CAMROSE FLOOD HAZARD STUDY

FINAL REPORT

Prepared for:

Alberta

14 September 2021

NHC Ref. No. 1004662

nhc
northwest hydraulic consultants
water resource specialists

CAMROSE FLOOD HAZARD STUDY

FINAL REPORT

Prepared for:

Alberta Environment and Parks
Edmonton, Alberta

Prepared by:

Northwest Hydraulic Consultants Ltd.
Edmonton, Alberta

14 September 2021

NHC Ref No. 1004662

Prepared by:

Md Makamum Mahmood, M.Eng., P.Eng.
Project Engineer

Robyn Andrishak, M.Sc., P.Eng.
Principal

Reviewed by:

Gary Van Der Vinne, MSc, PEng
Principal

DISCLAIMER

This report has been prepared by Northwest Hydraulic Consultants Ltd. (NHC) in accordance with generally accepted engineering practices, for the benefit of Alberta Environment and Parks for specific application to the Camrose Flood Hazard Study in Alberta. The information and data contained herein represent the best professional judgment of NHC, based on the knowledge and information available to NHC at the time of preparation.

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 Alberta Environment and Parks, its officers and employees. NHC 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.

nhc

EXECUTIVE SUMMARY

Alberta Environment and Parks retained Northwest Hydraulic Consultants Ltd. in April 2019 to complete a flood hazard study for the City of Camrose and adjacent areas of Camrose County. The flood hazard study area includes 19 km of Camrose Creek, extending from about 3 km upstream of the northern Camrose boundary at SE-22-47-20-W4M to about 1 km downstream of the southern boundary at NW-9-46-20-W4M, and for 6 km of Unnamed Creek upstream of its confluence with Camrose Creek to SE-8-47-20-W4M.

The study was done according to Flood Hazard Identification Program Guidelines, incorporating technical changes implemented in 2021 regarding how floodways are mapped in Alberta. The overall objectives of the study are to enhance public safety and to reduce potential future flood damages and disaster assistance costs.

The Camrose Flood Hazard Study is comprised of five major project components (***Survey and Base Data Collection, Open Water Hydrology Assessment, Open Water Hydraulic Modelling, Open Water Flood Inundation Mapping, and Design Flood Hazard Mapping***). This report summarizes the work of all five components. Together, these components include survey procedure and methodology, documentation on the collected survey and base data, flood history documentation, open water flood frequency flow estimations, construction and validation of the hydraulic model, a sensitivity analysis, computation of flood frequency water levels, the associated inundation mapping, floodway delineation, computation of design flood profiles and the floodway criteria and hazard mapping.

The majority of the survey program was completed in May 2019, with some follow-up work completed in September 2019. The objective of the survey program was to survey channel cross sections and hydraulic structures along the study reach to support the development of a one-dimensional (1D) hydraulic model. The DTM, aerial imagery, and other base mapping features were also collected to support the model development and flood mapping.

Open water flood frequency estimation was conducted at five locations along the study reaches. The flow routing effect through CP rail crossing and Mirror Lake was considered carefully to come up with the final adopted values. Flood frequencies have been estimated for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1000-year events.

The hydraulic model was developed in HEC-RAS based on the collected survey and base data, and the estimated flood frequencies. The roughness in the model was assigned based on literature and validated only for the low flow (2-year and lower floods). No high flow calibration was possible due to the unavailability of highwater marks.

The developed hydraulic model was used to calculate water surface profiles for the 13 flood frequency return periods. The computed flood frequency levels were then used to determine the extent of inundation for all return periods. The results of the inundation analysis are presented as the open water flood inundation map library, provided as an appendix to this report. A total of 13 flood scenarios based on the calibrated open water flood frequency profiles were mapped individually for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1000-year events.

The 100-year open water flood was used for the open water flood hazard identification and design flood hazard mapping. Open water flood hazard identification involves defining the open water flood hazard area, which is comprised of floodway, high hazard flood fringe, and flood fringe zones. The methods summarized in this report follow the provincial Flood Hazard Identification Program guidelines and criteria pertaining to the flood hazard identification process. The floodway criteria maps are the key deliverable for this project component and are provided as an appendix to this report. The design flood hazard map depicts the floodway, high hazard flood fringe, and flood fringe based on the information resulting from the floodway criteria mapping. The design flood hazard map series is also included as an appendix to this summary report.

CREDITS AND ACKNOWLEDGEMENTS

Northwest Hydraulic Consultants Ltd. would like to express appreciation to Alberta Environment and Parks for initiating this project, making extensive background information available, and providing the project team with valuable technical input throughout the project. Kurt Morrison, M.Eng., P.Eng., CFM managed and directed the Camrose Flood Hazard Study on behalf of Alberta Environment and Parks.

The following NHC personnel were part of the study team and participated in the different components of the study:

- Robyn Andrishak – co-authored this report and responsible for the overall direction of the project and also involved as a senior engineer throughout all the components of the project.
- Gary Van Der Vinne - Senior advisor and technical reviewer of this report.
- Ken Zhao – Involved in the Open Water Hydrology Assessment and worked as the senior reviewer for the hydraulic modelling.
- Makamum Mahmood – co-authored this report and involved in model development, sensitivity analysis, flood history documentation, and floodway determination. Also assisted in flood inundation mapping, floodway criteria, and flood hazard maps production.
- Rebecca Himsl – responsible for the development of all the mapping components and GIS deliverables.

TABLE OF CONTENTS

LIST OF APPENDICES vi

LIST OF TABLES vii

LIST OF FIGURES viii

1 INTRODUCTION 1
1.1 Study Background 1
1.2 Study Objectives 1
1.3 Study Area and Reach 2

2 SURVEY AND BASE DATA COLLECTION 3
2.1 Procedures and Methodology 3
2.1.1 Coordinate System and Datum 3
2.1.2 Control Network 3
2.2 Cross Sections 5
2.3 Hydraulic Structures 6
2.4 Flood Control Structures 8
2.5 Other Features 9
2.5.1 Water Survey of Canada Benchmarks 9
2.5.2 Site Photographs 9
2.5.3 Aerial Imagery 9
2.5.4 Base Mapping Features 9

3 FLOOD HYDROLOGY 10
3.1 Flooding History 10
3.1.1 General Information 10
3.1.2 Open Water Floods 10
3.1.3 Ice Jam Floods 11
3.2 Flood Frequency Analysis 11
3.2.1 Flood Frequency Flow Estimates 11
3.2.2 Comparison with Previous Study 12

4 HYDRAULIC MODELLING 14
4.1 Available Data 14
4.1.1 Digital Terrain Model 14
4.1.2 Existing Hydraulic Models 14
4.1.3 Highwater Marks 14
4.1.4 Design Drawings 14
4.1.5 Gauge Data and Rating Curves 15
4.1.6 Flood Photography 15
4.2 River and Valley Features 15
4.2.1 General Description 15
4.2.2 Channel Characteristics 15
4.2.3 Floodplain Characteristics 15
4.2.4 Anthropogenic Features 15
4.3 Model Construction 16

4.3.1 Methodology 16
4.3.2 Geometric Database 16
4.3.3 Model Calibration 19
4.3.4 Model Parameters and Options 23
4.3.5 Flood Frequency Profiles 26
4.3.6 Model Sensitivity 26
5 FLOOD INUNDATION MAPS 30
5.1 Methodology 30
5.2 Water Surface Elevation TIN Modifications 30
5.3 Flood Inundation Areas 31
5.3.1 Residential Areas 31
5.3.2 Commercial and Industrial Areas 32
5.3.3 Hydraulic and Flood Control Structures 32
6 FLOODWAY DETERMINATION 33
6.1 Design Flood Selection 33
6.2 Floodway and Flood Fringe Terminology 33
6.3 Flood Hazard Identification 34
6.3.1 Floodway Determination Criteria 34
6.3.2 Design Flood Profile 35
6.3.3 Floodway Criteria Maps 35
6.3.4 Flood Hazard Maps 36
7 POTENTIAL CLIMATE CHANGE IMPACTS 38
7.1 Comparative Scenarios 38
7.2 Results 38
7.3 Supplementary Information 38
8 CONCLUSIONS 39
9 REFERENCES 41

LIST OF APPENDICES

Appendix A Cross Section Properties

Appendix B Hydraulic Structure Details

Appendix C Reach-Representative Photographs

Appendix D Open Water Hydrology Assessment Memorandum

Appendix E Detailed Model Data

Appendix F Sensitivity Analysis Results

Appendix G Open Water Flood Inundation Map Library

Appendix H Floodway Determination Criteria and Design Flood Levels

Appendix I Floodway Criteria Map

Appendix J Flood Hazard Map

LIST OF TABLES

Table 1	Control point summary	4
Table 2	Control network errors	4
Table 3	Comparison between surveyed control point coordinates and reported CSRS-PPP values	5
Table 4	Comparison between surveyed coordinates and published Alberta Survey Control Monument coordinates	5
Table 5	Cross section survey summary	6
Table 6	Hydraulic structure summary	7
Table 7	Water Survey of Canada gauging station survey summary	9
Table 8:	Adopted flood frequency estimates for Camrose Creek and Unnamed Creek	12
Table 9:	Comparison with previous flood frequency estimates	13
Table 10	List of hydrometric gauges supporting model creation and calibration	15
Table 11	Summary of flow change locations	19
Table 12	Description of bed material and land cover types within the study reach	21
Table 13	Discharges measurements in Camrose Creek	22
Table 14	Comparison of measured and simulated water levels for May 2019 low flow conditions at Camrose Creek	23
Table 15	Adopted Manning's roughness values for the channel	24
Table 16	Adopted Manning's roughness values for the overbank areas	24
Table 17	Sensitivity analysis results for variation in 100-year flood frequency estimates	26
Table 18	Channel roughness values used in sensitivity analysis	27
Table 19	Sensitivity analysis results for variation in main channel roughness	28
Table 20	Overbank roughness values used in sensitivity analysis	28
Table 21	Sensitivity analysis results for variation in overbank roughness	28
Table 22	Sensitivity analysis results for variation in roadway weir coefficient	29
Table 23	Average increases in water level associated with more severe open water design flood scenarios	38

LIST OF FIGURES

Figure 1 Study area and basin overview
Figure 2 Survey and structure location and overview
Figure 3 1974 flood photographs
Figure 4 Comparison of adopted Mirror Lake rating curve to previous study (IDE, 1994)
Figure 5 Comparison of simulated rating curve to gauge data (WSC station 05FA025)
Figure 6 Comparison of simulated and measured water levels for low flow on Camrose Creek
Figure 7 Camrose Creek flood frequency profiles
Figure 8 Unnamed Creek flood frequency profiles
Figure 9 Computed 100-year water surface profile sensitivity to flood frequency estimates – Camrose Creek
Figure 10 Computed 100-year water surface profile sensitivity to flood frequency estimates – Unnamed Creek
Figure 11 Computed 100-year water surface profile sensitivity to downstream boundary condition – Camrose Creek
Figure 12 Computed 100-year water surface profile sensitivity to channel roughness – Camrose Creek
Figure 13 Computed 100-year water surface profile sensitivity to channel roughness – Unnamed Creek
Figure 14 Computed 100-year water surface profile sensitivity to overbank roughness – Camrose Creek
Figure 15 Computed 100-year water surface profile sensitivity to overbank roughness – Unnamed Creek
Figure 16 Computed 100-year water surface profile sensitivity to roadway weir coefficient– Camrose Creek
Figure 17 Computed 100-year water surface profile sensitivity to roadway weir coefficient– Unnamed Creek
Figure 18 Open water design flood profiles – Camrose Creek
Figure 19 Open water design flood profiles – Unnamed Creek

1 INTRODUCTION

1.1 Study Background

The Camrose Flood Hazard Study was initiated by Alberta Environment and Parks (AEP) to identify and assess flood hazards along Camrose Creek and Unnamed Creek through the City of Camrose and adjacent areas of Camrose County. A flood hazard mapping study was previously completed for the Camrose area by IDE (1994); however, the present study covers an expanded study reach and represents an update to the prior work.

Results from this study are designed to inform local land use planning decisions, flood mitigation projects, and emergency response planning. 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.

This flood hazard study is comprised of the five major study components listed below.

1) Survey and Base Data Collection
2) Open Water Hydrology Assessment
3) Open Water Hydraulic Modelling
4) Open Water Flood Inundation Mapping
5) Design Flood Hazard Mapping

1.2 Study Objectives

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

- River cross section surveys
- Hydraulic structure data collection
- Survey and digital terrain model (DTM) data integration
- Documentation of open water flood history
- Open water flood hydrology assessment
- Creation, calibration, and validation of a HEC-RAS hydraulic model
- Simulation of selected return-period floods and the creation of water surface profiles throughout the study reach

- Sensitivity analysis of the model inputs
- Production of flood inundation maps
- Determination of floodway criteria
- Production of floodway criteria maps and flood hazard maps

1.3 Study Area and Reach

Flood hazard study area is located approximately 90 km southeast of Edmonton. **Figure 1** shows the extent of the flood hazard study area and an overview of the contributing creek basins. The flood hazard study area includes the following reaches: 15 km of Camrose Creek below Unnamed Creek; 4 km of Camrose Creek above Unnamed Creek; and 6 km of Unnamed Creek above the confluence with Camrose Creek. Municipalities along these study reaches include the City of Camrose and Camrose County.

Camrose Creek is a relatively small prairie stream, which originates near Miquelon Lake located about 25 km north of the city of Camrose (**Figure 1**). It generally flows from north to south through Camrose and enters the Battle River just upstream of Driedmeat Lake. Within the city limit, there is a man-made lake on the creek: Mirror Lake, formed by an earthen dam immediately south of Highway 13 (48^{th} Avenue). The dam was constructed on the creek in the 1930s. Outflows from the lake are controlled by a concrete spillway in the dam.

The contributing Camrose Creek basin covers an area of about 460 km^2 at WSC Station No. 05FA025 (Camrose Creek near Camrose). Camrose Creek basin is located within the Central Parkland Natural Subregion. Land use in this basin is dominated by agriculture. The basin features relatively flat terrain with many undrained or intermittently draining wetlands/sloughs. Although this is a typical physiographic feature for prairie stream basins, it appears more significant in the Camrose Creek basin. According to the WSC, the effective drainage area for this station is only 31.7 km^2, or about 8% of the gross drainage area. This percentage is among the smallest of the gauged basins in Alberta, although a recent study by Ducks Unlimited Canada (DUC, 2019) suggests that the effective drainage area of Camrose Creek has likely increased due to wetland drainage.

High flows in Camrose Creek are dominated by spring runoff due to snowmelt with or without rain. The creek starts to flow in as early as mid-March and concludes in late May or early June. In summer the flood peak discharges are expected to be governed by rainfall volumes instead of rainfall intensity, and it is unlikely that the creek would respond to thunderstorms with short durations and low total rainfall volumes.

Unnamed Creek has a gross drainage area of 33.6 km^2 at its mouth. The headwaters of the sub-basin are located in Camrose County, west of the City of Camrose.

2 SURVEY AND BASE DATA COLLECTION

2.1 Procedures and Methodology

The majority of the survey program was completed in May 2019, with some follow-up work completed in September 2019. The objective of the survey program was to survey channel cross sections and hydraulic structures along the study reach to support the development of a one-dimensional (1D) hydraulic model.

Ground positioning was established using Real-Time Kinematic (RTK) Global Navigation Satellite Systems (GNSS) and Trimble R10 GNSS receivers. Boat-based surveys of Mirror Lake were done using a CEE ECHO dual-frequency digital echo sounder to measure water depth (in areas generally deeper than 0.30 m) and the GNSS receiver to record position and elevation of the transducer. Lake bed elevations were derived from depth soundings by subtracting depth from transducer elevations. Elsewhere, the GNSS receivers were mounted on a survey rod to record ground elevations directly. The channel banks and a portion of the overbank floodplains were surveyed to ensure sufficient overlap with the supplied digital terrain model (DTM).

2.1.1 Coordinate System and Datum

Horizontal positions were referenced to the local three-degree Transverse Mercator (3TM) projection of the Canadian Spatial Reference System (CSRS) North American Datum of 1983 (NAD83), which has a central meridian of 114°W. Orthometric heights are based on the Canadian Geodetic Vertical Datum of 1928 (CGVD28) and the HTv2.0 geoid model.

2.1.2 Control Network

A control network was established from local Alberta Survey Control Monuments (ASCMs) and GNSS surveying to provide a spatial reference for the survey program. Five ASCMs were used in the network along with three project control points established by NHC for the survey program. **Table 1** lists the control points in the network.

Control point coordinates were determined by running the GNSS receivers simultaneously in static mode for approximately one hour at pairs of control points and post-processing baselines between control points using Trimble Business Center software. The control network was adjusted to the published coordinates of ASCM 267195.

Table 1 Control point summary

Point Name	Type	Easting (m)	Northing (m)	Elevation (m)
ASCM 267195	ASCM	79642.561	5879924.594	740.189
ASCM 301481	ASCM	79204.804	5879965.845	739.145
ASCM 307389	ASCM	78386.664	5871802.083	739.339
ASCM 374652	ASCM	78230.307	5874350.315	743.291
ASCM 431791	ASCM	75161.713	5878466.902	752.391
NHC 1	Project Control Point	76798.972	5878878.856	741.583
NHC 2	Project Control Point	78816.553	5876150.947	734.532
NHC 3	Project Control Point	78614.278	5873424.391	740.795

The horizontal and vertical errors in the control network after post-processing and adjustment to the reference ASCMs are summarized in **Table 2**. The largest horizontal error was 0.003 m and the largest vertical error was 0.010 m.

Table 2 Control network errors

Point Name	Easting (m)	Northing (m)	Elevation (m)
ASCM 267195	N/A	N/A	N/A
ASCM 301481	0.002	0.002	0.006
ASCM 307389	0.002	0.002	0.009
ASCM 374652	0.002	0.003	0.010
ASCM 431791	0.002	0.002	0.008
NHC 1	0.001	0.002	0.006
NHC 2	0.001	0.002	0.006
NHC 3	0.002	0..002	0.008

The horizontal and vertical residuals between surveyed control point coordinates (after post-processing and adjustment) and the reported CSRS-PPP (Precise Point Positioning) coordinates are provided in **Table 3**. The largest horizontal and vertical residuals were -0.044 m and -0.037 m, respectively. A comparison between the surveyed coordinates (after post-processing and adjustment) and published ASCM coordinates is provided in **Table 4**. The mean of the elevation residuals in **Table 4** is -0.005 m, which indicates good vertical agreement between the control network and local ASCMs.

Table 3 Comparison between surveyed control point coordinates and reported CSRS-PPP values

Point Name	Residuals (Surveyed Minus CSRS-PPP)		
	Easting (m)	Northing (m)	Elevation (m)
ASCM 267195	0.007	-0.007	-0.013
ASCM 301481	-0.028	-0.044	0.016
ASCM 307389	0.023	0.003	-0.015
ASCM 374652	-0.012	-0.016	-0.009
ASCM 431791	0.010	-0.011	0.005
NHC 1	-0.015	-0.013	-0.022
NHC 2	0.024	0.004	-0.037
NHC 3	-0.019	-0.011	-0.014

Table 4 Comparison between surveyed coordinates and published Alberta Survey Control Monument coordinates

ASCM Number	Residuals (Surveyed Minus Published)		
	Easting (m)	Northing (m)	Elevation (m)
267195	0.000	0.000	0.000
301481	0.001	0.000	-0.016
307389	-0.011	0.007	0.018
374652	0.016	0.016	0.022
431791	0.014	0.019	0.000

2.2 Cross Sections

Cross section locations were selected to ensure adequate representation of the channel geometry in the hydraulic model with consideration given to the location of cross sections from the most recent floodplain study (IDE, 1994). The cross section survey was divided into reaches corresponding to the creek being surveyed. During the planning process for the survey, each cross section was assigned a number in an effort to organize the cross sections sequentially on each water body. However, cross section lines and associated survey points shown in **Figure 2** are labelled according to their river stationing.

A summary of the cross sections surveyed in each reach is provided in **Table 5**. A total of 246 cross sections were surveyed, 229 cross sections in the spring of 2019 and remainder in September 2019. Survey point data has been assembled and provided as part of the digital file submission.

Table 5 Cross section survey summary

Reach	Reach Length (km)	Number of Cross Sections	Average Spacing (m)	Minimum Spacing (m)	Maximum Spacing (m)
Camrose Creek	18.8	224	84	4	231
Unnamed Creek	5.7	22	260	11	698

The properties of cross sections surveyed on Camrose Creek and on Unnamed Creek are summarized in **Table A-1** and **A-2** of **Appendix A**. A total of 224 cross sections were surveyed for Camrose Creek, and a total of 22 cross sections were surveyed for Unnamed Creek. Thalweg elevation was taken as the minimum surveyed elevation at each cross section. The top of the bank (TOB) channel width was determined based on the survey data, an inspection of the LiDAR-derived DTM data, aerial imagery and cross section profiles.

The Trimble RTK GNSS receivers used for the survey of cross sections are accurate to ±0.02 m under optimal operating conditions. Optimal operating conditions are when the GNSS receiver is mounted to a tripod with a clear view of the sky and sufficient satellites to accurately establish the receiver position. Additional error may be introduced when the receiver is off-level, obstructed by nearby trees or vegetation, or the instrument height is incorrectly recorded. The overall expected accuracy of ground-based survey points is ±0.05 m, except in rare cases when points were surveyed in tree cover or near large vertical banks resulting in less than ideal satellite coverage. The digital echo sounder used for the boat-based surveys in Mirror Lake has an expected accuracy of ±0.01 m. Due to the pitch and roll of the boat when the boat is in motion, the overall expected accuracy of the boat-based survey is ±0.07 m.

2.3 Hydraulic Structures

Table 6 summarizes the hydraulic structures in the study reach. A total of 39 bridges, nine culvert crossings, and one spillway/weir were identified and surveyed within the study area (note that one site, 48th Avenue Bridge, has both a bridge and a culvert). Five of the nine culvert crossings consist of one or more corrugated steel pipe (CSP) culverts while the remainder are concrete box culverts. Hydraulic structure locations are shown in **Figure 2**. Survey data for these structures has been assembled and provided as part of the digital study file; bridge and culvert details are provided in **Appendix B**.

Data collected at each bridge includes:

- Span length
- Deck width
- High chord (top of curb or solid guardrail) elevations (upstream and downstream)
- Low chord elevations (upstream and downstream)
- Number, location and width of piers

- Type and shape of piers
- Photographs of the bridge

The information collected at each culvert includes:

- Culvert type
- Culvert shape
- Entrance condition
- Culvert material, dimensions and barrel length
- Upstream and downstream invert elevations
- Top of roadway elevations
- Photographs of the culvert

Table 6 Hydraulic structure summary

Reach	Description	River Station (m)	Structure Type
Camrose Creek	CN Railway Bridge	18,693	Bridge
	Golf Course Bridge	18,309	Bridge
	Golf Course Bridge	18,194	Bridge
	Golf Course Bridge	18,090	Bridge
	Golf Course Bridge	17,991	Bridge
	HWY 833 Bridge (BF1030)	17,491	Bridge
	Township Rd 472 Bridge (BF446)	16,638	Bridge
	CSP Culvert	16,308	Culvert
	Bailey Avenue Bridge (BF77950)	15,770	Bridge
	53rd Street Bridge (BF1029)	15,428	Bridge
	CSP Culverts	14,522	Culvert
	54th Avenue Bridge (BF79515)	13,933	Bridge
	Pedestrian Bridge	13,563	Bridge
	CP Rail Culvert (BF77937)	13,437	Culvert
	Private Road	13,379	Bridge
	Pedestrian Bridge	13,146	Bridge
	Golf Course Bridge	13,063	Bridge
	Golf Course Bridge	13,005	Bridge
	Golf Course Bridge	12,930	Bridge
	50th Avenue/Grand Drive (BF83008)	12,750	Culvert
	Mirror Lake Pedestrian Bridge	11,761	Bridge

Table 6 Hydraulic structure summary (Continued)

Reach	Description	River Station (m)	Structure Type
Camrose Creek	48th Avenue Bridge (BF445)	11,521	Bridge and Culvert
	Pedestrian Bridge	11,384	Bridge
	Mirror Lake Dam and Spillway	11,382	Dam/Weir
	47th Avenue Bridge (BF81006)	11,292	Bridge
	Pedestrian Bridge	11,129	Bridge
	Pedestrian Bridge	10,933	Bridge
	Pedestrian Bridge	10,637	Bridge
	44th Avenue Bridge (BF79353)	10,489	Bridge
	Pedestrian Bridge	10,109	Bridge
	Pedestrian Bridge	10,058	Bridge
	CSP Culverts	9,318	Culvert
	Box Culvert	8,841	Culvert
	Pedestrian Bridge	8,255	Bridge
	CN Railway Bridge	8,156	Bridge
	Pedestrian Bridge	8,135	Bridge
	Camrose Drive Bridge (BF806000)	7,898	Bridge
	Pedestrian Bridge	7,531	Bridge
	Township Rd 464 Bridge (BF366)	6,383	Bridge
	CN Railway Bridge	3,294	Bridge
	Trail Bridge	2,899	Bridge
	Trail Bridge	2,059	Bridge
	Trail Bridge	1,593	Bridge
	CN Railway Bridge	1,479	Bridge
	Trail Bridge	722	Bridge
	CN Railway Bridge	98	Bridge
Unnamed Creek	CSP Culvert	4,112	Culvert
	Range Rd 203 Culverts	2,367	Culvert

2.4 Flood Control Structures

In collaboration with AEP and local authorities, NHC has confirmed that there are no dedicated flood control structures within the study reach. The existing outlet control spillway/weir and embankments at the south (downstream) end of Mirror Lake were surveyed but are classified as a hydraulic structure and are not considered a dedicated flood control structure.

2.5 Other Features

2.5.1 Water Survey of Canada Benchmarks

The WSC benchmark at the gauging station Camrose Creek near Camrose (WSC Station No. 05FA025) was surveyed to tie historical water levels at the station to the study control network. **Table 7** lists the benchmark information and compares the published gauge height to the surveyed elevation. The survey results indicate that a gauge datum offset of 712.249 m should be applied to WSC gauge heights to convert to geodetic water surface elevations.

A comparison of surveyed water surface elevation and coincident WSC gauge height are also listed in **Table 7.** This data indicates the gauge datum offset as 712.208 m, which is 0.041 m lower than the gauge datum offset obtained from the surveyed benchmark. This difference is within the expected survey tolerances, and shows that the correct benchmark was surveyed. The gauge datum offset obtained from the benchmark survey was adopted for this study as it is expected to be more accurate.

Table 7 Water Survey of Canada gauging station survey summary

Station Name (ID)	River Station (m)	Survey Type	Description	Elevation (m)		
				WSC Gauge Height	NHC Survey	Gauge Datum Offset
Camrose Creek near Camrose (05FA025)	15,770	Benchmark	S.B.M. 06-01	19.470	731.719	712.249[1]
		Water Level	23 May 2019	17.747	729.955	712.208

Note: 1. Adopted offset for this study.

2.5.2 Site Photographs

Appendix C provides annotated reach representative photographs obtained during the 2019 survey program. The location, time, and other metadata information are embedded in the electronic images included as part of the digital file submission.

2.5.3 Aerial Imagery

Aerial imagery was acquired for AEP by OGL Engineering Ltd. On 27 May 2019. Fully-processed, orthophoto mosaics were provided to NHC by AEP on 04 February 2020.

2.5.4 Base Mapping Features

In addition to the data sets listed above, additional base mapping data were obtained to support modelling and mapping for the study, including road network, hydrography, administrative boundaries, topographic maps, AltaLIS LiDAR15 DEM and Alberta Township System (ATS) grids within the study area.

3 FLOOD HYDROLOGY

This section provides a summary of flood hydrology for the study. A more detailed assessment of open water hydrology is provided in the Open Water Hydrology Assessment Memorandum in **Appendix D**.

3.1 Flooding History

3.1.1 General Information

A description of local flood history has been prepared to provide context for the hydraulic model creation and calibration. The flood history documentation includes observational information and historical records for both open water and ice jam related flooding.

3.1.2 Open Water Floods

Historic and Observed 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.

The April 1974 event was a significant flood event on Camrose Creek. During this event, the Mirror Lake spillway was washed out, and some upstream road crossings were also washed out or overtopped. Alberta Transportation (AT) estimated the peak discharge at the Canadian Pacific (CP) Rail culvert crossing located upstream of Mirror Lake to be between 26 and 39 m^3/s (AT Bridge File #77937). The previous Camrose flood risk mapping study (IDE, 1994) cited the peak discharge for the same culvert estimated by an engineering company (De Leuw Cather Canada Ltd.) to be between 22.7 to 28.6 m^3/s. This estimation was adopted for the present study as it was likely based on more reliable information and thus expected to be more accurate than AT's estimation (which was solely based on a photo showing the flow condition at the culvert inlet).

In 1956, the culvert crossing for Township Road 472 located upstream of WSC Station 05FA025 was washed out, according to AT Bridge File #00446. The Highway 833 bridge located immediately upstream had a highwater mark over grade (AT Bridge File #01030). AT estimated the discharge of that event as 8.5 m^3/s. This estimate is higher than all annual peak discharges from the WSC Station 05FA025 record; therefore, it was included in the flood frequency analysis for this study.

Recent and Recorded Open Water Floods

Systematic flow measurements on Camrose Creek began in 2006 at WSC Station 05FA025. The highest maximum instantaneous discharge recorded at this gauge is 6.55 m^3/s, measured on 28 April 2018.

The WSC also reported some flow measurements from 1928 to 1930 at a discontinued gauge (05FA010 – Camrose Creek at Camrose); but the recorded maximum discharge was smaller than 1 m^3/s. As such, those data were not considered in this study.

3.1.3 Ice Jam Floods

No information on ice jam flood is available for Camrose Creek or Unnamed Creek.

3.2 Flood Frequency Analysis

A flood frequency analysis was carried out to determine estimates of flood frequencies for a range of return periods up to 1000 years. Details on the flood frequency analysis are provided in the Open Water Hydrology Assessment Memorandum in **Appendix D**.

3.2.1 Flood Frequency Flow Estimates

Flood frequency estimates from the 2- to 1000-year floods were provided at the following five flow change locations (**Figure 1**):

- Site 1: Unnamed Creek at the mouth.
- Site 2: Camrose Creek near Camrose (WSC Station No. 05FA025).
- Site 3: Camrose Creek above the CP Rail crossing.
- Site 4: Camrose Creek at Mirror Lake.
- Site 5: Camrose Creek at the downstream end.

Table 8 lists a summary of adopted flood frequency estimates at the above flow change locations.

Table 8: Adopted flood frequency estimates for Camrose Creek and Unnamed Creek

Return Period (years)	Peak Instantaneous Discharge (m^3/s)									
	Site 1 (Unnamed Creek at the mouth)		Site 2 (Camrose Creek at WSC Station 05FA025)		Site 3 (Camrose Creek above the CP Rail crossing)		Site 4 (Camrose Creek at Mirror Lake)		Site 5 (Camrose Creek at the downstream end)	
	Value	Upper 95% Limit / Lower 95% Limit	Value	Upper 95% Limit / Lower 95% Limit	Value	Upper 95% Limit / Lower 95% Limit	Value	Upper 95% Limit / Lower 95% Limit	Value	Upper 95% Limit / Lower 95% Limit
1000	12.3	14.9	66.5	80.3	71.1	85.9	53.6	68.4	57.2	72.8
		10.5		57.0		60.9		43.3		46.4
750	11.7	14.1	63.3	76.4	67.7	81.7	52.4	66.5	55.9	70.7
		10.0		54.2		58.0		42.7		45.6
500	10.8	13.1	58.6	70.7	62.7	75.5	50.7	63.6	53.9	67.5
		9.30		50.3		53.8		41.7		44.5
350	10.1	12.2	54.7	65.9	58.5	70.4	49.2	61.2	52.2	64.8
		8.69		47.0		50.2		40.9		43.4
200	8.94	10.7	48.3	58.1	51.7	62.1	46.6	57.1	49.3	60.3
		7.69		41.5		44.4		39.3		41.6
100	7.53	9.02	40.7	48.7	43.5	52.1	41.1	49.8	43.3	52.4
		6.48		35.0		37.5		35.0		37.0
75	6.97	8.34	37.6	45.1	40.3	48.2	38.9	46.8	40.9	49.3
		6.01		32.4		34.7		33.3		35.0
50	6.14	7.33	33.2	39.6	35.5	42.4	34.9	41.8	36.7	43.9
		5.30		28.6		30.6		30.0		31.5
35	5.45	6.50	29.5	35.1	31.5	37.5	31.3	37.3	32.9	39.3
		4.70		25.4		27.2		26.9		28.3
20	4.37	5.20	23.6	28.1	25.3	30	25.3	30.1	26.6	31.6
		3.76		20.3		21.7		21.8		22.9
10	3.11	3.71	16.8	20.0	17.9	21.4	18.0	21.5	19.0	22.6
		2.64		14.2		15.2		15.3		16.1
5	1.94	2.39	10.5	12.9	11.2	13.8	11.3	13.9	11.8	14.6
		1.54		8.31		8.89		8.93		9.40
2	0.69	1.09	3.74	5.90	4.00	6.31	4.02	6.34	4.22	6.66
		0.25		1.33		1.43		1.43		1.51

3.2.2 Comparison with Previous Study

The adopted flood frequency estimates from four study sites along Camrose Creek and Unnamed Creek study reach are compared with the results from the previous Camrose flood hazard study (AENV, 1993) in **Table 9**. The peak discharges from this study are noticeably higher than those from the previous study, with the exception of the 2-year estimates. While the previous study also used a regional analysis approach, it was based on flow records shorter than those for the current study and included some different gauging stations. In addition, the previous study likely used the National Topographic System (NTS) 1:50,000 scale maps to delineate drainage areas for the flood frequency estimates sites.

Table 9: Comparison with previous flood frequency estimates

	Site 1		Site 2		Site 3		Site 5	
	AENV (1993)	This Study	AENV (1993)	This Study	AENV (1993)	This Study	AENV (1993)	This Study
Drainage Area (km^2)	*31.3*	*33.6*	*355*	*409*	*411*	*457*	*444*	*500*
Return Period (year)	**Peak Instantaneous Discharge (m^3/s)**							
100	5.11	7.53	30.8	40.7	34.3	43.5	36.3	43.3
50	3.92	6.14	23.6	33.2	26.3	35.5	27.9	36.7
20	2.74	4.37	16.5	23.6	18.4	25.3	19.5	26.6
10	1.98	3.11	12.0	16.8	13.3	17.9	14.1	19.0
5	1.40	1.94	8.46	10.5	9.43	11.2	9.99	11.8
2	0.69	0.69	4.16	3.74	4.64	4.00	4.91	4.22

4 HYDRAULIC MODELLING

4.1 Available Data

The data available to develop and calibrate the hydraulic model are described below. Additional information such as past studies, historical flood photographs, and existing hydraulic models also informed model development.

4.1.1 Digital Terrain Model

A digital terrain model (DTM) based on airborne LiDAR data was supplied by AEP for this study. The DTM was based on data collected by Airborne Imaging in 2019.

4.1.2 Existing Hydraulic Models

A previous hydraulic model was developed as part of the 1994 Camrose Flood Risk Mapping Study. This model included Camrose Creek and a small portion of Unnamed Creek within the current study area. Various model parameters and a rating curve for Mirror Lake spillway reported in the 1994 Study were compared against current values.

4.1.3 Highwater Marks

The primary high flow calibration event of interest is the 1974 flood; however, there are no associated highwater mark data or independent estimates of discharge and highwater level that can be used for model calibration. An anecdotal estimate of the flood discharge (referenced in the 1994 study) appears to be calculated based on the estimated water level and culvert hydraulics, so the water level and discharge estimates are therefore coupled.

4.1.4 Design Drawings

NHC requested design drawings for bridges, culverts and Mirror Lake Spillway through Alberta Environment and Parks. Information was obtained for the following structures:

Camrose Creek

- 54th Avenue Bridge (BF79515)
- 50th Avenue / Grand Drive (BF83008)
- 48th Avenue Bridge (BF445)
- 47th Avenue Bridge (BF81006)
- Jubilee Park Pedestrian Bridge
- 44th Avenue Bridge (BF79353)
- Camrose Drive Bridge (BF806000)
- Mirror Lake Dam and Spillway

4.1.5 Gauge Data and Rating Curves

Water level (stage) records, rating curves and station description for WSC Station No. 05FA025 (Camrose Creek near Camrose) were obtained to support the creation and validation of the hydraulic model. **Table 10** lists the period of record and record type for the station.

Table 10 List of hydrometric gauges supporting model creation and calibration

Station Name	Station ID	Period of Record	Record Type
Camrose Creek near Camrose	05FA025	2006-Present	Seasonal

4.1.6 Flood Photography

Flood photographs are only available for the 1974 flood. The 1974 spring flood photographs are obtained from a previous flood hazard study (IDE, 1994) and are compiled in **Figure 3**.

4.2 River and Valley Features

4.2.1 General Description

The land use along Camrose Creek within the study area is primarily agricultural and urban parkland, with some adjacent urban development, golf courses, and Mirror Lake being notable features. Camrose Creek is an alluvial stream and usually carries large sediment loads during spring snowmelt runoff events. The land use along Unnamed Creek within the study area is predominantly agricultural.

4.2.2 Channel Characteristics

Camrose Creek above Mirror Lake and Unnamed Creek flow through predominantly flat, undulating prairie terrain. Below Mirror Lake, Camrose Creek follows an irregular meander pattern within a broad valley. The overall reach-average channel slope is 0.002 m/m for Camrose Creek and 0.003 m/m for Unnamed Creek.

4.2.3 Floodplain Characteristics

Floodplain vegetation consists mainly of cultivated crop lands upstream of the City of Camrose, where the predominant land use is agricultural. Through and downstream of the city, floodplain vegetation consists mainly of tall grasses, light brush, and some interspersed areas of dense tree stands and heavy brush.

4.2.4 Anthropogenic Features

A total of 49 hydraulic structures (e.g. bridges, culverts, spillway) have been documented along the study reaches. Details on these hydraulic structures are provided in **Appendix B**. Mirror Lake is a man-made reservoir with an outlet dam and spillway. Various parks, playgrounds, golf courses, and some residential developments are also situated along the study reach.

4.3 Model Construction

4.3.1 Methodology

The U.S. Army Corps of Engineers *Hydrologic Engineering Center-River Analysis System* (HEC-RAS) computer program (Version 5.0.6, November 2018) was used to calculate the flood levels along the study reaches. The basic inputs required by HEC-RAS are a series of cross sections with specified distances between sections, roughness coefficients for the channel and overbank areas at each cross section, inflow discharge at the upstream boundary of each reach, and a prescribed water level or normal depth condition at the downstream boundary.

HEC-RAS can perform one-dimensional (1D), two-dimensional (2D), or combined 1D and 2D hydraulic calculations for a network of channels and hydraulic structures. For this study, a 1D model was constructed to calculate water surface profiles for steady state gradually varied flow. The computational procedure for steady flow calculations is based on the solution of the 1D energy equation. Energy losses between river sections are calculated as friction losses (Manning's equation) and expansion/contraction losses. The momentum equation is used by the model where rapidly varied flow conditions arise, such as hydraulics through bridges, and evaluating water surface profiles at stream junctions. The analytical approach employed by HEC-RAS has the following assumptions and potential limitations:

- Flow is gradually varied so that the boundary friction losses between cross sections can be estimated by Manning's equation using section-average parameters.
- Changes in the channel and floodplain geometry resulting from erosion or mobile bed processes that might arise during a flood cannot be directly accounted for or modelled.
- The water level is constant across each cross section, with at least three separate conveyance components representing the main channel and each of the left and right overbank.
- Flow is one-dimensional, therefore only velocity components in the principal direction of flow are accounted for in the equations and calculations.

The following sections outline the model construction and parameter selection process for this study.

4.3.2 Geometric Database

The geometric database provides all of the components of the HEC-RAS model geometry, including cross sections, internal hydraulic structures, and boundary conditions. Each component is described below. Additional information and data are provided as part of the electronic deliverables of the study.

Cross Section Data

The geometric layout of the model and cross section data were developed as follows:

- Channel centerline alignments were drawn based on survey, topographic, and aerial imagery data. A single continuous centreline was created to represent each modelled reach with a break between reaches required at stream confluences. Three reaches were required for this study:
  - *Camrose Creek Upper* reach extending from the upstream study limit (north of the town of Camrose) to the confluence with Unnamed Creek;
  - *Camrose Creek Lower* reach extending from the confluence of Unnamed Creek to the downstream study limit (south of the town of Camrose); and
  - *Unnamed Creek Main* reach representing the entire segment of this tributary within the study area.
- Overbank flow path lines were drawn along the left and right floodplains so as to represent the average distance between successive cross sections in left and right overbank flow zones. Main channel distances are derived from the channel centerline alignments described above.
- Cross section alignments were digitized at each surveyed cross section. For the main channel, a straight line best-fitting the cross section survey points was drawn. The cross sections were then extended into the left and right overbank areas to cover the estimated 1000-year flood limits.
- Cross section elevation values from the survey point data were projected onto the cross section lines. The remainder of the cross section elevation data was sampled from the DTM provided by AEP, with a minimize area change filter applied, if required, to bring the number of cross section points below the 500 point per cross section limit of HEC-RAS.
- The locations of the left and right bank stations were determined by inspection of survey point codes generated in the field and simulated values for the 2- and 5-year flood levels.

Surveyed cross section details are tabulated in **Appendix A**.

Bridges and Culverts

The modelled reach includes 39 bridge crossings, nine culverts and one concrete spillway with earthen embankment. **Section 2.3** provides a summary of bridges, culverts, and weir included in the analysis. Key hydraulic structure design information incorporated into the model can be found in **Appendix E**. Any culverts in the study area that service local drainage only or were not relevant to the hydraulic model computations were not modelled.

The alignment of each structure was drawn primarily based on the survey data. Where necessary, adjustments were made to ensure the structure was represented properly in cross section profile. Structure cross sections included the approach roadway on both banks, high and low chord defining the bridge structure, pier locations and dimensions, and culvert inverts and dimensions. The approach roadway was extracted from the DTM and other components were extracted from the survey data, supplemented by available design drawings as needed.

For low flow conditions, the model was configured to use the energy method (standard step) or highest energy solution of the energy, momentum, or Yarnell methods. The highest energy solution was only used for bridges with piers. For high flow conditions that overtop the bridge, the energy method was used unless the bridge creates a significant obstruction to flow, in which case the pressure and/or weir method was used instead, as recommended in the HEC-RAS technical documentation.

Mirror Lake Dam and Spillway

The crest of the Mirror Lake Spillway is composed of a concrete slab about 16.5 m wide and 6.7 m long in the direction of flow, with a free overfall at the end. The slab is "V" shaped with the center being about 0.30 m lower than the sides. The centreline of the slab also drops 0.15 m from its maximum elevation of 728.17 m at the upstream end. Water falls freely from the end of the slab into a concrete stilling basin before being discharged into the downstream channel.

Due to its complex geometry, the spillway crest could not be modeled as an inline structure within HEC-RAS. Instead, the spillway crest and embankment were represented by a single surveyed cross section (RS 11,382) and a specified rating curve was imposed at the Mirror Lake outlet section (RS 11,394) upstream. This rating curve was developed using the geometry obtained from available design drawings to simulate flow over the crest slab, combined with flows overtopping the embankment simulated using the surveyed cross section outside of the spillway. These overtopping flows can occur when the discharge exceeds about 40 m^3/s.

Figure 4 compares the simulated rating curve and the one used in the previous flood hazard study (IDE, 1994). The rating curves are comparable, but the simulated rating curve shows lower Mirror Lake levels for higher flows compared with the IDE (1994) curve. The assumptions and methodology used to develop the IDE (1994) rating curve are unknown, and thus it is not possible to explain the differences in these two rating curves.

Boundary Conditions

A normal depth boundary condition with a slope of 0.002 m/m was used at the downstream boundary of Camrose Creek. This slope was estimated from the energy grade line for the downstream reach.

The downstream boundaries of the upper reach of Camrose Creek and Unnamed Creek are provided by a stream confluence junction. HEC-RAS will compute the energy losses across the junction to determine the water levels for the connected upstream cross sections. The energy method was used to compute losses at Unnamed Creek confluence.

A specified discharge is required at the upstream end of each modelled reach. An inflow discharge was assigned at the upstream boundary to both Camrose and Unnamed Creek sub-reaches. The flood frequency estimates at Site 1 were applied at the upstream boundary of Unnamed Creek and the flood frequency estimates at Site 2 and Site 3 were applied on the upstream boundaries of Camrose Creek upper and lower reach respectively.

Additional flow change locations were required along Camrose Creek's lower reach to capture noticeable changes in creek discharges within the study area. The flow change locations assigned in the HEC-RAS model are summarized in **Table 11.** These flow change locations were selected based on the outcome from open water hydrology assessment (provided in **Appendix D**).

The first flow change was assigned at the upstream cross section of the CP Rail crossing (RS 13,457 m). Site 4 discharges were applied for the reach through and below the CP Rail crossing, which believed to be reasonable in representing the upstream storage and routing effect at the crossing. Site 4 discharges were estimated at Mirror Lake Spillway from routing of Site 3 discharges through the CP Rail crossing and Mirror Lake. Though the discharge estimations were made at Mirror Lake Spillway, the influence of Mirror Lake on peak discharge estimations was found negligible. The routing also determined that the CP Rail crossing was the main control in reducing the Site 3 peak discharges (**Appendix D**).

A second flow change location is required to capture the noticeable change in discharges for Camrose Creek lower reach below the wastewater treatment plant and outside of the developed city limit. Site 5 discharges were used below this location.

Table 11 Summary of flow change locations

Stream Name	Reach	River Station (m)	Description	Flood Frequency Site
Camrose Creek	Upper	18,827	Camrose Creek above Unnamed Creek	Site 2
	Lower	14,760	Camrose Creek below Unnamed Creek	Site 3
	Lower	13,457	Camrose Creek below the CP Rail Crossing	Site 4
	Lower	6,221	Camrose Creek below the wastewater treatment plant	Site 5
Unnamed Creek	Main	5,730	Unnamed Creek above Camrose Creek	Site 1

4.3.3 Model Calibration

Methodology

Model calibration involved the selection of modelling parameters to simulate observed water levels along the study reach for both high and low flow conditions. Calibration parameters included:

- Manning's roughness coefficients for the channel and floodplain;
- Ineffective flow areas at each model cross section;
- Expansion and contraction loss coefficients; and

- Discharge coefficients for flow overtopping roadway crossings and embankments.

Of the above, the primary calibration parameter is typically Manning's roughness for the river channel. Values for each cross section are selected by comparing the simulated water surface profile elevations to observed water levels and highwater marks. The challenges or limitations that are typical to the calibration process include:

- The availability and accuracy of the highwater mark elevations.
- Proper identification of highwater mark locations.
- Uncertainties in estimates of the flood peak discharge.
- Insufficient channel geometry data.

For this study, the major factor affecting the calibration efforts was the unavailability of highwater mark data for flood events. Therefore, it was necessary to develop an uncalibrated model using channel and floodplain roughness values from the literature (e.g. Chow, 1959) based on geomorphic characteristics, low flow water levels and gauge data for validation.

Geomorphic Characteristics

A summary of bed material composition for the channel bed and land cover type for the overbank areas are provided in **Table 12**. Bed material composition was determined from field observations, while land cover type were based on a combination of field observations and aerial imagery.

Proposed Manning's roughness values for the various channel and overbank characteristics based on the literature (Chow 1959; Arcement and Schneider 1989) are also listed in **Table 12**. Changes in the Manning's roughness coefficient typically coincide with variations in flow or sediment regime, often indicated by changes in channel planform that can be identified from aerial imagery; therefore channel roughness coefficients were varied on a reach basis. Overbank roughness values vary with land cover and vegetation type. Constant overbank roughness values were selected for each land cover type.

Table 12 Description of bed material and land cover types within the study reach

Bed Material/Land cover type	Description	Proposed Roughness
Creek bed	Includes the wetted channel area with light vegetation that would be easily eroded away by high flow velocity during large flow events. The creek bed material consists of gravel over soft cohesive (shale) bedrock.	0.045
Mirror Lake	Fine sediments throughout most of the open water area where water is deep and velocity is low.	0.028
Mirror Lake Spillway	Concrete spillway	0.013
Light vegetation	Agricultural crops or pastureland within the overbank with grasses, light brush, and trees.	0.060
Dense vegetation	Medium to dense brush and trees.	0.085
Parks and golf courses	Covered with grasses and some manmade features (for example trails and pathways).	0.060
Urban	Development within the wetted width of the design flood with buildings taller than the maximum expected flow depth with transportation corridors comprised of either asphalt or gravel between the buildings.	0.085

Gauge Data and Rating Curve

The WSC gauge for Camrose Creek near Camrose (05FA025) is located at Bailey Avenue Bridge. **Figure 5** shows the discharge and water level measurement data at the gauge. The highest direct discharge measurement at the gauge about 5 m^3/s, and all the measured flows are well below the 5-year flood (10.5 m^3/s). As a result, the rating data cannot be used to verify roughness for larger floods of interest (i.e. 100-year flood). **Figure 5** also shows a simulated rating curve for discharges ranging from 0 m^3/s to 66.5 m^3/s (covering the 2- to 1000-year flood) generated using the HEC-RAS model with a bed roughness of 0.045. The simulated rating curve is above the water level associated with the highest measured flow; however, it is about 0.2 m below the WSC rating curve. This indicates that the proposed Manning's roughness values for channel and overbank may underpredict the water levels at the 2-year flood (3.74 m^3/s).

Increasing the roughness by 50% provides results that are more consistent with the WSC rating curve and the observed stage-discharge measurement data for low flows up to about the 2-year flood. This corresponds to a bed roughness of 0.068, which is high relative to roughness values in the literature (Chow, 1959) and from the previous study (IDE, 1994) for the gauge sub-reach. Vegetation growing in the channel could cause roughness increases for lower flows but this effect is reduced with higher flows, because the vegetation tends to flatten. The behavior of roughness in grassed channels provided in Henderson (1966) indicates that, for the gauge sub-reach, the transition from higher roughness to normal roughness would occur between the 2-year and 5-year flood discharge. Variable roughness factors were used in the HEC-RAS model to make this transition occur. **Figure 5** also illustrates the rating curve with variable roughness.

Low Flow Validation

Flow measurements and corresponding water elevations surveyed during the May 2019 survey were also used to validate the HEC-RAS model. **Table 13** summarizes the discharge measurements for Camrose Creek carried out on 08 May 2019. At the time of the survey there was no measurable flow in Unnamed Creek, so it was not possible to conduct a similar analysis for that reach.

Table 13 Discharges measurements in Camrose Creek

Date	River Station (m)	Discharge (m^3/s)
08 May 2019	15,536	0.278
	13,560	0.227
	6,420	0.269

The low flow profile for Camrose Creek was established in the model based on the measured flow data in **Table 13** and a measured water level at Mirror Lake, just upstream of the dam and spillway (RS 11,394 m). Channel and overbank roughness values were assigned based on the bed material and land cover types (**Table 12**); the roughness factor of 1.5 established from the gauge data for the reach above Mirror Lake.

The low flow profiles are shown in **Figure 6**, and a tabular summary of the results is provided in **Table 14**. The simulated water levels were on average 0.16 m below observed water levels, which is not unexpected due to the presence of several beaver dams and partially-obstructed culverts observed along the study reach. It is also consistent with the results of the rating curve comparison at very low flows. Low flow roughness values are typically higher than high flow roughness values due to the greater contribution of bed roughness and vegetation at low flow. A roughness factor even higher than 1.5 would be required to match the observed low flow water levels. While the model is not developed to simulate low flows, the results provide further confirmation of a trend of decreasing roughness with increasing discharge.

Table 14 Comparison of measured and simulated water levels for May 2019 low flow conditions at Camrose Creek

River Station (m)	Discharge (m^3/s)	Water Level (m)			Remarks
		Observed	Simulated	Difference	
15,548	0.278	730.01	729.78	-0.23	Observed water level may be affected by beaver dam
13,944	0.278	729.76	729.36	-0.40	Observed water level may be affected by blockage of 54th Ave bridge opening just 11 m downstream
13,606	0.278	728.91	728.81	-0.10	
13,467	0.227	728.82	728.79	-0.03	
13,295	0.227	728.71	728.61	-0.10	
13,143	0.227	728.61	728.54	-0.07	Observed water level may be affected by blockage of 50th Ave culvert 393 m downstream
12,736	0.227	728.47	728.46	-0.01	
11,846	0.227	728.51	728.46	-0.05	Observed water level is at Mirror Lake
11,367	0.227	723.86	723.63	-0.23	Observed water level is downstream of Mirror Lake Dam and Spillway
10,926	0.227	722.68	722.32	-0.36	
10,415	0.227	721.76	721.49	-0.27	Observed water level may be affected by blockage of three CSP culverts 1.1 km downstream
6,420	0.269	710.01	709.93	-0.08	

4.3.4 Model Parameters and Options

The following sections describe the key model parameters and options adopted in the HEC-RAS model. These include Manning's roughness coefficients for the channel and overbank areas, contraction and expansion loss coefficients, roadway weir coefficient and ineffective areas.

Channel and Overbank Roughness Values

Manning's roughness is used to account for an array of energy losses that may vary with respect to discharge. A minimum of three (one channel and two overbank) roughness values were used within each cross section. Where appropriate, roughness was varied horizontally across the channel to capture changes in river and floodplain characteristics. Roughness values were assumed to be constant with discharge.

Table 15 summarizes the selected channel roughness values at each model cross section. The adopted channel roughness values were comparable to those determined in the previous flood hazard study.

Table 15 Adopted Manning's roughness values for the channel

Reach Description	River Station (m)	Channel Roughness
Camrose Creek upstream of Mirror Lake	18,827 to 12,736	0.045
Camrose Creek through Mirror Lake	12,639 to 11,394	0.028
Mirror Lake spillway	11,382	0.013
Camrose Creek downstream of Mirror Lake	11,367 to 0	0.045
Unnamed Creek	5,730 to 702	0.045

Table 16 shows the adopted overbank roughness values for the modelled reaches. Uniform sub-reach averaged overbank roughness values were prescribed based on land cover types mentioned in **Table 12**. The adopted values are comparable with the previous flood hazard study.

Table 16 Adopted Manning's roughness values for the overbank areas

Reach Description	River Station (m)	Overbank Roughness
Camrose Creek upstream of Township Rd 472	18,827 to 16,648	0.060
Camrose Creek from Township Rd 472 to downstream of Bailey Avenue	16,632 to 15,704	0.085
Camrose Creek downstream of Bailey Avenue to 54th Avenue	15,536 to 14,014	0.060
Camrose Creek from 54th Avenue to CP Rail crossing	13,944 to 13,457	0.085
Camrose Creek from CP Rail crossing to downstream study limit	13,416 to 0	0.060
Unnamed Creek	5,730 to 702	0.060

The majority of the overbank areas were classified as either sparse vegetation or grasses and assigned a roughness value of 0.060. Other areas dominated by either densely vegetated or developed urban areas, were assigned a higher roughness of 0.085.

The adopted channel and overbank roughness values mentioned in **Table 15** and **Table 16** are applied directly for the 5-year and larger flood. However, for 2-year flood a flow roughness factor of 1.5 was assigned for Camrose Creek sub-reach upstream of the Mirror Lake (from RS 18,827 to 12,736 m). Assigning a roughness factor of 1.5 for the 2-year flood is based on the rating data at the WSC gauge.

Expansion and Contraction Coefficient

To account for the effect of flow contraction or expansion on the energy balance between successive cross sections, HEC-RAS multiplies the absolute difference in velocity head by a coefficient. The coefficients range from 0.10 for gradual transitions to 0.80 for abrupt transitions (Brunner, 2016).

The default values of 0.1 for expansion losses and 0.3 for contraction losses were used throughout the model, except for cross sections adjacent to bridge or culvert crossings where the values were increased to 0.3 and 0.5 to account for abrupt changes in flow area.

Weir Coefficient

HEC-RAS uses a broad crested weir formulation to represent flow overtopping road, rail, or similar embankments crossing the flow path. Typical discharge coefficients range between 1.4 to 1.7, with larger values generating less backwater. Flow overtopping a bridge deck is not an ideal broad crested weir, and it is generally recommended that lower values be used when an increased resistance to flow from obstructions such as bridge railings, curbs, and debris (FHA, 2012) is anticipated. For this study, a weir coefficient of 1.45 was assigned for all hydraulic structure embankments.

Blocked Obstructions

Blocked obstructions in the floodplain, such as buildings, walls, storage tanks, or elevated foundations were not specified in the HEC-RAS model. Obstructions associated with bridge piers and structural members were modelled using the standard bridge editor specifications in HEC-RAS.

Ineffective Flow Areas

Ineffective flow areas were specified at cross sections in the HEC-RAS model, based on a review of the local terrain and floodplain features both at and between cross sections. Ineffective flow areas can be specified within portions of cross sections where water is expected to pond, but where the velocity of that water, in the downstream direction, is also expected to be close to or equal to zero (Brunner, 2016). The downstream direction is taken relative to the cross section lines defined in the model, so the orientation of cross sections was considered when specifying ineffective flow areas.

Ineffective flow areas in the model may be specified as either permanent or non-permanent. Permanent ineffective flow areas apply regardless of the water surface elevation, whereas temporary ineffective flow areas become effective above a defined elevation. Non-permanent conditions often produce the undesirable result of water level profiles of high magnitudes dipping below water level profiles computed for lower flood magnitudes, so the selection of a non-permanent condition was avoided wherever possible.

Permanent ineffective flow areas were also used to account for flow patterns influenced by nearby bridge abutments and roadway embankments crossing the floodplain. These types of obstructions tend to direct flow towards the bridge opening. Several site-specific factors were taken into account when configuring ineffective flow areas at bridges/culverts in the study area, including distance from the cross section to the bridge, terrain features and bridge geometry. In case of multiple bridge openings (RS 11,521 m), more complex ineffective flow areas have been specified to direct flow towards multiple opening.

4.3.5 Flood Frequency Profiles

The hydraulic model was used to generate flood frequency profiles for the thirteen open water floods of varying magnitude ranging from 2-year to 1000-year return periods. The computed flood frequency water levels at each surveyed cross section on Camrose Creek and Unnamed Creek are provided in **Appendix E**. These results are plotted graphically in **Figure 7** for Camrose Creek and **Figure 8** for Unnamed Creek.

4.3.6 Model Sensitivity

The sensitivity of the open water hydraulic model to adjustments in boundary conditions, Manning's roughness values and weir coefficient for roadway overtopping was evaluated. These parameters affect the computed water surface profiles, and by direct result, predicted flood depths and inundation limits. The sensitivity analysis provides an indication of the plausible range of error in the model results and identifies the relative importance of each parameter to the overall error. When selecting the range of plausible parameters to test during the model sensitivity analyses, consideration was given to the variability of the factors with season and discharge. The 100-year flood was used as the baseline for the sensitivity analyses.

A summary of the sensitivity analysis results is provided below. All the sensitivity analysis profiles are presented in **Figure 9** to **Figure 17**; tabular results are presented in **Appendix F**.

Boundary Conditions

The lower and upper limits of the 95% confidence interval for the 100-year instantaneous peak discharges (as shown in **Table 8**) were examined in the sensitivity analysis. **Table 17** provides a summary of the deviation from the 100-year flood levels for the lower 95% limit discharge and the upper 95% limit discharge of Camrose Creek and Unnamed Creek. Water surface elevations for each creek are presented in **Appendix F** (**Table F-1**) and profiles are illustrated in **Figure 9** and **Figure 10.**

Table 17 Sensitivity analysis results for variation in 100-year flood frequency estimates

River	Difference from Baseline Profile (m)			
	Lower Flood Frequency Estimates		Higher Flood Frequency Estimates	
	Maximum	Average	Maximum	Average
Camrose Creek	-0.74	-0.27	1.19	0.39
Unnamed Creek	-0.07	-0.05	0.51	0.09

Camrose Creek is the most sensitive to changes in flood frequency estimation values with average deviations from the baseline 100-year profile reaching 0.39 m and maximum deviations reaching 1.19 m. The average and maximum deviations from the baseline profile on Unnamed Creek are up to 0.09 m and 0.51 m, respectively.

The adopted downstream boundary condition in the model was a normal depth, which was given by specifying an estimate of the energy grade slope equal to 0.002 m/m at the most downstream cross section. At the 100-year flood frequency discharge, this corresponds to a water surface elevation of 693.92 m at the downstream boundary. A plausible range of uncertainty in this elevation is approximate ±0.5 m. The results are presented in **Appendix F** (**Table F-2**).

The water surface elevation profiles (baseline, low downstream water level case and high downstream water level case) for Camrose Creek are illustrated in **Figure 11**. The deviation from the baseline profile falls below 0.01 m at RS 279 m for the low water level case and RS 640 m for the high water level case. Unnamed Creek is not impacted by changes to the downstream boundary condition.

Manning's Roughness

The sensitivity of the model to Manning's roughness was evaluated, with channel roughness examined independently of overbank roughness. The sensitivity of a lower and higher Manning's roughness was examined for all the modelled reaches. The results of the sensitivity analysis are discussed below.

The adopted channel roughness on Camrose Creek and Unnamed Creek was 0.045 except within Mirror Lake. A plausible range of channel roughness for the modelled length of Camrose Creek and Unnamed Creek excluding Mirror Lake is considered to be approximately ±20%. The same ±20% range was applied to the roughness values in Mirror Lake. The sensitivity analysis was run concurrently for Camrose Creek and Unnamed Creek using the values summarized in **Table 18.**

Table 18 Channel roughness values used in sensitivity analysis

River	Reach	Channel Roughness		
		Baseline	Low (-20%)	High (+20%)
Camrose Creek	All except Mirror Lake	0.045	0.036	0.054
Camrose Creek	Mirror Lake	0.028	0.022	0.034
Camrose Creek	Mirror Lake Spillway	0.013	0.010	0.016
Unnamed Creek	All	0.045	0.036	0.054

Table 19 provides a summary of the deviation from the 100-year flood levels for low and high channel roughness for reaches of Camrose Creek and Unnamed Creek. Water surface elevations for each creek are presented in **Table F-3** in **Appendix F** and profiles are illustrated in **Figure 12** and **Figure 13.**

Table 19 Sensitivity analysis results for variation in main channel roughness

River	Difference from Baseline Profile (m)			
	Low Roughness (-20%)		High Roughness (+20%)	
	Maximum	Average	Maximum	Average
Camrose Creek	-0.20	-0.06	0.16	0.05
Unnamed Creek	-0.13	-0.04	0.10	0.04

Both Camrose Creek and Unnamed Creek has an average deviations from the baseline 100-year profile reaching 0.06 m and 0.04 m respectively; and maximum deviations reaching 0.20 m and 0.13 m respectively.

The sensitivity of computed 100-year flood levels to overbank roughness variations was evaluated by selecting low and high roughness coefficients for each of the modelled river reaches. These plausible values were generally within 20% of the overbank roughness values adopted for the base model considering seasonal variations in vegetation growth and density. For the low and high roughness sensitivity runs, the overbank roughness values were adjusted by ± 20% to reflect this range (**Table 20**). The sensitivity analysis was run concurrently for Camrose Creek and Unnamed Creek.

Table 20 Overbank roughness values used in sensitivity analysis

River	Reach	Overbank Roughness		
		Baseline	Low (-20%)	High (+20%)
Camrose Creek	Upstream of HWY 472 bridge	0.060	0.048	0.072
	HWY 472 to downstream of Bailey Ave	0.085	0.068	0.102
	Downstream of Bailey Ave to 54th Ave	0.060	0.048	0.072
	54th Avenue to CP Rail crossing	0.085	0.068	0.102
	CP Rail crossing to downstream study limit	0.060	0.048	0.072
Unnamed Creek	All	0.060	0.048	0.072

Table 21 presents a summary of the results of the 100-year computed flood level sensitivity analysis for varying overbank roughness values. Water surface elevations for each case are presented in **Table F-4** in **Appendix F** and profiles are plotted on **Figure 14** and **Figure 15**.

Table 21 Sensitivity analysis results for variation in overbank roughness

River	Difference from Baseline Profile (m)			
	Low Roughness (-20%)		High Roughness (+20%)	
	Maximum	Average	Maximum	Average
Camrose Creek	-0.11	-0.05	0.10	0.04
Unnamed Creek	-0.04	-0.01	0.03	0.01

On average, flood levels were 0 to 0.11 m below baseline values for low overbank roughness. For high overbank roughness, computed flood levels were on average between 0 and 0.10 m above baseline values.

Roadway Weir Coefficient

The sensitivity of the model to the weir coefficient for roadway overtopping was evaluated. The adopted weir coefficient for the baseline model was 1.45. A sensitivity analysis was carried out only for a higher weir coefficient of 1.6, as it was considered unlikely that the weir coefficient would be lower than that adopted for the baseline. **Table 22** presents a summary of the results of the 100-year computed flood level sensitivity analysis for varying roadway weir coefficient. Water surface elevations for each case are presented in **Table F-5** in **Appendix F** and profiles are plotted on **Figure 16** and **Figure 17**.

Table 22 Sensitivity analysis results for variation in roadway weir coefficient

River	Difference from Baseline Profile (m)	
	High Weir Coefficient (C=1.6)	
	Maximum	Average
Camrose Creek	-0.03	0.00
Unnamed Creek	-0.01	0.00

The above table suggested that the computation of 100-year flood levels is not sensitive to the selection of roadway weir coefficient.

5 FLOOD INUNDATION MAPS

Flood inundation mapping shows areas of ground that could be covered by water under one or more flood scenarios for existing conditions. For this study, one flood inundation map series was created for each of the 13 flood frequency return periods from the 2-year through 1000-year scenarios. Additional information concerning the flood inundation map production is provided below. The open water flood inundation maps are provided in **Appendix G**.

5.1 Methodology

The methodology used to create the flood inundation maps followed four basic steps:

- Create a water surface elevation (WSE) triangular irregular network (TIN) representing a contiguous flood level profile along the modelled river reaches.
- Generate a WSE grid with the same grid geometry as the underlying DTM. Assign elevation values to each grid cell based on the corresponding value taken from the WSE TIN.
- Generate a depth grid (with the same grid geometry as the WSE grid) by subtracting elevation values from the underlying DTM from the corresponding WSE grid value. Negative depth values represent dry cells and were assigned a value of *NoData*.
- Generate inundation polygons based on the depth grids by converting depths greater than 0 m into inundation polygons.
- Draw minimum flood/inundation extents based on hydro-flattening breaklines for some relatively short reach segments at low return periods where the modelled water surface elevation falls below the hydro-flattened DTM. This will help to fill-in/bridge gaps in the inundation extents.

The inundation polygons were further processed by smoothing, filtering out wetted areas there were not directly inundated (or "isolated"), and removing very small dry areas (or "holes"). These inundation polygons were then used to clip the WSE grids and depth grids to the full inundation extent. All of the WSE TINs, WSE grids, depth grids, and inundation polygons are in standard Esri file format and were created using standard ArcGIS tool sets.

5.2 Water Surface Elevation TIN Modifications

Necessary modifications were made to the water surface elevation TIN for areas that need manual edits (for example overbank flooding area or backwater area) so that inundation polygons could be re-generated from the data using the procedure described in **Section 5.1** above.

Areas showing extensive overbank/backwater flooding directly connected to the channel at one distinct location (overtopping point) were adjusted such that the water surface elevation across that area was set equal to the water surface elevation at the overtopping point. This generally reduced the size of the inundated area extending upstream of an overtopping point and increased the size of the inundated area extending downstream of the overtopping point.

Roadway crossings overtopped at one distinct location were also adjusted such that the water surface elevation on top of the roadway crossing was set equal to the water surface elevation at the overtopping location.

TINs were adjusted downstream of Mirror Lake Spillway such that the water surface elevation between the spillway (RS 11,384 m) and downstream cross section (RS 11,367 m) was set equal to the water surface elevation at the downstream cross section (RS 11,367 m). Mirror Lake spillway has a vertical drop and thus interpolation of water surface elevation between Mirror Lake spillway and the downstream cross section is incorrect.

There is no flood control structure within the study reach and thus no water surface elevation TIN modifications were required for the potential flood control structure failure.

5.3 Flood Inundation Areas

5.3.1 Residential Areas

Residential areas in several communities have the potential to be impacted by flooding.

City of Camrose

- Residential properties west of 53rd Street near the confluence of Camrose Creek and Unnamed Creek would be flooded starting at the 50-year flood.
- Residential areas north of 54th Avenue and adjacent to 58th Street would be inundated starting at the 200-year flood. One residence north of 54th Avenue and on the left bank of Camrose Creek would also begin to be impacted at the 350-year flood.
- Flooding would occur at residential areas south of 54th Avenue to the CP Rail crossing. The flooding would mainly be caused by the backwater from the CP Rail box culvert. Direct inundation would begin on the left bank of Camrose Creek during the 20-year flood along 58th Street and 58th Street close. The residential area on the right bank of Camrose Creek just south of 54th Avenue would be flooded starting at the 50-year flood. The severity of the flooding would increase with the flood magnitude and more residencies would be impacted on both left and right banks.

Camrose County

- One residence east of Highway 833 and south of Township Road 472 would be inundated during the 200-year and larger floods. Few additional residence would be flooded starting at the 350-year flood.

- Residences at the community of Braim along Kent Street would begin to be impacted during the 20-year flood. Residences on the right bank adjacent to Highway 833 would also be inundated starting at the 10-year flood.

5.3.2 Commercial and Industrial Areas

Commercial and industrial areas in several communities have the potential to be impacted by flooding.

City of Camrose

- A portion of Camrose Golf Course, Mirror Lake Park, and Jubilee Park adjacent to Camrose Creek have the potential to be flooded. The overbank areas would begin to be flooded during 5-year flood and the inundation extent would increase with higher frequency floods.
- Several agricultural lands would be impacted by the flooding.

Camrose County

- Flooding would occur at the Whistle Stop Golf Course located on the east of Camrose Creek, starting at the 5-year flood. As the magnitude of the flood increases, several buildings would be impacted.
- Several agricultural lands would be impacted by the flooding.

5.3.3 Hydraulic and Flood Control Structures

The deck elevations for road and rail bridges crossing Camrose Creek are well above the 10-year flood level. Some bridges for example 48th Avenue Bridge and culvert, 47th Avenue Bridge, 44th Avenue Bridge, Camrose Drive Bridge and all CN rail truss bridges would not be flooded even in 1000-year flood. However, some smaller golf course, trail and pedestrian bridges would start to be impacted during the 2-year flood.

There are no flood control structures within the study reach; therefore, there would be no potential flooding due to flood control structure failure.

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 Guidelines (Alberta Environment, 2011), incorporating technical changes implemented in 2021 regarding how floodways are mapped in Alberta, is provided in Sections 6.1 and 6.2 below.

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. This is a flood with a statistical 100-year return period, also commonly referred to as the "one in one hundred year flood".

The 100-year open water flood was selected as the design flood for Camrose Creek and Unnamed Creek. The discharge values used for the design flood correspond to the 100-year return period discharges listed in **Table 8.**

6.2 Floodway and Flood Fringe Terminology

Flood Hazard Mapping

Flood hazard mapping identifies the area flooded for the design flood and is typically divided into floodway and flood fringe zones. Flood hazard maps can also show additional flood hazard information, including areas of high hazard within the flood fringe and incremental areas at risk for more severe floods, like the 200-year and 500-year floods. Flood hazard mapping is typically used for long-term flood hazard area management and land-use planning.

Flood Hazard Area

The flood hazard area is the area of land that would be flooded during the design flood. It is composed of the floodway and the flood fringe zones, which are defined below.

Floodway

When a floodway is first defined on a flood hazard map, it typically represents the area of highest flood hazard where flows are deepest, fastest, and most destructive during the design flood. The floodway generally includes the main channel of a stream and a portion of the adjacent overbank area. Previously mapped floodways do not typically become larger when a flood hazard map is updated, even if the flood hazard area gets larger or design flood levels get higher.

Flood Fringe

The flood fringe is the portion of the flood hazard area outside of the floodway. The flood fringe typically represents areas with shallower, slower, and less destructive flooding during the design flood. However, areas with deep or fast moving water may also be identified as high hazard flood fringe within the flood fringe. Areas at risk behind flood berms may also be mapped as protected flood fringe areas.

Design Flood Levels

Design flood levels are the computed water levels associated with the design flood.

6.3 Flood Hazard Identification

6.3.1 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.
- In no case should the floodway boundary extend into the main river channel area.
- For reaches of supercritical flow, the floodway boundary should correspond to the edge of inundation or the main channel, whichever is larger.

When a flood hazard map is updated, an existing floodway will not change in most circumstances. Exceptions to this would be: (1) a floodway could get larger if a main channel shifts outside of a previously-defined floodway or (2) a floodway could get smaller if an area of previously-defined floodway is no longer flooded by the design flood.

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

The floodway limit stations and limiting criteria for each cross section are tabulated in **Appendix H.** The limits of the floodway (also denoted as the floodway boundary) intersect cross sections at the floodway limit stations. In some instances the floodway limits are coincident with the inundation limits. This condition typically occurs when a limiting station (defined by the usual criteria) is very close to the extent of inundation and there is no practical width of flood fringe – along steep valley walls or high slopes, for example.

The floodway limit lines extending between cross sections were delineated based on the adjacent limiting criteria and drawn such that the resulting lines followed a *hydraulically-smooth* path. For previously mapped reaches, an existing floodway from the 1994 flood study was adopted and adjusted according to the aforementioned exceptions. For newly mapped reaches, the floodway mostly followed along the 1 m depth contour for Camrose Creek and the inundation extent for Unnamed Creek. In some instances, the floodway extended into depths less than 1 m where velocities were high. When the width of the flood fringe was impractically small, the floodway was drawn coincident with the water's edge.

6.3.2 Design Flood Profile

The design flood profile levels were those calculated for the 100-year open water flood condition. The resulting design flood level values are listed in **Appendix H**.

Figure 18 and **Figure 19** depicts the open water design flood level profiles for Camrose Creek and Unnamed Creek respectively.

6.3.3 Floodway Criteria Maps

The floodway criteria maps are a tool for determining floodway and flood fringe extents for the design flood, including boundaries of high hazard flood fringe and protected flood fringe areas.

The mapping exercise began with the computed water surface elevations and flow velocities for the 100-year open water flood. The extent of inundation was then mapped using the general procedure described in **Section 5.1**. This procedure included generation of the corresponding water surface elevation (WSE) triangular irregular network (TIN), WSE grid, and flood depth grid.

The 1 m depth contours and inundated areas where the depth of water is 1 m or greater were derived from the flood depth grid. The depth contours were then filtered and smoothed using the same parameters and procedures as those applied to the inundation extents.

Since an one-dimensional computational modelling approach was used for this study, flow velocities were only available at the cross section locations. HEC-RAS can apportion channel and overbank discharge into a maximum of 45 sub-sections at any cross section location. Discharge is apportioned based on the computed water level and a weighted flow area approach. This provides a convenient means to estimate the lateral variation in velocity across a section. For this study, the maximum number of velocity subsections were specified in the overbanks. The velocity values for each segment along the cross sections were symbolized on the floodway criteria maps to visualize the transverse variation in velocity along each cross section.

The open water floodway criteria maps are provided in **Appendix I**. The information documented on the maps include:

- inundation extents of the design flood;
- areas where the depth of water is 1 m or greater and the corresponding 1 m depth contour;
- the portions of each cross section where the computed velocity is 1 m/s or faster;
- the proposed floodway boundary, as well as the associated floodway limiting stations corresponding to the floodway determination criteria;
- isolated areas of non-flooded, high ground (i.e., “dry areas”) within the design flood extent;
- the location and extent of all cross sections used in the HEC-RAS model; and
- the previous-mapped floodway boundary (where it exists).

6.3.4 Flood Hazard Maps

The flood hazard maps divide the design flood extents into floodway and flood fringe zones, including boundaries of high hazard flood fringe. The information used to create the flood hazard maps was based on the open water floodway criteria mapping information detailed in the **Section 6.3.3** above.

The limits of the floodway were delineated by the floodway boundary developed for the open water floodway criteria map. Areas of high ground or areas of depth less than 1 m inside the floodway boundaries were included as part of the floodway. The resulting floodway was represented as a single contiguous polygon.

The design flood extent developed for the floodway criteria maps was adjusted to create the flood fringe. The limits of the flood fringe followed the extent of direct inundation of the design flood. Areas of high ground within the extent of direct inundation (and outside of the floodway) were preserved and were not indicated as flood fringe in the flood hazard map.

The resulting governing flood hazard maps are provided as **Appendix J**.

Areas in the Floodway

Notable overbank areas in the floodway include:

- A portion of the Whistle Stop Golf Course.
- Properties west of 53rd Street near the confluence of Camrose Creek and Unnamed Creek.
- Residential areas adjacent to 54th Avenue on right bank of Camrose Creek.
- A few residences at 58th Street Cl, south of 54th Avenue.

Areas in the High Hazard Flood Fringe

The high hazard flood fringe includes all inundated areas outside the floodway but within the deeper or faster moving water. Notable inundated areas within the high hazard flood fringe include:

- Residences along 58th Street ,south of 54th Avenue

Areas in the Flood Fringe

The flood fringe includes all inundated areas outside the limits of the floodway and high hazard flood fringe. Notable inundated areas within the flood fringe include:

- Residences at the community of Braim along Kent Street
- Residential properties west of 53rd Street near the confluence of Camrose Creek and Unnamed Creek
- Residencies at 58th Street and 58th Street Cl, south of 54th Avenue
- Portions of Camrose Golf Course, Mirror Lake Park, and Jubilee Park adjacent to Camrose Creek

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 in order 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 Scenarios

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 percent greater than the current 100-year flood estimates. This approach is consistent with guidelines prepared by Engineers and Geoscientists British Columbia (EGBC, 2018). EGBC recommends that for basins where no historical trend is detectable in local or regional streamflow magnitude frequency relations, a 10 percent upward adjustment 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 percent adjustment may be appropriate, particularly for smaller basins.

7.2 Results

The results of the analysis for the open water design flood hazard are provided in **Table 23**.

Table 23 Average increases in water level associated with more severe open water design flood scenarios

Stream	Average Increase in Design Flood Level (m)	
	100-Year Plus 10%	100-Year Plus 20%
Camrose Creek	0.21	0.42
Unnamed Creek	0.04	0.12

7.3 Supplementary Information

Climate change has the potential to affect many factors related to flood severity. For open water floods, more frequent and greater intensity summer rain storms are commonly attributed to future climate flood risks. A comprehensive analysis would consider meteorological and hydrological factors at the basin scale to assess changes in flood peak discharges and their associated return periods.

8 CONCLUSIONS

The Camrose Flood Hazard Study was done according to FHIP Guidelines, incorporating technical changes implemented in 2021 regarding how floodways are mapped in Alberta. The objectives of this study were to assess river flood-related hazards along 19 km of Camrose Creek reach, and 6 km of Unnamed Creek reach that includes the City of Camrose and Camrose County. A flood hazard mapping study was previously completed for the Camrose area by IDE (1994); however, the present study covers an expanded study reach and represents an update to the prior work.

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

The collection of survey and base data primarily supports the hydraulic modelling and flood mapping. Cross sections were surveyed along the study reaches. In total, 246 cross sections were surveyed using a combination of boat-based bathymetric and ground surveys to complement the LiDAR-derived DTM. In addition, geometric details were collected for 39 bridges, nine culverts, and one spillway/weir.

The primary purpose of the open water hydrology assessment is to develop flood frequency estimates for Camrose Creek and Unnamed Creek, in support of the hydraulic modelling and flood mapping tasks of the Camrose Flood Hazard Study. In expectation that noticeable changes in creek discharge would occur within the study reach, five sites were identified for flood frequency estimates. The sites are Unnamed Tributary at the mouth, Camrose Creek near Camrose (WSC Station 05FA025), Camrose Creek above the CPR crossing, Camrose Creek at Mirror Lake, and Camrose Creek at the downstream end of the study reach. Details on open water hydrology assessment were provided as a separate memorandum and attached under separate cover in **Appendix D**.

For the Open Water Hydraulic Modelling component, a numerical model has been developed using the HEC-RAS computer program from the U.S. Army Corps of Engineers. Stream bathymetry and digital terrain data from the Survey and Base Data Collection component as well as flood frequency estimates from the Open Water Hydrology Assessment component have been used to develop, validate, and apply the open water hydraulic model as described throughout this report. Channel and overbank roughness for the model were assigned based on a literature review. No high flow calibration for the model was possible due to unavailability of high water marks concurrent with discharge data. However, low flow validation was conducted based on field measurements during NHC survey and WSC gauge data. 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. These profiles showed that the deck elevations for road and rail bridges crossing Camrose Creek are well above the 10-year flood level, however some golf course, pedestrian, and trail bridges would start flooding as early as in the 2-year flood.

Flood inundation maps were created for the 13 flood frequency return periods from the 2-year through 1000-year scenarios. The Whistle Stop Golf Course and Camrose Golf Course would be affected by direct inundation at the 5-year flood level. Areas would be impacted at the 20-year flood level include: the community of Braim, residential areas along 58th Street and 58th Street Cl which is south of 54th Avenue. Areas would be affected at the 50-year flood level include: residential properties west of 53rd Street near the confluence of Camrose Creek and Unnamed Creek. A few other areas, including residential properties north of 54th Avenue and adjacent to 58th Street, residencies adjacent to Township Road 472 and Highway 833 along Camrose Creek would start inundating in 200-year and larger floods.

Floodway criteria maps were developed for the design flood with the criteria used to define the floodway and flood fringe. The design flood corresponded to the 100-year open water design flood. For Camrose Creek, the floodway boundaries were mostly limited by the existing floodway from 1994 study, and 1 m depth criterion. On a few occasions the floodway boundaries were limited by the 1 m/s velocity or main channel. Along steep valley walls and high banks the 1 m depth contours and/or 1 m/s velocity followed closely along with the extent of inundation, which would have resulted in a very narrow, impractical, band of flood fringe. In these instances, the floodway limits were set to coincide with the water's edge and an "Inundation Extent" condition was assigned to the corresponding cross sections. For Unnamed Creek, the floodway boundaries were mostly limited by inundation extent, on a few occasions by the 1 m depth, 1 m/s velocity, and main channel. The design flood hazard map depicts the floodway, high hazard flood fringe, flood fringe, and associated flood hazard boundary. Notable areas within the floodway include a portion of the Whistle Stop Golf Course, properties west of 53rd Street near the confluence of Camrose Creek and Unnamed Creek, residential areas adjacent to 54th Avenue on right bank of Camrose Creek, and few residences at 58th Street Cl and south of 54th Avenue.

9 REFERENCES

Alberta Environment (AENV), 1993. Flood Frequency Analysis Camrose Floodplain Study. Water Resources Management Services & Monitoring Division Hydrology Branch, Alberta Environment, April 1993.

Arcement, G.J., Schneider, V.R., 1989. Guide for selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains. US Geological Survey Water Supply Paper 2339. Prepared in cooperation with the United States Department of Transportation, Federal Highway Administration.

Brunner, G., 2016. HEC-RAS River Analysis System Hydraulic Reference Manual. Version 5.0. Hydrologic Engineering Center, U.S. Army Corps of Engineers. Davis, California. February 2016.

Chow, V.T., 1959. Open Channel Hydraulics, McGraw-Hill Book Company, NY.

DUC, 2019. Camrose Creek Research Project – Understanding the Link between Wetlands and Flooding. Presentation by Ducks Unlimited Canada, Camrose, 13 May 2019.

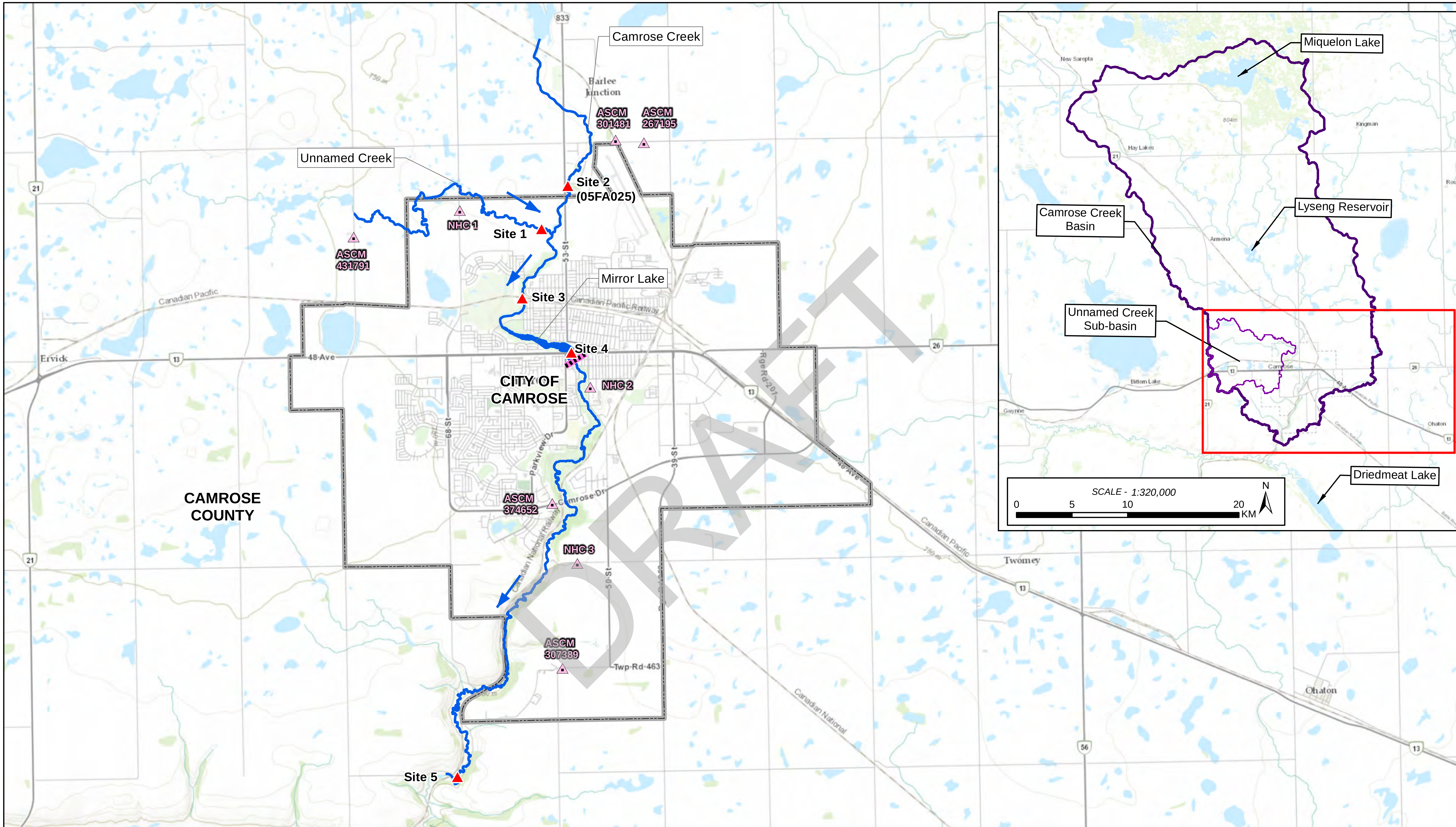
Engineers and Geoscientists British Columbia (EGBC), 2018. Legislated Flood Assessments in a Changing Climate in BC. Version 2.1.

Federal Highway Administration (FHA), 2012. Hydraulic Design of Safe Bridges (HDS-7), U.S. Department of Transportation, Federal Highway Administration, April 2012.

Henderson, 1966. Open Channel Flow. MacMillan Publishing Co. Inc., New York.

I.D. Engineering Company Limited (IDE), 1994. Camrose Flood Risk Mapping Study for Canada-Alberta Flood Damage Reduction Program, February 1994.

Figures



▲ FLOOD FREQUENCY ESTIMATE LOCATION

△ CONTROL POINT

STUDY REACH

MIRROR LAKE DAM

MUNICIPAL BOUNDARY

Alberta

nhc northwest hydraulic consultants

DATA SOURCES: NRCan, Esri World Topographic Basemap

SCALE - 1:55,000

0 0.5 1 2 KM

N

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

Job: 1004662 | Date: 30-APR-2020

CAMROSE
FLOOD HAZARD STUDY

STUDY AREA AND BASIN OVERVIEW

FIGURE 1

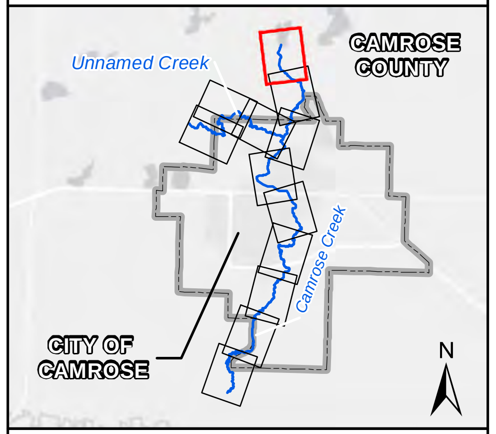
REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS\1004662_Fig1_StudyAreaBasinOverview_R0.mxd

Classification: Public

SHEET 2 →

Alberta

nhc northwest hydraulic consultants



- FLOW DIRECTION
- CONTROL POINT
- SURVEY POINT
- STUDY REACH
- CROSS SECTION
- DAM & SPILLWAY
- BRIDGE
- CULVERT
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- STUDY LIMIT
- CAMROSE CITY BOUNDARY

SCALE - 1:5,000

0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 *Date: 30-APR-2020*

CAMROSE
FLOOD HAZARD STUDY

SURVEY AND STRUCTURE LOCATION AND OVERVIEW

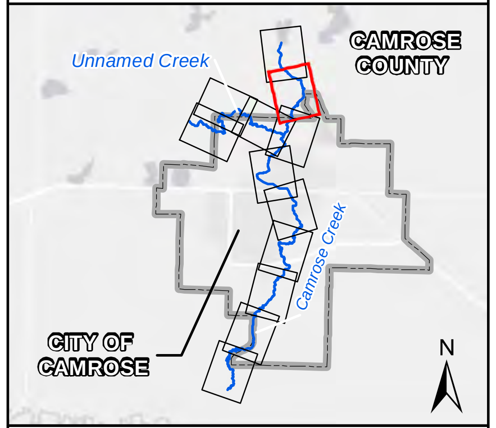
SHEET 1 OF 12 *FIGURE 2*

REH; P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS\1004662_Fig2_Survey.mxd

Classification: Public

Alberta

nhc northwest hydraulic consultants



- FLOW DIRECTION
- CONTROL POINT
- SURVEY POINT
- STUDY REACH
- CROSS SECTION
- DAM & SPILLWAY
- BRIDGE
- CULVERT
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- STUDY LIMIT
- CAMROSE CITY BOUNDARY

SCALE - 1:5,000

0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 | Date: 30-APR-2020

CAMROSE
FLOOD HAZARD STUDY

SURVEY AND STRUCTURE LOCATION AND OVERVIEW

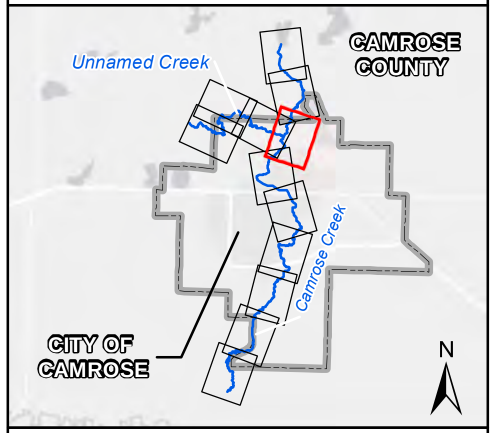
SHEET 2 OF 12 | FIGURE 2

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS\1004662_Fig2_Survey.mxd

Classification: Public

Alberta

nhc
northwest hydraulic consultants



- FLOW DIRECTION
- CONTROL POINT
- SURVEY POINT
- STUDY REACH
- CROSS SECTION
- DAM & SPILLWAY
- BRIDGE
- CULVERT
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- STUDY LIMIT
- CAMROSE CITY BOUNDARY

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

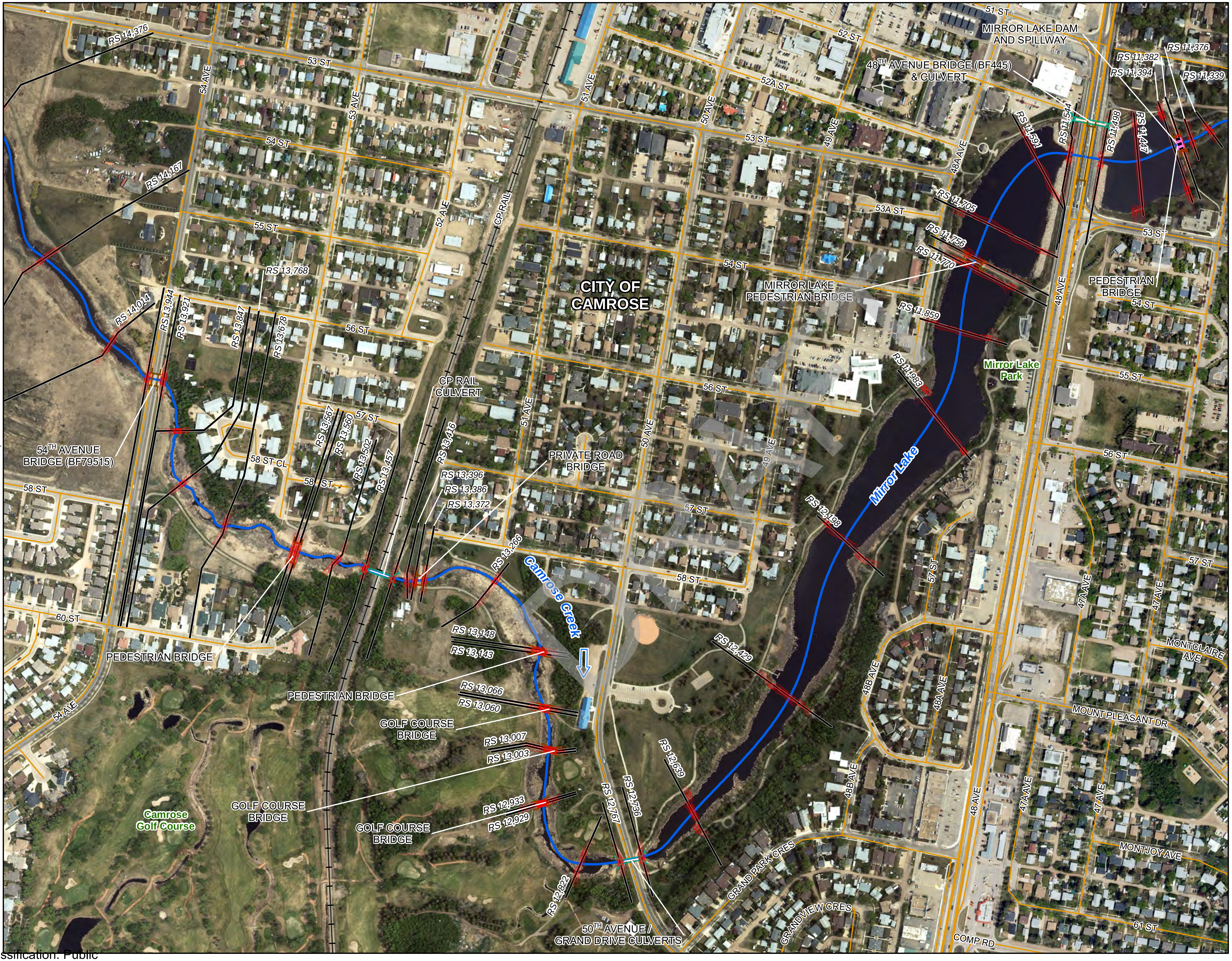
Job: 1004662 Date: 30-APR-2020

CAMROSE
FLOOD HAZARD STUDY

SURVEY AND STRUCTURE LOCATION AND OVERVIEW

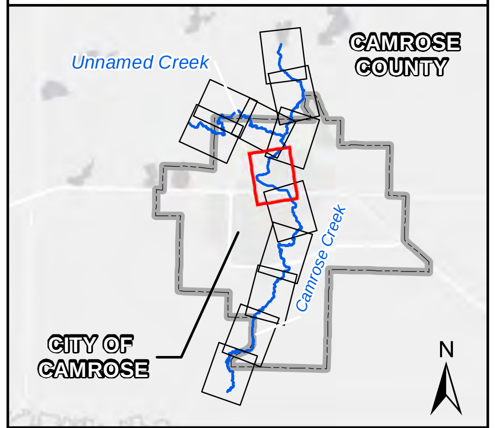
SHEET 3 OF 12 FIGURE 2

REH P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS\1004662_Fig2_Survey.mxd



Alberta

nhc
northwest hydraulic consultants



- FLOW DIRECTION
- CONTROL POINT
- SURVEY POINT
- STUDY REACH
- CROSS SECTION
- DAM & SPILLWAY
- BRIDGE
- CULVERT
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- STUDY LIMIT
- CAMROSE CITY BOUNDARY

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 | Date: 30-APR-2020

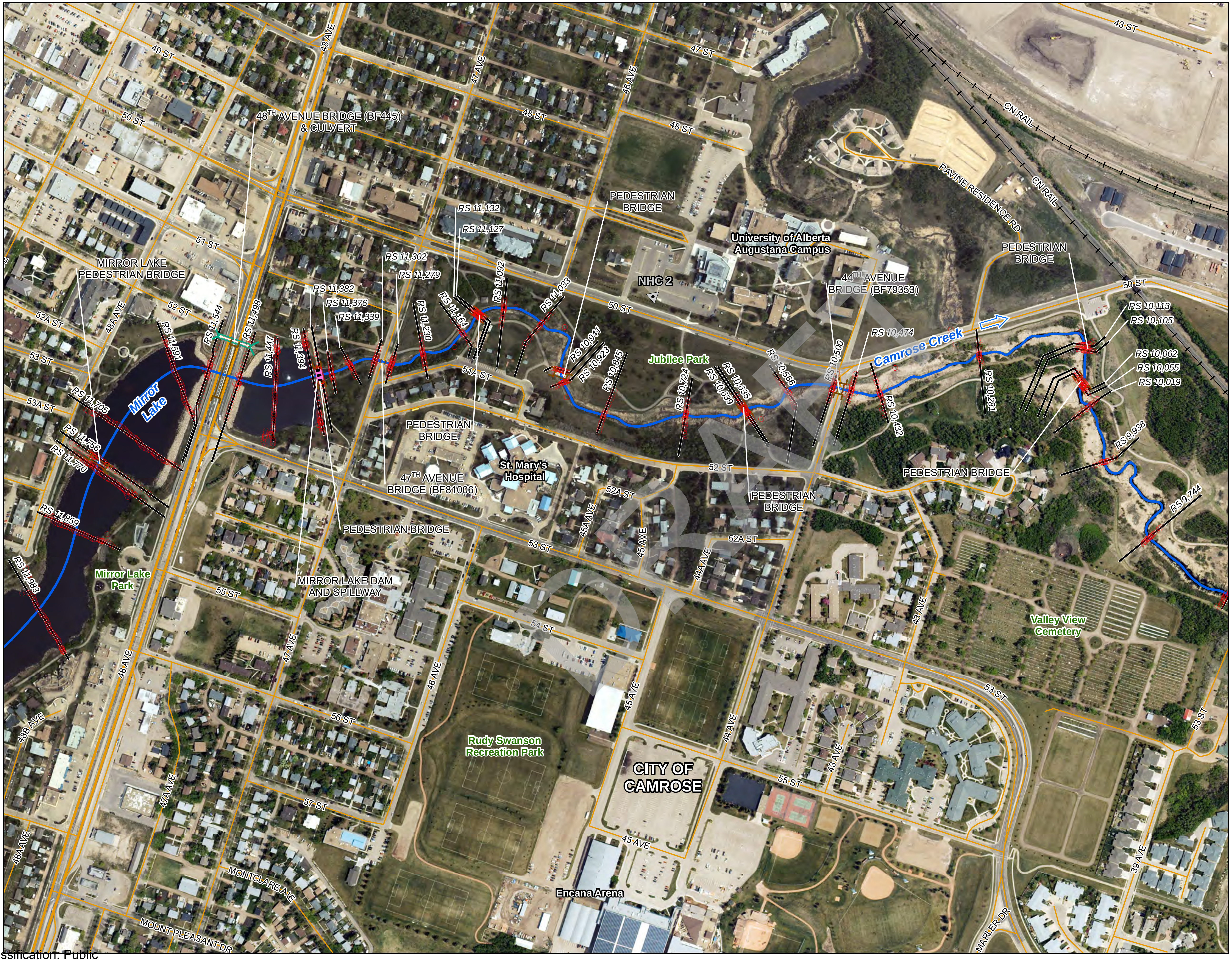
CAMROSE
FLOOD HAZARD STUDY

SURVEY AND STRUCTURE LOCATION AND OVERVIEW

SHEET 4 OF 12 | FIGURE 2

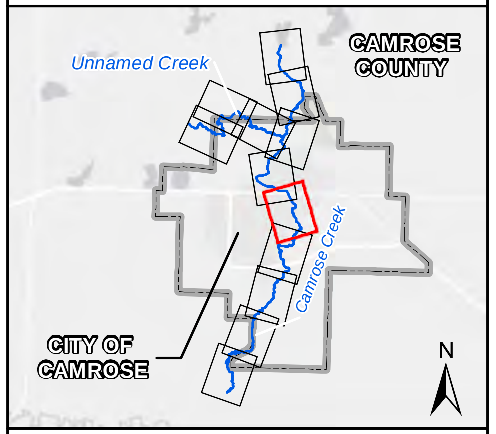
REH_P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS\1004662_Fig2_Survey.mxd

Classification: Public



Alberta

nhc
northwest hydraulic consultants



- FLOW DIRECTION
- CONTROL POINT
- SURVEY POINT
- STUDY REACH
- CROSS SECTION
- DAM & SPILLWAY
- BRIDGE
- CULVERT
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- STUDY LIMIT
- CAMROSE CITY BOUNDARY

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 | Date: 30-APR-2020

CAMROSE
FLOOD HAZARD STUDY

SURVEY AND STRUCTURE LOCATION AND OVERVIEW

SHEET 5 OF 12 | FIGURE 2

REH P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS\1004662_Fig2_Survey.mxd

Classification: Public

Alberta

nhc
northwest hydraulic consultants

FLOW DIRECTION
CONTROL POINT
SURVEY POINT
STUDY REACH
CROSS SECTION
DAM & SPILLWAY
BRIDGE
CULVERT
PROVINCIAL HIGHWAY
LOCAL ROAD
RAILWAY
STUDY LIMIT
CAMROSE CITY BOUNDARY

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 | Date: 30-APR-2020

CAMROSE
FLOOD HAZARD STUDY

SURVEY AND STRUCTURE LOCATION AND OVERVIEW

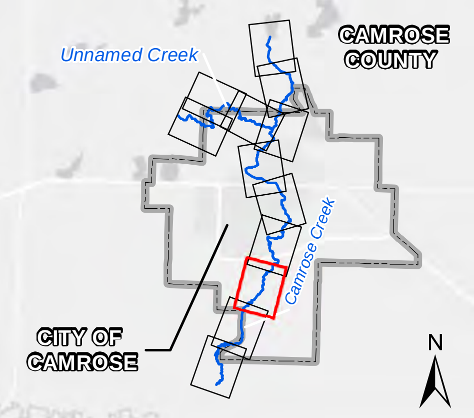
SHEET 6 OF 12 | FIGURE 2

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS\1004662_Fig2_Survey.mxd

Classification: Public

Alberta

nhc
northwest hydraulic consultants



FLOW DIRECTION
CONTROL POINT
SURVEY POINT
STUDY REACH
CROSS SECTION
DAM & SPILLWAY
BRIDGE
CULVERT
PROVINCIAL HIGHWAY
LOCAL ROAD
RAILWAY
STUDY LIMIT
CAMROSE CITY BOUNDARY

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 Date: 30-APR-2020

CAMROSE
FLOOD HAZARD STUDY

SURVEY AND STRUCTURE LOCATION AND OVERVIEW

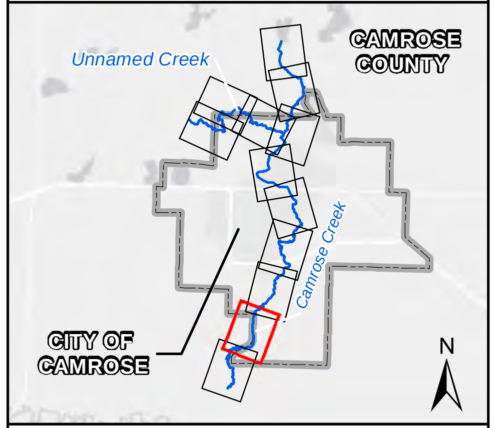
SHEET 7 OF 12 FIGURE 2

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS\1004662_Fig2_Survey.mxd

Classification: Public

Alberta

nhc northwest hydraulic consultants



- FLOW DIRECTION
- CONTROL POINT
- SURVEY POINT
- STUDY REACH
- CROSS SECTION
- DAM & SPILLWAY
- BRIDGE
- CULVERT
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- STUDY LIMIT
- CAMROSE CITY BOUNDARY

SCALE - 1:5,000

0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 | Date: 30-APR-2020

CAMROSE
FLOOD HAZARD STUDY

SURVEY AND STRUCTURE LOCATION AND OVERVIEW

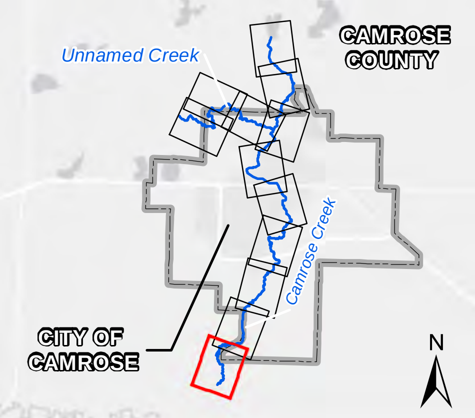
SHEET 8 OF 12 | FIGURE 2

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS\1004662_Fig2_Survey.mxd

Classification: Public

Alberta

nhc
northwest hydraulic consultants



- FLOW DIRECTION
- CONTROL POINT
- SURVEY POINT
- STUDY REACH
- CROSS SECTION
- DAM & SPILLWAY
- BRIDGE
- CULVERT
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- STUDY LIMIT
- CAMROSE CITY BOUNDARY

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 | Date: 30-APR-2020

CAMROSE
FLOOD HAZARD STUDY

SURVEY AND STRUCTURE LOCATION AND OVERVIEW

SHEET 9 OF 12 | FIGURE 2

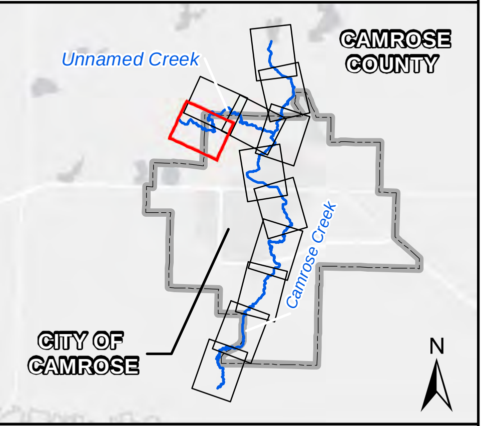
REH_P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS\1004662_Fig2_Survey.mxd

Classification: Public

Classification: Public

Alberta

nhc
northwest hydraulic consultants



FLOW DIRECTION
CONTROL POINT
SURVEY POINT
STUDY REACH
CROSS SECTION
DAM & SPILLWAY
BRIDGE
CULVERT
PROVINCIAL HIGHWAY
LOCAL ROAD
RAILWAY
STUDY LIMIT
CAMROSE CITY BOUNDARY

SCALE - 1:5,000
0 100 200 M
N

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

Engineer	GIS	Reviewer
MMM	REH	RBA

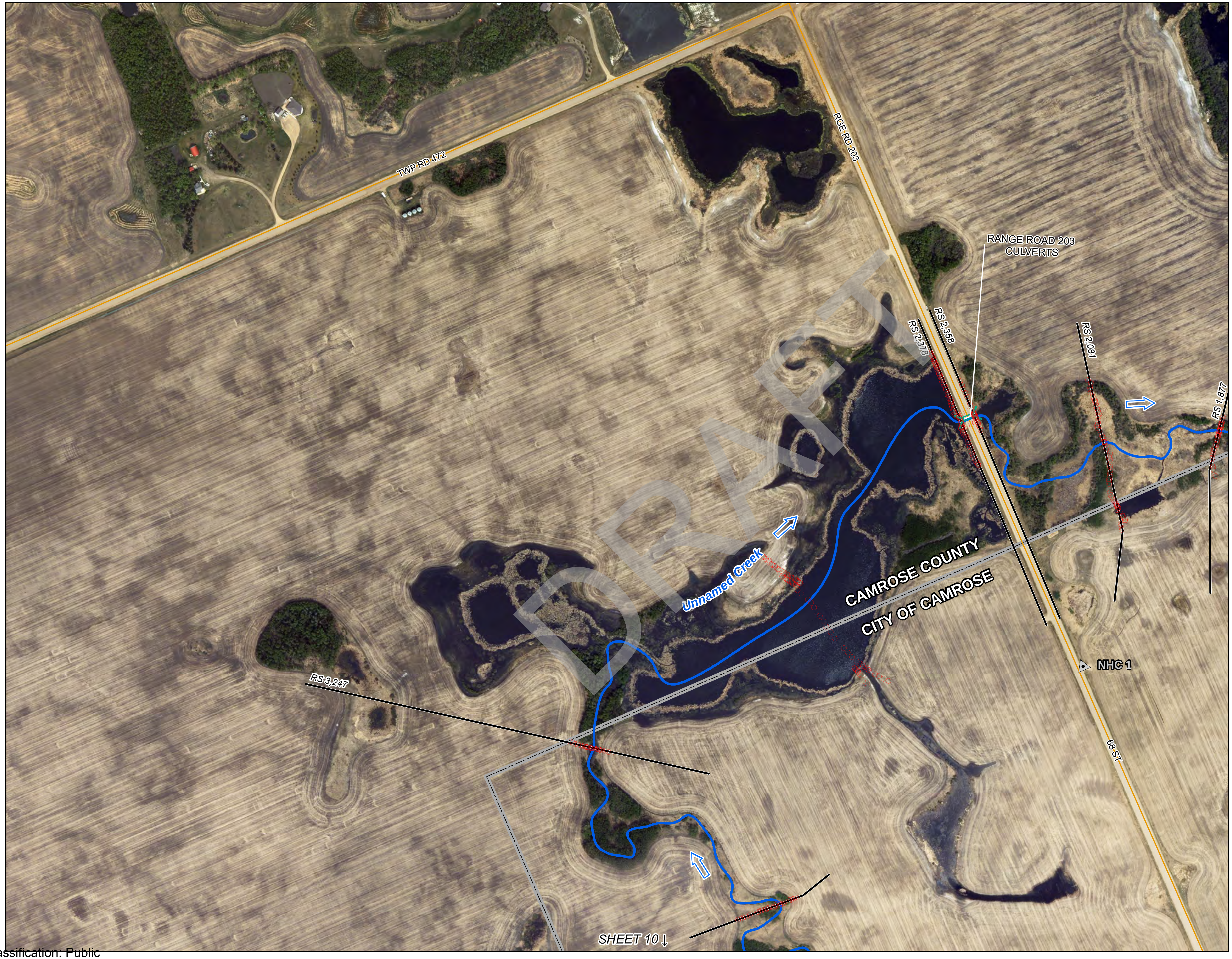
Job: 1004662 | Date: 30-APR-2020

CAMROSE
FLOOD HAZARD STUDY

SURVEY AND STRUCTURE LOCATION AND OVERVIEW

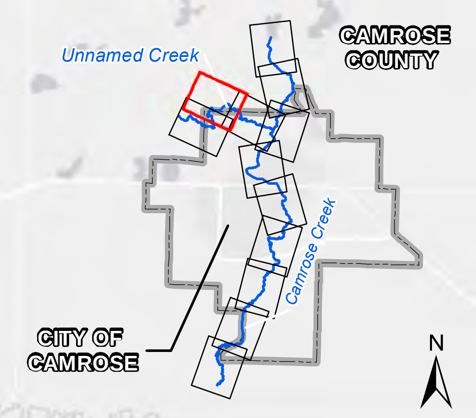
SHEET 10 OF 12 | FIGURE 2

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS\1004662_Fig2_Survey.mxd



Alberta

nhc
northwest hydraulic consultants



- FLOW DIRECTION
- CONTROL POINT
- SURVEY POINT
- STUDY REACH
- CROSS SECTION
- DAM & SPILLWAY
- BRIDGE
- CULVERT
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- STUDY LIMIT
- CAMROSE CITY BOUNDARY

SCALE - 1:5,000

0 100 200 M

N

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662	*Date: 30-APR-2020*

CAMROSE
FLOOD HAZARD STUDY

SURVEY AND STRUCTURE LOCATION AND OVERVIEW

SHEET 11 OF 12 *FIGURE 2*

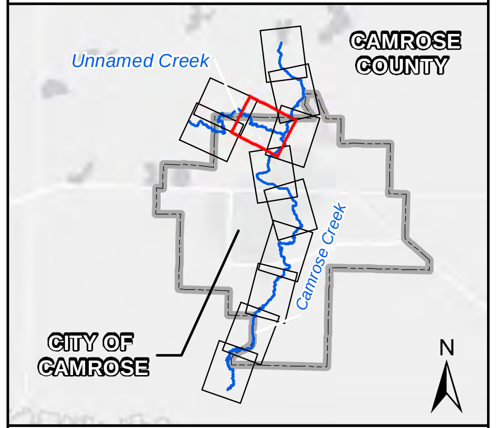
REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS\1004662_Fig2_Survey.mxd

Classification: Public

Classification: Public

Alberta

nhc northwest hydraulic consultants



- FLOW DIRECTION
- CONTROL POINT
- SURVEY POINT
- STUDY REACH
- CROSS SECTION
- DAM & SPILLWAY
- BRIDGE
- CULVERT
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- STUDY LIMIT
- CAMROSE CITY BOUNDARY

SCALE - 1:5,000

0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

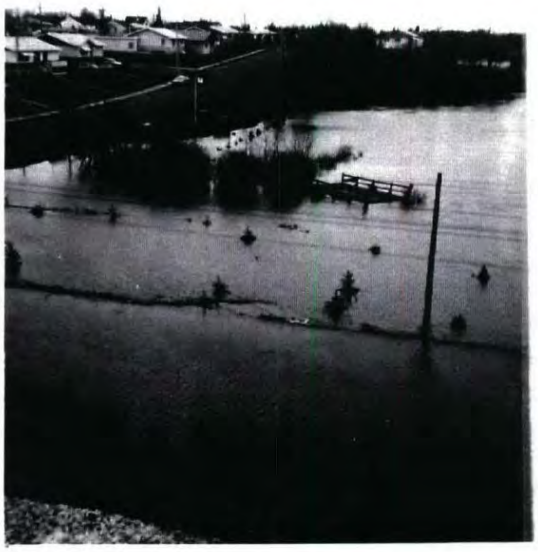
Job: 1004662	Date: 30-APR-2020

CAMROSE
FLOOD HAZARD STUDY

SURVEY AND STRUCTURE LOCATION AND OVERVIEW

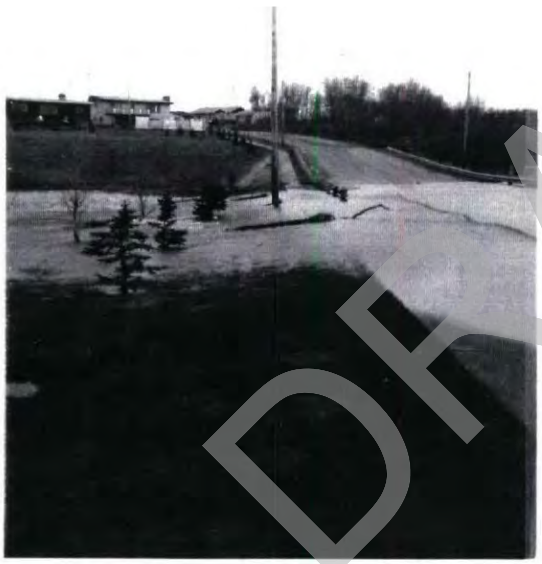
SHEET 12 OF 12 | FIGURE 2

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS\1004662_Fig2_Survey.mxd



LOOKING SOUTH-EAST FROM CPR TRACKS OVER THE CREEK - BRIDGE/ROADWAY SOUTH OF CPR CULVERT FULLY SUBMERGED

LOOKING WEST, SOUTH OF CPR EMBANKMENT - BRIDGE/ROADWAY FULLY SUBMERGED



LOOKING SOUTH-WEST ACROSS GRAND DRIVE - ROADWAY FULLY SUBMERGED

LOOKING NORTH AT JUBILEE PARK APPROXIMATELY AT 46 AVENUE AND 52 STREET

Notes: 1. Flood photographs are obtained from previous flood hazard study (IDE, 1994).

Alberta

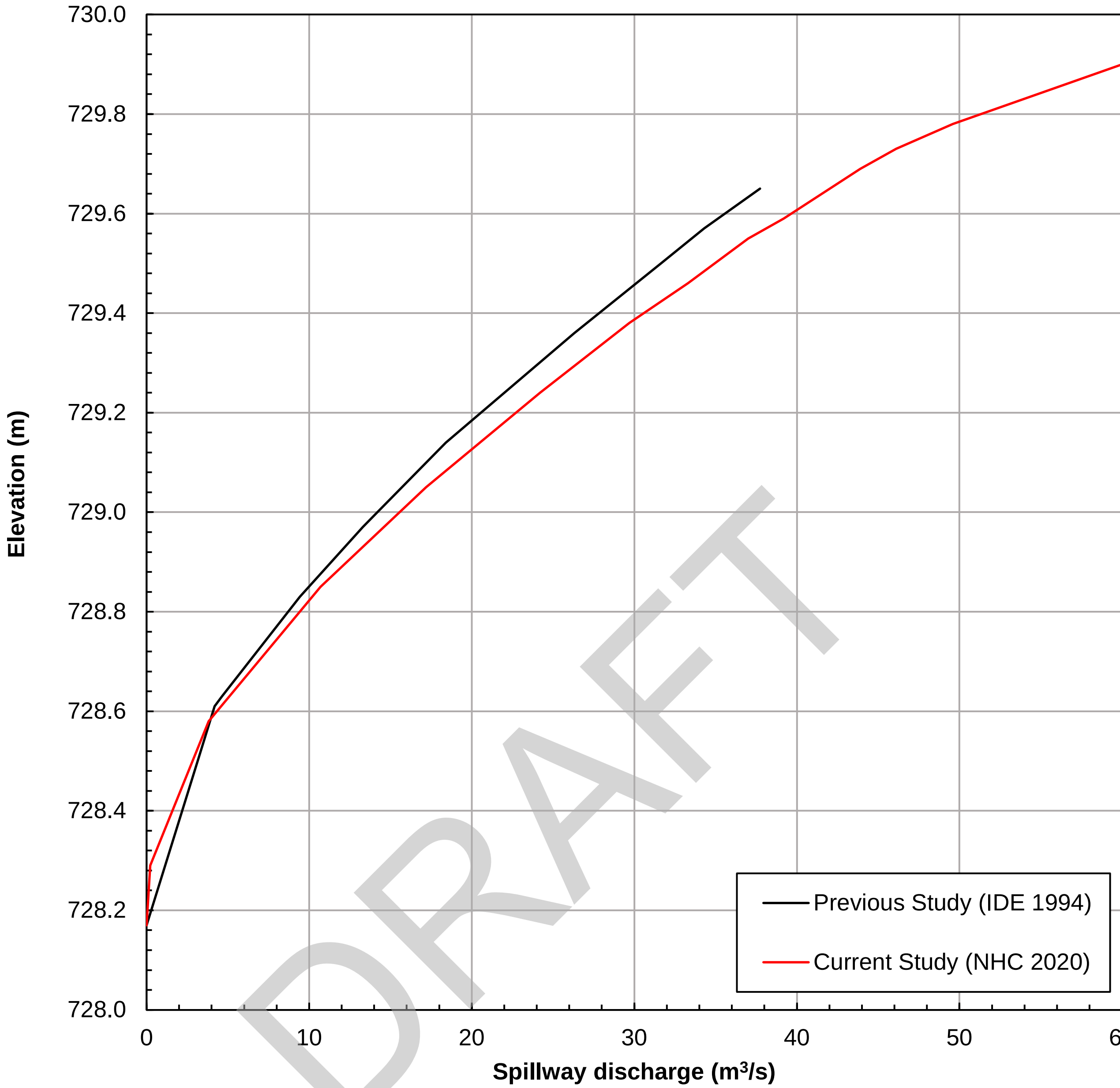
nhc northwest hydraulic consultants

Job: 1004662 | Date: 30-APR-2020

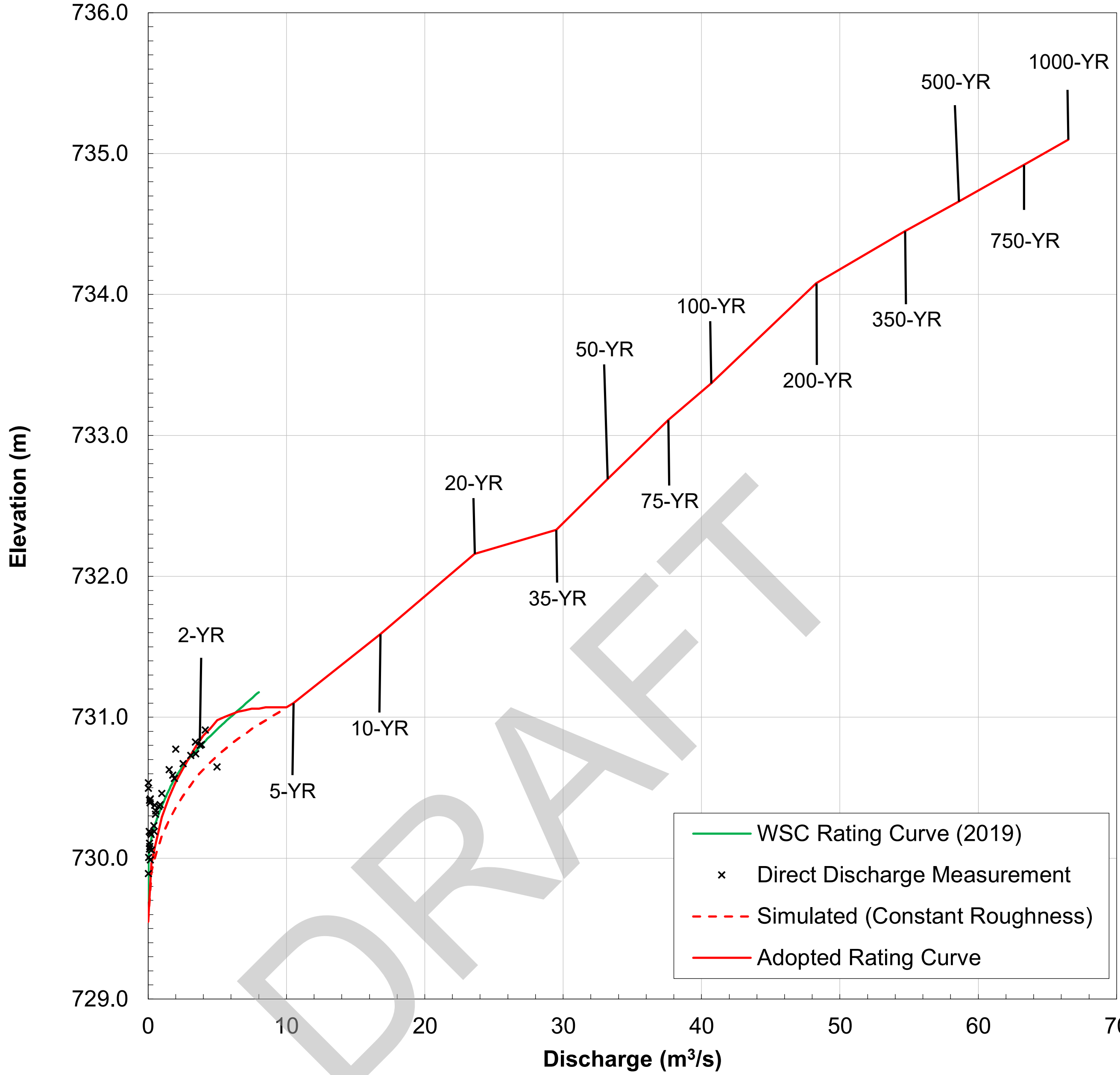
CAMROSE
FLOOD HAZARD STUDY

1974 FLOOD PHOTOGRAPHS

FIGURE 3

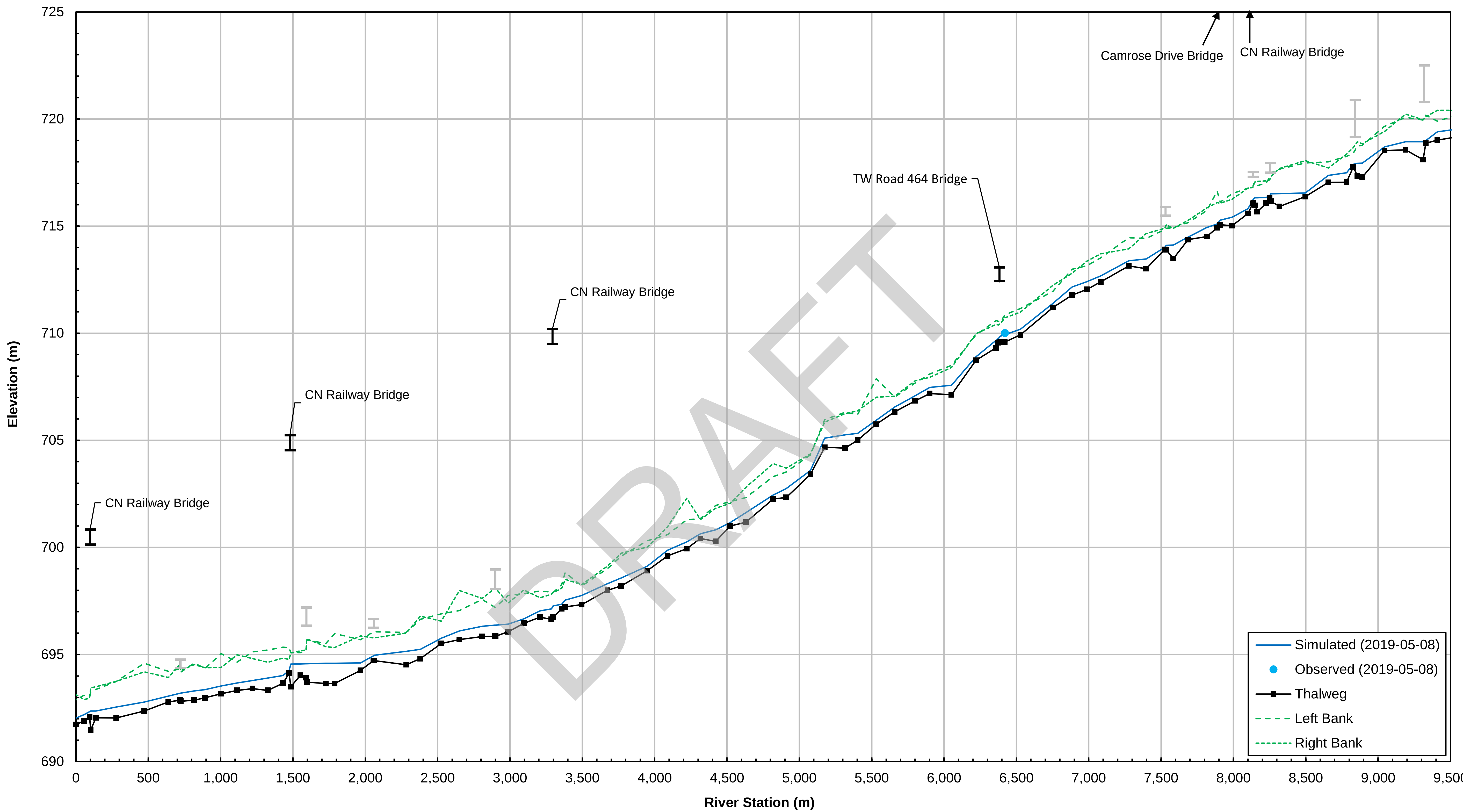


Alberta		CAMROSE FLOOD HAZARD STUDY
nhc northwest hydraulic consultants		*COMPARISON OF ADOPTED MIRROR LAKE RATING CURVE TO PREVIOUS STUDY (IDE, 1994)*
	Job: 1004662 / *Date: 30-APR-2020*	*FIGURE 4*



Notes: 1. The location of the 13 frequency floods are marked on the above curve.

Alberta		*CAMROSE FLOOD HAZARD STUDY*
nhc northwest hydraulic consultants		*COMPARISON OF SIMULATED RATING CURVE TO GAUGE DATA (WSC STATION 05FA025)*
	Job: 1004662	*Date: 30-APR-2020*
		FIGURE 5



Alberta

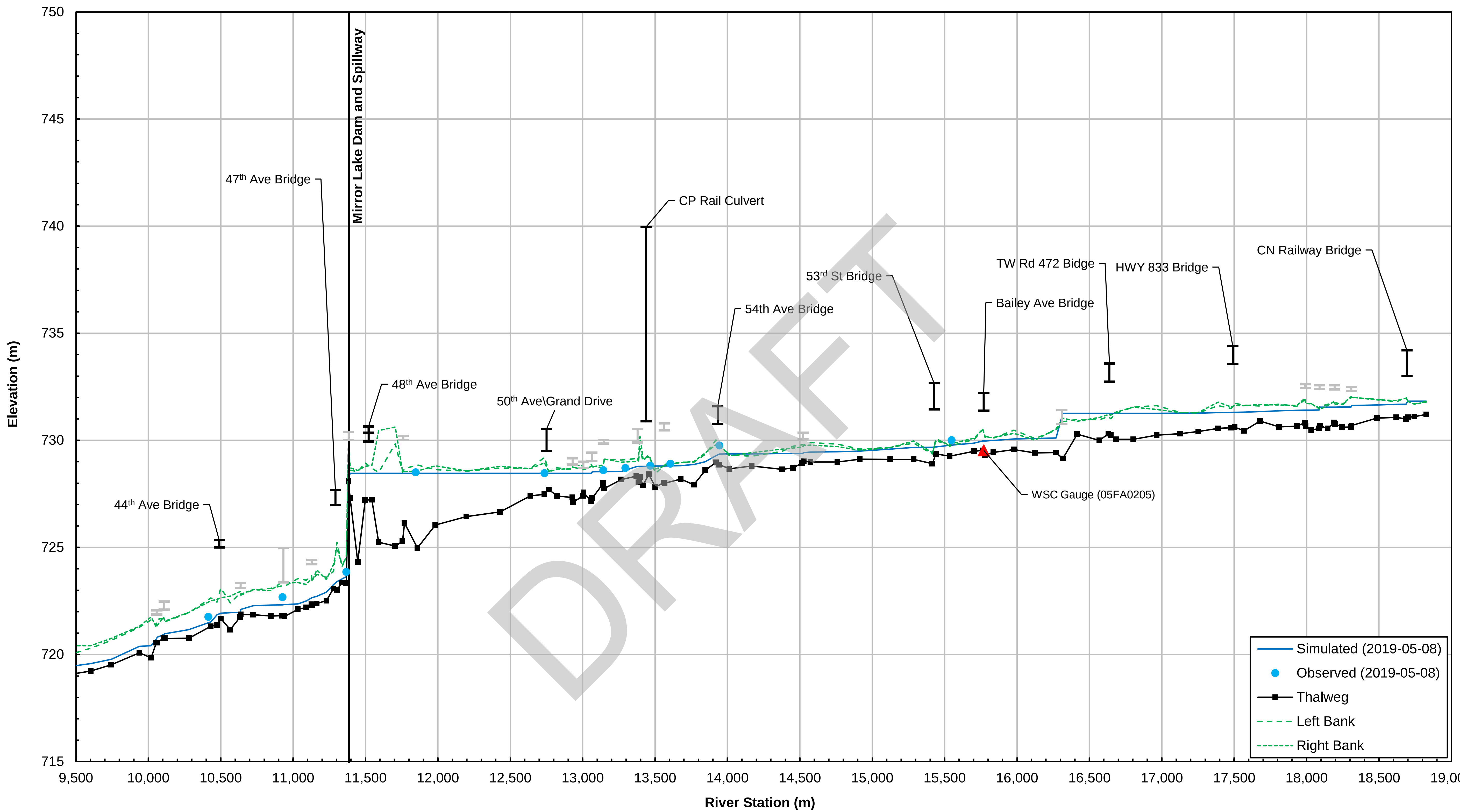
nhc northwest hydraulic consultants

Job: 01004662 | Date: 01-JUN-2021

CAMROSE
FLOOD HAZARD STUDY

CAMROSE CREEK LOW FLOW VALIDATION (1/2)

FIGURE 6A



Alberta

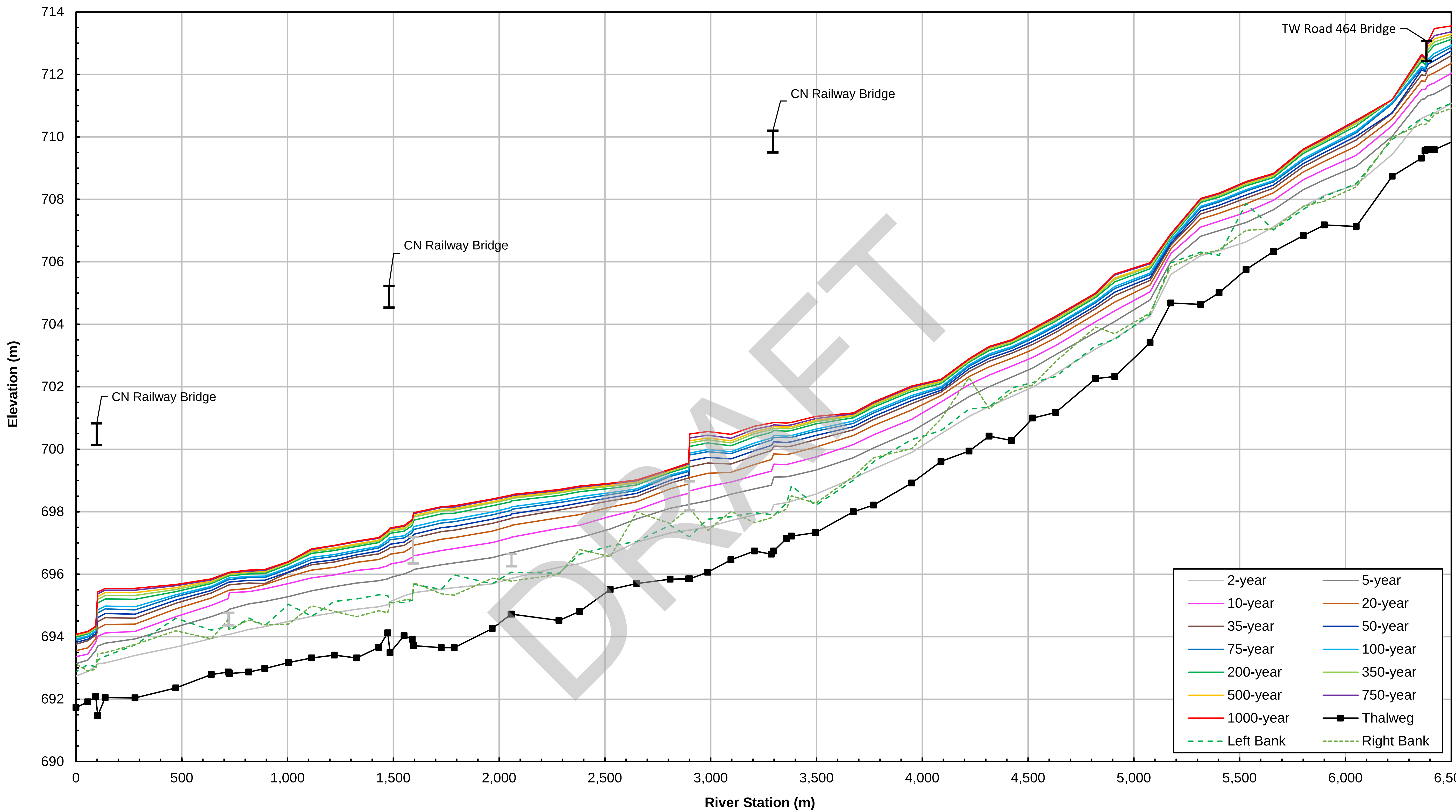
nhc northwest hydraulic consultants

CAMROSE
FLOOD HAZARD STUDY

CAMROSE CREEK LOW FLOW VALIDATION (2/2)

Job: 01004662 | *Date: 01-JUN-2021*

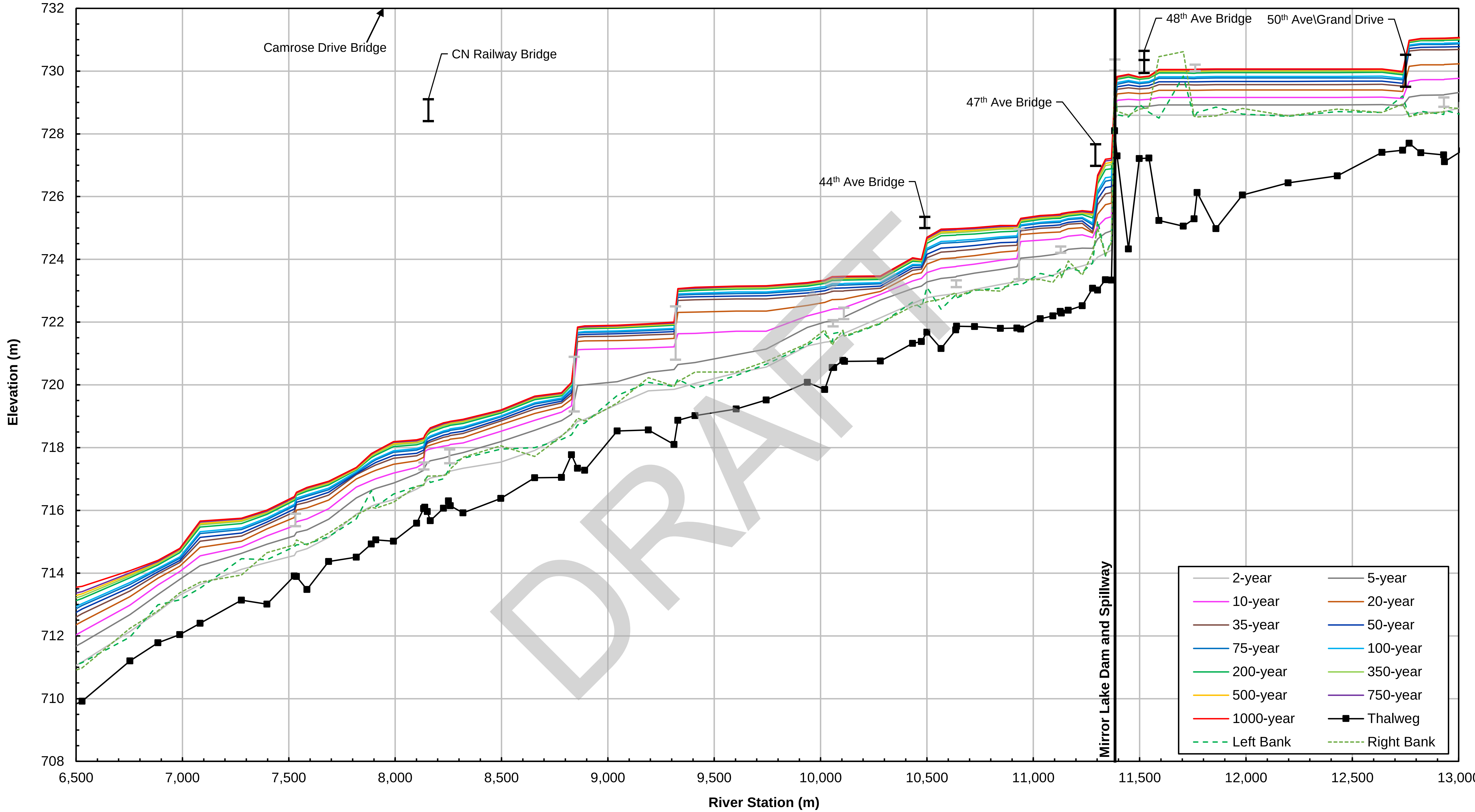
FIGURE 6B



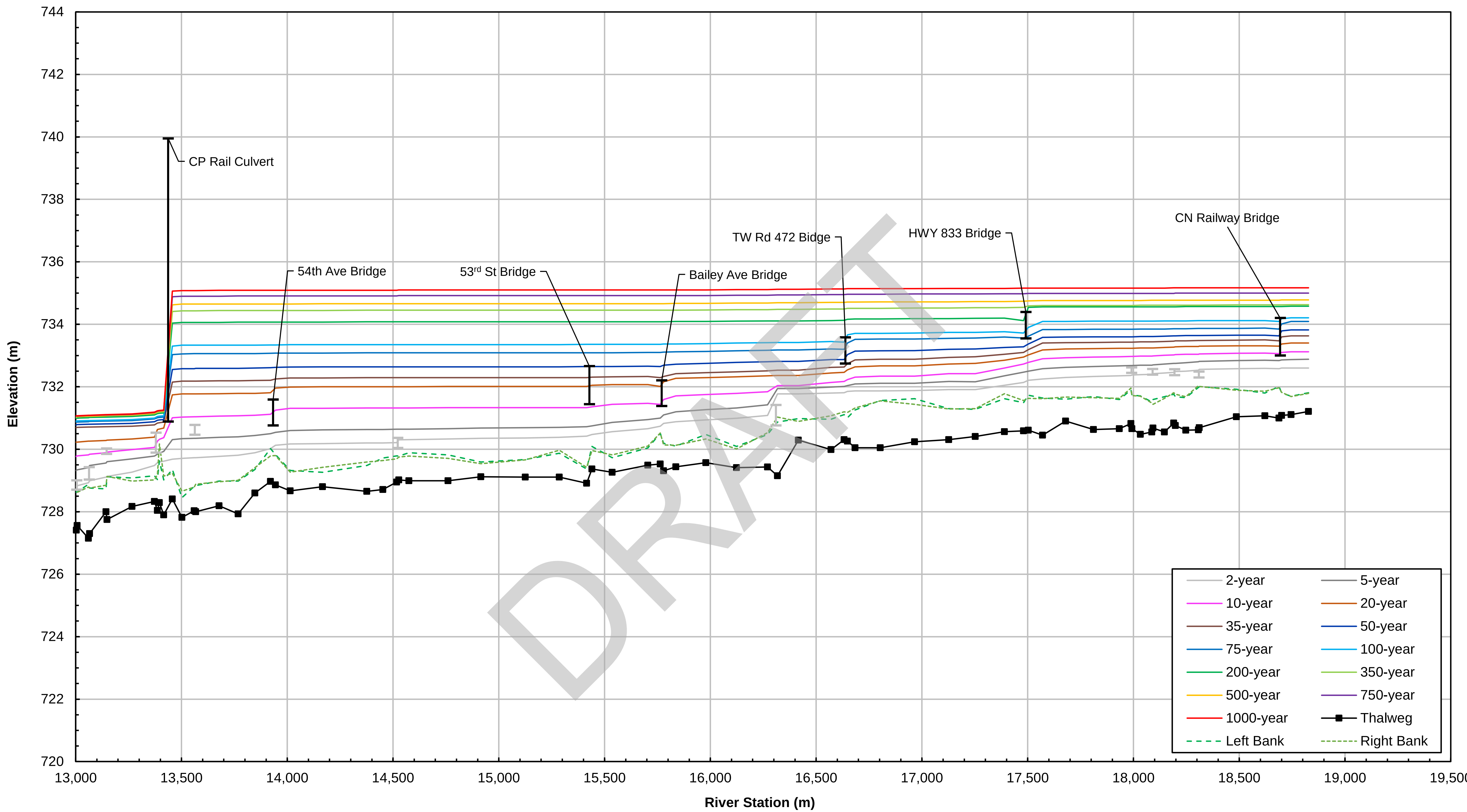
Alberta

nhc
northwest hydraulic consultants

		CAMROSE FLOOD HAZARD STUDY
		CAMROSE CREEK FLOOD FREQUENCY PROFILES (1/3)
Job: 01004662	*Date: 01-JUN-2021*	*FIGURE 7A*



Alberta			CAMROSE FLOOD HAZARD STUDY
nhc northwest hydraulic consultants			CAMROSE CREEK FLOOD FREQUENCY PROFILES (2/3)
	Job: 01004662	Date: 01-JUN-2021	FIGURE 7B



Alberta

nhc northwest hydraulic consultants

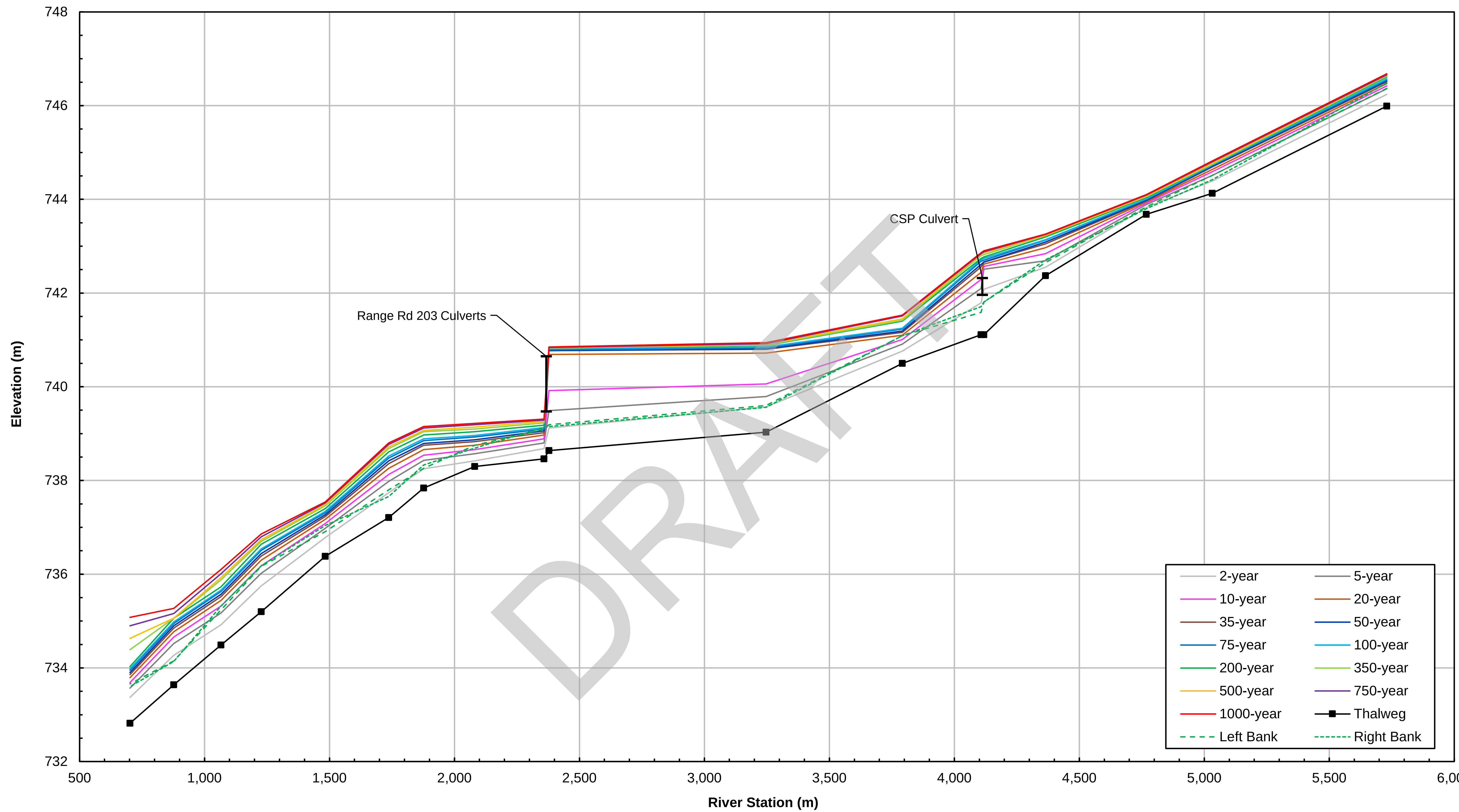
Job: 01004662

Date: 01-JUN-2021

CAMROSE FLOOD HAZARD STUDY

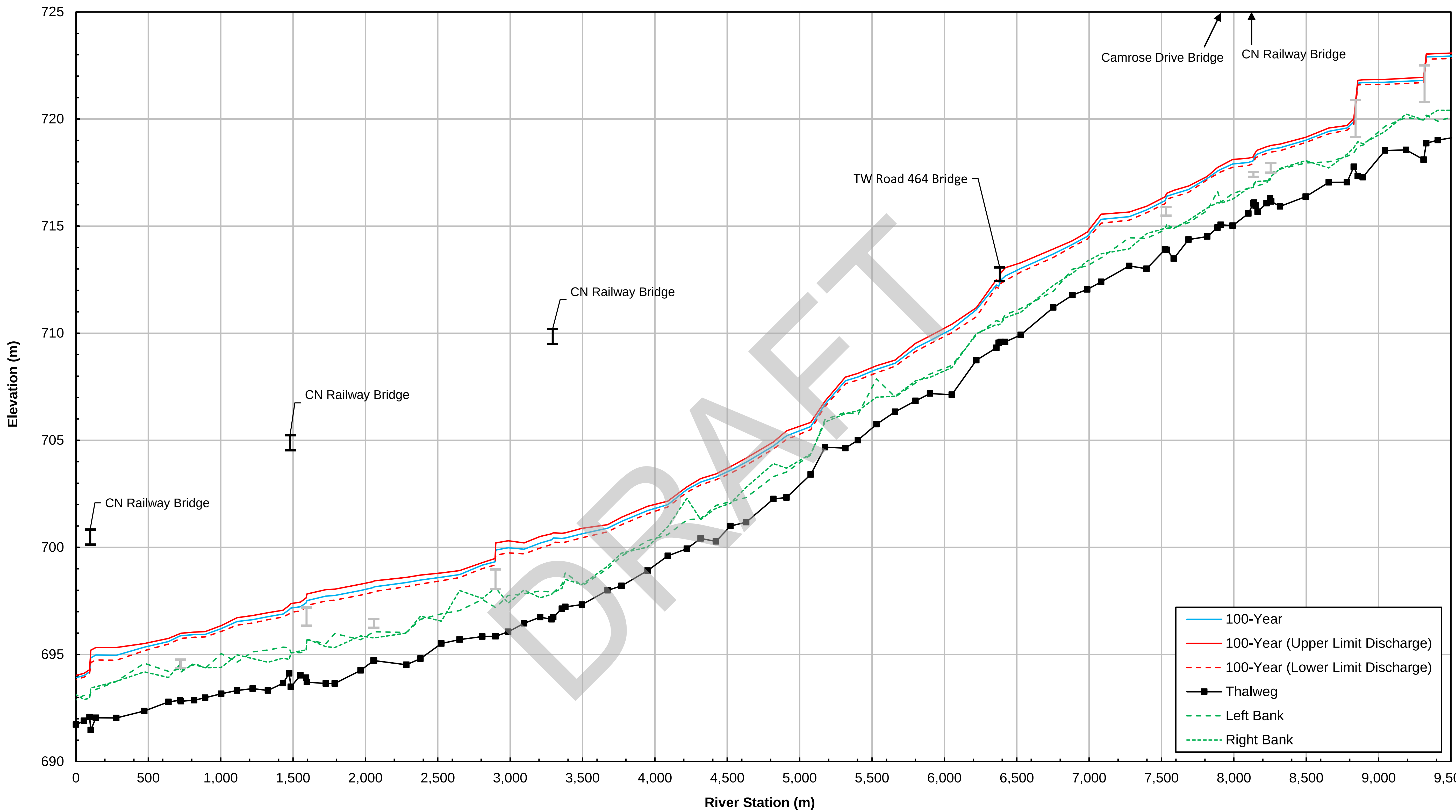
CAMROSE CREEK FLOOD FREQUENCY PROFILES (3/3)

FIGURE 7C



Alberta			CAMROSE FLOOD HAZARD STUDY UNNAMED CREEK FLOOD FREQUENCY PROFILES
nhc northwest hydraulic consultants		Job: 01004662	Date: 01-JUN-2021
			FIGURE 8

Classification: Public



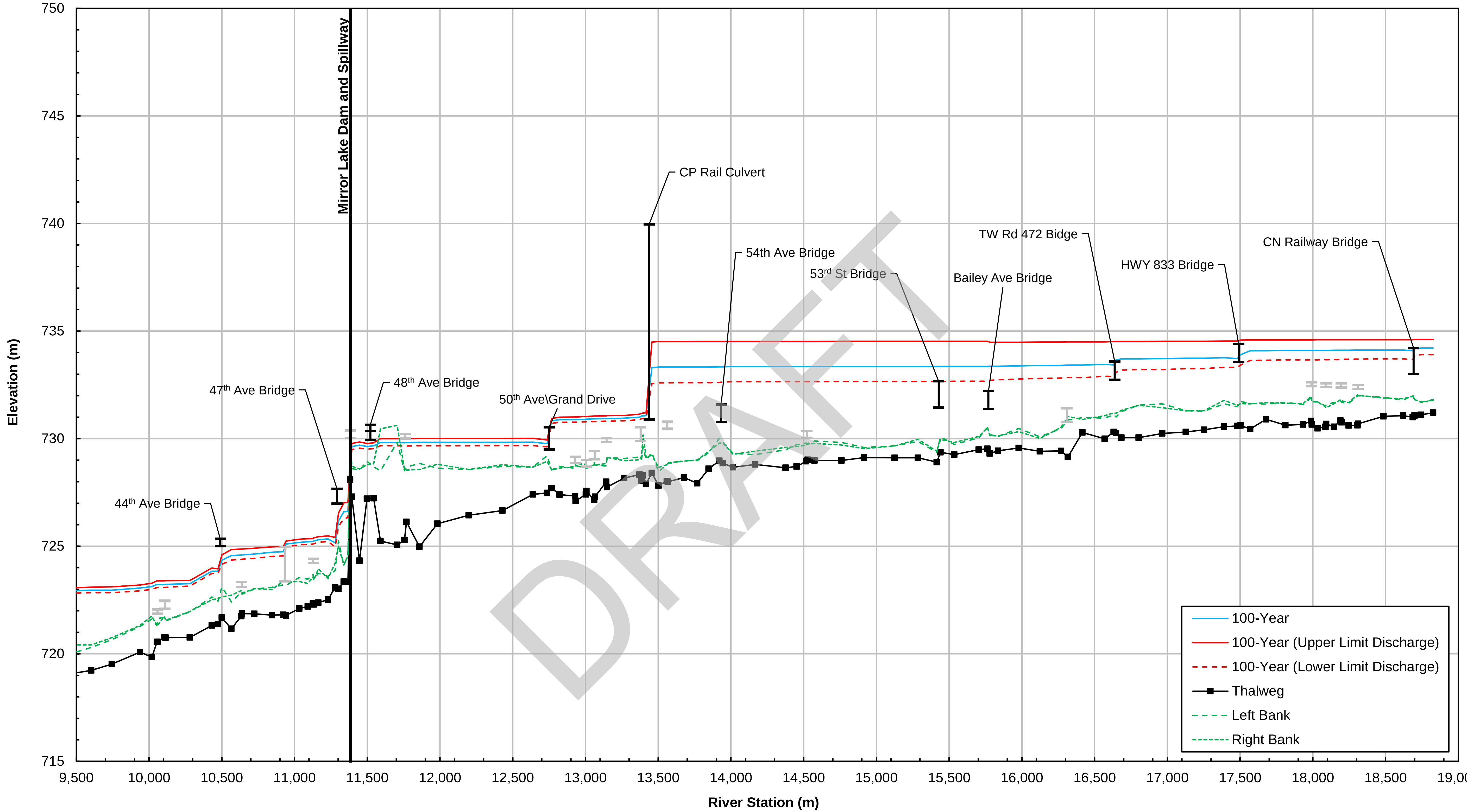
northwest hydraulic consultants

CAMROSE FLOOD HAZARD STUDY

COMPUTED 100-YEAR WATER SURFACE PROFILE SENSITIVITY TO FLOOD FREQUENCY ESTIMATES - CAMROSE CREEK (1/2)

Job: 01004662 | *Date: 01-JUN-2021*

FIGURE 9A



Alberta

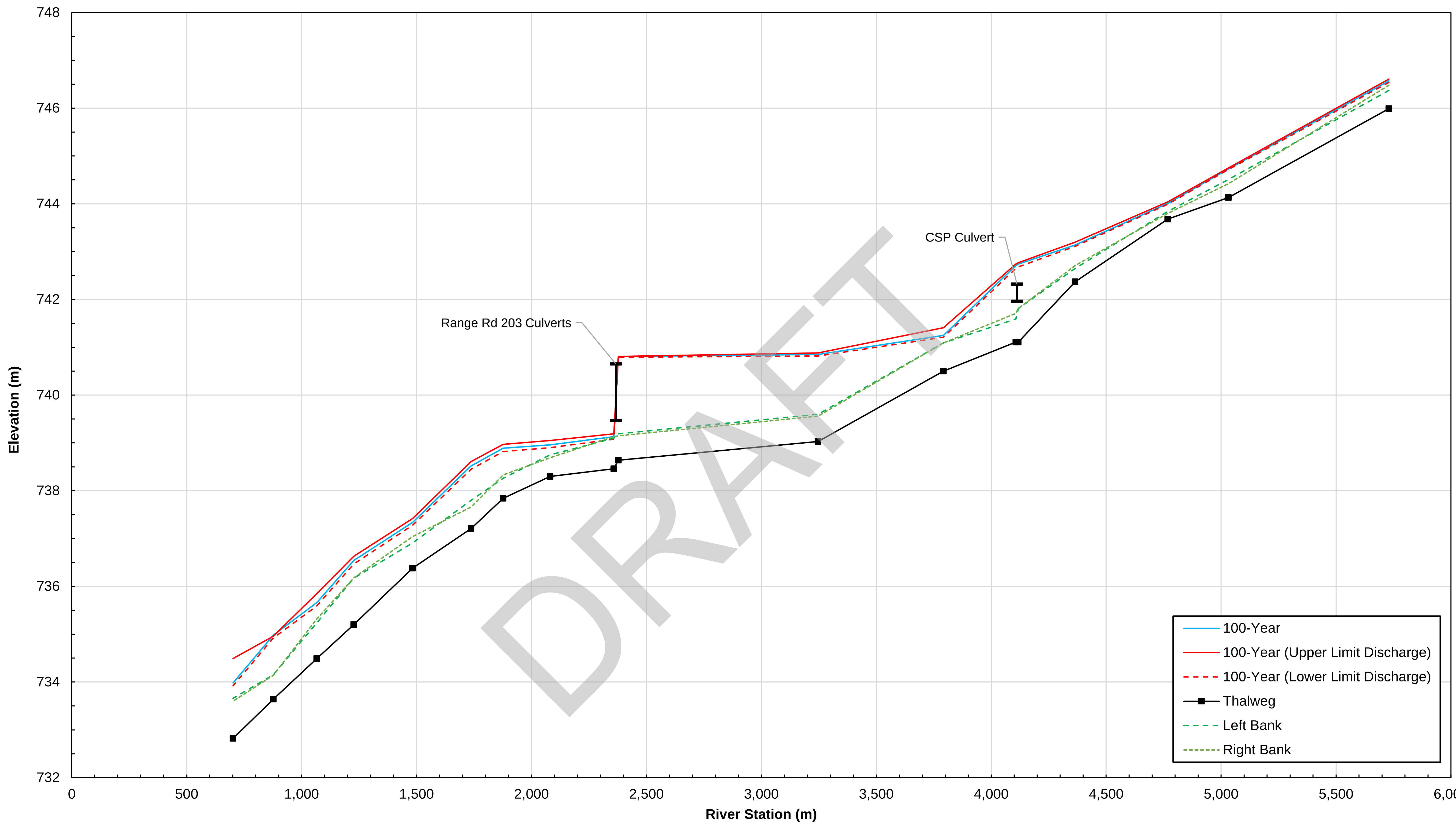
nhc northwest hydraulic consultants

Job: 01004662 | Date: 01-JUN-2021

CAMROSE FLOOD HAZARD STUDY

COMPUTED 100-YEAR WATER SURFACE PROFILE SENSITIVITY TO FLOOD FREQUENCY ESTIMATES - CAMROSE CREEK (2/2)

FIGURE 9B



Alberta

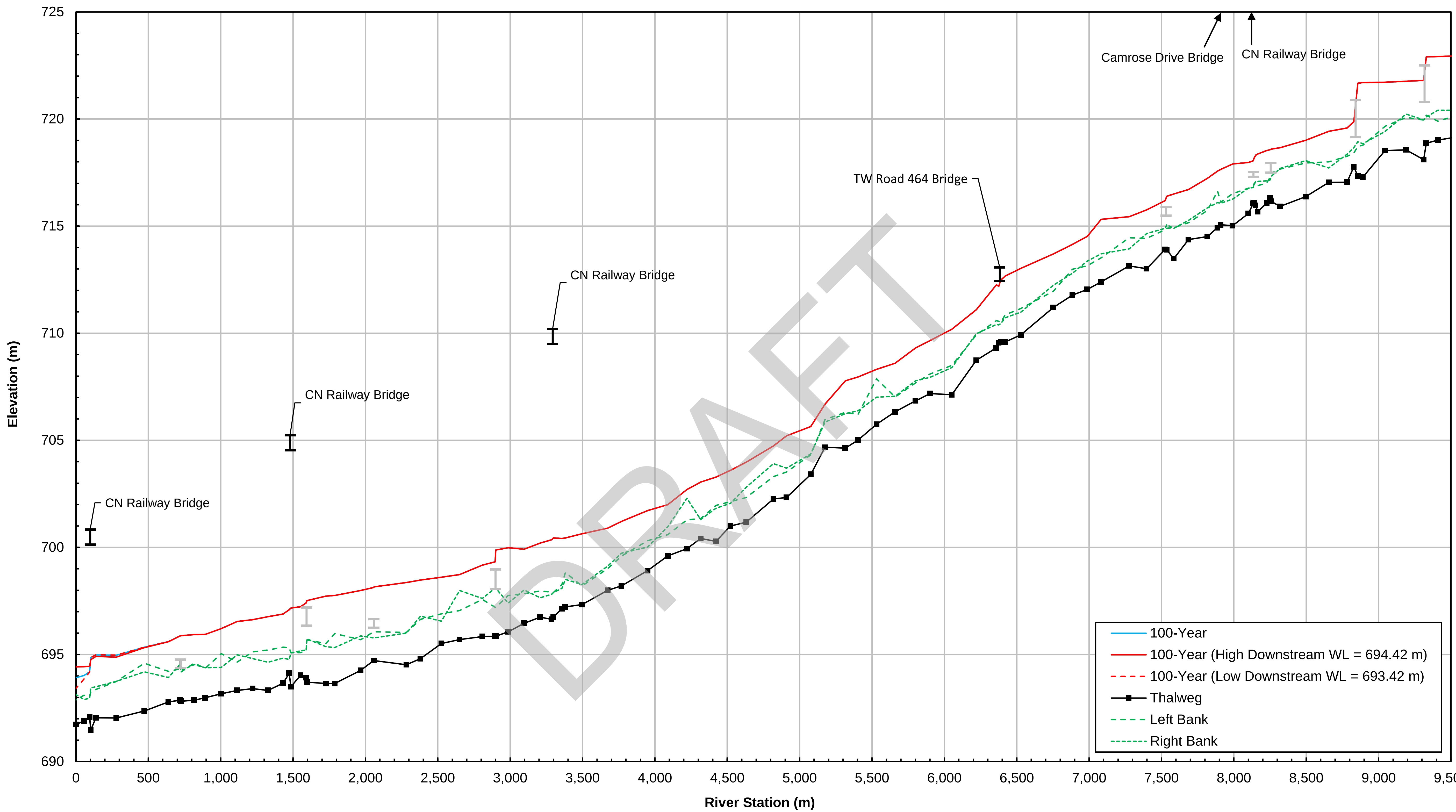
nhc northwest hydraulic consultants

CAMROSE
FLOOD HAZARD STUDY

COMPUTED 100-YEAR WATER SURFACE PROFILE SENSITIVITY TO FLOOD FREQUENCY ESTIMATES - UNNAMED CREEK

Job: 01004662 | *Date: 01-JUN-2021*

FIGURE 10



Alberta

nhc northwest hydraulic consultants

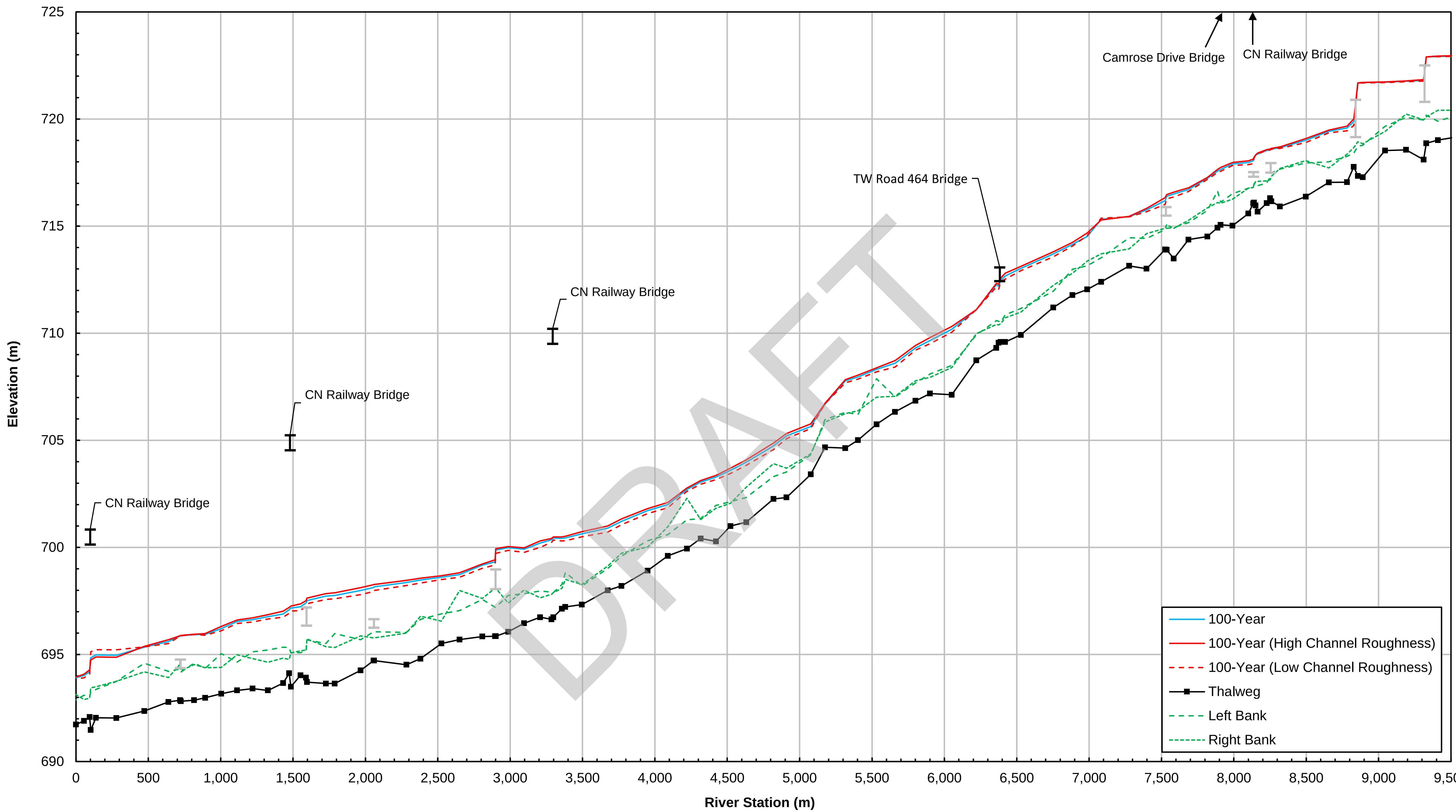
Job: 01004662

Date: 01-JUN-2021

CAMROSE FLOOD HAZARD STUDY

COMPUTED 100-YEAR WATER SURFACE PROFILE SENSITIVITY TO DOWNSTREAM BOUNDARY CONDITION- CAMROSE CREEK

FIGURE 11



Alberta

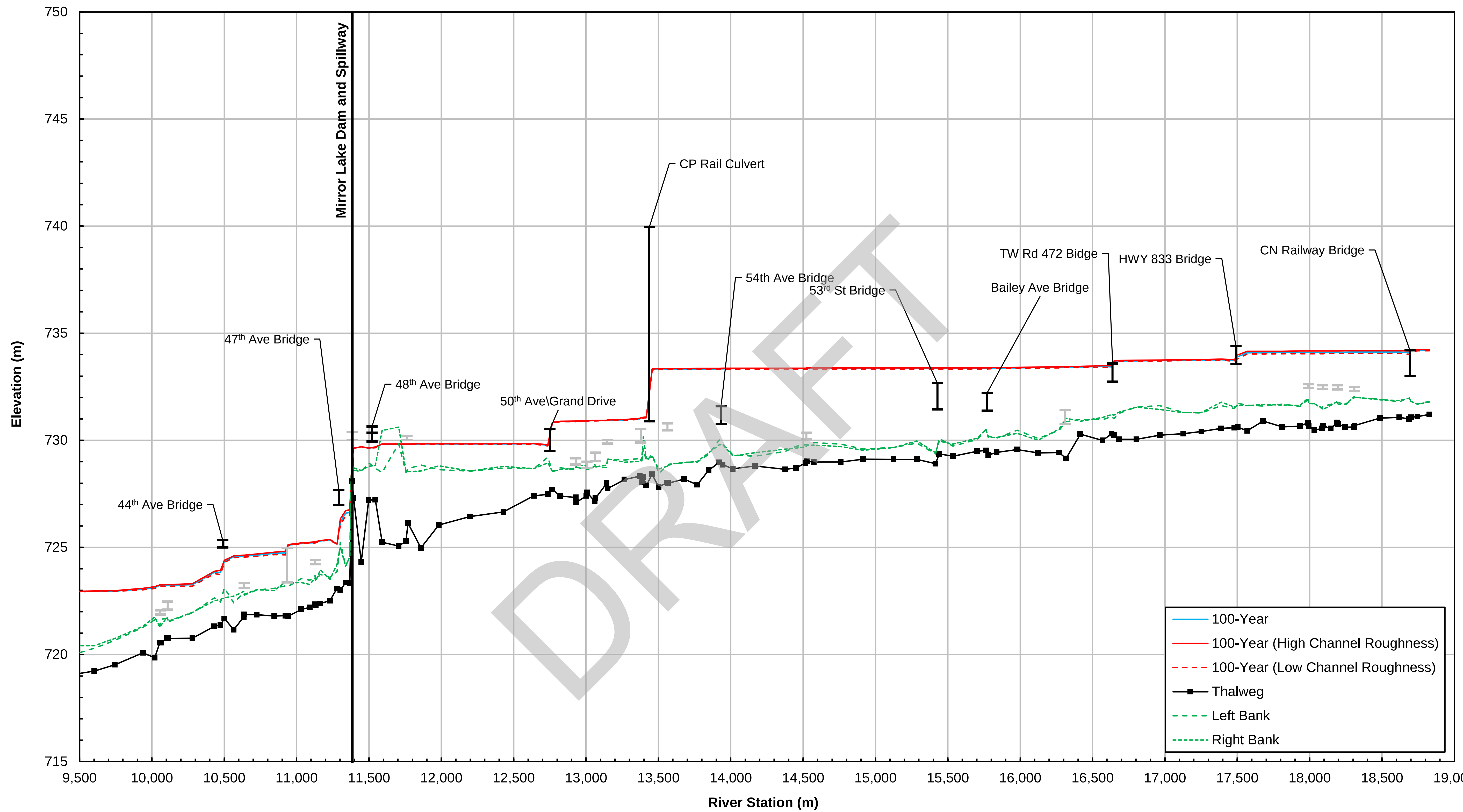
nhc northwest hydraulic consultants

Job: 01004662	Date: 01-JUN-2021

CAMROSE
FLOOD HAZARD STUDY

COMPUTED 100-YEAR WATER SURFACE PROFILE SENSITIVITY TO CHANNEL ROUGHNESS - CAMROSE CREEK (1/2)

FIGURE 12A



Alberta

nhc northwest hydraulic consultants

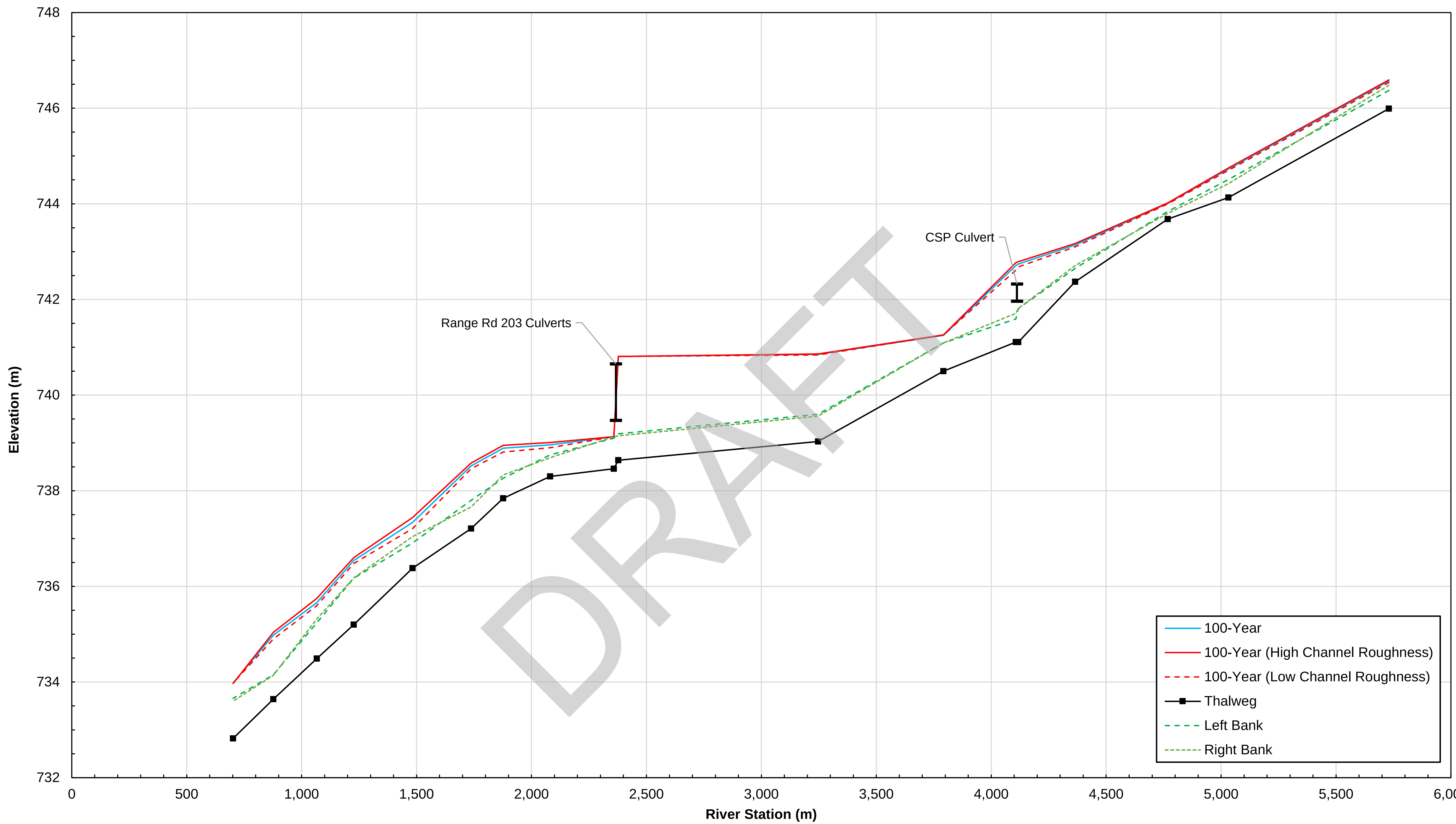
Job: 01004662

Date: 01-JUN-2021

CAMROSE FLOOD HAZARD STUDY

COMPUTED 100-YEAR WATER SURFACE PROFILE SENSITIVITY TO CHANNEL ROUGHNESS - CAMROSE CREEK (2/2)

FIGURE 12B



Alberta

nhc northwest hydraulic consultants

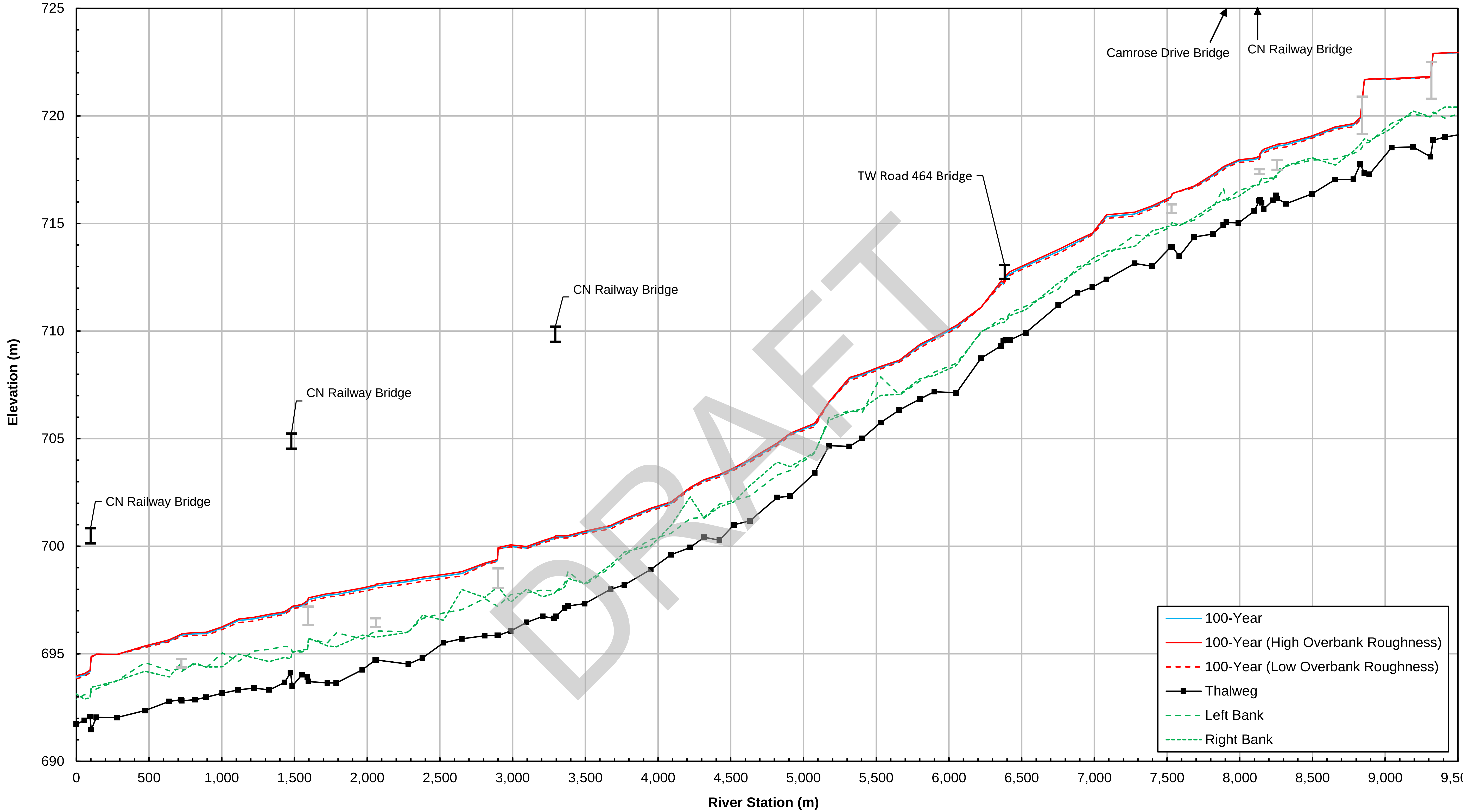
Job: 01004662

Date: 01-JUN-2021

CAMROSE
FLOOD HAZARD STUDY

COMPUTED 100-YEAR WATER SURFACE PROFILE SENSITIVITY TO CHANNEL ROUGHNESS - UNNAMED CREEK

FIGURE 13



Alberta

nhc northwest hydraulic consultants

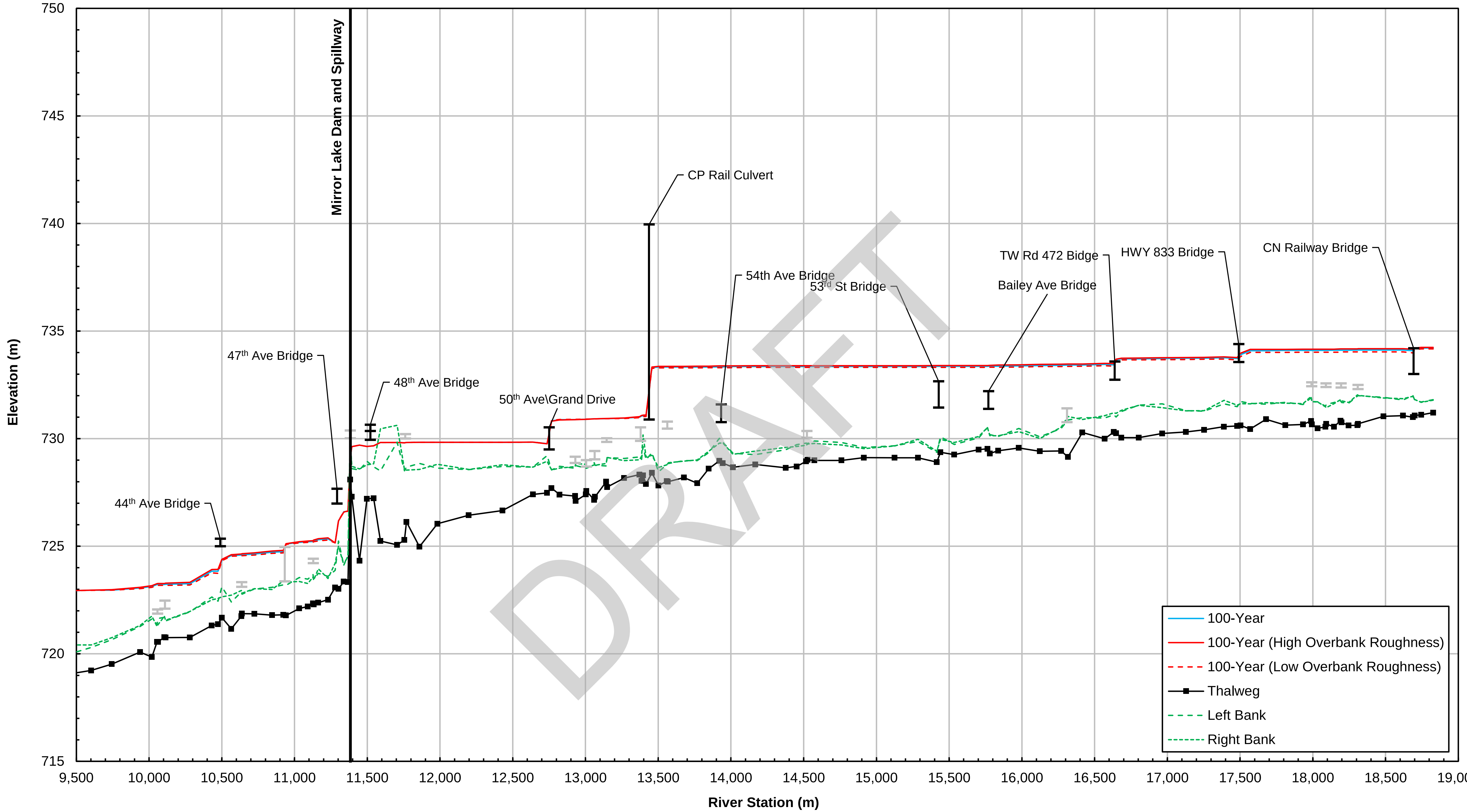
Job: 01004662

Date: 01-JUN-2021

CAMROSE
FLOOD HAZARD STUDY

COMPUTED 100-YEAR WATER SURFACE PROFILE SENSITIVITY TO OVERBANK ROUGHNESS - CAMROSE CREEK (1/2)

FIGURE 14A



Alberta

nhc
northwest hydraulic consultants

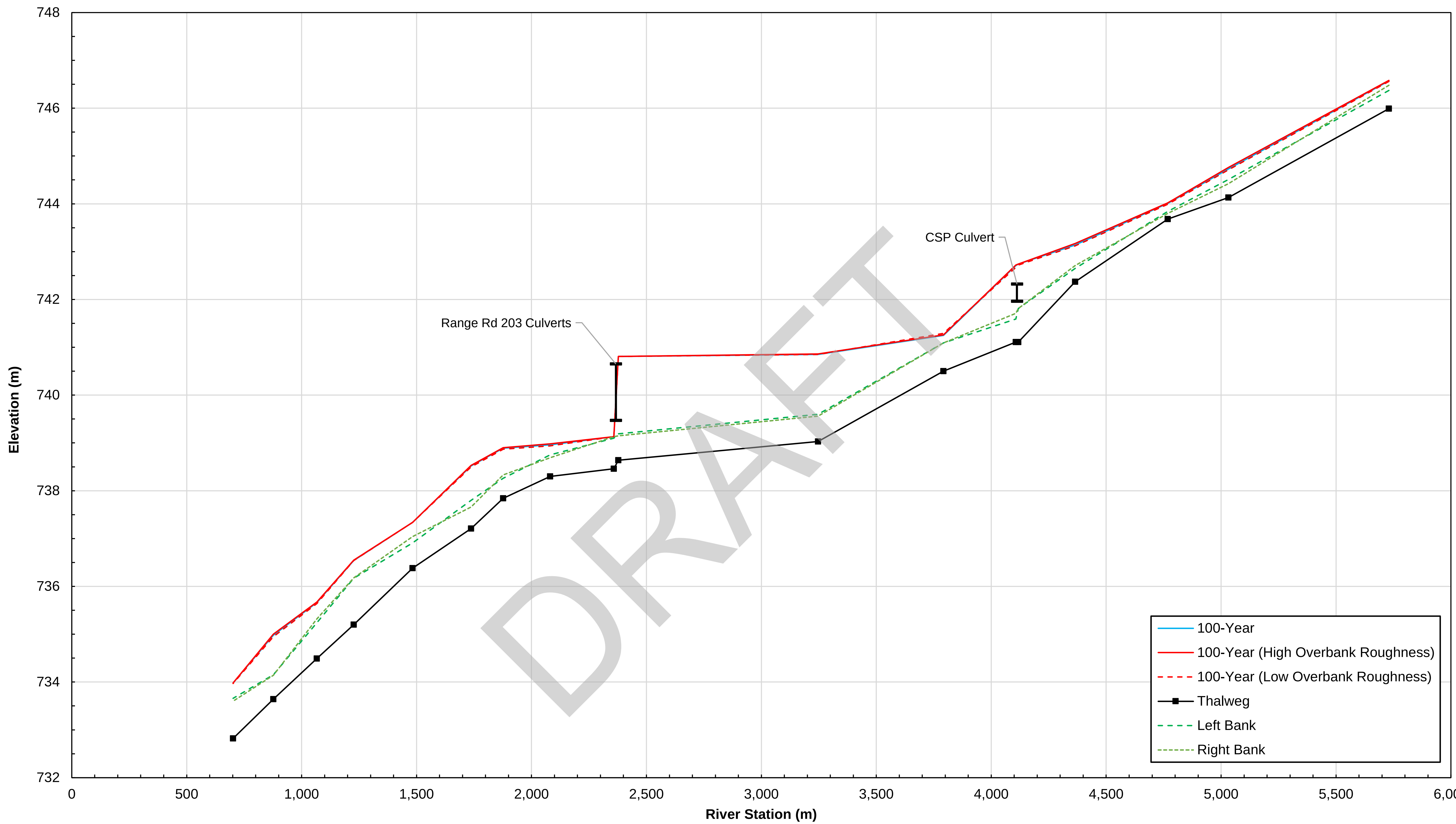
Classification: Public

CAMROSE
FLOOD HAZARD STUDY

COMPUTED 100-YEAR WATER SURFACE PROFILE SENSITIVITY TO OVERBANK ROUGHNESS - CAMROSE CREEK (2/2)

Job: 01004662 | *Date: 01-JUN-2021*

FIGURE 14B



Alberta

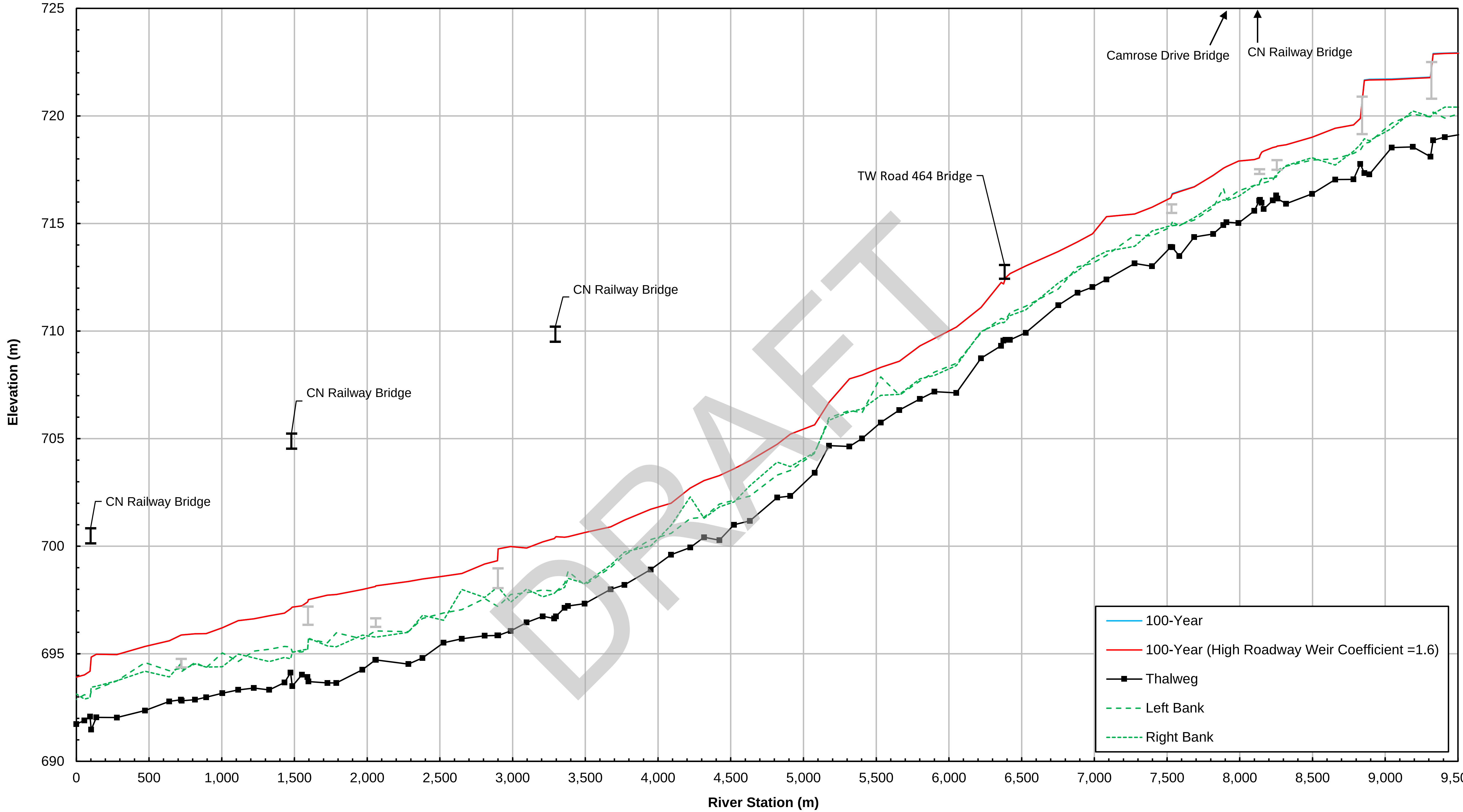
nhc northwest hydraulic consultants

CAMROSE
FLOOD HAZARD STUDY

COMPUTED 100-YEAR WATER SURFACE PROFILE SENSITIVITY TO OVERBANK ROUGHNESS - UNNAMED CREEK

Job: 01004662 | Date: 01-JUN-2021

FIGURE 15

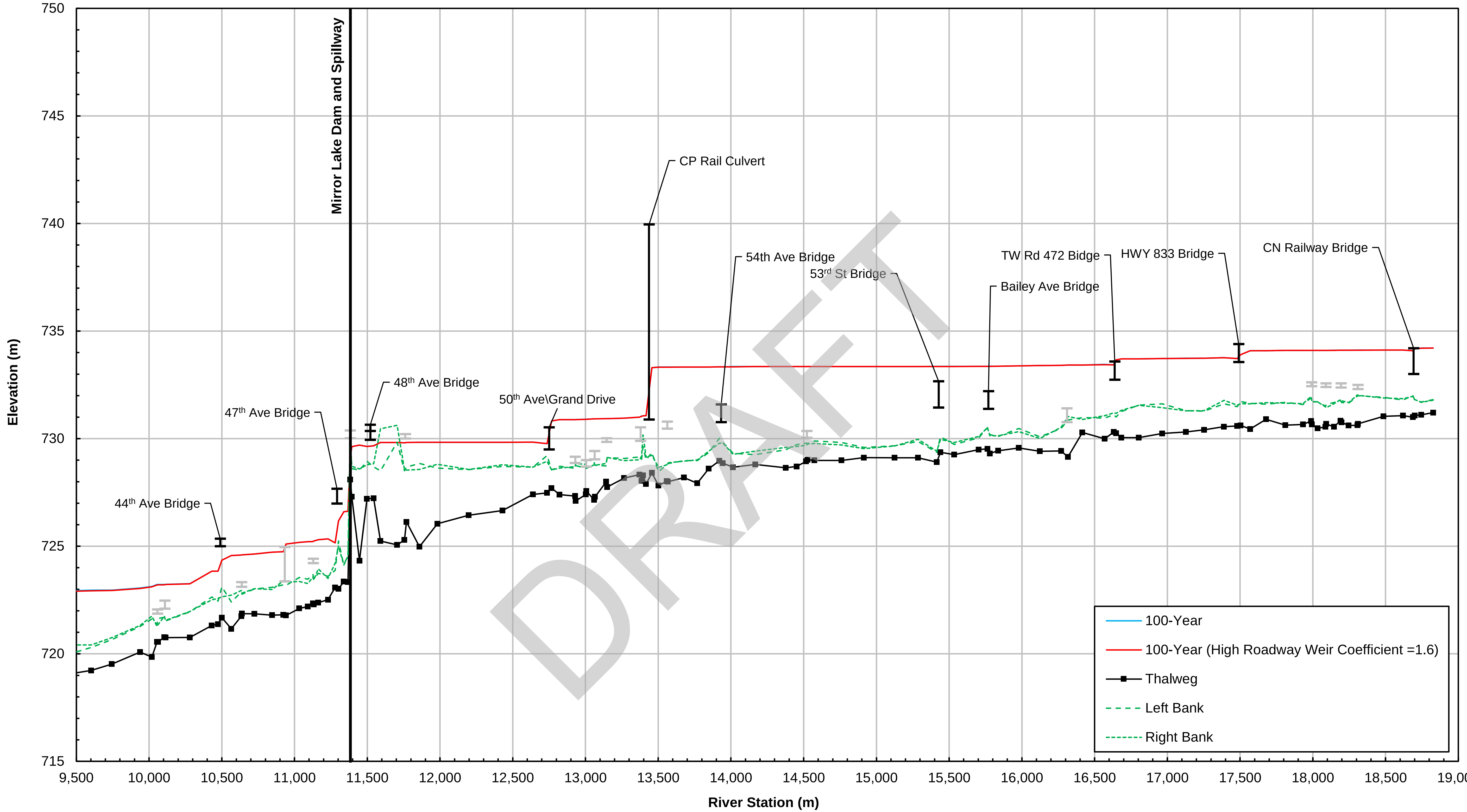


Alberta / nhc northwest hydraulic consultants	Job: 01004662	Date: 01-JUN-2021

CAMROSE FLOOD HAZARD STUDY

COMPUTED 100-YEAR WATER SURFACE PROFILE SENSITIVITY TO ROADWAY WEIR COEFFICIENT - CAMROSE CREEK (1/2)

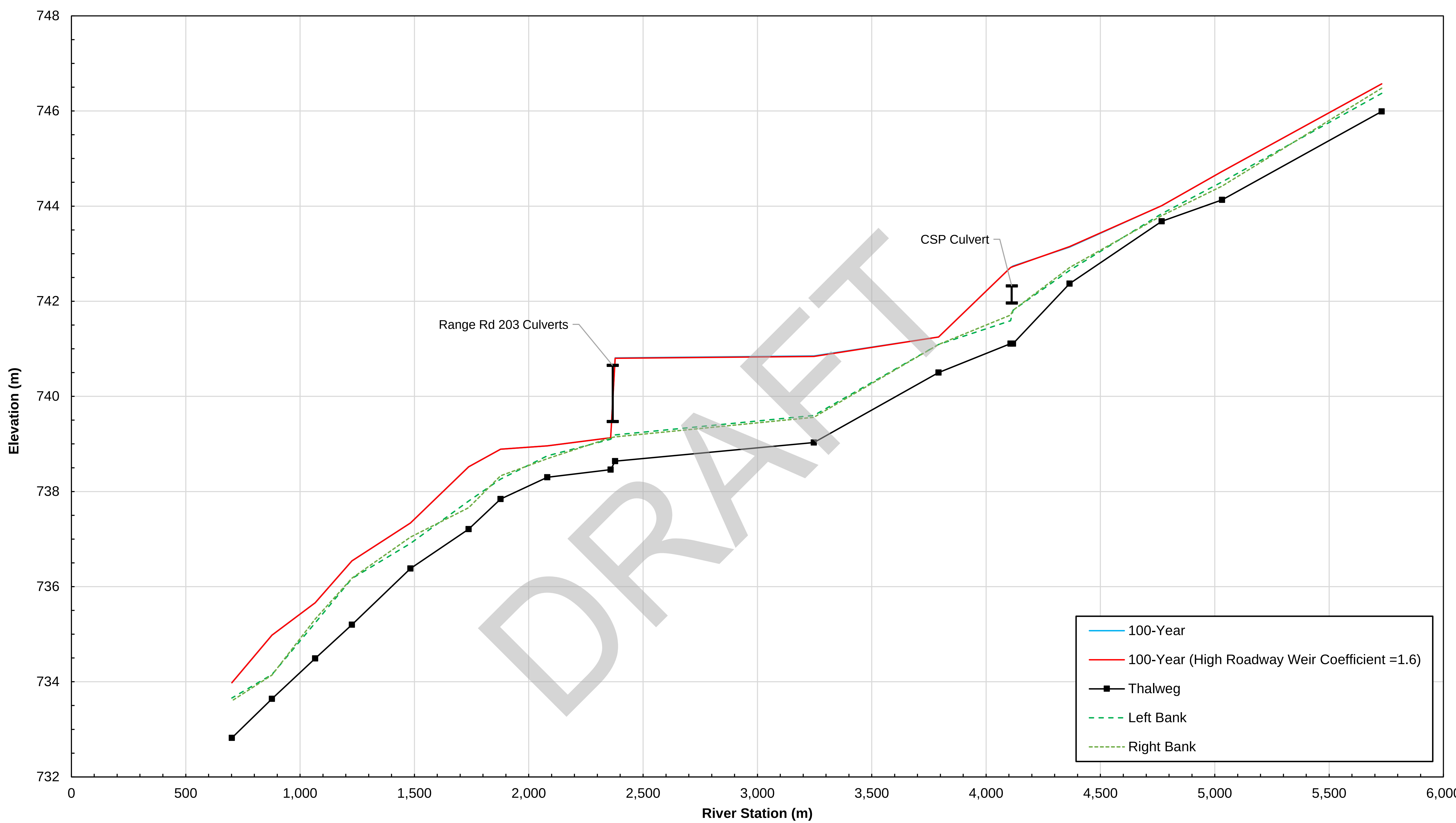
FIGURE 16A



Alberta

nhc northwest hydraulic consultants

		CAMROSE FLOOD HAZARD STUDY
		COMPUTED 100-YEAR WATER SURFACE PROFILE SENSITIVITY TO ROADWAY WEIR COEFFICIENT - CAMROSE CREEK (2/2)
Job: 01004662	Date: 01-JUN-2021	FIGURE 16B



Alberta

nhc northwest hydraulic consultants

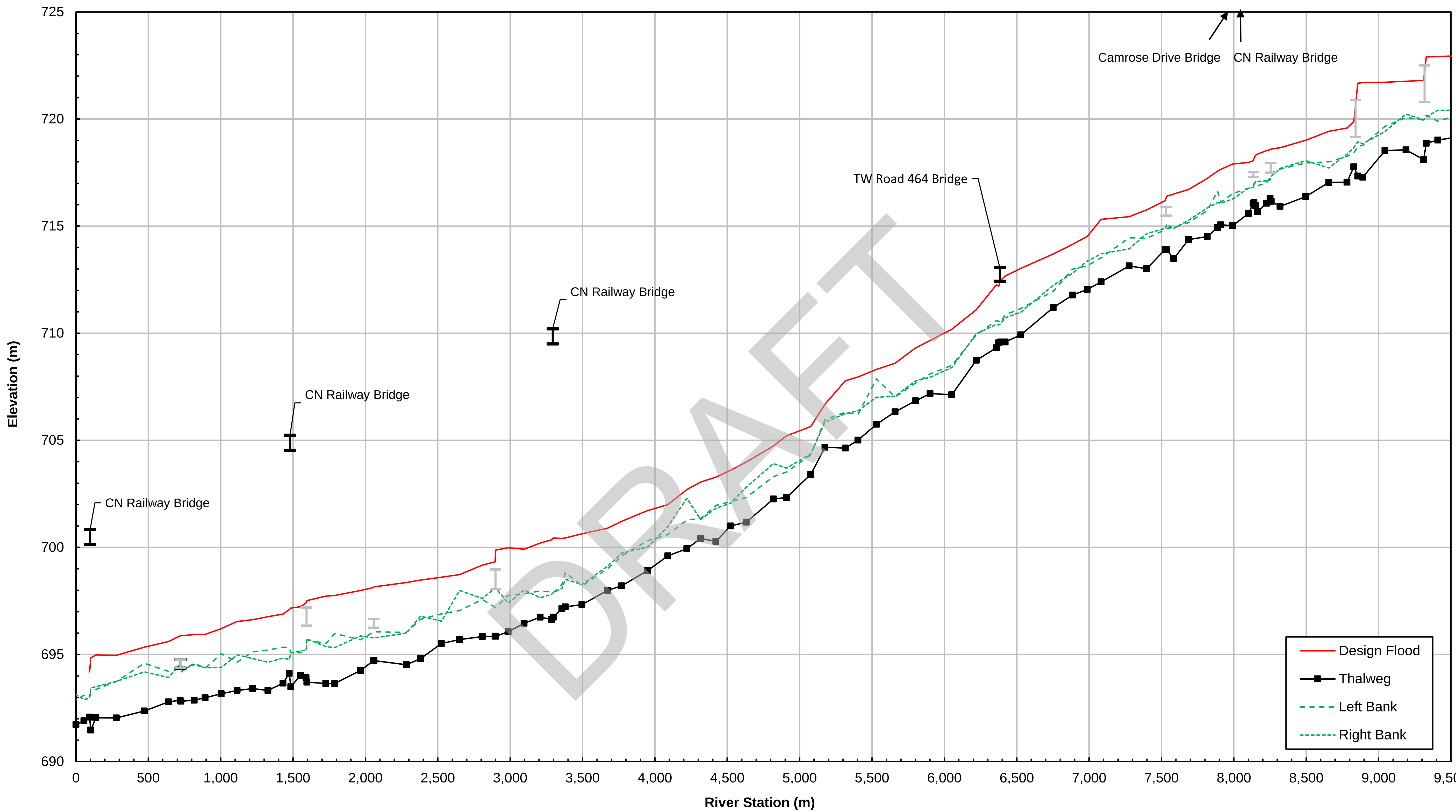
Job: 01004662

Date: 01-JUN-2021

CAMROSE FLOOD HAZARD STUDY

COMPUTED 100-YEAR WATER SURFACE PROFILE SENSITIVITY TO ROADWAY WEIR COEFFICIENT - UNNAMED CREEK

FIGURE 17



Alberta

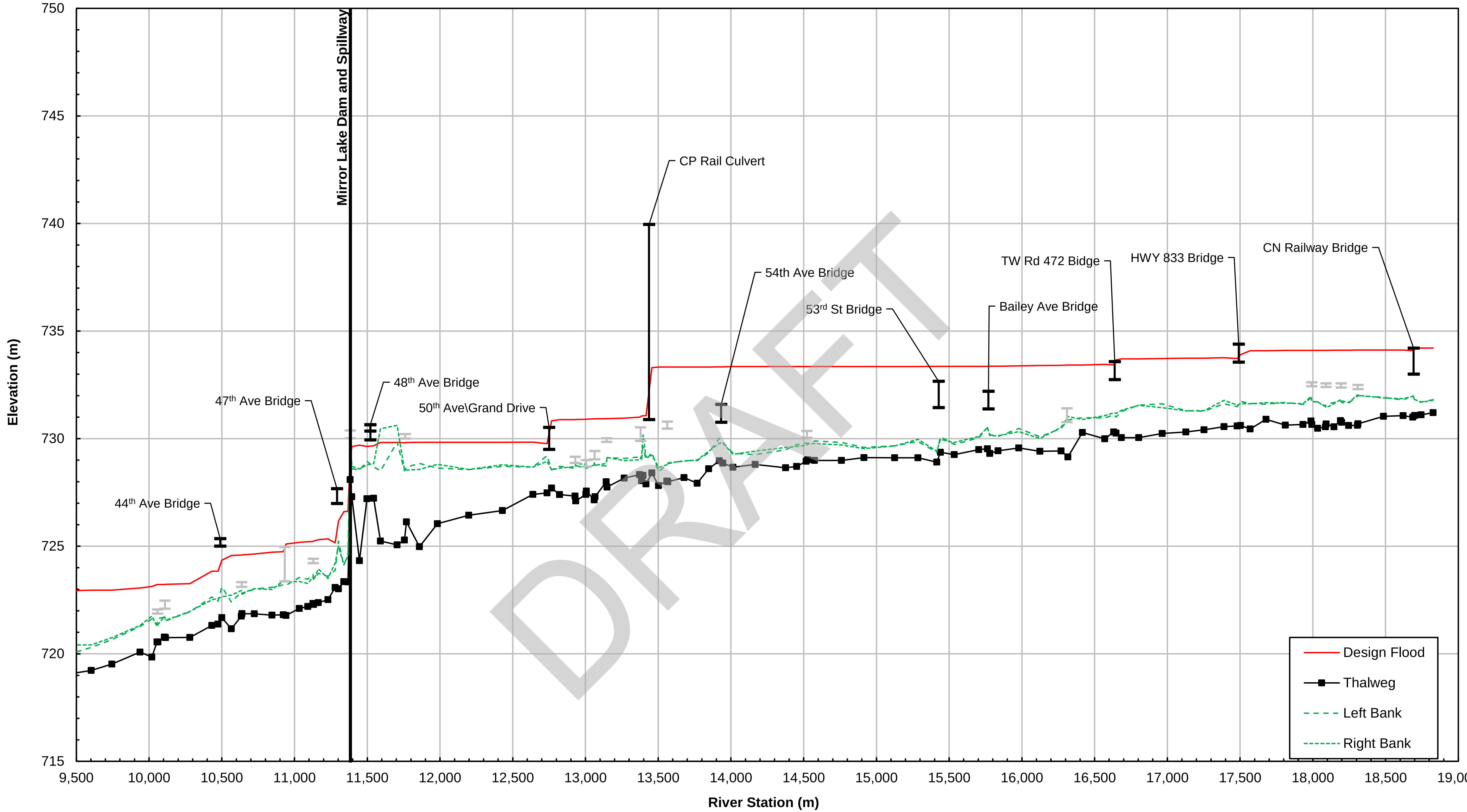
nhc northwest hydraulic consultants

CAMROSE FLOOD HAZARD STUDY

OPEN WATER DESIGN FLOOD PROFILES - CAMROSE CREEK (1/2)

Job: 01004662 | *Date: 01-JUN-2021*

FIGURE 18A



Alberta

nhc northwest hydraulic consultants

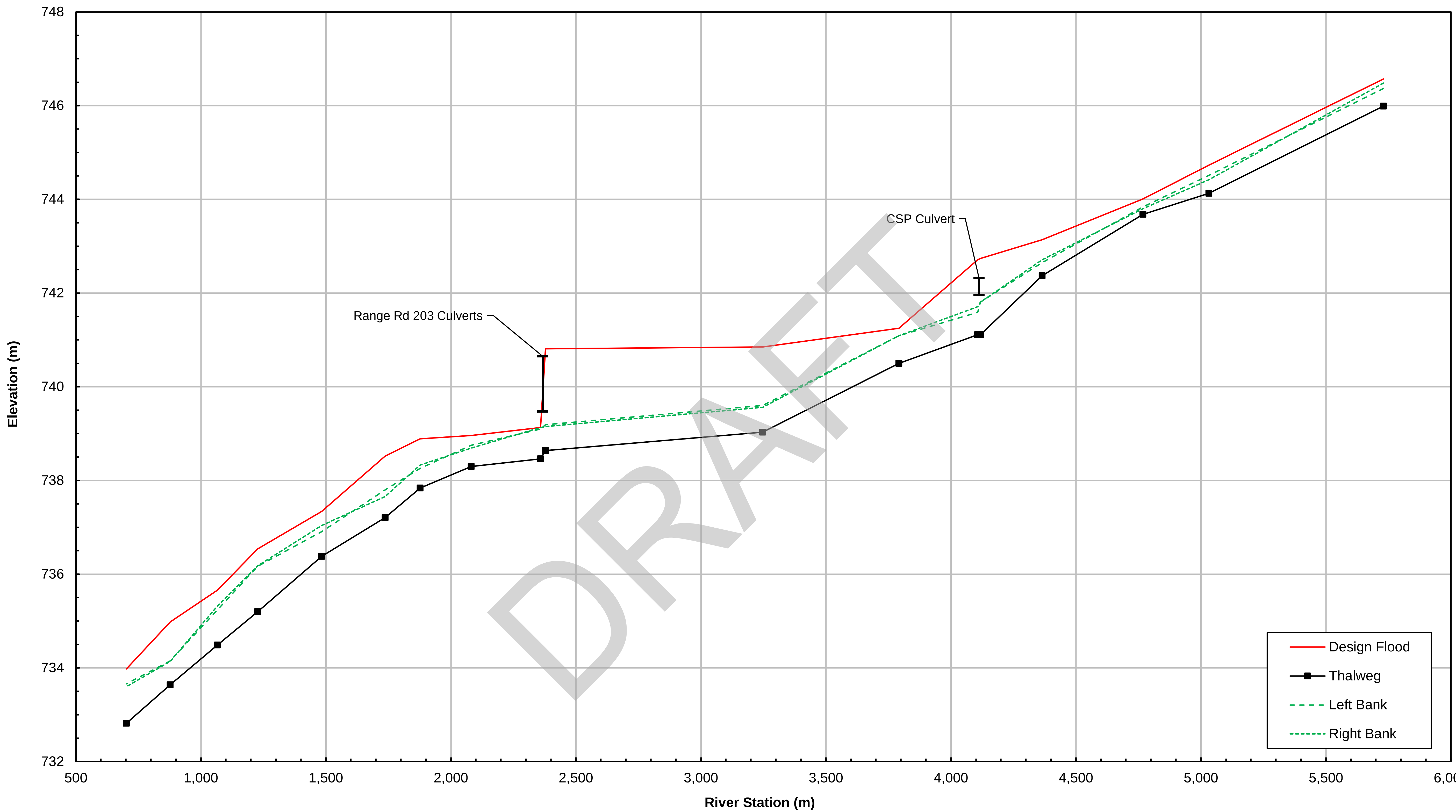
Job: 01004662

Date: 01-JUN-2021

CAMROSE
FLOOD HAZARD STUDY
OPEN WATER DESIGN FLOOD PROFILES
- CAMROSE CREEK (2/2)

FIGURE 18B

Classification: Public



Alberta

nhc northwest hydraulic consultants

Job: 01004662

Date: 01-JUN-2021

CAMROSE
FLOOD HAZARD STUDY
OPEN WATER DESIGN FLOOD PROFILES
- UNNAMED CREEK

FIGURE 19

Appendix A
Cross Section Properties

Table A-1 Cross section properties - Camrose Creek

River Station (m)	Date Surveyed	Thalweg Elevation (m)	Channel Width (m)	River Station (m)	Date Surveyed	Thalweg Elevation (m)	Channel Width (m)
18,827	2019-05-24	731.21	8.47	16,124	2019-05-23	729.41	5.28
18,745	2019-05-24	731.11	10.24	15,979	2019-05-23	729.57	11.05
18,700	2019-05-24	731.08	10.8	15,837	2019-05-23	729.44	6.54
18,688	2019-05-24	731	9.48	15,779	2019-05-23	729.31	7.38
18,621	2019-05-24	731.07	8.48	15,763	2019-05-23	729.53	7.01
18,486	2019-05-24	731.04	8.29	15,704	2019-05-23	729.49	8.03
18,311	2019-05-24	730.69	7.46	15,536	2019-05-23	729.26	8.65
18,307	2019-05-24	730.62	7.8	15,440	2019-05-23	729.37	10.15
18,247	2019-09-23	730.61	6.71	15,415	2019-05-23	728.91	13.91
18,198	2019-05-24	730.76	7.79	15,286	2019-05-23	729.11	10
18,190	2019-05-24	730.84	8.55	15,125	2019-05-23	729.11	8.55
18,146	2019-09-23	730.55	7.25	14,915	2019-05-23	729.12	11.5
18,092	2019-05-24	730.68	6.39	14,760	2019-05-23	728.99	15.69
18,087	2019-05-24	730.55	6.79	14,575	2019-05-23	728.99	35.74
18,033	2019-09-23	730.48	7.95	14,527	2019-05-23	729.02	17.13
17,993	2019-09-24	730.66	7.72	14,517	2019-05-22	728.95	18.93
17,988	2019-05-24	730.82	8.43	14,452	2019-05-22	728.71	17.28
17,933	2019-09-23	730.66	9.57	14,376	2019-05-22	728.65	15.18
17,811	2019-05-24	730.63	9.05	14,167	2019-05-22	728.8	15.71
17,679	2019-05-24	730.9	8.64	14,014	2019-05-22	728.67	15.6
17,570	2019-05-24	730.45	6.24	13,944	2019-05-22	728.86	9.71
17,503	2019-05-23	730.61	7.2	13,921	2019-05-22	728.97	12.71
17,480	2019-05-23	730.59	6.21	13,847	2019-05-22	728.6	9.44
17,390	2019-05-23	730.56	7.41	13,768	2019-05-22	727.93	5.1
17,252	2019-05-23	730.41	5.98	13,678	2019-05-22	728.19	8.01
17,127	2019-05-23	730.31	32.71	13,567	2019-05-22	728	4.38
16,965	2019-05-23	730.24	7.03	13,560	2019-05-22	728.03	6.24
16,803	2019-05-23	730.05	34.91	13,502	2019-05-22	727.82	4.64
16,684	2019-05-23	730.05	12.67	13,457	2019-05-22	728.41	9.88
16,648	2019-05-23	730.26	5.59	13,416	2019-05-22	727.9	8.13
16,632	2019-05-23	730.31	9.94	13,396	2019-05-22	728.29	12.98
16,570	2019-05-23	729.99	14.42	13,386	2019-05-22	728.04	8.14
16,416	2019-05-23	730.29	11.41	13,372	2019-05-22	728.33	9.09
16,317	2019-09-23	729.15	33.24	13,266	2019-05-22	728.17	7.83
16,270	2019-05-23	729.43	5.57	13,148	2019-05-22	727.75	12.52

Table A-1 Cross section properties - Camrose Creek (continued)

River Station (m)	Date Surveyed	Thalweg Elevation (m)	Channel Width (m)	River Station (m)	Date Surveyed	Thalweg Elevation (m)	Channel Width (m)
13,143	2019-05-22	728	9.83	10,923	2019-05-08	721.81	7.72
13,066	2019-05-22	727.3	8.59	10,845	2019-05-08	721.8	10.57
13,060	2019-05-22	727.15	7.47	10,724	2019-05-08	721.86	8.91
13,007	2019-05-22	727.56	8.12	10,639	2019-05-08	721.87	11.28
13,003	2019-05-22	727.41	9.36	10,635	2019-05-08	721.75	10.87
12,933	2019-05-22	727.11	10.75	10,566	2019-05-08	721.16	6.86
12,929	2019-05-22	727.33	9.93	10,500	2019-05-08	721.68	8.69
12,822	2019-05-22	727.4	40.36	10,474	2019-05-08	721.38	6.35
12,767	2019-05-22	727.7	10.04	10,432	2019-05-08	721.32	6.65
12,736	2019-05-28	727.48	13.59	10,281	2019-05-08	720.76	4.02
12,639	2019-05-28	727.41	52.49	10,113	2019-05-08	720.75	6.04
12,429	2019-05-28	726.66	77.39	10,105	2019-05-08	720.78	6.45
12,198	2019-05-28	726.44	71.93	10,062	2019-05-08	720.55	6.32
11,983	2019-05-28	726.05	103.83	10,055	2019-05-08	720.55	10.51
11,859	2019-05-28	724.98	79.31	10,019	2019-05-08	719.85	10.16
11,770	2019-05-28	726.13	86.18	9,938	2019-05-08	720.08	6.34
11,756	2019-05-28	725.29	22.14	9,744	2019-05-09	719.52	5.85
11,705	2019-05-28	725.06	146.59	9,603	2019-09-23	719.23	10.16
11,591	2019-05-28	725.24	118.26	9,410	2019-05-21	719.02	11.73
11,544	2019-05-28	727.23	13.05	9,329	2019-05-21	718.87	14.95
11,498	2019-05-28	727.21	13.49	9,311	2019-05-21	718.1	16.92
11,447	2019-09-23	724.33	118.77	9,190	2019-05-21	718.56	11.09
11,394	2019-05-28	727.3	110.72	9,044	2019-05-21	718.53	5.14
11,382	2019-05-28	728.1	16.84	8,891	2019-05-21	717.28	6.28
11,367	2019-05-08	723.34	11.49	8,857	2019-05-21	717.34	9.07
11,339	2019-05-08	723.35	8.99	8,829	2019-05-21	717.77	5.93
11,302	2019-05-08	723.02	4.97	8,782	2019-05-21	717.05	8.12
11,279	2019-05-08	723.08	12.35	8,656	2019-05-21	717.04	7.83
11,230	2019-05-08	722.52	12.81	8,497	2019-05-21	716.38	6.27
11,164	2019-09-23	722.38	18.77	8,319	2019-05-21	715.92	7.67
11,132	2019-05-08	722.29	5.71	8,259	2019-05-21	716.15	8.06
11,127	2019-05-08	722.34	6.28	8,251	2019-05-21	716.3	7.72
11,092	2019-05-08	722.2	4.96	8,227	2019-05-21	716.07	4.57
11,033	2019-05-08	722.11	10.78	8,165	2019-05-21	715.67	9.25
10,941	2019-05-08	721.78	10.16	8,151	2019-05-21	715.96	6.97

Table A-1 Cross section properties - Camrose Creek (continued)

River Station (m)	Date Surveyed	Thalweg Elevation (m)	Channel Width (m)	River Station (m)	Date Surveyed	Thalweg Elevation (m)	Channel Width (m)
8,139	2019-05-21	716.1	8.03	4,522	2019-05-29	701	5.23
8,134	2019-05-21	716.06	6.46	4,422	2019-05-29	700.28	8.14
8,101	2019-05-09	715.59	5.4	4,316	2019-05-29	700.42	5.05
7,992	2019-05-09	715.02	5.16	4,221	2019-05-29	699.94	7.49
7,909	2019-05-09	715.06	9.5	4,089	2019-09-24	699.61	6.5
7,888	2019-05-09	714.93	11.07	3,950	2019-09-24	698.92	6.02
7,817	2019-05-09	714.51	4.76	3,924	2019-05-29	698.62	14.83
7,687	2019-05-09	714.37	4.47	3,770	2019-05-29	698.21	6.74
7,585	2019-09-23	713.48	5.85	3,674	2019-05-29	698	5.74
7,536	2019-05-09	713.89	10.04	3,496	2019-05-29	697.33	5.8
7,526	2019-05-09	713.91	7.54	3,382	2019-05-29	697.22	6.76
7,397	2019-09-23	713.01	8.26	3,358	2019-05-29	697.14	6.89
7,277	2019-05-09	713.14	6.06	3,298	2019-05-29	696.74	6.55
7,083	2019-05-09	712.4	7.32	3,287	2019-05-29	696.64	6.5
6,987	2019-05-09	712.04	3.76	3,207	2019-05-29	696.74	5.92
6,885	2019-05-09	711.78	6.95	3,096	2019-05-10	696.46	5.66
6,753	2019-05-09	711.2	5.15	2,986	2019-05-10	696.06	5.32
6,528	2019-05-09	709.92	3.73	2,901	2019-05-10	695.85	5.55
6,420	2019-05-09	709.59	4.88	2,808	2019-05-10	695.84	6.42
6,389	2019-05-09	709.59	5.1	2,651	2019-05-10	695.7	5.73
6,376	2019-05-09	709.55	4.75	2,525	2019-05-10	695.51	4.39
6,360	2019-09-24	709.32	4.5	2,381	2019-05-10	694.81	5.82
6,221	2019-05-10	708.74	5.49	2,283	2019-05-10	694.52	5.36
6,051	2019-05-10	707.13	5.91	2,060	2019-05-10	694.72	4.76
5,901	2019-05-10	707.18	6.19	1,967	2019-05-10	694.26	5.19
5,801	2019-05-10	706.84	6.55	1,788	2019-05-10	693.65	6.54
5,660	2019-05-10	706.33	5.18	1,727	2019-05-10	693.65	7.37
5,531	2019-05-10	705.75	8.65	1,596	2019-05-10	693.71	6.57
5,403	2019-05-10	705.01	6.78	1,590	2019-05-10	693.92	5.5
5,316	2019-05-10	704.64	5.15	1,551	2019-05-10	694.03	4.6
5,175	2019-05-10	704.68	6.72	1,485	2019-05-10	693.49	4.31
5,077	2019-05-10	703.41	4.6	1,474	2019-05-10	694.12	5.35
4,910	2019-05-29	702.33	6.86	1,431	2019-05-10	693.66	6.36
4,819	2019-05-29	702.26	7.45	1,327	2019-05-10	693.32	9.46
4,631	2019-05-29	701.18	6.07	1,221	2019-05-10	693.41	5.93

Table A-1 Cross section properties - Camrose Creek (continued)

River Station (m)	Date Surveyed	Thalweg Elevation (m)	Channel Width (m)	River Station (m)	Date Surveyed	Thalweg Elevation (m)	Channel Width (m)
1,114	2019-05-10	693.32	6.75	472	2019-05-10	692.36	8.09
1,004	2019-05-10	693.17	5.72	279	2019-05-10	692.04	9.06
893	2019-05-10	692.98	6.77	138	2019-05-10	692.05	6.71
817	2019-05-10	692.87	6.87	103	2019-05-10	691.47	6.4
725	2019-05-10	692.82	5.73	94	2019-05-10	692.08	6.36
720	2019-05-10	692.87	7.41	56	2019-05-10	691.91	6.31
640	2019-05-10	692.79	5.55	0	2019-05-10	691.73	6.89

Table A-2 Cross section properties - Unnamed Creek

River Station (m)	Date Surveyed	Thalweg Elevation (m)	Channel Width (m)	River Station (m)	Date Surveyed	Thalweg Elevation (m)	Channel Width (m)
5,730	2019-05-27	745.99	40.8	2,081	2019-05-27	738.3	100.13
5,032	2019-05-27	744.13	10.06	1,877	2019-05-27	737.84	9.47
4,768	2019-05-27	743.68	20.11	1,737	2019-05-27	737.21	4.91
4,365	2019-05-27	742.37	8.81	1,483	2019-05-27	736.38	6.74
4,118	2019-05-27	741.11	3.94	1,227	2019-05-27	735.2	10.8
4,107	2019-05-27	741.11	4	1,066	2019-05-29	734.49	3.21
3,792	2019-05-27	740.5	6.82	877	2019-05-29	733.64	5.43
3,247	2019-05-27	739.03	15.12	702	2019-05-29	732.82	4.58
2,760	2019-05-27	737.89	146.63	498	2019-05-29	731.97	31.9
2,378	2019-05-27	738.64	10.69	285	2019-05-29	730.71	5.57
2,358	2019-05-27	738.46	8.26	132	2019-05-29	730.2	6.67

nhc

Appendix B
Hydraulic Structure Details

DRAFT

Bridge Description

Name:	CN Railway Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	18693

Geometry

Span (m):	24.6	**High Chord (m):**	734.20
Width (m):	4.3	**Low Chord (m):**	733.00
Pier Type:	Timber	**No. of Piers:**	6
Pier Shape:	Circular	**Pier Width (m):**	0.40

Photo(s)

Looking upstream at bridge from right bank

Looking upstream at bridge from left bank

Bridge Description

Name: Golf Course Bridge
River: Camrose Creek
Bridge File No.: N/A
River Station (m): 18309

Geometry

Span (m): 8.8
Width (m): 2.6
Pier Type: Timber
Pier Shape: Circular
High Chord (m): 732.49
Low Chord (m): 732.30
No. of Piers: 2
Pier Width (m): 0.20

Photo(s)

Looking upstream at bridge from right bank

Looking downstream at bridge from right bank

Bridge Description

Name:	Golf Course Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	18194

Geometry

Span (m):	8.3	**High Chord (m):**	732.56
Width (m):	3.7	**Low Chord (m):**	732.37
Pier Type:	Timber	**No. of Piers:**	1
Pier Shape:	Square	**Pier Width (m):**	0.20

Photo(s)

Looking upstream at bridge from right bank

Looking downstream at bridge from right bank

Bridge Description

Name:	Golf Course Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	18090

Geometry

Span (m):	9.2	**High Chord (m):**	732.57
Width (m):	2.8	**Low Chord (m):**	732.39
Pier Type:	Timber	**No. of Piers:**	2
Pier Shape:	Circular	**Pier Width (m):**	0.20

Photo(s)

Looking upstream at bridge from left bank

Looking downstream at bridge from left bank

Bridge Description

Name:	Golf Course Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	17991

Geometry

Span (m):	9.2	**High Chord (m):**	732.62
Width (m):	2.8	**Low Chord (m):**	732.44
Pier Type:	Timber	**No. of Piers:**	2
Pier Shape:	Circular	**Pier Width (m):**	0.19

Photo(s)

Looking downstream at bridge from right bank

Looking upstream at bridge from right bank

Bridge Description

Name:	Highway 833 Bridge	**Bridge File No.:**	BF1030
River:	Camrose Creek	**River Station (m):**	17491

Geometry

Span (m):	8.5	**High Chord (m):**	734.39
Width (m):	13.5	**Low Chord (m):**	733.55
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking upstream at bridge from left bank

Looking downstream at bridge from right bank

Bridge Description

Name:	Township Rd 472 Bridge	**Bridge File No.:**	BF446
River:	Camrose Creek	**River Station (m):**	16638

Geometry

Span (m):	10.2	**High Chord (m):**	733.58
Width (m):	8.7	**Low Chord (m):**	732.74
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking upstream at bridge from left bank

Looking downstream at bridge from left bank

Bridge Description

Name:	Bailey Avenue Bridge	**Bridge File No.:**	BF77950
River:	Camrose Creek	**River Station (m):**	15770

Geometry

Span (m):	6.2	**High Chord (m):**	732.20
Width (m):	8.6	**Low Chord (m):**	731.38
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking west across bridge from left bank

Looking upstream at bridge from center of channel

Bridge Description

Name:	53rd Street Bridge	**Bridge File No.:**	BF1029
River:	Camrose Creek	**River Station (m):**	15428

Geometry

Span (m):	4.5	**High Chord (m):**	732.26
Width (m):	13.0	**Low Chord (m):**	731.44
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking upstream at bridge from left bank

Looking downstream at bridge from center of channel

Bridge Description

Name:	54^{th} Avenue Bridge	**Bridge File No.:**	BF79515
River:	Camrose Creek	**River Station (m):**	13933

Geometry

Span (m):	11.0	**High Chord (m):**	731.59
Width (m):	15.9	**Low Chord (m):**	730.76
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking upstream at bridge from right bank

Looking downstream at bridge from left bank

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	13563

Geometry

Span (m):	24.1	**High Chord (m):**	730.78
Width (m):	3.0	**Low Chord (m):**	730.46
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking west across bridge from left bank

Looking downstream at bridge from left bank

Bridge Description

Name:	Private Road	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	13379

Geometry

Span (m):	8.5	**High Chord (m):**	730.53
Width (m):	6.2	**Low Chord (m):**	729.89
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking upstream at bridge from left bank

Looking downstream at bridge from center of channel

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	13146

Geometry

Span (m):	16.0	**High Chord (m):**	730.02
Width (m):	1.8	**Low Chord (m):**	729.85
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking upstream at bridge from left bank

Looking downstream at bridge from left bank

Bridge Description

Name:	Golf Course Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	13063

Geometry

Span (m):	9.2	**High Chord (m):**	729.42
Width (m):	3.8	**Low Chord (m):**	729.03
Pier Type:	Timber	**No. of Piers:**	2
Pier Shape:	Circular	**Pier Width (m):**	0.31

Photo(s)

Looking upstream at bridge from right bank

Looking north across bridge from left bank

Bridge Description

Name:	Golf Course Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	13005

Geometry

Span (m):	14.1	**High Chord (m):**	729.00
Width (m):	1.9	**Low Chord (m):**	728.70
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream at bridge from left bank

Looking upstream at bridge from left bank

Bridge Description

Name:	Golf Course Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	12930

Geometry

Span (m):	11.8	**High Chord (m):**	729.16
Width (m):	1.8	**Low Chord (m):**	728.86
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking south across bridge from right bank

Looking downstream at bridge from left bank

Bridge Description

Name:	Mirror Lake Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	11761

Geometry

Span (m):	27.5	**High Chord (m):**	730.20
Width (m):	3.0	**Low Chord (m):**	730.00
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream at bridge from right bank

Looking downstream at bridge from left bank

Bridge Description

Name:	48th Avenue Bridge	**Bridge File No.:**	BF445
River:	Camrose Creek	**River Station (m):**	11521

Geometry

Span (m):	13.7	**High Chord (m):**	730.64
Width (m):	36.5	**Low Chord (m):**	729.94
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking upstream at bridge from right bank

Looking downstream under bridge from right bank

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	11384

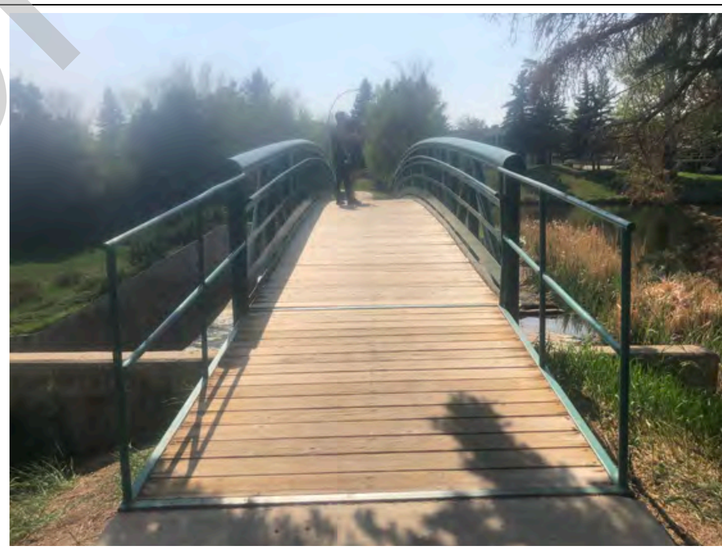
Geometry

Span (m):	21.8	**High Chord (m):**	730.37
Width (m):	1.9	**Low Chord (m):**	730.01
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking upstream at bridge from right bank

Looking south-west across bridge from left bank



Bridge Description

Name: 47th Avenue Bridge | **Bridge File No.:** BF81006
River: Camrose Creek | **River Station (m):** 11292

Geometry

Span (m):	5.1	**High Chord (m):**	727.67
Width (m):	13.2	**Low Chord (m):**	726.98
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream under bridge from center of channel

Looking downstream at bridge from center of channel

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	11129

Geometry

Span (m):	11.9	**High Chord (m):**	724.41
Width (m):	1.7	**Low Chord (m):**	724.21
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking upstream at bridge from right bank

Looking downstream at bridge from right bank

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	10933

Geometry

Span (m):	16.1	**High Chord (m):**	724.96
Width (m):	4.6	**Low Chord (m):**	723.36
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream at bridge from left bank

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	10637

Geometry

Span (m):	12.5	**High Chord (m):**	723.33
Width (m):	1.9	**Low Chord (m):**	723.11
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking west across bridge from left bank

Bridge Description

Name:	44th Avenue Bridge	**Bridge File No.:**	BF79353
River:	Camrose Creek	**River Station (m):**	10489

Geometry

Span (m):	10.9	**High Chord (m):**	725.35
Width (m):	14.6	**Low Chord (m):**	725.00
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking east across bridge from right bank

Looking upstream at bridge from left bank

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	10109

Geometry

Span (m):	7.6	**High Chord (m):**	722.46
Width (m):	4.2	**Low Chord (m):**	722.09
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

NOT AVAILABLE

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	10058

Geometry

Span (m):	16.0	**High Chord (m):**	722.06
Width (m):	1.7	**Low Chord (m):**	721.86
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

NOT AVAILABLE

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	8255

Geometry

Span (m):	9.2	**High Chord (m):**	717.94
Width (m):	4.9	**Low Chord (m):**	717.50
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream at bridge from center of channel

Bridge Description

Name:	CN Railway Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	8156

Geometry

Span (m):	59.4	**High Chord (m):**	729.10
Width (m):	2.7	**Low Chord (m):**	728.40
Pier Type:	Timber	**No. of Piers:**	31
Pier Shape:	Circular	**Pier Width (m):**	0.30

Photo(s)

Looking downstream at bridge from right bank

Looking upstream at bridge from right bank

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	8135

Geometry

Span (m):	7.0	**High Chord (m):**	717.52
Width (m):	1.9	**Low Chord (m):**	717.30
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream at bridge from left bank

Looking south across bridge from left bank

Bridge Description

Name:	Camrose Drive Bridge	**Bridge File No.:**	BF806000
River:	Camrose Creek	**River Station (m):**	7898

Geometry

Span (m):	180.0	**High Chord (m):**	736.56
Width (m):	14.6	**Low Chord (m):**	734.76
Pier Type:	Concrete	**No. of Piers:**	6
Pier Shape:	Elongated with Semi Circular Ends	**Pier Width (m):**	1.00

Photo(s)

Looking east under bridge from right bank

Bridge Description

Name:	Pedestrian Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	7531

Geometry

Span (m):	12.2	**High Chord (m):**	715.89
Width (m):	4.8	**Low Chord (m):**	715.49
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

NOT AVAILABLE

Bridge Description

Name:	Township Rd 464 Bridge	**Bridge File No.:**	BF366
River:	Camrose Creek	**River Station (m):**	6383

Geometry

Span (m):	8.2	**High Chord (m):**	713.07
Width (m):	6.6	**Low Chord (m):**	712.42
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking downstream at bridge from right bank

Looking downstream at bridge from center of channel

Bridge Description

Name:	CN Railway Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	3294

Geometry

Span (m):	77.6	**High Chord (m):**	710.20
Width (m):	4.0	**Low Chord (m):**	709.50
Pier Type:	Timber	**No. of Piers:**	20
Pier Shape:	Circular	**Pier Width (m):**	0.30

Photo(s)

Looking downstream at bridge from right bank

Looking downstream at bridge from center of channel

Bridge Description

Name: Trail Bridge
River: Camrose Creek
Bridge File No.: N/A
River Station (m): 2899

Geometry

Span (m): 24.2
Width (m): 3.0
Pier Type: N/A
Pier Shape: N/A
High Chord (m): 698.97
Low Chord (m): 698.05
No. of Piers: 0
Pier Width (m): N/A

Photo(s)

Looking downstream at bridge from right bank

Looking downstream at bridge from center of channel

Bridge Description

Name:	Trail Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	2059

Geometry

Span (m):	12.8	**High Chord (m):**	696.65
Width (m):	1.8	**Low Chord (m):**	696.25
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

NOT AVAILABLE

Bridge Description

Name:	Trail Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	1593

Geometry

Span (m):	20.3	**High Chord (m):**	697.19
Width (m):	3.0	**Low Chord (m):**	696.34
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking south-east across bridge from right bank

Bridge Description

Name:	CN Railway Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	1479

Geometry

Span (m):	47.3	**High Chord (m):**	705.23
Width (m):	4.0	**Low Chord (m):**	704.53
Pier Type:	Timber	**No. of Piers:**	13
Pier Shape:	Circular	**Pier Width (m):**	0.30

Photo(s)

Looking upstream at bridge from left bank

Bridge Description

Name:	Trail Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	722

Geometry

Span (m):	7.5	**High Chord (m):**	694.76
Width (m):	3.6	**Low Chord (m):**	694.36
Pier Type:	N/A	**No. of Piers:**	0
Pier Shape:	N/A	**Pier Width (m):**	N/A

Photo(s)

Looking upstream at bridge from left bank

Looking downstream from left bank

Bridge Description

Name:	CN Railway Bridge	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	98

Geometry

Span (m):	42.6	**High Chord (m):**	700.83
Width (m):	4.0	**Low Chord (m):**	700.13
Pier Type:	Timber	**No. of Piers:**	11
Pier Shape:	Circular	**Pier Width (m):**	0.30

Photo(s)

Looking upstream at bridge from left bank

Looking upstream at bridge from right bank

Culvert Description

Name:	CSP Culvert	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	16310

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	730.59
Diameter (m):	0.5	**Downstream Invert Elev (m):**	730.58
Culvert Type:	CSP	**Barrel Length:**	3.2
Culvert Shape:	Circular	**Minimum Road Elevation:**	731.41
Entrance Con:	Pipe Projecting From Fill		

Photo(s)

NOT AVAILABLE

Culvert Description

Name:	CSP Culverts (Barrel 1)	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	14522

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	729.05
Diameter (m):	0.9	**Downstream Invert Elev (m):**	729.31
Culvert Type:	CSP	**Barrel Length:**	8.8
Culvert Shape:	Circular	**Minimum Road Elevation:**	730.36
Entrance Con:	Pipe Projecting From Fill		

Photo(s)

Looking at downstream end of culverts from center of channel

Looking east across burried culvert span from right bank

Culvert Description

Name:	CSP Culverts (Barrel 2)	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	14522

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	729.07
Diameter (m):	0.9	**Downstream Invert Elev (m):**	729.06
Culvert Type:	CSP	**Barrel Length:**	8.8
Culvert Shape:	Circular	**Minimum Road Elevation:**	730.36
Entrance Con:	Pipe Projecting From Fill		

Photo(s)

Looking at downstream end of culverts from center of channel

Looking east across burried culvert span from right bank

Culvert Description

Name:	CSP Culverts (Barrel 3)	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	14522

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	729.23
Diameter (m):	0.9	**Downstream Invert Elev (m):**	729.15
Culvert Type:	CSP	**Barrel Length:**	8.8
Culvert Shape:	Circular	**Minimum Road Elevation:**	730.36
Entrance Con:	Pipe Projecting From Fill		

Photo(s)

Looking at downstream end of culverts from center of channel

Looking east across burried culvert span from right bank

Culvert Description

Name:	CSP Culverts (Barrel 4)	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	14522

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	729.21
Diameter (m):	0.9	**Downstream Invert Elev (m):**	729.04
Culvert Type:	CSP	**Barrel Length:**	8.8
Culvert Shape:	Circular	**Minimum Road Elevation:**	730.36
Entrance Con:	Pipe Projecting From Fill		

Photo(s)

Looking at downstream end of culverts from center of channel

Looking east across burried culvert span from right bank

Culvert Description

Name:	CP Rail Culvert	**Bridge File No.:**	BF77937
River:	Camrose Creek	**River Station (m):**	13437

Geometry

Span (m):	3.0	**Upstream Invert Elev (m):**	728.28
Width (m):	2.6	**Downstream Invert Elev (m):**	728.24
Culvert Type:	Concrete	**Barrel Length:**	35.5
Culvert Shape:	Box	**Minimum Road Elevation:**	739.95
Entrance Con:	Side Tapered		

Photo(s)

Looking at upstream end of culvert from center of channel

Looking at upstream end of culverts from left bank

Culvert Description

Name:	50th Avenue/Grand Drive (Barrel 1)	**Bridge File No.:**	BF83008
River:	Camrose Creek	**River Station (m):**	12750

Geometry

Span (m):	2.4	**Upstream Invert Elev (m):**	727.70
Width (m):	1.8	**Downstream Invert Elev (m):**	727.50
Culvert Type:	Concrete	**Barrel Length:**	27.9
Culvert Shape:	Box	**Minimum Road Elevation:**	730.52
Entrance Con:	Side Tapered		

Photo(s)

Looking at upstream end of culverts from left bank

Looking at upstream end of culverts from right bank

Culvert Description

Name:	50th Avenue/Grand Drive (Barrel 2)	**Bridge File No.:**	BF83008
River:	Camrose Creek	**River Station (m):**	12750

Geometry

Span (m):	2.4	**Upstream Invert Elev (m):**	727.70
Width (m):	1.8	**Downstream Invert Elev (m):**	727.50
Culvert Type:	Concrete	**Barrel Length:**	27.9
Culvert Shape:	Box	**Minimum Road Elevation:**	730.52
Entrance Con:	Side Tapered		

Photo(s)

Looking at upstream end of culverts from left bank

Looking at upstream end of culverts from right bank

Culvert Description

Name:	48th Avenue Bridge	**Bridge File No.:**	BF445
River:	Camrose Creek	**River Station (m):**	11521

Geometry

Span (m):	4.0	**Upstream Invert Elev (m):**	729.10
Width (m):	2.5	**Downstream Invert Elev (m):**	728.90
Culvert Type:	Concrete	**Barrel Length:**	45.0
Culvert Shape:	Box	**Minimum Road Elevation:**	730.64
Entrance Con:	Side Tapered		

Photo(s)

Looking at downstream end of culvert on left bank

Culvert Description

Name:	CSP Culverts (Barrel 1)	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	9318

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	718.80
Diameter (m):	2.0	**Downstream Invert Elev (m):**	718.20
Culvert Type:	CSP	**Barrel Length:**	15.1
Culvert Shape:	Circular	**Minimum Road Elevation:**	722.50
Entrance Con:	Pipe Projecting From Fill		

Photo(s)

Looking at upstream end of culverts from right bank

Looking at downstream end of culverts from right bank

Culvert Description

Name:	CSP Culverts (Barrel 2)	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	9318

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	718.80
Diameter (m):	2.0	**Downstream Invert Elev (m):**	718.20
Culvert Type:	CSP	**Barrel Length:**	15.1
Culvert Shape:	Circular	**Minimum Road Elevation:**	722.50
Entrance Con:	Pipe Projecting From Fill		

Photo(s)

Looking at upstream end of culverts from right bank

Looking at downstream end of culverts from right bank

Culvert Description

Name:	CSP Culverts (Barrel 3)	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	9318

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	718.80
Diameter (m):	2.0	**Downstream Invert Elev (m):**	718.20
Culvert Type:	CSP	**Barrel Length:**	15.1
Culvert Shape:	Circular	**Minimum Road Elevation:**	722.50
Entrance Con:	Pipe Projecting From Fill		

Photo(s)

Looking at upstream end of culverts from right bank

Looking at downstream end of culverts from right bank

Culvert Description

Name:	Box Culvert	**Bridge File No.:**	N/A
River:	Camrose Creek	**River Station (m):**	8841

Geometry

Span (m):	2.4	**Upstream Invert Elev (m):**	717.59
Width (m):	1.6	**Downstream Invert Elev (m):**	717.59
Culvert Type:	Concrete	**Barrel Length:**	26.3
Culvert Shape:	Box	**Minimum Road Elevation:**	720.89
Entrance Con:	Side Tapered		

Photo(s)

Looking at upstream end of culvert from left bank

Looking at downstream end of culverts from right bank

Culvert Description

Name:	CSP Culvert	**Bridge File No.:**	N/A
River:	Unnamed Creek	**River Station (m):**	4112

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	741.16
Diameter (m):	0.8	**Downstream Invert Elev (m):**	741.09
Culvert Type:	CSP	**Barrel Length:**	10.3
Culvert Shape:	Circular	**Minimum Road Elevation:**	742.32
Entrance Con:	Pipe Projecting From Fill		

Photo(s)

Looking at upstream end of culvert from left bank

Looking at downstream end of culvert from left bank

Culvert Description

Name:	Range Rd 203 Culverts (Barrel 1)	**Bridge File No.:**	N/A
River:	Unnamed Creek	**River Station (m):**	2367

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	738.65
Diameter (m):	0.8	**Downstream Invert Elev (m):**	738.49
Culvert Type:	CSP	**Barrel Length:**	18.2
Culvert Shape:	Circular	**Minimum Road Elevation:**	740.65
Entrance Con:	Mitered to Confirm Slope		

Photo(s)

Looking at upstream end of culvert from left bank

Culvert Description

Name:	Range Rd 203 Culverts (Barrel 2)	**Bridge File No.:**	N/A
River:	Unnamed Creek	**River Station (m):**	2367

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	738.69
Diameter (m):	0.8	**Downstream Invert Elev (m):**	738.53
Culvert Type:	CSP	**Barrel Length:**	18.2
Culvert Shape:	Circular	**Minimum Road Elevation:**	740.65
Entrance Con:	Mitered to Confirm Slope		

Photo(s)

Looking at upstream end of culvert from left bank

Culvert Description

Name:	Range Rd 203 Culverts (Barrel 3)	**Bridge File No.:**	N/A
River:	Unnamed Creek	**River Station (m):**	2367

Geometry

Span (m):	N/A	**Upstream Invert Elev (m):**	738.67
Diameter (m):	0.8	**Downstream Invert Elev (m):**	738.50
Culvert Type:	CSP	**Barrel Length:**	18.3
Culvert Shape:	Circular	**Minimum Road Elevation:**	740.65
Entrance Con:	Mitered to Confirm Slope		

Photo(s)

Looking at upstream end of culvert from left bank

Weir Description

Name: Mirror Lake Dam and Spillway

River: Camrose Creek

Bridge File No.: N/A

River Station (m): 11382

Geometry

Span (m): 16.6

Width (m): 5

Weir Type: Broad Crested Spillway

Crest Elevation: 728.1

Photo(s)

Looking upstream of weir from left bank

Looking downstream of weir from right bank

Appendix C
Reach-Representative Photographs

Camrose Creek

Camrose Creek (upstream view) near CN Rail Bridge at upstream study limit near River Station 18,700 m.

Camrose Creek at a Golf Course Bridge near River Station 17,993 m.

Camrose Creek (upstream view) at Highway 833 near River Station 17,570 m.

Camrose Creek (downstream view) north of Kent street near River Station 16,317 m.

Camrose Creek (downstream view) south of Bailey Avenue bridge near River Station 15,704 m.

Camrose Creek (downstream view) just north of developed city area in a local field near River Station 14,517 m.

Camrose Creek (upstream view) at 50th avenue near River Station 12,767 m.

Camrose Creek (upstream view looking at Mirror Lake) from the Mirror Lake pedestrian bridge near River Station 11,770 m.

Camrose Creek (downstream view looking at Mirror Lake) from the Mirror Lake pedestrian bridge near River Station 11,756 m.

Camrose Creek (upstream view looking at Mirror Lake) from 48th avenue near River Station 11,544 m.

Camrose Creek (downstream view) just downstream of Mirror Lake Dam and Spillway near River Station 11,382 m.

Camrose Creek (downstream view) near River Station 9,044 m.

Camrose Creek (downstream view) between River Station 8,656 m and 8,497 m.

Camrose Creek (upstream view) flowing through a pedestrian bridge and the CN Railway bridge near River Station 8,139 m.

Camrose Creek (upstream view) below Camrose Drive bridge near River Station 7,909 m.

Camrose Creek (upstream view) near River Station 6,885 m.

Camrose Creek (upstream view) near River Station 5,175 m.

Camrose Creek (downstream view) at a Trail Bridge near River Station 2,986 m.

Camrose Creek (downstream view) at the CN Railway Trussell Bridge near River Station 1,485 m.

Camrose Creek (upstream view) at a Trail Bridge near River Station 720 m.

Unnamed Creek

Unnamed Creek (downstream view) at study limit near River Station 5,730 m.

Unnamed Creek (downstream view) near River Station 4,112 m.

Unnamed Creek (upstream view) at Range Rd 203 near River Station 2,367 m.

Appendix D
Open Water Hydrology Assessment Memorandum

nhc
northwest hydraulic consultants

NHC Ref. No. 1004662

MEMORANDUM

Prepared by:	C.H. (Ken) Zhao	Date:	12 February 2020
Reviewed by:		Client File:	19STR830
Distribution:	Kurt Morrison (AEP)		

RE: Camrose Flood Hazard Study
Open Water Hydrology Assessment

1 INTRODUCTION

In April 2019, Alberta Environment and Parks (AEP) retained Northwest Hydraulic Consultants Ltd. (NHC) to complete a flood hazard study for the Camrose area. 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 memorandum presents details of the ***open water hydrology assessment***, for which the primary objective is to develop flood frequency estimates for Camrose Creek at the city of Camrose, in support of the hydraulic modelling and flood mapping tasks of the Camrose Flood Hazard Study.

2 STUDY AREA

As shown in **Figure 1**, the flood hazard study reach extends along approximately 18 km of Camrose Creek through the city, from about three kilometers north of the city limit to about one kilometer downstream of the southern limit. The study reach also includes approximately six (6) kilometers of an unnamed tributary west of Camrose Creek near the north boundary of the city. This tributary flows into Camrose

Creek downstream of the Water Survey of Canada (WSC) Station 05FA025 – Camrose Creek near Camrose.

In expectation that noticeable changes in creek discharge would occur within the study reach, five sites have been identified in **Figure 1** as the key locations where flood frequency estimates are required for this flood hazard study, including:

- Site 1: Unnamed Tributary at the mouth;
- Site 2: Camrose Creek near Camrose (WSC Station 05FA025);
- Site 3: Camrose Creek above the CPR crossing (located about 650 m upstream of Mirror Lake);
- Site 4: Camrose Creek at Mirror Lake; and
- Site 5: Camrose Creek at the downstream end of the study reach.

3 HYDROLOGIC CHARACTERISTICS

3.1 Basin Delineation

According to the WSC, the gross drainage area upstream of WSC Station 05FA025 (Camrose Creek near Camrose) is 460 km^2, which was delineated by Agriculture and Agri-food Canada (AAFC). This reported drainage area includes the 38.3 km^2 Miquelon Lakes sub-basin, which accounts for about 8% of the total drainage area. The Atlas of Alberta Lakes indicates that Miquelon Lake has no surface outflow since the 1920s except the diversion to Camrose between 1927 and 1930. According to the water level data for the discontinued WSC gauge station 05EB014 (Miquelon Lake at Provincial Park; period of record from 1972 to 1995) and the more recent data reported by Alberta Environment (AENV, 2006), the lake level has decreased by more than 1.5 m since 1972. Therefore, contribution from this sub-basin to Camrose Creek would be negligible during normal flow and flood events with shorter return periods. However, according to the information provided by AEP, the lake had much higher water levels in 1900 and 1901 and discharged to Camrose Creek, which indicates that Miquelon Lake overflows may not be negligible during extreme flood events. As such, the Miquelon Lakes sub-basin is considered as a contributing area for Camrose Creek in this study. This may result in slightly overestimating Camrose Creek flood peaks for shorter return periods; but the effect would be insignificant because the Miquelon Lakes sub-basin is small in comparison with the total drainage area of Camrose Creek.

The AAFC basin boundary for Camrose Creek was reviewed and compared with the basin boundary from the Hydrologic Unit Code (HUC) Watersheds of Alberta (the HUC 8 class) [1]. The HUC basin boundary was developed by AEP based on the Alberta ArcHydro Phase 2 data, which was also obtained and reviewed during this study. The AAFC and HUC basin boundaries for Camrose Creek have only some minor

[1] https://www.alberta.ca/hydrological-data.aspx#toc-5

differences. The HUC basin boundary was used for this study as it was delineated with more recent and detailed topographic data.

In this study, the HUC basin boundary near the city of Camrose was refined using LiDAR digital elevation model (DEM) data collected by AEP in 2018 for this flood hazard study and the AltaLIS LiDAR15 DEM (also provided by AEP). The final basin boundary for WSC Station 05FA025 is shown in **Figure 2**, which represents a gross drainage area of approximately 445 km^2. This estimate was adopted for this study.

Drainage areas for the other four flood frequency estimate sites were also delineated using the LiDAR DEMs provided by AEP, as shown in **Figure 2**. The drainage areas are summarized in **Table 1**. The total tributary area between WSC Station 05FA025 (Site 1) and the downstream boundary of the study area (Site 5) is approximately 91 km^2, of which about 28% is developed or under-development urban areas.

Table 1: Summary of drainage areas for flood frequency estimate sites

Flood Frequency Estimate Sites	Location	Gross Drainage Area (km^2)	Increased Area from 05FA025 (km^2)
Site 1	Unnamed Tributary at the mouth	33.6	-
Site 2	WSC Station 05FA025	445	0
Site 3	Camrose Creek above the CPR crossing	493	48
Site 4	Camrose Creek at Mirror Lake	497	52
Site 5	Camrose Creek at the downstream end	536	91

3.2 Basin Settings

Camrose Creek is a relatively small prairie stream, which originates near Miquelon Lake Provincial Park about 25 km north of the city of Camrose (**Figure 2**). It generally flows from north to south through Camrose and enters the Battle River just upstream of Driedmeat Lake. Within the city limit, there is a man-made lake on the creek: Mirror Lake, formed by an earthen dam immediately south of Highway 13 (48 Avenue). The dam was constructed on the creek in the 1930s. Outflows from the lake are controlled by a concrete spillway in the dam.

The Camrose Creek basin is located within the Central Parkland Natural Subregion. Land use in this basin is dominated by agriculture. The basin features relatively flat terrain with many undrained or intermittently draining wetlands/sloughs. Although this is a typical physiographic feature for prairie stream basins, it appears more significant in the Camrose Creek basin. According to the WSC, the effective drainage area for Station 05FA025 is only 31.7 km^2, or about 8% of its gross drainage area (or an effective-to-gross drainage area ratio of 0.08). This percentage is among the smallest of the gauged basins in Alberta, although a recent study by Ducks Unlimited Canada (DUC, 2019) suggests that the effective drainage area of Camrose Creek has likely increased due to wetland drainage.

DUC (2019) estimated that wetlands cover about 12% of the Camrose Creek basin area. These wetlands provide significant storage capacities and likely affect runoff patterns in Camrose Creek. Among them, a managed wetland, Lyseng Reservoir, is located on Camrose Creek approximately 10 km upstream of WSC Station 05FA025 (**Figure 2**). The drainage area upstream of the reservoir accounts for about 60% of the drainage area for WSC Station 05FA025. According to Underwood McLellan & Associated Ltd. (UMA, 1974), the reservoir was constructed on a slough area in the early 1950s to supplement the water supply for the City of Camrose, and was then taken over by Imperial Oil Resources Ltd. in 1965 for well injection use. In 1994, the license of this reservoir was transferred to DUC (the Government of Alberta – GoA, 2014). According to record drawings provided by DUC, Lyseng Reservoir has a surface area of about 1.26 km^2 at its full supply level (FSL) of El. 738.50 m, which is equal to about 3% of the total wetland area within the basin, or less than 0.5% of the drainage area. The design elevation of the top of the dykes impounding the reservoir is 740.0 m – only 1.5 m higher than the FSL. The reservoir discharges to Camrose Creek via an uncontrolled overflow weir with its crest at the FSL elevation. Immediately downstream of the overflow weir, Camrose Creek flows are affected by a culvert crossing at the intersection of Township Road 480 and Range Road 204. As water levels and outflow discharges of the reservoir are not recorded, it is impossible to perform flow naturalization for Lyseng Reservoir. Given the configuration of its outflow control structure, small surface area and relatively small water level fluctuation, the degree of regulation for Lyseng Rservoir is deemed low. The reservoir would affect lower flows in Camrose Creek; however, during flood events, it is not expected to have significantly different effects from other larger natural wetlands in this basin, of which outflows are not managed but could often be unintentionally affected by road crossings.

3.3 Flood Characteristics

Seasonal (March through October) flows of Camrose Creek have been measured by the WSC at Station 05FA025 since 2006. **Figure 3** shows the 2006-2018 daily flows for this gauge station. Over the entire period of record, excluding 2011, the creek started to flow in as early as mid-March and concluded in late May or early June. Flows are due to snowmelt with or without rainfall and flows after June were zero or negligible. The 2011 flow hydrograph presents two flood events. The first one peaked on 3 May 2011 during snowmelt. The second one resulted in the annual maximum discharge on 4 August 2011. The second event was related to the excessive rainfall amount of that summer. The Environment Canada Camrose climate station (Climate ID 3011240) recorded rainfall depths of 108 mm in June, 98 mm in July and 9 mm in August. Based on the 1946-2018 precipitation data for the Camrose climate station, the sum of the June and July 2011 rainfall depth would have an exceedance probability of about 10%. The hydrograph shape for this summer peak event (18 July – 31 August 2011) appears to be very similar to those for the spring events from the record, reflecting that Camrose Creek flows are affected by the significant storage capacity in the upstream basin due to the existing wetlands and Lyseng Reservoir. These observations indicate that:

- high flows in Camrose Creek near Camrose are dominated by spring runoff due to snowmelt with or without rain;
- summer flood peak discharges are expected to be governed by rainfall volumes instead of rainfall intensity; and
- it is unlikely that the creek would respond significantly to thunderstorms with shorter durations and lower total rainfall volumes.

3.4 Historic Flood Events

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 measurements on Camrose Creek began in 2006 at WSC Station 05FA025. The WSC also reported some flow measurements from 1928 to 1930 at a discontinued gauge (05FA010 – Camrose Creek at Camrose); but the recorded maximum discharge was smaller than 1 m^3/s. As such, those data were not considered in this study.

The April 1974 event was a significant flood event on Camrose Creek. During this event, the Mirror Lake spillway was washed out, and some upstream road crossings were also washed out or overtopped. Alberta Transportation (AT) estimated the peak discharge at the Canadian Pacific Railway (CPR) culvert crossing located upstream of Mirror Lake to be between 26 and 39 m^3/s (AT Bridge File #77937). The previous Camrose flood risk mapping study (IDE, 1994) cited the peak discharge for the same culvert estimated by an engineering company (De Leuw Cather Canada Ltd.), which ranges from 22.7 to 28.6 m^3/s. This estimation was likely based on more reliable information and thus expected to be more accurate than AT's estimation (which was solely based on a photo showing the flow condition at the culvert inlet). Therefore, the upper limit of the estimation from IDE (1994), 28.6 m^3/s, was adopted for the present study.

The culvert crossing for Township Road 472 located upstream of WSC Station 05FA025 was washed out in 1956, according to AT Bridge File #00446. The Highway 833 bridge located immediately upstream had a highwater mark over grade (AT Bridge File #01030). AT estimated the discharge of that event as 8.5 m^3/s. This estimate is higher than all annual peak discharges from the WSC Station 05FA025 record; therefore, it was included in the flood frequency analysis for this study.

4 FLOOD FREQUENCY ANALYSIS

4.1 Single Station Analysis

WSC Station 05FA025 – Camrose Creek near Camrose (Site 2) has an available record from 2006 to 2018, with annual peak instantaneous discharges reported in all years except 2008 and 2012. **Table 2** shows the annual peak flow series with the 2008 and 2012 instantaneous peaks being estimated from the relationship between available peak instantaneous (Q_i) and (Q_d) daily discharges shown in **Figure 4** . **Table 2** also includes the estimated discharges for the historic events discussed in Section 3.3: the April 1974 event with a peak discharge of 28.6 m^3/s, and the 1956 event with a peak discharge of 8.5 m^3/s. **Table 3** provides a summary of the statistical parameters for the Camrose Creek flow series.

Table 2: Annual peak instantaneous and daily discharges for Camrose Creek near Camrose

Year	Maximum Instantaneous Discharge (m^3/s) (1)	Date	Maximum Daily Discharge (m^3/s)	Date	Daily Discharge on Date of Maximum Instantaneous Discharge (m^3/s)
1956	8.5 (2)	1956-04			
1974	28.6 (2)	1974-04-20			
2006	0.820	2006-04-24	0.57	2006-05-02	0.231
2007	4.09	2007-04-22	4.06	2007-04-23	
2008	**<u>0.121</u>**	2008-05-02	0.12	2008-05-02	
2009	0.033	2009-07-08	0.02	2009-07-08	
2010	0.037	2010-06-08	0.02	2010-06-08	
2011	5.98	2011-08-04	5.93	2011-08-04	
2012	**<u>0.129</u>**	2012-04-01	0.13	2012-04-01	
2013	1.47	2013-05-11	1.44	2013-05-11	
2014	1.25	2014-04-28	1.23	2014-04-27	
2015(3)	3.73	2015-04-03	3.70	2015-04-03	
2016(3)	0.184	2016-07-10	0.11	2016-07-11	
2017(3)	5.62	2017-04-14	5.55	2017-04-14	
2018	6.55	2018-04-28	6.51	2018-04-28	

1. The bolded and underlined values are based on Q_i=1.01Q_d.
2. Estimates for historic events.
3. Preliminary data obtained from WSC.

Table 3: Summary of statistical parameters of annual peak discharge series for Camrose Creek at Camrose

Parameter	**Annual Peak Flow Series** 1956, 1974, and 2006-2018
Years of record	15
Mean (m^3/s)	4.48
Median (m^3/s)	1.47
Standard deviation (m^3/s)	7.25
Coefficient of variation	1.62
Skew coefficient (minimum, maximum, actual)	3.24, 3.26, 2.94

A frequency analysis was performed on the Camrose Creek peak instantaneous discharges shown in **Table 2**. The analysis was conducted using the USACE HEC-SSP (version 2.1) 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) and Guidelines on Flood Frequency Analysis by Alberta Transportation (AT, 2001), 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 positioning formula was used to plot data points for visualization purposes.

The USGS "Guidelines for Determining Flood Frequency" Bulletin 17C (USGS, 2018) was also reviewed and considered for the study. The USGS Guidelines provide a framework primarily intended to standardize the methods to account for historic flood information, zero flows or low outliers, and high outliers, and methods to estimate population parameters. They use the LP3 as the base method for flood frequencies with the parameters being estimated from the Expected Moments Algorithm (EMA).

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) and a least squares method. 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 least squares 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}, i.e. 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, visual assessment and Bayesian concepts as it is on the statistical ranking result.

Table 4 shows the ranking of the frequency distributions based on D_n and *SSE* values. The LP3 distribution has the lowest D_n and *SSE* values and is ranked the best in the combined ranking. The P3 and Weibull distributions also produce relatively small *SSE* values; so, despite their higher D_n values, they are ranked the second in the combined ranking, followed by the Bulletin 17C curve. These four distributions are compared in **Figure 5**. The other lower ranking distributions do not provide a better visual fit and are shown graphically in **Appendix A**.

Table 4: Goodness-of-fit comparison for probability distributions for Camrose Creek at Camrose

Distribution	D_n	Normalized *SSE* ($Q_{pm} = 4.48\ m^3/s$)	Rank by D_n	Rank by *SSE*	Combined Ranking
Normal (N)	0.145	0.255	8	9	9
Log-normal (LN)	0.017	0.252	2	8	5
Three parameter log-normal (LN3)	0.130	0.176	7	4	6
Pearson III (P3)	0.074	0.132	5	2	2
Log-Pearson III (LP3)	0.016	0.117	1	1	1
Gumbel (G)	0.170	0.198	9	7	8
Generalized extreme value (GEV)	0.125	0.185	6	5	6
Weibull (W)	0.028	0.156	4	3	2
Bulletin 17C	0.021	0.189	3	6	4

As shown in **Figure 5**, the LP3 distribution predicts much higher flood peaks for return periods longer than 10 years. Its 100-year value is more than twice as high as those from the other three curves. The LP3 curve appears to fit the 1974 data point (the largest historic event), suggesting that it has a 20-year return period. However, the plotting position for the 1974 data point in **Figure 5** was determined based on 15 events, and it does not account for the 32 year gap between the event and the systematic flow record (starting in 2006). This historic event is known as the largest event since 1974 or earlier. If its plotting position is calculated (using the Cunnane formula) based on a 45 year length (1974-2018), this data point would be plotted between the 45-year (using the Weibull formula) and 75-year (using the Cunnane formula) return periods, which is more reasonable and consistent with the other three frequency curves (P3, Weibull and Bulletin 17C). From a visual assessment, the P3 and Weibull distributions fit the data slightly better than Bulletin 17C. The Weibull distribution has found its greatest use in drought frequency analysis (Chow et al., 1988 and Haan, 1977), while the P3 distribution is more commonly used for flood frequency analysis. Accordingly, the P3 distribution has been adopted to represent the peak flow data for Camrose Creek near Camrose. The adopted P3 curve with 95% confidence limits is shown in **Figure 6**.

Note that the Bulletin 17C curve for Camrose Creek near Camrose is noticeably different from the LP3 curve as shown in **Figure 5**. The differences are due mainly to the missing years in the flow data record, which is accounted for in the Bulletin 17C but not by the standard LP3. Usually the Bulletin 17C produces results similar to the LP3 if regional skew estimation (not available in Alberta) is not used, the number of missing years is relatively small, and low outliers are not detected.

4.2 Regional Analysis

The single station analysis presented above was based on only 15 years of data. The relatively short period of record would result in significant uncertainties in flood peak estimates for longer return periods. A regional analysis was therefore performed to provide a second set of flood frequency estimates for Camrose Creek near Camrose (Site 2). The regional analysis was also used to develop estimates for the other three sites in the study area.

The regional analysis includes the WSC gauge stations summarized in **Table 5**. Their locations are shown in **Figure 7**. These gauge stations were selected in consideration of various factors including, primarily, their proximity to the Camrose Creek basin, basin size, length and period of record, basin landcover and topography, and climate condition (primarily mean annual precipitation). Another key factor is that each of the selected reference basins, except 05EB910, contains a significant portion of noneffective drainage area, although the percentage is not as large as for the Camrose Creek basin. WSC Station 05EB910 (Pointe-Aux-Pins Tributary No. 2 Near Ardrossan) has an effective area equal to its gross drainage area. This station is included in the analysis because of its relatively small drainage area (with a reasonably long record), which is expected to make the resulting regional flood frequency estimation better represent the unnamed tributary within the study area (Site 1, with a drainage area of approximately 27.8 km^2).

Table 5: Selected hydrometric stations for regional analysis

Station ID	Station Name	Gross Drainage Area (km^2)	Effective Drainage Area (km^2)	Period of Record
05EE009	Vermilion River at Vegreville	1620	367	1968-2018(1)
05FA012	Pipestone Creek near Wetaskiwin	1030	733	1972-2014, 2016-2017(2)(3)
05DF003	Blackmud Creek near Ellerslie	643	374	1974(4), 1977-2018
05FC002	Bigknife creek near Gadsby	281	194	1968-2014, 2018
05FA024	Weiller Creek near Wetaskiwin	236	90.1	1985-2014, 2016-2018(3)
05EB902	Pointe-Aux-Pins Creek near Ardrossan	106	63.2	1979-2018
05FA014	Maskwa Creek No. 1 above Bearhills Lake	79.1	61.2	1973-2014, 2016-2017(3)
05EE006	Vermilion River Tributary near Bruce	46.4	19.9	1978-2018
05EB910	Pointe-Aux-Pins Tributary No. 2 Near Ardrossan	8.1	8.1	1981-2009

1. The 1968-1986 data are from WSC Stations 05EE003 (Vermilion River near Vegreville).
2. The 1980-1990 data are from WSC Station 05FA022 (Pipestone Creek below Bigstone Creek).
3. The 2016-2017/2018 data are preliminary data from WSC.
4. The 1974 data was estimated by AENV (1981).

Note that, in this regional analysis, flood peak records for WSC Stations 05EE009 (Vermilion River at Vegreville) and 05FA012 (Pipestone Creek near Wetaskiwin) were extended using available data from adjacent discontinued stations: 05EE003 (Vermilion River near Vegreville, 1971-1986) and 05FA022 (Pipestone Creek below Bigstone Creek, 1980-1990), respectively. The 1974 flood is the largest peak flood by a large margin in many basins across central and northern Alberta. The peak discharges for this event were included for most of the selected gauge stations. For Blackmud Creek near Ellerslie (WSC

Station 05DF003), the 1974 flood peak discharge was estimated by AENV (1981) by subtracting Whitemud Creek flows measured near Ellerslie (WSC Station 05DF006) from measured flows near 23 Avenue downstream of the Whitemud and Blackmud creek confluence. All data series used for the regional analysis are presented in **Appendix B**.

The regional analysis is intended to provide an independent assessment for comparison with the single station analysis presented in Section 4.1. Therefore, the flood peak data for Camrose Creek near Camrose were not included in the regional analysis. Note that the Camrose Creek data set contains only 15 years of flood peak discharges and is much shorter than those used for the regional analysis. Moreover, the 13-year systematic record (2006-2018) for this gauge station consists mostly of dry years as suggested by the annual precipitation amounts plotted in **Figure 8**. Including the Camrose Creek data in the regional analysis would probably skew the results.

The annual peak instantaneous discharges (Q_p) for each of the selected stations listed in **Table 5** were normalized by their mean value (Q_{pm}) and plotted in **Figure 9** against their empirical return periods based on the Cunnane formula. To be consistent with the single station analysis presented in the previous section, the P3 distribution was selected to fit the data. The normalized P3 curve shown in **Figure 9** 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 gauge stations that contain the 1974 event (05EE009, 05FA012, 05DF003, 05FC002 and 05FA014) reached the minimum. As shown in the figure, the curve fit all data points reasonably well, although it represents the best fit for the data sets that include the 1974 flood peaks. As mentioned, the 1974 flood is the largest event which impacted many central and northern Alberta basins. The flood data series are highly skewed by this event, as shown in **Figure 9**. The normalized 1974 flood peak for WSC Station 05DF003 (Blackmud Creek near Ellerslie) is the highest among all regional data points. **Figure 9** also shows the 95% confidence limits for the normalized P3 curve, which are estimated based on the average length of the regional flood data series (40 years).

Figure 10 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 0.653. **Figure 10** also shows a data point representing Camrose Creek near Camrose. This data point appears to be consistent with the regional relationship but falls on the lower side due to the relatively low Camrose Creek discharge. Note that the mean peak discharge for Camrose Creek was estimated from only 15 years of data with the majority being in dry years.

Using the normalized P3 curve from **Figure 9** and the relationship of mean peak discharge versus drainage area from **Figure 10**, flood frequency estimates can be developed for ungauged basins with drainage area as the input.

Figure 11 shows a comparison of the flood frequency curves for WSC Station 05FA025 – Camrose Creek near Camrose (Site 2), derived from the regional analysis and from the single station analysis. The regional analysis results are higher than those from the single-station analysis. For return periods longer than 50 years, the differences are smaller than 20%, and the 100-year peak from the regional analysis is 18% higher.

The lower estimates from the single-station analysis may be attributed largely to the low effective-to-gross drainage area ratio for the Camrose Creek station (0.08), relative to those for the regional stations (0.23 to 0.77 excluding the smallest basin of WSC Station 05EB910, based on the data presented in **Table 5**). Moreover, as noted above, the period of WSC flow record for Camrose Creek (2006-2018) consists mostly of dry years with relatively low peak discharges. The low flows could be more subject to the regulation effect of Lyseng Reservoir, although the degree of regulation is deemed low and not expected to have significant effects on high flows (as discussed in Section 3.2). If flow naturalization could be performed for Camrose Creek, naturalized flood peaks would be higher than the gauge data, especially for the low-flow years. So, the single-station analysis likely tends to underestimate flood peaks of Camrose Creek. On the other hand, the regional gauge data are more representative of typical prairie streams under an unregulated, natural flow condition.

The regional frequency curve is below the upper 95% confidence limit for the single-station frequency curve. The slightly more conservative estimates would be more representative of the natural flow condition and be appropriate in consideration of the reducing storage capacity of the existing wetlands in the Camrose Creek basin (which tends to increase the effective drainage area), as noted by DUC (2019). Therefore, it is recommended that the flood frequency estimates from the regional analysis be adopted for the Camrose Creek study.

5 FLOOD FREQUENCY ESTIMATES

5.1 Flood Peak Discharges from Regional Analysis

Table 6 shows the mean annual peak discharges for the flood frequency estimate sites computed with the relationship shown in **Figure 10**. Flood frequency estimates for each site were then developed from the normalized P3 curve in **Figure 9**. The results are summarized in **Table 7**. Note that the estimated peak discharges for Site 3 (Camrose Creek above the CPR crossing) and Site 4 (Camrose Creek at Mirror Lake) are nearly identical as the difference in drainage area between the two sites (about 0.8%) is negligible. Further note that the estimates are more representative of the unregulated, natural flow condition because the regional analysis was based on gauge data for unregulated streams. As discussed later in Section 6, the estimated flood peaks at Sites 4 and 5 need to be adjusted as they would be affected by the CPR crossing and Mirror Lake.

Table 6: Computed mean annual peak discharges for flood frequency estimate sites

Flood Frequency Estimate Sites	Location	Gross Drainage Area (km^2)	Mean Flood Peak (m^3/s)
Site 1	Unnamed Tributary at the mouth	33.6	1.30
Site 2	WSC Station 05FA025	445	7.03
Site 3	Camrose Creek above the CPR crossing	493	7.51
Site 4	Camrose Creek at Mirror Lake	497	7.55
Site 5	Camrose Creek at the downstream end	536	7.93

Table 7: Flood frequency estimates from regional analysis

Return Period (years)	Computed Peak Instantaneous Discharge (m^3/s)														
	Site 1			Site 2			Site 3			Site 4			Site 5		
	Value	Upper 95% Limit	Lower 95% Limit	Value	Upper 95% Limit	Lower 95% Limit	Value	Upper 95% Limit	Lower 95% Limit	Value	Upper 95% Limit	Lower 95% Limit	Value	Upper 95% Limit	Lower 95% Limit
1000	12.30	14.9	10.5	66.5	80.3	57.0	71.1	85.9	60.9	71.5	86.3	61.2	75.1	90.7	64.3
750	11.7	14.1	10.0	63.3	76.4	54.2	67.7	81.7	58.0	68.0	82.1	58.3	71.5	86.3	61.2
500	10.8	13.1	9.30	58.6	70.7	50.3	62.7	75.5	53.8	63.0	75.9	54.0	66.2	79.8	56.8
350	10.1	12.2	8.69	54.7	65.9	47.0	58.5	70.4	50.2	58.8	70.8	50.5	61.8	74.4	53.0
200	8.94	10.7	7.69	48.3	58.1	41.5	51.7	62.1	44.4	51.9	62.4	44.6	54.6	65.6	46.9
100	7.53	9.02	6.48	40.7	48.7	35.0	43.5	52.1	37.5	43.7	52.4	37.6	45.9	55.0	39.6
75	6.97	8.34	6.01	37.6	45.1	32.4	40.3	48.2	34.7	40.5	48.4	34.9	42.5	50.9	36.6
50	6.14	7.33	5.30	33.2	39.6	28.6	35.5	42.4	30.6	35.7	42.6	30.8	37.5	44.7	32.3
35	5.45	6.50	4.70	29.5	35.1	25.4	31.5	37.5	27.2	31.7	37.7	27.3	33.3	39.7	28.7
20	4.37	5.20	3.76	23.6	28.1	20.3	25.3	30.0	21.7	25.4	30.2	21.9	26.7	31.7	23.0
10	3.11	3.71	2.64	16.8	20.0	14.2	17.9	21.4	15.2	18.0	21.5	15.3	19.0	22.6	16.1
5	1.94	2.39	1.54	10.5	12.9	8.31	11.2	13.8	8.89	11.3	13.9	8.93	11.8	14.6	9.38
2	0.69	1.09	0.25	3.74	5.90	1.33	4.00	6.31	1.43	4.02	6.34	1.43	4.22	6.66	1.51

5.2 Comparison with Previous Study

The flood frequency estimates for four of the study sites along the Camrose Creek study reach are compared with the results from the previous Camrose flood hazard study (AENV 1993) in **Table 8**. The peak discharges from this study are noticeably higher than those from the previous study, with the exception for the 2-year estimates. While the previous study also used a regional analysis approach, it was based on flow records shorter than those for the current study and included some different gauge stations. In addition, the previous study likely used the National Topographic System (NTS) 1 : 50,000 scale maps to delineate drainage areas for the flood frequency estimates sites, which are smaller than the current estimates, as shown in **Table 8**. Note that the 10-, 20-, 50- and 100-year flood peaks for Site 2 (WSC Station 05FA025) from AENV (1993) are also lower than the single-station analysis results presented in **Figure 6**.

Table 8: Comparison with previous flood frequency estimates

	Site 1		Site 2		Site 3		Site 5	
	AENV (1993)	This Study	AENV (1993)	This Study	AENV (1993)	This Study	AENV (1993)	This Study
Drainage Area (km^2)	*31.3*	*33.6*	*355*	*445*	*411*	*493*	*444*	*536*
Return Period (year)	**Peak Instantaneous Discharge (m^3/s)**							
100	5.11	7.53	30.8	40.7	34.3	43.5	36.3	45.9
50	3.92	6.14	23.6	33.2	26.3	35.5	27.9	37.5
20	2.74	4.37	16.5	23.6	18.4	25.3	19.5	26.7
10	1.98	3.11	12.0	16.8	13.3	17.9	14.1	19.0
5	1.40	1.94	8.46	10.47	9.43	11.2	9.99	11.8
2	0.69	0.69	4.16	3.74	4.64	4.00	4.91	4.22

5.3 Impacts of Urban Drainage

The footprint of the current Camrose city limit occupies an area of approximately 44 km^2, of which about 26 km^2 has been developed primarily for residential, industrial and commercial uses. Most runoff from this developed urban area will ultimately enter Camrose Creek between Site 2 and Site 4. The urban area accounts for about 5% of the gross drainage area of Camrose Creek, which is not higher than some of the reference basins included in the regional analysis (e.g. the Blackmud Creek basins consists of more than 10% of urban area). As such, the regional analysis results are of representative for the condition of urbanization in the Camrose Creek basin.

As discussed in Section 3, annual flood peaks of Camrose Creek are governed by snowmelt with or without rain, and high summer flows tend to be resulting from long-duration, large-volume rainfall events. In the urban area, snow tends to melt earlier, and surface water due to snowmelt or summer rainfall generally run off faster than in the rural area. Moreover, urban area flood peaks are dominated by shorter-duration, high-intensity thunderstorms, and consequently urban drainage design is typically based on design rainfall events with durations up to 24 hours. While urban development will result in increases in both runoff volume and peak discharge, stormwater management facilities (SMWFs) are used by the City of Camrose to mitigate the increase in peak runoff discharges.

According to the City of Camrose Stormwater Master Plan (Associated Engineering, 2008), SWMFs should be designed to have a maximum drawdown time of 3 days in residential areas, 4 days in industrial areas and 5 days in commercial areas. As discussed later in Section 6, the 2006-2018 WSC flow data for Camrose Creek near Camrose indicate that the time to peak for Camrose Creek is longer than 6 days. Therefore, it is highly unlikely that high runoff discharges from the Camrose urban area would coincide with flood peaks of Camrose Creek. The Stormwater Master Plan also requires that the maximum discharge from a SWMF should be limited to 0.50 $m^3/s/km^2$ (5 L/s/ha) during a 100-year rainfall storm event. If runoff from the entire urban area (26 km^2) is managed in accordance with this requirement, the total 100-year peak discharge would be 13 m^3/s, which is smaller than the 100-year Camrose Creek flood peak estimates from the regional analysis (**Table 7**). Therefore, the risk of creek flooding is governed by high flows from the upper Camrose Creek basin above the city.

Based on the discussions above, it is believed that urban drainage from the city of Camrose would have insignificant impacts on the flood frequency estimates for Camrose Creek at Sites 2, 3 and 4 presented in this study.

The unnamed tributary has a relatively small drainage area (33.6 km^2) and could respond much quicker than Camrose Creek. The time to peak for Site 1 is expected to be shorter than one or two days. As such, peak runoff from the rural portion of its basin area could coincide with urban runoff. The currently developed area within this tributary basin is approximately 2.0 km^2(approximately 6% of the total drainage area), and runoff appears to be managed with SWMFs. Based on the estimated 100-year peak discharge from the regional analysis (**Table 7**), the basin average unit-area runoff rate is 0.22 $m^3/s/km^2$. With the maximum SWMF release rate (0.50 $m^3/s/km^2$) adopted by the City, urban development of 2.0 km^2 would increase the 100-year peak discharge for Site 1 by up to 7% (0.56 m^3/s). As mentioned previously, the reference basins included in the regional analysis also have some degree of urban development; therefore, no adjustments are necessary for the Site 1 flood frequency estimates. However, a total of approximately 7.9 km^2 (about 24%) of the unnamed tributary basin is located within the city limit; if this entire area is developed in future with post-development runoff being managed based on the 0.50 $m^3/s/km^2$ maximum discharge rate, the 100-year flood peak for Site 1 could increase by about 29%. Clearly, the increase is due to the adopted SWMF release rate being much higher than the 100-year basin-average unit-area runoff rate.

6 FLOOD HYDROGRAPH ROUTING

The Terms of Reference (TOR) for this study require that flow attenuation through Mirror Lake be assessed and be incorporated into the flood frequency estimates if significant. Mirror Lake may affect flood peaks at Site 5 (Camrose Creek at the downstream end of the study area). In addition, the CPR crossing located about 650 m upstream Mirror Lake consists of a concrete box culvert (2.6 m in width and 3.0 m in height) and 11.7 m high embankment. This railway crossing may restrict inflows to Mirror Lake (Site 4) and subsequently affect flood peaks at Site 5. As such, attenuation due to the CPR culvert crossing also needs to be assessed. As described in the following sections, synthetic flood hydrographs were developed for Site 3 (Camrose Creek above the CPR crossing) and routed through the CPR culvert crossing and Mirror Lake using a level-pool routing approach, and the results were used to assess their effects on flood frequency estimates for Site 5. Note that local tributary inflows between Site 3 and Site 4 are neglected because the tributary area between the two locations is only about 3.6 km^2, or 0.8% of the Site 3 drainage area.

6.1 Synthetic Flood Hydrographs

The daily flow data for WSC Station 05FA025 shown in **Figure 3** were used to develop a dimensionless hydrograph for Camrose Creek. The recorded hydrographs for six significant flood events (with peak discharge greater than 1.5 m^3/s) were normalized by their peak discharges (Q_p) and time to peak (t_p), as shown in **Figure 12**. Except for the recession limb of the August 2011 event (a rainfall event), all normalized hydrographs could be represented reasonably well by a Gamma synthetic hydrograph with a shape factor of 1.9. The figure also shows the dimensionless hydrograph adopted by AENV (1993) for comparison. The AENV (1993) hydrograph was based on the 1974 flood hydrograph for Maskwa Creek (WSC Station 05FA014). As show in **Figure 12**, it does not fit the Camrose Creek flow data as well as the selected Gamma hydrograph.

The peak discharges for the selected events vary from 1.77 to 6.51 m^3/s, and the time to peak ranges from 6 to 18 days. The observed time to peak for the Camrose Creek basin appears relatively long in comparison with adjacent basins. For example, the average time to peak for major flood events in the larger Pipestone Creek basin is about 7 days. The longer time to peak for Camrose Creek is likely due to the significant storage capacity in the basin, which would be reduced in wet years when larger flood events tend to occur. The time base of the dimensionless hydrographs shown in **Figure 12** is about 4 times the time to peak. For a time to peak of 6 days, the corresponding time base is 24 days, which appears reasonable for Camrose Creek and is consistent with the value (25 days) adopted by AENV (1993). Therefore, the 6-day time to peak and 25-day time base (4.17 times the time to peak) were used to develop synthetic flood hydrograph for Camrose Creek above the CPR crossing (Site 3). The resultant synthetic flood hydrographs for various return periods from 2 to 1000 years are shown in **Figure 13**, with peak discharges corresponding to the values presented in **Table 7**.

6.2 Storage Volumes and Discharge Rating Curves

In addition to inflow flood hydrographs, required input data for the level-pool routing include an elevation – volume relationship representing the lake or storage area and stage – discharge rating curve representing the outflow structure. Similar routing analyses were performed as part of the 1994 Camrose flood risk mapping study (IDE, 1994).

The elevation – volume relationship for Mirror Lake provided by AENV for the 1994 study were used. The relationship is shown in **Figure 14**. IDE (1994) also provides a stage-discharge rating curve for the Mirror Lake spillway as shown in **Figure 14**. The rating curve was likely developed by assuming that critical flow depth would occur at the spillway. For this study, the spillway rating curve was computed using HEC-RAS based on the spillway crest geometry from the as-built drawings provided by the City of Camrose, dam crest profile from the 2018 LiDAR survey data, and surveyed cross sections upstream and downstream of the spillway. Note that, according to the City's as-built drawings, the design top elevation for the Mirror Lake dam is El. 729.84 m; however, the LiDAR data shows that a section of the dam crest east of the spillway would be overtopped at El. 729.62 m, while a west section would be overtopped at El. 729.78 m. Overflows from these two sections were calculated in HEC-RAS using a broad-crested weir equation. The new rating curve is compared with the IDE (1994) rating curve in **Figure 14**. The two curves are not significantly different. The new curve computed for the current study has been adopted as it is based on a more detailed analysis covering higher flows.

There is no defined reservoir or storage area upstream of the CPR crossing; but storage is available in the creek channel and floodplains. As the area upstream of the CPR crossing is relatively flat, a level-pool reservoir routing approach was undertaken in this hydrology assessment to estimate flow attenuation and downstream flood peak discharges.

Figure 15 shows the elevation – volume relationship used by IDE (1994) to represent the storage capacity upstream of the CPR crossing, which was based on information provided by AENV. A new curve was developed for the current study using the 2018 LiDAR survey data and AltaLIS LiDAR15 DEM (which covers a larger area). As shown in **Figure 15**, below El. 733.0 m, the new storage volume estimates are smaller than those from the IDE (1994) relationship. The decreased storage volume may be related to changes in topography (e.g. due to various reasons including urban development). Above El. 733.0 m, the estimated storage volumes from the LiDAR data are greater. As the LiDAR data are more representative of the current topographic condition and more accurate, the new curve has been adopted in this study. The full plot of the curve extending to the top of the railway embankment (El. 740.0 m) is shown in the lower half of **Figure 15**.

A stage-discharge rating curve for the CPR culvert was computed with the hydraulic model developed in HEC-RAS for this study. The curve is shown in **Figure 16**, which is consistent with the relationship developed by AENV for the IDE 1994 study but covers higher flows.

6.3 Routing Analysis and Results

The 13 synthetic flood hydrographs for Site 3 shown in **Figure 13** were routed through the CPR crossing and then Mirror Lake. For the CPR crossing, the starting water level was assumed to be the upstream invert elevation of the culvert (El. 728.30 m). The staring water level for Mirror Lake was assumed to be the spillway crest elevation, which is El. 728.17 m based on the as-built drawings provided by the City of Camrose.

Table 9 shows a summary of routed peak discharges downstream of the CPR culvert and Mirror Lake. For the floods with return period up to 100 years, flood peak attenuation through the CPR crossing is insignificant, with a 6% reduction for the 100-year flood and smaller reductions for shorter return periods. The attenuation is more significant for floods with longer return periods with peak discharge reductions from 10% for the 200-year flood to 25% for the 1000-year flood. On the other hand, Mirror Lake did not provide any additional attenuation. The maximum outflow discharges from Mirror Lake were the same as the discharges from the CPR culvert. The significance of flood attenuation is generally consistent with the assessment by IDE (1994) except that the 1994 study includes only floods of return period up to 100 years, with peak discharges smaller than those for the current study (**Table 8**).

For all the flood hydrographs assessed, the CPR embankment (top elevation 740.0 m) was not overtopped, while the Mirror Lake dam (minimum crest elevation 729.62 m based on the 2018 LiDAR data) was overtopped by the floods with return period of 100 years and longer. Note that the dam would not be overtopped by the 100-year flood if the minimum elevation of its crest were at the design elevation shown in the as-built drawings (El. 729.84 m). The computed water levels are not presented in this report as they must be confirmed through the hydraulic modelling task of this study.

Table 9: Summary of routing analysis results

Return Period (years)	Peak Discharge above CPR (Site 3) (m³/s)	Downstream of CPR		Downstream of Mirror Lake	
		Peak Discharge (m³/s)	Change	Peak Discharge (m³/s)	Change
1000	71.1	53.2	-25%	53.2	0%
750	67.7	52.1	-23%	52.1	0%
500	62.7	50.4	-20%	50.4	0%
350	58.5	48.9	-16%	48.9	0%
200	51.7	46.4	-10%	46.4	0%
100	43.5	40.9	-6%	40.9	0%
75	40.3	38.7	-4%	38.7	0%
50	35.5	34.7	-2%	34.7	0%
35	31.5	31.1	-1%	31.1	0%
20	25.3	25.2	0%	25.2	0%
10	17.9	17.9	0%	17.9	0%
5	11.2	11.2	0%	11.2	0%
2	4.00	4.00	0%	4.00	0%

7 ADOPTED FLOOD FREQUENCY ESTIMATES

From the routing analysis results presented in **Table 9**, the differences between the peak discharges upstream and downstream of the CPR crossing were taken and used to adjust flood frequency estimates for Sites 4 and 5 shown in **Table 7**, to account for flow attenuation due to the CPR culvert crossing. The adopted flood frequency estimates including the adjusted values are presented in **Table 10**.

Table 10: Adopted flood frequency estimates

Return Period (years)	Peak Instantaneous Discharge (m^3/s)														
	Site 1			Site 2			Site 3			Site 4			Site 5		
	Value	Upper 95% Limit	Lower 95% Limit	Value	Upper 95% Limit	Lower 95% Limit	Value	Upper 95% Limit	Lower 95% Limit	Value	Upper 95% Limit	Lower 95% Limit	Value	Upper 95% Limit	Lower 95% Limit
1000	12.3	14.9	10.5	66.5	80.3	57.0	71.1	85.9	60.9	53.6	68.4	43.3	57.2	72.8	46.4
750	11.7	14.1	10.0	63.3	76.4	54.2	67.7	81.7	58.0	52.4	66.5	42.7	55.9	70.7	45.6
500	10.8	13.1	9.30	58.6	70.7	50.3	62.7	75.5	53.8	50.7	63.6	41.7	53.9	67.5	44.5
350	10.1	12.2	8.69	54.7	65.9	47.0	58.5	70.4	50.2	49.2	61.2	40.9	52.2	64.8	43.4
200	8.94	10.7	7.69	48.3	58.1	41.5	51.7	62.1	44.4	46.6	57.1	39.3	49.3	60.3	41.6
100	7.53	9.02	6.48	40.7	48.7	35.0	43.5	52.1	37.5	41.1	49.8	35.0	43.3	52.4	37.0
75	6.97	8.34	6.01	37.6	45.1	32.4	40.3	48.2	34.7	38.9	46.8	33.3	40.9	49.3	35.0
50	6.14	7.33	5.30	33.2	39.6	28.6	35.5	42.4	30.6	34.9	41.8	30.0	36.7	43.9	31.5
35	5.45	6.50	4.70	29.5	35.1	25.4	31.5	37.5	27.2	31.3	37.3	26.9	32.9	39.3	28.3
20	4.37	5.20	3.76	23.6	28.1	20.3	25.3	30	21.7	25.3	30.1	21.8	26.6	31.6	22.9
10	3.11	3.71	2.64	16.8	20.0	14.2	17.9	21.4	15.2	18.0	21.5	15.3	19.0	22.6	16.1
5	1.94	2.39	1.54	10.5	12.9	8.31	11.2	13.8	8.89	11.3	13.9	8.93	11.8	14.6	9.40
2	0.69	1.09	0.25	3.74	5.90	1.33	4.00	6.31	1.43	4.02	6.34	1.43	4.22	6.66	1.51

8 CLIMATE CHANGE COMMENTARY

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.

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%.

The peak flows on Camrose Creek tend to be dominated by snowmelt events. Over the gauged period of 12 years, all except one of the annual peak events occurred in the spring due to snow melt with or without rain. Known historic flood events including the 1974 event also occurred in the spring. This hydrological regime appears typical for prairie basins. If changes in temperature and precipitation follow the trends described above, one would expect to see the following changes in the Camrose Creek basin:

1) Increase in winter precipitation will be offset by increased sublimation due to warmer winter temperatures. This will affect the snowpack available for runoff.

2) More winter precipitation as rain will reduce snow accumulation and spring runoff volumes.

3) Snowmelt runoff in spring would occur earlier and complete in a shorter time period due to warmer spring temperature than presently. At the same time, more temperature variability may increase the melt rate and subsequently runoff peaks.

4) The change in storage capacity, which likely is the most important parameter in the determination of runoff volumes, is somewhat of an enigma. The amount of storage available during spring melt is a function of summer precipitation and evaporation/evapotranspiration. Increased summer precipitation will be offset by increased evaporation due to warmer temperatures. Climate change experts indicate that there will generally be a northward shift in the forest-grassland boundary and that regions like that in which the Camrose Creek basin is located will become drier over time. This will certainly increase the available storage and reduce flood volumes and corresponding flood peaks.

Ultimately, if the increases in precipitation and spring temperatures are large enough to offset the increased sublimation, evaporation, and storage volumes due to warmer temperatures, the spring flood peaks would increase; otherwise, they would have no change or decrease.

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 use 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.

Dumanski et al. (2015) presents some research results on hydrological regime changes of the Smith Creek Research Basin (SCRB), which is located approximately 60 km southeast of Yorkton, Saskatchewan. This basin would provide a good analog to the Camrose Creek basin as they have a similar basin area, ratio of effective drainage area or wetland area versus gross drainage area, land use condition, and other physiographic and hydrological conditions. Moreover, the basin has also undergone similar changes in land use, including reduction in depression/wetland storage due to increased anthropogenic drainage enhancements. The following notes are made in the SCRB study: "*Annual streamflow volume and runoff ratio have increased 14-fold and 12-fold, respectively, since 1975, with dramatically increasing contributions from rainfall and mixed runoff regimes. Snowmelt runoff has declined from 86% in the 1970s to 47% recently while rainfall runoff has increased from 7% to 34% of discharge. Peak discharge has tripled since 1975, with a major shift in 1994. Recent flood volumes in SCRB have been abnormally large, and high flows in June 2012 and flooding in June 2014 were caused solely by rainfall, something never before recorded at the basin. Changes to the observed character of precipitation, runoff generation mechanisms and depressional storage are substantial, but it is unlikely that any single change can explain the dramatic shift in SCRB surface hydrology.*" While similar climate changes could occur in the Camrose Creek basin, as indicated by the SCRB study, the hydrological regime could be impacted by land use changes and increases in drainage, as much as, or more than by climate change. As noted by DUC (2019), many wetlands in the Camrose Creek have been drained or filled, which is expected to significantly increase the effective drainage area of the basin, and consequently increase creek flows. Similar to the SCRB, it is critical to consider the influence that land use change, including drainage, exerts on the Camrose Creek flood risk under a changing climate through further process-based hydrological studies.

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 risks along Camrose Creek.

9 REFERENCES

AENV (1981). Blackmud Creek Frequency Analysis: Saunders Lake to Highway 2. Hydrology Report H10-5D. Hydrology Branch, Alberta Environment, March 1981.

AENV (1993). Flood Frequency Analysis Camrose Floodplain Study. Water Resources Management Services & Monitoring Division Hydrology Branch, Alberta Environment, April 1993.

AENV (2006). Miquelon Lake Water Quality Monitoring Report. Monitoring and Evaluation Branch, Environmental Assurance Division, Alberta Environment, February 2006.

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

Associated Engineering (2008). The City of Camrose – Camrose Stormwater Master Plan Update. January 2008.

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

Chow, V.T., Maidment, D.R. and Mays, L.W. (1988). Applied Hydrology. McGraw-Hill Series in Water Resources and Environmental Engineering, McGraw-Hill Book Co., 1988.

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.

DUC (2019). Camrose Creek Research Project – Understanding the Link between Wetlands and Flooding. Presentation by Ducks Unlimited Canada, Camrose, 13 May 2019.

Dumanski, S., Pomeroy, J. W. and Westbrook, C. J. (2015). Hydrological regime changes in a Canadian Prairie basin. *Hydrological Processes, 29(18), 3893-3904.*

GoA (2014). Approved Water Management Plan for the Battle River Basin. The Government of Alberta, July 2014.

Haan, C.T. (1977). Statistical Methods in Hydrology. The Iowan State University Press, 1977.

I.D. Engineering Company Limited (IDE) (1994). Camrose Flood Risk Mapping Study for Canada-Alberta Flood Damage Reduction Program, February 1994.

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

NHC (2014). Nisku Flood Hazard Study Blackmud Creek. Northwest Hydraulic Consultants Ltd., March 2014.

The Atlas of Alberta Lakes. Accessed 7 August 2019, <http://albertalakes.ualberta.ca/>

UMA (1974). Report on Lyseng Reservoir for Imperial Oil Ltd. Underwood McLellan & Associated Ltd., August 1974.

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

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

10 CLOSURE

This document has been prepared by Northwest Hydraulic Consultants Ltd. (NHC) in accordance with generally accepted engineering practices, for the benefit of Alberta Environment and Parks for specific application to the Camrose Flood Hazard Study in Alberta. The information and data contained herein represent the best professional judgment of NHC, based on the knowledge and information available to NHC at the time of preparation.

Except as required by law, this document and the information and data contained herein are to be treated as confidential and may be used and relied upon only by Alberta Environment and Parks, its officers and employees. NHC 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.

Sincerely,

Northwest Hydraulic Consultants Ltd.

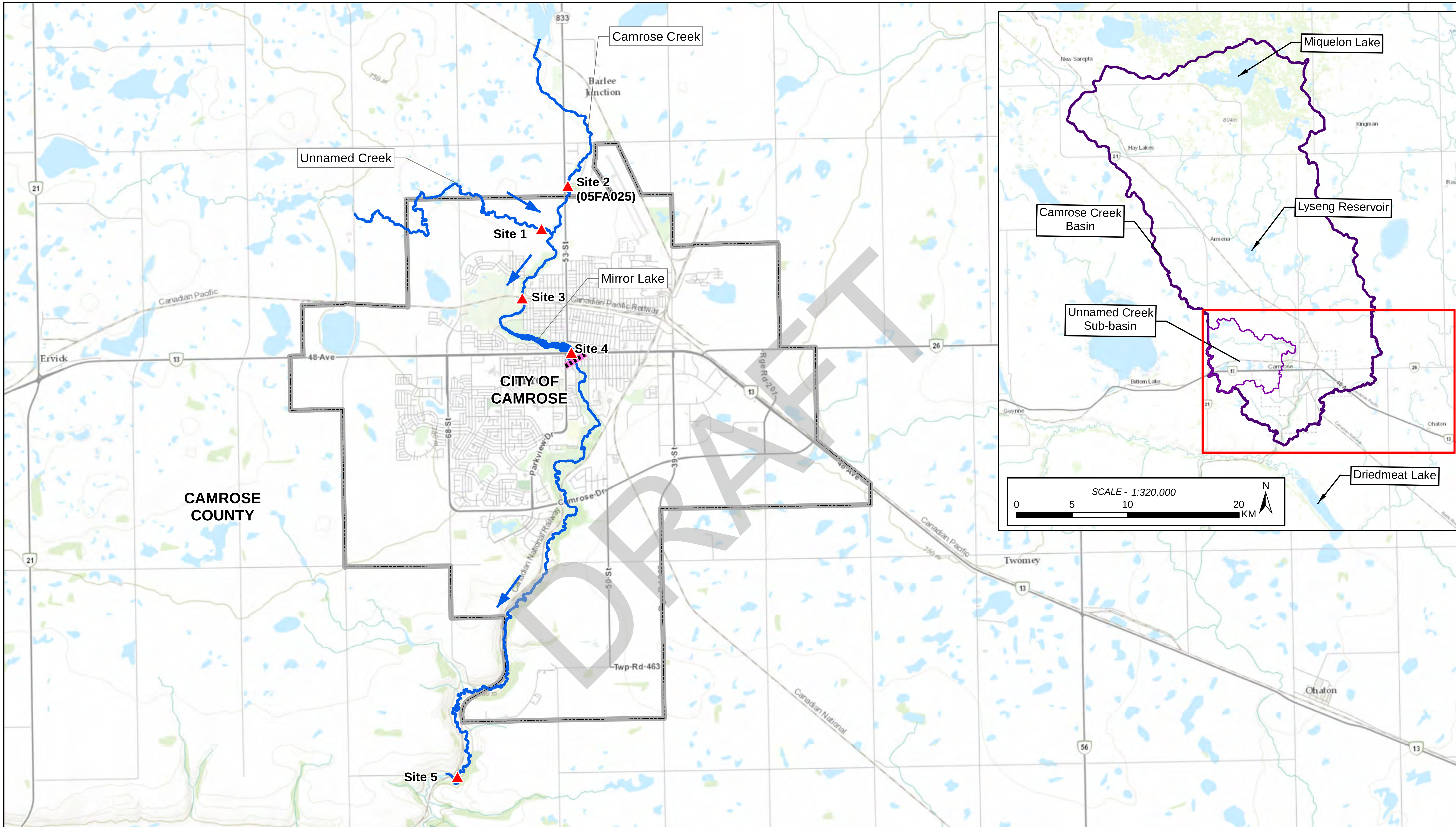
Prepared by:

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

Reviewed by:

Gary Van Der Vinne, MSc, PEng
Principal

Figures



FLOOD FREQUENCY ESTIMATE LOCATION

STUDY REACH

MIRROR LAKE DAM

MUNICIPAL BOUNDARY

Alberta

nhc
northwest hydraulic consultants

DATA SOURCES: NRCan, Esri World Topographic Basemap

SCALE - 1:55,000
0 0.5 1 2 KM
N

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

Job: 1004662

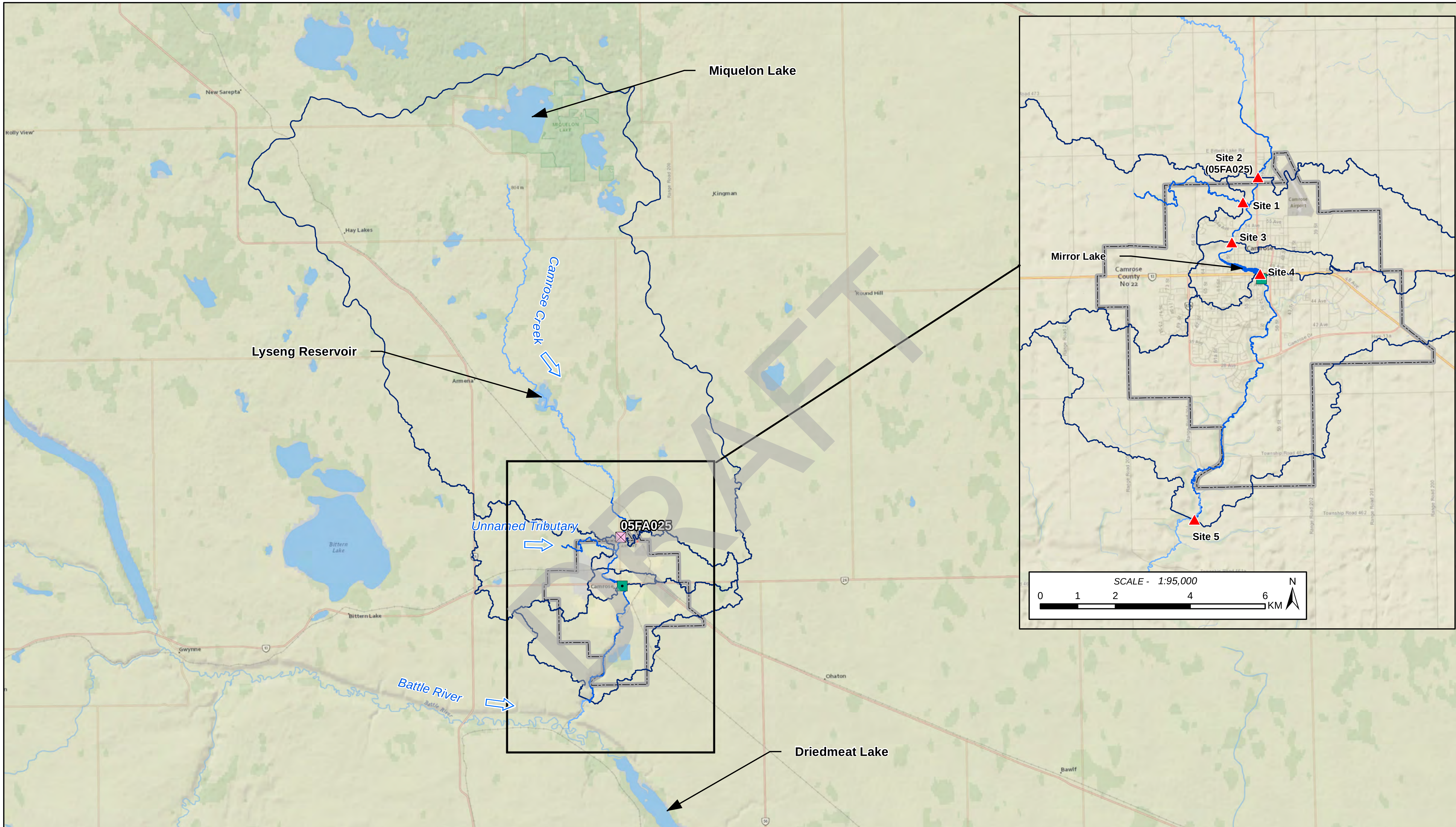
Date: 12-FEB-2020

CAMROSE
FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

FLOOD HAZARD STUDY AREA

FIGURE 1

Classification: Public



Alberta

nhc northwest hydraulic consultants

FLOOD FREQUENCY ESTIMATE LOCATION
MIRROR LAKE DAM
WSC GAUGE STATION
STUDY REACH
CAMROSE CREEK
CITY OF CAMROSE
CAMROSE CREEK BASIN

BASEMAP: National Geographic World Basemap

SCALE - 1:200,000
0 1 2 4 6 8 KM
N

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

Job: 1004662
Date: 12-FEB-2020

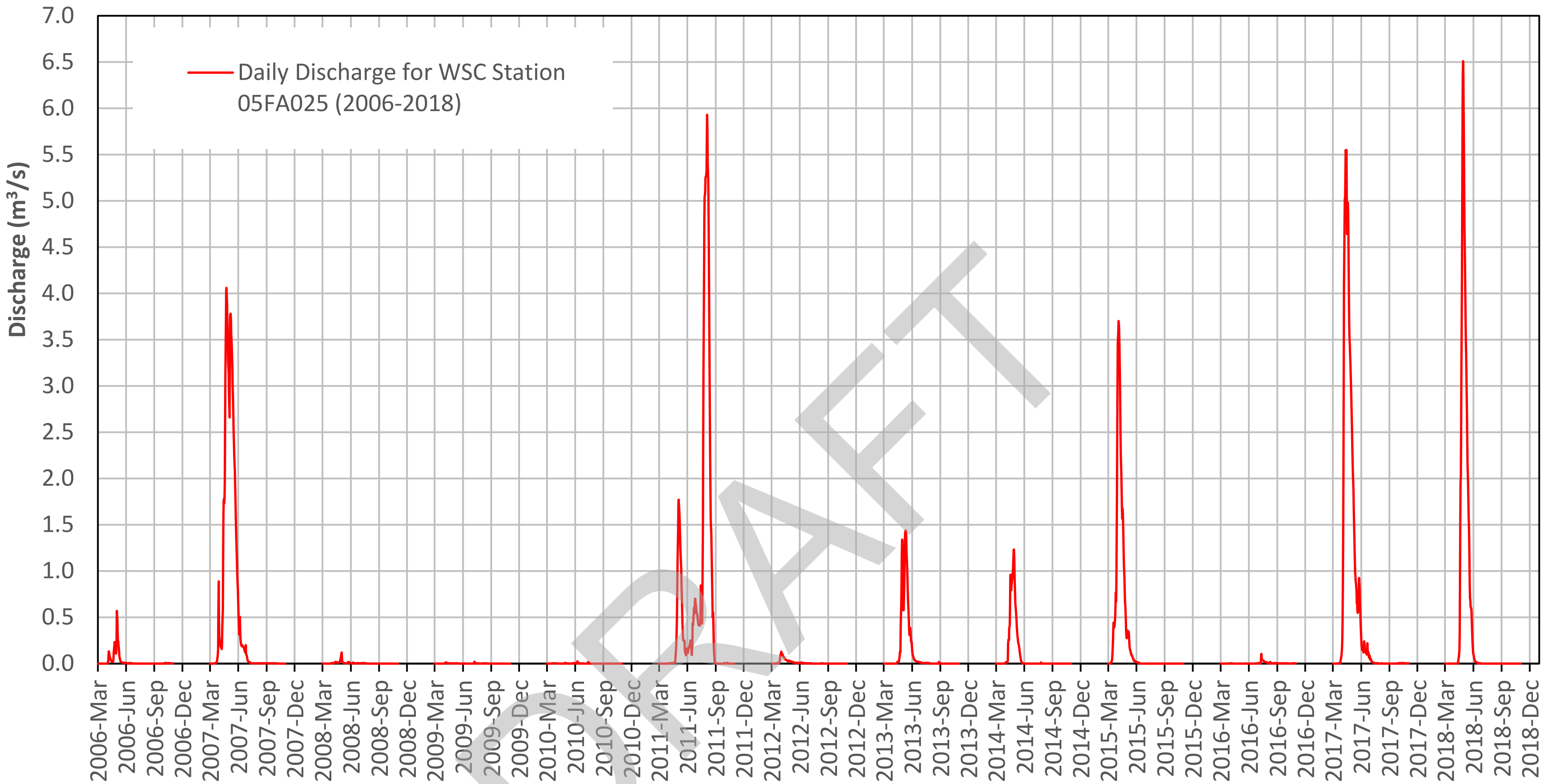
CAMROSE
FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

BASIN OVERVIEW

FIGURE 2

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS\1004662_OWH_Fig_2_BasinOverview.mxd

Classification: Public



Alberta

nhc northwest hydraulic consultants

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

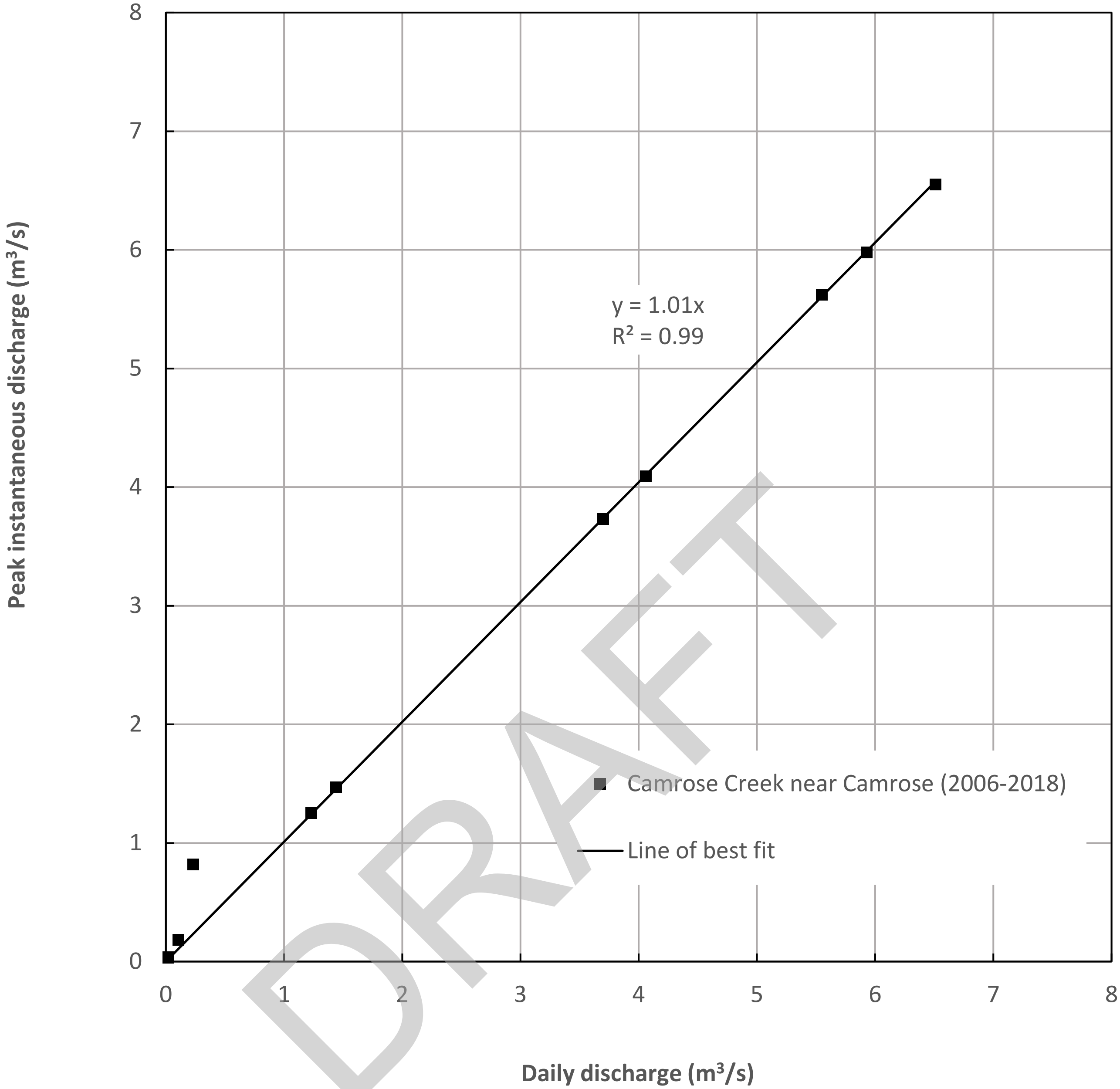
Job: 1004662

Date: Aug-2019

CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

RECORDED DAILY FLOWS FOR CAMROSE CREEK NEAR CAMROSE

FIGURE 3



Alberta

nhc
northwest hydraulic consultants

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

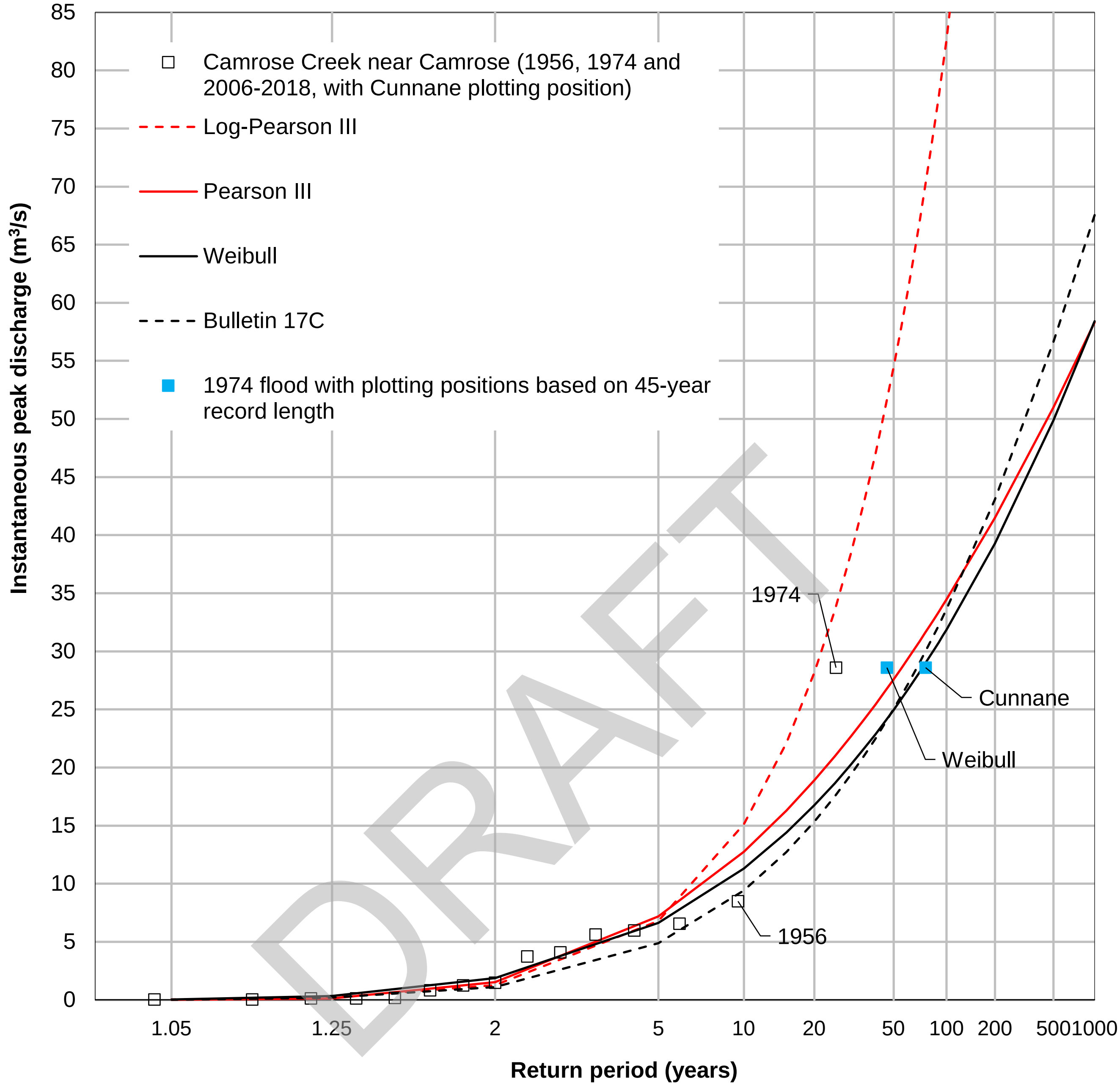
Job: 1004662

Date: Aug-2019

CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

CAMROSE CREEK NEAR CAMROSE
MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE RATIO

FIGURE 4



SCALE – AS SHOWN

Coordinate System:
Units: As Shown

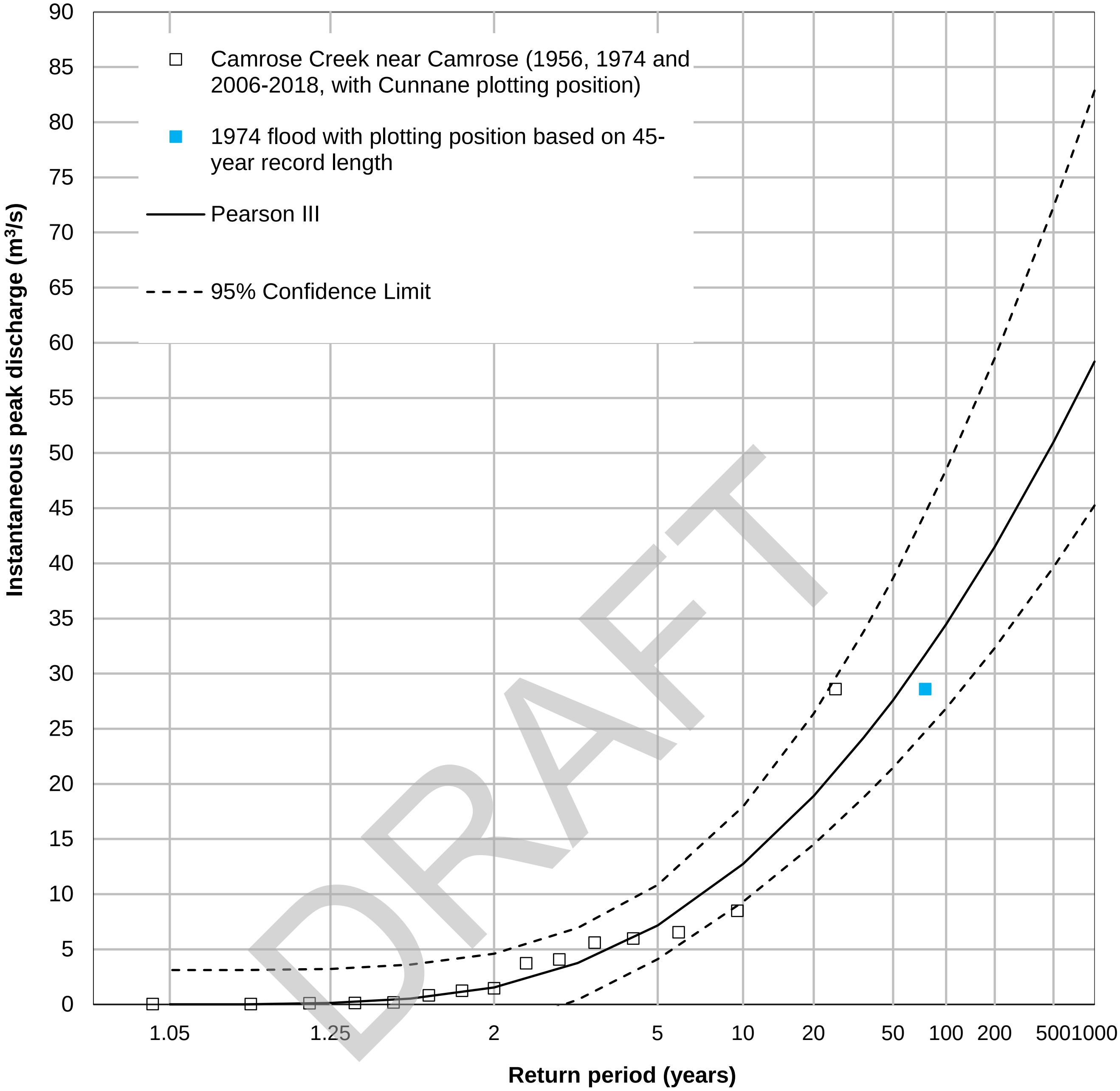
Job: 1004662 | *Date: Aug-2019*

CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

COMPARISON OF FLOOD FREQUENCY CURVES FOR CAMROSE CREEK NEAR CAMROSE

FIGURE 5

Classification: Public



SCALE – AS SHOWN

Coordinate System:
Units: As Shown

Job: 1004662

Date: Aug-2019

CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

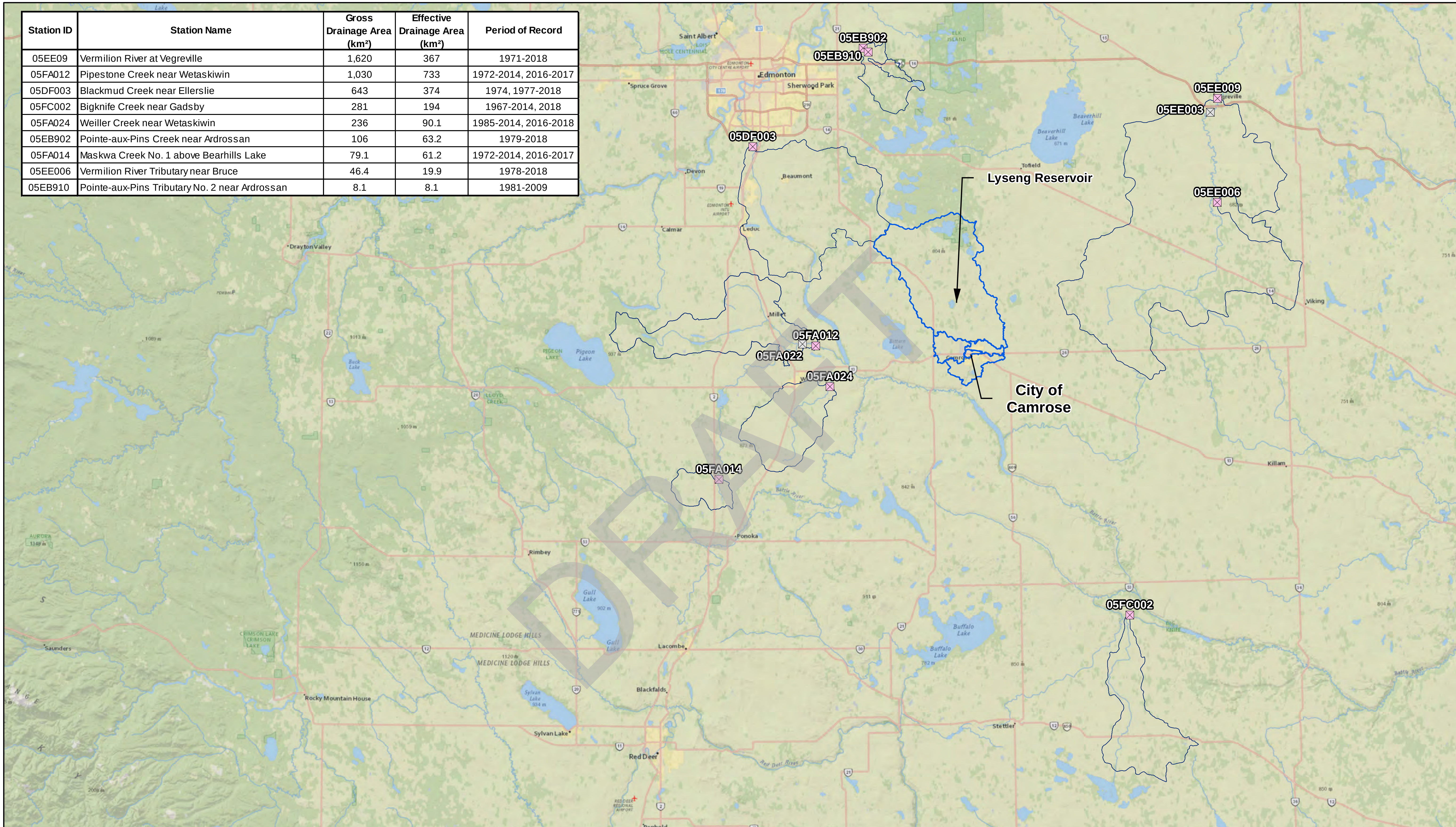
PEARSON III FLOOD FREQUENCY CURVES
FOR CAMROSE CREEK NEAR CAMROSE

FIGURE 6

Alberta

nhc
northwest hydraulic consultants

Station ID	Station Name	Gross Drainage Area (km²)	Effective Drainage Area (km²)	Period of Record
05EE09	Vermilion River at Vegreville	1,620	367	1971-2018
05FA012	Pipestone Creek near Wetaskiwin	1,030	733	1972-2014, 2016-2017
05DF003	Blackmud Creek near Ellerslie	643	374	1974, 1977-2018
05FC002	Bigknife Creek near Gadsby	281	194	1967-2014, 2018
05FA024	Weiller Creek near Wetaskiwin	236	90.1	1985-2014, 2016-2018
05EB902	Pointe-aux-Pins Creek near Ardrossan	106	63.2	1979-2018
05FA014	Maskwa Creek No. 1 above Bearhills Lake	79.1	61.2	1972-2014, 2016-2017
05EE006	Vermilion River Tributary near Bruce	46.4	19.9	1978-2018
05EB910	Pointe-aux-Pins Tributary No. 2 near Ardrossan	8.1	8.1	1981-2009



REFERENCE GAUGE BASIN

CAMROSE CREEK BASIN

WSC GAUGE STATION

USED FOR REGIONAL ANALYSIS

USED TO IMPUTE MISSING VALUES

BASEMAP: Esri National Geographic World Map.

SCALE - 1:750,000

0 5 10 20 30 KM

N

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

Job: 1004662 | *Date: 12-FEB-2020*

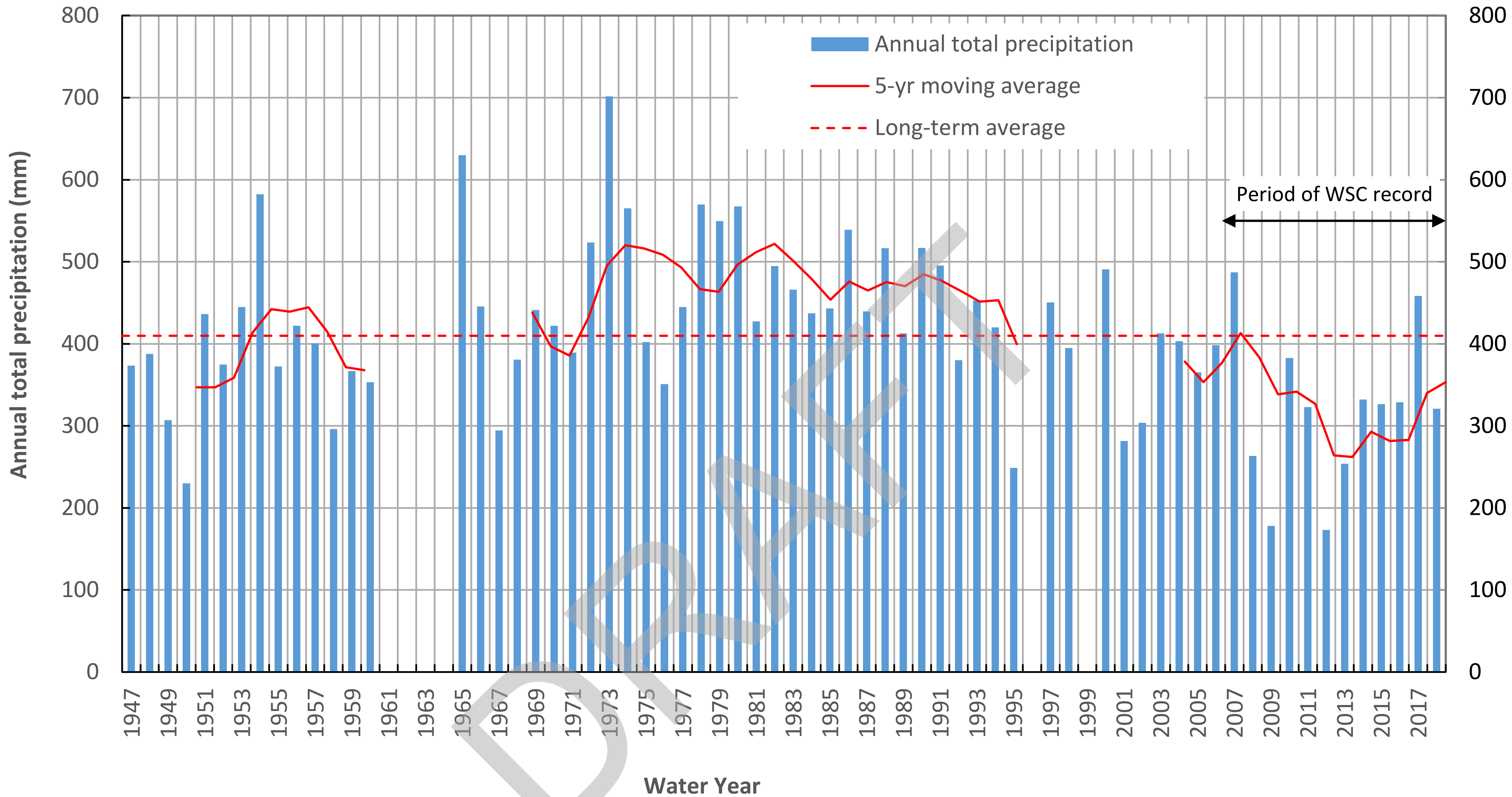
CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

WSC GAUGE STATIONS FOR REGIONAL ANALYSIS

FIGURE 7

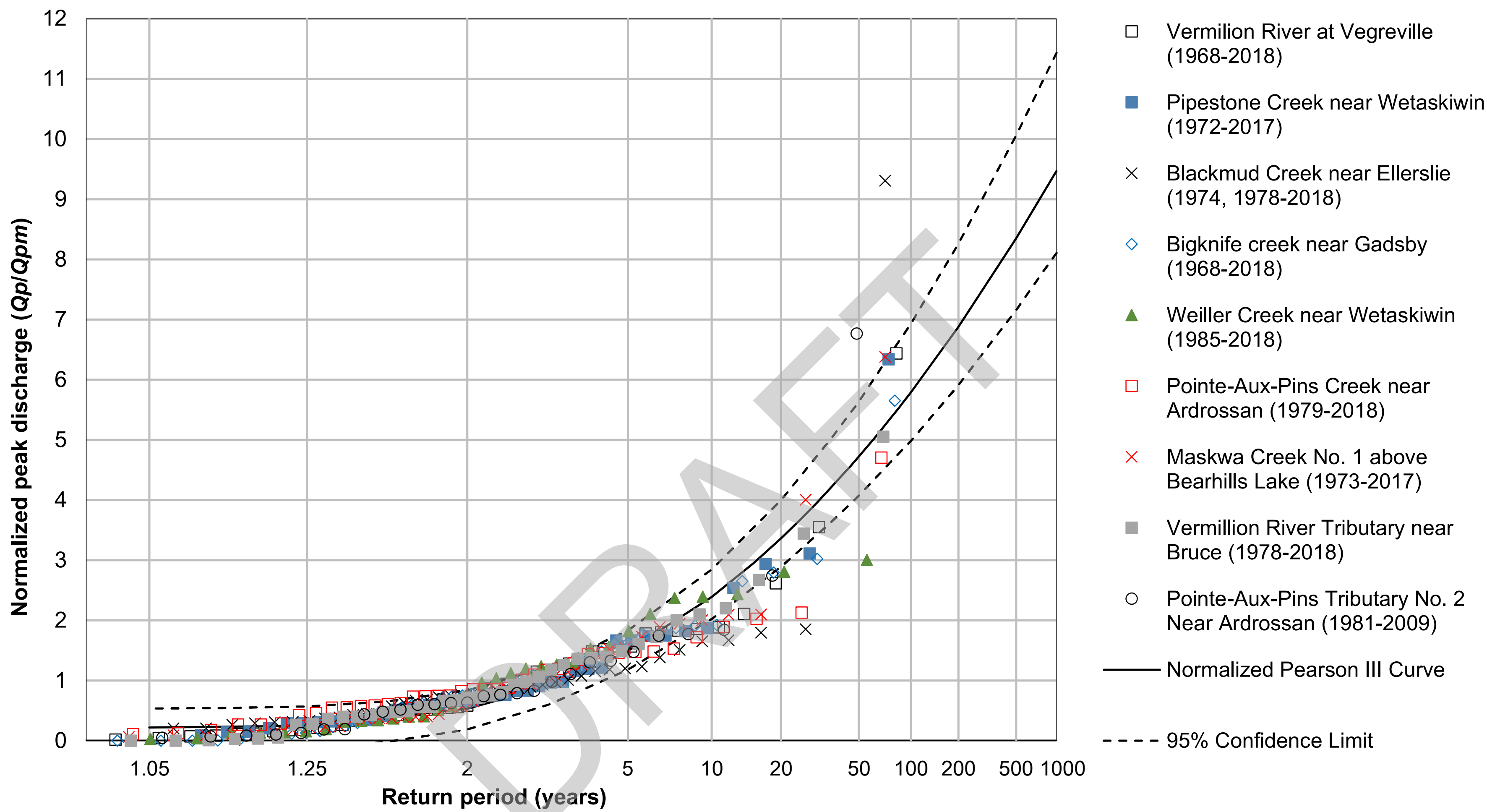
MSN, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS\1004662_OWH_Fig_7_WSC_Gauge_Stations.mxd

Classification: Public



Notes: 1. Based on daily precipitation data for the Camrose climate station (Climate ID 3011240).
2. Water year is defined as the period from October 1 to September 30.

Alberta	SCALE – AS SHOWN	*CAMROSE FLOOD HAZARD STUDY* *OPEN WATER HYDROLOGY ASSESSMENT* *ANNUAL PRECIPITATION FOR CAMROSE CLIMATE STATION*
nhc northwest hydraulic consultants	Coordinate System: Units: As Shown	
	Job: 1004662 | *Date: Aug-2019*	*FIGURE 8*



Alberta

nhc northwest hydraulic consultants

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

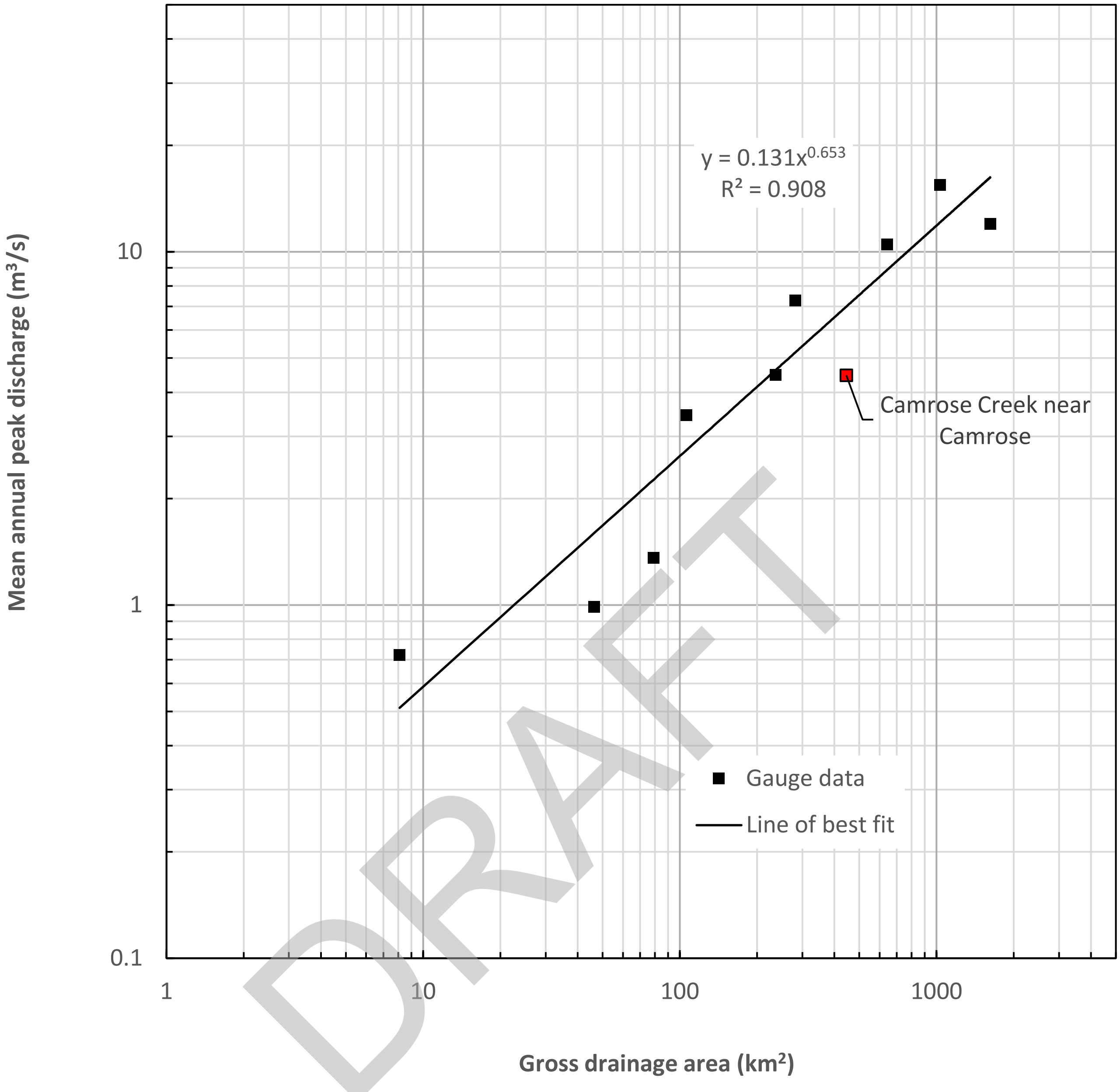
Job: 1004662

Date: Aug-2019

CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

REGIONAL ANALYSIS - FREQUENCY DISTRIBUTION FOR NORMALIZED FLOOD PEAK DISCHARGES

FIGURE 9



Alberta

nhc northwest hydraulic consultants

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

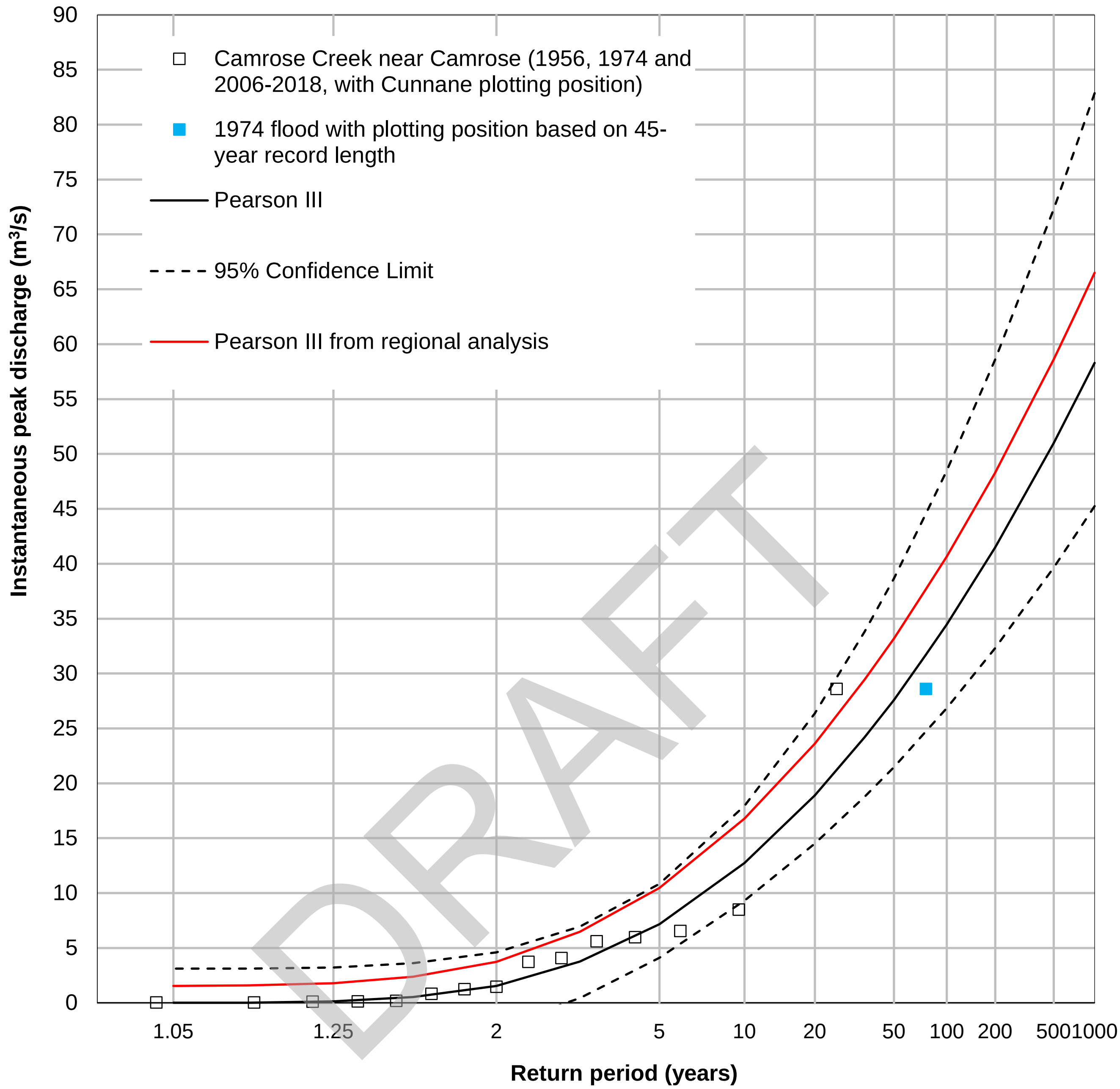
Job: 1004662

Date: Aug-2019

CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

REGIONAL ANALYSIS – RELATIONSHIP BETWEEN MEAN ANNUAL PEAK DISCHARGE AND DRAINAGE AREA

FIGURE 10



SCALE – AS SHOWN

Coordinate System:
Units: As Shown

Job: 1004662

Date: Aug-2019

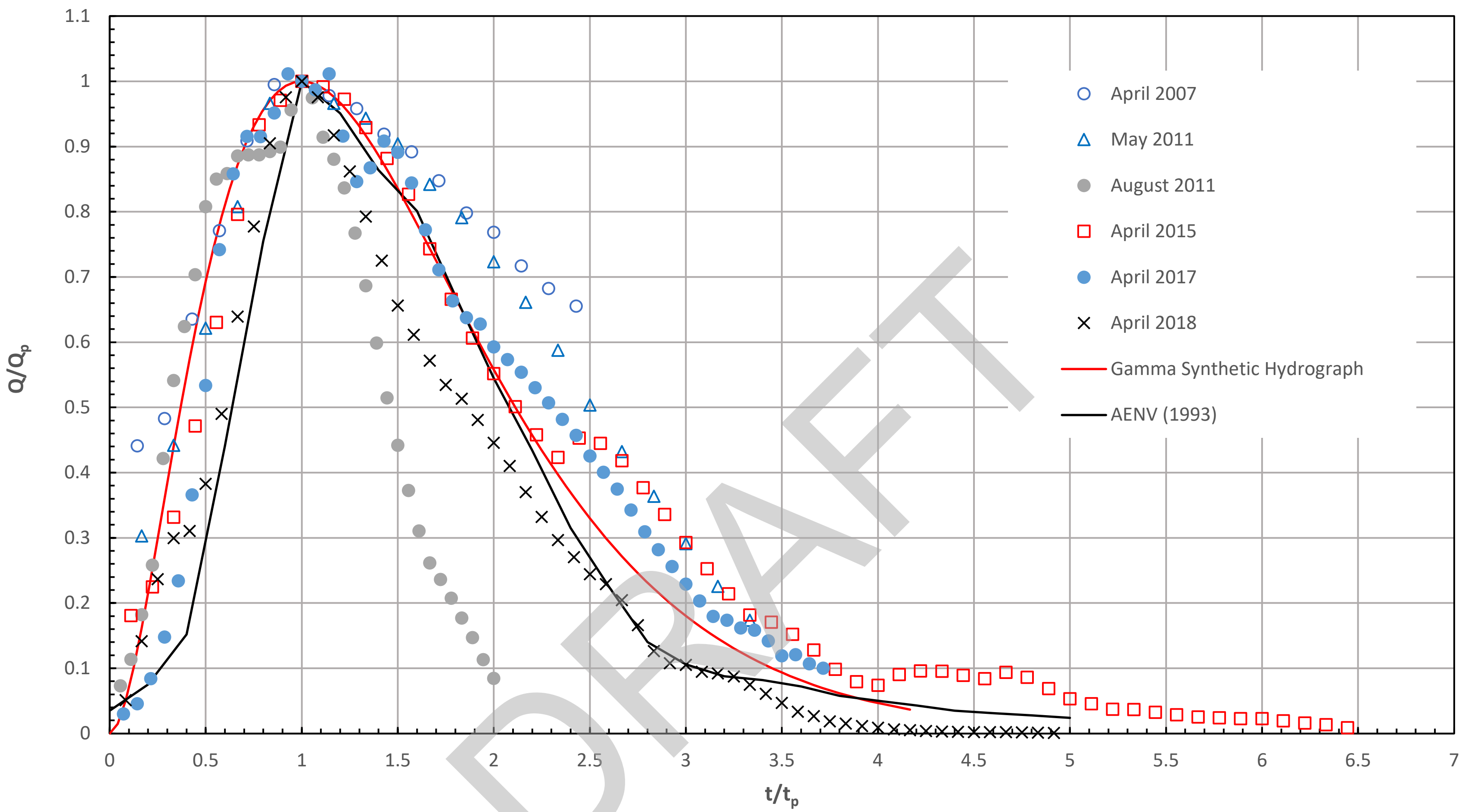
CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

COMPARISON OF REGIONAL AND SINGLE-STATION ANALYSES FOR CAMROSE CREEK NEAR CAMROSE

FIGURE 11

Alberta

nhc northwest hydraulic consultants



Alberta

nhc northwest hydraulic consultants

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

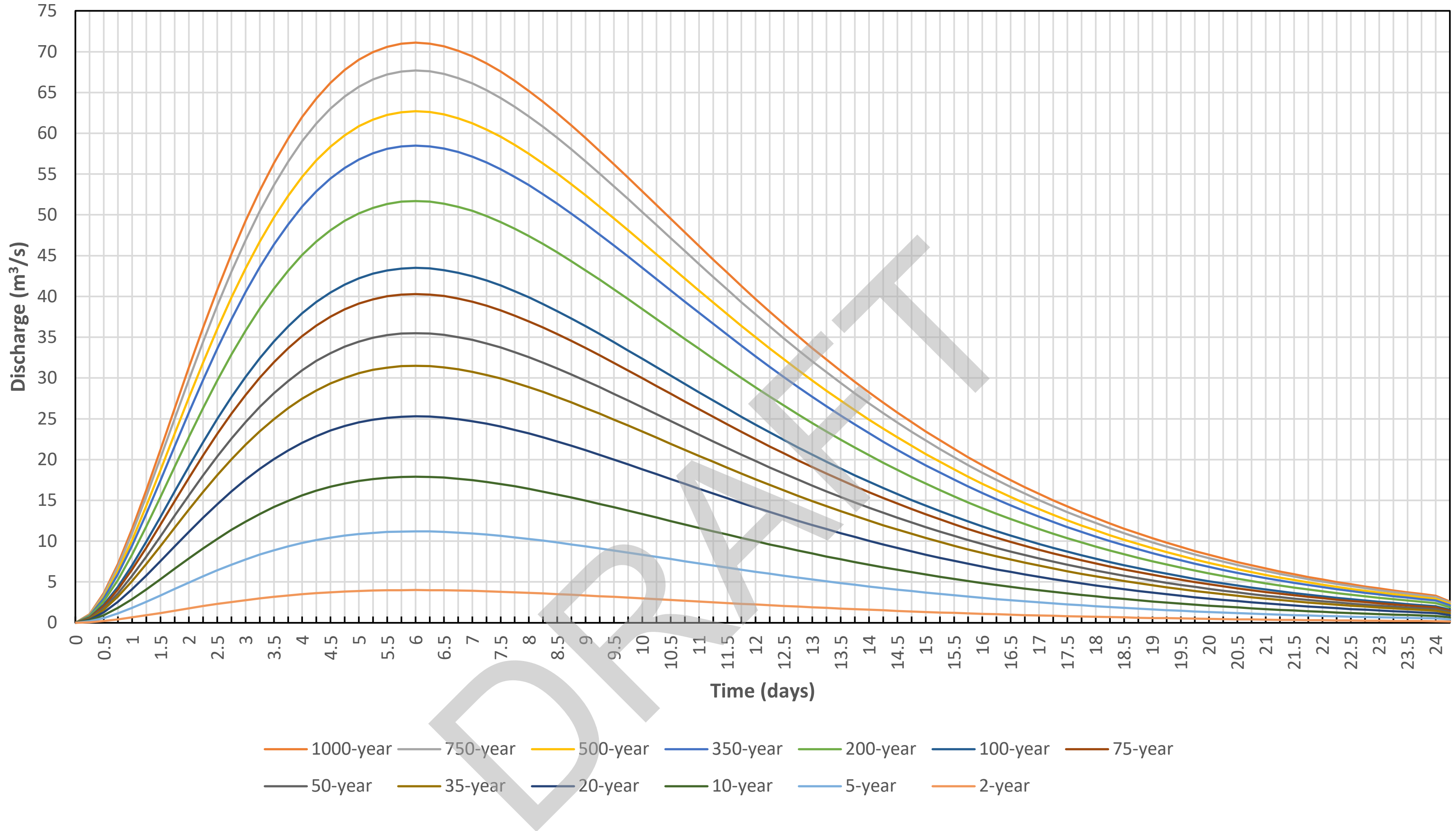
Job: 1004662

Date: Aug-2019

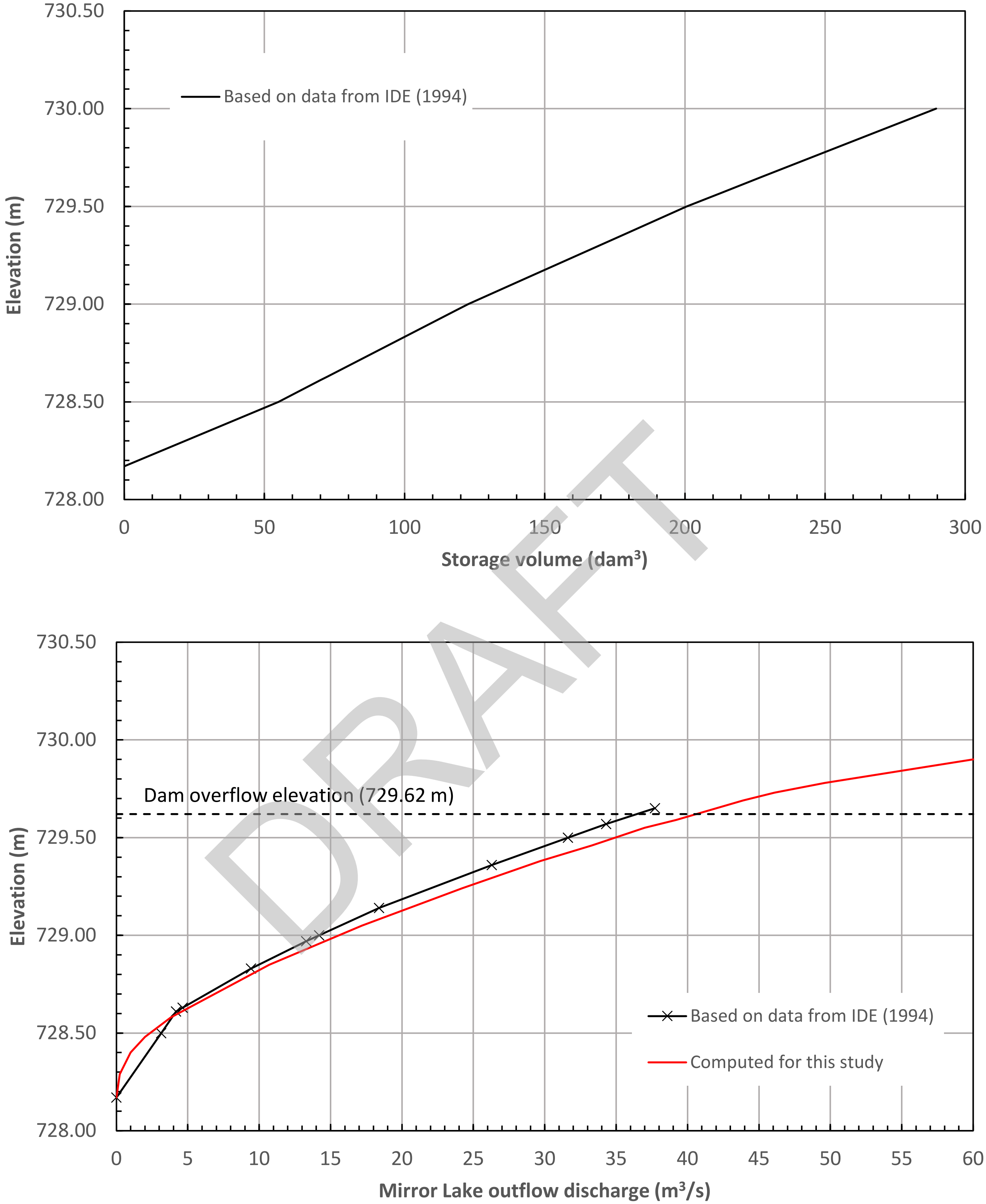
CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

DIMENSIONLESS HYDROGRAPHS FOR CAMROSE CREEK

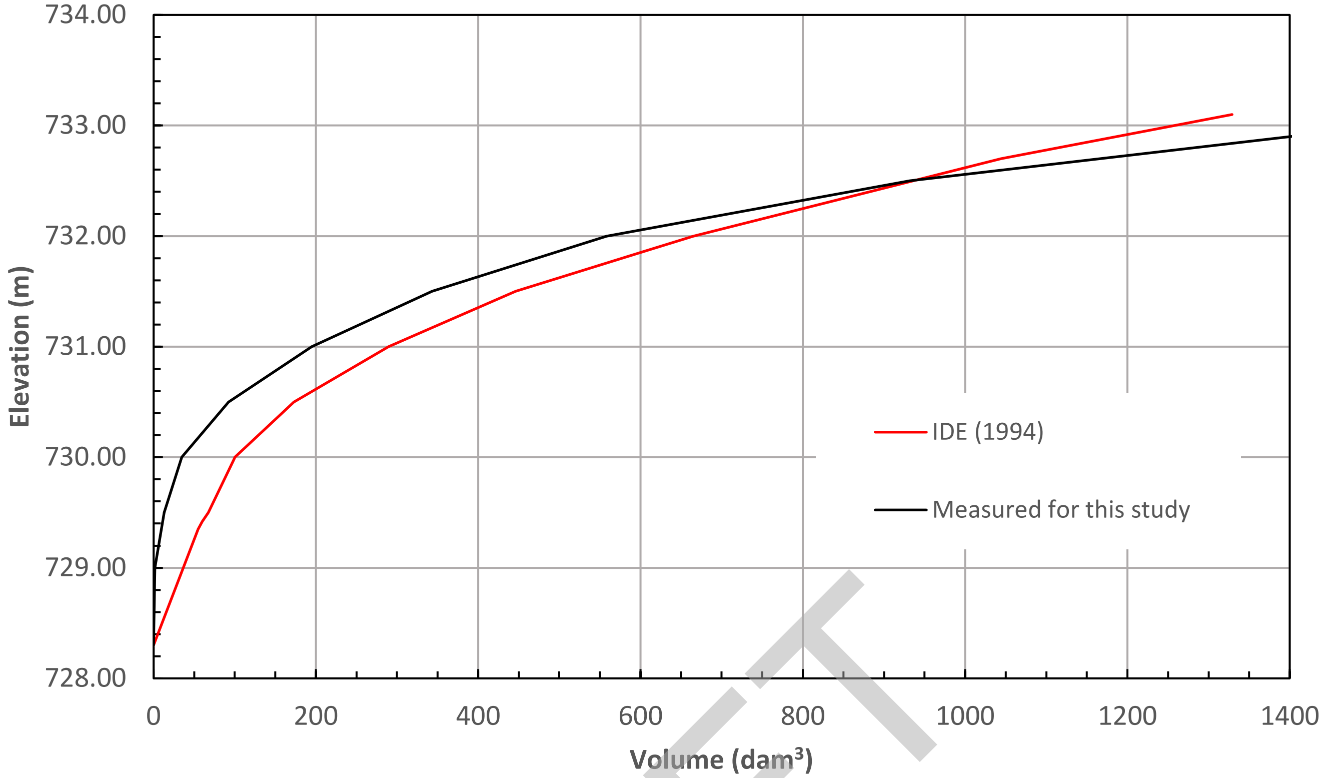
FIGURE 12

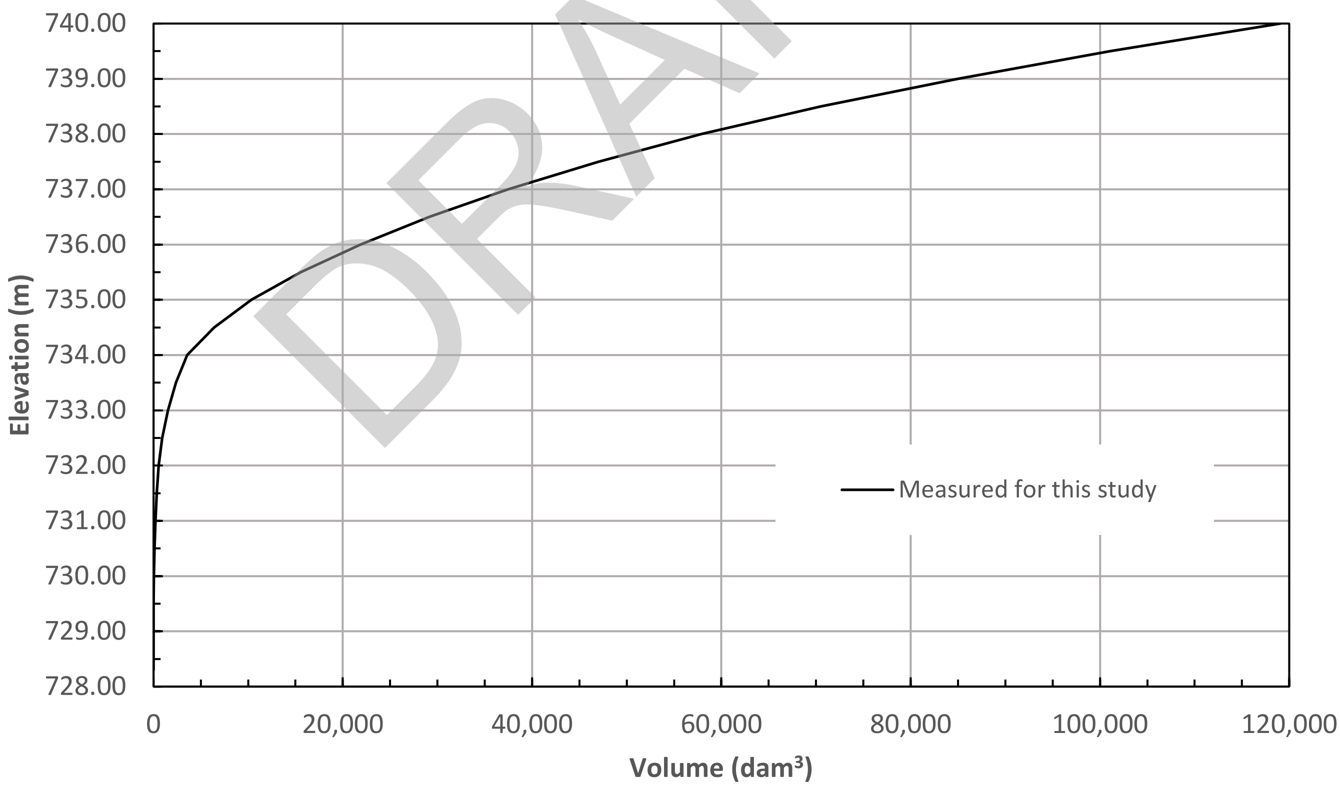


Alberta	SCALE – AS SHOWN	*CAMROSE FLOOD HAZARD STUDY* *OPEN WATER HYDROLOGY ASSESSMENT*
	Coordinate System: Units: As Shown	*SYNTHETIC FLOOD HYDROGRAPHS FOR CAMROSE CREEK NEAR MIRROR LAKE*
nhc northwest hydraulic consultants	*Job: 1004662* | *Date: Aug-2019*	*FIGURE 13*



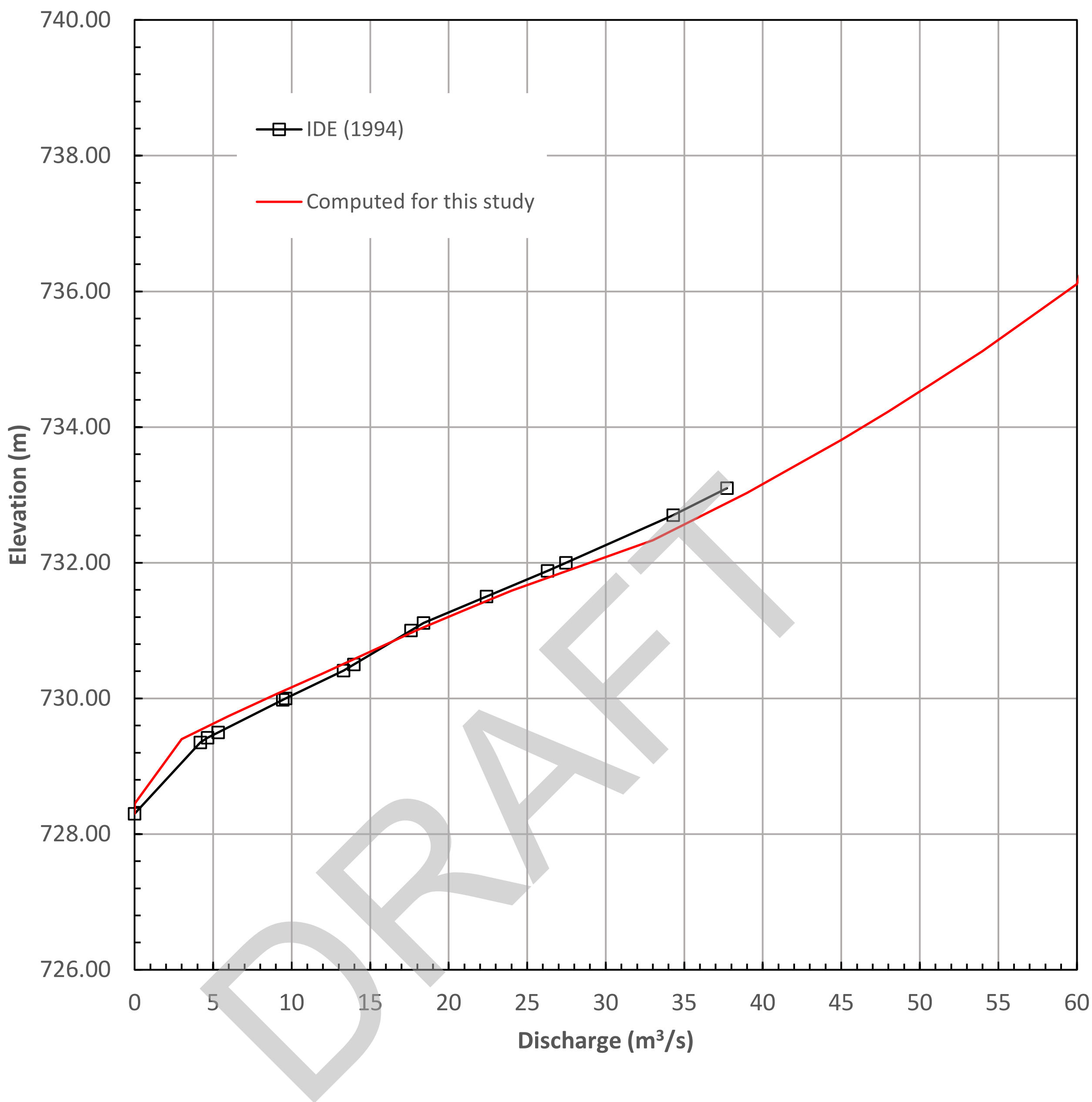
Alberta	SCALE – AS SHOWN	*CAMROSE FLOOD HAZARD STUDY* *OPEN WATER HYDROLOGY ASSESSMENT*
nhc northwest hydraulic consultants	Coordinate System: Units: As Shown	*MIRROR LAKE STORAGE CURVE AND SPILLWAY RATING CURVE*
	Job: 1004662 | *Date: Aug-2019*	*FIGURE 14*





DRAFT

Alberta	SCALE – AS SHOWN	*CAMROSE FLOOD HAZARD STUDY* *OPEN WATER HYDROLOGY ASSESSMENT*
nhc northwest hydraulic consultants	Coordinate System: Units: As Shown	*ELEVATION – STORAGE CURVE FOR CPR CROSSING*
	Job: 1004662 | *Date: Aug-2019*	*FIGURE 15*



Alberta

nhc northwest hydraulic consultants

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

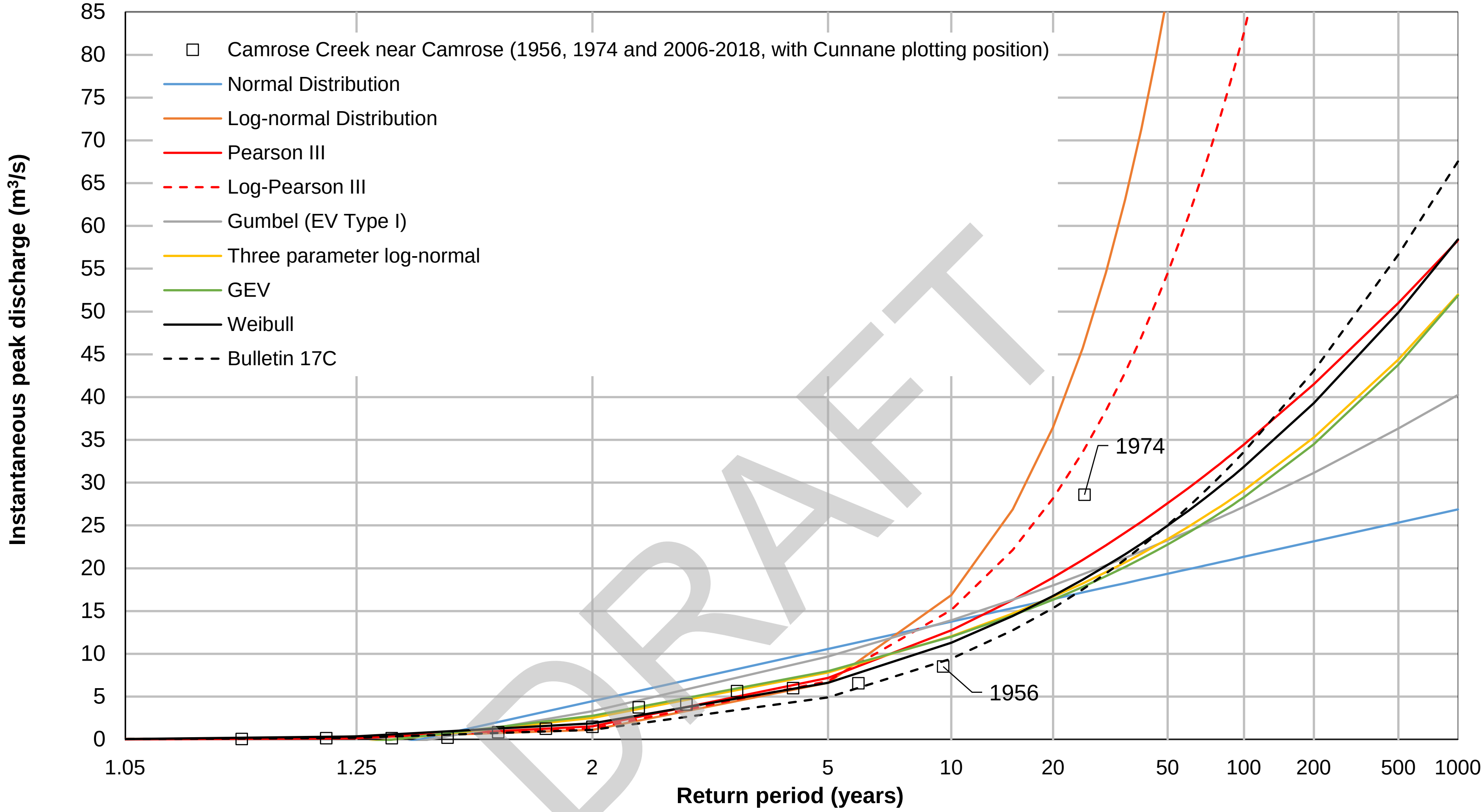
Job: 1004662 | *Date: Aug-2019*

CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

STAGE-DISCHARGE RATING CURVE FOR CPR CULVERT

FIGURE 16

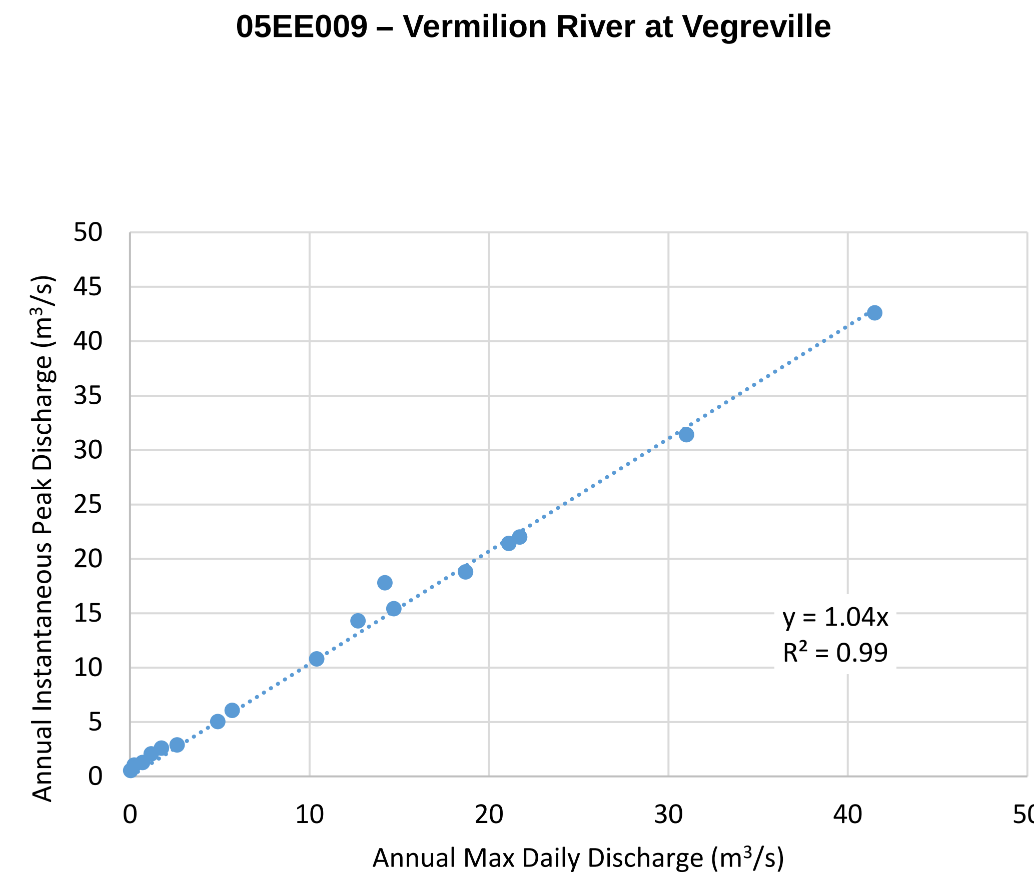
Appendix A
Additional Evaluated Frequency Distributions



Alberta	SCALE – AS SHOWN	*CAMROSE FLOOD HAZARD STUDY* *OPEN WATER HYDROLOGY ASSESSMENT*
nhc northwest hydraulic consultants	Coordinate System: Units: As Shown	*SINGLE STATION FLOOD FREQUENCY ANALYSIS*
	Job: 1004662 / *Date: Aug-2019*	*FIGURE A-1*

Appendix B
Flow Data Used for Regional Analysis

Year	Maximum Instantaneous Discharge (m³/s)[1]	Date	Maximum Daily Discharge (m³/s)	Date	Daily Discharge on Date of Maximum Instantaneous Discharge (m³/s)
1987	17.8	1987-04-10	14.2	1987-04-10	
1988	1.28	1988-08-20	0.686	1988-08-21	
1989	**1.86**	1989-04-02	1.80	1989-04-08	
1990	**14.1**	1990-04-08	13.6	1990-04-02	
1991	**0.876**	1991-03-18	0.846	1991-04-08	
1992	**4.31**	1992-04-14	4.16	1992-03-18	
1993	**3.18**	1993-04-04	3.07	1993-04-14	
1994	**11.4**	1994-03-25	11.0	1994-04-04	
1995	**9.29**	1995-04-11	8.97	1995-03-25	
1996	**6.23**	1996-04-19	6.02	1996-04-11	
1997	42.6	1997-04-19	41.5	1997-04-19	
1998	**1.40**	1998-04-08	1.35	1998-04-08	
1999	6.07	1999-04-09	5.69	1999-04-08	
2000	**0.201**	2000-04-04	0.194	2002-12-20	
2001	1.03	2001-05-12	0.227	2001-05-12	
2002	**0.083**	2002-04-19	0.080	2002-04-11	
2003	2.08	2003-04-19	1.17	2003-04-19	
2004	**4.40**	2004-04-06	4.25	2004-04-01	
2005	22.0	2005-04-06	21.7	2005-04-06	
2006	**18.2**	2006-04-22	17.6	2006-04-09	
2007	21.4	2007-04-22	21.1	2007-04-22	
2008	2.88	2008-05-02	2.61	2008-05-02	
2009	10.8	2009-04-13	10.4	2009-04-13	
2010	2.60	2010-06-12	1.84	2010-07-22	1.74
2011	18.8	2011-04-22	18.7	2011-04-22	
2012	0.539	2012-08-08	0.053	2012-05-24	0.037
2013	15.4	2013-04-26	14.7	2013-04-27	
2014	**6.10**	2014-04-01	5.89	2014-04-13	
2015	14.3	2015-03-31	12.7	2015-04-01	
2016	5.04	2016-07-12	4.88	2016-07-12	
2017					
2018	31.4	2018-04-23	31.0	2018-04-23	



Notes: 1. The bolded and underlined values are based on Qi=1.04Qd.

Alberta

nhc northwest hydraulic consultants

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

Job: 1004662

Date: Aug-2019

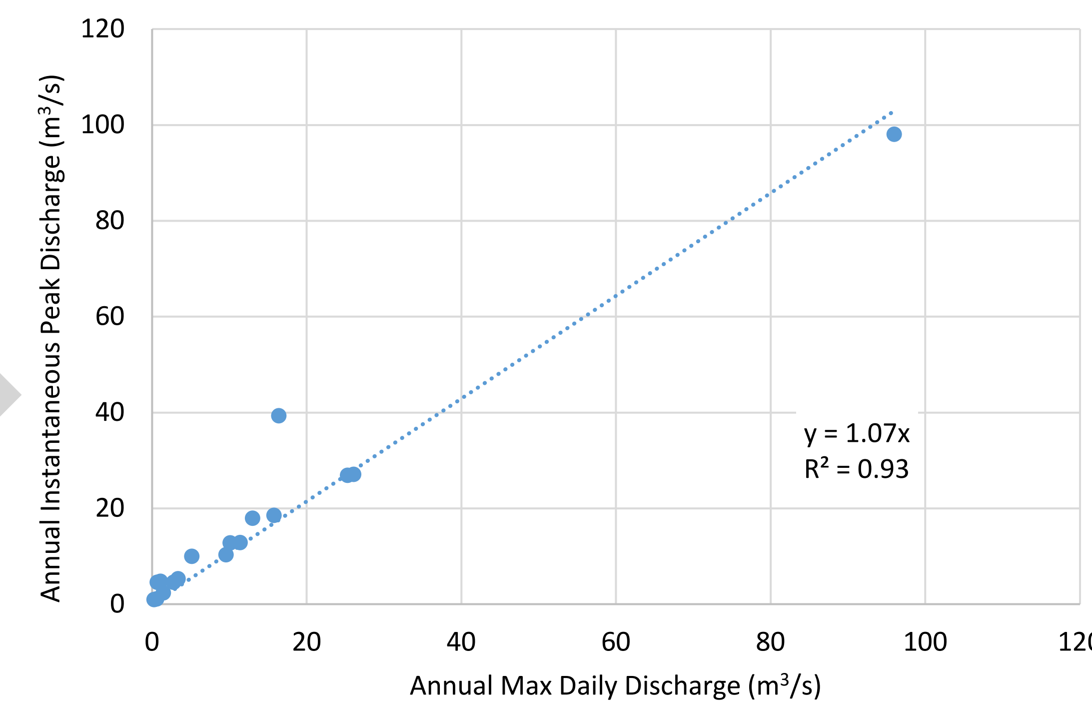
CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

VERMILION RIVER AT VEGREVILLE
MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

FIGURE B-1

Year	Maximum Instantaneous Discharge (m^3/s)[1,2]	Date	Maximum Daily Discharge (m^3/s)	Date	Daily Discharge on Date of Maximum Instantaneous Discharge (m^3/s)
1972	**15.2**		14.2	1972-04-07	
1973	18.5	1973-07-02	15.8	1973-07-02	
1974	98.0	1974-04-23	96.0	1974-04-23	
1975	**9.50**	1975-04-23	8.86	1975-04-23	
1976	**5.32**	1976-04-06	4.96	1976-04-06	
1977	4.59	1977-08-09	2.80	1977-08-10	
1978	5.32	1978-03-29	3.37	1978-03-29	
1979	12.8	1979-03-20	10.1	1979-03-20	
1980	11.7	1980-04-05	10.2	1980-04-06	
1981	10.4	1981-03-19	6.60		
1982	45.4	1982-04-24	41.4	1982-04-25	
1983	15.0	1983-07-08	14.8		
1984	5.09	1984-04-01	3.96		
1985	28.2	1985-04-03	23.2		
1986	8.60		7.85	1986-03-02	
1987	7.98		7.29		
1988	1.48	1988-07-06	0.926		
1989					
1990	48.1	1990-07-07	45.5		
1991	39.3	1991-07-06	16.4	1991-07-06	
1992	**11.6**	1992-03-22	10.8	1992-03-22	
1993	**9.17**	1993-03-28	8.55	1993-03-28	
1994	**5.02**	1994-03-30	4.68	1994-03-30	
1995	**3.18**	1995-03-23	2.97	1995-03-23	
1996	**14.0**	1996-04-10	13.1	1996-04-10	
1997	**25.7**	1997-04-13	24.0	1997-04-13	
1998	17.9	1998-07-05	13.0	1998-07-06	
1999	**25.7**	1999-04-13	24.0	1999-04-13	
2000	4.57	2000-07-02	1.52	2000-07-10	0.674
2001	1.06	2001-07-29	0.687	2001-08-01	0.584
2002	**6.43**	2002-04-24	6.00	2002-04-24	
2003	**11.8**	2003-04-11	11.0	2003-04-11	
2004	4.78	2004-07-19	1.11	2004-07-19	
2005	**18.8**	2005-04-04	17.5	2005-04-04	
2006	**8.52**	2006-04-06	7.95	2006-04-06	
2007	26.9	2007-05-08	25.3	2007-05-08	
2008	0.948	2008-05-16	0.282	2008-05-16	
2009	**0.226**	2009-04-12	0.211	2009-04-12	
2010	10.0	2010-07-14	5.17	2010-07-14	
2011	27.1	2011-07-29	26.1	2011-07-29	
2012	**2.15**	2012-04-15	2.01	2012-04-15	
2013	10.3	2013-04-26	9.57	2013-04-26	
2014	**28.9**	2014-04-11	27.0	2014-04-11	
2015					
2016	2.33	2016-07-11	1.48	2016-07-11	
2017	12.8	2017-03-29	11.4	2017-03-30	

05FA012 – Pipestone Creek near Wetaskiwin



Alberta

nhc northwest hydraulic consultants

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

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

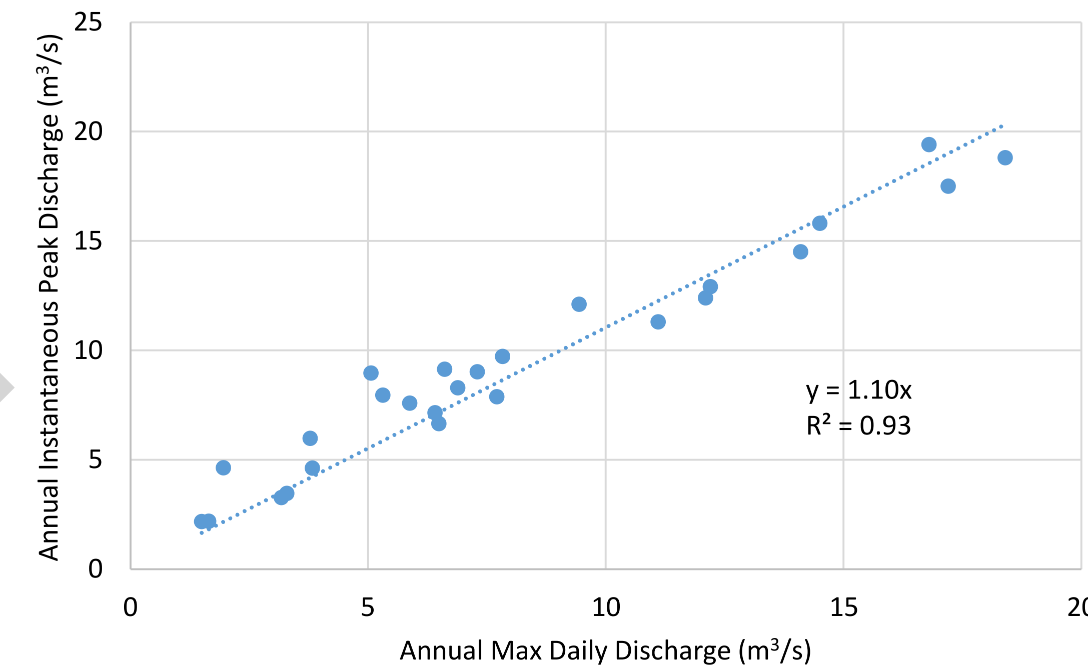
Job: 1004662 | Date: Aug-2019

CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT
PIPESTONE CREEK NEAR WETASKWIN
MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

FIGURE B-2

Year	Maximum Instantaneous Discharge (m^3/s)[1,2,3]	Date	Maximum Daily Discharge (m^3/s)	Date	Daily Discharge on Date of Maximum Instantaneous Discharge (m^3/s)
1935	**3.47**		3.14	1935-04-21	
1936	**17.7**		16.0	1936-04-16	
1974	**96.6**	1974-04-24	*87.8*	-	
1978	2.17	1978-04-09	1.78	1978-09-18	1.50
1979	9.02	1979-03-21	7.30	1979-03-21	
1980	7.58	1980-08-28	6.98	1980-04-18	5.88
1981	**6.96**	1981-03-26	6.30	1981-03-26	
1982	14.5	1982-04-27	14.1	1982-04-27	
1983	19.4	1983-07-07	16.8	1983-07-07	
1984	**4.09**	1984-03-27	3.70	1984-03-27	
1985	17.5	1985-04-04	17.2	1985-04-04	
1986	8.29	1986-03-20	6.89	1986-03-20	
1987	5.98	1987-08-05	3.84	1987-04-09	3.78
1988	12.1	1988-07-06	9.44	1988-07-06	
1989	4.62	1989-07-09	3.83	1989-07-09	
1990	**12.6**	1990-03-31	11.40	1990-03-31	
1991	8.95	1991-06-08	6.49	1991-05-14	
1992	**2.77**	1992-03-23	3.54	1992-03-23	
1993	**4.51**	1993-03-25	2.51	1993-03-25	
1994	**3.23**	1994-04-02	4.08	1994-04-02	
1995	**8.91**	1995-03-22	2.92	1995-03-22	
1996	**2.77**	1996-04-08	8.07	1996-04-08	
1997	15.8	1997-04-22	14.5	1997-06-25	
1998	9.72	1998-06-30	7.83	1998-07-01	
1999	6.65	1999-04-11	6.49	1999-04-11	
2000	3.46	2000-07-21	3.29	2000-07-22	
2001	9.13	2001-07-29	6.61	2001-07-30	
2002	**3.07**	2002-04-21	2.78	2002-04-21	
2003	**10.2**	2003-04-09	9.25	2003-04-09	
2004	**1.22**	2004-03-13	1.10	2004-03-13	
2005	**10.6**	2005-03-12	9.59	2005-03-12	
2006	3.27	2006-04-09	3.18	2006-04-09	
2007	12.9	2007-05-05	12.2	2007-05-05	
2008	2.18	2008-05-01	1.65	2008-05-01	
2009	**0.412**	2009-04-02	0.373	2009-04-02	
2010	4.63	2010-07-13	1.96	2010-07-13	
2011	18.8	2011-07-27	18.4	2011-07-27	
2012	7.15	2012-07-16	6.41	2012-07-16	
2013	12.4	2013-04-29	12.1	2013-04-29	
2014	11.3	2014-04-10	11.1	2014-04-10	
2015	**9.36**	2015-03-19	8.47	2015-03-19	
2016	7.95	2016-05-22	5.31	2016-05-23	
2017	7.88	2017-04-09	7.71	2017-04-09	
2018	17.3		16.54	2018-04-26	

05DF003 – Blackmud Creek near Ellerslie



Notes:
1. The bolded and underlined values are based on Qi=1.10Qd.
2. AEP estimated value for 1974 (italics)
3. Data for 2018 is preliminary from AEP.

Alberta

nhc northwest hydraulic consultants

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

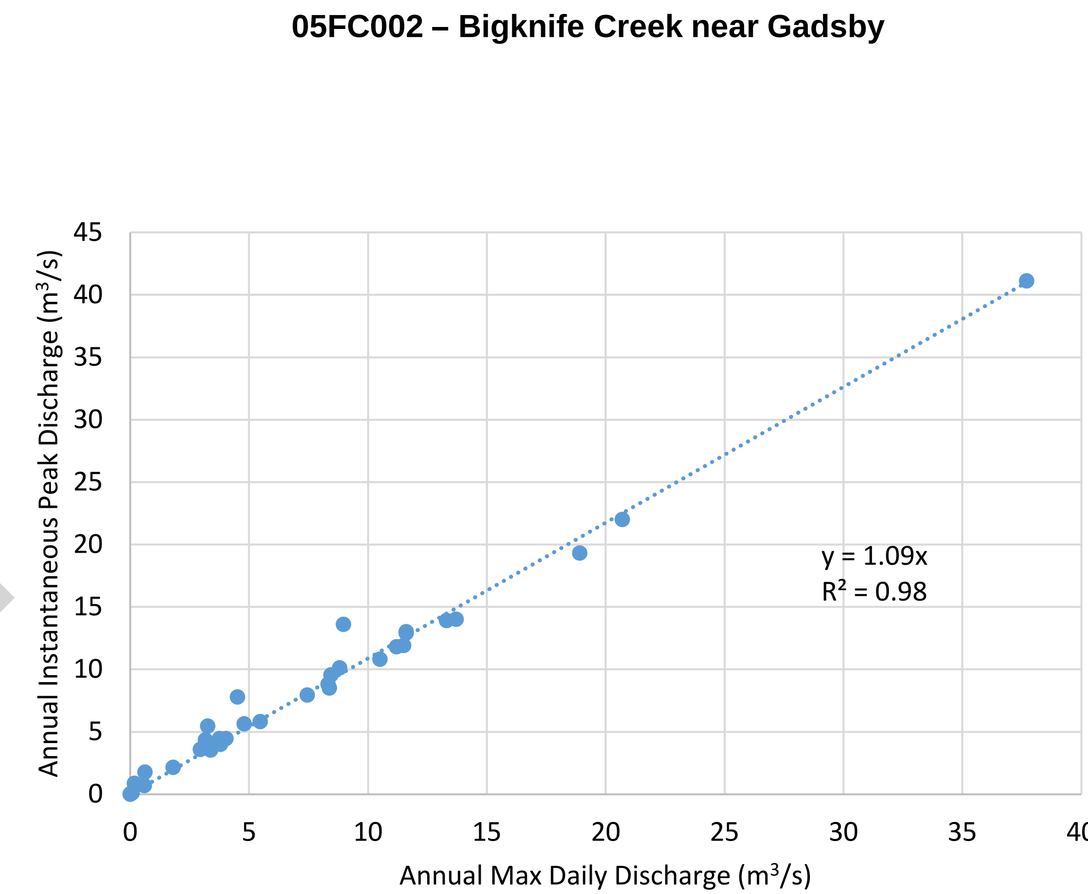
Job: 1004662

Date: Aug-2019

CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT
BLACKMUD CREEK NEAR ELLERSLIE
MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

FIGURE B-3

Year	Maximum Instantaneous Discharge (m^3/s)[1]	Date	Maximum Daily Discharge (m^3/s)	Date	Daily Discharge on Date of Maximum Instantaneous Discharge (m^3/s)
1968	**0.955**	1968-03-01	0.878	1968-03-01	
1969	**20.3**	1969-04-10	18.7	1969-04-10	
1970	19.3	1970-04-12	18.9	1970-04-12	
1971	14.0	1971-04-15	13.7	1971-04-15	
1972	5.44	1972-06-11	3.40	1972-04-08	3.26
1973	7.93	1973-06-18	7.45	1973-06-18	
1974	41.1	1974-04-22	37.7	1974-04-22	
1975	11.8	1975-04-26	11.2	1975-04-26	
1976	8.50	1976-04-09	8.38	1976-04-09	
1977	**0.00**	1977-03-01	0.00	1977-03-01	
1978	5.64	1978-09-14	4.79	1978-09-14	
1979	4.00	1979-03-16	3.80	1979-03-16	
1980	3.57	1980-04-12	3.35	1980-04-14	
1981	0.684	1981-03-15	0.59	1981-03-15	
1982	**2.93**	1982-04-17	2.69	1982-04-17	
1983	3.54	1983-07-05	3.38	1983-07-05	
1984	**0.561**	1984-03-31	0.52	1984-03-31	
1985	**5.46**	1985-04-03	5.02	1985-04-03	
1986	5.80	1986-07-31	5.47	1986-07-31	
1987	9.56	1987-04-05	8.44	1987-04-05	
1988	4.45	1988-04-09	3.75	1988-04-09	
1989	4.34	1989-07-02	3.17	1989-07-03	
1990	13.6	1990-07-07	8.97	1990-07-07	
1991	4.45	1991-05-16	4.03	1991-05-16	
1992	**1.65**	1992-03-06	1.52	1992-03-06	
1993	**6.40**	1993-07-28	5.89	1993-07-28	
1994	**8.04**	1994-03-17	7.39	1994-03-17	
1995	**5.22**	1995-03-18	4.80	1995-03-18	
1996	8.80	1996-04-09	8.32	1996-04-09	
1997	13.0	1997-03-28	11.6	1997-03-28	
1998	0.02	1998-07-12	0.017	1998-07-12	
1999	10.8	1999-07-18	10.5	1999-07-18	
2000	1.75	2000-04-03	0.878	2000-04-05	
2001	0.00	2001-03-01	0.00	2001-10-01	0.00
2002	0.007	2002-04-19	0.004	2002-04-19	
2003	2.15	2003-05-10	1.81	2003-05-11	
2004	**0.001**	2004-03-11	0.001	2004-03-11	
2005	10.1	2005-04-02	8.80	2005-04-03	
2006	11.9	2006-04-06	11.5	2006-04-06	
2007	22.0	2007-05-07	20.7	2007-05-07	
2008	0.856	2008-06-07	0.180	2008-06-07	
2009	0.097	2009-04-19	0.085	2009-04-20	
2010	12.9	2010-07-16	11.6	2010-07-16	
2011	**6.06**	2011-04-13	5.57	2011-04-13	
2012	**1.19**	2012-04-02	1.09	2012-04-02	
2013	7.77	2013-04-23	4.51	2013-04-23	
2014	**6.68**	2014-04-12	6.14	2014-04-12	
2015					
2016					
2017					
2018	13.9	2018-04-21	13.3	2018-04-22	



Alberta

nhc northwest hydraulic consultants

Notes: 1. The bolded and underlined values are based on Qi=1.09Qd.

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

Job: 1004662

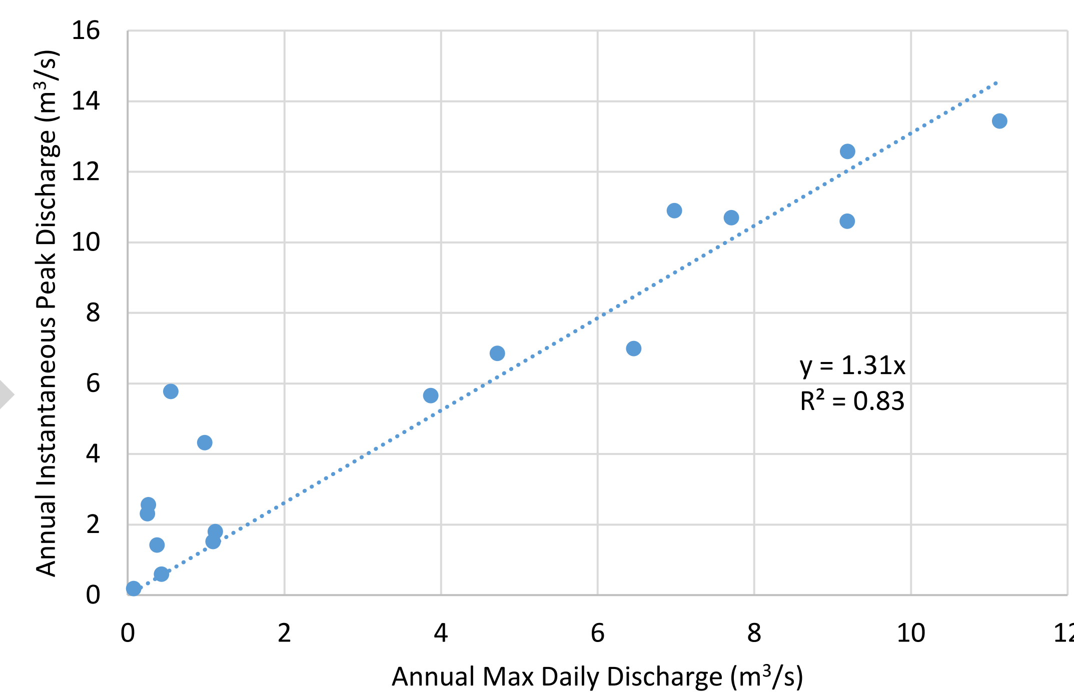
Date: Aug-2019

CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

BIGKNIFE CREEK NEAR GADSBY
MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

FIGURE B-4

Year	Maximum Instantaneous Discharge (m^3/s)[1,2]	Date	Maximum Daily Discharge (m^3/s)	Date	Daily Discharge on Date of Maximum Instantaneous Discharge (m^3/s)
1985	6.99	1985-03-20	6.46	1985-03-19	
1986	**4.65**	1986-03-02	3.55	1986-03-02	
1989	**0.608**	1987-03-31	0.465	1987-03-31	
1988	2.31	1988-10-24	0.885	1988-07-13	0.254
1989	2.56	1989-10-27	1.35	1989-04-04	0.264
1990	4.32	1990-07-04	2.30	1990-03-29	0.983
1991	**1.66**	1991-03-30	1.27	1991-03-30	
1992	**3.35**	1992-03-21	2.56	1992-03-21	
1993	**0.858**	1993-03-27	0.656	1993-03-27	
1994	**0.712**	1994-03-21	0.544	1994-03-21	
1995	0.597	1995-08-19	0.431	1995-08-19	
1996	**1.82**	1996-04-08	1.39	1996-04-08	
1997	**5.01**	1997-04-13	3.83	1997-04-13	
1998	1.52	1998-07-06	1.11	1998-06-29	1.09
1999	**9.42**	1999-04-11	7.20	1999-04-11	
2000	**0.628**	2000-03-31	0.480	2000-03-31	
2001	0.190	2001-07-29	0.075	2001-07-29	
2002	**1.48**	2002-04-19	1.13	2002-04-19	
2003	**5.53**	2003-04-10	4.23	2003-04-10	
2004	5.77	2004-07-05	0.551	2004-07-05	
2005	10.9	2005-03-11	8.13	2005-04-02	6.98
2006	**8.15**	2006-04-06	6.23	2006-04-06	
2007	10.7	2007-05-05	7.71	2007-05-05	
2008	**0.147**	2008-04-30	0.112	2008-04-30	
2009	**0.092**	2009-04-09	0.070	2009-04-09	
2010	6.85	2010-07-23	4.72	2010-07-23	
2011	10.6	2011-04-16	9.19	2011-04-16	
2012	1.80	2012-07-16	1.12	2012-07-16	
2013	5.65	2013-04-25	3.87	2013-04-25	
2014	**5.36**	2014-04-11	4.10	2014-04-11	
2015	-				
2016	1.42	2016-03-16	0.374	2016-03-16	
2017	12.6	2017-03-28	9.19	2017-03-28	
2018	13.4	2018-04-20	11.1	2018-04-19	



Notes: 1. The bolded and underlined values are based on Qi=1.31Qd.
2. Data for 2016-2018 is preliminary from AEP.

Alberta

nhc northwest hydraulic consultants

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

Job: 1004662

Date: Aug-2019

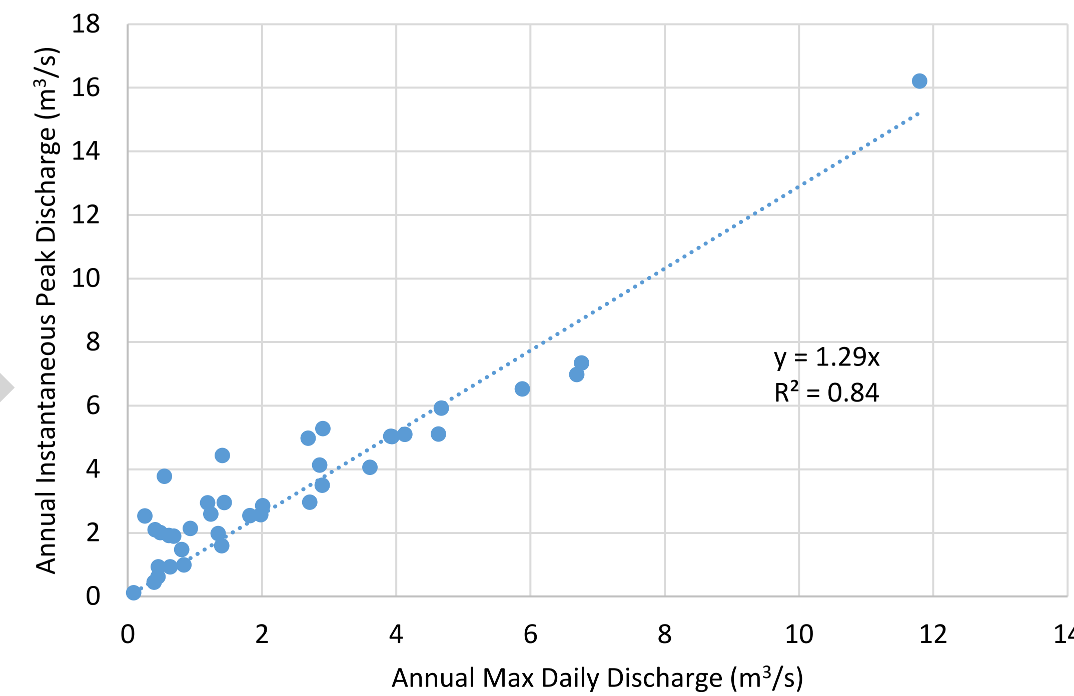
CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

WEILLER CREEK NEAR WETASKIWIN
MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

FIGURE B-5

Year	Maximum Instantaneous Discharge (m^3/s)[1]	Date	Maximum Daily Discharge (m^3/s)	Date	Daily Discharge on Date of Maximum Instantaneous Discharge (m^3/s)
1979	4.13	1979-07-14	2.86	1979-07-14	
1980	5.03	1980-04-11	3.92	1980-04-11	
1981	**3.03**	1981-03-18	2.35	1981-03-18	
1982	6.52	1982-04-24	5.88	1982-04-24	
1983	16.2	1983-06-25	11.8	1983-06-26	
1984	1.59	1984-03-25	1.40	1984-03-25	
1985	5.09	1985-04-02	4.13	1985-04-02	
1986	2.54	1986-03-04	1.82	1986-03-04	
1987	3.49	1987-04-05	2.90	1987-04-04	
1988	4.06	1988-07-06	3.61	1988-07-07	
1989	2.53	1989-04-21	0.937	1989-05-20	
1990	4.43	1990-07-06	1.72	1990-07-04	
1991	5.02	1991-05-14	3.94	1991-05-15	
1992	0.618	1992-03-14	0.534	1992-03-12	
1993	**0.365**	1993-06-24	0.283	1993-06-24	
1994	2.57	1994-03-31	1.98	1994-03-31	
1995	1.98	1995-03-19	1.35	1995-03-20	
1996	2.85	1996-04-06	2.01	1996-04-07	
1997	7.34	1997-06-23	6.76	1997-06-23	
1998	5.28	1998-07-02	2.91	1998-07-02	
1999	4.97	1999-03-27	2.69	1999-03-27	
2000	0.925	2000-03-27	0.549	2000-07-10	0.455
2001	1.47	2001-07-29	0.803	2001-07-29	
2002	1.89	2002-04-20	0.687	2002-04-20	
2003	3.78	2003-08-08	2.27	2003-04-10	0.545
2004	2.14	2004-03-30	0.934	2004-03-31	
2005	2.95	2005-03-10	1.44	2005-03-10	
2006	2.10	2006-05-25	1.01	2006-04-06	0.41
2007	5.92	2007-05-05	4.67	2007-05-05	
2008	0.115	2008-04-30	0.090	2008-04-30	
2009	0.992	2009-04-11	0.839	2009-04-11	
2010	0.924	2010-07-13	0.632	2010-07-14	
2011	6.98	2011-07-23	6.69	2011-07-23	
2012	0.443	2012-07-16	0.396	2012-07-16	
2013	2.59	2013-07-15	2.36	2013-04-27	1.24
2014	2.94	2014-07-25	1.19	2014-07-25	
2015	2.01	2015-04-09	0.879	2015-03-30	0.485
2016	1.91	2016-08-09	0.613	2016-08-09	
2017	2.96	2017-04-25	2.71	2017-04-25	
2018	5.10	2018-04-21	4.63	2018-04-21	

05EB902 – Pointe-Aux-Pins Creek near Ardrossan



Notes: 1. The bolded and underlined values are based on Qi=1.29Qd.

Alberta

nhc northwest hydraulic consultants

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

Job: 1004662

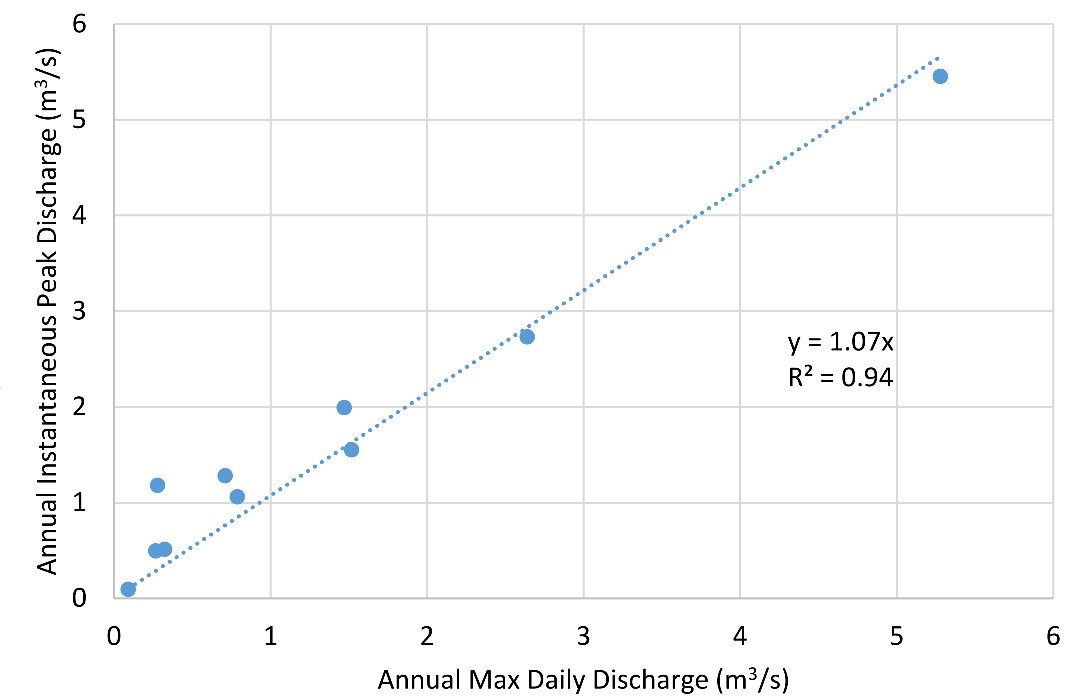
Date: Aug-2019

CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT
POINTE AUX PINS CREEK NEAR ARDROSSAN
MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

FIGURE B-6

Year	Maximum Instantaneous Discharge (m^3/s)[1,2]	Date	Maximum Daily Discharge (m^3/s)	Date	Daily Discharge on Date of Maximum Instantaneous Discharge (m^3/s)
1973	**2.85**	1973-07-01	2.66	1973-07-01	
1974	**8.68**	1974-04-20	8.10	1974-04-20	
1975	**1.73**	1975-04-20	1.61	1975-04-20	
1976	**0.544**	1976-04-07	0.507	1976-04-07	
1977	**0.139**	1977-05-16	0.130	1977-05-16	
1978	**0.318**	1978-03-29	0.297	1978-03-29	
1979	1.28	1979-04-18	0.924	1979-03-18	
1980	1.06	1980-08-28	0.788	1980-08-28	
1981	**1.48**	1981-03-15	1.38	1981-03-15	
1982	5.45	1982-04-21	5.28	1982-04-22	
1983	1.99	1983-04-02	1.47	1983-04-02	
1984	**0.121**	1984-03-30	0.113	1984-03-30	
1985	2.73	1985-04-04	2.64	1985-04-04	
1986	0.511	1986-02-26	0.325	1986-02-27	
1987	**0.549**	1987-04-12	0.512	1987-04-12	
1988	**0.241**	1988-06-09	0.225	1988-06-09	
1989	**0.514**	1989-04-12	0.479	1989-04-12	
1990	**2.07**	1990-03-31	1.93	1990-03-31	
1991	**1.20**	1991-04-04	1.12	1991-04-04	
1992	**0.779**	1992-03-18	0.727	1992-03-18	
1993	**0.600**	1993-03-21	0.560	1993-03-21	
1994					
1995	**0.175**	1995-03-19	0.163	1995-03-19	
1996	**2.10**	1996-04-11	1.96	1996-04-11	
1997	**1.28**	1997-04-18	1.19	1997-04-18	
1998	**0.12**	1998-06-29	0.112	1998-06-29	
1999	**2.57**	1999-04-10	2.40	1999-04-10	
2000	0.483	2000-03-29	0.267	2000-03-29	
2001	0.494	2001-07-29	0.279	2001-07-29	
2002	1.18	2002-04-25	0.597	2002-04-25	
2003	**2.36**	2003-04-10	2.20	2003-04-10	
2004	**0.145**	2004-03-29	0.135	2004-03-29	
2005	2.86	2005-04-05	2.83	2005-04-05	
2006	**0.308**	2006-04-07	0.287	2006-04-07	
2007	0.742	2007-05-05	0.639	2007-05-05	
2008	**0.047**	2008-04-29	0.044	2008-04-29	
2009	**0.086**	2009-04-13	0.080	2009-04-13	
2010	0.538	2010-07-13	0.219	2010-07-14	
2011	**2.65**	2011-04-14	2.47	2011-04-14	
2012	0.326	2012-04-20	0.176	2012-04-03	0.176
2013	**0.891**	2013-05-01	0.831	2013-05-01	
2014	**1.45**	2014-04-15	1.35	2014-04-15	
2015					
2016					
2017	1.55	2017-04-03	1.52	2017-04-03	

05FA014 – Maskwa Creek No. 1 above Bearhills Lake



Notes: 1. The bolded and underlined values are based on Qi=1.07Qd.
2. Data for 2017 is preliminary from AEP.

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

Job: 1004662 | Date: Aug-2019

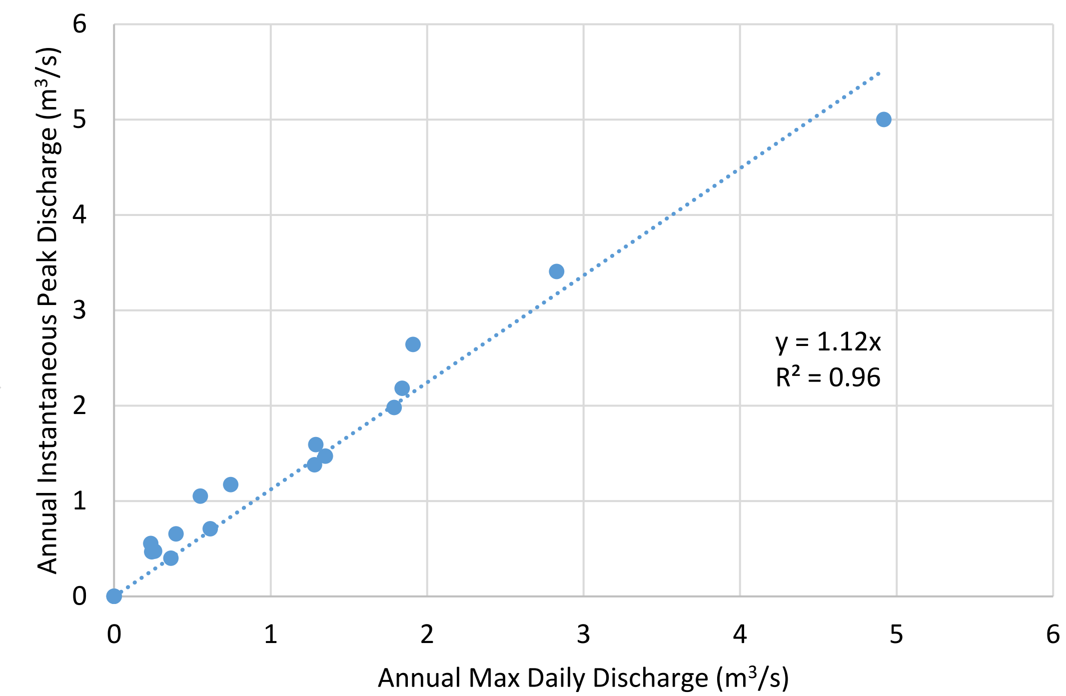
CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT
MASKWA CREEK NO. 1 ABOVE BEARHILLS LAKE
MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

FIGURE B-7

Alberta
nhc northwest hydraulic consultants

Year	Maximum Instantaneous Discharge (m^3/s)[1,2]	Date	Maximum Daily Discharge (m^3/s)	Date	Daily Discharge on Date of Maximum Instantaneous Discharge (m^3/s)
1978	**1.36**	1978-09-16	1.21	1978-09-16	
1979	**2.08**	1979-04-19	1.85	1979-04-19	
1980	**0.748**	1980-04-12	0.667	1980-04-12	
1981	**0.488**	1981-03-20	0.435	1981-03-20	
1982	**0.920**	1982-07-05	0.820	1982-07-05	
1983	1.98	1983-06-29	1.79	1983-06-29	
1984	**0.797**	1984-03-28	0.710	1984-03-28	
1985	1.38	1985-04-02	1.28	1985-04-01	
1986	2.64	1986-03-30	1.91	1986-03-30	
1987	1.59	1987-04-05	1.29	1987-04-06	
1988	**0.036**	1988-04-04	0.032	1988-04-04	
1989	0.473	1989-10-22	0.311	1989-04-05	0.259
1990	1.47	1990-04-02	1.35	1990-04-02	
1991	**0.026**	1991-04-04	0.023	1991-04-04	
1992	1.05	1992-04-10	0.552	1992-04-10	
1993	**0.395**	1993-04-06	0.352	1993-04-06	
1994	**0.713**	1994-04-06	0.635	1994-04-06	
1995	**1.35**	1995-03-22	1.20	1995-03-22	
1996	**0.673**	1996-04-09	0.600	1996-04-09	
1997	5.00	1997-04-18	4.92	1997-04-18	
1998	**0.281**	1998-04-03	0.250	1998-04-03	
1999	**0.359**	1999-04-06	0.320	1999-04-06	
2000	**0.009**	2000-03-31	0.008	2000-03-31	
2001	0.00	2001-03-01	0.00	2001-03-01	
2002					
2003	0.467	2003-04-25	0.240	2003-04-25	
2004	0.655	2004-03-30	0.396	2004-03-30	
2005	**0.974**	2005-03-11	0.868	2005-03-11	
2006	**0.558**	2006-04-06	0.497	2006-04-06	
2007	2.18	2007-04-20	1.84	2007-04-20	
2008	0.556	2008-04-12	0.338	2008-05-03	0.235
2009	1.17	2009-04-11	0.745	2009-04-12	
2010	0.399	2010-06-10	0.364	2010-06-10	
2011	**1.71**	2011-04-21	1.52	2011-04-21	
2012	0.002	2012-04-28	0.002	2012-04-28	
2013	0.709	2013-04-25	0.614	2013-04-26	
2014	**0.054**	2014-04-08	0.048	2014-04-08	
2015	**0.260**	2015-03-01	0.232	2015-03-01	
2016	0.422	2016-07-10	0.285	2016-05-05	0.285
2017	**1.25**	2017-03-01	1.11	2017-03-01	
2018	3.41	2018-04-01	2.83	2018-04-01	

05EE006 – Vermilion River Tributary near Bruce



Notes: 1. The bolded and underlined values are based on Qi=1.12Qd.
2. Data for 2018 is preliminary from AEP.

Alberta

nhc northwest hydraulic consultants

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

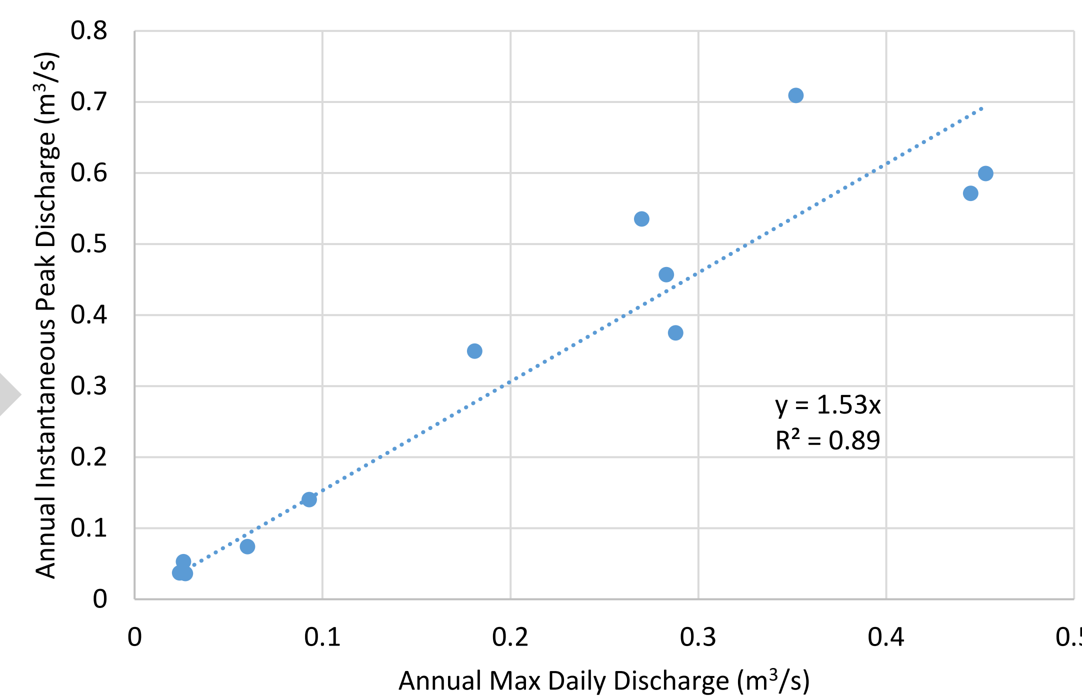
Job: 1004662 | Date: Aug-2019

CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT
VERMILION RIVER TRIBUTARY NEAR BRUCE
MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

FIGURE B-8

Year	Maximum Instantaneous Discharge (m^3/s)[1]	Date	Maximum Daily Discharge (m^3/s)	Date	Daily Discharge on Date of Maximum Instantaneous Discharge (m^3/s)
1981	**<u>1.07</u>**	1981-03-14	0.697	1981-03-14	
1982	1.98	1982-04-21	1.26	1982-04-22	
1983	4.88	1983-06-25			
1984	0.317	1984-03-22			
1985	0.940	1985-04-01	0.679	1985-04-01	
1986	1.33	1986-03-04			
1987	1.28	1987-04-03			
1988	0.96	1988-07-06			
1989	0.433	1989-04-04			
1990	0.450	1990-05-11	0.295	1990-03-19	0.097
1991					
1992	0.135	1992-05-14	0.073	1992-03-15	0.045
1993	**<u>0.063</u>**	1993-05-08	0.041	1993-05-08	
1994	0.440	1994-03-31			
1995	0.552	1995-03-17			
1996	0.599	1996-04-06	0.453	1996-04-08	
1997	0.799	1997-06-23	0.521	1997-03-31	0.454
1998	0.535	1998-07-02	0.270	1998-07-02	
1999	0.571	1999-03-26	0.445	1999-03-26	
2000	0.095	2000-07-10	0.045	2000-03-27	0.041
2001	0.053	2001-07-29	0.026	2001-07-29	
2002	0.037	2002-04-15	0.024	2002-04-16	
2003	0.349	2003-04-09	0.181	2003-04-09	
2004	0.457	2004-03-30	0.283	2004-03-31	
2005	0.709	2005-03-10	0.352	2005-03-10	
2006	0.140	2006-04-04	0.093	2006-04-04	
2007	0.375	2007-05-05	0.288	2007-05-05	
2008	0.036	2008-04-27	0.027	2008-04-27	
2009	0.074	2009-04-10	0.060	2009-04-10	

05EB910 – Pointe-Aux-Pins Tributary No. 2 Near Ardrossan



Alberta

nhc northwest hydraulic consultants

Notes: 1. The bolded and underlined values are based on Qi=1.53Qd.

SCALE – AS SHOWN

Coordinate System:
Units: As Shown

Job: 1004662 *Date: Aug-2019*

CAMROSE FLOOD HAZARD STUDY
OPEN WATER HYDROLOGY ASSESSMENT

POINTE AUX PINS TRIBUTARY NO. 2 NEAR ARDROSSAN MAXIMUM INSTANTANEOUS TO DAILY DISCHARGE COMPARISION

FIGURE B-9

Appendix E
Detailed Model Data

Table E-1 Bridge details

Reach	Description	River Station (m)	Municipality	Design Drawing/Info	Span (m)	Width (m)	Number of Piers	Pier Width (m)	Deck Skew (°)	Pier Skew (°)	Minimum Elevation (m)		Low Flow Modelling Approach	High Flow Modelling Approach
											Top Chord	Low Chord		
Camrose Creek	CN Railway Bridge	18,693	Camrose County	No	24.6	4.3	6	0.4	N/A	N/A	734.20	733.00	Highest Energy Answer	Pressure and/or Weir
	Golf Course Bridge	18,309	Camrose County	No	8.8	2.6	2	0.2	N/A	N/A	732.49	732.30	Highest Energy Answer	Energy Only (Standard Step)
	Golf Course Bridge	18,194	Camrose County	No	8.3	3.7	1	0.2	N/A	N/A	732.56	732.37	Highest Energy Answer	Energy Only (Standard Step)
	Golf Course Bridge	18,090	Camrose County	No	9.2	2.8	2	0.19	N/A	N/A	732.57	732.39	Highest Energy Answer	Energy Only (Standard Step)
	Golf Course Bridge	17,991	Camrose County	No	9.2	2.8	2	0.19	N/A	N/A	732.62	732.44	Highest Energy Answer	Energy Only (Standard Step)
	HWY 833 Bridge (BF1030)	17,491	Camrose County	No	8.5	13.5	0	N/A	N/A	N/A	734.39	733.55	Energy (standard step)	Energy Only (Standard Step)
	Township Rd 472 Bridge (BF446)	16,638	Camrose County	No	10.2	8.7	0	N/A	N/A	N/A	733.58	732.74	Energy (standard step)	Energy Only (Standard Step)
	Bailey Avenue Bridge (BF77950)	15,770	Camrose County	No	6.2	8.6	0	N/A	N/A	N/A	732.20	731.38	Energy (standard step)	Pressure and/or Weir
	53rd Street Bridge (BF1029)	15,428	City of Camrose	No	4.5	13.0	0	N/A	N/A	N/A	732.26	731.44	Energy (standard step)	Energy Only (Standard Step)
	54th Avenue Bridge (BF79515)	13,933	City of Camrose	Yes	11.0	15.9	0	N/A	N/A	N/A	731.59	730.76	Energy (standard step)	Energy Only (Standard Step)
	Pedestrian Bridge	13,563	City of Camrose	Yes	24.1	3.0	0	N/A	N/A	N/A	730.78	730.46	Energy (standard step)	Energy Only (Standard Step)
	Private Road	13,379	City of Camrose	No	8.5	6.2	0	N/A	N/A	N/A	730.53	729.89	Energy (standard step)	Energy Only (Standard Step)
	Pedestrian Bridge	13,146	City of Camrose	No	16.0	1.8	0	N/A	N/A	N/A	730.02	729.85	Energy (standard step)	Energy Only (Standard Step)
	Golf Course Bridge	13,063	City of Camrose	No	9.2	3.8	2	0.31	N/A	N/A	729.42	729.03	Highest Energy Answer	Energy Only (Standard Step)
	Golf Course Bridge	13,005	City of Camrose	No	14.1	1.9	0	N/A	N/A	N/A	729.00	728.70	Energy (standard step)	Energy Only (Standard Step)
	Golf Course Bridge	12,930	City of Camrose	No	11.8	1.8	0	N/A	N/A	N/A	729.16	728.86	Energy (standard step)	Energy Only (Standard Step)
	Mirror Lake Pedestrian Bridge	11,761	City of Camrose	No	27.5	3.0	0	N/A	N/A	N/A	730.20	730.00	Energy (standard step)	Energy Only (Standard Step)
	48th Avenue Bridge (BF445)	11,521	City of Camrose	Yes	13.7	36.5	0	N/A	N/A	N/A	730.64	729.94	Energy (standard step)	Energy Only (Standard Step)
	Pedestrian Bridge	11,384	City of Camrose	No	21.8	1.9	0	N/A	N/A	N/A	730.37	730.01	Energy (standard step)	Energy Only (Standard Step)
	47th Avenue Bridge (BF81006)	11,292	City of Camrose	Yes	5.1	13.2	0	N/A	N/A	N/A	727.67	726.98	Energy (standard step)	Energy Only (Standard Step)

Table E-1 Bridge details (continued)

Reach	Description	River Station (m)	Municipality	Design Drawing/Info	Span (m)	Width (m)	Number of Piers	Pier Width (m)	Deck Skew (°)	Pier Skew (°)	Minimum Elevation (m)		Low Flow Modelling Approach	High Flow Modelling Approach
											Top Chord	Low Chord		
Camrose Creek	Pedestrian Bridge	11,129	City of Camrose	No	11.9	1.7	0	N/A	N/A	N/A	724.41	724.21	Energy (standard step)	Energy Only (Standard Step)
	Pedestrian Bridge	10,933	City of Camrose	Yes	16.1	4.6	0	N/A	N/A	N/A	724.96	723.36	Energy (standard step)	Energy Only (Standard Step)
	Pedestrian Bridge	10,637	City of Camrose	No	12.5	1.9	0	N/A	N/A	N/A	723.33	723.11	Energy (standard step)	Energy Only (Standard Step)
	44th Avenue Bridge (BF79353)	10,489	City of Camrose	No	10.9	14.6	0	N/A	N/A	N/A	725.35	725.00	Energy (standard step)	Energy Only (Standard Step)
	Pedestrian Bridge	10,109	City of Camrose	No	7.6	4.2	0	N/A	N/A	N/A	722.46	722.09	Energy (standard step)	Energy Only (Standard Step)
	Pedestrian Bridge	10,058	City of Camrose	No	16.0	1.7	0	N/A	N/A	N/A	722.06	721.86	Energy (standard step)	Energy Only (Standard Step)
	Pedestrian Bridge	8,255	City of Camrose	No	9.2	4.9	0	N/A	N/A	N/A	717.94	717.50	Energy (standard step)	Energy Only (Standard Step)
	CN Railway Bridge	8,156	City of Camrose	No	59.4	2.7	31	0.3	N/A	N/A	729.10	728.40	Highest Energy Answer	Energy Only (Standard Step)
	Pedestrian Bridge	8,135	City of Camrose	No	7.0	1.9	0	N/A	N/A	N/A	717.52	717.30	Energy (standard step)	Energy Only (Standard Step)
	Camrose Drive Bridge (BF806000)	7,898	City of Camrose	Yes	180.0	14.6	6	1	N/A	N/A	736.56	734.76	Highest Energy Answer	Energy Only (Standard Step)
	Pedestrian Bridge	7,531	City of Camrose	No	12.2	4.8	0	N/A	N/A	N/A	715.89	715.49	Energy (standard step)	Pressure and/or Weir
	Township Rd 464 Bridge (BF366)	6,383	City of Camrose	No	8.2	6.6	0	N/A	N/A	N/A	713.07	712.42	Energy (standard step)	Energy Only (Standard Step)
	CN Railway Bridge	3,294	Camrose County	No	77.6	4.0	20	0.3	N/A	N/A	710.20	709.50	Highest Energy Answer	Energy Only (Standard Step)
	Trail Bridge	2,899	Camrose County	No	24.2	3.0	0	N/A	N/A	N/A	698.97	698.05	Energy (standard step)	Energy Only (Standard Step)
	Trail Bridge	2,059	Camrose County	No	12.8	1.8	0	N/A	N/A	N/A	696.65	696.25	Energy (standard step)	Energy Only (Standard Step)
	Trail Bridge	1,593	Camrose County	No	20.3	3.0	0	N/A	N/A	N/A	697.19	696.34	Energy (standard step)	Energy Only (Standard Step)
	CN Railway Bridge	1,479	Camrose County	No	47.3	4.0	13	0.3	N/A	N/A	705.23	704.53	Highest Energy Answer	Energy Only (Standard Step)
	Trail Bridge	722	Camrose County	No	7.5	3.6	0	N/A	N/A	N/A	694.76	694.36	Energy (standard step)	Energy Only (Standard Step)
	CN Railway Bridge	98	Camrose County	No	42.6	4.0	11	0.3	N/A	N/A	700.83	700.13	Highest Energy Answer	Energy Only (Standard Step)

Table E-2 Culvert details

Reach	Description	River Station (m)	Municipality	Culvert Shape	Culvert Type	Entrance Condition	Number of Barrel	Barrel Length (m)	Diameter, Rise, or Height (m)	Span or Width (m)	Upstream Invert Elevation (m)	Downstream Invert Elevation (m)	Loss Coefficient		Manning's n	
													Entrance	Exit	Top	Bottom
Camrose Creek	CSP Culvert	16,310	Camrose County	Circular	CSP	Pipe Projecting from Fill	1	3.2	0.5	N/A	730.59	730.58	0.9	1	0.023	0.023
	CSP Culverts	14,522	City of Camrose	Circular	CSP	Pipe Projecting from Fill	4	8.8	0.9	N/A	729.05	729.31	0.9	1	0.023	0.023
								8.8	0.9	N/A	729.07	729.06	0.9	1	0.023	0.023
								8.8	0.9	N/A	729.23	729.15	0.9	1	0.023	0.023
								8.8	0.9	N/A	729.21	729.04	0.9	1	0.023	0.023
	CP Rail Culvert (BF77937)	13,437	City of Camrose	Box	Concrete	Side Tapered	1	35.5	2.6	3.0	728.28	728.24	0.4	1	0.013	0.013
	50th Avenue/Grand Drive (BF83008)	12,750	City of Camrose	Box	Concrete	Side Tapered	2	27.9	1.8	2.4	727.70	727.50	0.7	1	0.013	0.013
								27.9	1.8	2.4	727.70	727.50	0.7	1	0.013	0.013
	48th Avenue Bridge (BF445)	11,521		Box	Concrete	Side Tapered	1	45	2.5	4	729.1	728.9	0.7	1	0.013	0.013
	CSP Culverts	9,318	City of Camrose	Circular	CSP	Pipe Projecting from Fill	3	15.1	2	N/A	718.8	718.2	0.9	1	0.023	0.023
								15.1	2	N/A	718.8	718.2	0.9	1	0.023	0.023
								15.1	2	N/A	718.8	718.2	0.9	1	0.023	0.023
	Box Culvert	8,841	City of Camrose	Box	Concrete	Side Tapered	1	26.3	1.56	2.4	717.59	717.59	0.7	1	0.013	0.013
Unnamed Creek	CSP Culvert	4,112	City of Camrose	Circular	CSP	Pipe Projecting from Fill	1	10.3	0.8	N/A	741.16	741.09	0.9	1	0.023	0.023
	Range Rd 203 Culverts	2,367	Camrose County	Circular	CSP	Mitered to Conform to Slope	3	18.2	0.8	N/A	738.65	738.49	0.7	1	0.023	0.023
								18.2	0.8	N/A	738.69	738.53	0.7	1	0.023	0.023
								18.3	0.8	N/A	738.67	738.50	0.7	1	0.023	0.023

Table E-3 Computed flood frequency water levels - Camrose Creek

River Station (m)	Water Surface Elevation for various Flood Return Periods (m)												
	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
18,827	732.60	732.88	733.12	733.40	733.63	733.82	734.09	734.21	734.58	734.63	734.78	735.00	735.17
18,745	732.60	732.87	733.12	733.40	733.63	733.82	734.09	734.21	734.58	734.63	734.78	735.00	735.17
18,700	732.60	732.86	733.10	733.37	733.60	733.79	734.01	734.18	734.57	734.62	734.78	735.00	735.17
18,688	732.58	732.84	733.06	733.30	733.47	733.63	733.85	734.09	734.57	734.62	734.77	735.00	735.17
18,621	732.59	732.85	733.08	733.31	733.50	733.65	733.88	734.12	734.57	734.62	734.77	735.00	735.17
18,486	732.58	732.84	733.07	733.31	733.49	733.65	733.87	734.12	734.57	734.62	734.77	735.00	735.17
18,311	732.56	732.81	733.05	733.30	733.48	733.64	733.87	734.12	734.57	734.61	734.77	735.00	735.17
18,307	732.53	732.80	733.04	733.29	733.48	733.64	733.87	734.12	734.57	734.61	734.77	735.00	735.17
18,247	732.50	732.77	733.04	733.29	733.47	733.64	733.86	734.11	734.57	734.61	734.77	735.00	735.17
18,198	732.49	732.75	733.03	733.28	733.47	733.63	733.86	734.11	734.56	734.61	734.77	735.00	735.17
18,190	732.46	732.75	733.02	733.27	733.46	733.63	733.86	734.11	734.56	734.61	734.77	734.99	735.17
18,146	732.44	732.73	733.01	733.26	733.45	733.62	733.85	734.11	734.56	734.61	734.77	734.99	735.16
18,092	732.42	732.70	732.99	733.24	733.44	733.61	733.85	734.10	734.56	734.61	734.77	734.99	735.16
18,087	732.40	732.69	732.98	733.24	733.44	733.61	733.85	734.10	734.56	734.61	734.77	734.99	735.16
18,033	732.39	732.69	732.98	733.24	733.44	733.61	733.85	734.10	734.56	734.61	734.76	734.99	735.16
17,993	732.38	732.68	732.97	733.23	733.43	733.60	733.84	734.10	734.56	734.60	734.76	734.99	735.16
17,988	732.36	732.68	732.97	733.23	733.43	733.60	733.84	734.10	734.56	734.60	734.76	734.99	735.16
17,933	732.35	732.67	732.96	733.23	733.43	733.60	733.84	734.10	734.56	734.60	734.76	734.99	735.16
17,811	732.33	732.65	732.95	733.22	733.42	733.60	733.84	734.10	734.56	734.60	734.76	734.99	735.16
17,679	732.30	732.62	732.93	733.21	733.41	733.59	733.83	734.09	734.56	734.60	734.76	734.99	735.16
17,570	732.25	732.58	732.90	733.18	733.40	733.58	733.83	734.09	734.56	734.60	734.76	734.99	735.16
17,503	732.21	732.50	732.78	733.02	733.19	733.37	733.62	733.90	734.54	734.59	734.75	734.99	735.16
17,480	732.14	732.47	732.73	732.95	733.10	733.28	733.56	733.72	734.12	734.54	734.74	734.98	735.16
17,390	732.05	732.35	732.60	732.85	733.04	733.26	733.59	733.76	734.20	734.53	734.73	734.98	735.15
17,252	731.91	732.16	732.42	732.75	732.96	733.21	733.56	733.74	734.19	734.53	734.73	734.97	735.15
17,127	731.91	732.17	732.42	732.73	732.94	733.20	733.55	733.74	734.18	734.52	734.72	734.97	735.15

Table E-3 Computed flood frequency water levels - Camrose Creek (continued)

River Station (m)	Water Surface Elevation for various Flood Return Periods (m)												
	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
16,965	731.88	732.11	732.34	732.67	732.88	733.16	733.53	733.72	734.18	734.52	734.72	734.97	735.14
16,803	731.87	732.11	732.34	732.67	732.88	733.15	733.53	733.71	734.17	734.51	734.72	734.96	735.14
16,684	731.87	732.09	732.31	732.64	732.86	733.14	733.52	733.71	734.17	734.51	734.71	734.96	735.14
16,648	731.85	732.04	732.23	732.54	732.74	733.03	733.40	733.66	734.16	734.51	734.71	734.96	735.14
16,632	731.81	732.01	732.17	732.46	732.63	732.87	733.20	733.43	734.13	734.49	734.70	734.95	735.13
16,570	731.80	731.99	732.14	732.44	732.62	732.87	733.21	733.45	734.12	734.49	734.70	734.95	735.13
16,416	731.77	731.94	732.04	732.36	732.53	732.81	733.18	733.42	734.11	734.48	734.69	734.94	735.12
16,317	731.77	731.94	732.04	732.36	732.53	732.81	733.18	733.42	734.11	734.48	734.69	734.94	735.12
16,270	731.08	731.42	731.84	732.35	732.51	732.80	733.17	733.41	734.11	734.47	734.68	734.93	735.11
16,124	730.99	731.32	731.79	732.32	732.48	732.78	733.15	733.40	734.10	734.47	734.68	734.93	735.11
15,979	730.94	731.27	731.75	732.29	732.45	732.75	733.13	733.38	734.09	734.46	734.67	734.92	735.10
15,837	730.88	731.20	731.71	732.27	732.42	732.72	733.12	733.37	734.09	734.45	734.67	734.92	735.10
15,779	730.83	731.10	731.59	732.16	732.33	732.69	733.11	733.37	734.08	734.45	734.66	734.92	735.10
15,763	730.74	731.00	731.44	732.01	732.29	732.65	733.10	733.36	734.08	734.45	734.66	734.92	735.10
15,704	730.66	730.95	731.47	732.07	732.33	732.66	733.10	733.36	734.08	734.45	734.66	734.92	735.10
15,536	730.56	730.86	731.44	732.07	732.32	732.65	733.09	733.36	734.08	734.45	734.66	734.92	735.10
15,440	730.47	730.75	731.36	732.05	732.31	732.65	733.09	733.36	734.08	734.45	734.66	734.92	735.10
15,415	730.42	730.72	731.33	732.01	732.29	732.65	733.09	733.36	734.08	734.45	734.66	734.92	735.10
15,286	730.38	730.70	731.33	732.01	732.29	732.64	733.09	733.35	734.08	734.45	734.66	734.92	735.10
15,125	730.36	730.69	731.33	732.01	732.29	732.64	733.09	733.35	734.08	734.45	734.66	734.92	735.10
14,915	730.35	730.68	731.33	732.01	732.29	732.64	733.09	733.35	734.08	734.45	734.66	734.92	735.10
14,760	730.33	730.66	731.33	732.01	732.29	732.64	733.09	733.35	734.08	734.45	734.66	734.92	735.10
14,575	730.31	730.64	731.32	732.00	732.29	732.64	733.09	733.35	734.08	734.45	734.66	734.92	735.10
14,527	730.30	730.64	731.32	732.00	732.29	732.64	733.09	733.35	734.08	734.45	734.66	734.92	735.10
14,517	730.21	730.64	731.32	732.00	732.29	732.64	733.09	733.35	734.08	734.45	734.66	734.91	735.09
14,452	730.20	730.63	731.32	732.00	732.29	732.64	733.09	733.35	734.08	734.45	734.66	734.91	735.09

Table E-3 Computed flood frequency water levels - Camrose Creek (continued)

River Station (m)	Water Surface Elevation for various Flood Return Periods (m)												
	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
14,376	730.20	730.63	731.32	732.00	732.29	732.64	733.09	733.35	734.08	734.45	734.66	734.91	735.09
14,167	730.18	730.62	731.31	732.00	732.28	732.64	733.08	733.35	734.07	734.44	734.66	734.91	735.09
14,014	730.17	730.60	731.31	731.99	732.28	732.63	733.08	733.35	734.07	734.44	734.65	734.91	735.09
13,944	730.13	730.54	731.25	731.96	732.25	732.62	733.08	733.34	734.07	734.44	734.65	734.91	735.09
13,921	730.02	730.50	731.12	731.81	732.21	732.61	733.07	733.34	734.07	734.44	734.65	734.91	735.09
13,847	729.89	730.44	731.09	731.79	732.20	732.60	733.06	733.33	734.07	734.44	734.65	734.91	735.09
13,768	729.81	730.40	731.07	731.79	732.19	732.59	733.06	733.33	734.07	734.44	734.65	734.91	735.09
13,678	729.77	730.38	731.06	731.78	732.19	732.59	733.06	733.33	734.06	734.44	734.65	734.90	735.09
13,567	729.73	730.35	731.04	731.77	732.18	732.59	733.06	733.33	734.06	734.43	734.65	734.90	735.08
13,560	729.73	730.35	731.04	731.77	732.18	732.58	733.06	733.33	734.06	734.43	734.65	734.90	735.08
13,502	729.71	730.34	731.03	731.77	732.18	732.58	733.05	733.33	734.06	734.43	734.65	734.90	735.08
13,457	729.68	730.31	731.01	731.74	732.15	732.55	733.03	733.30	734.04	734.41	734.62	734.88	735.06
13,416	729.62	729.93	730.37	730.68	730.87	730.95	731.03	731.07	731.16	731.20	731.22	731.24	731.25
13,396	729.59	729.88	730.32	730.65	730.85	730.94	731.02	731.06	731.15	731.19	731.21	731.23	731.24
13,386	729.57	729.84	730.26	730.63	730.84	730.93	731.01	731.05	731.14	731.18	731.20	731.22	731.23
13,372	729.48	729.78	730.06	730.39	730.78	730.88	730.97	731.00	731.10	731.14	731.15	731.18	731.19
13,266	729.27	729.69	729.99	730.33	730.74	730.83	730.92	730.95	731.05	731.09	731.10	731.12	731.13
13,148	729.13	729.60	729.91	730.29	730.72	730.81	730.90	730.93	731.03	731.07	731.08	731.10	731.11
13,143	729.11	729.56	729.89	730.28	730.72	730.81	730.90	730.93	731.03	731.07	731.07	731.10	731.11
13,066	728.99	729.48	729.84	730.26	730.71	730.80	730.89	730.92	731.02	731.05	731.06	731.08	731.09
13,060	728.93	729.41	729.82	730.26	730.71	730.80	730.88	730.92	731.01	731.05	731.06	731.08	731.09
13,007	728.83	729.34	729.79	730.23	730.70	730.79	730.87	730.91	731.00	731.04	731.04	731.06	731.07
13,003	728.82	729.32	729.77	730.23	730.69	730.78	730.87	730.90	730.99	731.03	731.04	731.06	731.07
12,933	728.71	729.25	729.74	730.21	730.68	730.77	730.85	730.89	730.98	731.01	731.02	731.04	731.05
12,929	728.70	729.24	729.73	730.20	730.68	730.77	730.85	730.88	730.97	731.01	731.02	731.04	731.05
12,822	728.68	729.23	729.73	730.20	730.68	730.76	730.85	730.88	730.97	731.00	731.01	731.03	731.04

Table E-3 Computed flood frequency water levels - Camrose Creek (continued)

River Station (m)	Water Surface Elevation for various Flood Return Periods (m)												
	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
12,767	724.45	729.17	729.67	730.15	730.64	730.72	730.80	730.83	730.91	730.95	730.95	730.97	730.98
12,736	724.42	728.90	729.13	729.35	729.52	729.61	729.72	729.77	729.88	729.93	729.95	729.97	729.99
12,639	724.45	728.93	729.17	729.40	729.58	729.68	729.78	729.84	729.96	730.00	730.03	730.06	730.07
12,429	724.42	728.92	729.16	729.40	729.57	729.68	729.78	729.83	729.95	730.00	730.03	730.05	730.07
12,198	724.45	728.92	729.16	729.40	729.57	729.67	729.78	729.83	729.95	730.00	730.02	730.05	730.07
11,983	724.42	728.92	729.16	729.40	729.57	729.67	729.78	729.83	729.95	730.00	730.02	730.05	730.07
11,859	724.45	728.92	729.16	729.40	729.57	729.67	729.78	729.83	729.95	730.00	730.02	730.05	730.07
11,770	724.42	728.92	729.16	729.39	729.56	729.66	729.77	729.82	729.94	729.99	730.01	730.04	730.06
11,756	724.45	728.92	729.16	729.39	729.56	729.66	729.76	729.81	729.93	729.98	730.00	730.03	730.05
11,705	724.42	728.92	729.16	729.39	729.57	729.66	729.77	729.82	729.94	729.99	730.01	730.04	730.05
11,591	724.45	728.92	729.16	729.39	729.57	729.66	729.77	729.82	729.94	729.98	730.01	730.04	730.05
11,544	724.42	728.88	729.10	729.30	729.45	729.54	729.63	729.67	729.77	729.80	729.82	729.83	729.84
11,498	724.45	728.87	729.08	729.28	729.43	729.51	729.60	729.64	729.74	729.77	729.79	729.80	729.81
11,447	724.42	728.88	729.10	729.31	729.47	729.56	729.66	729.70	729.81	729.85	729.87	729.88	729.90
11,394	724.45	728.87	729.07	729.27	729.42	729.50	729.58	729.63	729.74	729.77	729.79	729.81	729.83
11,382	724.42	728.60	728.73	728.86	728.95	729.00	729.06	729.10	729.17	729.21	729.22	729.24	729.26
11,367	724.45	724.91	725.36	725.79	726.13	726.32	726.53	726.63	726.89	727.02	727.09	727.16	727.22
11,339	724.42	724.84	725.30	725.74	726.09	726.29	726.49	726.60	726.86	726.99	727.06	727.14	727.19
11,302	724.45	724.65	725.05	725.44	725.74	725.92	726.09	726.18	726.41	726.51	726.57	726.64	726.68
11,279	724.42	724.35	724.69	724.84	724.88	724.97	725.10	725.16	725.32	725.40	725.44	725.48	725.52
11,230	724.45	724.36	724.78	725.01	725.15	725.22	725.30	725.34	725.43	725.47	725.49	725.52	725.55
11,164	724.42	724.32	724.74	724.98	725.12	725.18	725.27	725.30	725.38	725.42	725.45	725.48	725.50
11,132	724.45	724.21	724.68	724.90	725.05	725.12	725.21	725.24	725.33	725.37	725.40	725.43	725.46
11,127	724.42	724.20	724.66	724.87	725.02	725.10	725.18	725.22	725.31	725.35	725.38	725.41	725.44
11,092	724.45	724.15	724.64	724.86	725.01	725.08	725.17	725.21	725.30	725.34	725.37	725.40	725.42
11,033	724.42	724.10	724.61	724.84	724.99	725.06	725.15	725.18	725.27	725.31	725.34	725.37	725.40

Table E-3 Computed flood frequency water levels - Camrose Creek (continued)

River Station (m)	Water Surface Elevation for various Flood Return Periods (m)												
	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
10,941	723.34	724.04	724.57	724.79	724.91	724.98	725.07	725.10	725.18	725.22	725.25	725.28	725.31
10,923	723.29	723.77	724.03	724.27	724.45	724.55	724.70	724.75	724.90	724.97	725.01	725.06	725.08
10,845	723.20	723.68	723.97	724.23	724.42	724.53	724.67	724.72	724.88	724.96	725.00	725.04	725.08
10,724	723.04	723.56	723.85	724.12	724.32	724.44	724.58	724.64	724.81	724.89	724.93	724.98	725.01
10,639	722.91	723.46	723.78	724.06	724.27	724.39	724.54	724.60	724.78	724.85	724.90	724.95	724.98
10,635	722.91	723.44	723.77	724.05	724.26	724.39	724.54	724.59	724.77	724.85	724.89	724.94	724.98
10,566	722.85	723.39	723.72	724.02	724.23	724.36	724.51	724.57	724.75	724.83	724.88	724.92	724.96
10,500	722.78	723.28	723.58	723.85	724.05	724.16	724.30	724.35	724.51	724.59	724.63	724.67	724.70
10,474	722.71	723.15	723.39	723.57	723.69	723.75	723.81	723.84	723.92	723.95	723.96	723.99	724.00
10,432	722.59	723.07	723.31	723.52	723.65	723.73	723.80	723.84	723.94	723.98	724.00	724.03	724.05
10,281	722.14	722.70	722.88	722.98	723.08	723.15	723.22	723.26	723.36	723.40	723.43	723.45	723.47
10,113	721.65	722.17	722.47	722.74	723.00	723.09	723.18	723.23	723.34	723.38	723.41	723.44	723.46
10,105	721.60	722.10	722.43	722.73	722.99	723.09	723.18	723.22	723.34	723.38	723.41	723.43	723.46
10,062	721.40	722.05	722.42	722.72	722.99	723.08	723.17	723.22	723.33	723.38	723.40	723.43	723.45
10,055	721.39	722.05	722.41	722.72	722.98	723.08	723.17	723.22	723.33	723.37	723.40	723.43	723.45
10,019	721.36	722.00	722.34	722.63	722.91	723.00	723.08	723.13	723.23	723.27	723.30	723.32	723.34
9,938	721.24	721.83	722.20	722.53	722.84	722.93	723.01	723.06	723.15	723.19	723.22	723.24	723.26
9,744	720.57	721.14	721.71	722.35	722.74	722.84	722.92	722.96	723.06	723.09	723.12	723.14	723.16
9,603	720.38	720.96	721.71	722.35	722.74	722.83	722.91	722.96	723.05	723.08	723.11	723.13	723.15
9,410	720.05	720.71	721.64	722.32	722.71	722.81	722.88	722.92	723.01	723.05	723.07	723.08	723.11
9,329	719.89	720.65	721.63	722.31	722.69	722.79	722.86	722.90	722.98	723.02	723.04	723.05	723.07
9,311	719.86	720.49	721.21	721.48	721.62	721.70	721.77	721.80	721.90	721.93	721.95	721.97	722.00
9,190	719.81	720.40	721.18	721.44	721.59	721.66	721.73	721.76	721.86	721.89	721.90	721.93	721.95
9,044	719.38	720.10	721.15	721.41	721.55	721.63	721.69	721.72	721.81	721.84	721.85	721.88	721.90
8,891	718.90	720.00	721.13	721.40	721.54	721.61	721.67	721.70	721.79	721.82	721.83	721.85	721.88
8,857	718.84	719.98	721.12	721.38	721.52	721.59	721.65	721.67	721.76	721.78	721.80	721.82	721.84

Table E-3 Computed flood frequency water levels - Camrose Creek (continued)

River Station (m)	Water Surface Elevation for various Flood Return Periods (m)												
	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
8,829	718.61	719.06	719.33	719.54	719.68	719.76	719.84	719.88	719.98	720.02	720.04	720.06	720.08
8,782	718.38	718.86	719.13	719.30	719.42	719.48	719.54	719.58	719.65	719.69	719.71	719.73	719.75
8,656	717.91	718.55	718.87	719.09	719.23	719.31	719.39	719.43	719.53	719.57	719.59	719.62	719.64
8,497	717.54	718.19	718.52	718.73	718.85	718.91	718.98	719.01	719.10	719.14	719.16	719.18	719.20
8,319	717.34	717.84	718.15	718.32	718.45	718.52	718.61	718.66	718.77	718.82	718.85	718.88	718.90
8,259	717.25	717.75	718.10	718.27	718.39	718.46	718.55	718.60	718.71	718.76	718.79	718.82	718.84
8,251	717.22	717.72	718.07	718.24	718.36	718.43	718.52	718.57	718.69	718.74	718.77	718.80	718.82
8,227	717.12	717.67	718.05	718.21	718.33	718.40	718.49	718.53	718.65	718.70	718.73	718.76	718.79
8,165	717.03	717.58	717.96	718.08	718.18	718.24	718.33	718.37	718.49	718.54	718.57	718.60	718.63
8,151	716.97	717.52	717.93	718.05	718.14	718.19	718.27	718.31	718.41	718.45	718.47	718.50	718.52
8,139	716.87	717.38	717.87	717.95	718.01	718.05	718.13	718.17	718.28	718.32	718.35	718.38	718.40
8,134	716.81	717.28	717.50	717.69	717.84	717.92	718.00	718.05	718.16	718.22	718.25	718.29	718.31
8,101	716.68	717.16	717.37	717.58	717.74	717.82	717.92	717.97	718.09	718.15	718.19	718.22	718.25
7,992	716.34	716.87	717.19	717.47	717.66	717.75	717.85	717.90	718.03	718.09	718.13	718.17	718.19
7,909	716.19	716.70	717.01	717.28	717.45	717.53	717.61	717.65	717.76	717.81	717.84	717.87	717.89
7,888	716.13	716.64	716.95	717.22	717.38	717.45	717.53	717.57	717.68	717.73	717.75	717.79	717.81
7,817	715.88	716.40	716.74	717.00	717.14	717.17	717.21	717.23	717.29	717.31	717.33	717.36	717.37
7,687	715.14	715.72	716.05	716.33	716.49	716.58	716.66	716.71	716.81	716.86	716.88	716.91	716.93
7,585	714.78	715.38	715.73	716.08	716.26	716.35	716.45	716.50	716.61	716.66	716.69	716.71	716.73
7,536	714.68	715.30	715.64	716.01	716.18	716.26	716.34	716.39	716.48	716.52	716.54	716.56	716.58
7,526	714.56	715.19	715.51	715.77	715.95	716.04	716.14	716.19	716.31	716.36	716.38	716.41	716.44
7,397	714.34	714.92	715.19	715.41	715.55	715.63	715.71	715.76	715.87	715.92	715.95	715.98	716.01
7,277	714.12	714.63	714.83	715.02	715.18	715.28	715.39	715.44	715.58	715.65	715.68	715.73	715.75
7,083	713.64	714.24	714.55	714.82	715.02	715.14	715.26	715.32	715.47	715.54	715.58	715.63	715.66
6,987	713.30	713.80	714.05	714.22	714.34	714.40	714.47	714.52	714.65	714.71	714.74	714.77	714.79
6,885	712.77	713.32	713.62	713.84	713.97	714.04	714.11	714.15	714.26	714.31	714.34	714.37	714.41

Table E-3 Computed flood frequency water levels - Camrose Creek (continued)

River Station (m)	Water Surface Elevation for various Flood Return Periods (m)												
	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
6,753	712.14	712.68	712.98	713.25	713.43	713.54	713.64	713.70	713.85	713.91	713.96	714.01	714.08
6,528	711.17	711.78	712.14	712.46	712.71	712.86	712.97	713.03	713.19	713.27	713.34	713.41	713.58
6,420	710.76	711.38	711.73	712.05	712.29	712.44	712.57	712.67	712.93	713.04	713.14	713.24	713.47
6,389	710.69	711.31	711.64	711.95	712.17	712.32	712.41	712.48	712.69	712.79	712.88	712.98	713.03
6,376	710.64	711.22	711.51	711.78	711.96	712.10	712.14	712.19	712.32	712.40	712.45	712.50	712.54
6,360	710.60	711.20	711.51	711.79	711.99	712.14	712.20	712.26	712.41	712.49	712.55	712.60	712.64
6,221	709.44	710.02	710.36	710.58	710.76	710.77	711.06	711.10	711.19	711.19	711.19	711.19	711.19
6,051	708.47	709.06	709.41	709.70	709.90	710.02	710.13	710.19	710.35	710.42	710.46	710.50	710.53
5,901	708.13	708.63	708.95	709.22	709.40	709.50	709.61	709.66	709.81	709.87	709.90	709.94	709.97
5,801	707.77	708.31	708.63	708.88	709.05	709.15	709.25	709.31	709.47	709.53	709.56	709.59	709.61
5,660	707.12	707.67	707.97	708.21	708.36	708.46	708.56	708.60	708.70	708.75	708.77	708.81	708.83
5,531	706.64	707.26	707.59	707.86	708.04	708.14	708.26	708.31	708.43	708.48	708.51	708.55	708.57
5,403	706.36	707.00	707.30	707.55	707.72	707.81	707.92	707.96	708.07	708.12	708.15	708.18	708.20
5,316	706.20	706.82	707.11	707.37	707.53	707.63	707.73	707.78	707.90	707.95	707.98	708.01	708.03
5,175	705.60	706.00	706.26	706.41	706.53	706.59	706.66	706.69	706.78	706.83	706.85	706.88	706.90
5,077	704.26	704.78	705.04	705.26	705.41	705.49	705.59	705.64	705.78	705.84	705.87	705.94	705.97
4,910	703.55	704.09	704.43	704.71	704.92	705.03	705.15	705.21	705.36	705.44	705.48	705.58	705.61
4,819	703.21	703.74	704.08	704.33	704.50	704.59	704.69	704.74	704.86	704.91	704.94	704.98	705.00
4,631	702.42	703.03	703.32	703.57	703.74	703.83	703.93	703.98	704.10	704.16	704.19	704.23	704.26
4,522	701.99	702.60	702.94	703.19	703.36	703.45	703.55	703.60	703.72	703.77	703.80	703.84	703.86
4,422	701.69	702.31	702.66	702.91	703.07	703.15	703.23	703.28	703.38	703.43	703.45	703.48	703.50
4,316	701.37	702.00	702.37	702.64	702.82	702.91	703.00	703.05	703.16	703.21	703.24	703.27	703.29
4,221	701.05	701.69	702.07	702.33	702.49	702.58	702.66	702.70	702.79	702.83	702.85	702.88	702.90
4,089	700.50	701.13	701.51	701.72	701.83	701.89	701.96	702.00	702.10	702.15	702.18	702.22	702.24
3,950	699.90	700.57	700.96	701.26	701.46	701.56	701.66	701.72	701.85	701.91	701.95	701.99	702.02
3,770	699.37	700.04	700.46	700.76	700.95	701.05	701.16	701.22	701.35	701.40	701.44	701.48	701.51

Table E-3 Computed flood frequency water levels - Camrose Creek (continued)

River Station (m)	Water Surface Elevation for various Flood Return Periods (m)												
	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
3,674	699.07	699.73	700.15	700.44	700.62	700.72	700.83	700.90	701.01	701.06	701.09	701.13	701.16
3,496	698.56	699.33	699.75	700.07	700.31	700.44	700.58	700.64	700.81	700.88	700.93	700.98	701.05
3,382	698.34	699.15	699.55	699.86	700.10	700.24	700.38	700.44	700.60	700.67	700.72	700.78	700.86
3,358	698.29	699.12	699.51	699.83	700.08	700.22	700.37	700.42	700.58	700.66	700.71	700.76	700.84
3,298	698.23	699.11	699.52	699.85	700.10	700.24	700.38	700.44	700.60	700.67	700.72	700.78	700.86
3,287	698.02	698.85	699.30	699.67	699.96	700.12	700.29	700.36	700.54	700.63	700.69	700.75	700.84
3,207	697.90	698.73	699.16	699.51	699.79	699.95	700.12	700.20	700.40	700.50	700.56	700.64	700.74
3,096	697.72	698.56	698.95	699.26	699.53	699.69	699.86	699.92	700.11	700.20	700.27	700.35	700.48
2,986	697.51	698.35	698.81	699.23	699.56	699.74	699.92	699.99	700.20	700.30	700.36	700.45	700.57
2,901	697.41	698.24	698.67	699.09	699.44	699.63	699.82	699.88	700.09	700.20	700.27	700.36	700.49
2,896	697.41	698.23	698.59	698.89	699.08	699.18	699.29	699.33	699.43	699.47	699.50	699.53	699.56
2,808	697.32	698.11	698.44	698.73	698.91	699.00	699.13	699.17	699.25	699.29	699.31	699.34	699.36
2,651	697.03	697.77	698.06	698.32	698.49	698.59	698.68	698.73	698.86	698.92	698.95	698.99	699.02
2,525	696.63	697.45	697.85	698.15	698.35	698.45	698.55	698.61	698.75	698.81	698.85	698.89	698.91
2,381	696.34	697.17	697.57	697.91	698.17	698.28	698.40	698.48	698.64	698.71	698.75	698.79	698.82
2,283	696.22	697.05	697.47	697.81	698.05	698.16	698.29	698.36	698.52	698.60	698.64	698.68	698.71
2,060	695.87	696.69	697.19	697.57	697.80	697.93	698.08	698.16	698.35	698.43	698.47	698.52	698.55
2,057	695.86	696.69	697.17	697.55	697.78	697.90	698.04	698.13	698.32	698.41	698.45	698.50	698.53
1,967	695.69	696.53	697.01	697.38	697.63	697.76	697.90	697.99	698.19	698.28	698.32	698.38	698.41
1,788	695.57	696.36	696.82	697.17	697.41	697.53	697.68	697.76	697.95	698.05	698.10	698.15	698.19
1,727	695.52	696.30	696.76	697.12	697.36	697.49	697.64	697.73	697.93	698.02	698.07	698.13	698.16
1,596	695.41	696.15	696.59	696.93	697.16	697.28	697.43	697.52	697.73	697.83	697.88	697.94	697.97
1,590	695.39	696.11	696.54	696.87	697.09	697.21	697.33	697.41	697.56	697.64	697.68	697.73	697.75
1,551	695.31	696.01	696.41	696.71	696.92	697.03	697.16	697.23	697.38	697.45	697.49	697.54	697.56
1,485	695.12	695.89	696.32	696.64	696.85	696.96	697.10	697.17	697.31	697.37	697.42	697.46	697.48
1,474	695.02	695.85	696.27	696.59	696.79	696.90	697.02	697.09	697.23	697.29	697.33	697.37	697.39

Table E-3 Computed flood frequency water levels - Camrose Creek (continued)

River Station (m)	Water Surface Elevation for various Flood Return Periods (m)												
	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
1,431	694.96	695.79	696.19	696.47	696.65	696.74	696.84	696.89	697.01	697.06	697.09	697.15	697.17
1,327	694.88	695.72	696.12	696.38	696.55	696.62	696.71	696.77	696.89	696.94	696.97	697.04	697.06
1,221	694.77	695.60	695.98	696.22	696.39	696.46	696.57	696.63	696.76	696.81	696.84	696.91	696.92
1,114	694.65	695.47	695.88	696.13	696.30	696.37	696.47	696.54	696.67	696.72	696.75	696.79	696.81
1,004	694.49	695.28	695.70	695.92	696.05	696.07	696.17	696.21	696.31	696.35	696.36	696.39	696.40
893	694.32	695.13	695.53	695.67	695.70	695.81	695.90	695.94	696.02	696.07	696.09	696.12	696.15
817	694.23	695.05	695.44	695.54	695.72	695.80	695.89	695.93	696.01	696.05	696.08	696.10	696.13
725	694.07	694.88	695.41	695.49	695.66	695.75	695.83	695.88	695.95	695.99	696.01	696.04	696.06
720	694.08	694.83	695.22	695.48	695.65	695.74	695.82	695.87	695.94	695.98	696.00	696.03	696.05
640	693.94	694.64	695.00	695.24	695.40	695.48	695.57	695.61	695.70	695.74	695.78	695.82	695.85
472	693.67	694.31	694.64	694.89	695.07	695.17	695.28	695.34	695.44	695.51	695.57	695.63	695.67
279	693.40	693.93	694.17	694.40	694.59	694.72	694.86	694.96	695.20	695.32	695.41	695.49	695.55
138	693.16	693.79	694.12	694.39	694.61	694.74	694.89	694.98	695.21	695.32	695.41	695.49	695.54
103	693.13	693.70	694.01	694.26	694.48	694.61	694.76	694.85	695.08	695.20	695.28	695.37	695.43
94	693.05	693.56	693.83	693.93	694.05	694.10	694.16	694.19	694.26	694.28	694.30	694.32	694.33
56	692.89	693.25	693.44	693.64	693.87	693.92	693.99	694.02	694.09	694.12	694.14	694.16	694.17
0	692.74	693.14	693.36	693.55	693.76	693.82	693.88	693.92	693.99	694.03	694.05	694.07	694.08

Table E-4 Computed flood frequency water levels - Unnamed Creek

River Station (m)	Water Surface Elevation for various Flood Return Periods (m)												
	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
5,730	746.24	746.36	746.42	746.47	746.51	746.53	746.55	746.57	746.61	746.63	746.65	746.66	746.68
5,032	744.39	744.51	744.59	744.64	744.69	744.71	744.73	744.73	744.75	744.75	744.77	744.80	744.82
4,768	743.83	743.89	743.92	743.95	743.97	743.98	744.00	744.01	744.04	744.06	744.07	744.09	744.10
4,365	742.55	742.69	742.84	742.97	743.05	743.09	743.13	743.14	743.20	743.23	743.23	743.25	743.26
4,118	742.08	742.51	742.57	742.62	742.66	742.66	742.70	742.74	742.77	742.82	742.86	742.88	742.90
4,107	741.79	742.10	742.29	742.44	742.56	742.61	742.68	742.71	742.74	742.80	742.83	742.84	742.86
3,792	740.76	740.91	741.01	741.10	741.16	741.19	741.23	741.25	741.40	741.42	741.45	741.51	741.53
3,247	739.57	739.79	740.06	740.72	740.80	740.81	740.83	740.85	740.88	740.89	740.91	740.92	740.94
2,378	739.12	739.49	739.92	740.69	740.77	740.77	740.79	740.81	740.83	**<u>740.83</u>**	740.83	740.84	740.85
2,358	738.68	738.80	738.89	738.97	739.02	739.06	739.10	739.13	739.18	739.23	739.26	739.29	739.31
2,081	738.42	738.57	738.66	738.75	738.83	738.87	738.93	738.96	739.04	739.10	739.14	739.19	739.22
1,877	738.25	738.43	738.54	738.66	738.75	738.79	738.85	738.89	738.97	739.04	739.07	739.12	739.15
1,737	737.74	737.98	738.13	738.26	738.36	738.42	738.48	738.52	738.61	738.68	738.72	738.77	738.80
1,483	736.78	736.98	737.08	737.17	737.23	737.27	737.31	737.34	737.40	737.46	737.49	737.52	737.54
1,227	735.75	736.02	736.18	736.30	736.39	736.44	736.51	736.54	736.64	736.70	736.74	736.80	736.86
1,066	734.92	735.17	735.32	735.44	735.52	735.57	735.63	735.66	735.73	735.88	735.93	**<u>736.01</u>**	**<u>736.10</u>**
877	734.27	734.52	734.66	734.77	734.85	734.90	734.95	734.98	735.06	**<u>735.06</u>**	735.06	735.16	735.27
702	733.37	733.57	733.69	733.79	733.86	733.90	733.95	733.98	734.03	734.39	734.63	734.90	735.08

<u>*Bold and underline values are manually adjusted to avoid crossing profiles.</u>

nhc

Appendix F
Sensitivity Analysis Results

Table F-1 Sensitivity analysis results for flood frequency estimates

River Station (m)	100-Year Flood Levels (m) for Varying Flood Frequency Estimates		
	95% Lower Limit of Flood Frequency Estimates	Adopted Flood Frequency Estimates	95% Upper Limit of Flood Frequency Estimates
Camrose Creek			
18,827	733.90	734.21	734.61
18,745	733.90	734.21	734.61
18,700	733.87	734.18	734.61
18,688	733.68	734.09	734.60
18,621	733.71	734.12	734.60
18,486	733.71	734.12	734.60
18,311	733.70	734.12	734.60
18,307	733.70	734.12	734.60
18,247	733.69	734.11	734.60
18,198	733.69	734.11	734.60
18,190	733.68	734.11	734.60
18,146	733.68	734.11	734.60
18,092	733.67	734.10	734.60
18,087	733.67	734.10	734.60
18,033	733.66	734.10	734.60
17,993	733.66	734.10	734.59
17,988	733.66	734.10	734.59
17,933	733.66	734.10	734.59
17,811	733.66	734.10	734.59
17,679	733.65	734.09	734.59
17,570	733.64	734.09	734.59
17,503	733.42	733.90	734.58
17,480	733.32	733.72	734.54
17,390	733.31	733.76	734.54
17,252	733.26	733.74	734.53
17,127	733.25	733.74	734.53
16,965	733.21	733.72	734.53
16,803	733.21	733.71	734.52
16,684	733.19	733.71	734.52
16,648	733.08	733.66	734.52
16,632	732.89	733.43	734.51
16,570	732.90	733.45	734.50
16,416	732.83	733.42	734.50
16,317	732.84	733.42	734.50
16,270	732.82	733.41	734.49

Table F-1 Sensitivity analysis results for flood frequency estimates (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Flood Frequency Estimates		
	95% Lower Limit of Flood Frequency Estimates	Adopted Flood Frequency Estimates	95% Upper Limit of Flood Frequency Estimates
Camrose Creek			
16,124	732.80	733.40	734.49
15,979	732.77	733.38	734.48
15,837	732.74	733.37	734.48
15,779	732.71	733.37	734.48
15,763	732.67	733.36	734.53
15,704	732.67	733.36	734.53
15,536	732.67	733.36	734.53
15,440	732.66	733.36	734.53
15,415	732.66	733.36	734.53
15,286	732.66	733.35	734.53
15,125	732.66	733.35	734.53
14,915	732.66	733.35	734.53
14,760	732.66	733.35	734.53
14,575	732.65	733.35	734.52
14,527	732.65	733.35	734.52
14,517	732.65	733.35	734.52
14,452	732.65	733.35	734.52
14,376	732.65	733.35	734.52
14,167	732.65	733.35	734.52
14,014	732.65	733.35	734.52
13,944	732.63	733.34	734.52
13,921	732.62	733.34	734.52
13,847	732.60	733.33	734.52
13,768	732.60	733.33	734.52
13,678	732.60	733.33	734.51
13,567	732.59	733.33	734.51
13,560	732.59	733.33	734.51
13,502	732.59	733.33	734.51
13,457	732.56	733.30	734.49
13,416	730.95	731.07	731.20
13,396	730.94	731.06	731.19
13,386	730.93	731.05	731.18
13,372	730.88	731.00	731.14
13,266	730.83	730.95	731.08
13,148	730.81	730.93	731.07
13,143	730.81	730.93	731.06

Table F-1 Sensitivity analysis results for flood frequency estimates (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Flood Frequency Estimates		
	95% Lower Limit of Flood Frequency Estimates	Adopted Flood Frequency Estimates	95% Upper Limit of Flood Frequency Estimates
Camrose Creek			
13,066	730.80	730.92	731.05
13,060	730.80	730.92	731.05
13,007	730.78	730.91	731.03
13,003	730.78	730.90	731.03
12,933	730.77	730.89	731.01
12,929	730.77	730.88	731.01
12,822	730.76	730.88	731.00
12,767	730.71	730.83	730.94
12,736	729.62	729.77	729.94
12,639	729.68	729.84	730.02
12,429	729.68	729.83	730.01
12,198	729.67	729.83	730.01
11,983	729.67	729.83	730.01
11,859	729.67	729.83	730.01
11,770	729.66	729.82	730.00
11,756	729.66	729.81	729.99
11,705	729.67	729.82	730.00
11,591	729.67	729.82	730.00
11,544	729.54	729.67	729.81
11,498	729.51	729.64	729.78
11,447	729.56	729.70	729.85
11,394	729.50	729.63	729.78
11,382	729.01	729.10	729.21
11,367	726.33	726.63	727.04
11,339	726.29	726.60	727.02
11,302	725.92	726.18	726.54
11,279	724.97	725.16	725.41
11,230	725.22	725.34	725.48
11,164	725.19	725.30	725.44
11,132	725.12	725.24	725.39
11,127	725.10	725.22	725.36
11,092	725.09	725.21	725.35
11,033	725.06	725.18	725.33
10,941	724.98	725.10	725.24
10,923	724.55	724.75	724.99
10,845	724.53	724.72	724.97

Table F-1 Sensitivity analysis results for flood frequency estimates (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Flood Frequency Estimates		
	95% Lower Limit of Flood Frequency Estimates	Adopted Flood Frequency Estimates	95% Upper Limit of Flood Frequency Estimates
Camrose Creek			
10,724	724.44	724.64	724.91
10,639	724.40	724.60	724.87
10,635	724.39	724.59	724.87
10,566	724.36	724.57	724.85
10,500	724.16	724.35	724.60
10,474	723.75	723.84	723.95
10,432	723.73	723.84	723.99
10,281	723.15	723.26	723.41
10,113	723.09	723.23	723.40
10,105	723.09	723.22	723.39
10,062	723.09	723.22	723.39
10,055	723.08	723.22	723.39
10,019	723.00	723.13	723.28
9,938	722.93	723.06	723.20
9,744	722.84	722.96	723.11
9,603	722.84	722.96	723.10
9,410	722.81	722.92	723.06
9,329	722.79	722.90	723.03
9,311	721.70	721.80	721.95
9,190	721.66	721.76	721.90
9,044	721.62	721.72	721.85
8,891	721.61	721.70	721.83
8,857	721.59	721.67	721.80
8,829	719.76	719.88	720.03
8,782	719.48	719.58	719.70
8,656	719.31	719.43	719.58
8,497	718.91	719.01	719.15
8,319	718.52	718.66	718.83
8,259	718.46	718.60	718.77
8,251	718.44	718.57	718.75
8,227	718.40	718.53	718.71
8,165	718.24	718.37	718.55
8,151	718.19	718.31	718.46
8,139	718.05	718.17	718.33
8,134	717.92	718.05	718.23
8,101	717.83	717.97	718.17

Table F-1 Sensitivity analysis results for flood frequency estimates (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Flood Frequency Estimates		
	95% Lower Limit of Flood Frequency Estimates	Adopted Flood Frequency Estimates	95% Upper Limit of Flood Frequency Estimates
Camrose Creek			
7,992	717.75	717.90	718.11
7,909	717.53	717.65	717.82
7,888	717.45	717.57	717.74
7,817	717.17	717.23	717.32
7,687	716.58	716.71	716.87
7,585	716.36	716.50	716.67
7,536	716.26	716.39	716.53
7,526	716.05	716.19	716.37
7,397	715.63	715.76	715.93
7,277	715.28	715.44	715.66
7,083	715.14	715.32	715.56
6,987	714.40	714.52	714.72
6,885	714.04	714.15	714.32
6,753	713.54	713.70	713.93
6,528	712.86	713.03	713.29
6,420	712.45	712.67	713.06
6,389	712.32	712.48	712.80
6,376	712.10	712.19	712.40
6,360	712.15	712.26	712.50
6,221	710.77	711.10	711.19
6,051	710.02	710.19	710.42
5,901	709.51	709.66	709.88
5,801	709.15	709.31	709.53
5,660	708.46	708.60	708.75
5,531	708.15	708.31	708.48
5,403	707.82	707.96	708.13
5,316	707.64	707.78	707.95
5,175	706.59	706.69	706.83
5,077	705.50	705.64	705.84
4,910	705.04	705.21	705.44
4,819	704.60	704.74	704.92
4,631	703.84	703.98	704.17
4,522	703.46	703.60	703.77
4,422	703.16	703.28	703.43
4,316	702.92	703.05	703.21
4,221	702.58	702.70	702.83

Table F-1 Sensitivity analysis results for flood frequency estimates (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Flood Frequency Estimates		
	95% Lower Limit of Flood Frequency Estimates	Adopted Flood Frequency Estimates	95% Upper Limit of Flood Frequency Estimates
Camrose Creek			
4,089	701.89	702.00	702.16
3,950	701.57	701.72	701.92
3,770	701.06	701.22	701.41
3,674	700.73	700.90	701.06
3,496	700.45	700.64	700.89
3,382	700.25	700.44	700.68
3,358	700.23	700.42	700.66
3,298	700.25	700.44	700.68
3,287	700.14	700.36	700.64
3,207	699.97	700.20	700.51
3,096	699.70	699.92	700.21
2,986	699.75	699.99	700.31
2,901	699.64	699.88	700.21
2,896	699.18	699.33	699.48
2,808	699.01	699.17	699.29
2,651	698.59	698.73	698.92
2,525	698.45	698.61	698.81
2,381	698.29	698.48	698.71
2,283	698.17	698.36	698.60
2,060	697.94	698.16	698.44
2,057	697.91	698.13	698.41
1,967	697.77	697.99	698.28
1,788	697.54	697.76	698.05
1,727	697.50	697.73	698.03
1,596	697.29	697.52	697.83
1,590	697.21	697.41	697.64
1,551	697.04	697.23	697.45
1,485	696.97	697.17	697.38
1,474	696.90	697.09	697.29
1,431	696.75	696.89	697.07
1,327	696.63	696.77	696.95
1,221	696.47	696.63	696.82
1,114	696.37	696.54	696.72
1,004	696.08	696.21	696.35
893	695.82	695.94	696.07
817	695.81	695.93	696.05

Table F-1 Sensitivity analysis results for flood frequency estimates (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Flood Frequency Estimates		
	95% Lower Limit of Flood Frequency Estimates	Adopted Flood Frequency Estimates	95% Upper Limit of Flood Frequency Estimates
Camrose Creek			
725	695.75	695.88	695.99
720	695.74	695.87	695.98
640	695.49	695.61	695.75
472	695.18	695.34	695.51
279	694.73	694.96	695.33
138	694.75	694.98	695.33
103	694.62	694.85	695.20
94	694.11	694.19	694.29
56	693.94	694.02	694.12
0	693.83	693.92	694.03
Average Difference	-0.27	0.00	0.39
Max Difference	-0.74	0.00	1.19
Unnamed Creek			
5,730	746.54	746.57	746.61
5,032	744.72	744.73	744.75
4,768	743.99	744.01	744.04
4,365	743.11	743.14	743.20
4,118	742.68	742.74	742.77
4,107	742.65	742.71	742.74
3,792	741.21	741.25	741.41
3,247	740.82	740.85	740.88
2,378	740.79	740.81	740.81
2,358	739.08	739.13	739.19
2,081	738.90	738.96	739.05
1,877	738.82	738.89	738.97
1,737	738.45	738.52	738.61
1,483	737.28	737.34	737.42
1,227	736.47	736.54	736.63
1,066	735.59	735.66	735.85
877	734.92	734.98	734.96
702	733.92	733.98	734.49
Average Difference	-0.05	0.00	0.09
Max Difference	-0.07	0.00	0.51

Table F-2 Sensitivity analysis results for downstream boundary conditions

River Station (m)	100-Year Flood Levels (m) for Varying Downstream Boundary Condition		
	0.5 m Below Adopted S = 0.0097 m/m	Adopted Normal Depth S= 0.002 m/m	0.5 m Above Adopted S = 0.00053 m/m
Camrose Creek			
18,827	734.21	734.21	734.21
18,745	734.21	734.21	734.21
18,700	734.18	734.18	734.18
18,688	734.09	734.09	734.09
18,621	734.12	734.12	734.12
18,486	734.12	734.12	734.12
18,311	734.12	734.12	734.12
18,307	734.12	734.12	734.12
18,247	734.11	734.11	734.11
18,198	734.11	734.11	734.11
18,190	734.11	734.11	734.11
18,146	734.11	734.11	734.11
18,092	734.10	734.10	734.10
18,087	734.10	734.10	734.10
18,033	734.10	734.10	734.10
17,993	734.10	734.10	734.10
17,988	734.10	734.10	734.10
17,933	734.10	734.10	734.10
17,811	734.10	734.10	734.10
17,679	734.09	734.09	734.09
17,570	734.09	734.09	734.09
17,503	733.90	733.90	733.90
17,480	733.72	733.72	733.72
17,390	733.76	733.76	733.76
17,252	733.74	733.74	733.74
17,127	733.74	733.74	733.74
16,965	733.72	733.72	733.72
16,803	733.71	733.71	733.71
16,684	733.71	733.71	733.71
16,648	733.66	733.66	733.66
16,632	733.43	733.43	733.43
16,570	733.45	733.45	733.45
16,416	733.42	733.42	733.42
16,317	733.42	733.42	733.42

Table F-2 Sensitivity analysis results for downstream boundary conditions (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Downstream Boundary Condition		
	0.5 m Below Adopted S = 0.0097 m/m	Adopted Normal Depth S= 0.002 m/m	0.5 m Above Adopted S = 0.00053 m/m
Camrose Creek			
16,270	733.41	733.41	733.41
16,124	733.40	733.40	733.40
15,979	733.38	733.38	733.38
15,837	733.37	733.37	733.37
15,779	733.37	733.37	733.37
15,763	733.36	733.36	733.36
15,704	733.36	733.36	733.36
15,536	733.36	733.36	733.36
15,440	733.36	733.36	733.36
15,415	733.36	733.36	733.36
15,286	733.35	733.35	733.35
15,125	733.35	733.35	733.35
14,915	733.35	733.35	733.35
14,760	733.35	733.35	733.35
14,575	733.35	733.35	733.35
14,527	733.35	733.35	733.35
14,517	733.35	733.35	733.35
14,452	733.35	733.35	733.35
14,376	733.35	733.35	733.35
14,167	733.35	733.35	733.35
14,014	733.35	733.35	733.35
13,944	733.34	733.34	733.34
13,921	733.34	733.34	733.34
13,847	733.33	733.33	733.33
13,768	733.33	733.33	733.33
13,678	733.33	733.33	733.33
13,567	733.33	733.33	733.33
13,560	733.33	733.33	733.33
13,502	733.33	733.33	733.33
13,457	733.30	733.30	733.30
13,416	731.07	731.07	731.07
13,396	731.06	731.06	731.06
13,386	731.05	731.05	731.05
13,372	731.00	731.00	731.00
13,266	730.95	730.95	730.95
13,148	730.93	730.93	730.93

Table F-2 Sensitivity analysis results for downstream boundary conditions (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Downstream Boundary Condition		
	0.5 m Below Adopted S = 0.0097 m/m	Adopted Normal Depth S= 0.002 m/m	0.5 m Above Adopted S = 0.00053 m/m
Camrose Creek			
13,143	730.93	730.93	730.93
13,066	730.92	730.92	730.92
13,060	730.92	730.92	730.92
13,007	730.91	730.91	730.91
13,003	730.90	730.90	730.90
12,933	730.89	730.89	730.89
12,929	730.88	730.88	730.88
12,822	730.88	730.88	730.88
12,767	730.83	730.83	730.83
12,736	729.77	729.77	729.77
12,639	729.84	729.84	729.84
12,429	729.83	729.83	729.83
12,198	729.83	729.83	729.83
11,983	729.83	729.83	729.83
11,859	729.83	729.83	729.83
11,770	729.82	729.82	729.82
11,756	729.81	729.81	729.81
11,705	729.82	729.82	729.82
11,591	729.82	729.82	729.82
11,544	729.67	729.67	729.67
11,498	729.64	729.64	729.64
11,447	729.70	729.70	729.70
11,394	729.63	729.63	729.63
11,382	729.10	729.10	729.10
11,367	726.63	726.63	726.63
11,339	726.60	726.60	726.60
11,302	726.18	726.18	726.18
11,279	725.16	725.16	725.16
11,230	725.34	725.34	725.34
11,164	725.30	725.30	725.30
11,132	725.24	725.24	725.24
11,127	725.22	725.22	725.22
11,092	725.21	725.21	725.21
11,033	725.18	725.18	725.18
10,941	725.10	725.10	725.10
10,923	724.75	724.75	724.75

Table F-2 Sensitivity analysis results for downstream boundary conditions (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Downstream Boundary Condition		
	0.5 m Below Adopted S = 0.0097 m/m	Adopted Normal Depth S= 0.002 m/m	0.5 m Above Adopted S = 0.00053 m/m
Camrose Creek			
10,845	724.72	724.72	724.72
10,724	724.64	724.64	724.64
10,639	724.60	724.60	724.60
10,635	724.59	724.59	724.59
10,566	724.57	724.57	724.57
10,500	724.35	724.35	724.35
10,474	723.84	723.84	723.84
10,432	723.84	723.84	723.84
10,281	723.26	723.26	723.26
10,113	723.23	723.23	723.23
10,105	723.22	723.22	723.22
10,062	723.22	723.22	723.22
10,055	723.22	723.22	723.22
10,019	723.13	723.13	723.13
9,938	723.06	723.06	723.06
9,744	722.96	722.96	722.96
9,603	722.96	722.96	722.96
9,410	722.92	722.92	722.92
9,329	722.90	722.90	722.90
9,311	721.80	721.80	721.80
9,190	721.76	721.76	721.76
9,044	721.72	721.72	721.72
8,891	721.70	721.70	721.70
8,857	721.67	721.67	721.67
8,829	719.88	719.88	719.88
8,782	719.58	719.58	719.58
8,656	719.43	719.43	719.43
8,497	719.01	719.01	719.01
8,319	718.66	718.66	718.66
8,259	718.60	718.60	718.60
8,251	718.57	718.57	718.57
8,227	718.53	718.53	718.53
8,165	718.37	718.37	718.37
8,151	718.31	718.31	718.31
8,139	718.17	718.17	718.17
8,134	718.05	718.05	718.05

Table F-2 Sensitivity analysis results for downstream boundary conditions (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Downstream Boundary Condition		
	0.5 m Below Adopted S = 0.0097 m/m	Adopted Normal Depth S= 0.002 m/m	0.5 m Above Adopted S = 0.00053 m/m
Camrose Creek			
8,101	717.97	717.97	717.97
7,992	717.90	717.90	717.90
7,909	717.65	717.65	717.65
7,888	717.57	717.57	717.57
7,817	717.23	717.23	717.23
7,687	716.71	716.71	716.71
7,585	716.50	716.50	716.50
7,536	716.39	716.39	716.39
7,526	716.19	716.19	716.19
7,397	715.76	715.76	715.76
7,277	715.44	715.44	715.44
7,083	715.32	715.32	715.32
6,987	714.52	714.52	714.52
6,885	714.15	714.15	714.15
6,753	713.70	713.70	713.70
6,528	713.03	713.03	713.03
6,420	712.67	712.67	712.67
6,389	712.48	712.48	712.48
6,376	712.19	712.19	712.19
6,360	712.26	712.26	712.26
6,221	711.10	711.10	711.10
6,051	710.19	710.19	710.19
5,901	709.66	709.66	709.66
5,801	709.31	709.31	709.31
5,660	708.60	708.60	708.60
5,531	708.31	708.31	708.31
5,403	707.96	707.96	707.96
5,316	707.78	707.78	707.78
5,175	706.69	706.69	706.69
5,077	705.64	705.64	705.64
4,910	705.21	705.21	705.21
4,819	704.74	704.74	704.74
4,631	703.98	703.98	703.98
4,522	703.60	703.60	703.60
4,422	703.28	703.28	703.28
4,316	703.05	703.05	703.05

Table F-2 Sensitivity analysis results for downstream boundary conditions (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Downstream Boundary Condition		
	0.5 m Below Adopted S = 0.0097 m/m	Adopted Normal Depth S= 0.002 m/m	0.5 m Above Adopted S = 0.00053 m/m
Camrose Creek			
4,221	702.70	702.70	702.70
4,089	702.00	702.00	702.00
3,950	701.72	701.72	701.72
3,770	701.22	701.22	701.22
3,674	700.90	700.90	700.90
3,496	700.64	700.64	700.64
3,382	700.44	700.44	700.44
3,358	700.42	700.42	700.42
3,298	700.44	700.44	700.44
3,287	700.36	700.36	700.36
3,207	700.20	700.20	700.20
3,096	699.92	699.92	699.92
2,986	699.99	699.99	699.99
2,901	699.88	699.88	699.88
2,896	699.33	699.33	699.33
2,808	699.17	699.17	699.17
2,651	698.73	698.73	698.73
2,525	698.61	698.61	698.61
2,381	698.48	698.48	698.48
2,283	698.36	698.36	698.36
2,060	698.16	698.16	698.16
2,057	698.13	698.13	698.13
1,967	697.99	697.99	697.99
1,788	697.76	697.76	697.76
1,727	697.73	697.73	697.73
1,596	697.52	697.52	697.52
1,590	697.41	697.41	697.41
1,551	697.23	697.23	697.23
1,485	697.17	697.17	697.17
1,474	697.09	697.09	697.09
1,431	696.89	696.89	696.89
1,327	696.77	696.77	696.77
1,221	696.63	696.63	696.63
1,114	696.54	696.54	696.54
1,004	696.21	696.21	696.21
893	695.94	695.94	695.94

Table F-2 Sensitivity analysis results for downstream boundary conditions (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Downstream Boundary Condition		
	0.5 m Below Adopted S = 0.0097 m/m	Adopted Normal Depth S= 0.002 m/m	0.5 m Above Adopted S = 0.00053 m/m
Camrose Creek			
817	695.93	695.93	695.93
725	695.88	695.88	695.88
720	695.87	695.87	695.87
640	695.61	695.61	695.60
472	695.34	695.34	695.32
279	694.97	694.96	694.88
138	694.99	694.98	694.91
103	694.86	694.85	694.76
94	694.18	694.19	694.45
56	693.86	694.02	694.43
0	693.42	693.92	694.42
Average Difference	0.00	0.00	0.00
Max Difference	-0.50	0.00	0.50
Unnamed Creek			
5,730	746.57	746.57	746.57
5,032	744.73	744.73	744.73
4,768	744.01	744.01	744.01
4,365	743.14	743.14	743.14
4,118	742.74	742.74	742.74
4,107	742.71	742.71	742.71
3,792	741.25	741.25	741.25
3,247	740.85	740.85	740.85
2,378	740.81	740.81	740.81
2,358	739.13	739.13	739.13
2,081	738.96	738.96	738.96
1,877	738.89	738.89	738.89
1,737	738.52	738.52	738.52
1,483	737.34	737.34	737.34
1,227	736.54	736.54	736.54
1,066	735.66	735.66	735.66
877	734.98	734.98	734.98
702	733.98	733.98	733.98
Average Difference	0.00	0.00	0.00
Max Difference	0.00	0.00	0.00

Table F-3 Sensitivity analysis results for channel roughness

River Station (m)	100-Year Flood Levels (m) for Varying Channel Roughness		
	Low Channel Roughness (-20%)	Adopted Roughness	High Channel Roughness (+20%)
Camrose Creek			
18,827	734.18	734.21	734.24
18,745	734.18	734.21	734.24
18,700	734.12	734.18	734.22
18,688	734.02	734.09	734.17
18,621	734.06	734.12	734.18
18,486	734.06	734.12	734.18
18,311	734.06	734.12	734.18
18,307	734.06	734.12	734.18
18,247	734.05	734.11	734.18
18,198	734.05	734.11	734.17
18,190	734.05	734.11	734.17
18,146	734.05	734.11	734.17
18,092	734.04	734.10	734.17
18,087	734.04	734.10	734.17
18,033	734.04	734.10	734.17
17,993	734.04	734.10	734.17
17,988	734.04	734.10	734.17
17,933	734.04	734.10	734.17
17,811	734.04	734.10	734.16
17,679	734.03	734.09	734.16
17,570	734.03	734.09	734.16
17,503	733.82	733.90	733.99
17,480	733.69	733.72	733.76
17,390	733.74	733.76	733.79
17,252	733.72	733.74	733.77
17,127	733.72	733.74	733.76
16,965	733.70	733.72	733.75
16,803	733.70	733.71	733.74
16,684	733.69	733.71	733.73
16,648	733.63	733.66	733.70
16,632	733.39	733.43	733.48
16,570	733.41	733.45	733.48
16,416	733.39	733.42	733.45
16,317	733.40	733.42	733.44
16,270	733.38	733.41	733.43

Table F-3 Sensitivity analysis results for channel roughness (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Channel Roughness		
	Low Channel Roughness (-20%)	Adopted Roughness	High Channel Roughness (+20%)
Camrose Creek			
16,124	733.37	733.40	733.42
15,979	733.36	733.38	733.41
15,837	733.35	733.37	733.40
15,779	733.34	733.37	733.39
15,763	733.33	733.36	733.38
15,704	733.33	733.36	733.38
15,536	733.33	733.36	733.38
15,440	733.33	733.36	733.38
15,415	733.33	733.36	733.38
15,286	733.33	733.35	733.38
15,125	733.33	733.35	733.38
14,915	733.33	733.35	733.38
14,760	733.33	733.35	733.38
14,575	733.33	733.35	733.38
14,527	733.33	733.35	733.38
14,517	733.33	733.35	733.37
14,452	733.33	733.35	733.37
14,376	733.33	733.35	733.37
14,167	733.32	733.35	733.37
14,014	733.32	733.35	733.37
13,944	733.32	733.34	733.37
13,921	733.31	733.34	733.36
13,847	733.31	733.33	733.36
13,768	733.31	733.33	733.36
13,678	733.31	733.33	733.35
13,567	733.30	733.33	733.35
13,560	733.30	733.33	733.35
13,502	733.30	733.33	733.35
13,457	733.27	733.30	733.33
13,416	731.05	731.07	731.09
13,396	731.04	731.06	731.08
13,386	731.03	731.05	731.07
13,372	730.98	731.00	731.03
13,266	730.94	730.95	730.97
13,148	730.93	730.93	730.95
13,143	730.92	730.93	730.94

Table F-3 Sensitivity analysis results for channel roughness (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Channel Roughness		
	Low Channel Roughness (-20%)	Adopted Roughness	High Channel Roughness (+20%)
Camrose Creek			
13,066	730.91	730.92	730.93
13,060	730.91	730.92	730.93
13,007	730.90	730.91	730.92
13,003	730.89	730.90	730.91
12,933	730.88	730.89	730.90
12,929	730.87	730.88	730.90
12,822	730.87	730.88	730.89
12,767	730.81	730.83	730.84
12,736	729.74	729.77	729.80
12,639	729.82	729.84	729.85
12,429	729.82	729.83	729.85
12,198	729.82	729.83	729.84
11,983	729.82	729.83	729.84
11,859	729.82	729.83	729.84
11,770	729.81	729.82	729.83
11,756	729.80	729.81	729.83
11,705	729.81	729.82	729.83
11,591	729.81	729.82	729.83
11,544	729.65	729.67	729.69
11,498	729.64	729.64	729.64
11,447	729.70	729.70	729.70
11,394	729.63	729.63	729.63
11,382	729.10	729.10	729.10
11,367	726.51	726.63	726.76
11,339	726.47	726.60	726.72
11,302	726.04	726.18	726.33
11,279	725.16	725.16	725.16
11,230	725.33	725.34	725.37
11,164	725.30	725.30	725.32
11,132	725.23	725.24	725.27
11,127	725.20	725.22	725.26
11,092	725.20	725.21	725.24
11,033	725.18	725.18	725.21
10,941	725.10	725.10	725.13
10,923	724.65	724.75	724.82
10,845	724.66	724.72	724.78

Table F-3 Sensitivity analysis results for channel roughness (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Channel Roughness		
	Low Channel Roughness (-20%)	Adopted Roughness	High Channel Roughness (+20%)
Camrose Creek			
10,724	724.58	724.64	724.69
10,639	724.55	724.60	724.64
10,635	724.54	724.59	724.64
10,566	724.52	724.57	724.61
10,500	724.30	724.35	724.40
10,474	723.73	723.84	723.93
10,432	723.78	723.84	723.89
10,281	723.19	723.26	723.31
10,113	723.19	723.23	723.26
10,105	723.19	723.22	723.26
10,062	723.19	723.22	723.25
10,055	723.18	723.22	723.25
10,019	723.08	723.13	723.17
9,938	723.02	723.06	723.09
9,744	722.95	722.96	722.98
9,603	722.94	722.96	722.97
9,410	722.91	722.92	722.94
9,329	722.90	722.90	722.90
9,311	721.77	721.80	721.84
9,190	721.74	721.76	721.78
9,044	721.70	721.72	721.73
8,891	721.69	721.70	721.71
8,857	721.66	721.67	721.69
8,829	719.70	719.88	720.01
8,782	719.45	719.58	719.67
8,656	719.36	719.43	719.48
8,497	718.90	719.01	719.09
8,319	718.63	718.66	718.70
8,259	718.59	718.60	718.63
8,251	718.55	718.57	718.60
8,227	718.53	718.53	718.57
8,165	718.38	718.37	718.41
8,151	718.33	718.31	718.33
8,139	718.20	718.17	718.21
8,134	717.92	718.05	718.13
8,101	717.87	717.97	718.05

Table F-3 Sensitivity analysis results for channel roughness (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Channel Roughness		
	Low Channel Roughness (-20%)	Adopted Roughness	High Channel Roughness (+20%)
Camrose Creek			
7,992	717.83	717.90	717.97
7,909	717.56	717.65	717.74
7,888	717.50	717.57	717.65
7,817	717.18	717.23	717.27
7,687	716.62	716.71	716.79
7,585	716.36	716.50	716.59
7,536	716.28	716.39	716.47
7,526	716.01	716.19	716.33
7,397	715.67	715.76	715.83
7,277	715.43	715.44	715.46
7,083	715.37	715.32	715.29
6,987	714.56	714.52	714.68
6,885	714.07	714.15	714.24
6,753	713.57	713.70	713.80
6,528	712.92	713.03	713.12
6,420	712.52	712.67	712.80
6,389	712.42	712.48	712.58
6,376	712.06	712.19	712.28
6,360	712.16	712.26	712.33
6,221	711.11	711.10	711.10
6,051	710.05	710.19	710.32
5,901	709.51	709.66	709.80
5,801	709.21	709.31	709.43
5,660	708.42	708.60	708.72
5,531	708.20	708.31	708.38
5,403	707.86	707.96	708.04
5,316	707.69	707.78	707.83
5,175	706.71	706.69	706.73
5,077	705.55	705.64	705.77
4,910	705.08	705.21	705.32
4,819	704.57	704.74	704.87
4,631	703.83	703.98	704.09
4,522	703.45	703.60	703.70
4,422	703.17	703.28	703.36
4,316	702.95	703.05	703.12
4,221	702.62	702.70	702.77

Table F-3 Sensitivity analysis results for channel roughness (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Channel Roughness		
	Low Channel Roughness (-20%)	Adopted Roughness	High Channel Roughness (+20%)
Camrose Creek			
4,089	701.85	702.00	702.10
3,950	701.58	701.72	701.81
3,770	701.06	701.22	701.33
3,674	700.71	700.90	701.00
3,496	700.50	700.64	700.74
3,382	700.31	700.44	700.52
3,358	700.30	700.42	700.49
3,298	700.34	700.44	700.49
3,287	700.24	700.36	700.42
3,207	700.00	700.20	700.30
3,096	699.77	699.92	699.98
2,986	699.86	699.99	700.04
2,901	699.72	699.88	699.94
2,896	699.18	699.33	699.42
2,808	699.03	699.17	699.23
2,651	698.61	698.73	698.82
2,525	698.50	698.61	698.68
2,381	698.34	698.48	698.56
2,283	698.22	698.36	698.46
2,060	697.99	698.16	698.27
2,057	697.94	698.13	698.26
1,967	697.80	697.99	698.12
1,788	697.60	697.76	697.88
1,727	697.57	697.73	697.84
1,596	697.37	697.52	697.63
1,590	697.26	697.41	697.52
1,551	697.05	697.23	697.36
1,485	697.03	697.17	697.26
1,474	696.92	697.09	697.20
1,431	696.74	696.89	697.02
1,327	696.66	696.77	696.86
1,221	696.52	696.63	696.71
1,114	696.45	696.54	696.61
1,004	696.11	696.21	696.31
893	695.90	695.94	695.98
817	695.93	695.93	695.95

Table F-3 Sensitivity analysis results for channel roughness (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Channel Roughness		
	Low Channel Roughness (-20%)	Adopted Roughness	High Channel Roughness (+20%)
Camrose Creek			
725	695.88	695.88	695.89
720	695.87	695.87	695.88
640	695.51	695.61	695.69
472	695.36	695.34	695.38
279	695.22	694.96	694.87
138	695.23	694.98	694.89
103	695.13	694.85	694.75
94	694.07	694.19	694.28
56	693.91	694.02	694.08
0	693.87	693.92	693.95
Average Difference	-0.06	0.00	0.05
Maximum Difference	-0.20	0.00	0.16
Unnamed Creek			
5,730	746.54	746.57	746.59
5,032	744.70	744.73	744.75
4,768	744.00	744.01	744.02
4,365	743.10	743.14	743.17
4,118	742.68	742.74	742.79
4,107	742.61	742.71	742.77
3,792	741.26	741.25	741.26
3,247	740.84	740.85	740.86
2,378	740.81	740.81	740.81
2,358	739.13	739.13	739.13
2,081	738.90	738.96	739.01
1,877	738.81	738.89	738.95
1,737	738.46	738.52	738.58
1,483	737.21	737.34	737.44
1,227	736.48	736.54	736.60
1,066	735.60	735.66	735.75
877	734.90	734.98	735.04
702	733.98	733.98	733.97
Average Difference	-0.04	0.00	0.04
Maximum Difference	-0.13	0.00	0.10

Table F-4 Sensitivity analysis results for overbank roughness

River Station (m)	100-Year Flood Levels (m) for Varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted Roughness	High Overbank Roughness (+20%)
Camrose Creek			
18,827	734.17	734.21	734.24
18,745	734.17	734.21	734.24
18,700	734.13	734.18	734.21
18,688	733.99	734.09	734.16
18,621	734.03	734.12	734.18
18,486	734.03	734.12	734.18
18,311	734.03	734.12	734.18
18,307	734.03	734.12	734.17
18,247	734.03	734.11	734.17
18,198	734.03	734.11	734.17
18,190	734.02	734.11	734.17
18,146	734.02	734.11	734.16
18,092	734.02	734.10	734.16
18,087	734.02	734.10	734.16
18,033	734.02	734.10	734.16
17,993	734.02	734.10	734.16
17,988	734.02	734.10	734.16
17,933	734.02	734.10	734.16
17,811	734.01	734.10	734.15
17,679	734.01	734.09	734.15
17,570	734.01	734.09	734.15
17,503	733.82	733.90	733.97
17,480	733.66	733.72	733.77
17,390	733.70	733.76	733.80
17,252	733.69	733.74	733.78
17,127	733.68	733.74	733.77
16,965	733.67	733.72	733.76
16,803	733.66	733.71	733.75
16,684	733.66	733.71	733.74
16,648	733.62	733.66	733.69
16,632	733.37	733.43	733.49
16,570	733.39	733.45	733.50
16,416	733.37	733.42	733.47
16,317	733.36	733.42	733.47

Table F-4 Sensitivity analysis results for overbank roughness (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted Roughness	High Overbank Roughness (+20%)
Camrose Creek			
16,270	733.35	733.41	733.46
16,124	733.35	733.40	733.45
15,979	733.33	733.38	733.43
15,837	733.32	733.37	733.42
15,779	733.32	733.37	733.41
15,763	733.31	733.36	733.40
15,704	733.31	733.36	733.40
15,536	733.31	733.36	733.40
15,440	733.31	733.36	733.40
15,415	733.31	733.36	733.40
15,286	733.31	733.35	733.39
15,125	733.31	733.35	733.39
14,915	733.31	733.35	733.39
14,760	733.31	733.35	733.39
14,575	733.31	733.35	733.39
14,527	733.31	733.35	733.39
14,517	733.31	733.35	733.39
14,452	733.31	733.35	733.39
14,376	733.31	733.35	733.39
14,167	733.31	733.35	733.39
14,014	733.30	733.35	733.38
13,944	733.30	733.34	733.38
13,921	733.30	733.34	733.38
13,847	733.30	733.33	733.37
13,768	733.29	733.33	733.37
13,678	733.29	733.33	733.36
13,567	733.29	733.33	733.36
13,560	733.29	733.33	733.36
13,502	733.29	733.33	733.36
13,457	733.27	733.30	733.33
13,416	731.03	731.07	731.10
13,396	731.02	731.06	731.09
13,386	731.02	731.05	731.08
13,372	730.98	731.00	731.02
13,266	730.94	730.95	730.96
13,148	730.93	730.93	730.94

Table F-4 Sensitivity analysis results for overbank roughness (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted Roughness	High Overbank Roughness (+20%)
Camrose Creek			
13,143	730.93	730.93	730.94
13,066	730.92	730.92	730.92
13,060	730.92	730.92	730.92
13,007	730.91	730.91	730.90
13,003	730.91	730.90	730.90
12,933	730.90	730.89	730.88
12,929	730.90	730.88	730.88
12,822	730.89	730.88	730.87
12,767	730.85	730.83	730.81
12,736	729.77	729.77	729.76
12,639	729.84	729.84	729.84
12,429	729.83	729.83	729.83
12,198	729.83	729.83	729.83
11,983	729.83	729.83	729.83
11,859	729.83	729.83	729.83
11,770	729.82	729.82	729.82
11,756	729.81	729.81	729.81
11,705	729.82	729.82	729.82
11,591	729.82	729.82	729.82
11,544	729.67	729.67	729.67
11,498	729.64	729.64	729.64
11,447	729.70	729.70	729.70
11,394	729.63	729.63	729.63
11,382	729.10	729.10	729.10
11,367	726.63	726.63	726.64
11,339	726.60	726.60	726.59
11,302	726.19	726.18	726.18
11,279	725.16	725.16	725.16
11,230	725.29	725.34	725.39
11,164	725.25	725.30	725.35
11,132	725.21	725.24	725.29
11,127	725.19	725.22	725.26
11,092	725.18	725.21	725.24
11,033	725.16	725.18	725.21
10,941	725.09	725.10	725.12
10,923	724.69	724.75	724.81

Table F-4 Sensitivity analysis results for overbank roughness (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted Roughness	High Overbank Roughness (+20%)
Camrose Creek			
10,845	724.67	724.72	724.78
10,724	724.59	724.64	724.69
10,639	724.56	724.60	724.65
10,635	724.55	724.59	724.64
10,566	724.54	724.57	724.61
10,500	724.33	724.35	724.39
10,474	723.74	723.84	723.93
10,432	723.76	723.84	723.92
10,281	723.20	723.26	723.32
10,113	723.18	723.23	723.28
10,105	723.18	723.22	723.27
10,062	723.18	723.22	723.27
10,055	723.18	723.22	723.26
10,019	723.09	723.13	723.17
9,938	723.03	723.06	723.09
9,744	722.96	722.96	722.98
9,603	722.95	722.96	722.96
9,410	722.93	722.92	722.93
9,329	722.90	722.90	722.90
9,311	721.78	721.80	721.83
9,190	721.74	721.76	721.79
9,044	721.71	721.72	721.74
8,891	721.70	721.70	721.72
8,857	721.68	721.67	721.69
8,829	719.83	719.88	719.92
8,782	719.50	719.58	719.64
8,656	719.37	719.43	719.49
8,497	718.96	719.01	719.07
8,319	718.56	718.66	718.74
8,259	718.51	718.60	718.68
8,251	718.49	718.57	718.65
8,227	718.45	718.53	718.61
8,165	718.29	718.37	718.45
8,151	718.24	718.31	718.37
8,139	718.07	718.17	718.25
8,134	717.97	718.05	718.12

Table F-4 Sensitivity analysis results for overbank roughness (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted Roughness	High Overbank Roughness (+20%)
Camrose Creek			
8,101	717.89	717.97	718.04
7,992	717.84	717.90	717.96
7,909	717.59	717.65	717.71
7,888	717.49	717.57	717.64
7,817	717.16	717.23	717.29
7,687	716.66	716.71	716.74
7,585	716.49	716.50	716.51
7,536	716.38	716.39	716.39
7,526	716.15	716.19	716.23
7,397	715.68	715.76	715.82
7,277	715.35	715.44	715.53
7,083	715.24	715.32	715.40
6,987	714.48	714.52	714.56
6,885	714.08	714.15	714.23
6,753	713.60	713.70	713.79
6,528	712.95	713.03	713.10
6,420	712.59	712.67	712.76
6,389	712.39	712.48	712.58
6,376	712.09	712.19	712.27
6,360	712.17	712.26	712.33
6,221	711.09	711.10	711.11
6,051	710.12	710.19	710.26
5,901	709.59	709.66	709.72
5,801	709.23	709.31	709.38
5,660	708.55	708.60	708.65
5,531	708.24	708.31	708.36
5,403	707.89	707.96	708.02
5,316	707.71	707.78	707.84
5,175	706.68	706.69	706.71
5,077	705.56	705.64	705.71
4,910	705.16	705.21	705.26
4,819	704.68	704.74	704.79
4,631	703.90	703.98	704.04
4,522	703.54	703.60	703.65
4,422	703.21	703.28	703.33
4,316	702.99	703.05	703.09

Table F-4 Sensitivity analysis results for overbank roughness (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted Roughness	High Overbank Roughness (+20%)
Camrose Creek			
4,221	702.66	702.70	702.73
4,089	701.93	702.00	702.06
3,950	701.66	701.72	701.77
3,770	701.15	701.22	701.27
3,674	700.81	700.90	700.96
3,496	700.59	700.64	700.70
3,382	700.39	700.44	700.50
3,358	700.38	700.42	700.48
3,298	700.39	700.44	700.50
3,287	700.30	700.36	700.43
3,207	700.16	700.20	700.26
3,096	699.89	699.92	699.99
2,986	699.97	699.99	700.06
2,901	699.87	699.88	699.94
2,896	699.29	699.33	699.38
2,808	699.14	699.17	699.21
2,651	698.62	698.73	698.82
2,525	698.51	698.61	698.69
2,381	698.37	698.48	698.56
2,283	698.25	698.36	698.44
2,060	698.05	698.16	698.24
2,057	698.03	698.13	698.20
1,967	697.90	697.99	698.06
1,788	697.67	697.76	697.84
1,727	697.64	697.73	697.80
1,596	697.42	697.52	697.60
1,590	697.33	697.41	697.47
1,551	697.16	697.23	697.29
1,485	697.11	697.17	697.21
1,474	697.03	697.09	697.14
1,431	696.83	696.89	696.95
1,327	696.69	696.77	696.84
1,221	696.53	696.63	696.70
1,114	696.45	696.54	696.61
1,004	696.13	696.21	696.26
893	695.86	695.94	696.00

Table F-4 Sensitivity analysis results for overbank roughness (continued)

River Station (m)	100-Year Flood Levels (m) for Varying Overbank Roughness		
	Low Overbank Roughness (-20%)	Adopted Roughness	High Overbank Roughness (+20%)
Camrose Creek			
817	695.86	695.93	695.99
725	695.81	695.88	695.93
720	695.8	695.87	695.91
640	695.56	695.61	695.65
472	695.30	695.34	695.37
279	694.96	694.96	694.97
138	694.99	694.98	694.99
103	694.88	694.85	694.83
94	694.13	694.19	694.24
56	693.94	694.02	694.08
0	693.84	693.92	693.98
Average Difference	-0.05	0.00	0.04
Maximum Difference	-0.11	0.00	0.10
Unnamed Creek			
5,730	746.56	746.57	746.58
5,032	744.71	744.73	744.76
4,768	743.99	744.01	744.02
4,365	743.12	743.14	743.17
4,118	742.72	742.74	742.74
4,107	742.67	742.71	742.72
3,792	741.29	741.25	741.26
3,247	740.85	740.85	740.86
2,378	740.81	740.81	740.81
2,358	739.13	739.13	739.13
2,081	738.94	738.96	738.98
1,877	738.87	738.89	738.90
1,737	738.50	738.52	738.53
1,483	737.34	737.34	737.34
1,227	736.54	736.54	736.55
1,066	735.64	735.66	735.67
877	734.95	734.98	735.00
702	733.97	733.98	733.98
Average Difference	-0.01	0.00	0.01
Maximum Difference	-0.04	0.00	0.03

Table F-5 Sensitivity analysis results for Roadway Weir Coefficient

River Station (m)	100-Year Flood Levels (m) for Roadway Weir Coefficient	
	High Weir Coefficient (C=1.6)	Adopted Weir Coefficient (C =1.45)
Camrose Creek		
18,827	734.21	734.21
18,745	734.20	734.21
18,700	734.17	734.18
18,688	734.09	734.09
18,621	734.12	734.12
18,486	734.12	734.12
18,311	734.11	734.12
18,307	734.11	734.12
18,247	734.11	734.11
18,198	734.11	734.11
18,190	734.11	734.11
18,146	734.10	734.11
18,092	734.10	734.10
18,087	734.10	734.10
18,033	734.10	734.10
17,993	734.10	734.10
17,988	734.10	734.10
17,933	734.10	734.10
17,811	734.10	734.10
17,679	734.09	734.09
17,570	734.09	734.09
17,503	733.90	733.90
17,480	733.72	733.72
17,390	733.76	733.76
17,252	733.74	733.74
17,127	733.73	733.74
16,965	733.72	733.72
16,803	733.71	733.71
16,684	733.71	733.71
16,648	733.66	733.66
16,632	733.43	733.43
16,570	733.44	733.45
16,416	733.42	733.42
16,317	733.42	733.42
16,270	733.41	733.41

Table F-5 Sensitivity analysis results for Roadway Weir Coefficient (continued)

River Station (m)	100-Year Flood Levels (m) for Roadway Weir Coefficient	
	High Weir Coefficient (C=1.6)	Adopted Weir Coefficient (C =1.45)
Camrose Creek		
16,124	733.40	733.40
15,979	733.38	733.38
15,837	733.37	733.37
15,779	733.36	733.37
15,763	733.36	733.36
15,704	733.36	733.36
15,536	733.35	733.36
15,440	733.35	733.36
15,415	733.35	733.36
15,286	733.35	733.35
15,125	733.35	733.35
14,915	733.35	733.35
14,760	733.35	733.35
14,575	733.35	733.35
14,527	733.35	733.35
14,517	733.35	733.35
14,452	733.35	733.35
14,376	733.35	733.35
14,167	733.35	733.35
14,014	733.34	733.35
13,944	733.34	733.34
13,921	733.34	733.34
13,847	733.33	733.33
13,768	733.33	733.33
13,678	733.33	733.33
13,567	733.32	733.33
13,560	733.32	733.33
13,502	733.32	733.33
13,457	733.30	733.30
13,416	731.07	731.07
13,396	731.06	731.06
13,386	731.04	731.05
13,372	731.00	731.00
13,266	730.95	730.95
13,148	730.93	730.93
13,143	730.93	730.93
13,066	730.92	730.92

Table F-5 Sensitivity analysis results for Roadway Weir Coefficient (continued)

River Station (m)	100-Year Flood Levels (m) for Roadway Weir Coefficient	
	High Weir Coefficient (C=1.6)	Adopted Weir Coefficient (C =1.45)
Camrose Creek		
13,060	730.92	730.92
13,007	730.90	730.91
13,003	730.90	730.90
12,933	730.88	730.89
12,929	730.88	730.88
12,822	730.88	730.88
12,767	730.82	730.83
12,736	729.77	729.77
12,639	729.84	729.84
12,429	729.83	729.83
12,198	729.83	729.83
11,983	729.83	729.83
11,859	729.83	729.83
11,770	729.82	729.82
11,756	729.81	729.81
11,705	729.82	729.82
11,591	729.82	729.82
11,544	729.67	729.67
11,498	729.64	729.64
11,447	729.70	729.70
11,394	729.63	729.63
11,382	729.10	729.10
11,367	726.63	726.63
11,339	726.60	726.60
11,302	726.18	726.18
11,279	725.16	725.16
11,230	725.34	725.34
11,164	725.30	725.30
11,132	725.24	725.24
11,127	725.22	725.22
11,092	725.21	725.21
11,033	725.18	725.18
10,941	725.10	725.10
10,923	724.75	724.75
10,845	724.72	724.72
10,724	724.64	724.64
10,639	724.60	724.60

Table F-5 Sensitivity analysis results for Roadway Weir Coefficient (continued)

River Station (m)	100-Year Flood Levels (m) for Roadway Weir Coefficient	
	High Weir Coefficient (C=1.6)	Adopted Weir Coefficient (C =1.45)
Camrose Creek		
10,635	724.59	724.59
10,566	724.57	724.57
10,500	724.35	724.35
10,474	723.84	723.84
10,432	723.84	723.84
10,281	723.25	723.26
10,113	723.22	723.23
10,105	723.21	723.22
10,062	723.21	723.22
10,055	723.20	723.22
10,019	723.11	723.13
9,938	723.04	723.06
9,744	722.94	722.96
9,603	722.93	722.96
9,410	722.90	722.92
9,329	722.87	722.90
9,311	721.78	721.80
9,190	721.74	721.76
9,044	721.69	721.72
8,891	721.67	721.70
8,857	721.65	721.67
8,829	719.88	719.88
8,782	719.58	719.58
8,656	719.43	719.43
8,497	719.01	719.01
8,319	718.66	718.66
8,259	718.60	718.60
8,251	718.57	718.57
8,227	718.53	718.53
8,165	718.37	718.37
8,151	718.31	718.31
8,139	718.17	718.17
8,134	718.05	718.05
8,101	717.97	717.97
7,992	717.90	717.90
7,909	717.65	717.65
7,888	717.57	717.57

Table F-5 Sensitivity analysis results for Roadway Weir Coefficient (continued)

River Station (m)	100-Year Flood Levels (m) for Roadway Weir Coefficient	
	High Weir Coefficient (C=1.6)	Adopted Weir Coefficient (C =1.45)
Camrose Creek		
7,817	717.24	717.23
7,687	716.70	716.71
7,585	716.48	716.50
7,536	716.36	716.39
7,526	716.19	716.19
7,397	715.76	715.76
7,277	715.44	715.44
7,083	715.32	715.32
6,987	714.52	714.52
6,885	714.15	714.15
6,753	713.70	713.70
6,528	713.03	713.03
6,420	712.67	712.67
6,389	712.48	712.48
6,376	712.19	712.19
6,360	712.26	712.26
6,221	711.10	711.10
6,051	710.19	710.19
5,901	709.66	709.66
5,801	709.31	709.31
5,660	708.60	708.60
5,531	708.31	708.31
5,403	707.96	707.96
5,316	707.78	707.78
5,175	706.69	706.69
5,077	705.64	705.64
4,910	705.21	705.21
4,819	704.74	704.74
4,631	703.98	703.98
4,522	703.60	703.60
4,422	703.28	703.28
4,316	703.05	703.05
4,221	702.70	702.70
4,089	702.00	702.00
3,950	701.72	701.72
3,770	701.22	701.22
3,674	700.90	700.90

Table F-5 Sensitivity analysis results for Roadway Weir Coefficient (continued)

River Station (m)	100-Year Flood Levels (m) for Roadway Weir Coefficient	
	High Weir Coefficient (C=1.6)	Adopted Weir Coefficient (C =1.45)
Camrose Creek		
3,496	700.64	700.64
3,382	700.44	700.44
3,358	700.42	700.42
3,298	700.44	700.44
3,287	700.36	700.36
3,207	700.20	700.20
3,096	699.92	699.92
2,986	699.99	699.99
2,901	699.88	699.88
2,896	699.33	699.33
2,808	699.17	699.17
2,651	698.73	698.73
2,525	698.61	698.61
2,381	698.48	698.48
2,283	698.36	698.36
2,060	698.16	698.16
2,057	698.13	698.13
1,967	697.99	697.99
1,788	697.76	697.76
1,727	697.73	697.73
1,596	697.52	697.52
1,590	697.41	697.41
1,551	697.23	697.23
1,485	697.17	697.17
1,474	697.09	697.09
1,431	696.89	696.89
1,327	696.77	696.77
1,221	696.63	696.63
1,114	696.54	696.54
1,004	696.21	696.21
893	695.94	695.94
817	695.93	695.93
725	695.88	695.88
720	695.87	695.87
640	695.61	695.61
472	695.34	695.34
279	694.96	694.96

Table F-5 Sensitivity analysis results for Roadway Weir Coefficient (continued)

River Station (m)	100-Year Flood Levels (m) for Roadway Weir Coefficient	
	High Weir Coefficient (C=1.6)	Adopted Weir Coefficient (C =1.45)
Camrose Creek		
138	694.98	694.98
103	694.85	694.85
94	694.19	694.19
56	694.02	694.02
0	693.92	693.92
Average Difference	0.00	0.00
Maximum Difference	-0.03	0.00
Unnamed Creek		
5,730	746.57	746.57
5,032	744.73	744.73
4,768	744.01	744.01
4,365	743.15	743.14
4,118	742.73	742.74
4,107	742.71	742.71
3,792	741.25	741.25
3,247	740.84	740.85
2,378	740.80	740.81
2,358	739.13	739.13
2,081	738.96	738.96
1,877	738.89	738.89
1,737	738.52	738.52
1,483	737.34	737.34
1,227	736.54	736.54
1,066	735.66	735.66
877	734.98	734.98
702	733.98	733.98
Average Difference	0.00	0.00
Maximum Difference	-0.01	0.00

Appendix G
Open Water Flood Inundation Map Library

(provided under separate cover)

DRAFT

Appendix H
Floodway Determination Criteria and Design Flood Levels

Table H- 1 Selected floodway limit stations, limiting criteria, and open water design flood levels – Camrose Creek

River Station (m)	Left		Right		Open Water Design Flood Level (m)
	Floodway Limit Station (m)	Limiting Criteria	Floodway Limit Station (m)	Limiting Criteria	
18,827	129.86	1 m Depth	588.14	1 m Depth	734.21
18,745	108.68	1 m Depth	624.94	1 m Depth	734.21
18,700	444.43	1 m Depth	470.95	1 m Depth	734.18
18,688	451.42	1 m Depth	476.80	1 m Depth	734.09
18,621	196.93	1 m Depth	515.51	1 m Depth	734.12
18,486	294.52	1 m Depth	598.11	1 m Depth	734.12
18,311	312.10	1 m Depth	482.19	1 m Depth	734.12
18,307	326.59	1 m Depth	473.03	1 m Depth	734.12
18,247	317.13	1 m Depth	451.08	1 m Depth	734.11
18,198	366.31	1 m Depth	526.36	1 m Depth	734.11
18,190	356.21	1 m Depth	515.06	1 m Depth	734.11
18,146	357.58	1 m Depth	505.64	1 m Depth	734.11
18,092	360.17	1 m Depth	502.91	1 m Depth	734.10
18,087	361.86	1 m Depth	502.87	1 m Depth	734.10
18,033	311.77	1 m Depth	522.12	1 m Depth	734.10
17,993	160.78	1 m Depth	539.61	1 m Depth	734.10
17,988	166.99	1 m Depth	555.48	1 m Depth	734.10
17,933	302.88	1 m Depth	730.09	1 m Depth	734.10
17,811	347.18	1 m Depth	718.21	1 m Depth	734.10
17,679	488.88	1 m Depth	748.04	1 m Depth	734.09
17,570	636.38	1 m Depth	690.64	1 m Depth	734.09
17,503	653.95	1 m Depth	730.47	1 m Depth	733.90
17,480	717.09	1 m Depth	729.52	1 m Depth	733.72
17,390	514.51	1 m Depth	602.16	1 m Depth	733.76
17,252	361.01	1 m Depth	454.75	1 m Depth	733.74
17,127	139.28	1 m Depth	219.05	1 m Depth	733.74
16,965	182.62	1 m Depth	231.90	1 m Depth	733.72
16,803	114.37	1 m Depth	235.33	1 m Depth	733.71
16,684	142.60	1 m Depth	244.50	1 m Depth	733.71
16,648	160.45	1 m Depth	195.11	1 m Depth	733.66
16,632	241.48	1 m Depth	263.70	1 m Depth	733.43
16,570	255.50	Previous Floodway	301.34	Previous Floodway	733.45
16,416	84.56	Previous Floodway	144.88	Previous Floodway	733.42
16,317	191.46	Previous Floodway	244.73	Main Channel[1]	733.42
16,270	159.65	Previous Floodway	229.99	Previous Floodway	733.41

Table H- 2 Selected floodway limit stations, limiting criteria, and open water design flood levels – Camrose Creek (Continued)

River Station (m)	Left		Right		Open Water Design Flood Level (m)
	Floodway Limit Station (m)	Limiting Criteria	Floodway Limit Station (m)	Limiting Criteria	
16,124	180.46	Previous Floodway	270.01	Previous Floodway	733.40
15,979	262.73	Previous Floodway	304.80	Previous Floodway	733.38
15,837	303.05	Previous Floodway	364.69	Previous Floodway	733.37
15,779	272.27	Previous Floodway	367.60	Previous Floodway	733.37
15,763	262.76	Previous Floodway	358.53	Previous Floodway	733.36
15,704	220.64	Previous Floodway	361.57	Previous Floodway	733.36
15,536	304.26	Previous Floodway	452.49	Previous Floodway	733.36
15,440	299.88	Previous Floodway	573.64	Previous Floodway	733.36
15,415	309.71	Previous Floodway	570.93	Previous Floodway	733.36
15,286	315.76	Previous Floodway	484.75	Previous Floodway	733.35
15,125	313.23	Previous Floodway	549.84	Previous Floodway	733.35
14,915	418.00	Previous Floodway	695.17	Previous Floodway	733.35
14,760	449.14	Previous Floodway	733.02	Previous Floodway	733.35
14,575	423.52	Previous Floodway	650.59	Previous Floodway	733.35
14,527	462.96	Previous Floodway	660.48	Previous Floodway	733.35
14,517	483.19	Previous Floodway	669.86	Previous Floodway	733.35
14,452	466.05	Previous Floodway	715.36	Previous Floodway	733.35
14,376	228.75	Previous Floodway	435.82	Previous Floodway	733.35
14,167	176.13	Previous Floodway	296.94	Previous Floodway	733.35
14,014	31.38	Previous Floodway	143.75	Previous Floodway	733.35
13,944	99.44	Previous Floodway	242.47	Previous Floodway	733.34
13,921	100.44	Previous Floodway	201.34	Previous Floodway	733.34
13,847	194.63	Inundation Extent[2]	310.28	Previous Floodway	733.33
13,768	225.60	Previous Floodway	322.83	Previous Floodway	733.33
13,678	261.16	Previous Floodway	350.17	Previous Floodway	733.33
13,567	171.22	Previous Floodway	272.99	Previous Floodway	733.33
13,560	169.08	Previous Floodway	269.51	Previous Floodway	733.33
13,502	137.53	Previous Floodway	225.41	Previous Floodway	733.33
13,457	122.37	1 m Depth	235.78	1 m Depth	733.30
13,416	228.74	Previous Floodway	288.64	Previous Floodway	731.07
13,396	67.08	Previous Floodway	88.68	Main Channel[1]	731.06
13,386	86.62	Previous Floodway	104.89	Previous Floodway	731.05
13,372	51.80	Previous Floodway	109.59	Inundation Extent[2]	731.00
13,266	15.92	Inundation Extent[2]	69.69	Previous Floodway	730.95
13,148	43.51	Main Channel[1]	141.00	Previous Floodway	730.93

Table H- 3 Selected floodway limit stations, limiting criteria, and open water design flood levels – Camrose Creek (Continued)

River Station (m)	Left		Right		Open Water Design Flood Level (m)
	Floodway Limit Station (m)	Limiting Criteria	Floodway Limit Station (m)	Limiting Criteria	
13,143	45.34	Main Channel[1]	139.75	Previous Floodway	730.93
13,066	23.09	Previous Floodway	143.80	Previous Floodway	730.92
13,060	25.76	Previous Floodway	142.81	Previous Floodway	730.92
13,007	31.15	Previous Floodway	106.95	Previous Floodway	730.91
13,003	29.83	Previous Floodway	105.25	Previous Floodway	730.90
12,933	18.20	Previous Floodway	90.34	Previous Floodway	730.89
12,929	17.45	Inundation Extent[2]	88.75	Previous Floodway	730.88
12,822	32.65	Previous Floodway	103.59	Previous Floodway	730.88
12,767	57.31	Previous Floodway	136.27	Previous Floodway	730.83
12,736	83.61	Previous Floodway	113.44	Inundation Extent[2]	729.77
12,639	44.67	Previous Floodway	111.37	Previous Floodway	729.84
12,429	79.86	Previous Floodway	159.96	Previous Floodway	729.83
12,198	13.86	Previous Floodway	91.73	Previous Floodway	729.83
11,983	40.47	Main Channel[1]	144.84	Previous Floodway	729.83
11,859	18.79	Main Channel[1]	103.13	Inundation Extent[2]	729.83
11,770	55.56	Previous Floodway	146.95	Inundation Extent[2]	729.82
11,756	62.14	Previous Floodway	157.34	Inundation Extent[2]	729.81
11,705	33.19	Inundation Extent[3]	175.99	Inundation Extent[2]	729.82
11,591	26.95	Previous Floodway	138.41	Inundation Extent[2]	729.82
11,544	90.84	Inundation Extent[2]	119.88	Inundation Extent[2]	729.67
11,498	90.25	Inundation Extent[2]	110.62	Inundation Extent[2]	729.64
11,447	8.48	Previous Floodway	134.17	Previous Floodway	729.70
11,394	31.54	Previous Floodway	145.44	Previous Floodway	729.63
11,382	64.39	Previous Floodway	88.02	Inundation Extent[2]	729.10
11,367	20.31	Previous Floodway	41.85	Inundation Extent[2]	726.63
11,339	24.52	Previous Floodway	38.76	Previous Floodway	726.60
11,302	44.35	Inundation Extent[2]	54.57	Inundation Extent[2]	726.18
11,279	43.23	Inundation Extent[2]	57.59	1 m Depth	725.16
11,230	59.01	Previous Floodway	79.26	Main Channel[1]	725.34
11,164	38.69	Previous Floodway	64.69	Main Channel[1]	725.30
11,132	42.12	Previous Floodway	56.00	Previous Floodway	725.24
11,127	42.27	Previous Floodway	59.47	Previous Floodway	725.22
11,092	31.85	Previous Floodway	61.07	Previous Floodway	725.21
11,033	38.48	Previous Floodway	61.74	Previous Floodway	725.18
10,941	89.94	Previous Floodway	113.40	Previous Floodway	725.10
10,923	92.92	Inundation Extent[2]	113.08	Inundation Extent[2]	724.75
10,845	60.50	Previous Floodway	96.75	1 m Depth	724.72

Table H- 4 Selected floodway limit stations, limiting criteria, and open water design flood levels – Camrose Creek (Continued)

River Station (m)	Left		Right		Open Water Design Flood Level (m)
	Floodway Limit Station (m)	Limiting Criteria	Floodway Limit Station (m)	Limiting Criteria	
10,724	30.35	Previous Floodway	63.63	Previous Floodway	724.64
10,639	69.86	Previous Floodway	117.26	Previous Floodway	724.60
10,635	70.78	Previous Floodway	119.17	Previous Floodway	724.59
10,566	33.95	Previous Floodway	58.25	Previous Floodway	724.57
10,500	44.21	Previous Floodway	55.81	1 m/s Velocity	724.35
10,474	40.36	Inundation Extent[2]	54.32	Inundation Extent[3]	723.84
10,432	27.12	Previous Floodway	46.08	Previous Floodway	723.84
10,281	26.94	Previous Floodway	41.67	Previous Floodway	723.26
10,113	46.81	1 m Depth	63.05	Previous Floodway	723.23
10,105	47.38	Main Channel[1]	61.73	Previous Floodway	723.22
10,062	47.00	Main Channel[1]	73.90	Previous Floodway	723.22
10,055	27.74	Previous Floodway	77.47	Previous Floodway	723.22
10,019	23.15	Previous Floodway	45.58	Previous Floodway	723.13
9,938	52.06	Previous Floodway	63.86	Previous Floodway	723.06
9,744	44.80	Previous Floodway	95.54	Main Channel[1]	722.96
9,603	55.02	Previous Floodway	136.60	Main Channel[1]	722.96
9,410	39.54	Previous Floodway	70.87	Previous Floodway	722.92
9,329	60.93	Previous Floodway	100.26	Previous Floodway	722.90
9,311	63.89	Previous Floodway	92.75	Previous Floodway	721.80
9,190	23.97	Inundation Extent[2]	61.16	Previous Floodway	721.76
9,044	29.67	Previous Floodway	70.49	Previous Floodway	721.72
8,891	59.86	Previous Floodway	82.99	Previous Floodway	721.70
8,857	75.99	Main Channel[1]	91.19	Previous Floodway	721.67
8,829	71.76	Previous Floodway	83.60	Main Channel[1]	719.88
8,782	59.38	Main Channel[4]	67.50	Main Channel[4]	719.58
8,656	16.72	Previous Floodway	56.29	Main Channel[1]	719.43
8,497	71.76	Previous Floodway	92.69	Inundation Extent[3]	719.01
8,319	50.27	Previous Floodway	82.61	Main Channel[1]	718.66
8,259	61.55	Previous Floodway	85.36	Main Channel[1]	718.60
8,251	64.54	Previous Floodway	88.10	Previous Floodway	718.57
8,227	24.59	Previous Floodway	43.50	Previous Floodway	718.53
8,165	48.12	Previous Floodway	73.38	1 m Depth	718.37
8,151	57.23	Previous Floodway	77.97	Previous Floodway	718.31
8,139	68.96	Previous Floodway	86.95	Previous Floodway	718.17
8,134	69.11	Previous Floodway	85.87	Previous Floodway	718.05
8,101	35.83	Previous Floodway	49.75	Previous Floodway	717.97

Table H- 5 Selected floodway limit stations, limiting criteria, and open water design flood levels – Camrose Creek (Continued)

River Station (m)	Left		Right		Open Water Design Flood Level (m)
	Floodway Limit Station (m)	Limiting Criteria	Floodway Limit Station (m)	Limiting Criteria	
7,992	80.10	Previous Floodway	117.94	Previous Floodway	717.90
7,909	90.36	Inundation Extent[2]	104.42	1 m Depth	717.65
7,888	90.84	Previous Floodway	103.24	1 m Depth	717.57
7,817	33.69	Previous Floodway	46.12	1 m/s Velocity	717.23
7,687	30.56	Inundation Extent[3]	54.91	Previous Floodway	716.71
7,585	23.16	1 m Depth	34.70	1 m Depth	716.50
7,536	28.39	1 m Depth	43.72	1 m Depth	716.39
7,526	35.21	1 m Depth	44.13	1 m Depth	716.19
7,397	45.80	1 m Depth	55.44	Main Channel	715.76
7,277	33.11	Main Channel	41.29	1 m Depth	715.44
7,083	30.19	1 m Depth	41.57	1 m Depth	715.32
6,987	32.10	1 m/s Velocity	42.89	Inundation Extent[3]	714.52
6,885	23.39	1 m Depth	46.18	1 m/s Velocity	714.15
6,753	22.41	1 m Depth	29.55	1 m/s Velocity	713.70
6,528	17.15	1 m Depth	30.58	1 m Depth	713.03
6,420	28.25	1 m Depth	39.82	1 m Depth	712.67
6,389	23.47	1 m Depth	35.45	1 m Depth	712.48
6,376	25.30	1 m/s Velocity	34.62	1 m Depth	712.19
6,360	9.69	1 m Depth	26.07	1 m Depth	712.26
6,221	59.53	Inundation Extent[3]	69.94	1 m/s Velocity	711.10
6,051	111.74	1 m Depth	122.93	1 m Depth	710.19
5,901	68.81	1 m/s Velocity	80.27	1 m Depth	709.66
5,801	39.51	1 m Depth	52.44	1 m/s Velocity	709.31
5,660	94.12	1 m/s Velocity	107.82	1 m/s Velocity	708.60
5,531	29.05	1 m/s Velocity	37.70	1 m/s Velocity	708.31
5,403	74.35	1 m Depth	87.95	1 m Depth	707.96
5,316	43.42	1 m Depth	52.84	1 m Depth	707.78
5,175	13.01	Inundation Extent[3]	30.28	Inundation Extent[3]	706.69
5,077	58.13	1 m/s Velocity	78.74	Inundation Extent[3]	705.64
4,910	16.47	1 m Depth	36.06	1 m Depth	705.21
4,819	25.02	1 m Depth	35.53	Main Channel	704.74
4,631	17.27	1 m Depth	28.89	Main Channel	703.98
4,522	14.52	1 m Depth	32.98	1 m Depth	703.60
4,422	38.17	1 m Depth	47.27	1 m Depth	703.28
4,316	21.77	1 m Depth	35.32	1 m Depth	703.05
4,221	53.90	1 m Depth	65.65	1 m Depth	702.70

Table H- 6 Selected floodway limit stations, limiting criteria, and open water design flood levels – Camrose Creek (Continued)

River Station (m)	Left		Right		Open Water Design Flood Level (m)
	Floodway Limit Station (m)	Limiting Criteria	Floodway Limit Station (m)	Limiting Criteria	
4,089	71.87	1 m/s Velocity	80.21	Main Channel	702.00
3,950	42.43	1 m Depth	51.32	1 m Depth	701.72
3,770	33.03	1 m Depth	44.85	1 m Depth	701.22
3,674	53.38	1 m Depth	62.43	1 m Depth	700.90
3,496	90.53	1 m Depth	111.43	1 m Depth	700.64
3,382	15.88	1 m Depth	30.67	1 m Depth	700.44
3,358	8.05	1 m Depth	23.84	1 m Depth	700.42
3,298	34.41	1 m Depth	72.99	1 m Depth	700.44
3,287	36.13	1 m Depth	63.87	1 m Depth	700.36
3,207	37.21	1 m Depth	51.68	1 m Depth	700.20
3,096	27.80	1 m Depth	38.05	1 m Depth	699.92
2,986	25.99	1 m Depth	110.41	1 m Depth	699.99
2,901	59.02	1 m Depth	75.38	1 m Depth	699.88
2,896	64.43	1 m Depth	74.46	1 m Depth	699.33
2,808	78.92	1 m Depth	92.95	1 m Depth	699.17
2,651	47.61	1 m Depth	63.54	1 m Depth	698.73
2,525	49.64	1 m Depth	64.02	1 m Depth	698.61
2,381	38.89	1 m Depth	71.66	1 m Depth	698.48
2,283	82.46	1 m Depth	104.51	1 m Depth	698.36
2,060	45.18	1 m Depth	65.92	1 m Depth	698.16
2,057	45.10	1 m Depth	64.16	1 m Depth	698.13
1,967	33.56	1 m Depth	48.05	1 m Depth	697.99
1,788	24.91	1 m Depth	40.15	1 m Depth	697.76
1,727	41.90	1 m Depth	62.51	1 m Depth	697.73
1,596	33.82	1 m Depth	48.51	1 m Depth	697.52
1,590	32.75	1 m Depth	46.93	1 m Depth	697.41
1,551	31.51	1 m Depth	40.43	1 m Depth	697.23
1,485	40.21	1 m Depth	59.48	1 m Depth	697.17
1,474	39.68	1 m Depth	59.09	1 m Depth	697.09
1,431	13.89	1 m Depth	24.79	1 m Depth	696.89
1,327	19.06	1 m Depth	33.93	1 m Depth	696.77
1,221	37.94	1 m Depth	57.09	1 m Depth	696.63
1,114	79.46	1 m Depth	122.06	1 m Depth	696.54
1,004	86.87	1 m Depth	97.07	1 m Depth	696.21
893	55.74	1 m Depth	64.86	1 m Depth	695.94
817	41.00	1 m Depth	49.01	1 m Depth	695.93

Table H- 7 Selected floodway limit stations, limiting criteria, and open water design flood levels – Camrose Creek (Continued)

River Station (m)	Left		Right		Open Water Design Flood Level (m)
	Floodway Limit Station (m)	Limiting Criteria	Floodway Limit Station (m)	Limiting Criteria	
725	46.03	1 m Depth	54.57	1 m Depth	695.88
720	45.76	1 m Depth	54.26	Main Channel	695.87
640	89.35	1 m Depth	96.34	1 m Depth	695.61
472	99.59	Main Channel	109.11	1 m Depth	695.34
279	38.83	Main Channel	47.89	Main Channel	694.96
138	27.18	1 m Depth	140.79	1 m Depth	694.98
103	41.17	1 m Depth	57.49	1 m Depth	694.85
94	42.23	1 m/s Velocity	55.69	Main Channel	694.19

Notes:

1. Floodway limit positioned at main channel, as previous floodway limit is inside main channel.
2. The previous floodway is outside the inundation extent.
3. No viable flood fringe.
4. Channel has shifted from previous flood hazard study.

Table H- 2 Selected floodway limit stations, limiting criteria, and open water design flood levels – Unnamed Creek

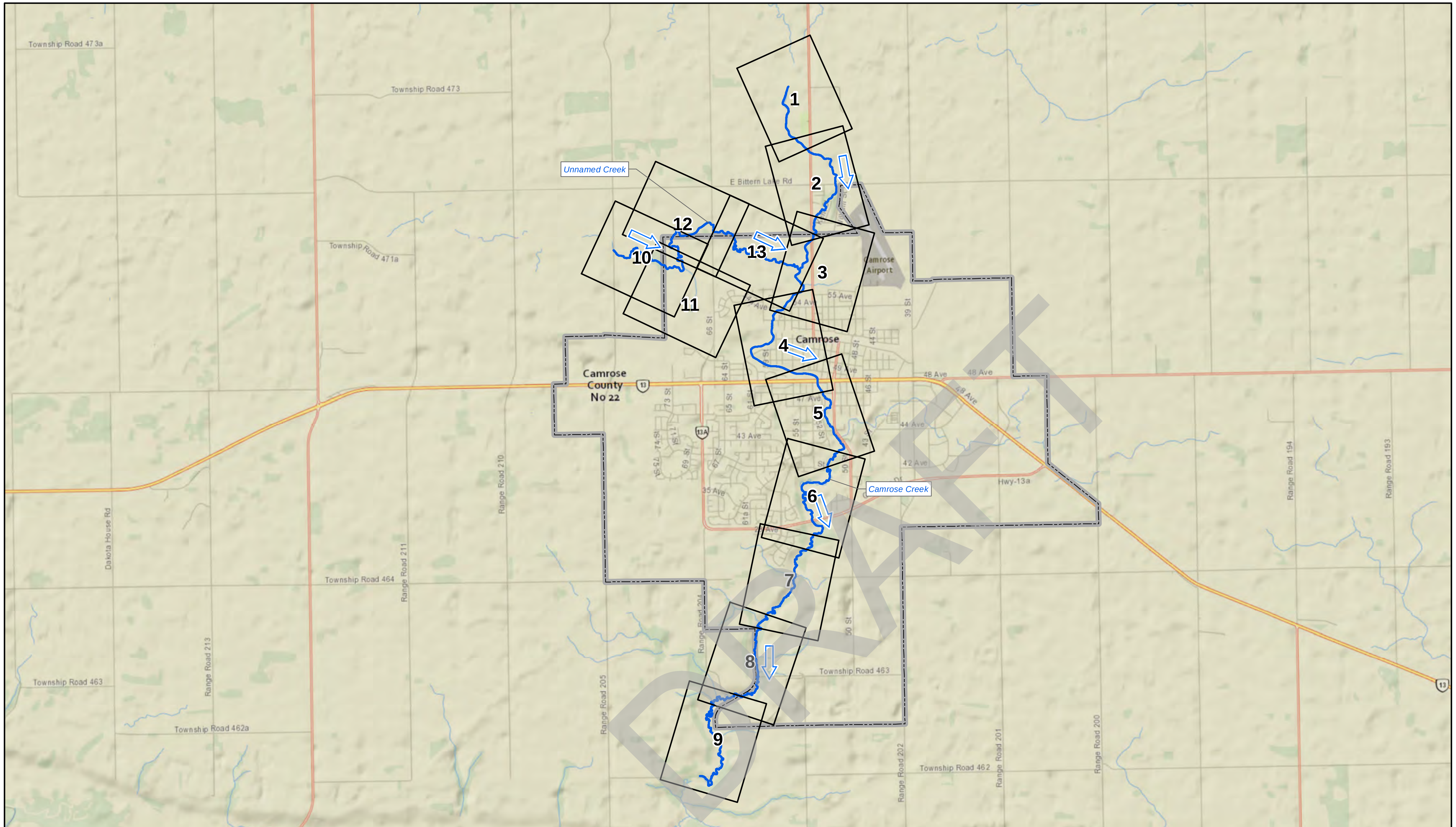
River Station (m)	Left		Right		Open Water Design Flood Level (m)
	Floodway Limit Station (m)	Limiting Criteria	Floodway Limit Station (m)	Limiting Criteria	
5,730	62.08	Inundation Extent[1]	143.05	Inundation Extent[1]	746.57
5,032	52.40	Inundation Extent[1]	63.60	Inundation Extent[1]	744.73
4,768	146.71	Inundation Extent[1]	163.46	Inundation Extent[1]	744.01
4,365	48.68	Main Channel	57.56	1 m/s Velocity	743.14
4,118	97.94	Main Channel	101.88	Main Channel	742.74
4,107	97.44	1 m Depth	101.64	Main Channel	742.71
3,792	129.38	Inundation Extent[1]	136.13	Inundation Extent[1]	741.25
3,247	400.51	1 m Depth	416.91	1 m Depth	740.85
2,378	191.76	1 m Depth	205.04	1 m Depth	740.81
2,358	196.63	Inundation Extent[1]	201.00	Inundation Extent[1]	739.13
2,081	91.08	Inundation Extent[1]	181.09	Inundation Extent[1]	738.96
1,877	57.37	Inundation Extent[1]	74.58	Inundation Extent[1]	738.89
1,737	12.60	Inundation Extent[1]	22.79	Inundation Extent[1]	738.52
1,483	29.47	Inundation Extent[1]	38.03	Inundation Extent[1]	737.34
1,227	35.27	Inundation Extent[1]	46.55	Inundation Extent[1]	736.54
1,066	35.80	Inundation Extent[1]	40.88	Inundation Extent[1]	735.66
877	25.13	Inundation Extent[1]	41.20	Inundation Extent[1]	734.98
702	23.97	Inundation Extent[1]	33.26	Inundation Extent[1]	733.98

Notes:

1. The floodway is drawn through inundation extent as the channel bank is not well defined.

Appendix I

Floodway Criteria Map



Alberta

nhc
northwest hydraulic consultants

FLOW DIRECTION
STUDY REACH
MAP SHEET
CAMROSE CITY BOUNDARY

SCALE - 1:70,000
0 500 1,000 2,000 3,000 M
N

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

Engineer MMM	*GIS* REH	*Reviewer* RBA

Job: 1004662	Date: 02-JUN-2021

CAMROSE
FLOOD HAZARD STUDY

FLOODWAY CRITERIA MAP

INDEX MAP

Notes to Users:

1. 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.
2. 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.
3. The flood inundation area is shown above the linework for bridges and flood control structures that are below flood levels.

Definitions:

Flood Hazard Map - A flood hazard map is a specific type of flood map that identifies the area flooded for the 1:100 design flood, and divides that flood hazard area into floodway and flood fringe zones. Flood hazard maps can also show additional flood hazard information, including the incremental areas at risk for more severe floods like the 1:200 and 1:500 floods. Flood hazard maps are typically used for long-term flood hazard area management and land-use planning.
Design Flood - The design flood standard in Alberta is the 1:100 flood, which is a flood that has a 1% chance of being equaled or exceeded in any given year. The design flood is typically based on the 1:100 open water flood, but it can also reflect 1:100 ice jam flood levels or be based on a historical flood event. Different sized floods have different chances of occurring – for example, a 1:200 flood has a 0.5% chance of occurring in any given year and a 1:500 flood has a 0.2% chance of occurring in any given year – but only the 1:100 design flood is used to define the floodway and flood fringe zones on flood hazard maps.
Floodway - When a floodway is first defined on a flood hazard map, it typically represents the area of highest flood hazard where flows are deepest, fastest, and most destructive during the 1:100 design flood. When a flood hazard map is updated, the floodway will not get larger in most circumstances to maintain long-term regulatory certainty, even if the flood hazard area gets larger or design flood levels get higher.
Flood Fringe - The flood fringe is the area outside of the floodway that is flooded or could be flooded during the 1:100 design flood. The flood fringe typically represents areas with

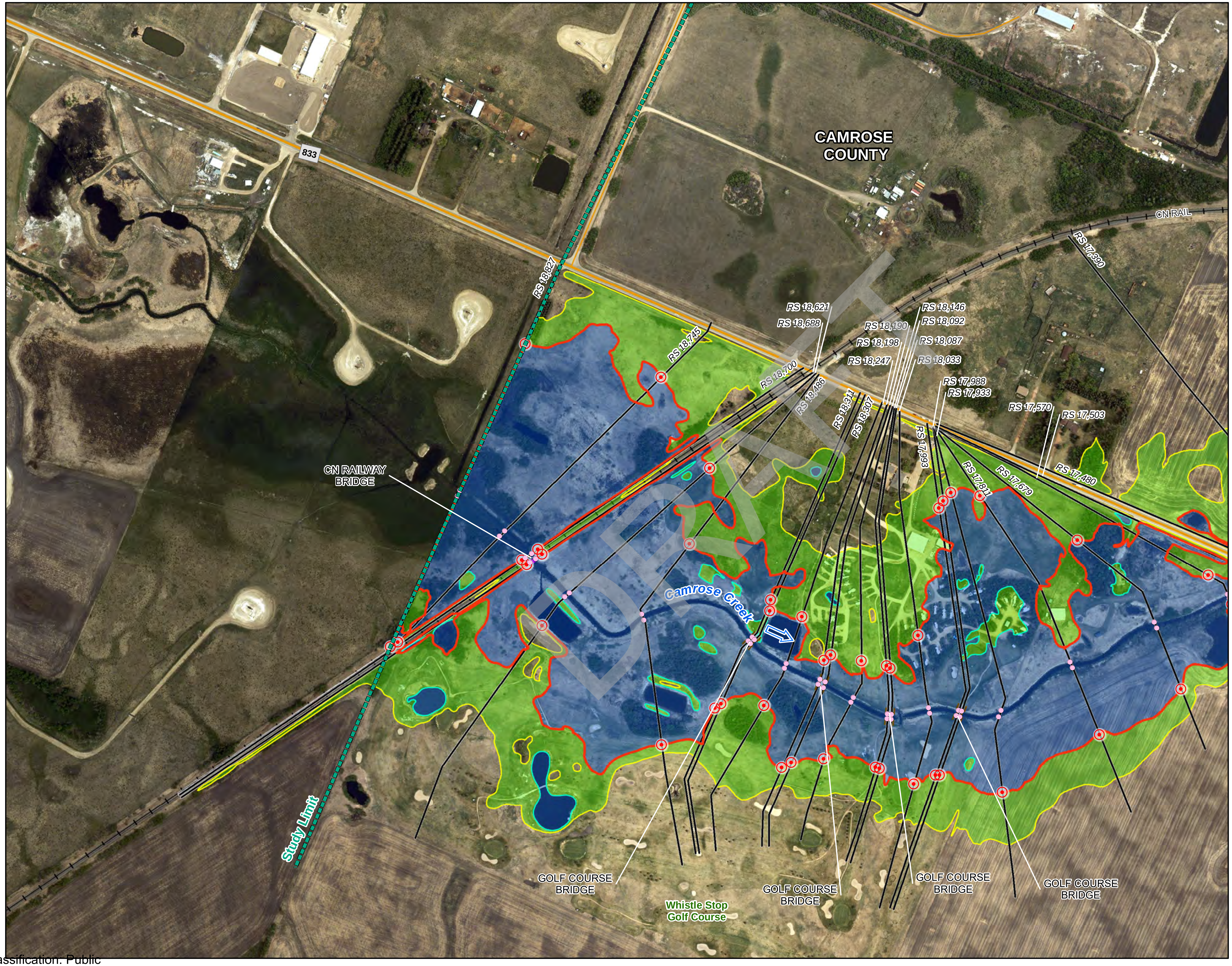
Definitions (continued):

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 most significant for flood maps that are being updated, but they 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 1:100 design flood, even if they are not overtopped. Protected flood fringe areas are part of the flood fringe and do not differentiate between areas with deeper or faster moving water and shallower or slower moving water.

Data Sources and References:

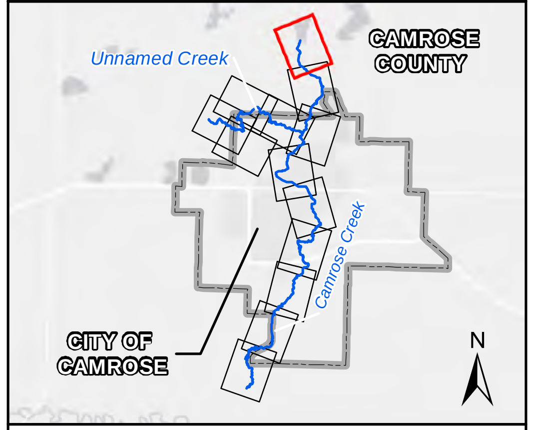
1. Orthophoto imagery acquired by OGL Engineering for Alberta Environment and Parks: *OGL Engineering (2019). Camrose aerial imagery acquisition memorandum, project number 2019-506, submitted to Alberta Environment and Parks, 5 pp.*
2. Base data from Natural Resources Canada, Alberta Environment and Parks, and Altalis.
3. Additional base mapping from Esri.

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T500_IndexMap.mxd



Alberta

nhc northwest hydraulic consultants



- FLOW DIRECTION
- BRIDGE
- CULVERT
- DAM & SPILLWAY
- MODEL CROSS SECTION
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- CAMROSE CITY BOUNDARY
- BANK STATION
- PROPOSED FLOODWAY STATION
- VELOCITY ≥ 1 m/s
- PROPOSED FLOODWAY BOUNDARY
- DEPTH = 1 m
- DEPTH ≥ 1 m
- 100-YEAR OPEN WATER DESIGN FLOOD EXTENT
- PREVIOUS FLOODWAY

DISCHARGE
Camrose Creek = 40.7 m^3/s

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 | Date: 02-JUN-2021

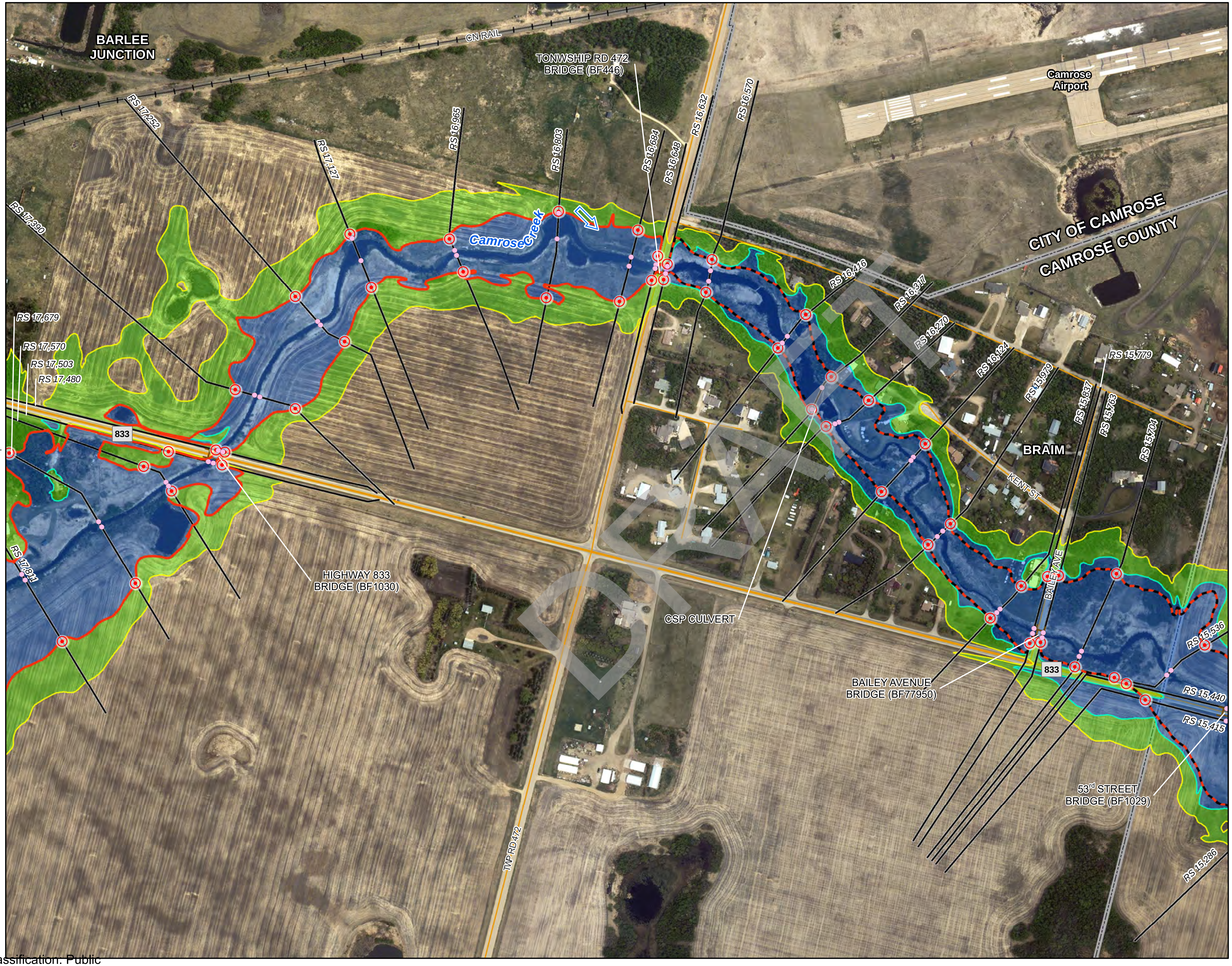
CAMROSE
FLOOD HAZARD STUDY

FLOODWAY CRITERIA MAP

SHEET 1 OF 13

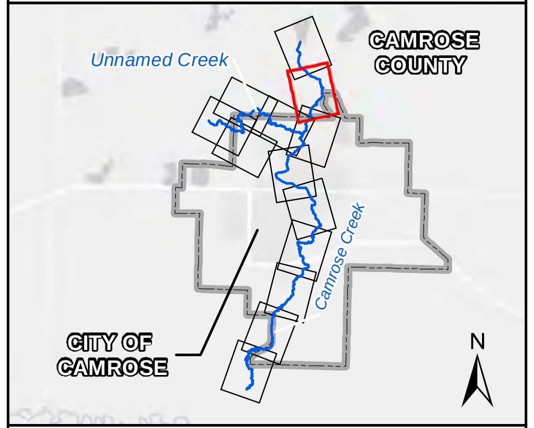
REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T500_FloodwayCriteria.mxd

Classification: Public



Alberta

nhc
northwest hydraulic consultants



FLOW DIRECTION
BRIDGE
CULVERT
DAM & SPILLWAY
MODEL CROSS SECTION
PROVINCIAL HIGHWAY
LOCAL ROAD
RAILWAY
CAMROSE CITY BOUNDARY
BANK STATION
PROPOSED FLOODWAY STATION
VELOCITY ≥ 1 m/s
PROPOSED FLOODWAY BOUNDARY
DEPTH = 1 m
DEPTH ≥ 1 m
100-YEAR OPEN WATER DESIGN FLOOD EXTENT
PREVIOUS FLOODWAY

DISCHARGE
Camrose Creek = 40.7 m^3/s

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

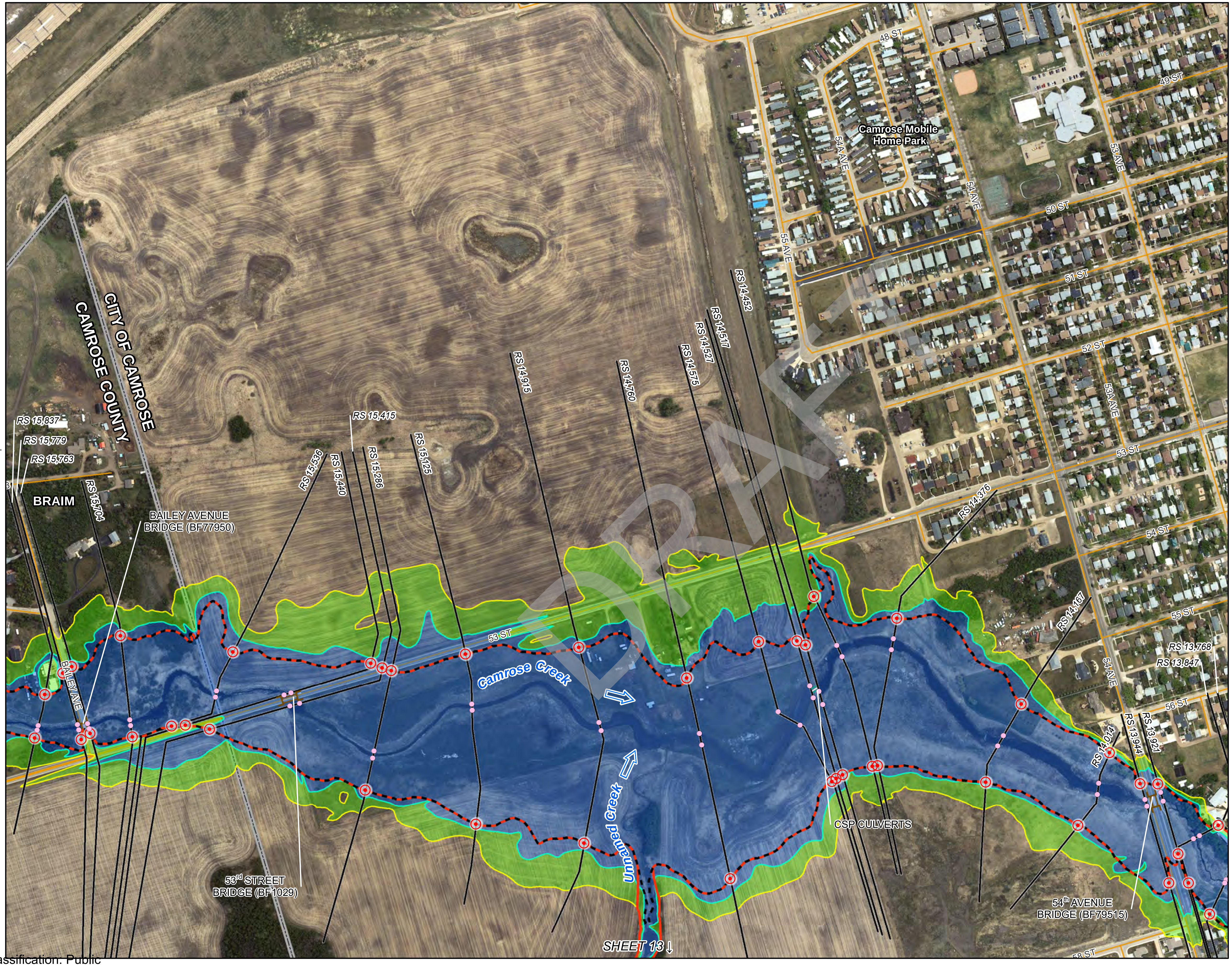
Job: 1004662 | Date: 02-JUN-2021

CAMROSE FLOOD HAZARD STUDY

FLOODWAY CRITERIA MAP

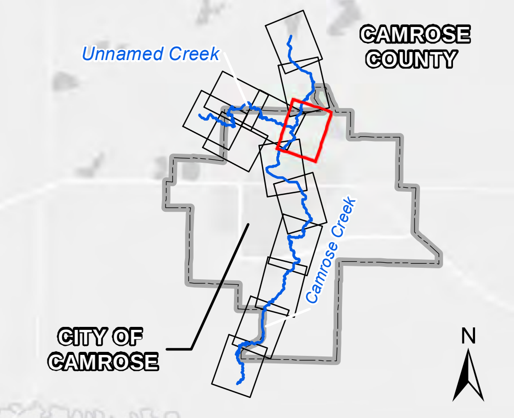
SHEET 2 OF 13

REH_P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T500_FloodwayCriteria.mxd



Alberta

nhc northwest hydraulic consultants



- FLOW DIRECTION
- BRIDGE
- CULVERT
- DAM & SPILLWAY
- MODEL CROSS SECTION
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- CAMROSE CITY BOUNDARY
- BANK STATION
- PROPOSED FLOODWAY STATION
- VELOCITY ≥ 1 m/s
- PROPOSED FLOODWAY BOUNDARY
- DEPTH = 1 m
- DEPTH ≥ 1 m
- 100-YEAR OPEN WATER DESIGN FLOOD EXTENT
- PREVIOUS FLOODWAY

DISCHARGE

Camrose Creek above Unnamed Creek = 40.7 m^3/s
Camrose Creek below Unnamed Creek = 43.5 m^3/s

SCALE - 1:5,000

0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 Date: 02-JUN-2021

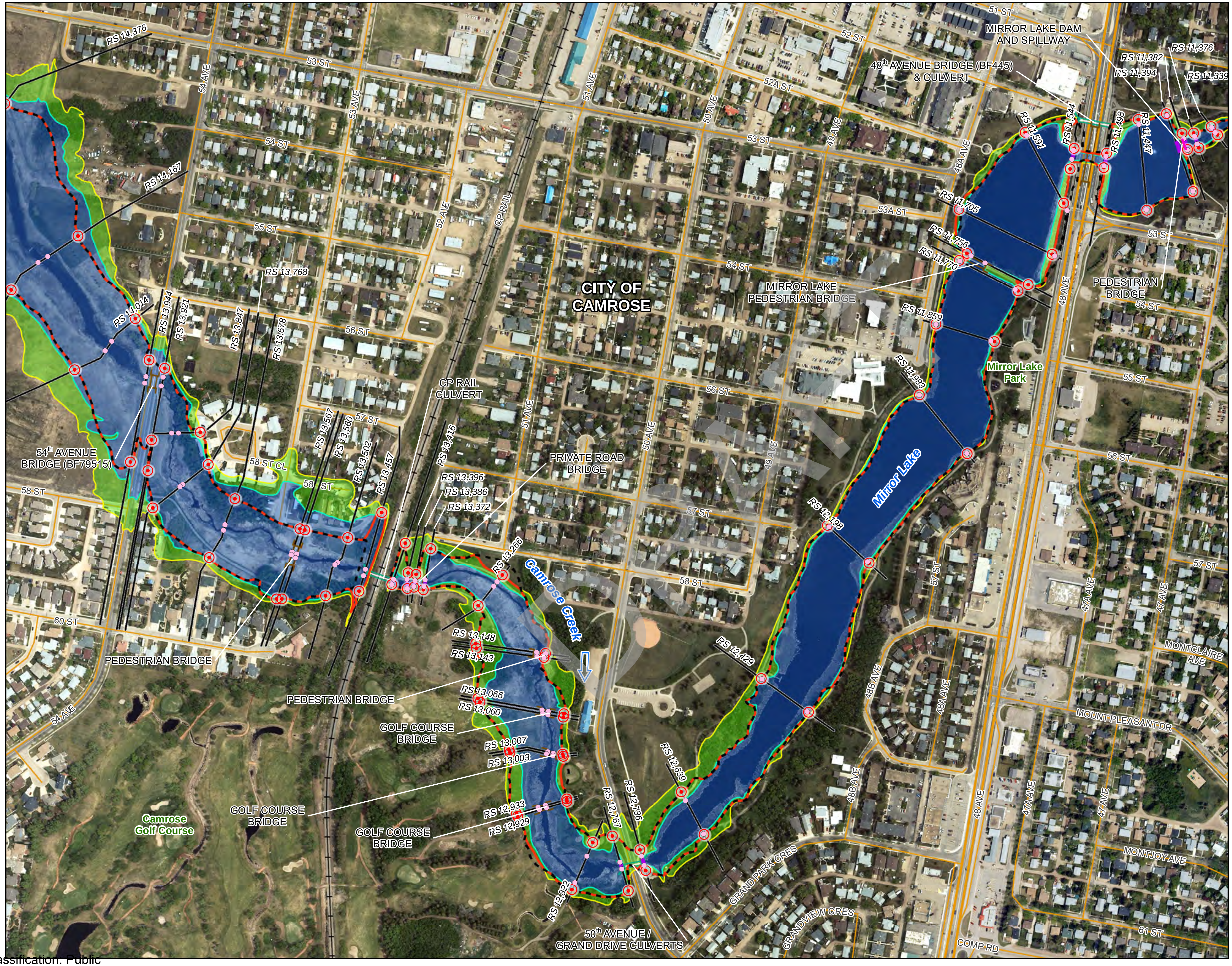
CAMROSE FLOOD HAZARD STUDY

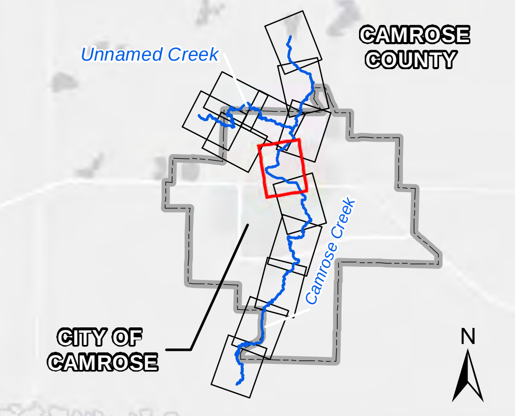
FLOODWAY CRITERIA MAP

SHEET 3 OF 13

REH_P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1004662_Map_T500_FloodwayCriteria.mxd

Classification: Public





- FLOW DIRECTION
- BRIDGE
- CULVERT
- DAM & SPILLWAY
- MODEL CROSS SECTION
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- CAMROSE CITY BOUNDARY
- BANK STATION
- PROPOSED FLOODWAY STATION
- VELOCITY ≥ 1 m/s
- PROPOSED FLOODWAY BOUNDARY
- DEPTH = 1 m
- DEPTH ≥ 1 m
- 100-YEAR OPEN WATER DESIGN FLOOD EXTENT
- PREVIOUS FLOODWAY

DISCHARGE
Camrose Creek above CP Rail Culvert = 43.5 m^3/s
Camrose Creek below CP Rail Culvert = 41.1 m^3/s

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

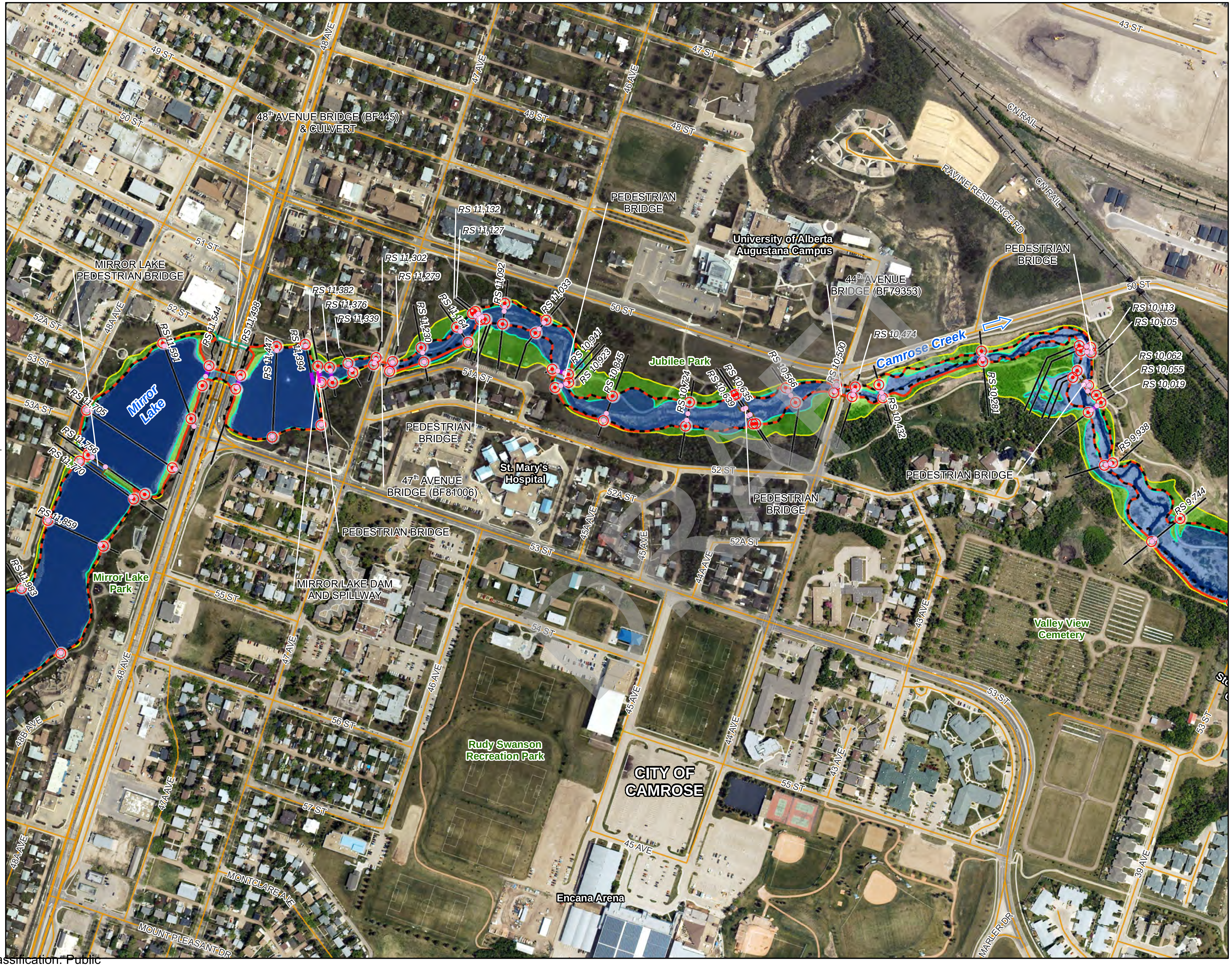
Job: 1004662 | Date: 02-JUN-2021

CAMROSE
FLOOD HAZARD STUDY

FLOODWAY CRITERIA MAP

SHEET 4 OF 13

REH P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T500_FloodwayCriteria.mxd



Alberta

nhc northwest hydraulic consultants

- FLOW DIRECTION
- BRIDGE
- CULVERT
- DAM & SPILLWAY
- MODEL CROSS SECTION
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- CAMROSE CITY BOUNDARY
- BANK STATION
- PROPOSED FLOODWAY STATION
- VELOCITY ≥ 1 m/s
- PROPOSED FLOODWAY BOUNDARY
- DEPTH = 1 m
- DEPTH ≥ 1 m
- 100-YEAR OPEN WATER DESIGN FLOOD EXTENT
- PREVIOUS FLOODWAY

DISCHARGE
Camrose Creek = 41.1 m^3/s

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 | Date: 02-JUN-2021

CAMROSE
FLOOD HAZARD STUDY
FLOODWAY CRITERIA MAP

SHEET 5 OF 13

REH P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1004662_Map_T500_FloodwayCriteria.mxd

Alberta

nhc northwest hydraulic consultants

- FLOW DIRECTION
- BRIDGE
- CULVERT
- DAM & SPILLWAY
- MODEL CROSS SECTION
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- CAMROSE CITY BOUNDARY
- BANK STATION
- PROPOSED FLOODWAY STATION
- VELOCITY ≥ 1 m/s
- PROPOSED FLOODWAY BOUNDARY
- DEPTH = 1 m
- DEPTH ≥ 1 m
- 100-YEAR OPEN WATER DESIGN FLOOD EXTENT
- PREVIOUS FLOODWAY

DISCHARGE
Camrose Creek = 41.1 m^3/s

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 Date: 02-JUN-2021

CAMROSE
FLOOD HAZARD STUDY

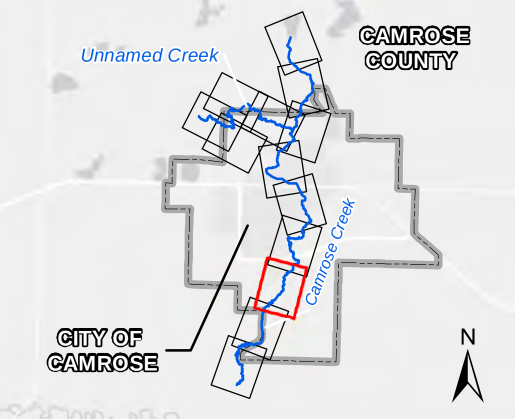
FLOODWAY CRITERIA MAP

SHEET 6 OF 13

REH_P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T500_FloodwayCriteria.mxd

Alberta

nhc northwest hydraulic consultants



FLOW DIRECTION
BRIDGE
CULVERT
DAM & SPILLWAY
MODEL CROSS SECTION
PROVINCIAL HIGHWAY
LOCAL ROAD
RAILWAY
CAMROSE CITY BOUNDARY
BANK STATION
PROPOSED FLOODWAY STATION
VELOCITY ≥ 1 m/s
PROPOSED FLOODWAY BOUNDARY
DEPTH = 1 m
DEPTH ≥ 1 m
100-YEAR OPEN WATER DESIGN FLOOD EXTENT
PREVIOUS FLOODWAY

DISCHARGE
Camrose Creek above RS 6,221 = 41.1 m^3/s
Camrose Creek below RS 6,221 = 43.3 m^3/s

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 Date: 02-JUN-2021

CAMROSE FLOOD HAZARD STUDY

FLOODWAY CRITERIA MAP

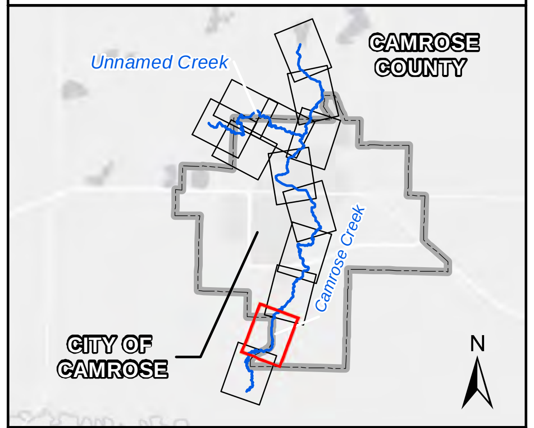
SHEET 7 OF 13

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T500_FloodwayCriteria.mxd

Classification: Public

Alberta

nhc
northwest hydraulic consultants



FLOW DIRECTION
BRIDGE
CULVERT
DAM & SPILLWAY
MODEL CROSS SECTION
PROVINCIAL HIGHWAY
LOCAL ROAD
RAILWAY
CAMROSE CITY BOUNDARY
BANK STATION
PROPOSED FLOODWAY STATION
VELOCITY ≥ 1 m/s
PROPOSED FLOODWAY BOUNDARY
DEPTH = 1 m
DEPTH ≥ 1 m
100-YEAR OPEN WATER DESIGN FLOOD EXTENT
PREVIOUS FLOODWAY

DISCHARGE
Camrose Creek = 43.3 m^3/s

SCALE - 1:5,000
0 100 200 M

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

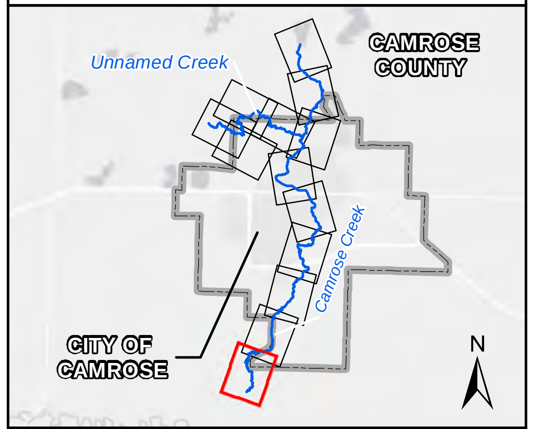
Engineer MMM	GIS REH	Reviewer RBA
Job: 1004662	Date: 02-JUN-2021	

CAMROSE
FLOOD HAZARD STUDY

FLOODWAY CRITERIA MAP

SHEET 8 OF 13

REH_P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T500_FloodwayCriteria.mxd



Alberta

nhc
northwest hydraulic consultants

- FLOW DIRECTION
- BRIDGE
- CULVERT
- DAM & SPILLWAY
- MODEL CROSS SECTION
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- CAMROSE CITY BOUNDARY
- BANK STATION
- PROPOSED FLOODWAY STATION
- VELOCITY ≥ 1 m/s
- PROPOSED FLOODWAY BOUNDARY
- DEPTH = 1 m
- DEPTH ≥ 1 m
- 100-YEAR OPEN WATER DESIGN FLOOD EXTENT
- PREVIOUS FLOODWAY

DISCHARGE
Camrose Creek = 43.3 m^3/s

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662	Date: 02-JUN-2021

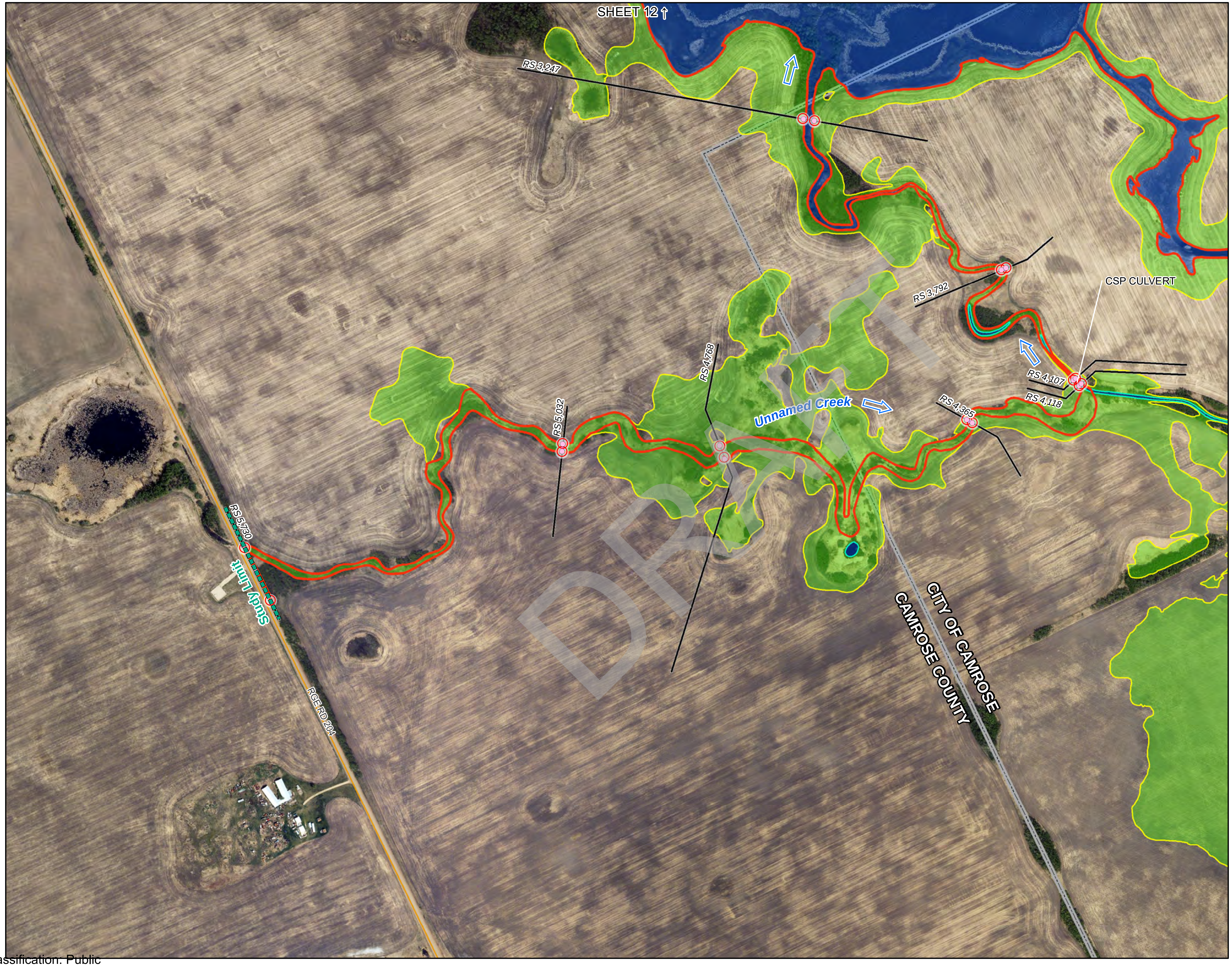
CAMROSE
FLOOD HAZARD STUDY

FLOODWAY CRITERIA MAP

SHEET 9 OF 13

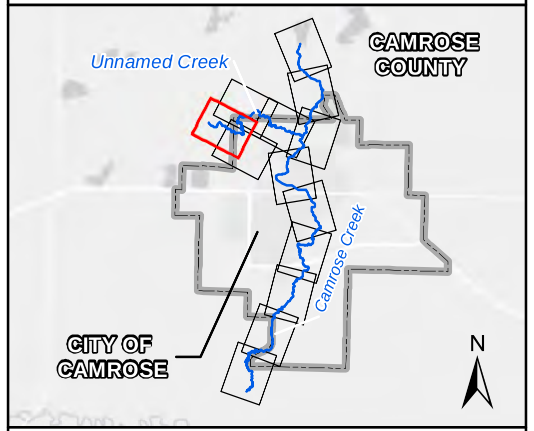
Classification: Public

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T500_FloodwayCriteria.mxd



Alberta

nhc
northwest hydraulic consultants



- FLOW DIRECTION
- BRIDGE
- CULVERT
- DAM & SPILLWAY
- MODEL CROSS SECTION
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- CAMROSE CITY BOUNDARY
- BANK STATION
- PROPOSED FLOODWAY STATION
- VELOCITY ≥ 1 m/s
- PROPOSED FLOODWAY BOUNDARY
- DEPTH = 1 m
- DEPTH ≥ 1 m
- 100-YEAR OPEN WATER DESIGN FLOOD EXTENT
- PREVIOUS FLOODWAY

DISCHARGE
Unnamed Creek = 7.53 m^3/s

SCALE - 1:5,000
0 100 200 M
N

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 Date: 02-JUN-2021

CAMROSE
FLOOD HAZARD STUDY

FLOODWAY CRITERIA MAP

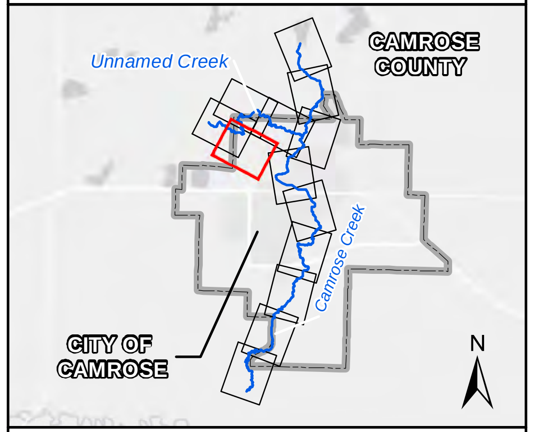
REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T500_FloodwayCriteria.mxd

Classification: Public

Classification: Public

Alberta

nhc northwest hydraulic consultants



- FLOW DIRECTION
- BRIDGE
- CULVERT
- DAM & SPILLWAY
- MODEL CROSS SECTION
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- CAMROSE CITY BOUNDARY
- BANK STATION
- PROPOSED FLOODWAY STATION
- VELOCITY ≥ 1 m/s
- PROPOSED FLOODWAY BOUNDARY
- DEPTH = 1 m
- DEPTH ≥ 1 m
- 100-YEAR OPEN WATER DESIGN FLOOD EXTENT
- PREVIOUS FLOODWAY

DISCHARGE
Unnamed Creek = 7.53 m^3/s

SCALE - 1:5,000
0 100 200 M

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

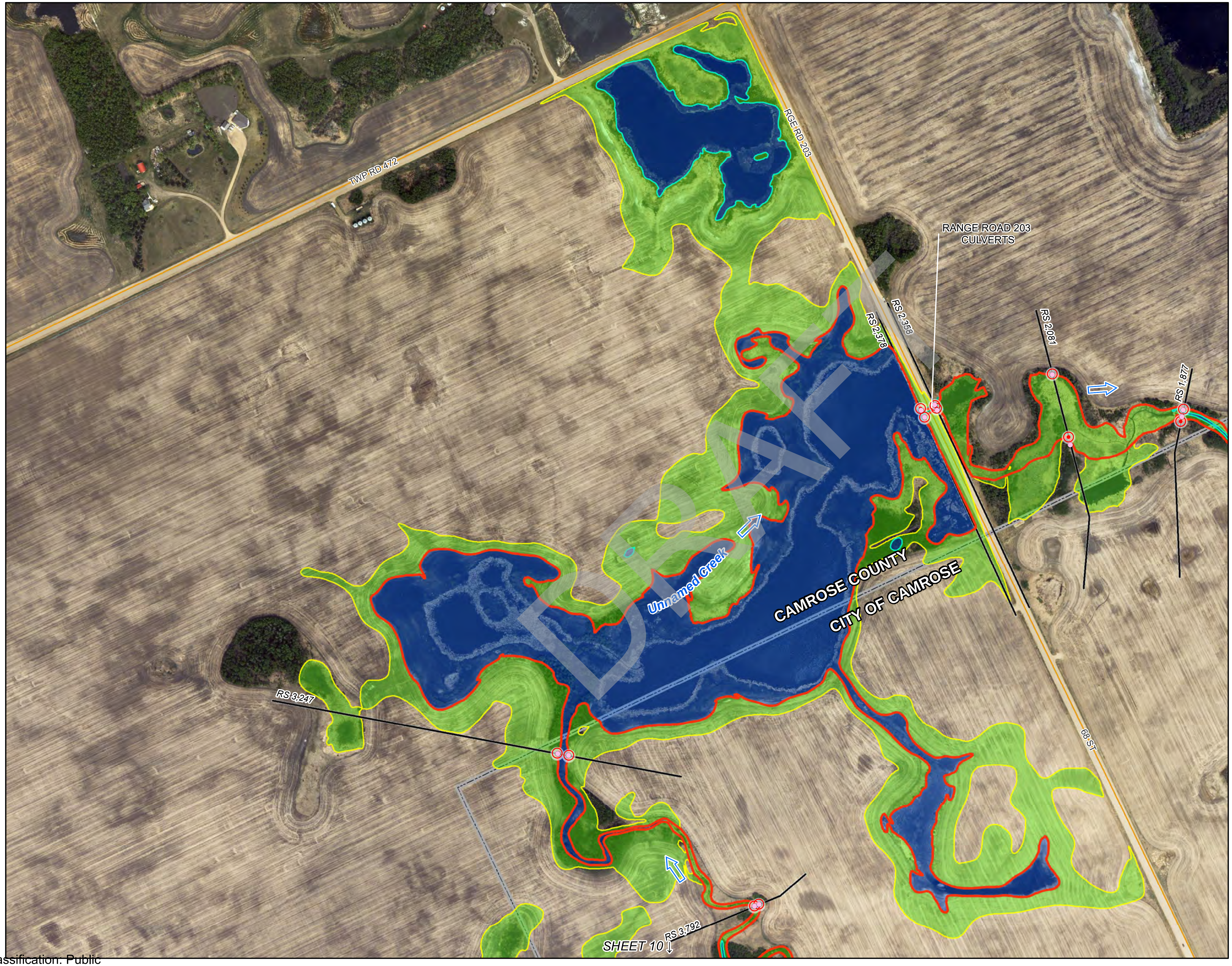
Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 Date: 02-JUN-2021

CAMROSE FLOOD HAZARD STUDY

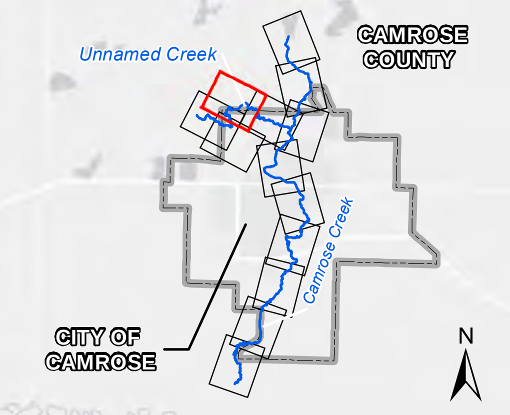
FLOODWAY CRITERIA MAP

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T500_FloodwayCriteria.mxd



Alberta

nhc
northwest hydraulic consultants



FLOW DIRECTION
BRIDGE
CULVERT
DAM & SPILLWAY
MODEL CROSS SECTION
PROVINCIAL HIGHWAY
LOCAL ROAD
RAILWAY
CAMROSE CITY BOUNDARY
BANK STATION
PROPOSED FLOODWAY STATION
VELOCITY ≥ 1 m/s
PROPOSED FLOODWAY BOUNDARY
DEPTH = 1 m
DEPTH ≥ 1 m
100-YEAR OPEN WATER DESIGN FLOOD EXTENT
PREVIOUS FLOODWAY

DISCHARGE
Unnamed Creek = 7.53 m^3/s

SCALE - 1:5,000
0 100 200 M
N

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

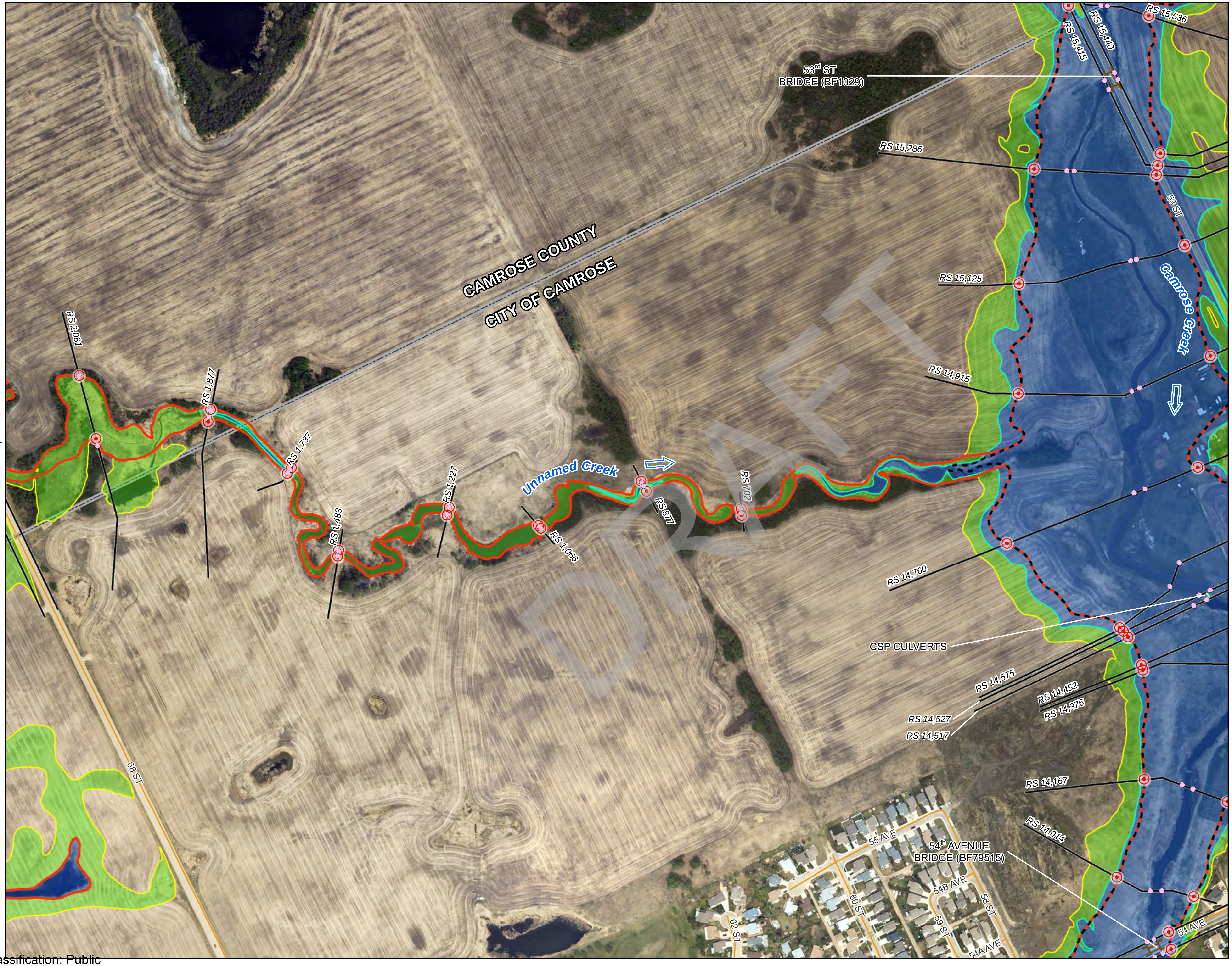
Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662	*Date: 02-JUN-2021*

CAMROSE
FLOOD HAZARD STUDY

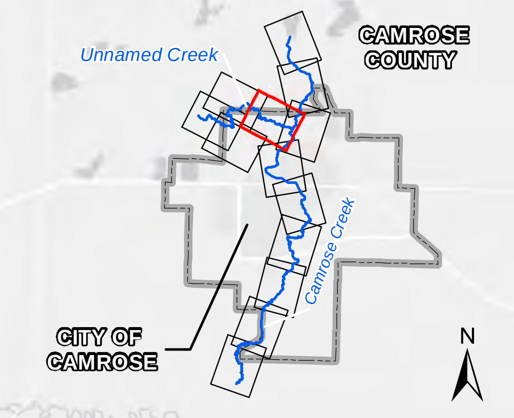
FLOODWAY CRITERIA MAP

Classification: Public



Alberta

nhc northwest hydraulic consultants



FLOW DIRECTION
BRIDGE
CULVERT
DAM & SPILLWAY
MODEL CROSS SECTION
PROVINCIAL HIGHWAY
LOCAL ROAD
RAILWAY
CAMROSE CITY BOUNDARY
BANK STATION
PROPOSED FLOODWAY STATION
VELOCITY ≥ 1 m/s
PROPOSED FLOODWAY BOUNDARY
DEPTH = 1 m
DEPTH ≥ 1 m
100-YEAR OPEN WATER DESIGN FLOOD EXTENT
PREVIOUS FLOODWAY

DISCHARGE
Unnamed Creek = 7.53 m^3/s
Camrose Creek above Unnamed Creek = 40.7 m^3/s
Camrose Creek below Unnamed Creek = 43.5 m^3/s

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 Date: 02-JUN-2021

CAMROSE
FLOOD HAZARD STUDY

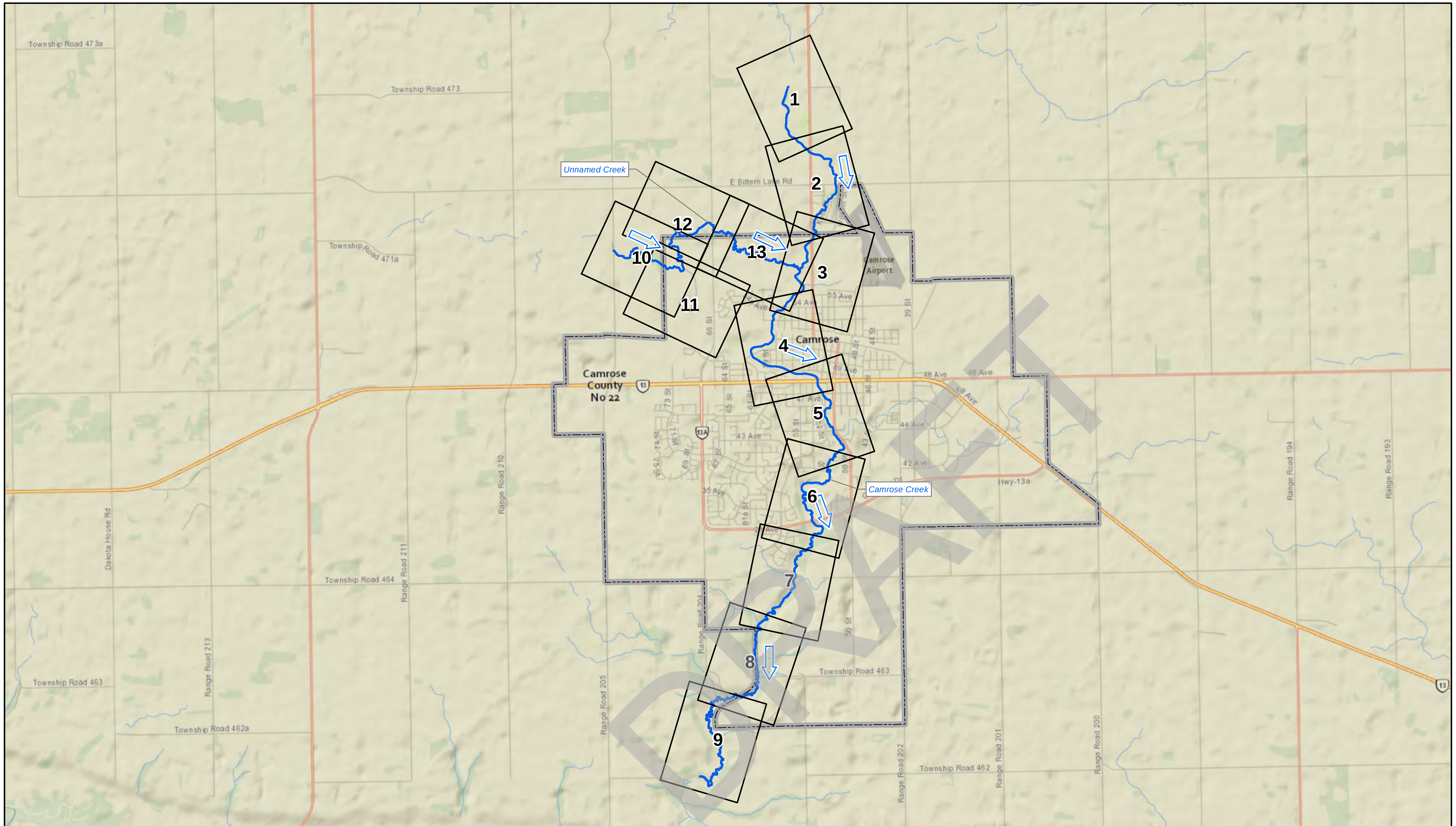
FLOODWAY CRITERIA MAP

SHEET 13 OF 13

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T500_FloodwayCriteria.mxd

Classification: Public

Appendix J
Flood Hazard Map



Alberta

nhc
northwest hydraulic consultants

FLOW DIRECTION
STUDY REACH
MAP SHEET
CAMROSE CITY BOUNDARY

SCALE - 1:70,000
0 500 1,000 2,000 3,000 M
N

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

Engineer	*GIS*	*Reviewer*
MMM	REH	RBA

Job: 1004662 Date: 11-JUN-2021

CAMROSE FLOOD HAZARD STUDY

DESIGN FLOOD HAZARD MAP

INDEX MAP

Notes to Users:

1. 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.
2. 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.
3. The flood inundation area is shown above the linework for bridges and flood control structures that are below flood levels.

Definitions:

Flood Hazard Map - A flood hazard map is a specific type of flood map that identifies the area flooded for the 1:100 design flood, and divides that flood hazard area into floodway and flood fringe zones. Flood hazard maps can also show additional flood hazard information, including the incremental areas at risk for more severe floods like the 1:200 and 1:500 floods. Flood hazard maps are typically used for long-term flood hazard area management and land-use planning.

Design Flood - The design flood standard in Alberta is the 1:100 flood, which is a flood that has a 1% chance of being equaled or exceeded in any given year. The design flood is typically based on the 1:100 open water flood, but it can also reflect 1:100 ice jam flood levels or be based on a historical flood event. Different sized floods have different chances of occurring – for example, a 1:200 flood has a 0.5% chance of occurring in any given year and a 1:500 flood has a 0.2% chance of occurring in any given year – but only the 1:100 design flood is used to define the floodway and flood fringe zones on flood hazard maps.

Floodway - When a floodway is first defined on a flood hazard map, it typically represents the area of highest flood hazard where flows are deepest, fastest, and most destructive during the 1:100 design flood. When a flood hazard map is updated, the floodway will not get larger in most circumstances to maintain long-term regulatory certainty, even if the flood hazard area gets larger or design flood levels get higher.

Flood Fringe - The flood fringe is the area outside of the floodway that is flooded or could be flooded during the 1:100 design flood. The flood fringe typically represents areas with

Definitions (continued):

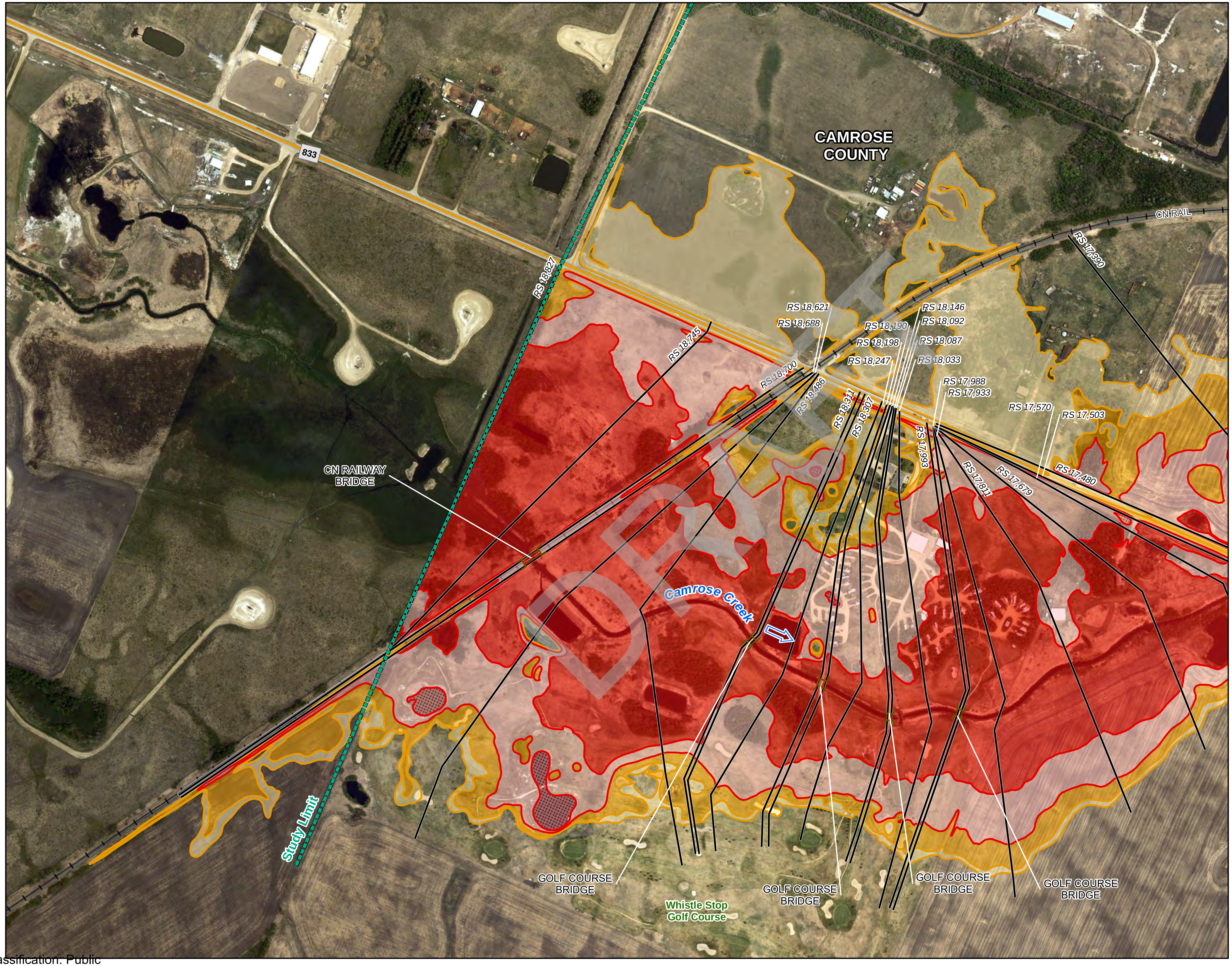
shallower, slower, and less destructive flooding, but it may also include "high hazard flood fringe" areas. Areas at risk of flooding behind flood berms may also be mapped as "protected flood fringe" areas.

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 most significant for flood maps that are being updated, but they 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 1:100 design flood, even if they are not overtopped. Protected flood fringe areas are part of the flood fringe and do not differentiate between areas with deeper or faster moving water and shallower or slower moving water.

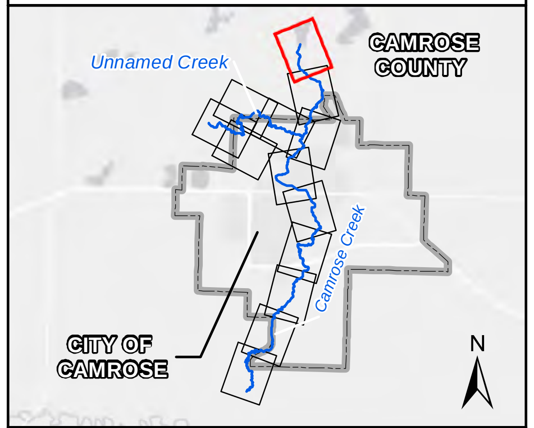
Data Sources and References:

1. Orthophoto imagery acquired by OGL Engineering for Alberta Environment and Parks: *OGL Engineering (2019). Camrose aerial imagery acquisition memorandum, project number 2019-506, submitted to Alberta Environment and Parks, 5 pp.*
2. Base data from Natural Resources Canada, Alberta Environment and Parks, and Altalis.
3. Additional base mapping from Esri.



Alberta

nhc northwest hydraulic consultants



- FLOW DIRECTION
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- DAM & SPILLWAY
- CAMROSE CITY BOUNDARY
- STUDY LIMIT
- MODEL CROSS SECTION
- GOVERNING FLOODWAY
- HIGH HAZARD FLOOD FRINGE
- FLOOD FRINGE
- 200-YEAR FLOOD EXTENT
- 500-YEAR FLOOD EXTENT

DISCHARGE
Camrose Creek = 40.7 m^3/s

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

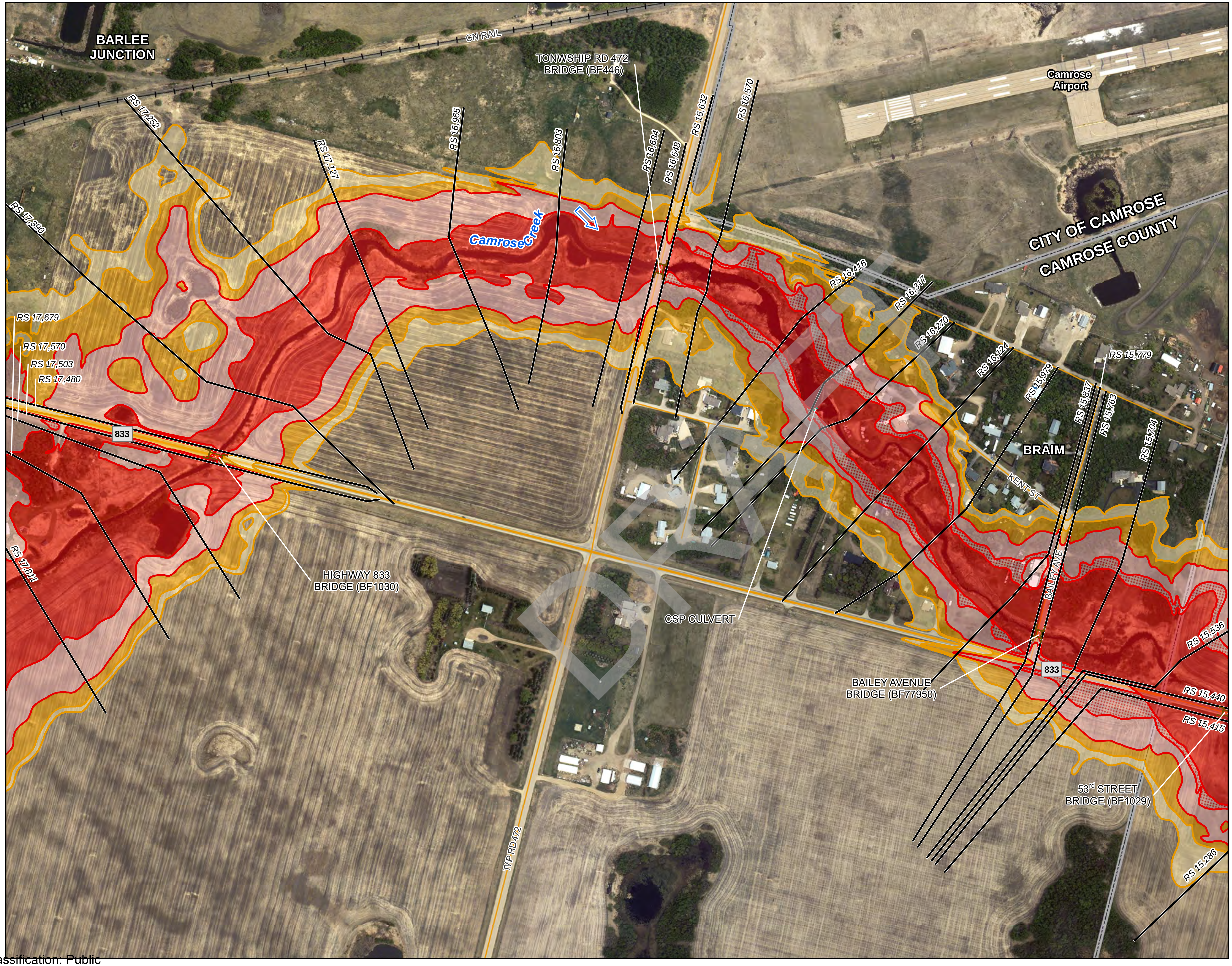
Job: 1004662 | Date: 11-JUN-2021

CAMROSE FLOOD HAZARD STUDY

DESIGN FLOOD HAZARD MAP

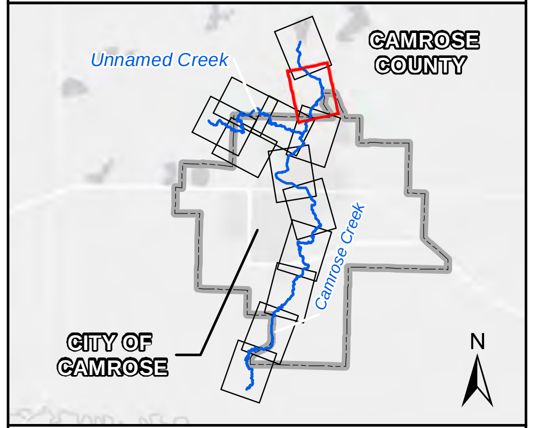
SHEET 1 OF 13

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T600_FloodHazard.mxd



Alberta

nhc northwest hydraulic consultants



FLOW DIRECTION
PROVINCIAL HIGHWAY
LOCAL ROAD
RAILWAY
BRIDGE
CULVERT
DAM & SPILLWAY
CAMROSE CITY BOUNDARY
STUDY LIMIT
MODEL CROSS SECTION
GOVERNING FLOODWAY
HIGH HAZARD FLOOD FRINGE
FLOOD FRINGE
200-YEAR FLOOD EXTENT
500-YEAR FLOOD EXTENT

DISCHARGE
Camrose Creek = 40.7 m^3/s

SCALE - 1:5,000
0 100 200 M

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

Engineer MMM	GIS REH	Reviewer RBA
Job: 1004662	Date: 11-JUN-2021	

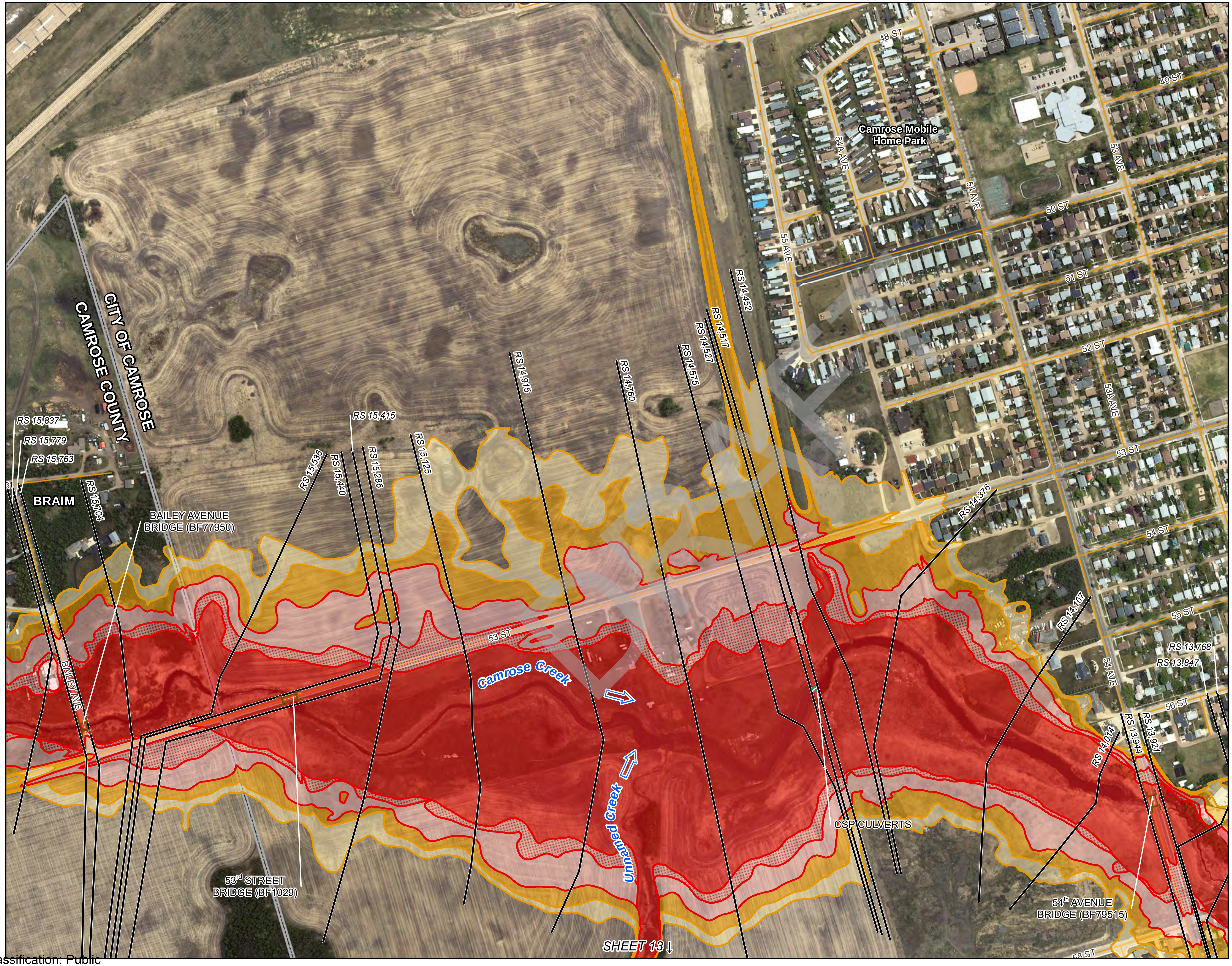
CAMROSE
FLOOD HAZARD STUDY

DESIGN FLOOD HAZARD MAP

SHEET 2 OF 13

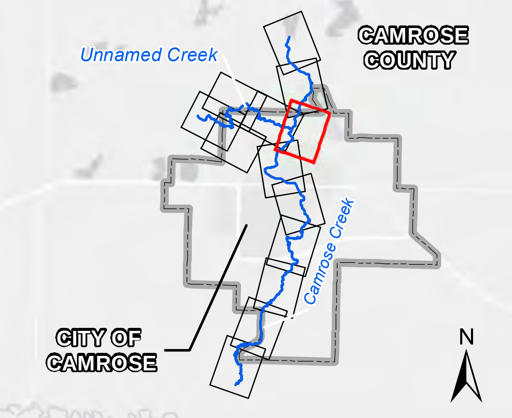
Classification: Public

REH; P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T600_FloodHazard.mxd



Alberta

nhc northwest hydraulic consultants



- FLOW DIRECTION
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- DAM & SPILLWAY
- CAMROSE CITY BOUNDARY
- STUDY LIMIT
- MODEL CROSS SECTION
- GOVERNING FLOODWAY
- HIGH HAZARD FLOOD FRINGE
- FLOOD FRINGE
- 200-YEAR FLOOD EXTENT
- 500-YEAR FLOOD EXTENT

DISCHARGE

Camrose Creek above Unnamed Creek = 40.7 m^3/s

Camrose Creek below Unnamed Creek = 43.5 m^3/s

SCALE - 1:5,000

0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

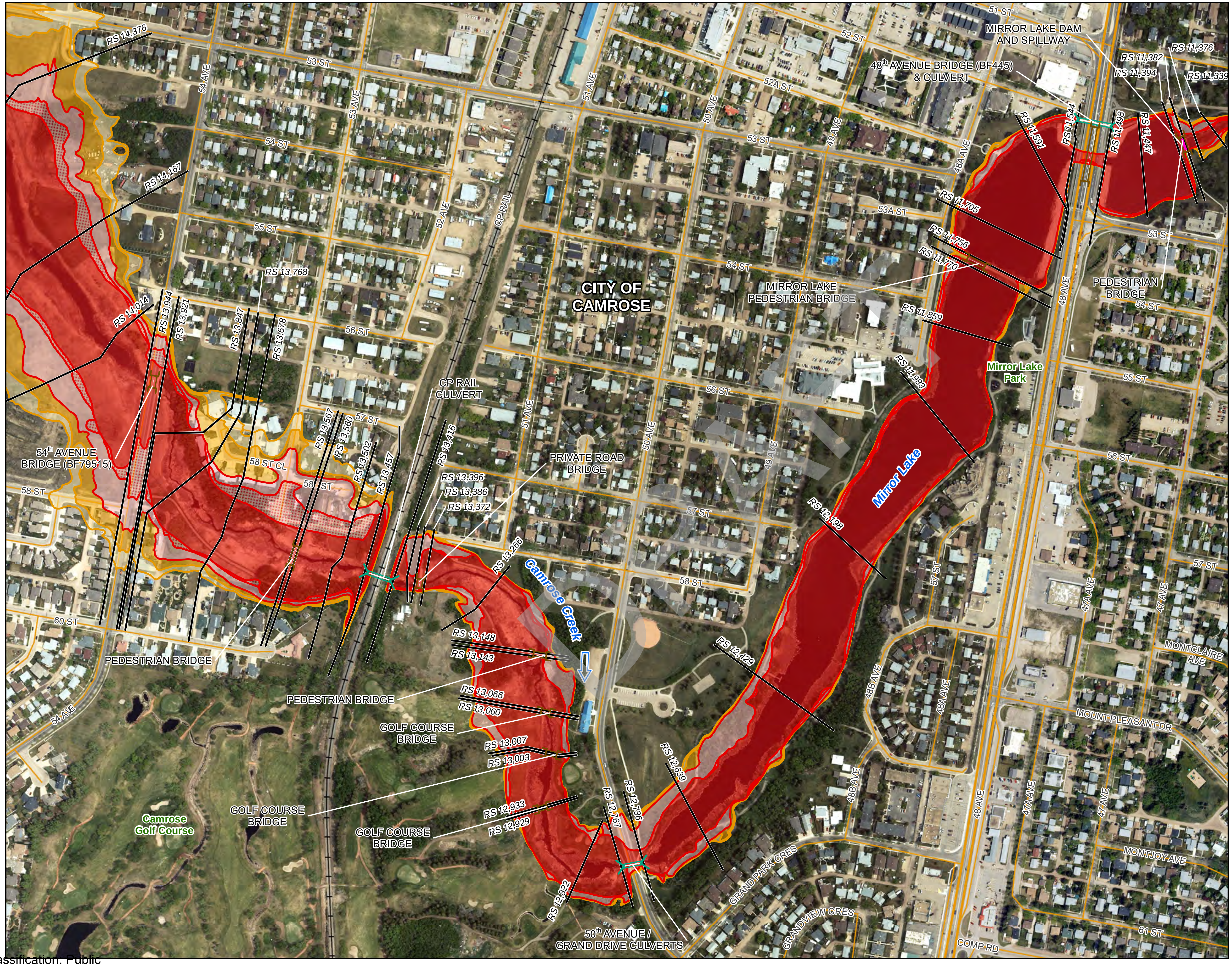
Job: 1004662 Date: 11-JUN-2021

CAMROSE FLOOD HAZARD STUDY

DESIGN FLOOD HAZARD MAP

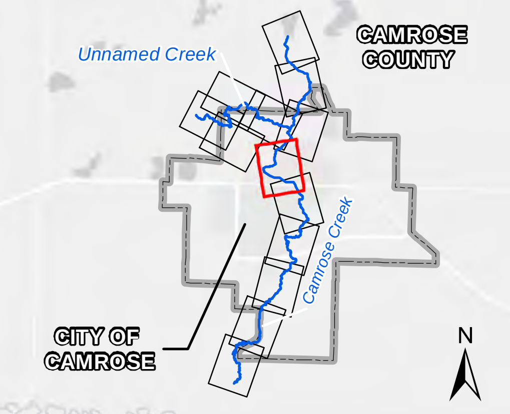
SHEET 3 OF 13

REH_P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T600_FloodHazard.mxd



Alberta

nhc
northwest hydraulic consultants



- FLOW DIRECTION
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- DAM & SPILLWAY
- CAMROSE CITY BOUNDARY
- STUDY LIMIT
- MODEL CROSS SECTION
- GOVERNING FLOODWAY
- HIGH HAZARD FLOOD FRINGE
- FLOOD FRINGE
- 200-YEAR FLOOD EXTENT
- 500-YEAR FLOOD EXTENT

DISCHARGE

Camrose Creek above CP Rail Culvert = 43.5 m^3/s
Camrose Creek below CP Rail Culvert = 41.1 m^3/s

SCALE - 1:5,000

0 100 200 M

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

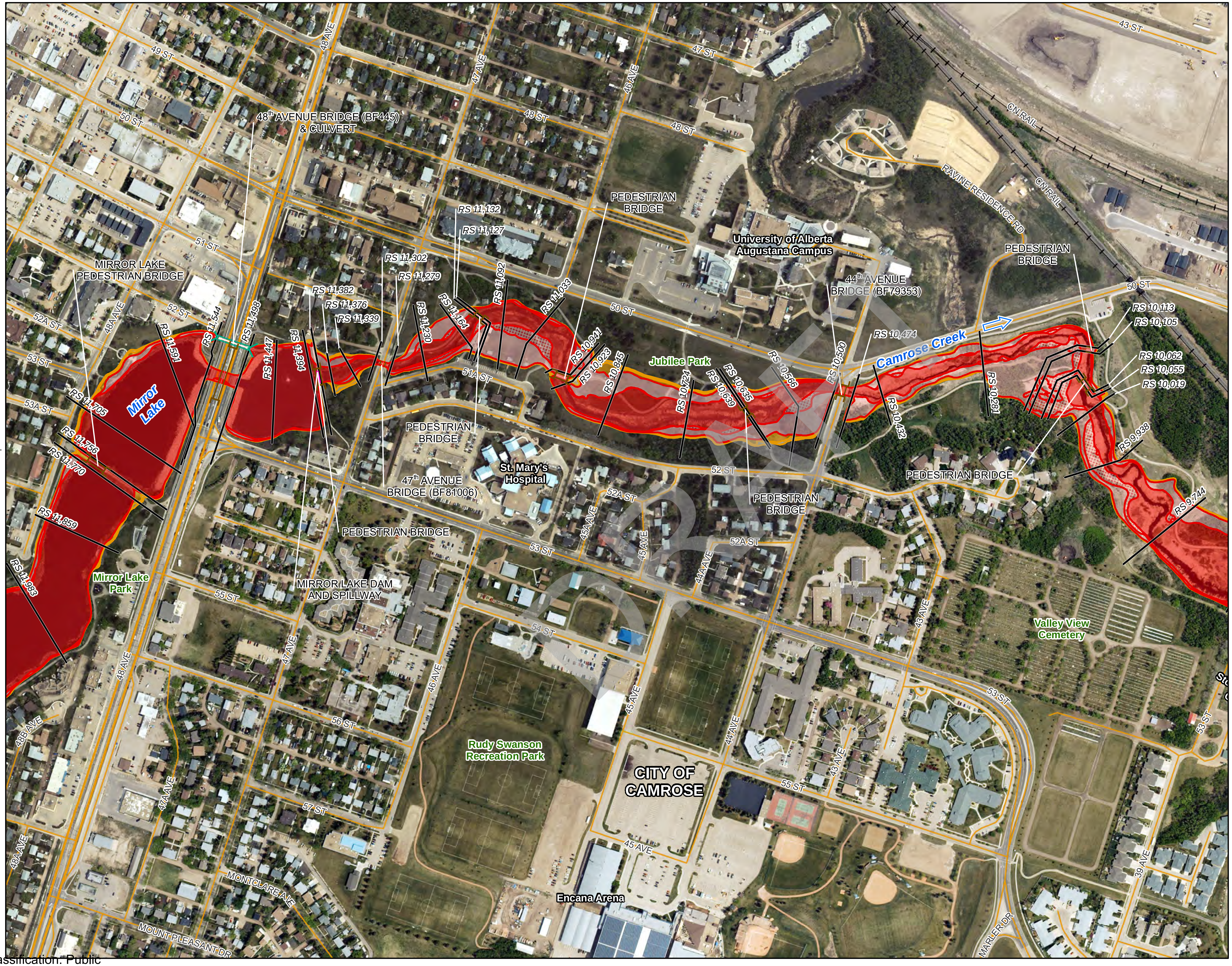
Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 Date: 11-JUN-2021

CAMROSE
FLOOD HAZARD STUDY

DESIGN FLOOD HAZARD MAP

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T600_FloodHazard.mxd



Alberta

nhc northwest hydraulic consultants

CAMROSE COUNTY
Unnamed Creek
Camrose Creek
CITY OF CAMROSE

FLOW DIRECTION
PROVINCIAL HIGHWAY
LOCAL ROAD
RAILWAY
BRIDGE
CULVERT
DAM & SPILLWAY
CAMROSE CITY BOUNDARY
STUDY LIMIT
MODEL CROSS SECTION
GOVERNING FLOODWAY
HIGH HAZARD FLOOD FRINGE
FLOOD FRINGE
200-YEAR FLOOD EXTENT
500-YEAR FLOOD EXTENT

DISCHARGE
Camrose Creek = 41.1 m^3/s

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 | Date: 11-JUN-2021

CAMROSE
FLOOD HAZARD STUDY

DESIGN FLOOD HAZARD MAP

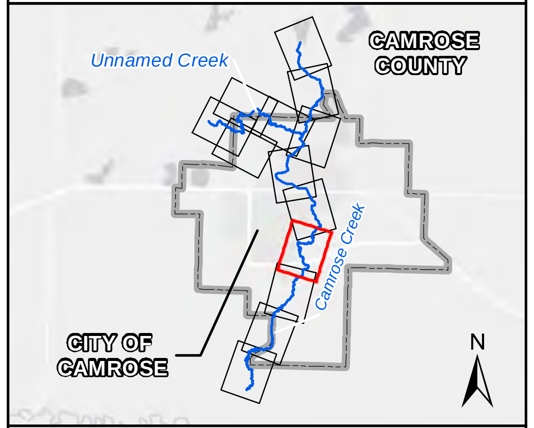
SHEET 5 OF 13

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1004662_Map_T600_FloodHazard.mxd

Classification: Public

Alberta

nhc northwest hydraulic consultants



- FLOW DIRECTION
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- DAM & SPILLWAY
- CAMROSE CITY BOUNDARY
- STUDY LIMIT
- MODEL CROSS SECTION
- GOVERNING FLOODWAY
- HIGH HAZARD FLOOD FRINGE
- FLOOD FRINGE
- 200-YEAR FLOOD EXTENT
- 500-YEAR FLOOD EXTENT

DISCHARGE
Camrose Creek = 41.1 m^3/s

SCALE - 1:5,000
0 100 200 M

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

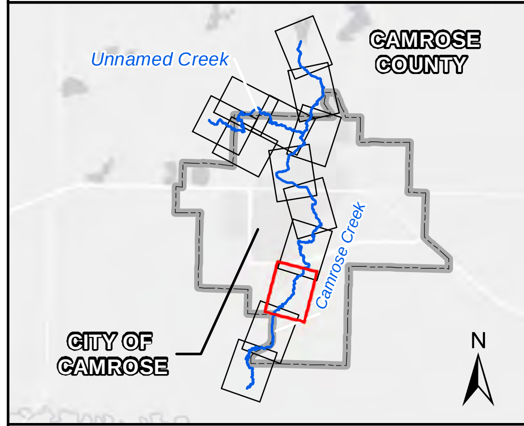
Engineer	GIS	Reviewer
MMM	REH	RBA
Job: 1004662	Date: 11-JUN-2021	

CAMROSE FLOOD HAZARD STUDY

DESIGN FLOOD HAZARD MAP

Alberta

nhc northwest hydraulic consultants



FLOW DIRECTION
PROVINCIAL HIGHWAY
LOCAL ROAD
RAILWAY
BRIDGE
CULVERT
DAM & SPILLWAY
CAMROSE CITY BOUNDARY
STUDY LIMIT
MODEL CROSS SECTION
GOVERNING FLOODWAY
HIGH HAZARD FLOOD FRINGE
FLOOD FRINGE
200-YEAR FLOOD EXTENT
500-YEAR FLOOD EXTENT

DISCHARGE
Camrose Creek above RS 6,221 = 41.1 m^3/s
Camrose Creek below RS 6,221 = 43.3 m^3/s

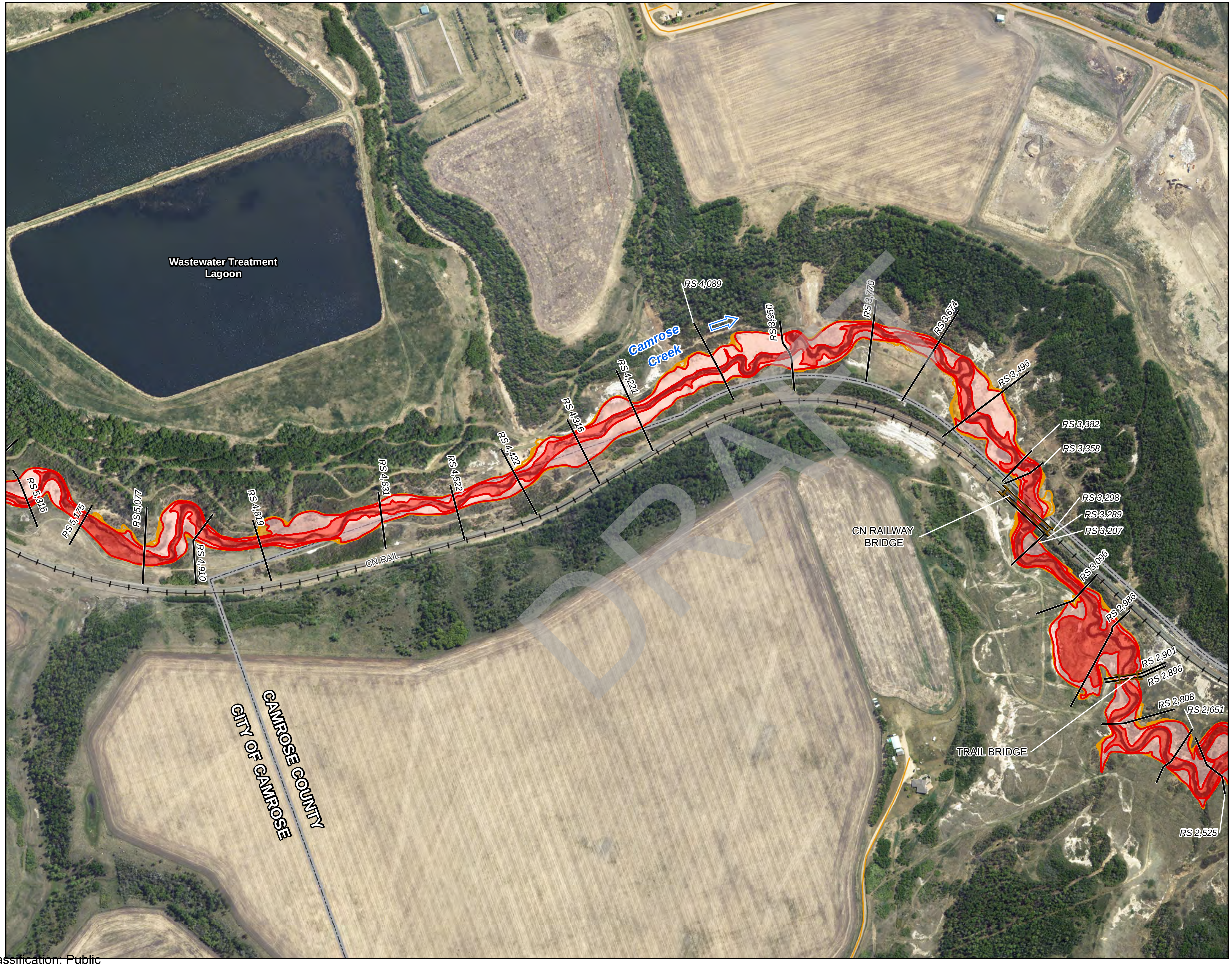
SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA
Job: 1004662	Date: 11-JUN-2021	

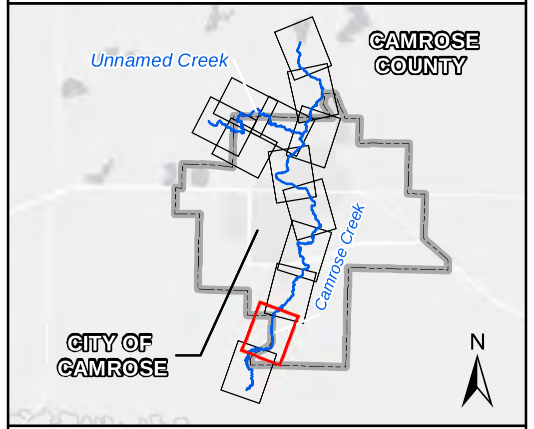
CAMROSE
FLOOD HAZARD STUDY

DESIGN FLOOD HAZARD MAP



Alberta

nhc
northwest hydraulic consultants



FLOW DIRECTION
PROVINCIAL HIGHWAY
LOCAL ROAD
RAILWAY
BRIDGE
CULVERT
DAM & SPILLWAY
CAMROSE CITY BOUNDARY
STUDY LIMIT
MODEL CROSS SECTION
GOVERNING FLOODWAY
HIGH HAZARD FLOOD FRINGE
FLOOD FRINGE
200-YEAR FLOOD EXTENT
500-YEAR FLOOD EXTENT

DISCHARGE
Camrose Creek = 43.3 m^3/s

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA
Job: 1004662	Date: 11-JUN-2021	

CAMROSE
FLOOD HAZARD STUDY

DESIGN FLOOD HAZARD MAP

SHEET 8 OF 13

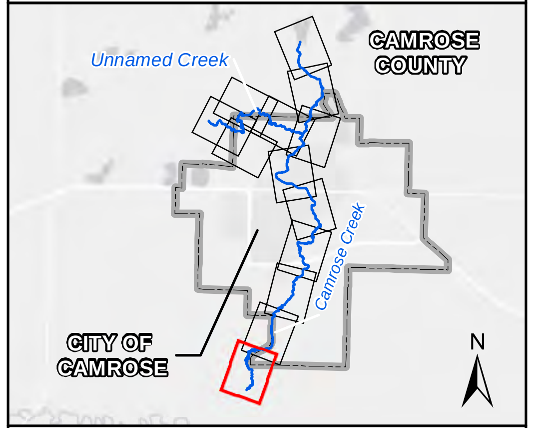
REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1004662_Map_T600_FloodHazard.mxd

Classification: Public

Classification: Public

Alberta

nhc northwest hydraulic consultants



- FLOW DIRECTION
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- DAM & SPILLWAY
- CAMROSE CITY BOUNDARY
- STUDY LIMIT
- MODEL CROSS SECTION
- GOVERNING FLOODWAY
- HIGH HAZARD FLOOD FRINGE
- FLOOD FRINGE
- 200-YEAR FLOOD EXTENT
- 500-YEAR FLOOD EXTENT

DISCHARGE
Camrose Creek = 43.3 m^3/s

SCALE - 1:5,000
0 100 200 M

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

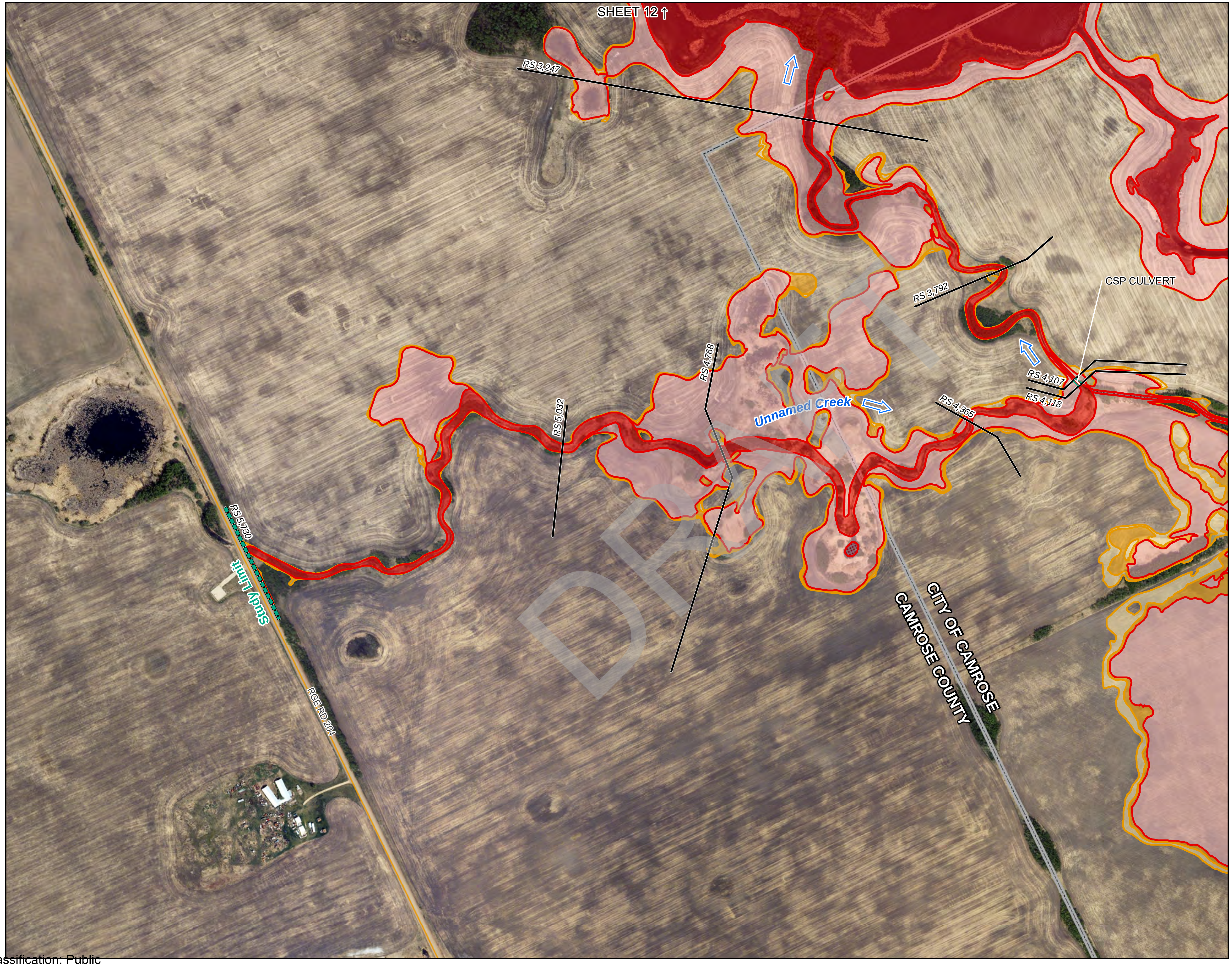
Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662	Date: 11-JUN-2021

CAMROSE
FLOOD HAZARD STUDY

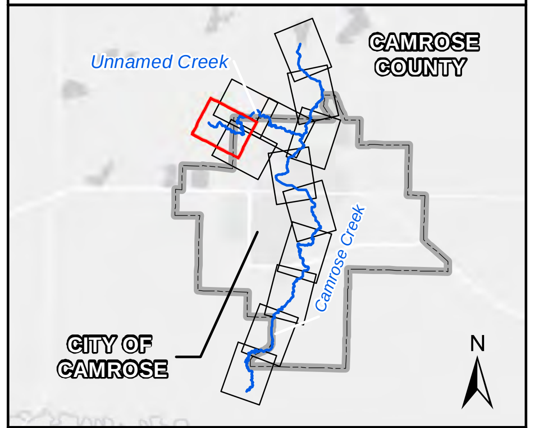
DESIGN FLOOD HAZARD MAP

REH P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T600_FloodHazard.mxd



Alberta

nhc northwest hydraulic consultants



FLOW DIRECTION
PROVINCIAL HIGHWAY
LOCAL ROAD
RAILWAY
BRIDGE
CULVERT
DAM & SPILLWAY
CAMROSE CITY BOUNDARY
STUDY LIMIT
MODEL CROSS SECTION
GOVERNING FLOODWAY
HIGH HAZARD FLOOD FRINGE
FLOOD FRINGE
200-YEAR FLOOD EXTENT
500-YEAR FLOOD EXTENT

DISCHARGE
Unnamed Creek = 7.53 m^3/s

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 | Date: 11-JUN-2021

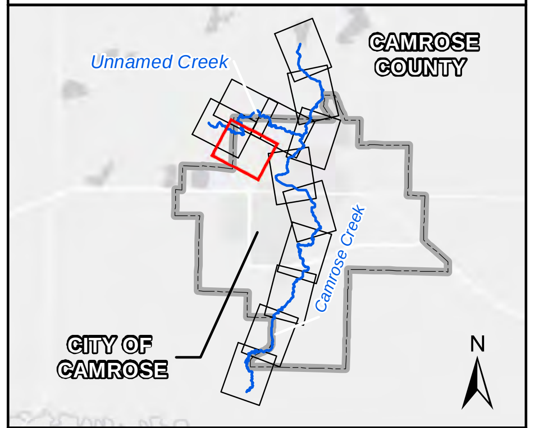
CAMROSE
FLOOD HAZARD STUDY

DESIGN FLOOD HAZARD MAP

SHEET 10 OF 13

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T600_FloodHazard.mxd

Classification: Public



Alberta

nhc northwest hydraulic consultants

FLOW DIRECTION
PROVINCIAL HIGHWAY
LOCAL ROAD
RAILWAY
BRIDGE
CULVERT
DAM & SPILLWAY
CAMROSE CITY BOUNDARY
STUDY LIMIT
MODEL CROSS SECTION
GOVERNING FLOODWAY
HIGH HAZARD FLOOD FRINGE
FLOOD FRINGE
200-YEAR FLOOD EXTENT
500-YEAR FLOOD EXTENT

DISCHARGE
Unnamed Creek = 7.53 m^3/s

SCALE - 1:5,000
0 100 200 M
N

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

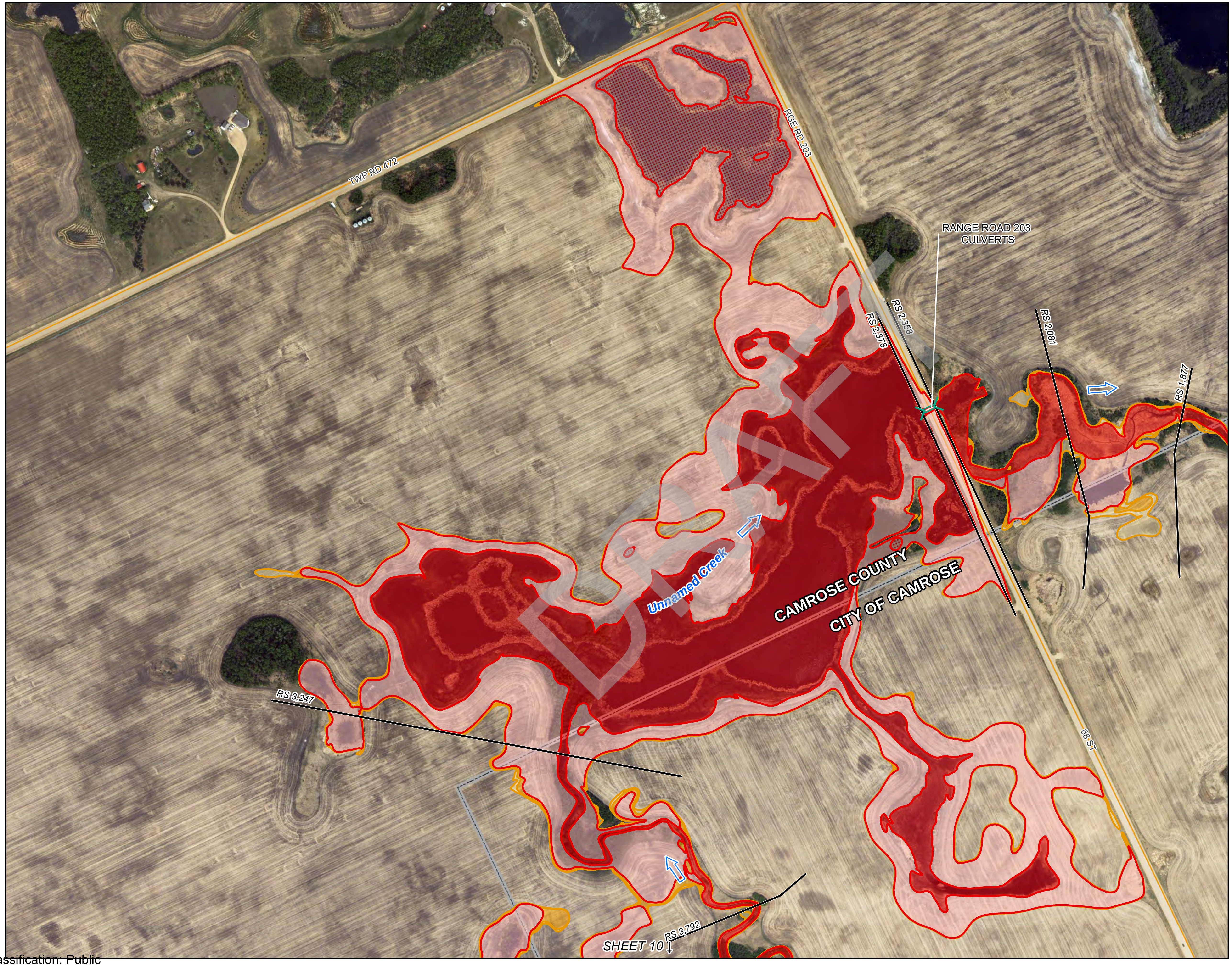
Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 | *Date: 11-JUN-2021*

CAMROSE FLOOD HAZARD STUDY

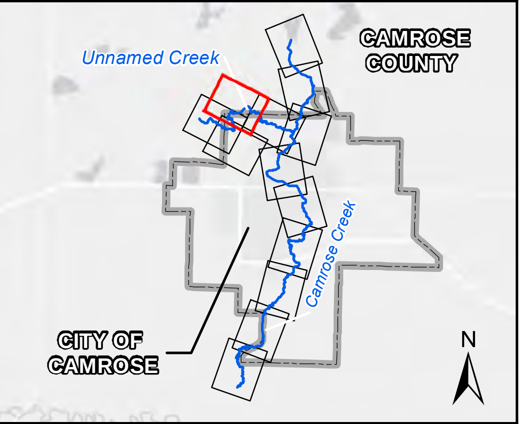
DESIGN FLOOD HAZARD MAP

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T600_FloodHazard.mxd



Alberta

nhc northwest hydraulic consultants



- FLOW DIRECTION
- PROVINCIAL HIGHWAY
- LOCAL ROAD
- RAILWAY
- BRIDGE
- CULVERT
- DAM & SPILLWAY
- CAMROSE CITY BOUNDARY
- STUDY LIMIT
- MODEL CROSS SECTION
- GOVERNING FLOODWAY
- HIGH HAZARD FLOOD FRINGE
- FLOOD FRINGE
- 200-YEAR FLOOD EXTENT
- 500-YEAR FLOOD EXTENT

DISCHARGE
Unnamed Creek = 7.53 m^3/s

SCALE - 1:5,000
0 100 200 M

N

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662	Date: 11-JUN-2021

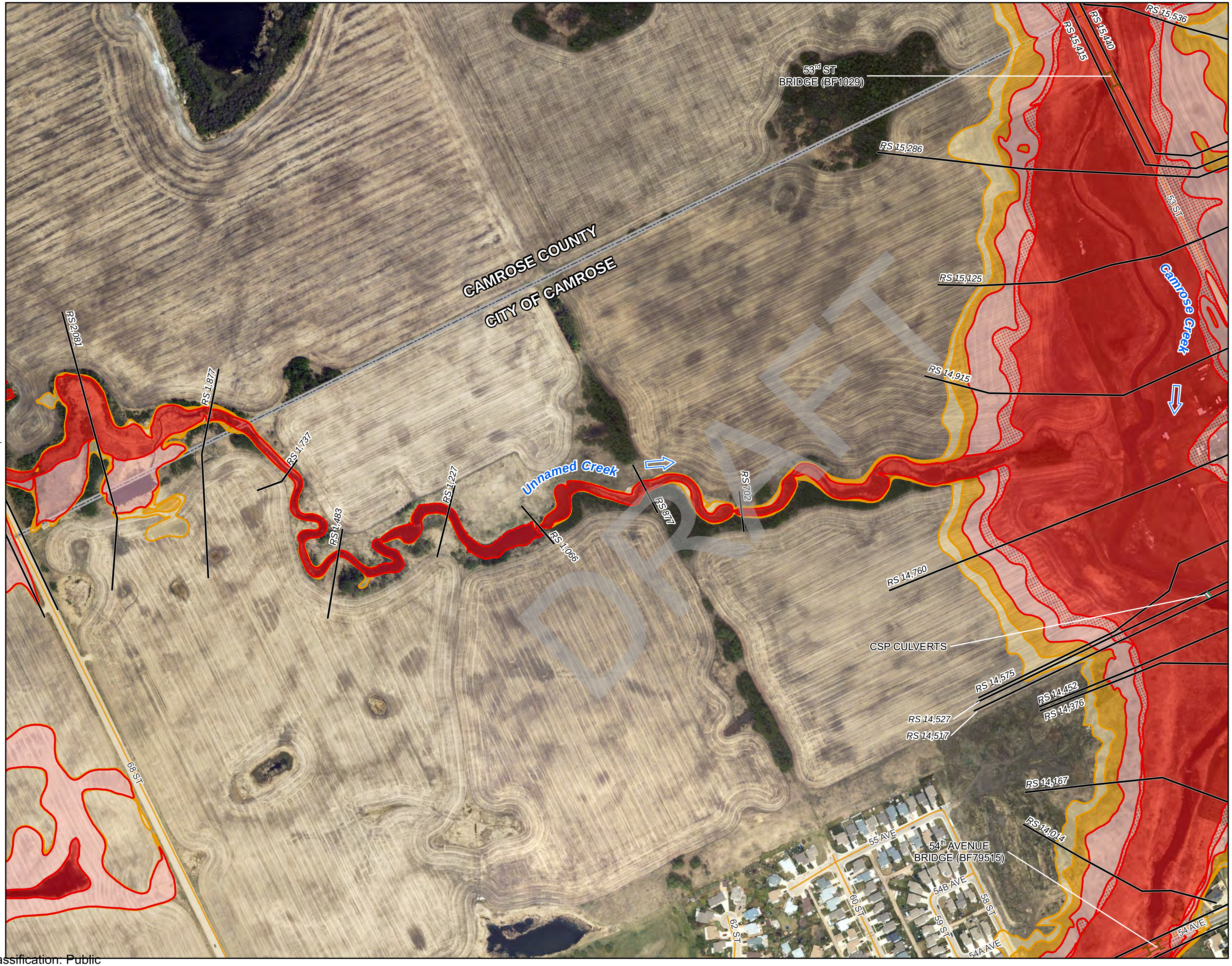
CAMROSE
FLOOD HAZARD STUDY

DESIGN FLOOD HAZARD MAP

SHEET 12 OF 13

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T600_FloodHazard.mxd

Classification: Public



Classification: Public

Alberta

nhc
northwest hydraulic consultants

Unnamed Creek
CAMROSE COUNTY
Camrose Creek
CITY OF CAMROSE
N

FLOW DIRECTION
PROVINCIAL HIGHWAY
LOCAL ROAD
RAILWAY
BRIDGE
CULVERT
DAM & SPILLWAY
CAMROSE CITY BOUNDARY
STUDY LIMIT
MODEL CROSS SECTION
GOVERNING FLOODWAY
HIGH HAZARD FLOOD FRINGE
FLOOD FRINGE
200-YEAR FLOOD EXTENT
500-YEAR FLOOD EXTENT

DISCHARGE
Unnamed Creek = 7.53 m^3/s
Camrose Creek above Unnamed Creek = 40.7 m^3/s
Camrose Creek below Unnamed Creek = 43.5 m^3/s

SCALE - 1:5,000
0 100 200 M
N

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

Engineer	GIS	Reviewer
MMM	REH	RBA

Job: 1004662 | *Date: 11-JUN-2021*

CAMROSE
FLOOD HAZARD STUDY

DESIGN FLOOD HAZARD MAP

SHEET 13 OF 13

REH, P:_Projects (Active)\1004662 Camrose Flood Hazard Study\90 GIS_1006302_Map_T600_FloodHazard.mxd

northwest hydraulic consultants
water resource specialists