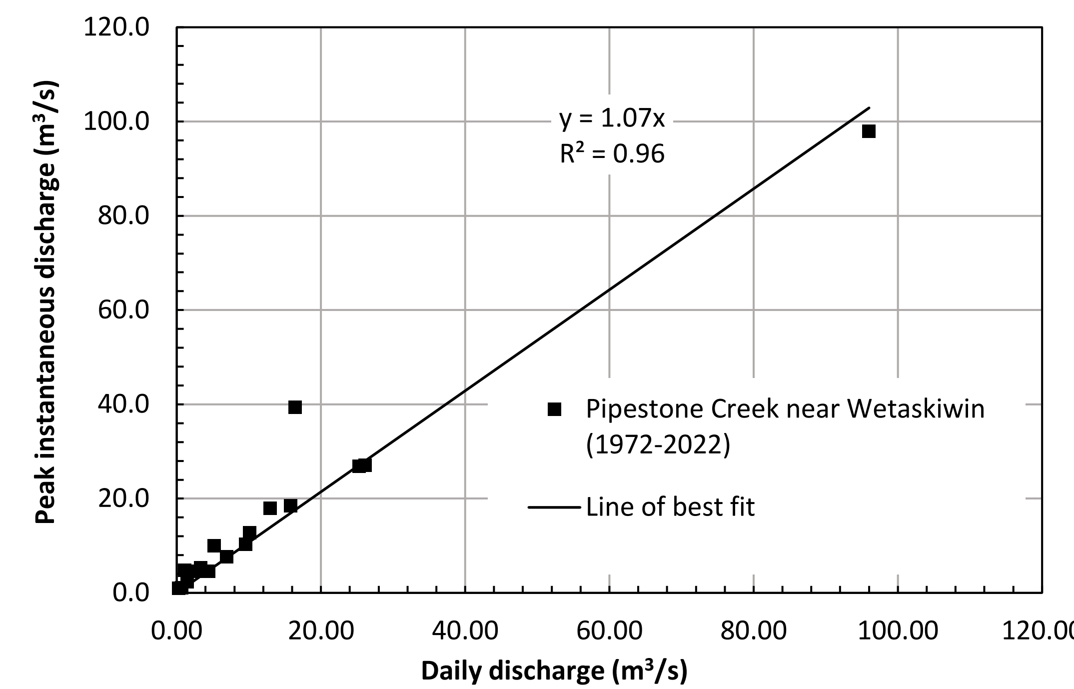
PONOKA FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

Haynes Creek near Haynes
MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

Figure A-2

Year	Peak Instantaneous Discharge (m^3/s)	Date	Peak Daily Discharge (m^3/s)	Date	Daily Discharge on Date of Peak Instantaneous Discharge (m^3/s)
1972	**15.22**		14.2	07-Apr	
1973	18.50	02-Jul	15.8	02-Jul	
1974	98.00	23-Apr	96	23-Apr	
1975	**9.50**		8.86	23-Apr	
1976	**5.32**		4.96	06-Apr	
1977	4.59	09-Aug	2.8	10-Aug	1.97
1978	5.32	29-Mar	3.37	29-Mar	
1979	12.80	20-Mar	10.1	20-Mar	
1980	11.7	05-Apr	10.2	06-Apr	9.79
1981	10.4	19-Mar	6.23	19-Mar	
1982	45.4	24-Apr	41.4	25-Apr	41.2
1983	15	08-Jul	14.8	08-Jul	
1984	5.09	01-Apr	3.96	01-Apr	
1985	28.2	03-Apr	23.2	03-Apr	
1986	**8.40**		7.85	02-Mar	
1987	**7.8**		7.29	08-Apr	
1988	1.48	06-Jul	0.926	06-Jul	
1989	**6.53**		6.1	11-Apr	
1990	48.1	07-Jul	45.5	07-Jul	
1991	39.30	06-Jul	16.4	06-Jul	
1992	**11.57**		10.8	22-Mar	
1993	**9.16**		8.55	28-Mar	
1994	**5.02**		4.68	30-Mar	
1996	**14.04**		13.1	10-Apr	
1997	**25.72**		24	13-Apr	
1998	17.90	05-Jul	13	06-Jul	10.40
1999	**25.72**		24	13-Apr	
2000	4.57	02-Jul	1.52	10-Jul	0.67
2001	1.06	29-Jul	0.687	01-Aug	0.58
2002	**6.43**		6	24-Apr	
2003	**11.79**		11	11-Apr	
2004	4.78	19-Jul	1.11	19-Jul	
2005	**18.75**		17.5	04-Apr	
2006	**8.52**		7.95	06-Apr	
2007	26.90	08-May	25.3	08-May	
2008	0.95	16-May	0.282	16-May	
2009	**0.23**		0.211	12-Apr	
2010	10.00	14-Jul	5.17	14-Jul	
2011	27.10	29-Jul	26.1	29-Jul	
2012	**2.15**		2.01	15-Apr	
2013	10.30	26-Apr	9.57	26-Apr	
2014	**28.94**		27	11-Apr	
2015	7.64	31-Mar	6.9	31-Mar	
2016	2.33	11-Jul	1.94	09-Oct	1.48
2017	**12.22**		11.4	30-Mar	
2018	**27.76**		25.9	21-Apr	
2019	**7.37**		6.88	29-Mar	
2020	**35.69**		33.3	19-Apr	
2021	4.64	20-May	4.43	20-May	

05FA012 – Pipeline Creek near Wetaskiwin



Notes:
1. The bolded and underlined values are based on Qi=1.07Qd.
2. Data for 2016 are preliminary from WSC.
3. The 1980-1990 data are from WSC Station 05FA022 (Pipestone Creek below Bigstone Creek)

Alberta
Canada
nhc

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

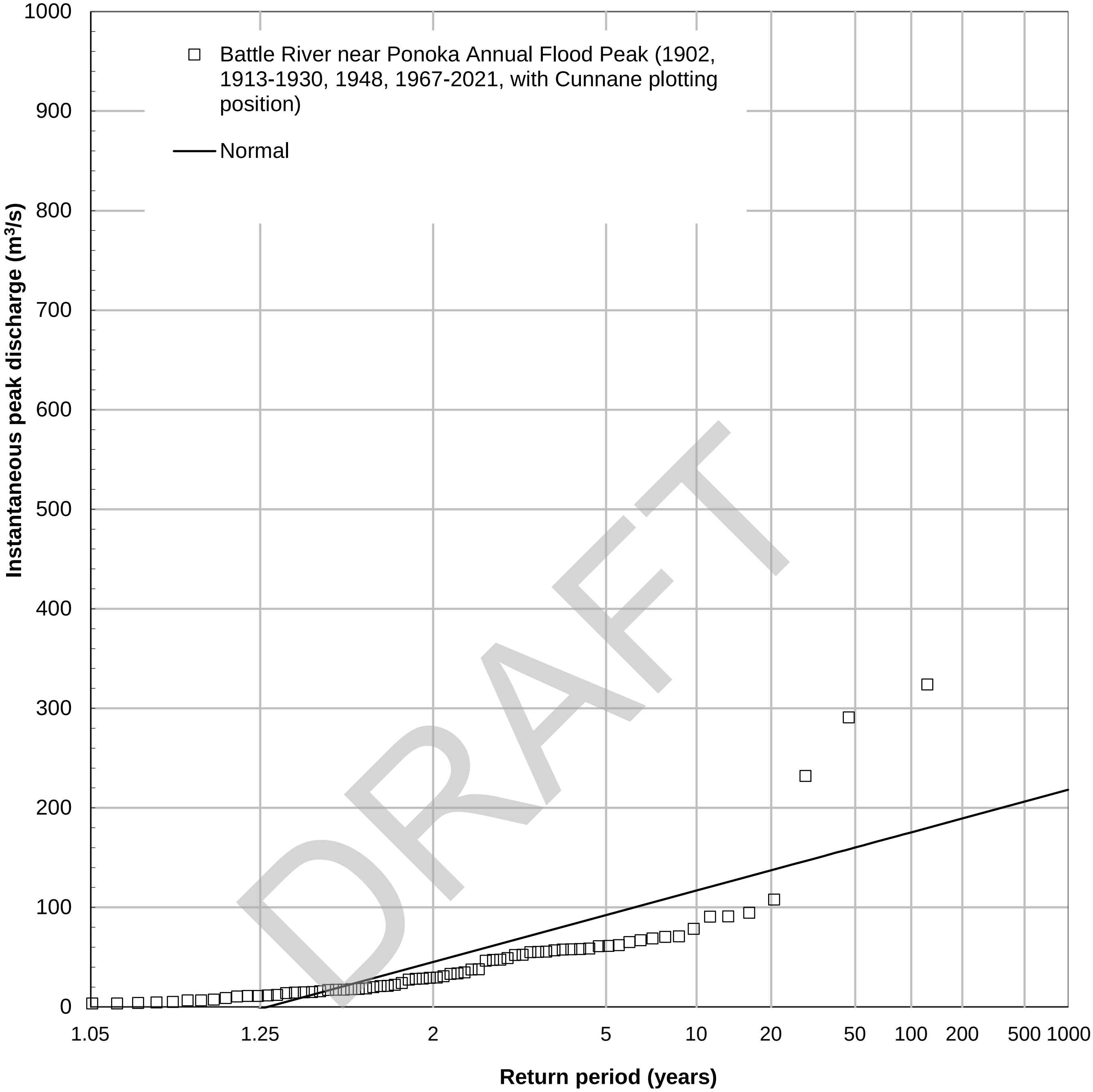
Job: 1008017 *Date: 20-OCT-2023*

PONOKA FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT
Pipestone Creek near Wetaskiwin
MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

Figure A-3

Appendix B

Additional Evaluated Frequency Distributions



SCALE – AS SHOWN

Coordinate System:
Units: As Shown

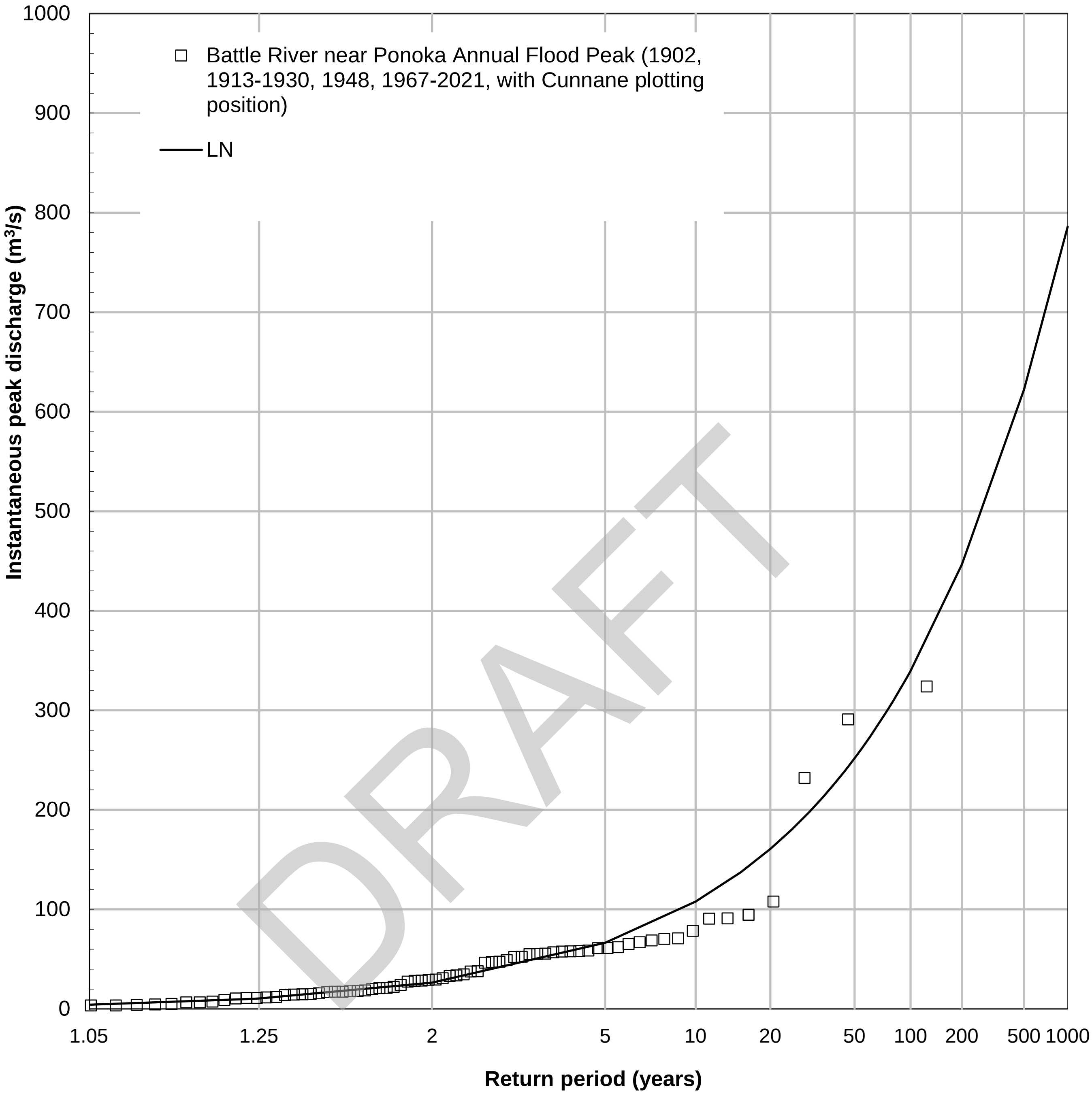
Job: 1008017

Date: 20-OCT-2023

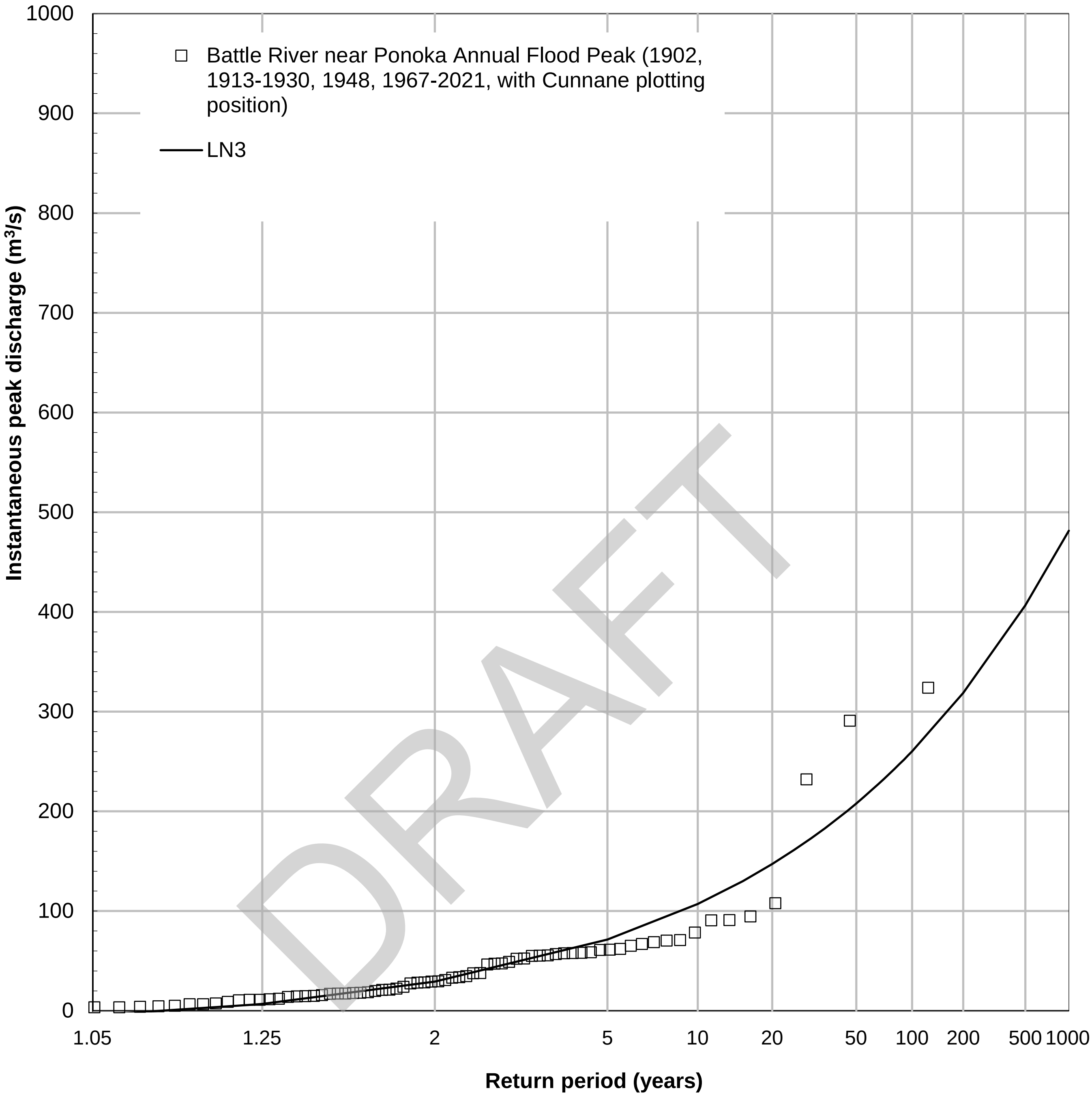
PONOKA FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

NORMAL FLOOD FREQUENCY CURVE FOR BATTLE RIVER AT PONOKA

FIGURE B-1



	SCALE – AS SHOWN	PONOKA FLOOD STUDY OPEN WATER HYDROLOGY ASSESSMENT
	Coordinate System: Units: As Shown	**LOG-NORMAL FLOOD FREQUENCY CURVE FOR BATTLE RIVER AT PONOKA**
	Job: 1008017 | *Date: 20-OCT-2023*	FIGURE B-2



SCALE – AS SHOWN

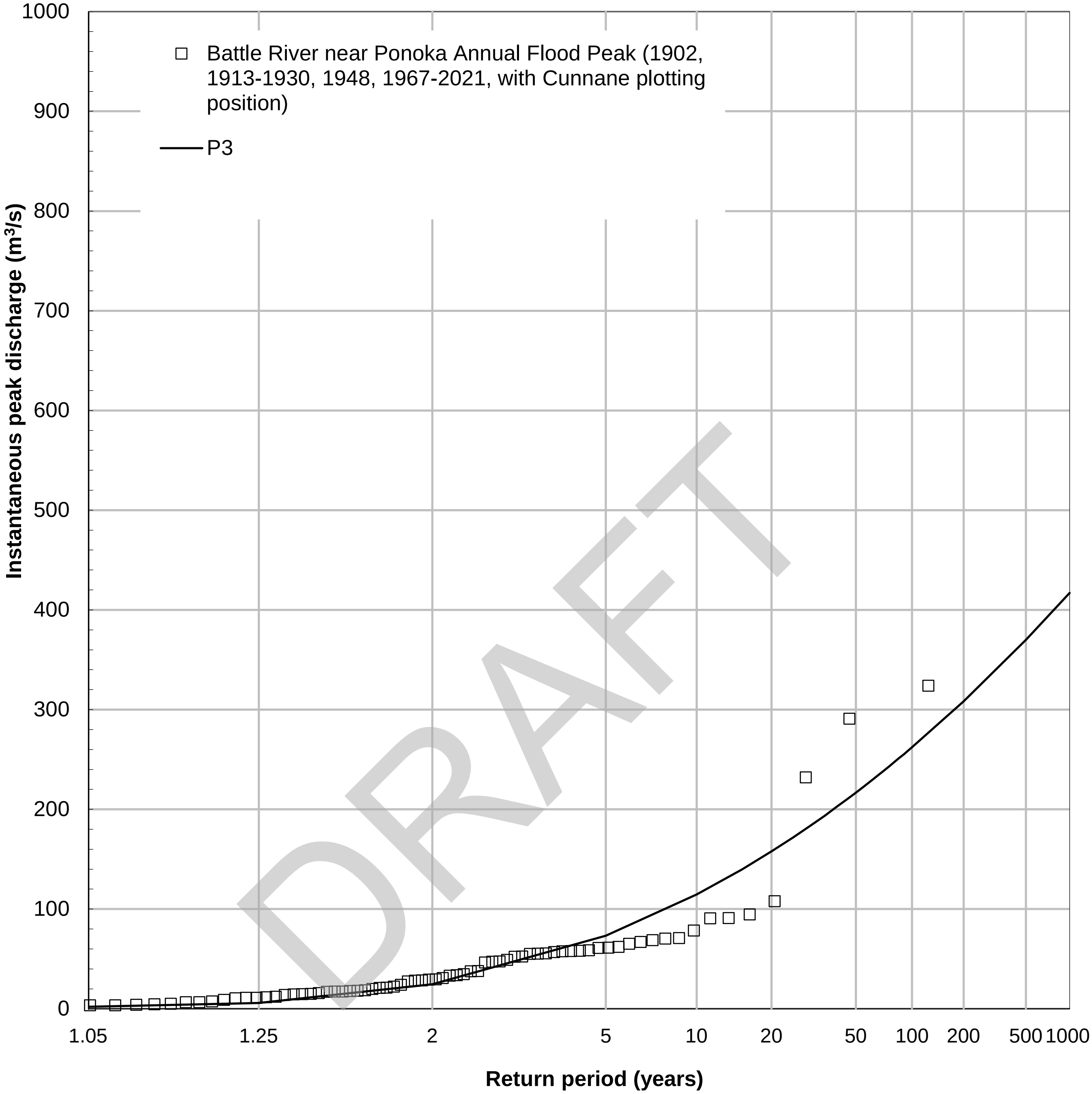
Coordinate System:
Units: As Shown

Job: 1008017 *Date: 20-OCT-2023*

PONOKA FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

THREE-PARAMETER LOG-NORMAL FLOOD FREQUENCY CURVE FOR BATTLE RIVER AT PONOKA

FIGURE B-3



SCALE – AS SHOWN

Coordinate System:
Units: As Shown

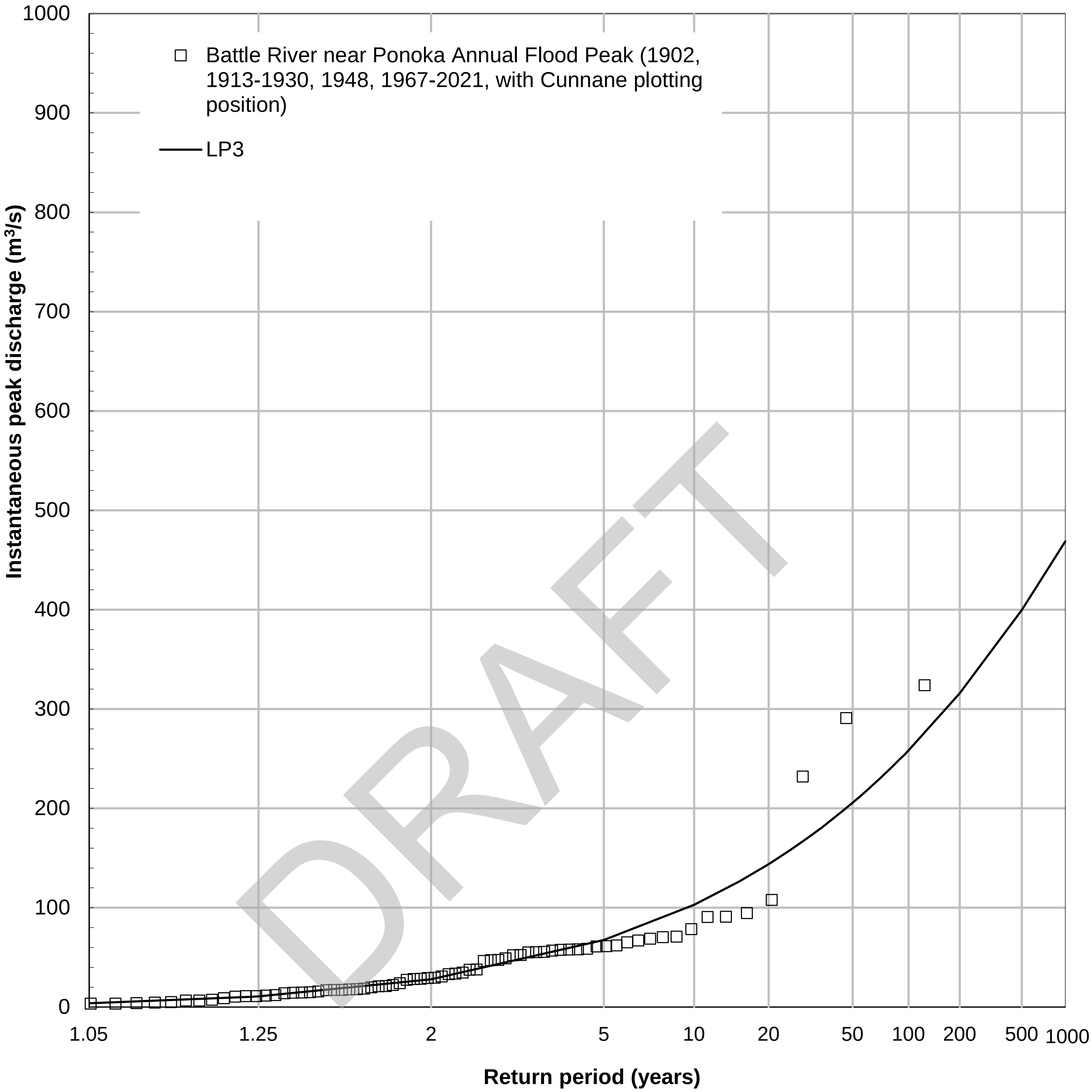
Job: 1008017

Date: 20-OCT-2023

PONOKA FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

PEARSON III FLOOD FREQUENCY CURVE FOR BATTLE RIVER AT PONOKA

FIGURE B-4



SCALE – AS SHOWN

Coordinate System:
Units: As Shown

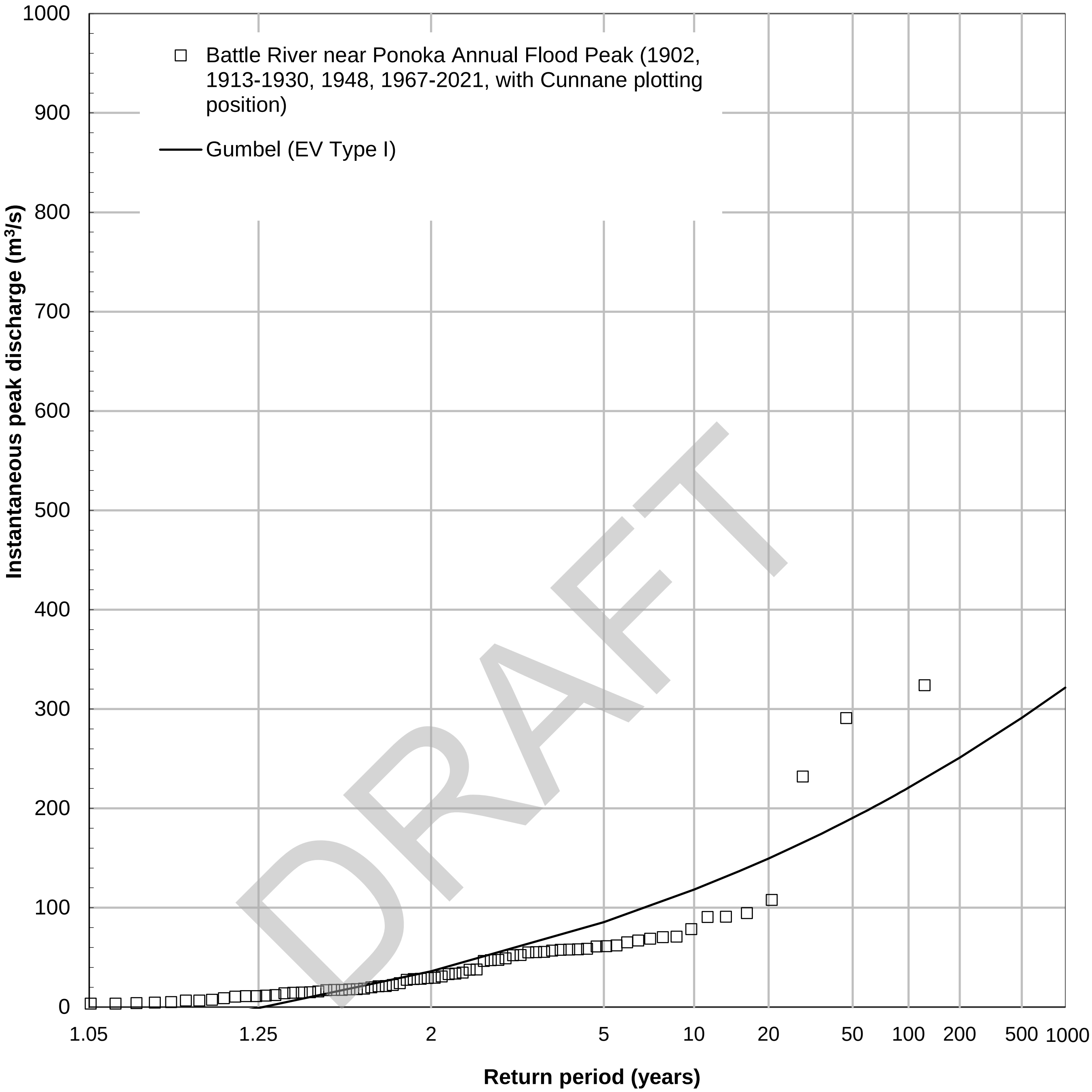
Job: 1008017

Date: 20-OCT-2023

PONOKA FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

LOG-PEARSON III FLOOD FREQUENCY CURVE FOR BATTLE RIVER AT PONOKA

FIGURE B-5



SCALE – AS SHOWN

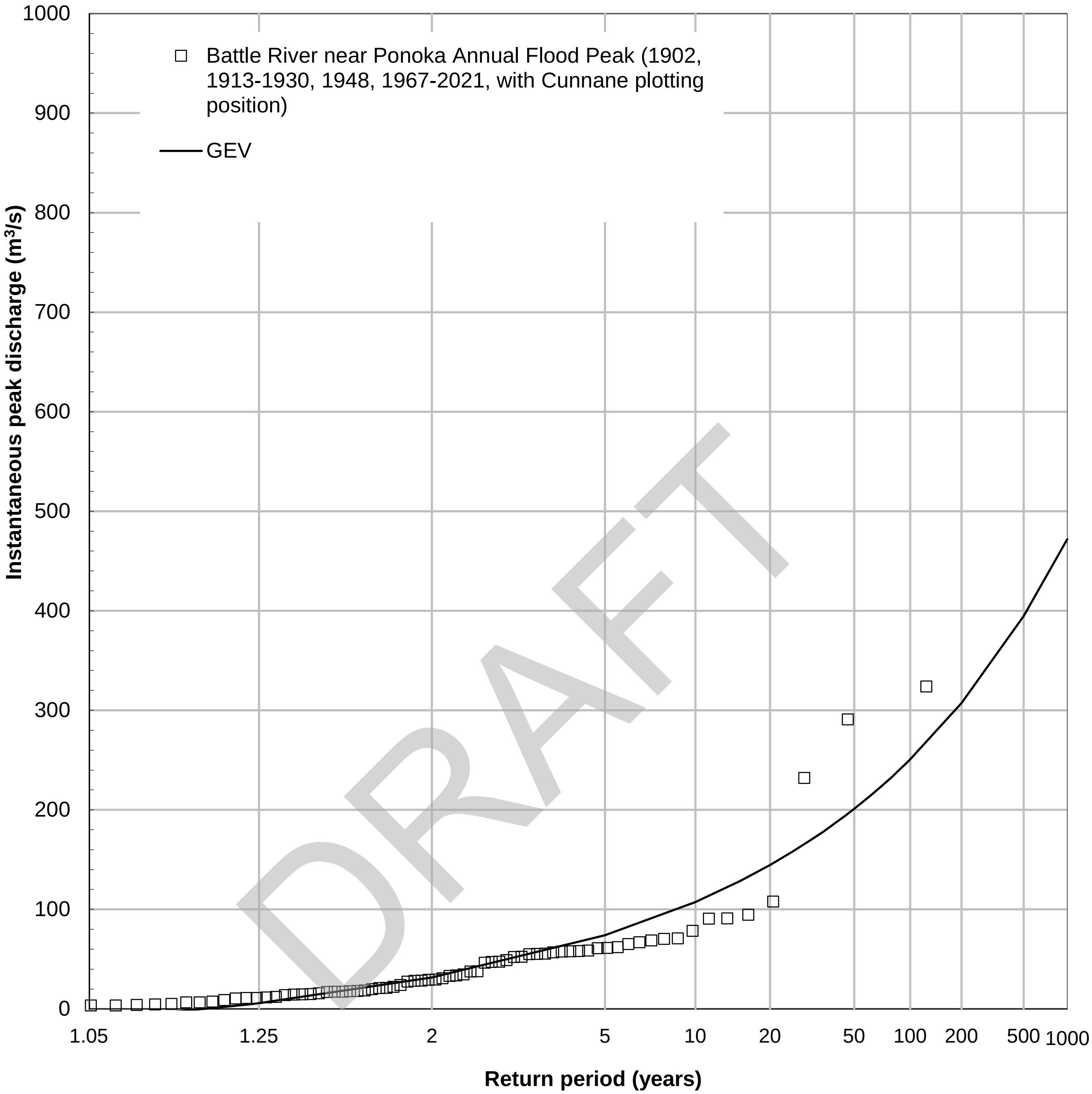
Coordinate System:
Units: As Shown

Job: 1008017 | *Date: 20-OCT-2023*

PONOKA FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

GUMBEL (EV TYPE I) FLOOD FREQUENCY CURVE FOR BATTLE RIVER AT PONOKA

FIGURE B-6



SCALE – AS SHOWN

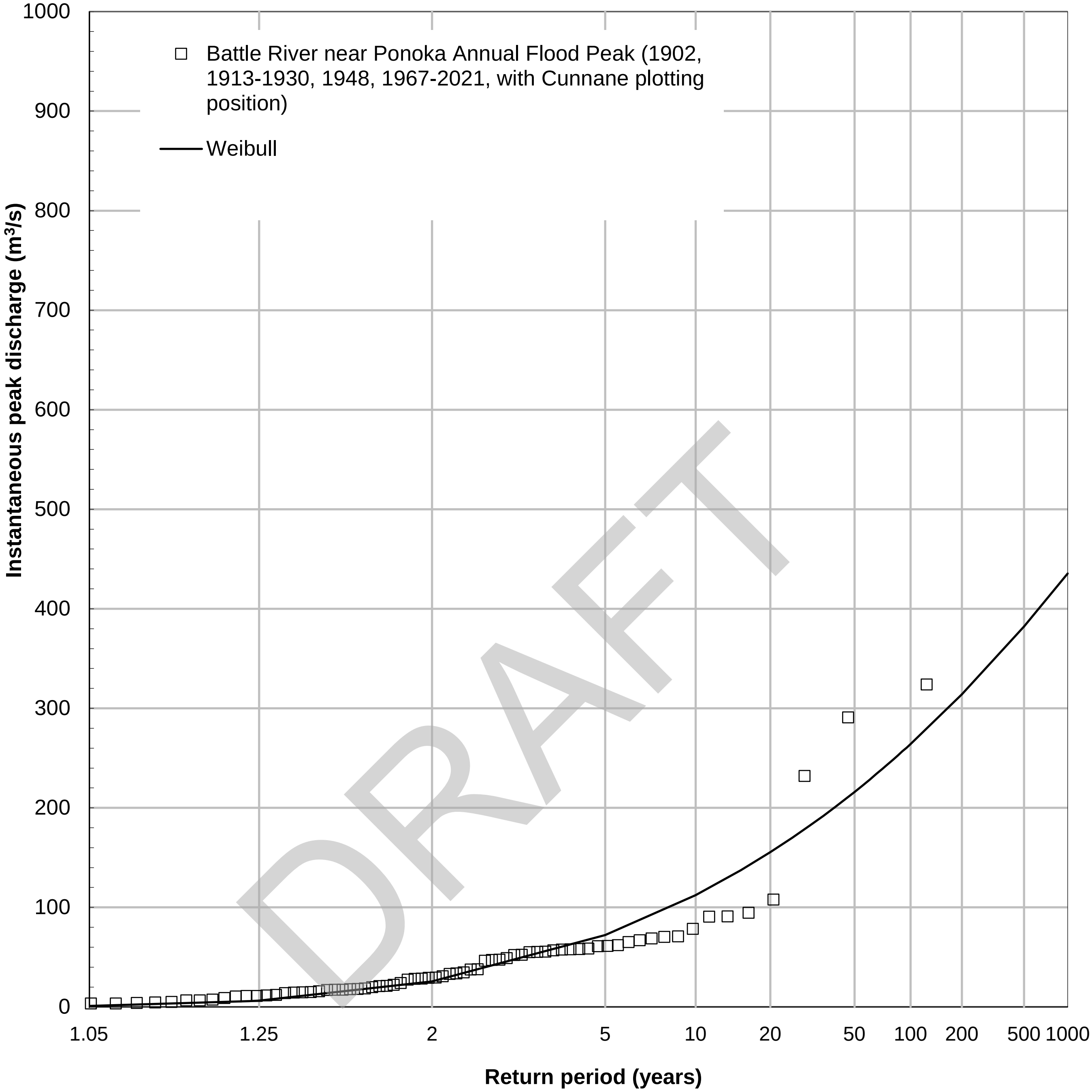
Coordinate System:
Units: As Shown

PONOKA FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

GENERALIZED EXTREME VALUE FLOOD FREQUENCY CURVE FOR BATTLE RIVER AT PONOKA

Job: 1008017 | *Date: 20-OCT-2023*

FIGURE B-7



SCALE – AS SHOWN

Coordinate System:
Units: As Shown

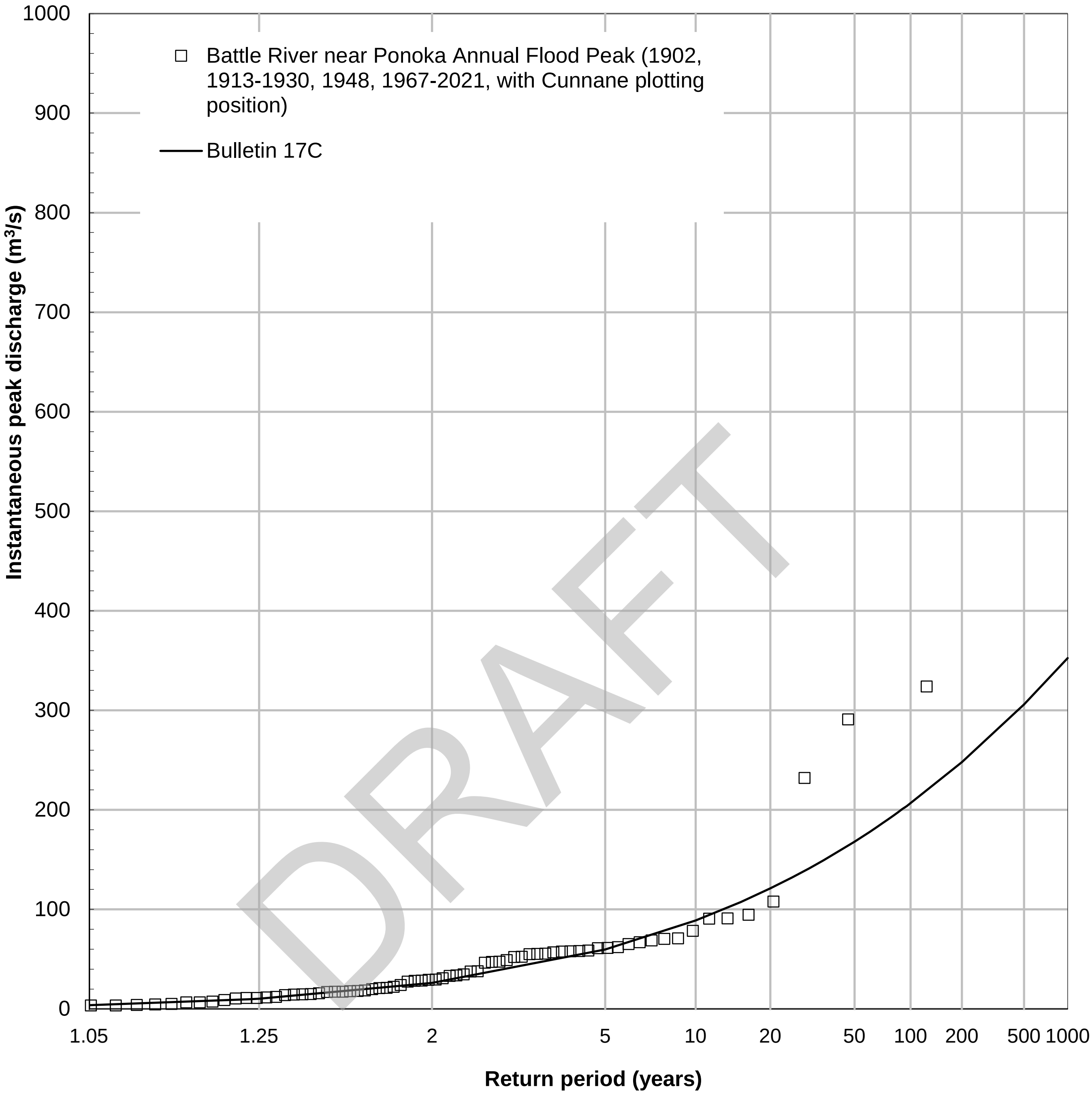
Job: 1008017

Date: 20-OCT-2023

PONOKA FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

WEIBULL FLOOD FREQUENCY CURVE FOR BATTLE RIVER AT PONOKA

FIGURE B-8



SCALE – AS SHOWN

Coordinate System:
Units: As Shown

Job: 1008017

Date: 20-OCT-2023

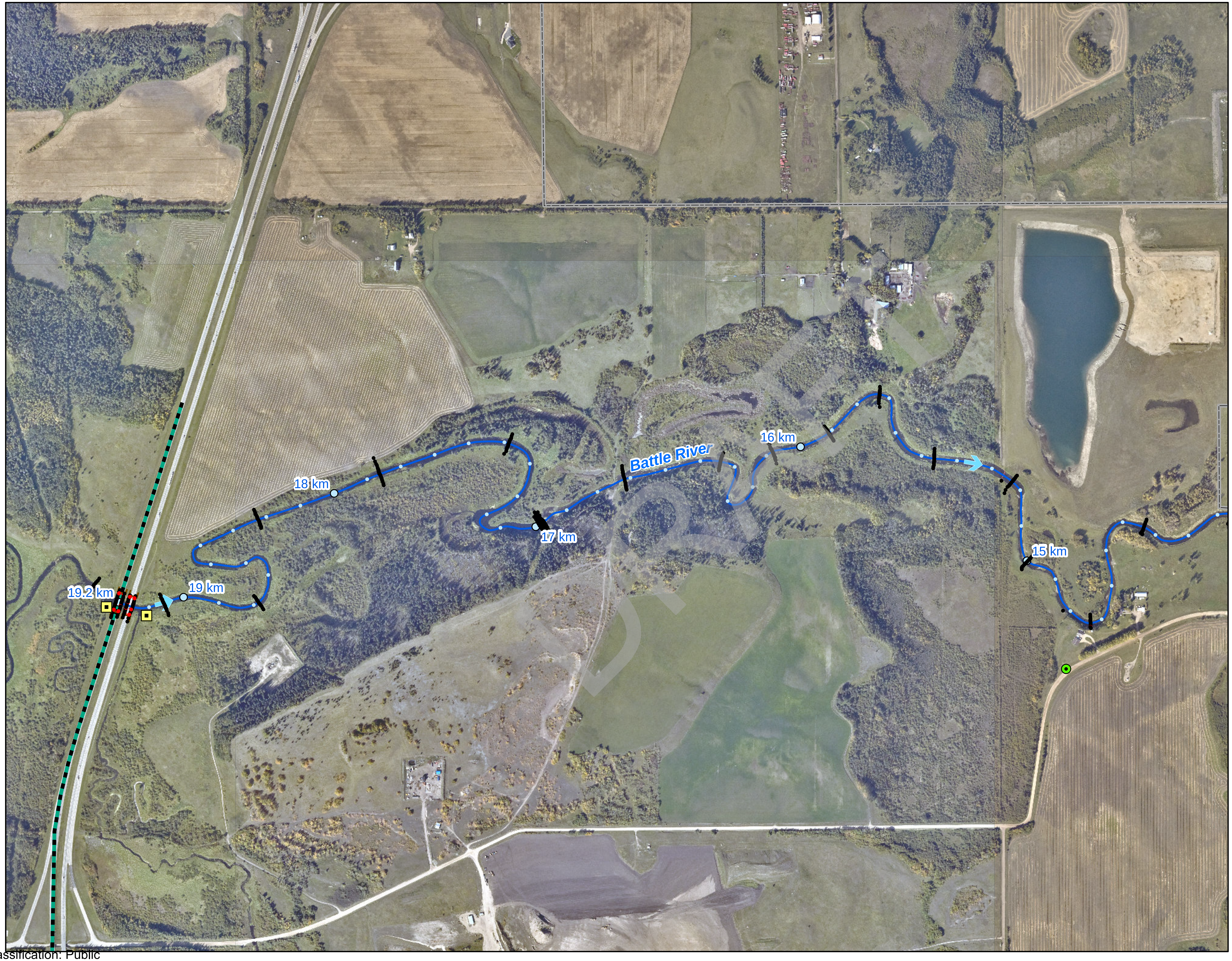
PONOKA FLOOD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

BULLETIN 17C FREQUENCY CURVE FOR BATTLE RIVER AT PONOKA

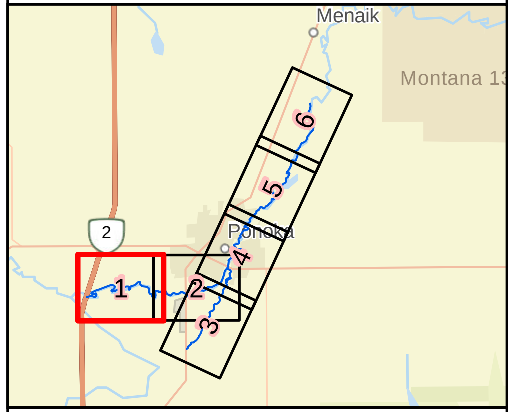
FIGURE B-9

APPENDIX B

SURVEY OVERVIEW



Alberta
Canada
nhc



MAJOR HIGHWAY
LOCAL ROAD
RAILWAY
BRIDGE
CULVERT
FLOOD BERM
TOWN OF PONOKA
STUDY BOUNDARY
RIVER CENTRE LINE
River Station Marker
100 m
1 km
FLOW DIRECTION
CHANNEL & OVERBANK
HYDRAULIC STRUCTURE
SURVEY CONTROL
HWM (1990)
HWM (1982)

SCALE - 1:10,000
0 100 200 M
N

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	DJH/JY	RBA

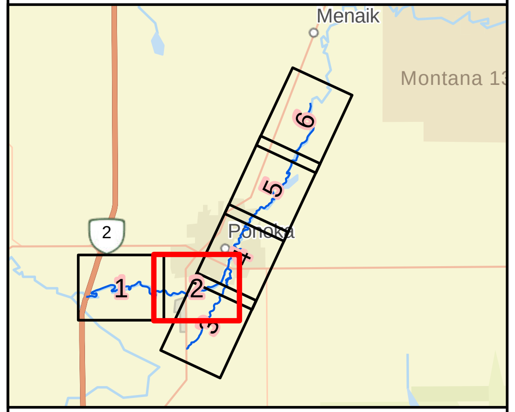
Job Number	Date
1008017	01-MAR-2025

PONOKA FLOOD STUDY
APPENDIX B
SURVEY OVERVIEW

SHEET B-1 OF B-6

DJH, P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\100 Survey\1008017_DJH_Survey_Overview.aprx

Classification: Public



MAJOR HIGHWAY
LOCAL ROAD
RAILWAY
BRIDGE
CULVERT
FLOOD BERM
TOWN OF PONOKA
STUDY BOUNDARY
RIVER CENTRE LINE
River Station Marker
100 m
1 km
FLOW DIRECTION
CHANNEL & OVERBANK
HYDRAULIC STRUCTURE
SURVEY CONTROL
HWM (1990)
HWM (1982)

SCALE - 1:10,000
0 100 200 M
N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	DJH/JY	RBA

Job Number	Date
1008017	01-MAR-2025

PONOKA FLOOD STUDY
APPENDIX B
SURVEY OVERVIEW

SHEET B-2 OF B-6

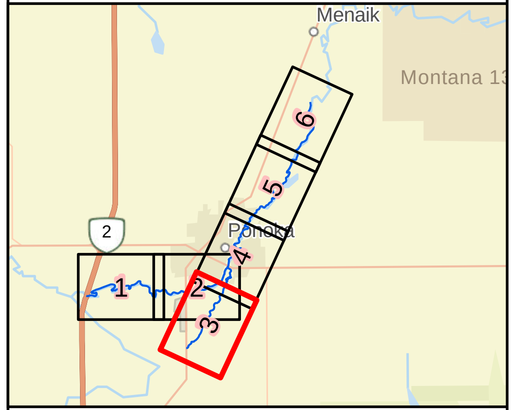
DJH, P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\100 Survey\1008017_DJH_Survey_Overview.aprx

Classification: Public

Alberta

Canada

nhc



- MAJOR HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- FLOOD BERM
- TOWN OF PONOKA
- STUDY BOUNDARY
- RIVER CENTRE LINE
- River Station Marker
  - 100 m
  - 1 km
- FLOW DIRECTION
- CHANNEL & OVERBANK
- HYDRAULIC STRUCTURE
- SURVEY CONTROL
- HWM (1990)
- HWM (1982)

SCALE - 1:10,000

0 100 200 M

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	DJH/JY	RBA

Job Number	Date
1008017	01-MAR-2025

PONOKA FLOOD STUDY

APPENDIX B

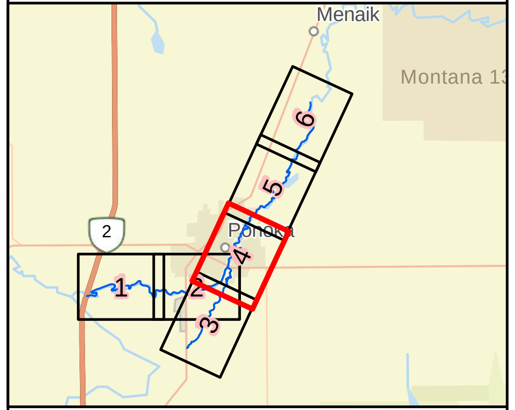
SURVEY OVERVIEW

SHEET B-3 OF B-6

Classification: Public

Alberta Canada

nhc



- MAJOR HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- FLOOD BERM
- TOWN OF PONOKA
- STUDY BOUNDARY
- RIVER CENTRE LINE
- River Station Marker
  - 100 m
  - 1 km
- FLOW DIRECTION
- CHANNEL & OVERBANK
- HYDRAULIC STRUCTURE
- SURVEY CONTROL
- HWM (1990)
- HWM (1982)

SCALE - 1:10,000

0 100 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	DJH/JY	RBA

Job Number	Date
1008017	01-MAR-2025

PONOKA FLOOD STUDY

APPENDIX B

SURVEY OVERVIEW

SHEET B-4 OF B-6

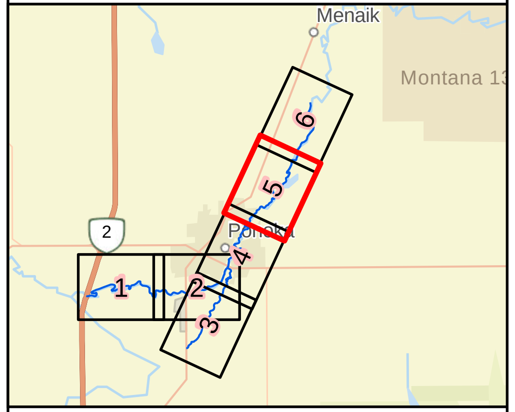
DJH, P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\100 Survey\1008017_DJH_Survey_Overview.aprx

Classification: Public

Alberta

Canada

nhc



- MAJOR HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- FLOOD BERM
- TOWN OF PONOKA
- STUDY BOUNDARY
- RIVER CENTRE LINE
- River Station Marker
  - 100 m
  - 1 km
- FLOW DIRECTION
- CHANNEL & OVERBANK
- HYDRAULIC STRUCTURE
- SURVEY CONTROL
- HWM (1990)
- HWM (1982)

SCALE - 1:10,000

0 100 200 M

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	DJH/JY	RBA

Job Number	Date
1008017	01-MAR-2025

PONOKA FLOOD STUDY

APPENDIX B

SURVEY OVERVIEW

SHEET B-5 OF B-6

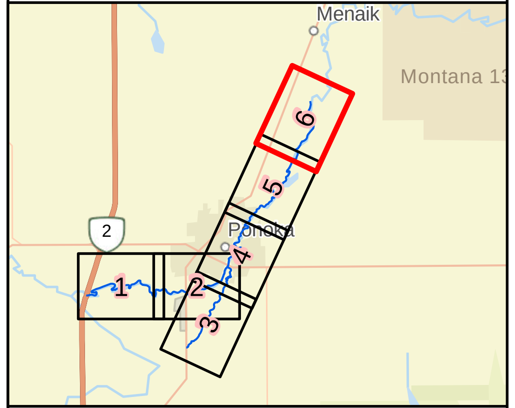
DJH, P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\100 Survey\1008017_DJH_Survey_Overview.aprx

Classification: Public

SHEET 5

Alberta Canada

nhc



- MAJOR HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- FLOOD BERM
- TOWN OF PONOKA
- STUDY BOUNDARY
- RIVER CENTRE LINE
- River Station Marker
  - 100 m
  - 1 km
- FLOW DIRECTION
- CHANNEL & OVERBANK
- HYDRAULIC STRUCTURE
- SURVEY CONTROL
- HWM (1990)
- HWM (1982)

SCALE - 1:10,000

0 100 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	DJH/JY	RBA

Job Number	Date
1008017	01-MAR-2025

PONOKA FLOOD STUDY
APPENDIX B
SURVEY OVERVIEW

SHEET B-6 OF B-6

DJH, P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\100 Survey\1008017_DJH_Survey_Overview.aprx

Classification: Public

APPENDIX C

HYDRAULIC STRUCTURES

Bridge Description

Name:	Highway 2 Bridge (SBL)	**Bridge File No.:**	75535
River:	Battle River	**River Station (m):**	19187.70

Geometry

Span (m):	47.15	**Minimum High Chord (m):**	809.809
Width (m):	13.9	**Minimum Low Chord (m):**	808.549
Pier Type:	Concrete	**No. of Piers:**	2
Pier Shape:	Elongated Semi Circular	**Pier Width (m):**	1

Photo(s)

Looking upstream on downstream side of the of bridge

Bridge Description

Name:	Highway 2 Bridge (NBL)	**Bridge File No.:**	75535
River:	Battle River	**River Station (m):**	19155.11

Geometry

Span (m):	47.75	**Minimum High Chord (m):**	809.817
Width (m):	13.8	**Minimum Low Chord (m):**	808.547
Pier Type:	Concrete	**No. of Piers:**	2
Pier Shape:	Elongated Semi Circular	**Pier Width (m):**	1

Photo(s)

Looking downstream on upstream side of the of bridge

Bridge Description

Name:	Highway 2A Bridge	**Bridge File No.:**	00278
River:	Battle River	**River Station (m):**	13023.15

Geometry

Span (m):	40.84	**Minimum High Chord (m):**	806.590
Width (m):	13.4	**Minimum Low Chord (m):**	805.257
Pier Type:	Concrete	**No. of Piers:**	2
Pier Shape:	Elongated Semi Circular	**Pier Width (m):**	0.75

Photo(s)

Looking downstream on upstream side of the of bridge

Looking upstream on downstream side of bridge

Bridge Description

Name:	CP Rail Bridge	**Bridge File No.:**	N/A
River:	Battle River	**River Station (m):**	11430.63

Geometry

Span (m):	42.00	**Minimum High Chord (m):**	806.330
Width (m):	5.4	**Minimum Low Chord (m):**	805.077
Pier Type:	Concrete	**No. of Piers:**	2
Pier Shape:	Triangular Nose (90^{o})	**Pier Width (m):**	Varies (1.25 - 1.8)

Photo(s)

Looking downstream on upstream side of the of bridge

Looking upstream on downstream side of bridge

Bridge Description

Name:	Highway 53 Bridge	**Bridge File No.:**	78896
River:	Battle River	**River Station (m):**	10682.48

Geometry

Span (m):	67.16	**Minimum High Chord (m):**	808.683
Width (m):	15.8	**Minimum Low Chord (m):**	807.044
Pier Type:	Steel	**No. of Piers:**	2
Pier Shape:	Circular	**Pier Width (m):**	0.75

Photo(s)

Looking downstream on upstream side of the of bridge

Looking upstream on downstream side of bridge

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	00348
River:	Battle River	**River Station (m):**	10362.71

Geometry

Span (m):	56.40	**Minimum High Chord (m):**	804.507
Width (m):	2.7	**Minimum Low Chord (m):**	803.407
Pier Type:	Steel	**No. of Piers:**	2
Pier Shape:	Circular	**Pier Width (m):**	0.5

Photo(s)

Looking downstream on upstream side of the of bridge

Looking upstream on downstream side of bridge

Bridge Description

Name:	50 Avenue Bridge	**Bridge File No.:**	01972
River:	Battle River	**River Station (m):**	8882.84

Geometry

Span (m):	47.75	**Minimum High Chord (m):**	805.233
Width (m):	16.8	**Minimum Low Chord (m):**	804.361
Pier Type:	Concrete	**No. of Piers:**	2
Pier Shape:	Circular	**Pier Width (m):**	0.6

Photo(s)

Looking downstream on upstream side of the bridge

Looking upstream on downstream side of the bridge

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Battle River	**River Station (m):**	7766.42

Geometry

Span (m):	42.00	**Minimum High Chord (m):**	806.570
Width (m):	2.2	**Minimum Low Chord (m):**	806.150
Pier Type:	N/A	**No. of Piers:**	N/A
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream on upstream side of the of bridge

Looking upstream on downstream side of bridge

Bridge Description

Name:	Township Road 434 Bridge	**Bridge File No.:**	05498
River:	Battle River	**River Station (m):**	0.02

Geometry

Span (m):	41.90	**Minimum High Chord (m):**	800.491
Width (m):	8.8	**Minimum Low Chord (m):**	799.865
Pier Type:	Concrete	**No. of Piers:**	2
Pier Shape:	Circular	**Pier Width (m):**	0.5

Photo(s)

Looking downstream on upstream side of the of bridge

Looking upstream on the downstream side of the bridge

Bridge Description

Name:	CP Rail Bridge	**Bridge File No.:**	N/A
River:	Unnamed Tributary	**River Station (m):**	3211.96

Geometry

Span (m):	6.20	**Minimum High Chord (m):**	808.110
Width (m):	4.2	**Minimum Low Chord (m):**	807.450
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream on upstream side of the of bridge

Looking upstream on downstream side of bridge

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Unnamed Tributary	**River Station (m):**	1063.26

Geometry

Span (m):	7.30	**Minimum High Chord (m):**	802.760
Width (m):	2.2	**Minimum Low Chord (m):**	802.370
Pier Type:	Steel	**No. of Piers:**	2
Pier Shape:	Circular	**Pier Width (m):**	0.2

Photo(s)

Looking downstream on upstream side of the of bridge

Looking upstream on downstream side of bridge

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Unnamed Tributary	**River Station (m):**	31.38

Geometry

Span (m):	7.60	**Minimum High Chord (m):**	801.650
Width (m):	2.2	**Minimum Low Chord (m):**	801.190
Pier Type:	N/A	**No. of Piers:**	N/A
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream on upstream side of the of bridge

Looking upstream on downstream side of the bridge

Culvert Description

Name:	Highway 2A Culvert (Barrel #1)	**Bridge File No.:**	09746
River:	Unnamed Tributary	**River Station (m):**	4843.31

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	807.35
Diameter (m):	1.8	**Downstream Invert Elev (m):**	807.325
Culvert Type:	CSP	**Barrel Length (m):**	26.0
Culvert Shape:	Circular	**Minimum Road Elevation (m):**	810.118
Entrance Con:	Pipe projecting from fill		

Photo(s)

Looking downstream on upstream side of culverts

Looking upstream on dowsntream side of culverts

Culvert Description

Name: Highway 2A Culvert (Barrel #2)
Bridge File No.: 09746
River: Unnamed Tributary
River Station (m): 4843.31

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	807.423
Diameter (m):	1.8	**Downstream Invert Elev (m):**	807.36
Culvert Type:	CSP	**Barrel Length (m):**	25.5
Culvert Shape:	Circular	**Minimum Road Elevation (m):**	810.118
Entrance Con:	Pipe projecting from fill		

Photo(s)

Looking downstream on upstream side of culverts

Looking upstream on dowsntream side of culverts

Culvert Description

Name:	Highway 2A Culvert (Barrel #3)	**Bridge File No.:**	09746
River:	Unnamed Tributary	**River Station (m):**	4843.31

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	807.300
Diameter (m):	1.8	**Downstream Invert Elev (m):**	807.267
Culvert Type:	CSP	**Barrel Length (m):**	26.0
Culvert Shape:	Circular	**Minimum Road Elevation (m):**	810.118
Entrance Con:	Pipe projecting from fill		

Photo(s)

Looking downstream on upstream side of culverts

Looking upstream on dowsntream side of culverts

Culvert Description

Name:	Highway 2A Culvert (Barrel #1)	**Bridge File No.:**	07270
River:	Tributary of Unnamed Tributary	**River Station (m):**	110

Geometry

Span (m):	1.1	**Upstream Invert Elev (m):**	807.64
Diameter (m):	1.6	**Downstream Invert Elev (m):**	807.592
Culvert Type:	CSP	**Barrel Length (m):**	29.3
Culvert Shape:	Arch	**Minimum Road Elevation (m):**	809.840
Entrance Con:	Pipe projecting from fill		

Photo(s)

Looking downstream on upstream side of culverts

Looking upstream on dowsntream side of culverts

Culvert Description

Name:	Highway 2A Culvert (Barrel #2)	**Bridge File No.:**	07270
River:	Tributary of Unnamed Tributary	**River Station (m):**	N/A

Geometry

Span (m):	1.1	**Upstream Invert Elev (m):**	807.652
Diameter (m):	1.6	**Downstream Invert Elev (m):**	807.630
Culvert Type:	CSP	**Barrel Length (m):**	29.3
Culvert Shape:	Arch	**Minimum Road Elevation (m):**	809.840
Entrance Con:	Pipe projecting from fill		

Photo(s)

Looking downstream on upstream side of culverts

Looking upstream on dowsntream side of culverts

Culvert Description

Name:	Private Culvert (Barrel #1 & 2)	**Bridge File No.:**	N/A
River:	Unnamed Tributary	**River Station (m):**	1575.37

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	803.46[1]
Diameter (m):	600 mm	**Downstream Invert Elev (m):**	803.45[1]
Culvert Type:	CSP	**Barrel Length (m):**	21.5[2]
Culvert Shape:	Circular	**Minimum Road Elevation (m):**	804.5[3]
Entrance Con:	Pipe projecting from fill		

1. Inverts approximated from DTM.
2. Barrel length estimated from DTM and Google 1990 imagery.
3. Minimum road elevation estimated from the 2023 lidar.

Photo(s)

Drone image looking upstream on upstream side of culverts

Google Earth 2009 image, flow is top to bottom (north downwards)

APPENDIX D

FLOOD CONTROL STRUCTURE MEMORANDUM

9819 – 12 Avenue SW | Edmonton, AB T6X 0E3 | 780.436.5868 | www.nhcweb.com

northwest hydraulic consultants

NHC Ref. No. 1008017

FINAL DRAFT MEMORANDUM

Prepared by:	Kevin Emmelkamp	Date:	5 December 2024
Reviewed by:	Dan Healy	Client File:	22RSD860
Distribution:	Jane Eaket (EPA)	No. of Pages:	6

RE: Ponoka Flood Study
Surveyed Flood Control Structure Details

1 INTRODUCTION

This memorandum summarizes several flood control structures (berms and dikes) identified by the Town of Ponoka. This information is provided supplementary to the survey data collected for hydraulic modelling and mapping.

2 STUDY AREA

The study reach includes the following:

- 19 km of the Battle River extending through the Town of Ponoka and Ponoka County, from the Highway 2 to Township Road 543
- 5 km of an unnamed tributary extending from Highway 2a near Township Road 424 in Ponoka County, to its confluence with the Battle River in the Town of Ponoka.

3 FLOOD CONTROL STRUCTURES

All of the identified flood control structures were considered as flood berms. A flood berm, as defined by the provincial Flood Hazard Identification Program (FHIP), is a "permanent barrier or engineered system that keeps water from entering and flooding an area."

Dedicated flood control structures typically require regulatory approval prior to construction, receive routine inspection and maintenance, and are officially recognized by local authorities as flood management infrastructure. As per the study terms of reference, geometric details for dedicated flood control structures identified by local authorities are to be collected either by survey or obtained from representative design drawings and survey-verified. While the flood berms found in this study may not be considered as dedicated flood control structures, NHC collected survey information for each of the three berms identified in this study.

4 RESULTS AND CONCLUSION

Three separate flood berms were located and surveyed. It is our understanding that the flood berms are owned and maintained by the Town of Ponoka. The location of the berms are indicated on **Figure 1**.

Berm 1 is located along the right bank of the Battle River, downstream of the pedestrian bridge near 46A Street. A typical section of the berm is shown in **Figure 2**. The crest of the berm is approximately 1 m above the surrounding floodplain and was not keyed into any surrounding terrain features. The berm does not appear to be protecting any infrastructure as the surrounding floodplain is being used primarily as park, with only playground structures and walking paths being located behind the berm. Due to this, there is little consequence if the berm were to fail. As the berm is not keyed into the surrounding terrain, it is likely that the berm will be outflanked before it fails due to overtopping. Although, it is still expected to be overtopped by minor floods.

Berm 2 is located within the right flood floodplain near 46A Street. A typical section of the berm is shown in **Figure 3**. The crest of the of the berm is approximately 0.5 m above the surrounding floodplain. Only the west side of the berm is keyed into the surrounding terrain. Due to this it is likely that the berm will be outflanked before it fails due to overtopping. The crest of the berm is expected to be exceeded by relatively minor flooding. There is a single residence behind this berm and this berm would offer limited protection to the residence from minor floods.

Berm 3 is located within the left floodplain upstream of the pedestrian bridge along 49 Street. A typical section of the berm is shown in **Figure 4**. The berm crest is over 2 m higher than the surrounding floodplain and was observed to be keyed into the surrounding terrain. The berm appears to be protecting a piece of infrastructure, likely a pump house or lift station. As such, overtopping and failure of this berm would likely have high consequence as it may damage vital infrastructure. However, failure by overtopping of the structure is considered unlikely as preliminary modelling shows that the berm would protect against extreme flooding.

Figure 1 Schematic depicting locations of berms.

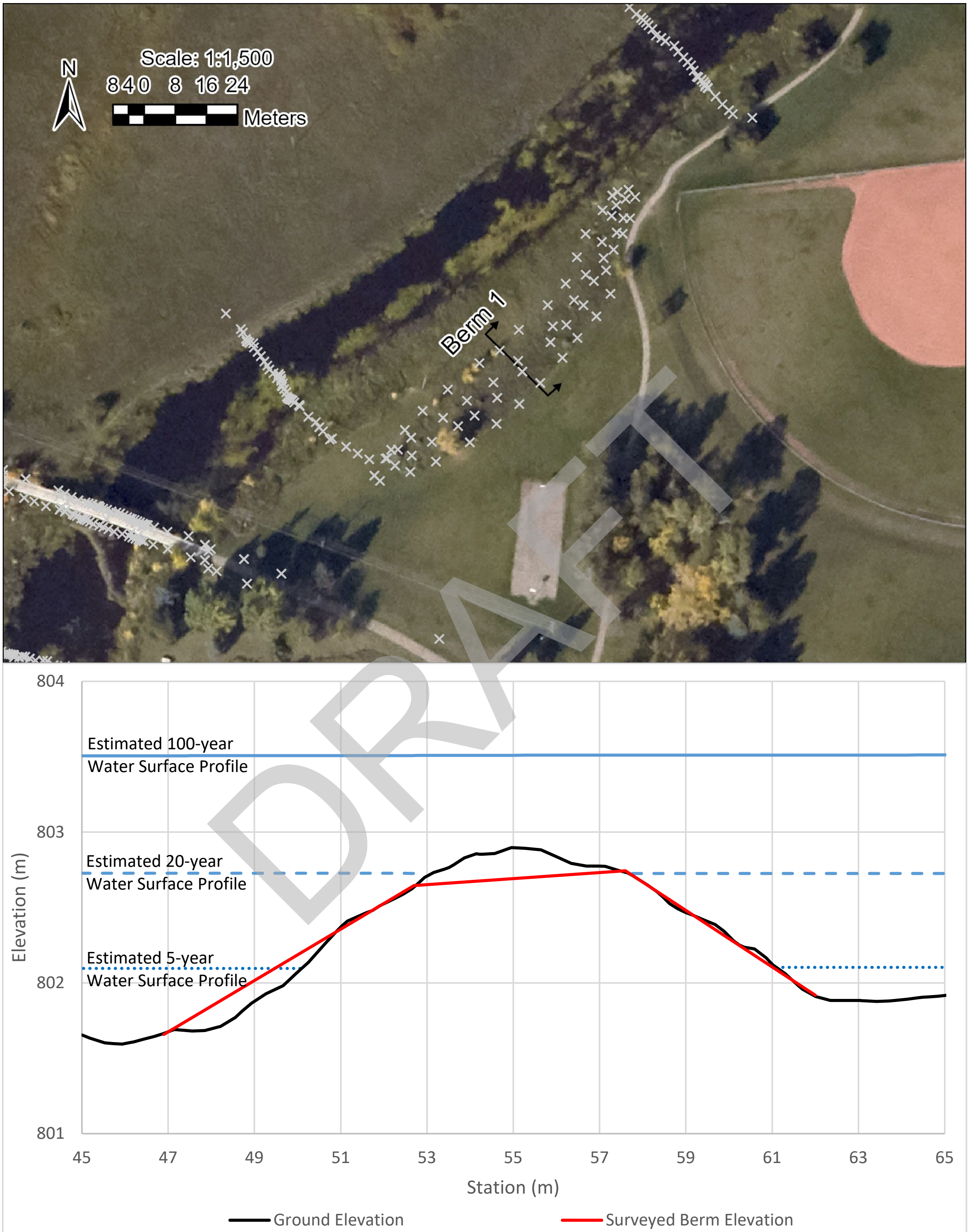


Figure 2 Plan View Schematic of Berm 1 typical sections (DEM and Survey).

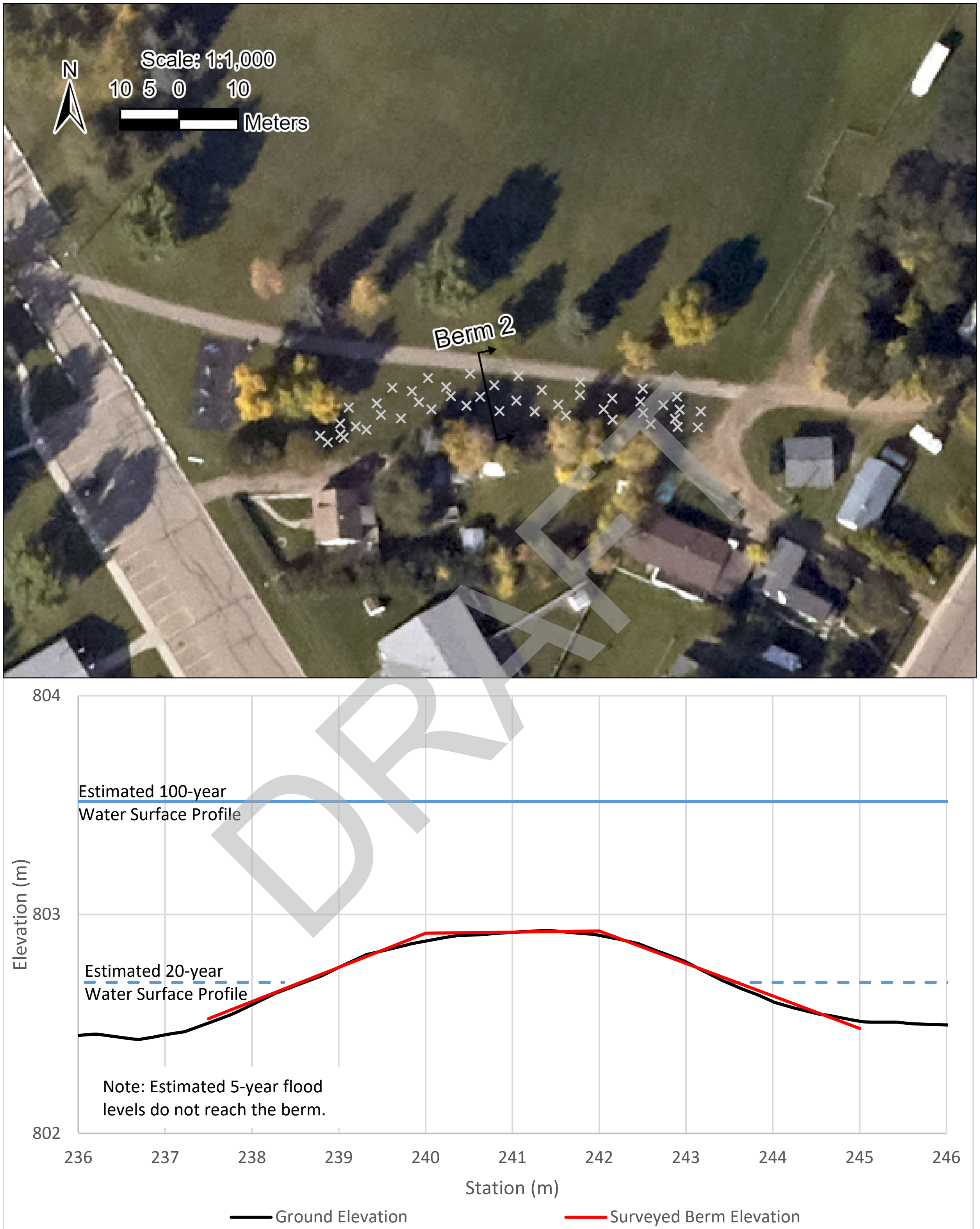


Figure 3 Plan View and Schematic of Berm 2 typical sections (DEM and Survey)

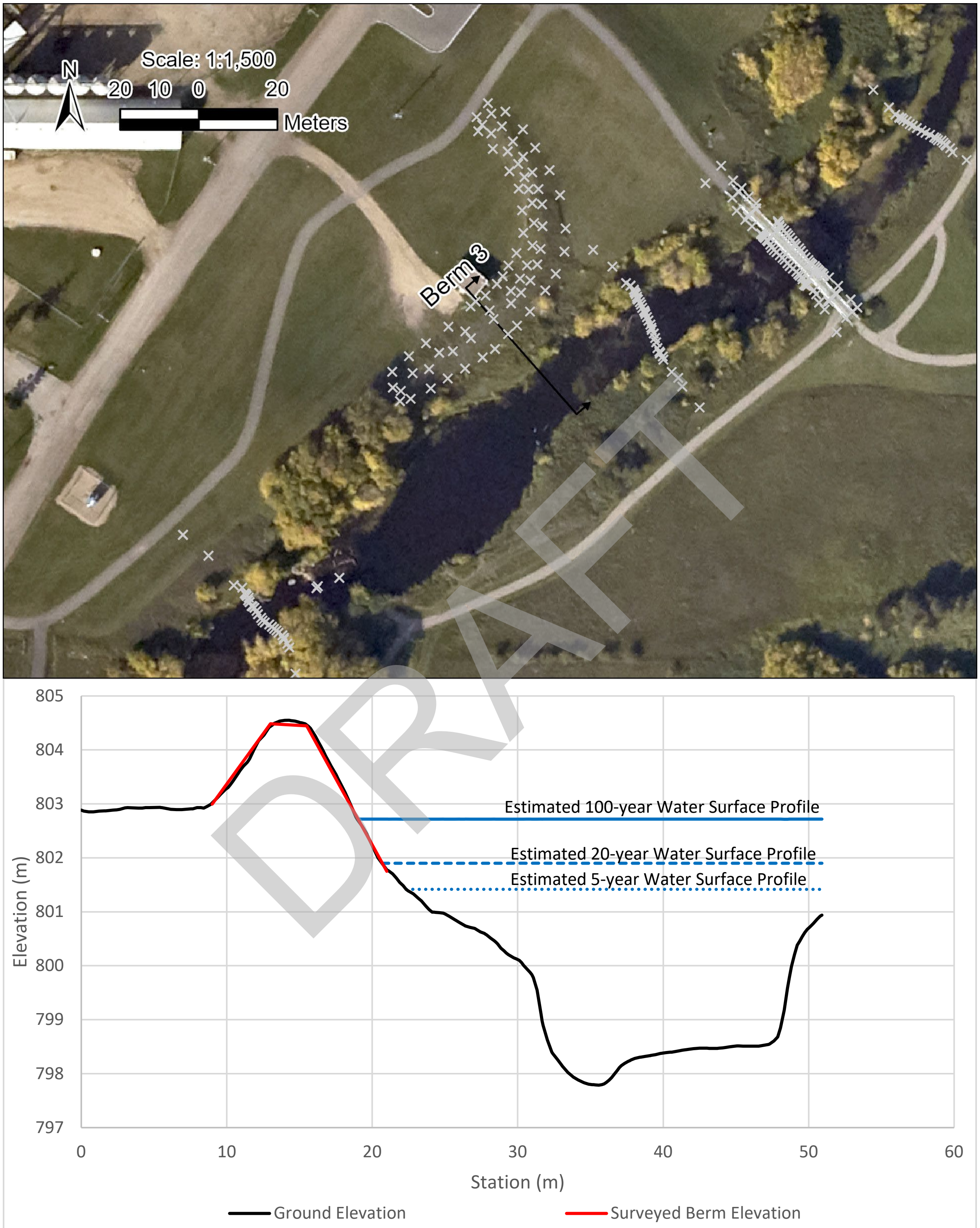


Figure 4 Plan View and Schematic of typical section of Berm 3

APPENDIX E

REACH REPRESENTATIVE PHOTOGRAPHS

1) Looking downstream on Battle River from RS 19223.

2) Looking upstream on Battle River from RS 18747.

3) Looking downstream on Battle River from RS 17826.

4) Looking upstream on Battle River from RS 16950.

5) Looking downstream on Battle River from RS 16048.

6) Looking downstream on Battle River from left bank of RS 15429.

Alberta Canada nhc

Note:

Photos taken by NHC during site visit on June 5, 2023, June 6, 2023, June 7, 2023, August 21, 2023, and August 22, 2023.

Job: 1008017 | Date: Jan-2025

PONOKA FLOOD STUDY

REACH REPRESENTATIVE PHOTOS CHANNEL AND FLOODPLAIN BATTLE RIVER

E-1

1) Looking downstream on Battle River from RS 14030.

2) Looking upstream on Battle River from RS 13600.

3) Looking downstream on Battle River from RS 12268.

4) Looking downstream on Battle River from right bank at RS 11025.

5) Looking upstream at old dam on Battle River from RS 9228.

6) Looking downstream on Battle River from RS 7792.

Note:

Photos taken by NHC during site visit on June 5, 2023, June 6, 2023, June 7, 2023, August 21, 2023, and August 22, 2023.

PONOKA FLOOD STUDY

REACH REPRESENTATIVE PHOTOS CHANNEL AND FLOODPLAIN BATTLE RIVER

Job: 1008017 | *Date: Jan-2025* | *E-2*

1) Looking upstream on Battle River from RS 7050.

2) Looking downstream on Battle River from RS 6218.

3) Looking downstream on Battle River from RS 4666.

4) Looking downstream on Battle River from RS 2889.

5) Looking downstream on Battle River from RS 1780.

6) Looking upstream on Battle River from RS 818.

Alberta
Canada
nhc

Note:

Photos taken by NHC during site visit on June 5, 2023, June 6, 2023, June 7, 2023, August 21, 2023, and August 22, 2023.

Job: 1008017 *Date: Jan-2025*

PONOKA FLOOD STUDY

REACH REPRESENTATIVE PHOTOS
CHANNEL AND FLOODPLAIN
BATTLE RIVER

E-4

1) Looking upstream at old overgrown beaver dam on Unnamed Creek from RS 225.

2) Looking upstream on Unnamed Creek from RS 1888.

3) Looking upstream on Unnamed Creek from RS 3750.

4) Looking downstream on Unnamed Creek from RS 4000.

5) Looking upstream on Unnamed Creek from RS 4363.

6) Looking upstream on confluence of Battle River and Unnamed Creek.

Note:

Photos taken by NHC during site visit on June 8, 2023, June 9, 2023, and August 22, 2023.

PONOKA FLOOD STUDY

REACH REPRESENTATIVE PHOTOS
CHANNEL AND FLOODPLAIN
UNNAMED TRIBUTARY

Job: 1008017 | *Date: Jan-2025* | *E-4*

1) Looking upstream at Beaver dam on Battle River near RS16950.

2) Looking downstream at channel feature on Battle River near RS 13600.

3) Looking upstream on Battle River at Beaver dam near RS 11700.

4) Looking along alignment of old dam on Battle River near RS 9228.

5) Looking downstream at control structure on Battle River near RS 2889.

6) Looking upstream at channel feature on Battle River around RS 2348.

Note:

Photos taken by NHC during site visit on June 5, 2023, June 6, 2023, June 7, 2023, August 21, 2023, and August 22, 2023.

PONOKA FLOOD STUDY

REACH REPRESENTATIVE PHOTOS IN-CHANNEL FEATURES BATTLE RIVER

Job: 1008017 | *Date: Jan-2025* | *E-5*

1) Looking upstream at Beaver Dam on Unnamed Creek near RS 3752.

2) Looking downstream at Beaver Dam on Unnamed creek near RS 3500.

3) Looking at road crossing travelling through Unnamed Creek at RS 989.

4) Looking upstream at Beaver Dam on Unnamed Creek near RS 225.

5) Suspected location of submerged culvert crossing near RS 1575 (culverts not found during survey).

Note:

Photos taken by NHC during site visit on June 5, 2023, June 6, 2023, June 7, 2023, August 21, 2023, and August 22, 2023.

PONOKA FLOOD STUDY

REACH REPRESENTATIVE PHOTOS
IN-CHANNEL FEATURES
UNNAMED TRIBUTARY

Job: 1008017 | *Date: Jan-2025* | *E-6*

APPENDIX F

FLOOD HISTORY PHOTOGRAPHS

1. 1948 flood – Battle River at Highway 2A near Ponoka.

2. 1948 flood – Battle River at Ponoka.

3. 1948 flood – Battle River at Ponoka.

4. 1948 flood – Battle River at Ponoka.

5. 1972 flood – Battle River at Ponoka.

6. 1972 flood – Battle River at Ponoka.

Photos provided by Alberta Environment and Protected Areas.

PONOKA FLOOD STUDY

FLOOD HISTORY PHOTOGRAPHS

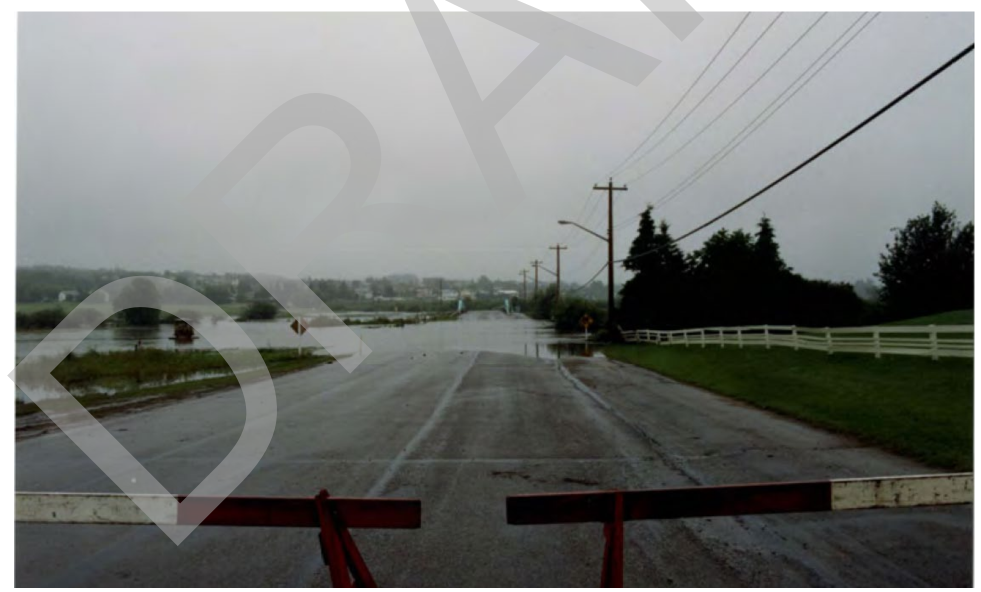
Job: 1008017	*Date: Jan-2025*	*F - 1*

1. 1990 flood – Battle River at Ponoka.

2. 1990 flood – Battle River at Ponoka.

3. 1990 flood – Battle River at Ponoka.

4. 1990 flood – Battle River at Ponoka.



5. 1990 flood – Battle River at Ponoka.

6. 1990 flood – Battle River at Ponoka.

Photos provided by Alberta Environment and Protected Areas.

PONOKA FLOOD STUDY

FLOOD HISTORY PHOTOGRAPHS

Job: 1008017 | *Date: Jan-2025*

APPENDIX G

FLOOD FREQUENCY PROFILE DATA

River Station (m)	Flood Return Period and Discharge (m^3/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**	**1000-year**
	29.5	**60.2**	**86.6**	**120**	**158**	**191**	**236**	**275**	**389**	**505**	**593**	**706**	**796**
	Water Surface Elevation (m) - Battle River												
19187.7	805.22	805.66	805.92	806.2	806.49	806.73	807.03	807.27	807.88	808.36	808.78	809.1	809.32
19100	805.21	805.62	805.87	806.13	806.39	806.61	806.89	807.12	807.74	808.18	808.47	808.8	809.04
19000	805.18	805.59	805.83	806.09	806.35	806.56	806.85	807.08	807.7	808.15	808.44	808.78	809.02
18900	805.15	805.57	805.81	806.07	806.33	806.54	806.83	807.06	807.68	808.13	808.43	808.76	809.01
18800	805.13	805.54	805.79	806.05	806.32	806.53	806.81	807.05	807.67	808.12	808.42	808.75	808.99
18700	805.11	805.52	805.77	806.04	806.3	806.52	806.81	807.04	807.66	808.11	808.41	808.74	808.98
18600	805.08	805.51	805.76	806.03	806.3	806.52	806.81	807.04	807.66	808.12	808.41	808.74	808.99
18500	805.06	805.5	805.76	806.03	806.3	806.52	806.81	807.04	807.67	808.12	808.42	808.75	808.99
18400	805.04	805.49	805.75	806.03	806.3	806.51	806.81	807.04	807.67	808.12	808.41	808.75	808.99
18300	805.01	805.48	805.74	806.01	806.29	806.5	806.79	807.03	807.66	808.11	808.4	808.74	808.98
18200	804.99	805.46	805.72	806	806.27	806.48	806.77	807.01	807.64	808.09	808.38	808.71	808.95
18100	804.98	805.45	805.7	805.98	806.25	806.46	806.75	806.99	807.61	808.06	808.35	808.68	808.92
18000	804.96	805.43	805.68	805.95	806.22	806.43	806.72	806.96	807.59	808.03	808.32	808.65	808.89
17900	804.94	805.41	805.66	805.92	806.19	806.4	806.69	806.92	807.55	807.99	808.28	808.61	808.84
17800	804.93	805.39	805.63	805.89	806.15	806.36	806.65	806.89	807.51	807.95	808.24	808.56	808.79
17700	804.92	805.37	805.61	805.87	806.12	806.33	806.62	806.85	807.48	807.91	808.2	808.52	808.75
17600	804.9	805.35	805.59	805.84	806.1	806.3	806.59	806.82	807.45	807.89	808.17	808.48	808.72
17500	804.89	805.34	805.58	805.83	806.08	806.28	806.57	806.81	807.43	807.87	808.15	808.46	808.69
17400	804.87	805.33	805.57	805.82	806.07	806.27	806.56	806.8	807.42	807.86	808.14	808.45	808.68
17300	804.84	805.32	805.56	805.81	806.07	806.27	806.56	806.8	807.43	807.86	808.14	808.46	808.69
17200	804.81	805.31	805.56	805.81	806.07	806.27	806.56	806.8	807.43	807.87	808.15	808.46	808.69
17100	804.79	805.3	805.55	805.81	806.06	806.27	806.56	806.8	807.43	807.86	808.14	808.46	808.69
17000	804.76	805.29	805.54	805.8	806.05	806.26	806.55	806.79	807.42	807.85	808.13	808.45	808.68
16900	804.69	805.25	805.51	805.77	806.03	806.24	806.53	806.77	807.4	807.83	808.11	808.43	808.66
16800	804.58	805.21	805.48	805.74	805.99	806.2	806.5	806.74	807.37	807.8	808.08	808.39	808.62
16700	804.45	805.15	805.43	805.69	805.95	806.16	806.45	806.7	807.34	807.77	808.04	808.35	808.58
16600	804.4	805.11	805.4	805.66	805.91	806.12	806.42	806.67	807.31	807.74	808.01	808.32	808.55
16500	804.37	805.08	805.37	805.63	805.89	806.1	806.4	806.64	807.29	807.72	807.99	808.3	808.52
16400	804.34	805.06	805.35	805.61	805.87	806.08	806.38	806.63	807.28	807.7	807.97	808.28	808.5
16300	804.31	805.04	805.33	805.6	805.86	806.07	806.37	806.62	807.27	807.7	807.97	808.28	808.5
16200	804.28	805.01	805.32	805.59	805.85	806.06	806.37	806.61	807.27	807.69	807.96	808.27	808.49
16100	804.26	804.99	805.3	805.57	805.84	806.05	806.36	806.61	807.26	807.69	807.96	808.26	808.48
16000	804.23	804.97	805.28	805.55	805.81	806.02	806.33	806.58	807.24	807.67	807.94	808.24	808.46
15900	804.21	804.94	805.25	805.52	805.78	806	806.31	806.56	807.22	807.65	807.92	808.22	808.44

River Station (m)	Flood Return Period and Discharge (m^3/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	1000-year
	29.5	60.2	86.6	120	158	191	236	275	389	505	593	706	796
	Water Surface Elevation (m) - Battle River												
15800	804.19	804.91	805.23	805.5	805.76	805.98	806.29	806.55	807.21	807.64	807.9	808.21	808.43
15700	804.17	804.88	805.2	805.47	805.74	805.96	806.28	806.53	807.2	807.62	807.89	808.2	808.42
15600	804.14	804.85	805.17	805.45	805.72	805.93	806.26	806.52	807.19	807.62	807.89	808.19	808.41
15500	804.1	804.81	805.13	805.41	805.68	805.9	806.23	806.49	807.18	807.6	807.87	808.18	808.4
15400	804.05	804.76	805.09	805.36	805.63	805.85	806.19	806.46	807.16	807.59	807.86	808.16	808.38
15300	803.99	804.7	805.04	805.31	805.58	805.8	806.15	806.43	807.15	807.58	807.85	808.15	808.37
15200	803.9	804.62	804.97	805.24	805.52	805.74	806.11	806.4	807.13	807.57	807.84	808.15	808.37
15100	803.77	804.51	804.87	805.16	805.45	805.69	806.07	806.38	807.12	807.56	807.83	808.14	808.36
15000	803.66	804.44	804.82	805.12	805.42	805.67	806.06	806.37	807.12	807.56	807.83	808.14	808.36
14900	803.58	804.39	804.79	805.1	805.4	805.65	806.05	806.36	807.11	807.55	807.83	808.13	808.36
14800	803.49	804.32	804.74	805.06	805.38	805.63	806.04	806.35	807.11	807.55	807.82	808.13	808.35
14700	803.4	804.23	804.66	805.02	805.36	805.62	806.03	806.34	807.1	807.54	807.82	808.13	808.35
14600	803.34	804.18	804.62	805	805.35	805.61	806.02	806.34	807.1	807.54	807.82	808.13	808.35
14500	803.29	804.14	804.6	804.99	805.33	805.6	806.01	806.33	807.09	807.54	807.81	808.12	808.34
14400	803.25	804.1	804.57	804.96	805.31	805.57	805.99	806.31	807.08	807.53	807.8	808.12	808.34
14300	803.21	804.07	804.54	804.93	805.28	805.54	805.97	806.29	807.06	807.51	807.79	808.1	808.32
14200	803.17	804.03	804.5	804.89	805.24	805.51	805.93	806.26	807.04	807.49	807.77	808.08	808.31
14100	803.13	803.99	804.47	804.86	805.21	805.48	805.91	806.24	807.02	807.48	807.76	808.07	808.29
14000	803.07	803.94	804.42	804.83	805.18	805.45	805.89	806.22	807.01	807.46	807.74	808.05	808.28
13900	803.01	803.89	804.37	804.79	805.15	805.43	805.87	806.21	807	807.45	807.73	808.04	808.27
13800	802.97	803.83	804.32	804.74	805.12	805.4	805.85	806.19	806.98	807.44	807.72	808.03	808.25
13700	802.92	803.78	804.27	804.71	805.09	805.37	805.83	806.17	806.97	807.42	807.7	808.01	808.23
13600	802.87	803.74	804.24	804.68	805.06	805.35	805.82	806.16	806.96	807.41	807.69	808	808.22
13500	802.83	803.69	804.19	804.64	805.02	805.31	805.79	806.13	806.94	807.39	807.67	807.97	808.19
13400	802.78	803.64	804.14	804.6	804.98	805.27	805.76	806.11	806.92	807.37	807.64	807.94	808.16
13300	802.72	803.58	804.09	804.55	804.94	805.23	805.73	806.08	806.9	807.34	807.61	807.91	808.13
13200	802.67	803.53	804.04	804.5	804.9	805.2	805.7	806.06	806.88	807.32	807.59	807.88	808.1
13100	802.6	803.46	803.97	804.44	804.85	805.15	805.66	806.02	806.85	807.29	807.55	807.85	808.06
13000	802.55	803.4	803.91	804.38	804.77	805.06	805.4	805.67	806.28	806.79	807.13	807.5	807.76
12900	802.5	803.35	803.85	804.32	804.71	805	805.34	805.6	806.22	806.74	807.08	807.46	807.72
12800	802.45	803.31	803.81	804.27	804.67	804.96	805.3	805.57	806.2	806.71	807.06	807.44	807.7
12700	802.41	803.26	803.76	804.22	804.62	804.91	805.26	805.53	806.16	806.67	807.03	807.4	807.66
12600	802.33	803.18	803.68	804.15	804.56	804.85	805.2	805.47	806.1	806.61	806.96	807.34	807.6
12500	802.29	803.13	803.63	804.1	804.5	804.79	805.13	805.39	806.01	806.52	806.86	807.23	807.48

River Station (m)	Flood Return Period and Discharge (m^3/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	1000-year
	29.5	60.2	86.6	120	158	191	236	275	389	505	593	706	796
	Water Surface Elevation (m) - Battle River												
12400	802.25	803.09	803.58	804.04	804.44	804.72	805.06	805.32	805.92	806.42	806.75	807.11	807.35
12300	802.22	803.05	803.53	803.99	804.38	804.66	804.99	805.25	805.84	806.32	806.65	806.99	807.22
12200	802.18	803	803.47	803.93	804.32	804.59	804.92	805.17	805.75	806.21	806.54	806.87	807.09
12100	802.14	802.95	803.42	803.87	804.25	804.52	804.84	805.1	805.66	806.12	806.44	806.77	806.99
12000	802.09	802.89	803.35	803.8	804.19	804.46	804.78	805.03	805.59	806.04	806.36	806.68	806.89
11900	802.06	802.86	803.32	803.76	804.14	804.41	804.72	804.97	805.51	805.95	806.27	806.58	806.78
11800	802	802.8	803.25	803.69	804.06	804.32	804.63	804.87	805.39	805.82	806.13	806.43	806.63
11700	801.97	802.76	803.2	803.63	803.99	804.24	804.54	804.77	805.28	805.7	806	806.29	806.48
11600	801.94	802.72	803.15	803.57	803.92	804.17	804.45	804.68	805.17	805.57	805.86	806.15	806.33
11500	801.9	802.67	803.1	803.51	803.85	804.09	804.37	804.59	805.08	805.48	805.77	806.06	806.24
11400	801.74	802.57	802.99	803.39	803.72	803.95	804.22	804.43	804.86	805.14	805.51	805.83	806.03
11300	801.62	802.47	802.88	803.27	803.58	803.8	804.06	804.26	804.7	805.05	805.46	805.8	806.01
11200	801.52	802.37	802.78	803.14	803.44	803.64	803.88	804.09	804.56	804.98	805.43	805.78	805.99
11100	801.43	802.3	802.69	803.05	803.33	803.52	803.75	803.97	804.47	804.92	805.4	805.76	805.97
11000	801.38	802.25	802.64	802.99	803.27	803.45	803.69	803.92	804.42	804.89	805.38	805.74	805.95
10900	801.36	802.24	802.62	802.96	803.23	803.42	803.66	803.89	804.4	804.87	805.36	805.72	805.93
10800	801.35	802.22	802.59	802.93	803.19	803.38	803.63	803.86	804.37	804.84	805.34	805.7	805.91
10700	801.34	802.2	802.57	802.9	803.16	803.35	803.59	803.82	804.32	804.79	805.29	805.66	805.87
10600	801.33	802.18	802.55	802.87	803.11	803.29	803.52	803.75	804.22	804.68	805.19	805.56	805.77
10500	801.31	802.16	802.52	802.84	803.08	803.25	803.48	803.71	804.19	804.64	805.16	805.53	805.74
10400	801.29	802.14	802.49	802.81	803.05	803.22	803.45	803.68	804.16	804.62	805.14	805.51	805.72
10300	801.25	802.1	802.45	802.76	802.98	803.15	803.36	803.53	803.98	804.45	805.05	805.44	805.65
10200	801.24	802.08	802.43	802.72	802.94	803.11	803.32	803.49	803.95	804.42	805.03	805.42	805.63
10100	801.22	802.06	802.39	802.68	802.9	803.06	803.27	803.45	803.92	804.39	805.01	805.4	805.61
10000	801.2	802.03	802.35	802.63	802.85	803.02	803.22	803.4	803.86	804.34	804.98	805.37	805.58
9900	801.19	802.01	802.32	802.59	802.81	802.97	803.18	803.35	803.82	804.3	804.95	805.35	805.56
9800	801.17	801.98	802.29	802.57	802.79	802.96	803.17	803.34	803.8	804.29	804.94	805.35	805.55
9700	801.14	801.95	802.26	802.54	802.77	802.94	803.16	803.33	803.79	804.29	804.94	805.34	805.55
9600	801.11	801.91	802.22	802.51	802.75	802.93	803.14	803.32	803.79	804.28	804.93	805.33	805.54
9500	801.08	801.87	802.19	802.49	802.74	802.92	803.14	803.31	803.78	804.28	804.93	805.33	805.54
9400	801.05	801.84	802.15	802.45	802.71	802.9	803.12	803.29	803.77	804.27	804.93	805.33	805.54
9300	801.02	801.8	802.11	802.42	802.68	802.87	803.09	803.27	803.75	804.25	804.92	805.32	805.53
9200	*800.98*	801.76	802.07	802.37	802.64	802.83	803.06	803.24	803.72	804.23	804.9	805.3	805.51
9100	800.94	801.72	802.02	802.32	802.59	802.78	803.02	803.21	803.7	804.21	804.89	805.29	805.5

River Station (m)	Flood Return Period and Discharge (m^3/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**	**1000-year**
	29.5	**60.2**	**86.6**	**120**	**158**	**191**	**236**	**275**	**389**	**505**	**593**	**706**	**796**
	Water Surface Elevation (m) - Battle River												
9000	800.92	801.69	801.98	802.27	802.54	802.73	802.97	803.16	803.66	804.18	804.87	805.27	805.48
8900	800.9	801.66	801.94	802.22	802.47	802.66	802.9	803.08	803.57	804.09	804.8	805.21	805.43
8800	800.89	801.64	801.91	802.17	802.41	802.58	802.8	802.98	803.43	803.81	804.07	804.37	804.59
8700	800.88	801.62	801.88	802.13	802.37	802.54	802.75	802.92	803.37	803.75	804	804.3	804.52
8600	800.86	801.59	801.85	802.1	802.34	802.51	802.72	802.89	803.33	803.71	803.97	804.27	804.49
8500	800.85	801.57	801.82	802.06	802.29	802.46	802.68	802.85	803.29	803.67	803.92	804.22	804.44
8400	800.83	801.54	801.78	802.02	802.25	802.43	802.64	802.82	803.26	803.64	803.89	804.19	804.41
8300	800.82	801.52	801.76	802	802.22	802.4	802.62	802.79	803.23	803.61	803.86	804.16	804.38
8200	800.8	801.51	801.74	801.98	802.21	802.38	802.6	802.77	803.21	803.59	803.84	804.14	804.36
8100	800.79	801.49	801.73	801.97	802.2	802.38	802.59	802.76	803.2	803.58	803.83	804.13	804.35
8000	800.77	801.47	801.72	801.96	802.19	802.37	802.59	802.76	803.2	803.58	803.83	804.13	804.35
7900	800.73	801.43	801.68	801.93	802.16	802.34	802.56	802.74	803.18	803.56	803.81	804.11	804.32
7800	800.71	801.41	801.66	801.91	802.14	802.32	802.54	802.71	803.15	803.53	803.78	804.07	804.29
7700	800.69	801.38	801.63	801.87	802.11	802.28	802.5	802.67	803.1	803.48	803.72	804.01	804.23
7600	800.67	801.36	801.62	801.86	802.09	802.26	802.48	802.65	803.08	803.46	803.7	803.99	804.2
7500	800.64	801.34	801.6	801.84	802.07	802.24	802.46	802.63	803.06	803.43	803.68	803.96	804.17
7400	800.62	801.33	801.58	801.82	802.05	802.22	802.44	802.61	803.04	803.4	803.65	803.93	804.14
7300	800.6	801.31	801.56	801.8	802.03	802.2	802.42	802.58	803.01	803.38	803.62	803.91	804.12
7200	800.57	801.28	801.53	801.77	802	802.18	802.39	802.56	802.99	803.35	803.6	803.88	804.09
7100	800.55	801.25	801.5	801.74	801.97	802.15	802.36	802.53	802.96	803.33	803.57	803.85	804.06
7000	800.53	801.23	801.48	801.71	801.94	802.12	802.33	802.5	802.93	803.3	803.54	803.82	804.03
6900	800.52	801.21	801.46	801.69	801.92	802.1	802.31	802.48	802.92	803.28	803.52	803.8	804
6800	800.5	801.19	801.44	801.68	801.91	802.09	802.3	802.47	802.91	803.27	803.51	803.79	804
6700	800.48	801.18	801.42	801.66	801.89	802.07	802.29	802.46	802.89	803.26	803.5	803.78	803.98
6600	800.46	801.16	801.4	801.64	801.87	802.05	802.26	802.43	802.87	803.23	803.47	803.74	803.95
6500	800.44	801.14	801.38	801.62	801.85	802.03	802.24	802.41	802.84	803.2	803.44	803.72	803.92
6400	800.43	801.12	801.36	801.6	801.84	802.02	802.23	802.4	802.83	803.19	803.42	803.7	803.9
6300	800.42	801.1	801.34	801.59	801.82	802	802.22	802.39	802.81	803.17	803.4	803.68	803.88
6200	800.4	801.07	801.32	801.57	801.81	801.98	802.2	802.37	802.79	803.15	803.38	803.65	803.85
6100	800.37	801.05	801.31	801.56	801.8	801.98	802.19	802.36	802.78	803.14	803.37	803.64	803.84
6000	800.35	801.03	801.3	801.55	801.79	801.97	802.18	802.35	802.77	803.13	803.36	803.63	803.82
5900	800.32	801.02	801.29	801.55	801.78	801.96	802.17	802.34	802.77	803.12	803.35	803.62	803.81
5800	800.29	801.01	801.28	801.54	801.77	801.95	802.17	802.33	802.76	803.11	803.34	803.61	803.8
5700	800.27	800.99	801.27	801.53	801.76	801.94	802.15	802.32	802.74	803.09	803.32	803.59	803.78

River Station (m)	Flood Return Period and Discharge (m^3/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**	**1000-year**
	29.5	**60.2**	**86.6**	**120**	**158**	**191**	**236**	**275**	**389**	**505**	**593**	**706**	**796**
	Water Surface Elevation (m) - Battle River												
5600	800.22	800.96	801.24	801.5	801.73	801.91	802.12	802.29	802.71	803.06	803.28	803.55	803.74
5500	800.19	800.93	801.22	801.47	801.7	801.88	802.09	802.25	802.66	803	803.22	803.48	803.67
5400	800.17	800.91	801.19	801.44	801.67	801.84	802.05	802.21	802.61	802.94	803.16	803.41	803.59
5300	800.16	800.89	801.17	801.41	801.64	801.8	802	802.16	802.55	802.87	803.08	803.32	803.5
5200	800.14	800.87	801.15	801.39	801.61	801.78	801.97	802.13	802.51	802.83	803.03	803.27	803.44
5100	800.13	800.85	801.14	801.38	801.59	801.76	801.95	802.1	802.48	802.79	802.99	803.22	803.39
5000	800.11	800.84	801.12	801.36	801.58	801.74	801.93	802.08	802.46	802.76	802.96	803.19	803.35
4900	800.1	800.83	801.11	801.35	801.56	801.72	801.91	802.06	802.43	802.73	802.92	803.14	803.31
4800	800.08	800.81	801.09	801.33	801.53	801.69	801.87	802.02	802.37	802.67	802.85	803.06	803.22
4700	800.05	800.79	801.07	801.3	801.5	801.65	801.83	801.97	802.31	802.59	802.77	802.97	803.12
4600	800.02	800.77	801.05	801.27	801.47	801.61	801.79	801.92	802.26	802.53	802.71	802.9	803.05
4500	799.99	800.75	801.04	801.26	801.46	801.61	801.78	801.92	802.25	802.53	802.7	802.9	803.04
4400	799.97	800.72	801.01	801.24	801.44	801.58	801.76	801.89	802.22	802.5	802.67	802.86	803
4300	799.94	800.69	800.98	801.21	801.4	801.54	801.71	801.85	802.17	802.44	802.6	802.79	802.92
4200	799.92	800.66	800.96	801.18	801.37	801.51	801.68	801.8	802.12	802.38	802.54	802.72	802.84
4100	799.9	800.64	800.94	801.15	801.34	801.48	801.64	801.76	802.07	802.32	802.47	802.64	802.76
4000	799.88	800.62	800.92	801.13	801.32	801.45	801.61	801.73	802.02	802.27	802.41	802.57	802.69
3900	799.86	800.6	800.9	801.11	801.29	801.42	801.58	801.69	801.98	802.22	802.36	802.51	802.61
3800	799.83	800.57	800.88	801.09	801.27	801.4	801.55	801.67	801.95	802.18	802.32	802.46	802.57
3700	799.81	800.55	800.86	801.07	801.25	801.38	801.53	801.65	801.93	802.16	802.29	802.43	802.54
3600	799.79	800.52	800.82	801.03	801.21	801.34	801.49	801.61	801.89	802.11	802.24	802.38	802.48
3500	799.77	800.49	800.8	801.01	801.19	801.32	801.47	801.58	801.86	802.08	802.2	802.33	802.43
3400	799.75	800.46	800.78	800.99	801.17	801.3	801.45	801.56	801.83	802.05	802.17	802.3	802.39
3300	799.72	800.43	800.76	800.98	801.16	801.29	801.43	801.55	801.82	802.04	802.16	802.28	802.37
3200	799.69	800.39	800.73	800.95	801.13	801.25	801.4	801.51	801.78	801.99	802.11	802.23	802.32
3100	799.66	800.36	800.7	800.92	801.09	801.21	801.35	801.46	801.72	801.92	802.04	802.15	802.24
3000	799.6	800.29	800.64	800.85	801.02	801.13	801.26	801.36	801.61	801.8	801.91	802.02	802.1
2900	799.41	800.15	800.53	800.72	800.87	800.97	801.09	801.18	801.4	801.58	801.67	801.78	801.85
2800	799.37	800.1	800.47	800.64	800.77	800.85	800.95	801.02	801.21	801.36	801.45	801.54	801.61
2700	799.33	800.05	800.4	800.56	800.66	800.73	800.81	800.87	801.03	801.16	801.24	801.33	801.4
2600	799.29	799.99	800.33	800.46	800.55	800.6	800.67	800.72	800.85	800.97	801.04	801.13	801.2
2500	799.23	799.92	800.25	800.37	800.44	800.5	800.56	800.61	800.73	800.83	800.9	800.98	801.05
2400	799.12	799.8	800.12	800.23	800.3	800.36	800.42	800.47	800.6	800.7	800.76	800.85	800.91
2300	799	799.68	799.97	800.08	800.16	800.23	800.32	800.38	800.5	800.61	800.67	800.76	800.84

River Station (m)	Flood Return Period and Discharge (m^3/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**	**1000-year**
	29.5	**60.2**	**86.6**	**120**	**158**	**191**	**236**	**275**	**389**	**505**	**593**	**706**	**796**
	Water Surface Elevation (m) - Battle River												
2200	798.91	799.57	799.85	799.95	800.04	800.13	800.22	800.29	800.41	800.51	800.58	800.68	800.76
2100	798.83	799.48	799.74	799.85	799.96	800.05	800.14	800.2	800.32	800.42	800.5	800.61	800.71
2000	798.73	799.36	799.6	799.74	799.87	799.96	800.05	800.11	800.24	800.35	800.44	800.56	800.67
1900	798.62	799.24	799.49	799.64	799.78	799.87	799.96	800.02	800.16	800.29	800.39	800.53	800.64
1800	798.48	799.11	799.34	799.48	799.62	799.7	799.79	799.86	800.02	800.17	800.3	800.46	800.58
1700	798.36	798.99	799.22	799.35	799.47	799.55	799.65	799.72	799.91	800.09	800.23	800.4	800.53
1600	798.24	798.89	799.12	799.26	799.38	799.46	799.57	799.65	799.86	800.06	800.2	800.38	800.51
1500	798.16	798.82	799.07	799.22	799.35	799.44	799.55	799.64	799.86	800.07	800.22	800.4	800.53
1400	798.06	798.72	799	799.18	799.32	799.43	799.55	799.64	799.87	800.08	800.24	800.43	800.56
1300	797.94	798.62	798.93	799.13	799.28	799.39	799.51	799.61	799.85	800.07	800.23	800.41	800.55
1200	797.81	798.52	798.85	799.06	799.22	799.33	799.46	799.56	799.81	800.03	800.19	800.38	800.51
1100	797.71	798.43	798.76	798.99	799.16	799.27	799.4	799.49	799.74	799.97	800.13	800.32	800.46
1000	797.62	798.33	798.66	798.89	799.06	799.17	799.29	799.38	799.63	799.85	800.02	800.22	800.36
900	797.53	798.23	798.57	798.8	798.95	799.06	799.17	799.26	799.51	799.73	799.9	800.1	800.24
800	797.45	798.14	798.47	798.7	798.84	798.93	799.05	799.14	799.38	799.6	799.78	799.99	800.14
700	797.32	798	798.34	798.57	798.72	798.81	798.94	799.04	799.29	799.53	799.71	799.93	800.08
600	797.21	797.9	798.24	798.49	798.64	798.74	798.88	798.98	799.25	799.49	799.68	799.9	800.05
500	797.14	797.81	798.14	798.38	798.54	798.66	798.81	798.92	799.2	799.44	799.63	799.86	800.01
400	797.04	797.71	798.01	798.25	798.45	798.59	798.77	798.88	799.16	799.4	799.59	799.82	799.97
300	796.98	797.66	797.96	798.21	798.42	798.57	798.74	798.85	799.13	799.37	799.56	799.79	799.94
200	796.94	797.62	797.92	798.17	798.38	798.53	798.7	798.82	799.08	799.32	799.51	799.74	799.89
100	796.88	797.54	797.85	798.1	798.31	798.46	798.64	798.75	799.01	799.23	799.43	799.66	799.81
0	796.81	797.47	797.77	798	798.19	798.33	798.49	798.58	798.82	799.02	799.2	799.42	799.56

River Station (m)	Flood Return Period and Discharge (m^3/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**	**1000-year**
	0.55	**1.45**	**2.24**	**3.07**	**3.78**	**4.23**	**4.75**	**5.11**	**6.02**	**6.78**	**7.24**	**7.79**	**8.17**
	Water Surface Elevation (m) - Unnamed Tributary												
4843.4	808.06	808.23	808.34	808.42	808.48	808.51	808.55	808.58	808.64	808.69	808.71	808.75	808.77
4800	808.05	808.22	808.3	808.36	808.4	808.43	808.45	808.47	808.51	808.54	808.55	808.57	808.58
4700	807.77	807.96	808.05	808.12	808.16	808.19	808.22	808.24	808.28	808.32	808.34	808.36	808.37
4600	807.57	807.71	807.82	807.91	807.97	808.01	808.04	808.07	808.12	808.15	808.17	808.19	808.21
4500	807.32	807.57	807.73	807.84	807.92	807.96	808	808.03	808.07	808.11	808.13	808.15	808.16
4400	807.09	807.36	807.52	807.64	807.7	807.73	807.76	807.77	807.8	807.82	807.83	807.84	807.85
4300	806.76	806.93	807.03	807.1	807.16	807.2	807.24	807.26	807.32	807.36	807.39	807.42	807.44
4200	806.62	806.78	806.88	806.97	807.04	807.08	807.13	807.15	807.22	807.27	807.29	807.32	807.34
4100	806.4	806.62	806.74	806.85	806.92	806.96	807.01	807.04	807.1	807.16	807.18	807.21	807.24
4000	806.34	806.55	806.67	806.76	806.84	806.87	806.92	806.95	807.01	807.06	807.09	807.12	807.14
3900	806.32	806.5	806.61	806.69	806.75	806.79	806.82	806.85	806.91	806.96	806.98	807.01	807.03
3800	805.95	806.21	806.36	806.46	806.54	806.58	806.63	806.66	806.73	806.79	806.81	806.84	806.87
3700	805.92	806.17	806.31	806.4	806.47	806.51	806.55	806.57	806.64	806.68	806.7	806.73	806.75
3600	805.91	806.14	806.26	806.34	806.38	806.4	806.42	806.44	806.47	806.49	806.5	806.52	806.53
3500	805.88	806.07	806.16	806.22	806.26	806.28	806.3	806.32	806.35	806.37	806.38	806.4	806.41
3400	805.78	805.94	806.04	806.1	806.15	806.17	806.19	806.21	806.24	806.27	806.28	806.3	806.33
3300	805.59	805.75	805.84	805.9	805.95	805.98	806.01	806.03	806.08	806.11	806.13	806.17	806.21
3200	805.58	805.72	805.8	805.85	805.89	805.91	805.94	805.95	805.99	806.02	806.03	806.06	806.12
3100	805.45	805.57	805.63	805.67	805.7	805.72	805.74	805.75	805.78	805.8	805.82	805.89	806.02
3000	805.15	805.27	805.34	805.4	805.44	805.46	805.49	805.51	805.55	805.58	805.63	805.81	805.99
2900	804.97	805.1	805.18	805.25	805.29	805.32	805.34	805.36	805.4	805.44	805.53	805.78	805.98
2800	804.8	804.92	804.99	805.06	805.11	805.14	805.17	805.19	805.24	805.29	805.47	805.77	805.97
2700	804.68	804.8	804.88	804.95	805	805.03	805.06	805.09	805.14	805.21	805.44	805.76	805.97
2600	804.48	804.63	804.71	804.79	804.85	804.88	804.92	804.94	805	805.1	805.41	805.75	805.97
2500	804.38	804.53	804.63	804.7	804.76	804.79	804.83	804.85	804.9	805.03	805.39	805.75	805.96
2400	804.27	804.42	804.51	804.59	804.65	804.68	804.72	804.74	804.8	804.98	805.38	805.75	805.96
2300	804.17	804.32	804.41	804.49	804.55	804.58	804.62	804.64	804.7	804.94	805.38	805.75	805.96
2200	804.1	804.24	804.33	804.4	804.45	804.48	804.52	804.54	804.61	804.91	805.38	805.74	805.96
2100	804.08	804.21	804.28	804.35	804.39	804.42	804.45	804.47	804.55	804.9	805.38	805.74	805.96
2000	804.08	804.19	804.26	804.32	804.36	804.39	804.42	804.44	804.51	804.89	805.37	805.74	805.96
1900	804.08	804.19	804.26	804.31	804.35	804.37	804.4	804.42	804.49	804.89	805.37	805.74	805.96
1800	804.08	804.19	804.25	804.3	804.34	804.36	804.39	804.41	804.48	804.88	805.37	805.74	805.96
1700	804.08	804.18	804.25	804.3	804.33	804.36	804.38	804.4	804.47	804.88	805.37	805.74	805.96
1600	804.07	804.18	804.24	804.29	804.32	804.34	804.37	804.38	804.46	804.88	805.37	805.74	805.96

River Station (m)	Flood Return Period and Discharge (m^3/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**	**1000-year**
	0.55	**1.45**	**2.24**	**3.07**	**3.78**	**4.23**	**4.75**	**5.11**	**6.02**	**6.78**	**7.24**	**7.79**	**8.17**
	Water Surface Elevation (m) - Unnamed Tributary												
1500	803.47	803.52	803.57	803.63	803.69	803.74	803.84	803.98	804.41	804.88	805.37	805.74	805.96
1400	802.96	803.04	803.19	803.33	803.46	803.55	803.71	803.91	804.4	804.88	805.37	805.74	805.96
1300	802.45	802.76	802.98	803.17	803.33	803.46	803.67	803.89	804.4	804.87	805.37	805.74	805.96
1200	802.38	802.66	802.88	803.07	803.25	803.42	803.66	803.89	804.4	804.87	805.37	805.74	805.96
1100	801.85	802.33	802.67	802.96	803.2	803.39	803.65	803.88	804.4	804.87	805.37	805.74	805.96
1000	801.54	802.26	802.61	802.93	803.19	803.38	803.64	803.88	804.4	804.87	805.37	805.74	805.95
900	801.42	802.23	802.59	802.92	803.18	803.38	803.64	803.88	804.4	804.87	805.37	805.74	805.95
800	801.38	802.21	802.58	802.91	803.18	803.38	803.64	803.88	804.4	804.87	805.37	805.74	805.95
700	801.37	802.21	802.58	802.91	803.18	803.38	803.64	803.88	804.4	804.87	805.37	805.73	805.95
600	801.36	802.21	802.58	802.91	803.18	803.38	803.64	803.88	804.4	804.87	805.37	805.73	805.94
500	801.36	802.21	802.58	802.91	803.18	803.38	803.64	803.88	804.4	804.87	805.36	805.73	805.94
400	801.35	802.21	802.58	802.91	803.18	803.38	803.64	803.88	804.39	804.87	805.36	805.73	805.94
300	801.35	802.21	802.58	802.91	803.18	803.37	803.63	803.87	804.39	804.86	805.36	805.72	805.93
200	801.35	802.21	802.58	802.91	803.18	803.37	803.63	803.87	804.38	804.86	805.35	805.71	805.92
100	801.34	802.21	802.58	802.91	803.17	803.37	803.62	803.86	804.37	804.85	805.34	805.71	805.91

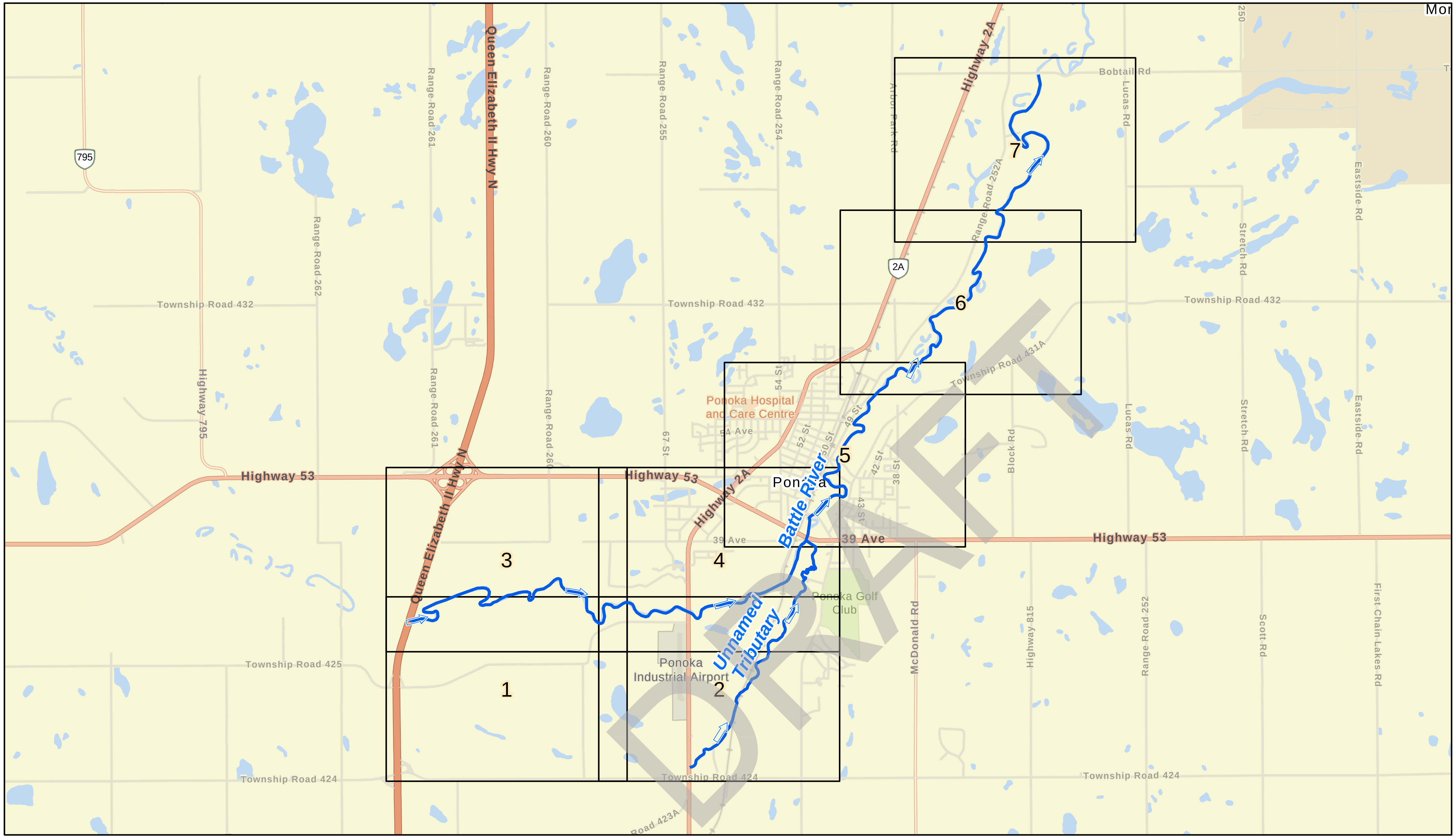
APPENDIX H

OPEN WATER FLOOD INUNDATION MAP LIBRARY

Provided under separate cover.

APPENDIX I

FLOODWAY CRITERIA MAP



Alberta **Canada**

nhc

STUDY REACH
FLOW DIRECTION
MAP SHEET

SCALE - 1:60,000
0 0.5 1 2 KM
N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	JY/DJH	RBA

Job Number	Date
1008017	01-MAR-2025

PONOKA FLOOD STUDY

INDEX MAP

INDEX MAP

Notes to Users:

1. Please refer to the accompanying Ponoka Flood Study Main Report for important information concerning these maps.
2. Within the flood inundation areas shown on this map, there may be isolated pockets of high ground. To determine whether or not a particular site is subject to flooding, reference should be made to the computed flood levels in conjunction with site-specific surveys where detailed definition is required.
3. Non-riverine and local sources of water have not been considered, and structures such roads, railways or barriers such as levees can restrict water flow and affect local flood levels. Channel obstruction, local stormwater inflow, groundwater seepage or other land drainage can cause flood levels to exceed those indicated on the map. Lands adjacent to a flooded area may be subject to flooding from tributary streams not indicated on the maps.
4. The flood inundation area is shown above the line work for bridges that are below flood levels.

Definitions:

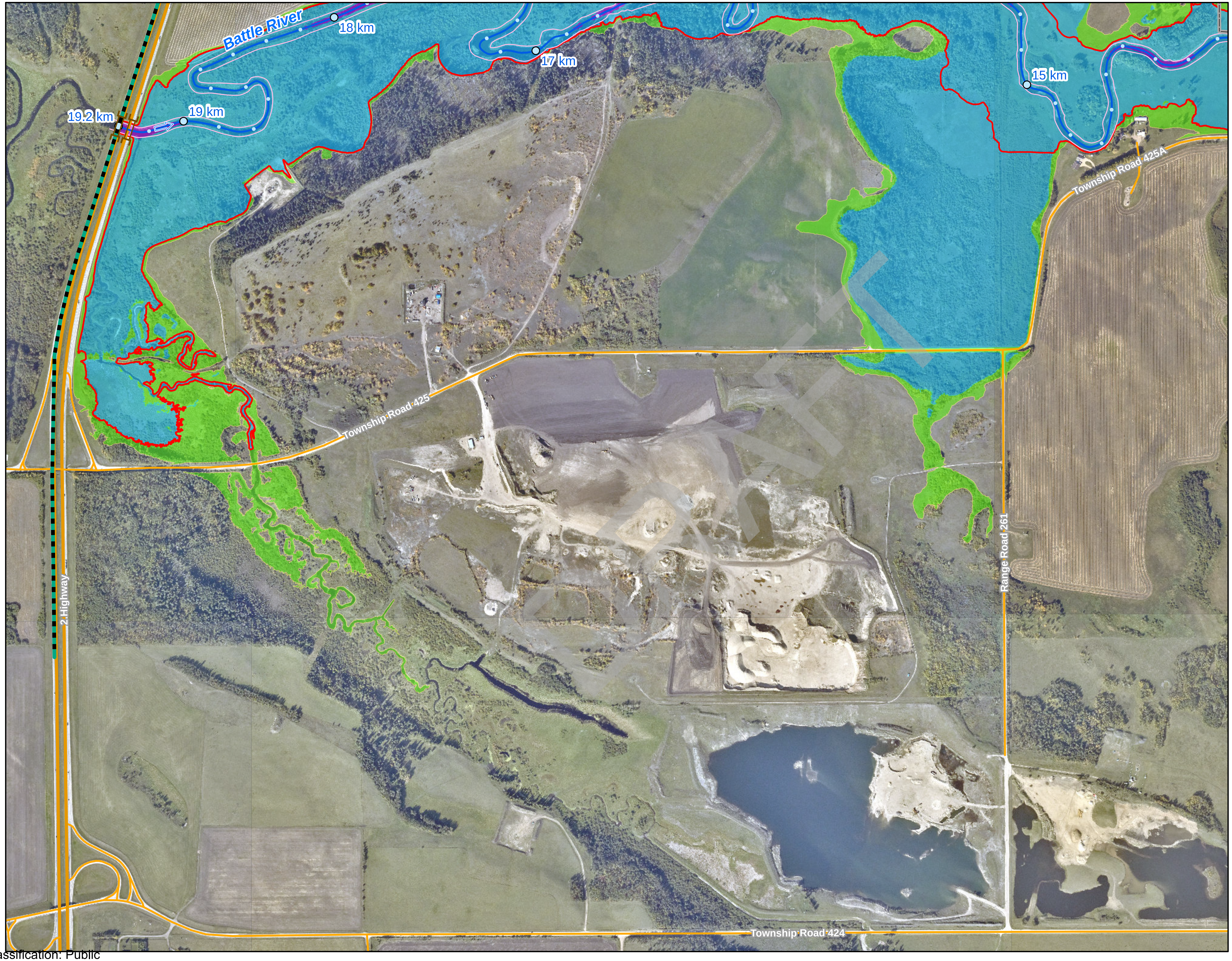
1. **Flood Inundation Mapping** - Delineates flood inundation areas, showing the extent of one or more flood scenarios under existing conditions. Depending on the particular flood scenario, the mapping may be divided into multiple zones. Flood inundation mapping is typically used for near real-time emergency response planning and operations.
2. **Flood Inundation Area** - The area inundated during a particular flood scenario under existing conditions. The flood inundation area may be divided into multiple zones, including isolated areas that may become inundated due to groundwater seepage or other subsurface connections. Flood inundation areas may change as a result of future development or flow obstructions.
3. **Flood Scenario** - Flow conditions that describe a particular flood event. Flood scenarios typically represent a range of flows, based either on flood frequency analysis or set flow intervals. The flood scenarios included with this map set include the 2-year, 5-year, 10-year, 20-year, 35-year, 50-year, 75-year, 100-year, 200-year, 350-year, 500-year, 750-year, and 1000-year flood events.

Data Sources and References:

1. Orthophoto imagery acquired by OGL Engineering on 2023-09-14 for Alberta Environment and Protected Areas: *Project Number 2023-503; Contract Number 21STR800-03.*
2. Base data from Natural Resources Canada, Alberta Environment and Parks, and Altalis. Additional background base mapping from Esri.

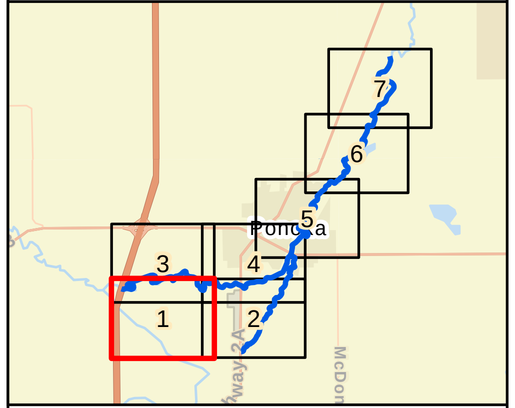
DJH, P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\500 Hazard Mapping\1008017_DJH_FWC_FINAL.aprx

SHEET 3



Alberta Canada

nhc



MAJOR HIGHWAY
LOCAL ROAD
RAILWAY
BRIDGE
CULVERT
FLOOD BERM
TOWN OF PONOKA
STUDY BOUNDARY
RIVER CENTRE LINE
FLOW DIRECTION
CHANNEL BANKS
PREVIOUS FLOODWAY
VELOCITY >= 1 m/s
DEPTH >= 1 m/s
100-YEAR FLOOD EXTENT
PROPOSED FLOODWAY LIMIT

SCALE - 1:10,000
0 100 200 M
N

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	JY/DJH	RBA

Job Number	Date
1008017	01-MAR-2025

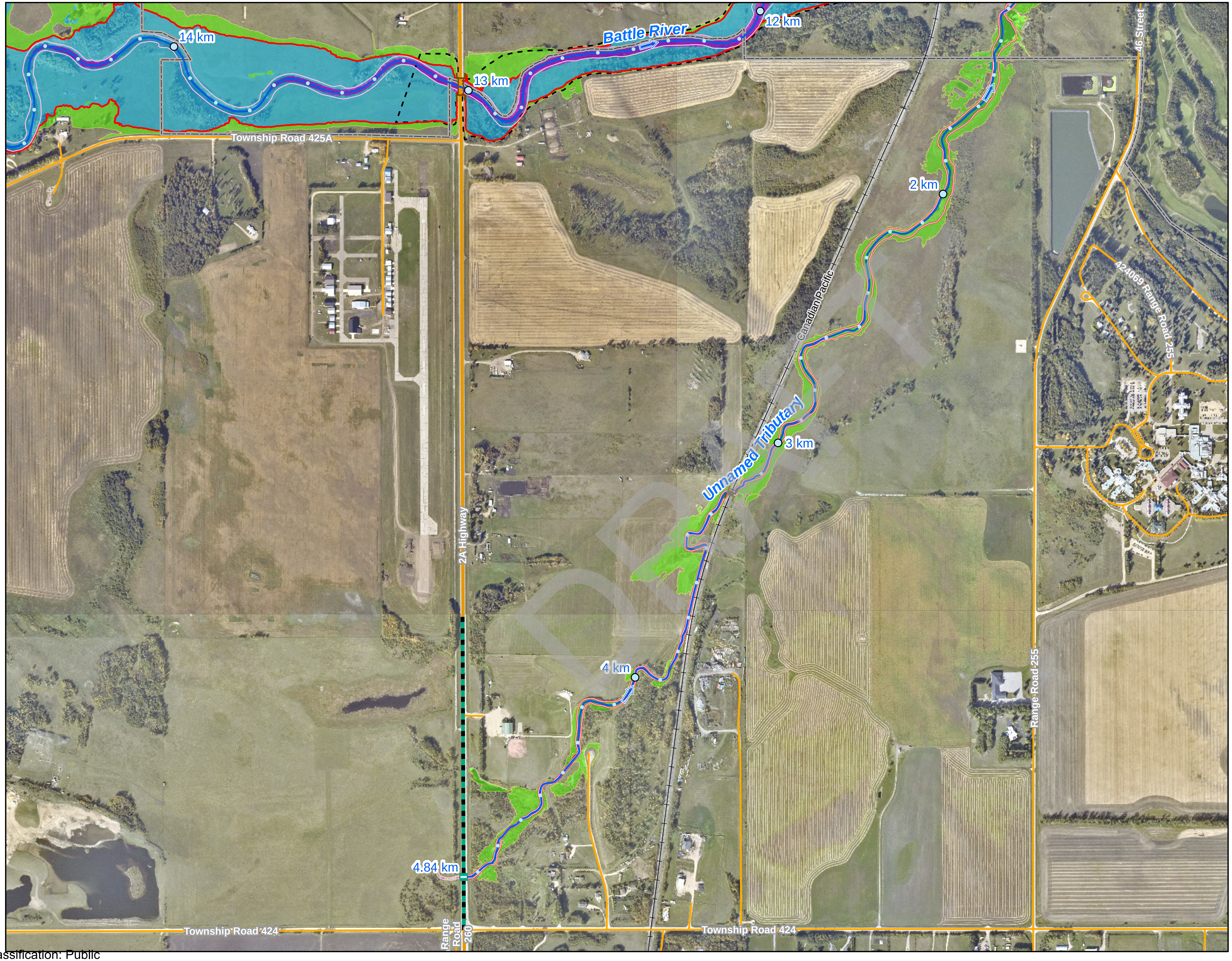
PONOKA FLOOD STUDY
FLOODWAY CRITERIA MAP

DJH, P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\500 Hazard Mapping\1008017_DJH_FWC_FINAL.aprx

Classification: Public

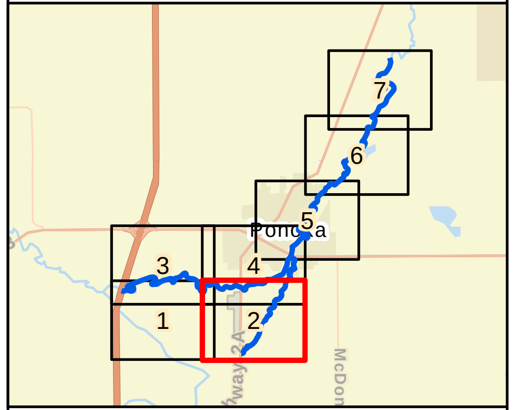
SHEET 4

SHEET 1



Alberta Canada

nhc



- MAJOR HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- FLOOD BERM
- TOWN OF PONOKA
- STUDY BOUNDARY
- RIVER CENTRE LINE
- FLOW DIRECTION
- CHANNEL BANKS
- PREVIOUS FLOODWAY
- VELOCITY >= 1 m/s
- DEPTH >= 1 m/s
- 100-YEAR FLOOD EXTENT
- PROPOSED FLOODWAY LIMIT

SCALE - 1:10,000

0 100 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	JY/DJH	RBA

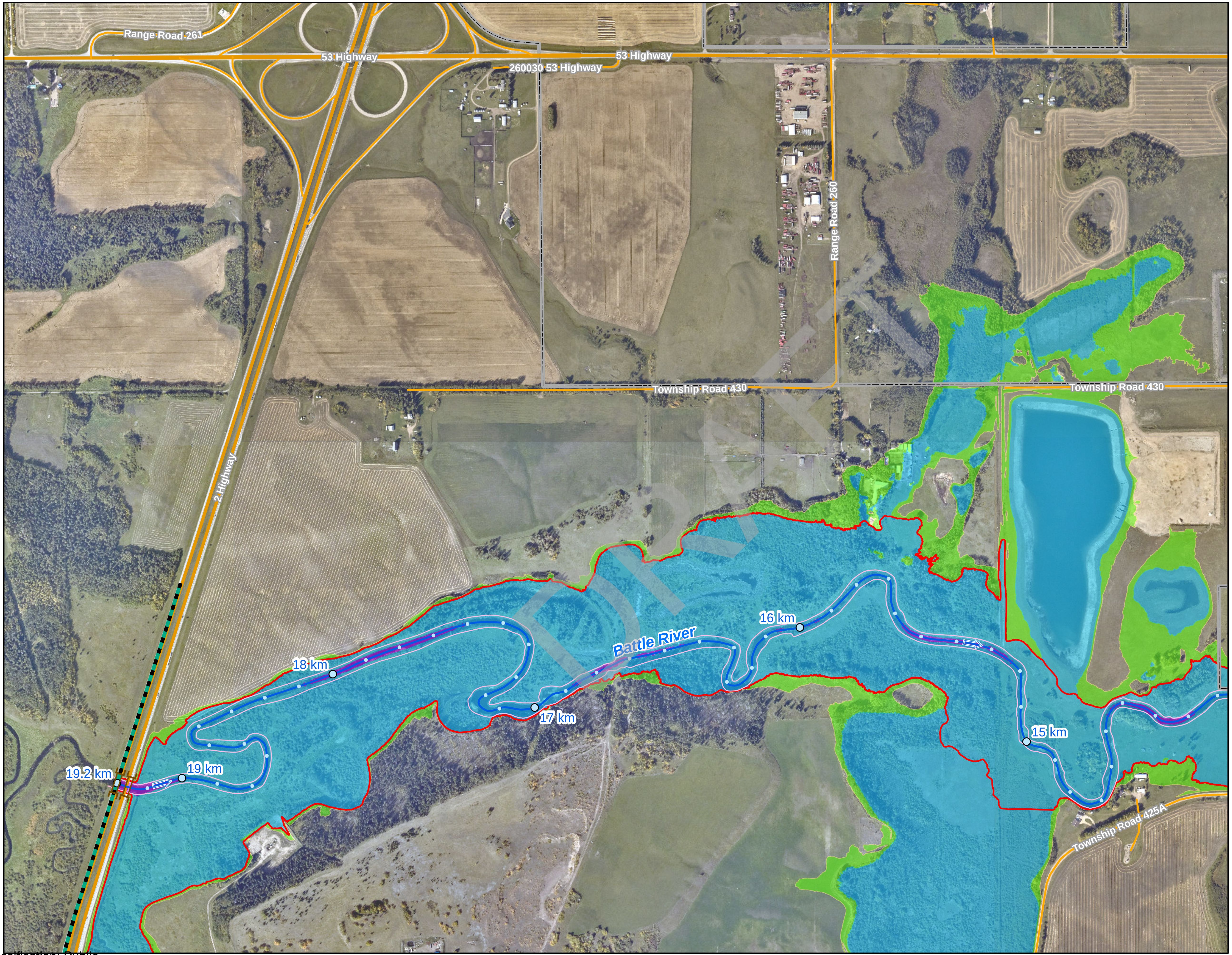
Job Number	Date
1008017	01-MAR-2025

PONOKA FLOOD STUDY
FLOODWAY CRITERIA MAP

SHEET 2 OF 7

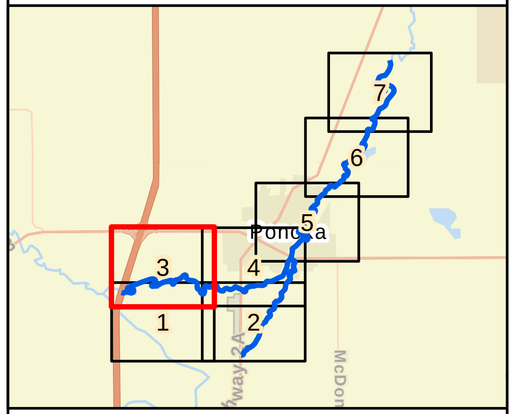
DJH, P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\500 Hazard Mapping\1008017_DJH_FWC_FINAL.aprx

Classification: Public



SHEET 1

Classification: Public



- MAJOR HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- FLOOD BERM
- TOWN OF PONOKA
- STUDY BOUNDARY
- RIVER CENTRE LINE
- FLOW DIRECTION
- CHANNEL BANKS
- PREVIOUS FLOODWAY
- VELOCITY >= 1 m/s
- DEPTH >= 1 m/s
- 100-YEAR FLOOD EXTENT
- PROPOSED FLOODWAY LIMIT

SCALE - 1:10,000

0 100 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	JY/DJH	RBA

Job Number	Date
1008017	01-MAR-2025

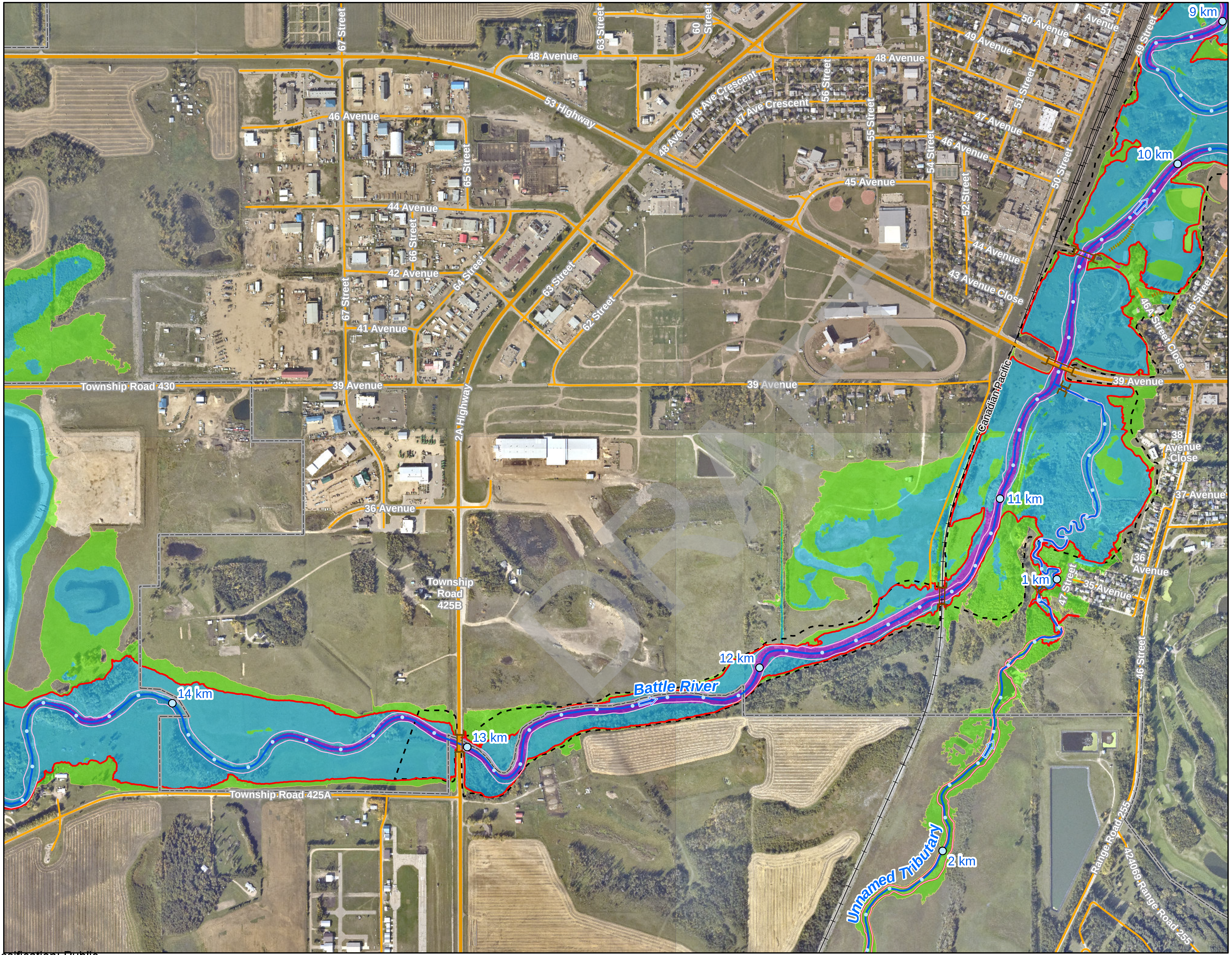
PONOKA FLOOD STUDY

FLOODWAY CRITERIA MAP

SHEET 3 OF 7

DJH, P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\500 Hazard Mapping\1008017_DJH_FWC_FINAL.aprx

SHEET 5



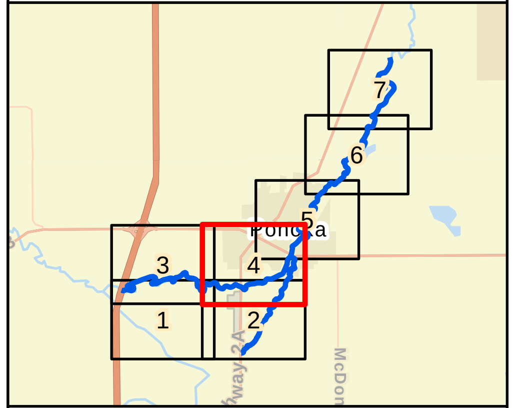
SHEET 1

SHEET 5

SHEET 2

Alberta Canada

nhc



MAJOR HIGHWAY
LOCAL ROAD
RAILWAY
BRIDGE
CULVERT
FLOOD BERM
TOWN OF PONOKA
STUDY BOUNDARY
RIVER CENTRE LINE
FLOW DIRECTION
CHANNEL BANKS
PREVIOUS FLOODWAY
VELOCITY >= 1 m/s
DEPTH >= 1 m/s
100-YEAR FLOOD EXTENT
PROPOSED FLOODWAY LIMIT

SCALE - 1:10,000
0 100 200 M
N

Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	JY/DJH	RBA

Job Number	Date
1008017	01-MAR-2025

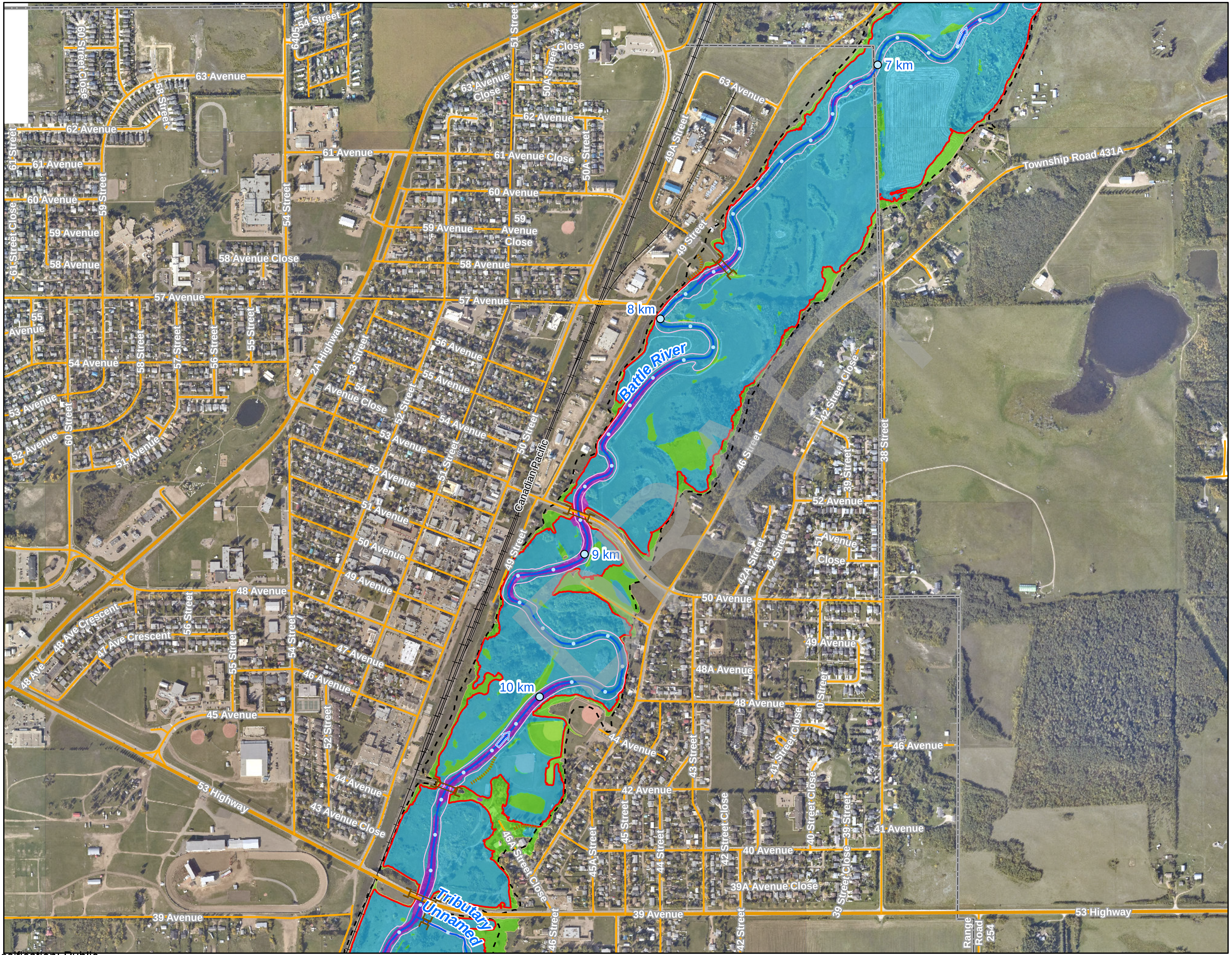
PONOKA FLOOD STUDY
FLOODWAY CRITERIA MAP

SHEET 4 OF 7

DJH, P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\500 Hazard Mapping\1008017_DJH_FWC_FINAL.aprx

SHEET 6

SHEET 4



SHEET 4

Classification: Public

Alberta Canada

nhc

- MAJOR HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- FLOOD BERM
- TOWN OF PONOKA
- STUDY BOUNDARY
- RIVER CENTRE LINE
- FLOW DIRECTION
- CHANNEL BANKS
- PREVIOUS FLOODWAY
- VELOCITY >= 1 m/s
- DEPTH >= 1 m/s
- 100-YEAR FLOOD EXTENT
- PROPOSED FLOODWAY LIMIT

SCALE - 1:10,000

0 100 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	JY/DJH	RBA

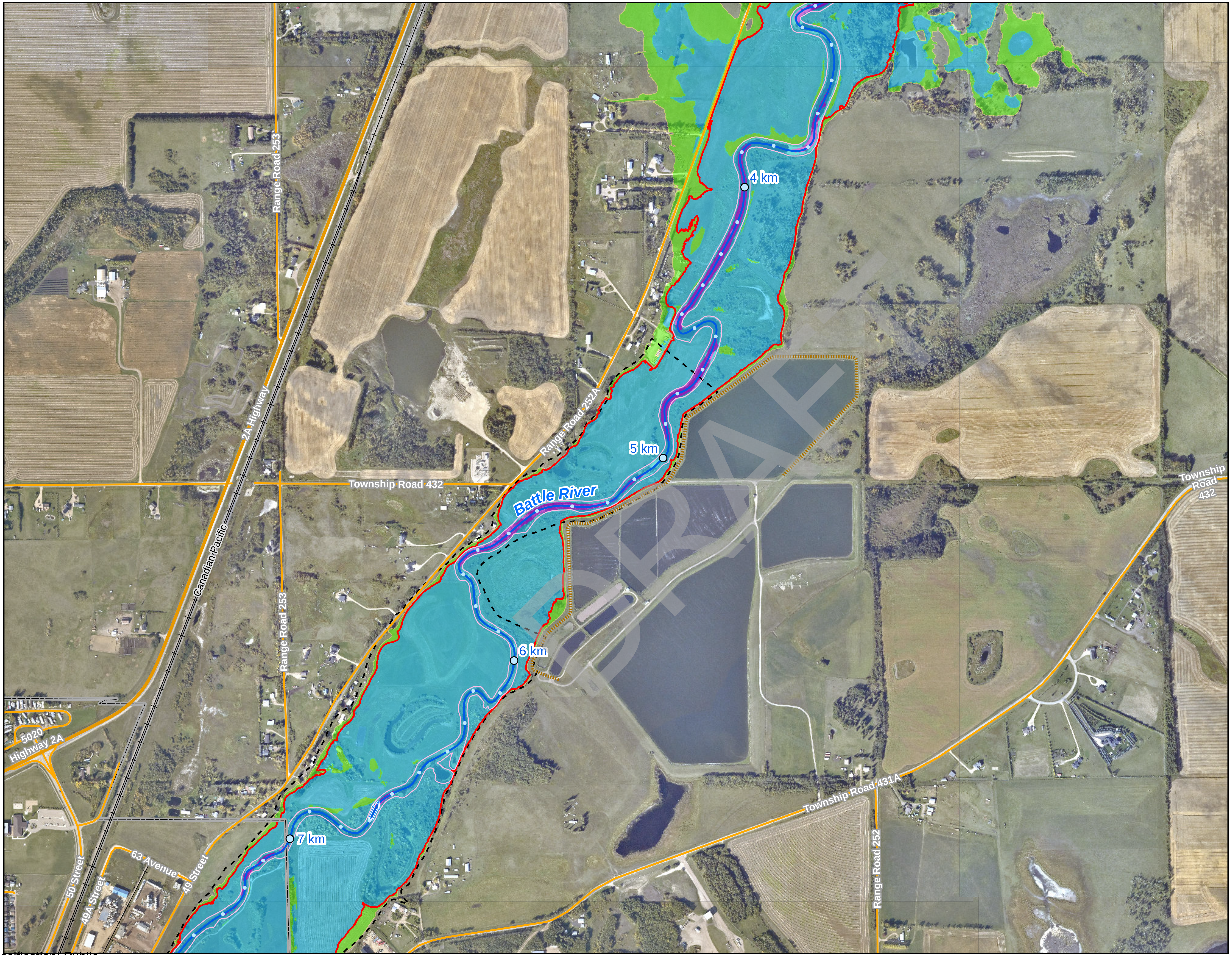
Job Number	Date
1008017	01-MAR-2025

PONOKA FLOOD STUDY
FLOODWAY CRITERIA MAP

SHEET 5 OF 7

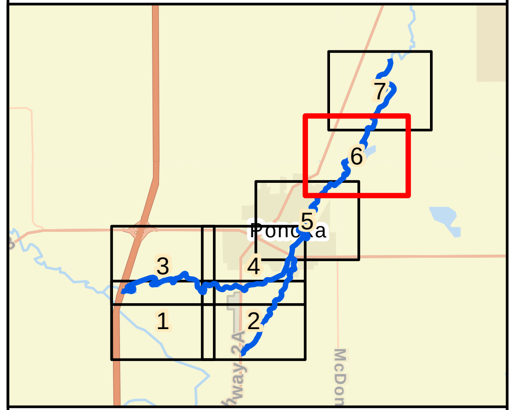
DJH_P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\500 Hazard Mapping\1008017_DJH_FWC_FINAL.aprx

SHEET 7



Alberta Canada

nhc



- MAJOR HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- FLOOD BERM
- TOWN OF PONOKA
- STUDY BOUNDARY
- RIVER CENTRE LINE
- FLOW DIRECTION
- CHANNEL BANKS
- PREVIOUS FLOODWAY
- VELOCITY >= 1 m/s
- DEPTH >= 1 m/s
- 100-YEAR FLOOD EXTENT
- PROPOSED FLOODWAY LIMIT

SCALE - 1:10,000

0 100 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

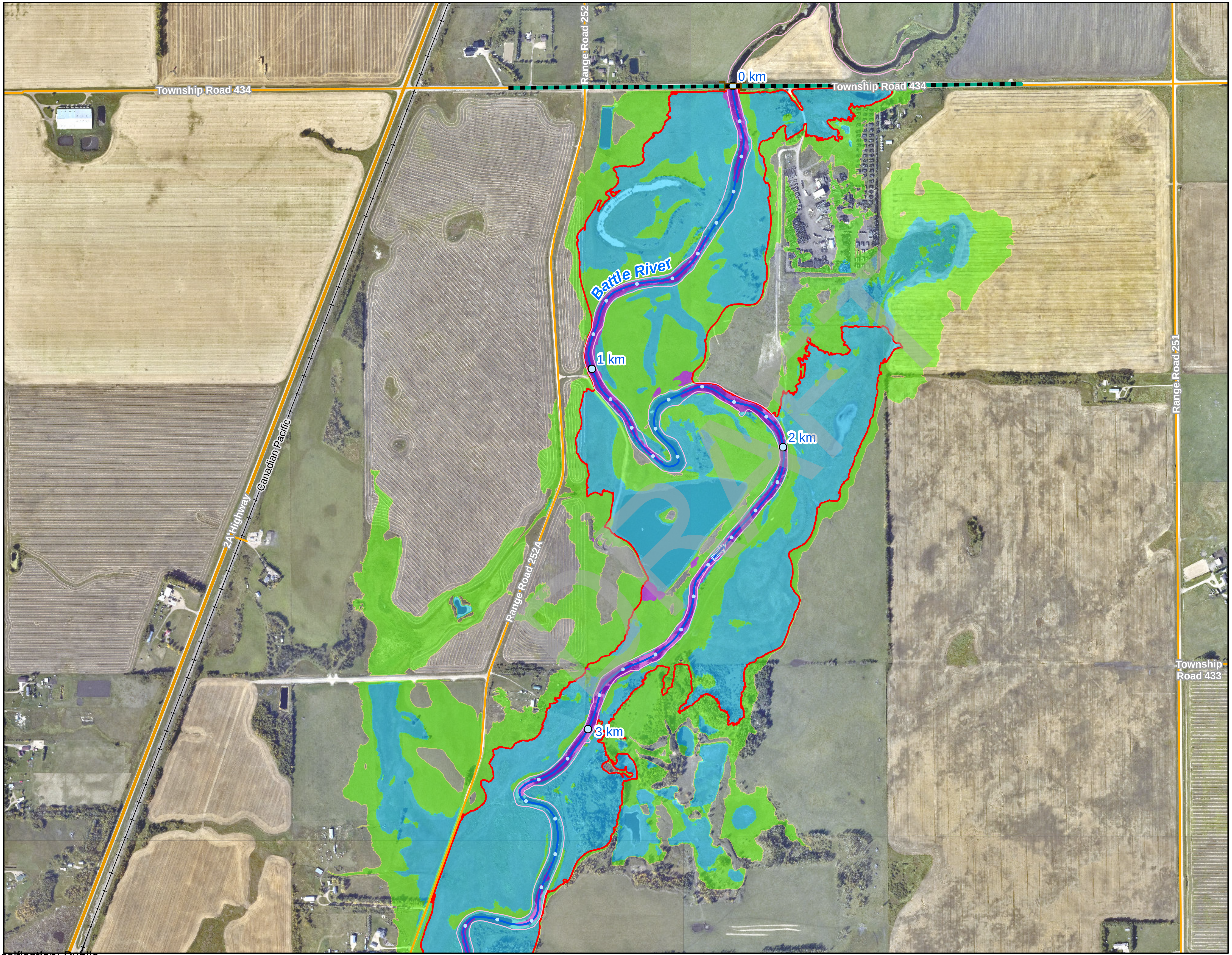
Engineer	GIS	Reviewer
DJH	JY/DJH	RBA

Job Number	Date
1008017	01-MAR-2025

PONOKA FLOOD STUDY
FLOODWAY CRITERIA MAP

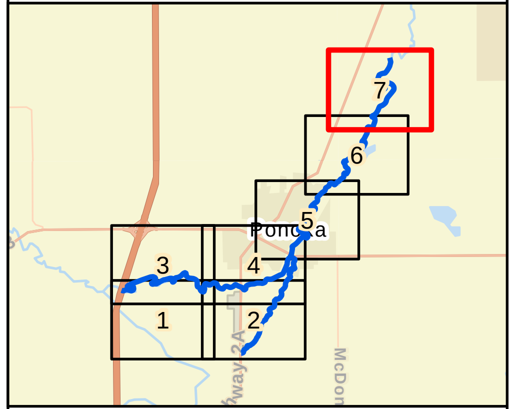
DJH, P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\500 Hazard Mapping\1008017_DJH_FWC_FINAL.aprx

SHEET 5



Alberta Canada

nhc



- MAJOR HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- FLOOD BERM
- TOWN OF PONOKA
- STUDY BOUNDARY
- RIVER CENTRE LINE
- FLOW DIRECTION
- CHANNEL BANKS
- PREVIOUS FLOODWAY
- VELOCITY >= 1 m/s
- DEPTH >= 1 m/s
- 100-YEAR FLOOD EXTENT
- PROPOSED FLOODWAY LIMIT

SCALE - 1:10,000

0 100 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	JY/DJH	RBA

Job Number	Date
1008017	01-MAR-2025

PONOKA FLOOD STUDY

FLOODWAY CRITERIA MAP

SHEET 7 OF 7

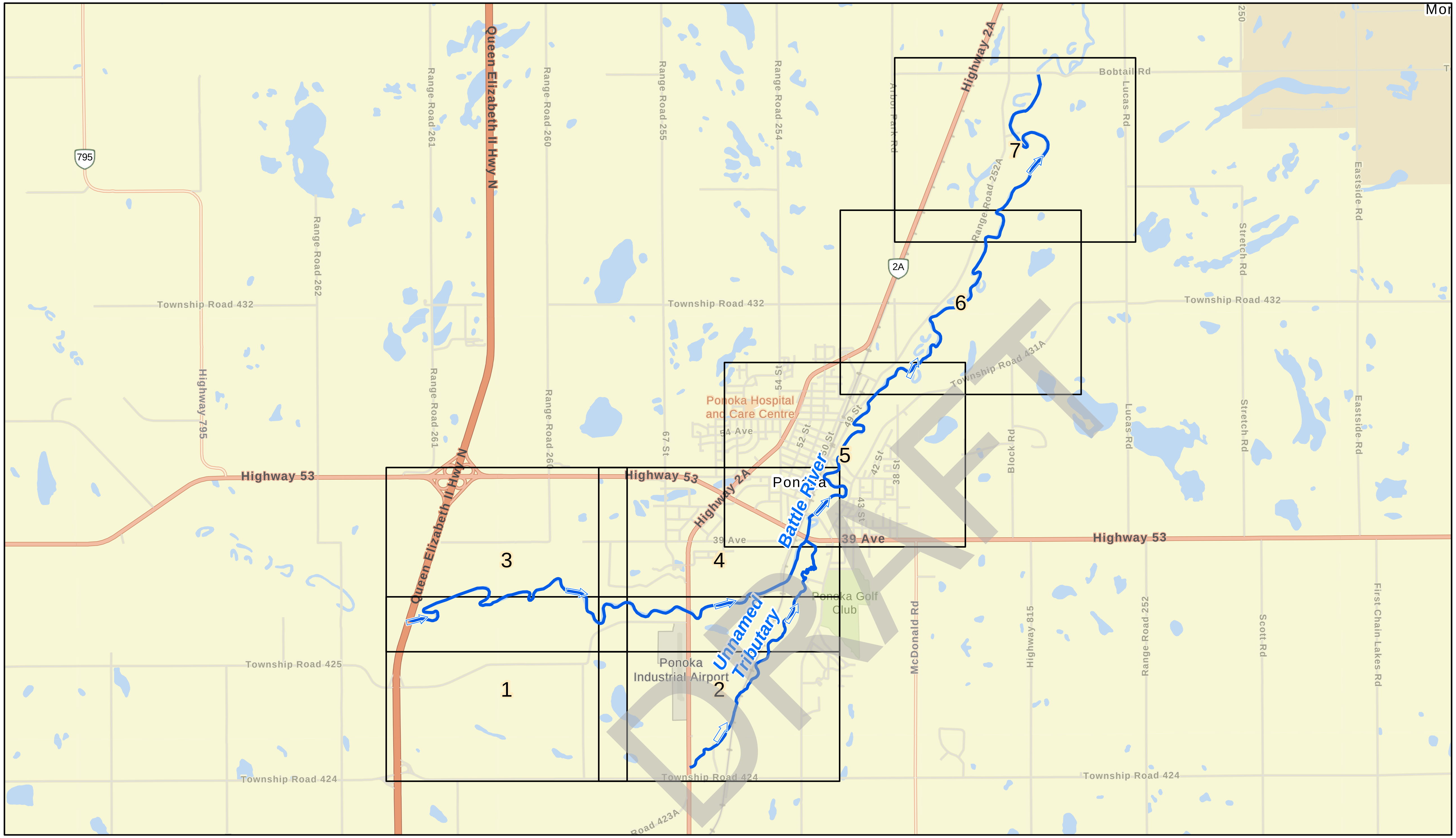
DJH, P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\500 Hazard Mapping\1008017_DJH_FWC_FINAL.aprx

Classification: Public

SHEET 6

APPENDIX J

FLOOD HAZARD MAP



Alberta Canada

nhc

STUDY REACH
FLOW DIRECTION
MAP SHEET

SCALE - 1:60,000

0 0.5 1 2 KM

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	JY/DJH	RBA

Job Number	Date
1008017	01-MAR-2025

PONOKA FLOOD STUDY

INDEX MAP

INDEX MAP

Notes to Users:

1. Please refer to the accompanying Ponoka Flood Study Main Report for important information concerning these maps.
2. Within the flood inundation areas shown on this map, there may be isolated pockets of high ground. To determine whether or not a particular site is subject to flooding, reference should be made to the computed flood levels in conjunction with site-specific surveys where detailed definition is required.
3. Non-riverine and local sources of water have not been considered, and structures such roads, railways or barriers such as levees can restrict water flow and affect local flood levels. Channel obstruction, local stormwater inflow, groundwater seepage or other land drainage can cause flood levels to exceed those indicated on the map. Lands adjacent to a flooded area may be subject to flooding from tributary streams not indicated on the maps.
4. The flood inundation area is shown above the line work for bridges that are below flood levels.

Definitions:

1. **Flood Inundation Mapping** - Delineates flood inundation areas, showing the extent of one or more flood scenarios under existing conditions. Depending on the particular flood scenario, the mapping may be divided into multiple zones. Flood inundation mapping is typically used for near real-time emergency response planning and operations.
2. **Flood Inundation Area** - The area inundated during a particular flood scenario under existing conditions. The flood inundation area may be divided into multiple zones, including isolated areas that may become inundated due to groundwater seepage or other subsurface connections. Flood inundation areas may change as a result of future development or flow obstructions.
3. **Flood Scenario** - Flow conditions that describe a particular flood event. Flood scenarios typically represent a range of flows, based either on flood frequency analysis or set flow intervals. The flood scenarios included with this map set include the 2-year, 5-year, 10-year, 20-year, 35-year, 50-year, 75-year, 100-year, 200-year, 350-year, 500-year, 750-year, and 1000-year flood events.

Data Sources and References:

1. Orthophoto imagery acquired by OGL Engineering on 2023-09-14 for Alberta Environment and Protected Areas: *Project Number 2023-503; Contract Number 21STR800-03.*
2. Base data from Natural Resources Canada, Alberta Environment and Parks, and Altalis. Additional background base mapping from Esri.

Classification: Public

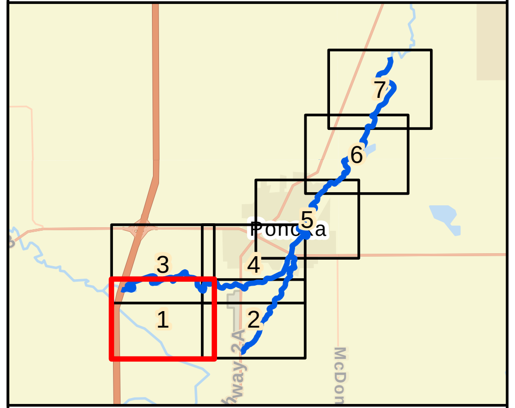
DJH, P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\500 Hazard Mapping\1008017_DJH_FWC_FINAL.aprx

SHEET 3

SHEET 2

Alberta Canada

nhc



- MAJOR HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- FLOOD BERM
- TOWN OF PONOKA
- STUDY BOUNDARY
- RIVER CENTRE LINE
- FLOW DIRECTION
- FLOODWAY
- FLOOD FRINGE
- HIGH HAZARD FLOOD FRINGE
- 200-YEAR FLOOD EXTENT
- 500-YEAR FLOOD EXTENT

SCALE - 1:10,000

0 100 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	JY/DJH	RBA

Job Number	Date
1008017	01-MAR-2025

PONOKA FLOOD STUDY

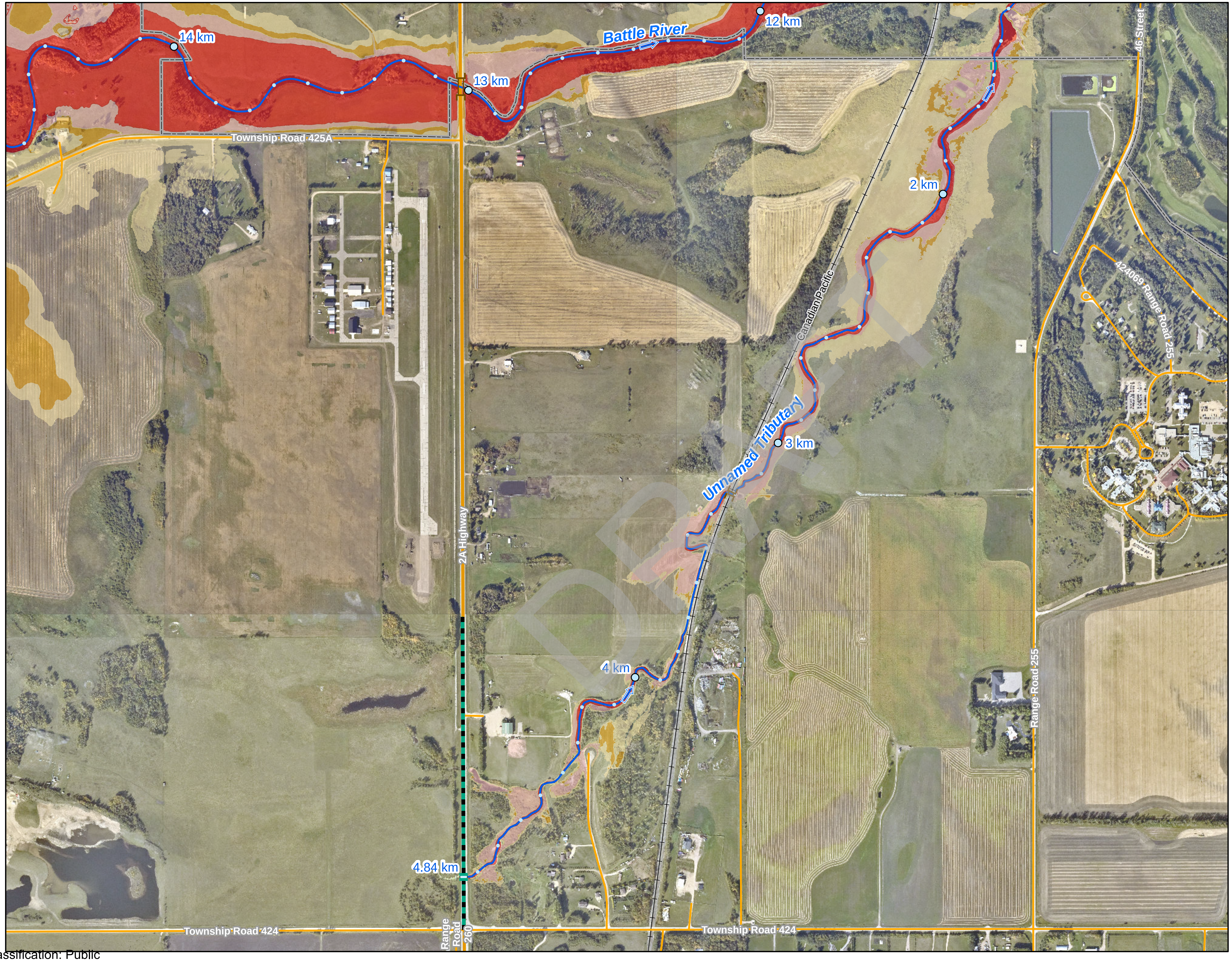
FLOOD HAZARD MAP

SHEET 1 OF 7

DJH_P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\500 Hazard Mapping\1008017_DJH_Flood_Hazard_FINAL.aprx

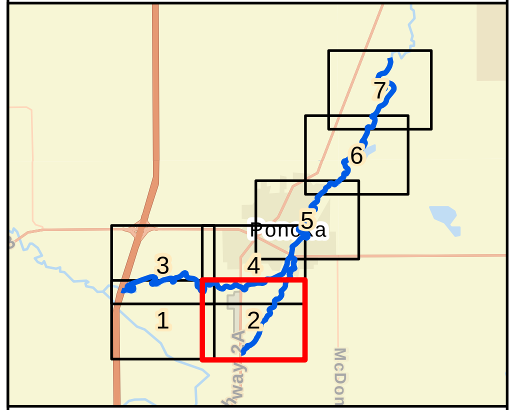
Classification: Public

SHEET 4



Alberta Canada

nhc



- MAJOR HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- FLOOD BERM
- TOWN OF PONOKA
- STUDY BOUNDARY
- RIVER CENTRE LINE
- FLOW DIRECTION
- FLOODWAY
- FLOOD FRINGE
- HIGH HAZARD FLOOD FRINGE
- 200-YEAR FLOOD EXTENT
- 500-YEAR FLOOD EXTENT

SCALE - 1:10,000

0 100 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	JY/DJH	RBA

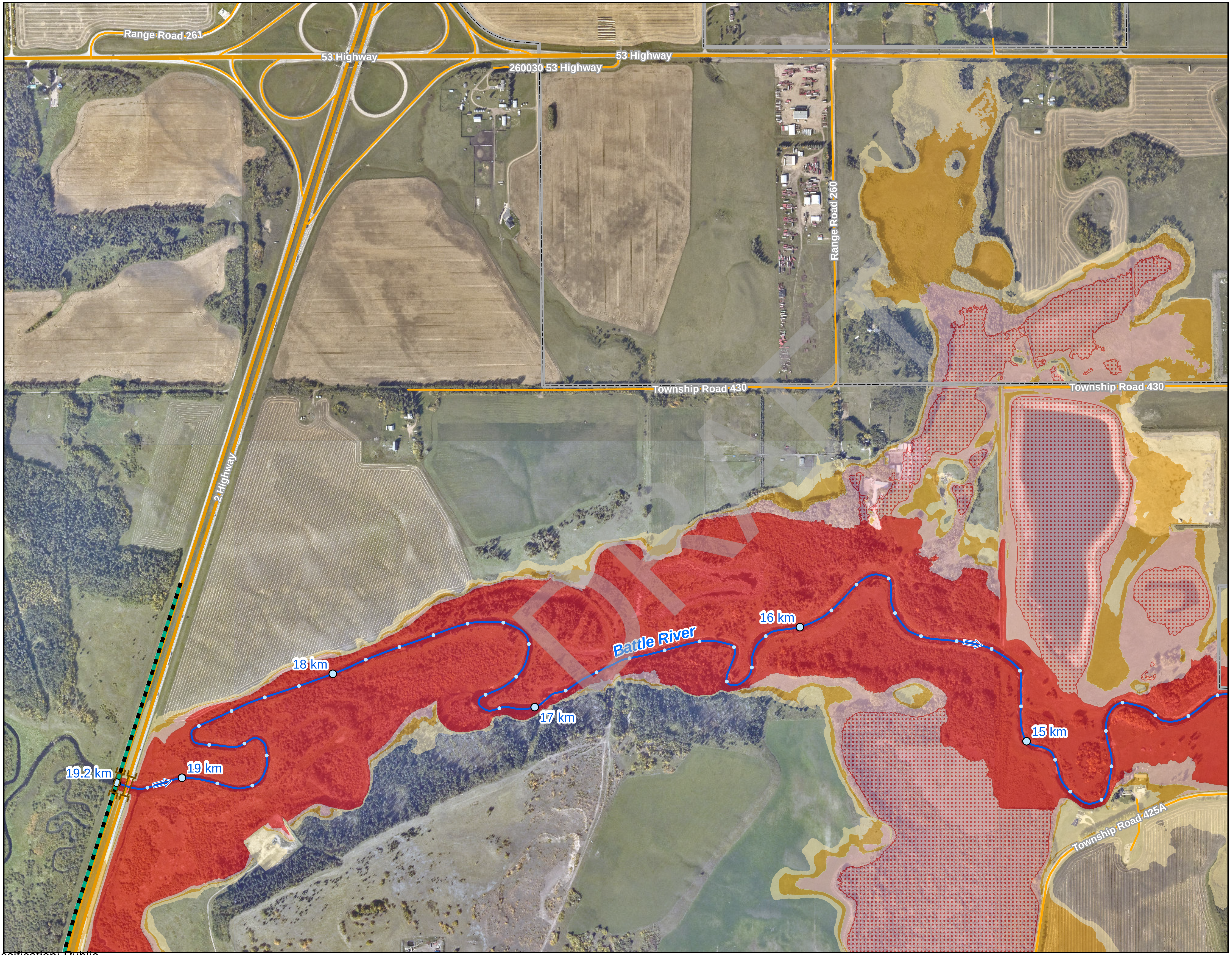
Job Number	Date
1008017	01-MAR-2025

PONOKA FLOOD STUDY
FLOOD HAZARD MAP

SHEET 2 OF 7

Classification: Public

DJH, P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\500 Hazard Mapping\1008017_DJH_Flood_Hazard_FINAL.aprx

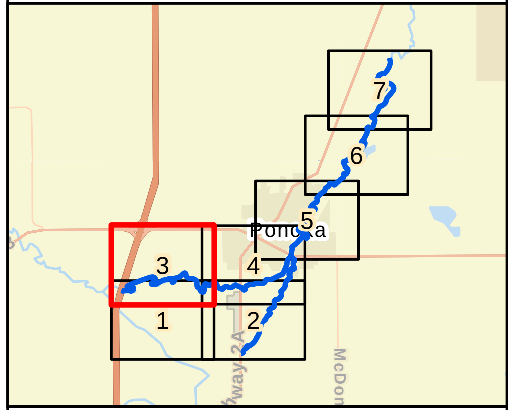


SHEET 4

SHEET 1

Alberta Canada

nhc



MAJOR HIGHWAY
LOCAL ROAD
RAILWAY
BRIDGE
CULVERT
FLOOD BERM
TOWN OF PONOKA
STUDY BOUNDARY
RIVER CENTRE LINE
FLOW DIRECTION
FLOODWAY
FLOOD FRINGE
HIGH HAZARD FLOOD FRINGE
200-YEAR FLOOD EXTENT
500-YEAR FLOOD EXTENT

SCALE - 1:10,000

0 100 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	JY/DJH	RBA

Job Number	Date
1008017	01-MAR-2025

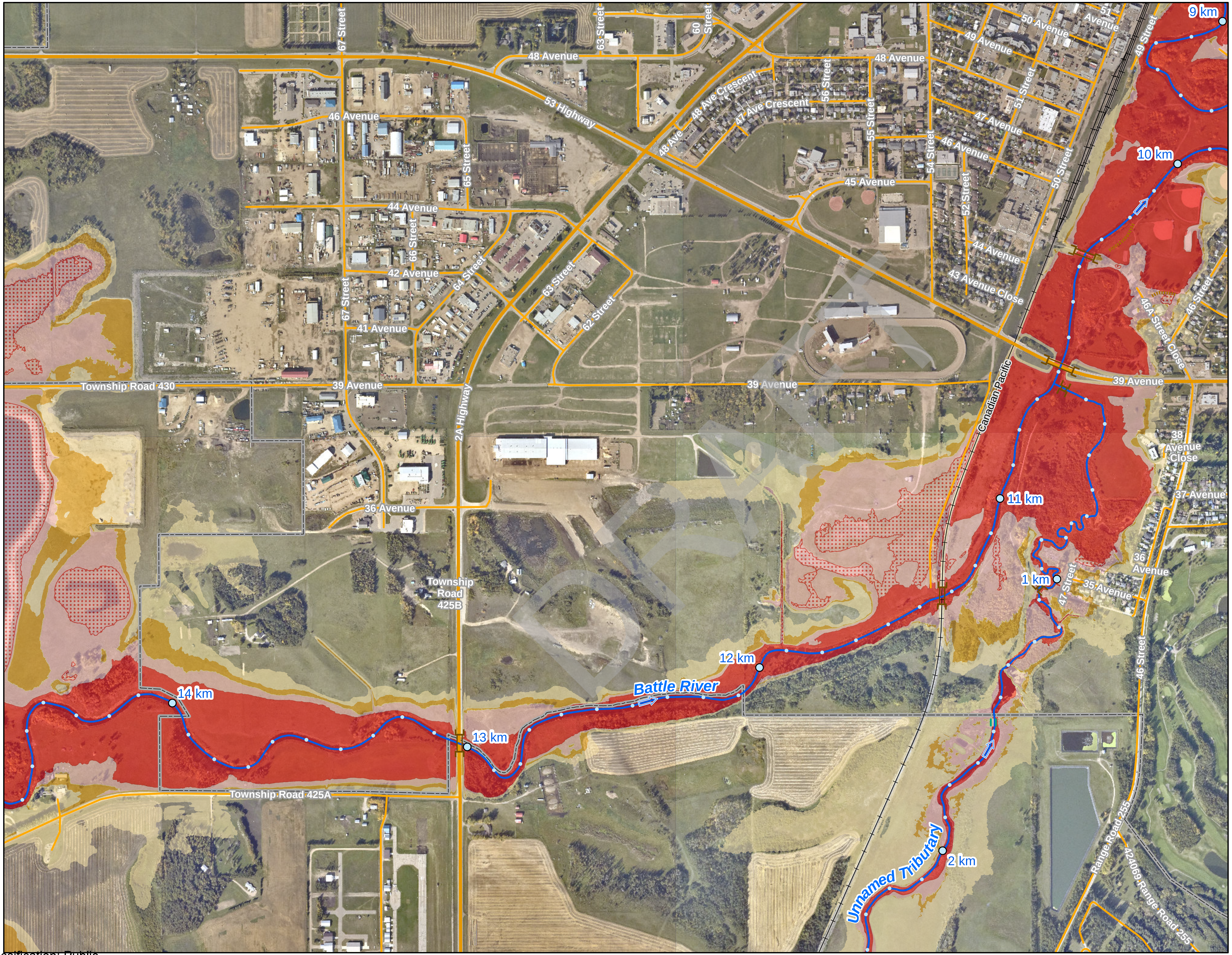
PONOKA FLOOD STUDY

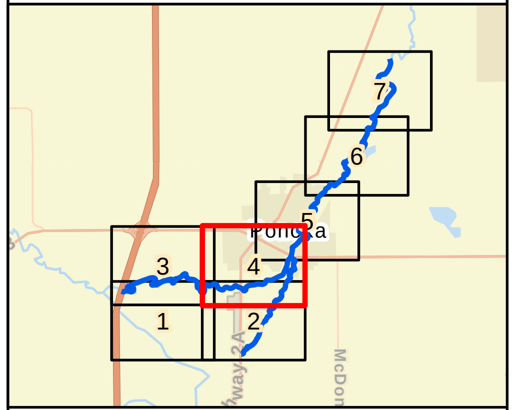
FLOOD HAZARD MAP

SHEET 3 OF 7

Classification: Public

DJH_P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\500 Hazard Mapping\1008017_DJH_Flood_Hazard_FINAL.aprx





Alberta
Canada
nhc

- MAJOR HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- FLOOD BERM
- TOWN OF PONOKA
- STUDY BOUNDARY
- RIVER CENTRE LINE
- FLOW DIRECTION
- FLOODWAY
- FLOOD FRINGE
- HIGH HAZARD FLOOD FRINGE
- 200-YEAR FLOOD EXTENT
- 500-YEAR FLOOD EXTENT

SCALE - 1:10,000
0 100 200 M
N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	JY/DJH	RBA

Job Number	Date
1008017	01-MAR-2025

PONOKA FLOOD STUDY
FLOOD HAZARD MAP

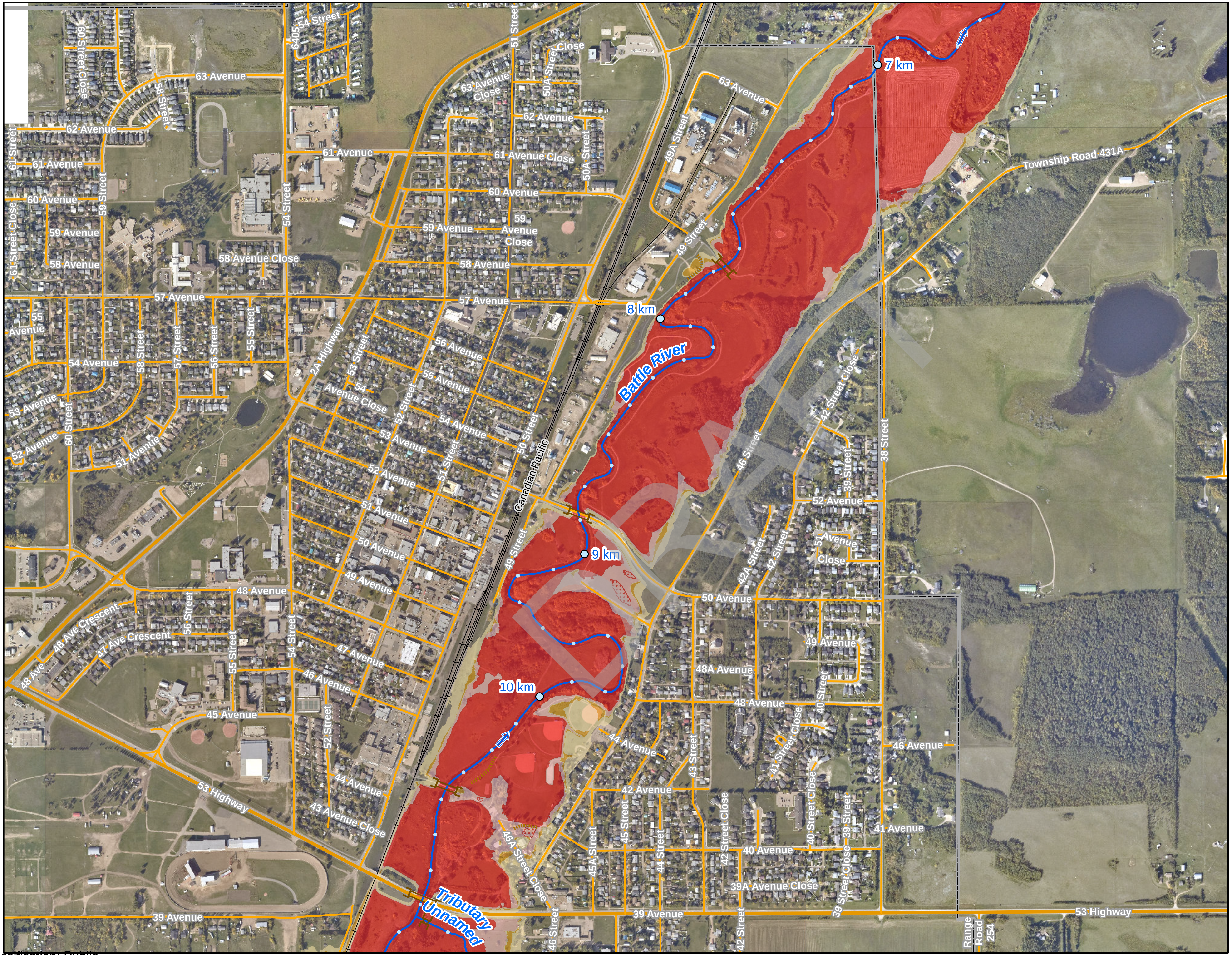
SHEET 4 OF 7

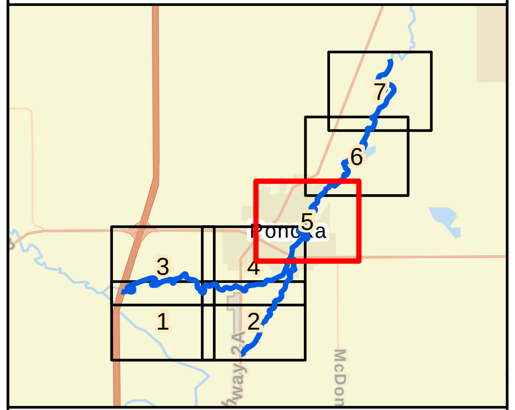
DJH, P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\500 Hazard Mapping\1008017_DJH_Flood_Hazard_FINAL.aprx

Classification: Public

SHEET 6

SHEET 4





Alberta

Canada

nhc

- MAJOR HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- FLOOD BERM
- TOWN OF PONOKA
- STUDY BOUNDARY
- RIVER CENTRE LINE
- FLOW DIRECTION
- FLOODWAY
- FLOOD FRINGE
- HIGH HAZARD FLOOD FRINGE
- 200-YEAR FLOOD EXTENT
- 500-YEAR FLOOD EXTENT

SCALE - 1:10,000

0 100 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	JY/DJH	RBA

Job Number	Date
1008017	01-MAR-2025

PONOKA FLOOD STUDY

FLOOD HAZARD MAP

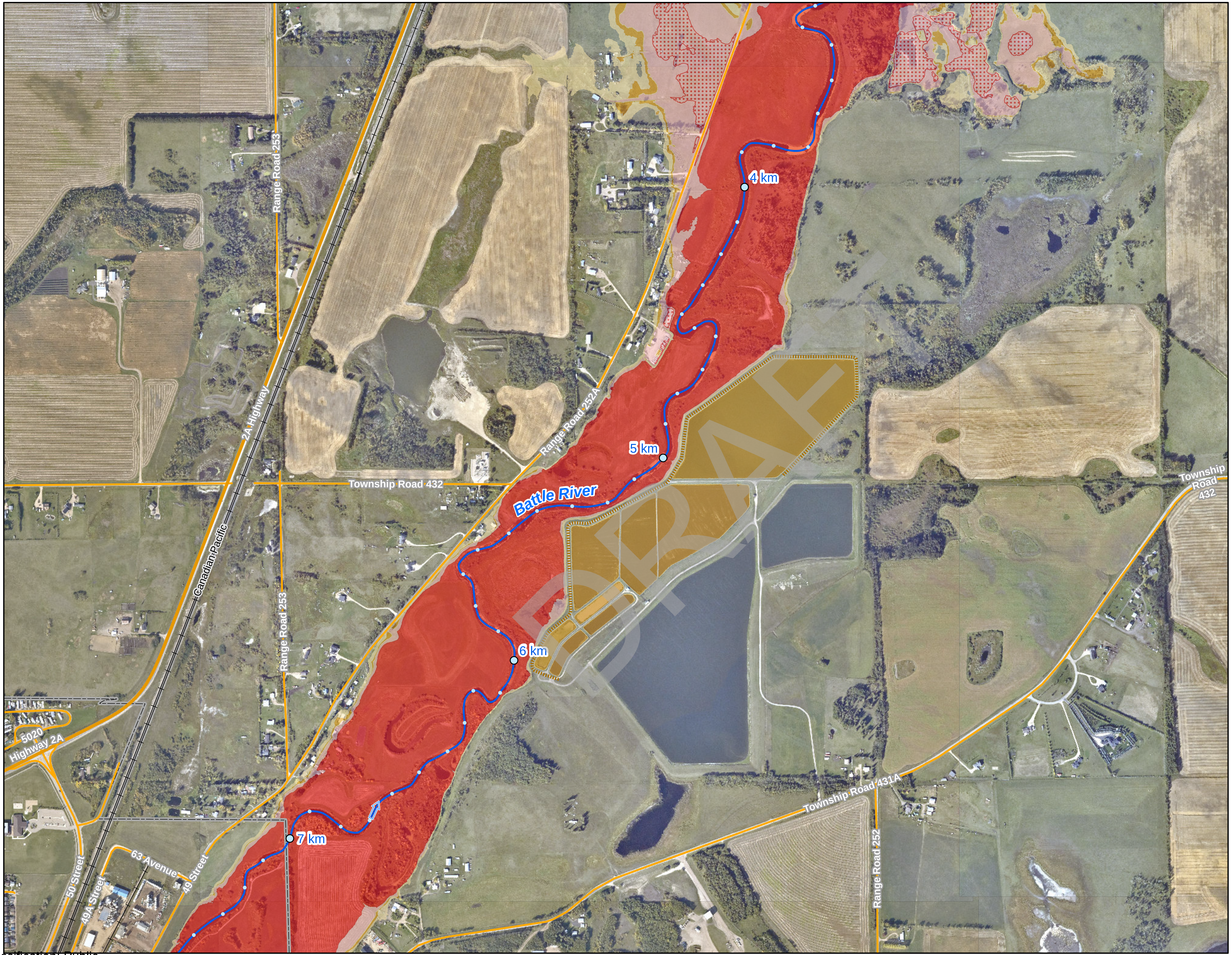
SHEET 5 OF 7

DJH, P:_Projects (Active)\1008017 Ponoka Flood Study\60 GIS\500 Hazard Mapping\1008017_DJH_Flood_Hazard_FINAL.aprx

Classification: Public

SHEET 4

SHEET 7

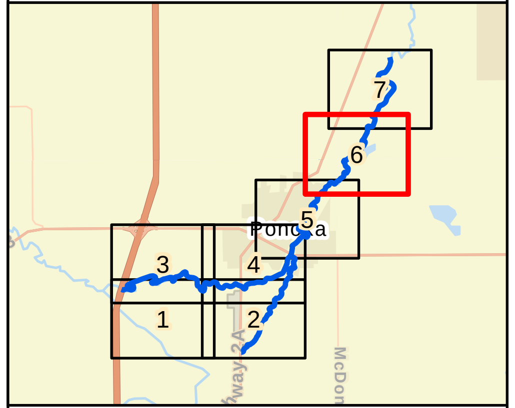


SHEET 5

Classification: Public

Alberta Canada

nhc



MAJOR HIGHWAY
LOCAL ROAD
RAILWAY
BRIDGE
CULVERT
FLOOD BERM
TOWN OF PONOKA
STUDY BOUNDARY
RIVER CENTRE LINE
FLOW DIRECTION
FLOODWAY
FLOOD FRINGE
HIGH HAZARD FLOOD FRINGE
200-YEAR FLOOD EXTENT
500-YEAR FLOOD EXTENT

SCALE - 1:10,000

0 100 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	JY/DJH	RBA

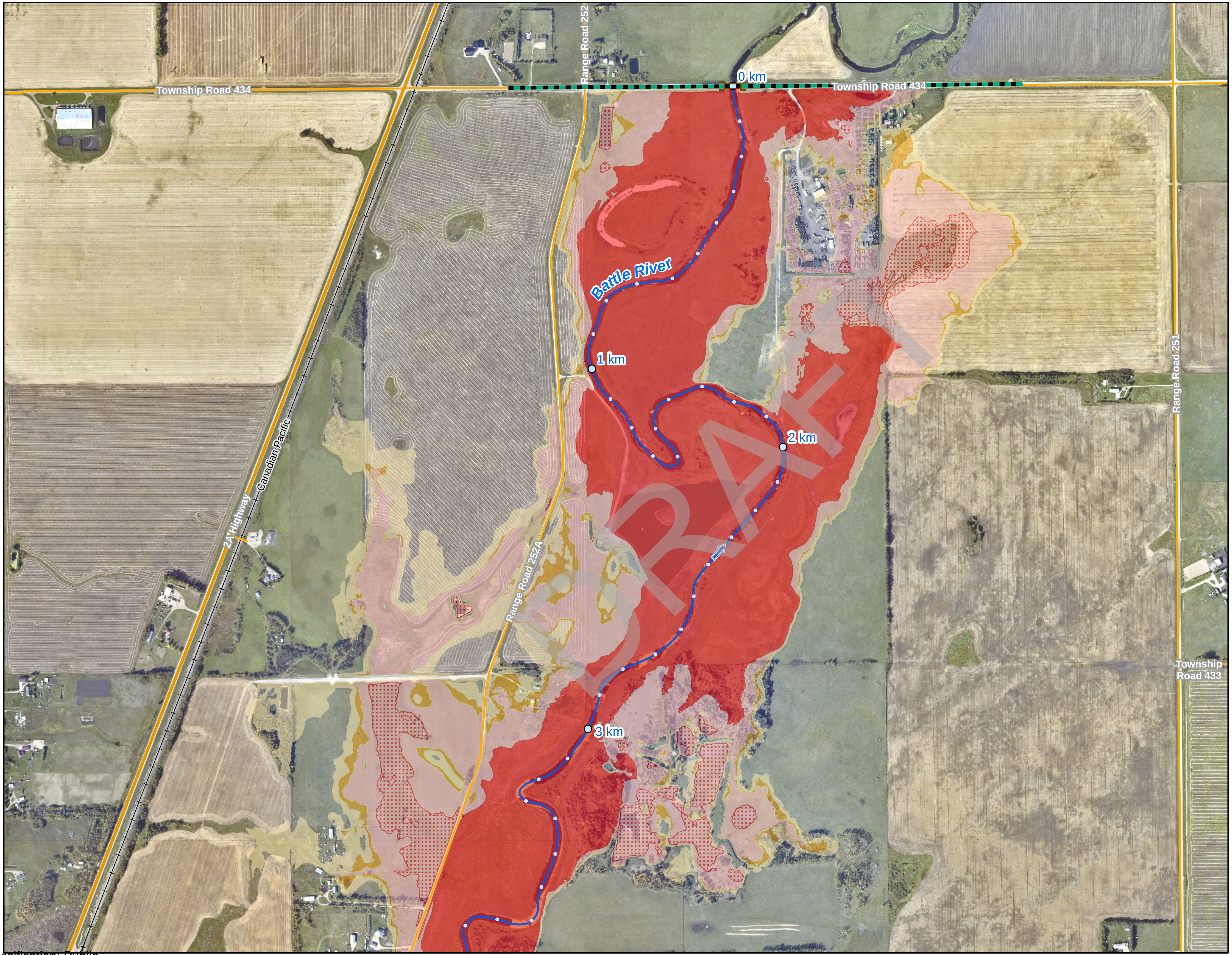
Job Number	Date
1008017	01-MAR-2025

PONOKA FLOOD STUDY

FLOOD HAZARD MAP

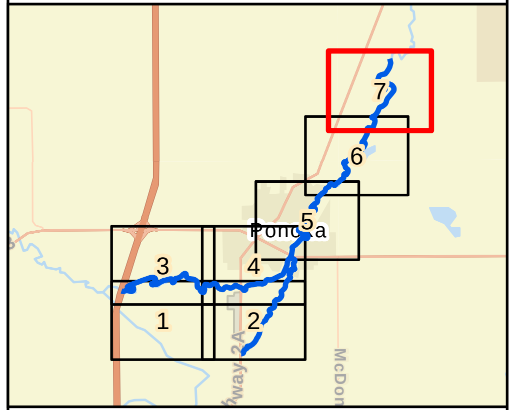
SHEET 6 OF 7

DJH, P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\500 Hazard Mapping\1008017_DJH_Flood_Hazard_FINAL.aprx



Alberta
Canada

nhc



	MAJOR HIGHWAY
	LOCAL ROAD
	RAILWAY
	BRIDGE
	CULVERT
	FLOOD BERM
	TOWN OF PONOKA
	STUDY BOUNDARY
	RIVER CENTRE LINE
	FLOW DIRECTION
	FLOODWAY
	FLOOD FRINGE
	HIGH HAZARD FLOOD FRINGE
	200-YEAR FLOOD EXTENT
	500-YEAR FLOOD EXTENT

SCALE - 1:10,000

0 100 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	*GIS*	*Reviewer*
DJH	*JY/DJH*	*RBA*

Job Number	*Date*
1008017	*01-MAR-2025*

PONOKA FLOOD STUDY

FLOOD HAZARD MAP

SHEET 7 OF 7

DJH, P:_Projects (Active)\1008017 Ponoka Flood Study\90 GIS\500 Hazard Mapping\1008017_DJH_Flood_Hazard_FINAL.aprx

Classification: Public

SHEET 6