



DRUMHELLER RIVER HAZARD STUDY

SURVEY AND BASE DATA COLLECTION REPORT



Prepared for:

Alberta



27 March 2020

NHC Ref. No. 1003877

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FINAL REPORT

Prepared for:

Alberta Environment and Parks
Edmonton, Alberta

Prepared by:

Northwest Hydraulic Consultants Ltd.
Edmonton, Alberta

27 March 2020

NHC Ref No. 1003877

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EXECUTIVE SUMMARY

Alberta Environment and Parks retained Northwest Hydraulic Consultants Ltd. in June 2018 to complete a river hazard study for the Town of Drumheller and surrounding areas of Kneehill County, Starland County, Wheatland County, and Special Areas No. 2. The river hazard study area includes 56.1 km of the Red Deer River, 7.9 km of Kneehills Creek, 5.3 km of Michichi Creek, 10.7 km of the Rosebud River, and 3.0 km of Willow Creek. The study is being conducted under the provincial Flood Hazard Identification Program; the overall objectives are to enhance public safety and to reduce future flood damages and disaster assistance costs.

The Drumheller River Hazard Study is comprised of six major project components. This report summarizes the work of the first component: **Survey and Base Data Collection**. This study component includes river cross section surveys, hydraulic and flood control structure data collection, survey and digital terrain model comparison, and aerial imagery coverage confirmation.

The survey program was carried out between July and September 2018, preceded by a site inspection in June 2018. A total of 444 river cross sections were surveyed, including 210 on the Red Deer River, 60 on Kneehills Creek, 41 on Michichi Creek, 120 on the Rosebud River, and 13 on Willow Creek. In addition, a total of 35 bridges, two sets of abandoned bridge piers, one culvert, and seven flood control structures (or “dikes”) were surveyed along the study reaches. Survey data and reach-representative photographs are provided with the geodatabase that accompanies this report. The overall accuracy of the survey is estimated to be ± 0.05 m for ground survey points and ± 0.07 m for boat-based measurements obtained using the digital echo sounder.

Additional base data collected includes bridge file information from Alberta Transportation, hydrometric station information and data from Water Survey of Canada, and design information for flood control structures from the Town of Drumheller, Alberta Environment, Alberta Transportation, and Alberta Infrastructure. This information will be used in subsequent components of the study.

A comparison of the LiDAR-derived DTM and the ground survey indicates that the two data sets are spatially-consistent. In other words, the DTM supplied by Alberta Environment and Parks is suitable for overbank cross section extraction and flood mapping in this river hazard study. Also, based on the DTM and preliminary estimates for the 1000-year flood extent, the aerial imagery extents proposed by Alberta Environment and Parks were found to provide sufficient coverage.

CREDITS AND ACKNOWLEDGEMENTS

Northwest Hydraulic Consultants Ltd. would like to express appreciation to Alberta Environment and Parks for initiating this project, making extensive background information available, and providing the project team with valuable technical input throughout the project. Mr. Peter Bezeau and Ms. Jane Eaket managed and directed the Drumheller River Hazard Study on behalf of Alberta Environment and Parks.

The following NHC personnel were part of the study team and participated in the survey and base data collection component of the study:

- Robyn Andrishak (Project Manager) – responsible for the overall direction of the project and survey program; author of this report.
- James Snyder (Survey Specialist) – assisted with field program coordination and surveys; reduced and post-processed survey data for subsequent use; co-author of this report.
- Agata Hall (Hydraulic Modelling Specialist) – participated in the site inspection and preparation of this report.
- Sarah North (GIS Specialist) and Makamum Mahmood (Project Engineer) – responsible for development of base maps.
- Gary Van Der Vinne (Senior Technical Reviewer) – provided senior review input and advice.

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LIST OF ABBREVIATIONS

Acoustic Doppler Current Profiler	ADCP
Acoustic Doppler velocimeter	ADV
Alberta Environment and Parks	AEP
Alberta Health Services	AHS
Alberta Survey Control Monuments	ASCM
Alberta Transportation	AT
Bridge File	BF
Canadian Geodetic Vertical Datum of 1928	CGVD28
Canadian Spatial Reference System	CSRS
Canadian Spatial Reference System Precise Point Positioning	CSRS-PPP
Control point	CP
Digital terrain model	DTM
Global Navigation Satellite Systems	GNSS
Light Detection and Ranging	LiDAR
North American Datum of 1983	NAD83
Northwest Hydraulic Consultants Ltd.	NHC
Planned cross section	PXS
Real Time Kinematic	RTK
Semi-permanent benchmarks	SPBM
Three-degree Transverse Mercator	3TM
Top of bank	TOB
Water Survey of Canada	WSC

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1 INTRODUCTION

1.1 Study Background

The Drumheller River Hazard Study was initiated by Alberta Environment and Parks (AEP) to identify and assess river and flood hazards along the Red Deer River, Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek within the Town of Drumheller and surrounding areas of Kneehill County, Starland County, Wheatland County, and Special Areas No. 2. A flood hazard mapping study was previously completed for the Drumheller area by Matrix Solutions (2007); however, the present study covers an expanded study reach and will represent a significant update to the prior work.

Results from this study are designed to inform local land use planning decisions, flood mitigation projects, and emergency response planning. This study is being undertaken as part of the Flood Hazard Identification Program (FHIP) with the intent of enhancing public safety and reducing future flood damages within the Province of Alberta.

This river hazard study is comprised of six major study components:

- 1) Survey and Base Data Collection
- 2) Open Water Hydrology Assessment
- 3) Hydraulic Modelling and Flood Inundation Mapping
- 4) Design Flood Hazard Mapping
- 5) Flood Risk Assessment and Inventory
- 6) Channel Stability Investigation

Each component includes a separate report and associated deliverables for that portion of the study.

1.2 Study Objectives

This report summarizes the work of the **Survey and Base Data Collection** study component. The objectives of this study component were to complete:

- River cross section surveys
- Hydraulic and flood control structure data collection
- Survey and digital terrain model (DTM) data comparisons
- Confirmation of the aerial imagery coverage area

The collection of survey and base data supports development of the hydraulic model and subsequent project components.

1.3 Study Area and Reach

The Town of Drumheller is located along the Red Deer River, approximately 100 km northeast of the City of Calgary and 115 km southeast of the City of Red Deer. **Figure 1** shows the location and boundaries of the river hazard study area and provides an overview of the upstream watershed boundaries. The study area includes the following river reaches and Alberta Township System quarter section boundaries:

- 56.1 km of the Red Deer River from the northern boundary of NW/NE-27-29-21-W4M to the southern boundary of SW/SE-3-27-17-W4M
- 7.9 km of Kneehills Creek from the western boundary of SE-15-29-21-W4M to the Red Deer River
- 5.3 km of Michichi Creek from the eastern boundary of SE-13-29-20-W4M to the Red Deer River
- 10.7 km of the Rosebud River from the southern boundary of SW-7-28-19-W4M to the Red Deer River
- 3.0 km of Willow Creek from the eastern boundary of NE-7-28-18-W4M to the Red Deer River

River cross section surveys extended beyond these boundaries to accommodate hydraulic modelling and inundation mapping requirements. Local authorities within the study area include the Town of Drumheller, Kneehill County, Starland County, Wheatland County, and Special Areas No. 2.

The contributing watershed covers a total area of about 29,970 km², extending from the headwaters of the Red Deer River in the Rocky Mountains to the downstream boundary of the river hazard study area. The Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek sub-basins account for 2,440, 1,170, 4,360, and 400 km² of the total watershed area, respectively. Floods are typically derived from rapid spring snowmelt augmented by heavy rainfall events, although the nature and timing of flooding on the tributary reaches is typically unique and independent of those experienced by the Red Deer River.

Dickson Dam is located approximately 250 km upstream of the study area. The primary purpose of the dam and associated reservoir is to provide flow augmentation and assist with water quantity and quality downstream. A secondary benefit of the dam and reservoir is attenuation of peak river flows (Stantec, 2014). Other small flow regulation and diversion projects exist on tributaries between Dickson Dam and Drumheller.

2 SURVEY PROGRAM

2.1 Methodology and Procedures

The survey program was completed between July and September 2018, some additional surveying conducted in January 2019. The objective of the survey program was to survey channel cross sections along the study reach to support development of a one-dimensional (1D) hydraulic model.

Once the control network was established (as described in Section 2.1.2), horizontal and vertical coordinates were surveyed using Trimble R10 Real Time Kinematic (RTK) Global Navigation Satellite Systems (GNSS) receivers. Boat-based surveys of the Red Deer River were done using an Odom Hydrotrac single-frequency digital echosounder with chart plotter to measure water depth (typically in areas covered by water deeper than 0.30 m) and the GNSS receiver to record position and elevation of the transducer. River bed elevations were derived from depth soundings by subtracting depth from the transducer elevation. Elsewhere, the GNSS receivers were mounted on a survey rod to record ground elevations directly. The channel banks and a portion of the overbank floodplains were surveyed to ensure overlap with the supplied LiDAR-derived DTM.

2.1.1 Coordinate System and Datum

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

2.1.2 Control Network

A control point (CP) network was established based on long-term GNSS observations and the Canadian Spatial Reference System Precise Point Positioning (CSRS-PPP) service provided by Natural Resources Canada (2017). Two Alberta Survey Control Monuments (ASCM) were used in the CP network along with thirteen semi-permanent benchmarks (SPBM) established by NHC for the survey program. The SPBMs consisted of 0.9 m long rebar with an aluminum cap. A list of CP coordinates is provided in **Table 1**.

CP coordinates were determined by simultaneously logging static GNSS positions for approximately one hour (or longer) at two to four CPs. Static baselines were post-processed and control network adjustment were performed using Trimble Business Center software. The two CPs having the smallest reported CSRS-PPP coordinate error estimates were used to constrain and minimize the errors in the network adjustment (refer to Section 2.7.1). CSRS-PPP and ASCM coordinates for CPs that are included within the NAD83 CSRS subset data published by AEP (2018) were used to validate the adjusted CP coordinates. The baseline processing, network adjustment, and CSRS-PPP reports are provided in **Appendix A** for information.

Surveyed coordinates for three additional local ASCMs, not used in the control network, are provided for reference in **Table 2**.

Table 1 Control point summary

Point Name	Type	Easting (m)	Northing (m)	Elevation (m)
NHC1	SPBM	78,975.986	5,705,411.571	698.545
NHC2	SPBM	80,248.791	5,707,604.347	693.226
470732	ASCM	82,946.070	5,705,141.085	699.947
NHC4	SPBM	87,014.401	5,705,189.967	777.691
NHC5	SPBM	90,441.680	5,705,779.995	691.031
NHC6	SPBM	91,961.575	5,701,840.312	685.465
NHC7	SPBM	95,048.094	5,699,272.053	686.955
NHC8	SPBM	93,349.459	5,697,613.100	689.899
NHC9	SPBM	92,971.264	5,695,936.533	702.269
NHC10	SPBM	92,850.971	5,694,004.216	706.598
440966	ASCM	98,156.258	5,696,784.261	684.331
NHC12	SPBM	101,903.190	5,694,753.371	678.998
NHC13	SPBM	106,124.490	5,689,025.736	682.881
NHC15	SPBM	113,172.339	5,686,264.263	679.439
NHC16	SPBM	118,574.973	5,682,294.778	676.781

Table 2 Surveyed coordinates for ASCMs not used in the control network

Point Name	Observation Type	Easting (m)	Northing (m)	Elevation (m)
333831	RTK	87,207.991	5,703,870.120	683.491
361741	RTK	93,348.248	5,697,612.653	689.747
376970	RTK	105,887.769	5,689,657.504	683.185

2.2 Cross Sections

River cross section locations were selected to ensure adequate representation of the channel geometry in the hydraulic model. The cross section survey was divided into reaches corresponding to the river or creek being surveyed. During the planning process for the survey, each river cross section was assigned a planned cross section (PXS) identifier to organize the cross sections sequentially on each water body and to associate survey point data with a corresponding cross section line. River cross section lines and associated survey points are shown in **Figure 2**.

A summary of the river cross sections surveyed in each reach is provided in **Table 3**. In total, 444 cross sections were surveyed, with coverage extending 537 m and 2302 m beyond the upstream and downstream study area boundaries of the Red Deer River, respectively. The farthest upstream river cross sections on Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek extended 107 m, 24 m, 158 m, and 114 m, respectively, to ensure adequate coverage for flood mapping. Cross section details are provided in **Appendix B**, where thalweg elevation was taken as the minimum surveyed elevation at each cross section and the top of bank (TOB) channel width was determined based on the survey data codes recorded by the survey crews. These values may be refined upon further inspection of the LiDAR-derived DTM data and cross section profiles during development and calibration of the hydraulic model.

Table 3 River cross section survey summary

Stream	Reach Length (m)	Number of Cross Sections	Average Spacing (m)	Minimum Spacing (m)	Maximum Spacing (m)
Red Deer River	56,139	210	269	15	604
Kneehills Creek	7,869	60	132	12	275
Michichi Creek	5,335	41	129	9	248
Rosebud River	10,702	120	89	7	238
Willow Creek	2,970	13	223	15	371

2.3 Longitudinal Profiles

Longitudinal profiles of surveyed thalweg and water levels for the Red Deer River, Kneehills Creek, Michichi Creek, Rosebud River, and Willow Creek are presented in **Figure 3**. Since water levels were surveyed over a ten week period between 10 July and 21 September 2018, the discharge associated with these measurements varied.

2.4 Hydraulic Structures

Table 4 summarizes the hydraulic structures in the study reach, along with Alberta Transportation (AT) Bridge File (BF) numbers, where applicable. A total of 35 bridges and one culvert were identified and surveyed within the study area. Two additional sets of abandoned bridge piers also exist on the Red Deer River, one from a railway bridge and the other from a highway bridge. Both are located immediately upstream of the Highway 10 bridge (BF 73277) at Cambria. There are no weirs spanning the Red Deer River or any of the tributaries within the study reaches. Hydraulic structure locations are shown in **Figure 2**.

Table 4 Hydraulic structure summary

River Station (m)	Structure Type	Description
Red Deer River		
44,430	Railway Bridge	Newcastle Mine Railway Bridge
40,815	Highway Bridge	Highway 56 Bridge at Drumheller
32,502	Road Bridge	Roper Road Bridge at Rosedale
31,204	Pedestrian Bridge	Star Mine Suspension Bridge
28,264	Abandoned Piers	Abandoned Piers (Railway Bridge)
28,204	Abandoned Piers	Abandoned Piers (Highway Bridge)
27,931	Highway Bridge	Highway 10 Bridge 8 km SE of Drumheller
16,778	Railway Bridge	Atlas Coal Mine Railway Bridge
16,259	Highway Bridge	Highway 10 Bridge at East Coulee
3,897	Highway Bridge	Highway 848 Bridge at Dorothy
Kneehills Creek		
3,017	Road Bridge	Range Road 211A Bridge
1,591	Highway Bridge	Highway 575 Bridge near Nacmine
Michichi Creek		
2,583	Road Bridge	Local Road (Unnamed Road) Bridge
2,435	Private Bridge	Private Road Access Bridge
1,326	Culvert	Highway 9 over Michichi Creek at Drumheller
1,009	Highway Bridge	Highway 838 Bridge in Drumheller
Rosebud River		
9,609	Railway Bridge	Abandoned Railway Bridge 9
9,562	Highway Bridge	Highway 10X (Historical Bridge No. 11)
8,697	Highway Bridge	Highway 10X (Historical Bridge No. 10)
8,668	Railway Bridge	Abandoned Railway Bridge 8
8,069	Railway Bridge	Abandoned Railway Bridge 7
7,947	Highway Bridge	Highway 10X (Historical Bridge No. 9)
7,315	Highway Bridge	Highway 10X (Historical Bridge No. 8)
7,233	Railway Bridge	Abandoned Railway Bridge 6
6,458	Railway Bridge	Abandoned Railway Bridge 5
6,370	Highway Bridge	Highway 10X (Historical Bridge No. 7)

Table 4 Hydraulic structure summary (continued)

River Station (m)	Structure Type	Description
Rosebud River (continued)		
5,892	Railway Bridge	Abandoned Railway Bridge 4
5,863	Highway Bridge	Highway 10X (Historical Bridge No. 6)
5,461	Highway Bridge	Highway 10X (Historical Bridge No. 5)
4,988	Highway Bridge	Highway 10X (Historical Bridge No. 4)
4,518	Highway Bridge	Highway 10X (Historical Bridge No. 3)
4,490	Railway Bridge	Abandoned Railway Bridge 3
2,245	Railway Bridge	Abandoned Railway Bridge 2
2,125	Highway Bridge	Highway 10X (Historical Bridge No. 2)
1,140	Highway Bridge	Highway 10X (Historical Bridge No. 1)
542	Highway Bridge	Highway 10 Bridge at Rosedale
340	Railway Bridge	Abandoned Railway Bridge 1
Willow Creek		
856	Highway Bridge	Highway 10 Bridge 10.5 km NW of East Coulee

Additional bridge and culvert details are provided in **Appendix C**. The data collected at each bridge includes: span length; deck width; top of curb or solid guardrail elevations; low chord elevations; number, width, type, shape, and location of piers; top of deck elevations; and photographs of the bridge. Culvert information collected includes: culvert type, shape, dimensions and length; entrance condition; upstream and downstream invert elevations; road elevations; and photographs of the culvert.

2.5 Flood Control Structures

There are seven dikes in the study area that were identified as dedicated flood control structures (**Table 5**), of which six are owned by AEP and one is owned by Alberta Health Services (AHS). All of these dikes are located along the Red Deer River, with one (Dike B) also extending into Michichi Creek. **Appendix D** provides an overview of the locations of these dikes and representative photographs of each structure. Crest elevation profiles and cross sections at key locations were surveyed along the flood control structures. Where the dikes included concrete barriers above the earthen embankment, both the top of the barrier and the crest of the earthen embankment were surveyed.

Table 5 Flood control structure summary

Name and Description	Owner	Stream	River Station (m)		Crest Length (m)
			Start	End	
Midland Dike North side of Red Deer River, adjacent to Midlandvale	AEP	Red Deer River	44,420	42,942	1,610
Newcastle Dike South side of Red Deer River, adjacent to Newcastle	AEP	Red Deer River	43,452	41,856	1,541
Hospital Dike North side of Red Deer River, adjacent to Drumheller Heath Centre	AHS	Red Deer River	42,341	41,734	511
Dike B East side of Michichi Creek and north side of Red Deer River, west of Bridge Street (Highway 56)	AEP	Red Deer River	41,346	40,844	962
	AEP	Michichi Creek	535	0	
Dike C North side of Red Deer River, east of Bridge Street (Highway 56)	AEP	Red Deer River	40,796	40,528	326
Dike D South side of Red Deer River from the Aquaplex to 5 Street E, north of 4 Avenue E	AEP	Red Deer River	40,712	39,549	1,063
East Coulee Dike North side of Red Deer River between 9 Street and 4 Street in East Coulee	AEP	Red Deer River	18,440	17,640	902

2.6 Other Data

2.6.1 Discharge Measurements

Discharge measurements were carried out along the Red Deer River, Kneehills Creek, and Rosebud River to support hydraulic model creation and calibration. Discharges along the Red Deer River were measured using a boat-mounted Sontek M9 RiverSurveyor Acoustic Doppler Current Profiler (ADCP) which has an accuracy of $\pm 0.25\%$ of measured velocity and can provide measurements in depths ranging from 0.06 m to 40 m. Discharges along Kneehills Creek and Rosebud River were measured with a Sontek FlowTracker Acoustic Doppler velocimeter (ADV) mounted to a wading rod. This instrument measures velocity with an accuracy of ± 2.5 mm/s. Discharges were measured using Water Survey of Canada (WSC) standard procedures. **Table 6** includes a summary of the date, location, and discharge measurement details.

Table 6 Discharge measurement summary

Reach	Survey Date	River Station (m)	Total Discharge (m3/s)	Instrumentation Method
Kneehills Creek	19 September 2018	5,529	0.0722	ADV
Rosebud River	20 September 2018	391	2.91	ADV
Red Deer River (1)	20 September 2018	54,234	19.1	ADCP
Red Deer River (2)	20 September 2018	39,423	22.3	ADCP
Red Deer River (3)	21 September 2018	19,493	25.1	ADCP

2.6.2 Water Survey of Canada Benchmarks

WSC benchmarks were surveyed at the two gauging station located within the study area. **Table 7** lists the surveyed benchmarks at each gauging station and compares their published and surveyed elevations. Based on the data collected, the published benchmark elevations at Station 05CE001 were on average 0.24 m lower than the NHC surveyed values. The reason for this difference is unknown. Much smaller differences were found for the Michichi Creek gauge that are within the expected accuracy of the RTK GNSS receiver. Detailed station descriptions from WSC are provided in **Appendix E** for reference.

Table 7 Water Survey of Canada gauging station benchmark summary

Station Name (ID)	River Station (km)	Benchmark Name	Elevation (m)		
			Published	Surveyed	Difference
Red Deer River at Drumheller (05CE001)	40,835	*BM-1	684.849	684.553	-0.296
		TBM-98-1	683.086	682.904	-0.182
Michichi Creek at Drumheller (05CE020)	1,017	*BM-03-1	684.799	684.802	0.003
		MP-2010	685.048	685.011	-0.037

Note: * Indicates a WSC primary benchmark.

2.6.3 Site Photographs

Appendix F provides annotated reach representative photographs obtained during the 2018 site inspection and survey program. The location, time, and other metadata information are imbedded in the electronic images.

2.7 Accuracy

2.7.1 Control Network

Easting, northing, and elevation error estimates were computed in Trimble Business Center for each of the CPs in the control network adjustment; the results are provided in **Table 8**. The coordinates for ASCM 470732 and NHC6 were constrained (i.e. fixed) to their reported CSRS-PPP values. The largest horizontal and vertical errors resulting from network adjustment were 0.016 m and 0.022 m, respectively.

The horizontal and vertical residuals between surveyed CP coordinates in the control network, after post-processing and adjustment, and the reported CSRS-PPP coordinates are provided in **Table 9**. The largest horizontal and vertical residual was +0.082 m and -0.058 m, respectively. A comparison between the surveyed CP coordinates and published ASCM coordinates is provided in **Table 10**. It should be noted that only ASCM 333831 is part of the NAD83 CSRS subset referred to in **Section 2.1.2**. However, the coordinate offsets are within the typical range for published ASCM coordinates. The mean of the elevation offsets in **Table 10** is -0.006 m, which indicates good vertical agreement between the control network and local ASCMs. Attempts made to locate and survey ASCM 428433 for one additional set of comparison coordinates were unsuccessful.

Table 8 Adjusted Network Error 95% Precision Confidence Level

Point Name	Point ID	Easting (m)	Northing (m)	Elevation (m)
NHC1	BASE_1	0.004	0.005	0.017
NHC2	BASE_2	0.004	0.005	0.016
470732	ASCM470732	N/A ¹	N/A ¹	N/A ¹
NHC4	BASE_4	0.003	0.004	0.012
NHC5	BASE_5	0.004	0.004	0.016
NHC6	BASE_6	N/A ¹	N/A ¹	N/A ¹
NHC7	BASE_7	0.004	0.005	0.016
NHC8	BASE_8	0.004	0.004	0.014
NHC9	BASE_9	0.004	0.005	0.011
NHC10	BASE_10	0.006	0.007	0.017
440966	ASCM440966	0.006	0.007	0.018
NHC12	BASE_12	0.007	0.009	0.020
NHC13	BASE_13	0.009	0.011	0.022
NHC15	BASE_15	0.011	0.013	0.016
NHC16	BASE_16	0.013	0.016	0.011

Note: 1. Coordinate was constrained in the network adjustment.

Table 9 Comparison between surveyed control point coordinates and reported CSRS-PPP values

Point Name	Residuals (Surveyed Minus CSRS-PPP)		
	Easting (m)	Northing (m)	Elevation (m)
NHC1	-0.018	-0.008	-0.058
NHC2	-0.017	-0.002	-0.037
470732	0.000	0.000	0.000
NHC4	-0.026	0.002	-0.035
NHC5	0.003	0.002	-0.006
NHC6	0.000	0.000	0.000
NHC7	0.011	-0.007	-0.026
NHC8	0.007	-0.007	-0.009
NHC9	0.014	-0.022	-0.003
NHC10	0.022	-0.034	-0.013
440966	0.030	-0.002	0.006
NHC12	0.038	-0.017	0.001
NHC13	0.036	-0.019	0.008
NHC15	0.045	-0.023	-0.027
NHC16	0.082	-0.035	0.030

Table 10 Alberta Survey Control Monument coordinate offsets

ASCM Number	Measurement Mode	Offset (Surveyed Minus Published)		
		Easting (m)	Northing (m)	Elevation (m)
333831	RTK	-0.027	-0.087	-0.004
376970	RTK	0.002	-0.010	-0.034
440966	Static	-0.012	-0.032	0.035
470732	Static	0.009	-0.130	-0.022

2.7.2 Cross Sections and Other Features

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

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3 ADDITIONAL BASE DATA

3.1 Digital Terrain Model

LiDAR data were collected for AEP by Airborne Imaging in May 2018 under a separate contract. The fully-processed and hydro-flattened bare earth DTM was provided in December 2018. The LiDAR derived DTM is reported to have a vertical accuracy of ± 0.15 m at 95% on hard, flat, open surfaces, based on a set of independently collected verification points.

DTM elevations were compared with elevations obtained by NHC at selected ground topography survey coordinates. Based on 5092 sampled spot ground elevations, surveyed values were within 0.01 m of the DTM elevation on average, with 95% of the samples within 0.39 m. Since the sample set included some sloping portions of the river banks where larger magnitude differences between the survey and DTM are to be expected, these results indicate good agreement between the survey and the DTM data.

3.2 Aerial Imagery

Orthorectified aerial imagery will be collected by Orthoshop Geomatics Ltd. for AEP in 2019. A preliminary estimate of the 1000-year flood extent was found to be contained well inside the aerial imagery coverage area proposed by AEP, confirming that the coverage area is sufficient.

3.3 Bridges and Culverts

NHC obtained bridge files and available design drawings from Alberta Transportation and the Town of Drumheller for the following 14 structures:

Red Deer River

- Highway 56 Bridge at Drumheller (BF06615)
- Roper Road Bridge at Rosedale (BF07329)
- Star Mine Suspension Bridge (BF74796)
- Highway 10 Bridge 8km SE of Drumheller (BF73277)
- Highway 10 Bridge at East Coulee (BF73077)
- Highway 848 Bridge at Dorothy (BF71085)

Michichi Creek

- Highway 9 over Michichi Creek at Drumheller (BF07524)
- Highway 838 Bridge in Drumheller (BF08584)

Kneehills Creek

- Highway 575 Bridge near Nacmine (BF13486)

Rosebud River

- Highway 10X (Historical Bridge No. 9) (BF08935)
- Highway 10X (Historical Bridge No. 4) (BF70512)
- Highway 10X (Historical Bridge No. 1) (BF70817)
- Highway 10 Bridge at Rosedale (BF08719)

Willow Creek

- Highway 10 Bridge 10.5 km NW of East Coulee (BF71746)

The available bridge details and summary sheets are provided in **Appendix C**.

3.4 Hydrometric Data

Current and historical rating curves, water level, and discharge records from WSC hydrometric gauging stations in the study area were obtained to support the open water hydrology assessment, hydraulic model creation and calibration, and channel stability investigation project components.

3.5 Base Mapping Features

The following data sets were obtained to support modelling and mapping during the study:

- Administrative – such as city, town, and county boundaries
- Land use / land cover
- Transportation – road and rail networks
- Facilities – such as boat launches
- Historic flood reports and mapping

3.6 Highwater Mark Reports

AEP provided highwater mark reports that document water levels that occurred during significant flood events within the study area. Water level measurements corresponding to the peak discharge of each flood event are required to calibrate the hydraulic model. Highwater marks are available for floods from 1915, 1954, 1990, 2005, 2013, and 2018 (**Table 11**); however, the reports for floods prior to 2018 do not include any highwater mark information for the tributary reaches in the study area. The Alberta Transportation bridge file database lists additional highwater marks on Red Deer River, Kneehills Creek, Michichi Creek and Rosebud River, but most of these observations are associated with ice jam floods or unspecified flood dates.

An additional 36 highwater marks along the Red Deer River, associated with the June 2005 flood, are documented in the previous Drumheller Flood Risk Mapping Study (Matrix 2007). These data were collected by Hunter Surveys for the Town of Drumheller. During the 2018 survey program, NHC noted and recorded a total of 73 apparent highwater marks believed to be associated with the April 2018 flood.

Table 11 Summary of highwater mark observations

Flood Date	Source	Number of Highwater Marks				
		Red Deer River	Kneehills Creek	Michichi Creek	Rosebud River	Willow Creek
28 June 1915	AEP	1	-	-	-	-
	AT	2	-	-	-	-
27 August 1954	AEP	4	-	-	-	-
	AT	1	-	-	-	-
5 June 1990	AEP	9	-	-	-	-
21 June 2005	AEP	12	-	-	-	-
23 June 2013	AEP	11	-	-	-	-
24 April 2018	AEP	-	7	4	29	5

4 CONCLUSIONS

The collection of survey and base data primarily supports the hydraulic modelling, flood mapping, flood risk assessment, and channel stability investigation components of the Drumheller River Hazard Study. River cross sections were surveyed along 56.1 km of the Red Deer River, 7.9 km of Kneehills Creek, 5.3 km of Michichi Creek, 10.7 km of the Rosebud River, and 3.0 km of Willow Creek. In total, 444 cross sections were surveyed using a combination of boat-based bathymetric and ground surveys to complement the LiDAR-derived DTM. In addition, geometric details were collected for 35 bridge crossings, two sets of abandoned bridge piers, one culvert, and seven flood control dikes.

The overall accuracy of the measurements is considered to be ± 0.07 m horizontally and vertically for the boat-based bathymetric points and ± 0.05 m horizontally and vertically for the ground-based RTK GNSS survey points. Comparison of the LiDAR-derived DTM and ground survey points showed that the two data sets are in agreement, indicating that the DTM is suitable for use in hydraulic model development and flood mapping. Also, a preliminary estimate of the 1000-year flood extent was found to be contained well inside the aerial imagery coverage area proposed by AEP, confirming that the coverage area is sufficient.

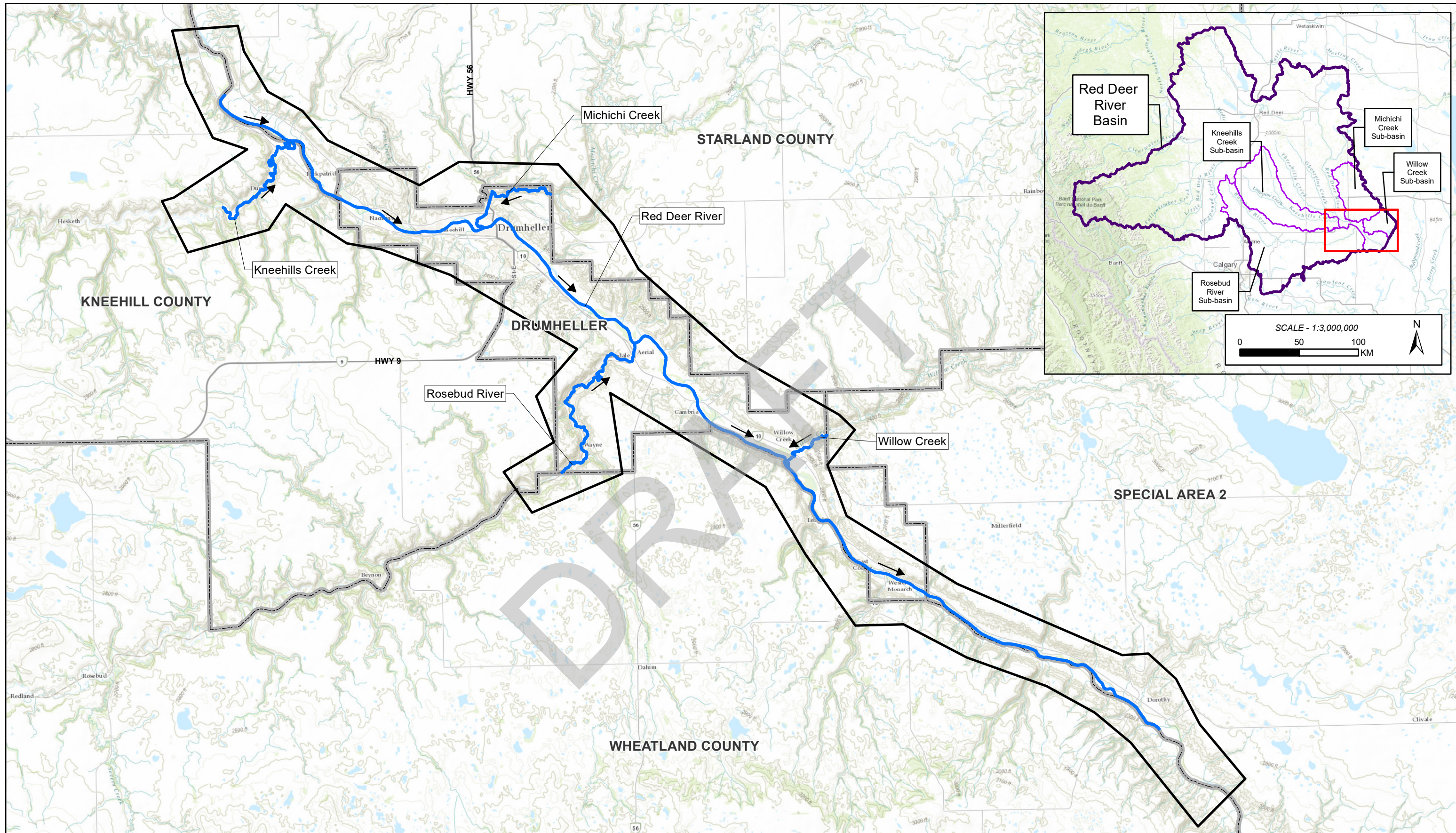
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- Matrix Solutions Inc. (2007). Drumheller Flood Risk Mapping Study. Report prepared for Alberta Environment, February 2007.
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- Stantec Consulting Ltd. (2014). Red Deer River Basin Flood Mitigation Study – Final Report. Report prepared for Government of Alberta Flood recovery Taskforce, May 2014.

FIGURES

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- FLOW DIRECTION
- STUDY REACH
- DTM/AERIAL IMAGERY COVERAGE
- MUNICIPAL BOUNDARY

SCALE - 1:150,000

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

**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

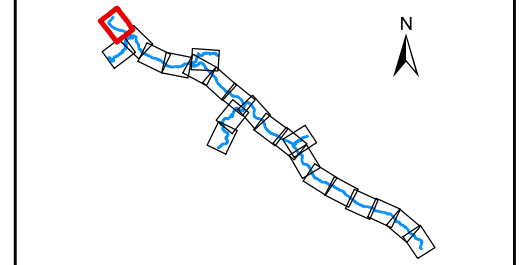
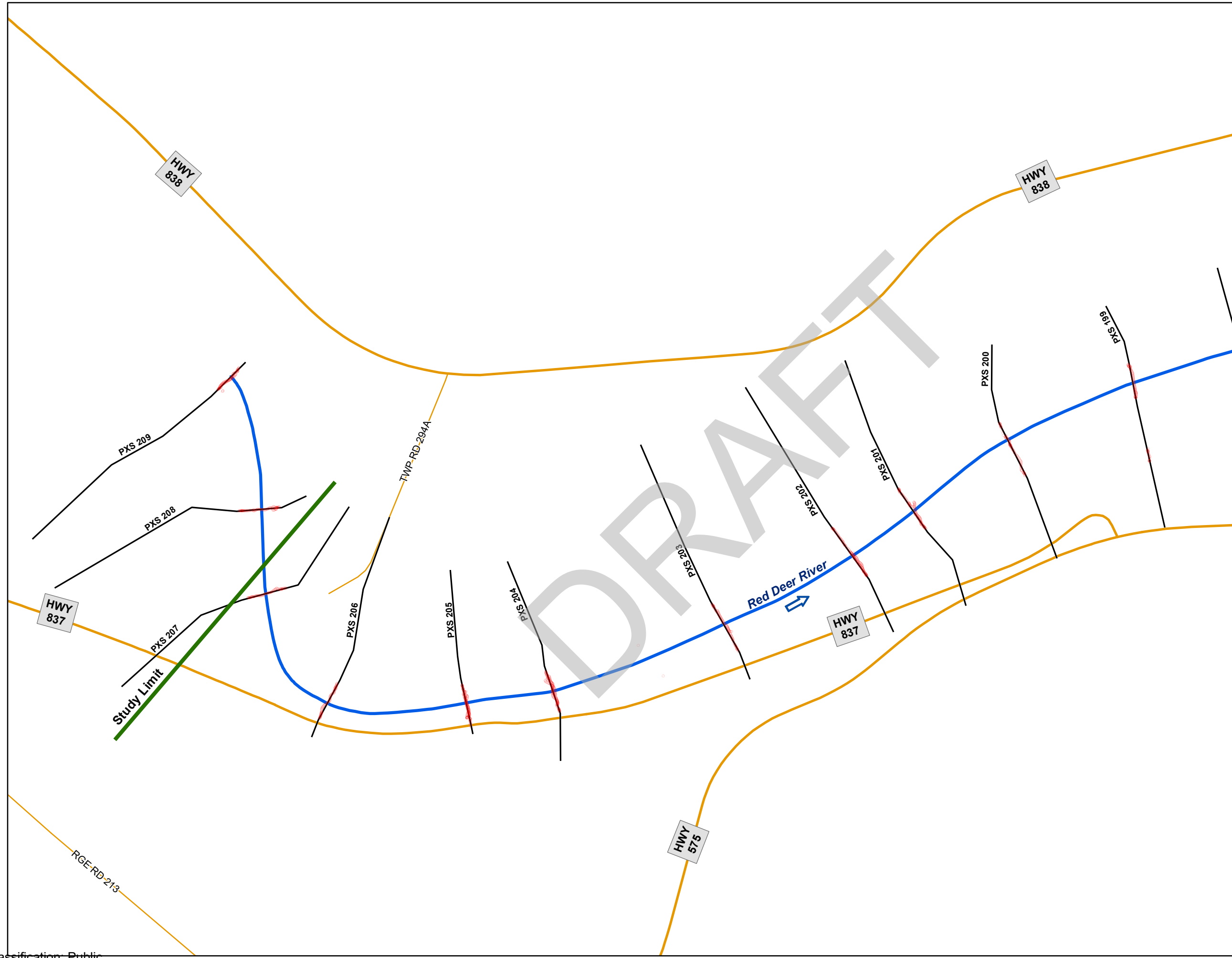
STUDY AREA

FIGURE 1

DATA SOURCES: Basemap from Esri & NRCan.

Job: 1003877

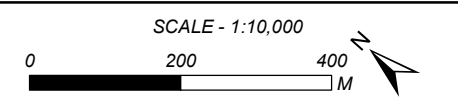
Date: 19-JUN-2019



- CONTROL POINT
- SURVEY POINT
- CROSS SECTION
- CULVERT
- BRIDGE
- FLOOD CONTROL STRUCTURE
- MAJOR ROAD
- MINOR ROAD
- FLOW DIRECTION
- APPROXIMATE CENTRELINE OF CURRENT CHANNEL

Sheet 2

DATA SOURCES: Basemap from Esri and NRCan.

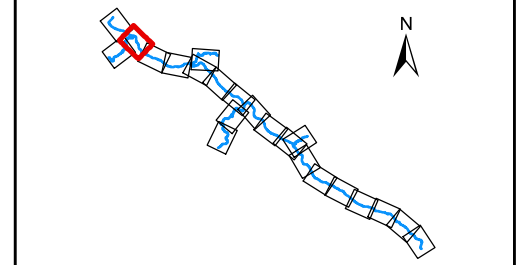
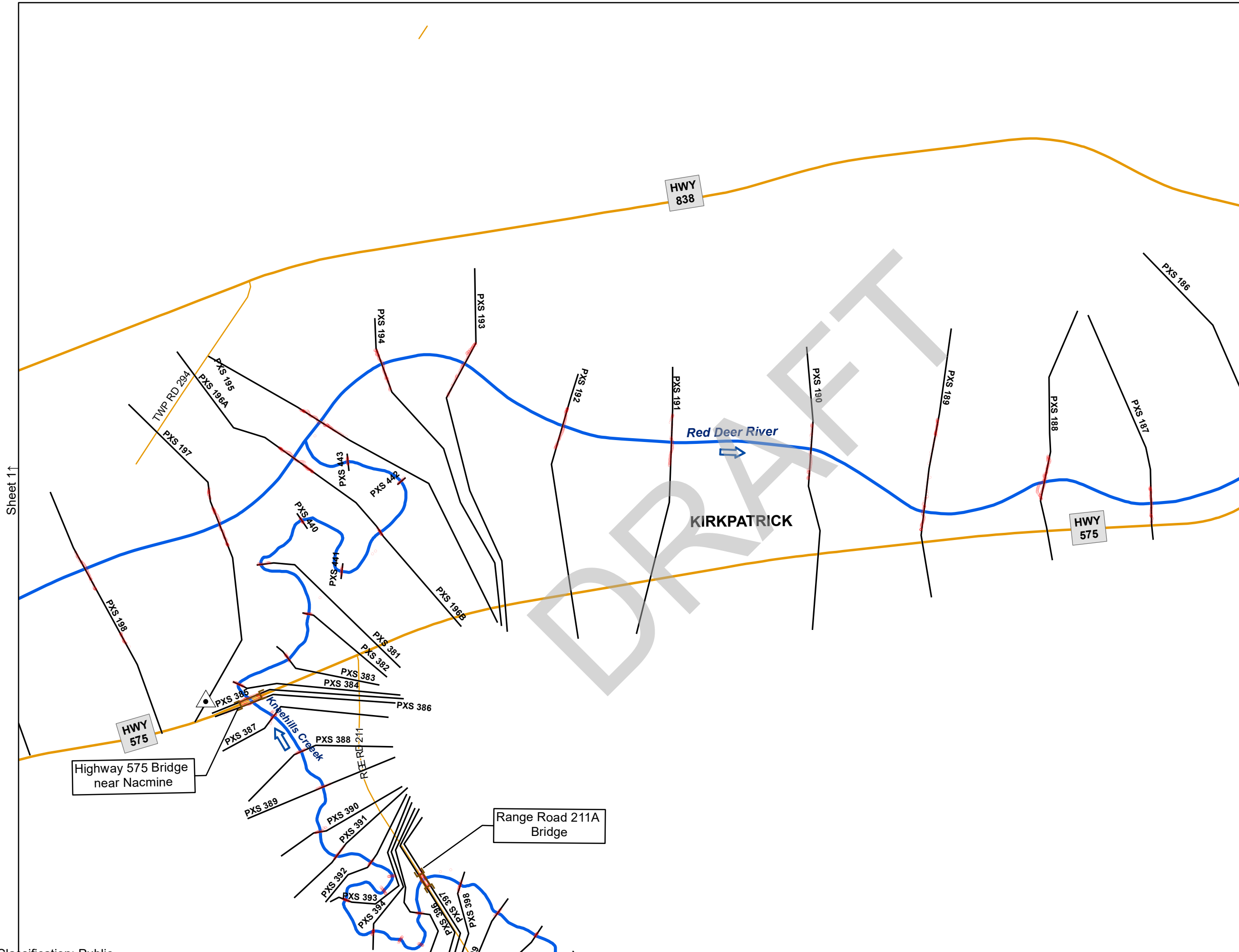












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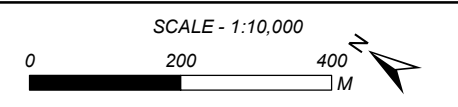
**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION
SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 1 OF 22**

FIGURE 2



-  CONTROL POINT
-  SURVEY POINT
-  CROSS SECTION
-  CULVERT
-  BRIDGE
-  FLOOD CONTROL STRUCTURE
-  MAJOR ROAD
-  MINOR ROAD
-  FLOW DIRECTION
-  APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.



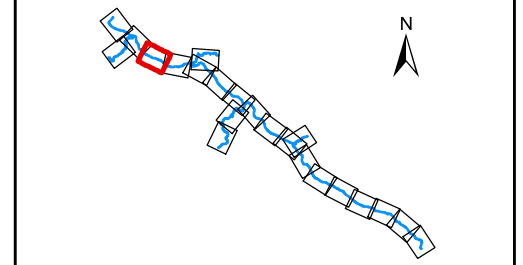
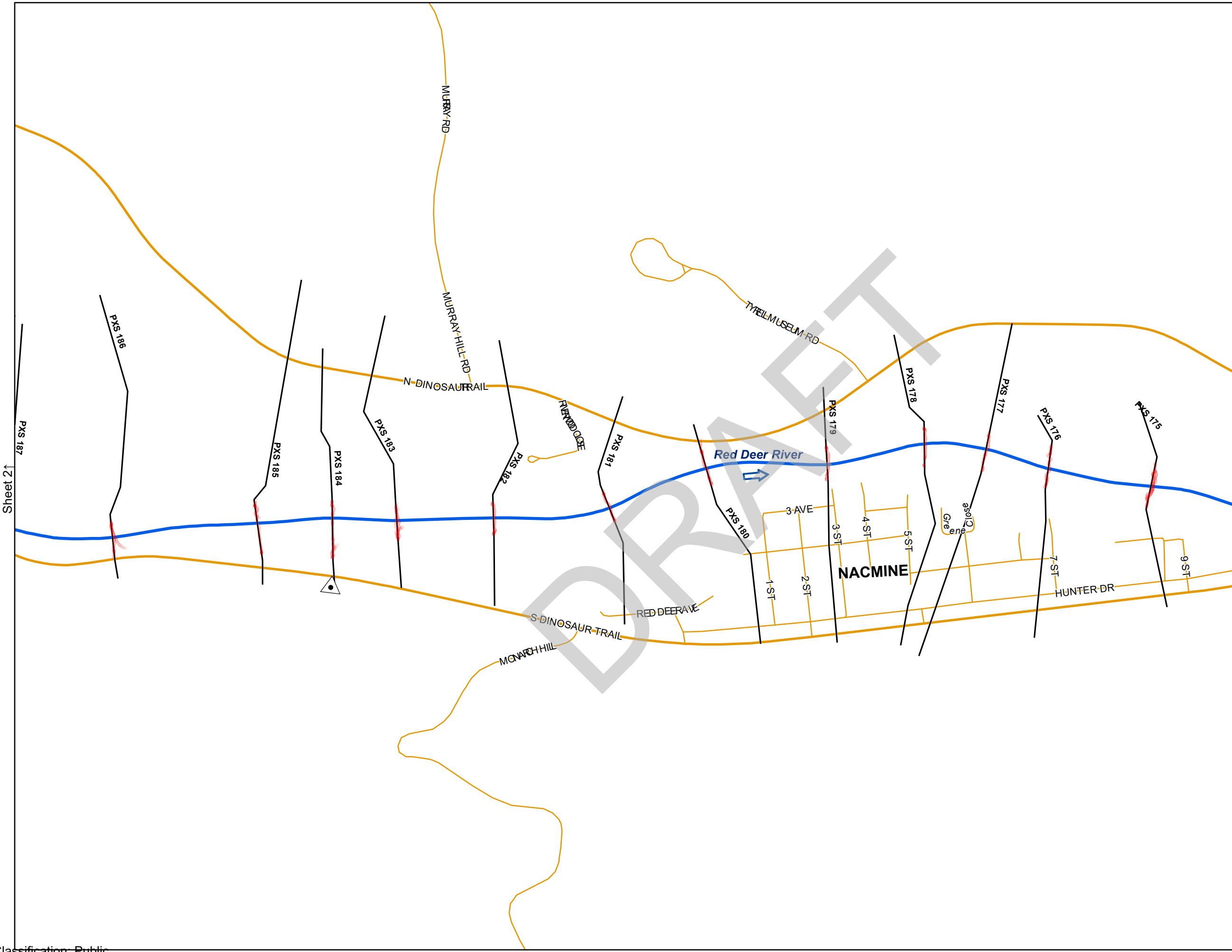
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**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

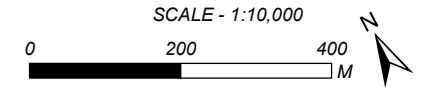
**SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 2 OF 22**

FIGURE 2



-  CONTROL POINT
-  SURVEY POINT
-  CROSS SECTION
-  CULVERT
-  BRIDGE
-  FLOOD CONTROL STRUCTURE
-  MAJOR ROAD
-  MINOR ROAD
-  FLOW DIRECTION
-  APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.



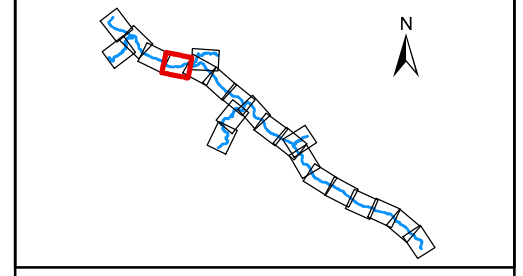
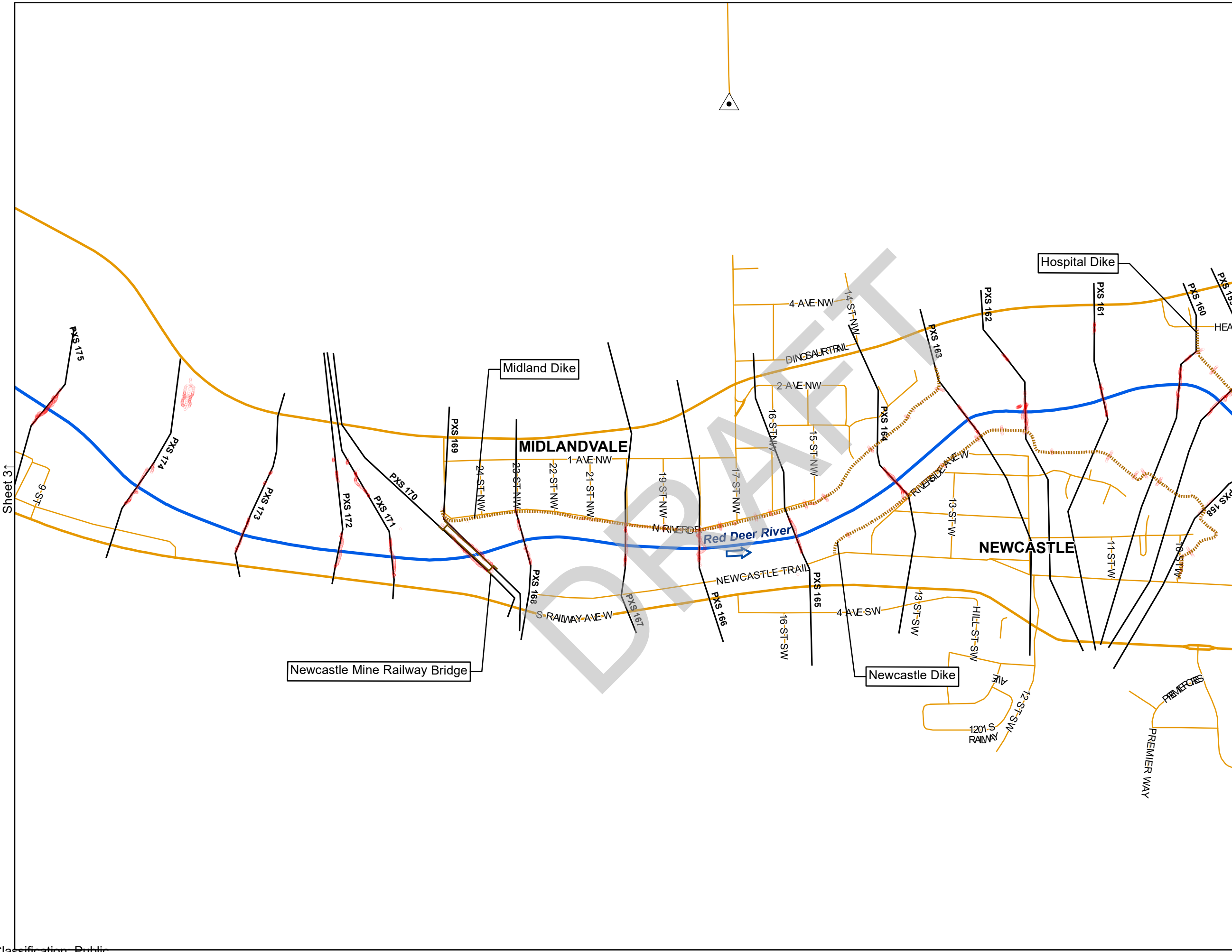
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Job: 1003877 | Date: 19-JUN-2019

**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

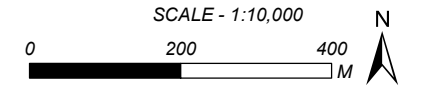
**SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 3 OF 22**

FIGURE 2



- CONTROL POINT
- SURVEY POINT
- CROSS SECTION
- CULVERT
- BRIDGE
- FLOOD CONTROL STRUCTURE
- MAJOR ROAD
- MINOR ROAD
- FLOW DIRECTION
- APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.

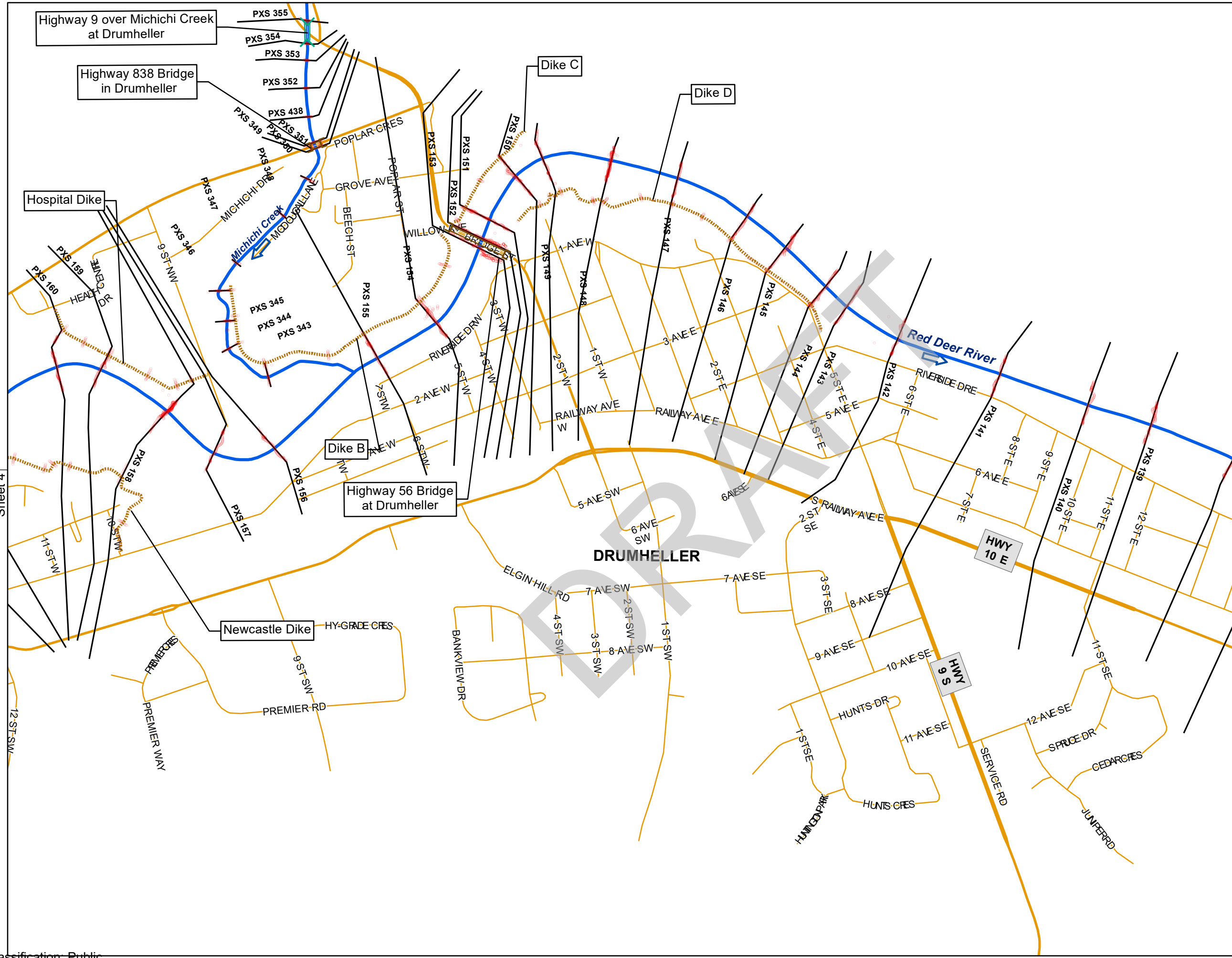



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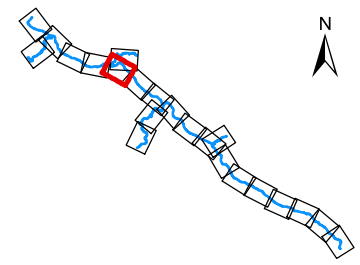
Job: 1003877 | Date: 19-JUN-2019











**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**
**SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 4 OF 22**

FIGURE 2



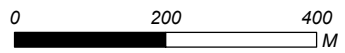




-  CONTROL POINT
-  SURVEY POINT
-  CROSS SECTION
-  CULVERT
-  BRIDGE
-  FLOOD CONTROL STRUCTURE
-  MAJOR ROAD
-  MINOR ROAD
-  FLOW DIRECTION
-  APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.

SCALE - 1:10,000



Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTV2.0; Units: Metres

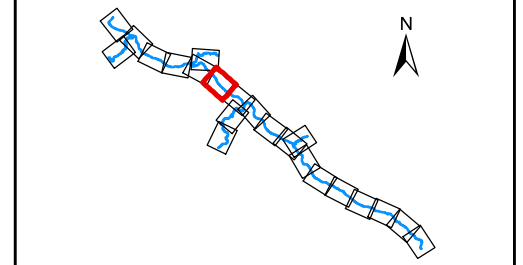
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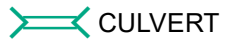






**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

**SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 5 OF 22**

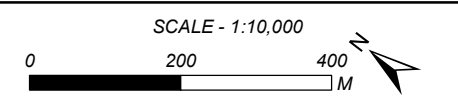
FIGURE 2

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-  CONTROL POINT
-  SURVEY POINT
-  CROSS SECTION
-  CULVERT
-  BRIDGE
-  FLOOD CONTROL STRUCTURE
-  MAJOR ROAD
-  MINOR ROAD
-  FLOW DIRECTION
-  APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.



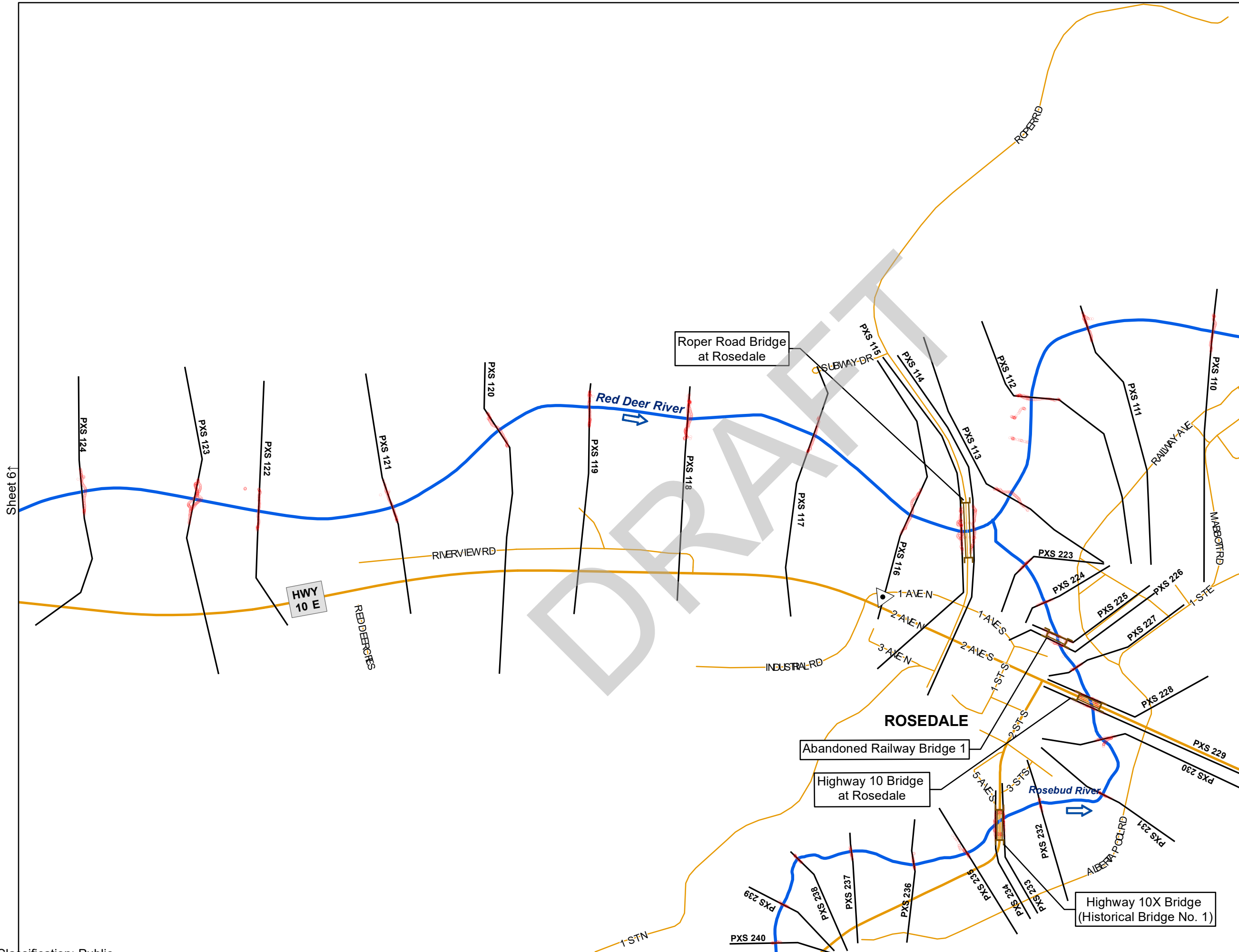
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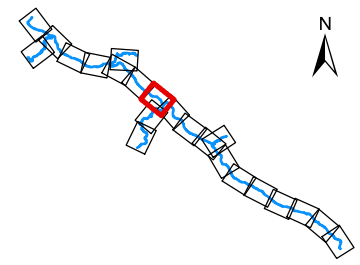
**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**











**SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 6 OF 22**

FIGURE 2



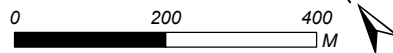




-  CONTROL POINT
-  SURVEY POINT
-  CROSS SECTION
-  CULVERT
-  BRIDGE
-  FLOOD CONTROL STRUCTURE
-  MAJOR ROAD
-  MINOR ROAD
-  FLOW DIRECTION
-  APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.

SCALE - 1:10,000



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

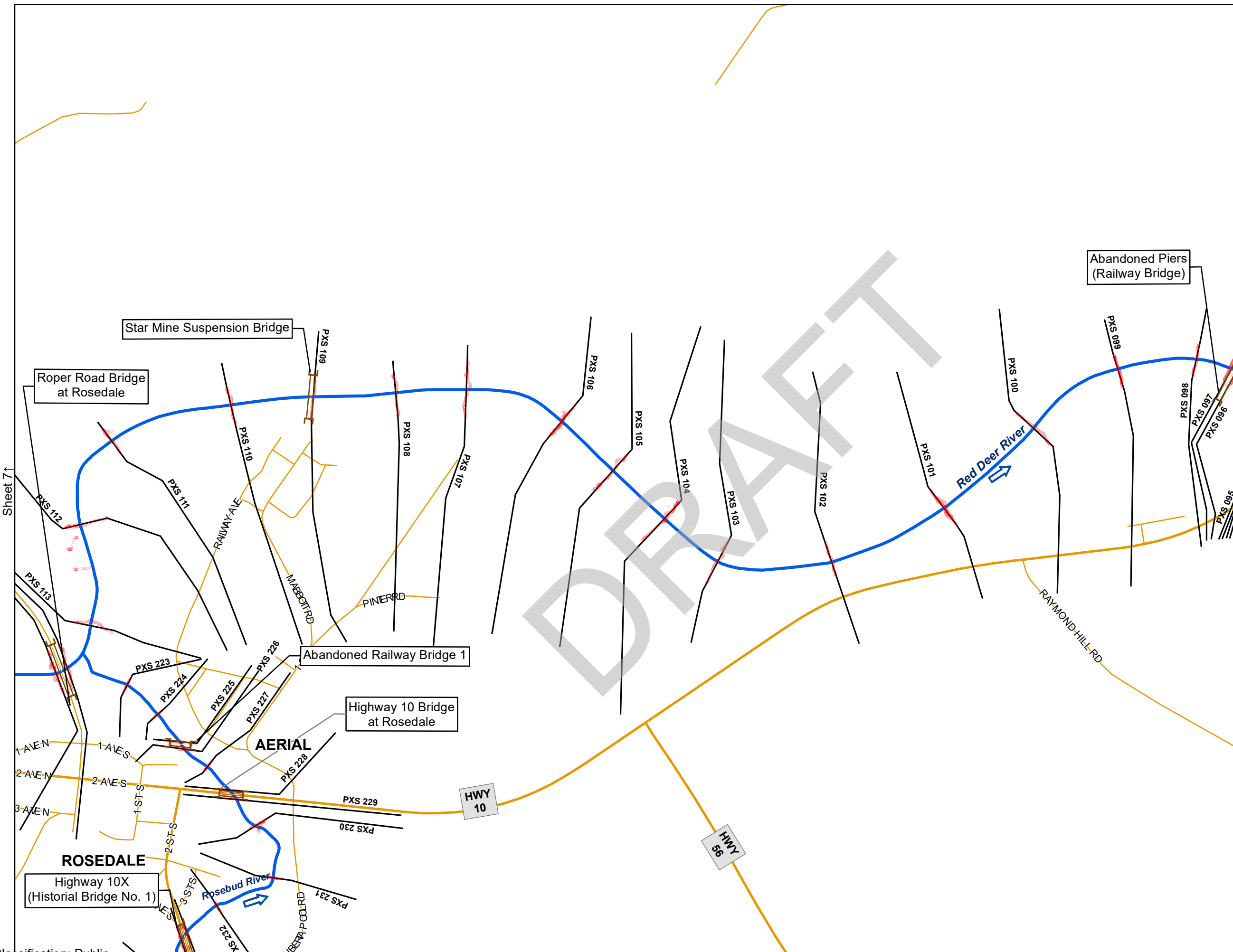
Job: 1003877

Date: 19-JUN-2019

**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

**SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 7 OF 22**

FIGURE 2



- CONTROL POINT
- SURVEY POINT
- CROSS SECTION
- CULVERT
- BRIDGE
- FLOOD CONTROL STRUCTURE
- MAJOR ROAD
- MINOR ROAD
- FLOW DIRECTION
- APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.

SCALE - 1:10,000

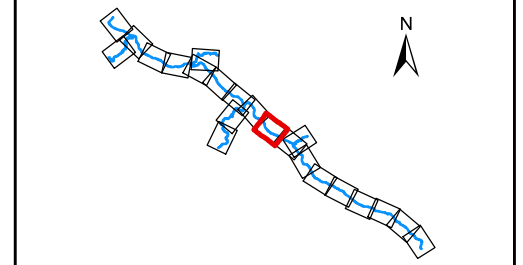
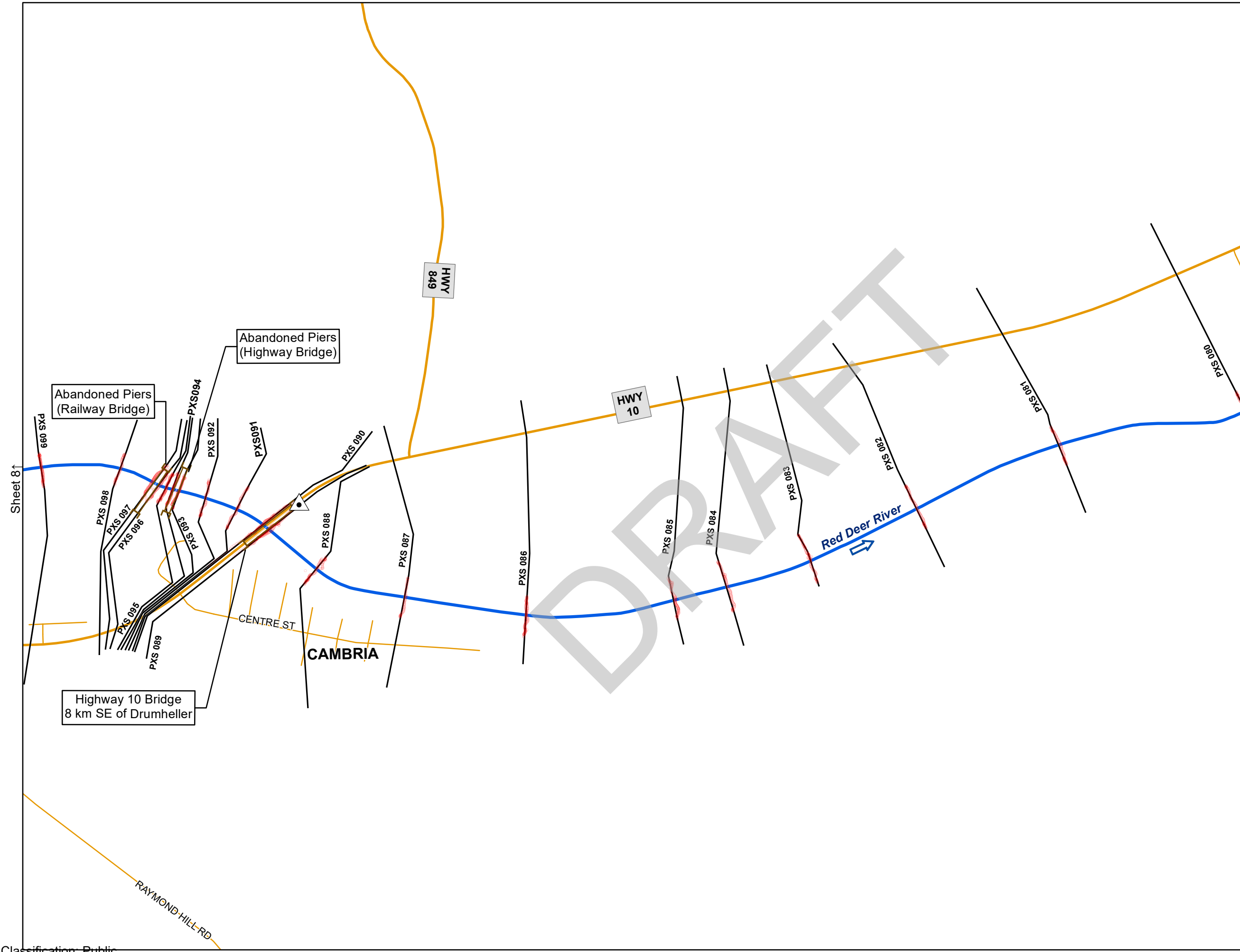
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Job: 1003877 | Date: 19-JUN-2019

**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

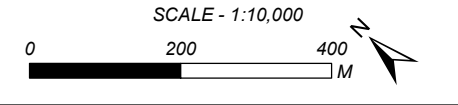
**SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 8 OF 22**

FIGURE 2



- CONTROL POINT
- SURVEY POINT
- CROSS SECTION
- CULVERT
- BRIDGE
- FLOOD CONTROL STRUCTURE
- MAJOR ROAD
- MINOR ROAD
- FLOW DIRECTION
- APPROXIMATE CENTRELINE OF CURRENT CHANNEL

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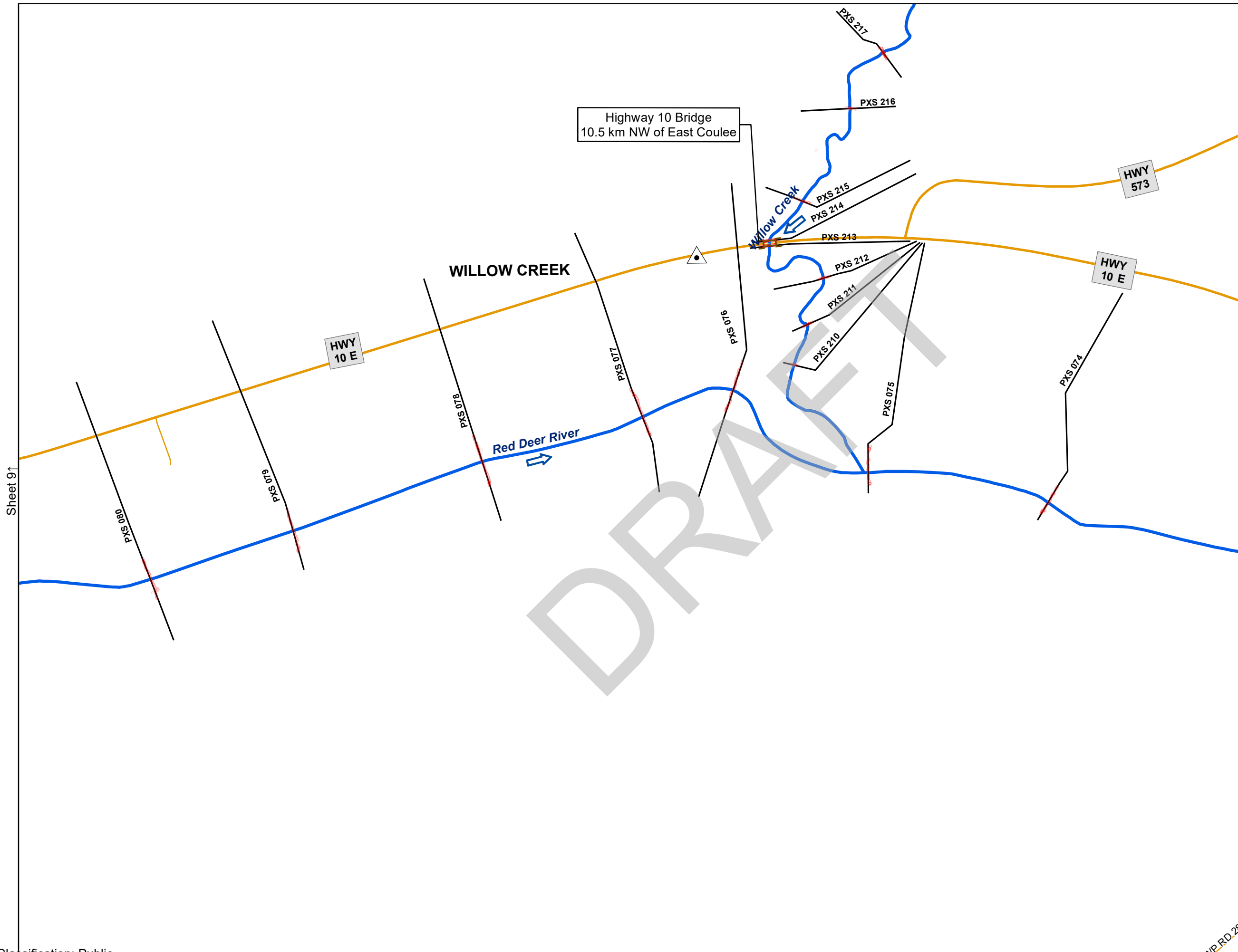
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Job: 1003877 | Date: 19-JUN-2019

**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

**SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 9 OF 22**

FIGURE 2



- CONTROL POINT
- SURVEY POINT
- CROSS SECTION
- CULVERT
- BRIDGE
- FLOOD CONTROL STRUCTURE
- MAJOR ROAD
- MINOR ROAD
- FLOW DIRECTION
- APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.

SCALE - 1:10,000

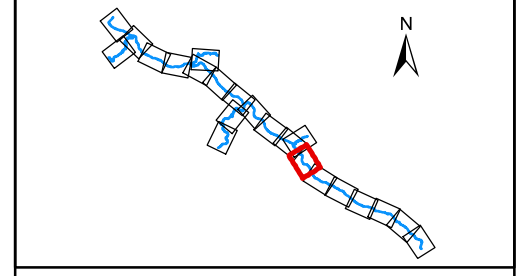
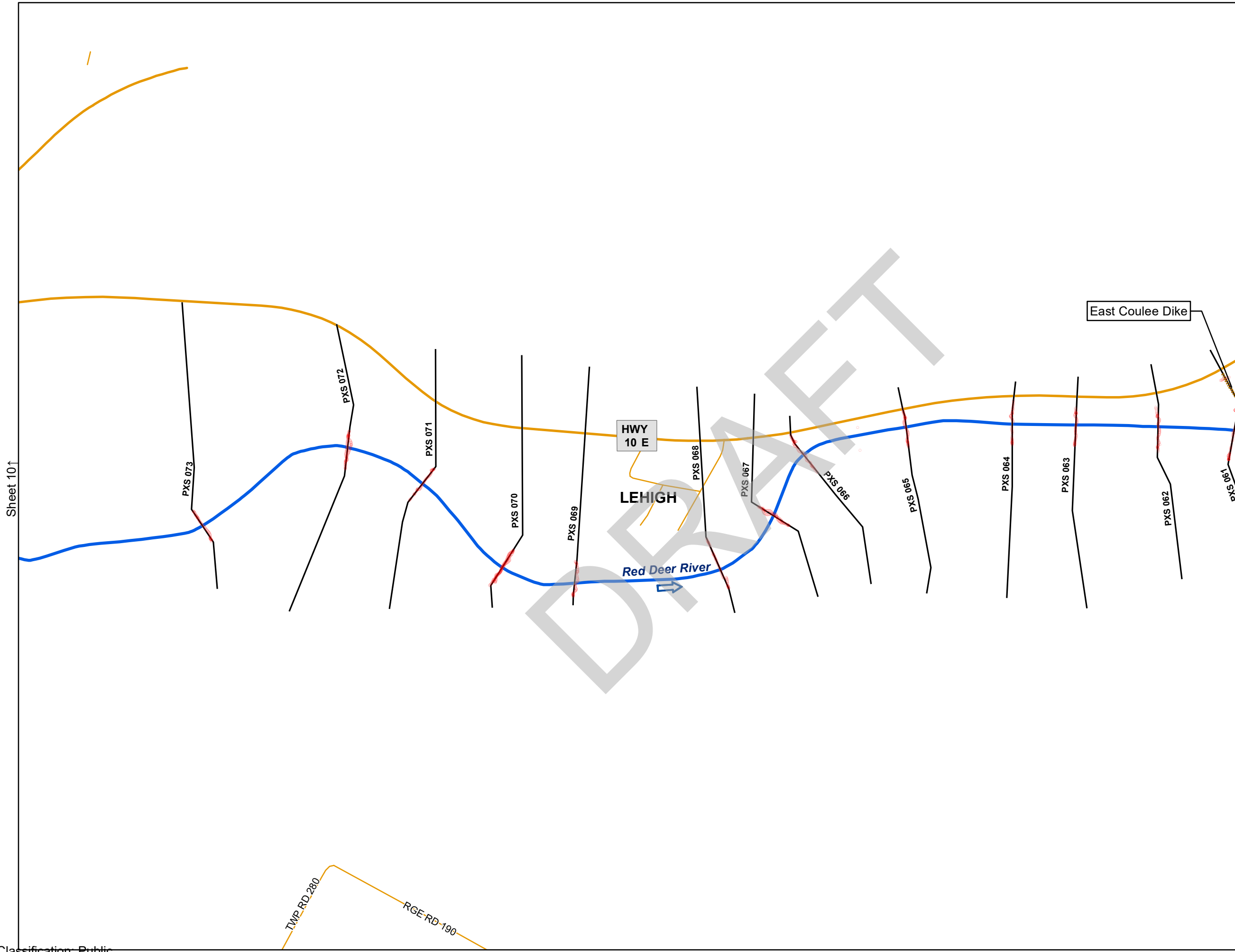
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Vertical Datum: CGVD28 HTv2.0; Units: Metres

Job: 1003877 Date: 19-JUN-2019

**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

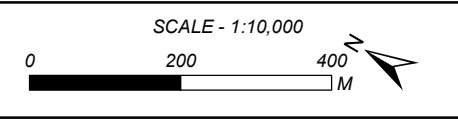
**SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 10 OF 22**

FIGURE 2



- CONTROL POINT
- SURVEY POINT
- CROSS SECTION
- CULVERT
- BRIDGE
- FLOOD CONTROL STRUCTURE
- MAJOR ROAD
- MINOR ROAD
- FLOW DIRECTION
- APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.



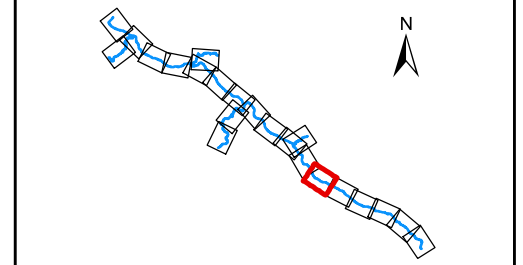
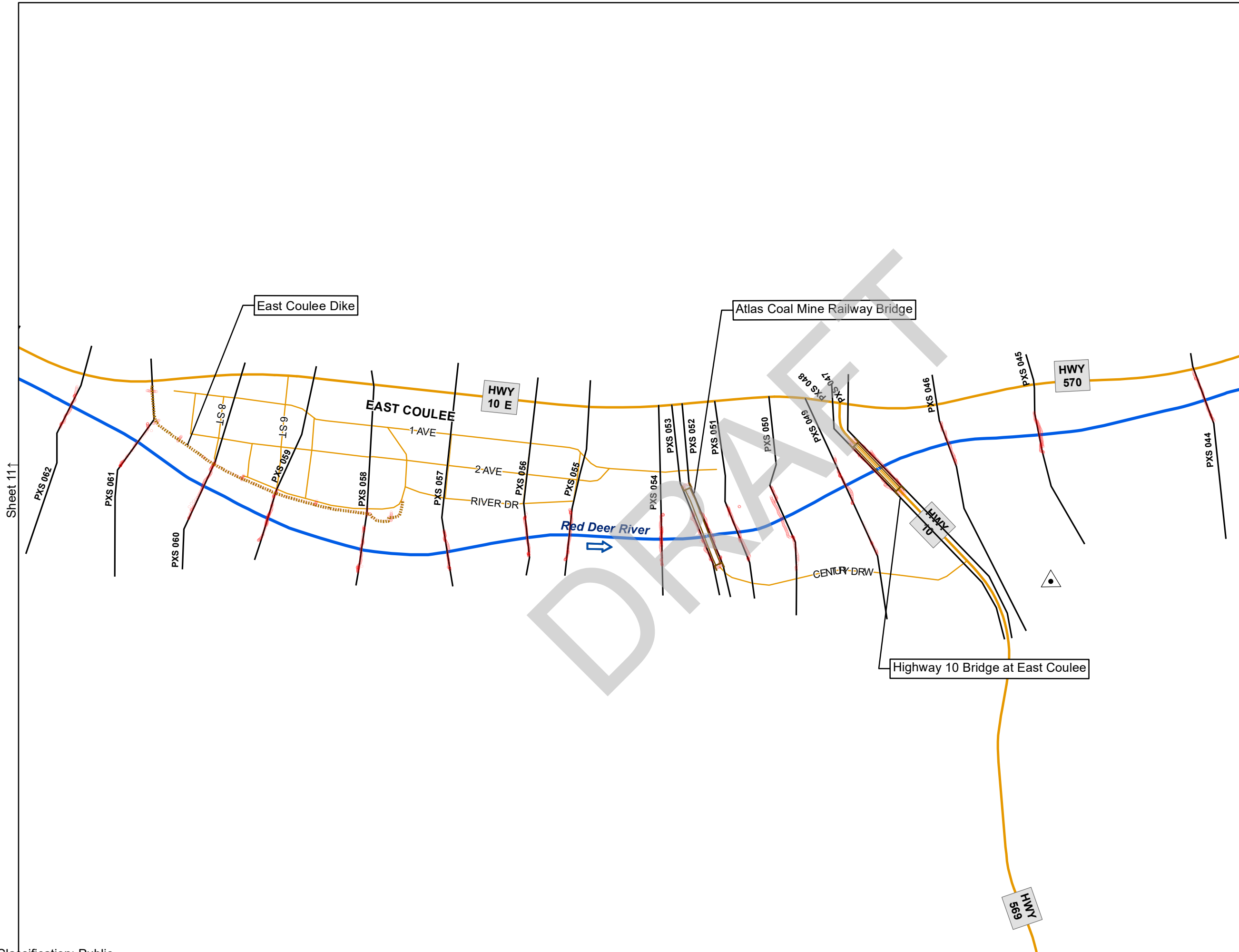
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**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

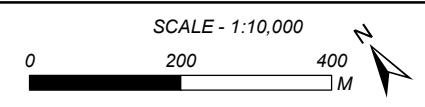
**SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 11 OF 22**

FIGURE 2



- CONTROL POINT
- SURVEY POINT
- CROSS SECTION
- CULVERT
- BRIDGE
- FLOOD CONTROL STRUCTURE
- MAJOR ROAD
- MINOR ROAD
- FLOW DIRECTION
- APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.



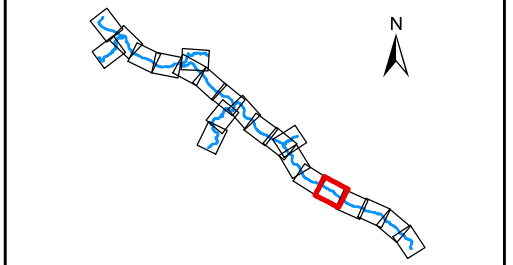
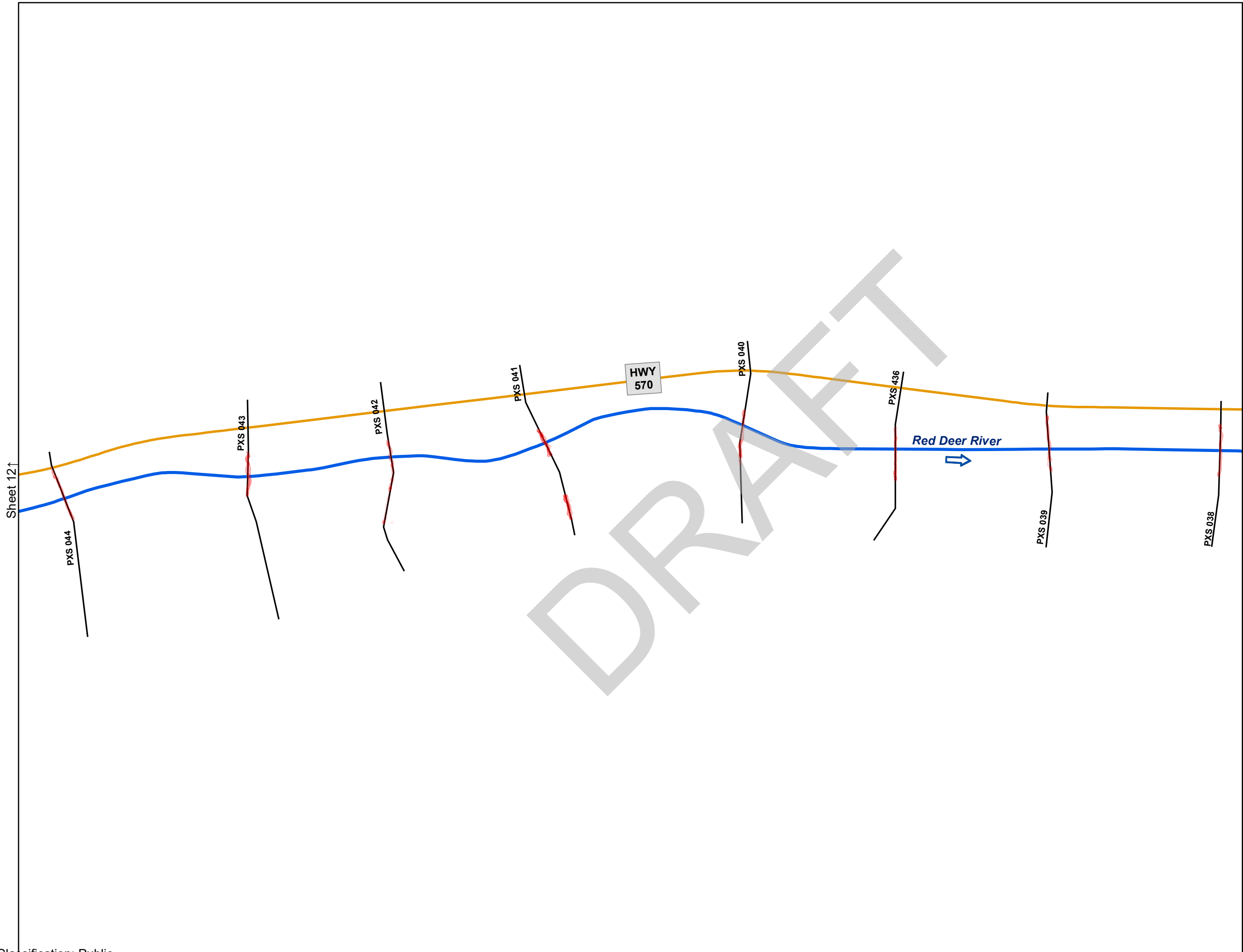
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







Job: 1003877 | Date: 19-JUN-2019

**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

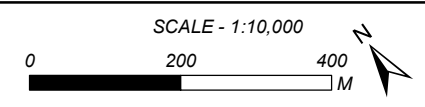
**SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 12 OF 22**

FIGURE 2



-  CONTROL POINT
-  SURVEY POINT
-  CROSS SECTION
-  CULVERT
-  BRIDGE
-  FLOOD CONTROL STRUCTURE
-  MAJOR ROAD
-  MINOR ROAD
-  FLOW DIRECTION
-  APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.



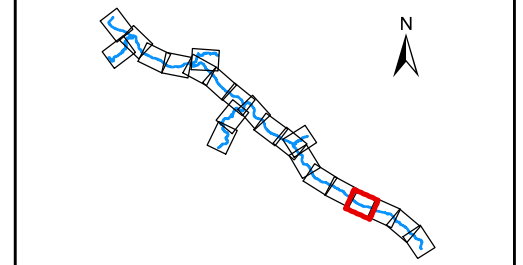
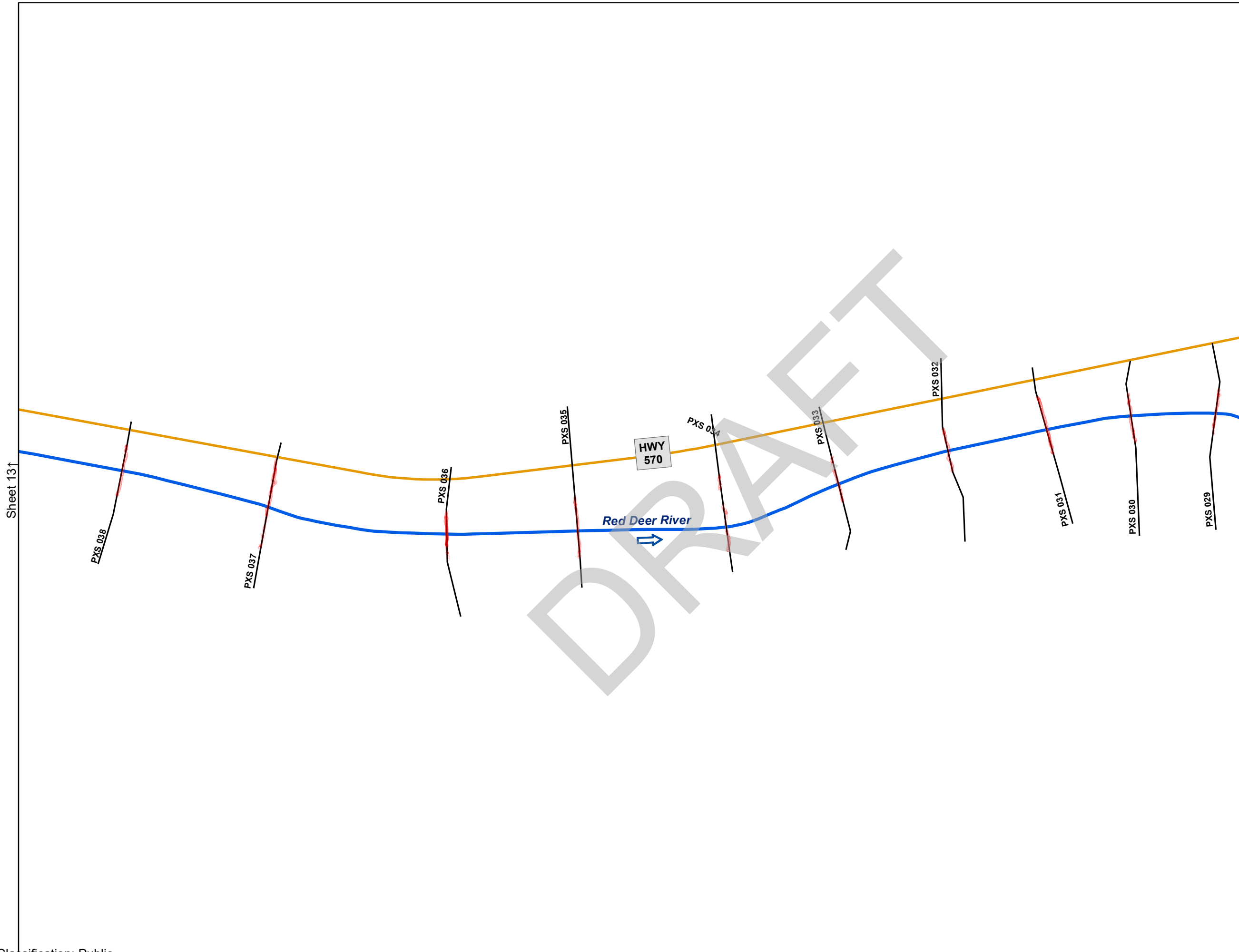
Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres











Job: 1003877 | Date: 19-JUN-2019

**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

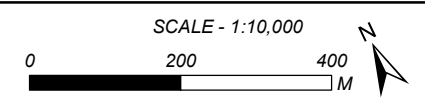
**SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 13 OF 22**

FIGURE 2



-  CONTROL POINT
-  SURVEY POINT
-  CROSS SECTION
-  CULVERT
-  BRIDGE
-  FLOOD CONTROL STRUCTURE
-  MAJOR ROAD
-  MINOR ROAD
-  FLOW DIRECTION
-  APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.



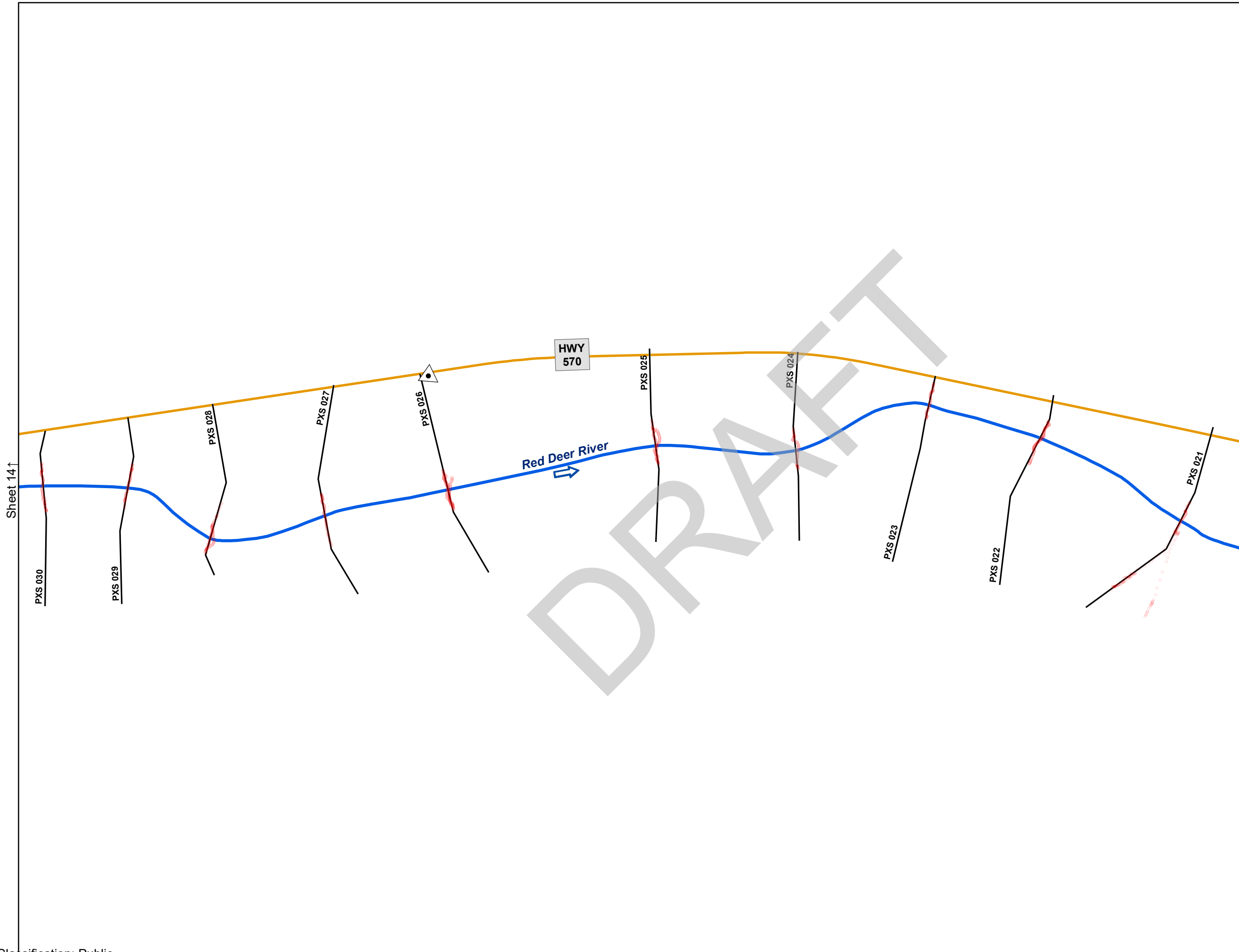
Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Job: 1003877 | Date: 19-JUN-2019

**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

**SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 14 OF 22**

FIGURE 2



- CONTROL POINT
- SURVEY POINT
- CROSS SECTION
- CULVERT
- BRIDGE
- FLOOD CONTROL STRUCTURE
- MAJOR ROAD
- MINOR ROAD
- FLOW DIRECTION
- APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.

SCALE - 1:10,000

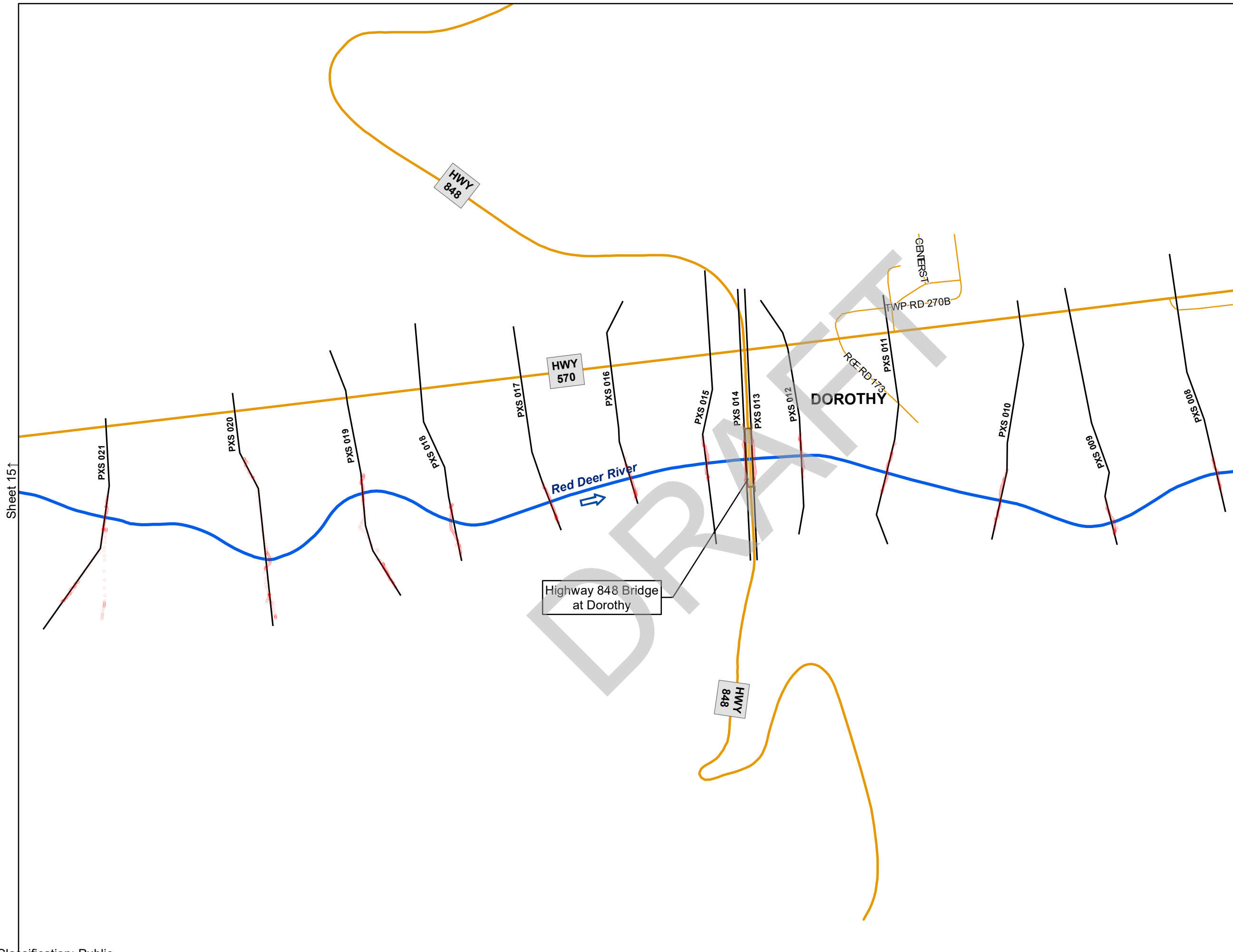
Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTv2.0; Units: Metres


Job: 1003877 | Date: 19-JUN-2019

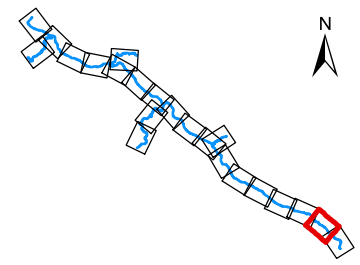
**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**








**SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 15 OF 22**

FIGURE 2



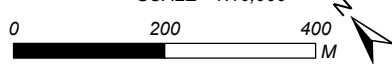




▲	CONTROL POINT
●	SURVEY POINT
—	CROSS SECTION
	CULVERT
	BRIDGE
	FLOOD CONTROL STRUCTURE
	MAJOR ROAD
	MINOR ROAD
	FLOW DIRECTION
	APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.

SCALE - 1:10,000



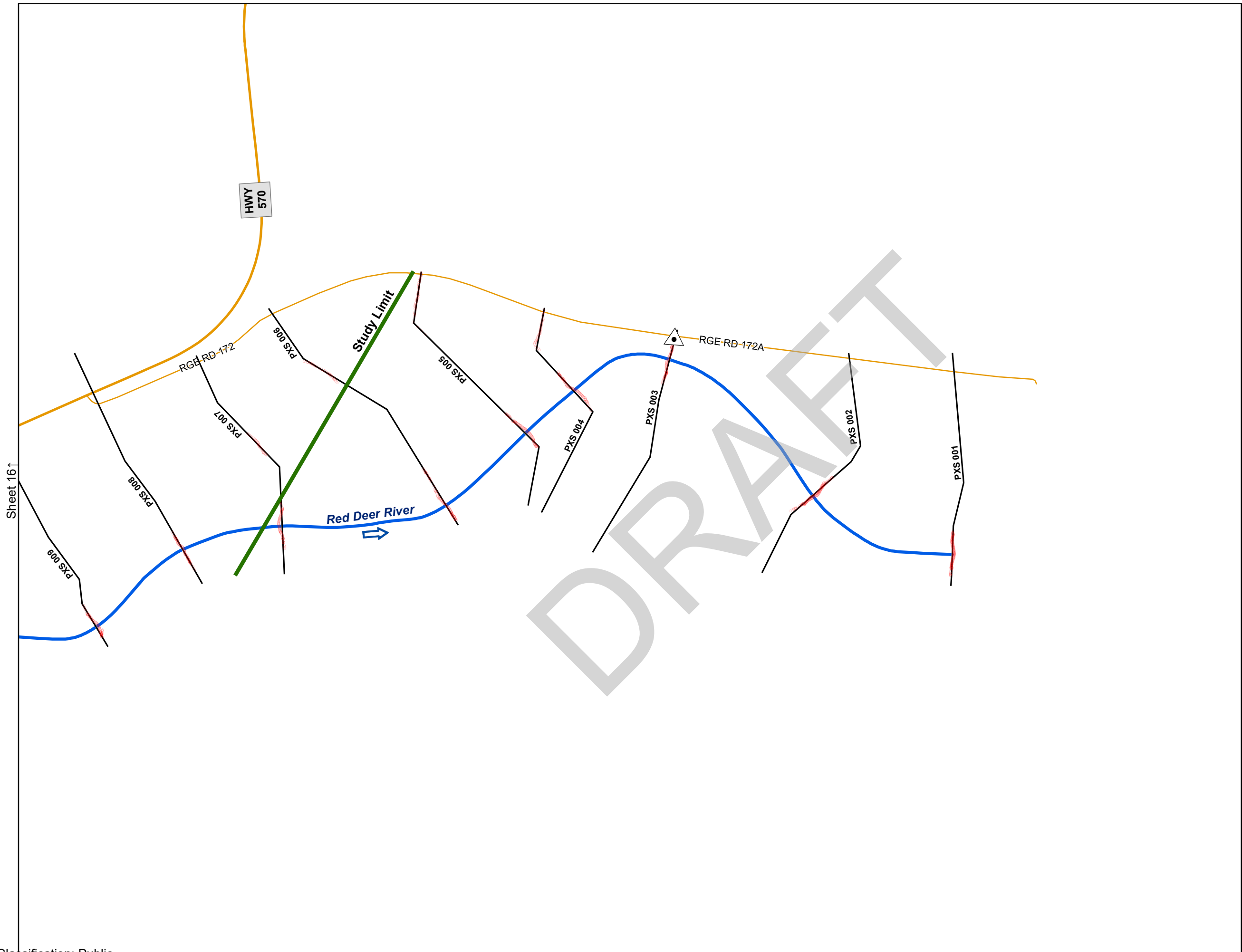
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Vertical Datum: CGVD28 HTv2.0; Units: Metres


Job: 1003877	Date: 19-JUN-2019
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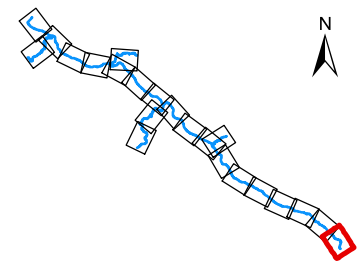
**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**











**SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 16 OF 22**

FIGURE 2



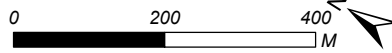




-  CONTROL POINT
-  SURVEY POINT
-  CROSS SECTION
-  CULVERT
-  BRIDGE
-  FLOOD CONTROL STRUCTURE
-  MAJOR ROAD
-  MINOR ROAD
-  FLOW DIRECTION
-  APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.

SCALE - 1:10,000



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

Job: 1003877	Date: 19-JUN-2019
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**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

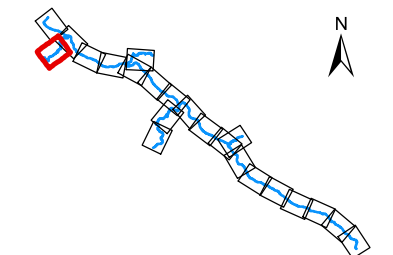
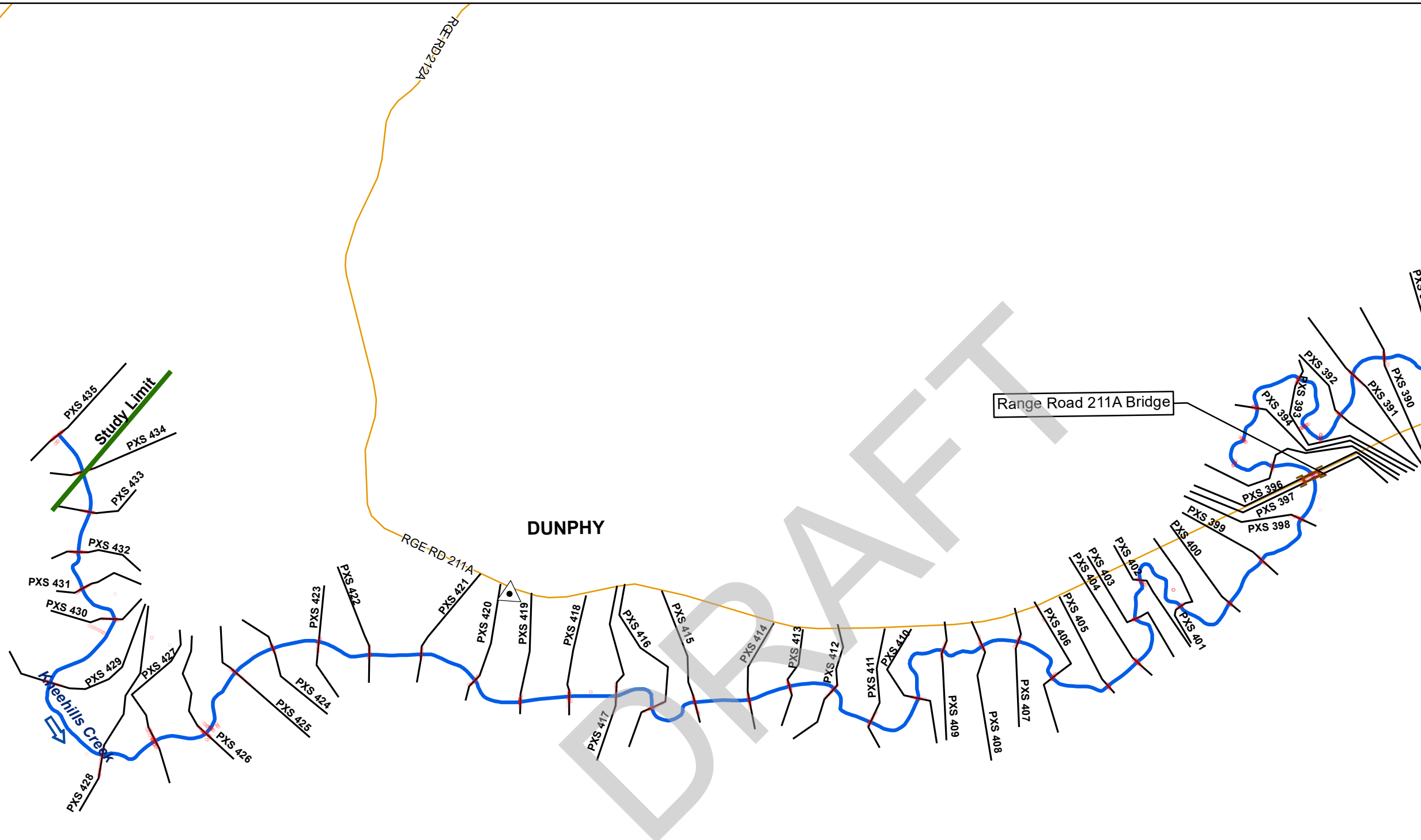
**SURVEY AND STRUCTURE
LOCATION OVERVIEW**

SHEET 17 OF 22

FIGURE 2

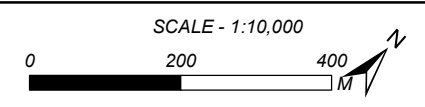
Sheet 20↑

Sheet 2↓



- CONTROL POINT
- SURVEY POINT
- CROSS SECTION
- CULVERT
- BRIDGE
- FLOOD CONTROL STRUCTURE
- MAJOR ROAD
- MINOR ROAD
- FLOW DIRECTION
- APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.



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

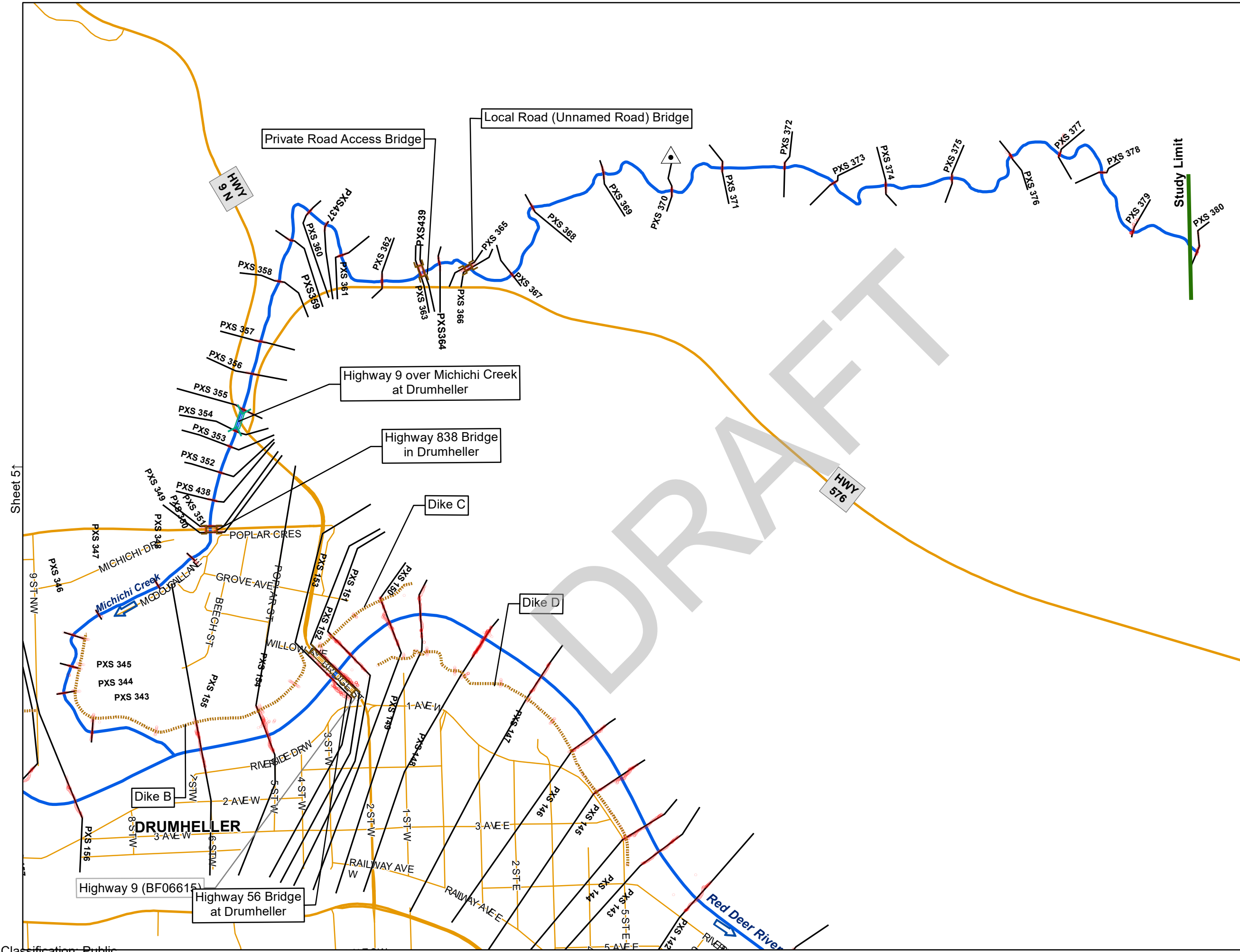
Job: 1003877 | Date: 19-JUN-2019

**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

**SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 18 OF 22**

FIGURE 2

REH_P:\Projects (Active)\1003877 Drumheller River Hazard Study\04 Models\GIS\Figures\1003877_T100_Fig02_SectionLayout_R1.mxd



- CONTROL POINT
- SURVEY POINT
- CROSS SECTION
- CULVERT
- BRIDGE
- FLOOD CONTROL STRUCTURE
- MAJOR ROAD
- MINOR ROAD
- FLOW DIRECTION
- APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.

SCALE - 1:10,000

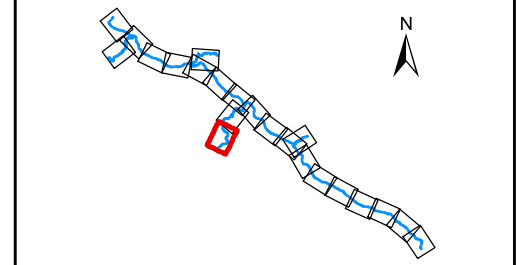
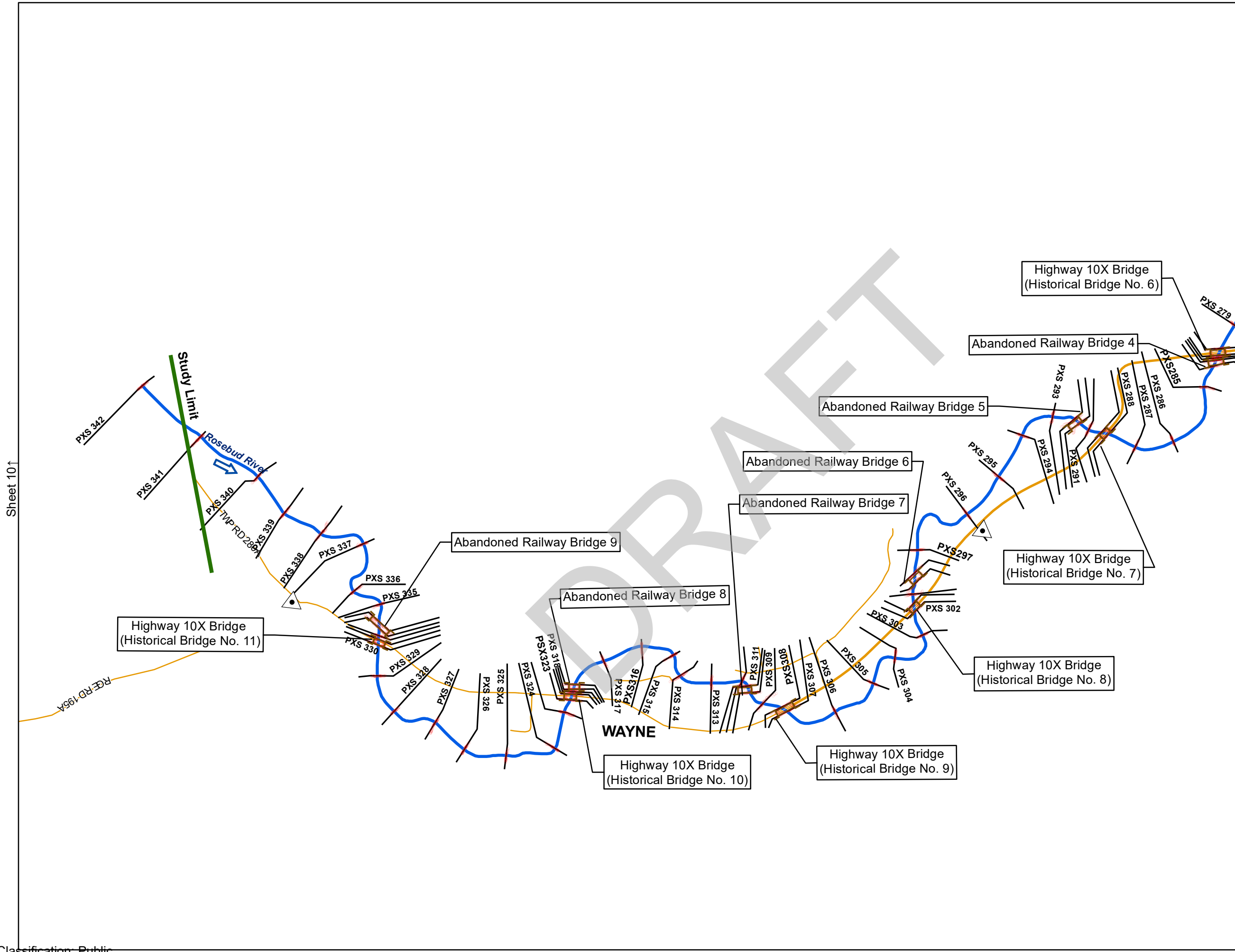
Coordinate System: NAD 1983 CSRS 3TM 114;
Vertical Datum: CGVD28 HTV2.0; Units: Metres

Job: 1003877 | Date: 19-JUN-2019

**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

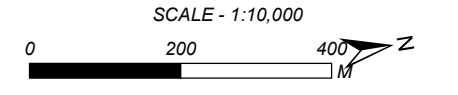
**SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 19 OF 22**

FIGURE 2



- CONTROL POINT
- SURVEY POINT
- CROSS SECTION
- CULVERT
- BRIDGE
- FLOOD CONTROL STRUCTURE
- MAJOR ROAD
- MINOR ROAD
- FLOW DIRECTION
- APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.



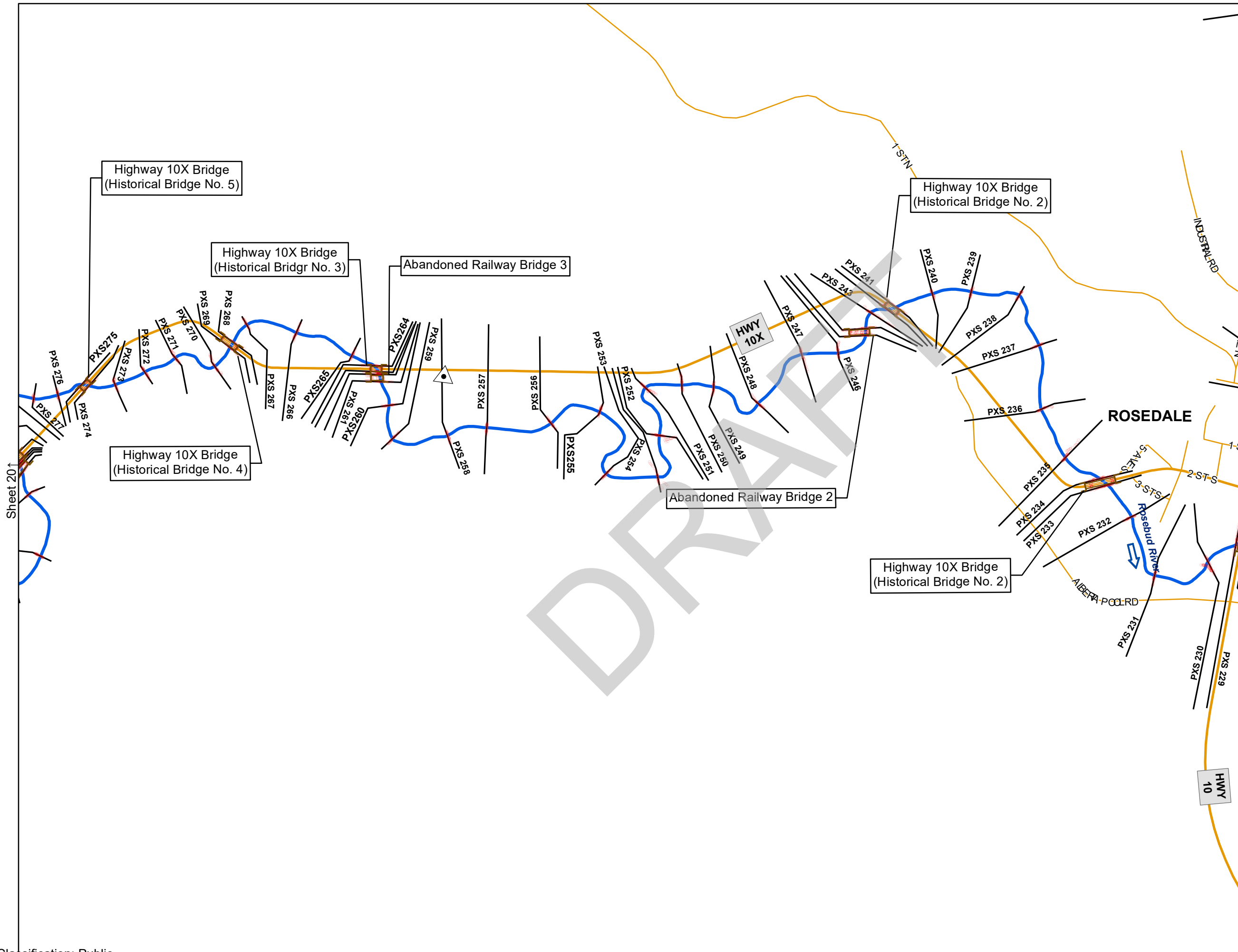
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 Vertical Datum: CGVD28 HTv2.0; Units: Metres

Job: 1003877 | Date: 19-JUN-2019

**DRUMHELLER RIVER HAZARD STUDY
 SURVEY AND BASE DATA COLLECTION**
**SURVEY AND STRUCTURE
 LOCATION OVERVIEW
 SHEET 20 OF 22**

FIGURE 2

REH_P:\Projects (Active)\1003877 Drumheller River Hazard Study\04 Models\GIS\Figures\1003877_T100_Fig02_SectionLayout_R1.mxd



- CONTROL POINT
- SURVEY POINT
- CROSS SECTION
- CULVERT
- BRIDGE
- FLOOD CONTROL STRUCTURE
- MAJOR ROAD
- MINOR ROAD
- FLOW DIRECTION
- APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.

SCALE - 1:10,000

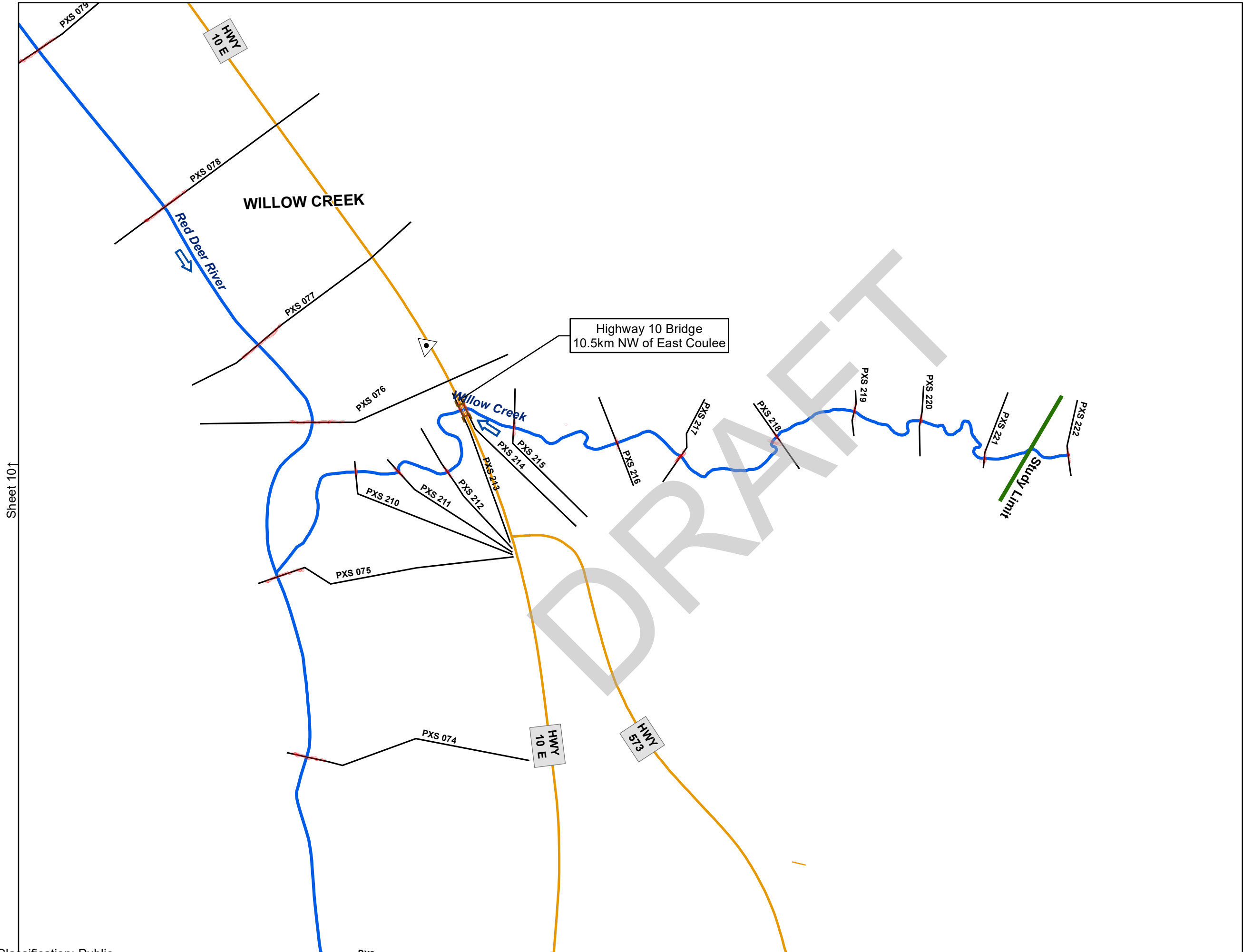
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Vertical Datum: CGVD28 HTv2.0; Units: Metres

Job: 1003877 Date: 19-JUN-2019

**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

**SURVEY AND STRUCTURE
LOCATION OVERVIEW
SHEET 21 OF 22**

FIGURE 2



- CONTROL POINT
- SURVEY POINT
- CROSS SECTION
- CULVERT
- BRIDGE
- FLOOD CONTROL STRUCTURE
- MAJOR ROAD
- MINOR ROAD
- FLOW DIRECTION
- APPROXIMATE CENTRELINE OF CURRENT CHANNEL

DATA SOURCES: Basemap from Esri and NRCan.

SCALE - 1:10,000

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

Job: 1003877 Date: 19-JUN-2019

**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

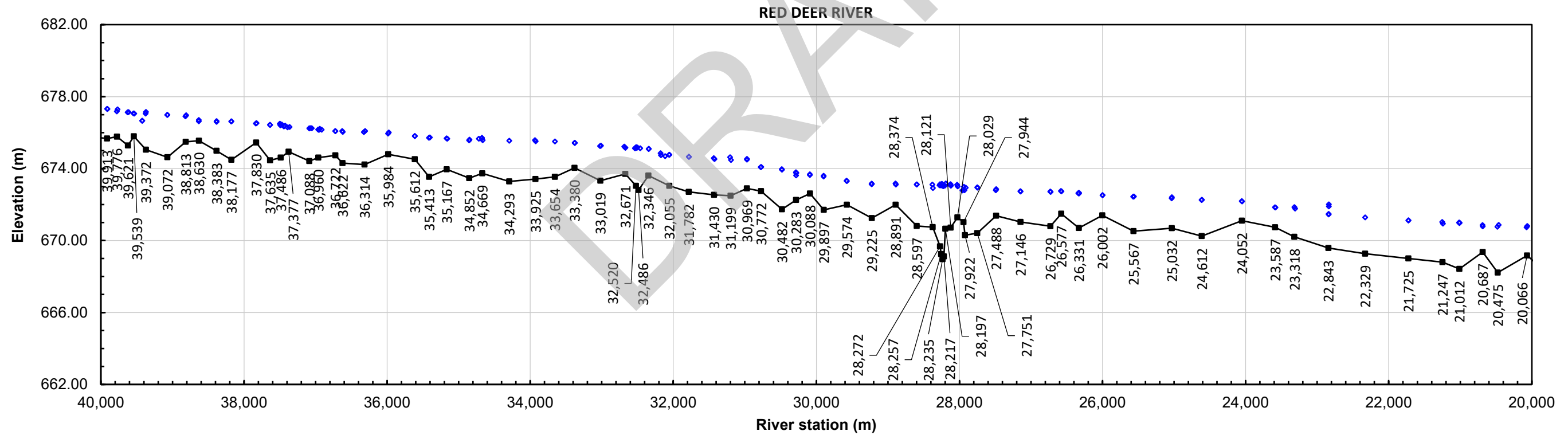
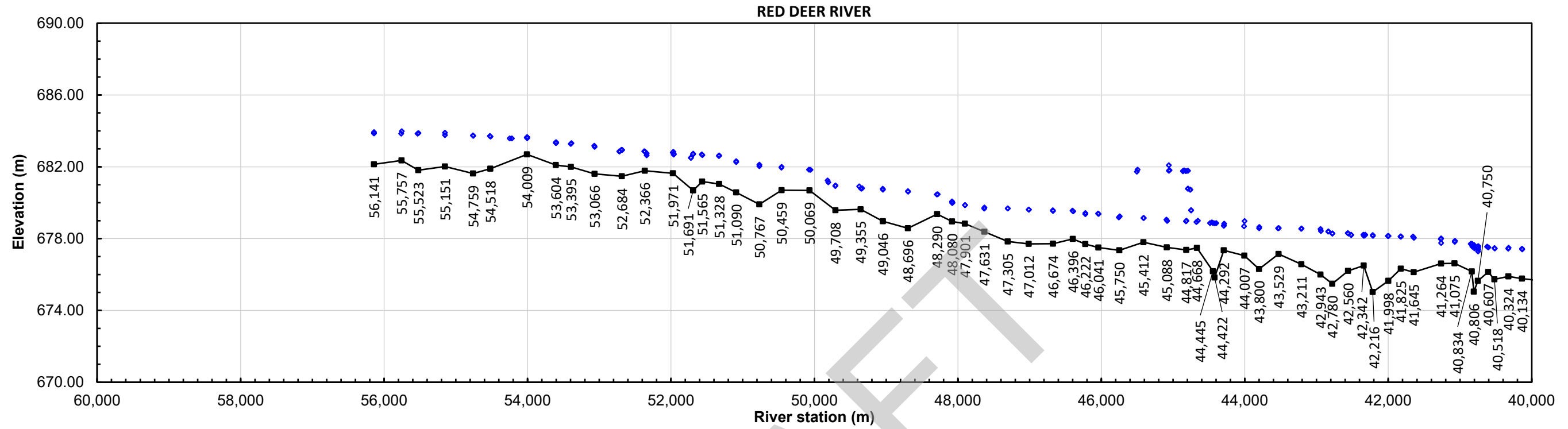
**SURVEY AND STRUCTURE
LOCATION OVERVIEW**

SHEET 22 OF 22

FIGURE 2

Sheet 10 ↑

Sheet 17 ↓



LEGEND

- ◆ Surveyed water level
- Thalweg

SCALE - AS SHOWN

Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

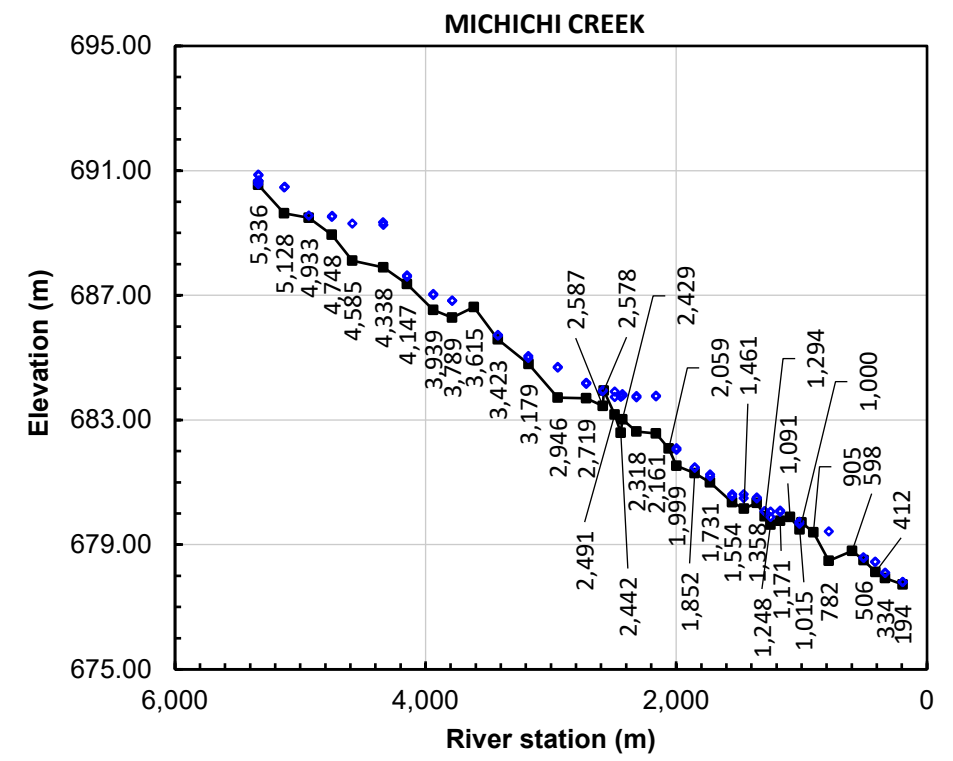
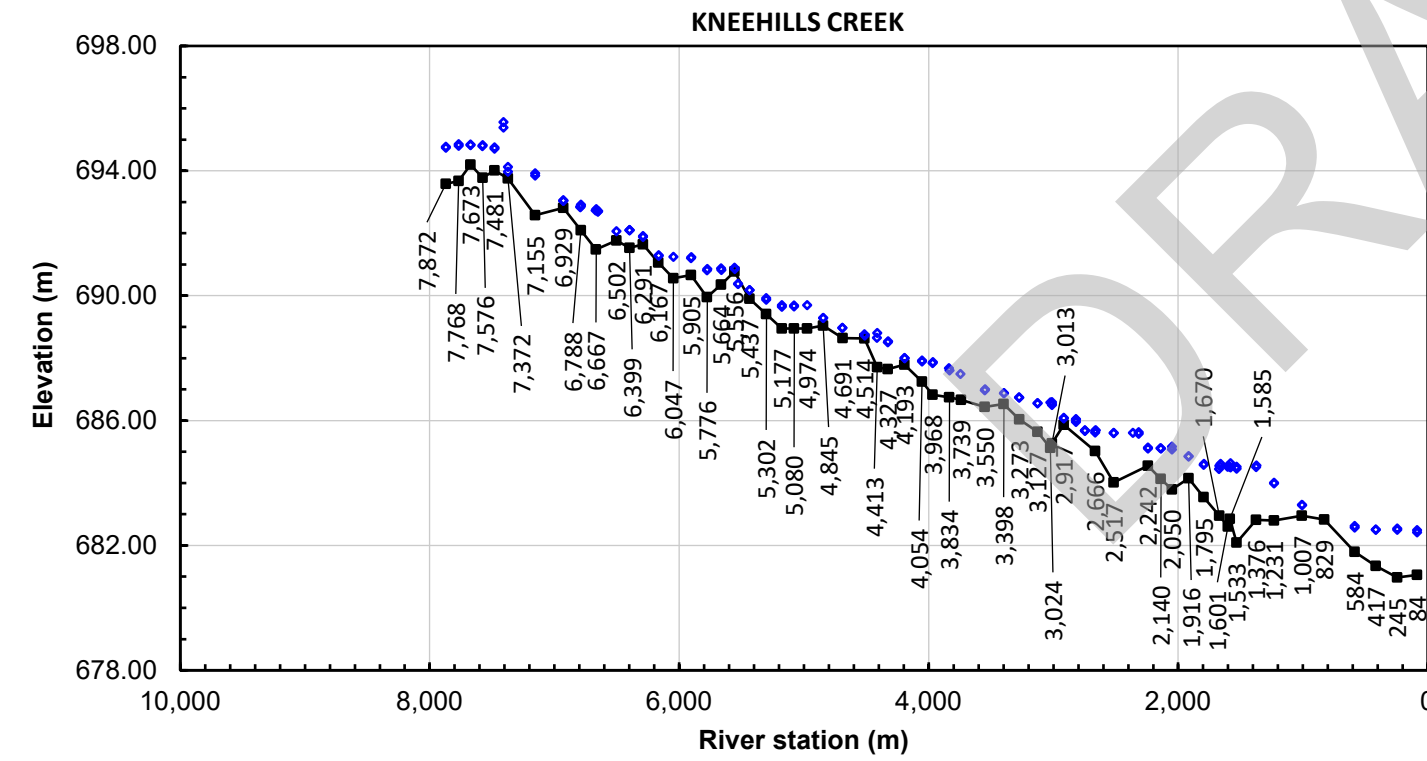
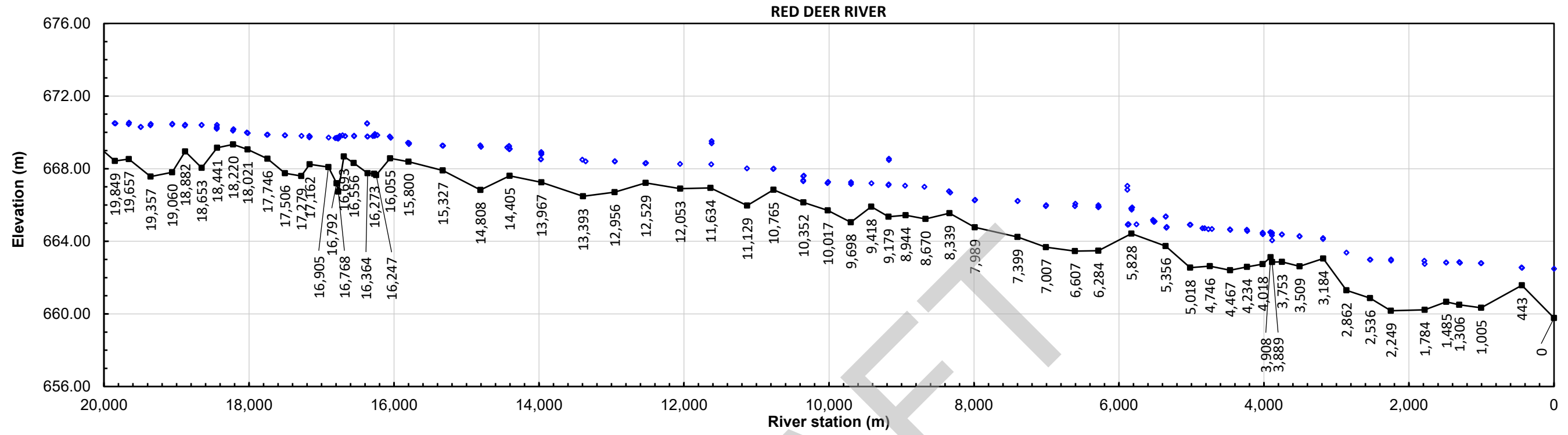
Job: 1003877

Date: 6-FEB-2019

**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

**SURVEYED THALWEG AND WATER LEVEL PROFILES
SHEET 1 OF 3**

FIGURE 3 (1 OF 3)



LEGEND

- ◆ Surveyed water level
- Thalweg

SCALE - AS SHOWN

Elevation Datum: CGVD28 (HTv2.0)
Units: As Shown

Job: 1003877 Date: 6-FEB-2019

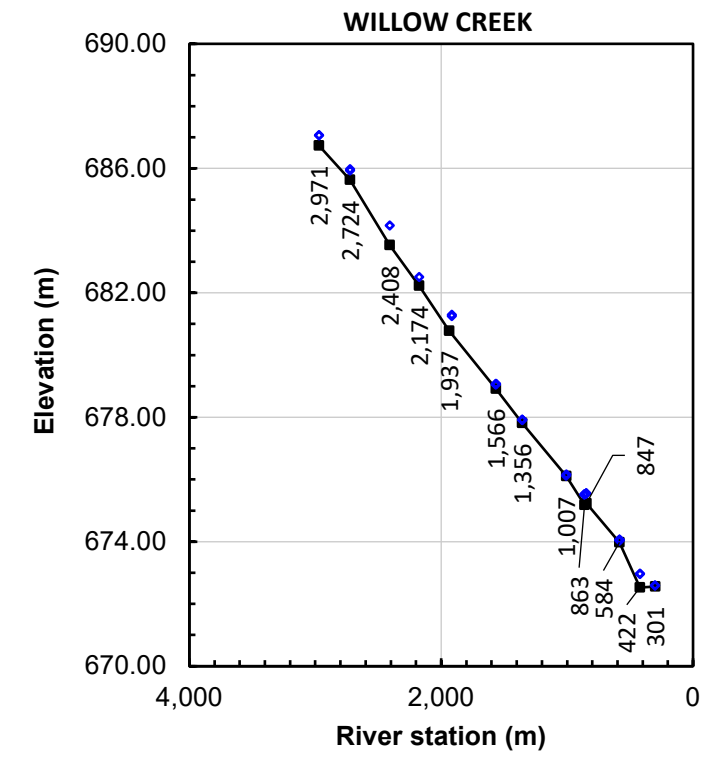
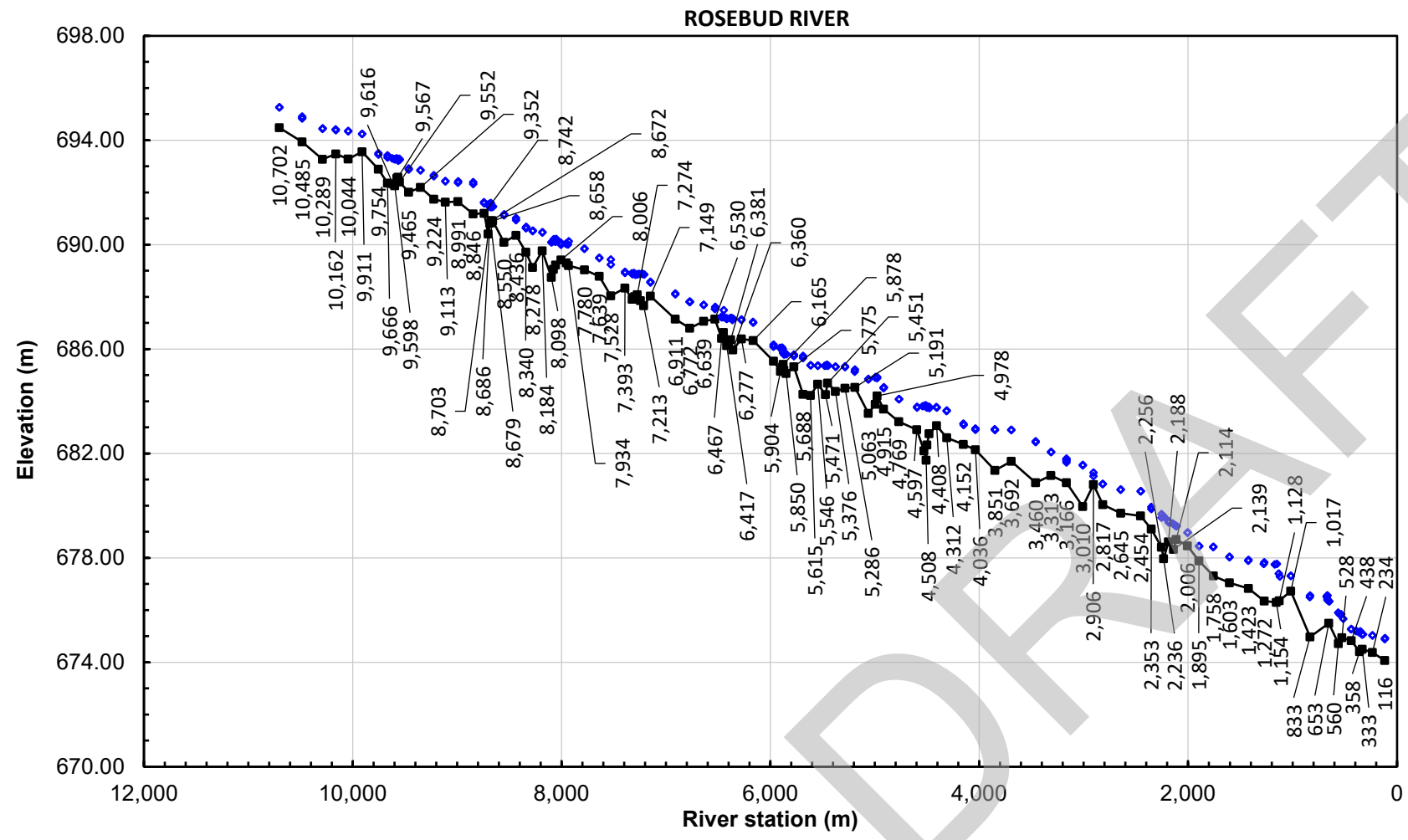
**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

**SURVEYED THALWEG AND WATER LEVEL PROFILES
SHEET 2 OF 3**

FIGURE 3 (2 OF 3)



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LEGEND
 ◆ Surveyed water level
 —■— Thalweg

SCALE - AS SHOWN

Elevation Datum: CGVD28 (HTv2.0)
 Units: As Shown

Job: 1003877

Date: 6-FEB-2019

**DRUMHELLER RIVER HAZARD STUDY
 SURVEY AND BASE DATA COLLECTION**
SURVEYED THALWEG AND WATER LEVEL PROFILES
SHEET 3 OF 3

FIGURE 3 (3 OF 3)

**APPENDIX A
CONTROL NETWORK SURVEY REPORTS**

DRAFT

A.1 Baseline Processing Report

Project file data		Coordinate System	
Name:	P:_Projects (Active)\1003877 Drumheller River Hazard Study\02 Data\Survey\3_Data Reduction\Drumheller Control Survey.vce	Name:	Canada/NAD 1983
Size:	117 KB	Datum:	NAD 1983 (Canada)
Modified:	2018-07-06 5:36:33 PM (UTC:-6)	Zone:	CM114W
Time zone:	Mountain Standard Time	Geoid:	Canada Geoid Model HT2_0
Reference number:		Vertical datum:	
Description:		Calibrated site:	
Comment 1:			
Comment 2:			
Comment 3:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ASCM470732 --- BASE_15 (B6)	ASCM470732	BASE_15	Fixed	0.007	0.025	122°55'06"	35635.803	-20.383
ASCM470732 --- BASE_13 (B18)	ASCM470732	BASE_13	Fixed	0.007	0.023	125°44'35"	28229.868	-16.924
ASCM470732 --- BASE_12 (B7)	ASCM470732	BASE_12	Fixed	0.006	0.021	119°39'16"	21616.451	-20.854
ASCM470732 --- ASCM440966 (B15)	ASCM470732	ASCM440966	Fixed	0.005	0.020	119°43'09"	17354.685	-15.571
ASCM470732 --- BASE_10 (B8)	ASCM470732	BASE_10	Fixed	0.009	0.030	139°17'03"	14904.318	6.795
ASCM470732 --- BASE_8 (B29)	ASCM470732	BASE_8	Fixed	0.007	0.028	126°49'25"	12841.420	-9.973
ASCM470732 --- BASE_7 (B12)	ASCM470732	BASE_7	Fixed	0.009	0.028	116°48'20"	13450.091	-12.975
ASCM470732 --- 6 (B9)	ASCM470732	6	Fixed	0.006	0.021	111°02'34"	9600.794	-14.489
ASCM470732 --- BASE_5 (B25)	ASCM470732	BASE_5	Fixed	0.006	0.019	86°03'44"	7522.835	-8.985
ASCM470732 --- BASE_4 (B13)	ASCM470732	BASE_4	Fixed	0.005	0.013	90°14'45"	4068.663	77.711
ASCM470732 --- BASE_2 (B34)	ASCM470732	BASE_2	Fixed	0.004	0.012	313°20'16"	3652.866	-6.758
ASCM470732 --- BASE_1 (B14)	ASCM470732	BASE_1	Fixed	0.005	0.013	274°49'55"	3979.361	-1.388
ASCM470732 --- 6 (B10)	ASCM470732	6	Fixed	0.006	0.021	111°02'34"	9600.794	-14.481

BASE_9 --- BASE_16 (B38)	BASE_9	BASE_16	Fixed	0.007	0.008	119°05'31"	29010.015	-25.533
BASE_9 --- BASE_16 (B37)	BASE_9	BASE_16	Fixed	0.008	0.028	119°05'31"	29010.018	-25.525
BASE_9 --- BASE_15 (B42)	BASE_9	BASE_15	Fixed	0.006	0.019	116°37'42"	22396.515	-22.842
BASE_9 --- BASE_13 (B39)	BASE_9	BASE_13	Fixed	0.008	0.032	118°45'40"	14857.865	-19.370
BASE_9 --- BASE_12 (B43)	BASE_9	BASE_12	Fixed	0.006	0.020	98°35'23"	9009.784	-23.333
BASE_9 --- ASCM440966 (B40)	BASE_9	ASCM440966	Fixed	0.004	0.014	81°45'31"	5253.764	-18.004
BASE_9 --- BASE_10 (B44)	BASE_9	BASE_10	Fixed	0.003	0.008	184°36'22"	1936.043	4.376
BASE_8 --- BASE_9 (B31)	BASE_9	BASE_8	Fixed	0.003	0.012	13°45'22"	1718.683	-12.406
6 --- BASE_9 (B3)	BASE_9	6	Fixed	0.005	0.011	351°20'22"	5989.457	-16.929
ASCM470732 --- BASE_9 (B11)	BASE_9	ASCM470732	Fixed	0.007	0.034	313°36'03"	13609.906	-2.436
ASCM470732 --- BASE_9 (B41)	BASE_9	ASCM470732	Fixed	0.006	0.023	313°36'03"	13609.913	-2.474
ASCM470732 --- BASE_16 (B23)	ASCM470732	BASE_16	Fixed	0.007	0.025	123°36'07"	42323.460	-23.096
ASCM470732 --- BASE_16 (B21)	ASCM470732	BASE_16	Fixed	0.007	0.009	123°36'07"	42323.464	-23.096
6 --- BASE_5 (B26)	6	BASE_5	Fixed	0.004	0.014	339°56'19"	4222.683	5.507
6 --- BASE_4 (B5)	6	BASE_4	Fixed	0.005	0.016	305°08'10"	5974.505	92.199
6 --- BASE_7 (B4)	6	BASE_7	Fixed	0.005	0.013	130°47'52"	4015.255	1.512
6 --- BASE_8 (B30)	6	BASE_8	Fixed	0.004	0.012	162°51'30"	4449.188	4.509
BASE_8 --- BASE_7 (B32)	BASE_8	BASE_7	Fixed	0.004	0.010	46°43'34"	2374.317	-2.990
ASCM440966 --- BASE_10 (B17)	ASCM440966	BASE_10	Fixed	0.005	0.015	243°26'50"	5989.472	22.384
BASE_12 --- ASCM440966 (B16)	BASE_12	ASCM440966	Fixed	0.005	0.013	299°36'08"	4261.823	5.338
BASE_12 --- BASE_13 (B20)	BASE_12	BASE_13	Fixed	0.005	0.017	144°45'10"	7114.891	3.949
BASE_15 --- BASE_13 (B19)	BASE_15	BASE_13	Fixed	0.005	0.018	292°39'47"	7569.168	3.480
BASE_15 --- BASE_16 (B24)	BASE_15	BASE_16	Fixed	0.005	0.018	127°34'20"	6703.677	-2.663
BASE_15 --- BASE_16 (B22)	BASE_15	BASE_16	Fixed	0.009	0.011	127°34'20"	6703.680	-2.664
6 --- BASE_1 (B2)	6	BASE_1	Fixed	0.010	0.028	286°24'43"	13467.835	13.112
6 --- BASE_2 (B35)	6	BASE_2	Fixed	0.008	0.029	297°14'15"	13054.347	7.721
6 --- BASE_4 (B1)	6	BASE_4	Fixed	0.008	0.010	305°08'10"	5974.504	92.201

Baseline processing report (continued)

BASE_2 --- BASE_1 (B33)	BASE_2	BASE_1	Fixed	0.003	0.009	211°02'15"	2535.462	5.373
BASE_2 --- BASE_4 (B36)	BASE_2	BASE_4	Fixed	0.006	0.018	110°32'38"	7183.592	84.482
BASE_5 --- BASE_4 (B28)	BASE_5	BASE_4	Fixed	0.005	0.014	261°15'02"	3477.704	86.681
BASE_7 --- BASE_5 (B27)	BASE_7	BASE_5	Fixed	0.005	0.018	325°46'39"	7973.172	3.998

Acceptance Summary

Processed	Passed	Flag	Fail
44	44	0	0

ASCM470732 - BASE_15 (1:42:04 PM-4:17:28 PM) (S7)

Baseline observation:	ASCM470732 --- BASE_15 (B6)
Processed:	2018-07-03 4:13:22 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.007 m
Vertical precision:	0.025 m
RMS:	0.012 m
Maximum PDOP:	1.728
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	2018-06-27 1:42:12 PM (Local: UTC-6hr)
Processing stop time:	2018-06-27 4:17:12 PM (Local: UTC-6hr)
Processing duration:	02:35:00
Processing interval:	1 Minute

Baseline processing report (continued)

Vector Components (Mark to Mark)

From: ASCM470732					
Grid		Local		Global	
Easting	82944.572 m	Latitude	N51°28'33.37124"	Latitude	N51°28'33.37124"
Northing	5705140.671 m	Longitude	W112°48'21.67387"	Longitude	W112°48'21.67387"
Elevation	698.651 m	Height	680.193 m	Height	680.193 m

To: BASE_15					
Grid		Local		Global	
Easting	113170.798 m	Latitude	N51°18'03.89347"	Latitude	N51°18'03.89347"
Northing	5686263.863 m	Longitude	W112°22'37.53492"	Longitude	W112°22'37.53492"
Elevation	678.166 m	Height	659.809 m	Height	659.809 m

Vector					
ΔEasting	30226.226 m	NS Fwd Azimuth	122°55'06"	ΔX	21734.017 m
ΔNorthing	-18876.808 m	Ellipsoid Dist.	35635.803 m	ΔY	-25495.391 m
ΔElevation	-20.485 m	ΔHeight	-20.383 m	ΔZ	-12156.957 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.003 m	σ Ellipsoid Dist.	0.003 m	σ ΔY	0.008 m
σ ΔElevation	0.013 m	σ ΔHeight	0.013 m	σ ΔZ	0.010 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000139542		
Y	0.0000223420	0.0000620916	
Z	-0.0000290462	-0.0000718818	0.0001052945

Baseline processing report (continued)

Occupations

	From	To
Point ID:	ASCM470732	BASE_15
Data file:	P:_Projects (Active)\1003877 Drumheller River Hazard Study\02 Data\Survey\3_Data Reduction\Drumheller Control Survey\50961781.T01	P:_Projects (Active)\1003877 Drumheller River Hazard Study\02 Data\Survey\3_Data Reduction\Drumheller Control Survey\base17801.18o
Receiver type:	R8 Model 2	Unknown
Receiver serial number:	4621115096	Q8F8JAIPEKG
Antenna type:	R8 GNSS/SPS88x Internal	TPS GR3
Antenna serial number:	-----	000
Antenna height (measured):	2.000 m	1.509 m
Antenna method:	Bottom of antenna mount	Bottom of antenna mount

DRAFT

Baseline processing report (continued)

A.2 Network Adjustment Report

10/16/2018 Network Adjustment Report

Project File Data	Coordinate System
Name: P:_Projects (Active)\1003877 Drumheller River Hazard Study\02 Data\Survey\3_Data Reduction\Drumheller Control Survey.vce	Name: Canada/NAD 1983
Size: 117 KB	Datum: NAD 1983 (Canada)
Modified: 2018-07-06 5:36:33 PM (UTC:-6)	Zone: CM114W
Time zone: Mountain Standard Time	Geoid: Canada Geoid Model HT2_0
Reference number:	Vertical datum:
Description:	Calibrated site:
Comment 1:	
Comment 2:	
Comment 3:	

Network Adjustment Report

Adjustment Settings

Set-Up Errors

GNSS

Error in Height of Antenna: 0.000 m
Centering Error: 0.000 m

Covariance Display

Horizontal:

Propagated Linear Error [E]: U.S.
Constant Term [C]: 0.000 m
Scale on Linear Error [S]: 1.960

Three-Dimensional

Propagated Linear Error [E]: U.S.
Constant Term [C]: 0.000 m
Scale on Linear Error [S]: 1.960

Adjustment Statistics

Number of Iterations for Successful Adjustment: 2
Network Reference Factor: 1.00
Chi Square Test (95%): Passed
Precision Confidence Level: 95%
Degrees of Freedom: 91

Post Processed Vector Statistics

Reference Factor: 1.00
Redundancy Number: 91.00
A Priori Scalar: 1.95

Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
6	Grid	Fixed	Fixed		Fixed
ASCM470732	Grid	Fixed	Fixed		Fixed
Fixed = 0.000001(Meter)					

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Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
6	91961.575	?	5701840.312	?	685.465	?	ENc
ASCM440966	98156.258	0.006	5696784.261	0.007	684.331	0.018	
ASCM470732	82946.070	?	5705141.085	?	699.947	?	ENe
BASE_1	78975.986	0.004	5705411.571	0.005	698.545	0.017	
BASE_10	92850.971	0.006	5694004.216	0.007	706.598	0.017	
BASE_12	101903.190	0.007	5694753.371	0.009	678.998	0.020	
BASE_13	106124.490	0.009	5689025.736	0.011	682.881	0.022	
BASE_15	113172.339	0.011	5686264.263	0.013	679.439	0.016	
BASE_16	118574.973	0.013	5682294.778	0.016	676.781	0.011	
BASE_2	80248.791	0.004	5707604.347	0.005	693.226	0.016	
BASE_4	87014.401	0.003	5705189.967	0.004	777.691	0.012	
BASE_5	90441.680	0.004	5705779.995	0.004	691.031	0.016	
BASE_7	95048.094	0.004	5699272.053	0.005	686.955	0.016	
BASE_8	93349.459	0.004	5697613.100	0.004	689.899	0.014	
BASE_9	92971.264	0.004	5695936.533	0.005	702.269	0.011	

Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
6	N51°26'41.58243"	W112°40'37.61352"	667.017	?	ENc
ASCM440966	N51°23'54.27253"	W112°35'21.95133"	665.936	0.018	
ASCM470732	N51°28'33.38384"	W112°48'21.59590"	681.489	?	ENe
BASE_1	N51°28'44.17955"	W112°51'47.07005"	680.103	0.017	
BASE_10	N51°22'27.54520"	W112°39'58.95010"	688.312	0.017	
BASE_12	N51°22'46.19492"	W112°32'10.27027"	660.609	0.020	
BASE_13	N51°19'38.12377"	W112°28'38.20208"	664.565	0.022	
BASE_15	N51°18'03.90532"	W112°22'37.45492"	661.083	0.016	
BASE_16	N51°15'51.54587"	W112°18'03.41210"	658.410	0.011	
BASE_2	N51°29'54.48002"	W112°50'39.32773"	674.731	0.016	
BASE_4	N51°28'32.76645"	W112°44'50.77777"	759.210	0.012	
BASE_5	N51°28'49.92113"	W112°41'52.67566"	672.524	0.016	
BASE_7	N51°25'16.66148"	W112°38'00.30105"	668.531	0.016	
BASE_8	N51°24'24.00655"	W112°39'29.76801"	671.524	0.014	
BASE_9	N51°23'29.98936"	W112°39'50.91199"	683.937	0.011	

Adjusted ECEF Coordinates

Point ID	X (Meter)	X Error (Meter)	Y (Meter)	Y Error (Meter)	Z (Meter)	Z Error (Meter)	3D Error (Meter)	Constraint
6	-1535928.094	?	-3675877.679	?	4965064.468	?	?	ENc
ASCM440966	-1531853.436	0.007	-3681955.750	0.012	4961838.958	0.014	0.020	
ASCM470732	-1543148.738	?	-3669930.142	?	4967228.792	?	?	ENc
BASE_1	-1546702.071	0.006	-3668149.747	0.011	4967435.528	0.013	0.018	
BASE_10	-1537609.181	0.007	-3681840.874	0.011	4960183.612	0.013	0.019	
BASE_12	-1529060.025	0.009	-3684893.238	0.013	4960521.765	0.016	0.023	

Network adjustment report (continued)

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Network Adjustment Report

BASE_13	-1527007.258	0.011	-3690660.627	0.016	4956894.680	0.018	0.026
BASE_15	-1521414.674	0.012	-3695425.548	0.014	4955071.800	0.015	0.024
BASE_16	-1517714.179	0.013	-3700395.186	0.013	4952510.987	0.013	0.023
BASE_2	-1544835.904	0.005	-3667087.569	0.010	4968784.297	0.013	0.017
BASE_4	-1539421.479	0.005	-3671563.849	0.007	4967277.711	0.009	0.013
BASE_5	-1536069.739	0.006	-3672459.204	0.010	4967540.120	0.012	0.017
BASE_7	-1533914.284	0.005	-3678943.061	0.010	4963429.325	0.013	0.017
BASE_8	-1536000.661	0.005	-3679453.051	0.009	4962416.646	0.011	0.015
BASE_9	-1536883.579	0.005	-3680506.739	0.007	4961384.730	0.009	0.013

Error Ellipse Components

Point ID	Semi-major axis (Meter)	Semi-minor axis (Meter)	Azimuth
ASCM440966	0.009	0.007	2°
BASE_1	0.007	0.005	9°
BASE_10	0.008	0.007	20°
BASE_12	0.011	0.009	2°
BASE_13	0.014	0.011	9°
BASE_15	0.017	0.013	8°
BASE_16	0.020	0.016	9°
BASE_2	0.006	0.005	174°
BASE_4	0.005	0.004	166°
BASE_5	0.005	0.004	171°
BASE_7	0.006	0.005	177°
BASE_8	0.006	0.005	13°
BASE_9	0.006	0.005	20°

Adjusted GNSS Observations

Transformation Parameters

Azimuth Rotation: 0.093 sec (95%) 0.073 sec
 Scale Factor: 1.00000149 (95%) 0.00000031

Observation ID	Observation	A-posteriori Error	Residual	Standardized Residual
BASE_9 -> BASE_8 (PV31)	Az.	13°45'21"	0.404 sec	-3.417
	Δ HL	-12.412 m	0.016 m	-0.683
	Ellip Dist.	1718.680 m	0.004 m	-1.605
BASE_9 -> ASCM470732 (PV11)	Az.	313°36'03"	0.047 sec	-3.347
	Δ HL	-2.448 m	0.011 m	-0.279
	Ellip Dist.	13609.907 m	0.003 m	0.906
BASE_9 -> 6 (PV3)	Az.	351°20'21"	0.114 sec	-2.370
	Δ HL	-16.919 m	0.011 m	0.924
	Ellip Dist.	5989.459 m	0.004 m	0.717
BASE_9 -> ASCM470732 (PV41)	Az.	313°36'03"	0.047 sec	2.271
	Δ HL	-2.448 m	0.011 m	1.307
	Ellip Dist.	13609.907 m	0.003 m	-0.934
ASCM470732 -> BASE_16 (PV21)	Az.	123°36'07"	0.023 sec	-1.215
	Δ HL	-23.080 m	0.011 m	1.571
	Ellip Dist.	42323.449 m	0.004 m	-2.119

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Network adjustment report (continued)

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Network Adjustment Report

ASCM470732 --> BASE_10.(PV8)	Az.	139°17'03"	0.063 sec	0.154 sec	1.886
	AHt.	6.823 m	0.017 m	0.027 m	0.919
	Ellip Dist.	14904.311 m	0.004 m	-0.004 m	-0.754
ASCM470732 --> ASCM440966.(PV15)	Az.	119°43'09"	0.050 sec	0.074 sec	1.873
	AHt.	-15.553 m	0.018 m	0.015 m	0.855
	Ellip Dist.	17354.679 m	0.004 m	-0.002 m	-0.605
BASE_15 --> BASE_13.(PV19)	Az.	292°39'47"	0.141 sec	0.113 sec	1.809
	AHt.	3.483 m	0.023 m	0.004 m	0.332
	Ellip Dist.	7569.167 m	0.005 m	0.000 m	0.150
ASCM470732 --> BASE_12.(PV7)	Az.	119°39'16"	0.044 sec	0.035 sec	0.939
	AHt.	-20.880 m	0.020 m	-0.030 m	-1.703
	Ellip Dist.	21616.446 m	0.005 m	-0.001 m	-0.308
BASE_9 --> BASE_10.(PV44)	Az.	184°36'22"	0.375 sec	-0.233 sec	-1.602
	AHt.	4.376 m	0.014 m	0.000 m	-0.030
	Ellip Dist.	1936.043 m	0.004 m	0.001 m	0.410
ASCM470732 --> BASE_8.(PV29)	Az.	126°49'25"	0.062 sec	-0.121 sec	-1.561
	AHt.	-9.965 m	0.014 m	0.006 m	0.242
	Ellip Dist.	12841.420 m	0.004 m	0.002 m	0.580
BASE_12 --> BASE_13.(PV20)	Az.	144°45'11"	0.146 sec	0.142 sec	1.517
	AHt.	3.957 m	0.023 m	0.007 m	0.571
	Ellip Dist.	7114.893 m	0.005 m	0.003 m	1.262
BASE_9 --> BASE_16.(PV38)	Az.	119°05'31"	0.034 sec	0.000 sec	-0.009
	AHt.	-25.527 m	0.011 m	0.000 m	0.070
	Ellip Dist.	29010.015 m	0.004 m	0.006 m	1.449
BASE_15 --> BASE_16.(PV24)	Az.	127°34'20"	0.149 sec	0.140 sec	1.410
	AHt.	-2.673 m	0.015 m	-0.011 m	-0.667
	Ellip Dist.	6703.679 m	0.005 m	0.002 m	0.886
BASE_15 --> BASE_16.(PV22)	Az.	127°34'20"	0.149 sec	0.051 sec	0.276
	AHt.	-2.673 m	0.015 m	-0.010 m	-1.332
	Ellip Dist.	6703.679 m	0.005 m	0.000 m	0.000
BASE_9 --> ASCM440966.(PV40)	Az.	81°45'31"	0.162 sec	-0.051 sec	-0.483
	AHt.	-18.001 m	0.017 m	0.001 m	0.123
	Ellip Dist.	5253.766 m	0.003 m	0.003 m	1.312
BASE_8 --> BASE_7.(PV32)	Az.	46°43'34"	0.342 sec	-0.050 sec	-0.346
	AHt.	-2.994 m	0.015 m	-0.004 m	-0.676
	Ellip Dist.	2374.314 m	0.004 m	-0.002 m	-1.254
ASCM470732 --> BASE_15.(PV6)	Az.	122°55'06"	0.027 sec	0.026 sec	0.988
	AHt.	-20.406 m	0.016 m	-0.029 m	-1.223
	Ellip Dist.	35635.794 m	0.004 m	-0.002 m	-0.479
6 --> BASE_8.(PV30)	Az.	162°51'30"	0.154 sec	-0.118 sec	-1.208
	AHt.	4.507 m	0.014 m	-0.002 m	-0.242
	Ellip Dist.	4449.188 m	0.004 m	0.001 m	0.379
BASE_12 --> ASCM440966.(PV16)	Az.	299°36'08"	0.210 sec	0.098 sec	1.065
	AHt.	5.327 m	0.019 m	-0.010 m	-1.177
	Ellip Dist.	4261.823 m	0.005 m	0.001 m	0.248
ASCM470732 --> BASE_4.(PV13)	Az.	90°14'45"	0.212 sec	0.080 sec	0.537
	AHt.	77.721 m	0.012 m	0.009 m	0.797
	Ellip Dist.	4068.665 m	0.004 m	0.003 m	1.167
BASE_9 --> BASE_15.(PV42)	Az.	116°37'42"	0.043 sec	-0.035 sec	-1.121

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Network adjustment report (continued)

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Network Adjustment Report

	AHt	-22.854 m	0.016 m	-0.016 m	-0.952
	Ellip Dist	22396.514 m	0.004 m	0.003 m	0.912
6 --> BASE_4 (PV5)	Az	305°08'10"	0.130 sec	0.079 sec	0.605
	AHt	92.193 m	0.012 m	-0.005 m	-0.339
	Ellip Dist	5974.507 m	0.004 m	0.003 m	1.075
ASCM470732 --> BASE_5 (PV25)	Az	86°03'44"	0.126 sec	0.045 sec	0.441
	AHt	-8.965 m	0.016 m	0.018 m	1.071
	Ellip Dist	7522.837 m	0.004 m	0.003 m	0.888
BASE_2 --> BASE_4 (PV36)	Az	110°32'38"	0.135 sec	0.090 sec	1.042
	AHt	84.479 m	0.018 m	-0.004 m	-0.258
	Ellip Dist	7183.593 m	0.005 m	0.003 m	0.892
ASCM470732 --> BASE_13 (PV18)	Az	125°44'35"	0.036 sec	-0.004 sec	-0.131
	AHt	-16.924 m	0.022 m	-0.004 m	-0.226
	Ellip Dist	28229.858 m	0.005 m	-0.004 m	-1.029
BASE_9 --> BASE_12 (PV43)	Az	98°35'23"	0.107 sec	-0.042 sec	-0.464
	AHt	-23.328 m	0.019 m	0.003 m	0.178
	Ellip Dist	9009.785 m	0.004 m	0.003 m	0.915
ASCM470732 --> 6 (PV9)	Az	111°02'34"	0.073 sec	-0.012 sec	-0.127
	AHt	-14.472 m	0.000 m	0.015 m	0.733
	Ellip Dist	9600.795 m	0.003 m	0.003 m	0.878
6 --> BASE_4 (PV1)	Az	305°08'10"	0.130 sec	-0.120 sec	-0.869
	AHt	92.193 m	0.012 m	-0.007 m	-0.777
	Ellip Dist	5974.507 m	0.004 m	0.004 m	0.681
6 --> BASE_1 (PV2)	Az	286°24'43"	0.085 sec	-0.059 sec	-0.513
	AHt	13.086 m	0.017 m	-0.022 m	-0.850
	Ellip Dist	13467.834 m	0.004 m	0.002 m	0.411
BASE_9 --> BASE_16 (PV37)	Az	119°05'31"	0.034 sec	-0.031 sec	-0.817
	AHt	-25.527 m	0.011 m	-0.007 m	-0.258
	Ellip Dist	29010.015 m	0.004 m	0.002 m	0.502
BASE_9 --> BASE_13 (PV39)	Az	118°45'41"	0.070 sec	0.034 sec	0.459
	AHt	-19.371 m	0.022 m	-0.004 m	-0.142
	Ellip Dist	14857.866 m	0.005 m	0.004 m	0.815
ASCM470732 --> 6 (PV10)	Az	111°02'34"	0.073 sec	-0.028 sec	-0.307
	AHt	-14.472 m	0.000 m	0.007 m	0.338
	Ellip Dist	9600.795 m	0.003 m	0.003 m	0.806
ASCM440966 --> BASE_10 (PV17)	Az	243°26'50"	0.159 sec	0.064 sec	0.753
	AHt	22.377 m	0.018 m	-0.006 m	-0.544
	Ellip Dist	5989.470 m	0.004 m	-0.001 m	-0.529
6 --> BASE_5 (PV26)	Az	339°56'19"	0.176 sec	-0.025 sec	-0.224
	AHt	5.507 m	0.016 m	0.000 m	-0.010
	Ellip Dist	4222.684 m	0.004 m	0.002 m	0.715
BASE_5 --> BASE_4 (PV28)	Az	261°15'02"	0.284 sec	0.069 sec	0.392
	AHt	86.686 m	0.017 m	0.006 m	0.570
	Ellip Dist	3477.703 m	0.004 m	-0.001 m	-0.205
6 --> BASE_7 (PV4)	Az	130°47'52"	0.199 sec	-0.074 sec	-0.568
	AHt	1.514 m	0.016 m	0.001 m	0.083
	Ellip Dist	4015.254 m	0.004 m	0.000 m	0.022
ASCM470732 --> BASE_16 (PV23)	Az	123°36'07"	0.023 sec	-0.004 sec	-0.154
	AHt	-23.080 m	0.011 m	0.009 m	0.383
	Ellip Dist	42323.449 m	0.004 m	-0.002 m	-0.550

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Network adjustment report (continued)

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Network Adjustment Report

BASE_2 -> BASE_1 (PV33)	Az.	211°02'15"	0.312 sec	0.061 sec	0.536
	ΔHt.	5.372 m	0.015 m	0.000 m	0.043
	Ellip Dist.	2535.461 m	0.004 m	-0.001 m	-0.422
ASCM470732 -> BASE_7 (PV12)	Az.	116°48'20"	0.068 sec	-0.041 sec	-0.460
	ΔHt.	-12.958 m	0.016 m	0.014 m	0.524
	Ellip Dist.	13450.090 m	0.004 m	0.002 m	0.359
ASCM470732 -> BASE_1 (PV14)	Az.	274°49'55"	0.257 sec	-0.049 sec	-0.328
	ΔHt.	-1.386 m	0.017 m	0.004 m	0.402
	Ellip Dist.	3979.359 m	0.004 m	-0.001 m	-0.495
6 -> BASE_2 (PV35)	Az.	297°14'15"	0.071 sec	-0.037 sec	-0.456
	ΔHt.	7.714 m	0.016 m	-0.004 m	-0.149
	Ellip Dist.	13054.345 m	0.004 m	0.001 m	0.191
BASE_7 -> BASE_5 (PV27)	Az.	325°46'39"	0.108 sec	-0.011 sec	-0.181
	ΔHt.	3.993 m	0.020 m	-0.004 m	-0.298
	Ellip Dist.	7973.172 m	0.005 m	0.001 m	0.324
ASCM470732 -> BASE_2 (PV34)	Az.	313°20'16"	0.213 sec	0.018 sec	0.159
	ΔHt.	-6.758 m	0.016 m	0.001 m	0.076
	Ellip Dist.	3652.865 m	0.004 m	-0.001 m	-0.258

Covariance Terms

From Point	To Point	Components	A-posteriori Error	Horiz. Precision (Ratio)	3D Precision (Ratio)	
6	BASE_2	Az.	297°14'15"	0.071 sec	1 : 3151422	1 : 3141999
		ΔHt.	7.714 m	0.016 m		
		ΔElev.	7.761 m	0.016 m		
		Ellip Dist.	13054.364 m	0.004 m		
6	BASE_5	Az.	339°56'19"	0.176 sec	1 : 1004147	1 : 1003748
		ΔHt.	5.507 m	0.016 m		
		ΔElev.	5.566 m	0.016 m		
		Ellip Dist.	4222.690 m	0.004 m		
6	BASE_8	Az.	162°51'29"	0.185 sec	1 : 1025193	1 : 1022472
		ΔHt.	4.507 m	0.014 m		
		ΔElev.	4.434 m	0.014 m		
		Ellip Dist.	4449.195 m	0.004 m		
ASCM470732	6	Az.	111°02'34"	0.000 sec	1 : 0	1 : 0
		ΔHt.	-14.472 m	0.000 m		
		ΔElev.	-14.482 m	0.000 m		
		Ellip Dist.	9600.810 m	0.000 m		
ASCM470732	ASCM440966	Az.	119°43'09"	0.082 sec	1 : 2830081	1 : 2822212
		ΔHt.	-15.553 m	0.018 m		
		ΔElev.	-15.616 m	0.018 m		
		Ellip Dist.	17354.705 m	0.006 m		
ASCM470732	BASE_1	Az.	274°49'54"	0.279 sec	1 : 949660	1 : 950330
		ΔHt.	-1.386 m	0.017 m		
		ΔElev.	-1.402 m	0.017 m		
		Ellip Dist.	3979.365 m	0.004 m		
ASCM470732	BASE_10	Az.	139°17'03"	0.089 sec	1 : 2557923	1 : 2550567
		ΔHt.	6.823 m	0.017 m		
		ΔElev.	6.651 m	0.017 m		
		Ellip Dist.	14904.333 m	0.006 m		

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Network adjustment report (continued)

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Network Adjustment Report

ASCM470732	BASE_12	Az.	119°39'16"	0.080 sec	1 : 2879142	1 : 2870598
		ΔHt.	-20.880 m	0.020 m		
		ΔElev.	-20.949 m	0.020 m		
		Ellip Dist.	21616.478 m	0.008 m		
ASCM470732	BASE_13	Az.	125°44'35"	0.078 sec	1 : 3005989	1 : 2996655
		ΔHt.	-16.924 m	0.022 m		
		ΔElev.	-17.066 m	0.022 m		
		Ellip Dist.	28229.901 m	0.009 m		
ASCM470732	BASE_15	Az.	122°55'06"	0.075 sec	1 : 3177115	1 : 3167251
		ΔHt.	-20.406 m	0.016 m		
		ΔElev.	-20.508 m	0.016 m		
		Ellip Dist.	35635.847 m	0.011 m		
ASCM470732	BASE_16	Az.	123°36'07"	0.074 sec	1 : 3244611	1 : 3234249
		ΔHt.	-23.079 m	0.011 m		
		ΔElev.	-23.166 m	0.011 m		
		Ellip Dist.	42323.512 m	0.013 m		
ASCM470732	BASE_2	Az.	313°20'16"	0.241 sec	1 : 838171	1 : 835208
		ΔHt.	-6.758 m	0.016 m		
		ΔElev.	-6.721 m	0.016 m		
		Ellip Dist.	3652.870 m	0.004 m		
ASCM470732	BASE_4	Az.	90°14'45"	0.193 sec	1 : 1250576	1 : 1257564
		ΔHt.	77.721 m	0.012 m		
		ΔElev.	77.744 m	0.012 m		
		Ellip Dist.	4068.671 m	0.003 m		
ASCM470732	BASE_5	Az.	86°03'44"	0.116 sec	1 : 2109273	1 : 2105864
		ΔHt.	-8.965 m	0.016 m		
		ΔElev.	-8.916 m	0.016 m		
		Ellip Dist.	7522.848 m	0.004 m		
ASCM470732	BASE_7	Az.	116°48'20"	0.072 sec	1 : 3197556	1 : 3186926
		ΔHt.	-12.958 m	0.016 m		
		ΔElev.	-12.992 m	0.016 m		
		Ellip Dist.	13450.110 m	0.004 m		
ASCM470732	BASE_8	Az.	126°49'25"	0.071 sec	1 : 3289156	1 : 3281509
		ΔHt.	-9.965 m	0.014 m		
		ΔElev.	-10.048 m	0.014 m		
		Ellip Dist.	12841.439 m	0.004 m		
ASCM470732	BASE_9	Az.	133°29'24"	0.074 sec	1 : 3159362	1 : 3151142
		ΔHt.	2.448 m	0.011 m		
		ΔElev.	2.322 m	0.011 m		
		Ellip Dist.	13609.927 m	0.004 m		
BASE_1	6	Az.	106°15'59"	0.082 sec	1 : 3206238	1 : 3203097
		ΔHt.	-13.086 m	0.017 m		
		ΔElev.	-13.080 m	0.017 m		
		Ellip Dist.	13467.854 m	0.004 m		
BASE_1	BASE_2	Az.	31°01'22"	0.319 sec	1 : 564818	1 : 565437
		ΔHt.	-5.372 m	0.015 m		
		ΔElev.	-5.319 m	0.015 m		
		Ellip Dist.	2535.465 m	0.004 m		
BASE_10	ASCM440966	Az.	63°23'13"	0.176 sec	1 : 1310210	1 : 1313265
		ΔHt.	-22.377 m	0.018 m		
		ΔElev.	-22.267 m	0.018 m		
		Ellip Dist.	5989.479 m	0.005 m		
BASE_12	ASCM440966	Az.	299°36'08"	0.224 sec	1 : 888426	1 : 884881
		ΔHt.	5.327 m	0.019 m		

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Network adjustment report (continued)

10/16/2018

Network Adjustment Report

		AElev.	5.334 m	0.019 m		
		Ellip Dist.	4261.829 m	0.005 m		
BASE_12	BASE_13	Az.	144°45'11"	0.164 sec	1 : 1247341	1 : 1242864
		ΔHt.	3.957 m	0.023 m		
		AElev.	3.883 m	0.023 m		
		Ellip Dist.	7114.903 m	0.006 m		
BASE_15	BASE_13	Az.	292°39'47"	0.159 sec	1 : 1450830	1 : 1443106
		ΔHt.	3.483 m	0.023 m		
		AElev.	3.442 m	0.023 m		
		Ellip Dist.	7569.178 m	0.005 m		
BASE_15	BASE_16	Az.	127°34'20"	0.167 sec	1 : 1348295	1 : 1340732
		ΔHt.	-2.673 m	0.015 m		
		AElev.	-2.658 m	0.015 m		
		Ellip Dist.	6703.689 m	0.005 m		
BASE_4	6	Az.	125°04'52"	0.121 sec	1 : 1668634	1 : 1656476
		ΔHt.	-92.193 m	0.012 m		
		AElev.	-92.226 m	0.012 m		
		Ellip Dist.	5974.516 m	0.004 m		
BASE_4	BASE_2	Az.	290°37'11"	0.143 sec	1 : 1523063	1 : 1515122
		ΔHt.	-84.479 m	0.018 m		
		AElev.	-84.465 m	0.018 m		
		Ellip Dist.	7183.604 m	0.005 m		
BASE_4	BASE_5	Az.	81°12'43"	0.289 sec	1 : 843015	1 : 820640
		ΔHt.	-86.686 m	0.017 m		
		AElev.	-86.659 m	0.017 m		
		Ellip Dist.	3477.708 m	0.004 m		
BASE_7	6	Az.	310°49'55"	0.230 sec	1 : 906443	1 : 902912
		ΔHt.	-1.514 m	0.016 m		
		AElev.	-1.490 m	0.016 m		
		Ellip Dist.	4015.260 m	0.004 m		
BASE_7	BASE_5	Az.	325°46'39"	0.129 sec	1 : 1469076	1 : 1465154
		ΔHt.	3.993 m	0.020 m		
		AElev.	4.076 m	0.020 m		
		Ellip Dist.	7973.183 m	0.005 m		
BASE_7	BASE_8	Az.	226°44'43"	0.345 sec	1 : 603280	1 : 605391
		ΔHt.	2.994 m	0.015 m		
		AElev.	2.944 m	0.015 m		
		Ellip Dist.	2374.318 m	0.004 m		
BASE_9	6	Az.	351°20'21"	0.151 sec	1 : 1236135	1 : 1232515
		ΔHt.	-16.919 m	0.011 m		
		AElev.	-16.804 m	0.011 m		
		Ellip Dist.	5989.468 m	0.005 m		
BASE_9	ASCM440966	Az.	81°45'31"	0.183 sec	1 : 1356684	1 : 1356226
		ΔHt.	-18.001 m	0.017 m		
		AElev.	-17.938 m	0.017 m		
		Ellip Dist.	5253.773 m	0.004 m		
BASE_9	BASE_10	Az.	184°36'22"	0.381 sec	1 : 460089	1 : 459674
		ΔHt.	4.376 m	0.014 m		
		AElev.	4.329 m	0.014 m		
		Ellip Dist.	1936.046 m	0.004 m		
BASE_9	BASE_12	Az.	98°35'23"	0.135 sec	1 : 1756590	1 : 1750578
		ΔHt.	-23.328 m	0.019 m		
		AElev.	-23.271 m	0.019 m		

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Network adjustment report (continued)

10/16/2018

Network Adjustment Report


		Ellip Dist.	9009.799 m	0.005 m		
BASE_9	BASE_13	Az.	118°45'40"	0.106 sec	1 : 2192130	1 : 2183674
		ΔHt.	-19.371 m	0.022 m		
		ΔElev.	-19.388 m	0.022 m		
		Ellip Dist.	14857.888 m	0.007 m		
BASE_9	BASE_15	Az.	116°37'42"	0.088 sec	1 : 2674974	1 : 2664983
		ΔHt.	-22.854 m	0.016 m		
		ΔElev.	-22.830 m	0.016 m		
		Ellip Dist.	22396.547 m	0.008 m		
BASE_9	BASE_16	Az.	119°05'31"	0.083 sec	1 : 2866620	1 : 2855623
		ΔHt.	-25.527 m	0.011 m		
		ΔElev.	-25.488 m	0.011 m		
		Ellip Dist.	29010.058 m	0.010 m		
BASE_9	BASE_8	Az.	13°45'21"	0.409 sec	1 : 432745	1 : 431788
		ΔHt.	-12.412 m	0.016 m		
		ΔElev.	-12.370 m	0.016 m		
		Ellip Dist.	1718.682 m	0.004 m		

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Network adjustment report (continued)

A.3 CSRS-PPP Reports



CSRS-PPP (V 1.05 11216)



BASE_1 (NHCI)		
Data Start	Data End	Duration of Observations
2018-06-26 15:30:00.000	2018-06-26 16:38:34.000	1h 8m 34.00s
Apri / Aposteriori Phase Std		Apri / Aposteriori Code Std
0.020m / 0.009m		2.0m / 2.000m
Observations	Frequency	Mode
Phase and Code	L1 and L2	Static
Elevation Cut-Off	Rejected Epochs	Observation & Estimation Steps
10.000 degrees	0.00 %	2.00 sec / 2.00 sec
Antenna Model	APC to ARP	ARP to Marker
TPSGR3	L1= 0.216 m L2= 0.218 m	1.535 m

(APC = antenna phase center, ARP = antenna reference point)

Estimated Position for base1770.18o

	Latitude (+n)	Longitude (+e)	Ell Height
NAD83(CSRS) (2002)	51° 28' 44.1798"	-112° 51' 47.0691"	680.162 m
Sigmas(95%)	0.024 m	0.038 m	0.074 m
Apriori	51° 28' 44.190"	-112° 51' 47.158"	679.344 m
Estimated - Apriori	-0.299 m	1.713 m	0.818 m

Orthometric Height
CGVD28 (HTv2.0)

698.603 m

(click for height reference information)

95% Error Ellipse (cm)
 semi-major: 4.868cm
 semi-minor: 2.801cm
 semi-major azimuth: 75° 0' 0.69"



UTM (North) Zone 12

5704732.835m (N) 370624.372m (E)

Scale Factors
 0.99980551 (point)
 0.99969878 (combined)

(Coordinates from RINEX file used as apriori position)

22:44:11 UTC 2018/07/03 / base1770.18o
1
NAD83v6VG / NRCan Rapid



CSRS-PPP (V 1.05 11216)



BASE_2 (NHC2)

Data Start	Data End	Duration of Observations
2018-06-26 15:41:36.000	2018-06-26 18:02:42.000	2h 21m 6.00s
Apri / Aposteriori Phase Std		Apri / Aposteriori Code Std
0.020m / 0.009m		2.0m / 1.782m
Observations	Frequency	Mode
Phase and Code	L1 and L2	Static
Elevation Cut-Off	Rejected Epochs	Observation & Estimation Steps
10.000 degrees	0.00 %	2.00 sec / 2.00 sec
Antenna Model	APC to ARP	ARP to Marker
TSPGR3	L1= 0.216 m L2= 0.218 m	1.557 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for base1770a.18o

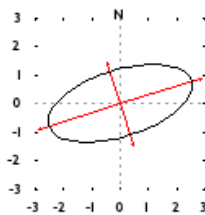
	Latitude (+n)	Longitude (+e)	ELL Height
NAD83(CSRS) (2002)	51° 29' 54.4801''	-112° 50' 39.3268''	674.768 m
Sigmatas(95%)	0.011 m	0.020 m	0.033 m
Apriori	51° 29' 54.506''	-112° 50' 39.414''	674.688 m
Estimated - Apriori	-0.812 m	1.675 m	0.080 m

**Orthometric Height
CGVD28 (HTv2.0)**

693.263 m

(click for height reference information)

95% Error Ellipse (cm)
 semi-major: 2.644cm
 semi-minor: 1.164cm
 semi-major azimuth: 72° 41' 13.20''



UTM (North) Zone 12

5706871.253m(N) 371985.694m(E)

Scale Factors
 0.99980120 (point)
 0.99969532 (combined)

(Coordinates from RINEX file used as apriori position)

CSRS-PPP reports (continued)



CSRS-PPP (V 1.05 11216)



3 (ASCM470732)

Data Start	Data End	Duration of Observations
2018-06-26 15:03:12.000	2018-06-26 23:22:50.000	8h 19m 38.00s
Apri / Aposteriori Phase Std		Apri / Aposteriori Code Std
0.020m / 0.010m		2.0m / 1.214m
Observations	Frequency	Mode
Phase and Code	L1 and L2	Static
Elevation Cut-Off	Rejected Epochs	Observation & Estimation Steps
10.000 degrees	0.00 %	2.00 sec / 2.00 sec
Antenna Model	APC to ARP	ARP to Marker
TRM60158.00	L1= 0.085 m L2= 0.081 m	2.000 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for 50661771.18o

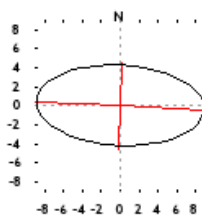
	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRs) (2002)	51° 28' 33.3837"	-112° 48' 21.5956"	681.492 m
Sigmat(95%)	0.003 m	0.007 m	0.015 m
Apriori	51° 28' 33.380"	-112° 48' 21.663"	683.957 m
Estimated - Apriori	0.113 m	1.306 m	-2.465 m

**Orthometric Height
CGVD28 (HTv2.0)**

699.950 m

(click for height reference information)

95% Error Ellipse (mm)
 semi-major: 8.876mm
 semi-minor: 4.226mm
 semi-major azimuth: 93° 1' 19.17"



UTM (North) Zone 12

5704300.039m(N) 374579.317m(E)

Scale Factors
 0.99979313 (point)
 0.99968620 (combined)

(Coordinates from RINEX file used as apriori position)

CSRS-PPP reports (continued)



CSRS-PPP (V 1.05 11216)



3 (ASCM470732)

Data Start	Data End	Duration of Observations
2018-06-27 14:39:16.000	2018-06-27 23:03:58.000	8h 24m 42.00s
Apri / Aposteriori Phase Std		Apri / Aposteriori Code Std
0.020m / 0.010m		2.0m / 1.220m
Observations	Frequency	Mode
Phase and Code	L1 and L2	Static
Elevation Cut-Off	Rejected Epochs	Observation & Estimation Steps
10.000 degrees	0.00 %	2.00 sec / 2.00 sec
Antenna Model	APC to ARP	ARP to Marker
TRM60158.00	L1= 0.085 m L2= 0.081 m	2.000 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for 50961781.18o

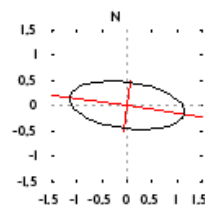
	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRs) (2002)	51° 28' 33.3840"	-112° 48' 21.5962"	681.486 m
Sigmat(95%)	0.004 m	0.009 m	0.015 m
Apriori	51° 28' 33.453"	-112° 48' 21.609"	683.352 m
Estimated - Apriori	-2.146 m	0.243 m	-1.866 m

**Orthometric Height
CGVD28 (HTv2.0)**

699.944 m

(click for height reference information)

95% Error Ellipse (cm)
 semi-major: 1.157cm
 semi-minor: 0.454cm
 semi-major azimuth: 97° 29' 9.94"



UTM (North) Zone 12

5704300.049m (N) 374579.305m (E)

Scale Factors
 0.99979313 (point)
 0.99968620 (combined)

(Coordinates from RINEX file used as apriori position)

CSRS-PPP reports (continued)



CSRS-PPP (V 1.05 11216)



BASE_4 (NHC4)

Data Start	Data End	Duration of Observations
2018-06-26 17:03:54.000	2018-06-26 19:24:54.000	2h 21m 0.00s
Apri / Aposteriori Phase Std		Apri / Aposteriori Code Std
0.020m / 0.009m		2.0m / 1.690m
Observations	Frequency	Mode
Phase and Code	L1 and L2	Static
Elevation Cut-Off	Rejected Epochs	Observation & Estimation Steps
10.000 degrees	0.00 %	2.00 sec / 2.00 sec
Antenna Model	APC to ARP	ARP to Marker
TSPGR3	L1= 0.216 m L2= 0.218 m	1.544 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for base17700.18o

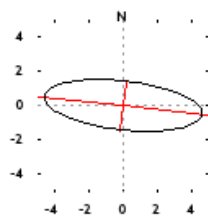
	Latitude (+n)	Longitude (+e)	ELL Height
NAD83(CSRS) (2002)	51° 28' 32.7664"	-112° 44' 50.7764"	759.246 m
Sigmatas(95%)	0.012 m	0.037 m	0.034 m
Apriori	51° 28' 32.789"	-112° 44' 50.843"	758.395 m
Estimated - Apriori	-0.701 m	1.275 m	0.851 m

**Orthometric Height
CGVD28 (HTv2.0)**

777.726 m

(click for height reference information)

95% Error Ellipse (cm)
 semi-major: 4.685cm
 semi-minor: 1.426cm
 semi-major azimuth: 96° 26' 20.10"



(Coordinates from RINEX file used as apriori position)

UTM (North) Zone 12

5704182.283m (N) 378645.436m (E)

Scale Factors
 0.99978081 (point)
 0.99966168 (combined)

CSRS-PPP reports (continued)



CSRS-PPP (V 1.05 11216)



BASE_5 (NHCS)

Data Start	Data End	Duration of Observations
2018-06-26 18:20:20.000	2018-06-26 20:44:14.000	2h 23m 54.00s
Apri / Aposteriori Phase Std		Apri / Aposteriori Code Std
0.020m / 0.010m		2.0m / 2.179m
Observations	Frequency	Mode
Phase and Code	L1 and L2	Static
Elevation Cut-Off	Rejected Epochs	Observation & Estimation Steps
10.000 degrees	0.00 %	2.00 sec / 2.00 sec
Antenna Model	APC to ARP	ARP to Marker
TSPGR3	L1= 0.216 m L2= 0.218 m	1.554 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for base17700a.18o

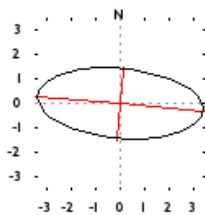
	Latitude (+n)	Longitude (+e)	ELL Height
NAD83(CSRS) (2002)	51° 28' 49.9211"	-112° 41' 52.6758"	672.530 m
Sigmatas(95%)	0.012 m	0.027 m	0.033 m
Apriori	51° 28' 49.928"	-112° 41' 52.750"	672.613 m
Estimated - Apriori	-0.208 m	1.427 m	-0.083 m

**Orthometric Height
CGVD28 (HTv2.0)**

691.037 m

(click for height reference information)

95% Error Ellipse (cm)
 semi-major: 3.420cm
 semi-minor: 1.424cm
 semi-major azimuth: 94° 56' 29.69"



(Coordinates from RINEX file used as apriori position)

UTM (North) Zone 12

5704631.346m(N) 382093.214m(E)

Scale Factors
 0.99977068 (point)
 0.99966515 (combined)

CSRS-PPP reports (continued)



CSRS-PPP (V 1.05 11216)



6 (NHC6)

Data Start	Data End	Duration of Observations
2018-06-26 14:36:18.000	2018-06-26 17:43:00.000	3h 6m 42.00s
Apri / Aposteriori Phase Std		Apri / Aposteriori Code Std
0.020m / 0.009m		2.0m / 1.236m
Observations	Frequency	Mode
Phase and Code	L1 and L2	Static
Elevation Cut-Off	Rejected Epochs	Observation & Estimation Steps
10.000 degrees	0.00 %	2.00 sec / 2.00 sec
Antenna Model	APC to ARP	ARP to Marker
TRM60158.00	L1= 0.085 m L2= 0.081 m	1.814 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for 50961770.18o

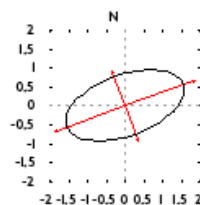
	Latitude (+n)	Longitude (+e)	ELL Height
NAD83(CSRS) (2002)	51° 26' 41.5825"	-112° 40' 37.6135"	667.012 m
Sigmatas(95%)	0.007 m	0.013 m	0.026 m
Apriori	51° 26' 41.593"	-112° 40' 37.688"	669.085 m
Estimated - Apriori	-0.310 m	1.430 m	-2.074 m

**Orthometric Height
CGVD28 (HTv2.0)**

685.460 m

(click for height reference information)

95% Error Ellipse (cm)
 semi-major: 1.643cm
 semi-minor: 0.309cm
 semi-major azimuth: 70° 43' 18.68"



UTM (North) Zone 12

5700633.666m(N) 383450.197m(E)

Scale Factors
 0.99976678 (point)
 0.99966212 (combined)

(Coordinates from RINEX file used as apriori position)

CSRS-PPP reports (continued)



CSRS-PPP (V 1.05 11216)



6 (NHC6)

Data Start	Data End	Duration of Observations
2018-06-26 18:38:16.000	2018-06-26 22:38:48.000	4h 0m 32.00s
Apri / Aposteriori Phase Std		Apri / Aposteriori Code Std
0.020m / 0.009m		2.0m / 1.311m
Observations	Frequency	Mode
Phase and Code	L1 and L2	Static
Elevation Cut-Off	Rejected Epochs	Observation & Estimation Steps
10.000 degrees	0.00 %	2.00 sec / 2.00 sec
Antenna Model	APC to ARP	ARP to Marker
TRM60158.00	L1= 0.085 m L2= 0.081 m	1.814 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for 50961772.18o

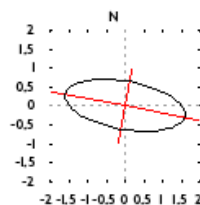
	Latitude (+n)	Longitude (+e)	ELL Height
NAD83(CSRS) (2002)	51° 26' 41.5824"	-112° 40' 37.6135"	667.022 m
Sigmatas(95%)	0.005 m	0.013 m	0.020 m
Apriori	51° 26' 41.533"	-112° 40' 37.679"	665.967 m
Estimated - Apriori	1.540 m	1.256 m	1.055 m

**Orthometric Height
CGVD28 (HTv2.0)**

685.470 m

(click for height reference information)

95% Error Ellipse (cm)
 semi-major: 1.619cm
 semi-minor: 0.637cm
 semi-major azimuth: 99° 57' 13.63"



UTM (North) Zone 12

5700633.663m(N) 383450.197m(E)

Scale Factors
 0.99976678 (point)
 0.99966212 (combined)

(Coordinates from RINEX file used as apriori position)

CSRS-PPP reports (continued)



CSRS-PPP (V 1.05 11216)



BASE_7 (NHC7)

Data Start	Data End	Duration of Observations
2018-06-26 19:47:24.000	2018-06-26 22:11:20.000	2h 23m 56.00s
Apri / Aposteriori Phase Std		Apri / Aposteriori Code Std
0.020m / 0.009m		2.0m / 1.629m
Observations	Frequency	Mode
Phase and Code	L1 and L2	Static
Elevation Cut-Off	Rejected Epochs	Observation & Estimation Steps
10.000 degrees	0.00 %	2.00 sec / 2.00 sec
Antenna Model	APC to ARP	ARP to Marker
TSPGR3	L1= 0.216 m L2= 0.218 m	1.556 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for base17701.18o

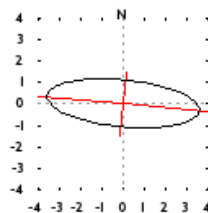
	Latitude (+n)	Longitude (+e)	ELL Height
NAD83(CSRS) (2002)	51° 25' 16.6617"	-112° 38' 00.3016"	668.557 m
Sigmatas(95%)	0.009 m	0.029 m	0.030 m
Apriori	51° 25' 16.702"	-112° 38' 00.411"	668.565 m
Estimated - Apriori	-1.257 m	2.121 m	-0.009 m

**Orthometric Height
CGVD28 (HTv2.0)**

686.981 m

(click for height reference information)

95% Error Ellipse (cm)
 semi-major: 3.598cm
 semi-minor: 1.104cm
 semi-major azimuth: 95° 19' 46.06"



UTM (North) Zone 12

5697941.888m(N) 386428.267m(E)

Scale Factors
 0.99975837 (point)
 0.99965347 (combined)

(Coordinates from RINEX file used as apriori position)

CSRS-PPP reports (continued)



CSRS-PPP (V 1.05 11216)



BASE_8 (NHCS)

Data Start	Data End	Duration of Observations
2018-06-26 21:10:20.000	2018-06-26 23:50:52.000	2h 40m 32.00s
Apri / Aposteriori Phase Std		Apri / Aposteriori Code Std
0.020m / 0.008m		2.0m / 1.965m
Observations	Frequency	Mode
Phase and Code	L1 and L2	Static
Elevation Cut-Off	Rejected Epochs	Observation & Estimation Steps
10.000 degrees	0.00 %	2.00 sec / 2.00 sec
Antenna Model	APC to ARP	ARP to Marker
TSPGR3	L1= 0.216 m L2= 0.218 m	1.442 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for base17701a.18o

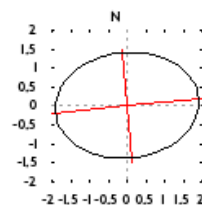
	Latitude (+n)	Longitude (+e)	ELL Height
NAD83(CSRS) (2002)	51° 24' 24.0068''	-112° 39' 29.7684''	671.533 m
Sigmatas(95%)	0.011 m	0.015 m	0.035 m
Apriori	51° 24' 24.020''	-112° 39' 29.880''	673.079 m
Estimated - Apriori	-0.423 m	2.149 m	-1.546 m

**Orthometric Height
CGVD28 (HTv2.0)**

689.908 m

(click for height reference information)

95% Error Ellipse (cm)
 semi-major: 1.915cm
 semi-minor: 1.393cm
 semi-major azimuth: 84° 25' 56.53''



UTM (North) Zone 12

5696354.228m(N) 384663.611m(E)

Scale Factors
 0.99976333 (point)
 0.99965796 (combined)

(Coordinates from RINEX file used as apriori position)

CSRS-PPP reports (continued)



CSRS-PPP (V 1.05 11216)



BASE_9 (NHC9)

Data Start	Data End	Duration of Observations
2018-06-27 15:03:48.000	2018-06-27 22:40:56.000	7h 37m 8.00s
Apri / Aposteriori Phase Std		Apri / Aposteriori Code Std
0.020m / 0.009m		2.0m / 2.171m
Observations	Frequency	Mode
Phase and Code	L1 and L2	Static
Elevation Cut-Off	Rejected Epochs	Observation & Estimation Steps
10.000 degrees	0.00 %	2.00 sec / 2.00 sec
Antenna Model	APC to ARP	ARP to Marker
TSPGR3	L1= 0.216 m L2= 0.218 m	1.527 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for base1780a.18o

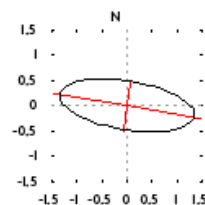
	Latitude (+n)	Longitude (+e)	ELL Height
NAD83(CSRS) (2002)	51° 23' 29.9901''	-112° 39' 50.9127''	683.939 m
Sigmatas(95%)	0.004 m	0.011 m	0.017 m
Apriori	51° 23' 29.977''	-112° 39' 50.990''	682.667 m
Estimated - Apriori	0.400 m	1.500 m	1.272 m

**Orthometric Height
CGVD28 (HTv2.0)**

702.272 m

(click for height reference information)

95% Error Ellipse (cm)
 semi-major: 1.364cm
 semi-minor: 0.483cm
 semi-major azimuth: 99° 15' 56.61''



UTM (North) Zone 12

5694694.955m (N) 384217.242m (E)

Scale Factors
 0.99976459 (point)
 0.99965728 (combined)

(Coordinates from RINEX file used as apriori position)

CSRS-PPP reports (continued)



CSRS-PPP (V 1.05 11216)



BASE_10 (NHC10)

Data Start	Data End	Duration of Observations
2018-06-27 15:13:40.000	2018-06-27 16:40:04.000	1h 26m 24.00s
Apri / Aposteriori Phase Std		Apri / Aposteriori Code Std
0.020m / 0.008m		2.0m / 2.087m
Observations	Frequency	Mode
Phase and Code	L1 and L2	Static
Elevation Cut-Off	Rejected Epochs	Observation & Estimation Steps
10.000 degrees	0.00 %	2.00 sec / 2.00 sec
Antenna Model	APC to ARP	ARP to Marker
TSPGR3	L1= 0.216 m L2= 0.218 m	1.531 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for base1780.18o

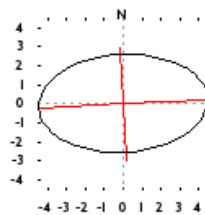
	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2002)	51° 22' 27.5463''	-112° 39' 58.9512''	688.325 m
Sigmatas(95%)	0.021 m	0.036 m	0.057 m
Apriori	51° 22' 27.536''	-112° 39' 59.033''	686.772 m
Estimated - Apriori	0.320 m	1.590 m	1.552 m

**Orthometric Height
CGVD28 (HTv2.0)**

706.611 m

(click for height reference information)

95% Error Ellipse (cm)
 semi-major: 4.488cm
 semi-minor: 2.577cm
 semi-major azimuth: 86° 46' 1.83''



UTM (North) Zone 12

5692769.652m (N) 384018.053m (E)

Scale Factors
 0.99976516 (point)
 0.99965716 (combined)

(Coordinates from RINEX file used as apriori position)

CSRS-PPP reports (continued)



CSRS-PPP (V 1.05 11216)



BASE_100 (ASCM440966)

Data Start	Data End	Duration of Observations
2018-06-27 15:35:48.000	2018-06-27 17:57:44.000	2h 21m 56.00s
Apri / Aposteriori Phase Std		Apri / Aposteriori Code Std
0.020m / 0.009m		2.0m / 1.11m
Observations	Frequency	Mode
Phase and Code	L1 and L2	Static
Elevation Cut-Off	Rejected Epochs	Observation & Estimation Steps
10.000 degrees	0.02 %	2.00 sec / 2.00 sec
Antenna Model	APC to ARP	ARP to Marker
TRM60158.00	L1= 0.085 m L2= 0.081 m	1.959 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for 50661780.18o

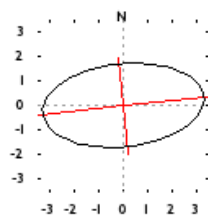
	Latitude (+n)	Longitude (+e)	ELL Height
NAD83(CSRS) (2002)	51° 23' 54.2726"	-112° 35' 21.9529"	665.929 m
Sigmatas(95%)	0.014 m	0.027 m	0.038 m
Apriori	51° 23' 54.322"	-112° 35' 22.026"	668.386 m
Estimated - Apriori	-1.532 m	1.410 m	-2.457 m

**Orthometric Height
CGVD28 (HTv2.0)**

684.325 m

(click for height reference information)

95% Error Ellipse (cm)
 semi-major: 3.347cm
 semi-minor: 1.686cm
 semi-major azimuth: 84° 14' 40.42"



(Coordinates from RINEX file used as apriori position)

UTM (North) Zone 12

5695329.675m(N) 389431.230m(E)

Scale Factors
 0.99975010 (point)
 0.99964561 (combined)

CSRS-PPP reports (continued)



CSRS-PPP (V 1.05 11216)



BASE_L2 (NHC12)

Data Start	Data End	Duration of Observations
2018-06-27 16:59:26.000	2018-06-27 19:26:20.000	2h 26m 54.00s
Apri / Aposteriori Phase Std		Apri / Aposteriori Code Std
0.020m / 0.009m		2.0m / 1.853m
Observations	Frequency	Mode
Phase and Code	L1 and L2	Static
Elevation Cut-Off	Rejected Epochs	Observation & Estimation Steps
10.000 degrees	0.00 %	2.00 sec / 2.00 sec
Antenna Model	APC to ARP	ARP to Marker
TSPGR3	L1= 0.216 m L2= 0.218 m	1.544 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for base17800.18o

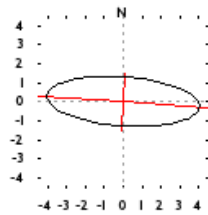
	Latitude (+n)	Longitude (+e)	ELL Height
NAD83(CSRS) (2002)	51° 22' 46.1955"	-112° 32' 10.2722"	660.608 m
Sigmatas(95%)	0.011 m	0.032 m	0.030 m
Apriori	51° 22' 46.233"	-112° 32' 10.348"	662.062 m
Estimated - Apriori	-1.144 m	1.473 m	-1.454 m

**Orthometric Height
CGVD28 (HTv2.0)**

678.997 m

(click for height reference information)

95% Error Ellipse (cm)
 semi-major: 4.056cm
 semi-minor: 1.294cm
 semi-major azimuth: 94° 10' 36.82"



(Coordinates from RINEX file used as apriori position)

UTM (North) Zone 12

5693147.833m (N) 393090.926m (E)

Scale Factors
 0.99974033 (point)
 0.99963668 (combined)

CSRS-PPP reports (continued)



CSRS-PPP (V 1.05 11216)



BASE_I3 (NHCI3)

Data Start	Data End	Duration of Observations
2018-06-27 18:23:42.000	2018-06-27 20:42:14.000	2h 18m 32.00s
Apri / Aposteriori Phase Std		Apri / Aposteriori Code Std
0.020m / 0.009m		2.0m / 0.923m
Observations	Frequency	Mode
Phase and Code	L1 and L2	Static
Elevation Cut-Off	Rejected Epochs	Observation & Estimation Steps
10.000 degrees	0.02 %	2.00 sec / 2.00 sec
Antenna Model	APC to ARP	ARP to Marker
TRM60158.00	L1= 0.085 m L2= 0.081 m	1.798 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for 50661781.18o

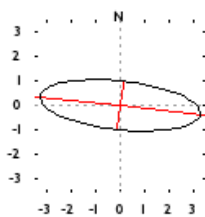
	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRs) (2002)	51° 19' 38.1244''	-112° 28' 38.2039''	664.558 m
Sigmat(95%)	0.008 m	0.026 m	0.030 m
Apriori	51° 19' 38.071''	-112° 28' 38.326''	665.965 m
Estimated - Apriori	1.667 m	2.361 m	-1.407 m

**Orthometric Height
CGVD28 (HTv2.0)**

682.873 m

(click for height reference information)

95% Error Ellipse (cm)
 semi-major: 3.314cm
 semi-minor: 0.995cm
 semi-major azimuth: 96° 2' 12.59''



UTM (North) Zone 12

5687254.152m (N) 397073.333m (E)

Scale Factors
 0.99973007 (point)
 0.99962580 (combined)

(Coordinates from RINEX file used as apriori position)

CSRS-PPP reports (continued)



CSRS-PPP (V 1.05 11216)



BASE_15 (NHC15)

Data Start	Data End	Duration of Observations
2018-06-27 19:42:22.000	2018-06-27 22:17:46.000	2h 35m 24.00s
Apri / Aposteriori Phase Std		Apri / Aposteriori Code Std
0.020m / 0.008m		2.0m / 2.11m
Observations	Frequency	Mode
Phase and Code	L1 and L2	Static
Elevation Cut-Off	Rejected Epochs	Observation & Estimation Steps
10.000 degrees	0.00 %	2.00 sec / 2.00 sec
Antenna Model	APC to ARP	ARP to Marker
TSPGR3	L1= 0.216 m L2= 0.218 m	1.509 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for base17801.18o

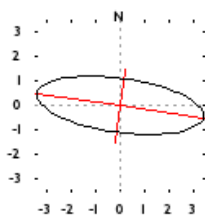
	Latitude (+n)	Longitude (+e)	ELL Height
NAD83(CSRS) (2002)	51° 18' 03.9061''	-112° 22' 37.4572''	661.109 m
Sigmatas(95%)	0.009 m	0.028 m	0.035 m
Apriori	51° 18' 03.920''	-112° 22' 37.539''	657.386 m
Estimated - Apriori	-0.415 m	1.590 m	3.723 m

**Orthometric Height
CGVD28 (HTv2.0)**

679.466 m

(click for height reference information)

95% Error Ellipse (cm)
 semi-major: 3.476cm
 semi-minor: 1.098cm
 semi-major azimuth: 97° 49' 57.23''



UTM (North) Zone 12

5684207.983m (N) 404000.183m (E)

Scale Factors
 0.99971315 (point)
 0.99960942 (combined)

(Coordinates from RINEX file used as apriori position)

CSRS-PPP reports (continued)



CSRS-PPP (V 1.05 11216)



BASE_16 (NHC16)

Data Start	Data End	Duration of Observations
2018-06-27 20:59:16.000	2018-06-27 21:07:54.000	0h 8m 38.00s
Apri / Aposteriori Phase Std		Apri / Aposteriori Code Std
0.020m / 0.008m		2.0m / 1.289m
Observations	Frequency	Mode
Phase and Code	L1 and L2	Static
Elevation Cut-Off	Rejected Epochs	Observation & Estimation Steps
10.000 degrees	0.00 %	2.00 sec / 2.00 sec
Antenna Model	APC to ARP	ARP to Marker
TRM60158.00	L1= 0.085 m L2= 0.081 m	1.813 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for 50661782.18o

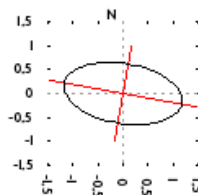
	Latitude (+n)	Longitude (+e)	ELL Height
NAD83(CSRS) (2002)	51° 15' 51.5503''	-112° 18' 03.4197''	658.309 m
Sigmatas(95%)	0.521 m	0.951 m	1.149 m
Apriori	51° 15' 51.507''	-112° 18' 03.501''	661.176 m
Estimated - Apriori	1.332 m	1.582 m	-2.867 m

**Orthometric Height
CGVD28 (HTv2.0)**

676.681 m

(click for height reference information)

95% Error Ellipse (m)
 semi-major: 1.201m
 semi-minor: 0.625m
 semi-major azimuth: 99° 58' 24.45''



UTM (North) Zone 12

5680022.747m(N) 409234.198m(E)

Scale Factors
 0.99970115 (point)
 0.99959786 (combined)

(Coordinates from RINEX file used as apriori position)

CSRS-PPP reports (continued)



CSRS-PPP (V 1.05 11216)



BASE_16 (NHC16)

Data Start	Data End	Duration of Observations
2018-06-27 21:09:14.000	2018-06-27 22:10:14.000	1h 0m 60.00s
Apri / Aposteriori Phase Std		Apri / Aposteriori Code Std
0.020m / 0.008m		2.0m / 1.323m
Observations	Frequency	Mode
Phase and Code	L1 and L2	Static
Elevation Cut-Off	Rejected Epochs	Observation & Estimation Steps
10.000 degrees	0.00 %	2.00 sec / 2.00 sec
Antenna Model	APC to ARP	ARP to Marker
TRM60158.00	L1= 0.085 m L2= 0.081 m	1.813 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for 50661783.18o

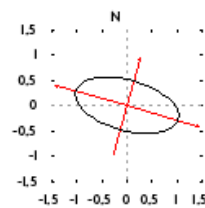
	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2002)	51° 15' 51.5471"	-112° 18' 03.4163"	658.379 m
Sigmas(95%)	0.045 m	0.083 m	0.110 m
Apriori	51° 15' 51.611"	-112° 18' 03.411"	663.341 m
Estimated - Apriori	-1.984 m	-0.107 m	-4.961 m

Orthometric Height
CGVD28 (HTv2.0)

676.751 m

(click for height reference information)

95% Error Ellipse (dm)
semi-major: 1.059dm
semi-minor: 0.502dm
semi-major azimuth: 105° 13' 49.01"



UTM (North) Zone 12

5680022.647m(N) 409234.262m(E)

Scale Factors
0.99970115 (point)
0.99959785 (combined)

(Coordinates from RINEX file used as apriori position)

CSRS-PPP reports (continued)

**APPENDIX B
CROSS SECTION PROPERTIES**

DRAFT

Table B1 Cross section properties – Red Deer River

Cross Section Name	River Station (m)	Date Surveyed	Thalweg Elevation (m)	TOB Channel Width (m)
PXS 209	56,139	27 Jul 2018	682.14	75.45
PXS 208	55,755	27 Jul 2018	682.35	100.06
PXS 207	55,521	27 Jul 2018	681.81	90.62
PXS 206	55,149	27 Jul 2018	682.02	96.98
PXS 205	54,759	27 Jul 2018	681.63	93.22
PXS 204	54,516	27 Jul 2018	681.89	107.16
PXS 203	54,007	27 Jul 2018	682.69	137.81
PXS 202	53,602	27 Jul 2018	682.10	156.84
PXS 201	53,393	26 Jul 2018	682.00	128.37
PXS 200	53,064	26 Jul 2018	681.61	151.99
PXS 199	52,682	26 Jul 2018	681.47	273.40
PXS 198	52,364	26 Jul 2018	681.78	248.81
PXS 197	51,970	23 Jul 2018	681.64	155.76
PXS 196A	51,689	23 Jul 2018	680.68	108.06
PXS 195	51,563	23 Jul 2018	681.18	94.59
PXS 194	51,326	23 Jul 2018	681.04	115.02
PXS 193	51,089	23 Jul 2018	681.47	165.78
PXS 192	50,765	23 Jul 2018	679.91	113.94
PXS 191	50,457	23 Jul 2018	680.69	140.14
PXS 190	50,067	23 Jul 2018	680.68	149.39
PXS 189	49,706	23 Jul 2018	679.58	266.41
PXS 188	49,354	23 Jul 2018	679.63	118.43
PXS 187	49,045	23 Jul 2018	678.96	75.82
PXS 186	48,695	23 Jul 2018	678.58	83.81
PXS 185	48,288	19 Jul 2018	679.36	138.55
PXS 184	48,079	19 Jul 2018	678.95	157.02
PXS 183	47,899	19 Jul 2018	678.83	93.38
PXS 182	47,630	19 Jul 2018	678.38	86.87
PXS 181	47,303	19 Jul 2018	677.84	87.21
PXS 180	47,010	19 Jul 2018	677.71	93.67

Cross Section Name	River Station (m)	Date Surveyed	Thalweg Elevation (m)	TOB Channel Width (m)
PXS 179	46,672	19 Jul 2018	677.72	91.97
PXS 178	46,395	19 Jul 2018	677.98	106.24
PXS 177	46,221	19 Jul 2018	677.70	107.54
PXS 176	46,039	19 Jul 2018	677.50	108.81
PXS 175	45,748	19 Jul 2018	677.35	105.75
PXS 174	45,410	19 Jul 2018	677.80	126.69
PXS 173	45,086	19 Jul 2018	677.51	143.32
PXS 172	44,815	19 Jul 2018	677.37	305.23
PXS 171	44,666	19 Jul 2018	677.48	255.65
PXS 170	44,443	18 Jul 2018	676.18	148.07
PXS 169	44,420	31 Aug 2018	675.83	208.71
PXS 168	44,290	31 Aug 2018	677.35	151.11
PXS 167	44,005	31 Aug 2018	677.05	114.92
PXS 166	43,798	31 Aug 2018	676.30	84.39
PXS 165	43,527	31 Aug 2018	677.14	95.72
PXS 164	43,209	17 Sep 2018	676.57	100.44
PXS 163	42,942	17 Sep 2018	676.00	197.75
PXS 162	42,779	17 Sep 2018	675.48	219.53
PXS 161	42,558	17 Sep 2018	676.20	261.21
PXS 160	42,341	17 Sep 2018	676.50	156.76
PXS 159	42,214	17 Sep 2018	675.02	332.64
PXS 158	41,996	17 Sep 2018	675.65	108.64
PXS 157	41,823	18 Jul 2018	676.32	108.69
PXS 156	41,644	18 Jul 2018	676.13	96.49
PXS 155	41,263	18 Sep 2018	676.61	130.07
PXS 154	41,074	17 Sep 2018	676.62	123.48
PXS 153	40,832	18 Jul 2018	676.17	111.72
PXS 152	40,804	18 Sep 2018	675.04	123.68
PXS 151	40,748	18 Sep 2018	675.65	135.25
PXS 150	40,606	18 Sep 2018	676.14	130.85
PXS 149	40,517	18 Sep 2018	675.73	113.19

Cross Section Name	River Station (m)	Date Surveyed	Thalweg Elevation (m)	TOB Channel Width (m)
PXS 148	40,322	18 Sep 2018	675.89	90.26
PXS 147	40,132	18 Sep 2018	675.77	92.51
PXS 146	39,912	18 Sep 2018	675.67	115.81
PXS 145	39,774	18 Sep 2018	675.77	114.20
PXS 144	39,619	18 Sep 2018	675.28	110.50
PXS 143	39,538	13 Jul 2018	675.79	123.37
PXS 142	39,370	13 Jul 2018	675.05	97.49
PXS 141	39,070	13 Jul 2018	674.63	104.30
PXS 140	38,812	13 Jul 2018	675.49	107.57
PXS 139	38,629	13 Jul 2018	675.55	109.50
PXS 138	38,381	13 Jul 2018	674.99	96.05
PXS 137	38,176	13 Jul 2018	674.49	91.15
PXS 136	37,829	12 Jul 2018	675.45	120.50
PXS 135	37,633	12 Jul 2018	674.46	106.11
PXS 134	37,484	12 Jul 2018	674.61	190.58
PXS 133	37,376	12 Jul 2018	674.94	96.35
PXS 132	37,086	12 Jul 2018	674.42	241.46
PXS 131	36,958	12 Jul 2018	674.61	133.00
PXS 130	36,721	12 Jul 2018	674.73	124.04
PXS 129	36,621	12 Jul 2018	674.30	107.66
PXS 128	36,313	12 Jul 2018	674.22	118.08
PXS 127	35,982	12 Jul 2018	674.79	134.18
PXS 126	35,611	12 Jul 2018	674.52	130.28
PXS 125	35,412	12 Jul 2018	673.54	106.98
PXS 124	35,165	12 Jul 2018	673.96	112.27
PXS 123	34,850	12 Jul 2018	673.47	111.98
PXS 122	34,667	12 Jul 2018	673.73	113.30
PXS 121	34,292	12 Jul 2018	673.29	104.97
PXS 120	33,924	12 Jul 2018	673.42	105.95
PXS 119	33,653	12 Jul 2018	673.54	97.64
PXS 118	33,378	12 Jul 2018	674.04	119.11

Cross Section Name	River Station (m)	Date Surveyed	Thalweg Elevation (m)	TOB Channel Width (m)
PXS 117	33,017	12 Jul 2018	673.33	99.43
PXS 116	32,670	10 Jul 2018	673.70	128.84
PXS 115	32,519	10 Jul 2018	673.13	117.57
PXS 114	32,484	10 Jul 2018	672.81	117.93
PXS 113	32,344	10 Jul 2018	673.61	95.05
PXS 112	32,054	10 Jul 2018	673.40	123.31
PXS 111	31,781	10 Jul 2018	672.70	81.83
PXS 110	31,429	10 Jul 2018	672.54	96.58
PXS 109	31,198	10 Jul 2018	672.49	109.12
PXS 108	30,968	10 Jul 2018	672.90	113.72
PXS 107	30,771	19 Sep 2018	672.75	112.70
PXS 106	30,480	17 Jul 2018	671.74	99.21
PXS 105	30,282	17 Jul 2018	672.26	125.86
PXS 104	30,086	17 Jul 2018	672.61	141.84
PXS 103	29,895	17 Jul 2018	671.70	121.14
PXS 102	29,573	17 Jul 2018	671.99	85.21
PXS 101	29,224	17 Jul 2018	671.25	110.44
PXS 100	28,890	17 Jul 2018	671.99	126.38
PXS 099	28,595	25 Jul 2018	670.81	82.40
PXS 098	28,373	25 Jul 2018	670.75	86.11
PXS 097	28,271	25 Jul 2018	669.68	98.13
PXS 096	28,255	25 Jul 2018	669.25	85.02
PXS 095	28,234	25 Jul 2018	668.96	88.38
PXS 094	28,215	25 Jul 2018	669.11	91.18
PXS 093	28,196	25 Jul 2018	670.65	93.96
PXS 092	28,120	25 Jul 2018	670.72	95.40
PXS 091	28,028	25 Jul 2018	671.29	117.62
PXS 090	27,943	19 Sep 2018	671.02	91.75
PXS 089	27,921	19 Sep 2018	670.30	80.73
PXS 088	27,749	25 Jul 2018	670.41	82.70
PXS 087	27,487	25 Jul 2018	671.38	105.69

Cross Section Name	River Station (m)	Date Surveyed	Thalweg Elevation (m)	TOB Channel Width (m)
PXS 086	27,145	25 Jul 2018	671.03	101.87
PXS 085	26,728	25 Jul 2018	670.80	101.13
PXS 084	26,576	25 Jul 2018	671.49	136.76
PXS 083	26,330	25 Jul 2018	670.70	94.26
PXS 082	26,001	25 Jul 2018	671.40	120.99
PXS 081	25,566	25 Jul 2018	670.52	96.08
PXS 080	25,030	25 Jul 2018	670.69	112.70
PXS 079	24,611	25 Jul 2018	670.25	111.90
PXS 078	24,051	25 Jul 2018	671.10	136.75
PXS 077	23,586	25 Jul 2018	670.74	132.79
PXS 076	23,316	25 Jul 2018	670.21	111.65
PXS 075	22,842	25 Jul 2018	669.58	106.56
PXS 074	22,328	25 Jul 2018	669.27	62.27
PXS 073	21,724	25 Jul 2018	669.00	88.21
PXS 072	21,245	25 Jul 2018	668.80	105.21
PXS 071	21,011	25 Jul 2018	668.42	109.39
PXS 070	20,686	20 Jul 2018	669.36	106.40
PXS 069	20,474	20 Jul 2018	668.22	86.24
PXS 068	20,065	20 Jul 2018	669.17	139.04
PXS 067	19,848	20 Jul 2018	668.42	81.42
PXS 066	19,656	20 Jul 2018	668.53	85.68
PXS 065	19,356	20 Jul 2018	667.57	78.28
PXS 064	19,059	20 Jul 2018	667.80	96.09
PXS 063	18,881	20 Jul 2018	668.95	89.48
PXS 062	18,652	20 Jul 2018	668.05	89.82
PXS 061	18,440	18 Sep 2018	669.15	140.80
PXS 060	18,219	18 Sep 2018	669.34	169.66
PXS 059	18,020	18 Sep 2018	669.06	140.23
PXS 058	17,745	18 Sep 2018	668.55	162.66
PXS 057	17,505	20 Jul 2018	667.75	100.77
PXS 056	17,278	20 Jul 2018	667.60	104.95

Cross Section Name	River Station (m)	Date Surveyed	Thalweg Elevation (m)	TOB Channel Width (m)
PXS 055	17,161	26 Jul 2018	668.24	140.26
PXS 054	16,904	26 Jul 2018	668.09	139.92
PXS 053	16,791	26 Jul 2018	667.20	137.58
PXS 052	16,767	26 Jul 2018	666.74	138.61
PXS 051	16,692	26 Jul 2018	668.67	154.89
PXS 050	16,555	18 Sep 2018	668.31	151.31
PXS 049	16,363	18 Sep 2018	667.75	252.00
PXS 048	16,272	26 Jul 2018	667.72	114.68
PXS 047	16,246	26 Jul 2018	667.65	117.40
PXS 046	16,054	26 Jul 2018	668.57	103.53
PXS 045	15,799	26 Jul 2018	668.38	106.71
PXS 044	15,326	26 Jul 2018	667.90	121.10
PXS 043	14,807	24 Jul 2018	666.83	107.37
PXS 042	14,404	24 Jul 2018	667.61	225.78
PXS 041	13,966	24 Jul 2018	667.25	196.26
PXS 040	13,392	17 Jul 2018	666.48	133.76
PXS 436	12,955	17 Jul 2018	666.71	126.56
PXS 039	12,528	17 Jul 2018	667.22	150.13
PXS 038	12,053	17 Jul 2018	666.90	139.40
PXS 037	11,633	17 Jul 2018	666.94	229.14
PXS 036	11,128	17 Jul 2018	665.97	116.99
PXS 035	10,764	17 Jul 2018	666.84	154.45
PXS 034	10,351	17 Jul 2018	666.14	207.18
PXS 033	10,016	17 Jul 2018	665.70	113.11
PXS 032	9,697	17 Jul 2018	665.05	108.32
PXS 031	9,417	17 Jul 2018	665.91	157.85
PXS 030	9,179	17 Jul 2018	665.35	130.45
PXS 029	8,943	17 Jul 2018	665.44	110.12
PXS 028	8,669	17 Jul 2018	665.23	101.32
PXS 027	8,338	16 Jul 2018	665.55	129.77
PXS 026	7,988	16 Jul 2018	664.77	105.03

Cross Section Name	River Station (m)	Date Surveyed	Thalweg Elevation (m)	TOB Channel Width (m)
PXS 025	7,398	16 Jul 2018	664.24	102.52
PXS 024	7,006	16 Jul 2018	663.68	95.08
PXS 023	6,606	16 Jul 2018	663.46	94.26
PXS 022	6,283	16 Jul 2018	663.48	130.77
PXS 021	5,827	16 Jul 2018	664.43	314.11
PXS 020	5,356	11 Jul 2018	663.74	433.65
PXS 019	5,018	11 Jul 2018	662.55	248.28
PXS 018	4,746	11 Jul 2018	662.63	131.51
PXS 017	4,466	11 Jul 2018	662.41	98.08
PXS 016	4,233	11 Jul 2018	662.59	100.35
PXS 015	4,018	11 Jul 2018	662.74	99.91
PXS 014	3,908	11 Jul 2018	663.12	115.96
PXS 013	3,888	11 Jul 2018	662.86	112.92
PXS 012	3,752	11 Jul 2018	662.87	97.77
PXS 011	3,508	11 Jul 2018	662.62	113.12
PXS 010	3,182	11 Jul 2018	663.05	119.92
PXS 009	2,861	11 Jul 2018	661.30	81.18
PXS 008	2,536	11 Jul 2018	660.87	98.63
PXS 007	2,249	18 Sep 2018	660.17	98.06
PXS 006	1,783	18 Sep 2018	660.23	159.59
PXS 005	1,484	18 Sep 2018	660.67	482.15
PXS 004	1,306	18 Sep 2018	660.50	312.27
PXS 003	1,004	11 Jul 2018	660.34	98.91
PXS 002	442	11 Jul 2018	661.58	132.00
PXS 001	0	11 Jul 2018	659.78	99.50

Table B2 Cross section properties – Kneehills Creek

Cross Section Name	River Station (m)	Date Surveyed	Thalweg Elevation (m)	TOB Channel Width (m)
PXS 435	7,869	14 Aug 2018	693.59	23.30
PXS 434	7,766	14 Aug 2018	693.67	19.58
PXS 433	7,671	14 Aug 2018	694.20	15.54
PXS 432	7,574	14 Aug 2018	693.78	15.86
PXS 431	7,479	14 Aug 2018	694.02	17.00
PXS 430	7,370	14 Aug 2018	693.76	27.62
PXS 429	7,153	14 Aug 2018	692.58	18.53
PXS 428	6,927	14 Aug 2018	692.82	8.16
PXS 427	6,786	14 Aug 2018	692.10	18.75
PXS 426	6,665	14 Aug 2018	691.48	17.17
PXS 425	6,500	14 Aug 2018	691.77	13.96
PXS 424	6,397	14 Aug 2018	691.53	11.86
PXS 423	6,289	14 Aug 2018	691.64	8.67
PXS 422	6,165	14 Aug 2018	691.07	10.27
PXS 421	6,045	14 Aug 2018	690.56	7.47
PXS 420	5,903	14 Aug 2018	690.66	8.42
PXS 419	5,774	14 Aug 2018	689.96	14.14
PXS 418	5,662	14 Aug 2018	690.35	15.07
PXS 417	5,554	14 Aug 2018	690.78	37.26
PXS 416	5,435	14 Aug 2018	689.90	9.79
PXS 415	5,300	14 Aug 2018	689.41	14.06
PXS 414	5,175	14 Aug 2018	688.95	18.31
PXS 413	5,078	14 Aug 2018	688.95	13.94
PXS 412	4,972	14 Aug 2018	688.95	10.94
PXS 411	4,844	14 Aug 2018	689.04	16.93
PXS 410	4,690	14 Aug 2018	688.64	10.41
PXS 409	4,513	14 Aug 2018	688.63	10.14
PXS 408	4,412	14 Aug 2018	687.71	15.49
PXS 407	4,326	14 Aug 2018	687.65	11.25
PXS 406	4,192	14 Aug 2018	687.79	11.26

Cross Section Name	River Station (m)	Date Surveyed	Thalweg Elevation (m)	TOB Channel Width (m)
PXS 405	4,053	14 Aug 2018	687.24	10.69
PXS 404	3,966	14 Aug 2018	686.83	15.22
PXS 403	3,833	14 Aug 2018	686.75	13.01
PXS 402	3,738	14 Aug 2018	687.01	13.34
PXS 401	3,549	14 Aug 2018	686.43	11.31
PXS 400	3,397	14 Aug 2018	686.53	11.53
PXS 399	3,272	14 Aug 2018	686.04	14.51
PXS 398	3,126	14 Aug 2018	685.63	14.97
PXS 397	3,023	14 Aug 2018	685.13	13.53
PXS 396	3,011	14 Aug 2018	685.27	14.87
PXS 395	2,916	16 Aug 2018	685.88	34.80
PXS 394	2,665	16 Aug 2018	685.02	16.66
PXS 393	2,517	16 Aug 2018	684.89	16.06
PXS 392	2,242	16 Aug 2018	684.55	16.50
PXS 391	2,139	16 Aug 2018	684.13	14.99
PXS 390	2,049	16 Aug 2018	683.80	17.69
PXS 389	1,915	16 Aug 2018	684.15	11.03
PXS 388	1,794	16 Aug 2018	683.55	18.79
PXS 387	1,669	16 Aug 2018	683.02	19.20
PXS 386	1,600	16 Aug 2018	682.60	20.65
PXS 385	1,584	16 Aug 2018	682.85	18.73
PXS 384	1,532	16 Aug 2018	682.09	20.92
PXS 383	1,375	16 Aug 2018	682.82	18.09
PXS 382	1,231	16 Aug 2018	682.80	14.94
PXS 381	1,007	16 Aug 2018	682.95	27.76
PXS 440	827	16 Aug 2018	683.20	10.35
PXS 441	583	16 Aug 2018	683.80	14.49
PXS 196B	416	16 Aug 2018	681.34	15.86
PXS 442	245	16 Aug 2018	680.97	17.35
PXS 443	84	16 Aug 2018	681.05	17.52

Table B3 Cross section properties – Michichi Creek

Cross Section Name	River Station (m)	Date Surveyed	Thalweg Elevation (m)	TOB Channel Width (m)
PXS 380	5,335	17 Aug 2018	690.56	19.13
PXS 379	5,127	17 Aug 2018	689.66	11.14
PXS 378	4,932	17 Aug 2018	689.49	11.30
PXS 377	4,747	17 Aug 2018	688.94	11.02
PXS 376	4,584	17 Aug 2018	688.11	12.21
PXS 375	4,337	21 Aug 2018	687.90	10.68
PXS 374	4,146	17 Aug 2018	687.37	14.21
PXS 373	3,938	17 Aug 2018	686.53	12.66
PXS 372	3,788	17 Aug 2018	686.28	7.46
PXS 371	3,614	17 Aug 2018	686.63	12.15
PXS 370	3,422	17 Aug 2018	685.59	14.52
PXS 369	3,178	21 Aug 2018	684.80	8.60
PXS 368	2,945	21 Aug 2018	683.71	8.21
PXS 367	2,718	21 Aug 2018	683.70	8.85
PXS 366	2,587	21 Aug 2018	683.45	9.51
PXS 365	2,577	21 Aug 2018	683.94	9.95
PXS 364	2,491	21 Aug 2018	683.17	11.55
PXS 439	2,442	21 Aug 2018	682.59	8.88
PXS 363	2,429	21 Aug 2018	683.02	8.74
PXS 362	2,318	21 Aug 2018	682.62	9.66
PXS 361	2,161	21 Aug 2018	682.57	12.05
PXS 437	2,059	21 Aug 2018	682.09	11.20
PXS 360	1,999	21 Aug 2018	681.53	7.19
PXS 359	1,852	21 Aug 2018	681.29	6.99
PXS 358	1,731	21 Aug 2018	681.00	6.86
PXS 357	1,554	21 Aug 2018	680.36	6.20
PXS 356	1,461	21 Aug 2018	680.15	7.25
PXS 355	1,358	21 Aug 2018	680.34	15.12
PXS 354	1,295	21 Aug 2018	679.91	9.63
PXS 353	1,248	21 Aug 2018	679.64	6.41

Cross Section Name	River Station (m)	Date Surveyed	Thalweg Elevation (m)	TOB Channel Width (m)
PXS 352	1,171	21 Aug 2018	679.76	6.54
PXS 438	1,091	21 Aug 2018	679.89	10.92
PXS 351	1,018	21 Aug 2018	679.49	8.91
PXS 350	1,001	21 Aug 2018	679.72	15.06
PXS 349	905	22 Aug 2018	679.40	15.10
PXS 348	782	22 Aug 2018	678.48	7.69
PXS 347	598	22 Aug 2018	678.80	8.95
PXS 346	506	17 Sep 2018	678.50	39.27
PXS 345	412	17 Sep 2018	678.12	25.56
PXS 344	334	17 Sep 2018	677.93	26.24
PXS 343	194	17 Sep 2018	677.72	11.68

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Table B4 Cross section properties – Rosebud River

Cross Section Name	River Station (m)	Date Surveyed	Thalweg Elevation (m)	TOB Channel Width (m)
PXS 342	10,702	22 Aug 2018	694.48	11.73
PXS 341	10,485	22 Aug 2018	693.94	13.54
PXS 340	10,289	22 Aug 2018	693.27	13.74
PXS 339	10,163	22 Aug 2018	693.48	21.91
PXS 338	10,045	22 Aug 2018	693.28	22.10
PXS 337	9,912	22 Aug 2018	693.56	18.83
PXS 336	9,755	22 Aug 2018	692.9	28.36
PXS 335	9,668	22 Aug 2018	692.36	19.24
PXS 334	9,618	22 Aug 2018	692.32	36.90
PXS 333	9,600	22 Aug 2018	692.26	29.99
PXS 332	9,580	22 Aug 2018	692.54	18.02
PXS 331	9,570	22 Aug 2018	692.58	22.67
PXS 330	9,554	22 Aug 2018	692.4	18.69
PXS 329	9,468	23 Aug 2018	692	17.82
PXS 328	9,355	23 Aug 2018	692.2	15.55
PXS 327	9,227	23 Aug 2018	691.74	13.47
PXS 326	9,116	23 Aug 2018	691.63	20.87
PXS 325	8,994	23 Aug 2018	691.65	19.99
PXS 324	8,849	23 Aug 2018	691.18	20.86
PXS 323	8,745	23 Aug 2018	691.19	17.88
PXS 322	8,706	23 Aug 2018	690.41	15.52
PXS 321	8,689	23 Aug 2018	690.82	16.63
PXS 320	8,682	23 Aug 2018	690.83	13.58
PXS 319	8,675	23 Aug 2018	690.92	14.45
PXS 318	8,661	23 Aug 2018	690.91	15.57
PXS 317	8,553	23 Aug 2018	690.09	21.49
PXS 316	8,439	23 Aug 2018	690.36	14.25
PXS 315	8,343	23 Aug 2018	689.71	15.46
PXS 314	8,281	23 Aug 2018	689.12	15.67
PXS 313	8,187	23 Aug 2018	689.76	14.72

Cross Section Name	River Station (m)	Date Surveyed	Thalweg Elevation (m)	TOB Channel Width (m)
PXS 312	8,101	23 Aug 2018	688.74	14.82
PXS 311	8,080	23 Aug 2018	689.05	20.28
PXS 310	8,060	23 Aug 2018	689.22	28.70
PXS 309	8,009	23 Aug 2018	689.41	19.99
PXS 308	7,958	23 Aug 2018	689.3	31.18
PXS 307	7,937	23 Aug 2018	689.2	22.91
PXS 306	7,783	27 Aug 2018	689.04	13.63
PXS 305	7,641	27 Aug 2018	688.79	20.05
PXS 304	7,530	27 Aug 2018	688.04	23.89
PXS 303	7,395	27 Aug 2018	688.34	12.50
PXS 302	7,326	27 Aug 2018	687.91	18.48
PXS 301	7,303	27 Aug 2018	688.01	20.69
PXS 300	7,276	27 Aug 2018	688.08	13.36
PXS 299	7,246	27 Aug 2018	687.86	33.77
PXS 298	7,215	27 Aug 2018	687.67	26.63
PXS 297	7,151	27 Aug 2018	688.03	18.23
PXS 296	6,913	27 Aug 2018	687.15	20.68
PXS 295	6,774	27 Aug 2018	686.8	22.49
PXS 294	6,641	27 Aug 2018	687.07	14.19
PXS 293	6,532	27 Aug 2018	687.15	22.13
PXS 292	6,469	27 Aug 2018	686.41	10.77
PXS 291	6,450	27 Aug 2018	686.63	12.69
PXS 290	6,419	27 Aug 2018	686.13	23.12
PXS 289	6,382	27 Aug 2018	686.36	19.45
PXS 288	6,361	27 Aug 2018	685.97	23.03
PXS 287	6,278	28 Aug 2018	686.39	18.08
PXS 286	6,166	28 Aug 2018	686.32	17.27
PXS 285	5,969	28 Aug 2018	685.54	13.15
PXS 284	5,904	28 Aug 2018	685.14	17.03
PXS 283	5,886	28 Aug 2018	685.3	18.78
PXS 282	5,879	28 Aug 2018	685.3	18.75

Cross Section Name	River Station (m)	Date Surveyed	Thalweg Elevation (m)	TOB Channel Width (m)
PXS 281	5,872	28 Aug 2018	685.18	17.40
PXS 280	5,851	28 Aug 2018	685.07	21.08
PXS 279	5,776	28 Aug 2018	685.32	16.68
PXS 278	5,689	28 Aug 2018	684.26	17.36
PXS 277	5,616	28 Aug 2018	684.88	12.58
PXS 276	5,547	28 Aug 2018	684.65	15.59
PXS 275	5,473	28 Aug 2018	684.26	26.14
PXS 274	5,452	28 Aug 2018	684.7	24.11
PXS 273	5,378	28 Aug 2018	684.38	13.45
PXS 272	5,288	28 Aug 2018	684.5	16.28
PXS 271	5,193	28 Aug 2018	684.53	29.74
PXS 270	5,065	28 Aug 2018	683.54	23.55
PXS 269	4,997	28 Aug 2018	683.89	13.90
PXS 268	4,980	28 Aug 2018	684.2	20.89
PXS 267	4,917	28 Aug 2018	683.7	22.04
PXS 266	4,771	28 Aug 2018	683.22	24.31
PXS 265	4,599	28 Aug 2018	682.91	18.38
PXS 264	4,530	28 Aug 2018	682.1	28.71
PXS 263	4,509	28 Aug 2018	682.13	15.88
PXS 262	4,501	28 Aug 2018	682.33	10.33
PXS 261	4,480	28 Aug 2018	682.76	16.01
PXS 260	4,409	29 Aug 2018	683.07	23.83
PXS 259	4,313	29 Aug 2018	682.6	17.27
PXS 258	4,153	29 Aug 2018	682.35	27.13
PXS 257	4,037	29 Aug 2018	682.14	16.08
PXS 256	3,852	29 Aug 2018	681.35	22.03
PXS 255	3,694	29 Aug 2018	681.71	14.32
PXS 254	3,461	29 Aug 2018	680.88	22.91
PXS 253	3,314	29 Aug 2018	681.16	15.56
PXS 252	3,167	29 Aug 2018	680.88	23.14
PXS 251	3,011	29 Aug 2018	679.97	29.50

Cross Section Name	River Station (m)	Date Surveyed	Thalweg Elevation (m)	TOB Channel Width (m)
PXS 250	2,907	29 Aug 2018	680.81	24.32
PXS 249	2,817	29 Aug 2018	680.04	13.44
PXS 248	2,645	29 Aug 2018	679.71	15.74
PXS 247	2,454	29 Aug 2018	679.61	20.33
PXS 246	2,352	29 Aug 2018	679.11	14.50
PXS 245	2,255	29 Aug 2018	678.41	19.30
PXS 244	2,235	29 Aug 2018	677.96	21.99
PXS 243	2,187	29 Aug 2018	678.61	20.71
PXS 242	2,138	29 Aug 2018	678.33	27.66
PXS 241	2,113	29 Aug 2018	678.71	29.35
PXS 240	2,005	29 Aug 2018	678.46	13.12
PXS 239	1,894	29 Aug 2018	677.89	15.00
PXS 238	1,757	29 Aug 2018	677.31	26.40
PXS 237	1,602	29 Aug 2018	677.05	17.10
PXS 236	1,422	29 Aug 2018	676.83	19.26
PXS 235	1,271	29 Aug 2018	676.35	18.88
PXS 234	1,155	30 Aug 2018	676.3	30.64
PXS 233	1,127	30 Aug 2018	676.36	25.98
PXS 232	1,017	30 Aug 2018	676.73	25.49
PXS 231	833	30 Aug 2018	674.98	19.03
PXS 230	652	30 Aug 2018	675.49	39.21
PXS 229	559	30 Aug 2018	674.71	26.10
PXS 228	527	30 Aug 2018	674.94	29.18
PXS 227	438	30 Aug 2018	674.83	15.75
PXS 226	357	30 Aug 2018	674.41	23.83
PXS 225	332	30 Aug 2018	674.51	24.86
PXS 224	234	30 Aug 2018	674.38	15.23
PXS 223	116	30 Aug 2018	674.07	16.82

Table B5 Cross section properties – Willow Creek

Cross Section Name	River Station (m)	Date Surveyed	Thalweg Elevation (m)	TOB Channel Width (m)
PXS 222	2,970	13 Aug 2018	686.73	6.98
PXS 221	2,723	13 Aug 2018	685.63	31.73
PXS 220	2,408	13 Aug 2018	683.54	8.15
PXS 219	2,174	13 Aug 2018	682.23	10.64
PXS 218	1,937	13 Aug 2018	680.78	19.07
PXS 217	1,566	13 Aug 2018	678.92	12.60
PXS 216	1,356	13 Aug 2018	677.82	8.31
PXS 215	1,007	13 Aug 2018	676.10	10.40
PXS 214	863	13 Aug 2018	675.18	14.40
PXS 213	848	13 Aug 2018	675.24	16.20
PXS 212	584	13 Aug 2018	673.98	10.50
PXS 211	422	13 Aug 2018	672.53	9.85
PXS 210	301	13 Aug 2018	672.56	7.34

DRAFT

**APPENDIX C
BRIDGE AND CULVERT DETAILS**

DRAFT

Bridge Description

Name:	Newcastle Mine Railway Bridge	AT Bridge File No.:	N/A
Watercourse:	Red Deer River	River Station (m):	44,430

Geometry

Length of Span (m):	167.8	Top of Curb/Solid Rail Elev. (m):	686.47
Deck Width (m):	5.8	Low Chord Elev. (m):	684.47
Pier Type:	Concrete	No. of Piers:	3
Pier Shape:	Circular	Pier Width (m):	2.6

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name: Highway 56 Bridge
at Drumheller
Watercourse: Red Deer River

AT Bridge File No.: 06615
River Station (m): 40,815

Geometry

Length of Span (m): 158.2
Deck Width (m): 15.2
Pier Type: Concrete
Pier Shape: Circular

Top of Curb/Solid Rail Elev. (m): 686.57
Low Chord Elev. (m): 684.49
No. of Piers: 4
Pier Width (m): 1.15

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Roper Road Bridge at Rosedale	AT Bridge File No.:	07329
Watercourse:	Red Deer River	River Station (m):	32,502

Geometry

Length of Span (m):	153.6	Top of Curb/Solid Rail Elev. (m):	684.31
Deck Width (m):	9.5	Low Chord Elev. (m):	682.21
Pier Type:	Concrete	No. of Piers:	4
Pier Shape:	Circular with Slope	Pier Width (m):	1.55 - 1.88

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Star Mine Suspension Bridge	AT Bridge File No.:	74796
Watercourse:	Red Deer River	River Station (m):	31,204

Geometry

Length of Span (m):	125.3	Top of Curb/Solid Rail Elev. (m):	679.52
Deck Width (m):	1.4	Low Chord Elev. (m):	679.47
Pier Type:	N/A	No. of Piers:	0
Pier Shape:	N/A	Pier Width (m):	N/A

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Abandoned Bridge Description

Name: Abandoned Piers (U/S)
Watercourse: Red Deer River

AT Bridge File No.: N/A
River Station (m): 28,264

Geometry

Length of Span (m): N/A
Deck Width (m): 6.9
Pier Type: Concrete
Pier Shape: Triangular

Top of Curb/Solid Rail Elev. (m): N/A
Low Chord Elev. (m): N/A
No. of Piers: 4
Pier Width (m): 3.0

Photo(s)

View from the Right Bank



Abandoned Bridge Description

Name: Abandoned Piers (D/S)
Watercourse: Red Deer River

AT Bridge File No.: N/A
River Station (m): 28,204

Geometry

Length of Span (m): N/A	Top of Curb/Solid Rail Elev. (m): N/A
Deck Width (m): 3.9	Low Chord Elev. (m): N/A
Pier Type: Concrete	No. of Piers: 1
Pier Shape: Triangular with Slope	Pier Width (m): 2.8

Photo(s)

**Upstream Side of
Bridge**



**View from the Right
Bank**



Bridge Description

Name:	Highway 10 Bridge 8km SE of Drumheller	AT Bridge File No.:	73277
Watercourse:	Red Deer River	River Station (m):	27,931

Geometry

Length of Span (m):	167.3	Top of Curb/Solid Rail Elev. (m):	683.56
Deck Width (m):	8.5	Low Chord Elev. (m):	681.76
Pier Type:	Concrete	No. of Piers:	4
Pier Shape:	Triangular with Slope	Pier Width (m):	0.90 - 1.8

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Atlas Coal Mine Railway Bridge	AT Bridge File No.:	N/A
Watercourse:	Red Deer River	River Station (m):	16,778

Geometry

Length of Span (m):	226.3	Top of Curb/Solid Rail Elev. (m):	677.47
Deck Width (m):	11.8	Low Chord Elev. (m):	675.7
Pier Type:	Concrete and Timber	No. of Piers:	15
Pier Shape:	Variable	Pier Width (m):	0.3 (7), 3.2 (1), 4.2 (1), 2.8 (2), 3.6 (1), 0.3 (3)

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Highway 10 Bridge at East Coulee	AT Bridge File No.:	73077
Watercourse:	Red Deer River	River Station (m):	16,259

Geometry

Length of Span (m):	170	Top of Curb/Solid Rail Elev. (m):	681.17
Deck Width (m):	11.5	Low Chord Elev. (m):	678.22
Pier Type:	Concrete	No. of Piers:	2
Pier Shape:	Circular	Pier Width (m):	1.8

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Highway 848 Bridge at Dorothy	AT Bridge File No.:	71085
Watercourse:	Red Deer River	River Station (m):	3,897

Geometry

Length of Span (m):	161.7	Top of Curb/Solid Rail Elev. (m):	673.47
Deck Width (m):	6.2	Low Chord Elev. (m):	672.17
Pier Type:	Concrete	No. of Piers:	2
Pier Shape:	Circular with Slope	Pier Width (m):	1.25 - 1.70

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name: Range Road 211A Bridge
Watercourse: Kneehills Creek

AT Bridge File No.: 13182
River Station (m): 3,017

Geometry

Length of Span (m): 38.1
Deck Width (m): 6.3
Pier Type: N/A
Pier Shape: N/A

Top of Curb/Solid Rail Elev. (m): 691.82
Low Chord Elev. (m): 690.72
No. of Piers: 0
Pier Width (m): N/A

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Highway 575 Bridge near Nacmine	AT Bridge File No.:	13486
Watercourse:	Kneehills Creek	River Station (m):	1,591

Geometry

Length of Span (m):	48.8	Top of Curb/Solid Rail Elev. (m):	691.70
Deck Width (m):	10.8	Low Chord Elev. (m):	690.20
Pier Type:	Steel Pile	No. of Piers:	2
Pier Shape:	Circular	Pier Width (m):	0.41

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Local Road (Unnamed Road) Bridge	AT Bridge File No.:	07522
Watercourse:	Michichi Creek	River Station (m):	2,582

Geometry

Length of Span (m):	21.2	Top of Curb/Solid Rail Elev. (m):	688.00
Deck Width (m):	6.0	Low Chord Elev. (m):	687.30
Pier Type:	N/A	No. of Piers:	0
Pier Shape:	N/A	Pier Width (m):	N/A

Photo(s)

End View (Looking SW)



Downstream Side of Bridge



Bridge Description

Name:	Private Road Access Bridge	AT Bridge File No.:	N/A
Watercourse:	Michichi Creek	River Station (m):	2,434

Geometry

Length of Span (m):	30.4	Top of Curb/Solid Rail Elev. (m):	688.07
Deck Width (m):	4.8	Low Chord Elev. (m):	686.67
Pier Type:	Timber Pile	No. of Piers:	1
Pier Shape:	Square	Pier Width (m):	0.32

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Culvert Description

Name:	Highway 9 over Michichi Creek at Drumheller	AT Bridge File No.:	07524
Watercourse:	Michichi Creek	River Station (m):	1,325

Geometry

Culvert Type:	Concrete Arch	Upstream Invert Elev. (m):	679.24
Entrance Condition:	Headwall with Wingwall	Downstream Invert Elev. (m):	679.15
Length (m):	48.0	Road Elev. (m):	686.18
		Arch Height (m):	4.9
		Arch Width (m):	9.0

Photo(s)

Upstream Side of Culvert



Downstream Side of Culvert



Bridge Description

Name:	Highway 838 Bridge in Drumheller	AT Bridge File No.:	08584
Watercourse:	Michichi Creek	River Station (m):	1,009

Geometry

Length of Span (m):	30.2	Top of Curb/Solid Rail Elev. (m):	685.02
Deck Width (m):	11.1	Low Chord Elev. (m):	684.17
Pier Type:	Steel Pile	No. of Piers:	2
Pier Shape:	Circular	Pier Width (m):	0.3

Photo(s)

**Upstream Side of
Bridge**



**Downstream Side
of Bridge**



Bridge Description

Name: Abandoned Railway Bridge 9
Watercourse: Rosebud River

AT Bridge File No.: N/A
River Station (m): 9,609

Geometry

Length of Span (m): 63.0
Deck Width (m): 5.3
Pier Type: Concrete
Pier Shape: Square

Top of Curb/Solid Rail Elev. (m): 699.15
Low Chord Elev. (m): 697.13
No. of Piers: 8
Pier Width (m): 0.30 (5),
 1.9 (3)

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Highway 10X (Historical Bridge No. 11)	AT Bridge File No.:	09315
Watercourse:	Rosebud River	River Station (m):	9,562

Geometry

Length of Span (m):	30.2	Top of Curb/Solid Rail Elev. (m):	698.48
Deck Width (m):	8.0	Low Chord Elev. (m):	697.40
Pier Type:	N/A	No. of Piers:	0
Pier Shape:	N/A	Pier Width (m):	N/A

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Highway 10X (Historical Bridge No. 10)	AT Bridge File No.:	08934
Watercourse:	Rosebud River	River Station (m):	8,697

Geometry

Length of Span (m):	30.5	Top of Curb/Solid Rail Elev. (m):	697.24
Deck Width (m):	7.9	Low Chord Elev. (m):	696.10
Pier Type:	N/A	No. of Piers:	0
Pier Shape:	N/A	Pier Width (m):	N/A

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Abandoned Railway Bridge 8	AT Bridge File No.:	N/A
Watercourse:	Rosebud River	River Station (m):	8,668

Geometry

Length of Span (m):	28.9	Top of Curb/Solid Rail Elev. (m):	699.45
Deck Width (m):	5.5	Low Chord Elev. (m):	696.68
Pier Type:	N/A	No. of Piers:	0
Pier Shape:	N/A	Pier Width (m):	N/A

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Abandoned Railway Bridge 7	AT Bridge File No.:	N/A
Watercourse:	Rosebud River	River Station (m):	8,069

Geometry

Length of Span (m):	35.6	Top of Curb/Solid Rail Elev. (m):	696.64
Deck Width (m):	5.5	Low Chord Elev. (m):	694.82
Pier Type:	Concrete	No. of Piers:	1
Pier Shape:	Circular	Pier Width (m):	1.87

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Highway 10X (Historical Bridge No. 9)	AT Bridge File No.:	08935
Watercourse:	Rosebud River	River Station (m):	7,947

Geometry

Length of Span (m):	49.4	Top of Curb/Solid Rail Elev. (m):	696.88
Deck Width (m):	5.8	Low Chord Elev. (m):	695.58
Pier Type:	N/A	No. of Piers:	0
Pier Shape:	N/A	Pier Width (m):	N/A

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Highway 10X (Historical Bridge No. 8)	AT Bridge File No.:	70514
Watercourse:	Rosebud River	River Station (m):	7,315

Geometry

Length of Span (m):	29.9	Top of Curb/Solid Rail Elev. (m):	694.04
Deck Width (m):	6.0	Low Chord Elev. (m):	692.97
Pier Type:	N/A	No. of Piers:	0
Pier Shape:	N/A	Pier Width (m):	N/A

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Abandoned Railway Bridge 6	AT Bridge File No.:	N/A
Watercourse:	Rosebud River	River Station (m):	7,233

Geometry

Length of Span (m):	35.2	Top of Curb/Solid Rail Elev. (m):	695.44
Deck Width (m):	5.4	Low Chord Elev. (m):	693.67
Pier Type:	Concrete	No. of Piers:	1
Pier Shape:	Triangular	Pier Width (m):	N/A

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name: Abandoned Railway Bridge 5
Watercourse: Rosebud River

AT Bridge File No.: N/A
River Station (m): 6,458

Geometry

Length of Span (m): 36.9
Deck Width (m): 5.6
Pier Type: Concrete
Pier Shape: Square

Top of Curb/Solid Rail Elev. (m): 693.56
Low Chord Elev. (m): 691.42
No. of Piers: 1
Pier Width (m): 1.7

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Highway 10X (Historical Bridge No. 7)	AT Bridge File No.:	70513
Watercourse:	Rosebud River	River Station (m):	6,370

Geometry

Length of Span (m):	30.3	Top of Curb/Solid Rail Elev. (m):	692.30
Deck Width (m):	6.4	Low Chord Elev. (m):	691.08
Pier Type:	Timber Box	No. of Piers:	1
Pier Shape:	Square	Pier Width (m):	1.27

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Abandoned Railway Bridge 4	AT Bridge File No.:	N/A
Watercourse:	Rosebud River	River Station (m):	5,892

Geometry

Length of Span (m):	41.1	Top of Curb/Solid Rail Elev. (m):	692.35
Deck Width (m):	5.2	Low Chord Elev. (m):	690.57
Pier Type:	Concrete	No. of Piers:	1
Pier Shape:	Square	Pier Width (m):	2.48

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Highway 10X (Historical Bridge No. 6)	AT Bridge File No.:	70774
Watercourse:	Rosebud River	River Station (m):	5,863

Geometry

Length of Span (m):	40.8	Top of Curb/Solid Rail Elev. (m):	691.77
Deck Width (m):	6.3	Low Chord Elev. (m):	690.49
Pier Type:	N/A	No. of Piers:	0
Pier Shape:	N/A	Pier Width (m):	N/A

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name: Highway 10X
(Historical Bridge No. 5)
Watercourse: Rosebud River

AT Bridge File No.: 70773
River Station (m): 5,461

Geometry

Length of Span (m): 30.4
Deck Width (m): 6.3
Pier Type: N/A
Pier Shape: N/A

Top of Curb/Solid Rail Elev. (m): 690.40
Low Chord Elev. (m): 689.34
No. of Piers: 0
Pier Width (m): N/A

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Highway 10X (Historical Bridge No. 4)	AT Bridge File No.:	70512
Watercourse:	Rosebud River	River Station (m):	4,988

Geometry

Length of Span (m):	49.4	Top of Curb/Solid Rail Elev. (m):	690.03
Deck Width (m):	6.3	Low Chord Elev. (m):	688.73
Pier Type:	Timber Box	No. of Piers:	1
Pier Shape:	Square	Pier Width (m):	1.25

Photo(s)

Upstream Side of Bridge



View from the Right Bank



Bridge Description

Name:	Highway 10X (Historical Bridge No. 3)	AT Bridge File No.:	70511
Watercourse:	Rosebud River	River Station (m):	4,518

Geometry

Length of Span (m):	30.4	Top of Curb/Solid Rail Elev. (m):	689.48
Deck Width (m):	6.3	Low Chord Elev. (m):	688.33
Pier Type:	N/A	No. of Piers:	0
Pier Shape:	N/A	Pier Width (m):	N/A

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name: Abandoned Railway Bridge 3
Watercourse: Rosebud River

AT Bridge File No.: N/A
River Station (m): 4,490

Geometry

Length of Span (m): 30.8
Deck Width (m): 5.4
Pier Type: Concrete
Pier Shape: Triangular

Top of Curb/Solid Rail Elev. (m): 690.83
Low Chord Elev. (m): 689.23
No. of Piers: 1
Pier Width (m): 1.48

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name: Abandoned Railway Bridge 2
Watercourse: Rosebud River

AT Bridge File No.: N/A
River Station (m): 2,245

Geometry

Length of Span (m): 49.1
Deck Width (m): 6.0
Pier Type: Concrete
Pier Shape: Triangular

Top of Curb/Solid Rail Elev. (m): 686.79
Low Chord Elev. (m): 684.99
No. of Piers: 2
Pier Width (m): 1.9

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Highway 10X (Historical Bridge No. 2)	AT Bridge File No.:	70510
Watercourse:	Rosebud River	River Station (m):	2,125

Geometry

Length of Span (m):	41.1	Top of Curb/Solid Rail Elev. (m):	685.25
Deck Width (m):	6.3	Low Chord Elev. (m):	683.87
Pier Type:	N/A	No. of Piers:	0
Pier Shape:	N/A	Pier Width (m):	N/A

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Highway 10X (Historical Bridge No. 1)	AT Bridge File No.:	70817
Watercourse:	Rosebud River	River Station (m):	1,140

Geometry

Length of Span (m):	61.6	Top of Curb/Solid Rail Elev. (m):	684.02
Deck Width (m):	8.9	Low Chord Elev. (m):	682.39
Pier Type:	N/A	No. of Piers:	0
Pier Shape:	N/A	Pier Width (m):	N/A

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Highway 10 Bridge at Rosedale	AT Bridge File No.:	08719
Watercourse:	Rosebud River	River Station (m):	0,542

Geometry

Length of Span (m):	49.5	Top of Curb/Solid Rail Elev. (m):	682.76
Deck Width (m):	10.9	Low Chord Elev. (m):	681.71
Pier Type:	Concrete	No. of Piers:	2
Pier Shape:	Circular	Pier Width (m):	1.3

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Abandoned Railway Bridge 1	AT Bridge File No.:	N/A
Watercourse:	Rosebud River	River Station (m):	0,340

Geometry

Length of Span (m):	53.1	Top of Curb/Solid Rail Elev. (m):	683.20
Deck Width (m):	4.8	Low Chord Elev. (m):	681.65
Pier Type:	Concrete	No. of Piers:	2
Pier Shape:	Circular with Slope	Pier Width (m):	1.35

Photo(s)

Upstream Side of Bridge



Downstream Side of Bridge



Bridge Description

Name:	Highway 10 Bridge 10.5 km NW of East Coulee	AT Bridge File No.:	71746
Watercourse:	Willow Creek	River Station (m):	0,856

Geometry

Length of Span (m):	33.0	Top of Curb/Solid Rail Elev. (m):	680.60
Deck Width (m):	13.5	Low Chord Elev. (m):	679.55
Pier Type:	Steel Pile	No. of Piers:	2
Pier Shape:	Circular	Pier Width (m):	0.61

Photo(s)

Upstream Side of Bridge

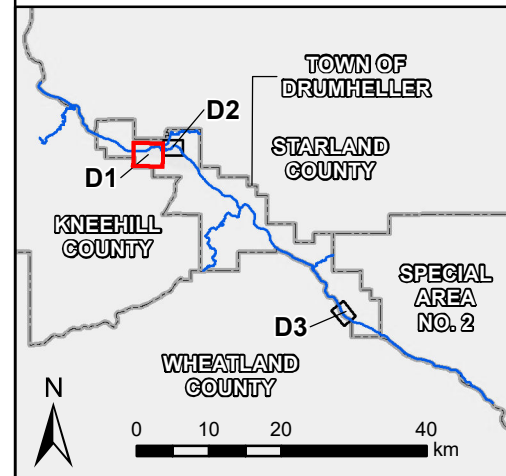


Downstream Side of Bridge

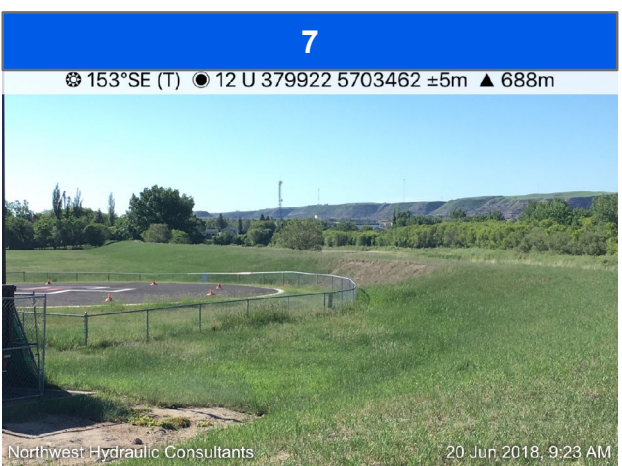


**APPENDIX D
FLOOD CONTROL STRUCTURE DETAILS**

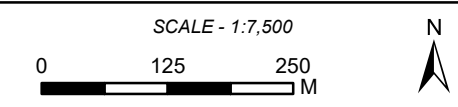
DRAFT



- FLOW DIRECTION
- IMAGE LOCATION
- FLOOD CONTROL STRUCTURE
- BRIDGE



DATA SOURCES: Basemap from Esri and NRCan



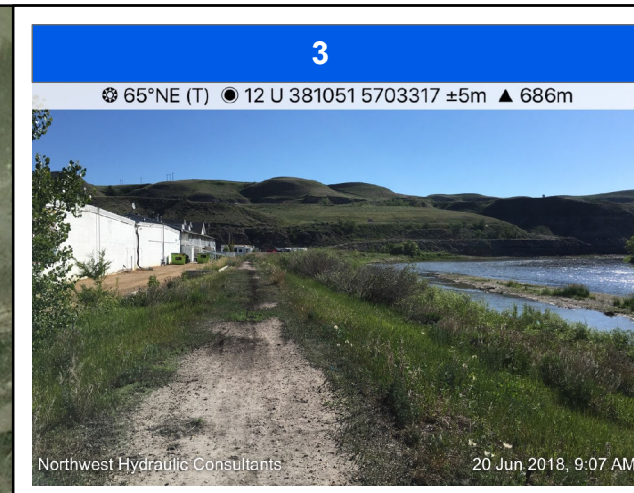
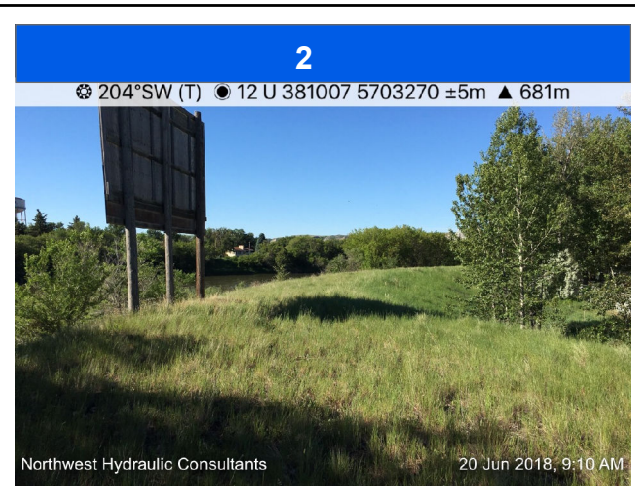
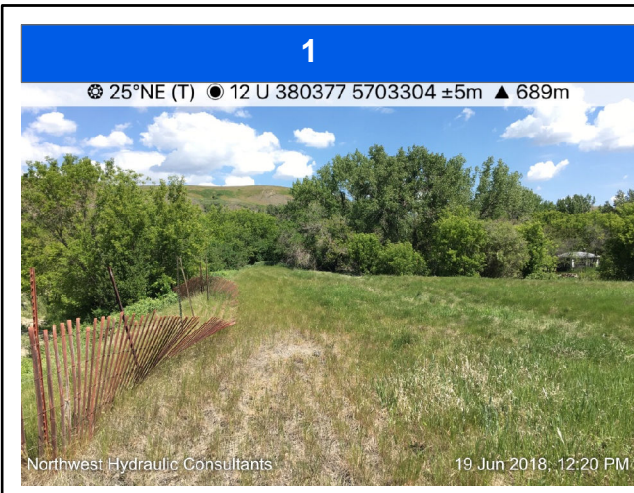
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Vertical Datum: CGVD28 HTv2.0; Units: Metres

Job: 1003877 Date: 27-MAR-2020

**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

**FLOOD CONTROL STRUCTURES
MIDLAND, NEWCASTLE &
HOSPITAL DIKES**

FIGURE D1



Alberta

nhc
 northwest hydraulic consultants

Map labels include: TOWN OF DRUMHELLER, STARLAND COUNTY, KNEEHILL COUNTY, WHEATLAND COUNTY, SPECIAL AREA NO. 2, D1, D2, D3.

Legend:
 → FLOW DIRECTION
 ■ IMAGE LOCATION
 — FLOOD CONTROL STRUCTURE
 = BRIDGE

DATA SOURCES: Basemap from Esri and NRCan

SCALE - 1:5,000

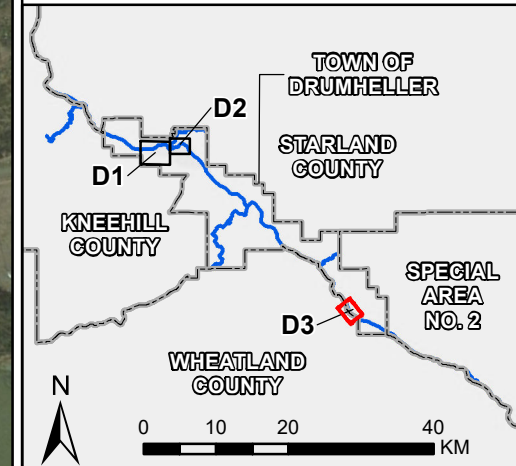
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Job: 1003877 | Date: 27-MAR-2020

**DRUMHELLER RIVER HAZARD STUDY
 SURVEY AND BASE DATA COLLECTION**

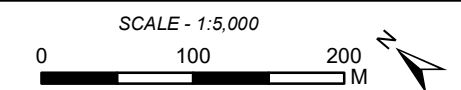
**FLOOD CONTROL STRUCTURES
 DIKES B, C & D**

FIGURE D2



- FLOW DIRECTION
- IMAGE LOCATION
- FLOOD CONTROL STRUCTURE
- BRIDGE

DATA SOURCES: Basemap from Esri and NRCan



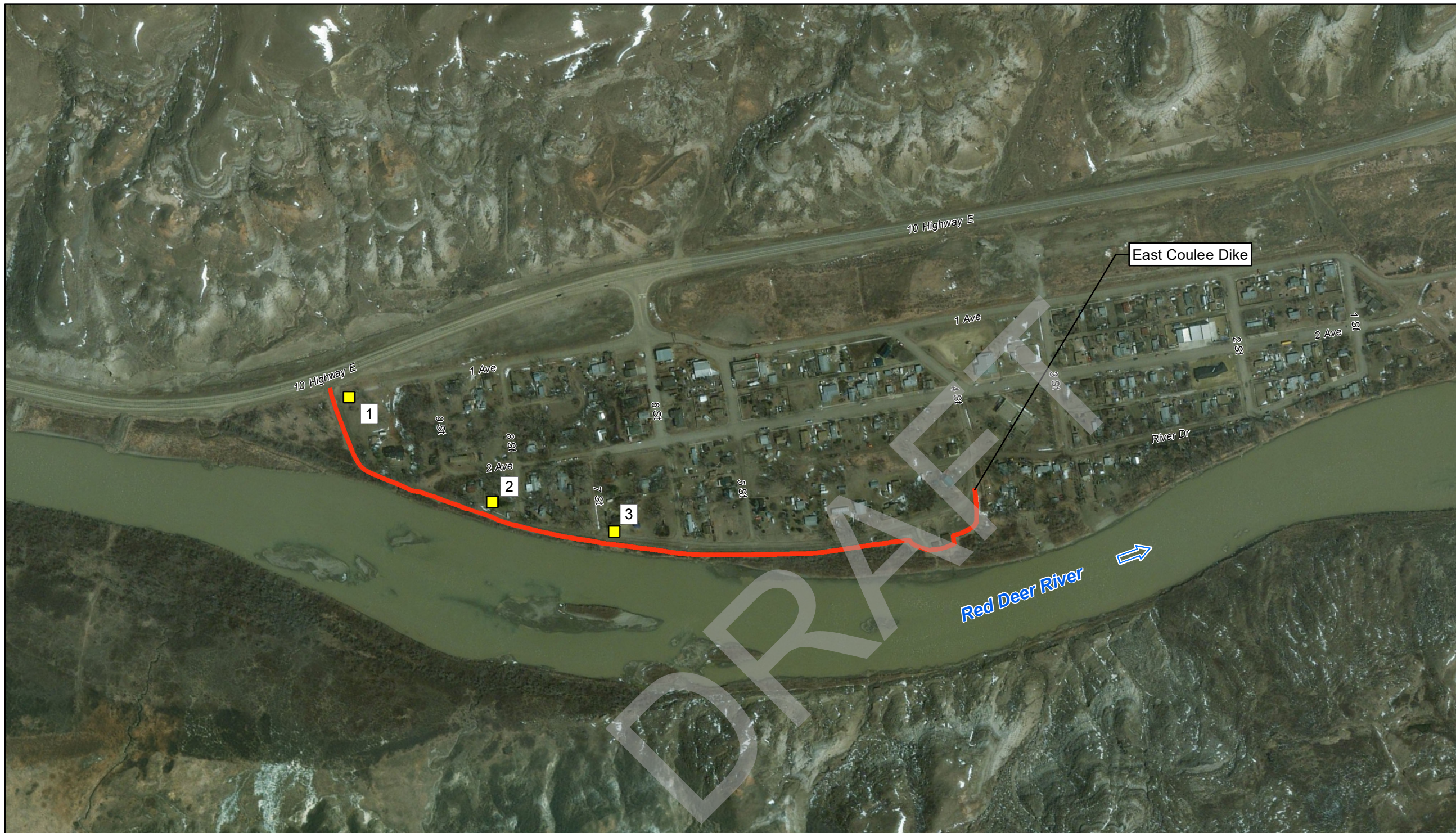
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Vertical Datum: CGVD28 HTv2.0; Units: Metres

Job: 1003877 | Date: 27-MAR-2020

**DRUMHELLER RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION**

**FLOOD CONTROL STRUCTURES
EAST COULEE DIKE**

FIGURE D3



APPENDIX E
HYDROMETRIC GAUGING STATION INFORMATION

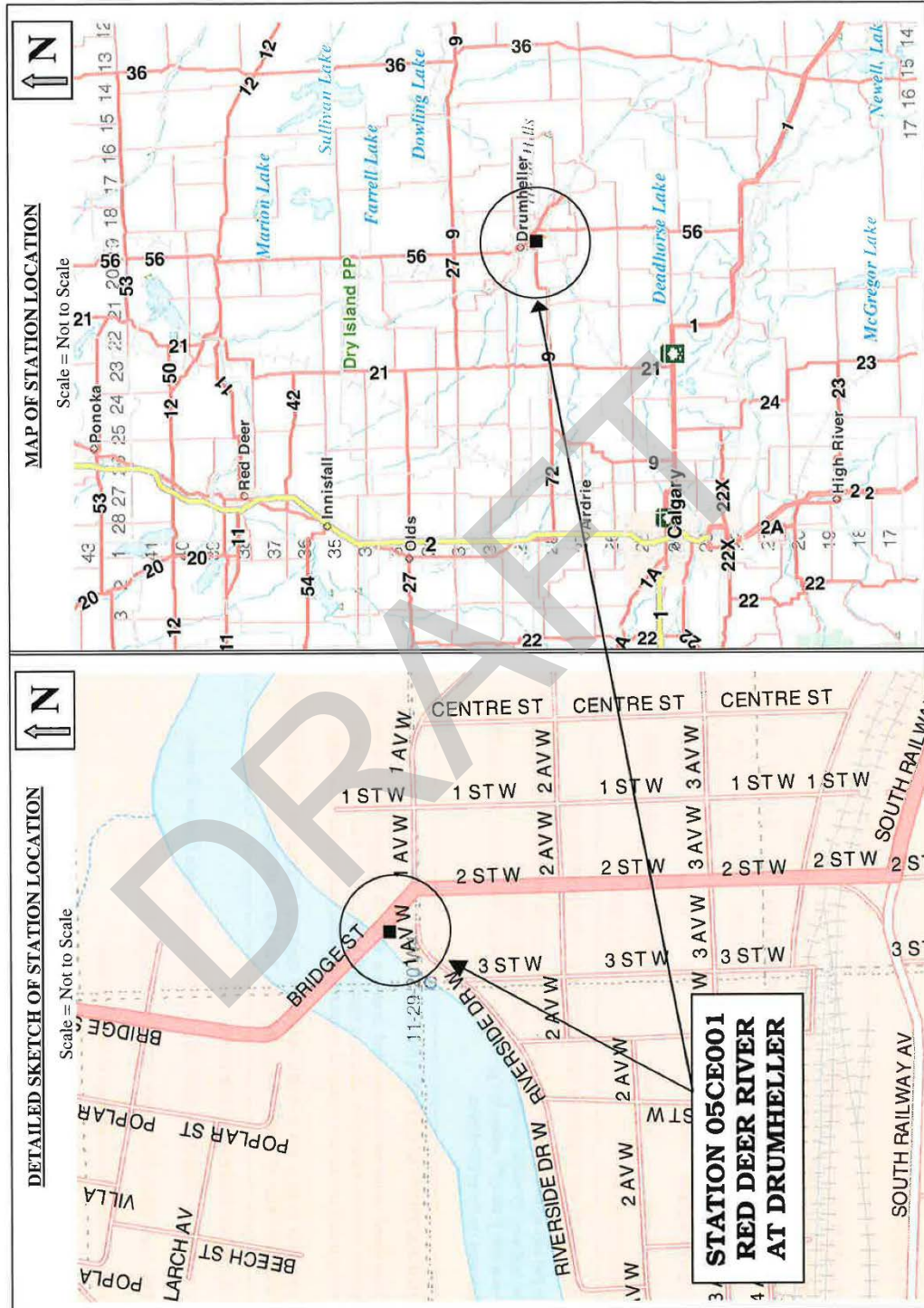
DRAFT

E.1 Red Deer River at Drumheller (05CE001)

WATER SURVEY OF CANADA		STATION DESCRIPTION	
STATION NO.:	05CE001	BENCH MARKS	
STATION NAME:	RED DEER RIVER AT DRUMHELLER	GIVE ELEVATIONS OF BENCHMARK TYPES AND NUMBERS OR MARKINGS.	
LOCATED IN SECTION	SW 11 TOWNSHIP 29 RANGE 20 W4M	GAUGE DATUM = 676.720m (G.S.C.)	
LATITUDE	51° 28' 2.1" N LONGITUDE 112° 42' 41.3" W N 51.46727° W 112.71149° (NAD 83)	*BM #1: Bolt – set vertically in the top of the SE concrete (old) abutment approx. 3m upstream of the new bridge (G.S.C.)	
ESTABLISHED	1959 BY Water Survey of Canada	TBM 98-1: Paint mark on concrete bridge abutment ledge approx. 1.5m below BM#1 Elev.: 683.086m (ref to BM #1)	
OBSERVER:	VEDAS	PHONE NO.: 403-823-3040	
LAND OWNER:		PHONE NO.:	
LOCATION OF STATION WITH RESPECT TO TOWNS, ETC. :		BM2002-2: Top of NE corner of metal storm drain (that is set in concrete) approx. 20m East SE of the gauge, along the pedestrian walk way Elev.: 682.173m (ref. to BM #1)	
In the city of Drumheller: The gauge is located on the upstream, right bank side of the highway #9 traffic bridge crossing the Red Deer River. From HWY #9 (2 nd street W) go west on 2 nd Street W, north on 3 rd Street W and then east on Riverside Drive.		TBM 04-1: Red paint mark on corner of steel, set in concrete by pedestrian walkway Elev.: 682.425m (Ref. to BM #1)	
DESCRIPTION OF GAUGE AND EQUIPMENT:	Cedar sided shelter on a wooden pad, houses a VEDAS II logger interfaced with an accubar pressure transducer. Gauge is operated on DC power with a solar panel, wiring board and 12 volt battery. Logger has a phone modem (403-823-3040).	BENCH MARK CLASSIFICATION: 3 * = PRIMARY B.M.	
LOGGER IS SET TO A WIRE WIEGHT GAUGE WHICH IS LOCATED ON THE UPSTREAM HAND RAIL OF THE TRAFFIC BRIDGE		REMARKS: Level check once per year with all bench marks tied in once every three years.	
MEASUREMENT DESCRIPTION:	Low water: Wading above rapids approx. 800m below gauge (below 30 cms). High water: From downstream side of traffic bridge below gauge. No good measurement sections for medium water.		
TYPE OF CONTROL:	Natural		
KIND AND MATERIALS -	Gravel and rock		
PREPARED BY:	C.Selman	DATE: Jun 30, 2010	

STATION DESCRIPTION

WATER SURVEY OF CANADA



Red Deer River at Drumheller (continued)

E.2 Michichi Creek at Drumheller (05CE020)

Page 1

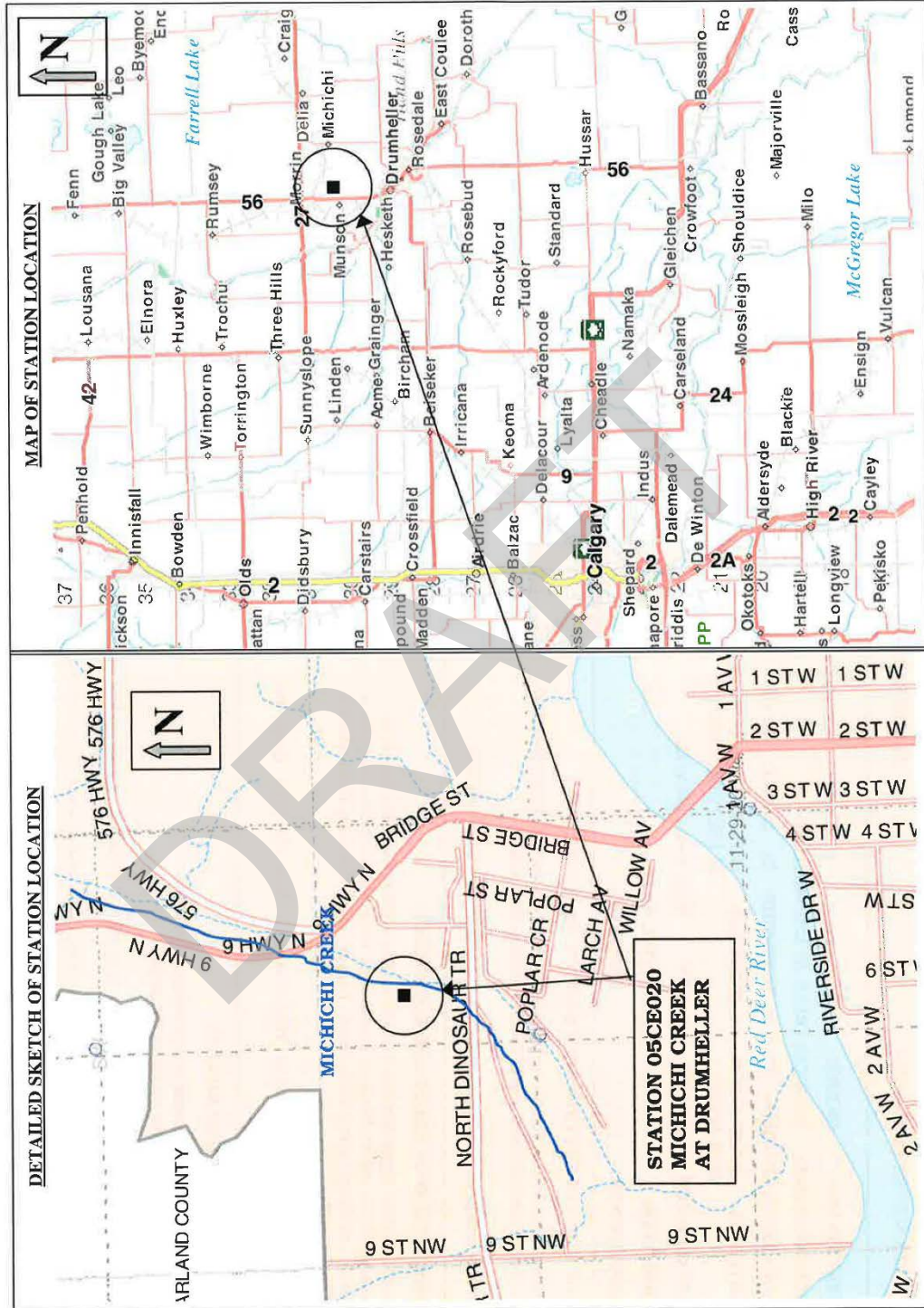
STATION DESCRIPTION

WATER SURVEY OF CANADA

<p>STATION NO.: 05CE020</p> <p>STATION NAME: MICHICHI CREEK AT DRUMHELLER</p> <p>LOCATED IN SECTION: NW 11 TOWNSHIP: 29 RANGE: 20 W4</p> <p>LATITUDE: 51° 28' 17.5" N LONGITUDE: 112° 43' 1.1" W N 51.47153° W 112.71699° (NAD 83)</p> <p>ESTABLISHED: Aug 2, 1978 BY: Water Survey of Canada</p> <p>OBSERVER: PHONE NO.:</p> <p>LAND OWNER: PHONE NO.:</p> <p>LOCATION OF STATION WITH RESPECT TO TOWNS, ETC.: On the Dinosaur Trail 0.5 km west of highway #9, in the town of Drumheller. Gauge is on right bank, upstream side of Dinosaur Trail traffic bridge.</p> <p>Wire weight gauge is on downstream side of bridge on pedestrian walk way</p> <p>DESCRIPTION OF GAUGE AND EQUIPMENT: Sutron Satlink2 logger interfaced with an accubar pressure transducer housed in standard Brytex shelter. Shelter is insulated and wired with AC power Gauge has a battery and charger with a wiring board Logger set to Measuring Point which is closer to orifice.</p> <p>GOES: 482393f4 Tx: 00:00:50 Win: 10 sec Int: 1 hour Ch: 052W Baud: 300</p> <p>MEASUREMENT DESCRIPTION: High water: From downstream side of pedestrian walk way Low water: Wading in the vicinity of the gauge.</p> <p>Station subject to beaver activity. Station can be affected by backwater from the Red Deer River.</p> <p>TYPE OF CONTROL: Natural – usually beaver dams KIND AND MATERIALS - Sticks, grass and mud</p> <p>PREPARED BY: Curtis Bertrand DATE: 2011-01-12</p>	<p>BENCH MARKS</p> <p>GIVE ELEVATIONS OF BENCHMARK TYPES AND NUMBERS OR MARKINGS.</p> <p>GAUGE DATUM = 677.881 (G.S.C.)</p> <p>*BM 03-1: SW bolt at base of lamp post 3.4m d/s of guard rail and 12.0m west of WWG. Elevation: 684.799 m (ref. to BM 78-1)</p> <p>BM 78-1: Brass cap in cement 6.5m north of TBM 82-1. Elevation: 683.977 m</p> <p>TBM 82-1: Head of lag bolt in power pole 2m north of the bridge the on right bank. Elevation: 684.639 m (ref. to BM 78-1)</p> <p>MP -2010 - Chiseled paint mark in the centre of upstream bridge curb. Elevation: 685.048 m (ref. to BM 03-1)</p> <p>BENCH MARK CLASSIFICATION: 3 * = PRIMARY B.M.</p> <p>REMARKS: Level check to gauge once a year, with all bench marks tied in once every three years</p> <p>SKETCH OF BENCH MARKS</p> <p>The sketch shows a plan view of the station area. A north arrow points upwards. Michichi Creek flows from the top towards the bottom. A bridge crosses the creek, with a pedestrian walkway on the downstream side. A gauge is located on this walkway. To the right of the walkway is the Dinosaur Trail. Several bench marks are marked: BM 78-1 is a dot on the left side; TBM 82-1 is a square on the walkway; MP 2010 is a dot on the walkway; and BM 03-1 is a dot on the right side. A 'Wire Weight Gauge' is also indicated near BM 03-1.</p>
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STATION DESCRIPTION

WATER SURVEY OF CANADA



Michichi Creek at Drumheller (continued)

**APPENDIX F
REACH-REPRESENTATIVE PHOTOGRAPHS**

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F.1 Red Deer River



Red Deer River (downstream view) from right overbank at river station 54,520 m.



Red Deer River (downstream view) from river station 44,702 m looking at an abandoned railway bridge.



Red Deer River (upstream view) from a gravel bar along the right bank at river station 42,168 m.



Red Deer River (downstream view) just downstream of the Highway 9 bridge at river stations 40,778 m.



Red Deer River (upstream view) from the Drumheller Badlands Community Facility at river station 39,905 m.



Red Deer River confluence with Rosebud River looking from the left bank from just downstream of Roper Road bridge at river station 32,470 m.



Red Deer River (downstream view) from the left overbank at the old Highway 10 bridge crossing from river station 28,196 m.



Red Deer River (downstream view) from the left overbank at river station 19,668 m.



Red Deer River (downstream view) from the right overbank at river station 16,759 m.



Red Deer River (upstream view) of the left overbank from river station 1,503 m.

F.2 Kneehills Creek



Kneehills Creek (downstream view) from river station 6,256 m.



Kneehills Creek (downstream view) from Township Road 292A at river station 3,701 m.



Kneehills Creek (downstream view) from Range Road 211A at river station 3,015 m.



Kneehills Creek (downstream view) from the South Dinosaur Trail at river station 1,576 m.



Kneehills Creek (upstream view) from the right overbank at river station 570 m.

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F.3 Michichi Creek



Michichi Creek (downstream view) from the right overbank at river station 4,340 m.



Michichi Creek (upstream view) from the right overbank at river station 3,552 m.



Michichi Creek (downstream view) from the left overbank at river station 2,577 m.



Michichi Creek (downstream view) from the highway 9 crossing at river station 1,300 m.



Michichi Creek (upstream view) from the right overbank at river station 485 m.

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F.4 Rosebud River



Rosebud River (downstream view) from Excelsior Avenue at river station 9,563 m.



Rosebud River (downstream view) from Jewell Street at river station 8,305 m.



Rosebud River (upstream view) from Excelsior Avenue at river station 7,949 m.



Rosebud River (downstream view) from Excelsior Avenue at river station 6,368 m.



Rosebud River (upstream view) from Highway 10X at river station 4,995 m.



Rosebud River (upstream view) from Highway 10X at river station 2,152 m.



Rosebud River (upstream view) from Highway 10 at river station 543 m.

F.5 Willow Creek



Willow Creek (upstream view) from the left overbank at river station 2,708 m.



Willow Creek (upstream view) from the right overbank at river station 1,003 m.

**APPENDIX G
DIGITAL DATA**

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Table G1 Digital data summary

File Name	Description
Directory: 01 Survey Data	
Drumheller RHS Survey Data_20181105.xlsx	Surveyed point coordinates and associated data in Excel format. RTK (ground survey) and depth soundings are provided on separate worksheets in this file. All coordinates are in NAD83 (CSRS) 3TM 114W CGVD28 HTv2.0 and metres.
Plan\Drumheller RHS Survey Plan_20180704.kmz	Survey plan documentation in Google KMZ format showing planned cross section alignments at the beginning of the survey program. Contents of this file are also provided in GIS shapefile format in the 'shapefiles' directory.
Directory: 02 Spatial Data	
Drumheller RHS Master.mxd	ArcMap 10.4 project file presenting survey information contained in the project geodatabase.
Drumheller RHS Master_10.3.mxd	ArcMap 10.3 version of Drumheller RHS Master.mxd.
Drumheller_RHS.gdb	Geodatabase containing all of the spatial data described in Table G2.
\Photos	Directory containing the geo-located photos referenced in the geodatabase.
Directory: 03 Supporting Documents	
[TO BE PROVIDED WITH THE FINAL REPORT]	[DIGITAL COPIES OF ALL DOCUMENTS REQUIRED FOR REPRODUCTION OF THE FINAL REPORT, INCLUDING TEXT, TABLES, FIGURES, MAPS, AND APPENDICES]

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Table G2 Spatial data inventory

Feature	Name	Description
Aerial imagery extents	Boundaries\AEP_2019_Imagery	Polygons: Proposed aerial imagery acquisition area (2019 data) prepared by AEP.
LiDAR extents	Boundaries\AEP_2018_LiDAR	Polygons: Anticipated LiDAR acquisition area (2018 data) prepared by AEP.
Approximate study reaches	Boundaries\AEP_Reaches	Polylines: River reach lines provided by AEP detailing approximate study area.
River hazard study limits	Boundaries\AEP_Study_Limits	Polylines: Study limits defined by AEP for the Drumheller River Hazard Study coincident with Alberta Township System boundaries listed in the TOR.
Alberta Township System grid	Boundaries\ATS_Sections	Polygons: Subset of the Alberta Township System quarter section grid covering the river hazard study area.
Municipal boundaries	Boundaries\Mun_Boundaries	Polygons: Municipal boundary for the Town of Drumheller.
Approximate 1000-year inundation extent	Boundaries\OW1000Y_APPROX	Polygons: Approximate 1000-year open water inundation extent. Information to be used for aerial imagery coverage confirmation only.
Study reaches	Model\M_Reaches	Polylines: Approximate channel centreline alignments that have been refined and prepared for model development. Basis for current river stationing.
Alberta Survey Control Monuments	Other\ASCM	Points: Published coordinates of selected ASCMs in the study area that are referenced in the survey.
2007 river hazard study cross sections	Other\Cross_Sections_2007	Polylines: Cross section alignments from the previous Drumheller Flood Risk Mapping Study.
Water Survey of Canada Hydrometric Stations	Other\WSC_Stations	Points: Approximate locations of WSC hydrometric gauging stations in the study area.
Bridge alignments	Structures\Bridges	Polylines: Bridge centreline alignments based on 2018 survey information.
Culvert alignments	Structures\Culverts	Polylines: Culvert centreline alignments based on 2018 survey information.
Flood control structure alignments	Structures\Dikes	Polylines: Flood control structure (dike) crest alignments based on 2018 survey information.
Cross section alignments	Survey\Cross_Sections	Polylines: Cross section profile alignments that have been adjusted and refined based on 2018 survey information.
Planned cross section alignments	Survey\Cross_Sections_Planned	Polylines: Originally-planned cross section alignments for the 2018 cross section survey. These are the same as those provided with the survey plan documentation.
Photo locations	Survey\Photos	Points: Reach-representative, hydraulic structure, and flood control structure photo locations.
Survey points	Survey\Points	Points: Complete inventory of all ground survey and boat-based survey coordinates. Data are organized by source (RTK or sounding) and classified by type (control point, cross section, water level measurement, highwater mark, structure, flood control structure, or other). Type classifications are preliminary and may be further refined during model development.

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northwest hydraulic consultants

water resource specialists