Alberta Environment and Parks

Pincher Creek Flood Hazard Study

Study Report

February 2023

Alberta Environment and Parks

Pincher Creek Flood Hazard Study

Study Report

EXECUTIVE SUMMARY

Alberta Environment and Parks (AEP) commissioned Klohn Crippen Berger (KCB) in March 2019 to conduct the Pincher Creek Flood Hazard Study (the study). The purpose of the study is to assess and identify flood hazards along Pincher Creek and Kettles Creek through the Town of Pincher Creek and adjacent areas in the Municipal District of Pincher Creek No. 9.

The project was conducted under the Provincial Flood Hazard Identification Program (FHIP), incorporating technical changes implemented in 2021 regarding how floodways are mapped in Alberta. The goals of the FHIP include enhancement of public safety and reduction of future flood damages through the identification of river and flood hazards. Project stakeholders include the Government of Alberta, the Town of Pincher Creek, Municipal District of Pincher Creek No. 9 and the general public.

The modelled reach included 14.3 km of Pincher Creek and 7.3 km of Kettles Creek, from its confluence with Pincher Creek and extending upstream. The upstream project limit is approximately 2.5 km upstream of the Town of Pincher Creek. The downstream boundary is approximately 2.6 km downstream of the town.

Surveying of the Pincher Creek and Kettles Creek channel was conducted by TROUT Hydrography Inc. (TROUT), a subcontractor to SG1 Water Consulting Ltd. (SG1), between May 16 and 22, 2019. The field program included surveying 270 cross sections, 13 bridges, one culvert, three flood control structures, and water levels along the study reach at the time of the survey. LiDAR data covering the Pincher Creek and Kettles Creek floodplains was captured in October 2018 by Airborne Imaging (AI).

An open-water hydrology assessment was undertaken to estimate the peak discharges in Pincher Creek, Kettles Creek, and Indianfarm Creek for events ranging from the 2-year to the 1000-year flood. A single station flood frequency analysis was undertaken for Pincher Creek based on the available 76 years of natural flow record. Resulting flows were slightly higher than those published in AE (1993). A regional flood frequency analysis was undertaken for Kettles Creek using the Index Flood method. The 12 year record for the Kettles Creek at Pincher Creek gauge was used to establish an average discharge for Kettles Creek for use in the Index Flood method. The resulting flood frequency discharges were slightly less than the estimates given in AE (1993). A regional flood frequency assessment was undertaken for the Indianfarm Creek catchment.

A one-dimensional hydraulic model was developed in HEC-RAS using a combination of topographic survey results and the Digital Terrain Model (DTM) provided by AEP. The developed model was calibrated against high water mark (HWM) data collected during the 1995 and the 2010 flood events. The 1995 event is the flood of record on Pincher Creek, whereas the 2010 event is the flood of record on Kettles Creek. For low flows, the measured water levels during the survey were used for calibration. The calibrated model was also checked against the Water Survey of Canada rating curves for both creeks. HEC-RAS (US Army Corps of Engineers 2019) was used for hydraulic model creation and the generation of flood inundation extents. For processing geospatial data ArcGIS was used. GeoHECRAS was used to aid model creation, and to make topographic and DTM data compatible with the HEC-RAS hydraulic model.

The calibrated model was used as the basis for generating water surface profiles. Sensitivity tests were carried out on the Manning's *n* roughness parameters for the main channel and floodplain. The Manning's *n* values for the channel range from 0.025 to 0.045. The Flood Inundation Maps were generated in ArcGIS using the water surface profiles. A number of modifications were made to the TIN following standard approaches described in the Terms of Reference. In addition, several more complex TIN modifications were required such that the results were appropriately represented.

Flood Inundation Maps were generated for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-. 750-, and 1000- year events. The inundation extents show a number of areas along Pincher Creek that are prone to flooding. The left floodplain of Pincher Creek, downstream of the Hewetson Avenue bridge is partially inundated at the 75-year event. The area between Church Lane and the Highway 6 bridge (including the Pincher Creek Veteran's Memorial Campground) is inundated at the 100-year event. The Sleepy Hollow Campground, on the left floodplain, downstream of the Highway 6 bridge is partially inundated at the 35-year event. The industrial area on the left floodplain of Kettles Creek, upstream of the Highway 785 bridge, is also prone to flooding and is inundated at the 20-year event.

Sensitivity tests were undertaken for channel roughness. It was found that changing the channel roughness by ±10% and ±20% resulted in an average change in water levels of ±0.02 m and ±0.05 m respectively on both Pincher Creek and Kettles Creek for the 100-year event. Changing the overbank roughness values by ±10% and ±20% resulted in an average change of ±0.03 m and ±0.06 m respectively on Pincher Creek, and an average change of ±0.02 m and ±0.04 m respectively on Kettles Creek.

Sensitivity tests were also carried out on the downstream boundary condition, with channel slope changed by ±20%. The resulting increase and decrease in water level at the downstream boundary was 0.09 m and -0.07 m respectively. The effect of this adjusted downstream boundary condition extends approximately 130 m upstream.

The open water design flood is the governing design flood for both Pincher Creek and Kettles Creek. The Floodway Criteria Maps are included in Appendix X. The floodway was defined based on a mix of the previous floodway, 1 m depth and 1 m/s velocity criteria. In general, however, the most common criterion for Pincher Creek was the previous floodway criterion and then the 1 m depth criterion. The most common criteria for Kettles Creek was the 1 m/s velocity criterion.

The Flood Hazard Maps are included in Appendix XII. These maps show the floodway and the flood fringe areas, including areas of high hazard flood fringe. Supporting GIS data include floodway and flood fringe limit polygons, including high hazard flood fringe areas; governing design flood water surface TIN; and governing design flood depth and water surface elevation grids.

The floodway is relatively wide in places upstream and downstream of the Town of Pincher Creek, due to the presence of some deep areas on the relatively wide floodplains. There is a residential building within the floodway downstream of the Highway 785 Bridge. The flood fringe is also relatively wide in places along Pincher Creek, due to the wide floodplains. The Kettles Creek flood fringe is generally more confined than Pincher Creek. Areas in the flood fringe include residential areas within the Town of Pincher Creek, the Sleepy Hollow Campground, residences and industrial areas downstream of the Town of Pincher Creek, residential areas on Kettles Creek downstream of the East Avenue Crossing, the industrial area upstream of Macleod Street and residences around the Pincher and Kettles Creek confluence.

ACKNOWLEDGEMENTS

The authors would like to express our thanks to Muhammad Durrani, M.Eng., P.Eng. and Jane Eaket, M.Sc., P.Eng., CFM. of Alberta Environment and Parks for their support, study management, provision of data, and technical guidance throughout the project. We would also like to thank Alan Roth of the Town of Pincher Creek for providing background information related to the flood control structures within the town.

The Klohn Crippen Berger Ltd. (KCB) project manager and lead engineer was Rob Cheetham, P.Eng. Wes Dick, M.Sc., P.Eng., was the senior hydrologist and Djordje Pesko, P.Eng. provided technical advice during hydraulic modelling. Kathy Chen, E.I.T. undertook the hydrological analysis and hydraulic modelling. She also provided support during the preparation of the inundation maps. Vilma Castillo and Tim Schoenhals, B.Sc., M.A. undertook the GIS component of the project. Chuck Slack, P.Eng. undertook senior review.

KCB was supported by SG1 Water Consulting Ltd. Darren Shepherd, M.Sc., P.Eng. managed the field survey and provided peer review of the interim technical memorandum describing the Kettles Creek regional analysis. David D. Andres, M.Sc.CE, P.Eng. provided technical guidance during the hydrological analysis and hydraulic model creation components. He also provided peer review of the hydrology memorandum and the interim Kettles Creek regional analysis technical memorandum. The field survey was led by Doug West, B.Sc., C.S.T. of TROUT Hydrography Inc.

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

TABLE OF CONTENTS
(continued)

List of Tables

List of Figures

TABLE OF CONTENTS
(continued)

List of Appendices

1 INTRODUCTION

1.1 Study Background

Alberta Environment and Parks (AEP) retained Klohn Crippen Berger (KCB) to conduct the Pincher Creek Flood Hazard Study under the Flood Hazard Identification Program (FHIP), incorporating technical changes implemented in 2021 regarding how floodways are mapped in Alberta. The objectives of the FHIP are to:

- Enhance public safety and reduce future flood damages through the identification of river and flood hazards.
- Promote appropriate development of flood hazard areas.
- Increase public awareness of the flood hazard in their communities.

Identification of flood hazards is the first step towards reducing and mitigating flood damages.

The Pincher Creek Flood Risk Assessment was completed in 1993 (Philips 1993). The current study will expand upon and update the deliverables that were part of the 1993 study. The identification of the river and flood hazards for Pincher Creek and Kettles Creek within the project area will then be used under the FHIP, incorporating technical changes implemented in 2021 regarding how floodways are mapped in Alberta, to enhance public safety and reduce future flood damages.

The key stakeholders of the project are the Government of Alberta, the Town of Pincher Creek, and the Municipal District of Pincher Creek No. 9.

KCB retained SG1 Water Consulting Ltd. (SG1) to coordinate topographic data collection, including a survey of channel cross sections, bridges, and flood control structures. The survey was undertaken by TROUT Hydrography Inc. (TROUT).

1.2 Study Objectives

The purpose of the study is to assess and identify flood hazards along Pincher Creek and Kettles Creek through the Town of Pincher Creek and adjacent areas in the Municipal District of Pincher Creek No. 9. This project is composed of the following 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

1.3 Study Area and Reach

The Town of Pincher Creek is located approximately 175 km south of Calgary and 85 km west of Lethbridge in southwest Alberta. The town has a mix of residential areas, downtown core, and a two-acre industrial park that is zoned for both light and heavy industry.

The project includes the hydraulic modelling of 14.3 km of Pincher Creek, extending from NE-13-6-1-W5M to SW-31-6-29-W4M, and 7.3 km of Kettles Creek, extending from SE-16-6-30-W4M to its confluence with Pincher Creek. The upstream project limit is approximately 2.5 km upstream of the Town of Pincher Creek. The downstream boundary is approximately 2.6 km downstream of the town. The study area is shown on Figure 1.1.

The headwaters of Pincher Creek are in the Rocky Mountains. The largest catchment has a high proportion of mountain and a relatively small area of foothills terrain. Pincher Creek flows through the Town of Pincher Creek and a number of flood berms have been constructed to protect parts of the town from river flooding. Downstream of the town, the Pincher Creek floodplain has a mix of wooded and agruicultural land. There are a number of bridges that cross Pincher Creek within the study area, including:

- The pedestrian bridge at the Pincher Creek community centre;
- Beaver Drive bridge;
- Hewetson Avenue bridge;
- Bev McLachlin Drive bridge;
- Pedestrian bridge to the south of James Avenue;
- Highway 6 bridge crossing; and
- Highway 785 crossing.

The downstream Pincher Creek model limit is 1.3 km downstream of the Highway 785 bridge.

The headwaters of the Kettles Creek catchment are in the Rocky Mountain foothills, with moderate relief and bedrock outcrops that are oriented perpendicular to the general catchment slope. The modelled reach can be divided into a rural upstream reach and an urban downstream reach, as the creek flows through the largely industrial area of the Town of Pincher Creek. The upstream limit of Kettles Creek is approximately 2.5 km upstream of the town. There are a number of crossings of Kettles Creek within the study area, including:

- Range Road 302 culvert crossing;
- Highway 6 bridge;
- Main Street bridge;
- Macleod Street (Highway 785) bridge; and
- Township Road 64/Range Road 301.

The Kettles Creek and Pincher Creek confluence is located downstream of the Town of Pincher Creek, approximately 1.25 km downstream of the Highway 6 crossing of Pincher Creek.

Indianfarm Creek is the second major tributary to Pincher Creek within the study area. Its confluence with Pincher Creek is towards the downstream project limit, approximately 0.25 km downstream of the Highway 6 Bridge. The Indianfarm Creek catchment has its headwaters in the Rocky Mountains, but its catchment is predominantly foothills and prairie. The Indianfarm Creek catchment land use is mainly agricultural.

File: Z:\A\CGY\Alberta\A03285C13 AEP Pincher Creek Fld Hazard S\400 Drawings\02 Open Water Hydrology Assessments\Fig1.1_Study_Area.mxd Date: May 08, 2020 Time: 11:04:40 AM Creator: : vcastillo

NOTES:

1. HORIZONTAL DATUM: NAD 83
2. GRID ZONE: CSRS 3TM 114
3. IMAGE SOURCE: ESRI DIGITAL GLOBE. WORLD TOPOGRAPHIC MAP.

LEGEND

- HYDROMETRIC STATION
- PINCHER CREEK STUDY REACHES
- FLOW DIRECTION

CLIENT	PROJECT
Alberta Government	PINCHER CREEK FLOOD HAZARD STUDY
Klohn Crippen Berger	TITLE: STUDY AREA
SCALE: 1:25,000	PROJECT No. A03285C13 / FIG No. 1.1

2 SURVEY & BASE DATA COLLECTION

2.1 General

Surveying of Pincher Creek and Kettles Creek within the study area was conducted by TROUT between May 16 and 22, 2019. The field program included surveying of cross sections, hydraulic structures, flood control structures, and water levels along the study reach. In addition, selected Alberta Survey Control Monuments (ASCM) were surveyed upon the request of AEP in support of Light Detection and Ranging (LiDAR) remote sensing data collection (by others) to confirm that the LiDAR-based DTM meets FHIP accuracy standards and to ensure consistency between the LiDAR and ground surveys.

SG1 prepared a survey plan that outlined in detail the requirements for survey and base data collection for the Pincher Creek Flood Hazard Study (SG1, 2019a). The survey plan was issued to AEP for their review and approval prior to commencing the field work. TROUT and SG1 carried out the field program in accordance with the survey plan.

A site reconnaissance was conducted on May 2, 2019 with representatives of AEP and the Town of Pincher Creek. Project team attendees included key personnel from KCB, TROUT, and SG1. Photographs taken during the site reconnaissance are included on the figures in Appendix I and in Appendix II.

For survey planning and logistical purposes, the study area was divided into five subreaches: three subreaches on Pincher Creek and two subreaches on Kettles Creek, as outlined in Table 2.1 and shown on Figure B-1 in Appendix I.

Table 2.1 Subreaches of Study Area

Subreach ID	Waterbody	Description of Subreach
1A	Pincher Creek	Upstream study boundary to Hewetson Avenue Bridge
1B		Hewetson Avenue Bridge to Highway 6 (Waterton Avenue) Bridge
1C		Highway 6 (Waterton Avenue) Bridge to downstream study boundary
2A	Kettles Creek	Upstream study boundary to Highway 6 (Waterton Avenue) Bridge
2B		Highway 6 (Waterton Avenue) Bridge to confluence with Pincher Creek

2.2 Procedures & Methodology

2.2.1 Survey Equipment and Control

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

- **Real-Time Kinematic (RTK) Global Positioning System (GPS)** – A Trimble® R8-3 RTK base station and Trimble® R10 RTK rover units, the latter of which were paired to Trimble® TSC3 and TSC7 hand-held data collectors running Trimble Access® survey software, were used to survey ground features, water levels, and creek bed levels in areas where hydraulic conditions allowed the surveyors to wade the channel or banks. The RTK system was also used to survey: (i) the control points and benchmarks that were found or placed within the study; and (ii) the flood control structures and portions of the bridge structures and the lone culvert.

- **Total Station** – A Trimble® S7 reflectorless total station was used to survey areas of the bridge structures and culvert that could not be accessed with an RTK rover unit. The total station utilized during the field program was fully robotic thus allowing full use by a single person.
- **Digital Echo Sounder** – A SonarMite V5 Echo Sounder® and an RTK rover unit were mounted onto a HyDrone-RCV® portable remote-control vessel (RCV) to survey areas of the channel cross sections where wading was not possible.

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

The survey crew set up an RTK base station daily and operated in the traditional RTK mode. All surveyed points were acquired either by wading the channel or walking on the banks. Each survey data point collected was attributed a specific code. A schematic of survey point codes and corresponding descriptions is shown on Figure 2.1 in Appendix I, which includes a complete list of survey codes for the RTK and total station.

Data collected during the field program using typical ground-based and acoustic-based technologies were calibrated and referenced to one of three ASCM benchmarks situated within town limits: ASCM 239970, ASCM 247536, and ASCM 289843. Quality assurance conducted by TROUT during the field program confirmed that these ASCM's compared well to one another, which is important for achieving survey precision. The calibration process involved having the field crew check the survey equipment readings against one of these benchmarks. In addition to checking against an ASCM at the start and end each survey day, the survey crew obtained a secondary check on data accuracy by having the static (temporary) RTK base station log data continuously over the course of the day.

All survey data were collected in the 3TM 114^{o} W coordinate system and referenced to NAD83 (CSRS) horizontal and CGVD28 vertical datums. The RTK and total station survey data outputs provided an orthometric elevation with correct northing and easting coordinates. The survey data were acquired by pre-loading geoid files into the survey equipment. Ellipsoidal heights were transformed to CGVD28 orthometric heights using the HTv2.0 geoid model.

2.2.2 River Cross Sections & Longitudinal Profiles

The locations of representative cross sections were selected to capture the variations in the physical characteristics of the channel and floodplain that could affect river flood levels along the study reach. Considerations of changes to the channel width, cross sectional area, channel bed and bank materials, and the presence of any confluences or islands, flood control structures, bridges, and other channel irregularities contributed to the selection of the cross section locations. The alignment of each cross section was established so that it would be orientated perpendicular to the direction of creek flow, as anticipated under high-flow conditions. A shapefile showing the alignment of each cross section was provided to the survey crew at the outset of the field work and uploaded to the data collectors to provide guidance on where along the study reach to acquire data. Most of the study area was surveyed by wading the channel. However, it was necessary for safety reasons to deploy an RCV in two areas along Pincher Creek where the water was too deep and swift to wade.

The main objective of the cross section surveys was to capture the characteristics of the main channel. However, limited overbank floodplain areas were also surveyed to overlap with the LiDAR survey (by others) where LiDAR coverage was assured. KCB was able to extend the cross sections onto the overbanks within the study area during the hydraulic model development phase using the topographic (LiDAR) data provided by AEP. A breakline survey technique was utilized to capture variances in the bank geometry (i.e., slope breaks), with enough data points collected along each cross section to properly define the channel geometry and the near-bank floodplain. Each recorded survey data point included Northing and Easting coordinate positions, water surface, and/or ground elevation and was attributed with a survey code that denotes its location (e.g., bank, stream bottom, edge of water, water level, top of bank, etc.).

The field program specifically included a cross section survey at the two WSC hydrometric station locations within the study area. The gauge on Pincher Creek (WSC 05AA004) is located on the left bank adjacent to Morden Avenue, approximately 100 m upstream of the Bev McLachlin Drive Bridge. The gauge on Kettles Creek (WSC 05AA033) is located on the right bank at the Highway 785 (Macleod Street) Bridge.

Reach-representative photographs were taken at key locations within the study area during the site reconnaissance on May 2, 2019 and throughout the field program. The photographs, which include salient details and features at surveyed cross sections, are georeferenced with appropriate metadata.

2.2.3 Hydraulic Structures

All hydraulic structures with the ability to affect channel conveyance and water levels within the study area were surveyed as part of the field program. Existing structures include traffic bridges, pedestrian bridges, and a roadway culvert.

The features of each bridge structure surveyed in May 2019 included the following:

- Length of span (corner points, abutment to abutment)
- Width of bridge (corner points, outside to outside)
- Top of curb or solid guard rail elevations
- Low chord elevations
- Number and width of piers
- Location of piers and the distance of each pier relative to the left abutment
- Type of piers (e.g., concrete, pile bent, steel column)

- Shape of pier (e.g., round nose, wedge, circular)
- Top of roadway profile

The following data were collected on the one culvert within the study area:

- Number of culverts
- Barrel length
- Culvert opening dimensions
- Upstream and downstream invert elevations
- Culvert type (e.g., corrugated steel pipe, concrete box, timber-framed)
- Culvert shape (e.g., circular, arch, elliptical, square, rectangular)
- Entrance condition (e.g., projecting from fill, mitered to conform to slope)
- Top of roadway profile

The hydraulic structures for this study were surveyed using a total station, RTK rover unit, or a combination thereof. The total station, when deployed, was used in reflectorless mode to collect survey points that were difficult to access. In this mode, the user targets the point to be surveyed and a laser beam is transmitted to the object and reflected from the structure without having to use a traditional total station prism (or reflector target). The RTK rover unit was used to collect structural data in clear sky areas where it was possible to connect to the GPS satellites. Georeferenced photographs of each hydraulic structure were taken during the field program.

Four cross sections were surveyed at each bridge and culvert, one located within a short distance upstream and downstream of the bridge face or culvert opening and one upstream and downstream where flow fully expanded. Ground and structure data were also collected at the inlet and outlet of the culvert to capture key elevations and dimensions.

2.2.4 Flood Control Structures

All flood control structures (berms and dikes) within the study area are located in the Town area and were surveyed as part of the field program. There are no flood control structures located in the Municipal District of Pincher Creek No. 9. For this study, applicable structures included earthen dikes and associated berms that are aligned parallel to Pincher Creek.

Surveying of each flood control structure was conducted to verify as-built elevations and to characterize its typical cross-sectional geometry. Survey data were collected along the crest of the flood control structure at regular intervals, of the order of 10 m or less, using a RTK rover unit. Reach-representative photographs of each flood control structure were taken to illustrate their characteristics.

2.3 Survey Standards & Accuracy

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

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

The RTK control network is considered accurate to within ±0.02 m at 95 percent confidence in both horizontal and vertical directions. A high level of accuracy was maintained throughout the field program by calibrating the spatial position and elevation of each RTK rover unit to an ASCM benchmark daily. Furthermore, the daily protocol required that the survey crew calibrate to, and then open and close on, an ASCM benchmark to maintain absolute positional accuracy. The hydraulic structures surveyed using a total station are considered to be even more accurate to ±0.01 m, compatible with the RTK system.

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

2.4 River Cross Sections & Longitudinal Profiles

The total lengths of Pincher Creek and Kettles Creek surveyed within the study area was 14.4 km and 7.4 km, respectively (Figure B-1, Appendix I). A total of 270 cross sections were surveyed. Table 2.2 provides a summary of surveyed cross sections.

Table 2.2 Surveyed Cross Sections within Study Area

Waterbody	Subreach ID	Subreach Description	Cross Section ID	No. of Cross Sections (1)	Average Cross Section Spacing (m)
Pincher Creek	1A	Upstream boundary to Hewetson Ave Bridge	P136 to P71	66	125
	1B	Hewetson Ave Bridge to Highway 6 Bridge	P70 to P48	23	80
	1C	Highway 6 Bridge to downstream boundary	P47 to P1	47	125
Kettles Creek	2A	Upstream boundary to Highway 6 Bridge	K134 to K46	89	60
	2B	Highway 6 Bridge to downstream boundary	K45 to K1	45	60

Appendix I contains plots of the surveyed main channel thalweg and measured water levels along Pincher Creek (Figures A-1 and A-2) and Kettles Creek (Figure A-3) during the hydrographic survey. An overview of the surveyed cross section locations is provided on Figures B-2 to B-12, and is also included in Appendix I.

2.5 Hydraulic Structures

The study area includes seven bridges on Pincher Creek, as well as six bridges and one road culvert on Kettles Creek. A summary of the hydraulic structures within the study area is provided in Table 2.3.

Table 2.3 Hydraulic Structures within Study Area

Waterbody	Structure ID	Structure Name / Location	Cross Section ID	Type	No. of Spans	Corresponding Figure Nos. in Appendix I
Pincher Creek	HS-01	SH-785 Bridge near Indianfarm Creek	P13	Traffic	3	B-8, C-1
	HS-02	Highway 6 (Waterton Ave) Bridge	P49	Traffic	3	B-5, C-2
	HS-03	Footbridge South of James Avenue	P59	Pedestrian	1	B-5, C-3
	HS-04	Bev McLachlin Drive Bridge	P65	Traffic	2	B-5, C-4
	HS-05	Hewetson Avenue Bridge	P72	Traffic	1	B-5, C-5
	HS-06	Beaver Drive Bridge	P81	Traffic	5	B-4, C-6
	HS-07	Footbridge near Community Centre	P91	Pedestrian	2	B-3, C-7
Kettles Creek	HS-08	RR-301 Bridge	K10	Traffic	1	B-12, B-13, C-8
	HS-09	SH-785 (Macleod Street) Bridge	K17	Traffic	1	B-12, C-9
	HS-10	Main Street Bridge	K33	Traffic	1	B-11, B-12, C-10
	HS-11	Highway 6 Bridge near Golf Course	K47	Traffic	1	B-10, B-11, C-11
	HS-12	Golf Course Footbridge #1	K50	Pedestrian	1	B-10, B-11, C-12
	HS-13	Golf Course Footbridge #2	K55	Pedestrian	1	B-10, B-11, C-13
	HS-14	SH-302 (East Avenue) Culvert	K79	Traffic	n/a	B-10, C-14

Bridge and culvert locations are shown on Figures B-3 to B-5, B-8, and B-10 to B-12 of Appendix I. Figures C-1 to C-14 of Appendix I include site photographs, survey data point locations superimposed onto (aerial) orthoimagery, and salient information regarding each hydraulic structure.

Background information and data (i.e., detailed design and/or as-built survey drawings) obtained from Alberta Transportation (AT) for several traffic bridges within the study area are not included in this report. Data for the pedestrian bridges were not available from the local authorities.

2.6 Flood Control Structures

Three flood control structures (berms) were identified on Pincher Creek. Details regarding the flood control structures are provided in Table 2.4. The location of each structure is shown on Figures B-5 and B-12 of Appendix I. A summary datasheet and site photographs of each flood control structure are provided on Figures D-1 to D-3 of Appendix I.

Table 2.4 Flood Control Structures within Study Area

Waterbody	Structure ID	Structure Location	Bounding Cross Sections	Approximate Length (m)	Side of River [1]	Corresponding Figure Nos.
Pincher Creek	FC-01	Adjacent to Sleepy Hollow Campground	P47 to P45	180	Left	B-5, B-12, D-1
	FC-02	Adjacent to Pincher Creek Veteran's Memorial Campground	P56 to P53	310	Right	B-5, D-2
	FC-03	Between Hewetson Avenue Bridge and Footbridge south of James Avenue	P71 to P58	500	Left	B-5, D-3

Notes:
1. *Left* or *right* refer to directions as seen by an observer looking downstream.

The berms on Pincher Creek are all characterized as earthen barriers that run parallel to the creek. A gravel pathway for pedestrian use is located on the crest of each berm. A corrugated steel pipe culvert passes through the most upstream flood control structure at the south end of Morden Avenue. The culvert is not equipped with a flap gate to prevent floodwater from flowing toward the street. The same culvert arrangement is evident near the upstream end of the second (middle) flood control structure at the north end of Church Avenue.

Details of all identified flood control structures were provided to AEP in a technical memorandum that was issued following completion of the field program (SG1, 2019b). A copy of the flood control structures memorandum is provided in Appendix I.

2.7 Additional Base Data

Additional base data collected in support of hydraulic modelling and mapping for the flood hazard study included:

- Infrastructure datasets comprised of construction drawings and/or as-built drawings of traffic bridges located within the study area, as provided by AT;
- Infrastructure datasets pertaining to one of the identified flood control structures on Pincher Creek, as provided by the Town of Pincher Creek;
- Orthoimagery of the study area provided by AEP; and
- Provisional streamflow data from hydrometric gauging stations operated by Water Survey of Canada (WSC) and situated within the study area on Pincher Creek (WSC 05AA004) and on Kettles Creek (WSC 05AA033).

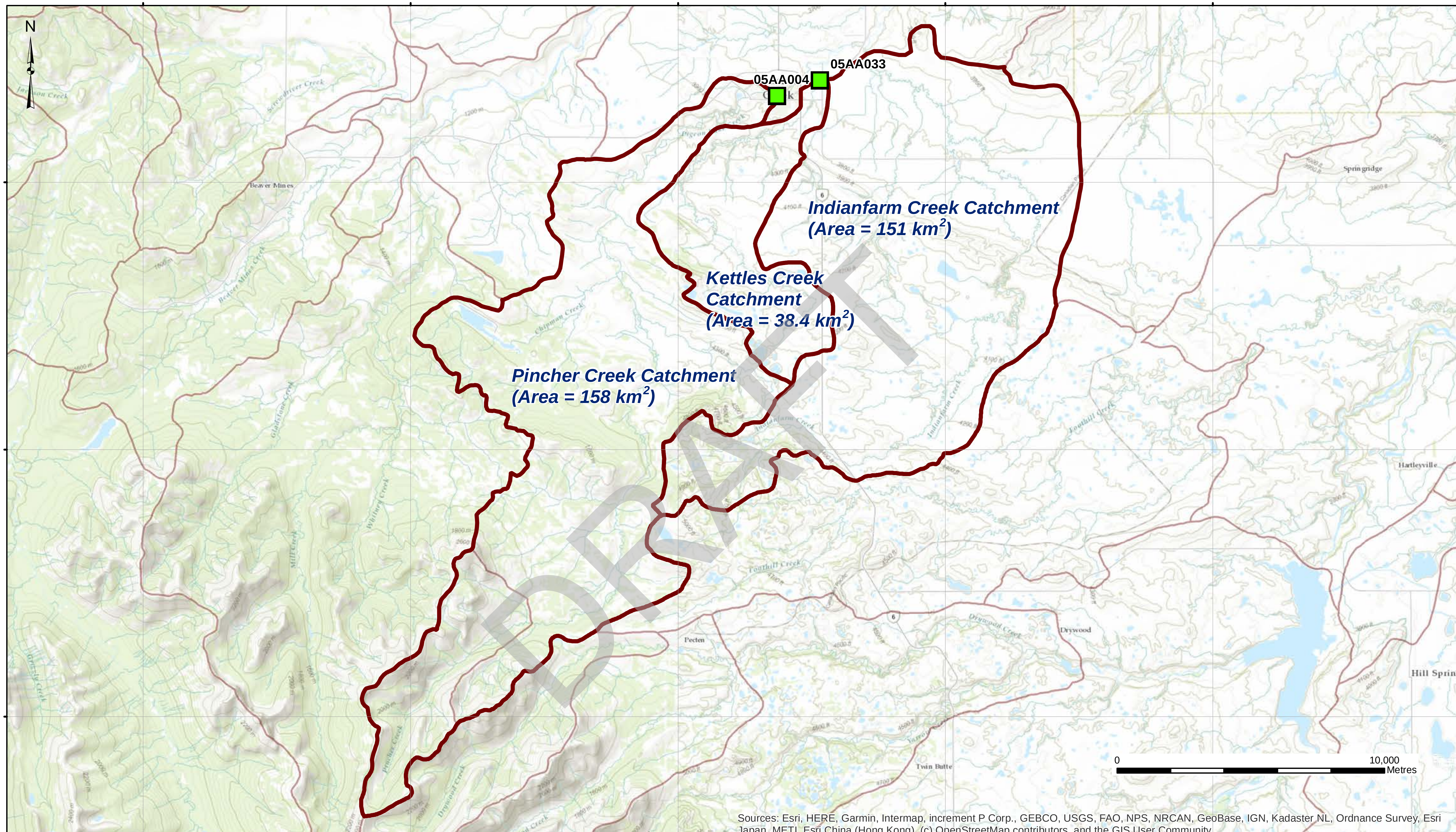
3 FLOOD HYDROLOGY

An open-water hydrology assessment was undertaken to estimate the flood frequencies in Pincher Creek and Kettles Creek for events ranging from the 2-year to the 1000-year flood. Flood frequency analyses focused on the annual maximum instantaneous discharge (hereafter "peak discharge"). The flood frequencies were used as inputs to the hydraulic modelling. The hydrological assessment was undertaken per Alberta Environment (2011), AT (2001) and USGS (2019) guidelines. The Hydrology Memorandum in Appendix III presents the detailed open water hydrological assessment undertaken for the project and the sections below provide a brief summary.

3.1 General Information

The watershed contributing to the study reaches is divided into three catchments as shown on Figure 3.1. The largest catchment, Pincher Creek, has its headwaters in the eastern slopes of the Rocky Mountains. Upstream of Pincher Creek, a high proportion of the catchment is mountainous, with a small area of foothills terrain. This is shown by the topographic mapping on Figure 3.1. A small downstream portion of the Pincher Creek catchment is flatter agruicultural land. The Kettles Creek catchment, located east of Pincher Creek, is mainly agricultural land-use terrain with short grassland. Indianfarm Creek catchment is similar size to Pincher Creek with similar catchment characteristics as Kettles Creek. In general, the catchments are oriented from a southwest to northeast direction.

Figure 3.1 shows the locations of the two key hydrometric stations for the project. Hydrometric station Pincher Creek at Pincher Creek, 05AA004, is located approximately 3.3 km upstream of the confluence with Kettles Creek. Hydrometric station Kettles Creek at Pincher Creek, 05AA033, is located less than 1 km above the confluence with Pincher Creek. Indianfarm Creek is ungauged and enters Pincher Creek about 2.5 km downstream of the confluence with Kettles Creek.



NOTES:

1. HORIZONTAL DATUM: NAD 83
2. GRID ZONE: CSRS 3TM 114
3. Source:
   Catchment Boundary: AAFC Watershed Projects 2012, Open Government Licence - Canada
   Basemap: ESRI Digital Globe. World Topographic Map

LEGEND

Hydrometric Station

Gross Catchment Boundary

CLIENT	PROJECT
Alberta Government	PINCHER CREEK FLOOD HAZARD STUDY
Klohn Crippen Berger	TITLE: PINCHER CREEK WATERSHED

SCALE	PROJECT No.	FIG No.
1:140,000	A03285C13	3.1

File: Z:\ACGY\Alberta\A03285C13 AEP Pincher Creek Fld Hazard St\400 Drawings\02 Open Water Hydrology Assessment\Fig1.2_PincherCrk_KettlesCrk.mxd Date: June 28, 2019 Time: 11:42:18 AM Creator: : vcastillo

3.2 Flooding History

3.2.1 Open Water Floods

The floods on Pincher Creek and Kettles Creek generally occur during the open water season, typically in May and June. Early summer floods have been more common in Pincher Creek with some minor floods in spring and autumn. The larger events are typically associated with spring rainfall and snowmelt, or as a result of major summer rainstorms. Table 3.1 presents a summary of the peak events recorded on Pincher and Kettles Creek.

Table 3.1 Highest Recorded Peak Discharge

Pincher Creek 05AA004		Kettles Creek 05AA003	
Time	Discharge (m^3/s)	Time	Discharge (m^3/s)
June 06, 1995	271	June 07, 2005	34
June 10, 1975	172	June 17, 2010	n/a[1]
June 07, 2005	100	June 18, 2014	10
June 10, 2002	80	June 08, 2011	9.9

Note 1 There was no recorded peak discharge for the 2010 event, the recorded maximum daily discharge was 16.5 m^3/s.

The flood of record on Pincher Creek occurred in June 1995, with a peak discharge of 271 m^3/s, during a widespread rainstorm that produced major floods in many southern Alberta streams. Based on the flood frequency analysis presented herein, the estimated return period for the event was a 200-year event. The second highest flood, in June 1975, had a substantially lower peak discharge of 172 m^3/s, corresponding to about a 60-year event. Additionally, a flood occurred in Pincher Creek on June 9th, 1953, when the Pincher Creek hydrometric station was not operating. The flood estimate for this event was 198 m^3/s (Environment Canada 1963), corresponding to about a 80-year event.

The 1995 event caused a significant amount of damage around Pincher Creek. AEP provided HWM data and documentation for the 1995 event. This documentation noted damage around the Highway 785 bridge abutments. It also appears that the low-level crossing (just upstream of the Picher Creek and Kettles Creek confluence) was severely damaged during the flood and was likely decommissioned post flood. There was some riprap present at the low-level-crossing location during the May 2, 2019 site reconnaissance, but the crossing itself was no longer there. The report shows photographs of the displaced Bev McLachlin bridge. The bridge was rebuilt after the flood with the gabion basket retaining wall providing protection to the right bank and re-built right abutment (see photograph 14, 15, and 16 in Appendix II). Damage was noted to the right bank downstream of the Beaver Drive bridge, getting close to the right abutment of the bridge.

The documentation for the 1995 event also includes extracts from the Pincher Creek Echo, dated Tuesday June 13. The paper describes the damage to Pincher Creek estimated at \$13M with a further \$2M related to damage in the M.D. The paper states that 82 mm of rainfall fell on June 6, 1995 and forced the evacuation of approximately 200 residents in the town. Within the M.D. there were 10 road washouts and 17 bridges closed. No fatalities due to the flooding were recorded. The paper reports that property owners along Pincher Creek suffered damage to buildings, the Sleepy Hollow

Campground downstream of Highway 6 suffered major flooding and damage, and the museum was flooded with some exhibits destroyed.

The flood of record for Kettles Creek occurred in June 2005. The maximum daily discharge was 22.2 m^3/s and the peak discharge was 33.9 m^3/s. There were also relatively high events during 2010 (maximum daily discharge of 16.5 m^3/s and no recorded peak discharge) and 2014 (peak discharge of 10.4 m^3/s). The 2005 flood peak corresponds to approximately a 20-year event.

3.2.2 Ice Jam Floods

Based on a review of available background information, there is no indication of significant ice jam flooding along Pincher Creek and Kettles Creek within the study area. Winter flows are generally low and it is understood that ice break up occurs in early spring before spring runoff. The Pincher Creek and Kettles Creek gauges are seasonal with records usually starting in March of any given year. Based on an assessment of WSC flow records in March, the Pincher Creek winter flows are generally less than 1 m^3/s. The Kettles Creek winter flows are generally less than 0.5 m^3/s.

It is noted that although there is the potential for ice jams to occur, ice jams are not a major factor in flooding within the study area (Alberta Environment 1980). In view of this, ice jams have not been considered in this study.

3.3 Flood Frequency Analysis

3.3.1 Flood Frequency Flow Estimates

The resulting flood frequency estimates for Pincher Creek and Kettles Creek are presented in Table 3.2.

Table 3.2 Flood Frequency Estimates

Return Period (years)	Peak Discharge (m^3/s)			
	Pincher Creek Above Kettles Creek	Pincher Creek Below Kettles Creek	Pincher Creek Below Indianfarm Creek	Kettles Creek Above Pincher Creek
2	18	21	33	3.2
5	45	55	92	9.7
10	71	86	144	15
20	104	125	205	21
35	137	163	262	26
50	160	189	300	29
75	191	224	350	33
100	214	250	385	36
200	279	321	480	42
350	340	388	568	48
500	383	434	626	51
750	438	492	698	54
1000	480	537	753	57

3.3.2 Comparison to Previous Studies

Table 3.3 presents the results of the frequency analysis for Pincher Creek above the Kettles Creek confluence and includes the results of the 1993 Flood Frequency Analysis (AE 1993). As a comparison, for the 100-year event, the current estimate is approximately 20% higher than the 1993 estimate. Considering the flood of record occurred in 1995, after AE (1993) and that the last thirteen years of record have been wetter than the overall historical record, this increase is deemed to be reasonable.

Table 3.3 Comparison of Pincher Creek Flood Frequency Estimates with AE (1993)

Return Period (years)	Pincher Creek above Kettles Creek, Peak Discharge (m^3/s)	
	KCB (2020)	AE (1993)
2	18	14
5	45	34
10	71	55
20	104	82
35	137	Not provided
50	160	131
75	191	Not provided
100	214	179
200	279	Not provided
350	340	Not provided
500	383	Not provided
750	438	Not provided
1000	480	Not provided

Table 3.4 compares the flood frequency estimates for Kettles Creek above Pincher Creek with the estimates given in AE (1993). The current flood frequency estimates are slightly lower than the estimates derived in AE (1993). As an example, for the 100-year event, the current estimate is 36 m^3/s, which is 8% less than the estimate of 39 m^3/s derived by AE (1993).

Table 3.4 Comparison of Kettles Creek Flood Frequency Estimates with AE (1993)

Return Period (years)	Kettles Creek above Pincher Creek, Peak Discharge (m^3/s)	
	KCB (2020)	AE (1993)
2	3.2	7
5	9.7	12
10	15	17
20	21	22
35	26	Not provided
50	29	32
75	33	Not provided
100	36	39
200	42	Not provided
350	48	Not provided
500	51	Not provided
750	54	Not provided
1000	57	Not provided

4 HYDRAULIC MODELLING

This section describes the development of the calibrated one-dimensional HEC-RAS model and the derivation of the resulting water surface profiles for events ranging from the 2-year to the 1000-year flood. The hydraulic model was developed using a combination of survey data described in Section 2 and the DTM provided by AEP. The model was calibrated against high water mark (HWM) data collected during flood events. The model was then used to simulate flood profiles for creation of flood inundation and hazard mapping. A single model was developed that can be used for all return period events.

HEC-RAS version 5.07 (March 2019) was used for hydraulic model creation and the generation of the water surface profiles used to derive flood inundation extents. HEC-RAS (River Analysis System) was developed by the Hydrologic Engineering Centre of the United States Army Corps of Engineers. ArcGIS Version 10.6 was used for processing geospatial data and developing inundation extents. The commercially available GeoHECRAS 2D software (CivilGeo Engineering Software 2019) was used to create the HEC-RAS model. GeoHECRAS 2D is a river modelling tool that supports HEC-RAS within a 2D and 3D GIS environment.

The following sections describe model creation undertaken for this project.

4.1 Available Data

4.1.1 Digital Terrain Model

Airborne Imaging (AI) collected LiDAR data for the Pincher Creek study on October 26, 2018. The minimum accuracy specification was ± 15 cm @ 95% in hard, flat, open areas. AI (2020) describes the methods used to acquire and verify the data and subsequent processing of the captured data. The Riegl VQ 1560i (38) LiDAR system was used to capture the data with an average point density of 25.56 pts/m^2. The Geodetic Control / Base station for Pincher Creek was CLTH A20955 (station type CanNet-LTHB ASCM). AI undertook calibration of the LiDAR data against ground-truth data collected along roads within the project area.

The LiDAR data was validated against an independent survey of ground truth control points (GTCPs) collected by All-Can Engineering & Surveys, who was retained by AEP. At least one GTCP was required per one kilometer of creek. The GTCPs were located in the overbank area, within 100 m of the creek.

Based on the information presented, it was concluded that the LiDAR and survey data are within tolerances specified by the data accuracy and can be used for hydraulic modelling.

4.1.2 Aerial Imagery

Aerial imagery of the study area, collected in July 2019, was provided by AEP. The imagery was used for flood inundation, floodway criteria, and flood hazard maps.

4.1.3 Existing Models

The hydraulic models for Pincher Creek and Kettles Creek, described by Philips (1993), were provided as part of this project. The hydraulic models were developed using the HEC-2 software.

The Pincher Creek model was calibrated against high water mark data collected for the June 1975 flood event. Available data included four HWMs surveyed along the reach from the Beaver Drive Bridge to the Highway 6 Bridge. The model was validated against HWMs surveyed during the June 1991 event.

Pincher Creek was divided into seven reaches, with Manning's *n* channel roughness varying from 0.023 along the upstream reach (i.e., upstream of the Town of Pincher Creek) to 0.032 for the downstream reach. Through the Town of Pincher Creek, Manning's *n* for the main channel varied from 0.035 to 0.043 (at the Hewetson Avenue Bridge).

There was no flood related data to enable calibration of the Kettles Creek model. The Manning's *n* values applied to the Kettles Creek main channel varied from 0.030 to 0.040.

4.1.4 Highwater Marks

The following sections summarize the flood documentation information provided by AEP.

Flood photography from the 1975 Pincher Creek high flow event

This file provides a selection of photographs taken on June 20, 1975. Photographs were taken upstream of the Town of Pincher Creek, through the town, and around the Highway 6 bridge. The peak discharge on Pincher Creek was 172 m^3/s, which is between the 50-year and 75-year flood frequency estimate.

HWM Report for the 1981 Event

This HWM report presents information related to the May 22, 1981 event on Pincher Creek. The report indicates that the peak discharge was 72 m^3/s. The flood frequency estimate of the event indicated it was less than a 10-year event.

The report indicates the flood on Kettles Creek was a 100-year event. This estimate is based on the HWMs and the results of the Floodplain Study undertaken by Stanley and Associates. The report notes that streamflow records were not kept on Kettles Creek at the time.

HWM Report for the 1995 Event

The initial peak flow for the Pincher Creek at Pincher Creek gauge was estimated to be 271 m^3/s on June 6, 1995. The report noted heavy rains began on June 6 at 20:55 and continued to 23:00 MST. Pincher Creek appeared to peak between 23:15 to 24:00 MST.

HWM Report for the 2010 Event

This report provides the HWM survey information related to the June 21-22, 2010 survey. The flood occurred on June 17, 2010 with a peak discharge of 76 m^3/s on Pincher Creek. This is approximately a

10-year event based on the flood frequency estimates presented in Table 3.2. The maximum daily discharge on Kettles Creek for this event is 16.5 m^3/s with no published peak discharge. The peak discharge on Kettles Creek was estimated to be 25.6 m^3/s through correlation with the maximum daily discharge. This is approximately a 35-year event based on the flood frequency estimates presented in Table 3.2.

HWM Report for the 2013 Event

This report presents the results of the June 30, 2013 HWM survey. The peak discharge on Pincher Creek and Kettles Creek was 31.8 m^3/s and 0.87 m^3/s, respectively. Based on the current analysis, this is between a 2- and a 5- year event on Pincher Creek.

Summary Spreadsheet

Additionally, a spreadsheet was provided by AEP that included Pincher Creek and Kettles Creek HWM data for a range of events, including:

- The 1981, 1991, 1995, 2010 and 2013 high flow events at Pincher Creek
- The 1981, 1986, 1991, 1995 and 2010 events on Kettles Creek

The spreadsheet contained information including: HWM identification, a description as to where the HWM was surveyed, coordinates of the HWM, the HWM elevation, date of survey, and creek name. Each entry has a link to a set of photographs taken at each site.

Summary of HWM data

Table 4.1 presents a summary of HWM data for the 2013, 2010, 1995, and 1981 events.

Table 4.1 Summary of High Water Mark Data

Event	Reach	HWM Elevation (m)	Location
2013	Pincher Creek Above Kettles Creek	1110.575	Debris line on left bank of river at confluence of Kettles Creek and Pincher Creek
		1134.705	Near left bank abutment, just downstream of Beaver Drive Bridge
2010	Pincher Creek Above Kettles Creek	1102.027	Hwy. 785 Bridge u/s 10 m
		1101.292	Hwy. 785 Bridge d/s 13 m
	Kettles Creek Above Pincher Creek	1116.132	Range Road 301 Bridge d/s 10 m
		1116.276	Range Road 301 Bridge d/s 8 m
		1116.056	Range Road 301 Bridge d/s 13 m
		1116.477	Range Road 301 Bridge u/s
		1117.888	Macleod Street Bridge d/s 10 m
		1118.610	Macleod Street Bridge u/s 10 m
		1124.264	Main Street Bridge d/s 8 m
		1125.198	Main Street Bridge u/s 10 m
		1134.785	Hwy. 6 Bridge Kettles Creek u/s 12 m
		1133.472	Hwy. 6 Bridge Kettles Creek d/s 5 m
		1110.533	Confluence of Kettles Creek and Pincher Creek
		1110.538	Confluence of Kettles Creek and Pincher Creek

Event	Reach	HWM Elevation (m)	Location
2010	Pincher Creek Above Kettles Creek	1135.185	Beaver Drive Bridge d/s 9 m
		1135.219	Beaver Drive Bridge u/s 8 m
		1111.128	Confluence of Kettles Creek and Pincher Creek
1995	Pincher Creek Below Kettles Creek	1101.95	Hwy. 785 Bridge d/s
		1103.02	Hwy. 785 Bridge u/s
	Kettles Creek Above Pincher Creek	1116.82	Range Road 301 Bridge u/s
		1116.67	Range Road 301 Bridge d/s
		n/a	Macleod Street Bridge d/s - HWM not evident
		1119.36	Macleod Street Bridge u/s 10m
		1126.26	Main Street Bridge d/s 5m
		1126.42	Main Street Bridge u/s
	Pincher Creek Above Kettles Creek	1121.78	Hwy. 6 Bridge Pincher Creek d/s
		1122.61	Hwy. 6 Bridge Pincher Creek u/s
		1131.26	Hewetson Avenue Bridge d/s
		1131.40	Hewetson Avenue Bridge u/s
		1137.09	Beaver Drive Bridge d/s 10 m
		1137.42	Beaver Drive Bridge u/s
		1112.41	Confluence of Kettles Creek and Pincher Creek
1981	Kettles Creek Above Pincher Creek	1116.20	Range Road 301 u/s 35 m
		1116.37	Range Road 301 u/s 10 m
		1116.12	Range Road 301 u/s
		1115.58	Range Road 301 d/s 20 m
		1115.49	Range Road 301 d/1 35 m
		1118.56	Macleod Street Bridge u/s 50 m
		1118.65	Macleod Street Bridge u/s 25 m
		1118.61	Macleod Street Bridge u/s 8 m
		1118.49	Macleod Street Bridge d/s 20 m
		1118.26	Macleod Street Bridge d/s 60 m
		1126.41	Main Street Bridge u/s 40 m
		1126.13	Main Street Bridge u/s 8 m
		1124.95	Main Street Bridge d/s 40 m
		1124.86	Main Street Bridge d/s 100 m
		1124.71	Main Street Bridge d/s 160 m
		1134.53	Hwy. 6 Bridge Kettles Creek u/s 35 m
		1134.30	Hwy. 6 Bridge Kettles Creek u /s 25 m
		1134.26	Hwy. 6 Bridge Kettles Creek u/s 10 m
		1133.77	Hwy. 6 Bridge Kettles Creek d/s 25 m
		1133.68	Hwy. 6 Bridge Kettles Creek d/s 50 m
	Pincher Creek Above Kettles Creek	1120.67	Hwy. 6 Bridge Pincher Creek u/s 55 m
		1120.37	Hwy. 6 Bridge Pincher Creek u/s 35 m
		1119.99	Hwy. 6 Bridge Pincher Creek u/s 10 m
		1119.94	Hwy. 6 Bridge Pincher Creek d/s 25 m
		1119.84	Hwy. 6 Bridge Pincher Creek d/s 80 m
		1127.82	Bev McLachlin Drive Bridge u/s 75 m
		1127.84	Bev McLachlin Drive Bridge u/s 35 m
		1127.60	Bev McLachlin Drive Bridge u/s 5 m
		1127.46	Bev McLachlin Drive Bridge d/s 15 m
		1127.05	Bev McLachlin Drive Bridge d/s 60 m
		1129.87	Hewetson Avenue Bridge u/s 150 m
		1129.07	Hewetson Avenue Bridge u/s 60 m

Event	Reach	HWM Elevation (m)	Location
1981	Pincher Creek Above Kettles Creek	1129.17	Hewetson Avenue Bridge u/s 10 m
		1129.02	Hewetson Avenue Bridge d/s 25 m
		1128.59	Hewetson Avenue Bridge d/s 60 m
		1135.75	Beaver Drive Bridge u/s 60 m
		1135.59	Beaver Drive Bridge u/s 60 m
		1134.98	Beaver Drive Bridge d/s 10 m
		1134.75	Beaver Drive Bridge d/s 35 m
		1134.19	Beaver Drive Bridge d/s 85 m

4.1.5 Gauge Data and Rating Curves

WSC provided rating curves for the Pincher Creek at Pincher Creek (WSC No. 05AA004) and the Kettles Creek at Pincher Creek (WSC No. 05AA033) gauges. Figure 4.1 shows the two rating curves for the Pincher Creek gauge. The first curve was developed from measurements taken between 1995 and 1996, with the June 1995 event estimated using the slope-area method. The second rating curve was developed based on measurements from 2005 and 2015. The gauge datum is 1125.782 m.

Figure 4.1 Rating Curves for the Pincher Creek at Pincher Creek Gauge (WSC 05AA004)

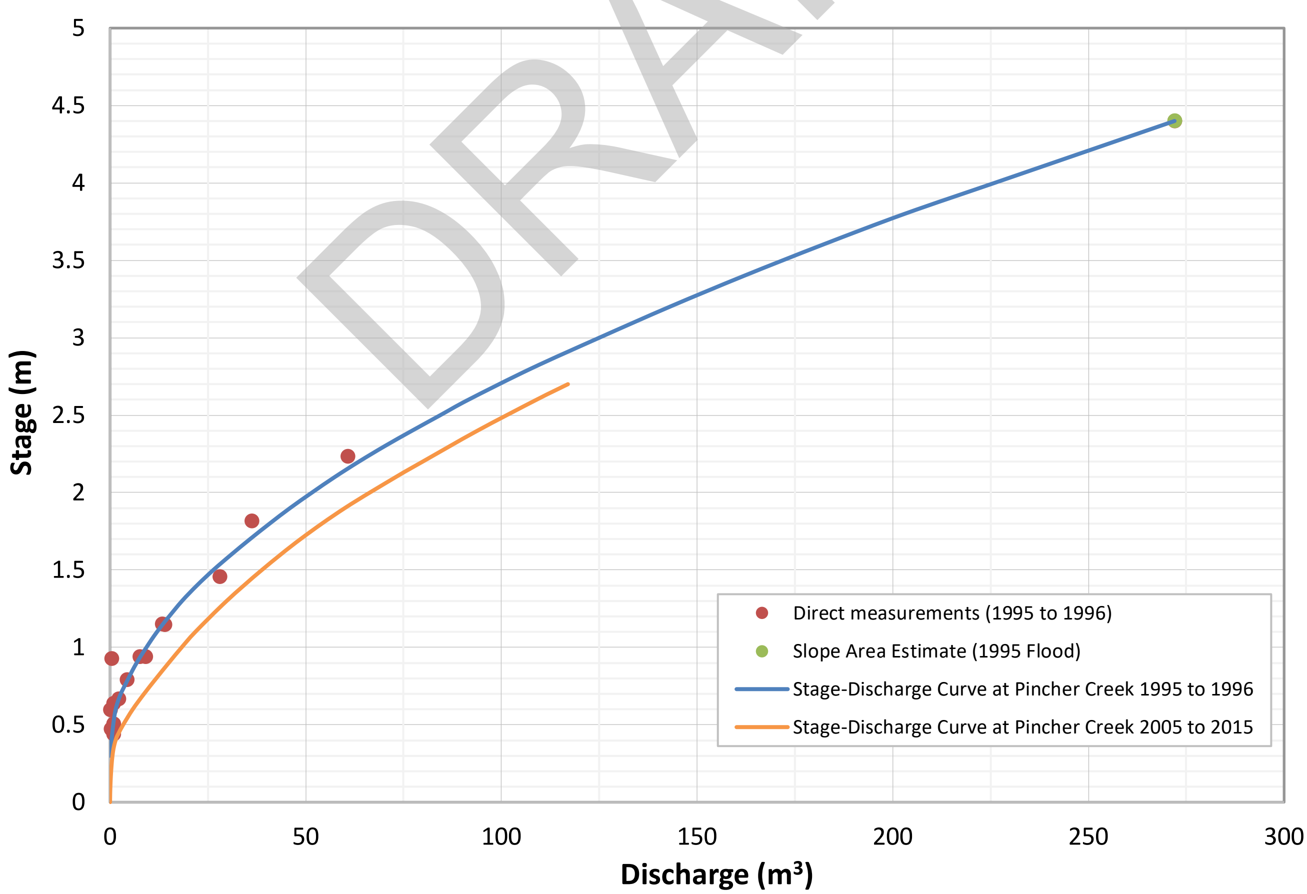
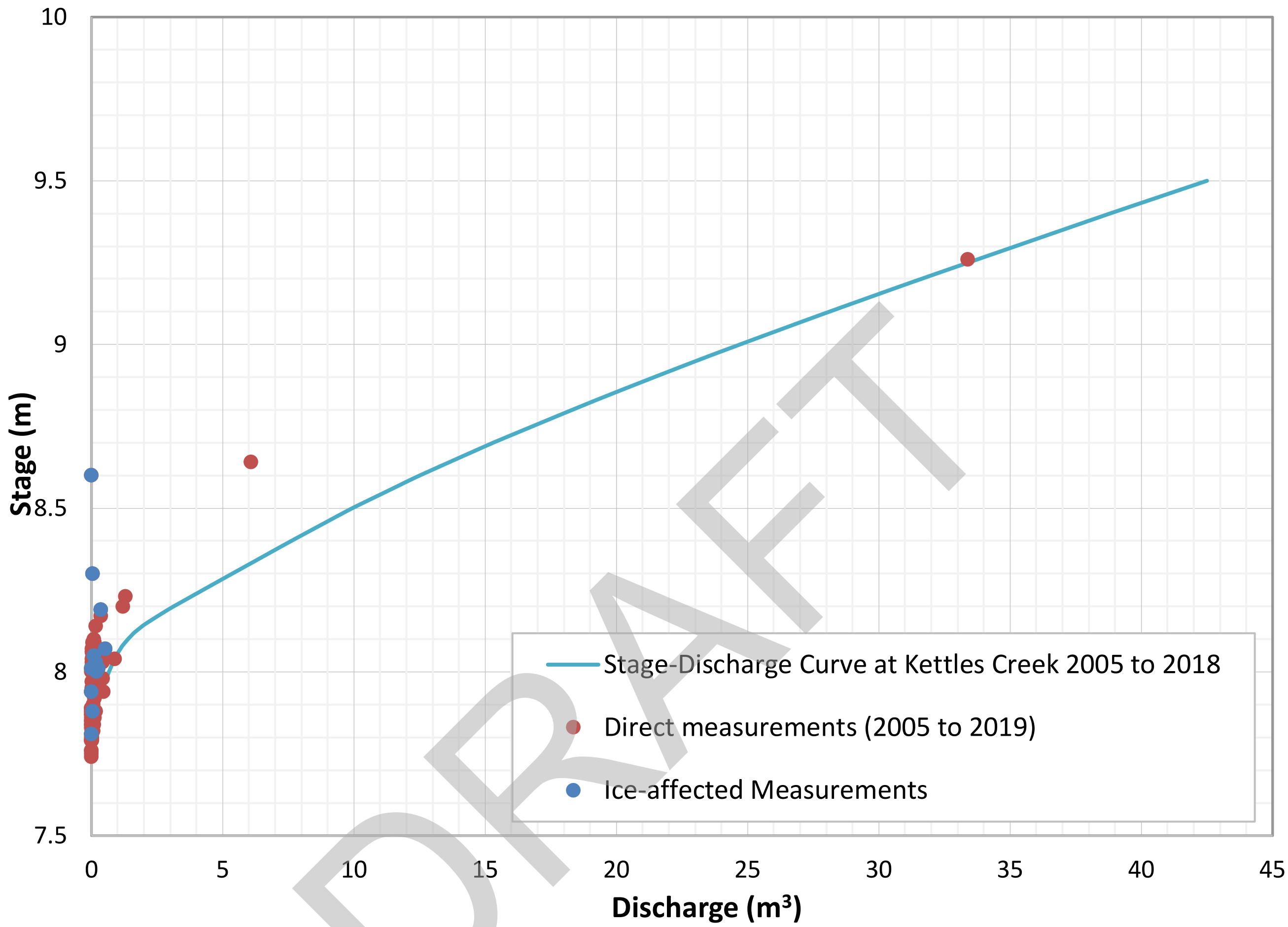


Figure 4.2 presents the rating curve for the Kettles Creek gauge. The gauge datum is 1109.31m.

Figure 4.2 Rating Curve for the Kettles Creek at Pincher Creek Gauge (WSC 05AA033)



4.1.6 Flood Photography of the 1995 Event

Photographs along Pincher and Kettles Creek taken after the 1995 event are presented in Appendix IV. There were no photographs available for the 2010 event on Kettles Creek.

Available photographs of the 1995 event indicate significant flooding and damage to infrastructure, as described in Section 3.2.1. Figure IV.1 in Appendix IV shows the level the flood waters rose to on the left floodplain. The smaller shrubs in Figure IV.4, upstream of the Hewetson Avenue Bridge, appear to have been overtopped by the flood waters, indicating the flood depth was relatively high. Downstream of the Hewetson Avenue Bridge, the flood waters got to the bottom sill of the patio doors of the building on the right floodplain of Pincher Creek (Figure IV.5). The level of this sill is estimated from the LiDAR data at 1,131.5 m. Figure IV.9 and Figure IV.10 show flooding on the right floodplain upstream of the Highway 785 Bridge. Figure IV.11 identifies some washout around the left abutment of the Range Road 301 crossing over Kettles Creek.

4.2 River & Valley Features

4.2.1 General Description

There are three distinct reaches of Pincher Creek within the study area. The Upstream Reach is from the upstream study limit to the Community Centre in the Town of Pincher Creek. The Urban Reach extends from the Community Centre to the Kettles Creek confluence. The Downstream Reach extends from the Kettles Creek confluence to the downstream project limits. There are two distinct Kettles Creek reaches. The Upstream Reach extends from the upstream project limit to the golf course. The Downstream Reach extends from the golf course to the Pincher Creek confluence. Table 4.2 summarizes these reaches and references the relevant photographs in Appendix II taken during the site reconnaissance.

Table 4.2 Summary of Photograph Locations

Creek Reach	Description	Appendix II Photographs
Pincher Creek Upstream Reach	Upstream of the Community Centre	1 -5
Pincher Creek Urban Reach	Community Centre to Kettles Creek Confluence	6 – 31
Pincher Creek Downstream Reach	Kettles Creek confluence to downstream boundary	32 – 37
Kettles Creek Upstream Reach	Upstream of the golf course	38 – 42
Kettles Creek Downstream Reach	Golf course to Pincher Creek Confluence	42 - 53

The Pincher Creek Upstream Reach has the characteristics of a creek in the foothills of the Rocky Mountains. The creek lies in the bottom of a deep, U-shaped valley around 500 m wide and 40 m deep and is heavily meandering. There are old channels within the floodplain, which are evidence of significant changes to creek planform during larger events. Along the Urban Reach, the creek is straighter and the severe meanders become gentler bends. The Town of Pincher Creek is located on flatter, prairie floodplain with the ground to the north of the creek lower than the land to the south. Downstream of the town, in the Downstream Reach, Pincher Creek flows through prairie farmland. There are some meanders, especially where there is high ground on one bank, but the creek is relatively straight.

The Upstream Reach of Kettles Creek also has the characteristics of a creek in the foothills of the Rocky Mountains. The creek has severe meanders and sits in the bottom of a deep U-shaped valley, with the base of the valley being narrower than the Pincher Creek valley. Downstream of the Range Road 302 culvert, Kettles Creek flows through the golf course before flowing through the largely industrial area between the Highway 6 Bridge and the Pincher Creek confluence. There are some residential properties near the confluence.

The following sections describe the channel and floodplain characteristics, making reference to these photographs.

4.2.2 Channel Characteristics

The channel slope is summarized in Table 4.3. It can be seen that the majority of the Pincher Creek channel is at a slope of between 0.5% and 0.6%. There is a steeper reach just upstream of the Town of Pincher Creek where channel slope increases to 1.3%. The channel slope for Kettles Creek is consistent along the entire modelled reach, with an average slope of 0.9%. Overall, Kettles Creek is slightly steeper than Pincher Creek.

Table 4.3 Channel Slope

Creek Name	Stationing (m)	Description	Slope (%)
Pincher Creek	0 to 8,424	Downstream boundary to upstream of Beaver Drive Bridge	0.5
Pincher Creek	8,434 to 10,006	Upstream of Beaver Drive Bridge to 1 km upstream of Community Centre	1.3
Pincher Creek	10,006 to 14,327	1 km upstream of Community Centre to upstream boundary	0.6
Kettles Creek	0 to 7,295	Entire modelled Kettles Creek Reach	0.9

4.2.2.1 Pincher Creek

As mentioned in the previous section, Pincher Creek can be characterized in three reaches. The channel in the Upstream Reach generally consists of coarse, angular, bed material consisting of large cobbles. The creek is highly meandering. The creek banks are generally grass lined with some trees or with bushes in places. Where the creek is up against the valley walls, the bank vegetation is generally grass or in places bare earth due to steepness of the valley walls and bedrock outcrops.

Through the Urban Reach, the bed material becomes progressively finer, with the large angular cobbles giving way to smaller cobbles. There are bedrock outcrops within the channel by the community centre, with the creek discharging over a series of bedrock ledges. The bed material between these ledges consists of large boulders. A gabion basket wall has been constructed to protect the steep bank by the Community Centre. Between the pedestrian bridge at the Community Centre and the Beaver Drive Bridge, the bed material still consists of large cobbles, but are more rounded than the cobbles in the Upstream Reach. Silt material was also observed in the bed material around the Beaver Drive Bridge. The right bank around the Beaver Drive bridge has been protected by a gabion basket wall. From Table 4.3, the channel slope reduces from 1.3% to 0.5% upstream of the Beaver Drive bridge.

Between the Beaver Drive Bridge and the Hewetson Avenue Bridge the bed material still consists of smaller cobbles, with some larger cobbles present. There are some high, steep river banks downstream of the Hewetson Avenue Bridge. The left bank is a steep eroding riverbank. The bank vegetation in this reach generally consists of grasses and some shrubs. The bed material between the Hewetson Avenue Bridge and the Bev McLachlin Drive Bridge generally consists of large cobbles, but more rounded than the Upstream Reach. The banks are lined with trees, grasses and bushes.

The bed material becomes less coarse downstream of the Bev McLachlin Drive Bridge. There are still some larger cobbles, but the bed material also consists of a lot of silt material. The right bank is steep around Bev McLachlin Drive and has been protected with a gabion basket wall. The left bank is shallower and is lined with trees, grasses and bushes. Between Bev McLachlin Drive and the Highway 6 bridge, there are reaches of fine bed material within pools between the riffle reaches that consist of a cobbly bed material. The river banks are shallower and are lined with grasses, trees, and shrubs. Downstream of the Highway 6 bridge, the bed predominantly consists of finer material and a layer of small cobbles in places. The bank vegetation is predominantly grass, with some shrubs and willows.

4.2.2.2 Kettles Creek

The Kettles Creek Upstream Reach channel is heavily meandering with a fine bed material. The creek meanders through agricultural land with high, eroding river banks in places. The bed and bank material is likely a till material, and the banks are near vertical in places. Bank vegetation tends to be grass, with some willows in places. The main channel itself has aquatic vegetation growing along some reaches. The Downstream Reach from the golf course to the Pincher Creek confluence, is much straighter than the channel in the Upstream Reach. The channel is a fine bed material and the banks are generally lined with grass. There are some sloughing and eroding riverbanks in places. Near the confluence with Pincher Creek, the Kettles Creek channel has been lined with riprap. There are a number of beaver dams along the Downstream Reach.

4.2.3 Floodplain Characteristics

4.2.3.1 Pincher Creek

The Pincher Creek Upstream Reach includes a relatively wide floodplain interspersed with reaches of little floodplain where the valley narrows. The floodplains in the Upstream Reach tend to include areas of woodland and grassland, and potentially pasture for the local farms. There are historic creek channels as the main channel has moved across the relatively wide floodplain. The Urban Reach includes mixed residential, commercial and recreation land uses on the left and right floodplains. The floodplains in the Downstream Reach include woodland and pasture.

4.2.3.2 Kettles Creek

The floodplains on the Kettles Creek Upstream Reach include mainly open grassland and pasture. The Downstream Reach includes the golf course and the industrial area of the Town of Pincher Creek. The right floodplain in the Downstream Reach is not clearly defined as the topography is generally flatter and tends to slope to the east, towards Indianfarm Creek.

4.2.4 Anthropogenic Features

The key anthropogenic features include:

- The bridges across Pincher Creek and Kettles Creek, as described in Table 2.3;
- The gabion basket wall protecting the Community Centre (see Photograph 8 in Appendix II);
- The gabion basket wall protecting the right bank upstream and downstream of the Beaver Drive bridge (see Photographs 9 – 11 in Appendix II) and riprap placed downstream of the gabion wall;
- The three flood berms protecting parts of Pincher Creek, as described in Table 2.4; and
- The general development associated with the Town of Pincher Creek.

4.3 Model Construction

4.3.1 Methodology

A one-dimensional hydraulic model was developed for Pincher Creek and Kettles Creek using HEC-RAS 5.0.7. The model was established per the HEC-RAS user manual (USACE 2016) and in close liaison with representatives of AEP. A single model was developed that could represent water surface profiles for the full range of required flood frequencies.

The one-dimensional model assumes flow is perpendicular to the orientation of the cross section and key outputs include in depth-averaged velocities and water surface profiles. The model was simulated in steady state conditions, which solves the Energy equation using the standard step method. In steady state, HEC-RAS can calculate water surface profiles for gradually varied flow conditions under sub-critical, supercritical and mixed flow regimes.

The hydraulic model was created using the cross-section survey described in Section 2 and the hydroflattened LiDAR data, or DTM, described in 4.1.1 and provided by AEP. The surveyed cross sections and LiDAR data were imported into GeoHECRAS 2D, which integrated the hydroflattened DTM and the topographic survey datasets. Model build was undertaken in the GeoHECRAS environment.

The surveyed cross-sections capture the main channel and part of the floodplain adjacent to the channel. The channel cross sections were extended across the floodplain with elevation data extracted from the DTM. The cross sections were extended to an elevation higher than the predicted 1000-year flood level. Care was taken to orientate the floodplain component of the cross sections perpendicular to the dominant direction of flow. This involved: identifying cross section alignments across the floodplain; simulating the model for the full range of events; evaluating whether the cross section was perpendicular to the flow direction; and modifying cross section alignments, if required. Multiple iterations were required to align all cross sections. In addition, a coarse two-dimensional HEC-RAS hydraulic model was constructed of the study area. Results from this coarse two-dimensional model were used to help define the orientation of the cross sections in the one-dimensional model.

The cross-section data and the DTM were used to create the stream centerline, flow path centerline, main channel banks, land-use areas (for specifying Manning's *n* values), and ineffective flow areas for import in the HEC-RAS model. Culverts, bridges, inline structures, levees and lateral structures were set up directly in HEC-RAS.

There are many locations along Pincher Creek where the floodplains narrow as the creek flows between narrowing valley walls. The wide floodplains typically include historic creek channels that have been infilled over time as the creek changed course. This often resulted in areas of the floodplain that were lower than the current creek bank. These areas were specified as not permanent ineffective flow areas in the model. The elevation at which these ineffective areas became active was specified based on topographic data in the vicinity of the affected cross section and the simulation results, which indicated the return period at which ineffective areas become active.

Permanent ineffective flow areas were assigned upstream of bridges and culverts where roads have been constructed on embankments across the floodplain. In addition, there is a pond by the Juan Teran Regional Park on the right floodplain downstream of Highway 6. This pond was designated as a permanent ineffective flow area, to the level of the floodplain around the pond.

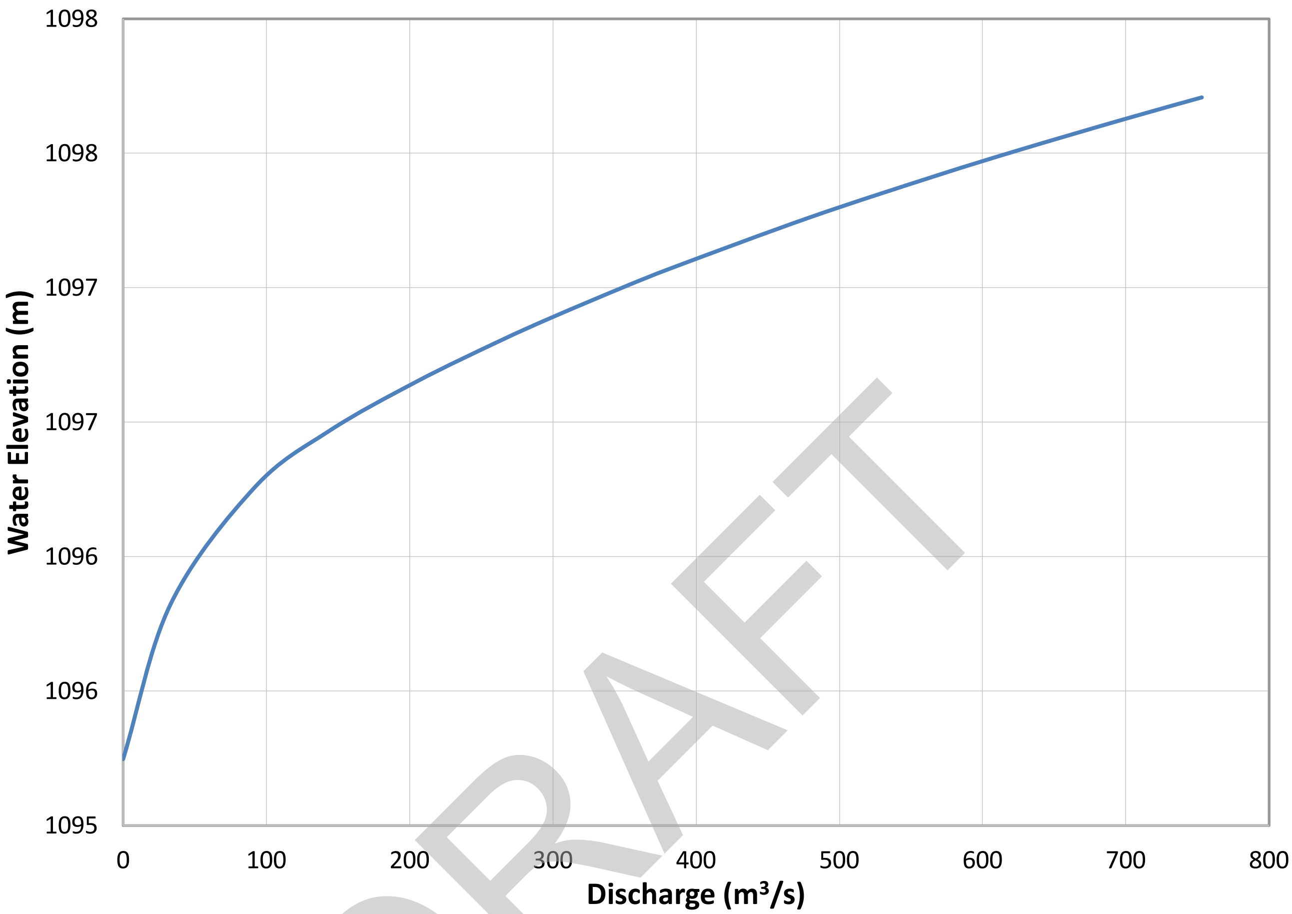
There are three flood control structures, or dikes, within the modelled reach of Pincher Creek. These dikes were modelled using levee markers in HEC-RAS. The levee markers prevent inundation of the floodplain behind the flood dike during events that do not overtop the dike. When creek levels rise above the dike crest elevation, the floodplain becomes active.

The channel banks were assigned by simulating the 2-year event and using the results to establish the bank markers. Manual adjustments, based on the physical channel appearance and general channel width, were made to most channel sections to align the bank markers with actual bank elevations. Examples include the steep banks in the Upstream Reach of Kettles Creek.

The aerial photography and outcomes of the site visit were used to delineate vegetation zones. Initial values of Manning's *n* for these vegetation zones and the channel were developed based on a review of suitable Manning's *n* values using information collected from the site visit, from a range of publications (including Kellerhals *et al* (1972), Chow (1959), Hicks and Mason (1998), Arcement and Schneider (1989)), and previous floodplain mapping studies commissioned by AEP.

Model boundary conditions included inflow discharges at the upstream model limits of Pincher Creek and Kettles Creek. The flood frequency estimates for these inflow discharges are presented in Section 3.3.1. The downstream boundary of Pincher Creek was a normal depth rating curve, as shown on Figure 4.3. The rating curve was based on the properties of the downstream model cross section and the average channel slope in this area of 0.0030.

Figure 4.3 Rating Curve at the Downstream Boundary



4.3.2 Geometric Database

The hydraulic model of Pincher Creek and Kettles Creek was developed using a combination of the AEP provided DTM and topographic data collected by the surveyor. Appendix V Figure 1 to Figure 9 shows the location of the cross sections, structures, flood control dikes included in the model. The following sections summarize key information related to the model build.

Cross Section Data

As described in Section 2, a total of 270 cross sections were surveyed. Of these surveyed cross sections, 252 were used for model build. Surveyed cross sections that were excluded from the model tended to be where there were tight meanders on the creeks and extending the cross sections across the floodplain caused issues in appropriately representing channel and floodplain flow paths. The cross sections consisted of the channel surveyed in May 2019 and the floodplain developed from the DTM.

The Pincher Creek reach upstream of the Kettles Creek confluence consists of 100 cross sections with six bridges. The Kettles Creek reach consists of 124 cross sections with six bridges and one inline culvert.

The Pincher Creek reach downstream of the Kettles Creek confluence consists of 28 cross sections with one bridge. Information related to the bridges and the culvert is included in Section 2.

Appendix V presents key information related to the cross sections included in the model.

Flood Control Structures

There are three flood control structures along Pincher Creek, which were included in the model. The first is on the left bank between the Hewetson Avenue Bridge and Downstream of the Bev McLachlin Bridge. The second is upstream of the Highway 6 bridge on the right bank, protecting part of the Pincher Creek Veteran's Memorial Campground and community to the south of the campground. The third is on the left bank downstream of the Highway 6 Bridge, protecting the Sleepy Hollow Campground that was badly inundated during the 1995 event.

4.3.3 Model Calibration

Model calibration involved adjusting key parameters until there was a reasonable match between model predictions and HWM data. Key parameters adjusted included the channel Manning's *n* and contraction and expansion coefficients at structures and cross sections. The following sections describe model calibration.

Summary of Calibration Information

The two recent significant events recorded by the Pincher Creek gauge used for model calibration are the June 2010 and the June 1995 events. Table 4.4 summarizes the calibration data available for these two events. The HWM data for these events is presented in Table 4.1.

Table 4.4 Calibration Event Data Summary

Year	Date of Flood Event	Number of HWM	Peak Flood Flow, Pincher Creek (m^3/s)	Peak Flood Flow, Kettles Creek (m^3/s)
2010	June 17	17	76	26
1995	June 6	14	271	n/a

The 1995 event is close to a 200-year flood on Pincher Creek, and the 2010 event is approximately a 10-year flood, based on the flood frequency estimates presented in Table 3.2. For Kettles Creek, there was no published peak discharge for the 2010 event. The peak discharge estimated through correlation with the maximum daily discharge is 26 m^3/s for the 2010 event, which is approximately a 35-year flood.

Approach and Selected Parameters

The hydraulic model was calibrated for both low and high flows. Low flow data was collected at the time of the May 2019 survey. For the high flow calibration, the model was calibrated against the HWM data described in Section 4.1.4; the 1995 event was used to calibrate the modelled Pincher Creek reach and the 2010 event was used to calibrate the modelled Kettles Creek reach. The 2010 event was also used to validate the modelled Pincher Creek reach. In addition, information from the Pincher Creek and Kettles Creek gauging stations was used in the calibration.

The key parameters modified during model calibration included Manning's *n* values for the channel and floodplain, contraction and expansion loss coefficients between channel cross sections and at structures, and coefficients in the bridge routines within HEC-RAS.

The hydraulic roughness of the channel and floodplain is highly variable and depends on a number of interdependent factors, including surface roughness, vegetation, channel irregularity and presence of obstructions (Chow 1959). Roughness coefficients for the main channel and floodplains were initially selected based on the information gathered during site visits and subsequent review of the photographs in Appendix II, aerial imagery and published estimates for typical conditions from the Manning's *n* table in Chow (1959). These initial Manning's *n* values were then refined during calibration until an acceptable match was achieved between model predictions and HWM data. The outcome was a single set of Manning's *n* values that was used for the full range of events. The resulting Manning's *n* values are shown in Table 4.5 for the range of land use types.

Table 4.5 Calibrated Manning's *n* Values

Land Description	Manning's *n* Value
Pincher Creek channel – Upstream and Urban Reaches (Station 3573 to 14327)	0.035
Pincher Creek channel – Downstream Reach (Station 0 to 3514)	0.030
Kettles Creek channel – Upstream and Downstream Reach	0.045
Grassed Areas	0.050
Gravel bars in the channel	0.025
Woodland areas, shrubs, and willows	0.100
Urban Area – Commercial	0.080
Urban Area – Residential	0.100

In addition, consideration was given to modifying the energy loss coefficients for hydraulic structures to improve model calibration at the structures. The following sections describe the low flow and high flow calibration results. Tabular results of the calibration exercise are provided in Appendix VI.

Low-Flow Calibration Results

The low flow calibration was undertaken based on water levels measured at the time of the survey. Flows for the low flow calibration were taken from WSC published data and were 7.1 m^3/s on Pincher Creek and 1.2 m^3/s on Kettles Creek. The approach was to simulate the model with the base parameters (i.e., Manning's *n* and contraction and expansion losses). Tabular results of the low-flow calibration are presented in Appendix VI. The water surface profiles are shown in Figure 4.4.

Reviewing Figure 4.4, the low flow calibration for Pincher Creek looks better than that for Kettles Creek. As described in Section 4.2.2, Kettles Creek has a number of beaver dams and it is likely that these dams would have influenced the surveyed water levels upstream of the structures. The one-dimensional model does not capture the beaver dams. In addition, one set of Manning's *n* values was obtained for the model, covering all events. It is possible that whilst the selected Manning's *n* values are appropriate for the higher return period events, they are on the low side for the more frequent events when creek depths are shallower.

Table 4.6 presents some key statistics related to the low flow calibration. The mean difference between predicted and surveyed water levels is -0.13 m for Pincher Creek and -0.20 m for Kettles Creek. These results are considered acceptable.

Table 4.6 Key Statistics Related to the Low Flow Calibration

Parameter[1]	Pincher Creek	Kettles Creek
Maximum difference (m)	0.22	0.09
Minimum difference (m)	-0.42	-0.62
Mean (m)	-0.13	-0.20
Standard deviation	±0.13	±0.18

Note 1 Difference is Modelled Water Level minus Surveyed Water Level

High Flow Calibration June 2010 Event Results

The June 2010 event was used to calibrate Kettles Creek and to validate the Manning's *n* roughness for Pincher Creek. The peak flow in the June 2010 event was 76 m^3/s on Pincher Creek and 26 m^3/s on Kettles Creek. The calibration results are conveyed in Table VI.3 in Appendix VI. A summary of the results of the calibration are given in Table 4.7. Figure 4.5 presents the longitudinal profile for Pincher Creek, and Figure 4.6 presents the longitudinal profile for Kettles Creek. The surveyed HWMs are included as the red dots on the profiles.

Table 4.7 Key Statistics Related to the June 2010 Calibration

Parameter[1]	Pincher Creek	Kettles Creek
Maximum difference (m)	0.69	0.73
Minimum difference (m)	-0.40	-0.14
Average (m)	0.05	0.16
Standard deviation	±0.36	±0.26

Note 1 Difference is Surveyed Water Level minus Modelled Water Level

Visually there is a reasonable match between the model predictions and the HWM data, and the average difference is deemed to be acceptable. There are several larger differences between predictions and observations, as summarized in the following bullet points:

- On Pincher Creek, the model over-predicts levels by 0.69 m compared to the HWM measured upstream the Beaver Drive Bridge.
- The model over predicts water levels downstream of three bridges on Kettles Creek: the Highway 6 Bridge (by 0.73 m), the Main Street Bridge (by 0.58 m), and the Macleod Street Bridge (by 0.31 m).

Sensitivity tests were undertaken on the contraction and expansion losses at the bridges, but the calibration could not be improved. It is likely that there were localized flow conditions at the aforementioned bridges in 2010 that cannot be reproduced by the hydraulic model.

Figure 4.4 Pincher Creek and Kettles Creek – Low Flow Calibration

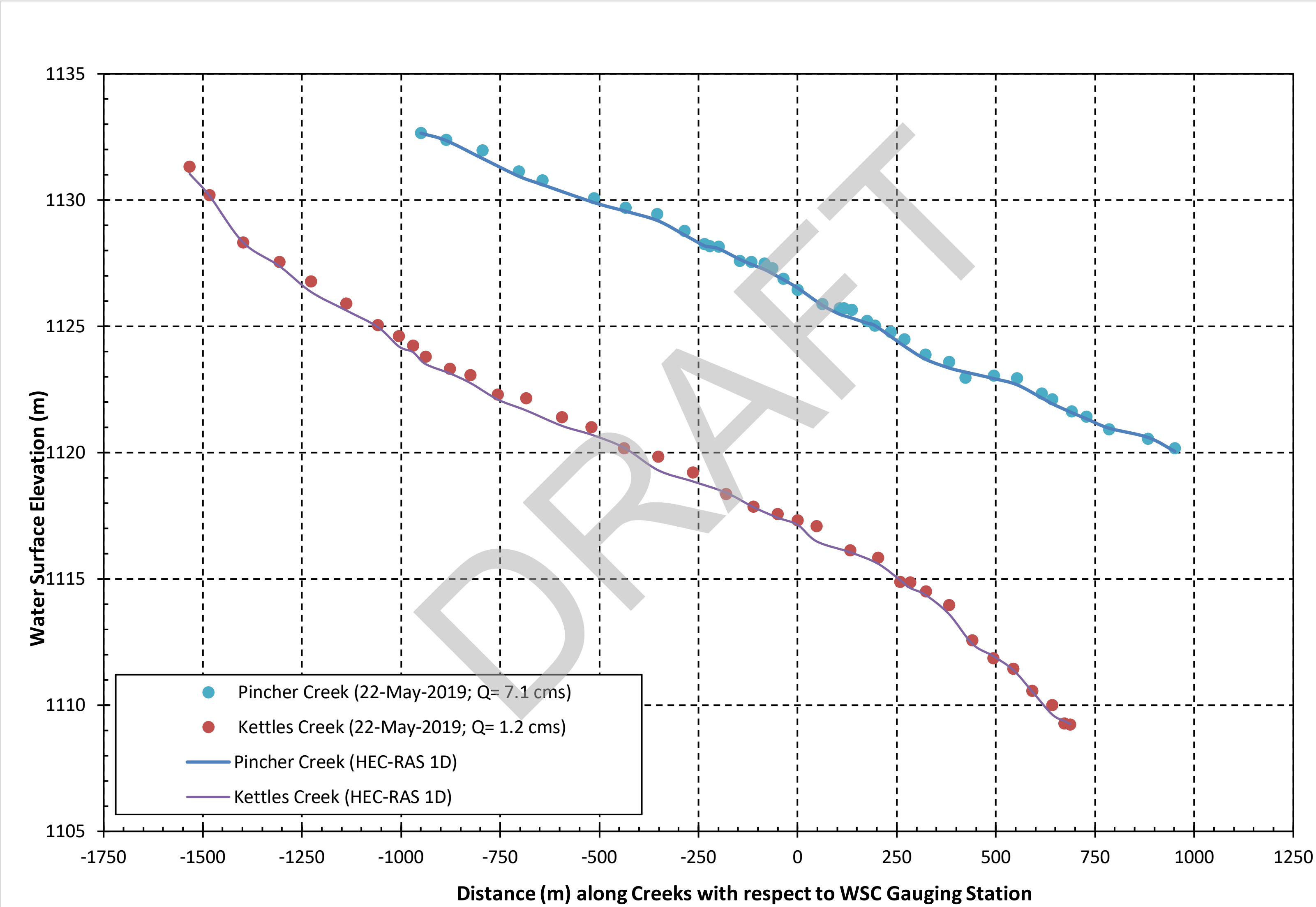


Figure 4.5 June 2010 Calibration Water Surface Profile - Pincher Creek

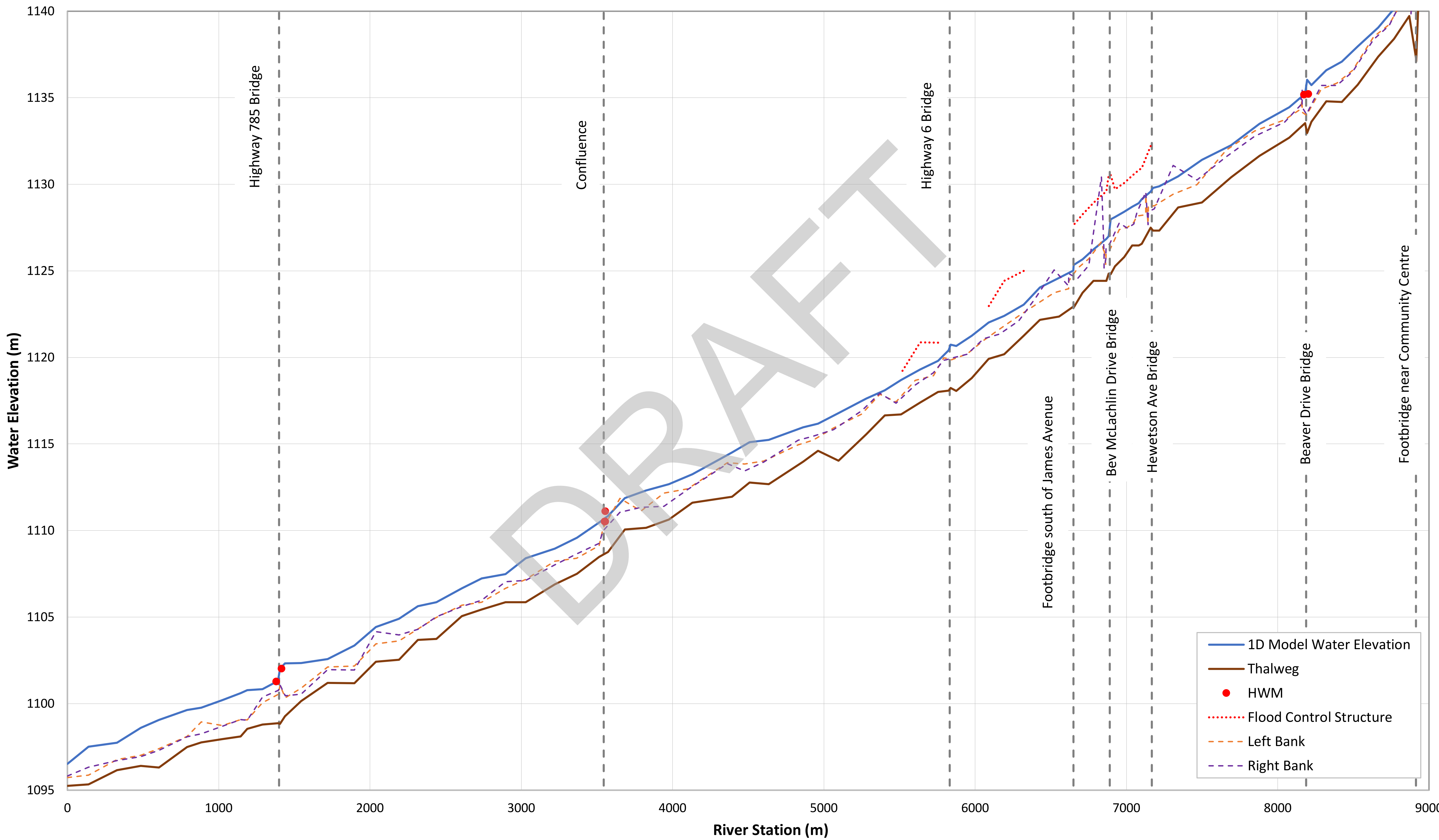
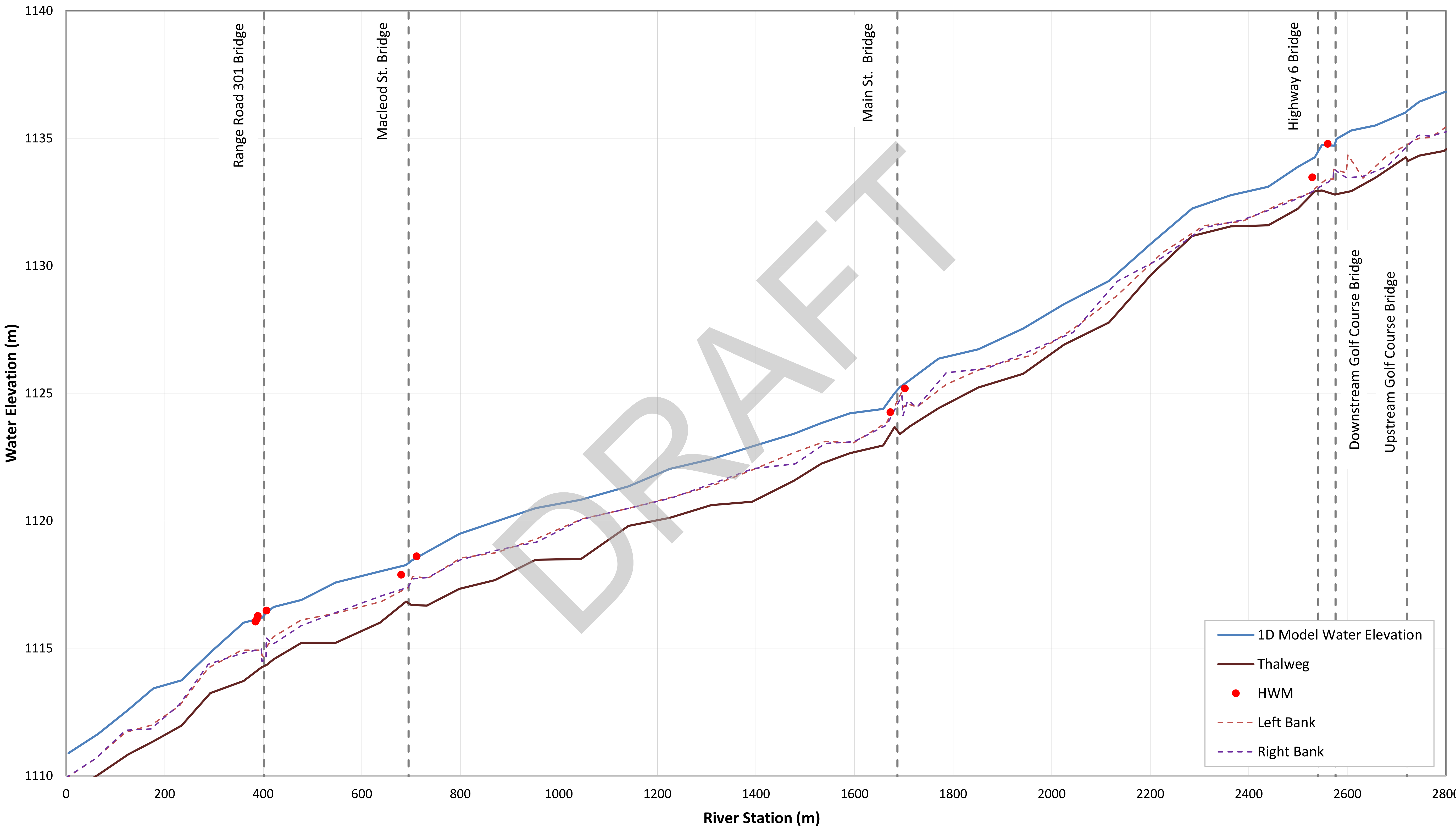


Figure 4.6 June 2010 Calibration Water Surface Profile - Kettles Creek



High Flow Calibration June 1995 Event Results

The June 1995 event was used to calibrate Pincher Creek and validate the Manning's *n* roughness for Kettles Creek. The peak flow in the June 1995 event was 271 m^3/s on Pincher Creek, which is approximately a 200-year flood. It should be noted that the Kettles Creek gauge only came into service in 2005 and so there is no recorded 1995 discharge on Kettles Creek. The applied Kettles Creek discharge of 42 m^3/s assumes that the 200-year event occurred concurrently on both Pincher Creek and Kettles Creek.

The calibration results are conveyed in Table VI.4 in Appendix VI. A summary of the results of the calibration are given in Table 4.8. Figure 4.7 presents the longitudinal profile for Pincher Creek, and Figure 4.8 presents the longitudinal profile for Kettles Creek. The surveyed HWMs are included as the red dots on the profiles.

Table 4.8 Key Statistics Related to the June 1995 Calibration

Parameter[1]	Pincher Creek	Kettles Creek
Maximum difference (m)	1.58	0.49
Minimum difference (m)	-0.29	-0.98
Mean (m)	0.56	-0.27
Standard deviation	±0.63	±0.51

Note 1 Difference is Surveyed Water Level minus Modelled Water Level

There was some difficulty in calibrating Pincher Creek model predictions to observations and in general, the model slightly over predicts water levels. The reason for the difficulty in calibrating is likely due to the presence of the flood berms through Pincher Creek, which were constructed along Pincher Creek after the 1995 event. The berms start to overtop during about the 200-year event and result in an unusual water surface profile (see section 4.4). These flood berms were included in the calibration model and result in concentrating the flow within the main channel, resulting in higher water levels than would have occurred. A sensitivity test was undertaken with the levee markers removed. The results indicated that levels in the vicinity of the Bev McLachlan Bridge reduced by a maximum of 0.17 m. Approximately 300 m of Pincher Creek upstream of the bridge showed a reduction in water level. Elsewhere, there was no significant change in levels. The Kettles Creek results are presented for information only, given the 1995 discharge is not known.

Figure 4.7 June 1995 Calibration Water Surface Profile - Pincher Creek

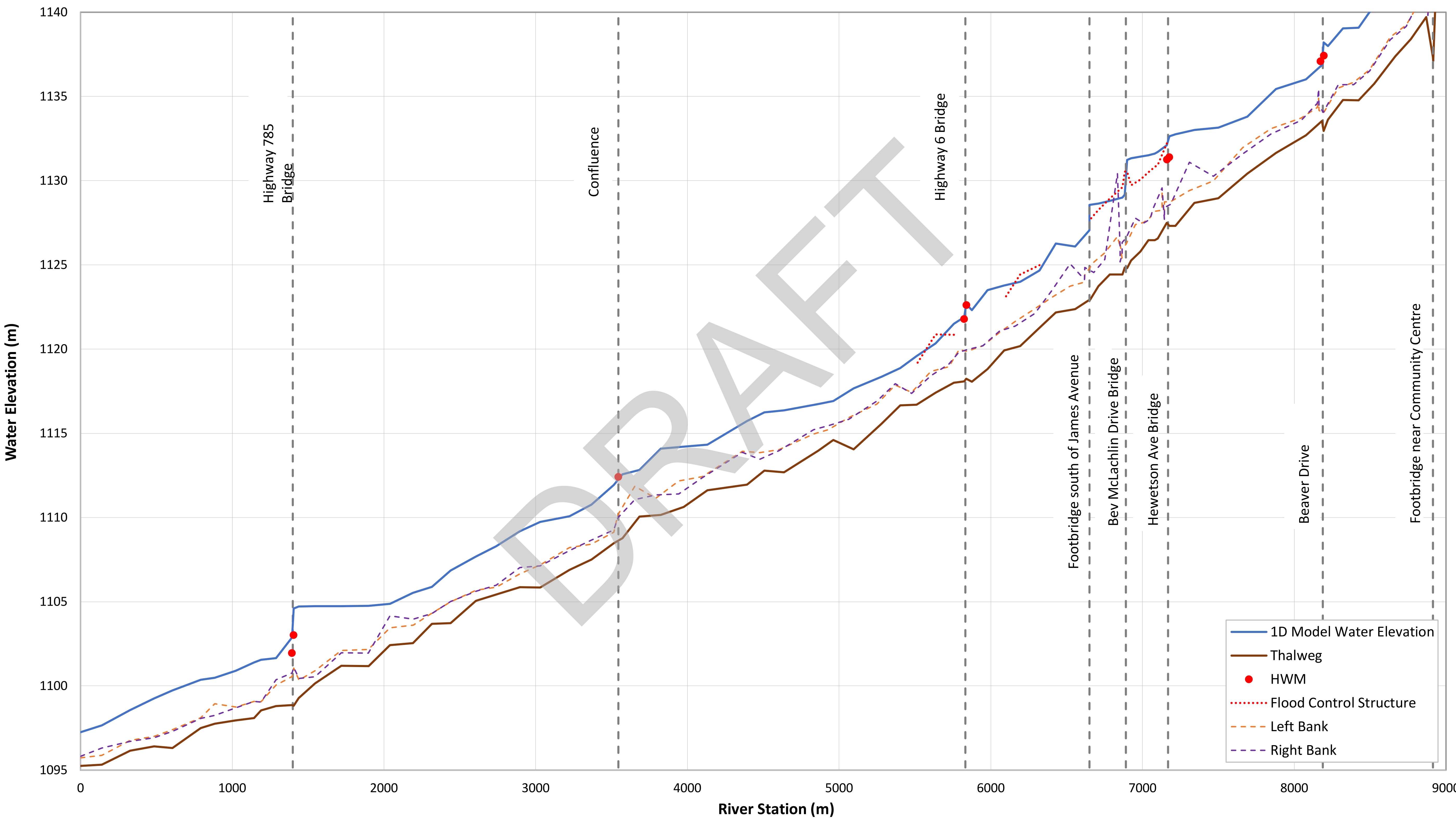
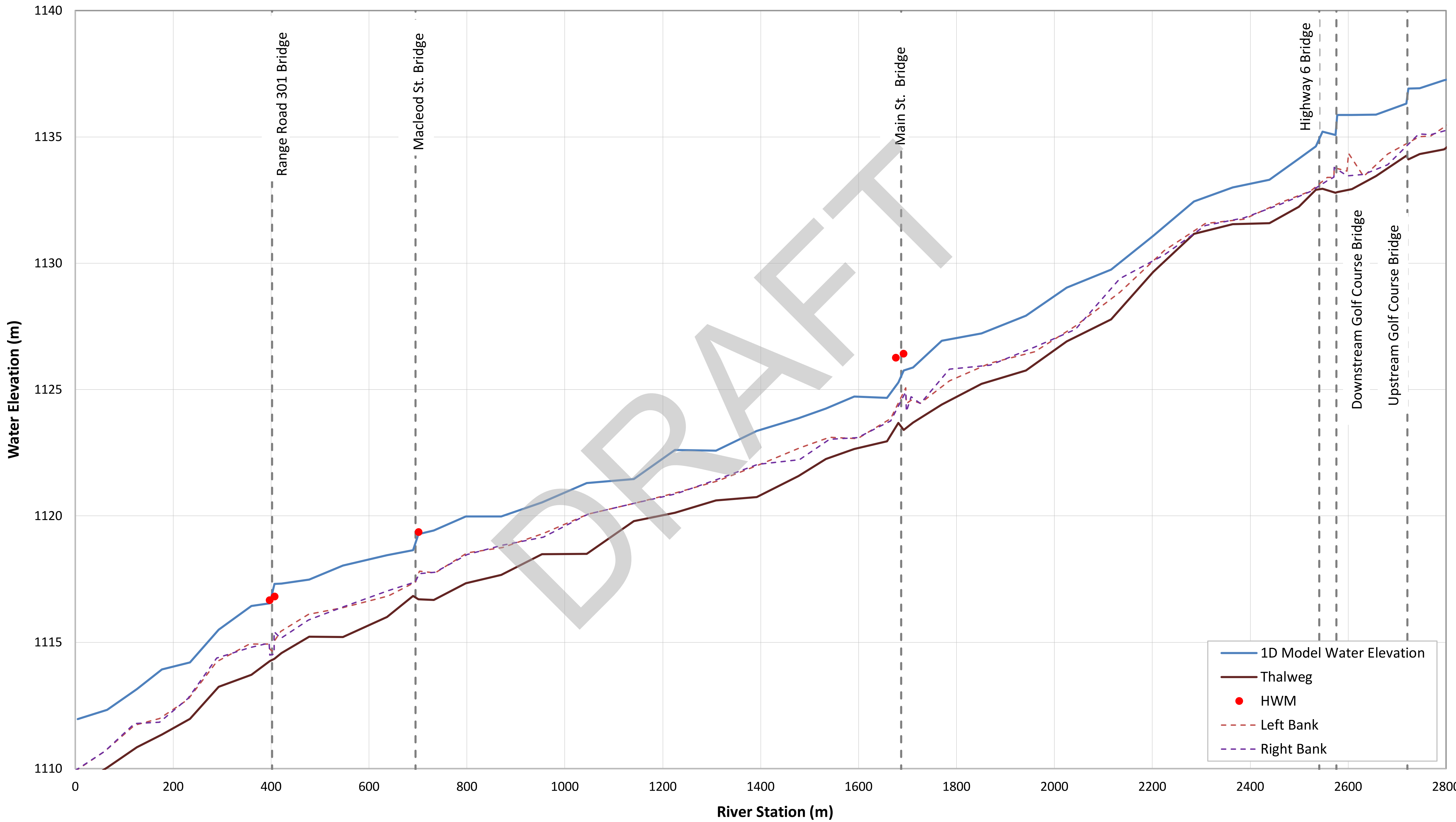


Figure 4.8 June 1995 Calibration Water Surface Profile - Kettles Creek



Rating Curve Comparison

Figure 4.9 compares the modelled and WSC rating curves at the Pincher Creek at Pincher Creek gauge site. The comparison indicates there is a reasonable alignment between the modelled and WSC rating curves up to a discharge of 60 m^3/s. At higher flows, the modelled rating curve gives higher levels for a given discharge than the equivalent WSC rating curve. The reduction in stage for flows higher than 350 m^3/s is due to the overtopping flood barriers where large areas of the floodplain suddenly become active.

Figure 4.9 Comparison of Rating Curves at the WSC Pincher Creek at Pincher Creek Gauge

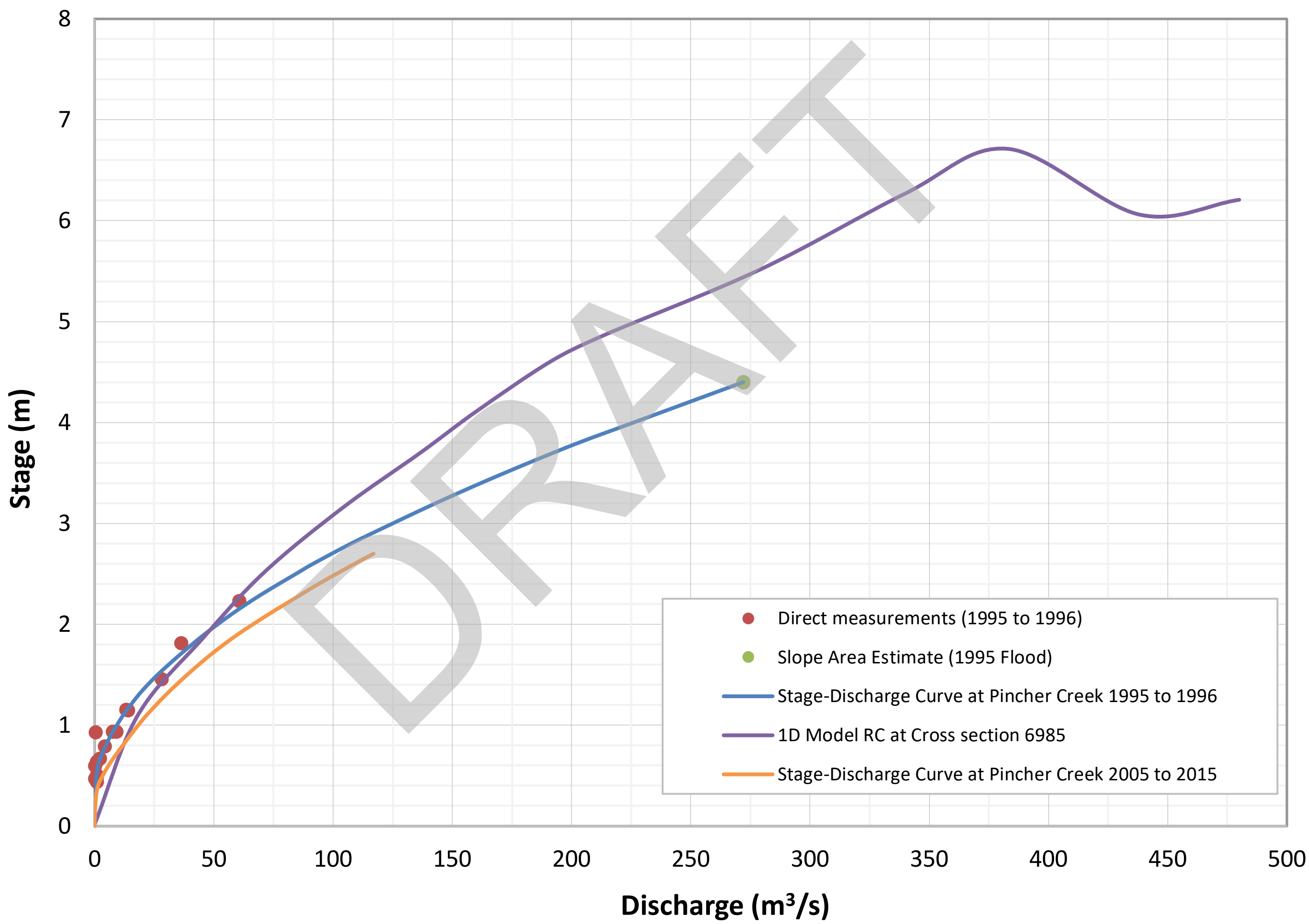
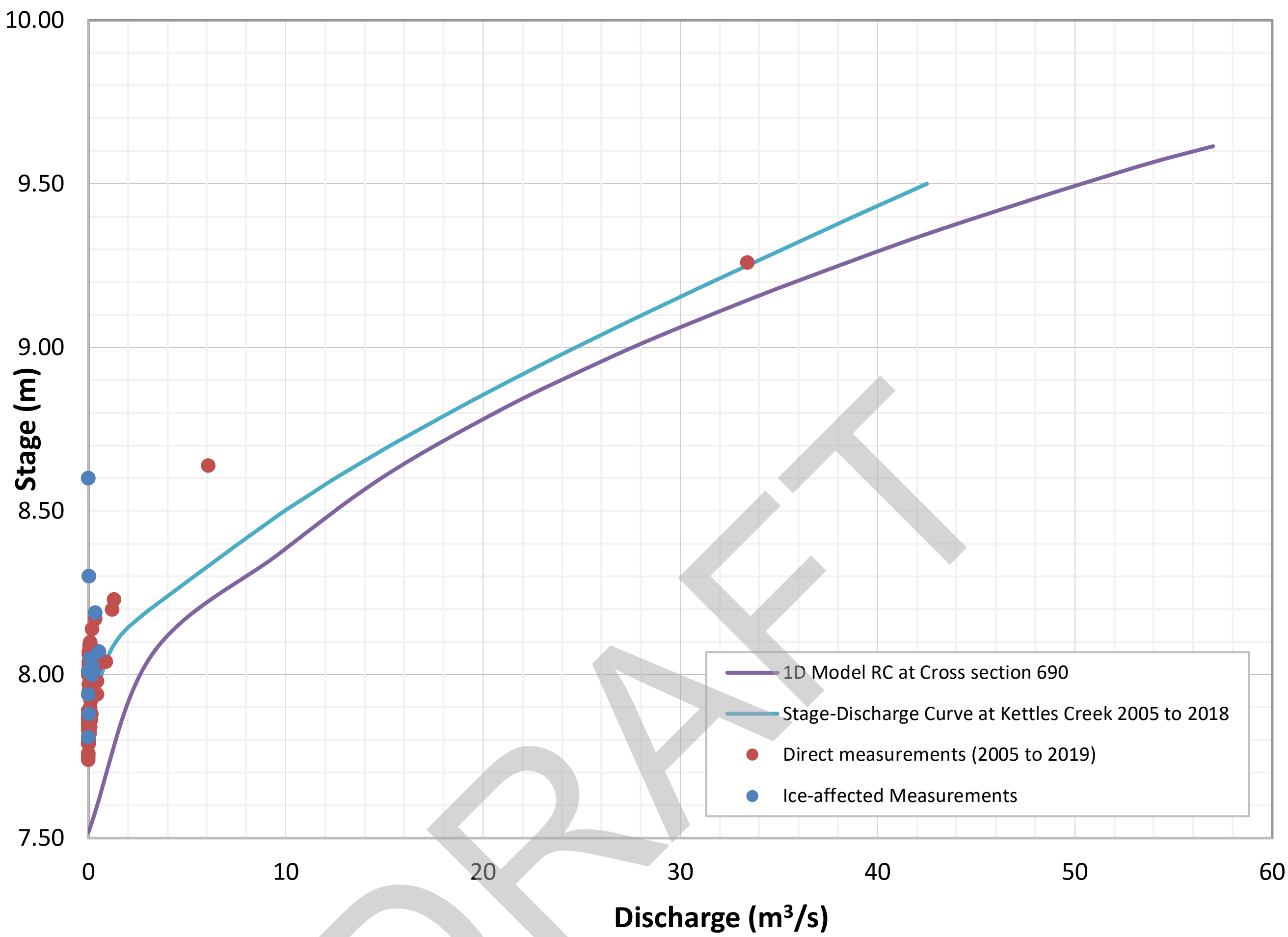


Figure 4.10 compares the modelled and WSC rating curves at the Kettles Creek at Pincher Creek gauge site. The two rating curves look similar in shape. The offset between the two curves is likely due to a difference between the gauge datum and the outcomes of the topographic survey in May 2019.

Figure 4.10 Comparison of Rating Curves at the WSC Kettles Creek at Pincher Creek Gauge



4.3.4 Model Parameters and Options

The outcomes of the calibration exercise resulted in establishment of values of Manning's *n* for Pincher and Kettles Creek, expansion and contraction loss coefficients, and ineffective flow areas. Table 4.5 summarizes Manning's *n* values used in the model. The following bullet points summarize the expansion and contraction loss coefficients:

- All cross sections default contraction /expansion loss coefficients of 0.1 and 0.3; and
- Default contraction/expansion coefficients of 0.3 and 0.5 for bridges.

The bridges were modelled using the energy method with the application of standard coefficients. The following exceptions were made to improve the calibration:

- At the Beaver Drive Bridge and the Highway 6 Bridge on Pincher Creek, the contraction and expansion coefficients were set at 0.1 and 0.3; and
- Upstream and downstream of the Golf Course Bridge on Kettles Creek, the contraction and expansion coefficients were set at 0.1 and 0.3. Since there is no embankment across the

floodplain, floodplain flow can easily bypass these small golf course bridges, and there will be little in the way of a contraction or expansion.

4.4 Flood Frequency Profiles

The calibrated model was used for flood frequency modelling and profile creation. The 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1000- year events were simulated with the inflow discharges for each return period event taken from Table 3.2. Several locations were encountered where water surface profiles of a given return period crossed the profile of a higher or lower return period event. This typically occurred when parts of the floodplain designated with ineffective flow areas or behind levee markers became active, resulting in a sudden increase in floodplain conveyance. This sudden change in conveyance resulted in the unusual flood profiles. To overcome this, several of the flood levels calculated by the HEC-RAS model were slightly modified in Excel to create water surface profiles that increased in elevation with increasing return period. The tabulated results are provided in Appendix VII.

Appendix VII presents the longitudinal profiles, which include: location of bridges and culverts, location of flood control structures, elevation of the top of banks, and stream thalweg. It can be seen from the longitudinal profiles that the flood control structures upstream and downstream of the Bev McLachlan Drive bridge start to overtop at about the 100-year event.

4.5 Model Sensitivity

Model sensitivity tests were undertaken to assess the impact of changing key parameters on resulting flood levels. The 100-year event was used as the baseline event for the sensitivity tests. The calibrated model was simulated for the 100-year event and the impact of the changed parameters on water surface profile were documented. The key parameters assessed included: downstream boundary condition and channel and floodplain roughness values. The results are presented in Appendix VII. These results show the impact on water levels and inundation widths. The following sections describe the sensitivity tests undertaken and results.

4.5.1 Sensitivity to Downstream Boundary Rating Curve

The purpose of this sensitivity test is to understand the backwater effect to changes in the downstream boundary assumption. As described in Section 4.3.1, the downstream boundary includes a normal-depth rating curve generated from the cross section properties of the cross section at Station 0 on Pincher Creek and a slope of 0.003 m/m. The sensitivity test involved increasing and decreasing the channel slope of 0.003 m/m by ±20%. The resulting channel slopes were 0.0036 m/m and 0.0024 m/m. The rating curve was recalculated and the tabular results with longitudinal profiles are presented in Appendix VII. The increase in level at the downstream boundary was 0.09 m. The decrease in level was 0.07 m. The effect of this adjusted downstream boundary condition extends approximately 130 m upstream.

4.5.2 Sensitivity to Channel Roughness

Calibrated channel Manning's n values are summarized in Table 4.5. These calibrated roughness values were varied by ±10% and ± 20%. The results of the 100-year simulations are presented in Appendix VII, including tabular data, profiles, and plots showing the difference in water levels resulting from the changes to Manning's n. A summary of the results is presented in Table 4.9.

Table 4.9 Impact of Changes to Channel Roughness on 100-Year Flood Levels

Creek	Simulated Water Elevation Difference[1] (m) for Various Channel Roughness Sensitivity Test			
	Calibrated Manning's *n* ±10%		Calibrated Manning's *n* ±20%	
	Average	Maximum	Average	Maximum
Pincher Creek	±0.02	±0.58	±0.05	±0.58
Kettles Creek	±0.02	±0.51	±0.05	±0.30

Note 1 Water elevation difference is calculation by sensitivity model results minus calibrated water elevation.

The results presented in Table 4.9 indicate that changes to Manning's *n* has an impact on predicted flood levels. Based on the longitudinal profile showing differences in flood levels presented in Appendix VII, a ±10% change in Manning's *n* results in an average change in water levels of the order of ±0.02 m on both Pincher Creek and Kettles Creek. A ±20% change in Manning's *n* results in an average change in water levels of ±0.05 m on both Pincher Creek and Kettles Creek. There are two locations where the change is more pronounced: the first is around Pincher Creek Station 2500 and the second is upstream of Station 13500. For Kettles Creek, there are noteworthy changes in flood level just upstream of Station 1000.

4.5.3 Sensitivity to Floodplain Roughness

Calibrated Manning's n values for the floodplain are presented in Table 4.5. These values were also increased by ±10% and ±20%. This is a plausible range of Manning's n values based on the calibration findings. The results of the 100-year simulations are presented in Appendix VII. A summary of the results is presented in Table 4.10.

Table 4.10 Overbank Roughness Analysis Water Elevation Differences Summary

Creek	Simulated Water Elevation Difference[1] (m) for Various Overbank Roughness Sensitivity Test			
	Calibrated Manning's *n* ±10%		Calibrated Manning's *n* ±20%	
	Average	Maximum	Average	Maximum
Pincher Creek	±0.03	±0.58	±0.06	±0.58
Kettles Creek	±0.02	±0.56	±0.04	±0.50

Note 1 Water elevation difference is calculation by sensitivity model results minus calibrated water elevation.

The results presented in Table 4.10 show a similar trend to the changes in channel roughness. There are three locations where there is a pronounced change in flood levels. The first is around Pincher Creek Station 2500, the second is upstream of Station 3500, and the third is upstream of Station 13500. For Kettles Creek, there are noteworthy changes in flood levels downstream of Station 500, upstream of Station 2500, and upstream of Station 3000.

5 FLOOD INUNDATION MAPS

5.1 Methodology

An Open Water Flood Inundation Map Library was produced for the project with flood inundation maps prepared for the 13 flood frequency scenarios assessed. A separate map for each return period flood was prepared from the flood elevations simulated from the calibrated hydraulic model.

Given the relatively small study area, the primary scale of the maps was set at 1:5,000. This resulted in nine map sheets for each return period event. The base maps were prepared in ArcGIS 10.6 using the appropriate local 3-Degree Transverse Mercator (3TM) zone, referenced to NAD83 (CSRS) horizontally, and the Canadian Geodetic Vertical Datum of 1928 (CGVD28) vertically.

The flood inundation extents include direct inundation areas that are connected to the main channel and indirect inundation areas behind flood control structures. These indirect inundation areas represent those areas that would flood should the flood control structures fail. In some flood events, the flood control structures are partially overtopped and flooding occurs behind the structure. In these cases, the area behind the flood control structure consists of direct and indirect inundation areas. Backwater areas were also identified from the model results and incorporated into the inundation extents. Isolated inundated areas which have no direct connection to the main channel were deleted. Some isolated areas were retained as they were considered to be hydraulically connected to the main channel (for example, by culverts) and directly inundated.

The flood inundation maps were developed using ESRI's ArcGIS software – 3D Analyst extension – Raster Math Tool. The general approach for developing the inundation extents for each of the 13 return period events was as follows:

- Export flood levels to the nearest 0.01 m from HEC-RAS to ArcGIS and create an initial TIN from these water levels, with no data assigned to dry cells.
- Identify candidate backwater areas from this water surface TIN and the flood extents developed in GeoHECRAS, focussing on significant areas of backwater where residents and landowners would be particularly affected.
- For the identified backwater areas, create backwater polygons with a constant water level based on water levels at the overtopping point.
- Create a modified TIN from the backwater polygons and truncated cross sections.
- Generate a water surface raster with a 0.5 m grid size from the modified TIN, commensurate with the AEP provided DTM.
- Generate a depth grid by subtracting levels in the original hydroflattened DTM surface from the water-elevation raster, interpolating where gaps in the depth grid occur due to high levels on the hydroflattened DTM.
- Create flood inundation polygons from the depth grid.

- Filter the resulting flood polygon and polygon elements to reduce visual complexity and GIS data sizes. This was done by removing discontinuities, such as areas not hydraulically connected to the main creek, and small areas less than 100 m^2, or deleting polygons along the edges of primary polygons in both the direct and potential inundation and filling in areas of high ground.
- Smooth filtered polygons and most polylines using the standard PAEK algorithm and smoothing threshold of 15 m, with checks undertaken to ensure consistency of results (i.e., a lower return period event does not have a larger flood extent than a larger event).
- Remove unconnected polygons and smooth and filter the remaining inundation polygons.
- Create a water surface grid by truncating the water surface raster to the flood inundation polygon extents.

The key outputs of this exercise are initial and modified TINs, water surface and depth grids to a 0.5 m grid size, the inundation polygons, and the inundation maps. The resulting depth grids were colour themed to help visualize the depth of flooding over the project area. The following sections describe the modifications made to the TIN to account for backwater areas and a description of the flood inundation areas.

5.2 Water Surface Elevation TIN Modifications

5.2.1 Backwater Areas

Generating flood extents directly from the HEC-RAS model predictions can result in overly conservative flood extents. This is because all areas on the cross section below the predicted water level are shown to be inundated, even if parts of the floodplain are not hydraulically connected to the main channel due to high ground. In some cases, the floodplain would only flood if hydraulically connected to the main channel at some upstream or downstream location. Backwater areas within the Pincher Creek flood limits include overflow areas connected at a single point where the flood extent is contained by the topography.

Examples of the backwater areas include (1) areas on floodplains that are not directly connected to a cross section but flood due to a downstream connection and (2) ponded flooding behind a road embankment or flood control structure that is overtopped at one location. In these cases, backwater polygons were identified and given a constant flood level. The water level for the backwater polygons was the same as the water level in the main channel at the overtopping/connection point. Areas where this type of backwater were applied include Indianfarm Creek and the left floodplain of Kettles Creek to the south of Highway 785.

The aim of the backwater flooding method is to develop flood maps that are as representative as possible. The areas described above were identified and incorporated into a modified TIN surface, following the approach described in Section 5.1. Where backwater flooding areas occur, a check was made that the resulting flood extent did not result in the formation of new overtopping points. It should be noted that minor backwater areas, especially in rural areas, were not modified and floodplain levels were taken from the cross section at that location, even if the floodplain was not hydraulically connected.

5.2.2 Floodplain Modifications

TIN modifications were required on the left Pincher Creek floodplain downstream of the Bev McLachlin Drive Bridge and downstream of the pedestrian bridge to the south of James Avenue. The steep hydraulic gradient of the main channel through the bridge openings, resulted in unrepresentative floodplain inunmdation areas. The result of the TIN modifications was a more gentle hydraulic gradiant in the left floodplain for cross sections downstream of the Bev McLachlin Bridge and the pedestrian bridge to create a more representative inundation. These modifications were done for the 75-, 100-, and 200-year flood events.

5.2.3 Overflow from Kettles Creek to Pincher Creek

Overflow from Kettles Creek spills into the Pincher Creek floodplain from upstream of the Macleod Street Bridge (Highway 785 bridge). This spill starts at around the 20-year event and flows to the north. To represent this flow path, a breakline was introduced into the TIN that captured ground levels along a ridge within the Pincher Creek floodplain, to the north of Macleod Street. A sloping TIN was created from the Kettles Creek cross sections to this ground-level breakline. At the 350-year flood and higher, the breakline was moved further north within the Pincher Creek floodplain, also capturing higher ground in the area. These modifications are deemed to provide a realistic representation of inundation in the area between Pincher Creek and Kettles Creek.

5.2.4 Creation of the Water Surface Elevation & Flood Depth Grids

As described in Section 5.1, the depth grids were created by subtracting the levels in the original hydroflattened DTM surface from the water surface raster. The water surface grid was created by truncating the water surface raster to the flood inundation polygon extents.

5.3 Flood Inundation Areas

Flood inundation polygons were developed for each return period following the procedure described in Section 5.1. The flood polygons were checked for consistency and accuracy based on a review of the topographic information, the hydraulic model results, and fundamental hydraulic principles. Modifications to the TIN were undertaken as described above.

The flood inundation polygons were then overlain on the base maps to create the Open Water Flood Inundation Map Library. These inundation extents were checked against the DTM to confirm the inundation extents were reasonable and the inundation maps are representative of the actual flood hazard.

The Open Water Flood Inundation Map Library is presented in Appendix VIII. These maps show both the direct and indirect inundation areas. As described in Table 2.4, there are three flood control structures within the project area. The maps illustrate the indirect inundation area due to the potential failure of the flood control structures, for those return period events that do not overtop the structures.

The left floodplain of Pincher Creek, downstream of the Hewetson Avenue bridge is inundated at the 75-year event. On the right floodplain there is an area between Church Avenue and the Highway 6 bridge (including the Pincher Creek Veteran's Memorial Campground) that is susceptible to flooding at the 75-year flood. The Sleepy Hollow Campground on the left floodplain of Pincher Creek, downstream of the Highway 6 bridge is also flood prone and is partially inundated at the 35-year flood. The industrial area on the left floodplain of Kettles Creek, upstream of the Highway 785 bridge is also susceptible to flooding and is inundated at the 20-year event.

6 FLOODWAY DETERMINATION

This section describes the identification of the floodway and flood fringe zones for the specified design flood. The outputs are the design flood elevations, floodway criteria maps, and flood hazard maps. A description of the 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 or naturalized (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 referred to as a "one in one hundred year flood" using common terminology. The design flood, for the purposes of defining the floodway and flood fringe for the Pincher Creek Flood Hazard Study, is the 100-year open water flood.

6.2 Floodway and Flood Fringe Terminology

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 100-year design flood. The floodway generally includes areas where the water is 1 m deep or greater and the local velocities are 1 m/s or faster. Typically, the floodway includes the main channel of a stream and a portion of the adjacent overbank area. Previously mapped floodways do not typically become larger when a flood hazard map is updated, even if the flood hazard area gets larger or design flood levels get higher.

Flood Fringe
The flood fringe is the portion of the flood hazard area outside of the floodway. The flood fringe typically represents areas with shallower (less than 1 m deep), slower (less than 1 m/s velocity), and less destructive flooding during the 100-year design flood. However, areas with deep or fast moving water may also be identified as high hazard flood fringe within the flood fringe. Areas at risk behind flood berms may also be mapped as protected flood fringe areas. New development in the flood fringe may be permitted in some communities.

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, incorporating technical changes implemented in 2021 regarding how floodways are mapped in Alberta, 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 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 depth and velocity criteria used to define high hazard flood fringe zones will be aligned with the 1 m depth and 1 m/s velocity floodway determination criteria for newly-mapped areas.

All areas protected by dedicated flood berms that are not overtopped during the design flood are excluded from the floodway. Areas behind flood berms will still be mapped as flooded if they are overtopped, but areas at risk of flooding behind dedicated flood berms that are not overtopped will be mapped as a protected flood fringe zone.

There was a previous floodway derived for Pincher Creek and Kettles Creek as part of Philips 1993. On Pincher Creek, the previous floodway extended from Station 9325 to 1393. On Kettles Creek, the previous floodway extended from Station 2499 to the confluence with Pincher Creek. This previous floodway was used as the basis of the floodway delineation, but was adjusted as required to capture the main channel, which has shifted in places since the 1993 study (Philips 1993) and according to the aforementioned exceptions.

The governing floodway determination criteria for the left and right floodway limits at each cross section are provided in Appendix XI. The governing criteria for Pincher Creek was generally based on the previous floodway and then the 1 m depth criteria. The governing criterion for Kettles Creek was the 1 m/s velocity criterion.

6.3.2 Design Flood Profile

The table in Appendix IX present the design flood levels, which were extracted from the calibrated HEC-RAS model. Figure 6.1 and Figure 6.2 present the longitudinal profiles of the design flood levels flood levels. All reaches were sub-critical.

Figure 6.1 Design Water Level – Pincher Creek

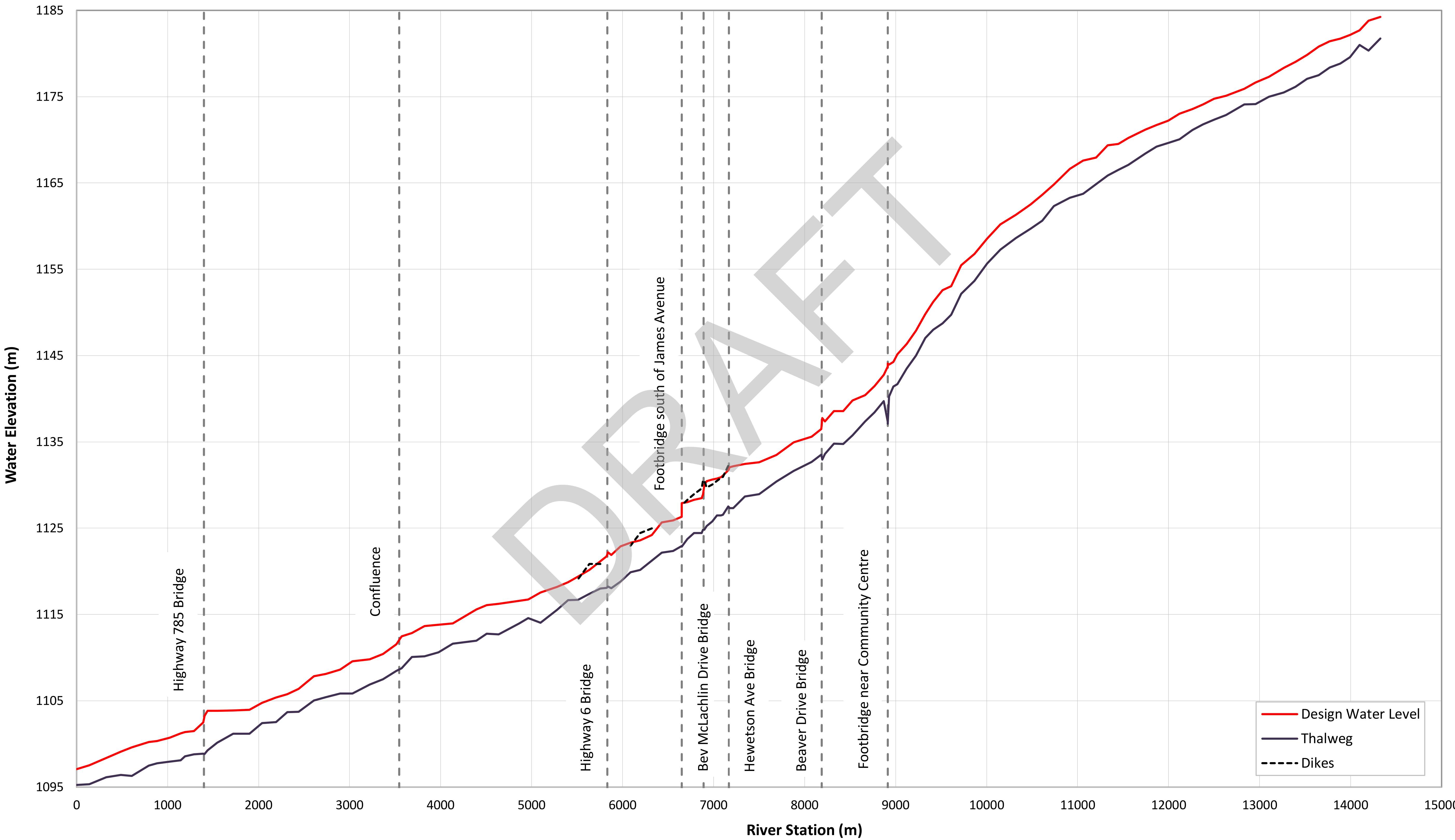
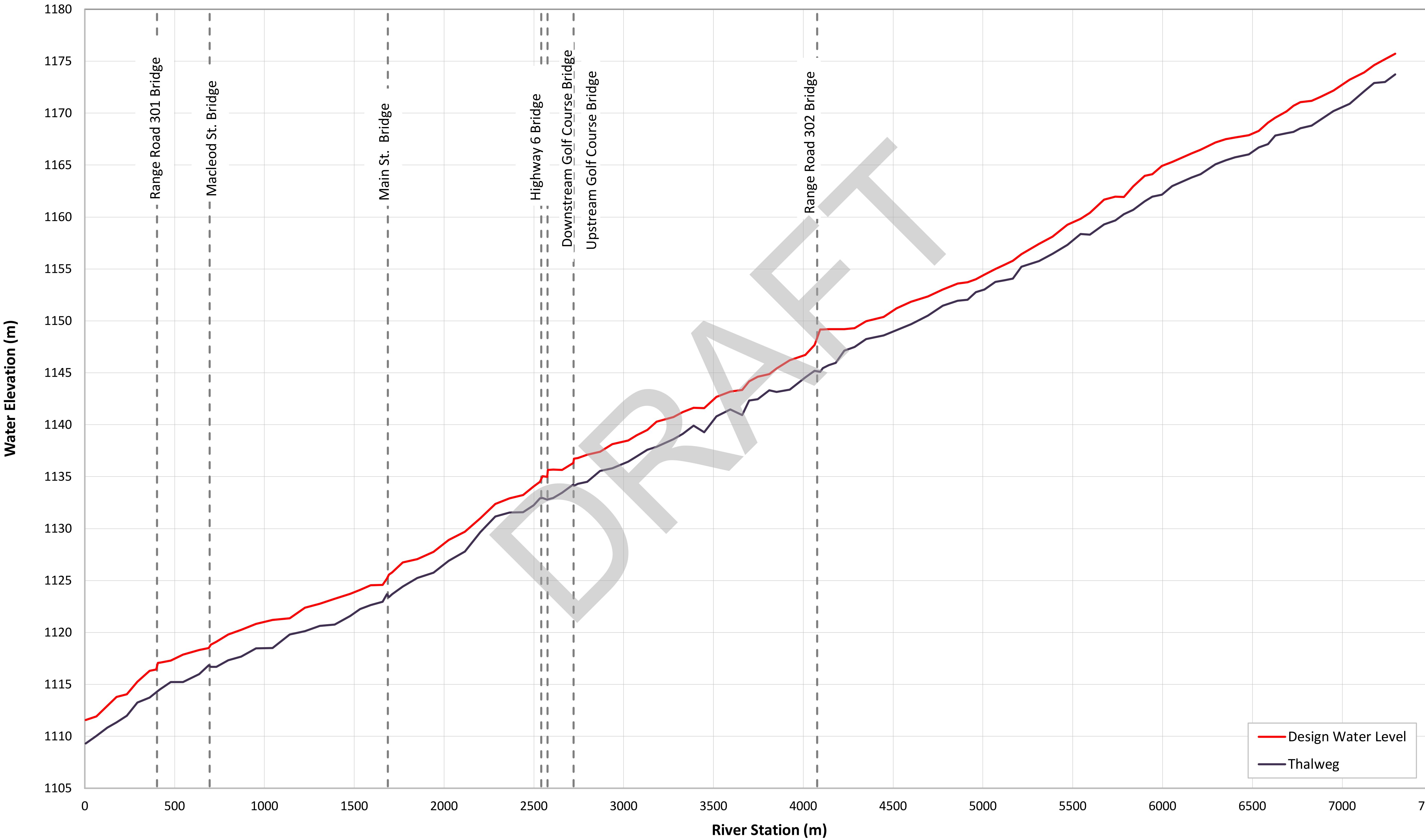


Figure 6.2 Design Water Level – Kettles Creek



6.3.3 Floodway Criteria Maps

Floodway criteria maps are a tool for determining floodway and flood fringe extents for the design flood, including boundaries of high hazard flood fringe and protected flood fringe areas. The Open Water Floodway Criteria Maps (Sheets 1 to 9) provided in the Maps and Drawings section of this report show:

- inundation extents of the 100-year open water 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 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).

For the open water design flood water surface elevations and flow velocities were generated from the calibrated HEC-RAS model. The supplied DTM and the water surface elevations were used to determine the resulting inundated areas.

A flood depth grid was generated from the design flood extents, which was used to identify areas that met the 1 m depth criterion. This flood depth grid was used to identify areas meeting or exceeding the 1 m depth criterion and to generate 1 m depth contour lines.

Flow velocities are only available at the cross section locations in HEC-RAS as one-dimensional computational modelling approach was used for the Pincher Creek study. HEC-RAS can apportion channel and overbank discharge into a maximum of 45 sub-sections or vertical bins at any cross section location. In each case, the velocity was assumed to have a constant value across each vertical bin, which is how the data are graphically presented in HEC-RAS. The vertical bins where computed velocities were equal or greater than 1 m/s were imported to GIS and plotted along each cross section line.

The floodway boundary was delineated such that a hydraulically smooth floodway boundary between cross sections was produced. The water surface elevation TIN was generated as described in Section 5.2. Water surface elevation and flood depth grids were prepared per the methodology presented in Section 5.2.4. In some areas, flood fringe has been allocated to backwaters or some ineffective flow areas even though the depth was more than 1 m. An example of this is downstream of cross section RS13100 on Pincher Creek.

For Pincher Creek, it can be seen that the governing criteria varies between the previous floodway and the 1 m depth, and 1 m/s velocity. In some cases the edge of the inundation was delineated as the floodway line where the edge of the main channel is up against the valley wall. In some cases, the governing criteria is classified as mixed and is reflective of hydraulic smoothing. Overall, the previous floodway and the 1 m depth criterion was the most common.

As per Pincher Creek, no single governing criteria dominates for Kettles Creek. The governing criteria varies between previous floodway, 1 m depth, 1 m/s velocity, or a mix of different criteria. Overall, the 1 m/s velocity criterion dominated.

6.3.4 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.

The flood hazard maps are included in Appendix XII and were prepared through minor adjustments to the open water flood hazard mapping products. The design flood extents developed for the floodway criteria maps were used to create the flood fringe, including the high hazard flood fringe. Areas of high ground (that were either dry or had shallow depths) within the floodway were mapped as floodway.

The floodway is relatively wide in places upstream and downstream of the Town of Pincher Creek, due to the presence of some deep areas on the relatively wide floodplains, often associated with the historic Pincher Creek channel. There are no buildings within the Kettles Creek floodway, but there is a residential building are located in the Pincher Creek floodway downstream of Highway 785 Bridge on Pincher Creek.

The flood fringe is also relatively wide in places along Pincher Creek, due to the wide floodplains. The Kettles Creek flood fringe is generally more confined than Pincher Creek. There are a number of buildings within the flood fringe, as described below:

- Residential community along left bank of Pincher Creek from Hewetson Avenue Bridge to John Avenue;
- Residential community along right bank of Pincher Creek from Church Avenue to Highway 6 Bridge;
- The Sleepy Hollow Campground on the left floodplain downstream of the Highway 6 Bridge;
- Industrial area along right bank of Pincher Creek between the Kettles confluence and Highway 785 Bridge on Pincher Creek;
- Residences downstream of Highway 785 Bridge on Pincher Creek;
- Residences downstream on Kettles Creek downstream of the East Avenue Crossing;
- The industrial area on the left floodplain of Kettles Creek, upstream of Macleod Street (Highway 785);
- Residences in the floodplain around the Pincher Creek and Kettles Creek confluence.

7 POTENTIAL CLIMATE CHANGE IMPACTS

Climate change is an important consideration when attempting to predict a future streamflow regime and to evaluate suitable freeboard between the design flood level and any earthworks or building guidelines for development. As discussed in the Hydrology Memorandum (Appendix III), and as AT (2001) noted, the variability in Alberta's flood discharge make it difficult to detect systematic change, and quantitative prediction of changes on the basis of climatic projections is highly uncertain. However, as Kuklichke, C. and Demeritt, D. (2016) stated, a 20% increase in estimated peak flood flows is effective in operational-level plans for risk-based management of fluvial flooding to take the incompletely understood impacts of climate change into account.

To undertake a cursory evaluation of the impact of climate change, and to obtain a measure of freeboard that may be generally appropriate for long-term planning purposes, the 100-year flows were increased by 10% and 20% and the results were compared to the design flood levels. Table 7.1 presents a summary of the results on a reach by reach basis.

Table 7.1 Summary of Climate Change Impact Assessment Results

Creek	Reach	Average Change in Flood Levels with Q_{100}+10% (m)	Average Change in Flood Levels with Q_{100}+20% (m)
Pincher Creek	0 to 14327	0.1	0.3
Kettles Creek	5 to 7295	0.1	0.2

Note Change in flood level taken from Appendix VII results with the maximum and average change the difference between the climate change scenario and the 100-year flood levels.

The results presented in Table 7.1 indicate that for Pincher Creek, a 10% increase in the 100-year discharge would result in an average increase in flood levels of 0.1 m, while a 20% increase would result in an average increase of 0.3 m. For Kettles Creek, a 10% and 20% increase in discharge would increase the 100-year level by an average of 0.1 m and 0.2 m respectively.

8 CONCLUSIONS

This project was undertaken per the FHIP guidelines, incorporating technical changes implemented in 2021 regarding how floodways are mapped in Alberta, and project Terms of Reference. Hydrological analyses were undertaken to estimate the flood frequency discharges for Pincher Creek and Kettles Creek. The flood frequency results for Pincher Creek were higher than previous estimates, but slightly lower for Kettles Creek.

The HEC-RAS model was created from the most up to date survey data collected in May 2019, which accurately represents the current channel and floodplain characteristics. This model was calibrated against highwater marks, water levels collected under low flow conditions during the channel survey, and available rating curves from WSC for Pincher and Kettles Creek. This model can be reliably used for simulating flood elevations for the various return period floods ranging from the 2- to 1000-year floods.

The main channel Manning's *n* varies from 0.030 to 0.045. These values are within the acceptable range of Manning's *n* values for similar channels. The calibrated model was used to generate water surface profiles for a range of return period events. Sensitivity tests were undertaken on Manning's *n* roughness for the channel and floodplain, as well as assumptions used to generate the downstream boundary condition. It was found that changing the channel roughness by ±10% and ±20% resulted in an average change in water levels of ±0.02 m and ±0.05 m, respectively, on both Pincher Creek and Kettles Creek for the 100-year flood. Changing the overbank roughness values by ±10% and ±20% resulted in an average change of ±0.03 m and ±0.06 m, respectively, on Pincher Creek, and an average change of ±0.02 m and ±0.04 m, respectively, on Kettles Creek.

Sensitivity tests were carried out on the downstream boundary condition, with channel slope changed by ±20%. The resulting increase and decrease in level at the downstream boundary was 0.09 m and 0.07 m respectively. The effect of this adjusted downstream boundary condition extends about 130 m upstream.

Flood Inundation Maps were generated for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-. 750-, and 1000- year events. The inundation extents show a number of areas along Pincher Creek that are prone to flooding. The left floodplain of Pincher Creek, downstream of the Hewetson Avenue bridge is partially inundated at the 75-year event. The area between Church Lane and the Highway 6 bridge (including the Pincher Creek Veteran's Memorial Campground) is inundated at the 100-year event. The Sleepy Hollow Campground on the left floodplain downstream of the Highway 6 bridge is partially inundated at the 35-year event. The industrial area on the left floodplain of Kettles Creek, upstream of the Highway 785 bridge is also prone to flooding and is inundated at the 20-year event.

The floodway boundary has been identified based on the current FHIP Guidelines, incorporating technical changes implemented in 2021 regarding how floodways are mapped in Alberta. The floodway was defined based on a mix of the previous floodway, 1 m depth, and 1 m/s velocity criteria. In general, however, the most common criterion for Pincher Creek was the previous floodway criterion and then the 1 m depth criterion. The most common criterion for Kettles Creek was the 1 m/s velocity criterion. The Floodway Criteria Maps are included in Appendix XI.

The Flood Hazard Maps present the floodway and flood fringe. The floodway is relatively wide in places upstream and downstream of the Town of Pincher Creek, due to the presence of some deep areas on the relatively wide floodplains. There is a residential building within the floodway downstream of the Highway 785 Bridge. The flood fringe is also relatively wide in places along Pincher Creek, due to the wide floodplains. The Kettles Creek flood fringe is generally more confined than Pincher Creek. Areas in the flood fringe include residential areas within the Town of Pincher Creek, the Sleepy Hollow Campground, residences and industrial areas downstream of the Town of Pincher Creek, residential areas on Kettles Creek downstream of the East Avenue Crossing, the industrial area upstream of Macleod Street and residences around the Pincher and Kettles Creek confluence.

SIGNATURE PAGE

KLOHN CRIPPEN BERGER LTD.

PROFESSIONAL ENGINEER ALBERTA
ROBERT CHEETHAM

February 16 2023
APEGA ID: 149178

Rob Cheetham, P.Eng.
Associate, Senior Civil Engineer

PERMIT TO PRACTICE
KLOHN CRIPPEN BERGER LTD.

RM SIGNATURE:

RM APEGA ID #: 48789

DATE: Feb. 16 2023

PERMIT NUMBER: P009196

The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

This is a copy of a digitally authenticated PWP

DISCLAIMER

This report is an instrument of service of Klohn Crippen Berger (KCB). The report has been prepared for the use of Alberta Environment and Parks for the specific application to the Pincher Creek Flood Hazard Study. 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. KCB has prepared this report in a manner consistent with the level of care, skill and diligence ordinarily provided by members of the same profession for projects of a similar nature at the time and place the services were rendered. KCB makes no warranty, express or implied.

REFERENCES

Airborne Imaging. 2020. AEP 8 Sites, LiDAR Acquisition and Processing – 2018, Report on: LiDAR Acquisition and Processing. Prepared for Alberta Environment and Parks.

Alberta Environment. 1980a. *Flood Frequency Analysis, Pincher Creek at Pincher Creek.*

Alberta Environment. 1980b. *Pincher Creek Floodplain Study.* River Engineering Branch.

Alberta Environment. 1993. *Flood Frequency Analyses Pincher Creek Floodplain Study.* Water Resources Management Services Technical Services Division, Hydrology Branch.

Alberta Environment. 2011. *Flood Hazard Identification Program Guidelines*. Water Management Operations, River Forecast Section.

Alberta Environment and Parks. 2019. *Pincher Creek Flood Hazard Study – Terms of Reference.* River Engineering and Technical Services, Watershed Adaption and Resilience.

Alberta Transportation. 2001. *Guidelines on Flood Frequency Analysis*. Transportation and Civil Engineering Division, Civil Projects Branch.

Alberta Transportation. 2004. *Guidelines on Extreme Flood Analysis*. Transportation and Civil Engineering Division, Civil Projects Branch.

Arcement Jr, G. A. and Schneider, V. R., 1989. *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains*, United States Geological Survey Water-supply Paper 2339.

Bobée, B. and Adlouni, S. A. 2008. HYFRAN-PLUS software. Version 2.2.Chow, V.T. 1959. *Open Channel Hydraulics*, University of Illinois, 1959.

Chow, B., Spittlehouse, D., Zwiers, F., Hopkins, K., Radhakrishnan, H., DesLauriers, L., Jakob, M., Hanacek, M. and Whitfield, P. 2017. *Design Flood Hydrology for BC Natural Resources Professionals Event.* Engineers and Geoscientists of British Columbia.

Environment Canada. 1963. *Flood of June 1953 in the South Saskatchewan River Basin.* Water Resources Paper No. 113F. Department of Northern Affairs and National Resources. Water Resources Branch.

Faulkner, D., Warren, S. and Burn, D. 2016. Design Floods for all of Canada. *Canadian Water Resources Journal* 41:3 pp. 398-411.

Grubbs, E. E. and G. Beck. 1972. Extension of Sample Sizes and Percentage Points of Significance Test of Outlying Observations. Technometrics, 14(4): 847-854

Hicks, D.M. and Mason, P.D. 1998. *Roughness Characteristics of New Zealand Rivers*, National Institute for Water and Atmospheric Research, September 1998.

Kellerhals R., C.R Neill and D.I Bray. 1972. *Hydraulic and Geomorphic Characteristics of Rivers in Alberta.* River Engineering and Surface Hydrology Report 72-1. Research Council of Alberta. 1972

Kite, G.W., 1977. Frequency and Risk Analyses in Hydrology. Water Resources Publications, Colorado, United States of America.

Kuklicke, C. and Demeritt, D. 2016. Adaptive and Risk-Based Approaches to Climate Change and the Management of Uncertainty and Institutional Risk: The Case of Future Flooding in England. Global Environmental Change., 37, pp. 56-68.

Klohn Crippen Berger Ltd. 2020. *Pincher Creek Flood Hazard Study, Hydrology Memorandum.* Prepared for Alberta Environment and Parks.

Mann, H.B. and Whitney, D.R. 1947. *On the Test of Whether One of Two Random Variables is Stochastically Larger Than the Other.* An. Math. Stat., 18, pp. 50-60.

National Environment Research Council. 1975. *Flood Studies Report: Volume 1, Hydrological Studies.* Natural Environment Research Council, London, England. National Environment Research Council. 1975. Flood Studies Report: Volume 1, Hydrological Studies. Natural Environment Research Council, London, England.

Philips Planning and Engineering Ltd. (Philips). 1993. *Pincher Creek Flood Risk Mapping Study*. Prepared for Alberta Environmental Protection.

Rood, S.B., S.G. Foster, E.J. Hillman, A. Luek, and K.P. Zanewich. 2016. “Flood Moderation: Declining Peak Flows along Some Rocky Mountain Rivers and the Underlying Mechanism.” *Journal of Hydrology* 526: 174 – 184.

Siegel, S. 1956. *Nonparametric Statistics for the Behavioural Sciences.* McGraw-Hill, New York, United States of America.

Sillmann, J., V. V. Kharin, F. W. Zwiers, X. Zhang, and D. Bronaugh. 2013. *Climate Extremes Indices in the CMIP5 Multi-Model Ensemble. Part 2: Future Projections.* J. Geophys. Res., doi:10.1002/jgrd.50188.

SG1 Water Consulting Ltd. (SG1), 2019a. *Pincher Creek Flood Hazard Study – Survey Plan (Final).* Technical report prepared for Alberta Environment and Parks, dated June 5, 2019. SG1 project no. 10139. 25 pp.

SG1, 2019b. *Pincher Creek Flood Hazard Study – Flood Control Structures Memorandum.* Letter report prepared for Alberta Environment and Parks, dated June 14, 2019. SG1 project no. 10139, 9 pp.

Terry, M.E. 1952. *Some Rank Order Test which are Most Powerful Against Specific Parametric Alternatives.* Annals of mathematical Statistics 23, 346-366.

The City of Calgary. 2014. *Data and Frequency Analysis Spreadsheet for the City of Calgary*.

U.S. Army Corps of Engineers. 2016. *HEC-RAS River Analysis System Version 5.0.3: User’s Manual and Hydraulic Reference Manual*.

US Army Corps of Engineers. 2019. *HEC-RAS. Version 5.0.7.*

US Army Corps of Engineers. 2016. *HEC-RAS River Analysis System, Hydraulic Reference Manual, Version 5.0*.

US Geological Survey. 1982. *Guidelines for Determining Flood Flow Frequency*. Bulletin #17B of the Hydrology Subcommittee. Interagency Advisory Committee on Water Data. US Department of the Interior.

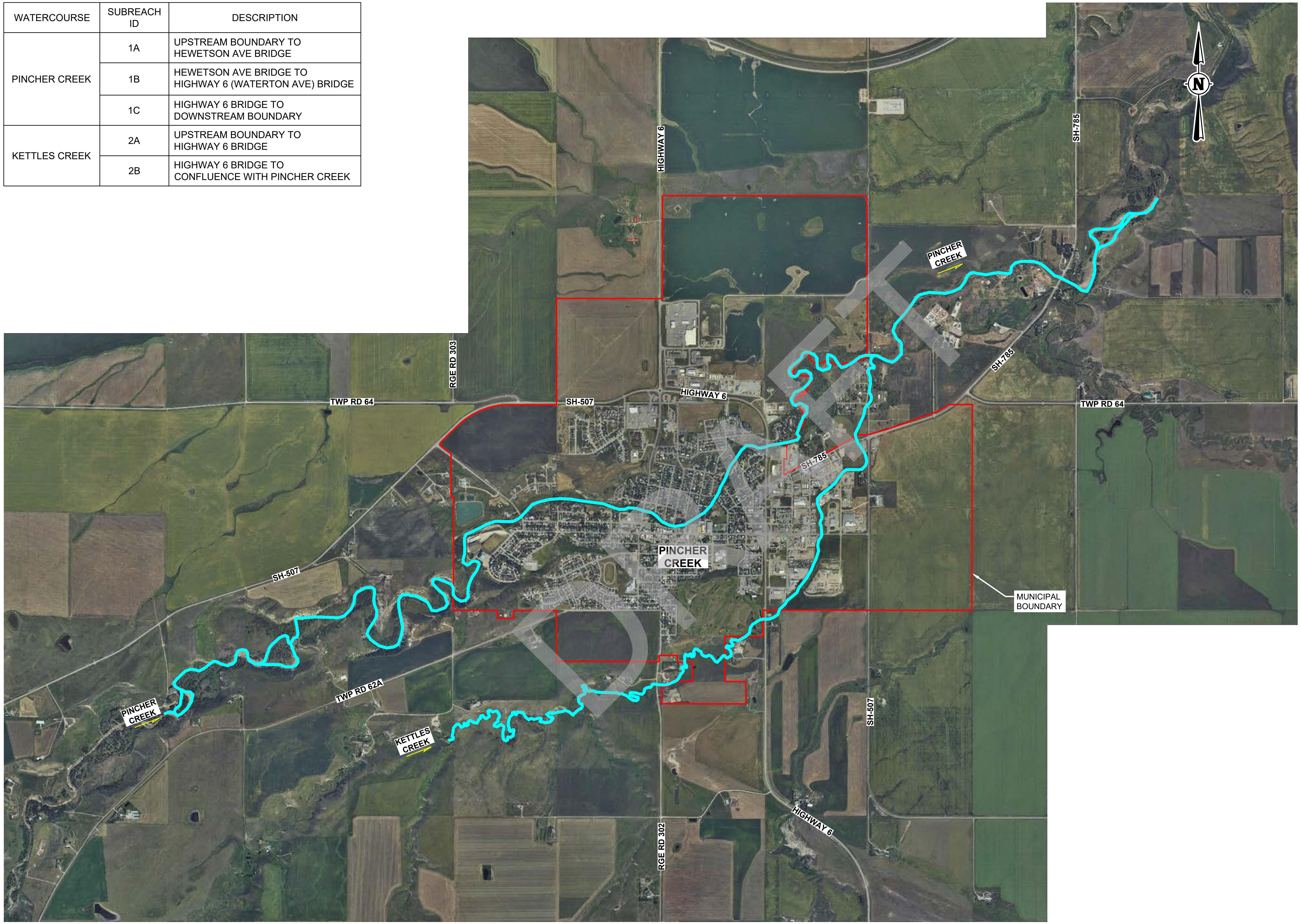
US Geological Survey. 2019. *Guidelines for Determining Flood Flow Frequency Bulletin #17C*. Chapter 5 of Section B, Surface Water Book 4, Hydrologic Analysis and Interpretation. US Department of the Interior.

Wald, A. and Wolfowitz, J. 1943. An Exact Test for Randomness in the Non-Parametric Case Based on Serial Correlation. An. Math. Stat., 14, pp. 378-388

APPENDIX I

Survey Plans, Profiles and Sections (SG1)

WATERCOURSE	SUBREACH ID	DESCRIPTION
PINCHER CREEK	1A	UPSTREAM BOUNDARY TO HEWETSON AVE BRIDGE
	1B	HEWETSON AVE BRIDGE TO HIGHWAY 6 (WATERTON AVE) BRIDGE
	1C	HIGHWAY 6 BRIDGE TO DOWNSTREAM BOUNDARY
KETTLES CREEK	2A	UPSTREAM BOUNDARY TO HIGHWAY 6 BRIDGE
	2B	HIGHWAY 6 BRIDGE TO CONFLUENCE WITH PINCHER CREEK



PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. THE STUDY AREA IS COMPRISED OF A 14.4 km LONG REACH OF PINCHER CREEK AND A 7.4 km LONG REACH OF KETTLES CREEK WITHIN THE TOWN OF PINCHER CREEK AND THE MUNICIPAL DISTRICT OF PINCHER CREEK NO.9.
3. WATER SURVEY OF CANADA (WSC) HYDROMETRIC STATIONS ARE LOCATED ON PINCHER CREEK NEAR BEV McLACHLIN DRIVE BRIDGE (WSC 05AA004) AND ON KETTLES CREEK AT THE MACLEOD STREET (SH-785) BRIDGE (WSC 05AA033). REFER TO FIGURES B-5 AND B-12 FOR HYDROMETRIC STATION LOCATIONS.

0 m 300 600 900 1200

1 : 30,000

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:

Location Map of Study Area

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-101		FIGURE NO: 1.1
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-101.dwg - 101, PLOT DATE: 18-Mar-2020

Classification: Public

TYPICAL STREAM CROSS SECTION POINT CODES

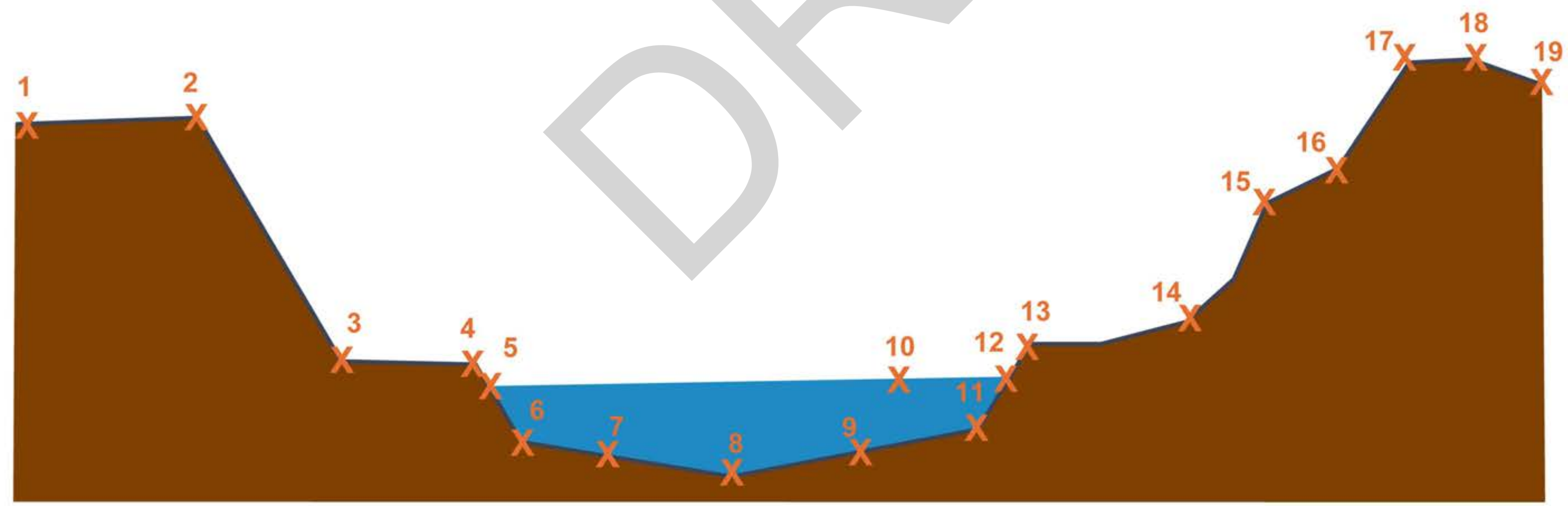
EACH CROSS SECITON WILL TYPICALLY BE SLIGHTLY DIFFERENT, THIS IS INTENDED TO PROVIDE A BRIEF VISUAL AID FOR DRAFTING AND MODELING SPECIALISTS WORKING FROM THE FIELD DATA.

WHEN NON STANDARD FEATURES ARE POSITIONED, PLAIN ENGISH WILL BE USED AS A DESCRIPTOR CODE.

TROUT HYDROGRAPHY

POINT	DESCRIPTION	POINT CODE
1	ORIGINAL GROUND	T_OG
2	TOP OF BERM/SLOPE/DITCH	T_TOP
3	TOE OF BERM/SLOPE/DITCH	T_TOE
4	EDGE OF BANK - TOP	T_EOBP
5	EDGE OF WATER	T_WE
6	EDGE OF BANK - TOE	T_EOBE
7	BOTTOM OF CHANNEL	T_BOTCH
8	CENTERLINE OF CHANNEL	T_CLCH
9	BOTTOM OF CHANNEL	T_BOTCH

POINT	DESCRIPTION	POINT CODE
10	TOP OF WATER	T_WAT
11	EDGE OF BANK - TOE	T_EOBE
12	EDGE OF WATER	T_WE
13	EDGE OF BANK - TOP	T_EOBP
14	TOE OF BERM/SLOPE/DITCH	T_TOE
15	BREAKLINE	T_BL
16	BREAKLINE	T_BL
17	TOP OF BERM/SLOPE/DITCH	T_TOP
18	BREAKLINE	T_BL
19	ORIGINAL GROUND	T_OG



PREPARED BY:
SG1
SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:
Klohn Crippen Berger
Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. THE SCHEMATIC AND SURVEY INFORMATION PROVIDED HEREIN WERE PROVIDED BY TROUT HYDROGRAPHY INC.
2. REFER TO SECTION 2.2 OF THE STUDY REPORT FOR MORE INFORMATION.

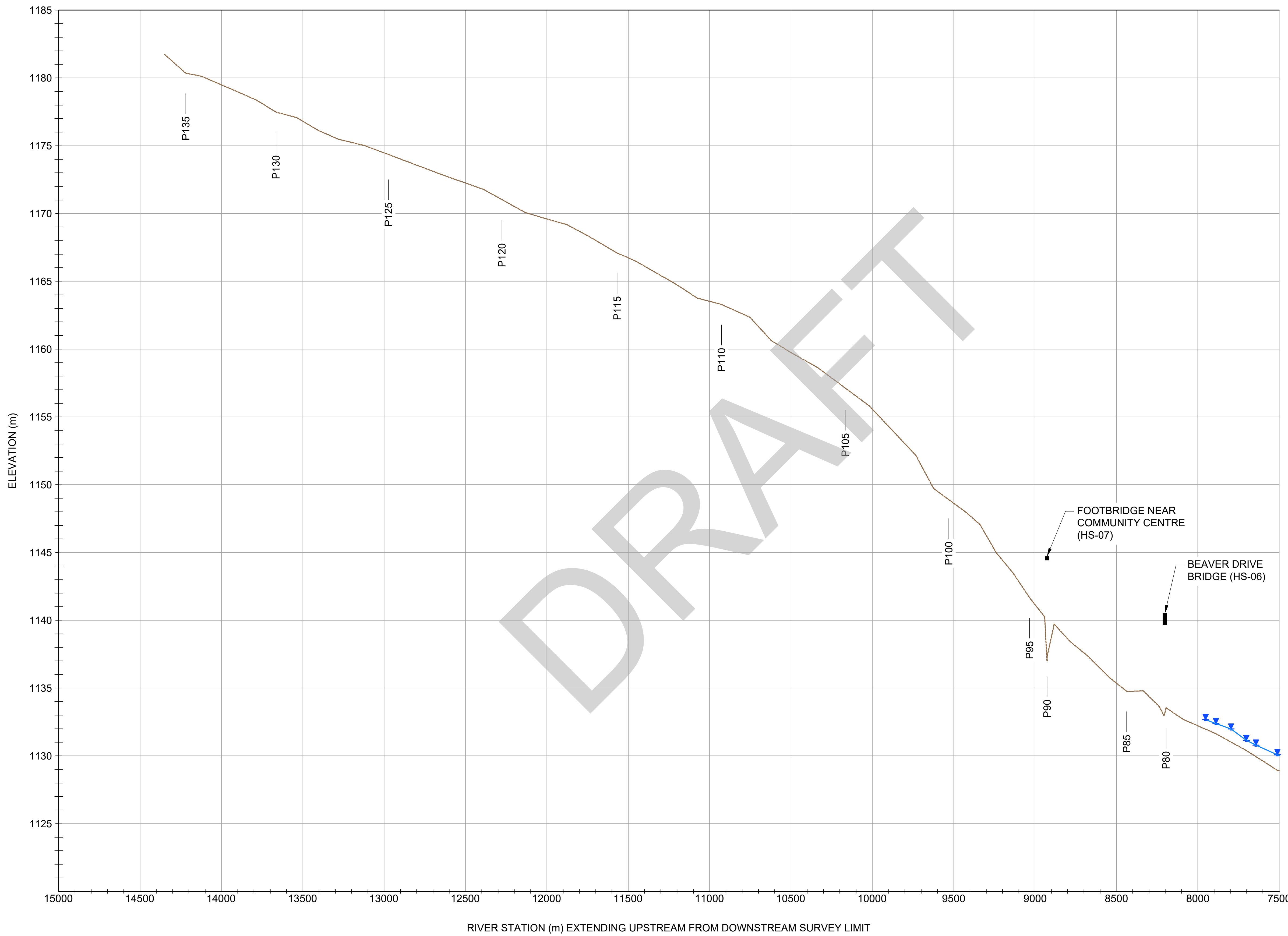
PREPARED FOR:
Alberta Government

PROJECT:
PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:
Schematic of Survey Point Locations and Code Descriptions

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-102		FIGURE NO: 2.1
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-102.dwg - 102, PLOT DATE: 18-Mar-2020



PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. GROUND AND WATER LEVEL DATA ON PINCHER CREEK WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 22-MAY-2019.
2. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
3. CREEK DISCHARGE AT THE TIME OF THE WATER SURFACE PROFILE SURVEY ON 22-MAY-2019 WAS ESTIMATED TO BE 7.1 m^3/s, WHICH IS BASED ON PROVISIONAL FLOW DATA OBTAINED FROM THE WATER SURVEY OF CANADA (WSC). THE HYDROMETRIC GAUGING STATION ON PINCHER CREEK (WSC 05AA004) IS LOCATED APPROXIMATELY 100 m UPSTREAM OF BEV McLACHLIN DRIVE BRIDGE NEAR CROSS SECTION P68.

LEGEND:

SURVEYED THALWEG (MAY 2019)

SURVEYED WATER LEVEL (22-MAY-2019)

0 m 200 400 600 800 1000

1 : 25,000 HORIZONTAL

0 m 3 6 9 12

1:300 VERTICAL

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

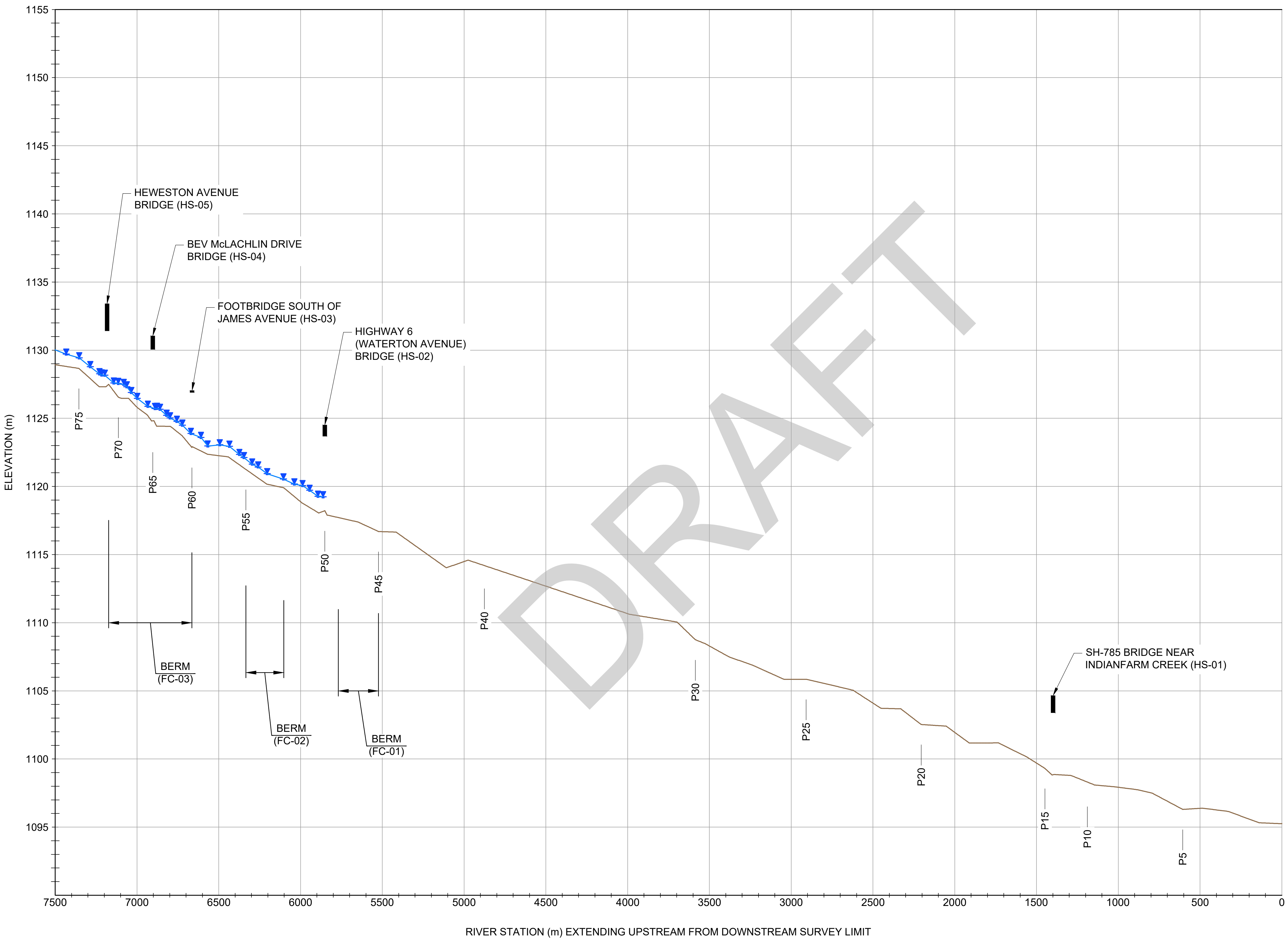
TITLE:

Surveyed Thalweg and Water Surface Profile
Pincher Creek
(Sheet 1 of 2)

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-103-104		FIGURE NO: A-1
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-103-104.dwg - 103, PLOT DATE: 18-Mar-2020

Classification: Public



PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. GROUND AND WATER LEVEL DATA ON PINCHER CREEK WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 22-MAY-2019.
2. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
3. CREEK DISCHARGE AT THE TIME OF THE WATER SURFACE PROFILE SURVEY ON 22-MAY-2019 WAS ESTIMATED TO BE 7.1 m^3/s, WHICH IS BASED ON PROVISIONAL FLOW DATA OBTAINED FROM THE WATER SURVEY OF CANADA (WSC). THE HYDROMETRIC GAUGING STATION ON PINCHER CREEK (WSC 05AA004) IS LOCATED APPROXIMATELY 100 m UPSTREAM OF BEV McLACHLIN DRIVE BRIDGE NEAR CROSS SECTION P68.

LEGEND:

SURVEYED THALWEG (MAY 2019)
SURVEYED WATER LEVEL (22-MAY-2019)

0 m 200 400 600 800 1000
1 : 25,000 HORIZONTAL

0 m 3 6 9 12
1:300 VERTICAL

PREPARED FOR:

Alberta Government

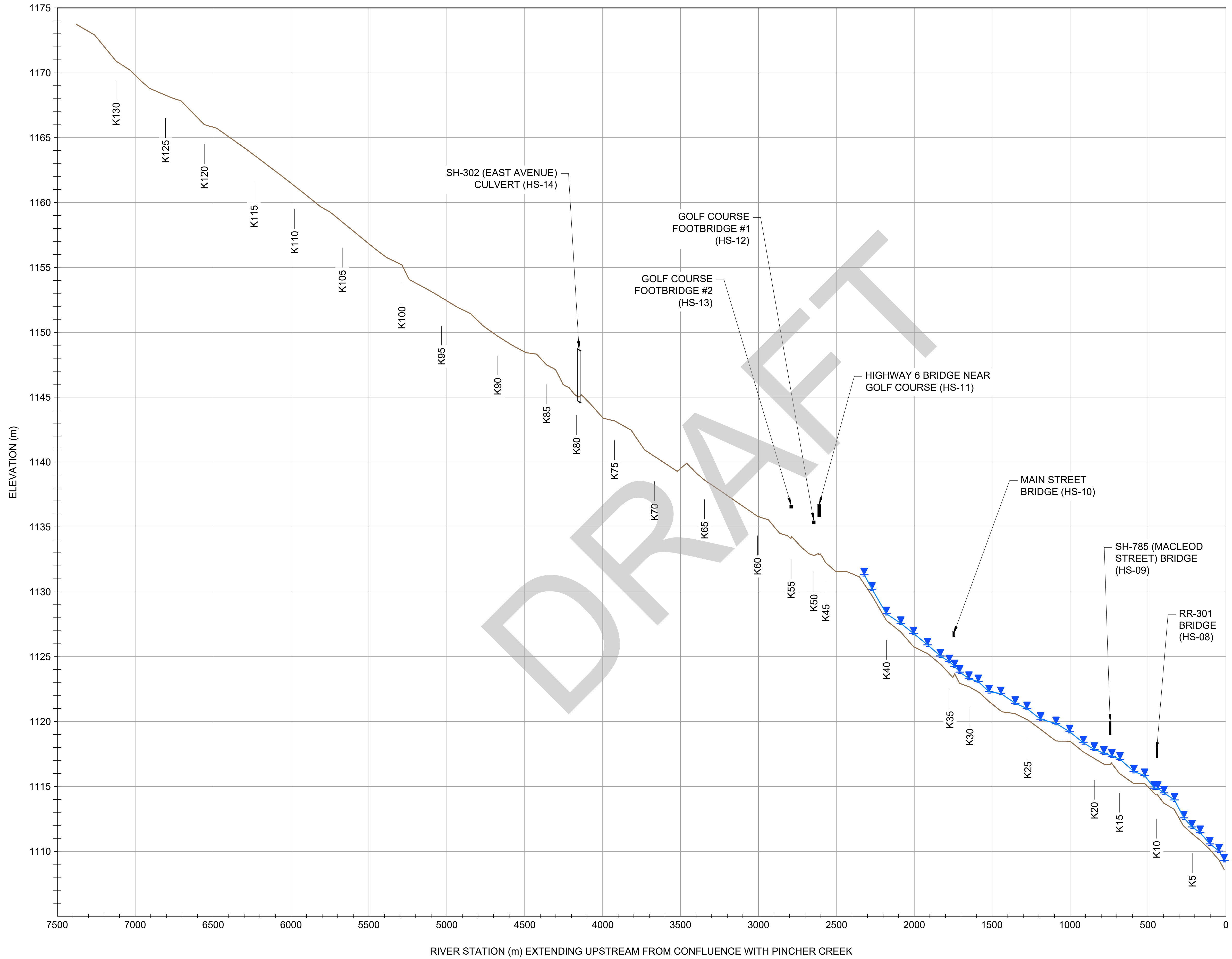
PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:

Surveyed Thalweg and Water Surface Profile
Pincher Creek
(Sheet 2 of 2)

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-103-104		FIGURE NO: A-2
DATE: 18-MAR-2020		



PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. GROUND AND WATER LEVEL DATA ON KETTLES CREEK WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 22-MAY-2019.
2. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
3. CREEK DISCHARGE AT THE TIME OF THE WATER SURFACE PROFILE SURVEY ON 22-MAY-2019 WAS ESTIMATED TO BE 1.2 m^3/s, WHICH IS BASED ON PROVISIONAL FLOW DATA OBTAINED FROM THE WATER SURVEY OF CANADA (WSC). THE HYDROMETRIC GAUGING STATION ON KETTLES CREEK (WSC 05AA033 IS LOCATED ON SH-785 (MACLEOD STREET) BRIDGE AT CROSS SECTION K16.

LEGEND:

SURVEYED THALWEG (MAY 2019)
SURVEYED WATER LEVEL (22-MAY-2019)

0 m 200 400 600 800 1000
1 : 25,000 HORIZONTAL

0 m 3 6 9 12
1:300 VERTICAL

PREPARED FOR:

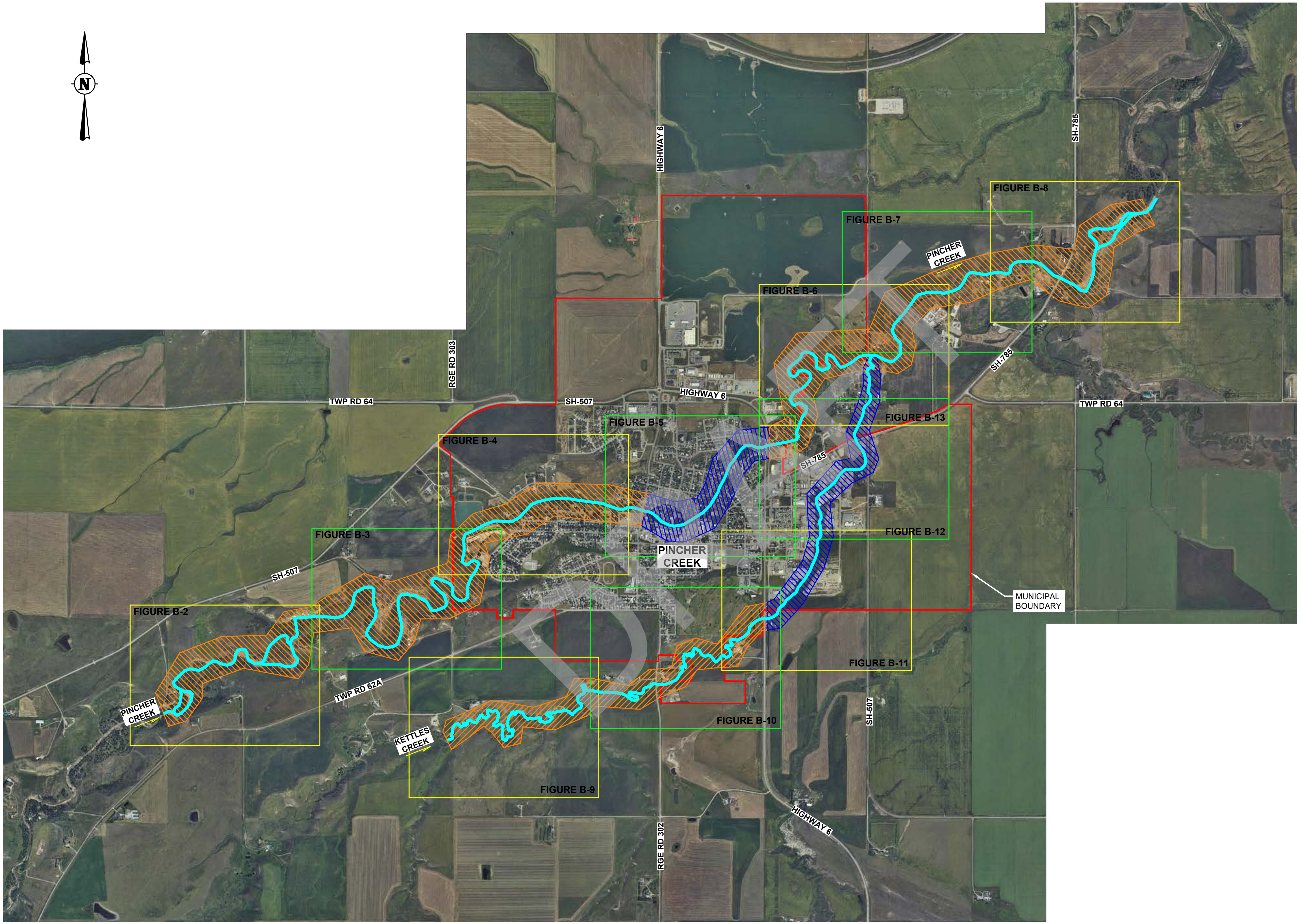
Alberta Government

PROJECT:
PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:
Surveyed Thalweg and Water Surface Profile
Kettles Creek

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-105		FIGURE NO: A-3
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-105.dwg - 105, PLOT DATE: 18-Mar-2020



PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. THE STUDY AREA IS COMPRISED OF A 14.4 km LONG REACH OF PINCHER CREEK AND A 7.4 km LONG REACH OF KETTLES CREEK WITHIN THE TOWN OF PINCHER CREEK AND THE MUNICIPAL DISTRICT OF PINCHER CREEK NO.9.
3. WATER SURVEY OF CANADA (WSC) HYDROMETRIC STATIONS ARE LOCATED ON PINCHER CREEK NEAR BEV McLACHLIN DRIVE BRIDGE (WSC 05AA004) AND ON KETTLES CREEK AT THE MACLEOD STREET (SH-785) BRIDGE (WSC 05AA033). REFER TO FIGURES B-5 AND B-12 FOR HYDROMETRIC STATION LOCATIONS.

0 m 300 600 900 1200

1 : 30,000

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

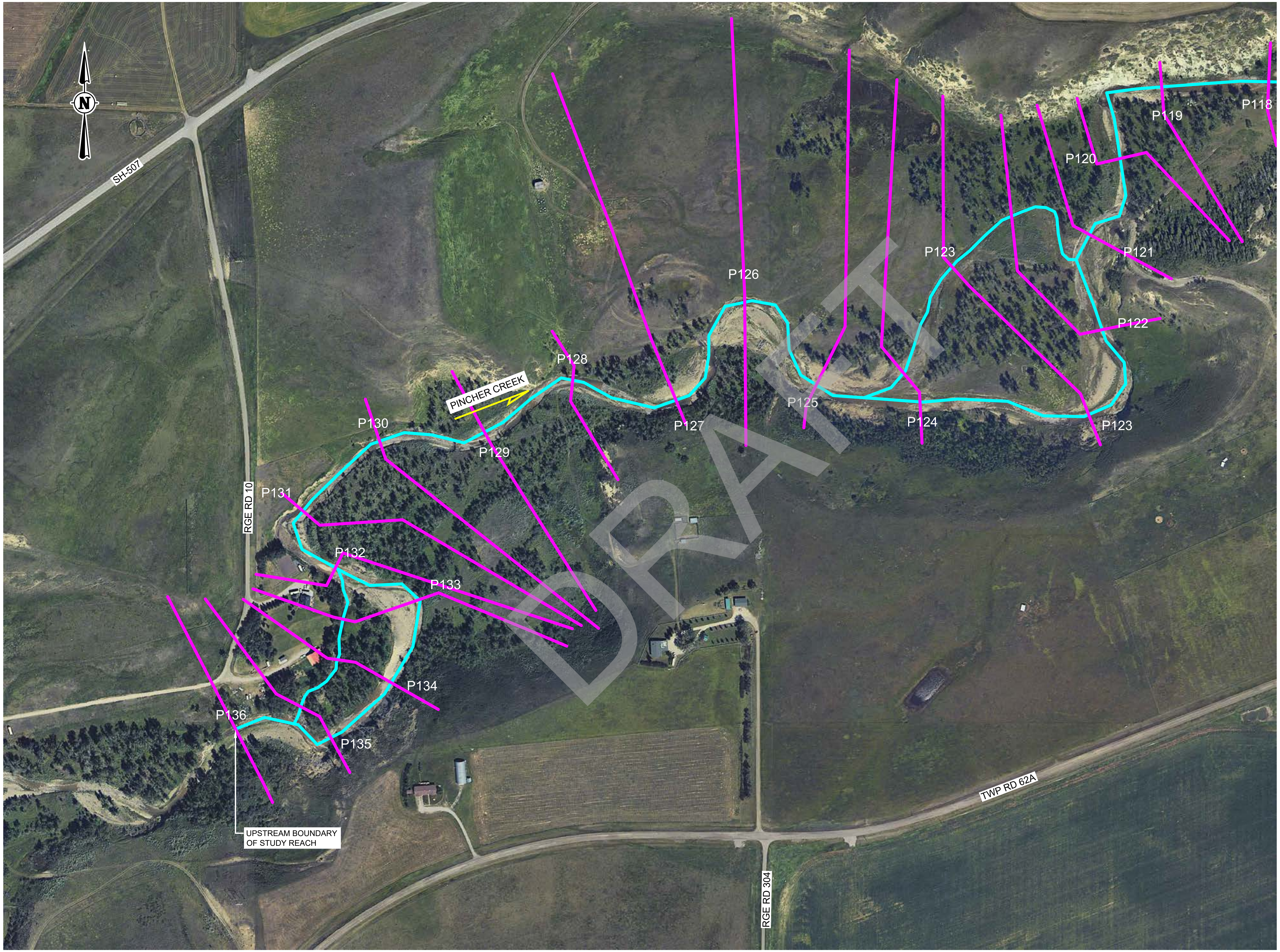
TITLE:

Location Map

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO:	10139-03-106	FIGURE NO: B-1
DATE:	18-MAR-2020	

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-106.dwg - 107, PLOT DATE: 18-Mar-2020

Classification: Public



PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

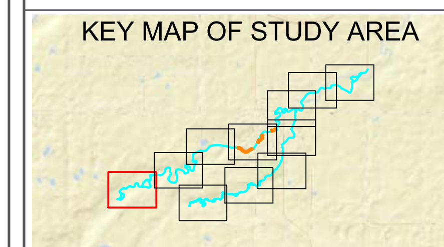
1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.

LEGEND:

CHANNEL CROSS SECTION (AS MODELLED)

HYDRAULIC STRUCTURE (BRIDGE/CULVERT)

KEY MAP OF STUDY AREA



0 m 50 100 150 200

SCALE (AS SHOWN)

PREPARED FOR:

Alberta Government

PROJECT:

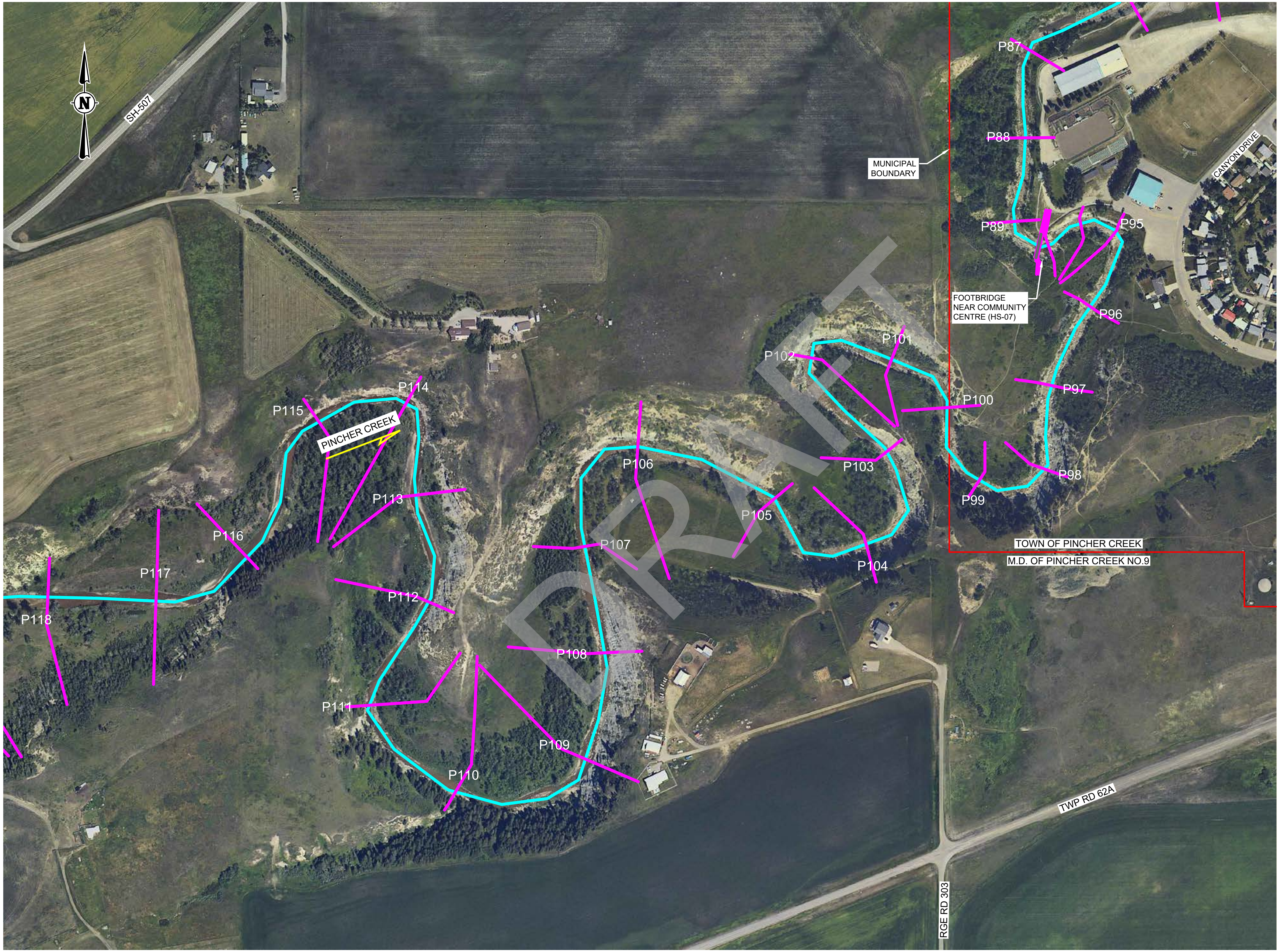
PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:

Cross Section, Hydraulic Structure, and Flood Control Structure Locations
Pincher Creek
(Sheet 1 of 7)

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-107		FIGURE NO: B-2
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-107.dwg - 108, PLOT DATE: 18-Mar-2020



PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

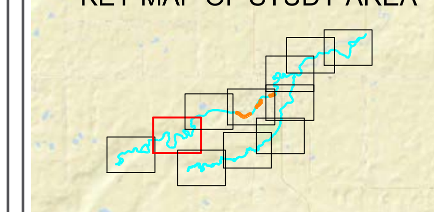
1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.

LEGEND:

CHANNEL CROSS SECTION (AS MODELLED)

HYDRAULIC STRUCTURE (BRIDGE/CULVERT)

KEY MAP OF STUDY AREA



0 m 50 100 150 200

SCALE (AS SHOWN)

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:

Cross Section, Hydraulic Structure, and Flood Control Structure Locations
Pincher Creek
(Sheet 2 of 7)

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO:	10139-03-108	FIGURE NO: B-3
DATE:	18-MAR-2020	

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-108.dwg - 109, PLOT DATE: 18-Mar-2020

Classification: Public

PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.

LEGEND:

- CHANNEL CROSS SECTION (AS MODELLED)
- HYDRAULIC STRUCTURE (BRIDGE/CULVERT)
- SURVEY CONTROL (ASCM)

KEY MAP OF STUDY AREA

0 m 50 100 150 200
SCALE (AS SHOWN)

PREPARED FOR:

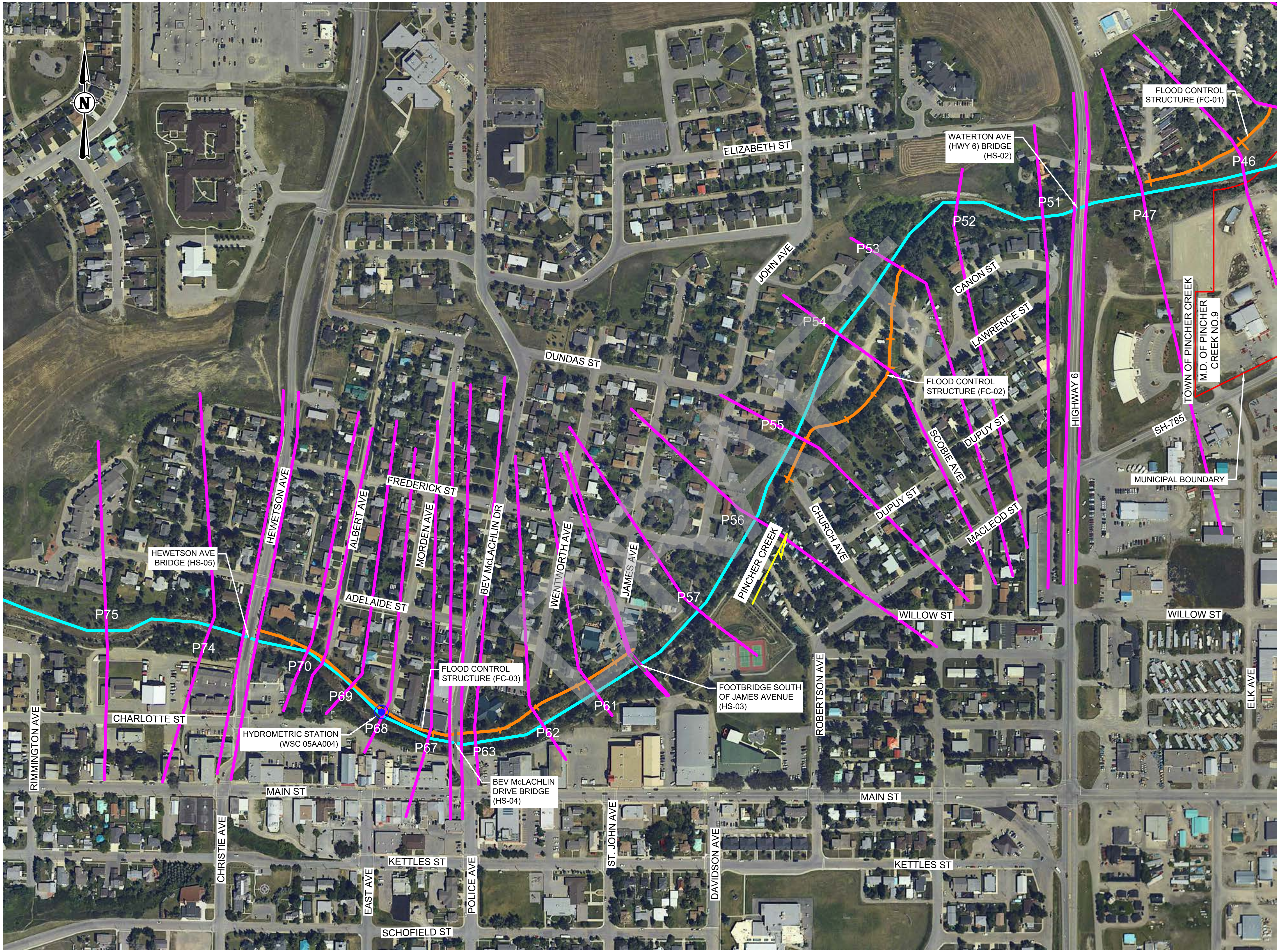
Alberta Government

PROJECT:
PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:
Cross Section, Hydraulic Structure, and Flood Control Structure Locations
Pincher Creek
(Sheet 3 of 7)

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-109		FIGURE NO: B-4
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-109.dwg - 110, PLOT DATE: 18-Mar-2020



PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

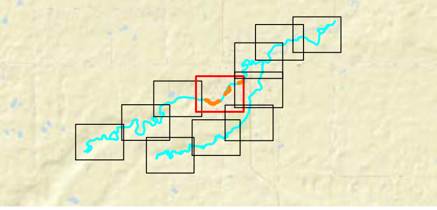
NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.

LEGEND:

- CHANNEL CROSS SECTION (AS MODELLED)
- HYDRAULIC STRUCTURE (BRIDGE/CULVERT)
- FLOOD CONTROL STRUCTURE
- HYDROMETRIC STATION

KEY MAP OF STUDY AREA



0 m 50 100 150 200

SCALE (AS SHOWN)

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

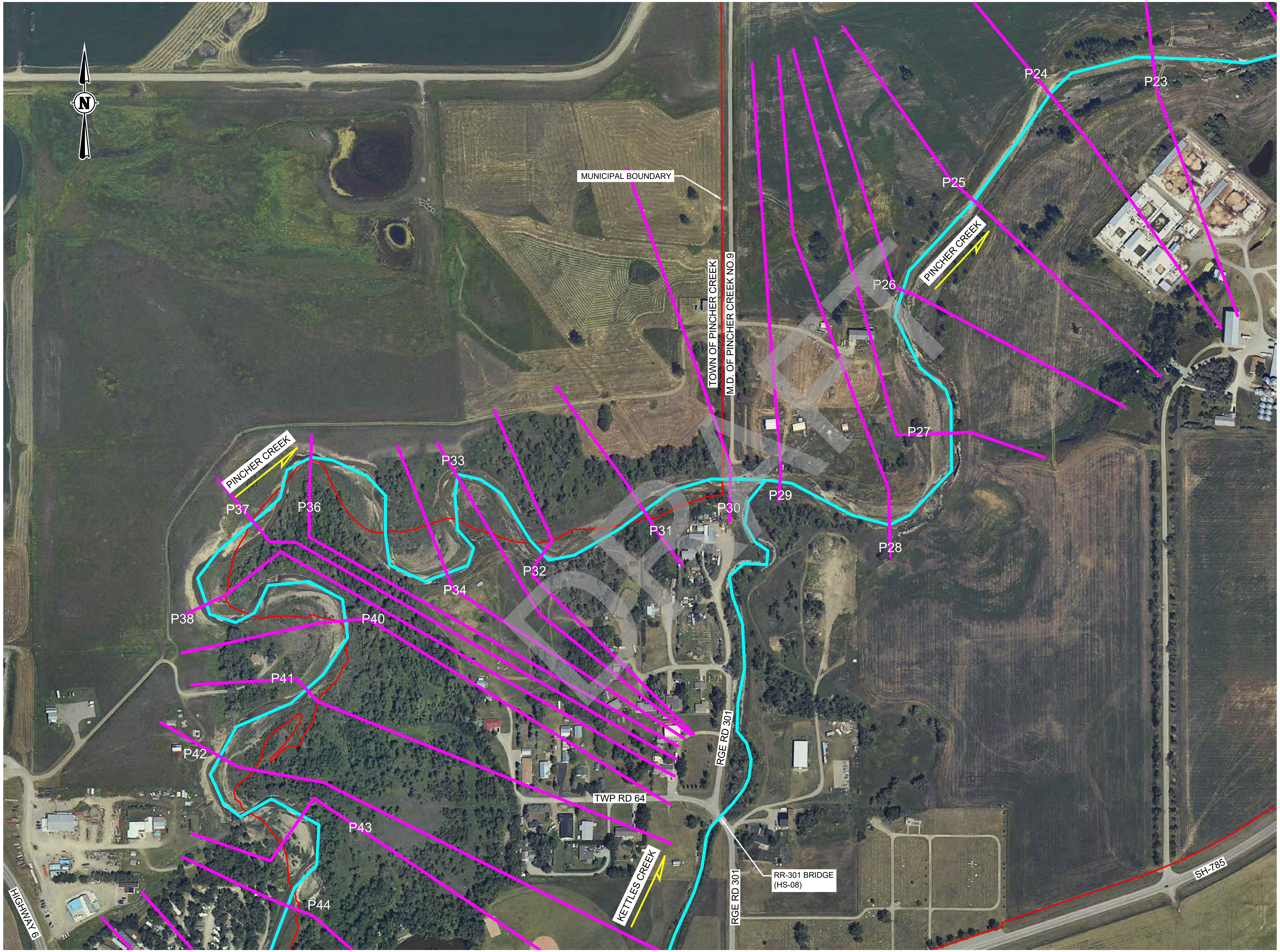
TITLE:

Cross Section, Hydraulic Structure, and Flood Control Structure Locations
Pincher Creek
(Sheet 4 of 7)

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO:	10139-03-110	FIGURE NO: B-5
DATE:	18-MAR-2020	

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-110.dwg - 111, PLOT DATE: 18-Mar-2020

Classification: Public



PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

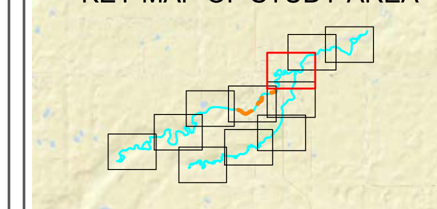
NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.

LEGEND:

- CHANNEL CROSS SECTION (AS MODELLED)
- HYDRAULIC STRUCTURE (BRIDGE/CULVERT)

KEY MAP OF STUDY AREA



0 m 50 100 150 200

SCALE (AS SHOWN)

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:

Cross Section, Hydraulic Structure, and Flood Control Structure Locations
Pincher Creek
(Sheet 5 of 7)

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-111		FIGURE NO: B-6
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-111.dwg - 112, PLOT DATE: 18-Mar-2020

Classification: Public

PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

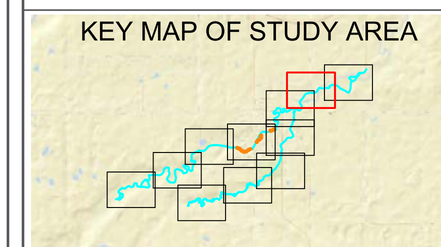
NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.

LEGEND:

CHANNEL CROSS SECTION (AS MODELLED)

KEY MAP OF STUDY AREA



0 m 50 100 150 200

SCALE (AS SHOWN)

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

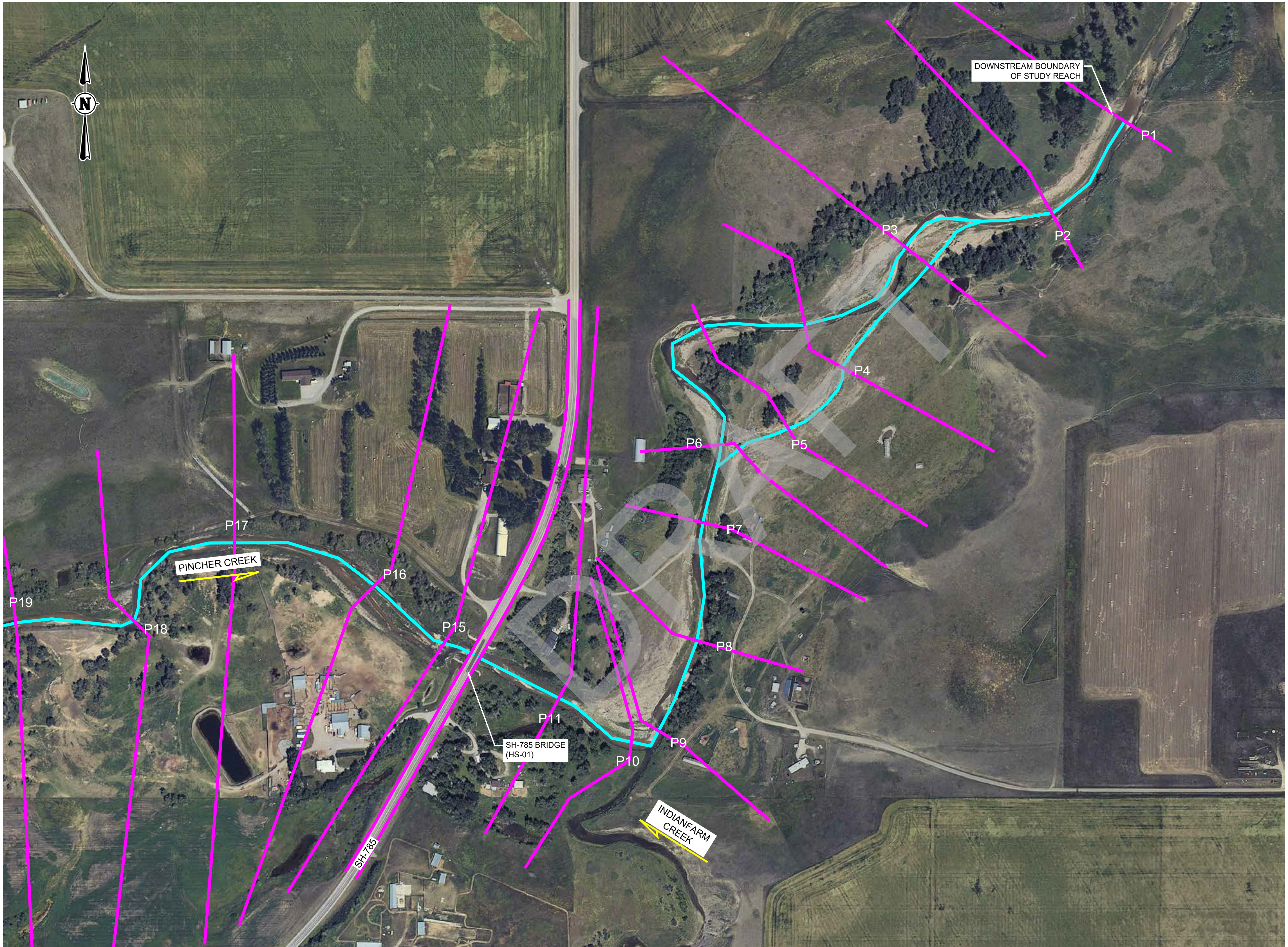
TITLE:

Cross Section, Hydraulic Structure, and Flood Control Structure Locations
Pincher Creek
(Sheet 6 of 7)

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO:	10139-03-112	FIGURE NO: B-7
DATE:	18-MAR-2020	

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-112.dwg - 113, PLOT DATE: 18-Mar-2020

Classification: Public



PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

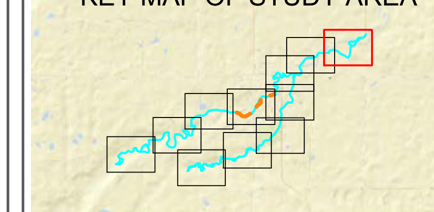
NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.

LEGEND:

- CHANNEL CROSS SECTION (AS MODELLED)
- HYDRAULIC STRUCTURE (BRIDGE/CULVERT)

KEY MAP OF STUDY AREA



0 m 50 100 150 200

SCALE (AS SHOWN)

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:

Cross Section, Hydraulic Structure, and Flood Control Structure Locations
Pincher Creek
(Sheet 7 of 7)

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-113		FIGURE NO: B-8
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-113.dwg - 114, PLOT DATE: 18-Mar-2020

Classification: Public

PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

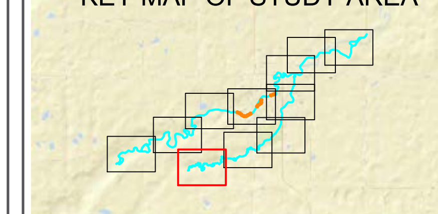
1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.

LEGEND:

CHANNEL CROSS SECTION (AS MODELLED)

SURVEY CONTROL (ASCM)

KEY MAP OF STUDY AREA



0 m 50 100 150 200

SCALE (AS SHOWN)

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

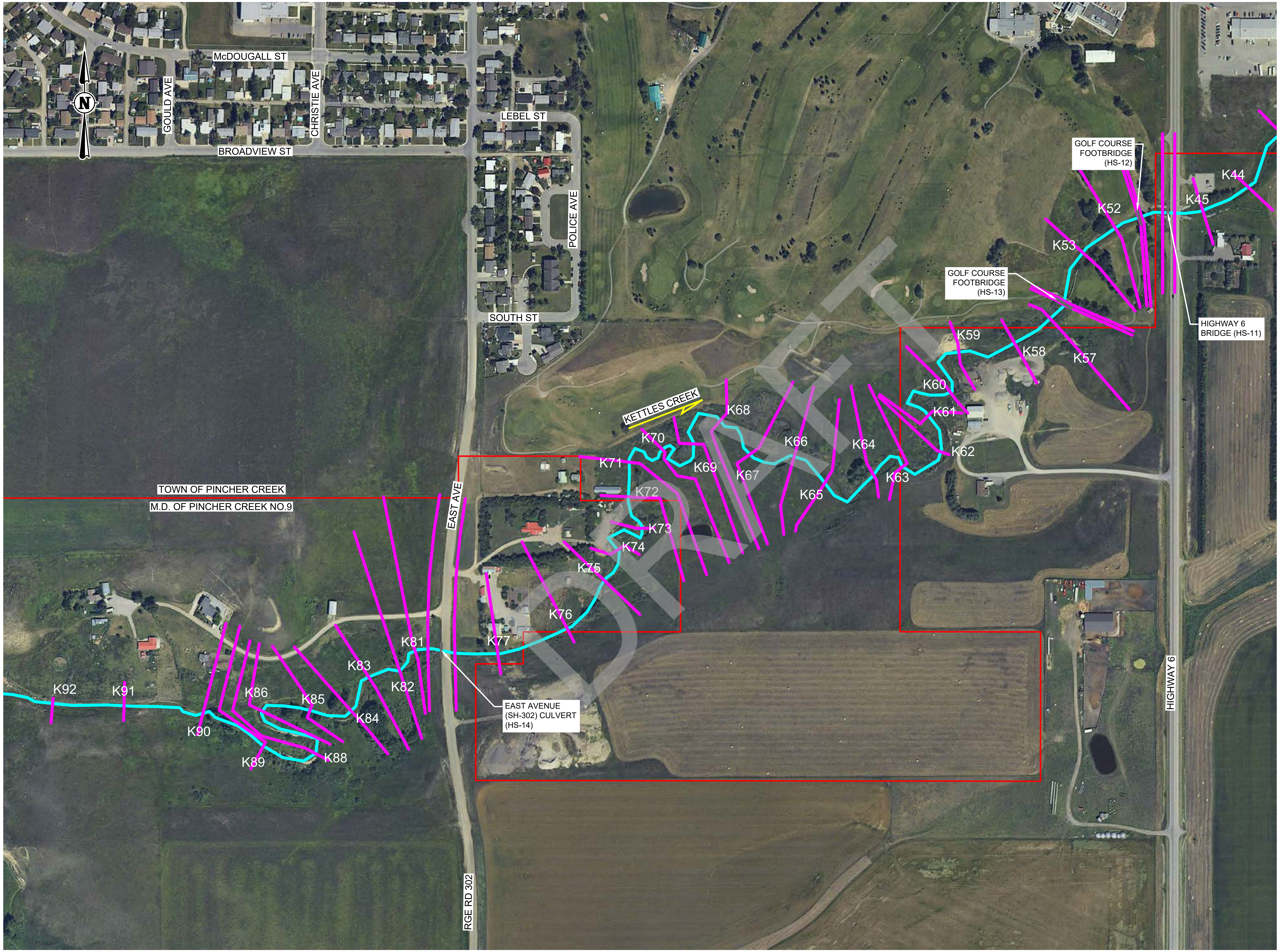
TITLE:

Cross Section, Hydraulic Structure, and Flood Control Structure Locations
Kettles Creek
(Sheet 1 of 5)

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-114		FIGURE NO: B-9
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-114.dwg - 115, PLOT DATE: 18-Mar-2020

Classification: Public



PREPARED BY:

SG1
SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger
Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

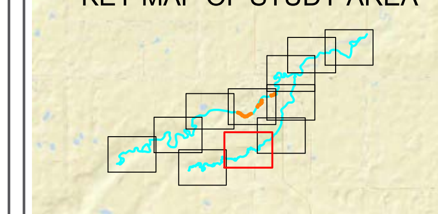
1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.

LEGEND:

CHANNEL CROSS SECTION (AS MODELLED)

HYDRAULIC STRUCTURE (BRIDGE/CULVERT)

KEY MAP OF STUDY AREA



0 m 50 100 150 200

SCALE (AS SHOWN)

PREPARED FOR:

Alberta Government

PROJECT:

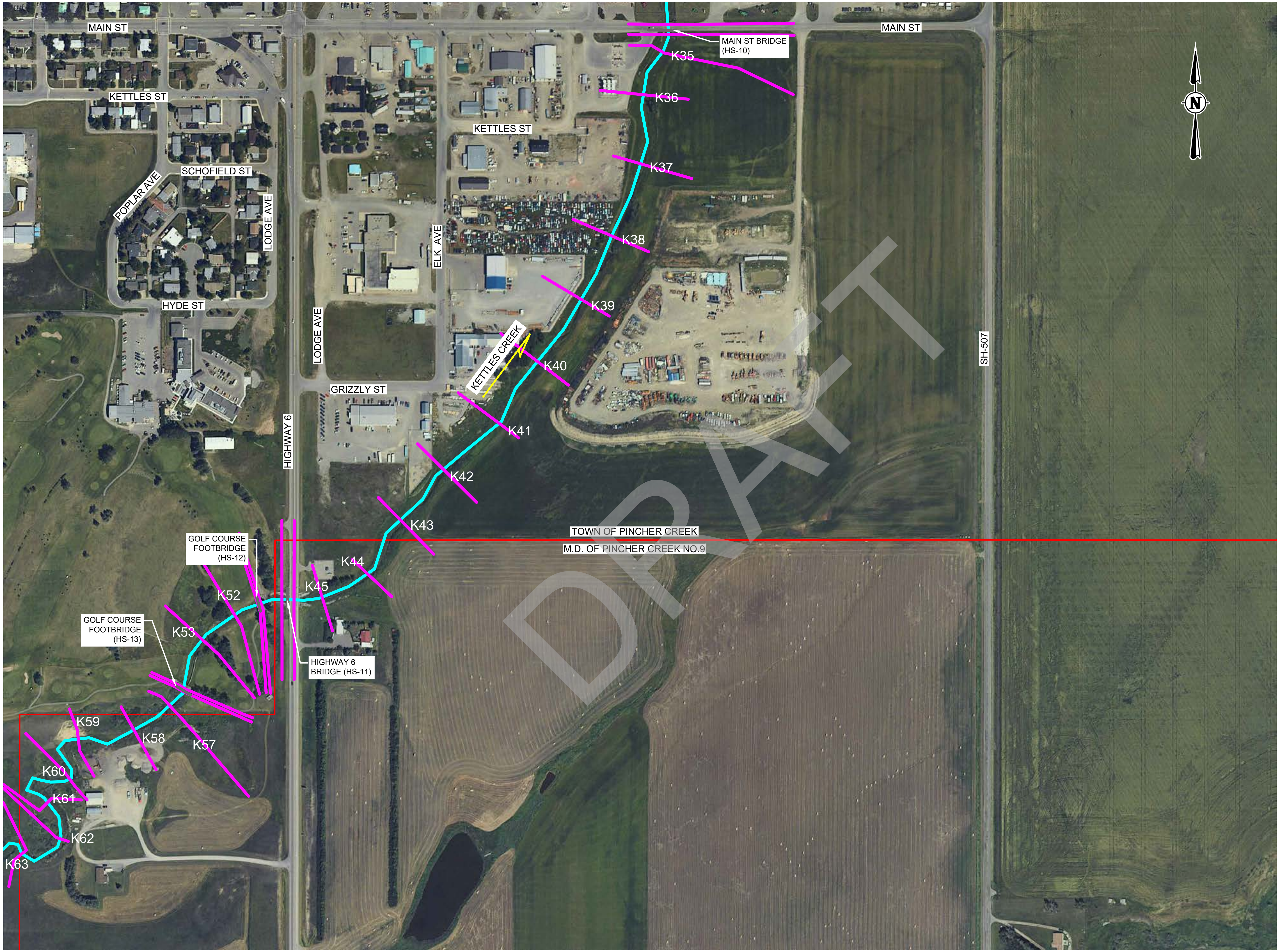
PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:

Cross Section, Hydraulic Structure, and Flood Control Structure Locations
Kettles Creek
(Sheet 2 of 5)

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-115		FIGURE NO: B-10
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-115.dwg - 116, PLOT DATE: 18-Mar-2020



PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

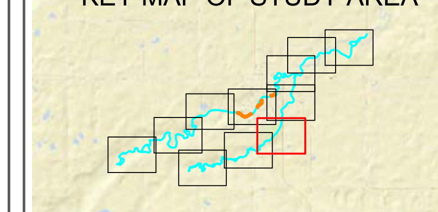
NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.

LEGEND:

CHANNEL CROSS SECTION (AS MODELLED)
HYDRAULIC STRUCTURE (BRIDGE/CULVERT)

KEY MAP OF STUDY AREA



0 m 50 100 150 200
SCALE (AS SHOWN)

PREPARED FOR:

Alberta Government

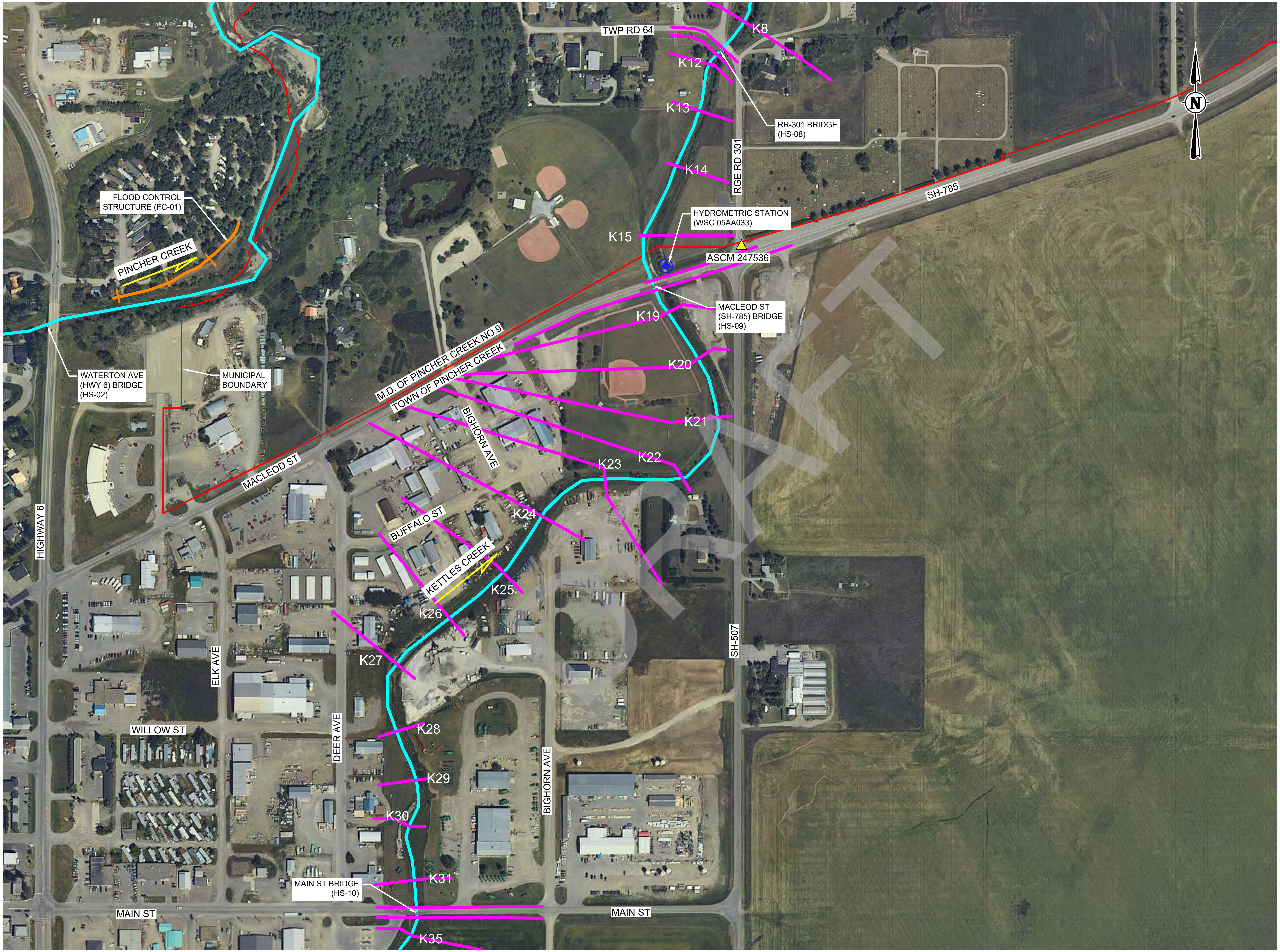
PROJECT:
PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:
Cross Section, Hydraulic Structure, and Flood Control Structure Locations
Kettles Creek
(Sheet 3 of 5)

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO:	10139-03-116	FIGURE NO: B-11
DATE:	18-MAR-2020	

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-116.dwg - 117, PLOT DATE: 18-Mar-2020

Classification: Public



PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

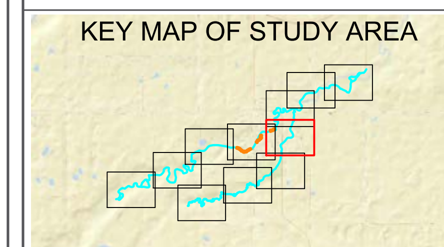
NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.

LEGEND:

- CHANNEL CROSS SECTION (AS MODELLED)
- HYDRAULIC STRUCTURE (BRIDGE/CULVERT)
- FLOOD CONTROL STRUCTURE
- HYDROMETRIC STATION
- SURVEY CONTROL (ASCM)

KEY MAP OF STUDY AREA



0 m 50 100 150 200

SCALE (AS SHOWN)

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

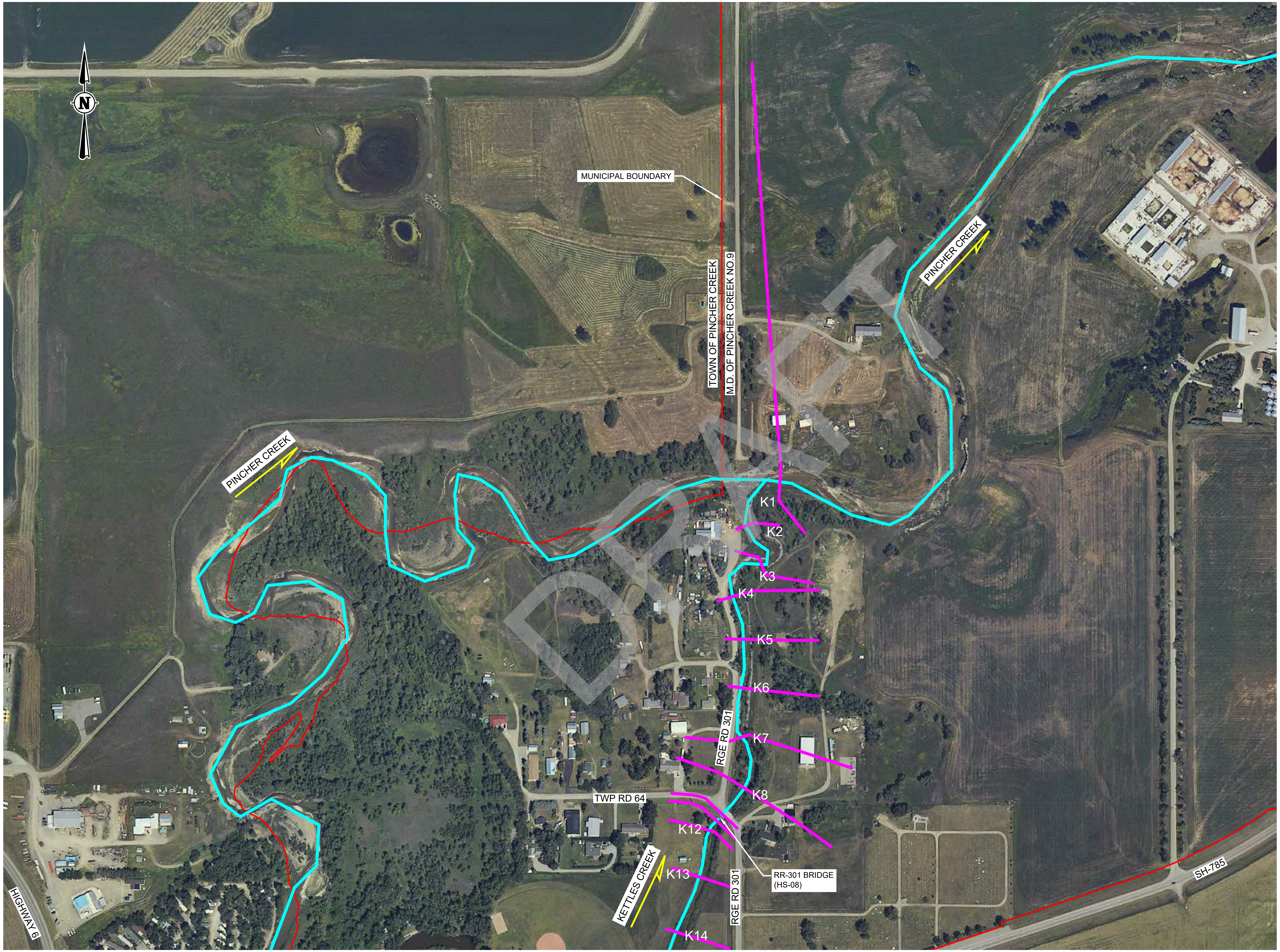
TITLE:

Cross Section, Hydraulic Structure, and Flood Control Structure Locations
Kettles Creek
(Sheet 4 of 5)

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-117		FIGURE NO: B-12
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-117.dwg - 118, PLOT DATE: 18-Mar-2020

Classification: Public



PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

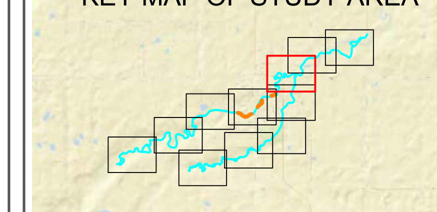
NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.

LEGEND:

CHANNEL CROSS SECTION (AS MODELLED)
HYDRAULIC STRUCTURE (BRIDGE/CULVERT)

KEY MAP OF STUDY AREA



0 m 50 100 150 200

SCALE (AS SHOWN)

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:

Cross Section, Hydraulic Structure, and Flood Control Structure Locations
Kettles Creek
(Sheet 5 of 5)

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO:	10139-03-118	FIGURE NO: B-13
DATE:	18-MAR-2020	

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-118.dwg - 119, PLOT DATE: 18-Mar-2020

Classification: Public

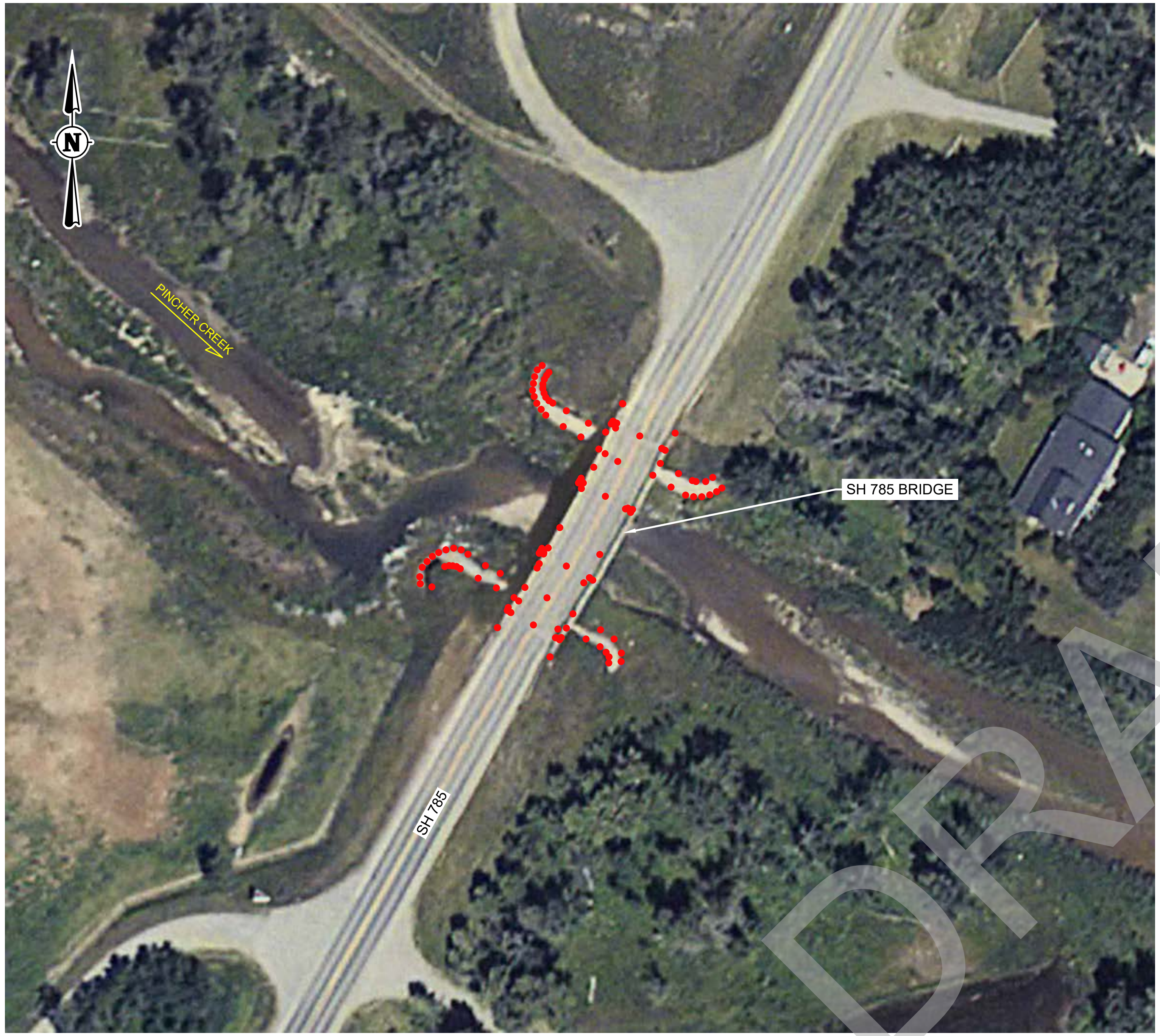


IMAGE REF: DSCN0051

1. View looking downstream from the island in the middle of the creek.

IMAGE REF: 10139-SR.177

2. View looking upstream from right bank.

WATERBODY	STRUCTURE NAME / LOCATION	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	YEAR CONSTRUCTED	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE LOW CHORD ELEVATION (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	LOW CHORD ELEVATION (m)		TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)		NUMBER OF SPANS	NUMBER OF PIERS	PIER DETAILS[(1)]			
										LEFT ABUTMENT	RIGHT ABUTMENT	LEFT ABUTMENT	RIGHT ABUTMENT			#	CENTRE STATION (m)	WIDTH (m)	DESCRIPTION
PINCHER CREEK	SH-785 BRIDGE NEAR INDIANFARM CREEK	13700	ALBERTA TRANSPORTATION	TRAFFIC	1988	36.77	10.66	1103.41	1104.67	1103.41	1103.41	1104.65	1104.69	3	2	1	11.4	0.94	CONCRETE PIER CAP SET ATOP CIRCULAR ARRAY (FOUR STEEL COLUMNS)
																2	25.4	0.94	

(1) Pier stationing is with respect to the centreline of the left abutment, viewed looking downstream (i.e., left abutment corresponds to station zero).

PREPARED BY:

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger
Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. TOPOGRAPHIC SURVEY DATA WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 20-MAY-2019.
3. DETAILS OF THE BRIDGE SURVEY WERE USED FOR HYDRAULIC MODELLING. PIER CENTRE STATIONS, AS SHOWN TABLE BELOW, ARE WITH RESPECT TO VALUES USED IN THE NUMERICAL MODEL.
4. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
5. REFER TO SECTION 2.5 OF THE STUDY REPORT AND THE HYDRAULIC (HEC-RAS) MODEL FOR MORE INFORMATION.
6. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

● SURVEY DATA POINT

0 m 10 20 30 40

1 : 1000

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:

Hydraulic Structure Datasheet (HS-01)
Traffic Bridge on Pincher Creek
SH-785 Bridge near Indianfarm Creek

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-119		FIGURE NO: C-1
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-119.dwg - 120, PLOT DATE: 18-Mar-2020

Classification: Public

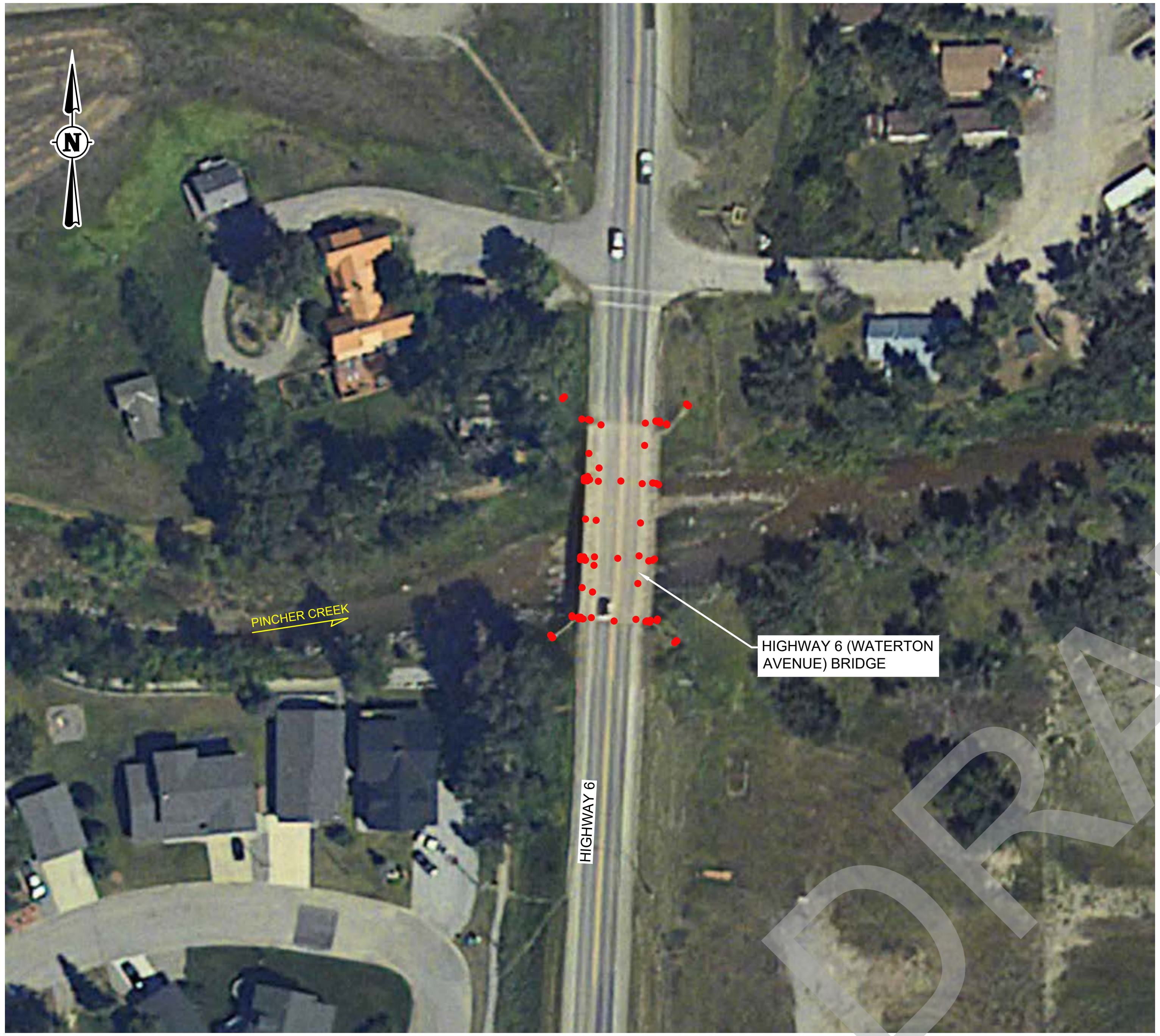


IMAGE REF: 10139-SR.134

1. View looking downstream from right bank.

IMAGE REF: DSCN0070

2. View looking upstream from the right side of the channel.

WATERBODY	STRUCTURE NAME / LOCATION	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	YEAR CONSTRUCTED	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE LOW CHORD ELEVATION (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	LOW CHORD ELEVATION (m)		TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)		NUMBER OF SPANS	NUMBER OF PIERS	PIER DETAILS(1)			
										LEFT ABUTMENT	RIGHT ABUTMENT	LEFT ABUTMENT	RIGHT ABUTMENT			#	CENTRE STATION (m)	WIDTH (m)	DESCRIPTION
PINCHER CREEK	HIGHWAY 6 (WATERTON AVENUE) BRIDGE	73636	ALBERTA TRANSPORTATION	TRAFFIC	1960	34.46	12.18	1123.69	1124.50	1123.76	1123.64	1124.37	1124.62	3	2	1	10.7	0.62	SOLID CONCRETE WALL WITH RECTANGULAR (FLAT) NOSE AND TAIL
																2	23.9	0.62	

(1) Pier stationing is with respect to the centreline of the left abutment, viewed looking downstream (i.e., left abutment corresponds to station zero).

PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. TOPOGRAPHIC SURVEY DATA WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 19-MAY-2019.
3. DETAILS OF THE BRIDGE SURVEY WERE USED FOR HYDRAULIC MODELLING. PIER CENTRE STATIONS, AS SHOWN TABLE BELOW, ARE WITH RESPECT TO VALUES USED IN THE NUMERICAL MODEL.
4. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
5. REFER TO SECTION 2.5 OF THE STUDY REPORT AND THE HYDRAULIC (HEC-RAS) MODEL FOR MORE INFORMATION.
6. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

● SURVEY DATA POINT

0 m 10 20 30 40

1 : 1000

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:

Hydraulic Structure Datasheet (HS-02)
Traffic Bridge on Pincher Creek
Highway 6 (Waterton Avenue) Bridge

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-120		FIGURE NO: C-2
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-120.dwg - 121, PLOT DATE: 18-Mar-2020

IMAGE REF: 10139-SR.115

1. View looking downstream from right bank.

IMAGE REF: 10139-SR.122

2. View looking upstream from left bank.

WATERBODY	STRUCTURE NAME / LOCATION	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	YEAR CONSTRUCTED	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE LOW CHORD ELEVATION (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	LOW CHORD ELEVATION (m)		TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)		NUMBER OF SPANS	NUMBER OF PIERS	PIER DETAILS[1]			
										LEFT ABUTMENT	RIGHT ABUTMENT	LEFT ABUTMENT	RIGHT ABUTMENT			#	CENTRE STATION (m)	WIDTH (m)	DESCRIPTION
PINCHER CREEK	FOOTBRIDGE SOUTH OF JAMES AVENUE	N/A	N/A	PEDESTRIAN	N/A	17.72	1.25	1126.89	1127.04	1126.61	1126.61	1126.78	1126.76	1	0	-	-	-	-

(1) Pier stationing is with respect to the centreline of the left abutment, viewed looking downstream (i.e., left abutment corresponds to station zero).

PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. TOPOGRAPHIC SURVEY DATA WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 19-MAY-2019.
3. DETAILS OF THE BRIDGE SURVEY WERE USED FOR HYDRAULIC MODELLING. PIER CENTRE STATIONS, AS SHOWN TABLE BELOW, ARE WITH RESPECT TO VALUES USED IN THE NUMERICAL MODEL.
4. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
5. REFER TO SECTION 2.5 OF THE STUDY REPORT AND THE HYDRAULIC (HEC-RAS) MODEL FOR MORE INFORMATION.
6. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

● SURVEY DATA POINT

0 m 10 20 30 40

1 : 1000

PREPARED FOR:

Alberta Government

PROJECT:
PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:
Hydraulic Structure Datasheet (HS-03)
Pedestrian Bridge on Pincher Creek
Footbridge South of James Avenue

DWN BY:	RDJ	CHK'D BY:	DMS	REV NO:	1
DWG NO:	10139-03-121			FIGURE NO:	C-3
DATE:	18-MAR-2020				

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-121.dwg - 122, PLOT DATE: 18-Mar-2020

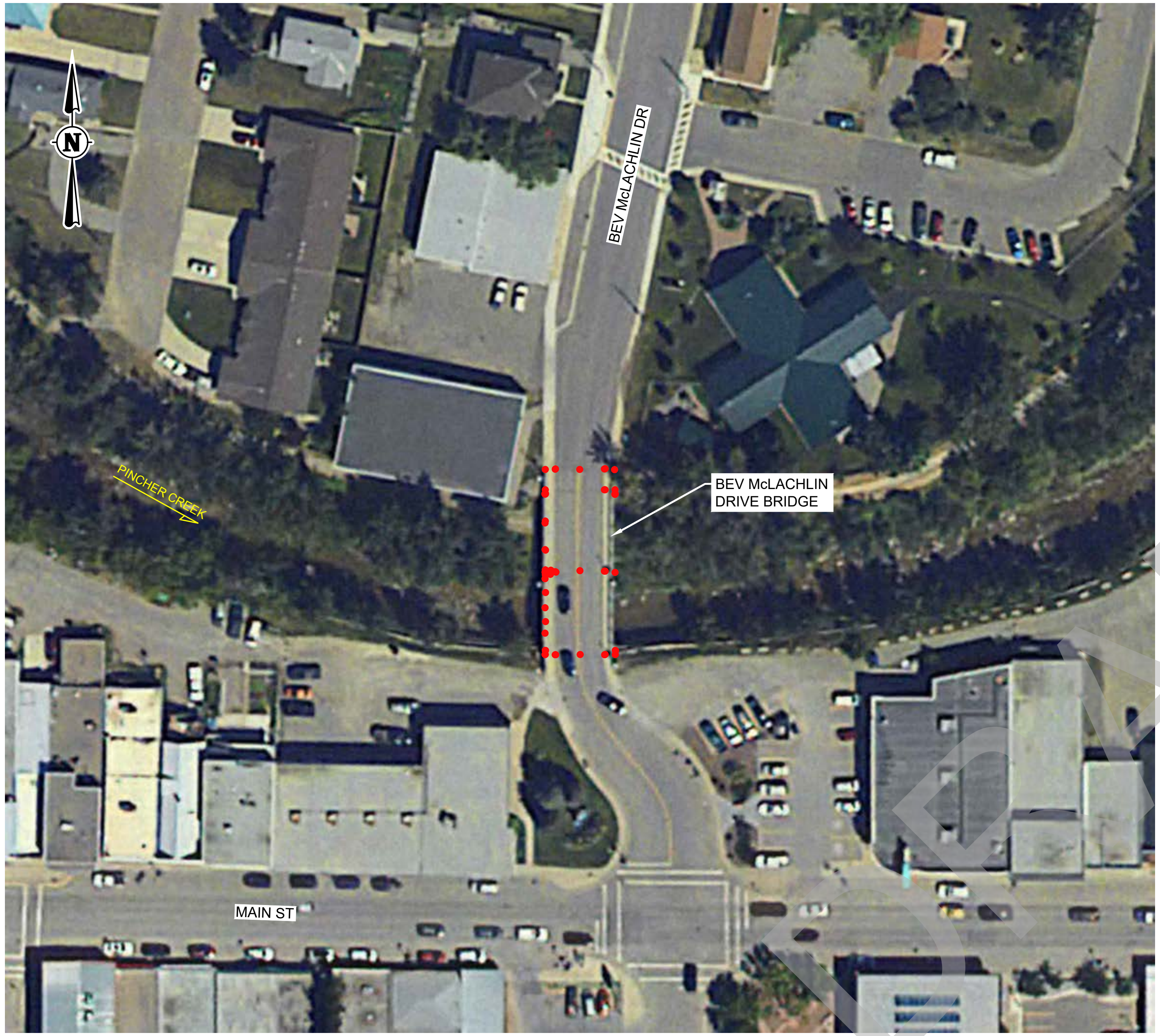


IMAGE REF: DSCN0059

1. View looking downstream from the top of the right bank revetment.

IMAGE REF: DSCN0064

2. View looking obliquely upstream across the creek from the top of the right bank revetment.

WATERBODY	STRUCTURE NAME / LOCATION	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	YEAR CONSTRUCTED	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE LOW CHORD ELEVATION (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	LOW CHORD ELEVATION (m)		TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)		NUMBER OF SPANS	NUMBER OF PIERS	PIER DETAILS[1]			
										LEFT ABUTMENT	RIGHT ABUTMENT	LEFT ABUTMENT	RIGHT ABUTMENT			#	CENTRE STATION (m)	WIDTH (m)	DESCRIPTION
PINCHER CREEK	BEV McLACHLIN DRIVE BRIDGE	01536	ALBERTA TRANSPORTATION	TRAFFIC	1995	28.08	12.24	1130.06	1131.05	1129.94	1130.19	1130.90	1131.19	2	1	1	13.6	0.73	CONCRETE PIER CAP SET ATOP CIRCULAR ARRAY (SIX STEEL COLUMNS)

(1) Pier stationing is with respect to the centreline of the left abutment, viewed looking downstream (i.e., left abutment corresponds to station zero).

PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. TOPOGRAPHIC SURVEY DATA WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 19-MAY-2019.
3. DETAILS OF THE BRIDGE SURVEY WERE USED FOR HYDRAULIC MODELLING. PIER CENTRE STATIONS, AS SHOWN TABLE BELOW, ARE WITH RESPECT TO VALUES USED IN THE NUMERICAL MODEL.
4. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
5. REFER TO SECTION 2.5 OF THE STUDY REPORT AND THE HYDRAULIC (HEC-RAS) MODEL FOR MORE INFORMATION.
6. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

● SURVEY DATA POINT

0 m 10 20 30 40

1 : 1000

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:

Hydraulic Structure Datasheet (HS-04)
Traffic Bridge on Pincher Creek
Bev McLachlin Drive Bridge

DWN BY:	RDJ	CHK'D BY:	DMS	REV NO:	1
DWG NO:	10139-03-122			FIGURE NO:	C-4
DATE:	18-MAR-2020				

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-122.dwg - 123, PLOT DATE: 18-Mar-2020

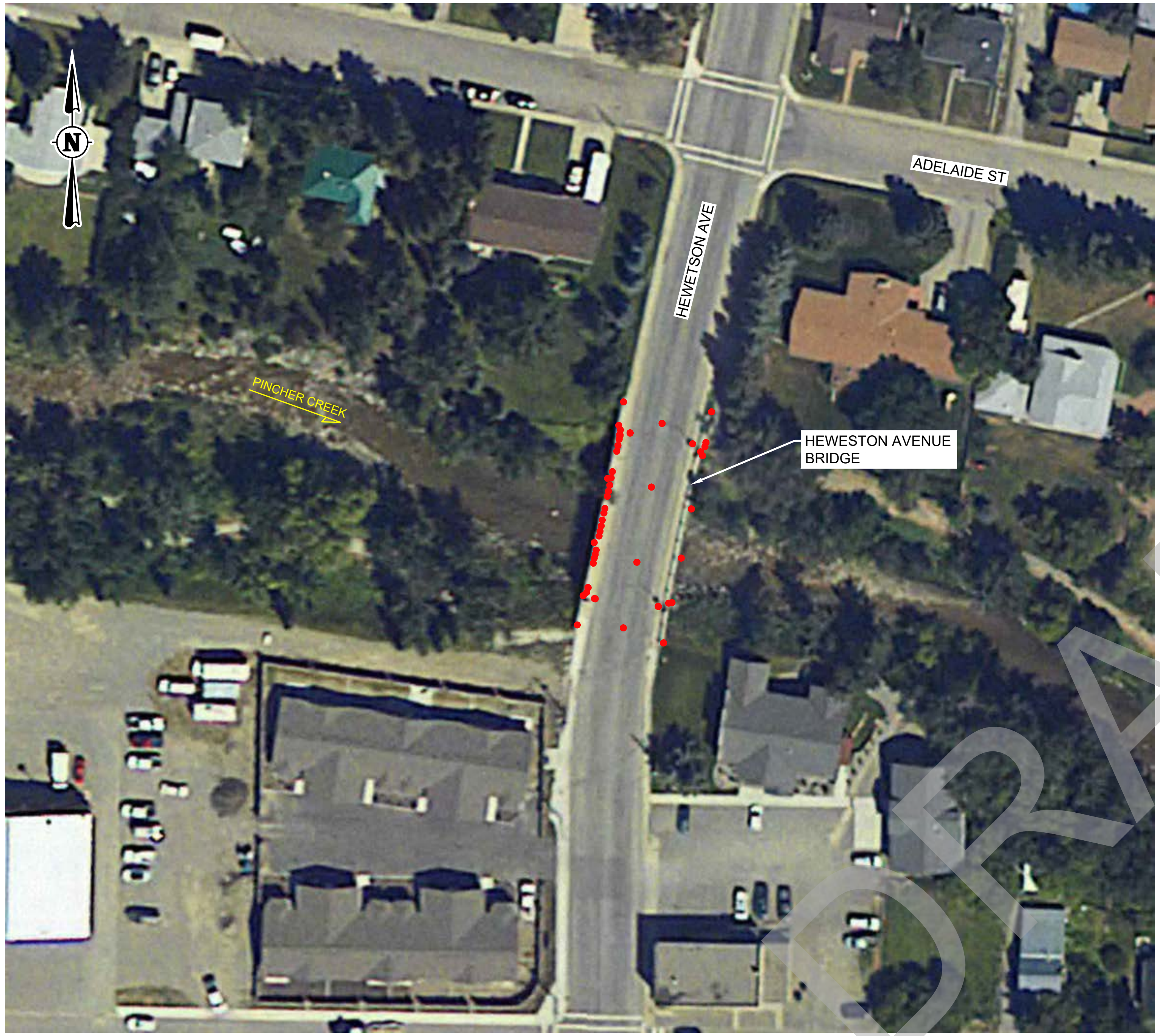


IMAGE REF: 10139-SR.082

1. View looking downstream from right bank.

IMAGE REF: 10139-SR.087

2. View looking obliquely upstream across the creek from the multi-use trail (berm) on left bank.

WATERBODY	STRUCTURE NAME / LOCATION	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	YEAR CONSTRUCTED	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE LOW CHORD ELEVATION (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	LOW CHORD ELEVATION (m)		TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)		NUMBER OF SPANS	NUMBER OF PIERS	PIER DETAILS(1)			
										LEFT ABUTMENT	RIGHT ABUTMENT	LEFT ABUTMENT	RIGHT ABUTMENT			#	CENTRE STATION (m)	WIDTH (m)	DESCRIPTION
PINCHER CREEK	HEWETSON AVENUE BRIDGE	74116	ALBERTA TRANSPORTATION	TRAFFIC	1954	28.97	14.44	1131.42	1133.42	1130.92	1131.25	1133.26	1133.58	1	0	-	-	-	-

(1) Pier stationing is with respect to the centreline of the left abutment, viewed looking downstream (i.e., left abutment corresponds to station zero).

PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. TOPOGRAPHIC SURVEY DATA WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 19-MAY-2019.
3. DETAILS OF THE BRIDGE SURVEY WERE USED FOR HYDRAULIC MODELLING. PIER CENTRE STATIONS, AS SHOWN TABLE BELOW, ARE WITH RESPECT TO VALUES USED IN THE NUMERICAL MODEL.
4. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
5. REFER TO SECTION 2.5 OF THE STUDY REPORT AND THE HYDRAULIC (HEC-RAS) MODEL FOR MORE INFORMATION.
6. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

SURVEY DATA POINT

0 m 10 20 30 40

1 : 1000

PREPARED FOR:

Alberta Government

PROJECT:
PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:
Hydraulic Structure Datasheet (HS-05)
Traffic Bridge on Pincher Creek
Hewetson Avenue Bridge

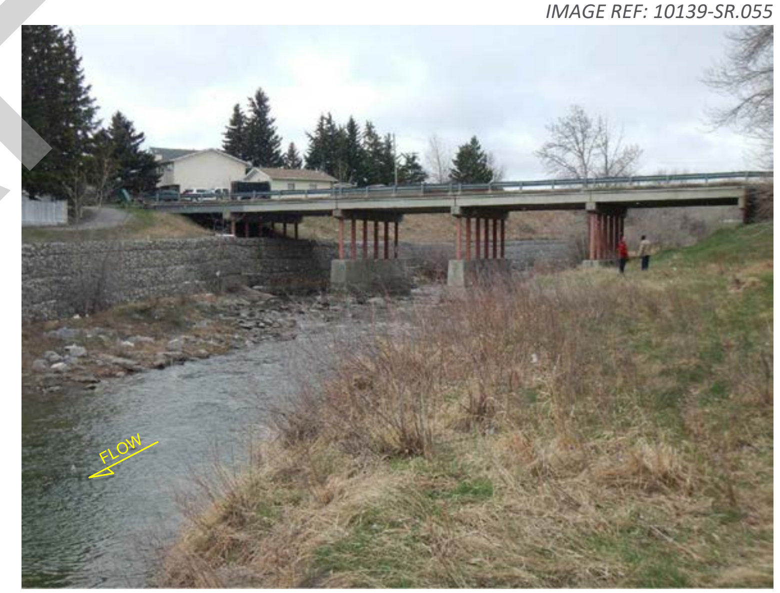
DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-123		FIGURE NO: C-5
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-123.dwg - 124, PLOT DATE: 18-Mar-2020

IMAGE REF: DSCN0056

1. View looking downstream from the top of the right bank revetment.

IMAGE REF: 10139-SR.055



2. View looking upstream from left bank.

WATERBODY	STRUCTURE NAME / LOCATION	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	YEAR CONSTRUCTED	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE LOW CHORD ELEVATION (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	LOW CHORD ELEVATION (m)		TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)		NUMBER OF SPANS	NUMBER OF PIERS	PIER DETAILS[1]			
										LEFT ABUTMENT	RIGHT ABUTMENT	LEFT ABUTMENT	RIGHT ABUTMENT			#	CENTRE STATION (m)	WIDTH (m)	DESCRIPTION
PINCHER CREEK	BEAVER DRIVE BRIDGE	07148	ALBERTA TRANSPORTATION	TRAFFIC	1970	39.54	10.16	1139.70	1140.53	1139.74	1139.64	1140.62	1140.45	5	4	1	8.8	1.14	CIRCULAR ARRAY (SIX STEEL COLUMNS) SET ATOP CONCRETE BASE WITH TRIANGULAR WEDGE NOSE AND TAIL (SLOPED)
																2	16.2	1.14	
																3	24.4	1.14	
																4	33.3	1.14	

(1) Pier stationing is with respect to the centreline of the left abutment, viewed looking downstream (i.e., left abutment corresponds to station zero).

PREPARED BY:
SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:
Klohn Crippen Berger
Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:
1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. TOPOGRAPHIC SURVEY DATA WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 20-MAY-2019.
3. DETAILS OF THE BRIDGE SURVEY WERE USED FOR HYDRAULIC MODELLING. PIER CENTRE STATIONS, AS SHOWN TABLE BELOW, ARE WITH RESPECT TO VALUES USED IN THE NUMERICAL MODEL.
4. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
5. REFER TO SECTION 2.5 OF THE STUDY REPORT AND THE HYDRAULIC (HEC-RAS) MODEL FOR MORE INFORMATION.
6. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:
● SURVEY DATA POINT

0 m 10 20 30 40
1 : 1000

PREPARED FOR:
Alberta Government

PROJECT:
PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:
Hydraulic Structure Datasheet (HS-06)
Traffic Bridge on Pincher Creek
Beaver Drive Bridge

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-124		FIGURE NO: C-6
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-124.dwg - 125, PLOT DATE: 18-Mar-2020

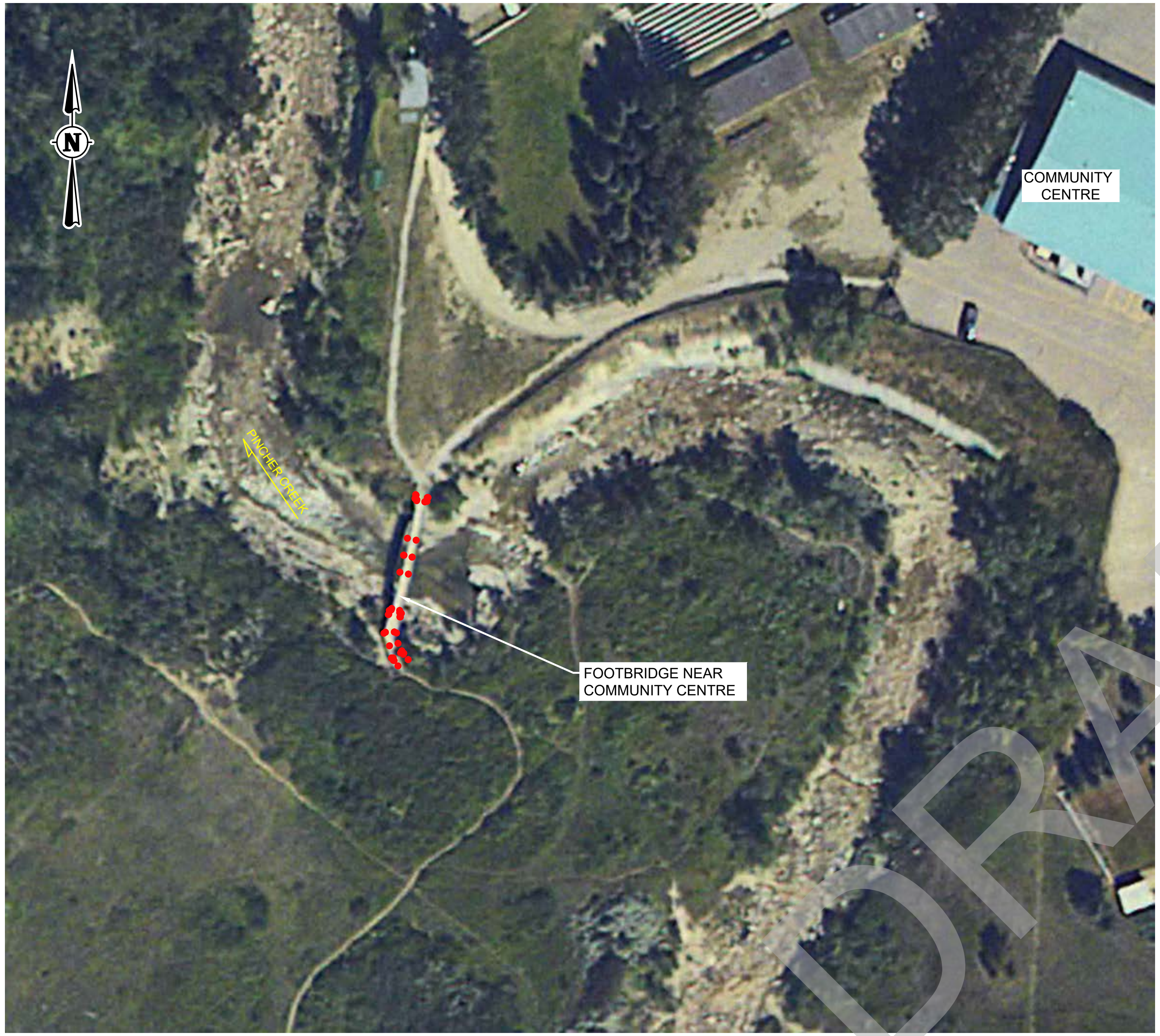


IMAGE REF: 10139-SR.025

1. View looking downstream from right bank.

IMAGE REF: 10139-SR.033

2. View looking upstream from left bank.

WATERBODY	STRUCTURE NAME / LOCATION	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	YEAR CONSTRUCTED	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE LOW CHORD ELEVATION (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	LOW CHORD ELEVATION (m)		TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)		NUMBER OF SPANS	NUMBER OF PIERS	PIER DETAILS[1]			
										LEFT ABUTMENT	RIGHT ABUTMENT	LEFT ABUTMENT	RIGHT ABUTMENT			#	CENTRE STATION (m)	WIDTH (m)	DESCRIPTION
PINCHER CREEK	FOOTBRIDGE NEAR COMMUNITY CENTRE	N/A	N/A	PEDESTRIAN	N/A	21.41	1.45	1144.43	1144.73	1144.21	1144.23	1144.52	1144.52	2	1	1	-	3.58	CONCRETE PIER (MID-SPAN ABUTMENT) NEAR LEFT BANK WITH FLAT FACE

(1) Pier stationing is with respect to the centreline of the left abutment, viewed looking downstream (i.e., left abutment corresponds to station zero).

PREPARED BY:
SG1
SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:
Klohn Crippen Berger
Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. TOPOGRAPHIC SURVEY DATA WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 22-MAY-2019.
3. DETAILS OF THE BRIDGE SURVEY WERE USED FOR HYDRAULIC MODELLING. PIER CENTRE STATIONS, AS SHOWN TABLE BELOW, ARE WITH RESPECT TO VALUES USED IN THE NUMERICAL MODEL.
4. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
5. REFER TO SECTION 2.5 OF THE STUDY REPORT AND THE HYDRAULIC (HEC-RAS) MODEL FOR MORE INFORMATION.
6. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

SURVEY DATA POINT

0 m 10 20 30 40

1 : 1000

PREPARED FOR:
Alberta Government

PROJECT:
PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:
Hydraulic Structure Datasheet (HS-07)
Pedestrian Bridge on Pincher Creek
Footbridge near Community Centre

DWN BY: RDJ | CHK'D BY: DMS | REV NO: 1

DWG NO: 10139-03-125 | FIGURE NO: C-7

DATE: 18-MAR-2020

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-125.dwg - 126, PLOT DATE: 18-Mar-2020

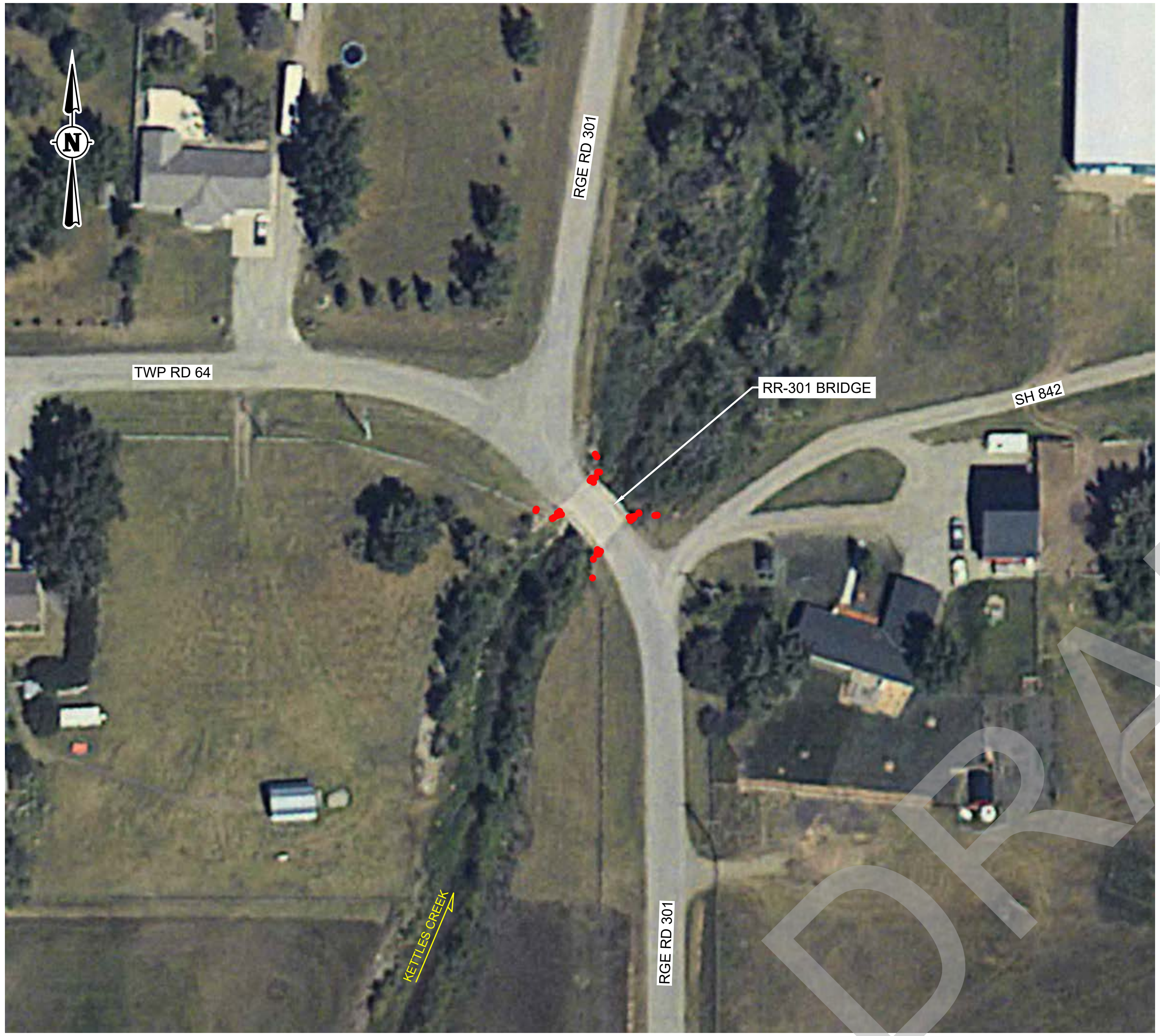


IMAGE REF: 10139-SR.225

1. View looking downstream from right bank.

IMAGE REF: 10139-SR.230

2. View looking upstream from right bank.

WATERBODY	STRUCTURE NAME / LOCATION	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	YEAR CONSTRUCTED	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE LOW CHORD ELEVATION (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	LOW CHORD ELEVATION (m)		TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)		NUMBER OF SPANS	NUMBER OF PIERS	PIER DETAILS(1)			
										LEFT ABUTMENT	RIGHT ABUTMENT	LEFT ABUTMENT	RIGHT ABUTMENT			#	CENTRE STATION (m)	WIDTH (m)	DESCRIPTION
KETTLES CREEK	RR-301 BRIDGE	74038	ALBERTA TRANSPORTATION	TRAFFIC	1980	9.75	8.74	1117.19	1118.00	1117.21	1117.17	1118.01	1118.00	1	0	-	-	-	-

(1) Pier stationing is with respect to the centreline of the left abutment, viewed looking downstream (i.e., left abutment corresponds to station zero).

PREPARED BY:
SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:
Klohn Crippen Berger
Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. TOPOGRAPHIC SURVEY DATA WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 20-MAY-2019.
3. DETAILS OF THE BRIDGE SURVEY WERE USED FOR HYDRAULIC MODELLING. PIER CENTRE STATIONS, AS SHOWN TABLE BELOW, ARE WITH RESPECT TO VALUES USED IN THE NUMERICAL MODEL.
4. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
5. REFER TO SECTION 2.5 OF THE STUDY REPORT AND THE HYDRAULIC (HEC-RAS) MODEL FOR MORE INFORMATION.
6. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

● SURVEY DATA POINT

0 m 10 20 30 40
1 : 1000

PREPARED FOR:
Alberta Government

PROJECT:
PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:
Hydraulic Structure Datasheet (HS-08)
Traffic Bridge on Kettles Creek
RR-301 Bridge

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-126		FIGURE NO: C-8
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-126.dwg - 127, PLOT DATE: 18-Mar-2020

IMAGE REF: 10139-SR.215

1. View looking downstream from left bank.

IMAGE REF: 10139-SR.221

2. View looking upstream from right bank.

WATERBODY	STRUCTURE NAME / LOCATION	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	YEAR CONSTRUCTED	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE LOW CHORD ELEVATION (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	LOW CHORD ELEVATION (m)		TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)		NUMBER OF SPANS	NUMBER OF PIERS	PIER DETAILS(1)			
										LEFT ABUTMENT	RIGHT ABUTMENT	LEFT ABUTMENT	RIGHT ABUTMENT			#	CENTRE STATION (m)	WIDTH (m)	DESCRIPTION
KETTLES CREEK	SH-785 (MACLEOD STREET) BRIDGE	00259	ALBERTA TRANSPORTATION	TRAFFIC	1961	8.83	9.49	1118.96	1120.00	1118.95	1118.96	1119.89	1120.10	1	0	-	-	-	-

(1) Pier stationing is with respect to the centreline of the left abutment, viewed looking downstream (i.e., left abutment corresponds to station zero).

PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. TOPOGRAPHIC SURVEY DATA WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 20-MAY-2019.
3. DETAILS OF THE BRIDGE SURVEY WERE USED FOR HYDRAULIC MODELLING. PIER CENTRE STATIONS, AS SHOWN TABLE BELOW, ARE WITH RESPECT TO VALUES USED IN THE NUMERICAL MODEL.
4. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
5. REFER TO SECTION 2.5 OF THE STUDY REPORT AND THE HYDRAULIC (HEC-RAS) MODEL FOR MORE INFORMATION.
6. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

● SURVEY DATA POINT

0 m 10 20 30 40

1 : 1000

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:

Hydraulic Structure Datasheet (HS-09)
Traffic Bridge on Kettles Creek
SH-785 (Macleod Street) Bridge

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-127		FIGURE NO: C-9
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-127.dwg - 128, PLOT DATE: 18-Mar-2020

IMAGE REF: 10139-SR.205

1. View looking downstream from left bank.

IMAGE REF: 10139-SR.209

2. View looking upstream from right bank.

DRAFT

WATERBODY	STRUCTURE NAME / LOCATION	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	YEAR CONSTRUCTED	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE LOW CHORD ELEVATION (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	LOW CHORD ELEVATION (m)		TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)		NUMBER OF SPANS	NUMBER OF PIERS	PIER DETAILS[1]			
										LEFT ABUTMENT	RIGHT ABUTMENT	LEFT ABUTMENT	RIGHT ABUTMENT			#	CENTRE STATION (m)	WIDTH (m)	DESCRIPTION
KETTLES CREEK	MAIN STREET BRIDGE	02298	ALBERTA TRANSPORTATION	TRAFFIC	1966	8.471	9.57	1126.56	1126.93	1126.57	1126.55	1127.28	1126.57	1	0	-	-	-	-

(1) Pier stationing is with respect to the centreline of the left abutment, viewed looking downstream (i.e., left abutment corresponds to station zero).

PREPARED BY:
SG1
SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:
Klohn Crippen Berger
Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:
1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. TOPOGRAPHIC SURVEY DATA WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 20-MAY-2019.
3. DETAILS OF THE BRIDGE SURVEY WERE USED FOR HYDRAULIC MODELLING. PIER CENTRE STATIONS, AS SHOWN TABLE BELOW, ARE WITH RESPECT TO VALUES USED IN THE NUMERICAL MODEL.
4. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
5. REFER TO SECTION 2.5 OF THE STUDY REPORT AND THE HYDRAULIC (HEC-RAS) MODEL FOR MORE INFORMATION.
6. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

SURVEY DATA POINT

0 m 10 20 30 40

1 : 1000

PREPARED FOR:
Alberta Government

PROJECT:
PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:
Hydraulic Structure Datasheet (HS-10)
Traffic Bridge on Kettles Creek
Main Street Bridge

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-128		FIGURE NO: C-10
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-128.dwg - 129, PLOT DATE: 18-Mar-2020

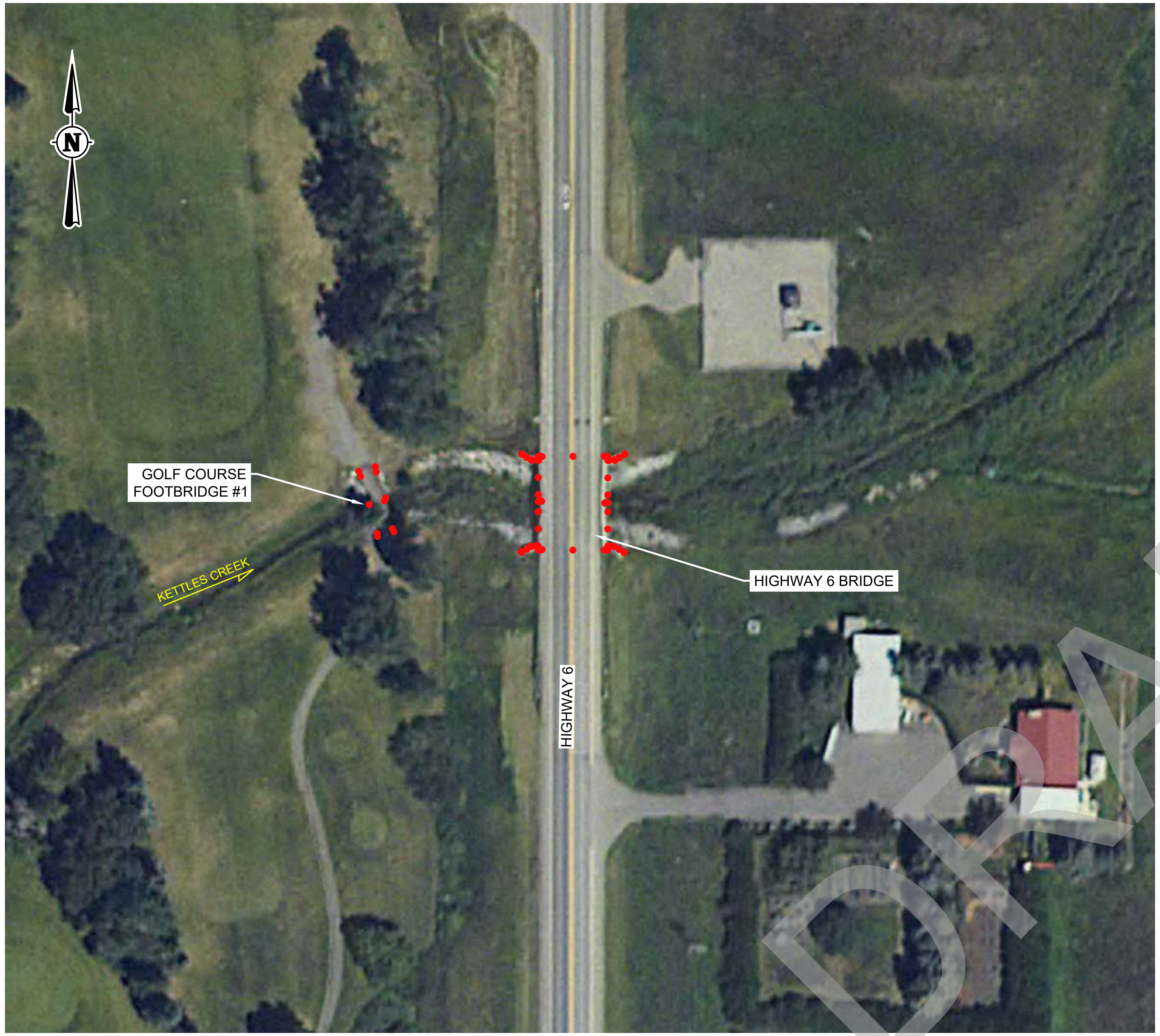


IMAGE REF: DSCN0082

1. View looking downstream from right bank.

IMAGE REF: DSCN0079

2. View looking upstream from right bank.

WATERBODY	STRUCTURE NAME / LOCATION	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	YEAR CONSTRUCTED	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE LOW CHORD ELEVATION (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	LOW CHORD ELEVATION (m)		TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)		NUMBER OF SPANS	NUMBER OF PIERS	PIER DETAILS[1]			
										LEFT ABUTMENT	RIGHT ABUTMENT	LEFT ABUTMENT	RIGHT ABUTMENT			#	CENTRE STATION (m)	WIDTH (m)	DESCRIPTION
KETTLES CREEK	HIGHWAY 6 BRIDGE NEAR GOLF COURSE	73638	ALBERTA TRANSPORTATION	TRAFFIC	2012	15.13	12.15	1135.77	1136.73	1135.79	1135.75	1136.75	1136.71	1	0	-	-	-	-

(1) Pier stationing is with respect to the centreline of the left abutment, viewed looking downstream (i.e., left abutment corresponds to station zero).

PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. TOPOGRAPHIC SURVEY DATA WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 20-MAY-2019.
3. DETAILS OF THE BRIDGE SURVEY WERE USED FOR HYDRAULIC MODELLING. PIER CENTRE STATIONS, AS SHOWN TABLE BELOW, ARE WITH RESPECT TO VALUES USED IN THE NUMERICAL MODEL.
4. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
5. REFER TO SECTION 2.5 OF THE STUDY REPORT AND THE HYDRAULIC (HEC-RAS) MODEL FOR MORE INFORMATION.
6. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

SURVEY DATA POINT

0 m 10 20 30 40

1 : 1000

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:

Hydraulic Structure Datasheet (HS-11)
Traffic Bridge on Kettles Creek
Highway 6 Bridge near Golf Course

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-129		FIGURE NO: C-11
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-129.dwg - 130, PLOT DATE: 18-Mar-2020

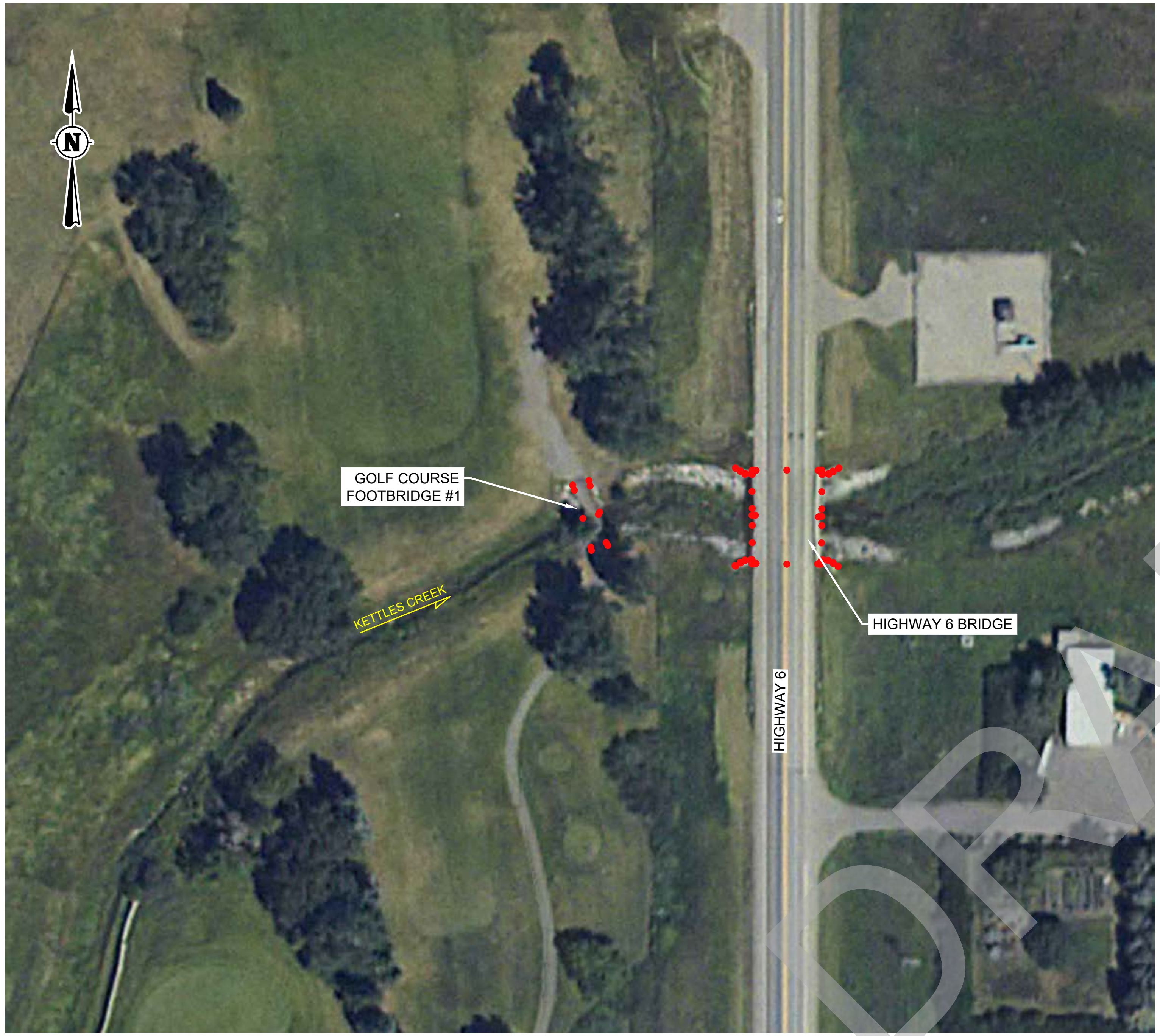


IMAGE REF: DSCN0086

1. View looking downstream from left bank.

IMAGE REF: DSCN0083

2. View looking upstream from right bank.

WATERBODY	STRUCTURE NAME / LOCATION	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	YEAR CONSTRUCTED	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE LOW CHORD ELEVATION (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	LOW CHORD ELEVATION (m)		TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)		NUMBER OF SPANS	NUMBER OF PIERS	PIER DETAILS(1)			
										LEFT ABUTMENT	RIGHT ABUTMENT	LEFT ABUTMENT	RIGHT ABUTMENT			#	CENTRE STATION (m)	WIDTH (m)	DESCRIPTION
KETTLES CREEK	GOLF COURSE FOOTBRIDGE #1	N/A	N/A	PEDESTRIAN	N/A	11.83	3	1135.23	1135.49	1135.24	1135.22	1135.49	1135.48	1	0	-	-	-	-

(1) Pier stationing is with respect to the centreline of the left abutment, viewed looking downstream (i.e., left abutment corresponds to station zero).

PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. TOPOGRAPHIC SURVEY DATA WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 20-MAY-2019.
3. DETAILS OF THE BRIDGE SURVEY WERE USED FOR HYDRAULIC MODELLING. PIER CENTRE STATIONS, AS SHOWN TABLE BELOW, ARE WITH RESPECT TO VALUES USED IN THE NUMERICAL MODEL.
4. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
5. REFER TO SECTION 2.5 OF THE STUDY REPORT AND THE HYDRAULIC (HEC-RAS) MODEL FOR MORE INFORMATION.
6. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

● SURVEY DATA POINT

0 m 10 20 30 40

1 : 1000

PREPARED FOR:

Alberta Government

PROJECT:
PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:
Hydraulic Structure Datasheet (HS-12)
Pedestrian Bridge on Kettles Creek
Golf Course Footbridge #1

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-130		FIGURE NO: C-12
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-130.dwg - 130, PLOT DATE: 18-Mar-2020

IMAGE REF: 10139-SR.183

1. View looking downstream from right bank.

IMAGE REF: 10139-SR.180

2. View looking upstream from the top of the right bank revetment.

WATERBODY	STRUCTURE NAME / LOCATION	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	YEAR CONSTRUCTED	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE LOW CHORD ELEVATION (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	LOW CHORD ELEVATION (m)		TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)		NUMBER OF SPANS	NUMBER OF PIERS	PIER DETAILS(1)			
										LEFT ABUTMENT	RIGHT ABUTMENT	LEFT ABUTMENT	RIGHT ABUTMENT			#	CENTRE STATION (m)	WIDTH (m)	DESCRIPTION
KETTLES CREEK	GOLF COURSE FOOTBRIDGE #2	N/A	N/A	PEDESTRIAN	N/A	11.83	3	1136.43	1136.68	1136.54	1136.32	1136.81	1136.55	1	0	-	-	-	-

(1) Pier stationing is with respect to the centreline of the left abutment, viewed looking downstream (i.e., left abutment corresponds to station zero).

PREPARED BY:

SG1
SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger
Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. TOPOGRAPHIC SURVEY DATA WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 20-MAY-2019.
3. DETAILS OF THE BRIDGE SURVEY WERE USED FOR HYDRAULIC MODELLING. PIER CENTRE STATIONS, AS SHOWN TABLE BELOW, ARE WITH RESPECT TO VALUES USED IN THE NUMERICAL MODEL.
4. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
5. REFER TO SECTION 2.5 OF THE STUDY REPORT AND THE HYDRAULIC (HEC-RAS) MODEL FOR MORE INFORMATION.
6. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

● SURVEY DATA POINT

0 m 10 20 30 40

1 : 1000

PREPARED FOR:

Alberta Government

PROJECT:
PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:
Hydraulic Structure Datasheet (HS-13)
Pedestrian Bridge on Kettles Creek
Golf Course Footbridge #2

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-131		FIGURE NO: C-13
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-131.dwg - 131, PLOT DATE: 18-Mar-2020

IMAGE REF: 10139-SR.193

1. View looking downstream from left bank.

IMAGE REF: DSCN0103

2. View looking upstream from left bank.

WATERBODY	STRUCTURE NAME / LOCATION	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	YEAR CONSTRUCTED	NO. OF CULVERTS	BARREL LENGTH (m)	INSIDE DIAMETER (m)	PIPE SLOPE (m/m)	CULVERT TYPE	CULVERT SHAPE	ENTRANCE CONDITION	CULVERT INVERT ELEVATION (m)		TOP OF ROADWAY ELEVATION (m)
													INLET	OUTLET	
KETTLES CREEK	SH-302 (EAST AVENUE) CULVERT	00253	ALBERTA TRANSPORTATION	TRAFFIC	1973	1	23.79	4	0.0071	CORRUGATED STEEL PIPE	CIRCULAR	PROJECTING OUT FROM FILL, SURROUNDED BY SLOPED CONCRETE HEADWALL	1144.73	1144.56	1150.34

PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. TOPOGRAPHIC SURVEY DATA WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 22-MAY-2019.
3. DETAILS OF THE BRIDGE SURVEY WERE USED FOR HYDRAULIC MODELLING. PIER CENTRE STATIONS, AS SHOWN TABLE BELOW, ARE WITH RESPECT TO VALUES USED IN THE NUMERICAL MODEL.
4. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
5. REFER TO SECTION 2.5 OF THE STUDY REPORT AND THE HYDRAULIC (HEC-RAS) MODEL FOR MORE INFORMATION.
6. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

SURVEY DATA POINT

0 m 10 20 30 40

1 : 1000

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:

Hydraulic Structure Datasheet (HS-14)
Culvert on Kettles Creek
SH-302 (East Avenue) Culvert

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1	
DWG NO:	10139-03-132	FIGURE NO:	C-14
DATE:	18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-132.dwg - 132, PLOT DATE: 18-Mar-2020

ADJACENT WATERBODY	STRUCTURE LOCATION	TYPE	SIDE OF RIVER	APPROXIMATE LENGTH (m)	MATERIAL TYPE
PINCHER CREEK	ADJACENT TO SLEEPY HOLLOW CAMPGROUND, BELOW HIGHWAY 6 BRIDGE	BERM	LEFT	180	EARTHEN BARRIER

IMAGE REF: DSCN0133_FC-01

1. View looking upstream at the berm approximately midway along its length.

IMAGE REF: DSCN0135_FC-01

2. View looking upstream at the downstream end of the berm. Pincher Creek is visible on the left side of the photograph.

IMAGE REF: DSCN0134_FC-01

3. View looking at the downstream end of the berm toward the creek (on the other side of the flood control structure).

PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. TOPOGRAPHIC SURVEY DATA WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 21-MAY-2019.
3. DETAILS OF THE FLOOD CONTROL STRUCTURE SURVEY WERE USED FOR HYDRAULIC MODELLING.
4. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
5. REFER TO SECTION 2.6 OF THE STUDY REPORT AND THE HYDRAULIC (HEC-RAS) MODEL FOR MORE INFORMATION.
6. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

● SURVEY DATA POINT

0 m 10 20 30 40

1 : 1000

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

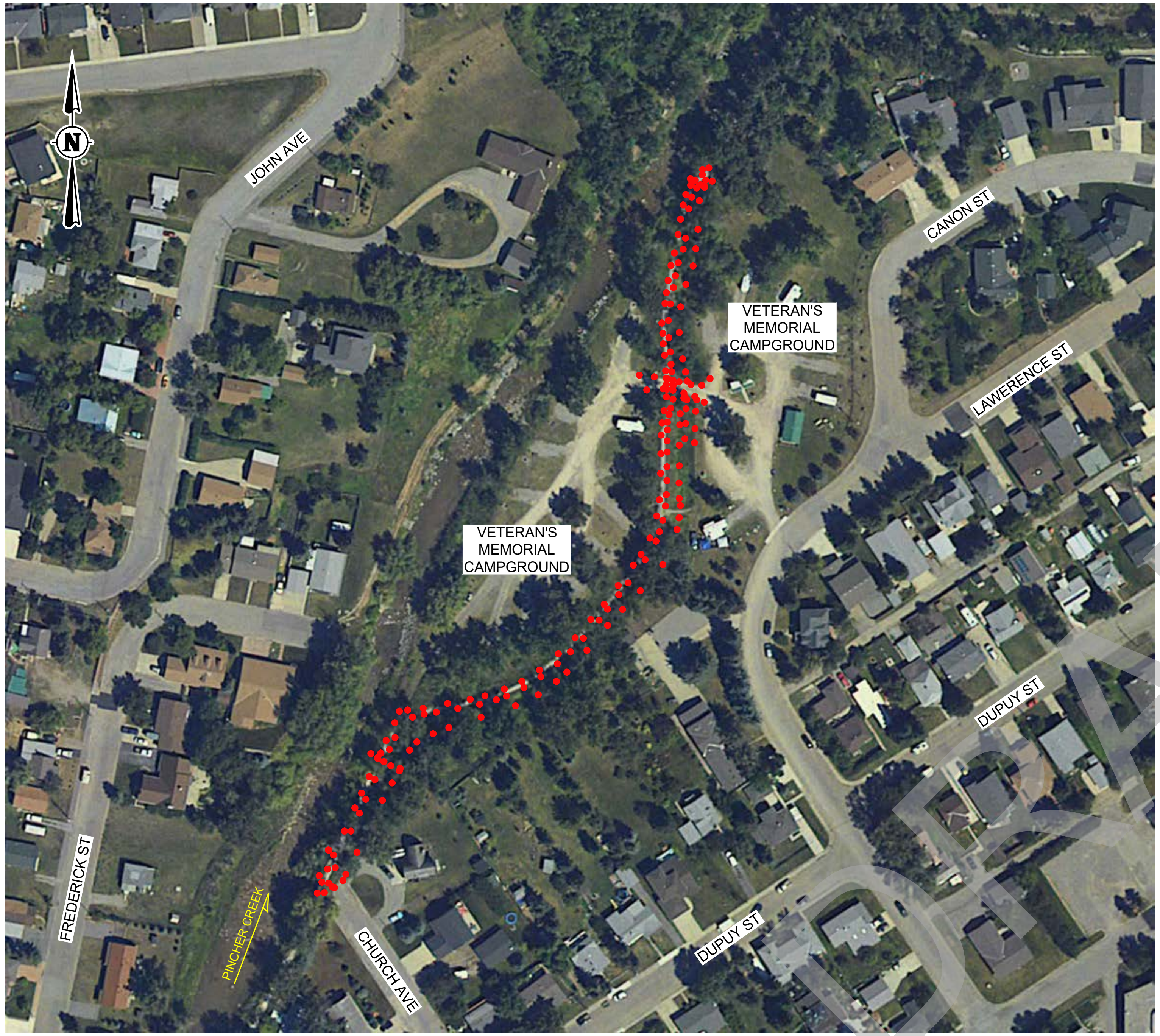
TITLE:

Flood Control Structure Datasheet (FC-01)
Pincher Creek
Berm near Sleepy Hollow Campground

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-133		FIGURE NO: D-1
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-133.dwg - 133, PLOT DATE: 18-Mar-2020

Classification: Public



ADJACENT WATERBODY	STRUCTURE LOCATION	TYPE	SIDE OF RIVER	APPROXIMATE LENGTH (m)	MATERIAL TYPE
PINCHER CREEK	ADJACENT TO PINCHER CREEK VETERAN'S MEMORIAL CAMPGROUND	BERM	RIGHT	310	EARTHEN BARRIER

IMAGE REF: 10139-SR.137

1. View looking at the upstream end of the berm toward the creek (on the other side of the flood control structure). Flow on the creek is from left to right. The corrugated steel pipe culvert that passes through the berm is not equipped with a flap gate to prevent floodwater from flowing toward the street (Church Avenue).

IMAGE REF: 10139-SR.130

2. View looking downstream along the berm within the campground. The photograph was taken from a low point in the berm, which provides vehicular access to campsites on the riverside of the berm.

IMAGE REF: 10139-SR.129

3. View looking upstream from the low point in the berm toward the west end of the campground.

DRAFT

PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. TOPOGRAPHIC SURVEY DATA WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 16-MAY-2019.
3. DETAILS OF THE FLOOD CONTROL STRUCTURE SURVEY WERE USED FOR HYDRAULIC MODELLING.
4. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
5. REFER TO SECTION 2.6 OF THE STUDY REPORT AND THE HYDRAULIC (HEC-RAS) MODEL FOR MORE INFORMATION.
6. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

● SURVEY DATA POINT

0 m 20 40 60 80

1 : 2000

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:

Flood Control Structure Datasheet (FC-02)
Pincher Creek
Berm near Pincher Creek Veteran's Memorial Campground

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-134		FIGURE NO: D-2
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-134.dwg - 134, PLOT DATE: 18-Mar-2020

ADJACENT WATERBODY	STRUCTURE LOCATION	TYPE	SIDE OF RIVER	APPROXIMATE LENGTH (m)	MATERIAL TYPE
PINCHER CREEK	BETWEEN HEWETSON AVENUE BRIDGE AND FOOTBRIDGE SOUTH OF JAMES AVENUE (NEAR PINCHER CREEK VISITOR INFORMATION CENTRE)	BERM	LEFT	500	EARTHEN BARRIER

IMAGE REF: 10139-SR.086

1. View looking downstream along the berm from Hewetson Avenue Bridge. The berm starts here and extends downstream to the footbridge south of James Avenue.

IMAGE REF: 10139-SR.090

2. View looking downstream along the berm at the south end of Morden Avenue and at the location of the Water Survey of Canada hydrometric station (WSC 05AA004) on Pincher Creek. A corrugated steel pipe culvert passes through the berm near the end of the driveway and is not equipped with a flap gate to prevent floodwater from flowing toward the street.

IMAGE REF: 10139-SR.105

3. View looking downstream along the berm in the vicinity of the Pincher Creek Visitor Information Centre, below Bev McLachlin Drive Bridge.

PREPARED BY:

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger
Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. ORTHOIMAGERY SHOWN HEREIN WAS ACQUIRED ON 26-JUL-2019. SOURCE: ALBERTA ENVIRONMENT AND PARKS.
2. TOPOGRAPHIC SURVEY DATA WERE COLLECTED BY TROUT HYDROGRAPHY INC. ON 16-MAY-2019.
3. DETAILS OF THE FLOOD CONTROL STRUCTURE SURVEY WERE USED FOR HYDRAULIC MODELLING.
4. THE COORDINATE SYSTEM IS 3TM MERIDIAN 114° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
5. REFER TO SECTION 2.6 OF THE STUDY REPORT AND THE HYDRAULIC (HEC-RAS) MODEL FOR MORE INFORMATION.
6. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

● SURVEY DATA POINT

0 m 30 60 90 120

1 : 3000

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

TITLE:

Flood Control Structure Datasheet (FC-03)
Pincher Creek
Berm between Hewetson Avenue Bridge and Footbridge South of James Avenue

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 1
DWG NO: 10139-03-135		FIGURE NO: D-3
DATE: 18-MAR-2020		

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 3\10139-03-135.dwg - 135, PLOT DATE: 18-Mar-2020

SG1 Ref. No. 10139

14 June 2019

ALBERTA ENVIRONMENT AND PARKS
River Engineering and Technical Services
11th Floor, Oxbridge Place
9820 106 Street NW
Edmonton, AB
T5K 2J6

Attention: Mr. Muhammad Durrani, M.Eng., P.Eng.
River Engineer

Via email: muhammad.durrani@gov.ab.ca

Re: Pincher Creek Flood Hazard Study
Flood Control Structures Memorandum

Dear Mr. Durrani:

1 INTRODUCTION

SG1 Water Consulting Ltd. (SG1) is pleased to submit the following document that outlines the surveyed flood control structures for the Pincher Creek Flood Hazard Study. This study is being conducted by Klohn Crippen Berger Ltd. (KCB) and its subconsultant, SG1 Water Consulting Ltd. (SG1) for Alberta Environment and Parks (AEP). SG1 retained TROUT Hydrography Inc. (TROUT) as a subcontractor with regard to performing field services related to the Survey & Base Data Collection task.

It is understood that the purpose of this memorandum is to provide local authorities with an opportunity to confirm ownership, maintenance, and operational responsibilities of the flood control structures prior to finalizing the hydraulic model and flood mapping. In this particular case, the local authority is the Town of Pincher Creek (the Town).

2 IDENTIFICATION OF FLOOD CONTROL STRUCTURES

A site reconnaissance was conducted on 2 May 2019 by key personnel from AEP, KCB, TROUT, and SG1 to familiarize the project team with Pincher Creek, Kettles Creek, and the study area in general. The site reconnaissance confirmed: (i) the presence of two flood control structures on Pincher Creek; and (ii) that no such features exist on Kettles Creek within the study area. The location of a third flood control structure on the left[1] (north) bank of Pincher Creek, extending downstream from the Highway 6 Bridge, was confirmed later by email communication with the Town. Mr. Alan Roth of the Town accompanied the project team in observing the most upstream flood control structure on Pincher Creek. Additionally, Mr. Roth provided KCB with a hardcopy of three engineering drawings from flood protection works that were carried out on Pincher Creek in 1995. Table 1 below provides details on the supplied drawings (also refer to Appendix A).

Table 1. Flood Control Barrier Drawings by UMA Engineering Ltd. (as supplied by the Town)

Project No.	File / Dwg No.	Drawing Title	Drawing Date	Drawing Status
0112-195-00	L1433-001	City of Lethbridge Storm Sewer Outlet No. 3 Project No. 1698 Replacement Structure General Arrangement Plans, Sections & Details	1995-10-05	Issued for Construction
0112-195-00	L1434-002	City of Lethbridge Storm Sewer Outlet No. 3 Project No. 1698 Replacement Structure Structural Plans & Sections	1995-10-05	Issued for Construction
0678-043-00	L1435-001	Municipal District of Pincher Creek 1995 Flood Reconstruction, Site 91 SE ¼ Sec. 15-6-30-4 Plan and Sections	1995-10-31	Issued for Tender

The first and second drawings listed in Table 1 above appear to be related to an outfall for The City of Lethbridge. However, without a location plan, it was not possible for KCB to determine whether or not this structure is located on Pincher Creek. The third drawing (File/Dwg. No. L1435-001) pertains to the 1995 Flood Reconstruction Project in Pincher Creek, but does not include a location plan. Furthermore, this drawing suggest that the plan and sections correspond to a section of roadway, not a flood control structure.

Figure 1 shows a location map of the study area, illustrating where the three identified flood control structures are situated within the Town of Pincher Creek. Figure 2 is a close-up view in plan showing the alignment and extents of each structure. Table 2 below provides a description of the flood control structures within the study area.

[1] "Left" or "right" refer to directions as seen by an observer looking downstream.

Table 2. Flood Control Structures within Study Area

Feature ID	Water-course	Location	Type	Side of Creek (1)	Approximate Length (m)	Material Type
FC-01	Pincher Creek	Adjacent to Sleepy Hollow Campground, below Highway 6 Bridge	Berm	Left	180	Earthen Barrier
FC-02		Adjacent to Pincher Creek Veteran's Memorial Campground	Berm	Right	310	
FC-03		Between Hewetson Avenue Bridge and footbridge near Information Centre	Berm	Left	500	

NOTE: "Left" or "right" refer to directions as seen by an observer looking downstream

All three flood control structures were surveyed during the field program in May 2019. The collected survey data were appropriately located to capture the alignment and typical cross-sectional geometry of the flood control structures. An additional cross section was surveyed on FC-03 wherever corrugated steel pipes (culverts) passed through the berm, thus allowing the pipe diameter and inlet and outlet elevations (inverts) to be properly documented. Capturing this detail on the FC-03 flood control structure was necessary given that none of the culverts are equipped with a flap gate to prevent floodwater from flowing toward the streets.

3 CLOSURE

We trust that the information contained in this document is sufficient for your present needs. Please do not hesitate to contact the undersigned by phone or email (780.238.5868; Darren@SG1water.ca) if you have any questions or require additional information.

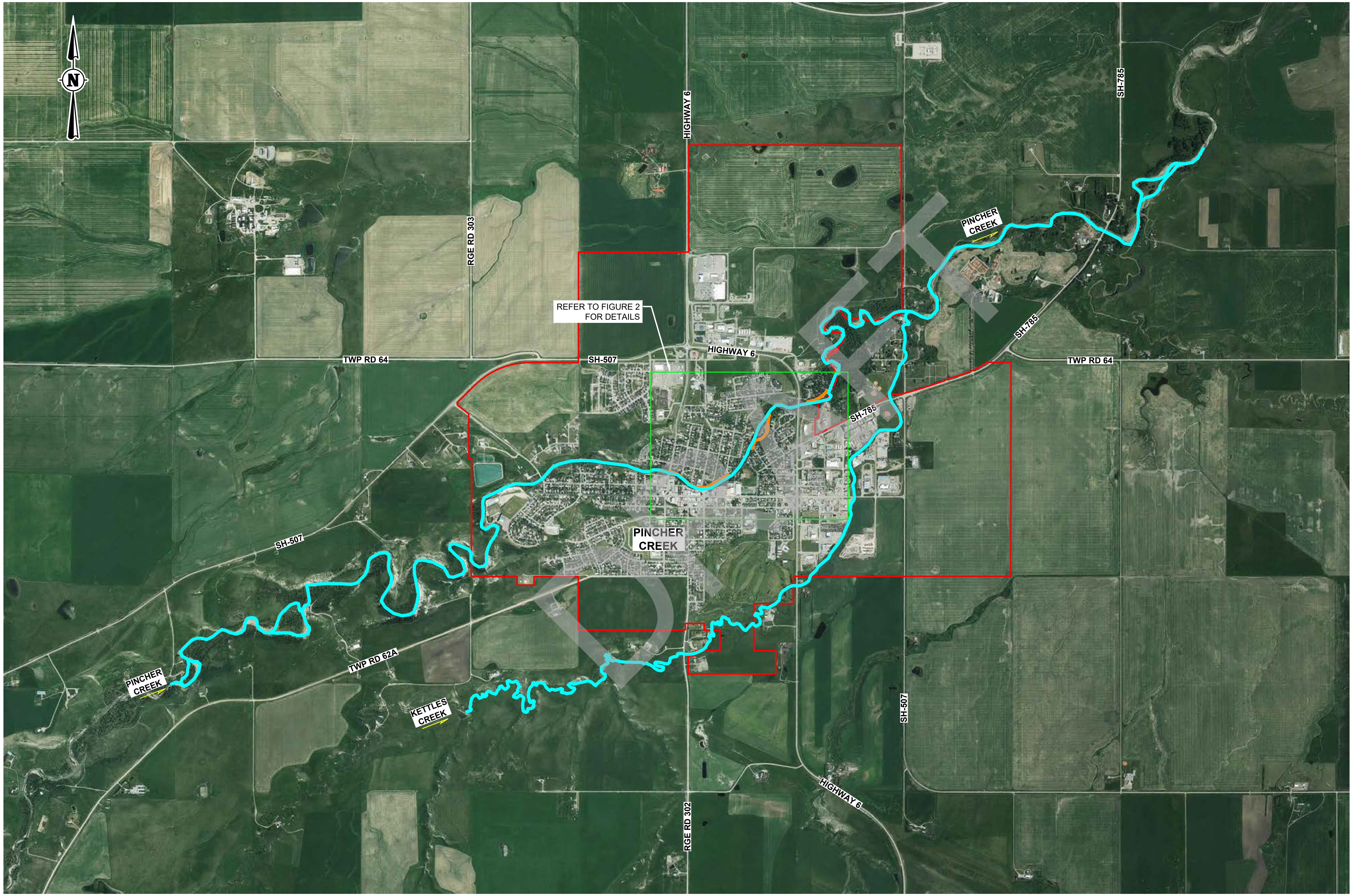
Sincerely,

SG1 WATER CONSULTING LTD.

Darren Shepherd, M.Sc., P.Eng.
President

ENCLOSURE

cc: Rob Cheetham, P.Eng. – KCB (rcheetham@klohn.com)
Kathy Chen, M.Eng., E.I.T. – KCB (kchen@klohn.com)



PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger
Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. WORLD IMAGERY BY ESRI INC, DATED 06-JUN-2015.
2. THE STUDY AREA IS COMPRISED OF A 13.9 km LONG REACH OF PINCHER CREEK AND A 7.4 km LONG REACH OF KETTLES CREEK WITHIN THE TOWN OF PINCHER CREEK AND THE MUNICIPAL DISTRICT OF PINCHER CREEK NO.9.
3. ALL THREE FLOOD CONTROL STRUCTURES, AS IDENTIFIED HEREIN, WERE CONFIRMED AS BEING OWNED, OPERATED, AND MAINTAINED BY THE TOWN OF PINCHER CREEK.

LEGEND:

- MUNICIPAL BOUNDARY
- WATERCOURSE
- FLOOD CONTROL STRUCTURE

0 m 300 600 900 1200

1 : 30,000

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

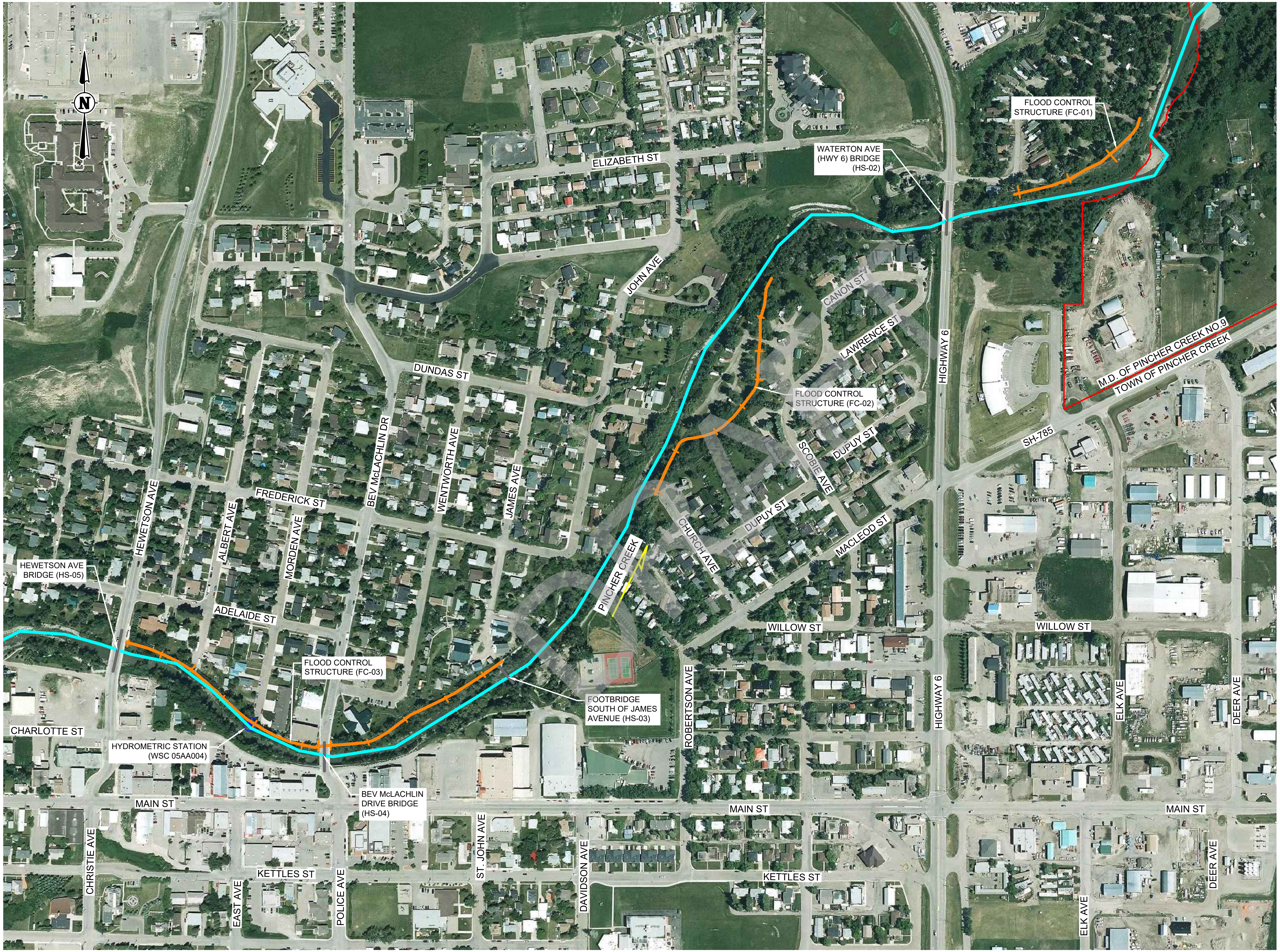
FLOOD CONTROL STRUCTURES

TITLE:

Location Map of Study Area

DWN BY: RDJ	CHK'D BY: DMS	REV NO: 0
DWG NO:	10139-02-101	FIGURE NO: 1
DATE:	5-JUN-2019	

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 2\10139-02-101.dwg - 101, PLOT DATE: 05-Jun-2019



PREPARED BY:

SG1

SG1 Water Consulting Ltd.
7303 118A St NW, Edmonton, AB, Canada T6G 1V3
Tel: 780.238.5868 | SG1water.ca

IN COLLABORATION WITH:

Klohn Crippen Berger

Suite 500, 2618 Hopewell Place NE
Calgary, AB, Canada T1Y 7J7
Tel: 403.730.6848 | www.klohn.com

NOTES:

1. WORLD IMAGERY BY ESRI INC, DATED 06-JUN-2015.
2. ALL THREE FLOOD CONTROL STRUCTURES, AS IDENTIFIED HEREIN, WERE CONFIRMED AS BEING OWNED, OPERATED, AND MAINTAINED BY THE TOWN OF PINCHER CREEK.

LEGEND:

- MUNICIPAL BOUNDARY
- WATERCOURSE (PINCHER CREEK)
- HYDRAULIC STRUCTURE (BRIDGE/CULVERT)
- FLOOD CONTROL STRUCTURE
- HYDROMETRIC STATION

0 m 50 100 150 200

SCALE (AS SHOWN)

PREPARED FOR:

Alberta Government

PROJECT:

PINCHER CREEK
FLOOD HAZARD STUDY

FLOOD CONTROL STRUCTURES

TITLE:

Flood Control Structure Locations
Pincher Creek

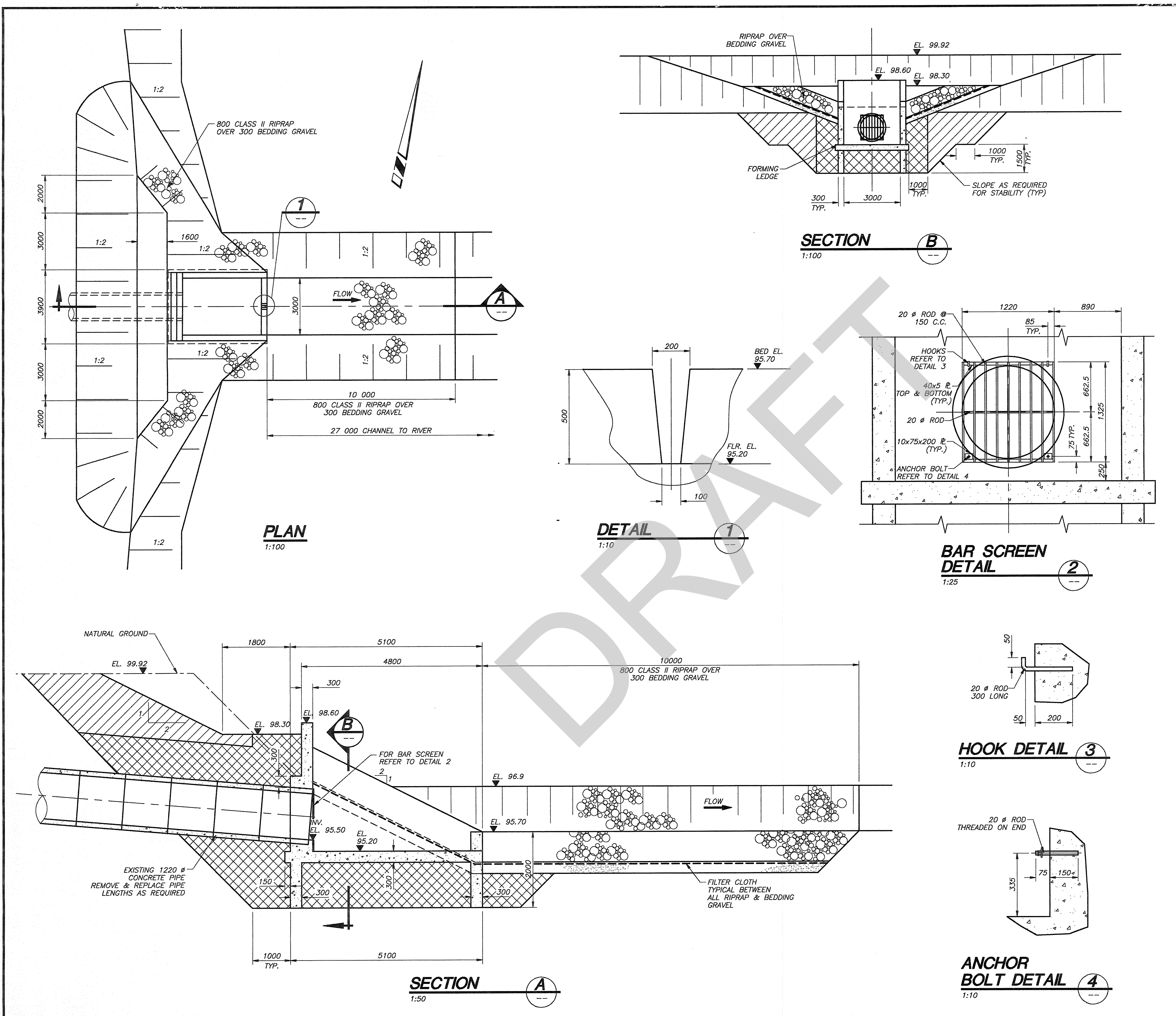
DWN BY: RDJ	CHK'D BY: DMS	REV NO: 0
DWG NO:	10139-02-102	FIGURE NO: 2
DATE:	5-JUN-2019	

FILE LOC: H:\SG1\OwnCloud\Drafting\10139 Pincher FHS\Task 2\10139-02-102.dwg - 102, PLOT DATE: 05-Jun-2019

Classification: Public

APPENDIX A

Engineering Drawings Supplied by the Town of Pincher Creek
(UMA Engineering Ltd., 1995)



LEGEND

ZONE 3 TAMPED PITRUN GRAVEL TO 95% STANDARD PROCTOR DENSITY

COMPACTED PITRUN GRAVEL TO 95% STANDARD PROCTOR DENSITY

REV	Y	M	D	REVISION DESCRIPTION	DES	DRN	CHK	ENG	ENGINEER STAMPED & SIGNED BY	PERMIT
0	95	10	05	FOR CONSTRUCTION	ICM	DMB	ICM	ICM	----	----

PROFESSIONAL ENGINEER ALBERTA

PERMIT TO PRACTICE
UMA ENGINEERING LTD.
Signature
Date Oct 5/95
PERMIT NUMBER: P 329
The Association of Professional Engineers, Geologists and Geophysicists of Alberta.

R.E.T. ENGINEER PERMIT

REPRODUCTION OF DRAWINGS

DRAWING ISSUE/REVISION

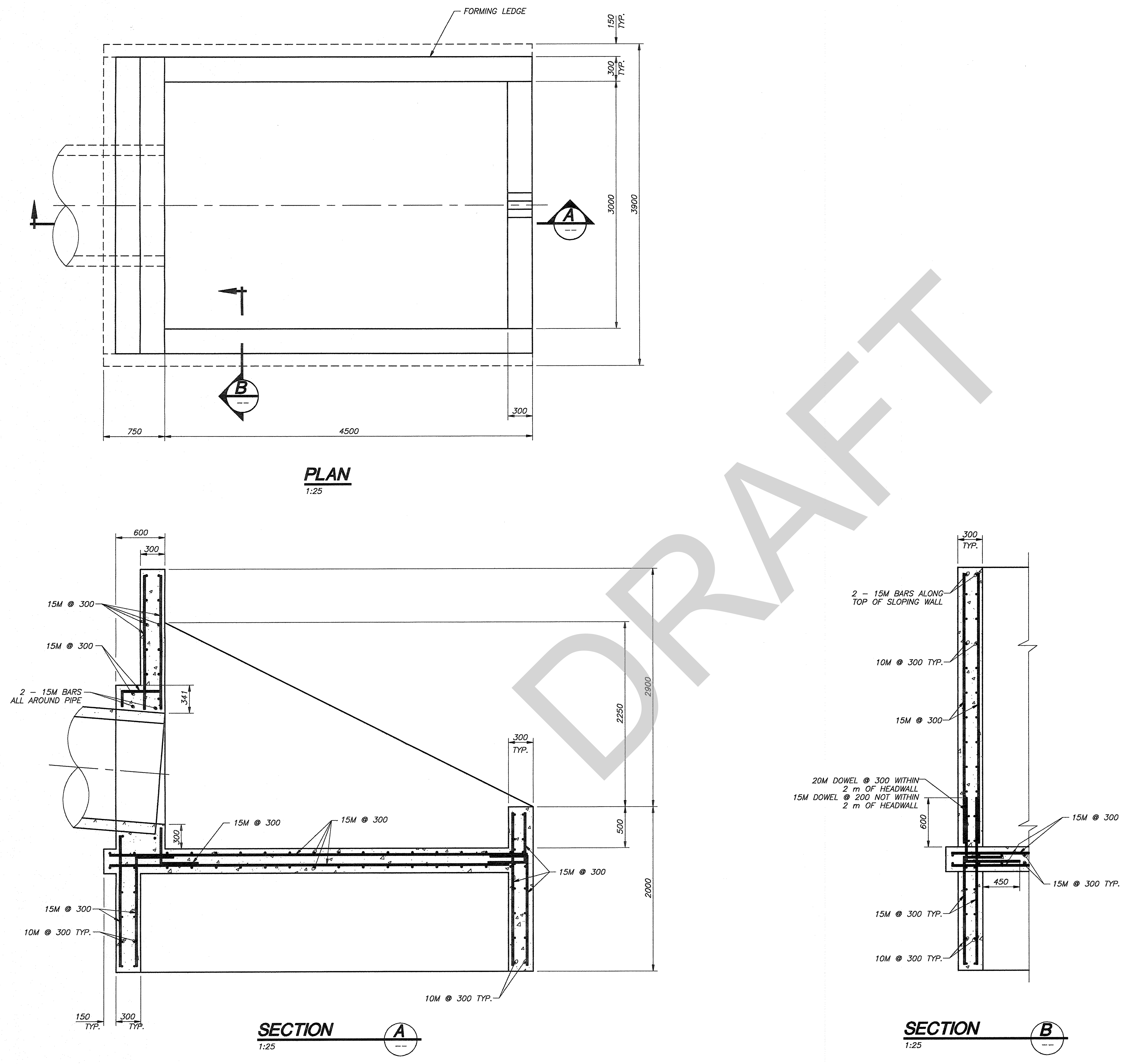
THIS DRAWING IS NOT APPROVED FOR CONSTRUCTION UNLESS STAMPED, SIGNED AND DATED. ALL DRAWINGS BEARING EARLIER DATE OR REVISION NUMBER ARE VOID.

UMA Engineering Ltd.
Engineers, Planners & Surveyors
2540 Kensington Road N.W., Calgary, Alberta, Canada T2N 3S3
514 Stafford Dr. N., Lethbridge, Alberta, Canada T1J 3Z4

CITY OF LETHBRIDGE
STORM SEWER OUTLET NO. 3
PROJECT No. 1698
REPLACEMENT STRUCTURE
GENERAL ARRANGEMENT
PLAN, SECTIONS & DETAILS

PROJECT No.	FILE No.	DRAWING No.	ISS/REV
0112-195-00 Lethbridge, Alberta	L1433	001	0

DWG. No. 001
FILE No. L1433
D SIZE 22.00" x 34.00" (559mm x 864mm)



NOTES:

1. INCLUDE CORNER REINFORCING WITH MINIMUM LAP DISTANCES.

REV	Y	M	D	REVISION DESCRIPTION	DES	DRN	CHK	ENG	ENGINEER	PERMIT
0	95	10	05	FOR CONSTRUCTION	ICM	DMB	ICM	ICM	----	----

STAMPED & SIGNED BY

R.E.T. | ENGINEER | PERMIT

PROFESSIONAL ENGINEER ALBERTA

PERMIT TO PRACTICE
UMA ENGINEERING LTD.
Signature
Date Oct. 5/95
PERMIT NUMBER: P 329
The Association of Professional Engineers, Geologists and Geophysicists of Alberta.

UMA Engineering Ltd.
Engineers, Planners & Surveyors
2540 Kensington Road N.W., Calgary, Alberta, Canada T2N 3S3
514 Stafford Dr. N., Lethbridge, Alberta, Canada T1J 3Z4

CITY OF LETHBRIDGE
STORM SEWER OUTLET NO. 3
PROJECT No. 1698
REPLACEMENT STRUCTURE
STRUCTURAL
PLAN & SECTIONS

PROJECT No.	FILE No.	DRAWING No.	ISS/REV
0112-195-00 Lethbridge, Alberta	L1434	002	0

DWG. No. 002

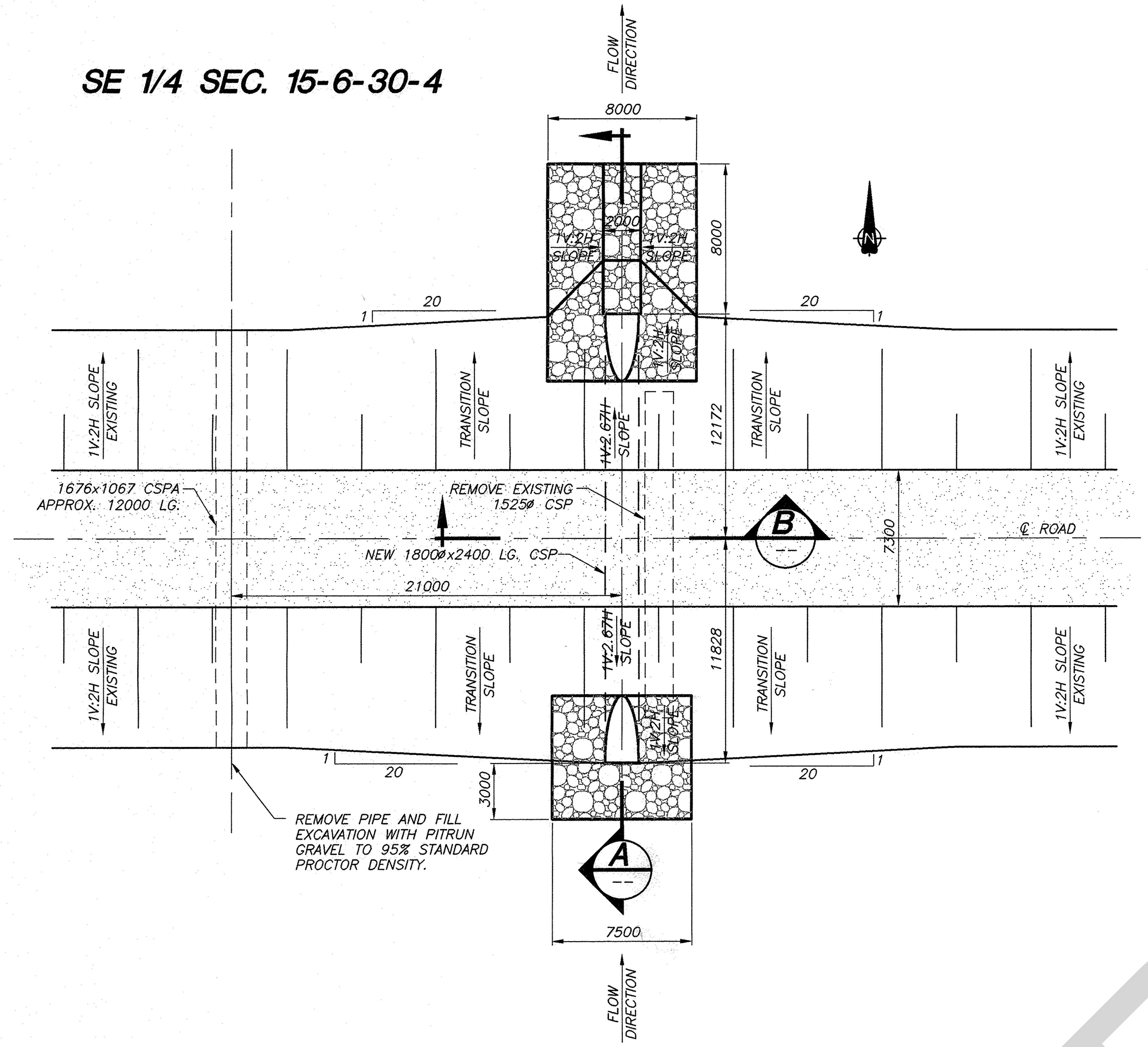
FILE No. L1434

D SIZE 22.00" x 34.00" (559mm x 864mm)

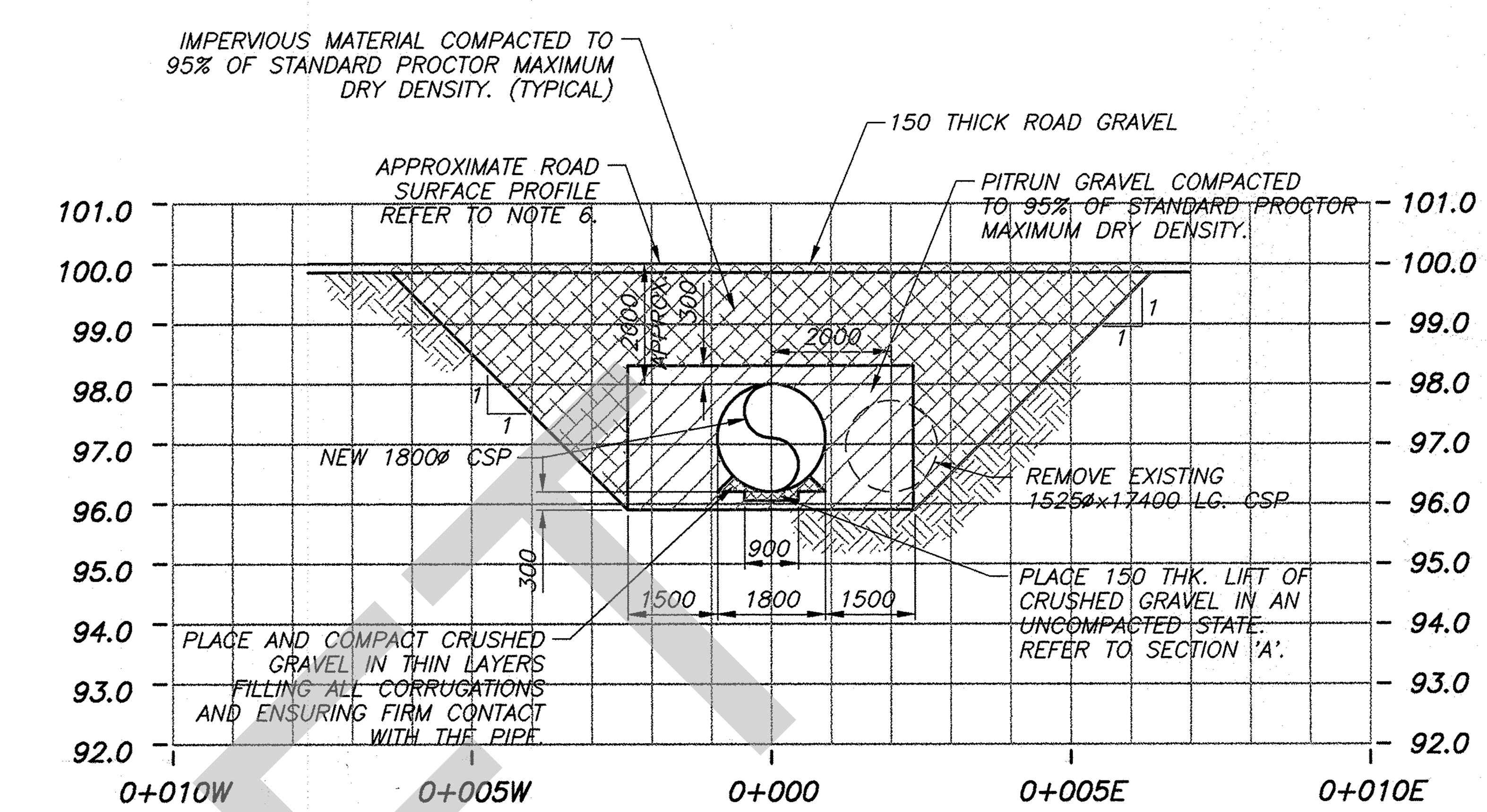
DWG. No. 001

FILE No. L1435

SE 1/4 SEC. 15-6-30-4

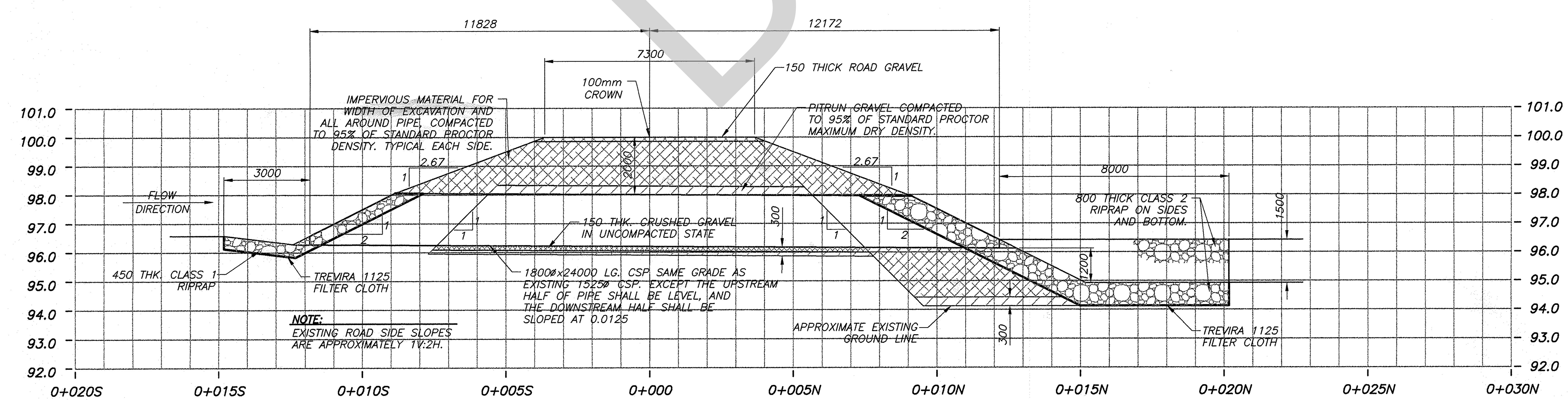


PLAN
1:200



SECTION B
1:100

NOTE:
ELEVATIONS ARE ASSUMED AND DO NOT RELATE TO ANY DATUM.



SECTION A
1:100

NOTES:

GENERAL

1. DIMENSIONS ARE GIVEN IN MILLIMETRES UNLESS NOTED OTHERWISE.

ASSEMBLY

1. CSP SECTIONS SHALL BE LAID SO THAT THE ENDS ARE IN CLOSE CONTACT. COUPLERS SHALL BE WELL FITTED & EVENLY TIGHTENED ALL AROUND THE PIPE. USE OAKUM FOR THE JOINT SEALANT.

BACKFILL

1. BACKFILL MATERIAL SHOWN IN THE LONGITUDINAL SECTION SHALL CONSIST OF GRANULAR MATERIAL. INORGANIC CLAYS SHALL FORM THE SEALS AT EACH END. BACKFILL MATERIAL SHALL BE NON–CORROSIVE & CONTAIN NO FROZEN MATERIAL, ROCKS EXCEEDING 80mm IN DIAMETER, ROOTS, SOD, RUBBISH OR ORGANIC MATERIAL.

2. GRANULAR MATERIAL SHALL MEET THE FOLLOWING GRADATION SPECIFICATIONS:

PIT RUN GRAVEL DESIGNATION 6, CLASS 80		CRUSHED GRAVEL DESIGNATION 2, CLASS 40	
µm SIEVE SIZE	% BY WEIGHT PASSING	µm SIEVE SIZE	% BY WEIGHT PASSING
80 000	100	40 000	100
50 000	55 – 100	16 000	55 – 85
25 000	38 – 100	10 000	44 – 74
16 000	32 – 85	5 000	32 – 62
5 000	20 – 65	1 250	17 – 43
315	6 – 30	630	12 – 34
80	2 – 10	315	8 – 26
		160	5 – 18
		80	2 – 10

3. PLACE & COMPACT STRUCTURAL FILL BY EQUIPMENT MOVING PARALLEL TO THE LONGITUDINAL AXIS OF THE PIPE WITH SIMULTANEOUS HANDWORK ALONG THE PIPE. OBTAIN ENGINEER'S APPROVAL BEFORE USING EQUIPMENT ABOVE OR ADJACENT TO THE PIPE.

4. HEAVY CONSTRUCTION EQUIPMENT & LARGE COMPACTION EQUIPMENT SHALL NOT BE PERMITTED WITHIN 1000mm OF THE PIPE.

5. PLACE & COMPACT PIT RUN GRAVEL SIMULTANEOUSLY IN LAYERS NOT EXCEEDING 150 WHEN COMPACTED. COMPACT TO A MINIMUM OF 95% STANDARD PROCTOR DENSITY AT OPTIMUM MOISTURE CONTENT. PLACE FILL SUCH THAT THE LEVEL ON ONE SIDE OF THE PIPE DOES NOT EXCEED THE LEVEL ON THE OTHER SIDE BY MORE THAN 300.

6. NEW ROAD SURFACE TO BE FINISHED TO SAME PROFILE AS ORIGINAL ROAD.

IMPERVIOUS CLAY SEALS (CLAY SEEPAGE CUTOFFS)

1. IMPERVIOUS CLAY SEALS SHALL BE PLACED AT EACH END OF THE PIPE. THE CLAY SEALS SHALL EXTEND TO 300 ABOVE THE CROWN OF THE PIPE AND FOR THE FULL WIDTH OF THE EXCAVATION. PLACE CLAY MATERIAL IN 150mm THICK LAYERS, AND COMPACT TO 95 PERCENT OF STANDARD PROCTOR DENSITY.

ROCK RIPRAP

1. ROCK RIPRAP SHALL COVER THE AREA SHOWN & SHALL BE PLACED TO THE FOLLOWING MINIMUM THICKNESS:

CLASS OF ROCK	1	2
THICKNESS (mm)	450	800

2. PLACE TREVIRA 1125 NON–WOVEN GEOTEXTILE FILTER FABRIC UNDER ALL ROCK RIPRAP.

REV	Y	M	D	REVISION DESCRIPTION	DES	DRN	CHK	ENG	ENGINEER (STAMPED & SIGNED BY)	PERMIT (STAMPED & SIGNED BY)
0	95	10	31	ISSUED FOR TENDER	ICM	GRC	ICM	ICM	I. MARTENS	

R.E.T. | ENGINEER | PERMIT

UMA Engineering Ltd.
Engineers, Planners & Surveyors
2540 Kensington Road N.W., Calgary, Alberta, Canada T2N 3S3
514 Stafford Dr. N., Lethbridge, Alberta, Canada T1J 3Z4

MUNICIPAL DISTRICT OF PINCHER CREEK
1995 FLOOD RECONSTRUCTION
SITE 91
SE 1/4 SEC. 15-6-30-4
PLAN AND SECTIONS

PROJECT No.	FILE No.	DRAWING No.	ISS/REV
0678–043–00 Lethbridge, Alberta	L1435	001	0

D SIZE 22.00" x 34.00" (559mm x 864mm)
Thu Nov 9 15:48:44 1995

APPENDIX II

Site Photographs

Photograph 1 Looking Upstream (west) to Project Limit at Location 1

Photograph 2 Looking Downstream (east) at Location 1

Photograph 3 Looking Upstream at Location 2

Photograph 4 Looking downstream at Location 2

Photograph 5 Looking Upstream at Location 3 - Community Centre

Photograph 6 Looking Downstream Towards Footbridge at Location 3 – Community Centre

Photograph 7 Looking Downstream at Footbridge by Community Centre at Location 4

Photograph 8 Looking upstream from the Footbridge at Location 4

Photograph 9 Looking at Gabion Basket Protection Upstream of Beaver Drive Bridge at Location 5

Photograph 10 Beaver Drive Bridge at Location 5

Photograph 11 Beaver Drive Bridge and Revetment on Right Bank at Location 5

Photograph 12 Hewetson Avenue Bridge at Location 6

Photograph 13 Pincher Creek Main Channel Downstream Hewetson Avenue Bridge at Location 7

Photograph 14 Flood Berm on Left Bank Downstream of Hewetson Avenue Bridge at Location 8

Photograph 15 Bev McLachlin Drive Bridge, Looking Upstream from Location 9

Photograph 16 Pincher Creek Looking Upstream from Bev McLachlin Drive Bridge, Location 10

Photograph 17 Pincher Creek Looking Downstream from Bev McLachlin Drive Bridge, Location 10

Photograph 18 Footbridge at Location 11

Photograph 19 Pincher Creek looking upstream at Location 12

Photograph 20 Pincher Creek Looking Downstream at Location 12

Photograph 21 Berm and Culvert at End of Church Avenue at Location 13

Photograph 22 Pincher Creek and Flood Berm on Right Bank, Looking Downstream at Location 13

Photograph 23 Pincher Creek Campground Looking Upstream from Location 14

Photograph 24 Highway 6 Bridge, Looking Downstream from Location 15

Photograph 25 Pincher Creek at Location 16, Looking Upstream

Photograph 26 Pincher Creek at Location 16

Photograph 27 Pincher Creek, Looking Downstream at Location 16

Photograph 28 Pincher Creek and Kettles Creek Confluence at Location 17

Photograph 29 Pincher Creek Upstream of Kettles Creek Confluence at Location 17

Photograph 30 Pincher Creek Looking Downstream Towards Kettles Creek Confluence, Location 17

Photograph 31   Kettles Creek Discharging into Pincher Creek at Location 17

Photograph 32   Pincher Creek Beaver Dam upstream of Hwy 785 Bridge, Location 18

Photograph 33 Highway 785 Bridge over Pincher Creek at Location 18

Photograph 34 Pincher Creek downstream of HWY 785 Bridge, Location 18

Photograph 35 Pincher Creek, Looking Upstream to Hwy 785 Bridge from Location 19

Photograph 36 Indianfarm Creek and Pincher Creek Confluence, Location 19

Photograph 37 Pincher Creek, Looking downstream towards Project Boundary, Location 19

Photograph 38 Kettles Creek at Upstream Project Limit, Location 20

Photograph 39 Upper Reach of Kettles Creek, looking downstream, Location 21

Photograph 40 Pipe Arch Culvert under Township Road 302, Location 22

Photograph 41 Kettles Creek Upstream of Township Road 302, Location 22

Photograph 42 Kettles Creek through Golf Course, Looking Upstream from Location 23

Photograph 43 Kettles Creek through Golf Course, Looking Downstream from Location 23

Photograph 44 Highway 6 Bridge over Kettles Creek at Location 24

Photograph 45 Main Street Bridge over Kettles Creek at Location 25

Photograph 46 Kettles Creek Downstream of Main Street Bridge, Location 25

Photograph 47 Highway 785 Crossing of Kettles Creek, at location of Gauging Station, Location 26

Photograph 48 Township Road 301 Bridge Over Kettles Creek, Location 27

Photograph 49 Kettles Creek Upstream of Township Road 301 Bridge, Location 27

Photograph 50 Kettles Creek Downstream Township Road 301 Bridge, Location 27

Photograph 51 Kettles Creek Near Pincher Creek Confluence, Looking Upstream from Location 28

Photograph 52 Kettles Creek Near Pincher Creek Confluence, Location 28 Looking Downstream

Photograph 53 Kettles Creek at Pincher Creek Confluence (also see Photograph 30) at Location 29

APPENDIX III

Hydrology Memorandum

Klohn Crippen Berger

Alberta Environment and Parks

Pincher Creek Flood Hazard Study

Hydrology Memorandum

March 2020

Alberta Environment and Parks

Pincher Creek Flood Hazard Study

Hydrology Memorandum

Klohn Crippen Berger

March 2020

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

List of Tables

List of Figures

TABLE OF CONTENTS
(continued)

List of Appendices

TABLE OF CONTENTS

(continued)

Acronyms and Abbreviations

AD	Anderson-Darling Test
AE	Alberta Environment
AEP	Alberta Environment and Parks
AIC	Akaike Information Criterion
AT	Alberta Transportation
BIC	Bayesian Information Criterion
DFASCC	Data and Frequency Analysis Spreadsheet for The City of Calgary
ESRI	Environmental Systems Research Institute
FHIP	Flood Hazard Identification Program
KCB	Klohn Crippen Berger Ltd.
KS	Kolmogorov-Smirnov Test
NDMP	National Disaster Mitigation Program
NERC	National Environment Research Council
USGS	US Geological Survey
WSC	Water Survey of Canada

1 INTRODUCTION

1.1 Objective

Alberta Environment and Parks (AEP) retained Klohn Crippen Berger Ltd. (KCB) to conduct a flood hazard study for Pincher Creek and Kettles Creek. The purpose of the study is to assess and identify flood hazards along Pincher Creek and Kettles Creek through the Town of Pincher Creek and adjacent areas in the Municipal District of Pincher Creek No. 9. The study reaches are shown on Figure 1.1.

Flood frequency estimates for Pincher Creek and Kettles Creek were derived by Alberta Environment (AE 1993) for a previous floodplain mapping study. The additional period of record now available, including the flood of record on Pincher Creek in 1995, merit an update to the flood estimates.

This hydrology assessment memorandum is submitted as part of the scope to summarize the hydrology analyses and results pertinent to the hydraulic modelling and flood mapping. This memo describes the data collection and review, as well as the flood frequency analysis to estimate peak discharges for flood events ranging from the 2-year to the 1000-year floods. In addition, commentary on the potential impacts of climate change is also included.

1.2 Overview

For Pincher Creek itself, the 76 years of available record were used in a single-station frequency analysis. For Kettles Creek, which has a comparatively short record, and Indianfarm Creek which has no hydrometric station, flood frequency estimates were obtained through a regional analysis.

Flood frequency analyses focused on the annual maximum instantaneous discharge (hereafter “peak discharge”). The annual maximum daily mean discharges (hereafter “maximum daily discharges”) and peak discharges for Pincher Creek and Kettles Creek were collected and reviewed. Gaps in the maximum daily discharge data series for the Pincher Creek station were filled by correlation with data from nearby stations. The completed maximum daily discharge dataset was then used to fill the gaps in the peak discharge data series, which was then used for flood frequency analysis.

The analysis followed guidance published by:

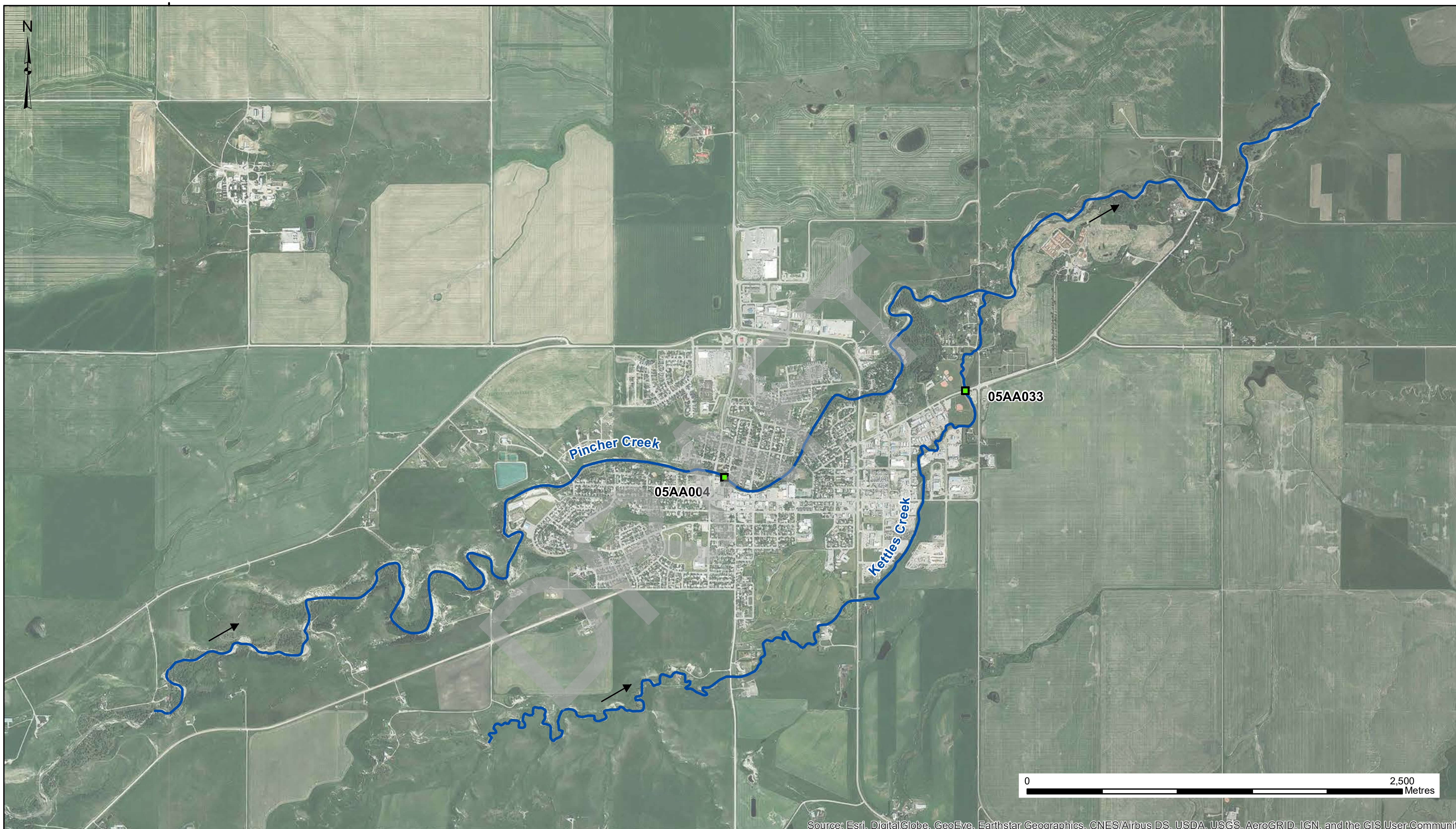
- FHIP (AE 2011);
- Alberta Transportation (AT 2001); and
- US Geological Survey (USGS 2019).

A climate change commentary is also included in this memorandum.

1.3 Watershed Description

The watershed contributing to the study reaches is divided into three catchments as shown on Figure 1.2. The largest catchment, Pincher Creek, has a high proportion of mountain and foothill terrain as shown by the contours on Figure 1.2. A small downstream portion of the Pincher Creek catchment is flatter agricultural land. The Kettles Creek catchment, located east of Pincher Creek, is mainly prairie terrain with agricultural land-use and short grassland. The Indianfarm Creek catchment is similar in size to Pincher Creek but is mostly prairie terrain with a small proportion of the catchment in the foothills.

Figure 1.2 shows the locations of the two key hydrometric stations for the project. Hydrometric station Pincher Creek at Pincher Creek, Water Survey of Canada (WSC) Station Number 05AA004, is located approximately 3.3 km upstream of the confluence with Kettles Creek. Hydrometric station Kettles Creek at Pincher Creek, 05AA033, is located less than 1 km above the confluence with Pincher Creek. Indianfarm Creek is ungauged and enters Pincher Creek about 2.5 km downstream of the confluence with Kettles Creek.



NOTES:

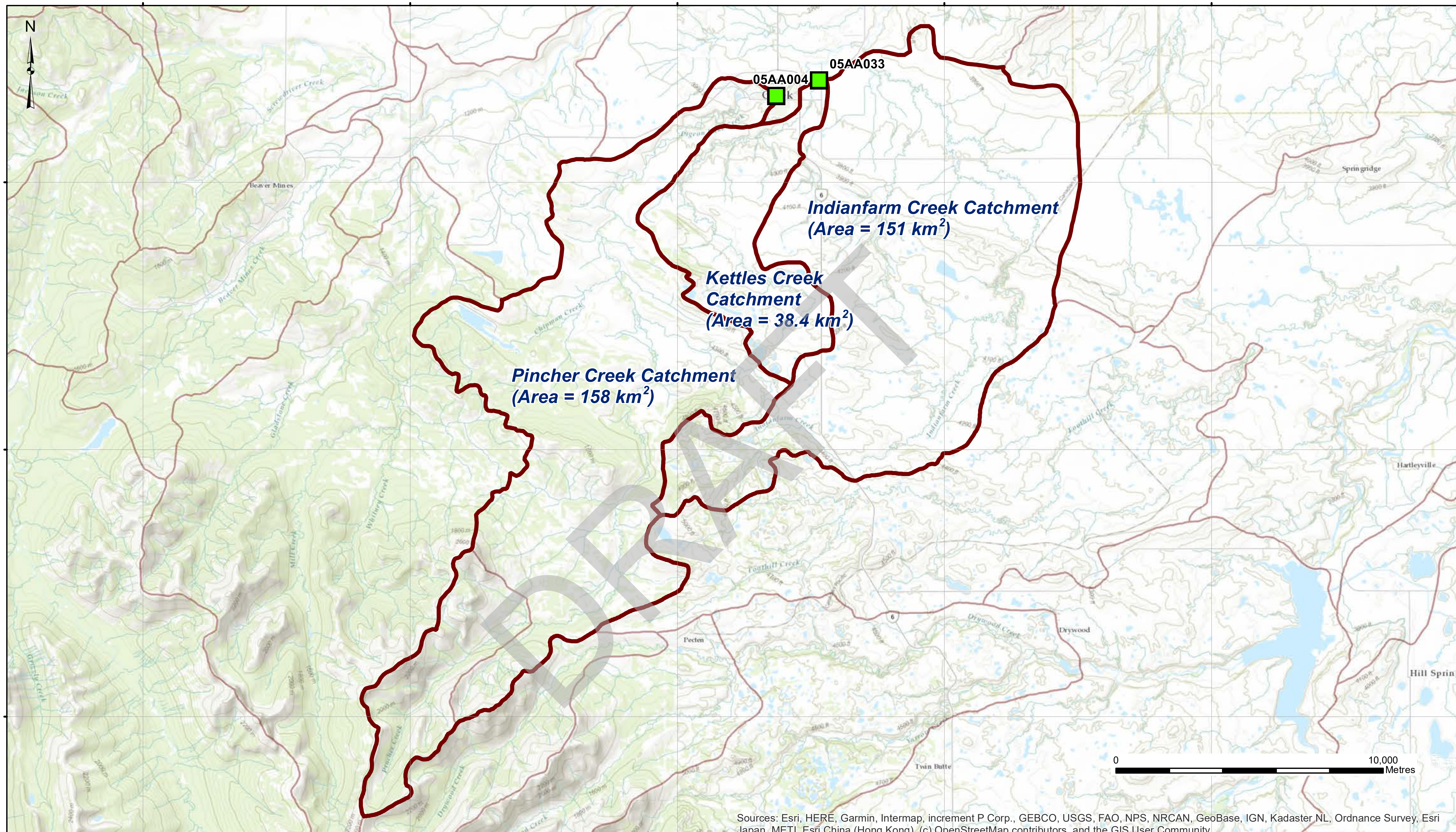
1. HORIZONTAL DATUM: NAD 83
2. GRID ZONE: CSRS 3TM 114
3. Source:
   Basemap: ESRI Digital Globe. World Topographic Map
   Study Reaches: Alberta Environment and Parks

LEGEND

- Hydrometric Station
- Pincher Creek Study Reaches
- Flow Direction

CLIENT	PROJECT		
Alberta Government	PINCHER CREEK FLOOD HAZARD STUDY		
Klohn Crippen Berger	TITLE: STUDY AREA		
	SCALE 1:25,000	PROJECT No. A03285C13	FIG No. 1.1

File: \\int.klohn.com\Proj\Data\ACGY\Alberta\A03285C13 AEP Pincher Creek Fld Hazard St\400 Drawings\02 Open Water Hydrology Assessment\Fig1.1_Study_Area.mxd Date: June 28, 2019 Time: 11:38:28 AM Creator: rbermundo



NOTES:

1. HORIZONTAL DATUM: NAD 83
2. GRID ZONE: CSRS 3TM 114
3. Source:
   Catchment Boundary: AAFC Watershed Projects 2012, Open Government Licence - Canada
   Basemap: ESRI Digital Globe. World Topographic Map

LEGEND

Hydrometric Station

Gross Catchment Boundary

CLIENT	PROJECT
Alberta Government	PINCHER CREEK FLOOD HAZARD STUDY
Klohn Crippen Berger	TITLE: PINCHER CREEK WATERSHED

SCALE	PROJECT No.	FIG No.
1:140,000	A03285C13	1.2

File: Z:\ACGY\Alberta\A03285C13 AEP Pincher Creek Fld Hazard S\400 Drawings\02 Open Water Hydrology Assessment\Fig1.2_PincherCrk_KettlesCrk.mxd Date: June 28, 2019 Time: 11:42:18 AM Creator: : vcastillo

2 HYDROMETRIC DATA ASSEMBLY

2.1 Approach

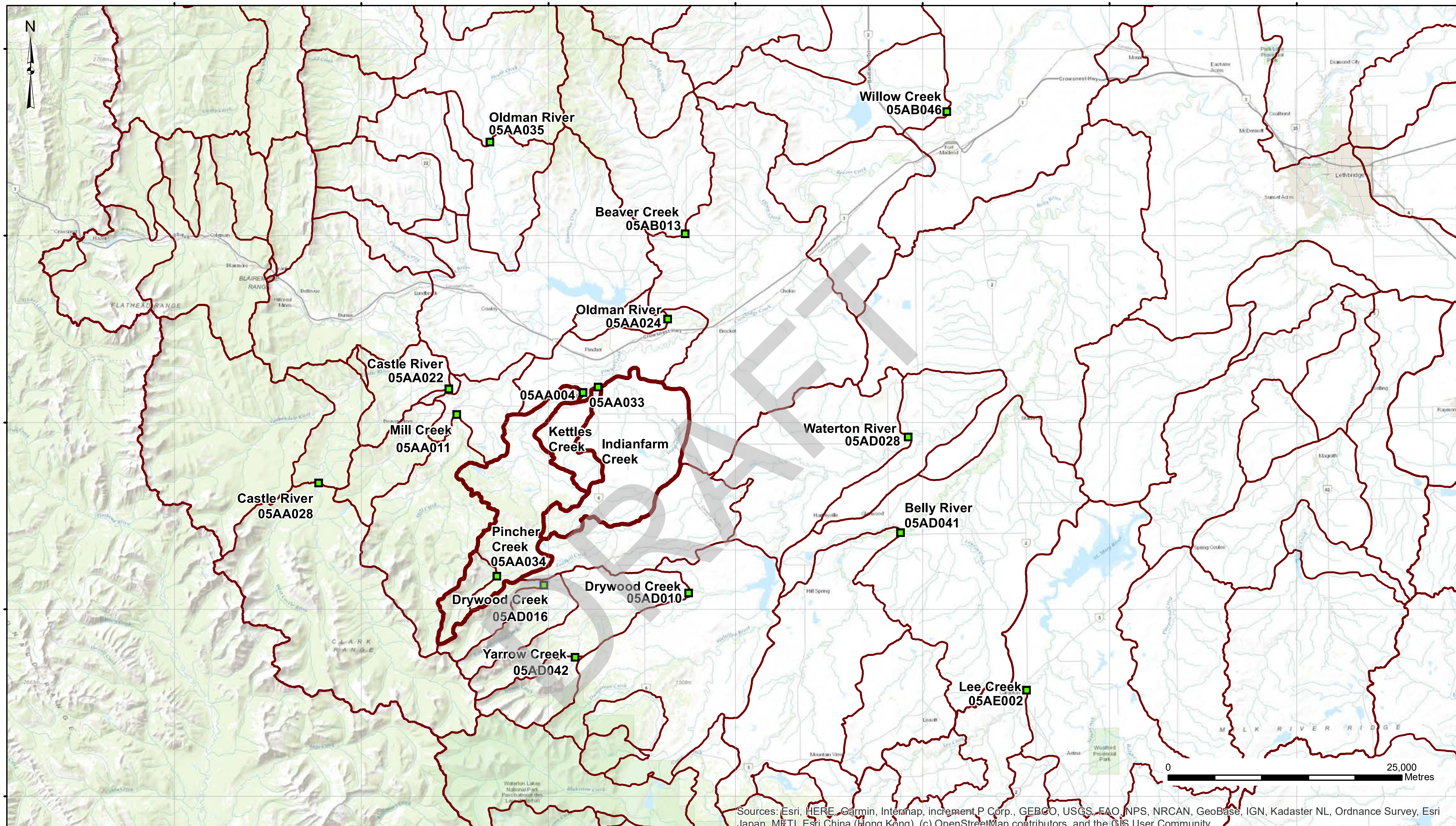
The following sections describe the assembly of available data, including review, consolidation and extension of the data series, in preparation for the frequency analyses described in Section 3.

2.2 Available Data

Historical discharge information has been collected at several locations around the study area as summarized in Table 2.1. Monitoring locations are shown on Figure 2.1. Periods of record for each station are illustrated on Figure 2.2.

Table 2.1 Selected Regional Hydrometric Stations

Station Number	Station Name	Natural or Regulated	Drainage Area (km^2)	
			Gross	Effective
05AA024	Oldman River near Brocket	Regulated	4400	4380
05AB046	Willow Creek at Highway No.811	Regulated	2510	2170
05AA035	Oldman River at Range Road No.13A	Natural	1830	1830
05AD028	Waterton River near Glenwood	Regulated	1630	1540
05AA022	Castle River near Beaver Mines	Natural	821	821
05AD041	Belly River near Glenwood	Regulated	653	538
05AA028	Castle River at Ranger Station	Natural	375	375
05AE002	Lee Creek at Cardston	Regulated	316	316
05AB013	Beaver Creek near Brocket	Natural	256	256
05AD010	Drywood Creek near the Mouth	Regulated	239	227
05AA011	Mill Creek near the Mouth	Natural	179	179
05AA004	**Pincher Creek at Pincher Creek**	**Natural**	**158**	**158**
05AD042	Yarrow Creek at Spread Eagle Road	Natural	47.9	47.9
05AA033	**Kettles Creek at Pincher Creek**	**Natural**	**38.4**	**36.9**
05AD016	Drywood Creek near Twin Butte	Natural	29.3	29.3
05AA034	Pincher Creek at Front Range Road	Natural	24	24



NOTES:

1. HORIZONTAL DATUM: NAD 83
2. GRID ZONE: CSRS 3TM 114
3. Source:
   Catchment Boundary: AAFC Watershed Projects 2012, Open Government Licence - Canada
   Basemap: ESRI Digital Globe. World Topographic Map

LEGEND

- Hydrometric Station
- Gross Catchment Boundary

CLIENT	PROJECT
Alberta Government	PINCHER CREEK FLOOD HAZARD STUDY
Klohn Crippen Berger	TITLE: SELECTED REGIONAL HYDROMETRIC STATIONS

SCALE	PROJECT No.	FIG No.
1:400,000	A03285C13	2.1

File: \\int.klohn.com\Proj\Data\ACGY\Alberta\A03285C13 AEP Pincher Creek Fld Hazard St\400 Drawings\02 Open Water Hydrology Assessment\Fig2.1_Regional_Hydrometric_Stations.mxd Date: June 26, 2019 Time: 16:42:34 PM Creator: rbermundo

Figure 2.2 Available Record at Nearby Hydrometric Stations

Station Number	Station Name	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010
05AA033	Kettles Creek At Pincher Creek												
05AA004	Pincher Creek At Pincher Creek												
05AD016	Drywood Creek Near Twin Butte												
05AA034	Pincher Creek at Front Range Road												
05AA028	Castle River At Ranger Station												
05AA011	Mill Creek Near The Mouth												
05AA022	Castle River Near Beaver Mines												
05AA035	Oldman River At Range Road No. 13A												
05AA024	Oldman River Near Brocket												
05AB013	Beaver Creek Near Brocket												
05AB046	Willow Creek at Highway No.811												
05AD042	Yarrow Creek At Spread Eagle Road												
05AD010	Drywood Creek Near The Mouth												
05AD041	Belly River Near Glenwood												
05AD028	Waterton River Near Glenwood												
05AE002	Lee Creek At Cardston												

Legend

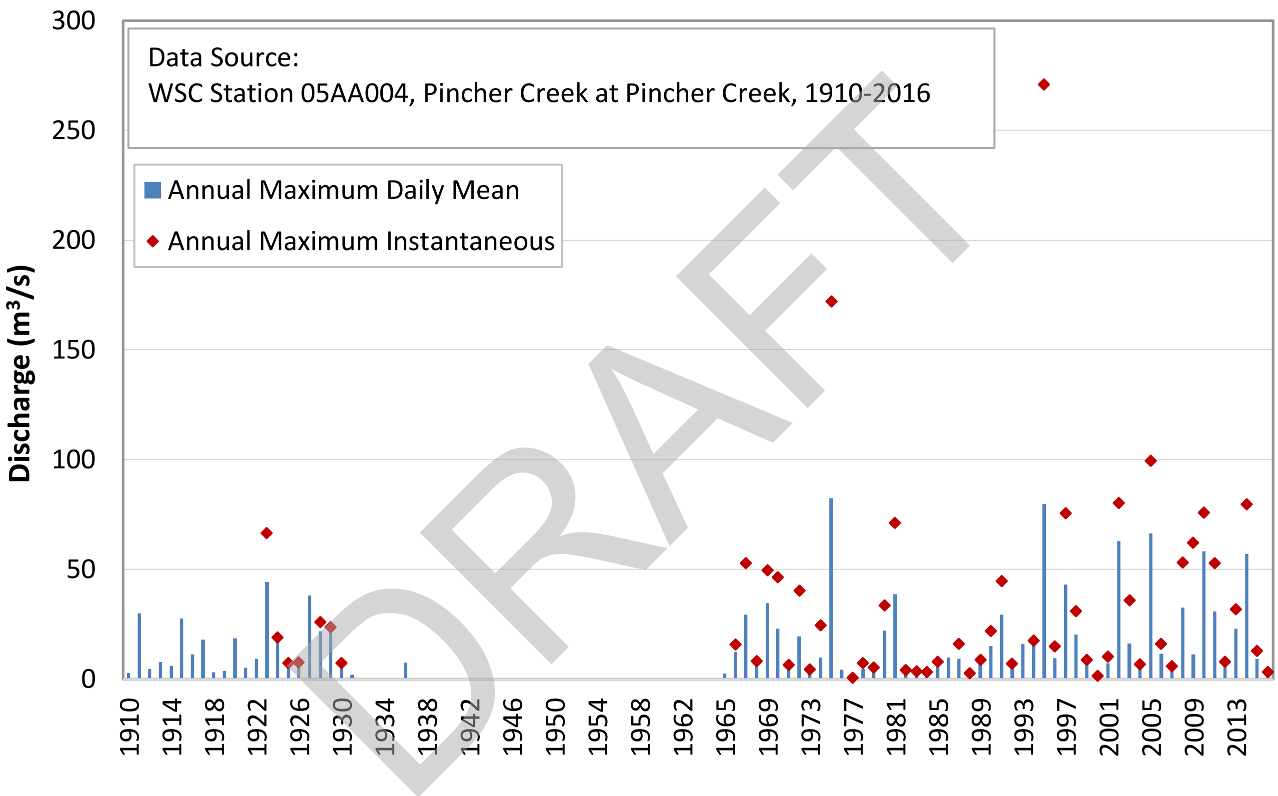
Annual (more than 300 days of record)
Seasonal (more than 210 days of record)
Partial (less than or equal to 210 days of record)

2.3 Pincher Creek at Pincher Creek

2.3.1 Flood Record

Discharge data for Pincher Creek from 1910 to 2016 is published by Water Survey of Canada (WSC) and formed the basis of the flood frequency analysis. The available data includes 76 years with recorded maximum daily discharge, and 55 years of recorded peak discharge, within that period. The data is shown on Figure 2.3.

Figure 2.3 Pincher Creek at Pincher Creek Flood History

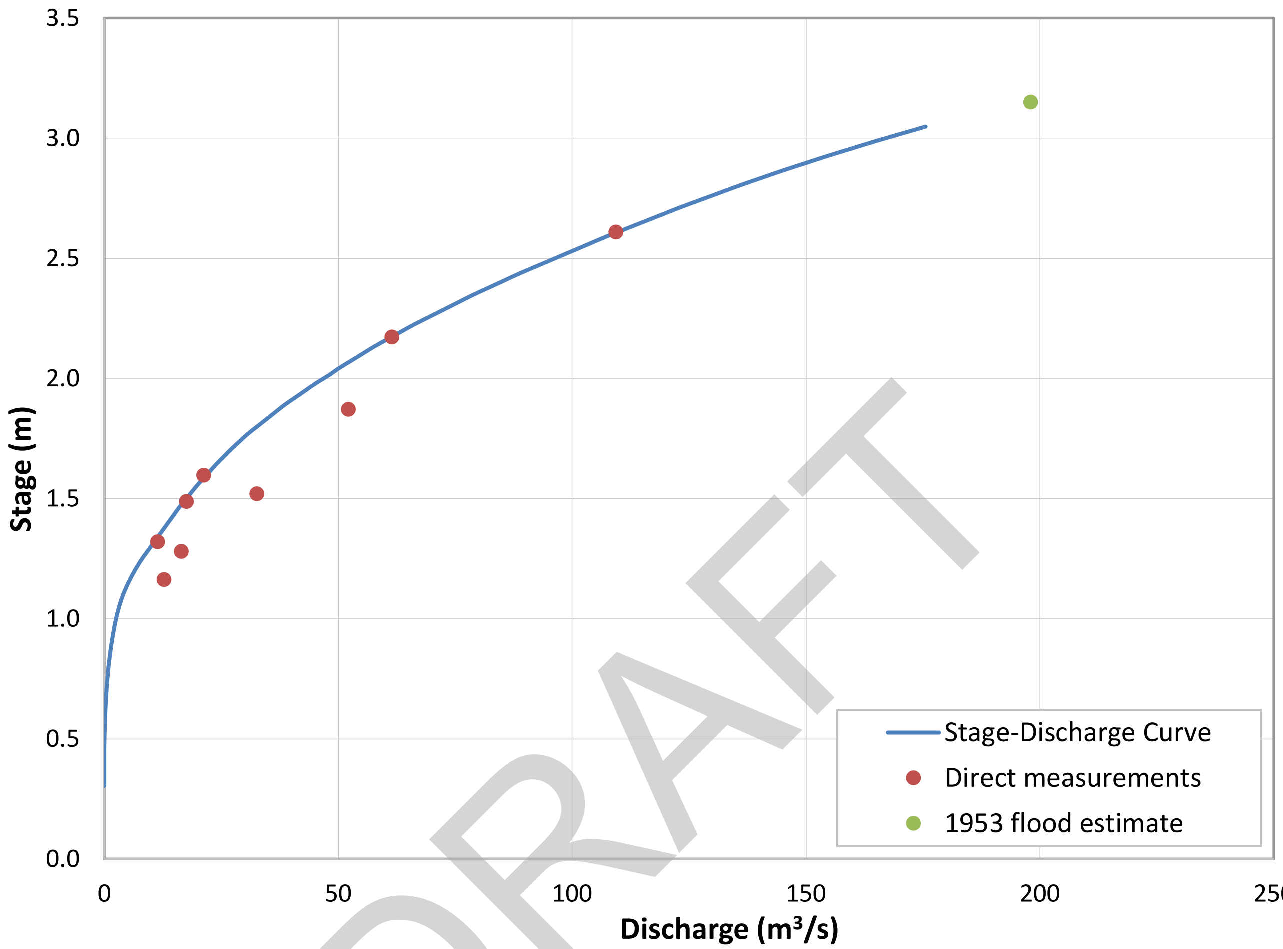


The flood of record occurred in June 1995, with a peak discharge of 271 m^3/s and a maximum daily discharge of 79.9 m^3/s, during a widespread rainstorm that produced major floods in many southern Alberta streams.

The second highest flood, in June 1975, had a slightly higher maximum daily discharge, 82.4 m^3/s, but a substantially lower peak discharge, 172 m^3/s, than the 1995 event.

A third significant flood event occurred in Pincher Creek on June 9th, 1953 (Environment Canada 1963), outside of the systematic record for Pincher Creek. AE (1980) estimated that the flood peak was 198 m^3/s based on a reported stage between 3.1 m and 3.2 m. AE used Rating Curve #8 (dated January 06, 1976) to estimate the discharge, as shown on Figure 2.4. The AE (1980) estimate of 198 m^3/s was included in the series of peak discharges in Pincher Creek.

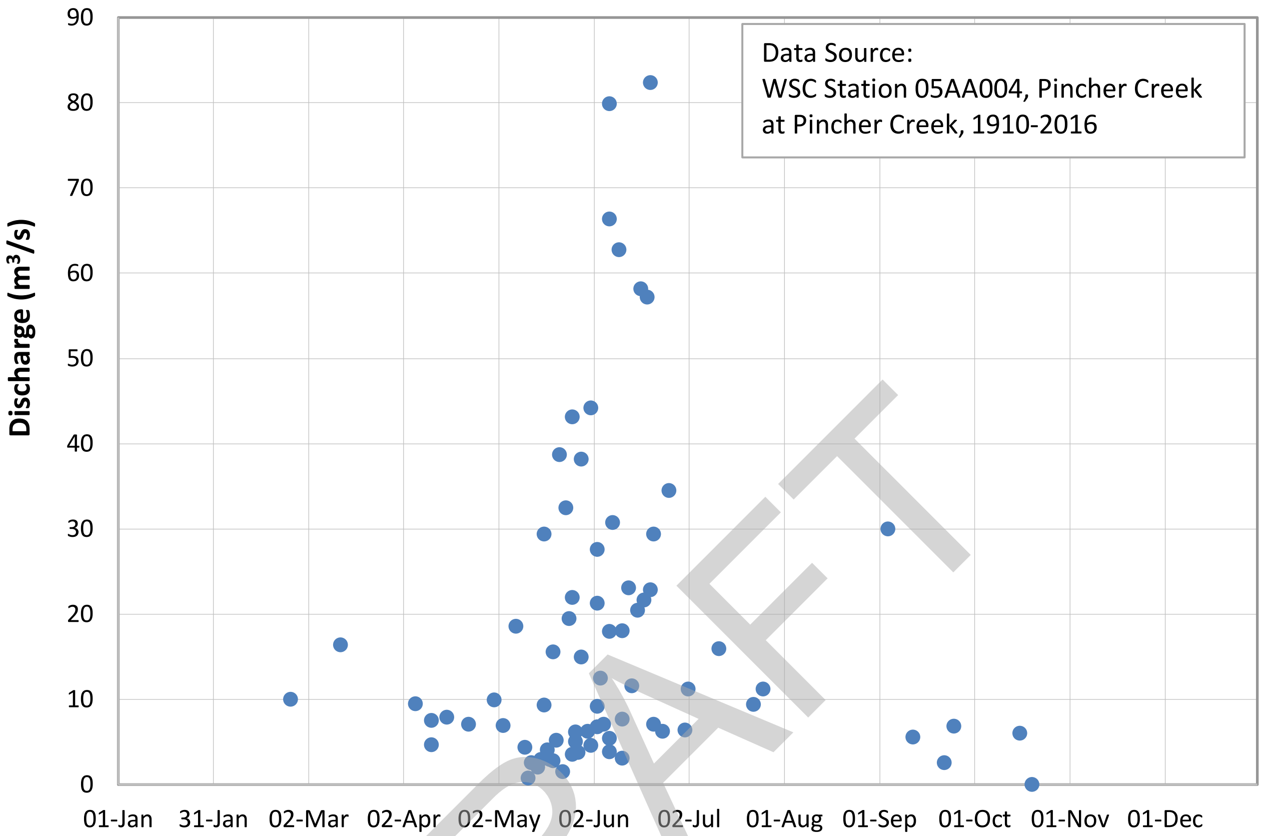
Figure 2.4 Stage Discharge Curve #8 for Pincher Creek (Dated 1976)



2.3.2 Flood Seasonality

Most of the maximum daily discharges in Pincher Creek, including all of the floods over 30 m^3/s, have occurred in early summer. High discharges in spring and autumn have been less frequent and less severe, as shown on Figure 2.5. For the current analysis, all of the maximum discharges were treated as a single population. See Section 3.1 for homogeneity test results to support this decision.

Figure 2.5 Seasonality of Maximum Daily Discharge at Pincher Creek



2.3.3 Data Quality

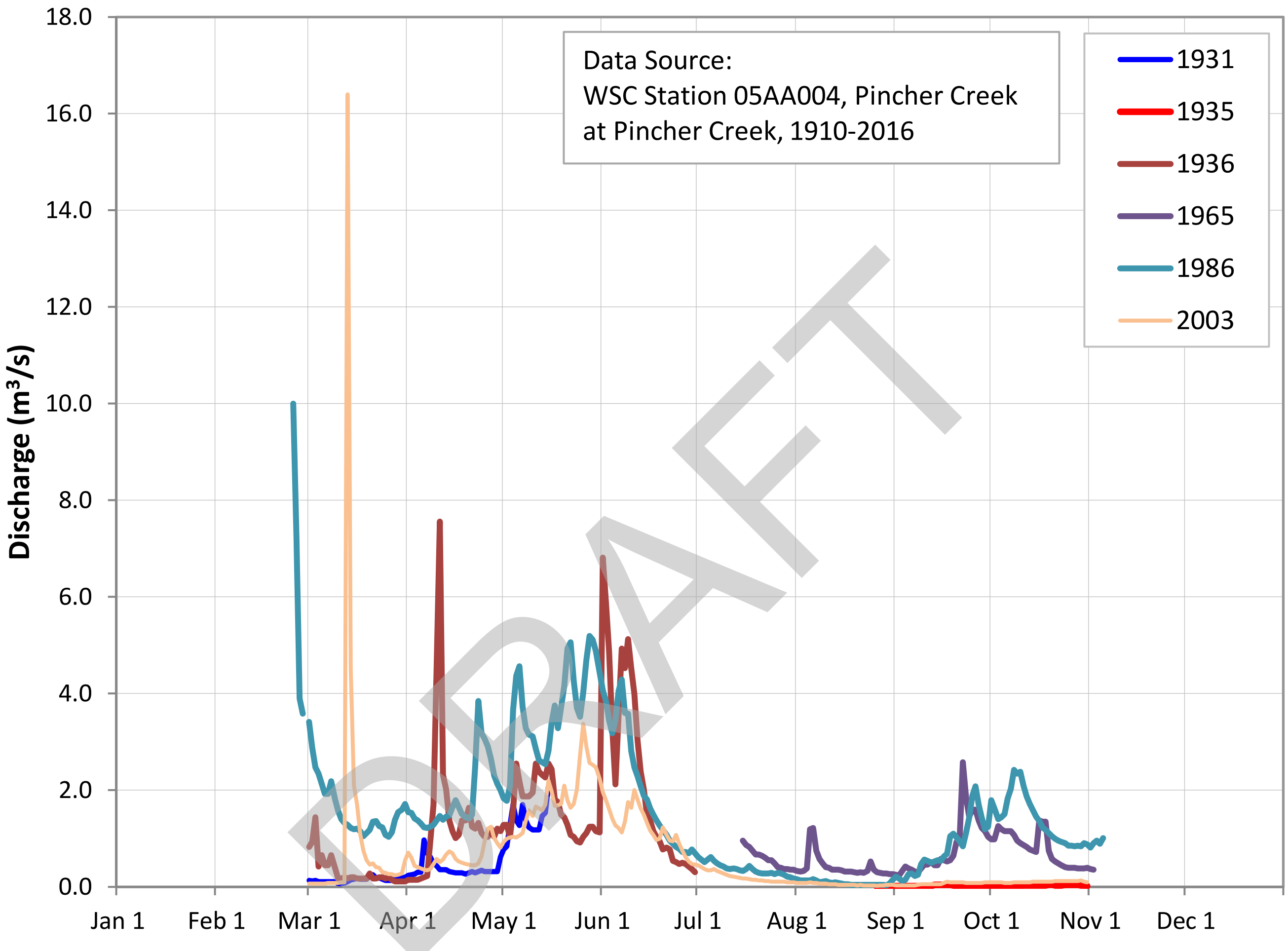
The hydrometric data was examined to confirm whether the WSC record had captured the maximum daily discharge, focusing on years with short data records or years with maximum daily discharge occurring in winter. Data for years 1931, 1935, 1936 and 1965 are shown on Figure 2.2 as light blue, which means there are less than 210 days of record. The 1986 and 2003 maximum daily discharge events occurred in February and March and are shown on Figure 2.5. The March 2003 event was classified as an "ice condition" event by WSC whereas the February 1986 event was not.

The hydrographs for the years mentioned above were plotted to evaluate if the maximum daily discharge is captured in the available dataset. This information is shown on Figure 2.6. The data from 1936 and 2003 appears to have captured the peak, but the hydrographs for 1931, 1935, 1965 and 1986 suggest that the peak was not recorded.

The maximum daily discharge for 1986 and 2003 was checked against the published historical climate data from WSC. In both years, there was an abrupt rise in temperature which could cause snow melt initiating the sudden change in discharge. A review of the historical climate data from WSC for the year 1936 confirmed that there was no significant precipitation after the end of the hydrograph.

Based on the above information, the maximum daily discharges from 1936 and 2003 were evaluated to be reliable data, and data for years 1931, 1935, 1965 and 1986 were discarded from the observed record as the peaks were not captured.

Figure 2.6 Discharge Hydrograph for Pincher Creek at Pincher Creek



2.3.4 WSC Rating Curve Review

Stage-discharge curves used by WSC to derive the discharge record at Pincher Creek were reviewed to confirm whether the extrapolated rating curves gave reasonable estimates of the high flood discharges. The stage-discharge rating curves and historical direct measurements for the station were provided by WSC. The rating curves used for the 1995 and 2005 floods (two large floods on recent record) were plotted, with the direct measurements used to derive the rating curves shown on Figure 2.7 and Figure 2.8. The 1995 peak flood discharge of 271 m^3/s, calculated by WSC using the slope-area method, dominates the stage-discharge curve estimate for Rating Curve #15 (used in 1995 – 1996, see Figure 2.7), and provides some confidence in the upper portion of the curve. Rating Curve #20 was used to estimate the peak discharge in the 2005 event. This rating curve is less well supported by measurements, with the highest direct measurement of 53.3 m^3/s compared to the reported peak of 99.5 m³/s. Although there is some uncertainty in the rating curve extrapolation, the reported discharge was accepted for the analysis.

Figure 2.7 Stage Discharge Curve #15 for Pincher Creek (1995 to 1996)

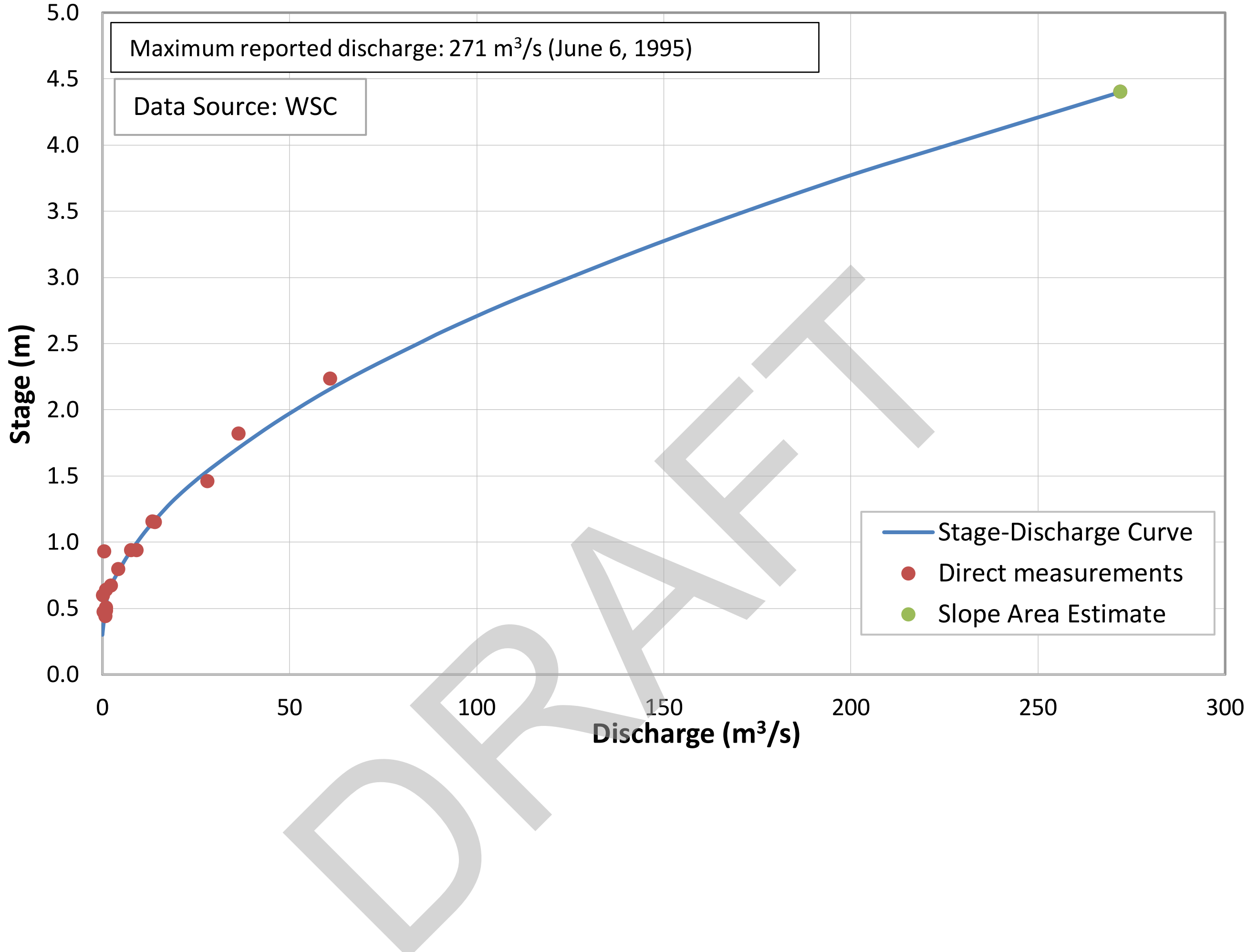
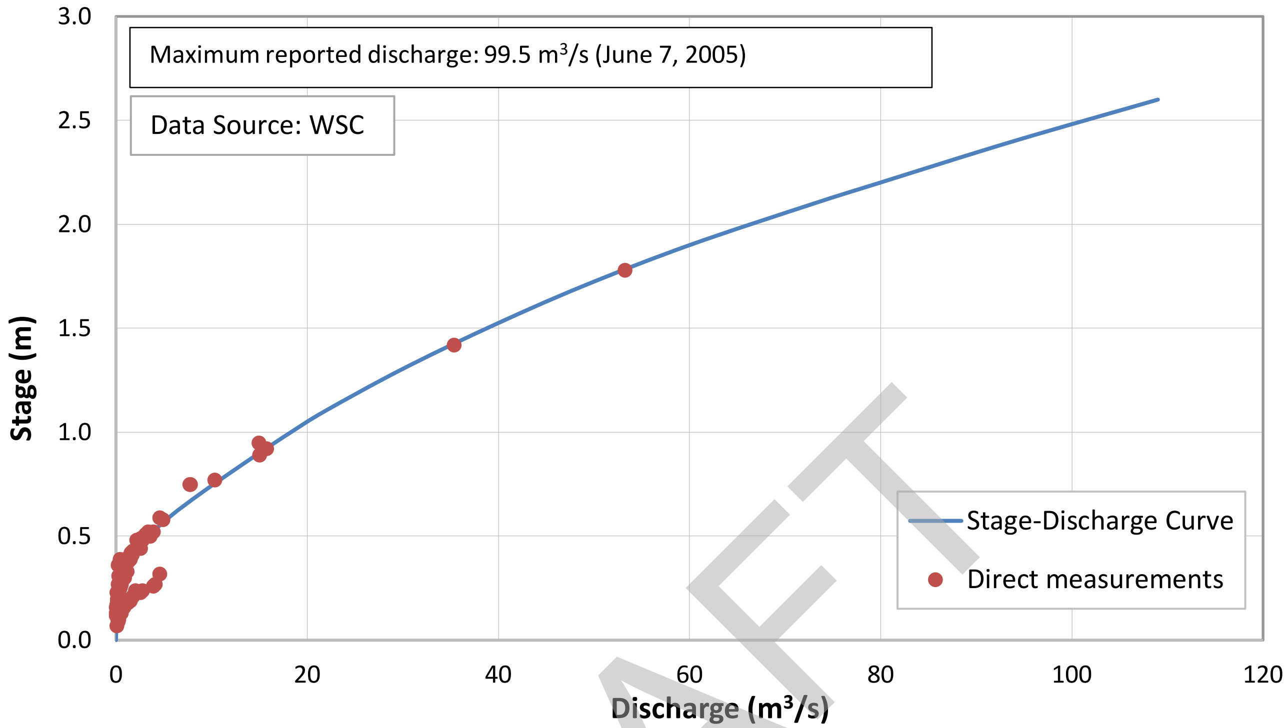


Figure 2.8 Stage Discharge Curve #20 for Pincher Creek (2005 to Current)

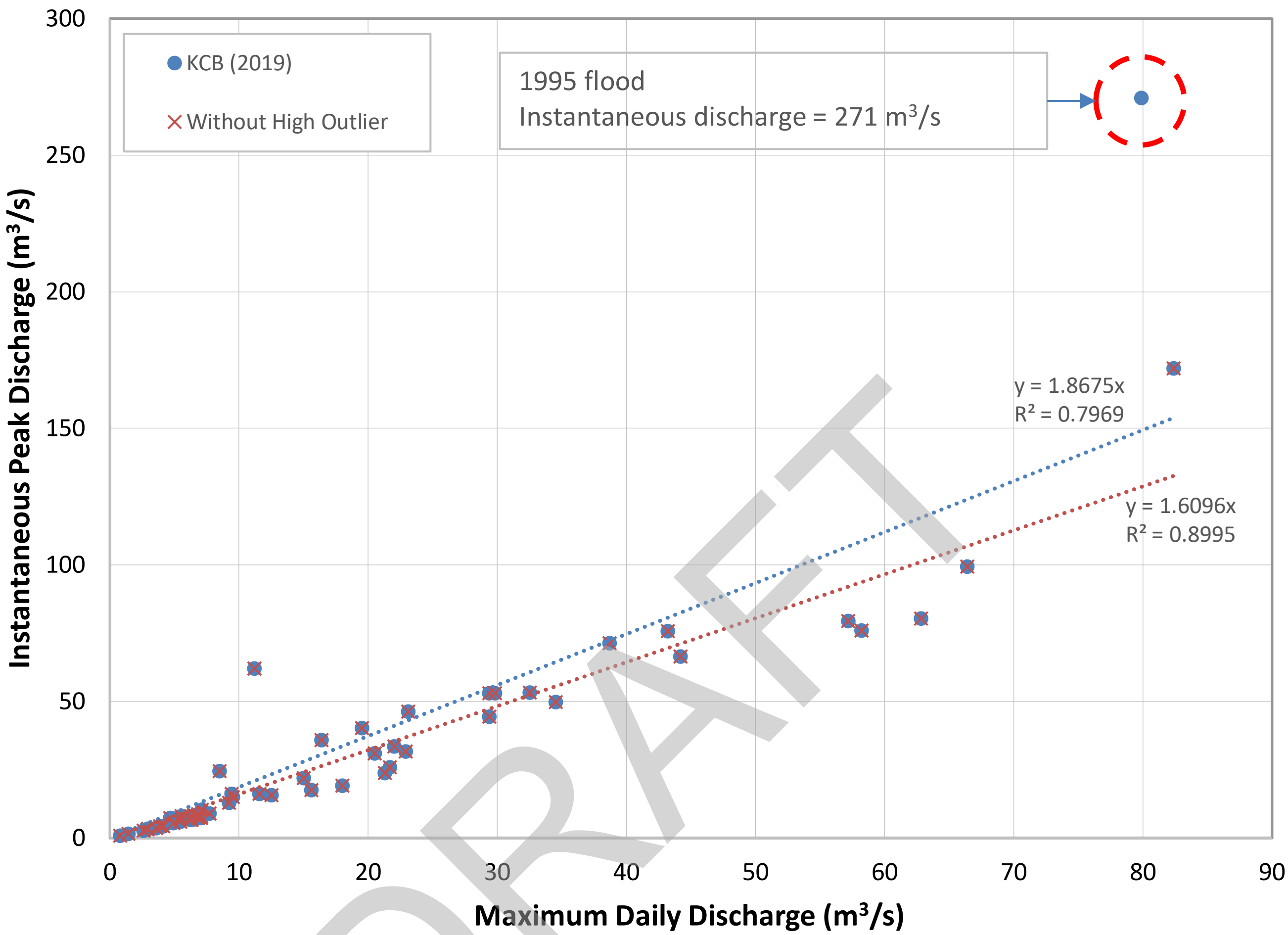


2.3.5 Estimation of Missing Peak Discharges

FHIP (2011), AT (2001) and USGS (2019) guidelines indicate that frequency analyses should preferably be conducted using peak discharges if there are only a few missing peak data. For Pincher Creek, the peak record is 72% complete (55 of 76 years), so the analysis was conducted with peak discharge data.

Missing peak discharges were estimated by correlation between peak and same-event daily discharges, in accordance with the AT (2001) guidelines. For years 1930, 1974, 1979, 1992, 2000, 2011 and 2016, the maximum daily and peak discharges in the WSC record did not represent the same event. The maximum daily discharge for these years was replaced with the highest daily mean discharge that occurred within 1 day of the peak discharge. Two resulting peak – same event daily mean discharge correlations are shown on Figure 2.9. The first includes the 1995 event, the second excludes this event.

Figure 2.9 Peak vs. Same-Event Daily Discharge at Pincher Creek



When plotting the peak versus daily discharge relationship for Pincher Creek, the 1995 peak discharge falls well above the trend of the rest of the data, as shown on Figure 2.9. It is concluded that the 1995 flood was anomalous in terms of the peak – daily ratio. Excluding the 1995 event reduced the slope of the correlation line and improved the peak vs. daily discharge correlation from an R^2 of 0.80 to a R^2 of 0.90, as shown on Figure 2.9. The relationship without the 1995 event was used to fill the missing values in the peak record. The 1995 event was, however, retained for the flood frequency analysis.

2.3.6 Pincher Creek Record Filling

The 76 years of natural flow record available on Pincher Creek provide a good basis for flood frequency analysis. However, as shown on Figure 2.2, there are data gaps from 1932 through 1934 and 1937 through 1965, and four incomplete years were discarded as discussed in Section 2.3.3. Gaps in the data series should be filled, if possible, using a more complete record from a nearby station with which the record is highly correlated (FHIP 2011, AT 2001 and USGS 2019).

AE (1993) filled the Pincher Creek record by correlation with Drywood Creek near Twin Butte, WSC Station No. 05AD016. As part of this study, a good correlation was found between the Pincher Creek and Drywood Creek peak discharges (see Figure 2.12) and so the same station was used to fill the gaps in the Pincher Creek record in the current study.

The hydrometric record for Drywood Creek near Twin Butte consists of 52 years of maximum daily discharges, and 44 years of peak discharge data, between 1935 and 1986. The highest recorded maximum daily discharge and peak discharge was in 1975 with 27.9 m^3/s and 39.9 m^3/s, respectively. The 1964 flood was the second largest on record with maximum daily and peak discharges of 25.3 m^3/s and 33.4 m^3/s, respectively. The flood record is illustrated on Figure 2.10.

Figure 2.10 Drywood Creek near Twin Butte Flood History

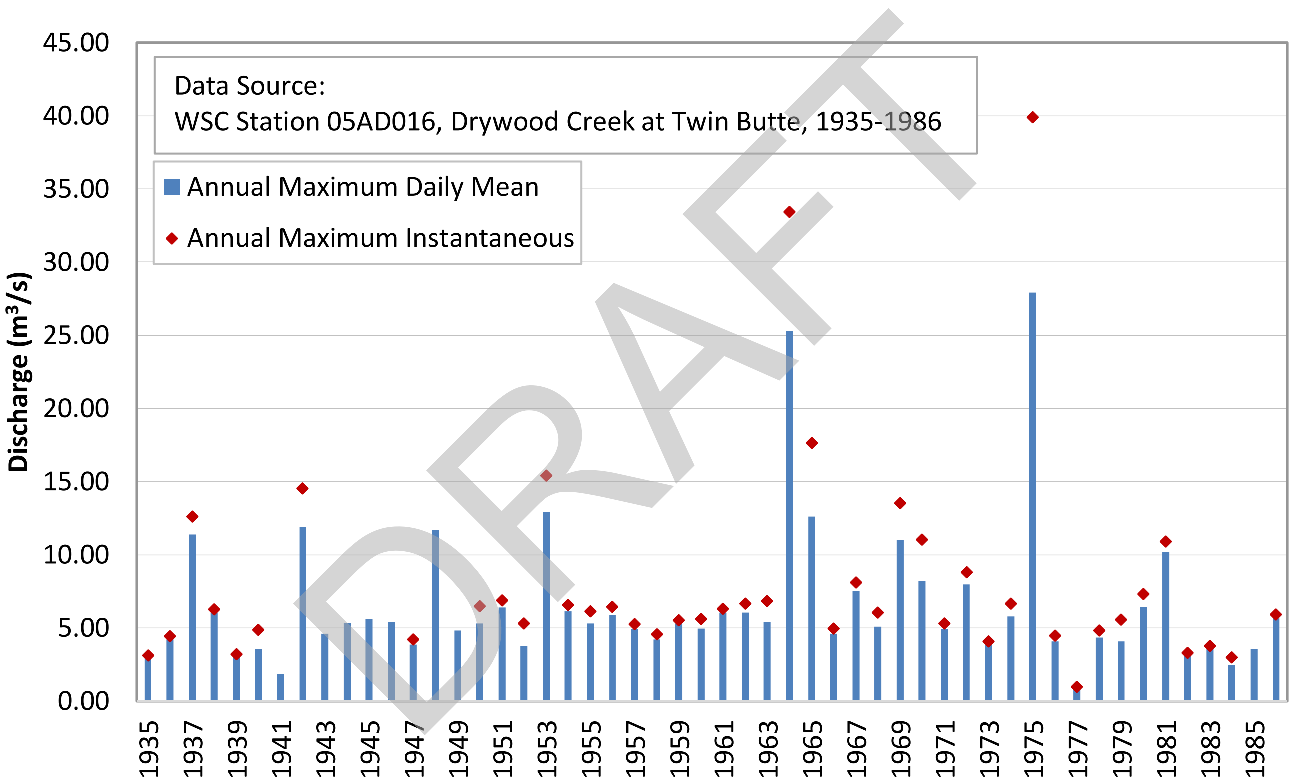


Figure 2.11 shows the correlation between the observed peak and same-event daily discharges at Drywood Creek, which was used to fill in the missing peak discharges in Drywood Creek. The completed peak discharge record was then used to fill in the gaps in the Pincher Creek record. The peak discharges of Drywood Creek and Pincher Creek over the 19 years of coincident data is highly correlated (R^2 = 0.93), as shown on Figure 2.12.

Figure 2.11 Peak vs. Same-Event Daily Discharge at Drywood Creek

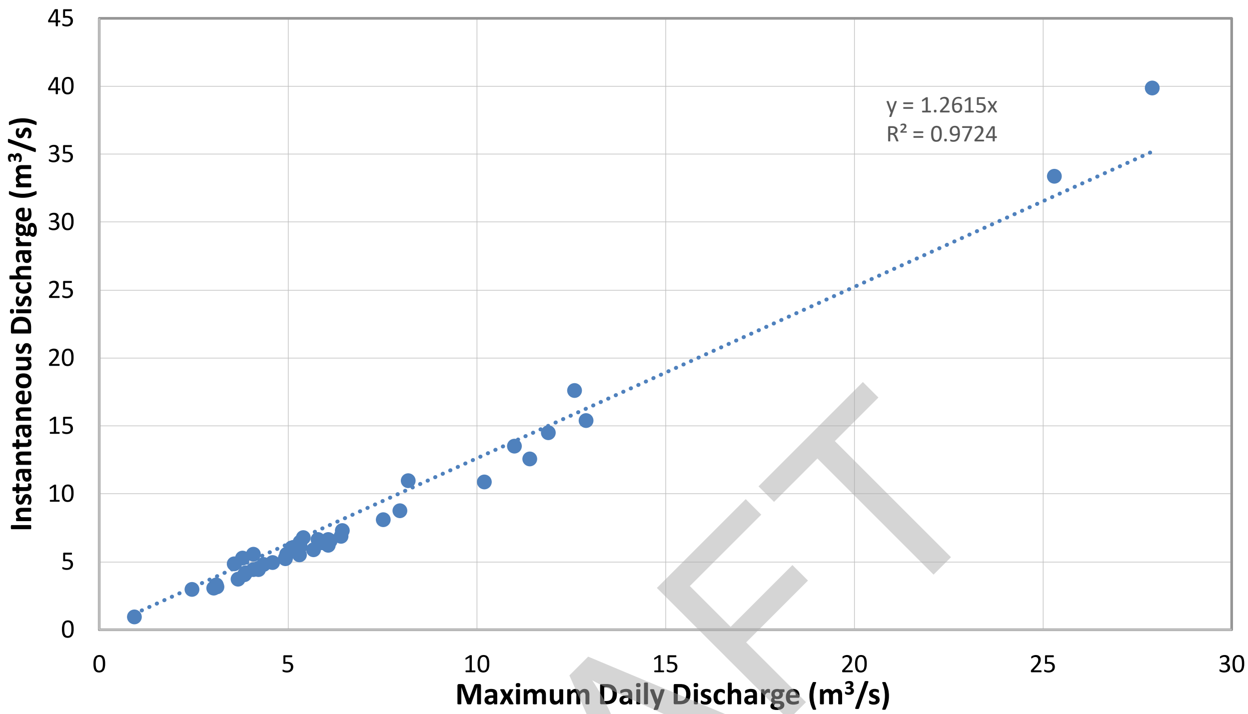
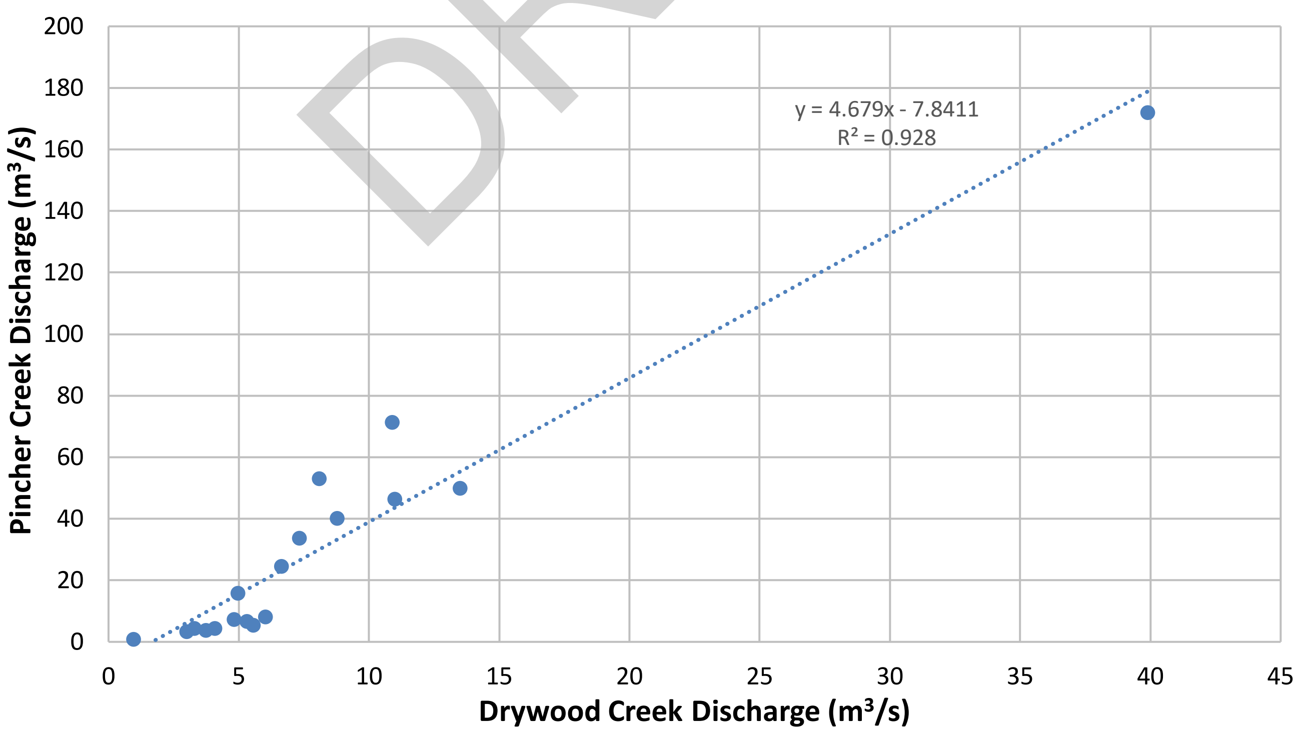


Figure 2.12 Drywood Creek and Pincher Creek Peak Discharge Correlation



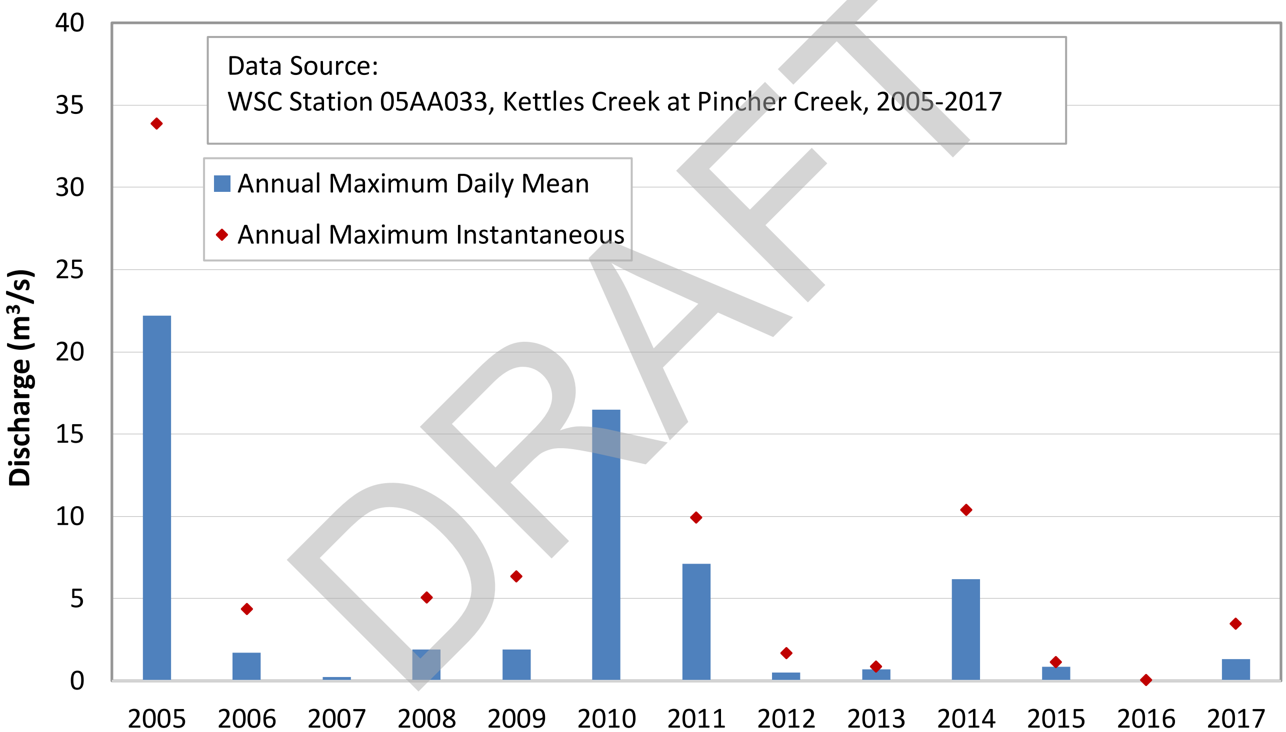
The filled peak discharge data series for Pincher Creek is provided in Appendix I. The data series contains 103 years of record.

2.4 Kettles Creek at Pincher Creek

2.4.1 Flood Record

WSC published Kettles Creek hydrometric data from 2005 to 2017, with peak discharge data available for 2005 to 2006, 2008 to 2009 and 2011 to 2017, as shown on Figure 2.13. The preliminary peak discharge data for 2018 was provided by WSC (pers. comm.) and was used for correlation purpose only.

Figure 2.13 Kettles Creek at Pincher Creek Flood History

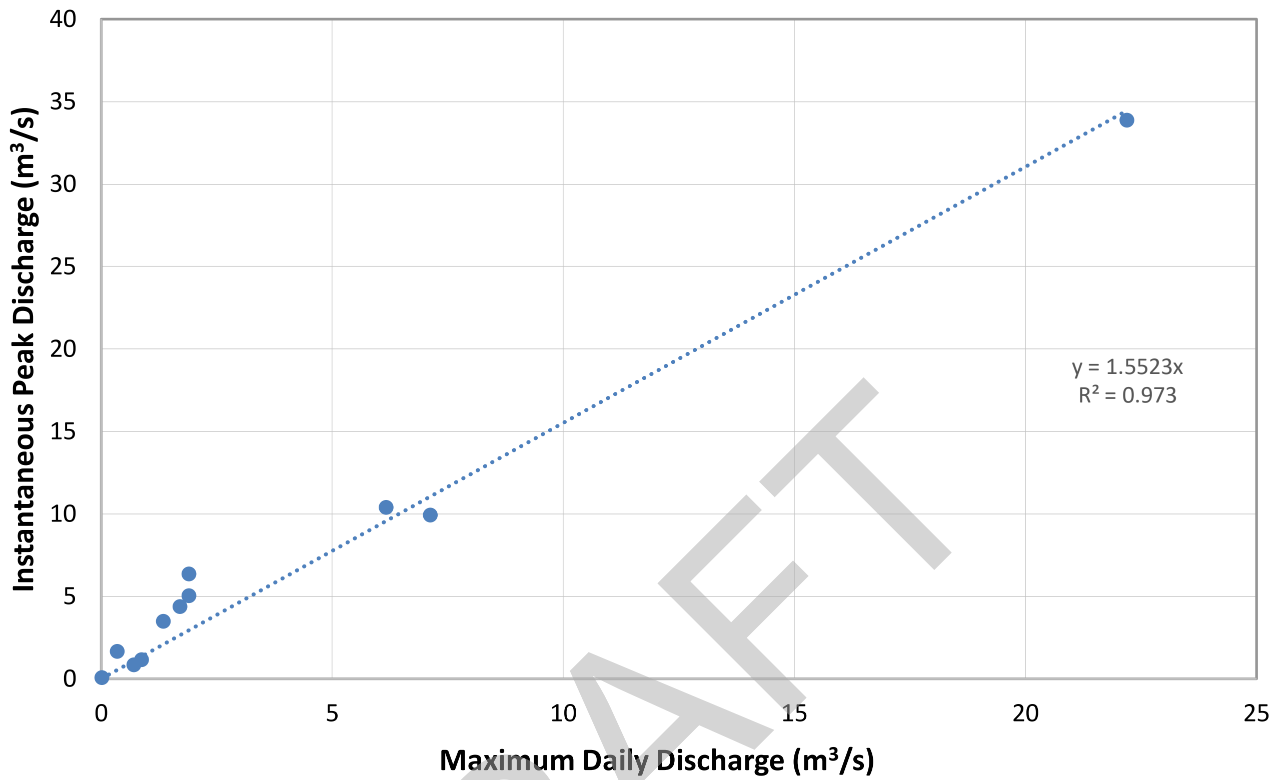


The flood of record for Kettles Creek for both the maximum daily discharge and the peak discharge occurred in June 2005. The maximum daily discharge was 22.2 m^3/s, and the peak discharge was 33.9 m^3/s.

2.4.2 Estimation of Missing Peak Discharges

Figure 2.14 shows the calculated linear regression between the observed peak and same-event daily discharges at Kettles Creek. (In 2012 and 2016, the reported maximum daily discharge and peak discharge occurred during different events.)

Figure 2.14 Peak vs. Same-Event Daily Discharge at Kettles Creek



2.4.3 Kettles Creek Record Extension

Figure 2.1 shows the location of the 15 regional stations that were considered for extending the Kettles Creek record. Table 2.2 presents the key information related to these stations. In addition, the correlation of the peak discharge of each regional station to the peak discharge at the Kettles Creek station is shown.

Table 2.2 Annual Peak Discharge Correlation Results

Station Number	Station Name	Regulated (Y/N)	Record Length	Length of Cumulated Record	Drainage Area (km²)		R^2
					Gross	Effective	
05AA033	Kettles Creek at Pincher Creek	N	14		38.4	36.9	
05AE002	Lee Creek at Cardston	Y	105	14	316	316	0.78
05AA011	Mill Creek near the Mouth	N	48	9	179	179	0.77
05AA024	Oldman River near Brocket	Y	54	12	4400	4380	0.76
05AA004	Pincher Creek at Pincher Creek	N	83	14	158	158	0.73
05AD041	Belly River near Glenwood	Y	35	11	653	538	0.71
05AB046	Willow Creek at Highway No.811	N/A	21	13	2510	2170	0.56
05AD028	Waterton River near Glenwood	Y	54	14	1630	1540	0.23
05AD042	Yarrow Creek at Spread Eagle Road	N	15	7	47.9	47.9	0.1
05AA034	Pincher Creek at Front Range Road	N/A	15	10	24	24	0.06
05AA035	Oldman River at Range Road No.13A	N	11	7	1830	1830	0.05
05AD010	Drywood Creek near the Mouth	Y	66	14	239	227	0.05
05AA028	Castle River at Ranger Station	N	53	12	375	375	0.01
05AA022	Castle River near Beaver Mines	N	75	13	821	821	0.01
05AB013	Beaver Creek near Brocket	N	60	9	256	256	0.01

Stations with catchment in mountain ranges, such as 05AD042, 05AA034, 05AA028 and 05AA035 showed poor correlation with the Kettles Creek data. Station 05AA024, Oldman River near Brocket, and 05AD041, Belly River near Glenwood, have a good degree of correlation, however, both stations are regulated and have much larger catchments than Kettles Creek. Therefore, the correlations from these stations are considered to be unreliable.

The peak discharges at Station 05AA004, Pincher Creek at Pincher Creek, Station 05AA011, Mill Creek near the Mouth, and 05AE002, Lee Creek at Cardston, showed the best correlation with Kettles Creek and have catchment areas within an order of magnitude of the Kettles Creek catchment. The correlation is not, however, as high as is typically desired with R^2 values less than 0.80. In view of the lack of suitable hydrometric data with which to extend the Kettles Creek record, a regional analysis was undertaken for Kettles Creek.

2.4.4 Selection of Hydrometric Stations for Regional Analysis

The headwaters of the Kettles Creek catchment are in the Rocky Mountain foothills, with moderate relief and bedrock outcrops that are oriented perpendicular to the general catchment slope. Ponds exist in the headwaters in undulations and local topographic depressions. Land use in the catchment is predominately agricultural with limited forested patches near the headwaters, with limited residential or urban infrastructure focused in areas near the confluence with Pincher Creek. The creek is confined to a defined ravine in mid-catchment and is conveyed through a constructed channel in the lower catchment near Pincher Creek. The Kettles Creek hydrometric station is approximately at elevation of 1120 m, and the highest elevation at the headwaters, according to Google Earth®, is approximately 1380 m.

A search was conducted over an approximately 50 km wide area extending up to 70 km northwest and 60 km southeast of Kettles Creek, near the Rocky Mountain Foothills, for hydrometric stations that might be appropriate for conducting a regional flood analysis. Regulated waterbodies within the area were not considered. Selected catchments were ranked based on period of record, years of record, drainage area, distance to the Kettles Creek gauge, land use, and whether the catchment headwaters were in the Rocky Mountain Foothills. Many hydrometric stations exist within the area of consideration, though few had greater than 30 years of record or were similar in catchment topography and land use to Kettles Creek; only such stations were considered in the analysis.

The assessment adopted five hydrometric stations for consideration in the regional analysis for Kettles Creek, as summarized in Table 2.3. Station locations and catchment boundaries are shown on Figure 2.1.

Table 2.3 Hydrometric Stations Selected for Regional Analysis of Kettles Creek

Station Name and No.	Period of Record	Years of Record	Gross Drainage Area (km^2)	Used in AE (1993) study?
Kettles Creek at Pincher Creek 05AA033	2005-present	13	38	N
Pincher Creek near Pincher Creek 05AA004	1910-1936, 1965-present	76	158	Y
Mill Creek near the Mouth 05AA011	1910-1920, 1967-1986, 2006-present	44	179	Y
Drywood Creek near the Mouth 05AD010	1920-1930, 1967-present	63	239	Y
Lee Creek near Cardston 05AE002	1909-1914, 1920-present	105	316	N

The regional stations identified in Table 2.3 have headwaters in the Rocky Mountains, which means they likely have a higher flood yield than the Kettles Creek catchment. While this characteristic might make them less than ideal for application to the regional analysis of Kettles Creek, there are no other gauged waterbodies of similar catchment area as Kettles Creek in the region with a record length of 30 years or more.

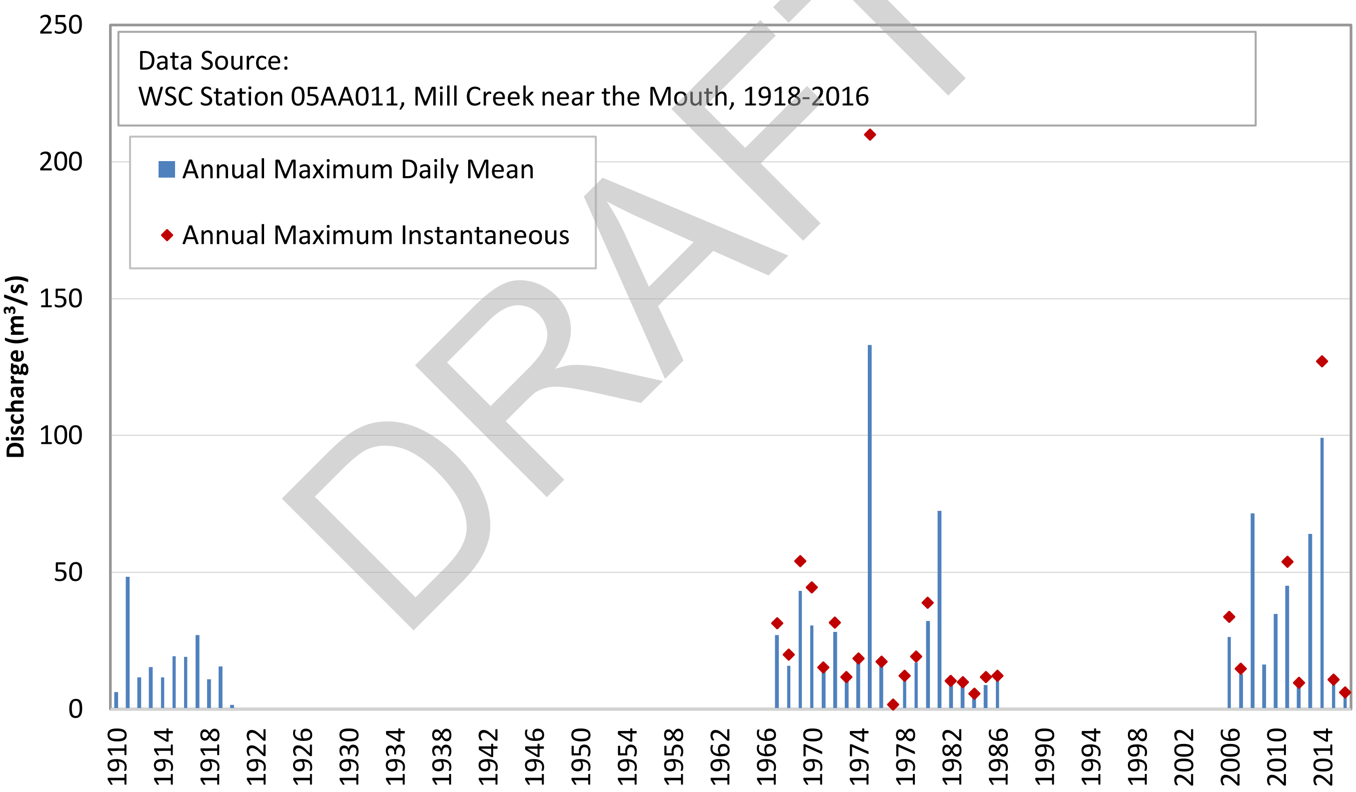
2.4.5 Flood History of Selected Regional Stations

The flood history of Pincher Creek is discussed in Section 2.3.1 and Kettles Creek in Section 2.4.1. The other three regional stations are discussed below.

Mill Creek

WSC published hydrometric data for Mill Creek near the Mouth station over a period from 1910 to 2016, as shown in Figure 2.15. There are long gaps in the record. The data includes 42 years of maximum daily discharges and 26 years of peak discharges. The flood of record occurred in June 1975, with a peak discharge of 210 m^3/s and a maximum daily discharge of 133 m^3/s. The second largest flood occurred in 2014, with a peak discharge of 127 m^3/s and a maximum daily discharge of 99 m^3/s.

Figure 2.15 Mill Creek Near the Mouth Flood History



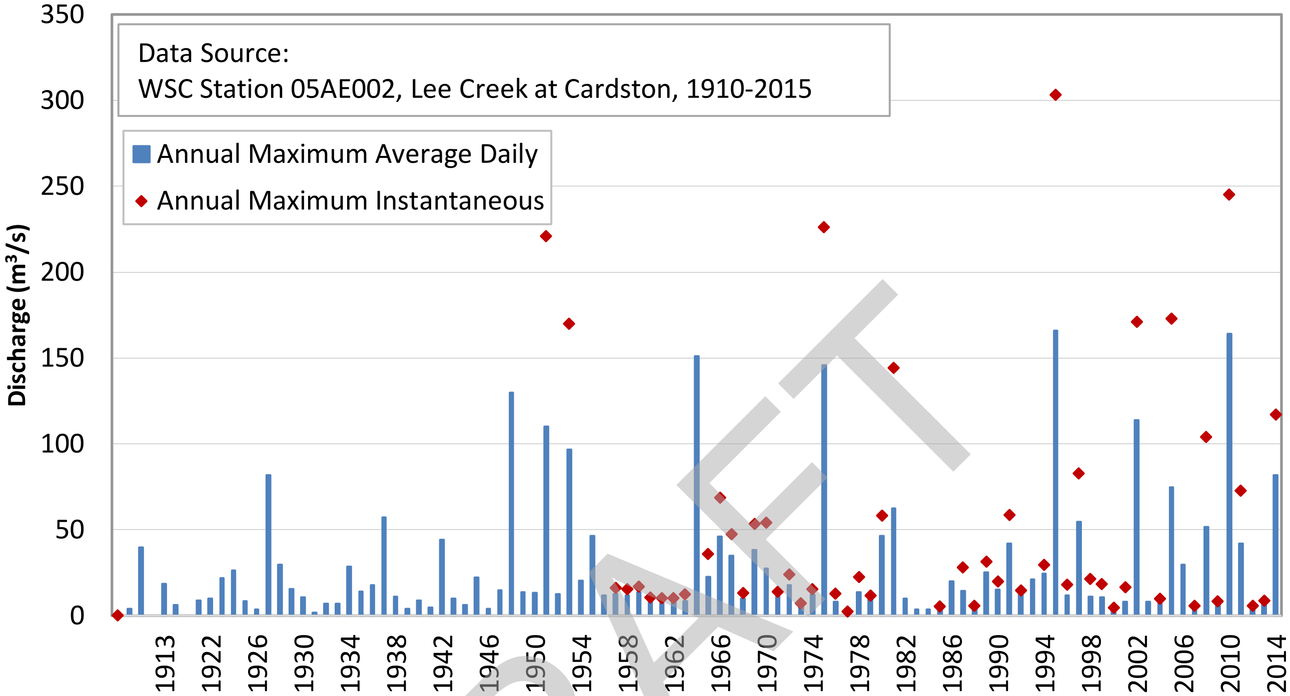
The peak discharges for the missing years, where maximum daily data exists, were filled in using the equation y=1.40x which had an R^2 of 0.98.

Lee Creek

WSC published hydrometric data for Lee Creek at Cardston station from 1910 to 2015 with 99 years of maximum daily discharge, shown on Figure 2.16. The peak discharge is available for 54 years out of the 101-year period of record. The flood of record occurred in June 1995, with a peak discharge of

303 m^3/s and a maximum daily discharge of 166 m^3/s. The second largest flood occurred in 2014, with a peak discharge of 245 m^3/s and a maximum daily discharge of 164 m^3/s.

Figure 2.16 Lee Creek at Cardston Flood History

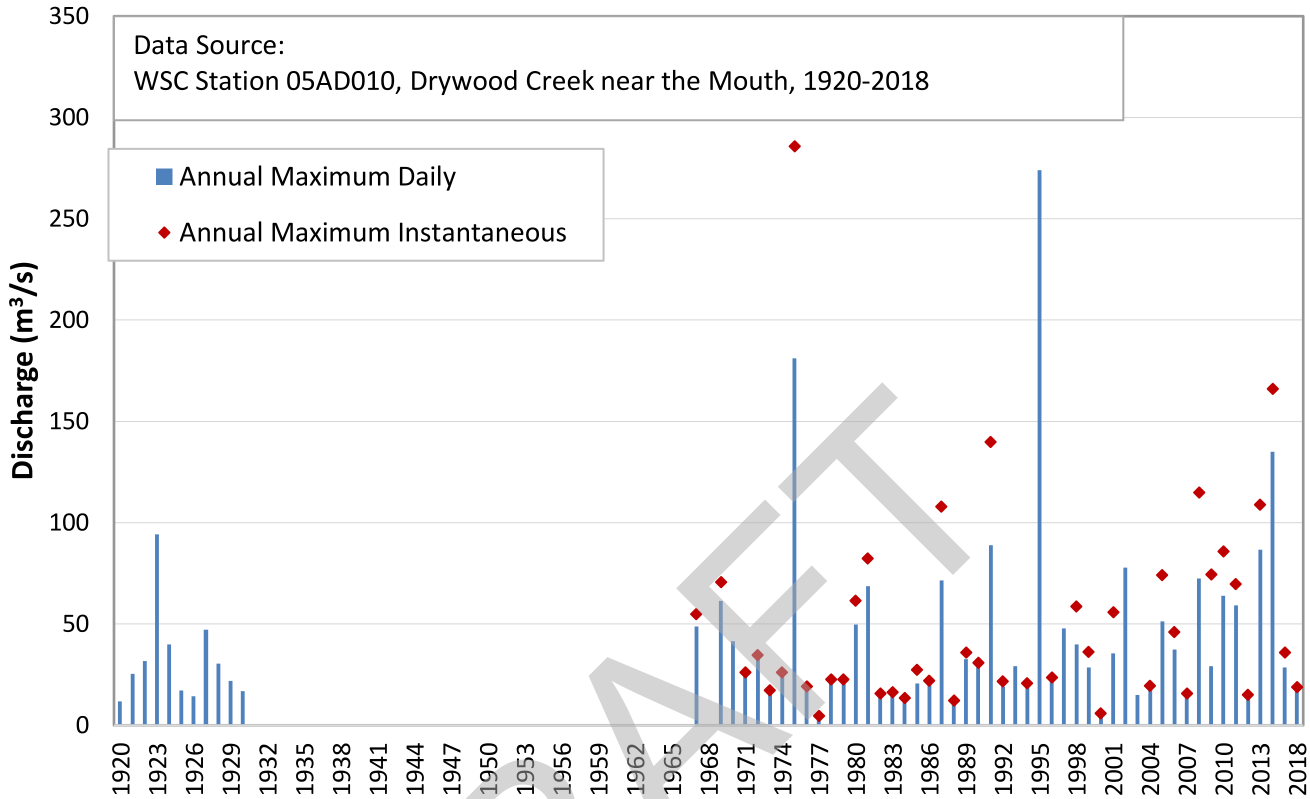


The peak discharges for the missing years, where maximum daily discharge data exists, were filled in using the equation y=1.74x and an R^2 of 0.96.

Drywood Creek near the Mouth

WSC published hydrometric data for Drywood Creek near the Mouth from 1920 to 1930 and 1967 to 2018. The peak discharge is available for 43 years out of the 63-year period of record, as shown on Figure 2.17. The largest flood during the period of record is believed to have occurred in 1995, although the peak discharge for that event was not recorded. Other major floods occurred in June 1975, with a peak discharge of 286 m^3/s and a maximum daily discharge of 181 m^3/s; and in 2014, with a peak discharge of 166 m^3/s and a maximum daily discharge of 135 m^3/s.

Figure 2.17 Drywood Creek near the Mouth Flood History



The peak discharges for the missing years, where annual maximum daily data exists, were filled in using the equation y=1.39x and an R^2 of 0.95.

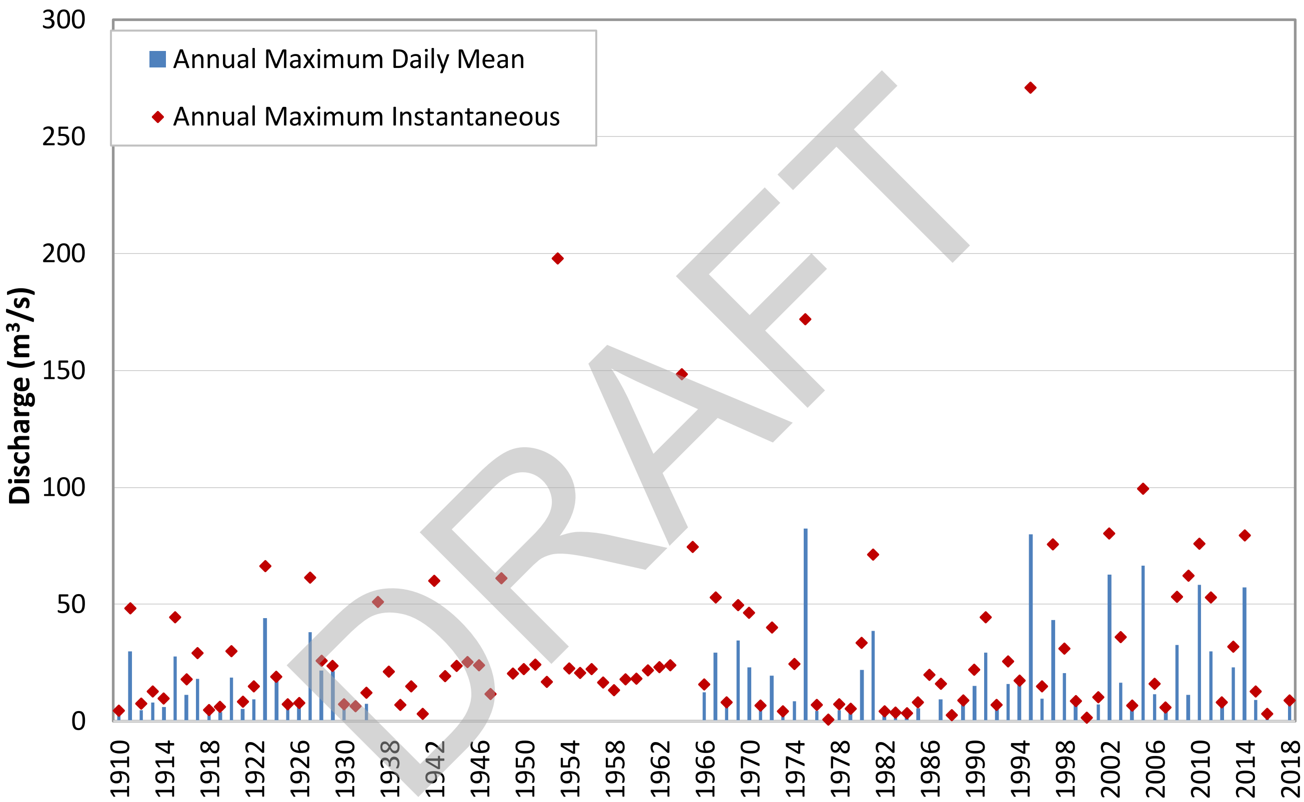
3 FLOOD FREQUENCY ESTIMATES

3.1 Pincher Creek at Pincher Creek Single-Station Frequency Analysis

3.1.1 Filled Flood Record

The completed Pincher Creek peak discharge data used for frequency analyses is shown on Figure 3.1 and listed in Appendix I, Table 1.

Figure 3.1 Pincher Creek Complete Flood Record



3.1.2 Data Scrutiny

The filled series of peak discharges at Pincher Creek was tested to confirm the appropriateness of the data for frequency analysis as recommended by AT (2001). The HYFRAN-PLUS software (Bobée and Adlouni 2008) and the Data and Frequency Analysis Spreadsheet for the City of Calgary (DFASCC) (City of Calgary 2014) were used to conduct the tests. The specific statistical tests include:

- Stationarity
  - Test for trends
    - Spearman rank order correlation coefficient test (National Environment Research Council [NERC] 1975)

- Test for jump
  - Mann-Whitney test for jump (Mann and Whitney 1947)
  - Wald-Wolfowitz test (Siegel 1956)
- Homogeneity
  - Homogeneity test at seasonal scale (Mann and Whitney 1947)
- Independence
  - Spearman rank order correlation coefficient (NERC 1975)
  - Wald-Wolfowitz test (Siegel 1956)
- Outliers
  - Grubbs and Beck test for outliers (Grubbs and Beck 1972)

The results of the data tests are shown in Table 3.1. The data series passed all the statistical data tests.

Table 3.1 Pincher Creek Data Test Results

Stationarity Test	Result
Spearman rank order correlation coefficient test for trend based on z	No significant trend at 0.05 significance level
Spearman rank order correlation coefficient test for trend based on t	No significant trend at 0.05 significance level
Mann-Whitney test for jump	No jump at 0.05 significance level
Wald-Wolfowitz test for jump	No jump at 0.05 significance level

Homogeneity Test	Result
Mann-Whitney test for homogeneity at seasonal scale, subdivided the data from Jan to July	Sample is homogeneous at 0.05 significance level

Independence Test	Result
Spearman rank order correlation coefficient	Data is independent at 0.05 significance level
Wald-Wolfowitz test	Data is independent at 0.05 significance level

Outliers Test	Result
Grubbs and Beck test	No high outliers present No low outliers present

3.1.3 Frequency Analysis

The completed series of peak data were analyzed using HYFRAN-PLUS software. The distributions and fitting methods tested are listed below:

- Log-Normal – Maximum Likelihood;
- 3-parameter log-normal – Method of Moments;
- Gamma - Method of Moments;
- Pearson Type 3 - Method of Moments;
- Log-Pearson Type 3 - Method of Moments;
- Gumbel – Method of Moments;
- Normal – Maximum Likelihood;
- General Extreme Value – Maximum Likelihood;
- Exponential – Maximum Likelihood; and
- Weibull – Method of Moments;

To assess the goodness of fit and adequacy of the theoretical distributions, AT (2001) recommended the Chi-squared and Kolmogorov-Smirnov (KS) test. The HYFRAN-PLUS software has built-in Chi-squared test and Empirical Moment test for selected distributions and the DFASCC was used to check the KS test and the Anderson-Darling (AD) test. The HYFRAN-PLUS software also uses the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) to rank models based on their goodness-of-fit. Along with the tests mentioned above, visual goodness of fit was also taken into consideration when selecting the better probability distribution.

Flood frequency plots for each of the tested distributions are provided in Appendix II, Figure 1 to Figure 10. The log-normal distribution passed all of the goodness of fit tests. The exponential, Pearson Type 3, Log-Pearson Type 3 and GEV distribution passed the KS and AD tests but did not pass the Chi-squared and empirical tests. The GEV distribution and the exponential distribution were rejected based on visual goodness of fit. The Pearson Type 3 and Log-Pearson Type 3 showed similar distribution estimates. Log-Normal ranked first in terms of AIC and BIC methods and also based on the goodness of fit and adequacy test results. In view of this, the Log-Normal distribution was selected as the flood frequency distribution.

Figure 3.2 and Table 3.2 present the results of the frequency analysis. Table 3.2 also shows the 1993 flood frequency analysis results (AE 1993). As a comparison, the current estimate is 23% higher than the 1993 estimate at a 100-year return period. The AE estimate was based on a 46 year period of record compared to the 103 years available for the current study. The flood of record in 1995 occurred after the AE study was completed. AE used the Log-Pearson Type III frequency distribution compared to the lognormal distribution used for the current study. Considering these factors, the increase in flood estimates is reasonable.

The peak discharge of the 1995 flood is slightly less than the estimated 1 in 200 year flood. The estimated discharge of the 1953 flood is between the 1 in 50 year and 1 in 100 year flood estimates.

Figure 3.2 Log-Normal Distribution for Pincher Creek at Pincher Creek

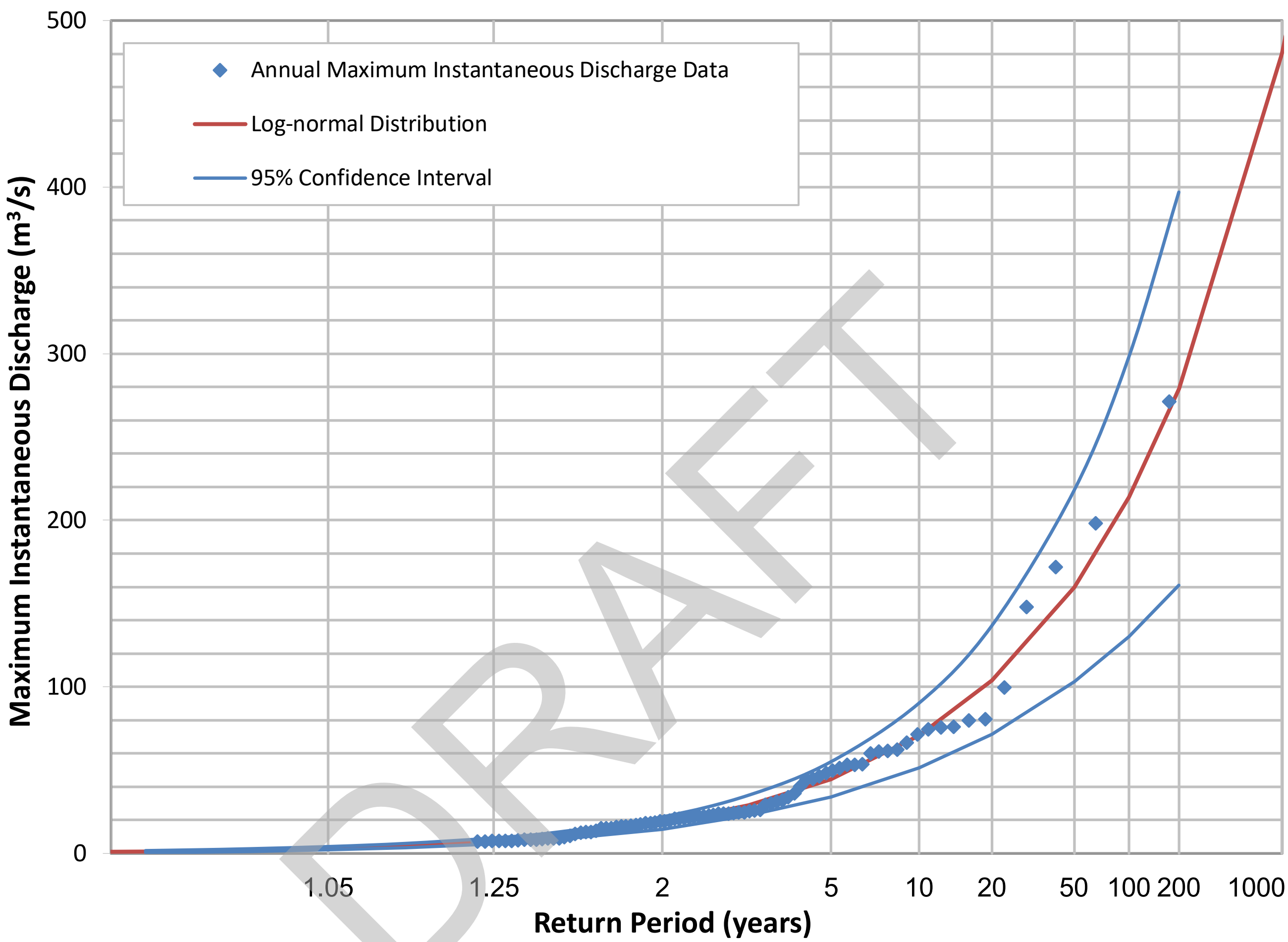


Table 3.2 Pincher Creek Flood Frequency Analyses Results

Return Period (year)	Peak Discharge (m^3/s)	
	Current	Alberta Environment (1993)
2	18	14
5	45	34
10	71	55
20	104	82
35	137	N/A
50	160	131
75	191	N/A
100	214	179
200	279	N/A
350	340	N/A
500	383	N/A
750	438	N/A
1000	480	N/A

3.2 Regional Analysis

3.2.1 Approach

As described in Section 2.4.3, a regional analysis was undertaken for Kettles Creek and Indianfarm Creek. Three regional analyses methods were considered, including:

- Regional relationships between catchment area and discharge. Two forms of such regional relationships were tested:
  - Power function (AT 2001), $Q_x = Q_{other} \frac{A_x}{A_{other}}^m$
    where m is an exponent, typically 0.7 to 0.8 (AT 2001), Q is peak discharge, A is catchment area, and x is the site of interest.
  - Creager equation (AT 2001), $Q = 0.503CA\left(\frac{A}{2.59}\right)^{0.936A^{-0.048}-1}$
    where C is a coefficient indicating flood severity.
- Index Flood Method, $Q_{n,x} = Q_{index,x} \frac{Qn_{Regional}}{Q_{\text{index}\ Regional}}$

The discharge vs. area relationship methods have these disadvantages:

- They do not account for the available record on Kettles Creek.
- They do not account for the varying degrees of mountain influence in the catchments.

The Index Flood Method uses the available data to derive a catchment-specific index flood (Q_{index}), which is typically an event in the range of 2- to 5- years. For the current study, the mean of the peak discharges was used as the index flood (Dalrymple 1960). The variation of flood severity with return period was then estimated based on data from the regional catchments. This approach accounts, at least partially, for the different physiography of the regional catchments. It allows for a comparison of regional flood peaks by removing the first order effects associated with the size of the catchment by scaling the flood peaks with the index flood. Therefore, the approach adopted to estimate return period flood events in Kettles Creek was the Index Flood Method.

3.2.2 Regional Dimensionless Flood Frequency Curve

A regional dimensionless flood frequency was developed as shown on Figure 3.3 by plotting the peak flood records (i.e., Q) for all five of the regional stations listed in Table 2.3, made dimensionless by dividing by the index flood (Q_{index}). Return periods were plotted using the Cunnane plotting position. The figure shows that, despite the differences between the catchments in terms of their size and physiography, the relationship between flood severity and return period is reasonably consistent among the five stations.

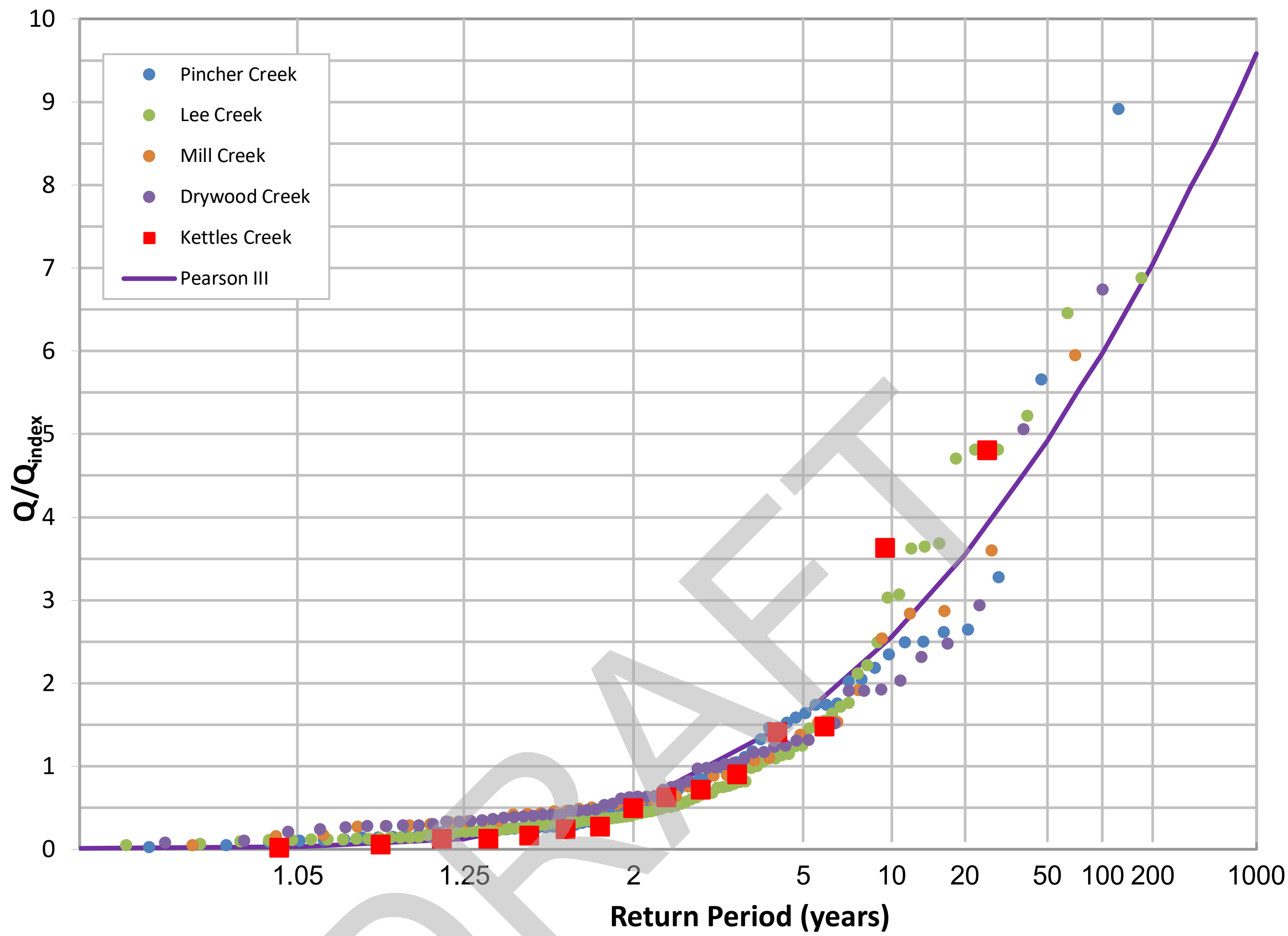
A regional flood frequency curve was fitted to the data of all five stations. The curve was developed using the Pearson Type III because the visual fit to the data was better using the Pearson Type III distribution than the other tested distributions, i.e., the lognormal and the log-Pearson Type III.

The curve was calculated using the average standard deviation and skew of all five stations, as shown in Table 3.3. The average theoretical maximum and minimum skew coefficient for Pearson Type III is 2.66 and 2.55, respectively. The actual sample skew of 2.82 is greater than the maximum skew and, therefore, the maximum skew was adopted when plotting the curve on Figure 3.3.

Table 3.3 Dimensionless Flood Frequency Parameters at Regional Stations

Station	Dimensionless Peak Discharge			
	Standard Deviation	Actual Skew	Maximum Skew	Minimum Skew
Kettles Creek	1.40	2.05	2.83	2.80
Pincher Creek	1.34	3.62	2.75	2.68
Drywood Creek	1.12	3.26	2.92	2.78
Mill Creek	1.12	2.72	2.36	2.25
Lee Creek	1.39	2.47	2.47	2.25
Average	**1.28**	**2.82**	**2.66**	**2.55**

Figure 3.3 Dimensionless Regional Flood Frequency Curve



The 2005 flood of record on Kettles Creek plots at a return period between 20 and 30 years.

3.2.3 High-Flood Period Adjustment

The dimensionless regional flood frequency curve shown on Figure 3.3 is based on the index flood, and therefore the calculated index flood for Kettles Creek affects the return period flood estimates. The 13-year period of record on Kettles Creek was above normal in terms of flood peaks based on the long-term records at regional stations, as it included several years (2005, 2008, 2010, 2013 and 2014) with relatively high annual peaks.

To quantify the flood potential of the 2005 – 2018 period compared to long-term conditions, the average of the peak floods for that period were compared to the long-term average peak floods at the four regional stations. The results are shown in Table 3.4.

Table 3.4 Comparison of Peak Discharges from 2005 to 2018

Station	Years of Record	Average Peak Discharge for the Concurrent Record (2005 to 2018) (m^3/s)	Average Peak Discharge for Entire Record (m^3/s)	Percentage Difference (%)
Pincher Creek	74	37.9	30.4	25
Lee Creek	102	59.5	46.9	27
Mill Creek	42	42.7	35.3	21
Drywood Creek	60	68.9	56.5	22

The difference between the concurrent period and the full record ranged from +21% to +27%, with a weighted average (based on period of record) of +24%. The index flood for Kettles Creek, based on the available record between 2005 to 2018, was 7.4 m^3/s. Based on the information presented above, the best estimate of the long-term average peak discharge would be 7.4 m^3/s / (1 + 24%) = 6.0 m^3/s. A Kettles Creek index flood (Q_{index}) of 6.0 m^3/s was, therefore, used with the curve presented on Figure 3.3 to estimate the flood frequencies for Kettles Creek.

3.3 Kettles Creek Flood Frequency Estimates

3.3.1 Flood Estimates

The Kettle Creek flood frequency estimates using the Index Flood Method are shown in Table 3.5. These estimates were derived using the Kettles Creek index flood of 6.0 m^3/s and the dimensionless regional flood frequency curve presented on Figure 3.3. The Kettles Creek flood estimates produced by the AE (1993) regional analysis are also included in this table for comparison.

Table 3.5 Kettles Creek Flood Frequency Estimates

Return Period (years)	Peak Discharge (m^3/s)	
	Current	AE (1993)
2	3.2	7
5	9.7	12
10	15	17
20	21	22
35	26	Not provided
50	29	32
75	33	Not provided
100	36	39
200	42	Not provided
350	48	Not provided
500	51	Not provided
750	54	Not provided
1000	57	Not provided

As shown by Table 3.5, the current results are slightly lower than those estimated in the AE (1993) study.

3.3.2 Interpretation and Discussion

Factors to be considered when interpreting the results of the Kettles Creek regional analysis include the following.

- There are no nearby monitored catchments that are physiographically similar to the Kettles Creek catchment, which has its headwaters in the foothills. However, the regional analysis suggests a good level of hydrologic homogeneity in the analyzed catchments because of the consistency between stations on Figure 3.3.
- The period of record available at the regional stations ranges from 42 to 99 years, which is relatively short for estimating events up to the 1000-year flood.
- Climate change will likely produce changes in the future flood regime.

3.4 Indianfarm Creek Flood Frequency Estimates

3.4.1 Index Flood

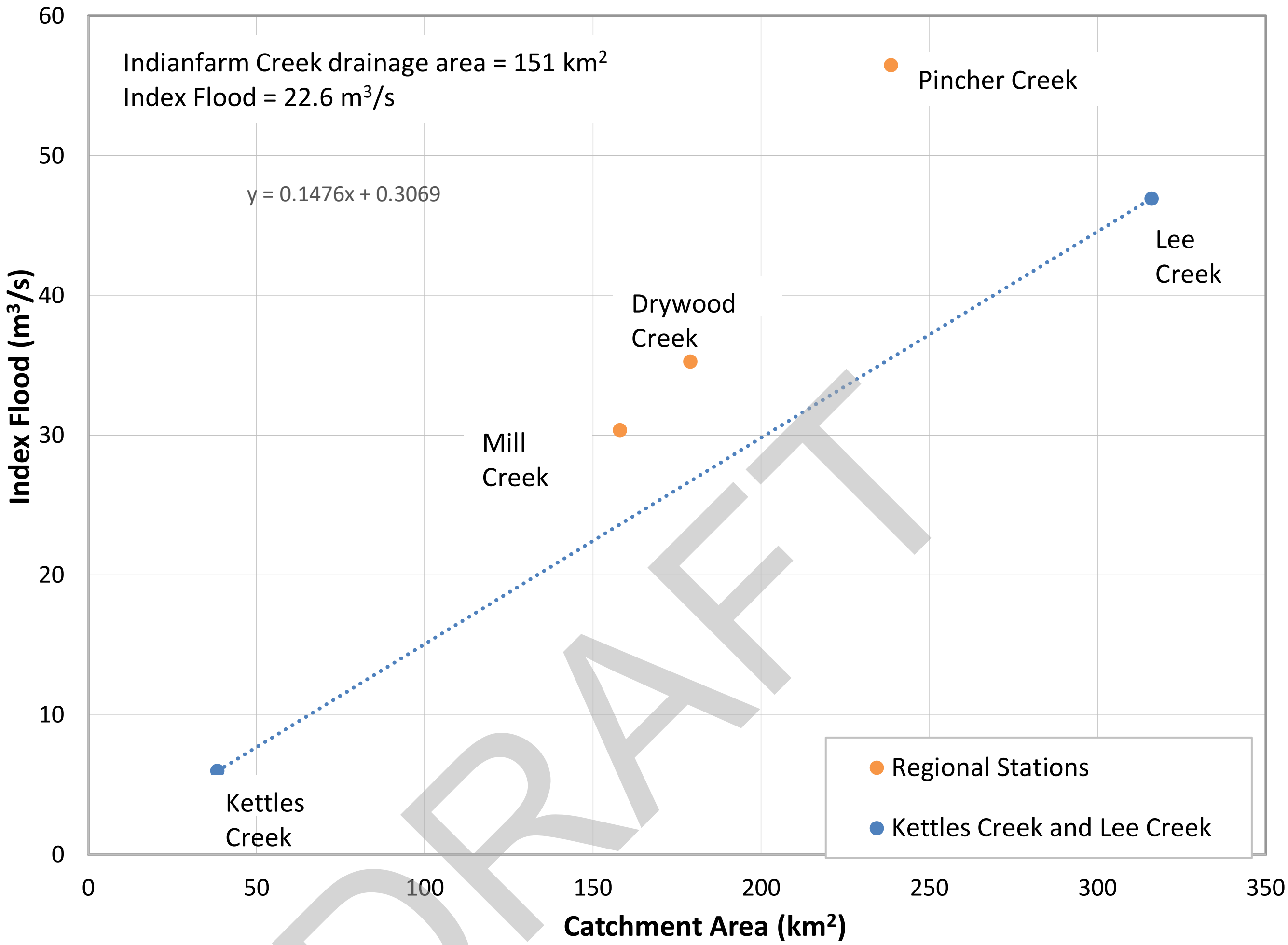
A regional analysis using the Index Flood Method was undertaken to derive the flood frequency flow estimates for Indianfarm Creek. At Indianfarm Creek, however, there are no historical hydrometric records. The index flood for the catchment was estimated using a regional relationship between index flood and catchment area.

The index flood and the catchment area for the five stations in the Kettles Creek regional hydrology analysis are listed in Table 3.6 and plotted on Figure 3.4. The Kettles Creek index flood is the estimated long-term average of 6.0 m^3/s. Considering the physiographical similarity between catchments for Kettles Creek, Lee Creek and Indianfarm Creek, the index flood for Indianfarm Creek is interpolated between Kettles Creek and Lee Creek. The other three regional stations with much more mountainous terrain are well above the trendline, as would be expected.

Table 3.6 Regional Station Data

Stations	Catchment Area (km^2)	Index Flood (m^3/s)
Kettles Creek	38.4	6.0
Pincher Creek	158	30.4
Lee Creek	316	46.9
Mill Creek	179	35.3
Drywood Creek	239	56.5

Figure 3.4 Indianfarm Creek Index Flood Estimate



The catchment area for Indianfarm Creek is 151 km^2, as shown on Figure 1.2. The index flood for Indianfarm Creek is estimated to be 22.6 m^3/s based on the linear interpolation between the Kettles Creek and Lee Creek data points. Using the same dimensionless regional flood frequency curve as used in the Kettles Creek regional analysis, as shown on Figure 3.3, the Q/Q_{index} ratio for each return period was applied to Indianfarm Creek's index flood to obtain estimates for the range of return periods. The results are shown in Table 3.7.

Table 3.7 Indianfarm Creek Flood Frequency Results

Return Period (years)	Peak Discharge (m^3/s)
2	12
5	37
10	58
20	80
35	99
50	111
75	126
100	135
200	159
350	180
500	192
750	206
1000	216

3.5 Streamflows by Reach

Table 3.8 presents the flood frequency estimates by reach, as needed for the hydraulic modelling. Of the four highest peaks on Pincher Creek that occurred during the concurrent record with Kettles Creek, the peaks on the two streams occurred less than two hours apart in three cases. In the fourth case, the time of the peak on Kettles Creek was not recorded but it was on the same day as the Pincher Creek peak. Therefore, it is assumed for modelling purposes that during major flood events, the peaks on Pincher Creek and Kettles Creek are concurrent. There is no historical data for peak timing on Indianfarm Creek, but the same assumption of concurrent peaks was conservatively adopted there. At each confluence, the peak discharge below the confluence is taken as the sum of the peaks in the tributaries.

Table 3.8 Summary of Flood Frequency Analysis by Reach

Return Period (years)	Estimated Peak Discharge (m^3/s)			
	Pincher Creek above Kettles Creek	Pincher Creek below Kettles Creek	Pincher Creek below Indianfarm Creek	Kettles Creek above Pincher Creek
2	18	21	33	3.2
5	45	55	92	9.7
10	71	86	144	15
20	104	125	205	21
35	137	163	262	26
50	160	189	300	29
75	191	224	350	33
100	214	250	385	36
200	279	321	480	42
350	340	388	568	48
500	383	434	626	51
750	438	492	698	54
1000	480	537	753	57

4 CLIMATE CHANGE COMMENTARY

Climate change is an important consideration when attempting to predict a future streamflow regime. Despite a large research effort, the effect of climate change on flood frequencies is still highly uncertain.

Climate change models generally predict future increases in extreme events, including floods, but there is wide variation in the predictions. The Canadian Centre for Climate Modelling and Analysis derived a range of indices of extreme events from 30 different climate change models. Sillmann et al. (2013) reported that projected changes in the RX5day index, which is the annual or monthly maximum five-day precipitation depth and is often used to describe changes in potential flood risks, ranged from +30% to -12% for June, July, and August in the Western North America region. The projected changes were for the period 2081 – 2100 compared to the baseline period 1981 – 2000.

A recent analysis by Rood et al. (2016) used data from Rocky Mountain rivers with little or no regulation and fairly pristine watersheds to isolate the effects of climate change from anthropomorphic influences, and concluded that, contrary to expectations from many other researchers, annual peak discharges in these streams are actually decreasing in response to climate change. Climate change effects observed in the historical streamflow data include: 1) declining annual discharge; 2) decreases in the proportion of the precipitation falling as snow, producing higher winter discharges and lower snowpacks; 3) earlier snowmelt initiation due to warmer temperatures; and 4) longer duration snowmelt, so that the timing of the snowmelt peak is almost unchanged. The combination of 3) and 4) reduce the snowmelt contribution to the peak as well as the extent of watershed saturation, resulting in 5) reduced annual peaks.

The historical peak discharge in Pincher Creek was tested for trend, as discussed in Section 3.1, and no trend was found.

As AT (2001) noted, the variability in Alberta's flood discharge make it difficult to detect systematic change, and quantitative prediction of changes on the basis of climatic projections is highly uncertain. The available data does not support a confident climate change estimate of increasing discharges on the flood frequency results. Scientific uncertainties still exist in the climate change research community, but as Kuklichke and Demeritt (2016) stated, a 20% increase in estimated peak flood flows is an effective approach for risk-based management of fluvial flooding to take the incompletely understood impacts of climate change into account.

5 SUMMARY

The following points present a summary of key information.

- Gaps in the Pincher Creek at Pincher Creek record were filled through correlation with the Drywood Creek near Twin Butte station to create a series with 103 years of peak discharge data.
- Flood frequency analyses for the Pincher Creek at Pincher Creek series concluded that the Log-Normal Distribution was the best fit.
- A regional flood frequency analysis was undertaken for Kettles Creek and Indianfarm Creek using the Index Flood Method.
- The index flood for Indianfarm Creek was derived from other regional stations based on catchment area.
- The Pincher Creek record does not indicate a trend that could be the result of climate change. Applying a 20% increase to the design discharge is an effective approach to account for the impacts of climate change for risk-based management of fluvial flooding.

Table 5.1 summarizes the flood frequency estimates for the study streams. Table 5.2 presents the flood frequency analysis results by reach. These estimates do not include a climate change adjustment.

Table 5.1 Summary of Flood Frequency Analysis

Return Period (years)	Peak Discharge (m^3/s)		
	Pincher Creek	Kettles Creek	Indianfarm Creek
2	18	3.2	12
5	45	9.7	37
10	71	15	58
20	104	21	80
35	137	26	99
50	160	29	111
75	191	33	126
100	214	36	135
200	279	42	159
350	340	48	180
500	383	51	192
750	438	54	206
1000	480	57	216

Table 5.2 Summary of Flood Frequency Analysis by Reach

Return Period (years)	Estimated Peak Discharge (m^3/s)			
	Pincher Creek above Kettles Creek	Pincher Creek below Kettles Creek	Pincher Creek Below Indianfarm Creek	Kettles Creek above Pincher Creek
2	18	21	33	3.2
5	45	55	92	9.7
10	71	86	144	15
20	104	125	205	21
35	137	163	262	26
50	160	189	300	29
75	191	224	350	33
100	214	250	385	36
200	279	321	480	42
350	340	388	568	48
500	383	434	626	51
750	438	492	698	54
1000	480	537	753	57

SIGNATURE PAGE

KLOHN CRIPPEN BERGER LTD.

PROFESSIONAL ENGINEER
WES DICK
ALBERTA

2020-06-24

Kathy Chen, E.I.T
Civil Engineer in Training

Wes Dick, M.Sc., P.Eng.
Senior Hydrotechnical Engineer

PERMIT TO PRACTICE
KLOHN CRIPPEN BERGER LTD.
RM SIGNATURE:
RM APEGA ID #: 48789
DATE: SEPT. 17, 20
PERMIT NUMBER: P009196
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

Robert Cheetham, P.Eng.
Associate, Senior Civil Engineer

APEGA Permit to Practice P09196

This is a copy of a digitally authenticated PWP

DISCLAIMER

This report is an instrument of service of Klohn Crippen Berger (KCB). The report has been prepared for the use of Alberta Environment and Parks for the specific application to the Pincher Creek Flood Hazard Study. 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. KCB has prepared this report in a manner consistent with the level of care, skill and diligence ordinarily provided by members of the same profession for projects of a similar nature at the time and place the services were rendered. KCB makes no warranty, express or implied.

REFERENCES

Alberta Environment. 1980. Pincher Creek Floodplain Study. River Engineering Branch.

Alberta Environment. 1993. Flood Frequency Analyses Pincher Creek Floodplain Study. Water Resources Management Services Technical Services Division, Hydrology Branch.

Alberta Environment. 2011. Flood Hazard Identification Program Guidelines. Water Management Operations. River Forecast Section.

Alberta Transportation. 2001. Guidelines on Flood Frequency Analysis. Transportation and Civil Engineering Division, Civil Projects Branch.

Bobée, B. and Adlouni, S. A. 2008. HYFRAN-PLUS software. Version 2.2.

Chow, B., Spittlehouse, D., Zwiers, F., Hopkins, K., Radhakrishnan, H., DesLauriers, L., Jakob, M., Hanacek, M. and Whitfield, P. 2017. Design Flood Hydrology for BC Natural Resources Professionals Event. Engineers and Geoscientists of British Columbia.

City of Calgary. 2014. Data and Frequency Analysis Spreadsheet for the City of Calgary.

Environment Canada. 1963. Flood of June 1953 in the South Saskatchewan River Basin. Water Resources Paper No. 113F. Department of Northern Affairs and National Resources. Water Resources Branch.

Grubbs, E. E. and G. Beck. 1972. Extension of Sample Sizes and Percentage Points of Significance Test of Outlying Observations. Technometrics, 14(4): 847-854

Kite, G.W., 1977. Frequency and Risk Analyses in Hydrology. Water Resources Publications, Colorado, United States of America.

Kuklicke, C. and Demeritt, D. 2016. Adaptive and Risk-Based Approaches to Climate Change and the Management of Uncertainty and Institutional Risk: The Case of Future Flooding in England. Global Environmental Change., 37, pp. 56-68.

Mann, H.B. and Whitney, D.R. 1947. On the Test of Whether One of Two Random Variables is Stochastically Larger Than the Other. An. Math. Stat., 18, pp. 50-60.

National Environment Research Council. 1975. Flood Studies Report: Volume 1, Hydrological Studies. Natural Environment Research Council, London, England.

Rood, S.B., S.G. Foster, E.J. Hillman, A. Luek, and K.P. Zanewich. 2016. Flood Moderation: Declining Peak Flows along Some Rocky Mountain Rivers and the Underlying Mechanism. Journal of Hydrology 526: 174-184.

Siegel, S. 1956. Nonparametric Statistics for the Behavioural Sciences. McGraw-Hill, New York, United States of America.

Sillmann, J., V. V. Kharin, F. W. Zwiers, X. Zhang, and D. Bronaugh. 2013. Climate Extremes Indices in the CMIP5 Multi-Model Ensemble. Part 2: Future Projections. J. Geophys. Res., doi:10.1002/jgrd.50188.

Terry, M.E. 1952. Some Rank Order Test which are Most Powerful Against Specific Parametric Alternatives. Annals of mathematical Statistics 23, 346-366.

US Geological Survey. 2019. Guidelines for Determining Flood Flow Frequency. Bulletin 17C. US Department of the Interior.

APPENDIX I

Data Series

Table 1
Station No. 05AA004 **Pincher Creek at Pincher Creek Data Series**

Year	Annual Maximum Daily Mean		Annual Maximum Instantaneous	
	Date	Discharge (m^3/s)	Date	Discharge (m^3/s)
1910	20-May	2.80		5.23
1911	04-Sep	30.0		56.0
1912	11-Apr	4.67		8.72
1913	16-Apr	7.90		14.8
1914	16-Oct	6.06		11.3
1915	03-Jun	27.6		51.5
1916	02-Jul	11.2		20.9
1917	11-Jun	18.1		33.8
1918	11-Jun	3.09		5.77
1919	28-May	3.82		7.13
1920	08-May	18.6		34.7
1921	21-May	5.21		9.73
1922	17-May	9.34		17.4
1923	01-Jun	44.2	01-Jun	66.5
1924	07-Jun	18.0	07-Jun	19.1
1925	23-Apr	7.08	23-Apr	7.36
1926	21-Jun	7.08	21-Jun	7.76
1927	29-May	38.2		71.3
1928	18-Jun	21.7	18-Jun	25.9
1929	03-Jun	21.3	03-Jun	23.8
1930	03-Jun	6.82	03-Jun	7.36
1931				
1932				
1933				
1934				
1935				6.62
1936	11-Apr	7.56		14.1
1937				51.1
1938				21.3
1939				6.99
1940				14.9
1941				3.20
1942				60.0
1943				19.4
1944				23.7
1945				25.3
1946				23.9
1947				11.8
1948				61.2
1949				20.6
1950				22.4
1951				24.4
1952				17.0
1953				198
1954				22.8
1955				20.8
1956				22.2
1957				16.7
1958				13.4
1959				18.0
1960				18.3
1961				21.7
1962				23.2
1963				24.0
1964				148
1965				74.5
1966	04-Jun	12.5	04-Jun	15.7
1967	17-May	29.4	17-May	53.0
1968	25-Sep	6.85	25-Sep	8.16
1969	26-Jun	34.5	26-Jun	49.8
1970	13-Jun	23.1	13-Jun	46.4
1971	31-May	6.31	31-May	6.63
1972	25-May	19.5	25-May	40.2
1973	18-May	4.11	18-May	4.33
1974	17-Mar	8.47	17-Mar	24.5
1975	20-Jun	82.4	20-Jun	172
1976	11-May	4.36		8.14
1977	12-May	0.767	11-May	0.818
1978	01-Jun	4.64	31-May	7.36

*underlined discharges are estimated values

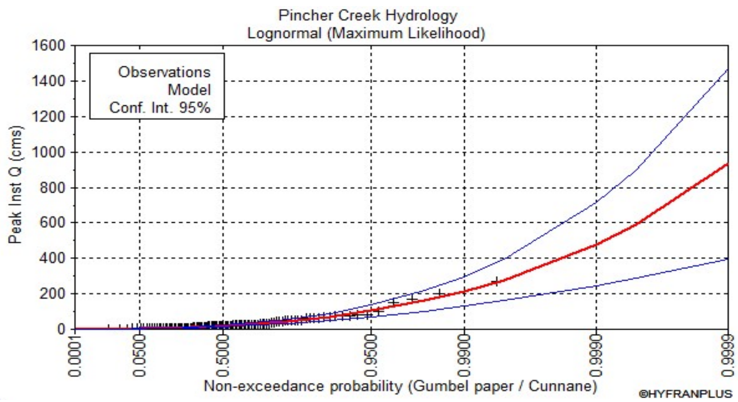
Year	Annual Maximum Daily Mean		Annual Maximum Instantaneous	
	Date	Discharge (m^3/s)	Date	Discharge (m^3/s)
1979	17-May	4.93	17-May	5.43
1980	26-May	22.0	26-May	33.7
1981	22-May	38.7	22-May	71.3
1982	07-Jun	3.87	07-Jun	4.30
1983	26-May	3.56	26-May	3.72
1984	16-May	2.94	16-May	3.40
1985	12-Sep	5.56	12-Sep	8.09
1986				19.8
1987	23-Jul	9.41	22-Jul	16.1
1988	13-May	2.61	13-May	2.78
1989	11-Jun	7.68	11-Jun	8.98
1990	29-May	15.0	29-May	22.0
1991	21-Jun	29.4	21-Jun	44.6
1992	10-Jul	5.46	10-Jul	7.16
1993	12-Jul	16.0		29.9
1994	20-May	15.6	20-May	17.5
1995	07-Jun	79.9	06-Jun	271
1996	06-Apr	9.53	05-Apr	15.0
1997	26-May	43.2	26-May	75.7
1998	16-Jun	20.5	16-Jun	31.0
1999	03-Jun	6.80	03-Jun	8.78
2000	30-May	1.42	30-May	1.67
2001	05-Jun	7.10	04-Jun	10.3
2002	10-Jun	62.8	10-Jun	80.4
2003	13-Mar	16.4	13-Mar	35.9
2004	27-May	6.21	27-May	6.72
2005	07-Jun	66.4	07-Jun	99.5
2006	14-Jun	11.6	15-Jun	16.1
2007	07-Jun	5.47	07-Jun	5.98
2008	24-May	32.5	24-May	53.3
2009	26-Jul	11.2	26-Jul	62.2
2010	17-Jun	58.2	17-Jun	76.0
2011	26-May	29.8	26-May	53.0
2012	24-Jun	6.30	24-Jun	8.03
2013	20-Jun	22.9	20-Jun	31.8
2014	19-Jun	57.2	18-Jun	79.6
2015	03-Jun	9.22	02-Jun	12.9
2016	24-May	2.91	24-May	3.22

*underlined discharges are estimated values

APPENDIX II

Flood Frequency Plots

Figure 1 Station 05AA004 Log-Normal Distribution



Pincher Creek at Pincher Creek

Results of the fitting

Lognormal (Maximum Likelihood)

Number of observations 104

Parameters

mu	2.906838
sigma	1.056882

Quantiles
q = F(X) : non-exceedance probability
T = 1/(1-q)

T	q	XT	Standard deviati	Confidence interval (95%)	
10000	0.9999	932	273	397	1470
2000	0.9995	593	156	286	899
1000	0.999	480	120	245	715
750	0.9987	438	107	228	647
500	0.998	383	90.1	207	560
350	0.9971	340	77.3	188	491
200	0.995	279	60.2	161	397
100	0.99	214	42.9	130	298
75	0.9867	191	36.8	118	263
50	0.98	160	29.4	103	218
35	0.9714	137	23.7	90.2	183
20	0.95	104	16.6	71.6	137
10	0.9	70.9	9.94	51.4	90.4
5	0.8	44.5	5.38	34	55.1
3	0.6667	28.8	3.12	22.7	35
2	0.5	18.3	1.9	14.6	22
1.4286	0.3	10.5	1.16	8.24	12.8
1.25	0.2	7.52	0.908	5.74	9.3
1.1111	0.1	4.72	0.662	3.42	6.02
1.0526	0.05	3.22	0.513	2.21	4.22
1.0204	0.02	2.09	0.383	1.34	2.84
1.0101	0.01	1.56	0.313	0.95	2.18
1.005	0.005	1.2	0.26	0.693	1.71
1.001	0.001	0.698	0.175	0.356	1.04
1.0005	0.0005	0.565	0.149	0.273	0.857
1.0001	0.0001	0.359	0.105	0.153	0.565

Pincher Creek at Pincher Creek

Adequacy test

Lognormal(Maximum Likelihood)

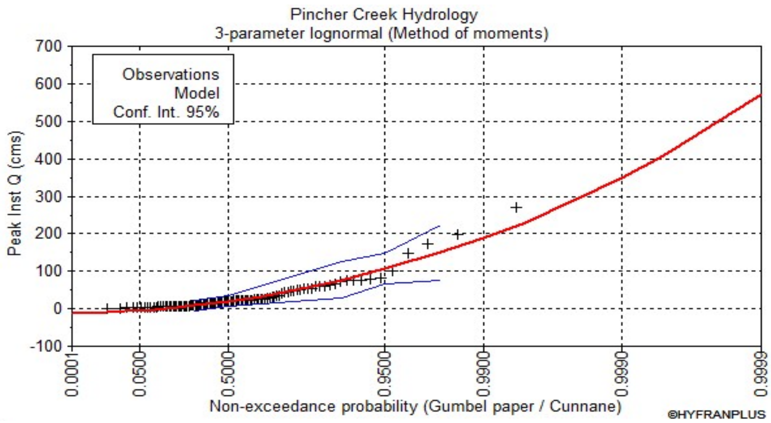
Hypotheses
H0 : The underlying distribution of this sample is Lognormal
H1 : The underlying distribution of this sample is not Lognormal

Results

Statistics result :	For Cs	For Ck
p-value :	-0.1	0
Degrees of freed	0.9171	0.9982

Conclusion
We accept H0 at a significance level of 5 %.

Figure 2 Station 05AA004 3-Parameter Log-Normal Distribution



Pincher Creek at Pincher Creek

Results of the fitting

3-parameter lognormal (Method of moments)

Number of observations 104

Parameters

m	-14.1898
mu	3.531548
sigma	0.764146

Quantiles
q = F(X) : non-exceedance probability
T = 1/(1-q)

T	q	XT	Standard d	Confidence interval (95%)	
10000	0.9999	572	830	N/D	N/D
2000	0.9995	408	451	N/D	N/D
1000	0.999	348	330	N/D	N/D
200	0.995	231	131	N/D	N/D
100	0.99	188	75.4	N/D	N/D
50	0.98	150	37.3	76.9	223
20	0.95	106	20.7	65.3	147
10	0.9	76.8	24.9	28	126
5	0.8	50.8	24	N/D	N/D
3	0.6667	33.3	17.3	N/D	N/D
2	0.5	20	7.51	5.26	34.7
1.4286	0.3	8.71	7.06	-5.14	22.6
1.25	0.2	3.78	14.5	N/D	N/D
1.1111	0.1	-1.36	24.3	N/D	N/D
1.0526	0.05	-4.47	31.4	N/D	N/D
1.0204	0.02	-7.08	38.3	N/D	N/D
1.0101	0.01	-8.41	42.3	N/D	N/D
1.005	0.005	-9.42	45.5	N/D	N/D
1.001	0.001	-11	51	N/D	N/D
1.0005	0.0005	-11.4	52.8	N/D	N/D
1.0001	0.0001	-12.2	56	N/D	N/D

Pincher Creek at Pincher Creek

Adequacy test

3-parameter lognormal(Method of moments)

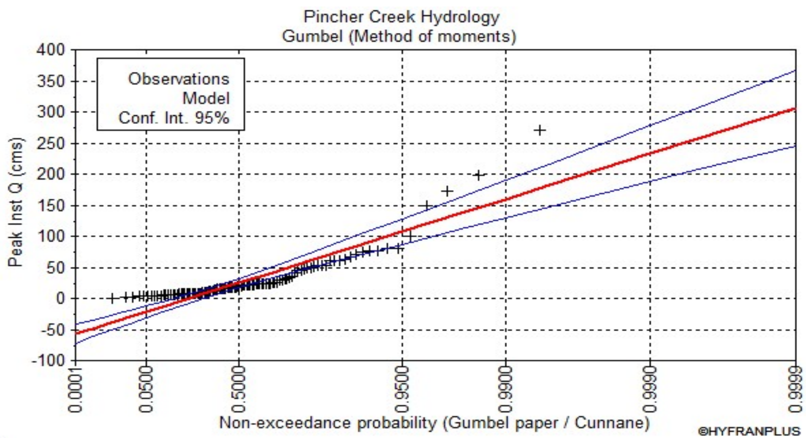
Hypotheses
H0 : The underlying distribution of this sample is 3-parameter lognormal
H1 : The underlying distribution of this sample is not 3-parameter lognormal

Results

	For Cs	For Ck
Statistics result :		
p-value :	-0.1	0
Degrees of freedom :	0.9171	0.9982

Conclusion
We accept H0 at a significance level of 5 %.

Figure 3 Station 05AA004 Gamma Distribution



Pincher Creek at Pincher Creek

Results of the fitting

Gumbel (Method of moments)

Number of observations 104

Parameters

u	13.23285
alpha	31.77641

Quantiles
q = F(X) : non-exceedance probability
T = 1/(1-q)

T	q	XT	Standard d	Confidence interval (95%)	
10000	0.9999	306	30.6	246	366
2000	0.9995	255	25.3	205	304
1000	0.999	233	23.1	187	278
200	0.995	182	17.9	146	217
100	0.99	159	15.7	129	190
50	0.98	137	13.5	111	164
20	0.95	108	10.5	87	128
10	0.9	84.7	8.34	68.4	101
5	0.8	60.9	6.18	48.8	73
3	0.6667	41.9	4.66	32.8	51.1
2	0.5	24.9	3.67	17.7	32.1
1.4286	0.3	7.33	3.37	0.727	13.9
1.25	0.2	-1.89	3.59	-8.92	5.14
1.1111	0.1	-13.3	4.15	-21.4	-5.14
1.0526	0.05	-21.6	4.71	-30.9	-12.4
1.0204	0.02	-30.1	5.35	-40.6	-19.6
1.0101	0.01	-35.3	5.78	-46.6	-24
1.005	0.005	-39.8	6.16	-51.8	-27.7
1.001	0.001	-48.2	6.9	-61.7	-34.6
1.0005	0.0005	-51.2	7.18	-65.3	-37.1
1.0001	0.0001	-57.3	7.74	-72.5	-42.2

Pincher Creek at Pincher Creek

Adequacy test

Gumbel(Method of moments)

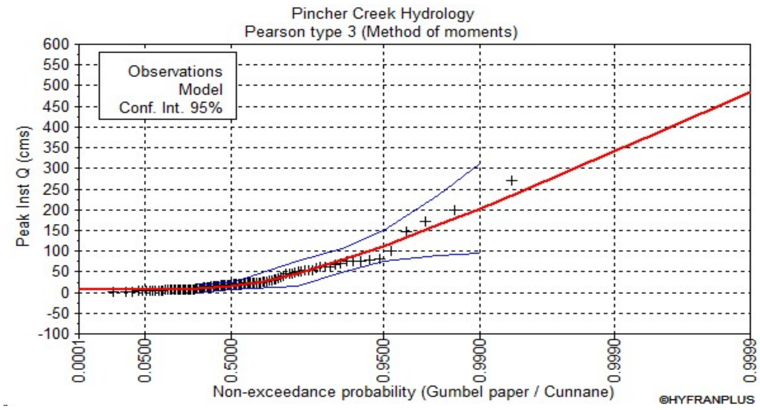
Hypotheses
H0 : The underlying distribution of this sample is Gumbel
H1 : The underlying distribution of this sample is not Gumbel

Results

Statistics result :	X^2= 104.62
p-value :	p = 0.0000
Degrees of freedom :	9
Number of classes :	12

Conclusion
We REJECT H0 at a significance level of 1 %.

Figure 4 Station 05AA004 Pearson Type 3 Distribution



Pincher Creek at Pincher Creek

Results of the fitting

Pearson type 3 (Method of moments)

Number of observations 104

Parameters

alpha	0.014528
lambda	0.350575
m	7.444009

Quantiles
q = F(X) : non-exceedance probability
T = 1/(1-q)

T	q	XT	Standard d	Confidence interval (95%)	
10000	0.9999	485	217	N/D	N/D
2000	0.9995	384	156	N/D	N/D
1000	0.999	341	131	N/D	N/D
200	0.995	243	76.3	N/D	N/D
100	0.99	202	55.2	93.8	310
50	0.98	162	36.7	90.5	234
20	0.95	112	19	75	150
10	0.9	77.1	14.9	47.8	106
5	0.8	45.7	14.9	16.5	74.8
3	0.6667	27.5	11	N/D	N/D
2	0.5	14.8	4.13	6.75	22.9
1.4286	0.3	9.06	5.62	-1.96	20.1
1.25	0.2	7.97	8.88	N/D	N/D
1.1111	0.1	7.6	10.8	N/D	N/D
1.0526	0.05	7.54	10.9	N/D	N/D
1.0204	0.02	7.44	10.4	N/D	N/D
1.0101	0.01	7.34	10	N/D	N/D
1.005	0.005	7.23	9.73	N/D	N/D
1.001	0.001	7.02	9.47	N/D	N/D
1.0005	0.0005	6.95	9.48	N/D	N/D
1.0001	0.0001	6.87	9.76	N/D	N/D

Pincher Creek at Pincher Creek

Adequacy test

Pearson type 3(Method of moments)

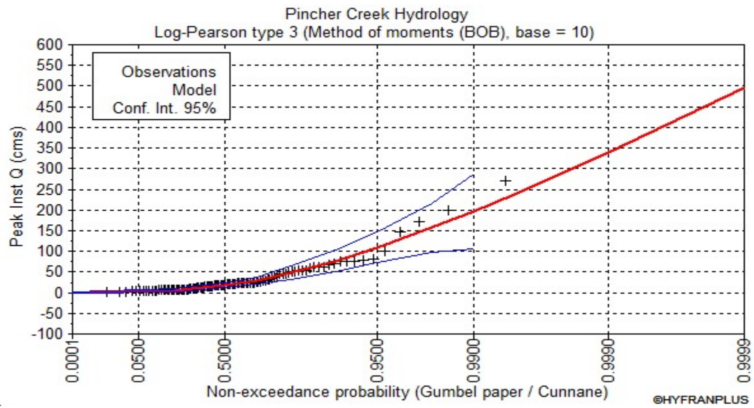
Hypotheses
H0 : The underlying distribution of this sample is Pearson type 3
H1 : The underlying distribution of this sample is not Pearson type 3

Results

Statistics result :	X^2= 63.77
p-value :	p = 0.0000
Degrees of freedom :	8
Number of classes :	12

Conclusion
We REJECT H0 at a significance level of 1 %.

Figure 5 Station 05AA004 Log-Pearson Type 3 Distribution



Pincher Creek at Pincher Creek

Results of the fitting

Log-Pearson type 3 (Method of moments (BOB), base = 10)

Number of observations 104

Parameters

alpha	-6.901743
lambda	15.08007
m	3.38485

Quantiles
q = F(X) : non-exceedance probability
T = 1/(1-q)

T	q	XT	Standard d	Confidence interval (95%)	
10000	0.9999	495	383	N/D	N/D
2000	0.9995	386	220	N/D	N/D
1000	0.999	340	165	N/D	N/D
200	0.995	238	71.3	N/D	N/D
100	0.99	196	46.3	106	287
50	0.98	157	30	98.2	216
20	0.95	109	18.8	72.3	146
10	0.9	76.6	13.4	50.4	103
5	0.8	48.1	7.92	32.6	63.6
3	0.6667	30.2	4.14	22.1	38.3
2	0.5	17.7	2.72	12.4	23
1.4286	0.3	8.77	2.82	3.25	14.3
1.25	0.2	5.57	2.71	0.252	10.9
1.1111	0.1	2.85	2.23	N/D	N/D
1.0526	0.05	1.58	1.72	N/D	N/D
1.0204	0.02	0.786	1.17	N/D	N/D
1.0101	0.01	0.482	0.862	N/D	N/D
1.005	0.005	0.303	0.633	N/D	N/D
1.001	0.001	0.11	0.309	N/D	N/D
1.0005	0.0005	0.0732	0.227	N/D	N/D
1.0001	0.0001	0.0293	0.112	-0.19	0.249

Pincher Creek at Pincher Creek

Adequacy test

Log-Pearson type 3(Method of moments (BOB), base = 10)

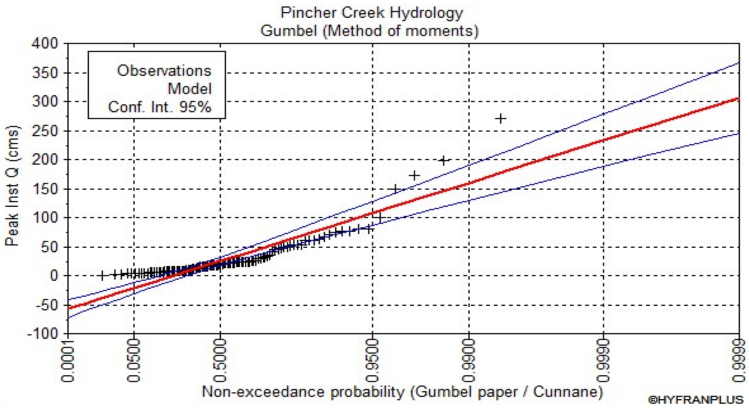
Hypotheses
H0 : The underlying distribution of this sample is Log-Pearson type 3
H1 : The underlying distribution of this sample is not Log-Pearson type 3

Results

Statistics result :	X^2= 22.92
p-value :	p = 0.0035
Degrees of freedom :	8
Number of classes :	12

Conclusion
We REJECT H0 at a significance level of 1 %.

Figure 6 Station 05AA004 Gumbel Distribution



Pincher Creek at Pincher Creek

Results of the fitting

Gumbel (Method of moments)

Number of observations 104

Parameters

u	13.23285
alpha	31.77641

Quantiles

q = F(X) : non-exceedance probability

T = 1/(1-q)

T	q	XT	Standard d	Confidence interval (95%)	
10000	0.9999	306	30.6	246	366
2000	0.9995	255	25.3	205	304
1000	0.999	233	23.1	187	278
200	0.995	182	17.9	146	217
100	0.99	159	15.7	129	190
50	0.98	137	13.5	111	164
20	0.95	108	10.5	87	128
10	0.9	84.7	8.34	68.4	101
5	0.8	60.9	6.18	48.8	73
3	0.6667	41.9	4.66	32.8	51.1
2	0.5	24.9	3.67	17.7	32.1
1.4286	0.3	7.33	3.37	0.727	13.9
1.25	0.2	-1.89	3.59	-8.92	5.14
1.1111	0.1	-13.3	4.15	-21.4	-5.14
1.0526	0.05	-21.6	4.71	-30.9	-12.4
1.0204	0.02	-30.1	5.35	-40.6	-19.6
1.0101	0.01	-35.3	5.78	-46.6	-24
1.005	0.005	-39.8	6.16	-51.8	-27.7
1.001	0.001	-48.2	6.9	-61.7	-34.6
1.0005	0.0005	-51.2	7.18	-65.3	-37.1
1.0001	0.0001	-57.3	7.74	-72.5	-42.2

Pincher Creek at Pincher Creek

Adequacy test

Gumbel(Method of moments)

Hypotheses

H0 : The underlying distribution of this sample is Gumbel

H1 : The underlying distribution of this sample is not Gumbel

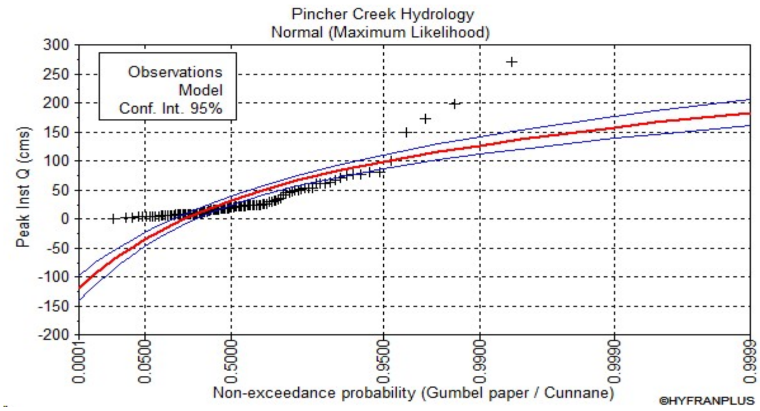
Results

Statistics result :	X^2= 104.62
p-value :	p = 0.0000
Degrees of freedom :	9
Number of classes :	12

Conclusion

We REJECT H0 at a significance level of 1 %.

Figure 7 Station 05AA004 Normal Distribution



Pincher Creek at Pincher Creek

Results of the fitting

Normal (Maximum Likelihood)

Number of observations 104

Parameters

mu	31.57469
sigma	40.75482

Quantiles
q = F(X) : non-exceedance probability
T = 1/(1-q)

T	q	XT	Standard d	Confidence interval (95%)	
10000	0.9999	183	11.3	161	205
2000	0.9995	166	10.2	146	186
1000	0.999	158	9.64	139	176
200	0.995	137	8.34	120	153
100	0.99	126	7.72	111	142
50	0.98	115	7.07	101	129
20	0.95	98.6	6.15	86.6	111
10	0.9	83.8	5.41	73.2	94.4
5	0.8	65.9	4.66	56.7	75
3	0.6667	49.1	4.18	40.9	57.3
2	0.5	31.6	4	23.7	39.4
1.4286	0.3	10.2	4.26	1.86	18.6
1.25	0.2	-2.72	4.66	-11.8	6.41
1.1111	0.1	-20.7	5.41	-31.3	-10.1
1.0526	0.05	-35.5	6.15	-47.5	-23.4
1.0204	0.02	-52.1	7.07	-66	-38.3
1.0101	0.01	-63.3	7.72	-78.4	-48.1
1.005	0.005	-73.4	8.34	-89.8	-57.1
1.001	0.001	-94.4	9.64	-113	-75.5
1.0005	0.0005	-103	10.2	-122	-82.6
1.0001	0.0001	-120	11.3	-142	-97.9

Pincher Creek at Pincher Creek

Adequacy test

Normal(Maximum Likelihood)

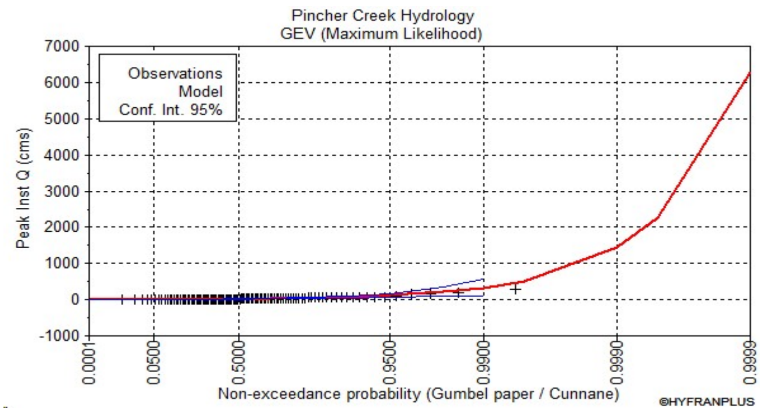
Hypotheses
H0 : The underlying distribution of this sample is Normal
H1 : The underlying distribution of this sample is not Normal

Results

Statistics result :	For Cs	For Ck
p-value :	14.95	0.05
Degrees of freedom :	0	0.9621

Conclusion
We REJECT H0 at a significance level of 5 %.

Figure 8 Station 05AA004 GEV Distribution



Pincher Creek at Pincher Creek

Results of the fitting

GEV (Maximum Likelihood)

Number of observations 104

Parameters

alpha	11.65013
k	-0.633317
u	12.71265

Quantiles
q = F(X) : non-exceedance probability
T = 1/(1-q)

T	q	XT	Standard d	Confidence interval (95%)	
10000	0.9999	6.27E+03	5.11E+03	N/D	N/D
2000	0.9995	2260	1480	N/D	N/D
1000	0.999	1450	852	N/D	N/D
200	0.995	521	224	N/D	N/D
100	0.99	333	122	94.5	572
50	0.98	212	64.2	86.1	338
20	0.95	115	25.9	64.1	166
10	0.9	70.8	12.3	46.8	94.9
5	0.8	41.9	5.44	31.2	52.6
3	0.6667	26.9	2.91	21.2	32.6
2	0.5	17.5	1.77	14.1	21
1.4286	0.3	10.7	1.12	8.49	12.9
1.25	0.2	7.93	0.891	6.18	9.67
1.1111	0.1	5.16	0.71	3.77	6.56
1.0526	0.05	3.5	0.656	2.21	4.79
1.0204	0.02	2.07	0.674	0.75	3.39
1.0101	0.01	1.31	0.716	-0.0927	2.71
1.005	0.005	0.716	0.765	-0.783	2.21
1.001	0.001	-0.273	0.879	-2	1.45
1.0005	0.0005	-0.591	0.924	-2.4	1.22
1.0001	0.0001	-1.17	1.02	-3.17	0.822

Pincher Creek at Pincher Creek

Adequacy test

GEV(Maximum Likelihood)

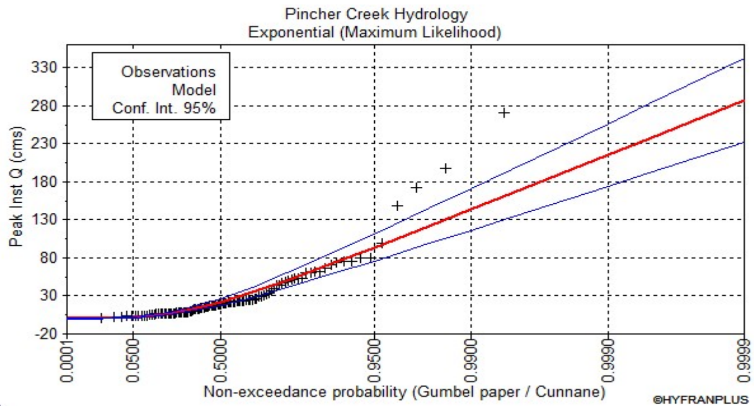
Hypotheses
H0 : The underlying distribution of this sample is GEV
H1 : The underlying distribution of this sample is not GEV

Results

Statistics result :	X^2= 23.85
p-value :	p = 0.0024
Degrees of freedom :	8
Number of classes :	12

Conclusion
We REJECT H0 at a significance level of 1 %.

Figure 9 Station 05AA004 Exponential Distribution



Pincher Creek at Pincher Creek

Results of the fitting

Exponential (Maximum Likelihood)

Number of observations 104

Parameters

alpha	31.0553
m	0.519391

Quantiles
q = F(X) : non-exceedance probability
T = 1/(1-q)

T	q	XT	Standard d	Confidence interval (95%)	
10000	0.9999	287	28.2	231	342
2000	0.9995	237	23.2	191	282
1000	0.999	215	21.1	174	256
200	0.995	165	16.2	133	197
100	0.99	144	14.1	116	171
50	0.98	122	11.9	98.6	145
20	0.95	93.6	9.14	75.6	111
10	0.9	72	7.02	58.3	85.8
5	0.8	50.5	4.9	40.9	60.1
3	0.6667	34.6	3.35	28.1	41.2
2	0.5	22	2.11	17.9	26.2
1.4286	0.3	11.6	1.1	9.43	13.8
1.25	0.2	7.45	0.718	6.04	8.86
1.1111	0.1	3.79	0.418	2.97	4.61
1.0526	0.05	2.11	0.325	1.48	2.75
1.0204	0.02	1.15	0.3	0.558	1.74
1.0101	0.01	0.832	0.299	0.246	1.42
1.005	0.005	0.675	0.299	0.089	1.26
1.001	0.001	0.55	0.3	-0.0372	1.14
1.0005	0.0005	0.535	0.3	-0.053	1.12
1.0001	0.0001	0.522	0.3	-0.0657	1.11

Pincher Creek at Pincher Creek

Adequacy test

Exponential(Maximum Likelihood)

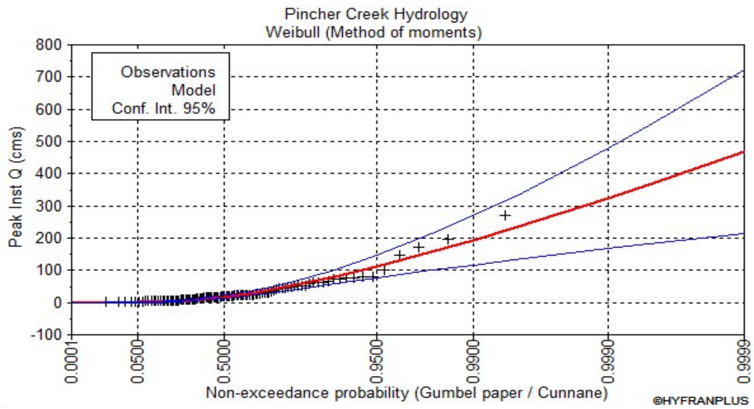
Hypotheses
H0 : The underlying distribution of this sample is Exponential
H1 : The underlying distribution of this sample is not Exponential

Results

Statistics result :	X^2= 22.92
p-value :	p = 0.0064
Degrees of freedom :	9
Number of classes :	12

Conclusion
We REJECT H0 at a significance level of 1 %.

Figure 10 Station 05AA004 Weibull Distribution



Pincher Creek at Pincher Creek

Results of the fitting

Weibull (Method of moments)

Number of observations 104

Parameters

alpha	27.42561
c	0.782724

Quantiles

q = F(X) : non-exceedance probability

T = 1/(1-q)

T	q	XT	Standard d	Confidence interval (95%)	
10000	0.9999	468	130	213	723
2000	0.9995	366	93.7	182	550
1000	0.999	324	79.4	168	480
200	0.995	231	49.9	133	329
100	0.99	193	38.8	117	269
50	0.98	157	28.9	100	213
20	0.95	111	17.8	76.5	146
10	0.9	79.6	11.1	57.8	101
5	0.8	50.4	6.15	38.3	62.4
3	0.6667	30.9	3.75	23.6	38.3
2	0.5	17.2	2.49	12.3	22
1.4286	0.3	7.35	1.51	4.38	10.3
1.25	0.2	4.04	1.04	2	6.08
1.1111	0.1	1.55	0.536	0.496	2.6
1.0526	0.05	0.617	0.268	0.0909	1.14
1.0204	0.02	0.188	0.103	N/D	N/D
1.0101	0.01	0.0769	0.0492	N/D	N/D
1.005	0.005	0.0316	0.023	N/D	N/D
1.001	0.001	0.00403	0.00377	N/D	N/D
1.0005	0.0005	0.00166	0.0017	N/D	N/D
1.0001	0.0001	0.000213	0.000262	-0.0003	0.000725

Pincher Creek at Pincher Creek

Adequacy test

Weibull(Method of moments)

Hypotheses

H0 : The underlying distribution of this sample is Weibull

H1 : The underlying distribution of this sample is not Weibull

Results

Statistics result :	X^2= 30.54
p-value :	p = 0.0004
Degrees of freedom :	9
Number of classes :	12

Conclusion

We REJECT H0 at a significance level of 1 %.

APPENDIX IV

Photographs of the 1995 Event

Appendix IV
Photographs of the 1995 Event

Figure IV.1 Looking Upstream from Beaver Drive Bridges,

Figure IV.2 Looking Downstream from Beaver Drive Bridge

Figure IV.3 Damage to Right Abutment of Beaver Drive Bridge

Figure IV.4 Looking Upstream from Hewetson Avenue Bridge

Figure IV.5 Looking Downstream from Hewetson Avenue Bridge – Flood Levels Reached Bottom Sill of Patio Doors

Figure IV.6 Upstream of Highway 6 Bridge

Figure IV.7 Looking Downstream of Highway 6 Bridge

Figure IV.8 Washout of the Low Level Crossing upstream of the Kettles Creek Confluence

Figure IV.9 Damage to Right Abutment of Highway 785 Bridge

Figure IV.10 Flood Damage looking Upstream from Highway 785 Bridge

Figure IV.11 Washout Identified on Township Road 301 Bridge Over Kettles Creek

APPENDIX V

Cross Section Data

Appendix V
Cross Section Data

Table V.1 Cross Section Data – Pincher Creek

River	Cross Section	Thalweg (m)	Channel Width (m)	Notes
Pincher Creek	14327	1181.74	9.99	
Pincher Creek	14196	1180.35	11.42	
Pincher Creek	14099	1180.99	20.07	
Pincher Creek	13994	1179.57	10.38	
Pincher Creek	13885	1178.82	19.69	
Pincher Creek	13770	1178.38	18.64	
Pincher Creek	13649	1177.48	15.07	
Pincher Creek	13520	1177.07	14.95	
Pincher Creek	13394	1176.16	9.42	
Pincher Creek	13265	1175.48	9.81	
Pincher Creek	13100	1175.00	10.29	
Pincher Creek	12957	1174.15	8.17	
Pincher Creek	12831	1174.12	21.42	
Pincher Creek	12630	1172.87	11.69	
Pincher Creek	12499	1172.34	23.90	
Pincher Creek	12377	1171.78	15.50	
Pincher Creek	12263	1171.13	17.05	
Pincher Creek	12119	1170.07	9.43	
Pincher Creek	11995	1169.62	20.35	
Pincher Creek	11868	1169.20	22.40	
Pincher Creek	11743	1168.41	16.90	
Pincher Creek	11556	1167.09	14.41	
Pincher Creek	11446	1166.52	12.41	
Pincher Creek	11332	1165.86	14.61	
Pincher Creek	11202	1164.85	14.81	
Pincher Creek	11062	1163.76	9.48	
Pincher Creek	10914	1163.29	12.82	
Pincher Creek	10738	1162.34	21.91	
Pincher Creek	10610	1160.64	15.82	
Pincher Creek	10484	1159.72	18.24	
Pincher Creek	10322	1158.63	19.66	
Pincher Creek	10153	1157.26	17.01	
Pincher Creek	10006	1155.67	17.49	
Pincher Creek	9868	1153.65	16.22	
Pincher Creek	9719	1152.16	15.34	
Pincher Creek	9610	1149.72	14.36	
Pincher Creek	9517	1148.72	14.09	
Pincher Creek	9415	1148.00	14.22	
Pincher Creek	9325	1147.05	12.75	
Pincher Creek	9225	1144.98	16.41	
Pincher Creek	9122	1143.48	14.15	
Pincher Creek	9021	1141.67	7.63	
Pincher Creek	8977	1141.40	16.88	
Pincher Creek	8928	1140.25	19.27	
Pincher Creek	8915	1137.11	8.98	Upstream of Pathway Bridge by the Pincher Creek Community Centre
Pincher Creek	8913	1137.34	10.33	Downstream of Pathway Bridge by the Pincher Creek Community Centre
Pincher Creek	8869	1139.72	14.84	
Pincher Creek	8769	1138.41	14.21	
Pincher Creek	8665	1137.38	14.64	
Pincher Creek	8528	1135.76	8.63	
Pincher Creek	8424	1134.76	10.42	
Pincher Creek	8321	1134.79	15.75	
Pincher Creek	8223	1133.62	9.35	
Pincher Creek	8194	1132.96	19.09	Upstream of Beaver Drive Bridge
Pincher Creek	8182	1133.54	19.92	Downstream of Beaver Drive Bridge
Pincher Creek	8077	1132.69	14.54	
Pincher Creek	7879	1131.65	21.11	
Pincher Creek	7691	1130.41	16.40	
Pincher Creek	7499	1128.96	11.31	
Pincher Creek	7342	1128.67	17.14	
Pincher Creek	7217	1127.32	15.13	
Pincher Creek	7176	1127.32	22.70	Upstream of Hewetson Avenue Bridge
Pincher Creek	7160	1127.50	20.76	Downstream of Hewetson Avenue Bridge
Pincher Creek	7101	1126.56	13.58	
Pincher Creek	7081	1126.47	13.18	

River	Cross Section	Thalweg (m)	Channel Width (m)	Notes
Pincher Creek	7038	1126.47	16.55	
Pincher Creek	6985	1125.80	15.54	
Pincher Creek	6924	1125.26	11.33	
Pincher Creek	6897	1124.81	11.04	Upstream of Bev McLachlin Drive Bridge
Pincher Creek	6883	1124.84	9.45	Downstream of Bev McLachlin Drive Bridge
Pincher Creek	6867	1124.43	12.34	
Pincher Creek	6783	1124.42	14.85	
Pincher Creek	6710	1123.73	16.16	
Pincher Creek	6651	1122.87	15.15	Upstream of Pathway Bridge 2 at the end of James Avenue
Pincher Creek	6649	1122.93	12.85	Downstream of Pathway Bridge 2 at the end of James Avenue
Pincher Creek	6555	1122.37	16.74	
Pincher Creek	6429	1122.18	17.67	
Pincher Creek	6321	1121.26	16.11	
Pincher Creek	6193	1120.18	15.50	
Pincher Creek	6089	1119.91	16.23	
Pincher Creek	5979	1118.81	12.76	
Pincher Creek	5875	1118.06	16.26	
Pincher Creek	5838	1118.23	24.98	Upstream of Highway 6 Bridge
Pincher Creek	5824	1118.09	23.49	Downstream of Highway 6 Bridge
Pincher Creek	5756	1118.01	17.32	
Pincher Creek	5636	1117.40	18.38	
Pincher Creek	5510	1116.70	10.09	
Pincher Creek	5402	1116.66	29.12	
Pincher Creek	5281	1115.56	11.49	
Pincher Creek	5096	1114.04	11.65	
Pincher Creek	4962	1114.60	12.81	
Pincher Creek	4863	1113.97	11.09	
Pincher Creek	4636	1112.68	10.77	
Pincher Creek	4508	1112.78	26.34	
Pincher Creek	4394	1111.96	14.16	
Pincher Creek	4132	1111.61	12.23	
Pincher Creek	3976	1110.63	13.86	
Pincher Creek	3824	1110.15	17.56	
Pincher Creek	3685	1110.06	20.64	
Pincher Creek	3573	1108.76	14.31	
Pincher Creek	3514	1108.48	16.13	
Pincher Creek	3367	1107.50	12.58	
Pincher Creek	3222	1106.89	15.31	
Pincher Creek	3030	1105.85	12.43	
Pincher Creek	2896	1105.86	19.96	
Pincher Creek	2739	1105.43	19.72	
Pincher Creek	2607	1105.05	22.11	
Pincher Creek	2438	1103.73	17.23	
Pincher Creek	2316	1103.69	19.37	
Pincher Creek	2192	1102.54	15.36	
Pincher Creek	2039	1102.42	18.31	
Pincher Creek	1898	1101.18	14.26	
Pincher Creek	1720	1101.19	22.27	
Pincher Creek	1545	1100.15	29.85	
Pincher Creek	1439	1099.27	22.48	
Pincher Creek	1405	1098.83	18.79	Upstream of Highway 785 Bridge
Pincher Creek	1393	1098.87	17.00	Downstream of Highway 785 Bridge
Pincher Creek	1289	1098.80	20.09	
Pincher Creek	1189	1098.55	11.65	
Pincher Creek	1144	1098.10	17.98	
Pincher Creek	1024	1097.96	21.66	
Pincher Creek	884	1097.76	18.51	
Pincher Creek	792	1097.50	14.22	
Pincher Creek	606	1096.31	8.54	
Pincher Creek	486	1096.40	10.15	
Pincher Creek	327	1096.16	15.00	
Pincher Creek	140	1095.33	13.04	
Pincher Creek	0	1095.25	22.08	

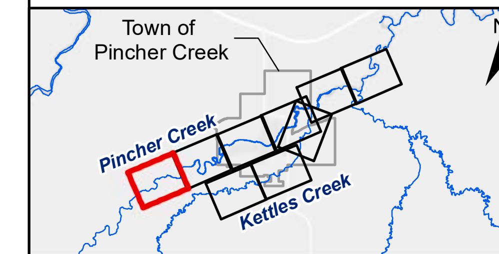
Table V.2 Cross Section Data – Kettles Creek

River	Cross Section	Thalweg (m)	Channel Width (m)	Notes
Kettles Creek	7295	1173.73	1.82	
Kettles Creek	7239	1173.01	4.70	
Kettles Creek	7178	1172.91	6.68	
Kettles Creek	7123	1172.11	5.31	
Kettles Creek	7041	1170.90	4.90	
Kettles Creek	6951	1170.20	4.47	
Kettles Creek	6880	1169.36	3.12	
Kettles Creek	6829	1168.79	3.49	
Kettles Creek	6768	1168.53	3.46	
Kettles Creek	6728	1168.20	4.13	
Kettles Creek	6690	1168.08	5.61	
Kettles Creek	6628	1167.83	7.87	
Kettles Creek	6586	1167.01	4.23	
Kettles Creek	6536	1166.69	7.90	
Kettles Creek	6480	1166.04	3.42	
Kettles Creek	6402	1165.73	4.16	
Kettles Creek	6352	1165.46	4.26	
Kettles Creek	6295	1165.08	3.34	
Kettles Creek	6212	1164.11	2.31	
Kettles Creek	6162	1163.80	4.29	
Kettles Creek	6053	1162.96	3.80	
Kettles Creek	5996	1162.16	3.50	
Kettles Creek	5943	1161.95	4.29	
Kettles Creek	5901	1161.50	5.41	
Kettles Creek	5837	1160.67	3.70	
Kettles Creek	5785	1160.26	3.86	
Kettles Creek	5736	1159.68	2.37	
Kettles Creek	5674	1159.27	2.60	
Kettles Creek	5596	1158.29	3.50	
Kettles Creek	5544	1158.36	4.50	
Kettles Creek	5471	1157.31	6.66	
Kettles Creek	5388	1156.45	3.65	
Kettles Creek	5312	1155.76	4.22	
Kettles Creek	5214	1155.20	6.56	
Kettles Creek	5166	1154.07	4.20	
Kettles Creek	5120	1153.90	3.33	
Kettles Creek	5069	1153.76	6.66	
Kettles Creek	5008	1153.03	3.24	
Kettles Creek	4960	1152.76	7.07	
Kettles Creek	4914	1152.03	6.62	
Kettles Creek	4859	1151.94	3.92	
Kettles Creek	4776	1151.46	6.49	
Kettles Creek	4693	1150.49	5.61	
Kettles Creek	4599	1149.69	6.39	
Kettles Creek	4518	1149.09	7.35	
Kettles Creek	4448	1148.61	6.92	
Kettles Creek	4350	1148.25	5.38	
Kettles Creek	4286	1147.48	8.14	
Kettles Creek	4229	1147.13	6.61	
Kettles Creek	4180	1145.96	3.98	
Kettles Creek	4142	1145.73	7.86	
Kettles Creek	4108	1145.46	4.84	
Kettles Creek	4094	1145.09	4.37	Upstream of Range Road 302 Bridge (East Avenue)
Kettles Creek	4062	1145.18	5.47	Downstream of Range Road 302 Bridge (East Avenue)
Kettles Creek	4011	1144.56	5.13	
Kettles Creek	3924	1143.38	6.05	
Kettles Creek	3851	1143.17	4.88	
Kettles Creek	3810	1143.30	6.12	
Kettles Creek	3746	1142.47	3.27	
Kettles Creek	3699	1142.34	6.29	
Kettles Creek	3659	1140.94	4.07	
Kettles Creek	3594	1141.48	5.97	
Kettles Creek	3517	1140.80	3.38	
Kettles Creek	3449	1139.28	4.90	
Kettles Creek	3390	1139.91	3.08	
Kettles Creek	3328	1139.13	3.91	
Kettles Creek	3277	1138.61	4.08	
Kettles Creek	3184	1137.86	5.27	
Kettles Creek	3132	1137.58	5.27	
Kettles Creek	3073	1136.94	4.35	
Kettles Creek	3025	1136.44	2.92	

River	Cross Section	Thalweg (m)	Channel Width (m)	Notes
Kettles Creek	2937	1135.82	5.09	
Kettles Creek	2868	1135.54	3.70	
Kettles Creek	2796	1134.51	5.24	
Kettles Creek	2746	1134.32	4.38	
Kettles Creek	2723	1134.11	4.18	Upstream of Upstream Golf Course Bridge
Kettles Creek	2719	1134.26	5.19	Downstream of Upstream Golf Course Bridge
Kettles Creek	2657	1133.45	3.87	
Kettles Creek	2608	1132.93	2.72	
Kettles Creek	2578	1132.81	5.04	Upstream of Downstream Golf Course Bridge
Kettles Creek	2574	1132.79	3.50	Downstream of Downstream Golf Course Bridge
Kettles Creek	2548	1132.95	7.82	Upstream of Highway 6 Bridge
Kettles Creek	2534	1132.91	5.47	Downstream of Highway 6 Bridge
Kettles Creek	2499	1132.23	2.57	
Kettles Creek	2439	1131.59	4.84	
Kettles Creek	2364	1131.55	2.33	
Kettles Creek	2285	1131.16	3.01	
Kettles Creek	2202	1129.66	5.22	
Kettles Creek	2116	1127.78	9.06	
Kettles Creek	2025	1126.91	4.52	
Kettles Creek	1942	1125.76	6.49	
Kettles Creek	1851	1125.23	7.35	
Kettles Creek	1770	1124.41	11.76	
Kettles Creek	1711	1123.69	3.69	
Kettles Creek	1692	1123.40	8.14	Upstream of Main Street Bridge
Kettles Creek	1681	1123.68	10.67	Downstream of Main Street Bridge
Kettles Creek	1658	1122.95	6.67	
Kettles Creek	1591	1122.65	2.77	
Kettles Creek	1533	1122.25	8.04	
Kettles Creek	1477	1121.58	6.06	
Kettles Creek	1392	1120.75	8.98	
Kettles Creek	1309	1120.62	9.14	
Kettles Creek	1225	1120.12	7.97	
Kettles Creek	1141	1119.80	8.08	
Kettles Creek	1045	1118.50	8.66	
Kettles Creek	953	1118.48	5.12	
Kettles Creek	870	1117.67	4.71	
Kettles Creek	798	1117.33	5.41	
Kettles Creek	732	1116.68	4.86	
Kettles Creek	701	1116.70	5.78	Upstream of Macleod St. (Highway 785) Bridge
Kettles Creek	690	1116.83	6.88	Downstream of Macleod St. (Highway 785) Bridge
Kettles Creek	637	1116.00	6.24	
Kettles Creek	547	1115.21	3.05	
Kettles Creek	478	1115.22	5.65	
Kettles Creek	421	1114.57	4.66	
Kettles Creek	407	1114.35	5.01	Upstream of Range Road 301 Bridge
Kettles Creek	397	1114.25	6.34	Downstream of Range Road 301 Bridge
Kettles Creek	360	1113.72	5.68	
Kettles Creek	293	1113.24	5.63	
Kettles Creek	234	1111.97	4.87	
Kettles Creek	177	1111.35	5.06	
Kettles Creek	126	1110.84	5.32	
Kettles Creek	65	1110.04	4.91	
Kettles Creek	5	1109.31	5.07	

Alberta Government

Klohn Crippen Berger



FLOW DIRECTION
CROSS SECTION
1325 RIVER STATION
FLOOD CONTROL STRUCTURE
BRIDGE
MAJOR ROAD
LOCAL ROAD
MUNICIPAL DISTRICT BOUNDARY
STUDY LIMIT
CREEK CENTRELINE

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

Coordinate System: NAD 1983 3TM 114
Units: METRES

Engineer	GIS	Reviewer
KC	VC / TS	RJC

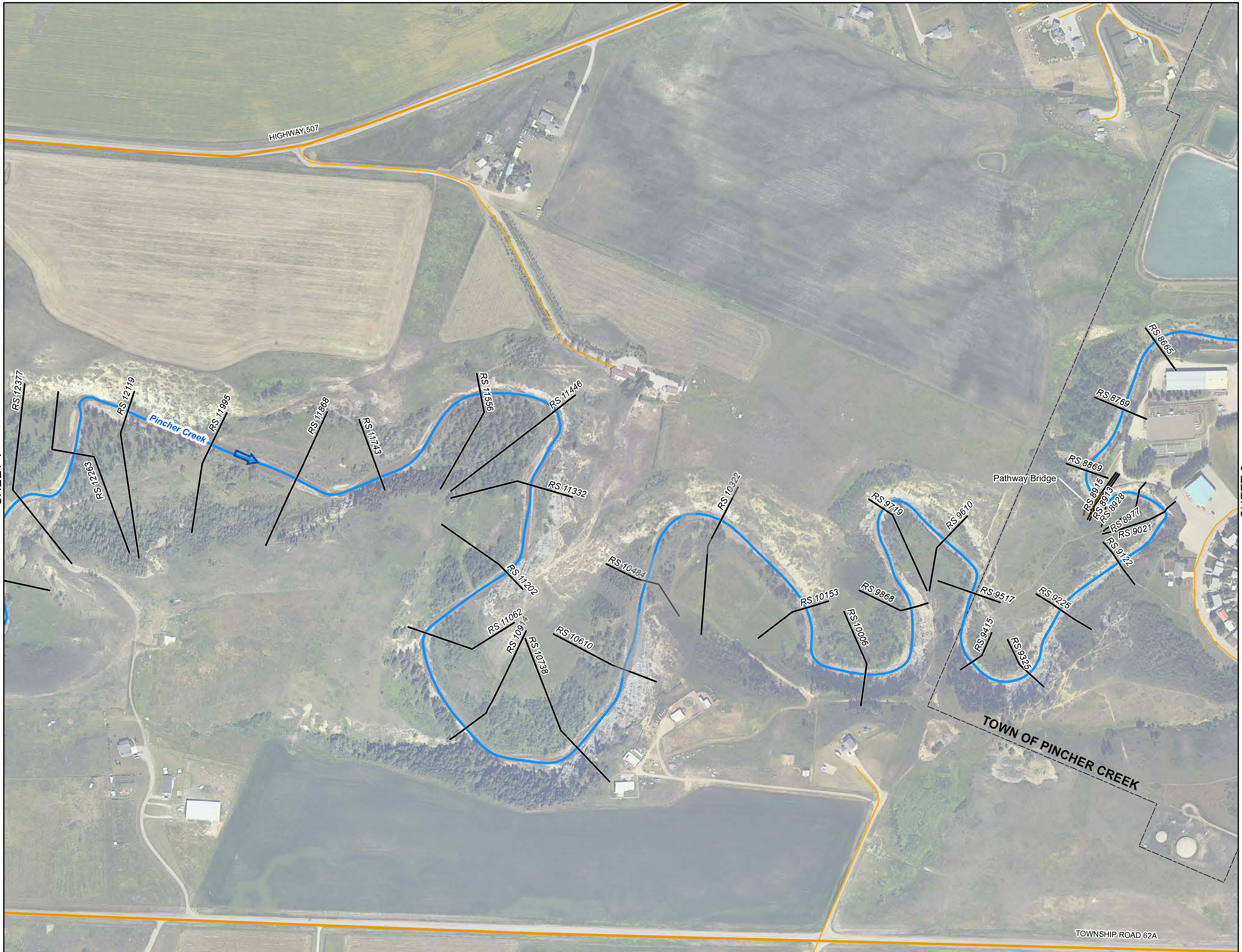
Job Number	Date
A03285C13	13-APR-2020

PINCHER CREEK HAZARD STUDY

HYDRAULIC MODEL SETUP
FIGURE 1

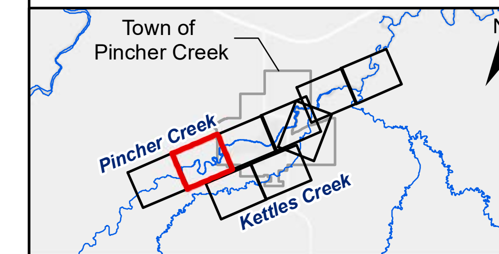
SHEET 1 OF 9

Classification: Public



Alberta Government

Klohn Crippen Berger



FLOW DIRECTION
CROSS SECTION
1325 RIVER STATION
FLOOD CONTROL STRUCTURE
BRIDGE
MAJOR ROAD
LOCAL ROAD
MUNICIPAL DISTRICT BOUNDARY
STUDY LIMIT
CREEK CENTRELINE

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

Coordinate System: NAD 1983 3TM 114
Units: METRES

Engineer	GIS	Reviewer
KC	VC / TS	RJC

Job Number	Date
A03285C13	13-APR-2020

PINCHER CREEK HAZARD STUDY

HYDRAULIC MODEL SETUP
FIGURE 2

SHEET 2 OF 9

Classification: Public

Classification: Public

Alberta Government

Klohn Crippen Berger

Town of Pincher Creek

Pincher Creek

Kettles Creek

N

FLOW DIRECTION
CROSS SECTION
1325 RIVER STATION
FLOOD CONTROL STRUCTURE
BRIDGE
MAJOR ROAD
LOCAL ROAD
MUNICIPAL DISTRICT BOUNDARY
STUDY LIMIT
CREEK CENTRELINE

SCALE - 1:5,000

0 100 200 M

N

Coordinate System: NAD 1983 3TM 114
Units: METRES

Engineer	GIS	Reviewer
KC	VC / TS	RJC

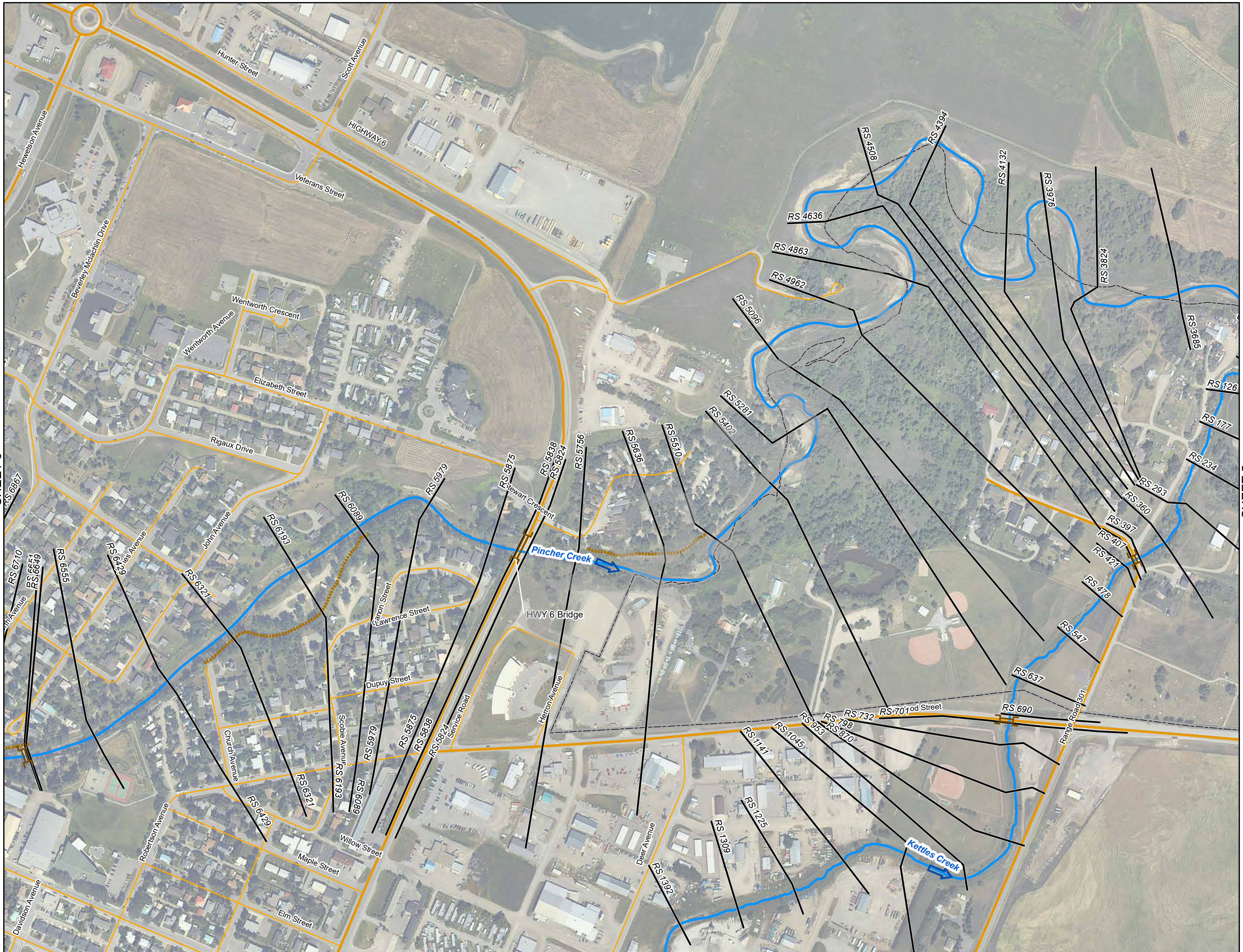
Job Number	Date
A03285C13	13-APR-2020

PINCHER CREEK HAZARD STUDY

HYDRAULIC MODEL SETUP
FIGURE 3

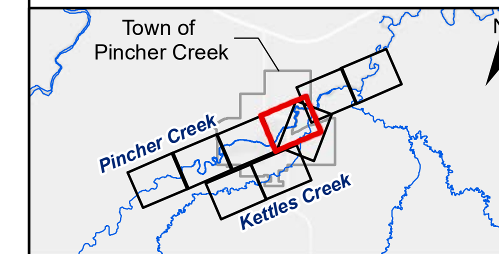
SHEET 3 OF 9

MSN_\\int.klohn.com\ProjData\A\CGY\Alberta\A03285C13 AEP Pincher Creek Fld Hazard St\400 Drawings\04 Open Water Flood Inundation Mapping\02 GIS\03_Maps\FIG 4.6.a-4.6.1_Hydraulic Model Setup.mxd



Alberta Government

Klohn Crippen Berger



FLOW DIRECTION
CROSS SECTION
1325 RIVER STATION
FLOOD CONTROL STRUCTURE
BRIDGE
MAJOR ROAD
LOCAL ROAD
MUNICIPAL DISTRICT BOUNDARY
STUDY LIMIT
CREEK CENTRELINE

SCALE - 1:5,000
0 100 200 M

Coordinate System: NAD 1983 3TM 114
Units: METRES

Engineer	GIS	Reviewer
KC	VC / TS	RJC

Job Number	Date
A03285C13	13-APR-2020

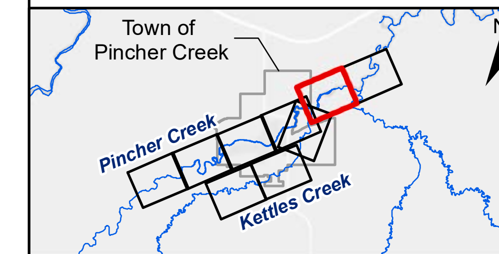
PINCHER CREEK HAZARD STUDY

HYDRAULIC MODEL SETUP
FIGURE 4

SHEET 4 OF 9

Classification: Public

MSN, \\int.klohn.com\ProjData\ACGY\Alberta\A03285C13 AEP Pincher Creek Fld Hazard S400 Drawings\04 Open Water Flood Inundation Mapping\02 GIS\03_Maps\FIG 4 6.a-4 6.1_Hydraulic Model Setup.mxd



Alberta Government

Klohn Crippen Berger

- FLOW DIRECTION
- CROSS SECTION
- 1325 RIVER STATION
- FLOOD CONTROL STRUCTURE
- BRIDGE
- MAJOR ROAD
- LOCAL ROAD
- MUNICIPAL DISTRICT BOUNDARY
- STUDY LIMIT
- CREEK CENTRELINE

SCALE - 1:5,000

0 100 200 M

Coordinate System: NAD 1983 3TM 114
Units: METRES

Engineer	GIS	Reviewer
KC	VC / TS	RJC

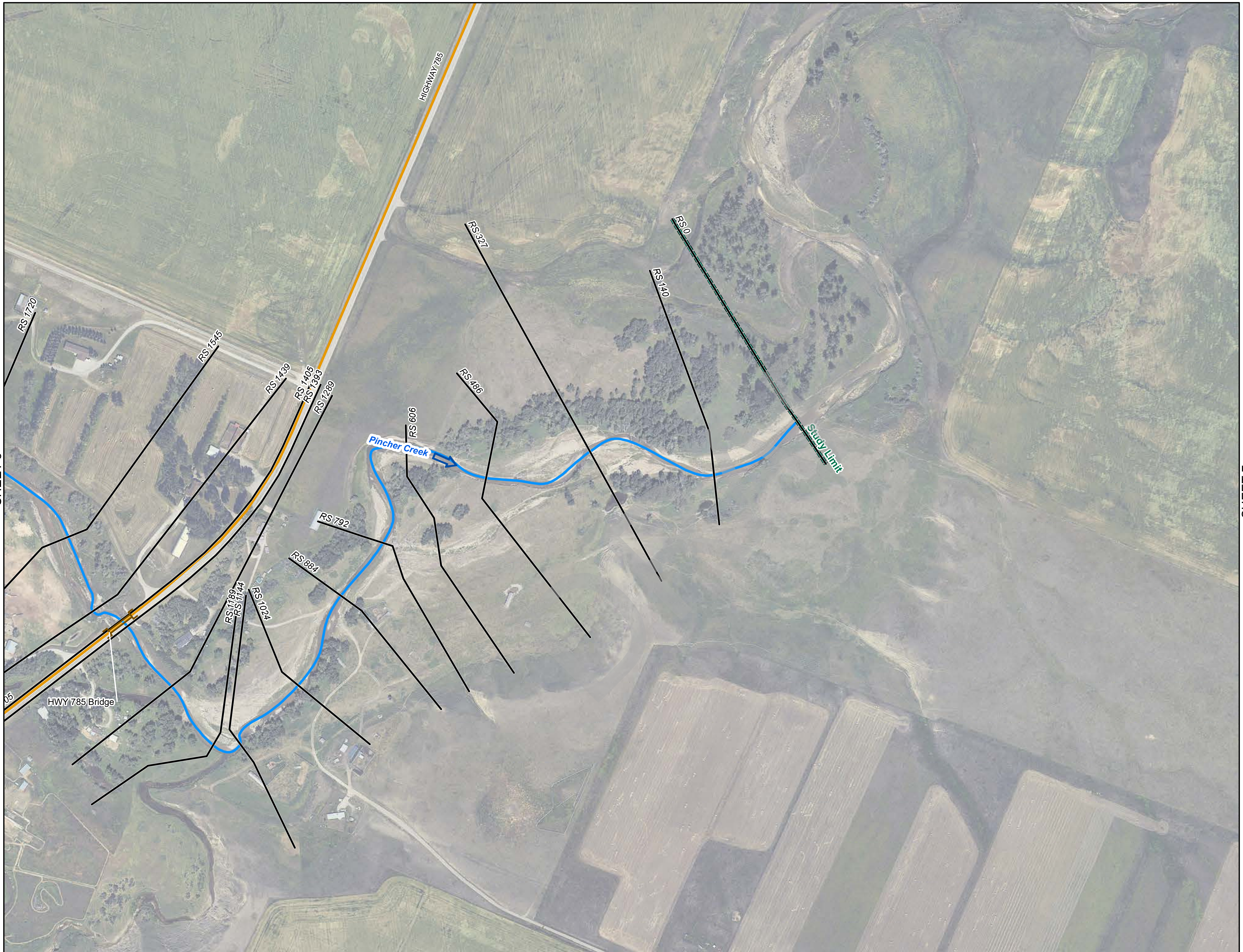
Job Number	Date
A03285C13	13-APR-2020

PINCHER CREEK HAZARD STUDY

HYDRAULIC MODEL SETUP
FIGURE 5

SHEET 5 OF 9

Classification: Public



Alberta Government

Klohn Crippen Berger

FLOW DIRECTION
CROSS SECTION
1325 RIVER STATION
FLOOD CONTROL STRUCTURE
BRIDGE
MAJOR ROAD
LOCAL ROAD
MUNICIPAL DISTRICT BOUNDARY
STUDY LIMIT
CREEK CENTRELINE

SCALE - 1:5,000
0 100 200 M

Coordinate System: NAD 1983 3TM 114
Units: METRES

Engineer	GIS	Reviewer
KC	VC / TS	RJC

Job Number	Date
A03285C13	13-APR-2020

PINCHER CREEK HAZARD STUDY

HYDRAULIC MODEL SETUP
FIGURE 6

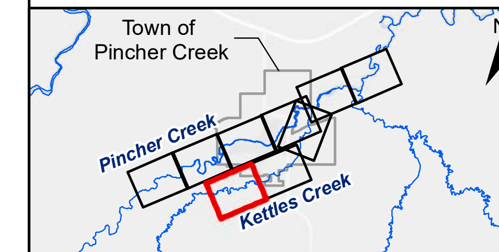
SHEET 6 OF 9

MSN, \\int.klohn.com\ProjData\ACGY\Alberta\A03285C13 AEP Pincher Creek Fld Hazard S400 Drawings\04 Open Water Flood Inundation Mapping\02 GIS\03_Maps\FIG 4.6.a-4.6.i_Hydraulic Model Setup.mxd

Classification: Public

Alberta Government

Klohn Crippen Berger



FLOW DIRECTION
CROSS SECTION
1325 RIVER STATION
FLOOD CONTROL STRUCTURE
BRIDGE
MAJOR ROAD
LOCAL ROAD
MUNICIPAL DISTRICT BOUNDARY
STUDY LIMIT
CREEK CENTRELINE

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

Coordinate System: NAD 1983 3TM 114
Units: METRES

Engineer	GIS	Reviewer
KC	VC / TS	RJC

Job Number	Date
A03285C13	13-APR-2020

PINCHER CREEK HAZARD STUDY

HYDRAULIC MODEL SETUP
FIGURE 7

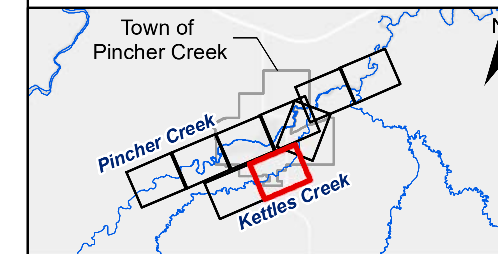
SHEET 7 OF 9

MSN, \\int.klohn.com\ProjData\ACGY\Alberta\A03285C13 AEP Pincher Creek Fld Hazard S400 Drawings\04 Open Water Flood Inundation Mapping\02 GIS\03_Maps\FIG 4.6.a-4.6.i_Hydraulic Model Setup.mxd

Classification: Public

Alberta Government

Klohn Crippen Berger



FLOW DIRECTION
CROSS SECTION
1325 RIVER STATION
FLOOD CONTROL STRUCTURE
BRIDGE
CULVERT CROSSING
MAJOR ROAD
LOCAL ROAD
MUNICIPAL DISTRICT BOUNDARY
STUDY LIMIT
CREEK CENTRELINE

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

Coordinate System: NAD 1983 3TM 114
Units: METRES

Engineer	GIS	Reviewer
KC	VC / TS	RJC

Job Number	Date
A03285C13	13-APR-2020

PINCHER CREEK HAZARD STUDY

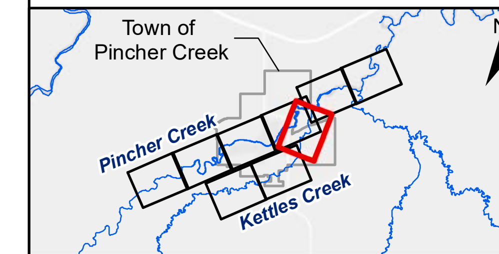
HYDRAULIC MODEL SETUP
FIGURE 8

SHEET 8 OF 9

Classification: Public

Government

Klohn Crippen Berger



FLOW DIRECTION
CROSS SECTION
1325 RIVER STATION
FLOOD CONTROL STRUCTURE
BRIDGE
MAJOR ROAD
LOCAL ROAD
MUNICIPAL DISTRICT BOUNDARY
STUDY LIMIT
CREEK CENTRELINE

SCALE - 1:5,000
0 100 200 M

Coordinate System: NAD 1983 3TM 114
Units: METRES

Engineer	GIS	Reviewer
KC	VC / TS	RJC

Job Number	Date
A03285C13	13-APR-2020

PINCHER CREEK HAZARD STUDY

HYDRAULIC MODEL SETUP
FIGURE 9

SHEET 9 OF 9

MSN, \\int.klohn.com\ProjData\ACGY\Alberta\A03285C13 AEP Pincher Creek Fld Hazard S400 Drawings\04 Open Water Flood Inundation Mapping\02 GIS\03_Maps\FIG 4.6.a-4.6.1_Hydraulic Model Setup.mxd

APPENDIX VI

Calibration Results

Appendix VI
Calibration Results

Table VI.1 Calibration Results – Low Flow Calibration Results for Pincher Creek

Year	Point Number	Northing	Easting	Distance from WSC Gauge	Surveyed Elevation (m)	Calibrated Water Elevation (m)	Difference (m)
2019	566	5483338.51	2885.58	-950	1132.67	1132.65	-0.02
2019	565	5483349.09	2947.96	-887	1132.38	1132.36	-0.02
2019	564	5483347.41	3039.63	-795	1131.98	1131.65	-0.33
2019	563	5483339.35	3131.71	-702	1131.14	1130.94	-0.19
2019	562	5483325.18	3189.07	-643	1130.79	1130.61	-0.18
2019	561	5483311.47	3319.03	-513	1130.08	1129.90	-0.17
2019	560	5483288.56	3394.25	-434	1129.71	1129.56	-0.15
2019	559	5483267.69	3472.07	-353	1129.44	1129.19	-0.25
2019	558	5483283.39	3538.43	-285	1128.79	1128.62	-0.17
2019	557	5483274.80	3587.78	-235	1128.27	1128.19	-0.08
2019	556	5483268.83	3599.95	-222	1128.18	1128.15	-0.03
2019	555	5483272.23	3622.89	-198	1128.16	1128.07	-0.09
2019	554	5483259.74	3674.59	-145	1127.59	1127.65	0.06
2019	553	5483249.74	3700.72	-117	1127.56	1127.46	-0.10
2019	552	5483231.56	3729.42	-83	1127.49	1127.25	-0.24
2019	551	5483216.78	3742.27	-64	1127.31	1127.09	-0.22
2019	550	5483195.43	3760.26	-36	1126.89	1126.85	-0.04
2019	567	5483173.36	3788.41	0	1126.46	1126.52	0.06
2019	568	5483149.44	3846.66	63	1125.88	1125.83	-0.05
2019	569	5483146.73	3889.68	106	1125.72	1125.48	-0.24
2019	570	5483148.26	3900.88	117	1125.73	1125.42	-0.30
2019	571	5483152.08	3919.40	136	1125.66	1125.33	-0.33
2019	572	5483161.34	3956.89	175	1125.22	1125.13	-0.09
2019	573	5483170.61	3974.78	195	1125.03	1125.03	0.00
2019	574	5483194.76	4007.32	236	1124.78	1124.59	-0.19
2019	575	5483215.53	4034.51	270	1124.50	1124.21	-0.29
2019	576	5483242.04	4079.84	322	1123.89	1123.70	-0.19
2019	577	5483276.72	4128.96	382	1123.60	1123.35	-0.25
2019	578	5483306.04	4156.78	423	1122.97	1123.19	0.22
2019	579	5483366.55	4196.90	495	1123.06	1122.93	-0.13
2019	580	5483419.30	4219.86	553	1122.95	1122.69	-0.26
2019	581	5483473.67	4250.03	615	1122.35	1122.17	-0.18
2019	582	5483499.01	4260.78	643	1122.12	1121.93	-0.19
2019	583	5483543.92	4280.73	692	1121.64	1121.58	-0.06
2019	584	5483578.33	4293.58	729	1121.43	1121.34	-0.09
2019	585	5483626.31	4323.15	785	1120.94	1120.97	0.03
2019	586	5483708.54	4378.29	884	1120.55	1120.60	0.05
2019	587	5483763.564	4416.888	951	1120.18	1120.05	-0.13
2019	588	5483779.881	4465.658	1003	1120.06	1119.63	-0.42

Year	Point Number	Northing	Easting	Distance from WSC Gauge	Surveyed Elevation (m)	Calibrated Water Elevation (m)	Difference (m)
2019	589	5483771.515	4507.307	1045	1119.72	1119.47	-0.25
2019	590	5483761.959	4554.112	1093	1119.28	1119.31	0.03
2019	591	5483769.863	4583.809	1124	1119.24	1119.28	0.04

Table VI.2 Calibration Results – Low Flow Calibration Results for Kettles Creek

Year	Point Number	Northing	Easting	Distance from WSC Gauge	Surveyed Elevation (m)	Calibrated Water Elevation (m)	Difference (m)
2019	521	4795.44	5482592.36	-1533	1131.32	1131.04	-0.28
2019	520	4829.96	5482629.31	-1483	1130.20	1130.16	-0.04
2019	519	4875.86	5482699.73	-1399	1128.32	1128.33	0.01
2019	518	4926.49	5482775.98	-1307	1127.56	1127.39	-0.17
2019	517	4964.06	5482846.13	-1228	1126.78	1126.37	-0.41
2019	516	4995.28	5482929.91	-1138	1125.91	1125.63	-0.28
2019	515	4999.10	5483009.73	-1058	1125.06	1124.97	-0.09
2019	514	5016.80	5483059.63	-1005	1124.62	1124.20	-0.41
2019	513	5027.85	5483093.06	-970	1124.24	1123.98	-0.26
2019	512	5027.03	5483124.64	-938	1123.81	1123.51	-0.30
2019	511	5012.54	5483184.00	-877	1123.32	1123.14	-0.18
2019	510	5026.28	5483235.05	-824	1123.08	1122.75	-0.33
2019	509	5004.55	5483300.31	-756	1122.30	1122.10	-0.20
2019	508	5003.78	5483371.45	-685	1122.16	1121.67	-0.49
2019	507	5071.93	5483430.63	-594	1121.41	1121.06	-0.35
2019	506	5129.02	5483478.29	-520	1121.00	1120.71	-0.29
2019	505	5177.41	5483545.49	-437	1120.18	1120.19	0.01
2019	504	5252.25	5483587.15	-351	1119.85	1119.30	-0.55
2019	503	5339.34	5483588.14	-264	1119.22	1118.86	-0.36
2019	502	5378.14	5483663.31	-180	1118.36	1118.41	0.05
2019	501	5359.88	5483729.40	-111	1117.86	1117.84	-0.02
2019	500	5326.80	5483781.11	-50	1117.56	1117.42	-0.14
2019	522	5309.56	5483827.86	0	1117.33	1117.14	-0.19
2019	523	5305.18	5483876.21	49	1117.10	1116.48	-0.62
2019	524	5339.07	5483953.90	133	1116.14	1116.05	-0.09
2019	525	5364.34	5484018.51	203	1115.84	1115.60	-0.24
2019	526	5376.65	5484073.95	259	1114.87	1114.94	0.07
2019	527	5392.33	5484092.36	284	1114.85	1114.64	-0.21
2019	528	5414.03	5484125.39	323	1114.50	1114.36	-0.14
2019	529	5408.11	5484184.03	382	1113.96	1113.60	-0.36
2019	530	5409.55	5484242.97	441	1112.57	1112.42	-0.15
2019	531	5409.11	5484295.67	494	1111.87	1111.94	0.07
2019	532	5403.98	5484346.29	545	1111.45	1111.38	-0.07
2019	533	5435.14	5484382.06	592	1110.57	1110.53	-0.04
2019	534	5422.11	5484430.10	642	1110.02	1109.63	-0.39
2019	535	5424.04	5484460.84	673	1109.28	1109.37	0.09
2019	536	5435.76	5484469.44	687	1109.23	1109.26	0.03

Table VI.3 Calibration Results – 2010 Event

Year	HWM Name	Northing	Easting	River	HWM Elevation (m)	Calibrated Water Elevation (m)	Difference (m)	Description
2010	2010-KET-001-a	-113.92519	49.49797	Kettles Creek	1110.533	1110.70	0.17	5 m u/s of confluence of Kettles and Pincher Creek, LB
2010	2010-KET-001-b	-113.925236	49.497934	Kettles Creek	1110.538	1110.73	0.19	10 m u/s of confluence of Kettles and Pincher Creek, LB
2010	2010-KET-002-a	-113.925579	49.494726	Kettles Creek	1116.132	1116.14	0.01	10 m d/s of Range Road 301 Bridge, LB
2010	2010-KET-002-b	-113.925494	49.494663	Kettles Creek	1116.276	1116.14	-0.14	8 m d/s of Range Road 301 Bridge, RB
2010	2010-KET-002-c	-113.925472	49.4947	Kettles Creek	1116.056	1116.09	0.03	13 m d/s of Range Road 301 Bridge, RB
2010	2010-KET-002-d	-113.925762	49.494449	Kettles Creek	1116.477	1116.40	-0.08	u/s of Range Road 301 Bridge, RB
2010	2010-KET-003-a	-113.926809	49.492289	Kettles Creek	1117.888	1118.20	0.31	10 m d/s of Macleod Street Bridge, LB
2010	2010-KET-003-b	-113.926731	49.492036	Kettles Creek	1118.61	1118.58	-0.03	10 m u/s of Macleod Street Bridge, LB
2010	2010-KET-004-a	-113.930582	49.485715	Kettles Creek	1124.264	1124.84	0.58	8 m d/s of Main Street Bridge, RB
2010	2010-KET-004-b	-113.93056	49.485472	Kettles Creek	1125.198	1125.38	0.18	10 m u/s of Main Street Bridge, RB
2010	2010-KET-005-a	-113.937038	49.479579	Kettles Creek	1134.785	1134.76	-0.03	12 m u/s of Highway 6 Bridge, RB
2010	2010-KET-005-b	-113.936517	49.479641	Kettles Creek	1133.472	1134.20	0.73	5 m d/s of Highway 6 Bridge, LB
2010	2010-PINC-002-a	-113.905002	49.503526	Pincher Creek D/S	1102.027	1102.10	0.07	10 m u/s of Highway 785 Bridge, RB
2010	2010-PINC-002-b	-113.90456	49.503405	Pincher Creek D/S	1101.292	1101.26	-0.03	13 m d/s of Highway 785 Bridge, RB
2010	2010-PINC-004-a	-113.925215	49.498044	Pincher Creek U/S	1111.128	1110.73	-0.40	10 m u/s of confluence of Kettles and Pincher Creek, RB
2010	2010-PINC-008-a	-113.962948	49.487022	Pincher Creek U/S	1135.185	1135.13	-0.06	9 m d/s of Beaver Drive Bridge, LB
2010	2010-PINC-008-b	-113.963234	49.486848	Pincher Creek U/S	1135.219	1135.91	0.69	8 m u/s of Beaver Drive Bridge, LB

Table VI.4 Calibration Results – 1995 Event

Year	HWM Name	Northing	Easting	Creek	HWM Elevation (m)	Calibrated Water Elevation (m)	Difference (m)	Description
1995	1995-KET-002-g	-113.925633	49.494526	Kettles Creek	1116.82	1117.31	0.49	u/s of Range Road 301 Bridge
1995	1995-KET-002-h	-113.925538	49.494609	Kettles Creek	1116.67	1116.54	-0.13	d/s of Range Road 301 Bridge
1995	1995-KET-003-e	-113.926612	49.49225	Kettles Creek	-99999	n/a	n/a	d/s of Macleod Street Bridge - HWM not evident
1995	1995-KET-003-f	-113.926561	49.492053	Kettles Creek	1119.36	1119.28	-0.08	10 m u/s of Macleod Street Bridge
1995	1995-KET-004-e	-113.93056	49.485686	Kettles Creek	1126.26	1125.28	-0.98	5 m d/s of Main Street Bridge
1995	1995-KET-004-f	-113.930552	49.485534	Kettles Creek	1126.42	1125.75	-0.67	u/s of Main Street Bridge
1995	1995-PINC-002-e	-113.904727	49.503438	Pincher Creek D/S	1101.95	1102.88	0.93	d/s of Highway 785 Bridge, RB
1995	1995-PINC-002-f	-113.904952	49.503518	Pincher Creek D/S	1103.02	1104.59	1.58	u/s of Highway 785 Bridge, RB
1995	1995-PINC-004-e	-113.925392	49.498187	Pincher Creek U/S	1112.41	1112.20	-0.21	u/s of confluence of Kettles and Pincher Creek
1995	1995-PINC-005-c	-113.936358	49.491639	Pincher Creek U/S	1121.78	1121.90	0.12	d/s of Highway 6 Bridge
1995	1995-PINC-005-d	-113.936618	49.491615	Pincher Creek U/S	1122.61	1122.65	0.04	u/s of Highway 6 Bridge
1995	1995-PINC-007-c	-113.949618	49.487246	Pincher Creek U/S	1131.26	1132.10	0.84	d/s of Hewetson Avenue Bridge, LB
1995	1995-PINC-007-d	-113.950006	49.487332	Pincher Creek U/S	1131.40	1132.64	1.24	u/s of Hewetson Avenue Bridge, LB
1995	1995-PINC-008-f	-113.962897	49.487002	Pincher Creek U/S	1137.09	1136.80	-0.29	10 m d/s of Beaver Drive Bridge
1995	1995-PINC-008-g	-113.963124	49.486875	Pincher Creek U/S	1137.42	1138.20	0.78	u/s of Beaver Drive Bridge

APPENDIX VII

Flood Frequency Profiles and Sensitivity Test Results

Appendix VII
Flood Frequency Profiles and Sensitivity Test Results

Table VII.1 Computed Water Elevation for Various Flood Frequency – Pincher Creek

River	Cross Section	Water Surface Elevation (m) for Given Return Period (years)												
		2	5	10	20	35	50	75	100	200	350	500	750	1000
Pincher Creek	14327	1182.93	1183.55	1183.57	1183.81	1183.95	1184.04	1184.15	1184.24	1184.48	1184.62	1184.73	1184.87	1184.97
Pincher Creek	14196	1182.35	1182.75	1182.94	1183.21	1183.40	1183.51	1183.69	1183.80	1184.14	1184.14	1184.25	1184.40	1184.51
Pincher Creek	14099	1181.84	1182.04	1182.14	1182.27	1182.42	1182.52	1182.60	1182.70	1182.82	1183.13	1183.23	1183.34	1183.42
Pincher Creek	13994	1180.82	1181.46	1181.61	1181.80	1181.94	1181.95	1182.07	1182.13	1182.32	1182.49	1182.60	1182.73	1182.83
Pincher Creek	13885	1180.08	1180.64	1181.06	1181.26	1181.43	1181.54	1181.72	1181.74	1181.91	1182.08	1182.19	1182.32	1182.42
Pincher Creek	13770	1179.41	1180.01	1180.48	1180.86	1181.08	1181.28	1181.43	1181.43	1181.64	1181.81	1181.92	1182.05	1182.15
Pincher Creek	13649	1178.65	1179.15	1179.39	1179.72	1180.16	1180.21	1180.21	1180.79	1180.99	1181.11	1181.19	1181.28	1181.34
Pincher Creek	13520	1178.23	1178.72	1179.01	1179.21	1179.43	1179.55	1179.71	1179.82	1180.09	1180.32	1180.46	1180.65	1180.78
Pincher Creek	13394	1177.41	1178.06	1178.32	1178.57	1178.72	1178.82	1178.94	1179.02	1179.22	1179.39	1179.49	1179.62	1179.72
Pincher Creek	13265	1177.05	1177.43	1177.61	1177.78	1177.89	1178.10	1178.24	1178.33	1178.56	1178.73	1178.85	1178.98	1179.09
Pincher Creek	13100	1176.30	1176.74	1176.96	1177.17	1177.18	1177.18	1177.26	1177.31	1177.45	1177.56	1177.63	1177.73	1177.80
Pincher Creek	12957	1175.49	1175.99	1176.24	1176.46	1176.59	1176.65	1176.65	1176.65	1176.65	1176.65	1176.65	1176.65	1176.65
Pincher Creek	12831	1175.03	1175.44	1175.67	1175.89	1175.91	1175.91	1175.93	1175.93	1176.07	1176.07	1176.12	1176.22	1176.29
Pincher Creek	12630	1174.07	1174.48	1174.67	1174.87	1175.07	1175.11	1175.11	1175.11	1175.19	1175.41	1175.52	1175.67	1175.78
Pincher Creek	12499	1173.32	1173.65	1173.88	1174.15	1174.32	1174.45	1174.62	1174.74	1174.92	1175.13	1175.26	1175.43	1175.55
Pincher Creek	12377	1172.73	1173.20	1173.55	1173.83	1173.84	1173.94	1174.04	1174.12	1174.31	1174.49	1174.61	1174.75	1174.86
Pincher Creek	12263	1172.01	1172.41	1172.72	1173.04	1173.29	1173.36	1173.48	1173.57	1173.80	1174.00	1174.13	1174.29	1174.41
Pincher Creek	12119	1171.17	1171.66	1172.01	1172.36	1172.72	1172.79	1172.91	1173.04	1173.31	1173.54	1173.68	1173.85	1173.97
Pincher Creek	11995	1170.63	1171.06	1171.37	1171.74	1171.74	1171.95	1172.20	1172.21	1172.41	1172.57	1172.68	1172.82	1172.90
Pincher Creek	11868	1169.93	1170.39	1170.74	1170.98	1171.24	1171.41	1171.60	1171.73	1172.06	1172.34	1172.51	1172.72	1172.87
Pincher Creek	11743	1169.26	1169.82	1170.17	1170.55	1170.78	1170.89	1171.07	1171.18	1171.47	1171.71	1171.85	1171.97	1172.07
Pincher Creek	11556	1168.48	1169.05	1169.48	1169.64	1169.86	1170.01	1170.12	1170.22	1170.43	1170.61	1170.74	1170.98	1171.15
Pincher Creek	11446	1167.53	1168.02	1168.42	1168.99	1169.20	1169.32	1169.43	1169.53	1170.26	1170.38	1170.61	1170.86	1171.04
Pincher Creek	11332	1166.77	1167.29	1167.68	1168.12	1168.52	1168.81	1169.15	1169.38	1170.08	1170.11	1170.31	1170.53	1170.70
Pincher Creek	11202	1165.75	1166.23	1166.59	1167.02	1167.40	1167.48	1167.71	1167.94	1168.11	1169.10	1169.26	1169.45	1169.58
Pincher Creek	11062	1165.06	1165.71	1166.21	1166.78	1167.30	1167.30	1167.47	1167.61	1167.98	1168.29	1168.49	1168.74	1168.90
Pincher Creek	10914	1164.38	1164.87	1165.18	1165.49	1165.81	1166.34	1166.52	1166.65	1166.94	1167.15	1167.31	1167.47	1167.64
Pincher Creek	10738	1163.01	1163.37	1163.64	1163.93	1164.19	1164.37	1164.67	1164.82	1165.29	1165.59	1165.75	1165.88	1166.01
Pincher Creek	10610	1161.51	1161.94	1162.26	1162.60	1162.90	1163.07	1163.50	1163.63	1163.92	1164.31	1164.49	1164.75	1164.90
Pincher Creek	10484	1160.58	1160.99	1161.27	1161.59	1161.87	1162.07	1162.31	1162.51	1162.92	1163.26	1163.43	1163.66	1163.96
Pincher Creek	10322	1159.42	1159.88	1160.22	1160.60	1160.90	1161.01	1161.17	1161.31	1161.76	1161.98	1162.16	1162.56	1162.71
Pincher Creek	10153	1158.05	1158.54	1158.83	1159.14	1159.44	1159.70	1160.03	1160.20	1160.60	1160.85	1161.01	1161.29	1161.51
Pincher Creek	10006	1156.43	1156.93	1157.25	1157.61	1157.92	1158.12	1158.37	1158.56	1159.06	1159.66	1159.90	1160.19	1160.38
Pincher Creek	9868	1154.79	1155.27	1155.59	1155.94	1156.18	1156.34	1156.56	1156.77	1157.36	1157.83	1158.11	1158.40	1158.58
Pincher Creek	9719	1153.36	1153.81	1154.15	1154.50	1154.85	1155.06	1155.31	1155.48	1156.10	1156.44	1156.73	1156.89	1157.21
Pincher Creek	9610	1150.89	1151.39	1151.78	1152.13	1152.51	1152.68	1152.89	1153.03	1153.48	1154.02	1154.13	1154.40	1154.59
Pincher Creek	9517	1150.01	1150.60	1150.99	1151.42	1151.81	1152.04	1152.35	1152.58	1153.21	1153.86	1153.91	1154.19	1154.39
Pincher Creek	9415	1149.00	1149.38	1149.74	1150.15	1150.51	1150.77	1151.05	1151.25	1151.72	1151.91	1152.82	1153.06	1153.24
Pincher Creek	9325	1147.97	1148.45	1148.72	1149.01	1149.27	1149.43	1149.64	1149.81	1150.17	1150.57	1150.75	1150.88	1151.19
Pincher Creek	9225	1145.78	1146.19	1146.53	1146.90	1147.21	1147.41	1147.66	1147.89	1148.41	1148.80	1149.08	1149.39	1149.61

River	Cross Section	Water Surface Elevation (m) for Given Return Period (years)												
		2	5	10	20	35	50	75	100	200	350	500	750	1000
Pincher Creek	9122	1144.24	1144.74	1145.07	1145.40	1145.69	1145.94	1146.19	1146.35	1146.71	1147.05	1147.27	1147.53	1147.73
Pincher Creek	9021	1142.77	1143.23	1143.52	1143.83	1144.11	1144.44	1144.88	1145.14	1145.75	1146.23	1146.53	1146.99	1147.26
Pincher Creek	8977	1142.17	1142.59	1142.91	1143.26	1143.57	1143.80	1144.06	1144.25	1144.77	1145.17	1145.45	1145.75	1146.04
Pincher Creek	8928	1141.27	1141.72	1142.11	1142.60	1143.06	1143.34	1143.70	1143.94	1144.58	1145.29	1145.56	1145.86	1146.10
Pincher Creek	8915	1141.16	1141.86	1142.33	1142.78	1143.22	1143.49	1143.83	1144.06	1144.69	1145.39	1145.66	1145.97	1146.22
Pincher Creek	8913	1141.11	1141.77	1142.21	1142.60	1142.97	1143.21	1143.52	1143.74	1144.29	1144.78	1145.09	1145.49	1145.77
Pincher Creek	8869	1140.66	1141.15	1141.52	1141.90	1142.17	1142.36	1142.59	1142.75	1143.19	1143.57	1143.82	1144.10	1144.30
Pincher Creek	8769	1139.24	1139.73	1140.09	1140.44	1140.78	1141.00	1141.28	1141.47	1142.04	1142.66	1142.92	1143.20	1143.41
Pincher Creek	8665	1138.30	1138.71	1138.99	1139.37	1139.70	1139.94	1140.22	1140.40	1140.87	1141.26	1141.52	1141.90	1142.17
Pincher Creek	8528	1136.91	1137.44	1137.86	1138.48	1138.94	1139.23	1139.58	1139.81	1140.26	1140.48	1140.62	1140.72	1140.96
Pincher Creek	8424	1136.19	1136.70	1137.03	1137.35	1137.77	1138.03	1138.36	1138.57	1139.60	1139.91	1140.07	1140.39	1140.80
Pincher Creek	8321	1135.50	1136.04	1136.51	1137.06	1137.59	1137.95	1138.33	1138.56	1139.11	1139.49	1139.73	1140.00	1140.19
Pincher Creek	8223	1134.64	1135.24	1135.66	1136.14	1136.52	1136.67	1137.02	1137.39	1138.08	1138.49	1138.74	1139.05	1139.25
Pincher Creek	8194	1134.72	1135.42	1135.95	1136.53	1137.02	1137.29	1137.56	1137.76	1138.26	1138.68	1138.95	1139.26	1139.48
Pincher Creek	8182	1134.38	1134.84	1135.18	1135.55	1135.87	1136.07	1136.31	1136.47	1136.91	1137.17	1137.38	1137.59	1137.74
Pincher Creek	8077	1133.57	1134.08	1134.41	1134.74	1135.03	1135.21	1135.45	1135.62	1136.06	1136.52	1136.71	1137.05	1137.25
Pincher Creek	7879	1132.67	1133.11	1133.43	1133.82	1134.17	1134.41	1134.71	1134.93	1135.50	1136.04	1136.05	1136.23	1136.37
Pincher Creek	7691	1131.21	1131.76	1132.19	1132.60	1132.92	1133.10	1133.32	1133.47	1133.85	1134.16	1134.83	1135.14	1135.35
Pincher Creek	7499	1130.35	1130.99	1131.37	1131.64	1131.91	1132.12	1132.42	1132.64	1133.19	1133.52	1133.67	1133.87	1134.07
Pincher Creek	7342	1129.49	1129.98	1130.40	1130.91	1131.39	1131.72	1132.15	1132.43	1133.05	1133.39	1133.64	1133.90	1133.90
Pincher Creek	7217	1128.57	1129.24	1129.79	1130.42	1131.00	1131.40	1131.87	1132.17	1132.79	1133.23	1133.49	1133.75	1133.75
Pincher Creek	7176	1128.38	1129.11	1129.69	1130.33	1130.90	1131.29	1131.76	1132.05	1132.69	1133.09	1133.34	1133.59	1133.59
Pincher Creek	7160	1128.22	1128.93	1129.49	1130.12	1130.68	1131.06	1131.47	1131.71	1132.13	1132.50	1132.86	1132.86	1132.86
Pincher Creek	7101	1127.86	1128.53	1129.05	1129.67	1130.22	1130.60	1130.96	1131.11	1131.63	1132.27	1132.68	1132.68	1132.68
Pincher Creek	7081	1127.70	1128.30	1128.82	1129.43	1129.98	1130.37	1130.70	1130.90	1131.53	1132.22	1132.64	1132.64	1132.64
Pincher Creek	7038	1127.38	1128.04	1128.60	1129.22	1129.77	1130.16	1130.47	1130.75	1131.39	1132.12	1132.56	1132.56	1132.56
Pincher Creek	6985	1126.88	1127.63	1128.30	1128.94	1129.49	1129.89	1130.38	1130.65	1131.30	1132.05	1132.49	1132.49	1132.49
Pincher Creek	6924	1126.37	1127.28	1127.99	1128.57	1129.06	1129.45	1130.10	1130.43	1131.18	1131.98	1132.43	1132.43	1132.43
Pincher Creek	6897	1126.24	1127.14	1127.85	1128.40	1128.85	1129.24	1129.77	1130.00	1131.03	1131.90	1132.38	1132.38	1132.38
Pincher Creek	6883	1125.95	1126.59	1126.95	1127.55	1127.94	1128.19	1128.39	1128.89	1129.44	1129.72	1130.03	1130.66	1130.79
Pincher Creek	6867	1125.85	1126.46	1126.81	1127.25	1127.67	1127.91	1128.26	1128.48	1129.03	1130.12	1130.26	1130.36	1130.59
Pincher Creek	6783	1125.35	1125.80	1126.17	1126.62	1127.08	1127.39	1127.82	1128.29	1128.85	1128.85	1129.15	1129.47	1129.58
Pincher Creek	6710	1124.50	1125.09	1125.58	1126.14	1126.65	1126.99	1127.46	1128.01	1128.71	1128.71	1128.75	1128.98	1129.19
Pincher Creek	6651	1124.08	1124.75	1125.25	1125.80	1126.28	1126.62	1127.13	1127.91	1128.64	1128.64	1128.64	1128.83	1129.05
Pincher Creek	6649	1123.97	1124.56	1124.95	1125.36	1125.68	1125.88	1126.13	1126.31	1127.13	1127.72	1127.85	1128.01	1128.03
Pincher Creek	6555	1123.58	1124.14	1124.53	1124.94	1125.29	1125.52	1125.79	1125.89	1126.10	1126.82	1127.00	1127.18	1127.32
Pincher Creek	6429	1123.07	1123.59	1123.97	1124.40	1124.79	1125.05	1125.39	1125.68	1126.34	1126.34	1126.34	1126.39	1126.57
Pincher Creek	6321	1122.13	1122.62	1122.97	1123.36	1123.70	1123.89	1124.12	1124.21	1124.74	1125.13	1125.29	1125.47	1125.55
Pincher Creek	6193	1121.36	1121.92	1122.33	1122.75	1123.08	1123.29	1123.39	1123.61	1124.04	1124.30	1124.55	1124.78	1124.91
Pincher Creek	6089	1120.92	1121.51	1121.95	1122.37	1122.70	1122.92	1123.17	1123.34	1123.84	1124.31	1124.62	1124.63	1124.93
Pincher Creek	5979	1120.16	1120.77	1121.18	1121.62	1122.01	1122.30	1122.67	1122.91	1123.56	1124.09	1124.44	1124.44	1124.74
Pincher Creek	5875	1119.65	1120.21	1120.59	1121.00	1121.34	1121.55	1121.84	1121.91	1122.36	1122.75	1123.00	1124.24	1124.62
Pincher Creek	5838	1119.63	1120.23	1120.65	1121.11	1121.50	1121.74	1122.06	1122.19	1122.71	1123.15	1123.43	1123.79	1124.21
Pincher Creek	5824	1119.39	1119.93	1120.34	1120.79	1121.19	1121.44	1121.73	1121.73	1121.93	1122.08	1122.17	1122.25	1122.30
Pincher Creek	5756	1118.92	1119.41	1119.76	1120.08	1120.35	1120.52	1120.73	1121.17	1121.54	1121.71	1121.83	1121.95	1122.01
Pincher Creek	5636	1118.38	1118.92	1119.26	1119.58	1119.86	1119.92	1120.07	1120.18	1120.38	1120.54	1120.65	1120.78	1120.91

River	Cross Section	Water Surface Elevation (m) for Given Return Period (years)												
		2	5	10	20	35	50	75	100	200	350	500	750	1000
Pincher Creek	5510	1117.93	1118.36	1118.65	1118.91	1119.06	1119.18	1119.30	1119.38	1119.59	1119.79	1119.88	1119.99	1120.07
Pincher Creek	5402	1117.63	1117.98	1118.09	1118.26	1118.44	1118.54	1118.66	1118.73	1118.88	1119.07	1119.15	1119.18	1119.23
Pincher Creek	5281	1116.68	1117.26	1117.58	1117.83	1117.97	1118.06	1118.15	1118.21	1118.37	1118.50	1118.58	1118.68	1118.75
Pincher Creek	5096	1116.05	1116.49	1116.77	1116.95	1117.16	1117.28	1117.46	1117.53	1117.65	1117.75	1117.82	1117.90	1117.95
Pincher Creek	4962	1115.70	1115.98	1116.12	1116.33	1116.44	1116.53	1116.65	1116.74	1116.94	1117.08	1117.17	1117.27	1117.36
Pincher Creek	4863	1115.18	1115.72	1115.94	1116.10	1116.30	1116.39	1116.48	1116.57	1116.75	1116.89	1116.99	1117.08	1117.16
Pincher Creek	4636	1114.32	1114.77	1115.16	1115.60	1115.91	1116.12	1116.16	1116.25	1116.39	1116.45	1116.54	1116.65	1116.73
Pincher Creek	4508	1114.00	1114.64	1115.04	1115.44	1115.80	1116.01	1116.01	1116.07	1116.27	1116.27	1116.34	1116.43	1116.49
Pincher Creek	4394	1113.65	1114.21	1114.47	1114.75	1114.98	1115.04	1115.53	1115.59	1115.74	1115.86	1115.88	1115.94	1115.99
Pincher Creek	4132	1112.54	1112.99	1113.23	1113.39	1113.52	1113.65	1113.84	1113.98	1114.38	1114.50	1114.68	1114.88	1115.00
Pincher Creek	3976	1111.80	1112.31	1112.63	1112.98	1113.29	1113.45	1113.67	1113.82	1114.26	1114.34	1114.51	1114.71	1114.85
Pincher Creek	3824	1111.31	1111.84	1112.24	1112.71	1113.10	1113.25	1113.49	1113.66	1114.14	1114.16	1114.32	1114.51	1114.63
Pincher Creek	3685	1110.86	1111.40	1111.82	1112.30	1112.66	1112.68	1112.77	1112.85	1112.86	1113.34	1113.46	1113.60	1113.74
Pincher Creek	3573	1109.91	1110.40	1110.75	1111.09	1111.61	1112.18	1112.38	1112.48	1112.57	1112.57	1112.57	1112.57	1112.57
Pincher Creek	3514	1109.46	1109.97	1110.31	1110.67	1111.02	1111.21	1111.46	1111.54	1111.57	1111.57	1111.67	1111.76	1111.84
Pincher Creek	3367	1108.65	1109.16	1109.45	1109.74	1109.91	1110.08	1110.29	1110.43	1110.81	1110.94	1111.05	1111.16	1111.20
Pincher Creek	3222	1107.98	1108.58	1108.86	1109.08	1109.34	1109.47	1109.63	1109.82	1110.09	1110.30	1110.39	1110.51	1110.61
Pincher Creek	3030	1107.31	1107.80	1108.19	1108.61	1108.95	1109.16	1109.42	1109.56	1109.76	1109.89	1109.97	1110.10	1110.17
Pincher Creek	2896	1106.80	1107.23	1107.42	1107.64	1107.94	1108.11	1108.32	1108.61	1109.21	1109.44	1109.52	1109.61	1109.67
Pincher Creek	2739	1106.38	1106.80	1107.10	1107.41	1107.67	1107.82	1107.98	1108.10	1108.31	1108.47	1108.57	1108.68	1108.76
Pincher Creek	2607	1105.70	1106.22	1106.52	1106.88	1107.18	1107.40	1107.63	1107.83	1107.83	1107.88	1107.97	1108.07	1108.13
Pincher Creek	2438	1105.01	1105.42	1105.73	1105.96	1106.17	1106.21	1106.37	1106.37	1106.86	1106.99	1107.06	1107.14	1107.18
Pincher Creek	2316	1104.48	1105.08	1105.47	1105.47	1105.62	1105.64	1105.71	1105.76	1105.89	1106.00	1106.10	1106.30	1106.30
Pincher Creek	2192	1103.99	1104.61	1105.00	1105.00	1105.14	1105.22	1105.31	1105.38	1105.54	1105.63	1105.83	1106.14	1106.14
Pincher Creek	2039	1103.10	1103.59	1103.98	1104.51	1104.61	1104.65	1104.73	1104.78	1104.88	1105.30	1105.63	1106.02	1106.02
Pincher Creek	1898	1102.68	1103.03	1103.26	1103.45	1103.52	1103.62	1103.78	1103.96	1104.78	1105.23	1105.58	1105.99	1105.99
Pincher Creek	1720	1101.99	1102.41	1102.52	1102.66	1103.07	1103.33	1103.64	1103.87	1104.75	1105.21	1105.56	1105.97	1105.97
Pincher Creek	1545	1101.02	1101.66	1102.14	1102.63	1103.05	1103.30	1103.63	1103.85	1104.74	1105.20	1105.56	1105.97	1105.97
Pincher Creek	1439	1100.82	1101.59	1102.11	1102.61	1103.03	1103.29	1103.62	1103.84	1104.74	1105.20	1105.55	1105.96	1105.96
Pincher Creek	1405	1100.72	1101.39	1101.84	1102.26	1102.60	1102.81	1103.07	1103.25	1104.61	1105.13	1105.51	1105.93	1105.93
Pincher Creek	1393	1100.44	1100.97	1101.24	1101.57	1101.89	1102.10	1102.34	1102.50	1102.92	1103.29	1103.56	1103.86	1104.52
Pincher Creek	1289	1099.95	1100.33	1100.63	1101.00	1101.19	1101.29	1101.39	1101.49	1101.66	1101.75	1101.77	1101.98	1102.06
Pincher Creek	1189	1099.75	1100.42	1100.70	1100.92	1101.09	1101.19	1101.31	1101.38	1101.57	1101.74	1101.84	1101.96	1102.05
Pincher Creek	1144	1099.60	1100.23	1100.55	1100.77	1100.93	1101.03	1101.15	1101.22	1101.41	1101.58	1101.68	1101.80	1101.88
Pincher Creek	1024	1099.30	1099.91	1100.16	1100.35	1100.48	1100.56	1100.67	1100.73	1100.91	1101.05	1101.14	1101.24	1101.32
Pincher Creek	884	1098.98	1099.48	1099.68	1099.89	1100.04	1100.14	1100.26	1100.33	1100.51	1100.65	1100.74	1100.84	1100.92
Pincher Creek	792	1098.60	1099.23	1099.58	1099.80	1099.95	1100.04	1100.14	1100.21	1100.37	1100.50	1100.58	1100.68	1100.75
Pincher Creek	606	1098.15	1098.92	1099.00	1099.20	1099.37	1099.44	1099.54	1099.61	1099.75	1099.91	1100.00	1100.09	1100.16
Pincher Creek	486	1097.61	1098.18	1098.51	1098.80	1098.92	1098.97	1099.05	1099.11	1099.28	1099.34	1099.38	1099.46	1099.50
Pincher Creek	327	1097.17	1097.78	1098.12	1098.12	1098.12	1098.14	1098.28	1098.37	1098.59	1098.72	1098.81	1098.92	1099.00
Pincher Creek	140	1096.41	1096.97	1097.41	1097.52	1097.52	1097.52	1097.52	1097.52	1097.67	1097.83	1097.93	1098.04	1098.13
Pincher Creek	0	1095.82	1096.26	1096.47	1096.65	1096.80	1096.89	1097.00	1097.08	1097.26	1097.42	1097.51	1097.63	1097.71

Table VII.2 Computed Water Elevation for Various Flood Frequency – Kettles Creek

River	Cross Section	Water Surface Elevation (m) for Given Return Period (years)												
		2	5	10	20	35	50	75	100	200	350	500	750	1000
Kettles Creek	7295	1174.55	1174.99	1175.28	1175.53	1175.56	1175.62	1175.68	1175.72	1175.79	1175.86	1175.89	1175.92	1175.94
Kettles Creek	7239	1173.88	1174.29	1174.51	1174.67	1175.07	1175.11	1175.15	1175.20	1175.26	1175.31	1175.33	1175.36	1175.42
Kettles Creek	7178	1173.46	1173.87	1174.13	1174.37	1174.46	1174.53	1174.56	1174.62	1174.63	1174.72	1174.73	1174.76	1174.78
Kettles Creek	7123	1172.60	1172.95	1173.18	1173.43	1173.71	1173.79	1173.92	1173.92	1174.12	1174.14	1174.22	1174.24	1174.27
Kettles Creek	7041	1171.58	1172.11	1172.43	1172.71	1172.89	1173.01	1173.14	1173.22	1173.40	1173.52	1173.55	1173.57	1173.59
Kettles Creek	6951	1170.91	1171.34	1171.56	1171.77	1171.92	1171.98	1172.08	1172.18	1172.30	1172.50	1172.79	1172.80	1172.80
Kettles Creek	6880	1170.23	1170.68	1170.88	1171.08	1171.22	1171.42	1171.50	1171.57	1171.69	1171.76	1171.80	1171.83	1171.86
Kettles Creek	6829	1169.72	1170.14	1170.41	1170.71	1170.96	1171.04	1171.14	1171.17	1171.19	1171.40	1171.42	1171.45	1171.52
Kettles Creek	6768	1169.32	1169.86	1170.20	1170.54	1170.80	1170.95	1171.05	1171.07	1171.16	1171.25	1171.29	1171.31	1171.34
Kettles Creek	6728	1168.99	1169.46	1169.70	1169.89	1170.06	1170.21	1170.46	1170.70	1170.77	1170.82	1170.90	1170.99	1171.01
Kettles Creek	6690	1168.84	1169.28	1169.50	1169.70	1169.86	1169.95	1170.08	1170.17	1170.34	1170.45	1170.49	1170.54	1170.57
Kettles Creek	6628	1168.44	1168.81	1169.03	1169.25	1169.37	1169.48	1169.49	1169.55	1169.64	1169.78	1169.84	1169.89	1169.96
Kettles Creek	6586	1167.60	1167.98	1168.21	1168.43	1168.67	1168.72	1169.02	1169.07	1169.21	1169.30	1169.40	1169.46	1169.46
Kettles Creek	6536	1167.32	1167.69	1167.85	1168.00	1168.10	1168.16	1168.23	1168.28	1168.37	1168.46	1168.50	1168.54	1168.58
Kettles Creek	6480	1166.98	1167.35	1167.50	1167.64	1167.74	1167.79	1167.85	1167.89	1167.96	1168.02	1168.06	1168.08	1168.10
Kettles Creek	6402	1166.43	1166.89	1167.15	1167.37	1167.52	1167.52	1167.59	1167.64	1167.75	1167.82	1167.86	1167.90	1167.93
Kettles Creek	6352	1166.18	1166.67	1166.93	1167.20	1167.42	1167.42	1167.42	1167.48	1167.62	1167.69	1167.73	1167.76	1167.80
Kettles Creek	6295	1165.87	1166.40	1166.73	1167.02	1167.02	1167.02	1167.10	1167.16	1167.26	1167.34	1167.39	1167.43	1167.47
Kettles Creek	6212	1165.00	1165.52	1165.75	1165.98	1166.14	1166.42	1166.46	1166.49	1166.56	1166.61	1166.62	1166.64	1166.69
Kettles Creek	6162	1164.75	1165.31	1165.62	1165.88	1166.03	1166.03	1166.08	1166.14	1166.24	1166.35	1166.39	1166.44	1166.49
Kettles Creek	6053	1163.68	1164.10	1164.35	1164.61	1164.84	1165.21	1165.26	1165.31	1165.39	1165.45	1165.50	1165.53	1165.55
Kettles Creek	5996	1163.10	1163.68	1164.01	1164.31	1164.53	1164.65	1164.80	1164.92	1164.96	1165.05	1165.09	1165.13	1165.18
Kettles Creek	5943	1162.76	1163.09	1163.32	1163.60	1163.82	1163.94	1164.08	1164.13	1164.52	1164.60	1164.63	1164.67	1164.70
Kettles Creek	5901	1162.10	1162.64	1163.00	1163.36	1163.61	1163.73	1163.86	1163.97	1164.20	1164.20	1164.25	1164.30	1164.35
Kettles Creek	5837	1161.50	1161.91	1162.09	1162.25	1162.44	1162.60	1162.84	1162.95	1162.98	1163.69	1163.74	1163.78	1163.82
Kettles Creek	5785	1160.94	1161.25	1161.45	1161.63	1161.79	1161.83	1161.93	1161.93	1162.14	1162.33	1162.39	1162.45	1162.52
Kettles Creek	5736	1160.49	1160.81	1161.06	1161.33	1161.56	1161.68	1161.83	1161.95	1162.22	1162.38	1162.44	1162.49	1162.56
Kettles Creek	5674	1159.88	1160.40	1160.72	1161.04	1161.28	1161.41	1161.56	1161.67	1161.91	1162.14	1162.24	1162.32	1162.43
Kettles Creek	5596	1159.31	1159.70	1159.88	1160.01	1160.10	1160.19	1160.31	1160.40	1160.59	1160.71	1160.80	1160.90	1160.90
Kettles Creek	5544	1158.77	1159.04	1159.22	1159.42	1159.56	1159.65	1159.75	1159.83	1159.97	1160.10	1160.17	1160.24	1160.31
Kettles Creek	5471	1157.98	1158.39	1158.63	1158.84	1159.00	1159.08	1159.18	1159.26	1159.39	1159.51	1159.57	1159.62	1159.67
Kettles Creek	5388	1157.07	1157.41	1157.59	1157.76	1157.89	1157.96	1158.05	1158.11	1158.25	1158.36	1158.42	1158.48	1158.54
Kettles Creek	5312	1156.49	1156.79	1156.98	1157.11	1157.21	1157.27	1157.35	1157.40	1157.49	1157.58	1157.61	1157.65	1157.68
Kettles Creek	5214	1155.62	1155.95	1156.05	1156.21	1156.28	1156.32	1156.38	1156.42	1156.49	1156.55	1156.59	1156.63	1156.66
Kettles Creek	5166	1155.05	1155.38	1155.50	1155.60	1155.67	1155.71	1155.75	1155.78	1155.84	1155.90	1155.92	1155.95	1155.97
Kettles Creek	5120	1154.80	1155.07	1155.17	1155.24	1155.30	1155.33	1155.37	1155.40	1155.45	1155.51	1155.53	1155.56	1155.59
Kettles Creek	5069	1154.30	1154.57	1154.68	1154.78	1154.84	1154.89	1154.94	1154.98	1155.05	1155.11	1155.14	1155.17	1155.20
Kettles Creek	5008	1153.76	1154.04	1154.16	1154.26	1154.36	1154.38	1154.42	1154.44	1154.51	1154.57	1154.61	1154.64	1154.67
Kettles Creek	4960	1153.16	1153.41	1153.58	1153.72	1153.83	1153.89	1153.96	1154.02	1154.13	1154.23	1154.28	1154.33	1154.37
Kettles Creek	4914	1152.82	1153.17	1153.31	1153.44	1153.54	1153.59	1153.67	1153.72	1153.83	1153.93	1153.99	1154.04	1154.10
Kettles Creek	4859	1152.64	1152.95	1153.10	1153.25	1153.37	1153.44	1153.53	1153.59	1153.72	1153.84	1153.90	1153.96	1154.02
Kettles Creek	4776	1151.97	1152.26	1152.44	1152.62	1152.76	1152.83	1152.94	1153.01	1153.15	1153.28	1153.34	1153.40	1153.46
Kettles Creek	4693	1151.14	1151.50	1151.74	1151.97	1152.13	1152.21	1152.30	1152.36	1152.46	1152.55	1152.59	1152.64	1152.68
Kettles Creek	4599	1150.37	1150.84	1151.12	1151.35	1151.52	1151.62	1151.74	1151.83	1151.92	1151.98	1152.02	1152.04	1152.06

River	Cross Section	Water Surface Elevation (m) for Given Return Period (years)												
		2	5	10	20	35	50	75	100	200	350	500	750	1000
Kettles Creek	4518	1149.93	1150.42	1150.69	1150.85	1150.99	1151.05	1151.11	1151.19	1151.38	1151.48	1151.51	1151.55	1151.58
Kettles Creek	4448	1149.58	1149.82	1149.95	1150.12	1150.20	1150.25	1150.34	1150.37	1150.37	1150.48	1150.68	1150.71	1150.73
Kettles Creek	4350	1148.76	1149.12	1149.34	1149.53	1149.70	1149.79	1149.88	1149.95	1150.01	1150.09	1150.12	1150.16	1150.19
Kettles Creek	4286	1148.30	1148.68	1148.82	1148.91	1148.94	1149.04	1149.18	1149.30	1149.57	1149.63	1149.65	1149.69	1149.73
Kettles Creek	4229	1147.58	1148.03	1148.30	1148.59	1148.84	1148.98	1148.98	1149.19	1149.36	1149.46	1149.50	1149.55	1149.60
Kettles Creek	4180	1146.90	1147.36	1147.69	1148.03	1148.36	1148.50	1148.98	1149.20	1149.36	1149.46	1149.51	1149.56	1149.60
Kettles Creek	4142	1146.56	1147.25	1147.67	1148.08	1148.44	1148.69	1148.97	1149.19	1149.35	1149.45	1149.50	1149.55	1149.59
Kettles Creek	4108	1146.44	1147.14	1147.56	1148.02	1148.42	1148.65	1148.96	1149.18	1149.34	1149.44	1149.48	1149.53	1149.59
Kettles Creek	4094	1146.41	1147.10	1147.52	1147.99	1148.41	1148.65	1148.95	1149.17	1149.34	1149.44	1149.49	1149.54	1149.58
Kettles Creek	4062	1145.93	1146.56	1146.85	1147.12	1147.33	1147.44	1147.57	1147.67	1147.82	1147.97	1148.04	1148.11	1148.17
Kettles Creek	4011	1145.25	1145.60	1145.86	1146.13	1146.32	1146.45	1146.61	1146.71	1146.90	1147.05	1147.11	1147.17	1147.23
Kettles Creek	3924	1144.51	1145.07	1145.38	1145.68	1145.90	1146.03	1146.11	1146.20	1146.31	1146.31	1146.34	1146.37	1146.38
Kettles Creek	3851	1144.21	1144.68	1144.89	1145.08	1145.19	1145.27	1145.36	1145.40	1145.55	1145.93	1145.94	1145.97	1146.06
Kettles Creek	3810	1143.90	1144.17	1144.35	1144.51	1144.64	1144.70	1144.77	1144.88	1144.99	1145.07	1145.08	1145.10	1145.10
Kettles Creek	3746	1143.39	1143.75	1143.95	1144.15	1144.30	1144.39	1144.52	1144.61	1144.79	1144.79	1144.79	1144.79	1144.79
Kettles Creek	3699	1142.80	1143.14	1143.34	1143.59	1143.77	1143.89	1144.05	1144.16	1144.33	1144.57	1144.67	1144.67	1144.67
Kettles Creek	3659	1142.29	1142.74	1142.93	1143.09	1143.19	1143.24	1143.30	1143.34	1143.50	1143.55	1143.55	1144.10	1144.10
Kettles Creek	3594	1142.12	1142.49	1142.67	1142.84	1142.97	1143.04	1143.12	1143.19	1143.32	1143.43	1143.49	1143.54	1143.60
Kettles Creek	3517	1141.36	1141.72	1142.03	1142.31	1142.43	1142.50	1142.60	1142.69	1142.84	1142.89	1142.94	1143.00	1143.04
Kettles Creek	3449	1140.69	1140.97	1141.07	1141.17	1141.37	1141.46	1141.55	1141.59	1141.70	1141.92	1141.98	1142.02	1142.07
Kettles Creek	3390	1140.51	1140.84	1141.06	1141.25	1141.41	1141.49	1141.56	1141.62	1141.72	1141.79	1141.83	1141.86	1141.89
Kettles Creek	3328	1140.07	1140.55	1140.76	1140.94	1141.09	1141.18	1141.19	1141.23	1141.32	1141.43	1141.45	1141.47	1141.50
Kettles Creek	3277	1139.60	1140.02	1140.23	1140.45	1140.62	1140.72	1140.75	1140.75	1140.79	1140.87	1140.92	1140.96	1141.02
Kettles Creek	3184	1138.77	1139.24	1139.53	1139.79	1140.03	1140.05	1140.17	1140.30	1140.47	1140.59	1140.67	1140.75	1140.75
Kettles Creek	3132	1138.40	1138.91	1139.22	1139.49	1139.49	1139.49	1139.49	1139.49	1139.55	1139.75	1139.75	1139.75	1140.12
Kettles Creek	3073	1137.95	1138.31	1138.43	1138.59	1138.59	1138.92	1138.96	1138.98	1138.98	1138.98	1138.98	1138.98	1139.01
Kettles Creek	3025	1137.24	1137.83	1138.00	1138.18	1138.28	1138.33	1138.42	1138.48	1138.59	1138.73	1138.78	1138.82	1138.87
Kettles Creek	2937	1136.72	1137.22	1137.46	1137.68	1137.84	1137.94	1138.06	1138.14	1138.29	1138.44	1138.51	1138.57	1138.63
Kettles Creek	2868	1136.08	1136.49	1136.76	1137.00	1137.16	1137.24	1137.33	1137.39	1137.51	1137.62	1137.67	1137.72	1137.78
Kettles Creek	2796	1135.49	1136.06	1136.38	1136.65	1136.82	1136.90	1137.02	1137.11	1137.24	1137.24	1137.28	1137.28	1137.51
Kettles Creek	2746	1135.17	1135.70	1135.98	1136.25	1136.45	1136.55	1136.71	1136.80	1136.93	1137.13	1137.26	1137.26	1137.26
Kettles Creek	2723	1135.02	1135.47	1135.72	1135.96	1136.12	1136.20	1136.43	1136.73	1136.91	1137.10	1137.23	1137.23	1137.23
Kettles Creek	2719	1134.98	1135.44	1135.68	1135.90	1136.03	1136.11	1136.26	1136.30	1136.32	1136.58	1136.64	1136.68	1136.84
Kettles Creek	2657	1134.29	1134.83	1135.10	1135.34	1135.51	1135.51	1135.56	1135.66	1135.82	1135.82	1135.83	1135.84	1135.91
Kettles Creek	2608	1133.97	1134.52	1134.81	1135.08	1135.31	1135.44	1135.62	1135.67	1135.70	1135.70	1135.76	1135.82	1135.88
Kettles Creek	2578	1133.82	1134.29	1134.55	1134.80	1134.99	1135.10	1135.25	1135.65	1135.68	1135.68	1135.74	1135.80	1135.87
Kettles Creek	2574	1133.80	1134.21	1134.42	1134.60	1134.72	1134.78	1134.89	1134.97	1135.07	1135.58	1135.68	1135.76	1135.84
Kettles Creek	2548	1133.66	1134.08	1134.34	1134.57	1134.75	1134.84	1134.96	1135.05	1135.21	1135.35	1135.42	1135.49	1135.56
Kettles Creek	2534	1133.49	1133.76	1133.92	1134.12	1134.26	1134.34	1134.43	1134.51	1134.63	1134.75	1134.81	1134.86	1134.91
Kettles Creek	2499	1133.18	1133.50	1133.63	1133.77	1133.88	1133.93	1134.00	1134.05	1134.14	1134.20	1134.23	1134.27	1134.31
Kettles Creek	2439	1132.46	1132.78	1132.94	1133.05	1133.10	1133.15	1133.20	1133.23	1133.30	1133.39	1133.42	1133.44	1133.47
Kettles Creek	2364	1132.17	1132.46	1132.58	1132.70	1132.78	1132.82	1132.88	1132.92	1133.00	1133.07	1133.11	1133.14	1133.17
Kettles Creek	2285	1131.73	1131.97	1132.08	1132.16	1132.25	1132.29	1132.35	1132.38	1132.45	1132.49	1132.51	1132.57	1132.60
Kettles Creek	2202	1130.33	1130.58	1130.69	1130.83	1130.88	1130.93	1130.97	1131.00	1131.08	1131.19	1131.25	1131.25	1131.27
Kettles Creek	2116	1128.49	1128.89	1129.09	1129.28	1129.42	1129.50	1129.59	1129.71	1129.75	1129.81	1129.84	1129.91	1129.96
Kettles Creek	2025	1127.57	1127.89	1128.11	1128.34	1128.52	1128.62	1128.76	1128.90	1129.04	1129.14	1129.20	1129.20	1129.25

River	Cross Section	Water Surface Elevation (m) for Given Return Period (years)												
		2	5	10	20	35	50	75	100	200	350	500	750	1000
Kettles Creek	1942	1126.61	1127.04	1127.24	1127.42	1127.55	1127.61	1127.70	1127.76	1127.93	1128.08	1128.13	1128.31	1128.36
Kettles Creek	1851	1125.87	1126.19	1126.39	1126.59	1126.75	1126.84	1126.96	1127.05	1127.23	1127.39	1127.46	1127.54	1127.54
Kettles Creek	1770	1125.26	1125.68	1125.92	1126.18	1126.37	1126.48	1126.62	1126.73	1126.93	1127.12	1127.20	1127.28	1127.28
Kettles Creek	1711	1124.38	1124.88	1125.15	1125.35	1125.50	1125.60	1125.71	1125.78	1125.88	1126.05	1126.14	1126.26	1126.67
Kettles Creek	1692	1124.39	1124.81	1124.85	1125.08	1125.25	1125.35	1125.48	1125.57	1125.75	1125.93	1126.02	1126.10	1126.18
Kettles Creek	1681	1124.23	1124.59	1124.77	1124.91	1125.01	1125.06	1125.13	1125.18	1125.28	1125.39	1125.44	1125.50	1125.55
Kettles Creek	1658	1123.80	1124.01	1124.14	1124.29	1124.39	1124.45	1124.52	1124.57	1124.67	1124.77	1124.84	1124.91	1124.98
Kettles Creek	1591	1123.28	1123.62	1123.84	1124.07	1124.24	1124.33	1124.46	1124.55	1124.72	1124.89	1124.97	1125.04	1125.12
Kettles Creek	1533	1122.92	1123.28	1123.49	1123.70	1123.84	1123.93	1124.03	1124.11	1124.25	1124.39	1124.46	1124.52	1124.58
Kettles Creek	1477	1122.39	1122.81	1123.04	1123.26	1123.42	1123.51	1123.63	1123.72	1123.87	1124.02	1124.10	1124.18	1124.25
Kettles Creek	1392	1121.92	1122.30	1122.53	1122.76	1122.92	1123.03	1123.15	1123.23	1123.36	1123.52	1123.59	1123.68	1123.74
Kettles Creek	1309	1121.36	1121.79	1122.03	1122.26	1122.44	1122.55	1122.67	1122.76	1122.76	1122.96	1123.03	1123.15	1123.22
Kettles Creek	1225	1121.00	1121.43	1121.66	1121.88	1122.05	1122.19	1122.30	1122.39	1122.61	1122.61	1122.61	1122.61	1122.61
Kettles Creek	1141	1120.39	1120.77	1120.99	1121.22	1121.30	1121.30	1121.30	1121.36	1121.46	1121.59	1121.59	1121.69	1121.70
Kettles Creek	1045	1119.69	1120.27	1120.57	1120.84	1120.84	1120.97	1121.11	1121.22	1121.30	1121.49	1121.49	1121.49	1121.49
Kettles Creek	953	1119.23	1119.78	1120.07	1120.33	1120.51	1120.61	1120.74	1120.83	1120.83	1120.83	1120.93	1121.00	1121.07
Kettles Creek	870	1118.84	1119.34	1119.58	1119.81	1119.97	1120.06	1120.18	1120.24	1120.29	1120.29	1120.29	1120.29	1120.29
Kettles Creek	798	1118.36	1118.85	1119.12	1119.33	1119.50	1119.59	1119.71	1119.79	1119.98	1120.03	1120.08	1120.08	1120.24
Kettles Creek	732	1117.66	1118.15	1118.35	1118.61	1118.78	1118.88	1119.00	1119.09	1119.43	1119.63	1119.92	1120.06	1120.24
Kettles Creek	701	1117.58	1117.98	1118.01	1118.25	1118.45	1118.56	1118.70	1118.81	1119.28	1119.48	1119.59	1120.03	1120.22
Kettles Creek	690	1117.37	1117.68	1117.92	1118.12	1118.27	1118.35	1118.44	1118.51	1118.65	1118.77	1118.82	1118.88	1118.93
Kettles Creek	637	1116.88	1117.43	1117.66	1117.87	1118.03	1118.11	1118.22	1118.30	1118.45	1118.58	1118.65	1118.71	1118.77
Kettles Creek	547	1116.43	1116.93	1117.19	1117.42	1117.59	1117.68	1117.79	1117.87	1118.03	1118.17	1118.24	1118.31	1118.38
Kettles Creek	478	1115.84	1116.29	1116.52	1116.74	1116.91	1117.01	1117.13	1117.29	1117.48	1117.54	1117.58	1117.66	1117.69
Kettles Creek	421	1115.23	1115.77	1116.09	1116.41	1116.63	1116.76	1116.92	1117.09	1117.32	1117.35	1117.47	1117.59	1117.68
Kettles Creek	407	1115.03	1115.57	1115.88	1116.19	1116.42	1116.54	1116.69	1117.06	1117.31	1117.33	1117.46	1117.58	1117.67
Kettles Creek	397	1114.98	1115.49	1115.77	1116.00	1116.20	1116.27	1116.37	1116.43	1116.54	1116.63	1116.63	1116.63	1116.63
Kettles Creek	360	1114.73	1115.25	1115.53	1115.79	1116.02	1116.09	1116.21	1116.30	1116.44	1116.55	1116.62	1116.68	1116.74
Kettles Creek	293	1113.86	1114.24	1114.47	1114.69	1114.83	1115.02	1115.17	1115.27	1115.50	1115.71	1115.73	1115.76	1115.80
Kettles Creek	234	1112.66	1113.09	1113.34	1113.58	1113.75	1113.84	1113.96	1114.05	1114.20	1114.35	1114.43	1114.51	1114.58
Kettles Creek	177	1112.18	1112.65	1112.95	1113.23	1113.44	1113.55	1113.68	1113.78	1113.92	1114.07	1114.15	1114.22	1114.29
Kettles Creek	126	1111.67	1112.11	1112.30	1112.46	1112.60	1112.72	1112.84	1112.93	1113.14	1113.28	1113.34	1113.39	1113.44
Kettles Creek	65	1110.73	1111.05	1111.27	1111.47	1111.64	1111.81	1111.90	1111.90	1112.32	1112.40	1112.42	1112.43	1112.51
Kettles Creek	5	1109.89	1110.43	1110.80	1111.20	1111.54	1111.57	1111.57	1111.57	1111.67	1111.67	1111.78	1111.89	1111.99

Figure VII.1. Pincher Creek Profile for 2-YR to 1000-YR Flood Event

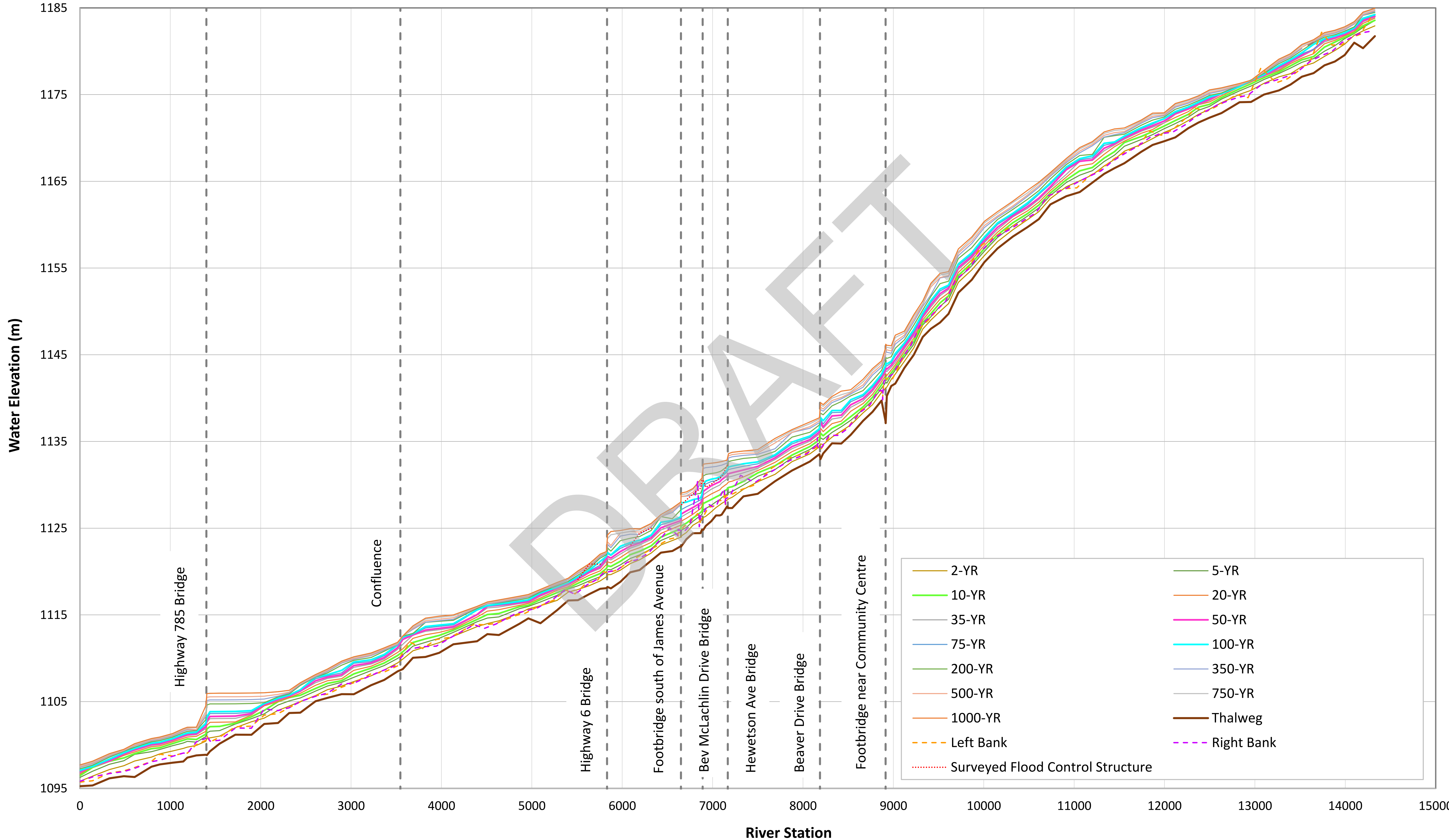


Figure VII.2. Kettles Creek Profile for 2-YR to 1000-YR Flood Event

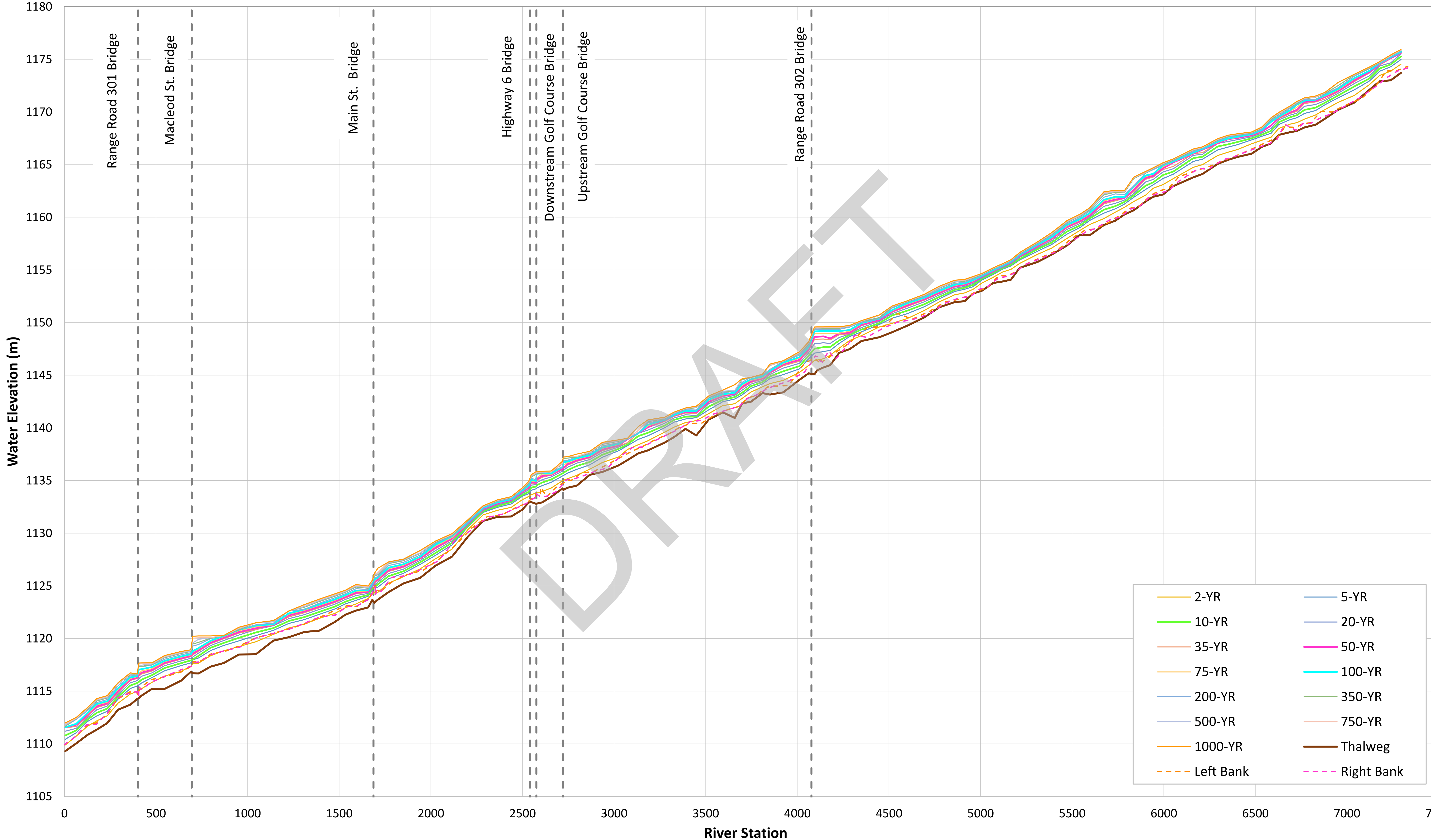


Table VII.3 Sensitivity Analysis Results for Downstream Boundary Condition

River	Cross Section	100-Year Flood Level (m) and Width (m) for Various Downstream Boundary Condition					
		-20% (S = 0.0024)		Calibrated (S = 0.0030)		+20% (S = 0.0036)	
		Elevation	Width	Elevation	Width	Elevation	Width
Pincher Creek	14327	1184.24	188.28	1184.24	188.28	1184.24	188.28
Pincher Creek	14196	1183.80	195.36	1183.80	195.36	1183.80	195.36
Pincher Creek	14099	1182.70	146.22	1182.70	146.22	1182.70	146.22
Pincher Creek	13994	1182.13	296.89	1182.13	296.89	1182.13	296.89
Pincher Creek	13885	1181.74	323.49	1181.74	323.49	1181.74	323.49
Pincher Creek	13770	1181.43	360.30	1181.43	360.30	1181.43	360.30
Pincher Creek	13649	1180.79	310.77	1180.79	310.77	1180.79	310.77
Pincher Creek	13520	1179.82	185.19	1179.82	185.19	1179.82	185.19
Pincher Creek	13394	1179.02	106.38	1179.02	106.38	1179.02	106.38
Pincher Creek	13265	1178.33	225.08	1178.33	225.08	1178.33	225.08
Pincher Creek	13100	1177.31	236.10	1177.31	236.10	1177.31	236.10
Pincher Creek	12957	1176.65	397.22	1176.65	397.22	1176.65	397.22
Pincher Creek	12831	1175.93	372.56	1175.93	372.56	1175.93	372.56
Pincher Creek	12630	1175.11	398.66	1175.11	398.66	1175.11	398.66
Pincher Creek	12499	1174.74	324.72	1174.74	324.72	1174.74	324.72
Pincher Creek	12377	1174.12	181.85	1174.12	181.85	1174.12	181.85
Pincher Creek	12263	1173.57	224.77	1173.57	224.77	1173.57	224.77
Pincher Creek	12119	1173.04	183.07	1173.04	183.07	1173.04	183.07
Pincher Creek	11995	1172.21	129.25	1172.21	129.25	1172.21	129.25
Pincher Creek	11868	1171.73	152.79	1171.73	152.79	1171.73	152.79
Pincher Creek	11743	1171.18	82.28	1171.18	82.28	1171.18	82.28
Pincher Creek	11556	1170.22	133.75	1170.22	133.75	1170.22	133.75
Pincher Creek	11446	1169.53	150.97	1169.53	150.97	1169.53	150.97
Pincher Creek	11332	1169.38	62.86	1169.38	62.86	1169.38	62.86
Pincher Creek	11202	1167.94	31.72	1167.94	31.72	1167.94	31.72
Pincher Creek	11062	1167.61	56.15	1167.61	56.15	1167.61	56.15
Pincher Creek	10914	1166.65	96.02	1166.65	96.02	1166.65	96.02
Pincher Creek	10738	1164.82	73.44	1164.82	73.44	1164.82	73.44
Pincher Creek	10610	1163.63	70.14	1163.63	70.14	1163.63	70.14
Pincher Creek	10484	1162.51	60.25	1162.51	60.25	1162.51	60.25
Pincher Creek	10322	1161.31	58.05	1161.31	58.05	1161.31	58.05
Pincher Creek	10153	1160.20	57.52	1160.20	57.52	1160.20	57.52
Pincher Creek	10006	1158.56	25.75	1158.56	25.75	1158.56	25.75
Pincher Creek	9868	1156.77	35.86	1156.77	35.86	1156.77	35.86
Pincher Creek	9719	1155.48	31.52	1155.48	31.52	1155.48	31.52
Pincher Creek	9610	1153.03	32.25	1153.03	32.25	1153.03	32.25
Pincher Creek	9517	1152.58	33.23	1152.58	33.23	1152.58	33.23
Pincher Creek	9415	1151.25	24.46	1151.25	24.46	1151.25	24.46
Pincher Creek	9325	1149.81	32.81	1149.81	32.81	1149.81	32.81
Pincher Creek	9225	1147.89	25.78	1147.89	25.78	1147.89	25.78
Pincher Creek	9122	1146.35	31.06	1146.35	31.06	1146.35	31.06
Pincher Creek	9021	1145.14	36.80	1145.14	36.80	1145.14	36.80
Pincher Creek	8977	1144.25	28.68	1144.25	28.68	1144.25	28.68
Pincher Creek	8928	1143.94	31.26	1143.94	31.26	1143.94	31.26
Pincher Creek	8915	1144.06	32.17	1144.06	32.17	1144.06	32.17
Pincher Creek	8913	1143.74	28.19	1143.74	28.19	1143.74	28.19
Pincher Creek	8869	1142.75	22.70	1142.75	22.70	1142.75	22.70
Pincher Creek	8769	1141.47	22.68	1141.47	22.68	1141.47	22.68
Pincher Creek	8665	1140.40	23.21	1140.40	23.21	1140.40	23.21
Pincher Creek	8528	1139.81	39.40	1139.81	39.40	1139.81	39.40
Pincher Creek	8424	1138.57	26.81	1138.57	26.81	1138.57	26.81
Pincher Creek	8321	1138.56	43.22	1138.56	43.22	1138.56	43.22
Pincher Creek	8223	1137.39	31.98	1137.39	31.98	1137.39	31.98
Pincher Creek	8194	1137.76	31.08	1137.76	31.08	1137.76	31.08
Pincher Creek	8182	1136.47	26.55	1136.47	26.55	1136.47	26.55
Pincher Creek	8077	1135.62	24.69	1135.62	24.69	1135.62	24.69
Pincher Creek	7879	1134.93	30.83	1134.93	30.83	1134.93	30.83
Pincher Creek	7691	1133.47	25.51	1133.47	25.51	1133.47	25.51
Pincher Creek	7499	1132.64	30.58	1132.64	30.58	1132.64	30.58
Pincher Creek	7342	1132.43	48.68	1132.43	48.68	1132.43	48.68
Pincher Creek	7217	1132.17	170.07	1132.17	170.07	1132.17	170.07
Pincher Creek	7176	1132.05	181.25	1132.05	181.25	1132.05	181.25
Pincher Creek	7160	1131.71	165.26	1131.71	165.26	1131.71	165.26
Pincher Creek	7101	1131.11	147.25	1131.11	147.25	1131.11	147.25

River	Cross Section	100-Year Flood Level (m) and Width (m) for Various Downstream Boundary Condition					
		-20% (S = 0.0024)		Calibrated (S = 0.0030)		+20% (S = 0.0036)	
		Elevation	Width	Elevation	Width	Elevation	Width
Pincher Creek	7081	1130.90	269.65	1130.90	269.65	1130.90	269.65
Pincher Creek	7038	1130.75	201.20	1130.75	201.20	1130.75	201.20
Pincher Creek	6985	1130.65	193.05	1130.65	193.05	1130.65	193.05
Pincher Creek	6924	1130.43	242.37	1130.43	242.37	1130.43	242.37
Pincher Creek	6897	1130.00	28.72	1130.00	28.72	1130.00	28.72
Pincher Creek	6883	1128.89	26.74	1128.89	26.74	1128.89	26.74
Pincher Creek	6867	1128.48	19.78	1128.48	19.78	1128.48	19.78
Pincher Creek	6783	1128.29	28.60	1128.29	28.60	1128.29	28.60
Pincher Creek	6710	1128.01	32.73	1128.01	32.73	1128.01	32.73
Pincher Creek	6651	1127.91	217.16	1127.91	217.16	1127.91	217.16
Pincher Creek	6649	1126.31	25.30	1126.31	25.30	1126.31	25.30
Pincher Creek	6555	1125.89	24.68	1125.89	24.68	1125.89	24.68
Pincher Creek	6429	1125.68	153.41	1125.68	153.41	1125.68	153.41
Pincher Creek	6321	1124.21	23.85	1124.21	23.85	1124.21	23.85
Pincher Creek	6193	1123.61	74.47	1123.61	74.47	1123.61	74.47
Pincher Creek	6089	1123.34	168.70	1123.34	168.70	1123.34	168.70
Pincher Creek	5979	1122.91	182.81	1122.91	182.81	1122.91	182.81
Pincher Creek	5875	1121.91	122.91	1121.91	122.91	1121.91	122.91
Pincher Creek	5838	1122.19	35.70	1122.19	35.70	1122.19	35.70
Pincher Creek	5824	1121.73	35.64	1121.73	35.64	1121.73	35.64
Pincher Creek	5756	1121.17	241.01	1121.17	241.01	1121.17	241.01
Pincher Creek	5636	1120.18	41.46	1120.18	41.46	1120.18	41.46
Pincher Creek	5510	1119.38	207.30	1119.38	207.30	1119.38	207.30
Pincher Creek	5402	1118.73	272.42	1118.73	272.42	1118.73	272.42
Pincher Creek	5281	1118.21	434.41	1118.21	434.41	1118.21	434.41
Pincher Creek	5096	1117.53	383.50	1117.53	383.50	1117.53	383.50
Pincher Creek	4962	1116.74	294.90	1116.74	294.90	1116.74	294.90
Pincher Creek	4863	1116.57	333.56	1116.57	333.56	1116.57	333.56
Pincher Creek	4636	1116.25	425.13	1116.25	425.13	1116.25	425.13
Pincher Creek	4508	1116.07	501.45	1116.07	501.45	1116.07	501.45
Pincher Creek	4394	1115.59	478.45	1115.59	478.45	1115.59	478.45
Pincher Creek	4132	1113.98	127.28	1113.98	127.28	1113.98	127.28
Pincher Creek	3976	1113.82	121.10	1113.82	121.10	1113.82	121.10
Pincher Creek	3824	1113.66	175.79	1113.66	175.79	1113.66	175.79
Pincher Creek	3685	1112.85	159.65	1112.85	159.65	1112.85	159.65
Pincher Creek	3573	1112.48	358.07	1112.48	358.07	1112.48	358.07
Pincher Creek	3514	1111.54	390.81	1111.54	390.81	1111.54	390.81
Pincher Creek	3367	1110.43	122.58	1110.43	122.58	1110.43	122.58
Pincher Creek	3222	1109.82	135.44	1109.82	135.44	1109.82	135.44
Pincher Creek	3030	1109.56	318.03	1109.56	318.03	1109.56	318.03
Pincher Creek	2896	1108.61	86.81	1108.61	86.81	1108.61	86.81
Pincher Creek	2739	1108.10	306.51	1108.10	306.51	1108.10	306.51
Pincher Creek	2607	1107.83	326.60	1107.83	326.60	1107.83	326.60
Pincher Creek	2438	1106.37	162.34	1106.37	162.34	1106.37	162.34
Pincher Creek	2316	1105.76	377.60	1105.76	377.60	1105.76	377.60
Pincher Creek	2192	1105.38	411.82	1105.38	411.82	1105.38	411.82
Pincher Creek	2039	1104.78	410.17	1104.78	410.17	1104.78	410.17
Pincher Creek	1898	1103.96	338.75	1103.96	338.75	1103.96	338.75
Pincher Creek	1720	1103.87	467.17	1103.87	467.17	1103.87	467.17
Pincher Creek	1545	1103.85	677.97	1103.85	677.97	1103.85	677.97
Pincher Creek	1439	1103.84	627.93	1103.84	627.93	1103.84	627.93
Pincher Creek	1405	1103.25	107.63	1103.25	107.63	1103.25	107.63
Pincher Creek	1393	1102.50	32.45	1102.50	32.45	1102.50	32.45
Pincher Creek	1289	1101.49	295.32	1101.49	295.32	1101.49	295.32
Pincher Creek	1189	1101.38	354.03	1101.38	354.03	1101.38	354.03
Pincher Creek	1144	1101.22	321.19	1101.22	321.19	1101.22	321.19
Pincher Creek	1024	1100.73	227.79	1100.73	227.79	1100.73	227.79
Pincher Creek	884	1100.33	255.92	1100.33	255.92	1100.33	255.92
Pincher Creek	792	1100.21	271.96	1100.21	271.96	1100.21	271.96
Pincher Creek	606	1099.61	337.80	1099.61	337.80	1099.61	337.80
Pincher Creek	486	1099.11	333.37	1099.11	333.37	1099.11	333.37
Pincher Creek	327	1098.37	314.96	1098.37	314.96	1098.37	314.96
Pincher Creek	140	1097.52	229.20	1097.52	229.20	1097.52	229.20
Pincher Creek	0	1097.01	278.12	1097.08	258.82	1097.17	254.37

Figure VII.3. Pincher Creek Profile - Downstream Boundary Sensitivity Analysis

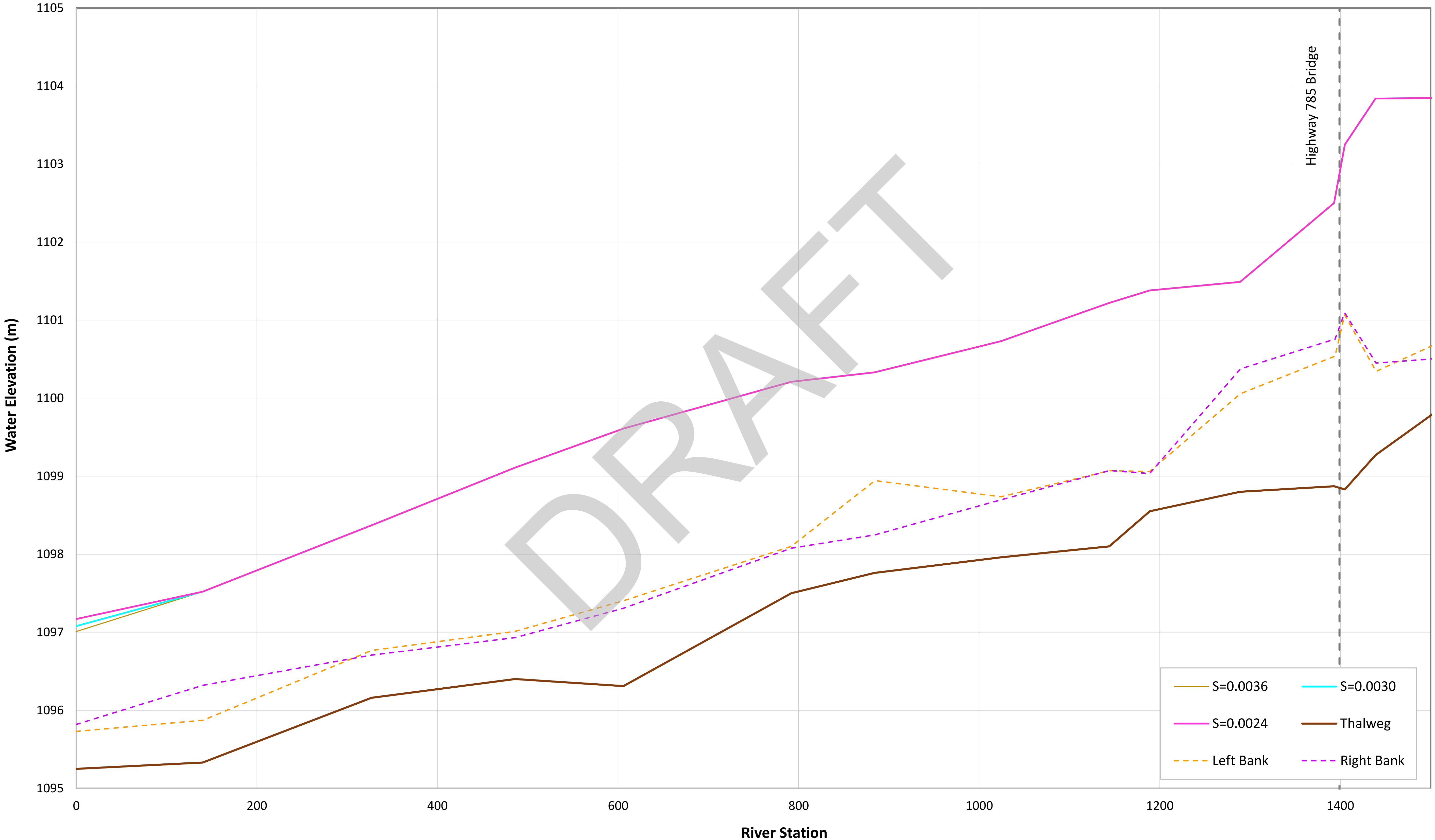


Table VII.4 Sensitivity Analysis Results for Channel Roughness – Pincher Creek

River	Cross Section	100-Year Flood Level (m) and Width (m) for Various Channel Roughness									
		-20%		-10%		Calibrated		+10%		+20%	
		Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width
Pincher Creek	14327	1184.24	188.38	1184.24	188.29	1184.24	188.28	1184.24	188.29	1184.24	188.30
Pincher Creek	14196	1183.75	185.71	1183.80	194.50	1183.80	195.36	1183.82	197.34	1183.82	197.35
Pincher Creek	14099	1182.83	164.97	1182.71	147.27	1182.70	146.22	1182.63	141.59	1182.64	141.91
Pincher Creek	13994	1182.14	296.94	1182.14	296.91	1182.13	296.89	1182.18	297.09	1182.17	297.07
Pincher Creek	13885	1181.70	322.29	1181.73	322.81	1181.74	323.49	1181.90	324.43	1181.90	324.40
Pincher Creek	13770	1181.40	357.62	1181.43	361.15	1181.43	360.30	1181.77	363.94	1181.75	363.88
Pincher Creek	13649	1180.83	313.01	1180.75	304.34	1180.79	310.77	1180.21	145.09	1180.21	145.09
Pincher Creek	13520	1179.66	153.95	1179.75	167.89	1179.82	185.19	1179.85	190.96	1179.91	202.42
Pincher Creek	13394	1179.12	107.84	1179.07	107.21	1179.02	106.38	1179.00	106.23	1178.94	105.09
Pincher Creek	13265	1178.20	197.44	1178.28	219.58	1178.33	225.08	1178.38	229.59	1178.40	232.11
Pincher Creek	13100	1177.37	242.91	1177.33	238.17	1177.31	236.10	1177.28	234.60	1177.28	234.29
Pincher Creek	12957	1176.65	397.22	1176.65	397.22	1176.65	397.22	1176.65	397.22	1176.65	397.22
Pincher Creek	12831	1175.93	372.56	1175.93	372.56	1175.93	372.56	1175.93	372.56	1175.93	372.56
Pincher Creek	12630	1175.14	401.55	1175.11	398.66	1175.11	398.66	1175.12	399.55	1175.14	401.04
Pincher Creek	12499	1174.68	324.44	1174.71	324.58	1174.74	324.72	1174.77	324.85	1174.79	324.97
Pincher Creek	12377	1174.11	181.07	1174.12	181.46	1174.12	181.85	1174.13	182.16	1174.14	182.59
Pincher Creek	12263	1173.57	224.81	1173.55	224.53	1173.57	224.77	1173.59	224.99	1173.61	225.20
Pincher Creek	12119	1172.99	182.72	1173.02	182.93	1173.04	183.07	1173.07	183.18	1173.08	183.27
Pincher Creek	11995	1172.22	129.45	1172.22	129.38	1172.21	129.25	1172.19	129.07	1172.18	128.89
Pincher Creek	11868	1171.70	152.44	1171.71	152.49	1171.73	152.79	1171.77	153.09	1171.81	153.44
Pincher Creek	11743	1170.95	80.83	1171.06	81.75	1171.18	82.28	1171.26	82.62	1171.33	82.89
Pincher Creek	11556	1170.27	133.88	1170.24	133.82	1170.22	133.75	1170.20	133.69	1170.17	133.63
Pincher Creek	11446	1169.61	152.76	1169.58	152.45	1169.53	150.97	1169.63	153.01	1169.69	153.63
Pincher Creek	11332	1169.29	62.23	1169.34	62.55	1169.38	62.86	1169.41	63.20	1169.43	63.45
Pincher Creek	11202	1167.95	31.77	1167.94	31.74	1167.94	31.72	1167.93	31.69	1168.00	32.39
Pincher Creek	11062	1167.48	54.63	1167.55	55.40	1167.61	56.15	1167.66	56.74	1167.71	59.88
Pincher Creek	10914	1166.67	96.19	1166.67	96.13	1166.65	96.02	1166.63	95.92	1166.61	95.82
Pincher Creek	10738	1164.81	73.08	1164.82	73.44	1164.82	73.44	1164.82	73.41	1164.82	73.66
Pincher Creek	10610	1163.64	70.20	1163.64	70.19	1163.63	70.14	1163.62	70.09	1163.62	70.09
Pincher Creek	10484	1162.38	50.38	1162.48	58.02	1162.51	60.25	1162.63	66.95	1162.77	69.47
Pincher Creek	10322	1161.30	56.10	1161.31	58.05	1161.31	58.05	1161.34	60.57	1161.41	63.80
Pincher Creek	10153	1160.19	57.39	1160.20	57.53	1160.20	57.52	1160.26	58.21	1160.42	61.64
Pincher Creek	10006	1158.55	25.66	1158.56	25.75	1158.56	25.75	1158.56	25.75	1158.56	25.78
Pincher Creek	9868	1156.76	35.65	1156.76	35.55	1156.77	35.86	1156.92	43.66	1157.14	44.63
Pincher Creek	9719	1155.49	31.73	1155.48	31.67	1155.48	31.52	1155.48	31.49	1155.47	31.45
Pincher Creek	9610	1153.07	32.43	1153.05	32.34	1153.03	32.25	1153.14	32.73	1153.27	33.26
Pincher Creek	9517	1152.29	31.50	1152.45	32.63	1152.58	33.23	1152.68	33.64	1152.78	33.95
Pincher Creek	9415	1151.25	24.46	1151.25	24.46	1151.25	24.46	1151.25	24.46	1151.25	24.45
Pincher Creek	9325	1149.88	33.47	1149.84	33.09	1149.81	32.81	1149.78	32.52	1149.76	32.30
Pincher Creek	9225	1147.89	25.77	1147.89	25.77	1147.89	25.78	1147.89	25.77	1147.89	25.76
Pincher Creek	9122	1146.38	31.24	1146.37	31.17	1146.35	31.06	1146.33	30.94	1146.31	30.84
Pincher Creek	9021	1144.96	36.40	1145.07	36.67	1145.14	36.80	1145.17	36.87	1145.20	36.91
Pincher Creek	8977	1144.25	28.67	1144.25	28.68	1144.25	28.68	1144.25	28.67	1144.25	28.67

River	Cross Section	100-Year Flood Level (m) and Width (m) for Various Channel Roughness									
		-20%		-10%		Calibrated		+10%		+20%	
		Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width
Pincher Creek	8928	1143.86	30.95	1143.90	31.08	1143.94	31.26	1143.96	31.37	1143.99	31.48
Pincher Creek	8915	1144.01	31.99	1144.04	32.08	1144.06	32.17	1144.07	32.21	1144.08	32.25
Pincher Creek	8913	1143.67	28.02	1143.69	28.08	1143.74	28.19	1143.76	28.26	1143.78	28.36
Pincher Creek	8869	1142.79	22.78	1142.77	22.76	1142.75	22.70	1142.74	22.68	1142.74	22.68
Pincher Creek	8769	1141.50	22.99	1141.48	22.86	1141.47	22.68	1141.46	22.57	1141.54	23.49
Pincher Creek	8665	1140.41	23.24	1140.40	23.23	1140.40	23.21	1140.39	23.20	1140.39	23.18
Pincher Creek	8528	1139.69	34.24	1139.77	37.62	1139.81	39.40	1139.86	39.89	1139.86	39.90
Pincher Creek	8424	1138.59	26.87	1138.58	26.84	1138.57	26.81	1138.57	26.82	1138.73	27.24
Pincher Creek	8321	1138.50	42.95	1138.53	43.04	1138.56	43.22	1138.60	43.38	1138.64	43.54
Pincher Creek	8223	1137.42	32.32	1137.40	32.15	1137.39	31.98	1137.37	31.76	1137.35	31.55
Pincher Creek	8194	1137.75	31.01	1137.75	31.05	1137.76	31.08	1137.76	31.12	1137.77	31.15
Pincher Creek	8182	1136.17	25.36	1136.38	26.20	1136.47	26.55	1136.53	26.79	1136.64	27.24
Pincher Creek	8077	1135.55	24.46	1135.54	24.42	1135.62	24.69	1135.81	25.57	1135.97	26.70
Pincher Creek	7879	1134.65	28.90	1134.83	30.53	1134.93	30.83	1135.02	31.10	1135.13	31.41
Pincher Creek	7691	1133.34	25.09	1133.33	25.07	1133.47	25.51	1133.61	25.99	1133.74	29.22
Pincher Creek	7499	1132.36	29.93	1132.52	30.31	1132.64	30.58	1132.74	30.82	1132.82	31.01
Pincher Creek	7342	1132.38	48.43	1132.40	48.55	1132.43	48.68	1132.46	49.34	1132.50	50.76
Pincher Creek	7217	1132.17	170.15	1132.17	170.12	1132.17	170.07	1132.18	173.82	1132.20	178.03
Pincher Creek	7176	1132.08	182.67	1132.06	181.97	1132.05	181.25	1132.06	181.65	1132.07	182.29
Pincher Creek	7160	1131.73	173.96	1131.72	171.08	1131.71	165.26	1131.71	169.76	1131.73	173.74
Pincher Creek	7101	1131.16	157.26	1131.14	152.05	1131.11	147.25	1131.12	148.05	1131.13	149.65
Pincher Creek	7081	1130.94	275.64	1130.93	275.26	1130.90	269.65	1130.91	274.80	1130.93	275.34
Pincher Creek	7038	1130.83	202.57	1130.80	201.55	1130.75	201.20	1130.74	201.20	1130.76	201.28
Pincher Creek	6985	1130.75	196.91	1130.71	196.35	1130.65	193.05	1130.65	192.97	1130.66	194.08
Pincher Creek	6924	1130.54	250.10	1130.50	246.46	1130.43	242.37	1130.43	242.39	1130.46	244.06
Pincher Creek	6897	1130.12	28.99	1130.08	28.90	1130.00	28.72	1130.01	28.72	1130.03	28.79
Pincher Creek	6883	1128.72	26.51	1128.72	26.51	1128.89	26.74	1129.19	27.21	1129.27	27.34
Pincher Creek	6867	1128.48	19.78	1128.47	19.76	1128.48	19.78	1128.47	19.76	1128.48	19.78
Pincher Creek	6783	1128.09	27.46	1128.25	28.44	1128.29	28.60	1128.31	28.71	1128.34	28.86
Pincher Creek	6710	1127.83	32.16	1128.00	32.71	1128.01	32.73	1128.00	32.71	1128.00	32.71
Pincher Creek	6651	1127.58	54.92	1127.91	217.07	1127.91	217.16	1127.89	216.47	1127.88	216.21
Pincher Creek	6649	1126.30	24.92	1126.30	24.53	1126.31	25.30	1126.43	33.92	1126.60	41.24
Pincher Creek	6555	1125.64	23.96	1125.75	24.38	1125.89	24.68	1126.00	24.89	1126.10	27.20
Pincher Creek	6429	1125.46	126.13	1125.59	131.12	1125.68	153.41	1125.72	173.75	1125.79	198.02
Pincher Creek	6321	1124.21	23.84	1124.21	23.84	1124.21	23.85	1124.38	24.58	1124.49	28.54
Pincher Creek	6193	1123.57	73.92	1123.60	74.38	1123.61	74.47	1123.61	74.47	1123.69	77.05
Pincher Creek	6089	1123.22	158.67	1123.28	162.43	1123.34	168.70	1123.39	172.66	1123.44	173.64
Pincher Creek	5979	1122.73	177.27	1122.83	181.67	1122.91	182.81	1122.98	183.82	1123.03	186.35
Pincher Creek	5875	1121.82	117.61	1121.86	119.89	1121.91	122.91	1121.97	128.15	1122.02	130.07
Pincher Creek	5838	1122.18	35.69	1122.18	35.69	1122.19	35.70	1122.20	35.71	1122.21	35.72
Pincher Creek	5824	1121.70	35.63	1121.70	35.62	1121.73	35.64	1121.75	35.65	1121.75	35.65
Pincher Creek	5756	1121.17	240.24	1121.23	251.32	1121.17	241.01	1121.17	240.73	1121.36	273.02
Pincher Creek	5636	1120.05	40.79	1120.11	41.10	1120.18	41.46	1120.19	41.60	1120.04	40.72
Pincher Creek	5510	1119.47	227.59	1119.41	211.78	1119.38	207.30	1119.46	222.33	1119.53	243.82
Pincher Creek	5402	1118.76	275.36	1118.75	272.79	1118.73	272.42	1118.73	272.23	1118.71	271.63

River	Cross Section	100-Year Flood Level (m) and Width (m) for Various Channel Roughness									
		-20%		-10%		Calibrated		+10%		+20%	
		Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width
Pincher Creek	5281	1118.19	425.09	1118.20	429.28	1118.21	434.41	1118.22	438.81	1118.22	438.83
Pincher Creek	5096	1117.59	383.84	1117.55	383.66	1117.53	383.50	1117.48	381.28	1117.46	379.60
Pincher Creek	4962	1116.69	289.39	1116.69	289.17	1116.74	294.90	1116.77	300.02	1116.79	302.94
Pincher Creek	4863	1116.54	328.02	1116.55	332.19	1116.57	333.56	1116.58	334.69	1116.59	336.09
Pincher Creek	4636	1116.22	422.04	1116.24	423.74	1116.25	425.13	1116.27	428.08	1116.28	431.30
Pincher Creek	4508	1116.09	512.30	1116.08	504.80	1116.07	501.45	1116.07	500.42	1116.07	501.06
Pincher Creek	4394	1115.63	490.11	1115.61	484.54	1115.59	478.45	1115.57	469.67	1115.55	463.56
Pincher Creek	4132	1113.84	116.84	1113.91	118.66	1113.98	127.28	1114.03	132.87	1114.08	136.23
Pincher Creek	3976	1113.75	119.24	1113.79	120.31	1113.82	121.10	1113.85	121.76	1113.88	122.37
Pincher Creek	3824	1113.58	173.05	1113.62	173.18	1113.66	175.79	1113.70	181.09	1113.73	183.66
Pincher Creek	3685	1112.47	69.46	1112.48	70.60	1112.85	159.65	1112.91	161.08	1112.98	162.27
Pincher Creek	3573	1112.57	369.88	1112.57	369.88	1112.48	358.07	1112.48	358.07	1112.47	354.63
Pincher Creek	3514	1111.57	403.49	1111.55	394.60	1111.54	390.81	1111.54	390.97	1111.55	393.52
Pincher Creek	3367	1110.49	128.28	1110.45	124.10	1110.43	122.58	1110.42	121.22	1110.41	120.29
Pincher Creek	3222	1109.87	146.07	1109.83	137.73	1109.82	135.44	1109.78	126.70	1109.72	113.34
Pincher Creek	3030	1109.50	284.33	1109.54	308.61	1109.56	318.03	1109.58	324.78	1109.59	329.48
Pincher Creek	2896	1108.62	90.54	1108.58	82.96	1108.61	86.81	1108.63	93.43	1108.67	105.83
Pincher Creek	2739	1108.07	302.01	1108.09	305.38	1108.10	306.51	1108.11	308.89	1108.13	311.59
Pincher Creek	2607	1107.53	259.19	1107.49	238.51	1107.83	326.60	1107.84	327.85	1107.85	329.60
Pincher Creek	2438	1106.76	282.21	1106.73	281.90	1106.37	162.34	1106.37	162.34	1106.37	162.34
Pincher Creek	2316	1105.79	390.82	1105.77	386.62	1105.76	377.60	1105.74	370.63	1105.73	365.50
Pincher Creek	2192	1105.42	415.21	1105.39	412.78	1105.38	411.82	1105.48	419.55	1105.44	416.25
Pincher Creek	2039	1104.83	412.29	1104.80	411.46	1104.78	410.17	1104.74	403.21	1104.73	397.73
Pincher Creek	1898	1103.95	337.82	1103.96	338.35	1103.96	338.75	1103.96	340.65	1103.96	343.92
Pincher Creek	1720	1103.89	468.12	1103.88	467.64	1103.87	467.17	1103.86	466.75	1103.85	466.42
Pincher Creek	1545	1103.88	685.87	1103.87	681.99	1103.85	677.97	1103.84	676.88	1103.83	676.31
Pincher Creek	1439	1103.87	629.39	1103.86	628.51	1103.84	627.93	1103.83	627.53	1103.82	627.22
Pincher Creek	1405	1103.24	107.06	1103.24	107.12	1103.25	107.63	1103.25	109.77	1103.26	111.83
Pincher Creek	1393	1102.51	32.47	1102.51	32.47	1102.50	32.45	1102.50	32.43	1102.50	32.42
Pincher Creek	1289	1101.53	296.82	1101.52	296.23	1101.49	295.32	1101.45	291.70	1101.44	290.98
Pincher Creek	1189	1101.44	355.94	1101.41	354.61	1101.38	354.03	1101.37	352.73	1101.36	352.52
Pincher Creek	1144	1101.23	321.25	1101.24	321.26	1101.22	321.19	1101.22	321.18	1101.22	321.20
Pincher Creek	1024	1100.73	227.66	1100.70	226.98	1100.73	227.79	1100.77	228.44	1100.80	228.80
Pincher Creek	884	1100.27	255.69	1100.30	255.79	1100.33	255.92	1100.34	255.98	1100.36	256.06
Pincher Creek	792	1100.22	272.17	1100.22	272.15	1100.21	271.96	1100.19	271.84	1100.19	271.83
Pincher Creek	606	1099.67	338.12	1099.62	337.86	1099.61	337.80	1099.64	338.01	1099.63	337.95
Pincher Creek	486	1099.20	353.44	1099.15	345.20	1099.11	333.37	1099.09	329.97	1099.13	338.23
Pincher Creek	327	1098.33	313.67	1098.35	314.50	1098.37	314.96	1098.38	315.45	1098.40	316.15
Pincher Creek	140	1097.52	229.20	1097.52	229.20	1097.52	229.20	1097.52	229.20	1097.52	229.20
Pincher Creek	0	1097.03	258.82	1097.06	258.82	1097.08	258.82	1097.10	258.82	1097.11	258.82

Table VII.5 Sensitivity Analysis Results for Channel Roughness – Kettles Creek

River	Cross Section	100-Year Flood Level (m) and Width (m) for Various Channel Roughness									
		-20%		-10%		Calibrated		+10%		+20%	
		Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width
Kettles Creek	7295	1175.69	63.51	1175.71	64.18	1175.28	64.99	1175.72	65.07	1175.73	65.14
Kettles Creek	7239	1175.23	52.89	1175.21	52.35	1174.51	51.66	1175.19	51.44	1175.17	50.27
Kettles Creek	7178	1174.49	79.36	1174.53	87.52	1174.13	96.88	1174.64	99.07	1174.65	100.06
Kettles Creek	7123	1174.07	46.92	1174.06	46.86	1173.18	34.43	1173.92	34.43	1173.92	34.43
Kettles Creek	7041	1172.92	14.46	1173.09	26.17	1172.43	32.42	1173.31	41.14	1173.37	52.19
Kettles Creek	6951	1172.21	16.54	1172.19	14.81	1171.56	14.32	1172.15	10.88	1172.14	10.84
Kettles Creek	6880	1171.56	61.40	1171.56	61.41	1170.88	61.45	1171.57	61.50	1171.58	61.57
Kettles Creek	6829	1171.12	19.17	1171.15	19.56	1170.41	19.78	1171.19	19.90	1171.21	20.05
Kettles Creek	6768	1171.07	83.64	1171.07	83.64	1170.20	83.64	1171.07	83.73	1171.08	84.66
Kettles Creek	6728	1170.71	47.40	1170.71	47.16	1169.70	47.01	1170.69	46.67	1170.64	41.30
Kettles Creek	6690	1169.97	21.92	1170.09	24.21	1169.50	26.34	1170.24	27.88	1170.30	31.09
Kettles Creek	6628	1169.46	11.08	1169.50	12.61	1169.03	14.43	1169.60	16.92	1169.63	20.53
Kettles Creek	6586	1169.06	16.26	1169.07	16.32	1168.21	16.30	1169.06	16.26	1169.06	16.24
Kettles Creek	6536	1168.19	12.70	1168.24	12.81	1167.85	12.91	1168.32	13.01	1168.35	13.10
Kettles Creek	6480	1167.83	19.50	1167.87	19.60	1167.50	19.68	1167.91	19.75	1167.93	19.82
Kettles Creek	6402	1167.61	81.07	1167.63	83.50	1167.15	85.99	1167.65	88.19	1167.68	93.08
Kettles Creek	6352	1167.46	90.11	1167.48	90.66	1166.93	90.70	1167.49	91.25	1167.54	94.45
Kettles Creek	6295	1167.06	53.18	1167.11	58.87	1166.73	65.70	1167.19	71.78	1167.23	74.25
Kettles Creek	6212	1166.56	70.87	1166.52	70.04	1165.75	68.87	1166.47	68.30	1166.46	68.09
Kettles Creek	6162	1166.04	54.86	1166.09	55.36	1165.62	55.46	1166.17	55.53	1166.20	55.59
Kettles Creek	6053	1165.34	45.16	1165.33	45.16	1164.35	45.11	1165.30	45.06	1165.27	44.98
Kettles Creek	5996	1164.91	45.06	1164.92	45.11	1164.01	45.10	1164.89	44.97	1164.89	44.95
Kettles Creek	5943	1164.05	18.84	1164.04	18.05	1163.32	27.42	1164.26	49.10	1164.34	53.73
Kettles Creek	5901	1163.81	28.29	1163.89	33.57	1163.00	41.34	1164.04	46.46	1164.10	49.15
Kettles Creek	5837	1162.95	9.27	1162.95	9.25	1162.09	9.23	1162.94	9.21	1162.94	9.19
Kettles Creek	5785	1161.93	18.13	1161.93	18.13	1161.45	18.13	1162.01	18.68	1162.01	18.67
Kettles Creek	5736	1161.93	16.27	1161.94	16.28	1161.06	16.30	1161.97	16.32	1161.98	16.33
Kettles Creek	5674	1161.55	15.32	1161.62	16.59	1160.72	17.43	1161.72	18.78	1161.74	20.09
Kettles Creek	5596	1160.44	8.21	1160.42	8.17	1159.88	8.14	1160.38	8.11	1160.39	8.14
Kettles Creek	5544	1159.74	14.57	1159.77	14.63	1159.22	14.71	1159.87	14.76	1159.91	14.80
Kettles Creek	5471	1159.04	10.01	1159.16	10.24	1158.63	10.33	1159.29	10.35	1159.34	10.39
Kettles Creek	5388	1158.18	11.79	1158.14	11.61	1157.59	11.53	1158.17	11.76	1158.22	11.90
Kettles Creek	5312	1157.28	11.71	1157.35	11.91	1156.98	12.00	1157.44	12.09	1157.47	12.15
Kettles Creek	5214	1156.46	25.43	1156.44	25.35	1156.05	25.28	1156.40	25.22	1156.39	25.16
Kettles Creek	5166	1155.81	55.89	1155.79	55.83	1155.50	55.81	1155.80	55.87	1155.81	55.90
Kettles Creek	5120	1155.37	52.99	1155.39	53.07	1155.17	53.11	1155.41	53.16	1155.42	53.20
Kettles Creek	5069	1154.95	54.08	1154.96	54.14	1154.68	54.20	1154.99	54.25	1155.00	54.29
Kettles Creek	5008	1154.44	38.60	1154.45	38.66	1154.16	38.63	1154.45	38.65	1154.46	38.71
Kettles Creek	4960	1153.95	36.82	1153.97	36.88	1153.58	37.00	1154.06	37.10	1154.09	37.17
Kettles Creek	4914	1153.66	21.05	1153.69	21.36	1153.31	21.73	1153.74	22.11	1153.76	22.29
Kettles Creek	4859	1153.55	31.23	1153.57	31.27	1153.10	31.30	1153.61	31.33	1153.63	31.36
Kettles Creek	4776	1152.90	14.27	1152.96	14.33	1152.44	14.38	1153.05	14.42	1153.09	14.46
Kettles Creek	4693	1152.25	12.88	1152.30	13.15	1151.74	13.43	1152.40	13.65	1152.44	13.85

River	Cross Section	100-Year Flood Level (m) and Width (m) for Various Channel Roughness									
		-20%		-10%		Calibrated		+10%		+20%	
		Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width
Kettles Creek	4599	1151.65	32.85	1151.75	38.63	1151.12	46.22	1151.88	53.30	1151.92	55.28
Kettles Creek	4518	1151.00	14.18	1151.09	15.12	1150.69	25.89	1151.27	39.45	1151.33	51.24
Kettles Creek	4448	1150.38	26.40	1150.38	26.28	1149.95	26.04	1150.36	25.57	1150.36	25.83
Kettles Creek	4350	1149.94	47.86	1149.94	47.97	1149.34	48.04	1149.95	48.12	1149.95	48.03
Kettles Creek	4286	1149.27	25.12	1149.28	26.30	1148.82	27.70	1149.30	27.78	1149.36	35.06
Kettles Creek	4229	1149.17	107.97	1149.18	109.42	1148.30	111.57	1149.20	112.45	1149.21	113.62
Kettles Creek	4180	1149.19	121.62	1149.19	121.80	1147.69	121.98	1149.20	122.23	1149.21	122.52
Kettles Creek	4142	1149.18	126.11	1149.19	126.90	1147.67	127.87	1149.19	128.60	1149.20	129.17
Kettles Creek	4108	1149.17	191.93	1149.18	192.06	1147.56	192.20	1149.18	192.34	1149.18	192.47
Kettles Creek	4094	1149.17	165.19	1149.17	165.29	1147.52	165.40	1149.17	165.50	1149.18	165.59
Kettles Creek	4062	1147.56	48.27	1147.60	49.08	1146.85	50.40	1147.70	51.01	1147.73	51.77
Kettles Creek	4011	1146.70	12.35	1146.71	12.41	1145.86	12.45	1146.71	12.48	1146.72	12.51
Kettles Creek	3924	1146.19	110.21	1146.20	110.42	1145.38	110.53	1146.21	110.70	1146.22	110.87
Kettles Creek	3851	1145.27	8.88	1145.30	9.09	1144.89	10.41	1145.48	12.50	1145.57	38.22
Kettles Creek	3810	1144.91	14.20	1144.89	13.51	1144.35	13.48	1144.87	13.43	1144.86	13.41
Kettles Creek	3746	1144.61	25.85	1144.60	25.66	1143.95	25.73	1144.61	25.75	1144.61	25.96
Kettles Creek	3699	1144.00	46.29	1144.10	55.36	1143.34	63.59	1144.19	71.76	1144.22	77.73
Kettles Creek	3659	1143.34	32.07	1143.33	31.99	1142.93	32.10	1143.43	32.77	1143.50	42.06
Kettles Creek	3594	1143.14	45.08	1143.17	49.57	1142.67	55.84	1143.22	59.71	1143.24	61.57
Kettles Creek	3517	1142.56	17.57	1142.63	17.70	1142.03	29.74	1142.72	35.73	1142.76	46.73
Kettles Creek	3449	1141.60	13.06	1141.60	12.99	1141.07	12.90	1141.59	12.90	1141.58	12.86
Kettles Creek	3390	1141.66	97.13	1141.63	96.28	1141.06	96.08	1141.61	95.93	1141.61	95.90
Kettles Creek	3328	1141.26	70.45	1141.22	67.50	1140.76	67.99	1141.24	68.64	1141.25	69.93
Kettles Creek	3277	1140.86	111.90	1140.74	75.00	1140.23	76.48	1140.75	80.81	1140.77	89.58
Kettles Creek	3184	1140.16	71.87	1140.26	77.63	1139.53	78.09	1140.34	78.41	1140.35	78.70
Kettles Creek	3132	1139.50	13.36	1139.49	13.33	1139.22	13.28	1139.45	12.96	1139.47	13.12
Kettles Creek	3073	1138.98	64.16	1138.98	64.16	1138.43	64.16	1138.98	64.16	1138.98	64.16
Kettles Creek	3025	1138.42	40.80	1138.45	40.87	1138.00	40.97	1138.50	41.03	1138.51	41.09
Kettles Creek	2937	1138.08	34.73	1138.12	35.44	1137.46	36.33	1138.16	36.53	1138.19	36.81
Kettles Creek	2868	1137.36	12.56	1137.34	12.49	1136.76	12.74	1137.46	12.96	1137.50	13.12
Kettles Creek	2796	1137.03	18.60	1137.07	18.78	1136.38	18.96	1137.15	19.16	1137.18	19.25
Kettles Creek	2746	1136.75	57.02	1136.78	59.64	1135.98	61.88	1136.87	68.67	1136.86	67.82
Kettles Creek	2723	1136.45	45.41	1136.70	76.92	1135.72	77.81	1136.83	80.13	1136.82	79.78
Kettles Creek	2719	1136.16	10.47	1136.16	10.45	1135.68	11.29	1136.42	22.36	1136.50	41.94
Kettles Creek	2657	1135.78	95.17	1135.78	95.17	1135.10	66.95	1135.63	63.30	1135.63	64.00
Kettles Creek	2608	1135.69	142.50	1135.67	141.85	1134.81	141.59	1135.67	141.61	1135.67	141.83
Kettles Creek	2578	1135.68	161.67	1135.66	161.30	1134.55	161.14	1135.65	161.11	1135.66	161.19
Kettles Creek	2574	1135.02	62.40	1134.99	57.75	1134.42	55.55	1134.97	55.20	1135.01	61.72
Kettles Creek	2548	1135.02	15.11	1135.04	15.12	1134.34	15.14	1135.06	15.15	1135.06	15.16
Kettles Creek	2534	1134.52	10.70	1134.51	10.66	1133.92	10.64	1134.50	10.63	1134.50	10.63
Kettles Creek	2499	1133.96	22.85	1134.01	23.25	1133.63	23.51	1134.05	23.48	1134.05	23.51
Kettles Creek	2439	1133.28	33.59	1133.26	32.05	1132.94	31.39	1133.26	32.06	1133.28	33.53
Kettles Creek	2364	1132.94	51.85	1132.92	51.52	1132.58	51.42	1132.92	51.43	1132.92	51.48
Kettles Creek	2285	1132.30	35.24	1132.35	35.87	1132.08	36.22	1132.40	36.39	1132.39	36.26
Kettles Creek	2202	1131.04	26.23	1131.02	26.09	1130.69	25.99	1131.00	25.97	1131.04	26.23

River	Cross Section	100-Year Flood Level (m) and Width (m) for Various Channel Roughness									
		-20%		-10%		Calibrated		+10%		+20%	
		Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width
Kettles Creek	2116	1129.56	17.51	1129.60	18.97	1129.09	27.59	1129.73	27.86	1129.75	28.05
Kettles Creek	2025	1128.73	31.59	1128.81	43.96	1128.11	45.86	1128.94	46.14	1128.98	46.40
Kettles Creek	1942	1127.61	9.56	1127.67	9.78	1127.24	10.76	1127.84	17.25	1127.91	19.05
Kettles Creek	1851	1126.89	14.69	1126.98	15.42	1126.39	16.98	1127.12	17.95	1127.19	18.85
Kettles Creek	1770	1126.69	14.77	1126.70	14.93	1125.92	15.17	1126.75	15.51	1126.78	16.34
Kettles Creek	1711	1125.82	8.93	1125.80	8.83	1125.15	8.73	1125.77	8.70	1125.75	8.65
Kettles Creek	1692	1125.85	11.49	1125.54	10.79	1124.85	10.84	1125.60	10.89	1125.63	10.93
Kettles Creek	1681	1125.15	11.18	1125.15	11.20	1124.77	11.30	1125.26	11.88	1125.29	11.92
Kettles Creek	1658	1124.61	13.72	1124.59	13.69	1124.14	13.66	1124.56	13.64	1124.60	13.71
Kettles Creek	1591	1124.50	27.26	1124.52	27.29	1123.84	27.33	1124.58	27.38	1124.61	27.43
Kettles Creek	1533	1123.94	12.47	1124.03	12.65	1123.49	12.83	1124.19	13.00	1124.26	13.15
Kettles Creek	1477	1123.51	13.98	1123.62	14.20	1123.04	14.41	1123.80	14.59	1123.87	14.76
Kettles Creek	1392	1123.09	80.79	1123.16	87.68	1122.53	88.02	1123.28	88.24	1123.33	88.49
Kettles Creek	1309	1122.64	122.25	1122.70	122.84	1122.03	123.38	1122.74	123.24	1122.48	69.82
Kettles Creek	1225	1122.30	145.83	1122.34	151.75	1121.66	157.90	1121.88	116.49	1122.48	173.48
Kettles Creek	1141	1121.37	222.98	1121.37	222.89	1120.99	222.76	1121.76	282.14	1121.34	221.59
Kettles Creek	1045	1121.18	347.12	1121.20	350.89	1120.57	353.71	1120.78	266.65	1120.99	320.19
Kettles Creek	953	1120.67	315.35	1120.75	317.50	1120.07	320.50	1120.90	324.75	1120.99	327.08
Kettles Creek	870	1120.12	283.16	1120.19	287.91	1119.58	295.84	1120.29	300.29	1120.33	305.30
Kettles Creek	798	1119.68	245.71	1119.74	262.12	1119.12	274.58	1119.83	280.25	1119.87	286.66
Kettles Creek	732	1119.06	74.23	1119.15	130.34	1118.35	92.54	1119.18	139.14	1119.25	154.42
Kettles Creek	701	1118.97	10.51	1119.01	10.62	1118.01	10.16	1118.86	10.28	1118.91	10.39
Kettles Creek	690	1118.42	9.89	1118.43	9.91	1117.92	10.09	1118.58	10.23	1118.64	10.35
Kettles Creek	637	1118.18	13.27	1118.24	13.54	1117.66	13.80	1118.34	14.01	1118.39	14.20
Kettles Creek	547	1117.76	16.62	1117.82	16.80	1117.19	16.93	1117.91	17.07	1117.94	17.20
Kettles Creek	478	1117.18	13.75	1117.24	13.99	1116.52	14.15	1117.34	14.31	1117.39	14.47
Kettles Creek	421	1117.08	25.27	1117.09	26.44	1116.09	26.11	1117.09	26.85	1117.11	29.33
Kettles Creek	407	1117.05	63.23	1117.06	63.40	1115.88	63.35	1117.07	63.42	1117.08	63.55
Kettles Creek	397	1116.29	10.04	1116.37	18.94	1115.77	26.03	1116.50	30.39	1116.54	32.51
Kettles Creek	360	1116.13	41.17	1116.23	52.68	1115.53	66.64	1116.35	94.64	1116.40	120.28
Kettles Creek	293	1115.25	12.60	1115.26	12.70	1114.47	12.82	1115.28	12.94	1115.29	13.03
Kettles Creek	234	1113.91	9.67	1113.95	9.87	1113.34	10.74	1114.12	11.43	1114.18	12.10
Kettles Creek	177	1113.62	63.21	1113.71	63.90	1112.95	64.32	1113.84	64.63	1113.89	64.99
Kettles Creek	126	1112.94	73.80	1112.93	73.73	1112.30	73.64	1112.92	73.56	1112.92	73.49
Kettles Creek	65	1111.91	56.67	1111.90	56.61	1111.27	56.62	1111.92	56.89	1111.99	58.50
Kettles Creek	5	1111.60	18.75	1111.58	17.71	1110.80	17.01	1111.57	17.01	1111.58	17.15

Figure VII.4. Pincher Creek Profile - Channel Roughness Sensitivity Analysis

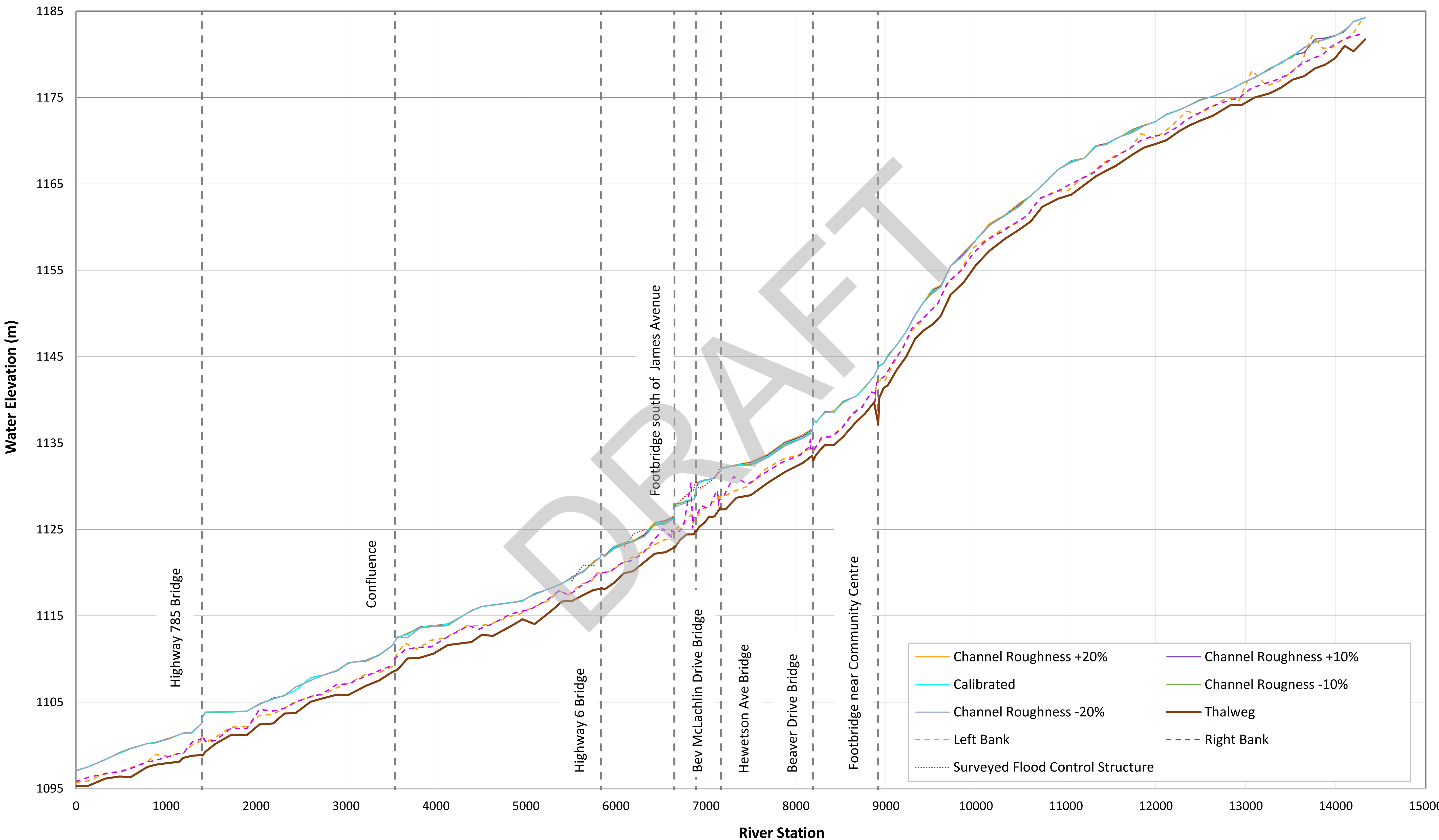


Figure VII.5. Kettles Creek Profile - Channel Roughness Sensitivity Analysis

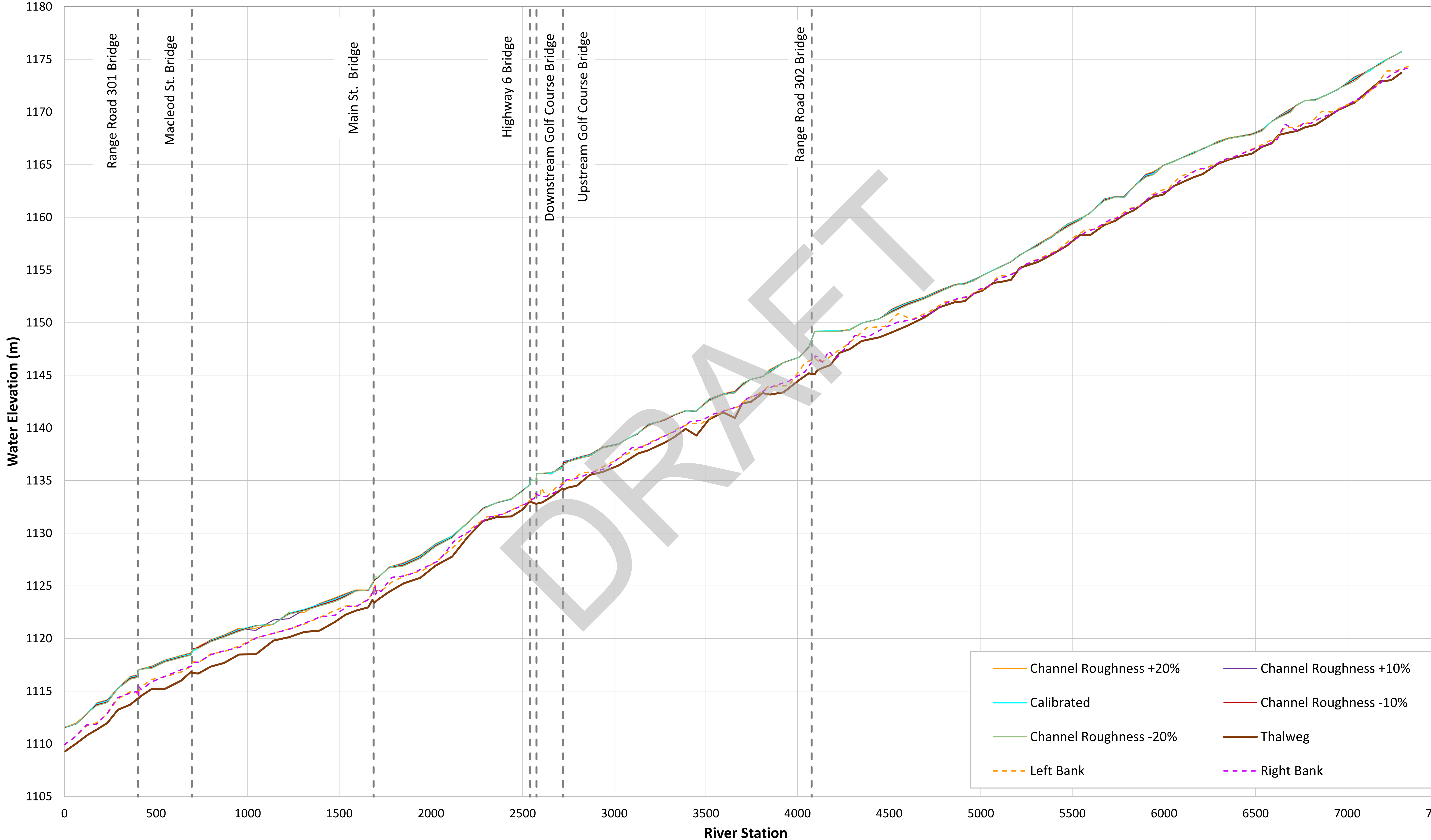


Figure VII.6. Pincher Creek Profile - Channel Roughness Sensitivity Analysis Comparison

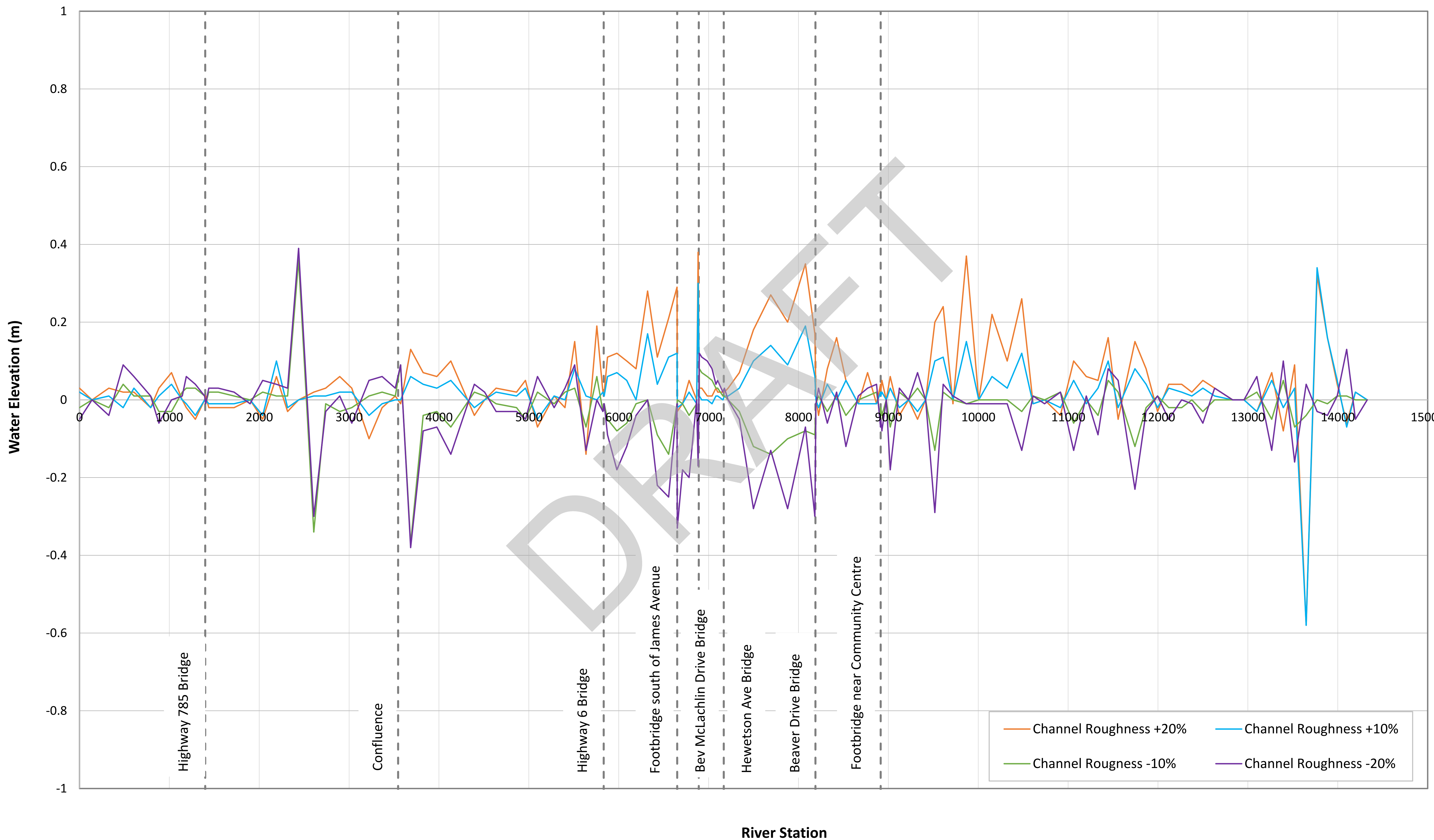


Figure VII.7. Kettles Creek Profile - Channel Roughness Sensitivity Analysis Comparison

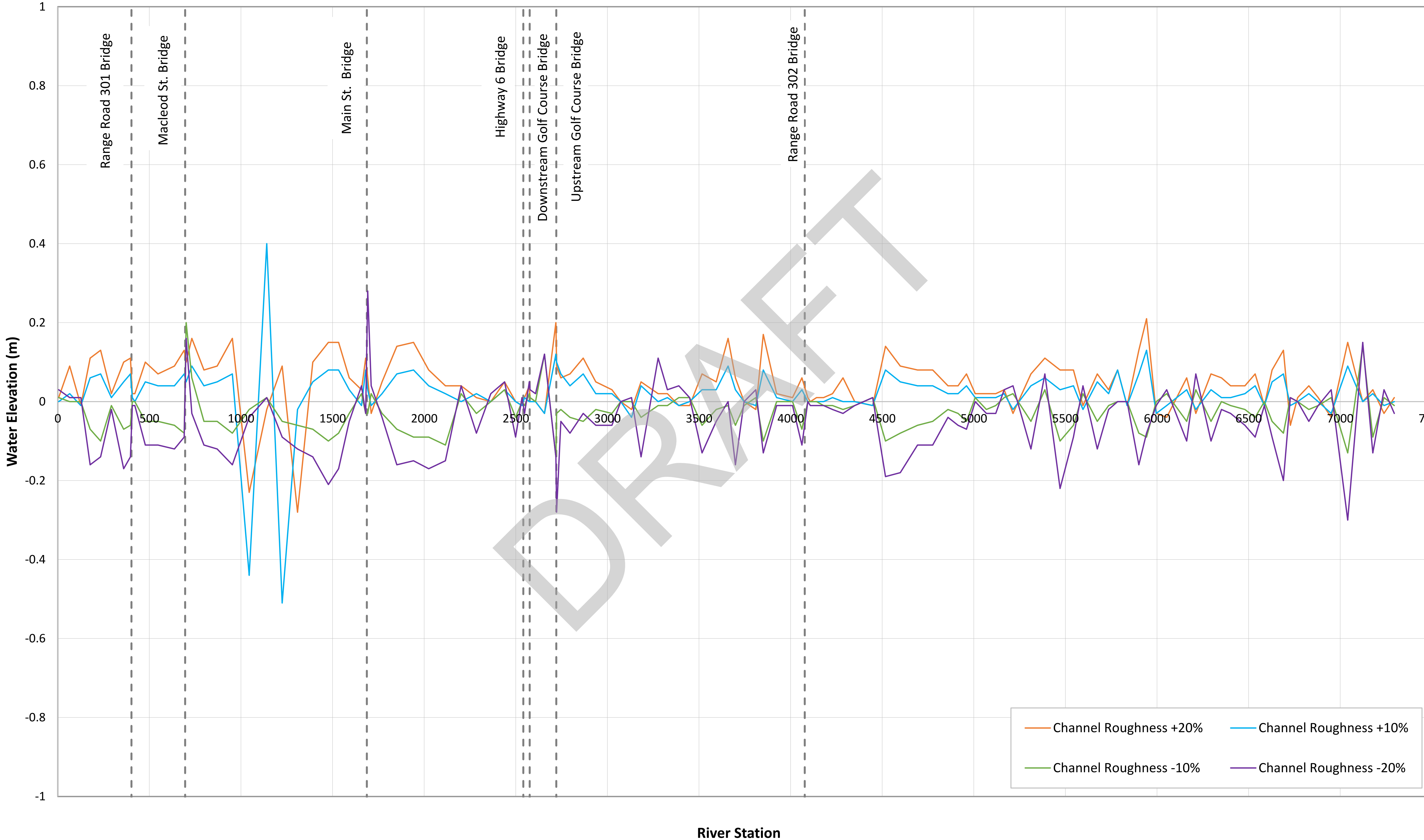


Table VII.6 Sensitivity Analysis Results for Overbank Roughness – Pincher Creek

River	Cross Section	100-Year Flood Level (m) and Width (m) for Various Overbank Roughness									
		-20%		-10%		Calibrated		+10%		+20%	
		Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width
Pincher Creek	14327	**1184.10**	**182.62**	**1184.17**	**186.58**	**1184.24**	**188.28**	**1184.30**	**190.12**	**1184.35**	**190.93**
Pincher Creek	14196	1183.68	180.72	1183.75	187.01	1183.80	195.36	1183.87	198.13	1183.89	198.29
Pincher Creek	14099	1182.60	139.35	1182.64	141.89	1182.70	146.22	1182.71	147.31	1182.82	163.52
Pincher Creek	13994	1182.06	295.69	1182.12	296.84	1182.13	296.89	1182.18	297.09	1182.22	297.26
Pincher Creek	13885	1181.78	323.76	1181.85	324.18	1181.74	323.49	1181.78	323.73	1181.81	323.93
Pincher Creek	13770	1181.65	363.59	1181.73	363.81	1181.43	360.30	1181.46	361.69	1181.56	363.31
Pincher Creek	13649	1180.21	145.09	1180.21	145.09	1180.79	310.77	1180.81	312.33	1180.59	260.47
Pincher Creek	13520	1179.70	158.98	1179.76	170.65	1179.82	185.19	1179.87	193.45	1179.91	203.91
Pincher Creek	13394	1178.93	104.73	1178.97	105.86	1179.02	106.38	1179.06	107.07	1179.10	107.65
Pincher Creek	13265	1178.22	207.37	1178.28	220.05	1178.33	225.08	1178.38	229.92	1178.42	234.43
Pincher Creek	13100	1177.27	233.85	1177.28	234.60	1177.31	236.10	1177.33	237.34	1177.35	240.93
Pincher Creek	12957	1176.65	397.22	1176.65	397.22	1176.65	397.22	1176.65	397.22	1176.65	397.22
Pincher Creek	12831	1175.93	372.56	1175.93	372.56	1175.93	372.56	1175.93	372.56	1175.97	375.24
Pincher Creek	12630	1175.11	398.66	1175.11	398.66	1175.11	398.66	1175.14	401.38	1175.17	405.05
Pincher Creek	12499	1174.70	324.51	1174.72	324.61	1174.74	324.72	1174.77	324.85	1174.72	324.60
Pincher Creek	12377	1174.02	170.31	1174.07	178.49	1174.12	181.85	1174.17	183.45	1174.22	185.41
Pincher Creek	12263	1173.47	222.07	1173.52	224.25	1173.57	224.77	1173.61	225.33	1173.66	225.95
Pincher Creek	12119	1172.94	182.42	1173.00	182.80	1173.04	183.07	1173.09	183.29	1173.13	183.49
Pincher Creek	11995	1172.17	128.82	1172.19	129.03	1172.21	129.25	1172.22	129.37	1172.22	129.43
Pincher Creek	11868	1171.64	151.88	1171.69	152.30	1171.73	152.79	1171.77	153.12	1171.81	153.46
Pincher Creek	11743	1171.08	81.85	1171.13	82.09	1171.18	82.28	1171.22	82.45	1171.26	82.61
Pincher Creek	11556	1170.16	133.59	1170.19	133.68	1170.22	133.75	1170.24	133.81	1170.26	133.86
Pincher Creek	11446	1169.45	147.65	1169.48	149.30	1169.53	150.97	1169.58	152.49	1169.60	152.64
Pincher Creek	11332	1169.30	62.25	1169.34	62.56	1169.38	62.86	1169.41	63.14	1169.43	63.52
Pincher Creek	11202	1167.93	31.64	1167.93	31.69	1167.94	31.72	1167.94	31.74	1167.94	31.76
Pincher Creek	11062	1167.49	54.70	1167.56	55.45	1167.61	56.15	1167.66	56.73	1167.70	59.75
Pincher Creek	10914	1166.60	95.77	1166.62	95.89	1166.65	96.02	1166.66	96.08	1166.67	96.14
Pincher Creek	10738	1164.82	73.61	1164.82	73.88	1164.82	73.44	1164.81	73.19	1164.82	73.42
Pincher Creek	10610	1163.61	70.02	1163.63	70.12	1163.63	70.14	1163.64	70.19	1163.64	70.21
Pincher Creek	10484	1162.53	60.62	1162.52	60.58	1162.51	60.25	1162.48	58.23	1162.46	56.91
Pincher Creek	10322	1161.33	59.34	1161.32	59.02	1161.31	58.05	1161.30	57.08	1161.30	57.16
Pincher Creek	10153	1160.19	57.37	1160.20	57.55	1160.20	57.52	1160.20	57.52	1160.19	57.42
Pincher Creek	10006	1158.56	25.75	1158.56	26.01	1158.56	25.75	1158.55	25.42	1158.55	25.64
Pincher Creek	9868	1156.78	36.25	1156.77	35.80	1156.77	35.86	1156.77	35.87	1156.76	35.47
Pincher Creek	9719	1155.47	31.44	1155.48	31.47	1155.48	31.52	1155.48	31.67	1155.49	31.71
Pincher Creek	9610	1153.01	32.12	1153.01	32.16	1153.03	32.25	1153.05	32.33	1153.07	32.40
Pincher Creek	9517	1152.53	33.05	1152.56	33.15	1152.58	33.23	1152.59	33.30	1152.61	33.35
Pincher Creek	9415	1151.25	24.45	1151.25	24.46	1151.25	24.46	1151.25	24.46	1151.25	24.46
Pincher Creek	9325	1149.75	32.22	1149.77	32.49	1149.81	32.81	1149.84	33.07	1149.87	33.31
Pincher Creek	9225	1147.89	25.77	1147.89	25.77	1147.89	25.78	1147.89	25.77	1147.89	25.77
Pincher Creek	9122	1146.31	30.81	1146.33	30.93	1146.35	31.06	1146.36	31.16	1146.38	31.22
Pincher Creek	9021	1145.04	36.61	1145.10	36.74	1145.14	36.80	1145.15	36.83	1145.15	36.83
Pincher Creek	8977	1144.25	28.67	1144.25	28.67	1144.25	28.68	1144.25	28.68	1144.25	28.68

River	Cross Section	100-Year Flood Level (m) and Width (m) for Various Overbank Roughness									
		-20%		-10%		Calibrated		+10%		+20%	
		Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width
Pincher Creek	8928	1143.89	31.05	1143.91	31.15	1143.94	31.26	1143.95	31.30	1143.96	31.35
Pincher Creek	8915	1144.01	31.96	1144.03	32.07	1144.06	32.17	1144.07	32.21	1144.08	32.25
Pincher Creek	8913	1143.66	27.99	1143.69	28.08	1143.74	28.19	1143.76	28.26	1143.78	28.37
Pincher Creek	8869	1142.73	22.66	1142.75	22.71	1142.75	22.70	1142.77	22.75	1142.78	22.77
Pincher Creek	8769	1141.46	22.56	1141.46	22.56	1141.47	22.68	1141.48	22.85	1141.49	22.95
Pincher Creek	8665	1140.39	23.18	1140.39	23.20	1140.40	23.21	1140.40	23.23	1140.40	23.23
Pincher Creek	8528	1139.70	34.87	1139.77	37.69	1139.81	39.40	1139.85	39.83	1139.89	40.10
Pincher Creek	8424	1138.54	26.74	1138.56	26.79	1138.57	26.81	1138.58	26.84	1138.58	26.86
Pincher Creek	8321	1138.44	42.69	1138.51	42.96	1138.56	43.22	1138.61	43.42	1138.66	43.58
Pincher Creek	8223	1137.34	31.46	1137.37	31.74	1137.39	31.98	1137.40	32.14	1137.42	32.29
Pincher Creek	8194	1137.77	31.16	1137.76	31.12	1137.76	31.08	1137.75	31.05	1137.75	31.03
Pincher Creek	8182	1136.38	26.19	1136.43	26.36	1136.47	26.55	1136.52	26.72	1136.56	26.88
Pincher Creek	8077	1135.61	24.67	1135.61	24.69	1135.62	24.69	1135.61	24.69	1135.61	24.68
Pincher Creek	7879	1134.92	30.82	1134.93	30.83	1134.93	30.83	1134.93	30.82	1134.92	30.82
Pincher Creek	7691	1133.41	25.31	1133.43	25.40	1133.47	25.51	1133.50	25.62	1133.53	25.74
Pincher Creek	7499	1132.52	30.30	1132.59	30.46	1132.64	30.58	1132.69	30.70	1132.71	30.74
Pincher Creek	7342	1132.35	48.31	1132.39	48.51	1132.43	48.68	1132.47	49.71	1132.47	49.67
Pincher Creek	7217	1132.12	163.48	1132.15	168.12	1132.17	170.07	1132.21	179.44	1132.19	175.45
Pincher Creek	7176	1131.99	172.78	1132.03	178.81	1132.05	181.25	1132.10	184.13	1132.08	183.06
Pincher Creek	7160	1131.64	154.46	1131.68	159.83	1131.71	165.26	1131.75	175.55	1131.73	174.85
Pincher Creek	7101	1131.08	142.20	1131.10	144.95	1131.11	147.25	1131.17	161.18	1131.22	182.24
Pincher Creek	7081	1130.80	36.59	1130.84	251.08	1130.90	269.65	1130.96	275.98	1131.01	277.23
Pincher Creek	7038	1130.66	200.72	1130.70	200.94	1130.75	201.20	1130.82	202.33	1130.87	204.90
Pincher Creek	6985	1130.59	191.56	1130.61	192.32	1130.65	193.05	1130.73	196.58	1130.77	197.34
Pincher Creek	6924	1130.40	240.44	1130.40	240.42	1130.43	242.37	1130.50	246.67	1130.55	251.19
Pincher Creek	6897	1130.00	28.71	1129.98	28.67	1130.00	28.72	1130.08	28.89	1130.12	28.98
Pincher Creek	6883	1129.19	27.22	1129.12	27.07	1128.89	26.74	1128.72	26.51	1128.73	26.53
Pincher Creek	6867	1128.47	19.77	1128.48	19.78	1128.48	19.78	1128.48	19.78	1128.48	19.78
Pincher Creek	6783	1128.25	28.43	1128.27	28.52	1128.29	28.60	1128.30	28.66	1128.31	28.69
Pincher Creek	6710	1127.98	32.65	1127.99	32.70	1128.01	32.73	1128.02	32.77	1128.02	32.78
Pincher Creek	6651	1127.90	216.94	1127.91	217.13	1127.91	217.16	1127.91	217.17	1127.90	216.83
Pincher Creek	6649	1126.30	24.92	1126.30	24.92	1126.31	25.30	1126.30	24.47	1126.30	24.92
Pincher Creek	6555	1125.84	24.58	1125.87	24.64	1125.89	24.68	1125.91	24.72	1125.92	24.74
Pincher Creek	6429	1125.65	145.12	1125.67	151.14	1125.68	153.41	1125.68	154.35	1125.68	155.39
Pincher Creek	6321	1124.19	23.80	1124.19	23.78	1124.21	23.85	1124.23	23.93	1124.25	24.02
Pincher Creek	6193	1123.61	74.53	1123.61	74.47	1123.61	74.47	1123.60	74.42	1123.58	74.06
Pincher Creek	6089	1123.27	161.58	1123.31	165.52	1123.34	168.70	1123.37	171.19	1123.40	172.70
Pincher Creek	5979	1122.87	182.21	1122.89	182.55	1122.91	182.81	1122.92	183.00	1122.93	183.14
Pincher Creek	5875	1121.88	121.52	1121.89	122.11	1121.91	122.91	1121.92	123.67	1121.94	125.59
Pincher Creek	5838	1122.15	35.66	1122.17	35.68	1122.19	35.70	1122.20	35.71	1122.22	35.73
Pincher Creek	5824	1121.64	35.59	1121.70	35.62	1121.73	35.64	1121.75	35.65	1121.77	35.66
Pincher Creek	5756	1121.24	253.13	1121.17	241.13	1121.17	241.01	1121.23	251.27	1121.23	251.17
Pincher Creek	5636	1120.07	40.88	1120.13	41.20	1120.18	41.46	1120.05	40.75	1120.24	199.89
Pincher Creek	5510	1119.31	197.27	1119.34	203.47	1119.38	207.30	1119.41	212.39	1119.42	215.20
Pincher Creek	5402	1118.70	271.08	1118.73	272.16	1118.73	272.42	1118.75	272.77	1118.76	273.06

River	Cross Section	100-Year Flood Level (m) and Width (m) for Various Overbank Roughness									
		-20%		-10%		Calibrated		+10%		+20%	
		Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width
Pincher Creek	5281	1118.12	410.04	1118.17	415.19	1118.21	434.41	1118.26	440.49	1118.29	451.44
Pincher Creek	5096	1117.45	378.48	1117.48	381.35	1117.53	383.50	1117.55	383.64	1117.58	383.78
Pincher Creek	4962	1116.61	279.00	1116.68	288.33	1116.74	294.90	1116.78	301.45	1116.83	310.45
Pincher Creek	4863	1116.45	311.13	1116.51	323.34	1116.57	333.56	1116.60	338.98	1116.65	351.36
Pincher Creek	4636	1116.17	411.12	1116.21	421.74	1116.25	425.13	1116.23	423.42	1116.26	426.78
Pincher Creek	4508	1115.99	466.99	1116.03	479.63	1116.07	501.45	1116.11	522.24	1116.14	525.02
Pincher Creek	4394	1115.54	460.08	1115.57	469.67	1115.59	478.45	1115.60	482.41	1115.62	487.48
Pincher Creek	4132	1113.87	117.38	1113.93	119.21	1113.98	127.28	1114.02	132.25	1114.06	135.77
Pincher Creek	3976	1113.72	119.08	1113.77	119.81	1113.82	121.10	1113.85	121.81	1113.89	122.51
Pincher Creek	3824	1113.60	173.10	1113.63	173.21	1113.66	175.79	1113.67	178.36	1113.69	180.59
Pincher Creek	3685	1112.77	146.28	1112.81	155.35	1112.85	159.65	1112.49	71.52	1112.47	69.08
Pincher Creek	3573	1112.47	354.68	1112.48	358.07	1112.48	358.07	1112.57	369.88	1112.57	369.88
Pincher Creek	3514	1111.49	366.10	1111.51	377.28	1111.54	390.81	1111.58	405.36	1111.62	424.77
Pincher Creek	3367	1110.41	120.44	1110.42	121.22	1110.43	122.58	1110.46	124.59	1110.48	127.45
Pincher Creek	3222	1109.68	104.87	1109.68	104.87	1109.82	135.44	1109.83	138.06	1109.85	141.53
Pincher Creek	3030	1109.52	297.30	1109.53	301.05	1109.56	318.03	1109.59	330.60	1109.61	341.65
Pincher Creek	2896	1108.59	84.31	1108.63	93.86	1108.61	86.81	1108.59	83.47	1108.61	88.44
Pincher Creek	2739	1108.00	294.61	1108.05	300.70	1108.10	306.51	1108.14	314.30	1108.17	320.39
Pincher Creek	2607	1107.71	301.52	1107.78	317.80	1107.83	326.60	1107.49	236.84	1107.51	252.78
Pincher Creek	2438	1106.37	162.34	1106.36	158.89	1106.37	162.34	1106.73	281.92	1106.75	282.13
Pincher Creek	2316	1105.67	333.20	1105.72	360.06	1105.76	377.60	1105.80	391.92	1105.83	399.45
Pincher Creek	2192	1105.31	407.08	1105.34	409.99	1105.38	411.82	1105.41	414.76	1105.44	416.50
Pincher Creek	2039	1104.72	396.87	1104.76	407.02	1104.78	410.17	1104.80	411.42	1104.82	412.05
Pincher Creek	1898	1103.87	320.14	1103.92	325.21	1103.96	338.75	1103.99	350.81	1104.03	355.41
Pincher Creek	1720	1103.80	463.40	1103.83	464.15	1103.87	467.17	1103.89	468.15	1103.92	468.98
Pincher Creek	1545	1103.79	670.00	1103.82	675.26	1103.85	677.97	1103.88	684.79	1103.90	689.13
Pincher Creek	1439	1103.78	624.83	1103.81	626.73	1103.84	627.93	1103.87	629.09	1103.89	630.53
Pincher Creek	1405	1103.20	94.31	1103.22	102.19	1103.25	107.63	1103.26	112.84	1103.28	116.30
Pincher Creek	1393	1102.49	32.41	1102.50	32.43	1102.50	32.45	1102.51	32.47	1102.51	32.48
Pincher Creek	1289	1101.42	289.78	1101.45	291.56	1101.49	295.32	1101.52	296.16	1101.54	296.87
Pincher Creek	1189	1101.27	349.70	1101.33	351.59	1101.38	354.03	1101.44	355.91	1101.49	357.30
Pincher Creek	1144	1101.11	314.66	1101.17	320.96	1101.22	321.19	1101.27	321.44	1101.32	321.67
Pincher Creek	1024	1100.65	226.03	1100.69	226.79	1100.73	227.79	1100.78	228.51	1100.82	228.98
Pincher Creek	884	1100.20	255.40	1100.27	255.68	1100.33	255.92	1100.38	256.14	1100.43	256.36
Pincher Creek	792	1100.09	271.12	1100.15	271.57	1100.21	271.96	1100.26	273.13	1100.31	276.65
Pincher Creek	606	1099.51	334.32	1099.55	337.01	1099.61	337.80	1099.66	338.11	1099.74	338.50
Pincher Creek	486	1099.04	315.95	1099.07	319.79	1099.11	333.37	1099.15	342.68	1099.15	345.47
Pincher Creek	327	1098.21	292.24	1098.29	309.40	1098.37	314.96	1098.44	318.46	1098.49	321.73
Pincher Creek	140	1097.52	229.20	1097.52	229.20	1097.52	229.20	1097.54	232.61	1097.60	253.06
Pincher Creek	0	1096.95	258.82	1097.02	258.82	1097.08	258.82	1097.14	258.82	1097.19	258.82

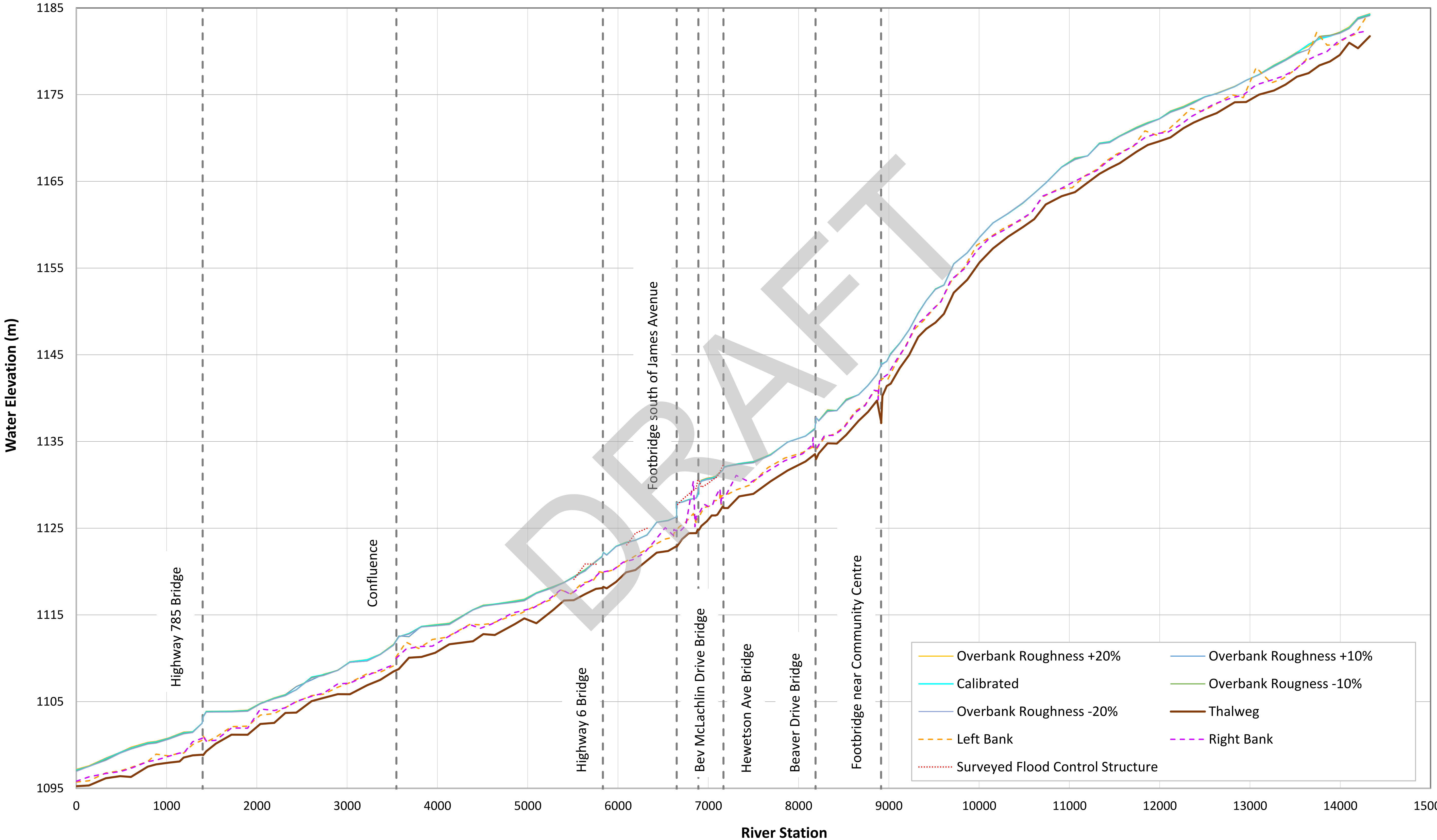
Table VII.7 Sensitivity Analysis Results for Overbank Roughness – Kettles Creek

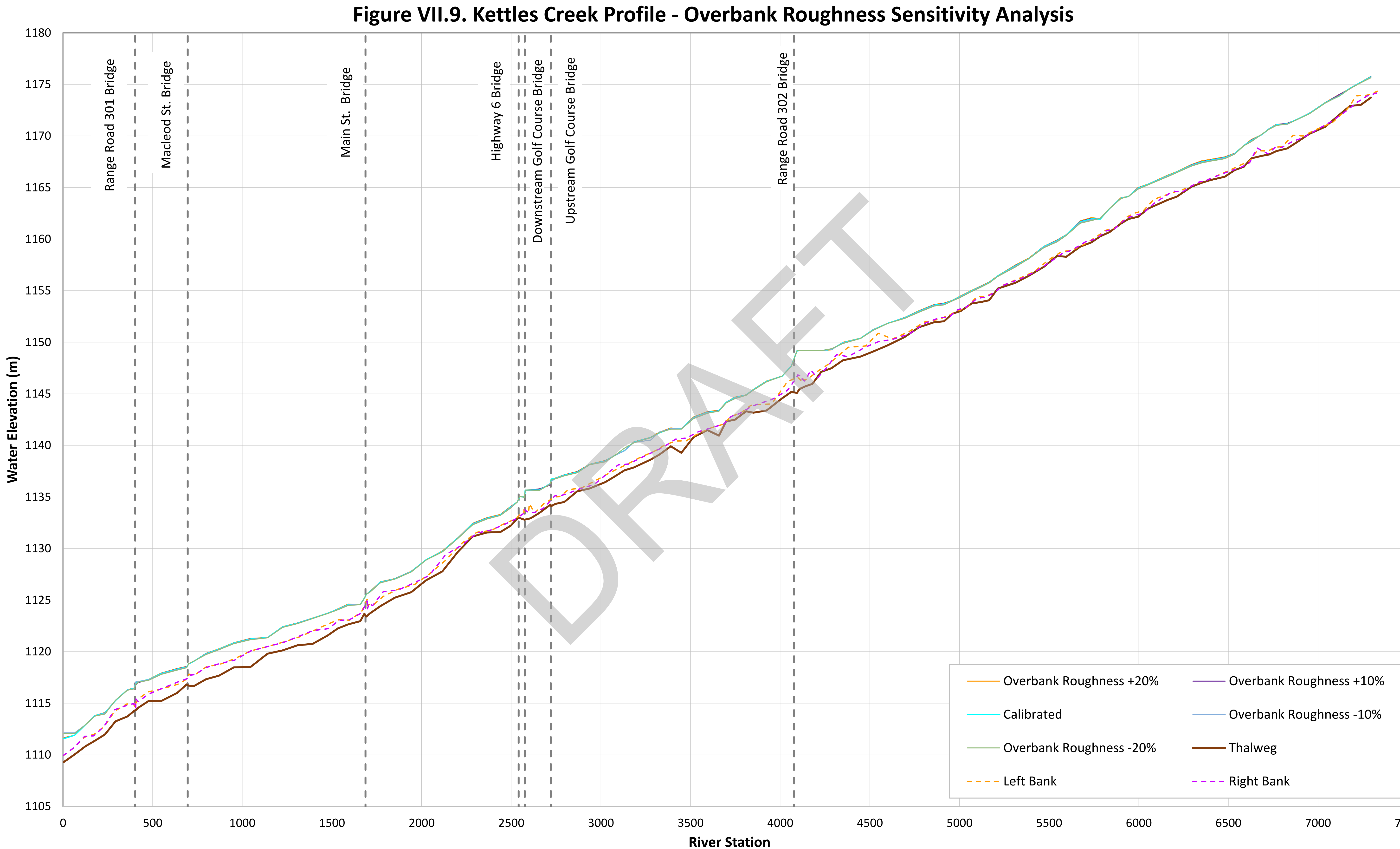
River	Cross Section	100-Year Flood Level (m) and Width (m) for Various Overbank Roughness									
		-20%		-10%		Calibrated		+10%		+20%	
		Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width
Kettles Creek	7295	**1175.68**	**63.41**	**1175.68**	**63.41**	**1175.28**	**64.99**	**1175.75**	**65.29**	**1175.65**	**62.92**
Kettles Creek	7239	1175.19	51.40	1175.19	51.40	1174.51	51.66	1175.21	52.33	1175.16	49.92
Kettles Creek	7178	1174.60	93.10	1174.60	93.10	1174.13	96.88	1174.57	90.96	1174.58	91.61
Kettles Creek	7123	1173.92	34.43	1173.92	34.43	1173.18	34.43	1174.06	46.84	1173.92	34.43
Kettles Creek	7041	1173.21	32.38	1173.21	32.38	1172.43	32.42	1173.23	32.60	1173.19	31.21
Kettles Creek	6951	1172.15	10.88	1172.15	10.88	1171.56	14.32	1172.20	15.26	1172.14	10.84
Kettles Creek	6880	1171.56	61.43	1171.56	61.43	1170.88	61.45	1171.58	61.59	1171.56	61.41
Kettles Creek	6829	1171.13	19.22	1171.13	19.22	1170.41	19.78	1171.23	20.53	1171.16	19.63
Kettles Creek	6768	1171.04	80.71	1171.04	80.71	1170.20	83.64	1171.10	85.82	1171.01	77.52
Kettles Creek	6728	1170.69	46.67	1170.69	46.67	1169.70	47.01	1170.71	47.18	1170.65	41.88
Kettles Creek	6690	1170.19	26.47	1170.19	26.47	1169.50	26.34	1170.16	26.18	1170.21	26.82
Kettles Creek	6628	1169.49	12.49	1169.49	12.49	1169.03	14.43	1169.60	17.19	1169.44	11.04
Kettles Creek	6586	1169.06	16.26	1169.06	16.26	1168.21	16.30	1169.07	16.33	1169.05	16.24
Kettles Creek	6536	1168.26	12.86	1168.26	12.86	1167.85	12.91	1168.30	12.97	1168.24	12.82
Kettles Creek	6480	1167.85	19.54	1167.85	19.54	1167.50	19.68	1167.93	19.84	1167.79	19.36
Kettles Creek	6402	1167.60	80.35	1167.60	80.35	1167.15	85.99	1167.68	92.63	1167.56	73.08
Kettles Creek	6352	1167.44	89.19	1167.44	89.19	1166.93	90.70	1167.52	92.62	1167.39	85.92
Kettles Creek	6295	1167.13	59.99	1167.13	59.99	1166.73	65.70	1167.20	72.30	1167.08	55.70
Kettles Creek	6212	1166.46	68.18	1166.46	68.18	1165.75	68.87	1166.50	69.48	1166.44	67.74
Kettles Creek	6162	1166.11	55.40	1166.11	55.40	1165.62	55.46	1166.16	55.51	1166.06	54.98
Kettles Creek	6053	1165.28	45.02	1165.28	45.02	1164.35	45.11	1165.32	45.14	1165.27	44.97
Kettles Creek	5996	1164.88	44.91	1164.88	44.91	1164.01	45.10	1164.96	45.25	1164.83	44.72
Kettles Creek	5943	1164.13	27.23	1164.13	27.23	1163.32	27.42	1164.14	28.03	1164.13	26.69
Kettles Creek	5901	1163.95	39.35	1163.95	39.35	1163.00	41.34	1163.99	43.15	1163.93	37.05
Kettles Creek	5837	1162.94	9.21	1162.94	9.21	1162.09	9.23	1162.95	9.24	1162.94	9.18
Kettles Creek	5785	1162.01	18.68	1162.01	18.68	1161.45	18.13	1161.93	18.13	1162.01	18.66
Kettles Creek	5736	1161.87	16.21	1161.87	16.21	1161.06	16.30	1162.02	16.38	1161.79	16.09
Kettles Creek	5674	1161.61	16.56	1161.61	16.56	1160.72	17.43	1161.72	19.05	1161.54	15.21
Kettles Creek	5596	1160.37	8.11	1160.37	8.11	1159.88	8.14	1160.41	8.17	1160.35	8.08
Kettles Creek	5544	1159.78	14.64	1159.78	14.64	1159.22	14.71	1159.87	14.75	1159.72	14.55
Kettles Creek	5471	1159.22	10.29	1159.22	10.29	1158.63	10.33	1159.29	10.35	1159.16	10.23
Kettles Creek	5388	1158.11	11.52	1158.11	11.52	1157.59	11.53	1158.13	11.59	1158.12	11.55
Kettles Creek	5312	1157.35	11.91	1157.35	11.91	1156.98	12.00	1157.44	12.08	1157.29	11.72
Kettles Creek	5214	1156.40	25.21	1156.40	25.21	1156.05	25.28	1156.43	25.35	1156.38	25.13
Kettles Creek	5166	1155.76	55.74	1155.76	55.74	1155.50	55.81	1155.81	55.89	1155.74	55.66
Kettles Creek	5120	1155.38	53.01	1155.38	53.01	1155.17	53.11	1155.42	53.21	1155.34	52.85
Kettles Creek	5069	1154.96	54.12	1154.96	54.12	1154.68	54.20	1155.01	54.30	1154.93	54.02
Kettles Creek	5008	1154.41	38.46	1154.41	38.46	1154.16	38.63	1154.47	38.76	1154.37	38.24
Kettles Creek	4960	1154.01	36.97	1154.01	36.97	1153.58	37.00	1154.04	37.05	1154.00	36.95
Kettles Creek	4914	1153.67	21.13	1153.67	21.13	1153.31	21.73	1153.76	22.34	1153.62	20.74
Kettles Creek	4859	1153.55	31.24	1153.55	31.24	1153.10	31.30	1153.63	31.36	1153.51	31.18
Kettles Creek	4776	1152.97	14.34	1152.97	14.34	1152.44	14.38	1153.04	14.42	1152.92	14.29
Kettles Creek	4693	1152.33	13.30	1152.33	13.30	1151.74	13.43	1152.38	13.54	1152.30	13.14

River	Cross Section	100-Year Flood Level (m) and Width (m) for Various Overbank Roughness									
		-20%		-10%		Calibrated		+10%		+20%	
		Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width
Kettles Creek	4599	1151.82	46.06	1151.82	46.06	1151.12	46.22	1151.83	46.46	1151.82	45.92
Kettles Creek	4518	1151.17	20.82	1151.17	20.82	1150.69	25.89	1151.21	29.38	1151.14	15.72
Kettles Creek	4448	1150.36	25.51	1150.36	25.51	1149.95	26.04	1150.38	26.26	1150.36	25.59
Kettles Creek	4350	1149.92	47.70	1149.92	47.70	1149.34	48.04	1149.97	48.39	1149.88	47.24
Kettles Creek	4286	1149.30	27.42	1149.30	27.42	1148.82	27.70	1149.29	26.37	1149.37	36.63
Kettles Creek	4229	1149.19	111.08	1149.19	111.08	1148.30	111.57	1149.19	111.95	1149.18	110.14
Kettles Creek	4180	1149.20	121.89	1149.20	121.89	1147.69	121.98	1149.20	122.09	1149.19	121.79
Kettles Creek	4142	1149.19	127.58	1149.19	127.58	1147.67	127.87	1149.19	128.14	1149.19	127.37
Kettles Creek	4108	1149.18	192.22	1149.18	192.22	1147.56	192.20	1149.18	192.19	1149.18	192.23
Kettles Creek	4094	1149.17	165.43	1149.17	165.43	1147.52	165.40	1149.17	165.36	1149.17	165.46
Kettles Creek	4062	1147.64	49.68	1147.64	49.68	1146.85	50.40	1147.68	50.69	1147.62	49.34
Kettles Creek	4011	1146.72	12.49	1146.72	12.49	1145.86	12.45	1146.71	12.40	1146.72	12.55
Kettles Creek	3924	1146.18	109.98	1146.18	109.98	1145.38	110.53	1146.22	110.90	1146.16	108.41
Kettles Creek	3851	1145.38	9.74	1145.38	9.74	1144.89	10.41	1145.41	10.98	1145.36	9.55
Kettles Creek	3810	1144.87	13.43	1144.87	13.43	1144.35	13.48	1144.89	13.53	1144.86	13.40
Kettles Creek	3746	1144.56	22.56	1144.56	22.56	1143.95	25.73	1144.64	27.16	1144.51	20.59
Kettles Creek	3699	1144.14	61.58	1144.14	61.58	1143.34	63.59	1144.17	64.97	1144.11	56.48
Kettles Creek	3659	1143.33	32.01	1143.33	32.01	1142.93	32.10	1143.37	32.30	1143.32	31.96
Kettles Creek	3594	1143.15	47.38	1143.15	47.38	1142.67	55.84	1143.23	60.69	1143.11	39.43
Kettles Creek	3517	1142.65	18.60	1142.65	18.60	1142.03	29.74	1142.72	35.17	1142.59	17.62
Kettles Creek	3449	1141.59	12.90	1141.59	12.90	1141.07	12.90	1141.60	12.98	1141.58	12.85
Kettles Creek	3390	1141.61	95.88	1141.61	95.88	1141.06	96.08	1141.66	97.04	1141.57	90.49
Kettles Creek	3328	1141.31	72.83	1141.31	72.83	1140.76	67.99	1141.26	70.42	1141.25	70.09
Kettles Creek	3277	1140.51	30.45	1140.51	30.45	1140.23	76.48	1140.77	88.70	1140.74	73.55
Kettles Creek	3184	1140.28	77.84	1140.28	77.84	1139.53	78.09	1140.32	78.30	1140.24	77.28
Kettles Creek	3132	1139.48	13.15	1139.48	13.15	1139.22	13.28	1139.49	13.33	1139.73	52.84
Kettles Creek	3073	1138.98	64.16	1138.98	64.16	1138.43	64.16	1138.98	64.16	1138.96	61.43
Kettles Creek	3025	1138.44	40.85	1138.44	40.85	1138.00	40.97	1138.51	41.09	1138.40	40.73
Kettles Creek	2937	1138.14	36.25	1138.14	36.25	1137.46	36.33	1138.15	36.43	1138.12	35.81
Kettles Creek	2868	1137.34	12.49	1137.34	12.49	1136.76	12.74	1137.44	12.89	1137.34	12.49
Kettles Creek	2796	1137.07	18.82	1137.07	18.82	1136.38	18.96	1137.13	19.06	1137.04	18.67
Kettles Creek	2746	1136.78	59.67	1136.78	59.67	1135.98	61.88	1136.81	62.54	1136.75	57.29
Kettles Creek	2723	1136.50	56.42	1136.50	56.42	1135.72	77.81	1136.73	77.79	1136.69	75.86
Kettles Creek	2719	1136.30	11.29	1136.30	11.29	1135.68	11.29	1136.16	10.45	1136.26	11.04
Kettles Creek	2657	1135.63	63.30	1135.63	63.30	1135.10	66.95	1135.78	95.17	1135.63	64.98
Kettles Creek	2608	1135.66	141.43	1135.66	141.43	1134.81	141.59	1135.68	142.04	1135.67	141.87
Kettles Creek	2578	1135.65	161.09	1135.65	161.09	1134.55	161.14	1135.66	161.30	1135.66	161.36
Kettles Creek	2574	1134.97	55.19	1134.97	55.19	1134.42	55.55	1134.98	57.49	1134.96	55.10
Kettles Creek	2548	1135.05	15.14	1135.05	15.14	1134.34	15.14	1135.04	15.13	1135.05	15.14
Kettles Creek	2534	1134.50	10.62	1134.50	10.62	1133.92	10.64	1134.51	10.66	1134.50	10.63
Kettles Creek	2499	1134.01	23.23	1134.01	23.23	1133.63	23.51	1134.08	23.74	1133.95	22.83
Kettles Creek	2439	1133.21	30.29	1133.21	30.29	1132.94	31.39	1133.26	32.86	1133.20	30.11
Kettles Creek	2364	1132.88	50.91	1132.88	50.91	1132.58	51.42	1132.95	51.98	1132.85	50.02
Kettles Creek	2285	1132.35	35.80	1132.35	35.80	1132.08	36.22	1132.42	36.61	1132.30	35.21
Kettles Creek	2202	1130.98	25.90	1130.98	25.90	1130.69	25.99	1131.02	26.08	1130.97	25.82

River	Cross Section	100-Year Flood Level (m) and Width (m) for Various Overbank Roughness									
		-20%		-10%		Calibrated		+10%		+20%	
		Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width	Elevation	Width
Kettles Creek	2116	1129.69	25.39	1129.69	25.39	1129.09	27.59	1129.73	27.87	1129.67	23.34
Kettles Creek	2025	1128.88	45.75	1128.88	45.75	1128.11	45.86	1128.90	45.90	1128.88	45.71
Kettles Creek	1942	1127.74	10.54	1127.74	10.54	1127.24	10.76	1127.78	11.28	1127.72	10.31
Kettles Creek	1851	1127.04	16.77	1127.04	16.77	1126.39	16.98	1127.07	17.13	1127.03	16.44
Kettles Creek	1770	1126.70	14.89	1126.70	14.89	1125.92	15.17	1126.75	15.52	1126.67	14.50
Kettles Creek	1711	1125.76	8.68	1125.76	8.68	1125.15	8.73	1125.80	8.83	1125.75	8.65
Kettles Creek	1692	1125.58	10.85	1125.58	10.85	1124.85	10.84	1125.57	10.84	1125.58	10.86
Kettles Creek	1681	1125.16	11.26	1125.16	11.26	1124.77	11.30	1125.19	11.47	1125.16	11.24
Kettles Creek	1658	1124.56	13.64	1124.56	13.64	1124.14	13.66	1124.59	13.69	1124.55	13.62
Kettles Creek	1591	1124.52	27.28	1124.52	27.28	1123.84	27.33	1124.58	27.38	1124.48	27.22
Kettles Creek	1533	1124.09	12.78	1124.09	12.78	1123.49	12.83	1124.13	12.88	1124.06	12.73
Kettles Creek	1477	1123.71	14.39	1123.71	14.39	1123.04	14.41	1123.72	14.43	1123.70	14.37
Kettles Creek	1392	1123.22	87.91	1123.22	87.91	1122.53	88.02	1123.25	88.09	1123.21	87.84
Kettles Creek	1309	1122.74	123.24	1122.74	123.24	1122.03	123.38	1122.78	123.53	1122.72	123.03
Kettles Creek	1225	1122.37	154.87	1122.37	154.87	1121.66	157.90	1122.41	168.49	1122.35	152.74
Kettles Creek	1141	1121.35	222.28	1121.35	222.28	1120.99	222.76	1121.36	222.83	1121.34	221.80
Kettles Creek	1045	1121.19	347.80	1121.19	347.80	1120.57	353.71	1121.26	356.92	1121.15	344.79
Kettles Creek	953	1120.80	318.94	1120.80	318.94	1120.07	320.50	1120.85	321.76	1120.77	318.01
Kettles Creek	870	1120.22	292.04	1120.22	292.04	1119.58	295.84	1120.26	297.29	1120.19	288.48
Kettles Creek	798	1119.76	267.13	1119.76	267.13	1119.12	274.58	1119.82	278.12	1119.72	259.89
Kettles Creek	732	1119.10	95.99	1119.10	95.99	1118.35	92.54	1119.09	91.52	1119.10	102.97
Kettles Creek	701	1118.82	10.19	1118.82	10.19	1118.01	10.16	1118.80	10.14	1118.83	10.22
Kettles Creek	690	1118.48	10.02	1118.48	10.02	1117.92	10.09	1118.55	10.15	1118.44	9.93
Kettles Creek	637	1118.26	13.59	1118.26	13.59	1117.66	13.80	1118.34	13.97	1118.21	13.37
Kettles Creek	547	1117.83	16.83	1117.83	16.83	1117.19	16.93	1117.90	17.04	1117.79	16.72
Kettles Creek	478	1117.28	14.14	1117.28	14.14	1116.52	14.15	1117.25	14.02	1117.22	13.89
Kettles Creek	421	1117.10	27.26	1117.10	27.26	1116.09	26.11	1117.01	21.44	1117.05	23.39
Kettles Creek	407	1117.08	63.57	1117.08	63.57	1115.88	63.35	1116.78	59.01	1116.83	60.57
Kettles Creek	397	1116.41	23.99	1116.41	23.99	1115.77	26.03	1116.45	28.11	1116.39	22.40
Kettles Creek	360	1116.28	60.22	1116.28	60.22	1115.53	66.64	1116.31	71.99	1116.26	56.44
Kettles Creek	293	1115.28	12.96	1115.28	12.96	1114.47	12.82	1115.26	12.72	1115.29	13.07
Kettles Creek	234	1114.01	10.35	1114.01	10.35	1113.34	10.74	1114.08	11.03	1113.95	9.88
Kettles Creek	177	1113.76	64.23	1113.76	64.23	1112.95	64.32	1113.79	64.38	1113.74	64.11
Kettles Creek	126	1112.92	73.55	1112.92	73.55	1112.30	73.64	1112.93	73.71	1112.92	73.47
Kettles Creek	65	1112.08	61.16	1112.13	63.35	1111.27	56.62	1111.90	56.62	1112.05	60.16
Kettles Creek	5	1112.08	42.37	1112.13	42.47	1110.80	17.01	1111.61	19.26	1112.07	42.37

Figure VII.8. Pincher Creek Profile - Overbank Roughness Sensitivity Analysis





A03285C13.
Pincher Creek Flood Hazard Study

Klohn Crippen Berger

2023-02-05
20200403 Longitudinal Profile.xlsx

Figure VII.10. Pincher Creek Profile - Overbank Roughness Sensitivity Analysis Comparison

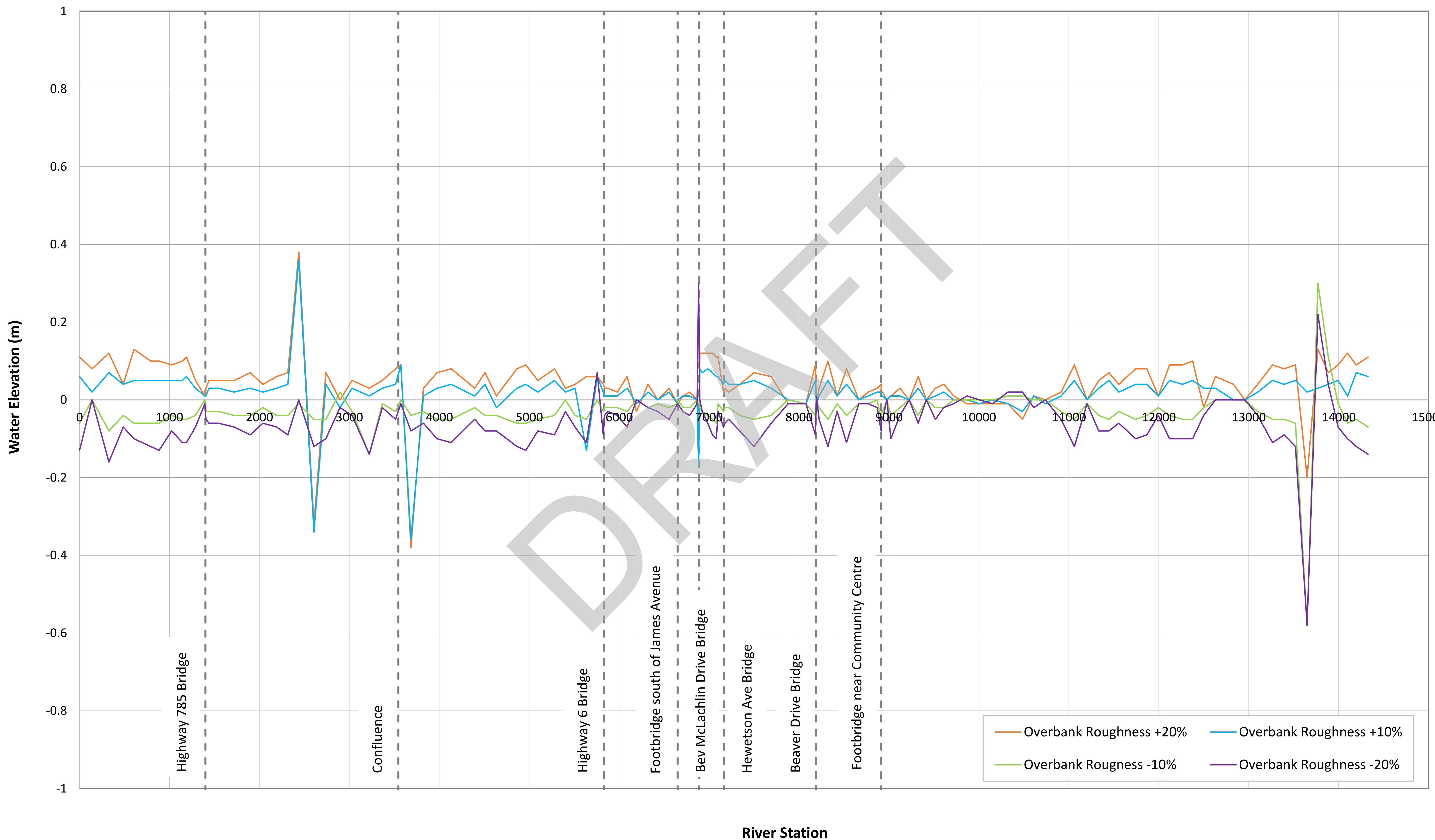
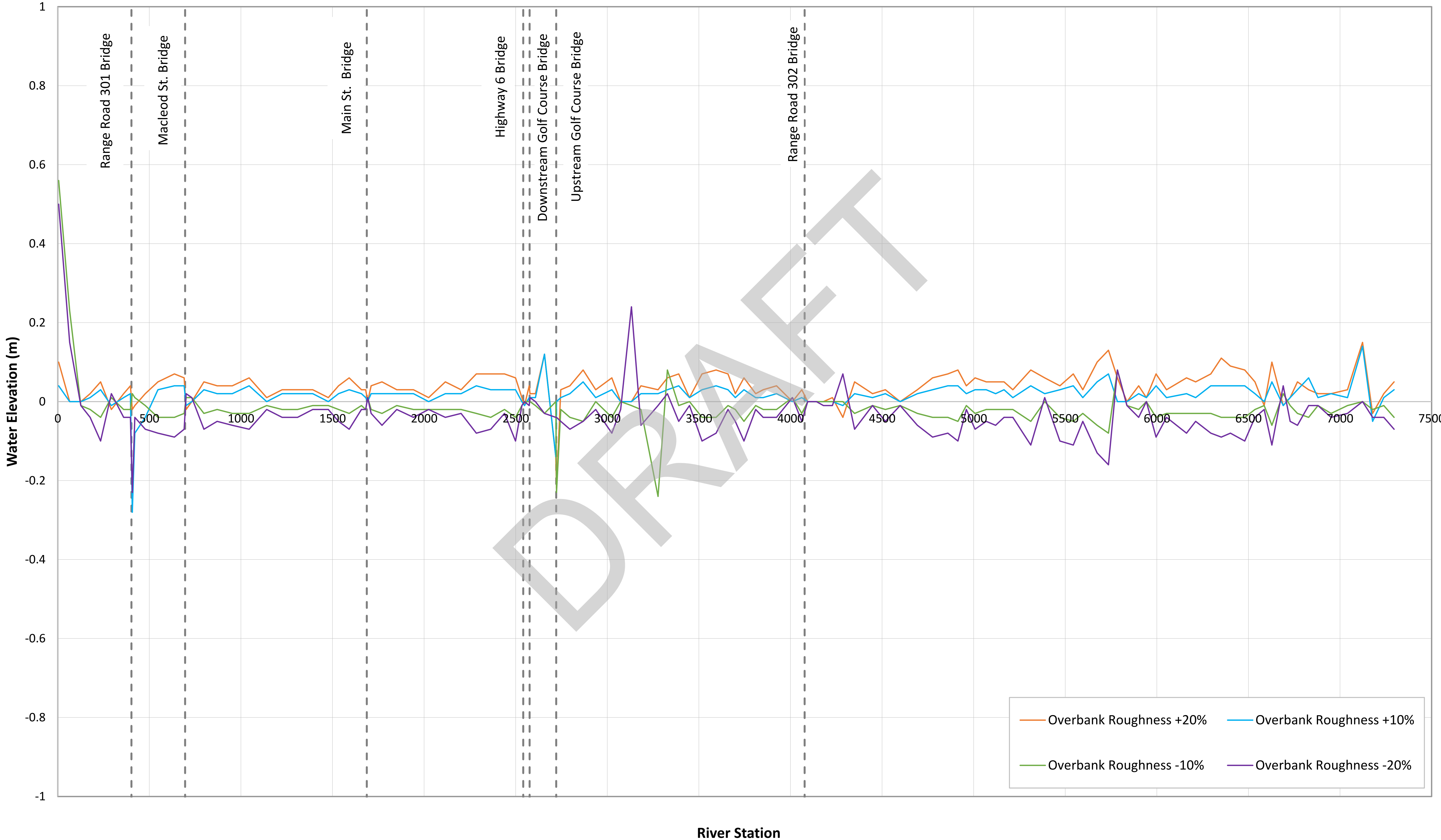


Figure VII.11. Kettles Creek Profile - Overbank Roughness Sensitivity Analysis Comparison



APPENDIX VIII

Flood Inundation Map Library

(Provided under separate cover)

APPENDIX IX

Design Flood Levels

Appendix IX
Design Flood Levels

Table IX.1 Design Flood Levels – Pincher Creek

River	River Station	Design Flood Level (m)
Pincher Creek	14327	1184.24
	14196	1183.8
	14099	1182.7
	13994	1182.13
	13885	1181.74
	13770	1181.43
	13649	1180.79
	13520	1179.82
	13394	1179.02
	13265	1178.33
	13100	1177.31
	12957	1176.65
	12831	1175.93
	12630	1175.11
	12499	1174.74
	12377	1174.12
	12263	1173.57
	12119	1173.04
	11995	1172.21
	11868	1171.73
	11743	1171.18
	11556	1170.22
	11446	1169.53
	11332	1169.38
	11202	1167.94
	11062	1167.61
	10914	1166.65
	10738	1164.82
	10610	1163.63
	10484	1162.51
	10322	1161.31
	10153	1160.2
	10006	1158.56
	9868	1156.77
	9719	1155.48
	9610	1153.03
	9517	1152.58
	9415	1151.25
	9325	1149.81
	9225	1147.89

River	River Station	Design Flood Level (m)
Pincher Creek	9122	1146.35
	9021	1145.14
	8977	1144.25
	8928	1143.94
	8915	1144.06
	8913	1143.74
	8869	1142.75
	8769	1141.47
	8665	1140.4
	8528	1139.81
	8424	1138.57
	8321	1138.56
	8223	1137.39
	8194	1137.76
	8182	1136.47
	8077	1135.62
	7879	1134.93
	7691	1133.47
	7499	1132.64
	7342	1132.43
	7217	1132.17
	7176	1132.05
	7160	1131.71
	7101	1131.11
	7081	1130.9
	7038	1130.75
	6985	1130.65
	6924	1130.43
	6897	1130
	6883	1128.89
	6867	1128.48
	6783	1128.29
	6710	1128.01
	6651	1127.91
	6649	1126.31
	6555	1125.89
	6429	1125.68
	6321	1124.21
	6193	1123.61
	6089	1123.34
	5979	1122.91
	5875	1121.91
	5838	1122.19
	5824	1121.73
	5756	1121.17
	5636	1120.18

River	River Station	Design Flood Level (m)
Pincher Creek	5510	1119.38
	5402	1118.73
	5281	1118.21
	5096	1117.53
	4962	1116.74
	4863	1116.57
	4636	1116.25
	4508	1116.07
	4394	1115.59
	4132	1113.98
	3976	1113.82
	3824	1113.66
	3685	1112.85
	3573	1112.48
	3514	1111.54
	3367	1110.43
	3222	1109.82
	3030	1109.56
	2896	1108.61
	2739	1108.1
	2607	1107.83
	2438	1106.37
	2316	1105.76
	2192	1105.38
	2039	1104.78
	1898	1103.96
	1720	1103.87
	1545	1103.85
	1439	1103.84
	1405	1103.25
	1393	1102.5
	1289	1101.49
	1189	1101.38
	1144	1101.22
	1024	1100.73
	884	1100.33
	792	1100.21
	606	1099.61
	486	1099.11
	327	1098.37
	140	1097.52
	0	1097.08
Kettles Creek	7295	1175.72
	7239	1175.2
	7178	1174.62
	7123	1173.92

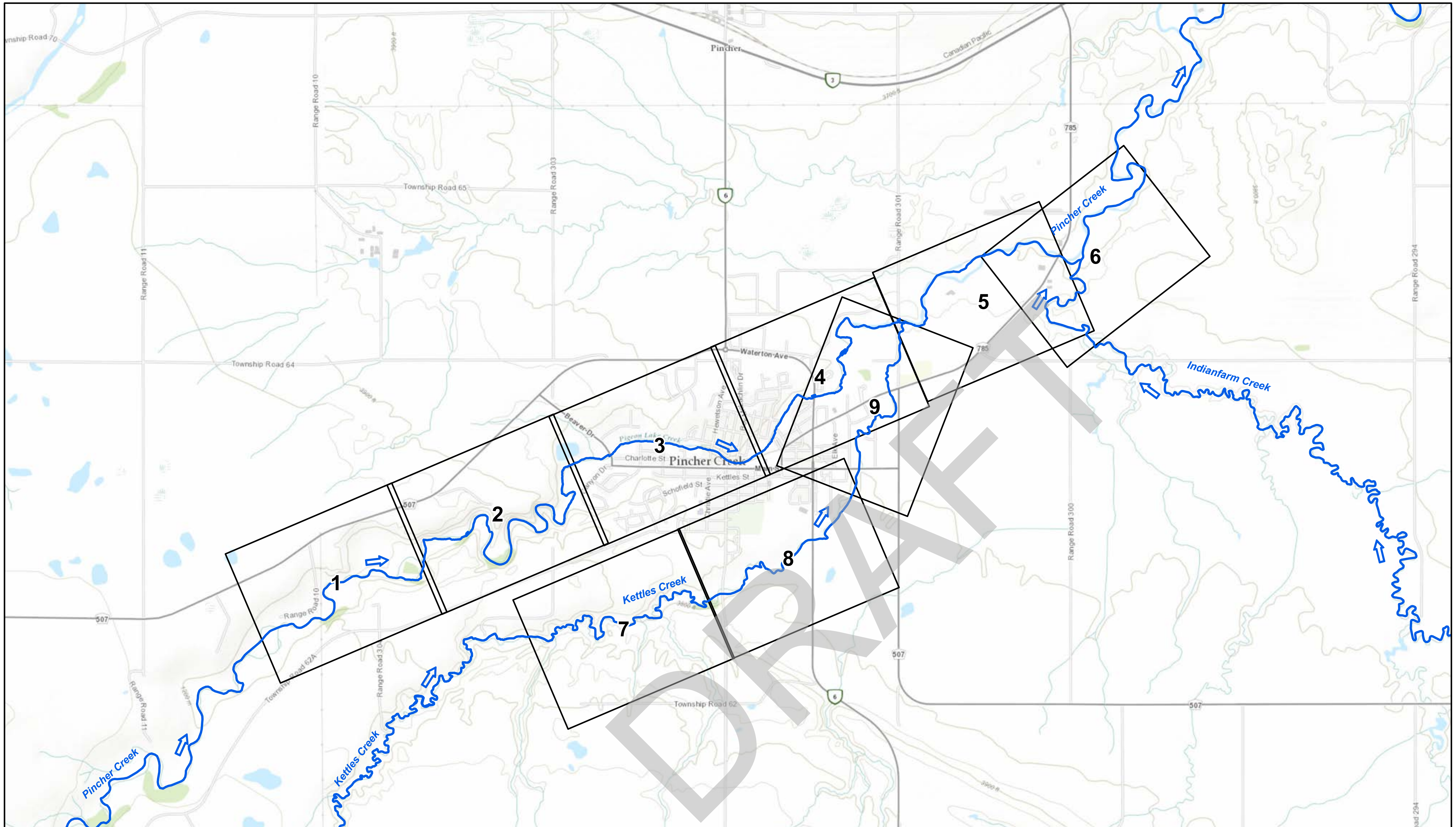
River	River Station	Design Flood Level (m)
Kettles Creek	7041	1173.22
	6951	1172.18
	6880	1171.57
	6829	1171.17
	6768	1171.07
	6728	1170.7
	6690	1170.17
	6628	1169.55
	6586	1169.07
	6536	1168.28
	6480	1167.89
	6402	1167.64
	6352	1167.48
	6295	1167.16
	6212	1166.49
	6162	1166.14
	6053	1165.31
	5996	1164.92
	5943	1164.13
	5901	1163.97
	5837	1162.95
	5785	1161.93
	5736	1161.95
	5674	1161.67
	5596	1160.4
	5544	1159.83
	5471	1159.26
	5388	1158.11
	5312	1157.4
	5214	1156.42
	5166	1155.78
	5120	1155.4
	5069	1154.98
	5008	1154.44
	4960	1154.02
	4914	1153.72
	4859	1153.59
	4776	1153.01
	4693	1152.36
	4599	1151.83
	4518	1151.19
	4448	1150.37
	4350	1149.95
	4286	1149.3
	4229	1149.19
	4180	1149.2

River	River Station	Design Flood Level (m)
Kettles Creek	4142	1149.19
	4108	1149.18
	4094	1149.17
	4062	1147.67
	4011	1146.71
	3924	1146.2
	3851	1145.4
	3810	1144.88
	3746	1144.61
	3699	1144.16
	3659	1143.34
	3594	1143.19
	3517	1142.69
	3449	1141.59
	3390	1141.62
	3328	1141.23
	3277	1140.75
	3184	1140.3
	3132	1139.49
	3073	1138.98
	3025	1138.48
	2937	1138.14
	2868	1137.4
	2796	1137.14
	2746	1136.88
	2723	1136.86
	2719	1136.3
	2657	1135.66
	2608	1135.77
	2578	1135.76
	2574	1135.04
	2548	1135.05
	2534	1134.51
	2499	1134.05
	2439	1133.23
	2364	1132.92
	2285	1132.38
	2202	1131
	2116	1129.71
	2025	1128.9
	1942	1127.76
	1851	1127.05
	1770	1126.73
	1711	1125.78
	1692	1125.57
	1681	1125.18

River	River Station	Design Flood Level (m)
Kettles Creek	1658	1124.57
	1591	1124.55
	1533	1124.11
	1477	1123.72
	1392	1123.23
	1309	1122.76
	1225	1122.39
	1141	1121.36
	1045	1121.22
	953	1120.83
	870	1120.24
	798	1119.79
	732	1119.09
	701	1118.81
	690	1118.51
	637	1118.30
	547	1117.87
	478	1117.29
	421	1117.09
	407	1117.06
	397	1116.43
	360	1116.30
	293	1115.27
	234	1114.05
	177	1113.78
	126	1112.93
	65	1111.90
	5	1111.57

APPENDIX X

Floodway Criteria Maps



Alberta Government

Klohn Crippen Berger

MUNICIPAL DISTRICT BOUNDARY

Notes to Users:

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

Definitions:

1. **Flood Hazard Mapping** - Identifies the areas flooded for the design flood, and is divided into floodway and flood fringe zones. Flood hazard mapping is typically used for long-term flood hazard area management and land-use planning.
2. **Floodway** - The portion of flood hazard area where flows are generally deepest, fastest, and most destructive during a design flood. The floodway typically includes the main channel of a stream and a portion of the adjacent overbank area.
3. **Flood Fringe** - The portion of flood hazard area outside the floodway. Water in the flood fringe is generally shallower and flows more slowly than in the floodway.
4. **Design Flood** - The design standard for flood hazard mapping in Alberta is the 100-year flood, which has a one percent chance of being equaled or exceeded in any given year.

Data Sources and References:

1. Aerial imagery was collected in July 2019 and was provided by Alberta Environment and Parks.
2. Additional base mapping from ESRI.

SCALE - 1:40,000

0 0.5 1 1.5 KM

N

Coordinate System: NAD 1983 3TM 114
Units: METRES

Engineer KC/AS	GIS VC/TS	Reviewer RJC

Job Number A03285D13	Date 13-FEB-2023

PINCHER CREEK FLOOD HAZARD STUDY

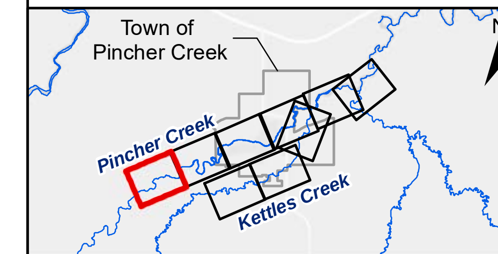
FLOODWAY CRITERIA MAP

INDEX MAP

MSN_Z:\ACGY\Alberta\A03285D13 AEP Pincher Creek Modifications\400 Drawings\2022 Pincher Creek_Edits\2022 Pincher Creek Edits\2022 Pincher Creek Edits.aprx

Alberta Government

Klohn Crippen Berger



- CROSS SECTION
- RS 1325 RIVER STATION (M)
- STUDY LIMIT
- FLOW DIRECTION
- MAJOR ROAD
- LOCAL ROAD
- MUNICIPAL DISTRICT BOUNDARY
- FLOOD CONTROL STRUCTURE
- CULVERT
- BRIDGE
- PROPOSED FLOODWAY BOUNDARY
- PROPOSED FLOODWAY STATION
- BANK STATION
- 100-YEAR DESIGN FLOOD EXTENT
- DEPTH ≥ 1 m
- VELOCITY ≥ 1 m/s
- PREVIOUS FLOODWAY

DISCHARGE
PINCHER CREEK ABOVE KETTLES CREEK = 214 m³/s

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

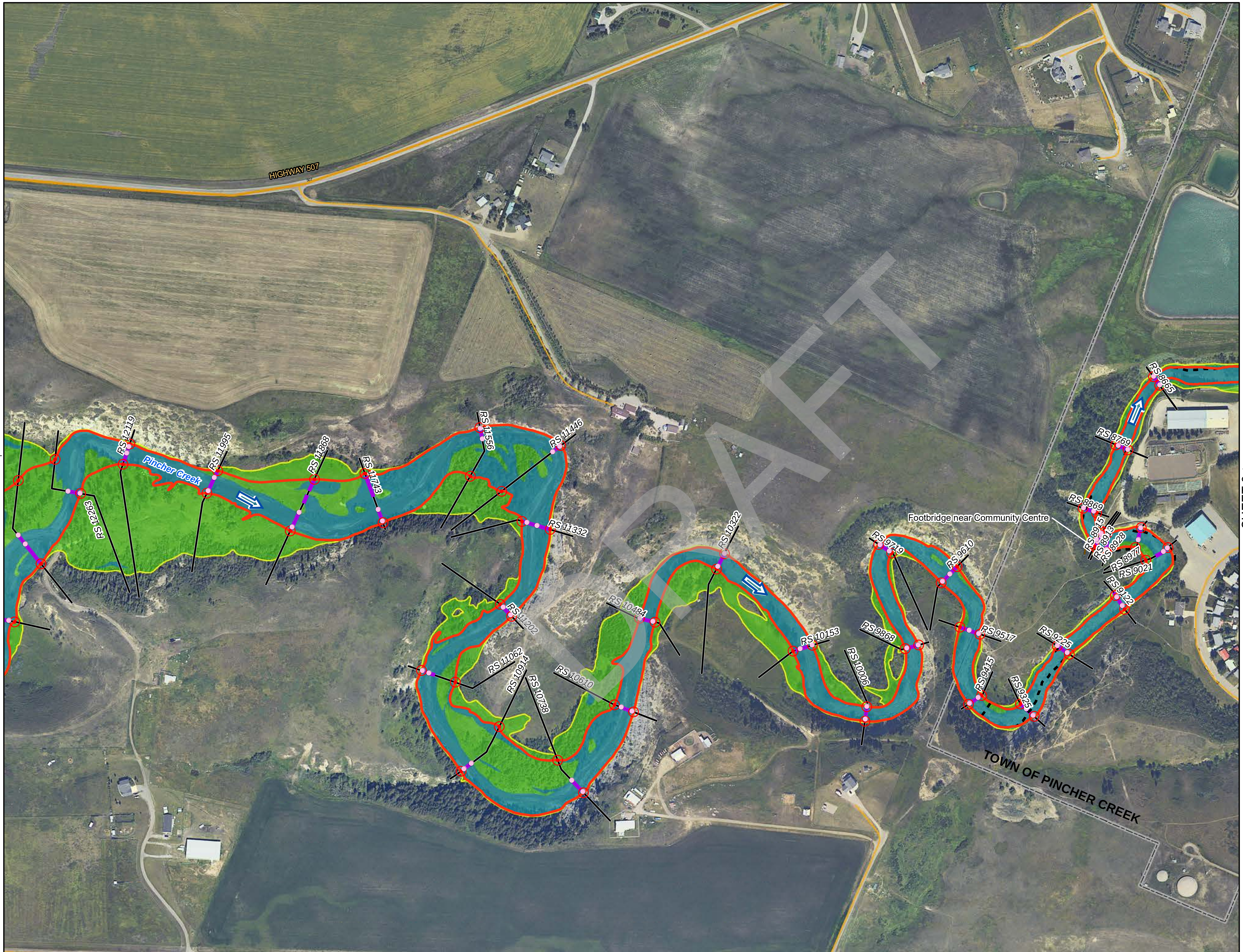
Coordinate System: NAD 1983 CSRS 3TM 114
Units: METRES

Engineer	GIS	Reviewer
KC / AS	VC / TS	RJC

Job Number	Date
A03285D13	13-FEB-2023

PINCHER CREEK FLOOD HAZARD STUDY

FLOODWAY CRITERIA MAP



Alberta Government

Klohn Crippen Berger

Town of Pincher Creek
Pincher Creek
Kettles Creek
N

CROSS SECTION
RS 1325 RIVER STATION (M)
STUDY LIMIT
FLOW DIRECTION
MAJOR ROAD
LOCAL ROAD
MUNICIPAL DISTRICT BOUNDARY
FLOOD CONTROL STRUCTURE
CULVERT
BRIDGE
PROPOSED FLOODWAY BOUNDARY
PROPOSED FLOODWAY STATION
BANK STATION
100-YEAR DESIGN FLOOD EXTENT
DEPTH ≥ 1 m
VELOCITY ≥ 1 m/s
PREVIOUS FLOODWAY

DISCHARGE
PINCHER CREEK ABOVE KETTLES CREEK = 214 m³/s

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

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

Engineer	GIS	Reviewer
KC / AS	VC / TS	RJC

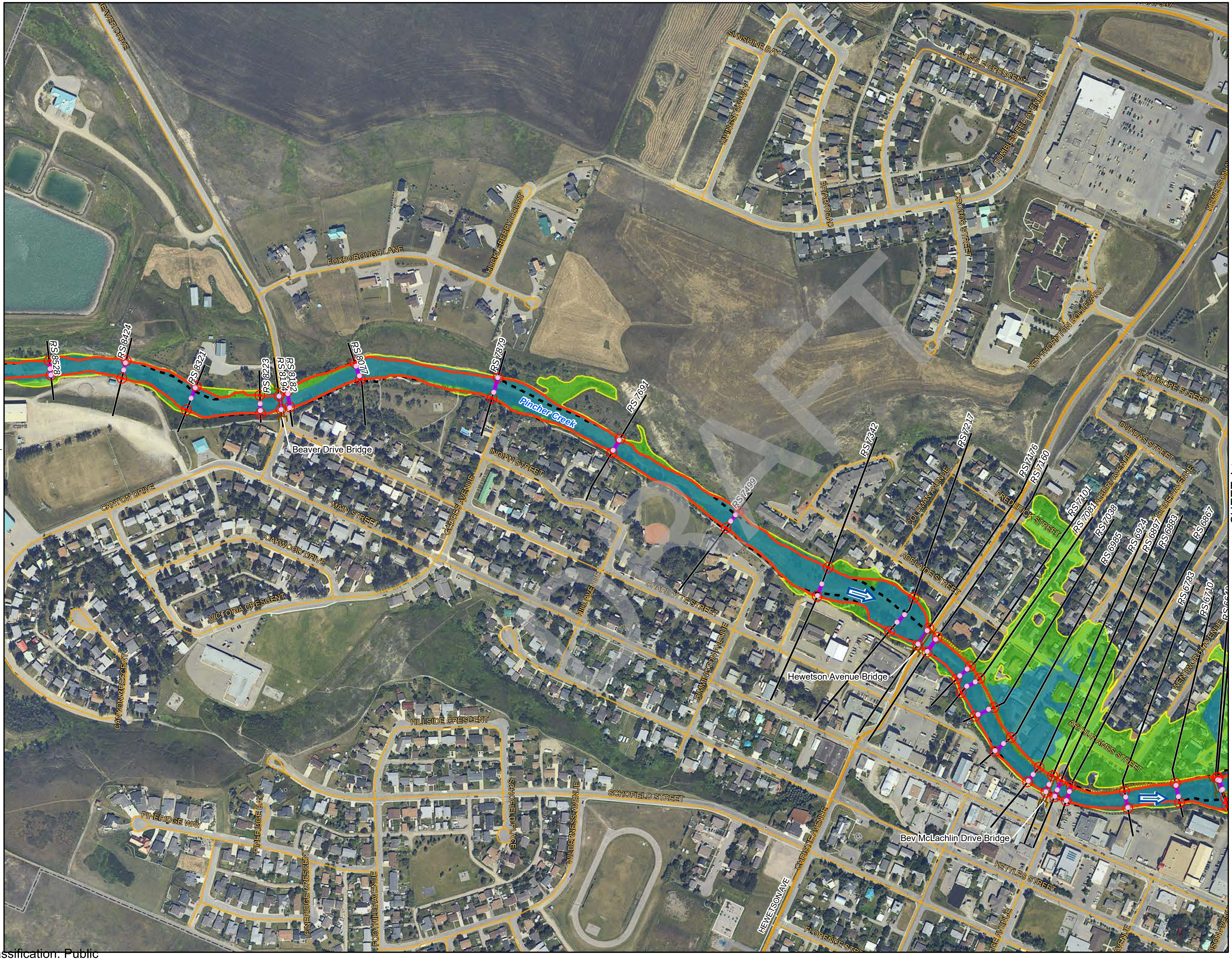
Job Number	Date
A03285D13	13-FEB-2023

PINCHER CREEK FLOOD HAZARD STUDY

FLOODWAY CRITERIA MAP

SHEET 2 OF 9

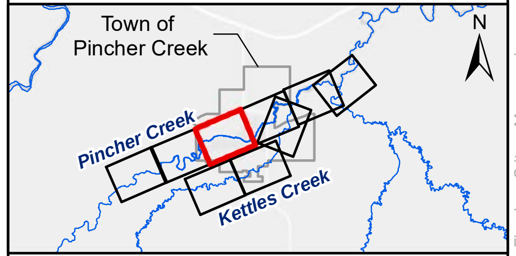
Classification: Public



SHEET 3 OF 9

Alberta Government

Klohn Crippen Berger



- CROSS SECTION
- RS 1325 RIVER STATION (M)
- STUDY LIMIT
- FLOW DIRECTION
- MAJOR ROAD
- LOCAL ROAD
- MUNICIPAL DISTRICT BOUNDARY
- FLOOD CONTROL STRUCTURE
- CULVERT
- BRIDGE
- PROPOSED FLOODWAY BOUNDARY
- PROPOSED FLOODWAY STATION
- BANK STATION
- 100-YEAR DESIGN FLOOD EXTENT
- DEPTH ≥ 1 m
- VELOCITY ≥ 1 m/s
- PREVIOUS FLOODWAY

DISCHARGE
PINCHER CREEK ABOVE KETTLES CREEK = 214 m³/s

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

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

Engineer	GIS	Reviewer
KC / AS	VC / TS	RJC

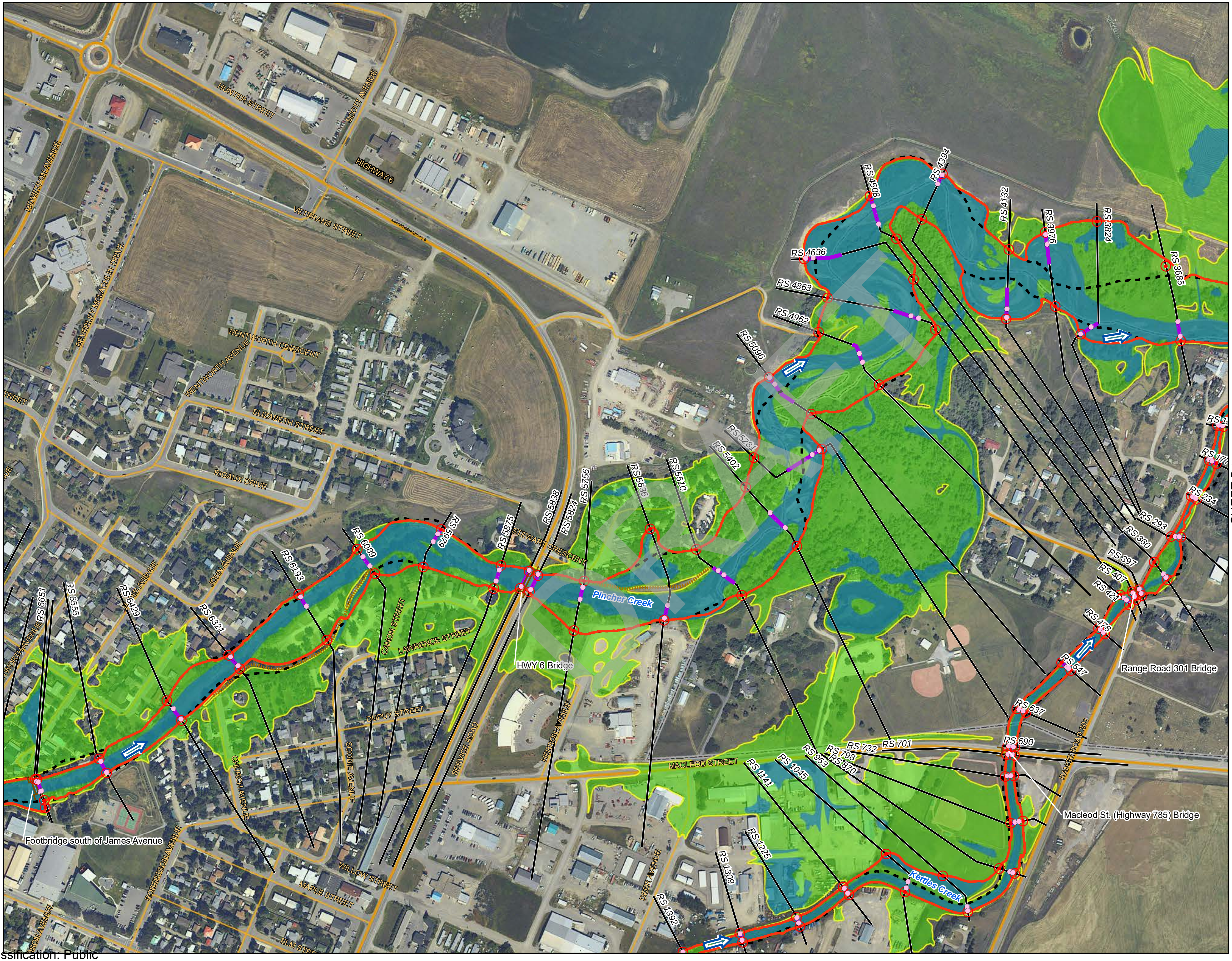
Job Number	Date
A03285D13	13-FEB-2023

PINCHER CREEK FLOOD HAZARD STUDY

FLOODWAY CRITERIA MAP

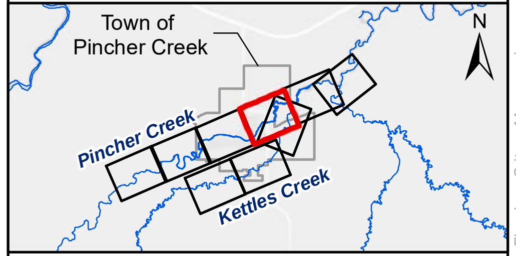
SHEET 3 OF 9

MSN_Z:\ACGY\Alberta\A03285D13 AEP Pincher Creek Modifications\700 Deliverables\741 2022 Digital Study Files\05_Design-Flood-Hazard\GIS\2023-01-31_PincherCreek_FINAL2_2023_Pincher Creek_FloodwayCriteria Maps.mxd



Alberta Government

Klohn Crippen Berger



- CROSS SECTION
- RS 1325 RIVER STATION (M)
- STUDY LIMIT
- FLOW DIRECTION
- MAJOR ROAD
- LOCAL ROAD
- MUNICIPAL DISTRICT BOUNDARY
- FLOOD CONTROL STRUCTURE
- CULVERT
- BRIDGE
- PROPOSED FLOODWAY BOUNDARY
- PROPOSED FLOODWAY STATION
- BANK STATION
- 100-YEAR DESIGN FLOOD EXTENT
- DEPTH ≥ 1 m
- VELOCITY ≥ 1 m/s
- PREVIOUS FLOODWAY

DISCHARGE
PINCHER CREEK ABOVE KETTLES CREEK = 214 m³/s
KETTLES CREEK = 36 m³/s

SCALE - 1:5,000
0 100 200 M

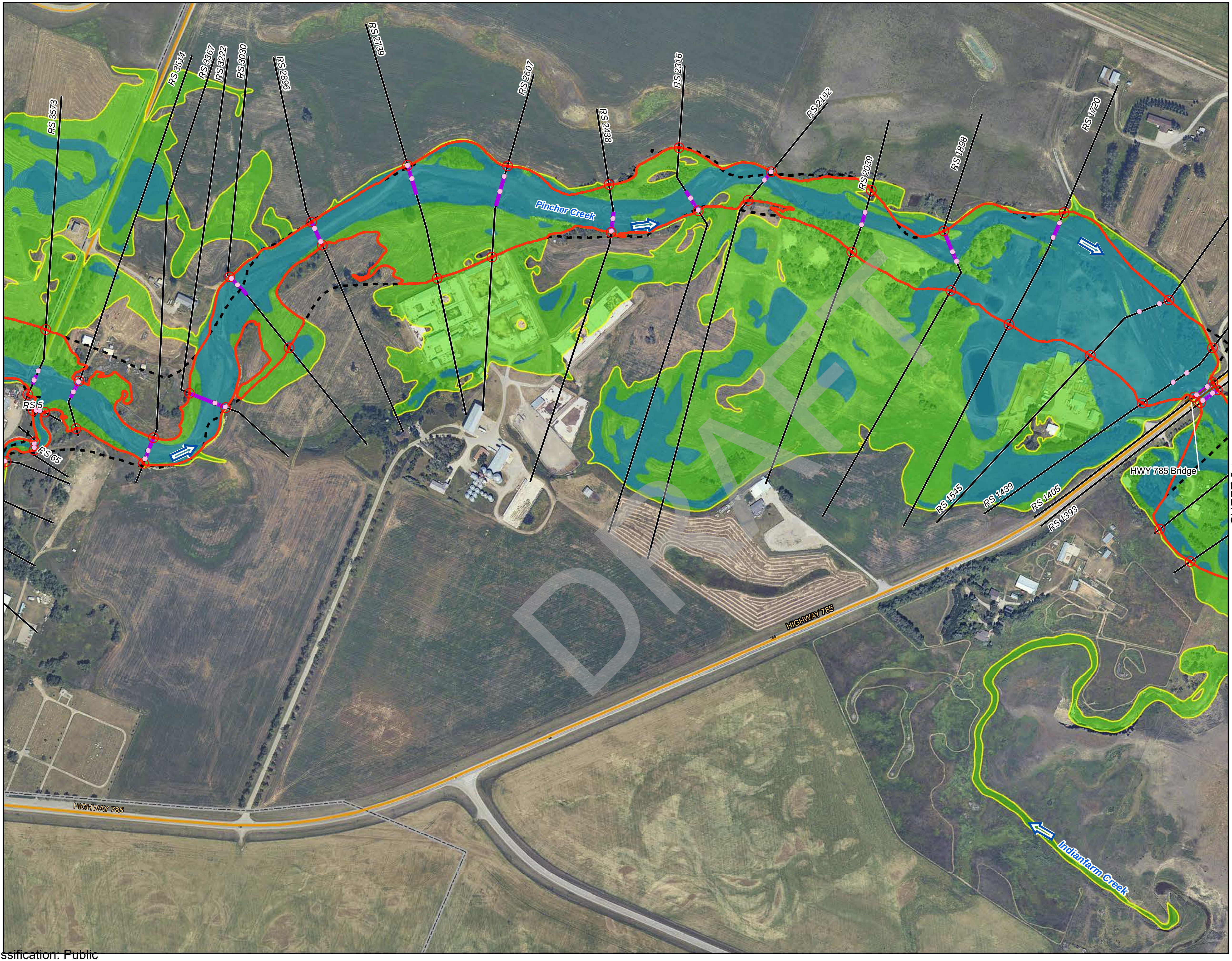
Coordinate System: NAD 1983 CSRS 3TM 114
Units: METRES

Engineer	GIS	Reviewer
KC / AS	VC / TS	RJC

Job Number	Date
A03285D13	13-FEB-2023

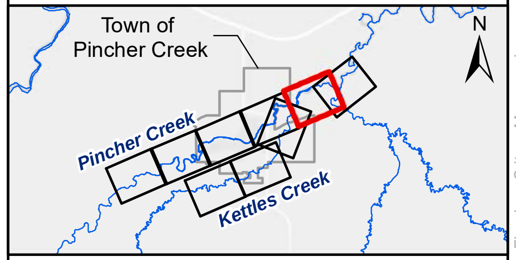
PINCHER CREEK FLOOD HAZARD STUDY

FLOODWAY CRITERIA MAP



Alberta Government

Klohn Crippen Berger



CROSS SECTION
RS 1325 RIVER STATION (M)
STUDY LIMIT
FLOW DIRECTION
MAJOR ROAD
LOCAL ROAD
MUNICIPAL DISTRICT BOUNDARY
FLOOD CONTROL STRUCTURE
CULVERT
BRIDGE
PROPOSED FLOODWAY BOUNDARY
PROPOSED FLOODWAY STATION
BANK STATION
100-YEAR DESIGN FLOOD EXTENT
DEPTH ≥ 1 m
VELOCITY ≥ 1 m/s
PREVIOUS FLOODWAY

DISCHARGE
PINCHER CREEK ABOVE KETTLES CREEK = 214 m³/s
PINCHER CREEK BELOW KETTLES CREEK = 250 m³/s
KETTLES CREEK = 36 m³/s

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

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

Engineer	GIS	Reviewer
KC / AS	VC / TS	RJC

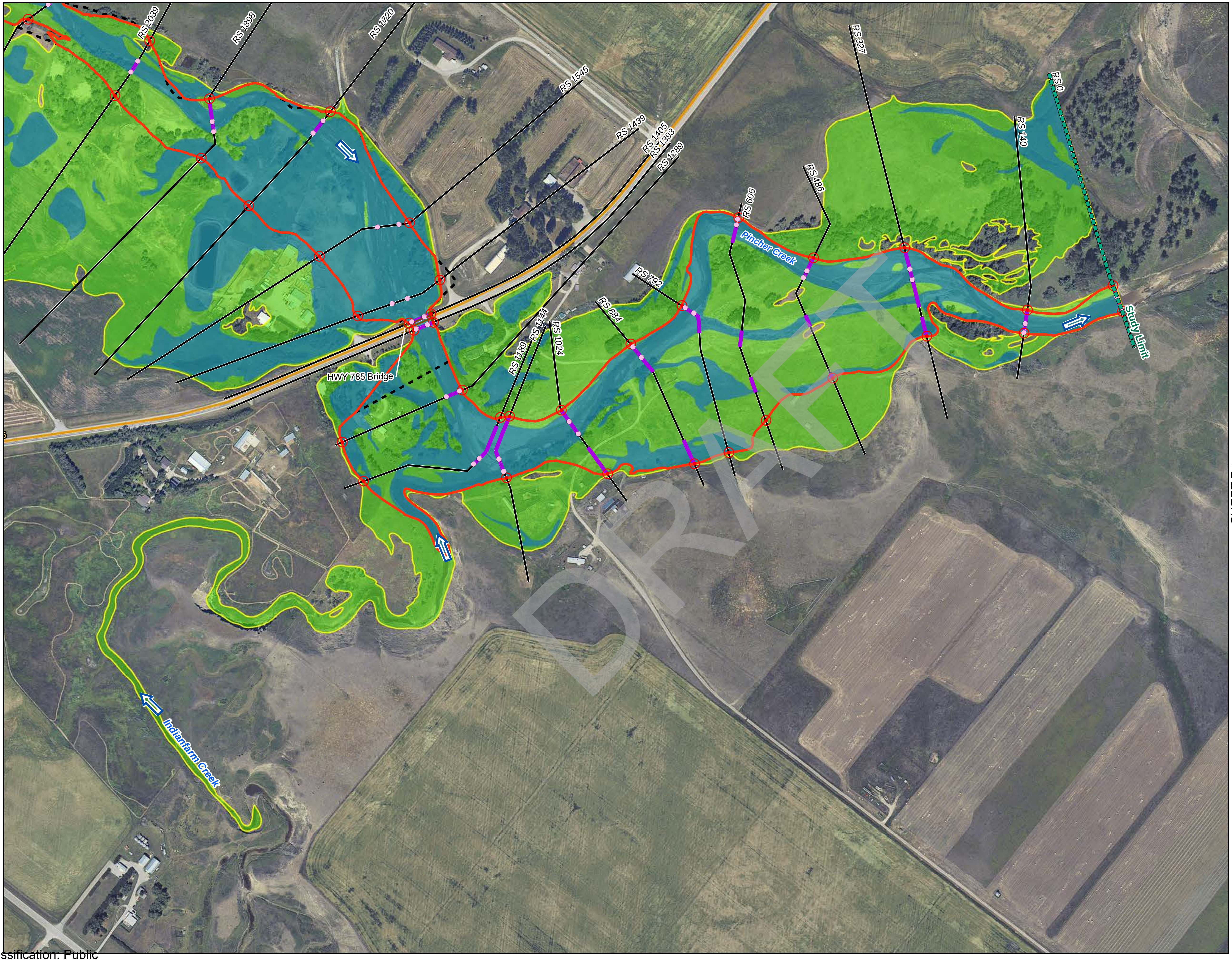
Job Number	Date
A03285D13	13-FEB-2023

PINCHER CREEK FLOOD HAZARD STUDY

FLOODWAY CRITERIA MAP

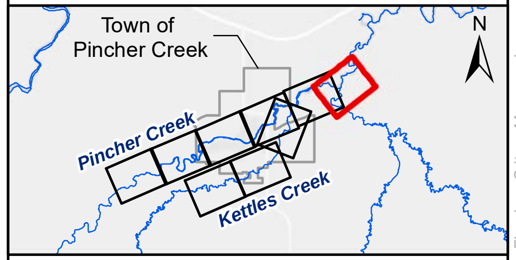
SHEET 5 OF 9

MSN, Z:\ACGY\Alberta\A03285D13 AEP Pincher Creek Modifications\700 Deliverables\741 2022 Digital Study Files\05_Design-Flood-Hazard\GIS\2023-01-31_PincherCreek_FINAL\2. 2023_Pincher Creek_FloodwayCriteria Maps.mxd



Alberta Government

Klohn Crippen Berger



CROSS SECTION
RS 1325 RIVER STATION (M)
STUDY LIMIT
FLOW DIRECTION
MAJOR ROAD
LOCAL ROAD
MUNICIPAL DISTRICT BOUNDARY
FLOOD CONTROL STRUCTURE
CULVERT
BRIDGE
PROPOSED FLOODWAY BOUNDARY
PROPOSED FLOODWAY STATION
BANK STATION
100-YEAR DESIGN FLOOD EXTENT
DEPTH ≥ 1 m
VELOCITY ≥ 1 m/s
PREVIOUS FLOODWAY

DISCHARGE
PINCHER CREEK BELOW KETTLES CREEK = 250 m^3/s
PINCHER CREEK BELOW INDIANFARM CREEK = 385 m^3/s

SCALE - 1:5,000
0 100 200 M

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

Engineer KC / AS	GIS VC / TS	Reviewer RJC
Job Number A03285D13	Date 13-FEB-2023	

PINCHER CREEK FLOOD HAZARD STUDY

FLOODWAY CRITERIA MAP

SHEET 6 OF 9

Classification: Public

Alberta Government

Klohn Crippen Berger

Town of Pincher Creek
Pincher Creek
Kettles Creek
N

CROSS SECTION
RS 1325 RIVER STATION (M)
STUDY LIMIT
FLOW DIRECTION
MAJOR ROAD
LOCAL ROAD
MUNICIPAL DISTRICT BOUNDARY
FLOOD CONTROL STRUCTURE
CULVERT
BRIDGE
PROPOSED FLOODWAY BOUNDARY
PROPOSED FLOODWAY STATION
BANK STATION
100-YEAR DESIGN FLOOD EXTENT
DEPTH ≥ 1 m
VELOCITY ≥ 1 m/s
PREVIOUS FLOODWAY

DISCHARGE
KETTLES CREEK = 36 m³/s

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

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

Engineer	GIS	Reviewer
KC / AS	VC / TS	RJC

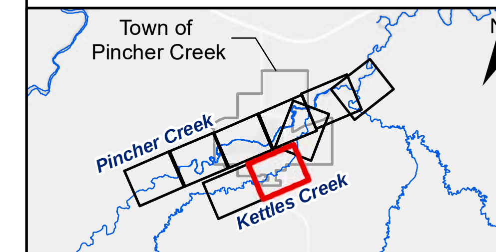
Job Number	Date
A03285D13	13-FEB-2023

PINCHER CREEK FLOOD HAZARD STUDY

FLOODWAY CRITERIA MAP

Alberta Government

Klohn Crippen Berger



- CROSS SECTION
- RS 1325 RIVER STATION (M)
- STUDY LIMIT
- FLOW DIRECTION
- MAJOR ROAD
- LOCAL ROAD
- MUNICIPAL DISTRICT BOUNDARY
- FLOOD CONTROL STRUCTURE
- CULVERT
- BRIDGE
- PROPOSED FLOODWAY BOUNDARY
- PROPOSED FLOODWAY STATION
- BANK STATION
- 100-YEAR DESIGN FLOOD EXTENT
- DEPTH ≥ 1 m
- VELOCITY ≥ 1 m/s
- PREVIOUS FLOODWAY

DISCHARGE
KETTLES CREEK = 36 m³/s

SCALE - 1:5,000
0 100 200 M

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

Engineer KC / AS	GIS VC / TS	Reviewer RJC
Job Number A03285D13	Date 13-FEB-2023	

PINCHER CREEK FLOOD HAZARD STUDY

FLOODWAY CRITERIA MAP

SHEET 8 OF 9

Classification: Public

SHEET 8 ↑

Alberta Government

Klohn Crippen Berger

Town of Pincher Creek

Pincher Creek

Kettles Creek

N

- CROSS SECTION
- RS 1325 RIVER STATION (M)
- STUDY LIMIT
- FLOW DIRECTION
- MAJOR ROAD
- LOCAL ROAD
- MUNICIPAL DISTRICT BOUNDARY
- FLOOD CONTROL STRUCTURE
- CULVERT
- BRIDGE
- PROPOSED FLOODWAY BOUNDARY
- PROPOSED FLOODWAY STATION
- BANK STATION
- 100-YEAR DESIGN FLOOD EXTENT
- DEPTH ≥ 1 m
- VELOCITY ≥ 1 m/s
- PREVIOUS FLOODWAY

DISCHARGE

PINCHER CREEK ABOVE KETTLES CREEK = 214 m^3/s

PINCHER CREEK BELOW KETTLES CREEK = 250 m^3/s

KETTLES CREEK = 36 m^3/s

SCALE - 1:5,000

0 100 200 M

Coordinate System: NAD 1983 CSRS 3TM 114

Units: METRES

Engineer	GIS	Reviewer
KC / AS	VC / TS	RJC

Job Number	Date
A03285D13	13-FEB-2023

PINCHER CREEK FLOOD HAZARD STUDY

FLOODWAY CRITERIA MAP

SHEET 9 OF 9

Classification: Public

APPENDIX XI

Floodway Limits and Governing Criteria

Appendix XI
Floodway Limits and Governing Criteria

Table XI.1 Selected Floodway Limits and Governing Criteria along Pincher Creek and Kettles Creek

River	Reach	Station	Left		Right	
			Floodway Limit (m)	Governing Criteria	Floodway Limit (m)	Governing Criteria
Pincher Creek	Pincher Creek-US	14327	127.7	1 m Depth	221.1	1 m Depth
Pincher Creek	Pincher Creek-US	14196	142.0	1 m Depth	230.8	1 m Depth
Pincher Creek	Pincher Creek-US	14099	116.3	1 m/s Velocity	207.1	1 m Depth
Pincher Creek	Pincher Creek-US	13994	103.4	1 m Depth	206.7	1 m/s Velocity
Pincher Creek	Pincher Creek-US	13885	78.5	1 m Depth	203.6	Mixed
Pincher Creek	Pincher Creek-US	13770	22.2	Mixed	161.0	1 m Depth
Pincher Creek	Pincher Creek-US	13649	46.9	1 m Depth	129.1	1 m Depth
Pincher Creek	Pincher Creek-US	13520	29.0	1 m Depth	101.7	1 m Depth
Pincher Creek	Pincher Creek-US	13394	58.2	1 m Depth	134.0	1 m Depth
Pincher Creek	Pincher Creek-US	13265	353.0	1 m Depth	416.1	1 m Depth
Pincher Creek	Pincher Creek-US	13100	325.0	1 m/s Velocity	389.9	1 m/s Velocity
Pincher Creek	Pincher Creek-US	12957	391.3	1 m Depth	410.6	1m Depth
Pincher Creek	Pincher Creek-US	12831	310.0	1 m Depth	404.5	1m Depth
Pincher Creek	Pincher Creek-US	12630	195.0	1 m/s Velocity	446.3	1m Depth

River	Reach	Station	Left		Right	
			Floodway Limit (m)	Governing Criteria	Floodway Limit (m)	Governing Criteria
Pincher Creek	Pincher Creek-US	12499	114.9	1 m Depth	331.4	1 m Depth
Pincher Creek	Pincher Creek-US	12377	80.1	Mixed	208.6	1 m Depth
Pincher Creek	Pincher Creek-US	12263	39.2	1 m Depth	119.7	1 m Depth
Pincher Creek	Pincher Creek-US	12119	19.7	1 m Depth	49.5	1 m Depth
Pincher Creek	Pincher Creek-US	11995	29.1	1 m/s Velocity	63.1	1m Depth
Pincher Creek	Pincher Creek-US	11868	43.0	1 m/s Velocity	121.6	1 m/s Velocity
Pincher Creek	Pincher Creek-US	11743	21.7	1 m Depth	84.3	1 m/s Velocity
Pincher Creek	Pincher Creek-US	11556	21.2	1 m/s Velocity	94.0	1 m Depth
Pincher Creek	Pincher Creek-US	11446	26.0	1 m/s Velocity	128.8	1 m Depth
Pincher Creek	Pincher Creek-US	11332	100.4	1m Depth	140.9	1 m/s Velocity
Pincher Creek	Pincher Creek-US	11202	98.0	1m Depth	120.5	1 m Depth
Pincher Creek	Pincher Creek-US	11062	93.7	1 m Depth	143.1	1 m Depth
Pincher Creek	Pincher Creek-US	10914	86.6	1 m Depth	169.8	1m Depth
Pincher Creek	Pincher Creek-US	10738	121.6	1m Depth	179.6	1 m/s Velocity
Pincher Creek	Pincher Creek-US	10610	94.4	1 m Depth	122.1	1 m/s Velocity
Pincher Creek	Pincher Creek-US	10484	49.5	1 m Depth	72.0	1 m Depth
Pincher Creek	Pincher Creek-US	10322	42.2	1m Depth	66.1	1 m Depth
Pincher Creek	Pincher Creek-US	10153	24.0	1m Depth	51.7	1m Depth

River	Reach	Station	Left		Right	
			Floodway Limit (m)	Governing Criteria	Floodway Limit (m)	Governing Criteria
Pincher Creek	Pincher Creek-US	10006	83.8	1 m Depth	104.0	1 m Depth
Pincher Creek	Pincher Creek-US	9868	68.7	1 m Depth	88.2	1 m/s Velocity
Pincher Creek	Pincher Creek-US	9719	15.1	1 m/s Velocity	36.6	1 m Depth
Pincher Creek	Pincher Creek-US	9610	22.0	1 m/s Velocity	53.3	1 m/s Velocity
Pincher Creek	Pincher Creek-US	9517	30.4	1m Depth	59.6	1 m/s Velocity
Pincher Creek	Pincher Creek-US	9415	35.8	1 m/s Velocity	57.8	1m Depth
Pincher Creek	Pincher Creek-US	9325	38.4	Previous Floodway	63.7	Main Channel
Pincher Creek	Pincher Creek-US	9225	32.9	Previous Floodway	53.0	Previous Floodway
Pincher Creek	Pincher Creek-US	9122	25.1	Previous Floodway	47.8	Previous Floodway
Pincher Creek	Pincher Creek-US	9021	15.0	Previous Floodway	50.7	Previous Floodway
Pincher Creek	Pincher Creek-US	8977	11.5	Previous Floodway	40.5	Main Channel
Pincher Creek	Pincher Creek-US	8928	32.8	Previous Floodway	59.1	Previous Floodway
Pincher Creek	Pincher Creek-US	8915	33.6	Previous Floodway	57.4	Previous Floodway
Pincher Creek	Pincher Creek-US	8913	34.0	Previous Floodway	55.4	Previous Floodway
Pincher Creek	Pincher Creek-US	8869	23.2	Main Channel	43.1	Previous Floodway
Pincher Creek	Pincher Creek-US	8769	30.4	Previous Floodway	48.5	Previous Floodway
Pincher Creek	Pincher Creek-US	8665	16.2	Previous Floodway	30.8	Previous Floodway
Pincher Creek	Pincher Creek-US	8528	27.5	Previous Floodway	47.4	Previous Floodway

River	Reach	Station	Left		Right	
			Floodway Limit (m)	Governing Criteria	Floodway Limit (m)	Governing Criteria
Pincher Creek	Pincher Creek-US	8424	32.1	Previous Floodway	47.4	Previous Floodway
Pincher Creek	Pincher Creek-US	8321	31.7	1 m Depth	67.3	Previous Floodway
Pincher Creek	Pincher Creek-US	8223	34.2	Previous Floodway	59.1	Previous Floodway
Pincher Creek	Pincher Creek-US	8194	53.3	Previous Floodway	72.0	Previous Floodway
Pincher Creek	Pincher Creek-US	8182	45.9	Previous Floodway	68.2	Previous Floodway
Pincher Creek	Pincher Creek-US	8077	28.1	Previous Floodway	52.7	Previous Floodway
Pincher Creek	Pincher Creek-US	7879	37.58	1 m Depth	67.3	Previous Floodway
Pincher Creek	Pincher Creek-US	7691	70.4	Previous Floodway	92.8	Previous Floodway
Pincher Creek	Pincher Creek-US	7499	31.7	1 m Depth	60.8	Previous Floodway
Pincher Creek	Pincher Creek-US	7342	193.4	Previous Floodway	236.1	Main Channel
Pincher Creek	Pincher Creek-US	7217	242.4	1 m Depth	300.3	Previous Floodway
Pincher Creek	Pincher Creek-US	7176	279.9	1 m Depth	307.4	Previous Floodway
Pincher Creek	Pincher Creek-US	7160	285.3	1 m Depth	310.0	Previous Floodway
Pincher Creek	Pincher Creek-US	7101	282.8	Previous Floodway	308.6	Previous Floodway
Pincher Creek	Pincher Creek-US	7081	273.6	Previous Floodway	306.8	Previous Floodway
Pincher Creek	Pincher Creek-US	7038	312.9	Previous Floodway	341.6	Previous Floodway
Pincher Creek	Pincher Creek-US	6985	304.7	Previous Floodway	334.5	Previous Floodway
Pincher Creek	Pincher Creek-US	6924	357.1	Previous Floodway	382.8	Previous Floodway

River	Reach	Station	Left		Right	
			Floodway Limit (m)	Governing Criteria	Floodway Limit (m)	Governing Criteria
Pincher Creek	Pincher Creek-US	6897	406.2	Previous Floodway	430.1	Previous Floodway
Pincher Creek	Pincher Creek-US	6883	405.2	Previous Floodway	429.3	Previous Floodway
Pincher Creek	Pincher Creek-US	6867	416.5	Previous Floodway	438.1	Previous Floodway
Pincher Creek	Pincher Creek-US	6783	303.3	Previous Floodway	327.2	Previous Floodway
Pincher Creek	Pincher Creek-US	6710	267.5	Previous Floodway	295.3	Previous Floodway
Pincher Creek	Pincher Creek-US	6651	250.0	Internal Inundation Limit	281.8	1 m Depth
Pincher Creek	Pincher Creek-US	6649	249.5	Internal Inundation Limit	280.8	Previous Floodway
Pincher Creek	Pincher Creek-US	6555	249.9	Internal Inundation Limit	272.1	Previous Floodway
Pincher Creek	Pincher Creek-US	6429	170.4	Previous Floodway	204.5	Previous Floodway
Pincher Creek	Pincher Creek-US	6321	84.9	Inundation Limit(1)	109.1	Internal Inundation Limit
Pincher Creek	Pincher Creek-US	6193	70.4	Inundation Limit(2)	145.0	Previous Floodway
Pincher Creek	Pincher Creek-US	6089	34.6	Previous Floodway	76.4	Previous Floodway
Pincher Creek	Pincher Creek-US	5979	27.0	Inundation Limit(1)	85.6	Previous Floodway
Pincher Creek	Pincher Creek-US	5875	91.4	Previous Floodway	125.4	Previous Floodway
Pincher Creek	Pincher Creek-US	5838	120.7	Previous Floodway	147.5	Previous Floodway
Pincher Creek	Pincher Creek-US	5824	122.6	Previous Floodway	148.1	Previous Floodway
Pincher Creek	Pincher Creek-US	5756	138.1	Previous Floodway	208.9	Previous Floodway
Pincher Creek	Pincher Creek-US	5636	92.55	1 m Depth	225.1	Previous Floodway

River	Reach	Station	Left		Right	
			Floodway Limit (m)	Governing Criteria	Floodway Limit (m)	Governing Criteria
Pincher Creek	Pincher Creek-US	5510	130.7	Previous Floodway	223.8	Previous Floodway
Pincher Creek	Pincher Creek-US	5402	75.4	Previous Floodway	184.9	Previous Floodway
Pincher Creek	Pincher Creek-US	5281	54.7	Previous Floodway	171.2	Main Channel
Pincher Creek	Pincher Creek-US	5096	74.5	Main Channel	153.1	Previous Floodway
Pincher Creek	Pincher Creek-US	4962	66.7	Previous Floodway	186.8	Previous Floodway
Pincher Creek	Pincher Creek-US	4863	72.8	Previous Floodway	232.0	Previous Floodway
Pincher Creek	Pincher Creek-US	4636	18.0	Main Channel	198.1	Previous Floodway
Pincher Creek	Pincher Creek-US	4508	44.1	Previous Floodway	119.7	Previous Floodway
Pincher Creek	Pincher Creek-US	4394	16.8	Previous Floodway	85.9	Previous Floodway
Pincher Creek	Pincher Creek-US	4132	69.2	Previous Floodway	165.9	Main Channel
Pincher Creek	Pincher Creek-US	3976	31.8	Main Channel	135.6	Previous Floodway
Pincher Creek	Pincher Creek-US	3824	24.4	1 m Depth	194.6	Main Channel
Pincher Creek	Pincher Creek-US	3685	86.9	Mixed	193.0	Previous Floodway
Pincher Creek	Pincher Creek-US	3573	324.5	Previous Floodway	419.7	Previous Floodway
Pincher Creek	Pincher Creek-DS	3514	479.6	Internal Inundation Limit	549.0	Inundation Limit(1)
Pincher Creek	Pincher Creek-DS	3367	538.1	Internal Inundation Limit	576.6	Inundation Limit(1)
Pincher Creek	Pincher Creek-DS	3222	476.7	Internal Inundation Limit	531.0	Previous Floodway
Pincher Creek	Pincher Creek-DS	3030	308.2	Main Channel	436.8	Previous Floodway

River	Reach	Station	Left		Right	
			Floodway Limit (m)	Governing Criteria	Floodway Limit (m)	Governing Criteria
Pincher Creek	Pincher Creek-DS	2896	235.1	Previous Floodway	270.7	Inundation Limit(1)
Pincher Creek	Pincher Creek-DS	2739	204.6	Main Channel	367.1	Previous Floodway
Pincher Creek	Pincher Creek-DS	2607	131.7	Previous Floodway	261.0	Previous Floodway
Pincher Creek	Pincher Creek-DS	2438	106.2	Previous Floodway	173.3	Inundation Limit(1)
Pincher Creek	Pincher Creek-DS	2316	113.5	Previous Floodway	209.9	Previous Floodway
Pincher Creek	Pincher Creek-DS	2192	122.6	Main Channel	173.9	Internal Inundation Limit
Pincher Creek	Pincher Creek-DS	2039	99.5	Previous Floodway	189.7	Previous Floodway
Pincher Creek	Pincher Creek-DS	1898	170.5	Previous Floodway	262.1	Previous Floodway
Pincher Creek	Pincher Creek-DS	1720	191.8	Previous Floodway	365.3	Previous Floodway
Pincher Creek	Pincher Creek-DS	1545	310.7	Previous Floodway	447.9	Previous Floodway
Pincher Creek	Pincher Creek-DS	1439	347.7	Inundation Limit	473.0	Previous Floodway
Pincher Creek	Pincher Creek-DS	1405	412.1	Previous Floodway	444.9	Previous Floodway
Pincher Creek	Pincher Creek-DS	1393	420.7	Previous Floodway	449.9	Previous Floodway
Pincher Creek	Pincher Creek-DS	1289	443.2	1m Depth	625.2	1 m Depth
Pincher Creek	Pincher Creek-DS	1189	129.4	Mixed	366.5	1m Depth
Pincher Creek	Pincher Creek-DS	1144	134.5	1 m/s Velocity	226.7	1m Depth
Pincher Creek	Pincher Creek-DS	1024	124.5	1 m/s Velocity	233.9	1 m/s Velocity
Pincher Creek	Pincher Creek-DS	884	76.1	1 m/s Velocity	265.6	1 m/s Velocity

River	Reach	Station	Left		Right	
			Floodway Limit (m)	Governing Criteria	Floodway Limit (m)	Governing Criteria
Pincher Creek	Pincher Creek-DS	792	80.8	1m Depth	303.1	1 m Depth
Pincher Creek	Pincher Creek-DS	606	19.7	1 m Depth	313.2	Mixed
Pincher Creek	Pincher Creek-DS	486	140.1	1 m/s Velocity	323.3	1 m/s Velocity
Pincher Creek	Pincher Creek-DS	327	317.3	1m Depth	444.0	1 m Depth
Pincher Creek	Pincher Creek-DS	140	269.4	1 m/s Velocity	301.6	1 m Depth
Pincher Creek	Pincher Creek-DS	0	307.8	1 m/s Velocity	346.2	1 m/s Velocity
Kettles Creek	Kettles Creek	7295	85.6	1 m/s Velocity	100.8	1 m/s Velocity
Kettles Creek	Kettles Creek	7239	59.0	1 m/s Velocity	68.7	1 m Depth
Kettles Creek	Kettles Creek	7178	72.6	1 m/s Velocity	82.4	1 m Depth
Kettles Creek	Kettles Creek	7123	44.1	1 m/s Velocity	56.9	1m Depth
Kettles Creek	Kettles Creek	7041	26.5	1 m Depth	36.6	1 m/s Velocity
Kettles Creek	Kettles Creek	6951	8.6	1 m/s Velocity	18.7	1 m/s Velocity
Kettles Creek	Kettles Creek	6880	6.2	1 m Depth	13.9	1 m Depth
Kettles Creek	Kettles Creek	6829	5.5	Mixed	16.0	1 m/s Velocity
Kettles Creek	Kettles Creek	6768	47.8	1 m/s Velocity	55.5	1 m Depth
Kettles Creek	Kettles Creek	6728	38.5	1 m Depth	47.2	1 m/s Velocity
Kettles Creek	Kettles Creek	6690	20.5	1 m/s Velocity	28.0	1 m Depth
Kettles Creek	Kettles Creek	6628	13.3	1 m/s Velocity	22.6	1 m/s Velocity

River	Reach	Station	Left		Right	
			Floodway Limit (m)	Governing Criteria	Floodway Limit (m)	Governing Criteria
Kettles Creek	Kettles Creek	6586	27.7	1 m/s Velocity	36.0	1 m Depth
Kettles Creek	Kettles Creek	6536	21.0	Mixed	33.3	1 m/s Velocity
Kettles Creek	Kettles Creek	6480	12.4	1 m/s Velocity	24.5	1 m/s Velocity
Kettles Creek	Kettles Creek	6402	17.8	1 m Depth	29.0	1 m/s Velocity
Kettles Creek	Kettles Creek	6352	85.1	1m Depth	93.7	1m Depth
Kettles Creek	Kettles Creek	6295	69.7	1m Depth	82.4	1 m Depth
Kettles Creek	Kettles Creek	6212	62.1	1m Depth	69.5	1m Depth
Kettles Creek	Kettles Creek	6162	66.0	1m Depth	74.2	1 m/s Velocity
Kettles Creek	Kettles Creek	6053	10.1	1m Depth	16.7	1m Depth
Kettles Creek	Kettles Creek	5996	10.0	1m Depth	17.9	1 m Depth
Kettles Creek	Kettles Creek	5943	14.2	1 m/s Velocity	21.2	1 m Depth
Kettles Creek	Kettles Creek	5901	27.3	1 m Depth	35.2	1 m Depth
Kettles Creek	Kettles Creek	5837	10.1	1 m/s Velocity	17.6	1m Depth
Kettles Creek	Kettles Creek	5785	30.8	1 m/s Velocity	41.9	1 m/s Velocity
Kettles Creek	Kettles Creek	5736	42.0	1 m/s Velocity	56.5	1 m/s Velocity
Kettles Creek	Kettles Creek	5674	21.7	1 m/s Velocity	31.3	1 m Depth
Kettles Creek	Kettles Creek	5596	68.8	1 m/s Velocity	76.6	1 m/s Velocity
Kettles Creek	Kettles Creek	5544	16.2	1m Depth	28.9	1 m/s Velocity

River	Reach	Station	Left		Right	
			Floodway Limit (m)	Governing Criteria	Floodway Limit (m)	Governing Criteria
Kettles Creek	Kettles Creek	5471	8.8	1m Depth	21.0	1 m/s Velocity
Kettles Creek	Kettles Creek	5388	11.7	1 m/s Velocity	22.9	1 m/s Velocity
Kettles Creek	Kettles Creek	5312	12.9	1 m/s Velocity	24.8	1 m/s Velocity
Kettles Creek	Kettles Creek	5214	17.9	1 m/s Velocity	41.4	1 m/s Velocity
Kettles Creek	Kettles Creek	5166	10.8	1 m/s Velocity	29.1	1 m/s Velocity
Kettles Creek	Kettles Creek	5120	7.2	1 m/s Velocity	58.8	1 m/s Velocity
Kettles Creek	Kettles Creek	5069	15.5	1 m/s Velocity	50.5	1 m/s Velocity
Kettles Creek	Kettles Creek	5008	33.8	1 m/s Velocity	63.9	1 m/s Velocity
Kettles Creek	Kettles Creek	4960	10.3	1 m/s Velocity	46.1	1 m/s Velocity
Kettles Creek	Kettles Creek	4914	8.8	1 m/s Velocity	27.9	1 m/s Velocity
Kettles Creek	Kettles Creek	4859	16.7	1 m/s Velocity	32.4	1 m Depth
Kettles Creek	Kettles Creek	4776	6.2	1 m/s Velocity	20.1	1 m/s Velocity
Kettles Creek	Kettles Creek	4693	23.9	1 m/s Velocity	37.3	1 m/s Velocity
Kettles Creek	Kettles Creek	4599	107.7	1 m Depth	116.8	1 m Depth
Kettles Creek	Kettles Creek	4518	172.6	1 m/s Velocity	180.6	1 m Depth
Kettles Creek	Kettles Creek	4448	187.2	1 m/s Velocity	199.1	1 m/s Velocity
Kettles Creek	Kettles Creek	4350	78.5	1 m Depth	96.4	1 m/s Velocity
Kettles Creek	Kettles Creek	4286	86.7	1 m/s Velocity	96.2	1 m/s Velocity

River	Reach	Station	Left		Right	
			Floodway Limit (m)	Governing Criteria	Floodway Limit (m)	Governing Criteria
Kettles Creek	Kettles Creek	4229	93.6	1 m/s Velocity	107.7	1 m Depth
Kettles Creek	Kettles Creek	4180	65.5	1 m Depth	159.9	1 m Depth
Kettles Creek	Kettles Creek	4142	144.2	1 m Depth	223.7	1 m Depth
Kettles Creek	Kettles Creek	4108	166.7	1 m Depth	223.7	1 m Depth
Kettles Creek	Kettles Creek	4094	165.8	1 m Depth	200.8	1 m Depth
Kettles Creek	Kettles Creek	4062	177.6	1 m/s Velocity	182.6	1 m/s Velocity
Kettles Creek	Kettles Creek	4011	91.2	1 m/s Velocity	97.7	1 m/s Velocity
Kettles Creek	Kettles Creek	3924	108.2	1 m/s Velocity	115.3	1 m Depth
Kettles Creek	Kettles Creek	3851	60.6	1 m/s Velocity	68.2	1 m Depth
Kettles Creek	Kettles Creek	3810	27.2	1 m/s Velocity	39.6	1 m/s Velocity
Kettles Creek	Kettles Creek	3746	24.1	1 m/s Velocity	39.6	1 m/s Velocity
Kettles Creek	Kettles Creek	3699	28.6	1 m/s Velocity	41.6	1 m/s Velocity
Kettles Creek	Kettles Creek	3659	52.9	1 m/s Velocity	63.9	1 m/s Velocity
Kettles Creek	Kettles Creek	3594	22.4	1 m/s Velocity	42.8	1 m/s Velocity
Kettles Creek	Kettles Creek	3517	32.7	1 m/s Velocity	49.2	1 m/s Velocity
Kettles Creek	Kettles Creek	3449	47.0	1 m/s Velocity	61.0	1 m/s Velocity
Kettles Creek	Kettles Creek	3390	47.5	1 m Depth	103.4	1 m Depth
Kettles Creek	Kettles Creek	3328	69.1	Mixed	88.2	1 m/s Velocity

River	Reach	Station	Left		Right	
			Floodway Limit (m)	Governing Criteria	Floodway Limit (m)	Governing Criteria
Kettles Creek	Kettles Creek	3277	88.4	1 m/s Velocity	103.2	1 m/s Velocity
Kettles Creek	Kettles Creek	3184	99.9	1m Depth	109.7	1 m Depth
Kettles Creek	Kettles Creek	3132	100.5	1 m/s Velocity	112.8	1 m/s Velocity
Kettles Creek	Kettles Creek	3073	87.0	Mixed	99.8	1 m/s Velocity
Kettles Creek	Kettles Creek	3025	60.8	1 m/s Velocity	73.5	1 m Depth
Kettles Creek	Kettles Creek	2937	65.4	1 m/s Velocity	75.8	1 m Depth
Kettles Creek	Kettles Creek	2868	33.5	1 m/s Velocity	45.5	1 m/s Velocity
Kettles Creek	Kettles Creek	2796	27.1	1 m/s Velocity	37.1	1 m/s Velocity
Kettles Creek	Kettles Creek	2746	20.1	1 m/s Velocity	33.1	1 m Depth
Kettles Creek	Kettles Creek	2723	29.6	Mixed	41.6	1 m/s Velocity
Kettles Creek	Kettles Creek	2719	29.1	1 m/s Velocity	39.9	1 m/s Velocity
Kettles Creek	Kettles Creek	2657	51.3	1 m/s Velocity	62.5	1 m/s Velocity
Kettles Creek	Kettles Creek	2608	89.1	1m Depth	111.34	Mixed
Kettles Creek	Kettles Creek	2578	77.7	Mixed	133.01	1 m Depth
Kettles Creek	Kettles Creek	2574	77.8	1 m/s Velocity	138.1	Mixed
Kettles Creek	Kettles Creek	2548	87.5	Mixed	101.5	1 m/s Velocity
Kettles Creek	Kettles Creek	2534	89.0	Mixed	100.4	Mixed
Kettles Creek	Kettles Creek	2499	24.4	Inundation Limit	47.6	Inundation Limit

River	Reach	Station	Left		Right	
			Floodway Limit (m)	Governing Criteria	Floodway Limit (m)	Governing Criteria
Kettles Creek	Kettles Creek	2439	7.6	Inundation Extent	39.8	Inundation Extent
Kettles Creek	Kettles Creek	2364	24.5	Previous Floodway	52.0	Previous Floodway
Kettles Creek	Kettles Creek	2285	27.4	Previous Floodway	54.1	Previous Floodway
Kettles Creek	Kettles Creek	2202	34.1	Inundation Extent	60.3	Inundation Extent
Kettles Creek	Kettles Creek	2116	31.8	Previous Floodway	59.5	Inundation Extent
Kettles Creek	Kettles Creek	2025	36.9	Inundation Extent	62.7	Previous Floodway
Kettles Creek	Kettles Creek	1942	43.4	Inundation Extent	54.9	Inundation Extent
Kettles Creek	Kettles Creek	1851	19.2	Inundation Extent	35.1	Inundation Extent
Kettles Creek	Kettles Creek	1770	37.9	Previous Floodway	52.7	Inundation Extent
Kettles Creek	Kettles Creek	1711	28.8	Inundation Extent	39.0	Inundation Extent
Kettles Creek	Kettles Creek	1692	32.8	Previous Floodway	44.6	Previous Floodway
Kettles Creek	Kettles Creek	1681	33.9	Main Channel	44.8	Inundation Extent
Kettles Creek	Kettles Creek	1658	36.3	Previous Floodway	47.2	Inundation Extent
Kettles Creek	Kettles Creek	1591	33.1	Main Channel	59.1	Previous Floodway
Kettles Creek	Kettles Creek	1533	37.0	Inundation Extent	49.8	Inundation Extent
Kettles Creek	Kettles Creek	1477	9.8	Inundation Extent	22.0	Main Channel
Kettles Creek	Kettles Creek	1392	86.9	Previous Floodway	96.7	Previous Floodway
Kettles Creek	Kettles Creek	1309	117.5	Previous Floodway	130.4	Inundation Extent

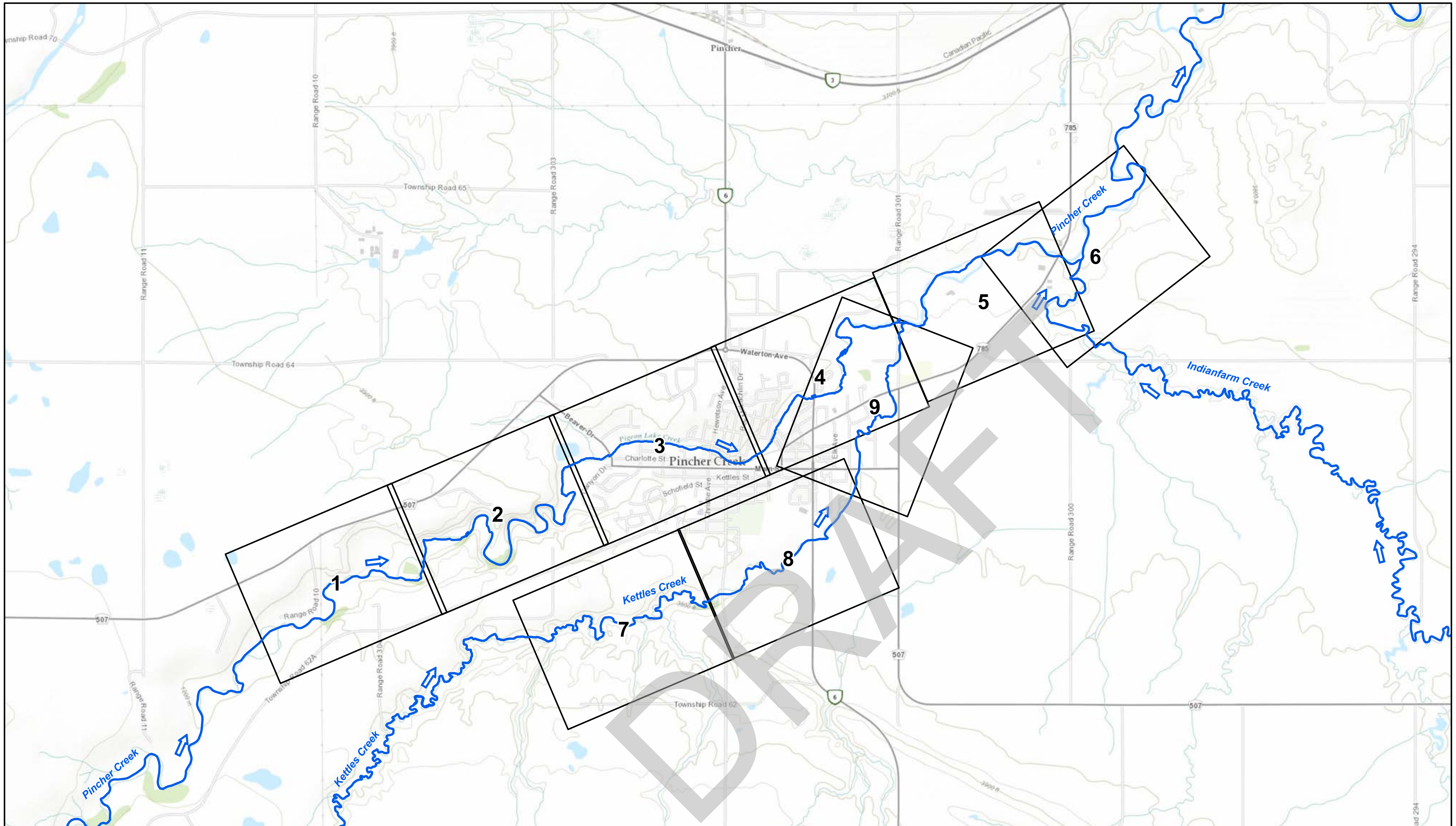
River	Reach	Station	Left		Right	
			Floodway Limit (m)	Governing Criteria	Floodway Limit (m)	Governing Criteria
Kettles Creek	Kettles Creek	1225	138.3	Previous Floodway	151.9	Inundation Extent
Kettles Creek	Kettles Creek	1141	220.1	Previous Floodway	233.6	Previous Floodway
Kettles Creek	Kettles Creek	1045	201.5	1 m Depth	271.4	Previous Floodway
Kettles Creek	Kettles Creek	953	253.7	1 m Depth	318.4	Previous Floodway
Kettles Creek	Kettles Creek	870	296.2	Internal Inundation Limit	319.1	Previous Floodway
Kettles Creek	Kettles Creek	798	276.5	Main Channel	293.6	Previous Floodway
Kettles Creek	Kettles Creek	732	223.8	Inundation Extent	235.9	Inundation Extent
Kettles Creek	Kettles Creek	701	173.3	Previous Floodway	183.8	Previous Floodway
Kettles Creek	Kettles Creek	690	6.8	Inundation Extent	16.9	Inundation Extent
Kettles Creek	Kettles Creek	637	4.8	Inundation Extent	18.5	Inundation Extent
Kettles Creek	Kettles Creek	547	5.5	Inundation Extent	22.3	Previous Floodway
Kettles Creek	Kettles Creek	478	28.2	Previous Floodway	39.9	Previous Floodway
Kettles Creek	Kettles Creek	421	40.3	Previous Floodway	60.1	Previous Floodway
Kettles Creek	Kettles Creek	407	29.1	Previous Floodway	70.9	Previous Floodway
Kettles Creek	Kettles Creek	397	66.0	Previous Floodway	75.0	Previous Floodway
Kettles Creek	Kettles Creek	360	61.1	Previous Floodway	91.6	Previous Floodway
Kettles Creek	Kettles Creek	293	53.8	Previous Floodway	66.9	Previous Floodway
Kettles Creek	Kettles Creek	234	7.3	Previous Floodway	15.7	Previous Floodway

River	Reach	Station	Left		Right	
			Floodway Limit (m)	Governing Criteria	Floodway Limit (m)	Governing Criteria
Kettles Creek	Kettles Creek	177	14.2	Previous Floodway	25.0	Inundation Extent
Kettles Creek	Kettles Creek	126	16.1	Previous Floodway	24.6	Previous Floodway
Kettles Creek	Kettles Creek	65	31.4	Inundation Extent	43.2	Inundation Extent
Kettles Creek	Kettles Creek	5	8.6	Main Channel	25.4	Previous Floodway

Notes:
(1) The previous floodway is outside the inundation limit.
(2) No viable flood fringe.

APPENDIX XII

Flood Hazard Maps



Notes to Users:

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

Definitions:

1. **Flood Hazard Mapping** - Identifies the areas flooded for the design flood, and is divided into floodway and flood fringe zones. Flood hazard mapping is typically used for long-term flood hazard area management and land-use planning.
2. **Floodway** - The portion of flood hazard area where flows are generally deepest, fastest, and most destructive during a design flood. The floodway typically includes the main channel of a stream and a portion of the adjacent overbank area.
3. **Flood Fringe** - The portion of flood hazard area outside the floodway. Water in the flood fringe is generally shallower and flows more slowly than in the floodway.
4. **High Hazard Flood Fringe** - The portion of flood hazard outside of the floodway where the flows are generally deepest, fastest and most destructive during the design flood.
5. **Design Flood** - The design standard for flood hazard mapping in Alberta is the 100-year flood, which has a one percent chance of being equaled or exceeded in any given year.

Data Sources and References:

1. Aerial imagery was collected in July 2019 and was provided by Alberta Environment and Parks.
2. Additional base mapping from ESRI.

Alberta Government

Klohn Crippen Berger

MUNICIPAL DISTRICT BOUNDARY

SCALE - 1:40,000

0 0.5 1 1.5 KM

N

Coordinate System: NAD 1983 3TM 114
Units: METRES

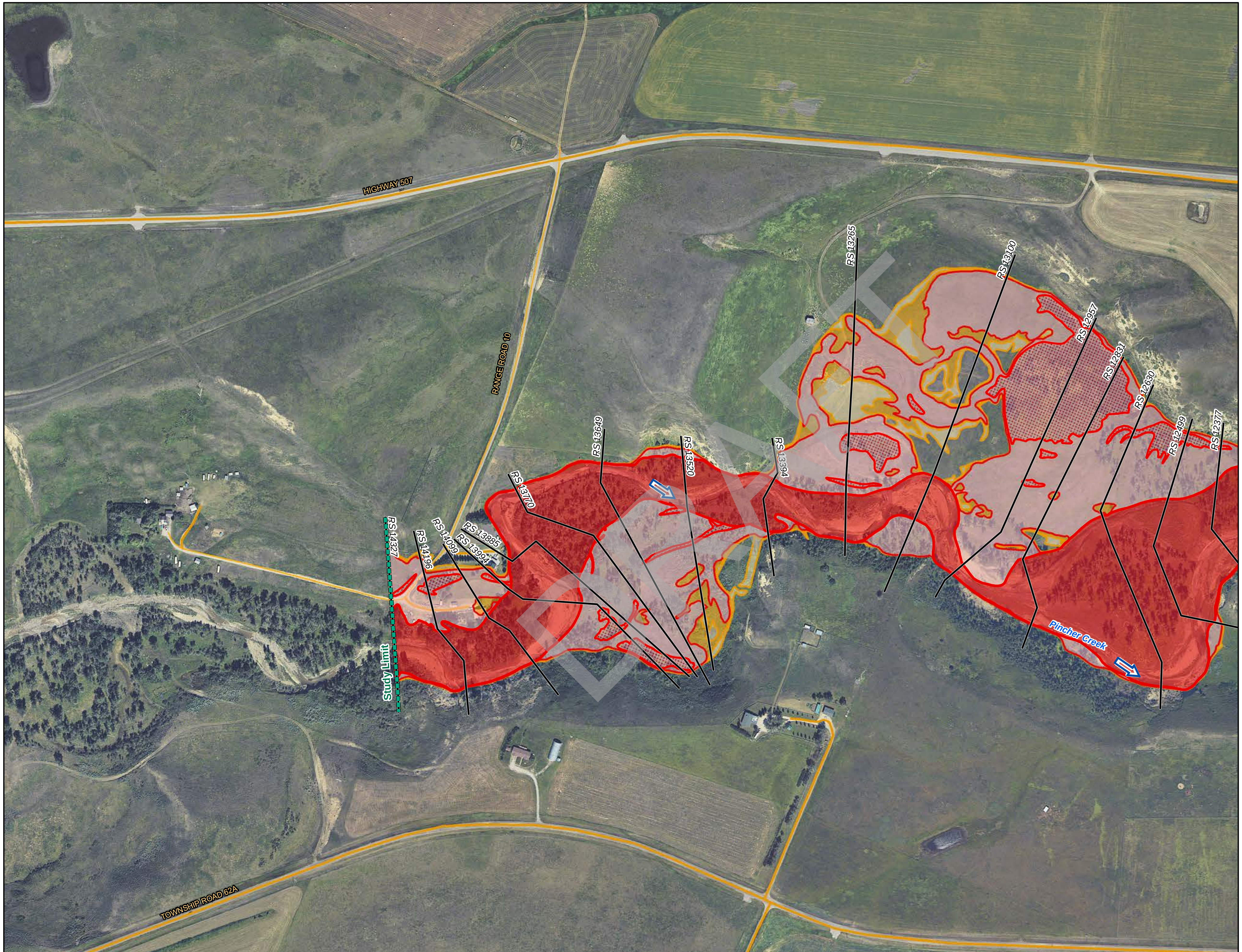
Engineer	GIS	Reviewer
KC/AS	VC/TS	RJC

Job Number	Date
A03285D13	13-FEB-2023

PINCHER CREEK FLOOD HAZARD STUDY

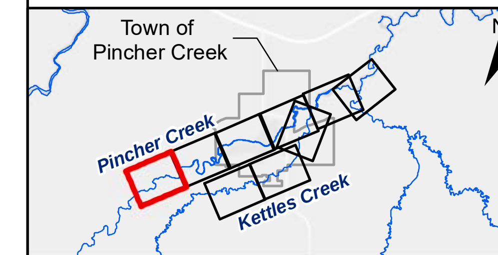
FLOOD HAZARD MAP

INDEX MAP



Alberta Government

Klohn Crippen Berger



FLOW DIRECTION
CROSS SECTION
RS 1325 RIVER STATION (M)
FLOOD CONTROL STRUCTURE
CULVERT
BRIDGE
MAJOR ROAD
LOCAL ROAD
MUNICIPAL DISTRICT BOUNDARY
STUDY LIMIT
PROPOSED FLOODWAY BOUNDARY
FLOOD FRINGE
HIGH HAZARD FLOOD FRINGE
200-YEAR FLOOD EXTENT
500-YEAR FLOOD EXTENT

DISCHARGE
PINCHER CREEK ABOVE KETTLES CREEK = 214 m^3/s

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

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

Engineer	GIS	Reviewer
KC / AS	VC / TS	RJC

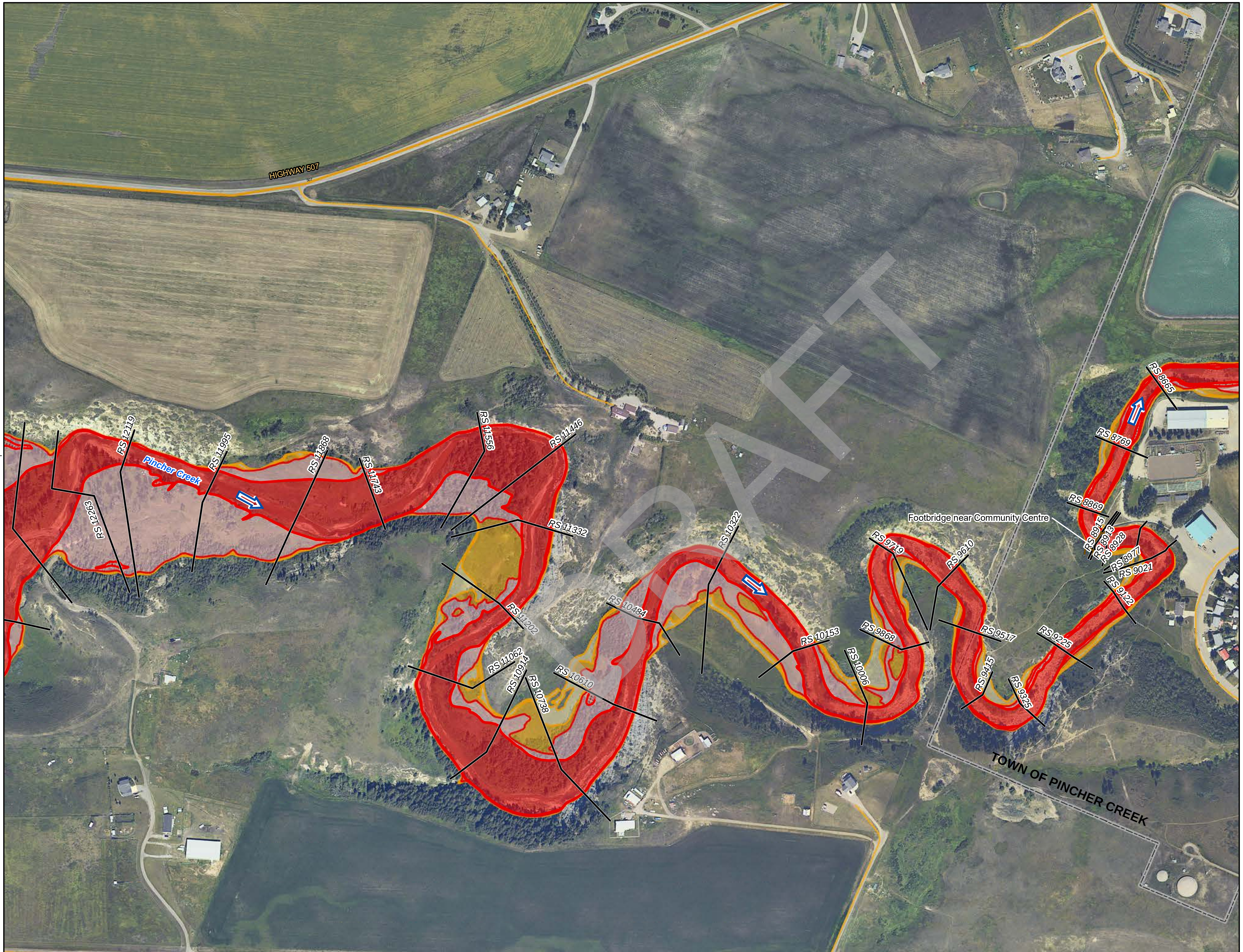
Job Number	Date
A03285D13	13-FEB-2023

PINCHER CREEK FLOOD HAZARD STUDY

FLOOD HAZARD MAP

SHEET 1 OF 9

SHEET 1 ↑



SHEET 3 ↓

Alberta Government

Klohn Crippen Berger

Town of Pincher Creek
Pincher Creek
Kettles Creek
N

FLOW DIRECTION
CROSS SECTION
RS 1325 RIVER STATION (M)
FLOOD CONTROL STRUCTURE
CULVERT
BRIDGE
MAJOR ROAD
LOCAL ROAD
MUNICIPAL DISTRICT BOUNDARY
STUDY LIMIT
PROPOSED FLOODWAY BOUNDARY
FLOOD FRINGE
HIGH HAZARD FLOOD FRINGE
200-YEAR FLOOD EXTENT
500-YEAR FLOOD EXTENT

DISCHARGE
PINCHER CREEK ABOVE KETTLES CREEK = 214 m³/s

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

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

Engineer	GIS	Reviewer
KC / AS	VC / TS	RJC

Job Number	Date
A03285D13	13-FEB-2023

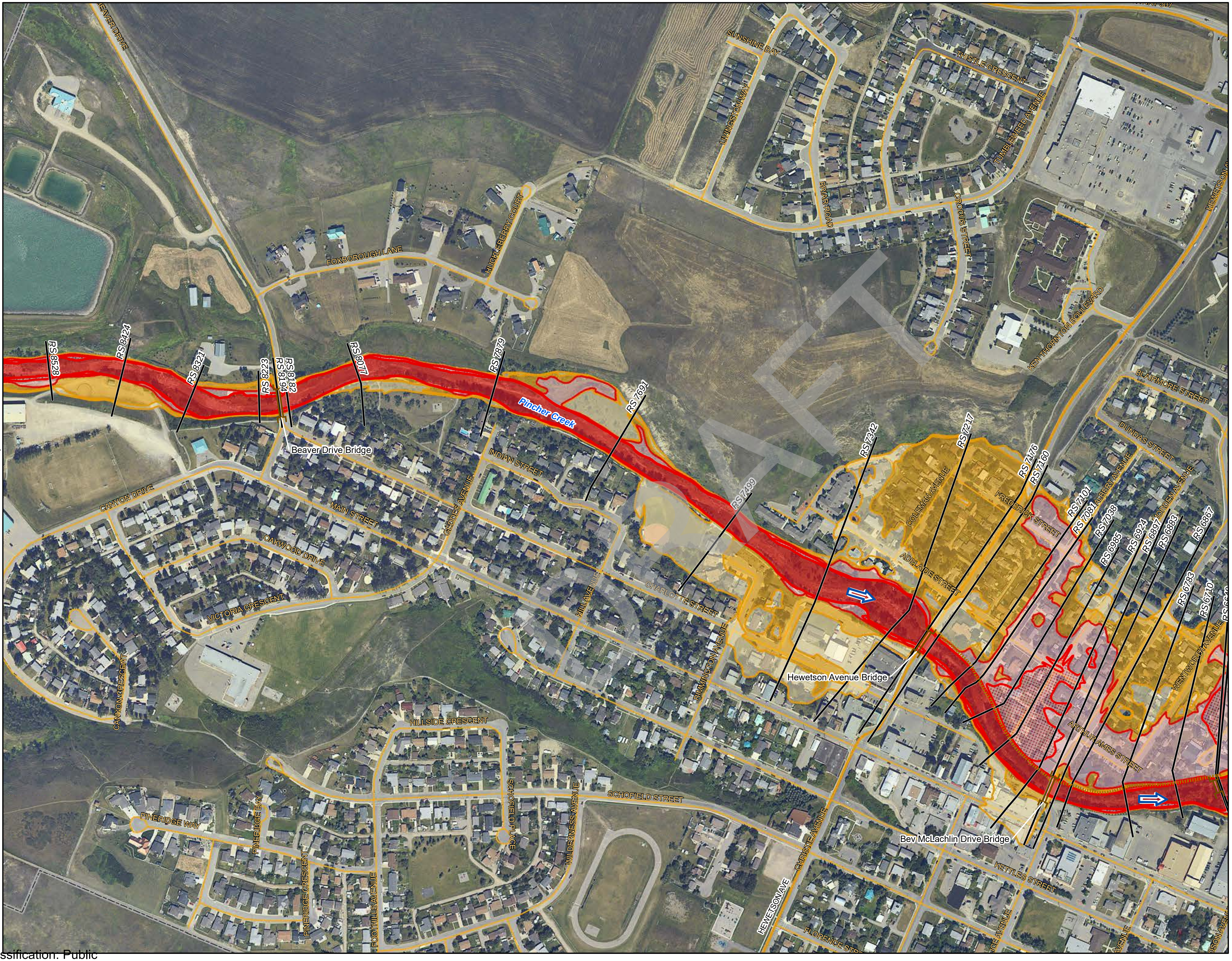
PINCHER CREEK FLOOD HAZARD STUDY

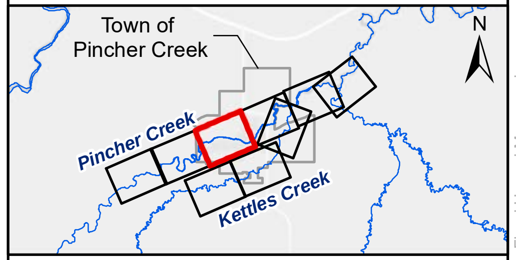
FLOOD HAZARD MAP

SHEET 2 OF 9

Classification: Public

MSN, Z:\ACGY\Alberta\A03285D13 AEP Pincher Creek Modifications\700 Deliverables\741 2022 Digital Study Files\05_Design-Flood-Hazard\GIS\2023-01-31_PincherCreek_FINAL\4. 2023_Pincher Creek_Flood Hazard Maps.mxd





Alberta Government

Klohn Crippen Berger

- FLOW DIRECTION
- CROSS SECTION
- RS 1325 RIVER STATION (M)
- FLOOD CONTROL STRUCTURE
- CULVERT
- BRIDGE
- MAJOR ROAD
- LOCAL ROAD
- MUNICIPAL DISTRICT BOUNDARY
- STUDY LIMIT
- PROPOSED FLOODWAY BOUNDARY
- FLOOD FRINGE
- HIGH HAZARD FLOOD FRINGE
- 200-YEAR FLOOD EXTENT
- 500-YEAR FLOOD EXTENT

DISCHARGE

PINCHER CREEK ABOVE KETTLES CREEK = 214 m³/s

SCALE - 1:5,000

0 100 200 M

Coordinate System: NAD 1983 CSRS 3TM 114

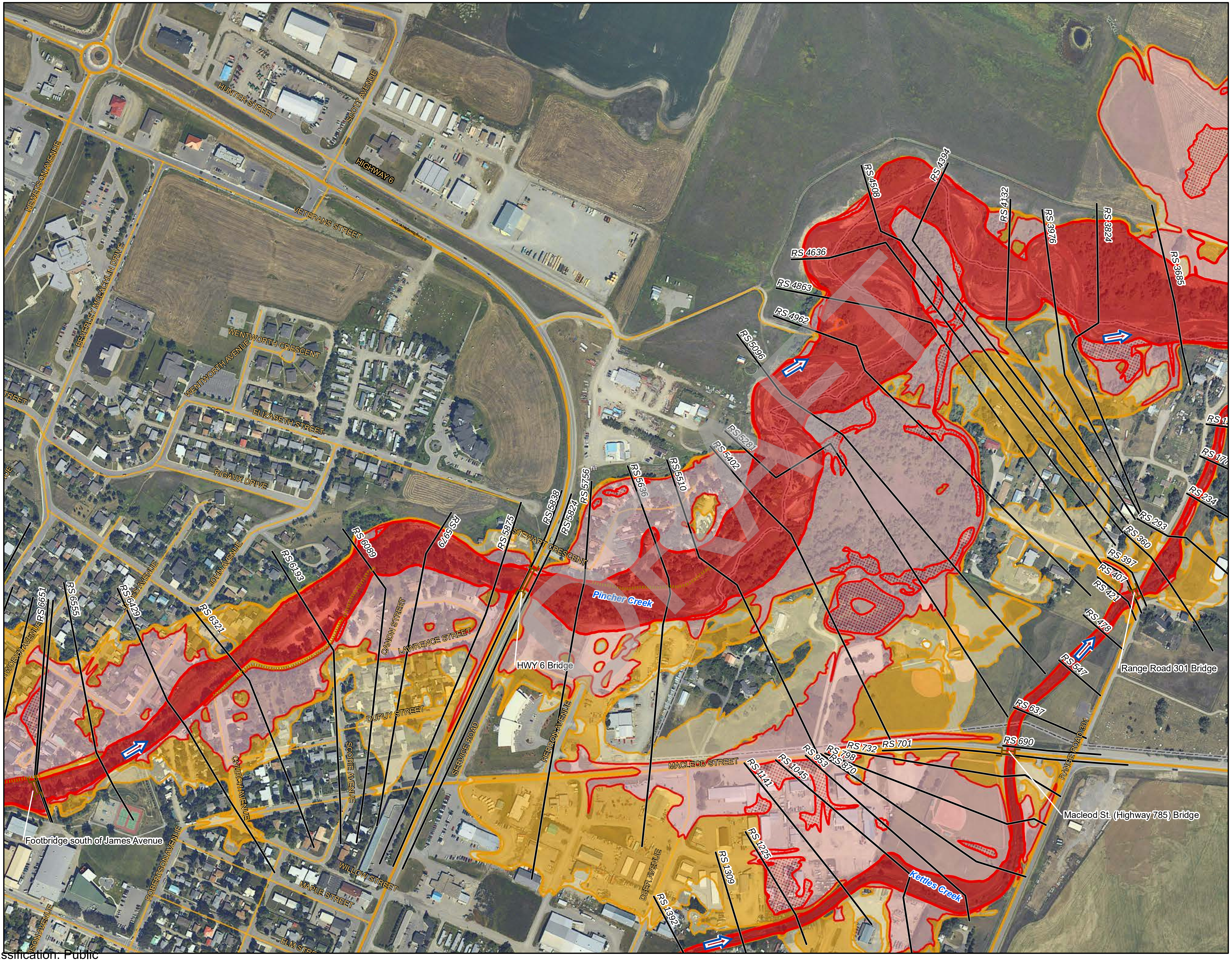
Units: METRES

Engineer	GIS	Reviewer
KC / AS	VC / TS	RJC

Job Number	Date
A03285D13	13-FEB-2023

PINCHER CREEK FLOOD HAZARD STUDY

FLOOD HAZARD MAP



Alberta Government

Klohn Crippen Berger

Town of Pincher Creek

Pincher Creek

Kettles Creek

N

FLOW DIRECTION
CROSS SECTION
RS 1325 RIVER STATION (M)
FLOOD CONTROL STRUCTURE
CULVERT
BRIDGE
MAJOR ROAD
LOCAL ROAD
MUNICIPAL DISTRICT BOUNDARY
STUDY LIMIT
PROPOSED FLOODWAY BOUNDARY
FLOOD FRINGE
HIGH HAZARD FLOOD FRINGE
200-YEAR FLOOD EXTENT
500-YEAR FLOOD EXTENT

DISCHARGE
PINCHER CREEK ABOVE KETTLES CREEK = 214 m³/s
KETTLES CREEK = 36 m³/s

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
KC / AS	VC / TS	RJC

Job Number	Date
A03285D13	13-FEB-2023

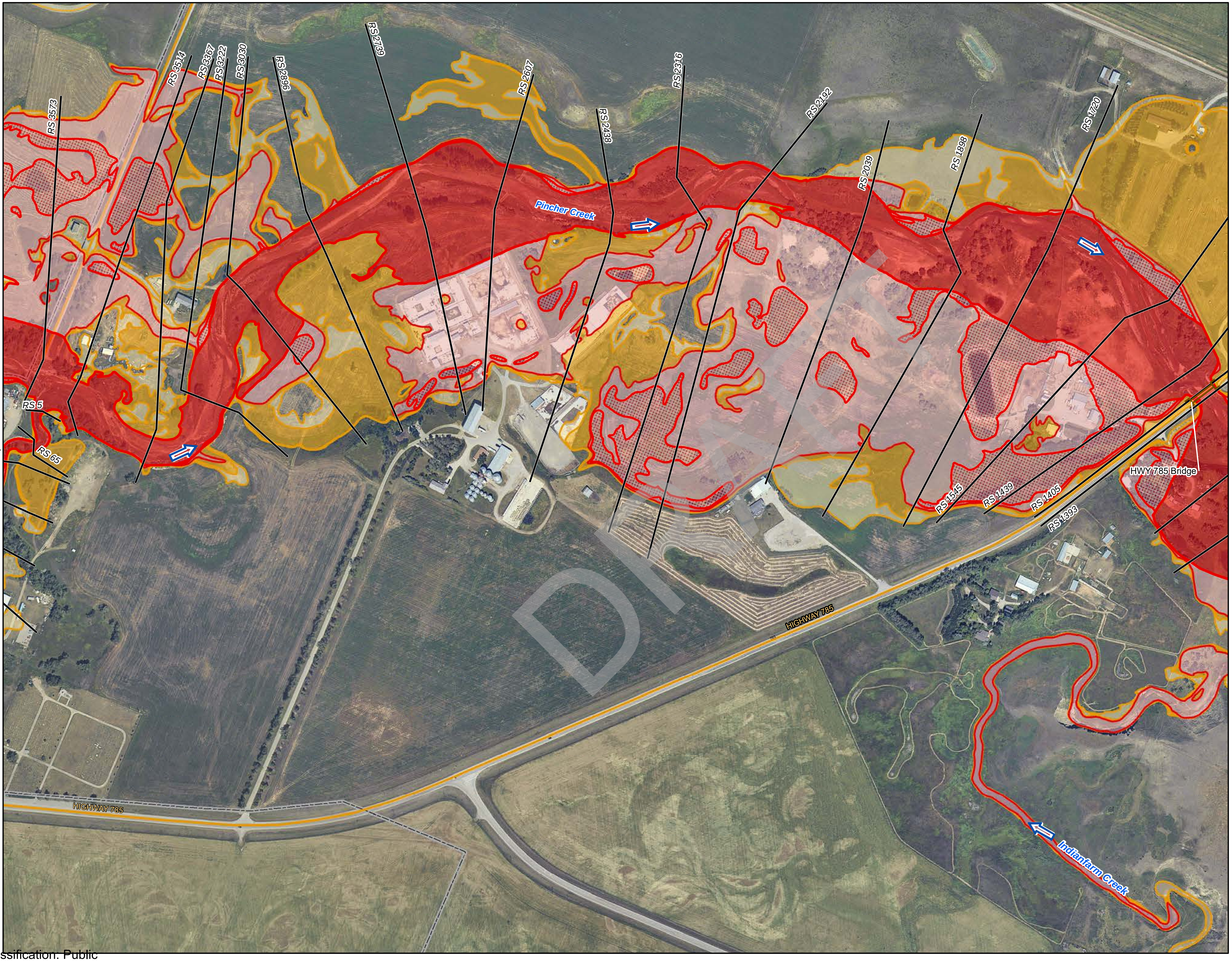
PINCHER CREEK FLOOD HAZARD STUDY

FLOOD HAZARD MAP

SHEET 4 OF 9

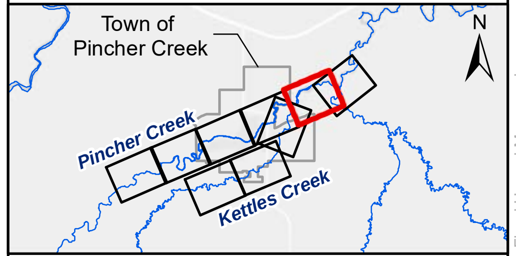
MSN, Z:\ACGY\Alberta\A03285D13 AEP Pincher Creek Modifications\700 Deliverables\741 2022 Digital Study Files\05_Design-Flood-Hazard\GIS\2023-01-31_PincherCreek_FINAL\4_2023_Pincher_Creek_Flood Hazard Maps.mxd

Classification: Public



Alberta Government

Klohn Crippen Berger



- FLOW DIRECTION
- CROSS SECTION
- RS 1325 RIVER STATION (M)
- FLOOD CONTROL STRUCTURE
- CULVERT
- BRIDGE
- MAJOR ROAD
- LOCAL ROAD
- MUNICIPAL DISTRICT BOUNDARY
- STUDY LIMIT
- PROPOSED FLOODWAY BOUNDARY
- FLOOD FRINGE
- HIGH HAZARD FLOOD FRINGE
- 200-YEAR FLOOD EXTENT
- 500-YEAR FLOOD EXTENT

DISCHARGE
PINCHER CREEK ABOVE KETTLES CREEK = 214 m³/s
PINCHER CREEK BELOW KETTLES CREEK = 250 m³/s
KETTLES CREEK = 36 m³/s

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

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

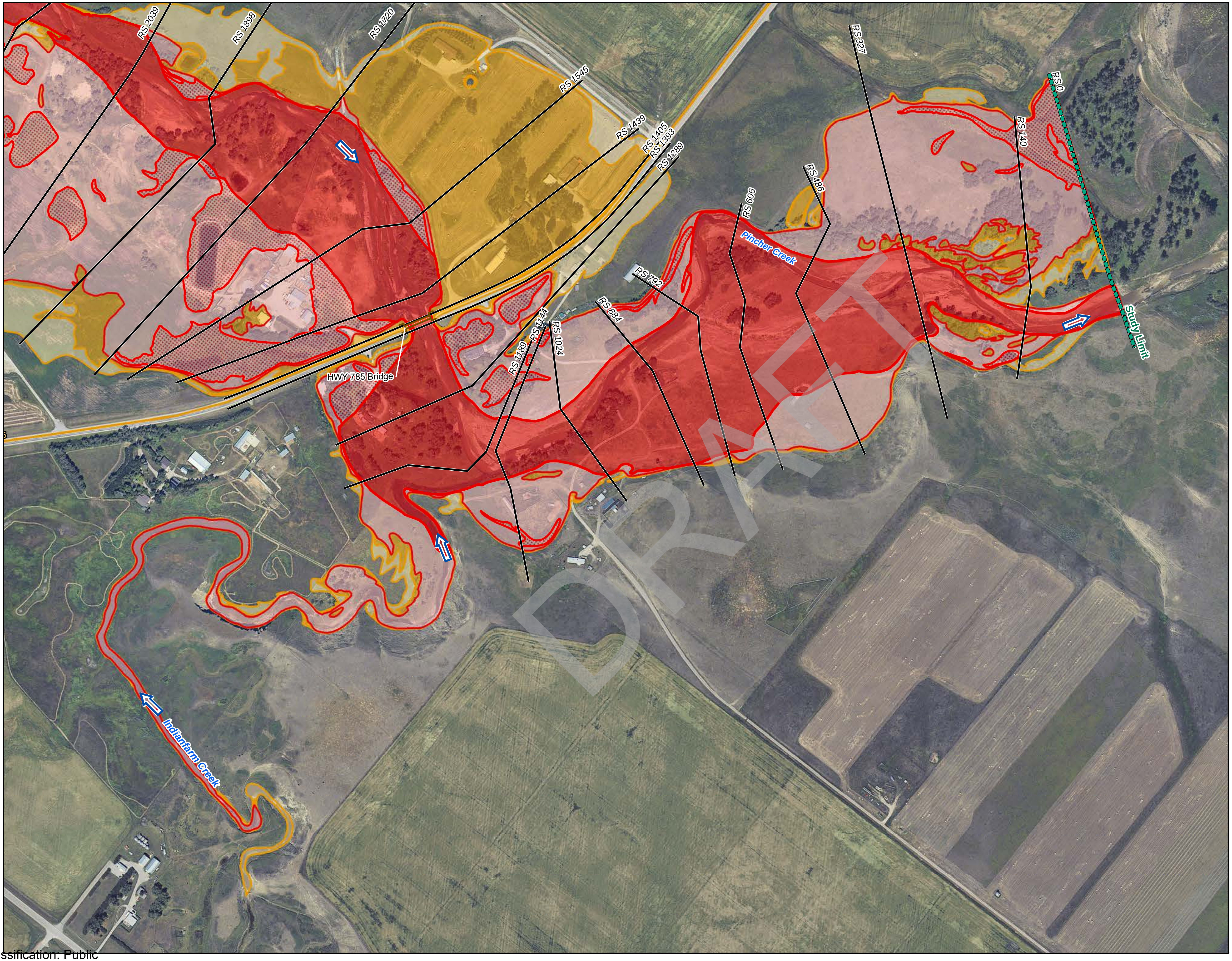
Engineer	GIS	Reviewer
KC / AS	VC / TS	RJC

Job Number	Date
A03285D13	13-FEB-2023

PINCHER CREEK FLOOD HAZARD STUDY

FLOOD HAZARD MAP

MSN, Z:\ACGY\Alberta\A03285D13 AEP Pincher Creek Modifications\700 Deliverables\741 2022 Digital Study Files\05_Design-Flood-Hazard\GIS\2023-01-31_PincherCreek_FINAL4_2023_Pincher_Creek_Flood_Hazard_Maps.mxd

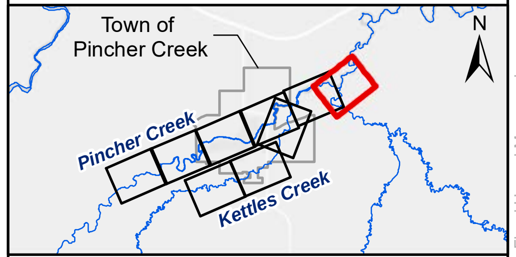


SHEET 5 ↑

SHEET 7 ↓

Alberta Government

Klohn Crippen Berger



- FLOW DIRECTION
- CROSS SECTION
- RS 1325 RIVER STATION (M)
- FLOOD CONTROL STRUCTURE
- CULVERT
- BRIDGE
- MAJOR ROAD
- LOCAL ROAD
- MUNICIPAL DISTRICT BOUNDARY
- STUDY LIMIT
- PROPOSED FLOODWAY BOUNDARY
- FLOOD FRINGE
- HIGH HAZARD FLOOD FRINGE
- 200-YEAR FLOOD EXTENT
- 500-YEAR FLOOD EXTENT

DISCHARGE
PINCHER CREEK BELOW KETTLES CREEK = 250 m³/s
PINCHER CREEK BELOW INDIANFARM CREEK = 385 m³/s

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
KC / AS	VC / TS	RJC

Job Number	Date
A03285D13	13-FEB-2023

PINCHER CREEK FLOOD HAZARD STUDY

FLOOD HAZARD MAP

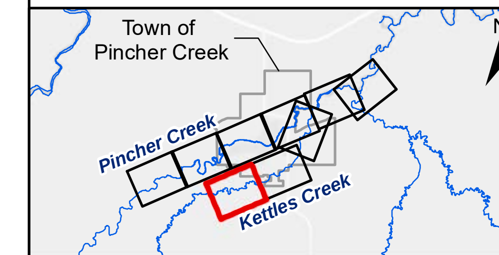
SHEET 6 OF 9

Classification: Public

MSN, Z:\ACGY\Alberta\A03285D13 AEP Pincher Creek Modifications\700 Deliverables\741 2022 Digital Study Files\05_Design-Flood-Hazard\GIS\2023-01-31_PincherCreek_FINAL\4. 2023_Pincher Creek_Flood Hazard Maps.mxd

Alberta Government

Klohn Crippen Berger



FLOW DIRECTION
CROSS SECTION
RS 1325 RIVER STATION (M)
FLOOD CONTROL STRUCTURE
CULVERT
BRIDGE
MAJOR ROAD
LOCAL ROAD
MUNICIPAL DISTRICT BOUNDARY
STUDY LIMIT
PROPOSED FLOODWAY BOUNDARY
FLOOD FRINGE
HIGH HAZARD FLOOD FRINGE
200-YEAR FLOOD EXTENT
500-YEAR FLOOD EXTENT

DISCHARGE
KETTLES CREEK = 36 m³/s

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
KC / AS	VC / TS	RJC

Job Number	Date
A03285D13	13-FEB-2023

PINCHER CREEK FLOOD HAZARD STUDY

FLOOD HAZARD MAP

SHEET 7 OF 9

SHEET 7 ↑

SHEET 9 ↓

Alberta Government

Klohn Crippen Berger

Town of Pincher Creek

Pincher Creek

Kettles Creek

N

FLOW DIRECTION
CROSS SECTION
RS 1325 RIVER STATION (M)
FLOOD CONTROL STRUCTURE
CULVERT
BRIDGE
MAJOR ROAD
LOCAL ROAD
MUNICIPAL DISTRICT BOUNDARY
STUDY LIMIT
PROPOSED FLOODWAY BOUNDARY
FLOOD FRINGE
HIGH HAZARD FLOOD FRINGE
200-YEAR FLOOD EXTENT
500-YEAR FLOOD EXTENT

DISCHARGE
KETTLES CREEK = 36 m³/s

SCALE - 1:5,000

0 100 200 M

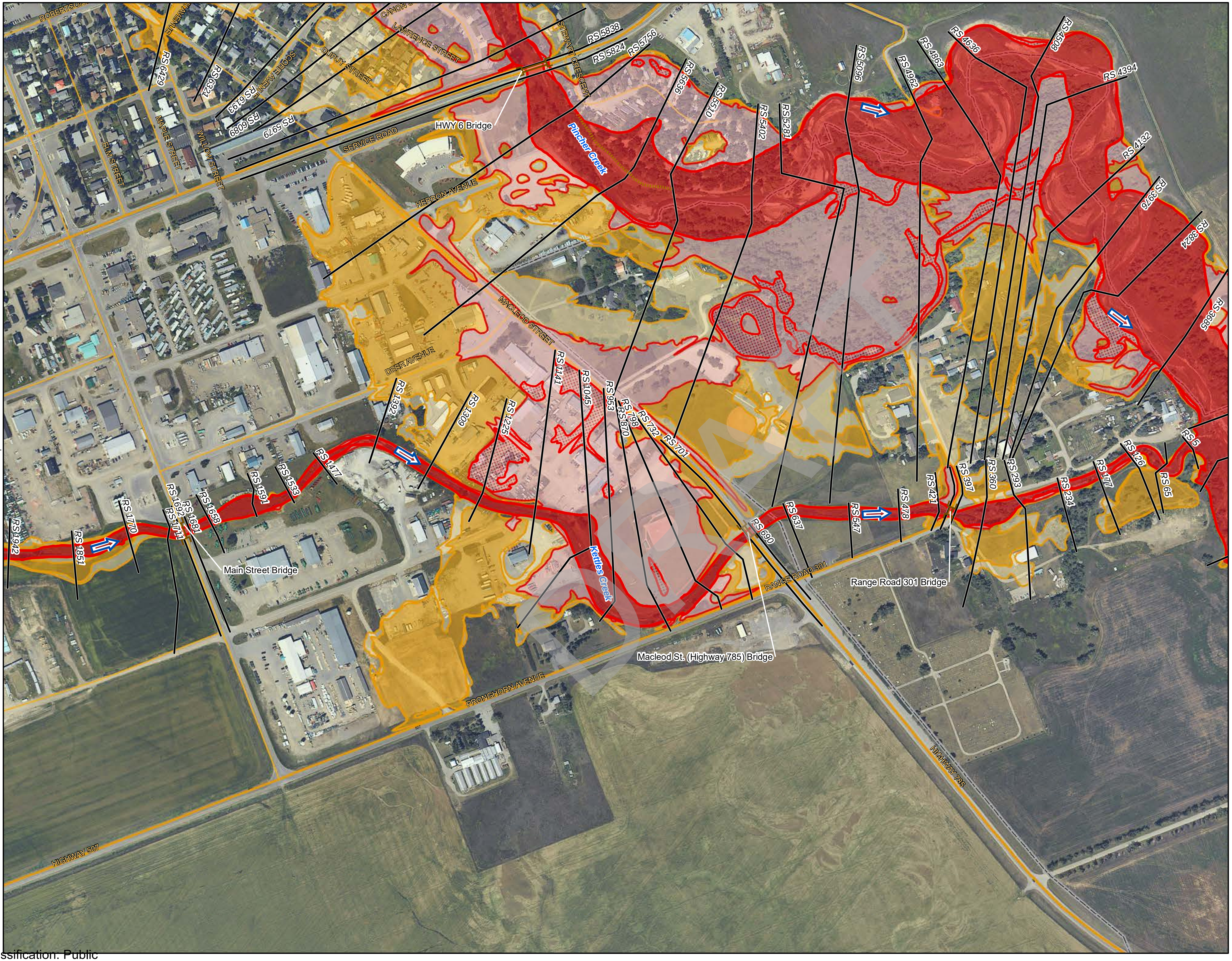
N

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

Engineer KC / AS	GIS VC / TS	Reviewer RJC
Job Number A03285D13	Date 13-FEB-2023	

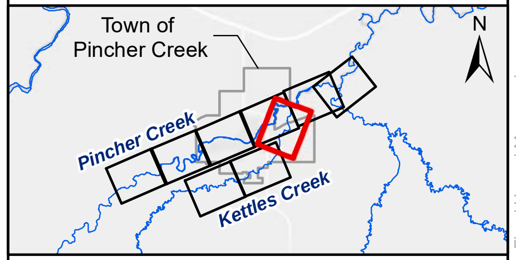
PINCHER CREEK FLOOD HAZARD STUDY

FLOOD HAZARD MAP



Alberta Government

Klohn Crippen Berger



FLOW DIRECTION
CROSS SECTION
RS 1325 RIVER STATION (M)
FLOOD CONTROL STRUCTURE
CULVERT
BRIDGE
MAJOR ROAD
LOCAL ROAD
MUNICIPAL DISTRICT BOUNDARY
STUDY LIMIT
PROPOSED FLOODWAY BOUNDARY
FLOOD FRINGE
HIGH HAZARD FLOOD FRINGE
200-YEAR FLOOD EXTENT
500-YEAR FLOOD EXTENT

DISCHARGE
PINCHER CREEK ABOVE KETTLES CREEK = 214 m^3/s
PINCHER CREEK BELOW KETTLES CREEK = 250 m^3/s
KETTLES CREEK = 36 m^3/s

SCALE - 1:5,000
0 100 200 M

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

Engineer	GIS	Reviewer
KC / AS	VC / TS	RJC

Job Number	Date
A03285D13	13-FEB-2023

PINCHER CREEK FLOOD HAZARD STUDY

FLOOD HAZARD MAP

SHEET 9 OF 9