April 2018

FORT MCMURRAY RIVER HAZARD STUDY

Survey and Base Data Collection Report

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REPORT

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SG1 WATER CONSULTING

Golder Associates

Executive Summary

Alberta Environment and Parks (AEP) retained Golder Associates Ltd. (Golder), in collaboration with SG1 Water Consulting Ltd. (SG1) and Hatch Ltd. (Hatch), in September 2016 to conduct the Fort McMurray River Hazard Study. The primary purpose of the study is to assess and identify river and flood hazards along the Athabasca River, the Clearwater River (including the Snye), and the Hangingstone River through Fort McMurray, Alberta in the Regional Municipality of Wood Buffalo (RMWB).

The study is conducted under the provincial Flood Hazard Identification Program (FHIP), the goals of which include enhancement of public safety and reduction of future flood damages through the identification of river and flood hazards. Project stakeholders include the Government of Alberta, the RMWB, and the public.

The Fort McMurray River Hazard Study includes multiple components and deliverables. This report documents the methodology and results of the survey and base data collection component, which supports the hydraulic modelling, ice jam assessment, flood mapping, flood risk assessment, and channel stability investigation components. The tasks associated with this component include a cross section surveys, hydraulic and flood control structure data collection, and aerial imagery acquisition for various reaches of the Athabasca, Clearwater, and Hangingstone rivers. Additional base data collected by Golder includes administrative, cadastral, and transportation data, structural design drawings, benchmark surveys, and other relevant data.

Topographic, control point, and shallow-water surveys were performed using Real-time Kinematic (RTK) GPS units. Bathymetric surveys were conducted on the Athabasca River and the Clearwater River using an Acoustic Doppler Profiler (ADP) in combination with a boat-mounted RTK unit where flow depths were too deep to wade. Bridge survey data were collected using either a RTK or total station.

The total length of the Athabasca River study reach is approximately 15 km. The total length of the Clearwater River study reach is approximately 20 km. The total length of the Hangingstone River study reach is approximately 5 km. The total length of the Snye study reach is approximately 1.5 km. The features surveyed as part of this project are summarized in Table i.

Table i: Summary of Survey Features

Feature	Athabasca River	Clearwater River	Hangingstone River	The Snye	Totals
Cross Sections	26	51	79	4	**160**
Bridges	3(1)	-	8	-	**11**
Culverts	1	-	-	-	**1**
Flood Control Structures	-	2	1(2)	1	**4**

Notes:

1. The bridges on the Athabasca River are treated as one bridge in the HEC-RAS model as their opening widths are similar and the piers are lined up in series with respect to the flow direction.
2. There is one flood control structure along the downstream reach of Saline Creek, a tributary to the Hangingstone River.

River discharge and water level measurements were completed on the Athabasca, Clearwater, and Hangingstone rivers to complement the bathymetric surveys. Water levels were recorded along each study reach while the discharge measurement was made to obtain a comprehensive and complete water surface profile for a specific flow rate. These hydraulic data will be used in this study to calibrate the hydraulic model for low-flow conditions.

ACKNOWLEDGEMENTS

The technical lead for the survey and base data collection component of the Fort McMurray River Hazard Study was Darren Shepherd of SG1 Water Consulting Ltd. (SG1) with senior technical review by David Andres. Wolf Ploeger of Golder Associates Ltd. (Golder) provided overall direction and support for this study component. The field survey was conducted by Carmen Orosz, Anna-Maria Viaud, Rob Hollingshead, and Megan Lewis (all of Golder).

The authors thank Maureen Nakonechny, Project Manager in the Engineering Department of the Regional Municipality of Wood Buffalo, for providing available information.

The authors express their special thanks to Abdullah Mamun, project manager for Alberta Environment and Parks (AEP), who provided overall study management, background data, and technical guidance.

The authors also express their gratitude to Patricia Stevenson, Jim Choles, and Peter Onyshko of AEP for their additional support and for providing background information and survey-related data.

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1.0 INTRODUCTION

1.1 Study Objectives

Alberta Environment and Parks (AEP) retained Golder Associates Ltd. (Golder), in collaboration with SG1 Water Consulting Ltd. (SG1) and Hatch Ltd. (Hatch), in September 2016 to conduct the Fort McMurray River Hazard Study. The primary purpose of the study is to assess and identify river and flood hazards along the Athabasca River, the Clearwater River (including the Snye), and the Hangingstone River through Fort McMurray, Alberta in the Regional Municipality of Wood Buffalo (RMWB).

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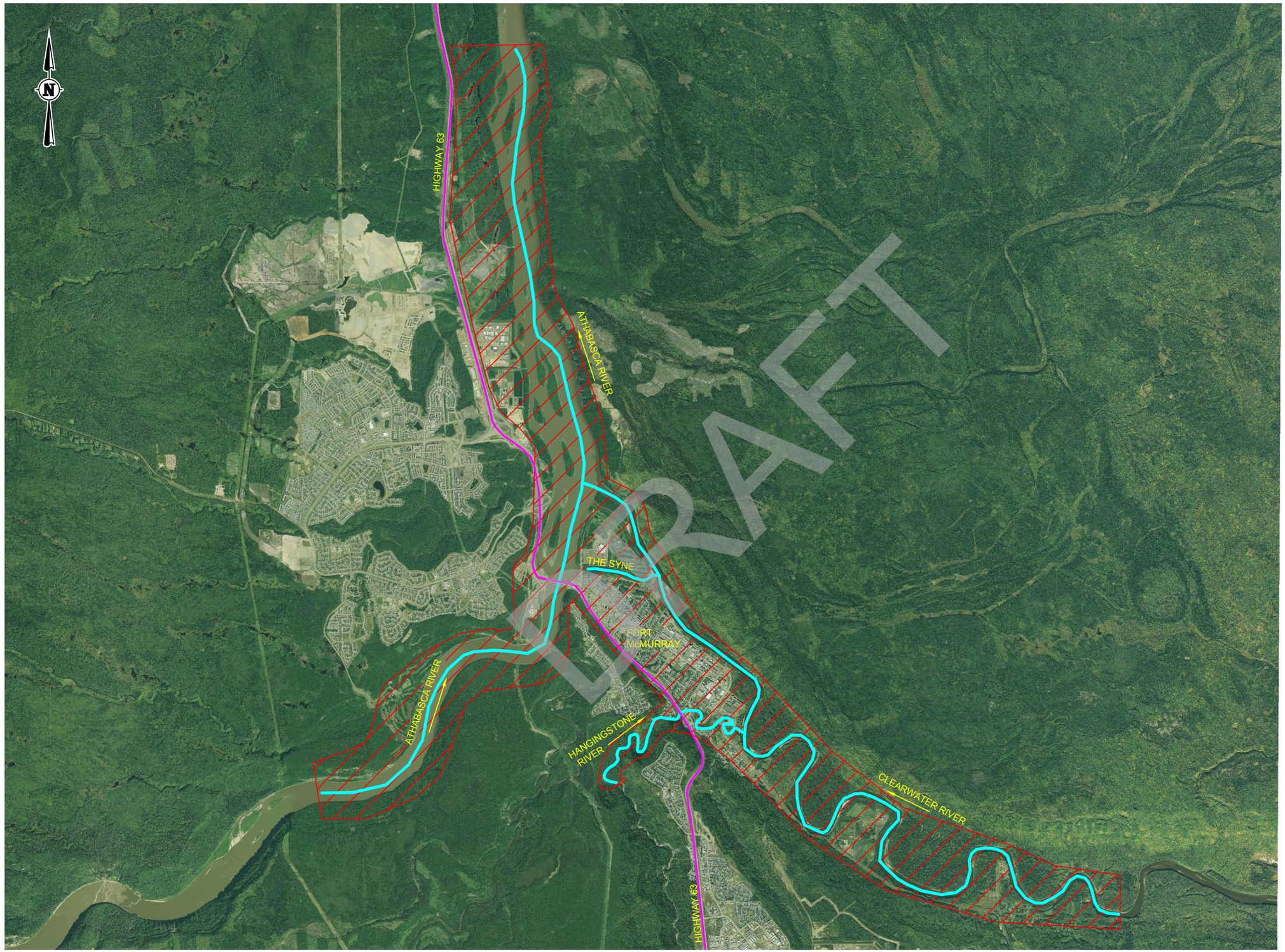
1.2 Study Area and Reaches

The study are includes approximately 15 km of the Athabasca River, approximately 20 km of the Clearwater River, approximately 5 km of the Hangingstone River, and the full length (1.5 km) of the Snye at Fort McMurray (Figure 1). The study area is located in the Regional Municipality of Wood Buffalo.

1.3 Scope of Work

The river survey program includes the survey of river cross sections, hydraulic structures, flood control structures and other features.

The base data collection includes aerial imagery acquisition, administrative, cadastral, and transportation data, structural design drawings, benchmark surveys, and other relevant data. These tasks are discussed within this report in Sections 2, 3, and 4, respectively.



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NOTES:

1. AERIAL IMAGERY (2013) PROVIDED BY AEP.
2. COORDINATE SYSTEM IS 3TM MERIDIAN 111° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.

LEGEND:

- PRIMARY HIGHWAY
- STUDY REACH
- RIVER HAZARD STUDY AREA

0 m 1000 2000 3000 m

1 : 75000

PREPARED FOR:

Alberta Government

PROJECT:

FORT McMURRAY RIVER HAZARD STUDY SURVEY AND BASE DATA COLLECTION

TITLE:

Location Map of Study Area

DWN BY:	CHK'D BY:	REV NO:
RDJ	DMS	0
DWG NO: 10058-02-101		FIGURE NO: 1
DATE: 19-DEC-2016		

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2.0 SURVEY PROGRAM AND COLLECTED DATA

2.1 General

Surveying of the study area began on September 27, 2016 and all field-related tasks were completed on October 8th, 2016. The field program included surveying of cross sections, hydraulic structures, and flood control structures along the study reaches. In addition, the temporary benchmarks associated with a high watermark survey by AEP in June 2013 on the Clearwater River and the Hangingstone River were surveyed. Discharge and water level measurements were recorded on the Athabasca, Clearwater, and Hangingstone rivers during the survey period to assist with calibration of the hydraulic model in subsequent study components.

Table 1 indicates the reaches of the Athabasca River, the Clearwater River (including the Snye), and the Hangingstone River that were surveyed and when each reach was surveyed.

Table 1: River Survey Coverage and Details

Waterbody	Reach Description	Survey Dates (2016)									
		September				October					
		27	28	29	30	1	2	3	4	5	6
Athabasca River	Above confluence with Clearwater River					X			X	X	
	Below confluence with Clearwater River							X	X		
Clearwater River	Above confluence with Hangingstone River				X	X	X				X
	Below confluence with Hangingstone River								X	X	
Hangingstone River	Above Memorial Drive (Highway 63)		X	X	X						
	Below Memorial Drive (Highway 63)	X	X	X	X						
The Snye	Snye Dyke to Confluence with Clearwater River							X			

2.2 Procedures and Methodology

2.2.1 Topographic, Bathymetric and Structure Surveys

The following survey equipment was used to collect the topographic, bathymetric, and structure data for this study:

- **Real-time Kinematic (RTK) GPS** – Trimble R8® and R10® RTK units were used to survey ground features and river bed levels in areas where hydraulic conditions allowed the surveyors to wade the channel. The RTK units were also used to survey in the control points and benchmarks found within the study area.
- **Acoustic Doppler Profiler (ADP)** – A SonTek RiverSurveyor M9® was used in combination with a boat-mounted RTK unit to survey the river bed in areas where wading was not permissible.

- **Total Station** – A Nikon Nivo 5M® reflectorless total station was used to collect bridge survey data.

All of the RTK data collected for this study were referenced to the Can-Net Virtual Reference System (VRS) Network[1]. This system utilizes network-corrected data calculated at multiple, fixed reference stations across Canada and broadcasts via a cellular network to define horizontal and vertical positions to within ±0.02 m. The survey data were acquired by RTK rover units with pre-loaded geoid files. The RTK data output for this study provides an orthometric elevation with correct northing and easting coordinates. All survey data were collected in the UTM coordinate system and subsequently converted to the 3TM Meridian 111° W projection and referenced to NAD83 (CSRS) horizontal and CGVD28 vertical datums. Ellipsoidal heights will be transformed to CGVD28 orthometric heights using the HTv2.0 geoid model.

Each survey point collected using either the RTK or total station was attributed a specific code. A schematic of survey point codes and corresponding locations is shown in Figure 2, which also includes a complete list of survey codes for the RTK and total station.

All survey data were imported into a Geographic Information System (GIS) to allow for validation and further processing. In addition to the quality assurance and quality control (QA/QC) procedures for field data collection, the survey data were checked in Esri ArcGIS® for outliers and through visual inspection of triangulated irregular network (TIN) surfaces developed from the survey data. Similar procedures were applied to ensure concurrence among all datasets collected on different dates and using different types of survey equipment.

[1] Can-Net operates a 24-hour base station in the Fort McMurray neighbourhood of Timberlea (FMWB/33). The study area is within 18 km of FMWB/333, which allowed field crews to utilize the VRS throughout the field program to maintain the required data accuracy for the study.

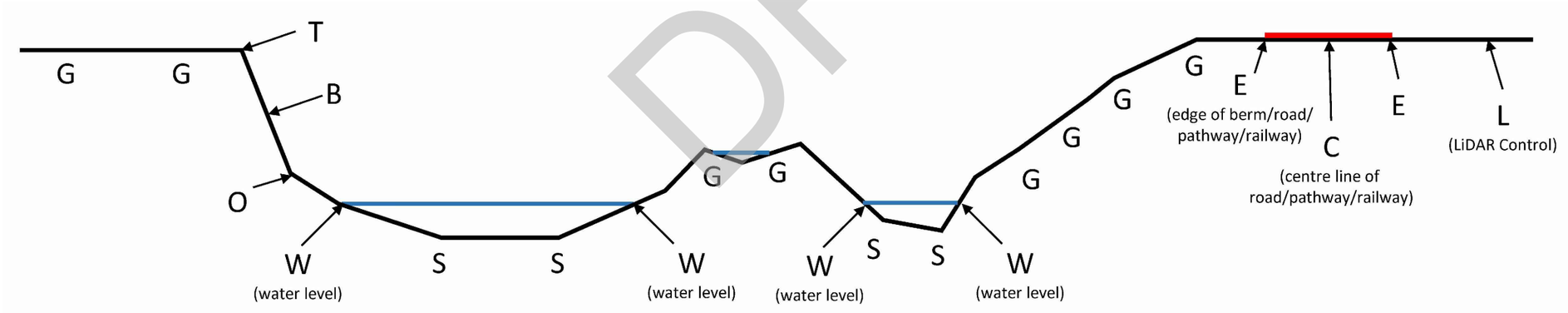
Survey Codes for RTK GPS River Surveys (No Structures)

Purpose: - Create common definitions for survey points collected in the field for easier data processing in the office
- Reduce confusion or uncertainty for field staff regarding coding of points

Location Code	
G	**G**round
T	**T**op of Bank
B	**B**ank
O	T**o**e of Bank
W	**W**ater Level
S	**S**tream Bottom (under water)
E	**E**dge of Road/Berm/Pathway/Railway
C	**C**entre Line of Road/Berm/Pathway/Railway
L	**L**iDAR control point

Material Code	
1	Mud/Silt (<0.063 mm)
2	Sand (0.063 mm - 2 mm)
3	Gravel (2 mm - 6.4 cm)
4	Cobble (6.4 cm - 25 cm)
5	Boulder (> 25 cm)
6	Bedrock
C	**C**oncrete
G	**G**rass
R	**R**iprap
T	**T**rees (large, trunk > 10 cm)
W	**W**illows and Shrubs
B	Gabion **B**asket
A	**A**sphalt

Examples	
G2	Ground, Sand
G4	Ground, Cobble
W3	Water Level, Gravel
GG	Ground, Grass
GT	Ground, Trees
CA	Centre Line, Asphalt
BR	Bank, Riprap
LC	LiDAR control, Concrete



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NOTES:
1. PROVIDED BY AEP. GROUND SURVEY CONDUCTED BY GOLDER IN OCTOBER 2016.
2. REFER TO REPORT SECTION 2.2.1 FOR MORE INFORMATION.

PREPARED FOR:
Alberta Government

PROJECT:
FORT McMURRAY RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION

TITLE:
Schematic of Survey Point Locations and Code Descriptions

DWN BY:	CHK'D BY:	REV NO:
RDJ	DMS	0
DWG NO: 10058-02-102		FIGURE NO: 2
DATE: 17-JAN-2017		

FILE LOC: H:\SG1\OwnCloud\Drafting\10058 FMRHS\Task 2\10058-02-102.dwg - 10058-02-102, PLOT DATE: 17-Jan-2017

Cross Section Surveys

In all cases, the field data were collected by surveying cross sections perpendicular to the direction of river flow. The study reach of the Clearwater River (including the Snye) was surveyed by boat. A majority of the cross sections on the Athabasca River was also surveyed by boat; however, there were some shallow areas along the braided reach below the Clearwater River confluence that were surveyed by wading. Flow depths along the Hangingstone River study reach were shallow enough to allow the channel to be surveyed by wading.

The following procedures were applied when carrying out a bathymetric survey by wading:

- RTK rover units were used to collect cross-sectional information from a location approximately 2-5 m beyond the top of bank on one side of the river channel to a location approximately 2-5 m beyond the top of bank on the other side. A minimum of 20 points was established across the channel and care was taken to reference points where the transverse bed slope changed significantly.
- Special attention was paid to surveying topographic slope breaks along the banks.
- Each of the surveyed data points was attributed with field codes that described substrate and vegetation types.
- The water surface elevation was surveyed at all points where the water made contact with the bank.

The adopted boat survey method used to define the bathymetry involved the following:

- The ADP was mounted onto a frame, which was fastened to the side of the river boat. Once the ADP was securely mounted on the boat, it was deployed in the water and the distance from the middle sensor to the water surface was measured using a standard tape measure.
- The RTK unit was attached to the top of the ADP mount at a measured offset from the water surface. This offset was measured and recorded on a daily basis.
- The ADP and RTK units were connected to a laptop data acquisition system that provided data storage and a real-time display of the position and data being collected. The system was checked to make sure that both units were communicating properly and data was being stored.
- A short calibration profile was run at the beginning of each day to verify that both the ADP offset and the level of the sounding head below the water surface remained consistent while the boat was in motion. Furthermore, the sounding depths were verified by direct measurements during the calibration process.
- The bathymetric data were collected by the ADP and RTK units at a frequency of one Hertz along the prescribed cross sections (i.e., a data point was collected every second). At a nominal boat speed of 0.75 m/s, this would correspond to a measured depth at intervals of about 0.75 m. In areas where the water depth was less than approximately 0.5 m, survey points were collected by wading the channel.
- Bank topographic data were obtained using RTK rover units, as described above.
- Water surface elevations were surveyed at all points where the water made contact with the bank.

Processing of the data collected using an ADP and RTK included the following steps:

- Data were sorted using the UTM easting values and any points with UTM coordinates of zero were removed.
- Data were sorted by altitude, which corresponds to the elevation value supplied to the ADP from the RTK unit (instrument offsets were applied to the data during post-processing).
- Data were sorted by combined depth and those points with a zero depth or depths well outside of the possible range were discarded.
- Data were sorted by difference between the vertical beam (VB) depth and the averaged bottom track (BT) depth. In cases where the VB returned an inaccurate value (i.e., shallow areas), the BT depth was used.
- Data were sorted by mean velocity. The ADP returns a value of zero when it cannot compute a flow velocity and vector. These values were removed, and the rest of the values within the data set were retained.

In total, less than five percent of the collected survey data points were removed during the above-mentioned process.

Hydraulic Structures

Hydraulic structures within the study area that could affect channel conveyance and subsequent water levels are limited to traffic bridges on the Athabasca River and both traffic and pedestrian bridges on the Hangingstone River. The features of the bridges that were surveyed included the following:

- Length of span (corner points, abutment-to-abutment);
- Width of bridge (corner points, outside-to-outside);
- Top of curb or solid guard rail elevations;
- Low chord elevations;
- Number and width of piers;
- Location of piers and the distance of each pier relative to the abutment;
- Type of piers (e.g., concrete, pile bent);
- Shape of pier (e.g., round nose, wedge-shaped, circular); and
- Top of roadway (or path) profile.

The inlet and gatewell structures comprising the gated culvert that passes through the Snye Dyke at MacDonald Drive were also surveyed.

The hydraulic structures were surveyed using a total station, RTK, or a combination thereof. The total station was used in reflectorless mode to collect survey points on the underside of the main bridge structure. In reflectorless mode, the user aligns the unit crosshairs on the point that is to be surveyed and a laser beam is transmitted to the object and reflected from the structure without having to use a traditional total station prism or reflector target. The

RTK unit was used to collect structural data when there was a clear view of the sky (i.e., bridge deck, railings, etc.). Since traffic volume made it difficult and unsafe to survey the bridge decks over the Athabasca River on foot, the RTK unit was mounted on a vehicle and driving along the desired path while collecting survey data at one-second intervals. Geo-located photos of each structure were taken during the surveys.

Flood Control Structures

Flood control structures located adjacent to the Snye, the Clearwater River, and the Hangingstone River were surveyed using an RTK to verify as-built elevations and to characterize their typical cross-sectional geometry. Survey data were collected along the crest(s) of each flood control structure at regular intervals of 20 m or less. In addition, a number of cross sections were surveyed along the structure length. Geo-located photos of all flood control structures were taken.

2.2.2 Discharge and Water Level Measurements

River discharge and corresponding water levels along the various study reaches were measured to provide additional data to support the low-flow hydraulic model calibration. The discharge data also provides a check on the provisional data obtained from the online database provided by Water Survey of Canada (WSC).

Figures B-2, B-3, B-5, and B-6 of Appendix B show the locations where discharges were measured on the Athabasca, Clearwater, and Hangingstone rivers. The measurement locations were purposefully selected to be in close proximity to the WSC hydrometric gauging stations on the Athabasca River below McMurray (07DA001), Clearwater River at Draper (07CD001), and Hangingstone River at Fort McMurray (07CD004).

Flow depths were sufficient on the Athabasca and Clearwater Rivers to allow discharge measurements to be made by deploying the ADP (*SonTek RiverSurveyor M9*®) from the river boat. However, the relatively shallow depth and narrow width of the Hangingstone River required that the discharge measurements be made by wading the channel with a handheld Acoustic Doppler Velocimeter (*SonTek FlowTracker2*® *ADV*) and top-set wading rod. Both methods provide a measurement accuracy of ±5 percent of the total discharge.

Water levels were measured along the study reach while the discharge measurement was being conducted (within ±30 minutes). Prior to taking the discharge measurement, those crew members who were not directly involved in acquiring discharge data were assigned to measuring water levels along the river. The crew members coordinated their efforts so that the measured water levels and discharge correspond to one another. This approach is superior to only measuring water levels when surveying the cross sections as doing so minimizes time discrepancies and also results in a complete water surface profile for the measured discharge.

Discharge Measurement using ADP

The ADP was mounted on the river boat and synchronized in the same manner as previously described with regard to the boat survey method used to survey cross sections. The survey crew ensured that an even number of transects (a minimum of four) with equal left-to-right transects as right-to-left transects were measured so that each individual measurement was within five percent of the others.

Bathymetric (flow depth) and flow velocity data collected by the ADP were processed and exported using the *SonTek RiverSurveyorLive*® software.

Discharge Measurement using ADV

Discharge measurements using the ADV were performed in accordance with standard WSC protocols, which include: (i) selection of a suitable measurement location; (ii) choosing an even number of transects with equal left bank to right transects and right bank to left transects; and (iii) ensuring that the data set of each transect is within a maximum standard deviation of five percent.

Discharge on the Hangingstone River was measured using standard WSC measurement techniques as described below.

- Survey points were selected to result in a minimum of 20 panels (flow segments across the stream thus requiring a minimum of 21 velocity measurement points).
- Velocity readings were taken at 0.6 of the total depth at measurement locations since flow depth was less than 1.0 m in all cases.
- Survey points were selected such that no panel discharge exceeded 10 percent of the total discharge (six panels were within the 5-10 percent range; the remaining 17 panels were all less than five percent).

2.3 Cross Sections

The total length of channel surveyed, combining all four study reaches, is approximately 42 km. Cross section surveys extended over a 15 km reach of the Athabasca River, a 20 km reach of the Clearwater River, a 5 km reach of the Hangingstone River, and the full reach of the Snye. The number of cross sections surveyed as part of the field program totalled 26 on Athabasca River, 51 on the Clearwater River, 79 on the Hangingstone River, and four on the Snye (for a total of 160 cross sections). A summary of the surveyed river cross sections is provided in Table 2.

Table 2: Surveyed Cross Sections within Study Area

Waterbody	Reach Description	Cross Section ID	No. of Cross Sections	Average Spacing (m) of Cross Sections
Athabasca River	Above confluence with Clearwater River	A1 to A15	15	500
	Below confluence with Clearwater River	A16 to A26	11	580
Clearwater River	Above confluence with Hangingstone River	C1 to C34	34	400
	Below confluence with Hangingstone River	C35 to C51	17	380
Hangingstone River	Above Memorial Drive (Highway 63)	H1 to H38	38	80
	Below Memorial Drive (Highway 63)	H39 to H79	41	70
The Snye	Snye Dyke to Mouth	S1 to S4	4	400

Appendix A contains plots of the surveyed main channel thalweg of each river reach and the water levels measured during the cross section survey for each of the four study reaches, along with a water surface profile for the Athabasca, Clearwater, and Hangingstone rivers that corresponds to the timing of the discharge measurements. An overview of the surveyed cross sections is provided in Appendix B.

2.4 Hydraulic Structures

2.4.1 Bridges

The study area includes a total of 11 bridge crossings, including three bridges on the Athabasca River and eight bridges on the Hangingstone River. Three of the bridges along the Hangingstone River are designated for pedestrian use only; all others are traffic bridges. A summary of the bridges within the study area is provided in Table 3.

Bridge locations are shown in the map sheets provided in Figures B-1, B-4, B-5, and B-6 of Appendix B. Summary datasheet that include site photos, survey data point locations, and detailed information with regard to the bridge deck and piers are provided in Figures C-1 to C-8 of Appendix C.

Bridge file data (detailed design and/or as-built survey drawings) were obtained from AEP and the RMWB, but are not included in this report.

2.4.2 Culverts

The culvert through the Snye Dyke (also referred to herein as the MacDonald Drive culvert) is the only flow conveyance structure of its kind that exists within the study area. This culvert has a gatewell chamber installed near its upstream (west) end to regulate the amount of flow that passes between the Athabasca River and the Snye. Flow in the Snye culvert can be in either direction depending on water levels within the Athabasca and Clearwater rivers. The MacDonald Drive culvert is operated and maintained by the RMWB. The gate remains fully open under normal river flow conditions and would only be closed during flood events. Table 3 includes details on the culvert through the Snye Dyke.

Table 3: Hydraulic Structures within Study Area

Waterbody	Description	Name / Identifier	Preliminary River Station (m)	Bridge Type	No. of Spans	Corresponding Figure No.
Athabasca River	Highway 63 (Memorial Drive)	Athabasca River Bridge (Northbound); Steinhauer Bridge (Southbound)	10640 10640	Traffic	7	C-1
	Highway 63 (Off-ramp to Franklin Avenue)	Grant MacEwan Bridge	10677	Traffic	7	
Hangingstone River	Memorial Drive (Southbound)	-	2420	Traffic	3	C-2
	Memorial Drive (Northbound)	-	2398	Traffic	3	
	Tolen Drive	Tolen Drive Bridge	2245	Traffic	1 (clear)	C-3
	Below Tolen Drive	Heritage Park Footbridge	2188	Pedestrian	1 (clear)	C-4
	Prairie Loop Boulevard	Prairie Loop Boulevard Bridge	1763	Traffic	4	C-5
	Below Prairie Loop Boulevard	Ptarmigan Court Footbridge	1373	Pedestrian	1 (clear)	C-6
	Saline Creek Drive	Saline Creek Drive Footbridge	1142	Pedestrian	1 (clear)	C-7
	Saline Creek Drive	Saline Creek Drive Bridge	1109	Traffic	1 (clear)	C-8
The Snye	MacDonald Drive (Snye Dyke)	-	n/a	Gated Culvert	n/a	C-9

The outlet structure on the downstream (east) end of the culvert could not be located during the survey.

The locations of the culvert and gatewell chamber are shown in Figures B-1 and B-4 of Appendix B. A summary datasheet prepared for the MacDonald Drive culvert is provided in Figure C-9 of Appendix C.

2.5 Flood Control Structures

The RMWB identified one flood control structure along the right (south) bank of the Snye River and three flood control structures along the left bank of the Clearwater River within the study area. These flood control structures are characterized as follows:

- *Reach 1 (Snye Dyke)* – Elevated pathway between MacDonald Drive and Borealis Park.
- *Reaches 5, 6 and 7 (Lower Townsite)* – Prairie Loop Boulevard (road) from McLeod Street to Saline Creek Drive intersection.
- *Reaches 10 and 11 (Waterways)* – Saline Creek Drive (road) from Prairie Loop Boulevard intersection to its junction with Draper Road.

- *Reach 10 (Saline Creek)* – Retaining structure along Pelican Drive

A summary of flood control structures within the study area is provided in Table 4. The locations of the flood control structures are shown in Figures B-1, B-3, B-4, and B-6 of Appendix B. Summary datasheets for the various flood control structures are provided in Appendix D.

Table 4: Flood Control Structures within Study Area

Waterbody	Description	Name / Identifier	Approximate Length (m)	Side of River (A)	Type	Corresponding Figure No.
The Snye	Elevated pathway between MacDonald Drive and Borealis Park	Reach 1 (Snye Dyke)	635	Right	Pathway	D-1
Clearwater River	Prairie Loop Boulevard between McLeod Street and Riedel Street (Riverwalk Villas)	Reach 5 (Lower Townsite)	210	Left	Road	D-2
Clearwater River	Prairie Loop Boulevard between Riedel Street and Franklin Avenue	Reach 6 (Lower Townsite)	1945	Left	Road	
Clearwater River	Prairie Loop Boulevard between Franklin Avenue and Saline Creek Drive intersection	Augment to Reach 7 (Lower Townsite)	465	Left	Road	
Clearwater and Hangingstone Rivers	Saline Creek Drive between Saline Creek Drive Bridge and Park Street	Reach 10 (Waterways)	1450	Right (Hangingstone); Left (Clearwater)	Road	D-3
Clearwater and Hangingstone Rivers	Saline Creek Drive between Saline Creek turnaround and Prairie Loop Boulevard	Reach 10 (Waterways)	95	Left (Hangingstone); Left (Clearwater)	Road	
Clearwater River	Saline Creek Drive between Park Street and junction with Draper Road	Reach 11 (Waterways)	1125	Left	Road	
Saline Creek	Retaining structure – gabion basket	Reach 10 (Waterways)	210	Left	Retaining Structure	D-4

Note:

A. Left or right refer to directions as seen by an observer looking downstream.

2.6 Discharge and Water Level Measurements

A discharge measurement was made on each of the Athabasca, Clearwater, and Hangingstone rivers as part of the field program. Water levels were recorded in consort with the three measurements to obtain a comprehensive water surface profile along the study reach for the given flow rates. Table 5 provides a comparison between measured flow and the data obtained from WSC.

Table 5: Comparison between Measured Flow and WSC Gauge Data (Athabasca, Clearwater, and Hangingstone River Reaches)

Waterbody	Date	Time of Day	Measurement Location	Corresponding WSC Gauge	Discharge (m^3/s)		Difference	
					WSC Gauge Reading	Measured during Survey	(m^3/s)	(%)
Athabasca River	30-Sep 2016	14:25 to 15:05	A22	Athabasca River below McMurray (07DA001)	602	571	31	5
Clearwater River	30-Sep 2016	17:05 to 17:40	C10	Clearwater River at Draper (07CD001)	166	159	7	4
Hangingstone River	29-Sep 2016	12:30 to 13:00	H38	Hangingstone River at Fort McMurray (07CD004)	3.6	3.3	0.3	9

Notes:

1. Discharge on the Hangingstone River was measured using an ADV.
2. Discharge on the Athabasca and Clearwater Rivers was measured using an ADP.
3. Discharge values for the WSC gauge reading are based on real-time data posted online by AEP. Data obtained from AEP are provisional and preliminary in nature and may be subject to change when manually reviewed and corrected.

In the case of discrepancies in flow magnitudes between the WSC data and those measured herein, the latter will govern. Discharges posted by WSC are provisional at this time and may be subject to change when manually reviewed and corrected by WSC.

2.6.1 Athabasca River below McMurray

Discharge and water level measurements on the Athabasca River along the study reach were taken on September 30, 2016 using the ADP. A total of four transects were measured as part of this discharge survey at cross section A22, which is located approximately 850 m downstream of the gauging station (WSC 07DA001 – Athabasca River below McMurray). Water levels were also measured over a reach length of approximately 13 km, extending from the upstream end of the Fort McMurray Golf Club (cross section A3) to the most downstream cross section (A26).

A discharge of 571 m^3/s was measured on the Athabasca River, which is approximately five percent less than the value estimated from the rating curve at the WSC gauge (602 m^3/s). The water surface profile shown in Figure A-1 of Appendix A corresponds to this discharge measurement.

2.6.2 Clearwater River at Draper

Discharge and water level measurements on the Clearwater River along the study reach were also taken on September 30, 2016 using the ADP. A total of seven discharge transects were measured on the Clearwater River at cross section C10, which is approximately 160 m downstream of the gauging station (WSC 07CD001 – Clearwater River at Draper). The ground crew was able to survey water levels over the entire length of the study reach while the discharge measurement was being made by the boat crew.

A river discharge of 159 m^3/s was measured on the Clearwater River, which is within 7 m^3/s (4 percent) of the value estimated from the rating curve at the WSC gauge (166 m^3/s). It was necessary to discard one of the discharge transects (Q-C10-3) in order to maintain data accuracy within a maximum standard deviation of five percent. The water surface profile shown in Figure A-2 of Appendix A corresponds to this discharge measurement.

2.6.3 Hangingstone River below Memorial Drive Bridge

Discharge and water level measurements along the Hangingstone River were taken on September 29, 2016 using the ADV and top-set wading rod. Flow rate was measured at cross section H10, which coincides with the gauging station (WSC 07CD004 – Hangingstone River at Fort McMurray).

A discharge of 3.3 m^3/s was measured on the Hangingstone River, which is within 0.3 m^3/s (9 percent) of the value estimate from the rating curve at the WSC gauge (3.6 m^3/s). However, one of the discharge transects (Q-C10-3) was discarded in order to maintain data accuracy within a maximum standard deviation of five percent. Concurrent water levels were surveyed along the Hangingstone River while the discharge measurement was being made. The water surface profile shown in Figure A-3 of Appendix A reflects the flow rate at the time of the discharge measurement.

2.6.4 The Snye

Water level measurements were taken along the length of the Snye on October 3, 2016. Refer to Figure A-4 of Appendix A for details.

2.7 Accuracy

The accuracy of the points collected using the RTK system in conjunction with Cansel's VRS network is considered to be within ±0.02 m in both horizontal and vertical directions. The spatial position and elevation of each RTK rover unit was calibrated daily to an Alberta Survey Control Marker (ASCM) benchmark. Furthermore, the daily survey protocol required that the field crews calibrate to and then open and close at an ASCM benchmark in order to maintain a ±0.02 m level of accuracy. The RTK data collectors were set to provide a warning when calculated maximum error exceeded 0.05 m for a manually-recorded point. When notified, the survey technician would either adjust their location or identify a better solution before surveying that point.

A portion of each bridge survey was conducted using a reflectorless total station that was set up over a temporary benchmark established using the RTK. The temporary benchmark setup and total station accuracy resulted in a combined total accuracy level of less than ±0.05 m. The exact accuracy for each point varied in proportion to the distance between the target and the survey instrument.

The bathymetric surveys conducted from the river boat using the RTK-ADP combination have a slightly reduced accuracy relative to the ground-based surveys, because the constant movement of the boat on the water surface creates pitch, roll, and yaw that influence the angle of the ADP beams. Depending on the water depth and the

angle of deviation from vertical, the ±0.02 m accuracy from the RTK can be reduced by a few centimetres. Overall, the bathymetric surveys conducted using the RTK-ADP combination is considered to have an accuracy of ±0.10 m in both the horizontal and vertical directions.

2.8 Survey and DTM Data Comparison

The LiDAR-based DTM provided by AEP has undergone independent quality control to ensure that it meets FHIP accuracy standards. Although a formal quality control assessment is not required for this study, surveyed overbank elevations for a randomly-selected cross section on the Snye near the Clearwater River confluence and on a flat road surface have been compared to the DTM to verify that the latter is suitable for overbank cross section data extraction and flood mapping purposes. As shown in Table 6 below, the differences in elevation between the selected survey points and the DTM data are considered to be within an acceptable range.

Table 6. Comparison between 2016 Survey Points and DTM

Northing (m)	Easting (m)	Surveyed Elevation (m)	Date of Survey	LiDAR DTM Elevation (m)	Difference (m)	Description
6,289,505.68	-22,434.42	243.42	2016-10-03	243.46	-0.04	Beach at Snye confluence
6,289,513.47	-22,440.95	243.02	2016-10-03	243.03	-0.01	Beach at Snye confluence
6,289,517.62	-22,443.92	242.45	2016-10-03	242.48	-0.03	Beach at Snye confluence
6,289,521.95	-22,447.07	242.23	2016-10-03	242.28	-0.05	Beach at Snye confluence
6,288,845.70	-22,132.54	247.99	2016-10-08	248.01	-0.02	Road surface Riedel Street at Gorden Avenue
6,288,850.12	-22,128.99	247.96	2016-10-08	247.99	-0.04	Road surface Riedel Street at Gorden Avenue

Note: Coordinates in 3TM 111°, NAD 83 CSRS

3.0 AERIAL IMAGERY ACQUISITION

Aerial imagery for the entire study area was collected by GeodesyGroup Inc. on May 18, 2017. The imagery has a 0.30 m Ground Sampling Distance (GSD) resolution and was delivered as 4-band orthophotos and stereo images, as per current study specifications. The deliverables include aerial triangulation data, metadata, camera calibration reports, flight report, and an index of the aerial imagery tiles. A technical memorandum describing the aerial imagery acquisition is provided in Appendix E.

4.0 ADDITIONAL BASE DATA

Additional base data provided by AEP for the study consisted of elevations of temporary benchmarks associated with high watermark survey measurements by AEP and the RMWB on the Clearwater River and the Hangingstone River during a high-flow event in June 2013. In addition, AEP provided survey control point information for two ASCMs within the study area (Nos. 89185 and 198754). Since both benchmarks have a third order horizontal classification, control points of higher order were also surveyed to ensure a high level of data accuracy.

Additional base data collected by the project team included the following:

- Survey data and as-built drawings of roadway and pedestrian bridges located within the study area. These bridge file datasets were provided by Alberta Transportation and the RMWB.
- Engineering design drawings for the gated culvert that passes through the Snye Dyke.
- Provisional streamflow data from gauging stations that are operated by WSC and situated within the study reaches of the Athabasca, Clearwater, and Hangingstone rivers.

5.0 CONCLUSIONS

Topographic, bathymetric, and supporting base data required to support subsequent components of the Fort McMurray River Hazard Study were collected in accordance with the requirements set forth by AEP. The following conclusions are made:

- *River Cross Section Surveys* – Cross section survey data collected for this study in September/October 2016 meet the current study requirements with regard to cross section spacing and alignment, extents of cross sections on the floodplains, labeling of survey points, and data accuracy.
- *Hydraulic and Flood Control Structure Surveys* – Hydraulic and flood control structure survey data collected in September/October 2016 meet the study requirements and include the necessary details for the hydraulic modelling to follow.
- *Digital Terrain Model* – The differences in elevation between the selected survey points and the DTM data are considered to be within an acceptable range. Therefore, the DTM is considered suitable for overbank cross section data extraction and flood mapping purposes.

Report Signature Page

We trust that the information contained in this updated version of the draft technical report, which addresses AEP's review comments, is sufficient for your present needs. It is recommended that the final version be submitted following collection of aerial imagery in the spring of 2017.

Please do not hesitate to contact Wolf Ploeger (403.216.8934; Wolf_Ploeger@golder.com) or Darren Shepherd (780.238.5868; Darren@SG1water.ca) if you have any questions or wish to discuss.

Prepared by

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DS/WP/DL/ak

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REFERENCES

Alberta Environment and Parks, 2016. *Athabasca River Temporary Benchmarks Requiring Tie-ins in Fort McMurray*. Technical (PDF) document prepared for the Fort McMurray River Hazard Study dated 23 September 2016. 11 pp.

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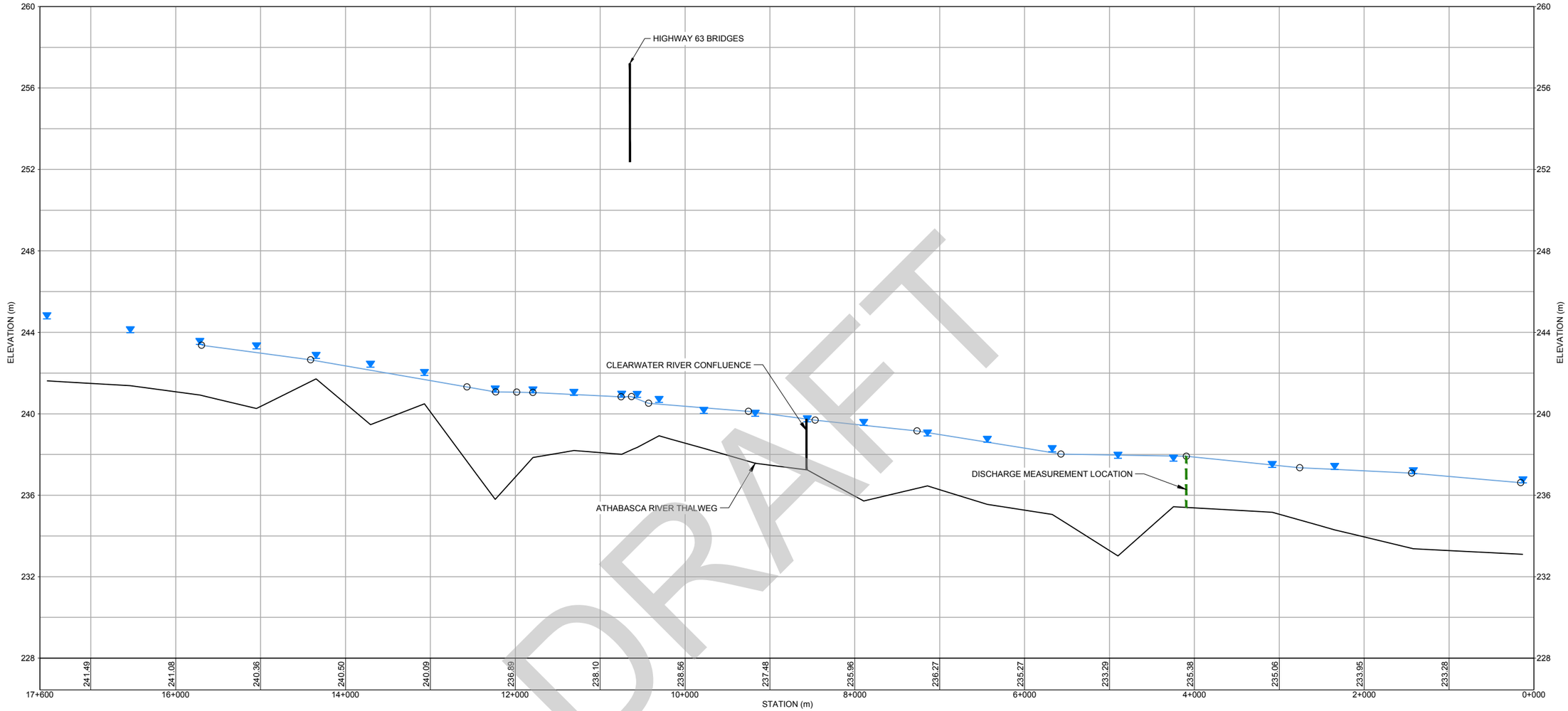
APPENDIX A

Surveyed Thalweg and Water Surface Profiles



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- MEASURED WATER LEVELS DURING CROSS SECTION SURVEY
- MEASURED WATER LEVELS DURING DISCHARGE MEASUREMENT ON SEPTEMBER 30, 2016 (Q = 571m³/s)

REFERENCE

SURVEY DATA COLLECTED BY GOLDER FROM SEPTEMBER 27 TO OCTOBER 6, 2016 (ATHABASCA RIVER, CLEARWATER RIVER, HANGINGSTONE RIVER, AND THE SNYE).

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HORIZONTAL SCALE 1:50,000
VERTICAL EXAGGERATION = 240X

CLIENT
ALBERTA ENVIRONMENT AND PARKS

PROJECT
FORT McMURRAY RIVER HAZARD STUDY

TITLE
SURVEYED THALWEG AND WATER SURFACE PROFILE - ATHABASCA RIVER REACH

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-01-17
PREPARED	MKH
DESIGN	WP
REVIEW	WP
APPROVED	DL

PROJECT No.	CONTROL	Rev.	FIGURE
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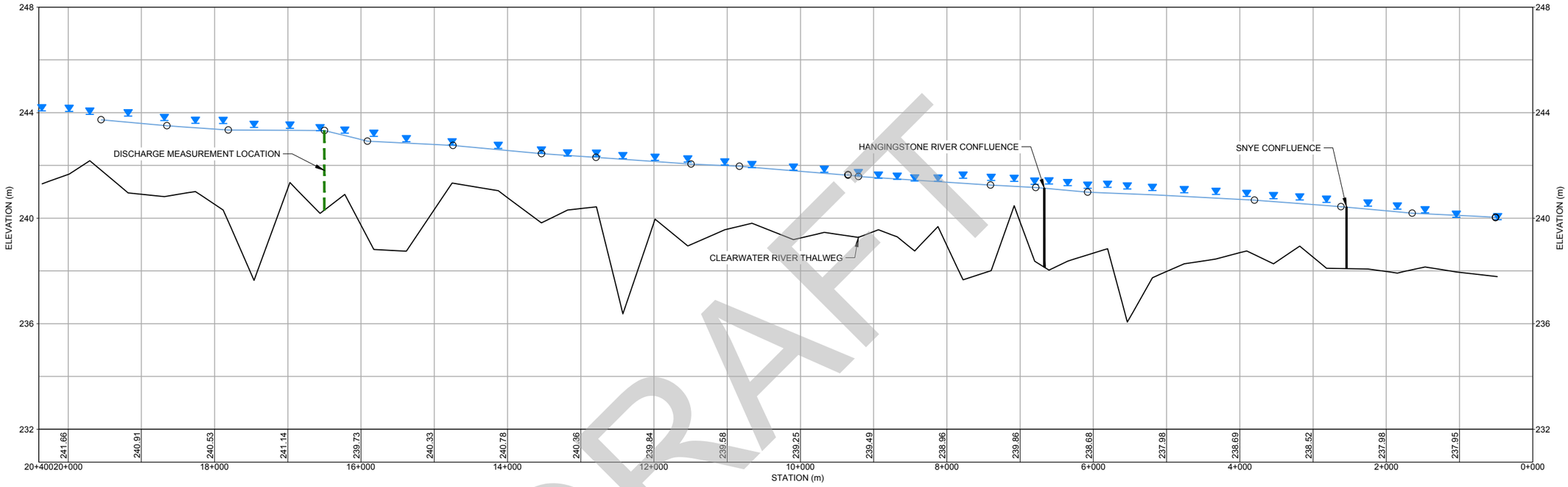

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- MEASURED WATER LEVELS DURING CROSS SECTION SURVEY
- MEASURED WATER LEVELS DURING DISCHARGE MEASUREMENT ON SEPTEMBER 30, 2016 (Q = 159m³/s)

REFERENCE

SURVEY DATA COLLECTED BY GOLDER FROM SEPTEMBER 27 TO OCTOBER 6, 2016 (ATHABASCA RIVER, CLEARWATER RIVER, HANGINGSTONE RIVER, AND THE SNYE).

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HORIZONTAL SCALE 1:60,000
VERTICAL EXAGGERATION = 360X

CLIENT
ALBERTA ENVIRONMENT AND PARKS

PROJECT
FORT McMURRAY RIVER HAZARD STUDY

TITLE
SURVEYED THALWEG AND WATER SURFACE PROFILE - CLEARWATER RIVER REACH

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-01-17
PREPARED	MKH
DESIGN	WP
REVIEW	WP
APPROVED	DL

PROJECT No.	CONTROL	Rev.	FIGURE
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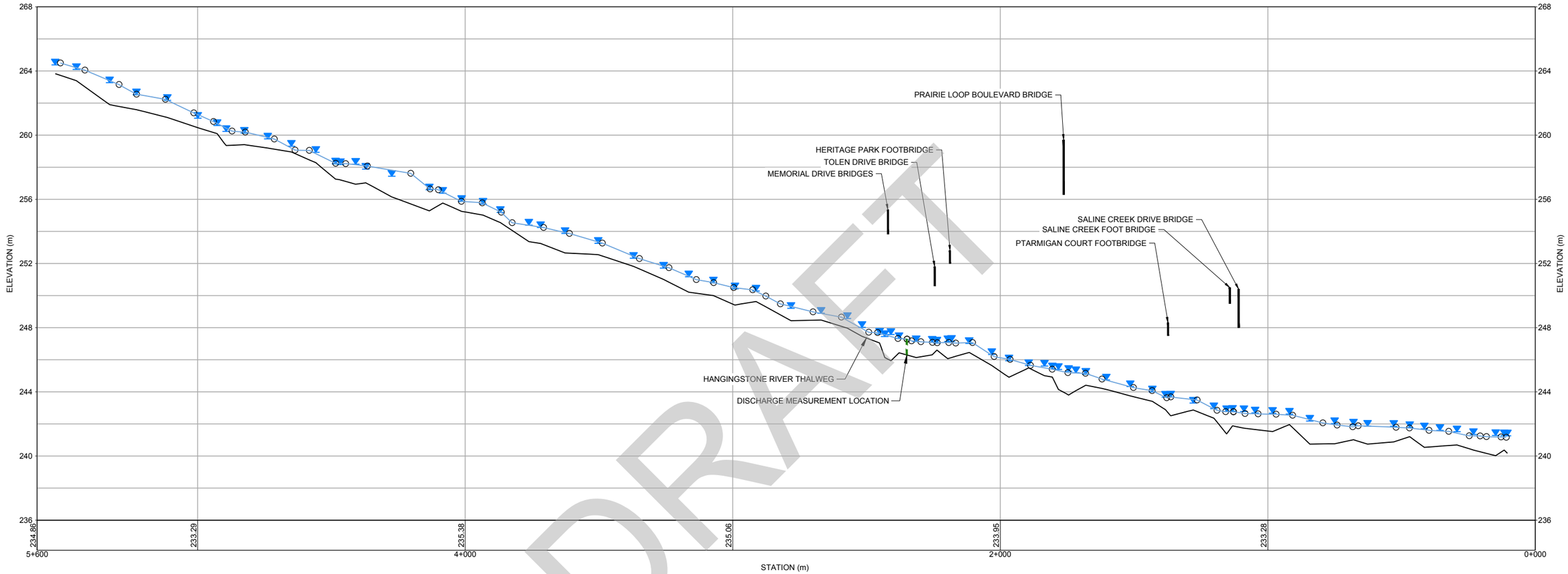

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- MEASURED WATER LEVELS DURING DISCHARGE MEASUREMENT ON SEPTEMBER 30, 2016 (Q = 3.3m³/s)

REFERENCE

SURVEY DATA COLLECTED BY GOLDER FROM SEPTEMBER 27 TO OCTOBER 6, 2016 (ATHABASCA RIVER, CLEARWATER RIVER, HANGINGSTONE RIVER, AND THE SNYE).

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VERTICAL EXAGGERATION = 60X

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ALBERTA ENVIRONMENT AND PARKS

PROJECT
FORT McMURRAY RIVER HAZARD STUDY

TITLE
SURVEYED THALWEG AND WATER SURFACE PROFILE - HANGINGSTONE RIVER REACH

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-01-17
PREPARED	MKH
DESIGN	WP
REVIEW	WP
APPROVED	DL

PROJECT No.	CONTROL	Rev.	FIGURE
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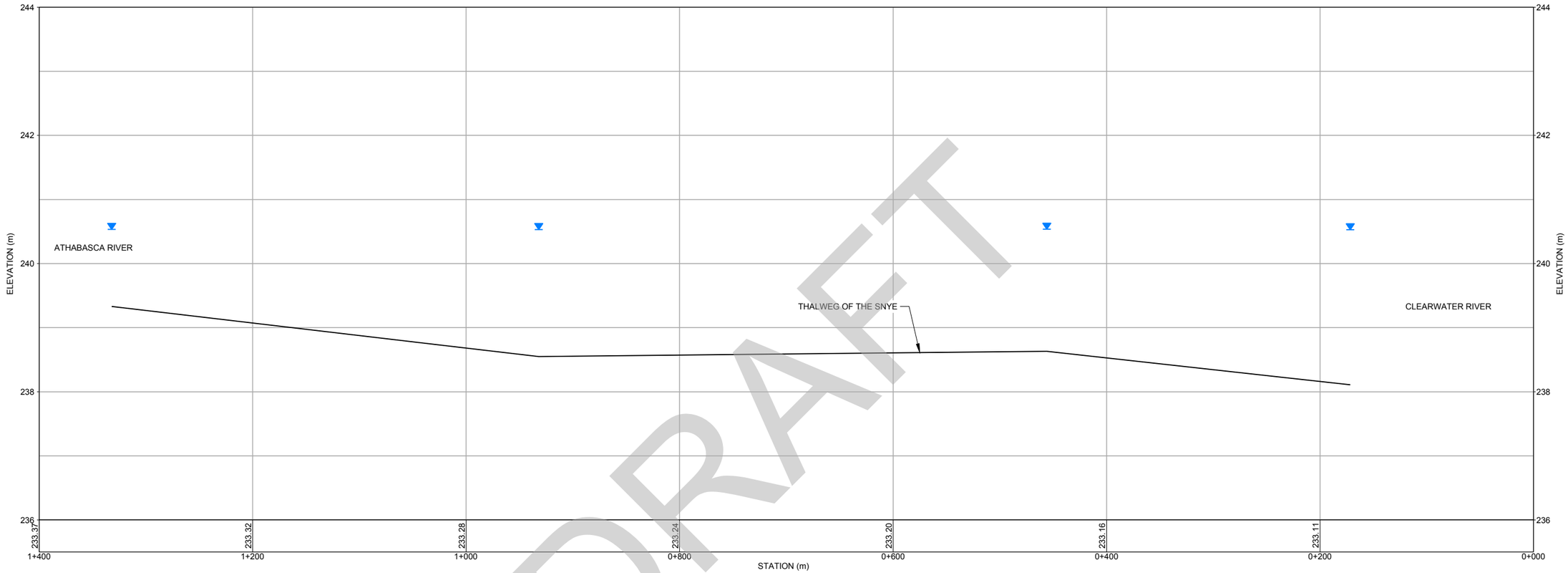

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REFERENCE

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HORIZONTAL SCALE 1:4,000
VERTICAL EXAGGERATION = 60X

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FORT McMURRAY RIVER HAZARD STUDY

TITLE
SURVEYED THALWEG AND WATER SURFACE PROFILE - THE SNYE REACH

CONSULTANT

Golder Associates

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PREPARED	MKH
DESIGN	WP
REVIEW	WP
APPROVED	DL

PROJECT No.	CONTROL	Rev.	FIGURE
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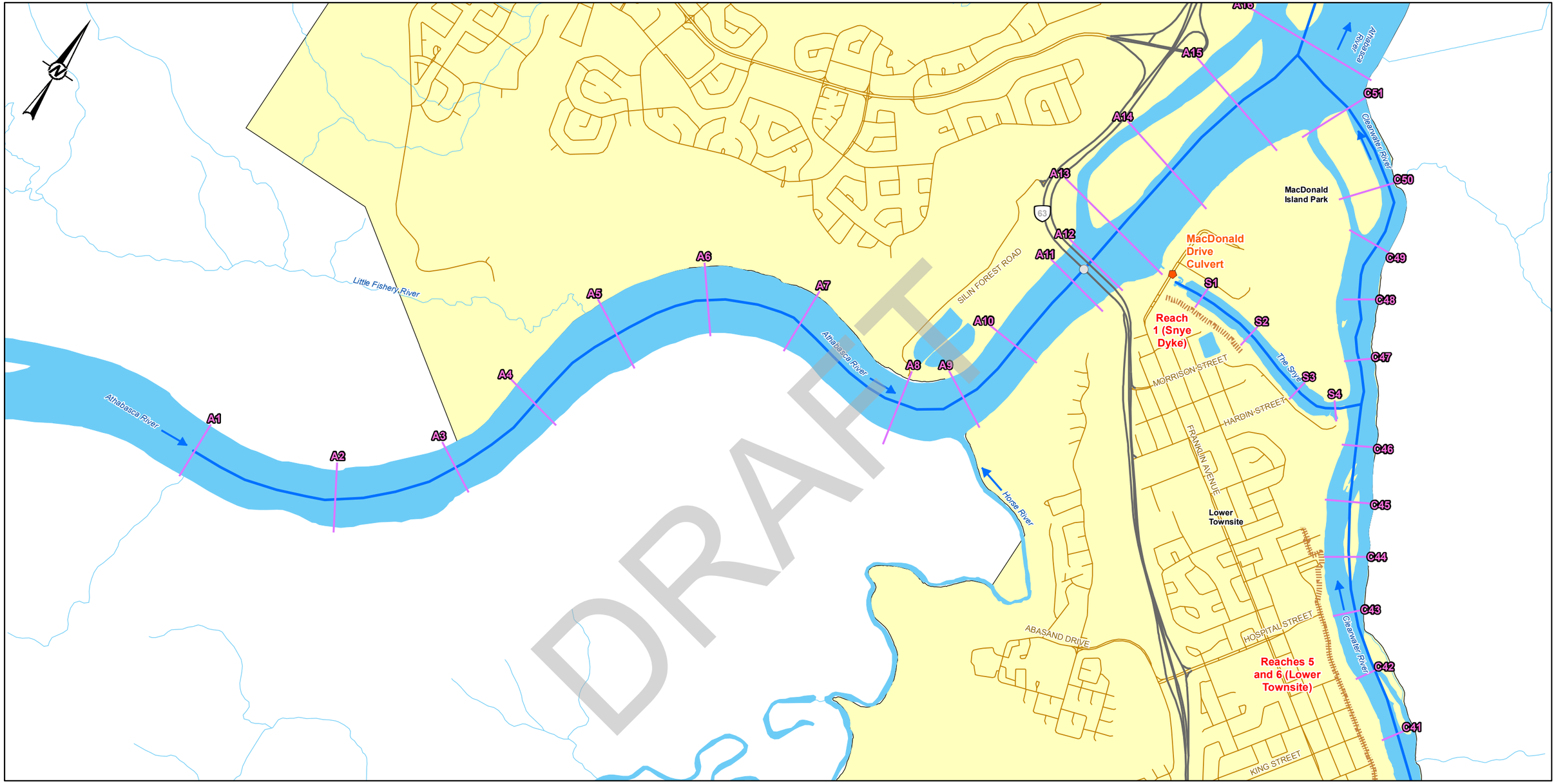
APPENDIX B

Cross Section, Hydraulic Structure, and Flood Control Structure Locations



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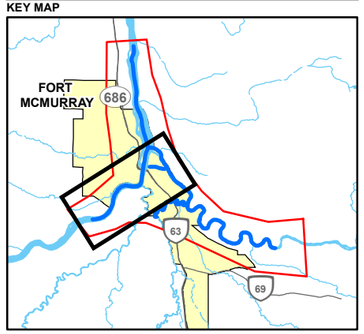
- PRIMARY HIGHWAY
- LOCAL ROAD
- WATERCOURSE
- WATERBODY
- POPULATED AREA

HYDRAULIC STRUCTURES

- BRIDGE
- CULVERT
- FLOOD CONTROL STRUCTURE
- SURVEYED CROSS SECTION (2016)
- SURVEY REACH

KEY MAP



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NOTE(S)

SALINE CREEK WATERCOURSE WAS MANUALLY EDITED BY GOLDER TO REFLECT CURRENT STREAM PATH.

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Golder Associates

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PREPARED	P. THIEDE
REVIEWED	W. PLOEGER
APPROVED	D. LONG

PROJECT
FORT McMURRAY RIVER HAZARD STUDY

TITLE
CROSS SECTIONS, HYDRAULIC STRUCTURES AND FLOOD CONTROL STRUCTURES - ATHABASCA RIVER ABOVE CONFLUENCE WITH CLEARWATER RIVER

PROJECT NO.	CONTROL	REV.	FIGURE
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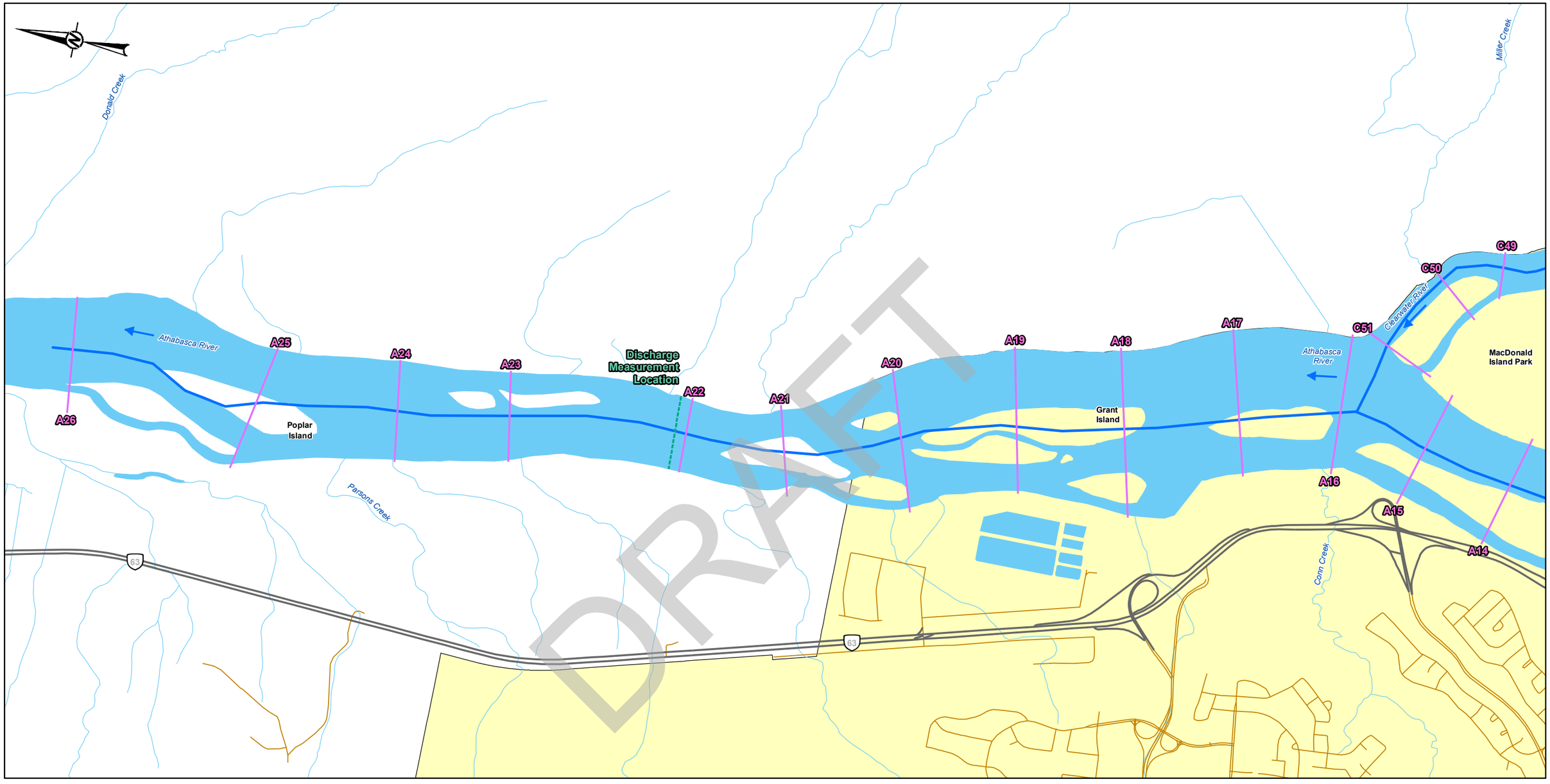

LEGEND

- PRIMARY HIGHWAY
- LOCAL ROAD
- WATERCOURSE
- WATERBODY
- POPULATED AREA

HYDRAULIC STRUCTURES

- BRIDGE
- DISCHARGE MEASUREMENT LOCATION
- SURVEYED CROSS SECTION (2016)
- SURVEY REACH

KEY MAP

0 1 2

1:25,000 KILOMETRES

NOTE(S)

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PROJECT
FORT McMURRAY RIVER HAZARD STUDY

CONSULTANT
Golder Associates

YYYY-MM-DD	2018-04-18
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TITLE
CROSS SECTIONS, HYDRAULIC STRUCTURES AND FLOOD CONTROL STRUCTURES - ATHABASCA RIVER BELOW CONFLUENCE WITH CLEARWATER RIVER

PROJECT NO.	CONTROL	REV.	FIGURE
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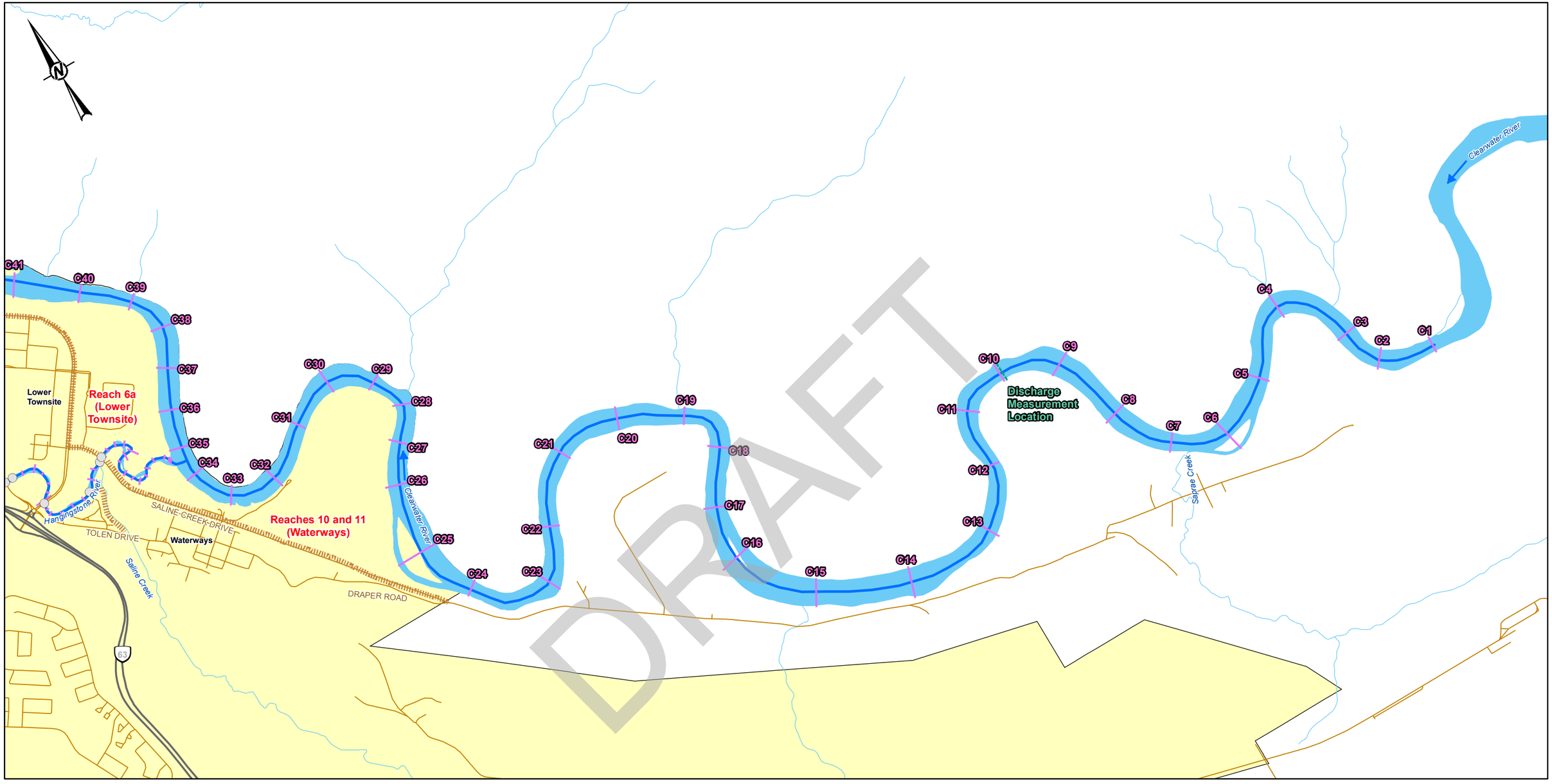


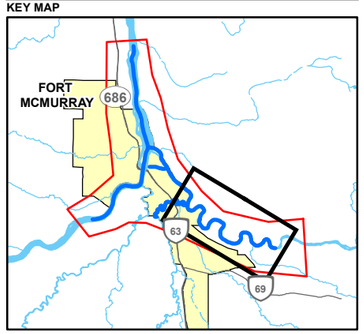
LEGEND

- PRIMARY HIGHWAY
- LOCAL ROAD
- WATERCOURSE
- WATERBODY
- POPULATED AREA

HYDRAULIC STRUCTURES

- BRIDGE
- FLOOD CONTROL STRUCTURE
- DISCHARGE MEASUREMENT LOCATION
- SURVEYED CROSS SECTION (2016)
- SURVEY REACH

KEY MAP



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NOTE(S)
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PROJECT
FORT McMURRAY RIVER HAZARD STUDY

TITLE
CROSS SECTIONS, HYDRAULIC STRUCTURES AND FLOOD CONTROL STRUCTURES - CLEARWATER RIVER ABOVE CONFLUENCE WITH HANGINGSTONE RIVER

PROJECT NO.	CONTROL	REV.	FIGURE
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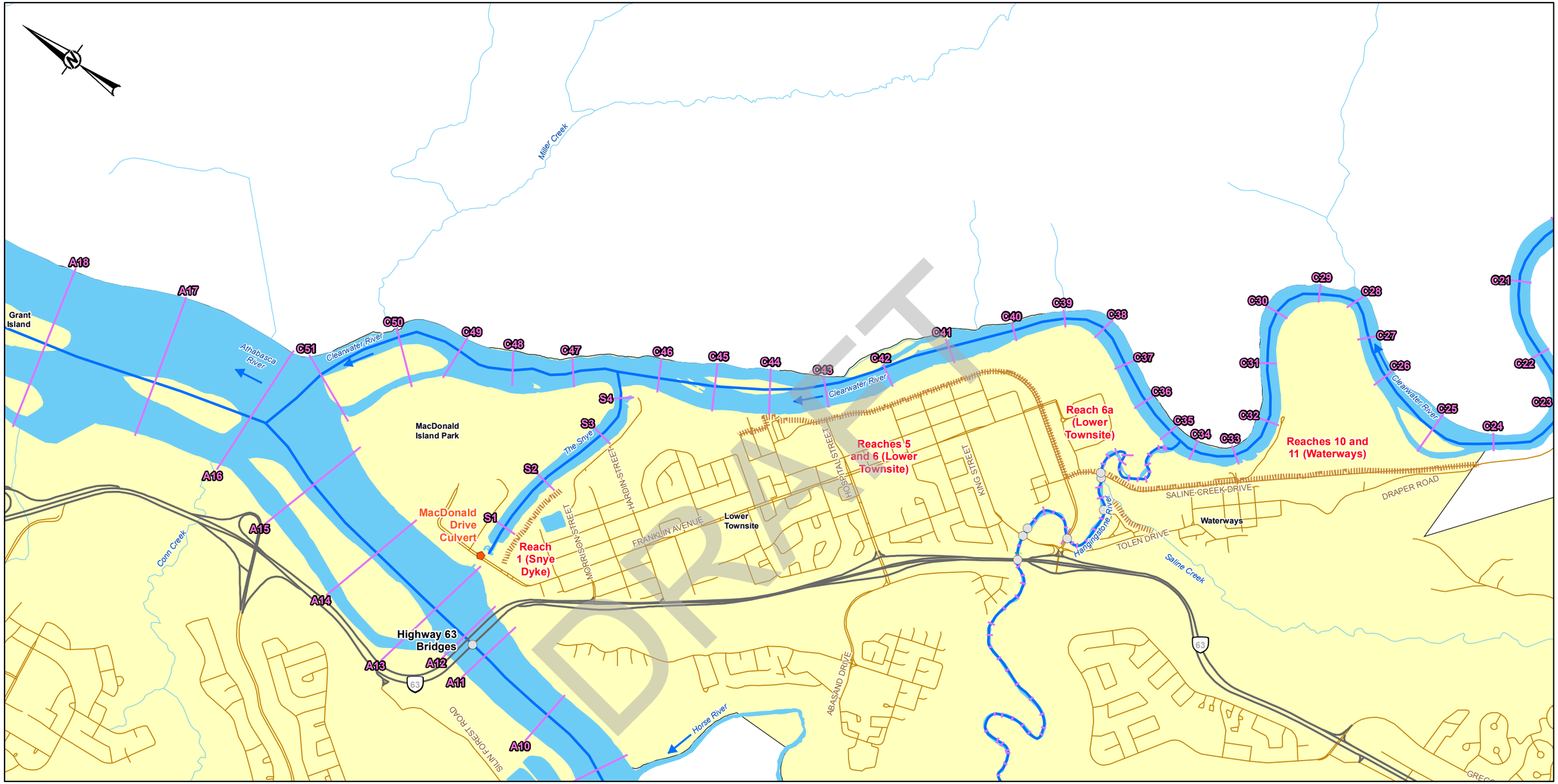


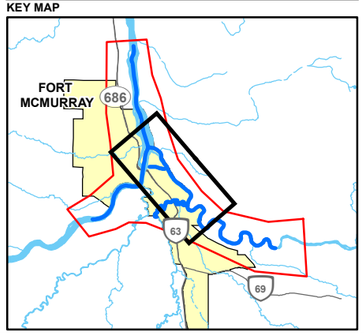
LEGEND

- PRIMARY HIGHWAY
- LOCAL ROAD
- WATERCOURSE
- WATERBODY
- POPULATED AREA

HYDRAULIC STRUCTURES

- BRIDGE
- CULVERT
- FLOOD CONTROL STRUCTURE
- DISCHARGE MEASUREMENT LOCATION
- SURVEYED CROSS SECTION (2016)
- SURVEY REACH

KEY MAP



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NOTE(S)

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DATUM: NAD 83 CSRS PROJECTION: 3TM 111

CLIENT
ALBERTA ENVIRONMENT AND PARKS

CONSULTANT
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PREPARED	P. THIEDE
REVIEWED	W. PLOEGER
APPROVED	D. LONG

PROJECT
FORT McMURRAY RIVER HAZARD STUDY

TITLE
CROSS SECTIONS, HYDRAULIC STRUCTURES AND FLOOD CONTROL STRUCTURES - CLEARWATER RIVER BELOW CONFLUENCE WITH HANGINGSTONE RIVER

PROJECT NO.	CONTROL	REV.	FIGURE
1662603		0	**B-4**

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

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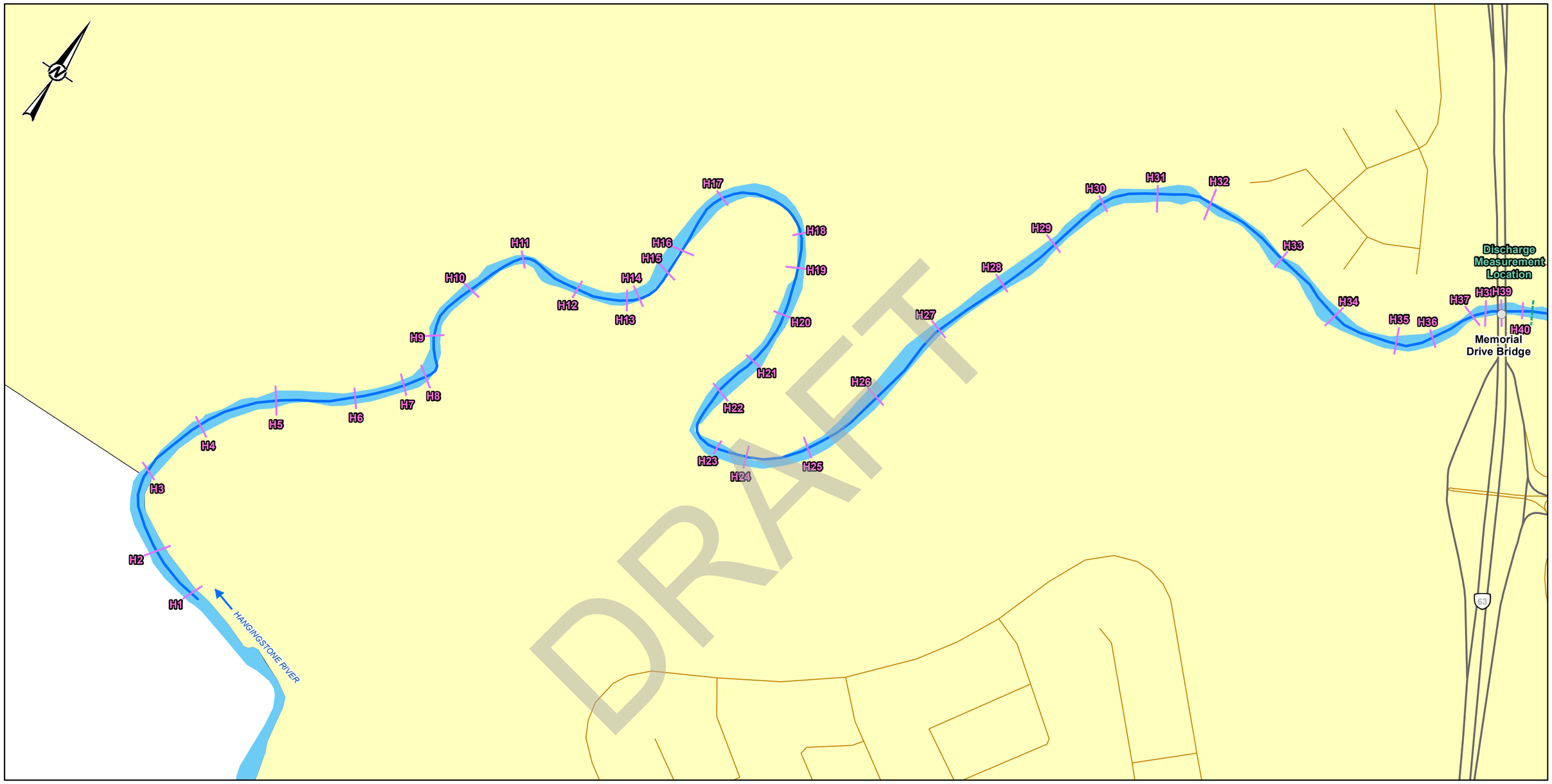


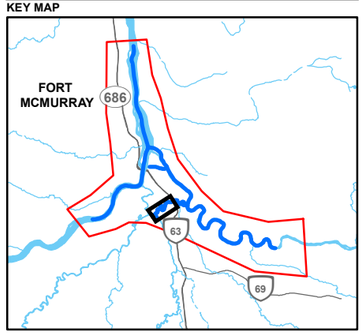
LEGEND

- PRIMARY HIGHWAY
- LOCAL ROAD
- WATERCOURSE
- WATERBODY
- POPULATED AREA

HYDRAULIC STRUCTURES

- BRIDGE
- DISCHARGE MEASUREMENT LOCATION
- SURVEYED CROSS SECTION (2016)
- SURVEY REACH

KEY MAP



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1:5,500 KILOMETRES

CLIENT
ALBERTA ENVIRONMENT AND PARKS

CONSULTANT
Golder Associates

YYYY-MM-DD	20178-04-18
DESIGNED	W. PLOEGER
PREPARED	P.THIEDE
REVIEWED	W. PLOEGER
APPROVED	D.LONG

NOTE(S)
SALINE CREEK WATERCOURSE WAS MANUALLY EDITED BY GOLDER TO REFLECT CURRENT STREAM PATH.

REFERENCE(S)
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DATUM: NAD 83 CSRS PROJECTION: 3TM 111

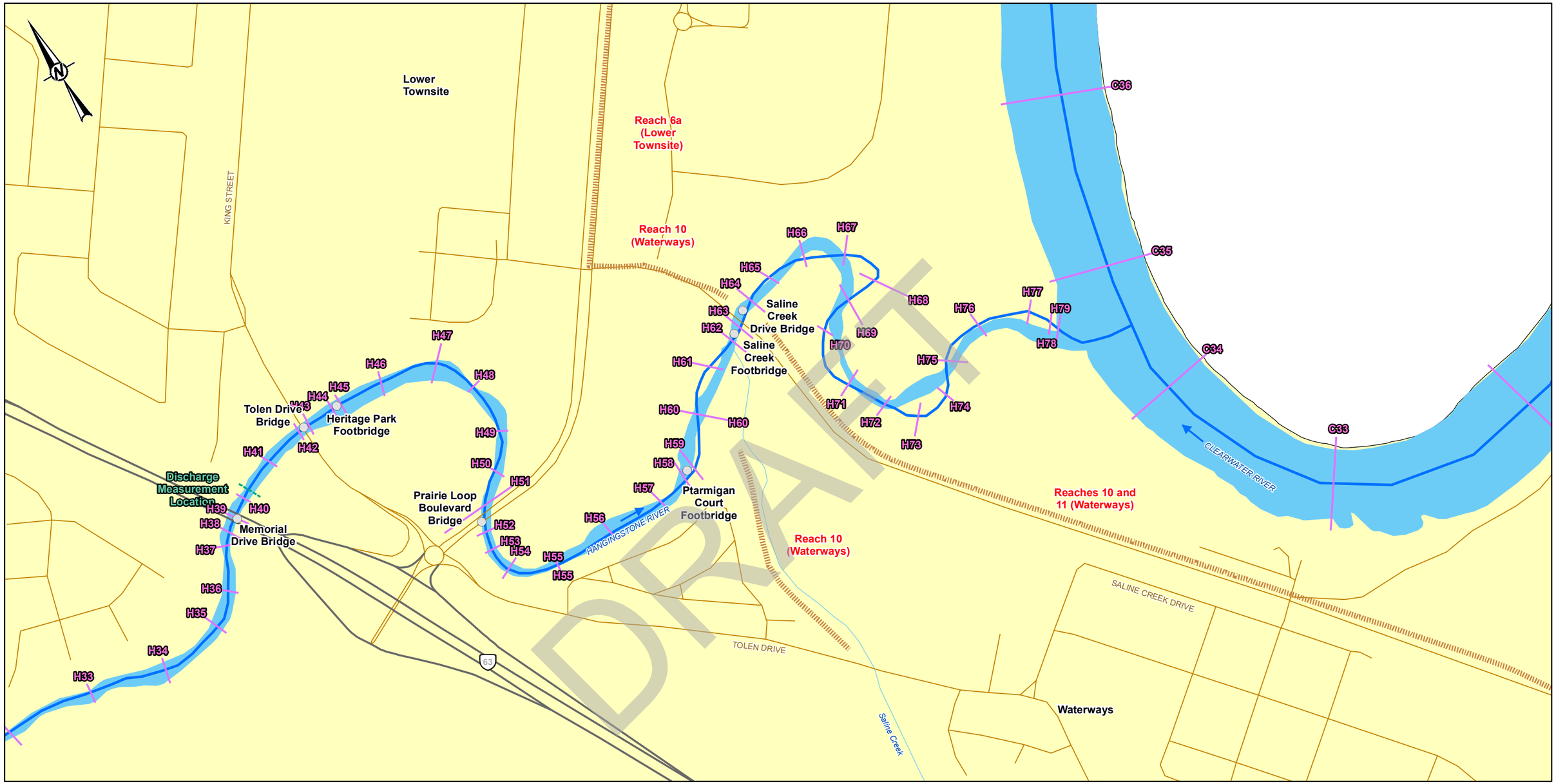
PROJECT
FORT McMURRAY RIVER HAZARD STUDY

TITLE
CROSS SECTIONS, HYDRAULIC STRUCTURES AND FLOOD CONTROL STRUCTURES - HANGINGSTONE RIVER ABOVE MEMORIAL DRIVE

PROJECT NO.	CONTROL	REV.	FIGURE
1662603		0	B-5

PATH: I:\2016\1662603\Mapping\MXD\Hydrology\02_Survey & Base Data Collection\1662603_AppendixB_Structures_Hangingstone_Rev0.mxd PRINTED ON: 2018-04-18 AT: 1:03:50 PM

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



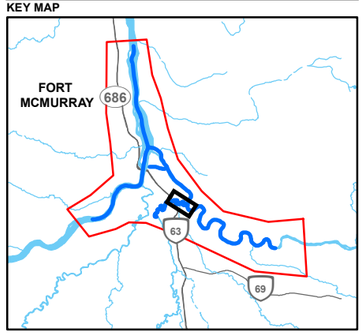
LEGEND

- PRIMARY HIGHWAY
- LOCAL ROAD
- WATERCOURSE
- WATERBODY
- POPULATED AREA

HYDRAULIC STRUCTURES

- BRIDGE
- FLOOD CONTROL STRUCTURE
- DISCHARGE MEASUREMENT LOCATION
- SURVEYED CROSS SECTION (2016)
- SURVEY REACH

KEY MAP



0 0.25 0.5 KILOMETRES

1:5,500

CLIENT
ALBERTA ENVIRONMENT AND PARKS

CONSULTANT
Golder Associates

YYYY-MM-DD	20178-04-18
DESIGNED	W. PLOEGER
PREPARED	P.THIEDE
REVIEWED	W. PLOEGER
APPROVED	D.LONG

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DATUM: NAD 83 CSRS PROJECTION: 3TM 111

PROJECT
FORT McMURRAY RIVER HAZARD STUDY

TITLE
CROSS SECTIONS, HYDRAULIC STRUCTURES AND FLOOD CONTROL STRUCTURES - HANGINGSTONE RIVER BELOW MEMORIAL DRIVE

PROJECT NO.	CONTROL	REV.	FIGURE
1662603		0	**B-6**

PATH: I:\2016\1662603\Mapping\MXD\Hydrology\02_Survey & Base Data Collection\1662603_Appendix_B_Structures_Hangingstone_Rev0.mxd PRINTED ON: 2018-04-18 AT: 1:04:00 PM

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APPENDIX C

Hydraulic Structure Datasheets

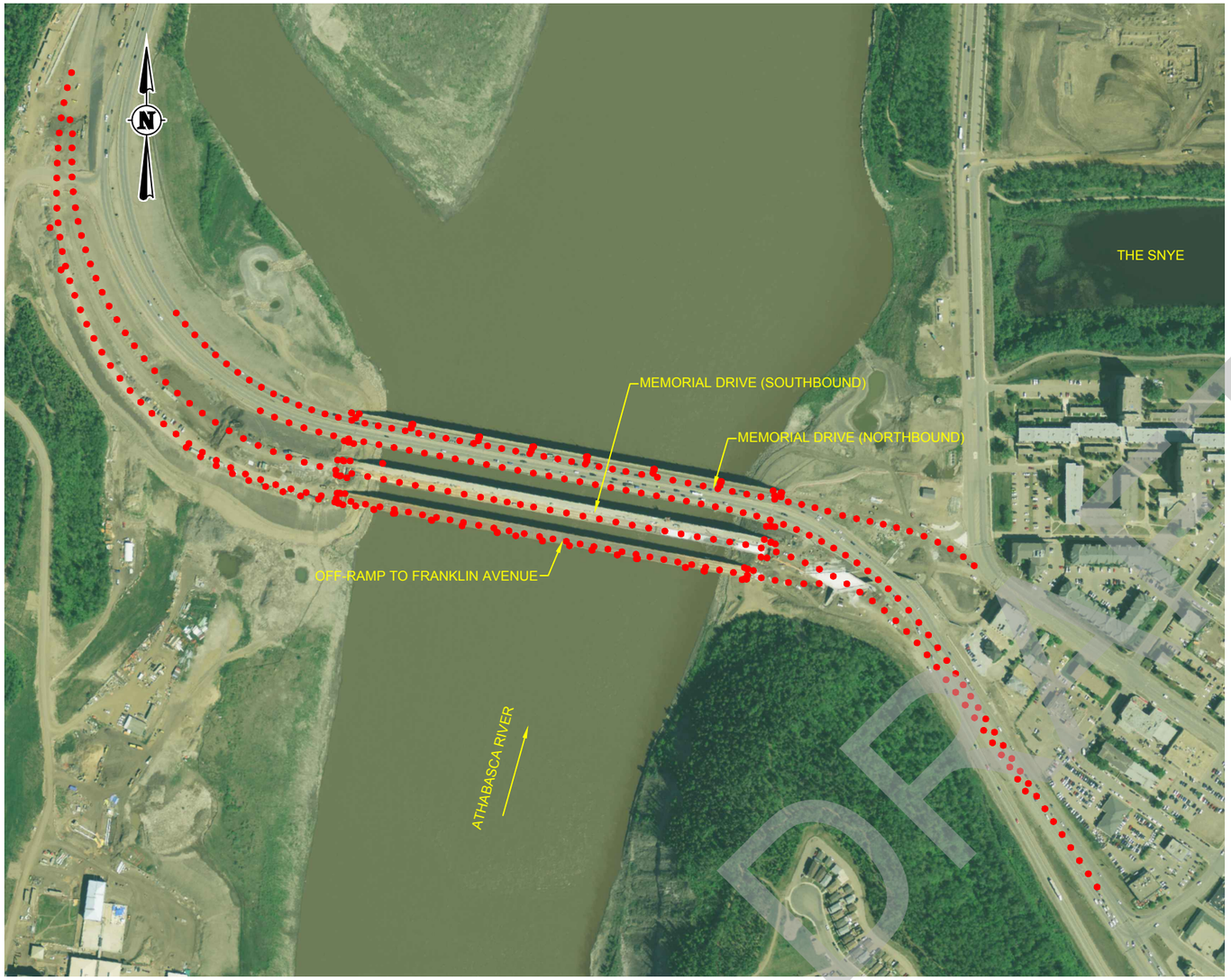

IMAGE REF. NO. 10058-SR.016

1. View looking downstream from left bank.

IMAGE REF. NO. 10058-SR.029

2. View looking upstream from right bank.

WATERBODY	DESCRIPTION	NAME / IDENTIFIER	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)		LOW CHORD ELEVATION (m)		NUMBER OF PIERS	PIER DETAILS				
								LEFT ABUTMENT	RIGHT ABUTMENT	LEFT ABUTMENT	RIGHT ABUTMENT		#	CENTRE STATION (m)	WIDTH (m)	TYPE	SHAPE
ATHABASCA RIVER	HIGHWAY 63 (NORTHBOUND)	ATHABASCA RIVER BRIDGE	78041N	AT	TRAFFIC	472.29	27.70	253.04	256.80	256.61	260.37	6	1	60.94	2.24	CONCRETE	SEMI-CIRCULAR NOSE AND TAIL
													2	137.12	2.24	CONCRETE	SEMI-CIRCULAR NOSE AND TAIL
													3	198.06	2.24	CONCRETE	SEMI-CIRCULAR NOSE AND TAIL
													4	259.00	2.24	CONCRETE	SEMI-CIRCULAR NOSE AND TAIL
													5	335.18	2.24	CONCRETE	SEMI-CIRCULAR NOSE AND TAIL
													6	411.35	2.24	CONCRETE	SEMI-CIRCULAR NOSE AND TAIL
	HIGHWAY 63 (SOUTHBOUND)	STEINHAUER BRIDGE	78041S	AT	TRAFFIC	472.44	15.18	253.72	257.28	257.92	261.48	6	SIMILAR TO ABOVE (PIER WIDTH = 2.18 m)				
	HIGHWAY 63 (SOUTHBOUND)	OFF-RAMP TO FRANKLIN AVENUE	75217SE1	AT	TRAFFIC	455.85	10.40	253.64	251.27	257.84	255.47	6	SIMILAR TO ABOVE (PIER WIDTH = 1.91 m)				

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NOTES:

1. AERIAL IMAGERY (2013) PROVIDED BY AEP. BRIDGE SURVEY CONDUCTED BY GOLDER IN OCTOBER 2016. PHOTOS TAKEN BY SG1 ON 30-SEP-2016.
2. DETAILS OF BRIDGE SURVEY WILL BE USED FOR HYDRAULIC MODELLING. PIER CENTRE STATIONS, AS SHOWN IN TABLE BELOW, ARE WITH RESPECT TO VALUES USED IN HYDRAULIC MODEL.
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4. REFER TO REPORT SECTION 2.4 AND HYDRAULIC MODEL FOR MORE INFORMATION.
5. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

SURVEY DATA POINT

0 m 50 100 150 200 m
1 : 6000

PREPARED FOR:

Alberta Government

PROJECT:

FORT McMURRAY RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION

TITLE:

Hydraulic Structure Datasheet
Traffic Bridge – Athabasca River:
Memorial Drive and Off-Ramp to Franklin Avenue

DWN BY:	CHK'D BY:	REV NO:
RDJ	DMS	0

DWG NO: 10058-02-103

FIGURE NO: C-1

DATE: 17-JAN-2017

FILE LOC: H:\SG1\OwnCloud\Drafting\10058 FMRHS\Task 2\10058-02-103.dwg - C1, PLOT DATE: 17-Jan-2017

IMAGE REF. NO. 10058-SR.103

1. View looking from right bank. Flow is from left to right.

IMAGE REF. NO. 10058-SR.106

2. View looking downstream from water's edge on right bank.

WATERBODY	DESCRIPTION	NAME / IDENTIFIER	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	AVERAGE LOW CHORD ELEVATION (m)	NUMBER OF PIERS	PIER DETAILS				
											#	CENTRE STATION (m)	WIDTH (m)	TYPE	SHAPE
HANGINGSTONE RIVER	MEMORIAL DRIVE (NORTHBOUND)	MEMORIAL DRIVE BRIDGE	78152N	AT	TRAFFIC	49.79	16.10	255.34	253.36	2	1	13.52	0.90	CONCRETE	SEMI-CIRCULAR NOSE AND TAIL
											2	36.27	0.90	CONCRETE	SEMI-CIRCULAR NOSE AND TAIL
	MEMORIAL DRIVE (SOUTHBOUND)	MEMORIAL DRIVE BRIDGE	78152S	AT	TRAFFIC	51.19	15.60	255.42	253.83	2	1	10.36	1.20	CONCRETE	SEMI-CIRCULAR NOSE AND TAIL
											2	40.83	1.20	CONCRETE	SEMI-CIRCULAR NOSE AND TAIL

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Tel: 403.299.5600 | www.golder.com

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4. REFER TO REPORT SECTION 2.4 AND HYDRAULIC MODEL FOR MORE INFORMATION.
5. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

SURVEY DATA POINT

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1 : 2000

PREPARED FOR:

Alberta Government

PROJECT:
FORT McMURRAY RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION

TITLE:
Hydraulic Structure Datasheet
Traffic Bridge - Hangingstone River at Memorial Drive

DWN BY:	CHK'D BY:	REV NO:
RDJ	DMS	0

DWG NO: 10058-02-104
DATE: 19-DEC-2016
FIGURE NO: C-2

FILE LOC: H:\SG1\OwnCloud\Drafting\10058 FMRHS\Task 2\10058-02-104.dwg - 10058-02-104, PLOT DATE: 17-Jan-2017

IMAGE REF. NO. 10058-SR.113

1. View looking from right bank. Flow is from left to right.

IMAGE REF. NO. 10058-SR.123

2. View looking upstream from pedestrian bridge.

WATERBODY	DESCRIPTION	NAME / IDENTIFIER	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	AVERAGE LOW CHORD ELEVATION (m)	NUMBER OF PIERS	PIER DETAILS				
											#	CENTRE STATION (m)	WIDTH (m)	TYPE	SHAPE
HANGINGSTONE RIVER	TOLEN DRIVE	TOLEN DRIVE BRIDGE	07047	RMWB	TRAFFIC	30.48	8.48	251.87	250.49	0	-	-	-	-	-

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LEGEND:

SURVEY DATA POINT

0 m 20 40 60 80 m
1 : 2000

PREPARED FOR:

Alberta Government

PROJECT:

FORT McMURRAY RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION

TITLE:

Hydraulic Structure Datasheet
Traffic Bridge - Hangingstone River at Tolen Drive

DWN BY:	CHK'D BY:	REV NO:
RDJ	DMS	0

DWG NO: 10058-02-105

DATE: 19-DEC-2016

FIGURE NO: C-3

FILE LOC: H:\SG1\OwnCloud\Drafting\10058 FMRHS\Task 2\10058-02-105.dwg - 10058-02-105, PLOT DATE: 17-Jan-2017

IMAGE REF. NO. 10058-SR.115

1. View looking downstream from right bank.

IMAGE REF. NO. 10058-SR.118

2. View looking from right bank. Flow is from left to right.

WATERBODY	DESCRIPTION	NAME / IDENTIFIER	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	AVERAGE LOW CHORD ELEVATION (m)	NUMBER OF PIERS	PIER DETAILS				
											#	CENTRE STATION (m)	WIDTH (m)	TYPE	SHAPE
HANGINGSTONE RIVER	BELOW TOLEN DRIVE	HERITAGE PARK FOOTBRIDGE	WB003	RMWB	PEDESTRIAN	42.00	4.23	252.34	250.33	0	-	-	-	-	-

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5. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

SURVEY DATA POINT

0 m 20 40 60 80 m

1 : 2000

PREPARED FOR:

Alberta Government

PROJECT:

FORT McMURRAY RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION

TITLE:

Hydraulic Structure Datasheet
Pedestrian Bridge - Hangingstone River below Tolen Drive

DWN BY:	CHK'D BY:	REV NO:
RDJ	DMS	0

DWG NO: 10058-02-106

DATE: 19-DEC-2016

FIGURE NO: C-4

FILE LOC: H:\SG1\OwnCloud\Drafting\10058 FMRHS\Task 2\10058-02-106.dwg - 10058-02-106, PLOT DATE: 17-Jan-2017

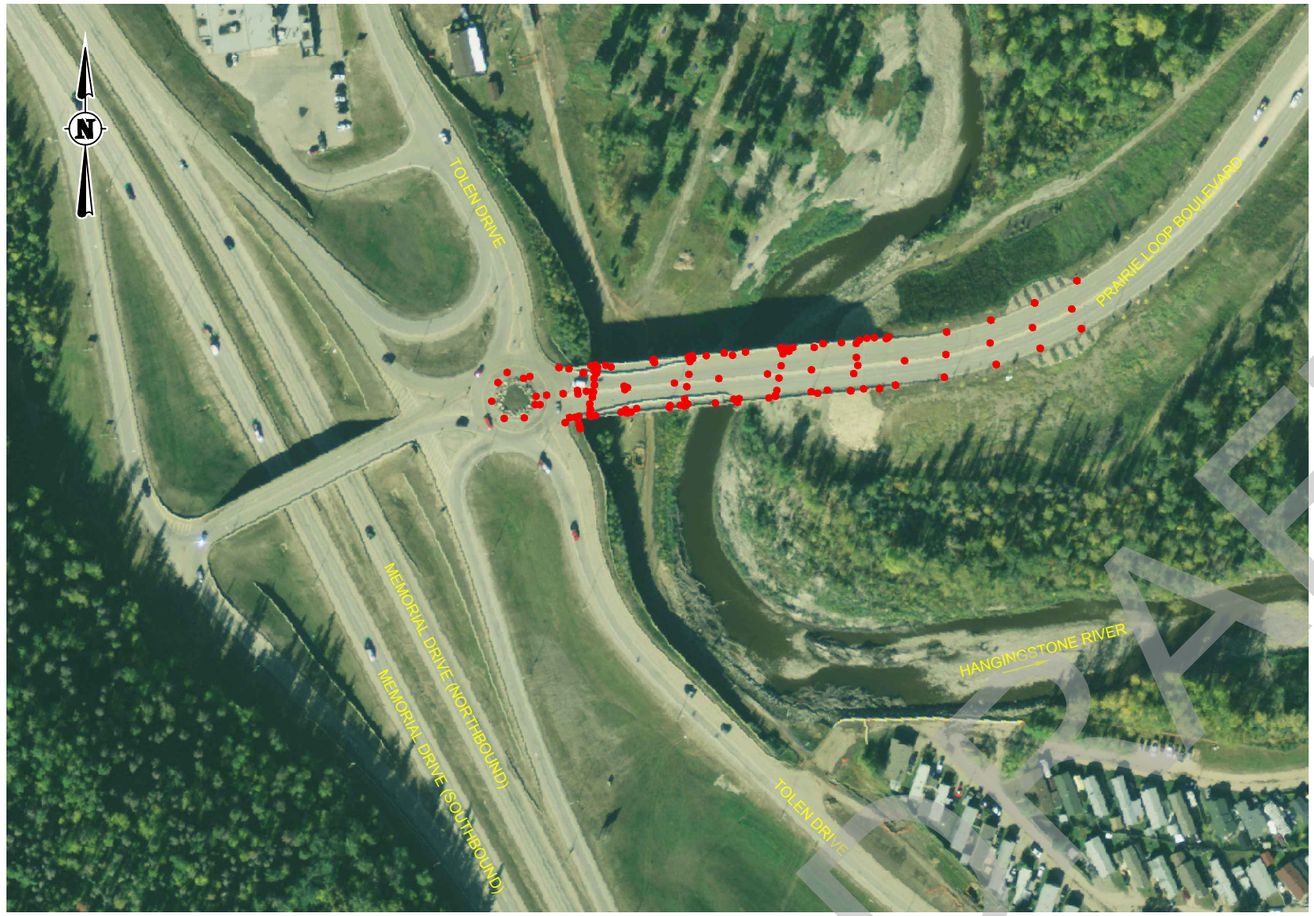

IMAGE REF. NO. 10058-SR.128

1. View looking downstream from right bank.

IMAGE REF. NO. 10058-SR.129

2. View looking downstream from right bank.

WATERBODY	DESCRIPTION	NAME / IDENTIFIER	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	AVERAGE LOW CHORD ELEVATION (m)	NUMBER OF PIERS	PIER DETAILS				
											#	CENTRE STATION (m)	WIDTH (m)	TYPE	SHAPE
HANGINGSTONE RIVER	PRAIRIE LOOP BOULEVARD	PRAIRIE LOOP BOULEVARD BRIDGE	85151	RMWB	TRAFFIC	112.00	20.10	259.76	255.71	3	1	32.00	1.50	CONCRETE	CIRCULAR (ARRAY OF FOUR)
											2	72.00	1.50	CONCRETE	CIRCULAR (ARRAY OF FOUR)
											3	112.00	1.50	CONCRETE	CIRCULAR (ARRAY OF FOUR)

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4. REFER TO REPORT SECTION 2.4 AND HYDRAULIC MODEL FOR MORE INFORMATION.
5. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

● SURVEY DATA POINT

0 m 20 40 60 80 100 m
1 : 2500

PREPARED FOR:

Alberta Government

PROJECT:

FORT McMURRAY RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION

TITLE:

Hydraulic Structure Datasheet
Traffic Bridge - Hangingstone River at Prairie Loop Boulevard

DWN BY:	CHK'D BY:	REV NO:
RDJ	DMS	0

DWG NO:	FIGURE NO:
10058-02-107	C-5

DATE: 19-DEC-2016

FILE LOC: H:\SG1\OwnCloud\Drafting\10058 FMRHS\Task 2\10058-02-107.dwg - 10058-02-107, PLOT DATE: 17-Jan-2017

IMAGE REF. NO. 20161001_112927

1. View looking upstream from right bank.

IMAGE REF. NO. 20161001_113027

2. View looking upstream from right bank.

WATERBODY	DESCRIPTION	NAME / IDENTIFIER	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	AVERAGE LOW CHORD ELEVATION (m)	NUMBER OF PIERS	PIER DETAILS				
											#	CENTRE STATION (m)	WIDTH (m)	TYPE	SHAPE
HANGINGSTONE RIVER	BELOW PRAIRIE LOOP BOULEVARD	PTARMIGAN COURT FOOTBRIDGE	WB002	RMWB	PEDESTRIAN	34.85	3.43	247.62	247.00	0	-	-	-	-	-

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LEGEND:

● SURVEY DATA POINT

0 m 20 40 60 80 m

1 : 2000

PREPARED FOR:

Alberta Government

PROJECT:

FORT McMURRAY RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION

TITLE:

Hydraulic Structure Datasheet
Pedestrian Bridge - Hangingstone River below Prairie Loop Boulevard

DWN BY:	CHK'D BY:	REV NO:
RDJ	DMS	0

DWG NO: 10058-02-108

DATE: 17-JAN-2017

FIGURE NO: C-6

FILE LOC: H:\SG1\OwnCloud\Drafting\10058 FMRHS\Task 2\10058-02-108.dwg - 10058-02-108, PLOT DATE: 17-Jan-2017

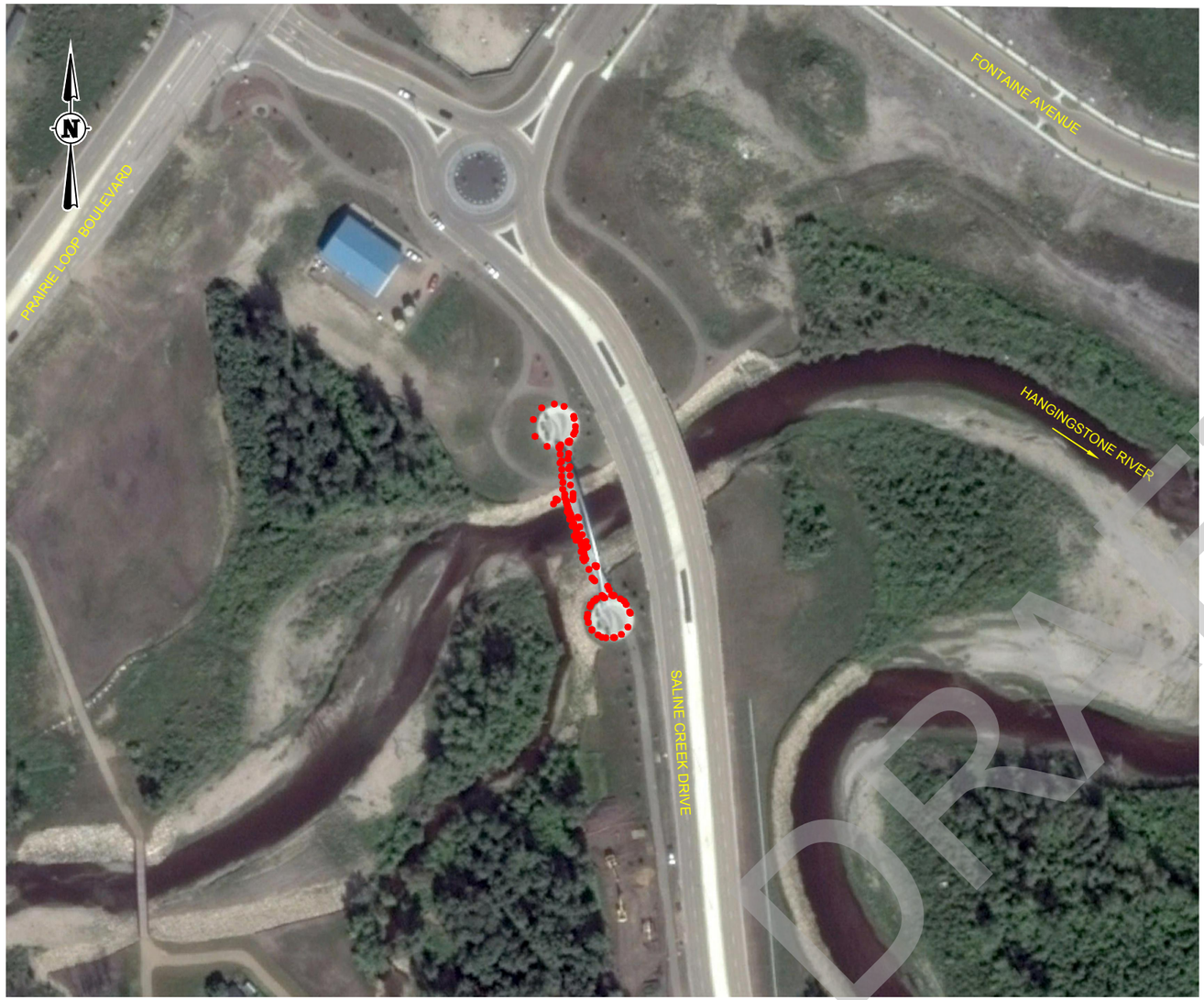

IMAGE REF. NO. 10058-SR.069

1. View looking downstream from left bank. Pedestrian bridge in foreground.

IMAGE REF. NO. 10058-SR.070

2. Pedestrian bridge in foreground. View looking downstream from left bank.

WATERBODY	DESCRIPTION	NAME / IDENTIFIER	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	AVERAGE LOW CHORD ELEVATION (m)	NUMBER OF PIERS	PIER DETAILS				
											#	CENTRE STATION (m)	WIDTH (m)	TYPE	SHAPE
HANGINGSTONE RIVER	SALINE CREEK DRIVE	SALINE CREEK DRIVE FOOTBRIDGE	85289-1	RMWB	PEDESTRIAN	56.35	3.60	250.00	248.95	0	-	-	-	-	-

PREPARED BY:

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5. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

● SURVEY DATA POINT

0 m 20 40 60 80 m

1 : 2000

PREPARED FOR:

Alberta Government

PROJECT:

FORT McMURRAY RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION

TITLE:

Hydraulic Structure Datasheet
Pedestrian Bridge - Hangingstone River at Saline Creek Drive

DWN BY:	CHK'D BY:	REV NO:
RDJ	DMS	0

DWG NO: 10058-02-109

DATE: 19-DEC-2016

FIGURE NO: C-7

FILE LOC: H:\SG1\OwnCloud\Drafting\10058 FMRHS\Task 2\10058-02-109.dwg - 10058-02-109, PLOT DATE: 17-Jan-2017

IMAGE REF. NO. 10058-SR.067

1. View looking downstream from left bank. Road bridge in background.

IMAGE REF. NO. 10058-SR.071

2. View looking downstream from left bank.

WATERBODY	DESCRIPTION	NAME / IDENTIFIER	BRIDGE FILE NUMBER	RECORD HOLDER	USAGE	TOTAL LENGTH OF SPAN (m)	DECK WIDTH (m)	AVERAGE TOP-OF-CURB OR SOLID GUARD RAIL ELEVATION (m)	AVERAGE LOW CHORD ELEVATION (m)	NUMBER OF PIERS	PIER DETAILS				
											#	CENTRE STATION (m)	WIDTH (m)	TYPE	SHAPE
HANGINGSTONE RIVER	SALINE CREEK DRIVE	SALINE CREEK DRIVE BRIDGE	85289-2	RMWB	TRAFFIC	42.48	25.00	251.24	247.50	0	-	-	-	-	-

PREPARED BY:

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

IN COLLABORATION WITH:

Golder Associates
Suite 102 - 2535 3 Avenue SW
Calgary, AB, Canada T2A 7W5
Tel: 403.299.5600 | www.golder.com

NOTES:

1. AERIAL IMAGERY (2016) OBTAINED FROM GOOGLE EARTH. BRIDGE SURVEY CONDUCTED BY GOLDER IN OCTOBER 2016. PHOTOS TAKEN BY SG1 ON 30-SEP-2016.
2. DETAILS OF BRIDGE SURVEY WILL BE USED FOR HYDRAULIC MODELLING. PIER CENTRE STATIONS, AS SHOWN IN TABLE BELOW, ARE WITH RESPECT TO VALUES USED IN HYDRAULIC MODEL.
3. COORDINATE SYSTEM IS 3TM MERIDIAN 111° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
4. REFER TO REPORT SECTION 2.4 AND HYDRAULIC MODEL FOR MORE INFORMATION.
5. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

● SURVEY DATA POINT

0 m 20 40 60 80 m
1 : 2000

PREPARED FOR:

Alberta Government

PROJECT:

FORT McMURRAY RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION

TITLE:

Hydraulic Structure Datasheet
Traffic Bridge - Hangingstone River at Saline Creek Drive

DWN BY:	CHK'D BY:	REV NO:
RDJ	DMS	0

DWG NO: 10058-02-110

DATE: 19-DEC-2016

FIGURE NO: C-8

FILE LOC: H:\SG1\OwnCloud\Drafting\10058 FMRHS\Task 2\10058-02-110.dwg - Hangingstone River at Saline Creek Drive, PLOT DATE: 17-Jan-2017

IMAGE REF. NO. 10058-SR.031

1. Oblique view looking upstream at culvert inlet structure on right bank of Athabasca River.

IMAGE REF. NO. 10058-SR.032

2. View looking upstream from gatewell concrete pad towards the Athabasca River.

WATERBODY	DESCRIPTION	NAME / IDENTIFIER	RECORD HOLDER	USAGE	NO.OF CULVERTS	CULVERT LENGTH (m)	INSIDE DIAMETER (m)	PIPE SLOPE (%)	TOP-OF-GATEWELL ELEVATION (m)	CULVERT TYPE	CULVERT INVERT ELEVATION (m)	
											INLET (WEST SIDE)	OULET (EAST SIDE)
THE SYNE ATHABASCA RIVER	MACDONALD DRIVE (CUTOFF BETWEEN ATHABASCA RIVER AND THE SNYE)	SNYE CULVERT	RMWB	GATED CULVERT	1	166.64	0.60	0.35	245.73	PVC (DR35)	239.25	238.65

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NOTES:

1. AERIAL IMAGERY (2016) OBTAINED FROM GOOGLE EARTH. CULVERT SURVEY CONDUCTED BY GOLDER IN OCTOBER 2016. PHOTOS TAKEN BY SG1 ON 30-SEP-2016.
2. COORDINATE SYSTEM IS 3TM MERIDIAN 111° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
3. REFER TO REPORT SECTION 2.4 AND HYDRAULIC MODEL FOR MORE INFORMATION.
4. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

● SURVEY DATA POINT

0 m 30 60 90 120 m

1 : 3000

PREPARED FOR:

Alberta Government

PROJECT:

FORT McMURRAY RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION

TITLE:

Hydraulic Structure Datasheet
Gated Culvert - Snye Dyke at MacDonald Drive

DWN BY:	CHK'D BY:	REV NO:
RDJ	DMS	0

DWG NO: 10058-02-111

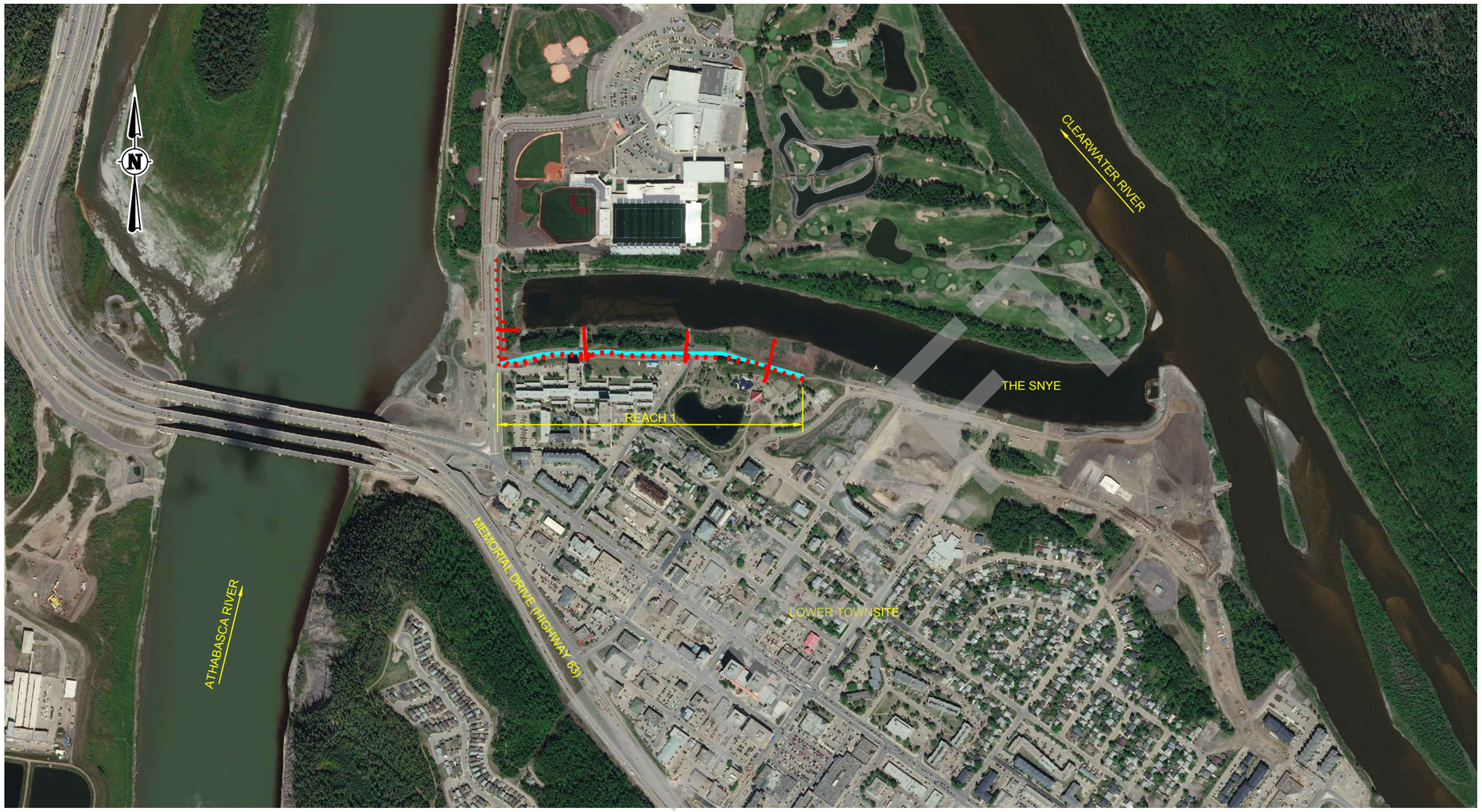
DATE: 19-DEC-2016

FIGURE NO: C-9

FILE LOC: H:\SG1\OwnCloud\Drafting\10058 FMRHS\Task 2\10058-02-111.dwg - Snye Dyke at MacDonald Drive, PLOT DATE: 17-Jan-2017

APPENDIX D

Flood Control Structure Datasheets



ADJACENT WATERBODY	DESCRIPTION	NAME / IDENTIFIER	APPROXIMATE LENGTH (m)	SIDE OF RIVER	TYPE
THE SYNE	WALKING TRAIL BETWEEN MACDONALD DRIVE AND BOREALIS PARK	REACH 1 - SYNE DYKE	635	LEFT	PATHWAY

PREPARED BY:

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IN COLLABORATION WITH:

Golder Associates

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Calgary, AB, Canada T2A 7W5
Tel: 403.299.5600 | www.golder.com

NOTES:

1. IMAGE SOURCE: WORLD IMAGERY BY ESRI INC., UPDATED NOVEMBER 2017. GROUND SURVEY CONDUCTED BY GOLDER IN OCTOBER 2016.
2. DETAILS OF FLOOD CONTROL STRUCTURE SURVEY WILL BE USED FOR HYDRAULIC MODELLING.
3. COORDINATE SYSTEM IS 3TM MERIDIAN 111° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
4. REFER TO REPORT SECTION 2.5 AND HYDRAULIC MODEL FOR MORE INFORMATION.
5. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

- SURVEY DATA POINT
- FLOOD CONTROL STRUCTURE

0 m 100 200 300 400

1 : 10,000

PREPARED FOR:

Alberta Government

PROJECT:

FORT McMURRAY RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION

TITLE:

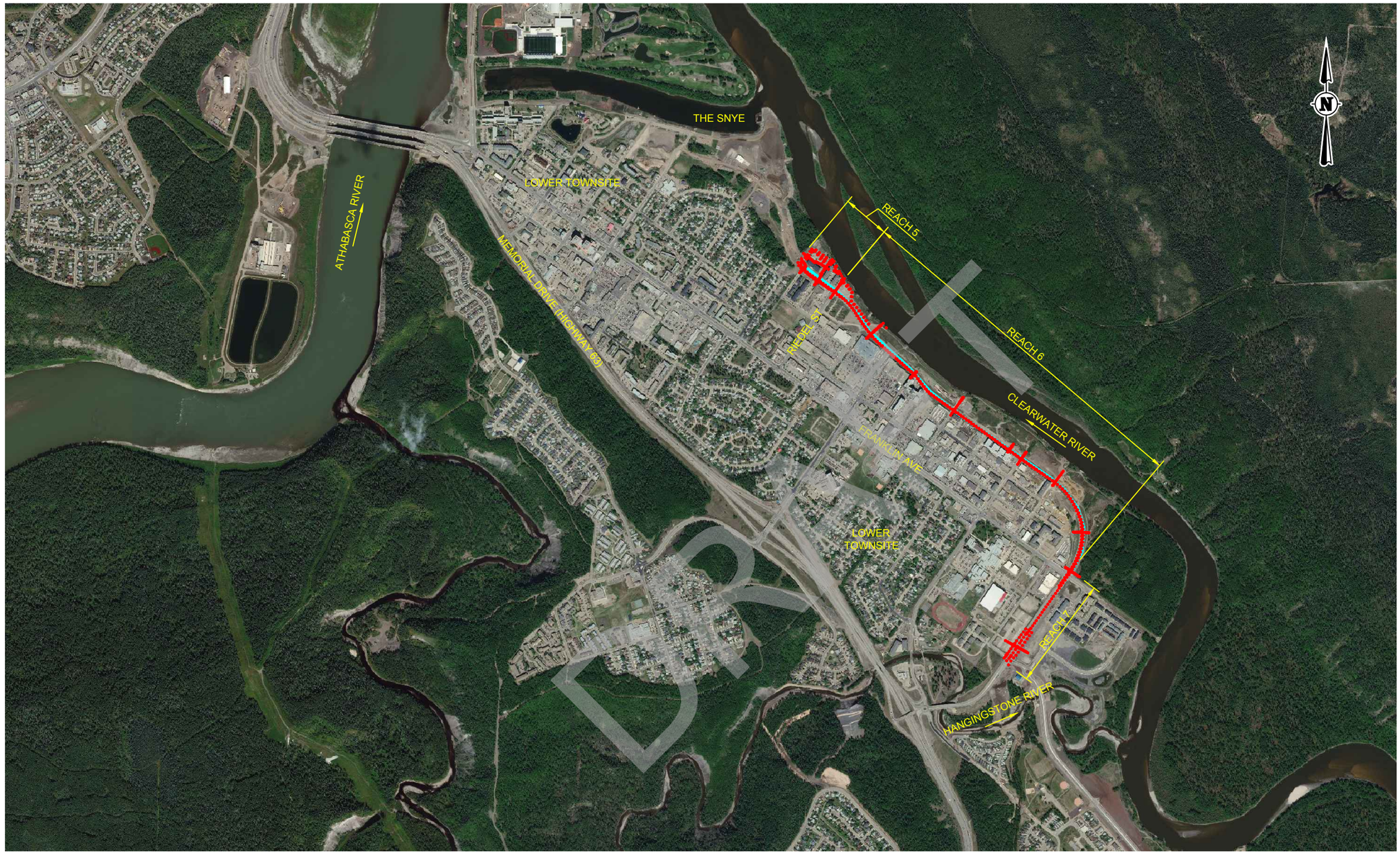
Flood Control Structure Datasheet
MacDonald Drive to Borealis Park
(Reach 1)

DWN BY:	CHK'D BY:	REV NO:
RDJ	DMS	0

DWG NO:	FIGURE NO:
10058-02-112	D-1

DATE: 10-NOV-2017

FILE LOC: H:\SG1\OwnCloud\Drafting\10058 FMRHS\Task 2\10058-02-112.dwg - 10058-02-112, PLOT DATE: 13-Nov-2017



ADJACENT WATERBODY	DESCRIPTION	NAME / IDENTIFIER	APPROXIMATE LENGTH (m)	SIDE OF RIVER	TYPE
CLEARWATER RIVER	PRAIRIE LOOP BOULEVARD BETWEEN MCLEOD STREET AND RIEDEL STREET (RIVERWALK VILLAS)	REACH 5 - LOWER TOWNSITE	210	LEFT	ROAD
CLEARWATER RIVER	PRAIRIE LOOP BOULEVARD BETWEEN RIEDEL STREET AND FRANKLIN AVENUE	REACH 6 - LOWER TOWNSITE	1945	LEFT	ROAD
CLEARWATER RIVER	PRAIRIE LOOP BOULEVARD BETWEEN FRANKLIN AVENUE AND SALINE CREEK DRIVE	REACH 7 - LOWER TOWNSITE	495	LEFT	ROAD

PREPARED BY:

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NOTES:

1. IMAGE SOURCE: WORLD IMAGERY BY ESRI INC., UPDATED NOVEMBER 2017. GROUND SURVEY CONDUCTED BY GOLDER IN OCTOBER 2016 AND MARCH 2017.
2. DETAILS OF FLOOD CONTROL STRUCTURE SURVEY WILL BE USED FOR HYDRAULIC MODELLING.
3. COORDINATE SYSTEM IS 3TM MERIDIAN 111° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
4. REFER TO REPORT SECTION 2.5 AND HYDRAULIC MODEL FOR MORE INFORMATION.
5. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

- SURVEY DATA POINT
- FLOOD CONTROL STRUCTURE

0 m 200 400 600 800

1 : 20,000

PREPARED FOR:

Alberta Government

PROJECT:

FORT McMURRAY RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION

TITLE:

Flood Control Structure Datasheet
Prairie Loop Boulevard between McLeod Street and Saline Creek Drive
(Reaches 5, 6, and 7)

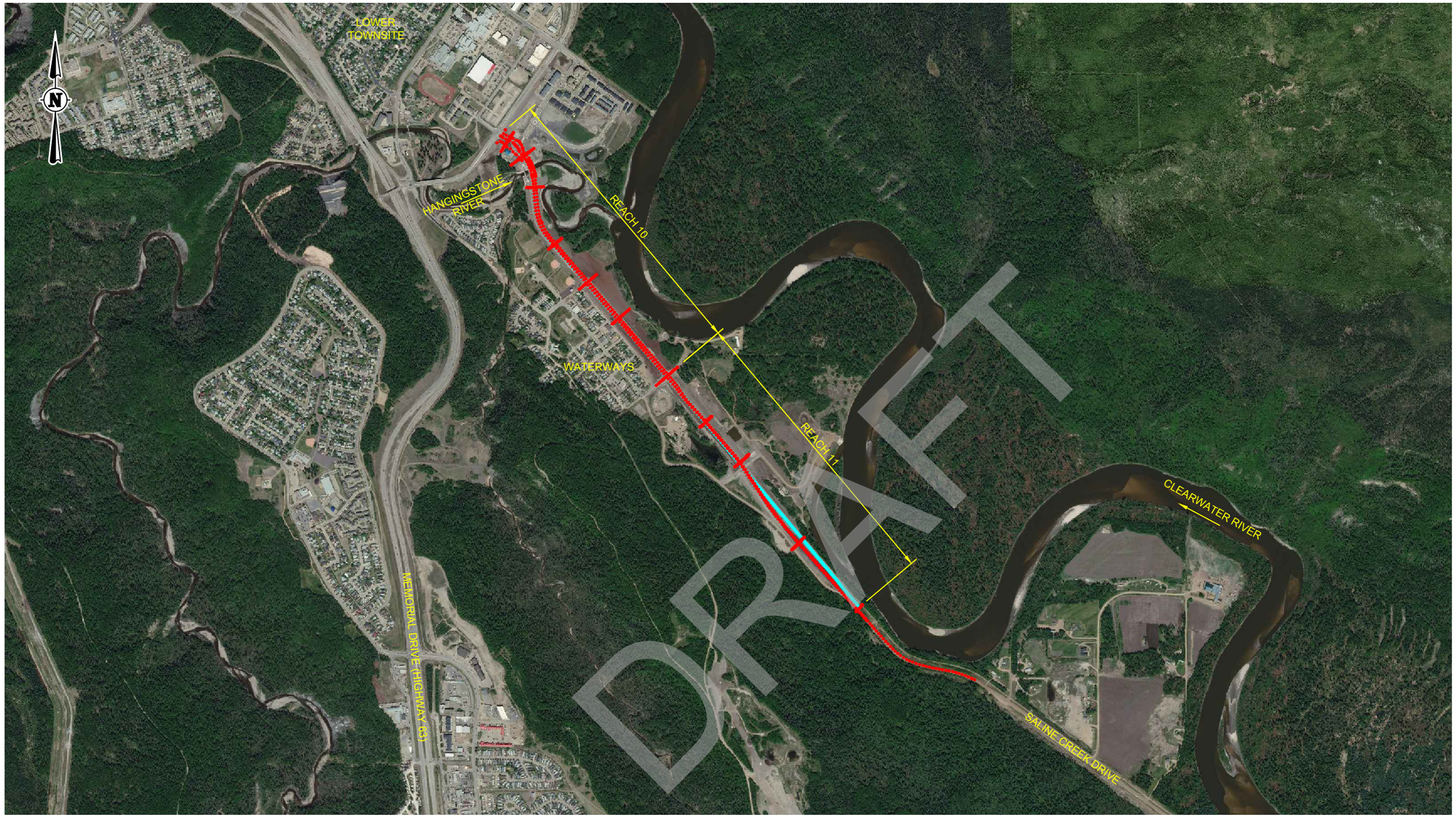
DWN BY:	CHK'D BY:	REV NO:
RDJ	DMS	0

DWG NO: 10058-02-113

DATE: 10-NOV-2017

FIGURE NO: D-2

FILE LOC: H:\SG1\OwnCloud\Drafting\10058 FMRHS\Task 2\10058-02-113.dwg - 10058-02-113, PLOT DATE: 13-Nov-2017



ADJACENT WATERBODY	DESCRIPTION	NAME / IDENTIFIER	APPROXIMATE LENGTH (m)	SIDE OF RIVER	TYPE
CLEARWATER RIVER HANGINGSTONE RIVER	SALINE CREEK DRIVE BETWEEN SALINE CREEK DRIVE BRIDGE AND PARK STREET	REACH 10 - WATERWAYS	1450	LEFT (CLEARWATER) RIGHT (HANGINGSTONE)	ROAD
CLEARWATER RIVER HANGINGSTONE RIVER	SALINE CREEK DRIVE BETWEEN SALINE CREEK DRIVE ROUNDABOUT AND PRAIRIE LOOP BOULEVARD	REACH 10 - WATERWAYS	95	LEFT (CLEARWATER) LEFT (HANGINGSTONE)	ROAD
CLEARWATER RIVER	SALINE CREEK DRIVE BETWEEN PARK STREET AND JUNCTION WITH DRAPER ROAD	REACH 11 - WATERWAYS	1125	LEFT	ROAD

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Tel: 403.299.5600 | www.golder.com

NOTES:

1. IMAGE SOURCE: WORLD IMAGERY BY ESRI INC., UPDATED NOVEMBER 2017. GROUND SURVEY CONDUCTED BY GOLDER IN OCTOBER 2016 AND MARCH 2017.
2. DETAILS OF FLOOD CONTROL STRUCTURE SURVEY WILL BE USED FOR HYDRAULIC MODELLING.
3. COORDINATE SYSTEM IS 3TM MERIDIAN 111° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
4. REFER TO REPORT SECTION 2.5 AND HYDRAULIC MODEL FOR MORE INFORMATION.
5. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

- SURVEY DATA POINT
- FLOOD CONTROL STRUCTURE

0 m 200 400 600 800 m
1 : 20000

PREPARED FOR:
Alberta Government

PROJECT:
FORT McMURRAY RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION

TITLE:
Flood Control Structure Datasheet
Saline Creek Drive between Prairie Loop Boulevard and Draper Road Junction
(Reaches 10 and 11)

DWN BY:	CHK'D BY:	REV NO:
RDJ	DMS	0
DWG NO: 10058-02-114		FIGURE NO: D-3
DATE: 10-NOV-2017		

FILE LOC: H:\SG1\OwnCloud\Drafting\10058 FMRHS\Task 2\10058-02-114.dwg - (Reaches 10 and 11), PLOT DATE: 13-Nov-2017

ADJACENT WATERBODY	DESCRIPTION	NAME / IDENTIFIER	APPROXIMATE LENGTH (m)	SIDE OF RIVER	TYPE
SALINE CREEK	NEAR PELICAN DRIVE BETWEEN PARK PLACE (CUL-DE-SAC) AND PEDESTRIAN BRIDGE	REACH 10 - WATERWAYS	210	LEFT	RETAINING STRUCTURE

PREPARED BY:

SG1

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IN COLLABORATION WITH:

Golder Associates

Suite 102 - 2535 3 Avenue SW
Calgary, AB, Canada T2A 7W5
Tel: 403.299.5600 | www.golder.com

NOTES:

1. IMAGE SOURCE: WORLD IMAGERY BY ESRI INC., UPDATED NOVEMBER 2017. GROUND SURVEY CONDUCTED BY GOLDER IN MARCH 2017.
2. DETAILS OF FLOOD CONTROL STRUCTURE SURVEY WILL BE USED FOR HYDRAULIC MODELLING.
3. COORDINATE SYSTEM IS 3TM MERIDIAN 111° W REFERENCED TO VERTICAL AND HORIZONTAL DATUMS OF CGVD28 AND NAD83 (CSRS), RESPECTIVELY.
4. REFER TO REPORT SECTION 2.5 AND HYDRAULIC MODEL FOR MORE INFORMATION.
5. LEFT OR RIGHT REFER TO DIRECTIONS AS SEEN BY AN OBSERVER LOOKING DOWNSTREAM.

LEGEND:

- SURVEY DATA POINT
- FLOOD CONTROL STRUCTURE

0 m 40 80 120 160

1 : 4000

PREPARED FOR:

Alberta Government

PROJECT:

FORT McMURRAY RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION

TITLE:

Flood Control Structure Datasheet near Pelican Drive between Park Place and Pedestrian Bridge
(Reach 10)

DWN BY:	CHK'D BY:	REV NO:
RDJ	DMS	0

DWG NO: 10058-02-115

DATE: 10-NOV-2017

FIGURE NO: D-4

FILE LOC: H:\SG1\OwnCloud\Drafting\10058 FMRHS\Task 2\10058-02-115.dwg - 10058-02-115, PLOT DATE: 13-Nov-2017

APPENDIX E

Aerial Imagery Acquisition Memorandum

TECHNICAL MEMORANDUM

DATE December 19, 2017 **PROJECT No.** 1662603 / 1000

TO Abdullah Mamun
Alberta Environment and Parks

CC Wolf Ploeger

FROM Vanessa Vallis **EMAIL**

FORT MCMURRAY RIVER HAZARD STUDY: 2017 AERIAL IMAGERY ACQUISITION MEMORANDUM

1.0 BACKGROUND

The Survey and Base Data Collection component of the Fort McMurray River Hazard Study requires the collection of current aerial photography. This aerial imagery was acquired on May 18, 2017 and is intended to be used for project analysis and mapping activities. This memorandum gives a high-level overview of the processing methodology, quality assurance results and related deliverables.

2.0 METHODOLOGY

As proposed, GeodesyGroup Inc. was retained to carry out acquisition and processing of the aerial photography, while Golder Associates Ltd. (hereafter 'Golder') was responsible for process oversight and review of deliverables. Prior to commencing image acquisition, the proposed flight plan and schedule was reviewed with the client. During the flight planning process Golder verified that the image collection parameters would meet Alberta Environment and Parks (AEP) specifications as specified in the Terms of Reference and the published guidelines (ESRD 2015). The 2017 colour aerial imagery was flown to cover the 'Fort McMurray LiDAR acquisition Area' (as received by Golder on July 20, 2016) at a resolution of 30 centimetres.

On May 18, 2017 the aerial photography survey was completed using a PIPER-PA46 aircraft outfitted with a gyro-stabilized Vexcel UltraCam XP digital frame camera, a differential Global Navigation Satellite System (GNSS) and an Inertial Measurement Unit (IMU) system. A GPS ground station was set-up near the Fort McMurray Airport for use in post-processing the IMU data. Ground and meteorological conditions were favourable for image collection as the ground was free of snow and fog, while skies were free of haze and smoke. After takeoff, two small clouds developed outside the imagery acquisition area, which cast small shadows that were captured in the imagery. The shadows are not expected to be problematic for the project due to their location above the crest of the river valley wall, which is well beyond the limits of the 1,000-year flood inundation extent. 55 photos were captured over five flight lines at an average height of 5,365 metres above sea level and a speed of 225 knots. Colour imagery was acquired in red, green, blue and near-infrared wavelengths with a bit depth of 8 bits per band, as specified in the Terms of Reference. A flight index map is attached for your reference in Appendix A.

Images were acquired between 09:06 and 10:06 MDT ensuring that the variation in the angle of solar illumination is low (30.5 to 39.7 degrees) and within the specified range; thus eliminating long shadows and large reflections on water. The flight design was planned so that the flight lines are oriented in a manner to best capture the irregular shape of the target area with 60% forward overlap and 30 % sidelap (between adjacent flight lines which are approximately 3,600 metres apart). The images acquired were flown at an approximate scale of 1:22,000 with a

focal length of 100.5 mm, which yields 30 cm resolution imagery after orthorectification. The camera and navigation systems were calibrated within the past year and dates of calibration are listed in the provided metadata.

After the aerial survey was completed, GeodesyGroup post-processed the GNSS and IMU data to calculate the parameters required by AEP. These values are visible within the attributes of the spatial metadata layers (see photo centres and footprints). The accuracy of the roll, pitch and yaw were found to be 0.008, 0.008 and 0.023 degrees respectively. The accuracy of vertical elevation measurements captured in flight was found to be 3.5 metres prior to post-processing. Digital image processing was carried out using Vexcel UltraMap® and Trimble Inpho® post-processing software packages. These software were used for aerial triangulation, the creation of stereo models as well as for orthophoto production. The process of aerial triangulation generated over 13,200 automatic tie points for 55 photos yielding an RMS error of 0.6 µ (X,Y) and a sigma naught of 0.8 µ (please refer to the aerial triangulation report for more information). Using the parameters determined during aerial triangulation, stereomodels were created so that the stereo imagery could be viewed in 3D using softcopy photogrammetry software.

Each raw image was orthorectified using resampled 1 m resolution bare earth LiDAR from 2016 and the calculated aerial triangulation data. After orthorectification, each image was colour balanced and mosaiced to create a seamless product which was then tiled and named according to the provided tiling index. An additional copy of the orthophotos was provided with a contrast stretch image enhancement, to optimize image display for mapping purposes. Based on our understanding of the provincial guidelines we expect that the unenhanced photos will best meet AEPs criteria. Throughout the data processing workflow, GeodesyGroup undertook random spot checks to ensure consistency and quality of the deliverables.

3.0 RESULTS

After receipt of the data from GeodesyGroup, Golder undertook a completeness check and a quality assurance check. These were done to ensure that all requested deliverables were received and that the quality of the deliverables would meet the needs of the project and conform to the AEP general specifications.

The quality of the deliverables was assessed in several ways. First, a visual check of the raw stereo imagery was done on a random sample of photos using ENVI® (v 5.3) to ensure that the images were free of blurs, clouds, shadows and other visual defects. This included checking the size of bright saturated areas (pixel values of 255), highlights and dark shadows to ensure that the pixel values were within the permissible range. The bit depth, number of bands and ‘no data’ values were also confirmed to meet the Terms of Reference. Next the orthorectified imagery was reviewed in ArcGIS® (v 10.4) to check that the geopositioning of the data matched the 2016 LiDAR (Light detection and ranging). Additional base data and online image services were used to spot check the geopositioning of the imagery beyond the city limits, as needed. The spatial reference of the data was also checked to ensure that all data is projected in the 3-degree Transverse Mercator (3TM) projection using the NAD83 Canadian Spatial Reference System (CSRS) datum and Canadian Geodetic Vertical Datum of 1928 (CGVD28).

In order to ensure that the aerial survey was conducted as specified, the geospatial metadata files were used for random spot checks to verify that the flight design resulted in the correct amount of forward overlap and sidelap, and that any changes in elevation or heading were within the specified amount. The attributes of the data were checked to ensure that they contained the correct information and that the file naming and tiling schemas used matched the AEP tiling index. The metadata files for each image were also checked for completeness in ArcCatalog® (v 10.4) and in XML Notepad 2007. Additional checks of the image processing undertaken by GeodesyGroup included the review of the Aerial Triangulation Report.

During our preliminary review, a small hole was identified in the orthophotography as well as some deficiencies in the supporting files and metadata. Golder requested revised files from GeodesyGroup and these were found to be satisfactory upon their subsequent delivery to Golder. An overview map showing the tiled and orthorectified imagery is attached in Appendix B.

4.0 DELIVERABLES

The following files and deliverables are included with this memorandum:

- Stereo images for the Imagery acquisition area;
- Aerial triangulation (external orientation) data in plain text format and DATEM compatible file formats;
- Colour (RGBI) digital orthophotos in 8-bit GeoTIF format with associated world (.tfw) files for the study area; tiled according to provided LiDAR tiling index;
- Metadata for the orthophotos and stereo images provided as shapefiles and FGDC.xml files;
- Aerial triangulation image adjustment report;
- Camera calibration reports;
- Flight report;
- Index of aerial imagery tiles as shapefile and unsecured PDF format map; and
- This memorandum documenting the methodology and results of aerial imagery acquisition, along with digital copies of this memorandum in Word and unsecured PDF formats.

Two digital copies of the above deliverables are being provided on the accompanying USB drives.

5.0 CLOSURE

We trust that the enclosed data meets your present requirements. If you have any questions or require additional details, please contact Wolf Ploeger at (403)216-8934.

Yours truly,

GOLDER ASSOCIATES LTD.

Prepared by:

ORIGINAL SIGNED

Vanessa Vallis, M.Sc.
Remote Sensing / GIS Analyst

Reviewed by:

ORIGINAL SIGNED

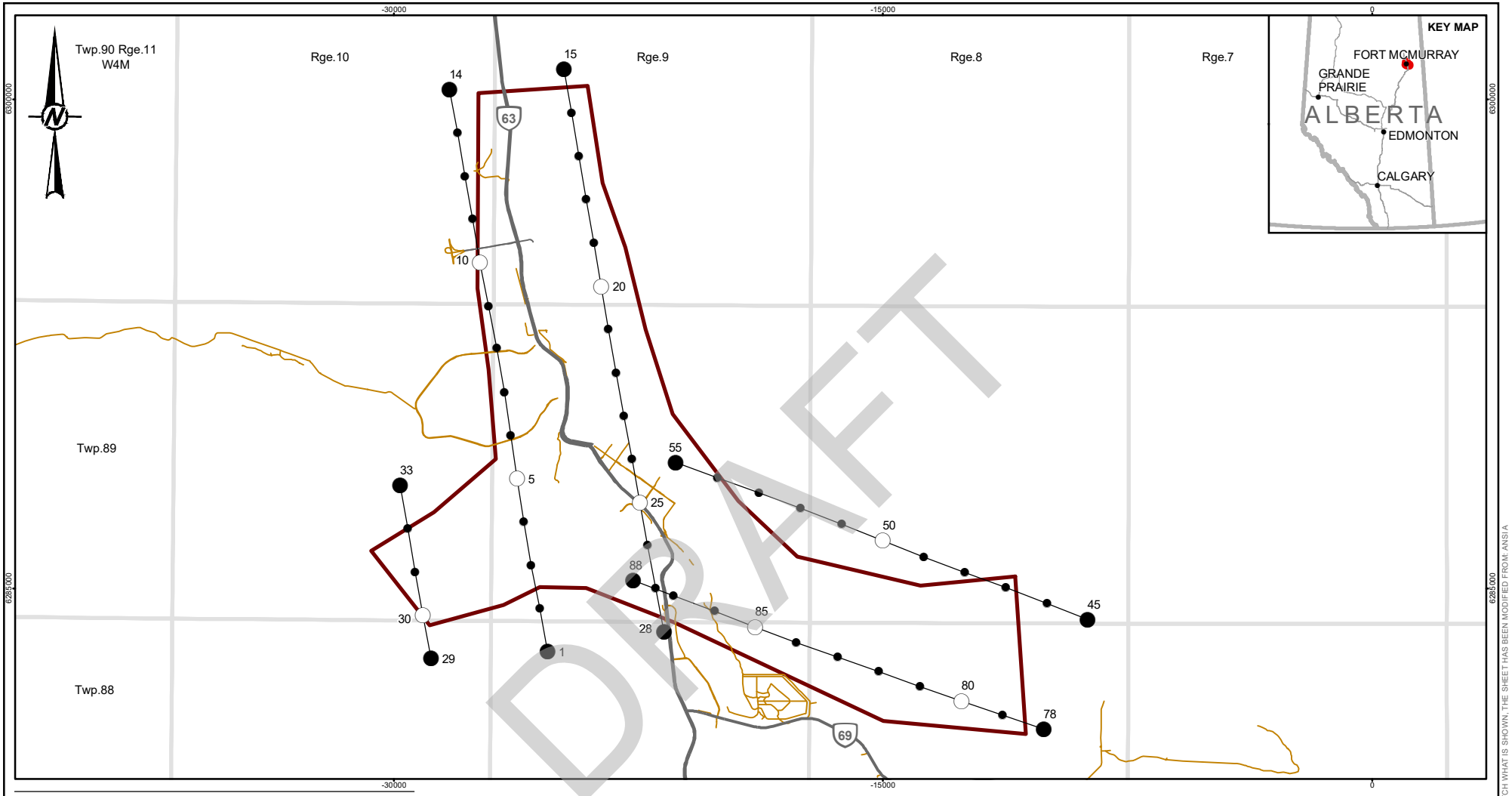
Wolf Ploeger, Dr.-Ing
Associate, Senior Water Resources Specialist

REFERENCES

Alberta Environment and Sustainable Resource Development (ESRD). 2015. General Specifications for Acquiring Aerial Photography, April 2015, ISSN No. 0-827-388X

APPENDIX A

Flight Index Map



LEGEND

- BEGINNING / END FLIGHT PATH PHOTO
- 5th PHOTO
- PHOTO
- FLIGHT LINE
- PRIMARY HIGHWAY
- SECONDARY HIGHWAY
- LOCAL ROAD
- IMAGERY ACQUISITION AREA
- PROJECT LOCATION

0 2,500 5,000
1:175,000 METRES

REFERENCE(S)

1. TRANSPORTATION FEATURES OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
2. TOWNSHIP DATA OBTAINED FROM © GOVERNMENT OF ALBERTA 2015. ALL RIGHTS RESERVED.
3. COORDINATE SYSTEM: 3TM 111 DATUM: NAD 83 CSRS

CLIENT
ALBERTA ENVIRONMENT AND PARKS

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-12-19
DESIGNED	V. VALLIS
PREPARED	V. VALLIS
REVIEWED	W. PLOEGER
APPROVED	W. PLOEGER

PROJECT
FORT MCMURRAY RIVER HAZARD STUDY

TITLE
FLIGHT DESIGN

PROJECT NO.	CONTROL	REV.	FIGURE
1662603	1000	0	A

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

APPENDIX B

Orthophotography Index Map

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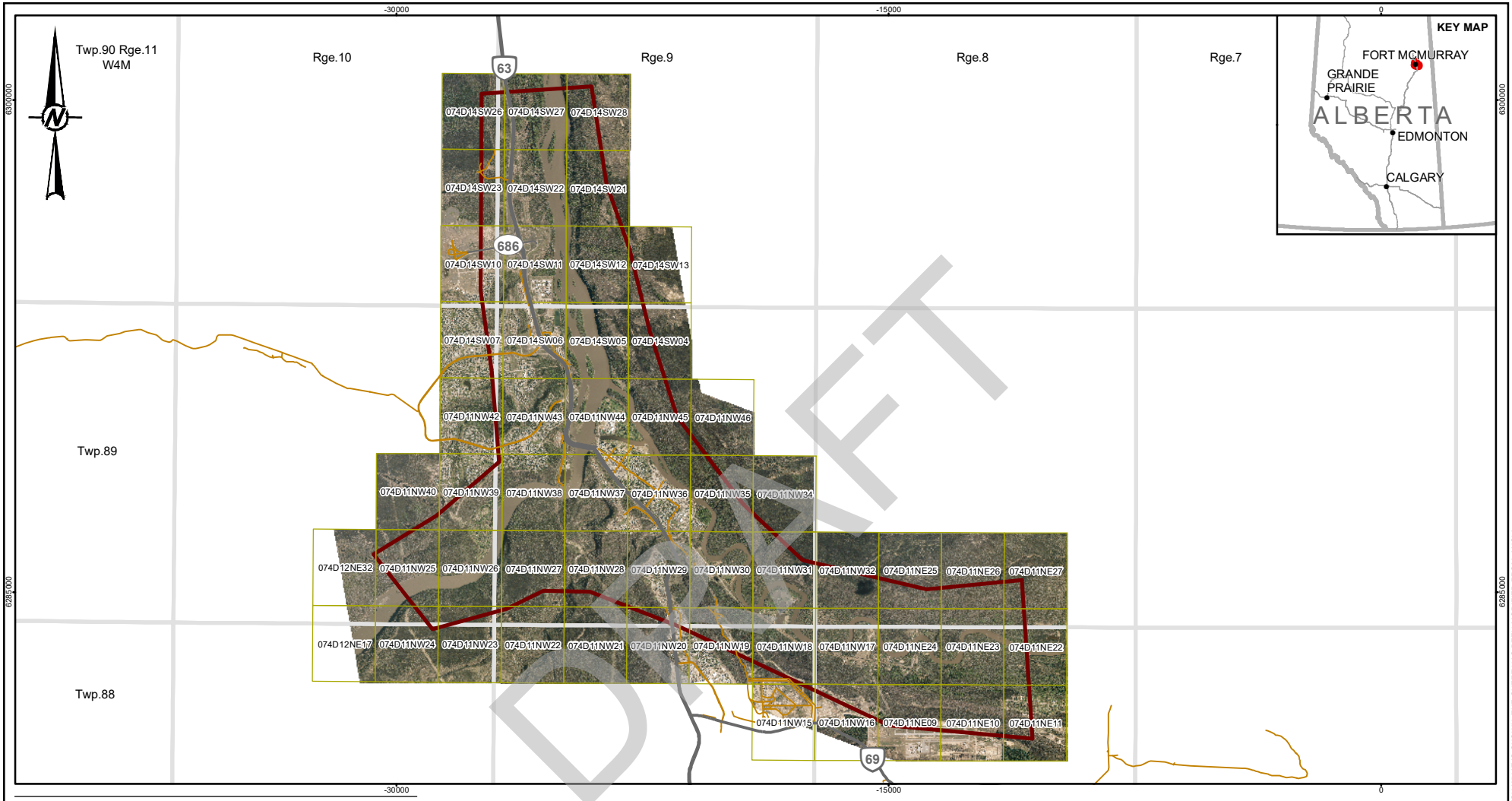

LEGEND

- PRIMARY HIGHWAY
- SECONDARY HIGHWAY
- LOCAL ROAD
- ORTHOPHOTO TILE
- IMAGERY ACQUISITION AREA
- PROJECT LOCATION

0 2,500 5,000

1:175,000 METRES

REFERENCE(S)

1. TRANSPORTATION FEATURES OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
2. TOWNSHIP DATA OBTAINED FROM © GOVERNMENT OF ALBERTA 2015. ALL RIGHTS RESERVED.
3. 30 CM ORTHOPHOTOGRAPHY FLOWN BY GEODESY GROUP ON MAY 18, 2017.
4. COORDINATE SYSTEM: 3TM 111 DATUM: NAD 83 CSRS

CLIENT
ALBERTA ENVIRONMENT AND PARKS

PROJECT
FORT MCMURRAY RIVER HAZARD STUDY

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-12-19
DESIGNED	V. VALLIS
PREPARED	V. VALLIS
REVIEWED	W. PLOEGER
APPROVED	W. PLOEGER

TITLE
ORTHOPHOTOGRAPHY INDEX MAP

PROJECT NO.	CONTROL	REV.	FIGURE
1662603	1000	0	B

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

25mm

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